DD-19(EN)

DANSK DEKOMMISSIONERING

Final survey report for DR 1

Clearance of building and land

Document approved by the nuclear regulatory authorities

Danish Decommissioning, Roskilde
December 2005

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Abstract This report describes the clearance measurements that were made to verify that the DR 1 building and the surrounding land can be unconditionally cleared. The rooms in the building and the surrounding land were divided into classes according to their potential of being contaminated. Measurements in the building and on the surrounding land were done mainly with high-sensitive ZnS contamination monitors. When materials had been activated and/or activity had penetrated into the material or when more convenient, measurements were performed with Ge-detectors having an efficiency of 100 % relative to a 4 × 4 NaI-detector. Measurements on the land were performed with either contamination monitors or Ge-detectors. No contamination above the clearance levels was found in the DR 1 building and no contamination originating from the operation of the reactor was found on the surrounding land.

Revisioner i forhold til tidligere udgaver			
	Dato	**Navn**	**Underskrift**
Revideret	**9.12.2005**	**Bente Lauridsen**	
Godkendt	**9.12.2005**	**Per Hedemann Jensen**	

Contents

1 Introduction

The reactor DR 1 was closed in 2001 and the decommissioning of the reactor began in 2004. Further description of the reactor and the decommissioning work can be found in [1] and [2].

All objects removed from the reactor during the decommissioning were classified in the following categories [3]:

- "Red" objects: Objects that are either activated or contaminated to a level higher than the clearance level, and where no decontamination is possible.
- "Yellow" objects: Objects that are activated or contaminated to a level higher than the clearance level, but can be decontaminated to a level lower than the clearance levels.
- "Blue" objects: Objects that are expected to be activated or contaminated to a level below the clearance level.
- "White" objects: Objects that are not activated or contaminated.

Objects marked "red" were stored in a special container or in the Storage for High Active Waste. Objects marked "yellow" and "blue" were stored in special containers for later decontamination or measurements in the Clearance Laboratory. Objects marked "white" were disposed of as ordinary waste. The classification was done during 2004 and 2005.

The demolition and clearance of most the biological concrete shield are described in [4].

The plan is to reuse the reactor building and, consequently, clearance measurements have to be carried out on both the building and the surrounding land area to document an unconditional clearance of the building and the land. The results of these measurements and how they are applied in the evaluation of the clearance index for the reactor building and the land are presented in this final survey report.

2 Clearance criteria

Clearance levels for reuse of buildings are given by the nuclear regulatory authorities in the *Conditions for Operation and Decommissioning* for Danish Decommissioning and the levels are based on recommendations given by the European Commission [5].

The condition for clearance of a surface is that the nuclide- and surface-specific clearance levels should be applied to the total activity on and below the surface, divided by the surface area, *i.e.* to the sum of fixed and non-fixed activity on the surface plus the activity that has penetrated into the material. Averaging of the surface concentration (surface contamination density) is allowed only square meter by square meter of the total surface area. In addition, the sum over all measured nuclides, i, of the ratios of the nuclide-specific surface concentrations, C_i, on the surface to the corresponding clearance level, CL_i, should be less than or equal to 1:

$$\sum_i \frac{C_i}{CL_i} \leq 1 \tag{1}$$

Due to uncertainties in the measurement of surface-concentrations it is necessary to include these uncertainties in the clearance criteria. Assuming that each of the measured surface-concentrations, C_i, has its own normal distribution, and that the standard deviation for each distribution is σ_i, being equal to the uncertainty of the measured surface-concentration, and requiring a minimum 95% probability of not releasing material with concentrations above the clearance level, an extended clearance index, CI, is defined as:

$$CI = \sum_{i=1}^{N} \frac{C_i}{CL_i} + 1.65 \cdot \sqrt{\sum_{i=1}^{N} \left(\frac{\sigma_i}{CL_i}\right)^2} \quad (2)$$

where N is the number of radionuclides.

If the contamination is only a surface contamination, measurements with a contamination monitor detecting both α- and β-contamination on the surface will be sufficient. The extended clearance index, can then for each single square meter be expressed as:

$$CI = \frac{\overline{C}_\alpha}{CL_\alpha} + \frac{\overline{C}_\beta}{CL_\beta} + 1.65 \cdot \sqrt{\frac{\sigma(\overline{C}_\alpha)^2}{{CL_\alpha}^2} + \frac{\sigma(\overline{C}_\beta)^2}{{CL_\beta}^2}} \quad (3)$$

where $\overline{C}_\alpha$ and $\overline{C}_\beta$ are the average α- and β-surface contamination over the square meter and $\sigma(\overline{C}_\alpha)$ and $\sigma(\overline{C}_\beta)$ are the corresponding uncertainties.

