Lessons Learned from the Fukushima Daiichi Accident indicated by Investigation Reports, and JANSI's Supporting Activities to Member Companies

December 2013

Japan Nuclear Safety Institute

Contents

1. Background

On March 11, 2011, an enormous tsunami brought about by the Great East Japan Earthquake struck Tokyo Electric Power Company's (TEPCO) Fukushima Daiichi Nuclear Power Station ("Fukushima Daiichi"), triggering a severe accident. Four accident investigation reports have been released for the purpose of investigating the accident, conducting inquiries into its cause and verifying responses, and, furthermore, analyzing the background behind the accident: Diet Accident Investigation Report (July 2012), Government Investigation Report (July 2012), Independent Investigation Committee Report (February 2012) and the TEPCO Accident Investigation Report (June 2012). In addition, the INPO released its report "Lessons Learned from the Nuclear Accident at the Fukushima Daiichi Nuclear Power Station" (August 2012) to contribute to the improvement of safety of nuclear power generation.

In addition to the above five reports, the Ohmae Report "What Should We Learn from the Severe Accidents at the Fukushima Daiichi Nuclear Power Plant? (December 2011)," the American Society of Mechanical Engineers' (ASME) "Forging a New Nuclear Safety Construct (June 2012)," the Carnegie Endowment for International Peace's "Why Fukushima Was Preventable (March 2012)," and the "Report by the Committee on the Prevention of Severe Accidents at Nuclear Power Plants (January 2013)" as well as TEPCO's "Fukushima Nuclear Accident Summary & Nuclear Safety Reform Plan," which further consolidates the principal underlying factors contributing to the accident, were released regarding the Lessons Learned from the Fukushima Daiichi Accident.

For the purpose of supporting activities of special member companies reflecting these Lessons Learned in their activities to improve safety, the Japan Nuclear Safety Institute (JANSI) has drawn the Lessons Learned, from the above ten reports (hereinafter, "accident investigations and other reports"), and compiled the principal activities, which may serve as references for other companies.

This report describes the compiled results of major Lessons Learned extracted from the ten accident investigations and other reports, the countermeasures of special members companies, the issues which JANSI thinks it is desirable to carry it out, and JANSI's proposed support activities concerning responses to the Lessons Learned.

2. Methodology

JANSI set up the Accident Investigation Report Working Group (WG) under the auspices the Lesson Reflection Taskforce, and then compiled and summarized the Lessons Learned (approximately 300 items) into 50 issues to be addressed.

The Lessons Learned comprising these issues are classified into ‘facilities,’ ‘design,’ ‘framework,’ ‘operations’ and ‘safety culture.’ In this JANSI review, lessons and countermeasures related to ‘facilities’ have been omitted as an object of the review.

During the review by the WG, issues with the exception of Lessons Learned and countermeasures related to ‘facilities’ were consolidated into the following seven areas, which JANSI considered it desirable to share information about, and proceeded with the review. Also, six items, about which information is shared for reference yet not included in these consolidated areas, were noted as other issues to be addressed.

- ✓ Strategy for assuring safety against high-impact, low-probability events
- ✓ AM strategy enabling a flexible response in keeping with plant status
- ✓ Implementation of SA education and practical training
- ✓ Construction of an emergency response framework and clarification of chain of command
- ✓ Building up a culture of safety to an even higher level
- ✓ Ensuring machinery, materials and communication means during a severe accident
- ✓ Radiation dose management and radiation control

3. Lessons Learned from Investigation Reports and Countermeasures of Special Member Companies

In this chapter, accident investigations and other reports summarizing the accident are noted with the following abbreviations.

Diet Accident Investigation Commission: “Official Report of the Fukushima Nuclear Accident Independent Investigation Commission”

Government Investigation Committee: “Investigation Committee of the Accident at Fukushima Nuclear Power Stations of the Tokyo Electric Power Company”

Independent Investigation Commission: “Report of the Independent Investigation Commission on the Fukushima Daiichi Nuclear Accident”

TEPCO Accident Investigation: “Fukushima Nuclear Accident Analysis Report of the Fukushima Nuclear Accident Investigation Committee”

INPO: “Lessons Learned from the Nuclear Accident at the Fukushima Daiichi Nuclear Power Station”

Ohmae Report: “What should we learn from the severe accidents at the Fukushima Dai-ichi Nuclear Power Plant?”

ASME: “Forging a New Nuclear Safety Construct”

Carnegie: Carnegie Endowment for International Peace "Why Fukushima was Preventable"
SA Prevention Committee: "Preventing Recurrence of Severe Accidents at Nuclear Power Plants," Report by the Committee on the Prevention of Severe Accidents at Nuclear Power Plants
Nuclear Safety Reform Plan: Fukushima Nuclear Accident Summary & Nuclear Safety Reform Plan

3.1. Strategy for Assuring Safety against High-Impact, Low-Probability Events

(1) Lessons Learned

Many of the accident reports prepared in Japan have emphasized the necessity of having safety assessments for events whose impact may be enormous if they occurred despite being low frequency, including natural phenomena, and of having responses based on those results. Also, investigations and reviews conducted outside Japan have taken such circumstances into account in discussing frameworks or other systems for ensuring the safety considered to be necessary in the future. It has been pointed out that the way safety should be ensured is mainly based on the concept of defense-in-depth, and proposals have been put forth also for the role of relevant regulations and other such areas. Furthermore, analyses have been conducted regarding the mode of systems capable of countering low probability events which may have an enormous impact.

The main Lessons Learned are as follows.

○ Consideration of High-Impact, Low-Probability Events

Events with a 'cliff edge' effect, in other words low-probability incidents that can potentially cause enormous damage if they occur, require particularly careful consideration when setting design criteria. While a tsunami represents a phenomenon with such a cliff edge effect, careful examination and consideration is given to other natural disasters and phenomena, in order to determine whether they have similar potentials (Diet Accident Investigation Commission). It is necessary to implement comprehensive safety assessments which take into account external events and to examine and develop severe accident countermeasures based on such (Government Investigation Committee). Anticipating 'unforeseen' natural disasters or human events associated with nuclear incident is imperative. A fundamental approach in anticipating the 'unforeseen' (event) is essential for ensuring nuclear safety, and will be developed. 'Unforeseen' is unacceptable in ensuring safety of nuclear power facilities. The regulator and operator should establish a framework for emergency preparedness and response for all credible natural disasters, human-induced and internal events, etc. (SA Prevention Committee Recommendation 1).

One of the important lessons learned from the events at Fukushima Daiichi is that it is difficult to predict the likelihood of rare natural phenomena and their severity. Therefore, in the sense of preventing fuel damage at a nuclear power generation plant and preventing major leakage of radioactive materials outside the plant, a mere return to traditional design standards is not sufficient. Although the ability to predict the magnitude and frequency of natural phenomena such as earthquakes and floods should be improved, significant levels of uncertainty will always remain. By definition, few data points exist on the occurrence of rare yet credible events. Even probabilistic techniques, which have served the industry well in considering beyond-design-basis combinations of failures, have limitations due to lack of data for estimating the probability/consequence relationship for rare yet credible events, especially for rare natural phenomena. The uncertainties in estimating the probability of rare yet credible events can be very large, and traditional techniques that rely on mean values might not be sufficient to inform all design decisions, especially for events that present a cliff edge challenge. It is the potential for common-cause failures, combined with uncertainties regarding event severity, that suggests special consideration be given to protective features for such events in the new safety construct (ASME).

