出國報告（出國類別：其他）

赴捷克布拉格參加第二十二屆國際核能工程研討會出國報告

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摘 要

「第二十二屆國際核能工程研討會」(22th International Conference on Nuclear Engineering, ICONE-22)於 2014 年 7 月 7 至 7 月 11 日在捷克布拉格舉行。本項研討會舉行的目的，希望能藉由核能技術與運轉經驗的持續密切交流，以提昇核能電廠的安全性與穩定性。本次研討會共分成二十項議題來進行討論。依據大會報告預估有六百多位學者參與盛會，共發表超過 600 篇的相關研究論文，內容從經驗分享到理論的研究都涵蓋在內，提供了一個與各國核能技術及經驗交流相當好的機會。日本核能政策，乃藉由節能、利用再生能源，及改善熱能發電效率，降低對核能發電的依賴。並以穩定供電、節省成本、全球暖化，以及維持核能技術與人力等因素，謹慎評估核能發電量。

福島事故後最嚴重的問題是民眾失去對核能的信心，而對於重建公眾信心，其作法為重新建立互信，以及確認相關人員或單位的責任包括持照者/經營者、主管機關、專家/學術界、政府、大眾/當地民眾、大眾傳播媒體。持照者/經營者的責任為確保核能機組安裝與運轉期間的核能安全，經營者自願與主動增加安全性的行為是關鍵的，而第三方的監督對確保經營者活動是必要的。核研所未來改隸屬經濟能源部後， 建議檢證中心可擔任第三方監督或公正單位。

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一、 目的

核能電廠運轉安全長期受到各界關注，自從日本福島事故後，又瞬間成為全球關心的焦點。國內核能電廠的安全當然也受到民眾高度重視，而其中良好的設備維護，對核能機組安全具有關鍵性的影響。核能電廠安全相關結構、系統及組件所使用的核能級產品，其主要功能為確保：(1)反應器冷卻水壓力邊界之完整性；(2)反應器停機並處於安全停機狀況；(3)放射性物質外洩量不超出法規限值。因此這些核能級產品都必須經過嚴格的驗證與品保程序，產生並維持完整的驗證文件，證明其能發揮安全功能。

本所執行「核一廠西屋 TYPE-W 馬達控制中心驗證工作」計畫，將馬達控制中心配電盤檢證與驗證相關技術，於國際會議中發表 1 篇論文。為掌握國際發展趨勢，研擬未來研發策略，促進國際交流與合作，以及提升本所的國際能見度，乃參加 ASME 於捷克舉辦之第二十二屆核能工程國際研討會。ASME ICONE 22 為國際上最重要的核能技術研討會之一，其主題一為核電廠運轉維護、工程改善、老化管理等。國際有關電廠延役與除役技術、安全分析、測試驗證等都會在此主題發表，另外核能品保精進與法規修訂也有專題討論，對目前本所執行中的核一、核二、核三廠整體安全評估與電氣設備老化評估，以及檢證技術精進與落實都非常有幫助。

本項研討會舉行的目的，希望能藉由核能技術與運轉經驗的持續密切交流，以提昇核能電廠的安全性與穩定性。本次研討會共分成二十項議題來進行討論（如下表一所示）。有六百多位學者參與盛會，共發表超過 600 篇的相關研究論文，內容從經驗分享到理論的研究都

涵蓋在內。

表一：ICONE22 的討論議題

TRK 1	Plant Operations, Maintenance, Engineering, Modifications, Life Cycle and Balance of Plant
TRK 2	Nuclear Fuel and Materials
TRK 3	Plant Systems, Structures and Components
TRK 4	Radiation Protection and Nuclear Technology Applications
TRK 5	Next Generation Reactors and Advanced Reactors
TRK 6	Nuclear Safety and Security
TRK 7	Codes, Standards, Licensing and Regulatory Issues
TRK 8	Fuel Cycle, Radioactive Waste Management and Decommissioning
TRK 9	Thermal Hydraulics
TRK 10	Computational Fluid Dynamics (CFD) and Coupled Codes
TRK 11	Reactor Physics and Transport Theory
TRK 12	Nuclear Education, Public Acceptance and Related Issues
TRK 13	Instrumentation and Controls (I&C)
TRK 14	Fusion Engineering
TRK 15	Beyond Design Basis Events
TRK 16	Innovative Nuclear Power Plant Design and New Technology Application
TRK 17	Student Paper Competition
TRK 18	Industry Forum: Keynote, Plenary, and Panel Sessions
TRK 19	Workshops and Professional Development Seminar
TRK 20	Nuclear Codes & Standards Workshop

二、 過程

日期	起迄地點	概要說明
7 月 5-6 日	桃園→捷克布拉格	去程
7 月 7 日	捷克布拉格	會議報到
7 月 8-11 日	捷克布拉格	開幕式及 ICONE 研討會
7 月 12-13 日	捷克布拉格→桃園	返回桃園

國際核工程大會(International Conference On Nuclear Engineering, ICONE)是由美國機械工程師學會(American Society of Mechanical Engineers, ASME)、日本機械工程師學會 (Japan Society of Mechanical Engineers, JSME)和中國核學會(China Nuclear Energy Association, CNS)共同主辦的大型國際核能工程會議。自從 1991 年首屆在日本東京舉辦以來，迄今已邁入第二十二屆，幾乎每屆的會議都吸引了世界各地從事核能相關領域的專家學者進行交流，可說是核工界的一大盛事。下屆會議 ICONE 23 將於 2015 年 5 月 17-20 日，在日本千葉暮張(Chiba Makuhari)舉行。在此同地點，第四代核能國際論壇(Generation IV International Forum, GIF)也於 5 月 18-20 日舉行。

