National Report for the Second Convention on Nuclear Safety Extraordinary Meeting

2012. 5

The Republic of Korea

EXECUTIVE SUMMARY

As of May 2012, the Republic of Korea, a party to the Convention on Nuclear Safety, has 21 nuclear reactors in operation and seven under construction. Out of the 21 in operation, 17 are pressurized light water reactors (PWRs) and four are pressurized heavy water reactors (PHWRs); the seven other units under construction are PWRs.

The March 2011 nuclear accident at Fukushima that was triggered by the Tohoku earthquake and subsequent tsunami raised public concerns over the safety of nuclear facilities in Korea. As the need for independent government evaluation became evident to secure and improve the safety of nuclear facilities, the Korean government conducted safety inspections of Korean nuclear facilities to determine the steps needed to cope with severe plant damage caused by an earthquake or tsunami beyond expectation.

Based on the inspection results, the regulatory body of Korea unveiled a list of required action plans in May 2011. The plans dealt with the following areas: safety of structures, systems, and components against earthquake and tsunami; integrity of electric power, cooling, and fire protection systems when inundation occurs; severe accident response; emergency response; The operator submitted its implementation plan to the regulatory body in July 2011 which was confirmed in September 2011. The action plans are to be completed by 2015, but the timeline will vary among the nuclear plants, depending on whether they are in operation, under commissioning or under construction. For example, nuclear power plants being commissioned will need to complete action plans such as installing emergency injection for cooling water from external sources and securing a mobile emergency AC power source before they are allowed to begin commercial operation.

As of May 2012, action plans have been implemented as scheduled and the regulatory body has set regulatory requirements for each action item and reviewed the adequacy of actions taken. In addition, the regulatory body is developing a national-level process to incorporate the lessons learned from the Fukushima nuclear accident into the operation of Korean nuclear power plants. The process will cover gathering, analyzing, and evaluating operating experience; and preparing action plans at operator and regulator levels; and establishing regulatory requirements to improve the safety of nuclear power plants.

Post-Fukushima actions taken in Korea are specifically described in II. Topical Assessment of this report.

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I Introduction

I.1 Nuclear Safety Regulatory Policy & Framework

I.1.1 National Policy & Strategy

Korea's national policy and strategy for nuclear safety are basically defined in the Nuclear Safety Act. The purpose of Nuclear Safety Act is "prevention of disaster resulting from radiation and to ensure safety of the general public", and the Act stipulate safety regulation requirements for safety assurance during all stages of activity associated with the use of radioactive materials, i.e., from construction to decommissioning of nuclear power facilities. In addition, the Act on Physical Protection and Radiological Emergency and the Nuclear Liability Act were respectively put in place for radiological emergency management and physical protection, and for compensation for nuclear damage.

The government also promulgated a policy statement and a safety charter to present its policy direction and demonstrate its strong commitment on the issue. The policy statement was published in 1994, declaring that nuclear safety is a top priority in the utilization of nuclear power and incorporating international developments in nuclear safety into the national policy. In the statement, the government declared a firm commitment to nuclear safety; emphasized the importance of establishing a safety culture; and presented five principles (independence, openness, clarity, efficiency, and reliability) and a 11-item policy direction for safety regulation.

In addition, the government proclaimed a Nuclear Safety Charter, stressing that nuclear safety is the first and foremost priority in the utilization of nuclear power. The Charter also presents the pledge, to be made by all who are engaged in nuclear and related industries, to maintain the highest standards of safety; make prompt and transparent disclosure of information; collect public opinions on safety measures; guarantee the independence and fairness of safety regulations; improve safety research and technical development; faithfully comply with laws and international conventions on safety; continuously improve laws and systems; and promote a culture of nuclear safety.

For effective implementation of nuclear safety legislation and regulatory policies, the Korean government establishes and implements a comprehensive nuclear safety plan every five years. To secure the effectiveness of the plan, the government also establishes an annual implementation plan and, based on that, monitors implementation.

I.1.2 Safety Regulatory Framework

The nuclear safety regulatory framework of Korea establishes the Nuclear Safety and Security Commission (NSCC) to be in charge of all aspects of nuclear safety regulation. NSSC is comprised of chairperson who is cabinet minister level, vice-chair who is cabinet vice-minister level, and staffs which is consisted of 2 bureaus and 8 divisions.

The authority to regulate nuclear safety and establish nuclear safety policies is clearly entrusted to the NSSC through relevant legislation including the Nuclear Safety Act. And the Commission maintains a close cooperative system with other government agencies which are in charge of some activities relating to nuclear safety management in pursuance of their own functions per the Government Organization Act. For example, under close cooperation with the Commission, the Ministry of Public Administration and Security (i.e., the National Emergency Management Administration under this Ministry) responsible for national emergency preparedness and management is in charge of safety management of flammable materials at nuclear power facilities, and rescue efforts in case of an emergency like a fire.

The government established the Korea Institute of Nuclear Safety (KINS) and the Korea Institute of Nonproliferation and Control (KINAC) as regulatory expert organizations per the Nuclear Safety Act to strengthen technical capabilities relating to nuclear safety regulation, because nuclear safety regulation requires considerable knowledge of specialized technology. Under entrustment from the NSSC, KINS is in charge of technical aspects of nuclear safety regulation, including safety reviews, inspections, education, and safety research, based on technical knowledge and accumulated regulatory experience. KINAC carries out tasks entrusted by the Commission with respect to physical protection of nuclear power related facilities and nuclear materials, related safety measures, and import and export control.

I.1.3 Effort at Improved Safety in Operating Nuclear Power Plants

With the Atomic Energy Act, enacted and promulgated in 1958, Korea established its first legal system for the use and development, and for safety regulation, of nuclear power.

Following the accident at Three Mile Island (TMI) in 1979, the government developed the Radiation Hazard Preparedness Measures for Areas around a Nuclear Power Plant to step up its radiological emergency measures. As the need for an environmental radioactivity monitoring system became evident upon the occurrence of the accident at Chernobyl in 1986, the Korean national radioactivity measurement network was strengthened. By joining the IAEA Convention on Early Notification of a Nuclear Accident, along with a technical support convention, cooperation with the international community was intensified in preparation for an emergency.

The government promulgated a Nuclear Safety Policy Statement in 1994 and founded a Nuclear Safety Committee which was operated as an advisory body in 1996 for independent deliberation and decision-making on important matters concerning nuclear safety.

In 2001, the Periodic Safety Review (PSR) was introduced to prevent safety degradation due to aging, and to improve safety by incorporating operating experience and research findings. Accordingly, the licensee shall conduct a periodic safety review every 10 years with regard to 11 items including the actual physical condition of the nuclear reactor facilities at the time of assessment.

In addition, the Policy on Severe Accidents was published in 2001, requiring the licensee to establish safety goals, perform a probabilistic safety assessment (PSA) for all operating nuclear power plants, secure the capabilities needed to cope with severe accidents, and develop a severe accident management plan. In accordance with the Policy, the licensee submitted the PSA results for all operating nuclear power plants. The licensee submitted the results of a PSA which incorporated a low-power shutdown PSA, starting with Yonggwang Units 5 and 6. In connection with its capability to cope with a severe accident, the licensee identified several ways to improve the safety of nuclear power plants based on the results of PSAs conducted by 2007, such as installing alternating AC power sources and increasing of battery availability time. The implementation of the safety improvement measures are periodically monitored by KINS in association with the Periodic Safety Review.

Following the September 11 terrorist attack in the United States, the Act on Physical Protection (of Reactor Facilities) and Radiological Emergency was enacted in 2003 in preparation for possible terrorist attacks and radiological accidents in the nation's key infrastructure. In 2005, legal and institutional frameworks to efficiently cope with radiological disasters were established by installing an On-site Emergency Management Center at each nuclear power site of Korea.

In addition, the Korean government has improved safety by requesting the licensee to implement action items for improvement, identified through the immediate regulatory response to significant operating experiences at overseas nuclear power plants (separate from licensee's operating experience feedback). For example, upon a feedwater line break accident at the Mihama nuclear power plant in Japan, a special inspection at a regulatory level was conducted, and the licensee was required to take action to improve the wall thinning management program of carbon pipe.

I.2 Installation Status of Nuclear Power Plant

Kori Unit 1, the first nuclear installation in Korea, started commercial operation in April 1978. As of May 2012, there are 21 units in operation, 2 units under commissioning, and 5 units under construction as shown in table I.1-1. Out of the 21 units in operation, 17 are pressurized light water reactors (PWRs) and four are pressurized heavy water reactors (PHWRs); the seven other units which are under commissioning or construction are PWRs.

Table I.1-1 Status of Nuclear Power Plants in Korea

In Operation

Plant Name		Reactor Type	Capacity (MWe)	Construction Start	Commercial Operation
Kori	1	PWR	587	Aug. 1971	Apr. 1978
	2	PWR	650	Jul. 1978	Jul. 1983
	3	PWR	950	Jun. 1979	Sep. 1985
	4	PWR	950	Jun. 1979	Apr. 1986
Shin-Kori	1	PWR	1,000	Jan. 2005	Feb. 2011
Wol-song	1	PHWR	678.7	Jun. 1977	Apr. 1983
	2	PHWR	700	Oct. 1991	Jun. 1997
	3	PHWR	700	Aug. 1993	Jul. 1998
	4	PHWR	700	Feb. 1994	Oct. 1999
Yong gwang	1	PWR	950	Oct. 1980	Aug. 1986
	2	PWR	950	Oct. 1980	Jun. 1987
	3	PWR	1,000	Jun. 1989	Mar. 1995
	4	PWR	1,000	Jun. 1989	Jan. 1996
	5	PWR	1,000	Sep. 1996	May 2002
	6	PWR	1,000	Sep. 1996	Dec. 2002
Ulchin	1	PWR	950	Jan. 1981	Sep. 1988
	2	PWR	950	Jan. 1981	Sep. 1989
	3	PWR	1,000	May 1992	Aug. 1998
	4	PWR	1,000	Jul. 1993	Dec. 1999
	5	PWR	1,000	Jan. 1999	Jul. 2004
	6	PWR	1,000	Jan. 1999	Apr. 2005

Under Commissioning

Plant Name		Reactor Type	Capacity (MWe)	Construction Start	Commercial Operation
Shin-Kori	2	PWR	1,000	Jan. 2005	-
Shin-Wolsong	1	PWR	1,000	Sep. 2005	-
	2	PWR	1,000	Sep. 2005	-

Under Construction

Plant Name		Reactor Type	Capacity (MWe)	Construction date	Commercial Operation
Shin-Kori	3	PWR	1400	Sep. 2007	-
	4	PWR	1400	Sep. 2007	-
Shin-Ulchin	1	PWR	1400	Apr. 2010	-
	2	PWR	1400	Apr. 2010	-

Operator: KHNP

The nuclear power plants in Korea are located at four different sites on the eastern and western coasts of the Korean peninsula. Of the operating nuclear power plants, Kori Unit 1, which started commercial operation in 1978, has seen the expiration of its original design life. After a safety review by the regulatory body, the continued operation of Kori Unit 1 has been permitted for 10 additional years from 2007.

I.3 Post-Fukushima Response

I.3.1 National Level Emergency Response to Protect the Public

Following the Fukushima accident, the Korean government set up an effective response led by a Prime Ministerial Task Force which coordinated actions by the regulatory body and other relevant government departments and agencies. The Government assigned clear responsibilities to departments and agencies involved in the response. MEST and KINS were put on full alert to protect the public from potential radiological impacts.

From 18:40, 11 March 2011, KINS and KIRAM operated a 24-hour emergency response centre under the oversight of MEST. The actions for monitoring and analysis of radioactivity in the environment appear to have been effective. The national network of 59 unmanned stations and 12 regional centres were used to take air, water and soil samples at increased frequency. Analysis of meteorological data was taken into account. Measures were taken in ports and airports to check for possible contamination. The contamination of food and tap water was also monitored. The Ministry of Foreign Affairs and Trade (MOFAT) set up an emergency headquarters to respond to the Japanese accident, performed protective actions for Korean residents and tourists in Japan, and dispatched experts for protecting Korean residents and rescue teams dispatched from the National Emergency Management Agency to Japan from radiation exposure

MEST and KINS communicated with the general public through diverse media including newspapers and major portal sites. In particular, MEST and KINS opened a special webpage at the KINS web site and set up a new telephone line to address concerns and questions of the public on March 12 2011. The web site recorded millions of hits, one indication of the rapidly growing interest by the general public at that time. The regulatory body posted approximately 70 Q&As on the web site concerning radiation risks, distributed a press release, held hundreds of interviews, and gave a briefing to the National Assembly of Korea.

MEST and KINS ensured communication with the general public through various media, including national newspapers and the Internet portals most frequented in Korea. Namely, MEST and KINS opened a special webpage accessible on KINS's homepage on 12 March 2011, and also opened several dedicated telephone lines to answer public inquiries. Radiation measurements from the environmental monitoring network were made publicly available on the KINS web site. The web site received a huge increase in public interest with millions of hits being recorded. The regulatory body posted around 70 sets of Q&As on health hazards arising from radioactivity on the most frequented Internet portals. The regulatory body also provided hundreds of press releases and interviews, and responded to numerous questions from representatives of the National Assembly.

With regard to international cooperation, KINS dispatched two experts to support the Japan Nuclear Energy Safety (JNES) Organization. Additionally, the Korea-Japan Expert Meeting was held in Japan twice, from April 11 to 13 and from June 14 to 15, 2011.

I.3.2 Efforts to Improve the Safety of Nuclear Power Plants

The Korean government decided to perform a targeted Special Safety Inspection on domestic nuclear facilities, after deliberation by the Nuclear Safety Committee. The 40-day inspection, from March 21 to April 30, 2011, was intended to secure countermeasures against a loss of electrical power and subsequently to a severe accident resulted from a large earthquake followed by a tsunami. The scope of safety inspection consisted in six following areas under the worst-case scenario assumption considered lessons learned from the nuclear accident at Fukushima.

- Area 1: Design of structures and equipment against earthquakes and coastal flooding;
- Area 2: Integrity of electrical power, cooling, and fire protection systems in case of inundation;
- Area 3: Counter measures against severe accidents;
- Area 4: Emergency response and emergency medical systems;
- Area 5: Long-term in-service plants;
- Area 6: Research reactors and nuclear fuel cycle facilities.

The safety inspection team consisted of experts from KINS, the industry, academia, and research institutes. To assure the objectivity and transparency of the inspection, opinions of civil participants (such as representatives of local residents and local governments) were gathered and were reflected in the inspection. Subsequently, a public hearing was held at each nuclear power site to explain inspection results and follow-up actions.

The results of the inspection confirmed that operating nuclear power plants, research reactors (including Hanaro), and nuclear fuel cycle facilities were safely designed and operated considering the current design basis earthquake and tsunami. However, the team identified short- and long-term items for safety improvement even in case of a natural disaster beyond the design basis.

In addition to the safety inspection, the Korean government allowed local residents to participate in periodic inspection of nuclear power plants as part of the effort to increase citizen involvement in nuclear safety. The Korean government also decided to hold regular public meetings at each nuclear power site to strengthen citizen communication. Furthermore, based on a decision to strengthen environmental radioactivity measurement in order to ensure early detection of radioactivity in case of a nuclear accident at home or abroad, the Korean government is additionally installing more unmanned measurement centers, starting at Dokdo (installed oin April 1, 2011). The target number is 120, up from the current 59. More local measurement centers will additionally be opened in densely populated areas (Southern Seoul, Incheon, Ulsan, and Jinju), until the number reaches 16, up from the current 12.