○ Compound Disaster Perspective and Risk Awareness

External threats to nuclear installations are dynamic. In recent years, threats due to natural causes have been augmented by threats from sabotage and terrorism. In the future, they will include local threats resulting from global climate change. In the aftermath of the Fukushima disaster, Japan, as well as all other nuclear power–generating countries, should make sure that nuclear power plants can withstand all such threats, including multi-threat scenarios that the Fukushima accident dramatically underscored were credible but until then had not been considered in the threat assessments of many nuclear programs worldwide. (Carnegie)

Although Japan is highly susceptible to natural disasters, severe accident countermeasures were taken that postulated only internal events such as operating mistakes and design trouble, while external events such as earthquakes and tsunamis were not postulated. In addition, internal event PSA results accorded high ratings to the low probability of core damage. In the future, to ensure safety, comprehensive assessments, which also take into account external events, will need to be undertaken and effective countermeasures, procedures and other actions readied on the assumption of a situation where design standards are significantly exceeded and the core sustains major damage. Despite TEPCO having made assumptions to a certain extent, they were overoptimistic. Furthermore, it is considered very important that the overall perspective of the picture be understood in order to ensure the appropriateness of problem solutions (Diet Accident Investigation Commission).

○ Implementation of Probabilistic Risk Assessments (PRA/PSA)

Nuclear facilities are installed in a natural environment, which is very diverse. Nuclear operators should conduct comprehensive risk analysis encompassing the characteristics of the natural environment including external events, not only earthquakes and their accompanying events but also other events such as flooding, volcanic activities or fires, even if their probabilities of occurrence are not high, as well as the internal events having been considered in the existing analysis. Nuclear regulators should check the operators' analysis. In doing so, nuclear operators should actively utilize currently available methods in their analyses of such external events, even if the PSA approach is not firmly established for them. The government should consider support to promote relevant research programs for such initiatives (Government Investigation Committee). Operators should continue to extract and categorize important accident sequences and implement PRA with consideration given to specific characteristics of each plant, and report the results of assessment and measures applied to the regulatory body. The PRA should include accident sequences caused by internal fire and cyber terrorism (undisclosed due to confidentiality of terrorist measures) (SA Prevention Committee Recommendation 5).

○ Integration of All-Risk Assessments and Deterministic Methods

The Fukushima Dai-ichi accident has reinforced the longstanding principal safety approach of maintaining core cooling over a wide range of events, because this is the most effective method of preventing significant radioactive releases with their potentially-enormous socio-political and economic impact on society. The accident has indicated that the events now needing to be protected against include large fires and explosions, extreme natural phenomena, station blackouts of indefinite duration, and combinations of internal failures that can cause the loss of normal and backup core cooling that provide protection from traditional design-basis events. This reasoning leads to the all-risk approach in the New Nuclear Safety Construct. In light of the events at Fukushima Daiichi, it is essential to implement an all-risk approach that would support avoidance of the socio-political and economic cost of severe accidents, including use of full-scope PRAs. All-risk, full-scope assessments, which include PRA level 3 assessments, should be combined with the deterministic approach to achieve even greater defense-in-depth. International efforts should continue to improve on methods which integrate risk assessments with deterministic approaches to defense-in-depth. Generic, high-level safety goals for new plants should be agreed internationally, with the aim of reducing the probabilities of core damage accidents and limiting radioactive releases to the environment. However, even PRA is not all knowing. Therefore, an all-risk approach is needed to turn the question around so that engineers provide systems and actions to ensure core cooling and prevent large releases of radioactivity for any rare yet credible event. (ASME)

○ Approach of Defense-in-Depth

Plant design features and operating procedures alone cannot completely mitigate the risk posed by a beyond-design-basis event. Additional preparations must be made to respond if such an event were to occur. Because the specific sequence of initiation events for beyond-design-basis events is unknown, emergency response strategies must be robust and provide multiple methods to establish and maintain critical safety functions using a defense-in-depth approach. (INPO)

At nuclear power plants, safety measures considered rigorous were implemented based on the concept of defense-in-depth. Also, these measures were not completed during the plant construction stage, and additional measures were taken along with periodic safety assessments. However, this accident was not able to be prevented. Behind this fact was an insufficient understanding of the independence of defense levels, which is at the root of the concept of defense-in-depth. Also, plant weaknesses need to be revealed based on risk assessment results and countermeasures added (Independent Investigation Commission).

With defense-in-depth, each layer should be independent of the other layers. The effectiveness of a layer should not be dependent on the former or latter layers. Countermeasures must be adopted as if each layer were the last stronghold. Also, on the assumption that the preceding layer will be completely useless, countermeasures must be taken in latter layers (Independent Investigation Commission).

○ Application of Defense-in-Depth

All related parties in the nuclear community must recognize responsibilities commensurate with assigned roles, and establish the top priority of ensuring safety. The regulatory body, in particular, must determine the fundamental principle (defense-in-depth level 4) for the prevention of and mitigation of consequences of severe accidents by hearing the opinions of a broad spectrum of experts. The licensees must determine severe accident measures and effectively implement them with a sense of vigilance (SA Prevention Committee Recommendation 3).

The regulatory body shall regulate plans and inspections for level 4. By cooperating with experts and operators, the regulatory body should develop effective accident management by combining measures, including the use of a variety of components and facilities for preventing and mitigating severe accidents (SA Prevention Committee Recommendation 5).

Reliability of safety functions for level 4 shall be ensured through elimination of common cause failures, by ensuring independent effectiveness through distributed arrangement and diversification of safety functions. Facilities used in preventing the occurrence of a severe accident and mitigating any impact should be regarded as permanent facilities, which includes having power sources that are multiplexed and independent similar to existing safety facilities (SA Prevention Committee Recommendation 6).

○ Examining Accident Countermeasures

In addition to the primary threats to nuclear facilities, such as ground movement, fault displacement, crustal deformation (uplifting and sedimentation of the ground) and tsunamis, earthquakes also cause various secondary effects both inside and outside nuclear power facilities. Measures should be developed by evaluating all conceivable induced phenomena, such as earthquake damage to civil engineering structures, electrical equipment, and turbine missiles; loss of external power supply due to earthquake damage to power transmission systems outside nuclear facilities or a dam; and flooding (Diet Accident Investigation Commission). In terms of countermeasures against future severe accidents, a proactive approach, which is different from the existing reactive approach, is needed in dealing with natural phenomena such as earthquakes, tsunamis, strong winds, landslides and volcanic eruptions, as well as fires, internal overflows, digital computer equipment failures due to common initiating events, and all internal, external and artificial events including terrorist attacks (Diet Accident Investigation Commission).

○ Establishing Systems Capable of Responding to Accidents

In the government as well as in private entities, a new approach to safety measures and emergency preparedness should be established for a disaster which potentially brings about serious damage across a broad range like a gigantic tsunami or the severe accident at the Fukushima Nuclear Power Station, regardless of its probability of occurrence (Government Investigation Committee). The Lessons Learned from this accident will be reflected when considering situations where past preparedness measures did not function. Based on that, crisis/emergency response plans will be redeveloped, measures to mitigate impact and prevent spread of damages will be reinforced, and effectiveness will be improved through training (TEPCO Accident Investigation). When periodic reviews or new information indicates the potential for conditions that could significantly reduce safety margins or exceed current design assumptions, a timely, formal, and comprehensive assessment of the potential for substantial consequences should be conducted. An independent, cross-functional safety review with a plant walkdown should be considered to fully understand the nuclear safety implications. If the consequences could include the potential for common-mode failures of important safety systems, compensatory actions or countermeasures must be established without delay (INPO).

The aforementioned are compiled as follows into Lessons Learned.

- Future safety measures need to respond to high-impact, low-probability events and nuclear accidents resulting from compound disasters, which were not given sufficient consideration previously, and to this end, the overall situation will be understood through comprehensive safety assessments which include evaluations of risks.

