Dismantling of the Amsterdam 700 MeV Linear Electron Accelerator MEA, Electron Storage Ring AmPS and the Experimental Halls.

Pieter W. F. Louwrier, C. N. M. Bakker, J. Spelt.
National Institute for Nuclear Physics and High-Energy Physics (NIKHEF), PO Box 41882, NL-1009 DB Amsterdam, The Netherlands.

INTRODUCTION.
On January 1, 1999 the electron scattering experiments with the 700 MeV linear accelerator were terminated. As no new accelerator facility is envisaged the accelerator and the experimental set-ups have to be dismantled and removed in order to terminate the licence to operate a nuclear facility. The removal of the facility has to be executed in accordance with a plan approved by the Dutch ministry of Housing, Spatial Planning and the Environment.

After an official clearance of the former irradiation vaults by the Dutch ministry of Housing, Spatial Planning and the Environment the buildings will be let to a commercial company.

OVERVIEW OF THE FACILITY.
An overview of the facility is shown in figures 1 and 2. The 200 m accelerator MEA produces 700 MeV electrons, which are injected into the 210 m electron stretcher/storage ring AmPS. The facility encompasses the beam switchyard AFBU, the electron scattering hall EMIN, the former pion-muon facility PIMU, and the low-energy irradiation facilities for chemistry and physics LECH and LEF. The accelerator, the beam switchyard, the experimental halls and the storage ring are located underground.

The accelerator and the experimental facilities were used for approximately 20 years for nuclear physics research. In 1990 the electron storage and stretcher ring was constructed.
Up to December 1998 electrons were extracted from the ring to provide a 10 $\mu$A electron current with a duty cycle of about 80 % for electron scattering experiments. From 1998 only experiments with a stored electron beam with polarised electrons and internal targets were performed.

STARTING PRINCIPLES.
The facility has to be dismantled on a short time schedule, as the licence does not allow NIKHEF to store radioactive materials for a long time. Further, reuse of components is useful only if they are available now. Re-use by other laboratories is preferred over recycling, recycling is preferred over storage as chemical waste or as radioactive waste.

CHARACTERISATION AND MEASUREMENT OF THE INDUCED ACTIVITY.
The activation of accelerator structures and of concrete shielding is well studied (1, 2, 3, 4). For this accelerator the prominent isotopes with half-lives longer that 60 days are given in table 1.

Table 1. Prominent activation products in the accelerator structures and the concrete shielding walls.

<table>
<thead>
<tr>
<th>isotopes</th>
<th>Half-lives</th>
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<tbody>
<tr>
<td>stainless steel</td>
<td>$^{55}$Co, $^{57}$Co, $^{58}$Co, $^{60}$Co $^{54}$Mn, $^{55}$Fe, 84 d</td>
</tr>
<tr>
<td>copper</td>
<td>$^{57}$Co, $^{58}$Co, $^{60}$Co, $^{54}$Mn</td>
</tr>
<tr>
<td>aluminium</td>
<td>$^{22}$Na</td>
</tr>
<tr>
<td>concrete</td>
<td>$^{152}$Eu, $^{155}$Eu</td>
</tr>
<tr>
<td>lead</td>
<td>$^{207}$Bi</td>
</tr>
</tbody>
</table>

An ISO standard for the determination of the activity in solid materials intended for recycling is published (5). For the determination of the radioactive content a calibrated portable germanium detector (86 cm$^3$, Oxford Instruments, Target, iSPEC plus analiser) is used for in-situ measurements. Small samples are measured with a 40 cm$^3$ germanium detector in a calibrated geometry. As the activation of the material is highly inhomogeneous, the activity in large objects has to be estimated by means of the computer program MicroShield 5®. Gamma dose rates are measured with a 1” x 2’ NaI detector (Target, FieldSPEC).

