公務出國報告（出國類別：研討會）

參加第十屆國際核能熱水流運轉及安全專題會議

服務機關：原子能委員會、核能研究所

姓名職稱：廖俐毅主任、吳文雄技士、黃議輝技士

出國地區：日本

出國期間：**103** 年 **12** 月 **13** 日至 **103** 年 **12** 月 **19** 日

報告日期：**104** 年 **01** 月 **20** 日

摘要

核能熱水流運轉及安全專題會議 (International Topical Meeting on Nuclear Thermal-Hydraulics, Operation and Safety)，目的在提供各國核能產業與學術機構交流研發技術成果與工程實務經驗之平台，第一屆會議自 1984 年在台北舉行，之後每二到四年舉辦一次，本次第十屆會議於 103 年 12 月 14 日至 103 年 12 月 18 日假日本沖繩舉行，會議由日本原子力學會(AESJ)贊助及國際原子能總署(IAEA)合作下共同舉辦，與會人員來自 26 個國家共 307 人，共有 238 篇論文發表。本會核能安全管制研究中心試運組於會中發表研究論文 2 篇，接受專家檢視，同時進行意見交流。此外，日本主辦單位正式邀請試運組主任前往擔任水冷式反應器熱水流及安全專題主席。透過與國際專家直接會談，可了解國際熱水流最新研究成果、應用、及未來發展方向，以利我國核能管制技術發展。

目錄

一、　目的

核能熱水流運轉及安全專題會議 (International Topical Meeting on Nuclear Thermal-Hydraulics, Operation and Safety)，目的在提供各國核能產業與學術機構交流研發技術成果與工程實務經驗之平台，第一屆會議自 1984 年在台北舉行，之後每二到四年舉辦一次，東京(1986)、首爾(1988)、台北(1994)、北京(1997)、奈良(2004)、首爾(2008)、上海(2010)及高雄(2012)，本次第 10 屆會議於 103 年 12 月 14 日至 103 年 12 月 18 日假日本沖繩舉行，會議由日本原子力學會(AESJ)贊助及國際原子能總署(IAEA)合作下共同舉辦。

原子能委員會(以下簡稱本會)未來將成立派出單位「核能安全管制研究中心」，該中心將承接研發重任。為加速經驗傳承，及早培育高素質核安管制專業人才，精進管制技術能量，故派遣人員參加國際會議，以因應本會針對核電廠事故分析之需求及提昇我國核能安全管制技術能力。

本會核能安全管制研究中心試運組投稿研究論文 2 篇且皆獲得接受，主要作者分別為吳文雄技士及黃議輝技士；此外，日本主辦單位正式邀請試運組廖俐毅主任前往擔任水冷式反應器熱水流及安全專題主席。故本次會議由試運組廖俐毅主任、吳文雄技士及黃議輝技士 3 人共同前往，發表研究成果並接受專家檢視，同時進行意見交流。另外透過與國際專家直接會談，可了解國際熱水流最新研究成果、應用、及未來發展方向，以利我國核能管制技術發展。

二、 行程

本次公差行程係參加第 10 屆核能熱水流及運轉安全專題會議，並簡報試運組最新研究成果。行程自民國 103 年 12 月 13 日起至 103 年 12 月 19 日止，共計 7 日，概要如下表：

日期	行程	摘要
12 月 13 日	台北-沖繩	去程
12 月 14 日 | 12 月 18 日	沖繩	出席第 10 屆國際核能熱水流運轉及安全專題會議(NUTHOS-10)，簡報試運組研究成果及擔任專題主席。
12 月 19 日	沖繩-台北	返程

三、　會議摘要

本次第 10 屆核能熱水流運轉及安全專題會議，會議主要內容分為專家座談、技術專題報告，技術專題報告內容涵蓋熱水流分析及核能安全、先進實驗及數值分析方法、電廠運轉及核能安全、嚴重事故及安全分析、特別專題、等 6 大項領域，各領域內容共細分 29 小項詳如表一，每日議程如附件一。與會人員來自 26 個國家共 307 人，共有 238 篇論文發表，各國參與人數及發表篇數如表二。

