Radiation protection tasks on dismantling and decommissioning of the Research Reactor ASTRA at the Austrian Research Centres Seibersdorf (ARCS)

Ferdinand Steger¹, Alexander Brandl², Franz Meyer¹, Jakob Feichtinger², Ernst Lovranich²

¹Nuclear Engineering Seibersdorf GmbH 2444 Seibersdorf Austria
E-Mail: ferdinand.steger@arcs.ac.at
²Department for Radiation Protection Austrian Research Centres Seibersdorf 2444 Seibersdorf Austria

Abstract. On 31st of July 1999 the Research Reactor (ASTRA) at the premises of ARCS was finally shut down after an operational period of nearly 40 years. The fuel elements were shipped back to DOE, USA in May 2001, and a team to carry out the decommissioning was compiled consisting of former reactor crew staff members to be reinforced by co-workers to perform the decommissioning. One of the most important decisions was the installation of a powerful and effective radiation protection crew under supervision of the radiation protection officer on site. Furthermore it was necessary to implement specific surveillance and monitoring programs for radiation protection and to acquire special new low-level measuring devices. Some preliminary results are given.

Appropriate standards and separate measuring procedures – also very important tasks of radiation protection - were established to decide whether materials removed (e.g. concrete, steel pipes, aluminium plates, cables etc.) could be regarded as “inactive” or “contaminated below clearance values”. Additional methods were also implemented to approve materials for recycling or dumping or pronouncing material as contaminated above limits to be treated as radioactive waste. Work instructions for radiation protection for handling and operating sequences were developed. In this paper the radiation protection procedures and standards for monitoring the dismantling and decommissioning staff are described. The surveillance of the exposure by internal contamination of the working staff by whole body counting, by excretion analysis and also by external dosimetric measurements is specified. Monitoring of aerosols in the air and contamination control of the working area is also described. Finally the clearance control of dismantled material and the procedure of clearance are stated.

1. Introduction

After 39 years (1960 to 1999) of successful operation, the 10 MW multipurpose MTR research reactor ASTRA at ARCS (FIG. 1.) is now in the state of decommissioning [1]. A team consisting of former reactor crew staff members (which could be temporarily reinforced by co-workers if demand should arise) was set up to perform the decommissioning. Special care was taken in preparing procedures for the removal of materials (e.g. concrete, steel-structures, aluminium plates, cables etc.) with contamination below clearance levels. Working instructions for radiation protection and for handling and operating sequences were developed. An extensive documentation describes the project.

FIG. 1. ASTRA-reactor – view on core

The planning took into account that all the work and operations for decommissioning could be performed inside the existing buildings (confinement or pump room) with the ventilation and radio-
logical monitoring systems in operation. Hence virtually no possibility for a release of activity to the environment during the whole decommissioning process would exist.

In immediate succession 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 removed and treated from 2001 to 2003 in a first stage of dismantling. The task of clearing the reactor building from remaining experimental equipment, obsolete storage facilities and the transfer of the structures of the industrial source services including a 21-ton-lead-cell were also 90% completed. This work ceased by May 2003 in the first stage.

During 2002 an environmental impact statement was prepared, the public hearing was held on Dec. 19th 2002 to be followed by a license for decommission, which was granted on April 8th 2003 and was legalized in May 2003 [2].

The second state of dismantling starts in 2004. It is intended, to take down the structures of the biological shield by cutting blocks between 7 and 9 tons (limited by the 10-ton-capacity of the crane) from the inactive zones using wire-cutting techniques (FIG. 2.) and to get clearance for the material by referencing the surfaces and by additional internal probing.

For release from control we intend to use an available ISOCS-device (In Situ Object Counting System) of the company Canberra [3]. A validation of the method under ASTRA-conditions is just being carried out [4]. It is planned to apply the validated ISOCS-procedure also to ensure final clearance of the building-structures at the last stage of the decommissioning.

Actual cutting is supposed to start in February 2004.

FIG. 2. Biological shield – Concept of block cutting

On behalf of the government, Radioactive Waste Management, a division of Nuclear Engineering Seibersdorf GmbH, acts as central facility for the collection, conditioning and intermediate storage of radioactive wastes produced within the country. Therefore the project of decommissioning ASTRA also includes the preparation of the occurring waste for intermediate storage specifications.

2. Radiation Protection Procedures

An important decision was the employment of a radiation protection crew under independent supervision of the ARCS radiation protection officer. In ARCS a group of radiation protection experts has existed since the start of the research centres foundation (1960). This group is involved in radiation protection when dismantling and decommissioning ASTRA.

The following procedures are implemented to protect all the workers from radiation hazards [5].