- Events having considerable uncertainty exceeding the scope of traditional design standards need to be addressed, and, to this end, safety functions will be assured with the concept of defense-in-depth and an emergency response strategy will be prepared.
- In order to achieve even greater defense-in-depth, risk assessments and the deterministic approach will be integrated, and international examination and consensus formation will also be the focus in constructing a stance for the way in which safety should be secured in the future.
- The status after core damage will also be subject to regulation based on the concept of defense-in-depth, and countermeasures will be effective. Safety functions hinging on these countermeasures will take into account multiplexing and independence, and the impact resulting from common cause failure will be excluded.
- Low-frequency events encompass significant uncertainty in probability theory as well, and when examining plant safety, there needs to be a continual awareness of such uncertainty. In conjunction with this, consideration should be given to measures in a proactive rather than a reactive manner so as to eliminate the 'unforeseen' which includes any secondary impact from natural phenomena.
- Systems and training should constantly be built up to be able to respond to high-impact, low-probability events, which should include the implementation of periodic verification through neutral and comprehensive safety reviews.

(2) Countermeasure Activities of Special Members Companies

In the aftermath of the Fukushima Daiichi Accident, plans have been laid promoting probabilistic risk assessments, stress tests and other such evaluations, and reviews have proceeded for understanding high-impact, low-probability events including natural phenomena and measures to counter such events with an awareness of defense-in-depth. The formulation of academic society standards and other benchmarks relevant to such reviews has also been a part of this work, which has contributed to the development of needed standards. Following the launch of the Nuclear Regulation Authority, new regulation standards have been laid down, but these requirements are also pending, and reviews are being conducted on enhancing safety measures using facilities and management means. Efforts have also been seen so that 'self-righteousness' does not result in nuclear safety, including the establishment of similar types of verification committees, which comprise outside members, to form company-wide organizations on nuclear safety. Also, peer reviews are being undergone in Japan and other countries, and it is expected that review results will be reflected.

With regard to specific measures, all companies are strengthening defense-in-depth, taking into account the assurance of reliability emphasizing diversity and positional dispersion, which is a shift away from securing reliability through traditional multiplexing so that there is no loss of safety functions due to common cause failures triggered by external events.

The ‘integration of risk assessments and deterministic approaches’ is an issue that academic societies will address in the future.

(3) Issues to be considered for the Future

It is desirable to have the knowledge and indications obtained from company-wide organizations or verification committees on nuclear safety as well as the results of peer reviews be more widely disseminated down to each worksite within the company. Also, there are many proposals and activities from other countries about the ideal mode for nuclear safety, so it would be desirable to have reviews promoted which have an even broader perspective and not just address domestic regulations.

JANSI also has considered collaboration and discussions among members about the status of each company’s efforts through reviews of plans for improving safety.

3.2 AM Strategy Enabling a Flexible Response in Keeping with Plant Status

(1) Lessons Learned

Accident investigations and other reports have indicated that assumptions about tsunami and other external events were overly optimistic, that strategies were insufficient in preparing for a long-term accident response to the simultaneous occurrence of power source failures at multiple units over an extended period of time, and that the mobile and portable facilities, materials and equipment as well as the response procedures were not maintained in case such an incident might occur. Also, it has been pointed out that neither the capabilities (knowledge and skills) of response personnel to handle the occurrence of a severe accident or unforeseen event nor the long-term response system were adequate.

The main Lessons Learned are as follows.

○ Concerning Assumed Events

Response strategies should be formulated for accidents occurring simultaneously at multiple units and for accident extending over the long-term, assuming every possible event including severe natural phenomena and terrorism. (INPO, Diet Accident Investigation Commission, Ohmae Report and Independent Investigation Commission)

○ Concerning Implementation Systems

Systems (personnel, infrastructure) should be developed which are capable of a sound response even if an accident occurs at night, non-working days, holidays or any other such circumstances. (Government Investigation Committee, TEPCO Accident Investigation, Ohmae Report)

- ○ Concerning Facility Measures and Materials & Equipment

  Mobile and portable facilities, materials and equipment are to be readied so that a flexible response can be undertaken even if permanent facilities are unusable. (INPO, Ohmae Report, Diet Accident Investigation Commission)

  Taking into account terrorism, it should be ensured that there is the respective multiplexing and separation. (Diet Accident Investigation Commission)

- ○ Concerning Procedures

  Response procedures should be developed in preparation for such contingencies and their effectiveness verified (taking into account time constraints caused by a deteriorating environment resulting from a natural disaster) (INPO, Diet Accident Investigation Commission, Government Investigation Committee, Ohmae Report).

  Written procedures should be developed which also take into account cases where monitoring cannot be performed from the main control room. (Diet Accident Investigation Commission)

  Operators should prepare an accident management procedure manual by confirming each item of the manual at the site, on the basis of which education, drills and exercises under all credible conditions shall be fully provided to the staff. (SA Prevention Committee)

- ○ Other

  It is necessary to establish training and guidance which takes into account the effects of psychological stress on responders in a stringent environment or tremendous external event. (INPO)

Based on such circumstances, it is necessary to:

- ➢ **Formulate an AM strategy enabling a flexible response in preparation for contingencies (including terrorism) where accident responses are long-term and severe accidents occur simultaneously at multiple units or there is a severe natural disaster or long-term power failure**
- ➢ **Develop response procedures which take into account the occurrence of unforeseen situations, and verify their effectiveness**

(2) Countermeasure Activities of Special Members Companies

Basic countermeasures are being addressed for the respective items:

a. Assumed Events

・Consideration is given to the long-term loss of off-site power due to a natural disaster (earthquake, tsunami) and the simultaneous occurrence of severe accidents at multiple units (contingencies).

・Review has begun also on B5b compatibility

・Reviews have begun also on responding to diverse hazards.

b. Implementation Systems

・Duty and standby personnel are being secured so that an initial response can always be mustered even on non-working days and at night

・Independent and self-managing first response personnel are being established, and the special capabilities required during an emergency defined and the number of such personnel reviewed

・Operations are being adopted where the head of the emergency response headquarters designates the leaders for the response at each unit

・Command and control systems for each unit have been clarified

・Several deputy disaster prevention managers have been selected, who are able to act on behalf of the disaster prevention manager

・The number of responders has been augmented at the Head Office and power stations

・Manufacturer and contactor support framework are being constructed

・Reviews are underway on shift reinforcement systems

・Consideration is being given to liaisons with industries for developing a framework

c. Facility Measures and Materials & Equipment

・Mobile facilities are also being deployed in addition to permanent facilities as part of emergency and safety measures.

・Materials and equipment are being deployed at each unit to respond to simultaneous disasters at multiple plants.

・Tungsten vests have been readied for handling work under high dose conditions.

d. Procedures

・Manuals have been prepared assuming severe accidents simultaneously at multiple units

・Written AM procedures have been prepared in cooperation with plant installation manufacturers

・AM measures have been reviewed based on analyses of accident progression (including events superimposing SBO and LUHS)

・Review has begun on responding to simultaneous disasters at multiple units based on the Japan-version EDMG and US FLEX strategy.

・Consideration has also been given to time margins in procedures referencing the Japan-version EDMG

(3) Issues to be considered for the Future

・Written response procedures should be developed which also take into account the occurrence of unforeseen situations, and the effectiveness of these procedures verified.