於節次 A-1-11 Thermal Hydraulics and Safety of Water-Cooled Reactors 11，吳員簡報一篇論文「The Assessment of the Fukushima Like Accident for Kuoshen BWR/6 with TRACE」，簡報如附件二。首先介紹斷然處置措施的發展，該措施是由台灣電力公司所提出的緊急操作流程，主要目的是為了因應類似福島一廠的假想事故。斷然處置措施主要內容是一套 DIVing 計畫，包括：(1)兩階段式降壓、(2)替代冷卻水注入、以及(3)圍阻體排氣。當以下其中一項情況發生，運轉員隨即開始執行斷然處置措施緊急操作流程：(1)喪失蒸汽驅動補水系統以外之電力驅動補水系統能力、(2)喪失所有交流電源、(3)強震急停，且海嘯警報發布。本論文評估核二廠發生類福島事故時 DIVing 的有效性，以及探討執行 DIVing 時需要注意的議題。接著簡單說明核二廠 TRACE 分析模式，包含模擬各系統所使用的組件。

為了驗證 DIVing 的有效性，我們假設了兩個案例來模擬類似福島一廠事故的情節。案例一假設喪失所有交流電源導致反應爐急停、主蒸汽隔離閥關閉，同時也造成飼水泵與再循環泵跳脫。此時反應爐爐心隔離冷卻系統是唯一可用的補水系統。另外又假設一個小時之後，反應爐爐心隔離冷卻系統也喪失功能。在無任何補水系統可用的情況下，必需執行緊急降壓使低壓的替代冷卻水系統可補水進入爐心。案例二的起始事件與案例一相同，但在案例二中應用 DIVing；在喪失所有交流電源後，立即開始執行控制降壓，將反應爐壓力降至約 15kg/cm^2。同樣假設在一個小時之後，反應爐爐心隔離冷卻系統喪失其功能，本案例緊急降壓

在較低的反應爐壓力下執行。兩案例中替代冷卻水流量均為一輛消防水車可提供的流量。

分析結果發現，若在反應爐爐心隔離冷卻系統尚可用時，預先執行控制降壓，在維持正常水位之情況下將反應爐帶到一個較安全的低壓力狀態，可大幅降低緊急降壓時流出反應爐的冷卻水流量，因而減小水位降低的幅度，縮短爐心裸露的時間。DIVing 的執行有效抑低事故過程中的尖峰燃料護套溫度。對核二廠而言，目前的策略為在控制降壓開啟一只安全釋壓閥，緊急降壓則開啟七只 ADS 閥。本論文另藉著靈敏度分析探討閥開啟數目對執行 DIVing 的影響，結果指出執行控制降壓時若開啟超過兩只安全釋壓閥，水位會降至低於有效燃料頂部。而緊急降壓時若可開啟的 ADS 閥低於兩只，則反應爐內壓力無法及時降低，尖峰燃料護套溫度將上升至超過 1088.7K，無法避免鋯水反應的發生。因此，目前的降壓策略為合適的策略。

於節次 A-1-7 Thermal Hydraulics and Safety of Water-Cooled Reactors 7，黃員簡報一篇論文「Multi-Dimensional Modeling and Simulation of Upper Plenum in URG Analysis of Lungmen Nuclear Power Plant using RELAP5-3D」，簡報如附件三。本論文評估龍門核電廠發生類福島事故時採行斷然處置措施的有效性。

本研究使用電廠熱水流分析程式 RELAP5-3D，分析採行斷然處置措施下，替代注水可能途徑、替代注水最小流量分析、最小替代注水流量下注水途徑：降流區注水、一維及三維爐心上部噴灑模擬冷卻模式差異分析等。

