REVIEW OF SOME ASPECTS OF RADIOLOGICAL INTEREST DURING THE ESTABLISHMENT OF THE SAFE ENCLOSURE OF THE THTR 300 PLANT

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Abstract

One of the first activities with the establishment of the safe enclosure was the disassembly of the reactor of the burn-up measurement facility. This was a graphite-moderated, air-cooled reactor with strip-shaped fuel elements made of an aluminium uranium alloy. The reactor contained 3.9 kg of high-enriched uranium (93% U-235), the thermal power output was 500 W. Because of the highly cramped conditions, the acceptable dose level and the limited number of fuel stripes, the decommissioning was executed almost exclusively manually. To reduce the collective dose of the personnel, an extensive training with a 1:1 scale mock-up was carried out prior to decommissioning. The removed fuel elements were put into special baskets and were shipped to the interim storage facility BZA in two CASTOR THTR/AVR casks.

In order to clear place for the installation of components of the new ventilation system and other systems, the components for high-purity helium compression and storage had to be dismantled. More than 90% of the metal were unconditionally released as iron scrap.

Extensive measurements had to be carried out on the dismounting and inspection equipment which had been mostly already in use during the 3 year time of operation. As a result 3 Mg had to be stored in the remaining controlled area, app. 183 Mg were stored within the supervised area and app. 49 Mg were released as free of contamination.

Due to the high tritium inventory, two containers with barrels filled with waste could not be shipped to external storage sites and therefore had to be stored in the remaining controlled area within the envelope of the safe enclosure.

Another interesting aspect of the low contamination level of the THTR 300 plant was the release of buildings from the restrictions of the Atomic Energy Act and reduction of the controlled area to a supervised area. Based on statistical methods we were able to prove the low-level contamination status with an acceptable amount of measurements.

Finally a new system for monitoring of released radioactivity with the new exhaust air system was designed and built. Government authorities requested a system with advanced sensibility for low emissions of tritium and carbon-14. The design especially had to consider the highest mean time between failures and the lowest mean time to repair possible.

1. Introduction

This paper is to give a brief review of some aspects of radiological interest during the establishment of the safe enclosure of the THTR 300 plant operated by the Hochtemperatur Kernkraftwerk GmbH (HKG). During the establishment of the safe enclosure, the consortium KSE (Noell-KRC and STEAG Kernenergie) as a general contractor was also responsible for radiation protection organization and waste management and provided one of the radiological health and safety officers and all of the health physics personnel.

2. Dismantling of the burnup measuring reactor

Loading and unloading of the THTR reactor core was carried out while the burnup of the pebble-shaped fuel elements was monitored by means of a burnup measuring system. The main component of this system was the burnup measuring reactor (Solid Moderated Reactor) in which a reactivity effect is caused by operating elements as they pass through the reactor. Evaluation of this effect permits determination of the type of element and, in case of fuel elements, the burnup of the element.

Unloading of the THTR reactor core was completed by 28 October 1994 with the establishment of the state "reactor core free of nuclear fuel". By then, the task of the burnup measuring reactor was completed so that dismantling of the burnup measuring reactor could be initiated in order to remove the nuclear fuel contained therein.

2.1. Initial situation

The burnup measuring reactor was a graphite moderated thermal reactor with a rated output of 500 W, arranged in the reactor hall below the prestressed concrete reactor vessel. The reactor core (1.0 m · 1.2 m · 1.1 m) consisted of various graphite plates provided with grooves for accommodation of the 767 strip-shaped fuel elements. The fuel elements have a rectangular cross-section (15 mm · 1.1 mm) and a length of between 89 and 711 mm. They contain 93% enriched uranium in a U-Al alloy (20% uranium, 80% aluminum). Total uranium content of the core was 3.9 kg.

The core was enclosed by a graphite reflector consisting of plates similar to those of the core. Outside dimensions of the SMR were thus 1.8 m · 2.0 m · 2.0 m. The operating element guide tube, used to guide the operating elements rolling through the core by gravitation, passed through the center of the reactor core. The entire reactor composed of graphite plates was mounted on a steel slab anchored to the floor and was supported by a steel structure installed around the reactor. Reactor instrumentation, absorber rods and the neutron source were arranged in twelve vertical drill holes through the reactor core. Figure 1 gives a general idea of the burnup measuring reactor.

