

The decommissioning of the KEMA Suspension Test Reactor (KSTR)

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1 Purpose

This paper is dealing with the decommissioning of the KEMA Suspension Test Reactor (KSTR). This reactor was developed, built and successfully operated in the sixties and seventies of the last century (KE87). It was a 1MWth reactor in which a suspension (5 μm spheres) of mixed $\text{UO}_2 / \text{ThO}_2$ in light water was circulated in a closed loop through a sphere-shaped vessel. The thorium was added to the fuel to breed fissionable ^{233}U .

Immediately after the shut down of the reactor, the nuclear fuel has been removed and transported to ORNL (USA). Directly thereafter, the preparation for the decommissioning of the reactor was started. In 1991 this decommissioning has been finished. The reactor compartments were left in tact. These compartments, in which separated subsystems (reactor vessel, heat exchanger, gas purification, etc.) had been located, were separated from each other by one to two meter thick concrete walls with a 8 mm steel lining. The internal contaminated pipe connections between the subsystems, which were embedded in the concrete walls, remained. After that, the building was used for other radiological work. But, gradually the amount of nuclear work reduced and was stopped totally in the mid nineties. Therefore, it was decided to demolish the remaining building to green meadow. Early 2003 this project has been finished. So, the decommissioning of the KSTR was performed in two distinct periods with an intermediate period of about 10 years. Evidently, the philosophies and regulations with respect to radiation protection and waste management differed significantly for both periods. Subsequently, the approaches of the decommissioning problem in both periods differ significantly as well.

2 Methods and materials

2.1 The decommissioning of the reactor installation

- Installation conditions

The installation was a complicated structure of 6 interconnected subsystems. The dimensions of the pipes were rather small (diameters ranged 3/6 to 76/84 mm). Due to the fact that the fuel

suspension was circulated through the system, the components were contaminated with fission products. Based on measurements, it was estimated that after removal of all the residual suspension from the system, in totally on the internal surfaces the following activities were absorbed: $20\text{-}60 \times 10^8$ Bq ^{144}Ce ; $2\text{-}5 \times 10^8$ Bq ^{106}Ru ; $2\text{-}14 \times 10^8$ Bq ^{137}Cs ; and $2\text{-}20 \times 10^8$ Bq ^{90}Sr .

Besides this contamination, also ^{60}Co was produced by neutron activation. Evidently, the reactor vessel was most activated (8×10^8 Bq $\simeq 5 \times 10^6$ Bq/g).

In two compartments with the most contaminated and activated components, the dose rates were significant (several mSv/hr) while in the other compartments the dose rates were much lower ($<0,1$ mSv/hr)

- Dismantling philosophy
 - The project was supervised by an internal committee and an external committee with 5 governmental officials;
 - For each compartment, a dismantling procedure was written, which had to be approved by both committees;
 - To prevent the spread of contamination, temporary tents were installed, covering the working area;
 - Besides radiation protection, much attention was paid to conventional safety (such as adequate climbing material fixtures, lifelines and reduced electrical voltages);
 - No material from the nuclear systems should be prepared for unrestricted release or reuse;
 - The aim was to restrict the cumulative radiation dose to a maximum of 200 mSv;
 - The project was seen as a demonstration and learning project.
- Radiation protection
 - Working procedures were discussed with the working team with special attention to ALARA;
 - Workers were provided with an official dosimeter (film badge) and additional TLD dosimeters which were evaluated once a week. For special jobs, finger badges were used. The doses were reported to the workers;
 - Workers were provided with adequate protective clothes and breath protection means;
 - The working area was kept below atmospheric pressure;
 - To leave the working area, a personnel contamination monitor had to passed;
 - A radiation protection technician was always present.
- Used technologies

- Fixation of fuel particles: Thin deposits of fuel particles left behind in tubes, were fixed in advance by covering the wall with a resin (Carboset);
- A variety of segmentation techniques were developed or modified for remote handling.

2.2 Demolition of the building to green meadow

- Installation conditions

All infrastructures (ventilation system, water cleaning and release system, etc) were still in tact and most probably internally contaminated. The steel in the wall (lining and reinforcement steel) of the reactor vessel-containment was activated. In the walls between the containments significantly contaminated pipes (former interconnections between the subsystems) were embedded in the very high quality concrete over long distances (up to ten meters). Furthermore, on several locations on walls and floors significant contaminations, immobilized by a coating, were present. The radiation dose rates were generally low.

- Dismantling philosophy

Mainly as in the first project, but with the following deviations:

- There was only an internal advisory committee;
- Working procedures and periodical reports were send to the governmental authorities;
- The goal was to prepare as much material as possible for reuse or unrestricted release, based on strict cost benefit considerations and the recent European (Eu96) and Netherlands regulations (BS01);
- No dose targets were set, but ALARA was embedded in the working procedures.

- Radiation protection

Radiation protection philosophy was identical to the first project.

- Used technologies

- Only on the market available demolition techniques were used. Much demolition work was done manually.
- The internally contaminated pipes were removed using a high pressure (1000 bar) water jet, which removed the concrete without damaging the steel pipe walls.

3 Results

3.1 The decommissioning of the reactor installation

- The project took a period of about 13 years and a manpower of 100 menyear;

- Total costs were about 10 million (2003) Euros of which 90% were personnel costs. This is about 15% of the construction costs;
- About 100 tons of waste has been removed (80% radioactive waste);
- The total collective dose was 115 mSv (far within the goal of 200 mSv). No internal contaminations occurred;
- After a final radiological survey with smear tests, the facilities could be released for radiological work.

3.2 Demolition of the building to green meadow

- The project took a period of 4 years;
- Total costs were about 3 million (2003) Euros;
- About 1650 tons of material has been removed (0,5 % radioactive waste; 0,5 % conventional waste; 99 % for reuse purposes);
- For about 40 tons lightly activated scrap (^{60}Co levels between 0,01 and 10 Bq/g) a cost effective solution still is looked for. In fact, the scrap below 1 Bq/g is no radioactive waste. But, it is not accepted by the recycling industry (it is detected by the entrance monitors), and according to Netherlands regulations, a licence is needed to store it on a conventional refuse dump;
- The total collective dose was 2,5 mSv. No internal contaminations occurred;
- After an intensive radiological survey, using smear tests, γ -spectrometrie and surfacecontamination monitoring, the building could be released for final demolition.

4 Discussion and conclusion

- The decommission costs of a nuclear installation are significant, but can be kept at a reasonable fraction of the construction costs (below 20%);
- Radiation doses can be kept low, mainly by using good procedures, including ALARA and intense communication with the workers;
- Internal contaminations can be avoided.

References

- BS01 Besluit Stralingsbescherming (Implementation of the Euratom directives 96/29/Euratom and 97/43/Euratom).
- Eu96 European directive 96/29/Euratom.
- KE87 Final report on the aqueous homogeneous suspension reactor project, KEMA, KSTR volume 5, number 1 1987, ISBN 90-353-0048-3.