February 14, 2018
Japan Atomic Energy Agency

Report on the contamination at Plutonium Fuel Research Facility

In accordance with the Article 62-3 of the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors, the Japan Atomic Energy Agency (JAEA) submits the revised version of the reports which JAEA submitted on June 19, 2017, July 21, 2017, September 29, 2017 and December 27, 2017 on the failure, etc. of a nuclear facility to the Nuclear Regulation Authority.

Attached sheets: Report on failure, etc. of a nuclear facility

Attached sheets

Report on failure, etc. of a nuclear facility

February 14, 2018

Japan Atomic Energy Agency

Title	Contamination at Plutonium Fuel Research Facility (PFRF) (third report)
Date and time of the occurrence of the event	Date and time: Tuesday, June 6, 2017; around 11:15 Date and time of decision: Wednesday, June 7, 2017; 13:00
Place of the occurrence of the event	Analyzing room of PFRF (in a controlled area)
Name of the nuclear facility where the event occurred	Plutonium Fuel Research Facility Oarai Research and Development Center (north zone) Japan Atomic Energy Agency
Situation of the event	Around 11:15, June 6, 2017, at the hood (H-1) of the analyzing room of PFRF (hereinafter referred to as "Room No. 108"), during the inspection work of a storage container of plutonium and enriched uranium that contains nuclear fuel materials (hereinafter referred to as "storage container"), vinyl bags double-encapsulating a container of nuclear fuel materials (hereinafter referred to as "resin bags") in the storage container burst. The contamination check conducted in the Room No. 108 by the workers using surface contamination test meter of α-ray showed all five workers were confirmed to be contaminated. Shown below is the situation of the occurrence of the event based on the interview with the workers. When Worker E (a worker at the hood (H-1)) was loosening the remaining two bolts of the storage container, after having removed four among the six bolts diagonally, he heard hiss of the inside pressure of the storage container leaking out. He also felt the lid raised upwardly. He collected samples of the smear of the entire circumference of the gap between the lid and the storage container, and confirmed that there was no

	contamination. As no contamination was confirmed, Worker E decided to continue the work. When Worker E removed the remaining two bolts, holding the lid with the other hand, the resin bags burst. He put the lid inside the hood.. Worker E felt wind pressure at the abdomen at the burst. All other workers also heard the bang. Through the half-face mask, Worker E confirmed there was not abnormal odor. Though wearing rubber gloves, Worker E, having touched the storage container, confirmed that there was no temperature rise. After the occurrence of the event, for preventing the expansion of the contamination, a greenhouse was set up at the entrance of the Room No. 108 at the corridor side. The gaps of the emergency exit of the Room No. 108 to the outside of the building was sealed from outside. The workers started to exit the Room No. 108 to the greenhouse at 14:30, June 6, 2017. By the body contamination test conducted in the greenhouse when they left the room, contamination was confirmed on the special work clothes, etc. of the five workers (more than 322 Bq/cm^2 (α-ray) at maximum). They carefully changed out of the contaminated half-face masks into the new ones and then took off the special work clothes. Skin contamination was detected in 4 workers out of five and nasal cavity contamination in three workers (24 Bq/cm^2 (α-ray) at the maximum). Based on the results of the body contamination test conducted when the workers exited the Room No. 108 and entered the greenhouse, the Room No. 108 was declared to be a restricted access area at 16:27. The workers with skin contamination conducted decontamination using neutral detergent, solid and liquid soap, shampoo, nasal irrigation kit, etc. in the shower room dedicated for decontamination in the controlled area. If the contamination test conducted by the decontamination assistant detected contamination, the decontamination was repeated with the cooperation of the decontamination assistant. When contamination was not detected any more, the workers received the final confirmation test by the body survey conducted by the

	radiation control staff. They left the controlled area after the level was confirmed to be lower than the detection limit (0.013 Bq/cm^2 (α-ray)). Before using the shower room for decontamination, the availability of the shower was confirmed. However, when the first worker used the shower for one or two minutes, the flow rate dropped. By drawing industrial water (filtered water) with a hose from the machine room of PFRF, decontamination using water resumed. Decontamination of the second worker was conducted with the shower as its flow rate recovered. However, the flow rate lowered again and other remaining workers' decontamination was conducted using the hose. Three of the five workers wore supplemental pocket dosimeters, and the read values were 2 μSv (Worker B), 3 μSv (Worker D) and 60 μSv (Worker E). The five workers were transported to Nuclear Fuel Cycle Engineering Laboratories, and the lung monitor measurement was conducted to get the information necessary for the decision of the need of urgent medical treatment (injection of chelate agent etc.). The results were 2.2×10^4 Bq and 2.2×10^2 Bq at the maximum for Pu-239 and Am-241 respectively. Accordingly, in cooperation with the National Institute of Radiological Science (hereinafter "NIRS"), injection of chelating agent was carried out aiming to promote removal of toxic substances taken in the body, such as Pu.. On June 7, 2017, the five workers were transported to the NIRS, and there the body surface was decontaminated again. Medical treatment including lung monitor measurement was provided. Based on the fact that 2.2×10^4 Bq and 2.2×10^2 Bq were confirmed, respectively, with regard to Pu-239 and Am-241 at maximum through the measurement of the five workers using lung monitor conducted at Nuclear Fuel Cycle Engineering Laboratories, their levels of exposure were considered to exceed or might exceed 5 mSv, the level at which report is required in the event of unplanned exposure of radiation workers entering a controlled area. Also there was a possibility that the surface contamination density of the floor etc. of the Room No. 108

	exceeded the level of the restriction area designated in the Oarai Research and Development Center (north zone) Operational Safety Program for Facilities Using Nuclear Fuel Material etc. (hereinafter referred to as "Operational Safety Program") (alpha nuclide: 4 Bq/cm^2). Therefore, it was judged at 13:27, June 7, 2017 that this accident was an incident of which report was required by laws and regulations based on the provision of the Article 62 – 3 of the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors. The incident was reported to the Nuclear Regulation Authority at 13:27. The surface contamination density of the Room No. 108 was confirmed to be 55 Bq/cm^2 (α-ray) and 3.1 Bq/cm^2 (β-ray (γ-ray)) at maximum by the measurement of the floor carried out on June 7, 2017. Also, the maximum dose equivalent of the Room No. 108 was 2 μSv/h. It was confirmed that there was no contamination at the corridor to the Room No. 108 which is inside the controlled area, or at the outside of the emergency exit of the Room No. 108 leading to the outside of the building.
Cause of the event	As for the efforts to investigate into the causes of the accident, fault tree analysis was conducted regarding the burst of the resin bags based on the results of the investigation on the situation at the time of the burst, interview with the workers and verification test of radiation decomposition of organic substances. As a result it was estimated that the factor which had led the resin bags to burst was "gas generation inside the bags". , Decomposition of "mixed organic substance", "plastic container" and "mixed water" brought about by α-ray from Pu generated gas such as hydrogen and methane, which caused inflation of the resin bags. Subsequently, by detailed investigation, the main factor of the burst of the resin bags was determined to be "mixed organic substance (epoxy resin)". Based on the estimated scenario of the process of the resin bags' burst, inside pressure of the resin bags for 21-year- storage period was calculated. The inside pressure was confirmed to exceed the level that can cause the burst of or damage to the resin bags of the same specification as the burst ones when opening the storage container.

	Through measurement and evaluation of the smear filters of the room contamination test and Pu dust monitor filters, and inspection and investigation on protective function of the half-face masks the workers were wearing, the factors that caused the intake of radioactive materials were estimated as below. - The half-face mask did not have function to prevent radioactive material adhered to the face etc. from entering the inside of the mask through the face contact parts. Therefore, it is likely that because of the masks' adhesion deterioration at the time of the burst, due to conversation, perspiration, etc., radioactive material having adhered to the face entered inside of the mask, and accordingly the workers took in the radioactive material. - When the workers removed the protective gears, measures to prevent the intake of radioactive material were not taken sufficiently; for example, when they wore new masks after putting off the old ones, they did not wipe off adhered contamination so faces etc. remained contaminated. Thus, it is possible that radioactive material such as Pu having adhered to the head and face were taken in. With regard to the direct causes, investigation on the situation at the time of the occurrence of the accident and analysis of the factors which brought about the contamination and exposure were conducted. Specifically, in addition to "the main cause for the bags' burst that is α-ray from Pu and 'mixed organic substance (epoxy resin)'" and the probable cause for the intake of radioactive materials that is "likely to be radioactive materials such as Pu which had adhered to the face etc. entering the inside of the mask through the face contact parts and being inhaled", the five problematic issues below were picked out based on the results of the interviews with people concerned. Then, the factors underlying these issues were analyzed and 12 direct causes were clarified. Shown below are the picked out five problematic issues ((1)～(5)), and 12 direct causes (①～⑫).

