Experience in Maintenance and De-commissioning of in-cell equipment of an operating alpha, beta, gamma hot cell facility


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Radiometallurgy Hot cell facility:

Major Objectives

- Post Irradiation Examination of Fuel subassemblies from Fast breeder test reactor.
- PIE of Control rods, reflector subassemblies & experimental subassemblies discharged from FBTR.
Major facilities

- Seven numbers of concrete shielded hot cells
- Two numbers of lead cells
- Kamini Reactor, 30 kW, below hot cell 3
- Glove boxes connected to hot cells
- Fume hoods
- Nitrogen gas recirculation and purification system.
- Active Lab for fuel & structural material characterization
- Fuel transfer systems; VTS & HTS (alpha tight transfer)
Techniques for Characterisation of Irradiated Materials

- Visual examination
- Profilometer & laser dismantling
- Sodium removal
- X & Neutron radiography
- Gamma scanning
- Fission gas analysis
- Remote metallography
- Small specimen testing
- High temperature tensile testing
- Electron microscopy
- Fuel receipt

- Techniques and equipments augmented in tune with increasing demands
- Infrastructure being developed for PIE of advanced fuels and structural materials
PIE campaigns completed

- PIE of FBTR carbide fuel subassemblies
  - Fuel sub-assemblies after 25, 50, 100 & 155 GWd/t burnup
  - Control rod assembly
  - Nickel reflector subassembly
  - FBTR Grid plate material
  - Failed FBTR fuel sub-assembly
- Evaluation and validation of PFBR MOX fuel design
  - PIE of Experimental MOX fuel pin
  - MOX test fuel sub-assembly after 112 GWd/t burn-up

Ongoing & future activities

- PIE of advanced fuels – sphere-pac & metallic fuel pins being irradiated in FBTR
- Out-of-core structural materials at low dose
Hot cells Details

- Commissioned in 1994; Type of cells: $\alpha$, $\beta$, $\gamma$; Total 7 cells
- Shielded by Heavy density concrete, 3.5 g/cc
- Wall thickness: 1.2 m (up to a height of 2.4 m)
- Floor Area: 5.5 m x 2.1 m each
- Head room: 3.02 m
- Roof thickness: 1.0 m; Roof opening: 1.0 m x 4 m
- Cells are lined with SS sheets, fully welded.
- Shielding glass window thickness: 1.2 m, 2 nos/cell
- Shielding door, 1.2 m thick, motorized (rear side)
- Atmosphere inside hot cells: Nitrogen gas- recirculation mode
- Pressure inside the cell: (-) 25 mm WC wrt operating area
- Max Activity: 150,000 Ci [5500 T Bq].
Cross sectional view of the radioactive areas of RML and zoning indicated by the respective colours.
Vertical transfer system

Fuel Bundle extracted from FSA
3-D view of a typical hot cell
Evolution of repair methodologies and its background

• Hot cells are continuously in operation without break for 20 years
• New techniques and equipment added year after year to meet PIE needs

❖ Repairs in the first two decades managed through
  (1) remote repair and replacement of modular elements
  (2) contact repairs through cell-back-access-door and
  (3) lifting of equipment / modules through hot cell roof opening

❖ New challenges faced

• (1) Repairs of non-generic nature not feasible through the above procedures
• (2) Congestion of cell-floor,
• (3) high dose levels and contamination on the cell floor and
• (4) non-accessible by remote handling devices and outside the viewing range

❖ Solution:
Minimally invasive technique conceived.
  (1) Man entry system- based on roof opening and
  (2) personnel working far from the floor level

❖ Execution.
• Detailed planning & Mock drills
• Use of modern safety gadgets
• Safety clearances & approved procedure
Repair of In-cell crane #1

- Incell crane: 1 Tonne capacity.
- Features: Long travel is driven by motor & clutch located outside the cell
- CT carriage: Electrically & mechanically detachable from the top (just by lifting)

**Problem noticed:** Failure of Hoist motion

- Dose rate in cell: 900 mR/hr
- Preparatory works.
- Shifting of active materials to adjacent cells
- Cell atmosphere changed from Nitrogen to air
- Safety clearance
- Opened the hot cell roof slab and lifted the CT carriage.

**Observations**
- Steel wire rope damaged; unwound & detached
- Rope guide also damaged.
- Rope drum not damaged
- Electrical motors, brake, cables are intact.
Repair sequences

✓ Rope guide decontaminated, checked hardness, deposited material to compensate worn out.  
✓ Rope guide: grinding & filing to get correct profile. All dimensions checked using CMM. Hardness checked.  
✓ Performance of the repaired rope guide and rope checked using a spare crane.  
✓ Finally, new rope and repaired rope guide were assembled to the cell crane CT carriage and tested functionally.  
✓ Incell crane CT carriage was lowered into the cell #1 and inserted into the slot to get correct alignment. Its performance was found good.
Photographs taken during the cell #1 Repair campaign
Repair of In-cell crane #2

• This crane is identical to cell #1 crane.
• **Problem:** Long travel movement of crane failed abruptly.
• **Observations** (using video clipping taken with PTZ camera).
• Bearing provided at gantry lateral guide got crushed and lost. Resulted in skewing (side ways movement or tilting) of the trolley on the rail. This caused tilting of gantry in horizontal plane and rubbing of gantry body on lateral rail. Hence not able to move.
• **Remote repair:** not feasible.
• **Constraints for contact repair:** High dose rate & contamination. Lifting up was not possible, due to location

**Solution:**

• A Man Entry System (MES-2) was designed and fabricated. This was provided with shield at sides and at bottom. This enabled personal entry into the cell from the roof slab opening safely.