2.1. Training and briefings

All co-workers must have completed the radiation protection training. Periodic radiation protection briefings supplement the state of training in this subject. External and/or foreign workers may enter the ASTRA only after detailed briefing and instructions.
2.2. Entering and leaving the reactor building, clothing regulations

In principle: The ASTRA-building must not be entered in street wear and walking shoes. For changing street wear to working clothes two changing rooms (cabs), each with an „inactive“ and an „active“ section, are provided for. The „inactive“ section, near the exit and the „active“ section, near ASTRA are partitioned off by a curtain. In the front section of the cab (inactive) the worker has to take off his street wear except for his underwear and deposit it in the respective box. Then he has to enter to the rear section of the cab (active) and to put on the working clothes (overall, working shoes and headgear and/or gloves). Afterwards he has to change his attendance card at the attendance board from the position „EX“ to the position „IN“, so that it can be verified immediately who is present in the reactor building. For entering the reactor building the radiation protection expert of ASTRA in the radiation protection control room opens the reactor air lock. The radiation protection control room must be permanently guarded during times, in which work is performed in the ASTRA.

When leaving ASTRA and after passing the air-lock the worker has to change the attendance card from the position „IN“ to the position „EX“. After that he in any case has to perform a contamination measurement using the body contamination monitor (FIG. 3.). If the body contamination monitor shows the message “NO CONTAMINATION” the worker has to enter the „active section“ of the changing cab and to take off the working clothes. Then he has to enter the „inactive“ section, get on his street wear and leave the cab afterwards. If the body contamination monitor shows the message “CONTAMINATION” the worker has to inform the responsible radiation protection expert immediately, who will arrange for the further steps. One of these measures is to protect the surrounding area against contamination. It is to be made certain that other objects or the soil are not contaminated as well. The radiation protection expert collects the contaminated clothes (overalls, shoes or overshoes, headgear etc.) and transfers them to a container intended for such purposes. Afterwards the worker has to perform the measurement again. If no contamination is measured the worker may proceed as described with the message “NO CONTAMINATION”.

![FIG. 3. Body Contamination Monitor, Dosimeters](image)

If body contamination is recognized the worker has to try clean himself in a washbasin and showers in the vicinity of the changing rooms and try to remove the contamination. If this is not possible, the radiation protection expert has to inform the radiation protection officer who has to arrange for further measures (intensive decontamination, evaluation of the dosimeter, incorporation measurements, etc.). If injuries without or with contamination arise, the radiation protection officer also has to inform the medical service, which will apply further measures (wound treatment, transfer into a hospital etc.)
3. Exposure control by external and internal radiation measurements

3.1. External radiation measurements (dosimeters)

Each worker of the reactor personnel has to carry with him two dosimeters, the official dosimeter (TLD) and also a directly readable (electronic) warning dosimeter (FIG. 3.). The official dosimeters are evaluated monthly, the warning dosimeters only if necessary. Both dosimeters have to be fastened in the chest area. The workers have to make sure that the dosimeters are not contaminated (by wrapping them into a plastic foil when doing contamination-suspicious work, formation of dust etc.). The deadline of the official dosimeters has to be strictly observed. As the result of measurements on 9 co-workers in 2003 we got a net mean dose of $600 \pm 200$ µSv/a (natural background: about 950 µSv/a). The maximum net dose of a co-worker was 900 µSv/a and the minimum dose 350 µSv/a. It can be said that the radiation risk according to the external doses of the co-workers in the first demolishing phase is very low and below the radiation protection limit of the population of 1000 µSv, according to the EU-Council Directive 96/29 [6].

3.2. Incorporation measurements

In addition to measurements of the external exposure, incorporation measurements are carried out for reason of a possible incorporation risk connected with the work. This is performed by whole body counter measurements on gamma-ray radionuclides (e.g. Co-60, Ba-133 etc.) and excretion analyses on beta ray radionuclides (H-3, C-14, etc.). These results of dose calculation of whole body counting and excretion analysis are obtained on the assumption of monthly measurements, intake as a result of an inhalation, 1µ AMAD and 15 days between intake and measurement.

3.2.1. Measuring intervals

The whole-body counter measurements and excretion analyses for routine work take place quarterly. When work with increased incorporation risk (cutting, sawing of plant parts etc.) is done as in the first stage of dismantling, the measurements are carried out monthly. Announced measuring dates are to be kept in any case, exceptions are only possible in agreement with the radiation protection expert and with convincing reasons like illness or office meeting. After incidents or unexpected radiation events a whole-body counter measurement or an excretion analysis has to be carried out immediately after the event, depending upon the presence of certain radionuclides. The radiation protection expert decides the necessity of such measurements in agreement with the radiation protection officer.