	(1) The samples used for x-ray diffraction measurement were encapsulated without epoxy resin removal treatment, and this information was not transferred to successors. ① The first Director of the Plutonium Fuel Technology Division should have made rules on the record of the condition of nuclear fuel materials stored in the storage containers and transferred the information to successors. However, as the management of nuclear fuel materials could be implemented with the nuclear fuel material transfer slip (including the slip for the transfer inside PFRF), rules were not made on the recording of nuclear fuel materials stored in the storage containers as well as of their condition. ② The first Director of the Plutonium Fuel Technology Division should have made rules on the work process that covered from applying oxidation heating to the samples used for x-ray diffraction measurement to storing the recovered nuclear fuel materials in the storage containers. Also he should have transferred the information to successors. However, knowing that stabilization treatment of carbonitride fuel etc. had been thoroughly achieved, he assumed that the same should have applied naturally for the samples used for x-ray diffraction measurement. Thus the rules were not made. ③ Around 1990, the Director of the Plutonium Fuel Technology Division determined that the nuclear fuel materials in the samples were stable without consulting with relevant people in the Plutonium Fuel Technology Division and in Plutonium Fuel Laboratory where the experiment was conducted. Also, he decided to abort the oxidation heating process of nuclear fuel materials mixed with organic substances that were taken over from the first Director of the Plutonium Fuel Technology Division. Since then, oxidation heating process of the samples used for x-ray diffraction measurement had not been implemented. ④ The Director of the Plutonium Fuel Technology Division was supposed to take the storage condition designated in the Guide to Safe Handling of Radiation into consideration and store the samples used for x-ray diffraction measurement after applying

	oxidation heating. In October 1991, however, contrary to the provision of the guide that stipulated the precondition for the storage that due attention must be paid to the rise in gas pressure caused by radiolysis (3. 3. 3., (4)), he considered without sufficient check that the epoxy resin in the samples used for x-ray diffraction measurement would rarely suffer influence of radiation from Pu that causes radiation damage and stored it without applying oxidation heating. ⑤ In 1996, while having confirmed the inflation of the resin bags and damage to the polyester container, the Director of the Plutonium Fuel Technology Division just replaced the resin bags and polyester container. In violation of the requirement of the Guide to Safe Handling of Radiation (the precondition for the storage), the Director did not take measures for improvement such as measures to avoid abnormal state, to provide a manual specifying the recording of the situation and to instruct periodic inspection. Since then improvement of the storage condition and periodic inspection had not been implemented. With respect to the failure to make rules on the matters concerning stabilization and storage of the nuclear fuel material and transferring the information, a manual concerning these matters should have been developed for implementation of the work, even though there was no clear requirement on "making the manual" in the Operational Safety Program at the time. Currently, based on the provision of "Making the Manual", the Article 2, Part 7 of the Operational Safety Program, "Matters concerning Nuclear Fuel Material Management" is provided in the two subsidiary rules; the "Guide to Using PFRF" and the "Work Manual of the Main Facility of PFRF". However, as they do not provide regulations for information transfer,, they need to be revised. With regard to the encapsulation of the samples used for x-ray diffraction measurement without removal treatment of epoxy resin whose trait it is to evolve gas was generally recognized, the precondition for the storage, "paying attention to the rise in gas

	pressure caused by radiolysis", which is stipulated in the subsidiary rule of the Operational Safety Program, the "Guide to Safe Handling of Radiation", was not considered. This lack of consideration conflicts with the Article 23, Part 6 of the Operational Safety Program of the time and the Article 19, Part 7 of the present Operational Safety Program, "Storage of Nuclear Fuel Material". (2) In reference to the storage of nuclear fuel material, technical information on handling and storing (safekeeping) Pu was not utilized. ⑥ With regard to the technical information indicated by the International Atomic Energy Agency (hereinafter referred to as "IAEA") and the Department of Energy (hereinafter referred to as "DOE") on handling and storing (safekeeping) Pu, the Directors of the Plutonium Fuel Technology Division, the General Managers of the Fuel Fabrication Monitoring Section and the Alpha-Gamma Section should have obtained the information and reflected it in the work as sections handling Pu, but they did not check this information. Therefore, measures to improve the storage condition of nuclear fuel material at PFRF, such as storing material in a metal container and excluding organic substances were not taken. With regard to the past failure to make use of the technical information on handling and storing (safekeeping) nuclear fuel material, technical information on handling nuclear fuel material should have been obtained and incorporated in the manual for preventing the occurrence of non-conformity, even though there was no clear requirement on prevention measures in the Operational Safety Program of the time. Today, a subordinate rule, the "Manual for Non-conformity Management and Measures for Improvement and Correction concerning Quality Assurance at the Oarai Research and Development Center" provides "matters concerning planning and implementing preventive measures". However, as the technical information was neglected, the procedures of preventive measures need to be improved.

	(3) At PFRF, the possibility of resin bag's burst and contamination of the room were not anticipated when opening a storage container to check the contents at the hood. ⑦ When developing the work plan for transferring the nuclear fuel material from the glove box, the General Manager of the Alpha-Gamma Section, the Manager and the person in charge should have selected equipment with high air-tightness, such as a cell and a glove box other than a hood. They should have prepared appropriate radiation protectors as well, if the work might involve opening the lid and checking the inside of the container etc. containing nuclear fuel material, even if it was a subsidiary task to check the storage container and inspect contamination. Also, they should have drafted a plan for non-regular work that includes detailed procedures. However, considering the stored nuclear fuel material had been kept properly with low-risk of contamination, thus assuming that the material had been treated with stabilization procedure, etc., they failed to make a detailed work plan (non-regular work plan) that would have prevented a risk of the room contamination by scattering nuclear fuel material and exposure of workers. ⑧The Safety and Nuclear Security Administration Department distributed the "Information on Nuclear Fuel Cycle Engineering Laboratories' interview with the Secretariat of the NRA" on January 26, 2017. However, the Director of the Fukushima Fuels and Materials Department, the General Manager of the Alpha-Gamma Section, the Manager and the person in charge did not notice the "Information on How to Handle in the Case That Involves Inflated Resin Bags" included in the attachments, as the distribution was aimed to disseminate the interview result. In reference to the failure to assume the possibility of the room contamination by the burst of the resin bags at the time of opening the lid and checking the contents of the storage container at the hood, even though a work plan was developed in accordance with the subsidiary rule of the Operational Safety

	Program the "Work Manual of the Main/Special Facility of PFRF" and with information available at the time of planning, occurrence of the accident was not anticipated due to the incorrect information on stabilization of the contents of the storage container. Therefore, procedures specified in the provisions of the paragraph 2, Article 16 of the Operational Safety Program need to be revised from the item 2, "Radiation Work Plan", to the item 4, "Consideration of Work Place, Work Contents and Radiation Protector". With respect to the failure of the relevant people in PFRF to notice the "Information on How to Handle in the Case That Involves Inflated Resin Bags" in the "Information on Nuclear Fuel Cycle Engineering Laboratories' Interview with the Secretariat of the NRA", the technical information was neglected as is the same with the above mentioned paragraph (2), and therefore, procedures of preventive measures should have been improved. (4) In reaction to the lid's floating and a hissing noise of inside air leak at the time when the bolts of the lid of the storage container was loosened, contamination test was conducted. However, the work was continued due to the failure to recognize the unusual situation such as the lid's floating as abnormal. ⑨ Worker E should have stopped the work when the lid floated and the hiss of inside air leak was heard. However, due to a lack of setting hold points (points to stop work), he could not recognize the incidents as abnormal and considered that he could remove the remaining bolts and open the lid without causing any problem. The work was continued from the failure to recognize the lid's floating and a hissing noise of inside air leak at the time when the bolts of the lid of the storage container was loosened as abnormality attributable to the gas generated through radiolysis. This is because nothing more than the contamination test was done as a response to the incidents by the judgement of the workers due to the lack of setting hold points. As a result, the work

