EU STRESS TEST FOR LM NPP
-LICENSEE REPORT
(Rev.1b)

Taiwan Power Company

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EU STRESS TEST FOR Lungmen NPP - LICENSEE REPORT

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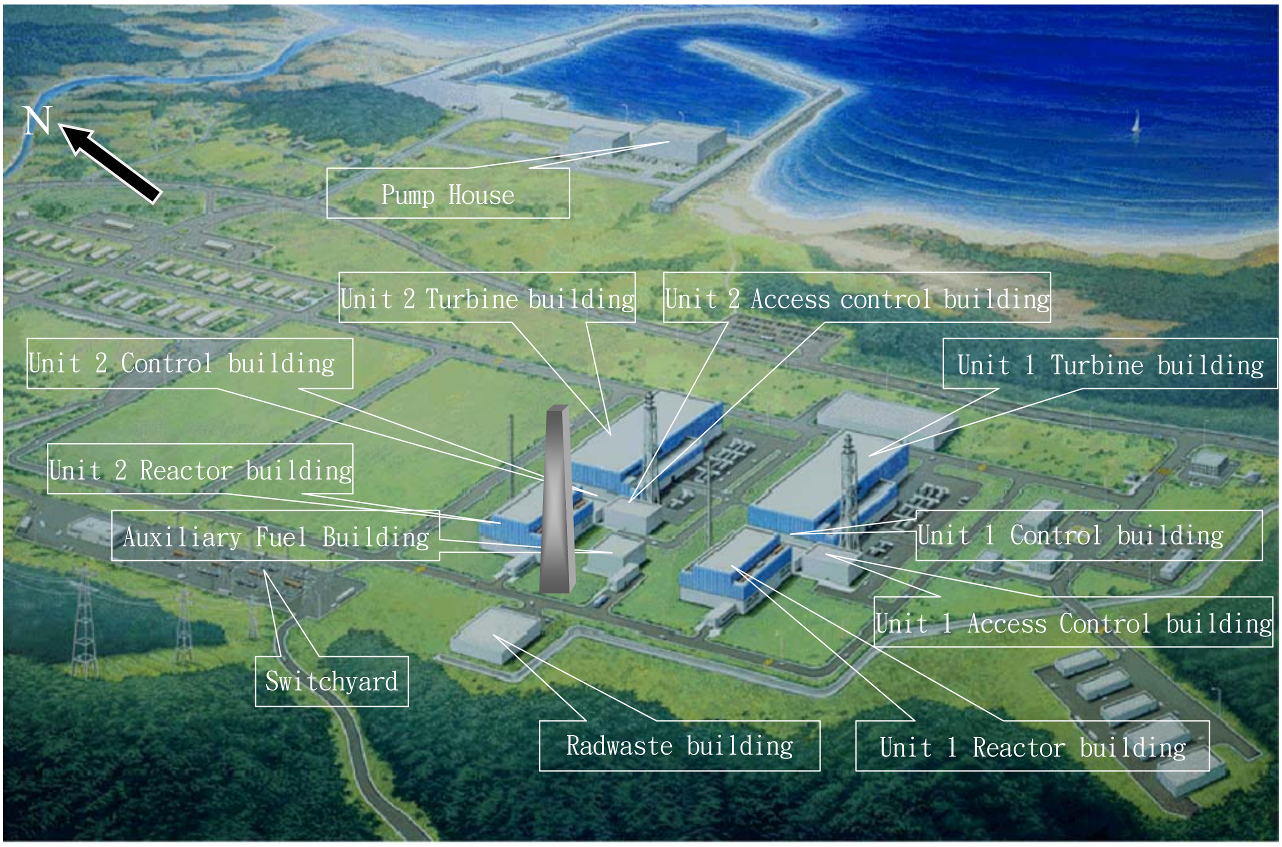
0. Executive summary

1.General data of site/plant

1.1 Site characteristics

Lungmen Nuclear Power Station (LMNPP), formerly referred to as the Fourth Nuclear Power Plant in Taiwan, is located at an inward bay area on the northeast coast of Taiwan and fronts on the Pacific Ocean. In terms of geographical coordinates, the Lungmen site lies at latitude 25^{o}02’17.593”N and longitude 121^{o}55’26.043”E. Most of the site elevations are about 12 to 30 meters above sea level. The site is approximately 20 kilometers southeast of Keelung city, 40 kilometers east of Taipei city, and 33 kilometers northeast of Yilan city. The total area of the site is about 480 hectares. The LMNPP site is located in the Shih-Ding Creek and Double Creek valley. The Shih-Ding Creek passes through the site from the north side. The watercourse inside the site is a dredged open compound ditch. The Double Creek is on the south side of the site and is about 2.5 kilometers away. It is separated from the site by hills above 50 meters. Both creeks flow to the ocean. Figure 1-1 shows the arrangement of the LMNPP facilities on site.

Figure 1-1 Bird’s Eye View of LMNPP



1.2 Characteristics of units

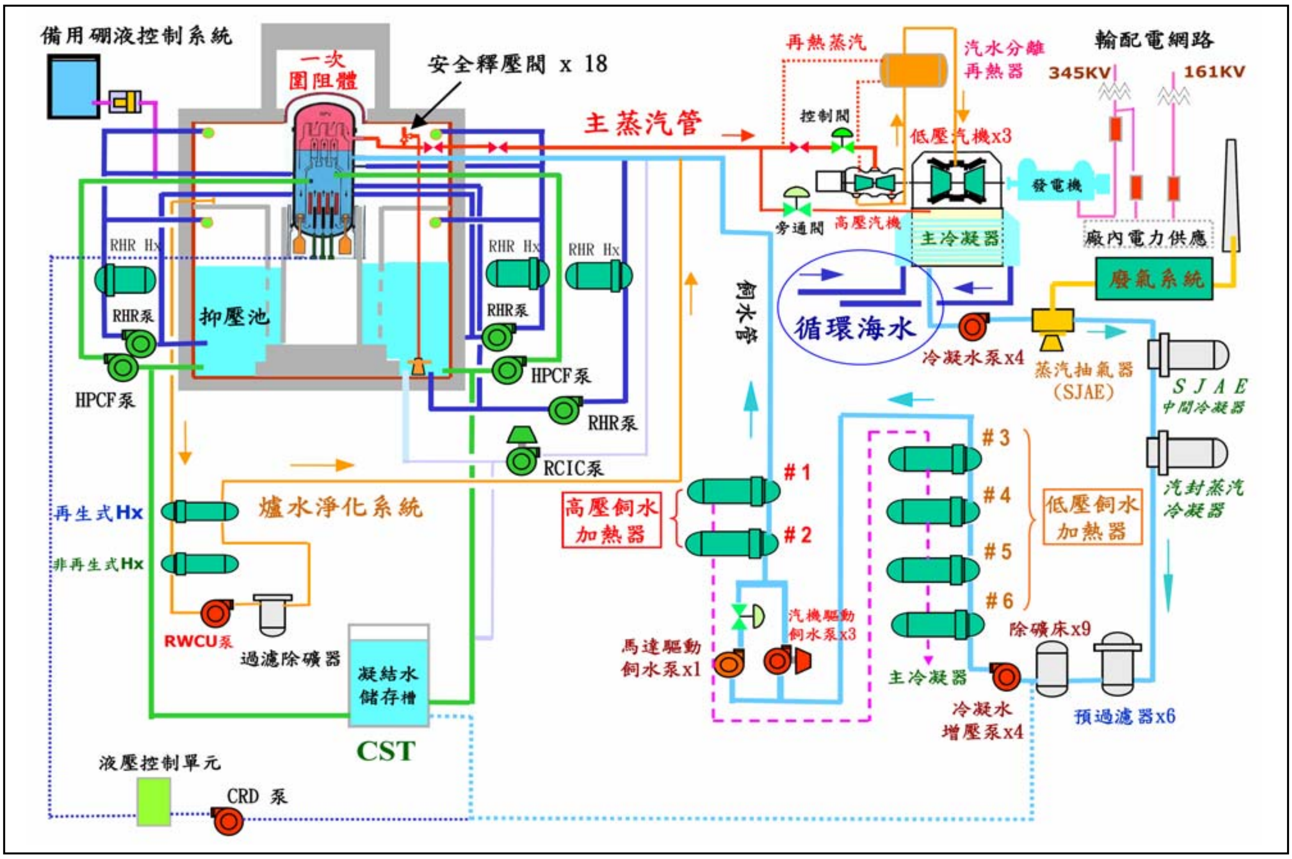
Two Advanced Boiling Water Reactors (ABWRs) are being installed at LMNPP. The ABWR nuclear island is designed and manufactured by General Electrical Co. (GE). The turbine and generator is manufactured by MHI. The radwaste system vendor is Hitachi. Table 1-1 shows the fundamental design parameters of the plant.

Table 1-1Design Specification and Parameters of LMNPP

<table>
<tr><td colspan="2">Reactor</td><td>ABWR</td></tr>
<tr><td colspan="2">Containment</td><td>Reinforced Concrete Containment Vessel (RCCV)</td></tr>
<tr><td colspan="2">Rated Power</td><td>3926 MWt</td></tr>
<tr><td colspan="2">Fuel Bundle</td><td>872 bundles</td></tr>
<tr><td colspan="2">Number of Control Rod</td><td>205 rods</td></tr>
<tr><td colspan="2">Reactor Pressure Vessel</td><td>Height(inside): 1770.3 cm, Inner Diameter:711.2 cm</td></tr>
<tr><td colspan="2">Primary Containment</td><td>Height: 36 m (Measured from the top of containment base to the top of drywell head)
Inner Diameter: 30 m</td></tr>
<tr><td colspan="2">Spent Fuel Storage Capacity</td><td>Spent Fuel Pool：3081 storage cells
Auxiliary Fuel Pool：Up to 10,000 storage cells.</td></tr>
<tr><td rowspan="3">Safety Equipment</td><td>Reactivity Control related systems</td><td>Control Rod and Fine Motion Control Rod Drive (205 control rods)
Standby Liquid Control System (2 pumps)</td></tr>
<tr><td>Emergency Core Cooling related systems</td><td>High Pressure Core Flooding System (2 divisions)
Reactor Core Isolation Cooling System (1 division)
Automatic Depressurization System (8 safety relief valves)
Residual Heat Removal system --- Low Pressure Flooder mode (3 divisions)</td></tr>
<tr><td>related Radiation release prevention systems</td><td>Primary Containment
Containment heat removal system, including RHR Suppression Pool cooling mode and drywell/wetwell spray mode.</td></tr>
</table>

	Supporting Systems	Emergency Diesel Generator (3 sets) Reactor building cooling water system (3 divisions, 3 pumps/division) Reactor Building Service water system (3 divisions, 3 pumps/ division)

Figure 1-2 Schematic of ABWR Major Systems at Lungmen



1.3 Significant differences between units

Triple redundancy is designed into each safety system at each Lungmen unit. Each safety sytem consists of three separate divisions, designated as Division A, Division B, and Division C. The term *division* means that all components and support equipment necessary to complete the intended safety function of each system is contained within the *division*. The arrangement of the redundant divisons of a system ensures adequate physical separation and electrical isolation between them. By such an arrangement, no single failure or malfunction in components of any division will result in a loss of the system function. In addition, any propagating failures, such as threats due to fires or floods, can be avoided from one division to other divisions. All major equipment at Unit 2 is essentially a duplicate of its counterpart at Unit 1. Systems and components required for safety are not shared between Units l and 2, except the following:

One set of air-cooled 4.16kV/7500kW emergency diesel engine generator (7th EDG): This EDG was designed to totally replace the water-cooled emergency diesel generator of either unit 1 or unit 2. After Fukushima Nuclear Accident on 3/11/2011, the new SOP 1451 allows the 7th EDG to simultaneously supply necessary power to the 4.16kV Essential Bus of unit 1 and 2. (Under proper loading management, the output of the 7th EDG is sufficient to supply power to operate one division of both unit.)

1.4 Results of probabilistic safety assessments

LMNPP completed its PRA model development and assessment and documented the results in 2007[1]. Currently, the PRA is undergoing peer review and continuous refinement. The LMNPP PRA program has developed two PRA models, one for power operation and the other for low power and shutdown modes. Broadly, the full power PRA model analyzes 4 categories of events, namely plant internal events, earthquakes, floods, and fires. The results are summarized as follows:

1. The total average Core Damage Frequency (CDF) at power operation is estimated to be 7.93E-6/RY.

   The total average CDF during low power and shutdown modes is estimated to be1.61E-7/RY.

2. The total average Large Early Release Frequency (LERF) at power operation is estimated to be 5.96E-7/RY.
3. Contributions to the total average CDF at power operation are:

   19.16% (1.55E-6/RY) from internal events,

   70.46% (5.70E-6/RY) from earthquakes,

   7.59% (6.14E-7/RY) from floods, and

   0.8% (6.46E-8/RY) from fires.

4. Contributions to the total average LERF at power operation are:

   1.58% (9.00E-9/RY) from internal events,

   97.54% (5.55E-7/RY) from earthquakes,

   0.08% (4.76E-9/RY) from floods, and

   0.03% (1.8E-10/RY) from fires.

References:

Taipower internal report, “The Development of Integrated Risk Assessment Model For Advanced Boiling Water Reactor,” Dec. 2007.

2. Earthquake

2.1 Design basis

2.1.1 Design base earthquake (DBE) of the plant

2.1.1.1 Characteristics of the DBE

The seismic resistance design of LMNPP basically follows the US nuclear regulations. According to the rules of the US nuclear power plant seismic design basis, the earthquake records in the past 400 years of the area within 320-kilometers radius of the site was collected in 1992 to calculate and determine the LMNPP seismic design basis. The seismic design basis was calculated conservatively and separately according to the geologic structure and the earthquake distribution in this area. We assumed that an earthquake magnitude of scale 7.3, which occurred in east Taiwan in 1908, happened near a seismotectonic province boundary 5 kilometers east of the site. Then the calculated safe shutdown Design Basis Earthquake (DBE) strength is 0.4g. The Operating Basis Earthquake (OBE) strength, which is half of the DBE, is 0.2g.

2.1.1.2 Methodology to evaluate the DBE

1、Tectonic Province Method

The tectonic province method is to conservatively assume that the historical biggest earthquake ever happened in a seismotectonic province may happen in a site without active faults if the site is in the same seismotectonic province area. For other earthquake happened in the nearby seismotectonic provinces, this method also assumes that the historical biggest earthquake may happen on the seismotectonic province boundary closest to the site. According to FSAR and the historical earthquake records, the area within 320-kilometers radius of the site was divided into 7 seismotectonic provinces. The historical biggest seismic magnitude, the distance of the seismic epicenter to the site, and the biggest peak ground acceleration calculated by Campbell formula, Joyner and Boore formula, Kanai formula and Japan Rock Site formula are shown as follows:

A. Philippine Sea plate province：

There are two major earthquakes on record ever happened in this area. One happened on Nov.14, 1986. Another one happened on Oct.13, 1815. The maximum potential seismic magnitude is scale 7.7. Assume that the earthquake center is 114.3 kilometers away from the site, then the calculated peak ground acceleration on the site rock base is about 0.05~0.06g.

B. Eastern Thrust zone province：

The biggest earthquake in history happened on Jan.11, 1908. The maximum potential seismic magnitude is scale 7.3. Assume that the earthquake center is 5.1 kilometers away from the site, then the calculated peak ground acceleration on the site rock base is about 0.23~0.41g.

C. Western Thrust zone province：

There are two major earthquakes on record ever happened in this area. One happened on Apr.20 1935. Another one happened on Dec.16, 1941. The maximum potential seismic magnitude is scale 7.2. Assume that the earthquake center is 5.0 kilometers away from the site, then the calculated peak ground acceleration on the site rock base is about 0.22~0.39g.

D. Volcanic zone：

The biggest earthquake in history happened on Dec.18, 1867. The maximum potential seismic magnitude is scale 7.0. Assume that the earthquake center is 27.4 kilometers away from the site, then the calculated peak ground acceleration on the site rock base is about 0.13~0.14g.

E. Western Seismic zone province：

The biggest earthquake in history happened on Dec.29, 1604. The maximum potential seismic magnitude is scale 8.0. Assume that the earthquake center is 30.0 kilometers away from the site, then the calculated peak ground acceleration on the site rock base is about 0.20~0.25g.

F. East China Sea zone province：

The biggest earthquake in history happened on Nov.9, 1966. The maximum potential seismic magnitude is scale 5.4. Assume that the earthquake center is 35.4 kilometers away from the site, then the calculated peak ground acceleration on the site rock base is about 0.03~0.05g.

G. Northeast seismic zone province：

There are two major earthquakes on record ever happened in this area. One happened on Jun.10, 1938. Another one happened on Jul.4, 1917. The maximum potential seismic magnitude is scale 7.7. Assume that the earthquake center is 17.7 kilometers away from the site, then the calculated peak ground acceleration on the site rock base is about 0.22~0.28g.

2、Geologic Structure Method

The major faults near LMNPP are Cyu-Chih fault, Ao-Di fault, Shuang-Xi fault, Gong-Liao fault, and Fang-Jiao fault. However all of these faults are non-active faults, they are irrelevant and are not considered in the seismic resistance design. After studying the geologic structure of the area within 320-kilometers radius of the LMNPP site, the most possible geologic structure which can affect the LMNPP seismic resistance is the plate-emerged zone in the open sea of east Taiwan. The seismic epicenter on this plate-emerged zone between the Philippine Plate and Euro-Asia Plate is about 80 kilometers away from the site. The biggest potential seismic magnitude is scale 8.1. The calculated peak ground acceleration is about 0.08~0.12g.

From the above analysis and calculation, the most affecting earthquake is the one happened in 1908. This seismic epicenter is about 5 kilometers away from the site. It's seismic magnitude is scale 7.3. The calculated peak ground acceleration according to the afore mentioned formula are 0.32g, 0.41g, 0.34g and 0.23g respectively. The average is about 0.33g. For conservative reason, the safe shutdown earthquake of LMNPP is set at 0.4g.

2.1.1.3 Conclusion on the adequacy of the DBE

According to the US Nuclear Regulatory Commission (NRC) regulations, the design basis of the plant seismic resistance must consider the geologic structure and the earthquake conditions in the area within 320-kilometers radius of the site. We must calculate the threats to the NPP from various active faults. Here the active fault means it had been active once in 35,000 years or at least twice in 500,000 years. The seismic specialist from domestic or abroad will calculate and determine the Design Basis Earthquake (DBE) referring to the biggest earthquake ever happened in history.

In 2001, The Energy Committee of MOEA contracted a research project to Dr. Yi-Ben Tsai (Dean, College of Earth Science, National Central University) to study the geologic structure and earthquake records around the LMNPP site. His research report "Summarization and Evaluation of the Geologic structure and seismic records near LMNPP Site" showed that both the seismic decay curve and seismic resistance design are in reasonable ranges. Therefore it is concluded that the design basis earthquake of the LMNPP is adequate.

In 2004, Taipower also contracted a project "Re-analysis and evaluation of Earthquake Threats to the LMNPP Site" to National Earthquake Research Institute to study the possible earthquake hazards to LMNPP. The results also showed that the original data used to calculate the earthquake hazards, designed seismic response spectrum, and seismic spectrum are still valid. It again reassures the rationality of the DBE (0.4g) of LMNPP.

Furthermore, according to the seismic regulation guide of buildings issued by Ministry of Interior in July, 2005, the seismic horizontal acceleration near Lungmen site is 0.28g. It is also well below the design basis of safe shutdown earthquake , which is 0.4g ,of LMNPP.

2.1.2 Provisions of the plant to protect against the DBE

2.1.2.1 Key SSC needed to achieve safe shutdown state after the earthquake

The following table shows the seismic resistance of the plant structure and equipment at LMNPP:

Parameters / Equipment	Elevation (above sea level) Meters	Seismic Category

Power	Offsite Power	345kV Main Transformer: 12.3 161kV Standby Aux. Transformer: 12.3	IIC IIC
	Emergency Diesel Generator	12.3	I
	7th Emergency Diesel Generator	12.3	I
Water Supply	Reactor Building Service Water Pump	5.3	I
Drainage or Discharge Trench	Drainage Channel No.2	6.97~6.60 (ditch bottom)/ 12 (ditch top)	IIC
	Drainage Channel No.3	7.52 ~3.75 (ditch bottom)/ 12 (ditch top)	IIC
RPV Cooling (Flooding)	Emergency Core Cooling System (ECCS)	Inside Containment	I
	Fire Water Supply (raw water tank/pool)	12.3/116	IIC/ IIA
	Sea Water (reactor injection)	N/A	N/A
Reactivity Control	Control Rod	Inside Containment	I
	Standby Liquid Control System	Inside Containment	I
	Standby Liquid Injection	Inside Containment	I
Containment/ Reactor Integrity	Flammable Gas Control System (FCS)	Inside Containment	I
	Containment Atmosphere Control System (ACS)	Inside Containment	I
	Standby Gas Treatment System (SGTS)	Inside Containment	I

The following table shows major water storage tanks:

Water Storage Tank	Capacity （M^3）	Seismic Category	Elevation	Structure Material
CST（unit 1）	4,372	I	12m, on ground	Steel Structure
CST（unit 2）	4,372	I	12m, on ground	Steel Structure
DST（unit 1）	1,846	Ⅱ C	12m, on ground	Steel Structure
DST（unit 2）	1,846	Ⅱ C	12m, on ground	Steel Structure
Raw Water Pool (Common）	48,000	Ⅱ A	116.6m, on slope land	Reinforced Concrete Structure with Cover
City Water Acceptance Pool （Common）	2,500	Ⅱ A	22.6m, on slope land	Reinforced Concrete Structure with Cover
Raw Water Storage Tank （unit 1）	1,230	Ⅱ C	12m, on ground	Steel Structure
Raw Water Storage Tank （unit 2）	1,230	Ⅱ C	12m, on ground	Steel Structure
Fire Water Storage Tank A（Common）	2,300	I	12m, on ground	Steel Structure
Fire Water Storage Tank B（Common）	2,300	I	12m, on ground	Steel Structure

The fuel storage tanks for Emergency Diesel Generators (EDG) are listed below:

Storage Tank	Seismic Category	Elevation above sea level	Overflow protection dike for oil leakage
EDG Fuel Storage Tank A（unit 1,2） 450 kiloliters	I	12m underground (EL 5.85m)	Underground Storage Tank
EDG Fuel Storage Tank B (unit 1,2） 450 kiloliters	I	12m underground (EL 5.85m)	Underground Storage Tank
EDG Fuel Storage Tank C (unit 1,2） 450 kiloliters	I	12m underground (EL 5.85m)	Underground Storage Tank

EDG Fuel Storage Tank S (unit 1,2) 450 kiloliters	I	12m underground (EL 5.85m)	Underground Storage Tank
EDG Fuel Storage Day Tank A (unit1,2),12 kiloliters	I	23.5m	In-building Storage Tank
EDG Fuel Storage Day Tank B (unit1,2),12 kiloliters	I	23.5m	In-building Storage Tank
EDG Fuel Storage Day Tank C (unit1,2),12 kiloliters	I	23.5m	In-building Storage Tank
EDG Fuel Storage Day Tank S (unit1,2),12 kiloliters	I	20m	In-building Storage Tank

The critical Structure, System, and Components (SSC) for reactor safe shutdown are:

1. Structures

   (1) Control Room --Seismic Category 1

   (2) Reactor Building ---Seismic Category 1

   (3) Reactor Building Service Water Pump House -------------------------------Seismic Category 1

   (4) Auxiliary Fuel Pool Building --Seismic Category 1

2. Systems and their Supporting Systems

   (1) Emergency Diesel Generator (DIV I/II/III and the 7th) ---------------------Seismic Category 1

   Emergency Diesel Generator Fuel Storage and Transfer System ----------Seismic Category 1

   Emergency Diesel Generator Lubrication Oil System ----------------------Seismic Category 1

   Emergency Diesel Generator Cooling Water Subsystem --------------------Seismic Category 1

   Emergency Diesel Generator Startup Air System (Valves and Pipes)------Seismic Category 1

   Emergency Diesel Generator Startup Air System (Air Storage Tank)--- --Seismic Category 1

   Emergency Diesel Generator Intake and Exhaust system ----------------Seismic Category 1

   (2) Emergency Core Cooling System ECCS (HPCF B&C, RHR A,B,&C) ---Seismic Category 1

   Power (EDG) --Seismic Category 1

   Cooling Water Supply Source (RBCW) --------------------------------------Seismic Category 1

3. Reactor Core Isolation Cooling System (RCIC) ---------------------------------Seismic Category 1

   Water Supply (Condensate Water Storage Tank) ----------------------------------Seismic Category 1

   125V DC Power Supply --Seismic Category 1

4. Automatic Depressurization system --Seismic Category 1

   High Pressure Nitrogen Storage Tank --Seismic Category 1

   125V DC Power Supply ---Seismic Category 1

5. Reactor Building Cooling Water System --Seismic Category 1

   Cooling Water Supply (RBSW) --Seismic Category 1

   Power Supply (EDG) --Seismic Category 1

6. Reactor Building Service Water System (RBSW) --------------------------------Seismic Category 1

   Power Supply (EDG) --Seismic Category 1

   Sea Water Intake Structure ---Seismic Category 1

Basically the above mentioned structures, systems, and components are all seismic 1 classified. They can assure reactor safe shutdown even if a design basis earthquake (DBE) happened.

2.1.2.2 Main operating provisions

All safe shutdown related structures, systems, and components (SSC) including reactor and spent fuel pool are designed per DBE requirements. The SSC are seismic sustainable and wouldn't fail after DBE earthquakes. The crew will follow procedure 528.01.01 "Emergency Operation Procedures for Earthquake" and procedure 528.01.02 "Reactor Restart Assessment Procedures after Earthquakes bigger than DBE" to conduct necessary dispositions and inspections. These operating procedures had been revised as per EPRI report NP-6695(Dec.1989) "Guideline for Nuclear plant Response to an Earthquake". The following explains the major operational guides and requirements in the operations:

A. Reactor Building:

There are 20 seismic sensors in the Reactor Protection System (RPS). These sensors are distributed in four different zones of the reactor building. Each zone equipped 2 horizontal sensors and 1 vertical sensor at the bottom level (EL.= -8.2m) and 2 horizontal sensors at the top level (EL.=31.7m). If the seismic sensors in any two zones actuate, the RPS will react to scram the reactor. If the seismic level reached the reactor scram set point and the reactor did not scram, the operator has to manual scram the reactor immediately. If the sensor signal at free field 1(2)C72-FBA-2003 reaches the alarm set point (0.02g), the seismic detection system will trigger the alarm in the control room to warn the operators to take proper actions. The following paragraphs describe the earthquake related emergency operating procedures and their objectives/abstracts:

1. Operation Procedure 528.01.01 "Emergency Operation Procedures for Earthquake"

   Objective: Provides operating procedures after earthquake.

Abstract: (referring to figure 2-1, Flowchart of Emergency Operation Procedure for Nuclear Power Plant after Severe Earthquake)

(1) If the seismic sensor panel detects signals above trigger set point, the crew must first confirm the alarm and then conduct all necessary emergency response actions. If the alarm was not triggered, then allow the reactor to operate continuously but, if necessary, also inform and request the crews of Instrument and Control division to conduct the functional check of the seismic sensors.

(2) If the seismic trigger alarm appears but the OBE alarm does not appear, then the on-shift operator must carefully monitor the variations of reactor power and the output of power generator. The operator must follow the standard operating procedures, the abnormal operating procedures, the emergency operating procedures, and the technical operation guides to stabilize the reactor operation. Besides, the on-shift crew must conduct the inspection and check as per "Control Room Inspection and Check List" and "Reactor Building Inspection walkdown Table" described in operating procedure 528.01.01. If any fact that may affect reactor operation was found, a report must be submitted to the Station Operation Review Committee (SORC) to determine whether the reactor has to be scrammed. If the committee determined to scram the reactor after evaluation, the following actions must be carried out:

a. Reset the seismograph in 24 hours and check the control channels in 5 days.

b. Conduct functional tests of all necessary equipment.

c. If any seismograph was not operable during earthquake, then submit a special report to the Atomic Energy Council (AEC) in 14 days.

(3) If OBE or SSE alarm appears during reactor operation, then the crew has to confirm the RPS did actuate the automatic seismic scram function and the reactor was scrammed. In case the reactor did not scrammed as it should be, then manual scram the reactor and conduct the related operating procedures. The following actions must be conducted after the reactor has been shutdown:

a. Conduct actions as per "Inspection, Testing, and Reactor Restart Assessment Flowchart ".

b. Conduct emergency mobilization as per 1401 guidelines.

c. Reset the seismograph in 24 hours and check the control channels in 30 days.

d. Collect all seismographic records and submit to Taipower headquarter for safety evaluation.

e. If any seismograph was not operable during earthquake, then submit a special report to the Atomic Energy Council (AEC) in 14 days.

f. Conduct all necessary equipment function tests.

2. Procedure 528.01.02 “Reactor Restart Assessment Procedures after Earthquakes bigger than DBE”

Objective: Provides procedures to assess the suitability of restarting the reactor after earthquakes bigger than OBE (Operating Basis Earthquake).

Abstract:

(1) This procedure is based on the request of procedure 528.01.01. The maintenance crew shall inspect the whole plant in detail according to the request from the on-shift manager or the Station Operation Review Committee (SORC). The inspection shall be conducted by qualified or well experienced maintenance crew. If the reactor is operating during inspection, then the following equipment or structure inspection can be waived. These include ADS/SRV accumulators, RIP, main steam tunnel, RWCU heat exchanger room, feed water heater related equipment, drywell and other high radiation areas.

(2) The maintenance crew shall inspect the key items listed in the documents “Inspection Check List of Essential Equipment and Structures” and “Inspection Standards of Essential equipment and Structures”. The inspected key items’ damage grade shall be evaluated according to the document “Earthquake Induced Damage Classification of Nuclear Power Plant Equipment”. The evaluation results will be reviewed by SORC. Whether the reactor can continuously operate or have to shut down depends on the SORC’s review conclusion. After reactor shut down, conduct the actions according to figure 2-2 “Flowchart of the Inspection, Test, and Reactor Restart Assessment after Earthquake Induced Reactor Shut Down ”

(3) If after earthquake no major damage was found on the safety related equipment, then conduct the following actions:

a. The on-shift operator shall carry out the following required surveillance tests:

(a) Control rod insert and withdraw test: Manipulate every control rod by insertion and withdrawal to confirm if its function is normal. If necessary, Nuclear Technology Section and Instrument Control Section shall be informed to dispatch staff to cooperate the test.

(b) Measure the leakage rate of Reactor Coolant System (RCS) and calculate the flow rate of drywell sump to assure its normality.

(c) Carry out any extra test requested by SORC.

b. The reactor can only be restarted after the reactor restart assessment report issued by Taipower headquarter is approved by AEC.

c. A special mission team must be organized by Taipower headquarter to conduct a long term evaluation of the earthquake effects.

(4) If the earthquake had damaged the safety related systems, structures or equipment, then conduct the following actions:

a. The maintenance crew shall broaden the scope of visual inspections. The items must be inspected include:

(a) All safety related equipment (include their hangers and supports) that are not in the key inspection list.

(b) All safety related subsystems and their hangers and supports.

(c) Containment and its penetrations.

(d) The structure of main condenser and sea water tunnel.

(e) The connections between the buried pipes and the buildings or tanks.

(f) The leakages of piping systems.

(g) The damages of low pressure tank.

(h) The damages of the equipment in switchyard .

(i) The actual liquid levels of the tanks which has its liquid level changed.

(j) Any rotating equipment with high bearing temperature, or high vibration, or high noise.

(k) Any items damaged by collision or dropping during earthquake.

(l) Any equipment that has its anchor bolts deformed or loose and any equipment that slid or rolled away from its original position.

(m) The damage conditions of addition pipes including flexible tubes, jump connector and cable conduits.

(n) Pipeline damage or pipe support displacement.

(o) If there is any deformation for electrical cabinets and instrument cabinets and the conditions of the components (include relays, switches and breakers) inside the cabinets.

(p) Any cracks and scale of the concrete.

(q) The operability of essential relays, breakers, and any other vibration sensitive electrical components.

(r) Any unfixed equipment that may drop on the safety related equipment.

(s) Safety related power distribution system and its support.

(t) Water gate valves and storage pools.

(u) Seismic category I buildings (including penetrations) and its structures.

b. Conduct the following actions based on the damage grades:

(a) Damage grade 1:

i. Repair damaged items

ii. Conduct the following tests:

- Control rod insert and withdraw test: Manipulate every control rod by insertion and withdrawal to confirm if its function is normal. Notify Nuclear Engineering Section and the I&C personnel to provide assistance as necessary.
- Measure the leakage rate of Reactor Coolant System (RCS) and calculate the flow rate the drywell sump to assure its normality.
- Test any repaired item.
- Carry out extra tests requested by SORC.

iii. The reactor can be restarted only after the reactor restart assessment report prepared by Taipower headquarter was approved by AEC. After the reactor restart, a long-term evaluation of the earthquake induced effects must be carried out. Typically, the reactor restart assessment report includes:

- Post-earthquake inspection checklist of essential equipment and structures.
- The contents and results of the broadened inspections.
- Repair report of the damaged equipment /structure and the test results after

repair.

- Assessment of the seismic resistance of equipment and structures after earthquake.

(b) Damage grade 2

i. Repair the damaged items

ii. Test containment leakage rate

iii. Conduct the following tests:

- Manipulate every control rod by insertion and withdrawal to confirm its functionality. Notify Nuclear Engineering Section and I&C personnel to provide assistance as necessary.
- Measure the leakage rate of Reactor Coolant System (RCS) and calculate the flow rate of drywell sump to assure its normality.
- Test any repaired item.
- Carry out extra tests requested by SORC.

iv. The reactor can be restarted only after the reactor restart assessment report prepared by Taipower headquarter was approved by AEC. After the reactor restart, a long-term evaluation of the earthquake induced effects must be carried out. Typically, the reactor restart assessment report includes:

- Post-earthquake inspection checklist of essential equipment and structures.
- The contents and results of the broadened inspections.
- Repair report of the damaged equipment/structure and the test results after repair.
- Assessment of the seismic resistance of equipment and structures after earthquake.
- Test report of containment integrated leakage rate test (ILRT).

(c) Damage grade 3

i. Inspect the interior of reactor vessel and the nuclear fuels.

ii. Repair the damaged items.

iii. Conduct containment leakage rate test.

iv. Conduct a long term assessment.

v. Conduct the tests of all periodical surveillance test items.

vi. The reactor can be restarted only after the reactor restart assessment report prepared by Taipower headquarter was approved by AEC. After the reactor restart, a long-term evaluation of the earthquake induced effects must be carried out. Typically, the reactor restart assessment report includes:

- Post-earthquake inspection checklist of essential equipment and structures.
- The contents and results of the broadened inspections.
- Repair report of the damaged equipment/structure and the test results after repair.
- Assessment of the seismic resistance of equipment and structures after earthquake.
- Test report of containment integrated leakage rate test (ILRT).
- Test reports of all periodical surveillance test items.
- Long term assessment report

c. Long term assessment

This long term assessment is carried out by a special mission team organized by Taipower headquarter. If the earthquake induced damage is categorized as grade 1 or 2, the long term assessment can be conducted after reactor restart. If the damage is categorized as grade 3, then the long term assessment must be complete before the reactor restart.

B. Spent Fuel Pool:

The general term "spent fuel pool" includes the spent fuel pool in the reactor building refueling floor (height: 31.7m) and the auxiliary fuel pool in the auxiliary fuel building (height: 12.3m). The auxiliary fuel pool is commonly shared by the two units.

1. Spent fuel pool in reactor building

(1) The liner structure of the spent fuel pool is qualified as seismic category I. It can maintain its integrity and water storage even if the earthquakes of magnitude level SSE and OBE occurs.

In addition, below the normal pool water level, there is no pipe connected to the pool. The water make up pipe is designed with anti-siphon function so that even the make-up pipe breaks, it wouldn't siphon off the spent fuel pool.

(2) A pool water leakage drain pipe is installed between the pool bottom liner and the concrete. This pipe can guide the leaked water to a collection tube. The water level detection device in the collection tube will send high level warning to main control room if the spent fuel pool leaks. The crew can also watch the water level through the sight-glass on the collection tube. If the spent fuel pool leakage alarm was triggered, the operator must take actions according to operating procedure 508.02 "Pipe Breaks inside reactor building (exclude pipes of main steam /feed water/core isolation coolant)".

(3) The equipment or heavy materials above or around the spent fuel pool including RB overhead crane, refueling platform, and jib crane are described as follows:

a. Overhead crane in reactor building

- The crane equipped with two hooks. The major hook can load 150 tons. The minor one can load 15 tons. Both can avoid hanged material dropping down due to hook failure.

- This crane is qualified as seismic resistance category II A. The hanged material wouldn't fall down even if a SSE earthquake happened.

- The crane will be automatically brake locked when it stops. So it wouldn't slide during earthquake. Besides, there are bolts between trolley and the beam frame to firm up the trolley. There are also bolts between beam frame and tracks to avoid slide displacement. So the crane can be totally secured when it is not in use.

- The crane also has an interlock design to prevent any material heavier than a single fuel bundle to be hanged over the fuel storage zone. This is to avoid any possibility of fuel damage due to heavy material falling.

b. Refueling platform

- This equipment is qualified as seismic resistance category IIA. It wouldn't fail or fall down if a SSE earthquake happened.

- The equipment is equipped with rail clamps between the trolley and beam and the beam and track to prevent falling during earthquake.

c. Cantilever (jib) crane

- This crane is designed as seismic category IIA equipment. It is fixed on the west-side wall of spent fuel pool building. It wouldn't fall even if a SSE earthquake happened.

- The crane is equipped with fixing bolts to keep its cantilever bound with the track when the crane is not in use. So the crane will not above the fuel pool area.

(4) Regularly inspect the welds of the crane as per procedure 704.F31.401 "Operation Procedures of Lifting" to assure the crane integrity.

2. Auxiliary fuel pool in auxiliary fuel building

This building is similar to the reactor building except that this building does not have a cantilever crane.

2.1.2.3 Indirect effects of the earthquake taken into account

1. As described in 2.1.2.1, all safety shut down related systems, structures, and components as well as their subsystems are seismic category I. They can sustain integrity and assure their safety function under DBE earthquake.

2. Effects of flood inside the reactor building:

(1) Usually no power equipment is need for the flood inside the reactor building. There are built-in flood drain holes and drainpipes on every floor. These drain holes and drainpipes will eventually collect water into a sump. Even if the flood is beyond the drainage capacity, most of the flood will flow to the storage tanks at the basement of radwaste building. The radwaste building design will mitigate the flood influence and save more time to secure essential equipment.

(2) In the 6 pumping rooms of Emergency Core Coolant System (ECCS) located on Reactor Building bottom floor, the floor water will drain to a sump exclusively for ECCS. These rooms also equipped with water-proof doors to prevent overland flow among the rooms and to avoid outside water flowing into the rooms. The flood prevention design can assure the integrity of ECCS equipment.

(3) If any circulating water pipe (eg. broken pipes of suppression pool) leaks, the sump warning signal and the leakage detection system will prompt to isolate and mitigate the leakage. The sitting base of safety equipment is 20 cm above ground to avoid flooding. The actuation of manual fire equipment and the limitation of water storage in the pipe/tank will also mitigate flooding in the plant.

(4) On Jun. 24, 2011, the plant has completed the inspection and verification of the integrity of waterproof gates, water tight gates, floor drainages, and wall penetration seals of the completed RB, CB, RWB, RBSWPH, and TB. As for the uncompleted parts, the plant will watch out for the construction quality through the complete quality assurance system. After completion, they will be inspected for functional verification again. Besides, the integrity of the wall penetration seals of the structures will be regularly inspected as per operating procedure 769.P16.117.

3. Loss of off-site Power:

(1) Each unit of LMNPP is equipped with 3 safety grade emergency diesel generators. These generators are designed to provide power to the emergency cooling system if the off-site power was lost.

(2) The plant also equipped a safety grade air-cooling emergency diesel generator, named 7^{th} EDG. This 7^{th} EDG is commonly shared by the two units. It can replace the failed DEG of any unit.

(3) All the above mentioned EDGs designed and manufactured to sustain DBE earthquake. Based on the Fukushima experience, the plant is now planning to build tsunami wall (top of wall = EL. 14.5 m) to prevent plant site from tsunami attack.

4. Personnel and equipment cannot reach the plant due to road blockade caused by earthquake:

(1) If the events happened during normal office hours:

a. In case the operator cannot reach the plant to take over the shift, the personnel in simulator center and the mobile supporting personnel (most of them are certified licensees) can take over or help the reactor operator.

b. There will be constantly about one hundred personnel including maintenance staff and long term contract personnel. It is enough to support any urgent equipment maintenance.

c. Normally there will be 8 firemen on duty. According to Station Emergency Response Organization, the plant can organize an emergency fire fighting team to help.

(2) If the events happened during abnormal office hours:

a. Most of the operators live in the plant dormitory-for-single. They can support reactor operation at first priority. Besides, the plant has already decided to build family dormitories at Gong-Liao and Shuang-Xi. The personnel lived in these dormitories can also help the plant operation before the crew arrives.

b. Currently, most of the maintenance personnel (include staffs of Mechanical, Electrical, Instrumentation, and Machine shop) live in the stand-by dormitory. They are available for emergency equipment rescue and repair. In the future, the maintenance staffs live in Gong-Liao and Shuang-Xi family dormitories can also be recalled to help emergency rescue and repair. Besides, the plant will, referring to other nuclear power plants, recruit long term contract technicians to support emergency maintenance.

c. The fire fighting team is currently contract out. During non office hours, only 6 firemen are on duty. But it is easy to collect other contract firemen during emergency since most of them live in Lungmen area. In addition, the plant security policemen can also support rescue if needed.

d. If off-site road can't be accessed due to earthquake, the station shall report to National Nuclear Emergency Response Center and apply for engineering corps' support for rush repair of the damaged road so as to restore the road access or request to utilize helicopter to transport the personnel and materials for rush repair or deliver the medical first aid.

e. Recruit the crews of onsite fire station to support the following activities:

(a) Conduct the following action sequentially:

i. Drive fire trucks to the west side of (unit 1,2) reactor building RB 12300.

ii. Connect the fire trucks hose to RHR C connection pipe.

iii. Open the manual isolation valve 1/2E11-BV-0047C.

iv. Inject make-up water to the reactor and spent fuel pool.

(b) Assist to connect fire hose near the spent fuel pool building RB 7F to inject make-up water to the spent fuel pool.

5. Fire prevention and firefighting facilities and capability

(1) The plant firefighting facilities are as described below:

a. Automatic sprinkler system: There are 100 automatic sprinkler systems installed inside the plant buildings and the plant site. The fire water comes from city water or surface water (from Shuang-Xi creek). This water is stored in a raw water reservoir after raw water pretreatments. This raw water storage is seismic resistant category IIA. It's capacity is 4.8 metric tons by gravity and is equipped with environmental monitoring and warning instruments like clinometers, water level observation well, and reinforcement meter. The water will flow to two fire water reservoirs of 2300 m^3 by gravity since there is an elevation drop of 100 meters between the raw water reservoir and the fire water reservoirs. In order to satisfy the requirement of ABWR severe accident, the fire water reservoir A will reserve 456 m^3 of water for nuclear island.

b. Fire water pumps: There are 3 fire water pumps. One is diesel engine driven, one is electrical driven (4.16kV AC), and the other one is a Jockey pump (480V AC). The first two pumps are 100% systematized. The water throughput of each pump is 11340 L/min at 862 kPa (125psi) water pressure. Both the electrical driven pump and the engine driven pump can be actuated by the push buttons at R499 1H11-PL-1703（WDP）panel in the control room. However, the pumps can only be stopped in the water pumping room. When manually or automatically actuate the fire suppression system，the fire water pump will automatically start due to system low pressure. The pipe pressure of the fire system is set at 1207 kPa.

c. IG-541 automatic fire extinguisher system: There are two sets of fire extinguisher installed at the electronics room of turbine building. These systems must be functionally tested every 6 months.

d. Fire foam sprinkler system: There are 4 sets of pre-action foam sprinkler systems installed in the EDG rooms (R412, R423, R432) of the reactor building, EDG room (R304) of auxiliary fuel building, and DG fuel oil tank building (OTV101,102,102,104). There are 38 sets of open type foam sprinkle systems installed near the EDG fuel oil day tanks (R610,620,630) in the reactor building and the auxiliary fuel building (R404). As long as the sensor fails or the electrical loop is incomplete or the sensor actuates, the LFAP and MFAP panel will display failure or fire alarm signals as well as the related information signals.

e. FM200 automatic extinguisher system: The extinguisher systems are installed at 9 places. They are distributed among the 1st and 3rd floors of the switchyard control room, the relay rooms (R203/R204) of the radwaste building (RWB), the 1st floor of solid waste building (B118), and the B1F laboratories (B107 A/B area). These systems must be functionally tested every 6 months.

f. Fire hydrants:

inside : 681 fire hydrants with nozzle diameter 1.5” or 2.5”

outside: 75 fire hydrants with nozzle diameter 2.5”.

g. All safety related mechanical and electrical fire protection systems are seismic category I.

(2). All fire protection equipment will be inspected, tested, and maintained per procedures 769.P16.110~769.P16.142, procedure 709.P16.101, procedure 709.P16.606, and the 705 series procedures.

(3). Facilities of LMNPP fire station:

a. Heavy tanker fire engine x1: The capacity of this fire engine is 12 tons. It is equipped with an skyward nozzle of injection pressure 10 kg/cm^2. The water throughput can be adjusted between 88 and 2400 L/min.

b. Chemical fire engine x1: The water tank capacity of this fire engine is 6 tons. The water throughput of the water pump is 3000 L/min at 10 kg/cm^2. The maximum foam throughput is 16 L and its output pressure is 27.6 kg/cm^2. The skyward nuzzle can rotate with 360 degrees and adjust upward or downward with 70 degrees. The injection ranges of the water-column and water-mist are more than 50 meters and 20 meters respectively.

c. Multipurpose fire truck x1: This fire truck is equipped with vehicle engine starter, high intensity jacklights (include six sets of 1500-watt vehicle-carried quartz halogen lamps, four sets of 1500-watt mobile quartz halogen lamps),50kVA 220V/110V power generator, air compressor (working pressure:200/300 kg/cm^2, can fill up 20 cylinders of 6.8 L size in 1 hour), tri-function destructor, multi-purpose power spreader, circular saw machine, ventilation machine, water pump, and other miscellaneous life saving and rescuing equipment.

6. Excavation and backfill:

No construction of this plant is built on an excavation-and- backfill land. Since all safety related equipment and structure sit on a solid rock base, there exists no possibility of soil liquefaction. The earthquake wouldn't affect the plant safety due to soil liquefaction.

The excavation procedure on the west side and south side mountain slopes follows the following two documents to satisfy the regulations of water and soil conservation, namely "Regulation Guide of Water and Soil Conservation" and "Handbook of Water and Soil Conservation". This procedure has been reviewed and approved by Soil and Water Conservation Bureau, Council of Agriculture. The excavated soil is stored in a soil and rubble junkyard. The land slope is refilled by rubble stones ladder by ladder. A two-meter width platform is built every 5-meter height ladder. RCP pipes are buried along the bottom of the valley to collect the flow from upstream watershed and the water penetrated from the rubble stone refilled ground surface. Besides, drainage system is built around the site and the land slope. All exposed area is covered by green plants to reinforce the stability of the land slope.

An operating procedure 1208 "Excavation and Back-fill Engineering" was issued to instruct and quality control all excavation and back-fill constructions. This procedure is to assure that any excavation and back-fill construction won't affect plant building structure and seismic resistance of the pipes.

2.1.3 Compliance of the plant with its current licensing basis (CLB)

2.1.3.1 Licensee's organization / processes to ensure compliance

1. The regular inspection and test periods all systems and equipment are defined in the plant operation regulations. The test procedures and the acceptance criteria are described in the series 600 “Inspection and Testing Procedures”.

2. The regular maintenance periods and test methods of the systems and components are described in the series 700 “Prevention and Maintenance Procedures”. These procedures illustrate all details of disassembling and assembling, lubrication, replacement of consumable parts (eg. oil seal, gasket, washer etc.), wrench torques of the equipment. The equipment must be inspected every reactor outage according to the 10-year long term maintenance program.

3. The inspection and maintenance method of structure is specified in procedure 152.07 “Maintenance rule of structural inspection and monitor”. The inspection results will be categorized according to the regulations of structure, civil engineering, and passive components. The inspection periods are 5 years for high safety related structures and 10 years for less safety related structures.

2.1.3.2 Licensee's organization for mobile equipment and supplies

According to LMNPP licensing basis, the safe shutdown required systems, structures, and components (SSC) can assure reactor safe shut down during DBE earthquake. The general rescue equipment prepared before Jun. 30, 2011 as per operating procedure 186.01 “Focuses of disaster prevention and Rescue” is listed in the following table:

Disaster Prevention and Rescue equipment

<table>
<tr><th>no</th><th>Title</th><th>Quant</th><th>location</th><th>Respon-sible section</th><th>no</th><th>Title</th><th>Quant</th><th>location</th><th>Respon-sible section</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">EDG</td><td>1</td><td>Tool Room</td><td>Mech.</td><td rowspan="3">14</td><td rowspan="3">Wireless Comm. System (PWT)</td><td rowspan="3">1</td><td rowspan="3">Admin. Building and Plant Buildings</td><td rowspan="3">Elect.</td></tr>
<tr><td>2</td><td>Central-4 Warehouse</td><td>Elect.</td></tr>
<tr><td>2</td><td>Water Pump</td><td>3</td><td>Admin. Building</td><td>Mech.</td></tr>
<tr><td rowspan="2">3</td><td>Mobile Hoist</td><td>1</td><td>#2 RPV Warehouse</td><td rowspan="2">Mech.</td><td rowspan="2">15</td><td rowspan="2">Computer Network System</td><td rowspan="2">1</td><td rowspan="2">Admin. Building</td><td rowspan="2">computer</td></tr>
<tr><td>Forklift Truck</td><td>2</td><td>Trailer</td></tr>
</table>

			House						
4	Forklift Truck	1	Machine Shop	Maint.	16	Flash light	10	warehouse	Industrial Safety
5	Identification Tape	1	Industrial Safety Section. Warehouse	Safety	17	Sand bag	100	Admin. Office, Simulation Center, Document Control Center	
6	Chemical Fire Truck	1	#2 RPV Warehouse		18	Telescope	—	Industrial Safety Section Office	
7	Fire Tanker	1			19	Oxygen Detector	2		
8	Dry Powder Extinguisher	10	#2 RPV Warehouse		20	Flammable Gas Detector	2		
9	Self-contained Breathing Apparatus	6			21	Anti-Static Shoes	—	Industrial Safety Section Warehouse	
10	Emergency floodlight	—			22	Triangle Warning Flag	2		
11	Ventilation Machine	—			23	Fire Water Pool（Also for Rescue stand-by Pool）	1	Lake Lover	
12	Rescue Equipment Vehicle	1	#2 RPV Warehouse		24	Life saving water, food	1	Restaurant	Supply
13	Rescue and Medical Items	1	Infirmary		25	Miscellaneous			TBD

2.1.3.3 Deviations from CLB and remedial actions in progress

Up to now, the design and construction of LMNPP meet all the commitments in the FSAR. If any deviation is found in the future, the plant will conduct the safety assessments and equipment modifications as per the following procedures:

1. The on-shift crew will issue a repair request as per procedure 1102.01 "Equipment Inspection and Repair Control ". Besides, the crew also has to evaluate and decide whether the equipment is in the condition of Limiting Conditions for Operation (LCO) as defined in related technical specification. If the equipment status will affect the safety related system, the crew shall declare that the equipment is non-operable and submit a report according to procedure 174.1 "Prompt Reporting Procedures for Abnormal Events" and procedure 175 "Written/Special Reporting Procedures for Abnormal Events ".
2. The personnel of Nuclear Safety Department and the related section shall issue a NCD (Non-Conformance Declaration) as per procedure 1115.01 "Process and Control of Quality Non-conformance Events". If the event is related to 10CFR21 regulations, then reports to the authorities as required.

3 The planning of repair request and NCD shall follow the following procedures as necessary:

(1) If the repair or modification may cause potential reactor scram, or the repair is for critical component/environment, then follow the procedure 190 "Assessment and Review Procedures for Repairing Work that May Cause Potential Reactor Scram or Other Risks".

(2) If it can cause operation and maintenance problem or it can cause labor safety, radiation safety, flood, and fire events, then follow the procedure 191 "Assessment and Review Procedures for Potentially Dangerous Work".

(3) Follow procedure 1114.03 "Procedures for Non-Operable Tag Control" to hang the non-operable tag.

(4) Follow the procedure 1110.01 "Control Procedures for QA On-Site Hold and Verification" to conduct quality verification.

(5) Follow the procedure 1109.09 "Procedures for Regulation Required Repair and Replacement of Mechanical Components" to conduct repairs.

(6) Follow the procedure 1109.08 "Repair Control for Non-Regulated Components" to conduct repair.

(7) Follow the procedure 1103.01 "Control of Plant Design Change" to propose a Design Change Request (DCR).

(8) Follow the procedure 1103.04 "Replacement Control of Plant Components and fittings" to propose an Equipment Modification Request (EMR).

(9) Follow the procedure 1102.02 " Control of Instrument and Electrical Equipment Set-Point Change" to propose a set-point change request.

(10) Follow the procedure 1102.03 "Control of Temporary Equipment Set-Point Change and Temporary Loop/Pipe Disconnection or Jump-Connection" to propose a temporary change request.

(11) Follow the procedure 1103.05 "Procedures of Nuclear Grade Item Dedication" to procure CGIs.

2.1.3.4 Specific compliance check already initiated by the licensee

1. After the Fukushima Accident, The LMNPP initiated a reinforcement action plan to improve the equipment seismic resistance and its operability under severe earthquake.

(1) RAP-LM-04-03-002: Make sure the fire water supply and fire system are available under SSE. The improvement includes: Change the MBV-5003/5004/5005/5006 and BV- 5007/5023 equipment to have automatic isolation function and modify their power supply to response the possibility of loss off-site power under SSE, upgrade the non-seismic category-I pipes of fire protection system to seismic category I, etc..

(2) RAP-LM-04-03-001: The make-up water pipe between the raw water reservoir and the fire system is on surface so that it can be visually inspected and repaired as soon as it has any damage. Part of the pipes are designed flexible to improve it seismic resistance.

(3) RAP-LM-03-04-001: Install extra seismic category I make-up water pipe and sprinkler pipe on the reactor building. These pipes, connecting the ground floor of reactor building to the water source, are exclusively used to make up and sprinkle water to the spent fuel pool.

(4) RAP-LM-03-05-001: Modify the ultrasonic water level meter G41-LT-0012A/B to extend its range to the effective fuel height. This meter is powered by essential AC power (R13). Besides, the measuring depth of the thermometer G41-TE-0013 is also modified to extend its monitoring range to the effective fuel height.

2. The spare parts, equipment, and material for various plants are summarized in the table below. This table includes the general rescue equipment already existed before Fukushima accident and the additional procuring equipment after Fukushima accident.

Planning of Spare parts, equipment, material, and tools for LMNPP

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
1	Mobile Diesel Generator	4.16 kV, 3Φ 1500 kW	Diesel	2 set	Supply power to 4.16 kV bus or RHR、RBSW RBCW water pump.	Warehouse of low level waste (EL:43.3m)	Procured	3 months	Elect.
2	Mobile Diesel Generator	480 V, 3Φ 200 kW	Diesel	2 set	SLC、FCS、SGT、CSTF、safety train of CVCF、Seal Pit of ultimate heat sink,	Switching yard (EL:29.8m)	Procured	3 months	Elect.
3	Mobile Diesel Generator	480 V, 3Φ 100 kW	Diesel	3 set	Supply power to 480 V PC/MCC for CVCF and DC battery charging	1 at outside of metal roll-up door of SGB (EL:12.3m) 2 at temporary fire-fighting station (EL:12.3m)	Procured	3 months	Elect.
4	Mobile Diesel Generator	380 V, 3Φ 100 kW	Diesel	1 set	OSC temporary power	Warehouse of low level waste (EL:43.3m)	Procured	3 months	Elect.
5	Gasoline Engine-Powered Generator	120/220V Rated Power: 7.2 kVA	Gasoline	2 set	Electrical tools, temporary lighting	storage room of #1 ACB B3 (EL:-1.85m) Base room of	Procured	3 months	Mech.

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
						administration building			
6	Gasoline Engine-Powered Generator	120/208 V, 3Φ 4W 10 kW	Gasoline	6 set	Sump pump	Warehouse of low level waste (EL:43.3m) Emergency pump room (EL:8.57m)	Procured	3 months	Elect.
7	Gasoline Engine-Powered Generator	120/220 V, 1Φ 10 kW	Gasoline	4 set	Sump pump ARM、communication	Warehouse of low level waste (EL:43.3m) Emergency pump room (EL:8.57m)	Procured	3 months	Elect.
8	Rectifier	Out Put: 125 VDC	NA	6 set	Convert 120VAC to 120VDC, for SRV operation	Warehouse of low level waste (EL:43.3m)	Procured	1 month	Elect.
9	Transformer	480 V/240 V	NA	6 set	Transfer 480 V to 240 V	Warehouse of low level waste (EL:43.3m)	Procured	1 month	Elect.
10	Engine Driven Water Pump	Suction/Discharge Dia: 4” Max. Lift: 25m Suction Depth: 5m Max. Pumping Rate:	Gasoline	2 set	Water suction and drainage	storage room of #1 ACB B3 (EL:-1.85m) Tool house at basement of administrating building	Procured	3 months	Mech.

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
		1500L/min							
11	Engine Driven Water Pump	Suction/Discharge Dia: 4” Max. Lift: 25m Suction Depth: 5m Max. Pumping Rate: 1500L/min	Gasoline	6 set	Water suction and drainage	Tool house of maintenance building (EL:24.9m)	2013/6	3 months	Mech.
12	Electrical Water Pump	110 V*1 220 V*1 Suction/Discharge Dia: 2”(50 ㎜) Max. Lift: 15m Max. Pumping Rate: 260L/min	Elect.	2 set	Water suction and drainage	Tool house at basement of administrating building / materiel and supplies room of ACB 2F	Procured	3 months	Mech./ waste
13	S.S. Submersion Pump	Output power: 5HP Discharge Dia: 4” Max. pumping rate: 0.95 m^3/min	Elect.	1 set	Water suction and drainage	storage room of #1 ACB B3 (EL:-1.85m)	Procured	3 months	Mech.

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
14	High Head S.S. Submersion Pump	Output power: 30HP Discharge Dia: 3” Max. pumping rate: 1.06 m^3/min	Elect.	4 set	Water suction and drainage SEAL PIT ultimate heat sink	storage room of #1 ACB B3 (EL:-1.85m)	Procured	3 months	Mech.
15	High Head S.S. Submersion Pump	Output power: 2HP Discharge Dia: 2” Max. pumping rate: 0.164 m^3/min	Elect.	2 set	Water suction and drainage	storage room of #1 ACB B3 (EL:-1.85m)	Procured	3 months	Mech.
16	Submersion Pump	220V, 3Φ Output power: 5HP	Elect.	3 set	Water suction and drainage	Tool house of maintenance building (EL:24.9m)	2013/6	3 months	Mech.
17	Submersion Pump	220V, 3Φ Output power: 2HP	Elect.	2 set	Water suction and drainage	Warehouse of low level waste (EL:43.3m)	2013/6	3 months	Waste.
18	Submersion Pump	Output power: 1HP 110V Dia: 2”(50 mm)	Elect.	1 set	Water suction and drainage	Warehouse of low level waste (EL:43.3m)	2013/6	3 months	Waste.
19	Submersion Pump	Output power: 1HP 110V Dia: 2”(50 mm)	Elect.	2 set	Water suction and drainage	storage room of #1 ACB B3 (EL:-1.85m)	Procured	3 months	Mech.

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
20	Submersion Pump	Output power: 1HP 110V Dia: 2"(50 mm)	Elect.	1 set	Water suction and drainage	Basement of dormitory A (EL:8.5m)	Procured	3 months	Elect.
21	Submersion Pump	Output power: 1HP 110V Dia: 2"(50 mm)	Elect.	1 set	Water suction and drainage	materiel and supplies room of ACB 2F (EL:17.15 m)	Procured	3 months	Waste.
22	2" Flexible Hose	Length: 20 m	NA	20 set	For sump pump	Warehouse of low level waste (EL:43.3m)	2013/6	3 months	Mech.
23	3" Hose	Length: 100 m	NA	12 roll	Water suction and drainage	Warehouse of low level waste (EL:43.3m)	2013/6	3 months	Mech.
24	Sand Bag	20 kg/bag	NA	1000 packs	Block water at doors	Office of Safety Div. (EL:12.3m)	Procured	3 months	Safety
25	Fire Tanker	12 tons	Diesel	1 set	Fire Protection (FP) (replace boron injection)	onsite fire station(EL:12.3m)	Procured	1 week	Safety
26	Chemical Foam Tender Fire Truck	6 tons	Diesel	1 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	1 week	Safety

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
27	Rescue Equipment Vehicle	12 tons	Diesel	1 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	1 week	Safety
28	Self-contained Breathing Apparatus	Conform to the NIOSH	NA	70 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	3 months	Safety
29	Dry Powder Extinguisher	Powder Type: ABC 20	NA	48 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	3 months	Safety
30	Engine Water Pump	15HP	Elect.	4 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	3 months	Safety
31	Inflatable water tank	10T/15T	NA	4 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	3 months	Safety
32	Explosion Proof Flashlight		Battery	50 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	3 months	Safety
33	Fire-fighter Coat		NA	10 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	3 months	Safety

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon -sible Section
34	Ambulance		Gasoline	1 set	Rescue	Infirmary of Lungmen construction office (EL:12.3m)	Procured	3 months	Safety
35	Anti-static Shoes		NA	10 pair	Fire Protection (FP)	Warehouse of Safety Div. (EL:12.3m)	Procured	3 months	Safety
36	Emergency Lighting Lamp		Battery	50 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	1 week	Safety
37	Fume Exhauster		Elect.	4 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	3 months	Safety
38	Dry Powder Extinguisher	Powder type: ABC 10	NA	20 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	3 months	Safety
39	Four Type Gas Detector	B.W O_2, CO, H_2S, and flammable gas detection	Battery	5 set	Gas Detection	Office of Safety Div. (EL:12.3m)	Procured	3 months	Safety
40	Hydrogen Detector	H_2 Detection	Battery	10 set	H_2 Detection	Office of Safety Div. (EL:12.3m)	Procured	3 months	Safety

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
41	Life Jacket		NA	8 set	Under water operation	Pump room X 6 (EL:8.57m) Raw water pool X 2 (EL:116m)	2013/6	3 months	Safety
42	Lifesaving Buoy		NA	8 set	Drowning rescue	Pump room X 6 (EL:8.57m) Raw water pool X 2 (EL:116m)	2013/6	3 months	Safety
43	Floating Rescue Cord		NA	5 set	Drowning rescue	Pump room (EL:8.57m)	2013/6	3 months	Safety
44	Triangular Warning Flag		NA	10 bundle	Danger zone segregation	Warehouse of Safety Div. (EL:12.3m)	Procured	3 months	Safety
45	Emergency Medical Apparatus and Medicine	Emergency Medical Apparatus and Medicine	NA	1 set	Emergency Medical Treatment	Infirmary of Lungmen construction office (EL:12.3m)	Procured	3 months	Safety
46	Oil Stop Rope		NA	1 set	Oil leakage treatment	Pump room (EL:8.57m)	Procured	3 months	Envir.

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
47	Oil Leakage Prevention Tool Box		NA	15 set	Oil leakage treatment	Sewage treatment plant (EL:12.3m) Sea water electrolysis plant (EL:8.57m) water treatment plant (EL:12.3m)	Procured	3 months	Envir.
48	Chemical Leakage Prevention Tool Box		NA	10 set	Chemical leakage treatment	Sewage treatment plant (EL:12.3m) Sea water electrolysis plant (EL:8.57m) water treatment plant (EL:12.3m)	Procured	3 months	Envir.
49	Oil Decomposer		NA	100 gal	Oil decomposition	Sewage treatment plant (EL:12.3m)	Procured	3 months	Envir.
50	Leak Mending Material		NA	30 set	Tank leak mending	Sewage treatment plant (EL:12.3m) Sea water electrolysis plant (EL:8.57m) water treatment plant (EL:12.3m)	Procured	3 months	Envir.

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
51	Lifter Vehicle	Max. Load：150kg Max. Lift Height: 12m Max. Working Radius: 7m	Battery	1 set	Working aloft	#1RPV warehouse heavy equipment warehouse (EL:12.3m)	Procured	3 months	Mech.
52	Lifter Vehicle	Max. Load：200kg Max. Lift Height: 20m Max. Working Radius: 12m	Diesel (Battery)	1 set	Working aloft	Switching yard (EL:29.8m)	Procured	3 months	Elect.
53	Forklift Truck	5-tons x2 3-tons x1	Diesel	3 set	Transport heavy items	#1RPV warehouse heavy equipment warehouse (EL:12.3m)	Procured	3 months	Mech.
54	Mobile Crane Vehicle	80-tons	Diesel	1 set	Hoist and transport heavy items	#1RPV warehouse heavy equipment warehouse (EL:12.3m)	2013/6	3 months	Mech.
55	Mobile Crane Vehicle	30-tons	Diesel	1 set	Hoist and transport heavy items	#1RPV warehouse heavy equipment warehouse (EL:12.3m)	Procured	3 months	Mech.
56	Multipurpose Vehicle	Generator: 110/220 V, 24kVA (rated) Provide: Lighting, Air-compressor, Welding, Electrical	Gasoline	1~~2~~ set	Outdoor urgent repair	#1RPV warehouse heavy equipment warehouse (EL:12.3m)	2013/12	3 months	Mech.

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
		Socket							
57	Truck (or hoist truck)	25-tons	Diesel	1 set	Heavy item delivery	warehouse of Lungmen construction office material Div. equipment warehouse (EL:12.3m)	Procured	3 months	Mech.
58	Platform Truck	40-ft	Diesel	1 set	Heavy item delivery	#1RPV warehouse heavy equipment warehouse (EL:12.3m)	2013/12	3 months	Mech.
59	Small Excavator	TBD	Diesel	1 set	Plant road repair	#1RPV warehouse heavy equipment warehouse (EL:12.3m)	2013/06	3 months	Mech.
60	Manual Chain Hoister	0.5~3-tons	NA	20 set	Repair and maintenance	Tool house of maintenance building (EL:24.9m)	Procured	3 months	Mech.
61	Portable Nitrogen cylinder	Al Alloy Capacity: 5.2L	NA	6 set	Pneumatic valve operation	Calibration room of I&C Div. (EL:20.85m)	Procured	1 year	I&C
62	Mobile Engine Driven Compressor	Above 10 kg/cm^2	Elect.	2 set	Emergency supply of compressed air to SRV	Periphery of RB 31700 (EL:31.7m)	Procured	3 months	Mech.

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
63	Explosion Proof Tools	Explosion proof wrench set and Brass Hammer	NA	2 set	H2 explosion proof tool	Tool house of maintenance building (EL:24.9m)	Procured	3 months	Mech.
64	RBSW Motor	4.16 kV /745 kW (997 HP)	NA	1 set	Emergency RBSW motor replacement	Warehouse of low level waste (EL:43.3m)	Before Commercial Operation	3 months	Elect.
65	RHR Motor	4.16 kV /475 kW (636HP)	NA	1 set	Emergency RHR motor replacement	Warehouse of low level waste (EL:43.3m)	Before Commercial Operation	3 months	Elect.
66	RBCW Motor	4.16 kV /190 kW (255HP)	NA	1 set	Emergency RBCW Motor replacement	Warehouse of low level waste (EL:43.3m)	Before Commercial Operation	3 months	Elect.
67	P16 Fire Pump Motor	4.16 kV/261 kW (350HP)	NA	1 set	Emergency fire pump motor replacement	Warehouse of low level waste (EL:43.3m)	Before Commercial Operation	3 months	Elect.
68	Spare cable	High, Medium, and Low Voltage Cables	NA	1 batch	Emergency electrical wiring	Warehouse of low level waste (EL:43.3m)	161kV: Procured Others: Procuring	3 months	Elect.
69	Spare Communication Parts		NA	1 batch	Communication urgent repair	Warehouse of low level waste (EL:43.3m)	Procuring	3 months	Elect.

