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Safety Measures for the Operation of the Materials and Life Science Experimental Facility (MLF) of J-PARC - Restart of MLF Operation from the Radioactive Material Leak Incident at the Hadron Experimental Facility-

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Abstract. The radioactive material leak incident at the Hadron Experimental Facility (HD) in J-PARC on May 23, 2013, is briefly introduced. After the incident, the framework of safety management and emergency response in J-PARC was reconstructed. As one of the main items of the change, introduction of an "Alert" status is described. In addition the resuming process of the operation of the Materials and Life Science Experimental Facility (MLF) is mentioned.

1. Introduction

On May 23, 2013, a radioactivity leak incident occurred at the Hadron Experimental Facility (HD). [1] The incident caused internal exposures of users and staff, and radioactive release to the environment outside the site boundary. In addition, reporting the incident to the authorities concerned was delayed significantly, although the event should have been reported to the relevant authorities because of deviation from legal regulation. We, J-PARC, were criticized seriously and lost public trust. For the reasons, we had to stop the operation of all J-PARC facilities[1], including the Materials and Life Science Experimental Facility (MLF), indefinitely just after the reporting on the incident.

For resume of the operation, the relevant authorities urged us to confirm the soundness of facilities in terms of radioactivity confinement and to reform the safety organization to enable quick and adequate response to abnormal incidents. The results of confirmation and the reformation plan were to be reviewed by an external expert panel organized for review of the incident. In addition, for recover of the public trust, briefing sessions for neighborhood inhabitant of J-PARC were held several times. After having tough days for 8 months, the beam operation for the MLF user program could start on February 17, 2014.[2]

In this report, we briefly describe the HD incident and the resuming process of the MLF operation. In addition, the design concept of the radiation safety measures of MLF, which is requested to explain at the external expert panel, is described.

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[1] The "all J-PARC" includes the accelerator, the Materials and Life Science Experimental Facility (MLF), the Hadron Experimental Facility (HD) and the Neutrino Experimental Facility (NU). The accelerator consists of a 400 MeV Linac, a 3 GeV Synchrotron and a 50 GeV Synchrotron for protons.

[2] The beam operation of NU also started on May 26, 2014. As for HD, since reformation of the ventilation system and the whole target system were required, the beam operation will be started later.

The outline of the HD incident is described in the next section, and how we reconstructed safety policy for resuming the J-PARC beam operation is shown in section 3. In section 4, the design concept of radiation protection measures in MLF are presented.

2. Outline of the incident of the Hadron Experimental Facility

In HD, beams of secondary particles such as K and π mesons were produced by bombarding a gold target with 30 GeV protons provided from the 50 GeV Synchrotron (MR).[3] The proton beam was provided by the slow extraction[4] method: in the normal operation 3×10^{13} protons are slowly extracted over 2 sec.

The user operation was going well until just before noon on May 23, 2013. At 11:55 a.m., an abnormally-short proton beam of 5 ms duration was bombarded to the hadron target because of a malfunction of the slow beam extraction system. At the incident, 2×10^{13} protons which are 2/3 of normal case were suddenly extracted in 5 ms. On that occasion, the gold target was partially melted owing to very high instantaneous heat input, although the beam operation to HD was stopped by interlock system.[5] Consequently, radioactive materials generated and accumulated in the gold target were released to the experimental hall of HD because the target was not hermetically shielded and confinement capability of primary proton beam line was not sufficient. For the radioactive contamination of HD hall, the gamma-ray radiation monitors in the experimental hall showed an increase to ~4 μSv/h at a maximum, and the staff and users in the experimental hall inhaled the airborne radioactivity.[6]

In this stage, the radiation monitors in the hall showed that radioactive products originated from the hadron target were entirely spread to the hall. However, the data and information were not collected and analyzed properly, and nobody recognized what was really happening until the late afternoon.

Furthermore, ventilation fans[7] equipped on the walls of the hadron hall were turned on to validate the monitor values, and the radioactive products in the hall were released to the environment outside of the radiation controlled area.

The Regulation Law of Japan requested us to report incidents on radiation matters such as radioactivity leakage to the environment and unexpected exposures of radiation workers, etc. In the J-PARC, the incident was not considered to report at the primary stage because the radioactivity leakage was considered only within the radiation controlled area.

On the next day of May 24, some of the experimenters who worked at the hadron hall at the time of the incident were inspected with a whole body counter for internal exposure. As the results, it was found that they received significant internal exposure up to 1.7 mSv. In addition, the Nuclear Fuel Engineering Laboratories of JAEA, which locates next to the J-PARC site, inquired on increase of radiation levels in their monitoring posts at the time of ventilation fan operation. The data log of the area monitors of J-PARC also proved to indicate leak of radioactivity to outside of the controlled area of HD. On the basis of these facts, J-PARC sent reporting to the relevant authorities on this incident at 10 p.m. on May 24; one and half days had passed since the primary incident occurred on May 23. Due to the considerable delay of reporting, the public trust to J-PARC was degraded seriously.

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[3] The 50-GeV synchrotron was being operated with acceleration energy of 30 GeV at the incident.

