Attachment 2

The results of the survey on the conduct of radiation exposure dose control at the TEPCO Fukushima Daiichi Nuclear Power Plant

30 October 2012

1. Objectives

(1) In response to the improper radiation exposure dose measurement at the TEPCO Fukushima Daiichi Nuclear Power Plant, the Ministry of Health, Labour and Welfare (MHLW) instructed the TEPCO on 24 July to implement screening studies in order to investigate similar incidence and the MHLW received the report from TEPCO on 31 August.

(2) Based on the report, the MHLW and the Fukushima Prefectural Labour Bureau conducted additional investigation and the individual interview.

(3) The following summarizes the results of the investigation, issues that emerged, and actions that needed to address the issues.

2. Analysis of the results presented in the TEPCO's report

(1) Investigation Result 1: When comparing the measurement results, the personal electrical alarm dosimeters (hereinafter referred to as "PADs") demonstrated lower values than the personal integrating dosimeters (hereinafter referred to as "glass badges") by 15% or more.(The excess doses of 5 mSv/month during the period from November last year to June this year have been reported for workers on duty).

a. Out of 1,813 cases153 cases fell under this category, and 57 cases showed lower doses by 20% or more.

b. <u>There were 34 cases with the +/-25% or more gap between the measurements of glass badge and PAD, including the cases with the measurements of PAD higher than that of glass badges.</u>

(2) Investigation Result 2: The actual exposure dose from work, considered to expose workers to 1mSv/day on average in June this year, was lower than the planned dose of individual tasks by 50% or more.

a. All of the 56 tasks fell under this category. In addition, the data indicated that 98.4% (16,862 out of 17,148 measurements) fell under this category.

b. <u>The total radiation exposure dose per day was 0 mSv (below 5μSv/h) for work that lasted one hour or longer</u>. (179 cases)

c. Although there were workers who received radiation exposure doses of 0.1 - 0.4 mSv or less in some tasks, other workers on the same group received 1 mSv or more doses on the same date and time. (22 workers in 13tasks).

3. Cases and methods of the investigation conducted by the MHLW and the Fukushima Prefectural Labour Bureau

(1) Studies related to the Investigation Result 1

a. Investigated cases: Cases of measurements obtained by glass badge and PAD with the +/-25% gap or larger were observed (28 cases managed by8 primary contractors).

- Among the entire data of the measurement results (1,813 data), the data concerning glass badge and PAD that matched in a pair with a total of 5 mSv/month or more doses received during the period from November last year to June this year was selected. The present investigation was focused on the data with the +/-25% or wider gap in measurements between doses obtained from a glass badge and PAD. From the standpoint of statistical analyses such cases are considered extremely uncommon. (See Annex 1 for details)

b. Investigation methods

- An individual interview with a primary contractor or a radiation administrator of a primary contractor (13 persons from 11 companies).
- An individual interview with workers (13 workers from 10 companies)

(2) Studies on the case in which radiation exposure doses were 0 mSv, among those in the Investigation Result 2

a. Investigated cases: The case with the radiation exposure dose of 0mSv (one hour or more work) (181 cases from 6 companies)

b. Investigation methods

- It was identified that the PAD used by the TEPCO reported 0.00 mSv if a radiation exposure dose was anywhere below 5 μSv (0.005 mSv).
- Thus, the data obtained by PAD lent for 1 hour or longer (181 data from 6 primary contractors) were eliminated from the analysis concerning the work details, workplace, and ambient dose rate at the workplace.

(3) Studies on cases with a large variation in radiation exposure dose measurements from the Investigation Result 2

a. Investigated cases: Tasks that generated radiation exposure doses of 0.1 - 0.4 mSv or below in some workers while other workers in the group received 1 mSv on the same date and time (13 tasks managed by 5 primary contractors).

b. Investigation methods

- In the beginning, the investigation intended to eliminate unusual data with actual doses 50% or lower than the planned doses. Surprisingly, however, almost all the data were actually 50% or lower than the planned doses. This is probably because the planned doses set in the beginning were too high.
- Therefore, we observed PAD lending records and extracted the data that was likely to be collected on the same day, at the same time, and from the same group employed by the same primary contractor. Then, work conducted under the high dose conditions with over 1 mSv/day of doses received by workers was identified. Finally, cases with extremely low exposure doses (0.1 - 0.4 mSv) (22 cases in 13 tasks managed by 5 primary contractors) were extracted and the workers were individually interviewed.

4. Results of the investigation

Although this study found no cases with intentionally tampered data, similar to the one seen in the "lead plate" case, the issue has been raised by cases with inappropriate management of doses.

(1) The Case with the +/-25% or wider gap in measurements between a glass badge and PAD (See Annex 2 for details).

The results of the interview with radiation administrators and workers were summarized as follows. Although some of the gaps were determined to be caused by improper dose management, the causes for other gaps could not be identified from our investigation.

a. Cases with identifiable cause for the data gap

(i) Data errors

- Errors were found in the data from glass badge or PAD. (2 cases)
- Although two glass badges were used in a worker who wore a tungsten vest, the data was available only from one of the badges. (1 case)

(ii) Improper management of glass badges

- Higher doses reported in the glass badge data might be attributed to the following reasons: A glass badge, which was individually controlled, measured additional exposure doses while the worker commuted by a contaminated vehicle that had been removed from the restricted area. (1 case)
- A glass badge measured extra exposure doses while the worker was engaged in the task at the stone pit in the restricted area where the ambient dose rate was high. (2 cases)
- After employees of a primary contractor and a primary subcontractor returned their PAD, extra exposure doses were measured while workers waited in the office, such as the former emergency measures office, in the seismically isolated building[1] where the

[1] The seismically isolated building was designated as a radiation controlled area where dose management was

ambient dose rate was high. (2 cases)

- A worker worked on the first floor of the seismically isolated building, wearing only a glass badge because they were not required to wear PAD for the work in the area last year. (1 case)

b. Potential causes of the gap

(i) Cases with higher glass badge measurements

- The exact cause for higher doses measured in glass badges is not clear. However, there is a possibility that glass badge reported higher doses due to the direction sensitivity. When workers worked in a place where exposure from a certain direction was dominant, the direction sensitivity of the glass badge might have become stronger than that of PAD. (9 cases)

(ii) Cases with higher PAD measurements

- Although the cause for higher PAD measurements has not been clearly pinpointed from worker tasks, there is a possibility that PAD measurements eventually became higher when workers were engaged in tasks near the radiation source, wearing PAD on their dominant arm (i.e., right chest). (6 cases)
- The cause cannot be identified from their tasks. (4 cases)

(2) Cases where exposure dose was 0 mSv (PAD was lent for one hour or longer) (See Annex 3 for detail).

