XII. Lessons learned from the accident so far

The accident of Fukushima Nuclear Power Station has the following aspects: it was triggered by a natural disaster; it led to a severe accident of damage to nuclear fuel, Reactor Pressure Vessels and Primary Containment Vessels; and accidents of multiple reactors were evoked at the same time. Moreover, nearly three months have passed after the occurrence of the accident, a mid- to long-term initiative for its termination is needed so that it has imposed a large burden on society such as many residents in the vicinity have been required to evacuate for an extended period, it has been making a major impact on industrial activities such as farming and livestock industries in the related area. In this manner, there are many aspects different from the accidents at Three Mile Island Nuclear Power Plant and Chernobyl Nuclear Power Plant in the past.

Also, it is characterized by the fact that emergency response work and nuclear emergency preparedness activities had to be performed in a situation where the earthquake and tsunami destroyed the social infrastructure such as electricity, communication and transportation across a wide area in the vicinity, and by the fact that aftershocks frequently limited a variety of accident response activities.

This accident led to a severe accident, shook the trust of the people, and warned people engaged in nuclear energy about their overconfidence in nuclear safety. Because of this, it is important to learn lessons thoroughly from this accident. We will present the lessons classified into five groups at this moment bearing in mind that the most important basic principle in securing nuclear safety is defense in depth.
We will present lessons learned up to this moment classified in five groups. We recognize that a fundamental review is unavoidable on nuclear safety measures in Japan based on these lessons. Some of them are specific to Japan. However, we will include these specific lessons from the standpoint to show the overall structure of lessons.

The lessons in group 1 are those learned based on the fact that this accident has been a severe accident, and from reviewing the sufficiency of preventive measures against a severe accident.

The lessons in group 2 are those learned from reviewing the adequacy of the responses to this severe accident.

The lessons in group 3 are those learned from reviewing the responses for nuclear emergency in this accident.

The lessons in group 4 are those learned from reviewing the firmness of the basis for securing safety was established in the nuclear power station.

The lessons in group 5 are those learned from summing up all the lessons and reviewing the thoroughness in safety culture.

(Lessons in group 1) Strengthen preventive measures against a severe accident

1. Strengthen measures against earthquakes and tsunamis

This earthquake was an extremely massive one caused by plural linked seismic centers. As a result, in Fukushima Dai-ichi Nuclear Power Station, acceleration response spectra of seismic ground motion observed on the base mat exceeded the acceleration response spectra of the design basis seismic ground motion in a part of the periodic band. Although damage to external power supply was caused by the earthquake, damage to important systems, equipment and devices have not been confirmed so far. However, detailed status still unknown should be further investigated

The tsunamis which hit Fukushima Dai-ichi Nuclear Power Station were 14-15m high, substantially exceeding the assumed height of the design or evaluation. The tsunamis severely seawater pumps etc, which caused failure to secure emergency diesel power supply and reactor cooling function. The procedure manual had no assumed the impact tsunamis and only measures against a backrush. The assumption on the frequency and scale of tsunamis was insufficient as shown above so that actions for large-scale tsunamis were not taken enough.

From a view point of design, in seismic design in a nuclear power station, an active period of a capable fault to be considered is stipulated to be within 120,000-130,000 years (50,000 years in the old guideline), and a recurrence period of a big earthquake is approximately considered, and moreover, “residual risks” are required to be considered. Compared with this, designs against tsunamis have been performed based on traditions on past tsunamis and assured traces so that they have not been done in a way in which an appropriate recurrence period is considered in relation to a safety goal.

Reflecting on the above issues, we are committed to considering handling of plural linked seismic centers as well as strengthening quake resistance of external power supply. Regarding tsunamis, from the viewpoint of preventing a severe accident, we will assume appropriate frequency and height of tsunamis in consideration of a sufficient recurrence period for attaining a safety goal. Then, we will perform a safety design of structures, etc. preventing them from the impact of immersion in the site caused by the assumed tsunamis in consideration of destructive capability of tsunamis. Moreover, from a viewpoint of defense in depth, supposing a possibility of tsunamis exceeding assumed tsunamis incorporated in the design of the buildings, we will take measures which can maintain important safety functions even in consideration of a flooded site and magnitude of destructive capability of a run-up wave.