・Training and guidance should be established which takes into account personal effects in high stress situations

3.3 Implementation of SA Education and Practical Training

(1) Lessons Learned

The accident investigation reports address the necessity of education and training for personnel to acquire the knowledge and skills for a severe accident response. Also, the reports call for severe accident training which takes into account accidents simultaneously occurring at multiple units and SBOs in a more practical manner, as well as considering time requirements and environmental conditions. (Some reports also call for training to immediately respond to terrorist attacks) Behind such requests, despite training having been conducted in disaster prevention and severe accident response, the myth of safety had taken hold in that it was believed that a true severe accident could not occur. Organizations did not conduct education and training focusing on making real attempts to improve the performance and abilities of each individual. Thus, it was pointed out that the stance toward a contingency, in which each individual is thinking about what to do, was insufficient in the response to the Fukushima Accident, and there was a lack of flexible and proactive consideration in responding to the crisis.

The main Lessons Learned are as follows.

○ SA Education

Emergency responders need to have in-depth accident management knowledge and skills to respond to severe accidents effectively. Training materials should be developed and training should be implemented using the systematic approach to training (INPO).

In addition, training and exercise courses on severe accidents for operators did not postulate the loss of DC power sources no conditions under which control panels in the main control room would be inoperable. The training courses focused on desktop training aimed at making trainees ‘capable of explaining’ the content of the ‘severe accident response,’ and there were no practical training sessions (Diet Accident Investigation Commission).

If the plant workers had acquired a high level of background knowledge about severe accidents and undergone training in a tense atmosphere based on the obtained expertise, and conducted inspections on necessary equipment and materials, they could have implemented the post-accident measures more effectively (Diet Accident Investigation Commission).

○ Implementation of Practical Training

Upon examination of the response to this accident, the ability to think about and confront the situation independently was poor, and there was a lack in flexible and proactive thinking, which is necessary in responding to a crisis. These were problems due to the failure to provide staff education and training focused on the enhancement of such qualities and capabilities. Therefore, it is strongly expected that a sincere revision of existing education and training contents be undertaken, as well as the implementation of practical education and training programs aiming at the enhancement of qualities and capabilities that are required in accident response (Government Investigation Committee).

In addition, in this accident response, a work environment deteriorated due to the earthquake and tsunami as well as environmental conditions without illumination at night delayed the work, and training should be conducted on the assumption that conditions are their worst (Ohmae Report).

Drills should address slower-developing accident scenarios with radioactivity releases that challenge onsite and offsite emergency responses over a prolonged period. The experience of Fukushima and recent severe-accident analytical studies, such as NRC's State-of-the-Art Reactor Consequence Analysis (SOARCA), have shown that accidents develop more slowly than typically regarded in drills and exercises (ASME).

Those with critical roles must be well-prepared to perform their roles under emergency conditions. Onsite ERO personnel, as well as off-site responders and local, prefectural, and central government officials must receive in-depth training on their responsibilities, and have the opportunity to practice execution of these responsibilities in drills and exercises that simulate real accident conditions to the extent feasible without impacting plant operation (ASME).

In training and exercises, there need to be sessions which also take into account preparatory work for connecting off-site machinery, assuming adverse conditions. Some of the adverse conditions considered are catastrophic conditions, excessive waste and high levels of radiation in the atmosphere which limit access to areas where equipment connections are assumed (ASME).

Based on such circumstances, it is necessary to:

Conduct education and training that equips personnel responding to an accident with the necessary knowledge and skills based on a recognition that a severe accident (including terrorist attacks) exceeding expectations may occur

And,

Proceed to redevelop responses for times when a crisis or contingency arises, and improve effectiveness through practical training aimed at mitigating the impact and preventing damage from spreading

(2) Countermeasure Activities of Special Members Companies

Countermeasures such as the following are being advanced.

a. Education that equips personnel responding to a severe accident exceeding expectations with knowledge and skills

・Implementation of training developing the ability to respond to disasters at multiple units

・Implementation of training assuming that areas cannot be approached due to high radiation or other such factors

・Implementation of operator simulator training which adds SAM functions

・Implementation of education for understanding SAMG, EDMG and other response procedures

・Implementation of communication training using transceivers and other equipment and the non-use of ordinary communication means

b. Implementation of training which improves effectiveness

Redevelopment is proceeding on plans for responding when a crisis or contingency arises, and the following improvements are being advanced.

・Construction of a framework for implementing blind training

・Planning the specific content of training based on JANTI training guidelines and JANSI nuclear disaster prevention guidelines

・Implementation of training based on nighttime, winter season or other unfavorable conditions

・Implementation of training assuming a variety of events (e.g.: training in debris removal during night, training for connecting off-site power supplies on the assumption that pylons have collapsed, etc.)

・Implementation of classroom training for establishing an off-site support framework in preparation for a prolonged accident response and providing assistance, and training assuming collaboration with all relevant organizations

(3) Issues to be considered for the Future

・Construction of effective education and training systems and the introduction of training methods

3.4 Construction of an Emergency Response Framework and Clarification of Chain of Command

(1) Lessons Learned

Many accident reports have discussed the initial response when multiple units are struck by severe events simultaneously and the important of establishing plans for an organizational structure for the long-term response after such an event. Underlying these calls are the fact that although consideration had been given to a system taking into account a disaster striking a single unit prior to the Fukushima Accident, the actual site situations forced personnel to respond under extremely difficult conditions due to multiple units having been hit simultaneously, and the situation was not one in which personnel were able to dedicate themselves solely to activities for bringing the accident to a resolution as activities were externally focused, including public relations and the filing of notifications. Also, confusion arose in the command and control system due to interference from the Prime Minister's Official Residence.

The main Lessons Learned are as follows.

○ Concerning Construction of an Emergency Response Framework

It is necessary to "establish strategies for staffing operating crews, other key plant positions, as well as site and corporate emergency response organizations quickly" in the initial stages of a multi-unit event and over the long duration of the event response (INPO). In order to achieve this, it is important that "environments and mechanisms be developed so that the necessary workers can be gathered, no matter when an emergency situation occurs" (TEPCO Accident Investigation).

The site's EP program should be self-sufficient for a range of severe accident conditions (e.g., SBO, multi-unit events, damage from external events) for an extended period of time (for as long as necessary), long enough that there is high assurance that necessary assistance can be supplied from offsite. This would include assuring that emergency response personnel can be protected from radiological exposure during this time; that there is sufficient access to water, food, and sanitary and sleeping facilities; and that emergency response equipment and facilities can function under the extreme conditions (ASME).

Moreover, there have also been indications about the insufficiency of ensuring the number of personnel. In other words, "ensure those who possess the expertise to operate specialized accident response equipment are available and are prepared to respond to a severe accident" (INPO), and to make this feasible, proposals have been put forward for securing such personnel through outside contracts along with training and certifying personnel.

In addition, in the response to this accident, personnel could not dedicate themselves to accident control activities, etc. for the station. For example, the head of the ERC at the Headquarters was swarmed with phone calls from external parties and technical employees were unavailable for accident control activities because they had to interact with the press and other outside organizations for hours (TEPCO Accident Investigation). On account of this, it is necessary that the accident response organization be separated into an organization, which is directly engaged in accident response, and an external interface organization (public relations, notifications, equipment procurement) so that personnel directly engaged in accident control can dedicate themselves to such" (TEPCO Accident Investigation). The role of the head office emergency response headquarters is to provide technical assistance including event analysis along with personnel and logistic support for the power station, and support should not be such that it hinders activities for resolving the accident, including confusion in leadership due to direct intervention.

○ Concerning Clarification of Chain of Command

It is necessary that there be a clear recognition that the site superintendent has the authority for command and control for the specific accident response in the field (TEPCO Accident Investigation). Moreover, it is realistically difficult to identify all actions that are required by unexpected events and define roles for each of them. Therefore, countermeasures were considered by the individuals who issued instructions. As a result, though it is a basic concept, it is necessary to "decide that individuals giving orders or persons supporting such individuals will clearly instruct who should do what. This will be checked during training to see whether it is conducted adequately" (TEPCO Accident Investigation).

