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Determination of the maximum individual dose exposure resulting from a hypothetical LEU plate-melt accident

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ABSTRACT

The objective of this study was to provide an estimate of the potential impact of accidental radioactive release from the testing cell of the Egyptian second research reactor ETRR-2 on the dose level of public around the reactor. The assessment was performed for two cases: an evaluation of the impact that accidental release has on the dose that would be received by public around the reactor in case of proper operation of testing cell filtration system; and an assessment of the potential dose in case of loss of testing cell filtration system. The results show that the filtration system has a great role in decreasing the dose received by an individual located outside the reactor to a dose level lower than the annual permissible dose.

1. Introduction

Molybdenum-99 (^{99}Mo) is the parent nucleus to technetium-99m (^{99m}Tc). ^{99m}Tc is used in nuclear medicine for liver, kidney, lung, blood pool, thyroid and tumor scanning. ^{99m}Tc decays to a stable isotope, technetium-99, emitting a low energy gamma ray that can be detected outside the body and used to reconstruct the image of an organ. ^{99m}Tc is preferred over many other radioisotopes for nuclear medicine because of its short half-life of approximately 6 h that results in reduced radiation exposure of organs relative to the exposure given by most other imaging radioisotopes. Most ^{99}Mo is produced in research and test reactors by the irradiation of targets containing high-enriched uranium (HEU). Because the worldwide effort to fuel research and test reactors with low enriched uranium (19.99% ^{235}U) instead of with HEU has been so successful, HEU is now used only for ^{99}Mo production in some countries. In addition, while there are only a few major producers of ^{99}Mo, many nations with developing nuclear programs are seeking to become producers of ^{99}Mo, both for domestic and foreign consumption (Allen et al., 2007; Mushtaq et al., 2009).

In ETRR-2, Egyptian second research reactor, the goal is to produce 250 Ci/week of Molybdenum-99 at the end of irradiation to meet the current demands of ^{99}Mo/^{99m}Tc generators in Egypt. In compliance with the requirements set forth in Safety analysis report (SAR, 2003) and on the guidance of Safety Series No. 35-G1 on the Safety Assessment of Research Reactors and Preparation of the Safety Analysis Report (IAEA, 1994), the radiological consequences of design basis accidents should be evaluated. A hypothetical plate-melt accident inside hot cell, testing cell, during transportation process is one of the accidents must be studied and evaluated to fulfill the requirements of preparing the safety analysis report of molybdenum production in ETRR-2.

Testing cell is a hot cell responsible of transporting irradiated LEU plates from the auxiliary pool to the main cell. During transporting process, a hypothetical accidental dispersion of radioactive nuclides inside the testing cell after melting of plate, discussed in detail in accident scenario section, and followed with releasing them to the environment through the stack of the reactor via the ventilation system. In order to take the worst case into consideration and for conservative assessment, the complete melting of plate will be expected and studied in this paper. By these means, a high degree of assurance is provided that any actual exposures to the public from the analyzed accidents are likely to be lower than the estimated values. The evaluation is based on dose calculations carried out by means of Gaussian model computer program "HotSpot 2.06" developed at the Lawrence Livermore National Laboratory, University of California, USA. The results present the assessment of radiation dose to a maximally exposed off-site individual (MEI) who is assumed to be present at locations outside of the reactor boundary. The results include the effective dose (E) and the committed equivalent dose (CED) to some organs; thyroid, bone marrow, and lung.

2. Testing cell confinement and scenario of accident

As mentioned above, the testing cell plays an important role in transporting the LEU plates and to determine its role, the structure