2.2 Evaluation of margins

2.2.1 Range of earthquake leading to severe fuel damage

2.2.1.1 Weak points and cliff edge effects

The purpose of this assessment is to find out the minimum withstanding value for the required equipment and facilities which can maintain unit safe shutdown via probabilistic risk assessment (PRA) event tree methodology and evaluation of equipment and facilities seismic withstanding extent when earthquake happens. It means that once seismic degree reaches the extent that all the above-mentioned equipment and facilities which is unable to withstand the seismic degree are assumed to lose their intended function and further to impact of unit safe shutdown. The PRA event tree methodology applied to find out the required first aid equipment and facilities of the minimum vibratory withstanding value for the successful first aid path is the cliff-edge defined in this section.

According to the equipment seismic capability assessment information in Appendix AC.3 of Lungmen FSAR, the plant has 97 structures, systems and component (as shown in attachment 2-2) may affect the integrity of the core fuel after earthquake. Based on the characteristics of the design, installation and spatial interaction, the individual seismic capability was assessed. The median seismic withstanding value of each equipment are different (comparing to the Peak Ground Acceleration (PGA) of the base rock), from the 0.3g of the offsite power supply to the 13.13g of the duct of the air-conditioning systems. Because there is a large number of the equipment on the list of seismic equipment and the seismic withstanding values vary, so the screening of the seismic withstanding capability was executed before the seismic cliff edge effect analysis, in order to focus on the equipment that have significant impact on the maintenance of the integrity of the fuel.

It requires HCLPF = 0.5 (elastic equipment) or 0.57 (inelastic equipment) as the screening value of the equipment seismic withstanding capacity in EPRI-1002988, but it also requires a more conservative screening values for the nuclear power plants located in high seismic risk zone. Lungmen nuclear power plant is located in a high seismic risk zone, the ground surface acceleration value for the design of safe shutdown of the base rock is 0.4g. According to the earthquake classification table in Central Weather Bureau, the ground surface acceleration value of the seismic intensity 7 is approximately 0.41g, therefore the ground surface acceleration value (HCLPF = 0.9 g) that is over two times the seismic intensity 7 was selected conservatively as the screening value to be used in the seismic cliff edge effects event tree.

According to the above screening analysis requirements, the plant has only 13 pieces of equipment must be included in the subsequent cliff edge effects analysis. A detailed list of equipment and seismic capacity parameters evaluated in the FSAR is shown in the following table.

The equipment included in the seismic cliff edge effects detailed analysis

Structure、System、Equipment	FSAR Table	Am	β_R	β_U	β_C
Offsite Power Transformer	AC.3-66	0.3	-	-	0.55
Condensate Storage Tank	AC.3-66	1.1	-	-	0.46
Fire Water Tank	AC.3-66	1.1	-	-	0.46
Fire Water Pump	AC.3-66	1.9	-	-	0.46
Reactor Building Service Water Pump	AC.3-66	2	-	-	0.46
EDG Fuel Oil Day Tank	AC.3-37	2.33	0.36	0.38	0.52
SDG Fuel Oil Day Tank	AC.3-37	2.33	0.36	0.38	0.52
Buried Piping	AC.3-66	2	-	-	0.40
Fire Water Buried Piping	AC.3-66	2	-	-	0.40
Fire Protection House	AC.3-66	2.3	-	-	0.45
Safety Related Transformer	AC.3-67	2.4	-	-	0.46
Air Handling Unit	AC.3-34	2.95	0.35	0.4	0.53
HVAC Damper	AC.3-55	2.8	0.33	0.38	0.50

Based on the existing design of the safety functions and the operating procedures, the plant has conducted seismic cliff edge effects assessment using the median seismic withstanding value listed in the table above. The resulting seismic cliff edge effects event tree of the Lungmen nuclear power plant is shown in Figure 7 of attachment 2-1. When the plant lose offsite power due to earthquake with intensity that is greater than 0.3g. There are four successful paths to achieve reactor core long-term heat removal.

Success path (1): All the necessary safety functions for the unit normal cold shutdown paths can be successfully performed. The related safety functions include: the essential DC power to start the emergency diesel generator; the service water system to cool the emergency diesel generators and safety injection system and to provide cooling water for the heat exchanger of the residual heat removal system; the emergency diesel generators to provide the AC power for the important equipment;, the residual heat removal system to execute safety injection and a variety of heat removal functions.

Success path (2): When the residual heat removal system is unavailable due to earthquake, the fire water system can provide the reactor core long-term cooling. The containment bypass pathway provided by the containment overpressure protection system can release the energy accumulated in the containment to achieve the purpose of long-term heat removal of the reactor core.

Success path (3): When the emergency diesel generator is unavailable due to earthquake, the RCIC can provide the reactor core short-term water makeup functions. The fire water system can provide the reactor core cooling. The containment bypass pathway provided by the containment overpressure protection system can release the energy accumulated in the containment to achieve the purpose of long-term heat removal of the reactor core.

Success path (4): When the service water system is unavailable due to earthquake, the rescue path the same as success path (3) can achieve the purpose of long-term heat removal of the reactor core.

The safety margin and cliff-edge of each success path are described as follows:

Success path (1): The seismic withstanding value of the service water system is the lowest, in which the RBSW pumps and the underground buried piping are the key equipment. The median seismic withstanding value is 2.0g. The safety margin is 1.7g (2.0g minus 0.3g).

Success path (2), Success path (3), and Success path (4): The seismic withstanding value of the fire water system is the lowest, in which the fire water storage tank is the key equipment. The medium seismic withstanding value is 1.1g. The safety margin is 0.8g (1.1g minus 0.3g).

The cliff edge in this case is defined as the lowest seismic withstanding value (listed on the heading of the event tree sequence) of the highest safety margin path among all the successful cooling paths. Therefore, after evaluation, the cliff edge of Lungmen nuclear power plant due to earthquake that can result in core fuel damage is 2.0g of success path (1).

2.2.1.2 Measures which can be envisaged to increase robustness of the plant

- Shorten the time needed to establish fire water flow path

  Operator must manually open at least two isolation valves, they are E11-BV-045C and E11-BV-046C (located in equipment channel division C of the reactor building, the building room number is 335), to establish the fire water system based on current system design. When loss of AC power, in addition, operator must manually open the E11-MBV-0005C electric valve (located in the ECCS division C valve room of the reactor building, the building room number is 431, locked during normal operation). Operator need to spend more time to do that because the locations of the three valves are not in open space, and there will be considerable obstacles in field during manual operation. If some kind of modification can be made, the time to establish the flow path can be shortened. In addition, the decision-making timing to establish the flow path by on duty operator in the control room is also an important key factor in the accident. If there are clear procedures guidelines with training, it can also help to shorten the time needed to establish the fire water flow path.

●Upgrade the seismic capability of raw water system

Raw water pool has various design functions. Therefore the upgrading of the seismic capability of raw water system mainly focus on the pipes and valves related to the provision of fire water and the hillside which is adjacent to the raw water reservoir and the plant boundary. Therefore, the raw water system can provide a stable water supply to fire water system after earthquake.

●Intake from raw water system through fire water pump

Because the seismic capability of fire water storage tank is low, and the feasibility of substantial improvements is also low. However, we consider to modify the interface of fire water system and raw water system. The raw water can be introduced directly into the intake pipe of fire water pump using fixed or unfixed pipes if necessary. Therefore, the fire water system can still perform its functions after the failure of fire water storage tank.

2.2.2 Range of earthquake leading to loss of containment integrity

The major enclosure structures for containment of this plant are containment building, reactor pedestal and RPV support skirt. According to the Lungmen FSAR Appendix AC.3 “Seismic Capacity Analysis”, it is estimated that the probability of loss of its containment enclosure capability due to earthquake is very low because the base rock surface acceleration median value of above-mentioned structures as listed below is very high.

Structure	Base rock surface acceleration median value
Containment Building	4.83g
Reactor Pedestal	12.63g
RPV Support Skirt	5.54g

In addition, the base rock surface acceleration median value of reactor building that encloses the above structure is 5.45g, therefore the probability of loss of containment enclosure capability due to earthquake is very low.

2.2.3 Earthquake exceeding the DBE and consequent flooding exceeding DBF

2.2.3.1 Physically possible situations and potential impacts on the safety of the plant

The Lungmen NPP site has a concave shoreline that faces the Pacific Ocean and the other side surrounded by hills. It is located at Yenliao Village, Gongliao District, New Taipei City, at an approximate longitude of 121°55’E and latitude of 25°03’ N in the northeastern coast of Taiwan. It is

about 20 km southeast of Keelung, 40 km east of Taipei and 33 km northeast of Yilan.
The plant site is on a coastal plain of the Shihting Creek and Shuang-Chi Creek. The Shihting Creek flows through the warehouse area and dormitory area located in the north side of the plant. The creek inside the plant is the rectified composite open channel. The Shuang-Chi Creek is located in the south side of the plant. There is a hill higher than 50 meters that blocks between the Shuang-Chi Creek and the plant site. The rise in Shuang Chi Creek water level will not affect the operation of the Lungmen NPP. This two creeks were not included in the list of potential mud flow areas determined by the Soil and Water Conservation Bureau of the Council of Agriculture, Executive Yuan. After many years of typhoon, rainstorm and earthquake, the plant does not have serious mud flow disasters. In addition, the excavation and site preparation area is maintained through good soil and water conservation engineering. Therefore the probability of mud flow disaster or changing course of Shihting Creek and Shuang-Chi Creek is very low based on the site natural conditions. Both of them are not considered as the flooding source of the plant due to earthquake.

The raw water reservoir is located on the west side flat hills with 116 meters of elevation, 112 meters long and 63 meters wide. The elevation of bottom plate is 116.6 meters. The elevation of full water level is 124.6 meters. The volume of water storage is 48,000 cubic meters. The base and walls are constructed using reinforced concrete structures. The tank is Seismic Category IIA structure and doesn’t collapse with seismic intensity that is less than 0.4 g. Moreover, the internal partitions of the pool can disperse and reduce the impact force due to water shaking after earthquake. The foundation of the raw water reservoir is built on the base rock. The bearing capacity is much higher than the total weight of the pool body plus water storage. Therefore, there is no concern for the lack of soil bearing capacity or the liquefaction. In addition, the rock stratum of upper raw water reservoir hillside is south-north direction, with dip of slope towards south at about 14°. In order to reduce the safety concern of dip-slope to stabilize slope naturally, the slope surface of upper raw water reservoir and the slope surface between upper and lower pool were trimmed with slope (1V:4H). We also remove all blocks that may slip along bedding surface so that the hill layer will not be exposed. When the bedding surface extends to the lower slope, there is no concern of dip-slope landslide caused by excavation at the toe of slope. The whole section of slope is safe and stable. However, when earthquake occurs with the intensity exceeding the withstanding range of the raw pool structure, the raw water reservoir may collapse caused by structural crack damage and affect plant safety.

2.2.3.2 Weak points and cliff edge effects

The construction garbage dump and power block area are located on the east side of raw water reservoir. The sub-drainage Channel No. III-1 on the west-south side of plant collected runoff from ground surface, and discharged into the Pacific Ocean after combined with the main drainage Channel No. III. There is an anonymous creek on the southern side of raw water reservoir that collects runoff from ground surface to Shuifangang village and discharged into Shuang-Chi Creek, as shown in Figure 2-3.

If the earthquake with intensity exceeding the design basis cause the raw water reservoir crack damage, based on the report of "the Raw Water Pool Leakage Analysis due to Crack Damage" made by Sinotech Engineer Consultants, LTD, if the southern side wall of raw water reservoir occur overall failure and the crack damage location of pool wall depend on the structural type. Assuming that the crack damage location is in the elevation of 116.6 meters (the base plate elevation of upper pool is 116.6 meters) and the crack damage section of pool wall is similar to the rectangular weir section with 112 meters bottom width (the crack damage width of pool wall is the design width of upper pool southern side), the maximum peak leakage flow is 46.6 cms and the passing direction of water flow is toward the Lungmen NPP after the wall crack damage. When the overland flow is caused by crack damage of pool wall pass to the plant, the flow of sub-drainage Channel No.III-1 is attenuation to 31.58 cms. However, the design flow of upstream sub-drainage Channel No.III-1 is 57.03 cms and is much higher than the flood discharge caused by wall crack damage. And the flood is transported to the downstream of marine outfall. According to the analysis result, the discharge of raw water reservoir flowing into the power block area of plant is introduced to leave the plant by the drainage channel of original drainage design, and that will not cause the plant flooding situation. Therefore, there is no weak point and cliff edge effects due to earthquake induced flood in this plant.

2.2.3.3 Measures which can be envisaged to increase robustness of the plant

Although the plant does not have to take enhancement measures to strengthen its protection capability due to earthquake induced flood. However, if the flood height exceeds the design basis height (greater than 12.0 meters), the plant will be flooded because the external gate of each building on ground floor have no watertight function. In addition to using the original of Sump Pump to drain the water, we can also use pre-prepared temporary pump, to restore the function of the equipment located on the ground floor of the plant as soon as possible. Also, the plant is now planning to build tsunami wall (top of wall = EL. 14.5 m) to prevent plant site from tsunami attack. Tsunami wall will upgrade the protection capacity against flood on the ground floor of each important building.

Reference

A. Government document

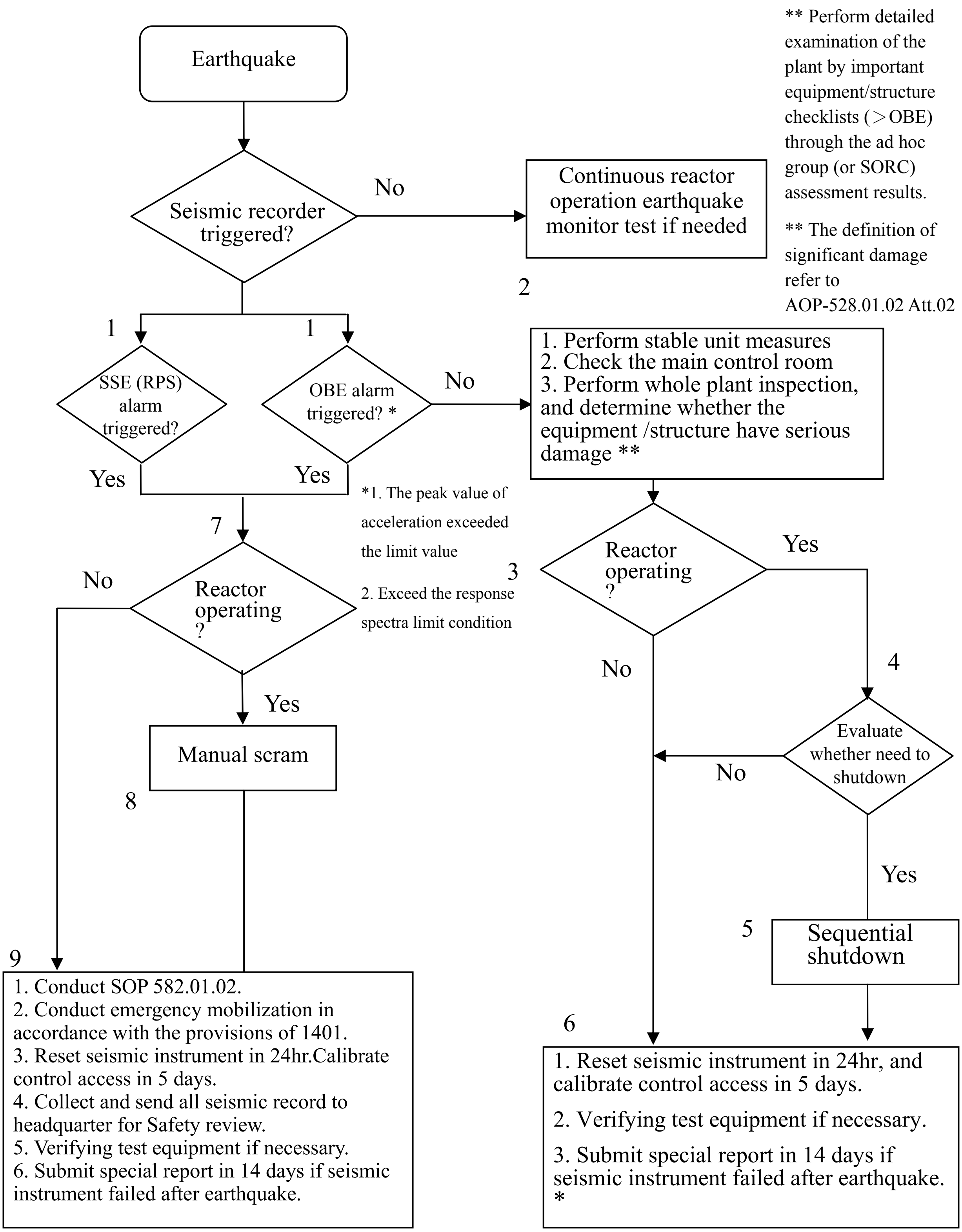
"Central Geological Survey Special XIX" (Central Geological Survey, MOEA)

B. Labor and organizational document

N/A

C. Taipower doccument

"Lungmen NPP Final Safety Analysis Report" (Taipower Company)
"Summarization and Evaluation of the Geologic structure and seismic records near LMNPP Site"(National Central University)
"Re-analysis and evaluation of Earthquake Threats to the LMNPP Site"(National Earthquake Research Institute)
Procedure 528.01.01 "Emergency Operation Procedures for Earthquake"
Procedure 528.01.02 "Reactor Restart Assessment Procedures after Earthquakes bigger than DBE"
Procedure 186.01 "Focuses of disaster prevention and Rescue"
Procedure 1102.01 "Equipment Inspection and Repair Control "
Procedure 174.1 "Prompt Reporting Procedures for Abnormal Events"
Procedure 175 "Written/Special Reporting Procedures for Abnormal Events "
Procedure 1115.01 "Process and Control of Quality Non-conformance Events"
Procedure 190 "Assessment and Review Procedures for Repairing Work that May Cause Procedure Potential Reactor Scram or Other Risks"
Procedure 191 "Assessment and Review Procedures for Potentially Dangerous Work"
Procedure 1114.03 "Procedures for Non-Operable Tag Control"
Procedure 1110.01 "Control Procedures for QA On-Site Hold and Verification"
Procedure 1109.09 "Procedures for Regulation Required Repair and Replacement of Procedure Mechanical Components"
Procedure 1109.08 "Repair Control for Non-Regulated Components"
Procedure 1103.01 "Control of Plant Design Change"
Procedure 1103.04 "Replacement Control of Plant Components and fittings"
Procedure 1102.02 " Control of Instrument and Electrical Equipment Set-Point Change"
Procedure 1102.03 "Control of Temporary Equipment Set-Point Change and Temporary Loop/Pipe Disconnection or Jump-Connection"
Procedure 1103.05 "Procedures of Nuclear Grade Item Dedication"
"Lungmen Nuclear Power Plant seismic cliff edge effect analysis"
"The Raw Water Pool Leakage Analysis due to Crack Damage" (Sinotech Engineer Consultants, LTD)
"Lungmen Nuclear Power Plant Comprehensive Safety Assessment Summary Report"



* The special report includes earthquake introduction, earthquake magnitude, the plant inspection and the impact of safety function caused by related results.

Figure 2-1 The emergency procedure flowchart of nuclear power station after strong earthquake

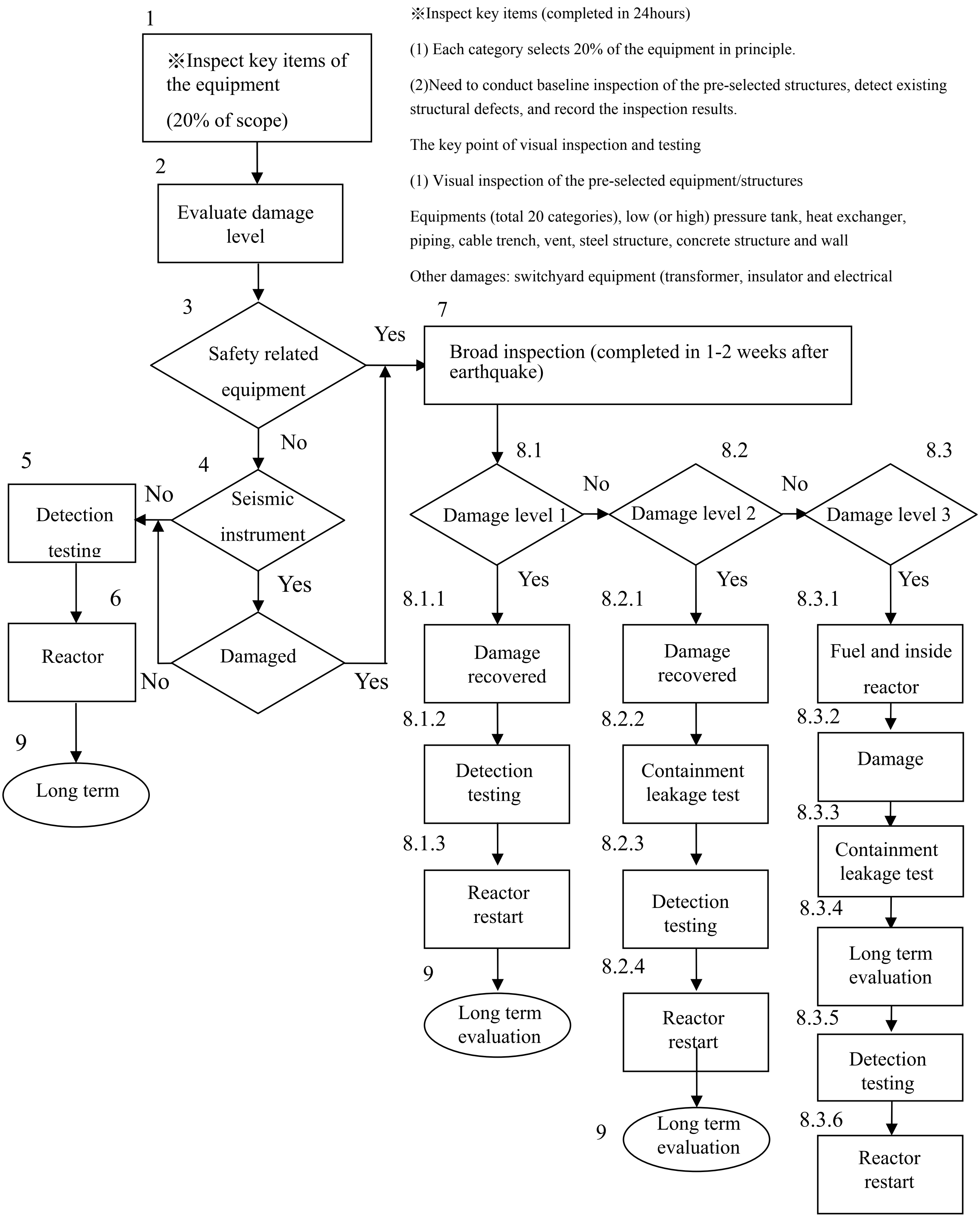


Figure 2-2 The evaluation flowchart of earthquake caused reactor shutdown inspection, testing and reactor restart

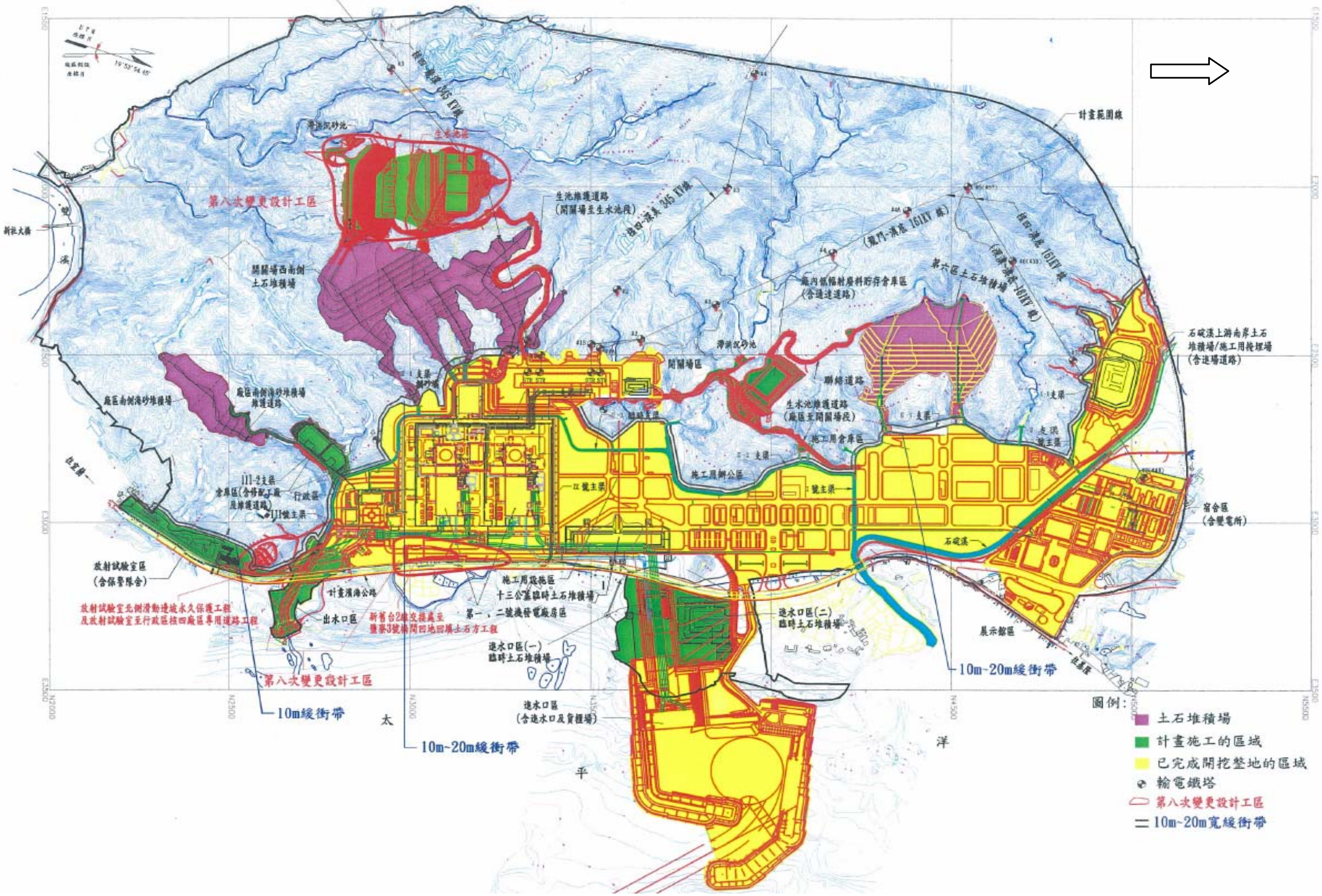


Figure 2-3 The map of the raw water reservoir of Lungmen power plant

Attachment 2-1 LMNPP Seismic case study

The LMNPP Seismic case study includes a total of 15 headings (or, top events), beginning with the initiating event as the first heading and ending with the state of plant shutdown cooling/damage as the last heading. Each of the 15 headings involved in the development of the event tree sequences is described as follows:

1. The offsite power:

According to the design of Lungmen Nuclear Power Plant, the offsite power supply is the weakest seismic capacity equipment of all system, structure and component. Because the offsite power supply status after earthquake has great impact in the accident analysis. Therefore, the offsite power is first considered in the event tree of seismic cliff edge effect. When the offsite power still maintain to supply AC power after earthquake, the possibility that the earthquake magnitude does not exceed the design basis seismic intensity is quite large. Therefore the offsite power system with much lower seismic capacity than other safe system components is not affected. Thus, the probability that the above-mentioned magnitude earthquake will affect other safe systems is relatively low. On the other hand, there are many safe systems powered by offsite power supply AC power can support the unit safe shutdown. Based on the above considerations, when the offsite power still provides AC power after earthquake, it can be considered as a transient that won't affect the plant operation. The loss of offsite power supply after earthquake will cause other system failure (balance of plant) and affect the normal AC power supply. Therefore, the emergency diesel generators have to supply AC power. The offsite power functional fault tree is shown in figure 1. From the assessment, the median seismic withstanding value of the ceramic insulation has the lowest value of all offsite power system, 0.3 g.

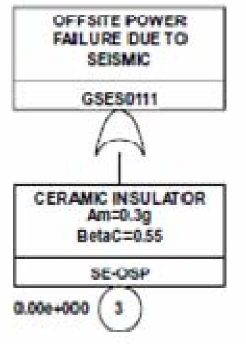


Figure 1. The functional fault tree for offsite power supply

2. The structural integrity of buildings:

This safety function discusses about the structural integrity of important buildings of LMNPP. These structures containing important safe systems are used to support the plant to achieve safe shutdown state. When these structures can't maintain their integrity after earthquake, the system within the building will be seriously damaged and result in core fuel damage. The buildings with safety function include reactor building, containment and control building. Other buildings that their failure won't cause directly the core fuel damage are not included in the analysis. According to the screening analysis result of the equipment seismic capacity, the seismic capacity of these structures with safety function are greater than the screening value, HCLPF=0.9g. So there is no need to conduct analysis for loss of structural integrity of these building.

3. The essential power:

The safety function mainly considers whether the essential DC power is available to start the emergency diesel generator after the offsite power failure. Because the offsite power cannot provide AC power, thus the essential power is powered by battery transmitted to essential power bus through rectifier and transformer, and then is used as the starting power of the emergency diesel generator. When loss of this safety function, it means that the plant DC power failure and cannot provide the essential power. Because all emergency diesel generator can't be started, and the reactor instrument equipment is also failed due to loss of essential AC power, so it is assumed that the condition will cause the reactor core damage. The essential DC power functional fault tree is shown in figure 2.

From the assessment, the medium seismic withstanding value of safety-related power transformer has the lowest seismic capacity equipment of all essential DC power system, 2.4 g.

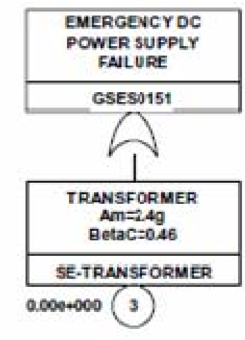


Figure 2. The functional fault tree for essential DC power

4. The essential AC bus:
When the safety function is successfully fulfilled, it means that the essential AC bus can receive transmission power from emergency diesel generator and transmit power to load end needed. However when the essential AC bus failed and loss of original offsite power, the unit condition is the same as station blackout event. According to the screening analysis result of the equipment seismic capacity, the seismic capacity of all equipment related to the essential AC bus are greater than the screening value, HCLPF=0.9g. So there is no need to conduct detailed analysis for essential AC bus failed.

5. The service water systems:
The emergency diesel generator will be loss of cooling capacity due to the service water system failed. At same time, The ECCS will not be used because loss of cooling capacity of the injection pump or pump house. Whether the service cooling water system is available or not, it relates to the availability of emergency diesel generator and the ECCS, so it first distinguishes differences before the front-line system. The Reactor Building Cooling Water (RBCW) system and the Reactor Building Service Water (RBSW) system are major objects for the consideration of this safety function. The pump room of RBCW system is located in the reactor building, the pump room is cooled rely on outside air convection without considering the pump room cooling. The service water systems functional fault tree is shown in figure 3. From the assessment, the median seismic withstanding value of the infection pump of RBSW system has the lowest seismic capacity equipment of all service cooling water system, 2.0 g.

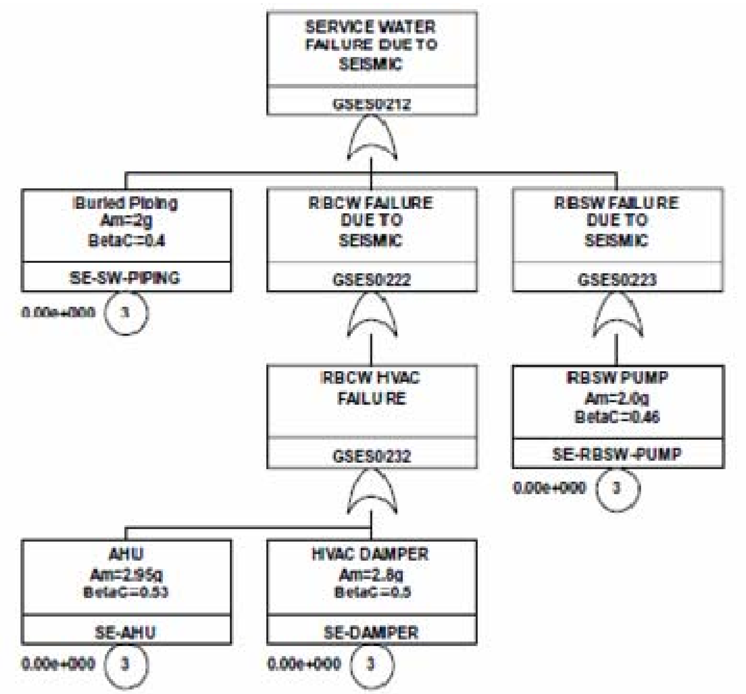


Figure 3. The functional fault tree for service water systems

6. The emergency diesel generator:
The emergency diesel generator take an important responsibility to provide AC power when loss of offsite power. Each unit is equipped with three EDGs. When the EDG is not available, it means that the unit has completely no self- available AC power. If loss of offsite power is occurred at this time and multi-unit site does not consider the conservative assumptions of SDG after the earthquake, the condition is the same as station blackout event. The unit must insert the control rod first at this time and then the reactor core isolation cooling system by DC cool the reactor core. The duty staff must establish the flow path of fire water injection at this time to maintain the long term integrity of the core fuel. The emergency diesel generator functional fault tree is shown in figure 4. From the assessment, the medium seismic withstanding value of the fuel oil daily tank has the lowest seismic capacity equipment of all emergency diesel generator system, 2.33 g.

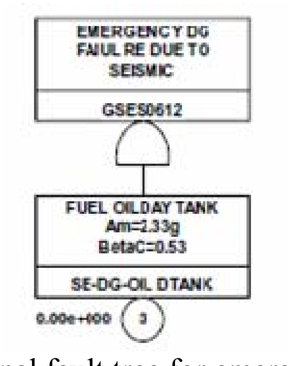


Figure 4. The functional fault tree for emergency diesel generator

7. The insertion of control rod
This safety function is mainly used to distinguish whether the unit complete the necessary scrammed measures, so that the reactivity of the reactor core obtain effective control, otherwise the unit will be in the anticipated transient without scram (ATWS) state. Whether the function of control rod insertion can operate after the earthquake, In addition to the control rods and related auxiliary systems are available, the integrity of the internal components of the reactor core will also affect the function of

control rod insertion. For example, the deformation of the side panels of reactor core or fuel components after the earthquake cause the rod insertion channel damage and affect the control rods into the reactor core. When this safety function isn't available, it means that the reactor core can't be inserted a sufficient number of control rods and effective control the reactivity of reactor core. According to the screening analysis result of the equipment seismic capacity, the seismic capacity of all equipment related to the control rod insertion are greater than the screening value, HCLPF=0.9g. So there is no need to conduct detailed analysis for control rod insertion failed, and simultaneously the standby liquid control system will also be excluded from the analysis.

8. The reactor core isolation cooling system
The reactor core isolation cooling (Reactor Core Isolation Cooling, RCIC) system is high pressure coolant injection system of ECCS. Each electrically operated valve of RCIC system is operated by the DC, the power of injection pump come from the turbine driven by the steam in the main steam pipe. RCIC system is a very reliable function of reactor core cooling in the accident process of loss of offsite power or station blackout. When this safety function isn't available, it means that the RCIC system can't provide sufficient cooling water to reactor core based on the design function. The low seismic capacity equipment of all RCIC system includes the condensate storage tank and the air-conditioning system of pump room. In the analysis of seismic cliff edge effects, the role played by the RCIC system is short term injection, and the condensate storage tank and pump room cooling are not necessary short term cooling equipment of the RCIC system. The seismic capacity of the RCIC system is higher than the screening value of HCLPF=0.9g as the screening analysis. Because the unit has no alternative system of the same function, once the RCIC system isn't available due to maintenance, the unit has no injection system relied on the DC operation. In addition the RCIC system is allowed disabled time for seven days by technical specification requirement, this means that the unit may continue to operate under the status of the RCIC system is unavailable. Therefore, it is necessary that the RCIC system is included in the analysis of seismic cliff edge effects. The necessary short term cooling equipment of RCIC system include piping, cable trays, turbine, injection pump, electrically operated valve and check valve. The lowest seismic capacity equipment of RCIC system is the injection pump. From the assessment, the medium seismic withstanding value is 3.54 g, and the corresponded HPCLF value is 1.03 g.

9. The high pressure coolant injection system
Although the high pressure coolant injection system is the high pressure injection system of ECCS, in the analysis of seismic cliff edge effects, the initial event is loss of offsite power, the high pressure coolant injection system is not a critical system maintained long term the integrity of core fuel, related to the RCIC system doesn't need to operate by AC power and the RHR system has long term heat removal and diversified cooling function.

10. Safety relief valves
18 safety relief valves are located in the main steam pipe, in the analysis of seismic cliff edge effects, the implementation of safety function is emergency relief of the reactor pressure vessel and the low pressure injection system will inject cooling water into the reactor core in time, such as residual heat removal system or fire water systems. According to the screening analysis result of the equipment seismic capacity, the seismic capacity of all equipment related safety relief valves are greater than the screening value, HCLPF=0.9g. So there is no need to conduct detailed analysis for loss of emergency relief function of safety relief valves.

11. The residual heat removal system
The residual heat removal system is low pressure injection system of ECCS, and has three identical and independent divisions such as A, B and C. Each division of the residual heat removal system in addition to having the low pressure safety injection function of the reactor core, because the system has sufficient capacity heat exchanger, so it will remove the heat of the reactor core or suppression pool to containment outside through the RBCW system. Therefore, the residual heat removal system

is also an important system of long term heat removal of reactor core or containment after the accident. According to the design of residual heat removal system, the long term heat removal of the unit after the accident will be conducted through the function of shutdown cooling, suppression pool cooling and containment spray, but only the heat exchanger of RHR system and its related support systems function must be normal operated. The scope of this safety function considers in addition to important equipment of the RHR system, also includes the isolation valve, injection pump, ventilation system, piping, instrument equipment and cable trays, etc. The heat exchangers have a significant impact for the analysis of seismic cliff edge effects, so it will include in the assessment as a separately safety function.

Each division of RHR system designs the 100% capacity of water injection and heat removal when the accident occurs, thus the RHR system can still conduct its safety function after the earthquake, and the operator can rely on the function of RHR system to conduct effective reactor core cooling and long term heat removal by other division at the same time. When the fire water system conducts the injection function of reactor core, the cooling water must be injected into the reactor core by the RHR system piping, and the injection pathway covers the low pressure safety injection isolation valve of the RHR system division C. According to the analysis result of the equipment seismic capacity, the HCLPF value of system piping and the electrically operated valve of RHR system are respectively 1.06 g and 1.35 g, all higher than the screening value, HCLPF = 0.9 g. Therefore, the analysis does not consider the condition that the RHR system failed will affect the fire water injection pathway, and consider the feasibility of long-term heat removal of the unit by the fire water system under the condition that the RHR system can't conduct the long term heat removal function due to failed. The RHR system functional fault tree is shown in figure 5. From the assessment, the medium seismic withstanding value of the damper of ventilation system of pump room has the lowest seismic capacity equipment of all RHR system, 2.8 g. If only consider the short term injection function of the RHR system and exclude of the pump room cooling equipment needed, the seismic capacity of all RHR system equipment are greater than the screening value, HCLPF = 0.9 g.

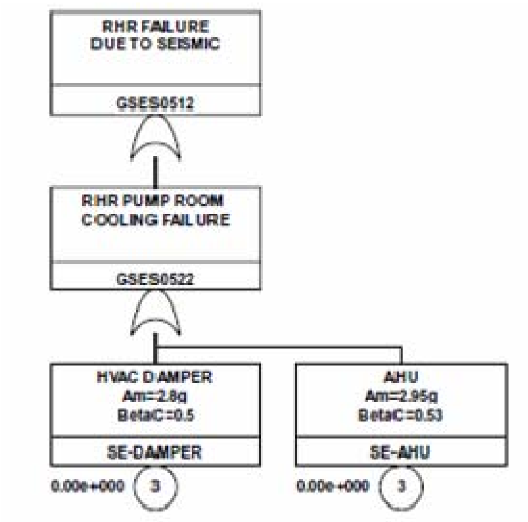


Figure 5. The functional fault tree for RHR system

12. The heat exchanger of RHR system

The heat exchanger of RHR system of LMNPP is the only heat exchanger had sufficient capacity after the accident. This heat exchanger can effectively discharge heat accumulated by the core decay heat from inside containment to outside, and while still maintain the integrity of the containment. According to the screening analysis result of the equipment seismic capacity, the seismic capacity of the heat exchanger of RHR system is greater than the screening value, HCLPF=0.9g. So there is no need to conduct detailed analysis for the heat exchanger failed.

13. The fire water system

The fire water system of LMNPP is not safety-related system. This system consists of two divisions, and one division of them is designed to support the reactor core cooling system, the designed seismic capacity of related components is equivalent to other safety-related systems. The driving power of injection pump comes from the independent diesel generator instead of the essential AC power, and the starting power needed to start the diesel generator is provided by the independent battery. Therefore, this division of fire water system can be used to pay into the reactor core, flood irrigation containment and become other water source in the accident.

In the accident of station blackout, loss of essential cooling water system or RHR system failed, the accumulated energy inside containment can't be discharged through the RHR system. The fire water system provide the reactor core cooling water from raw water reservoir or other external water source through the pipe of RHR system division C, in order to ensure that the reactor core is obtained long term and stable cooling capacity.

The fire water injection system functional fault tree is shown in figure 6. From the assessment, the median seismic withstanding value of the fire water storage tank has the lowest seismic capacity equipment of all fire water injection system, 1.1 g. Although the raw water reservoir can provide enough water for fire water system, but the cooling water from raw water reservoir must be imported into the fire water storage tank, and then injected into the reactor core through the fire water system. Therefore, the raw pool provides the cooling water function of the fire protection system, but is still limited by the integrity of the fire water storage tank. If considering the external water source without going through the fire water storage tank such as fire engines or water wheel, from the assessment, the medium seismic withstanding value of the fire pump has the lowest seismic capacity equipment of fire water system, 1.9 g. However, the plant must also consider that whether the local roads and access roads timely support a large number of external water transported to the fire water building, and distribute the offsite limited relief resources, so the related condition still need to be further evaluated.

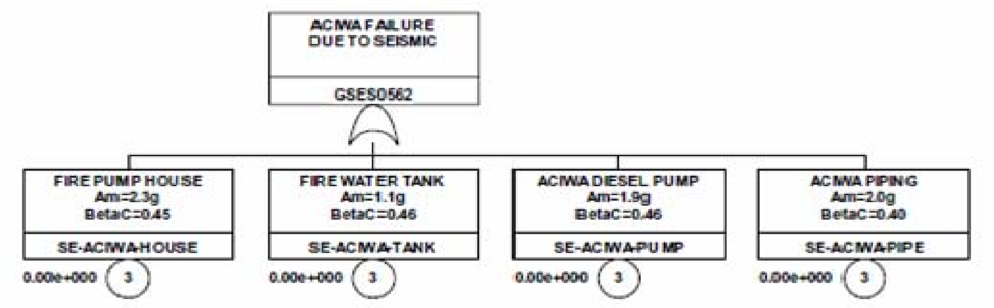


Figure 6. The functional fault tree for fire water system

14. The containment overpressure protection system

When the containment pressure reaches the overpressure set point, the containment overpressure protection system provide the ventilation channel of containment through the operation of two blast valves, in order to avoid excessive hydrogen concentration inside containment, or the containment can't effectively control the radioactive substances released to outside containment because containment overpressure resulting in containment failed. According to the screening analysis result of the equipment seismic capacity, the seismic capacity of containment overpressure protection system is greater than the screening value, HCLPF=0.9g. So there is no need to conduct detailed analysis for containment overpressure protection system failed.

15. The state of plant shutdown cooling/damage

The last configuration of plant is divided into normal cold shutdown, containment bypass cold shutdown and core fuel damage in the event tree of seismic cliff edge effects. The normal cold shutdown and the containment bypass cold shutdown represent the reactor core fuel long term maintains its integrity. The normal cold shutdown means the unit maintains the integrity conditions of containment to reach cold shutdown state after loss of offsite power. The containment bypass cold shutdown represents the unit release energy from the reactor core and accumulated inside containment through the containment bypass pathway in the control condition, in order to avoid unexpected containment failed modes affecting the implementation of the core cooling function.

Based on current design and operation, the developed event tree of seismic cliff edge effects of the LMNPP is shown in Figure 7.

According to the event tree analysis of seismic cliff edge of the LMNPP, including the safety margin of success path and the Cliff Edge described as follows:
Success path (1): All the necessary safety functions for the unit normal cold shutdown paths can be successfully performed. The related safety functions include: the essential DC power to start the emergency diesel generator; the service water system to cool the emergency diesel generators and safety injection system and to provide cooling water for the heat exchanger of the residual heat removal system; the emergency diesel generators to provide the AC power for the important equipment;, the residual heat removal system to execute safety injection and a variety of heat removal functions.

Success path (2): When the residual heat removal system is unavailable due to earthquake, the fire water system can provide the reactor core long-term cooling. The containment bypass pathway provided by the containment overpressure protection system can release the energy accumulated in the containment to achieve the purpose of long-term heat removal of the reactor core.

Success path (3): When the emergency diesel generator is unavailable due to earthquake, the RCIC can provide the reactor core short-term water makeup functions. The fire water system can provide the reactor core cooling. The containment bypass pathway provided by the containment overpressure protection system can release the energy accumulated in the containment to achieve the purpose of long-term heat removal of the reactor core.

Success path (4): When the service water system is unavailable due to earthquake, the rescue path the same as success path (3) can achieve the purpose of long-term heat removal of the reactor core.

The safety margin and cliff-edge of each success path are described as follows:

Success path (1): The seismic withstanding value of the service water system is the lowest, in which the RBSW pumps and the underground buried piping are the key equipment. The median seismic withstanding value is 2.0g. The safety margin is 1.7g (2.0g minus 0.3g).

Success path (2), Success path (3), and Success path (4): The seismic withstanding value of the fire water system is the lowest, in which the fire water storage tank is the key equipment. The median seismic withstanding value is 1.1g. The safety margin is 0.8g (1.1g minus 0.3g).

The cliff edge in this case is defined as the lowest seismic withstanding value (listed on the heading of the event tree sequence) of the highest safety margin path among all the successful cooling paths. Therefore, after evaluation, the cliff edge of Lungmen nuclear power plant due to earthquake that can result in core fuel damage is 2.0g of success path (1).

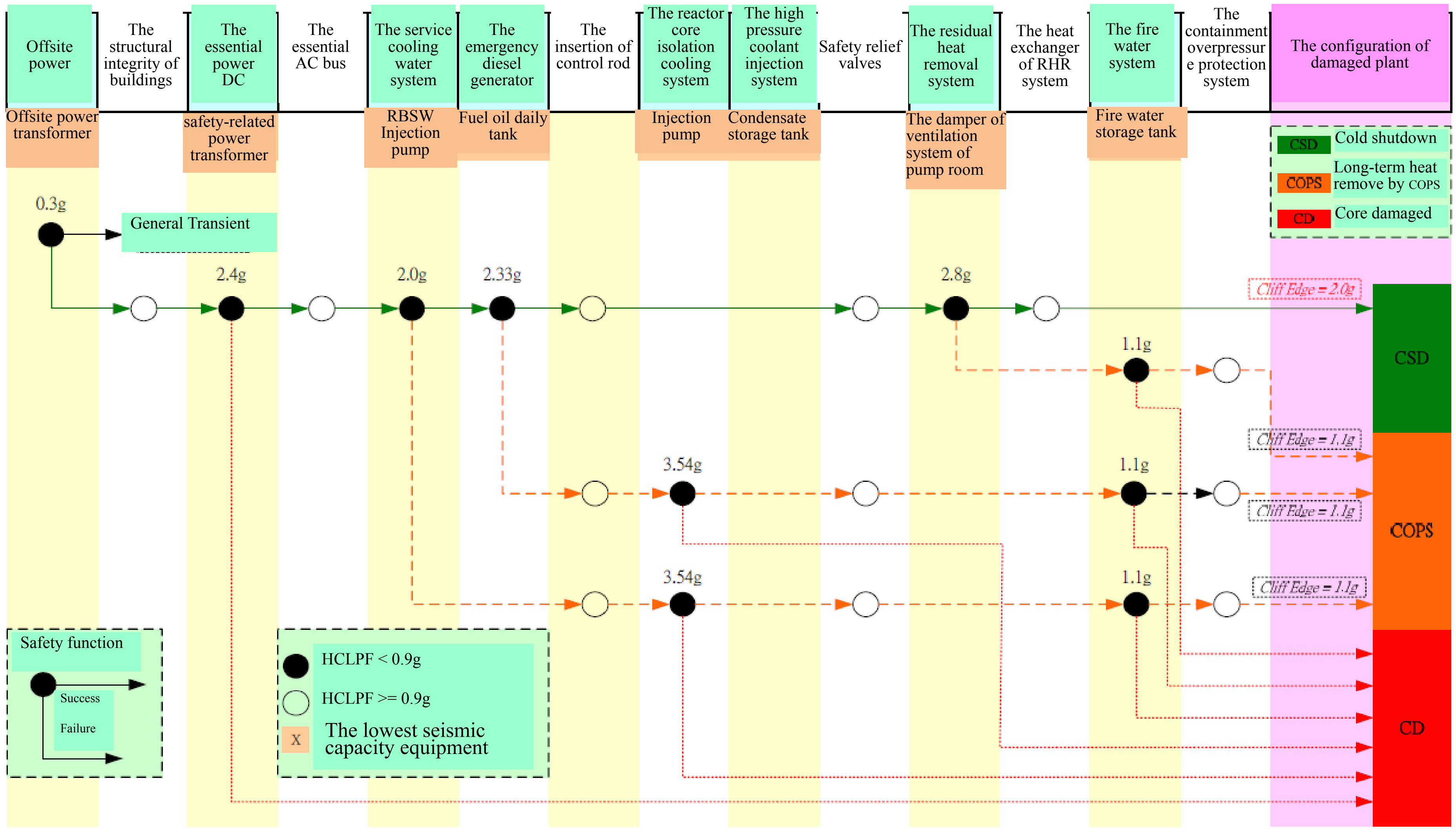


Fig. 1 Lungmen NPP Seismic Event Tree

Attachment 2-2 LMNPP SSC seismic capability

Structure/Component	**Failure Mode**	**FROM**	**Am**	**βR**	**βU**	**βC**
Offsite Power Transformers	Ceramic Insulator	AC.3-66	0.3			0.55
Condensate Storage Tank	Support Anchorage	AC.3-66	1.1			0.46
FP Tanks	Support Anchorage	AC.3-66	1.1			0.46
FP Pumps	Structural Integrity	AC.3-66	1.9			0.46
Reactor Building Service Water Pump	Loss of Function	AC.3-66	2			0.46
Emergency Diesel Generator Fuel Oil Day Tank	Tensile Failure of Anchor Bolt	AC.3-37	2.33	0.36	0.38	0.52
Emergency Diesel Generator Fuel Oil Day Tank	Tensile Failure of Anchor Bolt	AC.3-37	2.33	0.36	0.38	0.52
Buried Piping	Differential Settlement	AC.3-66	2			0.40
FP Buried Piping	Buckling	AC.3-66	2			0.40
Fire Protection House	Structural Integrity	AC.3-66	2.3			0.45
SR Transformer	Electrical Equipment	AC.3-67	2.4			0.46
Air Handling Units	Failure of the AHU anchor bolts	AC.3-34	2.95	0.35	0.4	0.53
HVAC Dampers	Anchorage Failure	AC.3-55	2.8	0.33	0.38	0.50
Hydraulic Control Unit	Yielding of the steel angles supporting the accumulator	AC.3-38	3.15	0.35	0.38	0.52
AC Switchgear or Motor Control Center	Functional Failure of Active Components	AC.3-40	3.38	0.31	0.44	0.54
Motor Control Centers and Transformers	Anchorage Failure	AC.3-62	3.02	0.33	0.38	0.50
Fuel Assembly	Exceeding the Allowable Seismic Moment of the Fuel Channel	AC.3-28	3.04	0.27	0.35	0.44
Containment	Rebar Flexure and Membrane Stress	AC.3-16	4.83	0.36	0.38	0.52
Main Control Room Panels (NONE)	Loss of Functionality	AC.3-61	2.32	0.31	0.41	0.51

Structure/Component	**Failure Mode**	**FROM**	**Am**	**βR**	**βU**	**βC**
Emergency Chilled Water Pumps(ECW)		AC.3-48	2.5	0.3	0.44	0.53
RPV Support Skirt	Yielding of Anchor Bolt	AC.3-24	5.54	0.25	0.25	0.35
Control Rod Drive Housing	Yielding of Housing	AC.3-27	6.64	0.33	0.36	0.49
Auxiliary Fuel Building	Rebar Flexure and Membrane Stress	AC.3-23	5.45	0.36	0.4	0.54
Reactor Building	Rebar Flexure and Membrane Stress	AC.3-15	5.45	0.36	0.38	0.52
Control Building	Rebar Flexure and Membrane Stress	AC.3-18	6.29	0.36	0.4	0.54
System Piping	Failure of Pipe Support	AC.3-44	4.02	0.38	0.43	0.57
C41-UV-CC-CHECK	Check Valves	AC.3-51	4.02	0.38	0.43	0.57
C41-MOV-CC-INJEC	Motor Operated Valves	AC.3-54	4.02	0.38	0.43	0.57
G31-MOV-OO-SUCTI (RWCU)	Motor Operated Valves	AC.3-54	4.42	0.33	0.45	0.56
C41-MOV-CC-SUCTI	Motor Operated Valves	AC.3-54	4.04	0.31	0.41	0.51
Control Rod Guide Tubes	Yielding of Tubes	AC.3-26	4.34	0.35	0.39	0.52
Shroud Support	Bulking of Shroud Support Legs	AC.3-25	3.97	0.3	0.35	0.46
SLC Tank		AC.3-32	5.7	0.32	0.41	0.52
Standby Liquid Control Pumps	Failure of bolts that hold pump to base plate	AC.3-58	7.2	0.39	0.39	0.55
Cable Trays in Reactor Building	Flexural Bending of Side Rails	AC.3-19	8.34	0.33	0.39	0.51
RPV Pedestal	Tension in Vertical Stiffeners	AC.3-17	12.63	0.36	0.42	0.55
FP Support Structure	Loss of Support	AC.3-66	3.8			0.61
FP and RBSW Valves	Loss of Function	AC.3-66	3.8			0.61
Safety-Related Fans	Failure due to fan blades rubbing housing	AC.3-52	3.18	0.32	0.43	0.54
AC Inverters and DC Switchgear	Anchorage Failure	AC.3-63	3.04	0.33	0.38	0.50

Structure/Component	Failure Mode	FROM	Am	βR	βU	βC
Main Steam Safety Relief Valves (SRV)	Loss of Actuator Operability	AC.3-60	3.9	0.31	0.54	0.62
RBCW Pumps		AC.3-30	3.6	0.35	0.42	0.55
Instrument Racks	Anchorage Failure	AC.3-57	3.45	0.36	0.38	0.52
RCIC Pumps	Loss of Operability of the Pump	AC.3-43	3.54	0.31	0.44	0.54
SR Inverters	Electrical Equipment	AC.3-67	3			0.46
Chilled Water Cooling Coils	Tube Support Failure	AC.3-53	3.32	0.33	0.38	0.50
Emergency Diesel Generator		AC.3-39	3.4	0.33	0.39	0.51
HPCF Piping	Support Failure	AC.3-33	4.02	0.38	0.43	0.57
E22-UV-CC-003BC	Check Valves	AC.3-51	4.02	0.38	0.43	0.57
E22-UV-CC-CHECK	Check Valves	AC.3-51	4.02	0.38	0.43	0.57
E22-UV-CC-SUCTI	Check Valves	AC.3-51	4.02	0.38	0.43	0.57
E51-UV-CC-INJEC	Check Valves	AC.3-51	4.02	0.38	0.43	0.57
E51-UV-CC-SUCTI	Check Valves	AC.3-51	4.02	0.38	0.43	0.57
E11-UV-CC-CHECK	Check Valves	AC.3-51	4.02	0.38	0.43	0.57
E11-UV-CC-SPC	Check Valves	AC.3-51	4.02	0.38	0.43	0.57
E51-UV-CC-STEAM	Check Valves	AC.3-51	4.02	0.38	0.43	0.57
RHR Pumps	Failure of the ring foundation anchor bolts	AC.3-41	3.48	0.31	0.41	0.51
FP Diesel Engine	Loss of Function	AC.3-66	3.1			0.46
Swing Diesel Generator	Loss of Function	AC.3-66	3.1			0.46
SR Medium Voltage Racks	Electrical Equipment	AC.3-67	3.1			0.46
SR Motor Control Center	Electrical Equipment	AC.3-67	3.1			0.46

Structure/Component	Failure Mode	FROM	Am	βR	βU	βC
Service Water Pump House	Structural Integrity	AC.3-66	3.1			0.45
RBCW Piping	Failure of Pipe Support	AC.3-56	5.45	0.38	0.57	0.69
RBSW Piping	Failure of Pipe Support	AC.3-45	4.34	0.38	0.43	0.57
RBCW Air Operated Valve	Loss of Valve Operability	AC.3-49	5.69	0.38	0.58	0.69
P21-UV-CC-CHECK	Check Valves	AC.3-51	5.69	0.38	0.58	0.69
P21-UV-CC-ISOLA	Check Valves	AC.3-51	5.69	0.38	0.58	0.69
E22-MOV-CC-INJEC	Motor Operated Valves	AC.3-54	4.42	0.33	0.45	0.56
E51-MOV-CC-0004	Motor Operated Valves	AC.3-54	4.42	0.33	0.45	0.56
RBSW MBV	Loss of Functionality of the Valve Actuator	AC.3-46	4.04	0.31	0.41	0.51
E11-MOV-CC---SPC	Motor Operated Valves	AC.3-54	4.04	0.31	0.41	0.51
E11-MOV-OO-0004C	Motor Operated Valves	AC.3-54	4.04	0.31	0.41	0.51
E11-MOV-OO-MINIF	Motor Operated Valves	AC.3-54	4.04	0.31	0.41	0.51
E22-MOV-FT-TRANS	Motor Operated Valves	AC.3-54	4.04	0.31	0.41	0.51
E51-MOV-FT-TRANS	Motor Operated Valves	AC.3-54	4.04	0.31	0.41	0.51
P21-MOV-CC-DGMOV	Motor Operated Valves	AC.3-54	4.04	0.31	0.41	0.51
P21-MOV-CC-RBCWH	Motor Operated Valves	AC.3-54	4.04	0.31	0.41	0.51
P21-MOV-CC-RHRHX	Motor Operated Valves	AC.3-54	4.04	0.31	0.41	0.51
P21-MOV-OO-MOTOP	Motor Operated Valves	AC.3-54	4.04	0.31	0.41	0.51
P21-MOV-OO-MOTOA	Motor Operated Valves	AC.3-54	4.04	0.31	0.41	0.51
Swing DG Battery	Functional Failure of Batteries	AC.3-65	4.6	0.31	0.46	0.55
Safety-Related Batteries and Battery Racks for Swing Diesel in Auxiliary Fuel Building	Electrical Equipment	AC.3-67	3.8			0.46

Structure/Component	**Failure Mode**	**FROM**	**Am**	**βR**	**βU**	**βC**
RHR Motor Operated Valves	Loss of Actuator Operated Valves	AC.3-31	4.9	0.33	0.45	0.56
E22-MOV-CC-MINIF	Motor Operated Valves	AC.3-54	4.9	0.33	0.45	0.56
E51-MOV-CC-0103	Motor Operated Valves	AC.3-54	4.9	0.33	0.45	0.56
RBCW Heat Exchangers		AC.3-35	4.88	0.35	0.42	0.55
Batteries	Functional Failure of Batteries	AC.3-50	5.23	0.31	0.5	0.59
ECW Chiller	Functional Failure of Active Components	AC.3-36	4.62	0.31	0.41	0.51
HPCF Pumps		AC.3-42	4.75	0.31	0.41	0.51
DG Fuel Oil Storage Tank	Shear Strength of Anchor Bolts	AC.3-64	2.39	0.18	0.13	0.22
RHR Heat Exchangers		AC.3-29	8.8	0.38	0.46	0.60
Cable Trays in Control Building	Flexural Bending of Side Rails	AC.3-20	8.34	0.33	0.39	0.51
EDG Fuel Transfer Pump		AC.3-59	6.9	0.29	0.31	0.42
EDG Starting Air Receivers	Yielding of support feet of the skirt	AC.3-47	8.58	0.3	0.42	0.52
HVAC Ducts in Reactor Building		AC.3-21	13.13	0.33	0.38	0.50
HVAC Ducts in Control Building		AC.3-22	13.13	0.33	0.38	0.50

3. Flooding

3.1Design basis

3.1.1 Flooding against which the plant is designed

3.1.1.1 Characteristics of the DBF

Owning to the characteristics of Lungmen NPP, the plant needs to particularly consider the influence of tsunamis and storms when making design for plant protection against floods.

1. Tsunami:

   When estimating possible height of tsunami waves near Lungmen NPP and evaluating its potential influence, the plant uses historic records as reference and considers influence of both climate and geographical landscape. The results of the estimate and the evaluation are used as the design basis of the plant. According to the evaluation result of FASR for Lungmen NPP, the maximum tsunami height is 7.5 meters; if change of tides is also considered, the maximum tsunami run-up is at least 8.07 meters. At last, conservatively, adding another 0.5 meters of freeboard, the plant decides the elevation of the design basis for the plant protection against tsunamis to be 8.57 meters EL, which is still lower than the ground elevation of the main building area, 12 meters.

2. Flooding:

   In regard to design basis flood, Lungmen NPP estimates the probable maximum precipitation (PMP) mainly based on the historic precipitation records measured at the Keelung Weather Station between 1901 and 1982. The formula of PMP is $R(PMP)=1.74D^{0.475}$ (R: inch. D: min.). Through which, the PMP at Lungmen NPP, 310 mm, is acquired. The runoff resulting from rainfall within the power block area will be collected by the yard drainage system. This system is designed to carry the run-off from a storm with an l00-year return period. Moreover, the drainage capability of the two main drainage channels around the plant, drainage Channel Nos. II and III, are designed based on the PMP of the plant. The drainage capability of both channels is 81.57 cms and 137.2 cms (cms = m^3/sec) respectively.

   Lungmen NPP is in Gongliao District and within the watersheds of Shiding Stream and Shuangxi Stream. Soil and Water Conservation Bureau, Council of Agriculture, does not include either stream in the government's list of mudslide-prone streams; in addition, considering the natural environment conditions around the plant, the chance for Shiding Stream and Shuangxi Stream to trigger mudslides is really low.

3.1.1.2 Methodology used to evaluate the design basis flood

1. Tsunamis:

   The most likely cause in Taiwan that can trigger tsunamis is earthquakes under the sea. As for Lungmen NPP, only tsunamis in north or northeast of Taiwan would cause influence on the plant. Thus, FSAR of Lungmen NPP mainly considers the possible threat by the tsunamis induced by undersea earthquakes in north or northeast of Taiwan when evaluating the design basis of the plant against tsunamis. According to Central Weather Bureau and Japan's documents, two severe tsunamis occurred in Taiwan in 1867 and 1918 respectively. Between which, the one that happened on June 11, 1867 at 134kms north of Keelung and was triggered by an undersea volcano was the more severe one, causing serious damage to the Keelung region. The historic documents just mentioned stated that the height of the tsunamis waves on this day was approximately 7.5 meters.

   Based on information regarding the movement of undersea crusts near the northeast of Taiwan as well as data simulation, Lungmen NPP concludes the maximum tsunami run-up height at the plant is 7.5 meters. The simulation uses earthquakes with magnitude of 7.2, a fault 20kms from the shore with a size of 50kms × 20kms, 4 meters of upward movement for the fault, and etc. as the parameters. After including the influence of the change of tides, 0.57meters, the tsunamis run-up water level at Lungmen NPP is 8.07 meters. At last, conservatively, adding another 0.5 meters of freeboard, the run-up elevation of design basis tsunamis is set to be 8.57meters EL, which is still lower than the ground elevation of the main building area, 12 meters.

2. Flooding:

According to FSAR 2.4.3.1, the probable maximum precipitation at Lungmen NPP is the main consideration when evaluating the design basis flood of the plant. Meanwhile, the plant plans the drainage capability it needs to deal with the rainfall brought by storms through hydrologic calculation.

Lungmen NPP is situated in the northeast corner of Taiwan, where there is abundant rainfall all year round. The main causes of storms in this area is northeast monsoon, plum rains (East Asia rain season), and typhoons. Because the weather station that is nearest to the plant is relatively new, the plant adopts the precipitation records measured at Keelung Weather Station from 1901 to 1982, which uses to derivate the PMP of Lungmen NPP. The formula of PMP is R(PMP) = $1.74D^{0.475}$ (R: inch. D: min.) and the PMP result of the calculation is 310 mm. Furthermore, the plant plans it storm drainage capability using this PMP figure, as well as four main drainage channels I, II, III, IV, shown in Fig. 3-1, considering the geographic landscape at the plant. Among them, drainage channel I, located in the dormitory area, collects precipitation from the hill region in northwest of the plant and release it via Shiding Stream, so storms would not cause any threat of flooding to the power block area. Thus, the drainage system of the plant is divided into three main parts.

The first part: Drainage in the power block area. The runoff resulting from rainfall in the power block area is released by the drainage system (Yard drainage system), which includes ditches around buildings, collecting pools, manholes, pipes, underground trenches (e.g., drainage Channel Nos. IV), and etc., to drain rainfall in the power block area (once every-100 year storms).

The second part: Drainage outside of the south fence of unit 1, in part of the bordering area between unit 1 and unit 2, and in switchyard area is done by drainage Channel Nos. III. Besides, the runoff caused by rainfall on hills in south, southwest, and west of the main building area is released by drainage Channel Nos. III.

The third part: Drainage in east of the switchyard and runoff resulting from rainfall on hills in west of the power block area are released via drainage Channel Nos. II.

As stated in FSAR 2.4.3.4, drainage Channel Nos. II /III are open man-made channels, whose drainage capabilities, 81.57 cms and 137.2 cms respectively, are designed and planned considering the amount of runoff as a consequence of the estimated PMP at the plant. Because the drainage system of the power block area is designed based on the rainfall intensity with an l00-year return period., temporary water accumulation may occur in areas of non-safety related facilities under the circumstance of probable maximum precipitation intensity. However, according to the analysis of FSAR, the temporary water accumulation would not exceed 0.1 meter. The maximum elevation that the temporary ponding can reach during a PMP situation is estimated to be about 12.10 m mean sea level (MSL) which is 0.20 m below all exterior access opening elevations.

3.1.1.3 Conclusion on the adequacy of the design basis for flooding

1. Adequacy of design basis tsunami

As described earlier, the design basis of the plant to resist against tsunamis is based on the worst tsunami in historic records of Taiwan, in order to estimate the height of probable maximum tsunamis waves, and based on the influence of factors of climate and geological landscape to the plant. After the Fukushima accident, National Science Council (NSC) published "Influence of Tsunami Induced by Potential Massive Scale of Earthquakes on the Nuclear Power Station in Taiwan" on Aug. 19 in 2011, after assessing the 22 earthquake origins of potential maximum tsunami in Taiwan. This NSC report shows the potential tsunami run-up heights of all the nuclear plants in Taiwan are lower than the design basis tsunami run-up elevations for all the power plants. The elevations of the nuclear plants Taipower Company presently has are designed based on the estimate, using the analyses of historic meteorological information as a basis, toward the elevation of tsunamis that have happened before and may happen in the future at and near the location the existing nuclear plants of Taipower Company. Meanwhile, considering the distribution of the oceanic trenches around the island as well as adding reasonable margin, the plant decides the final design for the elevation of the plant. Related elevations of the design basis tsunamis of all nuclear plants operated by Taipower Company and the elevations of these plants are shown in the chart below.