今年的研討會，在美國機械工程師學會理事長 J. Robert Sims、日本原子力研究開發機構(JAEA)執行長 Hiroshi Uetsuka、中國核學會 Lixin Shen 等的引言之下，為 ICONE-22 拉開序幕，如圖一所示。

圖一 ICONE 22 研討會場實景

在研討會開始第一天 7 月 7 日為報到日，而這天也有舉辦特定議題的研討會，不過需要另外付費。7 月 7-8 日，美國機械工程師學會與捷克核研所(UJV Rez)聯合舉辦為期二天的「ASME 核規範與標準研討會」(ASME Nuclear Codes and Standards)，會中介紹 ASME 的立場、核能標準及其認證項目。研討會共有 7 個主題，每個主題為半天，費用 30 歐元。簡要摘述如下：美國機械工程師學會(ASME)成立於 1880 年，其成立的宗旨在於建立技術資料、舉辦國際研討會以及發行工業製造規範標準等。其中與核能電廠關係最密切的部分，就屬「ASME 鍋爐及壓力容器規章」(Boiler and Pressure Vessel Code, BPV Code)的部分，這部分的內容因為被聯邦法規所引用而具有法律效力，其他法規指引所引用之規章雖然不具法律效力，但仍是管制單位所強列建議之檢查方法或者是操作規程，大多數電廠都將所使用之規章列於電廠之終期安全分析報告書(FSAR)上；會中管制單位、運轉單位及研究單位的人員，也就此項標準的施行及管制經驗進行討論及交

流。

研討會最受關注重點，就是日本福島事故經驗回饋與後續發展。大會邀請日本原子力產業協會(JAIF) Takuya Hattori 簡報 Nuclear Power after Fukushima。日本福島事故發生於 2011.03.11 至今已有 1200 天，目前有 13000 當地居民被疏散，仍處於困境。日本政府於今年 4 月訂定新的能源政策，即所謂 3E+S。其中 3E 為能源安全(Energy Security)、經濟效率(Economic Efficiency)、環境(Environment)，而 S 為安全(Safety)包括建構多層、多樣化，以及彈性的能源供應結構，而核能是其中重要的基載電力。福島事故後最嚴重的問題是民眾失去對核能的信心，以及當地公共事業瓦解。依據 USNRC 2013 年報告，福島事故並無造成急性的健康影響(如急性輻射併發症或確定效應)，自福島後觀察員工及居民皆無因輻射暴露而有引響。至目前為止，最重大的健康影響是心理健康及社會和諧。福島核電廠處理現況為執行阻止地下水洩漏進入廠房的預防措施，淨化汙水並儲存於儲存槽中，而且周圍環境去汙也正在進行中，以及受損的反應爐正進行除役。因應所有核電廠的停機，其後續影響包括重啟老舊的石化燃料火力電廠，原油與天然氣進口急遽上升，依賴中東的化石燃料上升到 88%，額外支出購買原油，碳排放量增加 9%，電價增加 20%等。日本核電廠已有 19 座申請重啟，目前管理機關以新的法規進行安全評估，預計今年稍晚重啟核電廠，但尚不清楚何時，以及多少座核電廠會重啟。依據日本共同通訊社對重啟核電廠的民意調查，目前仍有 56%過半數的反對意見。另一家日本讀賣新聞，調查 57%的反對意見，其結果相近。日本核能政策，乃藉由節能、引用再生能源，及改善熱能發電效率，降低對核能發電的依賴。以穩定供電、節省成本、全球暖化，以及維持核能技術與人力等因素，謹慎評估核能發電量。

對於重建公眾信心，其作法為重新建立互信，以及確認相關人員或單位的責任包括持照者/經營者、主管機關、專家/學術界、政府、大眾/當地民眾、大眾傳播媒體。持照者/經營者的責任為安裝期間的核能設備安全，經營者自願與主動增加安全性的行為是關鍵的，第三方的監督對確保經營者活動是必要的。主管機關的責任為獨立性。確保核能管制與核能應用推廣的單位有效區隔。美國 USNRC 的優良管制原則為獨立、公開、效率、清晰與可靠。專家/學術界責任為提供政策規劃者和決策者的科學建議，並獲得大眾對專家的信心與信任。重建公眾信心可能解決方法為由經營者主動增加安全性，並由獨立組織(單位)監督。風險溝通在打破安全神話時是很重要的，而公開透明在公共關係中是最重要因素。最後，日本在全球核能發展角色為分享福島經驗與加強全球核電安全性，促進國際合作於福島損壞反應爐的除役工作，提供正在發展核能國家的支持與協助，致力於確保不擴散核武和核能安全的國際制度，以及帶領國際核能創新研發計畫等。