簡報內容分為 URG 的介紹、分析模式介紹、一維及三維模型介紹、分析結果及結論，研究結果除了證實龍門核電廠目前的降壓策略為合適的策略外，並做了許多情境分析。情境分析的結果顯示當注水流量介於 8-18kg/s 之間時，注水流量較大情況下，爐心上方噴灑較降流區注水，對燃料護套尖峰溫度有更好的冷卻效果，然而在低注水流量情況下，則反之。噴灑案例的燃料護套溫度比降流區注水案例的燃料護套溫度來得高。另外發現使用多維爐心上部組件模擬並不一定能獲得較保守之計算結果。

這次會議論文數量眾多，以下摘記聆聽簡報及討論整理重點如下:

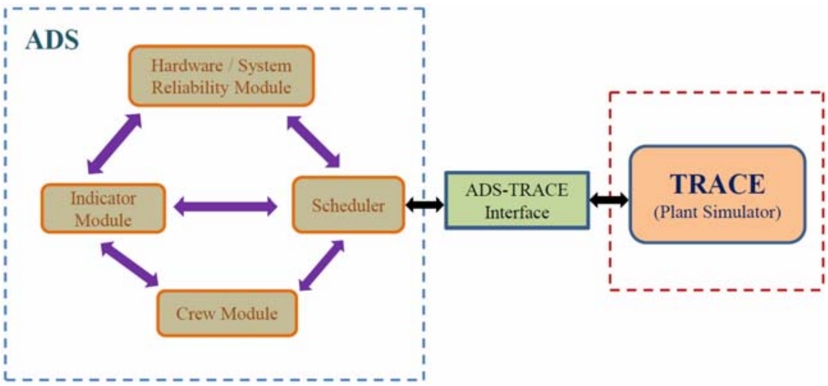
NUTHOS 10-1173

Treatment of Epistemic and Aleatory Uncertainties in DET simulations: Computational Framework with ADS-TRACE

作者：S. Rahman, D.R. Karanki, O. Zerkak, V.N. Dang

使用模擬程式分析電廠事故情節可提供一些量化的重要資訊，例如事故序列的結果以及安全系統的成功準則。事故序列呈現物理現象過程、安全設備與運轉人員反應間的複雜動態相互作用。動態事件樹整合了電廠物理現象模式、隨機設備與人員反應模式，可更精確地捕捉電廠事故動態。然而動態事件樹仍然包含了各種形式的不準度，例如熱水流模式參數、安全設備需求失效機率、以及人因失效機率。這些受到知識不確定性影響的不準度可能顯著的影響模擬的事故動態及最後算出來的風險，所以在使用動態事件樹時必需同時考慮知識不確定性造成的不準度。本篇論文建立一套計算架構，結合了動態事件樹、熱水流程式、不準度傳遞方法以定量風險的不準度。

其中 Paul Scherrer Institute 最新的研究是將 TRACE 與他們的事故動態模擬器結合，事故演變過程使用 TRACE 模擬，系統參數反應持續回傳至事故動態模擬器，再由事故動態模擬器依判斷規則建立動態事件樹。



ADS-TRACE 計算架構

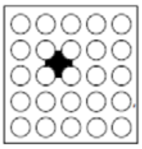
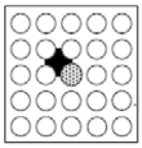
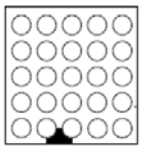
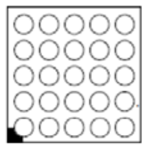
NUTHOS 10-1089