The initial radiological situation was determined by a burnup of approx. 3.1 MW·h/kg U after unloading of the THTR reactor core. Overall activity, originating mainly from the fission products, totaled $2 \cdot 10^{12}$ Bq/kg U. The measured dose rate in the room of installation of the SMR ranged from 500 to 800 µSv/h as regards gamma radiation and was below 1 µSv/h as regards neutron radiation. Values ranging from 1.5 to 20 Bq/cm² were determined for non-fixed contamination. When dismantling work was initiated, indoor air activity concentration was below 40 Bq/m³.

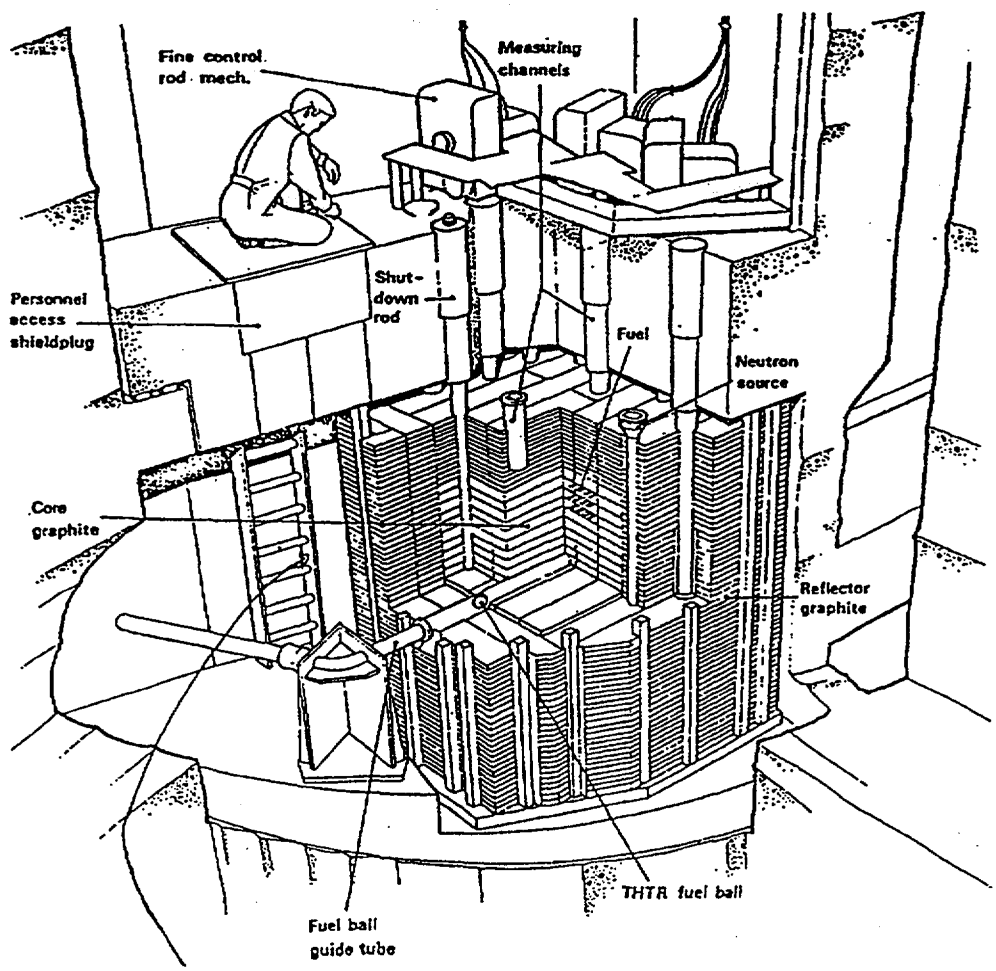

FIG. 1. Installation of the burnup measuring reactor

In terms of technology to be used for dismantling, the initial situation was characterized by extremely cramped spatial conditions in the SMR room of installation and difficult access to this room.