在會場展示方面，主要有美國西屋公司(Westinghouse)、日本東芝(Toshiba)、大陸國立核電技術公司(SNPTC)等三家廠商。西屋公司持續推廣 AP1000 機組，強調簡單、安全、創新。AP1000 吸取過去 50 年核能機組設計與運轉經驗，採用精簡卻擁有高可靠度的設計，大量減少了安全設備使用，如此也有利於降低運轉維護費用。在安全方面，目前電廠設計其爐心熔毀機率(CDF)約為 5E-05，而 AP1000 的安全提升至爐心熔毀機率 1E-07。在創新方面，仍強調其無須人員操作人員與電力的被動安全系統。雖然 AP1000 已經推廣了好幾年了，大陸也引進並創新改良。不過，當今 AP1000 仍為最受重視且已經逐漸成熟的核能機組。日本東芝展示的 ABWR1000 與龍門電廠同型，此型機組在 2010 年於大陸舉辦 ICONE 18 時展示過，所以比較沒有特殊性。現場反而熱烈討論福島事故處理，以及除役相關工作。畢竟這次日本派員參加

ICONE 22 的專家大多屬這方面的領域。大陸國立核電技術公司主要展示以模組化建造核電廠，大陸在這方面是全世界的先驅。另外，該公司也負責承接 AP1000 的相關技術，並加改良成更大容量的核能機組，目的在建立自主的第 III^+ 的核能機組設計製造技術。

研討會另外的一個重點，在於日本福島核電廠的除役規劃進度，以及相關技術。美國三哩島(TMI)核電廠事故，其受損燃料仍在反應爐內且圍阻體功能完整。日本福島核電廠事故的反應爐與圍阻體皆已破壞，其受損燃料可能散落在反應爐之外，因此相關除役工作比美國三哩島(TMI)核電廠複雜許多。日本積極開發各種除役技術包括切割、除汙、輻射偵測機器人等，受到現場許多人關注與發問。

在論文發表方面，此次本所發表商業級配電盤檢證核能應用，如圖二所示。重點在介紹台灣因應日本福島經驗所做的核電廠安全提升，以及核能零組件檢證現況。核研所於 1996 年成立「核能同級品零組件檢證中心」，以核能關鍵組件國產化為目標，建立零組件檢證技術，並完成等多項檢證案，用於核能安全系統，並有良好實績。此次發表的商業級配電盤檢證係使用於嚴酷環境(Harsh Environment)，且為因應福島事故的特定功能，所以市場並無現有商品。因此，從規劃設計，環境考量、檢證與驗證作業，以及不符合項目的處理，都有詳細說明，以分享台灣經驗。會中有幾位專家曾經來台灣參與龍門電廠工作，對台灣有很好印象，所以互動也特別親切。另外，現場也臨時出現好幾位大陸專家特別聆聽這場簡報。

圖二 會議論文的報告情況

三、 心得

日本福島事故至今已 3 年多，國際間核能發展並有停止，且已經有漸漸復甦的趨勢。目前各國對發展核能都已較低調方式處理，但是強調並沒有停下來。大陸已經開始較積極方式推動核能發展，來取代原本的污染高的火力發電。畢竟，大陸環境污染是目前最具挑戰的議題之一。ICONE 22 雖由美國、日本、大陸共同舉辦，但其呈現出來的方式卻很不一樣。美國僅推廣 AP1000，而其他方面顯得不積極。大陸做法還是跟以前一樣，強調市場很大，以及所建立的自主技術。日本仍陷於福島事故處理與後續相關除役工作。嚴格來說，日本專家由於簡報準備充分，也虛心檢討問題，以及相關技術發展，比較具有國際交流與經驗分享意義。美國與大陸比較強調宣傳，技術交流與經驗分享較少。

台灣對於核能政策的定位不明，總統馬英九今(2014.08.13)日出席民間主辦的「2014 能源願景高峰論壇」致詞表示，電力零成長是不切實際的想法，台灣不能放棄任何能源選項，包括核能在內；核能在全球發電結構中扮演重要角色，包括日本將重啟核電、韓國增加核電占比，顯示核能相當重要。總統還說，核四目前已決定安檢後、先封存 3 年，未來將由公投決定去留，這是替下一代保留選擇權。台灣核工專業人才的嚴重不足，可能成為維護電廠安全最大的挑戰。因為有許多現場資深技術人員，會在這幾年離退。目前各核能電廠雖然已經陸續進用新人，但也面臨經驗傳承需要時間。另外，鼓舞現場工作士氣也很重要，畢竟核能安全是大家的共識，不會因為核能立場不同而有差別。

台灣在國際核能交流上已顯得非常薄弱，記得在 2010 年於大陸西安舉辦的

ICONE 18，台灣學術界(清大)、研究單位(核研所、工研院)、台電等都有派員參加，但這次僅有核研所參加。核能人才的培育非一觸可及，且不易培養。如果中斷過久再回復也幾乎是重新來過，非常可惜。當然強知識的累積及管理，以及將工作程序標準化，並把過去累積的經驗以及專家的意見構成知識管理平台，變成了一項重要的工作。目前檢證中心已參考國外做法，建置核一、二、三廠所有安全設備驗證(EQ)資料庫，對後續的經驗傳承，具有一定的助益。不過，有些經驗還是需要透過師徒制猜能傳承的。