As the results of the investigation presented in the following, reasonable explanations for 0.00 mSv dose measurements were obtained from interviewing workers about the details of their tasks.

a. Workers were on duty outside the nuclear power plant

- Workers were on duty in material storage or other areas outside the nuclear power plant where the ambient dose rate was low. (151 cases)
- Workers were driving vehicles outside the nuclear power plant where the ambient dose rate was low. (3 cases)

b. Workers stayed in the rest areas due to cancellation of on-site tasks or short work hours.

- Workers were waiting in the rest areas where the ambient dose rate was low, due to cancellation of on-site tasks. (10 cases)
- Task sat the site were very short, and workers were waiting in the rest areas at the site for a long time. (17 cases).

(3) Cases with a large variability in exposure dose measurements for the same activity (See Annex 4 for detail).

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required until April this year. The second floor has been currently exempted from the radiation controlled area. The ambient dose rate at the rest area on the first floor has also been reduced.

As the study results shown below, reasonable explanations for considerable low exposure doses were obtained by interviewing workers about the details of their tasks.

a. Workers who were on duty in the seismically isolated building or outside the nuclear power plant
   - Workers were working in the seismically isolated building. (7 cases)
   - Workers were working outside the nuclear power plant. (1 case)

b. Workers were waiting for their shifts to begin at the location where the ambient dose rate was low.
   - Workers waiting for their shifts to begin, workers in charge of radio communications, or radiation administrator stayed in the shielded place apart from the spot with the high dose rate. (10 cases)
   - Workers were waiting for their shifts to begin in the seismically isolated building. (4 cases)

5. Results obtained through interviews regarding exposure dose management

It was possible to collect information on the current situation in detail on exposure dose management and identify its issues that need to be addressed, by interviewing directly with workers of not only primary contractors but also primary to tertiary subcontractors. The main results are described below. (See Annex 5 for detail.)

(1) Exposure dose limit defined by employers

a. Plant manufacturers and employers specializing in services at nuclear power plants (hereinafter referred to as "nuclear service companies")
   - All of the plant manufacturers and nuclear service companies defined 20 mSv/y as the exposure dose limit for their workers because their workers are also required to work in other nuclear facilities.

b. General constructors
   - The exposure dose limit was set 40 mSv/y at numerous sites operated by general constructors. This is because general constructors constitute many professional, skilled workers, such as scaffolders and heavy machine operators, who can relatively easily return to the normal construction work after their exposure doses reach the limit.

(2) Setting the planned dose and the alarm value

a. Basic concepts
   - The TEPCO instructed each of the primary contractors in July this year to define the planned exposure dose and the alarm value by multiplying the maximum ambient dose rate per day with the maximum working hours per day as the reference value.

b. Plant manufacturers and nuclear service companies

- Plant manufacturers and nuclear service companies set the alarm value by adding certain extra values(1.5 to 3 times) to the planned dose calculated with the above formula , in order to allow for any troubles. In some cases, this prevents the proper usage of the original alarming functions.

c. General constructors

- Almost all general constructors set 3 mSv/day as the maximum exposure dose limit for work under the high dose rate and 1 mSv/day for normal tasks, respectively and develop work plans based on each limit accordingly. Furthermore, general constructors usually set the alarm value at 2 mSv/d and 0.8 mSv/d, respectively.

(3) Borrowing and managing PAD

a. Borrowing procedures

- It is desirable that workers should borrow PAD individually from the standpoint of personal identification. However, there are many cases in which employers allow a representative person to borrow PAD collectively for a group of workers, when the stand-by areas (rest areas) for changing clothes are located outside the nuclear power plant. This practice has been accepted considering the time saved for workers' transportation and for contamination inspection before entering the seismically isolated building.

b. Confirming the dosimeter wear

- Reminding workers to wear PAD was the only measure taken until July. However, the primary contractors have started allocating personnel to visually check by actually touching PAD to make sure that all workers are wearing PAD since August.

(4) Managing glass badge

a. Procedures for managing glass badge

- Many of the primary contractors allow workers to manage their glass badges on their own and to bring the badges back to their accommodations. This has resulted in the report of extra exposure dose measurement unrelated to work.

b. Control badge

- In general, a control badge is reserved in a place where glass badges are stored when not in use in order to eliminate the exposure dose during the storage. However, many primary contractors commissioned a radiation administration company to manage glass badges and subtract a certain value without using a control badge.
- Consequently, there is a possibility that occupational exposure measurements with glass badges cannot determine overestimation or underestimation of the correct value.

(5) Managing exposure dose measurements

a. Managing PAD measurements

- Many of primary contractors confirm daily exposure doses by collecting exposure dose receipts produced at the time of returning PAD or recording the exposure doses in an exposure dose management ledger and the like. Furthermore, the TEPCO distributes PAD data every day via electronic media, and the primary contractors administer the data in their personal computer systems.
- For primary contractors using the dose management ledger per worker, it tends to be difficult to identify the variation of exposure doses within the same work group.

b. Comparing and recording PAD and glass badge measurements

- General constructors compare the monthly total cumulative dose of PAD with that of glass badge, and record the higher value.
- Most of the plant manufacturers and nuclear service companies adopt glass badge measurements for exposure dose recording without comparing the value with that of PAD, while one company adopts only PAD measurements for recording of exposure doses. One other company compares PAD and glass badge measurements and records the PAD measurements when the value was higher than the certain reference value.

c. Informing workers about their exposure doses

- Most primary contractors prepare individual dose notifications for workers employed by the entire subcontractors and send the notifications to each worker via respective subcontractors.
- Some primary contractors only distribute a list of exposure doses for each site while some subcontractors post a list of personal exposure doses on the wall of the administration offices instead of sending personal notifications to individual workers.
- Many primary contractors notify their employees of their individual dose records by making them available on intranet or other media.

