DECOMMISSIONING OF THE ASTRA RESEARCH REACTOR – DISMANTLING THE AUXILIARY SYSTEMS AND CLEARANCE AND REUSE OF THE BUILDINGS

by

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The paper presents work performed in the last phase of the decommissioning of the ASTRA research reactor at the Austrian Research Centers Seibersdorf. Dismantling the pump room installations and the ventilation system, as well as the clearance of the buildings is described. Some conclusions and summary data regarding the timetable, material management, and the cost of the entire project are also presented.

Key words: decommissioning, ASTRA research reactor, dismantling, clearance, material management, cost analysis

INTRODUCTION

The MTR multipurpose research reactor ASTRA at the Austrian Research Centers Seibersdorf (ARCS) was in operation from 1960 to 1999, at a thermal power of 10 MW. After 39 years of successful operation, on the 31st of July, 1999, the reactor was finally shut down. Decommissioning started after a short transition period in January 2000. The project's organization, planning and the dismantling work up to July 2003 have already been described in [1]. The dismantling procedures on the biological shield were explained in [2]. This final paper is a short discourse on the dismantling of the pump room installations and treatment of contaminated metals, the dismantling of the ventilation system, and the radiological clearance of the reactor building. In continuation, the paper summarizes on the timetable and flow of materials, analyses in a brief overview the costs of the project and reflects on the intended and actual re-use of the reactor building and the demolition of the pump room.

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DISASSEMBLING THE PUMP ROOM INSTALLATIONS – TREATMENT OF METALS

Parallel to the removal of the biological shield, the dismantling of the primary and secondary water installations in the pump room was initiated. The pump room was situated separately from the reactor, in a two-storey underground building. Therefore, prior to the dismantling, preparations to the building were necessary which were completed by the end of March, 2004. Additionally, economical methods for cleaning and radiological identification of the metals to be removed had to be developed.

The removal of the electrical installations in the pump room took place in May 2004. Thereafter, in the first stage, potentially inactive components of the secondary water systems were removed. In the second stage, initiated in June 2004, the dismantling of the structures of the primary water systems was carried out.

In order to reduce the amount of the estimated 60 tons of slightly contaminated metals, it was determined that introducing re-melting procedures would, economically, be the best approach. Since the amount of material could not justify a development of local facilities, contacts with potential European bidders were initiated; finally, a contract with the German company Siempelkamp was signed.

Nuclide fingerprinting of the components of the primary water system was thoroughly done, where Co-60 was established as the reference nuclide, as expected. As a surprise, a very low amount of alpha-contamination was also detected and identified as Cm-242. After some consideration, it was possible to attribute it to minor contents of natural uranium on the ppm-scale within the aluminum structures and the beryllium reflector elements. Due to the long exposure times in direct contact with the fuel elements, activation and subsequent decay to Cm-242 was possible.

THE DISMANTLING OF THE ASTRA VENTILATION SYSTEM

The installations for fresh-air supply and cross-ventilation of the reactor building were located in an area between the upper and intermediate floor. Exhaust air was led via independent ventilation conducts from defined areas of the building, *e. g.* pool-surface, thermal column, hot cells *etc*., into the filter and exhaust units located in the three rooms attached to the reactor building. The full system was kept in operation until the dismantling of the biological shield, cleaning, and the following radiological surveys of the pre-decontamination procedures of the building were completed.

Based on the data from local and continuous radiological surveillance of the exhaust air during reactor operation, no major contaminations were to be expected. This was confirmed by a sampling program initiated at the end of November 2005. Smear tests established levels not exceeding five times the background values. In January 2006, the dismantling of the cross-ventilation system was started at the conducts just below the rails of the crane, roughly 20 meters above floor level.

The segments of the conducts were fabricated out of steel-enforced asbestos-cement plates with surfaces sealed by decont-paint. This proved valuable, since even simple decontamination by a high-pressure water jet was sufficient to clean the surfaces well beyond the levels for unrestricted clearance. Since possible additional hazards due to the contents of asbestos were involved, a safety evaluation was initiated. No further precautions than the already adequate protection measures for the handling of contaminated equipment had to be enforced.

By use of a mobile lifting platform supported by the crane, fig. 1, the segments were dissected, covered with plastic-foil, transferred to a room suitable for wet decontamination situated within the area of our neighbourhood interim storage and conditioning plant, cleaned and, finally, cleared without restrictions via *in-situ* ISOCS measurement.

