Lessons Learned and Challenges for Nuclear Power in South Korea after Fukushima Nuclear Disaster

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Fukushima Accident

- East Japan Earthquake and Tsunami
  - 3/11/2011, 14:46, Magnitude 9.0, Tsunami Height > 14m
- Initiation of the Accident

(Quoted from material by Won-Pil Baek of KAERI, January 2013)
Fukushima Accident (cont)

- Progress of the Accident

- **Incomplete Design, Siting & Preparedness**
  - Site characteristics
  - Severe accident
  - Procedures & training

- **Earthquake + Tsunami**
  - Loss of power
  - Equipment failure
  - Loss of reactor instrumentation
  - Difficulty in external measures

- **Loss of Core Cooling**
  - Core Melt & Hydrogen Generation

- **Hydrogen Explosion**
  - + Reactor Building Damage

- **Large Release of Radioactive Materials**
  - (Atmosphere, Land, Sea)

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Secure Safe Cooling of Damaged Reactors/SFPs and Stop Further Radioactivity Releases

Decontamination, Decommissioning and Disposal of Facility (incl. Environmental Restoration)

(Quoted from material by Won-Pil Baek of KAERI, January 2013)
Fukushima Accident (cont)

- Key Characteristics of the Accident
  - Severe Accident Initiated by an Extreme Natural Disaster
    - TMI & Chernobyl: Design/equipment failure + human factors
    - Fukushima: Natural disaster+ siting/design/equipment failure + human factors
    - Prolonged losses in electricity supply & safety-related equipment due to earthquake/tsunami
  - Severe Accident in Multiple Units and for a Long Time
    - Extensive core melting in three (3) reactors
    - Large-scale hydrogen explosion in three (3) reactor buildings
    - Damage in reactor vessels and primary containment vessels
    - Threat to the integrity of spent fuels in SFPs
    - Several months in escaping from very urgent situation
  - Environmental Contamination and Societal Crisis due to Large Release of Radioactive Materials
    - Large radioactivity release: ~20% of Chernobyl, INES Level 7
    - No immediate casualty due to radiation exposure
    - Extensive contamination, large no. of evacuees, several decades for restoration ➔ societal crisis and enormous economic impact

(Quoted from material by Won-Pil Baek of KAERI, January 2013)
Lessons Learned from Fukushima Accident

- Lessons - Safety Approaches and Systems
  - Improvement and strengthening of defense in depth strategy
  - Consideration of societal crisis aspects in nuclear safety objectives
  - Further improvements of regulation and standards for radiation safety and emergency evacuation
  - Strengthened independence & expertise of regulatory bodies
  - Emphasized role and enhanced capability of operating organizations in assuring NPP safety

(Quoted from material by Won-Pil Baek of KAERI, January 2013)
Lessons Learned from Fukushima Accident (cont)

- Lessons - Prevention of Severe Accidents
  - Enhanced capability against natural disasters
  - Improvements in diversity & reliability of emergency power supply systems
  - Reliable decay heat removal by strengthened passive safety
  - Risk informed design and operation of NPPs
  - Reassessment & enhancement of the safety of spent fuel storage

(Quoted from material by Won-Pil Baek of KAERI, January 2013)
Lessons Learned from Fukushima Accident (cont)

- Lessons - Mitigation of Severe Accidents
  - Practical countermeasures against severe accidents
  - Improvement of NPP procedures, covering up to extreme severe accident scenarios: Imagine the unimaginable
  - Enhancement of NPP instrumentation to provide reliable information during accidents
  - Role of creative experts for events outside the scope of existing procedures

(Quoted from material by Won-Pil Baek of KAERI, January 2013)
Lessons Learned from Fukushima Accident (cont)

- Lessons - Emergency Response Systems
  - Strengthening of emergency response system against large-scale accidents
  - Reinforcement of emergency response facilities incorporating deteriorated conditions
  - Reliable monitoring & assessment of radiation & radioactivity
  - Enhanced medical systems for radiation emergency
  - Exposure management of emergency workers
  - Crisis communication
  - Preparedness for accidents at neighboring countries

(Quoted from material by Won-Pil Baek of KAERI, January 2013)
Lessons Learned from Fukushima Accident (cont)

