23 April 2013

Dr. Chuen-Horng Tsai, Chairman
Atomic Energy Council
8F. No. 80, Section 1, Chenggong Road
Yonghe District
New Taipei City 23452
Taiwan (R.O.C.)

SUBJECT: INDEPENDENT PEER REVIEW OF THE STRESS TESTS PERFORMED ON THE OPERATING REACTORS IN CHINESE TAIPEI

Dear Chairman Tsai,

The Independent Peer Review Team has completed its review of the National Report and the Stress Test Reports prepared in light of the accident at the Fukushima Daiichi Nuclear Power Station for the operating reactors at Chinshan, Kuosheng, and Maanshan Nuclear Power Plants (NPPs) as required by the Atomic Energy Council (AEC). The report attached provides the results of the team's review.

The team met with you and other representatives of the AEC, as well as representatives of TaiPower Company (TPC), between 4 and 15 March 2013. The preliminary findings were discussed with representatives from AEC and TPC at a meeting on 15 March 2013, and the preliminary findings were presented to the public in a press conference on the same day.

As was discussed, the findings were preliminary pending the finalization of the report by the team. Based on the finalization of the report, it was determined that a technical observation was not specifically discussed at the final meeting with AEC and TPC, or with the public, on 15 March 2013. This technical observation is in the seismic area and is discussed in Section 2.3.4 of the attached report. This technical observation relates to the as-built seismic capability of the alternate ultimate heat sink. While this observation was not specifically mentioned during the final meeting, it was discussed during the routine meetings held between the AEC, TPC, and the Independent Peer Review Team. The team appreciates your understanding of this oversight.

Overall, the team found that the stress test implemented at the operating reactors in Chinese Taipei met the criteria established by the AEC that were based on the specification endorsed by the European Union as developed by European Nuclear Safety Regulators' Group (ENSREG). Further, the enhancements that have been implemented or are in the process of being implemented at the operating reactors in response to the stress test evaluations were found to be a strength by the team.

The team appreciated the excellent support provided by the AEC and TPC during its review of the stress tests conducted in Chinese Taipei.

Sincerely,

Dr. Aybars Gurpinar Section 2*	Signature	10 April 2013 Date
Dr. David Squarer Section 3*	Signature	April 10, 2013 Date
Dr. Katsunori Ogura Section 4*	Signature	11 april, 2013 Date
Mr. Mel Fields Section 5*	Signature	April 10, 2013 Date
Dr. Hitoshi Muta Section 6*	牟田 仁 Signature	11. April. 2013 Date
Mr. John Nakoski Team Coordinator**	Signature	23 APRIL 2013 Date
Mr. Wei-Whua Loa AEC Liaison**	Signature	11. April. 2013 Date

* My signature indicates that the report attached to this letter accurately reflects the reviews conducted and observations I made during the independent peer review of the stress tests conducted in Chinese Taipei for the annotated section under my name. Further, I agree with the content of Section 1, "Overview of the Independent Peer Review," and Section 7, "Conclusions."

** My signature indicates that I have provided support to the independent peer review team, that I have reviewed the report attached to this letter and that I find that in general the report reflects the activities I observed during the independent peer review of the stress tests conducted in Chinese Taipei.

Attachment: Independent Peer Review Report of the Stress Tests Performed on the Operating Reactors in Chinese Taipei

Independent Peer Review Report
Of the Stress Tests Performed
On the Operating Reactors in Chinese Taipei

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Independent Peer Review Report

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1. Overview of the Independent Peer Review

1.1 Background on Independent Peer Review

The Chinese Taipei Atomic Energy Council (AEC) requested support from both the European Union (EU) and the Organisation for Economic Cooperation and Development (OECD) Nuclear Energy Agency (NEA) with identifying experts that could conduct an independent peer review of its National Stress Test report that was performed in light of the accident at the Fukushima Daiichi Nuclear Power Plant (NPP). The AEC was seeking support to identify technical experts with the knowledge, experience, and skills required to conduct a peer review of the stress tests conducted at the operating nuclear power plants in Chinese Taipei. The NEA agreed to support the AEC by identifying experts that would review the National Report and the stress tests for the three (3) sites in Chinese Taipei with operating reactors. The AEC indicated during the independent peer review that the peer review of the plant that is under construction will be performed later with support from the EU.

The AEC adopted the criteria endorsed by the EU that were developed by European Nuclear Safety Regulators' Group (ENSREG). Consistent with these criteria, the Chinese Taipei stress tests and national report focused on three principle areas:

1. Extreme external event initiators such as earthquakes, flooding or other extreme weather conditions
2. Loss of safety functions and systems due to loss of power and the ultimate heat sink, and the combination of loss of power and loss of ultimate heat sink
3. Accident management

The stress tests have been completed by the licensee for each of the operating units and reports were submitted to the regulator for review. The results of the stress test were used to identify enhancements that are being implemented to provide additional capability of the nuclear power plants to respond to beyond design basis events. The regulator completed its reviews of the licensee's Stress Test Reports and prepared a National Report documenting the results of its review. The one (1) National Report and three (3) licensee stress test reports written in Chinese were translated into English and provided to the independent experts in January 2013.

In support of the request from the AEC, the NEA identified five (5) experts with knowledge of pressurized water reactor (PWR) and boiling water reactor (BWR) technologies, mechanical and electrical systems, probabilistic safety assessment, and accident management that were necessary to conduct a thorough independent peer review. There were two experts from the United States of America, two experts from Japan, and one expert from Turkey. The scope of the review conducted by the experts identified by the NEA included the National Report and the stress tests conducted for the units located at the Chinshan (2 BWRs), Kuosheng (2 BWRs), and Maanshan (2 PWRs) sites.

The peer review effort focused on the methodologies used by the licensee to conduct the safety assessments of their nuclear power plants and the approach used by the regulatory authority to oversee the work done by the licensee and independently assess the licensee's reports. An assessment was performed to assure that the methodologies used for the Chinese Taipei National Stress Test were comparable with those used by other countries in conducting their own comprehensive national safety reviews in light of the Fukushima Daiichi NPP accident. Also, the team conducted a technical assessment of basis for the Chinese Taipei stress tests by reviewing a sample of the work done by the licensee and reviewed by the regulator.

The experts began their reviews of the National Report and the site specific stress test reports in January 2013. Preliminary questions were shared with the AEC and the licensee, TaiPower Company (TPC), in February 2013. On 4 March 2013, the team of experts arrived in Chinese Taipei to begin a 2 week series of meetings and discussions with the technical experts and management of the AEC and TPC. This included a 2-day site visit to the Kuosheng Nuclear Power Station (Kuosheng) during which the experts observed many of the enhancements that were put in place in response to the findings of the stress tests.

During the review, the experts identified issues that were followed up with the AEC and TPC technical staff and management. These issues were characterized as strengths, weaknesses, stress test recommendations, and technical observations. A strength was identified when the actions of the AEC or the TPC represented a commendable practice or a strong understanding of the technical issue was identified. A weakness was identified when the AEC or the TPC reviews and analyses did not have a strong technical basis undergirding their actions or where substantial technical issues were identified by the experts requiring significant followup by the AEC or TPC. A stress test recommendation was identified for an issue where the team concluded that the work performed by the AEC and TPC did not meet the expectations for stress test implementation consistent with the ENSREG criteria applied by the AEC. A technical observation was identified by the team on issues that met the criteria of the stress test, but were in the expert's view enhancements that could be made to the methodology or approach used to address lessons learned from the Fukushima Daiichi NPP accident.

The team did not identify any weaknesses in the stress test performed in Chinese Taipei. One stress test recommendation was identified related to a systematic methodology for combining external hazards (see sections 3 and 4 of this report). A number of strengths were identifed as well as a number of technical observations. These are discussed in detail in the body of this report.

1.2 General Observations on the Stress Tests

Based on the reviews of the National Report and the Stress Test reports for Chinshan, Kuosheng, and Maanshan Nuclear Power Plants (NPPs), the team concluded that the stress test met the criteria established by ENSREG and followed by the EU for the stress tests of NPPs in Europe. Building on the results of the stress test and insights from the actions being taken by other countries, the AEC established clear requirements to implement enhancements. These requirements were embodied in regulatory orders issued by AEC to TPC on 5 November 2012. The specifics on how the requirements in these orders are satisfied are subject to discussions between AEC and TPC with final approval by AEC. The orders issued are listed below.

1. **10101**: Requiring seismic hazard re-evaluations implementing the recommendation from the United States Nuclear Regulatory Commission (USNRC) Near Term Task Force (NTTF) Report Tier 1 recommendation 2.1 to conduct seismic and flood hazard re-evaluations.
2. **10102**: Requiring flood hazard re-evaluations implementing the USNRC NTTF Report Tier 1 recommendation 2.1 to conduct seismic and flood hazard re-evaluations.
3. **10103**: Requiring TPC to simulate the mechanism of seismic and tsunami hazards and the resulting risks based on comments from an AEC review meeting.
4. **10104**: Requiring the enhancement of the water tightness of buildings (or build seawall, or tidal barrier) to a level of 6 meters above current licensing bases based on the actions being taken at Japanese NPPs and as referred to in the USNRC NTTF Report, to address the uncertainty from the original design basis tsunami height by adding 6 meters of protection[1].
5. **10105**: Requiring seismic, flood and others external events walkdowns consistent with the USNRC NTTF Report Tier 1 recommendation 2.3 to conduct seismic and flood walkdowns
6. **10106**: Requiring TPC to take actions to address station blackout (SBO) consistent with the USNRC NTTF Report Tier 1 recommendation 4.1 on SBO regulatory actions.
7. **10107**: Requiring more than 2 emergency diesel generators (EDGs) to be in an operable state all the time even when the reactor is shut down so that if one unit is shut down with one EDG under inspection and the swing EDG is assigned to it according to the new requirement, the capability of the swing EDG to back up the other unit is restricted.
8. **10108**: Requiring TPC to enhance emergency DC power supply to secure a storage capacity of at least 8 hours with the storage capacity of the batteries of one system without isolating the load and at least 24 hours after the unnecessary loads are isolated.
9. **10109**: Requiring TPC to extend the SBO coping time to at least 24 hours based on specific issues for Chinese Taipei's NPP in that the original requirements of USNRC Regulatory Guide (RG) 1.155 do not include the effects resulting from earthquake and tsunami.
10. **10110**: Requiring TPC to install a seismic qualified extra gas-cooled EDG at each NPP to address specific issues with electrical power supplies defence-in-depth for Chinese Taipei.
11. **10111**: Requiring TPC to install an alternate ultimate heat sink (UHS) consistent with recommendations from the ENSREG action plan.

[1] Page 37 of USNRC NTTF report states: "As a practical matter, and to prevent undue delays in implementing additional SBO protections, the Task Force concludes that locating SBO mitigation equipment in the plant one level above flood level (about 5 to 6 meters (15 to 20 feet)) or in watertight enclosures would provide sufficient enhanced protection for this level of defense-in-depth".