(Unit: meter)

Name of NPP	Chinshan	Kousheng	Maanshan	Lungmen
Tsunami run-up height by FSAR (Note 1)	10.73	10.28	12.03	8.07
Ground elevation of the NPP	11.2	12.0	15.0	12.0

Note 1: According to the analysis of FSAR.

2. Adequacy of design basis flood

In accordance with the information in Table 2.4-4 in the FSAR for Lungmen NPP, the annual maximum precipitation data of one hour duration recorded by the Keelung hydrometric station from 1961 to 2006 are shown in Table 3.1. Even though the annual maximum precipitation data in recent years displays a slightly increasing trend, the annual maximum precipitation data in the last 40 years happening on Sept. 23, 1980, 107mm, is still far lower than the PMP figure, 310mm, adopted in the design basis flood for Lungmen NPP. Therefore, the design of the drainage capability for Lungmen NPP is adequate.

3.1.2 Provisions to protect against the DBF

3.1.2.1 Key SSC required to achieve safe shutdown state after the flooding

1. The ground elevation of the power block area is 12meters, which is higher than all probable tsunami heights described previously, including the elevation of the design basis tsunami triggered by an undersea volcano estimated by the FSAR for Lungmen NPP and the height of the tsunami induced by fault displacement estimated by NSC. Therefore, with existing design of elevations of all buildings, all onsite facilities would not be threatened by tsunamis.

2. As the description in FSAR 2.4.2.2, areas in the plant, except power block area, utilize drainage channels Nos. II and III to prevent flooding caused by extremely heavy rain. Moreover, the plant reexamines the record of the precipitation in recent years and does not see any PMP that exceeds

the design basis flood for the plant. Thus, the design of the drainage capability of the plant still has enough margins to deal with flooding caused by extremely heavy rain, so all onsite facilities would not be affected by flooding caused by storms.

3. After Fukushima accident, Lungmen NPP immediately followed the Recommendation 3 in WANO SOER 2011-2 (Recommendation 3：Verify the capability to mitigate internal and external flooding events required by station design) to complete verifying the adequacy of equipment and material needed to mitigate external and internal flooding by walkdown inspection. According to FSAR 3.4, the prevention design against flooding for the safety related structure system and components can be divided into two types based on the origin of internal flooding; one is to deal with the flooding resulting from water outside of buildings and the other one is to solve flooding caused by leaking from damaged equipment in buildings.

(1) Main preventive measures against internal flooding resulting from water outside of buildings are as below:

i. Make all exterior walls that are lower than the design basis of the plant against flooding thicker than 0.6 meters. Presently, the elevation of all buildings is 12.3 meters, except that of RBSW pump room, which is 12.0meters.

ii. All structure conjunctions of all buildings that are lower than the design basis of the plant against flooding have water stops.

iii. All penetration holes (doors) that are lower than the design basis of the plant against flooding are installed with water seal equipment.

iv. Coat all exterior walls that are lower than the design basis of the plant against flooding with water-proof material, and apply the material in a circle of diameter at least 150mm around each penetration hole.

v. Roofs of buildings are designed with a drainage system and weir walls to prevent massive flooding on building floors.

vi. Tunnels that are lower than the ground level do not penetrate exterior walls.

Water-proof function of foundations and exterior walls that are seismic class 1 and lower than ground level is basically completed by water stopping design. Generally speaking, structures of safety related systems as well as their components are all 30 cm higher than ground floor. The design of the plant against flooding also considers possible one resulting from rupture of storage tanks, so all entrances/exits of plant buildings are 30 cm higher than ground floor. With this design, water originating from rupture of onsite storage tanks would be drained before it could enter any buildings to cause damage to equipment inside.

(2) Preventive measures against internal flooding caused by leaking from damaged equipment in buildings are elaborated below in aspects of reactor building, control building, radwaste building, access control building, Reactor Building Service Water pump house, turbine buildings and auxiliary fuel building:

<u>Reactor Building</u> :

i. If massive flooding (e.g.: rupture of water-intake pipes for suppression pools) occurs, use water seal doors to prevent flooding from spreading to other regions.

ii. If the pipes of the circulating water system leak (e.g.: rupture of water-intake pipes for suppression pools), with the hint of sump warnings and the leaking detective system, the plant can isolate the systems that leak and further limit the amount of leakage. Moreover, there is a 20 cm margin to the height of the safety equipment base and this can prevent equipment from being affected by leaking.

iii. The actuation of manual fire equipment and the limitation of water storage in the pipe/tank will also mitigate flooding in the plant.

Control Building :

i. Flooding in a single safety sub-region in the buildings would not cause the safe shutdown function to be affected.

ii. High energy pipes that pass the control buildings are the main steam pipes and water-feeding pipes in the main steam pipe pathway connecting reactor buildings and turbine buildings. The main steam pipes in the control building area do not have any openings; the main steam pipes at the reactor buildings' ends are sealed and the openings of these pipes are located at turbine buildings. So, rupture of the main steam pipes or water-feeding pipes in all these areas would not cause any flooding in the reactor buildings.

Radwaste Building:

i. If flooding incidents happen, the radwaste building can collect and store a big amount of drained water. All drainage sumps are situated in underground water-tight areas. Drained leaked water from all buildings in the power block area is delivered via the underground waste corridor to the radwaste building. All penetration holes on the delivery routes are water-proof and sealed to prevent internal flooding from leaking to outside of the building.

Access Control Building:

i. Systems in Access control buildings would not cause massive flooding. The biggest type of pipe is chilled water pipe, whose diameter is 200 mm. If leaking occurs, the water will be drained as well as sent to the sump on the ground floor, and is released through two sump pumps.

Reactor Building Service Water pump house:

i. Malfunction of the Reactor Building Service Water system would not lead to flooding in the Reactor Building Service Water pump rooms.

ii. These pump rooms are designed to be able to provide flooding warnings in order to warn operators to adopt necessary measures when needed, so flooding incidents can be controlled and limited to be within the sub-region of RBSW system.

Turbine Buildings:

i. Circulating seawater system and Turbine Building Service Water system can cause massive flooding in the turbine buildings. Thus, the condenser pit is installed with water level alarm switch, which sends out both signals of flooding and of circulating water pump trip.

ii. If the alarm switch is not functional and therefore leaking resulting from pipe rupture cannot be detected or isolated, this could lead to flooding in the turbine buildings. However, the height of the flooding would not exceed EL (+)840 mm, so the flooding would not overflow to outside of buildings.

iii. All safety related components in the turbine buildings are located above EL (+)12300 mm, so flooding in the turbine buildings would not affect safety related components or impact safe shutdown function.

Auxiliary Fuel Building :

i. Flooding triggered by internal systems would not affect other safety related buildings or impact safe shutdown function.

Presently Lungmen NPP has not carry out fuel loading and is conducting PCT or POTP in order to ensure if the feasibility and functions of equipment meet the design requirements. After commissioning, all the flooding prevention equipment mentioned above will also be included in periodical testing and maintenance following quality control system and will be managed by MMCS.

3.1.2.2 Main associated design/construction provisions

1. The design of the elevation of main buildings in the plant is 12.3 meters, which is based on the total of the probable maximum tsunami run-up height and some reasonable margin. Not only can this design prevent the impact of tsunamis on the plant, but also avoid the direct influence on the safety system.

2. In response to probable maximum storms, the plant builds drainage channels based on hydrologic analyses and reroutes streams in the aspect of design, in order to solve runoff caused by probable maximum precipitation in the plant and further to protect buildings from flooding.

3. Lungmen NPP is in Gongliao District and within the watersheds of Shiding Stream and Shuangxi Stream. Soil and Water Conservation Bureau, Council of Agriculture, does not include either stream in the government's list of mudslide-prone streams; in addition, considering the natural environment conditions around the plant, the chance for Shiding Stream and Shuangxi Stream to trigger mudslides is really low. All excavation and development on all lands in the plant follow Water and Soil Conservation Technology Guidance as well as Water and Soil Conservation Manual in order to plan the design of facilities used to conserve water and soil. The design is also examined and proved by Soil and Water Conservation, Council of Agriculture. The landscape of the Lungmen NPP area is flat and slopes around nearby valleys and wild streams are not steep, either. There is no colluvium on stream beds and slopes on two sides of the plant are fully covered by vegetation. The watershed at the upstream is small and there is no collapse of rocks or lands. At last, water and soil conservation work is done in areas that have been excavated and developed, so there should be no concerns of mudslides in the plant area. Besides, to prevent new activities regarding land development in the plant area in order to decrease the risk of mudslides, the plant has added procedure 187.02--"Monitoring, warning, disaster prevention and mitigation procedure for active faults near the plant, precipitation, mudslide, and dip slopes" for mudslide monitoring, warning, preventing, and mitigating.

3.1.2.3 Main operating provision

The power block area has a drainage system, which includes side ditches around plant buildings, collecting pools, manholes, pipes, and etc, to discharge external flooding or accumulated water in the power block area caused by typhoons and extremely heavy rain. When external or internal flooring may happen, follow procedure 187.01--"Water accumulation/ flooding prevention and response during typhoons or extremely heavy rain" to plan in advance for prevention and response. Additionally, each building in the plant and emergency equipment areas has floor sumps and drainage pumps. When there is an abnormal water entry in buildings or these areas, the plant can monitor sump water level any time from control rooms or waste control rooms and follow procedure 233--"Inspection for abnormal water entry and leaking at sumps of buildings" to trace the origin of the water entry and to isolate it immediately in case it leads to flooding.

After Fukushima accident, the plant reviewed the drainage procedure for each building. Through revision and addition of related procedure, the plant can lower the chance of flooding and increase its capability to respond to flooding. If severe flooding resulting from natural events would happen in the power block area, follow procedure 528.03.01--"Flooding response" and the reactors take turn reducing power and achieve safe shutdown mode when needed, depending on the actual situations. If internal flooding happens, follow procedure 528.03.02--"Flooding response." In addition, due to the lesson learned, the plant adds procedure 528.03.03--"Emergency drainage operation during power outage and abnormal water entry in buildings." The plant also simulates measures to respond to power outage and internal flooding under the circumstance of severe natural events; the power station also plans about adopting mobile generators to provide temporary power source to sump pumps or mobile gasoline-driven engine drainage pumps during external flooding and a station blackout, so flooding can be drained to certain places that gather the water.

In order to enhance the mechanism of accident prevention and mitigation to lower damage, the plant has established handling procedure for flooding in buildings, emergency operating procedure for onsite flooding, typhoon-period operating procedure and other guideline regarding accident prevention and mitigation. Relevant procedures are as below:

Procedure 187.01--"Water accumulation/ flooding prevention and response during typhoons or extremely heavy rain": The main purpose of this procedure is to be fully prepared to prevent extremely heavy rain causes external or internal water accumulation during typhoon or extremely heavy rain warning periods. This procedure also describes methods of draining accumulated water once internal flooding occurs and includes response measures for different flooding situations based on the precipitation onsite, water level of drainage channels, and height of water accumulation on roads. The response process is shown in Chart 3-2.

Procedure 528.03.01--"Flooding response": When typhoons with extremely heavy rain (mountain floods), seawater encroachment, tsunamis, earthquakes, or combined natural events that may cause flooding seizing the plant, this procedure provides response measures to prevent internal flooding from affecting important equipment, to prevent flooding areas from expanding, and to protect the emergency reactor cooling system, ensuring the units to stay on a safe status and be able to recover after flooding recedes.

Procedure 528.03.02--"Flooding response": When flooding enters buildings or equipment pipes rupture in reactor buildings and floor sump pumps can not drain the water in time, internal flooding happens. Through the signs of and response measures for internal flooding listed in this procedure, operators make certain about the function of drainage pumps of sumps or add temporary drainage pumps to increase drainage capability, and further find out the origin of abnormal water entry and isolate it to control flooding. If flooding can not be effectively controlled, the plant has to stop motors and components that may be affected and cut off the power. If the safety of the plant operation is affected, immediately shut down reactors and achieve cold shutdown mode till the flooding is controlled or solved.

Procedure 528.03.03--"Emergency drainage operation during power outage and abnormal water entry in buildings": This procedure provides guidance about emergency drainage operation when there are power outage and abnormal water entry in reactor buildings during severe weather events, such as earthquakes, typhoons, tsunamis, and etc. The procedure prevents areas of water entry from expanding and directs how to drain the water, in order to further protect the safety of equipment, keep emergency reactor cooling related systems in operation, and make sure reactors stay in a safe status.

3.1.2.4 Other effects of the flooding taken into account

1. Consider synergistic effect of loss of offsite power:

   Power sources from outside of buildings of the station contain two systems 345kV and 161kV, which is at elevation of 29.8 meters. Both systems are far higher than the probable tsunami run-up height, so they would not inundated by tsunamis. If flooding indirectly causes loss of external power source, the plant still has 3 emergent diesel generators at each reactor building at elevation of 12.3 meters to provide power needed by emergency cooling systems. Moreover, the plant also has 1 gas-cooling emergent diesel generator (7^{th} EDG) in the auxiliary fuel building at elevation of

12.3meters, which is shared by the two units and can replace any emergent diesel generator (EDG) for one unit. The emergent diesel generators above are designed based on DBE (Design Base Earthquake), so they are strong enough to resist against DBE. Furthermore, the elevations of the buildings where they located are all higher than the probable maximum tsunami run-up water level, so they should not be seized by tsunamis.

Besides, as included in the mudslide information by Water and Soil Conservation Bureau, Counsel of Agriculture, Executive Yuan, the two streams near the plant, Shiding Stream and Shuangxi Stream, are not listed as mudslide-prone streams. And also based on the natural situation around the plant, the chance of either stream causing mudslides is very low, so as a result, the chance of the failure of offsite power systems resulting from mudslides and storms is also very low.

In response to the situation of tsunamis indirectly affecting offsite power supply, related review and response measures are detailed in the chapter 5 of this report "Loss of power sources and ultimate heat."

2. If offsite situations hinder/delay workers and equipment to arrive at the plant:

Onsite incidents can occur during office hours and off-duty hours:

(1) <u>If incidents happen during office hours:</u>

i. Other than the workers that are already on duty, workers from the training shift at the simulator center and standby support shift workers (mostly licensees) can be on duty and assist with operation and handling of the units.

ii. All workers from the maintenance department and long-term contractors should be onsite in the future during office hours. Therefore, maintenance manpower can reach around a hundred people, which is enough for meeting the demand of equipment maintenance during emergency.

iii. There are 8 workers from fire-fighting shifts in day shift. Additionally, emergency response team would organize people into standby emergency fire-fighting manpower.

(2) <u>If incidents happen during off-duty hours:</u>

i. Most operators live in the dormitory for singles, so they can be first informed to assist with the operation of reactors. Moreover, the plant has planned to build family dormitories for operators in Gongliao and Shuangxi regions. The workers in these two regions can also enter the plant first to help if plant workers on the next shift can not arrive in time in the future.

ii. Most maintenance (mechanics, electricity, instruments, and maintenance) workers live in the standby dormitories for singles. They can be emergently mobilized to perform equipment rescue and repair work, In the future, workers from the maintenance department who live in the family dormitories in Gongliao and Shuangxi regions can also be notified to come into the plant to aide emergency response. Furthermore, in the maintenance contracts signed by both the power station and these supporting contractors, emergency rescue and repairing work detail is included, so the plant can ask these supporting contractors to send workers nearby to help during emergency.

iii. Presently fire-fighting shift manpower is acquired via outsourcing. 6 fire-fighting workers remain onsite during plant off-duty hours. All the fire-fighting workers are local residents of Lungmen, so they get to the site quickly once there is an emergency. Furthermore, security guards working onsite can join to assist with emergency related work.

iv. If off-site road can't be accessed due to earthquake, the station shall report to National Nuclear Emergency Response Center and apply for engineering corps' support for rush repair of the damaged road so as to restore the road access or request to utilize helicopter to transport the personnel and materials for rush repair or deliver the medical first aid.

3.1.3 Compliance of the plant with its current licensing basis (CLB)

3.1.3.1 Licensee's organization to ensure compliance

In response to natural disasters, such as tsunami, storms, mudslides, and etc, the plant not only established Section 3.1.2.3 -- "Main operational procedure for warning and mitigating flooding," containing the three emergency operating procedures (187.01- "Water accumulation/ flooding prevention and response during typhoons or extremely heavy rain," 528.03.01--"Flooding response," 528.03.02--"Flooding response," and 528.03.03--"Emergency drainage operation during power outage and abnormal water entry in buildings."), but also set up disaster prevention and mitigation procedure for the plant to follow during normal operation period and during special time period when natural disasters are expected to affect the plant, in order to lower/ mitigate the potential damage the disasters may cause:

Procedure 187--"Operation during typhoons": Every year before the typhoon season or the end of May, the Industrial safety division will send a checklist to each department for them to conduct investigation and make improvement; moreover, because typhoons can slam the site area, the plant has established a typhoon emergency response team as well as related inspection operating procedure, such as Fig. 3-3- "Typhoon emergency response procedure" for each department to comply with in order to decrease potential damage caused by typhoons.

Procedure 528.02.01--"Reactor operation during typhoon warning period": Considering the strong winds carried by typhoons, the plant faces more threat than it does in a normal weather condition. Once main or auxiliary transformers in the units can not function due to typhoons, the power needed to complete safe shutdown can only be supplied from offsite power sources or onsite emergency diesel generators; to prevent the onsite power supply from being affected during typhoons, this procedure, based on the technical specification, lays out in detail about operation dealing with typhoons of different intensity, such as Appendix 3-1- "Procedure for operation during typhoon periods" for operation workers to follow.

Procedure 528.04—"Operation during tsunami warning period": this procedure provides guidance about operating reactors after tsunami warnings are issued and when tsunamis seize the plant. Operators need to make certain sea water level is not lower than the lowest water level (-1.33meters /-5.34meters) of the circulating water pump or of the seawater pumps in reactor buildings when the following situations happen: there is abnormal low (big receding tides) or high water level (flood tides) at the seawater inlet, Central Weather Bureau issues tsunami bulletins or earthquake warnings, the circulating water pump operates abnormally, or electric current or pressure at the outlet fluctuates or increases. If sea water level is lower than the lowest water level of the circulating water pump or the sea water pumps in reactor buildings, operators respond, depending on the actual situations, complying with procedure 501.04--"Reactor emergency shutdown," 501.1--" Recover reactors after emergency shutdown," 520.01--"circulating water pump skipping," 515.04--" Response to loss of seawater systems in turbine buildings," 515.02--"Response to loss of seawater systems in reactor buildings," and etc. in order to keep the reactors staying on a cooling status till Central Weather Bureau dismisses tsunami warnings.

3.1.3.2 Licensee's organization for mobile equipment and supplies

As stated in the Section 3.1.1.3 – "Conclusion of appropriative DBF," the potential tsunami run-up height at the plant is lower than the tsunami run-up elevation in the design basis, so this ensures important buildings and equipment would not be inundated by tsunami. Also, after reviewing record of the past 30 years, it is noticed that the onsite potential maximum rainfall is not higher than the PMP of the design basis for the plant, so the designed drainage capability of the plant is appropriative. Therefore, after evaluating the design basis in current license, it is concluded that no flooding would occur around plant buildings.

The existing mobile equipment for mitigation responding to any accidents and procured before June 30, 2011, is guided by procedure 186.01--"Important guidelines for disaster prevention and mitigation" and is specified in Chart 3-2- "Existing disaster prevention and mitigation equipment at Lungmen NPP." After the lesson learned, the plant has conducted a comprehensive review on the whole power station based on the request of the Atomic Energy Council and guidance of Taipower Company and has further planned and expanded mobile equipment for mitigation to respond to any accident conditions as Chart 3-3- "Additional procurement of disaster prevention and mitigation equipment at Lungmen NPP to respond to a design basis accident similar to the Fukushima Accident."

Under required compatible condition, the power station, Chinshan NPP, and Kuosheng NPP will support and supply mobile mitigating equipment when needed.

3.1.3.3 Deviations from CLB and remedial actions in progress

According to the "Lungmen NPP Tsunami Prevention Capability Review Report" by Taipower Company Nuclear Technology Division, presently Lungmen NPP is considered to have enough capability to sustain the design basis tsunami. Currently the plant is under construction, so it can increase its flooding prevention capability if some deviations are improved. Related deviations are outlined as follows:

- Penetration holes on interior walls in buildings basically have no direct relation with the routes tsunamis may seize the plant. However, if tsunamis can invade buildings via gaps near any openings on exterior walls, then whether all room doors are water sealed and whether penetration holes on interior walls and floors are sealed become important. The reason is that flooding will then be able to be restrained in a single system and would not spread to other systems, so consequently the function of safe shutdown can be maintained. In walkdown inspection on spots of the underground exterior walls of control building structures where cable pipes penetrate, leaking and permeating are found. These are mainly because all the water streams from cable pipes, not originating from tsunamis. Even the amount of leaking can not be compared with tsunamis since the pipe diameters and the amount of leaking are relatively small, these deviations still need to be handled, especially those near electricity panels or places that need to stay away from water.
- Structures in the inlet area are related to safety of the plant that may influence the safety of the plant when the flooding resulting from tsunamis seize are the RBSW pump houses; the designed strength of the water seal doors of the structures in the pump house areas can sustain water

pressure up to 12100 kg/m^2. On top of that, if the impact force of tsunamis is bigger than the strength, the plant can enhance the sustainability of the doors (D4) at the pathway on the first floor in the pump houses. In addition to the water seal doors that can keep water away from the pump houses, penetration holes at pipes at these pump houses will also be sealed with material required by the plant after installation each time, so flooding on the first floor brought by tsunamis would not flow into the pump houses or make the sealing material rupture due to unsustainability of the water pressure. As a result, the function and normal operation of safety related equipment in the pump houses would not be influenced. Through walkdown inspection, in the pump houses, all openings have been sealed after pipe installation, except the openings for the installation of the water level gauges in the feedwater areas as well as those for drain flanges that drain water in the pump houses. By far, after the inspection, the plant has installed two check valves at the drain flanges, which can prevent water in underground sumps from permeating into the pump houses due to the water pressure of tsunamis. As for the openings for water level gauges, they still need to be sealed with the required material in case water flows into the pump houses. Furthermore, in order to ensure no flooding would appear in the pump houses, the plant needs to make certain the sealing material for openings can sustain the water pressure caused by tsunamis or to directly enhance the openings with stainless steel pieces on the inner side or on both the inner and outer sides.

- The inlet of Lungmen NPP is located at Yanliao Bay. The bay is surrounded by coral groups on the outside and protected by two groins at elevation of approximately 8.2 meters on the inside, with one in the north and the other one in the south. The coral groups and groins can protect the pump houses in the inlet area. The elevation of the ground in the inlet area, 0.5 meters, is lower than that of the power block area and is designed with water sealing function, so normal operation of safety related equipment can be ensured even if tsunamis seize. However, if tsunami run-up height reaches at elevation of 8.57 meters, the exterior walls of RBSW pump houses will sustain additional water pressure of approximately 3.3 meters. Further, tsunamis do not only come with hydrostatic pressure but also with impact force. The completeness of the RBSW pump house structure needs to be inspected with the impact force, and the plant will decide whether enhancement and improvement measures need to be planned and added based on the speed of tsunamis approaching the shore near the plant after the completion of the tsunami simulation by Sinotech Engineering Consultants, LTD or Dr. Wu from National Central University.

3.1.3.4 Specific compliance check already initiated by the licensee

1. Having planned in RAP-LM-01-12-001, the plant will add gas turbine generators of total capacity of 120MW at the switchyard at elevation of 29.8 meters, so they can be connected to 161 kV GIS and through 161 kV RAT1 as well as RAT2 transformers to provide power to two reactors during station blackout. Besides, in order to increase the reliability of transmitting power to reactor safety systems from gas turbine generators during station blackout, the plant plans to add 4.16kV independent transmission lines at the spot where each turbine generator at the switchyard sends out power, in order to transmit power directly to the safety related medium voltage switchboxes from turbine generators, such as 4.16kV S4 BUS.

2. According to the evaluation result of a simulation of probable maximum tsunamis by the Nuclear Plant Tsunami Evaluation Team, elevation of main buildings is not affected by tsunamis. Nevertheless, to increase defense in depth to prevent external flooding from entering buildings resulting from storms as a result of extreme climate, related improvements conducted by the plant via enhancement measures are as follows:

(1) RAP-LM-02-09-001: the plant will install flood barrierplates of 1 meter in height at the doors on ground floors directly connecting to the outside of buildings at the following places: reactor buildings, control buildings, diesel fuel tanks, auxiliary fuel buildings, fire-fighting pump houses, and RBSW pump houses. The plant is now planning to build tsunami wall to prevent plant site from tsunami attack, so the installation of flood barrierplates at the external gates will be suspend.

(2) RAP-LM-02-06-002: to prevent flooding from flowing into auxiliary fuel buildings via the radwaste building, the plant will install flood barrierplates of 1 meter in height at the tunnel where the radwaste building enters auxiliary fuel buildings. The plant is now planning to build tsunami wall to prevent plant site from tsunami attack, so the installation of flood barrierplates at the external gates will be suspend.

(3) RAP-LM-02-06-001: to prevent flooding from flowing into reactor buildings /control buildings via the radwaste building at EL 12300, the plant will install flood barrierplates of 1 meter in height at the tunnel where the radwaste building enters reactor buildings /control buildings. The plant is now planning to build tsunami wall to prevent plant site from tsunami attack, so the installation of flood barrierplates at the external gates will be suspend.

(4) RAP-LM-02-05-001: to prevent flooding from flowing into reactor buildings /control buildings via access control buildings at EL 12300, the plant will install flood barrierplates of 1 meter in height at the passageway where access control buildings at EL 12300 enter reactor buildings. The plant is now planning to build tsunami wall to prevent plant site from tsunami attack, so the installation of flood barrierplates at the external gates will be suspend.

3. After the Fukushima accident, the plant immediately reviewed the design basis for protection against flooding as well as the drainage capability of the plant. As shown in historic information by Central Weather Bureau, the capability of the drainage trenches at Lungmen NPP is big enough to respond to storms. Furthermore, the plant also reviewed the drainage capability inside buildings and the details are as below:

(1) reactor buildings :

i. primary containment: There are a total of 4 sump pumps. Each pump has a 33 m^3/hr drainage capability, so the total capability is 132 $m^{3/}$ hr.

ii. secondary containment: There are a total of 16 sump pumps. Each pump has a 33 m^3/hr drainage capability and the total capability is 528 $m^{3/}$ hr.

iii. diesel building: There are a total of 2 sump pumps. Each pump has a 33 m^3/hr drainage capability and the total capability is 66 $m^{3/}$ hr.

(2) control buildings : There are a total of 14 sump pumps. The drainage capability of each of the first 8 pumps is 33 m^3/hr and that of each of the rest 6 pumps is 10m^3/hr, so the total capability is 324 m^3/hr.

(3) auxiliary fuel buildings : There are a total of 6 sump pumps. Each pump has a 33 m^3/hr drainage capability and the total capability is 198 m^3/hr.

Aside from the existing sump pumps, each building can also use the drainage pumps prepared in advance for temporary drainage to speed up the recovery of the functions of the equipment on the ground floor of each building.

4. After the Fukushima Accident, Taipower Company has finished the investigation on both the oceanic and terrestrial geographic landscapes near the plant and again reviewed the tsunami design basis as well as the safety of plant facilities reported in FSAR. According to the report "Influence of tsunami induced by potential massive scale of earthquakes over the station" published by the NSC Tsunami Simulation Study Group on Aug. 19 in 2011, the potential tsunami run-up height of the plant is lower than the elevation of the tsunami run-up design basis. Current design of the plant elevation is built on the statistic calculation of historic weather record of the neighborhood of the plant as well as on the consideration of the height of the historic tsunami that happened in this region and may seize the plant. Additionally, the design of the plant also takes the distribution of the oceanic trenches near the island into account, adding reasonable margin to be one elevation design basis of the plant. Related design basis of both tsunami elevation and plant elevation is detailed in Section 3.1.1.3 "Conclusion of appropriative DBF."

3.2 Evaluation of the margins

3.2.1 Envisaged additional protection measures based on the warning lead time

1. Tsunami lead time and additional protection measures

In order to fight for tsunami lead time, Taipower Company is planning on establishing a network between the earthquake and tsunami warning system of Central Weather Bureau and Lungmen NPP as well as on setting up the warning and maintenance mechanism of the plant. The network is continuously gathering and sending information for the seismological center of Central Weather Bureau to use as a related improvement reference. Besides, to be able to deal with the impact of different natural disasters in advance, the plant has included all protection measures for prevention, response, and enhancement in the procedure as follow:

Procedure 528.04-- "Operation during tsunami warning period": the plant needs to watch the following situations and regard them as signs of starting emergency responses, and further judges whether tsunamis would seize the plant.

(1) Abnormal low (big receding tides) or high water level (flood tides) at the seawater inlet.

(2) Central Weather Bureau tsunami bulletins. (Appendix 3-2)

(3) Earthquakes as well as earthquake warnings.

(4) Abnormal operation of the circulating water pump, or fluctuation or increase of electric current or pressure at the outlet.

If tsunami will slam the plant and are expected to cause damage after judgment, the plant will comply with procedure to enter cold shutdown status. However, if there is not enough time to respond, the plant will abide by EOP to manually trip the reactor, which is to lower the pressure and enter cold shutdown status. If tsunamis are very likely to seize, the plant will immediately order all workers at seawater pump houses to evacuate and move to the inside of the plant to gather.

When tsunamis affect the plant area, the plant will comply with the Taipower Company Emergency Response Plan, the 1400 series procedure, based on the level of influence; the plant and Taipower Company will also start mobilization workers. If there is a possibility that damage would expand, the plant will abide by the emergency response plan to establish Central Disaster Response Center and to mobilize government related agencies and organizations to respond, based on actual situations.

2. Additionally, warnings regarding extremely heavy rain or flooding include monitoring and protection response. These are explained with the following procedure:

Procedure 528.02.01--"Reactor operation during typhoon warning period": based on the warnings of typhoon category issued by Central Weather Bureau, and on the consideration of the measured speed of winds at the plant as well as the reliability of power supply, including offsite power and emergency diesel generators, the plant needs to reduce the power of reactors to the level when generators can be normally disconnected from grid or to shut the reactors down when necessary.

Procedure 187--"Operation during typhoons": Before the typhoon season or May every year, the Industrial safety division will send a checklist to each department for them to conduct inspection walkdown and make improvement to lower potential damage caused by typhoons; moreover, the plant needs to establish a typhoon emergency response team 18 hours prior the arrival of typhoons. The superintendent/ plant director assigns work to related departments as well as their workers based on previously appointed work, and the workers start all inspection as well as repair for the arrival of typhoons in order to lower potential damage and ensure the units to operate safely.

Procedure 187.01--"Water accumulation/ flooding prevention and response during typhoons or extremely heavy rain": the main purpose is to be fully prepared to prevent external/ internal water accumulation/flooding caused by extremely heavy rain during typhoons or extremely heavy rain warning period. The methodology is using onsite precipitation, water level at drainage channels, and height of accumulated water on roads as basis to plan about response measures in advance.

Procedure 528.03.01--"Flooding/Deluge response": When Central Weather Bureau issues early flooding forecasts, tsunami warnings, or extremely heavy rain warnings, or when the system operation department of Taipower Company informs the plant warnings regarding typhoons/ extremely heavy rain and the water level of onsite drainage trenches as well as water accumulation on the plant ground gradually increases, the plant will obey this procedure to monitor all sump water levels and to inspect operation of equipment as well as water accumulation at all low spots. Moreover, the plant will comply with Appendix 2-3- "External/ internal flooding handling procedure" to conduct inspections. If there is a concern that internal flooding may affect important equipment, the plant needs to have sandbags prepared at those concerned spots to prevent the influence of flooding. Moreover, when there are flooding warnings, all water seal doors and water seal hatches in all buildings need to be closed to prevent important equipment from being affected by internal flooding or to stop flooding areas from expanding.

Procedure 528.03.02--"Flooding response": upon warnings about high water level in the condenser pit of turbine buildings, warnings about high water level in the RBCW heat exchanger room in any areas of the control buildings, or warnings about high water level in other sumps of each building, the plant ensures functions of drainage sump pumps or add temporary drainage pumps to increase drainage capability, and to verify the origin of flooding as well as isolates it to control flooding.

Procedure 528.03.03--"Emergency drainage operation during power outage and abnormal water entry in buildings": when water brought by typhoons or extremely heavy rain enters buildings, the emergency response team of each building complies with the procedure to send workers to pile sandbags at entrances/exits of related buildings and to remove the accumulated water inside the buildings in order to keep flood from entering. If accumulated water enters reactor buildings, the plant needs to make sure that the floor drain sump pumps (4D and 4E) at the ground floor corridors of reactor buildings can function normally; next, the plant has the accumulated water at the ground floor corridors of reactor buildings drained and sent to waste treatment buildings for storage or handling. If reactors lose power supply, motors of these drain sump pumps (4D and 4E) can receive power through emergency buses or 480 VAC temporary emergency diesel generators to keep the drain sump pumps functioning. However, if the motors of these drain sum pumps can not receive power supply, responsible departments of each building can conduct emergency drainage by utilizing emergency mobile diesel generators, sump pumps and related cables, drainage pipes, ventilation equipment, diesel fuel and temporary lighting equipment.

3.2.2 Weak points and cliff edge effects

The design for the height of the building ground level at Lungmen NPP is based on the total of some safety margin and three figures from FSAR, which are maximum tsunami run-up height, maximum wave height, and maximum flood height. Hence, the height of the building floor height is enough for fighting against DBF.

Using the analysis methodology nuclear power plants in Japan adopted as a reference, Taipower Company uses the event tree method to look for Cliff Edge and safe margin. The result of Lungmen NPP Seismic Case Study is detailed in Appendix 3-3, but it is first summarized as below: the background situation in the case study is that, after the plant loses off-site power due to undersea earthquakes, reactor scram is completed and emergency diesel generators start operating. Afterward, the earthquake-triggered tsunami seizes the shore near the plant and causes the plant to lose ultimate heat sink. Under this condition, in order to reach the final goal of the reactor core shutdown cooling, the plant must complete the following issues in order, containing RCIC successfully feeding water into the reactor core, utilizing fire-fighting feedwater system to perform water feeding via the pipes of RHR C, successful operation of containment overpressure protection system, and so on.

The analysis result shows the complete successful path of reactor core shutdown cooling is: after the tsunami causes loss of ultimate heat sink, RCIC system starts its short-term water feeding function, which gives operators the time needed to manually start SRV and set up ACIWA system. Thereafter, ACIWA system provides long-term water feeding to reactors and COPS offers containments long-term heat removal, so reactors can reach cold shutdown mode. Because there is only one successful path of reactor core shutdown cooling, its cliff edge is the cliff edge of the tsunami case study. The safe margin of each issue should take the minimum value of those issues as the representative and that is 0.3 meters, which is acquired through deducting 12 meters from 12.3 meters. The cliff-edge as defined should take the minimum vibratory intensity value of those issues as the representative and that is 12.3 meters.

3.2.3 Envisaged measures to increase robustness of the plant

After the Tsunami Accident, Taipower Company immediately established a nuclear plant tsunami evaluation team to conduct an investigation on the oceanic and terrestrial geographic landscapes near the plant, once again review the tsunami design basis in FSAR and plant facility safety, and complete the following improvement measures:

1. The plant has re-evaluated the investigation and analysis on probable tsunami run-up height, and confirmed that the tsunami run-up height chosen by FSAR at the time the power station was building is safe enough.
2. In the process of evaluation, even though the elevation of safety related RBSW pump house is confirmed to be 5.3meters, equipment areas below elevation of 12meters already are designed with water-proof function, which is higher than the run-up height of the design basis tsunami, 8.07meters, so these equipment areas has enough protection capability against tsunami .
3. Lungmen has finished reviewing onsite flooding and onsite drainage function and again examined the historic record of the daily maximum rainfall to ensure that the drainage trenches of the plant can withstand storms resulting from extreme weather and there is no concern of flooding. The design of the drainage capability of the plant is based on the intensity of once every 100 year precipitation.
4. Aiming at the historic records of onsite environment and geography as well as at past daily maximum rainfall, the plant reviewed its prevention against mudslides. Furthermore, the plant has accomplished new procedure, which specifies related response measures the plant needs to adopt during extremely heavy rain warning periods or during periods of typhoons of above moderate intensity level; the new procedure also requires the plant to routinely at scheduled times send workers to monitor the water level of onsite drainage trenches as well as hourly precipitation, in order to prevent water accumulation onsite.
5. The power station has drawn maps of both inundation-prone areas inside and outside of buildings in order to plan drainage methods in advance; the station has added maps of flooding prevention for both inside and outside of buildings to further improve the drainage capability of buildings. Additionally, the power station also completed lists of all drainage routes and their capability for both inside and outside of buildings.
6. It is also confirmed that the operating procedure has required in detail the reliability of related sealing quality control mechanism after penetrating related work and asked no similar problems would happen again. The station has also finished walkdown inspection on the design and completeness of water-proof doors as well as barriers, including well grids and etc., in buildings, to ensure all water-proof mechanism can function normally after the completion of penetration sealing.
7. The plant is now planning to build tsunami wall (top of wall = EL. 14.5 m) to prevent plant site from tsunami attack.
8. When there is no power supply, the plant will utilize engines to get drainage pumps to operate at flooded areas in buildings. The power station has finished related standard operating procedure and has procured 6 engine-driven mobile, maneuverable drainage pumps as well as 12 electric drainage pumps, which can work with gasoline/diesel generators. Also, the plant will add 2 maneuverable drain sump pumps driven by engines and 20 electric drainage pumps, to increase maneuverable drainage capability.

Reference:

A. Government document

1. “Influence of Tsunami Induced by Potential Massive Scale of Earthquakes on the Nuclear Power Station in Taiwan” (National Science Council)

B. Labor and organizational document

1. WANO SOER 2011-2: --“ Fukushima Daiichi Nuclear Station Fuel Damage Caused by Earthquake and Tsunami Response Template” (WANO)

C. Taipower document

1. “Lungmen NPP Final Safety Analysis Report” (Taipower Company)
2. “Lungmen NPP Safety Protection Report” (Taipower Company)
3. Procedure 187.01--“Water accumulation/ flooding prevention and response during typhoons or extremely heavy rain”
4. Procedure 233 --” Inspection of abnormal water entry and leaking at sumps of buildings”
5. Procedure 528.03.01--“Flooding/Deluge response”
6. Procedure 528.03.02--“Flooding response.”
7. Procedure 528.03.03--“Emergency drainage operation during power outage and abnormal water entry in buildings.”
8. Procedure 187--“Operation during typhoons”
9. Procedure 528.02.01--“Reactor operation during typhoons warning period”
10. Procedure 528.04--“Operation during tsunami warning period”
11. Procedure 186.01--“Disaster prevention and mitigation”
12. --“Lungmen NPP Tsunami Prevention Capability Review Report” (Taipower Company)

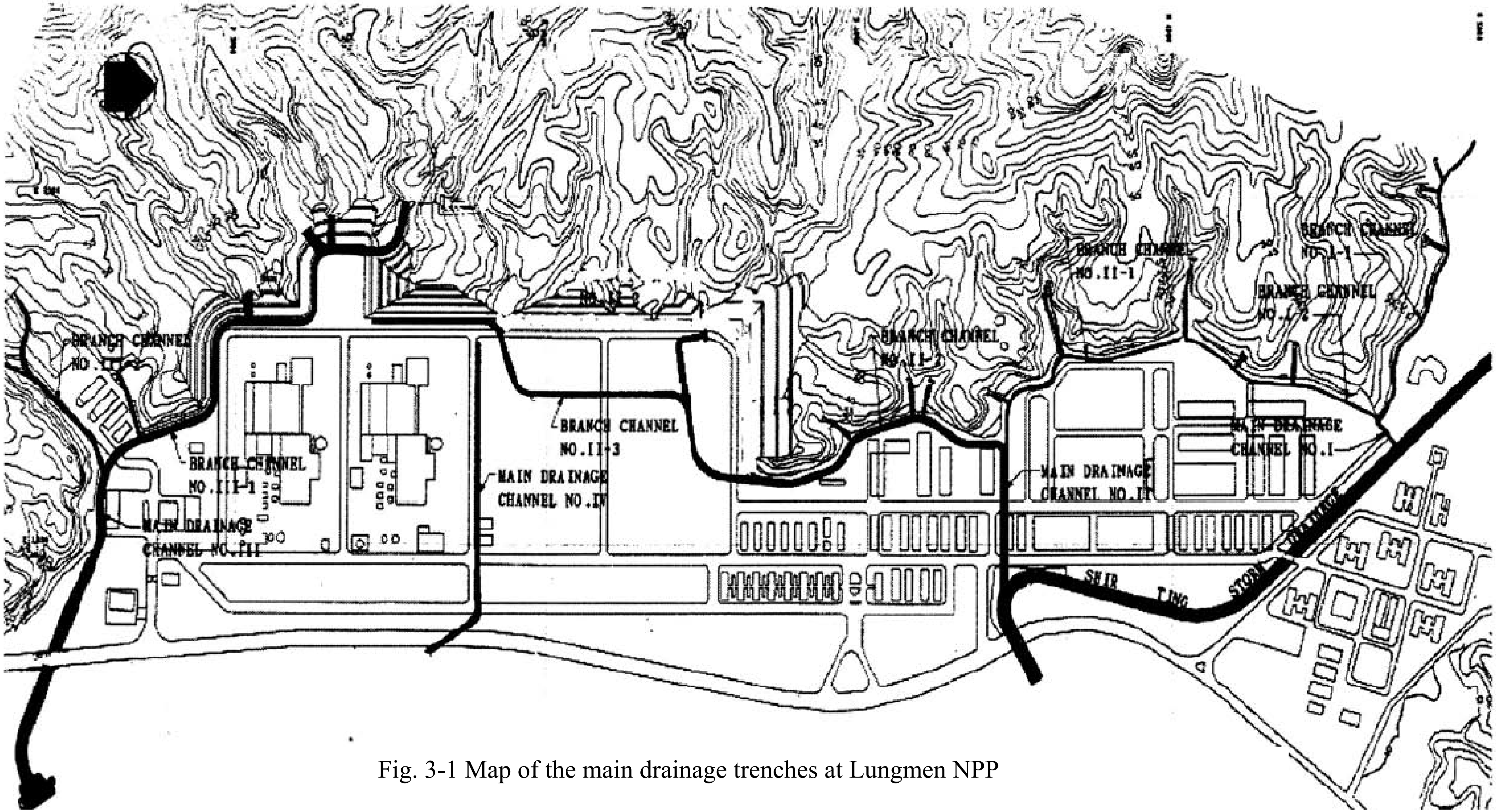


Fig. 3-1 Map of the main drainage trenches at Lungmen NPP

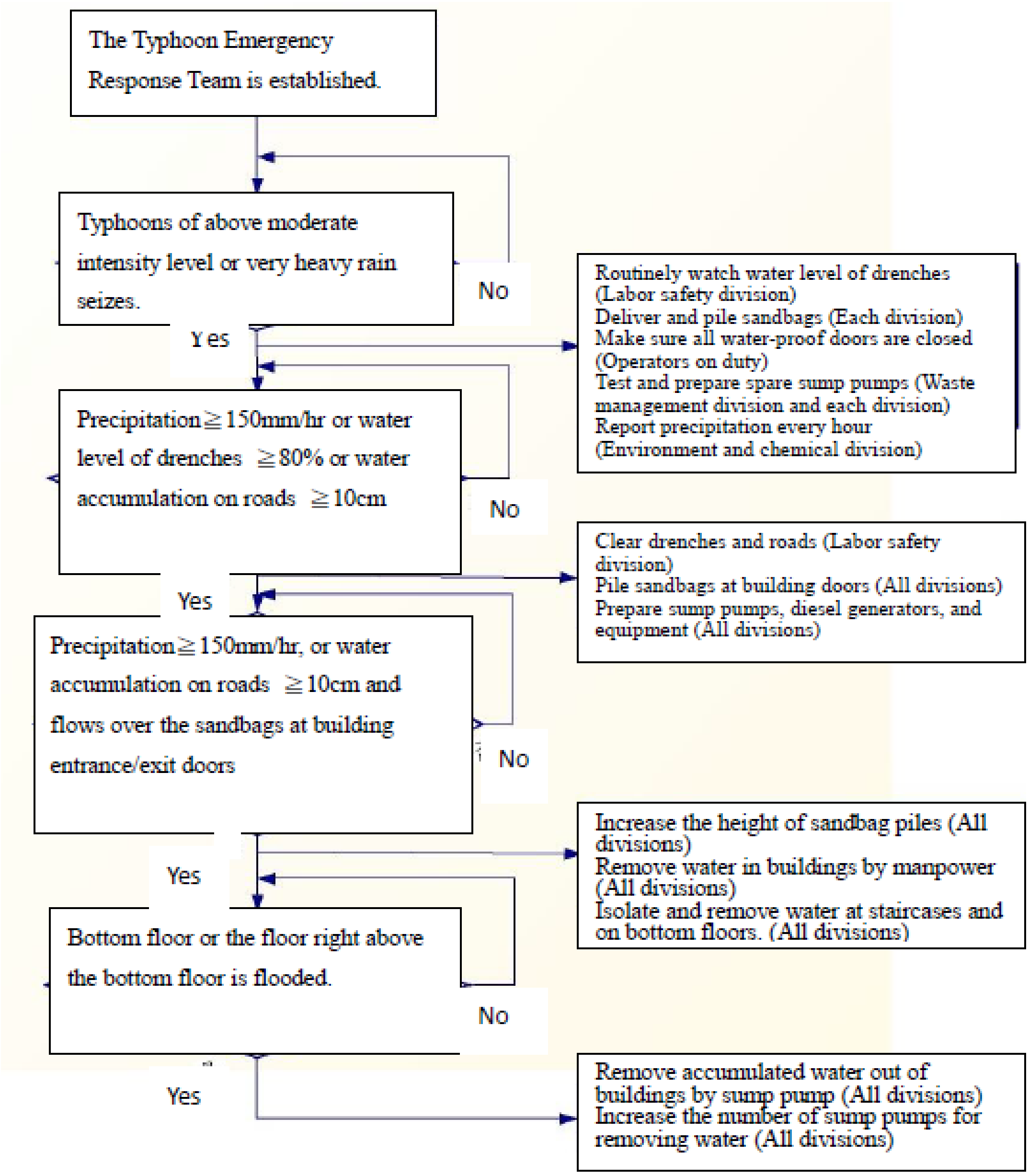


Fig. 3-2 Process of accumulation prevention and response during typhoons and extremely heavy rain

spots)

Fig. 2-3 Typhoon emerge

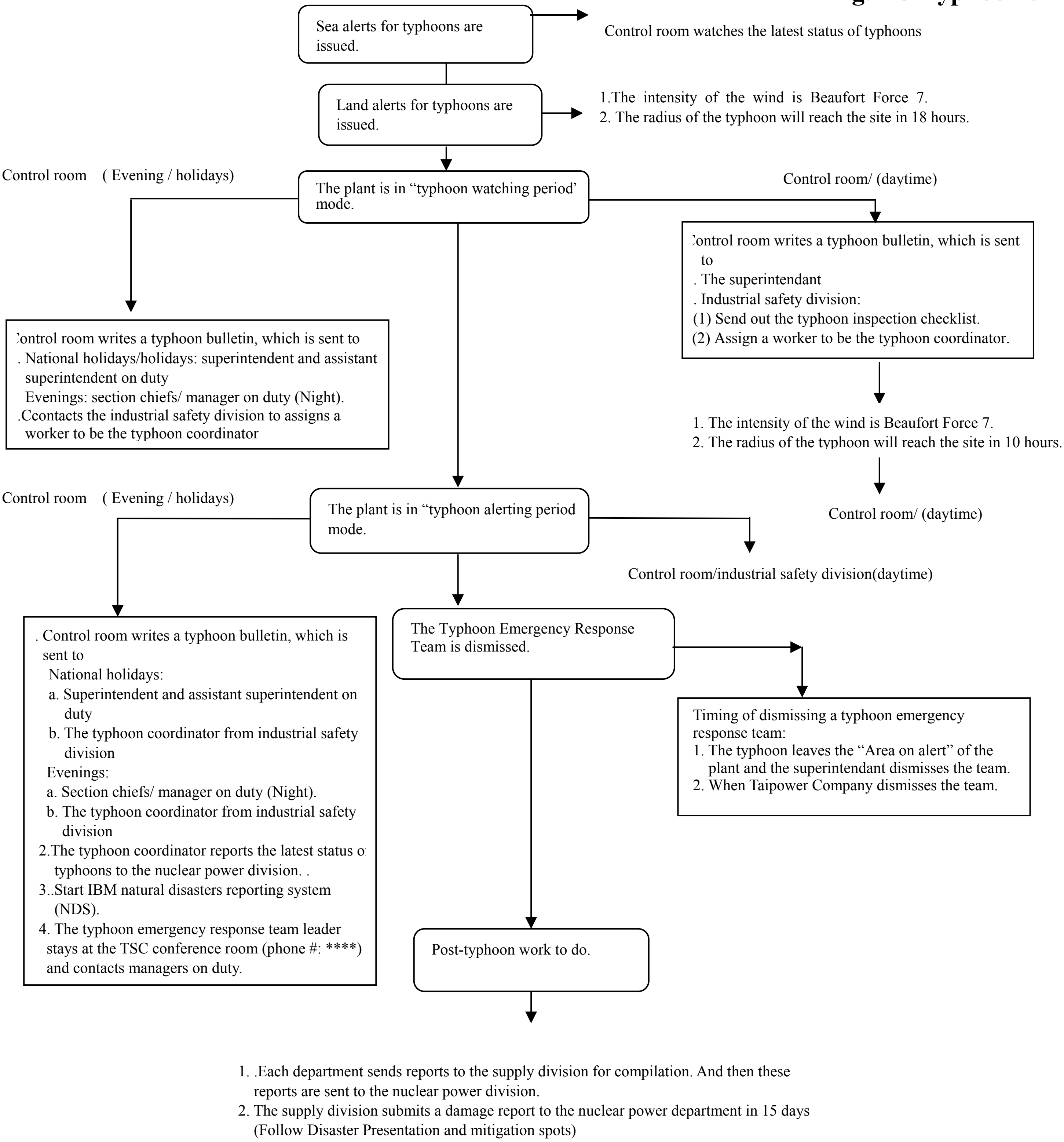


Fig. 3-3 Typhoon emergency response procedure

Chart 3.1 Maximum Hourly Precipitation Every Year at Keelung Weather Station in 1961-2006 (Unit: mm)

Year	**1961**	**1962**	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**
Precipitation (mm/hr)	62.1	47.5	40.5	32.8	71.4	43.4	59.0	53.0	43.0	47.0
Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Precipitation (mm/hr)	34.5	33.4	55.0	58.5	45.2	33.0	57.2	80.0	54.6	107.0
Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Precipitation (mm/hr)	66.5	30.0	54.8	76.0	70.8	55.8	95.3	81.1	33.5	56.7
Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Precipitation (mm/hr)	98.0	32.0	66.5	78.5	28.0	69.5	40.5	83.0	67.5	70.5
Year	2001	2002	2003	2004	2005	2006				
Precipitation (mm/hr)	52.5	53.0	34.0	85.5	61.0	38.5				

Chart 3.2, --"List of Lungmen NPP existing prevention and mitigation equipment"

Item #	Item name	Quantity	Location	Department in charge	Item #	Item name	Quantity	Location	Department in charge
1	Emergency generator	1 unit	Tool room	Mechanics division	14	Short-wave communication system (PWT)	1 unit	Administration building and each building	Electric division
		2 units	Zhongsi warehouse	Electric division					
2	Drainage pump	3 units	Administration building	Mechanics division					
3	Mobile crane	1 vehicle	#2 RPVwarehouse	Mechanics division	15	Computer and the Internet	1 unit	Administration building	Computer division
	Forklift truck	2 vehicle	Container						
4	Forklift truck	1 vehicle	Maintenance factory	Maintenance division	16	Flashlight	10units	warehouse	Industrial safety division
5	Label tape	1 unit	Industrial safety division warehouse	Industrial safety division	17	Water-shielding sandbags	100 bags	Administration building simulation center, document control center	
6	Chemical fire-fighti	1 vehicle	#2 RPVwarehou		18	Telescope	2units	Industrial safety division	

	ng truck								
7	Fire-fighting water tank vehicle	1 vehicle	se		19	Oxygen detector	2 units	office	
8	Dry powder fire extinguisher	10 units			20	Inflammable gas detector	2 units		
9	Air breather	6 units			21	Anti-electrostatic shoes	__pair	Industrial safety division warehouse	
10	Emergency light	__ units	#2 RPVwarehouse		22	Triangle warning flag	2 units		
11	Smoke blower	__ units			23	Fire-fighting water pool （also used as a mitigation pool）	1 unit	Lover’s Lake	
12	Emergency ymedical	1 vehicle	#2 RPVwarehou		24	Drinking water,	1 unit	Restaurant	Supply division

	aid vehicle		se			foods, and other life necessities			
13	Emergency medical equipment and medicine	__1__ unit	Medical room		25	Other necessary goods, equipment, and facilities			Based on managers' decisions or discussion conclusion

Chart 3.3-- Additional procurement of disaster prevention and mitigation equipment to respond to a design basis accident similar to the Fukushima Accident

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
1	Mobile Diesel Generator	4.16 kV, 3Φ 1500 kW	Diesel	2 set	Supply power to 4.16 kV bus or RHR、RBSW RBCW water pump.	Warehouse of low level waste (EL:43.3m)	Procured	3 months	Elect.
2	Mobile Diesel Generator	480 V, 3Φ 200 kW	Diesel	2 set	SLC、FCS、SGT、CSTF、safety train of CVCF、Seal Pit of ultimate heat sink,	Switching yard (EL:29.8m)	Procured	3 months	Elect.
3	Mobile Diesel Generator	480 V, 3Φ 100 kW	Diesel	3 set	Supply power to 480 V PC/MCC for CVCF and DC battery charging	1 at outside of metal roll-up door of SGB (EL:12.3m) 2 at temporary fire-fighting station (EL:12.3m)	Procured	3 months	Elect.
4	Mobile Diesel Generator	380 V, 3Φ 100 kW	Diesel	1 set	OSC temporary power	Warehouse of low level waste (EL:43.3m)	Procured	3 months	Elect.
5	Gasoline Engine-Powered Generator	120/220V Rated Power: 7.2 kVA	Gasolin e	2 set	Electrical tools, temporary lighting	storage room of #1 ACB B3 (EL:-1.85m) Base room of administration building	Procured	3 months	Mech.

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
6	Gasoline Engine-Powered Generator	120/208 V, 3Φ 4W 10 kW	Gasoline	6 set	Sump pump	Warehouse of low level waste (EL:43.3m) Emergency pump room (EL:8.57m)	Procured	3 months	Elect.
7	Gasoline Engine-Powered Generator	120/220 V, 1Φ 10 kW	Gasoline	4 set	Sump pump ARM、communication	Warehouse of low level waste (EL:43.3m) Emergency pump room (EL:8.57m)	Procured	3 months	Elect.
8	Rectifier	Out Put: 125 VDC	NA	6 set	Convert 120VAC to 120VDC, for SRV operation	Warehouse of low level waste (EL:43.3m)	Procured	1 month	Elect.
9	Transformer	480 V/240 V	NA	6 set	Transfer 480 V to 240 V	Warehouse of low level waste (EL:43.3m)	Procured	1 month	Elect.
10	Engine Driven Water Pump	Suction/Discharge Dia: 4” Max. Lift: 25m Suction Depth: 5m Max. Pumping Rate: 1500L/min	Gasoline	2 set	Water suction and drainage	storage room of #1 ACB B3 (EL:-1.85m) Tool house at basement of administrating building	Procured	3 months	Mech.

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
11	Engine Driven Water Pump	Suction/Discharge Dia: 4” Max. Lift: 25m Suction Depth: 5m Max. Pumping Rate: 1500L/min	Gasoline	6 set	Water suction and drainage	Tool house of maintenance building (EL:24.9m)	2013/6	3 months	Mech.
12	Electrical Water Pump	110 V*1 220 V*1 Suction/Discharge Dia: 2”(50 ㎜) Max. Lift: 15m Max. Pumping Rate: 260L/min	Elect.	2 set	Water suction and drainage	Tool house at basement of administrating building / materiel and supplies room of ACB 2F	Procured	3 months	Mech./ waste
13	S.S. Submersion Pump	Output power: 5HP Discharge Dia: 4” Max. pumping rate: 0.95 m^3/min	Elect.	1 set	Water suction and drainage	storage room of #1 ACB B3 (EL:-1.85m)	Procured	3 months	Mech.
14	High Head S.S. Submersion Pump	Output power: 30HP Discharge Dia: 3” Max. pumping rate: 1.06 m^3/min	Elect.	4 set	Water suction and drainage SEAL PIT ultimate heat sink	storage room of #1 ACB B3 (EL:-1.85m)	Procured	3 months	Mech.

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
15	High Head S.S. Submersion Pump	Output power: 2HP Discharge Dia: 2” Max. pumping rate: 0.164 m^3/min	Elect.	2 set	Water suction and drainage	storage room of #1 ACB B3 (EL:-1.85m)	Procured	3 months	Mech.
16	Submersion Pump	220V, 3Φ Output power: 5HP	Elect.	3 set	Water suction and drainage	Tool house of maintenance building (EL:24.9m)	2013/6	3 months	Mech.
17	Submersion Pump	220V, 3Φ Output power: 2HP	Elect.	2 set	Water suction and drainage	Warehouse of low level waste (EL:43.3m)	2013/6	3 months	Waste.
18	Submersion Pump	Output power: 1HP 110V Dia: 2”(50 mm)	Elect.	1 set	Water suction and drainage	Warehouse of low level waste (EL:43.3m)	2013/6	3 months	Waste.
19	Submersion Pump	Output power: 1HP 110V Dia: 2”(50 mm)	Elect.	2 set	Water suction and drainage	storage room of #1 ACB B3 (EL:-1.85m)	Procured	3 months	Mech.
20	Submersion Pump	Output power: 1HP 110V Dia: 2”(50 mm)	Elect.	1 set	Water suction and drainage	Basement of dormitory A (EL:8.5m)	Procured	3 months	Elect.
21	Submersion Pump	Output power: 1HP 110V Dia: 2”(50 mm)	Elect.	1 set	Water suction and drainage	materiel and supplies room of ACB 2F (EL:17.15 m)	Procured	3 months	Waste.

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
22	2” Flexible Hose	Length: 20 m	NA	20 set	For sump pump	Warehouse of low level waste (EL:43.3m)	2013/6	3 months	Mech.
23	3” Hose	Length: 100 m	NA	12 roll	Water suction and drainage	Warehouse of low level waste (EL:43.3m)	2013/6	3 months	Mech.
24	Sand Bag	20 kg/bag	NA	1000 packs	Block water at doors	Office of Safety Div. (EL:12.3m)	Procured	3 months	Safety
25	Fire Tanker	12 tons	Diesel	1 set	Fire Protection (FP) (replace boron injection)	onsite fire station(EL:12.3m)	Procured	1 week	Safety
26	Chemical Foam Tender Fire Truck	6 tons	Diesel	1 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	1 week	Safety
27	Rescue Equipment Vehicle	12 tons	Diesel	1 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	1 week	Safety
28	Self-contained Breathing Apparatus	Conform to the NIOSH	NA	70 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	3 months	Safety
29	Dry Powder Extinguisher	Powder Type: ABC 20	NA	48 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	3 months	Safety

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
30	Engine Water Pump	15HP	Elect.	4 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	3 months	Safety
31	Inflatable water tank	10T/15T	NA	4 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	3 months	Safety
32	Explosion Proof Flashlight		Battery	50 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	3 months	Safety
33	Fire-fighter Coat		NA	10 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	3 months	Safety
34	Ambulance		Gasoline	1 set	Rescue	Infirmary of Lungmen construction office (EL:12.3m)	Procured	3 months	Safety
35	Anti-static Shoes		NA	10 pair	Fire Protection (FP)	Warehouse of Safety Div. (EL:12.3m)	Procured	3 months	Safety
36	Emergency Lighting Lamp		Battery	50 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	1 week	Safety
37	Fume Exhauster		Elect.	4 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	3 months	Safety

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
38	Dry Powder Extinguisher	Powder type: ABC 10	NA	20 set	Fire Protection (FP)	onsite fire station(EL:12.3m)	Procured	3 months	Safety
39	Four Type Gas Detector	B.W O_2, CO, H_2S, and flammable gas detection	Battery	5 set	Gas Detection	Office of Safety Div. (EL:12.3m)	Procured	3 months	Safety
40	Hydrogen Detector	H_2 Detection	Battery	10 set	H_2 Detection	Office of Safety Div. (EL:12.3m)	Procured	3 months	Safety
41	Life Jacket		NA	8 set	Under water operation	Pump room X 6 (EL:8.57m) Raw water pool X 2 (EL:116m)	2013/6	3 months	Safety
42	Lifesaving Buoy		NA	8 set	Drowning rescue	Pump room X 6 (EL:8.57m) Raw water pool X 2 (EL:116m)	2013/6	3 months	Safety
43	Floating Rescue Cord		NA	5 set	Drowning rescue	Pump room (EL:8.57m)	2013/6	3 months	Safety
44	Triangular Warning Flag		NA	10 bundle	Danger zone segregation	Warehouse of Safety Div. (EL:12.3m)	Procured	3 months	Safety

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon -sible Section
45	Emergency Medical Apparatus and Medicine	Emergency Medical Apparatus and Medicine	NA	1 set	Emergency Medical Treatment	Infirmary of Lungmen construction office (EL:12.3m)	Procured	3 months	Safety
46	Oil Stop Rope		NA	1 set	Oil leakage treatment	Pump room (EL:8.57m)	Procured	3 months	Envir.
47	Oil Leakage Prevention Tool Box		NA	15 set	Oil leakage treatment	Sewage treatment plant (EL:12.3m) Sea water electrolysis plant (EL:8.57m) water treatment plant (EL:12.3m)	Procured	3 months	Envir.
48	Chemical Leakage Prevention Tool Box		NA	10 set	Chemical leakage treatment	Sewage treatment plant (EL:12.3m) Sea water electrolysis plant (EL:8.57m) water treatment plant (EL:12.3m)	Procured	3 months	Envir.
49	Oil Decomposer		NA	100 gal	Oil decomposition	Sewage treatment plant (EL:12.3m)	Procured	3 months	Envir.

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
50	Leak Mending Material		NA	30 set	Tank leak mending	Sewage treatment plant (EL:12.3m) Sea water electrolysis plant (EL:8.57m) water treatment plant (EL:12.3m)	Procured	3 months	Envir.
51	Lifter Vehicle	Max. Load：150kg Max. Lift Height: 12m Max. Working Radius: 7m	Battery	1 set	Working aloft	#1RPV warehouse heavy equipment warehouse (EL:12.3m)	Procured	3 months	Mech.
52	Lifter Vehicle	Max. Load：200kg Max. Lift Height: 20m Max. Working Radius: 12m	Diesel (Battery)	1 set	Working aloft	Switching yard (EL:29.8m)	Procured	3 months	Elect.
53	Forklift Truck	5-tons x2 3-tons x1	Diesel	3 set	Transport heavy items	#1RPV warehouse heavy equipment warehouse (EL:12.3m)	Procured	3 months	Mech.
54	Mobile Crane Vehicle	80-tons	Diesel	1 set	Hoist and transport heavy items	#1RPV warehouse heavy equipment warehouse (EL:12.3m)	2013/6	3 months	Mech.
55	Mobile Crane Vehicle	30-tons	Diesel	1 set	Hoist and transport heavy items	#1RPV warehouse heavy equipment warehouse (EL:12.3m)	Procured	3 months	Mech.

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
56	Multipurpose Vehicle	Generator: 110/220 V, 24kVA (rated) Provide: Lighting, Air-compressor, Welding, Electrical Socket	Gasoline	12 set	Outdoor urgent repair	#1RPV warehouse heavy equipment warehouse (EL:12.3m)	2013/12	3 months	Mech.
57	Truck (or hoist truck)	25-tons	Diesel	1 set	Heavy item delivery	warehouse of Lungmen construction office material Div. equipment warehouse (EL:12.3m)	Procured	3 months	Mech.
58	Platform Truck	40-ft	Diesel	1 set	Heavy item delivery	#1RPV warehouse heavy equipment warehouse (EL:12.3m)	2013/12	3 months	Mech.
59	Small Excavator	TBD	Diesel	1 set	Plant road repair	#1RPV warehouse heavy equipment warehouse (EL:12.3m)	2013/06	3 months	Mech.
60	Manual Chain Hoister	0.5~3-tons	NA	20 set	Repair and maintenance	Tool house of maintenance building (EL:24.9m)	Procured	3 months	Mech.
61	Portable Nitrogen cylinder	Al Alloy Capacity: 5.2L	NA	6 set	Pneumatic valve operation	Calibration room of I&C Div. (EL:20.85m)	Procured	1 year	I&C

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
62	Mobile Engine Driven Compressor	Above 10 kg/cm^2	Elect.	2 set	Emergency supply of compressed air to SRV	Periphery of RB 31700 (EL:31.7m)	Procured	3 months	Mech.
63	Explosion Proof Tools	Explosion proof wrench set and Brass Hammer	NA	2 set	H2 explosion proof tool	Tool house of maintenance building (EL:24.9m)	Procured	3 months	Mech.
64	RBSW Motor	4.16 kV /745 kW (997 HP)	NA	1 set	Emergency RBSW motor replacement	Warehouse of low level waste (EL:43.3m)	Before Commercial Operation	3 months	Elect.
65	RHR Motor	4.16 kV /475 kW (636HP)	NA	1 set	Emergency RHR motor replacement	Warehouse of low level waste (EL:43.3m)	Before Commercial Operation	3 months	Elect.
66	RBCW Motor	4.16 kV /190 kW (255HP)	NA	1 set	Emergency RBCW Motor replacement	Warehouse of low level waste (EL:43.3m)	Before Commercial Operation	3 months	Elect.
67	P16 Fire Pump Motor	4.16 kV/261 kW (350HP)	NA	1 set	Emergency fire pump motor replacement	Warehouse of low level waste (EL:43.3m)	Before Commercial Operation	3 months	Elect.
68	Spare cable	High, Medium, and Low Voltage Cables	NA	1 batch	Emergency electrical wiring	Warehouse of low level waste (EL:43.3m)	161kV: Procured Others: Procuring	3 months	Elect.

No	Title	Specifications	Power (Fuel)	Quant	Usages	Location (Elevation)	Procurement schedule	Test Period	Respon-sible Section
69	Spare Communication Parts		NA	1 batch	Communication urgent repair	Warehouse of low level waste (EL:43.3m)	Procuring	3 months	Elect.

Appendix 3-1 Procedure for operation during typhoon periods

Timing of use: when the typhoon forecasts show that the radius of the typhoon with Beaufort Force 10 has reached Lungmen Nuclear Power Station alert area.(Note)

Action:

Intensity / Action / Situation	Mild/ Moderate typhoon	Severe typhoon
A	The plant operates in the alert mode.	Reduce power to turbine trip bypass set point of RPS in 3 hours. (CTP<40%)
B	Reduce power to below turbine trip bypass set point of RPS in 3 hours. (CTP<40%)	Reduce reactor thermal power to about 30% in 3 hours.
C	Reduce reactor thermal power to about 30% in 3 hours.	Disconnect from grid and stay in hot standby mode in 4 hours.
A+D or A+E	Disconnect from grid and stay in hot standby mode in 4 hours.	Disconnect from grid and stay in hot standby mode in 4 hours. Then, achieve cold shutdown mode in 24 hours.
B+D	The reactors leave hot standby in 4 hours and reach the shutdown status in the following 24 hours.	Immediately shut down reactors and achieve cold shutdown mode as soon as possible.
B+E	The reactors leave hot standby in 4 hours, and reach the hot shutdown status in the following 8 hours and then cold shutdown status in 24 hours.	Immediately shut down reactors and achieve cold shutdown mode as soon as possible.
F	Immediately shut down reactors and achieve cold shutdown mode as soon as possible.	Immediately shut down reactors and achieve cold shutdown mode as soon as possible.

