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Decommissioning of DR 1

Final report

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Abstract (max. 2000 char.):

The report describes the decommissioning activities carried out at the 2kW homogeneous reactor DR 1 at Risø National Laboratory. The decommissioning work took place from summer 2004 until late autumn 2005. The components with the highest activity, the core vessel the recombiner and the piping and valves connected to these, were dismantled first by Danish Decommissioning's own technicians. Demolition of the control rod house and the biological shield as well as the removal of the floor in the reactor hall was carried out by an external demolition contractor. The building was emptied and left for other use. Clearance measurements of the building showed that radionuclide concentrations were everywhere below the clearance limit set by the Danish nuclear regulatory authorities. Furthermore, measurements on the surrounding area showed that there was no contamination that could be attributed to the operation and decommissioning of DR 1.

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Contents

Preface

The present report is the final decommissioning report submitted to the nuclear regulatory authorities as evidence that the decommissioning of reactor DR 1 has been completed in accordance with license and other legal requirements. The report documents the activities that were performed during the decommissioning of DR 1. This report is supplemented by a report describing the clearance measurements of the building and surrounding area and a report in Danish about the lessons learnt from this project that could be of benefit to the future decommissioning projects.

1 Background and objective

The decision to decommission all the nuclear facilities at Risø National Laboratory was taken in the autumn of 2000 when the largest reactor at the site, DR 3, was taken out of operation subsequent to problems with a leakage from the reactor tank. The Danish parliament accepted a proposal for decommissioning of all the nuclear facilities at the site to be carried out over a time period of 11 to 20 years. At the same time it was decided that the decommissioning should be carried out by a new organisation, Danish Decommissioning, which is financially independent of Risø National Laboratory and operating directly under the Ministry of Science, Technology and Innovation.

Decommissioning of reactor DR 1 was the first decommissioning project to be carried out, partly in order to serve as a "learning exercise" for the organisation before the larger reactors DR 2 and DR 3 were to be decommissioned.

The overall objective of the decommissioning at the Risø site is to reach "green field" so that the area and possible remaining buildings can be used for other purposes without any restrictions (with respect to radioactive materials and radiation). Concerning DR 1, Risø National Laboratory wishes to re-use the building for other purposes. Therefore, Danish Decommissioning has removed the reactor block and cleaned the building to a state where clearance levels can be met.

By October 6, 2004, Danish Decommissioning received the final approval from the nuclear licensing authorities that enabled us to initiate actual decommissioning work on DR 1. Until then, however, it had been possible to carry out some preparatory work, including removal of external parts of the cooling systems as well as the control rods. From October 2004 to January 2005 the main radioactive components were dismantled, and from May to August 2005 the reactor block was demolished, the floor in the reactor hall removed, and all contamination above clearance levels removed. Clearance measurements of the building took place thereafter, lasting until mid-November 2005.

The present report describes the work undertaken in the dismantling, demolition and clearance of the building. In addition, two other reports have been produced as part of the final reporting of the decommissioning of DR 1: a clearance report [1] and a "lessons learned" report [2]. The clearance report, like the present one, has been written in English, while the "lessons learned" report has been written in Danish because it is intended for use by all staff at Danish Decommissioning who are going to take part in future projects.

Some auxiliary facilities were not yet ready when the DR 1 project commenced, for example the intermediate waste storage hall, the clearance laboratory and the activity measurement laboratory. Therefore, the waste handling had to be carried out in a manner different from what is intended for the future projects, and a number of waste items that can probably be cleared still await measurement in the clearance laboratory.

2 Brief description of the reactor

Figure 1 shows a cut-away sketch of the reactor. It was a homogeneous reactor with a maximum power of 2 kW. The fuel was a solution of 20% enriched uranium in the form of uranyl sulphate in water. The core vessel was a spherical stainless steel vessel with a diameter of 32 cm. A recombiner served to recombine the hydrogen and oxygen that was formed by radiolysis when the reactor was in operation. The reactor had a graphite reflector with a diameter of 150 cm and a height of 130 cm, placed in a steel tank. The biological shield consisted of magnetite concrete (ρ~3700 kg/m^3) with a thickness of 120 cm. During its lifetime from 1957 to 2001 the reactor produced about 0.5 MWd, corresponding to a consumption of about 0.5 g of ^{235}U.

For a more detailed description of the facility the reader is referred to the project description [3] and to [4] and [5].

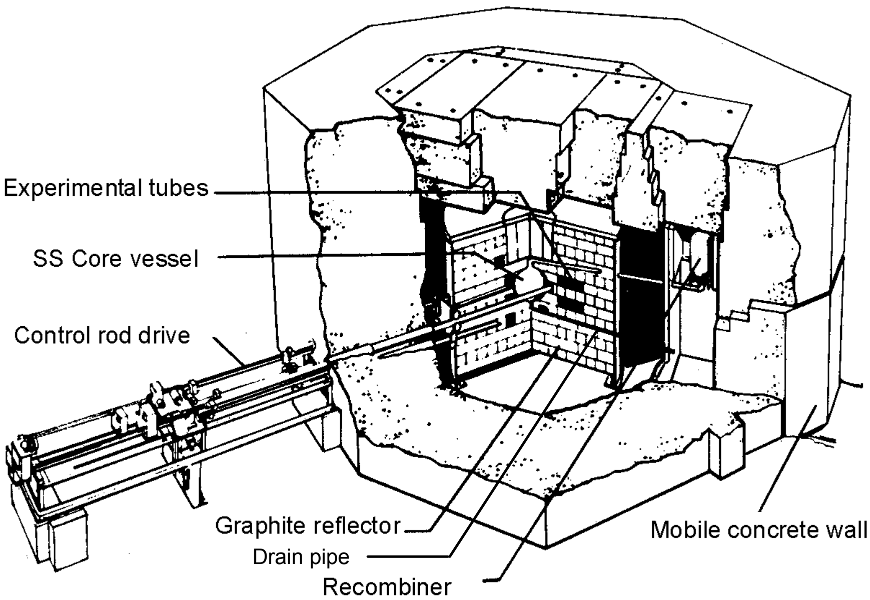

Figure 1 Cut-away drawing of the reactor

The major part of the activity in DR 1 was concentrated in the reactor vessel, the recombiner, and the 2⅜" pipe connecting the two. All three components were made of stainless steel. Although not very active, these components required some degree of remote handling and, of course, detailed planning of all operations and consideration of the risks involved in order to minimize personnel doses and occupational injuries.

For reference, Figure 2 shows a diagram of the reactor system with all the primary piping. The figure does not show the cooling systems, which comprised one cooling coil in the core vessel and two in the recombiner. The heat exchangers were placed in the control rod house, cf. Figure 3.

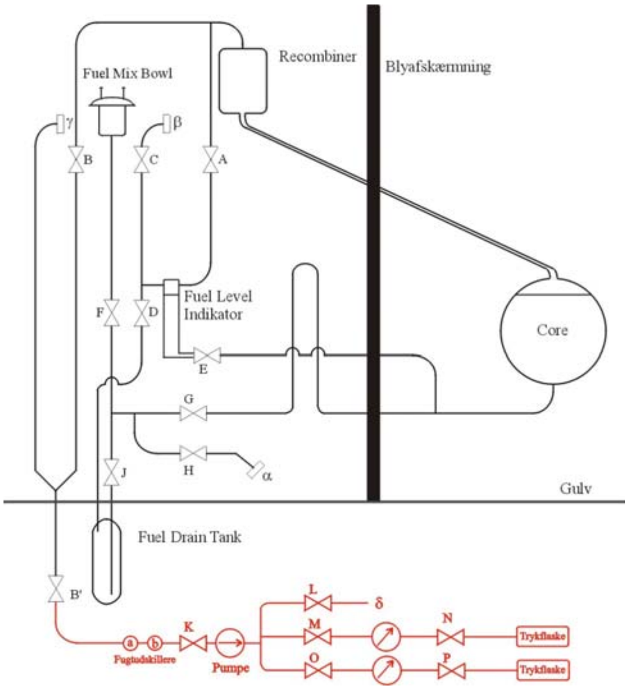

Figure 2 Sketch of the reactor and piping system

A horizontal cross section of the ground floor of the reactor building is shown in Figure 3. In Figure 4 the position is shown of three channels going below the floor from the reactor block to the South, West (control room) and North, as well as the fission gas station.

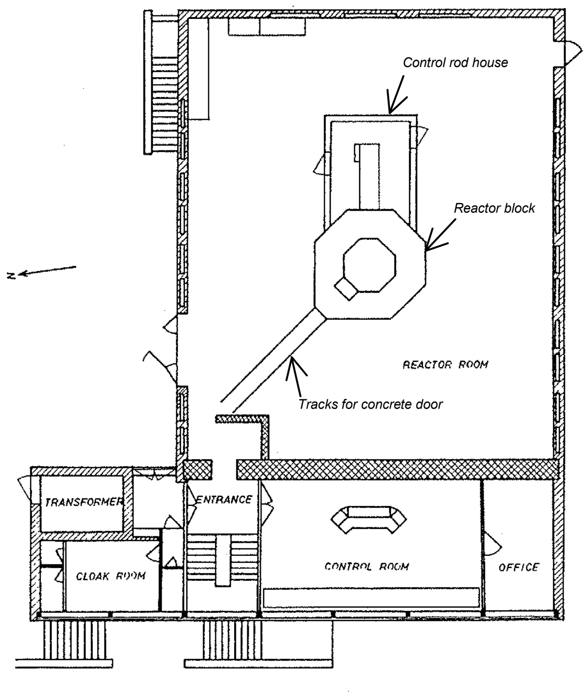

Figure 3 Horizontal cross section of the ground floor

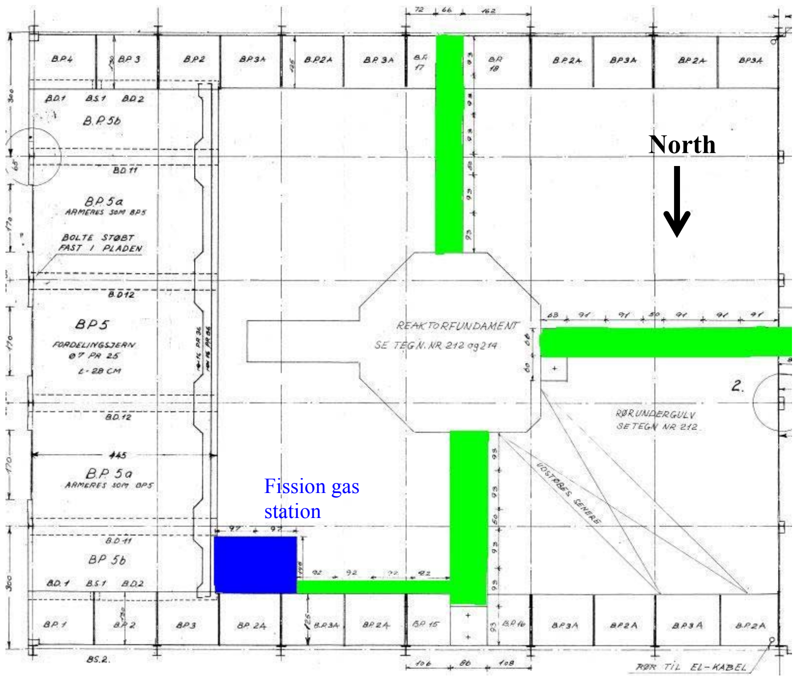

Figure 4 Sketch of the sub-floor structures in the reactor hall, showing the three channels (green) and the fission gas station (blue).

3 Initial conditions and preparatory work

In November 2002 the core solution was drained from the reactor into four stainless steel flasks and transferred to a storage facility at DR 3. Subsequently the core vessel and primary system were flushed with water to remove most of what was left of fuel solution.

In 2003 a characterisation project [6] was carried out in order to establish knowledge about the activity and its distribution in the reactor.

DR 1 did not have a special drainage system for contaminated water. Two wash-basins in the reactor hall drained to plastic bottles, which were brought to the Waste Treatment Plant when filled. But for the decommissioning it was decided to establish active washing and bathing facilities in the locker room on the first floor. The drainage system was rearranged so that the drains from the shower cabin and one wash-basin were led to a tank placed outside of the building on the western side.

4 Decommissioning approach and tools used

As mentioned in chapter 2, there were essentially only three components that could cause any concern with respect to radiation, namely the reactor vessel, the recombiner and the pipe connecting the two. Therefore, we chose the approach to remove these components as early as possible in order to reduce radiation levels for the remaining work.

4.1 Choice between the use of own staff and subcontractors

As a point of departure Danish Decommissioning has decided that as much as possible of the decommissioning work should be carried out by DD's own technical staff, many of whom have a long experience from the operation of the facilities. They thus both know the facilities and are experienced in work that involves radioactive materials and radiation. For DR 1 the majority of the dismantling work was carried out by two technicians, generally supervised by either the project leader or his deputy. For some operations one or two additional technicians assisted. DD's health physics staff supervised all operations.

For the demolition of the biological shield DD chose to let an external contractor do the work instead of acquiring equipment and educating our own staff. The presence of external staff required some extra instruction and supervision of the work in order to ascertain that the rules for work in radiologically classified areas were followed and that no material was taken away from the site without having been cleared.

4.2 Choice of methods of dismantling

Selection of decommissioning methods for DR 1 started when the first overall plans were drafted for decommissioning of all nuclear facilities at the site [4, 5]. At this point rough ideas about how to take apart the reactor were sketched and the required effort was assessed. A somewhat more detailed planning was made in the project description put forward for approval by the nuclear regulatory authorities. But the selection of precise approaches and tools to be used in the individual decommissioning operations to a large extent was made only during the detailed preparation of these operations.

In general, existing or off-the-shelf tools could be used, since there was no need for robots or other sophisticated remote handling equipment. In some cases special tools or modifications of existing tools were made in our own workshop. Only few items had to be bought.

4.3 Work planning

For each of the tasks involving work with radioactive materials or with systems that were connected to the primary system work plans were written and elaborated together with all those to be involved in the work. The extent of the work plans depended on the size of the task and the potential radiation doses that could be incurred.

Appendix 1 shows the work plan for removal of the control rods, cf. section 5.1.1, which was a relatively simple operation that would not result in significant doses to the workers. The plan, therefore, needed not be very extensive. The same applied to the removal of the external parts of the cooling system.

For the removal of the recombiner and the core vessel much more elaborate work plans were set up. Appendix 2 first shows the "text part" of the work plan for removal of the recombiner, then photos used as illustrations for the large Excel worksheet shown on page 69 with two somewhat better legible excerpts on page 70. The worksheet served as the primary planning and safety analysis tool for the two major dismantling jobs. In the first column are listed all individual tasks, very much down to the "nuts and bolts" level, and in the first row are listed all the factors that potentially had to be considered for each task. These factors include references to drawings, photos and other information as well as risks, radiation levels, necessary tools, personal protection equipment, waste container to be used, and the initials of the people to perform the task. The worksheet turned out to be an excellent tool in the planning and served as a quality assurance tool without being formally included in the QA system.

Before starting the two major dismantling jobs, formal assessments of the working place (Danish acronym: APV) were carried out by the safety group for DR 1 with a particular view to the "conventional" occupational safety. The planning for and surveillance of the radiological safety was taken care of by the Section of Applied Health Physics.

Planning for the demolition of the control rod house and the biological shield, including removal of the floor, was done together with the contractor, based on the specifications laid down by Danish Decommissioning when calling for bids for the work.

5 Dismantling- and demolition operations performed

5.1 Initial work

In July 2004 the authorities gave their consent to the dismantling of external non-active or only slightly active systems, such as the control rods and their drive mechanism and the secondary part of the cooling system.

5.1.1 Removal of control rods

Two of the four control rods had been taken out during the characterisation project and the dose rate at a distance of 10 cm measured to 60 µSv/h in the western end, which was the one that had received the highest neutron exposure. Therefore, brief direct contact with the rods did not present any problem, and they were just taken out by hand and transferred to plastic bags and subsequently placed in a container made for the purpose. Figure 5 to Figure 8 show some steps in the removal of the control rods. Radiation doses incurred to the operators were small.

Figure 5 Control rod being pulled out

Figure 6 Removing the pin connecting the control blade to the guide rod

Figure 7 Transferring a control blade to a plastic bag

Figure 8 Transferring a control blade to the special container

5.1.2 Removal of the external parts of the cooling system

There were three cooling loops; two for the recombiner and one for the core vessel. The secondary side of the cooling system was placed in the control rod house and consisted of two heat exchangers in addition to the pipes coming through the concrete shielding from the cooling coils in the recombiner and the core vessel. Figure 9 shows part of the secondary side of the cooling systems.

Prior to the dismantling the heat exchangers and piping were emptied for water. The water was collected in drums and samples were taken for γ-spectrometric analyses of possible content of radionuclides. No measurable amounts of radionuclides were found.

