出國報告(出國類別：開會)

赴美國參加「2018年太平洋盆地核能會議」出國報告

服務機關：行政院原子能委員會、行政院原子能委員會放射性物料管理局
姓名職稱：許明童 科長、李彥良 技正、戈元 技士
派赴國家/地區：美國
出國期間：107 年 09 月 29 日至 107 年 10 月 07 日
報告日期：107 年 12 月 04 日

摘　要

太平洋盆地核能會議(Pacific Basin Nuclear Conference，簡稱 PBNC)係為促進太平洋盆地地區核能和平用途研究與發展合作目的而每兩年辦理 1 次之國際大型會議，本屆 2018 太平洋盆地核能會議(Pacific Basin Nuclear Conference，簡稱 PBNC 2018)由美洲核能協會(American Nuclear Society，簡稱 ANS)與太平洋核能理事會(Pacific Nuclear Council，簡稱 PNC)共同主辦。

本屆會議之主題為「永續與先進的核能」(Sustaining and Advancing Nuclear Energy)，計有美國、加拿大、日本、澳洲、韓國、法國、英國、墨西哥、阿拉伯聯合大公國、沙烏地阿拉伯、中國大陸及我國等 12 個國家超過 300 人專家代表出席，發表的論文約 140 篇，還設有 36 個贊助公司的產品攤位展示。

原能會由許明童科長率同李、戈二員參加會議，3 員皆在技術專題中就各自專業領域發表論文，並藉由參加 PBNC 會議之各項技術議程，與各專家學者交換意見，瞭解目前各太平洋盆地核能國家核能發展現況、各國核能技術及核能安全措施等相關議題，會後更在主辦單位安排下參訪加州柏克萊大學核能技術中心，瞭解該中心最新核能技術研發項目，有助於促進國際核能合作交流、精進我國對於相關議題能量。

目　錄

壹、目的：

太平洋盆地核能會議(Pacific Basin Nuclear Conference，簡稱 PBNC)係為促進太平洋盆地地區核能和平用途研究與發展合作目的而每兩年辦理 1 次之國際會議，自 1976 年在美國夏威夷檀香山舉辦第 1 屆以來已是第 21 屆。2018 太平洋盆地核能會議(簡稱 PBNC 2018)係由美洲核能協會(American Nuclear Society，簡稱 ANS)與太平洋核能理事會(Pacific Nuclear Council，簡稱 PNC)共同主辦，也是美國第四次承辦 PBNC。

加拿大原子能公司(Atomic Energy of Canada Limited, AECL)重組成立新機構「加拿大核子實驗室」(Canadian Nuclear Laboratories)後，為了開展國際業務，也積極參與本次會議籌辦，其中專題論壇主席 Kathryn McCarthy 及技術議程主席 Corey McDaniel 等皆任職於該實驗室，並由愛達荷國家實驗室主任 Mark Peters 擔任名譽會議主席。

本屆會議主題為「永續與先進的核能」(Sustaining and Advancing Nuclear Energy)，計有美國、加拿大、日本、澳洲、韓國、法國、英國、墨西哥、阿拉伯聯合大公國、沙烏地阿拉伯、中國大陸及我國等 12 個國家，超過 300 位專家代表出席，發表的論文約 140 篇，還設有 36 個贊助公司的產品展示攤位。

原能會由許明童科長率李、戈二員參加會議，並在技術專題中就各自專業領域發表「台灣核能電廠彈性運轉管制經驗」、「台灣第一核能發電廠乾式貯存設施安全管制」、「原能會執行 2017 年臺北世界大學運動會輻射偵檢與惡意事件防範任務簡介」論文等 3 篇，與各國專家學者交換意見，瞭解目前各太平洋盆地核能國家核能發展現況、各國核能技術及核能安全措施等相關議題，會後更在主辦單位安排下參訪加州柏克萊大學核能技術中心，瞭解該中心最新核能技術研發項目，有助於促進國際核能合作交流、精進我國對於相關議題能量。

貳、過程：

一、行程：

日 期	地點與行程	工作內容
9月29日(六)	台北→美國舊金山	去程
9月30日(日)~ 10月3日(三)	Hyatt Regency飯店	出席2018 PBNC會議
10月4日(四)	加州柏克萊大學	技術參訪
10月5日(五)~ 10月7日(日)	美國舊金山→台北	資料整理及返程

二、出席「2018 年 PBNC 會議」

2018 年第 21 屆太平洋盆地核能會議係太平洋核能理事會每兩年辦理之國際會議，本次由美洲核能協會與太平洋核能理事會共同主辦，會議主題為「永續與先進的核能」，從管制、部會、產業、未來展望、科學技術及應用等不同觀點進行研討。

參與人員除美國核能相關機構與學術單位外，並有國際原子能總署(International Atomic Energy Agency，簡稱 IAEA)、加拿大、日本、澳洲、韓國、法國、英國、墨西哥、阿拉伯聯合大公國、沙烏地阿拉伯、中國大陸及我國等各國人士參加，共計超過 300 位核能有關之政府官員、學者、專家，參與各項先進技術、能源管理至管制政策等不同領域之專題，包括我國在內的環太平洋各國發表約 140 篇技術論文，每天上午有半天的專題研討論壇及下午半天的技術議題論壇(議程詳附件一)，以下謹就論壇進行過程及擇重要場次演講題目之內容摘述於下:

(一)報到、PNC 理事會議及歡迎晚會

大會在 9 月 30 日(週日)中午辦理報到及舉辦 2018 年第四季太平洋核能理事會(PNC)，PNC 會議由許明童科長與駐美代表處喬凌寰副組長參加。PNC 前身是「太平洋盆地核能合作委員會」(Pacific Basin Nuclear Cooperation Committee，簡稱 PBNCC)，當時之創會會員包括美、加(2)、韓、日(2)、墨等五國共七個會員團體。我國與中國大陸於 1990 年同時加入 PNC，其後數年澳洲核能協會、ANS 拉丁美洲分會

及印尼、泰國、俄羅斯、越南、馬來西亞等國相繼加入。PNC 目前共有 18 個會員團體。該理事會設有理事長、副理事長，任期二年。每兩年由理事會選出副（準）理事長，二年後接任理事長。

本次會議除確認前次會議決議辦理情形外，並決定 2020 年第 22 屆 PBNC 將於墨西哥坎昆市(Cancun, Mexico)舉行，同時也更新各國核能現況，日本主要說明目前重啟運轉機組與申請重啟機組之現況，以及福島第一核電廠 311 事故後目前處理現況；另外，喬凌寰副組長代表說明台灣目前核能現況，並提到 2018 年核二廠 2 號機加入運轉，可增供國內整體電力約 3%，最後依議程選出中國核學會副秘書長王志先生為副理事長，並徵詢各會員國辦理 2019 年 PNC 會議之意願。

當晚歡迎晚會由美國愛達荷州參議員 James Risch 致歡迎詞，以及進行「大會主題」(Congressional Keynote)演講，作為美國核能研發重鎮-愛達荷國家實驗室所在地選出的參議員，R 氏積極表達對下一代核電的支持，並明確指出下一代核電將成為美國能源戰略的一部分。

(二)會議開幕及論壇專題研討

PBNC 會議在 10 月 1 日(週一)上午 8 時正式開幕，由美洲核能協會會長 John Kelly 代表 ANS，另外 PBNC 大會專題研討論壇主席、加拿大核子實驗室(Canadian Nuclear Laboratories)研發副總兼實驗室主任 Kathryn McCarthy，以及 PBNC 大會名譽主席愛達荷國家實驗室主任 Mark Peters，分別對各國前來參加與會者表達歡迎之意，緊接著是一連 3 日的專題研討論壇:

1.「永續與先進的核能」-政府觀點(Government Perspective)主題演講

本主題分為管制、部會等兩個觀點，其中「管制觀點」由大會邀請美國核能管制委員會主席 Kristine Svinicki 及加拿大核能安全委員會(CNSC)管制業務主任 Ramzi Jammal 等貴賓，分別主講美國及加拿大的重要核能管制事項；「部會觀點」由美國能源部核能高級顧問 Suzanne Jaworowski 及加拿大能源部門電力資源處(Electricity Resources Branch, Energy Sector)主任 Marco Presutti 主講重要核能發展事項。

Ramzi Jammal 報告題目為「Regulating Innovative Nuclear Technologies」，首先介

紹加拿大核能安全委員會(CNSC)的使命、職權、組織、任務以及 2017 至 2018 年度之人力、財務及持照者申請與核發情形等。CNSC 是隸屬於加拿大政府的獨立的核能安全管制機關，擁有 70 多年管制經驗，其使命為監管核能及核子材料的使用，保護環境健康及安全，並執行和平使用核能的國際承諾。簡報中提及新任總裁及和首席執行官 Rumina Velshi 女士，其任期自 2018 年 8 月 22 日起生效；並說明加拿大核能安全委員會依據法規授權執行之事項，包含核能安全委員會在核發許可證時，須確認申請者對健康、安全及環境已採取適當措施、確保安全，並承諾遵守加拿大的國際承諾。

Jammal 主任也說明 CNSC 對於小型模組化反應爐(Small Modular Reactor，簡稱 SMR)的管制現況，雖然大多數 SMR 僅提供較小電網或獨立電網使用，惟設計概念仍基於既有核能電廠的技術與運轉經驗，但也採用許多創新技術。過去 CNSC 與其他許多國家的管制機關一樣，擁有審查傳統大型核能電廠新設計之經驗，面對小型模組化反應爐之設計審查及管制，CNSC 為能有效管制但不影響新技術發展，對於各類小型模組化反應爐設計，在符合加拿大的核安管制法規框架及管制要求下，允許申請者可提出靈活創新技術，以符合安全和環境保護的相關要求。在 SMR 設計審查方面，CNSC 也提供業者選擇設計審查預審(Pre-licensing vendor design review，簡稱 VDR)制度，進行方式非屬新設核電廠許可審查之必要程序，其目的在於驗證新核電廠的設計及加拿大核能法規、標準及管制要求的可接受性。另外，也說明智慧眼鏡(Smart Glasses)應用於即時顯示輻射量測值，及 Comanche Peak 核能電廠結合 Wi-Fi 網路與無線感測器做為遠端自動診斷系統等新技術，並實際應用於核能電廠之使用及測試情形。

隨後由 Terrapower 副董事長兼智慧事業部主任 Nathan Myhrvold 以「核能選項」為題進行主題演講，他強調福島的污染雖打擊核電的安全形象，但也促使核能界合作開發下一代技術，共同努力使核電更安全，更易於管理，他並以先進、落後國家間在「烤麵包」這件事耗費的電力差距為例，指出全球電力需求將隨消費水平提升而增加，Terrapower 的目標是開發新型核反應器幫助滿足預期能源需求，該新型核反應器使用耗乏鈾為核燃料，並可無限期地維持分裂過程。

2.「產業觀點」(Industry Perspective)的主題演講

本主題由加拿大 SNC-Lavalin 全球核能業務部門執行副總裁 William Bill Fox 擔任主席(表定主席總裁 Sandy Taylor 因故無法出席)，說明核能產業界發展現況與展望，講者包括中國核工業集團公司(China National Nuclear Corporation)總工程師雷增光、韓國水力核能電力(Korean Hydro and Nuclear Power)執行副總 Sang-Wook Han、日本原子力產業協會(Japan Atomic Industrial Forum, JAIF)高級顧問 Takuya Hattori，以及 NuScale Power 營運長兼核能長 Dale Atkinson 等專家學者。

大陸的核工業集團公司總工程師雷增光報告「中國核電的發展現況與展望」(The Development Status and Prospect of China’s Nuclear Energy)，分別說明大陸核能發展現況、核能創新發展與實踐及前景等，摘錄要點如下：

中國大陸對於核電發展基本的要求是在核能安全基礎上，建立具有高效率及技術多樣化的核電發展，截至會議當日(2018 年 10 月 1 日)止，計有 45 部核能機組運轉中，12 部機組興建中，2017 年核能發電占整體發電比例為 3.94%。中國大陸核電發展分為三個階段：初始階段(1980~1995)、奠定基礎階段(1995-2005)及擴大發展階段(2005 迄今)。成果包括：利用鈾資源的完整核燃料循環系統、完整的核電工業系統、維持良好安全紀錄的高品質核能電廠群，以及培養出數個核能研究、開發建造、運營維護方面的優秀團隊。中國大陸努力汲取日本福島事件經驗，配合國家優化能源組合目標，目前僅在「小型模組化反應器」(SMR)研發論文數量稍落後美國，但在「高溫氣冷反應爐」(High Temperature Gas-cooled Reactor，簡稱 HTGR)及「熔鹽反應爐」(Molten Salt Reactor，簡稱 MSR)方面已超越美、日，躍居世界第一。

中國大陸為了實現在巴黎協定中的諾言，到 2030 年將把每單位 GDP 的二氧化碳排放量降低至 2005 年的 60%至 65%，故將有效利用核能發電，並將核能視為優化中國能源組合、促進生態環境的重要解決方案。雖然全球核電的發展受到日本福島事故的影響，但綜觀中國整體核電的發展趨勢，仍朝如何使其更「安全而環保」的目標邁進。