Definition of the situations：

A. 10/15- minute sustained winds measured on site reach Beaufort Force 10 (over 24.5m/s).

B. 10/15- minute sustained winds measured on site reach Beaufort Force 12 (over 32.7m/s).

C. 10/15- minute sustained winds measured on site reach Beaufort Force 15 (over 46.2m/s)

D. When any unit has one of the following situations:

(1) One or two emergency diesel generators can not operate, or

(2) Only one or two 345 kV offsite power source loops can function, or

(3) Lose 161kV offsite power source

E. Lose one emergency diesel generator and an offsite power source

F. When any unit has one of the following situations:

(1) Lose two offsite power sources, or

(2) lose two emergency diesel generators and an offsite power source, or

(3) lose three emergency diesel generators.

Note: Definition of the “Area on alert” for Lungmen Power Station during typhoon: this area is centered in Taipei, ranging from 100kms east and south of Taipei as well as 50kms west and north of Taipei, namely 24°5 ～ 25°5 N, 121°～122°5 E.

Appendix 3-2 Tsunami warning announcement operation guide of Central Weather Bureau, Ministry of Transportation and Communication

1 Far-land earthquake-induced tsunami:

1.1 Once Central Weather Bureau receives a tsunami warning from Pacific Tsunami Warning Center, it immediately sends staff to observe onsite in order to judge potential seizing locations as well as the time, and response items.

1.2 3 hours before a tsunami reaches Taiwan, CWB judges that the tsunami may pose as a threat to the Taiwan region, it will send the tsunami warnings to related government agencies of coast guards and of disaster prevention and mitigation via cell phone text and fax.

1.3 2 hours before tsunami reach Taiwan, CWB judges that the tsunami may pose as a threat to the Taiwan region; it will issue tsunami warnings to related government agencies and the media to ask coastal residents to be prepared to respond.

2. Offshore earthquake-induced tsunami:

2.1 When the earthquake reporting system of Central Weather Bureau (CWB) detects an offshore earthquake of magnitude 6.0 or above and the depth of the epicenter is less than 35kms, CWB should note in the earthquake report that the coastal areas in Taiwan should be cautious about the sudden changes of seawater level.

2.2 When the earthquake reporting system of Central Weather Bureau (CWB) detects an offshore earthquake of magnitude 7.0 or above and the depth of the epicenter is less than 35kms, CWB should issue tsunami warnings to related government agencies and the media to ask coastal residents to be prepared to respond.

3. CWB should dismiss the tsunami warning in accordance with information from Pacific Tsunami Warning Center or CWB tidal stations after the tsunami event.

Appendix 3-3 Lungmen NPP Tsunami Case Study

The issues of Lungmen NPP Tsunami case study including the initiating event and the final cooling shutdown consequence have total 5 headings and its relevant event tree sequence development which are described as follows:

1. Initiating event -- The beginning of this event tree:

   After Lungmen NPP loses offsite-power resulting from the tsunami induced by undersea earthquakes, reactor scram is completed and emergency diesel generators start operating. However, the tsunami seizes the shore area where the plant is, so RBSW system is inoperable. Cooling water drainage pumps in both reactor buildings are located in the sump room, which is equipped with water seal doors and can resist water pressure up to 12,100 kg/m^2 (This is approximately the hydrostatic pressure at a height of 12 meters.). Besides, the bottom of the drainage pump houses are water seal and the structures around the pump houses are also water seal from the bottom to the height of 12 meters. Therefore, the critical equipment (weak point) for the water seal doors of RBSW pump houses to be able to sustain the height of the hydrostatic pressure (about 12m).

2. RCIC system: The tsunami causes RCIC feedwater pump, power system or control system to be inoperable. The RCIC feedwater pump is located in the reactor buildings at EL-8200, so the pump house is equipped with water seal doors to prevent flooding from entering the house. Both emergency DC power source, EL-2000, and main control rooms, EL-7600, are situated on the underground floors in the control buildings. The elevation of the entrances/exits of the reactor buildings and the control buildings that lead to outside of the buildings is 12.3meters, but these entrances/exits do not have doors that are designed to be tsunami-proof, so flooding needs to be first higher than these entrances/exits to be able to enter the buildings and to cause internal flooding. Therefore, the elevation of these entrances/exits, 12.3 meters, is the key equipment (weak point).

3. ACIWA system: the tsunami causes ACIWA system to fail. Fire-fighting water pump house, which is shared by two reactors, is located in the west of unit 1 reactor building. Fire-fighting water pump house and the ground outside of the house are at the same elevation of 12.3meters; around the pump house are 5 doors and none of which is designed to resist against tsunamis. Moreover, there

are 6 blinds around the pump house and the elevation of the bottom rim of the lowest blind is 13.3 meters, but the elevation of the fire-fighting water pump is 12.3meters. So, the critical equipment (weak point) is the elevation of the fire-fighting water pump, EL. 12.3meters.

4. COPS: The influence the tsunami causes on COPS is very little.

5. The final consequence of the plant: This is the ending of this event tree and there are two scenarios: A. reactor scram and reactor core cooling are successful, so reactor core is not melted. B. reactor scram and reactor core cooling fail, so reactor core is melted.

Lungmen NPP tsunami event tree is shown in Fig. 1. The sequences of the successful reactor shutdown cooling are as follows: the RICI system starts short-term water injection after the tsunami causes LOUH, so operators have time to manually start SRV and set up ACIWA system. Afterwards, ACIWA system provides long-term water injection to reactors and COPS offers containment long-term heat removal function, so reactors can achieve cold shutdown status.

Among them the safety margin and its cliff-edge of each successful path is described as follows: Because there is one successful path for reactor shutdown, its cliff edge is the cliff edge of this tsunami case study. The safety margin of each successful path shall take the minimum value of those issues as the representative, so it’s 0.3meters (12.3meters-12meters). The cliff-edge as defined shall take the minimum value of those headings as the representative and that is 12.3 meters.

In conclusion, the suggested improvement for the successful path of the safe margin and cliff edge in the Lungmen NPP Seismic Case Study includes:

1. Increase the protection of RBSW system pump to resist against tsunamis, such as installation of physical barrier, to lower the chance of the initiating event.
2. Enhance the water-proof facilities at the bottom floor of the reactor buildings to lower the chance of tsunamis damaging ECCS.
3. Enhance the protection of ACIWA system to resist against tsunamis, so operators can still manually start the reactors and set up reactor core water injection after tsunamis cause loss of ultimate heat sink.

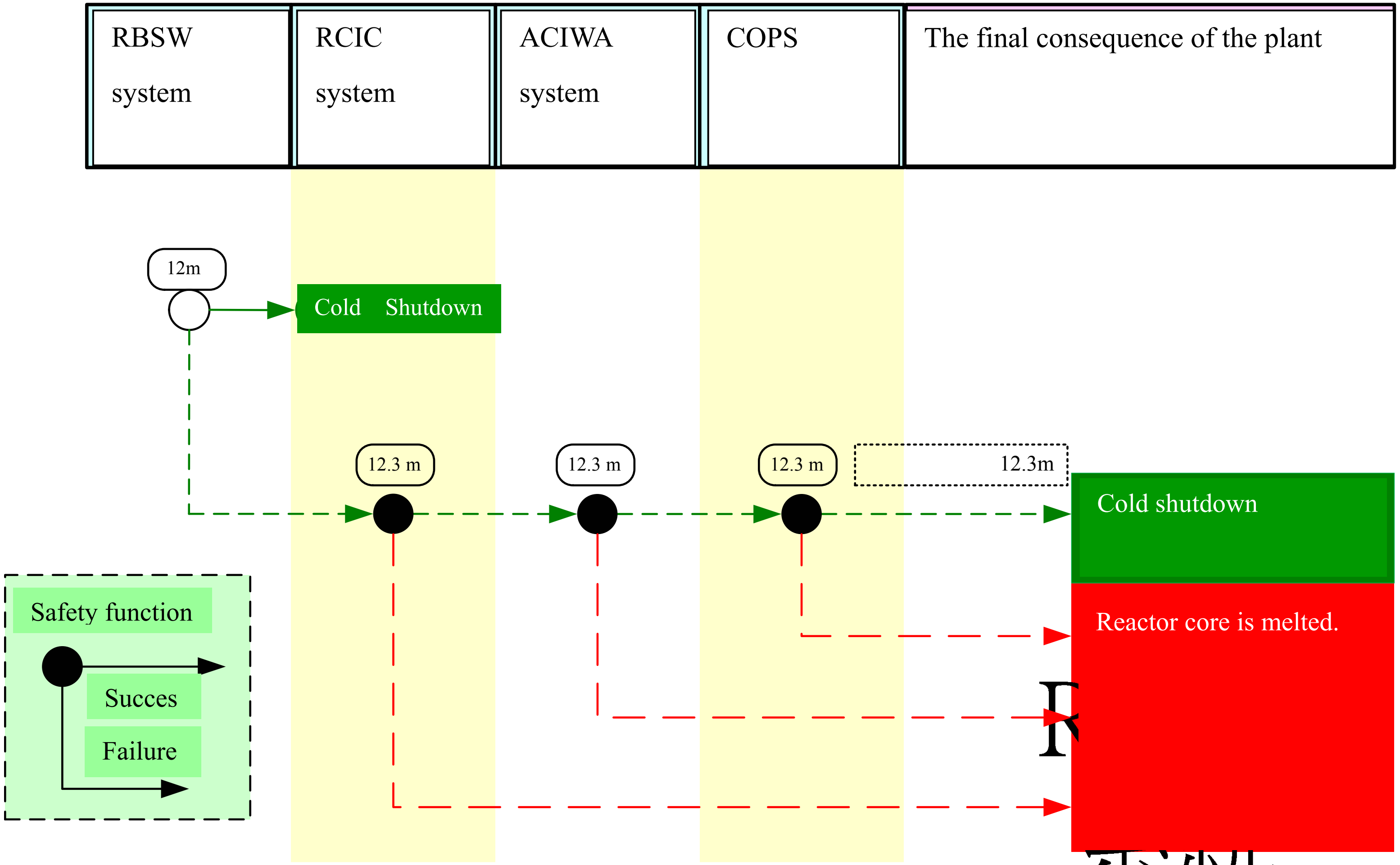


Fig. 1 Lungmen NPP Tsunami Event Tree

4. Extreme natural events

4.1 Very bad weather conditions (storm, heavy rainfalls)

Natural events in the past often occurred in synchronization with the climate cycle, displaying some patterns. However, abnormal weather conditions appear in recent years and the level of their influence increases. Even though human already have significant amount of knowledge about the change of climate, we still need to have the concept that we need to be fully prepared in terms of disaster prevention.

Taiwan Environment Information Center reported that the typhoon season in 2010 did not begin till late in August. In the mid-September, Typhoon Fanapi pounded and inundated southern Taiwan, being the most serious typhoon of the year. The first northeast cold front following Typhoon Fanapi flooded some part of northern Taiwan. After the destructive Typhoon Morakot, academic discussion started discussing whether extreme weather events are a special case or will become common in the future. No matter what, what is important here is that scholars have issued warnings stating “heavy rainfall” type of climate will threaten Taiwan.

Facing the impact of extreme weather, “adjusting” may be the only option. In Extreme Weather Situation of the Final Safety Analysis Report (FSAR) of Lungmen Power Station, the plant takes storms into consideration when deciding its design basis events. Lungmen Power Station has verified that all protection equipment of the plant meets the requirement of the design basis after the lesson learned. Meanwhile, to respond to the impact of extreme weather, by using stress tests for combined natural events of “typhoons and heavy rainfalls/mudslide,” and beyond design basis, Taipower Company reviewed the protection capability of all three power stations in September, 2011 in order to find out their weak points and cliff edge effects and to enhance measures aimed at protection capability of these power stations.

4.1.1 Events and any combination of events – reasons for a selection (or not) as a design basis event

Extreme bad weather and climate situations that may threat Lungmen NPP include typhoons, very heavy rain, and mudslides; however, the most serious compound events are concurrence of typhoons, very heavy rain, and mudslides. Thus, Lungmen NPP reviews its capability to resist against natural events, especially aiming at typhoons, very heavy rain, and mudslides. Description of related design for Lungmen NPP is as follows:

1. Elevation of the plant

Lungmen NPP is situated in Gongliao area of New Taipei City in northern Taiwan, spreading approximately 480 hectares. The plant faces Pacific Ocean to the east with coordinates of 121°55’E, 25°03’N.

Lungmen NPP is equipped with two reactors, whose capacity is both 1.35 million kilowatts. The elevation of the following important buildings is above 12.3 meters, which include reactor buildings (containing 6 emergency diesel generators), turbine buildings, control buildings, the auxiliary fuel building (containing 1 air-cooled diesel generator), the waste treatment building, auxiliary boiler buildings, the administration building, the make-up water building, access control buildings, and switch gear buildings. Power Block area is about 500 meters from the shore. The elevation of the circulating water pump house, RBCW pumps in control buildings, and the electrolysis and chloride adding plant is above 5.3meters. As for the switchyard, its elevation is 30 meters.

(1) Drainage design for outside of buildings

Elevation design to resist against flooding:

Ground elevation of Lungmen NPP is 12.0 meters, which is much higher than the maximum tsunami run-up elevation, 8.07meters. Besides, based on the current geographic information, the plant would not be affected by tsunamis, so there is no concern of inundation by tsunamis.

i. Drainage system

This drainage system is comprised of three main parts.

The first part: drainage and rainfall-induced surface flow in the main building area (power block) are removed via the drainage system in the main building area, a.k.a. yard drainage system, which is designed to be capable of mainly dealing with once every 100-year maximum precipitation in the main building area. Yard drainage system is made up with side ditches around buildings, collecting pools, pumps, manholes, pipes, and guide tubes.

The second part: drainage and rainfall-induced surface flow in the following areas are removed through drainage trench III, located in south of the simulation center. Specifically, they are drainage outside of the south fence of unit 1, in the bordering area between unit 1 and unit 2, and in the switchyard area; rainfall-induced surface flow in south and southwest of the main building area and in the hill region west of the plant.

The third part takes care of drainage in east of the switchyard and surface flow from rainfall at the hill in west of the main building area, and releases the water drained through trench II at the exit of Shiding Stream in the plant.

All the three drainage systems above have their own independent pipes to empty drained water into the sea.

ii. Drainage capability

a. Trenches II and III are open style of man-made trenches, whose drainage capability is 81.57 CMS and 137.2 CMS respectively. As described in FSAR, section 2.4.2.3.4, the drainage capability of the drainage system in the main building area can handle the probable maximum precipitation, which is stated in FSAR 2.4.3.1 as 310 mm/hr, so the PMP would not cause any damage to safety related structures. This is because open style of buildings and facilities are higher than the mean sea level, 12.3 meters, and the depth of the maximum temporary water accumulation or the probable maximum precipitation is estimated to be 12.1 meter. In other words, there is still 0.2 meters between the height of the ground floor of buildings and the dike top of trenches. Therefore, overflow would not happen, so trenches II and III still have drainage capability margin under the probable maximum precipitation condition.

b. In accordance with the information in Table 2.4-4 in the FSAR for Lungmen NPP, a chart of the PMP of every year from 1961 to 2006 measured at Keelung Weather Station is created as Chart 3.1 --"Maximum hourly precipitation at Keelung Weather Station in every year from 1961 to 2006." Even though the PMP figures in recent years displays a slightly increasing trend, the maximum PMP figure in the last 40 years happening on Sept. 23, 1980, 107mm, is still far lower than the PMP figure, 310mm, adopted in the design basis flood for Lungmen NPP. Therefore, the design of the drainage capability for Lungmen NPP is adequate.

c. There are main drainage trenches around buildings, which are designed based on the probable maximum precipitation of the plant, so they can effectively release surface flow resulting from very heavy rain. According to historic records, the maximum precipitation measured at Lungmen NPP was 491 mm when the typhoon Nari seized on Sept. 16, 2001. However, the precipitation data adopted in the plant design are all above 700 mm while the probable maximum precipitation is 310 mm/hr*2.26), so the drainage design of the plant has enough drainage capability.

2. Drainage design for inside of buildings

As stated in FSAR Sec. 3.4 of Lungmen NPP, the design for safety related structure systems and their components to resist against flooding can be divided into two parts; one is the design to fight against internal flooding caused by water from outside of buildings, and the other is the design to fight against internal flooding resulting from leaking from damaged equipment in buildings.

i. Internal flooding caused by water from outside of buildings is prevented mainly through the following design:

a. Width of the exterior walls that are lower than the elevation of the design basis flood in buildings (The elevation of all plant buildings is 12.3 meters, except for the RBSW pump house, which is 5.3meter.) is thicker than 0.6meters.

b. Structure conjunctions of each building that are lower than the elevation of the design basis flood have water stops.

c. Penetration holes/doors that are lower than the elevation of the design basis flood are water-tight.

d. Exterior walls that are lower than the design basis flood water level are treated with water-proof coating, and the coating material is applied in a circle of diameter at least 150mm around each penetration hole.

e. Roofs of buildings are designed with a drainage system and weir walls to prevent massive water accumulation/ flooding on roofs.

f. Parts of the tunnel that are lower than the ground level do not exceed the range of exterior walls.

Water-proof function of foundations and exterior walls that are class 1 seismic and lower than ground level is basically completed by water stopping design. Generally speaking, structures of safety related systems as well as their components, and the water stops that offers water-proof function to penetration holes are all 30 cm higher than ground floor.

The design of the plant against flooding also considers possible one resulting from rupture of storage tanks, so all entrances/exits of plant buildings are 30 cm higher than ground floor. With this design, water originating from rupture of onsite storage tanks would be drained before it could enter any buildings to cause damage to equipment inside.

Moreover, managerial procedure also helps with flooding protection. Once flooding signals are issued, all water tight doors and water tight hatches need to be closed (Procedure 528.03.01--"Flooding response").

ii. Preventive measures against internal flooding caused by leaking from damaged equipment in buildings are elaborated below in aspects of reactor buildings, control buildings, the radwaste building, the auxiliary fuel building, access control buildings, the seawater cooling system pump room in reactor buildings, pipes of the seawater cooling system in the tunnel of reactor buildings, and turbine buildings.

Reactor building :

a. If massive flooding (eg: rupture of water-intake pipes for suppression pools) occurs, use water tight doors to prevent flooding from spreading to other regions.

b. If the pipes of the circulating water system leak (e.g., rupture of water-intake pipes for suppression pools), with the hint of sump warnings and the leaking detective system, the plant can isolate the systems that leak and further limit the amount of leaking. Moreover, there is a 20 cm margin to the height of the safety equipment base and this can prevent equipment from being affected by leaking.

c. Manual start of fire protection equipment and limit of the total amount of stored water in pipes and tanks also lower the possibility of internal flooding. If the height of the base of safety equipment is at least 20cm, it can prevent equipment from being inundated.

Control building:

a. Flooding in a single safety sub-region in the buildings would not cause the safe shutdown function to be affected.

b. High energy pipes that pass the control buildings are the main steam pipes and water-feeding pipes in the main steam pipe pathway connecting reactor buildings and turbine buildings. The main steam pipes in the control building area do not have any openings; the main steam pipes at the reactor buildings' ends are sealed and the openings of these pipes are located at turbine buildings. So, rupture of the main steam pipes or water-feeding pipes in all these areas would not cause any flooding in the reactor buildings.

Radwaste building:

a. If flooding incidents happen, radwaste building can collect and store a big amount of drained water. All drainage sumps are situated in underground water-tight areas. Drained leaked water from all buildings in the power block area is delivered via the underground waste corridor to radwaste building. All penetration holes on the delivery routes are water-proof and sealed to prevent internal flooding from leaking to outside of the building.

Access control building:

a. Systems in access control buildings would not cause massive flooding. The biggest type of pipe is chilled water pipe, whose diameter is 200 mm. If leaking occurs, the water will be drained as well as sent to the sump on the ground floor, and is released through two sump pumps.

Turbine building:

a. Circulating seawater system and the seawater system in turbine buildings can cause massive flooding in the turbine buildings. Thus, the condenser pit is installed with water level alarm switch, which sends out both signals of flooding and of circulating water pump trip.

b. If the alarm switch is not functional and therefore leaking resulting from pipe rupture cannot be detected or isolated, this could lead to flooding in the turbine buildings. However, the height of the flooding would not exceed EL (+)840 mm, so the flooding would not overflow to outside of buildings.

c. All safety related components in the turbine buildings are located above EL (+)12300 mm, so flooding in the turbine buildings would not affect safety related components or impact safe shutdown function.

Seawater pump house in reactor building:

a. Malfunction of the seawater system in the reactor buildings would not lead to flooding in the seawater system pump rooms in the reactor buildings.

b. These pump rooms are designed to be able to send flooding warnings in order to signal operators to adopt necessary measures when needed, so flooding incidents can be controlled and limited to be within the sub-region of the seawater system in each reactor building.

Auxiliary fuel building:

a. Flooding triggered by internal systems would not affect other safety related buildings or impact safe shutdown function.

Seawater pipes tunnel in reactor building:

a. The seawater system in the reactor buildings may cause flooding in the seawater pipe tunnel in the reactor buildings, but it would not lead to a big scale of flooding in the tunnel.

b. This tunnel is designed to be able to send out flooding warnings to signal operators to adopt necessary measures, so flooding can be controlled and limited to be within a sub-region in the seawater pipe tunnel.

iii. Reactor buildings, control buildings, and the seawater pump houses in the reactor buildings are all installed with water -tight doors or semi-watertight doors. These doors pass water pressure tests before arriving at the plant for installation, in order to ensure their water-tight function is complete. The quantity of the water-tight doors and semi-water tight doors installed is as below:

a. water tight doors

* Unit 1 and 2 reactor buildings, EL-8200 mm: 3 units in each building;

* Unit 1 and 2 reactor buildings, EL 4800 mm: 1 unit in each building;

* Unit 1 and 2 control buildings, EL-8200 mm: 2 units in each building;

* Unit 1 and 2control buildings, EL-1850 mm: 3 units in each building;

* Unit 1 and 2 control buildings, EL 2900 mm: 1 unit in each building;

* Unit 1 and 2 control buildings, EL 7600 mm: 2 units in each building;

* Seawater system pump rooms in the reactor buildings, EL 530 mm: totally12 units.

b. semi-water tight doors

* Unit 1 and 2 reactor buildings EL-8200 mm: 15 units in each building

iv. Some of the penetration holes below EL 12300 mm in each building are temporarily sealed for now because the plant is still under construction, but the inspection on permanent sealing will be completed in the end.

a. After the plant finishes permanent sealing at the penetration holes below EL 12300 mm in each building, the plant will conduct inspection on the completeness of sealing.

b. Routine walkdown and inspection on the water-proof of penetration holes in the plant will comply with procedure 769.

3. Response measures aiming at external flooding that is beyond the design basis

The fact that the design of the elevation of the plant area is higher than the mean sea level, 12.0 meters, is partially based on the consideration of the following hydrological phenomena, included in section 2.4.2 of FSAR for Lungmen NPP: mountain flood at Shuangxi Stream and Shiding Stream, breaking of raw water reservoirs with totally 48000 tons of water, maximum flood water level resulting from the watershed in the plant, the probable maximum precipitation of 310 mm/hr, run-up height induced by typhoons or tsunamis (tsunamis: 8.07 meters; typhoons: 8.69 meters), and so on. This elevation can prevent typhoons, tsunamis, or flooding from causing external flooding. Nevertheless, if beyond design basis flood water level happens or, in other words, the elevation of the flood water level is higher than EL 12.0 meters, internal flooding would happen because all exterior doors on the ground floors of the plant buildings are not water-tight. At this moment, other than utilizing the existing sump pumps each building has for draining, the plant can also use temporary drainage pumps, in order to quickly recover the function of the equipment on the ground floor in each building.

According to the initial evaluation result of a simulation of probable maximum tsunamis by the Nuclear Plant Tsunami Evaluation Team, the design of the elevation of main buildings is not affected by tsunamis and the plant will improve the flooding-resisting function of exterior doors on the ground floor in all important buildings.

(1) Pile flood barriersandbags at the exterior doors on the ground floor at the following buildings, which lead to outside of buildings: reactor buildings, control buildings, diesel generators, fuel storage tanks, the auxiliary fuel building, fire-fighting pump house, and seawater pump houses in reactor buildings.

(2) Pile flood barriersandbags at places where access control buildings EL 12300 mm connect reactor buildings.

(3) Pile flood barriersandbags where the waste corridor EL 12300 mm connect reactor buildings /control buildings, and the auxiliary fuel buildings.

4. Response measures aiming at internal flooding that is beyond the design basis

(1) Review of internal and external flooding when there is or there is no power outage, and review of function, mechanism, process, and SOP regarding drainage

i. Prevention measures aiming at internal flooding does not require any power-driven equipment because they can be done through both floor drains and drain pipes on different floors and in different areas, and eventually drained water can be collected and go into sumps. However, if the amount of water needed to be drained is more than the amount that floor drains can handle in time, internal flooding on each floor of buildings would still occur, but with existing design to release flooding, flood water can be delivered to all sumps on the ground floor of the radwaste building to lower the potential damage.

ii. Water on the floor of the ECCS pump houses in the reactor buildings would be drained into sumps, which are exclusively for this area and not connected with any other areas. Moreover, the pump houses are designed with water-proof doors, which can prevent flooding in the houses from spreading to outside and vice versa to ensure the reliability of important equipment of ECCS.

iii. Buildings are equipped with emergency response equipment: 3 temporary drainage pumps and 3 mobile diesel generators, which can provide maneuverable emergency response to related affected building floors and areas.

iv. The plant has another 100 flood barriersandbags for maneuverable dispatching in order to respond to emergency flooding incidents at all places.

v. To prevent internal flooding from overflowing to outside of buildings, penetration holes on exterior walls of buildings are sealed. Though, other necessary openings on exterior walls of buildings, such as doors, still need to have their functions.

vi. Prevention of internal flooding is achieved by floor drains and water-proof doors on every floor of buildings and by sealing of penetration holes on walls. Furthermore, the plant has workers on duty to conduct walkdown inspection everyday over floor drains and water-proof doors.

vii. Drainage in each building is achieved via sumps, sump pumps, and related pipe valves inside each building.

viii. Procedure 528.03.01/528.03.02--“Flooding response” details guidance and measures responding to internal flooding.

ix. Procedure 186.01--"Important guidelines for disaster prevention and mitigation" lists spare equipment for disaster prevention and mitigation the plant needs to have, such as sump pumps, mobile diesel generators, flood barriersandbags, and etc. Also, equipment listed in the procedure is inspected once every year during a routine time period.

x. The maintenance cycle for sump pumps in each buildings, mentioned in procedure 704 is dependent on the scheduled maintenance cycle for the MMCS preventive maintenance sub-system of the plant.

(2) Drainage capability inside buildings

i. Flooding warnings will be issued when flooding incidents occur. When power supply is normal, pumps of floor sumps in emergency equipment areas will function. Meanwhile, control rooms monitor sump water level at all time. If water level becomes abnormal, sump pumps will automatically start operating. All these emergency equipment areas are installed with water-proof doors, so no equipment in other regions would be affected.

ii. Prevention of internal flooding is achieved by floor drains on each building floor and water seal doors at the ECCS pump house and by sealing of penetration holes on walls. Moreover, floor drains and on each building floor and water seal doors at the ECCS pump house are inspected by workers on duty every day.

iii. Drainage in each building is achieved via sumps, sump pumps, and related pipe valves inside each building. The drainage capability of the sump pumps of each building is described as below:

a. reactor building :

* primary containment: There are a total of 4 sump pumps. The drainage capability of each pump is 33 m^3/hr, so the total capability is 132 $m^{3/}$ hr.

* secondary containment: There are a total of 16 sump pumps. The drainage capability of each pump is 33 m^3/hr and the total capability is 528 $m^{3/}$ hr.

* diesel building: There are a total of 2 sump pumps. The drainage capability of each pump is 33 m^3/hr and the total capability is 66 $m^{3/}$ hr.

b. control building: There are a total of 14 sump pumps. The drainage capability of each of the first 8 pumps is 33 m^3/hr, and that of each of the rest 6 pumps is 10m^3/hr, so the total capability is 324 m^3/hr.

c. auxiliary fuel building: There are a total of 6 sump pumps. The drainage capability of each pump is 33 m^3/hr and the total capability is 198 m^3/hr.

d. turbine building: The total capability of the totally 26 sump pumps is 780 m^3/hr.

e. management building: The total capability of the totally 2 sump pumps is 60 m^3/hr.

f. radwaste building: The total capability of the totally 8 sump pumps is 120 m^3/hr.

Therefore, the total drainage capacity of all the sump pumps of the entire buildings is 15832 m^3/hr (4.4 m^3/sec).

Other than utilizing the existing sump pumps each building has for draining, the plant can also use temporary drainage pumps, in order to quickly recover the function of the equipment on the ground floor in each building.

5. Capability to resist against mudslides

Situated in Gongliao area in New Taipei City, Lungmen NPP is within the watersheds of Shiding Stream and Shuangxi Stream, having the Pacific Ocean in east of the plant. Both the Shiding Stream in north of the plant and Shuangxi Stream, 25 kms south of the plant flow toward east into the Pacific Ocean. According to information by Water and Soil Conservation Bureau, Council of Agriculture, these two streams are not mudslide-prone streams. Furthermore, based on the current natural condition at the site, the chance of Shiding Stream and Shuangxi Stream having mudslides is very low.

Local road Route 2 is right outside of the east part of the plant. This route is a fully developed 110-acre flat land at EL.9~12meters. The areas on the hill in the west of the plant that are under construction are: the raw water reservoir area, the temporary sand and rock stockpile southwest of the switchyard, the switchyard, the low-radioactive waste storage warehouse area, the temporary sand and rock stockpile north of the low-radioactive waste storage warehouse area, roads to take to go do maintenance work at the raw water reservoir, the temporary sand and rock stockpile at the south bank of the upstream area of Shiding Stream, and etc. The areas on the hill in the south of the plant that are planned to start land development include sea sand stockpile south of the warehouse area and in the south of the plant. All areas on hills that have been developed and are being developed comply with Water and Soil Conservation Technology Specification and with Water and Soil Conservation Guidebook to design all facilities to achieve water and soil conservation. Also, the design needs to be inspected and approved by Water and Soil Conservation Bureau, MOEA. At the stockpiles in the plant that have more rocks in its rockfill, the filling and building of the rockfill is in a staircase style, which is that a platform of 2 meters in width is created for every 5 meters of height is built, in order to stabilize hills on the sides. Before rockfill is filled and built, RC pipes need to be buried at the bottom of the valley in order to drain the surface flow from the upstream watershed and to drain water permeating into under the ground from rockfill. Additionally, drainage systems are installed in both the bordering areas and on hills of the plant; vegetation is also grown at spots where the drainage systems are exposed without being covered to prevent the systems from being directly eroded by rain water and to lower the chance of mudslides.

4 main drainage trenches (I~IV) and 7 sub-trenches have been installed along flat lands at the foot of the west side hill in the plant. The design of the drainage capability is based on the once every 100-year maximum precipitation intensity; the design of main drainage trench II (containing II-1~II-3 sub-trenches) and main drainage trench III (containing III-1 sub-trench) uses PMP as a basis. These drainage trenches are to drain storm-induced flooding and the mud as well as sand the flooding carries in the plant and on the west side hill, in order to ensure the safety of reactors and equipment. Lungmen NPP encompasses a land area of 480 acres. The geographic landscape on the east side is flat and next to the Pacific Ocean, and the slope ratio of the hills on the west and south sides is small, with the highest slope of about 170meters. Areas on the hills that are not developed are covered with prosperous vegetation and have no signs of collapse. Areas on the hills that have been developed have drainage facilities, retaining facilities on side slopes, and greenery. After being through many years of typhoons, storms, and earthquakes, these areas only have some regional collapse, but there is no severe disaster caused by mud or rocks. The geographic landscape of Lungmen NPP is quite flat. Upstream watersheds of all little streams in the valley are small and have no signs of collapse of mud or rocks. In addition, slopes in the valley where little streams flow through descend slowly and there is no piling of collapsed substances; vegetation on both sides of the valley is intact. Furthermore, areas that have been developed have been protected and maintained for water and soil conservation purpose, so there should be no concern of mudslides in

this area of the plant.

6. Capability to protect the plant from dip-slope sliding

There is no concern of mudslide at the plant. Even if beyond design basis causes mudslides, they would not cause influence on the unit 1 and unit 2 reactors because the dip-slopes on hills in the plant area go from north to south. Additionally, to establish the monitoring mechanism of mudslide prevention, the plant will add procedure for mudslide monitoring, warning, prevention, and mitigation.

7. Sustainability of exposed equipment against winds

(1) Building structure

According to Section 3.3. 2. in FSAR for Lungmen Power Station, the design wind speed as well as the maximum instantaneous wind speed of seismic category 1buildings (reactor buildings, control buildings, the switchbox building, the auxiliary fuel building, and the off gas stack) 9 meters above the ground are 121 mph (54 m/sec) and157 mph (70 m/sec) respectively. The design wind speed of other non- seismic category 1buildings (turbine buildings, the radwaste building, the water plant, the fire-fighting pump house, and the switchyard) 9 meters above the ground is 121 mph (54 m/sec). Section 3.13.2 in GE31113-OA23 -1000 Design Specification: Structure of Lungmen NPP states the structure, system, and components of Lungmen NPP should be the same as Chart 4-5 Lungmen NPP design parameters, to be able to resist against the impact of natural situations in order to perform required safety function. The design wind speed as well as the maximum instantaneous wind speed of each building structure 9 meters above the ground is 121 mph (54 m/sec) and 157 mph (70 m/sec). (Note: According to the typhoon intensity classification system of Central Weather Bureau in Taiwan, severe typhoons have winds that reach Beaufort scale 16 and wind speed higher than 51 m/sec.）

Because there is a difference of height between structures and ground, there is pressure difference between top of a structure and ground. Wind pressure is directly proportional to the square of wind speed, and wind speed increases with the increase of pressure gradient. Hence, when there is a rapid change of air pressure and wind speed at top of a structure escalates quickly, wind pressure force will increase significantly. Design wind speed and design wind pressure force at Lungmen Power Station are shown below in Table 4-5:

Lungmen NPP design parameters are as below:

i. Maximum ground flooding : 2 meters below ground floor(unit 1); ground floor(unit 2)

ii. Normal/design wind speed: 54 meters /sec @ 9 meters above ground floor (Force Level 16) maximum instantaneous wind speed: 70 meter/sec @9 meters above ground floor is (Force Level 17).

iii. Maximum flooding level: 30cm above the ground floor

iv. Maximum tsunami wave height: 7.5meters; maximum typhoon wave height: 8.69 meters

v. Roof design: when maximum rainfall rate is 11.4cms/hr, the PMP is 31cms

vi. Earthquakes: OBE =0.2 g, SSE = 0.4 g

vii. Elevation of the plant: 12.3 meter

Table 4-5 Design wind speed and design wind pressure at structures of Lungmen Power Station

	Normal wind speed	The maximum instantaneous

			wind speed	
Height (meters)	9	60	9	60
Wind speed: V(meters /sec)	54(Beaufort Force 16)		70(Beaufort Force 17)	
I=	1.0			
Kd=	0.85			
Kz=	1.16	1.61	1.16	1.61
Kzt=	1.13			
Wind pressure qz(kg/m²) =	203.23	282.06	341.50	473.97

Note:

1. ASCE7-02, Section6.0 WIND LOADS
2. qz = 0.613. Kz. Kzt. Kd. V2.I (N/ m²)

   Where I= Importance Factor, Kd= Wind Direction Factor

   Kz= Velocity Pressure Exposure Coefficient

   Kzt= Topographic Factor

(2) Switchyard structure

The early design wind speed of the structure of the transmission route towers of Taipower Company was that 50 mm/sec in eastern Taipower was Force 15 and 40m/sec in western Taiwan was Force 12.Besides, there was still 0.3 times of margin to resist against gust wind at 52m/sec, which is Force 16.

On July 25, 1977, Taiwan suffered from the seizure of Typhoon Thelma, which landed in southernTaiwanand resulted in severe destruction and accidents. Kaohsiung Port Transmission Substation, near Dalin Coal Power Station, was the only one very high pressure transmission substation in southern Taiwan. Because 10 very high pressure towers and exceptionally high pressure towers were destroyed, power supply system in Taiwan was seriously damaged. Power from the south could not be transported to the north. This led to power outage in many areas of Taiwan. A related report of this year stated this typhoon was the most serious destructive natural event in Taiwan since WWII. After Typhoon Thelma, Taipower Company reviewed and enhanced the capability of the structure of the transmission route towers against winds.

The description of the design guideline for the structure of the transmission route towers, provided by the power supply division, states that the transmission route of this plant is an important route in western Taiwan. The sustainability of the structure against winds is shown in Table 4-6. Design wind speed at 44.9m/sec is Force 14and gust speed that can reach 61.9m/sec is Force 17. However, even if the plant loses offsite power sources, the plant still has diesel generators, gas turbine generators, and the 7thdiesel generator. All of these can provide units the power needed for safe shutdown.

Table 4-6 The standard for supporting structure and cable design speed resistance

Condition		Design wind pressure qo (kg/m²)	Relative wind speed (m/sec)		
			Design wind speed (10-m in mean)	Gust rate	Gust
without typhoons (island-round)		20			17.5
During typhoons	Regular route at western Taiwan	200	39.8	1.45	57.7
	Important route at western Taiwan	230	44.9	1.38	61.9
	Regular route at eastern Taiwan	260	50.6	1.3	65.8
	Important route at eastern Taiwan	300	54.4	1.3	70.7
During maintenance work (island-round)		20			17.5

Additionally, according to Design Guideline for Power Switchyard at A Power Station (First edition, 1985), the design wind speed for Class A equipment as well as structures was 70 m/sec and wind-resistance strength should be 100 m/sec. After this, when the plant installed equipment, such as GCB and GCS, this design guideline was followed.

(3) The design wind speed for off gas stack

The elevation is at EL. 60 meters, and the design wind pressure is shown in the table below:

Elevation (meters)	Design /max. wind speed (meters /sec)	Design /max. wind pressure (kg/ meter²)
60	54/70	282.06/473.97

(Note: According to the typhoon intensity classification system of Central Weather Bureau in Taiwan, sever typhoons have winds that reach Beaufort scale 16and wind speed is higher than 51 m/sec.)

Based on all the description above, it is confirmed that the plant has enough protection capability to respond to severe weather. However, extreme weather may change more drastically and appear in the form of combined natural events. So, the plant uses the stress tests with scenarios of combined natural events of “storms, heavy rainfalls and/ or mudslides” of similar events that are beyond design basis, and of events that are beyond the knowledge of the plant, to examine the protection capability of the plant. The detail is described in Appendix 4-1 “Stress Tests of Combined Natural Events of Typhoons and heavy rainfall/mudslides”.

4.1.2 Weak points and cliff edge effects

Through the evaluation of Stress Tests of Combined Natural Events of Typhoons and Heavy Rainfalls/ and Mudslides for Lungmen Power Station in Appendix 4-1, weak points and cliff edge effects of the plant in extreme situations are estimated and described as follows, along with responding enhancement measures.

Scenario A: The power station is at elevation of 12.3 meters and 500 meters from the shore. The slope ratio of the hills on the west and south sides is small, with the highest slope of about 170meters. Areas on the hills that are not developed are covered with prosperous vegetation and have no signs of collapse. Areas on the hills that have been developed have drainage facilities, retaining facilities on side slopes, and greenery. Even if beyond design basis causes mudslides, they would not cause influence on the unit 1 and unit 2 reactors because the dip-slopes on hills in the plant area go from north to south. In a heavy rainfall scenario, through the drainage trenches II and III, the rainfall could be immediately emptied into the sea, so neither flooding nor mudslides would happen. However, if mudslides that are beyond expectation appear and cause flooding to reroute and to enter the main building area (power black area), units would be in danger scenarios.

Scenario B: The drainage capability of the plant is based on the assumption that probable maximum precipitation of a storm, 310mm/hr, falls in the plant. Now, in order to create a very extreme scenario of extreme weather, the plant assumes a beyond design basis storm seizes the plant without concurrence of any mudslides, the beyond design basis precipitation can not be drained by the drainage trenches and therefore generates surface flow entering the main building area of the plant, a.k.a. the power block area. Then, units of the plant may be affected.

Note: The assumed scenarios A and B are already beyond the design basis of the plant. This is to help the conduction of the stress tests to find weak points and cliff edge effects of the plant.

1 Weak points of extreme weather

For the enhancement measures responding to the assumed scenarios A and B described above, related procedure followed by the plant to respond to typhoons, heavy rainfalls, and mudslides are reviewed and subsequent enhance measures established are as follows:

(1) Procedure 187--“Operation during typhoons”

i. When the radius of the typhoon with winds of over Beaufort Force 7 will reach the site in 18 hours, the plant enters “typhoon watching period” mode. The main control room writes and sends typhoon bulletins to the plant director and the labor division.

ii. Each department performs inspection work, including closing doors and windows in buildings.

iii. When the radius of the typhoon with winds of over Beaufort Force 7 will reach the site in 10 hours, the plant enters “typhoon alert period” mode. The plant director asks Taipower Company headquarter to establish the typhoon emergency response team.

(2) Procedure 187.01--“Water accumulation/flooding prevention and response during typhoons or very heavy rain”

i. When typhoons of moderate intensity and above, or very heavy rain seizes, each division should conduct the following work after the typhoon emergency team is established:

a. Labor safety division records the height of drained water at onsite drainage trenches and inspects whether roads and ditches in the power generating building are clogged. Labor safety division asks the typhoon response group of each building to send workers to move sandbags to assigned locations at each building.

b. Operating shifts on duty of each division close the water-seal doors in each building.

c. Waste treatment division gives mobile diesel generators and sump pumps to the typhoon response group of each building for them to test and use.

ii. When water accumulation occurs because very heavy rain seizes, the water level of drainage trenches increases rapidly, or water in the protection area cannot be drained in time.

a. Response begins when the any of the following situations appears.

(i) Precipitation during typhoons of moderate intensity as well as above, or during very heavy rain period exceeds 150 mm/hr (The once every 100 year maximum precipitation at Lungmen NPP is 203 mm/hr.), or

(ii) the water level at drainage trenches has exceeded 80%, or

(iii) water accumulation on roads in the protection area is about 10 cm.

b. The leader of the typhoon emergency team asks the labor safety division to inform the typhoon response group of each building to pile sandbags at the exterior entrances/exits of each building. Labor safety division clears the roads and ditches in the protection area.

iii. When water enters buildings, rain water flows down through staircases and floor drains to bottom floors and sumps on bottom floors, and bottom floors or the floors right above are flooded:

a. Response begins when the any of the following situations appears:

(i) When precipitation exceeds the once every 100 year maximum precipitation at Lungmen NPP, which is 203 mm/hr, or

(ii) water accumulation on roads in the protection area exceeds 30 cm and is higher than the height of the sandbags at the exterior entrances/exits of each building.

b. The typhoon response group of each building sends workers to pile sandbags.

c. The typhoon response group of each building removes the rain water that has entered buildings.

d. If there is no power outage, unit directors of shifts on duty should maintain the operation ability of the sump drainage pumps in each building. If there is power outage, follow the next step before electric division utilizes 480V emergency diesel generators to supply power to the 4D and 4E sump motors in reactor buildings. If flooding and power outage exist simultaneously, refer to AOP 528.03.03.

e. The typhoon response group of each building isolates and blocks rain water at staircases and bottom floors, and utilizes sump pumps to drain it to outside of buildings.

(3) Procedure 528.02.01--"Reactor operation during typhoons warning period" (Appendix 4-2)

i. After inland typhoon warnings are issued or when weather forecasts predict the radius of typhoons may seize Taiwan, Jinmen, and Mazu in 18 hours, the director of the electric division on duty immediately reports to the manager on duty of shifts, group leaders, and labor safety division via typhoon bulletins, and the director complies with procedure 528.02.02 to perform all typhoon-related inspections. If the Typhoon Response Center is established, reports to Taipower Company by phone.

a. The plant manager on duty sends workers to close the exterior entrance/exit doors of all buildings and notifies workers on duty at the circulating water pump house to turn on traveling screens, in order to prevent debris from scramming pumps. Moreover, the manager on duty notifies the maintenance division to clear debris at inlets.

b. After Central Weather Bureau issues inland typhoon warnings, the plant should make sure in 8 hours that emergent diesel generators can operate if the plant is within the area warned by the typhoon warnings.

c. One hour before radius of typhoons with winds of Beaufort Force 7 (13.9 m/sec) reaches the plant area, the plant stops function tests at RPS, LDI, and SSLC to prevent scram or system isolation.

ii. When the 10/15- minute sustained winds measured on site reach Beaufort Force 10 or exceed 24.5m/s (When the plant is within the radius of the typhoon with winds of Beaufort Force 10):

a. When the intensity of the typhoon is mild/ moderate, follow the steps below:

(i) The reactors operate in the alert mode.

(ii) When any of the following situations at units happens, disconnect from grid and stay in hot standby mode in 4 hours.

* One or two emergency diesel generators inoperable, or

* Only one or two 345 kV offsite power source loops can function, or

* Lose 161kV offsite power source

b. When the intensity of the typhoon is severe, follow the steps below.

(i) Reduce power to below turbine trip bypass set point of RPS in 3 hours. (CTP<40%)

(ii) When any of the following situations happen at the units, the reactors leave hot standby in 4 hours and reach the cold shutdown status in the following 24 hours:

* One or two emergency diesel generators inoperable, or

* Only one or two 345 kV offsite power source loops can function, or

* Lose 161kV offsite power source

iii. When the 10/15- minute sustained winds measured on site reach Beaufort Force 12 or exceed 32.7m/s (When the plant is within the radius of the typhoon with winds of Beaufort Force 12):

a. When the intensity of the typhoon is mild/ moderate, follow the steps below.

(i) Reduce power to below turbine trip bypass set point of RPS in 3 hours. (CTP<40%)

(ii)When any of the following situations happen at the units, the reactors leave hot standby in 4 hours and reach the cold shutdown status in the following 24 hours:

* One or two emergency diesel generators not operable, or

* Only one or two 345 kV offsite power source loops can function, or

* Lose 161kV offsite power source

b. When the intensity of the typhoon is severe, follow the steps below.

(i) Reduce reactor thermal power to about 30% in 3 hours.

(ii) When any of the following situations happen at the units, immediately reach the cold shutdown status.

* One or two emergency diesel generators is inoperable, or

* Only one or two 345 kV offsite power source loops can function, or

* Lose 161kV offsite power source

iv. When the 10/15- minute sustained winds measured on site reach Beaufort Force 15 or exceed 46.2 m/s (When the plant is within the radius of the typhoon with winds of Beaufort Force 15):

a. When the intensity of the typhoon is mild/ moderate, reduce reactor thermal power to about 30% in 3 hours.

b. When the intensity of the typhoon is severe, disconnect from grid and stay in hot standby mode in 4 hours.

v. When any of the following situations at the units happens and “mild/moderate/ severe typhoons,” immediately shut down reactors and achieve cold shutdown status as soon as possible:

a. Lose two offsite power sources, or

b. lose two emergency diesel generators and an offsite power source, or

c. lose three emergency diesel generators.

d. When the 10/15- minute sustained winds measured on site reach Beaufort Force 16 or exceed 51 m/s (When the plant is within the radius of the typhoon with winds of Beaufort Force 16):

Reactors should follow procedure 203.01or 203.02 to disconnect from grid and stay in hot standby mode in 4 hours.

(4) Procedure 528.03.01--“Flooding response”

i. Inspect if there are signs of internal flooding and monitor sump water level as well as the operation of sump pumps.

ii. When flooding warnings are issued, all water-tight doors and water-tight hatches in all buildings need to be closed; pile sandbags at protective doors.

iii. If flooding is predicted to enter plant buildings, comply with the following steps for emergency response:

a. Abide by procedure 203.01--“Manually stop reactors”. Manually stop the reactors and start reactor core cooling.

b. Follow procedure 187--“Operation during typhoons:” Evaluate the actual situation and establish the Typhoon Emergency Team if needed. Gather workers on duty in advance to have them stay and stand by. Turn off all unnecessary electric equipment. If safety buses in the reactor buildings or safe power in the control buildings may be inundated and damaged, perform reactor scram complying with procedure 501.04--"Emergency shutdown;" in addition, abide by procedure SOP-411--"Steam bypass and pressure control system procedure" to utilize TBV to reduce RPV pressure to 3.15 MPaG, in order to maintain reactor cores on the cooling mode till flooding is solved. Before equipment returns to operation, the plant needs to inspect if equipment is flooded.] If so, abide by procedure 528.03.02--"Flooding response" .

(5) Procedure 528.03.02--"Flooding response"

i. If the 6 circulating water pumps trip, follow procedure 501.04--"Emergency shutdown"

ii. If the seawater pump in any area of the reactor buildings scrams, abide by procedure 501.04--"Emergency shutdown"

iii. Notify workers on duty to the site to isolate leaking. Ensure water level and the operation of sump pumps are normal.

iv. Increase the number of temporary drainage pumps to increase drainage function.

v. Increase the number of temporary drainage pumps to increase drainage function.

vi. If the safety of the operation of the plant is affected, shut down the reactors and bring them to cold shutdown till flooding is solved or under control.

vii. Notify maintenance workers to clean flooded sites.

(6) Procedure 528.03.03--"Emergency drainage operation during power outage and abnormal water entry in buildings"

i. If there is power outage at the reactors during severe natural disasters (such as earthquakes, typhoons, tsunamis, and very heavy rain), managers on duty immediately send bulletins to and call every manager.

ii. If earthquakes cause reactor scram or power outage, workers in the control rooms need to inspect if there is leaking at pipes and send workers to ensure if sump pumps in each building is operating normally.

iii. If there is abnormal water entry in buildings caused by typhoons or very heavy rain,

a. Managers on duty inform the Typhoon Emergency Team and the leader of the team asks the labor safety division to notify relevant divisions to pile sandbags and remove accumulated water at the doors of the entrances/exits of each building.

b. Director on duty at the reactors sends workers to make certain all water tight doors in each building is really closed.

(i) If power outage occurs after flooding incidents, ensure to maintain the operation ability of the floor drain and the drainage sump pumps on the bottom floor of reactor buildings, and drain the accumulated water and send it to the radwaste building. Moreover, the plant also needs to ensure the availability of power sources of floor drainage sump pumps, floor drainage sump pumps for equipment, and the floor drainage sump pumps in the ECCS rooms.

(ii) if power outage occurs before flooding incidents, ensure the motor of the floor drainage sump pumps at the corridor of the bottom floor of reactor buildings can be supplied with power via safety buses or 480V AC temporary diesel generators, so accumulated water on the corridor can be drained and sent to the radwaste building.

(iii) If power cannot be supplied to the motor of the floor drainage sumps at the corridor of the bottom floor of the reactor buildings, utilize mobile diesel generators, sump pumps, related cables, and drainage pipes to deliver the accumulated water to outside of buildings.

Other related procedures to comply with are as below.

(7) Procedure 192--"Risk management and response operation"

When the plant experiences different kinds of incidents, the Risk Management Team assists the plant to analyze and to decide strategies and mitigation/response measures while relevant divisions comply with procedure to respond and report. Therefore, development of incidents would be fully under control and no other unnecessary confusions or problems would occur. Related procedures to follow are: Procedure 174--"Immediate reporting of abnormal events," procedure 176--"Reporting of all incidents and emergency events," and procedure 1400--"Emergency event response and planning."

(8) Procedure 508.01 --"Pipe rupture in primary containment"

(9) Procedure 317.01 --"Liquid radioactive waste sumps in the nuclear island area"

(10) Procedure 317.02 --"Liquid radioactive waste sumps in turbine buildings"

(11) Procedure 317.03 --"Liquid radioactive waste sumps in the radwaste buildings"

(12) Procedure 356.01--"Miscellaneous non-radioactive drain system in nuclear island area"

(13) Procedure 356.02--"Miscellaneous non-radioactive drain system in non-nuclear island area

(14) Procedure 356.03--"Miscellaneous non-radioactive drain system in the radwaste building"

(15) Procedure 913 --"Control operation of gaseous and liquid radioactive waste release"

2. Cliff edge effect:

(1) The fact that the design of the elevation of the plant area is higher than the mean sea level, 12.0 meters, is partially based on the consideration of the following hydrological phenomena, included in section 2.4.2 of FSAR for Lungmen NPP: mountain flood at Shuangxi Stream and Shiding Stream, breaking of raw water reservoirs with totally 48000 tons of water, maximum flood water level resulting from the watershed in the plant, the probable maximum precipitation of 310 mm/hr, run-up height induced by typhoons or tsunamis (tsunamis: 8.07 meters; typhoons: 8.69 meters), and so on. This elevation can prevent typhoons, tsunamis, or flooding from causing external flooding. Nevertheless, if beyond design basis flood water level happens or, in other words, the elevation of the flood water level is higher than EL 12.0 meters, internal flooding would happen because all exterior doors on the ground floors of the plant buildings are not water-tight. At this moment, other than utilizing the existing sump pumps each building has for draining, the plant can also use temporary drainage pumps, in order to quickly recover the function of the equipment on the ground floor in each building. Furthermore, the sumps in the ECCS rooms, -8200 mm, in the reactor buildings are exclusively for this area and not connected with any other areas. Moreover, the pump houses are designed with water-proof doors, which can prevent flooding in the houses from spreading to outside and vice versa to ensure the reliability of important equipment of ECCS. When designing the plant, the storm drainage system and the influence of tsunamis were already considered. Therefore, there are no buildings that would be easily inundated by flooding. Only if natural disasters occur and the water level they bring is beyond the design basis and therefore leads to internal flooding, then the weak point is the floors in reactor buildings that are below elevation 4800 mm.

(2) The main weak point of flooding is flooding on the bottom floor, -8200 mm, of the reactor buildings because this floor has safety related emergency reactor core cooling system, such as

HPCF, LPFL, and RCIC. If they are all flooded, then all high-pressure and low pressure emergency injection system (including electric water pump and steam-driven water pump) would fail. Therefore, these emergency safety systems would lose their function of injecting water into the reactors and then only independent fire-fighting ACIWA or the raw water reservoir can inject water into reactors.

(3) ACIWA is non-safety related system, which connects fire-fighting water system and spreading pipes in containments, so it can function as a spare cooling water source for reactors and containments. When the back pressure of this diesel-driven fire-fighting pump or fire-fighting truck is smaller than 1.1MPaG, this system can inject water into reactors; however, before utilizing this system to feed water, its safe release valve needs to be opened to reduce the pressure of reactor. During the reactor depressurizing process, water level in the reactors may be at transient state lower than TAF. Nevertheless, based on the simulation and analysis by the nuclear safety department in Taipower Company, no zirconium hydrolysis reaction would happen.

(4) The next is the flooding at elevation of 4800mm in reactor buildings because safety related electric switchgear is located in this area, including 4.16 kV emergency buses A4, B4, and C4. If they are all flooded and result in safety related AC electric equipment malfunction, this would lead to station blackout and loss of ultimate heat sink. Then, only DC battery system would be available and it can only sustain up to 8 hours.

(5) Additionally, if the inlets of the seawater pump house in the reactor buildings are clogged by massive debris, causing further clogging at the mesh and affecting the water intake of the pumps, reactors would lose ultimate heat sink.

4.1.3 Measures which can be envisaged to increase robustness of the plant

1. Response to severe weather and climate

(1) When Central Weather Bureau issue sea and in-land warning s of typhoons and they may affect the plant, comply with procedure 187--“Operation during typhoons”.

(2) If Central Weather Bureau predicts radius of typhoons may seize the inland of Taiwan, Jinmen, and Mazu, and issues sea and land alert of typhoons, and the plant is in one of the warned area in the typhoon warning s”, abide by procedure 528.02.01 --“Reactor operation during typhoon warning period”.

(3) During the seizure of typhoons of moderate level or above as well as very heavy rain, after the Typhoon Emergency Team is established, the plant abides by procedure 187.01--“Water accumulation/ flooding prevention and response during typhoons or very heavy rain” and each division perform the following tasks.

i. Labor safety division sends workers to onsite drainage trenches to record the water level of the drained water, to inspect if trenches and roads in the power generating building area are clogged or blocked, and to report the leader of the Typhoon Emergency Team. Labor safety division asks the typhoon response group of each building to send workers to deliver sandbags to appointed locations in each building.

ii. Operators on duty from each division close water-tight doors in each building.

iii. Waste treatment division gives mobile diesel generators and sump pumps to responsible workers of each building for them to conduct testing and use.

(4) When there is internal or external flooding, follow procedure 528.03.01--“Flooding response,” or procedure 528.03.02--“Flooding response” , or procedure 528.03.03--“Emergency drainage operation during power outage and abnormal water entry in buildings”.

(5) If beyond design basis events happen and reactors lose all onsite and offsite AC power source or

no water can be injected into reactors, the plant needs to follow procedure 1451---"Reactor ultimate response procedure" to adopt decisive actions to be prepared to abandon reactors" .

2. Enhancement measures

(1) To respond to tsunami improvement programs, the plant piles flood barriersandbags at RB, CB, DG fuel tanks, AFB, fire-fighting pump houses, the RBSW pump house, the place where RBACB at elevation of 12300 mm enters RB, and the place where the waste corridor at elevation of 12300 mm enters RB/CB and AFB.

(2) Before the typhoon season or the end of May every year, related divisions comply with procedure 187--"Operation during typhoons" to conduct walkdown inspection on all drainage trenches in the plant as well as the drainage trenches of Shiding Stream to see if they are clogged. Every 18 months, labor safety division abides by procedure 769--"Walkdown inspection on the fire-proof and sealing of cable and ventilation duct penetration areas" to perform the inspection.

(3) Following procedure 1451- Unit ultimate response procedure, the plant:

i. Originally procures 2 gas turbine generators and 2 diesel generators that can start during station blackout,

ii. Originally procures two 4.16 kV 1500 kW diesel generators,

iii. has 2 EDGs to supply power,

iv. Originally procures three 480 V 100 kW and two 480 V 200 kW mobile diesel generators to provide power to 125 V charging machine, CVCF, SLC, FCS, and SGT,

v. Originally procures two 125 V battery sets and 5rectifiers, in order to provide temporary 125V power to SRV,

vi. Originally procures 8 diesel sump pumps and 32 power-driven drainage pumps.

Regarding the procured diesel generators, diesel sump pumps, power-driven drainage pumps, battery sets and 5rectifiers, are stored in the EL43M Low- Radioactive Drum Storage Building. When a heavy rainfall comes, water will flow to the EL12.1M plant drainage trench to prevent those equipment from over flood to cause damage.

Appendix 4-1 Stress Tests of Compound Natural Events of Typhoons and Heavy Rainfall/ Mudslides

1. Description of "Typhoons +Heavy Rainfalls/ Mudslides" Stress Tests

(1) Purpose: This is to test the capability of the plant to respond to compound natural events induced by extreme climate in the future, to find safety margin for protection design of the plant, and to find out the cliff-edge effect of the plant facilities/equipment in assumed scenarios.

(2) Beginning of the scenario:

1. A severe typhoon is going to seize the plant and is expected to bring heavy rainfalls.
2. Typhoon emergency team is established and 6 workers from a fire-fighting shift and typhoon emergency response workers are standby.
3. Next shift of workers is standby onsite.
4. 2 units are in full operation.

Next:

5. The typhoon brings in strong winds and very heavy rainfall, causing the loss of offsite power sources as well as emergency standby power sources and resulting in flooding spreading onsite because mudslides clogs drainage trenches. Further, the spreading flood leads to flooding on the ground of the main building area as well as on bottom floors of main buildings, and the subsequent loss of water feeding function of safety systems happens. Moreover, the seawater pump houses in the reactor buildings are flooded and lose ultimate heat.

Note: The scenario above is an assumption for the stress tests, but it is in fact against the knowledge of the plant:

1. An assumption is that the forecast information from Central Weather Bureau is different from actual wind strength/ precipitation and the plant misjudges that the units would not be in danger. However, accuracy of forecasts from Central Weather Bureau does give the plant enough time to make the units to stay in a safe status.

2. By far, severe typhoons and heavy rainfall have never seized at the same time, and the assumption is based on data that is more serious than a once every 10000-year storm. Therefore, the main building area is flooded in the stress test.

3. Based on the mudslide information by Water and Soil Conservation, Council of Agriculture and the investigation by the power station, mudslides would not cause onsite flooding. However, in the scenario, trenches are clogged due to mudslides, which leads to flooding spreading on-site, making flood water go to the main area of

the plant. Besides, all collecting sumps of the underground sewage system throughout the plant are clogged by mudslides, which also results in flooding.

4. After maintenance, the plant complies with procedure 796 --“Procedure for periodical inspection of cable penetrations at buildings and fire-proof shielding” to ensure complete sealing of penetration holes and ventilation ducts. The plant will also finish installing flood barrierplates at each main building. In this scenario, it is also assumed that these protections fail, so the ground floor of each building is flooded.

5. The seawater pump house of the reactor buildings is at elevation of 5.3 meters and next to the sea, but the pumps are at elevation of 12 meters and are protected by water-tight doors. Therefore, even if the height of the maximum tsunamis run-up waves is 8.07meters, it would not cause flooding or damage the equipment inside the seawater pumps in the reactor buildings.

- Time sequence of the stress tests (Fig. 1)
- Response sequence for the stress tests (Fig. 2)

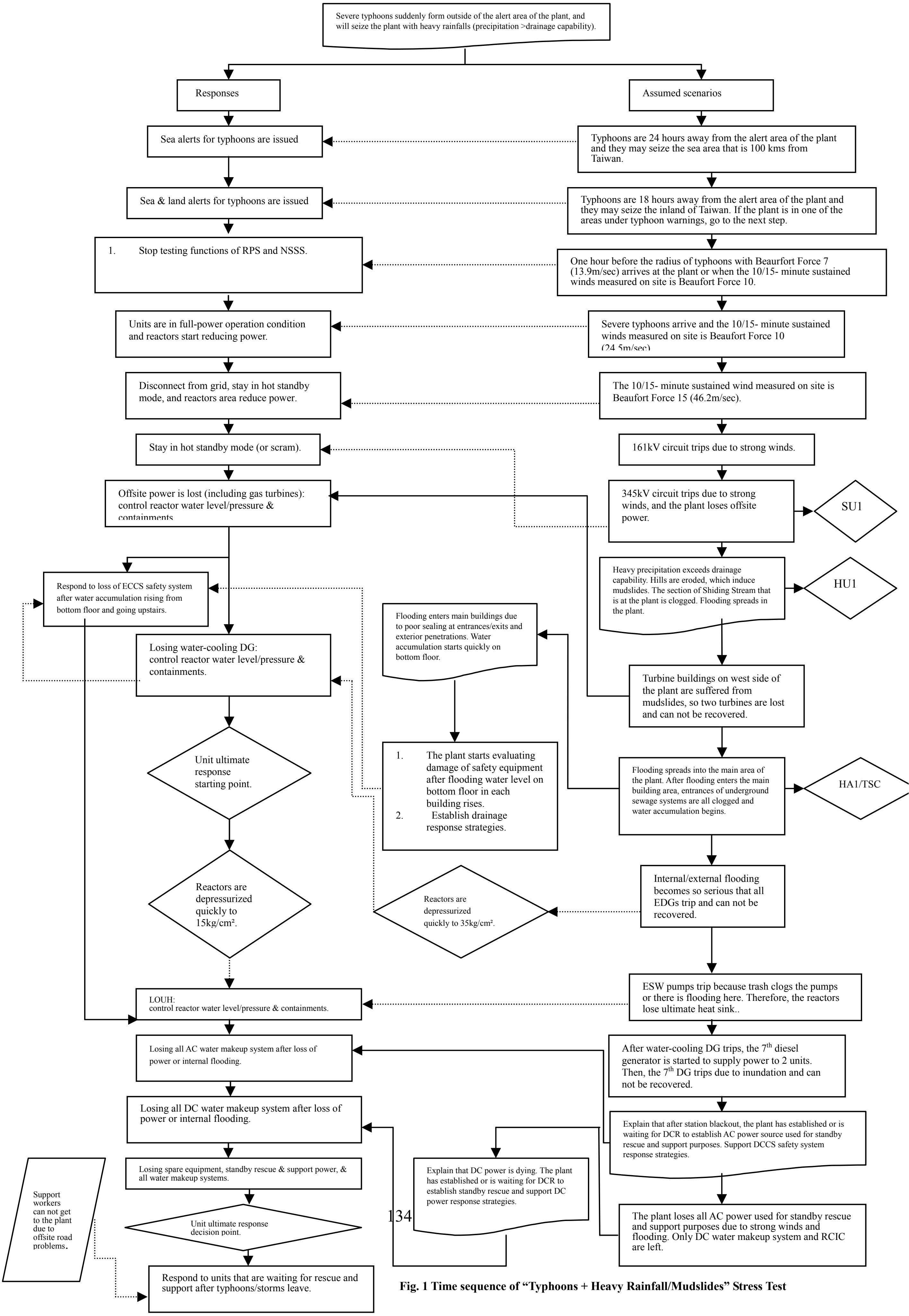


Fig. 1 Time sequence of "Typhoons + Heavy Rainfall/Mudslides" Stress Test

Scenario:
1. A severe typhoon is going to seize the plant and is expected to bring heavy rainfalls.
2. Typhoon emergency team is established and 6 workers from a fire-fighting shift and typhoon emergency response workers are standby.
3. Next shift of workers is standby in the standby dormitory.
4.2 units are in full operation.
Next:
5. The typhoon brings in strong winds and very heavy rainfall, causing the loss of offsite power sources and emergency standby power sources. Flooding spreads onsite because mudslides clogs drainage trenches, leading to flooding on the ground of the main building area as well as on bottom floor of main buildings and the subsequent loss of feedwater function of safety systems. ECW pumps are also flooded which results in LOUH.