For measurements with contamination monitors on a plane surface, the surface-specific clearance criterion is always met, when the measured surface-concentration does not exceed the detection limit of the monitor, because this detection is well below the clearance levels.

The clearance levels for surface-concentration of ^{60}Co, ^{137}Cs, and ^{152}Eu are 1 Bq/cm2.

3 Classification of the building

The DR 1 building and the areas surrounding the building are classified according to their potential of being contaminated or activated [6].

- Class 1 areas: Areas with a small probability of being contaminated or activated by neutrons to a level higher than the clearance levels. The measurement coverage of these surfaces is 100%.
- Class 2 areas: Areas with a large probability of being contaminated or activated by neutrons to a level below the clearance levels. The measurement coverage of these surfaces is 10 - 50%.
- Non-classified areas: Areas where there has been no or very little contact with radioactive materials. Only a few random measurements of these surfaces will be made to verify the classification.

Fig. 1 shows an outline of the rooms in the basement of the reactor building. The gray shaded area is not accessible from the basement, but is mainly concrete with channels used for cables. Fig. 2 shows an outline of the ground floor after the reactor and the biological shield have been removed.

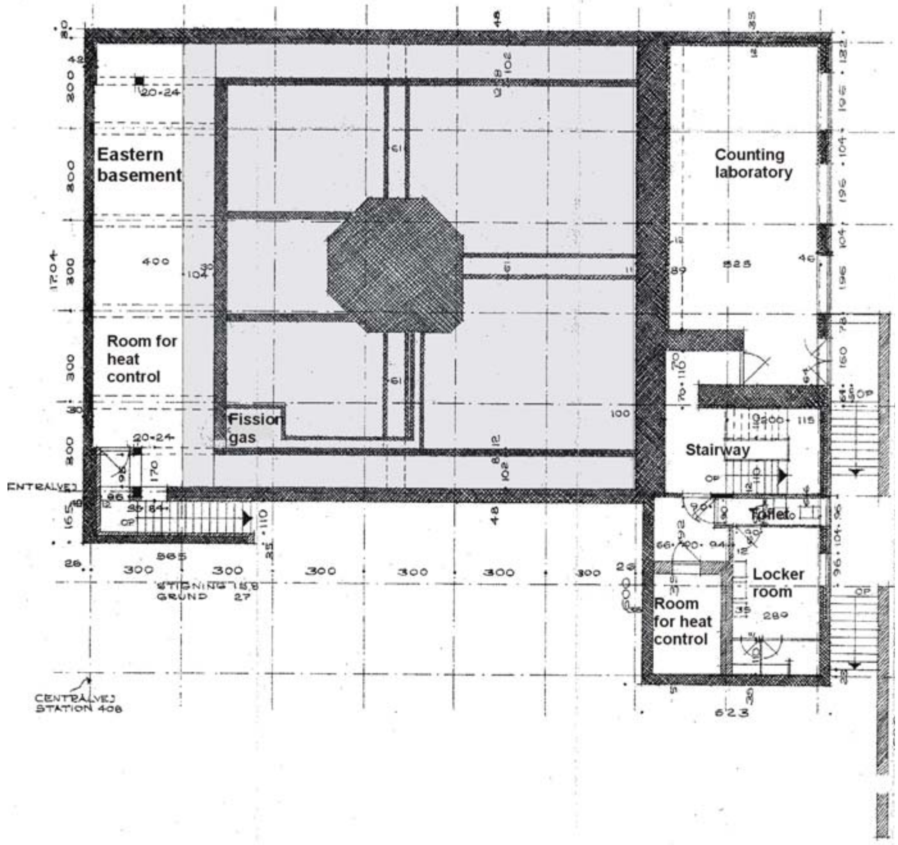

Figure 1. Eastern and western basement of the reactor building. The light gray area is not part of the basement.

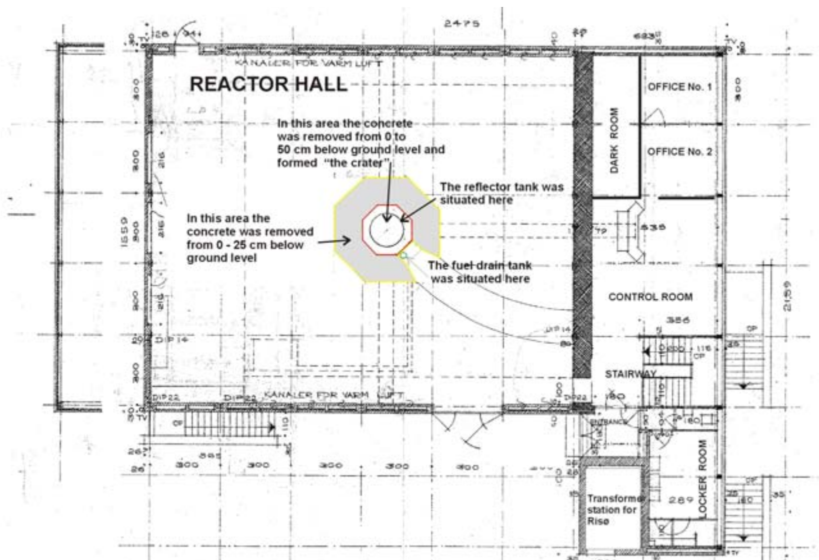

Figure 2. Ground floor of the reactor building after the reactor and the biological shield have been removed.