日本 JAIF 高級顧問 Takuya Hattori 報告題目為「Capacity Building is a cornerstone for Sustainable Development of Nuclear Power」，Hattori 首先介紹核能的優點及世界各國能源結構與核能發電所占比例，並說明核電可持續發展的條件，包含國家政策、核能

安全、核安管制、技術創新、營運管理、國際交流、公眾信心及商業競爭等項。目前日本核電發展面臨人力資源的關鍵問題，分別有:(1)目前核電環境，無法吸引年輕人投入核工業；(2)沒有新的技術，可以吸引未來的研究發展；(3)有能力與經驗豐富的工程師，將陸續退休；(4)目前核電商業條件，無法維持高品質的核工業供應鏈；(3)因經費及未來前景發展未明，已停止研究新的反應爐技術；(4)對於曾發生嚴重事故的反應爐，欠缺除役相關技術；(5)一般民眾對輻射沒有正確觀念且易感到不安等。日本為健全核電人力資源的發展，由產官學組成「日本核電人力資源發展網」(Japan Nuclear Human Resource Development Net, JNHRD)共同建置培訓核電人力，以滿足日本核電設施發展的需求，並解決前述人力資源問題。

3.「先進的核能」主題論壇

第二天 10 月 2 日(週二)上午的論壇主題為「先進的核能」(Advancing Nuclear Energy)，由論壇主席愛達荷國家實驗室「核能加速創新通路」(Gateway for Accelerated Innovation in Nuclear」辦公室主任 Rita Baranwal 女士介紹與引言。本論壇分為 2 個子題進行，第 1 子題是「未來展望」(The Path Forward)由美國核能產業委員會(Nuclear Industry Council)總裁 David Blee 主持，討論世界各地領先的核能研究、政策及各產業組織關於精進核能技術做法等，邀請講者包括澳洲核能科技組織(Australian Nuclear Science and Technology Organization，簡稱 ANSTO)執行長 Adi Paterson、英國核能創新研究諮詢委員會(UK Nuclear Innovation Research Advisory Board)主席 Sue Ion、美國 GE-Hitachi 核能執行副總 Jon Ball、日本文部科學省(MEXT)原子能司司長 Takashi Kiyoura、加拿大核子實驗室能源計畫主任 Gina Strati 等專家學者。

澳洲 ANSTO 執行長 Adi Paterson 博士報告題目為「The Nuclear Fuel Cycle in Australia」，Paterson 博士說明 ANSTO 是澳洲核能專業技術的發源地，也是澳洲唯一有核反應爐運轉營運的機構，並介紹澳洲 60 年來核能發展及亞太地區各國核能機組運轉、興建及未來機組規劃等情形；此外，澳洲鈾礦儲量豐富，並開採鈾礦提供世界各國的核電廠使用。

ANSTO 研究開發之開池式輕水型反應爐(Open-pool Australian Light-water Reactor;

OPAL)已於 2007 年 4 月開放使用，該反應爐為一個多功能小型研究用反應爐，主要為生產放射性同位素、輻射照射及中子束研究等用途。ANSTO 也推動核子科學的發展與技術研究，致力於建立核子科學對人類健康有益之核子醫學應用，以及預防、診斷、治療及疾病檢測技術等研究；同時也利用核子技術及同位素技術，研究開發可解決澳洲及世界各地具有挑戰性的環境問題(如水資源、環境變化及污染物影響等)；另外也可研究解決當前核子反應爐及未來新核能系統之核燃料循環中的關鍵問題。ANSTO 已於 2017 年 9 月加入第四代核能系統國際論壇(Generation IV International Forum, GIF)，以與國際合作共同開發具可行和性能更佳之新一代核能系統。

日本文部科學省(MEXT)原子能司司長 Takashi Kiyoura 以「日本對於核能創新的未來展望」(Japanese Future Vision for Nuclear Innovation)為題，說明福島事件後，日本對於事故機組除役過程所做種種努力，包括除役路徑圖執行現況、公私部門協力分工情形，及未來日本境內核設施(設備)的保留、除役規劃等。日本近年也因面臨核工系所學子、核電部門從業人員大幅減少的窘境，導致相關創新研究論文數量也從原本僅落後美國的坐二望一之勢，變成已遠遠低於美、中兩國。既然研發創新能量不足，日本在有限資源下，所能做的僅有對內做好「能源選擇」與「資源整合」，以及對外強化國際合作一途。

第 2 子題為「技術的領導」(Technology Leadership)，由加拿大核子實驗室業務發展副總 Corey McDaniel 主持，本論壇子題係邀請頂尖核能專家分享產業洞見、科學知識和精進核能技術之最新技術，講者都是「小型模組化反應器設計」的關鍵技術參與者(含供應商)，包括「核能的未來」(Future of Nuclear Energy)作者美國愛達荷州國家實驗室 David Petti、英國國家核子實驗室(National Nuclear Laboratory)副主任 Gordon Bryan、上海應用物理研究所副所長戴志敏、韓國原子能研究所(Korean Atomic Energy Research Institute)SMART 計畫主任 Han Ok Kang、加拿大 Terrestrial Energy 執行長 Simon Irish、美國 Nuscale 公司營運及電廠服務副總 Ken Langdon 等。

4.「永續的核能」主題論壇

10 月 3 日(週三)上午的「永續的核能」(Sustaining Nuclear Energy)主題論壇由主席加拿大 SNC Lavalin Global Nuclear Business 公司執行副總 William (Bill) Fox 介紹與引言，第 1 個論壇子題是「現有核能機組的永續－公用事業觀點」(Sustaining the Current Fleet－Utility Perspective)，由加拿大核子實驗室主任 Kathryn McCarthy 主持，討論「維續全球現有核能機組的關鍵因素」，邀請講者來自各環太平洋國家公用事業部門，包括美國 Arizona Public Service 公司電廠營運副總 Chuck Kharrl、韓國水力核能電力公司中央研究所(Central Research Institute)主任 Yunho Kim、美國 Southern Nuclear 公司創新與技術部門經理 Chris Comfort、日本電氣事業連合會(Federation of Electric Power Companies)核能部門總經理 Norio Atsumi 等專家學者。

韓國水力核能電力公司中央研究所(Central Research Institute)主任 Yunho Kim 以「南韓的核能永續」(Sustainable Nuclear in Korea)為題進行報告，金主任指出南韓因缺乏能源礦藏，南韓政府視核能為國家能源戰略重要一環，並已長期積極發展核能，至今核電已占整體發電量 28.2%，是全球核電機組第 6 多的國家，而且技術能力領先，已連續多年創下功率損失和非計畫停機次數最少紀錄。但福島事故後南韓內部反核聲浪高漲，民眾對於核電安全及核廢處理普遍存有疑慮。為此，南韓政府持續投入核電創新研發，寄望 2030 年問市的第四代反應器技術可以為這些問題提供技術解決方案。這些技術加上用過核燃料完全回收，可以從用過核燃料中提煉大量能量，並開發出在緊急情況下不需要任何外部操作的安全功能，強化核電安全性。

由於環境和經濟原因，南韓現階段仍須維持核電，否則將增加燃煤生產以維持電價，同時也放棄過去發展核電的基礎。金主任指出南韓核電的發展問題是社會問題，而非技術問題，為了維持南韓的核能永續性，發掘並解決現有核電廠安全管理缺失，重新獲得民眾信任，是目前政府的當務之急。

第 2 個論壇子題是「現有核能機組的永續－科技觀點」(Sustaining the Current Fleet－Science & Technology Perspective)，由前美國民用核能貿易諮詢委員會(U.S. Civil Nuclear Trade Advisory Committee)主席、Curtiss-Wright 核能部門市場發展副總 Gary Wolski Chair 主持，討論支持全球現有核能機組永續性的關鍵科技，邀請環太平洋國家

核能供應鏈和研究組織的專家，包括美國電力研究院(Electrical Power Research Institute) Sherry Bernhoft、加拿大 CANDU 業主組織(CANDU Owners Group)總裁 Fred Dermarkar、中國核動力研究設計院(Nuclear Power Institute of China)研究主任 Dan rong Song、日本丸紅商事公共事業部(Marubeni Utility Services) Hirokazu Ofuji、美國愛達荷州國家實驗室水反應器永續發展計畫(U.S. Light Water Reactor Sustainability Program)主任 Bruce Hallbert、加拿大核能產業組織(Organization of Canadian Nuclear Industries)主席 Ron Oberth 等專家學者。

CANDU Owners Group 總裁(兼首席執行長)Fred Dermarkar 說明題目為：核能未來的持續挑戰與機會(Challenges and Opportunities for Sustaining a Nuclear Future)，Dermarkar 表示，核能產業主要面對的挑戰包括資產管理、設備零件過時老化、網路安全、供應鏈安全、核廢料處理與核電廠除役、核電營運與除役的成本與安全管制，但可透由核能人才的培育、資產價值的最大化、小型核反應爐（SMR）開發與興建、供應商間的合作與各核能組織間的協調合作等，推進核能的發展。

美國愛達荷國家實驗室「輕水式核反應器持續研究計畫」(LWRS)技術總監 Bruce P. Hallbert 博士報告題目為「輕水式核反應器可持續性研究的科學與技術基礎」(Science and Technology Underpinning Light Water Reactor Sustainability Research)，Hallbert 博士說明，輕水式核反應器持續研究計畫目的，為提高美國核能機組安全與經濟效能，並延伸運轉年限，提供可靠電力來源，透過確保現有核電廠的長期運轉，以創新佈局(layout)方法來提升輕水式核反應器在未來市場的經濟競爭力，並增進可靠性與安全性。目前研究重點領域包含材料、核電廠現代化與風險資訊系統分析。

材料研究方面，透過實驗、監測和除役材料驗證，來建立反應器壓力槽(RPV)脆化的預測模型；了解輻射「促進應力腐蝕龜裂失效」(IASCC)與「應力腐蝕龜裂」(SCC)的發生機制，可預測並提出減緩策略；了解纜線退化模式，以預測性能並評估回復策略；建立纜線和混凝土結構的狀態監測技術；開發先進合金與開發先進的焊接技術，用於高輻射材料的焊接修復。其中焊接通常用於核組件的維修和升級，輻射照射材料的焊接可能導致脆化與開裂，為抑制裂隙發生，目前正在研究降低熱輸入焊接技術與

減少焊接應力拉伸區的技術，並使用類神經網絡監測焊接過程中的變量。

有關核電廠現代化研究與發展方面，為解決現有電廠數位儀控技術的長期老化和可靠性問題，已制定實施數位儀控技術長期現代化的策略，包含開發、測試與更新技術，並開發先進監測技術，以監測、檢測與減緩組件老化過程，並制定標準作業程序，減低技術、財物與監管風險，以提高電廠效率。另外在即時監測部分，將以更具成本效益的風險預測維護策略，改善現有步驟，透過提升風險評估能力(使用機率風險評估技術來提供決策資訊)，提高電廠自動化設備使用比例，來幫助輕水式核反應器電廠降低運營和維護成本，提高效率。

加拿大核工業組織(COG)總裁兼首席執行長 Ron Oberth 博士發表題目為「永續的核能-供應商的觀點」(Supplier Perspective)，Ron Oberth 博士表示，供應商在維持核工業方面，可發揮關鍵作用，透過創新、專注、合作與倡導，以幫助降低成本、縮短時程、提高品質與安全與增進社會和政治層面的支持。在創新部分，將邀請中小企業供應商提出創新方案，以解決加拿大核工業組織主要運營挑戰，並由供應商協助推動，項目主要包括機器人與無人機檢查作業、無紙化(電子化)工廠、人工智慧、虛擬實境工具與 3D 列印技術的研發。

更換組件為老化核電廠的一大挑戰，目前有些 OEM 公司已不再營業，導致部分組件已無法取得，但透過商業級通用技術，可生產符合核電廠的替換組件，節省成本和加快進度，並運用更多標準化作業流程，以降低成本。另外公營事業可鼓勵供應商結合多個合作夥伴提供綜合解決方案，透過共同合作開發，以創新產品與技術，並結合當地社區、地方政府與聯邦力量，創造就業機會取得社會支持。

(三)技術議題論壇

本次會議發表的技術論文約有 140 篇，依論文性質分別於 36 個技術議程中發表，同一時間有 6 個技術議程同時進行，由與會人員視需要自行選擇參加。技術論文的主題共有下列：核能安全與核子保安（Safety and Security）、運轉與維護（Operation and Maintenance）、新反應器的興建（New Build）、除役與廢料管理（Decommissioning Waste Management）、供應鏈與品質管理（Supply Chain and Quality Management）、燃料儲存

（Fuel Storage）、進步型反應器（Advanced Reactors）、公眾溝通(Public Communication)、經濟（Economics）、醫藥 (Medicine)等 10 項，謹就本會與會發表人員參加專題及其他重要論文說明：