2.2. Preparatory activities

Under the given radiological and spatial conditions, a dismantling concept was chosen which was based on manual dismantling using suitable auxiliary equipment and installations. Preparatory activities included mainly the installation of a 1:1 mock-up, staff training and testing of the auxiliary installations.

The mock-up consists of an SMR room of installation and the access area arranged above. Height of the mock-up totals approx. 7 m.

The mock-up was used to test all equipment and installations designed specifically for dismantling of the reactor (particularly the mobile shield) both individually and in interaction and the devices were optimized.

Testing of the devices was followed by training of the dismantling personnel. Training concentrated on

- assembly of the auxiliary installations under the cramped conditions;
- video-monitored handling of the fuel elements and graphite plates by means of auxiliary equipment;
- handling of the fuel element shielding container (up to storage of the fuel elements in the THTR 300 fuel element storage facility);
- conduct in case of incidents and management of abnormal situations.

The work papers and step sequence plans used for testing and staff training were revised on the basis of the experience made with the mock-up and provided thus the basis for a comprehensive set of work papers and step sequence plans for dismantling of the SMR.

2.3. Dismantling of the burnup measuring reactor

The burnup measuring reactor had to be dismantled only to the extent necessary for removal of the nuclear fuel.

In addition to the equipment and installations that had already been installed at the mock-up during testing, the following preparatory activities had to be developed in the THTR 300 nuclear power plant:

- preparation of the transport path leading up to the SMR room of installation, including assembly of the transport means (inclined haulage and hoist);
- provision of a charging aid for the shielding device, reloading into transport and storage cask transport cages;
- installation of an auxiliary ventilation system for the SMR room of installation.

The activities in the THTR 300 plant - from preparation via removal of fuel elements, loading into shielding device and until transfer to the THTR fuel element storage facility - were carried out by a staff of approx. ten persons in one shift over 30 work days. The collective dose for the personnel was only approx. 10% of the maximum value of 200 mSv stated in the application that had been filed for the licensing procedure under nuclear law, and approx. 20% of the dose expected according to the initial step sequence plans.

The SMR fuel elements were loaded into two transport and storage casks CASTOR THTR/AVR. Shipping of the two CASTOR casks to the Ahaus fuel element interim storage facility on 10 March 1995 completed the activities for management of the SMR fuel elements.

3. Some main sources of waste from decommissioning

The wastes arising from the relevant work for the implementation of the safe enclosure and their destination - except waste containing nuclear fuel – are compiled in figure 2. The following are some of the main sources which are discussed in detail.

License	Year	Works	Shipped: Unrestr. Release [Mg]	Shipped: Radioact. waste [Mg]	Stored in THTR [Mg]
7/12a					
	1994				
		Defueling of the core	14 1)	16	56 2)
		Final inspection			
Am.No.1	1995	Disassembly of the measurement reactor	16	5 3)	17
Am.No.2		Release of the steam-feedwater-circuit	88 4)	-	-
		Removal of mufflers	168	-	-
Am.No.3, 4		Sealing components, Helium compressor	62	1	60
	1996	Dismount. equipment	64	2	186
7/12b		New vent systems	88 5)	-	1
Am.No.1		Evaporator plant, Change status rooms	-	33 6)	-
		Reconnect vent syst.	21	3	10
		Remove vent stack	79	-	-
	1997				
		Total: 7)	730 8)	83	350

1) Pulverized resins from the condensate cleaning system
2) Graphite and absorber elements within the spent fuel element storage
3) Solid organic waste
4) Removed parts are included only.
5) Rubble
6) Evaporator concentrate and mud
7) Including works not listed above.
8) + 7,400 Mg structural steel and components
+ 44,400 Mg reinforced concrete

FIG. 2. Sources of waste during decommissioning

3.1. No-contamination-measurements for components of the secondary system

With a second amendment to the core unloading license (7/12a), no-contamination-measurements of components in the turbine hall and in the adjacent feedwater tank building and the disassembly of the steam-feedwater-cycle mufflers on the roof of the reactor hall were permitted. Only the waste water discharge station in the supervised area of the turbine hall continued to be subject to measurement after having achieved the state of safe enclosure.