Page 1

Assumed scenario	Design basis & various scenario base line	Protection intensity	Procedure Response	Manpower and work duration
Central Weather Bureau issues sea and land alerts for typhoons, and the plant is in an areas under the typhoon warning. Typhoons of Beaufort Force 7 is 18 hours away from the alert area of the plant The plant is in "typhoon watching period" mode.	Power switchyard/ transmission route gust design 57.7m/sec, namely Force 17 Main buildings 60 m/sec, namely Force17 and above	Power sources 1. 345kV 4 loops 2.161kV 2 loops 3. Water-cooling diesel generators (A/B/C) 4. Air-cooling generator (7th) 5. 2 gas turbine generators (under RAP ,expected to be done by commercial operation or by 103.3.15) 6.2 gas turbine generators fail, so start diesel generators (under RAP, ,expected to be done by commercial operation or by 103.3.15) 7. 2 Water-cooling diesel generators (A/B/C) are the backup of one another. 8. Add one safe guard diesel generator (To be done by 101.7.31) 9. 480V mobile diesel generators (supply power to safety and non-safety CVCF, and charger) 10. DC alternative feedwater system. Feedwater system 1. CP/FW 2. CRD 3.RCIC 4.HPCS 5.LPFL 6. SLC receives water from boric acid tank/test tank. 7. CSTF via RHR/HPCF/RCIC feedwater pipes 8.Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. 9. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors. Heat sink 1. Use air-cooling diesel generators or water-cooling diesel generators to be the backup of one another, or use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/SGT/FCS/CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established. 2. Verify RCIC can still feed water into reactor core when there is no AC power, and reduce pressure of reactors.	The plant goes to "typhoon watching period" mode. 1. Follow procedure 528.02.01 to water the development of typhoons. If typhoons are considered to seize the plant after judgment, follow procedure 187 "Operation during typhoons" to close all doors and windows in all buildings and inspect if onsite drainage trenches are not clogged. 2. Test all telecommunication system and ensure NDS is normal. 3. Confirm in 8 hours that DIV I.Ⅱ.Ⅲ emergency diesel generators can operate. 4. All divisions conduct inspection based on the "typhoon checklists" in procedure 187 and make improvement. Control air source 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.	On shift/8hrs (Step1-3) All divisions/ 10 hours before typhoons of Beaufort Force 7 arrive at the alert area of the plant (Step 4)
Central Weather Bureau issues sea and alerts for typhoons, and the plant is in an area under the typhoon warning. Typhoons of Beaufort Force 7 is 10 hours away from t the alert area of the plant. The plant is in "typhoon alert period" mode.	Power switchyard/ transmission route gust design 57.7m/sec, namely Force 17 Main buildings 60m/sec, namely Force17 and above	Same as above	When the typhoon emergency response team is established: 1.When the plant expects typhoons and heavy rainfall to hit the site, the superintendent (or his authorized person) reports to nuclear development division that the plant will be in the alert mode or hold typhoon meetings. 2.Typhoon coordinator informs the shift manager about the establishment of the team and the shift manager should stay in contact with the typhoon coordinator at all time. 3.The shift manager should assign workers to start NDS and confirm it is connected. 4. If abnormal situations or accidents regarding power generating at the plant occur due to typhoons, the plant should report obeying procedure for natural events or emergency events.	On shift/ 4hrs

Fig. 2"Typhoons +heavy rainfalls /mudslides" Stress Tests"

Assumed scenario	Design basis & various scenario base line	Protection intensity	Procedure	Manpower and work duration
		Response		
One hour before the radius of typhoons with wind of Beaufort Force 7 arrives at the site, or the site is expected to be within the radius of typhoons with wind of Beaufort Force 7 and the actual 10/15-minute sustain wind measured at the plant reaches Force 10.	Power switchyard/ transmission route gust design 57.7m/sec, namely Force 17 Main buildings 60m/sec, namely Force17 and above	Power sources 1. 345kV 4 loops 2.161kV 2 loops 3. Water-cooling diesel generators (A/B/C) 4. Air-cooling generator (7th) 5. 2 gas turbine generators (under RAP ,expected to be done by commercial operation or by 103.3.15) 6.2 gas turbine generators fail, so start diesel generators (under RAP, ,expected to be done by commercial operation or by 103.3.15) 7. 2 Water-cooling diesel generators (A/B/C) are the backup of one another. 8. Add one safe guard diesel generator (To be done by 101.7.31) 9. 480V mobile diesel generators (supply power to safety and non-safety CVCF, and charger) 10. DC alternative feedwater system. Feedwater system 1. CP/FW 2. CRD 3.RCIC 4.HPCS 5.LPFL 6. SLC receives water from boric acid tank/test tank. 7. CSTF via RHR/HPCF/RCIC feedwater pipes 8.Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. 9. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors. Heat sink 1. Use air-cooling diesel generators or water-cooling diesel generators to be the backup of one another, or use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/SGT/FCS/CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established. 2. Verify RCIC can still feed water into reactor core when there is no AC power, and reduce pressure of reactors.	1. Stop function tests related to RPS LDI, and SSLC system. --- Control air source 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.	On shift/ 0.5hr
Actual 10/15-minuet sustain wind measured at the plant reaches Beaufort Force 10. (24.5m/sec) Actual 10/15-minuet sustain wind measured at the plant jumps to Beaufort Force 15. (46.2m/sec)	Power switchyard/ transmission route gust design 57.7m/sec, namely Force 17 Main buildings 60m/sec, namely Force17 and above	Same as above	1. Beaufort Force 10, reduce power to below turbine trip bypass set point of RPS in 3 hours. (CTP<40%) 2. Beaufort Force 15, disconnect from grid and stay in hot standby mode in 4 hours.	1. On shift/ 3hr 2. On shift/ 4hrs, and disconnect from grid and leave on hot standby.

Fig. 2"Typhoons +heavy rainfalls /mudslides" Stress

Assumed scenario	Design basis & various scenario base line	Protection intensity	Procedure / Response	Manpower and work duration
161kV transmission cable trips >57.7m/sec.	Power switchyard/ transmission route gust design 57.7m/sec, namely Force 17	Power sources 1. 345kV 4 loops 2.161kV 2 loops//loss 3. Water-cooling diesel generators (A/B/C) 4. Air-cooling generator (7th) 5. 2 gas turbine generators (under RAP ,expected to be done by commercial operation or by 103.3.15) 6.2 gas turbine generators fail, so start diesel generators (under RAP, ,expected to be done by commercial operation or by 103.3.15) 7. 2 Water-cooling diesel generators (A/B/C) are the backup of one another. 8. Add one safe guard diesel generator (To be done by 101.7.31) 9. 480V mobile diesel generators (supply power to safety and non-safety CVCF, and charger) 10. DC alternative feedwater system. Feedwater system 1. CP/FW 2. CRD 3.RCIC 4.HPCS 5.LPFL 6. SLC receives water from boric acid tank/test tank. 7. CSTF via RHR/HPCF/RCIC feedwater pipes 8.Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. 9. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors. Heat sink 1. Use air-cooling diesel generators or water-cooling diesel generators to be the backup of one another, or use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/SGT/FCS/CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established. 2. Verify RCIC can still feed water into reactor core when there is no AC power, and reduce pressure of reactors.	*When the meteorological tower measured the speed of the gust at the plant is 60m/sec (Beaufort Force 17) and it poises a threat to the safety of the operation in the protection area or it seriously hinders workers from conducting safe operation, the plant immediately announces units go to HU1 using procedure 1401 as guidance and comply with procedure 528.02.01 to achieve cold shutdown. *When the speed of sustain wind of typhoons reaches 60m/sec and it poises a threat to the safety of the operation in the protection area or it seriously hinders workers from conducting Control air source 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.	On shift/ Continue
345kV transmission cable trips >57.7m/sec.	Power switchyard/ transmission route gust design 57.7m/sec, namely Force 17	Power sources 1. 345kV 4 loops 2.161kV 2 loops//loss 3. Water-cooling diesel generators (A/B/C) 4. Air-cooling generator (7th) 5. 2 gas turbine generators (under RAP ,expected to be done by commercial operation or by 103.3.15) 6.2 gas turbine generators fail, so start diesel generators (under RAP, ,expected to be done by commercial operation or by 103.3.15) 7. 2 Water-cooling diesel generators (A/B/C) are the backup of one another. 8. Add one safe guard diesel generator (To be done by 101.7.31) 9. 480V mobile diesel generators (supply power to safety and non-safety CVCF, and charger) 10. DC alternative feedwater system. Feedwater system 1. CP/FW//loss 2. CRD 3.RCIC 4.HPCS 5.LPFL 6. SLC receives water from boric acid tank/test tank.//loss 7. CSTF via RHR/HPCF/RCIC feedwater pipes //loss 8.Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. 9. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors.	1. Immediately shutdown reactor and achieve cold shutdown mode as soon as possible. 2. If reactors already scram, return to the original state. 3. Confirm if gas turbine generators supply power to A4, B4, C4bus, or emergency bus should be supplied with power from water-cooling DG. (528.02.01/524.04/501.01/203.01) Heat sink 1. Use air-cooling diesel generators or water-cooling diesel generators to be the backup of one another, or use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/SGT/FCS/CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established. 2. Verify RCIC can still feed water into reactor core when there is no AC power, and reduce pressure of reactors. Control air source 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.	On shift/ 12hrs till cold shut down

Fig. 2“Typhoons +heavy rainfalls /mudslides” Stress

Assumed scenario	Design basis & various scenario base line	Protection intensity	Procedure Response	Manpower and work duration
Mt. hills are seriously eroded by heavy rainfall and this leads to mudslides, which clog Shiding Stream and consequently flooding spreads in the plant. (precipitation >491mm/day) The auxiliary transformers of the reactors, RAT1 and rat2 are flooded and not operational. So, turbine generators can not supply power to 4.16kV essential bus via auxiliary transformers.	Onsite drainage capability 310mm/hr Drainage systems of the plant mainly utilize onsite man-made trenches II & III. Not only do they drain rainfalls and mountain floods from the upstream, they also drain rainfalls converged from the plant and around the plant. Information from Water and Soil Conservation, Council of Agriculture shows no mudslides of these two streams. Gas turbine generators EL.22m	Power sources 1. Water-cooling diesel generators (A/B/C) 2. Air-cooling generator (7th) 3. 2 gas turbine generators (under DCR)//loss 4.2 gas turbine generators fail, so start diesel generators (under DCR) 5. 2 water-cooling diesel generators (A/B/C) are the backup of one another. 6. Add one safe guard diesel generator (To be done by 101.7.31) 7. 480V mobile diesel generators (supply power to safety and non-safety CVCF, and charger) 8. DC alternative feedwater system. Feedwater system 1. CP/FW//loss 2. CRD 3.RCIC 4.HPCS 5.LPFL 6. SLC receives water from boric acid tank/test tank.//loss 7. CSTF via RHR/HPCF/RCIC feedwater pipes //loss 8.Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. 9. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors. Heat sink 1. Use air-cooling diesel generators or water-cooling diesel generators to be the backup of one another, or use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/SGT/FCS/CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established. 2. Verify RCIC can still feed water into reactor core when there is no AC power, and reduce pressure of reactors. Control air source 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.	1. Follow procedure 187 "Operation during typhoons:" Close all doors & windows in buildings and ensure Shiding Stream and onsite drainage trenches are not clogged. 2. Follow procedure 187.01 "Water accumulation/ flooding prevention and response during typhoons or very heavy rain:" Close the water-tight/semi-water tight doors in RB/CB/RBSW pump houses, and inspect if drainage inside and outside of buildings are normal. 3. Inspect all emergency essential buses and use water-cooling diesel generators to supply them power. 4. Follow AOP528.02.01 "Reactor operation during typhoon warning period:" inspect if drainage inside and outside of buildings are normal. 5. follow AOP 528.03.01 "Flooding response:" If the safety power source of RB/CB may be flooded, follow AOP501.04 "Emergency shutdown" and follow SOP411 to use steam bypass valve to reduce the pressure of RPV to 3.15MpaG, close the water-tight/semi-water tight doors in RB/CB/RBSW pump houses, and pile sandbags. 6. Follow AOP 528.03.02 "Flooding response:" ensure sump drainage pumps in buildings operate normally. 7. Follow AOP 528.03.03 "Emergency drainage operation during power outage and abnormal water entry in buildings:" use mobile diesel generators and sump pumps for drainage. 8. Follow procedure 769.P16: inspect the sealing of cable penetration and ventilation ducts in all buildings once every 18 months.	On shift/ 1hr
After flooding spreads into the main area of the plant, entrances/exits of the sewage system are clogged and accumulation starts quickly. , which is bigger than the once every-40 year precipitation>107mm/hr (The drainage capability design of the plant is 310mm/hr.)	Shiding Stream drainage capability 297mm/hr. Elevation of the main area of the plant is 12.3M. Capability of the ground drainage system is 4.43cms. Drainage systems of the plant mainly utilize man-made trenches (total capability is 218.7cms). Not only do they drain rainfalls and mountain floods from the upstream, they also drain rainfalls converged from the plant and around the plant. Install flood barrierplates at exterior doors of reactor buildings, air-cooling diesel generator (7th), and emergency seawater pump rooms.	Power sources 1. Water-cooling diesel generators (A/B/C) 2. Air-cooling generator (7th) 3. 2 gas turbine generators fail, so start diesel generators (under DCR) 4. 2 water-cooling diesel generators (A/B/C) are the backup of one another. 5. Add one safe guard diesel generator (To be done by 101.7.31) 6. 480V mobile diesel generators (supply power to safety and non-safety CVCF, and charger) 7. DC alternative feedwater system. Feedwater system 1.CRD 2.RCIC 3.HPCS 4.LPFL 5. SLC receives water from boric acid tank/test tank.//loss 6. CSTF via RHR/HPCF/RCIC feedwater pipes //loss 7.Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. 8. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors.	1. If water accumulation starts in the main area of the plant, follow procedure, confirm units are shut down and announce HA1, & establish TSC. 2. If TSC can not enter the plant, follow procedure 1408 "OSC mobilization and response procedure" to start emergency mobilization. 3. Monitor alarms for sumps outside of buildings/ Sump pumps are operating normally. 4. Pile sandbags at emergency equipment in main area of the plant or install flood barrierplates at entrances/exits of main buildings to prevent flooding from entering. (187/187.01/528.02.01/528.03.01/528.03.02 /528.03.03/769/1408) -- Heat sink 1. Use air-cooling diesel generators or water-cooling diesel generators to be the backup of one another, or use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/SGT/FCS/CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established. 2. Verify RCIC can still feed water into reactor core when there is no AC power, and reduce pressure of reactors. Control air source 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.	Continue
Place sandbags at entrances/exits of ground floor of reactor buildings				

Fig. 2"Typhoons +heavy rainfalls /mudslides" Stress Tests"

Assumed scenario	Design basis & various scenario base line	Protection intensity	Procedure / Response	Manpower and shift duration
Flooding enters main buildings because of poor sealing of entrances/exits or penetrations. Water starts accumulating quickly on the bottom floor. The plant evaluates the damage rising accumulation water level on bottom floor of all buildings. causes to safety systems. The plant evaluates the damage accumulation going upstairs. can cause to safety systems. Drainage response strategies. Describe the situation of flooding on bottom floor of all buildings going up to ground floor complying procedure.	1. Pile sandbags at the entrances/exits on the ground floor of buildings 2.Install flood barrierplates on the ground floor of RB/CB/AFB/ACB/ RWT/FPH/RBSW pump rooms/DG fuel oil tanks. 3. Inspect sealing of penetration holes and reserved holes on exterior walls of buildings (Procedure 769) 4. All room doors at ECCS rooms are water-seal to prevent containment suppression pools from leaking to inside of the rooms. There are two drainage pumps and flood alarms in each room. 5. Dry well has 4 sump pumps. RB has 16 sump pumps and the total drainage capability is 3840ch/hr. Diesel generator building has 2 sump pumps, so the total drainage capability is 60 cm/hr. Turbine building has 26 sump pumps, so the total capability is 780cm/hr. Control building has 14 sump pumps, so the total capability is 2100cm/hr. Aux. fuel building has 6 sump pumps, so the total capability is 540cm/hr. Restricted buildings has 2 sump pumps, so the total capability is 600cm/hr. Waste buildings have 8 sump pumps, so the total capability is 120cm/hr. 6. When flooding occurs, mechanic division provides drainage equipment (2 mobile generators to supply power and 5 electric sump pumps; procedure113.5)	Power sources 1. Water-cooling diesel generators (A/B/C)//loss 2. Air-cooling generator (7th) 3. 2 gas turbine generators fail, so start diesel generators (under DCR) 4. 2 water-cooling diesel generators (A/B/C) are the backup of one another. 5. Add one safe guard diesel generator (To be done by 101.7.31) 6. 480V mobile diesel generators (supply power to safety and non-safety CVCF, and charger) 7. DC alternative feedwater system. Feedwater system 1.CRD//loss 2.RCIC//loss 3.HPCS//loss 4.LPFL//loss 5. SLC receives water from boric acid tank/test tank.//loss 6. CSTF via RHR/HPCF/RCIC feedwater pipes //loss 7.Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. 8. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors. Heat sink 1. Use air-cooling diesel generators or water-cooling diesel generators to be the backup of one another, //loss or use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/SGT/ FCS/CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established. 2. Verify RCIC can still feed water into reactor core when there is no AC power, and reduce pressure of reactors. Control air source 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.	1.Monitor water level of building sumps. If water level is abnormal, follow procedure 187.01 “Water accumulation/ flooding prevention and response during typhoons or very heavy rain” and follow AOP 528.03.02 “Flooding response” to trace and isolate origins of accumulated water; ensure sump pumps operate normally for drainage. 2. Follow AOP528.03.03 “Emergency drainage operation during power outage and abnormal water entry in buildings:” to install mobile diesel generators and sump pumps to drain flood water outside of buildings. 3. The plant has prepared emergency rescue and support equipment, including various sizes of sump pumps, 13 drainage pumps, & 13 emergency generators, to provide emergency rescue and support to related damaged building floors and areas during flooding. 4. follow AOP 528.03.01 “Flooding response:” If the safety power source of RB/CB may be flooded, follow AOP501.04 “Emergency shutdown” and follow SOP411 to use steam bypass valve to reduce the pressure of RPV to 3.15MpaG	3workers/1. 5hrs/set up 1 drainage pump (the typhoon response group) Continue.

Fig. 2“Typhoons +heavy rainfalls /mudslides” Stress Tests”

Assumed scenario	Design basis & various scenario base line	Protection intensity	Procedure / Response	Manpower and work duration
Flooding enters main buildings because of poor sealing of entrances/exits or penetrations. Water starts accumulating quickly on the bottom floor. The plant evaluates the damage rising accumulation water level on bottom floor of all buildings. causes to safety systems. The plant evaluates the damage accumulation going upstairs. can cause to safety systems. Drainage response strategies. Describe the situation of flooding on bottom floor of all buildings going up to ground floor complying procedure. (Continuing to next page) next page)	Same as above	Same as above	5. When accumulation on 1F of the combined bldgs rises, water may start permeating via ECCS flood barrierdoors due to reversed water pressure. * Water in the reactor buildings, EL. -8.2M, starts accumulating. (1) Notify the typhoon response group to enhance drainage to outside of buildings by using mobile diesel generators and temporary sump pumps. (2) Use fire-fighting water (fire-fighting water, stream water, sea water) via diesel fire-fighting pump/fire truck or raw water reservoir via RHR and gravity to feed water into reactor core, or use mobile diesel generators to supply power to SLC pumps and CSTF pumps for them to feed water into reactor core. Follow EOP 583 "Control secondary containment:" (1) If water level of any floor sump tanks at RB> the highest normal water level during operation, or water level in RB area >0M, isolate the leaking water that is being drained into this area , except for the system that fire-fighting and EOP need. (2) If water level in any of the RB area> the highest safe water level during operation, follow EOP581 "Reactor control" and AOP501.1 "Reactor scram". (3) If water level in more than one RB areas> the highest safe water level during operation, follow EOP585 "Emergency reactor depressurizing" If all feedwater systems are not operational, the plant starts reactor ultimate response. 6. If accumulation on the ground of diesel generator Bldg>30cm, the plant will lose AVR panel and then DG. 7. Flooding on bottom floor of turbine bldgs will cause loss of feedwater system. 8. Flooding on bottom floor of the waste treatment bldg does not affect safety of reactors.	NA

Fig. 2"Typhoons +heavy rainfalls /mudslides" Stress Tests"

Assumed scenario	Design basis & various scenario base line	Protection intensity (Response)	Procedure (Response)	Manpower and work duration
Respond to flooding going upstairs from bottom floor of all buildings and subsequent loss of ECCS safety system.	1. Pile sandbags at the entrances/exits on the ground floor of buildings 2.Install flood barrierplates on the ground floor of RB/CB/AFB/ACB/ RWT/FPH/RBSW pump rooms/DG fuel oil tanks. 3. Inspect sealing of penetration holes and reserved holes on exterior walls of buildings (Procedure 769) 4. All room doors at ECCS rooms are water-seal to prevent containment suppression pools from leaking to inside of the rooms. There are two drainage pumps and flood alarms in each room. 5. Dry well has 4 sump pumps. RB has 16 sump pumps and the total drainage capability is 3840ch/hr. Diesel generator building has 2 sump pumps, so the total drainage capability is 60 cm/hr. Turbine building has 26 sump pumps, so the total capability is 780cm/hr. Control building has 14 sump pumps, so the total capability is 2100cm/hr. Aux. fuel building has 6 sump pumps, so the total capability is 540cm/hr. Restricted buildings has 2 sump pumps, so the total capability is 600cm/hr. Waste buildings have 8 sump pumps, so the total capability is 120cm/hr. 6. When flooding occurs, mechanic division provides drainage equipment (2 mobile generators to supply power and 5 electric sump pumps; procedure113.5)	Power sources 1. Air-cooling generator (7th) 2. 2 gas turbine generators fail, so start diesel generators (under DCR) 3. Add one safe guard diesel generator (To be done by 101.7.31) 4. 480V mobile diesel generators (supply power to safety and non-safety CVCF, and charger) 5. DC alternative feedwater system. Feedwater system 1.Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. 2. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors. Heat sink 1. Use air-cooling diesel generators or water-cooling diesel generators to be the backup of one another, //loss or use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/SGT/FCS/CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established. 2. Verify RCIC can still feed water into reactor core when there is no AC power, and reduce pressure of reactors. Control air source 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.	5. When accumulation on 1F of the combined bldgs rises, water may start permeating via ECCS flood barrierdoors due to reversed water pressure. * Water in the reactor buildings, EL. -8.2M, starts accumulating. (1) Notify the typhoon response group to enhance drainage to outside of buildings by using mobile diesel generators and temporary sump pumps. (2) Use fire-fighting water (fire-fighting water, stream water, sea water) via diesel fire-fighting pump/fire truck or raw water reservoir via RHR and gravity to feed water into reactor core, or use mobile diesel generators to supply power to SLC pumps and CSTF pumps for them to feed water into reactor core. Follow EOP 583 “Control secondary containment:” (1) If water level of any floor sump tanks at RB> the highest normal water level during operation, or water level in RB area >0M, isolate the leaking water that is being drained into this area , except for the system that fire-fighting and EOP need. (2) If water level in any of the RB area> the highest safe water level during operation, follow EOP581 “Reactor control” and AOP501.1 “Reactor scram”. (3) If water level in more than one RB areas> the highest safe water level during operation, follow EOP585 “Emergency reactor depressurizing” If all feedwater systems are not operational, the plant starts reactor ultimate response. 6. If accumulation on the ground of diesel generator Bldg>30cm, the plant will lose AVR panel and then DG. 7. Flooding on bottom floor of turbine bldgs will cause loss of feedwater system. 8. Flooding on bottom floor of the waste treatment bldg does not affect safety of reactors. 9. Water accumulates in the area where the power source of the essential buses A4, B4,& C4 of ECCS is: (1) The plant gives the stop order and stops using related equipment in this area: RBSW pump/RBCW pump/HPCF pump/RHR pump/ emergency chill-water equipment (2) Perform reactor alternative water injection. (3) Start unit ultimate response and reduce the pressure of reactors to below 15 kg/cm² (1451)	Continue.

Fig. 2“Typhoons +heavy rainfalls /mudslides” Stress Tests”

Assumed scenario	Design basis & various scenario base line	Protection intensity	Procedure / Response	Manpower and shift duration
Internal/external flooding is serious so all diesel generators trip and can not recover. (DG loss: reactor water level/ pressure & containment control)	Diesel generators are of redundancy and independence. Three of the areas in the buildings are at an elevation of 12.3M. Only one of them can supply enough power for safe shutdown. Install flood barrierplates or pile sandbags at exterior doors of ground floor of reactor buildings, air-cooling diesel generator (7th) room, and emergency seawater pump rooms.	Power sources 1. Air-cooling generator (7th) 2. 2 gas turbine generators fail, so start diesel generators (under DCR) 3. Add one safe guard diesel generator (To be done by 101.7.31) 4. 480V mobile diesel generators (supply power to safety and non-safety CVCF, and charger) 5. DC alternative feedwater system. Feedwater system 1.Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. 2. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors. Heat sink 1. Use air-cooling diesel generators or use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/SGT/FCS/CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established. 2. Verify RCIC can still feed water into reactor core when there is no AC power, and reduce pressure of reactors. Control air source 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.	1. Follow procedure 535 "Emergency diesel generators." This procedure guides the plant to operate 7th emergency DG to replace the emergency diesel generators for unit 1 or unit 2 or supply power to reactors. 2. Comply with related EOP. 3. Obey procedure 1451 to conduct unit ultimate response and do standby feedwater preparation. 4. Use procedure 1451 as a guideline to conduct unit ultimate response and depressurize to under 15kg/cm². Meanwhile, conduct containment venting.	On shift/ 0.6hr Maintenance division/ On shift/ 0.5hr
Emergency pump room trips due to flooding or trenches can no function due to debris (Heat loss: reactor water level/pressure & containment control)	Emergency seawater pump room elevation is 5.3M and the pump motor is even higher, 12M, so the motor will not be inundated easily. Install flood barrierplates at the inlets of the emergency seawater pump houses in reactor buildings to prevent flooding from entering and permeating.	Power sources 1. Air-cooling generator (7th) 2. 2 gas turbine generators fail, so start diesel generators (under DCR) 3. Add one safe guard diesel generator (To be done by 101.7.31) 4. 480V mobile diesel generators (supply power to safety and non-safety CVCF, and charger) 5. DC alternative feedwater system. Feedwater system 1.Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. 2. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors. Heat sink 1. Use air-cooling diesel generators or use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/SGT/FCS/CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established. 2. Verify RCIC can still feed water into reactor core when there is no AC power, and reduce pressure of reactors. Control air source 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.	Continue to follow EOP to maintain water level and containment pressure (1451/ EOP)	On shift/ 1hr

Fig. 2"Typhoons +heavy rainfalls /mudslides" Stress Tests"

Assumed scenario	Design basis & various scenario base line	Protection intensity	Procedure Response	Manpower and shift duration
After the 7th diesel generator supplies power to 2 units, it is inundated and can not recover. After explaining station blackout, the plant has established AC power Source for standby rescue and support, in order to support ECCS safety system and response strategies.	7th air-cooling diesel generator is at an elevation of 12.3M. 480V mobile diesel generators are stored at appropriate elevations to avoid flooding.	Power sources 1. Air-cooling generator (7th)//loss 2. 2 gas turbine generators fail, so start diesel generators (under DCR) 3. Add one safe guard diesel generator (To be done by 101.7.31) 4. 480V mobile diesel generators (supply power to safety and non-safety CVCF, and charger) 5. DC alternative feedwater system. Feedwater system 1.Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. 2. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors. Heat sink 1. Use air-cooling diesel generators//loss or use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/SGT/FCS/CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established. 2. Verify RCIC can still feed water into reactor core when there is no AC power, and reduce pressure of reactors.	1. 2 turbine generators fail, so start diesel generators or safe guard diesel generators or mobile diesel generators, in order to supply power to RHR/RBCW/RBSW/SLC/SGT/FCS/CSTF/SRV/CVCF so water can be fed into reactor cores and long term cooling can be established. 2. After onsite flooding recedes, use four 480v mobile diesel generators to supply power to safe and non-safe CVCF and charger (1451) Control air source 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.	Electric div./ 1hr/ one reactor On shift./1hrs
Due to loss of power or internal flooding, the plant loses all AC power. 480V mobile diesel generators are procured and prepared. If added with Feedwater System and Heat Sink, the plant would not lose LOUH or feedwater system function	1. Inside of the ECCS house is divided into 3 rooms and each room is isolated/ not connected with another. Each room has water-seal doors, so leaking at the suppression pool area in containments would not enter each room. Each room has two drainage pumps and flood signal system. 2. RB has 16 sump pumps, so the total capability is 3840cm/h. The diesel generator building has 2 sump pumps, so the total capability is 60ch/hr. 3. Low pressure residual heat removing system has separated 3 series. Only one of them can supply enough power for safe shutdown.	Power sources 1. 2 gas turbine generators fail, so start diesel generators (under DCR) 2. Add one safe guard diesel generator (To be done by 101.7.31) 3. 480V mobile diesel generators (supply power to safety and non-safety CVCF, and charger) 4. DC alternative feedwater system. Feedwater system 1.Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. 2. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors. Heat sink 1. Use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/SGT/FCS/CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established. 2. Verify RCIC can still feed water into reactor core when there is no AC power, and reduce pressure of reactors. Control air source 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.	Obey procedure 1451 to conduct unit ultimate response *Confirm if water source is available and plan about priorities. Meanwhile, Feedwater route has established and completed. *Primary containment ventilation operation route has been established. (When operating primary containment ventilation, must consider if the air would flow to the other unit and take protection measures (304.17)) Note: mobile DGs can be connected to SBGT and DC chargers of units.	Continue .

Fig. 2“Typhoons +heavy rainfalls /mudslides” Stress Tests”

Assumed scenario	Design basis & various scenario base line	Protection intensity	Procedure Response	Manpower and shift duration
The plant loses standby rescue and support AC power due to strong winds and flooding. Only DC water makeup system and RCIC system are left. Explain DC power will die or be inundated. The plant has established or is waiting for DCR to be set up and then establishes response strategies for standby rescue and support DC power.	The RCIC room has water-seal doors, so leaking at the suppression pool area in containments would not enter each room. There is one 50gpm drainage pump in the room. DC batteries can last for 8 hours. When they are in the unnecessary load mode and their essential buses are connected, they can last for 24 hours. 480 V mobile diesel generators.	Power sources 1. 2 gas turbine generators fail, so start diesel generators (under DCR) 2. Add one safe guard diesel generator (To be done by 101.7.31) 3. 480V mobile diesel generators (supply power to safety and non-safety CVCF, and charger) 4. DC alternative feedwater system. Feedwater system 1.Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. 2. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors. Heat sink 1. Use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/SGT/FCS/CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established.	1.Continue using RCIC to keep reactors covered in water (Watch primary containment pressure and conduct containment ventilation once. 2. Extend DC power: Unnecessary load is turned off. 3. Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. Or use wet well/dry well spray. 4. 2 turbine generators fail, so start diesel generators or safe guard diesel generators or mobile diesel generators, in order to supply power to RHR/RBCW/RBSW/SLC/SGT/FCS/CSTF/SRV/CVCF so water can be fed into reactor cores and long term cooling can be established. 5. Connect 480V mobile diesel generators with safe and non-safe CVCF and chargers (1451) (1451/540.7/535) Heat sink 2. Verify RCIC can still feed water into reactor core when there is no AC power, and reduce pressure of reactors. Control air source 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.	On shift 0.5hr On shift/ 0.5hr Electric div./ 1hr
The plant loses all DC water makeup system due to loss of power or internal flooding.	Same as above	Same as above	1.Confirm if water source is available and plan about priorities. Meanwhile, feedwater route has been completed. (500.EOP/1451) 2.Primary containment ventilation operation route is completed. (304.17))	On duty/0.5 hr Continue .
Ultimate response for the situation in which The plant loses all standby rescue and support power or all water makeup system.	Power sources 1. 2 gas turbine generators fail, so start safe guard/diesel generators (under DCR) Feedwater system 1.Fire-fighting water via diesel fire-fighting pump/fire truck or raw water reservoir via RHRC to be injected into reactors by gravity. 2. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors. Heat sink 1. Use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/SGT/FCS/CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established.	Power sources 1. 2 gas turbine generators fail, so start diesel generators (under DCR) 2. Add one safe guard diesel generator (To be done by 101.7.31) 3. 480V mobile diesel generators (supply power to safety and non-safety CVCF, and charger) 4. DC alternative feedwater system. Feedwater system 1.Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. 2. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors.	After confirming the plant loses all water makeup function for reactors, obey ultimate response procedure. 1.Depressurize to below the pressure for alternative feedwater. 2.Conduct containment ventilation (304.17)) --- Heat sink 1. Use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/SGT/FCS/CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established. Control air source 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.	On shift/ 0.5hr Control air source 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.

Fig. 2"Typhoons +heavy rainfalls /mudslides" Stress

sumed scenario	Design basis & various scenario base line	Protection intensity	Procedure Response	Manpower and work duration
Response during the time when the plant waits for rescue and support after typhoons and heavy rainfall. (Support workers on the way are hindered by poor offsite road conditions.)	Reactor cores must be covered in water at all time and containments need to maintain intact. Roads that connect the plant and offsite places: Danjin Highway. Communicative systems: microwave/fax machines/ satellite/the Internet/ phone lines directly connecting to Taipower Company, and etc. The minimum stored volume in 850,000-gallon oil tank is 450,000 gallons, which can supply oil to 4 DG at the same time for them to operate for 17 days (416hrs). The minimum stored volume in 35,000-metri kiloliter and 600-metri kilometer oil tanks is 12,000 metric kiloliters, which can supply oil to 1 DG for it to operate for 30 days. Based on the plant management specifications, control rooms must store the amount of food for 10 people for 5 days. DC batteries can last for 8 hours and are located on 2F. When they are in the unnecessary load mode and their essential buses are connected, they can last for 24 hours.	<u>Power sources</u> 1. 2 gas turbine generators fail, so start diesel generators (under DCR) 2. Add one safe guard diesel generator (To be done by 101.7.31) 3. 480V mobile diesel generators (supply power to safety and non-safety CVCF, and charger) 4. DC alternative feedwater system. <u>Feedwater system</u> 1.Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. 2. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors. <u>Heat sink</u> 1. Use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/ SGT/FCS/CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established. <u>Control air source</u> 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.	Reactors: *If possible, continue using RCIC to maintain RPV water level. * If the plant loses power sources, extend DC power: Unnecessary load is turned off. * If losing all feedwater systems, adopt alternative feedwater system to maintain water level. If the water level can not be maintained higher than TAF, use freshwater or seawater to be injected into reactors and then start ultimate response strategy making abiding by ultimate response procedure (1451). *Establish SRV alternative gas sources 1. Add mobile air compressor, spare nitrogen cylinders, and independent batteries as well as operation switch, and operate SRV, in order to have the capability of reactor depressurizing and containment ventilating. (1451) *When SRV is opened, use RHR suppression pool for cooling, or use ACS, SGT, or COPS to conduct primary containment ventilation once. Containment: *Pay attention to primary containment pressure and conduct containment ventilation once to ensure RCIC would not trip due to high ventilation pressure.). Fuel pool: Continue monitoring water temperature and confirm reactors are covered in water all the time.. (1451)	Continue
<u>Power sources</u> 1. 2 gas turbine generators fail, so start diesel generators (under DCR) 2. Add one safe guard diesel generator (To be done by 101.7.31) 3. 480V mobile diesel generators (supply power to safety and non-safety CVCF, and charger) 4. DC alternative feedwater system. <u>Feedwater system</u> 1.Fire-fighting water via diesel fire-fighting pump/fire truck (getting water from fire-fighting water, stream, and sea) or raw water reservoir via RHRC to be injected into reactors by gravity. 2. Mobile diesel generators supply power to SLC pump and CSTF pump injects water into reactors. <u>Heat sink</u> 1. Use mobile diesel generators to supply power to RHR/RBCW/RBCW/SLC/SGT/FCS/ CSTF/SRV/CVCF, so water can be fed into reactors and long-term cooling can be established. <u>Control air source</u> 1. Add mobile air compressor, spare nitrogen bottles, independent battery power source and switch, and operate SRV, in order to establish the capability of reactor depressurizing and containment venting.				

Fig. 2“Typhoons +heavy rainfalls /mudslides” Stress Tests”

Appendix 4-2 Procedure 528.02.01 “Reactor operation during typhoons warning period”

Preparedness before the typhoon season (187):
All divisions conduct related inspections by the typhoon season or the end of May every year and complete improvement ASAP if any abnormal situations are noticed.

When any of the following situations happens, the plant establishes TSC (HA1):
1. When typhoons or strong winds with 10/15-minute sustained wind exceeds 60km/sec (134mph), and they cause serious threat to safety of operation of the plant or hinder plant workers to perform safe operation. (528.02.01)

Sea alerts for typhoons are issued. → Typhoons are 24hours away, and they may seize the sea area that is 100kms from Taiwan. Control rooms watch the latest status of typhoons.

Sea and land alerts for typhoons are → Typhoons are 18 hours away, and they may seize the inland area. If the plant is in one of the areas under the typhoon warnings, go to the next step.

Start arrangement and preparedness after sea and land alerts for typhoons are issued. →

1.All divisions should complete inspection of items on the typhoon checklists before the typhoon emergency response center is established. (Please refer to appendix in 187.2~15)
2.Operation shift watches latest status of typhoons via the Internet at all time and request typhoon meetings when needed. (187)
3.When operation shift leader expects weather conditions may hinder changing shifts, request next shift workers to come in to the plant in advance or ask workers who just finish their shift to stay in order to help with operation, and make sure shift workers stay in good conditions to ensure safety of operation. (187)
4.Except when Taipower Company orders to go into alert period mode, if the plant suffers from strong winds and/heavy rainfall, the plant director (or his authorized person) judges whether to go into alert period mode based on actual situations or starts typhoon meetings to establish the typhoon emergency response team. No matter which decision the plant director makes, he needs to report to nuclear power division. (187)

Operation actions after sea and land alerts for typhoons are issued. →

After receiving sea and land alerts for typhoons from Central Weather Bureau:
1 .Main control rooms monitor latest status of typhoons at all time. Also, write and send typhoon bulletins to the plant director and labor safety divisions.
2. Close doors and windows of all rooms in buildings in advance. Improvement engineering division inspects if Shiding Stream and onsite drainage trenches are clogged.
3. Electric shift leader verifies all communicative systems and NDS connection are normal. When typhoons have reached the alert area of the plant, immediately sign in “Natural event notification system” to report. If change load due to typhoons, abide by rules of “Natural event notification system” to complete notification process.
4. The plant sends more workers to help clean screens at intakes of emergency seawater pumps and remove debris at the intakes of seawater pump house of reactor buildings.
5. After sea and land alerts for typhoons are issued, obey the following tests if judging typhoons may seize the plant:
a) The plant should verify if emergency diesel generators can operate in 8 hours. Conduct function tests on the generators that had their last tests more than a half of the time duration of a periodic inspection cycle ago.

One hour before the radius of the typhoon with Beaufort Force 7 (13.9m/s) arrives the plant. →

1. Confirm the reactor system boundary stays intact and monitor the operation of reactors at all time. Workers can not connect diesel generators and the system, so this can prevent diesel generators from tripping if power system is out of order.
2.Stop testing functions of related RPS and NSSS systems.

When the plant is within radius of typhoons, follow procedure 513

Intensity / Action / Situation	Mild/ Moderate typhoon	Severe typhoon
A	The plant operates in the alert mode.	Reduce power to turbine trip bypass set point of RPS in 3 hours. (Note 2)
B	Reduce power to turbine trip bypass set point of RPS in 3 hours.	Reduce reactor thermal power to about 30% in 3 hours. (Note 2)
C	Reduce reactor thermal power to about 30% in 3 hours.	Disconnect from grid and stay in hot standby mode in 4 hours.
A+D	Disconnect from grid and stay in hot standby mode in 4 hours.	Disconnect from grid and stay in hot standby mode 4 hours, then achieve cold shutdown mode in 24 hours.
B+D	The reactors leaves hot standby in 4 hours and reach the shutdown status in the following 24 hours.	Immediately shutdown reactor and achieve cold shutdown mode as soon as possible.
E	Immediately shutdown reactor and achieve cold shutdown mode as soon as possible.	Immediately shutdown reactor and achieve cold shutdown mode as soon as possible.

Situation note:
A. The actual 10/15-minute wind measured at the plant reaches Beaufort Force 10 (24.5m/sec) and above.
B. The actual 10/15-minute wind measured at the plant reaches Beaufort Force 12 (32.7m/sec) and above.
C. The actual 10/15-minute wind measured at the plant reaches Beaufort Force 15 (46.2m/sec) and above.
D. When any of the following situations happens to any units:
(1) The plant loses one or two emergency diesel generators. Or,
(2) Among all 345kV offsite loops, only two or fewer is available for use. Or,
(3) The plant loses 161kV offsite power source.
E. When any of the following situations happens to any units:
(1) The plant loses two offsite power sources. Or,
(2) The plant loses two emergency diesel generator and one offsite power source. Or,
(3) The plant loses three emergency diesel generators.

When external/internal flooding happens, obey procedure 528.03.01 & 528.03.02.

1.When the plant does not need to continue taking emergent actions and meteorological information shows less threat of typhoons to the plant, the plant can stop reducing power of reactors after the plant director (or his authorized person) considers the actual situation at the plant and thinks there no more concern of plant safety.
2.When the actual 10/15-minute sustain wind measured at the plant has decreased to Force 7 or radius of typhoons with wind of Beaufort Force 10 has left the alert area of the plant and meteorological information shows less threat of typhoons to the plant, the plant can start increasing power of reactors or make them start operating after the plant director (or his authorized person) considers the actual situation at the plant and thinks there no more concern of plant safety.

5. Loss of electrical power and loss of ultimate heat sink

5.1 Nuclear power reactors

5.1.1 Loss of off-site power (LOOP)

5.1.1.1 Design provisions of on-site back-up power sources

Current Design

The design features of Lungmen Station power distribution system is shown on Figure 5-1:

1. Safety related 4.16kV/480V bus

   Each unit has three 4.16kV Buses (A4/B4/C4) and downstream 480 V PC /MCC. Each 4.16kV Bus is connected to one Emergency Diesel Generator (EDG). Lungmen Station also has one 4.16kV Bus (S4) and downstream 480V PC/MCC common to both Units. The 4.16kV Bus (S4) is equipped with one common EDG(SEDG or 7th EDG).

   (1) 4.16kV A4 Bus has 5 power sources: UAT A, RAT1, RAT2, S4 Bus, and EDG A. A4 Bus provides power to the following 5 PCs: 480V PC 0100A4, 5000A4, 0400C3, 0500C3, and 0600C3. Bus C3 provides the standby power of PC 0400C3 to 0600C3. Each 480V PC provides power to the downstream 480V MCC。

   (2) 4.16kV B4 Bus has 5 power sources: UAT B, RAT1, RAT2, S4 Bus, and EDG B. B4 Bus provides power to 480V PC 0100B4 and 5000B4. Each 480V PC provides power to the downstream 480V MCC。

   (3) 4.16kV C4 Bus has 5 power sources: UAT C, RAT1, RAT2, S4 Bus, and EDG C. C4 Bus provides power to 480V PC 0100C4 and 5000C4. Each 480V PC provides power to the downstream 480V MCC.

   (4) 4.16kV S4 Bus has 3 power sources: 1RAT2, 2RAT2, and S-EDG. S4 Bus provides power to downstream480V PC 0100S4. This 480V PC provides power to the downstream 480V MCC.

2. Normal Power Supply

   (1) Power is provided from main turbine generator, through unit auxiliary transfer UAT A/B/C, to safety related 4.16kV A4/B4/C4 Bus and downstream PC/MCC。

   (2) Power is provided from off-site 345kV Shenmei Red/White and Longtan Red/White four transmission lines, through main transformer and auxiliary transformer UAT A/B, to safety related 4.16kV A4/B4/C4 Bus and downstream PC/MCC.

   (3) Power is provided from off-site 161kV Nangang -Pinglin and Ao-di two transmission lines, through161kV GIS and transformers, RAT1/RAT2, to safety related 4.16kV A4/B4/C4 /S4 Bus and downstream PC/MCC.

3. Emergency Power Supply

(1) Lungmen Station has three seismic category I EDGs(EDG-A/B/C) located on 3 corners of Reactor Building at elevation 12.3meters. In case of emergency, power can be provided from EDG-A/B/C to 4.16kV A4/B4/C4 /S4 Bus and downstream PC/MCC.

(2) If any one of EDG A/B/C fails, the 7^{th} EDG can take over its' design function. This 7^{th} EDG is also seismic category I designed and also located at elevation 12.3meters.

5.1.1.2 Autonomy of the on-site power sources

Emergency Diesel Generator (EDG A /B/C)

1. Fuel：Each unit has 3 EDGs. Each EDG is equipped with one day tank with capacity 12kiloliter and one storage tank with capacity 450kiloliter. They can provide 1 EDG to run continuously for 5 hours and 7days, respectively.
2. Cooling：Water-cooled.
3. Supporting System：

(1) Each unit has 3 safety related 4.16kV Bus. Each 4.16kV safety bus has one EDG to provide emergency power.

(2) DC controlling power of each EDG is provided from associated safety division DC system.

(3）Starting air system, which consists of two independent 100% capacity parallel subsystems, provides compressed air to start EDG and off-site power is not needed during starting. The EDG starting air storage tank can provide starting air for 5 times consecutively without running air compressor.

(4) Cooling water is provided from safety related Reactor Building Cooling Water (RBCW) system. Heat absorbed by RBCW is removed by the Reactor Building Service Water (RBSW) System, which serves as the ultimate heat sink.

(5)Through NPBD bus, EDG power is provided to associated buses.

(6) There is one air-cooled EDG common to both units. This EDG, located at Auxiliary Fuel Building, can provide power to any safety bus of both units.

5.1.1.3 Provisions to prolong the time of on-site power supply

1. Emergency Diesel Generator (EDG A /B/C)：

(1) Each EDG is equipped with one day tank with capacity 12kiloliter and one storage tank with capacity 450kiloliter. They can provide 1 EDG to run continuously for 5 hours and 7days, respectively. Fuel storage tank has gas cap to make up fuel from tank truck.

5.1.1.4 Envisaged measures to increase robustness of the plant

1. To ensure the integrity of EDG and 4.16kV switchgear room, enhance measures have been

implemented, for example, flooding-preventing baffle installation and door seal rubber modification.

2. To ensure power being provided properly in case of loss of offsite power, it is planned to provide power from 7th EDG, through S4 bus, to both units simultaneously. The related operating steps are included in Procedure No. 1451.

5.1.2 Loss of off-site power and on-site back-up power (SBO)

5.1.2.1 Design provisions

In case of loss of offsite power and onsite back-up power (EDG A/B/C), station has other emergency back-up power as following:

1. The 7th EDG
   The 7th EDG is air-cooled with capacity 7800kW. It is the backup for the 6 EDGs of Unit 1 and Unit 2. It can perform the same function as the specific EDG being substituted. The 7th EDG can be placed to substitute only one of the 6 EDGs at the same time. The target EDG to be substituted has to be pre-selected. The 7th EDG, in full load operation, can provide all the AC power required by ECCSs.
2. Gas Turbine (in construction)
   Station has planned to install air-cooled gas turbine generator with capacity 12MVA. In case of loss of all off site power, the gas turbine can provide AC power to safety and non-safety 4.16kV bus, through 161kV GIS or transformer (13.8kV to 4.16kV).
3. In case of SBO, reactor water level can be maintained by running RCIC. Under the condition of no AC available, turbine driven RCIC pump can run for 8 hours by relying on 125V DC power. Operator can control the flow rate in 182 m^3/h or100 m^3/h in control room. Based on the SBO analysis described in FSAR table 8.3-6 and FSAR table 8.3-7, RCIC can run at least for 21 hours. The RCIC turbine governor valve (GV) is mechanically operated and no electrical power is needed. Water source is Suppression Pool or Condensate Storage Tank (CST). The controlling and operating power of MOVs are：
   (1)DIV Ⅰ 120VDC and 480V AC
   (2)DIV Ⅱ 120V DC

5.1.2.2 Battery capacity and duration

The capacity of DIV. 0 125V DC Battery (Battery S4) for 7th EDG is 1800AH. Based on FSAR Table 8.3-6, this capacity can provide DC power at least for 3.5 hours. The battery duration can be prolonged if DC loads are controlled.

5.1.2.3 Autonomy of the site before fuel degradation

1. The 7th EDG

(1) Autonomy of operability

The 7th EDG, together with its building, is separated from other EDGs. It will not be affected by other system. It is an independent system with autonomous operability.

(2) Control Power

The start and control power are 125VDC, which is provided by independent battery set.

(3)Fuel

The capacity of Day tank is 12 kiloliter, which can provide fuel to 7th EDG continuously running for 5 hours. This EDG has one independent fuel Storage Tank with capacity 450 kiloliter, which can provide fuel to 7th EDG continuously running for 7 days. Fuel storage tank has gas cap to make up fuel.

(4) Cooling

Air-cooled

(5) Supporting System

NA

2. Gas Turbine (in construction)

(1) Autonomy of operability

The operation of Gas Turbine will not be affected by other systems. It is an independent system with autonomous operability.

3. In case of SBO, reactor water level and pressure can be maintained by running RCIC for at least 8 hours. The RCIC turbine governor valve (GV) is mechanically operated and no electrical power is needed. RCIC pump can be run by only manually open steam inlet valve E51-MBV-0103and water discharge valve E51-MBV-0004.

5.1.2.4 Foreseen actions to prevent fuel degradation

1. Station existing equipment, e.g., equipment of other unit

(1) To ensure power being provided properly in case of loss of offsite power, it is planned to provide power from 7th EDG, through S4 bus, to both units simultaneously. The related operating steps are included in Procedure No. 1451.

(2)Each unit has ADS/SRV, RCIC, and nitrogen system. The following systems/ equipment can be supported from other unit: CST, makeup water P11, fire water system P16, compressed air system and essential buses.

(3) Water can be makeup by gravity from raw water reservoir, located at elevation 116

meter, through fire piping to ACIWA piping, and finally to reactor.

(4) Station has several fire engines as following table. These fire engines can take suction from raw water reservoir, Chinren lakelet, or take sea water from discharge channel. The outlet of fire engine can be connected to RHR system to inject water into reactor or suppression pool to prevent fuel degradation.

Lungmen Station Fire Engine				
Name	Amount	Capacity (Liter)	Discharge Pressure	Remark
Fire Foam Vehicle	1	6,000	0～27.6 (kg/cm^2)	Discharge flow rate : 3000liter/min@10 kg/cm^2
Reservoir Vehicle	1	12,000	0～10 (kg/cm^2)	Discharge flow rate : 800~2400 liter/min@10.0 kg/cm^2

2. Supports available from offsite if all onsite equipment are unavailable

(1) If all units are damaged and also loss of ultimate heat sink（loss of power supply）, offsite supports include fire equipment (e.g. fire engine, fire pump, fire hose) from station, Gongliao, Shuangxi, and Ruifang District. However, the required precondition is ADS and SRV must be operable, and ACIWA piping has to be workable. Fire Engines in the Vicinity Districts of Lungmen Station is shown as Table 5-3.

(2) Offsite supports include one 4.16kV 1500kW mobile diesel generator and four 480V 200kW mobile diesel generators from Kuosheng station; and one 4.16kV 1500kW mobile diesel generator and eight 480V 500kW mobile diesel generators from Chinshan station.

(3) Lungmen station and New Taipei city government has signed a protocol of firefighting support. Depends on the characteristic of event, Fire Bureau will support manpower, vehicles, and equipment to site to mitigate calamity.

3. Power cable specifically connected to the power plants (such as hydro, gas turbine plant) in the vicinity

Kuosheng nuclear power plant and Linko fossil power plant are the two plants in vicinity. However, no specific power cables are connected to these two plants.

4. The required pre-stage time for above mentioned systems

(1) It will take about 30 minutes for station fire engine taking suction from raw water pump

room, through prestaged RHR piping system, and ejecting into reactor core.

(2) It takes about 10 minutes for fire engines driving from Gongliao district to station (assuming water filled and standby). If the water injection path has already lined-up. The total time will be only 10 minutes for driving to station.

(3) It takes about 30 minutes for fire engines driving from Shuangxi or Ruifang district to station (assuming water filled and standby). If the water injection path has already lined-up. The total time will be only 30 minutes for driving to station.

(4) It will take about 30 minutes to take suction from 48,000 ton raw water reservoir; and will take 25 minutes to take suction from fire engine, through newly installed SFP seismic class piping.

5. Availability of qualified operators to perform above actions

The operation of systems and equipment are described in Ultimate Response Guideline 1451 Phase 1 tables. The operation is performed by shift staff. Other required manpower is not much and must be supported from offsite. The support manpower is commanded by shift supervisor. The operation of fire engines and other fire equipment are performed by fireman.

The operators, who are responsible for the operating of above mentioned actions, are well trained and exercised. They can meet the mission requirements.

6. Confirming the critical time before the onset of damage in this scenario

During SBO, if the 7th EDG is unavailable, then:

(1) Reactor water level can be maintained by running RCIC. Based on the design bases, the DC power supply to RCIC system can last for 8 hours. FSAR table 8.3-6 and FSAR table 8.3-7show that RCIC can run at least 21 hours during SBO(If some of unnecessary loads are isolated, RCIC can run for 24 hours）. If air-cooled EDG performs its design function, the reactor water makeup and cooling function can be established. The time of cliff edge effect is the time of losing air-cooled EDG and the time of fuel being depleted.

(2) Following “Ultimate Response Guideline”，reactor water level is maintained by makeup raw water through “ Rescuing Reactor Heat Removal Path”. Using RELAP5-3D to calculate the makeup water under double units and combined event, the total required make up water for reactor and SFP is1947gpm(will be ensured)＝442.2ton/hour；the raw water storage amount is 3.84x10^4 ton(conservatively estimated at 80％）. Thus, raw water can supply continuously for 86.84hours（3.62 days）.

(3) Consider the case of continuous actuation of ADS/SRV. All the operating gas is supplied from nitrogen tank. Normally, nitrogen gas is supplied from T31 ACS nitrogen

tank. Abnormally, nitrogen gas is supplied from two groups of nitrogen cylinders (DIV. A and DIV. B) located on the 7F of reactor building. Each Division has 10 nitrogen cylinders. Total capacity of each Division can maintain SRV/ADS continuously in open position for at least 7 days. Besides, each SRV/ADS has accumulator. Thus, each SRV/ADS can be actuated once under drywell design pressure and five times under drywell normal pressure. If nitrogen pressure is low, replace the nitrogen gas cylinder or makeup nitrogen gas to the cylinders to ensure the operability of SRV. The amount of nitrogen cylinders should be maintained. Once ACS system has enough nitrogen gas, the operating power of SRV/ADS can be ensured.

(4) Based on above description, under the condition of no offsite support, 6903 ton of water is to cover the vent port of COPS. Each unit can withstand SBO for at least 86.8 hours by reactor depressurization and water injection (RCIC +Raw Water injection). However, approximate 15.6 hours after reactor depressurization and water injection, suppression pool water level will increase to the elevation of vent port. This will cause that suppression pool cannot be vented and the integrity will be affected.

5.1.2.5 Envisaged measures to increase robustness of the plant back-up power

1. Station has following enhancing measures. In case of SBO, emergency 4.16kV / 480V AC power can be provided.

(1) Add 2 gas turbine generator (in Construction)

These 2 gas turbine generators will be connected to 161kV GIS to provide AC power to 4.16kV A4/B4/C4/S4 BUS and downstream 480VAC PC/MCC, through 161kV RAT1、RAT2. (See Figure 5-1 Lungmen Station Electrical Power Diagram) .

(2) Starting diesel generators (4.16kV/1200KW) of gas turbine generators(in Construction)

Connecting the starting diesel generators of gas turbine generators to the switchyard 4.16kV auxiliary electrical panel to provide power to 4.16kV Bus and safety 480V PC/MCC.

(3) Adding two 4.16kV/1500KWmobile generators and connecting to AFB S4 Bus.

Emergency power can be supplied to safety 4.16kV Bus and AC power can be provided to any train of RHR motors (475KW)、RBSW motors (745KW)、RBCW motors (190KW).

(The electrical cable and wiring have been installed to reduce the emergency response time. The associated procedure and electrical line diagram from mobile generator to AFB S4 Bus have been prepared.)

(4) EDG(11.4Kv/1250KW) of security system provides power to 4.16Kv bus and

downstream 480VAC through switchyard auxiliary electrical panel..
(This response will be taken if gas turbine generator or 161kV RAT1/RAT2 unavailable)

(5) In emergency, 7th EDG simultaneously provides power to both units.

(6) Unit 1 EDGs and Unit 2EDGs can support each other in case of emergency. (Associate procedure is preparing.)

(7) 480VAC mobile diesel generators provide power to 480VAC PC/MCC (both Q and NON-Q). (In order to shorten the emergency response time, the associated electrical cable and wiring has to be installed. For the NON-Q part, the associated cable of 3Φ480V 100KWmobile diesel generator has been completed. For the Q part, FRP is designing and preparing.

(8) EDG of security system can provide power to 480VAC PC/MCC. (Refer to Figure 3.1.6)

2. Emergency supply DC power to RCIC

During SBO, if controlling the loads, the DC power supplied to RCIC can be lasted for 24 hours.

(1)The beginning 3 items of following list can ensure reliable and endurable DC power provided to RCIC.

a. In case of emergency, the 7th EDG can provide power to A4/B4/C4 Bus of both units simultaneously through S4 Bus.

b. Connecting gas turbine generator to AFB S4 Bus to provide power.

c. Station has prepared another five 480V 100kW mobile diesel generators. Anyone can supply AC power to 1R12-MCC-0140A4-9B. Thus, AC power is available to battery charger and DC power is available to DIV Ⅰ 125VDC bus and Div. Ⅰ CVCF.

d. The RCIC turbine governor valve (GV) is mechanically operated and no electrical power is needed. RCIC pump can be run by only manually open steam inlet valve E51-MBV-0103and water discharge valve E51-MBV-0004. These two valves locate at containment outside. It will have no problem to operate them.

(2) RCIC pump is displacement type. It can overcome the discharge head in emergency. Control room operator can use the “Override” function to transfer RCIC suction to CST in emergency. There will be no problem in NPPH. If CST water level low, water can be makeup from DST or manually makeup.

(3) If loss of offsite power for more than 8 hours, use mobile diesel generator to provide power to BKR 1R12- MCC- 0140A4-9B of 1R16-BYC- 0000A4. That will provide DC

power to all equipment of DIV.I. The items a.~ c. described in (1) can ensure reliable and durable DC power. The required DC power of RCIC and ADS can be supported.

(4)CST water can be backup from DST or from fire engine through DST.

(5) As reactor pressure drops below 0.6MPaG, RHR ACIWA MODE can be used to inject raw water into reactor directly (As shown in Figure 5-3) .

3. The related emergency operation steps have been incorporated into Procedure 1451. Operator can follow these steps to take right response.

5.1.3 Loss of off-site power, ordinary back-up power, and other diverse back-up power

5.1.3.1 Design provisions

If loss of offsite power, EDG A/B/C, and 7th EDG, station will have DC power remaining only. During SBO, reactor water level can be maintained by running RCIC. The operation of RCIC relies on 125VDC power. This DC power is designed available for 8 hours and available for the control power for SRV actuation. The design of station CVCF and DC power is as follows：

1. CVCF System

Current Design

(1) Safety essential AC power include following subsystems. They can provide uninterrupted AC power with stable voltage and frequency.

Subsystem	CVCF Location	Equipment number	Capacity
CLASS 1E CVCF	C/B: DIV. Ⅰ/Ⅱ/Ⅲ/Ⅳ	R13-CVCF-0000A4/B4/C4/D4	50kVA
CLASS 1E CVCF(Common to both Units)	AFB: DIV.0	0R13-CVCF-0000S4	50kVA
RBSW CLASS 1E CVCF	RBSW P H: DIV. Ⅰ/Ⅱ/Ⅲ	R13-CVCF-5000A4/B4/C4	5kVA

(2) The normal input of R13-CVCF-0000A4/B4/C4/D4 is three phases 480V AC and standby125VDC. The output of converter is single phase 480VAC. This output then supplies to panel1R13-PPL-0000 A4/B4/C4/D4 and to control building and reactor building after reducing voltge to 120 V through transformer. This 120V AC power

supplies downstream instrument loads including DRS system and RTIF. Normaly, converter is powered from switch EA. It will be shifted to switch EN automatically if converter is abnormal; and is powered from bypassed 480VAC.

(3) The normal input of R13-CVCF-0000S4 is three phases 480V AC and standby125VDC. The output of converter is single phase 480VAC. This output then supplies to panel 1R13-PPL-0000S4 and to AFB building for the power required by SEDG related equipment after reducing voltge to 120 V through transformer. Normaly, converter is powered from switch EA. It will be shifted to switch EN automatically if converter is abnormal; and is powered from bypassed 480VAC.

(4) The normal input of R13-CVCF-5000A4/B4/C4 is three phases 480V AC and standby125VDC. The output of converter is single phase 120VAC. This output then supplies to panel 1R13-PPL-5000A4/B4/C4 and to RBSW P H building for the power required by RBSW A/B/C related equipment. Normaly, converter is powered from switch EA. It will be shifted to switch EN automatically if converter is abnormal; and is powered from bypassed 480VAC.

(5) The design capacity of CVCFcan last for 8 hours. The safety essential CVCF 480Vpower can be supplied from EDG A/B/C and SEDG。

2. DC System

Current Design

(1) The safety DC system includes following subsystems to provide DC power to safety related equipment.

Subsystem	Location	Battery Number	Capacity (AH)
CLASS 1E 125VDC	C/B: DIV. Ⅰ/Ⅱ/Ⅲ/Ⅳ	1R16-BTRY-0000A4/B4/C4/D4	3600AH/3600AH/2400AH/1800AH
CLASS 1E 125VDC (common to both units)	AFB: DIV.0	0R16-BTRY-0000S4	1800 AH
RBSW CLASS 1E 125VDC	RBSW P H: DIV. Ⅰ/Ⅱ/Ⅲ	1R16-BTRY-5000A4/B4/C4	900 AH

(2)DC system has following equipment：Battery Bank, Normal Charger, Standby Charger, DC Power Center, Distribution Panel, protectve equipment, and associated control

/monitoring（including monitoring of Battery Bank）. In normal operation, DC Bus is charged from Normal Charger. The capacity of Normal Charger can provide the required power for normal operation, and can maintain battery bank in full charged condition（F1oating Charge）. The Battery Charger is powered from 480V bus. If Battery Charger fails, Battery will supply DC power to downstream loads.

(3) DC system provides reliable DC power to station essential equipment and systems, including（a）emergency lighting,（b）EDG/SDG magnetic field,（c）control and switch,（d）control relay,（e）instrument,（f）mutiplexer system (H23)、（g）RCIC DC equipment,（h） CRD Backup Scram valve(#104/105) 、（i） Main Steam system DC equipment, (j)CVCF standby power source.

(4) If design base accident (DBA） occurs，Class 1E 125 VDC provide reliable DC power required by I & C and safe reactor shutdown, such as breaker control, protective relay, and emergency standby hydraulic pump,etc.

(5) DC power of water injection systems, e.g. RCIC,ECCS, etc.
The ECCS safety related instrument panel is designed with DC power source (1R16). It can be diveded into Div. Ⅰ/Ⅱ/Ⅲ/Ⅳ divisions.
RCIC Pump Control panel (1R16-PPL-0100A4).

(6) SRV is powered from 1R16-PL-0100A4 or 1R16-PL- 0100B4.

5.1.3.2 Battery capacity and duration

In case of SBO，Class 1E Div. Ⅰ battery set can provide DC power continuously for at least 8 hours (Based on FSAR Table 8.3-6, Div. I Battery load list is shown on Table 5-1.)

CASE 1: 23.2hours (RCIC Random load in 0~3 Min and 120~123Min0)
CASE 2: 21.1hours (RCIC Random load in 0~3 Min and 477~480Min0)
CASE 3: 23.2hours (RCIC Random load in 117~3120 Min and 477~480 Min0). RCIC 125V DC Class 1E Div. Ⅰ can supply DC power for at least 8 hours.

If AC power cannot be recovered, follow Procedure 524.01 to isolate some DC loads to prolong the duration of battery set.

5.1.3.3 Autonomy of the site before fuel degradation

(1) In case of SBO and loss of 7^{th} EDG, reactor water level can be maintained by RCIC. Based on the design basis, DC power can support RCIC for at least 8 hours. Based on the analysis of FSAR 8.3, RCIC can run for at least 21hours（It is approximately 24 hours if isolating some unnecessary loads）. By means of reactor depressurization and containment ventilation, more time is available to recover AC power.

(2) Station has prepared another five 480V 100kW mobile diesel generators. Anyone can supply AC power to 1R12-MCC-0140A4-9B. Thus, AC power is available to battery charger and DC power is available to DIV Ⅰ 125VDC bus and Div. Ⅰ CVCF.

(3) The RCIC turbine governor valve (GV) is mechanically operated and no electrical power is needed. RCIC pump can be run by only manually open steam inlet valve E51-MBV-0103 and water discharge valve E51-MBV-0004. These two valves locate at containment outside. It will have no problem to operate them.

5.1.3.4 Foreseen actions to prevent fuel degradation

1. <u>Station existing equipment, e.g., equipment of other unit</u>

(1) Establish DC power 24 hours capability in SBO

Based on the SBO loads listed in FSAR Table 8.3-6 and Table 8.3-7, the battery set discharge capacity (amp-hour, AH) are calculated as following table：

Battery-S4 SBO discharge capacity (AH) = current (amp) x duration (hr)									
duration (minute)	0-1	1-2	2-119	119-120				Following 16hr	24 hous accumulation surplus(+)/ insufficient(-)
(A)	590.41	364.37	252.87	256.94				129	
(AH)	9.84	6.07	493.1	4.28				4106.34	6159.5 -4359.5

Battery-A4 CASE A SBO discharge capacity (AH) = current (amp) x duration (hr)										
duration (minute)	0-1	1-2	2-3	3-119	119-120	120-121	121-123	123-479	479-480	24 hous accumulation surplus(+)/ insufficient(-)
(A)	1224.09	600.03	482.93	420.03	420.03	358.17	125.58	62.68	62.68	
(AH)	20.4	10.0	8.05	812.04	7.0	5.97	4.186	371.9	1.05	3721.8 -121.8

Battery-A4 CASE B SBO discharge capacity (AH) = current (amp) x duration (hr)										
duration (minute)	0-1	1-2	2-3	3-119	119-120	120-477	477-478	478-480		24 hous accumulation surplus(+)/ insufficient(-)
(A)	1224.09	600.03	488.53	482.93	420.03	62.68	358.17	125.58		
(AH)	20.4	10.0	8.14	933.66	7.0	372.96	5.97	2.09		4080.7 -480.7

Battery-A4 CASE C SBO discharge capacity (AH) = current (amp) x duration (hr)										
duration (minute)	0-1	1-2	2-117	117-118	118-119	119-120	120-477	477-478	479-480	24 hous accumulation surplus(+)/ insufficient(-)
(A)	789.11	531.53	420.03	855.01	488.53	482.93	62.68	358.17	125.58	
(AH)	13.15	8.86	805.07	14.25	8.14	8.05	372.95	5.97	2.09	3715.6 -115.6

a. The above table shows that, in case of SBO, Div. I DC battery set can supply DC power to RCIC for at least 21.1 hours.

b. Following SBO procedure “524.01 SBO” to control the unnecessary DC loads, the battery set can supply DC power to RCIC for at least 24 hours.

(2) Station has planned to use 7th EDG to provide power to both units simultaneously in case of emergency. The plan includes response ability, load control/ estimation, power saving, providing power to battery charger, etc.

(3) Station has prepared mobile diesel generators to provide power to 1R12-MCC-0140A4-9B. Thus, battery charger will have power to charge the associated battery set to prolong the battery duration.

(4) Station has several fire engines as following table. These fire engines can take suction from raw water reservoir, Chinren lakelet, Shiding rivulet, Shuangxi rivulet, or take sea water from discharge channel. The outlet of fire engine can be connected to RHR system ACIWA to inject water into reactor or suppression pool to prevent fuel degradation.

Lungmen Station Fire Engine				
Name	Amount	Capacity (Liter)	Discharge Pressure	Remark
Fire Foam Vehicle	1	6,000	0～27.6 (kg/cm^2)	Discharge flow rate : 3000liter/min@10 kg/cm^2
Reservoir Vehicle	1	12,000	0～10 (kg/cm^2)	Discharge flow rate : 800~2400 liter/min@10.0 kg/cm^2

2. Supports available from offsite if all onsite equipment unavailable

   Same as described in Section 5.1.2.4 Item 2.

3. Power cable specially connected to gas turbine generators and to the power plants in the vicinity

   Same as described in Section 5.1.2.4 Item 3.

4. The required prestage time for above mentioned systems

   Same as described in Section 5.1.2.4 Item 4.

5. Availability of qualified operators to perform the above actions

   Same as described in Section 5.1.2.4 Item 5.

6. Confirming the critical time before the onset of damage in this scenario

If loss of DC power or battery exhausted to support RCIC and SRV operation, autonomy of the site as described in Section 5.1.3.3will not be valid. Then：

(1) If loss of DC power, ADS/SRV can release reactor pressure by the actuation of safety function. Normally, ACS nitrogen tank provides the working gas；abnormally, the two groups of nitrogen cylinders (DIV. A and DIV. B) located on the 7F of reactor building supply the working gas. Each Division has 10 nitrogen cylinders. Total capacity of each Division can maintain SRV/ADS continuously in open position for at least 7 days. Besides, each SRV/ADS has accumulator. Thus, each SRV/ADS can be actuated once under drywell design pressure and five times under drywell normal pressure.

If nitrogen pressure is low, replace the nitrogen gas cylinder or makeup nitrogen gas to the cylinders to ensure the operability of SRV. The amount of nitrogen cylinders should be maintained. Once ACS system has enough nitrogen gas, the operating power of SRV/ADS can be ensured.

(2) Following "Ultimate Response Guideline"，reactor water level is maintained by makeup raw water through " Rescuing Reactor Heat Removal Path". The total required makeup water, including reactor and SFP, under double units and combined event is1947gpm (442.2ton/hour).The raw water storage amount is $3.84x10^{4}$ ton (conservatively estimated at 80％）. Thus, raw water can supply continuously for 86.84hours（3.62 days）.

(3) Based on above description, under the condition of no offsite support, each unit can withstand SBO for at least 86.84 hours by reactor depressurization and water injection. However, approximate 15.6 hours after reactor depressurization and water injection, suppression pool water level will increase to the elevation of vent port. This will cause that suppression pool cannot be vented and containment integrity will be affected.