  Person entered inside the hot cell, removed damaged bearing and replaced it with a new bearing.

• The skewing of the crane trolley was corrected using a ‘C’ clamp.
  • Performance of the crane was tested and found good.
Shielded Man Entry System used for repair

Doing actual repair work inside hot cell #2
Cell #4 crane repair

- Problem: Long travel motion failed abruptly.
- Reason for failure: LT chain broken (observed using camera)
- For repair, accessibility at crane gantry level along the length of cell was essential.
- Man entry system (MES-1) with un-foldable platform was introduced from top.
- Damaged portion of SS chain replaced

Man entry system -1

- A rigid bridge resting over the cell roof opening
- A central vertical box frame that hangs down to the cell
- Two numbers of un foldable platform, which can be opened and closed inside the cell
- A shuttle cage for emergency rescue.

MES-1 : before use, got qualified through mockup trials.

Man-Rem: 25 mR
Repair duration: 2 hrs
Man Entry System [MES-1] for hot cell

MES-1 folded condition [initial]      MES-1 un-folded  inside hot cell
Cell #4 crane repair campaign

Testing of MES-1 during Fabrication

MES-1 above hotcell

Crew getting ready to enter into hot cell
De-commissioning of CNC Milling machine Inside hotcell #2

- Purpose of machine: Dismantling of irradiated fuel sub assemblies, Dimensional measurement & tensile test specimen preparation from irradiated specimen.
- Year of installation: 1990
- Major components: work bench, vertical column, with machine head, Baseplate with X-Y stage, Power and signal cables.
- Total weight: 2 tonnes approx.
De-commissioning of CNC Milling machine Inside hotcell #2

Why de-commissioned?

- Failed components, encoders of spindle, Y & Z; Bellow coupling etc
- Remote repair: not successful; Spares not available.
- This machine was very bulky.
- New compact machines installed for carrying out same operations.

De-commissioning and disposal campaigns.

- Most of the dismantling works were done remotely using master slave manipulators & power manipulator.
- Extended tools / special tools were used.
- For removal of inaccessible bolts, Man entry was effected using man entry system-1, for short duration.
- **Dose rate**: 1000 mR/hr initially, brought down to 200 mR/r by cleaning
De-commissioning of CNC Milling machine Inside hotcell #2

Sequence of steps involved.

- Detailed procedure
- Safety clearance
- Converting from nitrogen to air atmosphere
- Removal of all radioactive materials
- Health Physicist clearance
- Opening of roof slab
- Use of Man entry system -1 & special tools
- Dismantling of remaining components
- Lifting the components to isolation area (3 days operation)
- Packing the components into the leak tight SS boxes.
- Providing compensatory shields, wherever necessary.
- Disposal at RCC shielded trench.

new machine TSPM
Photographs taken during the campaign
Safety Issues in case of contact repair

- High levels of radioactivity, dose rate and radiological contamination
- Nitrogen gas environment inside the hot cells. Checking of oxygen level
- Safety clearance obtained before the work & detailed procedure followed
- Industrial Safety: Safety belt for persons working above cell area to prevent falling.
- Training of persons for cell entry / repair: Mockup trials
- Ventilated suit with fresh airline ventilation for man entry into the cell. Protective clothing & full face mask in all other cases.
- Radiological survey before work. Continuous air monitor, AGM, Teletector
- Actual jobs are always done under the supervision and control of a Radiological safety officer.
- After completion of the work: shower, contamination checks
- Yearly medical examination and whole body counting for all occupational workers.
- ‘ALARA’ Principle is followed.
- Dose received by the personnel are less than 10% of the limit value
Safety Management and Safety Culture during the Repair and Maintenance of Hot cell Equipments

Preparatory Activities
- Wearing Protective Suits & Clothing
- Radiation & Contamination monitoring, Survey & Checking Instruments
- Continuous air monitor
- Shoe Barrier & Work station
- Communication Systems

Execution of Repair Work
- Crane taken out of cell through cell roof after setting up a work station
- Safety Belt
- Hand Gloves
- In-cell crane repair
- Repair of Neutron Radiography rig
- Safety Intermediate Platform for working
- Full face mask

Winding up and cleaning the work area
- Active wastes being taken out
- Storing of Active waste for disposal
- Dismantling work station and contamination check

Checking for Contamination
- Checking for contamination after work & shower
Conclusion

- Many challenging repair campaigns were executed successfully with minimum Man–REM expenditure (Approximately 10% of the allowable exposure)

- Excellent Team work: Repair crew, Health physicist, Ventilation crew, MSM operators, Electricians, Instrumentations personnel, supervisors & Engineers.

- Future Plan: Replacing old equipments & Cell Refurbishment.
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