Experience in maintenance and decommissioning of in-cell equipment of an operating alpha, beta, gamma hot cell facility.

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Abstract

This paper describes various repair campaigns successfully undertaken for the in-cell equipments of the Radiometallurgy hot cell facility established at Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, India. Details of one major campaign executed for decommissioning and disposal of a CNC milling machine from the operating hot cell is also described. Experience gained and the safety measures employed during such campaigns are also discussed.

Key words: Hot cells; remote operation; fast breeder test reactor; fuel subassembly; post irradiation examination; decommissioning; hot cell man entry system, minimally intrusive technique.

1.0 Introduction

Radiometallurgy Laboratary (RML) at the Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam consists of seven concrete shielded α,β,γ hot cells, each having a floor area of 5.5m x 2.1m and wall thickness 1200 mm, designed to handle up to 5550 TBq activity (gamma,1 MeV). The hot cells are maintained in inert gas (nitrogen) atmosphere for handling reactive and pyrophoric fuels. The cells are equipped with remote handling devices and alpha-tight fuel transfer systems to carry out various non-destructive and destructive examinations for metallurgical characterization of the mixed carbide driver fuel of Fast Breeder Test Reactor (FBTR), core structural materials and various advanced fuel and structural materials irradiated / to be irradiated in FBTR. A multitude of post irradiation examination (PIE) campaigns have been undertaken including those on the

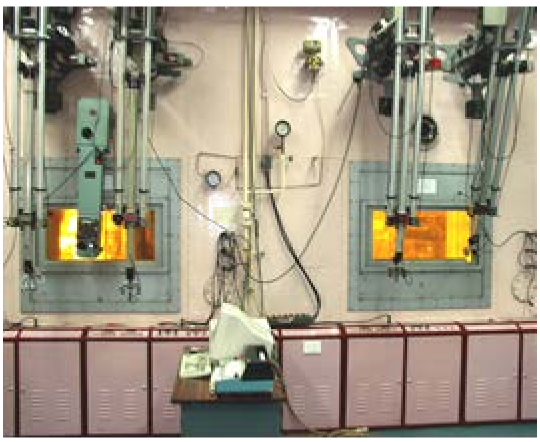

Fig 1 a. Front view of an RML hot cell

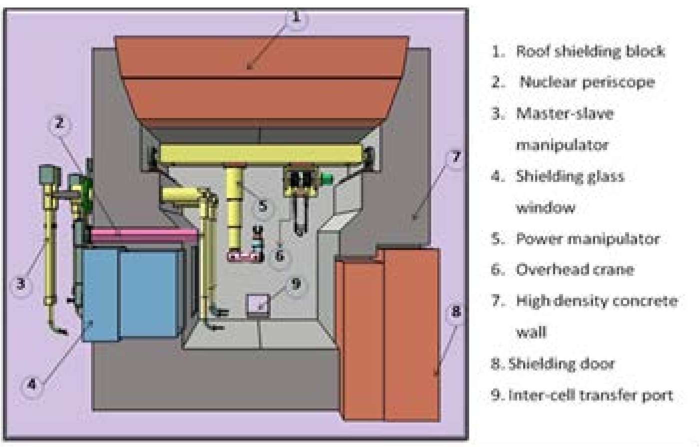

Fig 1 b. Typical cross sectional view of a Hot cell mixed carbide driver fuel, control rods, nickel reflector subassemblies of FBTR and a fuel subassembly with MOX fuel and D9 alloy clad and wrapper proposed to be used in the 500 MW Prototype Fast Breeder Reactor (PFBR).

2.0 Maintenance philosophy

2.1 The remote handling devices and hot cell equipment facilitate advanced techniques including laser based dismantling, helium leak testing, eddy current testing, X-radiography, neutron radiography, gamma scanning, fission gas analysis, metallography and tensile testing. Many equipment and systems in the hot cells (RML) are in service for more than 20 years. During the service life of these hot cells, a few obsolete systems as well as accumulated consumable and hardware wastes have been packed out and a large number of new systems were installed to increase the capabilities and to meet new requirements. In general, all the systems have performed well so far with minimum interruptions for remote maintenance. The concept of modularity adopted for in-cell equipment has paid rich dividends during these campaigns. It is planned to carry out a major shut down and refurbishment campaign to revamp the hot cells by repairing / replacing some of the aged remote handling and transfer systems.