[4] On the other hand, the proton beam was provided to NU by the fast extraction.

[5] The J-PARC interlock system consists of MPS (Machine Protection System) and PPS (Personnel Protection System). On the incident, the MPS stop the beam operation with alerting to proton beam loss and overvoltage of the electrical power supply for the extraction magnet system.

[6] The total number of personnel working in the radiation controlled area of HD during the incident was 102. As a result of the measurements with a whole-body counter, it was found that 34 personnel received detectable internal exposure in the range of 0.1-1.7 mSv.

[7] The "ventilation fun" is just a fan without filtering function for radioactive material. Ventilation system with filtering function had not been equipped in the hadron hall because this area was assigned as an uncontaminated controlled area.

Just after the reporting, the beam operation of all J-PARC facilities, including MLF, stopped indefinitely.

3. Reconstruction of J-PARC safety organization and the MLF management

After the incident, the minister of MEXT (Ministry of Education, Culture, Sports, Science and Technology) requested us to inspect the soundness of facilities in terms of radioactivity confinement and to reform the safety organization to respond to abnormal incidents quickly and adequately. We made serious effort to confirm the radiation safety of all facilities other than HD, and to establish a new system for emergency response to an abnormal incident.

The problem of the HD incident was 1) occurrence of the incident, and 2) improper emergency response to the incident. The aim of the reformation of the safety organization was to eliminate the problems. Three issues, a) unclear responsibility and command line, b) insufficient review capability for possible risks, and c) unclear criterion for judgement and actions, were traced to essential ones for suppression of recurrence of similar incidents. The J-PARC safety organization was reformed on the concept. In addition, cultivation of safety culture and drills for emergency situation was also important to support the organization. Various activities and drills were conducted for the purposes.

The result of inspection for the radioactivity confinement of the MLF is described in the next section. In this section, the new emergency-response system is presented in the following.

Before the HD incident, J-PARC had only one status for response to a serious accident, called “Emergency status”. We learned from the HD incident that we should have an intermediate status to respond to incident which may be abnormal but is not an apparent accident. In such situation, we learned that the important is systematic actions to collect and analyse the information. We introduced such one and call it as “Alert status”. The conceptual drawing of the structure of three kinds of risk-management statuses, “Normal”, “Alert” and “Emergency” is shown in Fig. 1.

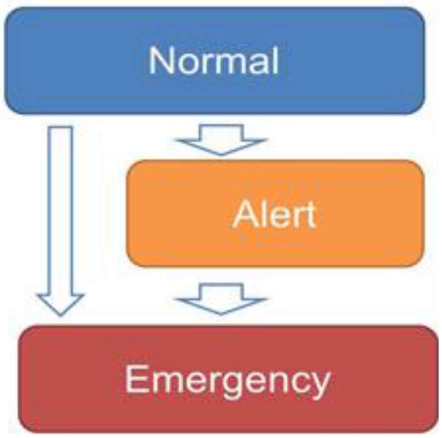

Figure 1. The conceptual structure of the new risk management system of J-PARC.

The normal status is one for normal cases and/or minor troubles which can be solved by actions within a division or a section. In the normal status, a shift leader[8] makes a decision to transition to the “Alert” status when the specified incidents related to the interlock system for personnel protection or the radiation monitors and so on.

If the high risk or rare interlock arises and radiation behaves abnormally, the situation needs systematic actions over sections and divisions to know what is happening. In the “Alert” status, the

[8] Shift teams, consisting of a shift leader and shift staff, are present at the central control room and the MLF control room during the beam operation.

facility manager or its deputy manager declares the situation, and they are responsible for collecting information and analysis of the incident together with the facility staff.

If they find that the incident is developing or may develop to a real accident, he declares transition to the "Emergency" status. In some cases such as fire or an undoubtable real accident, the shift leader has to make direct transition from "Normal" to "Emergency" status. In the emergency status, the emergency head quarter is set up at the Tokai site to report immediately to the relevant authorities and the neighboring local governments.

The new framework of the emergency response was reviewed at the external panel and explained at the briefing sessions for neighbourhood inhabitant.

In order to put into practice the policy change and to introduce that to the facility management, all operation-and-user manuals were fully revised. In addition, emergency drills were conducted several times on the basis of new safety framework in MLF.[9] The first drill was carried out on September 13, and the second one was done on November 15, 2013.[10] All MLF staff, including CROSS[11] and users, participated in the drill. The outline of the drill scenario was as follows:

- Radioactive gas products are detected during the beam operation by the radioactivity monitors in the hot cell where the circulation system of mercury which contain a huge amount of radioactivity has been installed,
- Declaration of transition to "Alert" status by a shift leader,
- Collecting and analysis of radiation monitoring data and other information under the direction of the facility manager of MLF,
- Recognizing the mercury leak from the mercury circulation system,
- Declaration of transition to "Emergency" status by the MLF manager,
- User evacuation and the radiological survey of their bodies,
- Taking measures to stop the mercury leakage,
- Reporting to the proper authorities.

The drills were accomplished without major problems, and all staff could understand the new system through the drills. We could restart, with confidence, the user operation of MLF on February 17, 2014.

