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出國報告（出國類別：其他）

"參加反應器水化學國際會議及冷卻水輻射分解暨電化學研討會"國外公差報告

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摘　要

核反應器系統國際水化學會議，2010 年在加拿大魁北克由加拿大核能　會(Canadian Nuclear Society, CNS)主辦，會議主題(一)壓水式反應器(PWR、VVER)和重水式反應器(CANDU，PHWR)水化學運轉經驗 (二) 沸水式反應器(BWR)水化學運轉經驗(三)沸水式反應器(BWR)水化學技術研究(四)老化及壽命管理 (五)壓水式反應器(PWR，VVER)和重水式反應器(CANDU/PHWR)水化學技術研究 (六)蒸汽循環水化學運轉經驗(七)水處理及輔助系統水化學(八)化學及燃料運作(九)化學及核電廠運作(十)清洗及除污(十一)水化學未來發展。本所自民國 73 年以來即開始核反應器水化學相關技術之研究，並從事核電廠系統之水質控制及管理，多年來提供原能會具體之水質管制參考依據。近年來在冷卻水總有機碳、爐水之矽土雜質及新建核電廠管線鈍化方面等的研究，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。參與此會議除了將國內近期在研發及解決電廠水質技術之成果與國外互相交換技術及心得外，並藉此機會瞭解國際水化學方面近年來的研發趨勢與方向，同時與各國相關人員相互砌磋，促進國內反應器水化學專業技術之再提升。

第八屆反應器冷卻水輻射分解暨電化學研討會也在同一地點舉辦,透過本研討會之討論以瞭解近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，對國內已施行之加氫水化學與電化學量測技術最適化控制，提供防制系統組件老化之管理方式及能力;除此之外也針對超臨界反應器(SCW)在水化學特性及材料選用方面之可能發展也一作前瞻性的規劃及研究，對爾後之水質控制方面或可提供較高可信度的參考。

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摘　要

一、目的

(一)參與 2010 年核反應器水化學國際學術會議，交換水化學技術

本次在加拿大魁北克市舉行的 2010 年核反應器系統水化學國際會議，其前身源自於 1977 年在英國 Bournemouth 由英國核能學會(British Nuclear Energy Society，BNES)所舉辦第一次與核電廠相關之水化學會議，初始每隔 2 年定期舉行一次。自 1988 年日本原子工業會(Japan Atomic Industrial Forum，JAIF)也主辦核能電廠水化學會議後，即於 1992 年開始調整舉辦地區，且改爲每隔一年舉行一次，本次會議爲第一次在加拿大舉行，此會議歷年之舉辦地點及主辦單位如表 1 所列。

表 1 歷年在國際上所舉辦之核反應器系統水化學會議

	會議日期 年 月	會議地點 國名 城市	會議主辦單位	備註
1.	1977 10	英 Bournemouth	BNES[1]	BNES 1
2.	1980 10	英 Bournemouth	BNES	BNES 2
3.	1983 10	英 Bournemouth	BNES	BNES 3
4.	1986 10	英 Bournemouth	BNES	BNES 4
5.	1988 04	日 Tokyo	JAIF[2]	JAIF 1
6.	1989 10	英 Bournemouth	BNES	BNES 5
7.	1991 04	日 Fukui	JAIF	JAIF 2
8.	1992 10	英 Bournemouth	BNES	BNES 6
9.	1994 04	法 Nice	SFEN[3]	SFEN 1
10.	1996 10	英 Bournemouth	BNES	BNES 7
11.	1998 10	日 Kashiwasaki	JAIF	JAIF 3
12.	2000 10	英 Bournemouth	BNES	BNES 8
13.	2002 04	法 Avignon	SFEN	SFEN 2
14.	2004 10	美 San Francisco	EPRI[4]	EPRI 1
15	2006 10	韓 Jeju	KAERI[5]	KAERI 1
16	2008 09	德 Berlin	VGB[6]	VGB 1
17	2010 10	加 Quebec	CNS	CNS 1

1. BNES：British Nuclear Energy Society
2. JAIF ：Japan Atomic Industry Forum
3. SFEN：French Nuclear Energy Society
4. EPRI：Electric Power Research Institute
5. KAERI: Korea Atomic Energy Research Institute
6. VGB: Verband der Großkessel-Besitzer
7. CNS: Canadian Nuclear Society

本次大會主席由加拿大 New Brunswick 大學之厲斯特教授(Prof. Derek Lister)主持，厲斯特教授曾於民國 76 年應邀到核研所訪問，並參與水化學方面的討論。本次大會有來自世界 30 個國家數十個機構共貳百餘人參加 ，口頭論文發表共 54 篇(如附錄 1)，壁報展示達 120 篇，國內總計有五人與會:清華大學 2 人(其中葉宗洸教授為中華核能學會水化學分會之負責人，也是國際水化學成員台灣代

表)、台灣電力公司 1 人、工業技術研究院材料研究所 1 人、核能研究所 1 人。美國、日本、法國、俄羅斯、印度、德國、瑞典與東歐匈牙利…等國均派多人與會，南半球的阿根廷、南非等也有代表參加，顯示這些國家對核反應器水化學之研究與推動極為重視。由論文的篇數及內容看來，在此領的確有長足的進步及不錯的表現，也證明水化學在維繫運轉安全、材料完整及減低廢料方面，的確有它獨特的重要性。美國、加拿大、日本、法國、等國在水化學研究方面的成果與電廠運轉之實績尤其突出;在亞洲，特別是印度近年來在此領域的投入與研究方面的成果在本次會議中更可看出它的企圖心。

(二)參與冷卻水輻射分解暨電化學研討會，提升模式應用技術

此研討會最初由東京大學石榑顯吉教授(Prof. K. Ishigure)及東芝公司化學部門之高木博士(Dr. J. Takagi)師徒共同籌辦，為日本早期推動水化學方面步入輻射分解(Radiolysis)與電化學(Electrochemistry)應用於電廠模式計算之討論會，於 1998 年 10 月在東京舉辦第一次研討會，開始將日本研發之輕水式冷卻水輻射分解模式溶入電廠內實際應用而互相結合，並與美國奇異(GE)、瑞典 Stüdsvik 等開發之模式比較，爾後逐年開發電化學腐蝕電位(Electrochemical Corrosion Potential，ECP)及高溫水化學等模式，使日本在反應器水化學模式計算及電廠評估方面初步建立相當厚實的基礎。國內核一、核二廠加氫水化學測試及相關數據之評估，除由清華大學系統及工程研究所的葉宗洸教授作模式計算研究外，電廠內現場實際注氫也是應用東芝公司之模式計算而來。研討會歷年舉行概況及議題重點如表 2 之說明。

表 2 輕水式反應器冷卻水輻射分解暨電化學研討會歷年舉行概況

屆次	會議日期 年 月	會 議 地 點 國名 城市	議 題 重 點
1	1998 10	日本 Tokyo	Modeling of water radiolysis in HWC environment
2	1999 10	日本 Kashiwasaki	ECP modeling and crack growth and crack propagation
3	2000 10	英國 Bournemouth	Crack modeling and water chemistry environment in BWR
4	2002 04	法國 Avignon	Mixed potential modeling and high temperature experiment
5	2004 10	美國 San Francisco	Radiolysis and mixed potential modeling
6	2006 10	韓國 Jeju	Modeling and evaluation of ECP in LWR
7	2008 09	德國 Berlin	Radiation chemistry application in LWR
8	2010 10	加拿大 Quebec	BWR/PWR Chemistry modeling and super critical water study

二、過程：

(一)核反應器系統水化學國際會議：

本年度之水化學國際會議 10 月 4～7 日在加拿大魁北克市舉行，與會人員來自 30 個國家，會議可分為十一個主要議題，共發表 174 篇論文，其中口頭論文發表 54 篇，壁報展示內容 120 篇。今將四天在 Leows Concord Hotel 會議廳開會及討論之內容依會議議題順序，內容歸納簡述如后:

1.壓水式反應器(PWR、VVER)和重水式反應器(CANDU/PHWR)水化學運轉經驗

整體而言，壓水式反應器水化學的改善及控制模式為本次的主軸，自 1990 年迄今，壓水式反應器因腐蝕而造成燃料護套故障 (Fuel failure)的可能性遠小於 BWR，但可能有燃料軸向偏差異常(Axial Offset Anomaly，AOA)問題而導致功率調降；近年來採行固定 $pH_T \cong 7.0 \sim 7.2$ 之運轉模式，對銹垢沉積及劑量率之控制已顯現相當正面的效果。今後如何加強燃料護套表面沉積物之檢視，進一步探討 $pH_T = 7.0 \sim 7.2$ 之運轉甚至提升 $pH_T =$

7.2 ~ 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)及輻射劑量升高之問題。VVER 屬於 PWR 反應器，一次側水質 pH_T 控制自 1990 年代後，採行硼/鉀修正式水化學(B/K Modified water chemistry)，另加入 Ammonia, Hydrazine 及 Hydrogen，以維持系統於還原態，此與西方 PWR 略有不同。壓水式反應器方面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當今 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，值得國內注意。

(1)加鋅水化學

PWR 一次系統注鋅理念源自於 BWR 加鋅水化學所獲之正面效益，加入適量的鋅，不但可以減低輻射場強度，也能抑制 PWSCC 起始及成長速率(Crack Growth Rate, CGR)。美國 Farley 2 廠在 1994 年首次作注鋅的測試，由於有正面的效益，因此 14 年後復開始進行注鋅，德國 Biblis B 廠在 1996 年 11 月開始注鋅，Biblis B 廠爲全世界進行加鋅最久且較成功的 PWR 電廠，從 Biblis 廠的測試結果顯示加鋅效益是相當值得肯定的。

加鋅水化學的目的是要藉 Zn 在爐水中取代 Co 而達到抑制管線輻射增建的目的， 2000 年開始也發現加鋅與燃料管理也可有某種程度相關，因從燃料運作、輻射場、材料完整性及環境衝擊等多種目標來看，加鋅水化學的效用的確不可忽視，這也就是爲什麼近年來，PWR 施行加鋅的電廠快速遞增的原因。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，分析並評估其效益。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，特別是對燃料完整性的衝擊，如抑制銹垢沈積，伴隨衍生的軸向異位偏差/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;法國電廠爲 PWR 反應器，由於美國及其他國家的經驗認爲加鋅水化學不會有負面影響，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。比利時的 Doel-3 機組於 1993 年更換蒸汽產生器(Steam Generator, SG)後，爲了要減少劑量率也考慮作加鋅的抑制措施。日本北海道電力泊-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，更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;令大家比較擔心的疑慮是加了鋅之後的機組初期造成的立即反應是:加入之鋅是否與爐心外之 Ni 氧化膜反應而放出 Ni 再進入冷卻水中又造成 Ni 沈積於爐心進一步引起燃料的問題，這就是為何初次注鋅後要審慎評估的原因，重點還是在是否對燃料有負面的影響。到 2009 年 6 月為止，全世界共有 57 個 PWR 機組進行加鋅，佔全世界 PWR 機之 22%，且在這兩年內仍將有 14 個 PWR 廠擬規劃進行加鋅的措施。

(2)蒸汽產生器更換後輻射沈積現象

PWR 電廠有許多運轉已超過 30 年，可能因蒸汽產生器塞管率偏高或洩漏嚴重而面臨更換蒸汽產生器(Steam Generator Replacement, SGR)的問題，更換新的蒸汽產生器，所使用的材質在法國主要是鎳合金 600、690、800 等，由於蒸汽管在一次系統所佔的表面積多達 ＞65%以上，^{58}Co 與 ^{60}Co 的沈積不可忽視，從運轉的輻射增建結果及 SGR 輻射變化，^{58}Co 活性沈積在 SGR 後 1-3 燃料週期是上升的，其後的下降視材質的前處理方法而改變，其次則視合金材質而定，^{60}Co 在管線表面的沈積則逐漸減少且增加速率甚低。比利時的 Doel-3 與 Doel-4 PWR 機組已運轉近 30 年且分別更換為 Inconel-800 及 Inconel-690 TT，從運轉的水化學策略來看均符合先進水化學標準採用調和式 pH_{Tave}＝7.2 方式，起爐與停機水化學也依循正常程序，但 SGR 後的沈積兩個機組均不相同，Doel-3 輻射增建較高，可見長期整體水質控制是相當重要的，有些措施也要加入考量，例如前述之加鋅水化學…等。

(3)腐蝕產物行為與抑制沈積

腐蝕產物的生成在 PWR、VVER 等電廠影響最主要的因素為冷卻水 pH_T的控制，生成較多的腐蝕產物往往造成在燃料表面沈積、活化、再沈積問題，首先耽心的是燃料表面因沈積過多形成 AOA 或燃料損毀，這些問題都與 SG 材質、水化學、熱流或運轉條件有關。近年來 SG 材質更換後則與 SG 材質之製造或處理較有關，特別是 SGR 後更明顯變化。近年來各國紛紛提高燃料轉週期，高燃耗(High burn-up)勢必要提高爐水之硼酸(H_3BO_3)濃度，因此降底 pH_T腐蝕產物沈積，將以提升鋰(Li)濃度調整，相

對的高濃度Li直接使材質的應力腐蝕龜裂面臨挑戰;初步在芬蘭VTT技術研究中心的研究發現，過高濃度的 Li 將使不銹鋼材質因輻射照射之影響增加 SCC 問題，因此法國電廠目前尚未有提升 Li 濃度到更高的限值，而仍以 3.5ppm 為上限濃度。

(4)蒸汽發生器雜質移除技術

VVER 電廠蒸汽產生器表面為了減少雜質蓄積新近開發於系統中注入微量添加物十八烷胺(Octadecylamine Microadditives, ODA)之技術，使表面形成活性抑制膜，抑制 Cl^-等雜質穿透影響材質腐蝕，不但可減少雜質於熱傳表面的沈積，也有移除沈積物的功能，減低發生裂縫成長的機會，改善的成效達 60～70%，對於 VVER 電廠延壽的功能極為正面，此種化學添加物的加入在俄羅斯的 Kola-2 廠測試已獲得驗証，將可減少 PWR 進行化學清洗的機會。俄羅斯建造的 VVER 與 RMBK 反應器對於加鋅水化學也都持極為正面的評價,也認為建新機組時即進行加鋅對輻射增建的抑制效果更具正面的意義，而更能發揮抑制沈積作用。

2.沸水式反應器(BWR)水化學運轉經驗

(1)歐洲 BWR 運轉經驗回顧

在歐洲運轉中的 BWR 電廠是由 3 個不同的供應商提供 19 個機組，雖然設計稍有不同，但是運轉的水化學條件極為相近，綜述如后:

a.具有內部循環設計之 12 個機組，屬於標準式並不採行加鋅水化學。

b.其餘 7 個機組屬於外部循環(Recirculation loop)系統設計，採行加氫水化學，並有兩個機組施行 OLNC (On-line Normal Metal Chemical Addition, OLNC)，並有 6 個機組施行加鋅水化學。

c.所有機組爐水均可控制於<0.09 μS/cm，且 Cl- < 1ppb，SO4= < 2ppb 飼水中之溶氧均控制於 25～55 ppb 之理想範圍，(Forward pumped drains 設計者，則控制於 65-400 ppb)。

d. 5 個機組有前置過濾器設計者，飼水不溶鐵最低，FW 溶氧與不溶鐵含量與電廠設計及特性較有關連性。

(2)停機及起動水化學控制

停機與起動期間水化學的控制及管理是近幾年來普受注重的程序，雖然對大修期是有某些程度的影響,但在整體營運績效及反應器本身的安

全考量也是相當重要的。BWR 早期有所謂的軟停機(Soft shutdown)，即是近年來爲了有效抑制燃料護套表面銹垢迸裂(Crud spalling)釋出的有效方法之一，採行加氫水化學、加鋅水化學及貴重金屬添加後，停機程序及水化學控制更成爲不可少的一環。至於起動水化學則偏向於材質的影響問題，特別是在進行加氫水化學之後，加氫始自於 20%功率後，在此之前，材質應力腐蝕龜裂尤爲明顯,主要因素是飼水中之溶氧或過氧化氫之含量偏高，於 150-200℃之高溫環境造成管線之 IGSCC 可能性增加。

(3)飼水及爐水雜質控制

沸水式反應器系統管線之破裂問題，特別是爐心內部組件與再循環系統之沿晶應力腐蝕龜裂現象(Intergranular Stress Corrosion Cracking，IGSCC)，爲目前 BWR 仍普遍存在的疑慮，爐水氯與硫酸根離子是主要因素，雖然加氫水化學、加鋅水化學、起動水質控制及貴重金屬添加(Noble Metal Chemical Addition, NMCA)等輔助改善措施，近年來已成爲抑制 IGSCC 與控制輻射增建之有效對策。

a.銅雜質控制

飼水及爐水銅含量常導致燃料、加氫效率及停機劑量的問題，有效掌握飼水 $Cu < 0.05$ppb 及爐水 $Cu < 1.0$ppb 的目標對加氫水化學、腐蝕電化學電位及貴重金屬添等措均有明顯的影響。

b.飼水鐵控制

從日本東海-2(Tokai-2)機組冷凝水除礦系統僅採用粒狀樹脂控制飼水不溶鐵的目標，藉由進步型樹脂清洗系統(Advanced Resin Cleaning System, ARCS)的應用，將 Fe≒0.5ppb 是一項重要的突破，但若 $Fe < 0.5$ppb，^{60}Co 之沈積也相對明顯上升，特別是當 $Fe < 0.1$ppb 時沈積現象更明顯。

3.沸水式反應器(BWR)水化學技術研究

全世界的 BWR 電廠目前 60%以上的機組進行加氫水化學(HWC)，其中有相當多的機組同時進行貴重金屬添加措施(NMCA)以達到更有效抑制爐內的 IGSCC 的現象，另外有幾個機組也採用注鋅以穩定管線氧化膜達到抑制 IGSCC 及降低輻射場的目的。整體而言，如何抑制 IGSCC 仍是 BWR 反應器水化學最重要的長期目標。

(1)抑制應力腐蝕龜裂之 Nano Noble™

運轉中的 BWR 電廠採行 NMCA 或 On-line NMCA(OLNC)方法抑制應力腐蝕龜裂現象者已有增多的趨勢，注入的貴重金屬物質通常爲 pt 的化合物;美國奇異公司最近開始研發以微米 pt 和 ptO_2 生成奈米 pt 粒子之技術加入系統成爲改善 ECP 的重要方法，且可逐漸取代 NMCA 而不致於有引入雜質的可能，並可於運轉或停機的任何時間加入而達到減少 IGSCC 的目標。圖 1 爲在 ZrO_2 表面形成之奈米 pt 粒子，而在反應器中扮演降低腐蝕電位之功能。

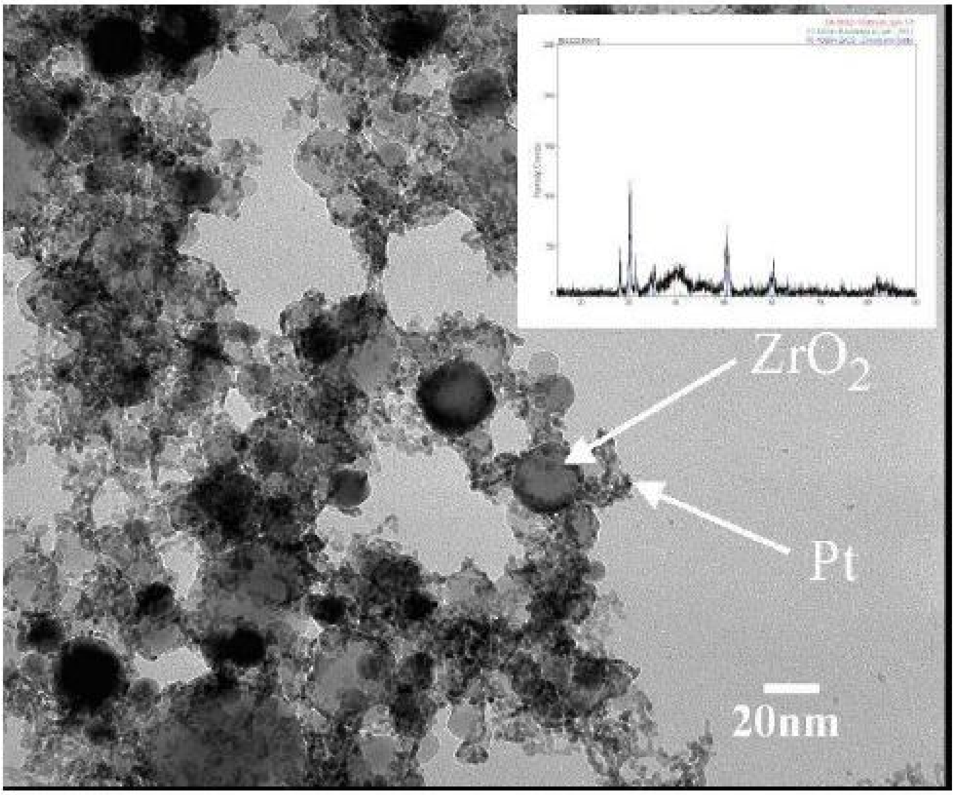


圖 1.奈米 Pt 粒子黏附於 ZrO_2 表面之 TEM 分析

(2)加鋅水化學中影響材質之雜質效應

在常態水化學(Normal Water Chemistry，NWC)時，注入適量的鋅可以達到抑制或減低 CGR 控制 IGSCC 的目的，從 GEH(General Electric-Hitachi)的測試結果顯示當注鋅 20ppb 與 Noble Chem™ 及 HWC 相互配合時可有效減低 CGR 值。加鋅的另一主要目的爲控制輻射場，由於自飼水注入鋅相對使爐水 Co-60 減少，當 Co-60/Zn 比值維持於 $2.0\times10^{-5}\,\mu Ci/ml/ppb$ 時，可

有效抑制活性物質之沉積，避免輻射場上升的可能，即使在導電度極低之純水(0.07 μScm^{-1})環境中仍不可避免因 Cl^-與 $SO_4^=$之存在而產生 SCC 現象，但其他的雜質離子如 CrO_4^{2}、NO_3^-等則並沒有負面的影響，從電化學探討不銹鋼與鎳合金裂縫成長速率發現 Cl^-與 $SO_4^=$是主要的破壞因子，但是 Zn^{++}則具正面的效應(圖 2)。

