**Decommissioning of the Austrian 10 MW Research Reactor, Results and Lessons learned**
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## ABSTRACT

After the decision to shut down the 10 MW ASTRA-MTR Research Reactor was reached in May 1998, the possible options and required phases for decommissioning and removal of the radioactive components were evaluated in a decommissioning study. To support the decisions at each phase, an estimate of the activity inventory in the various parts of the reactor and the waste volume to be expected was performed. Of the possible options an immediate dismantling to phase 1 of IAEA Technical Guide Lines after the immediately following, continued dismantling to phase 2 of these guide lines was identified as the most reasonable and under the auspices optimum choice.

The actual decommissioning work on the ASTRA-Reactor began in January 2000 after its final shutdown on July 31st, 1999.

Preliminary evaluations of the activity inventory gave an estimated amount of 320 kg of intermediate level waste, of about 60 metric tons of contaminated and another 100 metric tons of activated low level radioactive waste. The activities were roughly estimated to be at 200 TBq in the intermediate level and 6 GBq in the low level.

The structure of the decommissioning process was decided against cost-, time- and risk-optimization following the basic layout of the main tasks, e.g. the removing of the fuel, the recovering and the treatment of the intermediate level activities in the vicinity of the core, the handling and conditioning of the neutron exposed graphite and the Beryllium-elements. As an example, the dismantling of approx. 1400 metric tons of the biological shield is described in more detail from the determination of the dismantling technique to the clearing procedures and the deposition. The process of dismantling of the biological shield is presented in fast motion. The dismantling of the pump-room installations of the primary loop, the processing of the contaminated or activated metals, the dismantling of the ventilation system and the radiological clearance of the reactor building was done under optimized conditions and is explained in the following.

Spent fuel was generally delivered to the US Department of Energy - DOE in several shipments over the operational time of the ASTRA reactor. With the last shipment in May 2001 all the remaining spent fuel elements out of the ASTRA reactor consignment were transferred to DOE.

To reduce waste from concrete shielding, German regulations Dt.StrSchV, annex IV, table 1, two clearance values referring to “clearance restricted for permanent deposit” and to a clearance for unrestricted re-use were used.

In order to reduce the amount of an estimated 60 tons of slightly contaminated metals, it was determined that introducing re-melting procedures were the most economical way.

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

The results of the regular yearly medical examinations of the staff indicated no influence of the work related to decommissioning. The readings of the personal dosimeters over the entire project amounted to a total of 85.6 mSv, averaging to 1.07 mSv per year and person.

After finishing the decommissioning process, the material balance showed 89.6 % for unrestricted re-use, 6.6 % for conventional mass-dumping and 3.8 % of ILW and LLW.

The project was covered by an extensive documentation. All operations within NES followed ISO 9000 quality insurance standards. Experiences and knowledge were presented to and shared with the community, e.g. AFR and IAEA throughout the project.

## INTRODUCTION

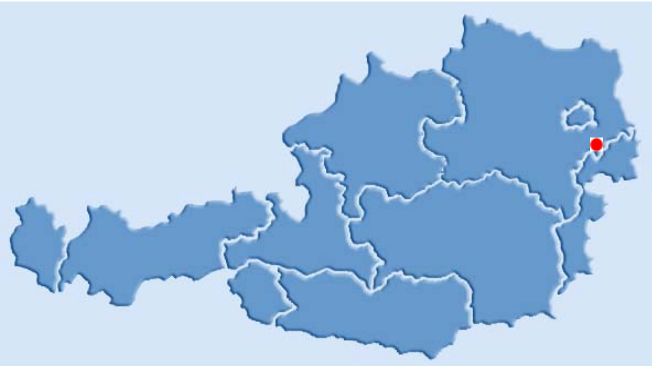
In 1955 the "Österreichische Studiengesellschaft für Atomenergie" (ÖSGAE) was founded with the proposition to provide the country with facilities to partake in nuclear research and to train staff for conceived nuclear power plants. The process was similar to the founding of other research facilities throughout Europe at more or less the same time.

In 1958 a federal agreement was reached to construct a 10 MW MTR multi purpose research reactor of the American Machinery and Foundry (AMF) design at a site approximately 30 km southeast of Vienna near the village of Seibersdorf (see picture 1).