Dismantling was delayed somewhat, because it turned out that the insulation of the pipes contained asbestos. This required the contracting of an authorised company to remove the asbestos, observing all the safety precautions prescribed for this type of work. But thereafter the components were taken down without further problems.

After dismantling smear tests were taken from the primary sides of the heat exchangers and – to some surprise – traces were found of ^{60}Co in the samples from the core cooling system. However, the contamination seemed to be rather loose and attempts will be made to clean the component for clearance. Due to the somewhat complicated geometry of the component clearance can not be achieved on the basis of ordinary contamination measurements but γ-spectrometric analyses have to be done in the clearance laboratory.

Figure 9 Heat exchangers and cooling pumps. The system to the left belongs to the core cooling circuit, the one to the right to the recombiner cooling circuits.

5.2 Removal of the recombiner

The recombiner was taken out during October 2004. Contact dose rates at the surface of the recombiner were of the order of 5 mSv/h. So, brief contacts with hands in order to place tools or lifting equipment was by no means excluded. Spectrometric measurements had shown that the main (and probably only) source of the γ-activity was ^{137}Cs.

Figure 10 shows the recombiner seen from above. Its outside diameter is 270 mm and the height ~500 mm. The weight is about 30 kg. At the bottom a flange connected it to the pipe leading to the core vessel, cf. Figure 11. The recombiner rested on four feet that were bolted to two beams below, as can be seen in Figure 10. A number of cooling pipes and cables for measuring equipment and power supply were attached to the recombiner.

Figure 10 The recombiner seen from above

Figure 11 Flange at the bottom of the recombiner

5.2.1 Dismantling

In the initial planning it was contemplated to cut the connecting pipe between the recombiner and the core vessel by means of a hydraulic tool, which DD already had. The tool is able to seal the two ends cut away by pressing them before cutting in the middle. In this way the risk of releasing possible contamination would be minimised. However, test cuts on similar piping showed that the tool probably would not be powerful enough to press and cut the 2⅜" stainless steel pipe. Since a larger tool would be very expensive and since radiation levels were moderate, it was considered justifiable to disconnect the recombiner by opening the flange at the bottom and quickly replacing the two open ends with blind flanges. This operation was carried out without any particular problems; the bolts and nuts came apart easily. In order to reduce doses to the technicians, extension-shafts were used for the spanners.

No loose contamination escaped during the dismantling; but smear tests confirmed that there was a layer containing ^{137}Cs at the inside of the pipe and flange.

The hydraulic cutting tool served well, however, for cutting smaller pipes, such as the one seen in the lower part of Figure 10. Figure 12 shows the tool in action; as can be seen it can be operated remotely in cases, where it can be lowered, hanging in the hydraulic hose. The result of the cut can be seen in Figure 13.

Very small diameter pipes (≤ ¼") were cut with an ordinary wire cutter, as were power- and signal cables.

Figure 12 Hydraulic cutting tool in action

For transferring the recombiner to a waste drum it was first considered to simply attach lifting gear to some of the pipes protruding from the component. This probably would have worked well; but in order to ascertain that there would be no risk of dropping it during the transfer, a simple collar was made, which could be mounted around the recombiner in a couple of minutes, cf. Figure 13.

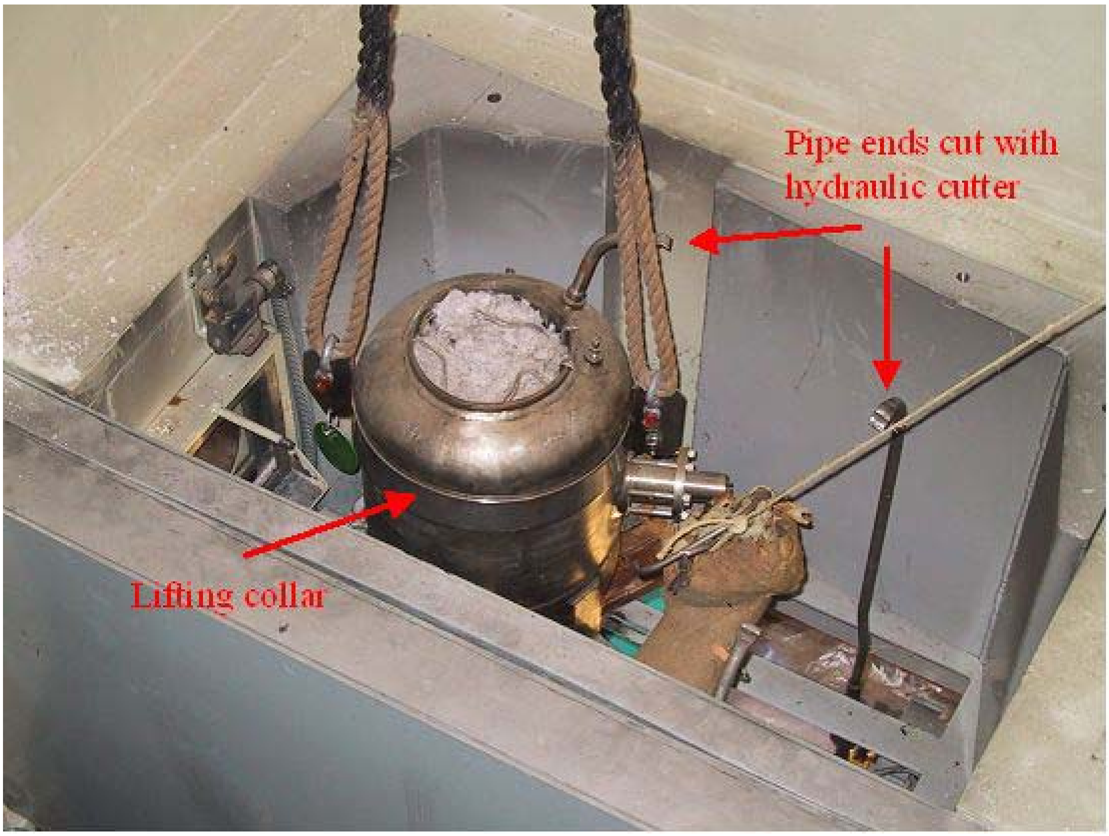

Figure 13 The recombiner ready for lifting

The recombiner was lifted out and placed in a shielded drum that was transferred to a shielded cell made of concrete blocks in the southern part of the reactor hall, cf. Figure 14. The lifting gear seen in Figure 13 was disposed of together with the recombiner in order to save doses to the personnel.

Figure 14 Photo taken from the overhead travelling crane.
The shielded cell is seen in the centre of the photo.

5.2.2 Radiation doses from the operations

Whole-body doses to the two technicians who carried out the work were measured to 102 and 30 μSv respectively (readings from their digital dosimeters). Doses measured with finger dosimeters were 500/650 and 150/100 μSv to fingers on left/right hand for the two. Doses to health physics technicians and various bystanders ranged from 1 to 24 μSv and summed up to a collective dose of 81 man μSv.

5.3 Removal of graphite reflector and core vessel

The core vessel was sitting in the middle of a tank, surrounded by the reflector. The reflector consisted of more than 300 graphite bars measuring 10×10 cm in cross section and having varying lengths between a few cm up to 126 cm. There were 13 layers, and the direction of the bars in each layer was perpendicular to that of the layers above and below. Figure 15 shows the top layer. The four ion chambers that were positioned in the three tubes shown in the figure were lifted out without any problems prior to starting the removal of the graphite.

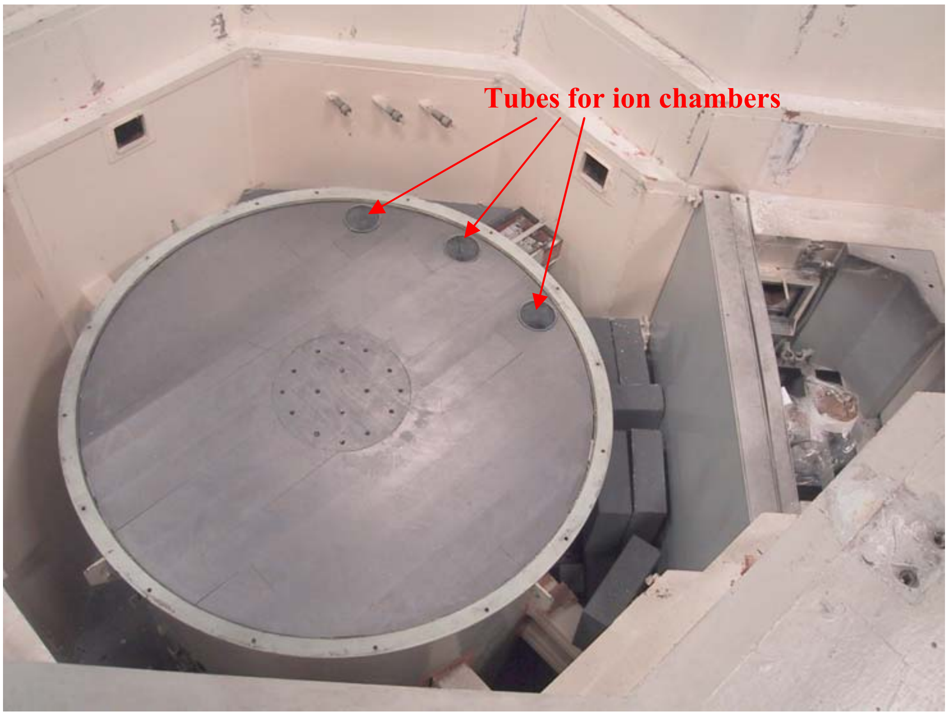

Figure 15 Reflector tank (and recombiner compartment to the right)

There were three pipes connected to the core vessel, which had to be removed before the vessel could be pulled out: the 2⅜" pipe leading to the recombiner, a ¼"drainpipe going from the bottom of the vessel and out through the reflector to the space below the recombiner, cf. Figure 1, and a 1" aluminium pipe going through a steel pipe that was welded into the core vessel. The aluminium pipe, which went through a stainless steel pipe that was welded into the core vessel, served to place small items in the centre of the reactor core for irradiation. This pipe could be pulled out fairly easily in pieces of about 20 centimetre's length, corresponding to the space between the reflector tank and the concrete shield.

5.3.1 Disconnecting the drainpipe from the core vessel

It was evident that in order to remove the core vessel at least seven layers of graphite would have to be taken out, and that the connecting pipe to the recombiner could be cut loose after the removal of six to seven layers. In order to minimize radiation doses to the personnel we wanted to find a way to disconnect the drainpipe at the bottom of the vessel without having to remove further layers of graphite. A number of possible approaches were considered:

1. Entering cutting tools through the two lower control rod channels and cutting the drainpipe just below the core vessel.
2. Drilling down through the core vessel (and the 2⅜" pipe coming out at the top) and drilling away the drainpipe in the bottom.
3. Drilling down through the graphite along the side of the core vessel after cutting the 2⅜" pipe away.
4. Drilling horizontally from the outside of the biological shield hitting the drainpipe below the core vessel.

5. Cutting the drainpipe where it protrudes from the reflector tank and pulling it (~75 cm) out together with the core vessel.
6. Drilling a 50 mm core through the graphite around the drainpipe, entering from the recombiner vault.

Advantages and disadvantages by the alternatives are summarised in Table 1.

Table 1 Assessment of alternative methods to cut the drainpipe

Nº	Advantages	Disadvantages
1	Could be done without any personnel doses. Attractive "smart" method.	Space was very restricted for entering tools and it was not possible to find the drainpipe when searching with an endoscope.
2	Could be performed at some distance using a special set-up. Low personnel doses.	Cooling coils inside the core vessel might be in the way. Requires the mounting of a stiff structure at the top of the reflector tank to keep the drill in line.
3	Could be performed at some distance and the active components could be shielded during the operation.	Setting up the drilling equipment will have to take place after six or seven layers of graphite have been taken out and will require the mounting of a stiff structure for the drilling machine.
4	Could be done without any personnel doses.	A long distance to drill (~225 cm) through concrete, steel and graphite. Risk of missing the target.
5	Easy approach.	Risk of failure (pipe stuck and potential damage to the core vessel). Considered too uncertain.
6	Relatively easy approach. Deviations from the correct direction could be monitored on the way by watching the cores taken out (~each 20 cm).	Radiation doses to technicians during mounting of equipment and during drilling. Spreading of graphite dust outside the reflector tank.

At the end alternative 6 was selected. The drilling could be carried out by means of already existing equipment. A frame was welded to the wall of the reflector tank for mounting of the drilling machine. Figure 16 shows the set-up at the start of the drilling. As far as possible, the graphite dust generated was caught at the entrance hole by a vacuum cleaner; but some (slightly active) dust found its way to the floor outside and caused some contamination. Nevertheless, the operation was considered very successful; the drill followed the correct direction and the drainpipe was cut exactly where it was supposed to be cut.

Figure 16 Drilling a core around the drainpipe

5.3.2 Removing the reflector and the core vessel

The characterisation project that had been carried out prior to the decommissioning itself indicated that the radiation level around the core vessel would be of the same order of magnitude as around the recombiner, i.e. ~5 mSv/h. The level at the top of the reflector was measured to 50-150 µSv/h before removal of the graphite started. It was, therefore, desirable to remove the graphite elements by some kind of remote handling.

Since the graphite elements had a very smooth surface and were not too heavy (the longest ones weighed around 23 kg) it was decided to investigate the possibility for using suction pads to lift out the elements. Three suction pads each with a diameter of 75 mm were bought and mounted on a beam as shown in Figure 17. Tests carried out in the workshop showed that the lifting capacity of the three was at least 75 kg. So, in principle one suction pad should be able to lift the heaviest of the graphite bars. We, therefore, decided to use this approach.

Two technicians operated the system: one stood at the top of the biological shield and manoeuvred the beam with suction pads into position by means of a long rod, and the other operated the air supply for the suction pads and the swinging crane used for lifting out the graphite elements and transferring them to the roof of the control rod house, cf. Figure 18 and Figure 19. Here each element was weighed, measured and registered. This kept two other people busy in addition to a health physics technician who surveyed the working environment and performed measurements of the radiation from each element. Finally the graphite elements were transferred to pallet containers, which were later transferred to the "Centralvejslageret". The meticulous registration was carried out with a view to being able to sort the elements into active and potentially non-active that could be cleared. As it turned out, there seemed to be activity levels above the perceived clearance levels in most of the elements (at the time of taking out the elements clearance levels had not yet been issued by the authorities). In order to reduce radiation levels during the operation bags with lead pellets were used to shield the core vessel, cf. Figure 17.

Figure 17 Beam with suction pads

Figure 18 One of the longest stringers

Figure 19 Registering data for a graphite stringer

After the removal of seven layers of graphite and parts of the eighth layer the 2⅜" pipe could be cut loose from the core vessel and a mounting could be fixed for lifting out the core vessel. After the removal of another layer the vessel could be lifted out and transferred to a shielded waste drum, cf. Figure 20. The weight of the core vessel was about 5 kg. The radiation level at the surface of the vessel was about 4 mSv/h.

Although the radiation level had decreased in the reflector tank after the removal of the core vessel, also the remaining layers of graphite were taken out by means of the suction pads and manoeuvred from the top of the biological shield. However, now it was more acceptable that the technician stepped down into the tank to force free graphite bars that were stuck together – this was the case in particular for the first bar to be taken out from a layer. Fortunately, it was mainly in the lower layers that this problem occurred.

In general, the lifting out of the graphite elements went surprisingly smooth. On the average it took about 1½ hour to take up one layer, consisting of about 30 individual bars.

Figure 20 The core vessel ready to be lifted out

5.3.3 Removal of the reflector tank

After being emptied and cleaned for graphite dust the reflector tank was lifted out and placed in an open space in the reactor hall. It is somewhat activated and has to be deposited as radioactive waste. In order to reduce volume it was cut into smaller pieces. As DD already had a nibbling machine that could cut this thickness of plate (6 mm carbon steel), this method was chosen because it does not produce any sparks or dust. Only the top flange had to be cut with a right-angle grinder. The cutting went very quickly, and the shroud of the tank was cut into pieces of ~50×80 cm. The bottom, which is somewhat thicker, was stored in one piece in the shielded cell in the southern part of the reactor hall until further.

5.3.4 Radiation doses from the operations

The whole-body radiation doses received by the two technicians who performed the majority of the work were 338 µSv and 130 µSv, respectively, as read from the digital dosimeters. Doses measured with finger dosimeters were 200/200 and 150/150 µSv to fingers on left/right hand for the two. Other participants received a total whole-body dose of 122 µSv. The collective dose as read from the digital dosimeters was 590 man µSv.

Figure 21 The nibbler and the half-cut reflector tank

5.4 Dismantling of the fission gas station

The fission gas station served to store fission gases produced in the reactor in order for the pressure in the reactor not to increase above the limit of 5 psi. The fission gas station, shown in Figure 22, was located in a shielded pit below the floor in the northern side of the reactor hall, cf. Figure 4. Two storage tanks were in operation at a time. Once a year gases were pumped from the reactor to the storage tanks. The following year the gases in the tanks were emptied via a carbon filter.