3.1 Room for heat control in the western part of the basement

This room is classified as a class 2 area, as no contamination is expected in this room. The room is shown from different angles in Fig. 3.

Figure 3. Room for heat control in the western basement.

3.2 Locker room and toilet in the basement

These rooms are classified as class 2 areas as they were used very seldomly; therefore no contamination is expected.

3.3 Counting laboratory in the basement

This room is classified as a class 1 area. It served as a laboratory and in here gamma spectrometric equipment was used to examine materials that were activated in the reactor. Also, a shielded 4π-counter was located in this room. Fig. 4 shows the counting laboratory.

Figure 4. The counting laboratory in the western basement.

3.4 Stairway

Some areas of the floor of the landing in the basement are classified as class 1 areas, as radioactive materials were stored here in cupboards. Also the small cupboards under the stairs and the steps of the staircase are classified as class 1 areas. The walls of the stairway are classified as class 2 areas not expected to be contaminated. Fig. 5 shows the area where the cupboard with the radioactive sources were located. Fig. 6 shows the small cupboards beneath the stairs.

Figure 5. The landing of the stairway in the western basement. The area where the cupboard with the radioactive sources was situated is marked in red.

Figure 6. The small cupboards below the staircase.

3.5 Rooms for heat control in the eastern part of the basement

The accessible areas on the floors in the eastern part of the basement are classified as class 1 areas as a few contaminated objects were found here during the decommissioning. Otherwise the rooms are classified as class 2 areas, as no contamination is expected in these rooms. Fig. 7 shows the northern end of one of the rooms in the eastern basement.

Figure 7. One of the rooms in the eastern basement.

3.6 Entrance

The entrance of the building is regarded as a class 2 area.

3.7 Locker room and toilet at the ground floor

The accessible parts of these rooms are classified as class 1 areas, as it was used during the decommissioning. The shower and one wash basin were connected to an "active tank" collecting potentially contaminated water.

3.8 Control room

This room is classified as a class 2 area. The room has always been classified as a white classified radiation and contamination area and no contamination is therefore expected.

3.9 Dark room

This room was checked for contamination a year before the commencement of the decommissioning and no contamination was found. During the decommissioning samples were stored at the floor and in the fume cupboard. Therefore the floor and the fume cupboard are classified as class 1 areas and the walls and the ceiling as class 2 areas. Fig. 8 shows the room seen from different angles. As seen in the figure, the fume cupboard was classified as a controlled area during decommissioning.

Figure 8. The dark room seen from the south (left) and from the north (right).

3.10 Office No. 1

This room is classified as a class 2 area as no contamination is expected.

3.11 Office No. 2

This room is classified as a class 2 area as no contamination is expected.

3.12 Reactor hall

The area where the reactor and the biological shielding was located is classified as a class 1 area. The walls, floor, ceiling and the crane in the reactor hall are also classified as class 1 areas.

The reactor hall is heated by air. The ducts for the air heating are classified as class 2 areas, as no contamination is expected here. The channels for the ducts are also regarded as class 2 areas.

4 Classification of the land surrounding the DR 1 building

Fig. 9 shows the reactor building and the immediate vicinity of the building. The photo is taken from north-east.

Figure 9. The DR 1 building seen from north-east. The asphalt in front of the building is classified as a class 1 area, staircases leading to the basements are classified as class 2 areas, while the rest of the land areas in the vicinity of the reactor building are regarded as non-classified.

The asphalt surface north of the building is classified as a class 1 area as all objects in the reactor building were transferred to containers outside the building via the gate in the reactor hall. The area was classified as a "blue contamination" area during the dismantling of the biological concrete shield, and, consequently, some contamination of the asphalt might have occurred.

The outdoor stairway at the western part of the building leading to the basement and the outdoor stairway leading to the eastern basement are classified as class 2 areas.

Towards south, west, and east there are meadows and cultivated fields. These areas are regarded as non-classified areas.

5 Measurements 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. Table 1 shows a list of the instruments used during the clearance measurements. The detection limits for each type of instruments are also shown in the table.

Table 1. The instruments used for the final survey of the building and the land.