For chemical and technical purposes, a permanent conventional disposal of the parts containing asbestos was required. The dismantling of the conducts for fresh- and cross-air was completed in March 2006.

Figure 1. Dismantling of the ventilation system

Work was continued after treatment and disposal of the materials removed during the dismantling of the metal conducts, fig. 2, permanent and emergency filters, blowers, and the cooling and heating registers in the rooms of the ventilation system within the reactor building, round about May 2006, to be fully completed by July 2007.The equipment was then dismantled and treated similarly to the segments consisting of asbestos-cement. The rather minor amounts of metals from the exhaust-air conducts were properly conditioned and prepared for processing via re-melting.

Finally, during August 2006, the thoroughfares into the attached rooms of the exhaust-air systems at ground-floor-level were dismounted. All together, about 16 tons of materials were treated during the dismantling of the ventilation system in the reactor building.

Figure 2. Dismantling metal conducts of the ventilation system

Since work on the ventilation systems was started at the upper-floor-level of the reactor building, gradually continuing towards ground-floor-level and also because of the minor contaminations encountered within the air-conducts, work on the radiological clearance of the building could be started parallel in May 2006.

RADIOLOGICAL CLEARANCE OF THE REACTOR BUILDING

To obtain the radiological clearance of the reactor building, compliance with the release limits of the Austrian Radiation Protection Ordinance had to be proved to the regulatory body. There, in general, the limits for unrestricted release are defined as a maximum dose rate of 10 μSv effective for an individual person per year.

Since the structures of the building were never in the effective range of neutron radiation, only contamination due to contact with radioactive materials was to be expected. By rule, these measurements were done by *in-situ* gamma spectroscopic devices, a Canberra ISOCS was available and already tried to successfully clear the surfaces of the blocks cut from the biological shield. To obtain results with sensitivity sufficient to prove unrestricted clearance, areas to be measured had to be limited to a surface not exceeding by much 1 m^2 at collecting times of around 1000 s.

When examining the whole extent of the building's surface amounting to 2500 m^2, the process proved to be time-consuming and with limited flexibility when decontamination is involved. Therefore, a system of direct measurements, using large-area contamination monitors (beta-gamma detector BERTHOLD LB165) was chosen. Allowing 10 s for the stabilising of the indication, 1 m^2 could be covered within roughly 50 seconds. In restricted areas, in order to localize contaminations detected by the LB165, hand-held monitors (BERTHOLD LB124) were used. In certain cases the results were referenced by indirect measurements, *e. g.* smear tests evaluated on ultra-low-level-alpha-beta-counters (*e. g.* PROTEAN MPC9604).

Threshold values for detectors LB165 and LB124 were established, taking into account an already defined nuclide vector, the natural background of the concrete and by applying the usual summation formula. For conservative measures and in order to cope with minor variations in the nuclide vector, threshold values for the actual readings were limited to 25% of the calculated values for unrestricted clearance.

These procedures were described in two work instructions which were accepted by the authorities prior to application. The following flow chart, fig. 3, illustrates the said procedures.