四、 建議事項

1. 國內核電廠目前正積極推動核一廠除役工作，日本福島核電廠除役相關技術與經驗也樂於分享，建議參與核一廠除役工作人員多與日本交流。

2. 由日本福島核電廠經驗可知，第三方的監督對確保經營者活動是必要的。核研所未來改隸屬經濟能源部後， 建議檢證中心可擔任第三方監督或公正單位。

3. 檢證分組 8 月份有三位正式職員退休，影響很大。建議積極進用新人承接檢證相關技術。

五、 附件

此次會議中核研所所發表的一篇研究論文名稱如下，全文與簡報如附件。

1. Dedicated Commercial Power Distribution Panels For Nuclear Safety Related Application.

Proceedings of the 2014 22nd International Conference on Nuclear Engineering
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DEDICATED COMMERCIAL POWER DISTRIBUTION PANELS FOR NUCLEAR SAFETY RELATED APPLICATION

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ABSTRACT

Six nuclear power reactors in Taiwan have been operating over beyond thirty years**.** They are all operated by Taiwan Power Company (TPC) and expected to have 40-year lifetimes. The limited original suppliers and obsolete components are the challenge to comply with current licensing basis and maintaining a high level reliability. Therefore, the procurement of basic components from the second source is very important to the plant safety and operation.

This paper describes the dedication process applied to commercial power distribution panels in a harsh environment. The safety functions of power distribution panels provided backup power input connection for mobile diesel generators while station blackout (SBO). After Fukushima-Accident, the utility needs to setup diversity power to comply with regulatory requirements in Taiwan. The power distribution panels dedication activity include the function testing, aging, seismic qualifications (SQ), and environmental qualifications (EQ) based on EPRI NP 5652, IEEE Std. 323, and IEEE Std. 344 standards. Some subcomponents could not meet the acceptance criteria during testing and the anomalies were noticed to the customer and the utility. One of these anomalies reported to regulatory due to the subcomponent failure after accident radiation endurance test.

Commercial-Grade Item dedication is second source to obtain safety related components according to 10 CFR 21.3 definitions. In the past nineteen years, Institute of Nuclear Energy Research (INER) has actively performed the dedication service to help local nuclear power plants solve their procurement problems of nuclear grade items, due to reduced availability of qualified suppliers and/or obsolete issues of qualified components. Although the codes and standards for dedication in Taiwan refer to those in USA, the challenges may happen due to different regulators, utility, manufacture's quality culture, and personal responsibility. This paper introduces the self-reliant experiences in dedication and economic benefit to local nuclear power plants.

1. INTRODUCTION

In response to the Fukushima-Accident, Taiwan Power Company (TPC) has set up several mobile diesel generators at nuclear power plants to comply with regulatory requirements. To increase robustness of electrical systems, the power distribution panels are designed to provide backup power input connection for mobile diesel generators while the emergency diesel generators malfunction. The power distribution panels and mobile diesel generators are located at the top level of combination structure to avoid tsunami or flooding attacks. The design environmental temperature 65℃ and radiation dose 0.2 Mrads are considered for the power distribution panels based on Fukushima-Accident experience. This environmental condition is higher than plant normal design service temperature 40℃ and radiation dose 0.01 Mrads. Therefore, the power distribution panels are considered to locate in harsh environment according to the plant design specification. Currently, the harsh environmental qualified electrical panels for nuclear power plants are limited. In addition, the functions of the market available electrical panel may not comply with the plant specific design requirements. Based on above reasons, the custom design followed by dedication process is a better approach for power distribution panels.

The power distribution panels are composed of breaker, contactor, fuse, terminal block, cable. The subcomponents such as breaker, contactor, are commonly used to the nuclear power plant. INER has performed power distribution panels dedication based on EPRI NP-5652 [1] and EPRI NP-6406 [2]. All subcomponents were conducted 100% baseline function tested before the panel assembly. Also, each type subcomponent was conducted to thermal and radiation test to demonstrate its qualified life. Some subcomponents could not meet the acceptance criteria including (1) high temperature rise of one type breaker and the fuse during rating current test, (2) contactor function fail after accident radiation

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endurance test. The lesson learns of this dedication show the commercial grade items need to pay more attention to safety related applications. The rigor of dedication process is necessary to find the subcomponents deficiency while used in harsh environment. Carefully selecting market available subcomponents is also very important to meet the plant specific design requirements.

2. DEDICATION PROCESS

The dedication process includes technical evaluation and acceptance process that are presented in EPRI NP-5652 and EPRI TR-102260, as shown in Figure 1. Technical evaluation assure that the requirements for acceptance item are specified in the procure document. Acceptance process reasonably assures the item received is the specified item.

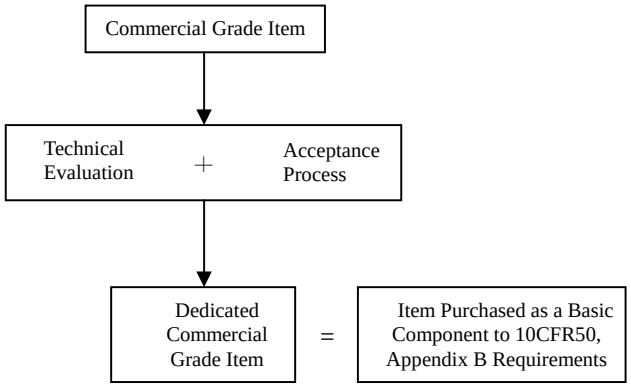

Figure1. Utilization of Commercial Grade Items

The technical evaluation referring to EPRI NP-5652 is to determine items critical characteristics for acceptance verification. Critical characteristics must be identifiable and measurable attributes to provide reasonable assurance. The commercial grade item procurement may be one of three scenarios - a like-for-like replacement, an alternative replacement, or an item required for first time. If like-for-like replacement has been evaluated, only minimal acceptance method need for applied. To avoid our regulator concern, the supplier may not provide correct information for like-for-like evaluation. In addition, the regulator concern that the counterfeit, fraudulent, and suspect items may not identified and prevented by the supplier certification of compliance. When performing the technical evaluation of replacement items, it is assumed that the items will be alternative replacement. This is only for conservative reason.

