

Report of Findings
by the External Expert Panel to Review the Radioactive Material Leak Accident
at the Hadron Experimental Facility of J-PARC

August 22, 2013

“The External Expert Panel to review the Radioactive Material Leak Accident at the Hadron Experimental Facility of J-PARC” (hereafter “the Panel”) has completed this Report concerning the validity of proposals formulated by the J-PARC Center to prevent recurrence of the accident that occurred at J-PARC on May 23, 2013, as well as the center’s efforts to review its safety management framework and emergency procedures. The Report was prepared in response to the following inquiries that were submitted by the heads of the Japan Atomic Energy Agency (JAEA), and the High Energy Accelerator Research Organization (KEK), which oversee the J-PARC Center.

Inquiries

- (1) Review of safety management system and emergency procedures at the J-PARC Center
- (2) Evaluation of the validity of the accident measures developed by the J-PARC Center

1. Accident examination and issues

To efficiently promote examination and evaluation of inquiry items (1) and (2), the Panel established a working group (WG) comprised of four experts and received its detailed report as shown in the attached report. An outline of the examination that was conducted based on the WG report and identified issues are presented below.

(Outline of the accident)

At around 11:55 A.M. on May 23, 2013, a power supply to two electromagnets in the 50-GeV synchrotron (MR) for slow (continuous) extraction of a 30-GeV proton beam to the Hadron Experimental Facility (hereafter HD facility) experienced a very brief malfunction of unknown cause. Due to this malfunction, a high intensity pulsed beam that was far in excess of designed parameters was hit the gold target for a moment. Although the gold target was cooled, its cooling capability was insufficient to handle the heat load being applied by the high

intensity beam. Thus, it is considered that the gold instantaneously melted along the beam axis and consequently various types of radioactive material that were generated within the gold target vaporized. It is believed that, because the container encasing the gold target was not hermetically sealed, the radioactive material's vapor diffused into the primary beamline area (class 1 radiation controlled area¹) and that, further, because the air of this area was under positive pressure, the vapor passed through gaps between concrete radiation shielding blocks and leaked into the Hadron experimental hall (HD hall) (class 2 radiation controlled area²), where many researchers were at work. Some of the workers noticed abnormal figures on area monitors that installed in the HD hall. However, they suspected that the monitors were malfunctioning. As they attempted to verify this, they released air of the HD hall to outside areas through ventilation fans. It subsequently took time until workers gained a correct understanding that the hall's air was contaminated with radioactive material, and thus reporting the situation to the relevant authorities including local governments was delayed. Moreover, workers who were late in evacuation inhaled the radioactive material and consequently received internal radiation doses.

(Problems and arising issues)

Problems associated with the accident can be summarized into three areas: 1) leakage of radioactive material, 2) delay in reporting to relevant authorities, and 3) radioactive exposure of workers.

Issues arising from the leakage of radioactive material are grouped into two categories, such as those regarding facilities and those regarding safety management system. Facility-related issues include the electromagnet's malfunction, insufficient hermetic sealing, and inadequate ventilation equipment. Safety management-related issues include an inadequate safety review system and therefore overly optimistic assumptions concerning anomalies, errors in judgment that led to operation of the ventilation fans, and inadequate procedures for restarting beam operation.

Regarding the delay in reporting, issues include insufficient information collection and poorly developed criteria for judgment, misunderstanding of laws and ordinances, and an inadequate command system that resulted in the absence of managers and non-appointment of

1: Area in which control of contamination of surfaces and air from radioactive material is required.
2: Area in which control of contamination of surfaces and air from radioactive material is not required.

representatives. These factors hindered an organizational response and led to delays in decision-making.

Factors behind the radioactive exposure of workers include deficient radioactivity alarms, inadequate evacuation standards, a poor system for sharing information, and inadequate education.

(Preventive measures against recurrence)

Tables 1 and 2 summarize the preventative measures, safety management system, and emergency procedures based the issues and subject matters.