Figure 22 The fission gas station

Apart from the components shown in Figure 22 the system comprised ordinary carbon steel piping connecting the fission gas station to the reactor system. The piping was joined by means of ordinary fittings and was thus easily dismantled. There was no significant external radiation from the components. However, measurements on a cut-off sample of the piping indicated that there was a level of ^{137}Cs close to the clearance limit. The components, therefore, were marked for decontamination and clearance measurements in the clearance laboratory.

5.5 Removal of the Fuel Drain Tank

The Fuel Drain Tank was a stainless steel cylinder, 109 cm long with a diameter of 18 cm. The geometry was criticality safe, but as an extra precaution the tank was wrapped with a layer of cadmium. The tank was placed in a vertical concrete pipe below the mobile concrete wall. Two 1¼" pipes connected it to the primary reactor system, cf. Figure 2.

The two connecting pipes could easily be cut by a wire cutter, and then the tank could be lifted out. As can be seen from Figure 23 the cadmium wrapping had disintegrated rather much and had to be handled with care due to its chemical toxicity.

Figure 23 The Fuel Drain Tank

Radiation measurements near the bottom of the vertical pipe where the Fuel Drain Tank had been standing did not show increased radiation. Therefore, it was assumed until further that there was no contamination in the pipe, and further work on the pipe, including removal of the pieces of 1¼" piping going through it, was postponed until after the demolition of the biological shield, see section 5.10.

It had been expected that the Fuel Drain Tank would be empty, since no reports had been found to indicate that it had been in use. But radiation measurements showed that there was some core fluid in it. It was, therefore, taken to the decontamination facility at DR 3 where a drain valve was inserted. About 0.125 l of core solution could be drained from the tank, which was subsequently cut in two pieces in order to examine the possibility for decontaminating it. As can be seen from Figure 24 the inner surface appears quite clean; the fluid that can be seen is cutting fluid. The tank will be decontaminated in Danish Decommissioning's new decontamination facility once this facility is operational. It is expected that the tank can be cleared as non-radioactive waste after decontamination.

Figure 24 The Fuel Drain Tank cut apart

5.6 Decontamination of a storage well

Under the floor in the southern part of the reactor hall there was a concrete shielded well for storage of the annual core samples that had been analysed and were waiting to be returned to the core the following year. Also other small radioactive items had been stored there. The position of the well was under the yellow mark seen in the centre of Figure 14 on page 14 (the yellow mark indicates a position for routine measurements carried out by the health physics technicians during operation of the facility). Apart from the well itself there were two 2" steel pipes into which small items could be stored, see Figure 25 and Figure 26.

Due to a leak in one of the bottles with samples of the fuel solution – and probably to other spillages in the course of time – there was some contamination at the bottom of the well and down the inner sides. The concrete at the sides and in the bottom was chiselled away until no further contamination could be detected with the hand-held contamination monitors (CoMo 170/300 and Eberline E 600). The concrete thus chiselled away was disposed of as radioactive waste.

The two 2" steel pipes could be taken up fairly easily. Smear tests revealed some contamination in one of the pipes, but it is expected that they can both be cleared as non-radioactive waste.

Figure 25 The well under the floor being demolished

Figure 26 The two storage pipes

5.7 Examination of activation and contamination in the remaining reactor structures

After the reflector tank had been taken out a number of core drillings were made in the concrete shielding from within the reactor cave and in the concrete floor below the reflector tank, in order to establish the activation levels and distribution in the concrete. The drilled-out cores were cut into smaller slices and analysed by γ-spectrometry. Samples were also taken from the experimental channels going through the concrete from the North and the South face. The results, which are reported in [7], showed that it was only necessary to cut away the innermost 10 to 20 centimetres of concrete in order to clear the rest. The steel plates that were sitting at the inside of four of the eight inner faces of the concrete shield had to be deposited as radioactive waste. Activation was also found in the inner parts of the experimental channels and it was, therefore, decided to deposit all of these as radioactive waste.

5.8 Preparations for the demolition work

Before demolition of the control rod house and the reactor block could start, all radioactive material that had been temporarily stored in the reactor hall was removed from the hall. Furthermore, all equipment and tables etc. that were not necessary for the demolition were taken out, subsequent to contamination control.

When everything had been removed the floor was cleaned and surveyed for contamination with a floor monitor, as shown in Figure 27. A number of contaminated spots were identified and marked with yellow paint, such as those shown in Figure 28, which were located just below the Fuel Mix Bowl. Here radioactive fuel samples, which were taken annually for analysis, had been returned to the system – and apparently sometimes with a shaking hand. Also other contaminated spots could be related to the handling of samples of the fuel solution. Some of the contaminated areas were removed by cutting away the affected parts of the floor. Other parts were covered with plastic and wooden plates, since we had decided to keep most of the floor in place during the demolition work; only the floor in a distance of about 1 metre from the reactor block was taken up in order to allow trays for collecting the cutting water to be placed as low as possible on the block, cf. section 5.9.2..

Figure 27 Survey of wooden floor

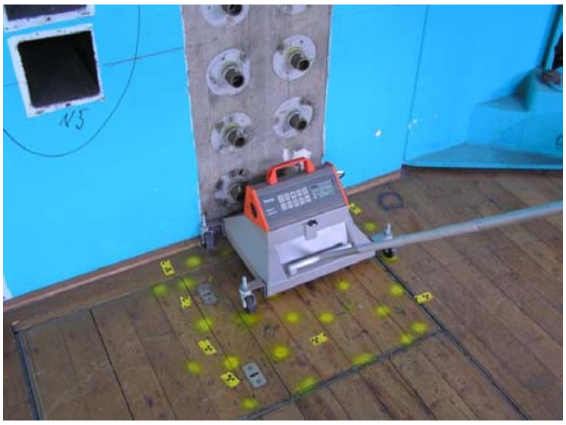

Figure 28 Contaminated area under the Fuel Mix Bowl

5.9 Demolition of the biological shield and other structures

The demolition of the control rod house, the concrete shielding as well as the removal of the wooden floor was performed by an external demolition contractor. Five Danish demolition companies were asked to give bids for the work (as one package) and four valid bids were received. Apart from the price, a very important parameter in the choice of contractor was their good record with respect to quality assurance. The contractor chosen was G. Tscherning A/S, who brought in MT Højgaard as a subcontractor to perform wire cutting of the concrete shield.

5.9.1 The control rod house

The walls and ceiling of the control rod house had not been exposed to neutrons but only to possible contamination. Therefore, it was chosen to start the demolition here after a check of all surfaces for contamination. In particular the roof had to be checked, because handling of the graphite stringers from the reflector took place here – and earlier in the reactor's history contaminated objects might have been placed there. The contamination control (cf. section 9.2.2) did not reveal any contamination, but unfortunately due to a misunderstanding (and poor quality control at the time) only the inner sides of the walls were checked, and this was not discovered before the house had been broken down. Therefore, the rubble from the walls had to be stored for later measurement in the F-lab (Clearance Laboratory) in order to document that they were free of contamination.

The roof of the control rod house consisted of a number of concrete slabs that could be lifted off and taken out in one piece. The walls, which were ordinary brick walls, were broken down by a demolition robot, as shown in Figure 29. The roof was disposed of as ordinary concrete waste at a waste dump outside the Risø area, and the rubble from the brick walls was stored in two containers, waiting for measurement to be carried out later.

Figure 29 Demolition of the control rod house

5.9.2 The biological shield

The method chosen for breaking down the biological shield was wet wire cutting combined with drilling away some of the experimental channels and hammering away the foundation for the shield and the reactor, where wire cutting could no longer be applied. The rationale for choosing wire cutting instead of other methods of demolition was a wish to be in better control of the origin of the concrete waste when it was to be sorted in waste that could be cleared and radioactive waste. As described in section 9.2.3 and in [7], the clearance of the concrete from the biological shield was based on the activity profile measured on drilled-out cores. The blocks were marked and numbered before cutting them away so that the reference between a given concrete block and the corresponding drill core could be maintained.

The rationale for preferring wet wire cutting to dry cutting was mainly economical. The cost of dry wire cutting would be higher due to a higher cost and possibly shorter lifetime of the wires used. Furthermore, dry wire cutting would necessitate the use of a tent around the block, whereas it was anticipated that the cutting water from wet cutting could be contained without needing a tent. After the closest 1 metre of wooden floor around the reactor block had been removed, trays were mounted at the foot of the walls of the block to collect the cutting sludge, which then was pumped to sedimentation tanks where the concrete could settle and the water could be recycled to the cutting machine. Furthermore, plastic curtains were mounted around the cutting machines and the cut in order to contain sprays of water. In general this arrangement functioned well, despite a few mishaps, e.g. a hose leading to the sedimentation tanks falling off and some litres of water running onto the floor.

After stripping the reactor block for all equipment (electrical outlets etc.) the cutting lines were drawn up on the walls, and the blocks were numbered, as shown in Figure 30. The vertical cuts were made in the eight corners of the octagonal block, as illustrated in Figure

31 and Figure 32. The maximum size of the concrete blocks to be cut away was determined by the lifting capacity of the crane, which is 5 tons. With a concrete density of 3.6 t/m^3 this leads to a maximum volume of about 1.4 m^3.

Figure 30 Horizontal cutting lines and block numbering on the south-western face

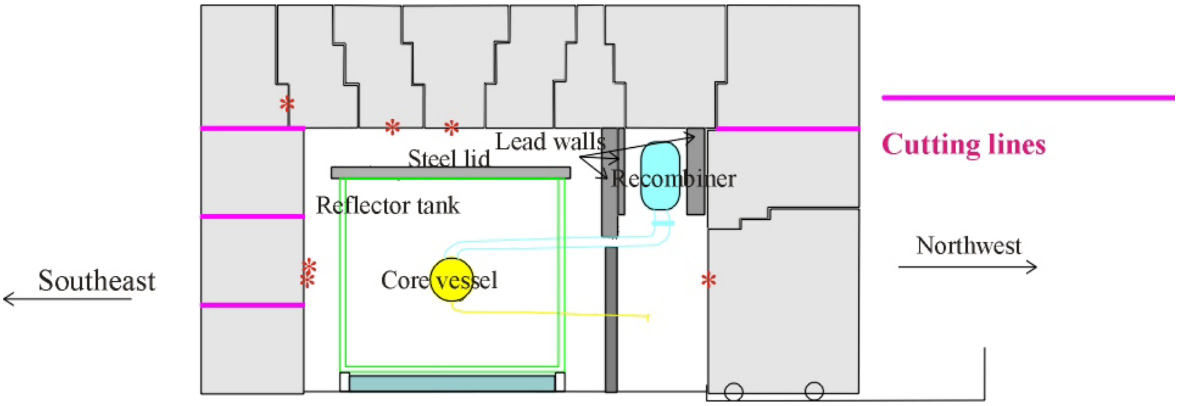

Figure 31 Horizontal cutting lines

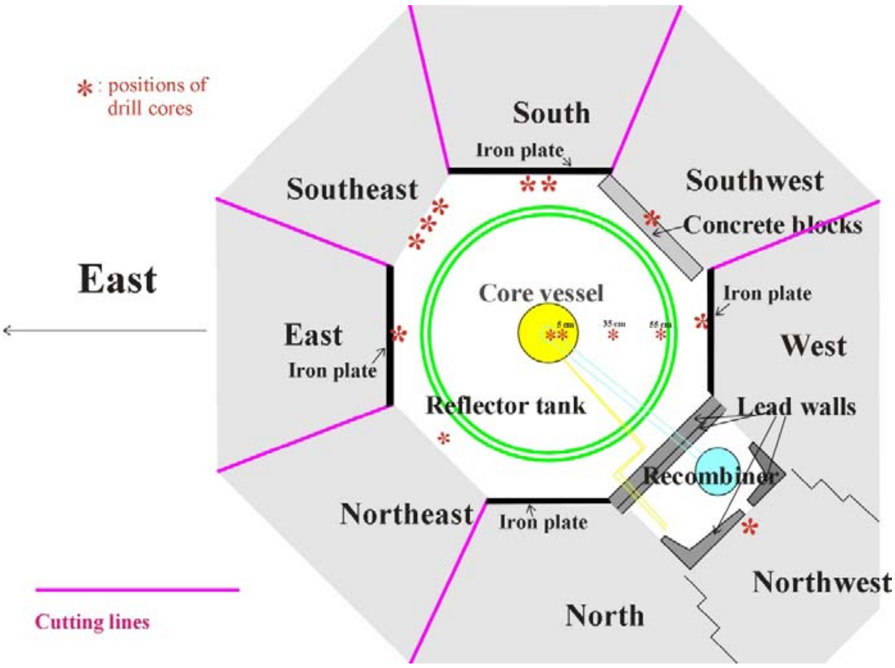

Figure 32 Vertical cutting lines

The first cuts to be made were cutting away the two blocks of experimental channels from the southern and the northern face, respectively. These blocks were cut out and disposed of as radioactive waste altogether, even though some of the concrete and the outer parts of the steel channels might have been cleared. Figure 33 and Figure 34 show how the cut of the four channels on the northern face was made. Figure 34 also shows that the first cut thereafter was cutting away the concrete above the movable concrete "door" to the recombiner vault, in order to facilitate access to the reactor cave. The cutting technicians had to go in there in order to mount the wire for a new cut. Figure 35 and Figure 36 illustrate the drilling-out of individual experimental channels.

Figure 33 Cutting the four experimental channels on the northern face

Figure 34 The block has been opened by cutting away the block above the "concrete door"

Figure 35 Channel on the western face being drilled out

Figure 36 A look through the upper channels on the northern and southern face

Thereafter all the vertical cuts in the corners of the octagonal block were made with the driving mechanism for the wire placed on top of the block, thus pulling the wire upwards while cutting. Subsequently, the horizontal cuts were made – often without removing the cut-loose blocks at once, as illustrated by Figure 37. Also shown in Figure 37 are some of the trays that were used for collecting the cutting water. The trays were made to fit to the bottom of the walls, and the gaps between tray and wall were sealed by means of foam. Reasons for not removing the blocks at once were the constrained space in the reactor hall and a wish from the contractor to get most of the wire cutting done before starting the cutting away of the inner, activated parts of the blocks, which was done by means of a circular saw, shown in Figure 38. This saw was placed in the western end of the reactor hall. Figure 39 shows a block after removal of the inner part that contained activity above the clearance levels.

Similar to the experimental channels the concrete surrounding the valve arrangement, which can be seen in the foreground on the left hand side of the block in Figure 34, was cut out in one piece and stored as radioactive waste. Inside the concrete block are the pipes leading from the Fuel Mix Bowl, containing traces of fuel solution, and on the inner side of the block the steel parts closest to the reactor core were activated above the clearance levels.

When concrete blocks had to be moved outside the reactor hall, either to be stored in an ISO container as radioactive waste or to be stored outside the building for future release, cf. chapter 7, cutting work was stopped. No cutting activities were permitted while the gate to the building was open.

Figure 37 Vertical and horizontal cuts in the reactor block. In the foreground trays used for collecting cutting water.

Figure 38 Circular saw cutting away the activated inner slab

Figure 39 Free-releasable block after removal of the activated slab

Wire cutting could only be done until approximately 10 centimetres above the floor level. Thereafter a "Brokk" hydraulic demolition robot was used to chisel away the concrete. In order to prevent the dispersion of dust in the hall, at tent was set up for this operation. The tent was equipped with filtered ventilation, cf. Figure 42.

Figure 40 The foundation of the reactor block

Figure 41 The tent being set up

Figure 42 Ventilators with HEPA filters

Figure 43 The Brokk demolition robot

The first concrete to be excavated was that, which was known to be activated, i.e. the central part where the reflector tank had been standing, and the inner 20-25 centimetres of the foundation of the biological shield. The depth to which excavation had to be done was determined on the basis of analyses of samples taken underway, cf. section 9.3.3.

As can be seen from Figure 44, local extraction ventilation was set up close to the chisel. The excavated material was transferred to big bags, cf. Figure 45, which were subsequently stored as radioactive waste in an ISO container. Once the analyses of samples showed that the activity content in the remaining concrete was so low that there was a high probability for it to be cleared, all loose rubble was transferred to the big bags. The remaining concrete in the foundation of the biological shield was excavated as ordinary concrete waste, however, still subject to control before being cleared – every batch that was taken out by a "mini dumper" was scanned with a radiation monitor. The concrete was chiselled down to the same level as the surrounding foundation for the floor. The further handling of the concrete is described in chapter 7.