2.2 The maintenance techniques adopted in RML for the remotely operated hot cell equipment have evolved drastically over the years. The prudent design philosophy initially adopted for the in-cell equipment facilitated their operation with minor remote repairs using Master Slave Manipulators (MSMs) during the initial ten years. It was followed by another decade where major contact repairs became necessary. This was overcome by developing techniques involving repairs either through the cell-back-access-door-opening or the roof-opening without direct entry of personnel into the hot cells.

2.3 Recent failure of the long travel motion of a crane which has served for nearly twenty two years necessitated direct man entry into the hot cell for the first time since the defect location was not visible through the hot cell windows and was beyond the accessible range of the MSMs. It was also inaccessible for repairs from outside through the cell-back-access-door and roof opening. A minimally intrusive hot cell man entry system (MES) was designed and fabricated in-house and used to execute the work safely, minimizing the spread of contamination and man-rem expenditure and ensuring safety of personnel. The above methodologies have also been adapted for dismantling and decommissioning of old equipment with minimum man-rem expenditure. Some of the major campaigns undertaken recently are described below.

3.0 Case studies of remote repairs / decommissioning

3.1 In-cell cranes: A major equipment failure that crippled the hot cell operations was the failure of in-cell cranes. Each hot cell has a 1 ton capacity in-cell crane for shifting of material within the hot cell. The in-cell overhead crane has a long travel (LT) motion of 5 m along the length of the hot cell on the rails fixed on walls and a cross travel (CT) motion of 2 m on the gantry. There is a sprocket and chain drive provided inside the hot cell for LT motion. The motor which drive the sprocket is provided outside the hot cell. Components of in-cell cranes in the 1st, 2nd and 3rd hot cells underwent failures at different points of time and the type of failure and location inside the cell varied for each of them. The solutions too had to be tailor-made each time.

3.2 Cell-1 in-cell crane: In case of hot cell #1, the in-cell crane rope came out of the drum while operating the crane due the excessive wear and tear of the rope guide. After converting the hot cell #1 environment from nitrogen to air the repair crew wearing Personal Protective Equipment (PPE) entered the Upper Isolation Area (UIA) and removed the roof plug. Using the UIA crane, the Cross travel (CT) carriage was lifted to the UIA. The rope guide in the crane was repaired. The crane was tested by arranging temporary power supply. Subsequently the CT carriage was put back and the roof opening was closed. After ensuring that the crane is working satisfactorily, the hot cell was brought to normalcy.

Fig 2: Repair campaign of hot cell #1 crane

3.3 Cell-4 in-cell crane: In case of hot cell #4 crane, the LT motion stopped abruptly during operation. The location of the chain-sprocket mechanism which drives the gantry of the crane was not accessible by MSMs and was not visible through the shielding glass windows and nuclear periscope. Video cameras sent into the hot cell through the available penetrations to assess the reason for the malfunctioning indicated failure of the chain in two locations and damaged links at some locations.

3.3.1 Repair of this crane necessitated man entry into the hot cell. Entry could be either from Lower Isolation Area (LIA) by opening the rear-access-door or from Upper Isolation Area (UIA) by opening the roof plug. The former was not chosen considering the possibility of spread of contamination from the highly contaminated floor of hot cell to LIA due to raising of dust by crew members entering the cell. Repair by man entry into hot cell from UIA using a new man entry system-I (MES-I) was conceived and executed. MES-I provided a 1m wide, 4 m long platform at an elevation of 1.2m above the hot cell floor. Repair crew in ventilated suits could safely enter through the roof opening using this MES and once inside they could move along the length of the hot cell and carry out repair jobs.

3.3.2 Execution of the work involved preparations for hot cell man entry, mock-up of the assembly and disassembly of components, obtaining safety clearances, dose limitation by transferring radioactive materials to the adjacent hot cells and conversion of hot cell from nitrogen to air environment. A repair crew comprising four members in personal protective equipment (PPE) and two in ventilated suit entered UIA. The repair crew opened the hot cell#4 roof plug. The health physicist checked radiation dose rate at the roof opening and at location of work inside the hot cell.

