DECOMMISSIONING OF THE ASTRA RESEARCH REACTOR – DISMANTLING OF THE BIOLOGICAL SHIELD

by

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Received on July 3, 2006; accepted in revised form on September 22, 2006

The paper describes the dismantling of the inactive and activated areas of the biological shield of the ASTRA research reactor at the Austrian Research Center in Seibersdorf. The calculation of the parameters determining the activated areas at the shield (reference nuclide, nuclide vector in the barite concrete and horizontal and vertical reduction behaviors of activity concentration) and the activation profiles within the biological shield for unrestricted release, release restricted to permanent deposit and radioactive waste are presented. Considerations of located activation anomalies in the shield, *e. g.* in the vicinities of the beam-tubes, were made according to the reactor's operational history. Finally, an overview of the materials removed from the biological shield is given.

Key words: decommissioning, ASTRA research reactor, dismantling, biological shield

INTRODUCTION

After 39 years of successful operation (1960-1999), the 10 MW MTR Research Reactor ASTRA was finally shut down. By the decision of the government based on concepts conceived by the reactor's management [1], an immediate dismantling was performed. During 2002, an environmental impact statement was prepared, a public hearing held on December 19, 2002, followed by a license for decommission which was legalized in May 2003 [2]. Working under this license, the structures of the biological shield were dismantled by cutting blocks in multiple section planes. Organizational, planning and dismantling work, carried out up to 2003, including radiation protection and waste management procedures, have already been presented in an earlier publication of *Nuclear Technology & Radiation Protection* [3].

Technical paper
UDC: 621.039.566/.74
BIBLID: 1451-3994, *21* (2006), 2, pp. 79-91

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PREPARATION FOR DISMANTLING OF THE BIOLOGICAL SHIELD

In order to reach a decision on dismantling techniques to apply on materials in the activated zone, an extensive sampling program started immediately after the decommissioning license was granted. To take down the inactive structures of the biological shield (400 m^3 of reinforced barite concrete, totaling approximately 1500 tons, (fig. 1), several techniques were taken into account. Finally, dividing the biological shield into blocks of between 7 and 9 tons (limited by the 10-ton-capability of the crane), applying wire cutting techniques, was chosen as the most promising method under ASTRA auspices.

There were several advantages to the choice of wire cutting techniques:

– Measurements and calculations have shown that the risk of spreading contamination due to cutting was almost non-existent. Since wire cutting requires a lot of water, no dust would occur and already considered, expensive housing, would be obsolete. A local installation of a high powered vacuum cleaner, after a prior cyclone unit reducing prematurely dust and fog particles, followed by absolute filters directly attached to the exhaust side, proved to be sufficient.

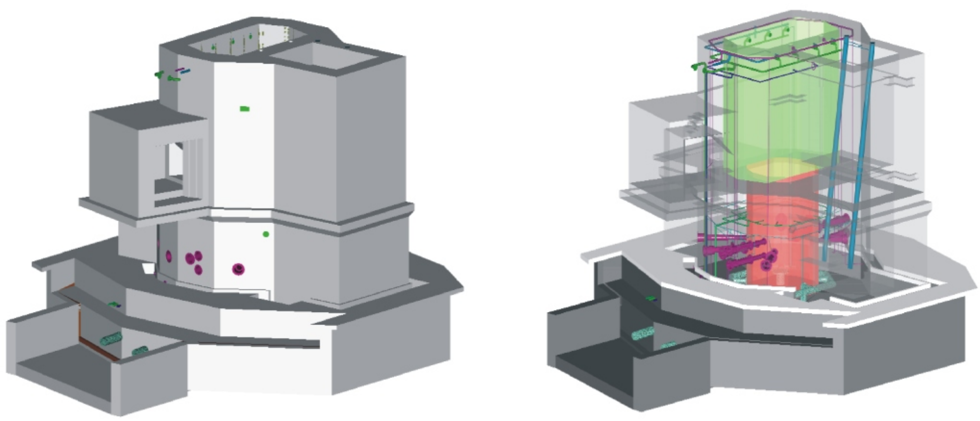


Figure 1. Autocard-3D-study, ASTRA reactor, biological shield, total and transparent view

- Work could be done with a minimum of manpower, only two external experts were needed for the handling of the cutting equipment, usually supported by two co-workers and one supervisor of the decommissioning crew, mainly responsible for the controlled gathering of the sludge.
- Last but not least, the possibility of applying surface measurements with higher sensitivity compared to the traditional in-barrel technique should guarantee levels of clearing to the standards of re-use.

In order to obtain sufficient data for "clearance measurements" and to give a clear picture of the sensitivity of the surface contamination of the cut blocks, a Canberra ISOCS device was evaluated, with positive results [4]. A program for additional intern probing and examining of embedded tubes completed the efforts to prove clearance [5]. The process was presented to and accepted by governmental experts in due time.

A building directly attached to the reactor was erected to give ample room for clearance measurements and clearance procedures. The ISOCS device was mounted to custom designed gimbals traveling along horizontal and vertical guide rails. All surfaces of the blocks could be reached with a minimum of crane work. Applied measuring started in April 2004. By the end of 2004, approximately 100 blocks totaling 600 metric tons (roughly 40% of the total) were already cleared.

Part of the sectional floors, supported on one side by the biological shield, had to be removed to give access to the shielding. A superstructure was raised to support the intermediate and the upper floor. The remaining sections of the floors and the control room had to be maintained, since a part of the ventilation system was housed within this area. An area of the reactor basement under the remains of the sectional floors was modified to an enclosed and separately ventilated working area, equipped with stationary cutting and shearing equipment for the preconditioning of contaminated metals from the dismantling of the primary water installations, transferred from the pump room within closed steel containers.