Figure 44 The central parts below the reactor being excavated

Figure 45 The demolition robot in action. Two big bags with excavated material in the background

5.9.3 Removal of the floor

After completion of the demolition of the biological shield and the concrete below the reflector tank the wooden floor was removed. Prior to removal, however, the whole floor was surveyed once again with a floor monitor and contaminated spots were identified. The contamination probably originates from spillages of small amounts of fuel solution in connection with the annual sampling. The samples were tapped into plastic bottles, which were carried to the storage well, mentioned in section 5.6, and a number of contaminated spots were found on the way from the recombiner vault (where the tapping took place) to the storage well. The contaminated areas were marked with yellow paint and cut away and stored as radioactive waste before the rest of the wooden floor was taken up, cf. Figure 46.

Figure 46 Contaminated parts have been cut out from the wooden floor. In the background a section of floor boards have been taken up.

Figure 47 Control measurement of the layer below the wooden floor.

After the removal of the wooden floor, the sub floor (floor beams with concrete in between and a layer of tar cardboard on top) was checked with the floor monitor, see Figure 47.

Again, some contaminated spots were found, indicating that some of the spillages had been sufficiently big to penetrate the wooden floor boards. The contaminated parts were removed before the demolition contractor was allowed to break up the sub floor, see Figure 48 and Figure 49.

Figure 48 Checking for contamination in the sub floor.

Figure 49 Removal of a contaminated area of the sub floor.

After the sub floor had been removed (Figure 50) the concrete base layer remained, and this was the condition in which it had been agreed with Risø National Laboratory to leave the floor. However, a further contamination check was carried out in the locations where contamination had been found in the sub floor. In some of these places contamination had, indeed, penetrated to the base layer, and concrete was chiselled out until the contamination was below the background level, Figure 51. Appendix 5 holds the original report in Danish of the measurement procedure during the removal of the floor.

Figure 50 Removal of the sub floor

Figure 51 Checking that material from the concrete base is free of contamination.

5.10 Removal of remaining piping to the Fuel Drain Tank and decommissioning of the concrete pipe

After the concrete demolition had been completed, DD's own staff undertook to remove the top steel collar of the concrete pipe where the Fuel Drain Tank had been standing, including the two pieces of ¼" piping that went through the collar. One of the penetrations where the pipes went through can be seen at the lower part of the collar in *Figure 53*

Figure 52 The collar on top of the FDT pipe being lifted out

Figure 53 The collar with penetrations for ¼" pipes

Unfortunately, some fuel solution must have been trapped in one of the ¼" pipes and have leaked out when attempts were made to pull the pipes out (prior to lifting out the steel collar), because the concrete pipe turned out afterwards to be contaminated, both along the sides and at the bottom. The pipe, which was 2.10 metres deep, is shown in Figure 54. It seemed to be composed of sections of glazed sewage piping. A number of methods to wipe off the contamination were attempted, ending up with the use of a drilling machine with steel brush mounted on a long shaft, as shown in Figure 55. By means of this tool the contamination could be removed so that the pipe could be cleared on the basis of measurements with a contamination monitor [1].

Figure 54 The pipe where the Fuel Drain Tank had been standing

Figure 55 Tool for decontaminating the pipe

5.11 Decontamination in channels below the floor

The three channels below the floor that extended from the reactor block to the South, West and North were checked for contamination by means of handheld contamination monitors. Since some contamination had already been detected on the floor above both the northern and the southern channel, it was not surprising to find contamination in the channels, too. In particular in the northern channel, just below the Fuel Mix Bowl, it had been expected that some fuel solution would be found. It was somewhat more surprising that contamination, mainly ^{137}Cs could be detected on large parts of the bottom of the southern channel. In both cases the contamination had penetrated a few centimetres into the concrete and could be chiselled away (although it might have been an advantage having a "scabbler" for this task).

Figure 56 Contamination measurement in the northern channel, below the Fuel Mix Bowl

Figure 57 Contaminated concrete being chiselled away (northern channel)

Figure 58 Extent of contamination in the northern channel

Figure 59 Decontamination work going on in the northern and the southern channel

Figure 60 Contaminated parts in the southern channel marked by yellow spray paint

Figure 61 The southern channel after decontamination

The concrete rubble that had been chiselled away from the channels as well as the bags from the vacuum cleaners was disposed of as radioactive waste.

No contamination was found in the channel going to the west (towards the control room).

5.12 Cleaning of the reactor hall

Before the clearance measurements of the reactor hall were initiated, all surfaces except the floor were cleaned by a professional cleaning company. The walls, the ceiling and the travelling crane were first vacuum-cleaned and then washed. The floor had been vacuum-cleaned in advance, but much (non-active) concrete dust inevitably remained.

Prior to the cleaning of the hall some tests had been carried out in order to determine the degree of cleaning necessary. Selected areas of the wall were measured with contamination detectors before cleaning and after various degrees of cleaning. As a matter of fact, these measurements showed that there was no contamination, neither before cleaning nor after (fortunately!). However, it was decided to carry out the cleaning anyway – if not for any other reason then in order to remove ordinary dust collected during 48 years. But only the modest cleaning method mentioned above was used.

6 Radiation protection and safety

6.1 Radiation protection of staff

All non-routine operations involving radiation were supervised by a health physics technician. In cases where the radiation field was well known, work could be performed without this supervision. All DD personnel working in radiation fields wore TL dosimeters as well as digital dosimeters. In addition, the technicians performing the dismantling work described in chapters 5.2 and 5.3 wore special dosimeters at fingers, around the wrists and at the front of the head, as appropriate.

For the two major pieces of radiation work, described in chapters 5.2 and 5.3 the total doses registered by the digital dosimeters were 440 and 160 µSv to the two most exposed technicians and 203 µSv to the other participants together, giving a collective dose of 803 man µSv. Minor doses have been incurred by other operations so that the total collective dose as measured by the digital dosimeters are not very much above 1 man mSv. In addition, there will be the doses to fingers and hands for the technicians who performed the dismantling. The readings from the finger dosimeters used by the two technicians who performed the work were 750/850 µSv and 300/350 µSv to fingers on left/right hand, respectively.

All staff from the contractors who carried out the concrete demolition wore TL dosimeters. Mainly for their personal reassurance, they were asked to deliver urine samples before the demolition work started and after its completion. They all did so, and the analysis of the urine samples did not show any signs of intake of radionuclides during the work. Furthermore, they were all – including the "reserves" – given a three-hour introduction to health physics and work in classified areas before they started.

Contrary to expectations, two of the contractor staff who carried out wire cutting achieved measurable doses on their TL dosimeters for one month. The doses measured for skin dose and penetrating radiation were 1.0/0.3 mSv for one of the men and 0.25/0.2 mSv for the other, i.e. not very much above the detection limit. The doses of penetrating radiation can be explained by the fact that they have been working inside the reactor cave for some time when they were mounting the wires for a new cut. The high skin dose measured for one of the men seems to have its explanation in the fact that at some time his dosimeter had fallen into a tray with cutting sludge. Thereby the sludge could have penetrated into the dosimeter house and come into direct contact with the TL pellets, which were then exposed permanently to the (low) activity content in the sludge. Unfortunately, this information did not come to our knowledge before a long time later, and it could not be said at which day the incident had happened, and no estimate could, therefore, be given of the time that the pellet had been exposed to the cutting sludge. But visual examination of the dosimeter house confirmed that there had been sludge inside.

6.2 Occupational accidents or incidents

With respect to other safety issues no major incidents have occurred. Protective clothing and helmets have been worn as required. A couple of minor accidents are worth mentioning, however, in order to learn from them.

One happened during the dismantling of the Fuel Drain Tank when the technician cut his hand on a protruding end of one of the ¼" pipes that had been cut with a wire cutter and thus had a rather sharp edge. The technician, who was one of DD's own staff, was aware that there was a contamination risk and went to the nurse at Risø National Laboratory who cleaned the wound and checked it for contamination without finding any.

A somewhat similar accident happened for one of the contractor's wire cutting operators who cut his hand on the wire. Contrary to the DD technician he wrapped a piece of (dirty) cloth around the hand and continued working. Fortunately DD's health physics technician observed the improvised bandage shortly after and ordered the man to go to Risø's nurse to have the wound cleaned and checked for contamination. Also in this case no contamination was found, but the incident underlines that special care should be taken to ensure that external staffs are aware of the particularities in work in classified areas and that they follow the rules.

6.3 Impact on the surrounding population and environment

Contamination measurements in the immediate vicinity of the reactor building, reported in [1], show that the decommissioning activities have not resulted in any contamination there. It is, therefore, concluded that there has been no impact further away from the building.

Wastewater from the bathroom was collected in a tank from which it was taken to the treatment plant for radioactive waste in order to be processed in the distillation plant. During the demolition of concrete the waste water became slightly contaminated, but it is expected that after distillation no excess contamination has entered into the environment from DR 1 via wastewater.

Observations during the dismantling and demolition work have not revealed any other types of impact to the surrounding population and environment, such as noise and dust – and no complaints have been received.

7 Waste handling

As the intermediate storage hall was not yet available at the outset of the decommissioning of DR 1, a shielded cell with a wall thickness of 60 cm was erected in the reactor hall for storage of the more active parts from the dismantling, such as the recombiner and the core vessel. The cell was constructed from standard 60×60×30 cm blocks of heavy concrete. Less active parts, such as the graphite, was placed in aluminium pallet containers (120×80×40 cm) in the reactor hall. The cell and some of the pallet containers can be seen in Figure 14. All waste items from the dismantling phase that could not be cleared on-site were moved to the buffer storage hall or the "Centralvejslageret" before demolition of the concrete began.

All waste items were marked with a number and registered on a form such as the example shown in Appendix 4. The waste was sorted into four categories:

1. Waste that without doubt has to be disposed of as radioactive.
2. Items that possibly could be decontaminated.

3. Items that are potentially non-radioactive i.e. have a content below the clearance limits.
4. Items that could be cleared on-site on the basis of analyses of samples for items that might have been activated, or based on measurements of surface contamination for items that had not been exposed to activation and where all surfaces could be measured with a contamination monitor.

The items in category 1 comprised the equipment from the reactor system itself (core vessel, recombiner, reflector graphite and miscellaneous piping), the inner parts of the biological shield and the concrete removed from below the reflector tank. The most active ones, i.e. core vessel, recombiner and some pipes, were transferred to shielded steel drums, which were placed in the above mentioned cell and later in a cave in the "Centralvejslageret". The less active items, such as the concrete slabs and rubble, were placed in an ISO container like the one shown in Figure 62. All items were wrapped in plastic foil or otherwise before being brought out to the containers outside of the building (the containers were too big to bring inside). The graphite stringers from the reflector were placed in pallet containers, which are temporarily stored in the "Centralvejslageret", not because they are very active but because the intermediate storage hall was not ready to receive waste at the time it was necessary to remove it from DR 1.

Figure 62 ISO container for storage of DR 1 waste in the buffer storage hall

There were only a few items that were placed in category 2, items that could be decontaminated, for example the Fuel Drain Tank and the heat exchanger, mentioned in section 5.1.2. These were wrapped in plastic foil and either brought directly to the AH hall1 at DR 3 or placed in an ISO container for storage at the buffer storage hall.

The items in category 3, "potentially non-radioactive", were wrapped in plastic and placed on flat pallets or in pallet containers, which were subsequently placed in an ISO container for storage at the buffer storage hall until the clearance laboratory is ready to measure them.

Items in the last category that had not been subject to activation were handled in the way that has been the routine during the operational phase of the reactor (and the other facilities

1 AH=Active Handling

at Risø National Laboratory). Material from the biological shield was cleared on the basis of measurements on samples taken, as described in chapter 9.2.3 and in [7].

The DR 1 project started – and ended – before all auxiliary facilities were available, such as the intermediate storage hall, the clearance laboratory, the activity measurement laboratory and the waste documentation system. Therefore, many aspects of the decommissioning, in particular the waste handling, were carried out in an ad-hoc manner. This may lead to some more work later, for instance in bringing the data for waste items into the waste documentation system and in preparing items for measurements in the clearance laboratory. It has not, however, resulted in loss of control of waste items or unsafe situations.

7.1 Amounts of waste produced

The tables in this chapter show the most important waste items produced by the decommissioning of DR 1, subdivided according to the four categories mentioned on page 37.

7.1.1 Primary decommissioning waste categorised as radioactive

This group comprises all the components and materials that have been activated above clearance levels or that have been contaminated by the fuel solution.

Table 2 Radioactive waste items produced

Waste item	Weight [kg]	Material	Surface radiation level [µSv/h]	Stored in
Control rods	15	Steel, boron carbide	600	Special container at CVL*
Top cover of reflector tank	200	Steel	30	A cave at CVL*
Reflector tank shroud (cut up)	325	Steel	50	A cave at CVL*
Reflector tank bottom plate	200	Steel	150	A cave at CVL*
Recombiner	35.0	Stainless steel	~5,000	A shielded drum at CVL*
Core vessel	5.5	Stainless steel	~4,000	A shielded drum at CVL*
Valves and piping from the primary system	22.8	Stainless steel	2 - 1000	A shielded drum at CVL*
Plugs from experimental channels	896	Steel	1 - 200	ISO container at the BSH**

Waste item	Weight [kg]	Material	Surface radiation level [µSv/h]	Stored in
Graphite from the reflector	4,141.0	Graphite	1-8	Pallet containers at CVL*
Concrete blocks with experimental channels	5,479	Concrete/iron	<100	ISO container at the BSH**
Cut-off slabs from the biological shield	13,162	Concrete/iron	<100	ISO container at the BSH**
Shielding blocks from the reactor cave	2,060	Concrete	1 – 15	ISO container at the BSH**
Miscellaneous concrete (rubble and flagstones)	10,010.5	Concrete	1	ISO container at the BSH**
Contaminated parts from floor	831.0	Wood	<1	ISO container at the BSH**
Miscellaneous	140.6	Steel, aluminium, wood, concrete, glass wool	1,5 - 8	BSH**
Total weight	**37,523.4**			

*CVL = Centralvejslageret ("The Central Road Storage")
** BSH = Buffer storage hall (same building as the Intermediate Storage Hall)

The amount of active waste is substantially larger than an early estimate of 2 m^3 [4]; if all waste were magnetite concrete the volume would be 10 m^3. One reason for the large difference is the fact that we have been conservative in determining the thickness of the slabs to be cut off on the inner side of the biological shield, and also that no large effort has been invested in segregating active and non-active parts of the concrete rubble.

7.1.2 Primary decommissioning waste categorised as possible to decontaminate

This group comprises items that are only slightly contaminated. By mass it is dominated by a lead flask that was used for shielding power reactor fuel pins, which were being examined by means of neutron radiography at DR 1. The inner pipe in this flask has been contaminated by fission products from the surface of the fuel pins.

Table 3 Waste item stored for decontamination

Waste item	Weight [kg]	Material	Surface radiation level [µSv/h]	Stored in
Miscellaneous concrete	75.0	Concrete	max 2	ISO containers at the BSH**
Fuel Drain Tank	36.0	Steel	<1	Decontamination facility in the AH hall at DR 3
Fission gas system	139.0	Steel	1	ISO container at the BSH**
Lead flask	3,800.0	Lead	<1	The AH hall at DR 3
Wood from floor	274.0	Wood	<1	ISO container at the BSH**
Miscellaneous items	435.0	Steel, aluminium, el. cables	max 1.5	ISO containers at the BSH**
Total weight	**4,759.0**			

7.1.3 Primary decommissioning waste categorised as potentially non-radioactive

By mass this group is dominated by the brick walls from the control rod house, which are almost certainly not contaminated, but where the documentation, as mentioned in section 5.9.1, is incomplete. The other items in Table 4 need to be measured in the Clearance Laboratory because their geometries do not permit a 100% check of all surfaces with a contamination monitor. It is the assumption that all this waste can be cleared.

Table 4 Waste item stored for clearance measurements

Waste item	Weight [kg]	Material	Surface radiation level [µSv/h]	Stored in
Brick walls from control rod house	17,476.0	Brick	<1	Container at the BSH**
Concrete from storage well	820.5	Concrete	<1	Container at the BSH**
Miscellaneous concrete	3,179.0	Concrete	<1	ISO containers at the BSH**
Beam plugs from experimental channels	868.0	Steel	<1	ISO container at the BSH**
Fission gas system	1.7	Steel	1	ISO container at the BSH**
Secondary cooling system	386.0	Steel	<1	In AH hall (for decontamination)

Waste item	Weight [kg]	Material	Surface radiation level [µSv/h]	Stored in
Various lead shielding items	1,830.0	Lead (+steel covers)	<1	ISO containers at the BSH**
Cadmium wrapping from Fuel Drain Tank	10.0	Cadmium	<1	ISO container at the BSH**
Wood from floor	201.0	Wood	<1	ISO container at the BSH**
Miscellaneous items	596.1	Steel, aluminium, el. cables	<1	ISO containers at the BSH**
Total weight	**25,368.3**			

7.1.4 Secondary waste

In addition to the actual decommissioning waste relatively large amounts of secondary waste were produced, in the form of plastic foil, disposable gloves, overalls, boiler suits etc. This waste, which in general was only slightly contaminated, was treated at the Waste Treatment Plant following the normal procedure; but the capacity of the plant was sometimes challenged by the amounts of waste.