Table 1: Correspondence between hardware-related arising issues and preventive measures against recurrence

Problems	Arising issues	Measures
Leakage of radioactive material	Malfunction of electromagnets	<ul style="list-style-type: none"> • Reinforcement of interlock system (prevention of overcurrent, etc.) • Faster interlocking system
	Insufficient hermetic sealing	<ul style="list-style-type: none"> • Making the target container airtight • Reinforcing airtightness of the primary beamline area
	Inadequate ventilation equipment	Venting the air in the HD hall through filters while monitoring concentration of radioactive material in the air
Delay in reporting to relevant authorities	—	—
Radioactive exposure of workers	Inadequate radioactive alarm system	Improving the monitoring system to observe radiation level in J-PARC facilities

Table 2: Correspondence between subject matters concerning the safety management system and preventive measures against recurrence

Problems	Arising issues	Measures
Leakage of radioactive material	Inadequate safety review system	Reinforcement of the radiation safety review system
	Ambiguous criteria for judgment	Review of the framework to respond to an anomaly (introduction of the “alert status”) Improvement of operating manuals
	Ambiguous description of procedures for restarting beam operation	Improvement of operating manuals
Delay in reporting to relevant authorities	Insufficient information collection	Review of the framework to respond to an anomaly (introduction of the “alert status”)
	Insufficient criteria for making judgment	Review of the framework to respond to an anomaly (introduction of the “alert status”) Improvement of operating manuals
	Misunderstanding of laws and ordinances	Review of the framework to respond to an anomaly (introduction of the “alert status”) Appointment of a Deputy Director to oversee safety
	Inadequate command system	Review of the framework to respond to an anomaly (introduction of the “alert status”) Appointment of a Deputy Director to oversee safety
Radiation exposure of workers	Ambiguous criteria for evacuation	Review of the framework to respond to an anomaly (introduction of the “alert status”) Improvement of operating manuals
	Poor system for information sharing	Review of the framework to respond to an anomaly (introduction of the “alert status”)
	Poor system for safety education	Enhancement of employee education and user education

(Impact on the surrounding environment and radioactive exposure of workers)

As is stated in the report from the WG, the radioactive material leak accident had sufficiently small impact on the environment (maximum of 0.29 μSv^3) and no health impact

3: Equivalent to $\sim 1/3400$ of the annual limit of radiation dose for members of the public recommended by the International Commission on Radiological Protection (ICRP) .
(1 mSv = 1,000 μSv)

even in the case of internal exposure (maximum of 1.7 mSv⁴). However, the accident exposed low awareness of safety and inadequate safety management system of the J-PARC Center as pointed out by the Minister of Education, Culture, Sports, Science and Technology.

(Risk assessment at three facilities other than the HD facility)

In addition to the HD facility, J-PARC includes the Materials and Life Science Experimental Facility, the Neutrino Experimental Facility, and the Accelerator Facility. The Panel also reviewed these facilities in terms of the appropriateness of their radiation control areas and managing systems, and safety of their equipment. It concluded that radiation control areas were appropriately established and managed and that equipment safety was sufficiently high at the three facilities.

2. Improvement plan to be executed by the J-PARC Center

The J-PARC Center proposed the following three core approaches as well as measures and an improvement plan that are based on the above-mentioned identified issues and geared toward their resolution to the Panel.

1. Building of an organization and system that makes safety the highest priority
2. Developing an action manual that instills safety awareness through all parts of all facilities
3. Cultivating a culture for sustained development of safety

(1) The safety management system and emergency procedures

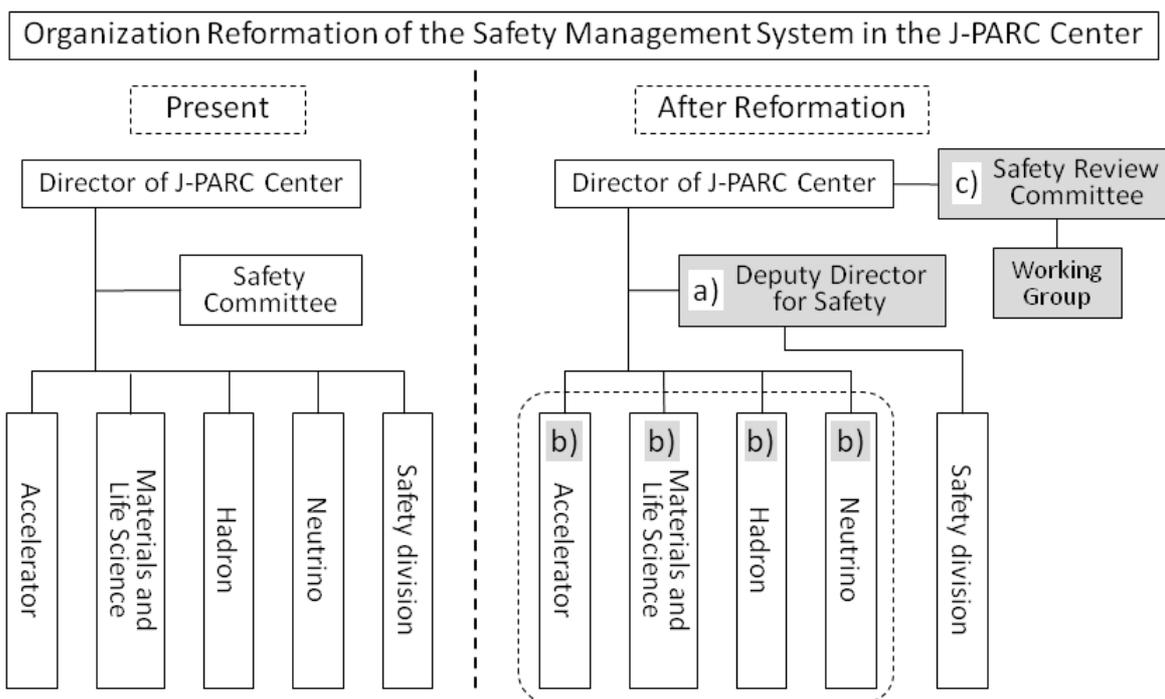
- 1) Cultivating a safety culture under the responsibility of Director of the J-PARC Center

