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1. Introduction

The Neuherberg Research Reactor is of type TRIGA MARK III with 1 MW steady state power and pulsable up to 2000 MW. In August 1972 the reactor reached criticality for the first time. During more than ten years of operation 12000 MWh and 6000 reactor pulses had been performed. Research by internal or external groups of experimenters had been done in the following fields:

- reactor safety and radiation protection
- environmental chemicals
- public health, especially neutron activation analysis in medicine and biology
- radiation biology
- general irradiation purposes.

In spite of its good technical condition and of permanent safe operation without any failures, the decommissioning of the Neuherberg research reactor was decided by the GSF board of directors to save costs for maintaining and personnel.
As the mode of decommissioning the safe enclosure was chosen. This means the fuel elements will be transferred back to the USA. All other radioactive reactor components will be enclosed in the reactor block.
The reasons for this choice are:

- radiological safety of the decommissioned reactor
- to keep radiation exposure for the decommissioning personnel as low as possible
- unrestricted usebility of the reactor hall and the surrounding rooms
- costs for decommissioning should be as low as possible.

2. Licensing procedure for decommissioning

To initiate the decommissioning procedure, until now the following supporting documents had been delivered to the Bavarian Ministry of State for Regional Development and Environmental Affairs:

- the approval contract for decommissioning the reactor according to section 7 of the German Atomic Energy Act

- a short description of the decommissioned reactor
- a description of the decommissioning procedure and an estimation of the radiation dose received by the decommissioning personnel
- a survey of the planned measures to keep clean water, air and soil
- a safety report.

To make our intentions more transparent we invited representatives of the involved administrative departments for a presentation of the single steps for decommissioning.

3. Time schedule

It is planned to shut-down the reactor on December 22nd, 1982. Then after 40 days waiting time and 20 days loading time the fuel elements can be carried off at the beginning of March 1983. On the rest of the year 1983 all other activities will be executed to achieve the state of safe enclosure.

4. Removal of non essential parts in the sense of the reactor operation license

Independent of the licensing procedure of the decommissioning the following activities can be accomplished because they do not figure essential changes in the sense of the operation license:
Removal and external deposition of
- the fuel elements
- the neutron source
- the experimental devices in the beam ports
- the in-core irradiation tubes
- the irradiation capsules
- the tubes of the pneumatic transfer system
- the rotating disk assembly for irradiations near the core
- the lead shielding cylinder of a special irradiation facility mounted on one additional grid plate
- all radioactive or contaminated lead walls and boxes in the reactor hall and in the exposure room
- the resin of the demineralizers
- all radioactive waste.

5. Removal of the fuel elements

After the final shut-down of the reactor all irradiated fuel elements will be transferred back to the USA to the US-DOE reprocessing plant Idaho Falls. GSF charged the firm TRANSNUKLEAR at Hanau with the execution of all administrative and technical procedures of the fuel element transport. A total of 124 irradiated fuel elements have to be disposed of:

- 119 standard fuel elements
- 2 instrumented fuel elements
- 3 fueled-follower control rods

For the fuel element transport three containers are necessary:

- 2 containers of type Goslar
- 1 container of type TN6/3

A Goslar container has a weight of 10 tons and a capacity of 60 standard fuel elements. The TN6/3 container weighs 6.3 tons and has six positions for special elements with a length up to 1500 mm.
The total burn-up of the fuel elements was calculated to be 617.5 g U-235 according to 12000 MWh released energy. Also relative burn-up was calculated for each element seperately taking into account its history and position in the core. So the average relative burn-up is 13 %, the highest burn-up of 22 % is in the fueled-follower safety rod and the lowest burn-up of 2,9 % is in an element which was only for a short time in the reactor core.

The activity inventory of the fuel elements after 40 days waiting time was estimated taking into account 23 relevant fission nuclides. For the element containing the highest fission product activity a dose rate of about 115 R/h at 1 m distance was estimated. So the fuel element handling during the loading procedure, which will be described now, presents no problems. Though the crane in the reactor hall is designed to lift charges up to ten tons, only charges of two tons maximal may be moved above the reactor block as required by the authorities.

So it is not possible to set the transport container directly at the bottom of the reactor pool. A special cylindrical steel tank of 2,5 m diameter and 4 m hight therefore must be installed in the reactor hall

and filled with water. Herein the Goslar or TN6 container is inserted and charged under water with fuel elements which are transferred separately from the reactor pool within the normally used fuel element transport bottle with a weight of 1.9 tons. For this procedure the collective dose was estimated to be lower than 0.1 manrem.

6. Estimation of the activity inventory

After the removal of the main activity of about 50000 Ci in the fuel elements the rest activity in the state of safe enclosure is contained in the following reactor components:

- core shroud and grid plates
- nose of the thermal column with beam ports and some areas of the aluminum pool liner
- supplementary grid plates
- impurities in the graphite of the thermal column
- concrete around the thermal column and exposure room
- rotary specimen rack.