3.3.3 The repair crew then assembled MES-I in the UIA near the roof plug opening. One member of repair crew climbed down through the ladder to the platform at the bottom of the system. He quickly disassembled the damaged portion of the chain and replaced it with a new one and returned to the UIA. Repair crew disassembled the MES-I, and closed the roof opening. After checking all functions of the in-cell crane, the hot cell was brought to normalcy

3.3.4 This was the first time that a repair crew has entered an active hot cell in RML and carried out equipment repair. The repair campaign was a demonstration of team work. Conceptualization of the scheme, obtaining safety clearances and execution was completed in 45 days. Totally about 20 personnel were involved in the campaign. The total man-rem expenditure for the entire campaign was less than 20mR. The experience gained has given confidence for taking up maintenance works in other cells safely and efficiently.

3.4 Cell-2 in-cell crane: The problem with the hot cell #2 in-cell crane was the stoppage of motion during its long travel motion. Visual inspection using video camera through roof opening showed that one of the lateral guide bearing of gantry had failed.

Fig 3. Photographs showing varous stages of cell #2 crane repair

The bearing had the function of preventing the skewing of the crane trolley.

3.4.1 A detailed study revealed that the crane can be repaired only by man entry into the hot cell. The MES-I made earlier which does not offer any radiation protection to the repair crew member, was not useful for this job. The floor of the hot cell was highly contaminated and had higher dose levels. Therefore a shielded Man Entry system-II (MES-II) was developed for the repair of hot cell #2 in-cell crane. It was provided with 10 mm thick mild steel shielding at sides and bottom, and an additional shielding of 6 mm lead at the bottom.

3.4.2 A member of repair crew climbed down to the bottom of the MES. He found that the trolley was in skewed condition necessitating correction. Using a C-clamp summoned immediately, he corrected it before replacing the damaged bearing. After he moved up, the MES was taken out. The operators stationed at the operating area tested the crane & ensured that all systems are functioning normally. Subsequently repair crew put back roof plug and brought back hot cell to normalcy.

3.5 Decommissioning of hot cell #2 CNC milling machine: The CNC milling machine was extensively used for the metrological inspections, diamond wheel based dismantling of irradiated subassemblies, and preparation of tensile specimen from the hexagonal wrappers of dismantled subassemblies. When the integral rotary encoders of servo motors of the Y and Z axis failed after a few years, it was initially solved successfully by installing and operating identical dummy motors with rotary encoders outside the hot cell. The dummy motors derived identical power input from the motion control system and the output of its encoders was used as the feedback to control the in-cell motors and to maintain the positional accuracy of the Y and Z axes. After about fifteen years of total service, further failures including that of the bellow coupling between the Z stage lead screw and motor necessitated complete replacement of the machine. After installing and commissioning newly developed compact machines like Dimensional Measurement-cum-