Moreover, the safety regulatory organization was separated from MEST and was re-established as the Presidential Commission of Nuclear Safety and Security in October 26, 2011, The intent is to improve the independence of nuclear regulation and to ensure the organizational separation of nuclear safety regulation from nuclear power promotion.

The regulatory body identified action items for improved safety at nuclear power plants, based on early lessons learned from the nuclear accident at Fukushima in May 2011. The licensee submitted a detailed action plans for each item identified in July 2011, which was confirmed in September 2011. In the implementation plan, priority was given to actions to improve depth in defense capability against a natural disaster beyond the design basis. Actions in the plan were targeted to be completed by 2015.

Actions for nuclear power plants under construction were also determined, depending on the construction situation. Nuclear power plants under commissioning are required to complete action plans prior to the start of commercial operation; these include installing reactor injection flow for emergency water cooling from external sources in order to secure emergency cooling and power against a tsunami; securing mobile emergency AC power sources and installing PARs (Passive Autocatalytic Hydrogen Recombiners) to secure the integrity of the containment building in case of loss of cooling and loss of power, and providing severe-accident training and education to boost emergency response capabilities. Nuclear power plants under construction permit are required to complete all action plans prior to the issuance of an operating license. In addition, a basic plant design which incorporates all action items is required to be included in the Preliminary Safety Analysis Report (PSAR) submitted at the time of application for a construction permit.

As of May 2012, the operator is in the progress of implementation as planned. The regulatory body has set regulatory requirements for each action item and checked the adequacy of actions implemented. Since fully understanding the causes and progress of the Fukushima nuclear accident requires continuous effort, the regulatory body is developing a national-level process to incorporate the lessons learned from Fukushima into the operation of Korean nuclear power plants. The process will cover gathering, analyzing, and evaluating operating experience; preparing action plans at operator and regulator levels; and establishing regulatory requirements to improve the safety of nuclear power plants. In accordance with the process, action plans for fire protection and operation areas such as human resources and organization will also be in the works.

II Topical Assessment

A. Topic 1 (External Event)

A.1 Overview

A.1.1 Earthquake

Korea locates in the eastern part of the Eurasian Plate, hundreds of kilometers away from the boundaries of the Pacific, Philippines Sea, and Eurasian plates. Earthquakes in Korea exhibit the characteristics of intra-plate seismicity. They are small in size, infrequent and widely diffused. Korea is classified as a stable continental region in scientific terms with a very low possibility of a large-scale earthquake. During past 34 years, from 1978 to 2011, the annual number of earthquake larger than magnitude 3.0 was 9 on average, that of earthquakes larger than magnitude 4.0 was about 1 and that of earthquake larger than 5.0 was about 0.1. Korean regulatory standards, equivalent to international standards, are applied in all stages of installing a nuclear power plant: site selection, design, construction and operation to secure the seismic safety of the facility. Moreover, technological development and research results in the related areas are continuously incorporated into the seismic design standards.

The peak ground acceleration of the safe shutdown earthquake (SSE) for Korean nuclear power plants is 0.2g (0.3g from Shin-Kori units 3 and 4). This is calculated by considering margin to the potential maximum ground acceleration at the nuclear power site through the investigations of seismic and geologic characteristics within a 320 km radius of a reactor, and detailed investigations of geological characteristics within a 8 km radius of a reactor. The SSE also satisfies the minimum requirement (the average exceeding frequency of SSE should be less than 1.0×10-3/year) in the Probabilistic Seismic Hazard Analysis (PSHA).

Each nuclear power plant has the seismic monitoring system. If ground acceleration is higher than the operating basis earthquake (OBE), the plants are shut down manually and the integrity of structures and components are checked according to abnormal operating procedures.

If ground acceleration greater than 0.01g is detected, a seismic alarm in the main control room (MCR) is triggered. If a peak ground acceleration exceeding the OBE of 0.1g occurs, the plant is shut down and a white-level alarm is issued. If a peak ground acceleration exceeding the SSE of 0.2g occurs, a blue-level alarm is issued.

In the safety inspection conducted after the Fukushima accident, the following items were checked for verifying the safety of the structures, systems and components against earthquakes:

- Seismic capacity of Seismic Category I structures and equipment
  - Maintenance of structures and equipments.
  - Effect of design change or additionally installed facilities on the existing facilities.
  - Adequacy of the anchorage of equipments, and potential interference between major equipments and adjacent facilities.
- Operability of the seismic monitoring system
  - Operability of the seismic monitoring and alarm system.
  - Adequacy of the data input in the seismic monitoring system as shutdown criteria in the event of an earthquake.
- Adequacy and feasibility of corresponding measures upon the occurrence of an earthquake.

It was confirmed that safety related structures and components have the same integrity to withstand design earthquakes due to periodic tests, inspections and maintenance.

- Design change and additionally installed facilities are designed not to affect the safety of the existing facilities.
- Aging management on the anchorage of the major equipment is being properly performed according to the relevant operation procedure.
- Separation between the major equipment and adjacent facilities is sufficiently maintained to prevent potential interference.
- Seismic monitoring systems are managed properly through monthly channel inspection, semiannual functional test, and calibration during planned overhaul, and the alarm system and the uninterruptible power supply system meet relevant requirements.
- If an earthquake occurs, necessary measures such as plant shutdown and seismic response analysis will be made in accordance to relevant abnormal operating procedures.

However, action items for improvement were identified in order to achieve safe shutdown capability and ensure adequate response on the earthquake. that exceeds the design basis.

- Installing an automatic seismic trip system

  To guard against operator failure or human errors, facility improvements would enable reactors to automatically trip when an earthquake is above a certain seismic level similar to that of SSE.

- Improving the seismic capacity of the safe shutdown system

  To reinforce the seismic capacity of the safe shutdown system to achieve and maintain safe shutdown if an earthquake exceeds the design basis.

- Investigating and researching the maximum potential earthquake for the nuclear sites

  To re-evaluate the deterministic seismic risk of nuclear sites by reviewing the maximum potential earthquake in Korea. This is prompted by the occurrence of the 2011 Japan earthquake that was stronger than the design earthquakes of Japanese nuclear sites.

- Improving plant seismic capacities of main control room (MCR) such as the seismic alarm window

  The seismic evaluation was not performed for the seismic alarm window in the MCR, which may hinder MCR operators in recognizing when an earthquake occurs. In addition, improper fixing of ceiling, lighting facility and office appliances in the MCR of Kori plants will likely lead to falling, collapse or dislocation of ceilings, lighting fixtures and office equipment, and furniture, which may injure MCR operators or interfere with their response actions. For that reason, improvement should be made.

- Improving the seismic capacity of the entrance bridge in the Wolsong nuclear power plant

  To improve the seismic capacity of the entrance bridge in the Wolsong plants, because seismic design is not applied to it, thereby would likely be damaged in an earthquake and be a possible obstacle to an emergency response to a nuclear accident.

A.1.2 Tsunami, Storm Surge and Sea Water Level

Since Korean nuclear power plants are located in coastal areas, the possibility of coastal flooding and the impact caused by waves on safety-related structures should be assessed. Main causes of coastal flooding are high tide, wind waves, storm surges and tsunamis. Therefore, the probable maximum sea water level is determined by combining the above factors and be the design basis on which the safety of the nuclear power sites and the possible impact on safety-related equipment should be reviewed. If necessary, a protection plan should then be incorporated in the plant design.

The design basis sea water levels (possiblehighest and lowest sea water levels) of Korean nuclear plants are calculated by evaluating the probable maximum tsunami and storm surge that may affect the sites.

- The possible highestsea water level is determined by combining the high tide level, the probable maximum tsunami (PMT) or storm surge (PMSS) (using the higher one between PMT and PMSS) and adding the height of wave run-up.
- The possible lowest sea water level is determined by combining the low tide level and the minimum sea water level due to a tsunami or a storm surge (using the lower one between PMT and PMSS).

When receiving a tsunami warning from the KMA (Korea Meteorological Agency), nuclear plants take pre-planned preventive measures against possible inundation.

In the safety inspection conducted after the Fukushima accident, the following items were checked for verifying the safety of the structures, systems and components against tsunamis and storm surges:

- Adequacy of plant design against tsunami or storm surges.
  - Adequacy of site elevation in preparation for coastal flooding (considering earthquakes, storms, etc.).
  - Resistance capability of safety-related structures against coastal flooding.
  - Capability of the intake structure to provide sufficient cooling water in low water conditions.

It was verified that there is no possibility the structures would be inundated under the possible highest sea water level conditions, and cooling water intake would be possible even for the possible lowest sea water level. The possible highest sea water level of the nuclear power plant site was calculated conservatively by combining the height of high tide level, PMT or PMSS, and wave run-up. There is no possibility of the inundation of structures because the possible highest sea water level is lower than the site elevation (including the sea wall). The possible lowest sea water level of nuclear power site was also calculated conservatively by combining the low tide level, and PMT or PMSS. Cooling water intake is possible even in the possible lowest sea water level condition by tsunami because the bell mouth of the intake pump is lower than the possible lowest sea water level.

However, action items for improvement were identified for securing enhanced safety to withstand any coastal flooding that exceeds the design basis.

- Building up the sea wall for Kori site
  It is difficult to accurately predict the probable maximum event of a natural disaster. Given the uncertainty, a sufficient freeboard should be considered in the design. Accordingly, the sea wall for Kori site, which is relatively low, needs to be built up (10m).
- Installing waterproof doors and discharge pumps
  Safety-related structures without waterproof doors are likely to be inundated by a tsunami that exceeds the site elevation. In particular, cooling water intake structures of some plants are installed at a relatively low elevation. In addition, emergency diesel generators (EDGs) and associated equipment areas have non-waterproof discharge pumps because only internal flooding was considered.
- Investigating and researching the design basis sea water level of nuclear power sites
  Korea needs to re-assess the current design basis sea water level, following the Fukushima accident.
- Reinforcing the intake capability for cooling water and improving facilities in preparation for tsunami
  Korea needs to improve flood protection and intake capability of cooling sea water pumps based on the reassessment results. In addition, the warehouse keeping spare parts and replacements is likely to be damaged by a large tsunami.

A.1.3 Forest Fire

Although nuclear power plants are located near coastal areas, they are surrounded by forests and fields. Therefore, a protection plan against forest fire is in place to contain a blaze in the early stage or to establish a defense line in case a fire grows.

A plant has a fire brigade and outdoor fire hydrants. Additionally a system to ensure assistance from local government agencies is established.

The fire protection system is designed to protect safety-related structures, systems and components so that safe shutdown functions of nuclear power plants is achieved even in case of a fire which is not promptly extinguished by fire fighting measures.

Separately, the impact of forest fire on a nuclear power plant was assessed. It showed that a rise in the temperature of the external wall of the containment building due to a forest fire would be insignificant, with a negligible impact on the safety of a nuclear power plants.

A.1.4 Rainfall and Inland Flooding

Although nuclear power plants are in coastal areas, the impact of inundation resulting from rainfall as well as flooding from a tributary should be reviewed, and if necessary, a protection plan needs to be established.

For Korean nuclear power plants, the inundation depth of the sites is calculated based on the probable maximum precipitation, and the invert elevation of the first floor of safety-related structures is designed to be higher than the inundation depth. As for Ulchin units 1 and 2, and Shin-Kori units 1, 2, 3 and 4 which are adjacent to a tributary, the simultaneous occurrence of a flood due to maximum precipitation and the break of small dams in the upstream river is considered in the plant design so the nuclear power sites are safe from the likelihood of inundation.

A.2 Operator's Activities

A.2.1 Earthquake

At the request of the regulatory body to prepare safety measures for structures against an earthquake in May 2011, KHNP established the detailed implementation plan and finalized it in September 2011. According to the plan, five items are undergoing safety improvement with completion targeted in 2014. The progress status by improvement item is as follows.

- Installing an automatic seismic trip system

  The automatic seismic trip system (ASTS) will be installed for all nuclear power plants, including ones under commissioning or construction. As of May 2012, the system has been installed at nine units, including Kori unit 1. The design criteria of ASTS are two-out-of-four logic for reactor trip, seismic category I, and Class-1E power.
- Improved seismic capacity of the safe shutdown systems

  For safety-related systems and the spent fuel pool system necessary to achieve and maintain cold shutdown, a success path (system analysis) and the scope for seismic performance evaluation will be defined and used as the basis of seismic performance to determine if the criteria (0.3g) is satisfied. If necessary, the seismic capacity of the safe shutdown systems will be improved by 2014. The basic plan to improve seismic capacity of the safe shutdown systems was established and the assessment for seismic capacity is ongoing.

- Investigating and researching the maximum earthquake for nuclear power sites
  The maximum potential earthquake in Korea will be re-assessed and be the basis for analyzing characteristics of seismic sources, ground motions and site amplification, probabilistic and deterministic hazard analysis, and so on. These will be completed by 2013 for seismic safety evaluation of nuclear power plants already operating or under construction. The investigation is underway.
- Improving the seismic capacity of the seismic alarm window in the main control room (MCR)
  Seismically qualified seismic alarm equipment (alarm lamp) will be newly installed in the main control room. To protect MCR operators, drop prevention measures such as applying seismic design to ceilings and lighting and improving lighting facilities will be completed by 2013. The work is ongoing.
- Improving the seismic capacity of the entrance bridge to the Wolsong site
  A precision safety diagnosis, including load test and structure analysis, will be conducted and the results will be used to improve the seismic capacity of the bridge by 2012. The seismic capacity evaluation process is underway.

I addition to the above, KHNP identified additional measures to improve the seismic safety of structures by taking into account the lessons learned from the Fukushima accident, and follow-up actions taken by overseas plants.

- Evaluating the seismic performance of water pipeline (from purifying plant to treatment plant)
  The seismic performance of water pipelines between the purifying plant and the treatment plant will be evaluated and if necessary, actions to strengthen the seismic performance of the pipeline will be taken by 2014.

A.2.2 Tsunami, Storm Surge and Sea Water Level

At the request of the regulatory body to prepare safety measures for structures against tsunami or storm surge in May 2011, the KHNP established the detailed implementation plan and finalized it in september 2011. Structures are being improved and targeted for completion in 2015.

- Building up the sea wall for the Kori site
  The sea wall for the Kori site, whose freeboard is relatively low, will be raised to

10m, the same elevation of other nuclear sites by 2012 to protect the plants against a tsunami or storm surge beyond the design basis. The construction work has been started in March 2011.

- Installing waterproof doors & discharge pumps

  Waterproof doors and structures will be installed by 2014 for exits and entrances, equipment hatch and ventilation openings in the path that are likely to be submerged by a tsunami or flood beyond the design basis in order to protect emergency power systems (EDG building, alternative EDG building, safety-class battery room) and significant safety systems (component cooling water building, emergency cooling water building, spent fuel pool cooling system) Waterproof doors are being designed for Kori unit 1 and 2.

  Waterproof pumps will be installed by 2014 to promptly discharge water from safety-related buildings that become flooded after a massive earthquake or tsunami. The detailed improvement plan is ongoing.