On July 31$^{st}$, 1999 the only Research Reactor (ASTRA) at the premises of ARCS (Picture 2) was finally shut down after an operational period of nearly 40 years. The paper describes the planning, financing and the strategy of the decommissioning process; references to the legal requirements according to Austrian regulations and the procedures to gain the decommissioning license (EIA) are given. Radiation protection procedures and results are reflected. The structure of the project is discussed as well as the recovering and the treatment of the intermediate level activities in the vicinity of the core, the handling and conditioning of the neutron exposed graphite and the Beryllium-elements. The dismantling of 1400 metric tons of the biological shield is described from the determination of the dismantling technique to the selection of clearing procedures and the deposition.

### Strategies for Decommissioning

In order to perform a safe and environmentally compatible decommissioning, the possible options and required phases for decommissioning and removal of the radioactive components were evaluated in a supporting decommissioning study from 1999 [1]. To support the decisions at each phase, an estimate of the activity inventory in the various parts of the reactor and the waste volume to be expected was performed. Measurements of various materials as far as accessible and numerical evaluations where not accessible were carried out.


Picture 1: Location of Seibersdorf ASTRA-Reactor


Picture 2: Austrian Research Centers Seibersdorf

Of the possible options an immediate dismantling to **phase 1** of IAEA Technical Guide Lines [3] (storage with surveillance) after the immediately following, continued dismantling to **phase 2** of these guide lines (restricted site use) was identified as the most reasonable and under the auspices optimum choice. The reasons were that the majority of radio nuclides possessed either half-lives of up to 80 days which decay sufficiently to permit a continuing dismantling after phase 1, or half-lives so long that waiting periods of more than 50 years would be required to substantially reduce exposure levels. Since the re-use of the reactor buildings had been established, the project should immediately continue to **phase 3** (clearance and re-use of site).

Preliminary evaluations of the activity inventory gave an estimated amount of 320 kg of intermediate level waste, of about 60 metric tons of contaminated and another 100 metric tons of activated low level radioactive waste. The activities were roughly estimated to be at 200 TBq in the intermediate level and 6 GBq in low level.

Another important issue with regard to dismantling and demolition were the methods and procedures to be employed to result in a minimal radiation exposure of the employed staff [2]. There was a long standing experience with cutting procedures regarding higher radioactive components in which the exposure of the staff never exceeded very low levels.

Based on the federal study from 1999 [1] the decommissioning of the reactor was discussed in numerous meetings with governmental experts. Detailed concepts were outlined and the main tasks were arranged on a time scale as shown in table I:

Table I. Decommissioning Concept

| Phase | Action |
|---|---|
| 0 | Removal of the fuel elements to DOE/Savannah River Plant till the end of 2000 |
| 1 | Removal of the intermediate level wastes till the middle of 2002 |
| 2 | Removal of low level wastes to be finished till the middle of 2005 |
| 3 | Clearing of the buildings till the end of 2005 |

Since the decommissioning work could be performed within the closed containment of the reactor building with pressure, ventilation and drainage fully in operation, sufficient safety standards could be guaranteed. Virtually no possibility for a release of activity to the environment during the whole decommissioning process would exist.

In November 1999 the project was finally presented to the public authorities and duly legalised. The financial covering of the estimated total of EURO 13 Mio., were divided into six equal parts over the years 2000 to 2005, was granted.

According to Austrian legislation [4], nuclear facilities operate under federal law, while decommissioning comes under the surveillance of the competent state governments, subject to an environmental impact assessment (EIA). It was therefore decided that the work carried out in phase 0 and phase 1 should be covered by the operating license of the reactor.

Prior to the start of decommissioning Euratom was informed according to Article 37 of the treaty [5, 6]. In a statement received in December 2001 no objections to the decommissioning plans were made.