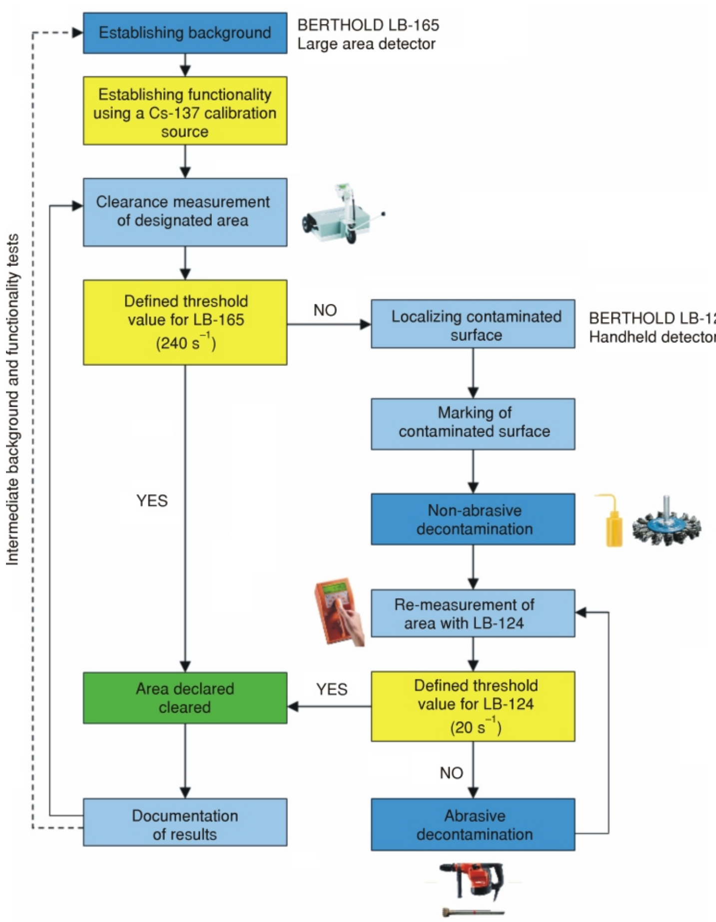


Figure 3. Flow chart of the clearance procedure

After the building was cleared from remaining debris and properly cleaned, the wall and floor-surfaces, starting at the upper-floor-level, were divided into marked and numbered areas in correlation to the area of the large-area contamination monitor. Documentation was initiated to follow the readings on each area, also describing, if necessary, the decontamination process until clearance levels were obtained.

In several small areas of the wall in the vicinity of the staircase, unexpected higher "contamination" levels exceeding the levels defined for unrestricted clearance were detected, fig. 2. Applying abrasive decontamination measures, after removing a surface-layer of plaster, it was discovered that the openings in the concrete structure of the staircase had been closed by conventional brickwork. Thereafter, higher threshold values due to the natural isotopes of K-40, Th-232, and Ra-226 within areas laid with bricks had to be defined. The following graphs, fig. 4, illustrate the effect of partly concrete embedded brick-filling. Corresponding gridlines and labels applied for the survey are also presented (two-dimensional surface, axes M_{sx}, M_{sy}).

Radiological clearance of the reactor building was initiated in May 2006 and successfully finished by October 2006. The work started at top-floor level and gradually continued downwards, until the ground floor was cleared. Decontamination followed immediately after the detection of activities and extensive documentation was drawn up parallel to the progress of the work. The tab. 1 gives an overview of the number of measurements, covered areas, and number of contaminations removed.

With the statement RU4-U-78/091 from October 11th, 2006, the unrestricted clearing of the reactor building was officially recognized.

SUMMARIZING THE DECOMMISSIONING OF THE ASTRA

Timetable

The timetable, tab. 2, of the project was based on the original plan drawn according to an overall study for the decommissioning of the ASTRA reactor dating from 1999. Over a period of six years, the removal of the fuel, the dismantling of the reactor, the decontamination of the remaining structures, *e. g.* the reactor building, the conditioning of the radioactive waste, and the disposal of conventional materials, as well as all matters related to health physics and the radiological survey had to be covered. After financial support was finally granted by the end of December 1999, the first steps in realizing the project were taken by January 2000.

Unforeseen delays afflicted during the process of the disposal of the fuel (7 months), by the comment according to article 37, Euratom (3 months), followed by the legalization of the decommissioning license (4 months), and administrative problems while erecting the building for clearance measurements (4 months), were counteracted by the project management by paralleling work using external co-workers on some of