	was continued without re-examining the work plan. Therefore, improved procedures of the "Consideration of Work Contents" need to be included in the Article 16, Part 2 of the Operational Safety Program, "Radiation Work Plan", when it is formulated. (5) Even though the workers wore half-face masks during the work to check the inside of the storage container in accordance with the work plan, they inhaled and took in scattered radioactive material because they did not anticipate the burst of the resin bags (causes concerning the work plan relate to (3) ⑦). ⑩ Radiation exposure could have been avoided when the whole body including the working gears and face were contaminated due to the burst of the resin bags by taking emergency steps to prevent the nuclear fuel material etc. having adhered to the skin from entering the inside of the half-face mask by sweat etc. However, as the Oarai Research and Development Center had not set clear procedures of emergency treatment, Worker E stayed where he had stood at the time of the occurrence of the accident until he exited the room in order not to expand contamination in the room, without taking measures such as wiping off and fixing (containment of) the contaminated parts or tightening the strings of the masks. ⑪ Advice by the staff of the Reprocessing Radiation Control Section on wiping off and fixing (containment of) the contaminated parts such as the face at the time of contamination, replacing the half-face masks and changing special working wears would have led to the prevention of exposure. However, he did not advise on wiping and fixing (containment of) contamination at parts such as the face, prioritizing replacing the half-face masks as there was no clear procedures of emergency treatment set at the Oarai Research and Development Center. ⑫ The Director of the Fukushima Fuels and Materials Department should have set up the greenhouse in as short a time as possible when there was necessity to set a greenhouse for workers to exit the room. However, they failed to anticipate the possibility of the accident of contamination spreading throughout

	the room in PFRF which requires setting up of a greenhouse. They were only ready for minor events, such as spot contamination induced by the pinhole of the glove. Thus it took time to procure material and set up the greenhouse. With respect to the workers' inhalation of nuclear fuel material scattered by the accident, the improvement at the planning stage is necessary as suggested at (3)⑦ Also, with regard to the infiltration of nuclear fuel material inside the half-face mask caused by the contamination around the face left without being removed immediately after the accident, the paragraph 4, "Removal of Contamination", of Article 19-2, "Measures Taken When Contamination is Confirmed", Part 2 of the Operational Safety Program needs improvement,. In regard to the fact that it took long time to set up the greenhouse, the subordinate rule of the Operational Safety Program, "Fukushima Fuels and Materials Department's Manual for Accident Response", requires that protective equipment be inspected and maintained at ordinary times for prompt and appropriate response to an accident, but the greenhouse materials was not covered in the manual. However, based on the accident response this time, which required the setting up of a greenhouse for the workers to exit, the matters relating to Article 28, Part 1 of the Operational Safety Program, "Activities in Emergencies", need to be improved. In order to identify the organizational factors lying behind the above direct causes, analysis of the underlying causes were conducted. For the analysis, organizational factors were categorized and sorted out in accordance with the national guideline "Perspective of organizational factors in analysis of underlying factors" and "JNES's table of organizational factors (hereinafter referred to as"JOFL"). As a result, 18 items were identified as the organizational factors lying behind the direct causes. Shown below are the 18 items of organizational factors (①～

	⑱) lying behind the direct causes for the problematic five issues ((1)～(5)). (1) For "the samples used for x-ray diffraction measurement were encapsulated without epoxy resin removal treatment, and this information was not transferred to successors." ① The Plutonium Fuel Technology Division (present Alpha-Gamma Section) was required to specify as a rule the storing and managing the record of nuclear fuel material in the storage container and its condition in addition to the information on measuring and administering (slip of nuclear fuel material transfer). However, as shown in the fact that management information explaining the storage condition of nuclear fuel material was not stored, work had been performed without developing the system for long-term storage in a safe manner, such as management standards. ② The Plutonium Fuel Technology Division (present Alpha-Gamma Section) was required to specify as rule the procedures for storing samples used for x-ray diffraction measurement in a storage container after putting it through the oxidation heating process. . However, a system for managing documents that ensures establishing and revising the work manuals etc. necessary for keeping facilities safe was not operated. ③ The Oarai Research and Development Center was required to hold education on operational safety by which the attending staff members understand the important items of the Guide to Safe Handling of Radiation. In fact, however, the relevant people in Oarai Research and Development Center (north zone) did not understand the points to consider concerning the condition of storing nuclear fuel material. Therefore, the Center did not confirm sufficiently the implementation of training of operational safety on the points to comply specified in the Guide (condition of storage). ④ The Oarai Research and Development Center was responsible for reviewing periodically the Guide to Safe Handling of Radiation for ensuring the understanding on the importance of compliance with the quality management system (hereinafter referred to as

	"QMS") and implementation of activities for operational safety. However, as indicated in the fact that the contents concerning the storage condition was no more than the description of general matters, failing to explain the targets and the background, it was not revised in the way that people using it can understand the rules. ⑤ The Plutonium Fuel Technology Division (present Alpha-Gamma Section) should have examined the effect on safety etc. with the concerned people including Scientists/Research Engineers with regard to the change of stabilization treatment including the method of oxidation heating treatment of the nuclear fuel material mixed with organic substance. However, as indicated in the fact that validity of the change was not discussed among the concerned people including Scientists/Research Engineers at the PFRF meeting etc., a system to check the validity of change in an important work process was not clearly established. ⑥ The Plutonium Fuel Laboratory (present Fuel High-Temperature Science Research Group)should have participated in the improvement of Pu handling technique which included oxidation heating treatment with regard to the stabilization treatment of nuclear fuel material mixed with organic substance. However, as indicated in the fact that the Scientists/Research Engineers who were also assigned other positions had little involvement in the activities for operational safety in the facility, the system for ensuring and maintaining safety was not integrated. ⑦ The Plutonium Fuel Technology Division (then) should have examined the necessity of replacing the polyester container with a metallic container after implementing oxidation heating treatment, as well as implementation of periodic inspection for the resin bags were used as boundary, and transfer of the relevant record. However, as indicated in the fact of failure to improve the storage condition by implementing periodic inspection, they just focused on restoring containers to the original condition by replacing the inside container and the resin bags with the new

	ones, measures for storing (safekeeping) nuclear fuel material safely for a long time were ignored at the workplace. (2) For "In reference to the storage of nuclear fuel material, technical information on handling and storage (safekeeping) of Pu was not utilized" ⑧ The Oarai Research and Development Center (Fukushima Administrative Department) should have appropriately improved the facility management based on the latest information on the safety management of facilities, which they should keep up with, on the basis of a safety-first policy. However, as indicated in the fact, they did not make efforts to collect overseas information and reflect such information in the facility management. A system to reflect knowledge obtained from overseas information etc. in the manual concerning preventive measures in the activities for operational safety was not made clear. ⑨ The Japan Atomic Energy Agency (hereinafter referred to as "JAEA") should have collected and explored information systematically on the basis of a safety-first policy through efforts which include obtaining and appropriately transmitting useful information on safety management of facilities such as overseas information on nuclear facilities. However, as shown in the fact that the department which assumes the responsibilities for compiling and transmitting such information was not appointed clearly the system to share overseas information and knowledge etc. at the organization was not made clear. (3) For "at PFRF, the possibility of resin bags' burst and contamination of the room were not anticipated when opening a storage container to check the contents at the hood." In addition to the organizational factors, those lying behind the (1) "the samples used for x-ray diffraction measurement were encapsulated without epoxy resin removal treatment, and this information was not transferred to successors " (①～⑦) are related. ⑩ The Alpha-Gamma Section should have fully examined the characteristics of the nuclear fuel material stored in the storage

	container and the materials mixed in before preparing the work plan. However, as pointed out, they assumed the contents had been kept safe in a stable condition as stabilization treatment was conducted by then Plutonium Fuel Technology Division, they lacked prudence required for handling nuclear fuel material safely. ⑪ The Fukushima Fuels and Materials Department (Alpha-Gamma Section) should have regarded the work of checking the storage condition of nuclear fuel material in a storage container sealed for a long time and that of transferring the nuclear fuel material as "3H work" (work prone to cause human error because a worker conduct the work for the first time or after a long interval or because the condition of the materials might have changed) and should have prepared detailed work plan which included work procedures and hold point. However, the "manual for planning and managing work" based on the quality assurance plan did not elucidate the preparation procedures for work plan of individual work. ⑫ The Oarai Research and Development Center should have made clear the procedures for preparing work plans concerning 3H work which has potential risks in a manual concerning safety management. However, a manual for planning 3H work which includes the definition of 3H work, work procedures, clear hold points was not prepared. ⑬ The manager of the Alpha-Gamma Section should have shared the shared information on the record of the inspection in 1996 among the Section (PFRF) and recognized it as important information when the storage container was opened. However, as indicated in the failure to check the provided past information on inspection, effort for face-to-face communication of important information concerning safety was insufficient. ⑭ The Fukushima Fuels and Materials Department should have reflected the useful information which was provided from other facilities in the facility management through efforts such as checking the contents and making enquiries. However, as pointed out in the fact that they did not check the contents as it was the