3.2.2. Whole-body counter measurements

The whole-body counter measurements are carried out at the incorporation-measuring laboratory of the department of radiation protection (FIG. 4.). For the efficient execution of the measurement it is necessary that the person takes a shower before the measurement and puts on freshly laundered underwear (both most appropriately at home). Therefore the measurements must take place early after arrival at work or it is has to be guaranteed that the person has not worked with radioactive substances on this day before the measurement is being taken. Instead street wear, special measuring clothes are used. Before the measurement the person is still examined with a contamination-measuring instrument for outside contamination, because such a contamination affects high incorporation contamination. The person examined is the first to be informed about the result of the measurement immediately after examination. The official result will then be sent to the radiation protection officer and to the radiation protection expert of ASTRA. In case of positive results a subsequent dose evaluation, a precise estimation of measurement and the further measures to be taken are determined (e.g. repeated measurements etc.).
The results of 7 co-workers in 2003 (8 positive results) showed that only Co-60 was found. The mean value was $305 \pm 280$ Bq. As a maximum value 766 Bq Co-60(s) was found corresponding to a committed effective dose equivalent of about 360 µSv. In no case were legal limits exceeded.

3.2.3. Excretion analysis

During dismantling of the ASTRA only H-3 and possibly C-14, Fe-55, Ni-63 or Sr/Y-90 (purely beta ray radionuclides) are relevant for incorporation monitoring. For H-3 it is mostly sufficient, that the monitoring is performed only with a spot sample of urine, approximately 100 ml, otherwise a 24h-Urine sample is collected. The excretion laboratory distributes the sample containers needed for the excretion analysis. During the urine collection it is necessary that the sample container be not contaminated. The spot sample shall take place, if possible after rising in the morning.

The results of 7 co-workers in 2003 showed that very often H-3 (28 positive results), sometimes C-14 (4 positive results), and very low amounts of Sr/Y-90 (6 positive results) were found. The mean value for H-3 was $270 \pm 220$ Bq/24h-Urine, for C-14 $31 \pm 4$ Bq/24h-Urine and $0,010 \pm 0,003$ Bq/24h-Urine for Sr/Y-90. As a maximum value of HTO was found 1130 Bq/d corresponding to a committed effective dose equivalent of 2,3 µSv, for C-14(Dioxide) of 32 Bq/24h-Urine corresponding to a committed effective dose equivalent of 1,6 µSv and for Sr/Y-90(s) of 0,017 Bq/24h-Urine corresponding to a committed effective dose equivalent of about 65 µSv. In no case were legal limits exceeded.

3.2.4. Limiting values

If the results of the incorporation measurements exceed default limits, which depend in each case on the radionuclides, further measurements take place to verify the measured results. The radiation protection officer decides about further procedures.

3.3. Further preventive measures

3.3.1. Breathing masks, headgear

If during work in the ASTRA, a formation of radioactive dust and/or a release of radioactive aerosols are to be expected, workers are obliged to additionally apply breathing masks and headgear. Overalls must be closely locked in order to avoid contamination of underwear or the skin.
3.3.2. Air collecting equipment

If during work air contamination is possible, the radiation protection expert of ASTRA can arrange the installation of air collecting equipment. The equipment should be installed where the highest air contamination is to be expected. The filters of the collecting equipment are evaluated and positive results are reported to the radiation protection officer who may initiate further measures.

3.3.3. Contamination measurements of different materials

When working with and handling contaminated material, the floor, the walls of the ASTRA and other objects may be contaminated. For a countermeasure the radiation protection staff of ASTRA has to perform daily measurements by means of contamination monitors and wipe tests. The radiation protection expert is responsible for such procedures. If contamination is recognized, it has been announced immediately. Elimination has to be carried out immediately. For decontamination suitable decontamination agents are at our disposals. If the contamination is serious, the radiation protection officer has to inform the workers about it and will coordinate further measures (use of cleaning personnel, removal of the contaminated areas etc.

4. The clearance control of dismantled material and the procedure of clearance

4.1. Release from Control

Austrian and international regulations demand that all material in controlled areas be checked for contamination, activation, or the presence of radioactive sources before it can be permitted into publicly accessible areas [7]. The release from control for reuse, recycling, or final disposal of materials found to be inactive by suitable measurements is an act of the competent Authorities and is expected to be finalized by their written authorization via a release certificate.

