Radiation Protection at J-PARC Neutrino Experimental Facility and Lessons Learnt

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Radiation Protection: Critical Limiting Factor on HPT Facility Operation

- On the way of designing J-PARC neutrino facility, we thought capacity of beam intercepting devices - target, beam window, electromagnetic horns and beam dump - will limit the acceptable beam power and operation.
- However in reality, radiation protection / safety issues become comparable or even severer limiting factors.
- As examples I will describe tough lessons learnt at J-PARC neutrino facility:
  - Radioactive air ventilation/exhaust
  - Disposal of tritiated cooling water
J-PARC Neutrino Experimental Facility

TS: Target Station, NU: Neutrino Utility building
NU3: Neutrino Utility Building #3

- Beam 1st FL
- B1+ 4.5 stand
- B1 FL
- B2 FL

- Decay Volume
- Pit
- Muon Pit
- Beam Dump Pit
- Passage
- [Hot Machine Room]
- [Super Hot]
- 18.5 m
- 10.2 m
- 6m
- 4m
- 1m

- Water circulation system for downstream half of DV and BD [B1]
- Air circulation system for BD / MuPit [B1+4.5]
The first continuous (only 20kW) beam

NU3 exhaust signal: Alert level = 0.05Bq/cc (Raw data) ⇔ Observed 0.06 Bq/cc

Beam operation was limited within only ~30min due to the radiation in the exhaust air.
Smoke Test

- Test with a smoke machine, normally used for theater plays!

- B2 PS/DS ⇒ smoke around heat-retention of square-ducts / penetration of cable bundles
- B1 ⇒ around service hatch / penetration of cable bundles
Environment air monitor suggests that irradiated air was leaked into super-hot machine room from (air-tightened) dump pit cooling loop.

[Most probably from degasifier of radioactive cooling water]

The air is going into 1F through service hatch and cable penetrations.
Air tightening (NU3)

- Remove insulation around ducts → seal with thin iron plates and caulking
- Liquid silicone glue for the cable penetrations
- Seal edges of concrete blocks at the delivery entrance to downstairs
- Doors sealed with tape, repeat smoke tests to find remaining leaks
Degasifier in BD/DV cooling water circuit

- **Guess:** Exhaust from pumps (evacuating hollow fiber membrane filters) may contain radioactive gas from cooling water
3 electromagnetic horns / a baffle are supported from the wall of vessel by support modules.

Apparatus on the beam-line are highly irradiated after beam. Remote maintenance is the key issue.
Flow of the Irradiated Air at Target Station

Jan. 2010 20kW beam

Chimney stack

~1.5Bq/cc

Storage area

Service pit

Superhot Machine room

Flow of the Irradiated Air at Target Station

⇔ law: 0.5mBq/cc
3 month average

Chimking to block gap

Add cyricone

Air-tightened duct
And dumper

Sheemok balloon sheet
**TS 1F Bypass Ventilation**

- Reduce ventilation flow to 10% w/o changing total flow
  \[ \Rightarrow \, r \, (110 \, \text{min}) \, \text{to decay} \]

Total 13,000m³/h

13,000m³/h

- Exhaust signal : 0.4mBq/cc@130 kW \( \Rightarrow \) 0.13mBq/cc
- 0.1mBq/cc(190kW) \( \Rightarrow \) 950kW acceptable!
Stop of ventilation system by single event upset
(2010 April)

- The control panel was located in B1F machine room, since limitation of 1F floor space. (Later we noticed it was around the level of target.)
- “Single event upset” on a CPU unit of the PLC by beam-induced fast neutrons.
- As temporary fix during Run-1, extract / relocate the CPU unit by 10m to area with less neutrons, then covered with LG blocks.
- Whole control panels of air-conditioning/cooling water at TS moved to the ground floor in 2010, summer.
Nested negative pressure control

- Negative pressure Control (-20Pa)
- Pressure: As-Is

- Negative pressure Control (-20Pa)
- Deeper Negative pressure (-40Pa)
- Very long duct (decay)

- It can be very standard idea at reactor facilities (JAEA ?)
- Worth to introduce to J-PARC

Past CENF facility design
Radioactive cooling water drainage @ NU2

25GBq HTO produced per $1 \times 10^{20}$POT
In Horn/TS He Vessel/Decay Volume Cooling Water

- Although radioactive nuclear ions (7Be..) can be removed using ion-exchange resins, there is no way to extract tritiated water (HTO).
- Disposal after dilution under control of Radiation Hazard Prevention Act
- Based on the working procedures by current drainage system, it is very hard to deal tritiated water from 750kW operation within the same year.
  - $750 \text{kW} \times 10^7 \text{sec (116 days)} = 15.6 \times 10^{20} \text{pot} \rightarrow 390 \text{GBq}
  - $x \sim 2$ larger than current capability
Radioactive cooling water drainage@ NU2

- Upgrade water dilution tanks to $x \sim 3$ larger volume ($84 \text{m}^3 \rightarrow 234 \text{m}^3$)
  - Piles of the building are not strong enough.
  - New facility building with larger tanks?
- 3 urgent improvements:
  1. Frequency of drainage (every 3d/60 times $\rightarrow 2d/90 : 600 \text{kW} \times 10^7 \text{s}$)
  2. Takeover by tank truck ($+150 \text{kW} \times 10^7 \text{s}$)
  3. Shortcut in the circulation system and apply partial dilution

Rehearsal of tank-truck takeover at NU3.
(Dec. 2015)
1st real takeover took place on Jan. 2016
Summary

- For J-PARC neutrino facility, currently most severe limiting factor on beam power (400kW x 107 sec/year) is from limitation on total amount of tritiated water drainage.
  - Improvement scenario is under consideration, which will count for > 700kW operation.
  - In the future MW operation we need new facility building with larger tank.
  - Or, to carry forward (part of) tritiated water to following years by keeping them in the system (risk when water leak happens)

- Radioactive exhaust air is another limiting factor (upgrade successful to accept ~1MW beam)
  - Nested negative pressure control may solve the problem.

- It should be worth to emphasize that facility design wrt. radiation protection, safety, and waste treatment are of vital importance to maximize the benefit of high power target facility.