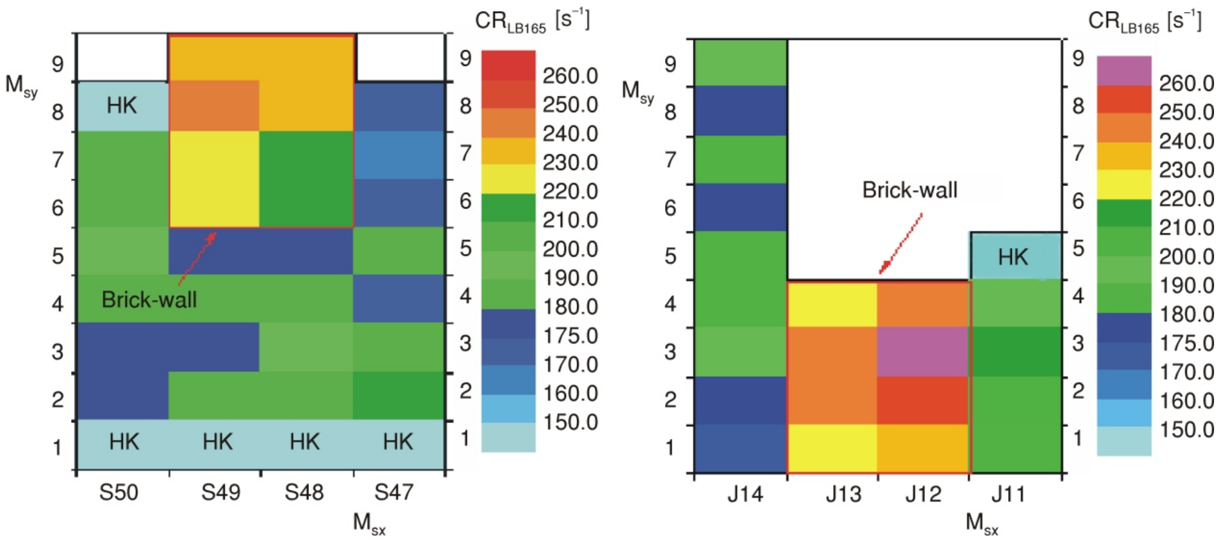
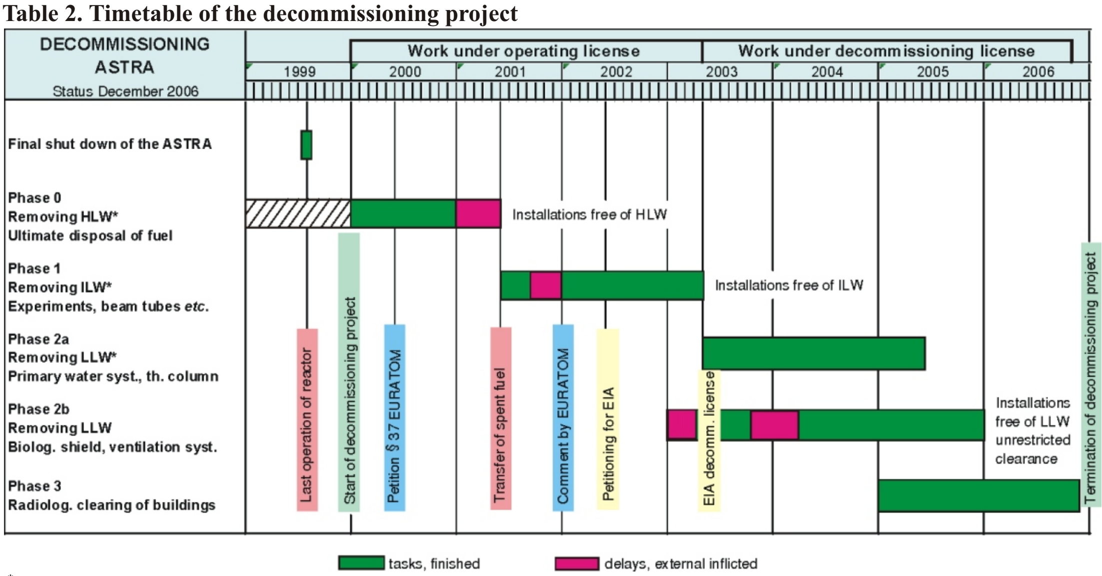


Figure 4. Effect of partly embedded brick-wall. Hand-held contamination monitor BERTHOLD LB-124 applied (CR_{LB165} – counting rate of the large area contamination monitor BERTHOLD LB 165; HK – Hand-held contamination measurement

Table 1. Number of measurements and necessary decontaminations

	Number of measurements	Covered area [m²]	Non-abrasive decontaminations	Abrasive decontaminations
Top-floor, floor area	1070	216	2	2
Top floor, wall area	1440	290	4	7
Intermediate floor, floor area	1836	370	0	7
Intermediate floor, wall area	3180	641	29	23
Staircase, floor area	436	88	0	0
Staircase, wall area	581	117	4	0
Ground floor, floor area	2300	464	0	66
Ground floor, wall area	1537	310	0	17
TOTAL	12380	2496	39	122

Table 2. Timetable of the decommissioning project



* HLW, ILW, LLW – High, intermediate, and low level waste

the tasks. Finally, work on the project ceased by the end of October 2006, with the formal acceptation of the cleared building by the authorities 10 month behind schedule. The project was officially terminated by the end of 2006.

