出國報告（出國類別：其他）

赴日本札幌參加 NPC2014 核電廠水化學國際研討會

服務機關：核能研究所
姓名職稱：沈錦昌　副研究員
派赴國家：日本
出國期間：103 年 10 月 25 日~103 年 11 月 1 日
報告日期：103 年 12 月 2 日

摘　要

Nuclear Plant Chemistry Conference (NPC2014) in Sapporo, Japan 爲兩年舉辦一次之國際核能電廠化學會議，NPC 會議始於 1977 年英國的伯恩茅斯(Bournemouth)會議，並已在亞洲、北美和歐洲以及英國每兩年舉辦一次，由各會員國輪流舉行。今年度於日本札幌舉行，主要目的在與各國放射化學專家交流核能電廠化學、低放射性廢棄物分析及劑量抑減等實際業務經驗共享，一方面瞭解世界各國核能電廠水化學運轉經驗及其貴重金屬鍍膜防蝕最新技術以及放射性廢水處理相關技術進展，包括日本福島第一核電廠目前情況與相關放射性廢水除污處理最新訊息。本次會議主席爲東京大學教授 勝村庸介(Yosuke Katsumura)，副主席爲原子力發電株式會社資深顧問 目黑芳紀(Yoshinori Meguro)博士擔任，advisor 有 3 位分別爲東京大學名譽教授石博顯吉(Kenkichi Ishigure)博士、東芝公司長尾博之(Hiroyuki Nagao) 博士、千葉科學技術院 高松弘(Hiroshi Takamatsu) 博士擔任。

此次會議除了解國際核能電廠運轉現況及其個案問題，除取得最新論文與技術資料外，並與專家當面討論問題、交流經驗，建立技術交流管道，方便日後各項業務推展、應用，以提升核能電廠與核能後端營運委託研究計畫的作業能力與品質。

NPC 2014 年國際水化學研討會會議於 10/27 舉行大會專題演講之後接續以下 11 個議題交流討論包括(1)BWR 運轉經驗；(2) PWR WER & CANDU/PHWR 運轉經驗；(3)水化學研究；(4)二次水(蒸汽循環)化學研究；(5)系統生命期管理與核電廠老化議題；(6)化學與燃料效能議題；(7) 化學的優化方案及合規管理；(8)核電廠系統保養；(9)輔助系統，供水和廢棄物處理系統；(10)未來的發展趨勢和新的發展等水化學營運議題；(11)福島第一核電廠事件特別議題。整個研討會共分成 11 個討論議題。會議會場採大會議室舉行，而於 11/29 日另外增加一中型會場專門介紹福島核電廠事件議題，11/29 日會議我選擇參加福島核電廠事件議題聆聽演講並蒐集資料，瞭解與計畫相關及不同領域的研究與技術之發展現況，會議中討論的內容相當豐富，本文有將參加的演講場次做重點紀錄與介紹，可作爲核研所現行執行計畫及未來在計畫規劃上之研究發展參考。

會議論文共有 244 篇，其中有篇 92 口頭報告，另 152 篇以壁報展示方式發表。與會人員共 357 人、來自 28 個國家，主要有日本(187)、美國(27)、法國(23)、南韓(21)、英國(19)、中國大陸(10)、台灣(8)、加拿大+瑞典+瑞士(9)、芬蘭+蘇聯(6)、阿根廷+傑克+德國(4)、斯洛伐克(2)等專家學者。

2016 年 NPC 研討會由英國籌辦，將於 2016 年 10 月 2 日至 7 日於英國 Brighton 舉行。

目　　次

一、目　的

參加 NPC2014 年核電廠化學會議發表論文，交換水化學技術

2014 年國際核電廠水化學會議訂於 10 月 26 日至 10 月 31 日於日本札幌舉行。本所在反應器水化學之研究與核電廠水質提昇已累積多年之技術及實務經驗，沈員將於研討會中各發表相關論文壹篇。參與會議除可交換彼此之工作經驗外，並可顯示國內之研發成果。NPC2014 會議後大會並安排於 10 月 31 日參訪日本壓水式反應器泊(Tomari)電廠，交換水化學技術與心得。本次會議主題爲(一)壓水式反應器水化學運轉經驗及技術探討，(二)沸水式反應器水化學運轉經驗及技術探討(三)輕水式二次側及輔助系統水質處理技術，(四)電廠劣化及壽限管理措施，(五)電廠化學、燃料及維護技術，(六)反應器水化學未來趨勢及發展(七) 福島一廠事件後電廠化學。本所在核反應器之水質控制及管理具有相當良好之研究成果及電廠實務經驗，近幾年來參與電廠水化學技術改善及新建核電廠管線鈍化方面等的研究及實作應用，對於推動及持續增進國內水化學領域之技術提升具有極大的助益。日本福島事件後爲掌握水化學最新之水質控制及防制劣化之管理機制，並因應事件後之方向調整，參與此國際會議更能進一步瞭解爾後國際水化學的研發步調與趨勢。會議中發表本組研發論文共三篇，並與各國相關人員相互交流，討論實際應用於電廠之控制措施，以提高國內電廠運轉之可靠度與安全性。

核反應器冷卻水輻射分解暨電化學研討會亦在同一地點舉辦，透過本研討會之討論以瞭解幾年來輕水式反應器冷卻水輻射分解機制模式與電廠實際運作參數之修正比較，進而提供國內目前加氫化學與電化學最適化之控制方法，增進防制系統組件老化之技術及能力。

二、過　程

(一)出國會議行程：

此次出國會議時間是從民國 103 年 10 月 25 日（星期四）至民國 103 年 11 月 1 日（星期六）共計 8 天，會議期間行程如下：

日　期	行　程	工　作　內　容
10/25	台灣→日本札幌	去程
10/26	札幌 Royton Hotel 三樓會場	辦理報到並領取會議文件、準備明日會議演講資料
10/27	札幌 Royton Hotel 三樓會場	參加開幕、參加會議演講及壁報論文技術交流
10/28	札幌 Royton Hotel 三樓會場	參加會議演講及壁報論文技術交流
10/29	札幌 Royton Hotel 三樓會場	參加會議演講及技術交流
10/30	札幌 Royton Hotel 三樓會場	口頭發表論文及參加會議演講及技術交流
10/31	參訪日本泊(Tomari)電廠	參訪日本泊(Tomari)電廠
11/1	日本札幌→台灣	回程

(二)NPC 2014 札幌國際核電廠水化學研討會

此行於 103 年 10 月 25 日從桃園國際機場出發，搭乘長榮航空空中巴士直飛日本北海道新千歲機場，飛行時間約 4h，出機場後搭乘機場捷運抵達札幌車站，再搭乘計程車抵達住宿地點 Royton Hotel(離車站約 2km)，10/26~10/30 日 NPC2014 研討會議在 Royton Hotel 3F 會議室舉行，10/31 日我參加參訪日本泊(Tomari)電廠行程。此次會議主要是由 Atomic Energy Society of Japan (AESJ)主辦之 2014 國際核電廠水化學研討會，依不同主題再細分爲(1)BWR 運轉經驗；(2) PWR WER & CANDU/PHWR 運轉經驗；(3)水化學研究；(4)二次水(蒸汽循環)化學研究；(5)系統生命期管理與核電廠老化議題；(6)化學與燃料效能議題；(7) 化

學的優化方案及合規管理；(8)核電廠系統保養；(9)輔助系統，供水和廢棄物處理系統；(10)未來的發展趨勢和新的發展等水化學營運議題；(11)福島第一核電廠事件特別議題。整個研討會共分成 11 個討論議題。會議會場採大會議室舉行，而於 11/29 日另外增加一中型會場專門介紹福島核電廠事件議題，11/29 日會議筆者選擇參加福島核電廠事件議題聆聽演講並蒐集資料，瞭解與計畫相關及不同領域的研究與技術之發展現況，會議中討論的內容相當豐富，本文有將參加的演講場次做重點紀錄與介紹，可作爲核研所現行執行計畫及未來在計畫規劃上之研究發展參考。

(三)議程

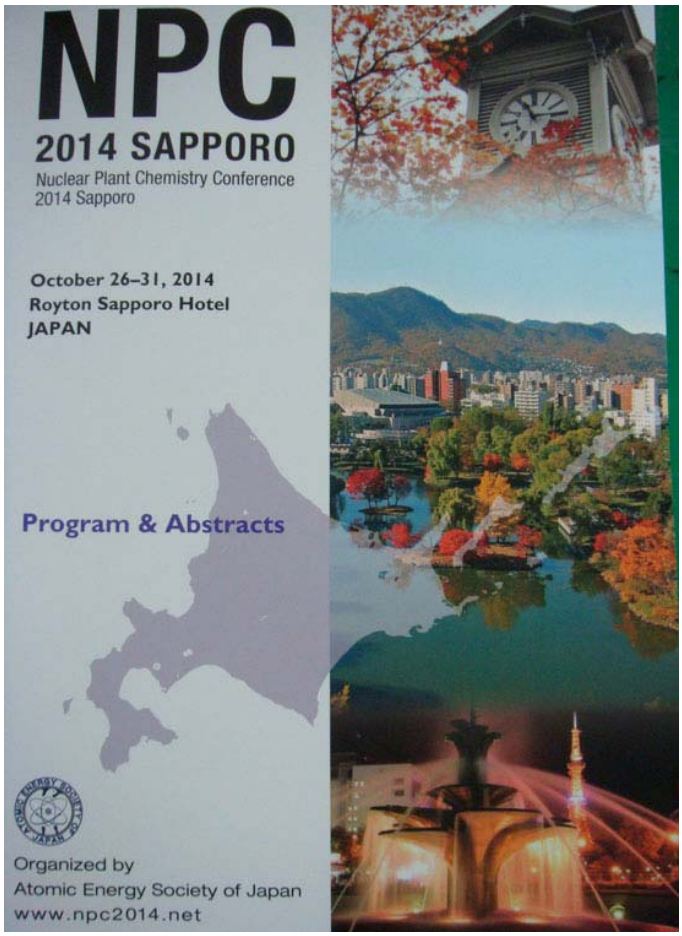
103 年 10 月 26 日至 10 月 30 日爲期 5 天的研討會議議程簡述如下：

1. Schedule for October 26, 2014

October 26, 2014 (Sunday)	
Conference Venue： Royton Hotel 3F	
17:30~19:30	**Welcome Reception**

10/26 爲此研討會議的報到註冊日，報到地點於札幌之 Royton Hotel 3 樓大廳，於會場註冊後領取了研討會識別證、會議流程表、NPC2014 Sapporo Nuclear Plant Chemistry Conference Program & Abstract 一本、會議論文全文資料檔案隨身碟 USB 一只，而後的研討會議進行地點將在本棟三樓大會議室舉行。

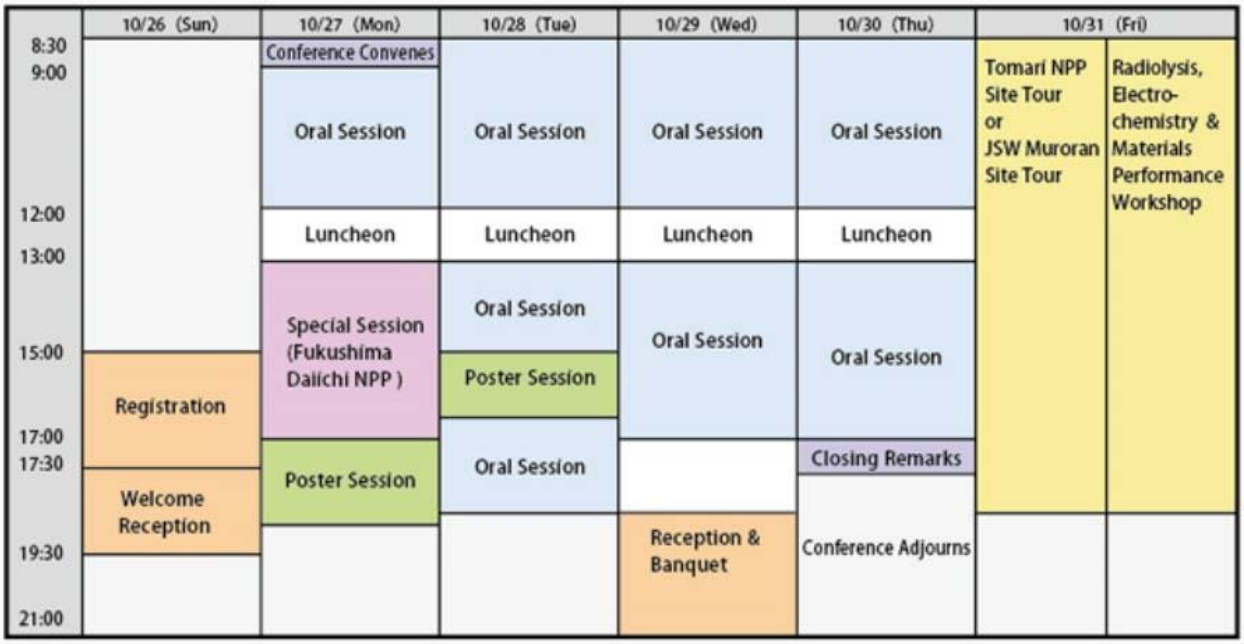
NPC 2014 會議舉辦地點於 Royton Sapporo Hotel 三樓



報到後領取之論文議程與摘要資料

會議論文全文資料檔案

會議議程內容



1.BWR 運轉經驗:基本運轉操作與實驗室研究或相關電腦模擬

2.PWR WER & CANDU/PHWR 運轉經驗:主冷卻劑內加氫，pH 值，鋰，硼酸的效果，豐富硼酸，氫，氨，鋅，活性積聚和輻射控制

3.水化學研究: 加氫水化學，貴金屬化學添加劑，鋅，瞬時化學，耐腐蝕，輻射和可燃氣體管理，活動積聚和輻射控制的問題

4.二次水(蒸汽循環)化學研究: 加氫水化學，貴金屬化學添加劑，鋅，瞬時化學，耐腐蝕，輻射和可燃氣體管理，活動積聚和輻射控制的問題

5.輔助系統，供水和廢棄物處理系統:水的純度控制和先進的工藝和監測技術，規模減緩冷凝器和冷卻塔，在輔助系統化學控制，廢水管理

6.系統生命期管理與核電廠老化議題:化學和腐蝕問題，關係到生命週期管理及對策

7. 化學與燃料效能議題:影響化學燃料性能的 CRUD 相關燃料的性能問題，包括污物引起的功率變化之鈾與裂變產物

8. 核電廠系統保養維護:淨化工程，化學清洗（蒸汽發生器），清潔燃料，在長期停機的水化學控制

9.福島第一核電廠事件特別議題:吸取 2011 年 3 月 11 日福島第一核電站事故教訓與除污的最新訊息等等

10.未來的發展趨勢和新的發展等水化學營運議題:化學的發展爲未來的反應器系統，包括超臨界水，GEN IV 和其他先進系統條件

主題演講 1

美國 Electric Power Research Institute (EPRI) Dr. Keith Fruzzetti 進行開場主題演講「BWR and PWR Chemistry Operating Experience and Perspectives」

一般認爲適當控制的水化學對確保沸水反應器(BWR)和壓水反應器(PWR)的安全可靠運行具有重要作用。現代的水化學課程可減少反應器冷卻劑系統、蒸汽循環設備和燃料包殼材料的腐蝕，確保循環成分的持續完整性，減少輻射場域。當核電廠部件已經安裝或廠房系統已構造，適當的水化學能減輕材料劣化問題，從而減少了昂貴的維修或更換，理解正確的化學控制和實際操作經驗之間的關係與重要的價值，EPRI 繼續收集監控和評估來自世界各地的沸水器和壓水器操作數據。寶貴的 BWR 和 PWR 經營化學數據收集超過 900 循環資料，其中包括的在線、啓動和關閉之化學數據超過 10 年以上（>20 年 BWR）。

文中提供的當前美國 BWR 和 PWR 化學的重點趨勢概述。重要的電廠化學參數被突顯出，提供並改變 EPRI BWR 和 PWR 水化學指南。

化學對全廠系統的重要影響，也是老齡化的管理和減量策略的關鍵。優化的化學控制將降低材料的降解速率，提高燃料性能和維護系統劑量率最低合理可行。反之，不良的化學反應控制，導致快速的組件退化，退化的燃料性能和完整性，並增加電廠吸收劑量率。幾十年來，在化學技術的進步已經顯著改善工廠運營。

在過去幾十年 BWR 化學已經顯著發展。美國 BWR 曾於高含氧正常的水化學(NWC)下操作。 於 1983 年，美國 BWR 初次實行加氫水化學(HWC)，以此降低電化學腐蝕電位(ECP)，以減輕反應器管道和內部材料晶體間應力腐蝕開裂(IGSCC)的目的。1986 年，美國初次實施 BWR 加鋅以用於減少電廠輻射的目的。貴金屬化學品的應用

(NMCA-$Na_2Pt(OH)_6$ and $Na_3Rh(NO_2)_6$) 於 1996 年首次在美國執行，策略爲減少給水加氫建立所需要的減緩 ECP 所需的時間 IGSCC(≤0.4 ppm，而不再是以往 1-2 ppm)以下。中等加氫(HWC-M)的結果得到重要的成果，它顯著地降低電廠劑量輻射，因而影響日後水化學。在 2006 年，線上 NobleChem™(OLNC)中的初次實行，使得較少量的催化材料($NA_2Pt(OH)_6$)，可以線上添加。加氫應用性已經成爲 BWR 一個越來越重要的度量，且已改善美國 BWR - 尤其是盡早添加氫到反應器系統(即初期的加氫水化學-EHWC)成爲最近焦點。最後，鈷螯合樹脂(CoSeq®)已經由 EPRI 作爲一種技術以更有效地從程序流中去除離子態的鈷。CoSeq®預計在 2014 年的後半部可商購。

PWR 水化學也得到顯著進步。在美國的主要化學方案變化導致增加 pH 值(因需要增加鋰的濃度)，以及轉向更恆定的 pH 計劃(其中的鋰濃度保持在一個恆定的 pH 值的部分的循環，從而使 pH 值提高而硼濃度降低)。自 1994 年法利開始在美國注入鋅，現於世界各地已有 80 壓水器機組成功應用，減少一般腐蝕速率，並降低劑量率得到顯著的好處。最近，加氫用於減少 600 合金裂紋擴展速率的目的，以及相關的焊接金屬，優化合金 82 和 182，導致了增加的加氫濃度，與 EPRI 的指引建議相一致，在 25-50 毫升 H_2(STP)/公斤 H_2O 範圍內。

PWR 二級單元其水化學的重點是降低材料的退化。最優化 pH 值的目的是降低流動加速腐蝕，從而減少腐蝕產物輸送到蒸汽發生器(SGS)。以分散劑減輕 SG 污染的應用越來越多，包括線上注入使用與啓動時循環清理。採用 690TT 合金於蒸汽發生器特別值得關注的是鉛輔助應力腐蝕開裂(PbSCC)，這已在 690TT 的腐蝕性化學實驗檢測被證明。