	interview information of another center or instructions for future interview, they lacked communication with the departments/sections providing important information on safety. ⑮ The departments/sections providing information (Safety and Nuclear Security Administration Department and Nuclear Safety Application Section of Oarai Research and Development Center) should have extracted information concerning safety from the information they acquired and added comments to attract attention of the people who would receive the information, as well as checked that the receiving side understood the information. However, there was not a clear system to specify appropriate communication with the receiving side concerning important information on safety obtained through interview with the Secretariat of Nuclear Regulation Authority. (4) For "In reaction to the lid's floating and a hissing noise of inside air leak at the time when the bolts of the lid of the storage container were loosened, contamination test was conducted. However, the work was continued due to the failure to recognize the unusual situation such as the lid's floating as abnormal". In addition to the organizational factors lying behind the above (1) concerning the management information of nuclear fuel material and (3) concerning work planning (①～⑦, ⑩ and ⑪), following organizational factors are pointed out. ⑯ The supervisor of the work should have stopped the work promptly in the event that a sign of abnormality was confirmed. However, while being in the position to supervise the work, he was engaged in the work himself, which made it difficult for him to make an appropriate decision for the work. Thus the personnel assignment was not suitable to implement the chain of command nor fulfill the role to make an appropriate decision. (5) For "Even though the workers wore half-face masks during the work to check the inside of the storage container in accordance with the work plan, they inhaled and took in scattered radioactive material because they did not anticipate the burst of the resin

	bags". In addition to the organizational factors underlying the above (1) concerning management information of nuclear fuel material and (3) concerning work planning (①～⑦ and ⑩～⑬), organizational factors below are pointed out. ⑰ The Oarai Research and Development Center (Director General, the Director of Fukushima Fuels and Materials Department, the Director of Health and Safety Department, and the supervisor) should have ordered the prevention of contamination expansion and internal exposure by measures such as simple decontamination by wiping the contaminated parts and fixation of contamination (containment) as initial response when body contamination was confirmed, aiming to prevent intake of nuclear fuel material attached to the skin that entered inside the half-face mask with sweat etc. However, the organizational system to check and make an appropriate judgement did not function as indicated in the oversight of the necessity of emergency treatment of body contamination. ⑱ The Oarai Research and Development Center (Director General, Director of Fukushima Fuels and Materials Department, and Director of Health and Safety Department) should have anticipated that there would be possible accidents at PFRF involving contamination by Pu of the entire areas of the room and whole body contamination. Also, they should have clarified the process of emergency response in the subordinate rules of the accident prevention rule. However, measures including implementation of periodic drill assuming accident involving whole body contamination and preparation for the equipment and material necessary for that were not made clear. (for the details refer to Attachments)
Kind of safety devices and their operating condition	No.
Impact of radiation	At the time of the occurrence of the event, the ventilation system of PFRF continued operation and appropriately kept the negative pressure in the controlled area, and also the values

	indicated by the monitoring posts and ventilation dust monitors of PFRF were within the normal fluctuation range. Accordingly, there was no impact on the environment by this event. - After the occurrence of the event, the ventilation system of PFRF keeps operation and continues to maintain appropriately the negative pressure in the controlled area. Also, values indicated by the Pu dust monitors of PFRF, ventilation dust monitors and monitoring posts on the site boundary were within the normal fluctuation range.
Workers' exposure	As efforts relating to exposure evaluation, in addition to evaluating the external exposure dose, analysis of bioassay samples of the workers and confirmation of the evaluation of internal exposure dose conducted by the NIRS as treatment were conducted. Also, evaluation of internal exposure dose was conducted taking into consideration the estimated result of the factors leading to the intake of radioactive material and the result of investigation concerning radiation control information of the Room No. 108. The effective dose concerning the external exposure was lower than the record level (0.1 mSv) with regard to all the workers. With regard to one of the workers, the effective dose (committed effective dose) concerning the internal exposure exceeded the dose limit of the radiation workers designated by the law and regulation, and also it was confirmed that there were workers whose level exceeded the warning level designated in the Operational Safety Program. Therefore, measures to limit radiation work of such workers in accordance with the Operational Safety Program.
Other damage	No.
Date and time of restoration	As efforts for the site restoration, following securing the route to access to the hood (H-1), fixation of the lid of the storage container in the hood (H-1), and transfer of the storage container from inside the hood (H-1) to the glove boxes (123-D and 124-D) in the Adjusting Room (hereinafter referred to as Room No. 101) were conducted. Subsequently, after enhancing the contamination management through efforts such as replacement of the greenhouse, contamination test and decontamination of the hood

	(H-1) and the Room No. 108 were conducted. With regard to the hood (H-1), decontamination and fixation of adhered contamination were carried out, while contamination check was conducted. With regard to the Room No. 108, contamination test and decontamination were conducted first for the floor and then for walls, ceiling and equipment such as the glove box. On September 8, 2017, there was occurrence of contamination incident of the workers' special work clothes at the Room No.101 in PFRF and subsequently the non-conformity management was implemented after emergency treatment. In reaction to this incident, the work in the Room No. 108 was suspended, and emergency inspection of the work procedures etc. was conducted. Also, the work plan was revised reflecting the points of improvement identified through the irregularity management of the contamination in the incident the Room No. 101, and training for the workers was carried out. After reinforcing safety measures of the work, contamination test and decontamination of the Room No. 108 were resumed. Decontamination and contamination test of the Room No. 108 were completed, and designation of the entrance restriction area was lifted on October 16, 2017.
Measures to prevent recurrence	[Countermeasures against direct factors] In terms of the 12 items of direct causes for the contamination and radiation exposure, prevention measures mentioned below will be implemented from two perspectives: (1) prevention of contamination and (2) prevention of exposure. Also, measures to be taken were considered with respect to the problems concerning the management of decontamination equipment and body contamination test that have become tangible in this accident. (1) Prevention of contamination (problematic incidents (1)～(4)) ① Measures against the cause ① The Alpha-Gamma Section will revise the "Guide to Using PFRF", which is a subordinate rule of the Operational Safety Program, and set out the creation and management of the record

	of nuclear fuel material stored in the storage container. Also, they will add the description concerning management of nuclear fuel material in the Work Manual of the Main Facility of PFRF, and in it clarify the necessary items of information on the storage of nuclear fuel material (radioactivity/radiation information, physical/chemical nature information, criticality management information etc., nature of the items included together, use history, etc.) and specify the creation of record and updating it every time work to store nuclear fuel material is conducted. Thus, the procedures for management of the record concerning such items will be developed and ensured. ② Measures against the cause ② The Alpha-Gamma Section will clarify the nature and storage situation of the nuclear fuel material that they handle at PFRF and store the nuclear fuel material in a safe and stable manner. The items below will be clarified for storing nuclear fuel material in a safe and stable manner. (a) In respect of the samples containing α-ray-emitting nuclides such as Pu and Am, organic substance, which is the source of radiolytic gas, the organic substance must be decomposed and removed by heating. (b) Powdery samples containing α-ray-emitting nuclides such as Pu and Am must be kept in a metal container in order to prevent contact with organic substance such as polyester. (c) As concerns the material of the container, appropriate incorruptible items that do not react physically or chemically with the contents must be chosen. (d) Material that is chemically active in the air or in the storage environment such as carbide must be applied stabilizing treatment or stored in an inactive environment. The above description is contained in the document of the management of nuclear fuel material added to the Work Manual of the Main Facility of PFRF as measures against the cause ①. ③ Measures against the cause ③

	The Alpha-Gamma Section will clarify the necessary items of information on the storage of nuclear fuel material (radioactivity/radiation information, physical/chemical nature information, criticality management information etc., nature of the items included together, use history, etc.) in consultation with relevant people and ensure the management of the record concerning such items by developing procedures for the management. 【same as the measures against the Cause ①】 The Alpha-Gamma Section will also clarify the nature and storage situation of the nuclear fuel material that they handle at PFRF and store the nuclear fuel material in a safe and stable manner. The items below will be clarified for storing nuclear fuel material in a safe and stable manner. 【same as the measures against the cause ②】 (a) In respect of the samples containing α-ray-emitting nuclides such as Pu and Am, organic substance, which is the source of radiolytic gas, the organic substance must be decomposed and removed by heating. . (b) Powdery samples containing α-ray-emitting nuclides such as Pu and Am must be kept in a metal container in order to prevent contact with organic substance such as polyester. (c) As concerns the material of the container, appropriate incorruptible items that do not react physically or chemically with the contents must be chosen. (d) Material that is chemically active in the air or storage environment such as carbide must be stabilized or stored in an inactive environment. ④ Measures against the cause ④ The Alpha-Gamma Section will provide training on the causes (gas generation attributable to epoxy resin and radiation of Pu) and measures concerning this accident with an aim to make the significance of 3.3.4 of the present Guide to Safe Handling of Radiation, “Pay due attention to the rise in gas pressure caused by radiolysis”, appreciated.