Materials management

One of the intentions of the project management was to minimize the waste, especially where expensive radioactive materials were involved, but also to include conventional waste, where unrestricted clearance and reusability were of first priority.

Major achievements of the project management in the reduction of radioactive waste were the accomplishment of smelting for the very low contaminated metals (roughly 60 tons) and the successful characterisation of the activated areas within the biological shield with a reduction of the estimated 60 to 70 tons to a final 25 tons.

Developing and applying different techniques to establish the clearance of uncontaminated materials, taking initiatives to find new applications for still usable materials and units and the introduction of the re-melting process for contaminated metals were rewarded with a rather high percentage in unrestricted, cleared, and re-used equipment. The strategy is reflected in tab. 3, where the amount of materials removed is accounted for under different auspices.

Cost analysis

The decommissioning project was financed in six equal yearly batches of € 2 180 000, according to the contract from December 1999, amounting to € 13 080 000 for the full period. In the contract, it was agreed to re-value the funds over the years according to the inflation-index. Further on, long-term storage costs as well as the costs of the transfer and disposal of fuel elements were definitely excluded, the costs of the disposal of the fuel to be covered through reserve funds being gathered throughout the years of reactor-operation, as intended for this purpose.

At the official termination of the project by December 2006, € 15 222 960 were credited to the project. Taking into account an average index of 2.5% over the years 2000 to 2005, the € 13 080 000 had to be re-valued, as agreed, to € 14 224 500, so the actual costs dif-

Table 3. Mass flow of the dismantling of the ASTRA reactor

	Mass flow dismantling reactor components excluding biological shield	
80 t	Inactive, unrestricted, materials for re-use (cleared by NES-decommissioning-project)	
11 t	Inactive, unrestricted, materials for re-use (cleared by decont-services, NES interim storage)	
42 t	Inactive, metals, cleared by smelting	
7 t	Inactive, restricted, materials into conventional mass-dump	
3 t	ILW, metals, activated, conditioned into 5 mosaik-containers	
9 t	LLW, metals activated/contaminated, conditioned into 1 Konrad-type-II container	
7 t	LLW, graphite, activated, conditioned into 1 Konrad-type-II container	
30 t	LLW, solid, not bumable, pre conditioned into 100-liter-drums	
3 t	LLW, bumable, pre conditioned into 100-liter-drums	
2 t	LLW, ionexchanger resins, bumable, pre-conditioned into 50-liter plastic-drums	
4 t	LLW, earth, contaminated, pre conditioned into 100-liter-drums	
0 t	LLW, liquid, not bumable, 122 liters	
198 t	Total	
	Mass flow dismantling the biological shield	
1430 t	Inactive, unrestricted, concrete for re-use	89,8%
137 t	Inactive, restricted, concrete rubble and sludges, into conventional mass-dump	8.6%
25 t	LLW, concrete, conditioned into 3 Konrad-type-II containers	1.6%
1592 t	Total	100.0%
	Mass flow, remaining structures within reactor building included	
198 t	Active/inactive, dismantling reactor components	
1592 t	Active/inactive, dismantling biological shield	
384 t	Inactive, unrestricted, dismantling remaining structures within reactor building (Oct. to Dec. 2006)	
2174 t	Total	
	Total mass removed until December 31, 2006, ways of disposal	
1947 t	Materials for unrestricted re-use	89.6%
144 t	Materials into conventional mass-dump	6.6%
83 t	ILW and LLW, intermediate and low level radioactive waste, NES interim storage	3.8%
2174 t	Total	100.0%

fered for € 998 500, equal to a raise of 7% in the total cost of the project.

Besides covering the delays within the project, different additional tasks were performed which were not considered in the original planning, *e. g.*:

– € 186 000 for the purchase of 5 Mosaik- and 3 KFK-Container,
– € 207 000 to cover additional costs of the fuel-disposal,
– € 500 000 (estimated) for the Wigner-conditioning of 1 ton of graphite and the full conditioning of the 25 beryllium-elements in hot cell laboratories,
– € 70 000 for the installation of a new whole-body-monitor
– € 17 000 for the purchase of 5 Konrad-Type-II containers, and

€ 164 000 for the erection of the building to perform the clearance measurements.

Taking this into consideration, the project can be judged as being calculated and performed within the given limits. In accordance with the SAP-bookkeeping, tab. 4 gives information about the costs devoted to following designations.