**Removal of Core-Interior**

Removal of the Fuel Elements

All the spent fuel was delivered to the US Department of Energy - DOE in several shipments over the operational time of the ASTRA reactor. In order to finalise a contract for shipment and ultimate disposal of the spent fuel originating from the USA and to meet the DOE specifications, leak-proving of the elements was carried out in the reactor pool between November 1999 and February 2000. Beforehand the fuel elements were shortened by mechanically cutting off the rather bulky aluminium bottom parts, also reducing the price of conditioning by DOE by approximately ten per cent.

Assigned by Transnucleaire, the transport to Rotterdam was carried out by Sommer+Grottke/Germany using two NAC-LWT-6 flasks. From Rotterdam to Savannah River NAC was responsible for the transport. Necessary federal and Euratom permits for the transfer of the fuel and for the international transports and transport insurances could be obtained just in time. The 54 spent MTR-fuel elements (310.5 kg of HLW) left the Seibersdorf site in May 2001.

In immediate succession to the transfer of the spent fuel and still under the operating license, all experimental facilities and components of the reactor within the vicinity of the core or in intermediate storage within the building (e.g. old beam-tube-inserts) were conditioned. Three GNS-Mosaik containers were filled, entirely under water (picture 3), and dried and placed into intermediate storage of NES.

The task of clearing the reactor building from the remaining experimental equipment and the obsolete storage facilities and the transfer of the structures of the industrial source services including a 21-ton-lead-cell (picture 4) to NES Hot Cell Laboratories HZL was accomplished to 90% under this phase.

Picture 3: GNS-Mosaik container, under-water loading

Picture 4: Mosaik container

During the performance of this task, 492 kg of ILW and 5212 kg of LLW were removed. ILW was fully conditioned within the premises of the reactor, LLW was pre-conditioned and transferred on site Waste Management Department (WMD) for further treatment. Work under phase 1 at the reactor ceased by May 2003, with the conditioning of the highly exposed graphites and the Beryllium-elements still to be continued at the Hot-Cell-Laboratories HZL.

**Environmental Impact Assessment (EIA)**

According to the original planning, during 2002, while work under **phase 1** was still under way, the environmental impact assessment EIA [7, 8] required to obtain the decommissioning license was prepared. There was almost no response during the publication period of the documents. The public hearing was held in December 2002 followed by a license to decommission in April 2003.

Responsibility for the decommissioning was transferred from the federal government to the government of the state of Lower Austria. Since Austria's Health Physics Law was just undergoing the process of homogenizing with EU regulations, it was decided that clearance standards according to German regulations should be applied throughout decommissioning.

Preparations for **phase 2** were well under way during phase 1; nevertheless, actual work could only be started after the license for decommissioning was granted following the EIA in April 2003. **Phase 2** mainly comprised the dismantling of the primary and secondary cooling facilities, the removal of the biological shield and finally the dismantling of the ventilation systems, amounting to roughly 160 tons of LLW. About 1500 tons of materials could be cleared.

**Conditioning of Hazardous Materials**

Rector-Material to be conditioned and stored included approximately 10 tons of **reactor-grade graphite** originating from the inner (picture 5) and outer thermal columns as well as from old-type reflector elements and moderators from late experiments. The activity of the main thermal-neutron activation product, C-14, in the material was on the order of 1000 Bq/g, with other radio nuclides, e.g., Co-60 and Eu-152, present in trace amounts.


Picture 5: Inner Thermal Column,
neutron dose, recovering of the graphite annealing

