Appendix 5

The Radioactive Material Leak Accident at the Hadron Experimental Facility of J-PARC
June 21, 2013
First External Expert Panel

J-PARC Center
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Issues with respect to the Accident

① Release of radioactive material to the outside of the radiation controlled area and to the environment outside of the Hadron experimental hall (HD hall)

② Delays in reporting to the relevant authorities, the local communities and the media

③ Internal radiation exposure on workers who inhaled contaminated air in the HD hall

④ Failure in timely disclosure of information
What is J-PARC?

- Jointly built and operated by Japan Atomic Energy Agency (JAEA) and High Energy Accelerator Research Organization (KEK)
- Opened for researchers in the world to study a wide range of research fields from the origin of the universe to the development of new medicine
Hadron Experimental Facility

A research facility for elementary particle and nuclear physics
- to investigate the fundamental components of matter
- to explore how they interact and constitute matter

Construction began in 2004 and was completed in January 2009. After commissioning, the users experiments started in January 2010.

Hadron Experimental Hall:
The building is 56 m long, 60 m wide, 16 m roof height with 6 m deep semibasement structure to accommodate experimental instruments.

Hadron Experimental Facility:
It consists of the Hadron experimental hall and associated machine and power supply buildings, etc.
11:55 on May 23

- An abnormal proton beam was injected to the gold target.
- The target heated up to an extraordinarily high temperature.
- Radioactive material was released from the target.
- The radioactive material was leaked into the HD hall.
  → Workers were exposed to radiation.
- The radioactive material was released to the outside of the radiation controlled area and to the environment outside of the HD hall.
J-PARC Accelerators and Beam Extractions

**Fast extraction**

- To Neutrino Experimental Facility
  - 600 nanoseconds
  - ~ 2 seconds

- To Hadron Experimental Facility
  - ~ 6 seconds
  - 40 milliseconds

**Slow extraction**

- To Hadron Experimental Facility
  - ~ 2 seconds
Abnormal Beam

- At around 11:55 on May 23, the power supply system of a special magnet in the 50 GeV Synchrotron malfunctioned.

→ $2 \times 10^{13}$ protons were extracted in a very short period of 5 milliseconds, while in normal operation $3 \times 10^{13}$ protons should have been slowly extracted over 2 seconds.
The target, when bombarded by high-energy protons, produces secondary particles (mesons), which then will be used for research.

- Radioactive material is produced by nuclear spallation reactions.
- In normal operation the radioactive material stays in the gold target.
- When the proton beam operation is stopped, nuclear spallation reactions stop and no new radioactive material is produced. Radioactive material decays within the target.

Gold, unlike uranium, is not a radioactive material.

→ No nuclear chain reaction occurs.
→ However radiations come out from radioactive material produced in nuclear spallation reactions induced by the proton beam in the gold target.
Target Temperature (Simulation Results)

- Temperature rise (K)
  - 3x10^{13} protons/pulse (2 seconds)
  - 2x10^{13} protons/pulse (5 milliseconds)

- Strom direction (mm)
  - Thermocouples
  - Gold
  - Copper base

- Cooling water

- Time (seconds)

- Radial direction (mm)

- Beam axis direction (mm)

- Temperature
  - Red: 2750-3000
  - Orange: 2500-2750
  - Yellow: 2250-2500
  - Green: 2000-2250
  - Cyan: 1750-2000
  - Blue: 1500-1750
  - Dark blue: 1250-1500
  - Black: 1000-1250
Apertural areas for secondary beam transport lines

Present status
- Target
- Experimental Hall
- First bulkhead
- Primary beam area
- Ventilation fans
- Exhaust stack
- Exhaust ventilation

Status after proposed revision
- Target
- Monitoring
- Experimental Hall
- Second bulkhead
- Primary beam area
- First bulkhead
- Monitoring
- Filter
- Circulation

Hadron Experimental Hall
May 23, 2013

- 11:55 Delivery of proton beam from 50 GeV Synchrotron (MR) was halted by Machine Protection System (MPS).
- 12:08 MPS was reset following the regular resetting procedure after discussing with relevant people and delivery of proton beam for users’ experiments was resumed.
- 13:30 Increase in radiation dose rate of an area monitor in the HD hall was acknowledged. The maximum value of 4 μSv/h is ten-fold of the normal value.
- 15:15 Ventilation fans were turned on. Further decrease in ambient dose rate was acknowledged.
- 17:00 Radiation survey of the HD hall found areas with high dose rate were localized.
- 17:30 Ventilation fans were turned on to reduce airborne radiation dose rate in the HD hall.
- 23:30 Completed evacuation and full-body radiation surveys of all workers in the radiation controlled area. Access to the HD Facility was restricted.