6. Other findings obtained through interviews

Some issues underlying the improper exposure dose management have emerged from the interview.

(1) Difficulties associated with exposure dose management

Workers commented on the following difficulties associated with exposure dose management. Improvement in making exposure dose management as practical as possible is required.

- Insufficient number of equipment (e.g., long boots, helmet, etc.) and survey meters.
- Limited space in rest areas
- Workers are supposed to leave the workplace when the fourth preliminary alarm[2] beeps. The investigation of causes when the alarm of PAD beeped or contamination was detected is considered as the heavy extra workload

[2] The PAD lent at the seismically isolated building is programmed to beep preliminary alarms when the measurement reaches one-fifth of the alarm value.

- Wait time during a vehicle contamination survey is too long.
- Due to frequent revisions, procedures for access administration are complicated and difficult to follow.
- It is difficult for workers to move or conduct tasks with no illumination available in the buildings

(2) Sufficiency of workforce

A common view concerning the sufficiency of current workforce is noted. Special points are as follows:

- Job rotation of the workforce is established across Japan so that workers will not reach the exposure dose limit.
- While workers of primary contractor or primary subcontractors engage in tasks which may cause their exposure doses to exceed 20 mSv/y, workers managed by the secondary and lower subcontractors observe 20 mSv/y and reserve experienced workers.
- Nationwide shutdown of nuclear power plants has reduced the business opportunities and it is making it difficult to provide sufficient jobs to workers.
- There is a concern that workers may not come back if employers once lay them off. Work teams should be organized only by entrusted workforce with the experience and the skill. Once other nuclear power plants that suspended operation start working, the shortage of highly skilled engineers is expected. Thus, every effort has been made to retain highly skilled engineers.

(3) Actions for workers whose exposure dose reached the limit

Primary and lower subcontractors held a discussion with their workers regarding future tasks and concluded to generally take the following actions, once their exposure doses reach the value close to the dose limit specified by their primary contractor.

- Once their exposure dose reach the value close to the dose limit specified by their primary contractor, general constructors should transfer the workers to the work under the low dose rate in the nuclear power plant. If their dose still exceeds the limit, transfer the workers to other duties such as general construction and decontamination (their career may be changed in some cases). Such transfer is not very difficult because many of the workers employed by general constructors are professionals with reliable skill such as scaffolders and heavy machine operators.
- Nuclear service companies adopt a job rotation system for workers within their nationwide branch offices to make workers' exposure doses consistent because it is difficult for them to work in a place other than nuclear power plants. These companies also intend to transfer workers to work under the low dose rate in the facility or to

involve them in decontamination work when their exposure dose reach the value close to the dose limit specified by their primary contractor.

7. Issues and response actions

The MHLW requires the TEPCO and its primary contractors to take necessary actions regarding the following matters, with an emphasis on preventing the recurrence of similar improper cases.

(1) Data management

Considering the fact that some cases involved faulty PAD exposure dose data or missing glass badge data, it is necessary to review the data management procedures at the radiation management department of primary contractors to prevent the recurrence of similar cases.

(2) Management of PAD

a. It is necessary to lend PAD to each worker so that his or her personal identification can be certainly confirmed. It is necessary to start operation in the dose management facility (which is now under construction) as soon as possible to ensure that PAD are distributed individually. However, the individual distribution of PAD is currently difficult because the available space for dose management in the seismically isolated building is insufficient.

b. It is recommended that operation will be conducted as quickly as possible so that all of the workers who need to wear PAD can quickly wear the chemical protective suits (Tyvek). Because Tyvek has a transparent chest part, one can easily confirm the appropriate wearing of PAD without taking the suits off..

c. It is necessary to identify workers' exposure doses without failure at the time of collecting PAD and confirming the details of their work tasks, not only in the case when PAD alarm beeped but also in the case when the uncommon exposure dose value was obtained, such as 0 mSv or extremely lower value than the alarm set value,. Furthermore, if an excessive alarm value was set for a task, it is necessary to recommend the change to the appropriate value.

d. Primary contractors should check the details of the tasks of a worker whose exposure dose is extremely low compared to others who work daily in the same work group with the same alarm set value. If this was the case and an excessive alarm value was set, it is necessary to recommend the change to an appropriate value.

(3) Management of glass badges

a. Management methods

Most primary contractors let individual workers control their glass badges on their own. In principle[3] occupational exposure dose measurement requires workers to wear glass badges only while on duty. A progress has been made to establish on-site administration offices.

Thus, it is becoming necessary to distribute glass badges in the beginning of the work day and collect them at the end of the day according to the principle.

b. Control Badge

It is necessary to use control badges properly and avoid measuring unnecessary exposure doses unrelated to work, although some primary contractors have not used control badges.

(4) Comparison and evaluation of PAD and glass badge measurements

a. Glass badges are considered to have higher reliability than PAD because of the fact that they can be worn throughout work hours, and they have less error due to properties, such as the directional sensitivity, than PAD. It is necessary to investigate the cause of error by examining the data if the gap beyond a certain reference value is found between the measurements in these instruments.

- JIS accepts PAD errors up to +/- 30%[4] while IAEA Safety Standards[5] accept the gap between two separate measurement instruments up to roughly 35%. However, more deliberate actions should be taken for workers who work in the TEPCO Fukushima Daiichi Nuclear Power Plant who receive exposure doses up to the close to the legal limit such as 40 mSv/y.
- Therefore, it is recommended that a criterion should be set at +/-20%, which is roughly twice as high as the standard deviation (0.094) obtained from the data analysis[6] in this study report, to determine whether a gap between the measurements should be examined.

b. The PAD measurement should be selected as the value for recording if it is still higher than that of the corresponding glass badge value even after the data was examined as described in a. above.