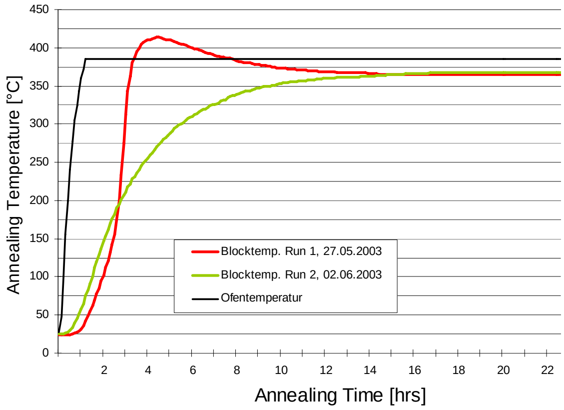


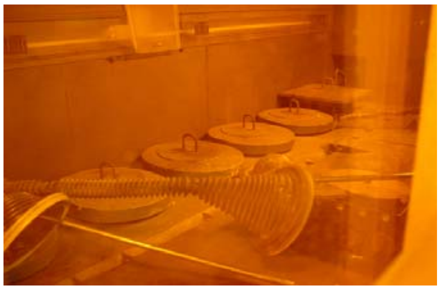

Fig. 1 Graphite exposed to high fast
Temperature behaviour during annealing

Over the 40 years of reactor operation, some of the graphite had been exposed to an estimated integrated fast-neutron flux of 2.2 x $10^{21}$ n/cm$^2$. Since the temperature of the graphite never exceeded 50$^o$C, annealing of lattice defects did not occur and the accumulation of significant amounts of Wigner energy was to be expected. It was decided to preheat graphite exposed to an estimated integrated fast-neutron flux of $10^{19}$ n/cm$^2$ and higher under controlled conditions. This work was successfully carried out at the Hot Cell Laboratories. The facilities and installations necessary were designed by the decommissioning crew. Temperature readings (Fig. 1) during the entire annealing process indicated that a considerable release of Wigner energy did in fact occur.

The contents of the outer thermal column, roughly 8 tons of graphite, were removed and conditioned into special made stainless steal inserts for the 200-liter standard drum during the summer of 2004. 2130 kg of graphite from the exterior section could be entirely cleared for re-use.

Another subject was the conditioning of the **ASTRA Beryllium elements**. Since no standard procedures were established, it was decided to tightly enclose each of the 25 elements individually into stainless steel containers with a wall-thickness exceeding 5 mm to prevent H3-release.

Picture 6: Workbench setup for Beryllium conditioning in Hot Cell



Picture 7: Hot Cell Laboratory

To cope with the rather intensive radiation of up to approximately 60 GBq of Co-60 in some of the individual Beryllium-elements, storage into two GNS-Mosaik containers was calculated to be sufficient.

The conditioning was again undertaken at the Hot Cell Laboratories. For this purpose, individual containers for each element were designed from high-grade stainless steel, a remote- controlled orbit welding facility was modified and adapted and a specific hot cell underwent general restoration to handle the work (see picture 6). Two GNS-Mosaik containers had been readied to store the 18 Be-reflector- and the 7 Be-radiation elements together with the active blades of the ASTRA Hf-control rods. The Be-elements and the blades of the control rods were finally stored in sealed condition using the Hot Cell Laboratories-pool for the transition into the containers.

So, for the permanent safe storage of the total of approximately 3 tons of intermediate level wastes arising through the decommissioning of the ASTRA reactor in all five GNS-Mosaik containers were needed.

**Dismantling of the Biological Shielding**

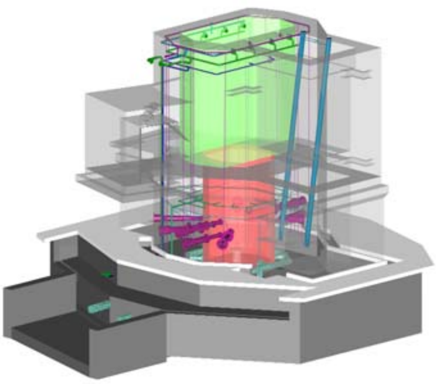
To take down the inactive structures of the biological shield (400 $m^3$ of reinforced Barite-concrete totalling to approx. 1500 tons), several techniques were under discussion [9, 10, 11]. Finally, wire cutting technique was chosen as the most promising method under ASTRA auspices, dividing the biological shield into blocks of between 7 and 9 tons (pictures 8, 9).

There were several advantages in preferring wire cutting:

- Measurements and calculations had shown that the risk for spreading contamination due to cutting was almost non-existent.
- Work could be done with a minimum of man-power, only two external experts were needed for the handling of the cutting equipment
- 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 to show a clear picture of the sensitivity of surface measurement, a Canberra ISOCS device was evaluated with positive results.

Actual cutting started in February 2004.