BWR 水化學研究

EPRI 的 BWR 化學監測與評估(CMA)的資料庫，建於 1997 年，最初是爲了幫助解決鐵的傳輸問題。EPRI 資料庫目前已經擴展到無數的化學相關項目和評估，並提供重要指標的機制。目前有 50 個 BWR 廠數據(35 個美國 BWR 和 15 個非美國 BWR 系統)。

圖 1 顯示在過去幾十年的應用發展中，幾種不同的化學技術進行於 48 個 BWR 系

統情形。2004 年起加氫用美國 BWR 在美國有顯著增加，達到最近約 98%系統。早期加氫水化學(即氫，早在 200°F(93.3℃)的添加進入水系統)仍然是發展的重要領域。自 2006 年 OLNC 程序應用在美國 BWR，OLNC+HWC 運轉的核電廠數量也急劇增加。加鋅繼續在美國的所有 BWR 使用，得到有效減少主系統輻射效果，因爲在 BWR 輻射程度評估和控制(BRAC)的反應器再循環系統(RRS)的位置測量，在 BWR 2 至 BWR 6 設計，所有操作化學機制(NWC、HWC-M、NMCA+ HWC 和 OLNC+ HWC)。

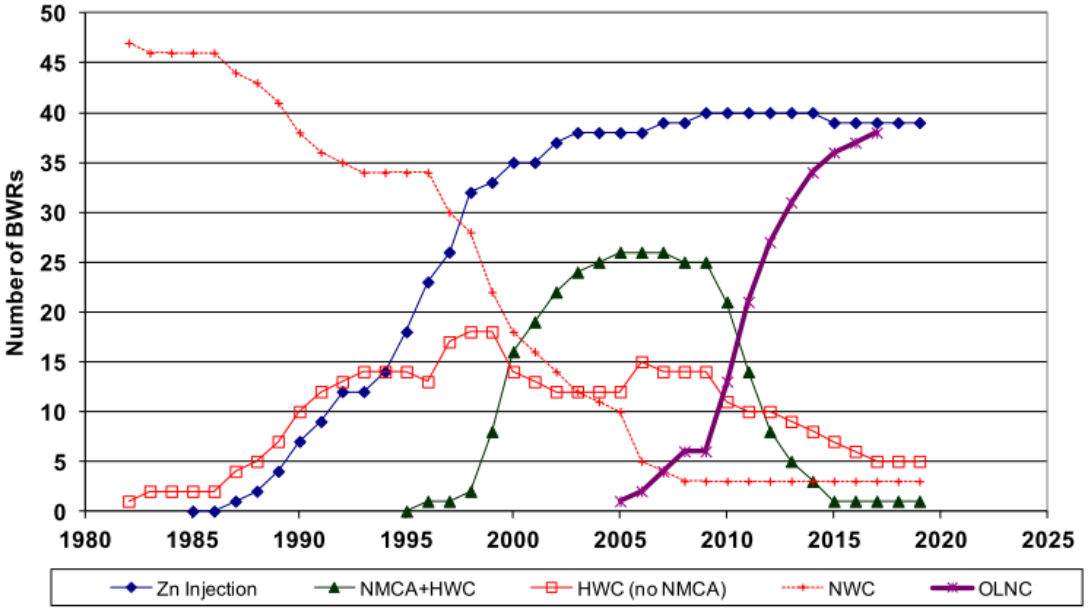


圖 1. 水化學應用方法技術演變統計(NMCA does not include OLNC)

EPRI 的 BWR 水化學指南包含重要的進樣水(FW)和反應堆冷卻水(RW)化學要求，以及其他核電廠內的系統。表 1 是 2012 年最新資料庫 BWR 系統之關鍵重點數值，如給水和熱井參數，從基準比較結果值與實施運作良好(good practice)數值及警示 1 級(AL1)數值。良好的實施值表示核電廠具有優化之水化學環境，該值可作爲努力的目標。警示 1 級(AL1)表示如果超出限額可能會威脅到系統的長期可靠性或工程數據之判斷，需進行運營實踐改善。

表 1. 近期 BWR 系統之關鍵重點數值 (2012)

Location	Parameter	U.S. Median	Non U.S. Median	Industry Median	Range* Min	Range* Max	Good Practice	AL1
RW	Conductivity, µS/cm	0.116	0.085	0.110	0.062	0.238	≤0.15 (w/zinc injection)	>0.30
							≤0.08 (w/o zinc injection)	
							≤0.08 (corrected w/zinc injection)	
RW	Chloride, ppb	0.25	0.25	0.25	0.06	0.63	≤1.0	≥5.0
RW	Sulfate, ppb	0.60	1.17	0.76	0.30	2.70	≤2.0	>5.0
RW	Silica, ppb	75	174	101	18	829	≤300	n/a
RW	Zinc Sol, ppb	11.3	0.7	9.3	0.01	18.87	Trend	n/a
RW	Co-60 Total, Bq/m3	6.19E+06	5.94E+06	6.07E+06	9.28E+05	1.93E+07	n/a	n/a
FW	Dissolved Oxygen, ppb	48	53	49	32	157	n/a	n/a
FW	Fe Total, ppb	0.21	0.55	0.22	0.008	2.458	≤1.0	>5.0
FW	Cu Total, ppb	0.013	0.007	0.011	0.001	0.175	≤0.05	>0.2
FW	Zn Total, ppb	0.39	0.02	0.37	0.001	0.646	n/a	n/a
HW	Conductivity, µS/cm	0.060	0.059	0.059	0.044	0.084	n/a	n/a

* The range of cycle median values for each BWR unit considered
RW = Reactor Water, FW = Feedwater, HW = Hotwell, n/a = not applicable

鈷移除技術(Cobalt Sequestration)最新進展

工廠停工維修期間，希望能減少冷卻劑中的放射性鈷核種濃度，以減少在斷電期間集體的輻射暴露。通常情況下，Co-58 和 Co-60 的濃度必須降低到預定的劑量標準，維修清理工人才能被允許進入容器和開始維修清理檢查活動，例如燃料的更換和檢查。更快速的完成工作能降低工人暴露劑量數值，在管制區域越早完工就能越早電廠開始恢復服務。更短的停機可以減少工人接觸劑量和節省潛在數百萬美元的替代電力成本。

CoSeq®技術已開發成功，應用於核電廠處理具有非常高的選擇性。實驗室評估結果顯示具有非常高的鈷去除率，比通過在典型的離子交換樹脂高約 3 倍且更大的吸收能力。CoSeq®可以與離子交換樹脂結合使用，應用於在核電廠中鈷移除技術使用。

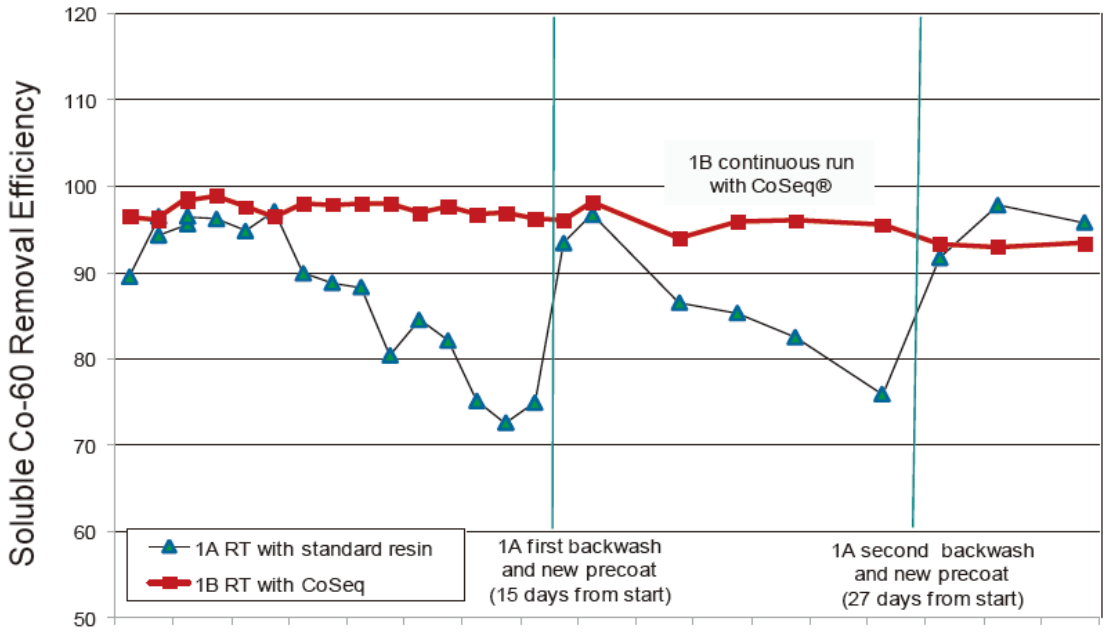


圖 2. CoSeq®與典型的樹脂在 BWR 系統比較

圖 2 示出在 BWR 運作操作期間從進水和出水活性濃度計算可溶性鈷 60 去除效率。反應器水清理(RWCU)過濾器/除礦質(F/D)“1A”指使用標準樹脂的電廠。“1B”使用 CoSeq®的系統，測試中呈現出更佳性能。

PWR 水化學研究

在 PWR 水化學中有許多新的技術，應用於一次系統水化學和二次系統水化學。一次系統水化學中較突出技術有酸鹼值控制 PH_T，加鋅控制和加氫氣控制; 二次系統水水化學控制有酸鹼值控制 PH_T，分散劑的應用，並努力解決鉛(Pb)沉積所導致裂化問題。

PWR 一次系統水化學運轉經驗及技術

PWR 系統因腐蝕物沉積而造成燃料故障，大都源自於燃料軸向偏差異常(Axial Offset Anomaly，AOA)問題而導致功率調降；早期一次系統冷卻水採行調和式水化學(Coordinated chemistry)固定 $pH_T \cong 6.9 \sim 7.0$ 之運轉模式，或提高 pH_T 至 7.2 左右以減少銹垢沉積，劑量率之控制雖顯現相當正面的效果，但燃料週期增長後如何加強燃料護套表面沉積物之檢視，探討 $pH_T=7.0 \sim 7.2$ 之運轉甚至提升 $pH_T=7.2 \sim 7.4$，再配合加鋅之

變化，有利於解決目前一次應力腐蝕龜裂(Primary Water Stress Corrosion Cracking, PWSCC)及輻射劑量升高等之相關問題，圖 3 爲美國 PWR 系統一次系統水化學主要的演變，目前系統一次系統水化學其提高 pH_T 至 7.2 左右以減少銹垢沉積，劑量率之控制雖顯現相當正面的效果，所以從圖上藍色 Bar 圖可見其趨勢。PWR 一次側應力腐蝕龜裂、爐水 pH_T 之控制模式、溶氫最適化及降低輻射場強度，爲現今 PWR 水質調整及修正的方向，特別是加鋅之應用具有雙重的正面效果，非常值得國內長期規劃水化學之參考。PWR 二次側的 PbSCC 仍是有待解決的問題，特別是其對 Alloy 690MA 的影響，抑制劑的研發仍進行中。

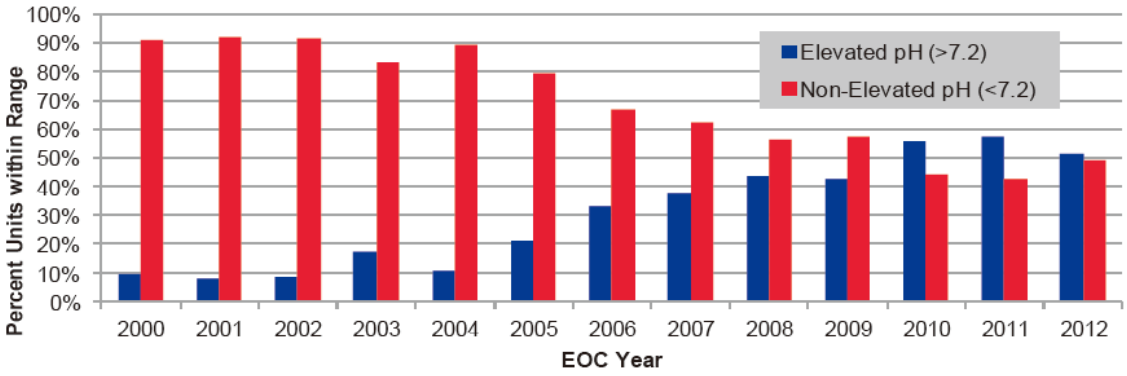


圖 3 美國 PWR 系統一次系統水化學主要的演變

加鋅水化學效益及影響

PWR 一次系統注鋅理念及應用近幾年來非常的熱門，不但 BWR 機組加鋅以減低管線輻射劑量率，連 PWR 一次系統注鋅之機組也快速自 2004 年的 20 固機組增加至 2013 年的 83 個機組以上。自從 2000 年開始也發現加鋅與燃料管理也有某種程度相關，即使如此，從輻射場、材料完整性及環境衝擊等多種目標來看，加鋅水化學的正面效用的確不可忽視，這也就是爲什麼近年來，甚至 CANDU、VVER 及新型反應器 EPR、AP1000 等也都開始推動進行加鋅的可行性規劃。

從整體上分析並評估加鋅效益，PWR 施行加鋅的電廠快速遞增的原因加鋅水化學的目的是藉 Zn 在爐水中可進入管線氧化膜內層之晶格取代 Co 及 Ni，使得氧化層更加

厚實、穩定，兼具保護作用而達到抑制管線輻射增建的目的，圖 4 爲表明氧化膜厚實而抑制 Ni 釋入爐水，不但可以減低輻射場強度，也能抑制 PWSCC 起始及減低裂縫成長速率(Crack growth rate, CGR)。從水化學的角度來看，加鋅時掌握最佳的環境條件，整體上是不可被忽視的一環，特別是鋅在燃料護套表面形成銹垢沈積，可能伴隨衍生的軸向偏差異位/銹垢誘發功率遷移(Axial offset anomaly/crud induced power shift, AOA/CIPS)及局部護套腐蝕風險等問題都要考量其影響。美國西屋公司(Westinghouse,WH) 所製造的 ZIRLO^{TM} 燃料護套經過多個電廠運轉之 PIE 測試，即使 Li 濃度達 3.5ppm 均不會有腐蝕問題。日本北海道電力公司泊-3(Tomari-3)機組於 2009 年 12 月商轉，爲要達到降低輻射劑量的長期指標，即於商轉前的熱功能測試階段(Hot functional test, HFT)即開始注鋅，使管線表面氧化膜具有抑制 Co 沈積的作用;令大家有些擔心的疑慮仍是加了鋅之後的機組初期造成的立即反應是否造成長期的負作用。日本九州電力公司已完成安全改善且可能於明年春季重新啓動之川內核電廠(Sendai Nuclear Power Plant)兩個機組及玄海(Genkai NPP)四個機組也曾經做加鋅之測試，探討 Inconel 690 蒸汽管材質受加鋅及停機維修後之 Co 沉積與鋅量關係，證實加鋅時表層形成穩定之 $ZnCr_2O_4$ 且 $ZnCr_2O_4$ 之溶解度較 $NiCr_2O_4$ 或 $FeCr_2O_4$ 均小，因此可以有較佳的保護作用，因此當一段時間未加鋅時對輻仍具有相當好的抑制作用。由於美國及其他國家的經驗證實加鋅水化學對系統僅造成極少的負面影響，因此法國也開始針對國內的反應器機組作加鋅的一系列規劃及風險分析，找出最佳的水化學條件推動加鋅水化學。

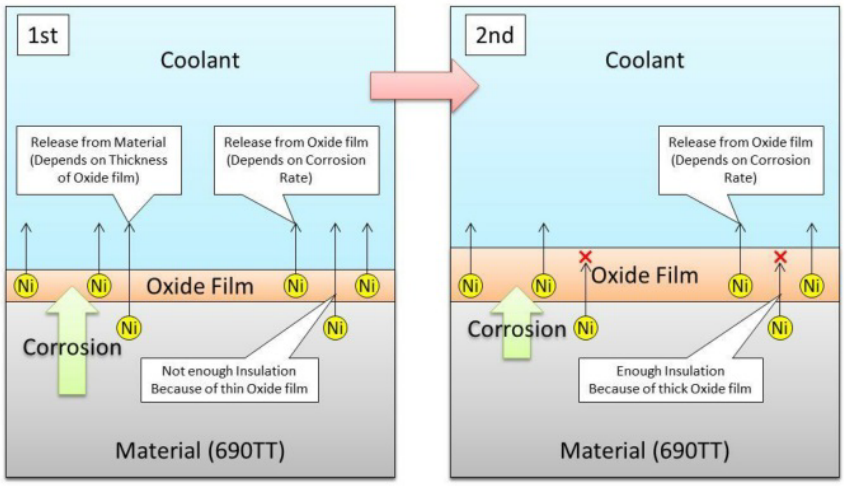


圖 4.Inconel-690 材質 Ni 釋入爐水機制

法國 EDF 的 Jean-Luc Bretelle 報告法國的核能與水化學發展現況與挑戰。法國並沒有針對現役核電廠的延役規劃，因此其核電比例將由目前的超過 75%，於 2025 年降爲 50%。該國反應器均爲自製 PWR，目前主要的水化學挑戰如下方結論所示，包括一次側的 PWSCC、二次側的 CSC、沉積物問題、硬銹垢(主要是鋁氧化物)、鉛離子(主要影響 690 合金的 SCC)。

法國共有 58 座 PWR 反應器，其中 15 個機組已自 2004 年開始注入醋酸鋅，其中大部份機組注鋅僅有 2-3 年，主要探討方向爲爐水化學、材料輻射場、燃料護套完整性及廢料等，各種測試結果尚沒有較具體結論，圖 5 爲法國 EDF 施行注鋅之整體策略，低濃度與高濃度注鋅量之目的並不一樣。