Summarizing the above, it is necessary to:

- **Construct an emergency response framework for initial and long-term responses which take into account multiple units visited by disasters simultaneously**

And

- **Clarify the command and control system so that the site superintendant and the rest of the emergency response organization are able to dedicate themselves to activities for bringing the accident under control**

(2) Countermeasure Activities of Special Members Companies

a. Response Framework

a) Initial Response Framework

Improvements to initial response frameworks are underway with the following sorts of measures.

・Duty and standby personnel are being secured so that an initial response can always be mustered even on non-working days and at night

・Independent and self-managing first response personnel are being established, the special capabilities required during an emergency defined and the number of such personnel reviewed

b) Framework for Multiple Simultaneous Disasters

Improvements are underway so that responses can be mounted to simultaneous disasters at multiple units with the following sorts of measures.

・Operations have been adopted where the head of the emergency response headquarters designates the leaders for the response at each unit

・Command and control systems for each unit have been clarified

・Shift team leaders are assigned to each unit

・Manuals have been prepared assuming severe accidents simultaneously at multiple units

・Training is being implemented which assumes simultaneous disasters at all plants

・Personnel are selected for information collection and accident response at each unit

c) System Capable of Long-Term Response

Improvements have been made applying the following sorts of measures in preparation for a case where a long-term response is necessary.

・Several deputy disaster prevention managers have been selected, who are able to act on behalf of the disaster prevention manager

・The number of responders has been augmented at the Head Office and power stations

・Food and other necessary supplies are stockpiled so that on-site personnel are able to respond for a fixed period of time (3~7 days) without support from outside the station, and personal toilets, as a measure to address such human necessities, and survival sheets, as protection against the cold, have been deployed.

b. Clarification of Chain of Command

Improvements have been made applying the following sorts of measures for clarifying the command and control system.

- The command route has been clarified with the headquarters chief presiding over the entire organization and on down to team leaders, deputy team leaders and team members.
- The roles of the Head Office and power stations have been clarified in rules. The Disaster Prevention Operating Plan stipulates that the “site superintendant may take emergency measures for matters outside of his authority, but which are necessary to implement urgently during an emergency.”
- Clarification of a system for responding to inquiries from outside

c. Other Framework Reassessments

In addition to the above, the following sorts of improvements have also been made.

- Changes in the composition of shift teams are being considered with an increase in shift personnel as a response to unanticipated events
- Manufacturer and contactor support framework are being constructed
- To prevent main control room personnel from being disturbed, communication devices for transmitting information externally have been distributed to allow response headquarters personnel to respond to questions from outside
- A prompt response center will be set up at the Head Office, liaisoning with the Nuclear Regulation Authority
- Personnel who function to assist the headquarters chief have been clarified
- Special teams have been set up to respond to unexpected events
- Reviews are underway regarding the establishment of support headquarters functions outside the power station so that power station personnel are able to dedicated themselves to responding to the plant.
- Development of a system for accepting emergency or contingency response monitors and Nuclear Regulation Authority Commissioners
- Revision into an organization following the Incident Command System (ICS), which has been adopted as the standard for emergency organizations in the United States

(*): The number of people managed by one manager is limited to a maximum of seven
Command and control system is clear (only order of the direct supervisor are followed)
Flexible organizational structure capable of expanding or contracting in keeping with the magnitude of the disaster Etc.

(3) Issues to be considered for the Future

The following matters are issues to be considered in the future.

・Developing a framework which takes into account the initial and long-term responses in the case of multiple simultaneous disasters, and how to ensure its effectiveness.

・Ensuring the effectiveness through effective training and other exercises of the clarified command and control system.

・Reviewing the construction of an initial response framework capable of responding to all accident scenarios or contingencies in new safety standards

・Building up the ability to respond to events other than earthquakes and tsunami, and developing a framework for responding to compound disasters

3.5 Building a Culture of Safety to an Even Higher Level

(1) Lessons Learned

Strengthening efforts to build a safety culture have been emphasized in the Lessons Learned of accident investigation reports. Also seen were indications related to the attitude of individual employees, suggestions for solidifying the stance toward questioning and learning as well as involvement in specific responses to issues concerning safety culture.

The main Lessons Learned are as follows.

・TEPCO should receive with sincerity the problems which the Investigation Committee raised and should make further efforts for building higher level safety culture on a corporate-wide basis. (Government Investigation Committee)

・TEPCO will continue its constant efforts so that each and every employee will continue to ask him/herself how to improve safety, identify intrinsic crises, and pursue safety. (TEPCO Accident Investigation)

・It is generally recognized that the special and unique aspects of the nuclear technology must be recognized and considered as a key aspect of the nuclear safety culture. TEPCO was prepared for various accident scenarios involving equipment failures and human errors; however, preparations were not sufficient to deal with the accident caused by a beyond-design-basis tsunami. (INPO)

・While there was an awareness of the weight of QMS issues, effective improvements were not implemented. It is possible that a climate was created in which it was all right just to perform operations as specified in manuals. (Nuclear Safety Reform Plan)

・Each individual should have the ability to keenly perceive risks and appropriately respond by sharing those with upper level supervisors. (Government Investigation Committee)

・Nuclear operating organizations should consider the safety culture implications of the Fukushima Daiichi event, focusing on strengthening the application of safety culture principles associated with a questioning attitude, decision-making, special & unique aspects of the nuclear technology, and organizational learning. (INPO)

・It would be beneficial for all nuclear operating organizations to examine their own practices and behaviors in light of this event and use case studies or other approaches to heighten awareness of safety culture principles and attributes. (INPO)

・Corporate enterprise risk management processes should consider the risks associated with low-probability, high-consequence events that could lead to core damage and spread radioactive contamination outside the plant. (INPO)

・There was a dependence on determinations made by regulators and a stance toward making profound observations on one's own to discover problems was lacking. (Nuclear Safety Reform Plan)

In light of the aforementioned reports based on knowledge and other information obtained from various activities, JANSI has compiled as shown below Lessons Learned from the perspective of a safety culture for the purpose of enriching discussions among members about a safety culture and reflecting such knowledge in JANSI's activities. However, when new facts are ascertained and the necessity arises for amending the content, reviews will be conducted again.

①Reconfirmation of nuclear safety

・We must always recognize that nuclear power technology is special and unique, and be conscious of nuclear safety.

・People involved with nuclear power should themselves be aware and recognize what 'nuclear safety ' is in each and every operation, and, regardless of their job duties or position, they should reflect nuclear safety in decision making based on a variety of opinions.

②Reconfirmation of operator responsibility

・We must reconfirm that ensuring 'nuclear safety' is the single most important responsibility of the operator, and act with an awareness of high goals without thinking that regulatory values are adequate conditions for assuring safety.

・Even in cases where sufficient corroboration or data is not obtained about potential risks, a workplace climate should also be fostered where even minority opinions are accepted and reviewed.

・These matters should be taken up and prioritized by the top person responsible for the operation.

③Reassessment of potential risks of nuclear power and solidifying the stance toward questioning and learning

・Viewing events such as earthquakes and tsunamis as occurring, but their timing is uncertain.

・Being aware that risks change depending on the internal and external environment, always being vigilant of changing risks, extracting events which are widely assumed to occur, conducting ‘impact assessments’ on the chance that one does arise, reviewing the necessity for countermeasures, working to share those results and provide information about them to concerned persons, and making preparations for such event as appropriate.