4. Safety measures of MLF

Finally, in this section, we describe the radioactivity-confinement capability of MLF, which is what we explain to the relevant authorities and the external expert panel after the HD incident to show the soundness of MLF for safety.

The schematic drawing of the multilayer system for radioactivity confinement of MLF is shown in Fig. 2. The mercury target has a double wall structure: the mercury container is covered by the safety hull which has channels of primary cooling water. Then even if the mercury container is ruptured because of the pressure wave generated by proton beam impingement, radioactive mercury spills can be contained in the target vessel.[12] In addition, the helium vessel and the confinement of the neutron-target station also work as barriers for radioactive products release.

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[9] Prior to the emergency drills, the education on the new emergency-response framework was conducted for all staff.

[10] The second drill on November 23 was positioned as one of the final tests for restart of MLF operation. Therefore the performance was inspected by the surrounding local government.

[11] "CROSS" is the Comprehensive Research Organization for Science and Society, which was established to promote the public access to the neutron beam facility.

[12] The leak monitors of resistance wires are set in the intermediate layer in order to detect the leaked mercury. The leak monitors are connected to the interlock system. In addition, the radioactive materials in the intermediate layer are always monitored by the radioactivity monitoring system: the detail of the monitoring system was presented in the ICANS-XIX held on March 8-12, 2010. See the reference in the following: Y. Kasugai, K. Ohtsu and T. Kai, "Monitoring System of Mercury Target Failure Using Radioactivity Measurement", Proceedings of ICANS-XIX (2010).

Therefore we could clearly respond to the question on radioactivity confinement as follows: MLF has an inherent safety system for preventing release of radioactivity generated in the targets even in abnormal incidents. The targets have been set in a multilayer structure with confinement capability of radioactivity.

On the other hand, the mercury circulation located on the hot cell is a single-barrier system: the piping wall of the mercury circulation system is just of a single barrier. We presume that there is very low possibility for leakage from the piping on the basis of the data on corrosion between flowing mercury and stainless steel as the piping material. Nevertheless radioactive materials in the hot cell are always monitored during the proton-beam operation in order to detect a small leakage of radioactivity and to take measures to stop leakage as soon as possible if the leak of radioactivity is detected. Even if the leakage occurs in the hot cell by any chance, the hot cell can be isolated from the external environment by stopping the ventilation and closing the air valves equipped in the ventilation duct.

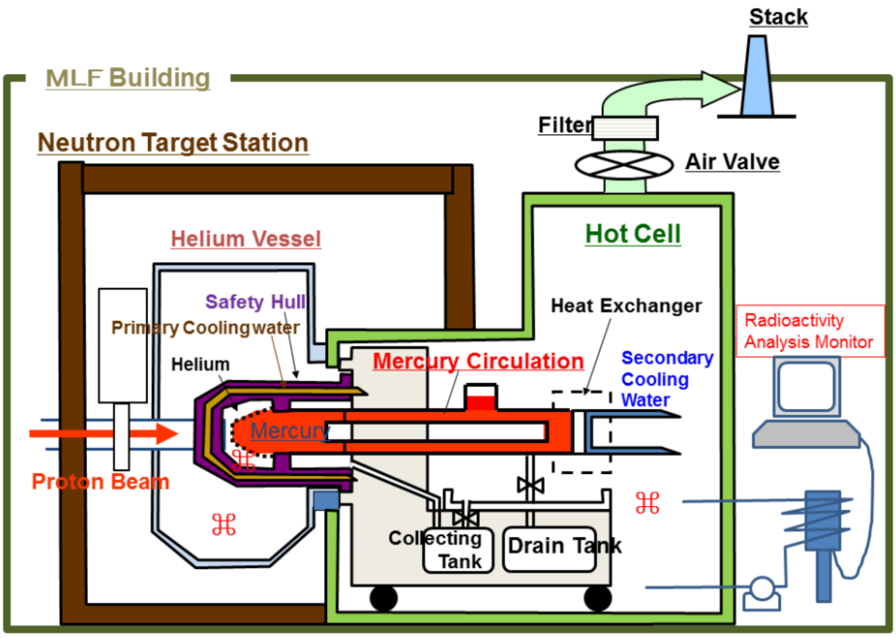

Figure 2. Schematic drawing of the multilayer system for radioactivity confinement of the neutron target at MLF. The leakage of the radioactive materials originated from the mercury for neutron production is monitored at the helium layer in the mercury target, the helium vessel and in the hot cell. (The monitoring positions are shown with ⌘ in the figure.)

5. Summary

The HD incident on May 23, 2013 and the reconstruction of the J-PARC safety management system were reviewed, and the radioactivity-confinement capability of MLF was explained.

After the incident, all J-PARC staff and users began to carry the safety card shown in Fig. 3 with them. We always keep the slogan “Science with Safety” in mind.

Figure 3. J-PARC Safety card. On the back side of the card, the emergency- call numbers and the map on the evacuation assembly spot are given.

References

[1] The detailed information on the HD incident can be found on the J-PARC web site. The address of the Japanese page is http://j-parc/jp/index.html and that of the English page is http://j-para.jp/index-e.html