The primary water was finally drained from all systems directly connected with the tank and the lower hot cell (usually filled with primary water) and the surfaces of the liners were cleaned using high water pressure. To prevent the spreading of contamination from metal surfaces following oxidation, after the depleting of the primary water, a thin layer of water diluted paint was found to be sufficient.

All connections, *e. g.* electricity, pressurized air, primary water supply, were disconnected from the biological shield, wires and tubes removed. The concrete surfaces of the upper hot cell (designed for dry use only) were cleaned of contamination.

DISMANTLING THE INACTIVE AREA OF THE BIOLOGICAL SHIELD

The liner of the tank was removed to a level 3 meters below the upper floor. After gaining some experience with wire cutting, at the lower levels aluminum and other metal structures on some surfaces were cut in the process of cutting the barite concrete, significantly reducing the efforts necessary to remove the partly embedded metal structures of the liner *in situ*.

In preparation for the cutting work on the biological shield, working platforms were installed in the pool and in the upper hot cell. Additional measures were taken to control the drain of the cutting fluid and to remove concrete and steel particles from the solution. Calculations showed that at least 30 tons of cake was to be expected, supposed to be inactive waste by definition. Therefore, careful collection and preparations to achieve clearance were essential in preventing contamination and/or cross contamination. The actual cutting started in February 2004.

In consideration of the sections in which the biological shield was originally molded (fig. 2), a top layer with a vertical extension of 2.4 meters was divided into 33 blocks (fig. 3). The cutting of level 1 was completed on March 16, 2004. After removing and clearing the blocks, cutting on level 2 with a vertical height of 2.15 meters was resumed in June 2004, producing another 43 blocks. By the end of September, cutting at level 3 with a vertical extension of only 0.94 meters (14 blocks) took place. The collection and clearance of the cake was successfully achieved.

Results obtained by subsequently probing the shield in a vertical pattern allowed for another cut at level 4, 1.8 meters below level 3, together with the reduction of the structures of the lower hot cell and the outer thermal column, to ground level (level 5). At blocks of the section plane 4, directly adjoining the activated part of the biological shield and crossing over to the activated zone, the compliance with the permissible limit was additionally proven by taking core drill samples at prominent regions. Cutting work at levels 4/5 ceased by the end of February 2005.

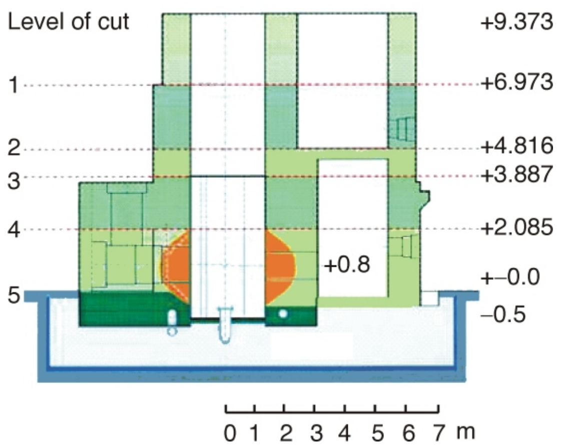


Figure 2. Layers designated for cutting

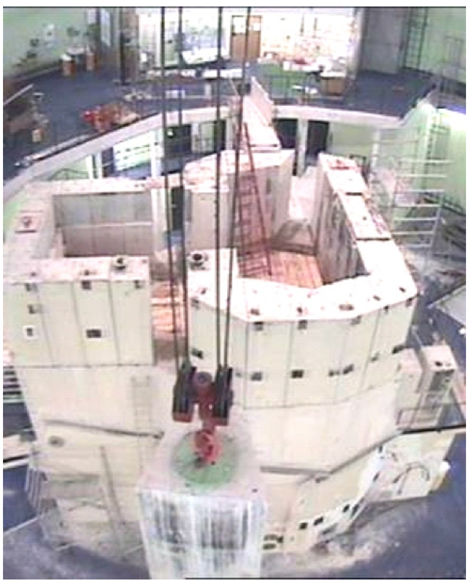


Figure 3. Removing of blocks 1st layer

Due to precautions taken during the cutting process and intensive clearance procedures, all barite concrete blocks could be released to a level sufficient for "buildings for re-use", after minor mechanical treatment. The cleared blocks (1091 tons) were transferred into a deposit specialized for recovered building materials (building-remainder-mass-dump). At the request of the authorities, the blocks were stored in a marked area for later recycling.

Additionally, the barite concrete-sludge was sufficiently dried to ensure safe transport. Clearance data were obtained by sampling at a rate of approximately one sample per 100 liter. Though, from a radiological point of view, most of it could be cleared without restrictions, it had to be transferred into a permanent remainder-mass-dump for technical/chemical reasons.

DISMANTLING THE ACTIVATED AREA OF THE BIOLOGICAL SHIELD

In March 2005, immediately after the dismantling of the inactive zone of the biological shield, the dissecting of the activated parts began.

The bottom part of the biological shield containing the activated zone consisted of rather highly activated concrete facing the side of the former core, with activity levels significantly exceeding levels for release. Still, there also had to be regions with less or non-activation, with materials fulfilling the requirements for conventional dumps or even re-use. Due to neutron flux measurements along the circumference of the pool carried out during the last operations of the reactor, activation analysis of the barite concrete samples and some additional calculations, a more or less homogenous estimated activation depth of 1 meter, with a mass of roughly 60 to 70 tons, was considered as the "activated" zone (fig. 2, area marked). In order to reduce the amount of radioactive waste remaining from the biological shield to a reasonable minimum, a more accurate definition of the periphery between the zones was necessary. Primarily, the vector of the radio nuclides within the activated concrete had to be determined and, with reference to the legal regulations, a "total weighting factor" according to Column (Spx)

($BF_{s(Spx)}$) for the release of the concrete had to be developed [6].