・To this end, the organization must learn extensively from knowledge and examples, and each individual must cultivate a sensitivity toward safety and always maintain a questioning attitude on his own in daily work

(2) Countermeasure Activities of Special Members Companies

Companies have made an effort to hold many types of study sessions and change their organizations. Many have been doing so since before the Fukushima Daiichi Accident, and their main activities are listed below. At many companies, activities related to safety culture are promoted, which include contractors.

・Dissemination of a safety culture throughout the organization (construction of a framework in which discussions of safety culture are conducted in a continuous and multitiered manner among organizations and according to occupational hierarchy)

・Encouragement of an ‘attitude of constantly questioning’ which is inwardly critical and questions current activities, rules and other aspects

・Construction of a framework for effectively utilizing safety information from other countries (events which have occurred somewhere in the world may also happen at our own company)

・Construction of a process for improving based on hazard analysis

・Improvement of inter-departmental communication to prevent the harmful effects of compartmentalized organizations

・Preparation of e-learning materials, distribution of leaflets, and holding lectures all related to safety culture

(3) Issues to be considered for the Future

It is important to continually promote activities for fostering a safety culture within one's company based on the Lessons Learned from the Fukushima Accident.

In the future, it will be necessary to:

- Review requisites for examples to be shared so as to contribute to fostering a safety culture within companies
- Review methods for sharing information with members.

3.6 Securing Machinery, Materials and Communication Means during a Severe Accident

(1) Lessons Learned

Communication tools have a key role as important tools used from the initial response and afterward during an emergency. Also, disaster prevention equipment and materials are an important part of the infrastructure supporting prolonged activities. Even in conditions where a compound disaster or severe accident has occurred, the necessity has been indicated of adopting diverse means for such preparation so as to secure the means for communicating as well as equipment and materials, and of training so that operations function smoothly.

○Securing Diverse Means of Communication

As communication lines with the outside, various communication lines (satellite communications systems, municipal disaster prevention administration radio frequencies, and J-ALERT) need to be mutually connected and shared. (Diet Accident Investigation Commission)

On the other hand within the company, power station top management did not know that HPCI was going to be shut down (Government Investigation Committee Interim Report). As such, it is necessary to enhance the quality, quantity and speed of information shared in real-time (Ohmae Report). In addition, it is preferable to develop communication equipment that can be used while wearing full-face masks (TEPCO Accident Investigation).

Even when communication systems do not function fully, it is necessary to accurately understand equipment conditions, make decisions quickly, and share information among involved parties during accidents. Therefore, a common template with major equipment status and important reactor parameters will be provided on whiteboards in the ERC room and MCR. The content will be checked appropriately. Training for mastery of such information communication methods needs to be provided through disaster preparedness and other training (TEPCO Accident Investigation).

○ Construction of System for Transporting Equipment and Materials

The equipment and materials were not able to be smoothly transported between the TEPCO Head Office and power stations. Also, it was difficult to provide supplies at the times required during severe accidents. On account of this, design and training are needed for a system when arranging for equipment and materials, communication means, specifications, and checking deliveries and shipments (Ohmae Report)

Air transport of power-supply vehicles, back-up power sources and other equipment and materials need to be utilized proactively and access needs to be provided to the power station (reinforcement of roads and bridges) (Ohmae Report).

○ Removal of Debris and Securing Access Routes

The radiation doses of workers involved in removing the debris increased because a large amount of the debris contaminated by a high concentration of radioactive materials was produced by the hydrogen explosion and other incidents. Therefore, it was necessary for TEPCO to consider removing debris by remote controlled heavy equipment to reduce the exposure to workers. (Government Investigation Committee Interim Report)

In addition, accessibility within the power station site after an earthquake or tsunami strikes needs to be improved (reinforcing major roads using measures to counter liquefaction, deploying heavy machinery and securing operators for debris removal, etc.). (Diet Accident Investigation Commission)

○ Clarification of Transit Bases for Delivering Equipment and Materials

During the accident response, the Onahama Coal Center and J-Village facilities that are distant from Fukushima Daiichi NPS, were used as access control centers for the accident response (decontamination areas, access points for contaminated areas). When J-Village was first set up, no infrastructure was available, such as power, water, and communication systems. However, facilities were enhanced gradually along with the Onahama Coal Center. They functioned as important centers not only for workers heading in for restoration activities at Fukushima Daiichi NPS but for people entering the evacuated area. Based on this experience, methods to establish an access control center as well as a transport relay center will be considered in advance (pre-selection of locations, radiation education for support workers, providing decontamination equipment). (TEPCO Accident Investigation)

Regional asset support centers should be considered that could be mobilized as necessary to provide assistance from off-site within the agreed upon response time, e.g., 48 to 72 hours. (ASME)

(2) Countermeasure Activities of Special Members Companies

Legal revisions have led companies to strengthen the network between the central government and operators, and to maintain rear-area logistic support bases.

To ensure the means for communicating, terrestrial systems and satellite systems have been developed, which use the country's broadband networks for external communication. Internally, the utilization of satellite phones, radiotelephones and temporary telephones provide for greater diversification.

With the increased sharing of information, plans have been laid for personnel to gain proficiency through training by readying templates for important parameters to increase the sharing of alternative information of SPDS.

To secure equipment and materials, the 'nuclear power emergency support organization' has been jointly launched by operators to gradually increase the supply of equipment and materials as well as expand the scope of activities.

To secure transport means, companies have implemented debris countermeasures and reinforced roads, and are utilizing heliports.

(3) Issues to be considered for the Future

It is important that companies verify their countermeasures though in-house disaster prevention training and continually strive to improve them.

JANSI will assess the effectiveness of various countermeasures through its peer reviews.

3.7 Radiation Dose Management and Radiation Control

(1) Lessons Learned

Many of the accident investigation reports indicated that earthquakes, disasters and various other events as well as compound disasters need to be considered in design and operation of dispersion prediction tools and monitoring equipment because the failure of power sources shut down the operation of monitoring posts and other monitoring equipment and disabled continuous monitoring of radiation released outside the site.

Also, in terms of human factors, the necessity has been indicated of constructing a flexible framework in which radiation control departments support operators and other personnel during an emergency and of providing radiation management education on a daily basis for people working at power stations.

In terms of facilities, indications have been made about securing power sources and maintaining the environment in seismic isolated buildings assuming a severe accident, maintaining whole body counters

(WBC), APDs and other equipment, and deploying iodine tablets, protective clothing, masks and so on to a sufficient degree along with machinery and materials.

The Lessons Learned and lessons in the accident investigation reports are as follows.

○Preparation of Dispersion Prediction Tools and Monitoring Equipment during an Emergency

One of the reasons why the central government's dispersion predication tool SPEEDI was not helpful was that power source failures and other factors caused monitoring equipment to shut down and there was no information about releasing sources. Accordingly, monitoring equipment should be developed on the assumption of a compound disaster and based on consideration of system design, consideration of convenience and positional dispersion, consideration of diversity, deployment of sufficient quantity, construction of internal and external site networks, and other factors. Also, along with this, methods should be developed for predicting the release quantity using environmental monitoring data, and radiation dispersion prediction tools should also be introduced for keeping the disaster from spreading. (Diet Accident Investigation Commission, TEPCO Accident Investigation, Government Investigation Committee, INPO, ASME)

In addition, training should be expanded for relevant persons so that facilities function effectively (Government Investigation Committee), movement when roads are damaged due to an earthquake or other such event should be assured along with patrol methods (Government Investigation Committee), and equipment maintained for measuring residents' body contamination (Diet Accident Investigation Commission).

