Engineering aspects of hot cells and in-cell equipments

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Reliable performance of nuclear fuels and critical core components has a large bearing on economics of nuclear power and radiation safety of plant operating personnel. In view of this, PIE is periodically carried out on fuels and components to generate feedback information which is used by the designers, fabricators and the reactor operators to bring about changes for improved performance of the fuel and components. Examination of the fuel bundles has to be carried out inside hot cells due to their high radioactivity. The new hot cell facility (NHF) has been designed, built and commissioned with additional features and capabilities. The NHF consists of two hot cells made of heavy density concrete and a number of lead cells. The new hot cells are designed to handle higher levels of β-γ radioactivity. NHF has fully automated ventilation system with improved safety systems. NHF has a charging port with adequate opening to accommodate irradiated reactor core components. All material transfer system in the cell has electronic and mechanical interlocks which eliminate chance of accidental personal exposure. NHF is provided with cranes in all radioactive areas which facilitate handling of larger irradiated components and heavier shielding cask. Automated data acquisition and monitoring systems are installed in NHF.

Various equipment are installed inside the hot-cells for the material property evaluation and performance assessment. The details regarding the engineering aspects of NHF and in-cell equipment will be discussed. A view of the operating area of the NHF is shown in Figure 4.

Figure 4: Operating area of the hot cells in the NHF showing the viewing windows and master slave Manipulators (MSMs)

Engineering aspects of New Hot Cell Facility (NHF):

The new hot cell facility has two areas for handling radioactive materials. They are:

- ***Hot cells for handling highly radioactive irradiated fuels and structural materials*.** The NHF consists of two hot cells, namely cell-1 & cell-2, and is designed to handle β–γ radiation. The front, rear and side walls of the cells are 1.5 m thick and are made of heavy density concrete (density=3.4 g/cc) (Bhandekar et al., 2015). The bigger cell (cell–1) is around 17 m long and the smaller cell (cell–2) is 5 m long. All regions of cell–1 and cell–2 are provided with lead glass viewing windows, master slave manipulators (MSMs), ports for in-cell camera and service plugs, which are essential for carrying out PIE. The salient features of the NHF are:
  - *Fuel transfer port size*. The new hot cells have transfer port which will facilitate loading of larger components like control blade assembly into the cells for PIE.
  - *Cell dimensions*. The length of the hot cell in the NHF is 17 meters. This provides the advantage of examining longer components such as full length irradiated pressure tube. The NHF provides the facility of continuous scanning of longer fuel elements.
  - *Shielding capacity*. The hot cells at the NHF are capable of handling higher activities up to 2.5 x10^5 Ci of Co^{60} or 2.6x 10^6 Ci of fission products.
  - *Ventilation in NHF*. The ventilation in the NHF is of once-through type and ensures dynamic confinement of radioactive particulates within the radioactive zones of the facility. The ventilation system is based on radioactive area zoning principles and satisfies the regulatory guidelines.
  - *Cranes for material handling.* Both cells have been provided with dedicated in-cell cranes of 2.0-ton capacity. The isolation area is on the rear of the hot cells and acts as a buffer between the cells and the high bay surrounding the cells. The isolation area is provided with a 2T hand operated overhead travel underslung crane. The cell exhaust filters are located in nine separate pits below the isolation area floor. The high bay surrounding the cells and isolation area on three sides is called the warm work area and houses a 40T/5T EOT crane. This area is used for receiving shielded casks containing radioactive materials. An airlock capable of accommodating a 30T trailer truck is provided.

Lead cells and low active laboratories for handling of specimens with a lower radiation field

The low active laboratory is primarily used for carrying out mechanical tests on irradiated test specimens. Towards this an instrumented drop tower, a servo hydraulic & screw driven universal testing machines, creep testing units and static load test setups have been installed in the low active laboratory. The front wall of the lead cells in this laboratory is made of 200mm thick steel cased lead bricks and the rear walls are made of 100mm thick lead bricks. The lead cells are fitted with articulated MSM, viewing windows, hatches/door for personnel entry, transfer ports, and other handling facilities. The radioactivity of the test specimens will be limited to a few mCi of Co^{60} equivalent.

Engineering aspects of the in-cell equipment

The NHF has a comprehensive PIE facility in terms of material characterization and analytical capabilities required for PIE studies on nuclear fuels and materials.

PIE involves dismantling of fuel bundles using mechanical cutting machine having saw blade, visual examination by high definition pan tilt zoom (PTZ) camera having optical zoom of 30X and 4MP resolution, leak testing using liquid nitrogen-alcohol test, laser profilometry, ultrasonic testing of fuel pins immersed in water in horizontal tank is carried out to detect the presence of incipient flaws in its cladding and also for the end-plug defects, gamma spectroscopy and scanning, fission gas release measurement, bow-measurement of the fuel pins, trepanning of 30 mm disc specimens for metallography and mechanical testing from the pressure tubes, drilling and notching for fracture toughness testing, canning and crimping of intact fuel pins after PIE operation for shifting to the storage pool for further processing or storage. All the in-cell equipment are designed so that it can be operated with MSM and maintenance should be easy.

Reference

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