- Investigating and researching the design basis sea water level of nuclear power sites

  The design basis sea water level and tsunami-triggering faults will be re-evaluated by 2013 in consideration of sufficient conservatism of input data used to evaluate the current design basis sea water level (simultaneous behaviors of seismic gaps, super typhoon, etc.) and to establish measures, and any necessary follow-up action. The investigation is underway.

- Reinforcing the intake capability for cooling water and improving facilities to prepare against a tsunami

  Actions to maintain the minimum water level such as rearranging the location of the bell mouse of intake pumps and installing an underwater dam on the basis of research and study on design basis water level of the nuclear sites (completed by 2013). This will be completed by 2015.

  Storage of spare parts and replacements will be relocated from the coastal area to a place that is safe from a tsunami by 2015.

A.3 Regulator's Activities

A.3.1 Seismic Safety of Structures and Components

The regulatory body of Korea has set regulatory standards to implement action plans, which incorporate lessons learned from the nuclear accident at Fukushima. The below is the summary of regulatory standards that have been set until now.

- Installing an automatic seismic trip system
  The review for some plants has been completed, and ongoing at other plants. During the review, the comprehensive evaluation of the system was conducted. The examination included the foundation of set values, component qualification, quality assurance requirements, software logic, reliability analysis of spurious alarms and malfunctions, cyber security, procedures for operation, tests and maintenance, and ergonomic aspects of the system.
- Improving the seismic capacity of the safe shutdown system
  Since plant walkdown was not considered in the operator's seismic performance evaluation process that proposed by the operator, the operator is required to include plant walkdown in the process. It was verified that the scope of evaluation that covers 41 systems (39 safety systems and two SFP systems), the selection of components based on the success path, and the use of methodologies of probabilistic safety assessment and seismic margin assessment are reasonable. However, a need to expand the scope to include systems related to isolation of containment building is still under review.
- Investigating and researching the maximum potential earthquake for the nuclear sites
  Independent review of the content of the operator's research will be conducted to make a regulatory decision.
- Improving the seismic capacity of the seismic alarm window in the main control room (MCR)
  According to the operator's plan, a seismic alarm of the seismic monitoring system will be transmitted to the Qualified Information and Alarm System-Channel N (QIAS-N) and displayed on the QIAS-N Alarm FPD and both of them are in the seismic category. Specific regulatory standards will be documented by 2013.
- Improving the seismic capacity of the entrance bridge to Wolsong nuclear power site
  The seismic design basis of the bridge to Wolsong nuclear power site is determined to be 0.2g. In addition, the potential damage of other off-site infrastructure will be also reviewed in line with preparing a strategy to respond to major accidents.

The deterministic methodology used in the earthquake risk evaluation has been in the middle of a debate between conservatism and adequacy of the design basis earthquake. The deterministic method neither analyzes uncertainties properly nor clarifies the relationship with performance goals of structures, systems and components. Therefore, the regulatory body embarked on the development of regulatory technology to help decide design basis performance during an earthquake on the basis of probabilistic seismic risk assessment.

A.3.2 Safety of Structures and Components against Tsunami, Storm Surge and Sea Water Level

The regulatory body of Korea has set regulatory standards to implement action plans, which incorporate lessons learned from the nuclear accident at Fukushima. The below is the summary of regulatory standards that have been set until now.

- Building up the sea wall for the Kori site

  Design criteria of the sea wall are determined to Quality Class A and Seismic Category II. It is required to perform an evaluation of wave run-up and reflect the evaluation results into the wave resistant design. In addition, the regulatory body requires that the operator shall perform various in-situ and laboratory tests, including boring investigations to evaluate the static and dynamic stability of soil foundation.
- Installing waterproof doors and discharge pumps

  Until now, discussions with the operator are under way to determine regulatory standards, however a need to check the method for verifying the seismic performance of waterproof doors was delivered to the operator. The regulatory standards for the waterproof capacity of waterproof doors will be determined with fire protection standards in mind to avoid any conflicts of interest.
- Investigating and researching the design basis sea water level of nuclear sites

  Independent review of the content of the operator's research will be conducted to make a regulatory decision.
- Reinforcing the intake capability for cooling water and improving facilities in preparation of tsunami

  They are actions to be taken based on the results of re-evaluation of design basis sea eater level, so specific standards are not prepared yet. Specific future standards will be based on a re-evaluation results of the design basis sea level.

B. Topic 2 (Design Issues)

B.1 Overview

B.1.1 Loss of Electrical Power

The off-site power system consists of two independent circuits to supply off-site power to safety and non-safety loads. During normal operations, electric power generated from the main generator is supplied to the on-site distribution system through an unit auxiliary transformer (UAT). If the main generator trips, a generator circuit breaker (GCB) is opened and off-site power is supplied from the power grid to the on-site power bus via a main transformer and an UAT. If the main transformer or the UAT fails, the power transfer is made from the UAT to the standby auxiliary transformer (SAT) and off-site power is supplied to the on-site distribution system through the SAT.

In preparation for a loss of off-site power (LOOP) event, two trains of safety-class EDGs meeting single-failure criteria are installed in separate areas of the auxiliary building and electrically independent. Fuel inventory is secured for each EDG to supply 100% power to full loads for seven days. The EDGs are water cooling type, using sea water as a heat sink. TThe EDGs reach the rated voltage and frequency within 10 seconds after startup and supply power to safety-related loads. The Technical Specifications require recovery from the loss of off-site power within 24 hours. However, the seven-day inventory of fuel and lubricant oil for each EDG is kept in preparation for a prolonged loss of off-site power that lasts for more than 24 hours.

To cope with a station blackout (SBO) in which both off-site power and EDG emergency power are all lost, an alternative alternating current (AAC) diesel generator per four units is installed separately from EDGs. One AAC diesel generator supplies emergency power to up to four units under assumption that a SBO event occurs only at one unit in one multi-unit site. The AAC diesel generator is manufactured by a different supplier from the one that supplies EDGs to minimize the possibility of a common-cause failure. Unlike water-cooled EDGs, the air-cooled AAC diesel generator is installed from the perspective of design diversity. The AAC diesel generator is designed to be started up either in the MCR or by a field operator manually within 10 minutes after the onset of the SBO. TThe ACC power and support systems can be remotely controlled and monitored in the local control panel or in the MCR.

Based on the lessons learned from the Fukushima nuclear accident, the safety inspection team raised a need to supplement a plan to ensure the recovery of off-site power within 24 hours as defined in the Technical Specifications and to review factors (e.g. damaged large transformer) that may make it difficult to recover from the loss of off-site power due to a massive earthquake or tsunami.

Assuming that a station blackout occurs only at one unit in one nuclear power site, one

AAC diesel generator is installed per two or four units and the AAC diesel generator fuel inventory is maintained based on the SBO coping time (four to eight hours). Therefore, the inspection team required KHNP to prepare measures to cope with a prolonged station blackout at multi-units, including securing mobile emergency power source.

- Securing mobile generators and batteries
- Upgrading the design basis of AAC diesel generator
- Fastening backup transformers with anchor bolts and improving the fuel injection ports of emergency power supply systems (EPS) of Wolsong plants
- Improving the management responsibility of switchyard facilities
- Improving the reliability of on-site power supply systems

B.1.2 Loss of Cooling

The essential cooling water system that uses sea water for UHS cools down essential equipment for heat removal and radiation protection, such as reactor, containment vessel (reactor building) and spent fuel pool (SFP). Major equipment cooled by the essential cooling water system include Reactor Shutdown Cooling System (or Residual Heat Removal System), Reactor Containment Building, Emergency Diesel Generator (EDG), Essential Chiller and SFP.

According to the "Regulation on Technical Standards for Nuclear Reactor Facilities, Etc." essential cooling water system is safety-class, redundant and seismic category I.

CCWS is a closed-loop, two train system and classified as seismic category I and safety class 3. Each train has a 100% heat removal capacity required in case of a design basis accident. And non-essential headers are automatically isolated with a safety injection actuation signal in an accident condition.

One out of two pumps of one train of both ESWS and CCWS as well as two out of three CCWS heat exchangers are operated during normal operation and in an accident condition. The standby pump of each system is automatically actuated with a pump outlet header low pressure signal.

In the event of the loss of UHS or ESWS, steam generator cooling through the auxiliary feed water system is available even with the loss of shutdown cooling system and CCWS. ESWS is able to retain its cooling function for a certain period of time by using the volume of cooling water in the system.

If an external event beyond the design basis leads to the loss of UHS or ESWS even with CCWS operable, the temperature of component cooling water in the closed loop of CCWS rises gradually, ending up with the cooling loss of CCWS. The rise in the temperature of CCWS is affected by thermal load transferred to CCWS. Operator actions to block unnecessary thermal load can reduce the rise in the temperature of CCW.

With the lessons learned from the Fukushima accident, the Special Safety Inspection team identified action items to address the possibility of coastal flooding due to a tsunami and the unavailability of UHS in efforts to secure the integrity of systems and components. (Action items to secure power source are described already in B.1.1 Loss of Electrical Power.)

- Securing the inundation prevention capability of the flooding prevention and restoration of UHS

  Although the ESWS pump room satisfies the current design basis water level, it is likely to be inundated due to exit and entrance doors, ventilation openings, and penetrations in case of a large storm or tsunami beyond the design basis water level.

  Since the motors and power cabinets of ESWS pumps are not waterproof, their operability may not be guaranteed if there is inundation due to a large storm or tsunami.

  Inundation of pump motors means loss of UHS which may lead to loss of core cooling, resulting in core damage. For that reason, the restoration of inundated pump motors should be done within the shortest period of time possible.
- Preparing countermeasures for damage of outdoor tanks

  Outdoor cooling water tanks (refueling water storage tank (RWST) and condensate storage tank (CST)) related to safety are seismically designed. For chemical storage tanks (sulfuric acid, hydrazine and ethanolamine) a dike designed to collect liquid chemicals coming from damaged tanks is installed.

  However, protection measures against a large tsunami exceeding the design basis water level should be prepared for outdoor tanks with no protective structures.
- Preparing countermeasures for flooding of main steam safety valve room and emergency water pump room

  The main steam safety valve rooms of Wolsong units 2, 3 and 4 are located on the ground level with low concrete walls and steel panels on top, vulnerable to inundation by a tsunami higher than the ground level.

  The emergency water system (EWS) pump room of the Wolsong nuclear power plants is seismically designed, but is in a standalone building on the ground level, which is likely to be inundated, allowing foreign materials to get into EWS pump suctions if a tsunami is higher than the ground level.

B.1.3 Containment Integrity

Containment building is designed to secure structural integrity and leak tightness under the design pressure predicted based on a design basis accident. However, it is also intended to prevent the release of radioactive material if a severe accident occurs because of a prolonged station blackout. (Prevention of release of uncontrolled radioactive materials after 24 hours of accident occurrence)

The Reactor Containment System of Korean standard nuclear power plants includes pre-stress concrete reactor building, containment spray system, containment air cleanup system, containment isolation system and containment combustible gas control system.

The design basis accident of the Reactor Containment System is the most severe accident in the spectrum of loss coolant and secondary system breakdown. The design basis to secure the safety of the containment building requires that radiation released during a accident should not exceed the limit . The following are the assumptions applied to the interpretation of pressure, temperature and compartment pressure of reactor building.

- Each accident occurs simultaneously with the loss of off-site power and the most severe single active failure of engineered safety feature (ESF) systems, provided off-site power is available in the event of a secondary system break.
- More than two accidents do not take place simultaneously or sequentially. The design basis accident due to the maximum pressure, the maximum temperature and the maximum compartment pressure, and the maximum external pressure of reactor building is defined as the accident that results in the most serious consequences in the loss of coolant and secondary system break. The difference between the design pressure and the calculation result is regarded as a design margin.

Based on the assumptions, containment building should not exceed the leak rate of 0.1v%/1 for the next 24 hours of an accident and 0.1v%/1½ after 24 hours of an accident.

With regard to severe accident, it is required that a rise in pressure due to steam should not reach the containment building break pressure or the Factored Load Category for the first 24 hours after a severe accident. In preparation for a station blackout, one unit of AAC diesel generator is installed at each nuclear site.

The safety inspection was conducted by the regulatory body in cooperation with outside experts after the Fukushima accident. As a result, two plans to address a station blackout are considered. The first plan is to reduce the probability of a station blackout leading to a severe accident, which includes the use of external power sources like a mobile generator as well as the installation of waterproof doors to prevent the inundation of power supply equipment. The second is to modify the design of the containment building to prevent the uncontrolled release of radioactive particles during an extended station blackout. Installing seismically qualified waterproof doors and discharge pumps (including inundation protection measures for ventilation openings and penetrations); securing vehicle-mounted emergency power generators and batteries for each nuclear site; and improving the design basis of AAC diesel generator are methods for reducing the possibility of a station blackout that could lead to a severe accident. These methods are specifically described in A.3.2 Safety of Structure and Component against Tsunami and B.1.1 Power Loss. The following are items for design change of the containment building to prevent the uncontrolled release of radioactive particles during an extended station blackout.

- Installing passive hydrogen recombiners
  Install passive hydrogen recombiners that are operable without power supply to secure containment hydrogen control capability even in case of an extended station blackout.
- Install filtered ventilation or depressurizing equipment in the containment building
  The use of containment spray, fan cooler and ventilation system is described as strategies to handle Fuel-Coolant Interaction (FCI) or Melt Coolability and Concrete Interaction (MCCI) in the reactor cavity upon a severe accident in the Severe Accident Mitigation Guide (SAMG), however they are not allowed to be used if an accident disrupts on-site power.
- Installing reactor injection flow for emergency cooling water from external sources
  The current SAMG is not fit for coping with a severe accident resulting from the loss of on-site power like the Fukushima nuclear accident because SAMG was prepared without considering the loss of on-site power conditions. Therefore, it is necessary to secure methods for primary and secondary-side cooling and revise SAMG to incorporate them in preparation for the accidental loss of on-site power.

B.1.4 Loss of Spent Fuel Pool Cooling

The spent fuel pool (SFP) of Korean nuclear power plants is in a building attached to the containment building, and SFP and its facilities are classified as seismic category I. SFP is designed to meet Article 33 (Fuel Treatment Device and Storage Facility) of the

"Regulation on Technical Standards for Nuclear Reactor Facilities, etc.", and to maintain sufficient safety margin against nuclear criticality. The spent fuel pool cooling system is designed to remove decay heat, which is generated by stored fuel assemblies from the water in the spent fuel pool. This is done by pumping the highly heated water from within the fuel pool through a heat exchanger, and then returning the water to the pool. The piping system is installed in the SFP to prevent drainage of the water in the pool even if a pipe is damaged.

The SFP cooling system consists of two independent trains, each of which is totally capable of removing design thermal load and powered by Class 1E safety bus. Both trains can be used simultaneously to remove decay heat at the maximum design thermal load when all the fuel in the reactor core is discharged to a SFP immediately after reactor shut down.

Components of the SFP cooling system (pipes, pumps, valves and heat exchangers) fall under safety class and Quality Class C. A normal make-up water source is a safety class refueling water storage tank under seismic category I, which is supplied with borated water through chemical and volume control system (CVCS) pipes and valves that are under seismic category I and quality class C. Additional makeup water sources to spent fuel pools are seismic category I condensate storage tank and non-seismic category demineralized water storage tank. That is, additional make-up water sources to SFP are a refueling water storage tank as a seismic category I borated water source; a condensate storage tank as seismic category I non-borated demineralized water; and non-seismic category demineralized water storage tank.