5.1.3.5 Envisaged measures to increase robustness of the plant

1. RCIC loss of DC power (manual start)

In order to makeup water into reactor and to depressurize reactor, Procedure 1451 "Ultimate Response Guideline" LM.1-05 has defined the steps, in case of loss DC power, to manually start RCIC and to manually throttle Trip & Throttle Valve locally.

2. Power Source Enhancement Measures

Before battery exhausted, use 480 VAC mobile diesel generator or security DG to provide power to 480V PC/MCC and then to CVCF and DC Battery charger. It is planned to provide AC power to battery charger by mobile DG. This measure can prolong battery capability to provide DC power. The 4.16 kV/480V AC power enhancement measures is described in Section 5.1.2.5.

3. Procedure for Power Source Rescuing Actions

Procedure1451 has following power source rescuing actions：

(1)LM.2-04 SDG provides power to both units operating guide in emergency.

(2)LM.2-05 Unit 1and Unit 2 EDG supports each other operating guide.

(3)LM.2-07 security system EDG supports onsite power operating guide.

(4)LM.2-11 4160V/1100 kW gas turbine diesel generator supports power operating guide.

(5)LM.2-12 4.16 kV mobile diesel generator supports onsite power operating guide.

5.1.4 Loss of ultimate heat sink

5.1.4.1 Design provisional autonomy of the site before fuel degradation

1. Normal ultimate heat sink

(1) Heat generating in reactor exhausts to condenser after performing work in steam turbine (a small part not performing work passes through turbine bypass valve). Circulating Water Pump (CWP) removes the exhausted heat to sea.

(2) For the decay heat, starting RHR shutdown cooling mode and using RBCW pump to provide cooling water to RHR heat exchanger to remove decay heat to sea.

(3) After reactor shutdown, if MSIV closure, SRV will be actuated. The decay heat is released to suppression pool. Starting RHR suppression pool cooling mode and using RBCW pump to provide cooling water to RHR heat exchanger to remove decay heat to sea.

(4) Operating RBSW system provides cooling water to RBCW heat exchanger to remove heat absorbed by RBCW.

2. Ultimate heat sink

(1) The heat dissipated from systems is removed by Turbine Building Cooling Water (TBCW) System, Reactor Building Cooling Water (RBCW) System, and main condenser. Through heat exchangers, the above systems remove heat into sea served as ultimate heat sink. The cooling water of the above mentioned heat exchangers are provided from TBSW, RBSW, and CCW system, respectively. Only RBSW is designed with safety function, as following description：

a. RBSW building is Seismic Category I design. For a design basis event, RBSW can perform the design function to transport sea water into heat exchanger.

b. RBSW pump room is designed with watertight door. Power supply breaker locates at reactor building. Power is transmitted to motor junction box through power cable. The junction box is watertight. It can be protected from to be wetted by tsunami invasion.

c. Equipment, piping, and electrical power of RBCW system are safety designed. The safety function can be performed if design basis event occurs.

e. Each train of RBSW system is designed to remove 50% of design basis heat load. The major equipment of each train are 2 RBSW pumps, 2 self-cleaned filters, 3 heat exchangers , related piping , valves, and instruments. Except the common sea water inlet and discharge piping, each train has independent electrical, mechanical, and hydraulic design. During normal operation, refueling, hot standby with AC power available, hot standby without offsite power, and operation with suppression cooling, 3 trains of RBSW system have to be run. In case of loss of cooling water event, 2 trains will have enough capacity to remove the designed heat load. In this condition, 2 pumps of each train have to be run.

f. The capacity of RBSW UHS reservoir is enough for 3 trains 6 RBSW pumps of both units continuously running for 23.2min~ 28.1 min. Because sea water will influx into inlet sump within 18 minutes after tsunami ebb, the sump water will increase. Therefore, there is no sump water level low concern.

(2) Decay heat is removed by RHR Shutdown Cooling Mode. After reactor shutdown, if 3 RHR pumps is running, reactor water temperature can be cooled to 60℃ within 24hours. At the moment to loosen e reactor head stud, the reactor water can be cooled to 54.4℃. It can be further cooled to 48.9℃ as reactor cavity is flooding. If only 2 RHR pumps can be operated in Shutdown Cooling Mode, the reactor water can be cooled to 100℃ within 36 hours after reactor shutdown.

(3) Suppression pool heat is removed by RHR Suppression Pool Cooling Mode. This operating mode can reduce suppression pool water temperature below 32℃.This temperature ensures suppression pool ability to absorb the heat discharged into it during LOCA. Suppression pool temperature can be maintained below 97℃ if absorb all the discharged heat.

(4) RBSW, RBCW, and RHR system are the three systems to be used for ultimate heat sin. The supporting systems are described as follows:

a. The AC power of these 3 systems are provided from safety bus R11-MSWG-0000A4/B4/C4. Besides offsite power 345kV and 161kV, emergency diesel generator serves as the backup power. There is one swing EDG common to both units. This swing EDG can provide power to the safety bus of either unit. Both EDGs and SEDG locate at elevation 12.3meter. EDG and SEDG buildings are

Seismic I design.

b. The RBSW pump room temperature can be maintained below 40℃ by its ventilation system. The design and manufacture of pump room ventilation fan meets Seismic category I and Electrical Class I requirements. The main function of this fan is providing RBSW pump a suitable working environment.

c. RBCW ventilation uses the heating and ventilation system of Control Building Safety-Related Equipment Area(SREA) to maintained RBCW pump room temperature below 40℃.The design and manufacture of pump room ventilation fan meets Seismic category I and Electrical Class I requirements. The main function of this fan is providing RBCW pump a suitable working environment. SREA ventilation duct is ESF duct and is Seismic category I design. ESF building, floor, door, and damper are designed, constructed, and tested based on ANSI N509 and ANSI N510 Chapter 6. ESF building is safety classed with ability to withstand the normal or abnormal positive or negative pressure. Typhoon and missile shielding are installed outside the air intake and exhaust louver to prevent typhoon caused foreign objects invasion.

d. RHR pump room ventilation uses reactor building safety-related equipment heating and ventilation system (RBSREHV). If license design basis event (LDBE) occurs， this ventilation system can provide suitable temperature for safety-related equipment area. During normal operation, RBSCHV provides ventilation for SREA. During LDBE and after system isolated, RBSREHV provides ventilation for SREA. In RHR, HPCF, and RCIC pump room, AHU will be started automatically following pump starting. Ventilation system circulates the air in pump room and is cooled by RBCW system.

(5) RBSW, RBCW, and RHR system are the three systems to be used for ultimate heat sink. Each system has 3 identical divisions. Ultimate heat sink function can be maintained if any division can perform its design function. No other system serves as the backup of ultimate heat sink.

5.1.4.2 Foreseen actions to prevent fuel degradation

1. Station existing equipment, e.g., equipment of other unit

Based on the lesson learned from Fukushima Daiichi NPP experience in loss of ultimate sink, the decay heat will vaporize the water injected into reactor. Through ADS/SRV, the steam will be discharged into suppression pool to be cooled. The mixture of non-condensible gas and non-condensed steam is released to atmosphere through containment venting system. This forms a temporary heat removal path. For loss of ultimate heat sink, station has following measures：

(1) Reactor heat removal

a. If RBSW loses function due to tsunami invasion, the response measures are described in “Reactor/ Containment Heat Removal” and “ Water Sources /Injection Paths and Power Sources”. First, makeup water into reactor from all possible water sources; then, vent the steam from reactor. Decay heat can be removed in this way. In other words, make up water into reactor continuously through ACIWA; then depressurize reactor by release steam into wetwell. Venting from wetwell to atmosphere serves as passive heat sink to replace the heat sink from RHR heat exchanger to RBSW. Once tsunami induced flooding is gone, recover RBSW system as soon as possible.

b. Loss of RBSW but RBCW available, one of following methods can be selected：

(a) Provide cooling water to RHR/EDG heat exchanger by feed and bleed RBCW. The cooling water is provided from fire water or provided from P11system to RBCW Surge Tank.

(b) Pumping sea water to RBCW heat exchanger through temporary piping by temporary pump.

(2) Reactor water make up

a. Prolong/enhance RCIC water injection duration

Running RCIC can consume steam in reactor and can inject water into reactor. Maintaining RCIC in operation can have multiple purposes. The speed governor of RCIC turbine requires DC power. Based on the existing design, DC power can be supplied for 8 hours. However, it can last for 24 hours if some unnecessary DC loads are isolated. In SBO, controlling the DC loads can prolong the period of DC power providing to RCIC and SRV/ADS.

b. Reactor water injection enhanced measures in responding to RCIC unavailable

If ECCS (including RCIC) is unavailable due to SBO, the reactor has to be depressurized immediately. Reactor pressure must be depressurized below 0.6MPaG by actuating SRV to allow water injection from low pressure water source, e.g. fire water (raw water), mobile pump, or fire engine, to reactor through ACIWA pipe of RHR system. Station has alternative injection flow paths. By these paths, the 24000 ton (x2)water in raw water reservoir, at elevation 116 meter, can be injected into reactor. (Refer to Figure 5-3).

These paths are described as follows：

- Path：0P16-TNK-5001A/B → 0P16-P-5001A/B → 0P16 pipe → E11-BV-0045C/46C → E11-MBV-0005C → E11-AOV-0006C → E11-BV-0007C →RPV。
- Path：raw water reservoir → 0P16-BV-5250/5497/5211 → 0P16 pipe → E11-BV-0045C/46C → E11-MBV-0005C → E11-AOV-0006C → E11-BV-0007C →RPV。
- Path：Fire engine → quick connector pipe → E11-BV-0047C → E11-BV-0045C/46C → E11-MBV-0005C → E11-AOV-0006C → E11-BV-0007C →RPV。

(3) Containment heat removal and venting：

If losing of ultimate heat sink, reactor has to be depressurized. Heat generated in reactor will be removed to the primary containment. Suppression pool water temperature will increase rapidly. If fuel is overheated, hydrogen will be generated. It is likely that suppression pool temperature and primary containment pressure will be higher than design limit. Therefore, the containment pressure has to be released to protect the integrity of containment.

Once event occurs, before suppression pool pressure increasing to pressure limit, Atmosphere Control System (ACS) can perform venting function for suppression pool. Radioactive material release can be reduced if filtered by pool water. After treatment by SBGT system, gas can be released to atmosphere. Therefore, primary containment pressure can be reduced. If it is in vain, venting can be performed from drywell. Station has Containment Overpressure Protection System (COPS), as wetwell pressure increases to 652kpaG, rupture disk will break to release pressure. The primary containment integrity can be maintained by preventing pressure exceeding limit.

2. Supports available from offsite if all onsite equipment unavailable

Same as described in Section 5.1.2.4 Item 2.

3. The required prestage time for above mentioned systems

Same as described in Section 5.1.2.4 Item 3.

4. Availability of qualified operators to perform the above actions

Same as described in Section 5.1.2.4 Item 4.

5. Confirming the critical time before the onset of damage in this scenario

During reactor depressurization and water injection, suppression pool water level will increase to the elevation of vent port. This will cause that suppression pool cannot be vented and containment integrity will be impacted.

5.1.4.3 Envisaged measures to increase robustness of the plant

1. Ultimate Heat Sink Enhancement

(1) Based on the existing design basis, the operation of only one train RBSW system can ensure the removal of decay heat and other heat generated by safety related equipment. Station already has emergency sea cooling water recovery plan, and has prepared spare RBSW and RBCW motors for emergency replacement. Once these motor fail, immediate replacement can recover these systems as soon as possible.

2. Increase heat removable path

(1) If RBSW loses function due to tsunami invasion, the response measures are described in "Reactor/ Containment Heat Removal" and " Water Sources /Injection Paths and Power Sources". First, makeup water into reactor from all possible water sources; then, vent the steam from reactor. Decay heat can be removed in this way. In other words, make up water into reactor continuously through ACIWA; then depressurize reactor by release steam into wetwell. Venting from wetwell to atmosphere serves as passive heat sink to replace the heat sink from RHR heat exchanger to RBSW. Once tsunami induced flooding is gone, recover RBSW system as soon as possible.

(2) Loss of RBSW but RBCW available, one of following methods can be selected：

(a) Provide cooling water to RHR/EDG heat exchanger by feed and bleed RBCW. The cooling water is provided from fire water or provided from P11system to RBCW Surge Tank.

(b) Pumping sea water to RBCW heat exchanger through temporary piping by temporary pump.

3. Reactor water make-up

(1) Makeup CST water into reactor through HPCF pipe by gravity

a. The top of core fuel is at elevation 14.1 meter. CST is at elevation 12.3m with stored water18m high. Thus, there will be 16 meters elevation difference available to make up water into reactor by gravity.

b. Makeup water flow path can pass through HPCF B/C train without pump operation. This flow mode has been demonstrated during preoperational test.

- Path：CST → P13-BV-5725/5726/5727 → E22-MBV-0001B → E22-P-0001B → E22-MBV-0004B → E22-AOV-0005B → RPV。
- Path：CST → P13-BV-5725/5726/5727 → E22-MBV-0001C → E22-P-0001C

→ E22-MBV-0004C → E22-AOV-0005C → RPV。

(2) Makeup CST water into reactor through RCIC pipe by gravity

a. The top of core fuel is at elevation 14.1 meter. CST is at elevation 12.3m with stored water18m high. Thus, there will be 16 meters elevation difference available to make up water into reactor by gravity.

b. Makeup water flow path can pass through RCIC without pump operation. This flow mode has been demonstrated during preoperational test.

- Path：CST → P13-BV-5725/5726/5727 → E51-MBV-0001 → E51-P-0001 → E22-MBV-0004 → E22-AOV-0005 → RPV。

(3) Use mobile diesel generator to provide power to SLC motor to pumping test tank water into reactor (480V/75 KW)(R12-LSWG-0100A4/B4)。

- Path：C41-TNK-0002 → C41-BV-0010 → C41-BV-0002A → C41-P-0001A → C41-MBV-0005A → RPV。
- Path：C41-TNK-0002 → C41-BV-0010 → C41-BV-0002B → C41-P-0001B → C41-MBV-0005B → RPV

(4) Use mobile diesel generator to provide power to CSTF charging pump (480V/23 KW)(R12-MCC-5020A1-5A/5030A2-4RA), or by gravity, to make up water into reactor through ECCS pipe.

- Path：CSTF → E11-BV-0030A →E11-MBV-0005A → E11-AOV-0006A → N22-AOV-0003A → N22-BV-0005A → RPV。
- Path：CSTF → E11-BV-0030B/C →E11-MBV-0005B/C → E11-AOV-0006B/C → E11-BV-0007B/C →RPV。
- Path：CSTF → E22-BV-0017B/C → E22-MBV-0004B/C → E22-BV-0006B/C→ RPV。
- Path：CSTF → E51-BV-0036 → E51-MBV-0004 → E51-AOV-0005 →N22-AOV-0003B → N22-BV-0005B → RPV。

(5) Use temporary pump to pumping sea water into reactor through feedwater or fire water pipe.

- Path：seal pit/well → temporary pump → temporary pipe → N22-BV-5086A/B/5085A/B →N22-MBV-0001A/B → N22-AOV-0003A → N22-BV-0005A → RPV.
- Path：seal pit/well → temporary pump →temporary pipe → fire water pipe →E11-BV-0045C/46C → E11-MBV-0005C → E11-AOV-0006C → E11-BV-0007C →RPV.

4. Primary/Secondary containment venting

Station has purchased 480V mobile diesel generators and accessary components to enhance the primary and secondary containment venting ability during loss of ultimate heat sink and SBO (Figure 5-5). The venting function can be improved. The hydrogen accumulated in the primary containment can be diluted and released. The related measures are described as follows:

(1) Primary containment venting path

a. Mobile diesel generator can provide AC power to SGTS (480V/45 KW)(R12-MCC-0120B4/C4) fan and FCS(480V/75 KW)(R12-LSWG-0100B4/C4) heater. AC power can be supplied from power center or directly to motors. Manually operates the dampers in the venting paths to filter the released gas and to control the hydrogen content.

- Path：Drywell → T49-MBV-0001B → T49-MBV-0002B → T49-MCV-1002B → T49-BLO-0001B → T49-MBV-0004B → T49-MBV-0005B →Wetwell.
- Path：Drywell → T49-MBV-0001C → T49-MBV-0002C → T49-MCV-1002C → T49-BLO-0001C → T49-MBV-0004C → T49-MBV-0005C →Wetwell.

b. All the containment isolation valves locate at CTMT outboard. It is accessible for operators to take manually operation and to fix in full open position.

(2) Secondary containment venting path

- Path：T41-AOV-0193A/B/C → T41-AOV-0198A → T41-AOV-0198B → T41-FAN-0902A/B/C → Atmosphere.
- Path：T22-MOV-0001B/C → T22-SGTR-0001B/C → T22-FAN-0001B/C → T22-MOV-0003B/C → Atmosphere.

5. Make up water source structure integrity evaluation and enhancement

To respond the possible damages by strong earthquake , station has performed seismic evaluations to enhance structural integrity

(1) Install new pipes for raw water transportation. The new pipes are seismic category II-A design and are not buried pipes. As the installation of new pipes has been completed, the existing pipe will not be moved out. However, the isolation valve will be closed to prevent water lost from the existing pipes.

(2) The newly installed pipes will have local flexibility. They will be connected to flexible pipes in certain locations to absorb displacement caused by earthquake. This design will

minimize the possibility to be damaged by earthquake.

5.1.5 Loss of the ultimate heat sink combined with station black out (SBO+LUHS)

5.1.5.1 Design provisional autonomy of the site before fuel degradation

In case of SBO and loss of ultimate heat sink, the alternative reactor cooling measures are described as follows：

RCIC can maintain reactor water level and control reactor pressure for at least 21.1 hours. If unnecessary loads are isolated, it can last for 24 hours.

5.1.5.2 Foreseen external actions to prevent fuel degradation

1. Station existing equipment, e.g. equipment of other unit

(1) It is planned to modify the 7^{th} EDG to provide power, through S4 Bus, to both units simultaneously.

(2) Each unit has ADS/SRV, RCIC, and nitrogen system. The following systems/ equipment can be supported from other unit: CST, makeup water (P11), fire water system (P16), compressed air system and essential buses.

(3) Water can be makeup by gravity from raw water reservoir through fire piping to ACIWA piping, and finally to reactor.

(4) Station has several fire engines as following table. These fire engines can pump water from raw water reservoir, Chinren lakelet, or sea water from discharge channel. The outlet of fire engine can be connected to RHR system to inject water into reactor or suppression pool to prevent fuel degradation.

Lungmen Station Fire Engine				
Name	Amount	Capacity (Liter)	Discharge Pressure	Remark
Fire Foam Vehicle	1	6,000	0～27.6 (kg/cm^2)	Discharge flow rate : 3000liter/min@10 kg/cm^2
Reservoir Vehicle	1	12,000	0～10 (kg/cm^2)	Discharge flow rate : 800~2400 liter/min@10.0 kg/cm^2

(5) If SRV loss of operating gas or electrical power due to beyond design basis event, the following methods can be used：

a. If SRV loss of operating gas, lineup temporary air compressor to the nitrogen gas system (P54) located at the northeast and southeast corner of reactor building 7th floor. Thus, operating air can be supplied to the SRVs with ADS function. Based on existing design, there are 20 nitrogen cylinders, which can maintain SRV/ADS in open position for at least 7 days.

b. If SRV loss of operating electrical power, start mobile diesel generator to provide AC power to CVCF, and then to SRV.

c. Bring portable DC power source to H23-PL-0302A/B (reactor building 3rd floor) to provide power to SRV directly, or to R51-EPEN-0001C1/C2 (reactor building 4th floor) to provide power to SRV directly.

2. Supports available from offsite if all onsite equipment unavailable

(1) If all units are damaged and also loss of ultimate heat sink（loss of power supply）, offsite supports include fire equipment (e.g. fire engine, fire pump, fire hose) from station, Gongliao, Shuangxi, and Ruifang District. However, the required precondition is ADS and SRV must be operable, and ACIWA piping has to be workable. Fire Engines in the Vicinity Districts of Lungmen Station are shown as Table 5-3.

(2) Offsite supports include one 4.16kV 1500kW mobile diesel generator and four 480V 200kW mobile diesel generators from Kuosheng station; and one 4.16kV 1500kW mobile diesel generator and eight 480V 500kW mobile diesel generators from Chinshan station.

(3) Lungmen station and New Taipei city government has signed a protocol of firefighting support. Depends on the characteristic of event, Fire Bureau will support manpower, vehicles, and equipment to site to mitigate calamity.

3. The required prestage time for above mentioned systems

(1) It will take about 30 minutes for station fire engine taking suction from raw water pump room, through prestaged RHR piping system, and ejecting into reactor core.

(2) It takes about 10 minutes for fire engines driving from Gongliao district to station (assuming water filled and standby). If the water injection path has already lined-up. The total time will be only 10 minutes for driving to station.

(3) It takes about 30 minutes for fire engines driving from Shuangxi or Ruifang district to station (assuming water filled and standby). If the water injection path has already lined-up. The total time will be only 30 minutes for driving to station.

(4) It will take about 30 minutes to take suction from 48,000 ton raw water reservoir; and will take 25 minutes to take suction from fire engine, through newly installed SFP seismic class piping.

4. Availability of qualified operators to perform the above actions

The operation of systems and equipment are described in Ultimate Response Guideline 1451. The operation is performed by shift staff. Other required manpower is not much and must be supported from offsite. The support manpower will be commanded by shift supervisor. The operation of fire engines and other fire equipment are performed by fireman.

The operators, who are responsible for the operating of above mentioned actions, are well trained and exercised. They can meet the mission requirements.

5. Confirming the critical time before the onset of damage in this scenario

After reactor depressurization and water injection, suppression pool water level will increase to the elevation of COPs vent port. This will cause that suppression pool cannot be vented and the integrity will be affected.

5.1.5.3 Envisaged measures to increase robustness of the plant

1. Enhanced measures for Loss of Ultimate Sink

Same as described in Section 5.1.4.3.

2. Enhancement of Emergency AC and DC Power

Same as described in Section 5.1.3.5.

3. Alternative long term cooling

(1)) If RBSW loses function due to tsunami invasion, the response measures are described in "Reactor/ Containment Heat Removal" and " Water Sources /Injection Paths and Power Sources". First, makeup water into reactor from all possible water sources; then, vent the steam from reactor. Decay heat can be removed in this way. In other words, make up water into reactor continuously through ACIWA; then depressurize reactor by release steam into wetwell. Venting from wetwell to atmosphere serves as passive heat sink to replace the heat sink from RHR heat exchanger to RBSW. Once tsunami induced flooding is gone, recover RBSW system as soon as possible.

(2) Loss of RBSW but RBCW available, one of following methods can be selected：

(a) Provide cooling water to RHR/EDG heat exchanger by feed and bleed RBCW. The cooling water is provided from fire water or provided from P11system to RBCW Surge Tank.

(b) Pumping sea water to RBCW heat exchanger through temporary piping by temporary pump.

(3) Response measures for loss of RBSW and RBCW

a. Emergency sea water cooling recovery plan, prepare RBSW and RBCW spare motors for emergency replacement.

5.2 Spent fuel pool

5.2.1 Loss of offsite power

5.2.1.1 Design provisions of on-site back-up power sources

Station has two spent fuel pools. One locates at refueling floor of reactor building for each unit. (elevation 31.7 m). The other locates at auxiliary fuel building ground level(elevation 12.3m). The later SFP is common to both units.

1. Spent Fuel Pool (SFP) make up water system

(1)Reactor Building

a. Fuel Pool Cooling and Cleanup(FPCU) System has two skimmer-surge tanks, two circulating water pumps, two filter-demineralizer(F/D) with 100% capacity, and two heat exchangers with 50% capacity. Power is provided from non-safety bus. Fuel pool water is circulated by means of overflow through skimmers around the periphery of the auxiliary fuel pool and a scupper at the end of the transfer pool drain tanks, pumped through the FPC heat exchangers and filter-demineralizer and back to the pool through the pool diffusers. The spent fuel decay heat is removed by RBCW and RBSW system, both of them has two trains.

b. Except filter-demineralizer /related piping and motor are seismic category II-A, all other components of FPCU system are seismic category I design. In case of SSE, the integrity of pressure boundary can be maintained.

c. Makeup water into SFP has following ways：(A) from suppression pool or CST through Suppression Pool Cleanup System(SPCU)；(B) from suppression pool through RHR A/B/C；(C) from fire water system, fire engine, or raw water reservoir through RHR-C piping system；(D)from CST through RHR A/B/C or FPCU surge tank, by Condensate Transferring System (CSTF).

d. Pumping by SPCU pump (480VAC / 75kW, powered fromR12-LSWG-0100B1-5C, rated capacity 250 m^3/h) from SFP makeup water pool or CST (4340 ton); or pumping by CSTF charging pump(480VAC / 22.5kW，powered fromR12-MCC-5020A1-5A，rated capacity30 m^3/h) from CST to fuel pool through SPCU/CSTF/RHR pipes and FPCU.

(2) Auxiliary Fuel Building

a. Auxiliary Fuel Pool Cooling and Cleanup (AFPC) system is seismic category II-A design. This system has two skimmer-surge tanks, two circulating water pumps, one filter-demineralizer(F/D) with 100% capacity, and two heat exchangers with 50%

capacity. Power is provided from non-safety bus.

b. Based on existing design, AFP water makeup is provided by CSTF.

2. SFP Cooling and Purification System Power Supply

(1)Reactor Building SFP

a. SFP Cooling and Cleanup System pump (FPCU pump) is powered from non-safety power center (480VAC / 93.3kW，R12-LSWG-0200A2-5B or R12-LSWG-0300C3-5A) to provide spent fuel pool cooling water.

b. For Reactor Building SFP Cooling and Cleanup System , cooling water is provided from DIV I/II RBCW and power is provided from safety-related buses A4/B4and downstream MCC.

c. RHR Fuel Pool Cooling mode has 3 Divisions. During outage, SFP can be cooled by anyone of the them。

d. The power of Spent Fuel Pool water level/ temperature monitors G41-LT-0012A/B/ G41-TE-0013 is provided from control room 120VAC instrument power and 120 V ICP.(These power come from non-safety CVCF power source R14-PPL-0220A3and R13-PPL-0110A3/0110B3)。

(2) Auxiliary Fuel Pool Cooling Capability

a. The power of AFPC pump is provided from 0R12-LSWG-1200B2-4B / 2200B2-4B.

b. The power of SFP water level/ temperature instrument 0G42-LT-0010A/B/ G41-TE-0013is 120VAC power(1/2R13-PPL-0130C3 and 0R12-FUBX-1212B2).

3. The design features of Lungmen Station power distribution system is shown on Figure 5-1:

(1) Safety related 4.16kV/480V bus

Each unit has three 4.16kV Buses (A4/B4/C4) and downstream 480 V PC /MCC. Each 4.16kV Bus is connected to one Emergency Diesel Generator (EDG). Lungmen Station also has one 4.16kV Bus (S4) and downstream 480V PC/MCC common to both Units. The 4.16kV Bus (S4) is equipped with one common EDG(SEDG or 7th EDG).

a. 4.16kV A4 Bus has 5 power sources: UAT A, RAT1, RAT2, S4 Bus, and EDG A.

b. A4 Bus provides power to the following 5 PCs: 480V PC 0100A4, 5000A4, 0400C3, 0500C3, and 0600C3. Bus C3 provides the standby power of PC 0400C3 to 0600C3. Each 480V PC provides power to the downstream 480V MCC.

c. 4.16kV B4 Bus has 5 power sources: UAT B, RAT1, RAT2, S4 Bus, and EDG B.

d. B4 Bus provides power to 480V PC 0100B4 and 5000B4. Each 480V PC provides power to the downstream 480V MCC .

e. 4.16kV C4 Bus has 5 power sources: UAT C, RAT1, RAT2, S4 Bus, and EDG C.

f. C4 Bus provides power to 480V PC 0100C4 and 5000C4. Each 480V PC provides power to the downstream 480V MCC.

g. 4.16kV S4 Bus has 3 power sources: 1RAT2, 2RAT2, and S-EDG.

h. S4 Bus provides power to downstream480V PC 0100S4. This 480V PC provides power to the downstream 480V MCC.

(2) Normal Power Supply

a. Power is provided from main turbine generator, through unit auxiliary transfer UAT A/B/C, to safety related 4.16kV A4/B4/C4 Bus and downstream PC/MCC.

b. Power is provided from off-site 345kV Shenmei Red/White and Longtan Red/White four transmission lines, through 345kV GIS, main transformer and auxiliary transformer UAT A/B, to safety related 4.16kV A4/B4/C4 Bus and downstream PC/MCC.

c. Power is provided from off-site 161kV Nangang -Pinglin and Ao-di two transmission lines, through 161kV GIS and transformers, RAT1/RAT2, to safety related 4.16kV A4/B4/C4 /S4 Bus and downstream PC/MCC.

(3) Emergency Power Supply

a. Emergency power can be provided from EDG-A/B/C to 4.16kV A4/B4/C4 /S4 Bus and downstream PC/MCC.

b. If anyone of EDG A/B/C fails, the 7th EDG can take over its' design function.

From above description, station is designed with one emergency diesel generator connected to each essential 4.16kV bus. In case of loss of offsite power, EDG will be started automatically and will reach rated speed and voltage within 20 seconds. Related breakers will be close automatically to provide emergency power to essential buses. If any one of DIV I/II/III EDG successfully provides power to essential bus, reactor can be maintained in safe shutdown condition. Station has 7th EDG common to both units. This swing EDG serves as the backup of Div. I/II/III EDG of either unit. If any EDG of either unit is unavailable, the 7th EDG can take over the design function.

5.2.1.2 Autonomy of the on-site power sources

If loss of offsite power, non-safety related bus will be de-energized and cannot provide AC power. FPCU pump cannot operate normally. No cooling water and no water makeup will be provided to SFP. In this case, RHR FPC mode will be operated to perform fuel pool water makeup and cooling function.

<u>Emergency Diesel Generator</u> (EDG A/B/C)

1. Fuel：Each unit has 3 EDGs. Each EDG is equipped with one day tank with capacity 12

kiloliter and one storage tank with capacity 450 kiloliter. They can provide 1 EDG to run continuously for 5 hours and 7days, respectively.

2. Cooling：Water-cooled.

3. Auxiliary system

(1) Starting and controlling power are supported from DIV 125VDC.

(2) Each EDG has independent air starting system, which has 2 motor driven air compressors. The compressed air is transported to air storage tank through air dryer. From storage tank, compressed air is sent to the diesel engine by two paths. Each path has two air starting motors. The air storage tank can provide starting air for 5 times consecutively without running air compressor .

(3) Cooling water is provided from Div. I & II safety related Reactor Building Cooling Water (RBCW) system. Heat absorbed by RBCW is removed by the Reactor Building Service Water (RBSW) System, which serves as the ultimate heat sink.

5.2.1.3 Provisions to prolong the time of on-site power supply

1. Emergency Diesel Generator (EDG A/B/C)

(1) Each EDG has One Day Tank of fuel. This tank has emergency gas cap to make up fuel from tank truck.

5.2.1.4 Envisaged measures to increase robustness of the plant

1. To ensure the integrity of EDG and safety /non-safety4.16kV switchgear room, enhance measures have been implemented, for example, flooding-preventing baffle installation and door seal rubber modification.

2. To ensure power being provided to the required loads in case of loss of offsite power, the 7th EDG will be modified to provide power, through S4 Bus, to both units simultaneously. All EDGs, Day Tanks, and accessories are located above ground. If the associated piping is installed underground, the installation follows industry standard. All non-safety 4.16/13.8 kV switch box and MCC are located above ground. For the purpose to protect 4.16kVswitchbox, low voltage MCC and ECCS system/ equipment located below ground level, it is planned to install watertight device to prevent flooding at the doors and openings of RBSW pump room,7th EDG, EDG buildings of both units .

3. To ensure the availability of onsite power, station evaluates the enhancement of the measures in response to loss of offsite power as follows：

Station Procedure “1451Ultimate Response Guideline” defines steps to provide power, through S4 Bus, to both units simultaneously. In this procedure, estimation of load control and power saving operations are also defined.

4. Reactor Building SFP water makeup and cooling in case of loss of offsite power

(1) Emergency Cooling

(a) If loss of offsite power only, ultimate heat sink and FPCU are still available, use mobile diesel generator to provide emergency power to FPCU pump(480VAC / 93.3kW, R12-LSWG-0200A2-5B or R12-LSWG-0300C3-5A)to recover FPCU. Fuel pool cooling can be maintained.【Prepare mobile diesel generator】

(b)RHR Fuel Pool Cooling serves as an alternative cooling method.

(2) Emergency Water Makeup

Among the power supply, ultimate heat sink, and FPCU, if two of them are unavailable, perform emergency water makeup measures.

(a) Available water source

i. Design water source：CST（4340ton, Seismic Category I）。

ii. Emergency water source：Firewater Storage Tank（2 for 4600ton, Seismic Category I）, Raw Water Reservoir（48000ton, Seismic Category II-A）, DST（1515ton）.

iii. Backup emergency water source：Raw Water Storage Tank（984ton）、Acceptance Reservoir（2500 ton）、Chinren lake（about 8000ton）。

iv. Offsite water source：Shiding rivulet, Shuangxi rivulet, sea water.

(b) Way to makeup water

i. Use mobile diesel generator to provide power to SPCU pump (480VAC / 75kW. Power is provided from R12-LSWG-0100B1-5C. Rated capacity is 250 m^3/h), or to CSTF charging pump (480VAC / 22.5kW. Power is provided from R12-MCC-5020A1-5A. Rated capacity is 30 m^3/h). Water is pumped from CST, through SPCU/ CSTF/ RHR pipes to FPCU, to SFP。

ii. In case of loss of onsite power, diesel driven fire pump (Seismic Category I) of fire water system can provide water from fire water storage tank to SFP, through RHR-C pipe, or through firewater system directly. Firewater can be injected into spent fuel pool by using the fire hose located on the side of SFP, or use permanent specific pipe lines .(Firewater pump capacity is 3000 gpm. Two hydrants can discharge a flow rate of 500 gpm.)【Install permanent makeup water pipe lines specific to SFP】

iii. Water can be makeup by gravity from raw water reservoir, located at elevation 116 meter, through RHR-C or fire piping to SFP.【Install raw water pipe above ground and upgrade seismic category】

iv. Inject water to spent fuel pool by fire engine, through RHR-C pipe, or through firewater system directly. Firewater can be injected into spent pool by using the fire hose located on the side of SFP, or use permanent specific pipe lines.【Install permanent makeup water pipe lines specific to SFP】

v. Lineup mobile pump to makeup water pipe to inject water into spent fuel pool.【Prepare mobile water pump】

(c) Time to makeup water

i. If event occurs, monitor water level and temperature of spent fuel pool continuously. Once pool water level low or water temperature high, perform emergency water makeup.

ii. To ensure SFP water level and temperature can be monitored during SBO, it has planned to use mobile diesel generator to maintain the monitoring ability from control room【 (1) Ultrasonic water level transmitter G41-LT-0012A/B should be modified to widen the monitoring range applicable to the fuel elevation. Modify the power to be provided from essential AC power source (R13). Another choice is pool water level being monitored by camera system (ITV). The camera should be power from essential AC power source (R13). (2)The depth of temperature measurement (G41-TE-0013) should be increased to be applicable to the fuel position.】

4. Auxiliary Fuel Pool of Auxiliary Fuel Building

(1) The emergency cooing and emergency water makeup of Auxiliary Fuel Pool Cooling and Cleanup System (AFPC) and Fuel Pool Cooling and Cleanup System (FPCU) is same except: AFPC has no RHR as alternation; no SPCU pump and RHR pipe serve as water injection; power of AFPC is provided from 0R12-LSWG-1200B2-4B / 2200B2-4B.

(2) Pool water level and temperature should be monitored during SBO.【The power of ultrasonic water level transmitter 0G42-LT-0010A /B should be modified to be provided from essential AC power source (R13).】

(3) Prepare operating procedure for AFP water makeup during SBO.

5.2.2 Loss of off-site power and on-site back-up power (EDG)

5.2.2.1 Design provisions

In case of loss of offsite power and onsite back-up power, station has other emergency back-up power as following:

1. The 7th EDG：

The 7th EDG is air-cooled with capacity 7800kW. It is the backup for the 6 EDGs of Unit 1 and Unit 2. It can perform the same function as the specific EDG being substituted. The 7th EDG can be placed to substitute only one of the 6 EDGs at the same time. The target EDG to be substituted has to be pre-selected. The 7th EDG, in full load operation, can provide all the AC power required by ECCSs and RBCW.

5.2.2.2 Battery capacity and duration

The capacity of DIV. 0 125V DC Battery for 7th EDG is 1800AH. Based on FSAR Table 8.3-6 and FSAR 8.3-7, this capacity can provide DC power at least for 3.5 hours to ensure the safety of nuclear systems.

5.2.2.3 Autonomy of the site before fuel degradation

1. 7th EDG

(1) Autonomy Operability

The 7th EDG is an independent system and is not affected by other systems. It has autonomy operability.

(2) Control：

The starting and control power is 125VDC and is provided from independent battery set.

(3) Fuel：

The capacity of Day tank is 12 kiloliter, which can provide fuel to 7th EDG continuously running for 5 hours. This EDG has one independent fuel Storage Tank with capacity 450 kiloliter, which can provide fuel to 7th EDG continuously running for 7 days. Fuel storage tank has gas cap to make up fuel.

(4) Cooling：Air-cooled.

(5) Supporting System : NA.

5.2.2.4 Foreseen actions to prevent fuel degradation

1. Station existing equipment, e.g., equipment of other unit

(1) Station procedure "1451Ultimate Response Guideline" defines the emergency steps to use 7th EDG to provided AC power to both units. This guideline also describes load estimation and load saving operations.

(2) Water can be makeup into fuel pool by fire water pump through fire hose located on pool side. The 7th floor of reactor building has fire system. The $4.8x10^4$ton raw water reservoir can provide backup water. Water can be makeup by gravity from raw water reservoir, located at elevation 116 meter, through RHR-C or fire piping system to fuel

pool.

(3) Station has several fire engines as following table. These fire engines can take suction from raw water reservoir, Chinren lakelet, Shiding rivulet, Shuangxi rivulet, or take sea water from discharge channel. The outlet of fire engine can be connected to RHR system to inject water into spent fuel pool to prevent fuel degradation.

Lungmen Station Fire Engine				
Name	Amount	Capacity (Liter)	Discharge Pressure	Remark
Fire Foam Vehicle	1	6,000	0～27.6 (kg⁄cm^2)	Discharge flow rate : 3000liter/min@10 kg⁄cm^2
Reservoir Vehicle	1	12,000	0～10 (kg⁄cm^2)	Discharge flow rate : 800~2400 liter/min@10.0 kg⁄cm^2

(4) Based on the recommendations in NEI 06-12, station will have following enhancements. Install seismic designed firewater piping to makeup and to spray firewater. This modification will have 500 gpm makeup and 200 gpm spray capacity additionally. In case of fuel pool or building damaged and spent fuel cannot be cooled normally, this modification enhances the capability of fuel pool cooling and water makeup.

2. Supports available from offsite if all onsite equipment unavailable

(1) If all units are damaged and also loss of ultimate heat sink（loss of power supply）， offsite supports include fire equipment (e.g. fire engine, fire pump, fire hose) from station, Gongliao, Shuangxi, and Ruifang District. However, the required precondition is ADS and SRV must be operable, and ACIWA piping has to be workable. Fire Engines in the vicinity districts of Lungmen Station is shown as Table 5-3.

(2) Offsite supports include one 4.16kV 1500kW mobile diesel generator and four 480V 200kW mobile diesel generators from Kuosheng station; and one 4.16kV 1500kW mobile diesel generator and eight 480V 500kW mobile diesel generators from Chinshan station.

(3) Lungmen station and New Taipei city government has signed a protocol of firefighting support. Following Procedure 1420, once fire occurs, Fire Bureau will immediately support manpower, vehicles, and equipment to site to mitigate calamity.

3. Power cable specially connected to the power plants (such as hydro, gas turbine plant) in the vicinity

Kuosheng nuclear power plant and Linko fossil power plant are the two plants in vicinity.

However, no specific power cables are connected to these two plants. Station is installing gas turbine generator s to provide AC power to switchyard 161kV Bus.

4. The required prestage time for above mentioned systems

(1) It will take about 30 minutes for station fire engine taking suction from raw water pump room, through prestaged RHR piping system, and ejecting into fuel pool.

(2) It takes about 10 minutes for fire engines driving from Gongliao district to station (assuming water filled and standby). If the water injection path has already lined-up. The total time will be only 10 minutes for driving to station.

(3) It takes about 30 minutes for fire engines driving from Shuangxi or Ruifang district to station (assuming water filled and standby). If the water injection path has already lined-up. The total time will be only 30 minutes for driving to station.

(4) It will take about 30 minutes to take suction from 48,000 ton raw water reservoir; and will take 25 minutes to take suction from fire engine, through newly installed SFP seismic class piping.

The time of cliff edge effect is about 9.5hours. At this moment, the members of TSC, AMT, OSC, HPC, and EPIC should be in site already. The supporting should be ready.

5. Availability of qualified operators to perform the above actions

The operation of systems and equipment are described in Procedure 1451 “Ultimate Response Guideline”. The operation is performed by shift staff. Other required manpower is not much and must be supported from offsite. The support manpower will be commanded by shift supervisor. The operation of fire engines and other fire equipment are performed by fireman.

The operators, who are responsible for the operating of above mentioned actions, are well trained and exercised. They can meet the mission requirements.

6. Confirming the critical time before the onset of damage in this scenario

Under the condition which loss of SFP cooling water and full core off loaded during outage, CFD (Computation Fluid Dynamic) calculation shows the pool water temperature increasing rate is 5.4℃/hr. If the initial pool water temperature is 49℃, pool water will begin to boil after 9.5 hours. If the initial AFP water temperature is 49℃, AFP water will begin to boil after151.6hours. Related input information are shown as follows：

(1) Reactor Spent Fuel Pool

(a) Decay heat at 7 days after reactor shutdown is12.88 MWt , including 872bundles of full core off load and 9 cycles of previous off loaded fuel bundles(2088 historic off loaded bundles).

(b) SFP cooling water effective volume (Assume gate is closed. No credit is given to cavity and core cooling water) is 2085 m^3 (2050 ton). Pool water density is 983.2 kg/m^3 (49 ℃/120 ℉).

(c) Calculation shows, if loss of cooling water (FPCU and RHR unavailable), the pool water temperature increasing rate is 5.4℃/hr. If the initial pool water temperature is 49℃, pool water will begin to boil after 9.5 hours.

(d) Calculation shows, if loss of cooling water (FPCU and RHR unavailable) and the initial pool water temperature is 49℃, pool water level will drop to the top of fuel after 91hours (3.79 days). The water level decreasing rate is 8.2 cm/hr and the pool water evaporating rate is19.09 m^3/hr.

(2) Auxiliary Fuel Pool of Auxiliary Fuel Building

(a) Initial Decay heat is1.55 MW, including 7888 historic off loaded bundles.

(b) AFP cooling water effective volume is 4042 m^3 (3974 ton). Pool water density is 983.2kg/m^3 (60 ℃/140 ℉).

(c) Calculation shows, if AFPC unavailable, the pool water temperature increasing rate is 0.336℃/hr. If the initial pool water temperature is 49℃, pool water will begin to boil after 151.6hours. Based on vender’s calculation, considering all heat transfer modes, the pool water temperature increasing rate is 0.23 ℃/hr, and pool water will increase to 65.6℃ (150 ℉) after 72 hours.

(d) Calculation shows, if AFPC unavailable with initial pool water temperature at 49 ℃, pool water level will drop to the top of fuel after 1195hours. The water level decreasing rate is 0.6531 cm/hr and the pool water evaporating rate is 2.51m^3/hr.

5.2.2.5 Envisaged measures to increase robustness of the plant

1. Station has following enhancing measures. In case of SBO, emergency 4.16kV / 480V AC power can be provided.

(1) Adding 2 gas turbine generators

(a) These 2 gas turbine generators will be connected to 161kV GIS to provide AC power to 4.16kV A4/B4/C4/S4 BUS and downstream 480VAC PC/MCC, through 161kV RAT1、RAT2. (See Figure 5-1 Lungmen Station Electrical Power Diagram).

(2) Connecting gas turbine generator to AFB S4 Bus through transformer.

(3) Adding two 4.16kV/1500KWmobile generators and connecting to AFB S4 Bus. Emergency power can be supplied to safety 4.16kV Bus and AC power can be provided to any train of RHR (475KW)、RBSW (745KW)、RBCW(190KW).

(a) In order to reduce response time, the electrical cable , wiring, and associated procedure should be pre-pared and completed.

(4) Use 11.4kV/1250KWsecurity system EDG, through switchyard auxiliary electrical panel, to provide power to 4.16kV Bus and downstream 480VAC.

(a) This response will be taken if gas turbine generator or 161kV RAT1/RAT2 unavailable. Power can be supplied to safety 480V PC/MCC.

(b) The modification of existing 11.4kV/1250KWsecurity system EDG is carrying on. Associated operating procedure has to be prepared.

(5) In emergency, 7th EDG simultaneously provides power to both units.

(6) Unit 1 EDGs and Unit 2EDGs can support each other in case of emergency.

(7) 480VAC mobile diesel generators provide power to 480VAC PC/MCC (both Q and NON-Q). (In order to shorten the emergency response time, the associated electrical cable and wiring has to be installed. For the NON-Q part, the associated cable of 3Φ480V 100KWmobile diesel generator has been completed. For the Q part, FRP is designing and preparing.)

(8) EDG of security system can provide power to 480VAC PC/MCC.

2. Mobility of Water Injection Equipment

Station plans to purchase 4 mobile firewater pumps(15HP) and air inflated water tanks (15 ton) to be the backup of firewater .

3. The related emergency operating steps have been incorporated into Procedure No.1451"Ultimate Response Guideline". This procedure gives emergency response instructions to operator.

4. Fuel Exhausted

(1) EDG A/B/C and Swing EDG

Every EDG has independent fuel storage tank. Each tank has gas cap. Fuel can be makeup from truck tank through gas cap.

5. Measures has been proposed to enhance the flooding prevention ability of EDG room at RB and AFB, etc., to ensure unit operation will not be affected by flooding.

5.2.3 Loss of off-site power, ordinary back-up power, and other diverse back-up power

5.2.3.1 Design provisions

If loss of offsite power, standby power (EDGs), and other types of standby power, SFP will lost forced cooling and normal water makeup function.

5.2.3.2 Battery capacity and duration

This system has no DC power design.

5.2.3.3 Autonomy of the site before fuel degradation

Although forced cooling and normal water makeup ability is lost, emergency water makeup is applicable. Reactor building 7th floor has fire water system. Firewater can be injected into spent fuel pool by using the fire hose located on the side of SFP, or use newly installed permanent seismic grade specific pipe lines. The water makeup and spray capacity at least are 500 gpm and 200 gpm, respectively. The backup raw water reservoir has capacity of 48,000 ton. If SFP water temperature still increases, following Procedure "1451Ultimate Response Guideline" to perform 2nd containment venting to discharge heat into atmosphere.

5.2.3.4 Foreseen actions to prevent fuel degradation

1. Station existing equipment, e.g., equipment of other unit:
   (1) Station procedure "1451Ultimate Response Guideline" defines the emergency steps to use 7th EDG to provided AC power to both units. This guideline also describes load estimation and load saving operations.
   (2) Station has several fire engines as following table. These fire engines can take suction from raw water reservoir, Chinren lake, Shiding rivulet, Shuangxi rivulet, or take sea water from discharge channel. The outlet of fire engine can be connected to RHR system to inject water into spent fuel pool to prevent fuel degradation.

Lungmen Station Fire Engine				
Name	Amount	Capacity (Liter)	Discharge Pressure	Remark
Fire Foam Vehicle	1	6,000	0～27.6 (kg/cm^2)	Discharge flow rate : 3000liter/min@10 kg/cm^2
Reservoir Vehicle	1	12,000	0～10 (kg/cm^2)	Discharge flow rate : 800~2400 liter/min@10.0 kg/cm^2

2. Supports available from offsite if all onsite equipment are unavailable:
   (1) Offsite supports include one 4.16kV 1500kW mobile diesel generator and four 480V 200kW mobile diesel generators from Kuosheng station; and one 4.16kV 1500kW mobile diesel generator and eight 480V 500kW mobile diesel generators from Chinshan station.
   (2) Lungmen station and New Taipei city government has signed a protocol of firefighting support. Following Procedure 1420, once fire occurs, Fire Bureau will immediately

support manpower, vehicles, and equipment to site to mitigate calamity.

(3) If all units are damaged and also loss of ultimate heat sink（loss of power supply）, offsite supports include fire equipment (e.g. fire engine, fire pump, fire hose) from station, Gongliao, Shuangxi, and Ruifang District.. Fire Engines in the Vicinity Districts of Lungmen Station is shown as Table 5-3.

3. Power cable specifically connected to the power plants (such as hydro, gas turbine plant) in the vicinity:

Kuosheng nuclear power plant and Linko fossil power plant are the two plants in vicinity. However, no specific power cables are connected to these two plants.

4. The required prestage time for above mentioned systems

(1) It will take about 30 minutes for station fire engine taking suction from raw water pump room, through prestaged RHR piping system, and ejecting into SFP.

(2) It takes about 10 minutes for fire engines driving from Gongliao district to station (assuming water filled and standby). If the water injection path has already lined-up. The total time will be only 10 minutes for driving to station.

(3) It takes about 30 minutes for fire engines driving from Shuangxi or Ruifang district to station (assuming water filled and standby). If the water injection path has already lined-up. The total time will be only 30 minutes for driving to station.

(4) It will take about 30 minutes to take suction from 48,000 ton raw water reservoir; and will take 25 minutes to take suction from fire engine, through newly installed SFP seismic class piping.

The time of cliff edge effect is about 9.5hours. At this moment, the members of TSC, AMT, OSC, HPC, and EPIC should be in site already. The supporting should be ready.

5. Availability of qualified operators to perform above actions

The operation of systems and equipment are described in Ultimate Response Guideline 1451. The operation is performed by shift staff. Other required manpower is not much and must be supported from offsite. The support manpower are commanded by shift supervisor. The operation of fire engines and other fire equipment are performed by fireman.

The operators, who are responsible for the operating of above mentioned actions, are well trained and exercised. They can meet the mission requirements.

5.2.3.5 Envisaged measures to increase robustness of the plant

1. During outage, SFP and reactor cavity are interlinked. Firewater pump, tank truck engine, or mobile fire engine can makeup water into SFP or reactor core through RHR system.

2. When unit is not in outage, SFP and reactor are isolated from each other. Firewater pump, tank truck engine, or mobile fire engine can makeup water into SFP through RHR-C piping system.
3. In case of loss of onsite power, diesel driven fire pump (Seismic Category I) of fire water system can provide water from fire water storage tank to SFP, through RHR-C pipe, or through firewater system directly. Reactor building 7th floor has fire water system. Firewater can be injected into spent fuel pool by using the fire hose located on the side of SFP, or use permanent specific pipe lines .(Firewater pump capacity is 3000 gpm. Two hydrants can discharge a flow rate of 500 gpm.) The backup raw water reservoir has capacity 48,000ton.
4. Water can be makeup by gravity from raw water reservoir, at elevation 116 m, through RHR-C or fire piping to SFP.
5.If loss of electrical power, connect mobile diesel generator to power center(PC) to provide fuel pool cooling system power to perform cooling function.
6. Complete SFP emergency water makeup response procedures (Procedure 515.5 " Fuel Pool Cooling and Cleanup System Failure" and 1451 "Lungmen Station Ultimate Response Guideline") . These procedure include:(1) mobile diesel generator provides power to related systems to make up water;(2)firewater system makeup water;(3)raw water reservoir makeup water by gravity;(4) fire engine makeup water.
7. Based on the recommendations in NEI 06-12, station will have following enhancements. Install seismic designed firewater piping to makeup and to spray firewater. This modification will have 500 gpm makeup and 200 gpm spray capacity additionally. In case of fuel pool or building damaged and spent fuel cannot be cooled normally, this modification enhances the capability of fuel pool cooling and water makeup.
8. Install above-ground piping system and upgrade piping seismic category of raw water reservoir.
9. Prepare fuel shuffle planning instruction. Define the chessboard layout of fuels during outage and non-outage period. For example: the spent fuels with low decay heat serve as the "heat sink" of high decay heat fuels, or layout the high decay heat fuels dispersedly to delay the time of cladding melting.

5.2.4 Loss of ultimate heat sink

5.2.4.1 Design provisional autonomy of the site before fuel degradation

If loss of ultimate heat sink and AC power is available, spent fuel pool cooling system can perform water make up function; but cooling function will be affected. Since decay heat cannot dissipate into ultimate heat sink, evaporation will be the only way to remove decay heat.

The SFP has following ways to makeup water:

1. During outage, SFP and reactor cavity are interlinked. Firewater pump, tank truck engine, or mobile fire engine can makeup water into SFP or reactor core through RHR system.
2. When unit is not in outage, SFP and reactor are isolated from each other. Firewater pump, tank truck engine, or mobile fire engine can makeup water into SFP through RHR-C piping system.
3. In case of loss of onsite power, diesel driven fire pump (Seismic Category I) of fire water system can provide water from fire water storage tank to SFP, through RHR-C pipe, or through firewater system directly. Reactor building 7th floor has fire water system. Firewater can be injected into spent pool by using the fire hose located on the side of SFP, or use permanent specific pipe lines .(Firewater pump capacity is 3000 gpm. Two hydrants can discharge a flow rate of 500 gpm.) The backup raw water reservoir has capacity 48,000ton.
4. Water can be makeup by gravity from raw water reservoir, at elevation 116 m, through RHR-C or fire piping to SFP.
5. Based on the recommendations in NEI 06-12, station will have following enhancements. Install seismic designed firewater piping to makeup and to spray firewater. This modification will have 500 gpm makeup and 200 gpm spray capacity additionally. In case of fuel pool or building damaged and spent fuel cannot be cooled normally, this modification enhances the capability of fuel pool cooling and water makeup.

In this condition, SFP decay heat is removed by evaporation. Station will follow procedure 1451 “Ultimate Response Guideline” to vent secondary containment to remove heat.

5.2.4.2 Foreseen actions to prevent fuel degradation

1. Station existing equipment, e.g., equipment of other unit
   If loss of ultimate heat sink, SFP decay heat can be removed only by water makeup and evaporation. Station will follow procedure 1451 “Ultimate Response Guideline” to provide AC power to both units from 7th EDG or use Unit1 /2 EDG to support each other.
2. Supports available from offsite if all onsite equipment unavailable
   (1) Offsite supports include one 4.16kV 1500kW mobile diesel generator and four 480V 200kW mobile diesel generators from Kuosheng station; and one 4.16kV 1500kW mobile diesel generator and eight 480V 500kW mobile diesel generators from Chinshan

station.

(2) Lungmen station and New Taipei city government has signed a protocol of firefighting support. Following Procedure 1420, once fire occurs, Fire Bureau will immediately support manpower, vehicles, and equipment to site to mitigate calamity.

(3) If all units are damaged and also loss of ultimate heat sink（loss of power supply）, offsite supports include fire equipment (e.g. fire engine, fire pump, fire hose) from station, Gongliao, Shuangxi, and Ruifang District. Fire Engines in the vicinity districts of Lungmen Station is shown as Table 5-3.

3. The required prestage time for above mentioned systems

(1) It will take about 30 minutes for station fire engine taking suction from raw water pump room, through prestaged RHR piping system, and ejecting into SFP.

(2) It takes about 10 minutes for fire engines driving from Gongliao district to station (assuming water filled and standby). If the water injection path has already lined-up. The total time will be only 10 minutes for driving to station.

(3) It takes about 30 minutes for fire engines driving from Shuangxi or Ruifang district to station (assuming water filled and standby). If the water injection path has already lined-up. The total time will be only 30 minutes for driving to station.

(4) It will take about 30 minutes to take suction from 48,000 ton raw water reservoir; and will take 25 minutes to take suction from fire engine, through newly installed SFP seismic class piping.

The time of cliff edge effect for Reactor Building and Auxiliary Fuel Building Fuel Pool are 9.5 and 151.6hours, respectively. At this moment, the members of TSC, AMT, OSC, HPC, and EPIC should be in site already. The supporting should be ready.

4. Availability of qualified operators to perform above actions

The operation of systems and equipment are described in Ultimate Response Guideline 1451. The operation is performed by shift staff. Other required manpower is not much and must be supported from offsite. The support manpower will be commanded by shift supervisor. The operation of fire engines and other fire equipment are performed by fireman.

The operators, who are responsible for the operating of above mentioned actions, are well trained and exercised. They can meet the mission requirements.

5. Confirming the critical time before the onset of damage in this scenario

Under the condition which loss of SFP cooling water and full core off loaded during outage, calculation shows the pool water temperature increasing rate is 5.4℃/hr. If the initial pool water temperature is 49℃, pool water will begin to boil after 9.5 hours. If the initial AFP water temperature is 49℃, AFP pool water will begin to boil after151.6hours.

5.2.4.3 Envisaged measures to increase robustness of the plant

1. Ultimate Heat Sink Enhancement

(1) Based on the existing design basis, the operation of only one train RBSW system can ensure the removal of decay heat and other heat generated by safety related equipment. Station already has emergency plan if RBSW motor unavailable, and is preparing spare RBSW motor for emergency replacement. This motor will be placed at the warehouse at elevation 43.3 m. Once RBSW motor fails, immediate replacement can recover these systems as soon as possible.

(2) Install above-ground piping system and upgrade piping seismic category of raw water reservoir.

(3) The proposed modification has been approved to install water baffle plate and water tight device at the doors and openings of RB, CB, DG Fuel Oil Tank, AFB, FPH, RBSWPH pump room, ACB EL.12.3 m into RB, and Radwaste tunnel (RWT) EL.12.3m into RB/CB and AFB. The proposed modification can prevent flooding invasion.

(4) Station will purchase two 4.16kV 1500kW mobile generators. Kuosheng station has same type diesel generators to support Lungmen. RBSW system power availability can be improved.

5.2.5 Loss of the ultimate heat sink combined with station black out

5.2.5.1 Design provisional autonomy of the site before fuel degradation

If SBO and loss of ultimate heat sink, spent fuel pool will lost normal cooling and water makeup function. Station will follow procedure 1451 “Ultimate Response Guideline” to take emergency response to recover SFP cooling and water makeup ability.

5.2.5.2 Foreseen external actions to prevent fuel degradation

1. Station existing equipment, e.g. equipment of other unit:

(1) Connect 480 V mobile DG to the power source of fuel pool cooing system at power center (PC) to support fuel pool cooling. Alternatively, follow procedure 1451 “Ultimate Response Guideline” to provide AC power to both units by 7^{th} EDG; or use EDG of Unit 1 and Unit 2 to support each other.

(2) In case of loss of onsite power, diesel driven fire pump (Seismic Category I) of fire water system can provide water from fire water storage tank to SFP, through RHR-C

pipe, or through firewater system directly. Reactor building 7th floor has fire water system. Firewater can be injected into spent fuel pool by using the fire hose located on the side of SFP, or use permanent specific pipe lines .(Firewater pump capacity is 3000 gpm. Two hydrants can discharge a flow rate of 500 gpm.） The backup raw water reservoir has capacity 48,000ton.

(3) Water can be makeup by gravity from raw water reservoir, at elevation 116 m, through RHR-C or fire piping to SFP.

(4) Based on the recommendations in NEI 06-12, station will have following enhancements. Install seismic designed firewater piping to makeup and to spray firewater. This modification will have 500 gpm makeup and 200 gpm spray capacity additionally. In case of fuel pool or building damaged and spent fuel cannot be cooled normally, this modification enhances the capability of fuel pool cooling and water makeup.

2. Supports available from offsite if all onsite equipment unavailable:

(1) Offsite supports include one 4.16kV 1500kW mobile diesel generator and four 480V 200kW mobile diesel generators from Kuosheng station; and one 4.16kV 1500kW mobile diesel generator and five 480V 500kW mobile diesel generators from Chinshan station.

(2) Lungmen station and New Taipei city government has signed a protocol of firefighting support. Following Procedure 1420, once fire occurs, Fire Bureau will immediately support manpower, vehicles, and equipment to site to mitigate calamity.

(3) If all units are damaged and also loss of ultimate heat sink（loss of power supply）, offsite supports include fire equipment (e.g. fire engine, fire pump, fire hose) from station, Gongliao, Shuangxi, and Ruifang District. Fire Engines in the Vicinity Districts of Lungmen Station is shown as Table 5-3.

3. The required prestage time for above mentioned systems:

(1) It will take about 30 minutes for station fire engine taking suction from raw water pump room, through prestaged RHR piping system, and ejecting into SFP.

(2) It takes about 10 minutes for fire engines driving from Gongliao district to station (assuming water filled and standby). If the water injection path has already lined-up. The total time will be only 10 minutes for driving to station.

(3) It takes about 30 minutes for fire engines driving from Shuangxi or Ruifang district to station (assuming water filled and standby). If the water injection path has already lined-up. The total time will be only 30 minutes for driving to station.

(4) It will take about 30 minutes to take suction from 48,000 ton raw water reservoir; and

will take 25 minutes to take suction from fire engine, through newly installed SFP seismic class piping.

The time of cliff edge effect for Reactor Building and Auxiliary Fuel Building auxiliary fuel pool are 9.5 and 151.6hours, respectively. At this moment, the members of TSC, AMT, OSC, HPC, and EPIC should be in site already. The supporting should be ready.

4. Availability of qualified operators to perform above actions

The operation of systems and equipment are described in Ultimate Response Guideline 1451. The operation is performed by shift staff. Other required manpower is not much and must be supported from offsite. The support manpower will be commanded by shift supervisor. The operation of fire engines and other fire equipment are performed by fireman.

The operators, who are responsible for the operating of above mentioned actions, are well trained and exercised. They can meet the mission requirements.

5. Confirming the critical time before the onset of damage in this scenario

Under the condition which loss of SFP cooling water and full core off loaded during outage, calculation shows the pool water temperature increasing rate is 5.4℃/hr. If the initial pool water temperature is 49℃, pool water will begin to boil after 9.5 hours. If the initial AFP water temperature is 49℃, AFP pool water will begin to boil after151.6hours.

5.2.5.3 Envisaged measures to increase robustness of the plant

1. During outage, SFP and reactor cavity are interlinked. Firewater pump, tank truck engine, or mobile fire engine can makeup water into SFP or reactor core through RHR system.
2. When unit is not in outage, SFP and reactor are isolated from each other. Firewater pump, tank truck engine, or mobile fire engine can makeup water into SFP through RHR-C piping system.
3. In case of loss of onsite power, diesel driven fire pump (Seismic Category I) of fire water system can provide water from fire water storage tank to SFP, through RHR-C pipe, or through firewater system directly. Reactor building 7th floor has fire water system. Firewater can be injected into spent pool by using the fire hose located on the side of SFP, or use permanent specific pipe lines .(Firewater pump capacity is 3000 gpm. Two hydrants can discharge a flow rate of 500 gpm.) The backup raw water reservoir has capacity 48,000ton.
4. Water can be makeup by gravity from raw water reservoir, at elevation 116 m, through RHR-C or fire piping to SFP.

5. If loss of power, connect 480 V mobile DG to the power source of fuel pool cooing system at power center (PC) to support fuel pool cooling.
6. Complete SFP emergency water makeup response procedures (Procedure 515.5 " Fuel Pool Cooling and Cleanup System Failure" and 1451 "Lungmen Station Ultimate Response Guideline") . These procedure include:(1) mobile diesel generator provides power to related systems to make up water;(2)firewater system makeup water;(3)raw water reservoir makeup water by gravity;(4) fire engine makeup water.
7. Based on the recommendations in NEI 06-12, station will have following enhancements. Install seismic designed firewater piping to makeup and to spray firewater. This modification will have 500 gpm makeup and 200 gpm spray capacity additionally. In case of fuel pool or building damaged and spent fuel cannot be cooled normally, this modification enhances the capability of fuel pool cooling and water makeup.
8. Install above-ground piping system and upgrade piping seismic category of raw water reservoir.
9. Prepare fuel shuffle planning instruction. Define the chessboard layout of fuels during outage and non-outage period. For example: the spent fuels with low decay heat serve as the "heat sink" of high decay heat fuels, or layout the high decay heat fuels dispersedly to delay the time of cladding melting.