12. **10112**: Requiring TPC to implement the actions of the USNRC's Post-9/11 action (B.5.b) to stage response equipment on or near site to respond to extreme external events (see USNRC 10 CFR 50.54(hh)(2)).
13. **10113**: Requiring TPC to address the USNRC NTTF Report Tier 1 recommendation 4.2 on equipment covered under USNRC regulation 10 CFR 50.54(hh)(2).
14. **10114**: Requiring TPC to install reliable hardened vents for Mark I and Mark II containments and request the installation of filtration for all different containment designs consistent with the recommendation of USNRC NTTF Report Tier 1 recommendation 5.1 on reliable hardened vents for BWR Mark I and Mark II containments.
15. **10115**: Requiring TPC to install spent fuel pool (SFP) instrumentation consistent with the recommendation of the USNRC NTTF Report Tier 1 recommendation 7.1 on SFP instrumentation.
16. **10116**: Requiring TPC to strengthen and integrate the emergency operating procedures (EOPs), severe accident management guidelines (SAMGs), and extensive damage mitigation guidelines (EDMGs) with the ultimate response guidelines (URGs) developed by TPC following the accident at Fukushima Daiichi NPP consistent with the USNRC NTTF Report Tier 1 recommendation 8 on strengthening and integration of EOPs, SAMGs, and EDMGs.
17. **10117**: Requiring TPC to perform a volcanic probabilistic risk assessment (PRA) for its NPPs and to study the impacts from ash dispersion based on comments during a high-level review meeting.
18. **10118**: Requiring TPC to enhance the water-tightness of the fire doors of essential electrical equipment rooms based on specific concerns with the location of the equipment at Chinese Taipei's NPPs and recommendations from the Japanese regulatory body for NPPs in Japan.
19. **10119**: Requiring TPC to enhance the seismic resistant for the fire brigade buildings to cope with beyond design basis earthquake (BDBE) conditions to address specific issues for Chinese Taipei's NPPs and on good practices from EU peer reviews.
20. **10120**: Requiring TPC to improve the reliability of offsite power supplies to address specific issues for Chinese Taipei's NPPs and recommendations from the Japanese regulatory body for NPPs in Japan.
21. **10121**: Requiring TPC to improve the seismic resistance of raw water reservoirs at the NPPs and to consider the installation of impermeable liners to address specific issues for Chinese Taipei's NPPs and consistent with the measures being taken by TEPCO in Japan to install impermeable liners.
22. **10122**: Requiring TPC to install passive autocatalytic recombiners (PAR) to prevent hydrogen explosions consistent with recommendations in the ENSREG action plan.
23. **101101**: An Executive Order of the Yuan, requiring TPC to conduct an enhancement evaluation of safety related structures, systems and components (SSCs) for the Chinshan Nuclear Power Plant followed by the upgrading of the licensing basis safe shutdown earthquake (SSE) from 0.3g to 0.4g for specific SSCs relied upon to respond to an accident.

24. **101301**: Requiring TPC to address the issue with the PWR reactor coolant pump (RCP) seal loss-of-coolant-accident leakage issue for Maanshan Nuclear Power Plant consistent with the ENSREG action plan.

In addition to the orders issued by the AEC's Department of Nuclear Regulation, there were three (3) orders issued by the Department of Nuclear Technology.

1. Requiring TPC to addressing staffing and communications issues for emergency preparedness consistent with the USNRC NTTF Report Tier 1 recommendation 9.3 on emergency preparedness regulatory actions.
2. Requiring TPC to enhance the structure of the existing non-seismically qualified technical support centre (TSC) used for emergency response to address specific seismic concerns with the NPPs in Chinese Taipei.
3. Requesting TPC to consider building a seismically isolated TSC building based on the practice being implemented in Japan in light of the accident at Fukushima Daiichi NPP and consistent with guidance provide by the International Atomic Energy Agency.

From these orders it is clear, as independently verified by the team, that the expectations of the ENSREG Stress Test criteria were met by the AEC and TPC addressing seismic, tsunami, flooding, and other lessons learned issues from the accident at Fukushima Daiichi NPP. Overall, the team found that AEC and TPC implementation of the stress test was satisfactory. Further, it was clear to the team that the enhancements that are planned or have been implemented by TPC building on lessons learned are comprehensive and consistent with the actions being taken by other countries in response to their own comprehensive safety assessments or stress tests. The ultimate response guidelines (URGs) developed by TPC and AEC go beyond actions taken by other countries.

2. Earthquake Evaluation (Dr. Aybars Gurpinar)

This section of the report covers all subjects related to earthquakes including seismic hazard analysis, re-evaluation of the seismic capacity of structures, systems and components (SSCs) and any upgrades resulting from these. This section also addresses those parts of the probabilistic risk assessment (PRA) that deal with seismic issues.

As a major potential initiator of event sequences, earthquake evaluations overlap with other sections of this report. In particular, there needs to be consistency in the parameters used in seismic hazard analysis and tsunami hazard analysis.

ENSREG established criteria for stress tests for earthquakes in the following areas:

1. Design Basis – this section provides information on the design basis earthquake, the approach used in its evaluation and its adequacy given the present knowledge. Regarding the plant design, the ways in which protection is provided against this earthquake are described. This leads to an assessment of the current licensing basis.
2. Evaluation of safety margins – this part relates to beyond design basis considerations and the ways in which the plant can cope with beyond design basis earthquakes. This includes core damage and containment integrity issues. Eventually a cliff edge effect is determined using an accepted methodology such as seismic margin analysis (SMA) or seismic probabilistic safety assessment (SPSA).

2.1 Overview of Safety Enhancements from Stress Test for Earthquakes

The application of the stress test has focussed the TPC efforts already in progress for seismic upgrades to issues specifically related to the Fukushima Daiichi NPP accident. In this way it was possible to put the seismic re-evaluation and upgrading in the context of more specific areas such as station blackout, loss of ultimate heat sink and severe accident management. Furthermore, considerations for the combination of seismic events with other correlated events, such as tsunamis, are a direct result of the stress test process.

The stress test independent review was performed on the basis of the information made available by AEC and TPC. Whether or not this information was generated for an ongoing seismic re-evaluation and upgrading process is not an important aspect of the review. What is essential, however, is the way in which this information was used in responding to the stress test requirements.

Investigations related to seismic safety improvements of the three operating NPPs in Chinese Taipei started before the Fukushima Daiichi NPP accident and therefore before the Stress Test requirements were issued by ENSREG. Both AEC and TPC have a keen awareness of seismic safety issues and have access to expertise who can deal with these in a professional manner. Information used to conduct the stress test review was a snap-shot of the work that TPC has ongoing in assessing the seismic hazards for its nuclear power stations. Much of the review conducted on seismic hazards during this independent peer review is based on the broader programme of work that TPC has in progress in this area. **[Strength: AEC and TPC have a very good understanding of seismic issues related to operating NPPs.]**

The work related to seismic hazard re-evaluation started at all three plants after two faults were identified and/or re-characterized. One of these faults (the Shanchiao Fault) passes between the two plants in the North (Chinshan and Kuosheng NPPs) and the other (Hengchun Fault) approaches within a kilometre of Maanshan NPP in the South. Although a significant amount of geological and geophysical work has been done both onshore and offshore, the probabilistic seismic hazard analysis (PSHA) work was not available at the time of the independent peer review, but is expected to be ready in May 2013. The PSHA refinement work will be extended by about three years as TPC implements a Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 study.

The start of comprehensive seismic upgrading work at TPC's nuclear power stations will be implemented once updated and re-evaluated seismic hazard values are developed with implementation of the SSHAC Level 3 study. Until then, within the context of the stress test, the results of the Seismic Margin Assessment (SMA) will continue using a Review Level Earthquake (RLE) to identify practical activities to enhance plant safety in light of the risks from seismic hazards.

What has been done in the area of seismic improvements (specifically within the stress test requirements) relates to those structures, systems and components (SSCs) that will be made available for providing further defence-in-depth for situations such as a beyond design basis SBO and loss of ultimate heat sink. These include, for example, the reinforcement of the raw water reservoir on top of the hill and the related piping (i.e., at the Chinshan NPP).

2.2. Independent Peer Review Effort for Evaluation of Earthquakes

During the independent peer review, the expert reviewed the AEC Stress Test National Report for Nuclear Power Plants, and the site specific stress test reports prepared by TPC. Specifically, the independent expert reviewed the following documents during the independent peer review:

1. Section 2 of the AEC Stress Test National Report for Nuclear Power Plants, “Earthquakes”
2. Section 2 of the TPC EU Stress Test for CHINSHAN NPP – Licensee Report, “Earthquakes”
3. Section 2 of the TPC EU Stress Test for KUOSHENG NPP – Licensee Report, “Earthquakes”
4. Section 2 of the TPC EU Stress Test for MAANSHAN NPP – Licensee Report, “Earthquakes”

In addition, to reviewing these documents, the independent expert met with technical experts from the AEC and TPC to discuss the assessment of the licensees' evaluations by the regulatory authority and the technical evaluations conducted by the licensee.

2.3 Independent Peer Review Issues on Evaluation of Earthquakes

The fact that both AEC and TPC had started the work on the seismic evaluation and improvement of the three NPPs before the Fukushima Daiichi NPP accident is a very positive aspect of this activity. AEC and TPC have followed some of the earlier events in Japan related to seismic safety such as those that were observed in the Onagawa NPP in 2005 and more particularly the damage incurred to the non-safety SSCs of the Kashiwazaki-Kariwa NPP after the 2007 Niigata-ken Chuetsu Oki earthquake. This is a good example of a voluntary “lesson learned” from an important event.

Both AEC and TPC follow the USA regulations and practice and Japanese practice in the seismic safety of their NPPs. Therefore, they are abreast of good international practice as well as lessons learned from real events. It can also be stated that both organizations had well qualified experts in the field of seismic safety and also had access to both national and international expertise when needed. **[Strength: AEC and TPC have succeeded in identifying the seismic issues that need to be further addressed and resolved.]**

2.3.1 Ongoing Re-evaluation of Seismic Safety

TPC has started the work on all their NPPs before the Fukushima Daiichi NPP accident and therefore before the stress test requirements. The seismic safety improvement programs are based on well-known USA practices that have also been adopted internationally and in particular by the IAEA.

The ongoing programme being implemented by TPC is a combination of deterministic and probabilistic approaches and specifically uses Seismic Margin Assessment (SMA) and Seismic PRA (SPRA) methodologies.

Recent (but before March 2011) findings indicated the presence of two faults that are designated as active by the Chinese Taipei geological survey office. The Shanchiao fault is in the north and extends to the offshore area between the Chinshan and Kuosheng

NPPs (within 5 to 8 kilometres of the plants). The Hengchun Fault in the south also extends offshore and approaches within about a kilometre to the Maanshan NPP.

A PSHA (intended to be SSHAC Level 2 study) was conducted and the results will be available by about the end of May 2013. However, the results from the ongoing study seem to contain significant uncertainties and may not be suitable for seismic PRA purposes. Further, TPC plans to conduct a SSHAC Level 3 PSHA. The SSHAC Level 3 study is expected to last at least three years. In the interim the re-evaluation and upgrading process being implemented by TPC with AEC oversight will use an RLE that can be deterministically based on the expectation of the ongoing studies for the actual seismic hazard. This process can also establish the target for earthquake related cliff edges.