	⑤ Measures against the cause ⑤ The Alpha-Gamma Section will clarify the nature and storage situation of the nuclear fuel material that they handle at PFRF and store the nuclear fuel material in a safe and stable manner. 【Same as the measures against the cause ②】 The items below will be clarified for storing nuclear fuel material in a safe and stable manner. (a) In respect of the samples containing α-ray-emitting nuclides such as Pu and Am, organic substance, which is the source of radiolytic gas, the organic substance must be decomposed and removed by heating. (b) Powdery samples containing α-ray-emitting nuclides such as Pu and Am must be kept in a metal container in order to prevent contact with organic substance such as polyester. (c) As concerns the material of the container, appropriate incorruptible items that do not react physically or chemically with the contents must be chosen. (d) Material that is chemically active in the air or storage environment such as carbide must be applied stabilizing treatment or stored in an inactive environment. Also, the Alpha-Gamma Section will revise the "Guide to Using PFRF" to specify the periodic inspection of nuclear fuel material in storage. Also the Section will add the description concerning this periodic inspection in the Work Manual of the Main Facility of PFRF in which the items of inspection, method of inspection and frequency of inspection of contents (including the clarification of standards for deciding normal state and abnormal state and for replacing) are clarified. ⑥ Measures against the cause ⑥ The Fukushima Fuels and Materials Department will revise the Guide to Using PFRF to add instructions incorporating the latest information and knowledge on the storage of nuclear fuel

	material, as well as appropriately obtaining, listing and reviewing the latest information and knowledge on the storage of nuclear fuel material and creating a manual in the form of questions and answers concerning the information that needs attention until it is incorporated into the relevant rules. In this way they will establish the system to appropriately obtain knowledge such as the latest safety information on the storage of nuclear fuel material appearing in the DOE-STD Report and IAEA Safety Report and domestic information on the management of nuclear fuel material, review such information and reflect it in relevant regulations. ⑦ Measures against the cause ⑦ The Fukushima Fuels and Materials Department will review the PFRF's Oarai Research and Development Center (north zone) application for permission of change in the use of nuclear fuel material and the Operational Safety Program, as well as revising the Guide to Using PFRF to specify that the work involving opening the lid of a storage container should be conducted in an airtight facility such as a globe box. Also, they will revise the Common Work Manual of the Main Facility of PFRF and Special Facility to specify that measures below should be taken with respect to the case where handling nuclear fuel material whose components are not known clearly and safety is not confirmed. ➢ Basic matters such as safe handling of nuclear fuel material and work method (including how to choose the work place and protective equipment) will be clarified in the procedures for making safe work plan that takes risks into consideration. ➢ Hold points will be clarified in the work plan to stop the work in order to avoid risks when incidents that are not included in the normal process occur or a sign of abnormality is confirmed. ⑧ Measures against the cause ⑧ The Fukushima Fuels and Materials Department will

	appropriately obtain knowledge such as the latest safety information on the storage of nuclear fuel material appearing in the DOE-STD Report and IAEA Safety Report and domestic information on the management of nuclear fuel material, review such information and incorporate it into relevant regulations. 【same as the measures against the cause ⑥】 ⑨ Measures against the cause ⑨ In respect of the case where handling nuclear fuel material whose components are not known clearly and safety is not confirmed, the Fukushima Fuels and Materials Department will clarify hold points in the work plan to stop the work in order to avoid risks when incidents that are not included in the normal process occur or a sign of abnormality is confirmed. 【same as the measures against the cause ⑦】 (2) Prevention of exposure (problematic incidents (5)) ① Measures against the causes ⑩ and ⑪ The Fukushima Fuels and Materials Department will revise the Common Work Manual of the Main Facility of PFRF and Special Facility to require choosing protective equipment with high safety in the case of handling radioactive material etc. of which trait is not clearly known and safety is suspicious, in case of the occurrence of contamination. The Health and Safety Department will revise the Guide to Safe Handling of Radiation of Oarai Research and Development Center (north zone) to specify the items, standards and frequency of inspection of the respiration protector and the response in the event that the face and surrounding areas are contaminated so as to clarify the response (involvement) to an accident. The Department will also take the following temporary measures to prevent exposure. ➢ Ensure and enhance inspection concerning items having influence on the protective capabilities such as stretch of "fastening strings" necessary for appropriate use of respiration protectors, and improve training for ensuring

	appropriate application of protectors. ➢ Clarify by indicating the procedures of the method to remove or fix radioactive material adhering to the vicinity of the face as emergency step of body decontamination in the case where the head and face are contaminated with α-ray-emitting nuclides such as Pu, and the method to temporarily intensify the contact of the mask by means such as tying up the "fastening strings" tighter in case of reduction in the contact of the half-face mask due to sweat etc. Consider the method to remove the protectors after exiting the contamination site with contamination at the head and face and the method to remove and fix the contamination at the time of replacing the half-face mask and taking nose smear sample. Also, specify the procedures for reducing the possibility of internal exposure. ➢ In terms of the items concerning contact of half-face masks, improve the measures for ensuring the right application of the masks such as prior-to-use inspection and fitting test. ② Measures against the cause ⑫ The Oarai Research and Development Center will take the measures shown below. For this purpose, the Center will revise the Guide to Safe Handling of Radiation of Oarai Research and Development Center (north zone) to specify the standards for exit in the event of body contamination, prevention of contamination expansion and method to maintain and manage the equipment and material. ➢ Define standards for exit (e.g. expansion of contamination to wide areas in the room, body contamination in the vicinity of the face, etc. is confirmed) and the measures to minimize the expansion of the contamination (e.g. preparation of curing sheets covering the body, simple tents, etc.) in order to prevent hesitation and delay in making a decision and response including making the workers exit from the accident site after taking measures to limit the scatter of body contamination (e.g. covering the body with curing sheets)

	accepting a certain degree of expansion of contamination within the controlled area. Also, stipulate measures to minimize the influence of expansion of contamination. As to the above measures, consider setting outside the work site a greenhouse for exit beforehand in preparation for the case where the impact at the time of the accident is expected to be large because of the specialty of the work or the hazardous nature of the handling object, or there is a risk of the spreading of contamination beyond the controlled area in exiting the accident site. Reconfirm the competency of the equipment for emergency, and staff necessary in the event of an accident. Establish the system for maintenance and management so that such equipment, material and staff are available at any time, as well as the system for immediate response to the accident through effective training. [Countermeasures against organizational factors] With regard to the identified 18 items, following measures will be taken for correction. ① Measures against the organizational factor ① The Alpha-Gamma Section will revise the Guide to Using PFRF, a subordinate rule of the Operational Safety Program, to specify management of the record of storage (safekeeping) and handling of nuclear fuel material in storage. Also, the Section will add the description concerning the management of nuclear fuel material in the Work Manual of the Main Facility of PFRF, specifying management standards which are necessary for storing (safekeeping) and handling nuclear fuel material in storage (for characteristics and condition of the nuclear fuel material, and characteristics etc. of the material included in it, etc.) and management book, as well as establish the system to use such management information in the organization. Also, with regard to the facilities other than PFRF of the Fukushima Fuels and materials Department, the Safe Work Manual of the Irradiation Fuel and Material Testing Facilities (south zone) will be revised to include description on the management of record concerning storage (safekeeping) and

	handling of nuclear fuel material it possesses. ② Measures against the organizational factor ② The Alpha-Gamma Section will add the work manual etc. in the document management system, clarifying the work procedures (including oxidation heating treatment) for ensuring appropriate storage (safekeeping) of nuclear fuel material. Also, the Section will revise the "Manual for the Irradiation Fuel and Material Testing Facilities", a plan for qualification assurance of nuclear reactor facilities and facilities using nuclear fuel material etc., to develop the system to systematize and periodically review the points and methods of document review for appropriately formulating and revising the work manuals etc. that are necessary for safely maintaining facilities. ③ Measures against the organizational factor ③ The Oarai Research and Development Center will revise the quality target of the Center to clarify the measures to implement training concerning the lessons learned from the accident (including the issues identified in the causes) and follow up implementation status of the training. The Center will continuously conduct evaluation of the achievement of qualification target and management review. Also, the Center will compile the result of the accident and the lessons learned as training material. ④ Measures against the organizational factor ④ The Health and Safety Department will make documents, in the form of a review manual etc., on the perspective of document review and the method of incorporation into a manual in the aim of maintenance and management of the rules concerning operational safety activities and promoting understanding on the purpose and background of the documents for conducting operational safety activities. 【related to the organizational factor ②】