Picture 8: 3D-Study Biological Shield of the ASTRA-Reactor

Picture 9: Removing of 1st layer

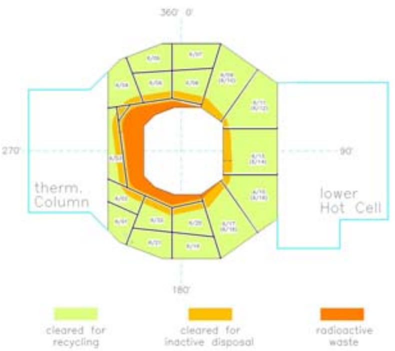
Results obtained by subsequently probing the shield in a vertical pattern allowed cutting down to a lower level. At the blocks of the lower section, directly adjoining the activated part of the biological shield and crossing over to the activated zone, the compliance with the permissible limit was additionally proven by inspection of core drill samples at prominent regions.

Due to the precautions during the cutting process followed by intensive clearance procedures, all barite concrete blocks could be released to a level sufficient for "buildings for re-use" after minor mechanical decontamination-treatment. The cleared blocks (1091 tons) were transferred into a deposit specialized for recovered building materials (building-remainder-mass-dump). By request of the authorities the blocks were stored in a marked area with the intention of later recycling. Additionally, barite-concrete-sludge was dried sufficiently to ensure safe transport. Clearance data were obtained by sampling at a rate of approximately one sample per 100 litres.

**Dismantling the Activated Area of the Biological Shield**

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 the levels for release.

Due to n-flux measurements along the circumference of the pool during the last operations of the reactor together with some activation analysis on barite concrete samples and with some calculations, a more or less homogeneous estimated activation depth of 1 meter with a mass of roughly 60 to 70 tons was considered as "activated" zone.



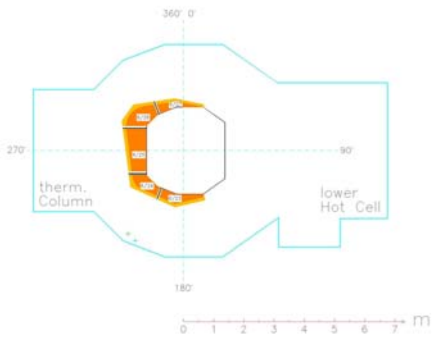

Picture 10: Determination of the cutting edges

Picture 11: Dissection in progress

Picture 12: Reduction of the blocks

After determination of the vertical and horizontal gradients of the activation, the cutting sections were set according to the obtained profiles (picture 10). As a conservative measure, actual cutting locations were chosen with a 10% safety margin against calculated borderlines. With a minimum of remachination, all blocks could be released without restrictions into a building-remainder-mass-dump (see picture 11 and 12).

The activated parts of the biological shield (picture 13) with activation levels distinctively exceeding the clearance levels 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 with a thickness from theoretical zero to a maximum of 0.8 meters (pictures 14 and 15).





Picture 13: Determination of the cutting edges

Picture 14: Biological shield; Activated zone remaining

Picture 15: Storing the blocks into Konrad Type-II container

Taking careful precautions to sustain the sludge, smaller blocks were cut and loaded into three Konrad Type-II steel-containers (see picture 15). Including approx. 5 tons of sludge from dissecting the lower part of the biological shield, pre-conditioned into barrels, 25 tons of activated materials in all had to be declared as radioactive waste and were transferred to the Radioactive Waste Management Department (WMD) within Nuclear Engineering Seibersdorf GmbH.

**Disassembling of other Installations**

Parallel to the removal of the biological shield, dismantling of the primary and secondary water installations in the pump room was initiated.

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

The fresh-air supply and cross-ventilation systems were kept in operation until the dismantling of the biological shield, the cleaning and the following radiological surveys of the building were complete.

In all, about 16 tons of dismantled materials were treated in the process of the dismantling of the ventilation system in the reactor building.

**Radiological Clearance of the Reactor-Building**

To obtain radiological clearance of the reactor building, compliance with the release limits according to 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 little contamination due to contact with radioactive materials was to be expected.

To examine the extensive surfaces of the building in the range of 2500 $m^2$, a system of direct measurements, using large-area contamination monitors (beta-gamma-detector BERTHOLD LB165) was chosen. 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).