The no-contamination-measurements of components of the steam-feedwater-circuit were performed at this early stage to enable reuse of these components at any other site.

Theoretical investigations based on measurements with pulverized resins from the condensate-cleaning system and certain experience from AVR led to the conclusion that the complete steam water cycle would stay clearly below the threshold value for unconditional release of iron scrap. The number of measurements to be made was comparatively small. Prior to granting of the second amendment to license 7/12a, HKG took 10 measurements at components that were easy to exchange (e.g. valves) and components easy to access (e.g. low pressure section of turbine above the condenser) to verify the theoretical model. After granting the second amendment an additional 20 measurements were carried out together with the experts. These gamma-spectrometric measurements were partly made in the laboratory and partly in situ. For the in-situ-measurements, the background level was subtracted and the calibration factor was calculated for the actual geometry. The detection threshold referring to Co 60 was 0.006 Bq/cm² (equivalent to 0.001 Bq/g at a minimum thickness of 8mm). The nuclear supervising authority approved the release of these components on October 20, 1995.

Six non-contamination-measurements of the mufflers were performed under the supervision of the Technical Inspection Service at two representative mufflers. Approval for disassembly of all 6 units and their unconditional release for scrapping was given on July 19, 1995. The total masses of iron scrap arising from these activities are shown in figure 2.

3.2. Disassembly of the high-purity helium compressors

The 4th amendment to license 7/12a was issued on October 27, 1995. It permitted the disassembly of components of the high-purity helium compression and storage system, aiming to clear space for the installation of components of the new ventilation and activity monitoring system.

The components to be removed were installed in the supervised area of the plant. Thus they actually had to be non-contaminated. It was known, however, that certain inner surfaces of pipes had been slightly contaminated due to back streaming gas during plant operation.

Contaminated and non-contaminated piping segments had to be determined. During these measurements, it was found that the two heavy four-stage helium compressors were slightly contaminated in their first stages. They were disassembled prior to being subjected to a thorough investigation. As far as necessary they were decontaminated.

Parts of the system for which no-contamination-measurements were easy, were brought to closed containers installed outside and stored there until approval by the authorities had been obtained. Parts for which the state of no-contamination was to difficult to prove, were packed into 200 l-barrels and stored in the supervised area for the time of safe enclosure.

The final no-contamination measurements for the helium compressors were made in March 1996. More than 90% of the material (approx. 62 Mg) was unconditionally released as iron scrap.

3.3. Measuring of the dismounting and inspection equipment

The THTR nuclear power plant was equipped with a partly shielded dismounting and inspection equipment. This equipment was used for work on the fuel circulating system, the helium purification system, the absorber rods and for the inner inspection of the prestressed concrete reactor vessel. In parts, this equipment had already been in use and was therefore contaminated.

Due to the fact that some of the equipment had already been disassembled, the number of contamination-measurements amounted to several hundred. As a result of the measurements, the single parts were classified into three groups: parts with a contamination higher than

5 Bq/cm² were stored within the remaining controlled area; parts with contamination between 5 and 0.5 Bq/cm² were stored in the supervised area of the remaining plant; and parts with a contamination level below 0.5 Bq/cm² were unconditionally released for scrapping.

As a result, 3 Mg had to be stored in the controlled area, approx. 183 Mg were stored within the supervised area, and approx. 49 Mg were released as free of contamination.

3.4. Waste from external conditioning

In September 1996, two containers with barrels filled with tritium-contaminated waste were stored within the cover of the safe enclosure. The 16 D350-barrels of high-grade steel were filled and sealed at the Karlsruhe research center. Due to the high tritium inventory of the barrels, storage at the final repository Morsleben is not possible today. The tritium-activity amounts to 2.9E+12 Bq per Barrel.