	⑤ Measures against the organizational factor ⑤ The Alpha-Gamma Section will revise the quality assurance plan of nuclear reactor facilities and facilities using nuclear fuel material “Manual of Facilities Testing Fuel Material” and “Work Manual of the Main/Special Facility of PFRF”. Thus the Section will establish the system for the management of change, such as the system for deliberation by the council including relevant researchers on the changes and effect on safety, in the event of changing important work process related to operational safety activities. ⑥ Measures against the organizational factor ⑥ The Fukushima Fuels and Materials Department will explore and implement the unification of the system for securing and maintaining safety for ensuring safe and systematic implementation of the decommissioning plan of PFRF which has already been decided, in cooperation with the Fuels and Materials Engineering Division (a fuel high temperature science research group belonging to the Alpha-Gamm Section). ⑦ Measures against the organizational factor ⑦ The Alpha-Gamma Section will revise the Manual for the Irradiation Fuel and Material Testing Facilities”, a plan for qualification assurance of nuclear reactor facilities and facilities using nuclear fuel material etc., to establish the system to raise sensitivity to potential risks and promote activities for improvement (always keep a “questioning attitude”), and conduct training which includes the study of the accident case of PFRF. Also, the Section will add a document concerning the management of nuclear fuel material to the Work Manual of the Main Facility of PFRF. The Manual will include the provisions on the management standards necessary for storing (safekeeping) and handling the nuclear fuel material (characteristics and condition of the nuclear fuel material, characteristics of other included materials, etc.) and the management book, as well as

	establishing the system to use the management information in the organization. 【same as the organizational factor ①】 ⑧ Measures against the organizational factor ⑧ The Fukushima Fuels and Materials Department will in cooperation with the Safety and Nuclear Security Administration Department revise the Manual for the Irradiation Fuel and Material Testing Facilities", a plan for qualification assurance of nuclear reactor facilities and facilities using nuclear fuel material etc. In order to reflect the information of the operational safety activities of other facilities in the prevention measures, well-developed systems will be established to obtain overseas and domestic information related to safety management of facilities and reflect it in the operational safety activities. Also, the Department will strive to improve the facility management appropriately. The Oarai Research and Development Center will in cooperation with the Safety and Nuclear Security Administration Department organize the system for sharing information useful for safety management among relevant sections and departments and establish the system to reflect the information in the improvement of the appropriate facility management. ⑨ Measures against the organizational factor ⑨ The Safety and Nuclear Security Administration Department will include relevant measures in the Manual of Application of Prevention Measures to Wide Areas for transmitting information such as the one from overseas and the one on interview with the regulatory body to the R&D centers effectively. The Nuclear Safety Application Section will develop the system for sharing information useful for safety management among relating sections and departments. ⑩ Measures against the organizational factor ⑩ The Alpha-Gamma Section will revise the "Manual for the Irradiation Fuel and Material Testing Facilities", a plan for

	qualification assurance of nuclear reactor facilities and facilities using nuclear fuel material etc. , the system to raise awareness of potential risks and implement improvement activities (always keeping a "questioning attitude") will be established. Also, the Section will provide training which includes the study of the accident case of PFRF for raising awareness of potential risks.【same as the organizational factor ⑦】 ⑪ Measures against the organizational factor ⑪ The Alpha-Gamma Section will develop the work procedures (including hold points) concerning the 3H work. To this end, the Section will revise the "Manual for the Irradiation Fuel and Material Testing Facilities", a plan for qualification assurance of nuclear reactor facilities and facilities using nuclear fuel material etc., and the Work Manual of the Main/Special Facility of PFRF and clearly indicate the process for making work plans concerning individual tasks. With regard to the facilities of the Fukushima Fuels and Materials Department other than the PFRF, the Section will clearly indicate the process for making work plans concerning individual tasks by revising the Manual for Safe Work of the Irradiation Fuel and Material Testing Facilities (south zone). ⑫ Measures against the organizational factor ⑫ The Oarai Research and Development Center will revise the "Manual for Safety Management of Work", the "Manual for Safety Management of Irregular Work" and the "Oarai Research and Development Center (north zone) Guide to Safe Handling of Radiation" to clarify the standards for developing the work plan which includes the hold point of the 3H work (including the consideration of condition change). 【related to the organizational factor ⑩】 ⑬ Measures against the organizational factor ⑬ The Alpha-Gamma Section will revise the "Manual for the Irradiation Fuel and Material Testing Facilities", a plan for

	qualification assurance of nuclear reactor facilities and facilities using nuclear fuel material etc. The Manual will include the description of appropriate reporting of information necessary for the facility management and the work management through consciously checking information on the operational safety activities from the members of the Section, as well as the description of implementation of information sharing on a face-to-face basis. ⑭ Measures against the organizational factor ⑭ The Fukushima Fuels and Materials Department will improve the "Manual for the Irradiation Fuel and Material Testing Facilities", a plan for qualification assurance of nuclear reactor facilities and facilities using nuclear fuel material etc. The Manual will include the system to gather domestic and overseas information related to safety management of facilities, aiming to reflect information gained from other facilities in the operational safety activities as preventive measures. Also, the Department will strive for appropriate facility management. 【same as the measures against organizational factor ⑧】 ⑮ Measures against the organizational factor ⑮ The Safety and Nuclear Security Administration Department will include measures to effectively transmit the information such as overseas information and information on the interview with the regulatory body in the Manual of Application of Prevention Measures to Wide Areas. The Nuclear Safety Application Section of the Oarai Research and Development Center will develop a system for sharing information useful for facility management among relevant sections and departments. ⑯ Measures against the organizational factor ⑯ The Director General of Oarai Research and Development Center and the Director of the Fukushima Fuels and Materials Department will establish the management structure of work to

	ensure check and appropriate judgement through the chain of command that enables managers to appropriately conduct facility management. ⑰ Measures against the organizational factor ⑰ The Oarai Research and Development Center (the Director General, the Director of the Fukushima Fuels and Materials Department, the Director of Health and Safety Department and managers) will clarify the roles in the emergency response to the accident causing body contamination. Also, they will establish the system to ensure check and appropriate judgement through the chain of command. 【related to the organizational factor ⑯】 ⑱ Measures against the organizational factor ⑱ The Oarai Research and Development Center will specify regular implementation of training for accident causing the contamination of the entire areas of the room and the whole body in the Medium Plan of Nuclear Disaster Prevention Drill. Also, the Center will determine the procedures of emergency response including the preparation of necessary equipment and materials in the accident response manual, etc. of the respective departments and sections. The Center will also clarify the method to decontaminate the radioactive material adhered on and near the face and the method to measure contamination using a survey meter after decontamination in the event of the occurrence of body contamination, and revise the Radiation Control Manual of the Guide to Safe Handling of Radiation (north zone). [Improvement of the problems having emerged after the occurrence of the accident] (1) Management of decontamination equipment As concerns the shower for decontamination, inspection had been implemented periodically in accordance with the subordinate rule of the Operational Safety Program, "Fukushima Fuels and Materials Department's Manual for Accident

	Response", and "Guide to Safe Handling of Radiation". However, as the decontamination shower was not available when it was necessary due to a trouble with it, water was drawn from another building by a hose as alternative means. Thus, it turned out that there is a problem in the radiation management of the controlled area, in the respect of the management of the cleansing equipment. Following are the causes and measures concerning this problem. · Direct causes: The person in charge in the Alpha-Gamma Section should have fixed (replaced) the pressure reducing valve, the cause of the trouble, to get it back to normal, when he noticed the lowered water pressure. However, he did not fix it appropriately, thinking there was no problem as the water came even though the pressure was low and without noticing that it would disrupt the long use of the shower. · Measures: With relation to the method to inspect the decontamination facilities and the maintenance and management of the system, the Alpha-Gamma Section will revise the Management Manual by adding to it the description of inspection items of decontamination facilities for ensuring inspection and appropriate maintenance and management. Also, organizational factors of these factors were identified, and measures were considered. · Organizational factor: The Alpha-Gamma Section should have clarified the maintenance and inspection methods in the event of failure of the facilities for emergency response and confirmation of signs of failure. However, the Section did not clarify the rules concerning maintenance and inspection of facilities based on the level of importance. Therefore, repair (replacement) was conducted in each case considering the situation of using. · Measures: The Alpha-Gamma Section will add document to the Work Manual of the Main/Special Facility of PFRF to