(5) Setting the planned exposure dose and the alarm value

a. The purpose for setting the alarm level is to control exposure doses below the maximum expected exposure dose per day. However, some primary contractors include a large extra value on the alarm set value, which often prevents the original intended alarming function from working properly.

b. The alarm set value should be as close as possible to the maximum expected exposure dose per day because ambient dose rates are determined except in some workplaces in the reactor building under the high dose rate conditions.

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[4] An error of +/- 30% is allowed as an energy response error. [Electrical personal dose (dose rate) measurement instrument for X-ray, gamma ray, beta ray, and neutron JIS Z4312: 2002]

[5] Assessment of Occupational Exposure Due to External Sources of Radiation, IAEA Safety Series: No.RS-G-1.3, 1999

[6] Statistically, the frequency that generates the value deviating twice larger than the standard deviation is only 5% (2.5% when PAD measurement is larger than that of the glass badge).

(6) Notification of doses

a. Some employers post a list of personal exposure doses on the walls of administration offices instead of distributing individual records in writing. In order to confirm the receipt of the records to workers, it is necessary to inform the exposure doses to each worker in writing.

b. Furthermore, some employers are falling behind in sending notifications of the determined doses. It is necessary to determine the causes of the delay and immediately establish an organizational structure that can send notifications within one month.

(7) Others

a. It is necessary to take the following actions in advance for workers whose exposure doses may exceed the limit specified by primary contractors.

- Measures to reduce exposure doses during work by using tungsten vests, effective shielding, etc. should be enforced. Efforts in job rotation in combination with work under the low dose rate should be arranged in order to avoid particular employers or workers from receiving large exposure doses.
- Mutual understanding of an employer and workers should be established about the job security of the workers before the exposure dose reaches the limit specified by each primary contractor.

b. The TEPCO should respond to other issues, such as shortage of equipment to lend and reduction of wait time during screenings of vehicles.

Comparison between PAD and glass badge measurements

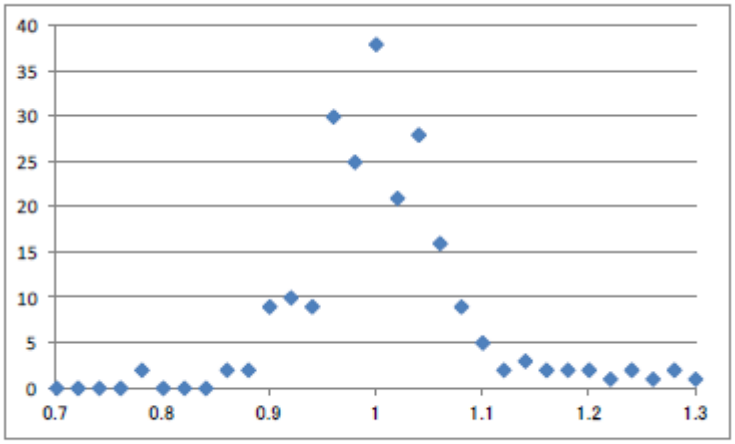
1. For comparison between PAD and glass badge (GB) measurements, all data (1,813 data) were used which had pairs of these measurements above 5 mSv/month during the period from November last year to June this year, and a frequency distribution of the ratios (PAD value/glass badge value) was evaluated. As a result, the mean was almost 1, and a normal distribution was obtained with the mean at the center. The mean and standard deviation[7] for the TEPCO personnel data (225 data), using glass badges and PAD of a single manufacturer, were 1.00 and 0.087, respectively, while those of all the data (1,813 data) were 0.97 and 0.094, respectively.
2. The interviewing was made to those workers whose data were apart from the mean of two measurements by +-25% or larger, which is three times larger than the standard deviation of the TEPCO data (this should be statistically very rare).

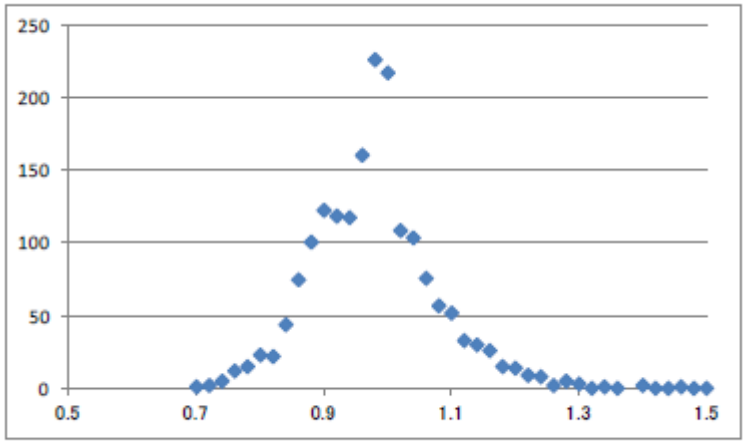
TEPCO data

	Average	Standard deviation	Number of data
APD Value/GB Value	1.00	0.087	225

All data

	Average	Standard deviation	Number of data
APD Value/GB Value	0.968	0.094	1813





7 The standard deviation is a measure to evaluate a dispersion width (variation) of the data distribution. Given mean and standard deviation (σ) values can broadly show how the data is distributed at what percentage in what range (distribution). A symmetrical bell-shaped distribution with the -centered mean (normal distribution) indicates that 68.3%, 95.5%, and 99.7% of all the data points fall within the range of the mean value +/-σ, +/-2σ, and +/-3σ, respectively.