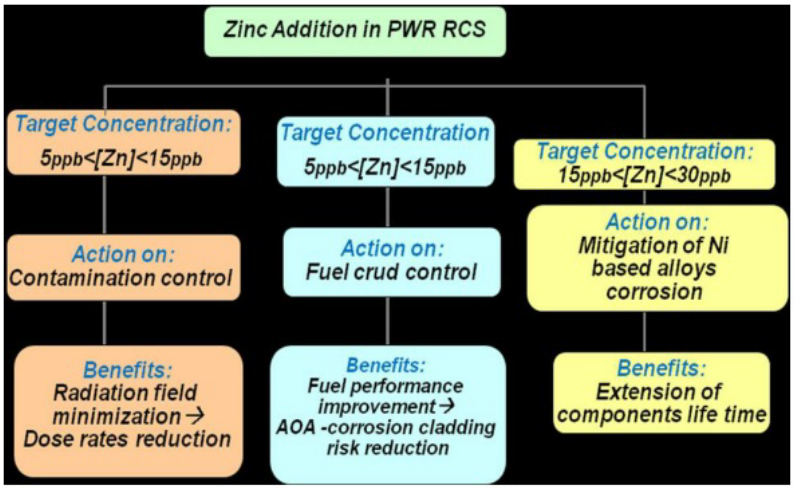


圖 5. 法國 EDF 公司之注鋅策略

爐水低溶氫與銹垢關係

PWSCC 裂縫起始與成長的 pH_T 在 $6.9 \leqq pH_T \leqq 7.5$ 之影響並不明顯，而腐蝕速率與釋出率隨著 pH_T 之增加而減少，增加 pH_T 對於爐心的沉積現象有下降的趨勢，縱使硼、鋰和其相關的 pH_T 對裂縫成長速率的影響並不大，但是溶氫量對鎳基合金 Alloy 600, Alloy 182/82 等之裂縫起始時間及 CGR 一直是 PWR 非常重要的因素，尤其在高溫環境下必需有延緩裂縫起始時間及抑制 CGR 之基本溶氫量，且可充分保持低的 ECP 電位。從美國電廠實際運轉也發現：溶氫量是朝規範值 25~50 ml-STP /kg-H_2O 上限的方向發展，目前已有朝 60 ml-STP /kg-H_2O 方向研究及測試。爐水中 H_2 濃度抑制水之輻射分解也是有爭論的議題，長久以來 PWR 爐水中 H_2 含量均維持於 25~35 ml/kg，且運行多年。美國電力研究所(Electric Power Research Institute, EPRI) 嘗試要提高溶 H_2 量到 50 ml-STP /kg 甚至更高，目的是要延緩破裂起始時間及抑低破裂成長速率，高溶氫配以高 pH_T 對減低鎳化合物的沉澱是有利的，圖 6 是美國近年來朝高溶氫運轉之證明。然而日本方面目前正在評估降低 H_2 濃度以延緩破裂起始問題。因此在低溶氫(5~25 ml-STP /kg-H_2O)環境表面所沉積的鎳鐵等氧化物，在目前的電廠環境不易看到。日本電力中央研究所(Central Research Institute of Electric Power Industry, CRIEPI)在環路測試中證明低溶氫之模擬條件銹垢快速生成，沉積層由 $NiFe_2O_4$ 及 NiO 所組成，並不會受到溶氫的影響。當 5~7 ml-STP/kg-H_2O 極低含量時 NiO 仍快速生成，即使在含硼 1200 ppm 之水質下仍不會在表面生成硼酸鐵鎳(Nickel iron borate,Ni_2FeBO_5)，此訊息給予進一步探討銹垢及溶氫變化更佳的證明。

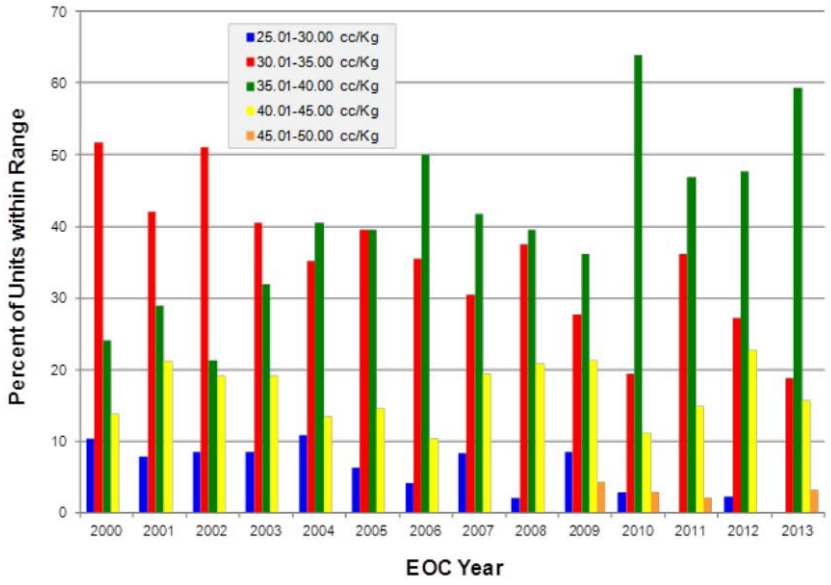


圖 6. 美國 PWR 一次系統各種溶氫量運轉機組占比

因應 EPRI 之 PWR 主要水化學指南，美國核電廠系統之近期 PWR 主反應器冷卻劑系統**(RCS)**關鍵數據之中數值如表 2 所示。

表 2. 近期 PWR 主反應器冷卻劑系統**(RCS)**關鍵數據之中數值數值

Location	Parameter	U.S. Median	Range*		AL1
			Min	Max	
RCS	Chloride, ppb	2.3	0.01	8.43	> 50
RCS	Co-58 Total, Bq/m^3	2.98E+07	5.33E+05	1.62E+08	n/a
RCS	Co-60 Total, Bq/m^3	2.07E+06	7.22E+04	2.18E+07	n/a
RCS	Fluoride, ppb	1.47	0.01	5.0**	> 50
RCS	Silica, ppb	440	0.23	4675	n/a
RCS	Sulfate, ppb	1.0	0.10	5.0**	> 50

* The range of cycle median values for each PWR unit considered
** For plants reporting only the lower limit of detection (LLD) of 5 ppb
RCS = Reactor Coolant System, n/a = not applicable

壓水式反應器二次系統水化學運轉經驗及技術探討

PWR 及 VVER 型核反應器二次系統早期使用的蒸汽管材質 Inconel-600MA 已逐漸被 Inconel-600TT、Inconel-690 及 Alloy-800 等所取代，最爲被關切而影響長期安全運轉的便是蒸汽產生器劣化及管線流動加速腐蝕(Flow Accelerated Corrosion, FAC)兩個問題。二次系統碳鋼管線因 pH 控制不良所導致 FAC 現象亦始終持續困擾著運轉中的電

廠，雖然近幾年來含鉻(Cr)材質的改良已大幅減少 FAC 引發之問題，但是仍待更換管線克服。爲了長期有效解決蒸汽產生器劣化與管線 FAC 現象，水化學整體性的規劃仍然是刻不容緩的，其中絕大部份的雜質如鐵(Fe)、鈉(Na)、鈣(Ca)、 鎂(Mg)、氯(Cl)、硫酸根($SO_4^{=}$)、硫化物(S)、氟(F)、有機物、矽土(Si)、鉛(Pb)、離子交換樹脂等與系統溶氧及 pH 的控制便是主宰二次系統的重要因子。二次系統水化學的規劃及依循策略彙整歸納如后:

(1) 高等胺的選用調整 pH

高等胺(Advanced amine) 與一般早期使用氨等互相的調節運用，減少管線流動加速腐蝕現象(FAC)，減低鐵(Fe)飼入 SG 內之重要控制因素。由於 pH 是掌握 Fe 含量的重要指標(如圖 7)，即使是混合使用有機胺，但仍以 pH 之控制爲主。目前美國電廠仍是乙醇胺(Ethanolamine, ETA)或 ETA/NH_3 或 MPA 之控制方式較多，主要考量是採用混合胺時也有區域控制管線 FAC 之功能。法國電廠大多使用 1,4-氧氮陸圜(Morpholine)，原因爲分布係數=1，而達到汽、液流域均可受到保護，不易有 FAC 問題。然而缺點爲易於生成有機酸，使得陽離子導電度(Cation Conductivity，C.C)偏高，不利於偵測到其他雜質的含量。相較於其他的胺類，乙醇胺具有高鹼度的特性，可使用較低之濃度，對環境影響較小，而且對冷凝水除礦器之相容性佳不需要時常再生，熱穩定性也較 Morpholine 爲佳。AVT 試劑的選用取決於電廠材質是否含 Cu 或 Cu 合金及是否有冷凝水除礦器及 SG 沖放系統之設計。爲減低碳鋼管線 FAC 現象，控制廠用系統(Balance of Plant, BOP)水質 pH 及溶氧促使管線表面形成硬質氧化膜是水化學最有效的方法，特別是碳鋼管線形成穩定的磁鐵礦(Magnetite)氧化層，有助於減低 FAC 現象。加入試藥控制 pH 考量因素主要還是材質之差異性，與汽相、液相及兩相共存都要考量，採行全揮發處理 (All volatile treatment, AVT)技術，兩相流區域選用進步型或替代胺之 pH 控制劑是較被接受的技術。其中控制氧含量之聯胺(N_2H_4)量與碳鋼管線之 FAC 也息息相關，國際上已有一致的共識，認爲加入的聯胺宜於>20 ppb 且爲 O_2 濃度的 8 倍左右， ANT 公司建議聯胺濃度爲 20~100ppb，目標值爲 50 ppb。

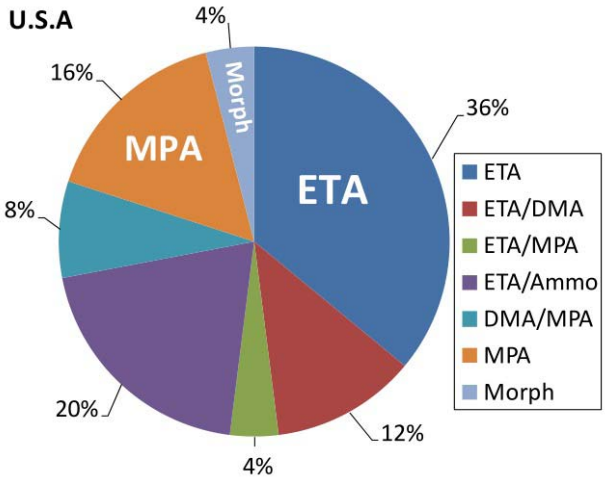


圖 7. 美國 PWR 二次系統使用各種胺類占比

(2) 使用 PAA 分散劑減少淤泥沉積

減少腐蝕產物飼入 SG 的最佳治本方式爲有效控制碳鋼管線之 pH_T 、溶氧或採用增裝過濾設施減少鐵氧化物， EPRI 證實美國電廠如 Arkansas Nuclear One unit 2、McGuire unit 2、Byron units 1&2、Braidwood units 1&2 及 South Texas units 1&2 等採用飼水系統加入 2~4ppb 的 Poly-acrylic acid(PAA)分散劑，可抑制二次系統鐵腐蝕產物蓄積在 SG 形成結垢及移除部份淤泥，爲避免鐵氧化物等成爲硬質結垢相當有效的策略之一，於系統加入 PAA 再藉沖放系統移除鐵。使用分散劑時機有二：一爲線上長期使用(LTU)，減低飼入之 Fe 被附著於 SG 管表面並利用沖放系統去除；另一爲離線應用，主要是濕式貯置時機(WLU)，特別是大修起動前之長路徑循環(LPR)期間能去除管線生成之氧化物。

(3) 鉛雜質對二次系統鎳合金 SCC 影響

蒸氣管除了受到一般鐵氧化物等沉積之影響外，近年來發現微量鉛的存在對 Alloy600MA、600TT 及 690TT 等蒸氣管材質的影響不可忽略。鉛除了因加入聯胺等化學添加物雜質可能有極微量導入外，其他都源自於系統組件或維修時之施工品引入，經由飼水系統沉積於 SG 內。目前的發現是鉛的存在導致鉛促進應力腐蝕龜裂

(Lead-assisted Stress Corrosion Cracking, PbSCC)，鉛在飼水與 SG 沖放系統含量雖僅有 20 及 200ppt 左右，經由穿透式電子顯微鏡(TEM)分析氧化物、淤泥或是於裂縫尖端，常發現大量的鉛；雖然許多的 PbSCC 形成機制尚未被確認，從初步的測試顯示於高溫時對 Alloy 材質更易發生，經由擴散進入氧化膜或裂縫尖端導致 PbSCC 現象。從二次系統 SG 管抽管的研究中發現，鉛在裂縫尖端造成劣化晶界問題愈來愈明顯，即使它對 IGA/SCC 的影響幾乎尚可忽略，但極微量的確造成類似 Cl^-及 $SO_4^=$所衍生的劣化現象，從基本研究目前所獲得的初步結論證明鉛於 280℃的環境中的確無法形成鈍化膜；而矽土的存在對 pb 的電化學機制也受到影響，因此可能是某些電廠因 Pb 會造成 Pb SCC，有些並不會有此問題發生，不論如何 pb 的問題會逐漸引起研究者的興趣。

因應 EPRI 之 PWR 主要水化學指南，美國核電廠系統之近期 PWR 主反應器二次側水化學關鍵數據之中數值如表 3 所示。

表 3. 近期 PWR 主反應器二次側水化學關鍵數據之中數值

Location	Parameter	U.S. Median	Range*		AL1
			Min	Max	
CPD	Dissolved Oxygen, ppb	4.84	0.7	20.16	>10**
Feedwater	Hydrazine, ppb	99.75	29.4	220.71	<8 X CPD [O2] or <20 ppb, whichever number is larger
Feedwater	Dissolved Oxygen, ppb	0.20	0.02	1.9	>5
Feedwater	pH(25)	9.75	9.47	10.07	n/a
Feedwater	Iron, ppb	1.26	0.47	2.43	>5
Feedwater	Copper, ppb	0.01	0.001	0.11	>1
Feedwater	Lead, ppb	0.009	0.001	0.019	n/a
SGBD	Sodium, ppb	0.18	0.05	0.44	>5
SGBD	Chloride, ppb	0.38	0.05	1.7	>10
SGBD	Sulfate, ppb	0.40	0.10	1.41	>10

* The range of cycle median values for each PWR unit considered
** Only applicable if CPD oxygen is a Control Parameter (defined in Reference [20])
CPD = Condensate Pump Discharge, SGBD = Steam Generator Blowdown, n/a = not applicable

主題演講 2

Activity of Water Chemistry Division of the Atomic Energy Society of Japan

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由本次大會主席日本東京大學勝村庸介教授，針對日本的核電廠水化學進展作介紹，日本水化學協會始於1982年，前身爲日本原子能學會（AESJ）的一個特別委員會。於2007年，該委員會已升格爲水化學協會。水化學部門的現狀進行了簡要介紹

- 水化學路線圖(**Water Chemistry Road Map)**

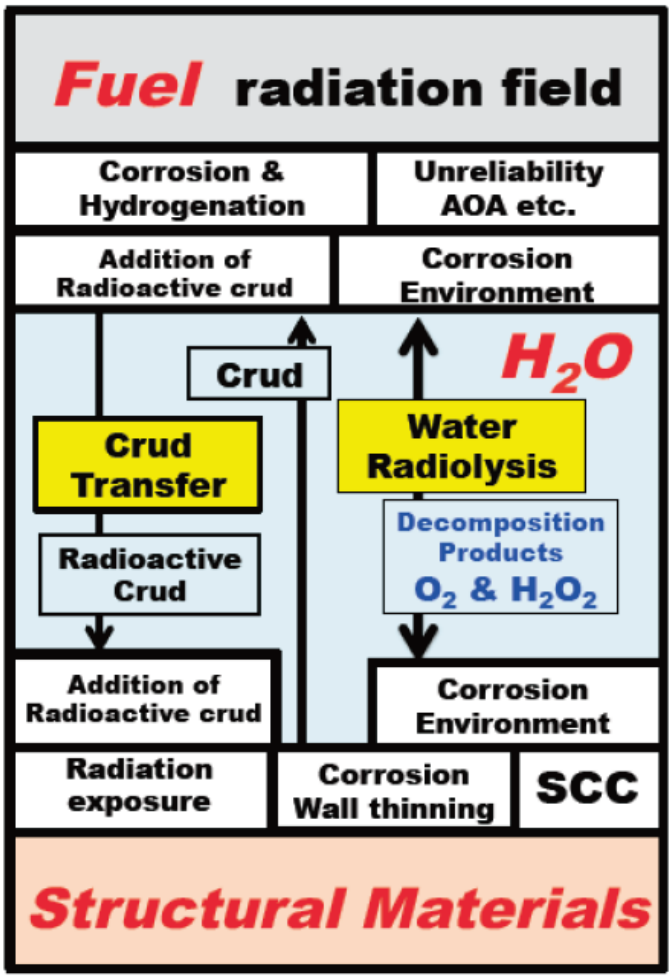

圖8．日本核電廠水化學路線圖

此爲水化學事業部於2007年所訂定的“水化學路線圖”，於2009年經第二次修

訂。雖然原則上路線圖將每年修訂，新的版本因福島第一核電站核事故如今仍在準備。編輯新的版本將會考量並納入福島核事故中所獲得的經驗教訓。

圖8 .爲日本核電廠水化學路線圖，冷卻水接觸到燃料及結構材料，因受燃料強輻射照射影響，水輻射分解生成水分解產物如O_2和H_2O_2，其影響控制了冷卻劑之化學環境。這些氧化性物種會引起材料不良影響，例如應力腐蝕開裂(SCC)。此腐蝕結構材料產生污染物，這污染物會轉移並激活在燃料。在燃料表面上的污物除去從上所述的結構材料，這增加了燃料的輻射程度，造成工人輻射暴露增加之結果。根據上述概念，日本嘗試舉辦材料科學講習班和研討會，協同技術部及核燃料加工業司一起合作。在2009年和2012年完成兩次聯合夏季的研討會。

亞洲水化學會議

亞洲水化學會議每兩年舉行一次，以交換亞洲各國之核電廠水化學資訊與操作經驗，起始於1993年台灣和日本之間水化學雙邊會議，每兩年舉行一次，輪流於日本與台灣舉行1995、1997、1999、2001年，於2001年韓國加入此水化學會議。此後會議從2003年開始於台灣、韓國和日本之間輪流主辦，每兩年舉辦一次直到2009年。在2011年因福島核事故被迫取消。在2013年，亞洲水化學會議在台灣舉行，協會邀請了印度和中國成爲核心成員，並同意2015年的會議將在印度舉行。如表4所示，目前，本協會核心成員有台灣、韓國、印度、中國和日本。

表4.亞洲水化學會議

Year	Place & Host	Year	Place & Host
1993	Taiwan	2005	Korea
1995	Japan / Tokyo	2007	Taiwan
1997	Taiwan	2009	Japan / Nagoya
1999	Japan / Tokyo	2011	Cancellation (Japan)
2001	Taiwan, Korea (independently)	2013	Taiwan
2003	Japan / Fukuoka	2015	India (to be held in Sept. 2015)

由於循環冷卻水在核反應器爐心中暴露於γ射線和快中子的強輻射，導致水分解。眾所周知，水的分解產物有H_2O_2和O_2，此產物具關鍵腐蝕作用，因此控制冷卻劑的化學條件，致使在反應器中的材料減少腐蝕，控制或塑造耐腐蝕的環境條件。因此，水的輻射分解在升高溫度約至300℃狀態下是重要評估條件，此爲冷卻劑化學條件重要評價的環境條件。相關反應器材料性能的水的輻射分解研討會，如表5國際水化學會議所示。