	clarify the rules on the method of maintenance and inspection in the event that facilities for emergency response breaks down or signs of failure is detected and ensure the facility management. With regard to the facilities other than PFRF in the Fukushima Fuels and Materials Department, the Section will revise the Safe Work Manual of the Irradiation Fuel and Material Testing Facilities (south zone) to ensure the facility management by clarifying the rules of maintenance and inspection on the occasion of the failure of emergency response facilities or noticing the sign of failure. (2) Management of body contamination test When the workers exited from the controlled area of PFRF after undergoing body decontamination, body contamination test was conducted in accordance with the subordinate rule of the Operational Safety Program, the "Guide to Safe Handling of Radiation". The result was lower than the lower detection limit. The problems is that even though the result of the contamination test was lower than the lower detection limit, body contamination still remained. Following are the causes and measures concerning this problem. · Direct causes: Staff of the Reprocessing Radiation Control Section took time to carefully conduct the direct survey of α-ray, but remaining contamination was overlooked. · Measures: In reference to the method to confirm body decontamination, the Health and Safety Department will revise the Radiation Control Manual (north zone) to clarify the method of body decontamination, procedures concerning the measurement after the decontamination, etc. The Manual will include provisions on method and process of body contamination measurement in the case of body contamination with radioactive material and implementation of training. Also, organizational factors of these causes were identified

	and measures to be taken were considered. · Organizational factor: The Health and Safety Department (Facility Radiation Protection Section II) should have implemented the measurement of contamination check after the body decontamination in a way to avoid oversight and confirmed the condition by following checks. However, the Department did not clarify the procedures etc. concerning contamination check after decontamination. · Measures: The Health and Safety Department (Facility Radiation Protection Section II) will clarify the method to decontaminate the radioactive material having adhered near the face and the method to measure contamination using a survey meter after decontamination in the event of the occurrence of body contamination, and revise the Guide to Safe Handling of Radiation and the Radiation Control Manual (north zone). These measures are the same as the organizational factors ⑱ of the "measures against the organizational factor". [Summary of the direct causes and the measures to be taken] (1) The 14 items of causes in total, which include 12 items of direct causes and two items of causes for identified other problems concerning the decontamination facilities and body contamination check, did not fulfil the safety requirements. Measures against respective causes must be taken. Among others, the following two factors are considered to be the most serious causes of the accident. ① In 1991, against the requirements of the Guide to Safe Handling of Radiation (condition of storage), samples having been used for x-ray diffraction measurement was stored in the storage container No. 1010 without oxidization heating treatment. ② In 1996, while break in the polyester container and inflation of the resin bags were confirmed, against the requirements of the Guide to Safe Handling of Radiation (condition of storage), appropriate measures of replacing the container with a metallic

	one and appropriate inspection were not taken and the information on the confirmed condition was not passed down to the successors. In short, nuclear fuel material was stored in the storage container without stabilization treatment against the requirements of the Guide to Safe Handling of Radiation (condition of storage). The nuclear fuel material in storage kept stored without periodic inspection, and such information was not transferred to the successors. Also, related rules were not established. Therefore, the following measures should be taken promptly. ➢ Training on the causes of the accident (occurrence of gas generation by the influence of epoxy resin and radiation of Pu) and appropriate measures will be implemented for ensuring understanding on the meaning of "to pay full attention to the rise in the gas pressure attributable to radiation degradation" which is a precondition for the storage of nuclear fuel material. (measures against the cause ④) ➢ Common "management standards" of the entire JAEA will be developed on the following matters for handling nuclear fuel material safely: matters concerning applying, in principle, stabilization treatment in the case of storing Pu for stable storage of nuclear fuel material; matters concerning conducting inspection in an airtight facility such as a cell and a glove box, if it involves opening the lid of the container storing Pu; and necessary items of information on such storage (radioactivity/radiation information, properties of the substances contained together, use history, etc.). (Measures against the cause ③, ④ and ⑤) (2) In addition to the causes mentioned in (1), opportunities to prevent the risk were missed as shown below. ① While information on the contents of the storage container was surveyed at the stage of planning inspection etc. of the storage

	containers, they assumed that the nuclear fuel material was stored in a stable condition. Accordingly, the hood was chosen as the place of work, and a detailed work plan to prevent the contamination risk was not made. As a result, the storage container containing nuclear fuel material exceeding the maximum handling amount of the hood (H-1) (< 300 g) was opened at the hood (H-1). ② During the inspection work, the workers failed to recognize the hiss of internal pressure being released as abnormality when the bolts fixing the lid of the storage container were loosen. As a result, they did not stop the work. From the perspective of preventing the occurrence of the similar accident in the future, it is important to take the following measures. ➢ Make safe work plans that take risks into consideration by clearly indicating in the procedures basic items which include selection of the sealed appropriate work place other than hood for opening the lid of an airtight storage container of which inside cannot be checked, and method of work (including the selection of work place and protectors) (the measures against the cause ⑦) ➢ For risk prevention, specify the hold point to stop work in the case of the occurrence of an event that is not expected in the procedures or the sign of abnormality being confirmed (the measures against the cause ⑨) (3) The emergency equipment and body contamination check were not appropriate. ① Due to the defect of the equipment such as the shower for decontamination and the inappropriate periodic inspection of the decontamination shower, the shower could not be used when it was necessary. Also, lack of assumption that accident requiring setting a greenhouse would occur, it took long to build the greenhouse.

	② With regard to the exit of the workers, appropriate contamination check was not conducted and remaining contamination was overlooked, and as a result, the workers were allowed to exit. The following measures will be taken for the above issues. ➢ Based on the result of checking the preparation situation of decontamination equipment (shower for decontamination and decontamination kit), greenhouses and curing material, which are necessary for emergency response, the equipment that is necessary for the response at the time of the occurrence of contamination will be clarified in the manual etc. Also, training is being provided on setting the greenhouse and conducting body decontamination. ➢ The common guideline of the JAEA concerning response in the event of the occurrence of body contamination was formulated. In it, basic items concerning the method to measure body contamination (points of consideration to avoid overlook contamination), as well as method to conduct decontamination of contaminated people, were clarified. [Summary of measures against the organizational factors] Eighteen items of the organizational factors were sorted out as below using the categorization of JOFL. Also, eight organizational factors were classified into the following three factors: factor concerning encapsulation, factor concerning encapsulation/storage management, and factor concerning planning/implementing work. (1) The system to manage work (decision-making process) was not clear (factor concerning encapsulation). ① The system to check appropriateness of work process is not clear. 【Organizational factor ⑤】 ② The structure for facility security is not united. 【Organizational factor ⑥】 ③ The system concerning storage of nuclear fuel material which

	includes technical standards is not developed. 【Organizational factor ①, ② and ⑦】 (2) The effort to reflect knowledge on nuclear safety in work was insufficient (factor concerning encapsulation/storage management). ④ Check of security training concerning storage of nuclear fuel material is not sufficient. 【Organizational factor ③】 ⑤ The effort for preventive measures to reflect international standards and knowledge of other facilities is not sufficient. 【Organizational factor ⑧, ⑨, ⑭ and ⑮】 (3) Attention was not fully paid to securing safety (questioning attitude) (factor concerning planning/implementing work). ⑥ The system to make rules on work procedures was not sufficient. 【Organizational factor ④, ⑪, ⑫ and ⑱】 ⑦ Ignorance of potential risks and lack of carefulness to securing safety. 【Organizational factor ⑩ (⑦) and ⑬】 ⑧ As the supervisor was engaged in the work, he could not fully accomplish the responsibility as supervisor. 【Organizational factor ⑯ and ⑰】 Also, the above factors (1), (2) and (3) were delved into deeper in order to determine the fundamental causes. The following measures will be taken against these causes. (a) Effort to improve the operational safety activity was not made. (Fundamental cause) With reference to the storage/handling of nuclear fuel material, investigation/reflection of the latest knowledge that can be obtained by sharing information concerning standards and similar facilities among relating sections and departments, as well as preparation for responding properly in the event of emergency, were not sufficient. (Measures) · For an appropriate security management of facilities, the

	managers (Director and General Manager) will ensure that the latest knowledge concerning storing/handling nuclear fuel material is reflected and the preparation measures for the presumable accident/trouble are clarified in the work procedures of emergency response. Specifically, the situation of the reflection of the latest knowledge on the storage/handling of nuclear fuel material for appropriate security management of the facilities as well as clarification of emergency work procedures will be clarified in the QMS document (review the manual etc.) as a perspective or review of planning individual work. · The Director will establish the system to make use of the non-conformity and findings that are common across organizations in the effort to prevent the occurrence of the similar accident again (implementation/improvement of the Corrective Action Plan (CAP) by respective departments, involvement of specialists (nuclear handling managers), etc. Specifically, it will be clarified in the QMS document (communication manual etc.) that information of non-conformity and findings (incident, response, etc.) will be confirmed in the communication among the respective organizations such as the meeting of the department. (b) Attention was not paid enough to potential risks. (Fundamental cause) When planning and implementing work, attention was not sufficiently paid to potential risks (questioning attitude), and the work that could cause Pu contamination was conducted at a hood as regular work. Thus, effort to avoid wrong judgment was not made. (Measures) · The supervisors (Directors and General Managers) will ensure checking potential risks. To this end, they will take measures such as confirming from several viewpoints the creation of the plan based on the procedures for developing the plan of individual work and the confirmation of appropriateness (identification of potential risks and