Investigation results on the case of the +/-25% gap or larger between PAD and glass badge measurements

Note: the gap is shown in “GB measurements and PAD measurements)

	Description of the gap	Investigation Results
1	25% gap or larger between PAD and GB measurements: 3 cases (-29%,-28%,-25%)	● PAD measurements are higher than those of GB in all the investigated data. Monthly data also indicate that PAD measurements are higher than those of GB in many cases. ● The cause could not be clearly identified from the details of the task. However, there is a possibility that the gap comes from the difference in where PAD and GB were worn on the body because the work site was located adjacent to the high radiation source.
2	25% gap or larger between PAD and GB measurements: 7 cases (-44 to-27%, 6 cases; 28%,1 case)	● PAD measurements of 6 workers out of 7 were higher. The workers working near the reactor in the building where radiation dose was high wore PAD on their right chests. The PAD worn closer to the radiation source may possibly have resulted in higher measurements because they were right-handed. ● The worker whose GB measurement was higher is an employee of the primary subcontractor. He was waiting in the seismically isolated building at the time, after returning his PAD. This probably caused the gap in measured doses.
3	The gap of 25% or larger between PAD measurements owned by TEPCO and the primary contractor (-27%)	● As it turns out, the corrected version of the dose data from the TEPCO have not been reflected in the MHLW system. The gap almost disappeared by properly correcting the data.
4	25% gap or larger between PAD and GB measurements (96％, 99%, -83%) : 3 cases	● One worker whose GB measurement was higher than that of his PAD wore the GB even while he was commuting by a contaminated vehicle, which had been removed from the restricted area. Therefore, the gap occurred probably due to the exposure while he was driving. (This was revealed in March this year. The vehicle is now in custody of the employer.) ● The other worker whose GB measurement was higher than that of his PAD wore only the GB while working on the first floor in the seismically isolated building where wearing PAD was not required last year. Therefore the gap occurred probably due to the exposure while he was in the building. (Currently, wearing PAD is required during work on the first floor in the seismically isolated building.) ● The worker whose PAD measurement was higher than that of his or her GB was engaged in a survey work using only his or her hand near the radiation source that emitted high levels of radiation, while hiding himself/herself behind a shield. The PAD may be exposed to more radiation as it was worn on the right side of the worker's chest.
5	25% gap or bigger between PAD and GB measurements: 2 cases (30%, 26%)	● When workers wear tungsten vests, they wear a GB outside the vests, and another GP and a PAD inside. Therefore, the measurements of the inner GB and PAD were compared. ● Two GB data are supposed to exist when a tungsten vest is worn. One of two GB data was missing for one worker, which might have occurred due to the loss of data or data collection failure. ● There was a big gap between the measurements of other worker's GB and PAD, both of which were worn inside his or her tungsten vest. The cause could not be identified from the task details.
6	25% gap or larger between PAD and GB measurements: 9 cases (- 94%,1 case; 25	● The -94% gap was identified to be caused by an input error of GB measurement. ● Other eight workers showed higher GB measurements, seven of who were on the bucket of a vehicle for high-lift work. A

	to 27%, 8 cases)	better directional sensitivity of GBs may possibly have led to the higher measurements because the exposure at the workplace was dominated by radiation from a particular direction.
7	25% gap or larger between PAD and GB measurements: 1 case (26%)	● The GB measurement has consistently been higher through the past months. The worker is from the primary contractor. After returning PAD, he or she was waiting at the former emergency measures office in the seismically isolated building where the ambient dose rate was high. This wait time may have caused his or her GB dose to accumulate. (Currently, standby workers are also required to wear PAD.)
8	25% gap or larger between PAD and GB measurements: 2 cases (25%, 26%)	● GB measurements were higher in both data. The interview revealed that both workers had kept wearing their GB, which were under their individual control, when they worked at the stone pit in the restricted area where the ambient dose rate was high. Thus, it is speculated that the gap may have been caused by the exposure received at the stone pit.

Investigation results on the cases where daily exposure doses were 0 mSv (PAD were borrowed for one hour or longer)

	Summary	Activity description	Workplace	Ambient dose rate at the workplace
1	PAD was borrowed for about 2.5 hours, and 2 cases with 0 mSv exposure were identified.	Reloading materials	J-village	< 0.01 μSv/h
2	PAD was borrowed for about 1 to 5 hours, and 10 cases with 0 mSv exposure were identified.	Waiting due to cancellation of the work at the site	Seismically isolated building	0.5 μSv/h
		Screening of workers leaving the contaminated areas (2 cases)	Former emergency measures office	10 μSv/h Note: This activity lasted as short as 10 minutes long. For the rest of the time, they were waiting in the stand-by area in the seismically isolated building where the dose rate was 0.5 μSv/h.
		Waiting in the stand-by area due to cancellation of the task concerning caring of the sick and wounded.	Seismically isolated building	0.5 μSv/h
		Waiting in the stand-by area due to cancellation of the task concerning hosting visitors.	Seismically isolated building	0.5 μSv/h
		Stayed at the Daini Nuclear Power Plant due to cancellation of the work at the Daiichi Nuclear Power Plant.	Seismically isolated building, the Daini Nuclear Power Plant	0.07 μSv/h
3	PADs were borrowed for about 1 to 4 hours, and 3 cases with 0 mSv exposure were identified	Unloading in front of a warehouse inside the facility (stayed about 20 minutes inside the facility).	Warehouse inside the facility	8 μSv/h
		Waiting in the stand-by area in the welfare department building and subsequently left without working.	Welfare department building inside the facility	1 μSv/h

4	PAD was borrowed for about 1 to 3 hours, and 12 cases with 0 mSv exposure were identified.	Site supervisor	Outside the facility (rest area, material storage site)	3 μSv/h
		Radiation management	Outside the facility (rest area)	3 μSv/h
		Driving work	Between J-village and the power plant	0.2 μSv/h
		Loading and unloading material (7 cases)	Outside the facility (rest area, material storage site)	3~15 μSv/h
		Loading and unloading material (2 cases)	Outside the facility (Yard for the ready-mixed concrete)	0.7 μSv/h
5	PAD was borrowed for about 1 to 7 hours, and 136 cases with 0 mSv exposure were identified.	Rest area administration	Rest area in the facility	< 3 μSv/h
		Cable cutting	Company office inside the facility	< 8 μSv/h
		Organizing material (134 cases)	Material storage yard outside the facility	< 1 μSv/h
6	PAD was borrowed for about 1 to 8 hours, and 18 cases with 0 mSv exposure were identified	Meeting (Visited the Daini Nuclear Power Plant only because the visit to the Daiichi Nuclear Power Plant was canceled.)	The Daini Nuclear Power Plant	1 μSv/h
		Driver (went inside the nuclear power plant but came back immediately after starting the engines of 8 vehicles for warming-up) (2 cases)	Site yard	10 μSv/h
		Driver (stand-by)	Seismically isolated building	6 μSv/h
		Mechanical and electrical related site supervisor	Reloading in the yard near J-village	3 μSv/h
		Site supervisor (borrowed PAD, but the on-site work was canceled)	Rest area in the facility	1 μSv/h
		Heavy machine operator (11 cases)	Rest area in the facility	1 μSv/h