Technical Observation: Ongoing seismic re-evaluation and upgrading effort should be continued using an interim reference review level earthquake

To assure that TPC implements seismic enhancements promptly the ongoing seismic re-evaluation and upgrading effort at the three NPPs should continue using an interim reference RLE. AEC should prepare regulatory guidance or requirements that would expedite TPC's re-evaluation and upgrading work until a new seismic hazard level is established for the three NPPs following the SSHAC Level 3 study.

2.3.2 Conduct of the Probabilistic Seismic Hazard Analysis (PSHA)

It appears that the results from the ongoing PSHA work (intended to be SSHAC Level 2 study) may contain significant uncertainties. TPC will start a new process to evaluate the seismic hazard at the three sites in the framework of a PSHA SSHAC Level 3 study. The major objective of a SSHAC Level 3 study is to appropriately capture the "Centre, Body and Range" of the "Informed Technical Community". In general, a balanced representation of international expertise of the methodology and the local site specific knowledge is very important in this process. Furthermore, a participatory peer review process is considered to be an integral part of SSHAC Level 3. This would involve two types of review: independent peer review on behalf of TPC and a regulatory participatory review. In the planning phase of SSHAC Level 3 study, it is important to understand some of the lessons learned from international applications of the SSHAC methodology. One such study that is about to finish soon (May 2013) is the Pegasos project (SSHAC Level 3/4) conducted for four Swiss sites by Swissnuclear.

2.3.3 Fault Displacement Hazard Analysis

When there are faults very near the NPP structures, in addition to the hazard related to vibratory ground motion (calculated through a PSHA), seismic hazard analysis should also include fault displacement hazard analysis that evaluates the potential impact of surface displacements caused by faulting on the safety of NPP SSCs. Both the USNRC 10 CFR Part 100 Appendix A and the IAEA Safety Guide SSG-9, address this issue explicitly.

The faults Shanchiao in the north and Hengchun in the south are within distances that may potentially have an impact on all three NPPs in terms of displacement hazard. The investigations presented at TPC indicate that there is good understanding of what aspects of the faults need to be investigated and also the methods to achieve this purpose. However, the intention in the characterization of the faults is limited to the inclusion of these results in the PSHA only. At the moment a separate fault displacement hazard analysis is not foreseen.

Technical Observation: Fault displacement hazards analysis should be performed

AEC has stated that its regulatory basis is USNRC's regulations under 10 CFR Part 100 Appendix A. In this regulation, the fault displacement hazard is addressed under the title “surface faulting”. Given the identification of these 2 new active faults, AEC should assure the appropriate implementation of the relevant sections of this regulation. The requirements of 10 CFR Part 100, Appendix A can be further enhanced by more recent approaches such as probabilistic fault displacement hazard analysis that is recommended by the IAEA Safety guide SSG-9.

TPC is performing detailed work both onshore and offshore to appropriately characterize these faults. Consideration could also be given to the deployment of a local seismic network (one in the north and one in the south) to capture small earthquakes in order to understand whether or not the pattern of the epicentres indicate correlation with postulated tectonic features.

2.3.4 Potential for Soil Failures

Earthquake caused vibratory ground motion needs to be considered in the plant design and also the same ground motion can induce geotechnical failures that may result in failures of safety related SSCs or create other challenges at the site if they involve non safety SSCs. These could involve potential foundation settlements of non safety structures. The lessons learned from the experience after the Niigata-ken Chuetsu Oki earthquake at Kashiwazaki-Kariwa NPP are good examples of these types of failures.

The major potential soil failures include liquefaction (for granular soils), slope instabilities and ground collapse (for limestone). These are normally considered in the FSAR and their potential for causing any hazard is evaluated using the seismic hazard analysis available for the site. When this hazard is changed (e.g. because of the discovery or re-characterization of a fault) there is a need to re-evaluate the potential for these secondary geotechnical hazards.

The potential for slope instability of the nearby hill at the Chinshan NPP site was discussed. This hill also hosts the large reservoir which is now intended to be used as part of the alternate UHS system. Both the slope stability issue and the adequacy of the seismic margin of the reservoir were checked by TPC. Some of the seismic margin values were provided verbally during the presentation to the independent expert by TPC. However, the information provided was not included in the documentation provided to the independent expert. Included within this issue is the piping that connects the reservoir with the plant. The piping is designated as Seismic Category 2 and therefore credit in licensing space is taken as 0.15g, whereas it was verbally reported by TPC that these pipes have a margin of up to 0.42g.

Technical Observation: As-built seismic capability of alternate UHS

Recognizing that the AEC issued an order for TPC to conduct seismic and flooding walkdowns, and from a defence-in-depth perspective it is clear that these walkdowns should assure that the alternate UHS is not disabled before a core damage accident considering the significant contribution of seismic initiators to core damage frequency (CDF). These walkdowns should address the seismic stability and integrity of the reservoir, the slope, and the piping to provide confidence that the as built seismic capability (demand) remains at an acceptable level. This should also be demonstrated by reflecting the as-built characteristics of these SSCs when implementing re-evaluations in terms of the RLE and the results of the SSHAC Level 3 PSHA. Further, in light of the potential significant increase in the hazard values, it would be useful to revisit the median capacity and β values (i.e., the SSC related HCLPF) also through dedicated plant walkdowns using appropriate quality control tools.

2.3.5 Post Earthquake and Post Tsunami Operator Action Procedures

It is good practice to have procedures in place for post-earthquake operator actions because these help in providing guidance to the operator at a time of potential distress and confusion. When the earthquake that is felt at the NPP site also has the potential for generating a tsunami (such as what happened at Onagawa, Fukushima Daiichi and Fukushima Daiini NPPs) it is important to adapt these procedures to the combined effects of two hazards occurring at the site. Specifically, visiting the potentially damaged areas of the plant due to the earthquake may be dangerous due to the threat of an imminent tsunami.

TPC has indicated that there are post-earthquake and post-tsunami operator action procedures however there is no interface between these two. Both AEC and TPC have agreed that there is a need to provide an interface between the two procedures. TPC indicated that they will modify the procedures accordingly.

2.3.6 Maximum Magnitudes Used for Seismic and Tsunami Hazard Analysis

The maximum magnitudes associated with faults have a major impact both on the seismic hazard as well as the tsunami hazard results. It is clear that historical data can only be used as supporting information for this purpose because of the lack of a sufficiently long seismological catalogue (even when including historical, i.e., pre-20th century, events). The major source of information should come from the seismotectonic characterization of the fault which includes the dimensions of the fault (length, down-dip, width), orientation (strike, dip), amount and direction of displacement, rate of deformation, maximum historical intensity and magnitude, paleoseismic data, geological complexity (segmentation, branching, structural relationships), earthquake data and comparisons with similar structures. When data is available, other information such as average stress drop and rheological profile (heat flow, crustal thickness and strain rate) needs to be considered in this estimation.

When the faults under consideration have segments in the offshore area, or if they are completely in the ocean (such as the subduction zones) the maximum potential magnitude estimates have a major impact also on the tsunami hazard analysis. In any case all the estimates and empirical relationships used in the determination of maximum potential magnitudes are associated with significant aleatory and epistemic uncertainties.

A study supported by TPC for the tsunami hazard of Chinese Taipei has identified maximum M_w values for the surrounding subduction zones (on different segments). These magnitudes range from 8.0 to 8.8. These values were used during the stress test and were developed based on a general country wide investigation of the seismic hazards as reported in official records of the Chinese Taipei National Science Council (NSC). A lesson learned from Fukushima Daiichi NPP accident is that site specific investigations and countrywide investigations differ in the level of detail that is needed to appropriately consider the seismic hazards that should be addressed for nuclear power plants. Furthermore, the potential for the rupture of multiple segments of subduction zone faults may need to be considered as a lesson learned from the Fukushima Daiichi NPP accident.

Technical Observation: Maximum magnitude values for faults

Since the length of the seismological catalogue is not sufficient for the determination of maximum magnitudes in these areas, other means should be used. Using similarity arguments higher values may be suggested (e.g., the Alaska earthquake of 1964, the Chile earthquake of 1960, the Aceh earthquake of 2004 and the Tohoku earthquake of 2011). All these events would indicate a value equal to or over 9.0 (based on similarity arguments). From the discussions with TPC it was not clear to the independent expert whether there were sufficient tectonic arguments to use the countrywide seismic values. Within the scope of the stress test, these values may be sufficient. However, moving forward as the seismic hazard is re-evaluated in the context of the SSHAC Level 3 study higher values could be applied when assessing the seismic hazards for the NPPs in Chinese Taipei considering the experiences of the other parts of the Circum Pacific belt. In the context of a NPP site specific seismic or tsunami hazard analysis, it may be necessary to revisit officially published maximum magnitude values for faults.

3. Flooding Evaluation (Dr. David Squarer)

This section of the report covers the consequences of the loss of safety function from conceivable initiating events at the plant site as a result of flooding.

Following the ENSREG stress test criteria, the assessment of the consequences of flooding should include:

1. The evaluation of the level of design basis flood (DBF), the methodology used to determine the DBF, sources of flooding (tsunami, tidal, storm surge, etc.), the validity of the data, and the adequacy of DBF.
2. Provision to protect the plant against DBF; SSCs needed to achieve safe shutdown after flooding including provision to maintain water intake function, provision to maintain emergency electrical power supply; identification of the main design provisions to protect the site against flooding; main operating provisions to warn against and to mitigate the effects of flooding; were other effects linked to flooding considered (e.g. loss of external power supply, delayed access to the site, etc.)?
3. Plant compliance with its current licensing basis including: periodic maintenance and inspections, ensuring off-site mobile equipment for emergencies, identification of any deviations and their consequences as well as plans for remediation, compliance check initiated by the licensee following the Fukushima accident.
4. What is the level of flooding that the plant can withstand without severe damage to the fuel (core or fuel storage): Depending on advanced warning of upcoming flooding, can additional protective measures be implemented? Identification of the weak points and cliff edge effects, and which buildings and equipment will be flooded first; Identification of any provisions that can prevent these cliff edge effects or increase the robustness of the plant (e.g. modifications of hardware, procedures, organizational provisions, etc.).

3.1 Overview of Safety Enhancements from Stress Test for Flooding

This section of the report provides a brief overview of the safety enhancements that have been implemented, are being implemented, or for which definitive plans have been committed to implement enhancements at the operating reactors in Chinese Taipei to address lessons learned from the stress test evaluation in light of the accident at Fukushima Daiichi NPP.