1.運轉與維護（Operation and Maintenance）

許明童科長 10 月 2 日(週二)發表「Regulatory Experience on Flexible Power Operation Application」論文，首先是台灣核能電廠營運現況背景介紹，基本上核能電廠在台灣係以基載運轉為主，雖然過去台電公司曾因測試、設備故障或因應颱風期間而降載運轉的經驗，但並未有長期彈性運轉之經驗。台電公司為電力系統調度需求，於 2016 年 5 月以核一廠 2 號機不改變已核准之總能量燃耗限值，且不超過 18 個月運轉技術規範規定之偵測試驗期限下，申請將該機組由 100%全功率運轉降至約 75%功率運轉，期使延長本次燃料週期結束時程。原能會參考國際原子能總署(IAEA)及美國電力研究院(EPRI)相關資料與國際案例，要求台電公司針對核一廠 2 號機降載運轉提出安全評估報告。

台電公司提出前述安全分析報告，係以核一廠 2 號機已經核准「週期 28 填換爐心安全分析報告(RLA)」及「爐心運轉限值報告(COLR)」之功率-流量運轉區(Power Flow Domain)內，維持約 75%額定功率運轉進行評估。其安全分析報告係從爐心營運、設備影響、人員操作及蒸汽乾燥器分析等面向進行評估，檢視機組維持在 75%功率運轉策略之可行性，並分別對爐心組件、燃料完整性、設備影響與因應策略、蒸汽乾燥器共振等進行評估，以及其評估結果與美國電力研究所 EPRI-3002002612 報告進行比對。

原能會參考 IAEA 及 EPRI 相關資料審查台電公司所提送安全分析報告及現場查核，確認台電公司對可能涉及之技術議題均已進行適當評估，並採取適切因應作為，遂同意核一廠 2 號機降載運轉。另外，雖然台電公司過去曾因設備故障、測試或因應颱風期間而降載運轉之經驗，但在台灣核能電廠一直以基載運轉為主，當核一廠 2 號機將採彈性運轉時，並無具體法規要求。故原能會依據「核子反應爐設施管制法」第 14 條規定發布解釋令，將核能機組採彈性運轉策略納入管制事項，要求台電公司應於彈性運轉前，備妥相關安全分析報告且須經原能會核准。若因颱風或豪雨等自然威脅

而降載運轉，以提高安全餘裕；或者對電廠之結構、系統及組件(SSC)執行例行維護與偵測試驗等，可以免除前述要求。

核一廠 2 號機長時間運轉於 75%功率是台灣核能電廠彈性運轉的第一個案例，雖不是很長時間降載的審查案例，但可作為未來核能電廠長時間降載運轉安全審查之參考。另外，原能會為強化社會溝通及公眾參與，舉辦說明會使民眾更進一步瞭解。

簡報結束後，現場與會人員提出核一廠 2 號機維持 75%功率運轉，後續是否恢復至滿載運轉？以及核能機組彈性運轉需審查多久？對於核能電廠採用彈性運轉是否有針對電廠設備(如腐蝕等)影響進行分析？對此部分現場回應說明，核一廠 2 號機維持 75%功率運轉約 1 個月時間，並未恢復至滿載運轉；另外，因核一廠 2 號機較為特殊，原能會立即要求台電公司提出安全分析報告進行審查，至於未來台電公司提出核能機組彈性運轉申請，至少需 3 個月審查時間。

2.除役與廢料管理（Decommissioning Waste Management）

李彥良技正於 10 月 2 日(週二)下午，發表「台灣第一核能發電廠乾式貯存設施安全管制(Regulatory control on fuel dry storage of Chinshan NPP in Taiwan)」，首先介紹核一廠乾式貯存設施概況，核一廠乾式貯存設施於 96 年 3 月向原能會提出建造執照申請，係由國內核能研究所技術引進美國 NAC 公司的 UMS 護箱系統，並加以改良成為 INER-HPS 貯存護箱，藉由密封鋼筒限制放射性物質之外釋，並由混凝土護箱及外加屏蔽降低輻射劑量。目前核一廠乾貯設施已興建完成，台電公司於 100 年 11 月提報核一廠乾貯設施試運轉計畫申請，經原能會審查後於 101 年 5 月核准試運轉計畫書。102 年 1 月台電公司完成核一廠乾貯設施功能驗證測試，並提報整體功能驗證之測試結果，經原能會邀請專家學者審查確認符合安全分析報告的要求，原能會於 102 年 9 月同意台電公司續依已核准的試運轉計畫書，可進行後續熱測試作業，惟台電公司尚未取得新北市政府核發水土保持完工證明，因此無法進行後續作業，核一廠運轉執照將於 107 年底到期，並將進入除役階段，如乾貯設施無法順利使用，將會影響除役作業之進行。

另說明原能會對於乾式貯存的安全管制作業，採取建造執照與運轉執照的兩階段審查制度，同時在設施興建、試運轉與運轉期間執行安全與品質檢查，以確保用過核

子燃料的貯存安全。設施興建申請階段，原能會依規定舉辦聽證；另為加強管制作業之公開透明，核一廠乾貯設施興建期間，原能會並邀請民眾參與訪查及現地監測，俾民眾對設施安全能充份了解。

簡報結束後，與會人員提出有關核一廠除役問題，目前核一廠除役環境影響評估尚未通過，是否會影響除役時程?另外有關乾貯設施除役，台灣目前尚未有高放處置場，如何確保乾貯設施於運轉期限後，能如期除役?李員針對除役時程回應說明，依據法令規定，核電廠除役應於發給除役許可後，25 年內完成除役作業。核一廠運轉執照將於 107 年 12 月到期，目前原能會已完成除役計畫審查，惟取得環境影響評估審查同意為除役計畫許可要件之一，因此原能會要求台電公司應盡速完成環境影響評估審查，以利原能會核發核一廠除役許可，順遂核一廠除役計畫之執行。另有關如何確保乾貯設施除役部分，目前台電公司依法提報用過核子燃料最終處置計畫，其處置設施預定於 144 年完工啟用，屆時乾貯設施除役，應可與最終處置場接續。

同時段我國高雄大學土木與環境工程學系張惠雲教授，發表「用過核子燃料乾貯系統氯離子沉積特性(Characteristics of Chloride Deposits in a Nuclear Spent Fuel Dry Storage System) 」論文。張教授研究係以台灣台電公司核能二廠規劃興建用過核子燃料之乾式貯存設施為對象，利用計算流體力學(Computational Fluid Dynamics，簡稱 CFD)模擬並搭配熱流實驗，探討乾貯系統之密封鋼筒、混凝土護箱與流道內於特定條件下之溫度分布與流場特性，結果將用於評估核能二廠用過核燃料乾式貯存箱內氯鹽沉積情形，與加裝減鹽裝置對乾貯設施散熱效能之影響。

研究方式為製作一內含用過核子燃料之密封鋼筒及圍繞鋼桶厚度約 1 公尺厚混凝土護箱之貯存箱，鋼筒與混凝土護箱之間留設寬度約 10 公分之通風流道，利用 CFD 模擬並搭配熱流實驗，觀察乾式貯存箱之熱流特性。根據熱流分析結果，相較於無裝置減鹽裝置，裝有長度 50 公分減鹽裝置之貯存箱，其流道氣流所帶走的熱可增加約 7.6%；裝有長度 100 公分減鹽裝置之貯存箱，其流道氣流所帶走的熱約增加 7.1%。

由於減鹽裝置為板狀構造，當 50 公分長之減鹽裝置設於貯存箱入風處時，具有類似整流的效果，可增加流道氣流平均流速，但如果減鹽裝置長度從 50 公分增加到 100

公分時，則因流動摩擦增加，而使平均流速稍降，但相較於沒有減鹽裝置流道，其平均流速還是較高，流道氣流所帶走的熱也較大。

有關乾貯系統內氯鹽沉積情形，依據日本電力中央研究所(CRIEPI)研究指出，流入乾貯系統的氯鹽大小顆粒，可分為直徑平均值 2.5μm 與 20μm 等兩個群組分佈。張教授依據 CFD 模擬核能二廠乾貯系統通風流道內空氣夾帶氯鹽之流速分佈結果，發現氯鹽顆粒大者將被系統下部彎曲流道所阻擋，而顆粒小者則隨著加熱空氣而被帶離系統。乾貯系統內氯鹽顆粒受到浮力、壓力、空氣阻力與重力所共同作用，當向上合力超過向下合力之 10 倍時，可判斷氯鹽顆粒將隨加熱的空氣離開系統，依此條件所推估出來的氯鹽顆粒臨界直徑將遠大於 20μm，也就是說流道內氯鹽顆粒幾乎全部上浮、隨空氣離開系統。本研究氯鹽沉積情形之推論與分析結果，與美國最近 Calvert Cliffs 與 Hope Creek 兩個電廠乾貯設施檢查結果相當接近。

3.核能安全與核子保安(Safety and Security)

分組研討會主持人為美國愛達荷州國家實驗室經理 Monica Regalbuto 女士。戈元技士發表「原能會 2017 年臺北世界大學運動會輻射偵檢與惡意事件防範任務簡介(Radiation Screening and Adverse Event Prevention at 2017 Taipei Summer Universiade)」，說明原能會為了守護 2017 年臺北世界大學運動會（簡稱「臺北世大運」）賽事每位觀眾與選手安全，原能會派遣「輻射應變技術隊」（簡稱「輻應隊」）執行臺北世大運輻射事件防範與應變作業，動用輻射專業人員 284 人次及各式輻射偵測儀器 106 具、輻射偵測車 2 輛，作業內容包含：1.臺北體育園區及周邊（含道路）背景輻射調查與場地安檢，2.開、閉幕日全面實施進場人員、車輛輻射偵測，3.重要賽事場館及選手村周邊區域機動巡邏偵檢，4.賽事期間輻射意外或涉及放射性物質事件之應變。

臺北世大運任務是我國第一次執行大型活動賽事之輻射事件防範及應變工作，原能會運用台美民用核能合作機制，邀請美國能源部於 104 年、106 年兩次來臺辦理大型活動輻射事件應變訓練，並兩次派員赴美觀摩美式足球超級盃賽前維安整備作業之後，自主發展建立大型賽事輻射偵檢與應變作業程序，並與臺北市政府簽署「2017 臺北世界大學運動會維安合作意向書」，協助臺北市政府執行臺北世大運期間輻射事件防

範與應變作業，計完成臺北世大運主場館所在之臺北體育園區輻射偵測 2 萬 2 千餘坪兩次，園區周邊道路輻射偵測 1.5 公里兩次，開、閉幕日進場人員輻射偵檢近 5 萬人次、車輛輻射偵檢 300 餘輛次，以及賽事期間執行雙北、桃園及新竹縣、市地區重要場館與選手村周邊區域車載巡邏偵檢 16 趟次、總距離 24 公里，賽事期間未發現涉及放射性物質之惡意事件，任務圓滿成功。

報告結束後與在場之來賓交換意見，其中一位來賓詢問對於比賽游泳池如何執行輻射偵測？戈員回答本次任務僅就開、閉幕主場館所在之臺北體育園區執行輻射偵測，若須對於比賽游泳池如何執行輻射偵測，須於游泳池注水前之空池執行，確認安全無放射性物質後再行注水，並封鎖場館進行維安監控，防止池水後續受到人為污染。另一位來賓詢問本會是否事前即掌握恐怖份子名單，入場時施以特別維安檢查?戈員回答國安單位並未提供恐怖份子名單，但原能會針對所有入場人員、車輛實施全面輻射偵測，亦派有巡邏偵測人員，對於場外可疑人員、車輛實施偵測，並與軍、警維安單位保持密切聯繫，若發現異常情況立即通報維安單位進行後續調查。第三位來賓詢問本次世大運任務圓滿成功，有無後續規劃？戈員回答原能會已總結任務經驗完成檢討報告，並持續精進人員訓練、儀器設備及作業程序，未來將配合我國政府國土安全部門需求，參與國家各項重大活動維安作業。

4.燃料儲存（Fuel Storage）

我國台電公司核能發電處黃平輝專業工程師，於 10 月 2 日(週二)下午亦以「核二廠用過燃料池護箱裝載池安裝格架安全分析(Safety Analyses for Installing Fuel Storage Racks in Cask Loading Pool at Kuosheng Nuclear Power Station)」為題發表論文，黃專業工程師說明台電公司核二廠一號機於 105 年 11 月大修時，即面臨用過燃料池貯存容量不足，無法繼續運轉窘境。經台電公司參考國際類似案例、評估各項可行性方案後，認為以在用過燃料池護箱裝載池，安裝 4 組龍門電廠二號機庫存格架方式，不僅技術上可行，效益上亦可讓機組增加 440 束用過燃料貯存空間(約為用過燃料池容量之十分之一)，足以使機組繼續運轉 3 年。

台電公司依據原能會「核能電廠用過燃料池貯存格架改裝安全分析報告審查規範」

要求提出安全分析報告，提交原能會審查，該安全分析報告主要內容包括 5 大技術範疇(臨界安全、熱流分析、結構分析、輻射安全、事故評估等)，黃專業工程師均一一詳細說明各項分析內容，以及原能會對於各項審查意見。全案於 106 年 4 月 6 日順利取得原能會核准，續經原能會 106 年 5 月 19 日正式同意一號機之裝載池燃料貯存格架可啟用放置用過燃料，一號機在完成燃料挪移作業後於 106 年 6 月 9 日併聯、6 月 16 日滿載發電。對於在夏季供電曾多次出現備轉容量率燈號為「紅燈」(限電警戒)的北台灣避免限電發生有著關鍵性的作用。.