2. Secure power supply

A major cause for this accident was failure to reserve the necessary power supply. This was caused by the facts that a diversity of power supply was not planned from a viewpoint of overcoming vulnerability related to defects derived from a common cause by an external event, and that equipment such as a switchboard was not installed to be able to withstand a severe environment such as flooding. Moreover, it was caused by the facts that battery life was short compared with the time required for restoration of AC power supply and that a require time goal was not clear for recovery of external power supply.

Reflecting on the above issues, we are committed to securing power supply at the site for a long time determined as a goal even in a severe situation of emergency by diversifying power supplies by means of preparing diverse emergency power supplies such as an air-cooled diesel generator, a gas turbine generator, etc., employing a power-supply car and so on, and preparing switchboards, etc. with high environmental tolerance and generators for battery charge, and so on.

3. Secure a firm cooling function of a reactor and a RCV

In this accident, the final place for release of heat (the final heat sink) was lost due to the loss of function of seawater pumps. Reactor cooling function was activated by water injection but core damage could not be prevented due to drain of water source and loss of power supplies, etc., and RCV cooling function also did not run well. We faced difficulties thereafter also, as it took time in reducing the pressure, moreover, in water injection after that also, water injection into a reactor by the heavy machinery such as a fire engine, etc. had not been prepared as a measure for accident management. In this manner, the loss of cooling function of reactors and RCVs aggravated the accident.

Reflecting on the above issues, we are committed to securing assured alternative cooling functions of reactors and RCVs by securing final alternative heat sinks for a long time such as diversifying alternative water injection functions, diversifying water sources for water injection and increasing volume, and introducing an air-cooling system and so on.

4. Secure a firm cooling function of spent fuel pools

This time, the loss of power supplies caused the failure to cool the spent fuel pools, requiring actions to prevent a severe accident due to the loss of cooling function of spent fuel pools in tandem with responses to the accident of the reactors. So far, a risk of a major accident of a spent fuel pool has been deemed small compared with a core event so that measures such as alternative water injection, etc. have not been considered.

Reflecting on the above issues, we are committed to securing firm cooling by introducing alternative cooling functions such as natural circulation cooling system or air-cooling system, and alternative water injection functions in order to maintain cooling of spent fuel pools even when power supplies are lost.

5. Thorough accident management (AM) measures

The accidents reached to the severe accident. The accident management measures had been introduced to Fukushima NPS as response to minimize the possibilities to reach the severe accidents or to reduce the influence in case of reaching to the severe accident. However, judging from the situation of the accidents, although the measures partially functioned such as alternative water injection from the fire extinguishing water system to the reactor, they did not fulfill a role in diverse responses including ensuring the power supplies and the reactor cooling function and were inadequate. In addition, the accident management measures are basically regarded as voluntary efforts by TEPCO, not legislative requirements, and so the details of improvement lacked strictness. Moreover the guideline of Accident Management has not been reviewed since its development in 1992 or strengthened or improved.

Reflecting on the above issues, we will be committed to position the accident management measures as legislative requirements, and develop the accident management to prevent severe accidents utilizing the probabilistic safety assessment including review of the design requirements as well.

6. Response to issues in concentrated siting of reactors

Accidents occurred at more than one reactor at the same time in the accidents, and the resources needed for accident response had to be dispersed. Moreover, because two reactors shared the facilities and physical distance between them was small, etc., progress of accident occurred at one reactor affected the emergency responses of nearby reactors.

Reflecting the above issues, we will be committed to make it possible to implement operation at the accident at a reactor where accident occurred independently from the operation at other reactors if one power station has more than one reactor, and assure the engineered independence of each reactor to prevent accident of one reactor from affecting nearby reactors. In addition, we will promote to develop the structure by Unit to carry out independent accident response with a central focus on person in charge of nuclear safety assurance.