表5.國際水化學輻射分解會議

#	Month Year	Place	Organizer
1st	October 1998	Tokyo, Japan	AESJ
2nd	November 1999	Kawasaki, Japan	AESJ
3rd	November 2000	Winfrith, UK	BNES
4th	April 2002	Avignon, France	SFEN
5th	November 2004	San Francisco, USA	EPRI
6th	November 2006	Jeju-do Island, Korea	AESJ
7th	November 2008	Berlin, Germany	VGB
8th	November 2010	Quebec, Canada	CNS
9th	November 2012	Paris, France	SFEN
10th	November 2014	Sapporo, Japan	AESJ

水冷卻劑在高溫下，氫注入到BWR系統和其使用材料的電化學特性、放射分解程序效果、在初始階段的放射分解爲主要課題。從反應器主體擴大到其他輻射引起的效應。NPC2014年擴展其他學科研究如計算機模擬水輻射分解、核電廠輻射引起的腐蝕、水輻射在高溫條件下先進的實驗技術與基本過程研究，如超臨界的條件下之輻水可作爲未來一代的反應器應用與海水輻射問題等。

福島第一核電廠放射性廢水吸附處理

福島第一核電廠放射性廢水處理系統吸附的研究，主題是銫(Cs)在吸收體的吸附特性。如沸石(Zeolite)等吸附劑可有效去除污水中的銫離子，然而因污水中含有海水及其他離子干擾，此沸石吸附劑的吸附性必須對不同溶液皆有效用。實驗觀察在純水及含NH^{4+}、K^+、Na^+、Ca^{2+}、Mg^{2+}的水溶液中 Cs 對 Natural zeolites、Artificial zeolites (IE-96)、Crystalline silicotitanate sorbent (IE-911)的吸附特性，結果顯示海水中鹽分濃度愈高，各種沸石吸附劑對 Cs 的吸附性愈低，各種離子對 Cs 在吸附劑的吸收程度之影響程度爲：

$NH^{4+} > K^{+} > Ca^{2+} > Na^{+} > Mg^{2+}$。

另也有人提出使用酚類官能機的離子交換樹脂(Dow chemical 產品)來吸附處理汙水中之銫離子，實驗結果顯示效果良好，具實際應用價值。

電鍍法回收放射性離子交換樹脂

核能研究所開發成功之濕式氧化與固化系統(WOHEST)用以處理具放射性用過離子交換樹脂。電廠中所產生之離子交換樹脂(IXR)的輻射問題管理一直是一個棘手的問題，爲了能達到減容目標，本所成功地發展出 WOHEST。WOHEST 可達 60%減容、具低能耗及不產有毒廢物等優點，實驗已利用 Bench&pilot 測試驗證其性能及可行性，且目前已著手建造可商用之 40 L/H 系統。另外，研究顯示藉著使用濕式氧化，離子交換樹脂之有機體可有效的分解 CO_2 與 H_2O，再結合本所已有高效率之固化技術，可得穩定之固體廢棄物。此系統預計於 2015 年終正式商用，預期將能有效節省空間及成本。

日本 Kurita Water Industries Ltd.利用電鍍技術回收具放射性離子交換樹脂中的鈷-60，結合熱酸洗及電鍍技術可使從核電廠舊離子交換樹脂中產生的 Co 及 Fe 穩定，此技術可對 Co 達到超過 1000 的除污因子(DF)。熱酸洗過程可使舊離子交換樹脂中不溶的銹垢分解，檸檬酸銨(Ammonium citrate)穩定劑的使用則可使電鍍技術有更廣的 pH 範圍，並避免產生懸浮氫氧化鐵粒子，此結合技術使酸能同時用於溶解銹垢及消除 Co 的應用上。

三、心得

(一)發表研究成果並與國外水化學專家交換技術及心得

本次水化學國際會議在日本札幌舉行，參加的國家多達 28 國，參與人數達 350 人以上；雖日本受到福島 311 事件影響，目前日本核能電廠停爐並正緊鑼密鼓提升其安全係數與抵抗地震與海嘯侵襲能力，以準備能夠通過日本核管單位安全要求後重新啓動，

日本從事核能電廠相關研究人員並沒減少，此次日本報名參加人數仍高達 180 人，從會議中發表論文內容看來，日本並未放棄核能方面的基本研究。在會議中所發表的論文或展示的壁報論文內容，都爲核能先進國家特別是法國、美國…等，與會人員透過國內外人員研究結果配合電廠的運轉實績及經驗，適時提出值得供人參考及應用的成果。本所化學組溫副組長持續參與於此領域研究已有 30 年，爲此領域重要前輩，感謝在他帶領下認識此領域先進與重要人士，向他請益水化學關鍵技術個人受益良多。本組發表 3 篇論文，1 篇 oral，2 篇 post (如附件 1,2)，能有機會與此領域專家認識討論能開展視野，也適時收集國際核電廠水質控制技術及各國核能現況，並與國外專家學者建立基本關係，其實台灣核電廠運轉實際績效在全世界名列前茅，值得感到相當高興並引以爲傲。其實我們需要自我肯定，並且持續努力往前邁步，我們不輸外國人，透過參與相關國際會議，不但可吸收他人寶貴的研究經驗，減少自我摸索的時間與步驟，更可透過論文的發表聽取他人的建議與看法，對於自我研究水準的提升有相當大的助益。

(二)核能技術互通與安全接軌，跨國研發爲時勢所趨

核能技術互通合作，透過合作提升系統安全，召開會議公開核能水化學研發進展，能有效提升核能技術並加速技術開展，減少摸索時間透過會議與壁報論文學習，目前歐、美、日等研究機構彼此間互通合作，相互推動的跨國計畫，在 3 年前福島一廠事件過後興建新機組極少，但目前中國和印度、英國爲彌補電力不足將持續建設核電廠，有些核電廠採取提升功率作因應電力持續增長的需求，而且爲了確保安全運轉，對水化學的控制技術及管理經驗仍需重視。其中 PWR、VVER 及 PHWR 電廠爲歐、美核反應器之主軸，大會在與 PWR 水化學方面相關的論文發表及討論尤爲熱烈。會議中溫副組長與清華大學葉宗洸教授曾多次在會議中發言與大會人員討論，有效提昇台灣的能見度，從研究領域及方向看來，本所在此領域受到經費短絀及人力不足和斷層等諸多因素限制，似乎很難有機會參與國外合作研究機會，長期而言仍要考慮調整執行方式及規劃方向。

(三) 水化學技術已漸漸被中國及亞洲其他國家趕上，但仍應推動基本研發

核反應器水化學國際學術會議全名爲 Nuclear Plant Chemistry Conference 2014(NPC 2014)，此會議每兩年固定於不同區域(洲)舉辦一次，基於客觀環境限制，我國的參加人數雖僅 8 人(本所 2 人、清華大學工程與系統科學系葉宗洸主任及碩、博士生等 4 人、清華原科中心王美雅博士、工業技術研究院材料研究所李宜親小姐等共 8 人)與會，但是在大會中兩場口頭論文發表及兩場的論文展示及解說，獲得熱烈的回響，尤其清華原科中心王美雅博士在壁報展示中獲得第三名，接受大會主席東京大學勝村庸介教授在全員晚宴中的表揚，與有榮焉。以往的 NPC 會議中國僅有 5~8 人與會，本屆會議參加人數包括國外研究生多達 10 人，有關水化學論文有 2 篇。

(四)日本北海道電力泊核電廠，其新建機組僅需 6 年即完工，積極提升電廠安全係數

參訪日本泊電廠參觀，發現其新建機組僅需 6 年即完工值得借鏡，採三菱重工 PWR 系統，目前因應提升其安全係數與抵抗地震與海嘯侵襲能力，建立 1 公里堤防高度 16.5m 以防海嘯，同時在後方小山丘建立幾只 5000 噸純水儲槽以備不及之需，備用電力也提高水平面並建立緊急發電系統，積極準備希望能夠通過日本核管單位安全要求後重新啓動，目前北海道電力 1/3 來自核電，在停爐期間每天都要花費鉅額金錢，採行天然氣發電補足核電缺口，目前缺口補不太足，北海道面臨電力不足之窘況，加上冬天北海道冰天雪地很冷，民眾與旅館旅遊業電力需求高，所以他們希望快速重啓核電廠滿足電力需求。

四、建議事項

(一)因應國內政策調整核電廠水化學研發能量與持續人才培育

亞洲水化學會議每兩年舉行一次，以交換亞洲各國之核電廠水化學資訊與操作經驗，台灣爲發起人之一，台灣和日本於1993年開啓水化學雙邊會議，輪流於日本與台灣舉行1995、1997、1999、2001年，直至2001年起韓國加入此水化學會議。從2003年開始

於台灣、韓國和日本之間輪流主辦，去年2013年，亞洲水化學會議成功在台灣舉行，參與者有來自台灣、韓國、印度、中國和日本專家學者，而2015年的會議將在印度舉行。核能安全相關的水化學研究十分重要，台灣在此領域也表現優異，然而受到國內政策調整趨勢影響已逐漸產生人才短缺。國內核反應器水化學研究，目前仍是以台電公司三個運轉中之核反應需求爲導向，本所在系統研究及改善方面曾經可獨當一面的協助電廠解決現場水質及提昇測試及應用方面的問題，但是在程式的開發和評估，僅清華大學葉宗洸教授有BWR、PWR加氫水化學及電化學方面的程式可供應用在電廠計算及評估，在人員短缺開發不易的情況下，如何強化現有的陣容並與國外研發單位合作，應是事半功倍的捷徑。在人力的培育方面，需規劃新血加入持續參與水化學國際會議，目前各國加入的新血甚多，且年輕研究人員的人數也逐年增加。就以日本而言，僅日本水化學負責人東京大學勝村教授(Prof.Y.Katsumura)、前東京大學石榑教授(Prof. K. Ishigure)、內田教授(Prof. S. Uchida)、東芝化學部資深專家(J.Takagi) 及日本原子力公司(Japan Atomic Power Company, JAPCO)前副總裁目黑博士(Dr.Y.Meguro)等，此與國內現況作比較差異甚多，顯示國內水化學的確有青黃不接及斷層的疑慮。我國在這個領域的研發因客觀因素的影響逐年下滑，從事此一領域的研究人員更少新血加入，因此建議若要持續舊機組運轉安全及加強新建機組方面的規劃，增加參與研發及培育新人爲長期不可或缺的規劃。藉由參與相關議題的國際會議，不但可吸收他人寶貴的研究經驗，減少自我摸索的時間與步驟，更可透過論文的發表聽取他人的建議與指教，對於自我研究水準的提升有相當大的助益。政府應面對現實，特別是二氧化碳減量議題，更應提供足夠經費支持國內各研究機構核能技術相關的研發。NPC 2016年會議將於10月2日至7日在英國Brighton舉行，2018年在美國舊金山舉行。

(二)需持續對大眾宣導說明我國能源政策並務實考量核能發電之需求

我國經濟及薪資成長已有一段時間停滯，目前已經遠遠落後新加坡，看著周遭與我國競爭國家持續大步前進建設國家，而我國卻在原地踏步打轉，國際競爭是殘酷的也很劇烈，雖然日前有爭議的競選廣告提及「韓國說謝謝您!」我國競爭力是原本比韓國強，

然而近期韓國已不把我們當成對手，有競爭力的韓國目前有 23 個核能發電機組，佔其國內發電量的 37%以上，建立反應器水化學方面的研究及推動也較我國爲晚，多年來非常積極參與國際會議，除了於 2003 年加入台日之水化學會議外也在 2006 年主辦大型之國際水化學會議。日本原來的核能政策受到福島一廠核災事件的嚴重衝擊，幾近於零核能發電，目前雖然已作全面的安全檢查及增強安全設計，若能進一步確保運轉安全民眾接受度提高，從維持穩定電力、有效減碳、自有能源極匱乏及長期經濟發展規劃的角度上，核能發電仍需佔有穩定的比率。國內飽受日本福島一廠核災事件的影響，反核聲浪似乎與日俱增，政府政策也朝非核家園方向推動，2018 至 2021 年舊有的 6 個機組面臨除役的壓力，龍門廠一號機即使通過安檢，短期內民眾接受度不易恢復，仍要經過全民公投才可能裝入燃料運轉。石化等能源價格雖已於近兩個月逐漸下降，但是爲抑制二氧化碳排放避免全球暖化，生質能、太陽能、風力發電及其他各種替代能源尚未達穩定及合理價位的前提下，短、中期永續能源政策中加強核安，適度維持核能發電的配比是必要立即推動的措施，因此適時調整此領域的研發有其需求，本所在這方面更應擔負重責大任以支持永續的能源及安全、有效率的核能發電。

(三)維持基本核能技術並拓展其它能源研究

政府雖然已於 100 年初宣布加強安全、穩漸減核，但是國內三個核電廠自 80 年代迄今始終能有效維持安全運轉，提供極爲穩定的基載電力，不得不認同核能發電對國家 30 年來整體經濟的發展的貢獻。日本 311 事件發生的直接影響，核能政策大幅調整，如今一旦走向減核、廢核，過去的貢獻度、運轉績效及累積經驗以現今民眾的認同及接受度似乎成了泡影。畢竟台灣終究是個海島型無自產能源的國家，賴以生存的條件首推經濟能否永續穩定發展，在短、中期甚至長期而言都是要面對接受的事實。目前三個核電廠正以最好績效而穩健的步伐中前進，以本所多年從事核能研究的經驗，整體效益發揮的極致非此刻莫屬，誠不忍目睹於健壯時走向人生盡頭；今後的十餘年核一、二、三廠仍要確保核安，站在協助國家持續推動經濟發展的角度除了要繼續推動運轉安全及提昇效益的措施外，保持所內現有核能技術提供維護安全的基本能力，仍是刻不容緩的事

實。更要以此基礎協助非核能領域發電或能源的研究提供新人轉型的技術及應用，以水化學而言，火力發電、電子業、食品製藥等均有相當的空間，其他能源領域也是占有不可或缺的角色。

(四)建立核廢水處理及核廢料處理能力及技術

日本福島一廠核災事件之前並未考慮甚至想像到會因事件而產生那麼大量的廢液，廠區內超高污染的廢液，若不能儘速建立處理技術，廢液污染層面及緊急處理效率會受到嚴重的延誤。事件發生後至今仍持續處理廠區反應器地下層及汽機廠房區高放射性污染廢液處理，雖可能未耽誤了後期有效冷卻反應器廠房及增加陸面、海域地區放射性污染的控制能力，但是徒增初期冷卻廠房的困難度，使用廠外未污染之冷卻水大幅地增加了大量的放射性污染廢液。國內目前雖有緊急應變處理反應器失水的多項措施，但是並沒有發生事件後其他因應方法的初步想法及規劃，建議以福島一廠高放射性廢液處理方式爲借鏡，開始建立大量高放射性污染廢液處理能力及技術。

(五)龍門電廠封存處理，可參考日方 311 事件後電廠之貯存經驗與技術

政府已宣布龍門廠啓動封存措施 3 年，從水化學的觀點看來，系統管線及相關組件造成腐蝕很難以避免，日本自從 311 事件後已有 3 年多期間沒有機組運轉，期間停止運轉與龍門廠的差別主要在燃料之置入與否，因此，日本電廠與燃料相關的冷卻水系統必需長期維持符合規範之較佳水質，龍門廠即使尚未置入燃料與爐心相關之冷卻水系統亦復如是；除了濕式貯存水質規範要符合冷停機標準之外，其餘大管線系統應於極低氧含量之長期乾式貯存，日本 BWR 電廠相當多東芝及日立等公司提供多面與封存累同的技術，台電公司可透過 GE-Hitachi 做整體規劃，本組水化學相關工作也可在此方面向台電公司提供推動方式，以確保管線材質之完整性。

五、附錄

附件 1　(A) NPC 2014 水化學化工組壁報論文內容

附件 1　(B) NPC 2014 水化學化工組壁報論文內容

10026

Preparation of Titanium Doped Sodium Niobium Oxide for the Removal of Radionuclides in Wastewater

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Abstract

The use of inorganic adsorbent to remove trace radionuclides from nuclear industry effluents is energy-efficient and promising. To realize the industrial application of inorganic adsorbent, a low-cost and easily scalenable production method is needed. In this study, a new synthetic route for preparing inorganic titanium doped sodium niobium oxide adsorbent was proposed.

Experimental

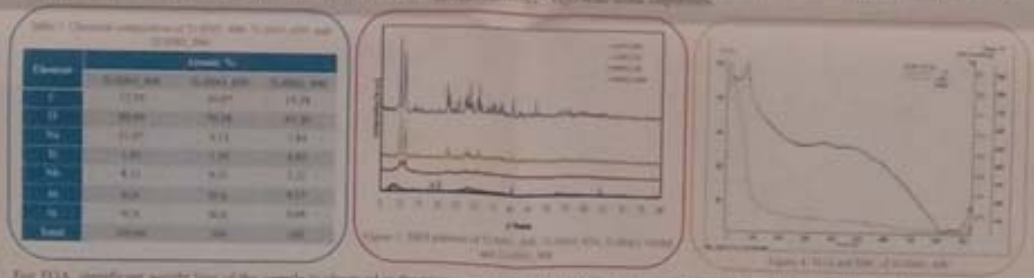
Titanium doped sodium niobium oxides (Ti-SNO) were prepared by mixing niobium oxide (Nb_2O_5), titanium oxide (TiO_2) and sodium hydroxide (NaOH) with Nb:Ti:Na molar ratio of 4:1:5. The mixtures was then calcined at various temperatures, namely 400, 650, and 900℃, with a heating rate of 1℃/min for 1 hr. In addition, a modified calcination procedure using a two-step heating profile was adopted in which the mixtures was first calcined at 300℃, and then calcined at 650℃. The adsorbent prepared with one-step calcination at 400, 650, and 900℃ was named as Ti-SNO_400, Ti-SNO_650, and Ti-SNO_900, respectively, while that prepared with two-step calcinations was named as Ti-SNO_650M. The prepared titanium doped sodium niobium oxides under different conditions were characterized and their performances were evaluated based on the removal efficiency of target ions in simulated wastewater.

Results and Discussion

It is apparent that the particles of Ti-SNO_400 exhibit spherical shape. The shape of Ti-SNO_650 particles, on the other hand, is rectangular shape with clear angles and edges, while that of Ti-SNO-900 is a mixture of spherical and rectangular shapes. The rectangular shape particles are evidence of crystallization resulted from high-temperature calculations.

For both Ti-SNO_400 and Ti-SNO_650 Nb, Ti, Na, and O and are observed, suggesting the presence of Nb, Ti and Na oxides. The ratio of Nb:Ti:Na is approximately 4:1:5, indicating $Na_4Nb_{13}Ti_4O_{37}(OH)_{14} \cdot H_2O$. Al and Si are observed only for Ti-SNO_900, implying that the adsorbent may have been contaminated by the aluminum oxide crucible (may contain some silicon) used for carrying out the calculations.