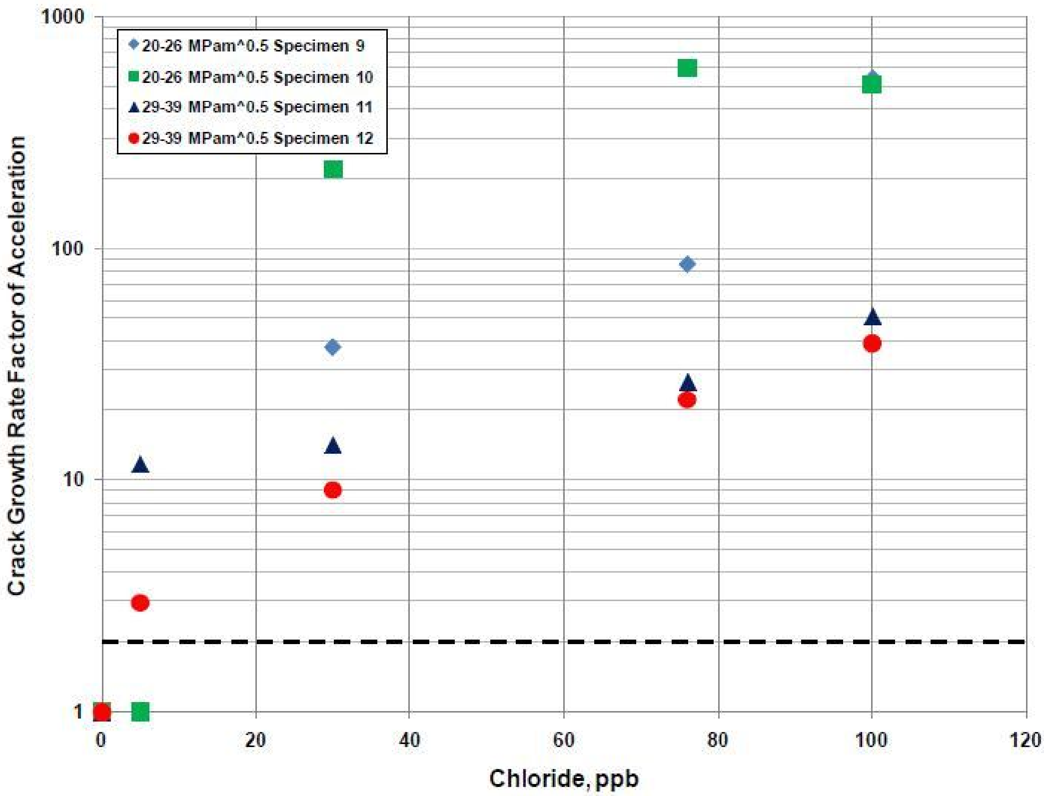


圖 2.NWC 水化學環境 Cl 對敏化 304SS CGR 加速之影響

(3)BWR 水化學環境 Fe、Ni 與輻射增建關係

德國 BWR 電廠除了提升水質、材質選用及前處理技術改善外並定期作 IGSCC 檢測，因此僅在水質控制上注入鋅的氧化物(Depleted Zinc Oxide，DZO)即達到降低輻射場的效果，並未做 HWC。美國及其他地區的 BWR 則採用加氫及加鋅水化學，做爲有效抑制 IGSCC 及減低輻射場之對策，大部份的電廠對注鋅量與飼水不溶鐵的控制，均認爲非常有關聯性，飼水不溶鐵偏高時，不但會沉積於燃料表面，也需要較高的注鋅量（＞0.6 ppb），高注鋅量會影響燃料表面之銹垢迸裂而增加管線表面沉積現象。

BWR 反應器中 Co 輻射增建常困擾著電廠運轉及維修人員，在何種環境下的雜質含量才不至於造成 Co 之沈積也是許多的研究人員想要突破的地方。瑞典的研究人員發現當 Ni 在爐水中的濃度達 10ppb 且 Fe^{+2}/Fe^{+3} 0.1ppb 時可以抑制 Co 沈積且已沈積的 Co 亦不至釋入水中;當 Fe^{+2}/Fe^{+3} 爲 2ppb，且 Ni^{+2} 由 0.5ppb 朝 10ppb 增加時，Co 之沈積爲逐漸增加，而沈積物金屬表面的氧化膜隨深度而有不同的型態結構，此可由表 3 的結構組成中看出其差異性。國內核一、二廠之飼水不溶鐵目前介於 0.5~2.0 ppb 之間，採行中量加氫(M－HWC，加氫量爲 1.0~2.0 ppm)，飼水鐵勢必需進一步控制到＜1.5 ppb，否則對輻射場控制及人員曝露劑量之抑低必定不利。

表 3. 氧化層厚度之化學組成分析

Sample	Thickness of inner oxide layer (nm)	Chemical formulas of inner oxide layer	Grain size of outer oxide (nm)	Chemical formulas for outer oxide grains
A	101±54	$Cr_{1.0}Ni_{0.4}Fe_{1.6}O_4$	171	$NiFe_2O_4/Cr_{(0\text{-}0.6)}Fe_{(2.4\text{-}3)}O_4$
B	164±56	$Cr_{0.6}Ni_{0.7}Fe_{1.7}O_4$	575	$NiFe_2O_4$
C	163±50	$Cr_{0.6}Ni_{0.5}Fe_{1.9}O_4$	636	$NiFe_2O_4$ and $(Cr_xFe_y)_3O_4$ $_{x=0\text{-}0.25\ y=0.75\text{-}1}$
D	171±48	$Cr_{0.4}Ni_{0.7}Fe_{1.9}O_4$	576	$NiFe_2O_4$ and $Ni_{0.7}Fe_{1.2}Cr_{0.1}O_3$

(4)氧化鈦於 BWR 環境中之電化學行爲

早期的研究中已証明氧化鈦沈積在不銹鋼表面會降低 ECP 電位，近年也發現即使沒有紫外線照射(UV)也有相同的功能，日本東芝及清華大學在氧化鈦沈積方面均有發表論文探討其電化學量測的效應，特別是陽極電流密度會隨 TiO_2 量增多而更有效能(如圖 3 所示)，國內清華大學葉宗洸教授也這在領域以電化學的角度探討 TiO_2 在 Hematite 與 Magnetite 氧化物表面之沈積爲 Anatase-type 構造，且經 UV 的照射後 ECP 會下降 100mV，若不經 UV 照射，看不出 TiO_2 其真正的電化學行爲。

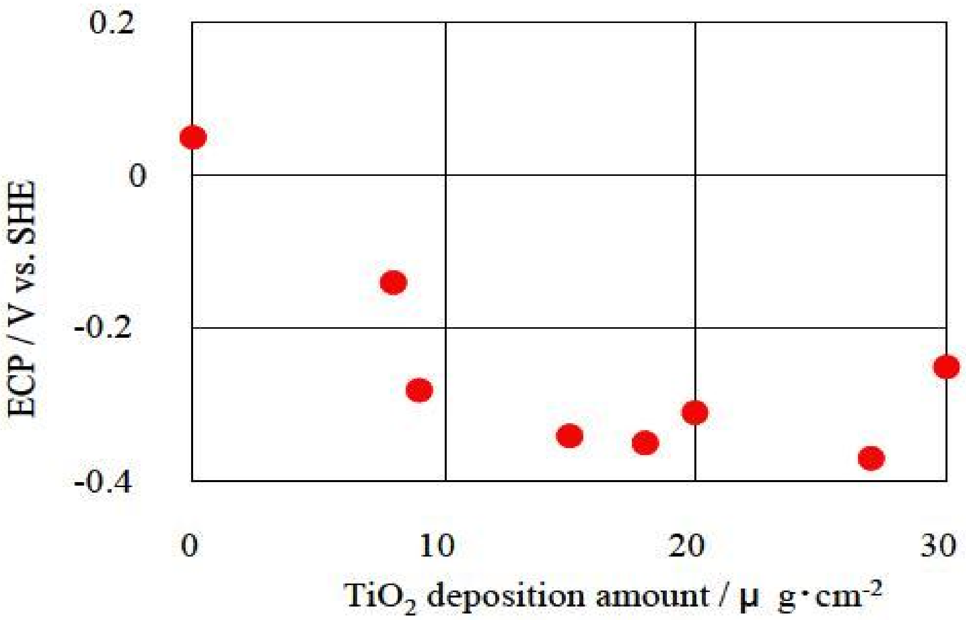


圖 3.TiO_2沉積量與 ECP 關係

(5)起動期間加入除氧化學物質

BWR 反應器起動期間即使有相當好的水質仍有因 ECP 偏高而有裂縫成長的顧慮(如圖 4)，且發生於 150-200℃甚爲明顯，ECP 無法藉 NMCA 之作用而注入 H_2，或功率不高無法加氫，由於此時水溫 < 200℃材質之 CGR 在此溫度下相當高，爲了要抑制 ECP，奇異公司針對這問題進行起動前添加化學物的研究，此等化合物包括聯胺、氫、二 胺(Carbohydrazide)、甲醇等，經過 NMCA、LTNC 與 OLNC 等處理後與不經過處理之樣品比較，加入上述化合物均有降低 ECP 的效果，但處理過的樣品效果更明顯。

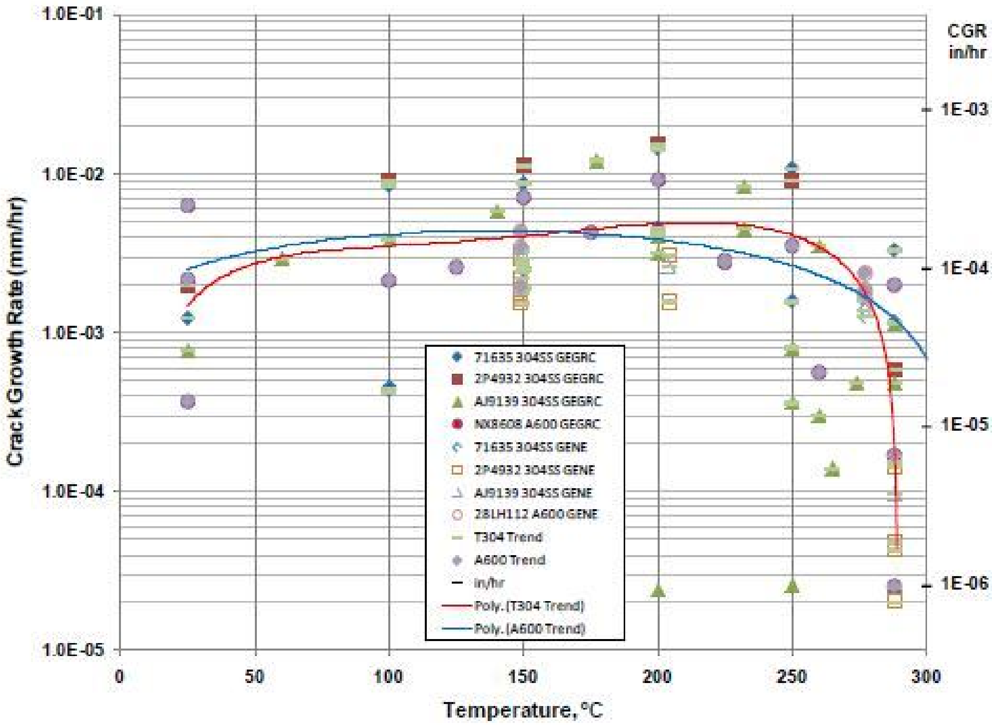


圖4.溫度對材質裂縫成長之效應

4.老化及壽命管理

(1)PWR 提高溶氫運轉

一次側管線鎳基合金破裂起始及成長受爐水鋰-硼之影響較小，主要是受到溶氫的影響較顯著，溶氫含量與鎳基合之破裂成長及溫度相互變化影響；溫度愈高時，要有更多的溶氫存在才能有抑制作用，PWR 反應器一般運轉的溶氫規範爲 25～50ml/kg-H_2O，較高的溶氫量可以抑制 PWSCC 的現象，在同時兼顧燃料完整性、材質可靠度及運轉安全性前提下，提高溶氫到 60 ml/kg-H_2O，需面臨燃料護套及組件完整性的挑戰。自 2007 年後 PWR 溶氫的運轉經驗已朝向上提升的趨勢(如圖 5 所示)，美國電力研究所(Electric Power Research Institute, EPRI)之氫管理計畫中目前也僅考慮溶氫最高上限值爲 60 ml/kg-H_2O。另外在 316N SS 材料疲勞檢測的結果証明 80 ml/kg-H_2O 的環境的確有較長材質壽命，因此溶氫研究仍在持續中。

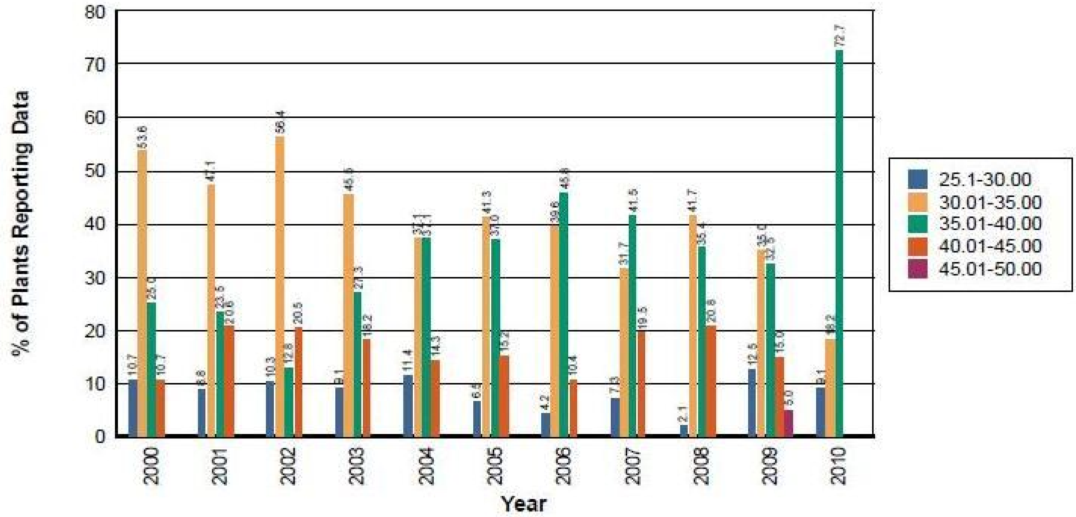


圖 5.PWR 冷卻水溶氫濃度經驗值

(2)流動加速腐蝕問題

不論 BWR 或 PWR 在水流動區域均有腐蝕的問題，但是藉由化學控制仍可將流動加速腐蝕(Flow Accelerated Corrosion, FAC)的現象抑制在最小的範圍，影響在 FAC 的主要因素為溫度、溶氧及 pH…等。某些有較高 FAC 可能區域並可利用程式分析找到最適化條件，以減低管件的薄化問題。日本敦賀-2(Tsuruga-2)PWR 廠也以此方式在飼水端增加溶氧緩制 FAC 現象，証實是正面的效果。從材質選用的方向來思考，碳鋼中含有鉻較高時抗 FAC 的能力也愈佳，從水化學的觀察則以溶氧及 pH 的影響較明顯，加入聯胺時溶氧降至極低，聯胺分解時之鹼性有助於減少 FAC 現象。

(3)減少不銹鋼材質腐蝕速率之技術

維持電廠終生不老化的前提為減少材質之腐蝕速率，尤其在不銹鋼材質中 Fe、Cr、Ni、Co 等的釋出，Co 的含量控制是最重要的，通常均控制於< 0.02%，其餘 Fe、Cr、Ni…等均為一般組成，減少釋出率的方法之一為於材質表面於使用前做鈍化膜(Pre-filming)控制。經過鈍化處理過的 SS 材質與未經鈍化膜控制的 Cr 釋出率比較減少 30%(如圖 6 所示)，與溶氧值並沒有顯著的關係。

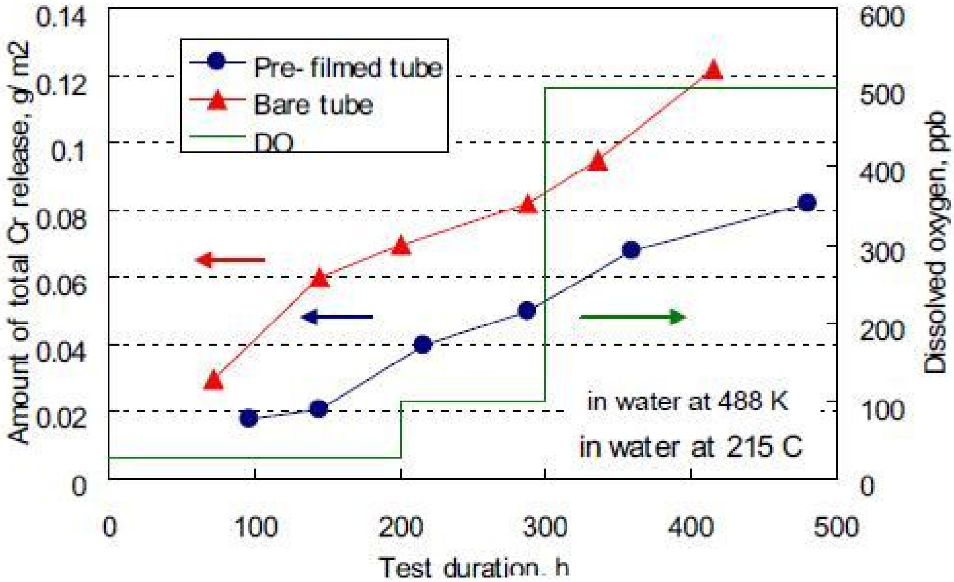


圖 6.TP304SS 材質於 215℃之 Cr 釋出率)

5.壓水式反應器(PWR，VVER)和重水式反應器(CANDU/PHWR)水化學技術研究

(1)計算模式的應用研究

法國 CEA 的 OSCAR Code 是與 EDF 及 AREVA NP 共同開發而成，爲模擬 PWR 之腐蝕、分裂產物在系統之腐蝕、輸送、沈積等，由早期的 PACTOLE 及 PROFIP 兩種模式結合而成，再加上與燃料有關的 ALCYONE/MARGARET Code 改良而成，目前此計算模式仍需藉實驗數據相互驗証。俄羅斯早期針對 VVER 反應器所開發之輻射分解計算模式 BORA(Boiling Radiolysis)則用以計算 BWR 輻射分解現象，日前應用於瑞典之 Oskarshamn-2 機組，驗證結果相當符合實驗值(如圖 7)。

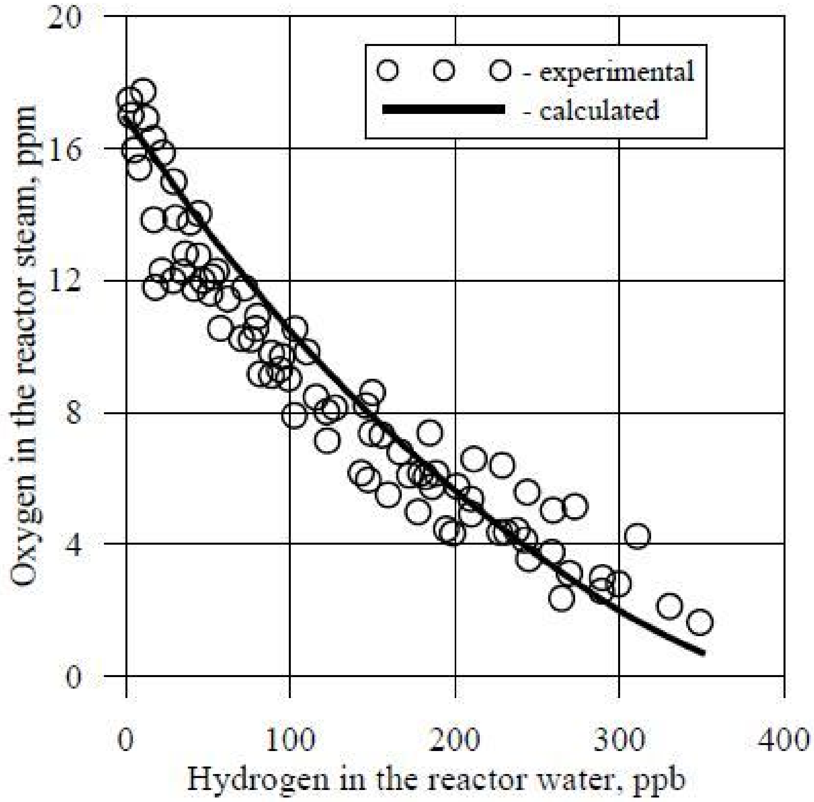


圖 7.OSCAR Code 對爐水溶氫等之計算值及實驗值比較

(2)二次系統分散劑使用與聯胺技術研究

分散劑(Dispersant)應用於核電廠是近幾年的事，將 Poly Acrylic Acid (PAA)加入飼水系統抑制二次系統鐵腐蝕產物蓄積在 SG 內結垢，並可藉沖放器移除鐵，成爲減少 SG 結垢問題相當有效的策略之一。二次系統加入適量的分散劑-PAA，加入的濃度約等於飼水鐵濃度即可移除 50%左右之鐵，基本上對 SG 管不會有負面的影響，但是可以減少鐵氧化物形成淤泥沈積於材料表面，EPRI 續在這領域評估氧化物形成影響性。聯胺在二次系統的使用主要是除氧，它的角色扮演多重性，也可以將α-Fe_2O_3還原成 Fe_3O_4甚至在高溫時還原成 Fe^{+2}，因此具有降低 ECP 的功能(如圖 8)，在這方面的研究與應用仍是不可忽視的。

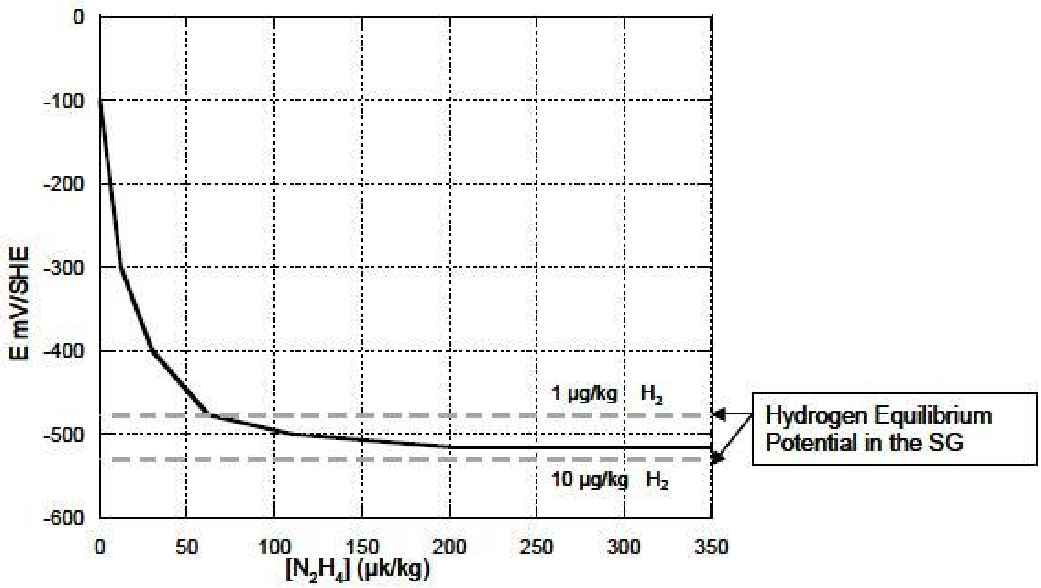


圖 8.聯胺於不同濃度於 SG 內之 ECP 量測變化

(3)鎳基合金表面處理研究

日本住友金屬工業公司爲了要減少鎳基合金中的 Ni 釋入水中，所做三種不同的表面處理方式，發現以氬氣環境中預氧化處理所得的氧化物結構能阻止 Ni 釋入水中而達到抗腐蝕的效果，對減少 Co-58 之生成有正面的效果。