Documentation, archive

The project was covered by an extensive documentation. All operations within NES followed ISO 9000 quality insurance standards. Overall planning on a yearly basis was detailed into monthly tasks. Monthly, quarterly and yearly reports and yearly statistics were prepared. Working instructions for radiation protection and for handling and operating sequences were developed.

Apart from standardized data collection following radiation protection, a daily journal covering the undertaken tasks was kept. So, for instance, in the case of positive results obtained by the monthly whole-body counting or by excretion analyses, tasks responsible could be easily retraced.

Precise data were obtained while material and components were handled. Each item, from the moment of disassembling to either the place in the already conditioned barrel in the intermediate storage or the way of cleared items for re-use, recycling or disposal, could be followed at all times. An overall number-based identification system was established and duly extended throughout the process. Via this system, all data, *e. g.* within the daily journal, the probes and samples, the CAD-drawings, the extensive photo-documentation and the legal clarification documents, interlocked.

Since there is no guarantee that digital copies will still be usable/readable after years of storage (for some items 30 years and more), it was decided it was preferable to collect important information and originals in hard copy. To accommodate the extensive doc-

Table 4. Cost analysis of the dismantling of the ASTRA reactor

Analysis of the costs decommissioning the ASTRA-reactor	EURO	%
Labour (80 years of man-power, 2000-2006)	5.244.420	34.45%
Material	703.500	4.62%
Subcontracts (specialists, experts, *etc*.)	2.322.810	15.26%
Conditioning in NES intermediate-storage-facility	2.790.620	18.33%
Conditioning in NES hot-cell-laboratory	1.009.220	6.63%
Common costs, administration, rents, *etc*.	2.549.250	16.75%
Further costs (transport, insurances, travelling, *etc*.)	602.870	3.96%
Total	15.222.690	100%

umentation from the decommissioning period and the operating period of the reactor, a room on the top-floor of the NES administration building was adopted. It was furnished with steel cabinets for long-term preservation of the documents.

The documentation pertaining to the subject of decommissioning contains:
– complete documentation of the decommissioning process, planning, operation, evaluation,
– monthly, quarterly and yearly reports on decommissioning,
– technical documentation on decommissioning,
– extensive documentation on radiological clearance measurements and materials flow,
– collection of working instructions valid for decommissioning, and
– papers and publications released in connection with decommissioning.

The documentation pertaining to reactor operation contains:
– detailed information on the fuel cycle and disposal over the full operating period,
– logbooks of the reactor operating room and the radiological surveillance,
– continuous records of exhaust air and surveillance of the surroundings,
– operating handbook and records of continuous survey by the regulators,
– theoretical and technical information concerning experiments (REX- and RBS-reports),
– a complete set of technical drawings of the reactor (AMF, SGAE, and supplier),
– daily administrative communication and picture documentation during reactor operation, and
– personal documentation of the former reactor management.

REUSE OF THE REACTOR BUILDING, DEMOLITION OF THE PUMP ROOM

The concept of the decommissioning of the ASTRA reactor from 1999, fig. 5, conceived a reuse of the reactor building as a part of the intermediate storage facility on the site [3]. Nevertheless, under the auspices dating to 2006/2007 and those under the aspect of already advanced planning, for safety reasons, the Austrian government, as the rightful owner, decided to