5.公眾溝通(Public Communication)

本項議題研討於 10 月 3 日(週三)下午舉行，議題聚焦於新核能科技及應用之公眾溝通，研討會由來自加拿大卡爾加里大學(University of Calgary)能源科學與傳播研究所的 Bethel Afework 女士主持，愛達荷國家實驗室夥伴關係部主管 Amy Lientz 女士發表「第一座小型模組化反應爐建造的公眾參與(Engaging the Public on the Building the First Small Modular Reactor)」論文，Amy Lientz 女士首先從其過去從事風電場及核電計畫之選址、環境影響評估工作等經驗，說明成功推動公眾參與能源議題，除了與地方政府、產業及與學術界合作外，事先與新聞媒體溝通、爭取利害關係人支持也極重要，特別是創新能源科技產業化後的不確定性(因過去並無商業運轉實績)，更易引發民眾疑慮。

Amy Lientz 女士以全美第一個示範用小型模組反應爐(SMR)將在 2020 年於愛達荷州建造為例，SMR 興建計畫推動工作由製造商 NuScale 公司及分佈在六個州(猶他州、愛達荷州、加州，內華達州，新墨西哥州及懷俄明州)的營運商負責主導，愛達荷國家實驗室則負責公眾溝通部分。愛達荷州政府以資訊公開主動豐富、對話持續透明、建立信任關係等為目標，成立副州長層級的「核能領導委員會(Leadership in Nuclear Energy，簡稱 LINE)」及「愛達荷州東部經濟發展區科學技術與研究小組委員會」推動公眾溝通工作。LINE 委員會每季舉行且完全公開，由副州長、愛達荷國家實驗室主任與全州各地區代表討論各項核能關鍵議題，向州長提出政策建議，並回答現場民眾問題。LINE 以下設有「愛達荷州東部經濟發展區科學技術與研究小組委員會」，其成立

目的是讓對核能議題關心民眾能藉由平台分享資訊，並就關心議題要求澄清改善。

在媒體經營部分，除了建立媒體合作夥伴清單，以協助相關宣導新聞訊息傳遞外，其他重要作法，包含在愛達荷國家實驗室舉辦「年度媒體日」廣邀媒體參觀，並透過媒體提供民眾核能科技新知，專人撰寫專欄供當地報刊雜誌刊登並參與其編輯會議，安排媒體專訪增加曝光率，以及成立快速輿情回應小組，專職負責輿情回應及更正媒體刊登錯誤訊息等。

10 月 3 日(週三)晚上閉幕會議及晚宴，由大會技術議程主席 Corey McDaniel 主持，宣布 22 屆 PBNC（PBNC 2020）將於 2020 年 4 月在墨西哥坎昆舉行，並由墨西哥核能協會會長 Javier Palacios 接續進行 22 屆 PBNC 舉辦場地介紹。

三、技術參訪

10 月 4 日(週四)是大會所安排之加利福尼亞大學柏克萊分校(簡稱柏克萊加大)核子工程實驗室的技術參訪活動。該校位於舊金山灣區柏克萊市，是一所世界著名的研究型大學。柏克萊加大的校地總面積約為 5 平方公里，而主校區約 72 公頃。大學部約有學生 23,000 人，研究生約有 10,000 人。柏克萊加大研究水平極高，截止 2018 年 9 月，共有 104 位教職員或校友成為諾貝爾獎得主，在全球各大學排名第三。

當參訪團一行抵達後，首先由柏克萊加大核工系系主任 Peter Hosemann 教授進行系務(簡史、學術、研究計畫及教授群)相關介紹，核子工程系成立於 1958 年，目前該系大約有 100 名研究生、100 名大學部學生及 9 名終身職教授(其中 1 名係與外系合聘)，前一會計年度(2016/2017)研究經費為 1.17 千萬美元。Hosemann 教授說明柏克萊加大對核能界貢獻極大，「原子彈之父」羅伯特·歐本海默教授及「氫彈之父」泰勒教授均曾長期任教該校；另外該校恩尼斯特·勞倫斯教授發明了迴旋加速器，柏克萊加大以及勞倫斯柏克萊國家實驗室的研究人員藉由該迴旋加速器找出了 16 種化學元素，其中鉳（Berkelium，原子序為 97）和鉲(Californium，原子序為 98)更以柏克萊加大的名字來命名。二次大戰時期，柏克萊加大獲邀參加美國軍方的原子彈研發計畫。1942 年的二戰期間，該校羅伯特·奧本海默教授甚至被任命領導曼哈頓計畫，為美國政府研發與製

造原子彈。

接著由該校同學導覽校園周圍的歷史地點，包括葛蘭·西柏格在 1941 年 2 月 23 日發現鈽的歷史地標 Gilman Hall，校園內的薩斯塔（Sather Tower）是加州大學最顯著的標誌，常被稱為「鐘樓」（The Campanile），完成於 1914 年，樓高 93.6 公尺，是世界第三高的鐘樓。鐘樓旁另有一座南樓(South Hall)，是校園內最古老的建築物。

最後是參觀重要實驗室，包括：(1)核子材料測試(nuclear materials testing)實驗室：目前的研究重點包含運用離子束照射加速材料測試、核反應器組件的結構材料腐蝕等。(2)熱工水力學(thermal hydraulics)實驗室：運用自建「氟鹽冷卻高溫反應器」(Fluoride-salt-cooled, High temperature Rector，簡稱 FHR)熱流迴路系統，進行「壓縮整合效應測試」(Compact Integral Effects Test，簡稱 CIET)是其研究核心，FHR 屬熔鹽反應爐的一種，利用熔鹽將熱量從反應爐爐心轉移出去而發電，反應爐因有冷卻劑而在低壓下操作，所以也不需要圍阻體來防止壓力釋放。此外，因輻射物質混在熔鹽中，碰到室溫就會冷卻成固態的「輻射鹽」，也不會跟著水蒸氣飄散到空氣中，造成輻射污染，即使反應器失去動力，冷卻劑也將依靠對流循環通過反應爐持續除去餘熱。

目前 CIET 除作為先進熔鹽反應爐熱流迴路系統測試台外，該實驗室也提供 NRC 和其他核安監管機構相關實驗驗證數據。導覽同學並說明該系教授亦會善用它系如物理、化學、材料、醫工等系所實驗室，進行核工、輻射相關應用研究，包括進步型反應爐安全和執照申請、反應器材料可靠性、檢測與成像醫學，以及核能安全等。

參、心得與建議：

一、 心得

(一) 本次會議專題研討與會專家強調公眾溝通「信使重於信息」(Messenger is more important than Message)，也就是「讓人產生信賴感的溝通者」加上「有溫度的論點」才是有效溝通的關鍵，核安宣導目標不應只是「安全」，還要讓民眾能「安心」，過於強調安全反而可能讓民眾不安。

(二) 綜觀各國核能產業主要面對的挑戰，包括:資產管理、設備零件老化、網路安全、供應鏈安全、核廢料處理與核電廠除役，事關核電營運、除役與核廢料處理的成本與安全管制等，亦為我國核能發展面臨的問題，參加各項國際會議，汲取相關經驗，對於我國研擬核安管制作法，頗具參考價值。

(三) 本次會議部分專家提及已有歐美國家核能電廠，研究運用各項創新科技，如機器人(運送核廢料)、人工智慧(辨識和量化裂縫系統)與智慧眼鏡(監測輻射數值)等，以提升電廠營運效能，身為我國核安管制機構的一員，深感強化個人專業職能，保持管制技術與時俱進的重要性。

二、 建議

(一) 為加強與鄰近國家核安管制技術交流、精進輻射防護作為，建議持續派員出席太平洋盆地核能會議，將我國長期以來優良的核電安全管制作為、現階段除役與廢料管理作法，以及辦理大型活動賽事之輻射事件防範應變的實務經驗，與國際社會分享。

(二) 我國的核電廠即將邁入除役或延役階段，早期興建電廠內之用過核燃料池(即溼式貯存)容量有限，均不足以容納運轉執照效期 40 年之所有用過核子燃料，因此用過核子燃料乾式貯存設施之推動，為國內核能發電廠除役或延役成功與否之關鍵，建議持續關注國際乾貯設施技術研發與安全管制等重要議題，以做為我國乾貯設施發展之參考。

肆、附件一：第 21 屆太平洋盆地核能會議議程

Daily Schedule

Sunday, September 30

12:00-5:00 pm	Exhibitors Move In	Grand Ballroom
3:00-6:00 pm	Registration	Regency A
5:00-7:00 pm	Welcome Reception	Grand Ballroom A/Foyer

Sponsored by Canadian Nuclear Laboratories / Laboratoires Nucléaires Canadiens

6:00-6:30 pm	U.S. Congressional Keynote Address by Senator James Risch	Grand Ballroom A/Foyer

Monday, October 1

7:00 am-5:00 pm	Registration	Regency A
7:00 am-5:00 pm	Exhibits Open	Grand Ballroom
7:30-8:00 am	Morning Coffee Service in Exhibit Hall	Grand Ballroom
8:00-10:00 am	Opening Plenary Morning Session I	Ballroom B/C
10:00-10:15 am	Refreshment Break in Exhibit Hall Grand	Ballroom A/Foyer

Sponsored by OCNI Organization of Canadian Nuclear Industries — Clean Energy for a Low Carbon Economy

10:15 am-12:00 pm	Opening Plenary Morning Session II	Ballroom B/C
12:00-1:30 pm	Lunch in Atrium	
12:00-1:30 pm	Coffee/Dessert in Exhibit Hall	Grand Ballroom A/Foyer
1:30-3:00 pm	Opening Plenary Afternoon Session–I	Bayview B
1:30-3:00 pm	Technical Sessions	
	• Probability Risk Assessment, Safety, and Control Systems	Seacliff A
	• Reactor Safety Analysis Methodologies and Codes—I	Seacliff B
	• Nuclear Fuels and Fluid Dynamics	Seacliff C
	• Advanced Chemistry and Processing Options	Seacliff D
	• Advances in Light Water Cooled Reactors—I: Pressured Water Reactors	Marina
	• Fuel, Core, and Related Topics—I	Golden Gate
3:00-3:30 pm	Refreshment Break in Exhibit Hall	Grand Ballroom A/Foyer

Sponsored by Westinghouse

3:30-5:00 pm	Opening Plenary Afternoon Session–II	Bayview B
3:30-5:00 pm	Technical Sessions	
	• Recent Advances in Nuclear Security	Seacliff A
	• Advances in Nuclear Materials Safety	Seacliff B
	• Enabling Long Term Operations	Seacliff C
	• Advances in Radionuclide Analysis in Support of Decontamination and Decommissioning	Seacliff D
	• Advances in Light Water Cooled Reactors—II: Integral PWRs	Marina
	• Fuel, Core, and Related Topics—II	Golden Gate

Daily Schedule

Tuesday, October 2

7:00 am-5:00 pm	Registration	Regency A
7:00 am-5:00 pm	Exhibits Open	Grand Ballroom
7:30-8:00 am	Morning Coffee Service in Exhibit Hall	Grand Ballroom A/Foyer
8:00-9:45 am	Advancing Nuclear Energy Morning Session–I	Ballroom B/C
9:45-10:15 am	Refreshment Break in Exhibit Hall *Sponsored by* **FLUOR.**	Grand Ballroom A/Foyer
10:15 am-12:00 pm	Advancing Nuclear Energy Morning Session–II	Ballroom B/C
12:00-1:30 pm	Lunch Break and Technical Poster Session	Atrium
12:00-1:30 pm	Coffee/Dessert in Exhibit Hall	Grand Ballroom
1:30-3:00 pm	Technical Sessions	
	• Enabling Factors for Advanced Reactors	Bayview B
	• Policy and Regulatory Approaches to Nuclear Safety	Seacliff A
	• Design Certification and Construction	Seacliff B
	• Recent Advances in Plant Digitization	Seacliff C
	• Advances in Fuel Storage Options and Review of Challenges—I	Seacliff D
	• Novel Reactor Concepts and Licensing Novel Reactors	Marina
	• Communication Impact of New Nuclear Technologies and Uses	Golden Gate
3:00-3:30 pm	Refreshment Break in Exhibit Hall	Grand Ballroom A/Foyer
3:30-5:00 pm	Technical Sessions	
	• Advancing Nuclear Medicine	Bayview B
	• Reactor Safety Analysis, Methodologies, and Codes—II	Seacliff A
	• Construction and International Considerations	Seacliff B
	• Technologies for Power Operations	Seacliff C
	• Advances in Fuel Storage Options and Review of Challenges—II	Seacliff D
	• Innovative Technologies for Advanced Reactors	Marina
	• Promoting Nuclear Energy Education	Golden Gate

#ANSMeeting

Daily Schedule

Wednesday, October 3

7:00 am-5:00 pm	Registration	Regency A
7:00 am-1:30 pm	Exhibit Open	Grand Ballroom A/Foyer
7:30-8:00 am	Morning Coffee Service in Exhibit Hall	Grand Ballroom A/Foyer
8:00-9:45 am	Sustaining Nuclear Energy Morning Session–I	Ballroom B/C
9:45-10:15 am	Refreshment Break in Exhibit Hall	Grand Ballroom A/Foyer
10:15 am-12:00 pm	Sustaining Nuclear Energy Morning Session–II	Ballroom B/C
12:00-1:30 pm	Lunch Break in Atrium	Atrium
12:00-1:30 pm	Coffee/Dessert in Exhibit Hall	Grand Ballroom A/Foyer
1:30-3:00 pm	Technical Sessions	
	• Sustainable Approaches to the Nuclear Fuel Cycle	Bayview B
	• Severe Accident Management	Seacliff A
	• Economics—I	Seacliff B
	• Advances in Engineering Design	Seacliff C
	• Recent Advances in World-Wide Decommissioning—I	Seacliff D
	• Enabling Advanced Reactors: Research Facilities	Marina
	• New Approaches to Nuclear Outreach	Golden Gate
3:00-3:30 pm	Refreshment Break	Seacliff Foyer
3:30-5:00 pm	Technical Sessions	
	• Addressing Challenges in the Global Nuclear Supply Chain	Bayview B
	• Thermal Hydraulics	Seacliff A
	• Economics—II	Seacliff B
	• Recent Advances in World-Wide Decommissioning—II	Seacliff D
	• Heat-Pipe Reactors and Sodium-Cooled Reactor	Marina
	• Advances in Nuclear Medicine	Golden Gate
6:00-10:00 pm	Wednesday Gala Dinner	Grand Ballroom B

Thursday, October 4

9:00 am-2:30 pm	UC Berkeley Nuclear Engineering Campus Technical Tour	Board the bus for the tour at the Market Street Foyer Exit at 8:45 am.