May 24, 2013

- 10:00 Members on the right held a meeting to discuss the situation. It was not considered this incident to be one for escalated reporting.
- 17:30 J-PARC Center received inquiry from Nuclear Fuel Engineering Laboratories concerning increased radiation levels recorded by their monitoring posts.
- 18:00 Data logs of gamma-ray area monitors on the boundaries of the controlled area of the HD Facility were examined. Found increased radiation levels at around 15:00 and 17:30 on May 23. Found that the increased dose rates coincide with the operations of ventilation fans in the HD hall.
- 21:10 Reported to an emergency post of the Nuclear Science Research Institute. Response headquarters was established.
- 22:40 As required by law, the first report to Nuclear Regulation Authority was transmitted by facsimile transmission.
- 22:40 As required under the terms of relevant agreements, the first report was faxed to Ibaraki Prefecture, Tokai Village and other authorities.

May 25, 2013

- 01:00 Found out that the maximum total exposure dose of the workers in the HD hall was 1.7 mSv.
• Evaluations based on measurements:
  1. Increases of the radiation dose rates at monitoring stations of Nuclear Fuel Cycle Engineering Laboratories
  2. Nuclides and radioactivities found in the airborne sample from the HD hall
  3. Direction and velocity of the winds at the time of release of radioactive material on May 23

• Two kinds of calculation methods used in estimations:
  1. Analytical method based on diffusion equations for radioactive material
  2. The WSPEEDI-II code

<table>
<thead>
<tr>
<th>nuclei</th>
<th>half life</th>
<th>radioactivities (Bq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{43}$K</td>
<td>22.3 hours</td>
<td>64.0</td>
</tr>
<tr>
<td>$^{24}$Na</td>
<td>15.0 hours</td>
<td>63.5</td>
</tr>
<tr>
<td>$^{199m}$Hg</td>
<td>42.6 min.</td>
<td>61.0</td>
</tr>
<tr>
<td>$^{197}$Hg</td>
<td>64.9 hours</td>
<td>39.5</td>
</tr>
<tr>
<td>$^{76}$Kr</td>
<td>14.8 hours</td>
<td>32.4</td>
</tr>
<tr>
<td>$^{131}$I</td>
<td>8.02 days</td>
<td>28.6</td>
</tr>
<tr>
<td>$^{82}$Br</td>
<td>35.3 hours</td>
<td>19.5</td>
</tr>
<tr>
<td>$^{195m}$Hg</td>
<td>41.6 hours</td>
<td>18.4</td>
</tr>
<tr>
<td>$^{123}$I</td>
<td>13.3 hours</td>
<td>17.2</td>
</tr>
<tr>
<td>$^{95}$Nb</td>
<td>35.0 days</td>
<td>9.10</td>
</tr>
<tr>
<td>total amount</td>
<td></td>
<td>353</td>
</tr>
</tbody>
</table>

Radioactive material in the 500 ml airborne sample collected from the Hadron experimental hall.
• The released radioactive material distributed within a narrow area of the west from the HD hall.

• The maximum integrated radiation dose at the site boundary is estimated to be 0.29 μSv at a location close to the HD hall.

• Examination of soil samples from four locations.
  → No radioactive material originating from the accident was detected at any of these locations.
Delays in Reporting and Announcing

【May 23】
Our investigation indicates the following:

• A part of the gold target was damaged. Radioactive material leaked into the HD hall and contaminated the floor, etc.
• Workers in the HD hall may were exposed to internal radiation.
  ← The leaders considered that contaminations were limited to a radiation controlled area and the exposure dose was below what was expected in normal operation. Hence they considered that this incident would not have to be reported as an accident.

【May 24】
Small increases of the dose rates were found at around 15:00 and around 17:30 on May 23, in coincidence with the operations of ventilation fans on that day.
  → The leaders determined that radioactive material had leaked to the area outside the radiation controlled area and they reported to an emergency post of Nuclear Science Research Institute.
Measurement on internal and external radiation exposure doses of all the persons who entered the radiation controlled area of the HD Facility after the accident:

- Total number of personnel: 102
- Number of personnel with detectable dose: 34  
  Note: All are registered radiation workers. Individual doses are in the range of 0.1–1.7 mSv.
- Number of personnel with no detectable dose: 66  
  The remaining two, who were from overseas, had their whole body counter measurements at home later, and have been found to have no detectable dose.
Other Facilities at J-PARC
Radioactive material is contained by:

- enclosure of target assembly in multiple layers of containment
- negative pressure control

- Muon target
  Carbon 20 mm thick, Water cooling

- Neutron target

- 1st Experimental hall

- 2nd Experimental hall

- A class 1 radiation controlled area
- A class 2 radiation controlled area

- Door way

- Contained in a vacuum chamber
- Separated from the experimental hall

- Multiple layered structure
  - Safety hull
  - Mercury vessel

- Materials and Life Science Experimental Facility
Radioactive material is contained by:

- filtered exhaustion of interconnection areas
- negative pressure control
Accelerator Facility Complex

Radioactive material is contained by:
- two-layered containment
- filtered exhaustion of interconnection areas

3 GeV Synchrotron
Radioactive material is contained by:

- filtered exhaustion of interconnection areas
- negative pressure control
Plans for the Near Future

• Continued investigation of facilities and instruments
  – Target area of the HD Facility
  – Power supply unit which experienced the malfunction causing the abnormal beam extraction

Determination of the causes and development of preventive measures

• Evaluation of the total amount of radioactive material released from the HD Hall to the environment
  – Detailed analysis of the air sample which was collected at the HD hall
  – Simulation to reproduce the radiation dose rates observed in the HD Facility

Evaluation of the effects on the environment
External Expert Panel: Viewpoints of Evaluation

- Evaluation of overall response to the accident, including the organizational framework
  - Investigation of causes of the accident, analysis of contamination, radiation exposure and environmental impact
- Evaluation of countermeasures
  - Revalidation of safety management system including developing preventive measures against recurrence of similar accidents and review of radiation controlled areas in the J-PARC facilities
- Organization of J-PARC
  - Relationships between the accident and the organization and operation of the J-PARC center that is jointly managed by KEK and JAEA
- Efforts to promote the safety culture, etc.
External Expert Panel
Validation at the J-PARC on:
- Safety management
- Emergency procedures, etc.

Working Group
(all external memberships)

Secretariat

J-PARC Center Investigation Teams
(all internal memberships)
Compiling the basic data for the working Group
Investigation Teams

Team A
(accelerators and beam transport)

Team B
(target system)

Team C
(building and air tightness)

Team D
(control and safety)
### Examination of Timeline of Incidents

#### Timeline of incidents, judgements and actions

<table>
<thead>
<tr>
<th>Serial number</th>
<th>Time</th>
<th>Source of information</th>
<th>Incident (What happened / What was done)</th>
<th>Who took action</th>
<th>Who made a judgement on what and why</th>
</tr>
</thead>
</table>
| 1             | 5/23/13    | 11:55                 | MPS set in to stop beam operation (Detected signals)  
- MR-EQ "over voltage", "tracking error"  
- MR-RQ "over current"  
- MR-BLM  
- HD experimental facility BLM  | Acc. Shift Leader  
Mag. PS staff | Magnet power-supply staff considered that the PS returned to its normal status. |
| 2             | ~12:06     | zlog                  | Acc. Shift Leader asked for Mag. PS's opinion concerning the EQ anomaly. The Magnet power-supply staff immediately checked the control screen of EQ at CCR. While this was the first occurrence of a tracking error on EQ, the MPS status of the PS was able to reset with the standard procedure. EQ overvoltage is a relatively familiar status, and usually it can be reset without problems.  | Acc. Shift Leader  
Mag. PS staff |  |
| 3             | ~12:06     | zlog                  | Magnet power-supply staff reset the MPS status of MR-BLM on consideration that it was due to mis-firing of the fast extraction kicker, since the BL-MPS was associated with abrupt beam loss of the MR.  | Acc. Shift Leader  
Mag. PS staff |  |
| 4             | ~12:06     | zlog                  | HD Shift Leader checked the status of magnet PS current vacuum in the proton beam line, and reported them to the Manager of Radiation Generator of HD, who were in charge of CCR. After consultation, HD Shift Leader reset the BLM MPS status.  | HD Shift Leader  
Acc. Shift Leader |  |

### Incident, Action, Judgement, and Reason

- Incident of abnormal beam
- Damage of the gold target?
- Contamination in the hall
- Release of radioactive material
- Delays in reporting the incident, suspending accelerator operation, and stopping ventilation fans
Summary

• Overview of the accident
  – occurrence, hall contamination, exposure, leakage of radioactive material to the outside of the radiation controlled area and responses after the accident

• Status of the other facilities

• Status of the investigation
  – hardware aspects (facilities and instruments)
  – software aspects (safety management system)
  – the Working Group, secretariat and investigation teams