(4)鉛與二次系統 SCC 影響

蒸氣管受鉛的影響愈被重視，鉛是源自於系統組件或聯胺等化學添加物雜質進入系統沉積於 SG 內，容易對 SG 管造成加速 SCC 現象，從二次系統 SG 管抽管的研究中發現，鉛(pb)在裂縫尖端造成劣化晶界問題愈來愈明顯，即使它對 IGA/SCC 的影響幾乎可忽略，但極微的含量的確造成類似 Cl^-及 SO_4^{-2}所衍生的劣化現象，從事基本研究目前所獲得的初步結論証明鉛於 280℃的環境中的確無法形成被動膜(Passive film)，而矽土的存在對 pb 的電化學機制也受到影響，因此可能是某些廠 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的興趣。

6.蒸汽循環水化學運轉經驗

影響 PWR 反應器水化學最適化的主要控制因素有*材料劣化 *燃料運作 *運轉因素等(如圖 9)。所有水化學控制的方法均要與上述因素或多或少的受到影響，其中一次側的規範中主要的控制因素近年來已有大的調

整方向，分別說明如下:

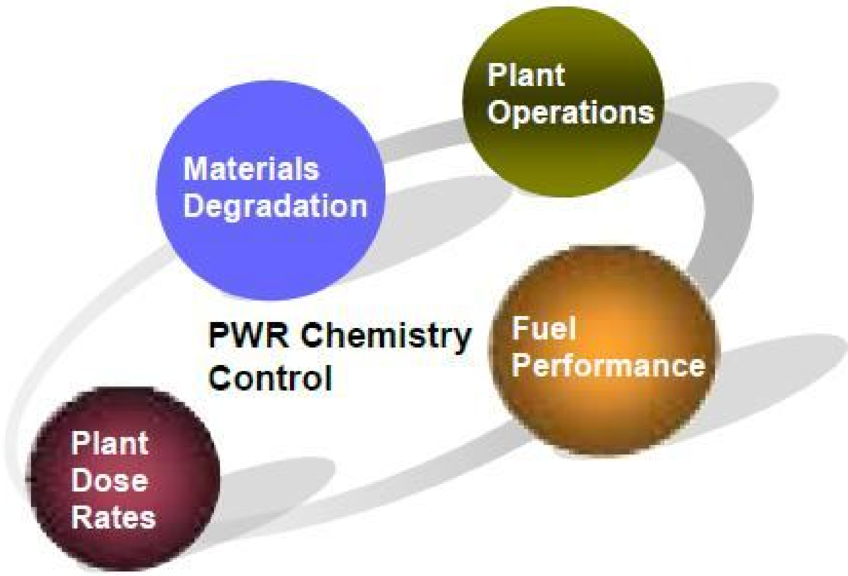


圖 9.影響 PWR 最適化水化學因素

(1)提升 pH_T

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，因此美國電廠近 10 年來 pH_T 的運轉模式朝 pH_T 上升的方向運作(如圖 10)。

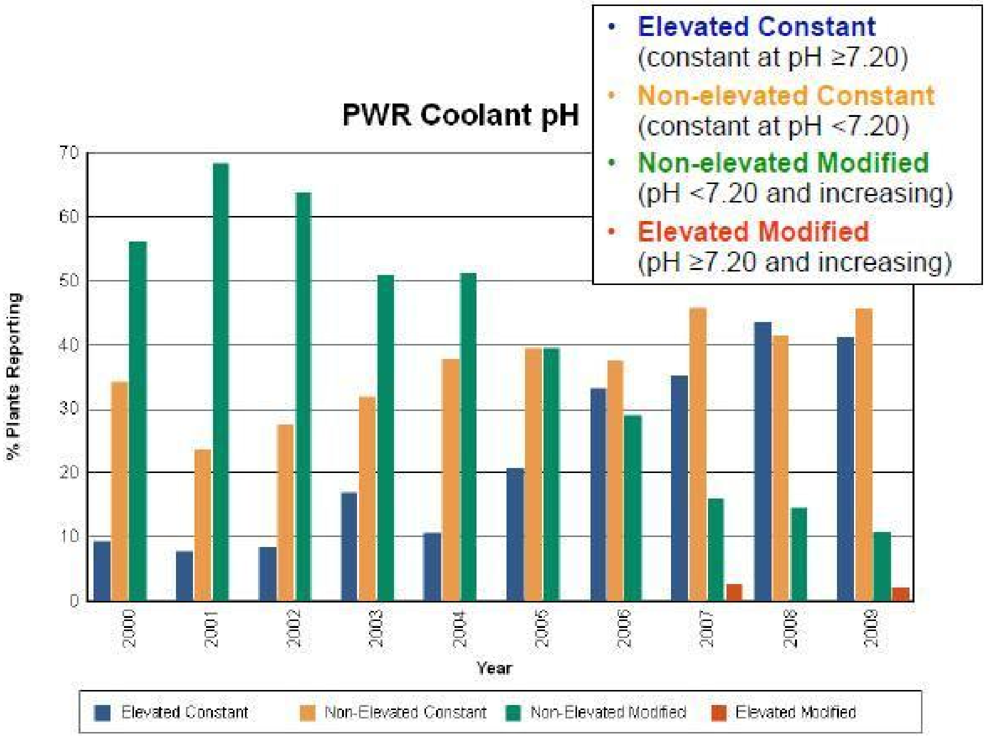


圖 10.美國 PWR 爐水 pH 演進趨勢

(2)氫的最適化

縱使硼鋰和其相關的 pH_T 對裂縫成長速率的影響並不大，但是溶氫的問題對鎳基合金一直是 PWR 非常重要的因素，尤其對 ECP 的影響，不同的溫度環境下必需有抑制 CGR 之基本溶氫量，以充分保持低的 ECP 電位。從圖 11 的電廠實際運轉也發現，溶氫量是朝規範值 25-50ml/kg-H_2O 上限的方向發展，目前已有朝 60ml/kg-H_2O 方向研究及測試。

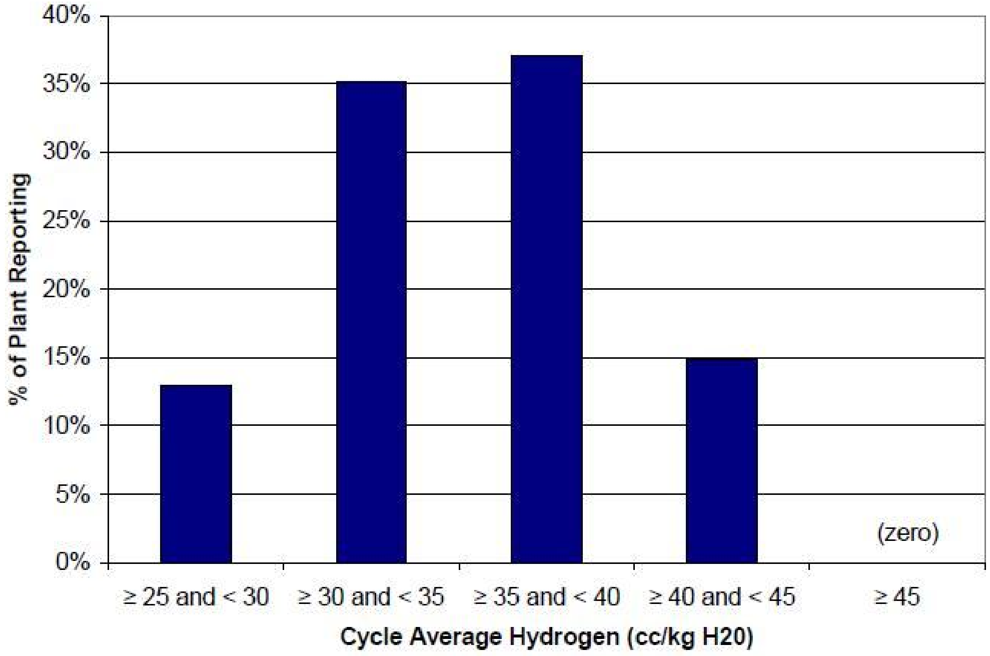


圖 11.PWR 爐水溶氫趨勢

(3)PAA 分散劑之應用

加入 PAA 的目的在於抑制氧化物沈積使 SG 沖放系統更易於有效移除淤泥，此法已於美國 ANO-2(Arkansas Nuclear One-2)廠做過 3 個月的短期測試(Short-Term Trial, STT)及在 Mc Guire-2 作長期測試(Long-Term Trial, LTT)，效果極為良好(如圖 12 所示)。除了在運轉中加入 PAA 之外，也利用 PAA 的特性在起爐的系統沖洗階段加入 PAA 以加速減少沈積及加速移除效率。而在 SG 濕式貯存期也注入 PAA，以改善清洗效果;由表 4 的分析結果研判，三浬島-1(TMI-1)在濕式貯存前加入 PAA 不但在管理上沒有問題，尤其對 Fe 的移除效果也提高很多，所以比利時的 Doel-3 與美國 Braidwood-1 均規劃於今年執行 SG 濕式貯存時注入 PAA，希望能減少爾後化學清洗的機會。PAA 試劑的純度及特性也要有一標準規範，加入 PAA 的濃度通常均<1ppm。

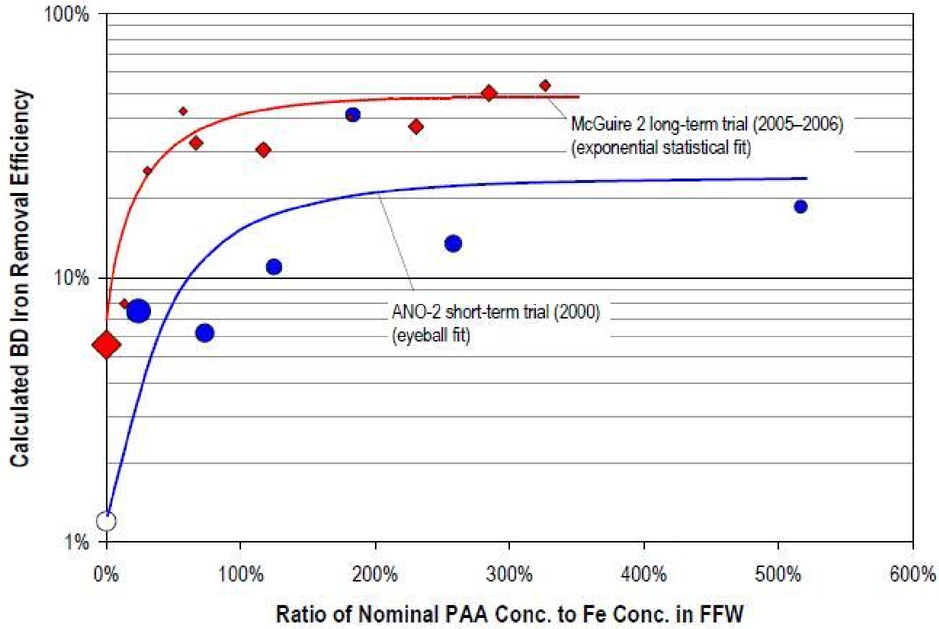


圖 12.SG 沖放鐵移除效率

表 4.TMI-1 濕式貯存洩水樣使用 PAA 後之金屬濃度

OTSG	Date / Time	Iron, ppm	Nickel, ppm	Chromium, ppm	Total Metal, ppm
"A" (with PAA)	11/11/09 16:45	10.93	0.187	0.046	11.16
	11/11/09 20:15	6.96	0.169	0.042	7.17
	11/12/09 19:00	11.86	0.189	0.040	12.09
	11/12/09 22:00	12.65	0.200	0.040	12.89
"B" (without PAA)	11/12/09 00:01	<0.2	----	----	<0.2
	11/16/09 14:50	0.014	----	----	0.014

7.水處理及輔助系統水化學

(1)冷凝器熱井洩漏偵測技術

冷凝器熱井洩漏常造成冷水貯存槽(CST)補水頻度增加及電廠廢液生成量驟增，美國 Peach Bottom-3 電廠使用微量鈉檢測儀置於冷凝泵後端偵測極微量鈉變化，即可掌握冷凝器熱井洩漏及除礦器對鈉之移除效率，此法主要是針對冷凝器軸封洩漏的偵測即時而有效。

(2)生物淤積處理

以海水冷卻的核電廠難以避免遭遇到生物淤積(Bio-fouling)的問題，減少生物膜的方法大都採用加氯處理，主要因為廉價、易處理，但環保因素限制其使用，因此改用二氧化氯(ClO_2)取代，取其不易生成對環境不利的化合物且效率亦佳，僅 0.2ppm 濃度即可達 90%的清除效率，使用 ClO_2 對鈦管、Cu-Ni 90/10 尤佳，表 5 為用 Cl_2 與 ClO_2 的效果比較。

表 5.使用 Cl_2 與 ClO_2 移除效果比較

Condenser materials	Biocidal Regime	% Reduction in treatments compared to controls							
		Biofilm solids		Biofilm org. matter		Total viable count		Slime former count	
		Cl_2	ClO_2	Cl_2	ClO_2	Cl_2	ClO_2	Cl_2	ClO_2
Titanium	Once in 8 h for 1 h	8	18	8	8	23	43	64	54
	Once in 4 h for 1 h	49	87	16	17	16	37	66	68
	Once in 2 h for 1 h	26	37	13	25	32	60	66	72
SS-316L	Once in 8 h for 1 h	21	58	3	7	56	66	22	39
	Once in 4 h for 1 h	9	69	10	16	56	78	13	45
	Once in 2 h for 1 h	1.8	8.8	1.6	70	55	79	55	80
CuNi 90:10	Once in 8 h for 1 h	2.4	-14.5	84	89	17	37	17	13
	Once in 4 h for 1 h	4.9	16	5.3	10	14	59	12	55
	Once in 2 h for 1 h	8.2	-25.3	5.8	4.6	40	77	63	84

8.化學及燃料運作

高燃耗電廠確保燃料運作之水化學最適化，國際原子能總署(IAFA)為確保電廠在高燃耗運作下的燃料完整性，針對水化學提出最適化控制技術(Optimization of Water Chemistry to Ensure Reliable Water Reactor Fuel Performance at High Burn up and in Aging Plant, FUWAC)，於 2006 年 7 月組成 16 人水化學小組，檢視各種反應器水化學與燃料運作之最適化規範，結論分別敘述如下:

(1)西方 PWR 廠

PWR 電廠冷卻水控制在於注入 H_3BO_3、LiOH、H_2、N_2H_4 及 H_2O_2 等化合物，加入之標準隨電廠功率、材質、腐蝕機制數據及放射活性作調整，

而近年來建議採行調和式硼鋰水化學(Coordinated B-Li Chemistry)爲主。加鋅水化學爲近年來相當有效的措施，在德國 Biblis 機組 10 年的加鋅經驗，証明 10-15%的輻射劑抑減目標是值得信賴的，法國電廠的加鋅效益也是正面的(如圖 13)。

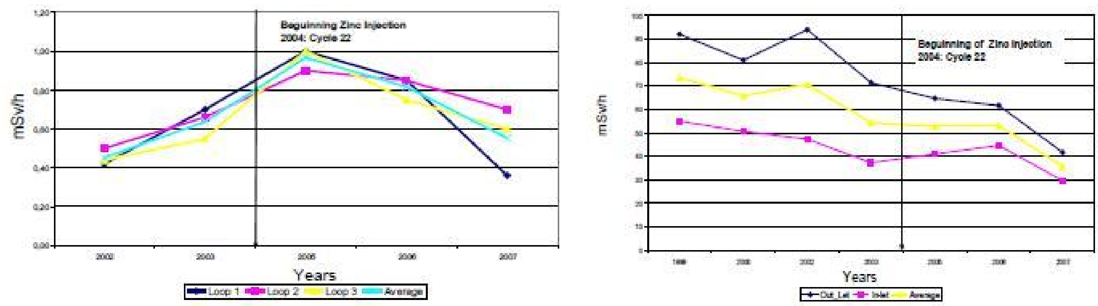


圖 13.法國電廠加鋅後之劑量率變變化

(2)BWR 電廠

西方的 BWR 廠與俄羅斯設計的 RBMK 廠屬於以純水爲冷卻劑，主要的水化學探討爲:*飼水之可溶/不可溶雜質 *爐心輻射分解之 O_2、H_2O_2、H_2 *燃料表面可溶/不可溶沈積與釋入 *淨化系統雜質移除…等。

(3)PWR 運轉期間碘物種形成及行爲

碘是所有電廠中最重要的分裂產物，由於它有高分裂產率、揮發性且對生物造成相當的危險性，所以 PWR 在運轉及停機時 I_2 造成的威脅極大，從模式計算及電廠的驗証說明確認 I^-是運轉中及停機期最主要的物種，在冷卻水中微量碘(< 2%)會轉換成 I^-或 IO_3^-/IO_4^-，取決於氧化條件， 圖 14 爲 ^{131}I 於停機時活度上昇的明顯趨勢，這也是一般 PWR 於注 H_2O_2 後需要移除碘物種的原因。

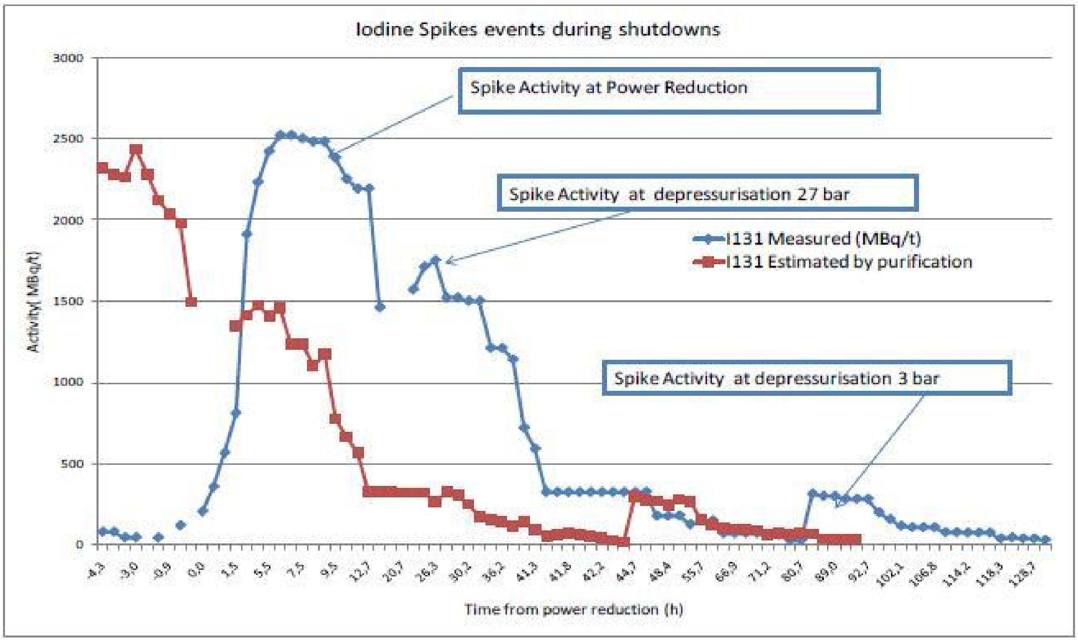


圖 14.PWR 停機 I-131 活度行爲

(4)腐蝕產物於燃料表面的沈積

瑞士 KKL(Kernkraftwerk Leibstadt) 利用 GEM(Gibbs Energy Minimization Selector Code)計算加鋅後，護套表面的鐵氧化物型態與電廠分析相當符合，加鋅後爐水 Ni 含量升高時將使得(Zn,Ni)Fe_2O_4形成機會增加，但在常態水化學時(NWC)，Fe_3O_4(Magnetite)與 FeO (Wustite)形成的可能性極微，而是以α-Fe_2O_3爲主。

9.水化學技術及核電廠運作

(1)水化學最近發展與最佳經驗

各個國家的核能機組除了提升功率外，也考慮作延壽的措施，水化學的角色絕對是不可忽視的，瑞典 ANT(Advanced Nuclear Technology International Europe AB)針對目前世界上各種反應器(PWR、VVER、BWR、CANDU)等的水化學運作，配合電廠及研究室結果提出最佳的水化學運作條件，以 PWR 一次側、二次側及 BWR 等簡述如下，相關的水質改善與最適化技術如圖 15 所示。

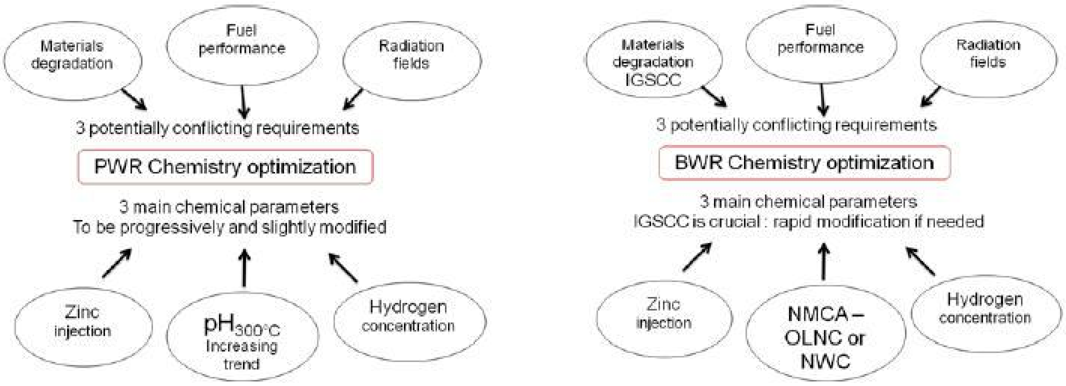


圖.15PWR 與 BWR 水化學最適化

a.PWR 一次側水化學

強調仍以輻射增建、燃料保證及材料腐蝕為主，但近年來高燃耗愈重要，硼之銹垢問題需考慮，改善水質的工具有: $pH_{300℃}$控制、加鋅水化學、溶氫調整、起動與停機水化學改進、化學除污等，其中化學除污為最後考量的方法。

b.PWR 二次側水化學

二次側水化學主要功能有: 減低碳鋼之 FAC、避免淤泥積影響熱傳、避免 TSP 堵塞造成流動感應振盪(Flow Induced Vibration)、減低其他材質的腐蝕。相對應的改善方法有: pH 及溶氧控制、聯胺量控制、替代胺選用(表 6)、化學清洗等，其中化學清洗採用維護性的軟性清洗為佳。