7. Consideration on basic design such as placement of NPS, etc.

Since the spent fuel pools were placed on the higher part of the reactor buildings, response to the accidents were difficult. In addition, contaminated water from the reactor buildings affected the turbine buildings and expansion of contaminated water to other buildings was not prevented.

Reflecting the above issues, we will be committed to prepare for adequate placement of facilities and buildings to ensure to develop necessary responses such as cooling, etc. and prevent expansion of the accident influence in consideration of occurrence of severe accidents during the stage of basic design of placement of NSP, etc. In this regard, additional response will be taken to add the same function to the existing facilities.

8. Ensuring the water-tightness of important equipment facilities

One of the causes of the accidents is that many important equipment facilities including component cooling sea water pump facilities, the emergency diesel generators, switchboards, etc. were flooded by the tsunami, which impaired power supply and cooling facilities.

Reflecting on the the above issues, we will be committed to ensure the important safety functions, in terms of achieving the target safety level, even if hit by unexpected tsunami and flood when these facilities are placed near rivers. In concrete terms, we will ensure the water-tightness of important equipment facilities by installing watertight doors based on the destructive power of tsunami and flood, blocking flood route such as pipes, and the installation of drain pumps, etc.

(Lessons in Group 2) Enhancement of measures against severe accidents

9. Enhancement of prevention of hydrogen explosion

In the accidents, a hydrogen explosion occurred at the reactor building in Unit 1 at 15:36 on March 12, and at the reactor in Unit 2 at 11:10 on March 14 as well. In addition, an explosion that was probably caused by hydrogen occurred at the reactor building in Unit 4 around 06:00 on March 15. Consecutive exposures occurred from the first one occurred at Unit 1 before taking effective measures. These hydrogen explosions worsened the situation of the accidents. In a BWR, inactivation is implemented and a flammability control system is installed in the containment in order to maintain the soundness of against the design basis accident. However, we did not assume the situation of an explosion in the reactor buildings caused by hydrogen leakage, and as a matter of course, the hydrogen measures for the reactor buildings were not taken.

Reflecting on the above issues, we will be committed to enhance the measures for prevention of a hydrogen explosion such as the installation of a flammability control system to function in the event of a severe accident in the reactor buildings, the establishment of facilities to blow off hydrogen, etc. in addition to the hydrogen measures in the containment.

10. Enhancement of containment vent system

In the accidents, we were interrupted by operability problems of the containment vent system in the situation in occurrence of severe accident. Moreover, as the function of removing released radioactive material in the containment system was inadequate, the system was not be able to be utilized effectively as accident management measures. In addition, the independence of the vent line was insufficient and so it may have had an adverse affect on other parts through connecting pipes, etc.

Reflecting on the above issues, we will be committed to enhance the containment vent system by increasing the operability and ensuring the independence of the containment vent system, strengthening the function of removing released radioactive material, etc.

11. Enhancement of accident response environment

In the accidents, the radiation dosage increased in the main control room and operators could not enter the room temporarily and it still remains diifficult to work in the room to this day for an extended period, and, as a result, the habitability in the main control room has decreased. Moreover, the accident response activities were affected at the on-site emergency station, a control tower of all emergency measures, in various sides as radiation dosage also increased and the communication environment and lighting deteriorated.

Reflecting on the above issues, we will be committed to enhance the accident response environment to implement the accident response activities in case of severe accidents such as strengthening radiation shielding in the control rooms and the emergency centers, enhancing the exclusive ventilation and air conditioning system on site, strengthening related equipment including communication, lightening, etc. without use of AC power supply, etc.

12. Enhancement of the radiation exposure management system at accident

In the accidents, although adequate radiation management became difficult as personal dosimeters were unusable, personnel engaged in radiation work were forced to work on site. In addition, radioactive material concentration measurements of the air were delayed, and as a result risk of internal exposure increased.