Nuclide vector of the activated barite concrete and total weighting factors [$BF_{s(Spx)}$]

Samples from different areas of the biological shield were taken and examined via gamma spectrometry and/or after additional chemical processing by Alpha Spectrometry, as well as by Liquid Scintillation Counting (LSC). It became evident that H-3 was dominant. Nevertheless, because of the easy detection by gamma spectrometry, Ba-133 was specified as the reference nuclide. As soon as the activity concentration of the reference nuclide was known, activity concentrations of other radio nuclides could quickly be specified. In tab. 1, the percentage fractions of the activity concentration of radio nuclides present within the barite concrete of ASTRA's biological shield are indicated in relationship to the reference nuclide Ba-133. In order to decide about the release levels of all nuclides present, a weighting factor ($BF_{s(Spx)}$), taking into consideration activity concentrations and clearance values of the radio nuclides, was determined as the sum of the quotients of the activity concentration (C_i) and clearance value ($FW_{i(Spx)}$) of the radio nuclides (i) in the nuclide vector of the barite concrete:

$$BF_{s(Spx)} \qquad \frac{C_i}{FW_{i(Spx)}}$$

Table 1. Nuclide-vector and clearance values ($FW_{i(Spx)}$): barite concrete, biological shield of the ASTRA research reactor, Seibersdorf

Nuclide	[%]	Normalized to Ba-133	$FW_{i(Sp9)}$ [Bq/g]	$FW_{i(Sp5)}$ [Bq/g]
Ba-133	15.9	1	30	1
Co-60	0.9	0.057	4	0.1
Eu-152	1.5	0.094	8	0.2
Eu-154	0.1	0.006	7	0.2
H-3	73.6	4.629	1,000	1,000
Fe-55	9.1	0.572	10,000	200

According to the "German Radiation Protection Regulation" (Dt.StrSchV) [7], annex IV, tab. 1, Column 9 (Sp9), clearance value $FW_{i(Sp9)}$ refers to the clearance of a material restricted to permanent deposit, whereas $FW_{i(Sp5)}$ refers to clearance for unrestricted re-use.

Also according to the German Radiation Protection Regulation, annex IV, lit. e, further radio nuclides detected or calculated, such as Ni-63, Ca-45, Ca-41, Am-241, and Pu-238/239/240, were not considered since the weighting factors of these radio nuclides amount to less than 10% of the total weighting factor – $BF_{others(Spx)} \quad 0,1.BF_{s(Spx)}$. Fortunately, reinforcement steel occurred rather deeply embedded in the barite concrete. Nevertheless, the nuclide vector and the penetration of activation were examined to the same depth as with barite concrete, but there was no need for special considerations within the following assumptions.

To take into account the values of the normalized nuclide vector (sum of the quotients of the particular normalized value and the clearance value), this weighting factor can also be calculated directly from the activity concentration of the reference nuclide Ba-133. The respective weighting factors according to tab. 1 were calculated as follows:
Reference nuclide Ba-133:

$$BF_{s(Sp9)} = 0.065\, C_{Ba\text{-}133}$$
$$BF_{s(Sp5)} = 2.078\, C_{Ba\text{-}133}$$

If $BF_{s(Sp9)}$ is less than 1, the concrete can be cleared for permanent deposit, If $BF_{s(Sp5)}$ is less than 1, clearance can be granted for unrestricted re-use.

Determination of the horizontal activation degree of the biological shield

To determine the horizontal activation profile of the biological shield, horizontal core-drill samples were taken at different locations along the circumference of the shield. Cores of approximately 5 cm in diameter and of lengths sometimes exceeding two meters were taken. From the cores and beginning with the most activated side, reference samples with an average length of 5 cm were cut (fig. 4).

These samples were examined by gamma spectrometry and the corresponding activity concentration of Ba-133 as the reference nuclide [Bq/g] was determined. Using the measurements of each drill core, a horizontal decrease in activity concentration could be determined. Figure 5 shows this behavior at drill core NF-411, at level $z = \quad 80$ cm (center axes of the reactor core, level $z = \quad 0$ cm, referring to the ground level of the reactor building), at orientation $x = 320°$ (0° is due north).

All these drill cores showed comparable reduction behaviors with insignificant differences relative to the penetration depth, easily approximated by an exponential function ($C_{z,y} = C_{z,0}\, e^{\ ky}$). For simple application, a so called "average activity ruler" could be developed.

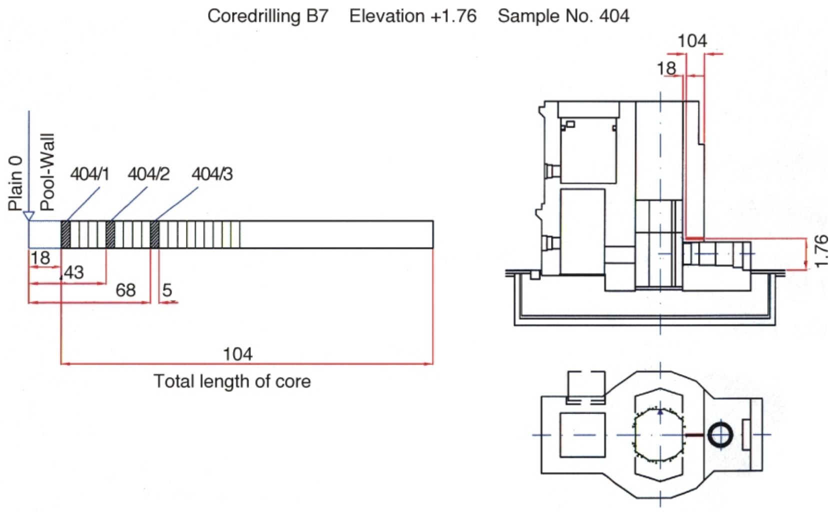


Figure 4. Typical preparation and location of a core-drill sample (Sample No. 404)