表 6.不含銅合金材質使用胺優缺點比較

	Morpholine	Ethanolamine	Ammonia
Advantages	Coefficient distribution of 1 ➔ constant concentration all over the secondary system	High alkalinity ➔ lower concentration ➔ more favourable for the environment	Easy treatment and monitoring, with potentially only hydrazine added if the ammonia is recycled
	Good protection against FAC and corrosion transport throughout the system at high pH.		No organic acids produced as by products. Thus, no impact on cation conductivity and impurity detection
	Compatibility with the operation of BD resin in exhausted (saturated) form	Low concentration of organic acids produced by thermal decomposition	
Disadvantages	Low alkalinity ➔ very high molar content hardly compatible with condensate polishers.	Partition coefficient < 1 ➔ non-homogeneous protection for the various parts of the secondary system.	Requires a high $pH_{25°C}$ (almost 10) to give sufficient protection against FAC and for corrosion product transport. High nitrogen release into the environment.
	Limited stability ➔presence of some organic acids, increasing the cation conductivity in the SGBD.	Lower possibility of BD resins operation in exhausted form (relative affinity) ➔ lower Na elimination or more frequent regeneration or replacement.	Limited possibility of BD resins operation in exhausted form (relative affinity) and high frequency of regeneration required. Not compatible with condensate polishers.

c.BWR 水化學

BWR 水化學早期是以 SCC 的控制為主，輻射增建為次之，近年來燃料問題破損較多，因此更嚴謹的水化學逐漸被重視，以減少銹垢在護套表的沈積，故有未雨綢繆的水化學策略，相關推動的水質改善方法有(如圖 15)、加氫水化學、加鋅水化學、NMCA(OLNC)、起動及停機水化學控制。

(2)日本 PWR SG 長期完整性策略

日本 Tsuruga-2 商轉於 1987 年，有廿餘年的運轉實績，為了要使電廠維持長期的完整性，除了一次系統，依循調和式水化學外，在二次系統也有相當前膽性的作法，其中以減低鐵氧化物飼入系統的高 pH 策略為特殊，企圖將二次系的水質純度提升外，更擬將飼水鐵自 3～6 ppb 制到 1 ppb，水質標準如表 7 所示。所採取的措施有:含銅材質更換、提高 NH_3濃至 pH=9.8±0.2、加裝前置過濾器、更換碳鋼材質為低合金材質，從圖 16 之結果看來目標是達成了，此作法是可以提供規劃 APWR 系統化學之參考。

表 7.日本敦賀-2 二次系統水質規範

	Feed Water	SGBD
pH(@25°C)	9.8±0.2	9.8±0.2
	9.8	9.7
Fe(ppb)	1	-
	<1	1
Cu(ppb)	0.05	-
	<0.01	<0.02
Na(ppb)	-	<1.0
	<0.1	0.2-0.3
Cl(ppb)	-	<1.5
	<0.1	0.4-0.6
SO4(ppb)	-	0.5
	0.3-0.5	0.5

the manegement target value
the normal value during operation

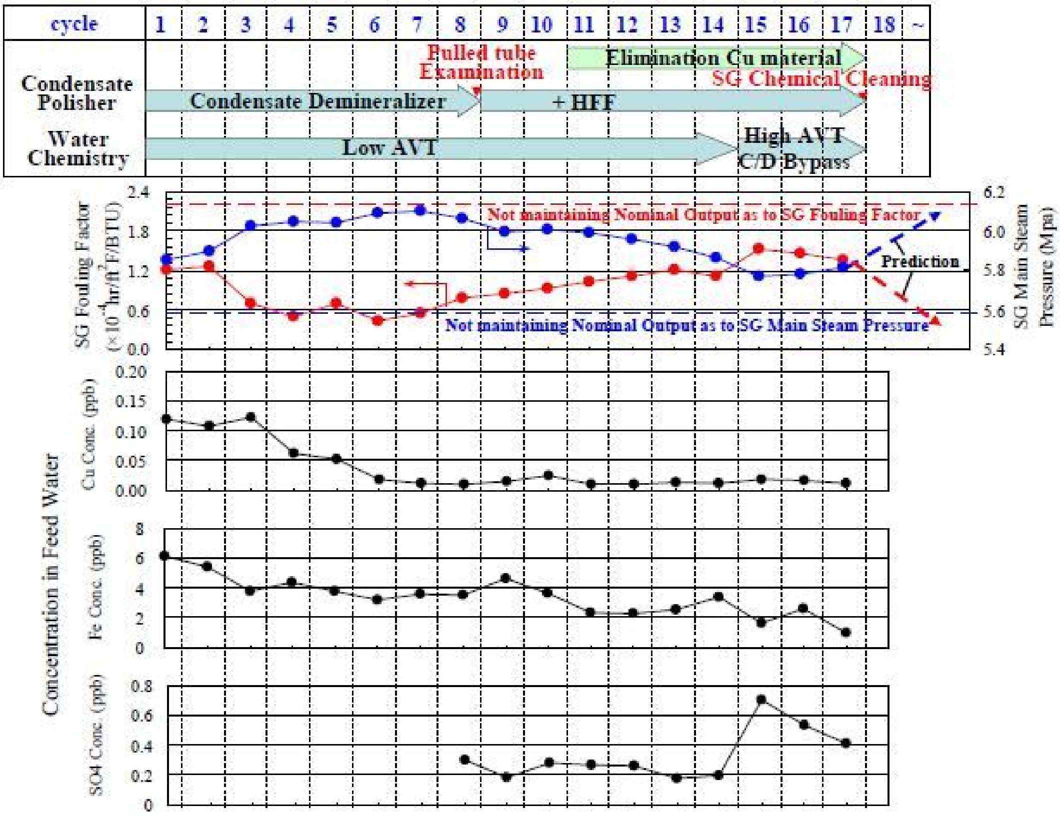


圖 16. 日本敦賀-2 水質改善實績

(3)BWR 化學指引探討

美國 EPRI 於 2008 年 10 月再次完成 BWR 水化學指引之修訂，其中主要的方向還是朝 IGSCC 的問題作調整，特別是希望於 2010 年底達到燃料零破損的目標。而最近 5 年來 BWR 電廠採行 NMCA(或 OLNC)或配合

加鋅水化學者更增加許多，但主要的限制因素為爐水 Co-60(S)/Zn(S) < 2× 10^{-5} μCi/ml/ppb 的問題，特別是飼水鐵偏高且 Co-60 也較高時，燃料沈積與輻射增建的雙重威脅不容小覷，圖 17 為目前全世界 BWR 電廠採行化學策略的電廠統計，加鋅水化學一直是穩定增加中，而從電廠運作的實績來看，爐水導電度的改善空間並不大，反而飼水不溶鐵(圖 18)尚有相當大必要性，此可供國內 BWR 機組參考。

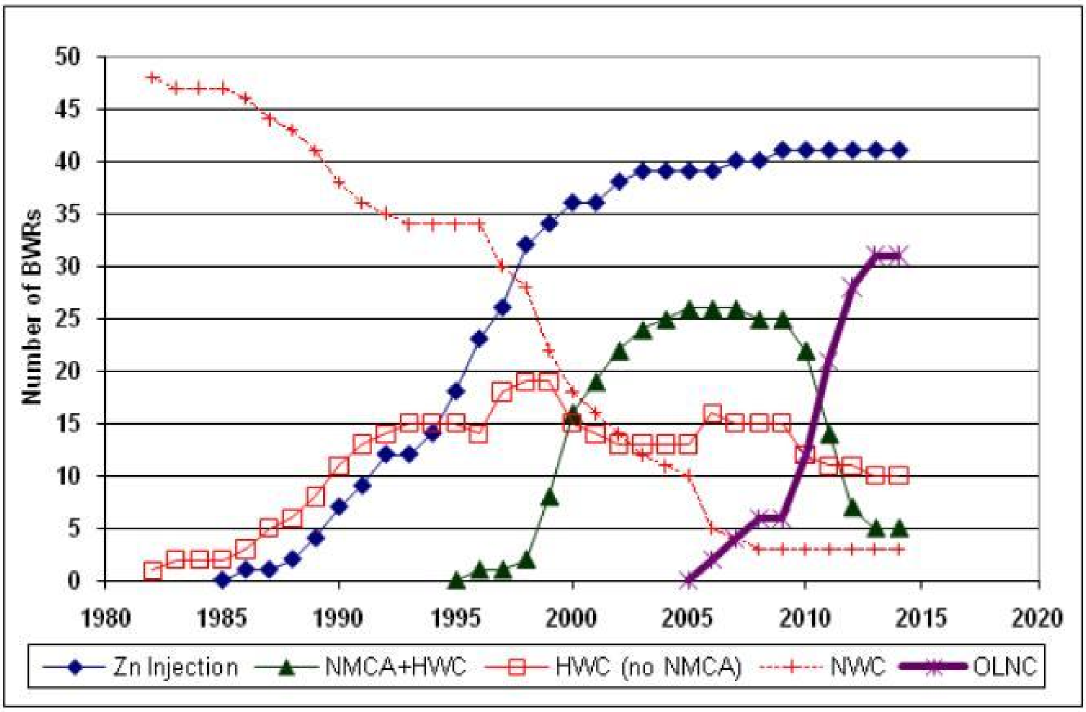


圖 17.BWRs 機組水化學應用趨勢

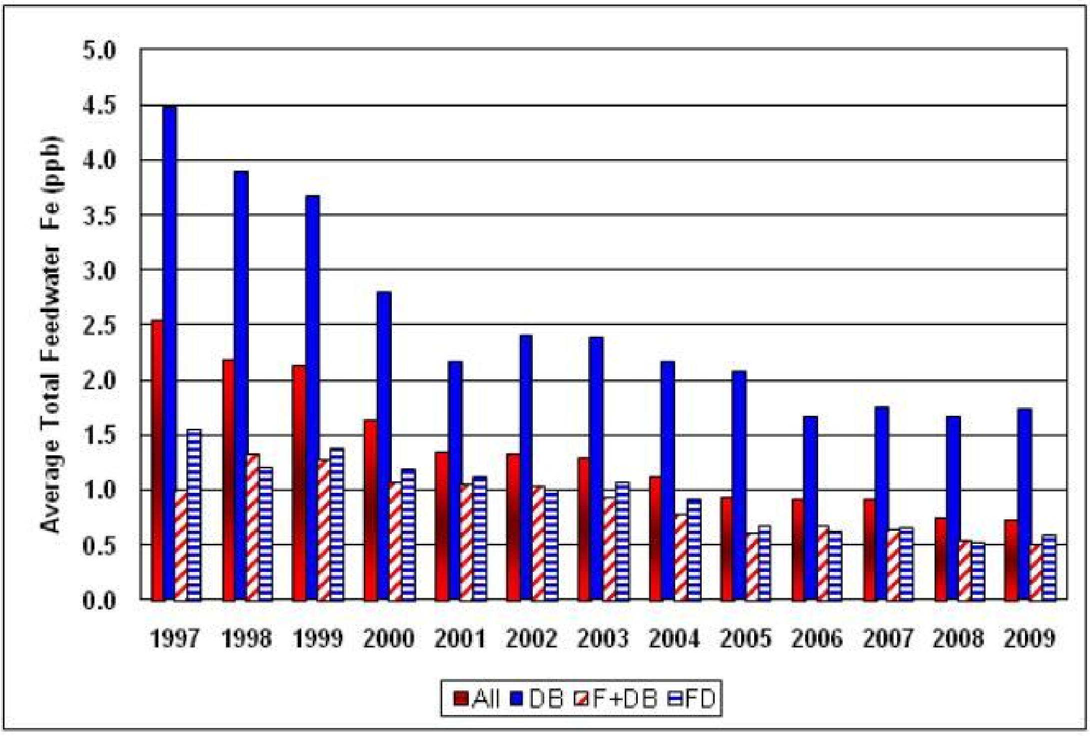


圖 18.BWRs 機組飼水不溶鐵改善趨勢

10.清洗及除污

(1)法國電廠清洗經驗

自 2007 至 2008 年兩年間，法國 EDF 電力公司 PWR 電廠總共有六個蒸汽產生器進行不加抑制劑的化學清洗，這些 SG 執行化學清洗的原因主要是避免管支持板(Tube Support Plate, TSP)受到淤泥堵塞而引起管破裂的問題，熱效率的回復是次要目的。採行的化學清洗方法是以美國 EPRI SGOG 所開發的方法，然後法國也於 2008 至 2010 年採用同樣的方法針對 Curas-3，Cruas-2 Belleville-1，Cattenom-1，Cattenom-3，Chinon B-3 及 Cattenom-3 等 7 個機組作化學清洗，平均每個機組清洗出 1100-4500kg 不等的沈積物，配合淤泥清洗(sludge lancing)後，TSP 堵塞的問題全部解決，以 7 個機組所採用的低溫化學清洗方法對四葉形管支持流孔區(Quatrefoil hole)之淤泥移除效果極佳，雖然在整體效果上很好，法國電廠考慮到此種方法在程序時間及成本上較不利，因此將於 2011 年開始擬採用西屋公司發展的 ASCA(Deposit Minimization Treatment)方法於 Gravelines-5 機組採行，同時也將 DMT AREVA 的軟性化學清洗應用到其他機組，表 8 為以

EPRI SGOG 所移除各個機組 SG 之沈積物總量平均達 3200kg。

表 8. 法國電廠 SG 化學清洗移除之沉積量

Removed Deposits [kg/SG]	Magnetite+ Zn0 dissolved	Copper dissolved	lancing	Total Removed	Max predicted
Cruas 3	2808	190	498	3496	4228
Cruas 2	3531	215	521	4267	4181
Belleville 1	1424	68	1451	2943	3125
Cattenom 1	2361	126	1192	3679	3100
Cattenom 3	1650	43	730	2423	3025
Chinon B3	2809	97	1511	4417	3967
Cattenom 4	905	42	145	1091	3100

雖然化學清洗是 PWR SG 在運轉一段時間後可能面臨的問題，但在執行化學清洗前也要針對下列問題作規則及研判評估，*SG 內淤泥量及組成 *淤泥在 SG 內分布 *現有的或是可能面的腐蝕問題 *產生廢液量及處理問題，對於每個機組之 SG 所採行之化學清洗也要考慮整體的長期效益，若是較輕微的問題只需採用預防性的清洗(Preventive Chemical Cleaning)，另一種治療性清洗(Curative Chemical Cleaning)則甚少使用，在整個 SG 生命週期僅可能使用 1～2 次，歐洲 AREVA 近年開發一種軟性清理技術 AREVA DMT 除了清洗效率極高、有極低的腐蝕率、不使用有毒物外，產生極低的廢料是一大特色。

(2)除污技術精進

CAN-DECON 於 1960 年末期開發後，於 1975 年再次應用於 Douglas Point 機組進行全系統除污，由於它對碳鋼材質較為不利，且除污後生成之廢液量多，而除污因子(DF)也不佳，因此經過數次改良而有 CAN-DEREM 和 CAN-DEREN Plus 等方法，CAN-DECON 主要含有 EDTA、Citric acid 及 Oxalic acid，而 CAN-DEREN 將 Oxalic acid 去除，CAN-DEREN Plus 則是針對高氧化物的系統進行除污，不論如何三種除污方法均屬於還原性(Reducing)方法，適用於 CANDU、PWR 及 BWR 反應器，為了提升 DF 值，仍將持續開發具氧化能力的除污方式，目前正在實驗中。

日本在化學除污方面雖然沒有新開發的除污方法，但是在除污後對

於系統表面的前理試圖有所突破，日立公司以減少 ^{60}Co 再染污的技術，配合加鋅水化學的測試，達到極佳的除污效果，開發此法的要件為*化學劑不能導致 SCC 且要形成 Ferrite film *薄膜形成後試劑需能分解，以減少廢料 *薄膜形成不需另備除污設施，相關設備如圖 19 所示，此種抑制 ^{60}Co 沈積的方法即所謂的 Hi-F Coat。從圖 20 的 SEM 看來，Hi-F Coat 並不會影響材質表之型態，而具有阻隔 ^{60}Co 沈積的作用。

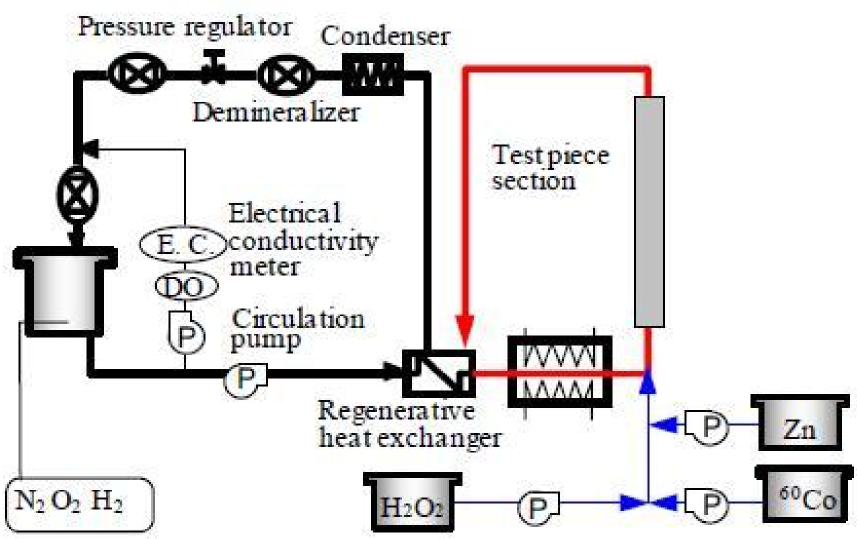


圖 19.Hi-F 預氧化及沉積測試環路

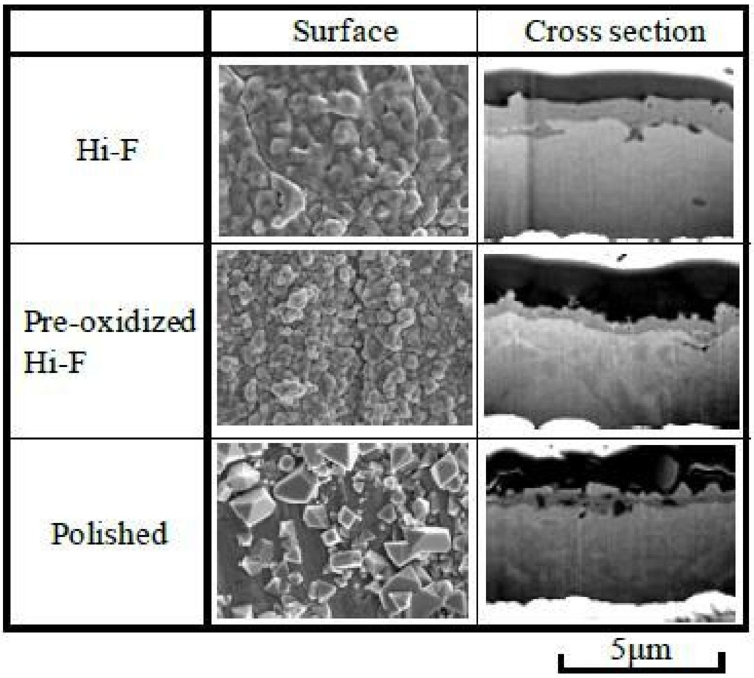


圖 20. Hi-F 技術處理樣品之 SEM 圖

11.水化學未來發展

(1)超臨界水反應器

雖然核能已有復甦跡象，除了將現有反應器提升功率外，建新反應器提高熱效率仍是要追求永續能源的目標之一，新一代的反應器所要的需求目標:安全性、廉價(< $1000/KWt-h)，環境政策符合、具經濟效益，符合上述條件者，超臨界水反應器(Supercritical Water-Cooled Reactors, SCWR)是選項之一，且符合第四代反應器(Gen-IV)之要求。SCWR 最大的挑戰除了燃料之材質選用及壽命考量外，也要考慮系統材質及水化學問題，畢竟在超臨界水(壓力 > 22.12 MPa、溫度 > 374.3℃)環境，目前所有 PWR、BWR 所面的環境問題均不足以克服，但從世界各國針對 SCWR 材質與水化學相關的研究看來，似乎也可找出有關的方向，初規劃爲*使用極純之中性水質 *水質處理技術爲全流量且具有特殊高溫過濾器 *使用鈦金屬冷凝管 *可藉注入 H_2、NH_3 及 N_2H_4 等抑制輻射分解 *可經由注鋅抑制輻射沈積。雖然 SCWR 之冷卻水基本上是不加入任何非揮發性碳性物質作 pH 控制，但是也有研究發現加入 LiOH 的可能性是存在的。由於腐蝕與沈積仍

是水化學中的重要課題，雖然材質的選用尚未有可被信賴的結果，但從各種研究研判 Fe_3O_4 的問題仍可能在 SCWR 中顯現，圖 21 爲 Fe_3O_4 與 LiOH 在 SCW 條件下所作的溶度測試結果，要將大部份可能被選用爲 SCWR 材質之腐沈積與水質關係完成後，方可能定出一被接受的水化學條件或採行方式。