During a public hearing upon completion of the environmental impact assessment for the decommissioning of ASTRA, a protocol for release from control of materials present in the reactor building, the reactor building structure, and any auxiliary components of the reactor operation systems area was agreed upon between the Competent Authorities, ARCS and all relevant stakeholders [2]. This procedure involves a four-step protocol, including initial measurements by reactor operations personnel, who are now responsible for decommissioning the reactor. The radiation protection officer or the Radiation Protection Department of ARCS is to assess the methods used by operations personnel, conduct additional measurements, and verify the results. An independent check of the results obtained by operations personnel and an external expert provides the radiation protection officer. The results are verified by checking the measurement data and by randomly sampling and measuring 5% of the material to be released from control. Provided the measurement data show compliance with the nationally regulated release levels, the Competent Authorities will issue of a release certificate for the materials under investigation, such that they are cleared for reuse, recycling, or final disposal.

The detailed documentation accompanying the release procedure includes the collection and archiving of all measurement data and results, photographic evidence of the materials, the proper signatures of personnel conducting the measurements, the radiation protection officer, and the external expert, and official request for issuing of a release certificate together with the release certificate.

All materials released from control have to be voluntarily accepted by the recipient, who issues a properly signed statement to this effect.

4.2 Methods, and Measurements

4.2.1. Various materials

The release from control material from the ASTRA involves various materials, such as concrete, steel and graphite, paraffin, cables and pipes, electronics, furniture, and flooring (FIG.5). In order to
investigate the potential of the various materials for containing radioactive sources, for being activated, or for being contaminated, an investigation of their modes of use during their lifetime in the reactor building is conducted. For activation products, the integral neutron fluency at the material’s location is estimated, and the material composition is determined. Contaminations is only expected to be present in reactor components and in tools and machinery previously used for handling active material, such as fuel or experimental equipment. Any other areas in the reactor building and materials have been checked continuously for surface contamination, even during regular reactor operation. Given these considerations, a list of expected nuclide vectors for the various materials is generated.

Various different measurement methods and techniques are employed, depending on the expected radionuclide vectors. Representative samples are taken from all the materials for alpha and beta emitting nuclides. Chemical preparation is performed, after which alpha spectrometry is employed for alpha emitters. Beta emitters are examined by liquid scintillation counting, or on a gas counter. Gamma emitting radionuclides in large amounts of material are detected, identified, and quantified by in-situ gamma spectrometry. Surface contamination is determined by hand-held gas counters or plastic scintillators, or by wipe test sampling.

4.2.2. Concrete blocks of the biological shield

The decision if a concrete block contains no contamination and/or is falling below release values is taken by ARC’s radiation protection officer measurements in co-operation with officially recognized consultants, who will transmit this information in written form to the authority who will then decide about possible release. Chances are that the top of the biological shield of the ASTRA was neither contaminated because primary cooling water could not contaminate the surface due to an aluminum liner nor activated because neutrons could not reach this part of the biological shield because of shielding by the cooling water. Nevertheless, in order to verify the acceptance, the blocks from this part of the biological shield shall be measured. For this purpose 2 measuring procedures are intended:

1. Measurements of a possible surface contamination by carrying out measurements with ISOCS [3].
2. Measurements of aliquots quantities (about ½ up to 1 liter) of the material by means of gamma spectrometry in a Marinellibeaker, taken from the concrete blocks.
5. Conclusions

After 39 years of operation, the research reactor at the Austrian Research Centres Seibersdorf is currently being decommissioned. The radiation protection procedures are very sufficient and satisfying. Various inactive materials from the reactor building and structure are being released from control by employing a four-step procedure, agreed upon by the Competent Authorities, ARCS and all relevant stakeholders during a public hearing.

The materials released to date include 16500 kg of steel re-enforced concrete from mobile shielding material and 5500 kg of furniture, cables, small machinery, and electronics as well as about 10000 kg of graphite from the thermal column and 3000 kg of paraffin from mobile neutron shielding.

After completion of the dismantling and release from control of the thermal column graphite, the next and biggest step in the decommissioning process will be approached. The dismantling, separation of active and inactive regions, and release from control of inactive material from the biological shield will be started.

Block cutting in the “inactive” zone of the biological shield starts end of February 2004. Every block will be measured and if it is released of control the blocks will be reduced to small pieces and disposed in inactive dumping grounds.

The blocks in the activated zone of the shield will be sealed and stored in the intermediate store of the Austrian Research centers Seibersdorf.

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Devotement: This paper is dedicated to Dr. Konrad MÜCK, the former radiation protection officer of the ARCS and former head of the radiation protection group of the decommission team of ASTRA who was killed in an accident while mountaineering in the Swiss Alps on August 17th 2001.