To determine the specific nuclides of the total activity, especially the radionuclides which are caused by impurities in the aluminum, concrete and graphite, representative material samples of the above mentioned reactor components were activated in the reactor neutron field and then analysed by gamma spectroscopy. From the irradiation data of these material samples as mass, irradiation time and neutron flux density and from their single activities the total activity may be calculated by comparison with the product of the neutron flux density distribution and the volume of the single components taking into account the reactor operation time. The spatial integrals over the flux density distribution were determined by one dimensional two-group diffusion theory under conservative assumptions. A total energy release of 12000 MWh of the reactor at the end 1982 was used in the calculation.

Neglecting all radionuclides with half-lifes shorter than 2.5 days one gets a total activity of about 30 Ci after shut-down of the reactor essentially caused by the radionuclides Cr-51, Co-60 and Fe-55. One year later the activity has decayed to a quarter of the original value. Then the nuclides

Co-60, Fe-55 and Eu-152 predominate. Ten years after shut-down the total activity is only about 2 Ci consisting of the main components Co-60, Eu-152, Fe-55 and Ni-63.
In the following table a summary of the most important nuclides is given for different decay times:

FRN activity inventory containing only radionuclides obeying the condition:
initial activity [mCi] x life-time [years] ≥ 1

radionuclid	activity [Ci] after different decay times				
	0	14 days	0.5 year	1.0 year	10 years
Ca-45	1,1	1,1	0,5	0,22	-
Sc-46	0,06	0,054	0,013	0,003	-
Sc-47	0,11	0,006	-	-	-
Cr-51	17	12	0,18	0,002	-
Mn-54	0,1	0,093	0,063	0,043	-
Fe-55	3,2	3,2	2,8	2,5	0,25
Fe-59	0,18	0,15	0,011	0,001	-
Co-58	0,12	0,1	0,02	0,003	-
Co-60	3,8	3,8	3,6	3,3	1
Ni-59	0,001	0,001	0,001	0,001	0,001
Ni-63	0,11	0,11	0,11	0,11	0,1
Zn-65	0,78	0,74	0,47	0,27	0,024
Ag-110m	0,01	0,01	0,006	0,004	-
Sb-122	1,3	0,037	-	-	-
Sb-124	0,62	0,53	0,076	0,009	-
Cs-134	0,078	0,077	0,066	0,056	0,003
Eu-152	0,87	0,87	0,85	0,82	0,51
Hf-181	0,015	0,012	0,001	-	-
Ta-182	0,008	0,008	0,003	0,001	-
sum expressed in round numbers	30	23	9	7,5	2

7. Dismantling of the reactor and the state of safe enclosure

After reception of the decommissioning license all essential changes of the reactor facility in the sense of the operation license may be carried out. All single performances to decommission the reactor are arranged to be not only technically rational but also in such a way that both the total radiation exposure and the irradiation dose for any single step are minimized for the decommissioning personnel. The knowledge of the expected radiation exposure is based on many years of operation experience and on special measurements during inspections and maintenance routines.

For the whole decommissioning project an upper limit of 0.54 manrem was estimated as the collective dose. The main activities are encountered in the following list:

- construction of a shielding wall in the exposure room towards the reactor pool
- removal of the control rod drives, the transient rod drive, the fission chamber drive, the diffuser system, 4 underwater lights, 4 fuel element quivers, the fuel element examination device
- removal and deposition inside the exposure room of all ionization chambers, of the transient rod and of the radioactive parts of the linkages
- lowering of the pool water level 1 m below normal
- chemical decontamination of the primary cooling loop and purification system, disconnection and tightening of pipes
- lowering of the pool water level 10 cm below the shroud flange and inserting a mounting platform around the core
- disconnection of the rotary specimen rack and of the core support and deposition on the bottom of the pool
- horizontal displacement of the reactor bridge of about 2 m and transportation of the rotary specimen rack at the roof of the hot cell for drying
- deposition of the reactor bridge in the reactor hall and its decontamination
- storing the rotary specimen rack in the exposure room
- lifting of the core support by 2.5 m for drying
- storing the core support and some minor radioactive parts in the exposure room

- disassambly of the mounting platform and complete removal of the pool water
- decontamination of the aluminum pool liner
- construction of a shielding wall in front of the thermal column and filling of the remaining hollow space with gravel
- closing of the reactor pool with coverplates

Subsequently the air in the reactor pool will be exhausted through filters and is controlled with an aerosol monitor permanently.

Now the state of safe enclosure is achieved. Control area will be only the inside of the reactor block.
To use the reactor hall in the future the installation of already existing particle accelerators is intended.