All samples show crystallization except for Ti-SNO_400, suggesting that calcination temperature of 400℃ is inadequate to induce the formation of crystals. Ti-SNO_650M exhibits the most intense X-ray diffraction peaks, implying that two-step calcination process did improve the reaction between metal oxides and NaOH. Ti-SNO_650 and Ti-SNO_650M were identified as $Na_4Nb_{13}Ti_4O_{37}(OH)_{14} \cdot H_2O$ with some impurities.



For TGA, significant weight loss of the sample is observed in the temperature range of 20–100℃, corresponding to the loss of water molecules. Slight weight loss is observed when the temperature is increased up to 1000℃, suggesting that the adsorbent is thermally stable. For DSC, a two-stage downward curve is noted in the temperature range of 100–1000℃, which corresponds to an exothermic reaction due to crystallization of the adsorbent.

Ti-SNO_650M adsorbent exhibits the highest Sr removal among other Ti-SNO adsorbents tested, suggesting that crystallization of Ti-SNO is beneficial for Sr removal. However, the improvement is not significant comparing with that of Ti-SNO_400, which may be due to the reduced surface area due to calcination. The trend of Co removal for Ti-SNO_650M is similar to that of Sr, while Co removal is extremely low.

Conclusion

In this study, various forms of titanium doped sodium niobium oxides (Ti-SNO) were successfully prepared by simple solid-state fusion technique, which makes their commercial production feasible. It was found that well-crystallized titanium doped sodium niobium oxide in the form of $Na_4Nb_{13}Ti_4O_{37}(OH)_{14} \cdot H_2O$ exhibits the highest removal efficiency as well as adsorption capacity for Sr and Co metal ions.

附件 2 投稿之演講(ORAL)論文

I0038

Development of Wet-Oxidation and Solidification System for Treatment of Spent Radioactive Ion-Exchange Resin

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ABSTRACT

Currently, spent ion exchange resin is dehydrated, loaded in 55-gallon drums and temporarily stored in nuclear power stations in Taiwan. As of the end of 2012, there have been 7,372 drums of spent resin stored in Kuosheng Nuclear Power Station (KNPS) and an estimated 450 drums per year are additionally produced. This kind of radioactive waste tends to deteriorate and is likely to pose a threat to the environment if not stabilized. Conventional treatment for spent resin via direct cementation produces a large amount of solidified waste, which results in high disposal costs. For volume reduction and stabilization of spent ion exchange resin, the Institute of Nuclear Energy Research (INER) has successfully developed a unique wet oxidation and high-efficiency solidification technology (WOHEST). WOHEST features performance of greater than 60% volume reduction, low energy consumption, and no secondary waste created. The full-fledged and viable process not only garners patents from U.S., Japan, EU, and Taiwan, but has also acquired its validation completely via bench and pilot (capacity: 3-5 L/H) tests. Accordingly, the environmentally friendly technology is the best option for the treatment of spent resin. In collaboration with Taipower Company, INER is currently developing a wet oxidation and high efficiency solidification system of 40 L/H in KNPS. The system is in the process of trial runs after finishing the conceptual, basic, and detailed design as well as equipment development and mimic configuration.

Keywords: Radioactive waste, Spent resin, Wet oxidation

1. INTRODUCTION

Ion exchange resin (IXR), normally in the form of small beads, is a unique type of polymer widely used for separation, purification, and decontamination among food, pharmacy, petro-chemistry, and nuclear industries. The majority of commercial IXRs are produced via copolymerisation of styrene and divinylbenzene. Four main types of IXRs are categorized according to the attached functional groups. Two of them are typically employed in nuclear power station (NPS), one featuring sulfonic acid groups for strongly acidic cation exchange resin and the other featuring quaternary amino groups for strongly basic anion exchange resin. When the ions in resin have mostly been replaced by those from an external solution, the resin is considered to be exhausted and needs to be regenerated. In Taiwan, however, exhausted IXR has no longer been regenerated since 1990 on account of providing better quality of reactor water. Fresh IXR is totally substituted for spent IXR which is dehydrated, loaded in 55-gallon drums and temporarily stored in NPSs. Hence, the number of drums of spent IXR has since proliferated dramatically. Take Kuosheng NPS of Taipower for example. As of the end of 2012, there have been 7,372 drums of spent resin stored in Kuosheng NPS and an estimated 450 drums per year are additionally produced. This kind of radioactive waste tends to deteriorate gradually and is likely to pose a threat to the environment if not stabilized. Conventionally, the most common way for the treatment of spent IXR is to directly mix with cement, bitumen, or polymers to form stable solidified wastes [1-3]. While this approach may come with a few advantages of low costs and simple operation, low waste loading, increased volume of final waste, and unsatisfactory quality of the solidified waste are some of the most commonly cited deterrents. There are several other processes [4-7] available for the treatment of spent IXR, Hot Super-compaction Process[8] (HSP), incineration[9,10], plasma treatment[11], Thermal Organic Reduction (THOR) process[12], just to name a few. The HSP is used to make water free and dense homogeneous organic blocks of spent IXR. A significant volume reduction factor of up to four is claimed to be achievable via the technique. However, how to offset spring back effect and duroplastic behavior of bead resin is still the most crucial issue leading to successful results. Incineration may be considered theoretically the best way to accomplish alarmingly large volume reduction factor for the treatment of spent IXR. It is also an energy-consuming process, generates toxic gases such SOx and NOx, and has a relatively high capital and maintenance cost. Plasma treatment process struggles with similar problems of incineration, albeit one with robust waste forms. THOR process, a pyrolysis/steam reforming system, developed by Studsvik, proves to be effective except that the final product, granular solid, has to be transported back to clients for further stabilization.

The Institute of Nuclear Energy Research (INER) has successfully developed a unique wet oxidation and high-efficiency solidification technology (WOHEST). WOHEST features substantial performance of greater than 60% volume reduction, low energy consumption, no secondary waste generated, and robust final solidified products. The well-developed technology is not only environmentally friendly, but also a total solution to the treatment of spent IXR. So far, WOHEST has garnered patents of Japan, U.S., EU, and Taiwan. After having completed verification and validation of WOHEST via bench and pilot (capacity: 3-5 L/H) tests, INER is currently establishing a wet oxidation and high efficiency solidification system of 40 L/H in Kuosheng NPS. The system is in the process of trial runs after finishing the conceptual, basic, and detailed design as well as equipment development and mimic configuration.

2. PROCESS DESCRIPTION

WOHEST is composed of four major processes which are wet oxidation, conversion and concentration, gas and liquid waste treatment, and solidification. The concept of treatment of spent IXR by WOHEST is shown in Figure 1. More details of each process are described as follows:

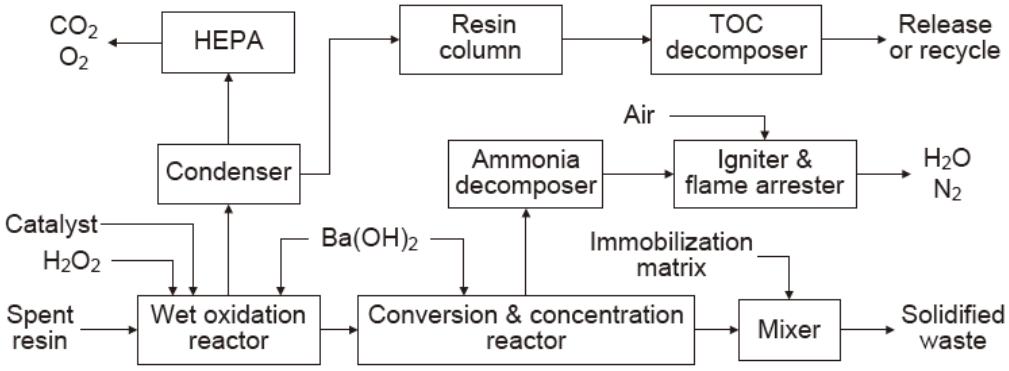

Figure 1. Flow chart of the WOHEST process

2.1 Wet oxidation

Inspired by Fenton reaction, spent IXR is first mixed with catalyst (Fe^{2+}) in excess water at ambient temperatures and pressures. The mixed waste is heated to about 95°C and hydrogen peroxide (50% by weight) is then continually added. When Fe^{2+} in the solution reacts with hydrogen peroxide, highly oxidizing hydroxyl radicals are generated. Once exposed to IXR, the hydroxyl radicals abstract hydrogen atoms, resulting in the formation of organic radicals. Reduction or oxidation by the catalyst allows further attack by hydroxyl radicals. This chain oxidation produces alcohol groups on the parent organic molecule, which may then be further oxidized to aldehydes or ketones and then carboxylic acid groups. Decarboxylation of these organic acids by further reaction with hydroxyl radicals produces carbon dioxide gas, and the organic chain length is reduced by one. Almost all the original organic carbon structure will ultimately be converted to carbon dioxide and water. Quaternary amino groups from strongly basic anion exchange resin tend to be transformed into ammonium cation (NH_4^+) whereas sulfonic acid groups from strongly acidic cation exchange resin are converted into sulfate ion (SO_4^{2-}). The ammonium cation further reacts with sulfate ion to form ammonium sulfate which dominates the major components in the sludge after process of wet oxidation is complete. Almost no additional heating is required during the whole oxidation process in that the heat generated by the exothermic reaction is sufficient to keep the mixture at the boiling point.

2.2 Conversion and concentration

Ammonium sulfate produced from the process of wet oxidation is highly soluble in water. If not treated properly, the dissociated sulfate ion tends to react with calcium carbonate and aluminum oxide from solidification agent to gradually produce ettrigite, which results in unstable quality of the final immobilized product. With this in mind, barium hydroxide is particularly used in the process of conversion to transform ammonium sulfate and sulfuric acid produced in wet oxidation into barium sulfate. Barium sulfate, a stable substance insoluble in water, can not only be pumped away without difficulty but also serve as aggregate in the solidified products to boost their mechanical strength. In addition to the

practice of conversion, superfluous water has to be eliminated in this stage to make sure the goal of volume reduction and qualified products is accomplished.

2.3 Gas and liquid waste treatment

Non-condensable gases produced either in wet oxidation process or in conversion and concentration process are forced through HEPA for removal of remnant radionuclides, if any. Since barium hydroxide is a strong base, ammonia gas is inevitably generated during the progress of conversion. Ammonia is further turned into nitrogen and hydrogen through ammonia decomposer packed with nickel-based catalyst. The hydrogen is then immediately burned into H_2O via igniters. On the other hand, condensate collected from both wet oxidation and concentration processes first flow through ion exchange towers to get rid of trace radionuclides. A small amount of organic compounds in the condensate proceeds to be decomposed via degradation process by SPO, a strong oxidant which is developed by INER.

2.4 Solidification

The ultimate sludge is mixed with a proprietary immobilization matrix in batches to allow the production of a waste form that is suitable for disposal.

Figure 2. WOHEST was applied to deal with radioactive mixed IXR on bench scale

3. TECHNIQUE VALIDATION

Experiments on bench scale were conducted to establish optimal reaction conditions for the treatment of IXR. Various controlled variables, including catalyst concentration, flow rate of H_2O_2, total amount of H_2O_2, and pH of solution were tested under scrutiny. With the optimal conditions selected along with high efficient solidification technique, WOHEST was successfully applied to deal with radioactive IXR. The volume reduction ratio of 3 was achieved, as shown in Figure 2. From this information, reaction conditions suitable for treatment at plant scale were hence identified. A pilot system with capacity of 3-5 L/H was established in 2003. To cut corners, wet-oxidation reactor in the system was also served as a reactor for conversion and concentration. The system shown in Figure 3 was operated with continuous supply of H_2O_2, yet an intermittent addition of nonradioactive IXR. When reaching the desired concentration of sulfuric salt in a batch, the reaction solution was discharged into a container for temporary storage. A couple of batches were conducted in this way to collect enough amount of solution for further treatment. When the process of wet oxidation was finished, the accumulative solution was transferred back to the reactor from the container to implement the process of conversion and concentration. The final concentrated sludge was mixed with an immobilization matrix in a 55-gallon drum to get a solidified product. Several tests were conducted to meet the requirements needed for WOHEST applicable at plant

scale, including (1) demonstration of capacity of the system, (2) consumption of H_2O_2, (3) control of foaming, (4) TOC in condensate and performance of degradation process, (5) examination of composition of gaseous effluent, (6) conversion rate of sulfate, and (7) the quality of solidified waste. According to the test runs, TOC in the condensate was less than 2,000 ppm, concentration of H_2O_2 was no greater than 0.001N, and concentration of SO_4^{2-} was lower than 20 ppm. After the process of ammonia decomposition, almost no ammonia gas was detected in the gaseous effluent and concentration of NOx was less than 50 ppm. TOC could drop dramatically to about 50 ppm when the condensate was further treated via degradation process by use of SPO. The results of test runs are summarized in Table 1, indicating that the expected performance of WOHEST has completely been demonstrated.

Figure 3. Pilot plant with capacity of 3-5 L/H in INER

Table 1. Test results of pilot plant and quality of the solidified product

IXR Vol. (L)	Slurry waste		Immob. matrix (kg)	Solidified product		Compressive strength (kg_f/cm^2)		
	Vol. (L)	Wt. (kg)		Vol. (L)	Wt. (kg)	28 days	After weather resistance test	After water resistance test
480	138	218	112	165	323	233	198	253

4. COMMERCIAL SYSTEM

Kuosheng NPS of Taipower commissioned INER to build a wet oxidation and high efficiency solidification system of 40 L/H at its second interim storage site. The system is designed to consist of 2 equivalent wet oxidation units in parallel, each of which deals with 20 liters of spent IXR per hour. Spent IXR is fed into wet oxidation reactors intermittently while H_2O_2 is continually introduced to the reactors dependent on the levels of foaming. If intense effervescent happens in the progress of wet oxidation, injection of antifoaming agent is an effective way to eliminate the occurrence of froth. In this way, the process of wet oxidation can be smoothly carried out with safety. Through the operation of conversion and

concentration in another reactor, the slurry waste generated is mixed with proprietary immobilization matrix to produce solidified waste.

In addition to meeting the fundamental requirements of volume reduction ratio, the system is deliberately designed in terms of safety, modularization, and flexibility. Diverse units are laid out according to radioactivity, function, and sequences of operation. Those subject to high radioactive dose rate are installed together. Additional shields made of lead are set up at the perimeter. Overscale equipment in the system is made to offer operation flexibility. Detachable components of machines are also used in the system for undemanding maintenance. Several measures are particularly carried out to ensure operational safety. Relief valves and rupture discs are ensconced in appropriate positions such as wet oxidation reactors, steam distributor. Since 50% hydrogen peroxide solution is adopted in the system, the importance of storage and pumping for H_2O_2 solution cannot be overemphasized. Operators have to be trained in advance and quick response to accidents is required according to contingency plans. The system is equipped with programmable logic controllers (PLC). Two same consoles are in operation as shown in Figure 4. If one of them fails, the other is spontaneously active to make sure the system operates seamlessly. Except solidification unit, all the others in the system are arrowed to pause, shut down and restart at any time if necessary. Emergency generator equipped in the system is always ready to finish the process of solidification in case power failure occurs.

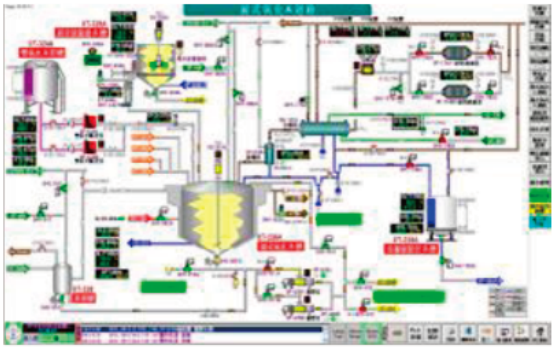

Figure 4. Human machine interface by PLC control

A preliminary test was conducted with 649 liters of fresh mixed IXR (cation/aion=1) feed to produce a solid form of 170 liters. The results are shown in Table 2. According to Table 2, the volume reduction ratio is about 3.4. The compressive strength of the solid form after 28 days of curing is 84 kg_f/cm^2. After the processes of weather and water resistance tests, the compressive strengths of the product are 94 kg_f/cm^2 and 109 kg_f/cm^2 respectively. All of the results are better than the regulatory standards of AEC of Taiwan.

Table 2. Test results of commercial system and quality of the solidified product

IXR Vol. (L)	Slurry waste		Immob. matrix (kg)	Solidified product		Compressive strength (kg_f/cm^2)		
	Vol. (L)	Wt. (kg)		Vol. (L)	Wt. (kg)	28 days	After weather resistance test	After water resistance test
649.0	170.3	252.0	108.0	191.3	360.0	84	94	109

5. CONCLUSION

The treatment of radioactive spent IXR generated from nuclear industry has long been a vexing problem. In order to achieve the goal of volume reduction and stabilization of the waste, INER has successfully developed WOHEST, which is environmentally friendly and is also a total solution to addressing the problem. WOHEST features efficiencies of greater than 60% volume reduction, low energy consumption, operating under milder conditions, undemanding maintenance, and no toxic waste created. The performance and feasibility of the process has been totally demonstrated from the results of bench and pilot tests. A commercial system of 40 L/H is currently under construction. A couple of test runs with non-radioactive surrogates support the conclusion that organic portions of ion exchange resin can be effectively decomposed into CO_2 and H_2O using wet oxidation. Combined with high efficient solidification, the final product is a stable solid waste form with good physical properties. The system is expected to begin commercial operation at the end of 2015. By substantially reducing the volume of spent resin, it makes possible to save both disposal costs and storage space.

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附件 3　NPC2014 國際水化學會議議程及內容

Program

OCTOBER 26

17:30 – 19:30 Welcome Reception — Royton Hall AB

OCTOBER 27

8:30 – 9:00 Opening Ceremony — Royton Hall CD

Chair: Yosuke Katsumura

Opening Remarks Kenkichi Ishigure
Welcome Addresses Ryoji Doi
Osamu Sakai

9:00 – 10:00 Keynote Lecture — Royton Hall CD

Chair: Yoshinori Meguro

10095 BWR and PWR Chemistry Operating Experience and Perspectives
Keith Fruzzetti, Susan Garcia, Nicole Lynch, Richard Reid

20002 The Chemistry at the Junction of the Main Stakes of the NPPs Operation
Jean-Luc Bretelle

10293 Activity of Water Chemistry Division of the Atomic Energy Society of Japan
Yosuke Katsumura

10:00 – 10:20 Coffee Break **Foyer (3rd floor)**
Sponsored by Hitachi-GE Nuclear Energy, Ltd.