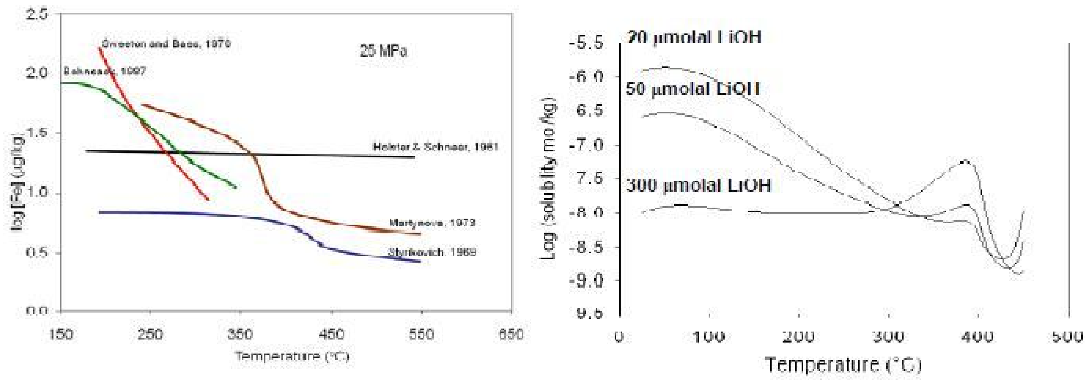


圖 21.高溫時 Magnetite 在水中之溶解度

(2)Gen Ⅲ+ BWR 反應器

目前於歐洲運轉中的 BWR 電廠期有 12 個機組採用爐內強制循環系統(Internal forced-circulation system)，這種設計的反應器目前仍採行標準的常態水化學概念，在德國持續運轉的六個機組中(如表 9)其水質規範爲依循 VGB 之水化學指引(如表 10);到目前爲止這些機組的運轉實績相當優良，因此在 1995 年中德國 Simemns/KWH(現今的 AREVA)依據此型的概念設計 KERENA 反應器(如圖 23) ，KERENA 反應器在水化學方面的特色爲*RWCU 系統爲低壓設計且具有過濾功能*沒有加氫設計。

表 9 德國 BWR 電廠具爐內強制循環系統之機組[1)]

Siemens KWU Sister Unit Groups	Plant Unit	Country	Power [MW_{el}] [1)]	
			Gross	Net
S00	Lingen	Germany	240	
	Würgassen	Germany	650	
S69	Brunsbüttel	Germany	806	771
	Isar 1	Germany	912	878
	Philippsburg	Germany	926	890
	Krümmel	Germany	1402	1346
S72	Gundremmingen B	Germany	1344	1284
	Gundremmingen C	Germany	1344	1288

表 10. 德國 BWR 電廠 VGB 之水化學規範

Control Parameter	Normal Operating Value	Action Level 1	Action Level 2	Action Level 3
Conductivity (25°C) µS/cm	< 0.15	> 0.25	> 1	> 5
Chloride µg/kg	< 2	> 5	> 20	> 50
Sulfate µg/kg	< 5	> 10	> 40	> 100
Diagnostic Parameter				
Silica µg/kg	< 200	--	--	--

Thermal power	3,370 MW_{th}
Net power	1,250 MW_e
Efficiency	37 %
Fuel type	ATRIUM™ 12A
Fuel elements	664
Control rods	157
Active height of core	3.0 m
Average power density	51 kW/l
RPV height	23.81 m
RPV inside diameter	7.12 m
System design pressure	88 bar
Forced-circulation pumps in RPV	8
Design lifetime	60 years

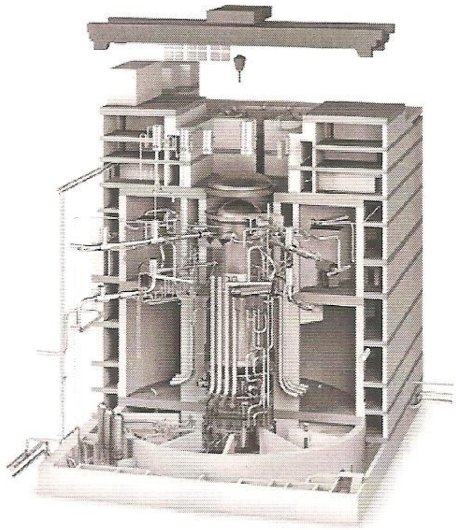


圖 22.KERENA 反應器主要設計資料

(3)新電廠水化學規範評估

美國電力研究所對 BWR、PWR 等電廠的水質規範都會每隔兩年左右根據各機組運轉實績或實驗室研究結果作適度調整或修正,並提出一套控制策略與管理措施，從 2010 年開始 EPRI 著手依據 DCD (Design Control Documents), COLA (Combined Construction and Operating License Application) 和運轉經驗等，擬訂進步型電廠的水化學指引之評估，特別是 GE-Hitachi/Toshiba ABWR 和 Westinghouse AP1000 等，爾後也陸續對 AREVA U.S. EPR、MHI U.S. APWR 及 GE-ESBWR 等進行評估作業。

(二)第八屆輕水式反應器冷卻水輻射分解暨電化學研討會

過去幾屆的研討會中大部份爲討論 BWR 相關之模式，本屆 12 篇報告中有 3 篇討論與 PWR 相關之計算模式。但是本屆與過去最大的不同爲對於超臨界環境下之高溫高壓輻射分解模式之推估及水化學與材料方面的選用特別值得重視，攸關爾後反應器發展之方向。在 PWR 的應用方面，重點仍以一次系統之輻射分解與電化學相關參數作程式計算，所獲得的結果，目前尚未能以實驗數據作驗證，因此仍有待環路或電廠實測值之證明。(會議相關議題內容如附錄 2 所示)

1.PWR 溶氫的重要性

加入氫氣的目的在於維持系統的還原態,加入氫氣至少達到臨界氫濃度 (Critical Hydrogen Concentration, CHC)　$OH + H_2 \rightarrow H + H_2O$ 反應速率要較 $H + H_2O \rightarrow OH + H_2$ 爲快且多才能維持系統於還原態的環境，基本的溶氫量隨溫度而變，此部份已於 4(1)章節中敘述。

2.BWR 計算模式精進

BWR 反應器中之 H2O 分解模式主要因素在於 G-Value, Rate constant ,Dose rate 等，目前模式開發的方向仍朝此三種因素的靈敏度 (Sensitivity)推動，Toshiba 公司並積極與 AECL 所開發之模式結果比較，圖 23 爲使用 AECL 數據所計算而得的 O_2 的 H_2O_2 等濃度略高於 Toshiba 公司開發模式之計算值，但基本上是大同小異在應用上沒有差別。

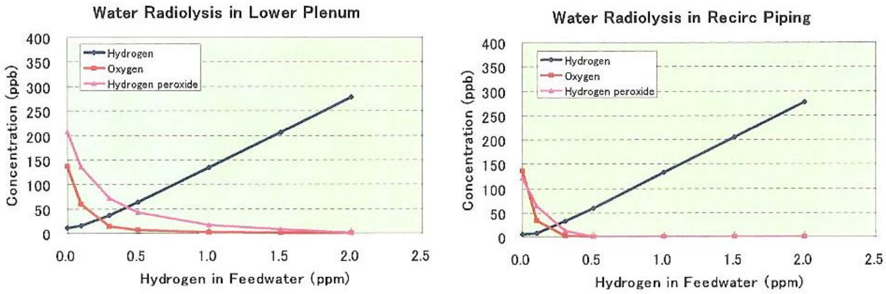


圖 23.加拿大 AECL 與日本東芝模式計算輻射分解氧化物比較

3.超臨界水反應器材料研究

Gen-IV 的六種類型反應器基本上都操作在相對高溫(500～1000℃)的環境下，遠高於現行之輕水式反應器之系統溫度，除了結構材料完整性外，反應器冷卻劑的化學特性也是值得注意的議題。超臨界水反應器(SCWR)冷卻劑會因反應器爐心的中子或加馬輻射照射而出現化學性質變化，SCWR 冷卻劑即有輻射照射分解的問題，產生之 H_2O_2 具有強氧化性，對爐心附近之結構材料及組件造成影響很大，因此研究項目需涵蓋(1)新型耐高溫、抗輻射、抗腐蝕合金研究(2)建立各種實驗迴路，進行材料腐蝕及冷卻劑成分變化研究(3)現有模式修正及新模式開發。

三、心得

(一)發表論文與國外水化學專家交換研究成果

核反應器系統水化學國際學術會議，今年為首次在加拿大舉行，由加拿大核能學會(CNS)主辦，參加的國家多達 30 國，在會議中所發表的論文或展示的壁報論文內容，大都為核能先進國家根據國內外電廠的運轉實績及經驗，配合水化學方面之研究，適時提出值得供人參考及應用的成果;本所發表的兩篇論文均為過去兩年台電委託計畫或自行研究的心得，除多次和與會人士討論內容外，也當場提供水質控制技術，使國外人士進一步瞭解本所及台灣核電廠運轉現況，相當值得欣慰。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。

(二)國外機構跨國研發可作為國內調整及規劃的參考

在會議及壁報論文中，很多是歐、美、日等研究機構彼此推動的跨國計畫，各國目前基於提升功率及延長使用壽命之迫切需求，對反應器水化學的控制技術及管理經驗尤其重視，其中 PWR、VVER 及 PHWR 電廠為歐、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為熱烈。本所在此領域受到經費短缺及人力 不足和斷層因素，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)水化學國際學術會議仍需持續爭取正名

核反應器水化學國際學術會議全名為 Nuclear Plant Chemistry Conference 2010(NPC 2010)，此會議每兩年固定於不同洲舉辦一次，基於客觀環境限制，我國的參加人數僅 5 人，包括本人、清華大學工程與系統科學系葉宗洸教授、清華原科中心王美雅博士、工業技術研究院材料研究所馮克林研究員以及台電公司核二廠環化組王介興先生。本年度會議的主席 Derek Lister 教授致歡迎詞時誤將我國名植為 Taiwan ,A Province of China , 清華大學葉宗洸教授稍後以台灣代表身份起身向所有與會人員澄清「台灣非中國之一省」 經立即反應後，獲得其他多數與會國代表的支持，D.Lister 教授亦於事後向本人及台灣代表道歉(D.Lister 教授曾於 1987 年到本所訪問)，我國惟有更積極參與此一會議，獲得與會國代表肯定，方能避免類似情形再度發生。

四、建議事項

(一)增加水化學研發比重及培育新陣容

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為導向，雖然歷經二十餘年來的經驗累積，本所在系統研究及改善方面可獨當一面的協助電廠解決現場水質提昇與模擬測試及應用方面的問題，但是在程式的開發和應用方面，僅清華大學葉宗洸教授有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，個人曾參與多次水化學國際會議，各國加入的新血甚多，就以日本而言，僅前東京大學石槫教授(Prof. K. Ishigure)、內田教授(Prof. S. Uchida)及 JAPC 之目黒芳紀(Y.Meguro)顧問，其餘近二十餘人均為新人，此與國內現況作比較差異甚多。鑒於石化能源的價格高漲，近年來核能科技相關的研究再度獲得全世界研究機構的重視，這種趨勢可由逐年增加的論文數與國際學術會議觀察出來，在國外年輕的研究人員人數也逐年增加中；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無新血加入，值得加以重視，因此建議若要持續做功率提升、延壽及

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。

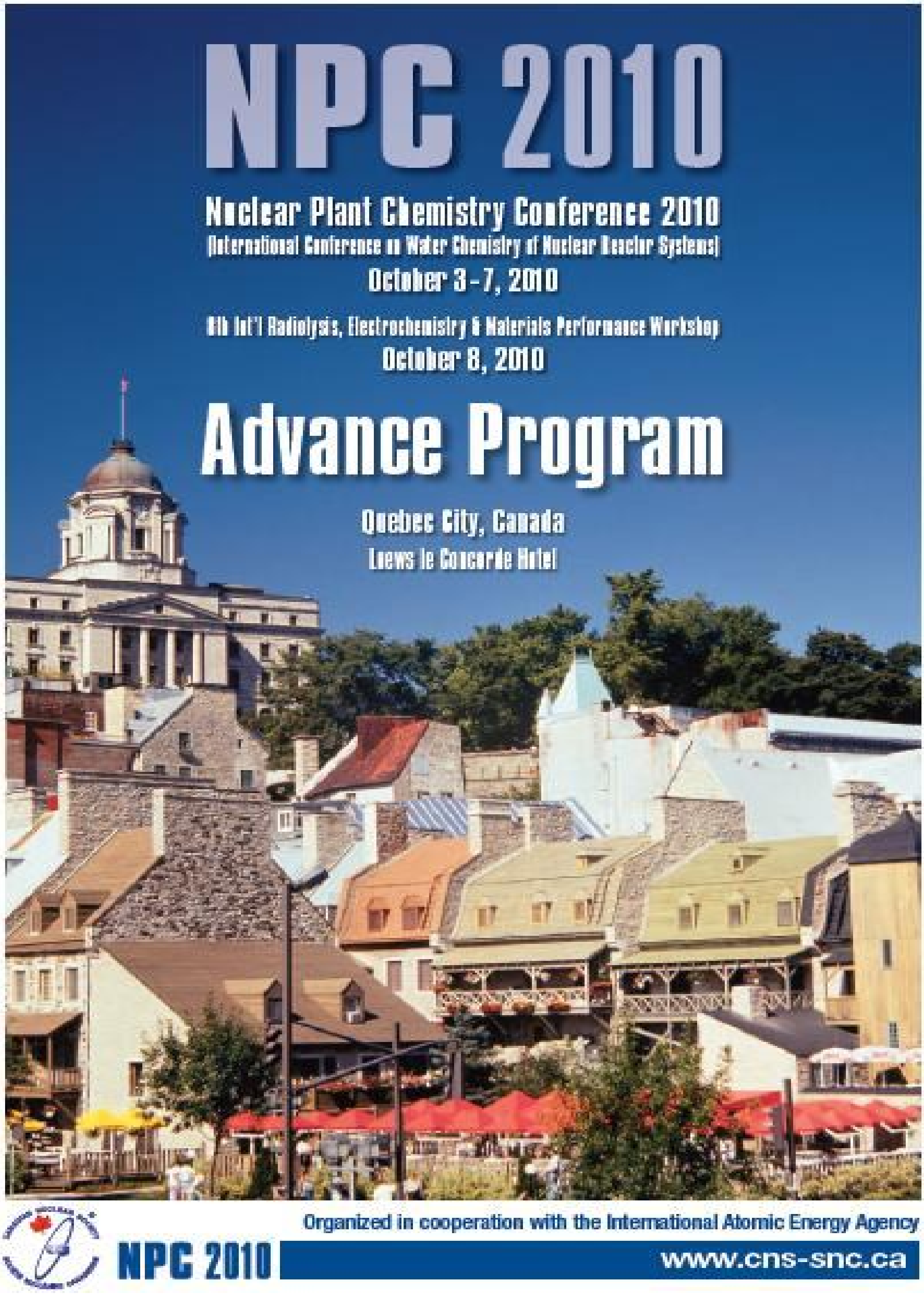
(二)爭取國際學術會議的主辦權要有強大的陣容支持作後盾

參與本次會議另一項重要任務爲台灣爭取 2014 年的水化學國際學術會議主辦權，葉宗洸教授以台灣代表身份臨時擬了一份請願函(如附錄 3)遞送 ICM (International Corresponding Member)Core Member, ICM 會中由主席 Derek Lister 教授逐字宣讀，然而最後投票結果，我方仍不敵有 30 多位代表參加該會議的日本，因此未能順利共同完成爭取 2014 年主辦任務，深感遺憾。

(三)要有持續性的能源政策及核能發電配比

韓國在反應器水化學方面的研究及推動較我國爲晚，十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，今年的國際水化學會議韓國因爲國內核能政策調整，參與會議的人數與論文報告銳減，甚至連 2011 年的亞洲水化學會議也因無經費而放棄主辦改由日本接辦。日本的核能政策目前以提昇功率爲主，老機組除役後在現址增建新型 Gen3+爲輔，長期的規劃上核能發電仍會佔有一穩定成長的比率。國內歷經停建核四的痛楚，在石化等能源價格高漲及全球暖化抑制二氧化碳排放的壓力下，永續能源政策中適度提昇核能發電的配比是必要長期推動的方向，因此加重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有效率的核能發電。

附件一


NPC 2010
Nuclear Plant Chemistry Conference 2010
(International Conference on Water Chemistry of Nuclear Reactor Systems)
October 3 - 7, 2010
8th Int'l Radiolysis, Electrochemistry & Materials Performance Workshop
October 8, 2010
Advance Program
Quebec City, Canada
Loews le Concorde Hotel
Organized in cooperation with the International Atomic Energy Agency
NPC 2010
www.cns-snc.ca

Preliminary Schedule of Events

Nuclear Plant Chemistry Conference

Sunday, October 3, 2010

15:00 – 19:00	Registration
15:00 – 18:00	Poster and Exhibits Set-up
18:00 – 19:30	Welcome Reception

Monday, October 4, 2010

07:00 – 08:00	Speakers-of-the-day Breakfast
07:30 – 17:30	Registration
07:30 – 08:30	Coffee & Pastries Breakfast
08:30 – 09:00	Welcome to the Conference
09:00 – 10:20	Session 1: PWR, VVER and CANDU/ PHWR Operational Experience
10:20 – 10:50	Refreshment Break
10:50 – 12:30	Session 1 (continued)
12:30 – 13:30	Luncheon
13:30 – 15:00	Session 2: BWR Operational Experience
15:00 – 15:30	Refreshment Break
15:30 – 16:30	Session 2 (continued)
17:00 – 18:30	Poster Session Reception - Poster Judging Sessions 1 & 2

Tuesday, October 5, 2010

07:00 – 08:00	Speakers-of-the-day Breakfast
07:30 – 17:30	Registration
07:30 – 08:30	Coffee & Pastries Breakfast
08:30 – 10:40	Session 3: BWR Scientific Studies
10:40 – 11:10	Refreshment Break & Poster Judging Session 3
11:10 – 12:30	Session 4: Aging and Lifetime Management
12:30 – 13:00	Poster Judging Session 4
12:30 – 13:30	Free time
13:30 – 16:30	Quebec City Fall Colours Motor Coach Tour

Wednesday, October 6, 2010

07:00 – 08:00	Speakers-of-the-day Breakfast
07:30 – 17:30	Registration
07:30 – 08:30	Coffee & Pastries Breakfast
08:30 – 10:20	Session 5: PWR, VVER & CANDU/ PHWR Scientific Studies
10:20 – 10:50	Refreshment Break & Poster Judging Session 5A
10:50 – 12:05	Session 5 (continued)
12:05 – 13:00	Luncheon
13:05 – 15:15	Session 6: Steam Cycle Operational Experience
15:15 – 15:45	Refreshment Break & Poster Judging Session 5B
15:45 – 17:00	Session 7: Water Treatment and Auxiliary Systems
17:00 – 18:00	Poster Judging Sessions 6 & 7
18:00 – 21:30	Reception and Banquet

Thursday, October 7, 2010

07:00 – 08:00	Speakers-of-the-day Breakfast
07:30 – 17:30	Registration
07:30 – 08:30	Coffee & Pastries Breakfast
08:30 – 10:00	Session 8: Chemistry and Fuel Performance
10:00 – 10:30	Refreshment Break & Poster Judging Session 8
10:30 – 12:00	Session 9: Chemistry and NPP Performance
12:00 – 13:30	Poster Judging Session 9
12:00 – 13:30	Free Time
13:30 – 15:10	Session 10: Cleaning and Decontamination
15:10 – 15:40	Refreshment Break & Poster Judging Sessions 10 & 11
15:40 – 16:40	Session 11: Future Developments
16:40	Conference Closing Remarks
17:00	Conference Adjourns

Radiolysis, Electrochemistry & Materials Performance Workshop

Friday, October 8, 2010

07:30 – 08:00	Registration
08:10 – 08:50	Session 1
08:50 – 10:20	Session 2
10:20 – 10:35	Refreshment Break
10:35 – 12:05	Session 3
12:05 – 13:30	Luncheon
13:30 – 14:40	Session 4
14:40 – 15:40	Session 5
15:40 – 15:50	Refreshment Break
15:50 – 16:50	Session 6
16:50	Workshop Adjourns

The Nuclear Plant Chemistry Conference

The **International Conference on Water Chemistry of Nuclear Reactor Systems** focuses on the latest developments in the science and technology of water chemistry control in nuclear reactor systems.

What began in the UK in 1977 as the Bournemouth Conference Series has of late been held biennially under the organization of a host country. For 2010, that country is Canada.

The Conference is a forum where utility scientists, engineers and operations people can meet their counterparts from research institutes, service organizations and universities to address the challenges of chemistry control and degradation management of their complex and costly plants for the many decades that they are expected to operate. In 2010 the focus will be on operating experience and the subsequent lessons to be learned, with supporting material on new developments and research.

NPC 2010 follows the successful recent conferences:

NPC 2008
Berlin, Germany, organized by VGB PowerTech

Int'l Water Chemistry Conference, 2006
Jeju Island, South Korea,
organized by KAERI, KNS in co-operation with KHNP

Int'l Water Chemistry Conference, 2004
San Francisco, USA, organized by EPRI

Int'l Conference on Environmental Degradation, 2007
Whistler, Canada, organized by CNS

Quebec City – the Conference will be held in the heart of Old Quebec City, which in 2008 celebrated its 400th anniversary. The city is renowned for its old-world charm, history and fine cuisine and as the centre of the Province's unique and very dynamic culture.

Table of Contents

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Paul Spekkens, *Ontario Power Generation*

Conference General Chair
Derek Lister, *University of New Brunswick*
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Technical Program Chair
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Poster Session Chair
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Conference Registration

See page 31 for the Registration Form, which can be faxed or mailed to the Conference Registrar. For on-line registration go to **www.cns-snc.ca** and click on the Nuclear Plant Chemistry Conference link, then go to the "Registration" link.

Fees for registration are as follows (all in CDN $ and inclusive of all taxes):

	By Aug. 27, 2010	After Aug. 27, 2010
CNS Member	$900	$1,000
Non-member	$1000	$1,100
Full-time Student	$160	$160
Retiree	$200	$250

Registration Fee Includes:

- All taxes
- Participation in all Conference Sessions
- Final Conference Program with Abstracts
- Advance Conference Proceedings CD (provided on-arrival)
- Final Conference Proceedings CD (mailed post-conference)
- Welcome Reception
- Coffee and Pastries Breakfasts each day
- Luncheons on Monday and Wednesday
- Morning and Afternoon Beverage Breaks each day
- Poster Session Reception
- Quebec City Fall Colours Motor Coach Tour (Tuesday afternoon)
- Banquet

Additional Banquet Tickets – for accompanying guests – $125/person.

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See page 31 for the Registration Form, which can be faxed or mailed to the Conference Registrar. For on-line registration go to **www.cns-snc.ca** and click on the Nuclear Plant Chemistry Conference link, then go to the "Registration" link.

Fees for the Workshop registration are as follows (all in CDN $ and inclusive of all taxes):

Registration	$200
Full-time Student	$40

Workshop Registration Fee includes: all taxes, participation in all Workshop sessions, Workshop Program with Abstracts, Workshop Proceedings CD (mailed after the Workshop), Coffee and Pastries Breakfast, Morning and Afternoon Beverage Breaks and Luncheon.