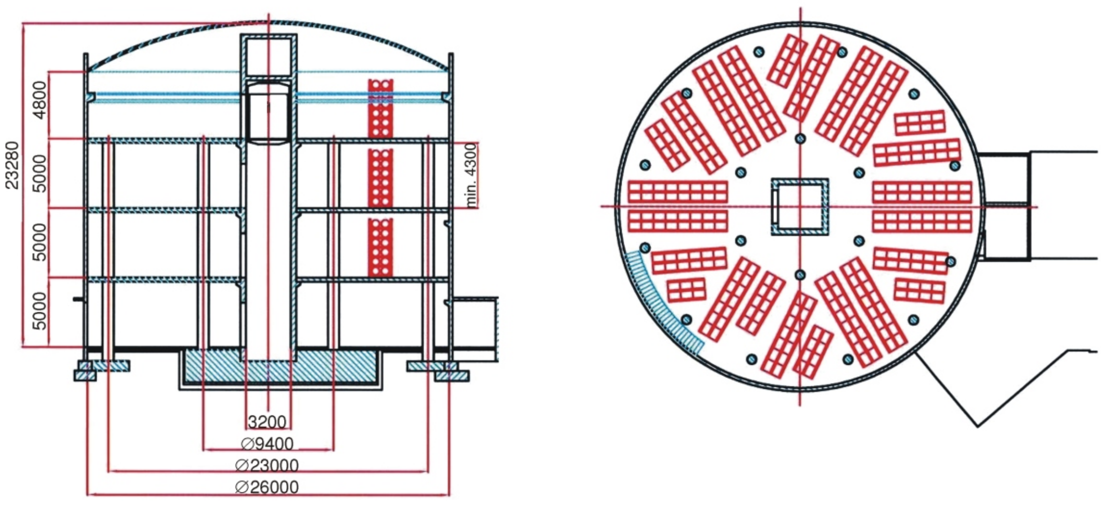


Figure 5. The concept of reuse of the ASTRA building from 1999

invest in further storage facilities within the enclosed controlled area, rather than to indulge in expensive rebuilding of the reactor containment close to, but outside the controlled area.

After extensive discussions, the now empty reactor containment will be adapted to house inactive and cleared casks and used for the interim storage of NORM-waste until the legal requirements for a suitable deposit are cleared. To fulfil the purpose, the ground floor will be renewed and new lighting installed by 2008. Still pending on a decision of the owner, an enlargement of the entrance door to a height of 4.2 meters and a basic ventilation system are also foreseen. The newly attached building for clearance measurements will continue its inherited designation into the future.

For the reuse of the underground pump room, no economically reasonable propositions were put forward. After unrestricted clearance was obtained, it was decided to demolish the structures, including the decay and storage tank and the basins of the cooling towers to at least a level of 0.7 meters beyond ground level, to refill the cavities with hygienically proper material and level the area to a green-field. The task was completed by the end of 2007.

Since the task of removing the structures was not included into and financed through the original decommissioning project, it was carried out under the project of the general radiological decommissioning of the Seibersdorf site.

CONCLUSION

The decommissioning of the ASTRA was initiated in 1999 after the conditions of transition were cleared, anticipating IAEA recommendations [4] released in 2004. The project's final goal was the release of the buildings for reuse and immediate dismantling was chosen to be the optimum strategy for the decommissioning. Decommissioning work followed IAEA's recommendations, starting with the removal of HLW and immediately followed by ILW and LLW, until the clearance of the buildings was achieved.

Experiences and knowledge gained were presented to and shared with the community, *e. g.* the AFR, IAEA, and through personal contacts throughout the project [1-24].

Summarizing the contents of the decommissioning of the ASTRA-reactor on the Seibersdorf site, taking into consideration the full duration of the project, it is possible to conclude that, in general, the dismantling work was carried out according to plan. The inevitable, unexpected events were dealt with successfully, usually in the run of the events. Significant delays were caused mainly due to external reasons for which the project's management was not responsible. Finally, the reactor building and the buildings connected to the reactor could be fully cleared according to the standards of unrestricted reuse.

Summarizing on the many single tasks of the project, the manifold administrative and technical challenges to be met until the set goal was reached are more than evident. It is evident that the successful decommissioning of the reactor in the described manner was based on responsible preparations by the previous operating management of the reactor, knowledgably continued by the management of NES and the decommissioning personal recruited from the operating staff, making use of the understanding of the installation's functions, in combination with the familiarity with applied techniques necessary for the safe handling of radioactive material. It was further essential to fully integrate the operative radiological survey directly into the working crew. Last but not least, the cooperative attitude of regulators, experts and consultants proved to be a perfect contribution to the positive outcome of the whole project.

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ДЕКОМИСИЈА ИСТРАЖИВАЧКОГ РЕАКТОРА АСТРА – УКЛАЊАЊЕ ПОМОЋНИХ СИСТЕМА, ЧИШЋЕЊЕ И ПОНОВНО КОРИШЋЕЊЕ ЗГРАДА

Приказан је рад обављен у последњој фази декомисије истраживачког реактора АСТРА у аустријском истраживачком центру у Сајберсдорфу. Описано је уклањање инсталација из просторије са пумпама и вентилационог система, као и чишћење зграда. Такође, изведени су неки закључци и приказани збирни подаци о роковима, располагању материјалом и цени читавог пројекта.

Кључне речи: декомисија, истраживачки реактор АСТРА, уклањање, чишћење, располагање материјалом, анализа трошкова