Before the dismantlement of the facility started, a comprehensive database of all activated components was set up. For each component the database contains the description, the function, the position, a unique number, the dose rate on the surface and at 30 cm and an electronic picture showing the number.
Apart from the beam dumps, the energy defining slits and some parts of the ring injection and ring extraction systems all components can be transported as LSA II or LSA III material. The accelerator sections can be transported as inactive material. The only slightly activated components of the accelerator are the section collimators. These can be removed easily to facilitate the transport.

REMOVAL OF THE ACCELERATOR, STORAGE RING AND BEAM SWITCHYARD TO JINR, DUBNA, RUSSIA.

The accelerator, part of the beam switchyard and the storage ring will be reused as components of a new synchrotron light source by the Joint Institute for Nuclear Research (JINR) in Dubna, Russia. The transport of all accelerator sections, the RF power supplies, the magnet power supplies and the control system is complete. The transport of the activated ring components, the beam switchyard magnets and the ring injection system is awaiting the required transport and import licences.

REMOVAL OF SLIGHTLY RADIOACTIVE COMPONENTS AS SCRAP-METAL.

Considerable amounts of slightly activated copper, steel and aluminium have to be removed. In the Netherlands there are no reference values for the clearance of activated materials. The destination of the material has to be approved by the Dutch ministry of Housing, Spatial Planning and the Environment. In the literature there are a number of values for the activity concentration below which the material can be recycled without further regulatory control (6, 7, 8). However, for large structures like magnets, which are only locally activated it is unclear whether averaging is allowed. At this moment the Swiss definition of clearance is considered (4). Activated materials are separated into 5 categories: inactive material, material with a dose rate of 0 to 0.1 µSv h⁻¹ at 0.1 m distance, of 0.1 to 10 µSv h⁻¹, of 10 to 100 µSv h⁻¹, and > 100 µSv h⁻¹. Factors to convert dose rate to an estimated activity concentration were determined for various materials, masses and geometry’s. To be considered as inactive, the activity concentration should be < 3 Bq g⁻¹ for ²²Na and < 1 Bq g⁻¹ for ⁶⁰Co, and the dose rate at 0.1 m should be < 0.1 µSv h⁻¹. Unfortunately, for large items even lower activity concentrations than 1 Bq g⁻¹ are required to meet the second criterion (4). The other categories are still a matter of negotiations with the government.

A definite criterion is the sensitivity of the radiation detector at the entrance of the scrap metal company involved. These detectors can easily measure an activity of 0.5 Bq g⁻¹ ²²Na or ⁶⁰Co averaged over a load of 6 to 10 tonnes.

ACTIVATED COMPONENTS.

Four aluminium beam dumps, the stainless steel energy defining slits and one pion production target are activated to dose rates levels > 1 mSv h⁻¹ at 0.1 m from the surface. Activity concentrations of the activated spots are in the order of 10⁵ Bq g⁻¹. These items are too large to be removed as radioactive waste, thus a special shielded area is set up to break up these components and condition them for disposal as radioactive waste. For every item a dedicated plan has to be made, as some of them are still shielded by 10 to 20 cm of lead. Some water-cooled components still contain water residues. The maximum activity concentration found so far is 0.6 Bq g⁻¹ ²²Na. This water is transferred into waste water tanks.

RADIOLOGICAL PROTECTION PROGRAM

As a large number of Russian guests are involved in the dismantling and packing of the facility for transport to Russia a special radiation protection program was set up. As a result of a stringent beam management system the radiation levels are generally low. However, the controlled access to the accelerator area and the stringent ban on the removal of any uncontrolled item from the area were maintained. On arrival there was a brief instruction about the Dutch regulations, about the rules of conduct in the accelerator area and about the operation of the various dose and dose rate meters. An interpreter was present to ascertain the correct interpretation of the information. For checking the dose rate FAG FH 40F2 meters were used. Regular TL dosimeters were used to measure the accumulated dose, for operations where some exposure could occur Siemens Plessey EPD’s were issued.

REFERENCES.


Figure 1. Plan of the stretcher-storage ring AmPS, EMIN electron scattering hall and internal target hall ITH.
Figure 2. Plan of the accelerator facility MEA-AmPS. Upper part: above ground level, lower part: below ground level