伍、附件二：行政院原子能委員會同仁發表論文集

一、許明童科長發表部分

REGULATORY EXPERIENCE ON FLEXIBLE POWER OPERATION APPLICATION

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KEYWORDS: flexible power operation, operating experience, flow induced vibration, hydrogen water chemistry, xenon transient, cyclic reverse stress, acoustic excitation, rulemaking

ABSTRACT: Most nuclear power plants (NPPs) built in the early stages were designed to operate at steady full power, known as 'base-load' operation. However, more and more nuclear power companies would like to have the flexibility to operate their NPPs depending on the load demand, which means to change how they operate from the base-load mode to flexible mode. Taipower company (TPC), the only utility in Taiwan, submitted an application for operating one reactor unit at a non-rated power level without changing the total rod power burnups in order to extend the operation period before next refueling outage. Since this was the first application, the Taiwan nuclear safety authority, Atomic Energy Council (AEC), thoroughly reviewed the impacts of the strategy by referring to the documents of flexible power operation experiences on nuclear power plants by the International Atomic Energy Agency (IAEA) and the US Electric Power Research Institute (EPRI). TPC plans to submit more applications to AEC in the near future. Both regulatory and operating experience feedbacks are important, since which are all good indicators to reflect whether the safety issues involved have been evaluated and/or the corresponding measures have been taken, if necessary.

1. INTRODUCTION

All the nuclear power plants in Taiwan were designed for baseload operation and were operated at rated full power except short period for test, recovery from the failure of structures, systems, and components (SSCs) or severe weather conditions such as typhoons or heavy rains. Recently, to meet the load demand, TPC planned flexible operation strategy for Chinshan (CS) unit 2, by manually reducing the power level to extend the fuel cycle with no design changes involved. CS is the first nuclear power plant built in Taiwan. TPC reduced the power level of CS unit 2 from 100% power to 75% on April 29, 2017 to extend the fuel cycle so that the end of the cycle was extended from June 1 to mid-June. While extending the fuel cycle, the total fuel burnup limit approved by the AEC was not exceeded, and the 18-month surveillance requirement of the technical specification was also satisfied. Table 1 summarizes the design features of CS unit 2.

Since the application of CS unit 2 was the first case adopting flexible power operation (FPO) concept in Taiwan, the regulatory authority AEC considered it as a pioneer for this important issue. Hence, although the scope of this FPO might not be dramatic and at that time the Nuclear Reactor Facilities Regulation Act (NRFRA) in Taiwan did not explicitly state that the flexible operation plan shall be submitted to AEC in advance, AEC requested TPC to submit the safety analysis report (SAR) for CS unit 2 flexible power operation application and amended the Act correspondingly. In order to review this issue thoroughly, AEC referred to the IAEA and the EPRI technical document on the flexible operation of nuclear power plants (reference 2, 3) and took CS unit 2's plant-specific operating experience into consideration as well.

TPC submitted the SAR for FPO application of CS unit 2 to AEC. After receiving the report from TPC, AEC immediately established a safety review taskforce to review relevant issues including the integrity of the fuel, the safety of reactor internals, and balance of plant (BOP). In addition, AEC held a public meeting to discuss FPO, exchanging opinions with the civic groups so that the public could have a better and deeper understanding of the review process on FPO application. After reviewing the application, the AEC approved the SAR of FPO that CS unit 2 could operate with a stable 75% power as proposed.

TABLE 1 Design features of Chinshan Unit 2 in Taiwan

Chinshan Unit 2	Design feature	Chinshan Unit 2	Design feature

Reactor Type Vender	BWR-4 GE	Containment	Mark-I (Steel)
Thermal Power (MWt)	1804	Fuel Burnup on April 29,2017 (MWd/MTU)	11750
Electrical Power (MWe)	636	Fuel Cycle Burnup Limit (MWd/MTU)	12723.7
Date of Commercial Operation	07/16/1979	Start Date of Flexible Operation	04/29/2017
Date of Operation License Expire	07/15/2019	Original and Extended Date of Refueling Outage	Original 06/01/2017 Extended 06/15/2017

2. SITE INPECTION AND OPERATING PARAMETERS COMPARISION BETWEEN FULL POWER AND 75% POWER STABLE OPERATION

Upon receiving the FPO application, several stability issues were reviewed by the AEC. The goal of flexible power operation of CS unit 2 is to maintain at 75% rated power and operate within the power/flow domain area of the Reload Licensing Analysis (RLA) and Core Operating Limit Report (COLR) for Cycle 28 previously approved by the AEC. The AEC required TPC to compare the key parameters operating at 75% power with that at 100% power level to determine the safety margins on the major parameters. The parameters selected to compare ~~compared~~ are primarily from reactor core monitoring system, BOP monitoring system and POWERPLEX results, as summarized in Table 2. In addition to stability assessment, the AEC also focused on the results of environment monitoring. The AEC required TPC to compare the results of Process Radiation Monitoring System (PRM) and Environment Radiation Monitoring System (ERM) at two different power levels.

The AEC selected several important SSCs and relevant parameters based on the EPRI technical report to check if they are consistent with TPC's evaluation results and measurement. To achieve this, the AEC conducted onsite inspections to confirm how the parameters change with the reduced operating power such that the temperature, pressure, vibration, wear, and leakage of certain SSCs were carefully examined. The lower operating power provides higher safety margins on the operating parameters, and no differences were observed for both the PRM and ERM systems at these two different power levels. Table 3 summarizes the major parameters from PRM and ERM for different operating power levels at CS unit 2.

During the reduced power operating period, the decrement in steam flow in the main steam line (MSL) leaded to the changes in the valve position of the main turbine governor valve (GV). When adjusting the valve position, oil leakage was found on Digital Electro-Hydraulic oil tubing at GV No.3. The TPC has made corrective actions including: changing the position of the GV-3 actuator stem and replacing the return oil filter.

TABLE 2 Major Parameters and Evaluation Results of Flexible Power Operation in Chinshan NPP Unit 2 (Provided by TPC)

Parameter	100% Power	75% Power	Evaluation Results
Thermal Power (MWt)	1840	1380	~~Increase~~ Safety Margin Increased
Electrical Power (MWe)	652	495	Increase Safety Margin
CMFLCPR	0.935	0.896	Increase Safety Margin
APRM	100%	75%	Increase Safety Margin
Jet Pump Flow(T/H)	A:11570 B:10760	A:10000 B:9590	Increase Safety Margin
Core Different Pressure(psid)	14.8	10.5	Increase Safety Margin
Recirc. Pump Speed	A:88.4% B:86.2%	A:74.8% B:72.6%	Increase Safety Margin
Core Flow	91.8%	80.9%	Increase Safety Margin
FW Control Valve Open	63~66%	29~31%	Increase Safety Margin
FW Inlet Temp (°C)	214	201	Increase Safety Margin
Condensor Flow(LPM)	60000	45000	Increase Safety Margin
Condensor Demin (unit)	8	6	Increase Safety Margin
Condensor Vaccuum (mm-Hg abs)	54	45	Increase Safety Margin
Gland Steam Press/Vaccum	0.35~0.4	0.35~0.4	No change
Turbine Bearing Vibration(mil)	MAX:3.6(6X) MIN:0.7(9)	MAX:3.3(6X) MIN:1.0(9)	No change
HP TB First Metal Temp (°C)	261	243	Increase Safety Margin
Generator Metal Temp (°C)	120~129	90~100	Increase Safety Margin

TABLE 3 PRM and ERM of Flexible Power Operation in Chinshan NPP Unit 2 (Provided by TPC)

Parameter	100% Power	75% Power	Evaluation Results
Reactor Building Vent (mR/hr)	0.14	0.13	Safety Margin Increased
Off-Gas(cps)	800~1300	500~850	Increase Safety

			Margin
Main Stack (cps)	8.3~9.3	8.5~8.7	Increase Safety Margin
Turbine Building Vent (cpm)	P:75 I:20	P:61 I:12.6	Increase Safety Margin
Liquid Monitor (cps)	40	38	Increase Safety Margin
CSCW Monitor (cps)	A:3.9 B:3.4	A:3.5 B:3.2	Increase Safety Margin
Envireonment Radiation Monitor (μ Sv/h)	0.048~0.079	0.048~0.079	No change

3. IMPACT ASSESSMENT OF REACTOR CORE COMPONENTS

Although several cases of reduced power operation were found in other countries, further investigation and discussions on the appropriateness of CS unit 2 FPO are necessary, which would be based on the lessons learned from other plants, relevant technical reports such as those from EPRI, and plant-specific considerations of CS2. The AEC required TPC to assess the impacts of FPO on several aspects such as reactor core components, fuel integrity, equipment and response strategy and steam dryer resonance vibration. This session is primarily on reactor core components, and other issues would be discussed in the following sessions. The AEC also required TPC to compare the results with the EPRI-3002002612 report (reference 3).

With regard to the changes in core flow due to the reduced power operation, the issue of Flow Induced Vibration (FIV) was evaluated. The impact assessment at the reduced power level is based on 80% core flow and recirculation pump speed at 996 rpm.

The GE Hitachi Nuclear Energy Company (GEH) provided impact assessment on the reactor core components at 75% power level for the TPC (reference 5). GEH also evaluated the effect of the secondary harmonic effect (Vane Passing Frequency, VPF) on the Jet Pump Sensing Line (JPSL), separator assembly, core shroud, feed water sparger and jet pump riser braces and so on. The results showed that the core flow of CS unit 2 in the range of 80%~99% with recirculation pump speed at 996 rpm will have the vibration frequencies between 100.5Hz and 133.3 Hz, and it will not get into the resonant frequencies of 42~77 Hz or above 139.3 Hz for JPSL. Since the entrance into the frequency range for resonance or JPSL is not possible, the impacts from FIV were ruled out.

The Hydrogen Water Chemistry (HWC) is usually implemented to provide protection against Intergranular Stress Corrosion Cracking (IGSCC) in operating BWRs. The Hydrogen Water Chemistry (HWC) injection system of CS unit 2 was designed such that it will not operate with power less than 90%, and it may change the crack growth rates after stopping hydrogen injection. The Boiling Water Reactor Vessel Internal Program (BWRVIP) 62-A (reference 6) defines the Factor of Improvement (FOI) as the ratio of average crack growth rate over a time period under Normal Water Chemistry (NWC) with a combination of NWC and HWC. The Hydrogen Water Chemistry (HWC) availability of CS unit 2 Cycle 28 was 84.65% and the corresponding FOI was 3.02 (ECP=-230mVSHE). Assuming HWC remained inoperable until the end of this cycle, the availability of HWC will be reduced to 77.86% and the corresponding FOI was 2.60 (ECP=-230mVSHE). Although the crack growth rate in the core components may be increased, operating at lower power level will also reduce stresses on the components. TPC will continue to follow the Internals Vessel Visual Inspection (IVVI) program to monitor the existing indications of these components.

The halt of HWC injecting system may not have adverse impacts on fuel assembly integrity. The CS unit 2 did not add zinc to its HWC system, and the oxide layer may not change its form with reduced heat transfer coefficient and may not cause fuel cladding damage. The radiation level in the turbine building will also be reduced after the cessation of HWC system operation.

4. IMPACT ASSESSMENT OF FUEL INTEGRITY

Although the proposed reduced power operation of CS unit 2 does not exceed the fuel burnup limit, many factors associated with the fuel integrity such as control rod patterns and thermal-hydraulics need to be considered. In addition, the licensed operators should have a thorough understanding on the details in the operating strategy and its process.