○Development of Framework Supporting Radiation Control during an Emergency

It has been pointed out that a framework had not been developed for the radiation control department to support the response of operators necessary for establishing or maintaining a safe shutdown during the emergency. Also, immediately after the accident, information about environmental radiation doses was not provided to workers. It has also been observed that exposure measurement devices for workers were not distributed to individuals. To that end, a radiation protection system, which allows for flexible support of operators in their response and other actions after an event, should be developed (INPO) and procedures, equipment and personnel should be maintained, which have been established for supporting emergency responses and measures in the radiation control department (INPO). Procedures should include the timely provision of work environment monitoring results to workers and the reliable implementation of personal dose monitoring.

In addition, personal dose management tools and other management for easy calculation of total dose should be prepared at places which function as centers including the seismic isolated building (TEPCO Accident Investigation), and the design should be such that a rise in dose is taken into account so as to maintain the building's function as a center for activities. (Government Investigation Committee Interim Report)

In addition, laws and regulations are demanding stricter dose limits for men and early evacuation routes for women who may not be emergency workers. (TEPCO Accident Investigation)

○Education on Radiation Control

The lack of basic knowledge about radiation management among all power station workers as well as knowledge about how to handle the relevant devices led to problems such as skin exposed to contaminated water and workers not wearing APDs, and workers were exposed to excessive amounts when radiation control personnel were not present. Accordingly, basic knowledge should be provided through daily education for all personnel working at a power station about risks from highly acute exposure doses and the importance of wearing APDs (legal requirements), and education and training should be given so that supplementary operations can be offered for radiation control in cases where radiation control personnel are not present. (TEPCO Accident Investigation, INPO, Government Investigation Committee Final Report)

○Personal Dose Limits and Assessment Methods

Several issues have arisen with this accident in regard to personal dose limits and assessment methods. First, revising the dose limits for times of emergencies is the role of the central government, but operators also should be prepared so that they are able to undertake the response necessary in an expeditious manner during an emergency (INPO). The methods and procedures for assessing internal exposure should incorporate specific timing for capturing radioactive nuclides and identification of nuclear for appropriate calibration of measuring devices, and these and other items should be prepared beforehand (TEPCO Accident Investigation, INPO). With regard to whole body counters for assessing internal exposure, temporary equipment should be readied and a back-up system from other companies should be put in place. (Government Investigation Committee Interim Report)

○Preparation of Radiation Protection Gear, Equipment and Materials

On the assumption that a compound disaster may occur, an environment as well as equipment and materials should be maintained which will not hinder the performance of activities by emergency responders for ensuring safety, for example, ensuring power supply to seismic-isolated buildings, a positive pressure (atmospheric pressure inside rooms), reinforced shielding, local air-exhaust ventilators, airline mask cleansing equipment and so on (Diet Accident Investigation Commission), maintenance of sufficient quantity of charcoal filters and other equipment in the main control room (Diet Accident Investigation Commission), as well as the deployment of protective clothing, masks, APDs, portable air purifiers, and other equipment and materials to appropriate locations (TEPCO Accident Investigation). In addition, to reduce internal exposure during the initial period, iodine tablets should also be distributed to the extent feasible to all workers including contractor employees (Diet Accident Investigation Commission).

Summarizing the above, it is necessary to

- Maintain a monitoring system ready for a compound disaster, and maintain a system which uses such measurement results to promptly assess and transmit data about the release source
- Construct a radiation control system in preparation for an emergency, enhance education for people working at the power station in radiation control, and develop a dose assessment system for emergencies
- Maintain the environment of activity bases such as seismic isolated buildings, and ensure sufficient equipment and materials.

(2) Countermeasure Activities of Special Members Companies

○Preparation of Dispersion Prediction Tools and Monitoring Equipment during an Emergency

- Power sources are being reinforced, data transmissions duplexed, and portable equipment deployed in consideration of a compound disaster.
- Systems and manuals are being developed for assessing released radiation when monitoring equipment operations shut down and other such cases, and training is being conducted for such situations.
- Additional monitoring cars utilized at Fukushima Daiichi have been deployed. Some monitoring cars (Land Cruisers), which are able to be used even when road conditions are poor, have also been deployed.
- Improvements for dispersion prediction tools are being considered. Some functions have also been added for event escalation prediction.
- The locations where alternate equipment is installed such as high ground has been dispersed.

○Development of Framework Supporting Radiation Control during an Emergency

- Systems have been created enabling personnel other than radiation control personnel to support simple radiation control work.
- Methods have been established allowing internal exposure to be promptly measured using survey meters other than WBC.
- Alternative tools for personal dose management have been deployed. One example is the deployment of alterative radiation control tools such as issuing entry permits to control zones by using computers.
- Prompt evacuation rules have been prescribed for women
- In preparation for an emergency, some companies have formulated plans for radiation work in advance by assessing dose rates in locations in regard to major events.

○Education on Radiation Control

- An education system has been developed for the basic knowledge and skills for radiation control including how to handle survey meters, radiation risks and so on for all people working at the power station and personnel supporting radiation control.

○Personal Dose Limits and Assessment Methods

- WBCs (including portable units) for measuring internal exposure have been augmented, alternative techniques established, and systems for back-up from other companies developed.

○Preparation of Radiation Protection Gear, Equipment and Materials

- Seismic isolated buildings, main control rooms and other tangible designs as well as protective clothing, masks and other equipment and materials have been prepared so that they will not impede the performance of emergency responders' work ensuring safety. Lists of the equipment and materials needed on the assumption of a station blackout have been prepared and the items deployed.
- To reduce internal exposure during the initial stage, iodine tablets have been deployed to appropriate locations so that they can be distributed to all workers including the contractor employees.
- Transportation relay points and specific means are considered for procuring equipment and materials. Also, adapters have been deployed which are compatible with other employees' APDs.

(3) Issues to be considered for the Future

○ Preparation of Dispersion Prediction Tools and Monitoring Equipment during an Emergency

・ Developing systems and manuals, securing personnel, and enhancing training for assessing released radiation and capable of meeting a variety of events that may arise
・ Assuring movement and patrol methods form times when roads are damaged during an earthquake

○Development of Framework Supporting Radiation Control during an Emergency

・ Construction of a flexible radiation protection system which allows for prompt support of operators performing work to secure safety during the initial stage
・ Development of procedures and personnel in radiation control departments supporting work during emergencies

○Education on Radiation Control

・ Raising awareness among support personnel outside radiation control departments and consideration of modes for effective education
・ Enhancement of education about wearing equipment during an emergency and radiation risks on a daily basis for persons working at power stations

○ Personal Dose Limits and Assessment Methods

・ Readiness as an operator for flexible revision of dose limits
・ Establishment of procedures for calibration of measuring devices which take into account nuclide compositions during an accident
・ Establishment of methods for specifying the time for internal capture of iodine

○ Preparation of Radiation Protection Gear, Equipment and Materials

・ Creation of rules concerning criteria, supervisors, manuals and so on for taking iodine tablets

3.8 Other Issues

Although included in the aforementioned important issues, other issues which should be considered have been extracted from accident investigation reports.

① Information Disclosure and Risk Communication

A system should be established, which includes the assignment of technical employees to respond to press inquiries so that the event is disclosed promptly and reliability as it progresses. Information pertinent to residents' safety will be given first priority for disclosure. (TEPCO Accident Investigation)

A framework should be constructed for studying methods of using social media (Twitter) which allows for interactive communication and for effectively utilizing such, and venues should be created for continuing communication with a broad range of the public about risks, and a dialogue should be continued with the public about the extent to which risks can be accepted (SA Prevention Committee).

(Countermeasure Activities)

Technical staffs are assigned to public relations departments at most companies.

In order to provide easy-to-understand information, simplified schematic diagrams and other such documents are being used, and information transmission forms (identical templates for the status of important equipment, reactor parameters, etc.) have also been developed.

Also, education is being planned with outside experts serving as instructors for risk communication during normal times. In addition, the posting of risk communication experts are planned.