	measures against them). Specifically, viewpoints of the review in checking the individual work plan will be clarified in the QMS document (review the manual etc.). · The supervisors (Directors and General Managers) will conduct case study with lessons learned from the accident, after understanding where the cause of the accident exists and reflect it in the work, for raising the sensitivity toward risks. While doing so, they will consider and execute measures to reduce the harm of the risks. Specifically, they will set the implementation of training concerning the lessons learned from this accident in the quality target, and evaluate the implementation situation which includes the levels of understanding of the trainees. The training also covers clerical staff. (c) The role of a senior supervisor was not achieved. (Fundamental cause) The understanding of the senior supervisor was not sufficient on the risks of nuclear fuel material long in storage and issues concerning emergency response. He did not formulate and execute policy, instruction, check, etc. concerning necessary safety measures and treatment. Thus, he failed to function as expected.. (Measures) · The senior supervisor (Director General and Director) will extract issues in the operational safety activities and display the specific activity policy (plan) concerning necessary safety measures, treatment, etc. as well as checking the situation of activities appropriately and giving instruction. Thus they will create the environment to entrench continuous improvement. Specifically, check of the work plan etc. by the Director General in the emergency safety inspection that is conducted in response to the contamination accident at PFRF etc. will be mentioned in the quality target as a responsibility of respective Directors to be continuously implemented periodically. [Information sharing among the relevant sections and

	departments for preventing the occurrence of the similar accident] The inappropriate point of the management (non-conformity) of nuclear fuel material led to the transferring work of the nuclear fuel material. The nuclear fuel materials with no use schedule was kept in a glove box etc. at the facility under the pretext that they were still in use. This non-conformity was observed at several other JAEA centers. It was pointed out in the meeting of the Nuclear Regulation Authority held on February 15, 2017, and correction of the situation was required. In response, correction work was being implemented in the four centers based on the correction plan for the use, storage and disposal of nuclear fuel material in accordance with the Operational Safety Program. The accident occurred during this correction work was carried out. After the occurrence of this accident, renewed effort was made to ensure the safety first policy in the entire JAEA, and similar work handling nuclear fuel material was all stopped. Investigation and inspection were conducted to check the management conditions of nuclear fuel materials and the soundness of the containers keeping or storing nuclear fuel materials (hereinafter "storage container"). Based on the results of the investigation, gas generation and break of the storage container etc. were checked and evaluated, and safe storage/keeping was confirmed. With reference to the containers of the same kind as the one that burst at PFRF, records have already been checked separately, and appropriate approach will be taken in line with the measures to prevent similar accident based on the result of the investigation into the causes. The causes of the accident compiled based on the result of investigation into/analysis of causes will be regarded as an issue of the entire JAEA. In accordance with JAEA's "Manual for Information Sharing among the Relevant Sections and Departments of JAEA", the measures will be taken concerning the following items in order to

	prevent the occurrence of the similar accident (already partially implemented). (1) Formulation of management standards of nuclear fuel material and their incorporation into the manuals of the centers The measures to prevent the similar accident was incorporated, and common "management standards" of the entire JAEA was formulated. The management standards include provisions on the items below based on the response to this accident. · With regard to the storage of Pu, stabilization treatment should be applied in order to prevent mixture with organic substance, unless the stabilization has an effect on the intended use and safety is confirmed. · Inspection of containers storing Pu that involves opening the container or when the soundness of the boundary of containment cannot be confirmed should be conducted in a cell, glove box or other airtight facilities (hereinafter referred to as "cell etc."). · Opening of a container of which contents cannot be clearly determined should be conducted in a cell etc. · The container storing nuclear fuel material should be made from material having corrosion resistance. With the tight lid that does not open easily, the container should have the structure to prevent leakage of nuclear fuel material and causing contamination. · The information on physical/chemical characteristic, weight, application situation of stabilization treatment, etc. of nuclear fuel material should be recorded for each container. Each center will incorporate these management standards into its own manual and start operation, as well as restarting the similar work that has been suspended. With regard to the above "container storing Pu", the metallic container outside the resin bags is the storage container of the use permission at PFRF. Therefore, at PFRF, work involving opening the storage container will be conducted in a cell etc. from now on.

	On the other hand, at other facilities of JAEA, the storage container is the container storing nuclear fuel material inside the resin bags, and the work involving opening the lid is being conducted in a cell etc. (2) Formulation of the guideline concerning measures taken in the event of body contamination and its reflection in the manuals of the centers Method and procedures of exit from the contaminated area in the event of body contamination with nuclear fuel material etc. and decontamination and body contamination measurement of the contaminated people were considered. Thus, the common guideline of the entire JAEA which incorporated the measures concerning prevention of exposure was formulated concerning the approach based on the contamination management in the event of body contamination. The following items were considered in the formulation of the guideline. · Basic principles of the approach to exit from contaminated area, decontamination of contaminated people and measurement of body contamination (priorities in response, respect for human life, prevention of internal exposure, prevention of contamination expansion, etc.) · Measures to prevent internal exposure of the contaminated people when they exit from the contaminated area, and measures to prevent contamination expansion from the contaminated area. · Decontamination measures based on the prevention of internal exposure of contaminated people and prevention of expansion of contamination (preparation before starting decontamination, check/judgement during/at the end of decontamination). · Method to measure contamination situation of contaminated people before and after decontamination and points to note at measurement. Each Center will establish/revise the manuals etc. based on

	this guideline by the end of FY 2017, and start operation sequentially. (3) Investigation of facilities and equipment for emergency response and implementation of training Based on this accident, the current situation including preparation situation of decontamination facilities (decontamination shower and decontamination kit), greenhouse, and curing material that are necessary for emergency response was checked at all the centers. As a result, currently, decontamination facilities etc. were maintained and managed appropriately in the condition that can respond promptly in emergencies. However, there were some cases where setting and inspection of them were not clearly mentioned in the manuals etc. Therefore, in order to ensure appropriate response to contamination in wide area of the room and internal exposure, facilities necessary for the response at the time of the occurrence of contamination at each facility is being clarified, and the method of periodic inspection for confirming the maintenance of facility's function is being incorporated into the manual in a planned way. It was confirmed that training using equipment for emergency response assuming serious body contamination that occurred in this accident was not implemented at many centers. Therefore, at the main facilities of all the centers (those facilities where contamination of wide area inside room was assumed), training on setting a greenhouse and body decontamination was planned and effective training is being conducted in sequence, taking the following items into consideration. · Conduct training with understanding its purpose in order to be able to set the equipment appropriately at the time of accident and other necessary occasion. · Conduct the training with the right procedures, people, equipment, etc. that correspond with the assumed accident and the circumstance of the site. · The evaluation of the training is conducted by a right person,

	and the problems identified in the evaluation are reflected in the next training. · Conduct training not only for the accident victims but also for the people who help decontamination of the victims. The knowledge gained through the training is reflected in the guideline mentioned at the above (2) as appropriate. Also, for continuing the training in future, training assuming contamination in wide area inside the room should be included in the each center's training plan of every fiscal year. Additionally, continuous effort will be made for improvement that includes increasing the number of workers who can respond at the time of the occurrence of the accident and improving the workers' skill for accident response. (4) Understanding of the issues by the senior management and ensuring operational safety activities Based on the measures against the fundamental causes, at each center, the senior managers (Director and General Manager) will extract problems in the operational safety activities and create the environment where continuous improvement is entrenched. To this end, they will lay out the specific action policy (plan) concerning measures etc. (measures for reducing risks /improvement of the measures), and check and instruct the situation of action appropriately. Therefore, they will set the quality target based on the following items to ensure understanding of problems and improvement of operational safety activities. · For appropriate execution of security management of the facilities, supervisors (Director and General Manager) will ensure review through efforts such as reflection of the latest knowledge on storage and handling of nuclear fuel materials and clarification of work procedures in preparation for possible accident and trouble. · The Director will establish the system to utilize the common non-conformity and findings to prevent the occurrence of accidents including the one similar to this accident.

	· The supervisors (Director and General Manager) will ensure check of potential risks through efforts including confirmation of development of a work plan and its validity check from several perspectives. · The supervisors (Director and General Manager) will conduct the case study of this accident for raising the sensitivity to risks. In doing so, they will consider and implement the measures to reduce risks and to improve measures of their own work.