The AREVA NP company re-evaluated the Reload Licensing Analysis (RLA), Core Operating Limits Report (COLR), Startup and Operation Report (SOR) of CS unit 2 reduced to 75% power with fuel burnup from the date of power reduction (11750 MWd/MTU) to the end of Cycle 28 (with the limit 12723.7 MWd/MTU approved by the AEC). The result showed that operating at 75% power level will have sufficient safety margins against the burnup limits, maximum fuel assembly burnup 54 GWd/MTU, fuel rod burnup 58.7 GWd/MTU, and axial power profile the SOR.

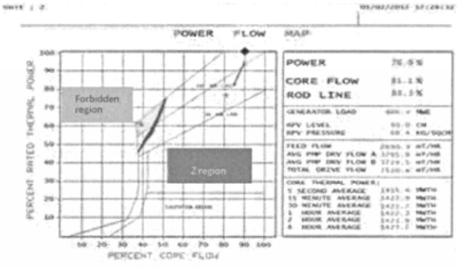
The CS unit 2 FPO at 75% power level actually starts with the combination of core flow being greater than 80 % and 10 control rods insertion in 3 groups. The operation strategy is to minimize the disturbance of core neutron flux and therefore minimizes the power peaking factors. The operation will also avoid the entrance of the instability regions of the Power/Flow Map with the limit ratio of 78.8%/54.7% along the 116.5% analytical rod line. The Oscillation Power Range Monitor (OPRM) will monitor the power oscillation and trip the reactor whenever the oscillation happens under the condition the reactor power being greater than 30% and the core flow being less than 60%. The OPRM is used to protect the fuel within the safety limit of Minimum Critical Power Ratio (MCPR). Figure 1 illustrated the Power Flow Map for Full-power, 75% power, and the instability regions.

When the power is reduced from 100% to 75%, the Xenon-135 concentration will change accordingly and the change of Xenon concentration is also included in the assessment. The Xenon concentration increased to 107.5% at

8 hours after power being reduced to 75%, and then remained at stable concentration (90% of that at full power level) no longer than 48 hours. Figure 2 illustrated how the Xenon-135 concentration change when the power level is reduced from 100% to 75%.

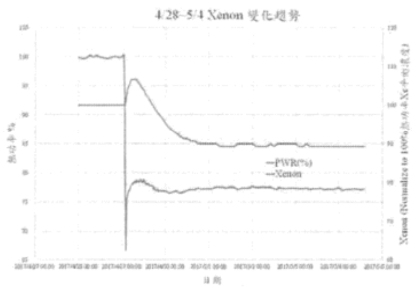
The TPC follows the operation limit set by full power for FPO, but re-assessed key factors including MCPR, Doppler coefficient, temperature coefficient, void coefficient, control rod withdraw scenario to ensure fuel integrity. TPC used POWERPLEX for CS unit 2 to continuously monitor the core parameters, including the power envelope margin, thermal limit, fuel consumption limit, and power distribution. The AREVA NP company used MICROBURN to predict fuel burnup rate, and consumptions of fuel elements and fuel rods. The results showed the FPO will keep fuel burnups within their original limits and also keep enough safety margins.

FIG. 1 Power Flow Map change from Full-power to 75% power level (source from TPC)



Note: Unstable region=forbidden region + Z region

FIG. 2 Xenon-135 concentration change from Full-power to 75% power level (source from TPC)



5. IMPACT ASSESSMENT OF EQUIPMENT AND RESPONSE STRATEGY

Besides feedbacks from elsewhere such as the operating experience of other plants and relevant technical reports, the operating experience of CS itself as well as its plant-specific parameters are crucial while evaluating the appropriateness of its FOP application. The discussions covered in this session focus on the turbine gland steam condenser air exhaust fan in CS.

The past operating experience of CS shows that the turbine gland steam condenser air exhaust fans no.1 and no.2 (normally only one needs to be in operation and the other one is as backup) sometimes were tripped due to overcurrent. This raised the concern about the reliability of these components so that the AEC requested TPC to evaluate and test the intended functions of the fans. Accordingly, one fan was put into service as testing so that the whole system could function normally by TPC to confirm its functionality, and later two fans were put into service simultaneously as testing.

The CS unit 2 operated at 75% will result in the increment in moisture. TPC has decided to put both fans into service and set up surveillance program to monitor the performance on these fans. The operator will record the current of these two fans every 4 hours and report to the maintenance division if any abnormalities were found.

Reduced power operation leads to the changes in some parameters such as feedwater flow rate and temperature. In addition, the impact on the valve position of the feedwater control valve also requires further investigations to ensure the stability of core water level.

The control signal of feedwater pump may cause the control valve C31-F001A/B fluctuated at about 70% power level, but TPC operated CS unit 2 at 75% stable power level, which will have enough safety margin to avoid the control valve fluctuation.

The FPO may change the equilibrium temperature and steam induced vibration on the turbine. The reduced power operation also changes reactor pressure, steam temperature and its quality. All of these could also have impacts on the fatigue life of low pressure (LP) turbine. The last stage of LP turbine with the maximum length and mass, also with the highest cyclic reverse stress, need to be re-evaluated at 75% power level. The temperature of the LP turbine blades at the last stage changed from 42 °C at full power to 39 °C at 75% power level, but the steam induced vibration also reduced at 75% level because of the reduced steam flowrate. The combinations of lower temperature and less steam induced vibration suggested that the cyclic reverse stress on the turbine blade may be reduced, and the vender also ruled out the possibility of resonance of turbine blade at FPO. Despite of this, online monitoring were conduct to ensure the operation safety of the turbine.

6. IMPACT ASSESSMENT OF STEAM DRYER RESONANCE

Recently, in BWR power uprate applications the issue of steam dryer integrity has received considerable attentions. The acoustic resonance vibration between the MSL and the safety relief valve (SRV) may occur when the vortex shedding frequency at the inlet of piping connected to the MSL is the same as one-quarter of the acoustic wave resonant frequency at connecting pipe. The frequency of the vortex shedding is related to the steam flow rate in the MSL and therefore the changes in steam flow could possibly induce the acoustic resonance vibration between the MSL and the SRV.

The changes in steam flow do not only apply for those proposed power uprate operations, but also for the FPO cases. The EPRI report indicates that when the power is reduced to around 70%, acoustic resonance vibration was observed in some plants. In addition, considering the fact that cracks were once found in the steam dryers of CS in the past, thorough evaluation of the impacts of reduced power on steam dryer integrity is necessary. TPC conducted relevant analyses of FPO on steam dryer resonance effects based on BWRVIP-182-A technical report (reference 7). The power level and core flow used in the analyses are respectively 75% and 80%.

The Strouhal Number of acoustic resonance from BWRVIP-182-A report is between 0.25 and 0.60, and TPC calculated the Strouhal Number with its specific geometric diameters, with steam pressure of 67.02 kg/cm^2 and with steam temperature of 282°C at 75% power level. The sound speed used in the calculation was 492 m/s, and the density was 34.76 kg/m3. The total steam flow rate (4 steam pipes) was 2563 T/hr, and the steam velocity was 31.41 m/s. TPC calculated the minimum Strouhal Number for 75% power was 0.99, and is outside the resonance range which is between 0.25 and 0.60. The results showed that the FPO at CS unit 2 could not cause acoustic resonance at the steam dryer. Table 4 summarizes the Strouhal Number calculated at two different power levels.

TABLE 4 Strouhal Number calculated at full-power and 75% power level (Provided by TPC)

	Flow sound speed (a)	Steam flow velocity (U)	Acoustic resonant frequency (f1)	Strouhal Number (S0)
Full-Power (1775MWt)	490 m/s	40.23 m/s (132 ft/s)	SRV-A: 179.4Hz Others: 201.5 Hz	SRV-A: 0.772 Others: 0.867
75% Power Level (1380MWt)	492 m/s	31.41 m/s (103.1 ft/s)	SRV-A: 180.1Hz Others: 202.3Hz	SRV-A: 0.99 Others: 1.11

7. REVIEW TO COMPARE WITH EPRI GUIDELINE REQUIREMENT AND RULEMAKING

In fact, EPRI already proposed a systematic approach to evaluate the safety issues involved when reducing the power level from base-load operation to flexible power operation. The AEC required TPC to compare the CS2 FPO with the items listed on the EPRI-3002002612 report. This includes a comprehensive description on the flexible power operation, the power output control assessment, the primary system and components impact assessment, balance of plant considerations, operational considerations and evaluation of operating procedures. The AEC also referred to the technical reports from IAEA and EPRI while reviewing CS unit 2 FPO application. The safety issues discussed in the reports were evaluated one by one for CS unit 2 FPO, and finally the FPO application was approved by the AEC.

Reduced power operations were proceeded successfully in other plants under supervision in the past. However, since the CS unit 2 FPO was the first case to operate the reactor at a power level other than the previously approved full power for an extended period of time, AEC issued a clarification on Articles 14 of the Nuclear Reactor Facilities Regulation Act (NRFRA) to include such a situation into the scope of the regulation. With this clarification, TPC could proceed reduced power operation accordingly, as well as to satisfy the load demand.

According to the clarification, TPC shall prepare safety analysis report and receive approval from the AEC before conducting FPO. However, power reduction in order to provide more safety margins against natural threats such as hurricane and heavy rains, or for conducting routine maintenance and surveillance programs on SSCs is exempted from the requirements specified in the clarification.

8. CONCLUSIONS

The FPO of CS unit 2 was the first case to operate the reactor at 75% for a longer period of time in Taiwan. It was considered as a pilot case in safety review, rule-making and public communication for future FPO in Taiwan. The safety analysis report provided by TPC evaluates the impacts to reactor core components, fuel integrity, equipment and operation strategies, and steam dryer resonance vibration demonstrating the compliances with safety requirements at this power level. The AEC also issued a clarification to include such a situation into the scope of the regulation and held a public meeting to discuss, share and exchange information with the civic groups. It is a valuable experience for the AEC on the CS unit 2 FPO in Taiwan.

REFERENCES

[1] RKF:17:003r1/FAB17-2143, "Transimittal of Information to Support Chinshan Unit 2 Cycle 28 Operation at Reduced Power," AREVA NP, 2017.

[2] 621-I2-TM-46216, "Technical Meeting on Flexible (Non-Baseload) Operation Approaches for Nuclear Power Plants," IAEA, 2013.

[3] EPRI-3002002612, "Program on Technology Innovation: Approach to Transition Nuclear Power Plants to Flexible Power Operations," EPRI, 2014.

[4] "The Safety Analysis Report of Maintaining 75% Power Level Operation in Chinshan Unit 2, Rev.2," TPC, 2017.

[5] 004N2675, Rev.0, "Chinshan 2 Operation at 75% Power, 80% Core Flow and 996 RPM Recirculation Pump Speed," GEH, 2017.

[6] BWRVIP-62-A, "BWR Vessel and Internals Project, Technical Basis for Inspection Relief for BWR Internal Components with Hydrogen Injection," EPRI, 2010.

[7] BWRVIP-182-A, "BWR Vessel and Internals Project, Guidance for Demonstration of Steam Dryer Integrity for Power Uprate," EPRI, 2010.

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二、李彥良技正發表部分

REGULATORY CONTROL ON SPENT FUEL DRY STORAGE OF CHINSHAN NPP IN TAIWAN

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The goal of phasing out nuclear power in Taiwan will be achieved by 2025 based on the Electricity Act of 2017. Removal of spent fuel from spent fuel pool is a critical step prior to performing nuclear power plant (NPP) decommissioning program. The Atomic Energy Council (AEC) issued the construction license for the first phase of spent fuel dry storage facility of Chinshan NPP in Dec. 2008, which accommodated with 2400 assemblies of spent fuel. Taiwan Power Company (TPC) will adopt an indoor storage concept for the second phase of the Chinshan dry storage facility, and the facility should be completed and commence operations by the end of 2024. The paper presents several aspects concerning the AEC's regulatory activities on licensing review progress, canister fabrication, and pre-operational inspections. Additionally, this paper will discuss several proactive measures the AEC performed in order to enhance the public understanding of spent fuel dry storage campaign of the Chinshan NPP.

I. INTRODUCTION

All NPPs in Taiwan are owned and operated by TPC, a state-run company. During the 40 years of operations, approximately 5,000 tons of spent fuel will be generated from three NPPs, including Chinshan, Kuosheng, and Maanshan NPP. The present spent fuel management measures in Taiwan are divided into three phases: (1) storage in spent fuel pools for the short term, (2) on-site dry storage for the medium term, and (3) final disposal for the long term, as shown in Fig. 1 (Ref. 1), based on the Policy for the Management of Radioactive Waste. At the moment when spent fuel is discharged from the reactor, the fuel will exhibit conditions of higher activity and heat, and will first be stored in the spent fuel pool of each NPP to let the activity and heat decay.

TPC implemented the Chinshan dry storage project since July 2005, and the Institute of Nuclear Energy Research-High Performance System (INER-HPS) was adopted for Chinshan NPP dry storage facility. The components of INER-HPS include transportable storage canisters (TSC), transfer casks (TFR), vertical concrete casks (VCC), and add-on shielding (AOS), as shown in Fig. 2.

Fig. 1. Spent fuel management measures in Taiwan.

Fig. 2. Components of INER-HPS cask system.