In the area of flooding, the following definite commitments by TPC were observed as a result of the following regulatory orders issued by AEC:

1. **10102**: Requiring flood hazard re-evaluations implementing the USNRC NTTF Report Tier 1 recommendation 2.1 to conduct seismic and flood hazard re-evaluations.
2. **10103**: Requiring TPC to simulate the mechanism of seismic and tsunami hazards and the resulting risks based on comments from an AEC review meeting.
3. **10104**: Requiring the enhancement of the water tightness of buildings (or build seawall, or tidal barrier) to a level of 6 meters above current licensing bases based on the actions being taken at Japanese NPPs and as referred to in the USNRC NTTF Report, to address the uncertainty from the original design basis tsunami height by adding 6 meters of protection (see foot note # 1 in section 1.2).
4. **10105**: Requiring seismic, flood and others external events walkdowns consistent with the USNRC NTTF Report Tier 1 recommendation 2.3 to conduct seismic and flood walkdowns
5. **10113**: Requiring TPC to address the USNRC NTTF Report Tier 1 recommendation 4.2 on equipment covered under USNRC regulation 10 CFR 50.54(hh)(2).
6. **10116**: Requiring TPC to strengthen and integrate the EOPs, SAMGs, and EDMGs with the URGs developed by TPC following the accident at Fukushima Daiichi NPPs consistent with the USNRC NTTF Report Tier 1 recommendation 8 on strengthening and integration of EOPs, SAMGs, and EDMGs.
7. **10117**: Requiring TPC to perform a volcanic PRA for its NPPs and to study the impacts from ash dispersion based on comments during a high-level review meeting[2].
8. **10118**: Requiring TPC to enhance the water-tightness of the fire doors of essential electrical equipment rooms based on specific concerns with the location of the equipment at Chinese Taipei's NPPs and recommendations from the Japanese regulatory body for NPPs in Japan.

During discussions with TPC as well as in response to questions from the independent expert, it was stated that TPC intends to build tsunami walls at the three NPPs sites within the scope of this review at a height of 6 meter above the current licensing basis (e.g., by 2016 at the Kuosheng NPP). Presentations made by TPC and Sinotech during the review included the tsunami and flooding analyses performed by Sinotech Engineering Consultants Ltd, working for TPC. These analyses, which employed

[2] Submarine volcano eruption is a potential tsunami source 18 km north of CS NPP and KSNPP. This potential hazard, as a source for a tsunami, should be evaluated in addition to the hazard due to volcano ash dispersion.

updated analytical tools developed by Sinotech, predict substantially lower tsunami run-up elevations at all nuclear plant sites in Chinese Taipei. Table 3-1 of National Report (January 6, 2013) shows even lower predicted elevations of tsunami run-up at the Chinshan NPP and Kuosheng NPP. These predictions were made by the NSC using its COMCOT code, and data of terrestrial geographic landscape from the Chinese Taipei National Resource data base.

However, there are still significant uncertainties in tsunami run-up predictions due to the definition of tsunami sources. The sources are primarily the 22 identified faults and trenches around Chinese Taipei. Also, an active submarine volcano was identified 18 km north of the Kuosheng NPP. This volcano can be considered a potential tsunami source. Another source of significant uncertainty is the use of approximate near-shore topography instead of accurate bathymetry. The inundation (run-up) analysis must be carried out at high resolution and at refined numerical cell size. The original calculations in the Final Safety Analysis Report (FSAR) of design basis tsunami (DBT) were very simplistic, since modern computer codes that could predict tsunami run-up were unavailable when the FSAR was written. In addition, the FSAR analysis used an approximate sea-bed slope (e.g. 1/5 or 1/10) instead of actual bathymetry data. These assumptions in the FSAR tsunami run-up analysis, and the more advanced computer codes used to perform the recent analyses by NSC and Sinotech, led the expert to conclude that the 10.28 m licensing basis tsunami run-up value at the Kuosheng NPP (and similarly at Chinshan NPP) could include substantial safety margin, which in addition to the planned tsunami walls could compensate for the uncertainties embedded in the definition of tsunami sources.

As a result of the independent peer review of Chinese Taipei’s stress test, AEC has stated that it will delete from the National stress test report, NSC’s prediction of the (lower) tsunami run-ups, and retain the predictions of the original FSAR tsunami run-up elevations. In addition, a tsunami wall of 6 meters above the tsunami “design maximum elevation of wave run-up” (i.e., a 4.28 meter wall in the case of Kuosheng NPP) will be constructed at Kuosheng NPP by 2016, as well as at the other nuclear plant sites.

3.2. Independent Peer Review Effort for Evaluation of Flooding

During the independent peer review, the expert reviewed the Chinese Taipei AEC Stress Test National Report for Nuclear Power Plants, and the site specific stress test reports prepared by TPC. Specifically, the independent expert reviewed the following documents during the independent peer review:

1. Section 3 of the AEC Stress Test National Report for Nuclear Power Plants, “Flooding”
2. Section 3 of the TPC EU Stress Test for CHINSHAN NPP – Licensee Report, “Flooding”
3. Section 3 of the TPC EU Stress Test for KUOSHENG NPP – Licensee Report, “Flooding”
4. Section 3 of the TPC EU Stress Test for MAANSHAN NPP – Licensee Report, “Flooding”

In addition to reviewing these documents, the independent expert met with technical experts from the AEC and TPC to discuss the assessment of the licensees’ evaluations by the regulatory authority and the technical evaluations conducted by the licensee.

During the site visit to the Kuosheng NPP, a number of safety enhancements that were either implemented or in the process of being implemented were observed, including:

1. An additional emergency diesel generator (EDG) was installed, a "5th" air-cooled EDG
2. The black-start generators for the two air-cooled gas turbines can supply electrical power to emergency loads
3. The raw water reservoirs at hill top can be used as an alternate UHS
4. Improved water tightness of the emergency circulating water (ECW) pump house
5. The motor control centre (MCC) in the ECW pump house is protected by stainless steel flood dyke
6. The emergency drain operation procedures for buildings were drafted
7. The emergency operation procedures for heavy rain or flooding were written
8. A tsunami emergency response procedure was issued, and
9. An emergency procedure to address limited access to the plant due to flooding was written.

3.3 Independent Peer Review Issues on Evaluation of Flooding

The independent expert requested additional information from AEC and TPC to obtain a comprehensive understanding of the results of the stress tests performed for the Chinese Taipei operating nuclear power plants. The responses confirmed that the actions discussed in the individual stress test reports and the recommendations described in the AEC Stress Test National Report were either complete or had dates established for completion. The AEC's and TPC's responses provided the details of how these action items were progressing at the sites. Issues discussed during the review are provided below.

3.3.1 Tsunami Run-up Elevations

The National report and the three plant-specific reports indicate that the tsunami run-up is a very important parameter needed for the stress test, perhaps the most important parameter. Many of the future upgrades to all three NPPs depend on the level of the tsunami run-up. As such, this was a key area reviewed during the independent peer review.

AEC informed the independent expert that after the Fukushima accident, the NSC immediately started a program to assess the potential earthquake-induced tsunami run-up heights from the sea around the country. The assessment of the potential tsunami run-up was performed by geophysics experts and considered 22 simulated earthquake sources (including 18 trenches and 4 faults). These earthquakes are considered to be the most likely to induce tsunamis that would affect Chinese Taipei.

The independent expert noted that the simulations of NSC did not model the tsunami resulting from undersea volcanic eruptions and undersea landslides. Further, it was noted that the NSC analyses did not consider the detail geological information near the plant site. Recognizing this, AEC noted that it does not directly use the calculations of government agencies, such as the NSC, unless they are specifically designated for nuclear reactor requirement by one of the regulatory guides adopted by AEC.

Acknowledging the uncertainty in the tsunami hazards and to provide additional margin, the AEC issued regulatory order 10104 (see Section 3.1) to TPC requiring that it increase the tsunami protection at each of the sites by 6 meters above the current licensing bases. The additional 6 meters above the current licensing bases, is based on engineering judgement of the AEC after consultation with the USNRC and considering information in the NRC's NTTF Report prepared following the accident at the Fukushima Daiichi NPP (see footnote # 1 in Section 1.2).

To avoid misunderstanding generated by the reference to the NSC results in the National Report on the stress test, Table 3-1 of National Report will be modified to remove the NSC run-up predictions and the report will retain the FSAR tsunami run-up levels for each site.

Tsunami run-up analysis defines the potential flooding risks for all three sites. To calculate the probable maximum tsunami (PMT) correctly it is necessary to calculate the initial tsunami wave form that depends on the tsunami sources, such as seismic sources. The modelling of the propagation of the generated wave follows the generation of the tsunami wave. The next step in the analysis is the inundation that yields the tsunami run-up. To reduce the uncertainty in the estimate of the DBT and run-up elevations, these analyses should be performed by state-of-the-art computer codes. Further, to correctly calculate the inundation, it is necessary to use near-shore bathymetry, geometry, structures, etc. Without actual near-shore data, the run-up analysis could have large uncertainties. TPC indicated that analyses are being performed for each of the sites using updated computer modelling and enhanced bathymetry, geometry, and other information that could impact the tsunami hazards analyses.

Understanding the importance of accurately assessing the tsunami hazard, the AEC issued regulatory order 10103 to TPC requiring it to perform a tsunami risk evaluation for each site (phase 2). Following this re-analysis according to orders 10102 and 10103, the AEC will determine whether additional regulatory actions are necessary (e.g., update the design basis and SSCs important to safety) based on the results of the analysis according to order 10102 (phase 1). Included within the scope of the re-analyses requested by the AEC is that TPC will re-analyse the tsunami run-up considering other conditions, such as submarine volcanic eruptions and submarine mountain collapse. TPC has hired a consultant company, Sinotech that has begun to re-analyse the tsunami hazard using more sophisticated modelling and more accurate site-specific data to estimate tsunami run-up. At Kuosheng, the preliminary results of the Sinotech analysis showed significant margin between the estimated tsunami run-up and the site elevation. However, additional analyses are being conducted to address improved understanding of the conditions that can cause tsunamis such as volcanic eruptions and more significant seismic events.

3.3.2 Combination of Events Considered for Flooding Assessment

It was noted during the review that for flooding at Kuosheng NPP, tsunami waves were considered in combination with typhoon driven winds. Further, at Maanshan NPP flooding analysis considered other extreme natural conditions, in addition to tsunamis, like typhoons, heavy rain, and mudslides, and at Chinshan NPP tsunami wave in combination with wind waves were considered. As discussed elsewhere in this report, an issue raised with AEC and TPC regarding the combination of events was that there did not appear to be a systematic approach for combining external initiators for consideration within the scope of the stress test. Based on this issue, the independent peer review team recommended that AEC and TPC assess the impact of this issue on the implementation of the stress test (see Section 3.4.2 of this report).

3.3.3 Probable Maximum Precipitation (PMP) and Drainage

During the review, discussions where held with TPC on the assumptions for the probable maximum precipitation (PMP) and whether the capability of the drainage systems at the three operating sites can cope with the PMP. TPC provided responses to the questions that indicated that the drainage systems at the three operating sites would be capable of handling the PMP considering the drainage area for each of the sites.