The J-PARC Center will strive to cultivate a safety culture that permeates throughout the center by clarifying safety objectives for the center and repeatedly providing education and training to maintain and improve safety awareness among all staff members. The learning level of the members will be evaluated to enforce ingraining the safety culture in the J-PARC Center. Efforts to cultivate this culture will take place under the leadership of Director of the J-PARC Center, who will have a full responsibility for safety at the center.

4: Equivalent to $\sim 1/30$ of the annually allowable radiation dose of radiation workers established by law (50 mSv).

2) Organizational reformation for thoroughgoing attention to safety

The J-PARC Center presented the concept for organizational reformation to overcome the issues mentioned in the previous section (Figure below). The a), b), and c) in the figure refer to the three points of the organizational reformation.



a) Creating a new position of a Deputy Director to take charge of safety throughout J-PARC

The J-PARC Center will build a framework that seeks to integrate safety reinforcement efforts throughout the center. The framework includes creation of a new Deputy Director position to uniformly implement radiation safety management in all J-PARC facilities and take overall command of responses to anomalies as well as placement of the Safety Division under this deputy director. The newly installed Deputy Director to take charge of safety at J-PARC will be an employee possessing high awareness and deep knowledge of safety and serve as a “control tower” for safety in J-PARC. The J-PARC Center will endeavor to appoint the most qualified person for the post by looking both inside and outside the center.

b) Clarification of persons in charge during emergencies at each facility

In an emergency situation, a Facility Manager of each facility will direct a task force and the newly appointed Deputy Director will be in charge of safety in an overall supervisory position. It will build a safety management system (the figure above) that clarifies jurisdictions and an integrated chain of command. It will also establish a framework that can make specific responses during emergencies by appointing persons in charge beforehand and conducting repeated training.

c) Reinforcement of radiation safety evaluations in J-PARC

To reinforce an evaluation function concerning facility and equipment safety standards and radiation safety standards (e.g., manual revisions, etc.), the J-PARC Center will reorganize the existing “Internal Radiation Safety Committee”, which has primarily been a body of rank-designated members of the J-PARC Center, into a Radiation Safety Review Committee to be comprised of experts (including external advisers) and build a framework for conducting thorough and specialized radiation safety evaluations.

3) Development of a response system for anomalies and clarification of criteria for judgment

To initiate emergency responses precisely and quickly, the J-PARC Center will introduce a new level called “alert status” between the existing “normal status” (ordinary situation) and “emergency status” (occurrence of an event requiring reporting). At this new status, the Facility Managers and persons involved will be called together when symptoms of an accident first appear in order to make an organized response. Leaders under this warning status (i.e., Facility Managers and their representatives) should make J-PARC their main base of their work in order to ensure precise and quick responses. The J-PARC Center will also revise operating manuals with clear criteria for judgment to ensure that judgments are made quickly and unfailingly during anomalies.

The J-PARC Center will immediately notify all personnel within J-PARC as well as local governments and others concerned whenever an emergency occurs.

4) Reinforcement of safety education for users

The J-PARC Center will provide users with appropriate safety education in accordance with the circumstances of each facility and develop awareness among not only

J-PARC staff members but also users on the need to improve safety.