7.1.5 Non-radioactive/cleared waste produced

Table 5 shows the items that could be cleared during the decommissioning work based on the methods described in chapter 9 and in [7]. The item "Miscellaneous" also includes some furniture and other items from the control room and office that went into the last container together with the wire cutting sludge.

Table 5 Waste items cleared

Waste item	Weight [kg]	Material	Clearance method	Disposal method
Concrete roof from the control rod house	10,000	Concrete	100% contamination measurement of all surfaces	Recycled
Concrete from the biological shield	110,980	Concrete	Based on sampling as described in [7]	Recycled
Concrete from the sub floor	14,060	Concrete	100% contamination measurement of top surface	Recycled
Wire cutting sludge	4,002	Concrete	Based on analysis of samples	Waste dump

Waste item	Weight [kg]	Material	Clearance method	Disposal method
Wood from the floor	3,800	Wood	100% contamination measurement of all surfaces	Incinerated
Miscellaneous	1,238	Iron, wood, electrical wires	100% contamination measurement of all surfaces	Recycled/-incinerated
Total weight	**144,080**			

In the very early planning [4] a rough estimate was made of the waste that could be cleared, resulting in a figure of 200 tons. If the totals from Table 3, Table 4 and Table 5 are added the result is about 175 tons, which is much closer to the early estimate than the corresponding figures for the active waste.

The waste that has been cleared has been disposed of in accordance with the regulations concerning sorting of waste. This will also be the case for the waste not yet cleared.

7.2 Other material released for other use without restrictions

The Steno Museum in Århus had expressed interest of having a number of objects from the reactors at Risø National Laboratory for an exhibition about the research using nuclear reactors. One of the objects was the control console from DR 1. The console was transferred to the museum on November 2, after being checked thoroughly for contamination.

Various tools that had been used at DR 1 were transferred to the workshop at DR 3 if they were considered useful. Otherwise they were checked for contamination and disposed of as ordinary waste.

8 Unexpected events and lessons learned

It was slightly unexpected to find asbestos in the insulation of the piping on the secondary side of the cooling circuits, since we had found no asbestos in the insulation used for the pipes in the recombiner vault (these pipes were also parts of the cooling circuits). The asbestos gave some extra expenses and delayed the dismantling for a couple of weeks – but fortunately at a less critical time.

It had been expected that the radiation level in the recombiner vault would decrease substantially once the recombiner had been removed. This turned out not to be the case because various pipes and valves belonging to the primary system still contained core solution – and probably also some activated material from the core. Therefore, a slight change of the sequence of removal of components was made, so that these active parts were taken out before proceeding with the reflector and core vessel.

A number of lessons learned, which may be useful for the future decommissioning projects at the site, have been described in [2] (in Danish).

9 Clearance of materials, building and surrounding area

9.1 Clearance criteria

For the clearance of materials the Danish nuclear regulatory authorities have prescribed the use of mass specific clearance levels given by the IAEA [8]. Values for the nuclides most relevant at DR 1 are shown in Table 6. Averaging over 1000 kg is permitted. However, parts of an item that have identified activity concentrations above the clearance levels must be separated if this is reasonably achievable.

Table 6 Clearance levels for materials

Radionuclide	(Bq/g)
^{3}H	100
^{14}C	1
^{60}Co	0,1
^{90}Sr	1
^{137}Cs	0,1
$^{152+154}Eu$	0,1
Actinides	0,1

For clearance of buildings for re-use the Danish nuclear regulatory authorities have prescribed the use of the surface specific clearance levels given by the European Commission [9]. These clearance levels also apply for the disposal, recycling and reuse of items. The surface specific clearance levels must be applied for the total activity on and below the surface divided by the area of the surface. Averaging over 1 m^2 is permitted. Table 7 shows the values for the nuclides most relevant at DR 1.

Table 7 Clearance levels for surfaces of buildings and objects

Radionuclide	(Bq/cm^2)
^{3}H	10.000
^{14}C	1.000
^{60}Co	1
^{90}Sr	100
^{137}Cs	1
$^{152+154}Eu$	1
^{238}U	1
Actinides	0,1

9.2 Clearance of materials

9.2.1 External equipment from the reactor and other equipment placed in the reactor hall

Tools and other equipment that had not been subject to activation were cleared in the way that has been the routine during the operational phase of the facilities at Risø National Laboratory, i.e. based on measurements of surface contamination if all surfaces were accessible for measurement with a contamination monitor. Items having a geometry not permitting direct measurement of all surfaces will be transferred to the Clearance Laboratory [10] for possible clearance on the basis of measurements of volume specific activity.

Items that could have been subjected to activation and from which external radiation could be measured on-site, but where a possibility for clearance exist, will be transferred to the Clearance Laboratory for possible clearance on the basis of measurements of volume specific activity.

9.2.2 Walls and roof from the control rod house

Since the walls and roof from the control rod house had not been exposed to neutrons it was decided to clear these on the basis of measurements with contamination monitors, and thereafter demolish the control rod house and bring the rubble outside the reactor building before any cutting in the activated parts of the reactor block started.

The measurements for fixed and loose contamination were carried out at the roof with a Thermo Delta5 Ratemeter (No. DD0010) and on the ceiling and inside walls with a CoMo 300 (No. 06694). No contamination above the background level (0.1 Bq/cm^2) was detected. In addition, two smear tests were taken from the ceiling and five from the roof showing a maximum non-fixed β-contamination of 25 Bq/m^2. No α-contamination was detected.

As mentioned in section 5.9.1 a misunderstanding resulted in the outside of the walls not being measured. Therefore, the rubble from these walls will be measured by the Clearance Laboratory by a combination of surface measurements of samples and γ-spectroscopic measurements on the whole container with Ge-detectors.

9.2.3 Concrete from the biological shield

Material from the biological shield was cleared on the basis of measurements on drill-core samples taken, both as part of the characterisation project [6] and during the decommissioning. As described in [7] a number of core drillings were carried out from the inside of the biological shield after the reflector tank had been removed. The drill-cores were cut in slices and a γ-spectrum was measured of each slice in order to determine the activity profile in the concrete and the depth of activation above the volumetric clearance levels. In order to determine the contents of pure β-emitters (^{55}Fe and ^{63}Ni) and establish scaling factors for these, a number of samples were analysed at the Department of Radiation Research at Risø National Laboratory.

Based on the measurements the thickness of the slabs to cut off from the inside of each block cut out of the biological shield was determined. In order to be certain that the part to be cleared did not contain activity in concentrations above the clearance level, a few centimetres were added in the actual cutting to cater for deviations of the saw.

When the cleared blocks were to be taken out from the reactor hall they were cleaned for cutting sludge and subsequently checked on all surfaces for loose contamination and for γ-radiation. Smear tests were taken from all surfaces (but not covering all the surface area), and a 100% survey was made on all surfaces with a ZnS detector for control for hot spots or unexpected high radiation levels. Figure 63 shows a measurement taking place. The results were registered in a form like the one shown in Appendix 6 and had to be accepted by either the health physicist or the head of the Health Physics Laboratory before the concrete block could be cleared and placed outside the building, as shown in Figure 64.

Figure 63 Concrete block being checked at the exit from the reactor hall

Figure 64 Cleared blocks stored outside the reactor building

As a last precaution for not sending anything active outside the Risø area, the external radiation from the load was measured immediately before the truck with the cleared material left.

9.2.4 Cutting sludge

During the cutting of the biological shield the cutting sludge was pumped into vessels where the solid material could settle so that the water could be recycled. About 4 tons of cutting sludge was produced and collected this way. The sludge was transferred to pallet containers when the vessels were filling up. Samples were taken from each vessel and pallet container and analysed by means of γ-spectrometers. Only ^{60}Co was detected in the samples. The ratio between the contents of ^{60}Co and the pure β-emitter ^{55}Fe was assumed to be the same as that measured for the drill-cores taken from the biological shield. The conclusion from the analysis of these samples was that the ^{60}Co content is determining for the clearance as non-radioactive waste. Table 8 shows the results of the analyses of the samples, as well as the clearance index, calculated according to the formula below [7].

$$\sum_i \frac{C_i}{CL_i} + 1.65 \times \sqrt{\sum_i \left(\frac{\sigma_i}{CL_i}\right)^2}$$

Where C_i is the activity concentration of nuclide i, CL_i is the clearance level for nuclide i, and σ_i is the uncertainty in the measurement of C_i.

Table 8 Results of analysis of samples of cutting sludge

Sample from	Activity concentration for ^{60}Co [Bq/g]	Clearance index
Pallet container A	0,028 ± 0,001	0,30
Pallet container B	0,035 ± 0,003	0,40
Pallet container C	0,050 ± 0,005	0,58
Pallet container D	0,022 ± 0,004	0,28
Vessel 1	0,022 ± 0,001	0,25
Vessel 2	0,018 ± 0,002	0,21

As can be seen from the table, all clearance indices were below 1. Therefore, the sludge was cleared as ordinary building waste. Appendix 7 shows a slightly more detailed description of the clearance measurements (in Danish).

The water from the cutting was sent to the distillation plant at the Waste Treatment Plant.

9.3 Clearance of the building

Clearance measurements for the building and the surrounding land are reported in detail in a separate report [1]. Therefore, this chapter will give only a brief summary of the measurements.

The rooms and structures in the building were classified in three groups, Class 1, Class 2 and non-classified, according to the likelihood of finding any contamination or activation.

The surfaces in the group with the highest likelihood of being contaminated were classified as Class 1 and measured to a coverage of 100%; those in the middle group, Class 2, were generally measured to a coverage of 10-50%, while a few random measurements were carried out on the non-classified surfaces that have had no or very little contact with radioactive materials. The reactor hall, the counting laboratory in the basement, and the locker room and toilet at the ground floor were classified as Class 1. The stairway, the rooms for heat control in the eastern part of the basement and the dark room were classified partly as Class 1 and partly as Class 2. All remaining rooms, including the control room and the offices were classified as Class 2. There were no non-classified surfaces in the building.

All measurements were made with either a contamination monitor, a Ge-detector or a NaI-detector using gamma spectrometry. Ge-detectors were used in larger rooms as one or two measurements can measure the surface-contamination in the whole room. Ge-detectors can also measure the radionuclides that have penetrated into the floor or walls. Furthermore, gamma spectrometric measurements can determine the radionuclide composition of γ-emitters. The measurement results with the Ge-detectors were analysed by means of the ISOCS software.

The conclusion in [1] concerning the building is: "The building was measured to a coverage of nearly 100 %. None of the measurements showed contamination levels above the clearance levels given by the authorities."

9.3.1 Walls and ceiling in the reactor hall

In the reactor hall the brick walls and the window sills were measured with contamination monitors. The concrete wall to the west was measured with a contamination monitor up to a height of 2 metres above the floor. The rest of the walls were measured with Ge-detectors. Each upper wall was measured in two steps, each covering at least half of the wall. The detectors were directed at a point three to four metres below the ceiling. It was conservatively assumed that all the activity seen by the detector was located in one square meter that was positioned farthest away from the detector. Most likely the contamination will be evenly distributed on the wall. Figure 65 shows the setup for measurement of part of a wall.

Contamination of the ceiling was measured with Ge-detectors. The crane was measured with both contamination monitors and Ge-detectors.

It was important to distinguish between the ^{137}Cs originating from fall out from the nuclear weapons tests and from the Chernobyl accident and potential ^{137}Cs-contamination originating from the operation of the reactor. Background spectra were, therefore, taken in a number of locations similar to those surrounding DR 1. These background spectra were subtracted from each of the spectra measured in the reactor hall where the detectors were pointing towards the walls to determine if the operation or the decommissioning of the reactor had caused any contamination in the reactor hall.

Figure 65 A Ge-detector set up for measurement on the upper part of the southern wall

9.3.2 Floor, channels and pits in the reactor hall

The floor was measured with Ge-detectors and contamination monitors after removal of contamination in spots, as mentioned in section 5.9.3. The same was the case for the fission gas station and the three channels extending from the reactor block to the south, west and north, cf. section 5.11.

After the decontamination of the well where the fuel drain tank had been placed, the whole surface of the well was measured in steps with a contamination monitor for both *α*- and *β*-contamination. The diameter of the well is 25 cm and the depth is two metres. Consequently the surface area of the whole well is about 1.5 m^2. The surface area of the detector is 100 cm^2, so about 150 measurements were made, i.e. 100 % measurement coverage. None of the measurements showed values above the clearance levels being 1 Bq/cm^2 for both ^{60}Co and ^{137}Cs. The clearance index, *CI*, was calculated for the first square meter of the well and the rest of the well, respectively. The clearance index for the first square meter was 0.48 and for the rest of the well 0.41. Both of these values are well below 1, and the well can therefore be cleared.

9.3.3 Concrete below the reactor

The "crater" left open after the removal of the reactor was measured with a Ge-detector. This surface is activated, and the activity is depth-distributed into the concrete. Drill-core samples have shown that the activity concentration decreases exponentially as a function of depth and that the relaxation length is about 10 cm. This value has been used to calculate the total activity below a surface of 1 m^2. Four measurements were made to determine the activity in the “crater”. In all the measurements the detector covered at least one square meter and it was conservatively assumed, that all the activity was concentrated below one square meter. The maximum clearance index for these four measurements was 0.59.

9.3.4 Heating and ventilation system in the reactor hall

The ducts for the heating system are not accessible. It was assumed that if any contamination were to be found in the ducts, it could be detected behind the outlet grills at the southern end of the hall. The walls behind the grills were measured with contamination monitor. No contamination was detected. Some dust behind the ventilation grills was scraped off and analysed by gamma-spectrometry in the laboratory. The sample showed small amounts of ^{137}Cs and ^{60}Co. Assuming conservatively that there was a dust covering of half a kilogram per square meter, the surface contamination of ^{137}Cs would be less than 1500 Bq/m^2 and that for ^{60}Co less than 200 Bq/m^2. It was, therefore, concluded, that the contamination of the ducts would be far below the clearance levels. The channels for the ventilation ducts, running along the northern and southern walls, had been covered with concrete and the wooden floor. One access hole to the channels was situated in the northern channel for the pipes leading to the fission gas station and another access hole in the southern channel for electric cables. It was assumed that if any contamination was to be found in these channels it would be close to these access holes. Therefore, the areas in the channels around the access holes were measured with a contamination monitor. No contamination was found. Figure 66 shows the wall behind one of the outlet grills and Figure 67 shows one of the channels with the ventilation ducts.

Figure 66 One of the three outlets for the air heating system

Figure 67 A view into the northern channel with an air heating channel to the right

Wipe tests from the inside of the ventilation channel revealed that the channel was slightly contaminated with ^{137}Cs. Although much of this contamination probably originated from weapons test fall-out or from the Chernobyl accident, this could not be verified by analyses of the wipe samples. Therefore, it was conservatively assumed that all of the ^{137}Cs in the ventilation outlet should be included in the calculations of the clearance index. A measurement was made with a collimated Ge-detector pointing directly at the ventilation channel, showing a surface concentration of ^{137}Cs less than 3000 ± 800 Bq/m^2 at any one square meter, i.e. well below the clearance level of 10^4 Bq/m^2.

9.3.5 Other rooms in the building

Although most of the rooms outside the reactor hall were classified as Class 2 areas they were measured to a near 100% coverage. The counting laboratory and the locker room and toilet in the basement were measured by means of both contamination monitors and spectrometers, because some contamination had been found (and removed) in the counting room, and slightly elevated radiation levels had been found in the locker room and toilet. The reason for the latter turned out to be that some tiles had a significantly higher content of ^{40}K than other tiles in the room.

Figure 68 Ge-detector in the counting laboratory

Figure 69 NaI detector in the locker room

All other rooms were measured with contamination monitors, and no contamination above clearance levels was detected.

9.4 Clearance measurements of the surrounding area

The asphalt to the north in front of the reactor building was measured to 100% coverage for contamination with contamination monitors, cf. Figure 70. No contamination was found. One measurement was made with a Ge-detector on the asphalt area. A background spectrum was measured at a Risø area with a similar type and age of asphalt. No radionuclides resulting from the operation and decommissioning of DR 1 was found in the measurement on the asphalt in front of the DR 1 building. East and south of the building measurements were made with a Ge-detector. Background measurements were made at areas at the Risø-site with similar characteristics. Figure 71 shows the measurement east of the DR 1 building. No contamination resulting from the reactor operation and decommissioning was found. The outdoor staircase to the basement on the west side of the building was measured with a contamination monitor. No contamination above background levels was found.

10 Release from other regulatory control

DR 1 has not been subject to any other regulatory controls than those supervised by the nuclear regulatory authorities, apart from general conditions that apply to the use of all buildings at the Risø area.