During the review, regional topographical maps were not available to the independent expert and therefore it was not possible to independently verify the accuracy of the drainage areas, as well as the impact of potential mud slides upstream of the NPP sites (causing channel diversion). However, during the visit to the Kuosheng NPP the independent expert observed the storage reservoir at the 90 meter elevation and noted by observing the area just outside the plant site fence that this site has a relatively small and confined drainage area. The independent expert concluded that the drainage areas of 1.8 km2 and 1.5 km2 shown on the satellite map for the Kuosheng NPP are reasonable and presumably determined from small-scale topographic maps. It was noticed that the hills surrounding the Kuosheng NPP site are covered with dense vegetation and trees that should help prevent land-slide during an intense precipitation.

3.3.4 Mud Slide Impacts on Flooding Analysis

In response to questions from the independent expert, the AEC noted that it had requested TPC to assess the potential level of mudslide at each of the operating sites. The mudslides analyses were discussed in Chapter 4 of the Chinese Taipei national report and TPC has addressed this issue in its stress report for each site. Based on TPC's assessments, the possibility of the plant damaged by mudslides is low. Further, it was noted that TPC conducts a mudslide monitoring programme, using routine walkdown inspections and taking periodic satellite images that looks for abnormal changes in the nearby area of the streams that could affect the plants.

3.3.5 Consideration of Indirect Effects from Tsunami

During the review, questions were raised about the consideration of the indirect effect from the tsunami on accident response. The concern was whether the impact on the site from the wave and the debris that could be deposited on the sites (i.e., fishing boats, and other items carried onto the site by the wave) were considered within the scope of the stress tests. TPC noted that the indirect effects from a tsunami were not considered for all of its NPPs (this issue was considered at Maanshan NPP). AEC responded to this issue by noting that it will request TPC to re-assess and to take adequate measures against the indirect effects of tsunamis at all of its sites. Further, within the context of enhancements being made as a result of the stress tests, AEC noted that TPC is planning to build a sea wall with a margin of 6 meters above the current licensing basis tsunami run-up height at each site. Installation of this sea wall will provide protection from both the direct flooding impact of a tsunami and the indirect impact of a tsunami from such things as debris getting in the way of accident response.

3.4 Peer Review Observations in the Area of Flooding

Based on the reviews conducted by the independent expert in this area the following assessments were made:

3.4.1 Overall Observations

Implementation of the stress test in the area of flooding is consistent with the ENSREG criteria. As a result of the stress test and subsequent AEC orders, TPC has implemented or is planning to implement flooding-related enhancements at all three NPPs (e.g. adding tsunami walls, backup power sources, portable pumps, issuing emergency procedures, etc.). After independently reviewing and verifying the results of the stress test, it is concluded that consequences similar to Fukushima Daiichi are unlikely to occur at Chinese Taipei's NPPs as a result of a Fukushima Daiichi NPPs-type event.

Auxiliary equipment such as portable drainage and sump pumps, hoses, air compressors, emergency generators, flood barriers, and other equipment in the storage facility at the Kuosheng NPP are stored at higher elevation than current 10.28 meter above mean sea level design basis tsunami elevation. This equipment should be available to augment the drainage capacity at the site during a beyond design basis event, as well as to drain buildings that experience internal flooding. Such portable equipment could drain the site directly into the sea if necessary. In addition, waterproofing of buildings containing safety related or other important equipment was observed. It was noted that under emergency conditions, the three northern NPP sites, i.e. Chinshan NPP, Kuosheng NPP and Lungmen NPP could share mobile mitigating equipment when needed.

It was noted by the expert that recommendations and requests made by the AEC of TPC, as listed in section 3.3 of the National Report ("Assessment and conclusions of the regulatory body"), are in general consistent with the observations listed in this section, in particular with respect to the need to re-analyze the design base tsunami which is used to determine the cliff edge effect. **[Strength: AEC has successfully identified the weaknesses in flooding assessment and has issued appropriate orders to TPC for remedial activities]**

3.4.2 Stress Test Recommendation: Combinations of Events for Flooding

The independent review concluded that although some combinations of events were considered in the determination of elevations of DBT (see Section 3.3.2), a systematic evaluation of combinations of events in the areas of flooding and extreme natural hazards was not performed.

An approach that was discussed with AEC and TPC would be to analyse the combinations of events in accordance with the methodologies described in Standard ANSI/ANS- 2.8, Standard ANSI/ANS-2.12, and USNRC Regulatory Guide 1.59, and to consider combinations of not only the maximum values of events, but combinations of lesser values. Examples of combinations of events that could be considered include: seismic, tsunami, low tide, high tide, storm-surge, seiche, mud slide (upstream of the site leading to channel diversion), change in mean-sea level, sedimentation, typhoon, volcano, heavy precipitation, land slide (due to seismic activity), lightning, salt fog, erosion, windstorm, site and roof drainage, failure of water reservoirs and containers (due to seismic), fluctuations in ground water elevation, and perhaps others.

Consequently, the independent peer review team recommends that a systematic evaluation of combinations of events be performed, and if the results of the re-evaluation will yield flood elevations higher than the DBF, the stress test should be amended (see Section 4.3 for the Stress Test Recommendation).

3.4.3 Technical Observation: Tsunami

As discussed previously (see Section 3.3.1 of this report), it was noted that the current licensing basis tsunami hazards used simplified assumptions and methodologies considering the methodology available at the time the FSAR was prepared. Recognizing the importance of an enhanced understanding of the tsunami risk and to reduce its uncertainty, the tsunami hazard should be re-analysed using state-of-the-art modelling and updated information and assumptions. By doing so, TPC will be able to better define the safety margin at all three NPP sites, and to determine more accurately the height of the proposed tsunami walls. To further reduce the uncertainty a recommendation was made by the expert to the AEC to validate the tsunami computer codes against scaled physical model replica of all NPP sites (including exact bathymetry).

4. Other Extreme Hazards Evaluation (Dr. Katsunori Ogura)

This section of the report covers the consequences of extreme hazards that originate from extreme natural events other than earthquakes and flooding.

Following the ENSREG stress test specification, the assessment of the extreme natural hazards other than earthquake and flooding considers verification of site-specific natural hazard conditions that were used as the design basis for various plants SSCs, including probable combination of these hazards. Safety margin against extreme natural hazards, and measures which can be envisaged to increase robustness of the plants against extreme natural hazards were considered.

4.1 Overview of Safety Enhancements from Stress Test for Extreme Hazards

As a result of the stress tests TPC has or is going to enhance plant safety as follows:

1. Measures considered in the stress tests, such as additional drainage pumps, modified procedures, and so on, based on the evaluation results of cliff edge effects, will further enhance plant safety. These measures may be performed in conditions beyond the existing design basis event (extreme weather and severe accident conditions) that could require manual activities outside the buildings. TPC has conducted training assuming such accident progression and simulated weather conditions at the plants.
2. Re-assessment of lightning protection will be conducted because a systematic evaluation of external events is required and recent short term data (2 years) seems to indicate an increasing trend in spurious alarms caused by lightning. In addition, TPC will conduct an assessment of volcanic hazards. These activities will provide for increased robustness of the plants in Chinese Taipei.
3. Periodic safety assessments are performed every 10 years. The safety reassessment of extreme natural events will reassess the robustness of the plants in Chinese Taipei considering new information and improved analysis methods.

4.2. Independent Peer Review Effort for Evaluation of Extreme Hazards

During the independent peer review, the expert reviewed the Chinese Taipei AEC Stress Test National Report for Nuclear Power Plants, and the site specific stress test reports prepared by TPC. Specifically, the independent expert reviewed the following documents during the independent peer review:

1. Section 4 of the AEC Stress Test National Report for Nuclear Power Plants, "Extreme natural events"
2. Section 4 of the TPC EU Stress Test for CHINSHAN NPP – Licensee Report, "Extreme natural events"
3. Section 4 of the TPC EU Stress Test for KUOSHENG NPP – Licensee Report, "Extreme natural events"
4. Section 4 of the TPC EU Stress Test for MAANSHAN NPP – Licensee Report, "Extreme natural events"

In addition, to reviewing these documents, the independent expert met with technical experts from the AEC and TPC to discuss the assessment of the licensees' evaluations by the regulatory authority and the technical evaluations conducted by the licensee. Although the stress tests applied a mostly deterministic approach, the licensee explained that a probabilistic approach was also applied to enhance plant safety.

4.3 Independent Peer Review Issues on Evaluation of Extreme Hazards

The design bases for the NPPs take "storms" into consideration in their FSARs when deciding events because the significant impact from strong storms in Chinese Taipei. After the destructive typhoon, Morakot, the academic discussion on extreme weather events started in Chinese Taipei and scholars had warned that "heavy precipitation" types of climatic events would threaten Chinese Taipei in the future. According to TPC, typhoons, heavy rainfalls, mudslides, high winds, lightning, hail, tropical cyclones, hurricanes, tornadoes, snowfall, sand storms/dust storms, and extreme temperatures were considered. TPC indicated that this was consistent with the approach documented in the Belgian stress test report for high consequence events that were considered for the stress tests. The independent expert noted that typhoons, heavy rainfalls, mudslides and dip-slope sliding were evaluated as extreme natural events in the Stress Tests reports. In addition a combined event of typhoons, heavy rainfalls and mudslides was also considered as the most severe event within the evaluation.

Within the ENSREG Stress Test criteria being followed in Chinese Taipei, it was noted that the stress test is not limited to earthquakes and tsunami, but includes flooding regardless of its origin, and was to address bad weather conditions as well. Further, the assessments of the loss of safety functions were required to consider any initiating event conceivable at the plant site and indirect initiating events as well, such as large disturbance from the electrical grid, forest fires, or airplane crashes. From this, the combinations of external hazards that are plausible were to be considered within the scope of the stress test review. Based on discussions with TPC, it was not clear what the basis was for selecting the other extreme hazards and their combination for consideration within the scope of the stress test.

Stress Test Recommendation: A systematic approach for selecting and combining extreme hazards should be implemented

Based on its reviews (see also Section 3.4.2 of this report), the independent peer review team recommends that the TPC and the AEC clarify the basis for the effects of natural events and the combinations considered within the stress test by performing a systematic assessment of external hazards. This could be accomplished by TPC developing a comprehensive table that includes the probable site-specific combination of events, subject to AEC review, and informing the AEC of the screening process applied by TPC to exclude combinations of hazards. This would provide assurance of the completeness of extreme natural events evaluated in light of the accident at Fukushima Daiichi NPP. Once the basis is clarified, TPC and AEC should consider systematically assessing the extreme natural events included within the scope of the stress test, and as appropriate implement the evaluation for cliff edge effects and the identification of safety enhancements to address new weakness that may be identified. This process could then be incorporated into the periodic safety review process to assure updated information on extreme natural events is regularly considered for its impact on the design basis of NPP in Chinese Taipei.

In addition to the approach discussed in Section 3.4.2 for combining external hazards, (i.e., the methodologies described in Standard ANSI/ANS- 2.8, Standard ANSI/ANS-2.12, and USNRC Regulatory Guide 1.59) other information that may be useful to the AEC and TPC in this regard is how the combination of various natural events (i.e., biological events, forest fire, volcanic activity, lighting, and so on) have been consider in model improvements for probabilistic risk assessment described in international accepted standards, such as ASME/ANS Appendix 6-A to ASME/ANS RA-Sa-2009, "Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant, 2009;" ANSI/ANS-2.12-1978, "Guidelines for Combining Natural and External Man-Made Hazards at Power Reactor Sites;" and IAEA Safety Guide NS-G-1.5, "External Events Excluding Earthquakes in the Design of Nuclear Power Plants, International Atomic Energy Agency (IAEA), Nov 2003."