Analysis of Void Fraction in single channel using TRACE, MARS-KS, and RELAP5

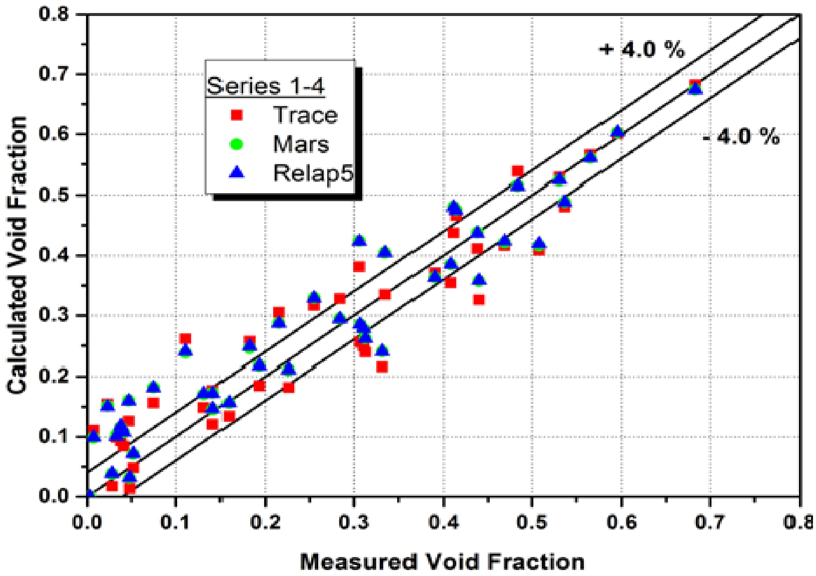
作者：K.C.Le,T.Kim

空泡分率的準確預測在次通道的分析中是非常重要的，一般而言，次通道的分析是使用次通道分析專用程式，例如 COBRA-TF、VIPRE-02、MATRA、FLICA-OVAP 等。然而，近來系統分析程式的發展，包含雙相流計算模式及三維組件，有助於更準確的預測反應爐系統中多相的物理現象。本篇論文評估三個不同的系統分析程式用來分析次通道的適用性，驗證的方式是將程式計算結果與 NUPEC 實驗設施的數據進行比對，在單通道的實驗中包含了四種次通道幾何型式。系統分析程式則包括 TRACE、MARS-KS、RELAP5，其中 MARS-KS 是由韓國的 KAERI 所發展，用來進行輕水式反應爐多維度的熱水流分析。每個系統分析程式輸入模式建立的方式完全相同，將單通道分為 25 個節點，計算空泡分率的位置在第 23 節點。

四種次通道幾何共進行 44 組計算，計算結果發現在量測所得的空泡分率小於 0.3 時，程式計算有高估的現象。線性迴歸分析的結果發現，整體而言所有程式的空泡分率計算結果均稍微大於量測值，系統分析程式用來分析次通道的適用性仍需進一步與專用程式的計算結果進行比對。

Item	Data			
Assembly (Subjected subchannel)	 S1	 S2	 S3	 S4
Subchannel type	Center (Typical)	Center (Thimble)	Side	Corner
Number of heaters	4×1/4	3×1/4	2×1/4	1×1/4
Axial heated length (mm)	1555	1555	1555	1555
Axial power shape	Uniform	Uniform	Uniform	Uniform