Reference：

a. Official Documents

b. Industrial Publications

1.CFD Thermal hydraulic Analysis of Longnen Station SFP Loss of Cooling Capability (Institute of Nuclear Energy Research)

2. Auxiliary Fuel Pool Cooling And cleanup (AFPC) system Heat Load Calculation (GE)

3. Lungmen Station Ultimate Response Guide RELAP5-3D Analysis(National Chinhwa University)

c. Taipower Documents

1. Lungmen Station FSAR (Taipower)

2. Lungmen Station Safety Evaluation Report (Taipower)

3.AOP-524.01 SBO

4. AOP-515.05 SFP Loss of Cooling

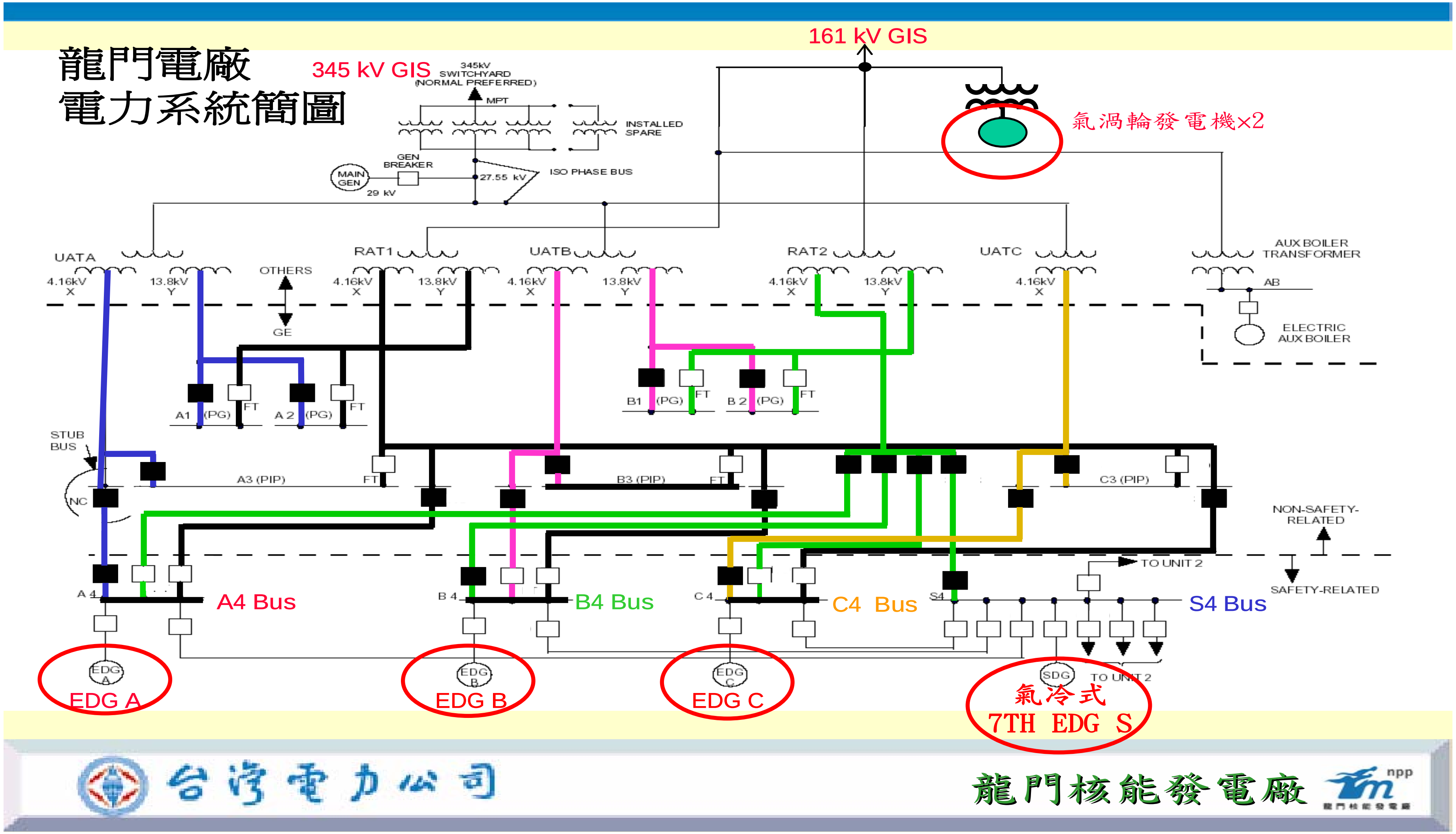


Figure 5-1 Lungmen Station Electrical Power Distribution Line Diagram

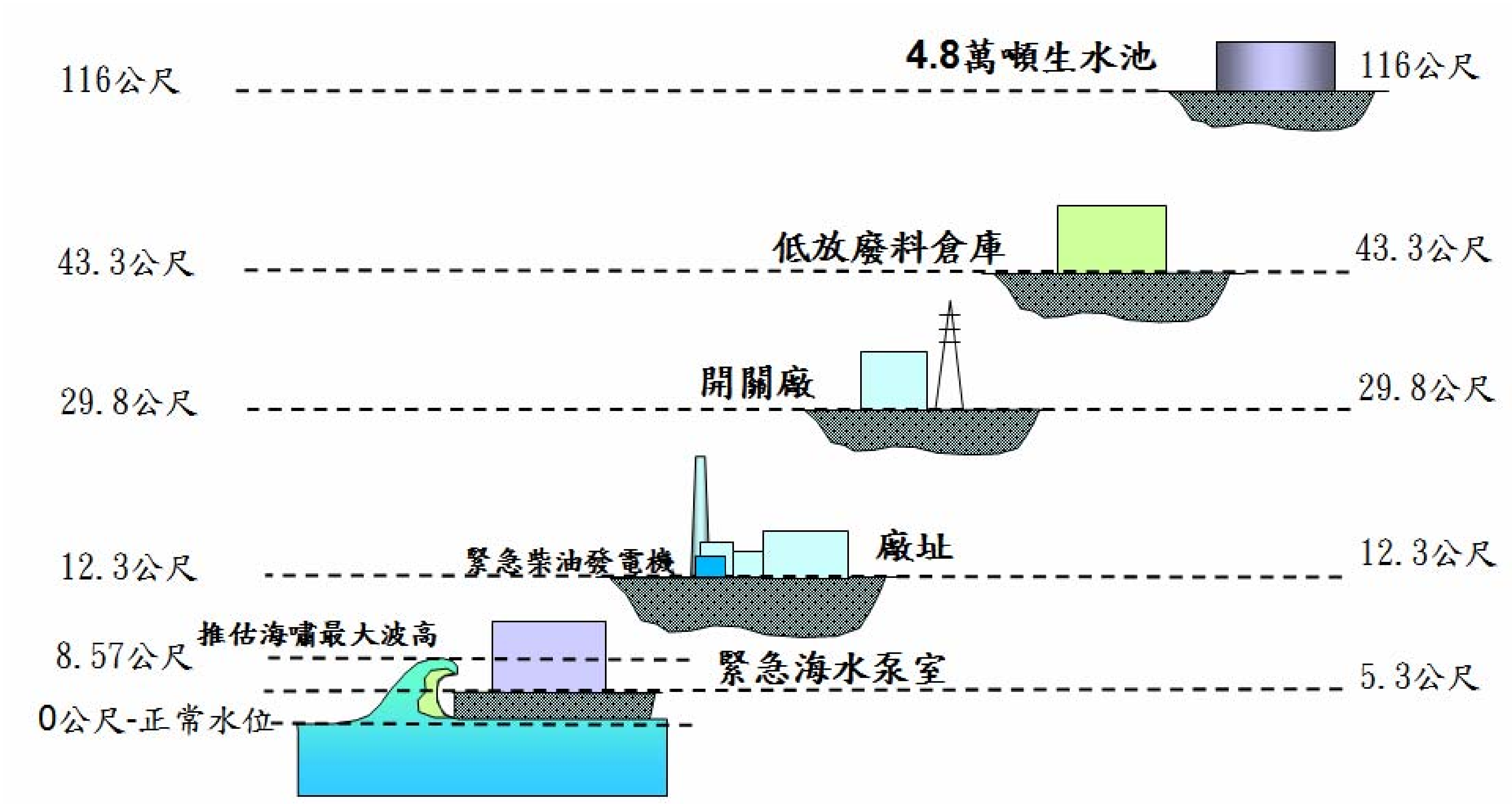


Figure 5-2 Lungmen Station Major Equipment Elevation

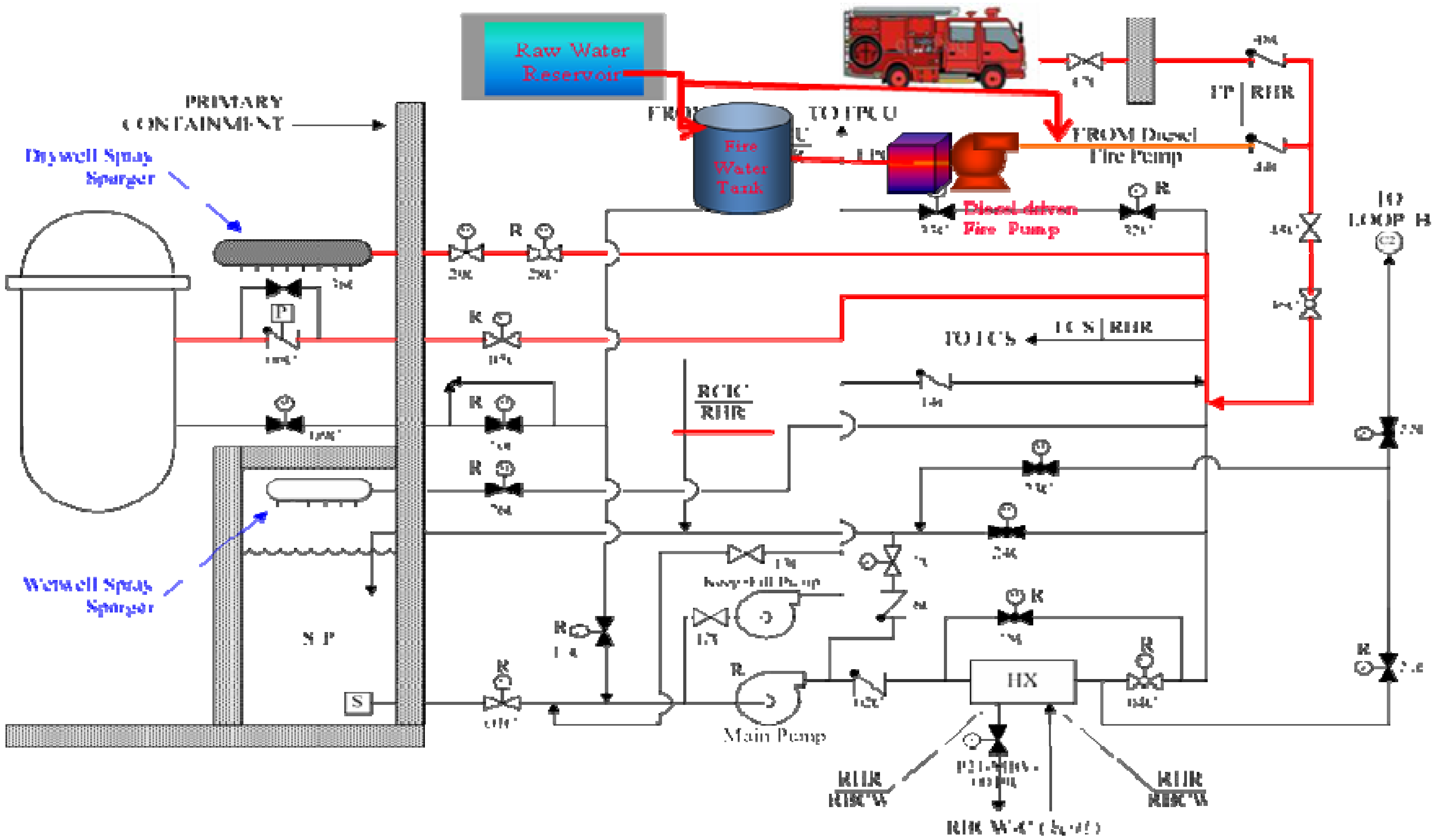


Figure 5-3 Betterment of Reactor Water Injection and Heat Removal

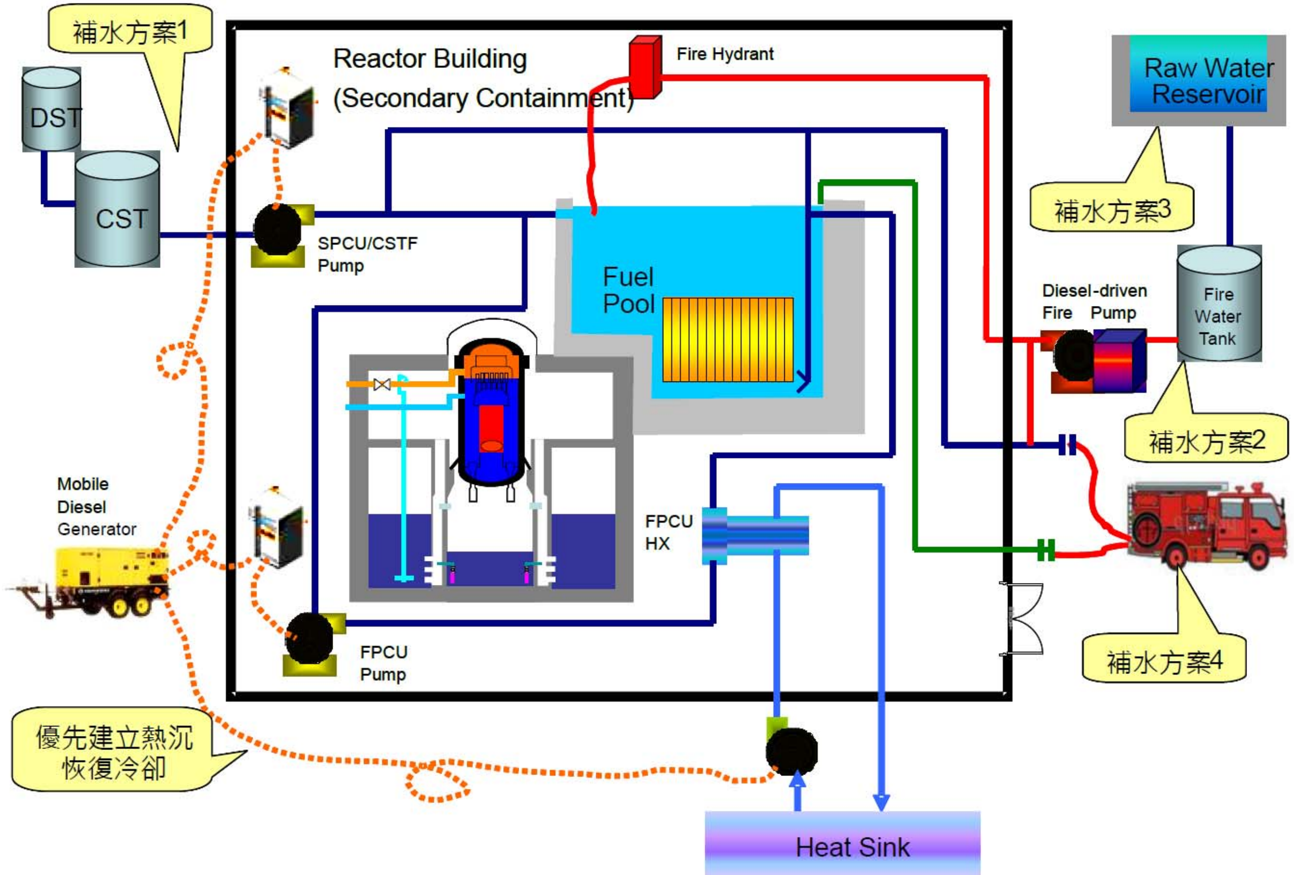


Figure 5-3.1 Measures Responding Reactor Building SPF Loss of Water Injection and Heat Removal

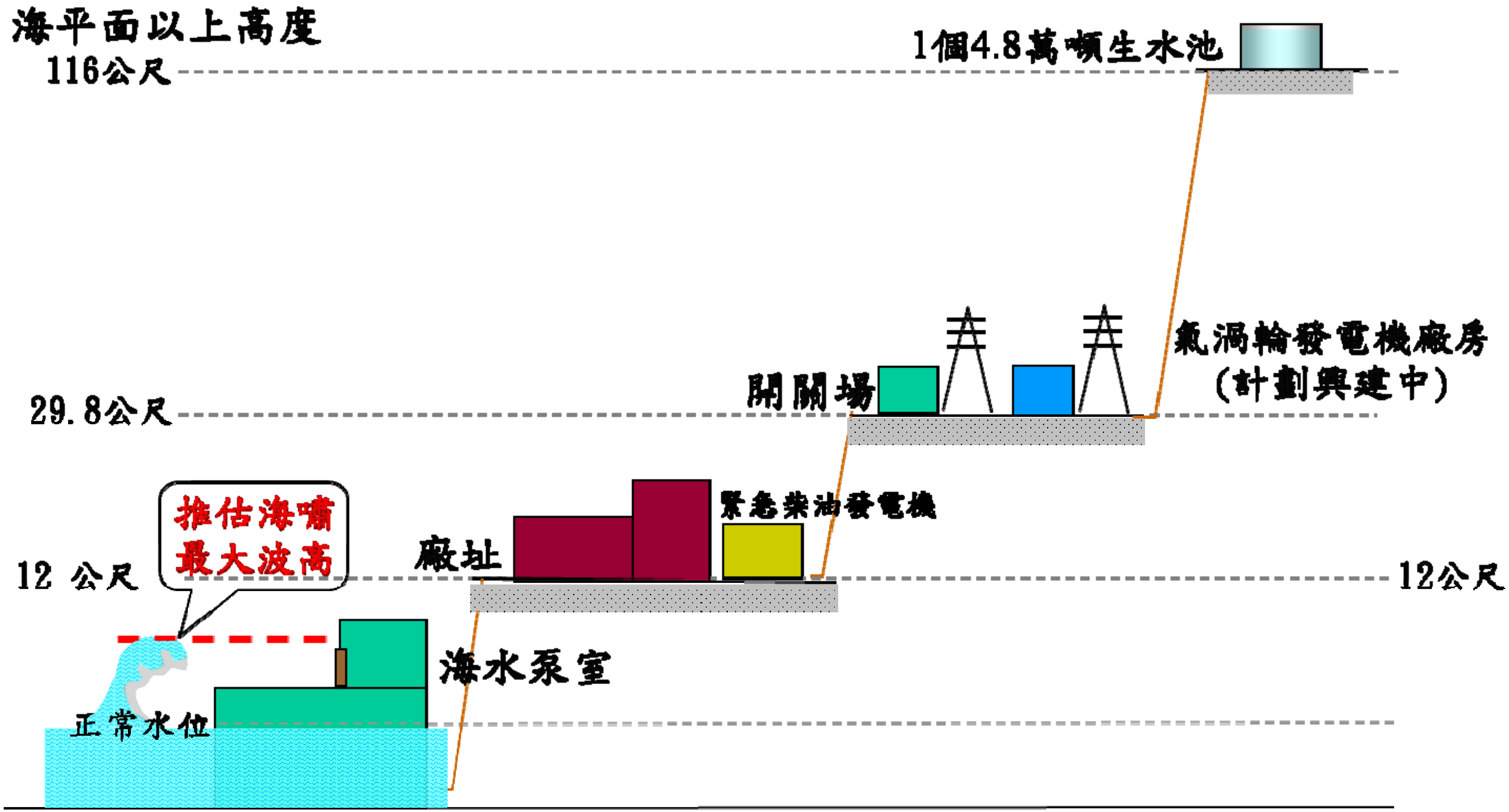


Figure 5-4 Elevation of Lungmen Station Facilities

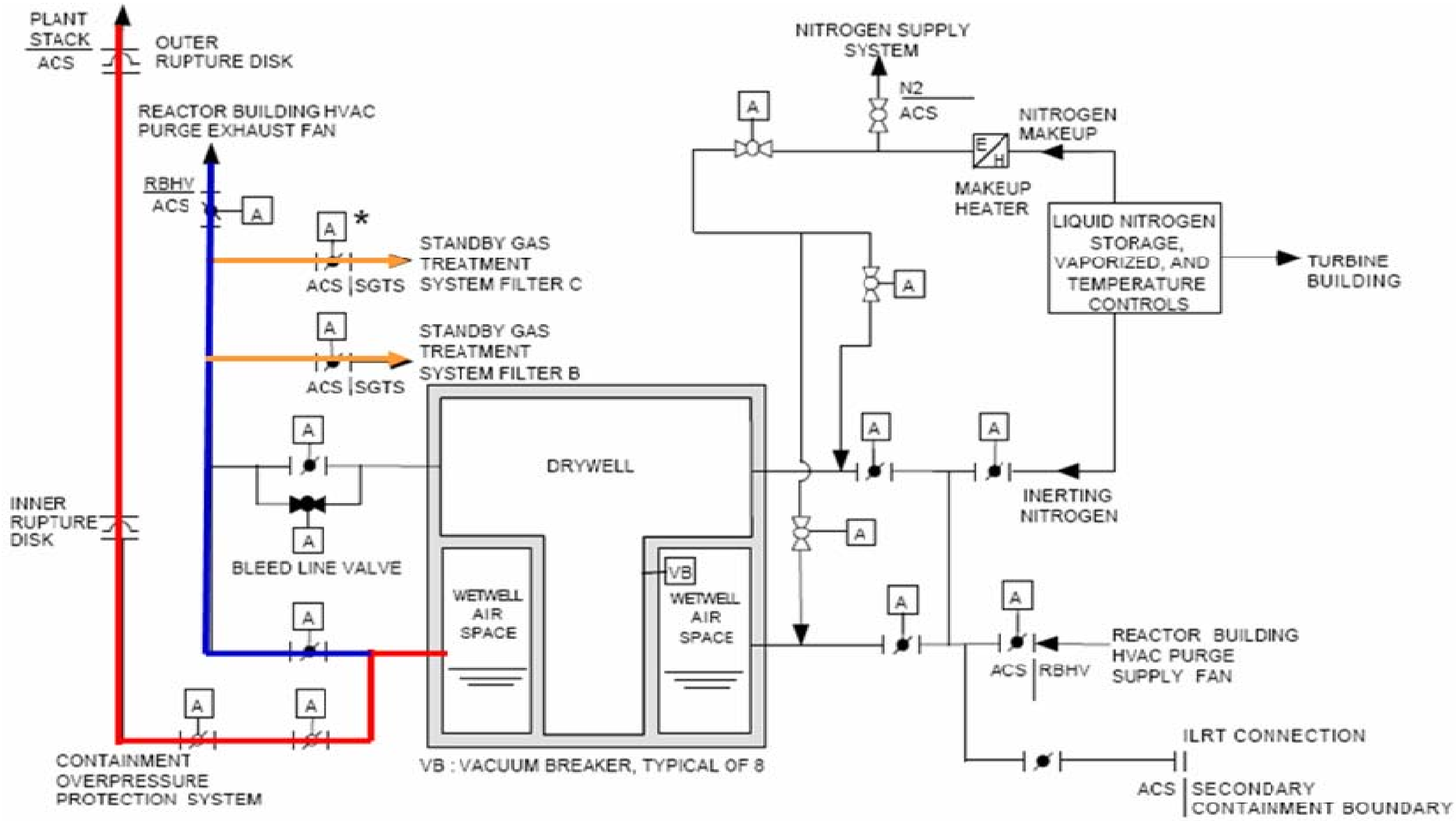


Figure 5-5 Containment Normal Venting Function

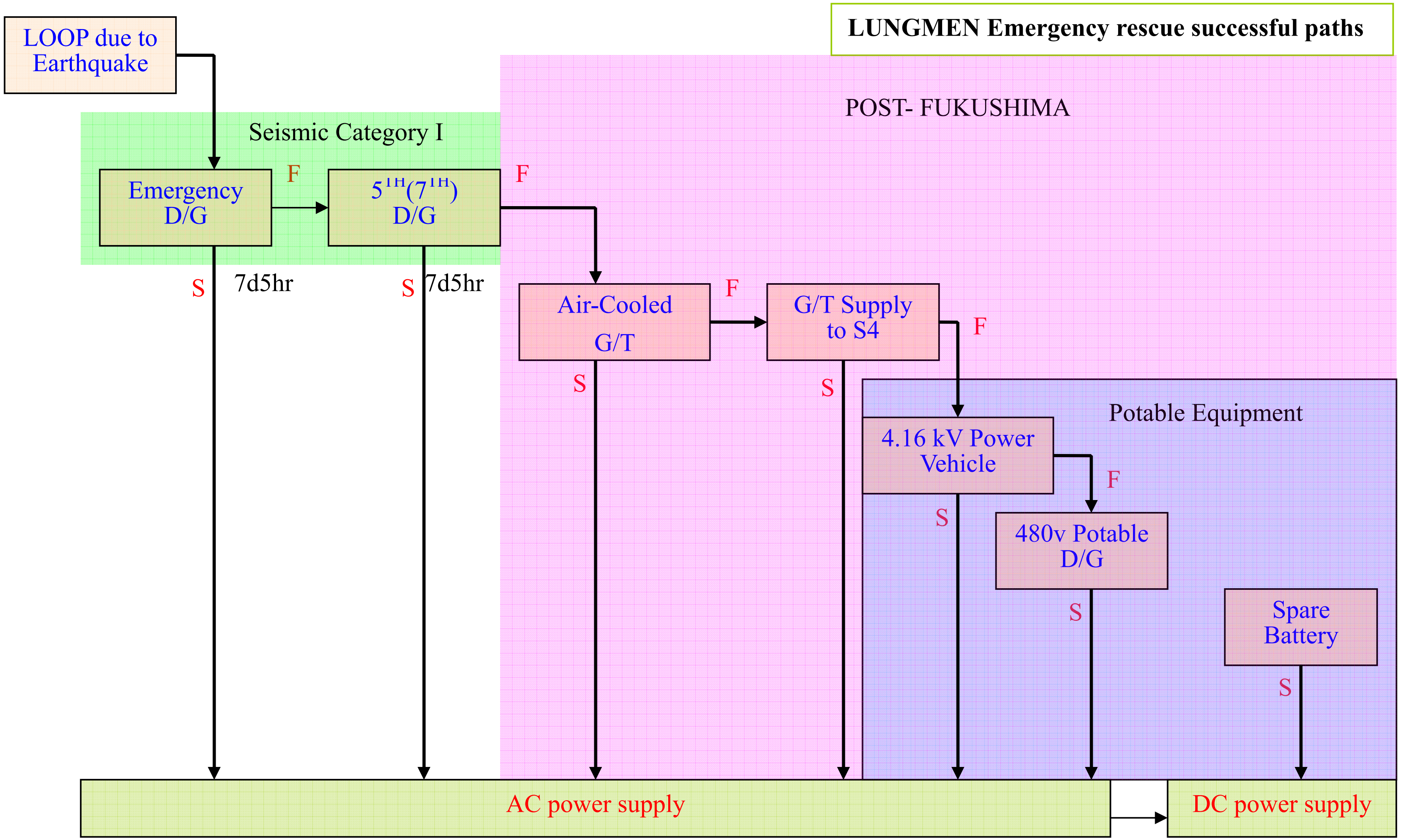


Figure5-6.1 Loss of electrical power rescue successful paths

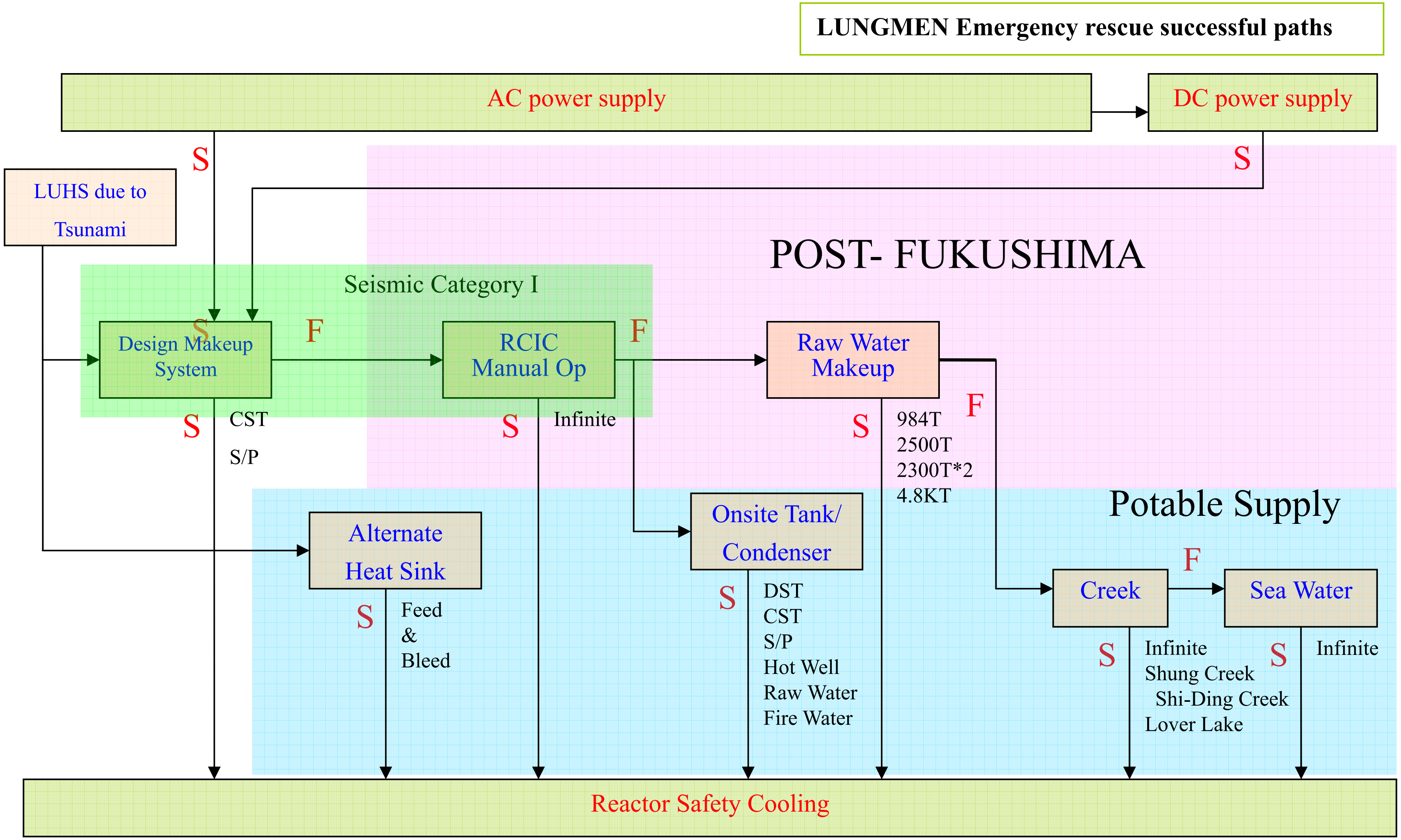


Figure5-6.2 Loss of ultimate heat sink rescue successful paths

Table 5-1 DIV. I Battery Load

DIV I CASE 1	
8HR Duty Cycle(SBO)-RCIC Random Load in 0-3 Min and 120-123 Min	
1224.09x1=	1224.09
600.03x1=	600.03
482.93x1=	482.93
420.03x117=	49143.51
358.17x1=	358.17
125.58x2=	251.16
62.68x357=	22376.76
	74436.65
74436.65/60=	**1240.61**
(1800x2/1240.61)x8=	**23.214(HR)**

DIV I CASE 2	
8HR Duty Cycle(SBO)-RCIC Random Load in 0-3 Min and 477-480 Min	
1224.09x1=	1224.09
600.03x1=	600.03
488.53x1=	488.53
482.93x116=	56019.88
420.03.x1=	420.03
62.68x357=	22376.76
358.17x1=	358.17
125.58x2=	251.16
	81738.65
81738.65/60=	**1362.3**
(1800x2/1362.3)x8=	**21.14(HR)**

DIV I CASE 3	
8HR Duty Cycle(SBO)-RCIC Random Load in 117-120 Min and 477-480 Min	
789.11x1=	789.11
531.53x1=	531.53
420.03x115=	48303.45
855.01x1=	855.01
488.53.x1=	488.53
482.93.1=	482.93
62.68x357=	22376.76
358.17x1=	358.17
125.58x2=	251.16
	74436.65
74436.65/60=	**1240.61**
(1800x2/1240.61)x8=	**23.214(HR)**

上述分析負載包括：**1R16-MCC-0100A4,1R16-PPL-0100A4,1R16-PPL-0200A4,1R16-PPL-0300A4**
1R16-PPL-0400A4,1R16-PPL-0500A4,1R13-CVCF-0000A4

Table 5-2 Lungmen Station Water Source List

No.	Tank	Structure Material	Seismic Category	Water Delivery	Elevation	Pumping Device
1	Condensate Storage Tank (CST) 4340ton	Steel Structure	I	Existing Piping	Base above sea level 12.3m	HPCF B/C (MSWG-B4/C4) RCIC(turbine driven) CSTF 5001A/B (MSWG-A3/B3) CSTF 5002/5003 (MCC-5020A1/5030A1) CRD A/B (MSWG-A3/B3)
2	Demineralized Water Storage Tank (DST) 1515ton	Steel Structure	IIC	Existing Piping	Base above sea level 12.3m	DST 5023A/B (LSWG-5000A1/B2)
3	Firewater Storage Tank A 2300ton	Steel Structure	I	Existing Piping	Base above sea level 12.3m	Fire Pump5001A (diesel driven) Fire Pump 5001B (MSWG-A3) Fire Pump 5002 (MCC-5320A2)
4	Firewater Storage Tank B 2300ton	Steel Structure	I	Existing Piping	Base above sea level 12.3m	Fire Pump 5001A (diesel driven) Fire Pump 5001B (MSWG-A3) Fire Pump5002 (MCC-5320A2)
5	Row Water Storage Tank 984 ton	Steel Structure	IIC	Existing Piping	Base above sea level 12.3m	NA
6	Raw Water Reservoir 48000 ton	Reinforced Concrete with Cover	IIA	Existing Piping	Base above sea level 116m	NA
7	Suppression Pool 3580 ton	Reinforced Concrete with Cover and liner	I	Existing Piping	Base above sea level -8.2m	HPCF B/C (MSWG-B4/C4) RCIC(turbine driven) RHRA/B/C (MSWG-A4/B4/C4)
8	Hot well 530 ton	Steel Structure	IIA	Existing Piping	Base above sea level 2.5m	CP A/B/C/D (MSWG-A1/A2/B1/B2) CBP A/B/C/D (MSWG-A1/A2/B1/B2)

Table 5-3 Fire Engines in the Vicinity Districts of Lungmen Station (including Gongliao、Shuangxi and Ruifang District)

Gongliao District Fire Engines				
Name	Amount (Unit)	Capacity (ton)	Discharge Pressure (kg/cm^2)	Remarks
Water Tank Vehicle	1	3.0	10	3ton
Water Tank Vehicle	1	2.0	10	
Shuangxi District Fire Engines				
Name	Amount (Unit)	Capacity (ton)	Discharge Pressure (kg/cm^2)	Remarks
Water Tank Vehicle	1	3.0	10	
Water Tank Vehicle	1	2.0	10	
Ruifang District Fire Engines				
Name	Amount (Unit)	Capacity (ton)	Discharge Pressure (kg/cm^2)	Remarks
Water Tank Vehicle	1	3.0	10	
Reservoir Vehicle	1	10.0	10	
Chemical Foam Vechicle	1	6,0	10	
Total	7			

6. Management of severe nuclear accidents

6.1 Organization of the licensee to manage the accident and the possible disturbances

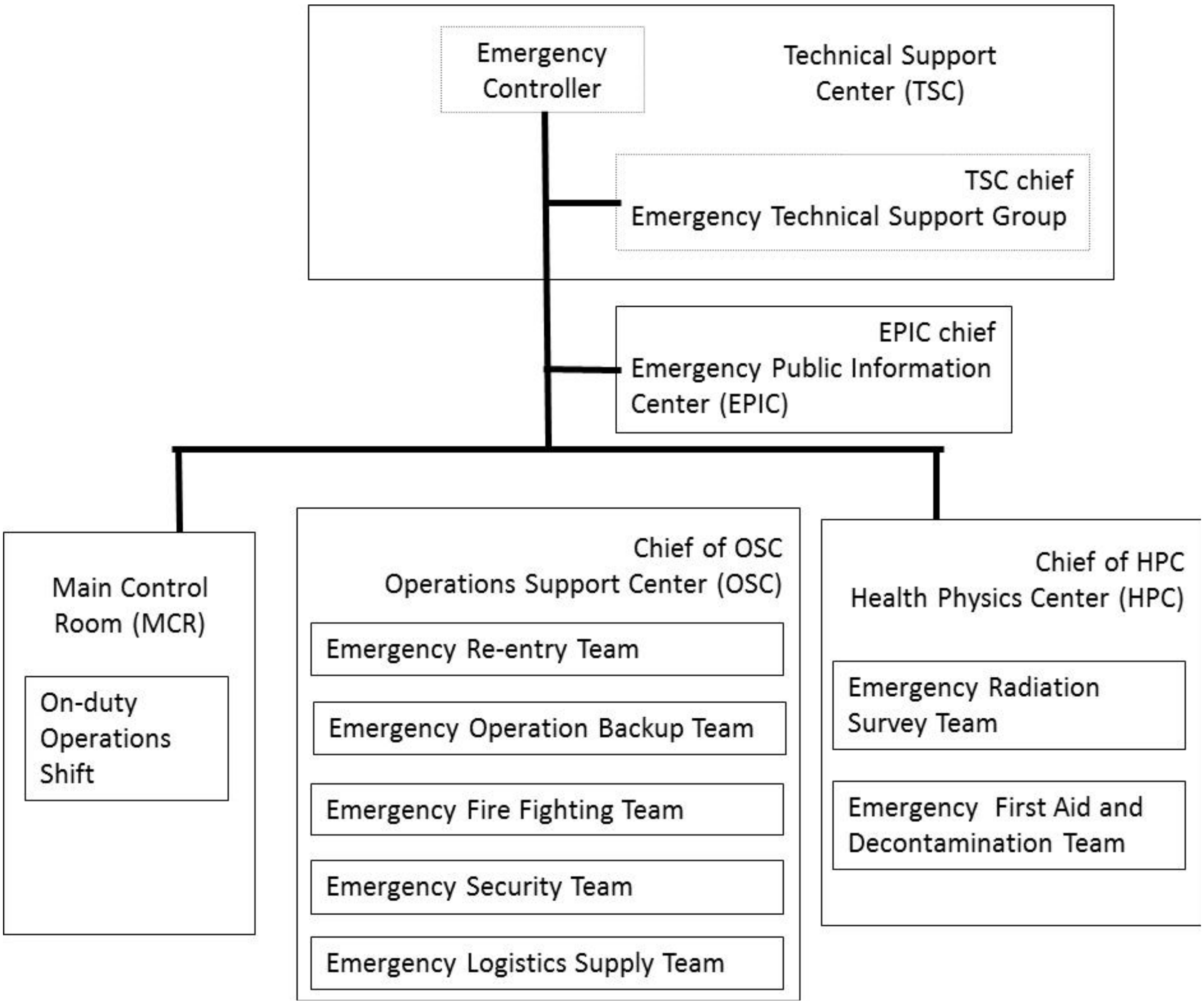
6.1.1 Organization plan

6.1.1.1 Organization of the licensee to manage the accidents

TPC prepared the Emergency Response Plans, detailed in 1400 series procedures for Lungmen NPP, according to the stipulations of AEC " The regulation of Nuclear Accident Emergency Response and the related derived regulations" as well as the requirements in "TPC Emergency Preparedness Plan for Nuclear Reactor Facilities" and performed periodical drill accordingly.

When the emergency accident occurs, Station Emergency Control Team is the core of the Station Emergency Control Organization according to the Emergency Preparedness Plan which consists of ten emergency working teams for different emergency missions including Technical Support Center (TSC), Emergency Public Information Center (EPIC), Health Physic Center（HPC）, Operation Support Center（OSC）and Main Control Room.

The station emergency control organization is shown as figure 6-1:



In order to response the serious nuclear accidents, the station has developed its dedicated Severe Accident Management Guideline (SAMG as shown in figures 6-1 & 6-2) reference to the Severe Accident Management Guideline (SAMG) developed by the United States BWROG and has established an Accident Management Team (AMT) by function grouping.

According to Procedure 1450 「Severe Accident Management Guideline」 (SAMG), Accident Management Team (AMT) shall provide assistance to TSC for diagnosing the accident conditions and proposing the response strategies.

The detailed responsibilities of AMT are described below:

1. The Operation Section Manager acts as the team leader of AMT and the full-time instructors (Senior SROs) in Simulation Center are team members and act as the first deputy. AMT leader is responsible for assessment of AMT setup timing, supervision of AMT and provides the suggestions to Station Emergency Control Team Brigade for appropriate decisions making and forecast the rescue actions.
2. The head of Mobile Support Station shall act as the team leader of the Operation Coordination Team (Operation Team), and Operation Subsection Chief is a team member and act as the first deputy. The Operation Coordination Team Leader shall be responsible for the following missions according to the "Operation Coordinator Manual" in SAMG procedure:
   (1) To confirm if transfer to SAGs process
   (2) To determine the SAG classifications
   (3) Flooding impacts on containment
   (4) The optimized rescue timing
   (5) System recovery priority sequences.
3. The Quality Section Manager shall act as the team leader of the Nuclear Safety Evaluation Team (NSE team) and Safety Evaluation Section Chief is team member and acts as the first deputy. The Safety Evaluation Team leader shall be responsible for the following missions according to the "System Analysis Engineer Manual" in SAMG procedure:
   (1) To control parameters trend
   (2) To assess RPV flows
   (3) To assess system status.
4. The Nuclear Engineering Section Manager shall act as the team leader of the Reactor Engineering Technology Assessment Team (Reactor Team) and Nuclear Engineering Section Chief is a team member and acts as the first deputy. The Reactor Assessment Team leader shall be responsible for the following missions according to the "Reactor Engineer Manual" in SAMG procedure:
   (1) To confirm if reactor is shutdown
   (2) To confirm if RPV is ruptured
   (3) To confirm if fuel is damaged
   (4) To request TSC / Emergency Executive Committee to provide with the data of containment atmosphere specimen and forecast dose release rate.
5. The team leader of AMT shall assign a Licensed Operator as SPDS Operator. The SPDS Operator shall be responsible for the following missions according to the "SPDS Operator Manual" in SAMG procedure:
   (1) To assess control parameters
   (2) To assess instrumentation and controls
   (3) To follow-up parameters trend.

If severe nuclear accident occurs that TSC has not been established yet, Main Control Room shall carry out accident response management according to relevant processes of SAG-1/2 guideline until TSC is established and AMT starts to operate. And then, the accident response management processes and decision making shall be transferred to TSC.

6.1.1.2 Possibility to use existing equipment

After Fukushima accident in Japan, Lungmen station immediately follows WANO SOER 2011-2 four proposed items to carry out the relevant verifications and countermeasures. Regarding the item 1.a "The inspections and verifications on adaptability and availability of those equipment used to mitigate severe accident" [note], the station shall comprehensively check the current planning procedures for accident managements including Severe Accident Management Guideline (SAMG), Emergency Operation Procedure (EOP; 581～590.25) and availability of required equipment and instrumentation for a loss of spent fuel pool water makeup. The checkup scope of equipment' functions shall include reactor water makeup, reactor vent & pressure control, reactivity control, hydrogen control, containment exhaust, emergency water makeup system of spent fuel pool, emergency power supply, emergency circulating water system, and the required instrumentation and indications for post-accident management (including ERF and the panel instrument meters) and so on. Except that the systems requested to be available and functional by technical specification shall be verified through test or inspection, non-routine inspection items shall be tested or inspected or walked down according to their attributes (active or passive).

After thoroughly checkup, the above-mentioned equipment is already incorporated in the station periodical test and preventive maintenances scope in order to maintain each rescue equipment operable anytime.

[Note]: WANO SOER 2011-2 Recommendations:

1. Verify the capability to mitigate conditions that result from beyond design basis events. Include, but do not limit.

   1.a Verify through test or inspection that equipment designed for severe accident mitigation is available and functional. Active equipment shall be tested and passive equipment shall be walked down and inspected.

6.1.1.3 Provisions to use mobile devices (availability of such devices, time to bring them onsite and put them in operation)

If the unit lost on-site and off-site AC power supply or reactor water makeup when beyond design-basis accidents occurred, the station already established the procedure 1451 "Ultimate Response Guideline (URG)" including each kind of alternative flooding-paths, power supply and water source, etc. The station will also mobilize all possible manpower, materials and physical resources to complete available water source arrangement in the shortest time. If operators judge that the design basis reactor coolant injection and cooling functions cannot be recovered in short time, the available backup water sources will be injected into the reactor immediately to insure that the nuclear fuel is covered by water and to prevent fuels from damaging.

In case the station experiences compound disasters beyond design-basis accidents such as earthquake, tsunami and so that the unit lost Reactor Building Seawater (RBSW) or Reactor Building Cooling Water (RBCW) and all off-site (on-site) AC power sources. Due to the failure of the above-mentioned equipment, the reactor water makeup will lost and the water level of spent fuel pool will drop and decay heat couldn't be removed. The procedure 1451 "Ultimate Response Guideline" (URG) provides instructive strategies to take the ultimate disposal actions in order to achieve the following purposes:

1. To maintain reactor core cooling.
2. To maintain control room monitoring functions.
3. To prevent and to mitigate the radioactive material release to outside the containment.
4. To maintain fuel pool cooling and the spent fuel covered with water.

The target of the guideline is to repair aid equipment first as soon as possible and to restore long term core cooling capability, spent fuel pool cooling, and to maintain spent fuel covered with water. Each strategy has been established in advance and incorporated in the station procedure 1451[URG] (described as below) and it can be rapidly carried out accordingly.

Attachment 1: The Ultimate Response executive condition process and announce & report timing flow-chart for LMNPP. (Figure 6-3)

Attachment 2: The Ultimate Response Process flow-chart (Figure 6-4).

Attachment 3: The Ultimate Response Process flow-chart for spent fuel pool (Figure 6-5A & 5B)

Attachment 4: Restoration of unit long term cooling capability flow chart (Figure 6-6)

Attachment 5: The operation items and the personnel arrangement table for Ultimate Response. (Attachment 6-1)

Attachment 6: Three-phased check list for Ultimate Response. (Attachment 6-2)

Attachment 7: Unit Ultimate Response Guideline.

Attachment 8: Spent fuel pool Emergency Operation Guideline .

Attachment 9: Lungmen Power Station normal water sources data list.

6.1.1.4 Provisions for and management of supplies (fuel for diesel generators, water, etc.)

In case the emergency accident occurs and "the emergency accident alert" condition is achieved, the Station On-Site Emergency Organization is then mobilized and established, and the Emergency Supply Team shall provide the backup services and equipment supports as per station procedure 1411 "the backup service and equipment support procedure".

The Subsection Chief of Supply Section acts as the leader of Emergency Supply Team, and the other Supply Section members as team members. The Emergency Supply Team leader should be responsible for the backup service management:

1. Responsible for vehicles dispatch, material supply, emergency materials preparation and procurement, food and lodging arrangement for the personnel.
2. To coordinate Accountant Team to do financial and accounting support in order for response to each kind emergency procurement.
3. To provide document and information transmitting manpower support in each response area.
4. To dispatch someone as a coordinator in the collection and on-call spot in order for evacuation operation need.
5. To assess current and future manpower and equipment request.
6. To coordinate backup manpower to support Emergency Response Organization.
7. To understand off-site situations such as weather, wind direction, rainfall, and traffic road condition so on to provide for the planning need for emergency response personnel and material transportation into the station.
8. To fill out Emergency Supply Team mobilization records.

9. To continuously update the name list of on-site emergency working team members and its assembly place.

TPC shall establish NEPEC(Nuclear Emergency Preparedness Executive Committee) according to the emergency plan if the accident expands continuously, or the Central Disaster Response Center is established by the government to provide the following necessary support and assistance depending on the accidental severity extent.

6.1.1.5 Management of radiation releases, provisions to limit them

Once severe accident occurs, management of radiation releases and preparation of limiting radiation for the station can be divided into two portions: radioactive gas release and radioactive liquid release which are described as follows:

1. Aspect of radioactive gas release
   (1) Under normal condition, primary containment may enclose the radioactive substance within containment by means of its designed automatic isolation function so as to prevent from fission product release during accident in order to insure that the off site radiation dose rate shall not exceed the requirement of 10CFR 100.
   (2) If plant boundary radiation dose rate achieved 0.1 mSv/hr after the accident occurred, the station shall carry out all relevant isolations to isolate all leakages according to EOP procedure 584 " Radiation release control". If accident continuously worsen to the extent for the need of entering SAG and Secondary Containment RBSCHV Exhaust radiation intensity or Refueling Floor radiation intensity exceeded 0.21mSv/hr, the station shall confirm if RBSCHV is isolated or not and start SGT to effectively filtrate radioactive material.
   (3) If containment is subject to high pressure and high hydrogen concentration or containment is unable to withstand the RPV energy-blowdown so that containment might be failed (containment pressure suppression capability)during the executing process of EOP/SAG rescue actions, the station shall force to carry out containment exhaust (its operation process please refer to URG attachment LM.1-07 Primary Containment Exhaust operating procedure) according to EOP/SAG in order to insure the integrity of primary containment and to avoid radioactive gas off site release out of control.
   (4) If the compound disaster similar to the Fukushima accident occurs and it is anticipated the containment flush / exhaust system may loss its intended function due to power loss, the station shall operate in accordance with the programmed URG phase-1 strategy LM.1-07 "Primary Containment Exhaust Operation Procedure" and phase-2 strategy LM.2-02 "Secondary Containment Exhaust Operation Procedure". The station has already incorporated SGTS power supply into priority restore item in order to rapidly restore containment exhaust and filtration operability.
2. Liquid release
   (1) The possible paths of the radioactive liquid release:

   Per the design features of Lungmen Power Station, the equipment piping and tanks for radioactive liquid waste discharge collection, transmission, storage, treatment, recovery and release are all located in the Radwaste Tunnel and the lowest floor of each building. The elevation of the lowest floor of each building plant is lower than ground elevation. After the accident, liquid radwaste will be accumulated in the lowest floor of each building, there is no external release path. Unless temporary power sources and temporary pipings are used for pumping and transfer, otherwise liquid radwaste cannot be released to the environment.

   As per procedure 913, radioactive liquid release shall be immediately stopped as soon as operator informs stop of radioactive liquid release when earthquake happens. Radioactive liquid release is not permitted until earthquake is stopped and Radwaste System and radwaste liquid release route relevant equipment and instrumentation are inspected and confirmed all safety as well as all functioned normal.

(2) Response countermeasures:

The accident resulted in the radioactive substance release will impact the station. It is assessed that the largest waste liquid storage space of the station is 17,968 cubic meters (Each building sump or waste liquid collection tank for both units can temporarily store 1,968.2 cubic meters; Turbine building Main Condenser can be temporarily used to store waste liquid and each unit has about 8,000 cubic meters and total 16,000 cubic meters for both units)

TPC Nuclear Emergency Planning Executive Committee and Central Disaster Response Center shall be immediately reported. If necessary, Central Disaster Response Center shall coordinate with Radiation Detection Center to dispatch the specialists to station on the coast to enhance the detection.

The station had comprehensively programmed the relevant entrance process and radiation protection control process for urgent repair support manpower. However, it is still requested that the few specialists for compound disaster response need are enrolled into Emergency Working Team and then carry out urgent repair by mission grouping as per current procedure in case condition permitted.

Considering they are unable to be enrolled into Emergency Working Team in case emergency urgent repair condition, HPC personnel shall carry out 5~10 minutes urgent repair radiation safety lecture to explain emergency exposure regulations, risk of accepted radiation dose, site radiation condition and radiation dose alert value as well as to get their dose rate permission signature. HPC personnel shall accompany with support personnel to site and guide them the relevant radiation notice items.

Before urgent repair personnel enter radiation control area, HPC personnel shall distribute badge and auxiliary dose alert meter to each person and guide them how to wear radiation protection cloth and relevant radiation protection equipment.

After urgent repair, HPC personnel shall assist them to reach the appointed temporary control station for overall body decontamination and detection and carry out necessary dose rate check and medical care in order to assure their radiation safety.

6.1.1.6 Communication and information systems (internal and external)

1. PA System

(1) PA System is powered from Uninterruptible Power Source CVCF 1(2)R13-CVCF-5001 .

(2) PA System in Reactor Building, Control Building, Switchgear Building, Turbine Building, Access Control and Administration Building, and outdoors PA System can be isolated and independent operation in order to avoid overall PA System inoperable due to single building PA System inoperable.

2. On-site landline telephone system

(1) On-site landline telephone system has set up a 48 VDC 400AH independent battery and charger which is at least 8 hours capacity and it is fed from 110VAC 1F43-CVCF-5001 (1R12-NPPL-5062A2-5) single phase power and its backup power source is fed from mobile diesel generator.

(2) Its switchboard is setup on unit 1 Access Control and Administration Building.

3. Low power DECT

(1) Low power DECT which is attached on plant telephone system is under setup.

(2) It is set up in general way for business communication.

4. SP telephone system

There are four loops of SP telephone systems provided for the communication purpose among Control Building, Turbine Building, Reactor Building, Main Guard House, Auxiliary Fuel Building, and Switchgear Building.

5. VHF radio system

(1) VHF radio system has total three channels and their frequencies are 153.13/153.16/153.19 MHz, 167.2625/ 167.2875/ 167.325 MHz.

(2) On-site Uninterrupted Power System (UPS) can provide 8 hour power supply capacity during station blackout and it can be transferred from the backup relay station in radioactive Laboratory for continuous use if its relay station is malfunctioned. Besides, eight operator consoles which are separately installed in unit 1 & 2 Reactor Building, Control Building, and Technical Support Center in Switchgear Building can be used to communicate with off-site radio cell phone and automobile cell phone. Moreover, 204 sets of hand type radio cell phones (equipped with chargeable Lithium battery) and 16 sets of automobile cell phones are provided for offsite communication.

6. Off-site telephone system

(1) The station switchboard is connected with Chunghwa Telecom via dedicated line and its power is fed from Uninterruptible Power Source 0Y86-CVCF-5002(0Y86-PPL-5092 and its backup power source is fed from security diesel generator.

(2) TPC microwave communication system has set up 48 VDC 1300AH (800AH + 500AH) independent battery set which is at least 8 hours capacity and support each other and its charger is fed from 220VAC single phase power.

(3) Off-site telephone system is directly connected from Control Room to Aoti Police station and Gong-Liao Fire Brigade and its power is provided by Chunghwa Telecom.

7. Satellite telephone

The satellite telephone is powered by 1R15-NPPL-0112B2-8 equipped with1000VA capacity Uninterruptible Power Source and its backup power source is fed from mobile diesel generator.

6.1.2 Possible disruption with regard to the measures envisaged to manage accidents and associated management

6.1.2.1 Extensive destruction of infrastructure around the site including the communication facilities

1. Response for the access difficulty of Off-site supports

The plant 1400 series procedures for Emergency Preparedness and Response Plan had already explicitly stipulated the division responsibilities and mobilization methods for Emergency Control Team each organization including on-shift operator, emergency backup operation team. Moreover, the reviewing result of the emergency response manpower during the accident time period falling on “normal” or “unusual” working time is described as follows:

(1) The accident occurs during the normal working time interval:

a. If the operation shift personnel are unable to arrive at site to take over, there are training shift manpower in the Simulation Center and approximately ten mobile support shift people (most of them are licensed personnel) can take over and assist unit operation.

b. Maintenance manpower of each division is all at site and there are long-term contractors resided at the site. Therefore, the maintenance manpower can reach hundred peoples to meet equipment maintenance need under emergency condition.

c. On-site Fire-Fighting Station consists of 8 people on the day shift and Emergency Backup Fire-fighting Team comprises 45 peoples who can assist the fire-fighting task during normal working time interval according to the emergency plan organization.

(2) The accident occurs during the non- office hours:

a. In future before fuel loading, the station shall follow the directives of TPC on other plants to investigate the shift operation personnel including Operation Team who lived in station district single standby duty dormitory and they may be first informed to assist unit operation work in order for response to insufficient shift operation manpower in case takeover operation manpower can't arrive at site. Moreover, the station had already planned to build household dormitory at Gong-Liao, Shungsi district such that shift operation personnel can be informed to enter into site for operation assistance if necessary.

b. In future before fuel loading, the station shall follow the precedence of friend plant to investigate the maintenance personnel (Mechanical Section, Electrical Section, Instrumentation Section, Machine Shop Section) who lived in station district single standby duty dormitory and they can be emergently mobilized to do urgent repair work. Moreover, the station had already planned to build household dormitory at Gong-Liao, Shungsi district such that maintenance personnel can be informed to enter into site for maintenance assistance if necessary.

c. The fire-fighting manpower on unusual working time interval maintains 6 people at site. Outcontracted fire-fighting manpower has priority to recruit the residents in Gong-Liao, Shungsi, Refine, and Keelung District etc and they can be urgently informed to enter site in case of accident condition. Besides, the plant-resided security police manpower can also assist the disaster rescues.

d. If off-site roads are obstructed, the station shall apply for engineering soldiers' support to urgent repair the damaged roads from National Nuclear Emergency Response Centre led by Central Government or apply for helicopter to transport urgent repair personnel, materials and facilities as well as emergency delivery of personnel for medical care.

2. To use off-site technical support as accident management (including off-site unavailable emergency response measures)

In responses to the compound disaster accident, the station has planned shift personnel arrangement and three phase check list in URG appendix 05 & 06. Its relevant items at phase-1 including reactor depressurization, alternative water injection, and urgent repair to restore power supply for essential systems and instrumentation via mobile power source, etc which shall be completed in a short time (within 1 hour) shall be finished by the station itself so as to effective control in order not to let the accident become worsen. If off-site supports are not available due to off-site road interrupted, the station had reorganized Emergency Response Organization each work team into 2~3 sub-work teams for alternative turnover and urgent repair unit by ways of on-site existing backup equipment.

The time limits of phase-2 action items and that of phase-3 action items in URG appendix 06 are respectively 8 hours and 36 hours. At the moment, each emergency response organization had gradually been mobilized and the fore-mentioned staffs who lived in station district single backup-duty dormitory, Gong-Liao, and Shungsi district as well as the subcontractors might as well arrived at site one after another. The manpower can continuously carry out the disaster-rescue and disaster-mitigation tasks. In addition, the station can apply for the demands on large-scale machines and tools and manpower support from TPC Nuclear Emergency Planning Executive Committee depending on the disaster condition. TPC Nuclear Emergency Planning Executive Committee will overall command TPC overall manpower and material resources to support the emergency accident management. The Central Disaster Response Center shall dispatch the engineering solders to urgent repair the damaged road or utilize the helicopter to transport personnel and the commodity equipment for urgent repair, as well as delivery the personnel to hospital for emergency medical care if necessary so that the compound disaster accident condition can be overall and long term controlled.

3. The possibility to use the existing equipment

The station major safety systems are designed as seismic category 1 and are all built at the altitude of more than 12 meters above sea level that they are enough to prevent from loss of their intended function resulted from anticipated natural hazards such as earthquake, Tsunami, and extra heavy rain etc. Please refer to relevant chapters of this report for relevant review and enhance programs. In view of Japanese Fukushima accident, the station had carried out the assessment of "Overall Physical Examinations for Nuclear Safety Protection". The station existing mobile disaster rescue equipment used for accidental conditions as well as the further expanded planned mobile equipment (Details please refer to chapter 2 Attachment 2-6 "The existing disaster rescue equipment" and Attachment 2-7 "Additional procurement disaster rescue equipment to for response to Fukushima accident") after Fukushima accident proposed by the review results of "Nuclear Overall Physical Examinations" under the AEC supervision. The above-mentioned relevant facilities and equipment had been planned to be stored in the place where is not susceptible to disaster harm if beyond design basis accident occurs so that plant personnel can rapidly allocated them to achieve the goal of the emergency rescue.

4. Communication enhancement plan on-site and off-site

   (1) The switchboard charger for plant telephone and DECT use is currently equipped with backup power fed from single phase 110Vmobile diesel generator.
   (2) The basement station (BTS) of the VSAT satellite telephone system installed by TPC Communication Department is designed as seismic class.
   (3) The frequencies of ten sets of radio cell phones for emergency communication use are CH1:158.2875/167.3375 MHz, CH2:167.3/167.3 MHz, CH3:167.325/167.325 MHz, CH4:167.35/167.35 MHz that are appropriated by TPC Communication Department.
   (4) Cellular Phone is planned and under procurement for emergency communication use.

[Note]: The relevant power enhancement programs are described in detail on the chapter 5.

6.1.2.2 Impairment of work performance due to high local dose rates, radioactive contamination and destruction of some facilities on site

1. The major rescue works for the station each unit including Spent Fuel Pool are controls and manipulations of Main Control Room. The functions of its relevant safety facilities and equipment shall not be impacted by radiation or contamination. If safety system lost its intended function due to compound disasters, the station shall dispatch personnel to enter the site for urgent repair or take URG strategies to carry out rescue works via each kind of mobile facilities and equipment The station radiation protection countermeasures for building and area local high dose rate or radioactive contamination are described as follows:

   (1) Before urgent repair, HPC shall first dispatch personnel to carry out the detections of site radiation, contamination and radioactive air concentration.
   (2) The radiation protection measures according to the site radiation condition are planned as follows:
      a. The feasibility of installation of radiation shielding on site is assessed to reduce site radiation dose rate and further reduce worker's exposure rate.
      b. The necessary radiation protection equipment such as radiation protection suit, breathing protection mask, and lead clothes so on are provided and urgent repair personnel are instructed how to wear each kind of radiation protection equipment if necessary.
      c. The longest working time is assessed and timing control is carried out if necessary.
   (3) To provide one EPD for each urgent repair personnel and to instruct them to immediately leave the site to avoid the dose rate out of control when alarm appears.
   (4) To set up the mobile Area Radiation Monitor (ARM) at site to provide urgent repair personnel with immediate radiation information. Once site radiation condition is changed, urgent repair personnel can be immediately evacuated to safer place.
   (5) After urgent repair personnel leaving the working area, they must go to the assigned place to accept the radiation surveillance in order to assure no external contamination.

2. The enhancement programs of Control Room Habitability and its access control shall be prepared when Control Room may have radiation contamination:

(1) The detections of radiation, contamination and radioactive concentration in air of the control room are regularly executed.

(2) The radiation protection measures are planned according to control room radiation condition:

a. The feasibility of the installation of radiation shielding is assessed in order to reduce site radiation dose rate and further reduce on-shift personnel exposure rate.

b. The necessary radiation protection equipment such as radiation protection suit, breathing protection mask and lead clothes so on are provided and instruct urgent repair personnel how to wear each kind of radiation protection equipment if necessary.

c. The longest working time is assessed and its timing control is carried out if necessary.

(3) The personnel contamination door frame detector is installed in the proper place to assure no contamination while on-shift personnel leaving.

3. The process mechanism of off-site support rescue teams entering the radiation area and contaminated area are as follows:

(1) According to the station procedure 1426 “The operating procedure of coordination supports from outside to the plant”, TPC Nuclear Emergency Planning Executive Committee (TNEPE) shall be responsible for overall command TPC overall manpower and material resources to support the emergency accident management. After TNEPE prepared the entrance processes, OSC Director shall takeover to command the urgent repair operations. All support personnel shall be enrolled into “the station emergency working team on-shift list” by OSC Director and then join the urgent repair work.

(2) According to the station procedure 1419 “The re-entry procedure”, the Emergency Re-entry Team Leader and the Emergency Radiation-detection Leader shall plan together the suitable re-entry urgent repair steps according to the task contents and the site condition. Before re-entry, Emergency Radiation Detection Team shall select the detection instruments first and dispatched personnel to detect in and out routes and site radiation, airborne, and contamination condition. After obtaining the site radiation condition, the re-entry personnel working time limit shall be determined and the other necessary processes shall be arranged. If there is need to exceed the dose rate limit for work need, it shall get approval of the Station Emergency Control Team Brigade and advise the re-entry personnel about site radiation, airborne, contamination condition as well as possible exposure dose rate and the related radiation protection attentive items. The detection personnel and the re-entry workers shall carry the auxiliary dosage alarm meter, dedicated TLD Badge and wear the proper protection clothes and equipment.

(3) When the site radiation dose rate is too high, the individual dose rate shall be legally authorized to meet the emergency exposure requirements and its acceptance dose rate shall be controlled and the workers shall be changed if necessary in order to meet the regulation requirements.

(4) With regard to the support personnel who have never been trained with radiation-protection courses, the station had already reviewed and proposed the related radiation protection enhancement measures.

a. If the situation permitted, it is still requested that they are enrolled into the station emergency work team and then carry out the urgent repair work by mission grouping according to current procedure.

b. If specialists are requested to enter high radiation area for urgent repair and considering they are unable to be enrolled into Emergency Working Team in this emergency urgent repair condition, the relevant stipulations are incorporated in procedure 1414. Health Physic Section shall assign the radiation protection personnel to advise them the relevant emergency exposure regulations, acceptance risk of radiation, and site radiation condition etc in advance instead of legal radiation protection training and meanwhile get their approval and then accompany with support personnel to site and guide them the relevant radiation notice items anytime.

c. Before the urgent repair personnel enter the radiation control area, radiation protection personnel shall distribute a Badge and an auxiliary dosage alarm meter to each urgent repair personnel and instruct them how to wear the related radiation protection clothes and how to use the related radiation protection equipment. The spare parts and spare part list of the related radiation protection clothes, badges and the dosage alarming meters for support repair personnel during the emergency accident period had been prepared since 100.05.31.

6.1.2.3 Feasibility and effectiveness of accident management measures under the conditions of external hazards (earthquakes, floods)

The station major safety systems are designed as seismic category 1 and are all built at the altitude of more than 12 meters above sea level that it is enough to prevent from them loss of their intended function resulted from anticipated natural hazards such as earthquake, Tsunami, and extra heavy rain etc. In view of Japanese Fukushima nuclear accident, the station had already carried out the assessment of “The Station Nuclear Safety Protection Overall physic Examination” to review the beyond design basis conditions and carried out their correspondent improvements including setup of Ultimate Response Guidelines (URG).

1. Effectiveness: The major strategies of URG are to take actions in the shortest time to prevent the accident from worsening and are different from the strategies in EOP/SAG which is based on the consideration of symptom via item by item assessment so that further control the station status to achieve the goal of population safety protection.
2. Feasibility: As above-mentioned descriptions in “The existing disaster rescue equipment”, the station existing mobile disaster rescue equipment used for accidental conditions as well as the further expanded planned mobile equipment after Fukushima accident proposed by the review results of “the nuclear comprehensive physical examination”. The above-mentioned relevant facilities and equipment had been planned to be stored in the place where is not susceptible to disaster harm if the beyond design basis accident occurs so that plant personnel can rapidly allocated them to achieve the goal of the emergency rescues.
3. Validity: According to each assessment result, the station had set up its Ultimate Response guidelines whose relevant strategies had already considered defense-in-depth conception and set up diversity and redundant strategies (e.g. each kind of water source, electric power, gas source etc.) so as to assure the validity of rescue action capability for responding compound disaster.

6.1.2.4 Unavailability of power supply

The station had carried out the review of power supply capability and its enhancement plans for response to the accident similar to Fukushima accident and it is described in detail as this report Chapter 5 “ Loss of power source and the Ultimate Heat Sink”. Thus it can provide redundant power supplies under the accident condition to achieve the goals of maintaining long-term core cooling so as to avoid fuel damage.

6.1.2.5 Potential effects from the other neighboring unit(s) at site

With regard to the compound disaster conditions simultaneously occurred at both units, the following four aspects are discussed:

1. Review on common equipment for mutual supports :

After Fukushima first nuclear power plant accident in Japan occurs, the station had carried out self-overview of "Overall physical examinations on safety protection". The item of "The countermeasures of mutual support between unit No.1 and unit No.2" had been already reviewed and verified in connection with those items: (1) RBCW system, (2) CSTF system, (3) Water Makeup System P11 and Fire Water System P16, (4) Compressed air system, (5) Essential Bus System and had already completed the associated countermeasures to common equipment for current mutual-support as well as the verifications of their accident mitigation and rescue functions:

(1) RBCW System
RBCW system train C of both units can provide cooling water to 0G42 AFPC Heat Exchanger A/B and support each other.

(2) CSTF System
CSTF System of both units can support each other by ways of Radwaste Building piping.

(3) Water Makeup System P11/ Fire Water System P16
Water Makeup System P11/ Fire Water System P16 can support to both units in ACIWA mode operation.

(4) Compressed Air System
a. Instrument air system P52 for both units can support each other by ways of yard piping located in east side of Turbine Building.
b. Plant air system P51 for both units can support each other by ways of yard piping located in east side of Turbine Building.

(5) Essential Bus System
The 7th Diesel Generator (SDG) can provide power for both units Essential Bus System.

2. Regarding the above-mentioned equipment, the station had already carried out the following enhancement strategies after overall physical examination:

The station Instrument air system P52 and Plant air system P51 which are designed with a check valve 1(2)P52-UV-5069 & 1(2)P51-UV-5060 for both units had been tied-in connection. This check valve is needed to be removed so that Instrument air system P52 and Plant air system P51 for both units can be connected through each other. Moreover, 1(2)P52-BV-5037 /5038 & 1(2) P51-BV-5150 /5152 shall be changed from normal open to normal close.

(1) To avoid diesel fuel oil fire pump inoperable during beyond design basis accident, baffle plate is installed in fire pump room outward door.

(2) The power enhancement plans include (1) the seventh EDG supplies power for both units (2) DIV Ⅰ/DIV Ⅱ/DIV Ⅲ EDGs for both units can support each other. (3) Gas turbine associated two sets of 4.16kV 1100kW diesel generators provide the essential power supply (4) Procurement of 2 sets of 480V 200kW mobile diesel generators (5) Procurement of 5 sets of 480V 100kW mobile diesel generators and (6) 4.16kV 1500kW diesel generator power truck. They are all described in detail in this report Chapter 5.

(3) For compressed air system, the station will procure additional mobile engine-driven air compressors to provide SRV operation air source for both units.

3. Assessment of on-shift operation manpower dispatch:

(1) Currently the station is under construction and commissioning test phase, the organization plan of operation shift personnel shall consult the precedence of Chinshan and Kuosheng Nuclear Power Station. Except for those stationed in periphery, unit operators will be separately allocated on unit 1 and unit 2 Main control Room. Manpower resources shall be dispatched by Shift Manager and Unit Shift Supervisors shall support each other so that the manpower can be used in the emergency operation needs of essential systems.

(2) The equipment layouts of both units are designed with the same arrangement so that manpower resources can be mutual dispatch and support the emergency operation needs of essential systems.
(3) During the outage of unit 1 and unit 2, one shift operation personnel and each person from the other shifts are transferred to support the outage work so that shift operation personnel can experience the operation career of different position and can support the different post operations during the accident.
(4) Normal operation training for both units adopts the same criteria so that operator can familiar with the other unit equipment layout and operation if operator is transferred or shift-substituted. Therefore, it is undoubtedly that unit shift operators can support each other.
(5) If severe accident occurs, Shift Manager can dispatch personnel to the most required position depending on the condition at that time.(For example: When Pump House happens bad sea condition or big volume of trash or fish swarm invasion, Shift Manager can immediately dispatch personnel to support. If severe accident occurs, the rule shall be followed to execute support operation.)

4. Enhancement on manpower mobilization:

The review of emergency response manpower is described as follows:

(1) If accident occurs in the normal working time period:

a. The condition may happen that on-shift operation personnel can't access to the station for takeover, the training shift manpower in Simulation Center and Inspection Control Team members can take over and assist unit operation.

b. Except for manpower of each maintenance division at site, the station shall follow the precedence of friend plant to sign a long term maintenance manpower contract in future in order to meet the equipment maintenance need in emergency condition.

c. The station fire-fighting station manpower on the second working time period is allocated 11 persons including leader 1person, nurse 1person, fire equipment supervisors 3 persons, and team members 6 persons and each shift is allocated 6 persons. During normal working time period, Emergency Backup Fire Fighting Team is allocated 46 persons who can assist fire-fighting tasks as per emergency plan organization.