**Summarizing the Decommissioning of the ASTRA**

The project officially started in January 2000 due to unforeseen delays inflicted during the process of disposing of the fuel (7 months), the comment according to article 37, Euratom (3 months), followed by the legalizing of the decommissioning license (4 months) and administrative problems while erecting the building for clearance measurements (4 months); these time lags were counteracted by the project management by paralleling work using external co-workers on some of the tasks. Finally, work on the project ceased at the end of October 2006 with the formal acceptance of the cleared building by the authorities, 10 months behind schedule. The project was officially terminated by the end of 2006.

One of the intentions of the project management was to minimize waste, especially where expensive radioactive materials were involved, but also including conventional waste, where unrestricted clearance und reusability had first priority. The major achievements of the project management in the reduction of radioactive waste were the accomplishment of melting 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 tons to a final 25 tons.

The decommissioning project was financed according to the contract of December 1999, amounting to EURO 13.08 Mio. over the full period. The costs for the transfer and disposal of the fuel elements were definitely excluded, the costs of conditioning and the disposal of Radioactive Waste were to be covered through the fund.

The project was officially terminated in December 2006. Taking into account an average index of 2.5% from 2000 to 2005, the actual costs differed by approximately 7 % of the project’s total costs.

Table II: Mass flow dismantling the ASTRA-reactor

| | Mass Flow Phase 1: dismantling of reactor components under operating license |
|---|---|
| 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 burnable, pre conditioned into 100-liter-drums |
| 3 t | LLW, burnable, pre conditioned into 100-liter-drums |
| 2 t | LLW, ionexchanger resins, burnable, pre-conditioned into 50-liter plastic-drums |
| 4 t | LLW, earth, contaminated, pre conditioned inte 100-liter-drums |
| 0 t | LLW, liquid, not burnable, 122 liters |
| 198 t | |

| | Mass Flow Phase 2: dismantling the biological shield under decommissioning license | |
|---|---|---|
| 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 | | 100,0 % |

| | Total Mass, remaining structures within cleared reactor building included |
|---|---|
| 198 t | active/inactive, dismantling of reactor components (work in phase 1 under operating license) |
| 1592 t | active/inactive, dismantling the biological shield (work in phase 2 under decommissioning license) |
| 384 t | inactive, unrestricted, dismantling remaining structures within cleared reactor building (Oct. to Dec. 2006) |
| 2174 t | total |

| | Total Mass removed until 31.12.2006, Ways of Disposal | |
|---|---|---|
| 3 t | ILW, intermediate level radioactive waste, NES interim storage | 0,1 % |
| 80 t | LLW, low level radioactive waste, NES interim storage | 3,7 % |
| 144 t | materials into conventional mass-dump | 6,6 % |
| 1947 t | materials for unrestricted re-use | 89,6 % |
| 2174 t | total | 100,0 % |

## Manpower and Nuclear Safety

As already explained before, the decommissioning of the ASTRA was basically planned by employees of the remaining reactor staff and was supported by external experts.

Contracts were also extended to already retired staff members to establish historical facts and data. Therefore a team consisting of 8 former reactor crew staff members (which could be temporarily reinforced by co-workers if demand should arise) was set up to perform the decommissioning.

In all, 58 years of manpower went into the dismantling work. Another 25 years of manpower were applied into radiological survey and safety, amounting to a total of 83 years of manpower with 23 people involved full-time or part-time. After the termination of the project only 2 members of the original team still remained.

The results of the regular annual medical examinations indicated no influence of the work related to decommissioning. Regular control measurements at monthly intervals on a whole-body-counter gave no cause to alter extensively established working procedures. The readings of the personal dosimeters over the entire project amounted to a total 85.6 mSv, averaging to 1.07 mSv per year and person. The maximum dose rate encountered for one single person was 11.2 mSv over the period 1999/2006 amounting to approx. 5% of the theoretical maximum permissible dose of 120 mSV for the same time (see table III).