Instrument	Detector	Detectable radiation	Detection limit $\left[\frac{Bq}{m^2}\right]$	
CoMo 170	ZnS	α, β	α: 100	β: 1,000
CoMo 300	ZnS	α, β	α: 60	β: 600
E600	ZnS	α, β	α: 200	β: 2,500
Thermo Delta 5	ZnS	α, β	α: 100	β: 1,000
Exploranium	NaI	γ		
Ge-detector	Ge	γ	Depends on the measuring time.	

With the software ISOCS, efficiencies for the Ge-detectors can be calculated for different geometries [6]. For most of the clearance measurements made at DR 1 the geometries used were:

- Rectangular plane for modelling surface contamination.
- Exponential circular plane for modelling exponential distribution of the radionuclides into the surface.
- Marinelli beaker for modelling radionuclides distributed on the inside surface of *e.g.* a pipe.

All measurements were made, so that $\sum_i MDC_i/CL_i$ was well below 1 where i refer to the relevant nuclides. MDC is the minimum detectable activity concentration and described in [7]. Some of the measurements with the Ge-detector were stopped, when the MDC-value was far below the clearance level. The MDC value is then used to determine the maximum clearance index.

5.1 Room for heat control in the western basement

Although this area was considered as a class 2 area, it was measured to a 100% coverage.

The floor was measured with a contamination monitor (Thermo Delta 5 Ratemeter No. DD10), and no contamination was found. The background was 0.07 - 0.08 Bq/cm^2, and the measurement showed values between 0.08 Bq/cm^2 and 0.11 Bq/cm^2.

The floor along the walls was measured with a CoMo 170 No. DD5, and no contamination was detected. The background count rate was 15 - 16 cps, and the measurements showed 15.5 - 17.5 cps, which is considered as background.

The walls were measured with a CoMo 300 No. 6694. No contamination was found.

The pipes, the valves, the walls over the piping, and the ceiling were measured with an Eberline E600 No. 6647, and no contamination was detected.

5.2 Locker room and toilet in the basement

Although the room is classified as a class 2 area, the measurement coverage was 100%. The measurements at the floor in the locker room were performed with a Thermo Delta 5 ratemeter No. DD10 and a CoMo 170 No. DD5. The measurements at the floor in the shower cabin were performed with a CoMo 170 No. DD5. The measurements at the floor in the toilet was performed with a CoMo 170 No. DD5. These measurements indicated values somewhat higher than the normal background and, therefore, supplementary measurements were made with the portable NaI-gamma-spectrometer Exploranium GR-130 miniSPEC No. 3273. The measurements showed that the tiles had a significantly raised content in ^{40}K, compared to other tiles in the room, which explained the elevated background. Fig. 10 shows one of the measurements with the Exploranium GR-130 detector.

Figure 10. The measurement in the shower-cabin with the Exploranium NaI-detector.

One corner of the floor showed even higher levels than the remaining part of the floor. Around this area one square meter was marked and measurements were made in the area. The measurement results showed that the clearance index, CI, was 0.11, and, consequently, the surface contamination was below the clearance levels. Fig. 11 shows the measurements in this area.

Figure 11. The potentially contaminated area in the locker room. Measurements were made with a contamination monitor CoMo 170.

The walls were measured with contamination monitors, CoMo 170 No. DD5 and CoMo 300 No. 6694. No contamination was found from these measurements.

5.3 Counting laboratory in the basement

The floor was measured with a Thermo Delta 5 Ratemeter No. DD10. Along the walls the floor was measured with a CoMo 300 No. DD5. A contaminated area was found where the barrel with the shielding for the 4π counter had been located. The contaminated spot was marked with tape as shown in Fig. 12.

Figure 12. The contaminated area in the counting laboratory. It is clearly seen, where the barrel for the 4π-counter was situated.

The spot contamination was removed by vacuum cleaning. The vacuum cleaner bag was analysed by γ-spectrometry and the analysis showed small amounts of ^{60}Co, ^{137}Cs, and ^{152}Eu.

The cupboards towards the south were measured with a contamination monitor, Eberline E600 No. 6647, and no contamination was found.

The remaining part of the room was measured with a Ge-detector, B05053. The detector was placed in the middle of the room without any shielding, thus covering all room surfaces, including walls and ceiling.

The soil surrounding the DR 1 building contains both naturally occurring radionuclides as well as ^{137}Cs from nuclear weapons fall-out and from the Chernobyl accident. As ^{137}Cs is one of the radionuclides, which could be a contaminant from the operation of the reactor, a background spectrum was measured in a private basement outside the Risø-area. This background spectrum was subtracted from the spectrum measured in the counting laboratory to determine if the operation or the decommissioning of the reactor had caused any contamination in the laboratory. No contamination was found.

Fig. 13 shows the measurement with the Ge-detector in the counting laboratory in the basement.

Figure 13. Measurement in the counting laboratory with the Ge-detector B05053.