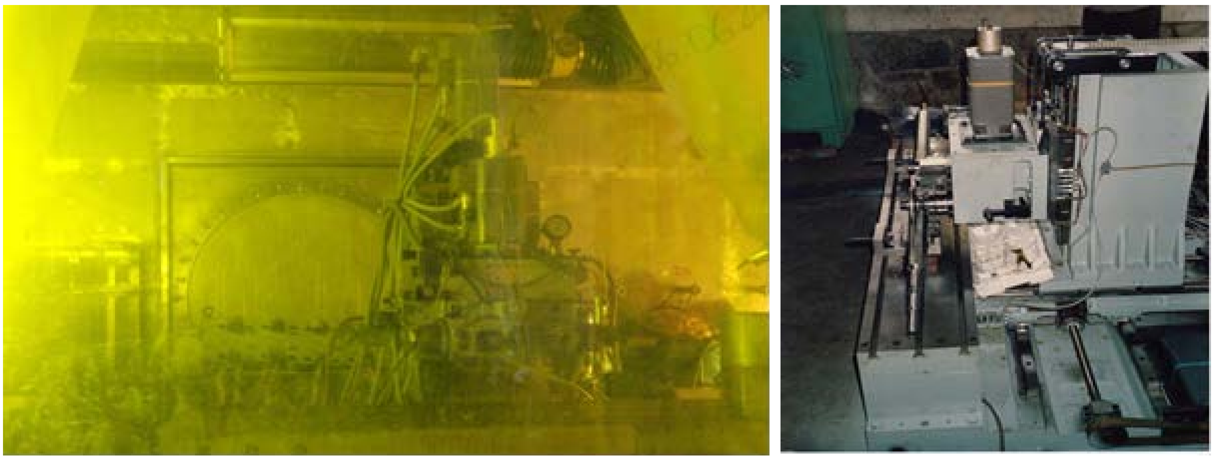

Fig 4 a: CNC milling machine inside the hot cell 4 b) CNC machine before commissioning

Laser Dismantling machine (DMLD) and Tensile specimen Preparation Machine (TSPM), it was decided to decommission the old CNC milling machine to clear up prime space in the hot cell. This machine was designed for repair and maintenance through replaceable parts but it did not have enough design features suitable for easy decommissioning. All preparatory dismantling activities were done remotely.

3.5.1 The CNC machine was installed over a base plate bolted to the hot cell floor on which an XYZ stage and a work bench were assembled. It occupied space of 1578 mm x 1025 mm x 1118 mm (L x B x H). A detailed study of the machine was carried out to decide the manner in which the dismantling has to be carried out. After considering factors such as the shape, size and weight of the various components, and the ease with which these components can be disassembled remotely or manually, it was decided to dismantle the machine into three major parts and transport them to waste management facility in three separate leak tight SS 304 boxes. The three parts are the work bench, vertical column (Z-stage) including the machining head, and the base plate with XY stage.

3.5.2 The work bench was bolted to the base plate with six numbers of M12 bolts. These bolts were loosened and removed using the in-cell power manipulator. Special tools were used for this operation. The hot cell environment was then converted to air. After getting safety clearance, the dismantling crew wearing personal protective gadgets entered upper isolation area (UIA) and the roof shielding door of cell #2 was opened. The work bench was then lifted to the UIA using the UIA crane and it was transferred to the 1840 mm x 540 mm x 680 mm (L x B x H) size stainless steel box. Its lid was closed and tightened with gasket in place using bolts and nuts.

3.5.3 The vertical column was fixed on top of the Y-carriage using eight M12 hexagonal socket head cap screws. Before the commencement of dismantling operation, the column was supported using the in-cell crane to avoid its accidental fall during the loosening of screws. Some of the power and signal cables also were cut and removed using the manipulators. Modified spanners and cutting tools were used for this job.


Fig 5 Disposal of CNC machine in leak tight containers and its transport.

Due to the lack of visibility and non-accessibility, some of the screws and a few stainless steel shielded cables, hydraulic lines, etc could not be removed remotely.It was therefore decided to disassemble the vertical column through man entry inside the hot cell using specially designed man entry system (MES-1). The dose levels in the cell floor was brought down considerably by transferring materials to adjacent cells and by repeated clean-up, including vacuum cleaning.