II. LICENSING REGULATION OF SPENT FUEL DRY STORAGE

Two-step licensing processes are adopted for spent fuel dry storage facility in Taiwan: a construction license, which is based on the Preliminary Safety Analysis Report (PSAR), and an operating license, which is based on the Final Safety Analysis Report (FSAR) (Ref. 2). Construction shall not commence until the application has been reviewed and approved by the AEC to satisfy the following criterions (Ref. 3):

(1) The construction is consistent with the intentions of relevant international conventions. Application documents must meet the requirements of the IAEA Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (1997) (Ref. 4).
(2) Facilities and equipment are sufficient to protect public health and safety. AEC shall confirm the provisions of public health and safety are satisfied the requirements of the PSAR review.
(3) Environmental and ecological protections are in compliance with relevant laws and regulations.
(4) The technology, management abilities and financial bases of the applicant are competent to operate the facilities. TPC must submit the financial guarantee statement to the AEC for review. The Back-end Management Foundation shall provide a letter of guarantee for funding of the project.

Once these criterions have been met, the AEC will issue a construction license.

Even once the facility construction is completed, the facility must not be formally operated until the AEC has approved and issued an operating license. To ensure construction engineering quality and pre-operation test meet qualification standards, the AEC may dispatch inspectors to inspect the facility at any time, and may ask the facility operator to submit relevant documents during the construction and operation of a dry storage facility. Regulatory activities for licensing a dry storage facility are shown in Fig 3 (Ref. 1).

Fig. 3. Regulatory activities for licensing a dry storage facility

III. SAFETY CONTROL ON SPENT FUEL DRY STORAGE FACILITIES

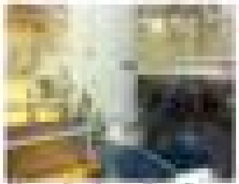
In July 2005, TPC entrusted the INER to construct the Chinshan dry storage facility. After evaluation, INER decided to introduce concrete storage casks (INER-HPS) by means of a technology shared from NAC International. In March 2007, TPC submitted the application for construction license to the AEC. After reviewing the documents, the AEC verified all regulatory requirements and issued a construction license in December 2008.

TPC started the manufacturing of TSCs in September 2008, and all 27 TSCs were completed by August 2010. AEC inspected the Quality Assurance (QA) activities regarding TSC fabrication quarterly until completion. TPC commenced the site construction of the facility in October 2010. The concrete pad was completed in July 2012. AEC continues to perform the monthly inspection of construction activities (shown in Fig. 4). To ensure transparency to the public, all related inspection reports and technical documents are available at the AEC website.

TPC submitted the pre-operational test plan for approval in November 2011, which was reviewed and approved by the AEC in May 2012. TPC has completed the first stage pre-operational test (i.e. cold test). After checking that the test results met the limit conditions of operation (LCOs), AEC approved the test result report in September 2013, and agreed that TPC may carry out the second stage pre-operational test (i.e. hot test).

Inspections on fuller assembling of dry storage

Inspection on construction of concrete storage pad



Heavy load transfer of pre-operational test

Positioning of pre-operational test by air pad systems

Fig. 4. Inspection activities for Chinshan dry storage facility

IV. PUBLIC ACCEPTANCE

The key issue for making process with regard to radioactive waste policies in Taiwan is increasing public acceptance. In order to promote public acceptance on regulatory measures of radioactive waste management, the AEC continually endeavors to encourage the public to participate in various regulatory activities. Such activities include public hearings regarding spent fuel dry storage facility installations, public observation activities during the construction of these facilities, and public participation in environmental radiation monitoring. As well, information transparency is also vital for increasing public acceptance level.

IV.A. Public Hearings

According to the articles of Nuclear Materials and Radioactive Waste Management Act (Ref. 6), AEC should display and publicize the utility's application for spent fuel dry storage facility within 10 days of receiving it. the PSAR will be displayed on a government website as well as the local and nearby townships for 60 days preceding a public hearing. Announcements of public hearings will be released through government bulletins, the AEC website and also through the Press. During these time period for publication and display, individuals, government agencies or organizations may submit to AEC reference opinions in written document form. Moreover, preliminary hearings will be held at nearby townships for scoping topics to be discussed. Finally, at formal hearings held by the AEC, to make sure all opinions of participants have been expressed completely, the hearing records will be released on the AEC website and all opinions should be well addressed.

According to the applications for spent fuel dry storage facilities for the Chinshan NPP and Kuosheng NPP, around 20 issues of contention were collected from the pre-hearing process meetings (Ref. 7). These issues could be grouped into three categories: (1) Necessity of the facility; (2) Safety of the facility; (3) Energy policy, financial and credibility issues.

Once these issues were collected and categorized, a hearing was held with the aim of reaching consensus on these issues (shown in Fig. 5). Participants in the hearing included experts in related agencies, members of Congress, as well as people from local communities and environmental groups.

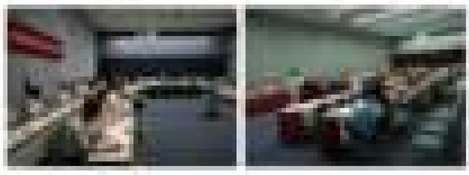


Fig. 5. Public hearing of the application for spent fuel dry storage facility construction.

IV.B. Public Observation Activities on the Construction of the Spent Fuel Dry Storage Facility

The licensing for a spent fuel dry storage facility requires much more consideration than just technical or regulatory decisions. Broad public consent and measures designed to gain public acceptance have become prerequisites for implementing independent spent fuel storage installation (ISFSI) program. In order to enhance the confidence of the public, a public observation program was instituted by AEC in 2011. AEC organized an Observation Team that includes 20-25 people and consists of community delegates (village chiefs, directors of community associations, stakeholder representatives), local government officials, civil engineering experts, and environmental NGO delegates.

Public observation activities during the construction phase of spent fuel dry storage facilities are performed periodically, which include site visits, environmental background radiation monitoring, and construction quality control (shown in Fig. 6). The activities for the public observation program are arranged by AEC. The observation members are invited to observe the construction quality of the spent fuel dry storage facility at Chinshan NPP. AEC and TPC would respond to concerns presented by the members at the meeting. During the public observation activities, the members are arranged to check the radiation level at ISFSI site. There is currently no spent fuel stored in Chinshan ISFSI facility, so the measured radiation dose at the ISFSI site remains falls within the variation range of background radiation doses. These data can be used as a baseline for comparing the design criteria in SAR. Once the spent fuel has been stored in the ISFSI site, the radiation levels will be compared with that of the background radiation to demonstrate the safety of the ISFSI. Up to the end of 2013, 13 Public Observations have been held.

Concrete overpack construction survey

Site visiting of spent fuel dry storage facility

Public participation in environmental radiation detection

Environmental background radiation detection

Fig. 6. Public observation activities for spent fuel dry storage facility construction.

The public issues proposed by the public team members have been classified into 3 categories: safety, sustainable management and feedback. Most of these members agree that the spent fuel storage facility is safe under AEC supervision. They asked TPC to implement long-term monitoring of the safety of the facility, and that real-time monitoring data including temperature, nuclear security, environmental radiation, and slope stability be made accessible to the public. AEC demanded that the TPC must set up a comprehensive monitoring system (shown in Fig. 7) to display monitoring information to the stakeholders after the initial loading of the spent fuel. This system can serve as a communication platform between stakeholders and TPC, and all data would be transferable to the Nuclear Safety Duty Center of AEC via the Security Control Room of TPC headquarters. Data regarding the temperature of canisters and radiation doses at the dry storage site can also be displayed in real-time on the AEC website.

Adequate feedback is the biggest issue in the communities where NPPs are located. As a regulatory body, AEC encouraged the TPC to increase dialogue with local communities to get a consensus regarding appropriate feedback. Furthermore, AEC has granted local residents a whole-body count for radiation, instructed people in the community about radiation safety as well as usage of radiation monitoring instruments. Finally, AEC provided an instrument to each township which may be used to measure local environmental radiation level within the community.

Fig. 7. Monitoring system of Chinshan dry storage facility

IV.C. New Trend for Chinshan Spent Fuel Dry Storage Program

Taking into account social consensus and public acceptance levels, AEC has requested to the TPC that the Chinshan NPP's second phase dry storage facility adopt an indoor dry storage type. The facility shall be completed construction and start operation by 2020, in order to facilitate moving spent fuels out of the reactor building and continuing the subsequent decommissioning and dismantlement. While spent fuel is still in the nuclear reactor vessel and the spent fuel pool, the AEC will continue strict regulations on its storage safety to ensure the public health and the environmental quality.

In accordance with the Nuclear Materials and Radioactive Waste Management Act and related laws, AEC will issue operating license for spent fuel dry storage facility for a maximum length of 40 years. If a facility is needed to continue its operation, the operator shall submit the license renewal application to AEC for review and approval no later than two years before the license expiration date. Taking into account public acceptance, and to relieve the concerns of public safety, AEC will grant a 20-year storage license first for dry storage facilities. The TPC could apply for the license renewal at least two years prior to the expiration of the existing license.

V. CONCLUSIONS

The decommissioning process of Chinshan NPP will be started by the end of 2018. To smoothly carry out the above program, a dry storage facility must firstly well prepare to remove and store spent fuel from reactor building safely. Spent fuel management is not only a technical issue, but also involves social concerns that need patience and much time to resolve. In addition to safety control, AEC requests TPC to increase communications with the general public in order to build consensus and improve confidence levels of local residents neighboring the spent fuel storage facilities.

These related public awareness activities, including hearings, observation activities, and participation in environmental radiation monitoring, have been launched by AEC to enhance public confidence, and results have shown that the public acceptance for Chinshan dry storage project is gradually increasing.

REFERENCES

1. AEC, *National Report as Referred to by the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*, Taiwan, R.O.C. (2015).
2. FCMA/AEC, *Guideline for the Safety Analysis Report of Spent Fuel Dry Storage Facility*, Taiwan, R.O.C. (2005).
3. FCMA/AEC, *Regulations for the Review and Approval of Applications for Construction Radioactive Wastes Treatment, Storage and Final Disposal Facilities*, Taiwan, R.O.C. (2004).

4. International Atomic Energy Agency, *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*, INFCIRC/546, IAEA, Vienna (1997).
5. K. C. YEN and F. H. LEE, "Licensing Program and Public Involvement of Spent Nuclear Fuel Dry Storage in Taiwan," *Proceedings of the 18th International Symposium on the Packaging and Transportation of Radioactive Materials*, Japan, September 18-23, No.4046 (2016).
6. FCMA, AEC, *Nuclear Materials and Radioactive Waste Management in Taiwan, R.O.C.* (2002).
7. T. W. LAN, K. C. Yen and M.T. Chang, "Public Participation in Radioactive waste management in Taiwan," *PBNC*, Beijing China, April 1-8 (2016).

四、戈元技士發表部分

RADIATION SCREENING AND ADVERSE EVENT PREVENTION AT 2017 TAIPEI SUMMER UNIVERSIADE

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KEYWORDS: MPE, 2017 TAIPEI SUMMER UNIVERSIADE, RADIATION SCREENING, AEC RADIOLOGICAL EMERGENCY RESPONSE TEAM

ABSTRACT:

To protect participants of 2017 Taipei Summer Universiade from radiological attacks, the Atomic Energy Council (AEC), the nuclear regulatory authority of Taiwan, dispatched AEC Radiological Emergency Response Team to perform the task of radiation screening and adverse event prevention. It was the first time for AEC to perform the adverse radiological event prevention and emergency preparedness for a Major Public Event (MPE). The AEC invited experts from the U.S. Department of Energy's National Nuclear Security Administration (DOE/NNSA) to conduct International Radiological Assistance Program Training for Emergency Response (I-RAPTER) for MPE in October 2015 and May 2017 in Taipei. Through these training programs, AEC has upgraded the radiation screening capacity and techniques, and developed the operational procedures of radiation screening and emergency response for MPEs. On the days of Summer Universiade opening and closing ceremony, a variety of radiation detection instruments were deployed at all pedestrian and vehicle entry points around the arena. Each person, baggage or vehicle entering the site was screened for radioactive or nuclear material. There were a total of 2 alarms found and proved harmless nuclear medical treatment cases. Besides, the vehicle equipped with radiation detection instruments was dispatched to survey the surrounding area of the athletes' village and important competition venues. By the end of the Summer Universiade, over 44,000 people and 300 vehicles had undergone radiation monitoring, and no malicious event involving radioactive material occurred.

1. INTRODUCTION

The 2017 Taipei Summer Universiade was the largest multi-sport event in the world apart from the Olympic Games. The name "Universiade" is a combination of the words "University" and "Olympiad", often referred to in English as the 'World University Games 'or 'World Student Games'

2017 Taipei Universiade opened on August 19th, and closed on August 30th, 152 countries registered entries, 7,639 athletes joined the opening and closing ceremony, including the spectators, media, VIPs and staffs, the total number of participants was more than 26,000. The main stadium for Opening and closing was Taipei Stadium, located in the Taipei Sports Park, downtown of Taipei City, the site was designated the hard zone for security, meaning that the risk and consequences of a terrorist-related event would be both 'High' and 'Catastrophic'.

As a result, securing the Taipei Sports Park was the highest priority of Executive Yuan Office of Homeland Security (OHS), who organized "Central Government Safety Command Center" to against all conceivable threats. This center had 17 specific working groups, including chemical, biological, radiological or nuclear (CBRN) group, to prevent 2017 Taipei Universiade from the highest impact risk scenario.