4.4 Peer Review Observations in the Area of Extreme Hazards

In the area of other extreme hazards, the TPC's as well as the AEC's reviews were implemented along the stress tests specification and their reports were summarized well following the EU stress test process.

During the site visit to the Kuosheng NPP, a number of safety enhancements that were either implemented or in the process of being implemented were observed. Measures for responding to extreme natural events beyond the design basis, which might require manual operation of mobile components, become of concern under these conditions. Training outside the buildings, assuming initiation of extreme natural events, has been conducted at the site. Efforts were taken to minimize the coping time that could have an effect on accident progression, and to prevent erroneous connection from mobile components to the installed conventional systems. For instance the cable connectors from a portable 480VAC diesel generator to the emergency bus are color-coded as shown in Figure 4-1 to enhance the clarity of instructions between an operator in the main control room and a local worker making the connection. This should result in the prevention of incorrect connections as well as in a reduction of time necessary to make the connection. **[Strength: Efforts were implemented to minimize the coping time**

that could affect accident progression, and to prevent improper connection of mobile components to installed conventional systems.]

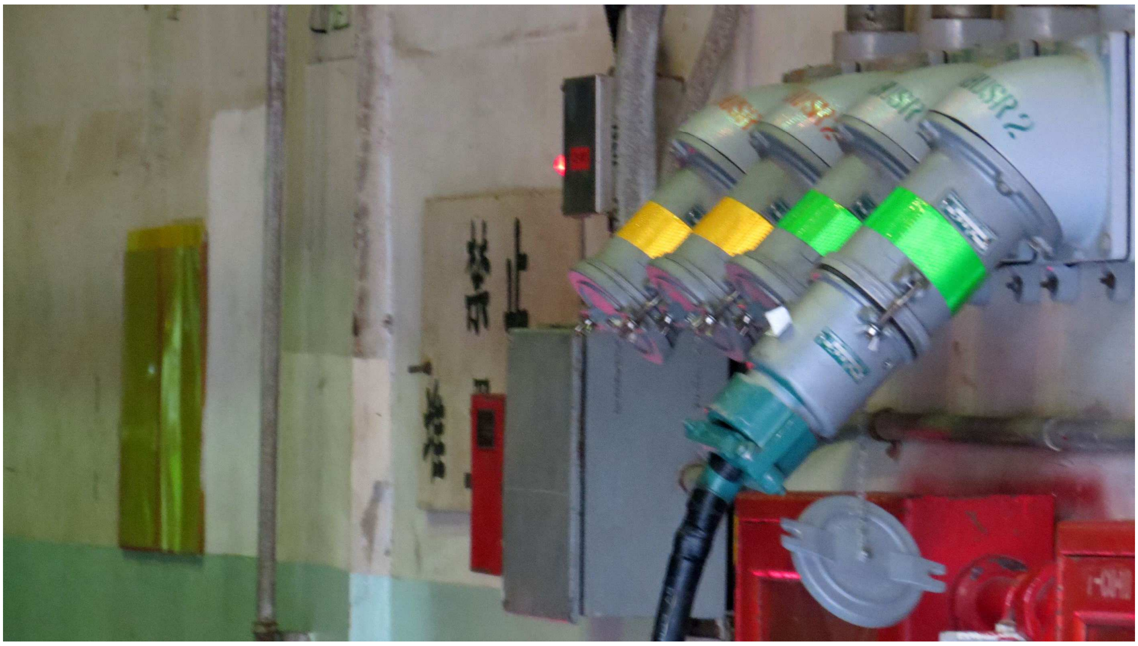

Figure 4-1 Connector for Electric Cable from Mobile DG

Based on the reviews conducted by the independent expert in this area the following observations were made:

1. The approach and methodology to evaluate the extreme natural events and the combination of events considered within the stress test were appropriate. To account for uncertainty when there were insufficient historic records of for a specific weather condition did not exist, the historical evidence for the 10,000 year return period were applied to evaluate the effect of this weather condition on the plant.
2. The approach and methodology to identify and evaluate weak points and cliff edge effects based on results from extreme natural event evaluations, and to make plans to implement measures to protect against the identified weak points, were appropriate.
3. The AEC reviewed these results and identified two more probable events that were not considered originally by TPC. These were lightning and volcanic events. The regulatory review process was also appropriate.
4. A positive aspect that was noted in this area was the training that was conducted with the workers outside and exposed to the hypothetical conditions of extreme natural events, (i.e., flooding, typhoon and so on). This activity was clearly based on lessons learned from Fukushima accident, even though it is outside the scope of the stress tests assessment. Regardless, the independent expert suggests that TPC continue to implement such training periodically. **[Strength: Training that was conducted with the workers outside provided limited simulation of conditions associated with extreme weather (see Section 6.3.1 of this report for a related technical observation).]**

5. Loss of Electrical Power and Loss of Ultimate Heat Sink Evaluation (Mr. Mel Fields)

This section of the report covers the consequences of the loss of electrical power and/or loss of UHS when faced with the extreme situations envisaged in the EU Stress Test Specifications. These combinations include:

1. The loss of offsite electrical power, including loss of normal backup emergency alternating current (AC) generators (defined as an SBO), followed by loss of other sources of emergency AC generators.
2. The loss of the UHS
3. The combination of both the loss of all electrical power and the UHS

Following the ENSREG stress test specification, the assessment of the consequences of the loss of these safety functions considers situations in which indirect initiating events, for instance large disturbances to the electrical power grid impacting the AC electrical power distribution systems, forest fires, airplane crashes, and others events, that result in a loss of electrical power and/or the ultimate heat sink. In essence, the loss of these safety functions should be considered regardless of the event that contributes to the loss of electrical power and the ultimate heat sink.

5.1 Overview of Safety Enhancements from Stress Test for Loss of Safety Functions

This section of the report provides a brief overview of the safety enhancements that have been implemented, are being implemented, or for which definitive plans have been committed to implement enhancements at the operating reactors in Chinese Taipei to address lessons learned from the stress test evaluation in light of the accident at Fukushima Daiichi NPP.

The licensing basis of the operating plants in Chinese Taipei is based on the United States of America regulatory requirements contained in Title 10 of the *Code of Federal Regulations* (10 CFR). Each site has multiple transmission lines that provide offsite power to normal and emergency plant loads. In the event of loss of normal sources of offsite power to the onsite power system, each unit has two EDGs that will start and be put in service automatically. In the case of a loss of off-site power and a loss of the EDGs identified above (SBO), each site has a swing diesel generator and two air-cooled gas turbine generators that can be used as diverse emergency power sources. Each of the Kuosheng units has a third EDG dedicated to the high pressure core spray system and each of the Maanshan units has a diesel-driven auxiliary feedwater pump.

Based on the lessons learned from the accident at Fukushima Daiichi NPP, the following enhancements to the electrical power systems for the operating plants in Chinese Taipei have been implemented:

1. The swing diesel generator can now supply the necessary emergency loads for both units simultaneously.
2. The two black-start diesel generators used to start the two gas turbine generators can now supply the necessary emergency loads for both units simultaneously.
3. An additional 4.16 kV power vehicle has been provided to each site that can supply the necessary emergency loads for both units simultaneously.

4. Multiple sets of 480 V portable DGs have been procured for each site to power the emergency 480 V buses.

It is worth noting that the diesel generators identified in the plant enhancement discussions are air cooled, and therefore do not require the operability of the ultimate heat sink.

In addition to the completed enhancements identified above, the licensee has committed to extend the coping time of direct current (DC) power in response to SBO events from 8 hours to 24 hours.

There are several fuel supply sources for the diesel and gas turbine generators described above. For example, the safety grade common fuel oil storage tank at the Chinshan NPP can provide sufficient fuel to run all four EDGs continuously for 17 days. For Kuosheng NPP and Maanshan NPP, dedicated safety grade fuel oil storage tanks can support each EDG continuous running for 7 days. The gas turbine fuel storage tanks at each site can support long-term operation of the gas turbine generators. For example, the capacity of the gas turbine fuel storage tank at the Kuosheng NPP is enough for two gas turbine generators to run continuously 72 days at full load. Each site also has means of transferring fuel between tanks and has established protocols for obtaining fuel from off-site sources.

The normal and emergency UHSs for each site take suction from the sea. If normal UHS is not available, the safety grade emergency UHS is designed to remove decay heat loads for the purpose of maintaining the reactors in a safe shutdown condition and maintaining the spent fuel pools in a stable and cooled condition.

Based on the lessons learned from the accident at Fukushima Daiichi NPP, the following enhancements to provide alternative sources of cooling water for the operating plants in Chinese Taipei have been implemented:

1. Developed transportation and injection procedures for all water resources available, both onsite and offsite.
2. Verified sufficient redundancy of fire engine resources and portable fire pumps.
3. Developed schemes of alternative reactor water injection and spent fuel pool water injection using various injection paths.
4. Developed schemes for alternate heat sink and recovery of ultimate heat sink.
5. Procured portable air compressors and spare nitrogen bottles for safety relief valves and air-operated valves.

5.2 Independent Peer Review Effort for Loss of Safety Functions

During the independent peer review, the expert reviewed the Chinese Taipei AEC Stress Test National Report for Nuclear Power Plants, and the site specific stress test reports prepared by TPC. Specifically, the independent expert reviewed the following documents during the independent peer review:

1. Section 5 of the AEC Stress Test National Report for Nuclear Power Plants, “Loss of electrical power and loss of ultimate heat sink”
2. Section 5 of the TPC EU Stress Test for CHINSHAN NPP – Licensee Report, “Loss of electrical power and loss of ultimate heat sink”

3. Section 5 of the TPC EU Stress Test for KUOSHENG NPP – Licensee Report, "Loss of electrical power and loss of ultimate heat sink"
4. Section 5 of the TPC EU Stress Test for MAANSHAN NPP – Licensee Report, "Loss of electrical power and loss of ultimate heat sink"

In addition, to reviewing these documents, the independent expert met with technical experts from the AEC and TPC to discuss the assessment of the licensees' evaluations by the regulatory authority and the technical evaluations conducted by the licensee.

During the site visit to the Kuosheng NPP, the safety enhancements identified in Section 5.1 above were observed by the independent expert.