- Lessons - Other Aspects
  - Strengthening of safety culture, including an independent assessment system
  - Effective nuclear safety research and sharing of research outputs
  - Efforts to enhance public understanding on radiations and their effects

(Quoted from material by Won-Pil Baek of KAERI, January 2013)
Lessons Learned from Fukushima Accident (cont)

- Fukushima Accident Asks Us:
  - To Escape from Self Satisfaction or Over-Confidence on NPP Safety
  - To Strengthen Countermeasures against External Events as well as Internal Equipment Failures
    - Consider very low-likelihood natural events in design
    - Prepare against prolonged loss of AC power
  - To Strengthen Countermeasures against Severe Accidents
    - Reliable measurement of plant parameters even for severe accidents
    - Severe accident mitigation features including hydrogen control
    - Consideration of severe accident in procedures and operator training
    - Emergency planning and exercise against worst scenarios
  - To Strengthen the Communication of Safety Information

(Quoted from material by Won-Pil Baek of KAERI, January 2013)
Status and Prospect of Nuclear Power in South Korea

(Quoted from material by Hoon-Pyo Hong, MEST, January 2013)
Status and Prospect of Nuclear Power in South Korea (cont)

Figure. Installed nuclear capacity in South Korea (1980-2030)
** Actions Taken in South Korea after Fukushima Accidents **

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar 11, 2011</td>
<td>Special Safety Inspection - 50 recommendations</td>
</tr>
<tr>
<td>Mar. 23, 2011 - Apr. 30</td>
<td>Licensee’s implementation plan(Jul. 8, 2011) &amp; Regulatory review</td>
</tr>
<tr>
<td>Apr 6, 2011</td>
<td>Task Force (Office of Prime Minister, Government Ministry)</td>
</tr>
<tr>
<td>Oct 26, 2011</td>
<td>NSSC launched</td>
</tr>
</tbody>
</table>

(Quoted from material by Chang-Sun Kang of NSSC, April 2012)
Actions Taken in South Korea after Fukushima Accidents (cont)

- Identification of Vulnerability and Safety Improvements
  - Special Safety Inspection (SSI) on NPPs (2011.3-4)
  - Determine Safety Improvements vs. Fukushima (2011.5-7)

- Strengthened Regulatory System
  - Refinement of Safety Inspection System (2012.4)

- Public Outreach and International Cooperation
  - Strengthening Environmental Radiation Monitoring
  - Daily Briefing at Press Conference and Web-pages
  - Cooperation with Neighboring Countries
  - Korea-Japan-China Cooperation, including Top Regulators’ Meeting (TRM)

(Quoted from material by Chang-Sun Kang of NSSC, April 2012)
Actions Taken in South Korea after Fukushima Accidents (cont)

- Special Safety Inspection (SSI) by Regulatory Body
  - March 23 ~ April 30, 2011; 73 Experts
  - 21 Operating NPPs, 1 Research Reactor, and Emergency Medical System
  - Main Focus on Unlikely Worst Case Scenarios, including
    - Extreme natural disaster (earthquake + tsunami)
    - Loss of off-site power and failure of emergency DGs (SBO)
    - Severe accident

- Objectives
  - How well are the NPPs designed against natural disasters?
  - How well can they mitigate the severe accident?
  - How much effective are the emergency response systems in place?

(Quoted from material by Won-Pil Baek of KAERI, January 2013)
Actions Taken in South Korea after Fukushima Accidents (cont)

- Approaches of SSI

Defense-in-Depth Actions to secure safety of NPPs against extreme natural hazards

1. Strengthen emergency plan against extreme accidents
   - To improve emergency preparedness, manage accident and consider multi-units accident

2. Minimize radioactive release to environment
   - To ensure the containment integrity to prevent hydrogen explosion

3. Avoid severe accidents
   - To secure reactor cooling and power supply capabilities under the failure of safety system by natural hazards

4. Protect NPPs from natural hazards
   - To prepare countermeasures against beyond design earthquake and tsunami

(Quoted from material by Chang-Sun Kang of NSSC, April 2012)
Actions Taken in South Korea after Fukushima Accidents (cont)

- Outcomes of the SSI
  - No Imminent Risks to Operating Nuclear Facilities
  - 50 Action Items to Further Strengthen Defense in Depth
    - To minimize the impact of extreme natural disaster
    - To make available emergency power and ultimate heat sink
    - To ensure containment building integrity and emergency response capability

- Examples of Action Items
  - Re-evaluation of seismic capability of safe shutdown system
  - Installation of a mobile emergency generator and battery
  - Installation of passive hydrogen removal equipment
  - Modification of 'radiological emergency plan' considering multiple emergency, etc.