Reflecting on the above issues, we will be committed to enhance the radiation exposure management system at accident by providing personal dosimeters and protection suits and gears for accident, developing the system to be able to expand personnel at accident and improving the structure and equipment to promptly measure radiation dose of radiation workers..

13. Enhancement of training responding to severe accident

Effective training to respond to accident restoration at nuclear power plants and adequately work and communicate with relevant organizations in the wake of severe accidents were not sufficiently implemented. For example, it took time to communicate between the emergency office inside of the power station, the Nuclear Emergency Response Headquarters and the Local Headquarters and also to build collaborative structure with Self Defense Force, Police, Fire Authorities and other organizations which played important roles in responding to the accident. Adequate training could have prevented these problems in advance.

Reflecting the above issues, we will be committed to enhancing training to respond to severe accidents by promptly responding to accident restoration, identifying situations within and outside of power plants, facilitating the gathering of human resources needed for securing safety of residents and to effectively collaborate with relevant organizations.

14. Enhancement of instrumentation reactors and PCVs

Because instrumentation of reactors and PCVs was insufficiently functioned in the severe accident, it was difficult to promptly and adequately obtain important information such as, water levels and the pressure of reactors, and the source and amount of released radioactive materials. Reflecting the above issues, we will be committed to enhance instrumentation of reactors and PCV in the wake of severe accidents.

15. Central control of emergency supplies and equipment and rescue team in place

Logistics support has been diligently provided by those responding to the accident and supporting sufferers with supplies and equipment gathered mainly at J Village. However, because of the damage from the earthquake and tsunami in the surrounding area when the accident occurred, we could not promptly and sufficiently mobilize a rescue team to provide emergency supplies and equipment and support accident control activities. This is why the on-site accident response did not sufficiently function.

Reflecting on the above issues, we will be committed to centrally control emergency supplies and equipment and reinforce a rescue team for the operation of them in order to smoothly provide emergency support even under fierce circumstances.

(Lessons in Group 3) Enhancement of nuclear emergency response

16. Response to combined emergency of both large-scale natural disaster and nuclear accident

We had tremendous difficulty in communicating with relevant individuals and organizations, using telecommunications, mobilizing human resources, procuring supplies and others because it concurrently occurred with a massive natural disaster. As the nuclear accident has been prolonged, some measures such as evacuation of residents, which was originally assumed to be a short-term measure, have been forced to be extended.

Reflecting the above issues, we will be committed to prepare a structure and an environment where appropriate communication tools and devices and channels to procure supplies and equipment will be ensured in coincidental emergency of both massive natural disaster and nuclear accident. Also, assuming a prolonged nuclear accident, we will be committed to enhance emergency response including effective mobilization plans to gather human resources in fields who are involved with the accident response and sufferers support..

17. Reinforcement of environment monitoring

Currently, local governments are responsible for environment monitoring in an emergency. However, appropriate environment monitoring was not possible immediately after the accident because equipment and facilities for environmental monitoring owned by local governments were damaged by the earthquake and tsunami and the relevant individuals had to evacuate from the Off-site Center. To make up for this lack, MEXT cooperated with relevant organizations has conducted environment monitoring.

Reflecting on the above issues, the government will be committed to developing a structure to implement environment monitoring in a reliable and well-planned manner.

18. Segregation of duties between relevant central and local organizations, etc.

Communication between local and national offices as well as with other organizations was not sufficiently achieved due to lack of communication tools immediately after the accident and also roles and responsibilities of each side were not clearly defined. Specifically speaking, responsibilities and power were not clearly defined in the relationship between the NERHQs and Local NERHQs, between the government and TEPCO, between the Head Office of TEPCO and NPS on site, and also segregation of duties within the government. Especially, communication was not sufficient between the government and TEPCO at the initial point of the accident. Also, the Local Headquarters did not sufficiently function because the Off-site Center functioned because the Local Headquarters became unusable in the middle of the emergency response process.