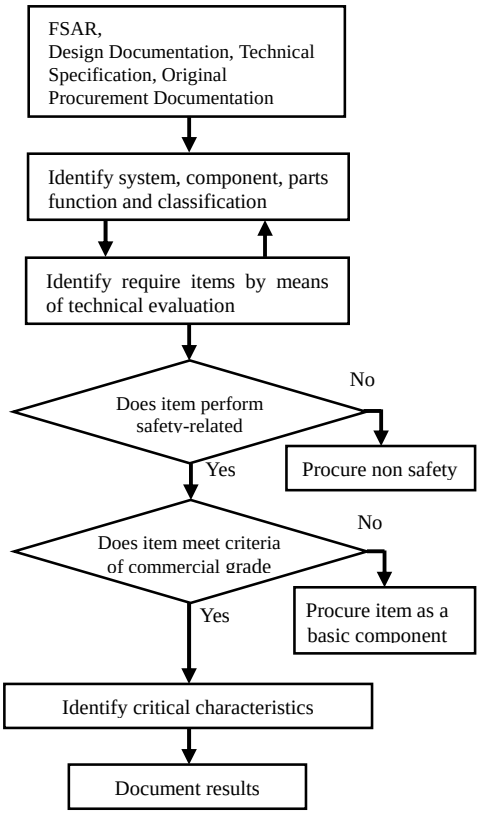

Figure 2. Technical Evaluation of Replacement Items

The dedication plan must contain items critical characteristics, acceptance criteria, and acceptance methods. Each critical characteristic has its own acceptance criteria and acceptance method that specify in dedication plan. Based on above, the supplier should be able to provide the information about design, specification of replacement items, drawing, test reports for evaluation.

The acceptance methods specify in EPRI NP-5652 as following:

Method 1 - Special tests and inspections
Method 2 - Commercial grade survey of supplier,
Method 3 - Source verification,
Method 4 - Acceptable supplier/item performance record

In our practice, Method 1 will be used if the technical data are known; test facilities are available. Electrical components such as fuse, breaker, and relay are belonging to this group. Method 3 will be used if components are complex; test facilities and test procedure are unavailable for laboratory. Mechanical components such as valve, pumps, and heat exchanger are belonging to this group. Method 2 and Method 4 will not be used if the other two methods are available to verify critical characteristic. The document control and traceability may be a problem on Method 2 and Method 4 for many suppliers.

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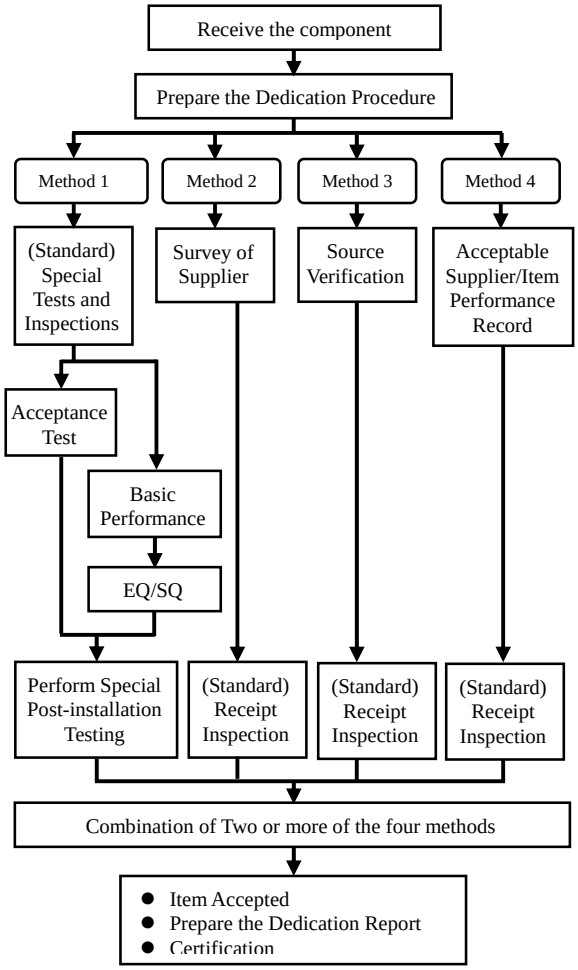

Figure 3. Acceptance Process for Commercial Grade Items

3. TECHNICAL EVALUATION

The power distribution panels are new plant construction design for the mobile diesel generators. Based on EPRI NP-5652, the power distribution panels are regarded as scenarios 3 - initial procurement of commercial grade items. Technical evaluation is performed to ensure the appropriate technical and quality requirements are specified in the procurement documents for the power distribution panels.