International Corresponding Members

Maurizio Chocron, CNEA	Argentina
Coralie Goffin, LABORELEC	Belgium
Ubirahy Caldeira da Silva de Souza, Electronuclear	Brazil
Katya Minkova, Kozloduy NPP – EAC	Bulgaria
Derek H. Lister, University of New Brunswick	Canada
W. Zhang, IRIS, China Institute of Atomic Energy	China
Jan Kysela, Nuclear Research Institute REZ plc	Czech Republic
Timo Saario, Technical Research Centre of Finland (VTT)	Finland
Jean-Luc Bretelle, Electricité de France	France
Fred Böttcher, NPP Neckarwestheim	Germany
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Hartmut Venz	Switzerland
F. Chu, Taiwan Power	Taiwan
Alexander Arkhipenko, State Enterprise National Nuclear Energy Generating Company "Energoatom"	Ukraine
Malcolm Pick, Magnox South	United Kingdom
Keith Fruzzetti, EPRI	USA
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Francis Nordmann, (Emeritus)	

Conference Venue

Loews le Concorde Hotel
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Loews Le Concorde Hotel is a luxury, urban property located in the heart of Quebec City. The hotel is ideally located, just 30 minutes from the Jean-Lesage International Airport, and steps away from Old Quebec City.

The hotel is offering Conference and Workshop participants the preferred rate of CAD $235.00/night single or double occupancy, plus applicable taxes. Reservations are to be made directly with the hotel before the cut-off date of September 2, 2010. To ensure your accommodation be sure to book early and provide the Conference Booking Code: **WAT020**.

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Conference Proceedings

Preliminary Conference Proceedings on CD will be provided at the Conference. The Final Proceedings CD will be mailed to all participants following the Conference.

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Cancellation of paid registration must be submitted in writing to the Conference Registrar no later than September 3, 2010. Refunds, less a $105 processing fee will be issued after the conference. No refunds will be provided for cancellation of paid registrations after September 3, 2010.

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Technical Sessions

08:30 **Welcome to the Conference**
Derek H. Lister, *Conference General Chair*

Session 1: PWR, VVER and CANDU®/PHWR Operational Experience

Session Co-Chairs: Derek H. Lister, *University of New Brunswick* and Kenkichi Ishigure, *Japan Radioisotope Association*

09:00 Paper 1.01
Trends in Pressurized Water Reactor Chemistry
Paul Spekkens, *Ontario Power Generation, Honorary Chair*

09:30 Paper 1.02
Zinc Injection Implementation Process at EDF: Risk Analysis, Chemical Specifications, and Operating Procedures
Arancha Tigeras and Agnes Stutzmann, *EDF-CEIDRE*; Oystein Bremnes, *EDF/R&D/MFEE;* Miriam Claeys, *EDF/DCN;* Gilles Ranchoux and Jean-Claude Segura, *EDF/SEPTEN;* Josselin Errera and S. Bonne, *EDF/UTO*

09:55 Paper 1.03
The Impact of Steam Generator Replacement on PWR Primary System Contamination
Frédéric Dacquait and Hervé Marteau, *CEA, DEN;* Luc Guinard and Gilles Ranchoux, *EDF/SEPTEN;* Stéphane Taunier and Matthieu Wintergerst, *EDF/CEIDRE;* Jean-Luc Bretelle and Alain Rocher, *EDF/UNIE*

10:20 **Refreshment Break**

Session Co-Chairs: Warren Mawhinney, *New Brunswick Power Nuclear* and Fred Böttcher, *EnBW Kernkraft GmbH*

10:50 Paper 1.04
Dose Rate and Contribution of the Nuclides on the Primary Components During Shutdown Chemistry in Beznau NPP
Irene Mailand and Patrick Franz, *Axpo AG, Nuclear Power Plant Beznau*

11:15 Paper 1.05
Primary Chemistry as an Action Lever to Reduce the Source Term. Review of the Experience at Doel 3 and 4
Philippe Schnongs and Raphael Lecocq, *Laborelec;* Alain Minne and R. Wyckmans, *Electrabel GDF Suez;* E. Girasa, *GDF Suez*

11:40 Paper 1.06
Corrosion Particles in the Primary Coolant of VVER-440 Reactors
Nora Vajda and Zs. Molnár, *RadAnal Ltd.*; Zs. Mácsik, É. Széles and P. Hargittai, *Isotope Institute of the Hungarian Academy of Sciences;* A. Csordás and T. Pintér, *Atomic Energy Research Institute of the Hungarian Academy of Sciences;* T. Pintér, *Paks Nuclear Power Plant*

12:05 Paper 1.07
Corrosion Products Behavior and Source Term Reduction: Guidelines and Feedback for EDF PWRs, Concerning the B/Li Coordinations and Steam Generators Replacement
Stéphane Taunier, Matthieu Wintergerst and Odile de Bouvier, *EDF – Ceidre*; Cédric Pokor and Florence Carrette, *EDF R&D*; Aki Toivonen, *VTT Technical Research Centre of Finland, Industrial Systems*; Gilles Ranchoux, *EDF – SEPTEN*; Jean-Luc Bretelle, *EDF UNIE*

12:30 – 13:30 **Luncheon (provided) and Poster Session**

PWR, VVER and CANDU®/PHWR Operational Experience Posters

Poster 1.08
Embalse Modifications in the Water Chemistry for PLIM. Plant Experience and Design Manual Updated Issue
Mauricio Chocron, Leandro Hornos, Marina Strack, Ivanna Rodriguez, *Comisión Nacional de Energía Atómica*; Narciso Fernández, Raul Manera, Diego Quinteros, Luis Ovando, Ricardo Sainz, *Central Nuclear Embalse, Nucleoeléctrica Argentina S.A.*

Poster 1.09
Feasibility of the Injection of H_2 in the Primary Coolant of Atucha II Nuclear Power Plant
Mauricio Chocron, *Comisión Nacional de Energía Atómica*; J. Duca, M. Guala, R. Fernandez and Betina Schonbord, *Nucleoelectrica Argentina S.A., Central Nuclear Atucha II*; Joerg Fandrich, U. Ramminger and F. Roumiguiere, *AREVA NP, STC-G*; Hans-Jürgen Sell, *AREVA NP, FDWM-G*

Poster 1.10
Experience of Oil in CANDU® Moderator During A831 Planned Outage at Bruce Power
Guoping Ma, Rod Nashiem and Shane Matheson, *Bruce Power*; Craig Stuart, *Atomic Energy of Canada Limited*; John G. Roberts, *CANTECH Associates Ltd.*

Poster 1.11
Development of a Modified Ion Exchange Resin Column for Removal of Gadolinium from the Moderator System of PHWRs
Padma Sasikumar, S. Velmurugan and S.V. Narasimhan, *BARC Facilities, Water and Steam Chemistry Division*

Poster 1.12
Reduction in Cobalt Ingress from Fuelling Machine Stellite Wear Products into Primary Heat Transport System: Results from Modeling Assessment of Ion Exchange Clean-Up
Stephen Strikwerda, Aamir Husain and Yury Verzilov, *Kinectrics Inc.*; Tom Wong and Lee Wells, *Ontario Power Generation*

Poster 1.13
Effect of Octadecylamine Microadditives (ODA) on Reducting Local Corrosion Damages of Steam Generating Equipment Heating Surfaces
A.A. Avdeev, A.N. Kukushkin and D.A. Repin, *Russian Institute of Nuclear Power Engineering (VNIIAM)*; V.V. Omelchuk, L.F. Barmin, *Kola Nuclear Power Plant*; Victor A. Yurmanov, *N.A. Dollezhal Research and Development Institute of Power Engineering (NIKIET)*; E. Czempik, *REICON GmbH*

Poster 1.14
The Benefit of Specialty Macroporous Resins in the Nuclear Power Plant Operations
Terry Heller and Claude Gauthier, *The Purolite Company*

Poster 1.15
Zinc Injection from Hot Functional Test (HFT) in Tomari Unit 3
Hitoshi Hayakawa, Yoshitaka Mino, Satoshi Nakahama and Yamato Aizawa, *Hokkaido Electric Power Company*; Takao Nishimura, Ryuji Umehara, Yuichi Shimizu, Noritaka Kogawa and Zenjiro Ojima, *Mitsubishi Heavy Industries, Ltd.*

Poster 1.16
Primary Chemistry Response to Initial Zinc Injection
Chuck R. Marks and Matt Dumouchel, *Dominion Engineering, Inc.*; Carey Haas, *Electric Power Research Institute*

Poster 1.17
Corrosion Product Balances for the Ringhals PWR Plants Based on Extensive Fuel Crud and Water Chemistry Measurements
Klas Lundgren and Gunnar Wikmark, *ALARA Engineering AB*; Bernt Bengtsson, *Ringhals AB*

Poster 1.18
Improvement Factors for Steam Generator Tubing Alloys
Samuel Choi, *Electric Power Research Institute*; Chuck R. Marks, Carly E. Anderson, Matt Dumouchel and Jeffrey A. Gorman, *Dominion Engineering, Inc.*

Poster 1.19
Prospects for Zinc Injection in Russian Design Reactors
Victor A. Yurmanov, *ENES/NIKIET - Engineering Center of Nuclear Equipment Strength, Reliability and Lifetime*; V.N. Belous and E.V. Yurmanov, *NIKIET - N.A. Dollezhal Research and Development Institute of Power Engineering*; S.V. Filimonov and D.V. Timofeev, *FSUE "Production Association "Electrochemical Plant"*

Poster 1.20
Experience with Chemistry Control of Primary Circuit and Operation of High Temperature and High Pressure Mechanical Filtration at Temelin VVER-1000/320 NPP
Miroslav Martykan and Zdenka Pavkova, *ČEZ a.s., Temelin NPP*

Poster 1.21
Gadolinium Depletion Event in a CANDU® Moderator – Causes and Recovery
David W. Evans, J. Price, D. Swami, E. Fracalanza, M.E. Brett, F.V. Puzzuoli and A. Garg, *Ontario Power Generation*; O. Herrmann and Andreas Rudolph, *Kinectrics Inc.*; Craig R. Stuart and Glenn Glowa, *Atomic Energy of Canada Limited*; Jeremy Smee, *Niagara Technical Consultants*

Poster 1.22
Operation Experience with Elevated Ammonia
Katerina Vonkova, V. Svarc and Jan Kysela, *Nuclear Research Institute Rez plc*; M. Malac and I. Petrecky, *ČEZ-EDU, NPP Dukovany*

Poster 1.23
Hot Functional Test Chemistry – Long Term Experience
Katerina Vonkova and Jan Kysela, *Nuclear Research Institute Rez plc*; P. Marcinsky, *ENEL-SE, NPP Mochovce*; M. Martykán, *ČEZ-ETE, NPP Temelin*

Session 2: BWR Operational Experience

Session Co-Chairs: Craig R. Stuart, *Atomic Energy of Canada Limited* and Keith Fruzzetti, *Electric Power Research Institute*

13:30 Paper 2.01
Water Chemistry Control Practices and Data of the European BWR Fleet
Bernhard Stellwag, Alexander Laendner and Steffen Weiss, *AREVA NP GmbH*; Frank Huettner, *Vattenfall Europe Nuclear Energy GmbH*

14:00 Paper 2.02
BWR Startup and Shutdown Activity Transport Control
Susan E. Garcia, *Electric Power Research Institute*; Joseph F. Giannelli and Alfred J. Jarvis, *Finetech, Inc.*

14:20 Paper 2.03
Review of Water Chemistry and Corrosion Products in a NWC Plant Transitioned to Hydrogen Injection and OLNC
Lena Oliver, Britta Helmersson and Eva Fredriksson, *Westinghouse Electric Sweden AB*; Guido Ledergerber and Wilfried Kaufmann, *Kernkraftwerk Leibstadt (KKL)*; Gunnar Wikmark, *Alara Engineering AB*; Bo Cheng and Aylin Kucuk, *EPRI*

14:40 Paper 2.04
Water Chemistry Improvements in an Operating Boiling Water Reactor (BWR) and Associated Benefits
Samson Hettiarachchi, *GE-Hitachi Nuclear Energy, Vallecitos Nuclear Center*; Christoph Weber, *BKW FMB Energie AG, Kernkraftwerk Mühleberg*

15:00 **Refreshment Break**

Session Co-Chairs: Ram Kameswaran, *Canadian Nuclear Safety Commission* and John C. Killeen, *International Atomic Energy Agency*

15:30 Paper 2.05
The Technical Basis for Limiting Copper in the BWR Primary Coolant
Robert L. Cowan, *EPRI Consultant*; Susan E. Garcia, *EPRI*

15:50 Paper 2.06
Mobile Crud and Transportation of Radioactivity in BWR
Hans-Peter Hermansson, *Studsvik Nuclear AB and Division of Chemical Engineering, LTU*; *Jimmy Hägg, Ringhals AB*

16:10 Paper 2.07
Accurate Feedwater Iron Control for Dose Rate Reduction by Advanced Resin Cleaning System in Tokai-2
Hiroyuki Sasaki, Eiichi Kadoi and Hidehiro Tobita, *Japan Atomic Power Company*

16:30 **Adjourn**

17:00 – 18:30 **Poster Session Reception**

Monday, October 4, 2010

BWR Operational Experience Posters

Poster 2.08
Application of Hi-F Coat to Reduce Recontamination at Shimane Unit 1
Makoto Nagase, N. Usui and S. Oouchi, *Hitachi-GE Nuclear Energy, Ltd.*; Hideyaki Hosokawa, *Hitachi, Ltd*; H. Kajitani, A. Yamashita and T. Minami, *The Chugoku Electric Power Company, INC*

Poster 2.09
The Alkaline Pre-filming Process on the RWCU Piping Surface
Dah-Yu Kao and Tung-Jen Wen, *Atomic Energy Council, Institute of Nuclear Energy Research*; Clinton Fong, *Industrial Technology Research Institute*; Ju-Huang Lu, *Taiwan Power Company, Lungmen Nuclear Power Plant*

Poster 2.10
Reactor Water Chemistry Control
A.K. Kundu, *Nuclear Power Corporation of India Limited, Tarapur Atomic Power Station 1 & 2*

Poster 2.11
Radiation Levels at Boiling Water Reactors of a Commercial Nuclear Power Plant Fleet
Andrew D. Odell and K.E. Russel, *Exelon Generation*; Mary L. Jarvis, *Finetech Inc.*

Session 3: BWR Scientific Studies

Session Co-Chairs: Clara J. Wren, *The University of Western Ontario* and Shunsuke Uchida, *Japan Atomic Energy Agency*

08:30 Paper 3.01
Formation and Application of Nano Noble Metal Particles to Mitigate Stress Corrosion Cracking in BWR
Young-Jin Kim and Peter L. Andresen, *GE Global Research Center;* Samson Hettiarachchi, *GE Hitachi Nuclear*

09:00 Paper 3.02
Effect of Two Impurities and Zinc on Stress Corrosion Cracking of Stainless Steel and Nickel Alloys in BWR Environments
Barry M. Gordon, *Structural Integrity Associates, Inc.;* Susan E. Garcia, *Electric Power Research Institute*

09:25 Paper 3.03
New Model of Cobalt Activity Accumulation on Stainless Steel Piping Surfaces Under Boiling Water Reactor Conditions
Kazushige Ishida, *Hitachi, Ltd., Energy and Environmental Systems Laboratory;* Derek H. Lister, *University of New Brunswick, Department of Chemical Engineering*

09:50 Paper 3.04
Influence of Iron and Nickel Species Upon Activity Build-up Under Simulated BWR Conditions
Sofia Björnsson and Jiaxin Chen, *Studsvik Nuclear AB;* Johan Lejon, *OKG AB;* Göran Granath, *Ringhals AB;* Margareta Tanse-Larsson, *Forsmark kraftgrupp AB*

10:15 Paper 3.05
Electrochemical Behavior of TiO_2 Deposited Stainless Steel in High Temperature Water
Masato Okamura, S. Yamamoto, H. Urata and Junichi Takagi, *Toshiba Corporation*

10:40 **Refreshment Break**

BWR Scientific Studies Posters

Poster 3.06
An Investigation into the Electrochemical Behavior of Oxygen on TiO_2-Treated Type 304 Stainless Steels in High Temperature Pure Water
Tsung-Kuang Yeh, Yu-Jen Huang and Chuen-Horng Tsai, *National Tsing Hua University*

Poster 3.07
Predicted Impact of Power Coastdown Operations on the Water Chemistry for Two Domestic Boiling Water Reactors
Mei-Ya Wang and Tsung-Kuang Yeh, *National Tsing Hua University;* Charles F. Chu and Ching Chang, *Taiwan Power Company;* Jin-Der Lee, *Chin Min Institute of Technology*

Poster 3.08
Thermochemistry in BWR. An Overview of Applications of Program Codes and Databases
Hans-Peter Hermansson, *Studsvik Nuclear AB;* Richard Becker, *Division of Chemical Engineering, LTU*

Tuesday, October 5, 2010

Poster 3.09
Effect of Hydrazine, Carbohydrazide and Hydrogen Injection on Noble Metal Treated Stainless Steel ECP and IGSCC Mitigation During BWR Startups
Stephen G. Sawochka, M.A. Leonard, *NWT Corporation;* Joseph F. Giannelli, *Finetech, Inc.;* Andrew Odell, *Exelon Corporation;* Susan E. Garcia, *Electric Power Research Institute*

Session 4: Aging and Lifetime Management

Session Co-Chairs: Peter Angell, *Atomic Energy of Canada Limited* and Jean-Luc Bretelle, *Electricité de France*

11:10 Paper 4.01
PWR Operation with Elevated Hydrogen
Carey Haas, Richard Reid and Jeff Deshon, *Electric Power Research Institute (EPRI)*

11:40 Paper 4.02
Evaluation of Wall Thinning of PWR Feed Water Piping with the Coupled Model of Static Electrochemical Analysis and Dynamic Double Oxide Layer Analysis
Shunsuke Uchida, M. Naitoh and H. Okada, *The Institute of Applied Energy;* T. Ohira and Hideki Takiguchi, *Japan Atomic Power Co.;* S. Koshizuka, *University of Tokyo;* Derek H. Lister, *University of New Brunswick*

12:00 Paper 4.03
The Mitigation of Flow-Accelerated Corrosion in the Feedwater Systems of Nuclear Reactors – the Influence of Dissolved Oxygen under Different Operating Conditions
Derek H. Lister, A. Feicht, Mahsa Khatibi and L. Liu, *University of New Brunswick, Department of Chemical Engineering;* K. Fujiwara, *Central Research Institute of Electric Power Industry;* T. Ohira, *The Japan Atomic Power Co.;* Shunsuke Uchida, *Japan Atomic Energy Agency*

12:20 Paper 4.04
Corrosion Control for the NRU Reactor Vessel
Craig R. Stuart, David S. Mancey and Michael D. Wright, *Atomic Energy of Canada Limited, Chalk River Laboratories*

12:40 **Adjourn**

13:30 – 16:30 **Quebec City Fall Colours Motor Coach Tour**

Aging and Lifetime Management Posters

Poster 4.05
Zirconium Fuel Cladding Corrosion Prediction in Fuel Assembly Operation Conditions
Vladimir G. Kritsky and Irina G. Berezina, *Leading Institute "VNIPIET"*

Poster 4.06
Mechanistic Study of LPSCC of Stainless Steels - Temperature Dependence of Corrosion in Hydrogenated Water
Takumi Terachi, Tomoki Miyamoto, Takuyo Yamada and Koji Arioka, *Institute of Nuclear Safety System, Incorporated*

Poster 4.07
Potential Dependence of SCC Growth of Cast Stainless Steels and Weld Material in Water
Takuyo Yamada, Takumi Terachi, Tomoki Miyamoto and Koji Arioka, *Institute of Nuclear Safety System, Incorporated*

Poster 4.08
Effect of Carbon Steel Microstructure on High Temperature Aqueous Corrosion
H. Subramanian, V.S. Sathyaseelan, S. Rangarajan, S. Velmurugan and S.V. Narasimhan, *BARC Facilities, Water and Steam Chemistry Division*

Poster 4.09
Investigation of the Noble Metal Deposition Behaviour in Boiling Water Reactors – the NORA Project
Stefan Ritter, Vasil Karastoyanov, S. Abolhassani-Dadras, I. Güenther-Leopald and N. Kivel, *Paul Scherrer Institute (PSI)*

Poster 4.10
Metal Release Reduction in Stainless Steel for LWR
Kiyoko Takeda, *Sumitomo Metal Industries, Ltd., Corporate Research and Development Laboratories;* Hiroyuki Anada and T. Yokoyama, *Sumitomo Metal Industries, Ltd., Special Tube Works*

Poster 4.11
The Effects of Dissolved Hydrogen Contents on the Low Cycle Fatigue Behaviors of a 316LN Stainless Steel in Simulated PWR Conditions
Pyung-Yeon Cho, Changheui Jang, Hun Jang and Jong-Dae Hong, *Korea Advanced Institute of Science and Technology;* Tae-Soon Kim and Jae-Gon Lee, *Korea Hydro & Nuclear Power Co., LTD, NETEC*

Poster 4.12
Investigating the Inhibiting Effect of Sodium Nitrite on Equipment Corrosion
A.A. Zverev, D.A. Kirpikov, M.M. Kostin and Igor V. Miroshnichenko, Oleg Yu. Pykhteev, *Alexandrov Research Institute of Technology*

Poster 4.13
Crevice Chemistry Investigation Using Crevice Model in Real Plant Condition
Anna Hojna, Dalibor Karnik, Marek Postler, *Nuclear Research Institute, Rez;* Ivan Smiesko, *Slovenske elektrarne, NPP Bohunice*

Poster 4.14
Comparison of Iron Measurements: ICP-MS, AAS and UV-Vis-Spectrometry
Michael Bolz, B. Felgenhauer, R. Schorle, Andreas Speck and H. Wacker, *EnBW Kernkraft GmbH*

Session 5: PWR, VVER & CANDU®/PHWR Scientific Studies

Session Co-Chairs: David Evans, *Ontario Power Generation* and Jei-Won Yeon, *Korea Atomic Energy Research Institute*

08:30 Paper 5.01
Modeling Activity Transport in the CANDU® Heat Transport System
David A. Guzonas and Liyan Qiu, *Atomic Energy of Canada Limited, Chalk River Laboratories*

09:00 Paper 5.02
Effect of Shutdown Chemistry on Corrosion Product Release from Oxide Film of Alloy 600
Masafumi Domae and K. Fujiwara, *Central Research Institute of Electric Power Industry*