Annex4

Investigation results of the case where some workers' exposure doses were considerably lower than those of others in the same work group entering the same site on the same date and time

	Description of the Noticeable Data Variation	Investigation Results
1	Among workers in 4 work groups entering the site on the same date and time (A total of 51 workers), exposure doses of 8 workers were 0.1 mSv or below while other workers in the same group demonstrated the doses that exceeded 1 mSv/day.	● Providing work instructions to heavy machine operators in the seismically isolated building (3 workers). ● Operating radio-controlled demolishing of heavy machines from the operation room of the seismically isolated building (2 workers). ● Providing work instructions in the seismically isolated building (Primary contractor) (2 workers). ● Providing work instructions and checking equipments in the rest area outside the nuclear power plant (near the west gate) (1 worker).
2	Among workers in a work group entering the site on the same date and time (6 workers), exposure doses of 3 workers were 0.4 mSv or below while other workers in the same group demonstrated the doses that exceeded 1 mSv/day.	● Responsible for radio communication. No access to areas under the high dose rate (1 worker). ● Transferring items to a lower dose rate area after cleaning heavy machines (2 workers).
3	Among workers in 3 work groups entering the site on the same date and time (18 workers in total), exposure doses of 5 workers were 0. 2mSv or below while exposure doses of other workers in the same group exceeded 2 mSv/day.	● Conducting inspection and maintenance of machines and tools in the cooperative company building inside the facility and waiting in the stand-by area (3 workers). ● Helping workers wear and take off Tyveks at an area under relatively low dose rate as an on-site radiation administrator (1 worker). ● On-site radiation management. The worker waited in the stand-by area for his or her shift to begin in the seismically isolated building (1 worker).
4	Among workers in 2 work groups entering on the same date and time (A total of 20 workers), exposure doses of 1 worker was 0.3 mSv or below while those of other workers in the same group exceeded 2 mSv/day.	● Maintenance and repair work of robots. Unless any trouble occurs work in the rest areas of the buildings No.1 and No.2 by assessing the on-going situations.
5	Among workers in 4 work groups entering on the same date and same time (A total of 33 workers), exposure doses of 5 workers were 0.3 mSv or below while those of other workers in the same group exceeded 4 mSv/day.	● The safety officer of the head office. Waiting in the stand-by area in the seismically isolated building without involving in the work. ● The manager of the district. Waiting in the stand-by area to fulfill the responsibility for progress management in the seismically isolated building. ● The workers waited in the stand-by area as a support worker for work conducted behind the shield , but the workers left without working due to cancellation (2 workers). ● First timer to work with a full-face mask. The worker was waiting in the stand-by area for his or her shift to begin in the seismically isolated building, but he/she did not receive the call.

Results of interviews regarding exposure dose management

[Dose limit, Alarm management]

	Issues	Comments obtained from interviews
1	The exposure dose limit defined by employers	● Control doses at 19.5 mSv per year. (Plant manufacturer) ● 20 mSv per year in principle. Assign employees exclusively of the primary contractoror primary subcontractor to engage in work when allowing exposure exceeding the limit. (Plant manufacturer) ● 16 mSv per year and 80 mSv per five years are set as the dose limit to control. (Plant manufacturer) ● 40 mSv per year (Nuclear service companies, etc.) ● 40 mSv per year and 80 mSv per five years. Some have their own policies for controlling doses of younger workers to below 20 mSv per year. (General constructor) ● Control doses below 45 mSv (40 mSv for external exposure) for any period of 12 months. Control less than 95 mSv per five years. In principle, if a worker's dose exceeds the limit, he or she would have to be returned to the general construction work. (General constructor)
2	The concept of determining the planed exposure dose and the alarm set value	● Based on tasks under the maximum ambient dose rate, but the tasks are controlled so that the exposure dose received by each worker does not exceed 3 mSv. Some tasks do not have the added extra value to the alarm set value. (Plant manufacturer) ● Based on tasks under the highest expected dose rate with the added value by a factor of 1.5-3. This is the precautious measure toward the situation in which tasks required under the high dose rate cannot be managed within the planned work time in case of trouble. (Plant manufacturer) ● The alarm value is set by considering the need to continue activities after the beep because work cannot be interrupted as desired if the maximum exposure dose allowed is set as the alarm value. (Plant manufacturer) ● A manual has been developed regarding how to determine the alarm set value. Planned exposure dose is calculated by multiplying the maximum dose rate of the work area with the maximum work hours per worker. The alarm value is set at the value lower than the planned exposure dose. The added value is chosen, basically based on experiences. The larger the value for the task, the more likely it is to be a trouble.(Nuclear service companies, etc.) ● Exposure dose limits are agreed to be established below 1 mSv for normal work and 3 mSv for work under the high dose rate, respectively. No particular rationale exists behind the limit value of 3 mSv. While the planned exposure dose is set at 3 mSv, the alarm value is set at 2 mSv to allow for a certain added value. The 2 mSv is uniformly adopted by all workers in the high dose rate areas. (General constructor) ● 0.8 mSv is the alarm set value of the PAD distributed at the J-village. Even the highest exposure dose in our work plan does not exceed 1 mSv. (General contractor) ● The maximum exposure dose per day (1 mSv) is used as the alarm set value. (General constructor)
3	Actions in response to the alarm activation	● Immediately egress at the fourth alarm beep. (Plant manufacturer, General constructor) ● Control the exposure doses through time management and PAD worn on arms instead of depending on the alarm. (Plant manufacturer)