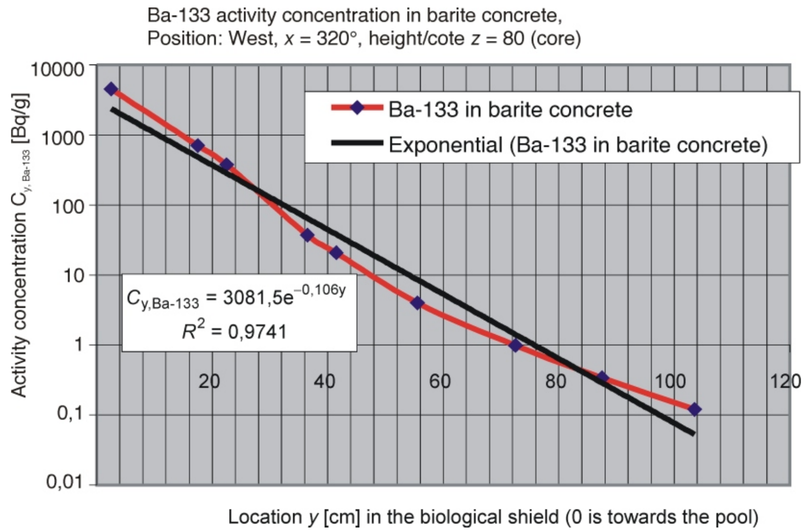


Figure 5. Depth distribution of the Ba-133 activity concentration inside the biological shield

Figure 6 shows the exponential reduction of the activity concentration of all measured distributions, at different orientations *x* around the pool and at different levels *z*. From all these exponential reduction values, an average reduction (average activity ruler) was determined.

Now, based on this "average activity-ruler", with the determined activity concentration of a

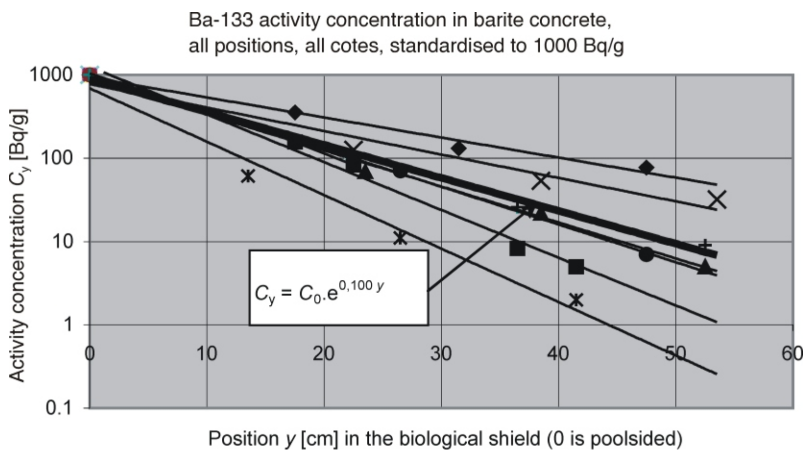


Figure 6. Exponential decrease of the activity-concentration of Ba-133. Horizontal borehole in the biological shield of the ASTRA. Average decrease marked C_y

shallow sample taken from the inside of the pool-wall at a known position *x*/*z*, it was possible to calculate the accompanying location $y_{(\mathrm{BFSpx}\ =\ 1)}$ (where activity concentration equals the desired clearance value) for this position within the shield, with an accuracy sufficient for practical application.

Determination of the vertical activation profiles within the biological shield

The distribution of activity concentrations at the inner surface of the pool at a distinctive orientation *x* and at different levels *z* was measured by core drilling samples to a depth of 5 cm (fig. 7). Since all these samples were drilled inside the pool, no uncontrolled spreading of contamination occurred.

The distribution of activity concentration at the inner pool surface was found to be dependent on altitude by a normal distribution across height with an expected maximum at the reactors effective core center with $z =$ 80 cm (the actual vertical center of the fuel-zone being at level $z =$ 90 cm, due to control-rod positions usually at less than 100%, effective neutron flux maximum was at $z =$ 80 cm). The Gauss function σ was determined with $s = 27$ cm (level-difference: 27 cm) (see fig. 8).

Based on this normal distribution, the calculation of the vertical distribution of the activity concentration along the inner pool wall by determining the activity concentration at any orientation *x* and level $z =$ 80 cm, was possible.

Determination of the horizontal activation profiles within the biological shield

From all these exponential reductions of activity concentrations in different orientations and heights of the shield, an average gradient of the exponential function *k* of 0.100 (0.025) was calculated. On this assumption and on the assumption of height distribution, it was possible to calculate the activity concentration at any location *y* at a given level *z* by determining the activity concentration of the barite concrete at the surface adjoining the pool at the direction *x* and level $z =$ 80 cm.

Applying the functions described above and by knowing the activity concentrations at the orientations *x* at $z =$ 80 cm, the locations $y_{\mathrm{BFs(Spx}\ =\ 1)}$ (clearance values according to the German radiation Protection Regulations equal or less than FW_{Sp5} respectively FW_{Sp9}) could be calculated. Figure 9 shows the locations *y* in the circumference of the pool at level $z =$ 80 cm (level of core center with the highest activation present).