Despite having the radiation terrorist attacks contingency plans already, AEC as the central government anti-radiation disaster authorities, planed gradually to promote preparedness after evaluation of the international anti-terrorism situation. First of all, AEC collected the experience of the previous radiation disaster response exercise and accidental handling of radioactive material, including Radiation Screening passengers from Japan in Taoyuan airport after Fukushima accident.

Leveraging the Taiwan-US civil nuclear cooperation mechanism, AEC invited experts from the U.S. Department of Energy's National Nuclear Security Administration (DOE/NNSA) to conduct International Radiological Assistance Program Training for Emergency Response (I-RAPTER) for MPE twice in Taipei is shown in Fig. 1.

Participants attended from the Executive Yuan Office of Homeland Security (OHS), Taipei City Police Department, Department of Environment Protection, Army Chemical Corps, National Police Agency, and AEC, Fuel Cycle and Materials Administration, Institute of Nuclear Energy Research.

AEC was also invited by DOE to observe the security preparedness of NFL Super Bowl 50 & LI at 2016 & 2017 at San Francisco and Houston is shown in Fig. 2. Through these training programs and observation, AEC built up the radiation screening capacity and techniques, and developed the operational procedures for radiation screening and emergency response for Taiwan major public events.

Fig. 1. All attendants of I-RAPTER of 2017 in Taipei Stadium

Fig. 2. Observation of security preparedness of Super Bowl LI

2. MISSION PROCESS

2.1 Progress in Preparation

Taipei City Government, organized by the Executive Yuan, held Press conference on June 30, 106, shown in Fig. 3, the mayor of the Taipei City Government, signed the letter of intentions of the security cooperation with AEC, MND, NPA, to let citizens know Taiwan was ready for security of Taipei Summer universidae. The press conference also displayed a number of special high-tech anti-terrorism security equipment, including AEC radiation detection equipment.

July 24, 2006 the 6th AEC committee meeting was reported "Radiation incident prevention and contingency planning for 2017 Taipei Summer Universiade ", the minute resolution shows that Executive Yuan has relevant security Contingency plans for 2017 Taipei Universiade, as the central government anti-radiation disaster authorities, AEC will take preventive measures to prevent radiation and contingency measures to assist the Taipei city government. July 26, 2006, AEC called all the mission staff to explain procedure of radiation detection, including baseline survey, venue entrance portal screening and discussing how to adjudicate alarm.

August 5, 2006, AEC participated Security System Test with Taipei Police Department, Taipei stadium opened for 6,000 citizens, AEC tested radiation detection procedures for Venue entrance portal screening, baseline survey, and Roving Patrol route. 2 custom officers from Kaohsiung Custom also join us to observe how we do for major public events.

Fig. 3. Taipei City Government security press conference

Fig. 4. AEC staff tested radiation detectors installation

2.2 Pre Screening

Two mobile vehicle surveys were carried out, the first several weeks before the events and eve of the opening and closing day. AEC vehicle patrolled surrounding streets and lanes of Taipei Sports Park, to make sure the soft zone radioactive clean. Both mobile vehicle surveys were carried out using DOE/NNSA provided Spectral Advanced Radiological Computer System, Model A (SPARCS-A) shown in Fig. 5. This system comprised of 2 off 4"x4"x16" Nal detectors mounted in van of INNER, AEC.

INNER, AEC also dispatched three professional technicians, drove 2 vans; one was for radiation detection, the other one was for radiation analysis, went around the streets and lanes of Taipei Sports Park, to do the surrounding road radiation detection. If suspicious vehicles are found, interviews will be conducted with the assistance of the policeman, and also the 2nd investigation and interview.

On August 18th, 29th, eve of the opening and closing day, the second just prior to "lock down", AEC performed venues security checks with police at Taipei Stadium and Taipei Arena shown in Fig. 6, blanket detecting all stadium seats, rooms, and the parking garage, to make sure venues clean. AEC dispatched 43 staffs totally, Taipei Stadium 27 and Taipei Arena 16, each one carried a radiation detection equipment , to do radiation background survey.

AEC used 2 γ radiation detectors, DG-5 and RadEye PRD, Radioisotope Identifier (RIID), and Mobile Environment Radiation Monitor, which was manufactured by INNER, AEC. Where any high spots were found a follow up measurement was carried out using RIID Detectors on the ground.

Fig. 5. Spectral Advanced Radiological Computer System, Model A (SPARCS-A)

Fig.6. AEC staff checked venue's security with Taipei police

2.3 Radiation Screening

As the opening and closing hour arrives, a variety of radiation detection instruments, more than 100, were deployed at all pedestrian and vehicle entry points in the stadium and arena. Each person, baggage or vehicle entering the site was screened for radiological or nuclear material.

At each check point, the detectors were belted on metal detector gate columns and bench table legs afterward X-ray machine to screen all the pedestrians and their own handy bags or backpacks. About 40 AEC staffs used 60 radiation detectors, worked together with TPPD to perform radiation detection at all spectators, VIPs, media, athletes, workers entry points of Taipei Stadium, and Taipei Arena. and also the vehicles entrance. While finding hot spots, AEC need to do interview, 2nd detection, and complete record list with policeman's assistance.

In addition to the above-mentioned fixed check points, several AEC walking staffs carried radiation detector to patrol specific route between venues in the Taipei Sports Park, to detect trash box, grass, mobile toilets and lining people. They use 3 environmental radiation detectors, 3 DG-5s, and each one was belted Pager PRD, which is more sensitive, for first line detection. If any suspicious person or item was found, AEC need to inform the police immediately for following investigation. All vehicles passing check point also need to be screened by SPARCS of INNER, AEC.

Fig. 7. Detector belted on metal detector gate columns

Fig.8. Detector belted on bench table legs afterward X-ray machine

2.4 Radiological Emergency Response

There're three emergency operation centers for the opening and closing ceremony of the Taipei Summer Universiade. At central government, AEC officer joined the "CBRN response group "of Central Security Command Center at National Police Department shown in Fig. 9. Taipei city government also has Response Center at Taipei Arena to coordinate support from central government and quell disturbance directly. AEC on-site Technical Operation Center (TOC) located an office building nearby Taipei Stadium in order to respond ASAP.

71 AEC Radiological Emergency Response Teamers settled in AEC TOC, which had 4 working groups there, such as home base group, advise group, technical group, and liaison group. Not only as command function, the home base group also need to handle logistic and equipment management. There're contingency plans in place to deal with terrorist attack or other catastrophes.

AEC also vehicle patrolled surrounding area of the athletes' village(route mapping was shown in Fig. 10), and other major venues in New Taipei city, Taoyuan city, and Hsinchu County during the two weeks of event. And all the measurements were consistent with background values.

Fig. 9. Central Security Command Center at National Police Department

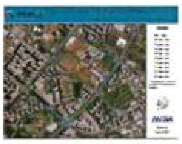

Fig.10. Vehicle patrolled route mapping of the athletes' village

3. OUTCOMES, FINDINGS & EFFECTS

3.1 Outcomes

On the days of Summer Universiade opening and closing ceremony, totally 106 radiation detectors were deployed shown in Table I, and Manpower in screening for radiological or nuclear material was 284. All radiation survey areas of Taipei Sports Park are more than 159,452 square meters before opening ceremony day eve. During the event, total survey distance of the surrounding of the player village and major venues is about 24 kilometers. By the end of the Summer Universiade, over 44,000 people and 300 vehicles had undergone radiation monitoring.

Table I Radiation Detectors List

Item	Qty.
Rad Eye	71
PAGER PRD	12
DG5	10
RIID	04
Environment Radiation Monitors	03
AT1121	03
SPARCS	01
AT6101	01
Portal Monitor	01
Total	**106**

3.2 Findings

There were a total of 2 alarms found and proved harmless cardiac scan diagnostic cases, Thallium 201, both are young females, and no malicious event involving radioactive material was found on the opening and closing day.

3.3 Effects

Based on this event, AEC developed our own Radiation detection procedures for MPE, and built relationship with the security departments as well, including central and local government. It's the best platform for AEC to practice detection skill at Taipei Summer Taipei summer universidae.

Based on this experience, AEC can develop more procedures for Taiwan major public events in the future. Most procedures AEC'll further develop are for outdoor Events, such as election campaign, New Year's Eve count down. May be in outdoor Major Public Events, there will be some other technical problems different than venues event.

4. CHALLENGES

The principal challenges was to develop a system that was both capable of detecting and identifying radiological material yet would not slow down the flow rate of people entering the Taipei Sports. The radiation detector AEC use most is PRD. PRD is small, low profile, remove & install quickly, easy to combine with X-ray machine & metal detector gate. However, PRD has more response time and Dead time, which would slow down the flow rate of people entering the site.

Radiation Portal monitor, which was designed for lining pedestrian radiation screening, has less response time and performs better than PRD where there are high pedestrian flow ,but not easy to combine with X-ray machine & metal detector gate, so we could not settle too many RPMs at limited entrance space.

AEC also have some technical problem like how to Combine radiation detectors & X-ray machine. According to our experience, radiation detectors should be kept 1m away from X-ray machine port for not to be triggered alarm by leaked X-ray.

5. CONCLUSIONS

It's the very first time that AEC perform Radiation Screening and Adverse Event Prevention for Taiwan Major

Public Event and very successfully. Based on this experience, AEC'll further develop more procedures for different Major Public Events based on this experience in the future.

Most procedures AEC'll further develop are for outdoor Events. May there will be some other technical problems different than venues event.

REFERENCES

[1] "2015 The International Radiological Assistance Program Training Manual for Emergency Response - Major Public Event, I-RAPTER-MPE", DOE/NNSA, 2015 October.

[2] "2017 The International Radiological Assistance Program Training Manual for Emergency Response - Major Public Event, I-RAPTER-MPE", DOE/NNSA, 2017 May.

[3] "Observation on Nuclear and Radiological Security Preparedness Measures for Major Public Events- Super Bowl 50", Juneyuan Huang, R.O.C. Taiwan, 2016 .

[4] "Observation on Nuclear and Radiological Security Preparedness Measures for Major Public Events- Super Bowl LI", Yuan Ko & Tze-Chieh Horng, R.O.C. Taiwan, 2016 .

[5] "Radiation Screening at the London 2012 Olympics," M. James & C. Ryden, Atomic Weapons Establishment (AWE), UK, Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), 2013 IEEE, Seoul, South Korea, Oct. 2013.

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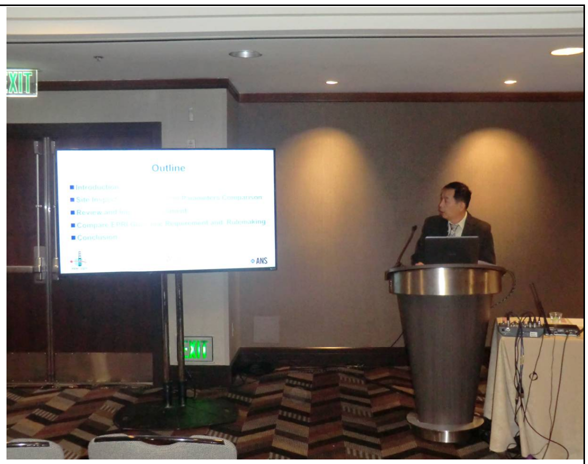
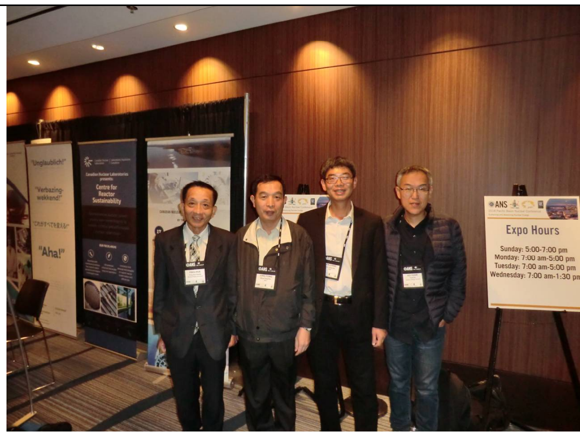
陸、附件三：出席會議照片集

照片一 PBNC 大會開幕式主席團致詞

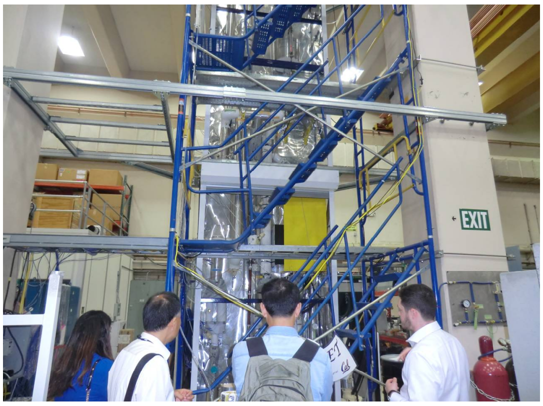


照片二 許明童科長發表專題演講

照片三 戈元技士發表專題演講



照片四 我國與會人員合影



照片五 柏克萊加大核工系實驗室參觀

照片六 柏克萊加大核工系主任系務介紹