The safety inspection conducted by the regulatory body together with external experts after the Fukushima accident focused on the make-up of SFP cooling water and the cooling function of SFP if a large earthquake or tsunami exceeds the design basis.

- Countermeasure for loss of spent fuel pool cooling

  SFP consists of redundant trains, which means that one healthy train can function properly even if the other train fails due to a design basis accident. Multiple sources of cooling water such as refueling water storage tank and demineralized water storage tank are available for SFP in preparation against the loss of cooling function.

  Considering the lessons learned from the Fukushima power plants hit by the tsunami beyond the design basis, it is necessary to identify an alternative cooling source in case SFP cooling is lost for a prolonged period.

B.1.5 Fire Protection

Fire protection laws and regulations in Korea are nuclear-related and fire-fighting related. Under the nuclear related laws, Periodical evaluation for fire hazard analysis is performed every 10 years to confirm the safe shutdown capability even during fire accidents pursuant to the regulatory requirement. In addition, the fire protection program has been established and implemented to prevent and extinguish fires and to secure the safe shutdown capability.

The regulatory body with experts from industry, academia, research institutions conducted the targeted inspection to look into the adequacy of fire protection facilities and the emergency response capability of nuclear power plants.

The inspection found that fire protection facilities are properly designed and installed in accordance with laws and regulations related to fire fighting and nuclear power. However, inspectors identified action items to improve internal fire-fighting capability and coordination with external fire station, and required the operator to take follow-up actions.

- Improving the fire protection plan and reinforcing cooperation systems
- Improving fire protection facilities and response capability of plant firefighting teams
- Introducing a performance-based fire protection design

B.2 Operator's Activities

B.2.1 Loss of Electrical Power

In response to a May 2011 request by the regulatory body, KHNP prepared and submitted a detailed plan on september 2011 for securing emergency power in case a tsunami causes a station blackout. KHNP is now implementing five action items under the plan to enhance the safety of power systems, including securing alternative emergency power sources, with a target year of 2014.

- Securing mobile generators and batteries

  In order to have an alternative emergency power source on hand in case there is a prolonged station blackout, mobile generators will be deployed in Kori and Wolsong nuclear sites by 2012 and the rest of nuclear sites by 2014 and terminal box for connecting electrical power sources will be installed.

  Essential control power equipment that is vulnerable to inundation due to its underground location will be reinforced by 2014.

- Upgrading the design basis of AAC diesel generator

  A project to re-evaluate the capacity adequacy of AAC diesel generators is under way and based on the results of re-evaluation, follow-up actions will be taken.

  A project to reinforce the AAC DG fuel storage tank with the capacity of less than one-day is also in progress and based on which, actions such as installation of new tank will be completed by 2014.

- Fastening backup transformers with anchor bolts and improving the fuel injection ports of EPS of Wolsong plants

  17 transformers at 10 nuclear units which are not fixed with anchor bolts would likely be damaged or float away in the event of a massive earthquake or tsunami, To address this issue, a ground condition check such as hardness of foundation concrete is ongoing to install anchor bolts. Consequently, the standby transformers at 10 nuclear units will be fixed with anchor bolts at a proper level by 2012.

  The injection port of the fuel storage tank of the emergency power supply system (EPS) has been relocated above the ground level of Wolsong plants and the injection port has been changed into sealing type.

- Improving the management responsibility of switchyard facilities

  In order to clarify the management responsibility of switchyard facilities for prompt recovery following the loss of off-site power due to an earthquake or tsunami, the operator had a met with KEPCO, the owner of switchyard facilities, in February 2012. They discussed responsibilities for emergency attention to breakers and auxiliary equipment in the event of an abnormal situation at operating nuclear power plants. The recovery plan for each type of failure for switchyard facilities in consideration of the loss of off-site power following a massive earthquake or tsunami is prepared by KEPCO.

- Improving the reliability of on-site power supply systems

  At Kori unit 1, the 4.16kV non-safety bus is connected to a safety bus so the failure of the non-safety bus would likely affect the safety bus. To improve the reliability of on-site power supply system of Kori unit 1, a facility improvement plan is established and a design change project is in course of preparation.

The operation also has identified the below action item to cope with an extended station blackout, taking into consideration the lessons learned from the Fukushima nuclear accident and follow-up actions taken by overseas plants.

- Securing emergency power to Wolsong unit 1 local air cooler

  The supply power to Wolsong unit 1 local air cooler will be made redundant and a temporary connection point will be installed to prepare for a prolonged station blackout including inoperable emergency & backup power.

B.2.2 Loss of Cooling

At the request of the regulatory body made in May 2011, KHNP established the detailed implementation plan and finalized it in september 2011. Implementation of the plan is scheduled to be completed by 2013.

- Preparing a plan for prevention and restoration of inundation of UHS
  The recovery procedure in case of the loss of essential service water (ESW) pump motor is being developed into the relevant procedures of each plant. Essential back-up motors for emergency recovery will be additionally secured by 2013.
- Preparing a plan for prevention of damage of outdoor tanks
  Protective barriers like a L or straight line type facing the direction of seawater inflow to prevent the damage of outdoor cooling water tanks and chemical storage tanks will be installed by December 2014. The height and performance criteria for the barriers will be based on study of the design basis sea water level of nuclear sites (to be completed in December 2013).
- Preparing a plan for prevention of inundation of main steam safety valve room and emergency feed water pump room
  The criteria for inundation prevention measures will be based on the results of research on design basis sea water level of nuclear sites (to be completed in December 2013) with a target of completion in December 2014.

On top of them, KHNP identified action items for improvement additionally after taking into consideration the lessons learned from the nuclear accident at Fukushima and post-Fukushima actions taken by overseas nuclear plants.

- Installing a auxiliary feed water storage tank additionally at Ulchin unit 1.
  One auxiliary feed water storage tank will be installed additionally by 2015 to secure a safety class makeup water source for Ulchin units 1 & 2.

B.2.3 Containment Integrity

The nuclear power plants are currently drafting or implementing action plans to reduce the chances of a station blackout and consequential loss of integrity of containment building and release of radiation over populated areas

- Installing PARs

PARs (Passive Auto-catalytic Hydrogen Recombiners) that would prevent the accumulation of hydrogen will be installed to prevent an explosion of accumulated hydrogen in the containment building. The PAR had been installed at Kori unit 1 even before the Fukushima nuclear accident and installed at Wolsong unit 1 in July 2011. Installation of the other 18 units is to be completed from June 2012 to December 2013. In addition, a PAR for a design basis accident and an igniter for a severe accident had been installed at newly constructed plants including Shin-Kori unit 1, however, a PAR for a severe accident was additionally installed as part of post-Fukushima actions.

- Installing containment building ventilation or depressurizing equipment

  The containment filtered ventilation equipment will help maintain the integrity of the containment building if core damage causes over pressurization and threatens the general population with radiation leakage.

  The filtered ventilation system will be installed for Wolsong unit 1 containment vessel by 2012 and for the other nuclear units by 2015. A separate review of the effectiveness of the new installation is under way. It will evaluate the chances of the new installation adversely affecting current safety equipment as well as the system functions such as containment building isolation and prevention of local negative pressure. It also will strengthen the effectiveness of ventilation strategies in the severe accident management guide.
- Installing reactor injection flow for emergency cooling water from external sources

  The process to install reactor injection flow for emergency cooling water from external sources has been initiated to ensure reactor cooling if all cooling functions are lost due to a protracted station blackout caused by a natural disaster. The installation has been already completed at Shin-Kori unit 2 and Shin-Wolsong units 1 & 2 under commissioning. Operating plants are currently in the phase of evaluation to identify the optimized injection flow or in the phase of concept design (to be completed in December 2012) with a completion target of December 2015. Additionally, the amount of injected water required to recover reactor cooling and the injection timing are being evaluated. The findings will be used to determine the pipe size, flow rate, pressure, water source, injection method, accessibility, injection time and scenarios. Accordingly, a temporary emergency operating procedure for injection of emergency cooling water from external sources will be developed.

B.2.4 Loss of Spent Fuel Pool Cooling

At the request of the regulatory body, KHNP has submitted to the regulatory body an action plan to maintain the cooling capacity of the spent fuel pool even in the event of a natural disaster beyond the design basis. The plan is to be implemented by 2014.

- Preparing countermeasures for the loss of spent fuel pool cooling
  The direct water make-up method using a hydrant inside the fuel building and a fire engine accessing the fuel building via the entrance have been incorporated into the relevant procedure (in 2011). The seismically qualified pipes and connection points will be installed in 2012 to enable a fire engine to supply cooling water if SFP cooling is lost. This will be based on a study of SFP thermal load.

KHNP identified actions additional items to prevent the loss of spent fuel pool cooling in consideration of the lessons learned from the accident at Fukushima and post-Fukushima actions taken by overseas plants.

- Install safety class instruments to monitor water level, temperature and radiation level
  Safety class instruments that can withstand the design basis environment will be installed to transmit key parameters of spent fuel pool (water level, temperature and radiation level) to the MCR by 2014.
- Revising technical standards related to securing emergency power of spent fuel pool
  Technical standards will be revised by September 2012 to require one train of onsite emergency electrical power be secured when fuel assemblies are stored in the spent fuel pool regardless of operation mode.

B.2.5 Fire Protection

At the request of the regulatory body, KHNP submitted a detailed action plan to the regulatory body. Complete implement of the plan is by 2015.

- Improving the fire protection plan and reinforcing cooperation systems
  The fire fighting plan was supplemented in December 2011 to incorporate simplified procedures for fire fighting support from public fire departments; improve entry & exit procedures for fire fighters; establish an effective coordination system for fire fighting; and countermeasures to handle a major fire.
  Public fire departments and the nuclear power sites singed an agreement on cooperation between internal and external fire brigades in December 2011 to strengthen fire fighting coordination.
- Improving fire protection facilities and response capability of plant firefighting teams
  A branch pipe connected to the water supply pipe of the purification plant will be installed to secure an alternative water source for a fire engine. In addition,

professional manpower to operate a fire engine will be employed in efforts to improve fire protection facilities and the capability of internal fire fighters. Currently a design project is under way with completion targeted for 2012.

- Introducing a performance-based fire protection design

  The operator is seeking to change fire-fighting regulations to classify nuclear power plants into facilities subject to performance-based fire fighting design to optimize fire fighting in consideration of fire frequency and impact.

B.3 Regulator's Activities

B.3.1 Loss of Electrical Power

The Korean regulatory body has set regulatory criteria to ensure implementation of action plans after taking into account the lessons learned from the Fukushima nuclear accident. Below is a summary of regulatory criteria that have been determined up to now:

- Securing mobile generators and batteries

  Design basis and characteristics of mobile generators; load capacity; analysis of coping time and capability, location, and power supply capacity; periodic test to maintain the target reliability of design; procedures for operation, maintenance and test; and operator training are examined to determined the regulatory criteria.

  The regulatory body is lan to make its position clear on design criteria with regard to a prolonged loss of power. Discussions are ongoing. One example is that additional batteries would be needed if a waterproof door is not installed at a battery room that is lower than 100 feet below ground.

- Improving Upgrading the design basis of AAC diesel generators

  The regulatory body is plan to decide the design basis. Discussions are still under way. One example is that equipment with a proper capacity to cope with simultaneous SBO at multi-units should be installed per reactor unit. On-site portable or fixed resources should be considered under the assumption that the plant is not accessible due to damage to roads and bridges.

- Fastening backup transformers with anchor bolts and improving the fuel injection ports of EPS of Wolsong plants

  The resistance of large transformer to an earthquake or tsunami should be raised to increase the possibility of securing off-site power. The areas of switchyards vulnerable to an earthquake or tsunami also are still being examined to determine necessary measures. The review of repositioning the injection port of the fuel storage tank of

EPS of Wolsong nuclear power plants has been completed in accordance with the current technical standards. In the future, the position of the injection port will be re-assessed when the technical standards are revised to incorporate the results of re-evaluation of the probable maximum earthquake and the design basis sea level for nuclear power sites.

- Improving the management responsibility of switchyard facilities

  The regulatory body is currently reviewing the implementation report including KEPCO's procedure for urgent power recovery submitted by the nuclear operator. The focus will be on scenarios involving urgent power recover; failure degree; input manpower and equipment; and the necessary time to restore stable power to a plant.

- Improving the reliability of on-site power supply systems

  While a large-scale change in Kori unit 1 power system is ongoing, the regulatory body will start to review the design modification package before the operator submits design modification results. Korea’s operating experience on issues resulting from design modification will be considered. The focus of review will be on system behavior in an abnormal situation and adverse impact resulting from design modification based on the lessons learned from operating experiences.

B.3.2 Loss of Cooling

The Korean regulatory body has set regulatory standards to ensure implementation of action plans after taking into account the lessons learned from the Fukushima nuclear accident. Below is the summary of regulatory standards that have been determined up to now:

- Preparing a plan for prevention and restoration of inundation of UHS

  Waterproofing measures should be implemented after a comprehensive evaluation of all the possible paths of water inflow, such as ventilation openings, and operating experiences, including the ones from the Fukushima nuclear accident. To prepare against inundation, waterproofing measures for electrical equipment such as motors and power cabinets should be taken in tandem with installation of waterproof discharge pumps. In addition, studies are on going to determine regulatory standards for assessment of the optimized number and capacity of portable discharge pumps; selection of motors with spare part requirements; recovery procedures; and recovery equipment & manpower. In this sense, the regulatory body requested the operator to supplement the Basic Plan for Prevention and Restoration of Inundation of UHS of All Nuclear Power Plants to incorporate preparation and execution of a plan for management check and performance inspection of pump motor spare parts for urgent use; assessment of the inventory adequacy of motor pump spare parts and additional procurement of spare parts based on the assessment results, and assessment of the maximum time spent from pump motor replacement and performance test completion.

- Preparing countermeasures for damage of outdoor tanks

  The operator is required to prepare a countermeasure for damage of outdoor tanks such as emergency and fire fighting water storage tanks and chemical (sulfuric acid, caustic soda and ethanolamine) storage tanks. The standards for the protective barrier will be determined before 2014 when installation begins.

- Preparing countermeasures for inundation of main safety valve room and emergency water pump room.

  Regulatory standards will be determined before 2014 at the time of commencement of countermeasures.

B.3.3 Containment Integrity

The regulatory body discuss with the owner of nuclear power plant about the implementation of action plans after taking into account lessons learned from the Fukushima nuclear accident. Based on the results of the discussion and review results, the establishment of performance and design criteria about the improved items will be performed and those criteria will be imposed to the owner of nuclear power plants. The below is the summary of regulatory standards that have been determined until now:

- Installing passive hydrogen recombiners

  While the operator is installing PARs (Passive Auto Catalytic Recombiners), the regulatory body is conducting a review of hydrogen removal rate and PAR capacity, environmental qualification in terms of temperature, pressure, humidity, radiation and water spray, seismic qualification, and the impact of volatile organic compounds (VOCs) in the containment atmosphere. Regarding the impact of VOCs, standards for performance test have been set for each manufacturer.

- Installing containment building ventilation or depressurizing equipment

  Design consideration should be given to preventing the damage of the containment building due to overpressure and to mitigating the release of radiation into the atmosphere. To this end, requirements for system design such as seismic criteria, internal pressure, filter performance, and test & inspection requirements are under review. Radiation protection such as shielding in operation and post-accident handling of radioactive particles should be possible. In addition, operating procedures for filtered vent system that contains passive and manual operation, measuring instruments and handling of condensate water should be prepared. Moreover, system independence and the impact on existing safety system should be fully examined. Operator training for operation, maintenance and test of the system should also be conducted.