Figure 70 Measurement with contamination monitor north of the building

Figure 71 Measurement with Ge-detector east of the building

11 Remaining equipment, buildings and areas

In the reactor hall all equipment has been removed except a "log N meter" and a "Reactor in operation" lamp hanging on the western wall

12 Conclusion

DR 1 was a small reactor without very high activity contents. Therefore, demolishing it was not a very demanding task in itself. But as this was the first decommissioning task in Denmark much focus was put on doing the work without any incidents on the way. Furthermore, since two more complicated reactors and a hot cell facility wait in the future, it was also part of the DR 1 task to examine methods and tools.

In general, the dismantling could be carried out by means of tools and equipment that DD already had or that could be made in DD's own workshop. In particular, the use of suction pads for taking out the graphite reflector was a cheap way of reducing personnel doses. All choices of tools and methods were made in close cooperation between project leader, project engineer, technicians and health physics staff. This was a very fruitful approach, securing the utilisation of all relevant skills and knowledge and giving a common understanding of the tasks and their performance.

The dismantling and demolition resulted in very modest personnel doses, which can be attributed mainly to the fact that the radioactive inventory was small, but also to good planning and careful approach to the work. Also the "conventional" occupational health impacts were minor; there were no accidents resulting in sick-leave.

The clearance measurements of the building documented that levels were below the clearance levels set up by the nuclear regulatory authorities. Also the measurements on the surrounding area showed that the operation and decommissioning of DR 1 had not left any contamination.

13 References

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Appendix 1 Work plan for removal of the control rods (in Danish)

Notat

DANSK DEKOMMISSIONERING

Arbejdsplan for udtagning af kontrolstave

30. juli 2004

J.nr. DD-2004-412-2

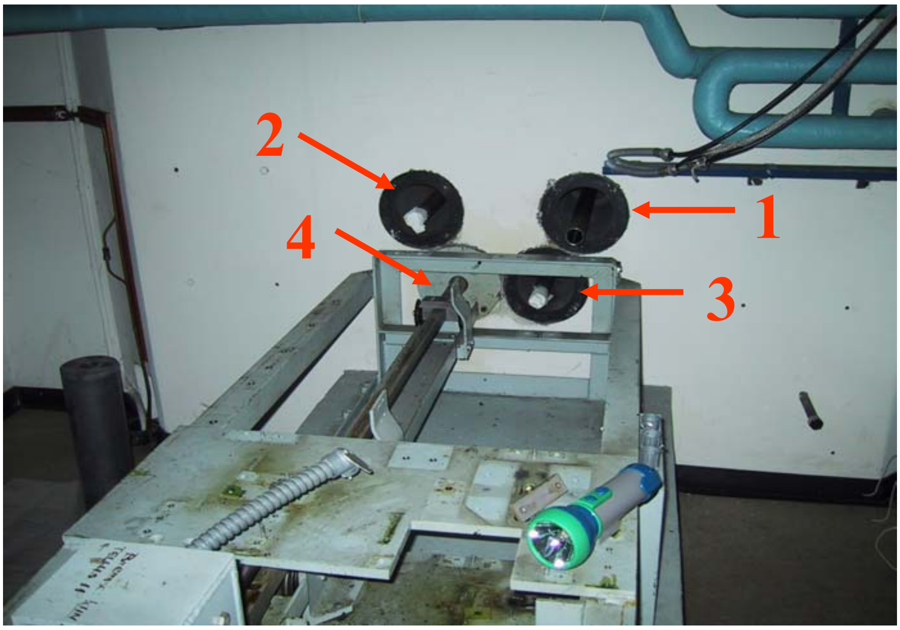
Ref PEB
Projektkontoret

Indledende arbejder

- Oprydning i kontrolstangshus (helsefysisk kontrol og paller)
- Etablering af lys og eludtag (mobil eltavle og mobile lamper)
- Fremstilling af aftrækker for rørsplitter i fæstet mellem stang og kontrolblad – er sket
- Fremstilling af midlertidig opbevaringsbeholder for kontrolblade – er sket
- Fremstilling af fire plastposer til kontrolbladene ved svejsning af "strømper" (~15×150 cm) i den ene ende
- Frigørelse af den fjerde stang (sikkerhedsstav) dvs. demontering af køreskinne og diverse beslag fra stativ, afmontering af ydre del af forbindelsesstang og udtagning af blybøsning i væg.

Udtagning

- 1. sikkerhedsstav **(øverst til højre i huset – nr. 1 på fig. 1)** trækkes ud til blyklods og fæste er frit (se fig. 2)
- Rørsplitter (2 stk.) og bolt fjernes og forbindelsesstang frigøres (se fig. 2).
- Kontrolblad mærkes med "1" (som i fig. 1) i den mindst aktive ende, udtages og placeres i en plasticpose (~15×150 cm), som nedsættes i beholder.



Figur 1 Indføring af kontrolstave

- 2. sikkerhedsstav **(nederst til venstre – nr. 4 på fig. 1)** osv. (Kontrolbladet mærkes med "4")
- 1. reguleringsstav **(nederst til højre – nr. 3 på fig. 1)** osv. (Kontrolbladet mærkes med "3")
- 2. reguleringsstav **(øverst til venstre – nr. 2 på fig.1)** osv. (Kontrolbladet mærkes med "2")

Figur 2 Samling af kontrolelement og forbindelsesstang

Kontrolbladene placeres efter udtagning i opbevaringsbeholder, som derefter placeres i betoncelle.

Nedbrydning

- Alle beslag mm. inkl. lodder demonteres, således at kun det svejste stativ er tilbage.
- Stativet frigøres fra betonfundament (6 stk. ½" NV 22 og 8 stk. ¾" NV 36 indstøbte bolte).
- Stativ overskæres.

Strålingsniveauer

I forbindelse med karakteriseringsprojektet blev der med en afstand mellem kontrolstav og detektor på 10 cm målt følgende maksimale strålingsniveauer på de to udtagne kontrolstave:

- Ved vestligste ende af blad (mest eksponerede del): 60 μSv/h (måleinstrumentvisning 10 mR/h)
- Ved fæste: < 60 nSv/h (måleinstrumentvisning <10 μR/h)

Da de aktive dele af kontrolstavene kun skal håndteres uafskærmet i ganske kort tid, forventes hele operationen kun at give ubetydelige personaledoser.

Deltagere og opgaver:

Deltager	Opgaver
Per Becher	Leder og hjælper ved udtagningen.
Brian Rømer	Foretager udtagningen.
Helle Borch (?)	Helsefysisk overvågning og vejledning.
Kurt Lauridsen	Generel overvågning af arbejdet. Fotografe-ring.

PSP element til timeregistrering: 3513100-6 (Demontering af ydre systemer)

Per E. Becher, Kurt Lauridsen

Appendix 2 Work plan for removal of the recombiner (in Danish)

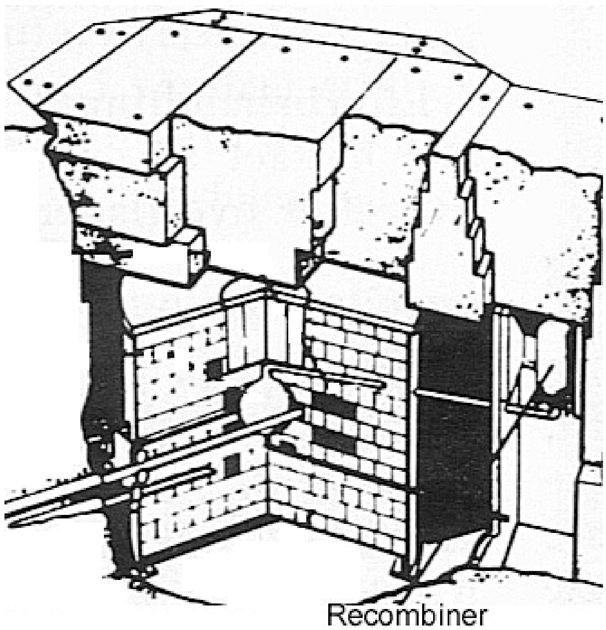
Projektkontoret
7. oktober 2004
Kurt Lauridsen

Dekommissionering af DR 1

Arbejdsplan for nedtagning af recombiner

Indledning

Recombineren har under driften af reaktoren sikret, at den frie brint og ilt, som blev dannet, igen indgik kemisk forbindelse til vand, som blev ledt tilbage til core-beholderen, således at risikoen for knaldgaseksplosioner blev elimineret. Recombinerens placering i reaktorblokken fremgår af Figur 3.



Figur 3 Snit i reaktorblokken

Recombineren indeholder radioaktive stoffer, primært ca. 10^9 Bq ^{137}Cs, som er aflejret under driften. Dosishastigheden er målt til 150 µSv/h i en afstand af 100 cm over toppen af recombineren og 90 µSv/h 100 cm under bunden[2]. Disse dosishastigheder er af en sådan størrelse, at der ved arbejdets planlægning og udførelse skal tilstræbes, at operatørerne holder så stor afstand til selve recombineren som muligt, og at de enkelte arbejdsoperationer kan udføres hurtigt. Placeringen af recombineren i reaktorens afskærmning sikrer, at der ikke vil være synderligt forhøjet strålingsniveau i bygningen i øvrigt.

2 Povl L. Ølgaard, DR-1 karakteriseringsprojektet. Risø-I2029(DA). Juni 2003.

Forberedende arbejder

Forud for selve demonteringen af recombineren skal alle løse genstande, som befinder sig i hulen neden under recombineren, fjernes. Disse genstande er antagelig alle (let) kontaminerede. Endvidere skal nødvendige beslag m.v. til løft af recombineren og centrering af denne i affaldstromlen fremstilles.

Kølesystemet for recombineren skal tømmes for vand (kan ske fra kontrolstangshuset).

Der skal foretages målinger af strålingsniveauerne på de steder, hvor operatørerne skal opholde sig under demonteringen. Herunder skal foretages målinger af niveauerne ved kontakt med toppen af recombineren, flangen til røret til core-beholderen samt selve røret.

Der skal forberedes for udsugning ved arbejdsstedet samt målinger af luftkontaminationen i hallen under arbejdet. Endvidere skal fotografering og føring af logbog være forberedt.

Blændplader til lukning af flangen i bunden af recombineren skal fremstilles.

Da det ikke vil være muligt at anbringe betoncontainere til radioaktivt affald inde i reaktorhallen, er der inde i reaktorhallen etableret en afskærmet celle, hvor tromler med affald – herunder recombineren – midlertidigt kan placeres, således at der kan arbejdes videre i hallen uden ekstra dosisbelastning hidrørende fra det oplagrede.

Demontering

Recombineren frilægges ved at løfte betonblokken i reaktorblokkens top væk med hallens kran samt åbne betondøren i reaktorblokkens nordvestlige hjørne (medmindre denne dør allerede er åben). Efter fjernelse af betonblokkene er strålingsniveauet ikke højere end at personalet kan opholde sig kortvarigt ved åbningen.

For at opnå en bedre arbejdsstilling for operatøren og reducere hans doser ved arbejde på recombineren ovenfra, fjernes også de tre nærmeste afskærmningsblokke over core/reflektortank. Operatøren kan så stå på låget over reflektortanken og have blyvæggen ind mod recombineren som afskærmning.

Da recombineren er indvendigt kontamineret med ^{137}Cs (og antagelig også med ^{90}Sr), udtages den som et samlet hele til en affaldsbeholder. Recombineren har en udvendig diameter på 270 mm (10¾"), en højde inklusiv forbindelsesrør på ca. 500 mm og vejer ca. 30 kg. På siden af recombineren rager en stuts til tryktransduceren ca. 110 mm ud. Af hensyn til strålingen fra recombineren skal personalet holde afstand til enheden, som kan løftes ud med kran.

Nedtagningen kan opdeles i følgende delprocesser:

1. Demontering af elkabler til varmelegeme samt ledninger til tryktransducer og termoelementer.
2. Overklipning af rør (fire i alt) til køling af recombineren.
3. Forbindelsesrør til recombiner brydes. Røret på toppen af recombineren lukkes ved sammenklemning og overklippes. Rørforbindelsen til core-beholderen er af så kraftig dimension at sammenklemning og overklipning ikke vil være mulig med det til rådighed værende udstyr; denne forbindelse vil derfor blive afbrudt ved at åbne flangen, hvor røret er tilsluttet recombineren. De to åbne ender bliver straks lukket med blændplader. Ved anbringelse af blændpladerne vil det antagelig blive nødvendigt at løfte recombineren lidt; dette skal gøres ved hjælp af en talje og ikke med portalkranen, da

denne er for vanskelig at styre til små bevægelser. Taljen kan eventuelt ophænges i portalkranen, idet det skal sikres, at den hænger helt lodret over recombineren.
4. Løsning af bolte/ møtrikker på de fire fødder, recombineren står på.
5. Overførsel af recombineren til en betonforet affaldstromle og anbringelse af denne i en et afskærmet område i hallen.
6. Udtagning af prøve til karakterisering af aktivitetsindhold
7. Kontrolmåling af afklippede kølerør samt andet materiale og overførsel af disse til frigivelsesmåling eller til affaldscontainer.

Hele processen skal overvåges af helseassistenter og de medvirkende skal være iført tilstrækkeligt beskyttelsesudstyr og dosimetre til de enkelte procedurer.

Der skal foretages mærkning og registrering af alle de genstande, der lægges i affaldsbeholdere med henblik på deponering.

Som led i dokumentationen af dekommissioneringen vil der blive tage fotos og eventuelt videooptagelser af arbejdet med nedtagningen af recombineren (og alle andre dekommissioneringsarbejder).

De enkelte arbejdsoperationer er detaljeret beskrevet i vedlagte tabel. Her er også anført særlige forhold, som skal iagttages før, under og efter nedtagningen. Arbejdsplanen stopper efter udtagning af recombineren og placering af denne i en affaldsbeholder. Efterfølgende fjernelse af ledningsender, rørender m.v. bør afvente en fornyet måling af strålingsforholdene i recombinerhulen.

Vurdering af aktivitetsindhold i recombineren

Efter fjernelse af recombineren tages en aftørringsprøve øverst i røret, som fører til coreholderen. Det må antages, at nuklidsammensætningen her er tæt på at være den samme som i recombineren; derfor kan doserne ved prøvetagning reduceres ved at tage prøven her og ikke på selve recombineren. Det absolutte indhold af aktivitet i recombineren kan herefter fastlægges ved kombination med målinger af eksternstrålingen fra denne.

Sikkerhedsmæssig vurdering

De sikkerhedsmæssige problemer i forbindelse med nedtagningen er alene af arbejdsmiljømæssig, herunder helsefysisk, art. I den vedlagte tabel er der for de enkelte operationer anført tænkelige risici, som bør haves in mente under udførelsen af arbejdet.

Strålingsrelaterede forhold

Ved arbejde tæt på recombineren vil operatørerne modtage strålingsdoser, især til hænder og arme. Så vidt muligt bør der anvendes værktøjer, som tillader operatøren at holde en vis afstand til recombineren. Strålingsniveauet på overfladen af recombineren er dog ikke højere, end at kortvarigt arbejde med hænderne tæt på overfladen er fuldt forsvarligt - fx ved løsning af boltene på flangen i bunden af recombineren.

Ved adskillelse af flangen mellem recombineren og røret til core-beholderen er der en risiko for, at radioaktivt materiale - primært ^{137}Cs (og antagelig også ^{90}Sr) - trænger ud. Der vil derfor ved denne operation blive etableret afdækning under flangen og udsugning. Det vurderes dog, at risikoen for udtrængning af radioaktivt materiale er lille, idet det må formodes at være bundet til overfladerne i recombineren.

En særlig strålingsrisiko vil være til stede ved udløftning af recombineren og overførsel af denne til en afskærmet affaldstromle.

Andet arbejdsmiljø
Ved løft af betonafskærmningsblokken oven over recombineren skal denne løftes lige op, så den ikke kommer i svingninger, når den er fri af hullet. Endvidere bør operatørerne være opmærksomme på risikoen for at få fødderne i klemme ved nedsætning af blokken på reaktortoppen (eller på gulvet).

Ved arbejde under recombineren er der en risiko for at støde hovedet mod betonloftet i døråbningen. Såfremt det ikke er meget hæmmende for arbejdets udførelse, bør der derfor bæres beskyttelseshjelm. Alternativt kan en kollega stå udenfor og minde operatøren om at passe på hovedet; dette er specielt relevant, når man trækker sig tilbage fra arbejdsstedet. Under alle omstændigheder vil det være tilrådeligt at bære en eller anden form for hovedbeklædning.