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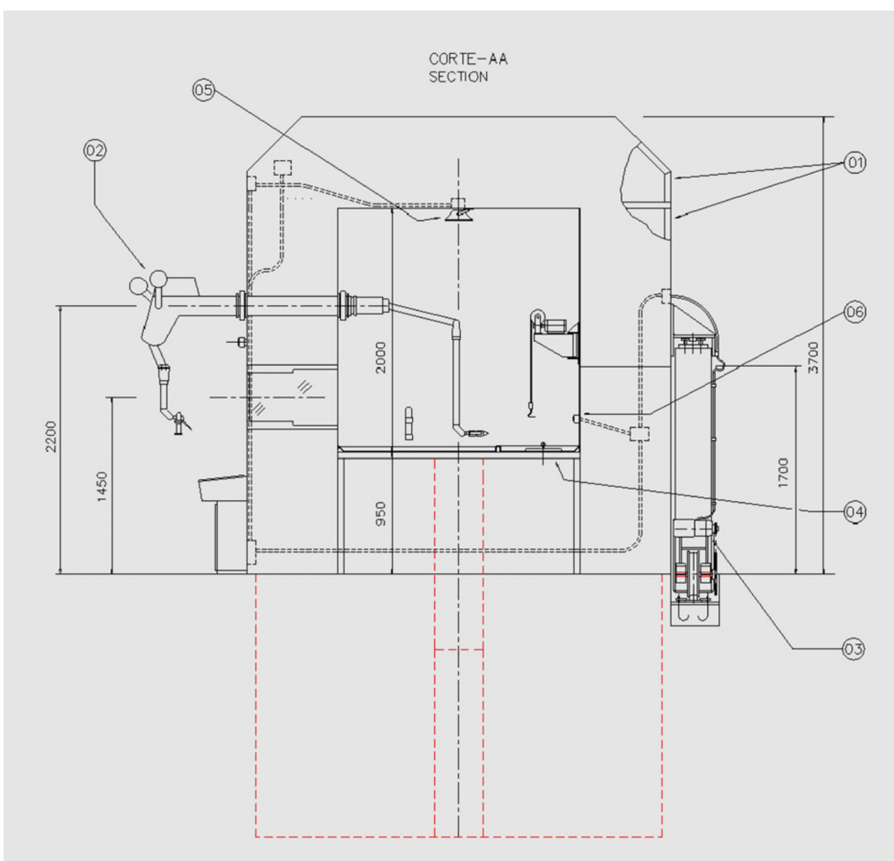
and maneuvering process inside it are presented in this section. The testing cell, as shown in Fig. 1, has dimensions of 2.5 × 2.5 m and a height of 3 m (SAR, 2003). The shielding walls are made of heavy concrete of thickness of 0.8 m with a vision of lead glass window 4.57 m wide by 4.57 m height (SAR, 2003). So, the shielding geometry in this part is approximately considered as a slab of 0.8 m thickness. The cell is connected to the main ventilation system via filtration system. The filtration system consists of group of absolute and charcoal filters. The absolute filters has an efficiency of 90% and responsible of aerosols retention and the charcoal filters are responsible of iodine retention in case of accidental release. Maneuvering tools are connected to the cell and enable the worker to control and move the irradiated samples inside the cell.

A holder of six plates, separated with air gaps as shown in Fig. 2, is delivered to the cell by an elevator from the auxiliary pool and two plates are individually extracted from the holder and loaded in a shielded container by maneuvering tools. After loading, the container is delivered to the main cell by maneuvering tools.

Maneuvering is very important in this process and the plate must be extracted individually from the holder. Hypothetically, if the plates during extraction inside the hot cell are coming in contact position for a long time and accompanying with insulation boundary conditions, the heat accumulation due to irradiated LEU plates decay heat, initial power of 3.4 KW per plate after shutdown, will cause the plate surface to be melted and the radioactive nuclides will be dispersed inside the cell (SAR, 2003). And consequently, the dispersed radioactive nuclides will be discharged to the stack via the main ventilation system of the reactor. The radioactive nuclides will be discharged via the stack at height of 27 m with a flow rate of 3400 m^3/h and depending on the metrological conditions of the site around the reactor the wind will transport the nuclides to the receptors. So, the quantity of the radionuclides inside the cell and the meteorological conditions around the reactor must be determined as input data.

A Gaussian plume model Hotspot code will be used in this study to evaluate the total effective dose equivalent to the receptors located around the reactor site and present effect of proper working of filtration system in decreasing the impact of radioactive release to public and so there are two cases of study.

- A case of postulated loss of filtration system where the radioactivity would be released directly to the atmosphere without significant retention of fission products.
- A case of proper working of filtration system where the radioactivity would not be released directly to the atmosphere and approximately 10 % of the LEU plate fission products would be released to the atmosphere.



01 Structure
02 Master slave manipulator
03 Shielding door
04 Work
05 Illumination system
06 Internal terminal board
Dimensions in cm

Fig. 1. Diagram of testing cell.