Figure 10 shows the horizontal activation profile at level $z =$ 80 cm (maximum at core center

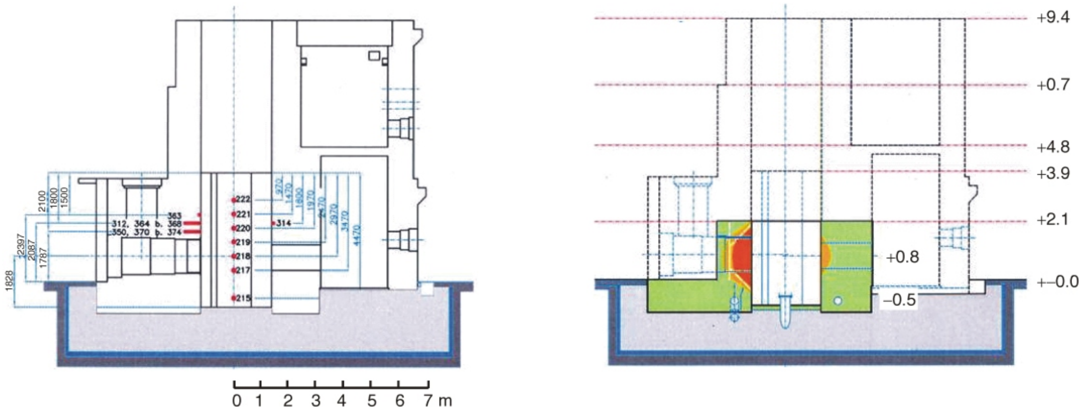


Figure 7. Vertical sample positions and corresponding activation levels indicated

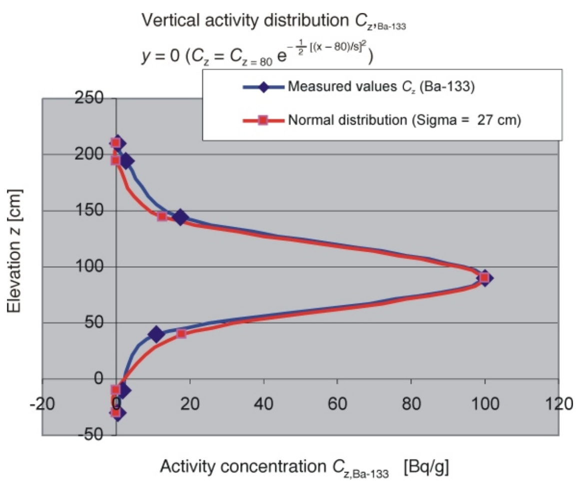


Figure 8. Vertical distribution of the activity-concentration of Ba-133, location $y = 0$

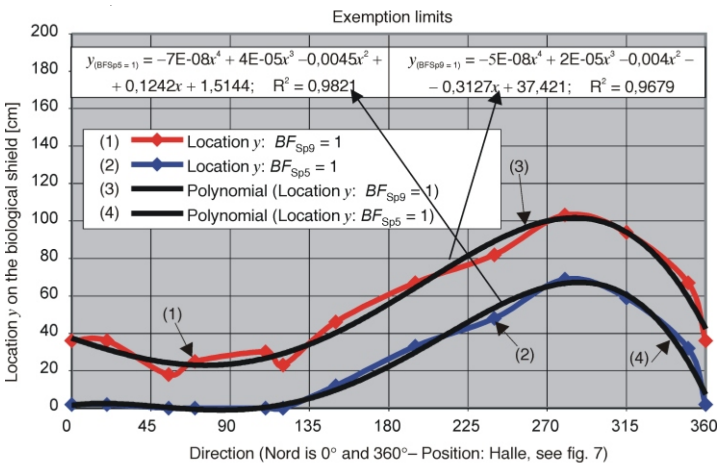


Figure 9. Exemption limits in the barite concrete of the biological shield BF_{Sp9} and BF_{Sp5} = 1, level z = 80 cm

height) and several vertical profiles at different angles, as calculated by applying the algorithm above. The major amount of barite concrete was estimated with activities below $BF_{s(Sp5)}$ 1 (unrestricted release), followed by a rather narrow rim containing materials activated below release restricted for permanent deposit $BF_{s(Sp9)}$ 1. Only the innermost zone was designated as radioactive waste.

From a total of approximatelyy 360 tons of the lower biological shield, finally only 26.5 tons of barite concrete, including sludge and some debris beyond clearance level, had to be conditioned as radioactive waste. Determining the activation degree by applying the reflections above also resulted in considerable reduction of the sampling. Since most samples were recovered from the inside of the pool, the spreading of contamination was of no real concern. Severe cross-contaminations of the samples were counteracted by recovering samples with expected low activities first.

Considering the reactor's operational history, establishing plausibility

Throughout the dismantling of the ASTRA reactor, findings were usually compared with the reactor's operational history and the plausibility of the results established as close as possible. Arguments and decisions on choosing a particular technique or ways to cope with the deferring tasks were drawn according to this knowledge. Also, to draw on the