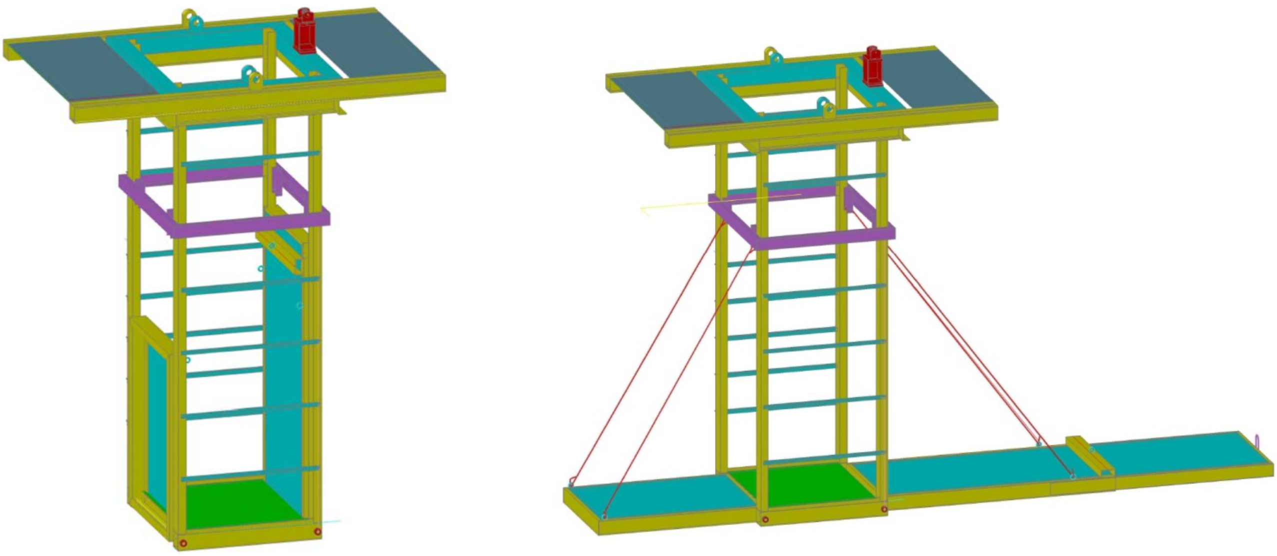

Fig 6 Sketch of the Man Entry System (MES I): folded and unfolded states.

3.5.4 After completing the initial preparations for hot cell man entry, dismantling crew assembled MES-I at the UIA, climbed down into hot cell with necessary tools through MES-1, made the working platform horizontal, cut and removed most of the remaining screws, shielded cables and copper hydraulic lines from the vertical column using special tools. After the completion of the work, the MES-I was disassembled and removed from the roof plug opening. The vertical column was lifted to the UIA using the crane, and was transferred to the 1340 mm x 900 mm x 1240 mm (L x B x H) stainless box. Subsequently the roof plug was put back and the hot cell was brought back to normalcy. The box was then shifted out and transported for disposal.

3.5.5 The base plate with XY stage has a footprint of about 1600 mm x 1048 mm and it weighs more than 1200 kgf. It was anchored to the hot cell floor using studs provided on the floor. The height of the base plate is 73 mm. Three numbers of recesses or side pockets each are provided on the front and back vertical faces of the base plate for inserting the nuts and tightening the base plate with the hot cell floor. During the initial installation of the machine, after assembling the base plate with the floor, the side pockets were filled with epoxy resin to prevent them from becoming contamination traps in the long run. Epoxy resin from the three front side pockets was remotely removed using an electrically operated drilling machine held with master slave manipulators. The anchoring nuts were removed remotely using special spanners with extended handles. Both master-slave manipulators and power manipulator were used for loosening of nuts.

3.5.7 The side pockets at the back vertical face of the base plate were not visible from the operating area through the shielded glass viewing windows. The inspection of the location using cameras revealed that the location cannot be accessed from top using MES-I with extended tools for the removal of epoxy resin and nuts from side pockets. Therefore, it was decided to access the location by opening the hot cell rear-access-door and to carry out the work manually. It was carried out by persons in ventilated suits, standing in front of the opened door, from LIA, using extended tools. Subsequently, hot cell roof plug was opened and the base plate with XY stage was lifted to UIA using UIA crane, packed in SS container and disposed.

4.0 Summary

4.1 Continued availability of hot cells have been ensured to facilitate crucial PIE campaigns, by repairing ageing equipment through short campaigns. Minimally intrusive techniques were successfully employed for carrying out repair of many crucial in-cell equipment. An aged, bulky and unserviceable CNC milling machine was decommissioned from an operating hot cell. A shielded man entry system in combination with suitable personal protective gears ensured that Man–REM expenditure was bare minimum and that none of the repair crew members received radiation dose exceeding 10 % of allowed values. A major refurbishment is planned in the near future to replace the aged components and to provide the hot cell with advanced techniques and equipment. The repair and decommissioning techniques established now will be refined further to embark on this major refurbishment program to extend the life and to enhance the capabilities of the hot cells for PIE of advanced fuels.

5.0 Acknowledgements

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