5.4 Stairway

The floor of the landing in the basement was measured with contamination monitors, Thermo Delta 5 Ratemeter No. DD10 and CoMo 170 No. DD5. The walls were measured with a contamination monitor CoMo 300 No. 6694. No contamination was found. The wooden cupboard on the wall, seen in Fig. 5, was removed and the wall behind was measured with CoMo No. 6649. The telephone and LAN cabinet seen in the background was temporarily removed and the floor and walls behind it were measured with a contamination monitor CoMo 170 No. 6649. The ceiling was measured with a contamination monitor CoMo 170 No. DD5 and CoMo 300 No. 6694. No contamination was found.

The stairs were measured with contamination monitors CoMo 170 No. DD5 and CoMo 300 No. 6694. The walls along the stairs were measured to a 100% coverage to a height of one meter. On the remaining part of the walls, three surfaces, each of one square meter, were randomly chosen and measured with a contamination monitor CoMo 300 No. 6694. No contamination was found. Fig. 14 shows the marking of the wall.

The landing at the first floor was measured to a nearly 100 % coverage. The floor was measured with a contamination monitor Thermo Delta 5 No. DD10, and the walls, doors, ceiling, and ventilation pipe were measured with a contamination monitor CoMo 170 No. DD5. No contamination was found. The wall behind the ventilation pipe and the ceiling over the ventilation pipe were not measured. Figure 15 shows the measurement on the floor with the contamination monitor Thermo Delta 5.

Figure 14. A surface of one square meter is marked on the wall of the stairway.

Figure 15. The measurement of the floor at the upper landing of the stairway.

5.5 Room for heat control in the eastern basement

The rooms and the objects in the rooms were measured to a nearly 100 % coverage. The instruments used were CoMo 170 No. 6651 and CoMo 170 No. DD5. No contamination was found.

5.6 Entrance

Although the entrance was classified as a class 2 area, it was measured for contamination to a nearly 100% coverage. The walls, the ceiling, and the doors were measured with contamination monitor CoMo 170 No. DD5. The floor was measured with the contamination monitor Thermo Delta 5 No. DD10. No contamination was found.

5.7 Locker room and toilet on the ground floor

The walls, the ceiling, the floor, and all objects in the locker room were measured for contamination with contamination monitors CoMo 170 No. DD5 and DD21. No contamination was found.

In the toilet, the floor, the door, the walls, the toilet and other objects were measured for contamination with a CoMo 170 No. DD5. No contamination was found.

Fig. 16 shows the locker room and the toilet.

Figure 16. The locker room and the toilet at the first floor.

5.8 Control room

Although the control room is regarded as a class 2 area it was measured to a nearly 100% coverage. The floor was measured with a contamination monitor Thermo Delta 5 No. DD10. The walls, the ceiling, the doors, the window sills, the different objects and the furniture and fixtures were measured with a CoMo 170 No. DD5. No contamination was found.

Fig. 17 shows the control room after the control console has been removed.

Figure 17. The control room seen from different angles.

5.9 Dark room

This room was measured to a nearly 100% coverage with contamination monitors. The instrument used was CoMo 170 No. DD5. Two contaminated spots were found on the table in the fume cupboard as indicated in Fig. 18.

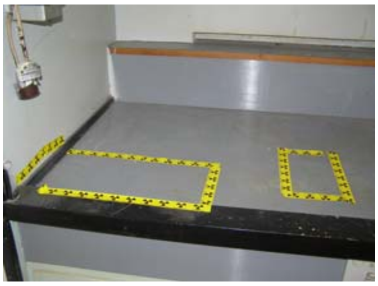

Figure 18. The contaminated spots in the fume cupboard.

The table was decontaminated with a piece of cotton moistened with methylated spirit. The cotton was analysed by gamma spectrometry and traces of ^{137}Cs was detected. After the decontamination the fume cupboard was checked for contamination with CoMo 170 No. DD5, and no contamination was found.

The remaining part of the room, walls ceiling etc. were checked for contamination with a CoMo 170 No. DD5. No contamination was found.

5.10 Office No. 1

Although classified as a class 2 area, the room was checked for contamination to a nearly 100 % coverage. The floor was measured to a 100 % coverage with a Thermo Delta 5 No. DD10 contamination monitor. The walls, window sills, ceiling, objects, papers and furniture were measured with a contamination monitor CoMo 170 No. DD5. No contamination was found. Fig. 19 shows the office.

Figure 19. Office No. 1.

5.11 Office No. 2

Although classified as a class 2 area, the room was checked for contamination to a nearly 100 % coverage. The floor was measured with a Thermo Delta 5 No. DD10 contamination monitor. The walls, window sills, ceiling, objects, papers and furniture were measured with a contamination monitor CoMo 170 No. DD5. No contamination was found. Fig. 20 shows the office.