- Installing reactor injection flow for emergency cooling water from external sources
  Method for primary and secondary-side depressurization; possibility of depressurization; the amount of cooling water required and adequacy of design flow rate through accident analysis; equipment availability in consideration of the impact of natural disaster; the feasibility of water source and connection point; the adequacy of operation plan in connection with SAMG; and the impact on existing safety system are examined to determine the standards for injection of emergency cooling water from external sources.

The regulatory body continues to have discussion with KHNP with regard to the scope and methodology of each action item. Based on what is discussed with KHNP and reviewed by KINS, the regulatory body will set the performance and design standards for action item.

B.3.4 Loss of Spent Fuel Pool Cooling

The Korean regulatory body in cooperation with outside experts conducted the safety inspection of the cooling function of SFP cooling system in preparation of design basis earthquake and tsunami; and measures to cope with the prolonged loss of SFP cooling due to a beyond design basis earthquake or tsunami.

As a result, it was verified that the SFP cooling system of Korean nuclear power plants are able to remove the decay heat generated by fuel assemblies stored in the spent fuel pool in the event of a design basis accident.

However, the regulatory body requires the operator to prepare an action plan to monitor the water level and temperature of the pool: secure emergency power supply equipment and an alternative cooling water source to retain the cooling function in case SFP cooling is lost for a long time because of a natural disaster beyond the design basis.

Based on the lessons learned from the Fukushima nuclear accident such as causes and sequence of event, the operator is required to install safety class instruments in the pool which are designed to allow the MCR to see key parameters (water level, temperature, radiation level) of SFP in case of a design basis natural disaster.

The Korean regulatory body has set regulatory standards to ensure implementation of action plans after taking into account the lessons learned from the Fukushima nuclear accident.

Below is the summary of regulatory standards that have been determined until now:

- Preparing countermeasures for the loss of spent fuel pool cooling and a station blackout accident.

  The operator has installed an injection flow of emergency cooling water at Shin-Kori unit 2 and Shin-Wolsong units 1 & 2 to cope with the cooling loss of SFP. The review of installation of injection flow of emergency cooling water at nuclear units under commissioning has been completed in accordance with the current technical standards and it will be re-assessed when the regulatory standards for the coping equipment are revised to incorporate the results of re-evaluation of an earthquake and tsunami.

  In order to maintain the cooling function of SFP, key parameters should be transmitted to the MCR, and pumps and valves should be driven by a safety class power source. In addition, equipment for injection of emergency cooling water should be seismically qualified. Moreover, the operating system such as operating procedure and operator training should be properly supplemented.

B.3.5 Fire Protection

The Korean regulatory body together with outside experts inspected the adequacy of fire protection facilities and emergency response capability.

It was verified that fire protection facilities are properly designed and installed in accordance with related laws, and the fire fighting system at the early stage of a fire is also adequately established.

However, the regulatory body identified three action items to improve fire fighting capability and coordination with public fire departments and required the operator to take follow-up actions.

- Improving fire protection facilities and response capability of plant firefighting teams

  The nuclear operator submitted an implementation report on actions taken to improve the fire fighting and coordination with public fire departments.

  To prepare a fire fighting plan for a nuclear power plant and to strengthen the fire fighting capability of public fire departments (professional manpower, fire fighting helicopter), a project was conducted. It clarified the timing to request fire fighting support and simplified the request procedure; conducted radiation response training for internal and external fire fighters; improved entry and exit procedures for fire fighters; established effective cooperation system for fighting fires and established action plans for areas vulnerable to fire. Based on the review results, the operator was required to take follow-up actions.

- Improving fire protection facilities and response capability of plant firefighting teams
  An alternative water source for a fire engine is required in case designated fire fighting water is not available at the nuclear power plant due to a natural disaster. Considering the alternative water source also will be used as emergency water to cool reactors, the regulatory body will look at what fire fighters and the cooling function need. To this end, the basic plan was prepared and the regulatory body signed a cooperation agreement with NEMA in April 2012.

The regulatory body continues to have discussion with KHNP with regard to the scope and methodology of each action item. Based on what is discussed with KHNP and reviewed by KINS, the regulatory body will set the performance and design standards for action items. The regulatory body also requires the operator to conduct the seismic evaluation of fire protection systems and their fire response capability of nuclear power plants. Based the results of the evaluation, the regulatory body will re-assess regulatory standards for post-Fukushima fire protection.

C. Topic 3 (Management and Restoration of Severe Accident)

C.1 Overview

Installing measures to handle and recover from a major accident is a complicated process that requires careful planning. Various scenarios need to be considered. Necessary procedures must be developed and verified. Equipment availability has to be checked and large-scale drills should be conducted. The accident at Fukushima demonstrated the complications that may occur from a catastrophic event. Among them unavailability of essential equipment, radiation leakage, damage of multiple reactors at one site, prolonged loss of power, and communication disruption.

Regulatory requirements for Emergency Operation Procedures and severe accident management program are prepared based on safety review guideline 13.5.2.1-1 (emergency operating procedures), 19.3 (accident management), regulatory guidelines and technical reports.

With regard to emergency measures taken by reactor operators, nuclear power plants have established multiple guidelines and procedures in accordance with the type and magnitude of on-site accidents. Therefore, nuclear power plants are designed to cope with the loss of off-site power using emergency diesel generators. The loss of off-site power accident is a design basis accident and can be addressed in accordance with plant procedures (Abnormal Operating Procedures, Alarm Response Procedures, Emergency Operating Procedures). Those procedures prescribe actions to be taken by operators at every essential step of the process that the plant reaches, from full power operation to safe shutdown mode.

The safety inspection team checked the below areas:

- Adequacy of facilities for preventing and coping with severe accidents
- Adequacy of severe accidents strategies and accident management plans
- Adequacy of cooling methods for the nuclear reactor in the event of a station blackout

The results of the safety inspection on severe accident management are as follows:

- Facilities against severe accidents have continuously supplemented for operating nuclear power plants in accordance with TMI Action Plan Requirements, the Policy on Severe Accident, and standards for continued operation. The development of Severe Accident Management Guide (SAMG) has helped improve the operator's capability to cope with severe accidents.
- Equipment and relevant procedures necessary for reactor cooling in case of the loss of on-site power are put in place so that a reactor core can be cooled for a certain period of time after an accident.
- SAMG is established with assumption that a power supply is available for the cooling of a nuclear reactor, hydrogen control, and containment spray and ventilation in the event of severe accidents.

It was verified that facilities are properly put in place in accordance with current technical standards, and related procedures are well prepared. However, the below actions items were identified to further ensure safe handling of a worst-case scenario in which loss of all cooling function leads to a core melt-down.

- Strengthening severe accident training and education

  Train the operators using various severe accident scenarios from the SAMG and the severe accident simulator

Extend the training time from two hours every two years to 10 hours every year

- Revise SAMG to improve the effectiveness of accident management strategies

  Evaluate the availability for filling flow and the cooling capacity in terms of the current strategies for filling the reactor cavity with cooling water and reflecting them in SAMG

  Evaluate the viability of equipment and instruments necessary to cope with severe accidents that cause long-term loss of off-site power and establish a power supply procedure that is based on the priority of power recovery.

- Develop Low-Power Shutdown Severe Accident Management Guides

  Develop Low-Power Shutdown Severe Accident Management Guides based on the evaluation of severe accident during low-power shutdown operation which also incorporates the loss of spent fuel pool cooling accident.

Besides, actions such as installing PARs; operating emergency response organizations in case of a multi-unit accident; conducting emergency preparedness drills based on a natural disaster; acquiring key parameters necessary for monitoring the nuclear reactor and on-site situations in case of a long-term loss of power; operating an emergency broadcasting system in preparation of communication disruption; and reinforcing significant equipment against an earthquake and tsunami have been described in other Topic sections.

C.2 Operator's Activities

The KHNP, the owner of nuclear power plant established the implementation plan to proceed the improvement items of severe accident management program which has been required by regulatory body, dated at May, 2011.

- Strengthening severe accident training and education

  Actions to strengthen severe accident training and education have been taken to ensure the operator's prompt response to a severe accident like the nuclear accident at Fukushima. The severe accident training time is extended from two hours every two years to 10 hours every year, which has been reflected in the refresher training plan for operators, and the severe accident training will be provided to the essential staff of Technical Support Center in connection with the operator refresher training. In addition, severe accident scenarios have been developed to improve severe accident theories and computation code practice so as to nurture severe accident experts as well as to identify the characteristics of progress of severe accidents by initiating event and the characteristics of progress of severe accidents in case of operator's action taken in accordance with SAMG.

- Revising SAMG to improve the effectiveness of accident management strategies
  A method for detailed evaluation of the possibility of core melt cooling by filling the reactor cavity with water will be determined. The possibility of filling the reactor cavity with water will be reviewed in parallel with plant walkdown. In addition, availability and cooling capacity in terms of filling water flow, filling time and the maximum filling water level will be evaluated. At the same time, a temporary EOP will be developed to ensure effective review and implementation of filling water flow. Furthermore, the feasibility of external reactor vessel cooling and the likelihood of side effects such as a steam explosion will be evaluated.
  To secure the viability of equipment and instruments necessary for coping with severe accidents considering the long-term loss of off-site power, a evaluation methodology will be determined and the scope of components and equipment will be defined and environmental conditions of the components within the scope such as power source, pressure, temperature, radioactivity, and humidity will be analyzed and based on them, necessary actions will be taken. In addition, the grouping of components and instruments will be performed in terms of significance and location to set the priority for power recovery and a power recovery procedure will be developed. Based on the prioritizing of power recovery, SAMG will be revised in the first round by December 2012 and revised again in the second round by 2015 to incorporate the results of above actions.
- Developing Low-Power Shutdown Severe Accident Management Guides
  Low-Power Shutdown Severe Accident Management Guides are under development to improve severe accident response capabilities during low-power shutdown operations like that at Fukushima. The Generic Low-Power Shutdown Severe Accident Management Guide will be developed by the late 2012 and based on that, the Specific Low-Power Shutdown Severe Accident Management Guide, Power Operation Severe Accident Management Guide will be developed by the late 2012.

Regarding the nuclear accident at Fukushima, the operator established a process to analyze actions taken by international organizations, including WANO, Japan and other nuclear power plant operating countries and to review the feasibility of their application to Korean nuclear power plants. The operator also set up a process to identify actions items by conducting a vulnerability analysis internally. According to the process, the below items were additionally identified.

- Mobile diesel-driven pumps will be secured by 2014 to inject cooling water to SFP; to inject emergency cooling water to a reactor and a steam generator from external sources; and to discharge water out of inundated areas. However it will be implemented when decided in connection with strategies to prevent and mitigate severe accidents.

- Long-distance hoses will be secured by 2015 for use when cooling water is supplied from the water purifying plant to the nuclear power plant using a fire engine or mobile diesel-driven pump.
- Efforts to develop the Extensive Damage Mitigation Guide (EDMG) is being made to respond to simultaneous accidents at multiple-units due to a natural disaster such as earthquake, tsunami, terrorist attack, flooding or fire as well as human errors with a target of December 2015. In the first phase, the Generic EDMG will be developed for Wolsong, Kori, Yonggwang, Ulchin, Shin-Kori, Shin-Wolsong sites by 2013 and in the second phase, the Specific EDMG will be developed for six nuclear power plants that represent each type of reactors by 2015. To this end, initiating events, their impact to be considered during the development of EDMG, and the association between existing EOPs SAMG and EDMG will be determined based on discussion with the regulatory body.
- EOPs are based on design basis accidents and loss of on-site power accidents only. Therefore, an integrated procedure that combines SAMG and EOPs will be developed by 2015 to prevent severe accidents as much as possible by using equipment installed as part of post-Fukushima actions, such as securing reactor injection flow for emergency cooling water from external sources. The EOP-SAMG integrated procedure will be reviewed in association with EDMG and SAMG and based on the review results, an optimized accident response procedure will be developed to prevent and mitigate severe accidents.

C.3 Regulator's Activities

The regulatory body of Korea has set the following activities to ensure the implementation of actions plans that incorporate the lessons learned from the nuclear accident at Fukushima:

- Strengthen severe accident training and education

  The operator's plan to extend the severe accident training time to 10 hours a year using various severe accident scenarios and the severe accident simulator are judged appropriate. However, the results of implementation and the adequacy of training will be checked constantly through periodic inspections or emergency preparedness drills.

- Revise SAMG to improve the effectiveness of accident management strategies
  The strategies for filling the reactor cavity with water have positive impact of in-core retention and core melt cooling, but if the strategies fail, a steam explosion could occur. Therefore, a sufficient review will be made for the strategies. For PHWRs, strategies for filling reactor compartments with water should be developed.
- Develop Low-Power Shutdown Severe Accident Management Guides
  The operator's in-step approach is deemed appropriate, but specific regulatory standards are currently under review.

In accordance with the implementation plan for action items identified during the safety inspection, the licensing review for nuclear power plants under construction and Wolsong unit 1 who has applied for continued operation are completed or in the works. Unlike those in operation, plants under construction are required to install major equipment to cope with severe accidents prior to the issuance of operating license or the start of commercial operation. Accordingly, among severe accident measures, the review for installation of emergency cooling water injection flow from external sources to both the reactor and the SFP has been completed for Shin-Kori unit 2 and Shin-Wolsong units 1 and 2.

In addition, in order to set specific regulatory standards for some actions plans and to decide the regulatory position with regard to severe accident response, the regulatory body will request the operator to provide information on the list of structures, system and components; quantity; location; related building and connection pipe path; seismic category; safety class; fire protection facilities;, and waterproof facilities with regard to the operability of equipment (including auxiliary and supportive equipment) necessary for reactor safe shutdown, severe accident mitigation and reactor building integrity in an extreme environment.

Then, the regulatory body will analyze information and discuss the scope and methods for each action item with the operator and set performance and design standards based on decisions by the Nuclear Safety and Security Commission. In addition, the regulatory body continues to review the causes and the sequence of the nuclear accident at Fukushima to determine whether the PSA’s scope should be widened, including an infrequent external event PSA; the possibility of containment building isolation in a SBO; installation of equipment to prevent primary and secondary overpressure; and control of SFP hydrogen.

D. Topic 4 (National Organization)

D.1 Overview

The ultimate responsibility for safety of nuclear facilities rests with the operator and this is in no way diluted by separate activities or responsibilities of designers, suppliers, constructors or regulators. The government establishes the legal framework for the nuclear industry and an independent regulatory body is tasked with authorization and regulation of nuclear power plants. The responsibilities of the regulatory body are clearly separated from other agencies. This ensures the regulatory body's independence in overseeing nuclear safety and shields it from undue pressure. In addition, designers, suppliers and constructors have their own roles and responsibilities to secure safety at each stage of the lifetime of nuclear facilities such as design, construction and maintenance.

The legal and regulatory framework for emergency preparedness and response to cope with a radiation emergency or radiological accident are prescribed in the Act on Physical Protection and Radiological Emergency (APPRE). The NSSC is a competent authority having overall responsibilities and the leading role relating to radiological emergency preparedness and response of the Korean Government and has established the National Radiological Emergency Plan pursuant to the APPRE. In addition, the local government and the nuclear operator have also made the Local Radiological Emergency Plan and the Radiological Emergency Plan respectively, and are ready for emergency situations. The APPRE and the associated sub-regulations clearly prescribe not only emergency measures but also follow-up measures (such as mid- and long-term radiological impact analysis and damage restoration plan, implementation of post-radiological disaster measures, disaster investigation, and so on). The roles and responsibilities assigned to each agency in case of a nuclear emergency are described in Topic 5.