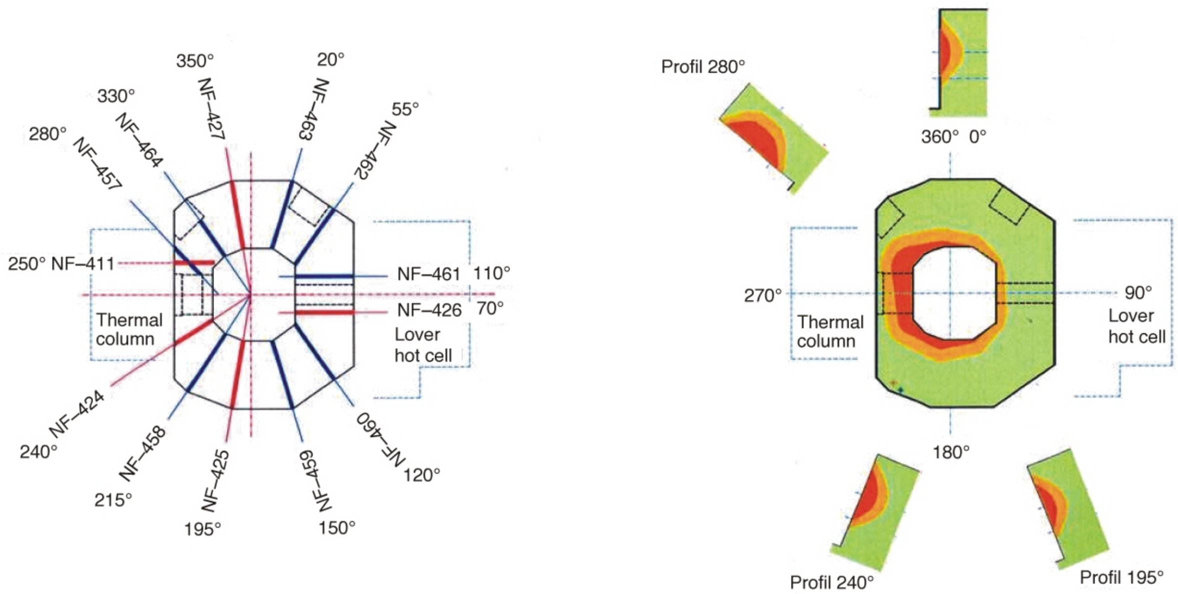


Figure 10. Horizontal sample positions and corresponding activation levels

experiences of retired former staff members and scientists experimenting at the reactor at one time or another, contact with them was established. These efforts proved to be very useful, particularly concerning the examination of the activated area. For instance, higher activity levels towards the thermal column were expected. First of all, the core was closer to the pool-wall and the connection between the core via the inner part of the thermal column had to be considered. A thermal shield machined from lead-plates covered the inside of the pool, with the exception of the area covered by the thermal column (shaded in fig. 11). Finding a maximum between the angles 280 and 330 came as a surprise and was not so easy to explain. Looking into the experimental history of the beam-tube E gave some answers.

On the other hand, slightly higher activity levels in the direction of 180 than in that of 360 came as no surprise at all. After beam-tube experiments ceased in the early 1980's, the remaining few experiments were transferred to beam-tubes from E to H. Inserts from A to D, as well as J and K, were entirely removed. At the side of the core towards 180 , subsequently as many as 5 silica doping facilities were erected. The neutron-flux was homogenized using cylindrical nickel-shapers around the rotating silica-ingots. To gain the desired accuracy, it was essential to keep the shape of the *n*-flux over the vertical as constant as possible. Therefore, the reactor was operated with the two of its four control-rods closer to the irradiation rigs, constantly drawn at 100%. Reactor-power was entirely regulated by means of the other two control-rods further off the irradiation-rigs. Hence, the neutron flux at the side 180 , during the last 15 years of reactor-operation was, on average, higher than towards direction 360 . The results of the determination of horizontal activity distribution over the circumference of the pool clearly reflected the anticipated.

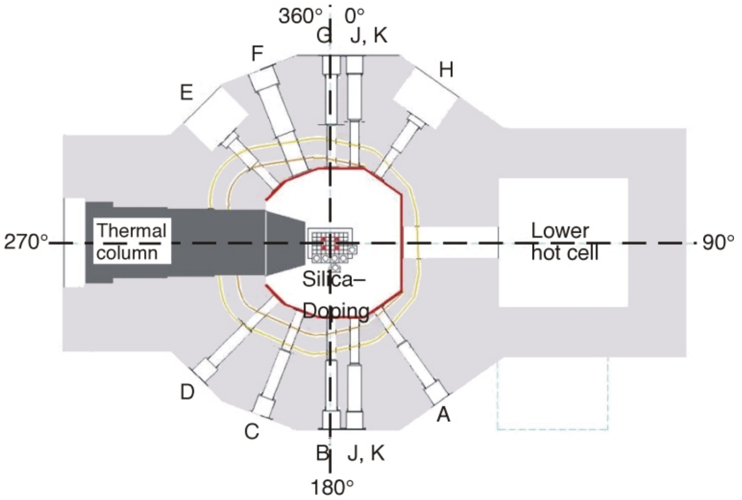


Figure 11. Horizontal cross-section of the ASTRA biological shield at level 0.8 m (neutron flux maximum)

Considerations of possible activation anomalies in the vicinity of the beam-tubes

Some considerations were directed into the detection of activation anomalies in the close vicinity of the ten horizontal beam-tubes, possible due to neutron deflections within former beam-tube-experiments. To minimize the risks of cross-contamination probably increasing the amount of radioactive waste, during the dismantling of the outer part of the activated zone, it was decided to remove the entire beam-tube liner via core-drilling, by using core-drills with a diameter of 60 cm and of lengths up to more than 2 meters (fig. 12). Closer radiological examinations of the activation profiles along the

Figure 12. Core-drilling along beam tubes

removed drill-cores were intended. Nevertheless, the attempt failed.

Due to the vast amounts of reinforcement-steel present in the area (fig. 13), tangential cuts through steel bars dissecting rather small, moon shaped steel segments (fig. 14) were unavoidable. The segments, now loosely embedded within the concrete-matrix of the drill-core, immediately caused the obstruction of the tool, usually maiming the diamond-impregnated cutting edges, too. Time-consuming recovering tasks became necessary afterwards. After several similar incidents, penetrating not more than 0.5 meters along the first beam-tube, the whole attempt was terminated.

Figure 13. Reduction of blocks dissected at level 6

Figure 14. Moon-shaped steel segments cut from reinforcement

To gain at least some of the desired data, it was decided to resume horizontal core-drilling of 50 mm diameter samples in a regular pattern at level 0.8 m at the angles between the beam-tubes (fig. 10, additional samples at 20 , 55 , 110 , 120 , 150 , 215 , 280 and 330), not essential for, but also used in confirming the activation profiles already established. No irregularities of any relevance to the intended dismantling were detected.