Figure 20. Office No. 2.

5.12 Reactor hall

In the reactor hall contamination of the walls, the ceiling and the floor was measured with Ge-detectors and contamination monitors. The well, where the fuel drain tank had been placed, was measured with a contamination monitor; the crane was measured with both contamination monitors and Ge-detectors; the channels for the heating system were measured with contamination monitors; and the outlet with the ventilation fan was measured with contamination monitors and a Ge-detector.

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.

A background spectrum was therefore taken in a private home, where the detectors overlooked a landscape similar to the one surrounding DR 1. This background spectrum was 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.

The background measurements for the ceiling was performed in a workshop at Risø. The construction design of this workshop is very similar to the architecture of the DR 1 building; however, the inner ceiling in the workshop is made of concrete instead of insulation bats as in DR 1. Therefore it was necessary to correct the background spectrum for the difference between the two materials regarding photon transmission.

5.12.1 Well for the fuel drain tank

The well had been contaminated during reactor operation or, more likely, during the decommissioning. Firstly, an attempt to decontaminate the well using methylated spirit was made; later it was decontaminated mechanically with a special steel brush. A smear-sample was taken of the whole surface of the well and analysed on a gamma-spectrometer. The analysis showed that the well was contaminated with ^{60}Co and ^{137}Cs. Direct contamination measurements could decide whether or not the well could be cleared.

After the decontamination, the whole surface of the well was measured in steps with a contamination monitor E-600 No. 6647 for both α- and β-contamination. The diameter of the well is 25 cm and the depth is two meters. 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.* a 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 uncertainties of the measurements were estimated to about 25%. The clearance index, CI, was calculated according to Eq. (3) 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.

5.12.2 Ducts and channels for the heating system

The ducts for the heating system are not accessible. It was assumed that if any contamination was to be found in the ducts, it could be detected behind the ventilation grills of the outlet from the hall. The wall behind the grills were measured with contamination monitor CoMo 170 No. DD5. No contamination was detected. Some dust behind the ventilation grills was scraped off the wall 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 at each square meter, the surface contamination of ^{137}Cs would be less than 1500 Bq/m^2 and less than 200 Bq/m^2 for ^{60}Co. It was therefore concluded, that the contamination of the ducts would be far below the clearance levels.

The channels for the ventilation ducts had been covered with concrete and a 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 the access holes. Therefore, the areas in the channels around the access holes were measured with a contamination monitor CoMo 170 No. DD5. No contamination was found. Fig. 21 shows the wall behind one of the ventilation grills and Fig. 22 shows one of the channels with the ventilation ducts.

Figure 21. The heating air outlet from the reactor hall. The ventilation grills have been removed for measurements behind the grill and in the ducts.

Figure 22. One of the channels with the ventilation ducts. To the left, the access to the channel is shown. To the right, the channel is seen. The channel has a height of 90 cm.

5.12.3 Channel for the fission gas system and the channels for electric cables

Contamination measurements showed that the channels leading to the north was contaminated close to the former reactor location. This was not surprising as the Fuel Mix Bowl was placed just above the channel. The channel leading to the south was also contaminated but no explanation for this has been found. The contaminated concrete was removed and subsequent measurements showed no contamination.

5.12.4 Ceiling

Four measurements were made in the reactor hall with the Ge-detector pointing upwards. The ceiling of the workshop at Risø, where the background measurement - also with the detector pointing upwards - was made, consisted of 12 cm thick plates made of light concrete with a density of about 1 g/cm^3. From the background measurement in the workshop it was calculated that the contamination of the roof at the workshop from weapons and Chernobyl fall-out was 111 $\pm$ 30 Bq/m^2 of ^{137}Cs. From the measurements in the reactor hall a surface contamination of 116 $\pm$ 32 Bq/m^2 ^{137}Cs on the roof was calculated. It is therefore concluded, that the ^{137}Cs detected at DR 1 with the detector pointing towards the ceiling is not significantly different from the ^{137}Cs-contamination background measured at the workshop.

5.12.5 Ventilation channel

Wipe tests from the inside of the ventilation channel revealed that the channel was slightly contaminated with ^{137}Cs. These wipe tests were analysed for ^{90}Sr in an attempt to determine the origin of the contamination. If the contamination originated from weapons fall-out and/or from the operation of the reactor, ^{90}Sr would be expected on the wipe tests. If the contamination originated from fall-out from the Chernobyl accident there would be no or very little ^{90}Sr on the wipe tests. In the latter case, it could then be concluded that the contamination did not originate from the operation of the reactor.

^{90}Sr *was* found on the cloth, so the possibility that the contamination originated from the operation of the reactor could not be ruled out. 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, although the origin most likely is fall-out.