② Preparation of Predictive Analysis Tools Capable of Updating in Real-Time to Track the Progression of a Severe Accident

At each nuclear power station, predictive analysis tools that can be updated on a real-time basis regarding the progress of a severe accident at each unit, as well as experts who are familiar with the utilization of such analysis tools, shall be deployed. Such analysis tools should be able to provide support for accidents in nuclear reactors and spent fuel pools. (Diet Accident Investigation Commission)

(Countermeasure Activities)

The systems with functions for predicting dispersion and for analyzing accident progression are preparing to be introduced.

Some companies are preparing the collection of knowledge obtained with SA analysis systems and other resources into databases (manuals) in order to enable accident progression to be predicted by plant status. Such databases are being improved by reflecting the most recent information, and disaster training and SA education are also being utilized.

③ Establishment of Organizations Specializing in Technical Support for Severe Accidents

An organization should be set up which is dedicated to providing technical assistance at the time of a severe accident, and managed properly through constant training and exercises. (Diet Accident Investigation Commission)

In a nuclear disaster, people at the accident site and at the T-ERC of the head office may find it difficult, while scrambling to respond, to simultaneously consider and implement short-term and medium-to-long-term measures that anticipate future developments. The Commission believes that it is important to have an established structure like the above-mentioned technical support team, which is separate from any emergency-response organization, to predict the progression of an accident and consider measures that should then be taken, by gathering the necessary know-how. (Diet Accident Investigation Commission)

(Countermeasure Activities)

For emergencies, a separate framework has been developed from the framework for plant operations during normal times, and technical support is being provided for the power station site. Separate from the organization responding to an accident, a support framework studying the prediction of accident progression as well as short and long-term measures is also being developed with the cooperation of manufacturers and contractors.

In addition, field training exercises for response measures are being practiced regularly so that such contingency systems function effectively.

④ Healthcare for Responders

Many people, who had long and continuous working hours and who had to conduct activities under total exhaustion, became ill. Healthcare for employees remaining at power stations needs to be augmented (TEPCO Accident Investigation).

(Countermeasure Activities)

At nuclear disaster base facilities, the current medical system has been adopted, and when there is a shortage of staff, the necessary personnel are secured by deploying physicians and nurses from other offices. The procedures necessary for contracts or agreements with medical institutions will be prepared.

⑤ Management of Human Error in Accident Response

To reduce the propensity, rate of occurrence, and opportunities for human error, decrease risks attributable to failure of existing complex systems to lead to improved safety, more focus should be placed on human functions in decision making before, during and after a low-probability event occurs and from the standpoint of such management (Carnegie).

(Countermeasure Activities)

Headquarters personnel are posted to provide necessary advice in consideration also of the excessive burden placed on the headquarters chief when making major decisions. Also, reviews will be conducted on the necessity for emergency countermeasures, training and guidance which take into account the mental impact on decision-making.

⑥ Construction of Framework Capable of Extracting, Sharing and Utilizing Beneficial Information from Numerous Data during an Emergency

In order to effectively utilize support and useful information from abroad, it is also necessary to consider a mechanism to select support that is truly necessary. It is also necessary to have an appropriate allocation of employees with a technical background. (TEPCO Accident Investigation)

(Countermeasure Activities)

There are mechanisms to obtain, analyze, assess and expand the use of information about accidents and failures which have occurred at nuclear power stations as well as information from the NRC, INPO, WANO and United States vendors. Also, companies are obtaining information about measures to improve safety from JANSI and responding at their own plants.

The issues to be considered are screened from the standpoint of causes or other factors pertaining to target equipment and events in reviews of data concerning problems, and there are companies also that recognize as a problem the fact that reviews focusing on the extent of event impact or plant weaknesses are not proactively undertaken, and schemes are needed to implement effective lateral development.

4. JANSI Support Activities

(1) Items Supporting Members' Requests

For the purpose of supporting requests by members regarding lessons in Fukushima accident investigation reports, proposals for JANSI support activities were stated based on the remaining issues to be considered and Lessons Learned. In response, there were requests for support put to JANSI regarding several issues, which are noted below along with JANSI's response to the requests.

① Formulating guidelines for creating standards for EAL determinations, implementing training, and making EAL determinations promptly and appropriately

(JANSI's response)

・Regarding the "creation of standards for EAL determinations," the Japan Electric Association is proceeding with the work of revising "JAEG4102 (emergency measure guidelines for nuclear power stations)," which reflects the Lessons Learned from the Fukushima Accident. Within this revision work, the understanding is that information is to be noted in regard to standards for EAL.

・With regard to 'training,' support will be provided for improving the effectiveness of electric power companies' training through the 'disaster prevention training review committee' which was set up within JANSI.

② Review of training plans and formulation training programs which reflect 'psychological stress responses' for the capabilities required of upper management including directors

(JANSI's response)

Based on accident investigation reports and other data, the abilities demanded of the leader of an emergency response office have been clarified, and preparations are underway for holding seminars for such study in FY2013. Reviews are being conducted for having seminars comprising the aforementioned content.

③ Education and training including seminars in which results from other countries are referenced for decision makers and other upper management at power stations

(JANSI's response)

Plans have been made to hold a seminar referencing results from other countries during FY2013.

④ Provision of data for creating benchmarks for assessing whether a constructed emergency response framework is effective

(JANSI's response)

In the 'disaster prevention training review committee,' which was set up within JANSI, examples from Japan and other countries are shared, and plans made for holding seminars and other workshops. Such sessions are scheduled to be held in November of this year and at the end of the fiscal year, and, these are scheduled for continued support in the coming fiscal year and afterward.

⑤ Sharing information about companies' activities to foster a safety culture and requisites for examples to be shared so as to contribute to fostering a safety culture

(JANSI's response)

・Information is being shared through various committee bodies and includes good practices and common issues from after the Fukushima Accident.

・Reviews will be conducted on the content and requisites of examples to be shared through discussions and various committee bodies with committee members.

（2）Other Items Supporting Planned Implementation (Including Those Underway)

① How to assure safety against high-impact, low-probability events

- Continuing implementation of safety improvement plan reviews of operator companies based on research related to SA measures in other countries with the aim of initiating proactive measures
- Implementation of review of mechanisms for disseminating knowledge, indications and peer review results from company-wide organizations and verification committees to internal worksites as an item for specific review

② Implementation of SA education and practical training with third-party reviews about the effectiveness of frameworks, procedures, facility measures and so on

- Assessments will be conducted of frameworks constructed and implemented which are capable of providing education and training to have personnel responding to an SA possess the necessary skills. Also, support will be offered for such construction.

③ Construction of an emergency response framework and clarification of the chain of command

- Providing data for creating benchmarks for assessing whether a constructed emergency response framework is effective
- Assessing the status of training by operators and providing assistance for improvement

④ Radiation dose management and radiation control

- Supporting the development of standards, including simplified procedures for measuring thyroid dose, procedures for whole body counter measurements, methods for calibrating monitoring devices during emergencies, which have been formulated by academic and other such societies.
- Providing information as appropriate at briefings and other such explanatory meetings regarding the aforementioned.

5. Conclusion

Lessons Learned indicated in accident investigations and other reports have been extracted and the status of company responses compiled about such Lessons Learned with the cooperation of special member companies.

Based on the extracted Lessons Learned and the countermeasures of member companies, issues to be further studied have been compiled for Lessons Learned. JANSI's support activities are also described which include the request put forth by members. In the future, this report will be utilized when holding seminars, Peer Reviews, Specific Reviews and in the activities by JANSI senior representatives (SR), and support will be provided for members' activities to reflect these lessons in safety improvement operations.