四種次通道幾何型式



計算與量測所得的空泡分率比較

NUTHOS 10-1182

Post-test Analysis of OECD/NEA ROSA-2 Test 4 using TRACE

作者：Clifford I, Zerkak O, Pautz A

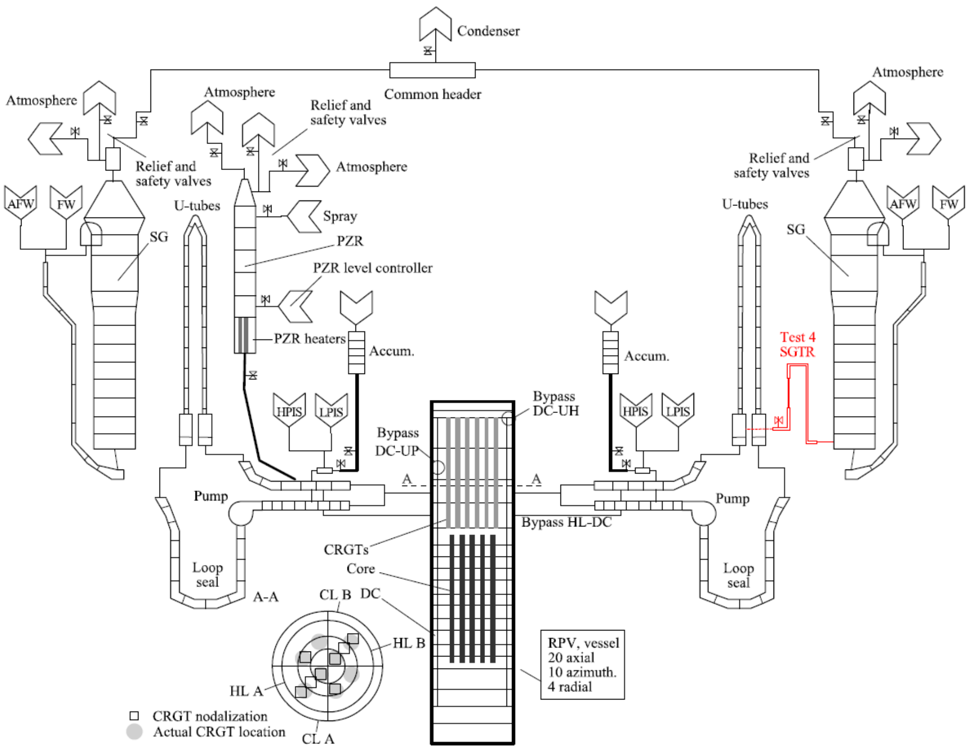
本篇論文為 Paul Scherrer Institute (PSI)執行 STARS 計畫所完成的成果，目的在驗證 ROSA/LSTF 模式的使用彈性，方法為將熱水流程式 TRACE 計算得到的穩態參數與暫態變化與整合的實驗設施所得數據比對以評估其準確性。實驗數據取自 OECD/NEA ROSA-2 Test 4，該實驗於 2010 年在日本原子力研究開發機構的 ROSA/LSTF 進行，是一項關於蒸汽產生器斷管的 ISLOCA 實驗。論文中使用的 ROSA/LSTF 模式是以 PSI 既有的分析模式為基礎，既有分析模式已使用七項 ROSA/LSTF LOCA 及蒸汽產生器斷管實驗數據進行驗證。

針對 TEST 4 分析模式所需要進行的小修改包括調壓槽噴灑閥及汽機旁通閥，這些修改與蒸汽產生器斷管後的事故處理有關，整體而言 TRACE 模擬的結果與實驗數據一致，但蒸汽產生器的水位被高估，這個現象直接影響事故過程的時序；由斷裂的 U 型管流出的臨界冷卻水質量流率稍微被低估，但在壓力降低後，冷卻水質量流率未達到臨界即無此現象；熱端及冷端的冷卻水質量流率和溫度則可準確的計算得到。經過多次的驗證 ROSA/LSTF 分析模式已成為一個具使

用彈性及可靠的分析模式。討論時作者表示有許多議題尚待解決，如一次側的壓力下降實驗值呈現 Overdamped 的趨勢，而分析值呈現 Underdamped 的趨勢。另外還有提到當冷卻水注入斷管的蒸汽產生器冷端時，實驗觀察到水溫會產生熱分層，但使用一維的分析模式無法捕捉到此物理現象。

Event	**Measured Time [s]**	**Simulated Time [s]**	**Difference [s]**
Break	0	0	0
Generation of SCRAM signal	350	376	26
Termination of SG main feedwater	385	407	22
Initiation of HPIS in both loops	497	480	-17
Initiation of AFW in both loops	570	540	-30
Closure of SG MSIVs	954	976	22
Initiate manual depressurisation of intact SG secondary-side	1075	1096	21
Termination of AFW in affected loop	1100	826	-274
Initiation of PZR auxiliary spray	2110	2171	61
Termination of HPIS	2285	2451	166
Termination of PZR auxiliary spray	2560	2897	337
Restart of primary coolant pump in intact loop	3000	3334	334
Termination of manual SG depressurisation	3060	3374	314