To consider the functions of power distribution panels are provided backup power input connection of mobile diesel generators while station blackout. The power distribution panels within emergency diesel generators functional boundaries that do not perform a safety-related function, but whose failure could prevent accomplishment of safety-related functions. In addition, the power distribution panels shall maintain its function during and after station blackout to comply with regulatory requirements. Due to the above reasons, the power distribution panels are regarded as Class 1E components.

Lessons learned from Fukushima-Accident, the higher temperature and radiation may occur at mild environment beyond design environmental conditions when a plant severe accident happens. As a result, the design temperature and radiation refer to residual heat removal (RHR) system. The design environmental temperature 65℃ and radiation dose 0.2 Mrads are decided. To avoid tsunami or flooding attack, the power distribution panels are requested to setup at high ground level. Thus, the top level of combination structure is selected for the power distribution panels' location.

According to the design requirements of the nuclear power plant in Taiwan, the Class 1E component located in harsh environment need to be environmental and seismic qualified based on IEEE Std. 323-1974 [4] and 344-1975 [5] standards. These two qualification standards are also applied to the power distribution panels.

The technical evaluation results need to identify the critical characteristic for acceptance that can provide reasonable assurance to show the components received meets specified requirements. Verifying all critical characteristics is not the intent of EPRI NP-5652. The critical characteristics for acceptance are composed of partial critical characteristic for design and the other item's characteristic to provide reasonable assurance. All critical characteristics must be verified once selected. Justification why an identified critical characteristic for acceptance is not verified should be documented.

Based on above reasons, the critical characteristics for acceptance of the power distribution panels include marking, configuration, dimension, dielectric strength, rating, pickup / dropout voltage for contactor, and time-current characteristics for breaker / fuse. The selection of critical characteristics for the power distribution panels were referred to EPRI JUTG Commercial-Grade Item technical evaluation. Also, the critical characteristics described in dedication plan were approved by TPC. Total 24 test items were conducted in the power distribution panels.

4. ACCEPTANCE PROCESS

The dedication acceptance method 1"special tests and inspections" and method 3"source verification" are applied to the power distribution panels dedication. The critical characteristics, acceptance criteria, and acceptance method of the power distribution panels including subcomponents should be identified in the dedication plan. INER prepared the dedication plan and approved by the customer or/and nuclear power plant.

The power distribution panels dedication procedure described the critical characteristics that identified in dedication plan. Also, the dedication procedure included inspection, function test, aging test, seismic test, and environmental test to comply with the plant procurement requirements.

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The subcomponents of power distribution panels were 100% functional tested in dedication laboratory as shown in Figure 4 . Therefore, the dedication acceptance method 1 was applied.

Figure 4. Functional test of the subcomponents in dedication laboratory

The test results showed that three test items did not meet the acceptance criteria specified in the dedication procedure. These deviations included higher temperature rise of fuse, fail to continue pickup of contactor, higher temperature rise of breaker. The cause of higher temperature rise has been clarified due to fuse material design for high temperature application. Evaluation results showed the deviation would not affect neighborhoods components. Therefore, this deviation was accepted. Two of ten contactors failed to continue pickup test while the coils were energized. The contactor manufacture evaluated this deviation belong to random failure. Thus, the failure coils were replaced. Two contactors were retested to meet acceptance criteria. However, the contactors have been replaced after the coils fail to the radiation endurance test. Temperature rise of the breakers can meet industry standards but still cannot meet the acceptance criteria in dedication procedure. The temperature rise will affect the qualified life of components. Breaker qualified life was calculated by Arrhenius equation based on temperature rise data. The results showed that the qualified life of breaker did not meet procurement requirement. For obtaining longer qualified life , the frame size of breakers had been changed.

Aging tests of subcomponents include thermal aging, operational aging, and radiation aging. Aging tests demonstrated the qualified life of the subcomponents. The thermal aging was performed in dedication laboratory as shown in Figure 5.

Figure 5. Thermal aging test of the subcomponents in dedication laboratory

Critical materials and its activation energy of the subcomponents were identified to determine the aging temperature 120℃.

Operational aging of the subcomponents was determined according to the plant's operation experience. Evaluation results showed two hundred fifty times for 500A breaker (one breaker); one hundred twenty-five times for 800A breaker (one breaker); Two hundred fifty times for contactor (two contactors). Rated current was applied during operational aging test. The subcomponents were irradiated with 0.2 Mrads shown in Figure 6(a) and 6(b) according to the plant's design environment. The total radiation dose 0.2 Mrads includes normal operation and accident condition.

Figure 6(a). Radiation endurance test of the contactors in INER's radiation laboratory

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Figure 6(b). Radiation endurance test of the breakers in INER's radiation laboratory

Aged subcomponents were conducted functional test. Test results showed that the two aged contactors was malfunction and the other subcomponents complied with acceptance criteria. Aged contactors failed to pickup/dropout test. These aged contactors were inspected and checked the problem. The coil containing an electronic circuit design was considered very challenging to radiation environment. To evaluate radiation endurance of the electronic circuit, a fresh coil as shown in Figure 7 was exposed to 0.2 Mrads dose and then restored in contactor followed by pickup/dropout test.