		● It depends on the work. (Plant manufacturer) ● Actions in response to preliminary alarms are not defined yet. In some cases, workers egress when the final alarm beeps. (Nuclear service companies, etc.) ● Workers may set the alarm set value on their own to make better use of preliminary alarms. (General constructor) ● As the primary contractor, we do not specify common actions in response to the preliminary alarm activation. The subcontractors carry out the work under high dose rate in accordance with the rules that stipulate that workers prepare egressing at the second alarm activation and egress at the third. (General constructor) ● No primary alarm is set in PAD at the J-village. (General constructor) ● A preliminary alarm beeps when reaching the one-fifth value of the alarm set value. Regardless of whether the workers are in a good place to leave their work off, they are required to egress the site as soon as the third alarm beeps. (General constructor)

[PAD Management]

	Issues	Comments obtained from interviews
1	Procedures for borrowing PAD (collectively or individually)	● Borrow collectively or individually. PAD for workers who work under the high dose rate are borrowed individually. (Plant manufacturer) ● Collective borrowing continues to be a common practice.(Plant manufacturer) ● Borrow individually (General contractor, nuclear service companies, etc.) ● Borrow collectively for workers who assemble at the rest area. Workers in the seismically isolated building borrow their PAD individually. (General constructor)
2	A place to pick up PADs when a group representative borrow PADs	● Distribute PAD at a rest area when borrowing collectively. (Plant manufacturer, General constructor) ● PADs are distributed at the office of the primary contractorin the nuclear power plant. (Plant manufacturer) ● PADs are distributed at the seismically isolated building. (Plant manufacturer)
3	Type and administration of PADs if companies use their own PADs	● PD prepared during the period from later March to May last year. TEPCO's PAD have been used since June (Plant manufacturer) ● Doses of workers staying between the J-village and the nuclear power plant are independently added. (General contractor) ● Our own PD are used in addition to TEPCO's PAD. (General constructor)
4	Procedures for confirming wearing of dosimeters at the site (up to June this year)	● Nothing specifically done. (Plant manufacturer, general constructor) ● Remind workers to wear dosimeters. (Plant manufacturer, general constructor, nuclear service companies, etc.) ● Check by opening workers' chest during morning assemblies. (General constructor) ● Check during morning assemblies. (General constructor)
5	PAD while resting (collected or left under the individual control)	● PAD remains worn during the break (Plant manufacturer). ● While PAD are supposed to be detached at non-controlled areas and rest areas, some workers keep wearing them during the break in the seismically isolated building. Workers on duty in the seismically isolated building are required to wear PAD. (Nuclear service

		companies, etc.) ● PAD remains worn during the break. Upon completion of tasks, workers detach PAD at a temporary rest area and return them collectively. (General constructor) ● Workers return PAD once at the end of morning tasks and borrow them again after the break. (General constructor)

[Management of glass badges]

	Issues	Comments obtained from interviews
1	Frequency of the measurement with glass badges	● Monthly (one company measured once every 3 months until August this year)
2	Procedures for distributing glass badges	● Glass badges are ordered based on the quantity, and the primary contractor put name labels with the Tepra (tape printing machine). Dose measurements are written on a name list and electronically processed later for administration. (Plant manufacturer) ● Glass badges are ordered based on the quantity. Workers write down their names on the badge by hand. A list is prepared for measurement. The result is processed along with their individual names. (Plant manufacturer) ● Glass badges are ordered based on the quantity, and the primary contractor put name labels with the Tepra. As the measurement results are provided with individual names, the results are notified by calling names individually (Plant manufacturer, general constructor) ● Badges with individual names (Nuclear service companies, etc.) ● Glass badges are ordered based on the quantity. Doses are administered per worker assigned with GB numbers (a name list prepared) (General constructor)
3	Management of glass badges	● By individual workers (Plant manufacturer, general constructor, nuclear service companies, etc.) ● Stored in a locker per employer (offices outside the nuclear power plant). ● Stored in a locked space per employer by a radiation administration company (upon contract). (General constructor) ● Managed by the office along with identification cards of workers of the primary contractor. The primary and lower subcontractors are instructed to do the same, but some glass badges are managed individually. (General constructor)
4	Storage of glass badges	● By individual workers (Plant manufacturer, general constructor, nuclear service companies, etc.) ● Stored in offices outside the nuclear power plant. (Primary contractor, secondary subcontractor) (Plant manufacturer) ● J-village (General constructor) ● Office outside the nuclear power plant (the primary contractor only) (General constructor)
5	Location to wear and detach glass badges	● By individual workers (Plant manufacturer, general constructor, nuclear service companies, etc.) ● At the offices outside the nuclear power plant. (Plant manufacturer) ● J-village (General constructor) ● Wear at the offices (The primary contractor only) (General constructor)

6	Methods for checking for wearing of glass badges on site	● Nothing special but just reminding workers about wearing glass badges (Plant manufacturer, general constructor, nuclear service companies, etc.) ● Give reminders at morning assemblies (General constructor) ● Give reminders at and after morning assemblies (General constructor)
7	Location to store unused glass badges	● Stored in offices outside the nuclear power plant. (Plant manufacturer, general constructor, nuclear service companies, etc.) ● J-village (General constructor)
8	Location for control badges	● Offices outside the nuclear power plant. (Plant manufacturer, general constructor) ● In the seismically isolated building in the Daini Nuclear Power Plant (Nuclear service companies, etc.) ● Control badges are not used. According to the manufacturer, the value is adjusted, without measuring the background dose, by subtracting a certain value from the measurement. (General constructor) ● J-village (General constructor)

[Administration of exposure dose measurements]