A measurement was made with a collimated Ge-detector pointing directly at the ventilation channel. In section 5.12.4 it was concluded that the ^{137}Cs detected with the collimated detector pointing upwards (not seeing the ventilation channel) originated from fall-out at the roof. This measurement was used as a background measurement.

The measurement on the ventilation channel showed a surface-concentration of ^{137}Cs less than 3000 $\pm$ 800 Bq/m^2 at any one square meter. Fig. 23 shows the measurements on the ventilator.

5.12.6 Crane

Most of the crane was measured with the contamination monitors CoMo 170 No. DD5 and CoMo 170 No. 6147. These measurements showed no contamination. The remaining part of the crane was measured with a Ge-detector. The result of this measurement showed a surface contamination of less than 4,800 $\pm$ 1,200 Bq/m^2 of ^{137}Cs.

Figure 23. Measurement on the ventilator channel.

5.12.7 Walls and floor

The brick walls and the window sills were measured with contamination monitors, CoMo 170 No. 6147 and CoMo 170 No. DD21. The concrete wall to the west was measured with a contamination monitor CoMo 170 No. DD5 up to a height of 2 meters above the floor.

The floor was measured with contamination monitors CoMo 170 No. DD5 and CoMo 300 No. 6694. The frame around the fission gas pit was contaminated and therefore removed. A small contaminated spot in the south-western part of the hall was removed by vacuum cleaning.

The rest of the walls were measured with Ge-detectors B5064 and B5053. 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 meters below the ceiling. It was conservatively assumed that all the activity seen by the detector was situated in one square meter that was positioned farthest away from the detector. Most likely the contamination will be evenly distributed on the wall and for comparison the average surface concentration has also been determined.

Fig. 24 shows the measurement where the detector is pointing at the western upper part of the southern wall. Similar measurements were made for all the other walls. In total eight measurements were made on the walls.

Figure 24. The detector is pointing at the western upper part of the southern wall.

Fig. 25 shows the square meter assumed to contain all the activity measured on the eastern part of the northern wall.

Figure 25. The one square meter assumed to contain all the activity found on the eastern part of the northern wall.

Fig. 26 shows the use of a laser beam to determine the line of sight of the detector.

Figure 26. A laser beam is used to position the detector at the western part of the northern wall.

The only artificial radionuclide found in the measurements was ^{60}Co. Table 2 shows:

- the surface contamination density, $C_{1\ m^2}$, if all the activity measured is placed at the square meter, which is positioned farthest away from the detector.
- the clearance index, $CI_{1\ m^2}$, if all the activity measured is placed at the square meter, which is positioned farthest away from the detector
- the surface contamination density, C_{even}, if all the activity measured is evenly distributed on the whole wall

Table 2. The results of the gamma-spectrometric measurements of surface concentration on the walls in the reactor hall. The only radionuclide found was ^{60}Co.

Wall	$C_{1\ m^2}$ [Bq/m^2]	C_{even} [Bq/m^2]	$CI_{1\ m^2}$
Northern wall			
Western part	$4.90 \cdot 10^3 \pm 8.6 \cdot 10^2$	19.3 ± 3.3	0.63
Eastern part	$< 4.3 \cdot 10^3 \pm 1.1 \cdot 10^3$	$< 29.8 \pm 7.5$	< 0.61
Eastern wall			
Northern part	$< 3.69 \cdot 10^3 \pm 9.2 \cdot 10^2$	$< 48 \pm 12$	< 0.52
Southern part	$< 4.3 \cdot 10^3 \pm 1.1 \cdot 10^3$	$< 48 \pm 12$	< 0.61
Southern wall			
Eastern part	$< 3.61 \cdot 10^3 \pm 9.0 \cdot 10^2$	$< 24 \pm 6$	< 0.51
Western part	$2.99 \cdot 10^3 \pm 6.8 \cdot 10^2$	13.3 ± 2.9	0.41
Western wall			
Southern part	$< 4.8 \cdot 10^3 \pm 1.2 \cdot 10^3$	$< 16.8 \pm 4.2$	< 0.68
Northern part	$3.00 \cdot 10^3 \pm 8.3 \cdot 10^2$	11.3 ± 3.1	0.44

5.12.8 Reactor foundation

The area left open after the removal of the reactor, the "crater", was measured with the Ge-detector. This surface is activated, and the activity is depth-distributed into the concrete. Drill samples have shown that the activity concentration is decreasing 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 the first measurement the detector was pointing to the middle of the "crater" and covering the whole "crater". The concrete below the reactor was ordinary concrete, and the radionuclides to be expected in activated concrete are ^{152}Eu and ^{60}Co. It was conservatively assumed that all the activity seen by the detector was situated below only one square meter.