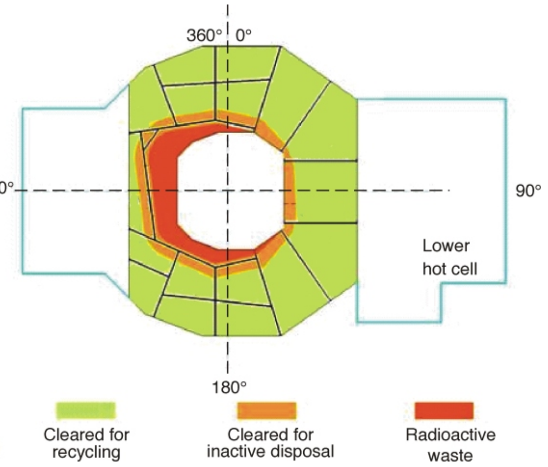
Dismantling and radiological clearance of the outer part of the activated zone

Starting from the location *y* in the biological shield (clearance location), with the total weighting factor less than 1 ($BF_{s(Spx)}$ 1), the outer areas remaining from the biological shield could be disposed into dumps. With $BF_{s(Sp5)}$ 1 unrestricted release into "building-remainder-mass-dump" was possible, with $BF_{s(Sp9)}$ 1 permanent deposit into conventional "remainder-mass-dumps" required.

After the determination of the horizontal and vertical gradients of activation, the cutting sections were set according to the obtained profiles (fig. 15a). As a conservative measure, actual cutting locations were chosen with a 10% safety margin against the calculated borderlines. The barite concrete was first cut along the exemption limit activation profile, according to the German radiation Protection Regulation, FW_{Sp5}. From these blocks (roughly 170 tons), radiological clearance according to the German radiation Protection Regulation, FW_{Sp5}, was verified via ISOCS-measurements on all surfaces and additionally via evaluation of various core-drill-samples obtained from prominent positions. With a minimum of re-machining, all blocks could be released without restrictions into a building-remainder-mass-dump.

The concrete along the activation profile was cut into blocks according to the German radiation Protection Regulation FW_{Sp9}. The blocks were reduced to small pieces; metal parts (10.5 tons of reinforcement steel and the alumina structures from and around the beam-tubes) separated. The debris was filled into 200-liter-barrels at a rate of approximately three barrels per ton, a total of about 670 barrels had to be handled. The reduction of the blocks was achieved by using an electrically powered, remote-controlled Brock-pneumatic-excavator within a separately ventilated, housed area erected within the reactor building (see fig. 15c).

The clearing of the barrels containing barite-concrete debris was performed by a Rados RTM640lnc in-barrel measuring system available at the company's waste-treatment department [8]. The



(a)

(b)

(c)

Figure 15. Dismantling the outer part of the activated zone
(a) Determination of the cutting edges; (b) Dessecting in progress; (c) Reduction of the blocks

RTM640lnc in use is equipped with 10 equal sized plastic scintillators arranged around the barrel so as to reach optimal efficiency. The RTM640lnc-system was calibrated using an especially prepared calibration barrel filled with a homogenous cutting cake with a nuclide-vector similar to barite concrete.

All barrels were inspected and 95% could be released without further treatment, either according to the clearance value FW_{Sp5} (137 tons) or that of FW_{Sp9} (87 tons) of the German radiation protection regulation. Due to the results of the RTM640lnc-inspections, the positions of materials with higher activations in barrels with higher activities were known. Approximately 30 barrels were emptied, debris with higher activities manually removed. All barrels containing the reconditioned debris could be cleared in the second run; 8 barrels with selected, higher active debris were deposited together with the active remains of the biological shield.

About 10.5 tons of recovered reinforcement steel could be entirely cleared for re-use via ISOCS-measurement. The recovered alumina-structures were prepared for re-melting.

After completing the task, only the area of the shield with activities clearly exceeding clearance levels remained to be conditioned into the substantially more expensive repository for radioactive waste.

Dismantling of the inner, activated part of the biological shield (21 tons)

The activated parts of the biological shield with activation levels distinctively exceeding clearance levels FW_{Sp9} comprised about 270 degrees around the circumference of the pool, starting from an elevation of 2.1 meters above floor level to approximately 0.5 meters beyond floor level (the bottom of the pool being at level $z = 0.9$ meters), with a thickness from a theoretical zero to a maximum of 0.8 meters (figs. 16a and 16b).

Taking careful precautions to sustain the sludge, smaller blocks were cut and loaded into three Konrad Type-II steel-containers (see fig. 16c). Together with the remaining contents of the 8 barrels of debris (manually separated during the Rados clearance procedures), 21 tons were placed into three Konrad Type-II containers.

All together, including the 5.5 tons of sludge from the dissection of the lower part of the biological shield, pre-conditioned into barrels, 26.5 tons of activated materials had to be declared as radioactive waste and were transferred to the Radioactive Waste Management Department of the Nuclear Engineering unit, Seibersdorf GmbH.