5.3 Independent Peer Review Issues on the Loss of Safety Functions

The independent expert requested additional information from AEC and TPC to obtain a comprehensive understanding of the results of the stress tests performed for the Chinese Taipei operating nuclear power plants. The responses confirmed that the actions discussed in the individual stress test reports and the recommendations described in the AEC Stress Test National Report were either complete or had dates established for completion. As an example, the National Report included statements that TPC should address action items in the USNRC NTTF Report. TPC's response provided the details of how these action items were progressing at the sites. Other issues discussed during the review included:

1. Verification that all required independence and isolation electrical design features of safety systems were maintained during the plant modifications to allow the use of alternative AC power sources to provide backup power.
2. Verification that upgrades to the DC power capacity from 8 hour to 24 hour capacity would be implemented for Maanshan and Kuosheng (already complete for Chinshan).
3. Verification that the "cliff edge" results presented in the stress test reports were based on the operating plants as built and operated as of June 30, 2011.
4. Provided "cliff edge" results for the Chinshan and Maanshan spent fuel pools (already provided for Kuosheng). Assuming the most limiting fuel loading pattern and no recovery actions, the time for the hottest fuel cladding to reach degradation temperature is approximately 90 hours for Chinshan and 101 hours for Maanshan.
5. Demonstration during the site visit that reasonable precautions have been taken to assure safe connections of portable AC power supplies to plant equipment during adverse weather conditions.
6. Discussion of containment venting strategy for the BWR units to support alternative reactor cooling injection options. One of the cooling strategies for BWR plants when normal sources of AC power are not available is to use either fire trucks or gravity feed from onsite water tanks to inject water into the reactor vessel. Part of this strategy involves containment venting to assure the equipment can overcome the backpressure that would be associated with high containment pressures. To support this strategy, TPC has included procedural steps in the URGs (see Section 6 of this report) to open the motor-driven isolation valve in the containment vent system to assure its availability. TPC discussed the implications of this action to the satisfaction of the independent expert, describing how the motor-driven valve could

be closed using portable AC power sources if necessary, and verifying that both the motor and air-operated containment isolation valves would be able to open and close against expected containment pressures. It should be noted that opening of the motor-driven isolation valve in the containment vent system would only occur when plant conditions warrant entry into the URGs.

7. Discussions of the implications of RCP shaft seal leakage for the Maanshan units. For typical PWR plant designs, leakage through RCP shaft seals is an issue for SBO scenarios because the plant design does not support injecting coolant into the reactor primary system without AC power before the primary system has been depressurized. The analysis presented in Section 5.1.5.2 of the Maanshan Stress Test Report assumed RCP shaft seal leakage occurred 8 hours after SBO and that the total leakage through the three seals would be 63 gallons per minute (gpm). The results of this analysis showed that the plant operators would have approximately 18 hours to effect recovery actions before fuel temperatures began to increase rapidly. The independent expert questioned the use of these seal leakage assumptions and it was revealed that these values were not consistent with the values used in the FSAR design basis calculations. TPC re-analysed the response of the Maanshan units for SBO conditions using the FSAR values (leakage beginning 10 minutes after SBO and total leakage of 75 gpm). The results of this analysis showed that the plant operators would have approximately 9 hours to effect recovery actions before fuel temperatures began to increase rapidly. TPC discussed the measures available (e.g., using Emergency Operating Procedures to depressurize the primary system and alternative AC power sources to inject coolant into the primary system) to effectively maintain the core in a safe condition within this time frame to the satisfaction of the independent expert. The expert did note that, in general, FSAR design values should be used to analyse system responses unless a thorough and systematic process is followed to justify using more realistic values.

5.4 Peer Review Observations in the Area of Loss of Safety Functions

The content of the individual stress test reports is consistent with the EU Stress Test Specifications in that sources of electrical power and cooling water/ultimate heat sinks were sequentially assumed to be defeated, all operational states were considered, and all reactors and spent fuel storage facilities at the site were assumed to be impacted at the same time.

The AEC and TPC have taken a number of proactive actions to improve the availability of multiple sources of electrical power and multiple sources of cooling water. In addition, the results of the “cliff edge” analyses show that the plant operators will have a reasonable amount of time to prevent reactor core and spent fuel damage. For example, reactor core isolation cooling (RCIC) in the BWR units, which does not require AC power, can be maintained until alternative means of injecting water into the reactor system can be accomplished. TPC has performed calculations and conducted drills to demonstrate that these alternate sources (fire trucks, for example) can effectively supply water to the primary system well before RCIC would be lost due to low steam pressure.

The EU Stress Test Specifications state that the site should be evaluated assuming it is isolated from offsite deliveries by road, rail, or waterways for 72 hours that could assist in the recovery from loss of offsite power and/or loss of the ultimate heat sink. Portable light equipment could arrive to the site after the first 24 hours. The capabilities of the

Chinese Taipei operating nuclear power plant sites to operate using onsite fuel and water sources significantly exceed this 72 hour criteria. Section 5.1 of this report discusses the extent of diesel fuel available to the diesel and gas turbine generators and also discusses the diverse methods of obtaining water from alternate sources. **[Strength: Availability of fuel supplies, water supplies, and other associated supplies, to maintain the plants in a safe shutdown condition substantially exceeds the Stress Test expectations.]**

6. Severe Accident Management (Dr. Hitoshi Muta)

This section of the report covers the independent peer review of the severe accident management aspects of the stress test.

Following the ENSREG stress test specification, the assessment of the severe accident management considers verification whether necessary organization structure, guidelines, systems or components, procedures of operation and plans of training of severe accident management are in place and they are effective for all of NPPs. Included within the scope of the stress test in the area of severe accident management were the following issues:

1. The means to protect from and to manage the loss of the core cooling function.
2. The means to protect from and to manage the loss of cooling function in the fuel storage pool.
3. The means to protect from and to manage the loss of containment integrity.

In the severe accident management area, while the stress test review was to focus on the licensee's onsite provisions, it could also include relevant planned off-site support for maintaining the safety functions of the plant.

6.1 Overview of Safety Enhancements for Severe Accident Management

This section of the report provides a brief overview of the safety enhancements that have been implemented, are being implemented, or for which definitive plans have been committed to implement enhancements at the operating reactors in Chinese Taipei to address lessons learned from the stress test evaluation in light of the accident at Fukushima Daiichi NPP. In the area of severe accident management, TPC has committed to making the following enhancements:

1. Establishing an organization structure including Accident Management Teams, on-site technical support centres and an off-site technical support centre with support from the National Nuclear Emergency Organization at a national level and the Emergency Organization at the TPC headquarters office at the company level, to manage severe accident.
2. Developing and implementing URGs that are implemented in 3 phases, consisting of phase-1 that are tasks to restore or verify the core cooling function within 1 hour; phase-2 that are tasks to restore or verify the supporting functions for continuous core cooling within 8 hours; and phase-3 that are tasks to restore or verify the long term decay heat removal function within 36 hours. The goal is to eliminate core damage event sequences when implemented and to work in conjunction with SAMGs.

3. Enhancing severe accident management measures by developing and implementing alternative power supply systems, injection systems, and supporting system including water and air supplies.
4. Developing and implementing severe accident management measures for spent fuel pool events to prevent fuel damage using alternative cooling measures and to mitigate releasing radioactive materials.

6.2. Independent Peer Review Effort for Severe Accident Management

During the independent peer review, the expert reviewed the National Report prepared by the AEC and the site-specific Stress Test Reports prepared by TPC. Specifically, the independent expert reviewed the following documents during the independent peer review:

1. Section 6 of the AEC Stress Test National Report for Nuclear Power Plants, "Severe Accident Management"
2. Section 6 of the TPC EU Stress Test for CHINSHAN NPP – Licensee Report, "Severe Accident Management"
3. Section 6 of the TPC EU Stress Test for KUOSHENG NPP – Licensee Report, "Severe Accident Management"
4. Section 6 of the TPC EU Stress Test for MAANSHAN NPP – Licensee Report, "Severe Accident Management"

In addition, to reviewing these documents, the independent expert met with technical experts from the AEC and TPC to discuss the assessment of the licensees' evaluations by the regulatory authority and the technical evaluations conducted by the licensee.

During the site visit to the Kuosheng NPP, a number of safety enhancements that were either implemented or in the process of being implemented were observed, including:

1. 4.16kV power vehicles, black start diesel generators, 480V portable diesel generators and portable generators.
2. Fire trucks, fire pumps and gravity driven injection line from raw water reservoir with two independent injection lines.
3. Establishing several water sources such as raw water reservoir on the hill, creek in the power station and sea.
4. Hook-up points for power, water and air supply.
5. Alternative components for replacement of ECW.
6. Air supply connection for depressurization of the reactor pressure vessel (RPV).
7. Configuration of components related to primary containment early venting.

6.3 Independent Peer Review Issues on Severe Accident Management

In General, the independent experts found that the AEC followed the specification of ENSREG stress test to review the national report. The approach included the evaluation of severe accident management including the necessary organizational structure, accident management guidelines, systems or components used for accident management response, procedures for operation of the equipment for accident management response, and plans for training. The independent expert found that the activities of TPC and AEC in this area were generally appropriate and consistent with the requirements of the stress test as implemented in Chinese Taipei.

Based on the reviews conducted by the independent expert in this area, the following areas were discussed with TPC and AEC.

6.3.1 Enhancement of Severe Accident Management Measures

After Fukushima Daiichi NPP accident, the AEC issued its "Program for Safety Re-assessment" on 19 April 2011. Following the AEC requirements TPC did a re-assessment in the following areas related to severe accident management:

1. Capability for Loss of AC power (SBO)
2. Cooling of spent fuel pool
3. Capability of heat removal and ultimate heat sink
4. Re-evaluation of Emergency Operating Procedures (EOPs)
5. Implementing Ultimate Response Guidelines (URGs)
6. Support between different units
7. Mitigation beyond design basis accidents (DBAs)
8. Preparedness and backup equipment

In each of these areas, TPC implemented various measures to address both prevention and mitigation of severe accidents including such measures as alternative mobile diesel generators, procurement of portable generators, the use of fire trucks or portable pumps for cooling water supplies, providing alternative water sources including sea water, providing alternative air supplies for safety relief valves (SRVs), among other measures to enhance safety. **[Strength: There is a large diversity and amount of mobile equipment for responding to a severe accident (see loss of electrical power and UHS).]**

Technical Observation: The storage of mobile equipment for severe accident management response is at one location at Kuosheng NPP.

During the review at the Kuosheng NPP, the independent expert noted that some of equipment, for example mobile diesel generators and fire trucks, are located in separated places from each other. However, four 480V portable generators and numbers of fire pump that are to be used for responding to beyond design basis events are stored in a single warehouse. From a defence-in-depth perspective this could provide for a common cause failure of all components in single event. TPC should consider storing some of the components separately in another warehouse.

Technical Observation: Training has been conducted for severe accident management strategies; however, this training could be enhanced by better simulating extreme weather conditions (see also Section 4.4).

There are effective plans for training in the area of severe accident management, including the use of URGs. Further, TPC has conducted training frequently enough to manage severe accident response of plant personnel. Recognizing, it is difficult to simulate actual situations that may be encountered by extreme weather conditions and widespread and significant infrastructure damaged simultaneously with a severe accident, the independent experts believes that training could be enhanced by better simulating extreme weather conditions building on the experiences from other industries or from training provided to first responders to an accident (i.e., fire fighters, military personnel, etc.).