D.2 Regulator's Activities

Upon the nuclear accident at Fukushima in March 2011, the Korean government urgently conducted a field inspection and strived to identify issues in the organizational framework of Korea. At that time, the regulatory function had been transferred from one agency to the other since the introduction in 1967 so that it was far from regulatory independence that the IAEA required. Another issue was that in 2011, the regulatory activities were conducted by Nuclear Regulatory Bureau under the Ministry of Education, Science and Technology, which was also responsible for promotion, research and development of nuclear power plants.

To address the issues and satisfy the regulatory independence of the IAEA, the regulatory organization was separated from MEST to become the Presidential Commission on Nuclear Safety and Security on October 26, 2011. The Commission consists of nine members, which are two standing members (Chair and Vice-Chair Persons) and seven non-standing members. Accordingly, KINS and KINAC were transferred under the Secretariat Office of the Commission to conduct and support technical analysis and evaluation of safety.

The organization change was intended to maximize the independence of the regulatory body and the emergency response of nuclear power plants. In line with them, technical committees operate under the NSSC. Furthermore, the chairmanship and the vice-chairmanship of the Commission were raised to the minister- and deputy minister-level to strengthen the Commission’s status.
In efforts to strengthen the standing of the regulatory activities at home and abroad, the Korean government invited the IAEA Integrated Regulatory Review Service (IRRS) mission team to verify the regulatory activities of Korea in 2011. During the IRRS mission, 15 good practices, 10 recommendations, and 12 suggestions were identified and it was verified that the Korean government, through the activities of MEST and KINS, has implemented a technically capable and effective nuclear safety regulatory program. It was also confirmed by the mission team that Korea's response to the accident at Fukushima had been prompt and effective. In retrospect, the transformation to the Presidential Commission on Nuclear Safety and Security served as a turning point to further improve the independence, expertise and transparency of the regulatory activities in Korea.

The NSSC has worked closely with government agencies for management of nuclear safety. For example, the NSSC has established a cooperative system with Ministry of Public Administration and Security (MOPAS) and National Emergency Management Agency (NEMA) that are responsible for emergency preparedness and disaster management in Korea. After the nuclear accident at Fukushima, the NSSC signed an agreement with NEMA in February 2012 to ensure effective response to protect people and property from radiation risks in the event of a nuclear power plant fire or accident. The both parties agreed to work together closely with regard to regular training and education to handle radiation emergencies, expanded joint drill for emergency preparedness, and actions for prompt rescue and relief.

Given the fact that there are many agencies directly and indirectly involved in radiation-related activities, the establishment of an effective and integrated administrative system was required. To detect an accident in neighboring countries quickly, in April 2012, the NSSC signed an agreement on establishment of a strong cooperative system with the Korea Meteorology Administration (KMA) and based on the agreement, the KMA will provide the NSSC with information on atmosphere and ocean meteorological data, analysis of long-distance airflow and analysis of long-term meteorological data. One step further, the NSSC decides to establish a system to monitor and exchange information on radiation level, atmosphere, earthquake and the environment at home and abroad.
Besides, the NSCC will reach an agreement with Korea Food & Drug Administration (KFDA) and Ministry of Land, Transportation and Maritime Affairs (MLTM) in efforts to pursue administrative convergence to protect the public from radiation.

E. Topic 5 (Emergency Response)

E.1 Overview

The foundation of radiation emergency response and preparedness lies in the Act on Physical Protection and Radiological Emergency (APPRE) as well as the Framework Act on Disaster and Safety Management and the Framework Act of Civil Defense, which define disaster management at the national level. Pursuant to the APPRE, the Nuclear Safety and Security Commission (NSSC) supervises the radiation emergency preparedness and emergency response of the Korean government. The NSSC and KINS have conducted regulatory activities such as review and inspection in accordance with laws, regulations and guides related to radiation emergency response and preparedness. They have reasonably verified that protective measures will be taken in a timely and effective manner if a radiation emergency occurs at nuclear power reactors and other nuclear power facilities (research reactors, nuclear fuel cycle facilities, radioactive waste management facilities).

The legal and regulatory framework for emergency measures and response to cope with a nuclear emergency or radiological accident is prescribed in the APPRE. The NSSC is a competent authority having overall responsibilities and the leading role relating to radiation emergency preparedness and response of the Korean government and has established the National Radiation Emergency Plan, pursuant to the APPRE. In addition, local governments and the nuclear operator have also made the Local Nuclear Emergency Plan and the Nuclear Emergency Plan respectively, and are ready for emergency. The APPRE and the associated sub-regulations clearly prescribe not only emergency measures but also follow-up measures (such as mid- and long-term radiological impact analysis and damage restoration plan, implementation of post-radiological disaster measures, and disaster investigation).

In accordance with the APPRE, the emergency organization of Korea consists of the followings: the National Emergency Management Committee (NEMC) and the Off-Site Emergency Management Center (OEMC) run by NSSS; the Local Emergency Management Center (LEMC) operated by the local government; the Radiological Emergency Technical Advisory Center (RETAC) run by KINS; and the Emergency Operations Facility (EOF) managed by the nuclear operator. KINS provides technical support for the radiation emergency response by establishing and operating the Radiological Emergency Technical Advisory Center (RETAC) and Korea Institute of Radiological & Medical Sciences (KIRAMS) establishes the Radiological Emergency Medical Service Center (REMSC) to operate a national radiological emergency medical system.

If a nuclear emergency occurs at a nuclear facility, the plant operator informs the NSSC, KINS and the local government. When a nuclear emergency occurs in a place other than a nuclear facility, it is reported to the NSSC by the person who has discovered it or a relevant organization that has been notified of the accident. In the event of a nuclear or radiological emergency inside or outside of Korea, the emergency is communicated through the NSSC and KINS, which have been designated as the National Competent Authority (NCA) and the National Warning Point (NWP), respectively, in accordance with the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency.

In Korea, emergency exercise to secure and maintain effective emergency preparedness and response capabilities are performed as follows: the on-site emergency exercise at a nuclear power plant once a year; the Integrated Emergency Exercise organized by the local government once every four years; and the Unified Emergency Exercise organized by the central government once every five years. Through them, the regulatory body is able to evaluate and check the on-site and off-site response capabilities of nuclear facilities in accordance with the Nuclear Emergency Plan, and maintain the response capabilities of emergency staff.

In preparation of a radiological disaster, the national emergency medical system is operated by approximately 400 emergency medical staff at 22 emergency medical institutions. They include KIRAMS, primary emergency medical institutions near a nuclear power plant, and secondary emergency medical institutions at city and provincial levels. In addition, approximately 120,000 tablets of potassium iodine (KI) and 61,700 pieces of gas mask are kept by KHNP or local governments to protect local residents who live near a nuclear power plant.

Additionally, Korea runs an environmental monitoring vehicle, operates an information-sharing system for use of nuclear emergency response and establishes a radiological medical service system to ensure effective emergency response. Publication videos are manufactured and distributed to improve the general public's understanding on radiation emergency preparedness. In addition, KINS operates the Emergency Response Information Exchange System (ERIX) which enables related organizations to share information in case of an emergency.

- Environmental Monitoring Vehicle

  The APPRE requires the operation of an environmental monitoring vehicle if an environmental laboratory is located in the emergency planning zone. Since the environmental laboratory of Korean nuclear power plants are all located in the emergency planning zone, one environment monitoring vehicle for each four nuclear power site is in operation.

  The environmental monitoring vehicle is to function as a laboratory when an environmental laboratory is not able to perform its functions due to contamination resulting from a radiation accident, and to establish a system where the vehicle is dispatched to a contamination suspect area to collect and analyze environmental samples in the field.

  The environmental monitoring vehicle is equipped with a mobile nucleus analyzer, an air sample analyzer, a liquid scintillation counter, a radiation measuring instrument and a meteorological instrument. The location of the vehicle and the radiation levels measured by the vehicle are transmitted on-line to emergency response facilities and environmental laboratories for use in mitigating and responding to emergency.
- Cyber Education System for Radioactive Emergency Preparedness

  Workers at nuclear power plants are required to undergo 18 hours of training for nuclear emergencies to qualify as radiological emergency personnel. Afterwards, they have to take a eight-hour refresher training every year. Workers who are not designated as a radiological emergency worker should take four-hour training for emergency preparedness first and take two-hour refresher training every three years.

To ensure more efficient and effective training, the operator has developed and operated a cyber lessons, which teaches relevant laws and general radiation in a easy-to-understand way. At the end an online examination is administered. The education system is operated in the same way at all nuclear plants in accordance with the operator's Standard Technical Administrative Procedure.

The regulatory body reviews the results of the education system and the curriculum once a year. Going forward, the education will be provided to workers of plant suppliers as well and the cyber education system for the supplier employees will also be developed.

- Information-Sharing System for Radioactive Emergency Preparedness

To prepare for a nuclear emergency, the nuclear operator has developed an information-sharing system among on-site radiation emergency organizations. This system is internally developed by the nuclear operator and the performance of the system is verified when an nuclear emergency exercise is conducted at each plant. Since the system is able to simulate an accident situation during a nuclear emergency exercise, the system enables to give reality to the exercise so as to maximize the effect of the exercise.

- Radiological Emergency Medical System

The radiological emergency medical system of Korea consists of the operator's radiological emergency medical system and the radiological emergency medical system designated by the government. According to the laws related to the establishment of national radiological emergency medical system, the government designates and operates primary and secondary radiological emergency medical institutions and the nuclear operator establishes a emergency medical system for patient treatment in case of an emergency under an agreement with hospitals adjacent to a nuclear power plants.

Similar to the national designation system of radiological emergency medical institutions, the operator also designates hospitals nearby a nuclear plant as primary and secondary medical institutions and signs an agreement with them to ensure prompt response in case of a radiological medical accident at a nuclear power plant.

In addition, the operator has established Radiation Health Research Institute (RHRI) to conduct a research on the radiological emergency medical system and provide a professional treatment.

Under the radiological emergency medical system of Korea, if a nuclear power plant worker needs urgent attention, the resident nurse at the plant handles the emergency and transfers the patient to the primary or secondary medical institution. If the worker requires professional and long-term medical treatment, the patient is transferred to the RHRI. At this point, if the patient requires more professional treatment, the patient will be treated in cooperation with the Korea Institute of Radiological Medical Sciences (KIRAMS).

- Publication Videos for Nuclear Emergency Preparedness

  The nuclear operator creates publication videos to promote nuclear power plants. Judging that there is a need for publication videos in the nuclear emergency preparedness, the operator also creates publication videos about nuclear emergency preparedness and safe operation and safety countermeasures. The publication videos are periodically updated and deliver topics such as nuclear emergency preparedness and relevant laws, emergency organizations, emergency plan, emergency response facilities, emergency exercise and training in an easy-to-understand way.

- Information Sharing System among Related Organizations

  KINS develops and operates the Emergency Response Information Exchange System (ERIX) to share information among related organizations during an emergency exercise or in case of an emergency. The system enables to share information on situations and actions taken among related organization that are geographically distant from each other, making effective emergency response possible. The ERIX is a web-based system to send and receive information easily and quickly via the internet.

Due to a earthquake and tsunami beyond expectation, a severe accident occurred at multiple units at the Fukushima nuclear site in Japan, causing severe damage to the nuclear site and adjacent infrastructure. Many lessons are learned from the nuclear accident with regard to emergency response and post-accident management.

Considering that situation, a safety inspection led by the regulatory body was conducted to prepare a plan to improve domestic emergency response and the emergency medical service system. The areas inspected were:

- Emergency plan related to the standards, procedures and organization for issuing an emergency classification
- Emergency response facilities and equipment
- System operating status for protecting residents in case of an emergency
- Emergency medical system
- Exercises to test emergency response capabilities
- Response system to simultaneous emergencies at one nuclear site’s reactors

As a result, it was verified that emergency response and the emergency medical system based on existing design and accident concept are appropriate. However, 11 action items were identified to respond to a natural disaster beyond the design basis and simultaneous emergencies at multiple reactors.

- Securing additional radiation protection equipment for protecting residents near a nuclear power plant
- Amending the nuclear emergency plan considering the simultaneous emergency classification at multiple units
- Securing additional equipment to prepare for a prolonged emergency
- Increasing equipment of emergency medical treatment organizations
- Reinforcing nuclear emergency exercise
- Securing necessary information in case of a prolonged loss of electrical power
- Securing countermeasures for protecting maintenance workers
- Improving emergency response facilities
- Amending the information disclosure procedure in the event of a nuclear emergency
- Evaluating protective measures for residents who live beyond the emergency planning area
- Reinforcing the function of an emergency alerting system

E.2 Operator's Activities

The operators of nuclear power plants, research reactors and nuclear cycle facilities as well as KIRAMS, the emergency medical institution prepared a detailed action plan with regard to emergency response and medical service at the request of the regulatory body in May 2011.

- Securing additional radiation protection equipment for protecting residents near a nuclear power plant

  The operator keeps 10 days inventory of Potassium Iodine (KI) for the all ERO staff at nuclear emergency response facilities. For local residents who live nearby a nuclear plant, the operator has secured up to 1.25 million potassium iodide (KI) tablets for population within the emergency planning zone (8 to 10 km). However, based on lessons learned from the Fukushima accident, the operator will purchase an additional 3.8 million tablets of potassium iodine (KI) by September 2012 to raise the inventory to 5 million so as to supply to local residents within an extended radius of a nuclear power plant. In addition, the operator, together with local and central governments will increase the inventory of gas masks to 480,000 for protecting residents near nuclear power plants.

A management system for radiation protection medicines, including potassium iodide and Prussian Blue (that traps radioactive cesium), has been more systematically established. In addition, the thyroid protection medicine is an ethical drug, so the management responsibility has been changed to Radiation Health Research Institute (RHRI), a medical service organization of plant operators.

- Amending the nuclear emergency plan considering the simultaneous emergency classification at multiple units

The nuclear emergency organizations were structured to cope with a nuclear emergency at a single-unit. Now, the nuclear emergency organizations are restructured based on three scenarios: first, a nuclear emergency at single unit, second, simultaneous emergencies at two units in one site, third, simultaneous emergencies at more than three units in one site, and the revision of the nuclear emergency plan considering the simultaneous emergency classification at multiple units has been already completed in December 2011.

In the revised nuclear emergency plan, the magnitude of tsunami is added to the criteria for issuing an emergency classification with respect to a natural disaster. In addition, the revised nuclear emergency plan defines the emergency response time objective: issuing a nuclear emergency classification within 15 minutes, organizing a response group within one hour after the issuance of a emergency classification and putting the emergency group into operation within two hours.

- Securing additional equipment to prepare for a prolonged emergency

Pursuant to the nuclear emergency plan, the operator keeps the approximately 350 units of seven different types of radiation (radioactivity) instruments including high-level beta-gamma dose rate meters, 8,600 pieces of 13 different types of radiation production equipment including protective clothing, 166,000 tablets (130 g) of thyroid protection medicine. In response to a prolonged emergency like the nuclear accident at Fukushima, 440 units and 12 types of radiation (radioactivity) instruments will be additionally secured by 2012 so that the inventory will rise to 200% of the current level.