Reflecting on the above issues, we will be committed to review and define roles and responsibilities of relevant organizations and clearly specify and reorganize roles and responsibilities in communication as well as such tools.

19. Enhancement of communication on the accident

Communication to residents in the surrounding area such as evacuation instructions was difficult because communication tools were damaged by the large-scale earthquake. The subsequent information to residents in the surrounding area, etc. and local governments was not always provided in a timely manner. The impact of radioactive materials on health and the radiological protection guideline of the ICRP, which are the most important information for residents in the surrounding area and others, were not sufficiently explained. We have focused on publicizing mainly accurate facts to the citizens and have not sufficiently present future outlook of the risks, which sometimes gave rise to concerns,

Reflecting on the above issues, we will be committed to reinforce adequate provision of information on the accident status and response etc. and appropriate explanation about the radiation effect to the residents in the vicinity. Also, we will keepin mind that the future outlook is included in the information delivered while incidents are ongoing status.

20. Enhancement of response to support from overseas and communication to the international community

The Japanese government did not appropriately respond to the support offered by other countries across the world because a specific structure to accommodate such support offered by other countries with the domestic needs in the Japanese government. Communication with the international community including prior notification to neighboring countries and areas on the discharge of water with low-level radioactivity to the sea was not always sufficient.
Reflecting on the above issues, we will be committed to developing an effective global structure, cooperating with international community, in order to develop a list of supplies and equipment effectively responding to any accident to be prepared internationally, clearly specify contact points for each country in advance in case of accident and encourage to share information through such an improved international notification structure.

21. Adequate identification and forecast of effect of released radioactive materials

The environmental effects of released radioactive materials were not fully identified because release source information could not be obtained when the accident occurred. Also, The System for Prediction of Environmental Emergency Dose Information (SPEEDI) was not fully utilized to forecast effect of radioactive materials based on release source information, which is the primary function of this system because source information at the time of the accident could not be obtained. Even with such a constraint, SPEEDI should have been utilized as a reference of evacuation activities and other purposes by presuming diffusion trend of radioactive materials under a certain assumption. Although the results generated by SPEEDI are now being disclosed , it should have been done so from the initial stage.

Reflecting on the above issues, we will be committed to improving the instrumentation and facilities to ensure release source information can be obtained. Also, we will develop a plan to effectively utilize SPEEDI and other systems to address various incidents and disclose the data and results from SPEEDI, etc. from the beginning.

22. Clear definition of widespread evacuation area and radiological protection guideline in nuclear emergency

Immediately after the accident, evacuation area and “stay indoors” area were established and cooperation of residents in the vicinity, local governments, police and relevant organizations facilitated to implement evacuation and “stay indoor” instruction. As the accident prolonged, the residents had to stay indoors for a long period. Subsequently, however, guidelines of the ICRP and the IAEA were suddenly decided to be used when establishing deliberate evacuation area and evacuation prepared area in case of emergency. The size of the protection area defined after the accident was considerably larger than 8 to 10 km, which was defined as the area where protection measures should be carefully focused.

Reflecting on the above issues, we will be committed to clearly defining the scope of widespread evacuation area and guidelines of radiological protection criteria based on the experience of the current accident.

（Lessons in Group 4）Reinforcement of safety infrastructure

23. Reinforcement of safety regulatory bodies

Governmental organizations have different responsibilities for securing nuclear safety. For example, NISA of METI is responsible for safety regulation as a primary regulatory body, the Nuclear Safety Commission of the Cabinet Office is responsible for regulation monitoring of the primary governmental agency and relevant local governments and ministries are in charge of emergency environmental monitoring. This is why it was not clear who has the primary responsibility for providing sufficient activities to ensure citizens' safety in an emergency. Also, we cannot deny that the existing organizations and structures made mobilization of capabilities difficult to promptly respond to such a large-scale nuclear accident.