10:20 – 12:00 Session I – BWR Operating Experience — Royton Hall CD

Chairs: Richard Kohlmann & Young-Jin Kim

10031 Reducing Radiation Levels at Boiling Water Reactors of a Commercial Nuclear Power Plant Fleet
Andrew Odell, Mary Jarvis

10086 Investigations into Surface Treatment Methods for Reduction of Recontamination of BWR Reactor Systems
Bernhard Stellwag, Juan de Dios Sanchez Zapata, Ashim Basu, Tomas Berasaluce, Stephan Hoffmann-Wankerl, Luis Sempere Belda

10041 **Uncommon Water Chemistry Observations in Modern Day Boiling Water Reactors**
Samson Hettiarachchi, Christoph Weber

10194 **Behavior of Shut-Down Dose Rate of Recirculation Piping of BWR under Noble Metal Application**
Motomasa Fuse, Makoto Nagase, Motohiro Aizawa, Yoichi Wada, Kazushige Ishida, Hideyuki Hosokawa, Samson Hettiarachchi, Christoph Weber

10227 **Effect of Seawater Infiltration from Main Condenser, Damaged by Break on the Reactor Facilities, Hamaoka Unit 5**
Tadashi Tsukada, Tsugitaka Egami, Yoshiaki Watanuki, Kazumi Mitani, Tetsuya Watanabe

12:00 – 13:30 Lunch Royton Hall AB

13:30 – 14:40 Special Session (Invited) – Fukushima Daiichi NPP Accident

Royton Hall CD

Chairs: Kenkichi Ishigure & Derek Lister

20003 **Current Status of Fukushima Daiichi NPS - Efforts for Decommissioning and Contaminated Water Control -**
Ryoji Doi

10287 **Current Situation of Decommissioning Work in Fukushima Daiichi Nuclear Power Station**
Sakae Muto

10174 **Latest Activities of the AESJ Investrigation Committee on the Nuclear Accident at the Fukushima Daiichi NPP**
Shunsuke Uchida, Masanori Naitoh, Hiroaki Suzuki, Hidetoshi Okada

14:40 – 15:00 Coffee Break Foyer (3rd floor)
Sponsored by Hitachi-GE Nuclear Energy, Ltd.

15:00 – 17:20 Special Session (Invited) – Fukushima Daiichi NPP Accident

Royton Hall CD

Chairs: Kenkichi Ishigure & Derek Lister

10290 **Implementation and Planning of Preventive and Multi-Layered Contaminated Water Treatment**
Tomoyuki Arai, Takeshi Takahashi

10199 **Influence of Radiolysis and Gas-Liquid Partition of I-131 in Accumulated Water on Late Phase Source Terms at Fukushima NPP Accident**
Akihide Hidaka

20004 **The TMI-2 Recovery & Cleanup**
Chuck Negin

20001 **State of Radioactive Water in the Ruined Unit 4 of Chernobyl Nuclear Power Plant and Hydro-Geological /Monitoring of Groundwater**
Victor Krasnov

10286 **An Overview of Approach to Corrosion Issues in Fukushima Daiichi Nuclear Power Station**
Yuichi Fukaya, Toshifumi Hirasaki, Katsuhiko Kumagai, Teruhisa Tatsuoka, Kenro Takamori, Shunichi Suzuki

10292 **Progress on Off-Site Cleanup Efforts in Japan**
Teruyoshi Hayamizu

Poster session
❶
17:30~19:00

OCTOBER 28

8:00 – 10:00 Session2 – PWR, VVER & CANDU/PHWR Operating Experience

Royton Hall CD

Chairs: Milan Simoncic & Takumi Terachi

10002 **The Evolution of Chemistry in PWR Nuclear Power Plants: Overview and Safety Perspectives**
Ian de Curieres

10019 **Actions Taken to Significantly Reduce Activity Levels on Primary Loop Surfaces at Loviisa NPP**
Kari Makela, Sari Jarvimaki, Roger Kvarnstrom, Minna Makinen

10211 **Zinc Injection on the EDF Pressurized Light Water Reactors: Current Results and Operating Experience Feedback**
Olivier Piana, Arnaud Duval, Edgar Moleiro, Moez Benfarah, Jean-Luc Bretelle, Guy Chaigne

10198 **Appropriate Zinc Addition Management into PWR Primary Coolant after the Plant Long-Term Maintenance**
Atsushi Hirose, Ryo Matsui, Haruki Imamura, Akira Takahashi, Yuichi Shimizu, Noritaka Kogawa, Kunitaka Nagamine

10125 **The Effects of Zinc Injection from HFT at TOMARI Unit 3**
Yamato Aizawa, Kenji Ouchi, Hitoshi Hayakawa, Satoshi Nakahama, Takao Nishimura, Ryuji Umehara, Yuichi Shimizu, Noritaka Kogawa, Zenjiro Ojima

10085 **Primary Heat Transport System Return to Service Following the Refurbishment Outage at the Point Lepreau Generating Station**
Craig Stuart, William Cook, Eric Gardner

10:00 – 10:20 Coffee Break Foyer (3rd floor)
Sponsored by Hitachi-GE Nuclear Energy, Ltd.

10:20 – 11:00 Session2 – PWR, VVER & CANDU/PHWR Operating Experience

Royton Hall CD

Chairs: Ivan Smiesko & Nobuo Ishihara

10192 **Westinghouse Fuel Performance in Modern RCS Chemistry**
Jayashri Iyer

10077 **First Steam Generator Cleanup Application with Dispersant at Doel 3**
Charles Laire, Dominique Ceursters, Steven Bosmans, Rene Delporte, Stephanie Coart, Raphael Lecocq

11:00 – 12:00 Session3 – Water Chemistry Scientific Studies

Royton Hall CD

Chairs: Susan Garcia & Jiaxin Chen

10251 **A Novel Technology for Fouling Mitigation and Dose Reduction in BWR**
Young-Jin Kim, Juan Varela

10021 **Effects of Zinc Injection on Electrochemical Corrosion and Cracking Behavior of Stainless Steels in Borated and Lithiated High Temperature Water**
Xinqiang Wu, Xiahe Liu, En-Hou Han, Wei Ke

10045 **Uptake of Co-60 on Alloy 690 and Stainless Steel Type 304L Surfaces in Simulated PWR Primary Chemistry**
Johan Oijerholm, Bernt Bengtsson, Peter Gillen, Pernilla Svanberg, Jiaxin Chen

12:00 – 13:30 Lunch Royton Hall AB

13:30 – 15:10 Session3 – Water Chemistry Scientific Studies

Royton Hall CD

Chairs: Arancha Tigeras & Katerina Vonkova

10066 **New Insights into Activity Transport within the Primary Heat Transport Systems of CANDU Reactors**
Yury Verzilov, Aamir Husain

10065 **Modelling Material and Radioactivity Transport in the Primary Circuit of CANDU Reactors**
Olga Palazhchenko, Derek Lister

10237 **New Data for Thermodynamic and Kinetic Behaviour of Nickel Phases in PWR Physicochemical Conditions**
Dominique You, Gabriel Plancque, Patrick Lovera

10142 **The OSCAR Code: Modelling and Simulation of the Corrosion Product Behaviour under Nucleate Boiling Conditions in PWRs**
Frederic Dacquait, Alexandre Ferrer, Benoit Gall, Gilles Ranchoux, Mathieu Corbineau

10146 **Electrochemical and Microstructural Characterization of Crud**
Fabio Scenini, Jonathan Duff, Nicholas Stevens, Andrea Cioncolini, Anthony Cook, Andrew Banks

Poster session
❷
15:10 – 16:40

16:40 – 18:00 Session3 – Water Chemistry Scientific Studies

Royton Hall CD

Chairs: Andy Rudge & Hirotaka Kawamura

10112 **Modeling Chemistry in PWR Fuel Crud**
Jim Henshaw, Amit Agarwal, John McGurk, Sarah Connolly, Shirley Dickinson, Dan Wells, Aylin Kucuk

10135 **Characteristics of Fuel Crud from Ringhals Unit 4 - A Comparison of Crud Samples from Ultrasonic Fuel Cleaning and Fuel Scrape**
Jiaxin Chen, Chuck Marks, Bernt Bengtsson, John Dingee, Daniel Wells, Jonas Eskhult

10207 **Capacity of Ammonia, ETA, and MPA on Corrosion Inhibition and Delay of Carbon Steel in PWR Secondary Condition**
In Hyoung Rhee, Hyunjun Jung, Young In Kim

10124 **Reactor Coolant Cleanup Optimization**
Joel McElrath, Daniel Wells, Al Jarvis, David Morey

OCTOBER 29

8:00 – 10:00 Session4
– Secondary Water Chemistry (Steam Cycle)

Royton Hall CD

Chairs: Shunsuke Uchida & In Hyoung Rhee

10058 **The Effect of Polyacrylic Acid on Iron Oxides Formed on Steam Generator Tubes and on Metallic Copper Present in Pressurized Water Reactors**
Marion Roy, Carine Mansour, Dominique You

10120 **Hard Sludge and Denting in the Secondary Side of PWR Steam Generators**
Rocio Fernandez Saavedra, Marta Fernandez Diaz, Maria Belen Gomez Mancebo, Gonzalo de Diego, Alberto Jose Quejido Cabezas, Maria Dolores Gomez Briceno

10273 **Secondary System Return to Service Following the Refurbishment Outage at the Point Lepreau Generating Station**
William Cook, Eric Gardner, Jason Lee, Craig Stuart

10137 **PWR Steam Generator Tube Denting at Top of Tubesheet**
Samuel Choi, Chuck Marks, Ryan Wolfe

10255 **Impacts of WWER Power Increase on Horizontal Steam Generators**
Roman Krautschneider, Lukas Joch

10039 **Study of Corrosion Resistance and Semiconductor Properties for the Passive Film of Nuclear Grade Stainless Steel Welding Joint**
Xin Changsheng, Wang Hui, Hai Zhengyin, Hu Yong

10:00 – 10:20 Coffee Break Foyer (3rd floor)
Sponsored by Mitsubishi Heavy Industries, Ltd.

10:20 – 12:00 Session5
– Life Time Management and Plant Aging

Royton Hall CD

Chairs: Bernt Bengtsson & Tsung-Kuang Yeh

10291 **The IAEA Activities on Plant Life Management and Ageing Management**
Keeyoung Kim, Ki-Sig Kang

10084 **Concept Study of Steam-Water Cycle Sampling System Modernization at NPP Borssele**
Andreas Drexler, Niels van Dijke, Manuel Sigrist

10181 **Role of Cavity Formation in SCC of Cold-worked Alloy 690 in High-Temperature Water**
Takuyo Yamada, Masanori Aoki, Tomoki Miyamoto, Koji Arioka

10128 **A Comprehensive Investigation of the Platinum Application to BWRs to Mitigate Stress Corrosion Cracking**
Pascal Grundler, Lyubomira Veleva, Amuthan Ramar, Stefan Ritter

10036 **System Safety Analysis of Aging NPPs Based on Probabilistic Risk Evaluation of Flow-Accelerated Corrosion**
Hidetoshi Okada, Shunsuke Uchida, Masanori Naitoh, Hiroaki Suzuki, Seiichi Koshizuka, Derek Lister

12:00 – 13:30 Lunch Royton Hall AB

13:30 – 15:30 Session6 – Chemistry and Fuel Performance

Royton Hall CD

Chairs: Jim Henshaw & Jayashri Iyer

10131 **Impact of Long Term Injection of Platinum (HWC/OLNC) on Water Chemistry, Crud Behavior and Platinum Deposition**
Lena Oliver, Britta Helmersson, Peter Cronstrand, Guido Ledergerber, Aylin Kucuk

10001 **AREVA M5™: A Zirconium Alloy Highly Resistant to Detrimental Water Impurities**
Pierre Guillermier, Damien Kaczorowski, Delphine Perche, Charles Brussieux

10159 **Studies on ZIRCALOY-4 Cladding Corrosion in the Halden Reactor**
Peter Bennett, Reka Szoke

10152 **Study for Nickel Deposition on the Fuel Cladding by DH transition under Simulated PWR Conditions**
Yuichi Shimizu, Takao Nishimura, Ryuji Umehara, Noritaka Kogawa, Zenjiro Ojima, Kunitaka Nagamine, Masashi Suzuki

10075 **Effect of Concentration Ratios of Ni/Fe Ions on the Fuel Crud Deposition**
Do Haeng Hur, Seung-Heon Baek, Hee-Sang Shim, Kyung Soo Im, Uh Chul Kim

10212 **Ukraine's WWER-1000 Primary Coolant Chemistry Optimization**
Mykhaylo Tretyakov, Volodymyr Krasnorutskyy, Viktor Grytsyna, Valeriy Zuyok, Roman Rud, Ivan Petelguzov

15:30 – 15:50 Coffee Break Foyer(3rd floor)
Sponsored by Mitsubishi Heavy Industries, Ltd.

15:50 – 17:50 Session7 – Chemistry Optimization Programs and Compliance Management

Royton Hall CD

Chairs: Keith Fruzzetti & Jean-Luc Bretelle

10006 **Recent Advances in BWR Water Chemistry**
Susan Garcia, Nicole Lynch, Joseph Giannelli, Mary Jarvis, Alfred Jarvis

10203 **Chemistry Evaluation in French EDF Nuclear Power Plants**
Herve Jacquier

10171 **Current Status of Regulatory Aspects Relating to Water Chemistry in Japanese NPPs**
Masatoshi Sato

10179 **BWR Water Chemistry Guidelines in Japan**
Hideo Hirano, Naoshi Usui, Hideaki Kitajima, Hirotaka Kawamura, Yuki Fukabori, Junichi Suzuki, Norio Kawai, Tsunaki Yamaguchi, Satoshi Uemura, Satoshi Onodera, Kenji Hisamune, Yutaka Ueyama, Hidehiro Urata

10155 **Primary Water Chemistry Guidelines for Japanese PWR Plants**
Hirotaka Kawamura, Yasuhiko Shoda, Yasuo Tsuzuki, Hideo Hirano, Yoshihumi Watanabe, Kotaro Takeda, Takumi Terachi, Nobuaki Ishihara, Akira Takahashi, Kenji Hisamune, Yusuke Nakano, Takao Nishimura

Poster Award
19:00 – 19:20
Royton Hall AB

19:20 – 21:30 Reception & Banquet Royton Hall AB
Sponsored by Dow Chemical Japan Ltd.

10:20 – 12:00 Special Session – Fukushima Daiichi NPP Accident

Empress Hall

Chairs: Chuck Negin & Junichi Takagi

10215 **Study on the Radioactive Wastewater Treatment System for Fukushima Daiichi Nuclear Power Station (II) Sr Adsorption Characteristics on Zeolite**
Takatoshi Hijikata, Kenta Inagaki, Takeshi Tsukada, Tadafumi Koyama, Eiji Ishizaki, Minoru Matsukura

20005 **TMI-2 Cleanup Operations**
Chuck Negin

10092 **Predicting Ion Exchange Resins Decontamination Factors - Experiments on Synthetic Primary Coolant Containing Ni, Co and Ag and Modeling Results**
Martin Bachet, Loic Jauberty, Laurent De Windt, Etienne Tevissen, Caroline de Dieuleveut, Helene Schneider

10197 **Application of Phenol-Based Ion-Exchange Resin for Radioactive Cesium Removal from Contaminated Seawater**
Kenta Mino, Wataru Sugino, Kenji Hisamune, Yoshinori Meguro, Shintaro Tsuzuki, Katsuya Takuwa

10229 **Development of the Radioactive Cesium Decontamination Technology from Radioactive Fly Ash**
Keita Takakura, Tsuguyuki Kobayashi, Hideki Nakamura, Hisao Oomura, Shinichi Makino

12:00 – 13:30 Lunch Royton Hall AB

13:30 – 15:30 Special Session – Fukushima Daiichi NPP Accident

Empress Hall

Chairs: Shirley Dickinson & Ryuji Nagaishi

10043 **Effect of Oxygen on Radiolytic Hydrogen Production from X-Type Zeolite-Water Mixtures**
Yuta Kumagai, Atsushi Kimura, Mitsumasa Taguchi

10165 **Effects of Seawater Components on Radiolysis of Water at Elevated Temperature**
Yoichi Wada, Masahiko Tachibana, Kazushige Ishida, Nobuyuki Ota, Naoto Shigenaka, Hiromitsu Inagaki, Hiroshi Noda

10242 **Consideration of Radiolytic Behavior in Diluted and Concentrated Systems of Seawater for Computational Simulation of Hydrogen Generation**
Ryuji Nagaishi, Masao Inoue, Ryutaro Hino, Toru Ogawa

10030 **Nordic Owners Group Study on Radiolysis Gas Management Post-Fukushima**
Jorgen Finne, Peter Cronstrand, Ylva-Li Lindh, Frida Karlen, Erik Slobe, Richard Faxen, Ingemar Jansson, William Eek, Hakan Wennerstrom

10100 **Iodine Chemistry in Nuclear Reactor Accident Conditions: Recent Studies and Hypotheses**
Shirley Dickinson, Ari Auvinen, Loic Bosland, Dana Powers, Glenn Glowa, Beatrice Teisseive, Sabrina Tietze

10240 **Effects of Environmental Factors on Oxidation of Iodide under 254 nm Ultra-Violate Irradiation**
Jei-Won Yeon, Sang-Hyuk Jung, Sue Young Hong, Kyuseok Song

15:30 – 15:50 Coffee Break Foyer (3rd floor)
Sponsored by Mitsubishi Heavy Industries, Ltd.

15:50 – 17:10 Special Session – Fukushima Daiichi NPP Accident

Empress Hall

Chairs: Martin Bachet & Motohiro Aizawa

10254 **Application of Nanofiltration to Separate Strontium from Seawater**
Yusuke Shinoda, Yasushi Maeda, Shintaro Tsuzuki, Supriyo Das, Elbir Jove, Scott Beardsley, Garth Parker, Steven Rosenberg

10245 **An Electro-de-Ionization Device for the Continuous Measurement of the Conductivity after a Cation Exchanger**
Heini Maurer, Martin Aicher

10184 **Lay up Practices at EDF PWR Fleet and Future Developments**
Olga Alos Ramos, Sergio De Maria Pablo, Matthieu Wintergerst, Alexandra Postic, Jean-Pierre Courtaudiere, Christian Fournier, Robin Vialette, Jacques Waeber, Didier Couturier, Philippe Robillart

10190 **Reverse Osmosis and its Use at the Nuclear Power Plants-Purification of Primary Circuit Coolant by the Means of Reverse Osmosis**
Katerina Vonkova, Pavel Kus, Katerina Kunesova, Sarka Bartova, Martin Skala, Tomas Moucha

Poster Award
19:00 – 19:20
Royton Hall AB

19:20 – 21:30 Reception & Banquet Royton Hall AB
Sponsored by Dow Chemical Japan Ltd.