	Issues	Comments obtained from interviews
1	Procedures for submitting and checking dose receipts	● Each worker fills daily data in his or her record card. (Plant manufacturer) ● Monthly dose data is stored in our own system. (Plant manufacturer) ● A form to affix the receipts is prepared for collection. (Plant manufacturer, general constructor) ● Receipts are individually managed. (Plant manufacturer, general constructor, nuclear service companies, etc.) ● Each worker submits the dose receipt to the staff who enter the data in the system at the office (General constructor) ● A radiation administration company keeps the receipts and stores the data in the PC system. (General constructor) ● Collect daily and keep by affixing the receipts on a notebook. (General constructor)
2	Methods for checking variation within the same group	● No comparison (Plant manufacturer, general constructor, nuclear power companies, etc.) ● Daily doses are processed as per company. Thus, making a comparison between companies is possible. (Plant manufacturer) ● Confirm measurements in daily dose administration records. (General constructor) ● The variation within the same group can be checked because the receipt is issued by each site. (General constructor)
3	Frequency and methods of comparison between glass badge and PAD measurements	● PAD and GB measurements stored in the management ledger are compared (The gap of 15% or larger is currently defined as the level that requires the investigation.) (Plant manufacturer) ● GB values are adopted if the errors fall within 40%. (Plant manufacturer) ● When GB measurements are calculated, the values are considered only as a reference. (Plant manufacturer)

		● When the significant gap has been found between PAD and GB measurements, the investigation may be needed. (Nuclear service companies, etc.) ● Compare on a monthly basis after the GB measurements are finalized. (General constructor) ● Make comparisons once every several months to make sure if there is any change in the trends. (Not monthly) (General constructor)
4	The choice for the recorded value between a glass badge and PAD	● GB values are adopted if the GB errors fall within 40%. (Plant manufacturer) ● PAD (Because the daily data management for PAD is complicated, plant manufacturer is planning to replace PAD with GB if the opportunity arises.) (Plant manufacturer) ● GB (General constructor, nuclear service companies, etc.) ● Adopt higher value out of the two: PAD or GB. (General constructor)
5	Frequency and methods of dose notification	● The primary contractor prints out forms for individual notifications from their computer system and distributes them to the involved subcontractors. (Four months after the measurement was conducted for employees of each subcontractor.) (Plant manufacturer, general constructor) ● The primary contractor sends a list of the doses to subcontractors once a week to 10 days and to individual workers once a month. (Plant manufacturer) ● Notification used to be made for each work group on a weekly basis. Currently, a system is in operation which allows workers to view their individual monthly cumulative doses. (Nuclear service companies, etc.) ● A list of final and tentative values received per site is presented to the involved subcontractors on a monthly basis. Many of the involved subcontractors distribute a copy of the list. (General constructor) ● Spreadsheets with tentative values are provided to the subcontractors via email every week. The primary contractor provides GB values to each worker through their operation leader. (General constructor) ● The doses are informed monthly to individual workers by sending notifications. (General constructor)

[Others]

	Issues	Comments obtained from interviews
1	Difficulties in dose administration	● Insufficient number of equipments (long boots, helmets, etc.) and survey meters (Geiger counters, ionization chambers, etc.) (Plant manufacturer, General constructor) ● Insufficient space for rest areas, etc. (Plant manufacturer) ● A heavy burden imposed by the TEPCO concerning the investigation of the situation when PAD alarm beeped or contamination was

		detected. (Plant manufacturer) ● The survey of vehicles is time consuming. (Plant manufacturer, general constructor) ● Difficulty in securing high quality workers is the current issue. (Advanced technicians are unwilling to work under the high dose rate because they may not be allowed to work at other nuclear power plants.) (Plant manufacturer, nuclear service companies etc.) ● The interpretation of internal exposure dose records should be clarified. (Plant manufacturer, general constructor) ● Administration has becoming more complicated and harder to follow as tasks for access control and managing workers have gradually increased(e.g., separate access permit and worker identification card, multiple locations of windows for PADs lending). (General constructor, nuclear service companies, etc.) ● A request to use multiple PADs for individuals to collect real time exposure dose data was not accepted. (General Constructor) ● The complaints should be made when mass media reports false information about the radiation administration at the nuclear power plants. (General constructor) ● Indoor work is difficult because no permanent illumination is available in the buildings. (General constructor) ● Coordination with other companies is required regarding the issues related to work areas (to secure work areas, evacuation areas, etc.) (Plant manufacturer)
2	Sufficiency of workforce	● The primary contractors consider that the workforce is sufficient. The involved subcontractors, on the other hand, consider that the current workforce is becoming scarce because retaining employees has proven to be a challenge due to lack of businesses. (Plant manufacturer) ● Workforce is sufficient. While employees of primary contractors or primary subcontractors conduct tasks which may cause their exposure doses to exceed 20 mSv per year, employees of secondary and lower subcontractors follow the limit of 20 mSv/y in order to preserve experienced workers. (Plant manufacturer) ● Requests are made to subcontractors to secure the workforce. (General constructor) ● Difficult to distribute workforce and secure the engineers. (companies in general) (Plant manufacturer) ● Nuclear service and other related companies are struggling with their businesses. The number of orders is becoming fewer mainly because the nuclear power plants across the nation have suspended their operation and companies are forced to take competitive bids at the Fukushima Nuclear Power Plants. ● There seems to be some work available under the high dose rate. However, the number of contracts is restricted by the exposure dose limit. (Nuclear service companies, etc.)

		● Concerned about the loss of workers who may not come back once they are laid off due to current difficulties associated with business management. If experienced and skilled personnel leave their jobs, it will be difficult to reorganize the entrusted team, and companies will face the problem of workforce shortage. This will probably lead to a shortage of advanced engineers if other suspended nuclear power plants resume operation. (Nuclear service companies, etc.)
3	Work after reaching the dose limits	● Once a worker's exposure dose reaches close to the dose limit specified by the primary contractor, the worker is transferred to work under the lower dose rate in the nuclear power plant. If his or her dose still exceeds the limit, he or she will be transferred to general civil engineering work. (General constructor) ● The worker is transferred to other work. (Plant manufacturer, general constructor, nuclear service companies, etc.) ● The worker is transferred to construction, decontamination or other work. (General constructor) ● Nuclear service companies have been making a certain level of provision to control workers' exposure doses by rotating their tasks because the services they provide are limited to nuclear power business only. A worker will be transferred to duties concerning decontamination or work under the low dose rate when his or her exposure dose comes close to the limit. (Nuclear service companies, etc.)