6.3.2 Ultimate Response Guidelines (URGs)

Implementing the URGs is one of the essential enhancements discussed in the National Report. After the Fukushima Daiichi NPP accident, TPC developed and implemented plant specific URGs for each operating plant to prevent core damage assuming the situation encountered at the Fukushima Daiichi NPP units 1 through 3. The entry conditions for the URGs are clearly defined as:

1. The loss of all of reactor water supply systems
2. A complete station blackout (loss of all AC power)
3. A beyond design base earthquake and tsunami have affected the site

Although the URGs are event-based guidelines, there could be a little confusion on how they are to be used in conjunction with EOPs and SAMGs. The purpose of URGs is to maintain reactor core safety and containment integrity, which is same purpose for EOPs. So this independent expert requested clarification on the URGs' relationship to the EOPs. Based on discussions between the independent expert and TPC, the relationship among these procedures and guidelines were clarified as follows:

1. Before the plant reaches the entry condition of the URGs, EOPs are usually followed to manage the event. But once the plant reaches the entry condition of the URGs, the URG is followed to manage the event instead of the EOPs.
2. The URGs have several kinds of procedures to prepare ultimate responses such as depressurization of the RPV, reactor core injection, early primary containment venting and spent fuel pool makeup or spray among others.
3. In the case that URG procedures fail to secure the core cooling function or other functions, the EOPs will be re-introduced to manage the event. As necessary, SAMGs will be introduced to manage a severe accident should they be required.

The most positive aspect noted in the severe accident management area is establishing URGs to deal with the emergency situation such as loss of all of reactor water supply systems, station blackout and beyond design base earthquakes and tsunamis. This activity is clearly based on lessons learned from Fukushima accident. **[Strength: The URGs deal with emergency situations such as loss of all of reactor water supply systems, station blackout and beyond design basis earthquakes and tsunamis.]**

6.3.3 Scope of Severe Accident Management

To establish effective severe accident management, it is necessary to consider certain scenarios that need strategies and measures to prevent and mitigate the consequences of a severe accident. With this in mind it is important to clarify which severe accident scenarios need to be considered when developing accident management responses.

Based on discussions with the AEC and TPC, it was clarified to the independent expert that insights from Level 1 and 2 PRA results were used and referenced to identify dominant accident sequences and containment failure modes to establish severe accident management strategies. Moving forward, TPC is carrying out upgrades to the PRA model and incorporating recent experience that will include internal and external events. Further it is considering Level 1 and 2 PRAs for rated power and shutdown conditions.

Technical Observation: Continuous improvement of site specific PRAs could be used to provide better insights for severe accident management including extending the PRA scope to plant shutdown

When the Level 1 and 2 PRAs are completed, it is expected that TPC will reflect any new insights gained into its severe accident management strategies. Continuous improvement of site specific PRAs should be used to provide better insights to develop and implement severe accident management strategies. This should include insights gained by extending the PRA scope to plant shutdown conditions to manage severe accidents that could occur when a plant is shutdown.

6.3.4 Severe Accident Management Measures for Spent Fuel Pools (SFPs)

The accident at Fukushima Daiichi NPP highlighted the potential for accidents to occur in the SFPs at the same time as an accident in the reactor. As such, it is important that severe accident management strategies be developed and implemented for the loss of cooling to the SFPs.

The independent expert discussed with AEC and TPC the severe accident management strategies that TPC has in place for SFP loss of cooling. Based on the discussions with the AEC and TPC, it was clarified that there is enough time for TPC to manage the event because the water temperature of SFP will increase slowly. From the discussions the independent expert understood that there are more than 10 hours before boiling would occur in the SFP and that it would be more than 5 days to reach the top of active fuel (TAF). Using this information, TPC has developed and implemented URGs to deal with severe accident situations for both the reactors and the SFPs.

During the visit to the Kuosheng NPP, TPC explained and walked the independent expert through the alternative coolant injection measures for the SFP using fire hoses and newly installed piping and the use of the SFP spray line. Moreover, at the Kuosheng NPP inject water into the SFP using fire trucks through the entrance gate of the SFP building is possible, and easier than the other sites, because the SFP is located at ground level at Kuosheng NPP.

The independent expert noted that there are several alternative spent fuel pool cooling backups and are sufficient to manage a severe situation in the SFP. In addition, the use of the spray header provides for mitigating releasing radioactive materials in addition to cooling the spent fuel if the pool is drained below the TAF. The independent expert considers this to be a strength in TPC's severe accident management strategies for the loss of SFP cooling. **[Strength: Several alternative spent fuel pool cooling backups and installed spray header for mitigating radioactive material release.]**

7. Conclusions

The Stress Tests performed by TPC and the National Report prepared by the AEC reflect a very good understanding of seismic issues related to operating NPPs. The stress test exercise has clearly succeeded in identifying the seismic issues that need to be further addressed and resolved. The NPP Reports and the National Report are good examples of what needs to be included and highlighted in a stress test report. The interfaces of seismic with extreme plant states is also included in the stress test reports. Continuing forward the AEC and TPC should further develop the areas that are identified in the stress test reports (e.g. PSHA using the SSHAC Level 3 approach) and should consider the technical observations noted above in the seismic area as it develops and implements their plans of actions in response to the stress test results.

Implementation of the stress test in the area of flooding is consistent with the ENSREG criteria. As a result of the stress test and subsequent AEC orders, TPC has implemented or is planning to implement several flooding-related enhancements at all three NPPs (e.g. adding tsunami walls, backup power sources, portable pumps, issuing emergency procedures, etc.). After independently reviewing and verifying the results of the stress test, it is concluded that consequences similar to those experienced at Fukushima Daiichi NPPs are unlikely to occur at Chinese Taipei's NPPs as a result of Fukushima Daiichi NPP-type of event.

In the area of other extreme hazards, the TPC's evaluations as well as the AEC's reviews were implemented along the ENSREG stress test specifications and their reports were summarized following the EU stress test process. A strength observed was the training that was conducted with the workers outside the buildings and exposed to the hypothetical conditions of extreme natural events, e.g., flooding, typhoon and so on. While not within the scope of the stress test, this training is a practical response to the lessons learned from Fukushima NPP accident. TPC is encouraged to continue to implement such training periodically to enhance the safety of all its nuclear power plants.

A **stress test recommendation** made by the independent peer review team is that TPC and AEC need to consider systematically assessing the combinations of events in the areas of flooding and extreme natural events included within the scope of the stress test. After this is performed, and as appropriate, TPC should re-evaluate for potential cliff edge effects and identify safety enhancements to address any new weakness found.

With regard to the loss of electrical power and the ultimate heat sink, the content of the individual stress test reports is consistent with the ENSREG stress test specifications in that sources of electrical power and cooling water/ultimate heat sinks were sequentially assumed to be defeated, all operational states were considered, and all reactors and spent fuel storage facilities at the site were assumed to be impacted at the same time. The AEC and TPC have taken a number of proactive actions to improve the availability of multiple sources of electrical power and multiple sources of cooling water. In addition, the results of the "cliff edge" analyses show that the plant operators will have a reasonable amount of time to prevent reactor core and spent fuel damage. For example, RCIC in the BWR units, which does not require AC power, can be maintained until alternative means of injecting water into the reactor system can be accomplished. TPC has performed calculations and conducted drills to demonstrate that these alternate sources (fire trucks, for example) can effectively supply water to the primary system well before RCIC would be lost due to low steam pressure.

The EU stress test specifications state that the site should be evaluated assuming it is isolated from offsite deliveries by road, rail, or waterways for 72 hours that could assist in the recovery from loss of offsite power and/or loss of the ultimate heat sink. Portable light equipment could arrive to the site after the first 24 hours. **An observed strength** was that the capabilities of the Chinese Taipei operating nuclear power plant sites to operate using onsite fuel and water sources significantly exceed this 72 hour criteria. Section 5.1 of this report discusses the extent of diesel fuel available to the diesel and gas turbine generators and also discusses the diverse methods of obtaining water from alternate sources.

In the area of severe accident management, TPC's evaluations as well as the AEC's reviews were implemented along the ENSREG stress tests specifications and their reports followed the EU stress test process. **An observed strength** was the development and implementation of the Ultimate Response Guidelines that is a practical response to the lessons learned from Fukushima Daiichi NPP accident. TPC is encouraged to continue to enhance severe accident management based on PRA improvement for all of nuclear power plants in Chinese Taipei.

Based on the reviews of the National Report and the Stress Test reports for Chinshan, Kuosheng, and Maanshan NPPs, the independent peer review team concluded that the stress test met the criteria established by ENSREG and followed by the EU for the stress tests of NPPs in Europe. Building on the results of the stress test and insights from the actions being taken by other countries, the AEC established clear requirements to implement enhancements. Based on the observations by the independent peer review team, it is concluded that the AEC and TPC effectively implemented a comprehensive safety review that has resulted in significant enhancements that have better prepared the operating reactors in Chinese Taipei to respond to extreme external events and severe accidents should they occur.

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9. List of Acronyms

1. 10 CFR - United States Title 10 of the *Code of Federal Regulations*
2. AC - alternating current
3. AEC - Atomic Energy Council
4. BDBE - beyond design basis earthquake
5. BWR - boiling water reactor
6. CDF - core damage frequency
7. DBAs - design basis accidents
8. DBF - design basis flood
9. DBT - design basis tsunami
10. DC - direct current
11. ECW - essential components cooling water system
12. EDGs - emergency diesel generators
13. EDMGs - extensive damage mitigation guidelines
14. ENSREG - European Nuclear Safety Regulators' Group
15. EOPs - emergency operating procedures
16. EU - European Union
17. FSAR - Final Safety Analysis Report
18. HCLPF – High Consequence Low Probability of Failure
19. MCC - motor control centre
20. NEA - Nuclear Energy Agency
21. NPPs - Nuclear Power Plants
22. NSC - Chinese Taipei’s National Science Council
23. NTTF Report - USNRC Near Term Task Force Report
24. OECD - Organisation for Economic Cooperation and Development
25. PAR - passive autocatalytic recombiners
26. PMP - probable maximum precipitation
27. PMT - probable maximum tsunami
28. PRA - probabilistic risk assessment
29. PSA - probabilistic safety assessment
30. PSHA - probabilistic seismic hazard analysis
31. PWR - pressurized water reactor
32. RCIC - reactor core isolation cooling system
33. RCP - reactor coolant pump
34. RG - USNRC Regulatory Guide
35. RLE - Review Level Earthquake
36. RPV - reactor pressure vessel

37. SAMGs - severe accident management guidelines
38. SBO - Station blackout
39. SFP - spent fuel pool
40. SSCs - structures, systems and components
41. SSE - shutdown earthquake
42. SMA - seismic margin analysis
43. SPSA - seismic probabilistic safety assessment
44. SRVs - safety relief valves
45. SSHAC - Senior Seismic Hazard Analysis Committee
46. TAF - top of active fuel
47. TPC - TaiPower Company
48. TSC - technical support centre
49. UHS - ultimate heat sink
50. URGs - ultimate response guidelines
51. USNRC - United States Nuclear Regulatory Commission