The second, third and fourth measurement covered the edge of the "crater", *i.e.* the area where the biological shield were situated. One measurement was made where the biological shield had the lowest activity, and one measurement, where the biological shield had the highest activity. The last measurement was made on one of the remaining edges to confirm the other measurements. Again, the detector covered at least one square meter and it was conservatively assumed, that all the activity was concentrated below one square meter.

Fig. 27 shows the measurement on the "crater".

Figure 27. The measurement at the reactor foundation area.

In Fig. 28 the measurement on one of the edges of the "crater" is shown.

Figure 28. The measurement at the north-eastern part of the area where the biological shield was situated.

Table 3 shows the result of the measurement in the area, where the reactor was situated. The radionuclides found were ^{152}Eu and ^{60}Co.

Table 3. The results of the measurement at the reactor foundation area.

Position	$C_{1\ m^2}$ [Bq/m^2]		$CI_{1\ m^2}$
Middle	^{152}Eu: ^{60}Co:	$5.285 \cdot 10^3 \pm 8.6 \cdot 10^1$ $0.437 \cdot 10^3 \pm 0.2 \cdot 10^1$	0.59
North-east	^{152}Eu: ^{60}Co:	$2.099 \cdot 10^3 \pm 8.3 \cdot 10^1$ $0.265 \cdot 10^3 \pm 0.4 \cdot 10^1$	0.25
South-east	^{152}Eu: ^{60}Co:	$3.45 \cdot 10^3 \pm 1.1 \cdot 10^2$ $0.388 \cdot 10^3 \pm 0.5 \cdot 10^1$	0.40
South-west	^{152}Eu: ^{60}Co:	$5.29 \cdot 10^3 \pm 1.6 \cdot 10^2$ $< 0.322 \cdot 10^3 \pm 8.3 \cdot 10^1$	< 0.59

6 Measurements of the land

The asphalt to the north of the front of the reactor building was measured to a 100% coverage for contamination with contamination monitors Thermo Delta 5 No.6578, Thermo Delta 5 No. DD10, and CoMo 170 No. DD5. No contamination was found.

Fig. 29 shows the contamination measurement on the asphalted area north of the building.

Figure 29. The measurement with a contamination monitor on the area north of the building.

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.

Fig. 30 shows the measurements on the asphalt area north of the building.

Figure 30. Gamma-spectrometric measurement at the asphalt area north of the 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. Fig. 31 shows the background measurement and the measurement east of the DR 1 building.

 

Figure 31. Gamma-spectrometric measurement of the background the area east of the DR 1 building.

Again, no contamination resulting from the reactor operation and decommissioning was found.

7 Summary of the measurements in the building and on the outside areas

Table 4 shows a summary of measurements inside the building and of the measurements on the outside areas.

Table 4. Summary of the measurements.

Location	Instruments used	Conclusion
Room for heat control in the western basement	Thermo Delta 5, CoMo 170, CoMo 300	No contamination
Locker room and toilet in the western basement	Thermo Delta 5, CoMo 170, CoMo 300, Exploranium	Walls: no contamination Spot at floor $CI = 0.11$
Counting laboratory in the western basement	Thermo Delta 5, CoMo 300, E-600, Ge-detector	No contamination
Stairway	Thermo Delta 5, CoMo 300, CoMo 170	No contamination
Room for heat control in the eastern basement	CoMo 170	No contamination
Entrance	CoMo 170, Thermo Delta 5	No contamination
Locker room and toilet on the ground floor	CoMo 170	No contamination
Control room	CoMo 170, Thermo Delta 5	No contamination
Dark room	CoMo 170	No contamination
Office No. 1	CoMo 170, Thermo Delta 5	No contamination
Office No. 2	CoMo 170, Thermo Delta 5	No contamination
Reactor Hall:		
Well for the fuel drain tank	E-600	$CI_{upper\ part} = 0.48$ $CI_{lower\ part} = 0.41$
Channels for the heating system		No contamination
Channels for fission gas system and for electric cables	CoMo 170	No contamination
Ceiling	Ge-detector	No contamination
Ventilation channel	Ge-detector	$CI < 0.37$
Crane	Ge-detector	$CI < 0.68$
	CoMo 170	No contamination
Eastern wall	Ge-detector	$CI < 0.61$
Western wall	Ge-detector	$CI < 0.68$
Northern wall	Ge-detector	$CI < 0.63$
Southern wall	Ge-detector	$CI < 0.61$
The reactor foundation area	Ge-detector	$CI < 0.59$
Outside areas	Ge-detector, Thermo Delta 5	No contamination

8 Conclusion

Clearance measurements have been performed for the DR 1 building and the surrounding land.

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.

The measurements on the surrounding land showed no artificial activity resulting from the operation and decommissioning of DR 1.

It can, therefore, be concluded that the DR 1 building and the surrounding land can be unconditionally cleared.

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