09:30 Paper 5.03
pH Dependence of H_2O_2 in the Radiolysis of Water
Jay A. LaVerne and Olivia Roth, *University of Notre Dame, Radiation Laboratory;* Simon M. Pimblott, *University of Manchester, School of Chemistry*

09:55 Paper 5.04
The OSCAR Code Package: A Unique Tool for Simulating PWR Contamination
Jean-Baptiste Génin, Hervé Marteau, Frédéric Dacquait, G. Bénier, J. Francescatto, F. Broutin, F. Nguyen, Marianne Girard, L. Noirot, S. Maillard, V. Marelle, A. Bouloré, D. You and Gabriel Plancque, *CEA, DEN;* Gilles Ranchoux, J. Bonnefon, V. Bonelli, *EDF, SEPTEN;* Martin Bachet, *EDF, R&D;* Geoffrey Riot and F. Grangeon, *AREVA NP*

10:20 **Refreshment Break**

Session Co-Chairs: William G. Cook, *University of New Brunswick* and Per-Olof Andersson, *Vattenfall AB*

10:50 Paper 5.05
Correlation Between Ni Base Alloys Surface Conditioning and Cation Release Mitigation in Primary Coolant
Maryline Clauzel, Michael Guillodo, Marc Foucault, *AREVA NP SAS, Technical Centre;* Nathalie Engler, Farah Chahma and Christian Brun, *AREVA NP SAS, Chemistry and Radiochemistry Group*

11:15 Paper 5.06
Results of Experimental Studies and Numerical Modeling of Influence of Water-Chemical Parameters Upon Intensity of Metal Erosion-Corrosion in Single- and Two-Phase Fluid Flows at HPPs and NPPs
Grigoriy V. Tomarov and Andrey A. Shipkov, *JSC "Geotherm-EM"*

11:40 Paper 5.07
The Effect of Hydrodynamics and Solution Chemistry on the Corrosion of Carbon Steel in High-Temperature Water
Uncharat Setthanan, *University of New Brunswick, Department of Chemistry;* David R. Morris and Derek H. Lister, *University of New Brunswick, Department of Chemical Engineering*

12:05 – 13:00 **Luncheon and Poster Session**

PWR, VVER & CANDU®/PHWR Scientific Studies Posters

Poster 5.08
Verification of Computer Code for Calculation of Coolant Radiolysis in the VVER Reactor Core with Regard for Boiling in its Upper Part
Oleg Arkhipov and Sergey Kabakchi, *OKB "Gidropress"*

Poster 5.09
Experimental Studies of Formation and Development of Corrosion Damages of Heat Exchanging Tubes in Steam Generators at NPP with VVER-1000
V.S. Popadchuk, Nikolay B. Trunov, S.I. Brykov, Yu.V. Kharitonov, M.S. Metalnikov, V.D. Bergunker and R.I. Popkov, *EDO "GIDROPRESS"*

Poster 5.10
Electrochemical Corrosion Behavior of Alloy 690 in Simulated SG Crevice Solutions in PWR Secondary Circuit
Xinqiang Wu, Junbo Huang, En-Hou Han and Wei Ke, *Chinese Academy of Sciences, Institute of Metal Research*

Poster 5.11
Validation and Verification of a Deterministic Model for Corrosion and Activity Incorporation Using Operational Data from Kozloduy NPP
I. Betova, *Technical University of Sofia, Department of Chemistry*; Martin Bojinov, *University of Chemical Technology and Metallurgy, Department of Physical Chemistry*; Katya Minkova, *Kozloduy Nuclear Power Plant*

Poster 5.12
Laboratory Testing to Further Evaluate the Effect of Dispersant on the Oxide Formation on Alloy 690TT Steam Generator Tubing
Chuck R. Marks and J. Luszcz, *Dominion Engineering, Inc.*; Keith Fruzzetti and Misty Pender, *Electric Power Research Institute*

Poster 5.13
Crystal Habit Modification of Nickel-ferrite: Development and Results of Initial Laboratory Testing
Carly E. Anderson, Robert D. Varrin, Jr. and Chuck R. Marks, *Dominion Engineering, Inc.*; Aaron Barkatt, *The Catholic University of America, Department of Chemistry*; Karen Kim and Keith Fruzzetti, *Electric Power Research Institute*

Poster 5.14
The Effect of Surface Treatment on Reducing the Metal Release from Ni-base Alloy in High Temperature Water
Manabu Kanzaki, Yasuyoshi Hidaka and Yasuhiro Masaki, *Sumitomo Metal Industries, Ltd.*

Poster 5.15
Modification of Magnetite Coating Formation in Presence of Alkaline Acrylic Acid
P. Chandramohan, M.P. Srinivasan, Sinu Chandran, S. Rangarajan, S. Velmurugan and S.V. Narasimhan, *BARC Facilities, Water and Steam Chemistry Division*

Poster 5.16
Pulsed Laser Deposition of Zinc Ferrite Coatings on SS316 and Characterization Studies
P. Chandramohan, Sinu Chandran, M.P. Srinivasan, S. Rangarajan, S. Velmurugan and S.V. Narasimhan, *BARC Facilities, Water and Steam Chemistry Division*; R. Krishnan and Sitaram Dash, *IGCAR, Materials Science Group*

Wednesday, October 6, 2010

Poster 5.17
Tritium Management in the EPR™ and ATMEA1™ Reactors: An AREVA Computer Tool AbsoluT-3
Julie Colin, A. Long, Farah Chahma and Christian Brun, *AREVA NP SAS, Chemistry and Radiochemistry Group*

Poster 5.18
Study on the Mechanism of Flow-hole Blockage of Steam Generator Tube Support Plates Under PWR Secondary Conditions
Hideo Hirano, K. Yoneda, Masafumi Domae and K. Miyajima, *Central Research Institute of Electric Power Industry (CRIEPI)*

Poster 5.19
Comparison of Calibration Techniques of Ag/AgCl Electrode Between the Electrical Conductivity and the Spectral Active Techniques
Jei-Won Yeon, Myung-Hee Yun, Jaesik Hwang and Kyuseok Song, *Korea Atomic Energy Research Institute*

Poster 5.20
Detection of Boron in Simulated Corrosion Products by Using a Laser Induced Breakdown Spectroscopy
Kyuseok Song, Jei-Won Yeon, Sang-Hyuk Jung, Jaesik Hwang and Euo-Chang Jung, *Korea Atomic Energy Research Institute*

Poster 5.21
Secondary Side TSP Deposit Buildup: Lab Test Investigation Focus on Electrokinetic Considerations
Morgan Barale, Michael Guillodo and Marc Foucault, *AREVA NP SAS, Technical Centre;* Natacha Ryckelynck, Marie-Hélène Clinard, Farah Chahma and Christian Brun, *AREVA NP SAS, Chemistry and Radiochemistry Group;* Geraldine Corredera, *Electricité de France, Centre d'Expertise et d'Inspection dans les domaines de la Réalisation et de l'Exploitation*

Poster 5.22
REDOX Properties and Stability of Hydrazine in the Context of the Secondary Circuits of PWR Plants
Sophie Delaunay, Carine Mansour and Ellen-Mary Pavageau, *EDF R&D/MMC;* Gilles Berger, *LMTG-CNRS Toulouse;* Gérard Cote, Grégory Lefèvre, and Michel Fédoroff, *ENSCP-LECIME-UMR CNRS*

Poster 5.23
Solubility of Hydrogen in High Temperature Liquid Water at Pressures Above Saturation
Martin Bachet, *Electricité de France, R&D Division*

Poster 5.24
Nickel and Cobalt Sorption on Two Main Ferrites – Application to Primary Circuit of Nuclear Power Plant
B. Martin-Cabañas and Stéphanie Leclercq, *EDF/R&D/MMC;* P. Barboux, Grégory Lefèvre, and M. Fedoroff, *CNRS, LECIME, ENSCP*

Poster 5.25
Thermal Stability of Hydrazine Hydrate in a Flow Reactor Under Conditions Relevant to a SCWR
Andriy Plugatyr and Igor M. Svishchev, *Trent University, Chemistry Department*

Poster 5.26
New Advanced Amine for Secondary Systems in Pressurized Water Reactor Plants
Jim Stevens, *Comanche Peak Nuclear Power Plant*; Seifollah Nasrazadani, *University of North Texas*

Poster 5.27
The Phase Transport and Reactions of γ-Irradiated Aqueous-Ionic Liquids
Susan Howett, J.M. Joseph, J.J. Noël and J. Clara Wren, *The University of Western Ontario, Department of Chemistry*

Poster 5.28
Surface Analysis of Gamma-Radiation-Induced Carbon Steel Corrosion
Kevin Daub, X. Zhang, James J. Noël and J. Clara Wren, *The University of Western Ontario, Department of Chemistry*

Poster 5.29
The Effect of NO_3 and NO_2 on Water Radiolysis Kinetics During γ-Irradiation
Pamela A. Yakabuskie, J.M. Joseph and J. Clara Wren, *The University of Western Ontario, Chemistry Department*; Craig R. Stuart, *Atomic Energy of Canada Limited, Chalk River Laboratories*

Poster 5.30
The Effect of Steady-State Water Radiolysis on Metal Ion Solubility
J.M. Joseph, Pamela A. Yakabuskie, L.M. Alrehaily, P. Keech and J. Clara Wren, *The University of Western Ontario, Chemistry Department*; David Guzonas, *Atomic Energy of Canada Limited, Chalk River Laboratories*

Poster 5.31
Electrochemical Evaluation of PbSCC Mechanism in Steam Generators
Samuel Choi, *Electric Power Research Institute*; Jesse Lumsden, *Teledyne Scientific and Imaging Company*

Poster 5.32
Boric Acid Corrosion of Low Alloy Steel
Ryan Jones, Glenn White, Jean Collin and Chuck R. Marks, *Dominion Engineering, Inc.*; Richard Reid and Paul Crooker, *Electric Power Research Institute*

Poster 5.33
High Temperature Speciation of the Nickel/Iron System for Use with the MULTEQ Model
Shirley Dickinson, *National Nuclear Laboratory*; Martin Bachet, *EDF R&D*; Richard Eaker, Richard W. Eaker, *LLC*; Dennis Hussey, *Electric Power Research Institute*; Chuck R. Marks, *Dominion Engineering, Inc.*; Peter Tremaine, *University of Guelph*

Session 6: Steam Cycle Operational Experience

Session Co-Chairs: Rod Nashiem, *Bruce Power* and Timo Saario, *VTT Technical Research Centre of Finland*

13:05 Paper 6.01
PWR Water Chemistry Controls: A Perspective on Industry Initiatives and Trends Relative to Operating Experience and the EPRI PWR Water Chemistry Guidelines
Keith Fruzzetti, Samuel Choi, Carey Haas, Misty Pender and David L. Perkins, *Electric Power Research Institute*

13:35 Paper 6.02
Fouling and Tube Support Plates Blockage of Steam Generators: Chemical Modelling of the Phenomena
Gabriel Plancque and D. You, *CEA, DEN*; Carine Mansour, *EDF R&D*; Marie-Hélène Clinard, *AREVA-NP*

14:00 Paper 6.03
Steam Generator Performance Update for German PWRs
Andreas Drexler, *AREVA NP GmbH*; Fred Böettcher, *EnBW Kernkraft GmbH*; Helmut Barth, *Gemeinschaftskernkraftwerk Grohnde GmbH & Co. oHG*; Heinz-Rudolf Sauer, *Kernkraftwerk Brokdorf GmbH & Co. oHG*; Bernd Markgraf, Harry Neder and Sigrid Schütz, *E.ON Kernkraft GmbH*

14:25 Paper 6.04
Use of Oxygen Dosing to Prevent Flow Accelerated Corrosion in British Energy's Advanced Gas-cooled Reactors
Graham Quirk, Ian S. Woolsey and Andy Rudge, *British Energy – Part of EdF Energy*

14:50 Paper 6.05
Using of New Chemical Regime on Secondary Circuit in Nuclear Power Plant "Kozloduy" - Bulgaria
Katya Minkova and Stanimir Stanchev, *Kozloduy Nuclear Power Plant*; Zdravko Kalpakchiev, *Energy Institute JSC*

15:15 **Refreshment Break**

Steam Cycle Operational Experience Posters

Poster 6.06
Effect of Water Chemistry on Flow Accelerated Corrosion Rate of Carbon Steel Measured by On-line Corrosion-Monitoring System
Kazutoshi Fujiwara, Masafumi Domae, K. Yoneda and F. Inada, *Central Research Institute of Electric Power Industry*

Poster 6.07
Corrosion Monitoring of the Steam Generators of Vth and VIth Energy Blocks of Nuclear Power Plant "Kozloduy"
G. Raichevski and N. Boshkov, *Bulgarian Academy of Sciences, Institute of Physical Chemistry*; Katya Minkova and P. Penev, *Nuclear Power Plant "Kozloduy"*

Poster 6.08
Dispersant Application: (1) During Steam Generator Wet Layup for Removal of Existing Deposits; and (2) During the Long-path Recirculation Cleanup Process of the Condensate/Feedwater System to Reduce Startup Corrosion Product Transport to the Steam Generators
Keith Fruzzetti, *Electric Power Research Institute;* Carly E. Anderson, Chuck R. Marks and Marc A. Kreider, *Dominion Engineering, Inc.;* P. Robert Walton, *Exelon Corporation/TMI Nuclear Generating Station;* William Reecher, *Exelon Corporation/Byron Nuclear Generating Station;* David Morey, *Exelon Corporation*

Poster 6.09
Surface Analytical and Electrochemical Characterization of Oxide Films Formed on Incoloy-800 and Carbon Steel in Simulated Secondary Water Chemistry Conditions of PHWRs
S. Rangarajan, Sinu Chandran, V. Balaji and S.V. Narasimhan, *BARC Facilities, Water and Steam Chemistry Division*

Poster 6.10
Newly Developed Erosion-Corrosion Problems in Secondary Side of Paks Nuclear Power Plant Units
Gábor Patek, Janos Schunk, T. Pintér, P. Tilky and Á. Doma, *Paks Nuclear Power Plant Co. Ltd.;* Janos Ösz, *Budapest University of Technology and Economics*

Poster 6.11
Attachment of Iron Corrosion Products on Steam Generator Tube and Feed-Water Pump in PWRS Secondary Systems
Yasuhiko Shoda, Nobuo Ishihara, Hirokazu Miyata, Taku Ohira, Yoshifumi Watanabe and Yasuo Nonaka, *Mitsubishi Heavy Industries, Ltd.*

Poster 6.12
Corrosion Product Behavior in VVER Secondary Systems
Victor A. Yurmanov, *ENES - Engineering Center of Nuclear Equipment Strength, Reliability and Lifetime;* S.V. Velikopolskya and E.V. Yurmanov, *NIKIET - N.A.Dollezhal Research and Development Institute of Power Engineering*

Wednesday, October 6, 2010

Session 7: Water Treatment and Auxiliary Systems

Session Co-Chairs: Wendy Walker, *Pall Corporation* and Victor Yurmanov, *N.A. Dollezhal Research and Development Institute of Power Engineering*

15:45 Paper 7.01
Mitigation of Organically Bound Sulphate from Water Treatment Plants at Bruce NGS and Impact on Steam Generator Secondary Side Chemistry Control
Rod Nashiem, Ram Davloor, Bill Harper and Kim Smith, *Bruce Power;* Claude Gauthier, *CTGIX Services Inc.;* Sandy Schexnailder, *GE Water & Process Technologies*

16:10 Paper 7.02
Radioactive Sludge and Wastewater Analysis and Treatment in the Hungarian VVER-440/213-Type NPP
Gyorgy Pátzay and L. Weiser, *Budapest University of Technology and Economics;* F. Feil, Janos Schunk, Gábor Patek and T. Pintér, *Paks Nuclear Power Plant*

16:35 Paper 7.03
Scaling Prediction and Prevention in Condenser Cooling Circuits with Cooling Towers
Olga Alos Ramos, *EDF, LNHE;* Khalil Shakourzadeh, *Université de Technologie de Compiègne, Département de Génie des Procédés Industriel;* Céline Thomas, *EDF, STEP*

17:00 **Adjourn**

Water Treatment and Auxiliary Systems Posters

Poster 7.04
Bivalves and Their Control at the Process Water System of Embalse N.P.P.
Raul Manera, Narciso Fernández and Luis Ovando *Nucleoeléctrica Argentina S.A., Central Nuclear Embalse*

Poster 7.05
Experiences on Reduction of Reactor Water Silica and Fresh Resin Leaching Organics for Kuo-Sheng Nuclear Power Plant
Tung-Jen Wen, *Institute of Nuclear Energy Research, Atomic Energy Council;* Chieh-Hsin Wang, *Taiwan Power Company, Kuo-Sheng Nuclear Power Plant*

Poster 7.06
Improvement of Leaching Characteristics of TOC from Condensate Demineralizers by Advanced Resin Bed Arrangement Methods
Y. Egawa, Takeshi Izumi, T. Ino, T. Deguchi, and M. Hagiwara, *Ebara Corporation;* H. Saneshige, T. Sakurai, H. Hasegawa, M. Abe and M. Furuya, *Tokyo Electric Power Company*

Poster 7.07
Commissioning of the Water Demineralization Plant of Atucha II Nuclear Power Plant
Betina Schönbrod, Germán Grasso and Miguel Ormando, *Nucleoelectrica Argentina S.A.; Central Nuclear Atucha II;* Mauricio Chocron, Ivanna Rodriguez and Ana Ma. Lagamma, *Comisión Nacional de Energía Atómica*

Poster 7.08
Chemical Tracer Test to Identify Main Condenser Dogbone Seal Leakage at Peach Bottom Unit 3
Andrew D. Odell, R. Scholz and K.E. Russell, *Exelon Generation;* Joseph F. Giannelli, *Finetech Inc.*

Poster 7.09
Electrochemical Ion Exchanger in the Water Circuit to Measure Cation Conductivity
Bernt Bengtsson, Rolf Ingemarsson and Gustav Settervik, *Ringhals AB;* Anna Velin, *Vattenfall Research and Development AB*

Poster 7.10
Biofouling Evaluation in the Seawater Cooling Circuit of an Operating Coastal Power Plant
P. Sriyutha Murthy, P. Veeramani, M.L. Mohamed Ershath, and V.P. Venugopalan, *BARC Facilities, Water and Steam Chemistry Division*

Poster 7.11
Comparative Efficacy of Chlorine and Chlorine Dioxide Regimes for Condenser Slime Control in Seawater Cooled Heat Exchangers
P. Sriyutha Murthy, P. Veeramani, M.L. Mohamed Ershath, R. Rajamohan, Y.V. Harinath, T.V.K. Mohan and V.P. Venugopalan, *BARC Facilities, Water and Steam Chemistry Division*

Poster 7.12
Treatment of Arsenazo III Contaminated Heavy Water Stored at Darlington
Sriram Suryanarayan and Aamir Husain, *Kinectrics Inc.;* Denny Williams, *Ontario Power Generation, Darlington Nuclear Generating Station*

Poster 7.13
Study for Highly Functional Resin (Macroporous Resin) Superior in Removing Micro Particles in PWR Primary Circuit: On-Site Test
Ayumu Itou, Keiichi Kondo and Yoshihide Kouzuma, *Kyusyu Electric Power Co., Inc.;* Ryuji Umehara and Yuichi Shimizu, *Mitsubishi Heavy Industries, Ltd.;* Noritaka Kogawa and Kunitaka Nagamine, *Nuclear Development Corporation*

Poster 7.14
Remote Sampling and Analysis of Highly Radioactive Samples in Shielded Boxes
D.A. Kirpikov, Igor V. Miroshnichenko and Oleg Yu. Pykhteev, *Alexandrov Research Institute of Technology*

Poster 7.15
Analytical Monitoring of Corrosive Impurities in NPP Coolant Water
Igor V. Miroshnichenko, Oleg Yu. Pykhteev, N. Ya. Vilkov and V.S. Gurski, *Alexandrov Research Institute of Technology*

Poster 7.16
Emergency Core Cooling System Sump Chemical Effects on Strainer Head Loss
Matt K. Edwards, Liyan Qiu and David A. Guzonas, *Atomic Energy of Canada Limited, Chalk River Laboratories*

Session 8: Chemistry and Fuel Performance

Session Co-Chairs: John Krasznai, *Kinectrics Inc.* and Ivan Smieško, *Slovenske Elektrarne*

08:30 Paper 8.01
Optimisation of Water Chemistry to Ensure Reliable Water Reactor Fuel Performance at High Burnup and in Ageing Plant (FUWAC): An International Atomic Energy Agency Coordinated Research Project
John Killeen, *International Atomic Energy Agency;* Francis Nordmann, *Consultant;* Janos Schunk, *Paks, NPP;* Katěrina Vonková, *National Research Institute Rez*

08:50 Paper 8.02
Influence of Operating and Water-Chemistry Parameters on Fuel Cladding Corrosion and Deposition of Corrosion Products on Cladding Surfaces
Vladimir G. Kritsky, Irina G. Berezina and Yury A. Rodionov, *Leading Institute "VNIPIET"*

09:10 Paper 8.03
Recent Developments of BOA Version 3
Jeff Deshon and Dennis Hussey, *EPRI;* John Westacott, *CSAI;* Mike Young and Jeff Secker, *Westinghouse;* Kenny Epperson, *Consultant;* John McGurk and Jim Henshaw, *NNL*

09:30 Paper 8.04
Fission Product Iodine Behaviour in Sizewell B Coolant
Howard E. Sims and Shirley Dickinson, *National Nuclear Laboratory;* Gavin Lancaster, *British Energy, Sizewell B Power Station;* Keith Garbett, *British Energy*

10:00 **Refreshment Break**

Chemistry and Fuel Performance Posters

Poster 8.05
Effect of Water Chemistry on Crud Deposition Behavior on Heated Zircaloy-4 Surface in Simulated PWR Primary Water
Hirotaka Kawamura and Masahiro Furuya, *Central Research Institute of Electric Power Industry*

Poster 8.06
Comprehensive Study of Uranium and Transuranium (Pu, Cm) Accumulation on Stainless Steel and Zr+Nb Cladding Material Surfaces
Kálmán Varga, P. Kádár, B. Baja, Z. Németh and T. Kristóf, *University of Pannonia;* Nora Vajda, *RadAnal Ltd.;* Zs. Stefánka and Z. Schay, *Hungarian Academy of Science;* T. Pintér and Janos Schunk, *Paks NPP Ltd.*

Poster 8.07
Iodine Speciation and Behavior Under Normal PWR Operating Primary Coolant Conditions: Analysis of Thermodynamic Evaluations and NPP Feedback
Arancha Tigeras, *EDF/CEIDRE;* Martin Bachet and Hubert Catalette, *EDF/R&D;* E. Simoni, *Université Paris XI*