- Increasing the equipment of emergency medical organizations

Assuming a sudden increase in patients due to a radiological disaster, emergency medical equipment will be increased and more emergency medical institutions will be designated by 2013 to ensure prompt and effective response even beyond a medical facility’s capacity.

- Reinforcing nuclear emergency exercise

In order to strengthen emergency response capabilities of the operator's emergency response organization (ERO) staffs, an blind exercise is conducted once a year under the recommendation of the NSSC. Blind means the personnel participating in the exercise must not be advised in advance, of the exact date, time and scenario of the exercise, therefore, it is expected that the blind exercise will contribute to strengthening emergency response capabilities of ERO staffs.

A research has been launched to develop exercise scenarios based on natural disaster such as earthquake, tsunami and large scale fire. The newly developed scenarios will be applied to the Unified Emergency Exercise organized by the government and conducted in July 2012.

- Securing necessary information in case of a prolonged loss of electrical power

In case of the prolonged loss of power, it is indispensable for acquisition of key plant parameters that the power supply system to emergency response facilities as well as the plant main computer. The EDG together with the UPS is secured to prepare for the loss of power to emergency response facilities, however the capacity of UPS is not sufficient in case of long-term loss of power. The operator plans to secure a separate backup power sources to the plant main computer by 2013.

- Improving emergency response facilities

The licensee is planning to improve the inhabitability and scale of emergency response facilities such as Technical Support Center (TSC) and Operation Support Center (OSC) and to prevent inundation of emergency facilities due to a large tsunami by the late 2015.

As with the nuclear accident at Fukushima, if events such as a prolonged black-out, flooding and facility damage occur simultaneously at one plant and in a neighborhood area due to a large earthquake or tsunami, the Environmental Radiation Monitoring System (ERMS) installed in the emergency planning zone is likely to be damaged irrevocably. Therefore, 19 units of mobile ERMS which are able to transmit radiation monitoring data via wireless communication will be deployed in 2012 for environmental radiation monitoring in case of an emergency.

- Securing countermeasures for protecting maintenance workers

The standard Procedure for Protecting Emergency Workers, which describes procedures for input of emergency workers for accident mitigation and emergency measures, was developed in August 2011. This is a procedure that standardizes the decision and approval of emergency work to avoid confusion of radiation protection during a radiation emergency. It will enable emergency workers to perform emergency work promptly.

Employees of subcontractors are important in an emergency, they are mandated to take the same training for radiation emergency preparedness as operator's employees do.

Training for subcontractors on emergency preparedness will be prepared and executed from 2012.

- Amending the information disclosure procedure in the event of a nuclear emergency

  With respect to improvement of the national radiological disaster management system after the nuclear accident at Fukushima, the operator had a discussion with the NSSC and KINS regarding dealing with the media. Based on that, the government manual for crisis management and the operator's radiation emergency plan will be revised to incorporate concrete information and information disclosure timing by the late 2012 to secure the transparency in informing the media, the public and residents near nuclear plants.

- Evaluating protective measures for residents who live beyond an emergency planning zone

  The APPRE requires the nuclear operator to establish an emergency planning zone between 8 to 10 km. More detailed EPZ should be determined considering topography, meteorology, towns and administrative regions around the nuclear plant. The EPZ is approved by NSSC after a consultation with local government. As a need to improve protecting measures for residents who live beyond an emergency planning zone rises after Fukushima nuclear accident, the related research will be established by 2013.

- Reinforcing the function of an emergency alerting system

  A emergency alerting system to protect local residents around a nuclear plant and send an alert to the local residents.

  Accordingly, the operator has established an emergency alerting system (Amplifier and Speaker) for the local residents and the integrity of the system has been maintained via self-inspection and joint inspection attended by the local and central governments. The joint inspection has been conducted to check the status of sound and the operation of the system on a quarterly basis.

  As a need to improve the emergency alerting system rises after the nuclear accident at Fukushima, an emergency power source will be established in preparation against the loss of power following an earthquake and tsunami.

KHNP, the nuclear power plant operator, identified the below action items additionally in consideration of lessons learned from the Fukushima nuclear accident and prepared a detailed action plan.

- Improving a cooperation system with relevant organizations

  KHNP, the nuclear operator, strives to establish a close cooperation with relevant organizations, and based on which, respond to an accident promptly and prevent the expansion of an accident in case of a nuclear emergency. One example, the Agreement on Prompt Response and Cooperation in Case of a Nuclear Emergency that KHNP and

National Emergency Management Agency (NEMA) signed in September 2011. According to the agreement, in the event of a nuclear accident, NEMA allows National 119 Rescue Services to provide a helicopter for rescues, patient transfers, and transporting experts while KHNP provides nuclear facility experts and radiation protection equipment to NEMA.

The role of Emergency Operation Facility (EOF) at the operator's head office is incorporated into a national crisis response manual to strengthen coordination with relevant organizations. The participation of the operator's top management in the National Emergency Management Committee is required for efficient communication with the government and the dispatch of technical support team from expert organizations to the field is considered for an emergency.

- Operating an dose assessment program for the public protection measures

The APPRE requires the nuclear operator to assess the estimated dose and recommend protective actions for the public to NSSC in case of nuclear emergency. To this end, the nuclear operator has developed a dose assessment program, Korea Radiological Emergency Dose Assessment Program (K-REDAP) and operated. The reliability of the program has been secured through emergency exercise at a nuclear power plant.

Currently, real-time meteorological data is not considered in the process of the estimated dose calculation, which undermines data accuracy. Therefore, the system will be upgraded to use real-time meteorological and environmental radiation data to assess the impact to the public. The reliability of the system will be improved by comparing calculated estimates with environmental radiation monitoring data and then evaluating and reflecting the difference repeatedly to arrive the most accurate results.

E.3 Regulator's Activities

To “Reinforcing nuclear emergency exercise,” one of the operator's action plans, the operator introduces blind exercise, which will require the regulatory body to take a lead role in evaluating the exercise scenarios and results. At the same time, simultaneous emergency exercise at multiple units in preparation for a natural disaster such as an earthquake and tsunami is expected to strengthen the cooperation with off-site emergency organizations. With regard to “Amending the information disclosure procedure in the event of a radiation emergency,” the regulatory body will secure the transparency of information disclosure by revising the government manual for crisis management and the operator's nuclear emergency plan to incorporate concrete information and the period of information disclosure to be provided to the media, the public and local residents by the late 2012.

The regulatory body is striving to ensure prompt and accurate monitoring of the environment for protective measures for residents and to incorporate the concept of Urgent Protective action planning Zone (UPZ) into related laws and systems for prompt evacuation of residents. The regulatory body is also working on the revision of laws and systems for substantial compensation for damage caused by nuclear accident.

- Environmental Monitoring

  In order to protect public health from radiation through early detection of domestic or foreign radiation emergencies and furthermore to preserve the environment, KINS operates a central monitoring station, 12 local monitoring station and 59 unmanned monitoring posts in accordance with the Nationwide Environmental Monitoring Program, and thereby monitors and evaluates the environmental radiation and radioactivity throughout Korea.

  The central monitoring station of KINS prepares a comprehensive environment monitoring plan for all the Korean territory; analyzes and evaluates environmental monitoring data of local monitoring station and real-time environmental radiation-level change monitoring data of radiation monitoring posts; and judges an abnormal increase in radioactivity/radiation.

  As part of post-Fukushima actions, KINS also will open local monitoring station and unmanned monitoring posts for a CLEAN System (Computerized Local & overall country‘s Environmental Monitoring Station Network) until the number reaches 16 and 104 respectively so as to strengthen nuclear safety.

- Protective Measures for Residents

  The decision-making criteria for urgent actions to protect the public, as well as the specific details of the public protective actions are prescribed in the APPRE and its subsequent regulations. In the event of an emergency, the Regulatory Body determines the public protective actions by applying the Generic Intervention Levels (GILs), and decides upon the Operational Intervention Levels (OILs), which are applicable in the early stage of response, in the Crisis Response Manual. In addition, the Regulatory Body provides consulting to the local government when it performs a mid- to long-term radiological impact assessment, or formulates a restoration plan and the General Post-radiological Disaster Measures. The Regulatory Body supervises and supports the local government so that the OILs will be applied when establishing or executing the long-term restoration measures.

  In order to adopt the concepts of the precautionary action zone (PAZ) and the urgent protective action planning zone (UPZ) instead of the emergency planning zone (EPZ), the regulatory body is working on a research to amend the protection objective of EPZ in line with the IAEA standards, and based on the research results, will revise related laws and systems.

- Compensation for Damages incurred by the accident

  The Nuclear Liability Act is legislated not based on the experience of damage incurred by a nuclear accident but based on the legal consideration to prepare for just in case of a nuclear accident. However, the nuclear accident at Fukushima has made real all the possible legal issues such as the astrological amount of compensation, specific coverage for nuclear damage, accession to international conventions, compensation of trans-border nuclear damage, procedures for quick resolution of conflicts. Therefore, the Korean government has embarked on the research to improve the related legal system to minimize legal conflicts with regard to compensation for damages.

F. Topic 6 (International Cooperation)

F.1 Overview

The Government of the Republic of Korea has been participating in international activities in a wide range for contributing to establishment of the global nuclear safety regime. Theses activities include implementation of the international treaties and conventions for nuclear safety, exchange of information on nuclear safety and regulation, cooperation of research and development (R&D) on nuclear safety and various international cooperation and supports. The Government conducts the international activities for nuclear safety pursuant to the Atomic Energy Act (ACT), the Act on Physical Protection and Radiological Emergency (APPRE), and various international treaties, conventions and other instruments, and aims at enhancing the safety of peaceful use of nuclear energy nationally and internationally. To achieve this objective, the regulatory body has been making efforts to promote effectiveness and efficiency of the nuclear safety regulation, by sharing the operating and regulatory experience, and the good practices through various bilateral and multilateral cooperation programs. The regulatory body is actively developing programs to provide support to the countries which have interests in construction of new nuclear power plants in their establishment of regulatory infrastructure, and is particularly contributing to establishment of the global nuclear safety regime by leading regional nuclear safety networks.

After the accident of Fukushima Dai-ichi nuclear power plants, the public and press of

Korea have showed considerable interest in the accident and the Korean government has taken prompt and active measures to cope with the accident since Korea is the closest neighboring country to Japan. The Korean Government supplied the Japanese Government boric acid, for controlling the accident, and has dispatched radiation safety experts to the Embassy of the Republic of Korea in Japan to promptly collect the accident-related information and provide technical consulting. A couple of Korea-Japan expert meetings were held in Japan for the assessment of impact of the Fukushima accident on the Korean Peninsula, information collection, and opinion exchange. Korea also has dispatched nuclear safety experts to the Japan Nuclear Energy Safety Organization (JNES) for a joint analysis of the accident and speedy information exchange. Through these activities, the cooperation between Korea and Japan has been strengthened.
In addition, Korea has sent domestic experts to the radiological impact analysis team and the international fact-finding expert mission of IAEA to support the accident response activities of the international organization. By participating in the international experts meetings, ministerial-level meetings, and summit meetings after the Fukushima accident, Korea has actively cooperated with the international organizations and community.

F.2 Operator's Activities

F.2.1 Sharing Operating Experience.

It is expected that Korea's post-Fukushima actions will continue for at least 10 years. Immediately after the nuclear accident occurred at Fukushima, Korea initiated a process to identify and implement areas for improvement in order to further enhance the safety of its nuclear power plants. At the same time, Korea established a system to analyze the lessons learned from the Fukushima accident and from the operating experiences of WANO, other international organizations, Japan, and other nuclear power plant operating countries, and to apply the results of that analysis to the operation of Korean nuclear power plants. Accordingly, the operator reviewed the feasibility of overseas operations and prepared action plans to apply it to Korean nuclear power plants, after deliberation by the Advisory Committee on Post-Fukushima Actions.

The operator reviewed three significant operating experience reports (SOERs) released by WANO and implemented action plans to improve the safety of nuclear power plants in connection with them. For example, the operator verified its capability to mitigate conditions that result from beyond-design-basis events, and is in the process of implementing action plans to further improve the safety of nuclear power plants under the assumption of a large earthquake and tsunami exceeding the design basis in connection with SOER 2011-2 (Fukushima Daiichi Nuclear Station Fuel Damage Caused by Earthquake and Tsunami). With regard to SOER 2011-3 (Fukushima Daiichi Nuclear Station Spent Fuel Pool/Pond Loss of Cooling and Makeup), the operator is taking action to be able to cope with the loss of the cooling function by the spent fuel pool. The operator is also implementing action plans to improve the power system, such as deploying power generating vehicles and batteries, to prevent or mitigate a significant accident, to ensure the survivability of essential equipment and instruments, and to improve emergency alarming systems, which are all associated with SOER 2011-4 (Near-Term Actions to Address an Extended Loss of All AC Power).

To take further steps, the operator additionally identified 10 action items for improvement, such as installing safety-level transmitters and temperature & radiation level instruments to the SFP, after and in-depth review of follow-up actions taken by overseas plants.

F.2.2 International Exchange

On April 8, 2011, two KHNP's experts in severe accidents, emergency preparedness, and radiation protection were dispatched to WANO Tokyo Center to follow the progress of the Fukushima nuclear accident and to collect accurate information, while supporting the restoration work for the Fukushima nuclear power plants.

In addition, as Executive Vice President of the Power Generation Division, KHNP participated in the WANO Post-Fukushima Commission. The Commission was launched in April 2011 to improve WANO programs and systems with a view to efficiently implement the lessons learned from the Fukushima accident. The Commission made five recommendations with regard to WANO Scope Expansion, Event Response Strategy, Credibility, Transparency, and Internal Consistency.

F.3 Regulator's Activities

F.3.1 IAEA Peer Reviews

The Korean government actively uses peer review services provided by international organizations including the IAEA. A case in point is that the Korean government requested an IAEA Integrated Regulatory Review Service (IRRS) mission in 2009 and received the IRRS mission including the Korean government response to the Fukushima Dai-ichi Nuclear accident in July 2011, the first one after the nuclear accident at Fukushima. The mission team concluded that the Korean regulatory body had implemented a technically capable and effective nuclear safety regulatory program; that the transition to a new regulatory framework has the potential to enhance regulatory independence, expertise and transparency; and that Korea's response to the accident at Fukushima has been prompt and effective. The IRRS final report lists 15 good practices (a clear and structured national approach for nuclear safety; strong support for the global nuclear safety regime; provision of training and education for Korean and foreign trainees), 10 recommendations for enhancing the overall performance of the future regulatory system (regulations and guides should be developed for decommissioning and managing spent fuel), and 12 suggestions (revisions of regulation to ensure the 10-year period of PSR). The final report contained what is considered to be one of the finest evaluations, compared to previous IRRSs in nuclear advanced countries such as the USA and France.

Currently the Korean government is preparing action plans for each recommendation and suggestion identified by the IRRS mission team, and appropriate measures for 15 recommendations and suggestions will be taken till 2013 except for the following 7 items that has already completed. In addition, the Korean government is considering a follow-up IRRS Mission in accordance with IRRS Guidelines.