Figure 7. Electronic circuit design in the coil of contactor

This contactor failed to the pickup/dropout functional test. This anomaly has reported to regulatory due to the subcomponent failure after radiation endurance test. Also, the contactors were replaced. Many enhancement activities were performed based on the lessons learned of Fukushima-Accident. The reason of reporting to regulatory was the multifunction electrical components containing electronic circuit may applied to new design electrical system.

The power distribution panels were assembled and tested at the local manufacture as shown in Figure 8. Therefore, the dedication acceptance method 3 was applied. Dedication procedure specified hold point and witness during the power distribution panels integrated functional test. Dedication quality program was applied to the power distribution panels. Dedication process verified the technical and quality requirements to comply with procurement requirements.

Figure 8. Scene of the power distribution panels

The seismic and environmental qualifications are not addressed in EPRI NP-5652. However, the dedication procedure in INER address these qualifications. Also, the procurement specification of nuclear power plant in Taiwan requested the seismic and environmental qualifications. This paper focus on dedication activities and do not described the qualifications for details. The seismic qualification of power distribution panels was based on the required response spectrum (RRS) of the plant location and IEEE Std. 344-1975. The environmental qualification of power distribution panels was based on IEEE Std. 323-1974. To simulate design base accident (DBA) condition, the power distribution panels were placed in aging chamber with temperature 65℃and relative humidity 95 percent. The power distribution panels were energized with 70% rated load for 12 hours and de-energized for 12 hours during 4 days test.

5. DISCUSSION

Commercial grade item dedication provides reasonable assurance by technical evaluation and acceptance process. Carefully selecting critical characteristics for acceptance is based on the safety function of components and engineering judgment. It is important to address critical characteristics for acceptance in dedication plan and to approve by the customer or/and nuclear power plant.

The design of commercial products should be evaluated when applied to harsh environment. Qualified life and environmental qualification of components are considered to comply with specific design requirement of the nuclear power plant. Although one random failure was found on contactor, the breaker, contactor, and fuse still have high quality to comply with industry standards. The lesson learns of this dedication showed that the commercial grade items needed to pay more attention to safety related applications. Carefully selecting market available subcomponents is also very important to meet the plant specific design requirements.

The higher temperature rise affected the qualified life of components. The multifunction electrical components

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contained the electronic circuit that could not passed radiation endurance test. Therefore, rigor of dedication process is necessary to find the subcomponents deficiency while used in harsh environment.

6. CONCLUSIONS

INER has dedicated the power distribution panels for local manufacturer to support the design enhancements of the domestic nuclear power plant. The custom-designed products followed by dedication process provided second source to obtain safety related components.

The power distribution panels were designed and manufactured by local vendor and dedicated by INER to establish the self-reliant capability which can supported domestic nuclear power plants continually safety operation. Also, INER provides dedication service for local vender to enhance its design capability and product quality to apply nuclear industry.

ACKNOWLEDGMENTS

The authors like to thank the participants of the dedication project, mainly the colleagues of INER for endeavoring work on each dedication. Authors also like to thank many expertise's that from TPC to support this project.

REFERENCES

1. EPRI NP-5652. Guideline for the utilization of commercial grade items in nuclear safety related applications (NCIG-07), June 1988.
2. EPRI NP-6406. Guidelines for the technical evaluation of replacement items in Nuclear Power Plants (NCIG-11), December 1989.
3. EPRI TR-102260. Supplemental Guidance for the Application of EPRI Report NP-5652 on the Utilization of Commercial Grade Items. 1994
4. IEEE Std.323. Standard for qualifying Class 1E equipment for nuclear power generating stations. 1974.
5. IEEE Std.344. IEEE recommended practices for seismic qualification of Class 1E equipment for nuclear power generating stations. 1975.

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Dedicated Commercial Power Distribution Panels for Nuclear Safety Related Application

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- Introduction
- Dedication Process
- Power Distribution Panels Dedication
- Seismic Qualification
- Environmental Qualification
- Discussion
- Conclusions

Introduction (1/5)

- In response to the Fukushima-Accident, Taiwan Power Company (TPC) has set up several mobile diesel generators at nuclear power plants to comply with regulatory requirements.
- The power distribution panels are designed to provide backup power input connection for mobile diesel generators.

Introduction (2/5)

- Power distribution panels and mobile diesel generators are located at the top level of combination structure to avoid tsunami or flooding attacks.
- Design environmental temperature 65℃ and radiation dose 0.2 Mrads are considered for the power distribution panels.

Introduction (3/5)

- Power distribution panels are considered to locate in harsh environment according to the plant design specification.
- Currently, the harsh environmental qualified electrical panels for nuclear power plants are limited. Therefore, the custom design followed by dedication process is a better approach for power distribution panels.

Introduction (4/5)

According to 10 CFR 21.3 definitions:

- Basic components are items designed and manufactured under a quality assurance program complying with appendix B to part 50 or commercial grade items which have successfully completed the **dedication process**.