4. Downgrading from controlled area to supervised area

With the first amendment to license 7/12b (establishment of the safe enclosure) issued on July 15, 1996 HKG was allowed to change the status of rooms outside the cover of the safe enclosure from controlled to supervised area. Therefore it had to be proved that the surface contamination of the buildings and components did not exceed 5 Bq/cm² and that the dose rate did not exceed 7.5 μSv/h in this area. In addition, HKG demanded that in rooms which should be accessible without any restrictions to persons who are not occupationally exposed to radiation, the dose rate should not exceed 2 μSv/h.

For a total area of about 12000 m² (170 rooms) the fulfillment of the above conditions had to be proved. The proof was provided in two steps: through the analysis of the history of operation of the plant and through measuring at representative locations. For regions on the floor with high probability of contamination, the number of measurements was 1 measurement per 2 m²; for regions with low probability of contamination and for walls up to a height of 2 m the number of measurements was 1 per 10 m². For components, the number of measurements was 1 per m². Dose rate measurements were done in every room. Spots with higher dose rates were either decontaminated or shielded. Components that continued to fail meeting the specifications of the supervised area even after decontamination were dismantled and stored in the remaining controlled area.

Due to the low-level contamination of the former controlled area the change to a supervised area was achieved with a relatively small amount of measurements. The total number of contamination measurements was 2316. Only 87 measurements showed values higher than 0.5 Bq/cm². All measurements were taken in the presence of members of the Technical Inspection Service.

5. Release of buildings from the scope of nuclear legislation (AtG)

The first amendment to license 7/12b allowed initiation of measurements for the release of buildings from the area of application of nuclear legislation. All buildings of the site outside of the safe enclosed plant were to be released from the restrictions of the Nuclear Energy Act, that is they were no longer subject to nuclear legislation.

From the analysis of the history of plant operation the buildings were divided into three classes:

- AE: slightly contaminated;
- BE: probably not contaminated;
- CE: clearly not contaminated.

All buildings outside the supervised area belonged to class CE. The turbine hall and the feedwater tank building belonged to class BE just as the health physics laboratory and some rooms of the access and safety building. Only the waste water disposal duct and parts of the waste water discharge station in the turbine hall were known to be contaminated and therefore allocated to class AE.

After thoroughly cleaning the waste water disposal duct of contaminated mud and dismantling of the contaminated parts of the waste water piping, it was possible to provide proof of no-contamination. For that proof, it had to be shown that the surface contamination was below the limits of the German radiation protection ordinance: 0.50 Bq/cm^2 for most of the beta/gamma-nuclides and 0.05 Bq/cm^2 for alpha-nuclides. From experience it was known that only Co 60, Cs 134, Cs 137 and Sr 90 (and in special cases H 3) were relevant in most cases.

Material samples to prove falling below the mass-specific clearence level of 0.1 Bq/g were taken from the waste water duct and from several sumps in the turbine hall and the feedwater tank building. In other cases, proof was provided by means of gamma-spectrometric in-situ measurements.

The number of contamination measurements was 1 per 25 m^2, however, at least 3 per room, in order to permit evaluation of representativeness. Locations with an increased probability of contamination were chosen as measuring points, such as floor drains, sumps and transport paths. At the outset, the number of measurements to be taken at certain components was increased to 1 measurement per 10 m^2.

All gamma-spectrometric measurements showed values of contamination by Cs 137 exceeding significantly the clearence level. By means of the relations of activities of Cs 137/Cs 134, it was possible, however, to prove that this contamination was due to the Chernobyl incident and not due to the THTR 300 operation.

A total of 729 contamination measurements had been carried out. About 30 samples were tested with the gamma-ray spectrometer and 10 in-situ measurements were taken with a portable gamma-ray spectrometer.

6. Summary

In general, exposure to radiation during all activities for the establishment of the safe enclosure was significantly lower than expected. Due to the low level of contamination in the controlled and supervised areas, it was possible to furnish the radiological proof required for downgrading of the controlled area to the supervised area and for release of buildings from the supervision under nuclear law by means of a relatively small number of measurements.