Table III. Overview doses encountered against theoretical maximum permissible doses

| Company | labour [months] | Theoretical Maximum Permissible Dose [mSv] | Dose Encountered 1) [mSv] | Dose Relative to Max. Perm. [%] |
|---|---|---|---|---|
| NES | 66.8 | 1403 | 75,8 | 5,7 |
| Lindeberg | 91 | 153 | 5,8 | 3,8 |
| BBS | 69 | 116 | 4,0 | 3,5 |
| Total | 1002 | 1670 | 85,6 | 5,1 |

1) Total accumulated internal and external dose

## Conclusions

It should be manifested that the dismantling of the ASTRA-reactor in the 50th year after the founding of Austrian Research Centers Seibersdorf within the given limits in time and financial resources and under strict observation of the legal and radiological requirements was performed without any incidents, neither in the sense of personal safety nor in radiological hazards to the environment, thus continuing the successful tradition of 40 years of safe and acknowledged reactor operation to a termination in dignity.

Summarizing the history of the decommissioning of the ASTRA-reactor on the Seibersdorf site considering the full period of the project it should be recapitulated that in general the dismantling work advanced according to plan. Inevitable unexpected events were dealt with successfully, usually in the course of the events. Remarkable delays were caused mainly by external influences, which were not in the responsibility of the project management. Finally, the reactor building and the buildings connected to the reactor could be entirely cleared to the standards of unrestricted re-use.

## Literature

[1] J. Casta, Mück, K., Fiedler, H., Steiner, R., "Untersuchungen und Evaluierungen zur sicheren und kostengünstigen Stilllegung des ASTRA-Reaktors", Endbericht des Forschungsauftrages GZ 140.548/2-V/A/6/98 des Bundesministeriums für Wissenschaft und Verkehr Abt: V/A/6, April 1999, (in German, restricted distribution)

[2] K. Mück (†), J. Casta, A. Hefner, N. Vana, Vor- und Nachteile einer zügigen Stilllegung des ASTRA-Reaktors, Strahlenschutz für Mensch und Gesellschaft im Europa von Morgen, Gemeinsame Tagung des österreichischen Verbandes für Strahlenschutz und dem Fachverband für Strahlenschutz e.V. (FS), 33. Jahrestagung des FS, Herausgeber: K. Mück, A.

[3] IAEA. Planning and Management for the Decommissioning of Research Reactors and Other Smaller Nuclear Facilities, Technical Reports Series Nr. 351, Vienna 1993
Hefner, N. Vana, Gmunden 17–21 September 2001

[4] K. Mück (†), Decommissioning of the ASTRA-Reactor, Seibersdorf, Description of project, legal aspects, Environmental aspects, documentation, Research Reactor Operator Group Meeting, 16-17 April 2002

[5] Informationen und Daten gemäß Empfehlung der Kommission vom 6. Dezember 1999 (Anwendung des Art. 37 des Euratom-Vertrages), Aktenzeichen K(1999)3932 (1999/829/EURATOM); Amtsblatt der Europäischen Gemeinschaften, L 324/23, 16.12.1999

[6] J. Casta, Mück, K., "Information und Daten in Bezug auf den Plan zur Dekommissionierung des ASTRA Forschungsreaktors im Österreichischen Forschungszentrum Seibersdorf, Österreich" Beilage zum Ansuchen laut Artikel 37 des Euratom-Vertrages, April/Mai 2000, (in German, restricted distribution)

[7] K. Mück (†), Meyer, F., Casta J., Dekommissionierung des ASTRA-Reaktors, Projektbeschreibung, Seibersdorf, Mai 2002, (in German, internal paper)

[8] K. Mück, Meyer, F., Environmental Impact Assessment on Decommissioning the ASTRA Reactor, (in German), Amt der N.Ö. Landesregierung, Bescheid RU4-U-078/047, 8. April 2003

[9] H. Kistmacher, Haferkamp, H., Seebaum, D., Feld, A., Bach, Fr.-W., Einsatzmöglichkeiten des Lasers in der Stilllegungstechnik, Stilllegungskolloquium Hannover, Juni 1997

[10] W. Hajek. Dismantling and Decommissioning Technologies and Techniques for Research Reactors, 25th anniversary WM99, 28. Feb. – 4. March 1999, Tucson, Arizona

[11] IAEA. Decommissioning Techniques for Research Reactors, Technical Reports Series Nr. 373, Vienna 1994