(2) Measures against similar accidents

Because absolutely eliminating equipment malfunctions is difficult even if all possible measures are implemented, the J-PARC Center will execute improvement measures to minimize damage if a malfunction occurs. Specifically, it will implement all possible measures to prevent malfunctions, take steps to minimize radioactive material leaks even if the target is damaged, and ensure that absolutely no radioactive material is leaked outside of radiation controlled areas of the facility. To achieve these aims, it will implement the following multi-layered measures.

- 1) Take measures to deal with malfunctions of the 50-GeV synchrotron electromagnets (such as prevention of over current, etc.).
- 2) Place the target of the HD facility in a hermetic container and strengthen the air-tightness of the primary beamline boundary.
- 3) Constantly monitor the air in the HD hall and pass it through filters when releasing it.
- 4) Revise and improve monitoring systems for observing radiation level in the J-PARC facilities.

The J-PARC Center will proceed with improvements to the HD facility based on the above-mentioned measures, paying full attention to ensure that secondary accidents do not occur.

3. Report of Findings

The Panel submits the following report prepared from the results of its deliberations of the preventive measures proposed by the J-PARC Center to the heads of JAEA and KEK.

(1) Confirmation of the safety management system and emergency procedures

The Panel evaluates the measures to be implemented by the J-PARC Center as follows:

1) Cultivating safety culture under the responsibility of Director of the J-PARC Center

Subject matters that were identified in connection with the accident include issues in the organizational response (specifically, a deficient chain of command), ineffective

response to anomalies and poorly developed criteria for judgment, and overly optimistic evaluation of facility and equipment safety. The cause behind these issues is thought to be deficient safety awareness throughout the J-PARC Center as an organization.

The Panel confirms that the above-described measure “cultivating culture of safety under the responsibility of Director of the J-PARC Center” includes establishment of safety awareness as well as provision of education and training for appropriate staff members to resolve the problems mentioned above. The Panel therefore deems this measure to be appropriate.

2) Organizational reform for thoroughgoing attention to safety

a) Assignment of a person to take charge of safety throughout the J-PARC Center

The causes of insufficient information collection, poorly developed criteria for judgment, and misunderstanding of laws and ordinances that led to the delay in statutory reporting; the errors in judgment that led to operation of the ventilation fans, which caused the leakage of radioactive material; and the poor system for sharing information on radiation exposure for workers can be found in the fact that current responses to anomalies depend upon a facility. No center-wide system for appropriate information collection and decision-making is in place, and thus the center cannot handle events such as the relevant accident that involve multiple facilities.

The Panel finds that the above-described measure “assignment of an officer (Deputy Director) to take charge of safety throughout the J-PARC Center” will realize integrated safety management throughout the center and is thus appropriate.

b) Clarification of persons in charge during emergencies at each facility

The accident revealed an inadequate command system. Because it was not clearly established that the Facility Manager of each facility became the person in charge of that facility at an emergency, Facility Managers were not present at the time of the accident. Moreover, no representatives were assigned to act for absent Facility Managers.

The Panel finds that the above-described measure “clarification of persons in charge during emergencies in each facility” is capable of maintaining an effectual command system all the time and is thus appropriate.

c) Reinforcement of radiation safety evaluation in J-PARC

The accident brought into relief the poor development of guides concerning facility and equipment matters and safety management. There is no getting around the fact that this was the result of inadequate supposition of anomalies that can lead to radiation accidents and insufficient technical discussions in radiation safety evaluation process at J-PARC. More specifically, it was caused by functional problems in the Internal Radiation Safety Committee, which currently conducts reviews/evaluations of radiation safety issues at J-PARC.

The Panel finds that the above-described measure “reinforcement of radiation safety evaluations in the J-PARC Center” will be essential in realizing safety in terms of both hardware and software and is thus appropriate.

3) Development of a response framework for anomalies and clarification of criteria for judgment

The current manual on safety management presents guidelines for responding to anomalies when the discoverer of an event is capable of identifying it as an accident. However, it does not envision events like that addressed in this Report that demand accurate ascertainment of anomalous “symptoms” when circumstances are changing from moment to moment. This led to the delay in statutory reporting and misjudgments concerning the radioactive material leak.

The Panel finds that the above-described measure “development of a response framework for anomalies and clarification of criteria for judgment” — specifically, the establishment of the new “alert status” and development of manuals that clarify criteria for judgment — is appropriate.