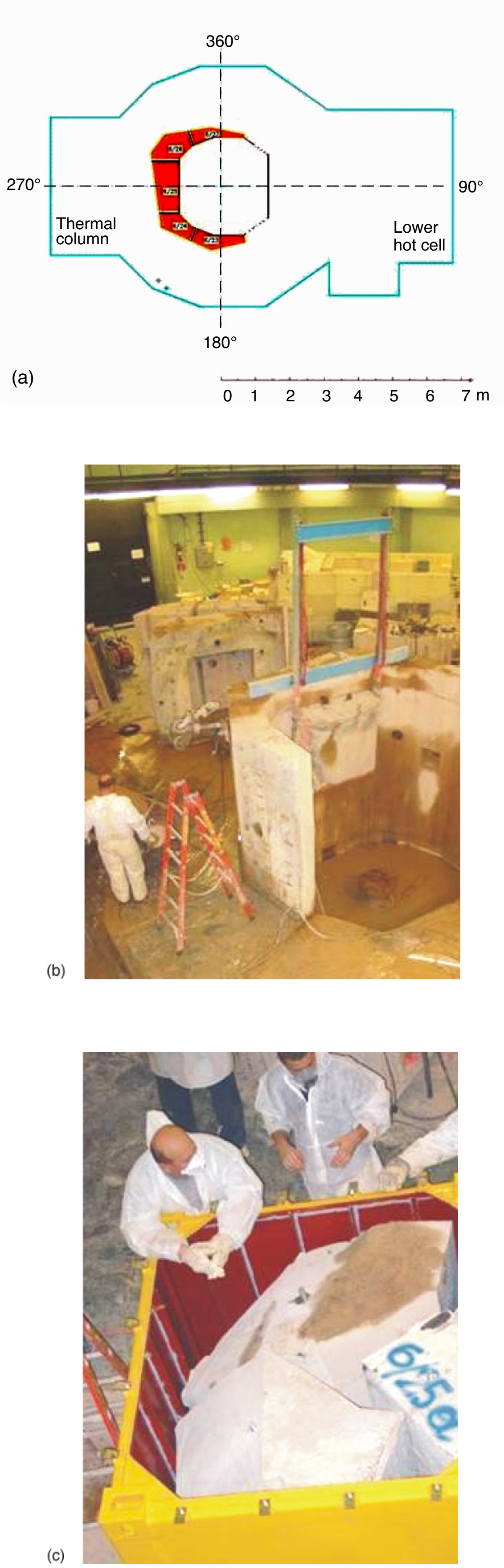


Figure 16. Dismantling the activated zone
(a) Determination of cutting edges; (b) Dissecting in progress; (c) Storing the blocks

Removing of the primary tubing embedded within the foundations of the biological shield

After the removal of the biological shield to ground level, respectively to the bottom of the pool, segments of the primary cooling system (inlet and outlet, 30 to 35 cm diameter alumina tubes) and parts of the primary auxiliary circuits (*e. g.* overflow, emergency cooling, 7.5 and 10 cm diameter) remained embedded in the foundations of the biological shield. In order to remove the tubing with rather low contaminations on the inside, wire cutting techniques were applied, once more.

Down to a level of –2.1 m beyond floor level, concrete containing primary circuit tubing was dissected (fig. 17), the metal structures removed. The concrete was either cleared via ISOCS measurements on the surfaces of the remaining blocks or by clearing the debris via in-barrel measurements, as described in the chapters above. The regained metals were prepared and treated for re-melting.

Materials removed from the biological shield

Table 2 shows a statistic of the removed material from the biological shield of the ASTRA Reactor in Seibersdorf. It is evident that the majority of the shield's parts could be released either as unrestricted (90.5%) or restricted (7.8%), while only a minor part had to be treated as radioactive waste (1.7%).

CONCLUSION

Choosing wire-cutting techniques for the dismantling of the biological shield of the ASTRA reactor proved a very satisfactory approach. Clearing the blocks on the outer surfaces using ISOCS was another success achieved with limited resources available. Clearing the applied techniques and procedures with the regulatory bodies responsible in advance was also essential for carrying out the work on a continual basis. Combining the mechanical methods used while dissecting the structure of the shield with the practical manner of establishing activation parameters was rewarded by a reduction in the amount of radioactive waste to a very reasonable minimum. Another advantage of this approach was the considerable reduction of possible radiation hazards to the operators, as well as the prevention of cross-contamination to the remaining structures, as proved by the clearance and release procedures of the building.

Figure 17. Removing of the primary tubing embedded within the foundations of the biological shield

Table 2. Concrete and steel removed from the biological shield

Barite concrete, inactive zone level 1 to level 5 in blocks	Unrestricted release	1091 t
Barite concrete, activated zone level 6 to level 8 in blocks	Unrestricted release	100 t
Barite concrete, activated zone level 6 to level 8, debris	Unrestricted release	137 t
Reinforcement steel, activated zone level 6 to level 8	Unrestricted release	10 t
Barite concrete, activated zone level 6 to level 8, debris	Restricted release	87 t
Normal concrete, sectional floors *etc*.	Unrestricted release	92 t
Concrete sludge, sufficiently dry for transport	Restricted release	36 t
Barite concrete, activated zone level 6 to 8, blocks and debris	Radioactive waste	21 t
Concrete sludge, activated zone, free water removed	Radioactive waste	5,5 t
Total of materials removed		**1580 t**

The intention of the management of the NES was to keep the project within the limits of available funds and the timetable defined by the original plan. Due to unforeseen events, *e. g.* the delay of fuel transfer, environmental impact statement and the administrative difficulties observed while erecting the building for clearance measurements, the project was finished 13 months behind the original schedule. With counteractions such as paralleling work at the water systems and biological shield and optimizing dismantling techniques, *e. g.* the introduction of wire cutting, a certain amount of time was gained. The entire project, scheduled to last 6 years beginning with the ultimate disposal of the fuel in 2000, up to the final clearance of the emptied building for re-use, ceased in September 2006, about 9 months later than predicted.

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ДЕКОМИСИЈА ИСТРАЖИВАЧКОГ РЕАКТОРА АСТРА – УКЛАЊАЊЕ БИОЛОШКОГ ШТИТА

У раду је описано уклањање неактивираних и активираних делова биолошког штита истраживачког реактора АСТРА у аустријском истраживачком центру у Сајберсдорфу. Приказани су прорачуни параметара који карактеришу активиране делове штита (референтни нуклиди, вектор нуклида у баритном бетону и хоризонтално и вертикално слабљење концентрације активности), активациони профили унутар биолошког штита расположиви за нерестриктивно одстрањивање, одстрањивање ограничено на стално одлагалиште, као и радиоактивни отпад. У сагласности са радном историјом реактора, разматране су активационе аномалије лоциране у штиту, на пример, у околини експерименталних канала. Дат је преглед материјала уклоњеног из биолошког штита.

Кључне речи: декомисија, истраживачки реактор АСТРА, уклањање, биолошки штит