OCTOBER 30

8:20 – 10:00 Session8 – Maintenance

Royton Hall CD

Chairs: Bernhard Stellwag & Hideki Takiguchi

10214 **Study on the Radioactive Wastewater Treatment System for Fukushima Daiichi Nuclear Power Station (I) Cs Adsorption Characteristics on Sorbent**
Takeshi Tsukada, Takatoshi Hijikata, Kenta Inagaki, Tadafumi Koyama, Eiji Ishizaki, Minoru Matsukura

10272 **Recent Decontamination Experiences in BWRs and the Effect of Operational Water Chemistry on the Decontamination Application**
Ashim Basu, Johan Lejon, Monika Mattsson

10233 **Sorbents for Effective Removal of Radioactive Antimony during Chemical Decontamination**
Padala Abdul Nishad, Anupkumar Bhaskarapillai, Sankaralingam Velmurugan

10083 **Electrochemical Decontamination Methods Applied at Paks Nuclear Power Plant in Hungary**
Pal Baradlai, Norbert Kosa, Gabor Patek, Janos Schunk, Zoltan Laszlo, Karoly Nyitrai

10129 **Hard Sludge Formation in Modern Steam Generators of Nuclear Power Plants -Formation, Risks and Mitigation**
Franz Strohmer

10:00 – 10:20 Coffee Break Foyer (3rd floor)

10:20 – 12:00 Session8 – Maintenance

Royton Hall CD

Chairs: Kari Makela & Damien Feron

10104 **ASCA Applications: 2014 Experience Update**
Michael Little, Anisa McCree, Robert Varrin, Aaron Pellman, Marc Kreider

10178 **Research of the Extended Layup on the Secondary Side in Japanese PWR Plants**
Takumi Terachi, Nobuo Ishihara, Yasuhiko Shoda, Nobuo Nakano, Yusuke Nakano, Tatsuya Satou, Shunsuke Yagi, Tooru Morisaki, Akira Takahashi

10081 **Model Corrosion Investigations of the Material Used in the Steam Generators of NPP Energy Blocks**
Nikolai Boshkova, Neil Boshkova, Vasil Bachvarov, Miglena Peshova, Ludmil Lutov

10018 **On Performance Capabilities of Alkaline Anolyte in Wastewater Management**
Alexander Shimkevich

10170 **Development of an Electro-Plating Process for Retrieving ^{60}Co Removed from Radioactive Spent Ion Exchange Resins**
Shingo Miyamoto, Mamoru Iwasaki, Mami Hirose, Motohiro Aizawa, Nobuyuki Ota, Kazushige Ishida

12:00 – 13:30 Lunch Foyer (3rd floor)

13:30 – 14:50 Session9 – Auxiliary Systems, Water and Waste Treatment System

Royton Hall CD

Chairs: Irene Mailand & Shinichi Ohashi

10038 **Development of Wet-Oxidation and Solidification System for Treatment of Spent Radioactive Ion-Exchange Resin**
Yih-Ping Chen, Chao-Rui Chen, Tzeng-Ming Liu

10235 **EDF Operational Experience of Primary Circuit Filter Usage: Analysis of Results and Strategy for Optimizing Filtration and Reducing Solid Wastes**
Darren Mascarenhas, Edgar Moleiro, Estelle Bancelin, Jean-Luc Bretelle

10262 **Theoretical-Experimental Investigations into the Behaviour of Catalyst, Silica Gel and Activated Carbon in the GWTS System for Flamanville3 EPR**
Arancha Tigeras, Nicolas Arias, Samuel Barret, Donato Aquaro, Francesca Annunzi

10236 **Electron Beam Irradiation on Cation Exchanger Used for Strontium Recovery**
Sou Watanabe, Masahiro Nakamura, Kazunori Nomura, Yasuo Nakajima, Yoshihiro Okamoto

14:50 – 15:10 Coffee Break Foyer (3rd floor)

15:10 – 16:30 Session10 – Future Trend and New Development / Scientific Basis

Royton Hall CD

Chairs: William Cook & Yutaka Watanabe

10027 **Development of High Temperature Reference Electrodes for Potentiometric Analyses in Supercritical Water Environments**
Tsung-Kuang Yeh, Yu-Ming Tung, Mei-Ya Wang

10068 **PWR Primary System Chemistry Control during Hot Functional Testing**
Richard Reid, Michael Little

10154 **Deposition Behavior of TiO_2 on Fuel Cladding Surface in Boiling Water under Simulated BWR Operating Conditions**
Koji Negishi, Osamu Shibasaki, Masato Okamura, Seiji Yamamoto, Junichi Takagi

10276 **Multi-Scale Multi-Physics Computational Chemistry Simulation Based on Ultra-Accelerated Quantum Chemical Molecular Dynamics Method for Structural Materials in Boiling Water Reactor**
Akira Miyamoto, Etsuko Sato, Ryo Sato, Kenji Inaba, Nozomu Hatakeyama

16:30 – 17:00 Closing Ceremony

Royton Hall CD

Announcement of NPC 2016 Andy Rudge
Closing Remarks Yosuke katsumura

Poster session ❶
October 27

Sponsored by Toshiba Corporation

Chairs: Hideo Hirano, Makoto Nagase, Motomasa Fuse, Seiji Yamamoto

17:30 – 19:00 Poster I Foyer (3rd Floor)

10008 **EPRI BWR Water Chemistry Guidelines Revision**
Susan Garcia, Joseph Giannelli

10009 **BWR Zinc Addition Sourcebook**
Susan Garcia, Alfred Jarvis, Joseph Giannelli

10010 **Approaches to Enhancing Early Hydrogen Water Chemistry for IGSCC Mitigation During BWR Startups**
Susan Garcia, Andrew Odell, Joseph Giannelli, James Tangen

10011 **Mitigation Performance Indicator for Boiling Water Reactors**
Susan Garcia, Joseph Giannelli, Mary Jarvis

10012 **Boiling Water Reactor Shutdown Dose Rate Experience after On-Line NobleChem™**
Susan Garcia, Joseph Giannelli, Mary Jarvis

10013 **BWR Shutdown and Startup Chemistry Experience and Application Sourcebook**
Susan Garcia, Joseph Giannelli, Alfred Jarvis

10025 **Cobalt Sequestration Resin Plant Demonstration Experience in BWRS**
Susan Garcia, Paul Frattini, Andrew Odell, Michelle Mura, Joseph Giannelli

10099 **Modeling of Platinum Deposition on BWR Surfaces During On-Line Noblechem™**
Susan Garcia, Jim Henshaw, Joseph Giannelli

10109 **Measures to Reduce the Generation of LCW Spent Resin at the Shika Nuclear Power Station**
Daigo Hatake, Takeshi Saito, Hideyuki Takashima

10176 **Initiatives to Reduce the Occupational Radiation Exposure of ABWR Plants**
Hajime Hirasawa, Hidehiro Urata, Taku Ueda, Seiji Yamamoto, Yumi Yaita

10239 **Application of the Hi-F Coat to the Shimane Nuclear Power Station**
Satoshi Uemura, Tadashi Kanaoka, Hiroyasu Kajitani, Makoto Nagase, Satoshi Ouchi

10265 **Update on the Use of Dissolved Oxygen Addition to Monitor the Effectiveness of Noble Metal Applications in External Manifolds**
Juan Varela, Hubert Huie, Andrew Odell, Russell Seeman, Carl Bourne

10275 **The Planning of NMCA Application and ECP Monitoring in Tokai-2**
Katsuhiko Kato, Yutaka Ueyama, Takehiko Takahashi, Kenji Hisamune

10295 **Noble Metals Sampling Experience**
Richard Kohlmann, Alan Drehmel

17:30 – 19:00 Poster3 (BWR) Foyer (3rd Floor)

10005 **Circulating Crud Characterization in Condensate System of Boiling Water Reactors at NWC/HWC Environments**
Tung-Jen Wen, Yu-Hung Shih, Charles Fang Chu, Sze Chieh Shen

10028 **An Investigation into Stress Corrosion Cracking Susceptibility of 304 Stainless Steel in Simulated Boiling Water Reactor Start-Up Environments**
You-Wen Chiou, Tsung-Kuang Yeh, Mei-Ya Wang

10029 **An Investigation into the Electrochemical Behavior of Hydrogen Peroxide on TiO_2 Treated Type 304 Stainless Steels in High Temperature Water**
Tsung-Han Li, Tsung-Kuang Yeh, Mei-Ya Wang

10102 **The Influences of ECP and Metal Dopants on Radiation Field Build-Up on Stainless Steel Surfaces**
Charlotta Obitz, Johan Lejon, Margareta Tanse Larsson, Jimmy Hagg, Arne Johansson, Jiaxin Chen

10136 **Identification of Chromium Oxides and Other Solids in BWR Reactor Water**
Jiaxin Chen, Petter Andersson, Fredrik Lindberg, Johan Lejon, Jimmy Hagg, Margareta Tanse-Larsson, Charlotte Lager, Charlotta Obitz

10139 **On The Interation of Injected Zinc with Oxide Films Formed on Stainless Steel under Cyclic Oxidising and Reducing Conditions**
Jiaxin Chen, Charlotta Obitz, Fredrik Lindberg, Johan Lejon, Jimmy Hagg, Margareta Tanse-Larsson, Arne Johansson

10162 **Evaluation of Silica Behavior for Reducing the Precoating Frequency of the Reactor Water Cleanup System of the Hamaoka NPS**
Miyuki Ito, Hiromitsu Inagaki, Toshio Kuzuya

10166 **Development of a Suppression Method for Deposition of Radioactive Cobalt by a Platinum Deposition Treatment after Chemical Decontamination**
Hideyuki Hosokawa, Tsuyoshi Ito, Makoto Nagase, Motohiro Aizawa, Motomasa Fuse

10168 **The Effect of Chloride Ion on the Iron Elution from Carbon Steel in High Temperature Water**
Masato Okamura, Taku Ueda, Seiji Yamamoto, Hiromitsu Inagaki, Takehiko Minamikawa

10218 **"Radiation-Induced Electrolysis" - A Potential Root Cause Of Hydrogen Explosions In The Fukushima Daiichi Accident -**
Genn Saji

10219 **Development of Evaluation Tool for Radiation Dose Rate Distribution in PCV of Hamaoka BWR Plants based on Water Chemistry**
Hiromitsu Inagaki, Toshio Kuzuya

10246 **Effect of Gadolinium Nitrate Concentration on the Corrosion Compatibility of Structural Materials in a Proposed Indian Tube Type Boiling Reactor**
Sinu Chandran, Puspalata Rajesh, Debasis Mal, Rangarajan Srinivasan, Shaju K. Albert, Velmurugan Sankaralingam

17:30 – 19:00 Poster5 Foyer (3rd Floor)

10016 **The Corrosion Model of Zirconium Alloys in the Water Coolant**
Irina Berezina, Vladimir Kritsky, Elizaveta Motkova

10032 **Boiling Water Reactor Vessel INternals Project (BWRVIP) - Continuing a Proactive Approach for Managing Degradation**
Andrew Odell, Andrew McGehee, Raj Pathania, Robert Carter, Robin Dyle

10060 **Zirconia Membrane ECP Electrode for Water Chemistry Experiments in the JMTR**
Satoshi Hanawa, Kuniki Hata, Akira Shibata, Yasuhiro Chimi, Shigeki Kasahara, Nobuyuki Tsutsui, Akihiro Iwase, Yutaka Nishiyama

10063 **Impact of Iron Oxide Deposition on seal #1 of Reactor Coolant Pump**
Ingrid Sellier, Gregory Lefevre, Bruna Martin-cabanas, Jean-Luc Riviere, Carole Monchy-leroy

10093 **Cleanliness Requirements in Nuclear Power Plants: Revision of German Standards DIN 24510 and DIN 25493**
Andreas Drexler, Janine Winkler, Steffen Weiss

10144 **Laboratory Investigations on the Corrosion Rate of A42 Carbon Steel in Various Secondary Circuit Chemistries Representative of Hydraulic Tests Conditions**
Charles Brussieux, Olga Alos-Ramos, M.H Clinard, Michael Guillodo

10182 **The Study of Cavity Formation in SCC of Cold Worked Carbon Steel in High-Temperature Water**
Masanori Aoki, Takuyo Yamada, Tomoki Miyamoto, Koji Arioka

10209 **Effect of Liquid Film Velocity and Thickness on Thinning Rate of Flow Accelerated Corrosion under Water-Steam Two-Phase Flow**
Masaaki Satake, Kimitoshi Yoneda, Ryo Morita, Kazutoshi Fujiwara, Fumio Inada

10228 **Quality Assurance Program Applied in European NPPs to Minimize Corrosion Risks Induced by Auxiliary Products**
Andreas Drexler

10266 **Characterization of the Oxide Film Formed in the Flow-Accelerated Corrosion of Carbon Steels**
Takuma Yano, Hiroshi Abe, Takamichi Miyazaki, Yutaka Watanabe, Kazutoshi Fujiwara, Fumio Inada

17:30 – 19:00 Poster8 Foyer (3rd Floor)

10003 **Corrosion Evaluation of Structural Materials during Chemical Cleaning of Steam Generator Tubing in the Secondary System**
Clinton Fong, Yi-Ching Lee, Meng-Jen Chen

10098 **Fouling of Steam Generator Tubes in Nuclear Power Plants: Laboratory Tests to Reproduce Oxides Deposition and Chemical Cleanings**
Christophe Goujon, Carine Mansour

10105 **Steam Generator Cleaning Experience at Korean PWRs: 2014 Experience Update**
In-Ho Hwang, Young-Bok Kang, Man-Gil Lee, Robert Varrin, Michael Little, Peter Krull

10110 **Development of Advanced Electrodes for Corrosion Monitoring in Nuclear Power Plants**
Hee Kwon Ku, Dong Seok Lim, Jae Seon Cho

10141 **Effect of Electrochemical Corrosion Potential on ^{60}Co Deposition on Corrosion Oxide Formed under Boiling Water Reactor Conditions**
Tsuyoshi Ito, Hideyuki Hosokawa, Toru Kawasaki, Makoto Nagase, Motohiro Aizawa, Motomasa Fuse

10234 **Material Compatibility during Removal of Antimony by Oxidative Process Using Hydrogen Peroxide**
Chandramohan Palogi, Rufus A.L, Srinivasan M.P, Velmurugan Sankaralingam

17:30 – 19:00 Poster9

Foyer (3rd Floor)

10004 **Replacement of Hydrazine in Closed Cooling Systems Using 3-Step Treatment System**
Jimmy Hagg, Pernilla Svanberg, Jenny Rouden, Stjepan Jagunic, Thomas Cole

10007 **Cesium Separation Using Integrated Electro-Membrane Technique**
Partik Fors, Anna Velin, Christina LillforsPinter, Bernt Bengtsson, Henrik Widestrand

10026 **Preparation of Titanium Doped Sodium Niobium Oxide for the Removal of Radionuclides in Wastewater**
Chi-Hung Liao, Kuang-Li Chien, Sheng-Wei Chiang, Shih-Che Huang, Kou-Ming Lin, Jen-Chren Chung

10061 **Effects of Spilled Chemicals on Fouling, Heat Transfer and Corrosion in the Cooling Water Systems of NPPs**
Essi Velin, Saija Vaisanen, Johanna Lukin, Timo Saario

10089 **Crud Removal by Ion Exchange Resin DIAION HPAN10 and its Mechanisms**
Ryosuke Tsuhara, Takashi Goda, Izuru Tokumaru, Katsuhiko Yano

10091 **Application of Mixed Bed Ion Exchange Resins with High Durability for Condensate Polishing in Air-Cooled Ultra-supercritical Pressure Steam Power Plants**
Izuru Tokumaru, Huanfang Li

10108 **The Study of Radioactive Organic Wastewater Treatment of INER**
Chin-Chang Shen, Chao-Rui Chen, Jen-Chren Chung

10115 **Chemical Effects on Sump Strainer Clogging Under Post-Accident Conditions: Review on ANL Testing**
Chi Bum Bahn

10122 **Closed Cooling Water Chemistry Guidelines Revision**
Joel McElrath, Richard Breckenridge

10123 **Open Cooling Water Chemistry Guidelines**
Joel McElrath, Richard Breckenridge

10147 **Purification of Liquid Radwaste Using Hollow Fiber Membrane Cross Flow Filtration at Ringhals NPP**
Khaled El Tayara, Henrik Widestrand, Bernt Bengtsson, Patrik Fors, Carl-Henrik Hansson, Anders Hoglund

10150 **Thermodynamic Data for the Assessment of SG Blowdown Demineralizers Performance**
Jacques Ly, Delphine Hainos, Virginie Blin, Bruna Martin-Cabanas, Carine Mansour

10167 **New System Applying Image Processor to Automatically Separate Cation Exchange Resin and Anion Exchange Resin for Condensate Demineralizer**
Tsuneyasu Adachi, Nobuaki Nagao, Yasuhide Yoshimori, Takashi Inoue, Shuji Yoda

10175 **Development of Decomposition Method of Hydrogen Peroxide in Spent Fuel Pool**
Tatsuya Deguchi, Takeshi Izumi, Makoto Komatsu, Daisuke Akutagawa, Takeshi Manabe, Yusuke Nakano

10222 **Change of Cation-Exchange Resin by Heat in a Simulated Pressurized Water Reactor Environment**
Kotaro Nakata, Michihiko Hironaga

10243 **Basic Study on Radiation Degradation of Potassium Nickel Ferrocyanide**
Yoichi Arai, Sou Watanabe, Youko Takahatake, Masahiro Nakamura, Yasuo Nakajima

10248 **Conditioning Alkaline Coolant Radioactive Waste from Research Reactor BR-10**
Kirill Butov, Vladimir Smykov, Mikhail Kononyuk

17:30 – 19:00 Poster (Special) — Foyer (3rd Floor)

10035 **Evaluation of Short- and Long-Term Fission Product Sources at the Fukushima Daiichi NPP**
Shunsuke Uchida, Masanori Naitoh, Hiroaki Suzuki, Hidetoshi Okada, Marco Pellegrine, Andrea Achilli, Yokio Manamoto, Hiroaki Sasaki

10059 **Post-Severe Nuclear Accident Chemical Water and Surface Clean-Up Methods for LWRs to Reduce the Amounts of Highly Contaminated Waste Water**
Sabrina Tietze, Mark Foreman

10076 **Safety Regulations Regarding to Accident Monitoring and Accident Sampling at Russian NPPs with VVER Type Reactors**
Nataliya Kharitonova, Rachet Sharafutdinov, Michail Lankin

10107 **Effects of Dissolved Species on Radiolysis of Diluted Seawater**
Kuniki Hata, Satoshi Hanawa, Shigeki Kasahara, Takafumi Motooka, Takashi Tsukada, Yusa Muroya, Shinichi Yamashita, Yosuke Katsumura

10140 **Corrosion of the Stainless Steel in the Zeolite Containing Diluted Artificial Seawater under Gamma-Ray Irradiation**
chiaki kato, Tomonori Satoh, Junichi Nakano, Fumiyoshi Ueno, Isao Yamagishi

10143 **Development of the Granular Adsorbent Manufactured by Titanate which can Adsorb Sr Selectively in Aqueous Solution with High Salinity**
Koichi Mori, Mamoru Iwasaki, Hitoshi Kanda, Yuichi Niibori, Hitoshi Mimura