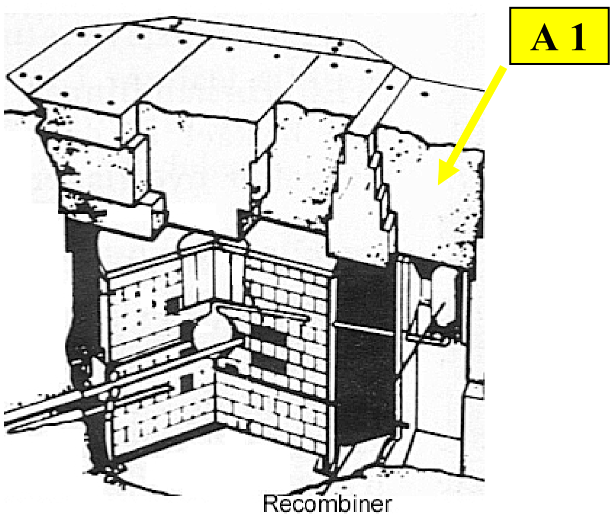
Forventede personaledoser

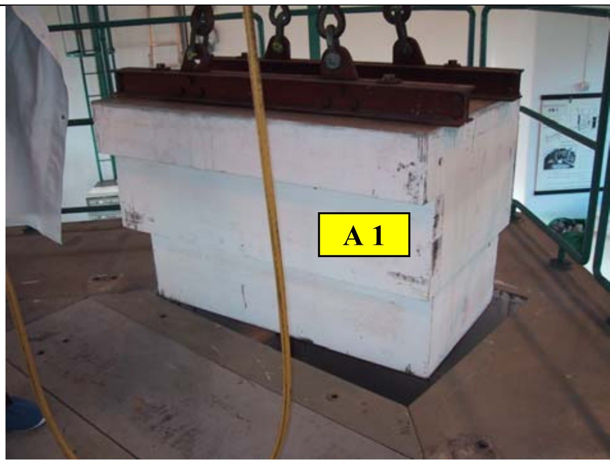
Dosishastighederne omkring recombineren er målt til følgende værdier:

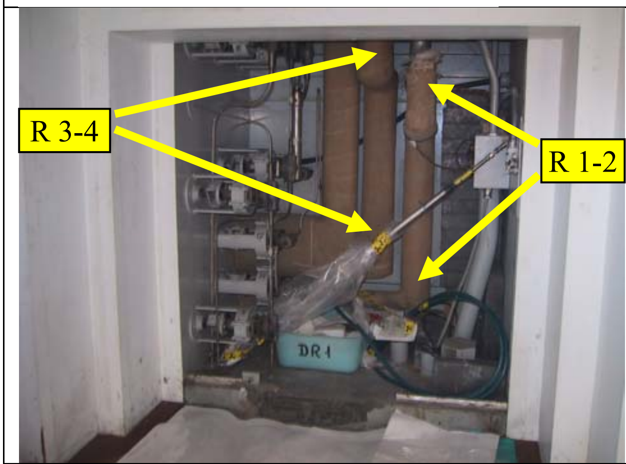
Sted	**Dosishastighed µSv/h**
Kontakt med flange i bunden af recombineren	2500
20 cm fra bunden af recombineren	550
Lige uden for døråbningen for betondøren til recombinerhulen	120
Ved kanten af hullet over recombineren	60
Ved toppen af recombineren	9500
1 meter over toppen af recombineren	200

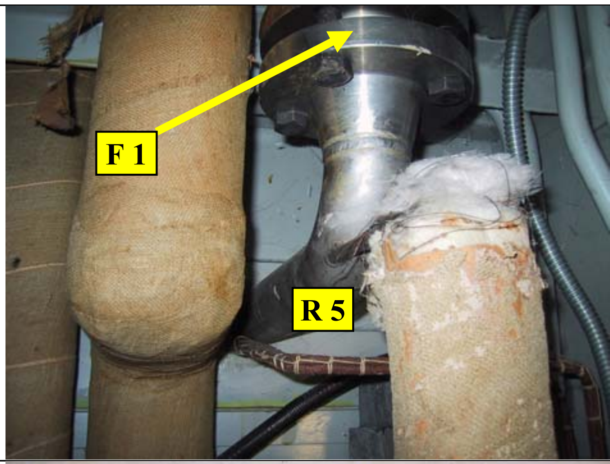
I vedlagte detaljerede arbejdsplan er der på basis af ovenstående dosishastigheder skønsmæssigt angivet personaledoserne for de enkelte arbejdsoperationer. Ved addition af disse skønsmæssige værdier findes en forventet kollektivdosis (helkropsdosis) for hele nedtagningen af recombineren på under 0,3 milli person Sv.

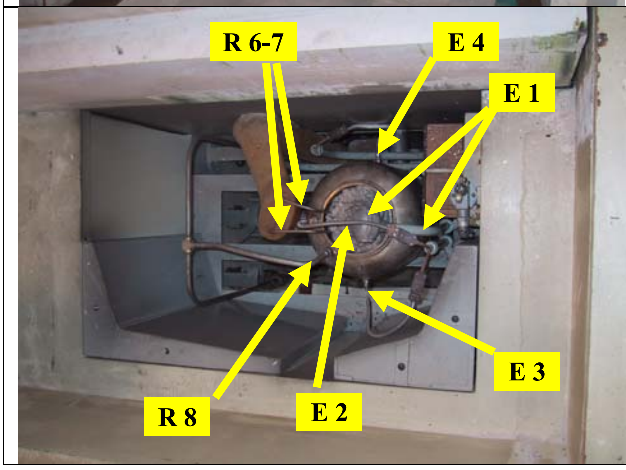
Pictures for the work plan for removal of the recombiner

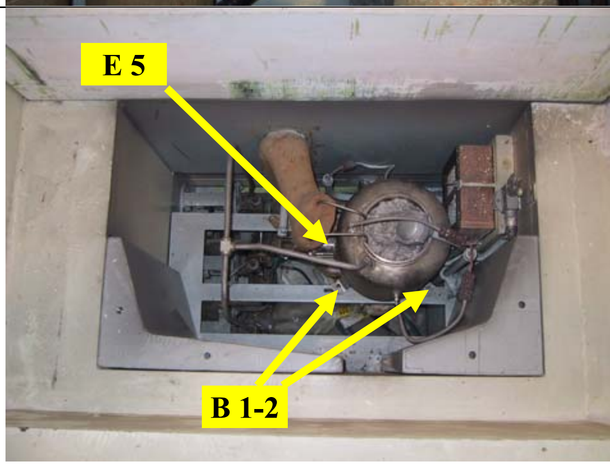


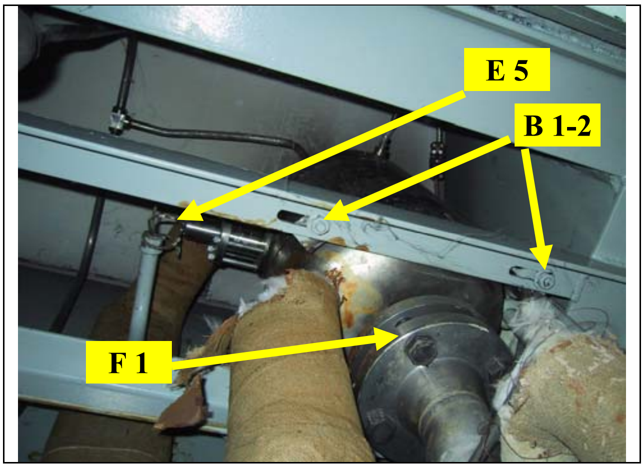











E 5
B 1-2
F 1

OK for udført	Arbejdsoperation	Identifikation på foto	Relevant tegning	Bemærkninger	Risici	Udføres af	Nødvendigt værktøj og andet udstyr	Personlige værnemidler udover arbejdstøj og sikkerhedssko	Andre forholdsregler	Forventet dosishastighed ved arbejdsstedet	Forventet tidsforbrug (for arbejde i strålingsfelter)	Forventede strålingsdoser	Dosimetre, som skal anvendes udover persondosimeter	Anvendt affaldsbeholder	Forventet mængde radioaktivt affald [enh]	Forventet mængde ikke aktivt affald [enh]	Berøres BD eller andre specielle regler?	Kontrolleret af AHF	Kvalitetssikring	Færdig (dato)	Målte strålingsdoser	Tidsforbrug faktisk	Pris Estimeret/ faktisk
	Arbejde, som foregår under hele forløbet:																						
	Fotografering/videooptagelser					KL	Kameraer med opladede batterier						Alnor digitaldosimeter										
	Dokumentation af forløbet og af de udtagne dele					KL/PEB	Forberedte skemaer Evt. PC																
	Forberedende arbejde:																						
	Rekvirere betonforet affaldstromle					HJ/PEB																	
	Fremskaffe beholdere til andet affald end selve recombineren samt etablere placeringsmuligheder for disse			Blå pallecontainer og plastforet kasse		HJ/PEB																	
	Fremstille løftebeslag til at løfte recombineren i					HJ																	
	Fremstille blændplader til at lukke flangen i bunden af recombineren.					HJ																	
	Fremstille afstandsholdere til at holde den udtagne recombiner centreret i affaldstromlen					HJ																	
	Planlægge målinger af strålingsniveauer samt helsefysisk overvågning					AHF																	
	Indledende arbejde:																						
OK	Fjerne løse genstande i hulen under recombineren			Alle genstande her skal betragtes som muligt kontaminerede																			
	Udføre målinger af strålingsniveauer					HA																	
OK	Etablere arbejsområdet					HJ/HY																	
OK	Tømme vand af de kølerør, der skal overklippes (til coren og til recombineren)					PEB								To blå tønder									
OK	Fjerne betonblokke oven over reflektortank/core			Egentlig er det kun den blok, der er nærmest recombineren, som skal fjernes	Fod i klemme ved nedsætning	HJ/HY	32 mm nøgle til løftebeslag	Sikkerheds-sko			30 min.				–	–	Nej						
OK	Fjerne betonblok oven over recombineren	A 1	9097-78602, 1&2 samt Steensen & Warming tegning 706		Fod i klemme ved nedsætning	HJ/HY	32 mm nøgle til løftebeslag	Sikkerheds-sko			10 min.				–	–	Nej						
	Arbejde fra bunden af recombineren:																						
OK	Fjerne isolering på kølerør til corebeholder	R 1-2			Asbest? - nej	HJ/HY	Evt. ekstra lamper	Evt. sikkerhedshjælm					Fingerdosimetre, Alnor digitaldosimeter	Plastsæk									
Udføres først når recombineren er væk	Klemme og klippe kølerør til corebeholder (2 rør) så tæt som muligt på det tykke rør	R 1-2	9097-71002, 1&2	Rørdiameter: 1/4"		HJ/HY	Evt. ekstra lamper Klippeværktøj																
	Klemme og klippe kølerør til corebeholder så langt nede som muligt	R 1-2		Husk at have fat i toppen af det afklippede rørstykke med en lang tang		HJ/HY	Evt. ekstra lamper Klippeværktøj Lang tang																
	Anbring afklippede rørstykker i affaldsbeholder (rørene skal evt. bukkes eller klippes i mindre stykker)					HJ/HY								Blå pallecontainer									
OK	Fjerne isolering på kølerør til recombiner	R 3-4			Asbest? - nej	HJ/HY	Evt. ekstra lamper						Fingerdosimetre, Alnor digitaldosimeter	Plastsæk									
OK	Klemme og klippe kølerør til recombiner (2 rør) så tæt som muligt på recombineren	R 3-4		Rørdiameter: 1/4"		HJ/HY	Evt. ekstra lamper Klippeværktøj						Fingerdosimetre, Alnor digitaldosimeter										
Udføres først når recombineren er væk	Klemme og klippe kølerør til recombiner så langt nede som muligt	R 3-4		Husk at have fat i toppen af det afklippede rørstykke med en lang tang		HJ/HY	Evt. ekstra lamper Klippeværktøj Lang tang																
	Anbring afklippede rørstykker i affaldsbeholder (rørene skal evt. bukkes eller klippes i mindre stykker)					HJ/HY								Blå pallecontainer									
	Arbejde fra toppen af recombineren:																						
	Sikre afbrydelse af strømforsyning til varmelegeme					PEB																	
	Klippe elledning til varmelegeme	E 1				HJ	Kraftig bidetang eller boltsaks						Fingerdosimetre, Alnor digitaldosimeter										
OK	Klemme og klippe to kølerør til indre del af recombiner så tæt som muligt på recombineren	R 6-7		Rørdiameter: 1/4"		HJ	Klippeværktøj						Fingerdosimetre, Alnor digitaldosimeter										
	Klemme og klippe det tykke rør som er sluttet til toppen af recombineren så tæt som muligt på denne	R 8		Rørdiameter: ½"		HJ	Klippeværktøj						Fingerdosimetre, Alnor digitaldosimeter										
	Klippe ledninger til termoelement på toppen af recombineren	E 2				HJ	Langskaftet tang/saks						Fingerdosimetre, Alnor digitaldosimeter										
	Klippe ledninger til termoelement foroven på siden af recombineren så tæt som muligt på denne	E 3				HJ	Langskaftet tang/saks						Fingerdosimetre, Alnor digitaldosimeter										
	Klippe ledninger til termoelement forneden på siden af recombineren så tæt som muligt på denne	E 4				HJ	Langskaftet tang/saks						Fingerdosimetre, Alnor digitaldosimeter										
	Klippe tilledningen til trykmåler på siden af recombineren	E 5				HJ	Langskaftet tang/saks						Fingerdosimetre, Alnor digitaldosimeter										
	Anbringe løftebeslag på recombiner					HJ							Fingerdosimetre, Alnor digitaldosimeter										
	Arbejde fra både toppen og bunden af recombineren:																						
	Fjernelse af bolte/ møtrikker på de fire fødder, recombineren står på	B 1-4		Nøglevidde: 17 mm		HJ/HY	Specialbeslag til modhold på boltene skal evt. fremstilles	Evt. sikkerhedshjælm					Fingerdosimetre, Alnor digitaldosimeter	Blå pallecontainer?									
	Arbejde fra bunden af recombineren:																						
	Etablere afdækning og udsugning ved flangen mellem recombiner og det tykke rør, som kommer ud af bunden på denne (og går til corebeholderen)					HJ/HY							Fingerdosimetre, Alnor digitaldosimeter										
	Åbne flangen	F 1 R 5		Rørdiameter: Flangediameter: Nøglevidde på bolte og møtrikker: 24 mm Placering af bolthuller	Udtrængning af radioaktivt materiale fra recombiner. Risiko for at flangens pakning er groet fast	HJ	Evt. ekstra lamper Nøgler til bolte og møtrikker	Evt. sikkerhedshjælm. Støvmaske, briller eller visir. Handsker	Afdækning under arbejdsstedet, udsugning	1 mSv/h ?			Fingerdosimetre, Alnor digitaldosimeter	Ingen (dog evt. til pakningen, hvis den ikke kan genbruges)									
	Indskyde afblænding på den øvre flangedel (recombinerdelen)	F 1 R 5		Såfremt recombineren skal løftes ved denne operation, bør der anvendes et mindre løfteværktøj end den store kran	Udtrængning af radioaktivt materiale fra recombiner.	HJ	Blændplader, bolte/"clips"	Evt. sikkerhedshjælm. Støvmaske, briller eller visir. Handsker	Afdækning under arbejdsstedet, udsugning	do.			Fingerdosimetre, Alnor digitaldosimeter										
	Afdække flangen på røret til core-beholder	F 1 R 5			Udtrængning af radioaktivt materiale	HJ	Plastpose	Evt. sikkerhedshjælm. Støvmaske, briller eller visir. Handsker	Afdækning under arbejdsstedet, udsugning	do.			Fingerdosimetre, Alnor digitaldosimeter										
	Arbejde fra toppen af recombineren:																						
	Sikre, at recombineren er løs og alle forbindelser afbrudt					HJ							Fingerdosimetre, Alnor digitaldosimeter										
	Kontrollere maksimalt tværmål (kan den være i en tromle?)					HJ							Fingerdosimetre, Alnor digitaldosimeter										
	Løfte recombineren ud					HJ/HY							Fingerdosimetre, Alnor digitaldosimeter										
	Anbringe recombineren i betonforet affaldstromle og lægge låg på					HJ/HY							Fingerdosimetre, Alnor digitaldosimeter	Betonforet affaldstromle									
	Afsluttende arbejder:																						
	Anbringe tromlen i et afskærmet område i reaktorhallen					HJ/HY							Fingerdosimetre, Alnor digitaldosimeter										
	Eventuelt efterfylde affaldstromlen med stålkugler					HJ/HY							Fingerdosimetre, Alnor digitaldosimeter										
	Tage aftørringsprøve fra øverste del af røret til core-beholder	F 1 R 5		Denne prøve kan anses for at være repræsentativ for indholdet i recombineren. Instrukser hertil fra Behandlings-stationen	Udtrængning af radioaktivt materiale	HA		Evt. sikkerhedshjælm. Støvmaske, briller eller visir. Handsker.	Afdækning under arbejdsstedet, udsugning				Fingerdosimetre, Alnor digitaldosimeter										
	Montere blændplade på røret til core-beholder	F 1 R 5			Udtrængning af radioaktivt materiale	HJ	Blændplade, bolte	Evt. sikkerhedshjælm. Støvmaske, briller eller visir. Handsker.	Afdækning under arbejdsstedet, udsugning				Fingerdosimetre, Alnor digitaldosimeter										
	Foretage øvrige karakteriseringsmålinger på eller udtage prøver af affald til deponering			Instrukser hertil fra Behandlings-stationen		HA								Evt. beholder til prøver									
	Kontrollere strålingsniveau ved det afskærmede område					HA																	
	Kontrollere strålingsniveau i recombinerhulen					HA																	
	Genplacere betonblok oven over recombinerhulen (medmindre det er blevet besluttet at sætte den permanent på gulvet i hallen)	A 1				HJ/HY	32 mm nøgle til løftebeslag	Sikkerheds-sko															
	Genplacere betonblokke oven over core/reflektortank	A 1				HJ/HY	32 mm nøgle til løftebeslag	Sikkerheds-sko															
	Opgøre dosisregnskab					HA/HF																	
	Indlægge data i database					HF/KL																	
	Skrive rapport over arbejdet					KL																	