Poster 8.08
Crud Formation on Low Duty PWR Fuel in the Halden Reactor
Peter Bennett, *OECD Halden Reactor Project*

Poster 8.09
Corrosion Product Deposits on BWR Cladding: A Comparison of Thermodynamic Modelling Predictions with Experimental Analytical Results
Andrey Orlov, D.A. Kulik, C. Degueldre and Gerhard Bart, *Paul Scherrer Institute;* Wilfried Kaufmann, *Kernkraftwerk Leibstadt;* S. Valizadeh, *Westinghouse AB*

Poster 8.10
Characterization of PWR Fuel Crud by High Resolution Transmission Electron Microscopy
Jiaxin Chen and Daniel Jädernäs, *Studsvik Nuclear AB;* Hans Bergqvist, *Royal Institute of Technology;* Bernt Bengtsson, *Ringhals AB*

Poster 8.11
Fuel Assembly Inspections Performed During the Refuelling Outage of Paks Nuclear Power Plant Unit 4
T. Pintér, P. Németh, Á. Menyhárt, I. Buránszky, Janos Schunk and Gábor Patek, *Paks Nuclear Power Plant Co. Ltd.*

Poster 8.12
The Synergic Impact of the Boiling and Water Radiolysis on the Pressurized Water Reactor Fuel Claddings' Chemical Environment
Ivan Dobrevski (retired) and Neli Zaharieva, *Bulgarian Academy of Sciences, Institute for Nuclear Research and Nuclear Energy*

Session 9: Chemistry and NPP Performance

Session Co-Chairs: Ian Hey, *CANDU Owners Group* and Andy Rudge, *EDF Energy Nuclear New Build*

10:30 Paper 9.01
Improving Chemistry Performance in CANDU® Plants
Carl Turner and David A. Guzonas, *Atomic Energy of Canada Limited, Chalk River Laboratories*

10:50 Paper 9.02
ANT International Chemistry Update and Best Practices
Francis Nordmann, Suat Odar, Hartmut Venz, Jan Kysela, W. Ruehle and Rolf Riess, *ANT International Europe AB*

11:10 Paper 9.03
Application of Online Chemistry Monitoring Programs and Technology
David L. Perkins, Samuel Choi and Carey Haas, *Electric Power Research Institute*

11:30 Paper 9.04
Primary Water Chemistry Control at Units of Paks Nuclear Power Plant
Janos Schunk, Gábor Patek, Tóth Pintér, P. Tilky and Á. Doma, *Paks Nuclear Power Plant Co. Ltd.;* János Ősz, *Budapest University of Technology and Economics*

12:00 – 13:30 **Free time for lunch on your own**

Chemistry and NPP Performance Posters

Poster 9.05
Alpha Nuclides in Nuclear Power Plants
Marcel Schienbein and Peter Zeh, *AREVA NP GmbH;* Matthias Rosskamp, *VENE, Kernkraftwerk Brunsbüttel GmbH & Co oHG;* Wolfgang Schwarz, *E.ON Kernkraft GmbH, Kernkraftwerk Isar*

Poster 9.06
Approach to Maintain Long-term Integrity of Steam Generator and Secondary System of Tsuruga-2
Yuji Fukuda, Wataru Sugino, Ayumi Abe, Kenji Hisamune, Hideki Takiguchi and Yoshinori Meguro, *The Japan Atomic Power Company*

Poster 9.07
QA Practice for Online Analyzers in Water Steam Cycles
Lukas Staub, *Swan Analytical Instruments*

Poster 9.08
An Overview of KANUPP Operating Experience in Chemistry
Tehseen Hashmi, *Pakistan Atomic Energy Commission, Karachi Nuclear Power Plant*

Poster 9.09
BWR Chemistry Control Status: A Summary of Industry Chemistry Status Relative to the BWR Water Chemistry Guidelines
Susan E. Garcia, *Electric Power Research Institute;* Joseph F. Gianelli and Mary L. Jarvis *Finetech, Inc.*

Poster 9.10
Comparison of Ammonia, Morpholine and Ethanolamine as Conditioning Agent on the Formation and Deposition of Iron Oxides on Stainless Steel and Carbon Steel in Conditions of PWR Secondary Circuits
Sophie Delaunay, Ellen-Mary Pavageau and Carine Mansour, *EDF R&D, Materials and Mechanics Department;* Gérard Cote, Grégory Lefèvre and Michel Fédoroff, *Chimie ParisTech- CNRS UMR*

Poster 9.11
Analysis of Steam Generator Tube Sections Removed from Gentilly-2 Nuclear Generating Station
Jaleh Semmler and Allen J. Lockley, *Atomic Energy of Canada Limited, Chalk River Laboratories;* David Doyon, *Hydro-Québec, Centrale Nucléaire Gentilly-2*

Poster 9.12
Analysis of Boron at Koeberg Power Station
Nestor van Eeden, Nomalanga G. Tasana and Herman J. Morland, *Eskom Holdings Ltd., Koeberg Power Station*

Poster 9.13
Lay–Up Condition During ENPP Refurbishment Outage
Ricardo Sainz, Gustavo Diaz, Cecelia Herrera, Pilar Lascano, Maribel Mendizabal and Alejandro Margaritini, *Nucleoeléctrica Argentina S.A., Embalse Nuclear Generating Station*

Poster 9.14
EMECC Campaign at Trillo: Results and Comparison with French Feedback
Gilles Ranchoux, *EDF/SEPTEN*; Frédéric Dacquait, *CEA/Cadarache*;
E. Velasco-Marcelo and J.M. Garces de Marcilla Bayo, *CNAT/Trillo*

Poster 9.15
Primary Side Chemistry Online Monitoring at the Kozloduy Nuclear Power Plant (Units 5 & 6)
Katya Minkova, *Kozloduy Nuclear Power Plant*; Susan M. Wozniak and John Balavage, *Westinghouse Electric Company*

Poster 9.16
Prescription Launching Related to the Chemical Measurement Methods in the Waste and Environmental Field with Regards to the Regulation Framework Dedicated to the NPP Chemical Releases
Marine Pierre, Michel Dupin, Christelle Cosse, D. Lepetit and A. Gacon, *EDF/CEIDRE/DLAB*

Poster 9.17
Anion Analysis Using Capillary Electrophoresis in the Halden Reactor
Kari Lye Moum and Torill Solheim, *OECD Halden Reactor Project*

Poster 9.18
Safety Regulations Regarding to Water Chemistry in Russia's NPPs
R.B. Sharafutdinov, Nataliya L. Kharitonova and L.G. Denisova, *Scientific and Engineering Centre for Nuclear and Radiation Safety (SEC NRS)*

Poster 9.19
WITHDRAWN
Improvement of Shutdown Chemistry through Non-volatilization of Radioiodine in the Case of Defected Fuel
Jong-Suk Park, Ho-Yeon Yang, and Jung-Jin Lee, *Korea Hydro & Nuclear Power Co., LTD.*

Poster 9.20
Lithium Control During Normal Operation
Sriram Suryanarayan and Dev Jain, *Kinectrics Inc.*

Poster 9.21
Analytical Monitoring of Uranium in Reactor Coolant Water
Igor V. Miroshnichenko, D.A. Kirpikov, M.S. Markizov and Oleg Yu. Pykhteev, *Alexandrov Research Institute of Technology*

Poster 9.22
ECP Measurements Under Neutron and Gamma Ray in In-pile Loop and their Data Evaluation by Water Radiolysis Calculations
Satoshi Hanawa, Takehiko Nakamura and Shunsuke Uchida, *Japan Atomic Energy Agency*; Pavel Kus, Rudolf Vsolak and Jan Kysela, *Nuclear Research Institute REZ plc*

Poster 9.23
New Design Architecture Decisions on Water Chemistry Support Systems at New VVER Plants
V.E. Kumanina and A.V. Yurmanova, *Joint Stock Company Atomenergoproekt*

Poster 9.24
ECP Measurements in the BWR-1 Water Loop Relative to Water Composition Changes
Pavel Kus, Rudolf Vsolak and Jan Kysela, *Nuclear Research Institute Rez plc*; Satoshi Hanawa, Takehiko Nakamura and Shunsuke Uchida, *Japan Atomic Energy Agency*

Session 10: Cleaning and Decontamination

Session Co-Chairs: David Guzonas, *Atomic Energy of Canada Limited* and S.V. Narasimhan, *BARC Facilities*

13:30 Paper 10.01
Comparative Study of the Corrosion and Surface Analytical Effects of the Decontamination Technologies
Kálmán Varga, B. Baja, E.H. Deák, K. Radó and Z. Németh, *University of Pannonia*; Gábor Patek and Janos Schunk, *Paks NPP Ltd.*; A.N. Szabó, *University of István Széchenyi, Department of Physics and Chemistry*

13:50 Paper 10.02
EDF Feedback on Recent EPRI SGOG SG Chemical Cleanings Applications for TSP Blockage Reduction and Heat Transfer Recover
Michel Dijoux, Odile de Bouvier, Stephane Mercier, Danielle Pages, *EDF-DIN-CEIDRE*; Jean-Luc Bretelle, *EDF-DPN-UNIE*; Philippe Leclercq, *EDF-DPN-UTO*; Anne Mermillod, *EDF-DIN-CIPN*

14:10 Paper 10.03
Recent Advances in Canadian Decontamination Technologies
Jaleh Semmler, *Atomic Energy of Canada Limited, Chalk River Laboratories*

14:30 Paper 10.04
High Temperature Dissolution of Ferrites, Chromites and Bonaccordite in Chelating Media
V.S. Sathyaseelan, H. Subramanian, B. Anupkumar, A.L. Rufus, S. Velmurugan and S.V. Narasimhan, *BARC Facilities, Water and Steam Chemistry Division*

14:50 Paper 10.05
Cleaning the Primary Circuit After the First High Temperature Oxidation of Steam Generator Tubing: Why and How to Do It
Martin Bachet and Stéphanie Leclercq, *Electricité de France, R&D Division*

15:10 **Refreshment Break**

Cleaning and Decontamination Posters

Poster 10.06
Development of a Suppression Method for Deposition of Radioactive Cobalt after Chemical Decontamination: Enhancement of Suppression Performance on Ferrite Film Coating
Hideyuki Hosokawa, *Hitachi Ltd., Energy and Environmental Systems Laboratory;* Makoto Nagase and Motomasa Fuse, *Hitachi Works, Hitachi-GE Nuclear Energy, Ltd.*

Poster 10.07
Evaluation of a Process for the Decontamination of Radioactive Hotspots Due to Activated Stellite Particles
Veena Subramanian, P. Chandramohan, M.P. Srinivasan, S. Rangarajan, S. Velmurugan and S.V. Narasimhan, *BARC Facilities, Water and Steam Chemistry Division;* R.C. Khandelwal, *Kakrapara Atomic Power Station*

Poster 10.08
Design, Fabrication and Testing of an Electrolytic Membrane Cell to Minimize the Active Waste Generated during Decontamination
S. Rangarajan, Suresh Sumathi, V. Balaji and Rajesh Puspalata, *BARC Facilities, Water and Steam Chemistry Division*

Poster 10.09
Chemical Cleaning as an Essential Part of Steam Generator Asset Management
Christoph Stiepani and Franz Ammann, *AREVA GmbH;* Dennis Jones, Sarah Evans and Kayla Harper, *AREVA Inc.*

Poster 10.10
Electrochemical Regeneration of Spent Ion Exchange Resin
Lisheng Chi and Jaleh Semmler, *Atomic Energy of Canada Limited, Chalk River Laboratories*

Poster 10.11
Influence of Decontamination and Preconditioning on Corrosion Layer
V. Svarc, Katerina Vonkova and Jan Kysela, *Nuclear Research Institute Rez plc;* Kálmán Varga, *Pannon University;* Janos Schunk, *Paks Nuclear Power Plant*

Poster 10.12
Steam Generator Chemical Cleaning Experience and Prospects in Korea
Kwayng Kyu Park and Seok Won Yoon, *Korea Electric Power Corporation*

Poster 10.13
Chemical Preventive Remedies for Steam Generators Fouling and Tube Support Plate Blockages
Maria Alves Vieira, M. Mayos, N. Coquio and H. Foucroy, *Electricité de France, Nuclear Engineering Division – CEIDRE;* ; P. Battesti, *Electricité de France, Dampierre*

Session 11: Future Developments

Session Co-Chairs: John Roberts, *Bruce Power (retired)* and Jan Kysela, *Nuclear Research Institute REZ plc*

15:40 Paper 11.01
Potential Chemistry and Operational Strategies to Minimize Corrosion-Product and Activity Transport in a CANDU®-SCWR
William G. Cook and Robert P. Olive, *University of New Brunswick, Department of Chemical Engineering*

16:00 Paper 11.02
Chemistry and Corrosion Issues in Supercritical Water Reactors
Victor A. Yurmanov, V.N. Belous, V.N. Vasina and E.V. Yurmanov, *NIKIET - N.A. Dollezhal Research and Development Institute of Power Engineering*

16:20 Paper 11.03
Chemistry Control Strategies for a Supercritical Water-cooled Reactor
David A. Guzonas, *Atomic Energy of Canada Limited, Chalk River Laboratories*

16:40 **Conference Closing Remarks**

17:00 **Conference Adjourns**

Future Developments Posters

Poster 11.04
The AREVA Boiling Water Reactor Kerena™: Design Features and Water Chemistry of an Evolutionary Generation III+ BWR
Alexander Laendner, Bernhard Stellwag, Thorsten Borrmann and Steffen Weiss, *AREVA NP GmbH;* Steffen Pankow, *E.ON Kernkraft GmbH*

Poster 11.05
Nuclear Chemistry of Water-Cooled Fusion Reactors: Issues and Solutions
Andrei Petrov and George Flanagan, *Oak Ridge National Laboratory*

Poster 11.06
An Experimental Study of Commercially Available Alloys for Potential Use in the CANDU®-SCWR
William G. Cook, James Miles and C. Bradley, *University of New Brunswick, Department of Chemical Engineering;* Jian Li and W. Zheng, *CANMET-MTL*

Poster 11.07
Assessment of EPRI Water Chemistry Guidelines for New Nuclear Power Plants
Karen Kim, Keith Fruzzetti and Susan Garcia, *Electric Power Research Institute;* Richard Eaker, *Richard W. Eaker, LLC;* Joseph Giannelli, *Finetech, Inc.;* Jeffrey A. Gorman and Chuck R. Marks, *Dominion Engineering, Inc.;* Stephen G. Sawochka, *NWT Corporation*

Friday, October 8, 2010

Radiolysis, Electrochemistry and Materials Performance Workshop

08:00 **Welcome and Introductory Remarks**
John Roberts, *Workshop Chair*

Session 1

08:10 **Modelling 'Steady-State' Water Radiolysis in Nuclear Reactors: Status of the Reaction Set, Rate Constants and g-Values for 20° – 350°C**
John Elliot, *AECL (retired)*

Session 2

08:50 **The Critical Hydrogen Concentration in PWR Coolant**
Howard E. Sims and Jim Henshaw, *National Nuclear Laboratory;* David M. Bartels, *University of Notre Dame, Radiation Laboratory*

09:20 **AISI 316L Ageing at High Temperature and High Pressure Under Proton Irradiation in Model PWR Solutions**
Benoît Muzeau and Catherine Corbel, *CEA/DSM/RAMIS/LSI - École Polytechnique;* S. Perrin, D. Féron and Oliver Raquet, *CEA/DEN/DPC/SCCME/LECA - CEA/Saclay;* D. Simon, *CNRS/CEMHTI - CEMHTI*

09:50 **The Effect of Aqueous-Gas Partitioning on Water Radiolysis Under γ-Irradiation**
Pamela A. Yakabuskie, J.M. Joseph and J. Clara Wren, *The University of Western Ontario, Department of Chemistry;* Glenn A. Glowa, *Atomic Energy of Canada Limited, Chalk River Laboratories*

10:20 **Refreshment Break**

Session 3

10:35 **Array-type Sensors to Determine Corrosive Conditions in High Temperature Water Under Gamma Ray Irradiation**
Tomonori Satoh, Takashi Tsukada, Shunsuke Uchida and Chiaki Katoh, *Japan Atomic Energy Agency*

11:05 **A Comprehensive Study on the γ-Radiation Induced Corrosion of Carbon Steel**
Kevin Daub, X. Zhange, James J. Noël and J. Clara Wren, *The University of Western Ontario, Department of Chemistry*

11:35 **Radiolysis of High Temperature and Supercritical Water Studied by Pulse Radiolysis Up to 400°C**
Yosuke Katsumura, *University of Tokyo, Department of Nuclear Engineering and Management;* Minzhang Lin, *Japan Atomic Energy Agency, Science Research Center;* Yusa Muroya, *University of Tokyo, Nuclear Professional School;* Jintana Meesungnoen and Jean-Paul Jay-Gerin, *Université de Sherbrooke, Département de Médecine Nucléaire et de Radiobiologie;* Mehran Mostafavi, *Université Paris-Sud, Laboratoire de Chimie Physique/ELYSE*

12:05 **Luncheon**

Session 4

13:30 **ECP Modelling and Uncertainties in Water Cooled Reactors for Mitigation of Stress Corrosion Cracking Under Irradiation**
Kenkichi Ishigure, *Japan Radioisotope Association*

14:10 **Progress and Current Status in Water Radiolysis and Electrochemical Corrosion Potential Calculation**
Hideki Takiguchi, *The Japan Atomic Power Company;* Seiji Yamamoto, Nagayoshi Ichikawa, Hidehiro Urata and Junichi Takagi, *Toshiba Corporation;* Yoichi Wada, *Hitachi, Ltd.;* Nobuyuki Ohta and Motomasa Fuse, *Hitachi-GE Nuclear Energy, Ltd.*

Session 5

14:40 **Reference Electrode Using Zirconium as Electrode Pole to Measure Electrochemical Corrosion Potential in High Temperature Pure Water**
Kazushige Ishida, M. Tachibana and Yoichi Wada, *Hitachi, Ltd., Energy and Environmental Systems Laboratory;* N. Ohta and Motomasa Fuse, *Hitachi-GE Nuclear Energy, Ltd.*

15:10 **ECP Evaluation by Water Radiolysis and ECP Model Calculations**
Satoshi Hanawa, Takehiko Nakamura and Shunsuke Uchida, *Japan Atomic Energy Agency;* Pavel Kus, Rudolk Vsolak and Jan Kysela, *Nuclear Research Institute Rez plc*

15:40 **Refreshment Break**

Session 6

15:50 **Hydrogen Water Chemistry: Can it Work in a Supercritical Water Reactor?**
David M. Bartels, *University of Notre Dame, Radiation Laboratory*

16:20 **Summary and Closing Remarks**

16:50 **Workshop Adjourns**

Nuclear Plant Chemistry Conference 2010

Registration Form

International Conference on Water Chemistry of Nuclear Reactor Systems .... October 3-7, 2010
8th International Radiolysis, Electrochemistry and Materials Performance Workshop .. October 8, 2010

Name: ______________________________
Dr./Mr./Ms. First Last

Title: ______________________________

Organization: ______________________________

Business Address: ______________________________
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City Province/State Postal/Zip Code Country

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Register on line: www.cns-snc.ca

Other Registration & Payment Options

In all cases, after submission of form, fee payment may be made by phone if desired.

Conference Registration Fee Includes: all taxes, participation in all Conference Sessions, Conference Program with Abstracts, Advance Conference Proceedings CD (provided on-arrival), Final Conference Proceedings CD (mailed post-conference), Welcome Reception, Quebec City Fall Colours Motor Coach Tour (Tuesday afternoon), Coffee and Pastries Breakfasts each day, Luncheons on Monday and Wednesday, Morning and Afternoon Beverage Breaks each day, Poster Session Reception and Banquet.

Workshop Registration Fee includes: all taxes, participation in all Workshop sessions, Workshop Program with Abstracts, Workshop Proceedings CD (mailed after the Workshop), Coffee and Pastries Breakfast, Morning and Afternoon Beverage Breaks and Luncheon.

Preliminary Conference Proceedings CDs will be provided at the Conference. **Final Conference Proceedings** CDs will be mailed to all participants following the Conference.

Cancellation Policy

Cancellation of paid registration must be submitted in writing to the Conference Registrar no later than September 3, 2010. Refunds, less a $105 processing fee will be issued after the conference. No refunds will be provided for cancellation of paid registrations after September 3, 2010.

Your Privacy

The CNS will ensure that all personal information that you provide is kept in strict confidence. The CNS does not share its mailing lists with other organizations. Please add your initials to the appropriate line to indicate whether or not you accept to have your name, organization and e-mail address published as part of the Conference Participants list.

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Dietary: ❑ Vegetarian ❑ Other ____________

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Name: ______________________

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附件二

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14:10 **Electrochemical and Corrosion Control in Water-Cooled Nuclear Reactors**
Digby D. Macdonald, *Pennsylvania State University, Department of Materials Science and Engineering*

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附件三

Taiwan's Petition to Hosting the NPC Conference in 2014

by
Tsung-Kuang (TK) Yeh
National Tsing Hua University, Taiwan
tkyeh@mx.nthu.edu.tw

This is an official petition to hosting the NPC conference in 2014 by Taiwan. As one of the ICMs of NPC2010, I would like to express Taiwan's interest in hosting the NPC conference in 2014 at the ICM Core Members Meeting. For qualifying ourselves, it must be stressed that scientists and engineers from academia, research institutes, and the power industry in Taiwan have been engaged in water chemistry related research and on-site work for decades. Delegates from Taiwan have been continuously attending this series of conferences since 1977 without any interruption, and we have accumulated abundant and relevant experiences on hosting this conference in Taiwan. As an example, we would like to mention that the ICG-EAC annual meeting with more than 100 international attendants was successfully hosted in Taiwan in 2007, and the responses from the attendants were extremely positive and encouraging. In addition, we have also held quite a number of regional water chemistry conferences in the past two decades. For the 2014 NPC conference, we have already obtained a written approval of funding support from the government, primarily from Atomic Energy Commission and National Science Council, and we will be able to offer a very cost-effective conference for all the prospective attendees, for example THREE high-standard meals per day and a local tour during the entire conference time at a registration fee of less than 900 USD. According to our preliminary planning, the conference will be held in Taipei, the capital city of Taiwan, which allows easy access from all over the world. The venue will be a renowned five-star hotel located in the heart of Taipei. In particular, for encouraging the young generation in this field, we will offer special discounts for student participants.

With the experiences and planning mentioned and the hearty enthusiasm, we would like to sincerely ask the core members to consider and accept our petition to hosting the conference in 2014. Thank you very much.