10163 **Seawater Immersion Tests of Irradiated Zircaloy-2 Cladding Tube**
Yoshihiro Sekio, Ichiro Yamagata, Shinichiro Yamashita, Masaki Inoue, Koji Maeda

10169 **Corrosion Resistance of Tank Material for Flock Storage in the Fukushima Daiich Nuclear Power Plant**
Yuichi Sano, Hiromu Anbai, Masayuki Takeuchi, Hideki Ogino, Kenji Koizumi

10172 **Chemical Composition of Artificial Seawater after Leaching Tests of Irradiated Fuel**
Takashi Onishi

10173 **Corrosion of Uranium and Plutonium Dioxides in Aqueous Solutions**
Haruyoshi Otobe, Yoshihiro Kitatsuji, Masaki Kurata, Masahide Takano

10193 **Effect of Oxide Film Formed During Gamma-Ray Irradiation on Pitting Corrosion of Fuel Cladding in Water Containing Sea Salts**
Takafumi Motooka, Takashi Tsukada

10213 **JAEA's Research on the Effects of Seawater and Radiation on Corrosion of Zircaloy and PCV/RPV Steels.**
Takashi Tsukada, Takafumi Motooka, Junnichi Nakano

10224 **Revaluation of Hydrogen Generation by Water Radiolysis in SDS Vessels at TMI-2 Accident**
Ryuji Nagaishi, Keisuke Morita, Isao Yamagishi, Ryutaro Hino, Toru Ogawa

10230 **Removal of the Radioactive Materials from the Trench Submergence in Fukushima**
Takeshi Okita, Akira Ikeda, Hisao Oomura, Chiaki Kojima, Keiji Nozawa

10238 **Desalination Processes for Spent Fuel Pools of Fukushima Daiichi Nuclear Power Plant**
Toru Kawasaki, Masao Kataoka, Motohiro Aizawa

10241 **Contaminated Water Purification by Simultaneous Adsorption of Cs and Sr**
Yuko Kani, Takashi Asano, Shin Tamata

10267 **Effect of Non-Halide Anions on Repassivation of Crevice Corrosion on the Austenitic Stainless Steel**
Tomohiro Sekiguchi, Yutaka Watanabe, Hiroshi Abe

10269 **Change in Corrosion Potential of SUS304 in Natural River Water**
Masahiro Yamamoto, Hideki Katayama, Yomonori Satoh, Takashi Tsukada

10271 **Calculation for the Water Chemistry Condition in the Spent Fuel Pool in Fukushima-Daiichi Nuclear Power Station**
Tomonori Satoh, Takafumi Motooka, Kuniki Hata, Masahiro Yamamoto, Takashi Tsukada

10284 **Development of the Multi Radio-Nuclide Removal System to Reduce the Contaminated Water at Fukushima-Daiichi Nuclear Power Station**
Hidehiro Urata, Teruki Fukumatsu, Hiroyuki Arai, Hidechika Nagayama, Kei Kobayashi

10285 **Estimation of the Cesium Concentration in Spent Zeolite Vessels**
Keisuke Morita, Isao Yamagishi, Kenji Nishihara, Yasuhiro Tsubata

20000 **Sorption-Coagulation Treatment of Liquid Radioactive Waste with Complex Composition by Using New Inorganic Coagulants and Sorbents**
Victor Krasnov

Poster session ❷
October 28

Chairs: Hideki Takiguchi, Junichi Takagi, Motohiro Aizawa, Yoichi Wada

15:10 – 16:40 Poster2 — Foyer (3rd Floor)

10014 **A Radiochemical Tracer for the Determination of the Silver Release Source in the PWR Primary Coolant**
Moez Benfarah, Benoit Picaud

10015 **PWR 440 Water Chemistry Optimizatin to Reduce AOA Effect**
Anton Gavrilov, Vladimir Kritsky, Yuri Rodionov, Irina Berezina

10042 **Experience in Performing the Commissioning Procedures for Meeting the Requirements of Water Chemistry at NPP with VVER**
Sergey Susakin, Sergey Brykov

10044 **Precipitation of Iron Species on the Cold Side of PWR Steam Generator and its Possible Correlation to Dose Rate Elevation**
Bernt Bengtsson, Jiaxin Chen, Petter Andersson

10073 **Influence of the S/N Ratio on the Corrosion Release of Alloy 690 Tubes in a Primary Coolant**
Hee-Sang Shim, Myung Sik Choi, Tack-Sang Choi, One Yoo, Kyung Mo Kim, Myung Ji Seo, Do Haeng Hur

10087 **Hot Functional Testing of the Pressurized Heavy Water Reactor Plant Atucha II with Light Water**
Bernhard Stellwag, Andreas Drexler, Jorge Duca, Pedro Friebe, German Grasso, Miguel Ormando, Guillermo Galarza, Betina Schonbrod, Mauricio Chocron, ,

10090 **Dispersant Application - Significant Operating Experience and Status**
Keith Fruzzetti, Marc Kreider, Iain Duncanson, Stephen Sawochka, Dave Morey

10116 **Optimal Resin Operation in Primary System Demineralizers at Ikata Nuclear Power Station**
Yutaka Fujimoto

10126 **The Improvement for PWR Secondary System Integrity at Tomari Unit 3 Commercial Operation from 2009**
Keisuke Sasaki, Hitoshi Hayakawa, Satoshi Nakahama, Yamato Aizawa, Yasuhiko Shoda, Katsuhiko Yamakami, Kazutoyo Murata, Masato Kanedome

10127 **Results of Work Radiation Control Based on Dose Reduction Effect Caused by Zinc Injection at Tomari NPS Unit 3**
Satoshi Watanabe, Yuki Nakagawa, Akira Sasaki, Shigeki Matsuda, Ryoma Watari

10130 **Application of BAT Assessments for Sampling and Monitoring Techniques in the UK EPR**
Erwan du Fou de Kerdaniel, Julie Colin, Florian Moyano, Audrey Ardon

10153 **Dose Rate Determining Factors of PWR Primary Water**
Takumi Terachi, Toshiharu Kuge, Nobuo Nakano, Kazunori Yamaguchi, Tomokazu Nakagawa, Masakazu Murashita, Tetsuya Tanabe, Takuya Okada, Fumiaki Iwaki, Kazufumi Sakata, Takao Nishimura, Ryuji Umehara, Yuichi Shimizu

10157 **Effect of Surface Stress State on Dissolution Property of Alloy 690 in Simulated Primary Water Condition**
Kyung Mo Kim, Hee-Sang Shim, Eun Hee Lee, Myung Ji Seo, Jung Ho Han, Do Haeng Hur

10187 **Primary Shutdown Chemistry Guidelines for EDF PWRs: A New Approach for Better Results**
Arnaud Duval, Patrice Varry, Jean-Luc Bretelle, Edgar Moleiro, Damien Deforge, Moez Benfarah

10225 **Sulphate Issues and Learning for Secondary Loop System at Dayabay Nuclear Power Plant**
Changchun Wang, Jun Fang, Xuehong Yao, Yanhong He, Bin Chen

10253 **Investigation of 08Ch18N10T (AISI321) Stainless Steel Corrosion Behavior in SG Crevice Environment**
Ivan Smiesko, Marek Postler, Dalibor Karnik, Martin Krondak

15:10 – 16:40 Poster3 (PWR)

Foyer (3rd Floor)

10050 **Effect of Dissolved Hydrogen on Corrosion Behavior of Ni-Base Alloy in High-Temperature Water**
Eun-Hee Lee, Kyung-Mo Kim, Hee-Sang Shim, Deok-Hyun Lee, Do-Haeng Hur

10055 **Influence of n,γ-field Fluctuations on Critical Hydrogen Concentration in the Reactor Primary Coolant**
Oleg Arkhipov, Sergey Kabakchi

10057 **Study on the Impact of the Criteria to Take Offline the Last Reactor Coolant Pump**
Priscilla Mondit, Julien Bonnefon, Serge Blond, Christelle Dinse

10062 **Colloids in PWR Primary and Secondary Coolant Innovative Analytical Methods**
Karsten Nowotka, Carsten Burchardt, Roland Geier, Robert Lehr, Michael Guillodo, Bernhard Stellwag

10069 **Modelling of the Local Chemistry in Stagnant Areas in the PWR Primary Circuit**
Richard Reid, Keith Fruzzetti, Kawaljit Ahluwalia, Alexander Summe, Cecile Dame, Kyle Schmitt

10072 **Effect of Zinc on Corrosion Product Release Behavior under PWR Primary System Conditions**
Richard Reid, Dennis Hussey, Chuck Marks, Jack Dingee

10080 **Complexation of Nickel Ions by Boric Acid or (Poly)borates**
Anais Graff, Martin Bachet

10088 **Oxide Phases Induced by Electron Irradiation of 316L/PWR interfaces at High Temperature and Pression**
Catherine Corbel, Mi Wang, Stéphane Perrin, Catherine Corbel, Damien Feron

10101 **Validity Range of the Meissner Activity Coefficient Model Used in MULTEQ**
Shirley Dickinson, Martin Bachet, Richard Eaker, Chuck Marks, Peter Tremaine, Daniel Wells

10113 **Modeling of Sample Line Behaviour in PWRS Systems**
Jim Henshaw

10114 **Modelling Zinc Behavior in PWR Plant**
Jim Henshaw, John McGurk, Shirley Dickinson, Dan Wells, Keith Garbett, Joan Pau Barrios Figueras, Santiago Maldonado Sanchez, Enrique Fernandez Lillo

10121 **EPRI PWR Primary Water Chemistry Guidelines Revision**
Joel McElrath, Keith Fruzzetti

10134 **Simulation of Alpha Contamination in PWR with the OSCAR Code**
Jean-Baptiste Genin, Moez Benfarah, Christelle Dinse, Mathieu Corbineau

10148 **Characterisation of Particulate Material in PWR Primary Coolant**
John McGrady, Fabio Scenini, Nicholas Stevens, Nicholas Bryan, Andrew Banks

10149 **EELS and Electron Diffraction Studies on Possible Bonaccordite Crystals in PWR Fuel CRUD and in Oxide Films of Alloy 600 Material**
Jiaxin Chen, Fredrik Lindberg, Daniel Wells, Bernt Bengtsson

10160 **Magnetite Solubility Studies Under Simulated PWR Primary-Side Conditions, Using Lithiated, Hydrogenated Water**
John Hewett, Jonathan Morrison, Christopher Cooper, Clive Ponton, Brian Connolly, Shirley Dickinson, Jim Henshaw

10195 **Oxide Characterization for the Mechanistic Understanding of the Initiation Behaviors of Alloy 182 Weld In Various Water Chemistry Conditions**
Jong-Dae Hong, Junho Lee, Changheui Jang, Ji Hyun Kim, Yun Soo Lim, Masashi Watanabe, Jain Xu, Testuo Shoji, Ho-Sup Kim

10201 **Contamination Simulation of DOEL-4 PWR Using the OSCAR V1.2 Code and Parametrical Studies during Cycles or Cold Shutdowns**
Benoit Habert, Frederic Dacquait, Raphael Lecocq, Kim Schildermans

10206 **Corrosion and Deposition of Metal Oxides in the Primary Coolant System of PWR's**
Jonathan Morrison, John Hewett, Chris Cooper, Clive Ponton, Brian Connolly, Andrew Banks

10210 **Evaluation of pH Control Agents Influencing on Corrosion of Carbon Steel in Secondary Water Chemistry Condition of Pressurized Water Reactor**
In Hyoung Rhee, Hyunjun Jung, Daechul Cho, Hong Jin Yoo

10223 **In-Situ Oxide Investigation of Oxide Films on Zr-Cladding with Varying Dissolved Hydrogen Concentration**
Tae Ho Kim, Jong Jin Kim, Seung Hyun Kim, Ji Hyun Kim

10226 **Understanding of Early Stage Oxidation Behavior on Ni Surface Using Ab-Initio Molecular Dynamics**
Kwang Beom Ko, Ji Hyun Kim, JongJin Kim

15:10 – 16:40 Poster4

Foyer (3rd Floor)

10064 **Streaming Potential Technique in Determining Zeta Potential of Magnetite in PWR Secondary Side Water Treated with Ammonia or Morpholine**
Essi Velin, Timo Saario, Konsta Sipila, Saija Vaisanen

10079 **Qualification of FFA Treatment for the Water-Steam Cycle as an Innovative Lay-up Strategy for the Long Term Outage of a CANDU-6 Reactor**
Jorg Fandrich, Ricardo Sainz, Luis Ovando, Cecilia Herrera, Maribel Mendizabal, Adriana Dumon, Mauricio Chocron

10183 **Outcomes and Analyses of the Secondary Circuit Water Chemistry Strategy for the French PWR Fleet**
Thomas Duchassoy, Olga Alos Ramos, Gonghao Qiu, Kelly Knight, Guillaume Fontan, Jean-Luc Bretelle

10200 **Application of Nano-Structured Coatings to Mitigate Flow-Accelerated Corrosion in Secondary Pipe Systems of Nuclear Power Plants**
Seung Hyun Kim, Jong Jin Kim, Seung Chang Yoo, Ji Hyun Kim

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10020 **Experience with High Efficiency Ultrasonic Fuel Cleaning Using a Side-Stream Sampling System at Ringals Unit 4**
Bernt Bengtsson, Pernilla Svanberg, John Dingee, Abbey Pellman, Daniel Wells

10096 **Optimization of Fuel Deposit Properties for Reducing Plant Radiation Fields an Assessment**
Keith Fruzzetti, Daniel Wells, Dave Morgan, Joseph Giannelli, Charles Marks, Cecile Dame

10133 **Crevice Corrosion Behavior of Stainless Steel in High Temperature Diluted Seawater**
Masahiko Tachibana, Kazushige Ishida, Yoichi Wada, Ryosuke Shimizu, Nobuyuki Ota, Motohiro Aizawa, Naoto Shigenaka

10151 **CANDU Fuel Deposits and Chemistry Optimizations - Recent Regulatory Experience in Canadian Nuclear Power Plants**
Ram Kameswaran

10161 **Out-of-Reactor Test of Corrosion and Hydrogen Pickup in Fuel Cladding Materials**
Daniel Wells, Richard Becker, Clara Anghel, Jayashri Iyer, Jacqueline Stevens

10177 **Influence of Welding on Corrosion Resistance of Zircaloy-4**
Yosuke Sato, Shinji Ono, Yoshihiro Tsuchiuchi

10188 **Pressurised Light Water Reactor Failed Fuel Monitoring : Comparison of International Strategies Used in the Surveillance of the Primary Barrier**
Robin Aldworth, Christelle Dinse, Didier Mole

10221 **The Benefits of Using Enriched Boric Acid in Commercial Nuclear Power Plants**
Kevin Cook, Debra Wiedenmann

10264 **Review of BWR Industry Implementation of Online Noblechem™ Process Update and Operating Experience**
Russell Seeman, Juan Varela, Hubert Huie, Kimberly Sbrocchi, Peter Andresen

10294 **Three Dimensional Multiphysics Modeling and Validation of CRUD-Induced Localized Corrosion (CILC) In PWRs**
Andrew Dykhuis, Michael Short

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10247 **Analysis of Data on Evaporator Module Steel Corrosion as a Result of BN-600 Third Circuit Chemical Clean-Ups**
Vladimir Smykov, Artur Tzekh

10263 **Boron Recycling Strategy for FLAMANVILLE3-EPR Reactor**
Arancha Tigeras, Yvan Bouhlassi

10274 **New Method of Study on the Leachable Behavior of Cation Exchange Resin**
Dah-Yu Kao, Liang-Cheng Chen, Tung-Jen Wen, Charles-Fang Chu

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10017 **Ion Exchange Filter Transition Plan for BWRs and PWRs**
Susan Garcia, Joel McElrath, Joseph Giannelli, Jeremie Varnam

10034 **The Effectiveness of Early Hydrogen Water Chemistry on Corrosion Mitigation for Boiling Water Reactors**
Mei-Ya Wang, Tsung-Kuang Yeh

10037 **Water Chemistry Contorol to Meet the Advanced Design and Operation of Light Water Reactors**
Hiroshi Shirai, Shunsuke Uchida, Masanori Naitoh, Hidetoshi Okada, Masatoshi Sato

10138 **Formation of Platinum Oxide Nanoparticle Colloidal Solution under Gamma-Ray Irradiation**
Kazushige Ishida, Yoichi Wada, Masahiko Tachibana, Nobuyuki Ota, Motohiro Aizawa

10145 **Experimental and Computational Approaches to Evaluate the Environmental Mitigation Effect in Narrow Spaces by Noble Metal Chemical Addition (NMCA)**
Ryosuke Shimizu, Nobuyuki Ota, Makoto Nagase, Motohiro Aizawa, Kazushige Ishida, Yoichi Wada

10156 **Development of ^{60}Co Monitoring System for RRS Piping during Plant Operation**
Hirofumi Matsubara, Toru Kawasaki, Nobuyuki Ota, Makoto Nagase, Katsunori Ueno, Takahiro Tadokoro, Koichi Takamiya

10180 **A Leading-edge Condensate Polishing System Design**
Jumpei Fukawa

10191 **Optimization of Operational Water Chemistry for Supercritical-Water Cooled Reactor**
Marketa Zychova, Monika Sipova, Katerina Vonkova, Zuzana Skoumalova, Jan Macak

10196 **Development of Advanced Radioactivity Control Method (ARCOM) in LWR Primary Systems**
Masafumi Domae, Kazutoshi Fujiwara, Yutaka Ueyama, Wataru Sugino, Kenji Hisamune

10202 **Inhibition of Self-Passivation of SUS304 Stainless Steel in Tritiated Water Solution OF Sulfuric Acid**
Makoto Oyaidzu

10216 **Scientific Root-Causes of Component Degradation of Aged LWRs - Radiation-Induced Long-Cell Action Corrosion -**
Genn Saji

10217 **Manufacture and Evaluation of Integrated Metal-Oxide Electrode Prototype for Corrosion Monitoring in High Temperture Water**
Yoshinori Hashimoto, Jun-ich Tani

10220 **3M™ Neutron Quench: Compounds with Substantial Water Solubility and Boron Content**
Kevin Cook, Alex Blake, C. Jody Neef

10232 **Fuel Cell as Burner for Converting Hydrogen (D_2) Formed in Primary and Moderator System of PHWRs**
Chandramohan Palogi, Murugesan N, Harinath Y.V, Srinivasan M.P, Ramesh C, Velmurugan Sankaralingam

10257 **Improvement of the Pre-Filming Technique for the Reduction of the Metal Release from TP304L**
Kiyoko Takeda, Yasuyoshi Hidaka, Akihiro Uehira

10277 **Experiment-Integrated Multi-Scale Multi-Physics Computaional Chemistry Simulation Applied to Corrosion Behavior of BWR Structual Materials**
Nozomu Hatakeyama