Godkendelse af plan

Rolle/Enhed	Navn	Godkendt dato
Projektleder	Kurt Lauridsen	20-10-2004
Værkstedet	Arne Würtz	20-10-2004
AHF	Bente Lauridsen	20-10-2004
BEH	Steen Carugati	20-10-2004
Sikkerhedsgruppe	Søren Roed	20-10-2004

Anvendte forkortelser:

AHF	Anlægshelsefysik	PEB	Per E. Becher
HA	Helseassistent		
HF	Helsefysiker		
HJ	Henning Jørgensen		
HY	Hamid Youssef		
KL	Kurt Lauridsen		

Arbejdsoperation	Identifikation på foto	Relevant tegning	Bemærkninger	Risici	Udføres af	Nødvendigt værktøj og andet ude…
Arbejde, som foregår under hele forløbet:						
Fotografering/videoop-tagelser					KL	Kameraer med oplade-de batterier
Dokumentation af forløbet og af de udtagne dele					KL/PEB	Forberedte skemaer Evt. PC
Forberedende arbejde:						
Rekvirere betonforet affaldstromle					HJ/PEB	
Fremskaffe beholdere til andet affald end selve recombineren samt etab-lere placeringsmuligheder for disse			Blå pallecontainer og plastforet kasse		HJ/PEB	
Fremstille løftebeslag til at løfte recombineren i					HJ	
Fremstille blændplader til at lukke flangen i bunden af recombineren.					HJ	
Fremstille afstandsholdere til at holde den udtagne recombiner centreret i					HJ	

Arbejdsoperation	Identifikation på foto	Relevant tegning	Bemærkninger	Risici	Udføres af	Nødvendigt værktøj og andet udstyr	Personlige værne-midler udover arbejdstøj…
Fjerne løse genstande i hulen under recombineren			Alle genstande her skal betragtes som muligt kontaminerede				
Udføre målinger af strålingsniveauer					HA		
Etablere arbejsområdet					HJ/HY		
Tømme vand af de kølerør, der skal overklippes (til coren og til recombineren)					PEB		
Fjerne betonblokke oven over reflektortank/core			Egentlig er det kun den blok, der er nærmest recombi-neren, som skal fjernes	Fod i klemme ved nedsæt-ning	HJ/HY	32 mm nøgle til løftebeslag	Sikkerheds-sko
Fjerne betonblok oven over recombineren	A 1	9097-78602, 1&2 samt Steensen & Warming tegning 706		Fod i klemme ved nedsæt-ning	HJ/HY	32 mm nøgle til løftebeslag	Sikkerheds-sko
Arbejde fra bunden af recombineren:							
Fjerne isolering på kølerør til corebeholder	R 1-2			Asbest? - nej	HJ/HY	Evt. ekstra lamper	Evt. sikker-hedshjælm

Appendix 3 Examples of instructions (in Danish)

Instruks

Frigivelse af dekommissioneringsaffald på basis af kontaminations-målinger

27. juli 2005

J.nr. DD-2004-412-6

Ref KL
Projektkontoret

Såfremt et affaldsemne, som er fremkommet ved dekommissionering af et anlæg, med sikkerhed ikke har været udsat for neutronstråling, kan emnet frigives på basis af en måling af overfladekontaminationen på emnet. Målingerne dokumenteres i et dertil indrettet skema (som det på næste side), og før emnet kan frigives skal måleresultaterne granskes og godkendes af den ansvarlige helsefysiker og projektlederen for det pågældende dekommissioneringsprojekt (eller disses stedfortrædere). Helsefysikeren og projektlederen skal begge skrive under på skemaet.

Kurt Lauridsen

Måling udført af:	**Dato:**

Målt emne	**Instrument**	**Maksimal måle-værdi Bq/m^2**	**Bemærkninger**
Baggrundsmåling			

Evt. smear tests:

Målt overflade	**Metode**	**Aktivitet pr. overfladeenhed Bq/m^2**	**Bemærkninger**

Godkendelse

Målingerne er kontrolleret og materialet

	Kan frigives
	Kan eventuelt dekontamineres
	Skal deponeres som radioaktivt affald

Dato og underskrift:

______________________________ ______________________________

Helsefysiker / Laboratoriemester Projektleder / stedfortræder

Instruks

DANSK DEKOMMISSIONERING

Bortkørsel af frigivet materiale fra DR 1

6. juli 2005

J.nr. DD-2004-412-5

Ref KL
Projektkontoret

Materiale (primært beton), som er blevet målt til at have et aktivitetsindhold under de gældende frigivelsesniveauer, kan køres ud fra Risø området og deponeres som almindeligt bygningsaffald efter de herfor gældende regler under følgende forudsætninger:

1. De enkelte emner er blevet kontrolmålt af en af DD's helseassistenter og målingerne er blevet indført i det dertil indrettede måleskema, som er blevet godkendt af hhv. projektlederen og en helsefysiker eller laboratoriemesteren for AHF.
2. I forbindelse med læsning af materialet på lastvogn eller i container skal der foretages en kontrol af, at det er de rigtige emner, som læsses, og at kontrolskemaerne herfor er udfyldt og godkendt.
3. Umiddelbart forud for bortkørslen foretages en sidste kontrol af strålingen fra læsset.
4. Vedlagte skema udfyldes i to eksemplarer og underskrives. Det ene eksemplar gives til repræsentanten for entreprenøren, det andet opbevares af projektlederen.
5. Entreprenøren dokumenterer over for DD, at de fornødne tilladelser til deponering foreligger.
6. DD modtager en kopi af vejesedlen fra aflevering af materialet på affaldspladsen.

Når bortkørsel skal iværksættes gøres følgende:

1. Entreprenøren rekvirerer vognmanden til at køre materialet bort
2. DR 1 medarbejder sender en e-mail til Risøs portvagt med kopi til DD's tekniske vagt indeholdende følgende information (jf. omstående skabelon):
    - Navnet på vognmandsfirmaet
    - Cirka tidspunkt for ankomst
    - Instruks om, at der skal ringes til DR 1 og indhentes accept herfra, før vognen lukkes ind, og understregning af, at den under ingen omstændigheder må lukkes ind, hvis der ikke er opnået kontakt med en DR 1 ansvarlig medarbejder
    - Instruks om at henvise vognen til DR 1
3. DR 1 medarbejderen kontrollerer, at det er de rigtige emner, som læsses, og at kontrolskemaerne herfor er udfyldt og godkendt.
4. Helseassistenten kontrollerer strålingsniveauet fra lasten og noterer dette i skemaet.

5. Helsefysiker / Laboratoriemester samt projektlederen (eller dennes stedfortræder) godkender bortkørslen på skemaet.

Kurt Lauridsen

Skabelon for e-mail til Risøs portvagt

Til: risoe.portvagt@risoe.dk
Cc: rdd-tekvagt@risoe.dk

Den dd-mm-åå kommer en lastvogn fra vognmandsfirmaet XXXX for at afhente dekommissioneringsaffald fra DR 1. Vognen er tilsagt til at komme i tidsrummet kl. x-y.

Før lastvognen må lukkes ind, skal der ringes til DR 1 (4928 eller 4929) og opnås accept af, at man kan modtage den. Er der ikke nogen her, kan der ringes til xxx på xxxx xxxx.

Lastvognen må under ingen omstændigheder lukkes ind, hvis der ikke er opnået kontakt med en DR 1 ansvarlig medarbejder.

I bedes sikre jer, at chaufføren er helt klar over DR1's beliggenhed, så han ikke kører forkert.

Med venlig hilsen
xxx

Kontrolskema for bortkørsel af dekommissioneringsaffald fra DR 1

Dato:
Container nummer:

Affaldsemne ID	Kontrolmåleskema findes og er godkendt	Maksimalt strålingsniveau målt forud for bortkørsel	Bemærkninger

Godkendelse

	Måleskema er kontrolleret og materialet kan køres bort og deponeres ifølge gældende regler for bygningsaffald

Underskrift:

____________________________ Helsefysiker / Laboratoriemester

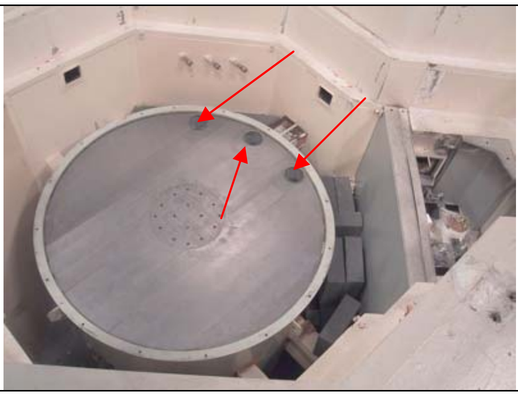
____________________________ Projektleder / Stedfortræder

Appendix 4 Example of a waste documentation form (in Danish)

DANSK DEKOMMISSIONERING

11-02-2005; KL

Identifikation og karakterisering af affaldsemne fra DR 1

Identifikation af emne:	
Emner / System	Kontrolsystem
Oprindelsessted	Ionkamre
Koordinater på oprindelig placering (x,y,z)	
Beskrivelse	3 stk. Al-rør hvori ionkamrene var placeret
Foreløbigt ID	DR1-28
Evt. henvisning til konstruktionsteg-ning	
Foto	
Vægt	14,5 kg
Dimensioner (l×b×h) eller (l×d) cm	130 x Ø10
Materialesammensætning	Aluminium
Mærkning af emnet	DR1-28
Emballage	Plast
Placering efter udtagning	Reaktorhal

Karakterisering (på anlæg):	
Ved emner, der er fremkommet ved deling af et større emne:	
ID (eller beskrivelse) for moderemne	
Resultater af håndmåling:	
Tidspunkt	29-04-2005
Sted	DR 1
Måling udført af:	PFP
Max. β-γ strålingsniveau i 1 meters afstand	0,7 μSv/h
Max. β-γ strålingsniveau ved overflade	1,5 μSv/h
Instrument	
Max. α-β kontaminationsniveauer	10^5 Bq/m^2
Instrument	
Klassificering:	
Formodet ikke aktivt	X
Formodet dekontaminerbart	
Aktivt	
Kommentarer og bemærkninger:	

Udfyldt af: PEB og KEC

Dato: 16-03-2005

Appendix 5 Contamination control of the floor in the reactor hall prior to clearance (in Danish)

Notat

DANSK DEKOMMISSIONERING

Kontaminationskontrol af gulv i DR 1 hallen forud for frigivelse

15. juli 2005

J.nr. DD-2005-412-5

Ref KL
Projektkontoret

Efter afslutning af nedbrydning af beton blev hallens trægulv støvsuget og derefter vasket med en gulvvaskemaskine.

Efter denne rengøring blev hele gulvet kontrolleret med en gulvmonitor (Nummer 6578), og partier med kontamination blev rammet ind med gul spraymaling. Disse partier blev dernæst brudt op som de første og overført til en container for radioaktivt dekommissioneringsaffald.

Resten af trægulvet blev herefter brudt op og alle brædder blev kontrolleret på undersiden med kontaminationsmonitorer (CoMo nummer 6147, 6694 og DD0005 samt Eberline E-600 nummer 4497), før de blev lagt i en affaldscontainer uden for reaktorbygningen. Ingen brædder blev fundet kontamineret på undersiden. Splinter og småstykker blev fejet sammen og lagt i grabben på en minidumper, som blev kontrolleret med en kontaminationsmonitor før udkørsel til containeren. Der blev heller ikke her konstateret niveauer over baggrund.

Efter at underlaget for trægulvet (strøer med betonpuds udstøbt imellem og med et tjærepaplag på toppen) var blevet fejet og støvsuget blev dette gennemmålt med gulvmonitoren (Nummer 6578) og de steder, hvor der var kontamination blev markeret med gul spraymaling. Afrivning af tjærepappen viste, at kontaminationen i flere tilfælde befandt sig her. I andre tilfælde var der (også) kontamination i betonpudsen og på strøerne. Alle kontaminerede dele blev taget op og overført til en beholder for radioaktivt affald. Efterfølgende kontrol med en E-600 (nummer 4497) godtgjorde, at der ikke længere var niveauer over baggrund.

Efter at alle kontaminerede partier således var fjernet, blev strøer og betonpuds brudt op og overført til affaldscontainere uden for reaktorbygningen.

Bente Lauridsen   Kurt Lauridsen

Appendix 6 Control form used for clearance (in Danish)

Kontrolskema for kontaminationsmåling på betonblokke fra DR 1's biologiske afskærmning forud for frigivelse

Måling udført af: TSC	**Dato: 21/6-05**
Blokkens nummer: 1-N-1-1	**Evt. ID:**

Smeartests:

Målt overflade	**α-aktivitet Bq/m²**	**β-aktivitet Bq/m²**	**Bemærkninger**
1. Top	< 0.5	< 0.8	
2. Bund	< 0.4	< 0.8	
3. Inderside	< 0.4	< 0.7	
4. Yderside	< 0.4	< 0.8	
5. Afskæringsside	< 0.5	<1.0	

Usikkerheden på aktivitetsbestemmelserne er ca. 50 %
< a : a er den mindste detekterbare aktivitet for den anvendte detektor

På alle flader er der ligeledes foretaget et totalt survey med en følsom ZnS-detektor (Termo Eberline E600 eller Como 170) for kontrol af hotspots eller unormalt høje strålingsniveauer. Der er ved dette survey ikke konstateret noget unormalt.

Godkendelse

Målingerne er kontrolleret og materialet

X	Kan frigives
	Kan eventuelt dekontamineres
	Skal deponeres som radioaktivt affald

Dato og underskrift:

Helsefysiker / Laboratorieleder

Projektleder

Appendix 7 Control of cutting sludge (in Danish)

Notat

DANSK DEKOMMISSIONERING

Måling på slam fra wireskæring af DR 1's biologiske afskærmning

3. august 2005

J.nr. DD-2005-412-5

Ref KL
Projektkontoret

I forbindelse med wireskæring af reaktorblokken blev der frembragt store mængder skæreslam, som løbende blev opsamlet i dertil indrettede kar. Efterhånden som karrene blev fyldt, blev slammet skovlet over i pallecontainere. Efter fyldning af pallecontainerne blev der udtaget prøver af slammet til analyse for aktivitetsindhold, ligesom der efter afslutning af skæringen blev taget prøver af det slam, der var tilbage i opsamlingskarrene.

Slamprøverne blev analyseret i γ-spektrometre B05053 og B05064 med nedenstående resultater. Der er kun detekteret ^{60}Co i slammet. Forholdet mellem ^{55}Fe og ^{60}Co i slammet antages at være det samme som for de boreprøver af betonafskærmningen, der blev udtaget forud for nedbrydningen. Konklusionen fra analyse af disse prøver var, at ^{60}Co indholdet er bestemmende for frigivelse som ikke-aktivt affald.

Beregning af frigivelsesindekset er beskrevet i DD-16, "Aktivitetsindhold i betonblokken på DR 1. Måleresultater som dokumentation for frigivelse". Indekset skal være mindre end 1 for at materialet kan frigives i henhold til frigivelseskriterierne.

Prøve fra	Aktivitetskoncentration for ^{60}Co [Bq/g]	Frigivelsesindeks
Pallecontainer A	0,028 ± 0,001	0,30
Pallecontainer B	0,035 ± 0,003	0,40
Pallecontainer C	0,050 ± 0,005	0,58
Pallecontainer D*	0,022 ± 0,004	0,28
Kar 1	0,022 ± 0,001	0,25
Kar 2	0,018 ± 0,002	0,21

*Oprindelig mærket "Lille kar"

Som det fremgår af tabellen, er frigivelsesindeks for alle prøverne mindre end 1, hvorfor slammet kan frigives som almindeligt bygningsaffald.

Bente Lauridsen　　Kurt Lauridsen