- Defining the responsibilities within the new regulatory body, avoiding overlaps between the secretariat, KINS and the Advisory Committee, and allocating the resources and staff to be commensurate with those responsibilities.
- Development of a Management System to cover all activities of the new Nuclear Safety Commission and its secretariat
- Development of a process on Resource Management in order to achieve a fully integrated Management System in KINS
- Establishing the selection criteria of the members to reflect the need of independence and nuclear safety competence within the Commission
- Preparing human resources plans for the Secretariat that provides appropriate staff to enable the accomplishment of its administrative function in support of the Commission without undue burden
- Establishment of an advisory committee to support decision-making process
- Enhancement of a stakeholder and general public involvement in the drafting process

for regulations and guides

F.3.2 Expanded Use of IAEA Safety Standards

The Korean government is actively involved in IAEA's Safety Standards Commission and four committees (Nuclear Safety and Security, Radiation, Transport, and Waste Safety), contributing to the development and revision of IAEA safety standards. The published safety standards are used in various ways for improving technical standards and regulatory activities in Korea. The application and use of international safety standards including those by the IAEA are summarized as follows:

- Direct citation in regulations
- Indirect reflection in regulations
- Application as references in regulatory guidelines
- Practical application to regulatory activities (Safety Review and Inspection)

The regulatory body also analyses the latest international safety standards and studies their applicability to the domestic regulatory system, thereby endeavoring to maintain conformity between domestic technical standards and international safety standards. In particular, between 2009 and 2010 KINS developed integrated regulatory standards and guides that focused on utilizing the latest IAEA safety standards. KINS also attends some 60 IAEA meetings a year that are directly or indirectly related to development, review, and implementation of IAEA Safety Standards, thus making a contribution to the internationally harmonized application of IAEA Safety Standards in various ways.

The Korean regulatory body will actively continue to participate in the effort of the international community to implement action plans for nuclear safety, including revision of IAEA Safety Standards after the nuclear accident at Fukushima. In particular, the Korean government embarked on a regulation standard and guide maintenance project to revise laws, technical standards, and guides related to nuclear safety in line with the international standards.

F.3.3 Communication with Neighboring Countries and the International Community

Cooperation with Japan

In connection with the Fukushima accident, the cooperation for prompt information sharing and emergency response among neighboring countries became an issue. Thus, Korea has made every effort to collect information and to intensify collaboration with Japan by diversifying cooperation channels and methods.

With the request from the Japanese Government following the accident, the Korean Government provided Japan with 200 full-face masks, filters and 52. tons of boric acid that operators possess.

Through the diplomatic channel after the accident, MEST and KINS suggested to the Japanese Government that Korea would send Korean nuclear safety experts to Japan. Upon the acceptance of this suggestion by the Japanese Government, KINS has dispatched nuclear safety experts to JNES. This has paved the way for a more intimate cooperation between Korea and Japan, such as sending liaison officers from a very early stage of an emergency.

In view of the public concerns and interest about the Fukushima Daiichi nuclear accident, the Korean Government asked the Japanese Government to provide information on the status and progress of the accident to Korea and hold Korea-Japan expert meetings. As a result, the following first Korea-Japan expert meeting was held in Tokyo on 11-13 April 2011 and relevant information was exchanged and accident mitigation activities and follow-up measures were discussed.

- Korea Side: a total of 10 experts and government officials including 1 MEST staffer, 4 KINS staffers, and 2 KAERI staffers, and 3 staffers from the Embassy of the Republic of Korea in Japan
- Japan Side: a total of 16 experts and government officials from Ministry of Foreign Affairs (MOFA), Ministry of Education, Culture, Sports, Science, and Technology (MEXT), Ministry of Health, Labor, and Welfare (MHLW), Ministry of Agriculture, Forestry, and Fisheries (MAFF), NISA, and JNES
- Main Content: Information exchange on the current status of the Fukushima accident, Japan's response strategies, radiation monitoring, and food safety
- Follow-Up Measure: Dispatch of liaison personnel of KINS to JNES for more efficient information exchange

And the following second Korea-Japan expert meeting was held in Tokyo on 14-15 June 2011 where the follow-up measures and future plans of both countries were reported, information about the Fukushima accident was exchanged, comments on the Japanese national report prepared for the IAEA Ministerial Conference on Nuclear Safety were given by the Korean experts, and further collaboration between Korea and Japan was discussed.

- Korea Side: a total of 9 experts and government officials including 1 MEST staff, 7 KINS staff, 1 staff from the Embassy of the Republic of Korea in Japan

- Japan Side: a total of 22 experts and government officials from Ministry of Foreign Affairs (MOFA), Ministry of Education, Culture, Sports, Science, and Technology (MEXT), NISA, and JNES
- Main Contents: Information exchange on the activities taken by both countries, future plans, and the progress of the Fukushima accident and comments by the Korean experts on the Japanese national report prepared for the IAEA Ministerial Conference on Nuclear Safety (questions, answers, and comments)
- Follow-Up Measures: Further enhancement of the function of Early Notification System for an emergency situation and measures such as dispatching liaison personnel in case of a nuclear accident

Cooperation with Neighboring Countries

The Korea-China-Japan Summit Meeting was held in May 2011 for nuclear safety cooperation, and the three countries agreed to strengthen information sharing and collaboration with regard to nuclear accidents. In November 2011, the 4th Top Regulators' Meeting on Nuclear Safety (TRM) was held to discuss specific ways for cooperation among Korean, China, and Japan. The TRM was a working-level meeting for discussing the exchange of information regarding safety standards and technologies. The chief delegates, at the deputy-minister level, signed on to the Korea·China·Japan Nuclear Safety Cooperation Initiative proposed by Japan and revised by Korea. Based on the Initiative, the TRM was transformed into a trilateral cooperation channel to implement the agreements on Nuclear Safety Cooperation at the Korea-China-Japan summit meeting in May 2011. To this end, the three nations agreed to revise the MoC and develop a ToR to establish a framework for substantial cooperation. In addition, it was agreed that a Coordination Group attended by working-level representatives from all three nations was to be formed within one month to discuss specific ways to finalize the agenda, such as the revision of the MoC and the ToR, the establishment of an information exchange framework to actively share experiences of construction and operation including lessons learned from the accident at the TEPCO Fukushima Dai-ichi nuclear power station, and the preparation of an information exchange plan for normal situations and emergencies, for the next summit meeting, to be held in Seoul.

F.3.4 Cooperation with International Organizations

In order to actively support the accident investigation and impact assessment of IAEA, Korean experts provided technical consulting on radiation impact analysis by participating in the radiation impact analysis team of IAEA, and also performed a preliminary assessment on the Fukushima accident by taking part in the fact-finding expert mission of IAEA.

In the Nuclear Safety Convention fifth review meeting, Korea presented its safety investigation plan for operating nuclear power plants in connection with the Fukushima accident, and exchanged information with participating countries especially to derive preliminary lessons learned from the accident. Subsequently Korea disseminated information on actions taken in Korea following the Fukushima accident at the important international meetings including MDEP steering committee meeting, INRA meeting, ANSN steering committee meeting, INSAG meeting, G20 nuclear safety ministerial-level meeting, NEA Forum on Fukushima accident, and IAEA Ministerial conference on Nuclear Safety.

In the fourth summit meeting of Korea, Japan and China held in Tokyo on 22 May 2011, it was decided to strengthen practical cooperation through the Top Regulator’s Meeting among the three countries which was established in 2008. It was also agreed to start discussion on establishing an early notification framework in case of emergency and exchanging experts, and to contemplate on exchange of information regarding the analysis and forecast of air flow trajectory on a real time basis in case of a nuclear accident.
So as to fulfill the duty as a nuclear export country for the UAE (United Arab Emirates) nuclear regulatory body (FANR), KINS provided its action plan for operating nuclear power plants in connection with the Fukushima accident. KINS also continues to support FANR by sharing regulatory technologies and experiences.

Through the accident of the Fukushima Daiichi nuclear power plants, it has been reaffirmed that prompt information sharing and response among neighboring countries are of utmost importance in order to protect public health and facilitate public acceptance of nuclear energy. To that end, the early accident notification framework should be strengthened with the international organizations including IAEA as the center, and international cooperation especially among neighboring countries should be further enhanced.

III Summary Table

Activity	Activities by the Operator			Activitie	
	Activity	Schedule	Result Available	Activity	
Topic 1 - External Events					
Installing an automatic seismic trip system	Ongoing	2013	Yes(partly)	Ongoing	
Improving the seismic capacity of the safe shutdown system	Ongoing	2014	No	Ongoing	
Investigating and researching the maximum potential earthquake for the nuclear sites	Ongoing	2013	No	Ongoing	
Improving plant seismic capacities of main control room (MCR) such as the seismic alarm window	Ongoing	2013	No	Ongoing	

Activity	Activities by the Operator			Activitie
	Activity	Schedule	Result Available	Activity
Improving the seismic capacity of the entrance bridge in the Wolsong nuclear power plant	Ongoing	2012	No	Ongoing
Building up the sea wall for Kori site	Ongoing	2012	Yes(partly)	Ongoing
Installing waterproof doors and discharge pumps	Ongoing	2014	No	Ongoing
Investigating and researching the design basis sea water level of nuclear power sites	Ongoing	2013	No	Ongoing
Reinforcing the intake capability for cooling water and improving facilities in preparation for tsunami	Ongoing	2015	No	Ongoing
Evaluating the seismic performance of water pipeline (from purifying plant to treatment plant)	Ongoing	2014	No	Ongoing

Activity	Activities by the Operator			Activitie	
	Activity	Schedule	Result Available	Activity	
Topic 2 - Design Issues					
Securing mobile generators and batteries	Ongoing	2014	No	Ongoing	
Upgrading the design basis of AAC diesel generator	Ongoing	2014	No	Ongoing	
Fastening backup transformers with anchor bolts and improving the fuel injection ports of emergency power supply systems (EPS) of Wolsong plants	Ongoing (partly Taken)	2012	Yes(partly)	Ongoing	
Improving the management responsibility of switchyard facilities	Ongoing	2013	Yes	Ongoing	
Improving the reliability of on-site power supply systems	Ongoing	2013	No	Ongoing	
Securing emergency power to Wolsong unit 1 local air cooler	Ongoing	2012	No	Ongoing	

Activity	Activities by the Operator			Activitie	
	Activity	Schedule	Result Available	Activity	
Preparing a plan for prevention and restoration of inundation of UHS	Ongoing	2013	No	Ongoing	
Preparing a plan for prevention of damage of outdoor tanks	Ongoing	2014	No	Ongoing	
Preparing a plan for prevention of inundation of main steam safety valve room and emergency feed water pump room	Planned	2014	No	Planned	
Installing a auxiliary feed water storage tank additionally at Ulchin unit 1	Ongoing	2015	No	Ongoing	
Installing PARs	Ongoing	2014	Yes(partly)	Ongoing	
Installing containment building ventilation or depressurizing equipment	Ongoing	2015	No	Ongoing	

Activity	Activities by the Operator			Activitie
	Activity	Schedule	Result Available	Activity
Installing reactor injection flow for emergency cooling water from external sources	Ongoing	2015	Yes(partly)	Ongoing
Preparing countermeasures for the loss of spent fuel pool cooling	Ongoing	2012	Yes(partly)	Ongoing
Install safety class instruments to monitor water level, temperature and radiation level	Ongoing	2014	Yes(partly)	Ongoing
Revising technical standards related to securing emergency power of spent fuel pool	Ongoing	2012	Yes(partly)	Ongoing
Improving the fire protection plan and reinforcing cooperation systems	Taken	2011	Yes	Taken

Activity	Activities by the Operator			Activitie
	Activity	Schedule	Result Available	Activity
Improving fire protection facilities and response capability of plant firefighting teams	Ongoing	2013	No	Ongoing
Introducing a performance-based fire protection design	Ongoing	2012	Yes(partly)	Ongoing
Topic 3 - Severe Accident Management				
Strengthening severe accident training and education	Taken	2011	Yes	Taken
Revising SAMG to improve the effectiveness of accident management strategies	Ongoing	2015	No	Ongoing
Developing Low-Power Shutdown Severe Accident Management Guides	Ongoing	2015	No	Ongoing
Securing Mobile diesel-driven pumps	Planned	2014	No	Planned

Activity	Activities by the Operator			Activitie	
	Activity	Schedule	Result Available	Activity	
Securing long-distance hoses	Planned	2015	No	Planned	
Development of EDMG	Planned	2015	No	Planned	
Development of EOP-SAMG integrated procedure	Planned	2015	No	Planned	
Topic 4 – National Organizations					
Establishment and operation of the NSSC	-	-	-	Taken	
Establishment of an agreement with NEPA	-	-	-	Taken	
Establishment of an agreement with KMA	-	-	-	Taken	
Establishment of an agreement with KFDA and MLTM	-	-	-	Planned	

Activity	Activities by the Operator			Activiti
	Activity	Schedule	Result Available	Activity
Topic 5 - Emergency Preparedness and Response and Post-Accident Managem				
Securing additional radiation protection equipment for protecting residents near NPP	Ongoing	2012	No	Ongoing
Amending the emergency plan to include such events as a simultaneous emergency at multiple units	Taken	2011	Yes	Taken
Securing additional protective equipment in preparation for a prolonged emergency	Ongoing	2012	No	Ongoing
Securing additional equipment of emergency medical institutes	Planned	2013	No	Planned
Reinforcing radiological emergency exercises	Ongoing	2012	Yes(partly)	Ongoing

Activity	Activities by the Operator			Activitie
	Activity	Schedule	Result Available	Activity
Devising a means of securing the necessary information in case of a prolonged loss of electrical power	Ongoing	2013	No	Ongoing
Securing countermeasures for protecting maintenance workers	Ongoing	2015	No	Ongoing
Improving the emergency response facilities	Ongoing	2012	Yes(partly)	Ongoing
Amending the information disclosure procedures in the event of a radiation emergency	Ongoing	2012	No	Ongoing
Evaluating protective measures for residents who live beyond the emergency plan zone	Ongoing	2013	No	Ongoing

Activity	Activities by the Operator			Activitie
	Activity	Schedule	Result Available	Activity
Reinforcing the performance of emergency alarm facilities	Ongoing	2014	No	Ongoing
Improving a cooperation system with relevant organizations	Taken	2011.9	Yes	-
Operating an dose assessment program for the public protection measures	Ongoing	2014	No	Ongoing
Strengthening environmental monitoring	-	-	-	Ongoing
Protective Measures for Residents	-	-	-	Ongoing
Compensation for Damages incurred by the accident	-	-	-	Ongoing

Activity	Activities by the Operator			Activitie	
	Activity	Schedule	Result Available	Activity	
			Topic 6 – International Cooperation		
Operating Experience Feedback for the lessons learned of Fukushima accident	Ongoing	continue	Yes(partly)	Ongoing	
IRRS Mission	-	-	-	Taken	
Taking a measure for recommendations and suggestions identified by the IRRS				Ongoing	
Expanding the use of IAEA safety standards	-	-	-	Ongoing	
Strengthening cooperation and information exchange with neighboring countries (Korea-Japan-China)	-	-	-	Ongoing	
Dispatching nuclear safety experts to enhance the cooperation channel and information sharing with Japan	-	-	-	Taken	

Activity	Activities by the Operator			Activitie	
	Activity	Schedule	Result Available	Activity	
Participating in the radiation impact analysis team and the fact-finding expert mission of IAEA	-	-	-	Taken	
NEA mission to Japan on nuclear safety organisations	-	-	-	Taken	