Target system maintenance experience in hot cell at J-PARC

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J-PARC 1MW spallation neutron source

Mercury target vessel
- Total length: 2 m
- Total weight: 1.6 ton
- Material: SS 316L

Mercury circulation system

Cryogenic hydrogen system

Materials and Life science Facility (MLF)

Helium vessel

Moderators

Proton beam window

3 GeV 25 Hz proton beams

Target trolley

Mercury circulation system

Neutron beam lines (23)
**Mercury target and circulation system**

**Target trolley**
- Total length: 12 m
- Height: 4 m
- Width: 2.6 m
- Total weight: 315 ton

- Mercury inventory: 1.5 m³
- Rated flow rate: 41 m³/h

**Gas supply system**

- Pressure sensors
- Mercury pipe (150A)
- Surge tank (0.7 m³)

- Heat exchanger (550 kW)
- Mercury pump
- Target exchange truck

- Helium

- Target vessel

- Red: experience replacement

- Special care for treat liquid metal target

- Target vessel fixing on target trolley with Mercury Circulation System
- Target vessel, MCS components (pressure sensor, gas supply system, etc) can be replaced by remote handling
- Possibility to drop radioactive mercury from opening portion in replacement work

⇒ Special care for treat liquid metal target
Hot cell design policy for J-PARC mercury target

- **Mercury collectable structure, in case of mercury leak in hot cell**
  → Stainless lining floor and drain piping in hot cell and trolley

- **A few hands-on maintenance are necessary in hot cell**
  → Keep low-level contamination in hot cell

- **Control high-radioactive noble gas and tritium exhaust**
  → Off-gas processing system to filtering and decaying noble gas
Remote handling area in hot cell (1F)

Hot cell (MLF 1F)
L: 40 m × W: 13 m × H: 12 m
Separate two area
Mercury area, moderator area

Ceiling hatch: 12×5 (2), 4×4 (1), 2.4×2.4 (5) m
Carry equipments into
hot cell from high-bay

Floor hatch: 2.4×2.4 (3)
Carry used components into
storage room/dry up room

Mercury target handling area
(Stainless lining for mercury)

M/S manipulators
Target vessel
Target trolley
Stainless lining
to dump tank
Moderator, etc. handling area
Dike
Operation position
Maintenance position
23 m
40 m
Storage room for used components

Storage room (MLF B1F)
L : 20 m × W : 8 m × H : 10 m
Ceiling hatch : 2.4×2.4 (1) m
In-cell crane 12 ton
M/S manipulator 2 pairs
Capacity:6~8 used targets

From hot cell

Target storage container

Storage area for used target etc.

Drying area for PBW, moderators

Hot cell design policy

High bay

Hot cell (1F)

Sectional plan

B1F Plan

Figure 1: Storage room for used components at the MLF B1F.
Equipment for target vessel replacement

- 20 ton crane: 1
- M/S manipulator: 9 pairs
- Power manipulator: 1
- In-cell camera: 10 (target area)

Tools for power manipulator

- M12 & M20 nut runners
- M20 angle tool
- Hand
- 6-axis power manipulator (Max. fastening torque 250 Nm)

In-cell camera

Video camera tube

- Target replace by remote handling using these equipments because used target has high-dose rate (ca.350 Sv/h)
Outline of target vessel replacement

**Target vessel removal sequence**

1. **Storage container**
   - Target exchange truck and storage container sets in front of target

2. **Remove bolts and H₂O, He, Hg pipings**
   - Insert target into storage container

3. **Separate target from target trolley**
   - Raise storage container and change to new target

**Installation sequence is reverse to the removal procedure**

- Off-gassing and flushing inside mercury vessel and circulation system
- Dose rate of target vessel is ca. 350 Sv/h after 77 days operation
- 21 staff members involved for replacement work
- Actual result in 2017 was 20 working days (12 days for exclude off-gas processing)
  (Optimized replacement procedure, adopt new tools, increase worker skill)
• Regularly inspection and maintenance work should be done in hot cell
• Catch pans are placed before removing mercury and water piping to contamination control of hot cell floor
Maintenance experience

**Off-gas processing system at J-PARC**

Roll of off-gas processing system
- Remove mercury from cover gas in MCS
- Remove tritium
- Separate and decay noble gas (mainly Xe-127 for 0.5~1 Y)

- Move cover gas from MCS, and flushing in MCS before opening mercury piping
- Off-gas caused by leak test and fill-up mercury should be processed
- Evacuate gas from MCS to off-gas processing system to make flow when MCS piping is opening (Airflow control)
Measures to reduce tritium release

- Plugs made of silicon rubber were inserted into mercury pipe by MSM with crane.
- Evacuation of mercury piping was continued until a new target vessel was installed.
- Tritium release is reduced to <15% by adopting air flow control and plugs.

*North and South of photos are inverted*
Additional shield for in-cell maintenance

July, 2017
1.5 month after beam operation

W/O additional shield
With additional shield

Improvements based on experience

- Need regularly in-cell work for preparation of target cutting and crane inspection, etc
- Dose rate in hot cell is increased after draining mercury
  Spallation products (Osmium, etc.) attached inside mercury pipe may increase dose rate
Sniffer helium leak test by remote handling

- Takes long time for detecting small leakage by pressure change method (1 month for $10^{-6}$ Pa·m³/s)
- Impossible to detect leak location in the system with multiple test section
- Adoption of sniffer leak test with remote handling for reducing test time
Summary

-Introduced hot cell design policy for the J-PARC liquid mercury target: mercury collectable structure, frequently enter in hot cell, noble gas and tritium control

- Measures to reduce tritium release by air flow control with off-gas processing system made a fine performance for the safety target replacement

- Improvements learned from 10 years operation experience were introduced