Introduction (5/5)

Codes and Standards for Dedication in Taiwan

- Nuclear Reactor Facilities Regulation Act
- Regulations on the Dedication of Commercial Grade Items and of Dedication Agency
- EPRI NP-6406
- EPRI NP-5652
- IEEE std. 323
- IEEE std. 344

Dedication Process (1/4)

Utilization of Commercial Grade Items

Commercial Grade Item

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Technical Evaluation + **Acceptance Process**

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Dedicated Commercial Grade Item = **Item Purchased as a Basic Component to 10CFR50, Appendix B Requirements**

Dedication Process (2/4)

Technical evaluation

- Ensures replacement items equivalent to the originals
- Determine items critical characteristics for acceptance verification
- Critical characteristics must be identifiable and measurable attributes to provide reasonable assurance
- Can be conducted by utility itself or dedication party (INER)
- Must have safety classification, codes and standards, failure modes and effects analysis, items safety function, and effects of maintenance and surveillance
- EPRI Joint Utility Task Group (JUTG) Commercial Grade Item provide technical evaluation for reference.

Dedication Process (3/4)

Acceptance process

- Reasonably assure the item received is the item which specified
- The acceptance methods specify in EPRI NP-5652 as following:
  - Method 1 - Special tests and inspections
  - Method 2 - Commercial grade survey of supplier,
  - Method 3 - Source verification,
  - Method 4 - Acceptable supplier/item performance record

Dedication Process (4/4)

In our practice

- **Method 1** will be used if the technical data are known; test facilities are available. Electrical components such as fuse, breaker, and relay are belonging to this group.
- **Method 3** will be used if components are complex; test facilities and test procedure are unavailable for laboratory. Mechanical components such as valve, pumps, and heat exchanger are belonging to this group.
- **Method 2** and **Method 4** will not be used if the other two methods are available to verify critical characteristic. The document control and traceability may be a problem on Method 2 and Method 4 for many suppliers.

Power Distribution Panels Dedication (1/4)

- 14 power distribution panels were dedicated. The power distribution panels are composed of breaker, contactor, fuse, terminal block, and cable.
- Subcomponents of the power distribution panels were 100% functional tested in dedication laboratory.

Power Distribution Panels Dedication(2/4)

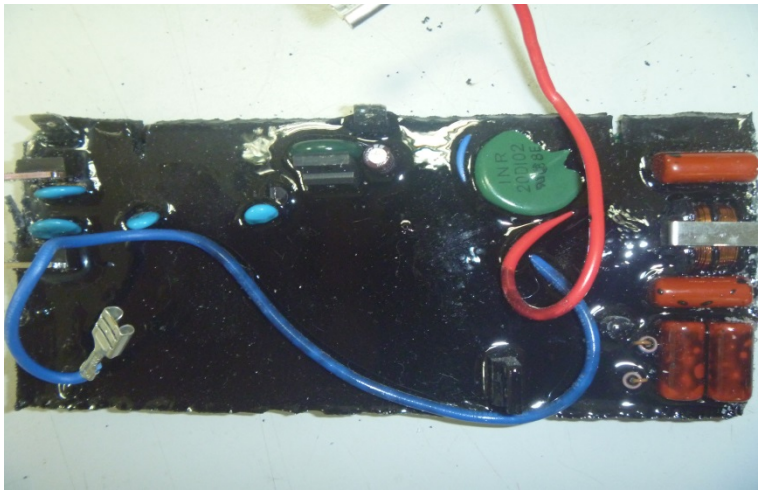
- Thermal aging test of the panels in dedication laboratory. Critical materials and its activation energy of the subcomponents were identified to determine the aging temperature 120℃.

- Radiation endurance test of the panels in INER's radiation laboratory. The total radiation dose 0.2 Mrads includes normal operation and accident condition.

Power Distribution Panels Dedication (3/4)

- Radiation aged contactors failed to pickup/dropout test. The coil containing an electronic circuit design was considered very challenging to radiation environment.

- To evaluate radiation endurance of the electronic circuit, a fresh coil was exposed to 0.2 Mrads dose and then restored in contactor followed by pickup/dropout test.



Power Distribution Panels Dedication (4/4)

Anomaly reported

- This contactor failed to the pickup/dropout functional test. This anomaly has reported to regulatory due to the subcomponent failure after radiation endurance test. Also, the contactors were replaced. The reason of reporting to regulatory was the multifunction electrical components containing electronic circuit may applied to new design electrical system.

Seismic Qualification

- The seismic and environmental qualifications are not addressed in EPRI NP-5652. However, the dedication procedure in INER address these qualifications.
- The seismic qualification of power distribution panels was based on the required response spectrum (RRS) of the plant location and IEEE Std. 344-1975.
- The functions of contactors and breakers were monitoring during seismic test.

Environmental Qualification

- The environmental qualification of power distribution panels was based on IEEE Std. 323-1974.
- To simulate design base accident (DBA) condition, the power distribution panels were placed in aging chamber with temperature 65℃and relative humidity 95 percent.
- The power distribution panels were energized with 70% rated load for 12 hours and de-energized for 12 hours during 4 days test.

Discussion

- Commercial grade item dedication provides reasonable assurance by technical evaluation and acceptance process.
- Carefully selecting critical characteristics for acceptance is based on the safety function of components and engineering judgment.
- It is important to address critical characteristics for acceptance in dedication plan and then to approve by the customer or/and nuclear power plant.

Conclusions

- The custom-designed products followed by dedication process provided second source to obtain safety related components.
- The power distribution panels were designed and manufactured by local vendor and dedicated by INER to establish the self-reliant capability which can supported domestic nuclear power.
- INER provides dedication service for local vender to enhance its design capability and product quality to apply nuclear industry.
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Q & A

Thank you for your attention!!

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