4) Reinforcement of safety education for users

At the time of the accident addressed in this Report, there were many users who were not evacuated despite being aware of the rising radiation level. J-PARC is a globally advanced research facility that brings together many researchers from inside and outside Japan. Accordingly, ensuring the safety of J-PARC absolutely requires that not only staff members but also this broad range of users keep safety firmly in mind and be fully cognizant of necessary responses.

The Panel finds that the above-described measure “reinforcement of safety education

for users” will be effective in raising awareness among users and is thus appropriate.

(2) Confirmation of validity of accident measures plan

The Panel finds the following accident measures plan that was proposed by the J-PARC Center to be valid and urges its immediate execution.

The J-PARC Center will:

- 1) take measures to deal with malfunctions of the 50-GeV synchrotron electromagnets (such as prevention of overcurrent, etc.),
- 2) place the target of the HD facility in a hermetic container and strengthen the air-tightness of the primary beamline boundary,
- 3) constantly monitor the air of the HD hall and pass it through filters when releasing it, and
- 4) improve monitoring system for observing radiation doses within the J-PARC facilities.

4. Other matters and recommendations produced from deliberations

In addition to the producing the findings presented above, the Panel conducted deliberations and evaluations that took into account several basic standpoints.

J-PARC is a research facility that was constructed with the globally oriented objective of producing cutting-edge science and technology research achievements using high-intensity proton beams. The J-PARC accelerators and experimental facilities have the responsibility of providing research opportunities to numerous researchers, including users from overseas. Thus, the early restart of their operation will meet the expectations of the public in Japan and also overseas researchers.

However, it must also be remembered that J-PARC can only fulfill its mission as an international public asset if it secures peace of mind in the local community as well as public understanding. This requires the establishment of shared recognition within the J-PARC Center that the safety of the local community, users, and staff members comes before research value and efficiency. At the same time, gaining understanding from local communities will require efforts oriented toward natural cultivation of deeper mutual understanding and trust. This should be achieved with not only routine publicity through public relations activities but also active utilization of activities that bring people face-to-face with J-PARC staff members. Such activities could include creating opportunities for dialogue on research with local

students and other members of society.

Based on these observations, the Panel recommends the following to the heads of the JAEA and KEK.

- 1) Measures should be implemented side-by-side with efforts to fully explain the causes of the accident and preventive measures against recurrence to local communities and to gain their understanding.
- 2) Greater attention should be given to local communities when reporting accidents, and a faster statutory reporting and communications framework should be established.
- 3) The Panel recommends that evaluations of the safety of the new hadron target and restart of operations at the HD facility be subjected to external evaluation. The Panel has determined that the setting of radiation control areas at facilities other than the HD facility (namely, the Accelerator Facility, Materials and Life Science Experimental Facility, and Neutrino Experimental Facility) and their management are being executed appropriately, and that the safety of devices/equipment to handle severe events is assured. The Panel believes that it will be appropriate to restart these facilities when the new safety management system is in place, prescribed procedures are completed, and local communities' understanding is obtained.
- 4) Under the leadership of Director of the J-PARC Center, safety culture must be cultivated to improve safety awareness among organizations concerned with the operation of facilities throughout the center as well as staff members and users and to promote safe behavior. The Panel presents the following concrete proposals intended to strengthen this activity.
 - Among other items, formulate (1) a safety policy and (2) behavior guidelines as basic policies for facility operation. Study having staff members and users carry cards noting the safety policy, behavioral guidelines, and actions to be taken in emergencies as a means of fostering constant awareness of them.
 - In order to clarify latent risks that can cause anomalies and accidents,
 - continue efforts to expand the scope of foreseeable anomalies,
 - conduct risk assessment,
 - study the effects and root causes of troubles and near-misses that occur in daily operations and evaluate repercussions on other facilities,
 - encourage staff members and users to make suggestions or comments that help

improve safety, and build a mechanism that allows them to report problems they simply notice or have concerns about at any time, and

- require users to note suggested or desired improvements when filling out their post facility-use reports.

5. Summary

In response to inquiries from JAEA and KEK, the Panel reviewed the safety management system and procedures to be carried out in emergency situations that were presented to it by the J-PARC Center in connection with the recent accident in J-PARC and discussed the accident measures. The Panel concluded that each of them is appropriate and hereby reports this conclusion to both heads.

The Panel expects the J-PARC Center to build an organization and a framework that are primarily oriented toward ensuring safety by immediately executing the content of this Report as it also seeks to gain the understanding of its local communities and society at large. The Panel also expects J-PARC to quickly return to a state in which it can produce cutting-edge research achievements so that it may meet the expectations of public in Japan and overseas researchers.