(Quoted from material by Won-Pil Baek of KAERI, January 2013)
Actions Taken in South Korea after Fukushima Accidents (cont)

- Major Improvement

Safety Improvement against Extreme Natural Disasters

1. Higher seawall of Kori site (7.5m → 10m)
2. Mobile emergency generator and battery
3. Watertight door
4. Placement of Emergency Diesel Generator and Alternative AC in higher location
5. Water-proof pump
6. Installation of passive hydrogen removal system
7. Installation of venting/depressurization device

(Quoted from material by Chang-Sun Kang of NSSC, April 2012)
### Actions Taken in South Korea after Fukushima Accidents (cont)

- **Major Improvement Based on Follow-up Measures**

<table>
<thead>
<tr>
<th>Accident Scenario</th>
<th>Major Means of Improvement</th>
<th>End Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occurrence of Earthquake</td>
<td>Installing an Automatic Seismic Trip System</td>
<td>End by 2013</td>
</tr>
<tr>
<td>Occurrence of Coastal Flooding</td>
<td>Extension of Sea Wall of Kori NPP</td>
<td>End by 2012</td>
</tr>
<tr>
<td>Station Blackout</td>
<td>Stand-by of a Movable Generating Vehicle</td>
<td>End by 2014</td>
</tr>
</tbody>
</table>
| Loss of Cooling of Coolant and SFP | • Installing Conduits for Injecting from External Sources  
                                  | • Ensuring Countermeasures when Loss of the Cooling Function of SFP Occurs                   | • End by 2015  
                                  | • End by 2012                                                                          |          |
| Hydrogen Explosion                 | Installing Passive Hydrogen Removal Equipment                                               | End by 2013 |
| Release of Radioactive Substance   | • Installing Containment Building Ventilation or Depression Facilities  
                                  | • Securing Additional Radiological Protection Equipment                                      | • End by 2015  
                                  | • End by 2012                                                                          |          |

(Quoted from material by Chang-Sun Kang of NSSC, September 2012)
Actions Taken in South Korea after Fukushima Accidents (cont)

- Nuclear Safety and Security Commission (NSSC)

  NSSC : Nuclear Safety and Security Commission  
  KINS : Korea Institute of Nuclear Safety  
  KINAC : Korea Institute of Nuclear Nonproliferation and Control

(Quoted from material by Chang-Sun Kang of NSSC, October 2012)
Actions Taken in South Korea after Fukushima Accidents (cont)

- Specific Activities of NSSC

- Licensing of Nuclear Facilities, Materials & Activities
- Inspection & Enforcement of Nuclear Facilities, Materials & Activities
- Incident & Emergency Preparedness & Response
- Non-Proliferation & Safeguards for global peaceful uses of nuclear energy
- Physical Protection against malevolent acts and terrorism
- Export & Import Control of sensitive material and technology

- Safety-related activities are technically supported by
- Security-related activities are supported by

(Quoted from material by Chang-Sun Kang of NSSC, April 2012)
Challenges of Nuclear Power in South Korea

- Draft legislation on “Nuclear Phase-out” by a numbers of National Assembly
- Publications of risk simulation report on postulated severe accident at NPPs by NGO
- Strong opposition to nuclear activities by local residents
  - Kori Unit 1 and Wolsong Unit 1
- Attitude of the Mass Media report raising suspicion

(Quoted from material by Kun-Woo Cho of KINS, January 2013)
Conclusions

- Fukushima disaster triggered South Korea to strengthen its NPPs safety unprecedentedly by incorporating measures based on lessons learned from the accident.

- Trust building among nuclear establishment and public needs to be more emphasized to resolve nuclear safety concerns of the public.
  - People cannot be safe without being feel safe.