(2) If accident occurs in the unusual working time period:

a. In future before fuel loading, the station shall follow the precedence of friend plant to investigate the shift operation personnel including Operation Team who live in factory district single standby duty dormitory and they may be first informed to assist unit operation work in order for response to insufficient shift operation manpower in case takeover operation manpower can't arrive at site. Moreover, the station had already planned to build a household dormitory at Gong-Liao, Shungsi district such that shift operation personnel can be informed to enter into site for operation assistance if necessary.

b. In future before fuel loading, the station shall follow the precedence of friend plant to investigate the maintenance personnel (Mechanical Section, Electrical Section, Instrumentation Section, Machine Shop Section) who live in factory district single standby duty dormitory and they can be emergently mobilized to do urgent repair work. Moreover, the station had already planned to build a household dormitory at Gong-Liao, Shungsi district such that maintenance personnel can be informed to enter into site for maintenance assistance if necessary.

c. The fire-fighting manpower on unusual working time period maintains 6 persons at site. Outcontracted fire-fighting manpower has the priority to recruit the residents in Gong-Liao, Shungsi, Refine, and Keelung District etc and they can be urgently informed to enter into site in case of accident condition. Besides, the site-resided security police manpower can also assist the disaster-rescues.

6.2 Nuclear Power Reactors

6.2.1 Loss of core cooling: Accident management measures currently in place before occurrence of fuel damage in the reactor pressure vessel

When core cooling function is lost, the station immediately follows EOP 581~587 to carry out the unit control including water injection via water injection subsystem or alternative water injection system (including fire water system) in order to maintain normal water level between L3 and L8 such that the core is flooded with water so as to avoid fuel damage. (The purpose of EOP is to avoid the accident worsened to the extent that reactor core fuel is melt.)

In case that the station suffered from the beyond design basis accident resulted from earthquake and tsunami etc, Reactor Building Cooling Seawater System (RBSW) or Reactor Building Cooling Water System (RBCW) lost its intended function such that decay heat is unable to be removed, and under the conditions that reactor lost its water makeup capability, all off-site and on-site power are lost, and spent fuel pool water level dropped, the station shall follow procedure 1451"Ultimate response guideline (URG)" to take decisive actions including each kind of alternative water flooding path, power sources, and water sources etc. All possible and available manpower and materials are mobilized to arrange all available water sources in the shortest time period. Judging in the shortest time that water injection and cooling function can't be restored to the design base function, available backup water sources shall be immediately injected into reactor in order to insure that fuel is covered with water and prevent from fuel damage.

6.2.1.1 Preventive actions to prevent fuel damage and to eliminate high pressure fuel damage

When core cooling function is lost, EOP actions of reactor pressure control (RC/P)as well as the above-mentioned measures shall be simultaneously performed till reactor pressure lower than 1MPaG (The 55℃/h temperature decreasing rate limit can be exceeded if necessary) in order to avoid fuel damage due to reactor core high pressure.

In case that design basis accident occurred, the unit lost its on-site and off-site AC powers or reactor water makeup function, the station shall follow URG appendix LM.1-06 "Reactor Pressure Relief operating procedure" to depress the reactor pressure to 1.5 MPaG (The limit of 55℃/h temperature decreasing rate can be exceeded if necessary) as soon as possible, to makeup water to reactor by ways of RCIC and to control reactor pressure (Manual operation can be used) in order. As the alternative water flooding measure is ready, the in-advanced built-up water sources shall be injected to reactor in coordination with SRV emergency pressure relief to ensure that core fuel is covered with water so as to avoid fuel damage.

6.2.1.2 Risks of cliff edge effects and deadlines

Reactor water level can be maintained via RCIC which is designed with 8 hours DC power supply (24 hours DC power supply in case of unnecessary loads isolated) in case that the station lost all both on-site and off-site AC powers and reactor water makeup. During the time of this period, the station shall follow URG appendix LM.2-04~07 & LM.2-11~14 to set up normal power supply and alternative power supply including the Seventh Diesel Generator, GTG, and backup mobile power which is set aside on high elevation to provide long term RCIC required power. Furthermore, depending on the station condition, emergency water can be injected to reactor by means of the backup alternative water makeup measure as described in the URG attachment 02 "Long term water source plan" and via backup alternative water sources as well as flooding path after reactor emergency pressure relief （URG appendix LM.1-06） in order to maintain that core fuel is long term covered with water and not to occur the above-mentioned cliff edge effects .

The Institute of Nuclear Energy (INER) committed by TPC Nuclear Safety Department assess the risks of cliff edge effects and deadlines with MAAPs . Under the conservative assumption, it is assumed that RCIC is failed after 8 hours & 24 hours respectively so as to result in loss of core water makeup and cooling. The calculation result is described as follows:

- RCIC keeps operation for 8 hours:

  The time of core water level drops to TAF (top of active fuel) is 1.63 hrs.

- RCIC keeps operation for 24 hours:

  The time of core water level drops to TAF (top of active fuel) is 4.33 hrs.

6.2.1.3 Adequacy of the existing management measures and possible additional provisions

Considering under the condition similar to Japan, Fukushima 311 nuclear compound disaster accident resulted from earthquake accompanying tsunami attack, the facilities designed for mitigation of severe accident may be inoperable at the same time or inoperable gradually; The station had already reviewed all the response procedures, facilities, and mechanisms used for coping with design basis accident so as to concretely enhance the station response capability.

Compound disaster is a kind of aspect impact and it is not limited to the threat of the containment integrity. The management of compound disaster condition is very urgent in the time limit and the reciprocating judging process and treatment process of EOP or SAMG can't cope with the worsen extent of accident. In order to cope with the compound disaster condition, TPC had already prepared the "Ultimate Response Guidelines (URG)" for station to follow and its initiation opportunity and action basis shall follow this guideline based on the site-specific basis because each kind of defense equipment or water facilities may simultaneously lose its function when compound disaster accident happens. Therefore, TPC had programmed to incorporate all site and off-site available resources and measures into enhance strategies to program mobile power, water, and air sources based on the redundant, diversity and independent defense-in-depth strategy and emphasize their mobility to shorten their management deadlines in order to response to each kind of compound disaster condition.

According to the analysis results via Three Dimensional Two-Phase Thermal-Hydraulic Model(REAP5-3D) and considering the station URG reasonable operation process, it is analyzed that after reactor emergency pressure relief, URG water injection to reactor by ways of fire water piping, the minimum required individual flows, that keep fuel cladding temperature below 1500 ℉ (hydrogen producing point), are 1974gpm(1hr), 1483gpm (4hr), and 1335gpm (8hr) respectively , in case that all water makeup system are lost and RCIC continuously control reactor pressure as well as the three conditions of water injection failed after 1 hr, 4hrs, 8hrs respectively (the former assumption is very conservative because RCIC actually operate exceed 24 hrs as per Fukushima experience).

In order for the station to response compound disaster condition, the station had already mapped out the shift personnel arrangement and three phase check list as shown in the URG attachment 05 & 06. Its relevant items including reactor pressure relief, alternative water injection, and the required power for essential systems and instrumentation control via mobile power source in phase-1 shall be independently completed by the station manpower itself within 1 hr so that the accident worsen condition can be avoid at first time and effectively controlled. Therefore, the station URG measures can be ready before the cliff-edge effect of fuel damage occur and each kind of water sources is prepared to inject water to reactor to insure that core fuel is covered with water and the cliff-edge effect of fuel damage will not occur.

6.2.2 Loss of cooling: Accident management measures currently in place after occurrence of fuel damage in the reactor pressure vessel

6.2.2.1 Mitigation measures

If there is any damage found on the core fuel, the station shall follow URG to timely restore the core water level to prevent core fuel from further damage. Meanwhile, the station shall coordinate with Severe Accident Management Guideline (SAMG) to carry out the evaluation of each kind of first aid care and proposal actions to every different condition (RC/F-1 ～ RC/F-6) so as to achieve the goal for termination of fuel degradation. Moreover, URG & SAMG cover all of the control measures including containment pressure, removal of hydrogen and residual heat so that the availability of containment integrity can be continuously maintained and the possibility of radioactive materials release is mitigated.

Furthermore, the station's overall program for ultimate response guideline includes each kind of alternative flooding measures and mobilizations of all possible manpower and material resources that can ensure that core is covered with water and possibility of fuel damage is reduced, and it can further assure the integrity of reactor pressure vessel. To the condition that RPV may be damaged, the station may plan the optimize measure in URG in connection with SAMG that set up emergency power and water sources in advance and then inject water to reactor to ensure that core fuel with melt residue is long term covered with water and fuel continuous degradation is terminated.

6.2.2.2 Risks of cliff edge effects and deadlines

The Institute of Nuclear Energy (INER) committed by TPC Safety Department assesses the risks of cliff edge effects and deadlines with MAAP5 .Under the conservative assumption, it is supposed that RCIC is failed after 8 hours & 24 hours respectively so as to result in loss of core water makeup and cooling. The calculation result is described as follows:

- RCIC keeps operation for 8 hours:

  The time of core water level drops to TAF (top of active fuel) is 1.63 hrs.

  The time RPV failed: 9.73 hrs.

- RCIC keeps operation for 24 hours:

  The time of core water level drops to TAF (top of active fuel) is 4.33 hrs.

  The time RPV failed: 15.11 hrs.

6.2.2.3 Adequacy of the existing management measures and possible additional provisions

The required DC power for RCIC operation to relieve reactor pressure and water makeup can be maintained for 24 hours after shed of partial unnecessary loads per station's procedure (If necessary, it can also be manually operated). Besides, water can be continuously injected to reactor by means of various water sources in the shortest time to ensure that core is covered with water and possibility of fuel damage is reduced in accordance with URG as described in section 6.2.1.3.

If there is any damage found on the core fuel, the station shall follow the programmed measures in URG to carry out each phase-1 flooding measures as per the phase-1check list so as to ensure that core is covered with water again and the possibility of fuel damage is reduced. Moreover, the station shall complete the phase-2 measures in the phase-2 check list including setup of the required system DC & AC power supply within 8 hours. Activation and preparation shall be completed within the check time as in each phase check list so as to further ensure the integrity of RPV.

The station containment is designed that by way of suppression pool scrubbing, fission products can be limited in the containment by the containment enclosure capability and the station shall re-setup the system function of Standby Gas Treatment System (SGTS) to mitigate the release of radioactive substances via URG power restoration measures. Furthermore, Zirconium and water reaction to produce hydrogen whenever loss of adequate cooling will be described in the following section 6.2.3.1 “The risk of hydrogen control”.

In response to the fuel damage condition, the station shall continuously carry out the URG rescue actions and initiate severe accident management (SAG) as per EOP. The On-site Accident Management Team (AMT) shall carry out each kind of the optimize rescue actions in view of each kind of accident conditions (RCF/F-1～6) in order to achieve the goal of termination of fuel degradation.

6.2.3 Accident management measures and installation design features for protecting containment integrity after occurrence of fuel damage

6.2.3.1 Management of hydrogen risks (inside and outside the containment)

Both EOP & SAG for the station are programmed with hydrogen concentration control (PC/G) measures inside containment. Besides that hydrogen igniter and hydrogen recombine shall be started to reduce containment hydrogen concentration, containment exhaust (if necessary, it is allowed to exceed radiation release rate) or containment spray shall be started to reduce containment pressure and hydrogen concentration depending on the station condition so as to secure the containment integrity.

In case that design basis accident occurred, the unit lost its off-site and on-site AC power, the station shall immediately follow URG appendix LM.1-07 " Primary Containment Exhaust Operation procedure" to open Containment Atmosphere Control System (ACS) relevant isolation valves in order for containment be connected to atmosphere so that containment hydrogen concentration can be reduced and occurrence of hydrogen explosion condition can be avoided by way of containment pressure relief and containment exhaust.

Besides, in order to avoid hydrogen accumulated in the Secondary Containment, the station shall immediately follow URG appendix LM.2-02 "Secondary Containment Exhaust operating procedure" to open 4 sets of blasting windows located on Reactor building 7F (1 set on North side, 3 sets on south side) to release hydrogen to outside of containment by natural convection in order to prevent hydrogen accumulated in the Secondary Containment to result in hydrogen explosive condition.

During the station emergency rescue process, besides the reactor water makeup as per URG to avoid hydrogen to continuously produce, the station shall corporate with containment exhaust measure to start hydrogen recombination to reduce hydrogen concentration in order to avoid hydrogen explosive condition once the required power for hydrogen control system is restored.

6.2.3.2 Prevention of containment overpressure

The station's containment is designed to have suppression function that the exhaust steam from SRV / RCIC is condensed by suppression pool to mitigate containment pressure rising condition. Besides, both EOP & SAG for the station are programmed with containment pressure control (PC/P) strategy to effectively reduce containment pressure by means of containment spray and containment vent. As per the station emergency operating procedure EOP-582, it is permitted that primary containment can vent air to atmosphere via COPS in case COPS was opened no matter radiation release rate. Containment vent can't be isolated until post-accident recovery.

The station Containment design pressure is 310kPaG; Containment Overpressure Protection System (COPS) passive destructive pressure is 620.5kPaG; containment structure destructive pressure is 1025.3kPaA so that the integrity of containment can be long term maintained.

During the station emergency rescue process, the required power for SGTS is programmed with the first priority item in URG. Once the station power is restored, SGTS shall be restarted to exhaust containment air to effectively reduce containment pressure and radioactive substance release and further secure the integrity of containment.

6.2.3.3 Prevention of re-criticality

The station EOP first priority action is to confirm if reactor was already scrammed (RC/Q). Once reactor is at critical, the station shall follow procedure 590.13 to insert the alternative control rod and depending on the condition that power oscillation or Suppression Pool exceeding boron injection initiative temperature, Boric acid shall be injected into reactor via Standby Liquid Control (SLC) or via alternative boron injection measure (proc. 590.14) to maintain the reactor at sub-critical condition. In case that SAG condition entered, Boric acid in SLC tank shall be absolutely immediately injected to reactor.

In case that design basis accident occurred, the unit lost its off-site and on-site AC power that resulted in the above -mentioned boron injection failure, Boric liquid will be extracted by fire engine and then inject to reactor core via Residual Heat Removal System to prevent reactor re-critical.

The procurement of standby boric acid, borax for the station is according to the required quantity comparing with the required born concentration for containment water injection to TAF and for RPV safe shutdown and consideration of station's storage capacity. The quantities procured for standby boric acid, borax are 72 tons each.

6.2.3.4 Prevention of base mat melt through: retention of the corium in the pressure vessel

The station's major response measures for mitigation of core molten residue falling down to core cavity are AC- Independent Water Addition (ACIWA), and Lower Drywell Flooder (LDF) to utilize flooding water to cover molten liquid to mitigate the reaction between molten residue and concrete to prevent containment base mat melt through condition. It is described as follows:

1. ACIWA: In case that all on-site and off-site power is lost, the station shall start diesel-driven fire pump or utilize fire water reservoir truck to carry water and carry out lower drywell flooding via ACIWA piping and spray spargers in containment. If diesel-driven fire pump failed to start, water of 4.8 metric ton raw water reservoir, located at 116 M above sea level, would flow through the check valve by gravity to flood drywell via ACIWA piping and spray spargers in containment.
2. Lower Drywell Flooding (LDF) System: Lower Drywell Flooding System, a passive system, is used as an alternative flooding system whenever ACIWA failed. After RPV bottom head is molten through, the molten core will drop down upon the drywell basemat, Suppression Pool water would flood into Lower Drywell to form a pool of 1.55 M depth when its high temperature fusible plug acts. As per BWROG EPG / SAG Rev. 2 Appendix B 17.18, drywell liner would avoid to be molten through, the reaction between molten core and concrete would be limited, and the temperature of core debris bed would be effectively reduced when water floods1.22M above drywell bottom. There is no active equipment or instrumentation in this system and it can also operate its intended function under high radiation condition.

6.2.3.5 Need for and supply of electrical AC and DC power and compressed air to equipment used for protecting containment integrity

The primary containment protections during EOP/SAG are containment spray and containment vent . The containment vent mode is by ways of COPS which includes two sets of normal open pneumatic control valves, rupture disks and vent piping connected to Secondary Containment. Those pneumatic control valves would keep open when loss of its pneumatic power happens. Therefore, it would function without power and Primary Containment overpressure can be avoided. Moreover, Containment Spray which is designed with safety related ESF power is one of the RHR designed functions.

In case that Beyond Design Basis Accident occurred and lost all of its related powers, the station shall follow the measures in URG attachments LM.2-04~07& LM.2-11~14 to setup the normal and alternative power including startup of the Seventh D/G, GTGs, or mobile diesel generators etc as described in this chapter 5 in order to restore the availability of each kind of rescue facilities.

6.2.3.6 Risks of cliff edge effects and deadlines

The Institute of Nuclear Energy (INER) committed by TPC Nuclear Safety Department assesses the risks of cliff edge effects and deadlines with MAAP5 .Under the conservative assumption, it is assumed that RCIC is failed after 8 hours & 24 hours respectively so as to result in loss of core water makeup and cooling. The calculation result is described as follows (calculated from the time of RCIC inoperable):

- RCIC keeps operation for 8 hours:

  The time of containment overpressure (in case of no reactor pressure relief and no containment venting): 9.73 Hrs.

- RCIC keeps operation for 24 hours:

  The time of containment overpressure (in case of no reactor pressure relief and no containment venting): 3.57 Hrs.

Besides that the station shall follow the existing EOP/SAG to consider how to manage the overall accident response strategies in symptom base, the station shall simultaneously follow the advanced programming measures in URG for response to compound disaster accident to complete all mobilizations and preparations of each phase checks as described in the check list within time limits, including the phase-2 measures to setup of the required system DC & AC power supply within 8 hours so that the integrity of containment can be ensured before the cliff-edge effect occurs.

6.2.4 Accident management measures currently in place to mitigate the consequences of loss of containment integrity

In response to the compound disaster condition similar to Fukushima accident and in consideration to avoid large scale of populace evacuated, the station had already developed the Ultimate Response Guidelines (URG). When judging that the injection and cooling function can't be restored to the designed base function in a short time, the station shall take decisive actions to prepare to give up the reactor that all available water sources are arranged in a short time to immediately inject water into reactor to insure that fuel was covered with water to prevent from radioactive substances release.

Based on this chapter above-mentioned descriptions of each strategy, URG can insure that core fuel is covered with water and the integrity of fuel clad is secured as well as the fission product release is limited when compound disaster accident happens. In case that containment integrity is failed, large amount of radioactive substance release may not occur because the integrity of fuel clad can be secured and large scale of populace evacuation can be avoided. Moreover, the URG programmed time, manpower, and relevant response measures in each phase check list can be effectively performed to secure its containment control and the integrity of containment.

For loss of containment integrity condition, the station shall take each kind of rescue action as per URG that the station existing EOP / SAG procedures had already specified the corresponding response measures to primary containment and secondary containment radiation intensity. (Please refer to section 6.1.1.5 "The management of radiation release and the preparation of radiation limitation)

TPC already programmed the response measures for each kind of nuclear accidents including radioactive substances release condition as per the related codes and standards as well as 「Emergency Response Program for nuclear reactor facilities」 that its response scope includes the overall emergency accident such as the conditions of core meltdown and containment failure etc. Its relevant programs are described as follows:

6.2.4.1 Design, operation and organization provisions

1. The Emergency Response Organization planned:

   (1) A. Taiwan Power Company have already set up the nuclear accident emergency response measures, emergency response organizations, and implementing procedures in the Head Office and each nuclear power plant. Emergency Control Team of each nuclear power plant is the core unit of emergency response organizations. Taiwan Power Company Nuclear Emergency Planning Executive Committee is the direct support organization and Nuclear Accident Central Disaster Response Center is the off-site support organization. The station relevant response personnel training and the drill for Emergency Preparedness Plan of nuclear facilities will be performed 3 months before the first fuel loading as per station procedure.

   (2) Common items of drill:

Common items of drill include TSC technical support operations, unit operation and accident management. Items of yearly drill are first aid care & decontamination operation, building & site area radiation detection operation, environmental radiation detection operation, fire-fighting operation, OSC damage control operation, emergency re-entry urgent repair operation, population information consultant operation, site area collection & on-call operation, and site area security operation.

(3) Nuclear safety drill including above-mentioned items is performed every 4 year.

(4) Ordinary and on-site drill can request support according to agreement items on the above-mentioned agreement content.

2. Agreements / contracts for assistance of accident management:

(1) The station current support agreement:

a. The related fire-fighting and disaster relief:

The station already signed an agreement of mutual support with New Taipei City Fire Bureau the Sixth Brigade. Both parties can support each other to perform fire-fighting and the disaster relief as per the station procedure 1420 if fire accident happens. The station shall request supports including the support items if the station itself has not sufficient capability to rescue the accident when the station suffered from fire, wind, flooding, earthquake, and explosion or the station performs yearly fire-fighting drill or yearly emergency response drill. The support scopes include the scope under the jurisdiction of property areas including radiation control area (the personnel who needs to enter radiation control area shall not enter until advanced training of radiation protection and radiation monitor)

b. The support agreement for protection of endangered event or destruction event as well as army and police manpower support for natural disasters as per the station's procedure 1421:

—The 13rd Brigade of Coast Patrol Bureau, Defense Patrol Department, Executive Yuan.

—The Riding Squadron of National Army Guan-Du Command Department

—The Rui-Fang Branch Police Bureau of New Taipei Police Bureau.

(2) The following support contracts are signed by TPC Head Office:

a. An agreement for "Radiation Injury Prevention and Control "with National Defense Medical Center of Tri-Service General Hospital,

b. The support contracts with GE, WH, Bechtel , and Ebasco were included in TPC Emergency Planning Executive Committee[Overseas Support Operation procedures].

(3) The domestic technical support teams often contact or co-operate with TPC:

a. The Institute of Nuclear Energy Research: Responsible for serious accident analysis and assessment, calculation of area range for Emergency Preparedness and Response Plan .

b. Tsing-Hua University nuclear Engineering: Responsible for nuclear safety analysis.

c. Chiao-Tung University traffic and transportation engineering research institute: Responsible for the plan of evacuate path and its pattern analysis.

6.2.4.2 Risks of cliff edge effects and deadlines

If accident is worsened to the extent of fuel damage and the integrity of containment is also simultaneously lost, radioactive substances may be released to off-site, and the populace nearby the station shall be evacuated. Because the populace evacuation command is according to the evaluation result of the populace possible dose rate, the populace evacuation command will be instructed by the Central Accident Response Center .Therefore, the failure time of containment integrity is used for the cliff-edge time based on conservative assumption

As mentioned above, the Institute of Nuclear Energy (INER) committed by TPC Nuclear Safety Department assesses the risks of cliff edge effects and deadlines with MAAP5 .Under the conservative assumption, it is assumed that RCIC is failed after 8 hours & 24 hours respectively so as to result in loss of core water makeup and cooling. The calculation result is described as follows(calculated from the time of RCIC inoperable):

- RCIC keeps operation for 8 hours:

  The time of RPV overpressure (in case of no reactor pressure relief and no containment exhaust gas): 9.73 hrs.

- RCIC keeps operation for 24 hours:

  The time of RPV overpressure (in case of no reactor pressure relief and no containment exhaust gas): -3.57 hrs.

6.2.4.3 Adequacy of the existing management measures and possible additional provisions

If it is anticipated that the station existing design safety systems can't function normally in response to the compound disaster accident and in consideration to avoid large scale of populace evacuation, the station had already developed the Ultimate Response Guidelines (URG) that the station shall take decisive actions to immediately inject water into reactor to insure the integrity of nuclear fuel.

In response to the "Overall Emergency Accident" condition similar to Fukushima accident and if its endanger scope is already increased to endanger the populace safety, the activation level of emergency plan will be upgraded to be led by the government level that organization grouping set up by the Government each department as mentioned in above-mentioned "ROC Nuclear Accident Emergency Response Organization" including the support manpower from army and police to secure the safety of the populace life and assets through the response program for the advanced planning populace protection, security, and medical care etc.

6.3 Spent Fuel Pool

6.3.1 Measures for managing the consequences of a loss of cooling function for the pool water

The Spent Fuel Pool for the station consists of the Spent Fuel Pool located on the Reactor Building refueling floor (Elevation 31.7M) and Auxiliary Fuel Pool of both units common use located on the Auxiliary Fuel Building (AFB) ground floor (Elevation 12.3M). Auxiliary Fuel Pool which is designed to store spent fuels after 10 years of unit commercial operation shall not be described in this chapter because there is no risk of loss of spent fuel cooling during the station initial operation period of time.

The residual heat removal and water makeup of the Spent Fuel Pool during normal operation is by ways of Fuel Pool Cleanup System (FPCU) and it can also use Residual Heat Removal System as alternative fuel pool cooling system. The Spent Fuel Pool is designed to makeup water from Suppression Pool Cleanup System (SPCU) and Condensate Transfer System (CSTF) and to makeup water by ways of RHR system or fire water system in case of emergency. The detailed design of its related power supply is described in the section 2 of chapter 5.

In order for the response to each kind of corresponding compound disaster conditions, the station had already programmed the spent fuel pool emergency water makeup processes and programmed its cooling or water makeup methods according to different conditions in the station procedure 510.05 "Loss of Spent Fuel Pool Cooling and Cleanup" and procedure 1451"Ultimate Response Guideline".

The major response measure for the spent fuel pool is to set up its water makeup measure to avoid loss of pool water. If fuel pool only loses its cooling function and there is no obvious water level drop, it shall have sufficient time to take the relevant rescue action strategies and arrangements as per the analysis results of Calculated Fluid Dynamics(CFD), the station shall carry out the relevant measures as per procedure 515.05 "Loss of spent fuel pool cooling and cleanup" and there is no need to take URG.

The spent fuel pool cooling and water makeup in accordance with different conditions is described as follows:

If it is found that Fuel Pool water level is dropped after accident, the station shall carry out Spent Fuel Pool emergency water makeup / spray measures depending on the station status that the arrangement of the phase-1 strategies shall be completed within 2 hours and those of the phase-2 strategies shall be completed within 8 hours.

The phase-1 Spent Fuel Pool emergency water makeup / spray measures in URG:

- LM.SFP.1-01 RB Spent Fuel Pool water makeup by ways of outdoor fire hydrant
- LM.SFP.1-02 RB Spent Fuel Pool water makeup by ways of fire water reservoir truck operation guideline.
- LM.SFP.1-03 RB Spent Fuel Pool water makeup by ways of engine-driven fire water pump operation guideline.
- LM.SFP.1-04 RB 7F Spent Fuel Pool water makeup by ways of indoor fire hydrant operation guideline.

The phase-2 spent fuel pool emergency water makeup / spray measures in URG:

- LM.SFP.2-01 RB Spent Fuel Pool water makeup by ways of FPCU and CSTF pumps operation guideline.

6.3.1.1 Before and after losing adequate shielding against radiation

1. Before loss of adequate shielding against radiation:

   Judging from the condition of power supply and water supply available or not, the station shall follow above-mentioned measures as described in URG appendix LM.SFP.1-04 & LM.SFP.2-01 to carry out the spent fuel pool cooling or water makeup.

2. After loss of adequate shielding against radiation:

   In case that personnel can't access the spent fuel pool after loss of adequate shielding against radiation, the station shall follow above-mentioned operation processes as described in URG appendix LM.SFP.1-01～03 to carry out the spent fuel pool water makeup or spray by ways of its dedicated water makeup or spray piping.

6.3.1.2 Before and after the water level of the spent fuel pool drop to the top of fuel

1. Before the water level of the spent fuel pool drop to the top of fuel assemblies:

   (1) If the change of radiation condition is not too much and the personnel can still access the fuel pool, the management measure is same as 6.3.1.1 item 1"Before loss of adequate shielding against radiation".

   (2) If the radiation dose is too high and the personnel can't access the fuel pool, the management measure is same as 6.3.1.1 item 2 "After loss of adequate shielding against radiation".

2. After the water level of the spent fuel pool drop to the top of fuel assemblies:

   If the radiation dose is too high and the personnel can't access the fuel pool, the management measure is same as 6.3.1.1 item 2 "After loss of adequate shielding against radiation".

6.3.1.3 Before and after severe damage of the fuel in the spent fuel pool

1. Before severe damage of the fuel in the spent fuel pool:

(1) If the change of radiation condition is not too much and the personnel can still access the fuel pool, the management measure is same as 6.3.1.1 item 1"Before loss of adequate shielding against radiation".

(2) If the radiation dose is too high and the personnel can't access the fuel pool, the management measure is same as 6.3.1.1 item 2 "After loss of adequate shielding against radiation".

2. After severe damage of the fuel in the spent fuel pool:

   If the radiation dose rate is too high and the personnel can't access the fuel pool, the management measure is same as 6.3.1.1 item 2 "After loss of adequate shielding against radiation".

6.3.1.4 Risks of cliff edge effects and deadlines

1. The decay heat of the spent fuel decreases as the unit shutdown time increases. During the specific fuel cycle, the decay heat of the spent fuel is the maximum at the moment after completion of core fuel transfer that all spent fuels are pulled out to be stored in the spent fuel pool. The station has no spent fuels yet. The decay heat of the spent fuel is calculated based on that there are of spent fuels discharged from last 9 cycles with the addition of all core fuels discharged after 7 days of unit shutdown. The total decay heat at this moment is 12.88MW and the temperature of fuel pool water is 49 ℃.Each cliff-edge time under the conditions of loss of spent fuel pool cooling and water makeup is evaluated as follows:
   - The temperature rising time till boiling: 9.5 hrs
   - Time of water level drop to the level (8 feet above top of active fuel) which cannot maintain adequate shielding against radiation: 52 hrs
   - Time of water level drop to the top of active fuel elements: 91 hrs
   - Time of beginning of the fuel degradation (1200℃): 98.37hrs [note]

Note: The spent fuel pool is arranged in a tight sequence.

2. Effectiveness of the existing management measures

   Based on the above-mentioned analysis under the most severe condition (all spent fuels are discharged in the spent fuel pool at the seventh days of outage after unit shutdown) , fuels will not start to degrade till 98.37 hrs (about 4 days) after loss of spent fuel pool cooling and water makeup.

   Therefore, the station has enough time to cope with the restoration of power supply or to prepare the alternative power supply in order to provide for the required power supply or alternative power supply for restoring spent fuel pool cooling or water makeup capability. In case loss of adequate radiation shielding or high temperature at site, the station can also carry out spent fuel pool water makeup or spray by ways of its dedicated water makeup or spray piping from each kind of alternative water sources (fire water, CST water sources etc) outside building so as to effectively avoid the cliff-edge effect of fuel damage.

6.4 Implemented safety improvement and further work enhancing robustness

6.4.1 Adequacy and availability of the instrumentation control

The major safety related instrumentation for the station is designed as seismic category 1 design. However, major instrumentation may lose its monitor and control functions due to loss of power as occurred in Fukushima compound disaster accident. The DC powers including Uninterruptible Power Systems (UPS) for instrumentation and controls are designed to cope with 24 hours power supply capability at the initial stage of station blackout condition. Various power restoration and extension programs have been programmed in the station URG, please refer to this chapter 5 "Loss of power and ultimate heat sink" for detailed descriptions . There will be enough time to restore the power supply for I&C system.

Besides the effort for power supply, the SPDS personnel of Severe Accident Management Team

(AMT) will evaluate instrument reading from similar instruments and compare each other per parameter assessment table (PAT) for the effectiveness of the measured data in case of high building temperature or flooding (or strategic flooding) . The evaluation result will be submitted to AMT Leader and Station Emergency Control Team Brigades for them to grasp the status of the plant and to ensure the accident under control.

For the enhancement of the Spent Fuel Pool monitor and control capability, the type of water level instrument G41-LT-0012A/B shall be changed to improve its monitor range to at least the height of TAF and its power is fed from essential Ac power (R13) as well as its temperature indicator G41-TE-0013 shall be changed to improve its depth of measuring point and monitoring range to at least the height of TAF.

6.4.2 Availability and Habitability of Control Room

Main Control Room of each unit is seismic category 1 design. Besides that it shall be maintained operable during earthquake, tsunami, and other compound disaster accident, there are two trains of independent and redundant (Division B & C) Ventilation Systems to maintain Control Room in positive pressure and air intake and filtration capability that it meets the habitability requirements in NRC NUREG- 0696 Functional Criteria for Emergency Response Facility. Therefore, if there is off-site radiation release condition (including Fuel building) in each kind of accident condition, Main Control Room Habitability can be maintained.

If the beyond design basis accident (DBA) happens and it is anticipated that unit will lose on-site and off-site AC power, the station shall follow URG appendix LM.2-12 “4.16kV mobile diesel generator backup on-site power supply operation guideline” to restore the Control Room Ventilation System to normally operate at first priority in order to maintain Control Room long-term habitability. Meanwhile, power coping program can assure that all related lighting and instrumentation control capability in Control Room can be long term maintained.

When Control Room has the possibility of being contaminated, the station has already prepared the enhancement programs of Control Room habitability and personnel entrance control measures as follows:

A. The detection of radiation, contamination and radioactive air concentration in control room shall be carried out periodically.

B. The radiation protection countermeasures according to Control Room radiation condition shall be programmed:

a. It is assessed that the feasibility for installation of the radiation barrier in order to reduce on-site radiation dose rate and further reduce acceptance radiation dose rate of shift personnel.

b. It is provided that the required radiation protection equipment such as radiation protection cloth, absorber protection mask, lead cloth, and etc and personnel shall be guided how to wear radiation protection equipment if necessary.

c. It is assessed that the longest work hours of shift personnel and dose measurement and control shall be carried out if necessary.

C. The personnel contamination door-frame monitor is planned to install in the proper place in order to assure that shift personnel will not be contaminated while leave.

6.4.3 Hydrogen gas possibly accumulated in the buildings other than containment building

In case that beyond design basis accident occurs and it is anticipated that the loss of off-site and on-site AC power is inevitable, in order to avoid hydrogen explosion due to hydrogen accumulated in containment and it resulted in failure of containment enclosure capability, the station shall immediately follow URG appendix LM.1-07 “Primary Containment Exhaust operation guideline” to open Containment Atmosphere Control System to connect it through atmosphere no matter radiation release rate so as to reduce hydrogen concentration inside containment to avoid hydrogen explosion.

Besides, in order to prevent hydrogen accumulated in the Secondary Containment due to Primary Containment leakage, the station shall follow URG appendix LM.2-02 “Secondary Containment

Exhaust operation guideline" to open the blast windows located in Reactor Building 7F (1 on north side and 3 on south side) to release hydrogen outside by natural flow to prevent hydrogen accumulated in the Secondary Containment such that resulted in hydrogen explosion.

If the auxiliary spent fuel pool cooling system is inoperable due to power loss and the above-mentioned URG water makeup measures are also all failed because of the compound disaster situation, the decay heat of spent fuel can't be removed and fuels are uncovered with water and damaged and then hydrogen gas gradually produced, the station shall manually open the traffic access door located in the upper of Spent Fuel Pool to remove hydrogen gas. Because the station Auxiliary Fuel Building is independent with the other buildings and its HVAC system is also separated from that in the other buildings, the produced hydrogen gas will not spread out to the other buildings.

Once normal power or alternative power is setup, the station shall set up power supply for spent fuel pool emergency water makeup pump to makeup water to spent fuel pool in order to avoid or reduce hydrogen generation.

Reference

1. The Government documents

   N/A

2. Industrial organization documents

   N/A

3. TPC documents:

   (1) TPC Lungmen NPP Safety protection Physic Examination

   (2) LMNPP Procedure 1451 [Ultimate Response Guideline]

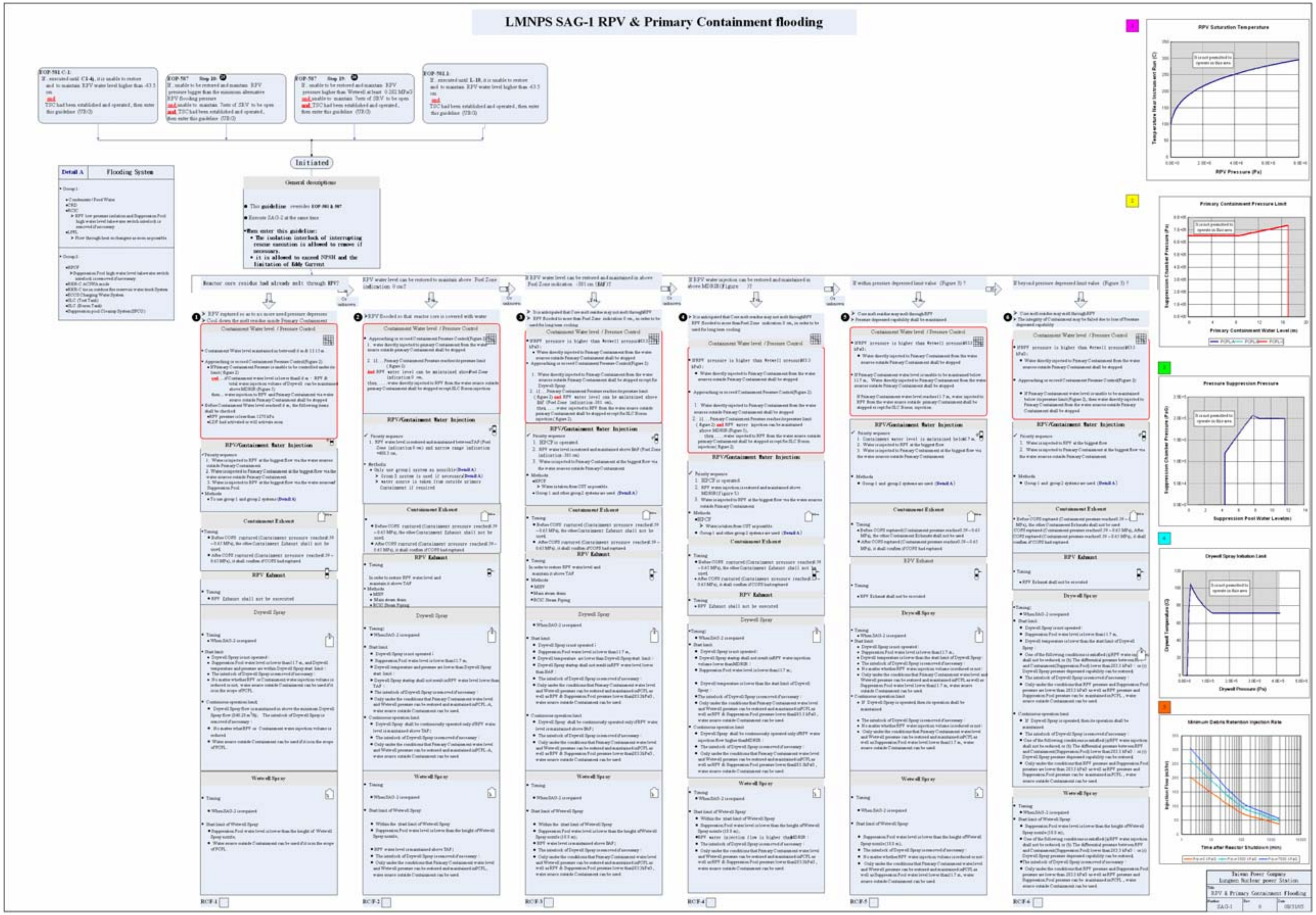


Figure 6-1

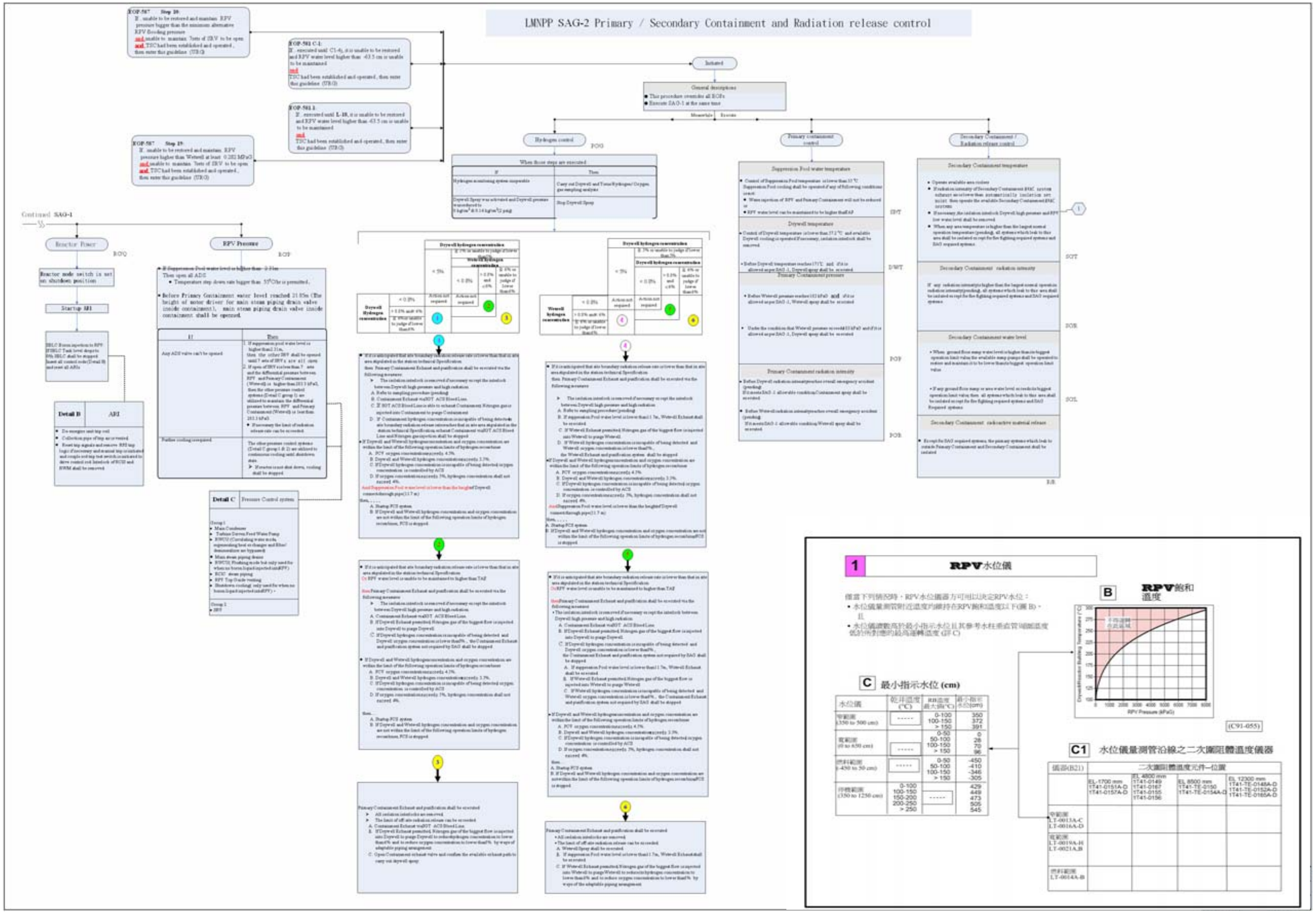

LMNPP SAG-2 Primary / Secondary Containment and Radiation release control

Figure 6-2

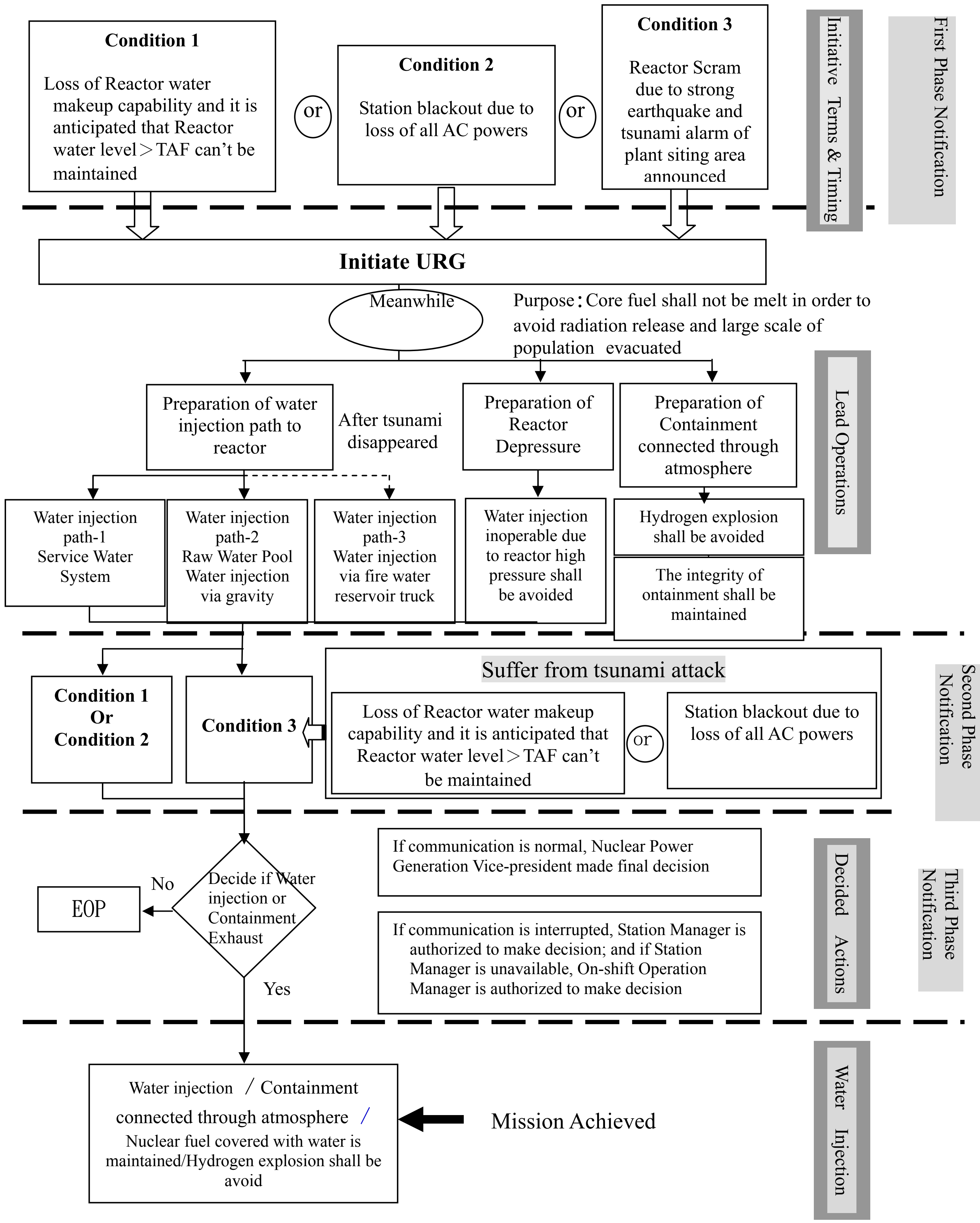


Figure 6-3 The Ultimate Response executive condition process and announce & report timing flow-chart for LMNPP

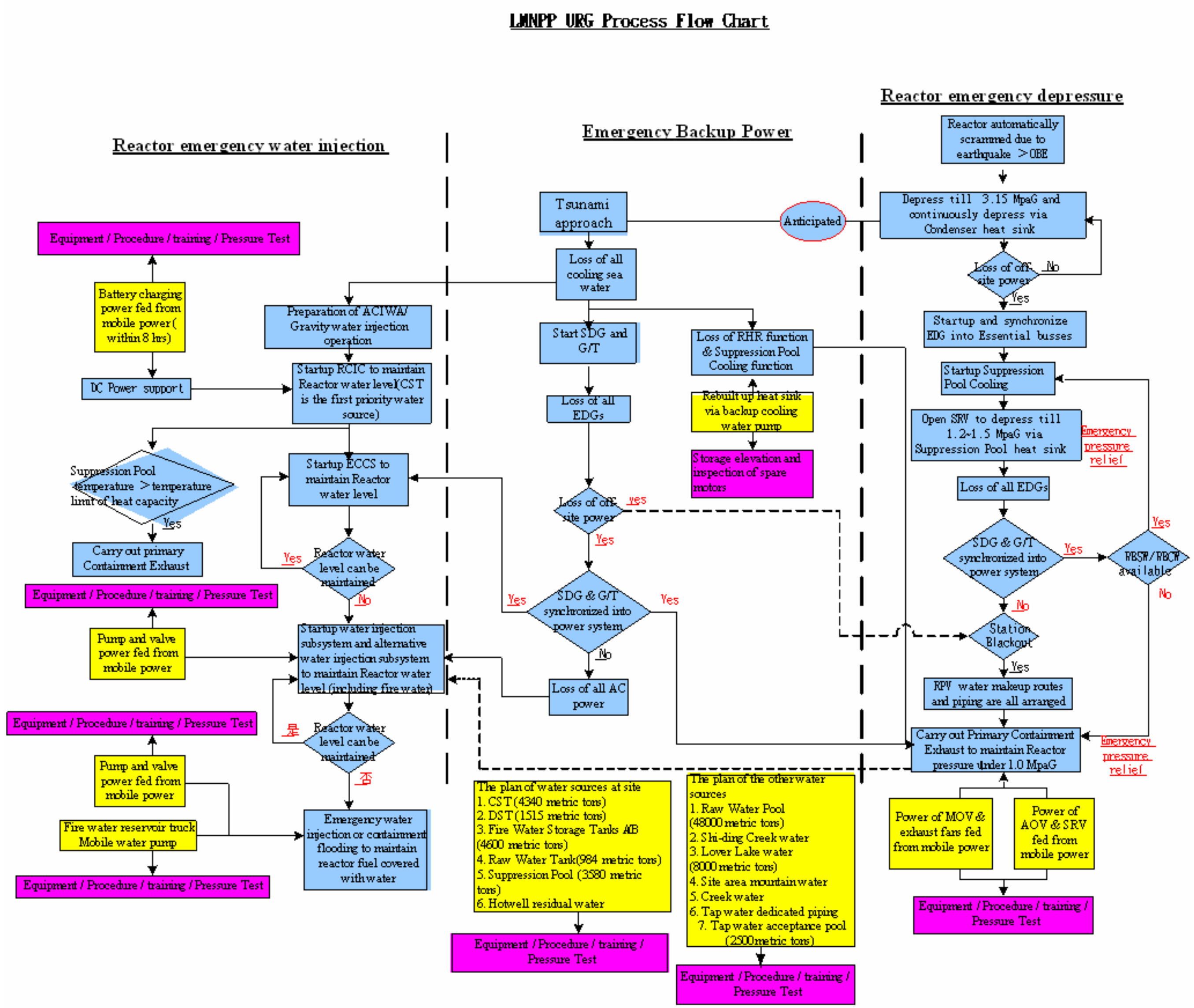


Figure 6-4 he Ultimate Response Process Flow-Chart for LMNPP

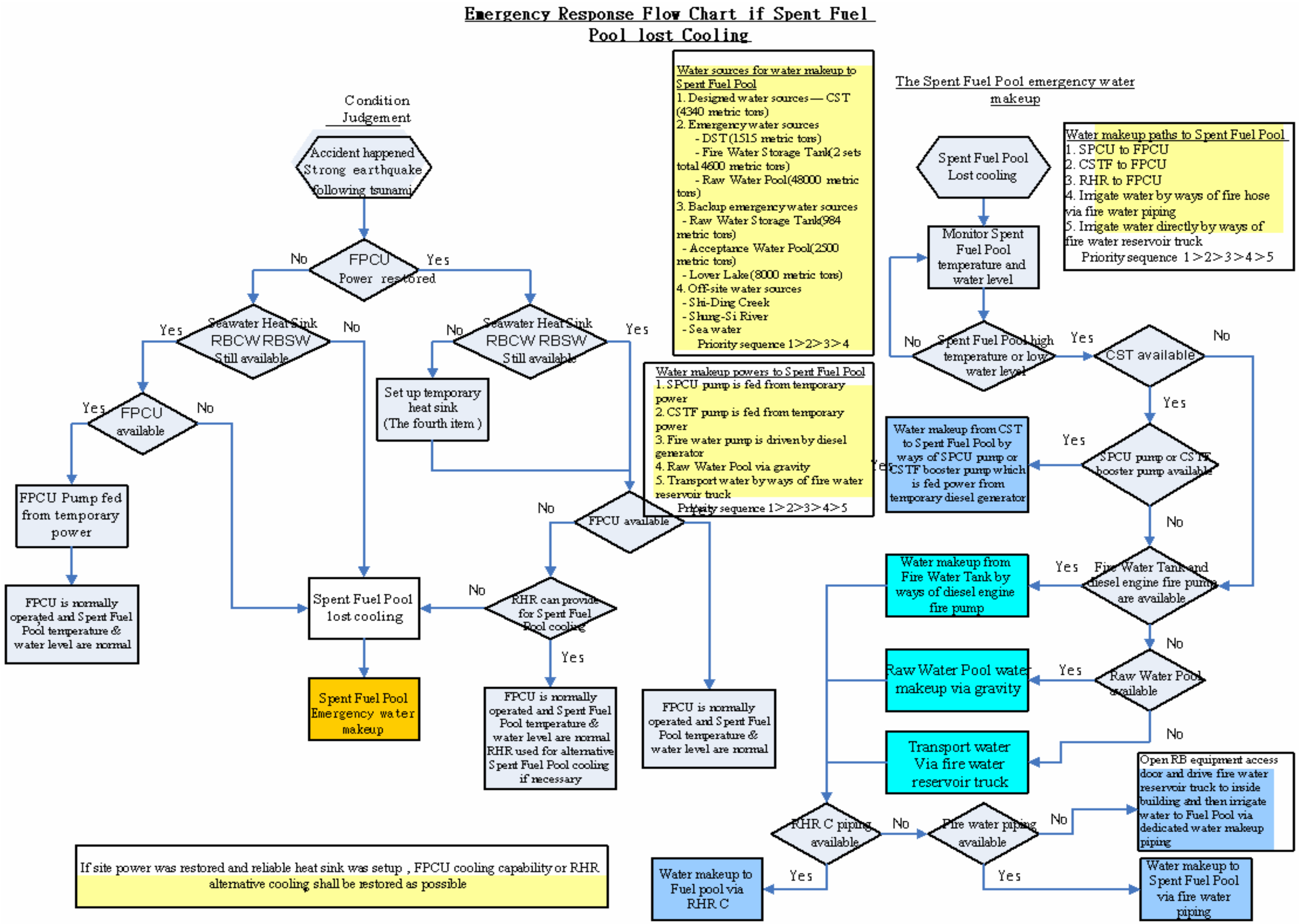


Figure 6-5 A LMNPP Ultimate Response Process Flow Chart for Spent Fuel Pool (Reactor Building)

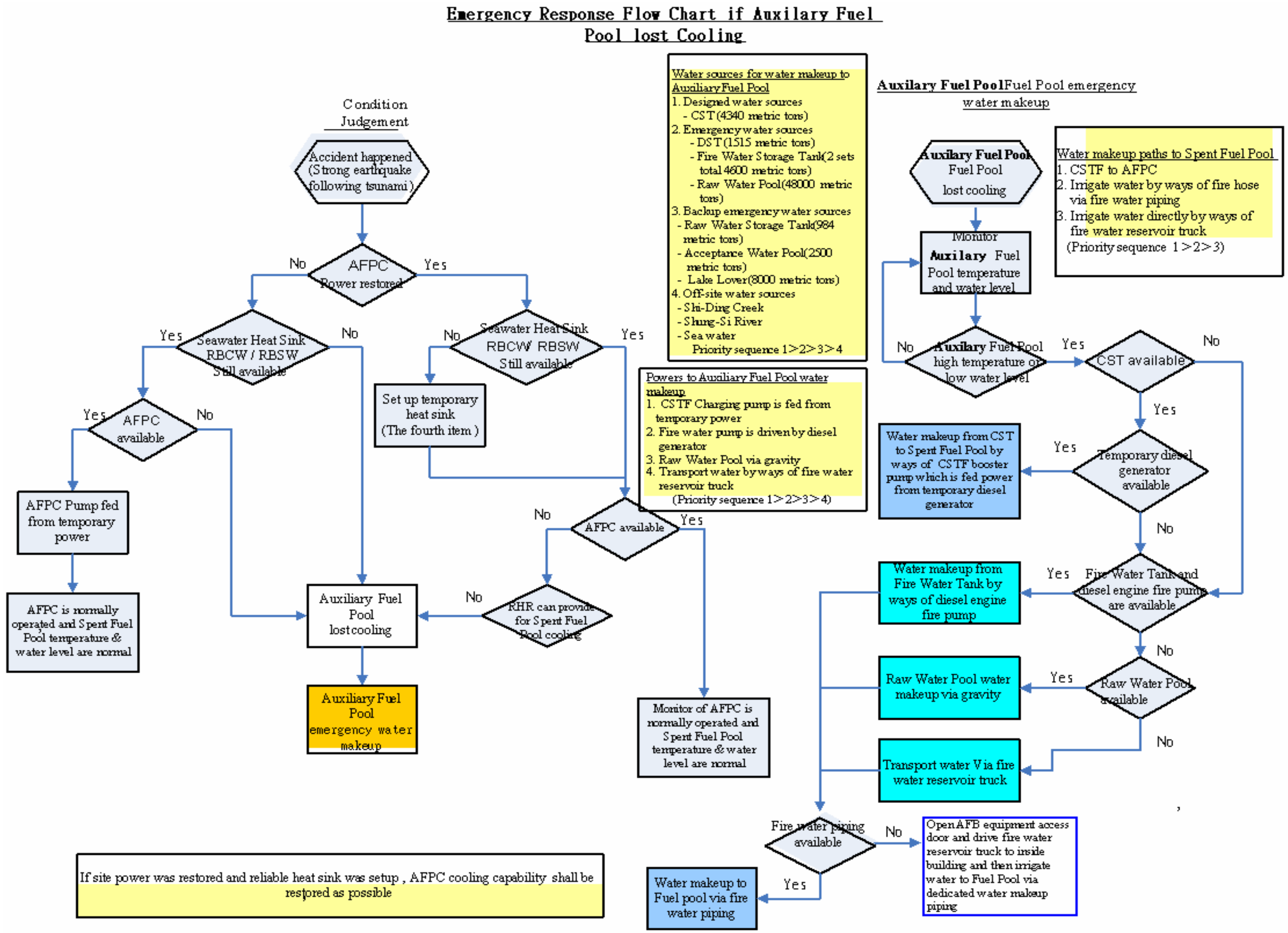


Figure 6-5 B LMNPP. Ultimate Response Process Flow Chart for Auxiliary Fuel Pool (Auxiliary Fuel Building)

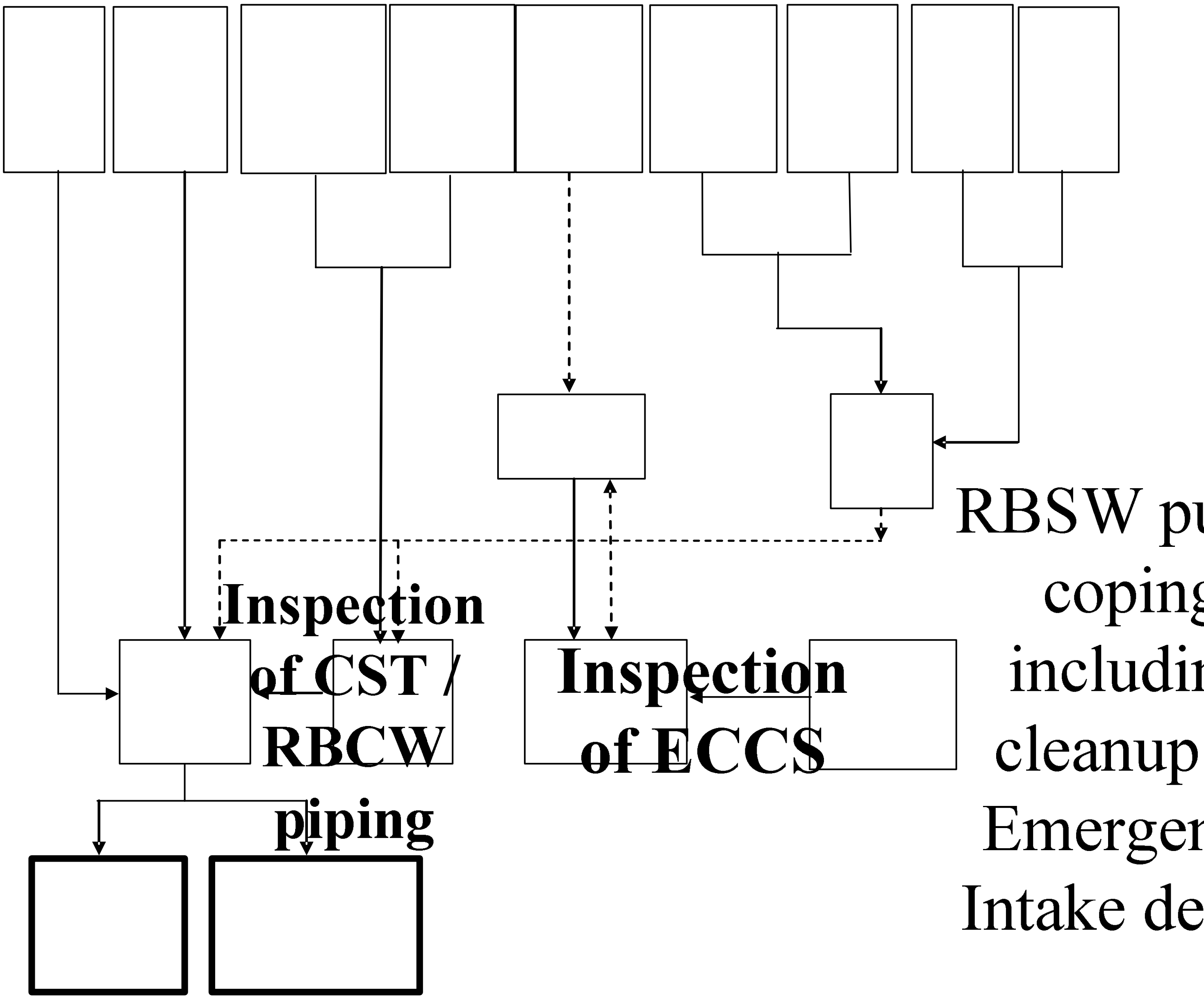


Figure 6-6 Restoration of Long Term Cooling Capability Flow Chart for LMNPP

Appendix 6-1: Phase-1 Facilities and manpower Arrangement List for LMNPP URG

Operation Items	First priority person-in charge	Second priority person-in charge	Remarks
1.HPCF Water makeup to Reactor via Gravity Operation Guideline	Mechanical Leader On-shift Reactor Operator	Waste Control Leader Waste Control On-shift Personnel	
2.RCIC Water makeup to Reactor via Gravity Operation Guideline	Mechanical/ Electrical Assistant Electrical On-shift Personnel	Mechanical Leader HP Station On-shift Personnel	
3. Fire Water makeup to Reactor Operation guideline	Mechanical/ Electrical Assistant Electrical On-shift Personnel	Mechanical Leader HP Station On-shift Personnel	
4.Reactor Depressurization Operation Guideline	On-shift Unit Director On-shift Reactor Operator	On-shift Reactor Operator (RO) Turbine On-shift Personnel	
5.Manual operate RCIC to makeup water to reactor under loss of power	Mechanical/ Electrical Assistant Turbine On-shift Personnel	Mechanical leader On-shift Reactor Operator	
6.Primary containment exhaust Operation Guideline	Electrical On-shift Director On-shift Assistant Reactor Operator (ARO)	On-shift Unit Director Electrical On-shift Personnel	
7. SRV operation guideline during loss of normal DC power Operation Guideline	Mechanical/ Electrical Assistant Electrical On-shift Personnel	Electrical On-shift Director Turbine On-shift Personnel	
8.SDG simultaneously feeds power to both units Operation Guideline	Electrical On-shift Director On-shift Assistant Reactor Operator (ARO)	On-shift Unit Director Electrical On-shift Personnel	
9. Fire Water Emergency Makeup to RB Spent Fuel Pool Operation Guideline	Fire station personnel -1 Water Plant On-shift Personnel	Fire station personnel -2 Boiler On-shift personnel	
10.Fire Water Emergency Makeup to Auxiliary Fuel Pool Operation Guideline	Fire station personnel -1	Fire station personnel -2 Boiler On-shift personnel	

Appendix 6-2: Three Phase Check List for LMNPP URG Strategies

Phase	Strategy	Timing Limit
Phase-1	LM.1-01 HPCF Water Makeup to Reactor via Gravity operation Guideline	Within 1 hr
	LM.1-02 RCIC Water Makeup to Reactor via Gravity Operation Guideline	
	LM.1-03 Fire Water Makeup to Reactor Operation Guideline	
	LM.1-04 Water Makeup to Reactor via Fire Water Reservoir Truck Operation Guideline	
	LM.1-05 Manual Operation of RCIC to inject water to reactor under loss of normal DC power Operation Guideline	
	LM.1-06 Reactor Depressurization (Decay Heat Removal) Operation Guideline	
	LM.1-07 Primary Containment Exhaust Operation Guideline	
	LM.SFP.1-01 RB Spent Fuel Pool Water Makeup via Outdoor Fire Hydrant Operation Guideline	Within 2 hrs
	LM.SFP.1-02 RB Spent Fuel Pool Water Makeup via Fire Water Reservoir truck Operation Guideline	
	LM.SFP.1-03 RB Spent Fuel Pool Water Makeup via Engine-driven Fire Water Pump Operation Guideline	
	LM.SFP.1-04 RB 7F Spent Fuel Pool Water Makeup via Indoor Fire Hydrant Operation Guideline	
Phase-2	LM.2-01 SRV Operation Guideline during loss of normal DC power	Within 8 hrs
	LM.2-02 Secondary Containment Exhaust Operation Guideline	
	LM.2-03 Auxiliary Fuel Building Exhaust Operation Guideline	
	LM.2-04 SDG simultaneously provides power for both units in case of emergency Operation Guideline	
	LM.2-05 #1 EDG& #2 EDG mutual support Operation Guideline	
	LM.2-06 480VAC mobile diesel generator feeds power to plant equipment Operation Guideline	
	LM.2-07 On-site backup power from Security System EDG Operation Guideline	
	LM.2-08 Mobile Air Compressor supplies air to Reactor Building AOV Operation Guideline	
	LM.2-09 Nitrogen Supply System check valve dismantle Operation Guideline	
	LM.2-10 Water intake from Lungmen Lover Lake/ Shi-Ding Creek / Shung Creek etc backup water sources Operation Guideline	
	LM.2-11 4160V/1100kW Gas Turbine Diesel Generator Lead Connection Operation Guideline	

Phase	Strategy	Timing Limit
	LM.2-12 On-site backup power from 4.16 kV Mobile Diesel Generator Operation Guideline LM.2-13 120VAC/125VDC rectifier Operation Guideline LM.2-14 Mobile Diesel Generator feeds power to SLC Motor Water Injection to RPV Operation Guideline LM.2-15 CST Water Makeup via Fire Water Reservoir Truck Operation Guideline LM.2-16 Control Room Monitoring Reactor and Containment Parameter Recovery Operation Guideline LM.2-18 Extract water from Discharge Well Operation Guideline LM.2-19 Hydrogen Detection Operation Guideline LM.2-20 Water makeup to Reactor via mobile fire water pump Operation Guideline LM.SFP.2-01 FPCU 及 CSTF Pump Water Makeup to RB Spent Fuel Pool Operation Guideline LM.SFP.2-02 AFB Spent Fuel Pool Water Makeup via Outdoor Fire Hydrant Operation Guideline LM.SFP.2-03 AFB Spent Fuel Pool Water Makeup via Fire water Reservoir Truck Operation Guideline LM.SFP.2-04 AFB Spent Fuel Pool Water Makeup via Engine-driven Fire Water Pump Operation Guideline LM.SFP.2-05 AFB Spent Fuel Pool Water Makeup via Indoor Fire Hydrant Operation Guideline	
Phase-3	LM.3-01 Extract Sea Water from Discharge seal pit / Discharge Well for RBCW Heat Exchanger Operation Guideline LM.3-02 Emergency pump House trash cleanup and transport Operation Guideline LM.3-03 Reactor Building Cooling Sea Water (RBSW) Pump Replacement Operation Guideline LM.3-04 Reactor Long Term Cooling and Recovery Operation Guideline	Within 36 hrs