Reflecting on the above issues, we will be committed to separate NISA from METI, review regulatory and administrative frameworks on nuclear safety and a structure of environment monitoring operation including NSC Japan and ministries and launch discussion on them.

24. Establishment and reinforcement of legal structure, criteria and guidelines

Many different issues were brought about regarding legal structures on nuclear safety and nuclear emergency preparedness and related criteria and guidelines based on the current accident. Also, based on the experiences of this nuclear accident, many issues would be identified as issues to be reflected in the standards and guidelines of IAEA.

Reflecting on the above issues, we will be committed to reviewing and improving the legal structures of nuclear safety and nuclear emergency preparedness and related criteria and guidelines. In doing so, considering not only structural reliability but also new knowledge and expertise including the progress of system concepts, measures taken for age-related degradation of the existing facilities should be reviewed and improved. Also, we will address technical requirements based on new laws and new findings and knowledge for facilities already approved and licensed, or in other words, how backfitting will be accommodated with laws and regulations. We will contribute to improve standards and guidelines of the IAEA with utmost effort by providing related data.

25. Human resources for nuclear safety and nuclear emergency preparedness

All the experts of nuclear safety, nuclear emergency preparedness, risk management and radiation medicine should get together to address the accident by making use of the latest and best knowledge and experience to respond to such a severe accident. Also, it is extremely important to develop human resources who are involved with nuclear safety and nuclear emergency preparedness in order to ensure mid-and-long term efforts on nuclear safety as well as to restore the current accident.

Reflecting on the above issues, we will be committed to enhancing human resource development of nuclear operators and regulatory organizations along with focusing on education of nuclear safety, nuclear emergency preparedness, crisis management and radiation medicine at educational organizations.

26. Securing independency and diversity of safety system

Although multiplicity was sought out to ensure reliability of safety systems, avoidance of common cause failures has not been carefully responded and independency and diversity have not been sufficiently secured.

Reflecting on the above issues, we will strongly committed to ensuring adequate response to common cause failures and the independency and diversity of safety systems to further improve the reliability of safety functions.

27. Effective use of Probabilistic Safety Assessments (PSA) in risk management

PSA has not always been effectively utilized when reviewing processes and efforts of risk reduction at nuclear power plants. While quantitative evaluation of rare risks such as large-scale tsunami may be associated with difficulty and uncertainty even in PSA, we have not made sufficient efforts to clearly identify such risks.

Reflecting the above issues, considering knowledge and experiences of uncertainties, we are committed to further actively utilizing PSA and developing safety improvement measures including effective accident management measures based on PSA.

（Lessons in Group 5）Raise awareness of safety culture

28. Raise awareness of safety culture

All those involved with nuclear energy should be equipped with a safety culture. “Nuclear safety culture” is stated as “A safety culture that governs the attitudes and behavior in relation to safety of all organizations and individuals concerned must be integrated in the management system.” (IAEA) Learning this message and putting it into practice is the starting point, duty and responsibility of those who are involved with nuclear energy. Without a safety culture, there will be no constant improvement of nuclear safety.

Reflecting on the current accident, the nuclear operators whose organization and individuals have primary responsibility for securing safety should look at every knowledge and finding, verify whether any weakness of a plant is suggested by this knowledge, and if they consider the presumption that risks regarding the public safety of the plant are sufficiently maintained as low is negatively affected, they should reflect whether they have seriously made efforts to take appropriate measures to improve safety.

Also, both organizations and individuals who are involved with nuclear regulations are responsible for securing nuclear safety for citizens should not overlook any suspicion about securing safety and should reflect whether they have seriously made efforts to respond to new knowledge and findings sensitively and quickly.

Reflecting the above issues, we will be committed to ensuring that a safety culture is kept in place by returning to the starting line that pursuit of defense in depth is indispensable for securing nuclear safety, ensuring that those involved with nuclear safety constantly learn professional expertise regarding safety and taking a stance to continuously examine whether there is any weakness in securing nuclear safety and any room for safety improvement.