實驗與模擬所得時序比較



ROSA/LSTF 分析模式節點圖

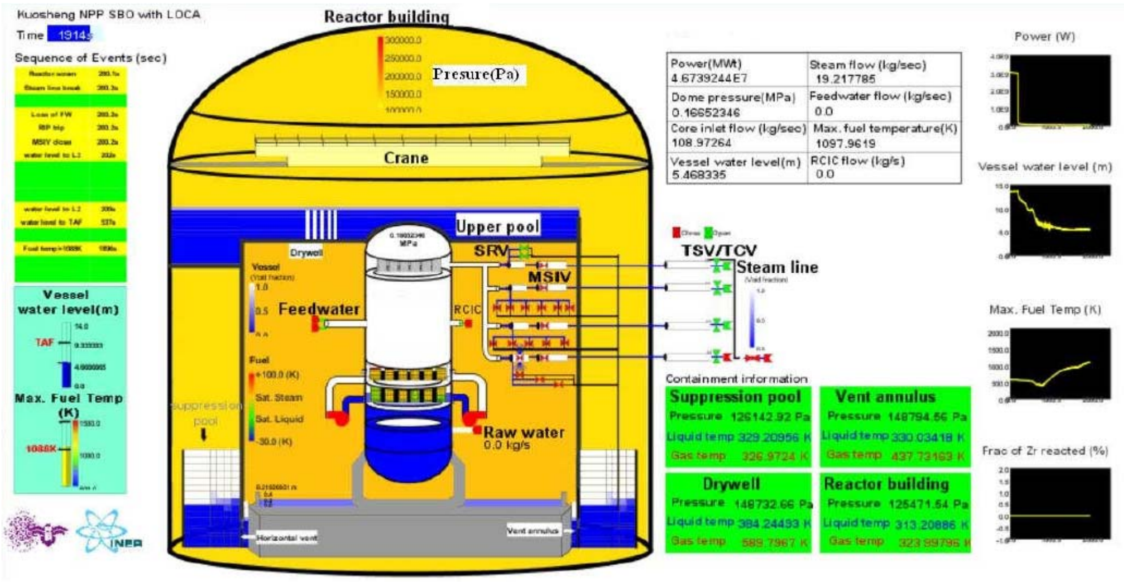
NUTHOS 10-1075

TRACE/FRAPTRAN Analysis of Kuosheng (BWR/6) Nuclear Power Plant for the Similar Fukushima Accident

作者：Jong-Rong Wang, Hao-Tzu Lin, Hsiung-Chih Chen, Jung-Hua Yang, Chunkuan Shih

本篇論文應用核二廠 TRACE/FRAPTRAN 分析模式分析核二廠的類福島事故，內容主要包含三部分：第一部分為核二廠 TRACE/FRAPTRAN 的建立，第二部分是核二廠在發生類似福島事故或更嚴重事故時的暫態分析，第三部分使用 FRAPTRAN 分析來確認事故過程中核燃料的機械性質及其完整性。事故假設在電廠全黑之後飼水泵及再循環泵跳脫、主蒸汽隔離閥關閉，事故過程中無任何補水系統可用。尖峰燃料護套溫度在 4730 秒上升至超過 1088.7K，鋯水反應開始發生，FRAPTRAN 的計算結果指出在這個時間點氧化層的厚度尚未超過限值。此外，當水位降至低於有效燃料頂端以下，燃料護套 Hoop Stress 及 Hoop Strain 產生明顯的變化。

本篇論文另外評估了更嚴重的複合型嚴重事故：電廠全黑同時發生喪失冷卻水事故。事故假設在電廠全黑之後飼水泵及再循環泵跳脫、主蒸汽隔離閥關閉，於此同時一條蒸汽管路發生斷管。共分析了兩個案例，案例一中無任何補水系統可用；案例二中消防水可用，其流量為 39kg/sec。案例一尖峰燃料護套溫度在 1900 秒上升至超過 1088.7K，鋯水反應開始發生，FRAPTRAN 的計算結果指出在這個時間點氧化層的厚度尚未超過限值，但在節點 18 的地方已產生破損的現象。燃料護套 Hoop Stress 及 Hoop Strain 隨著燃料溫度上升而上升，在 1900 秒後 Hoop Strain 上升至超過 NUREG-0800 所規定的限值。案例二水位在 700 秒時降至有效燃料頂端以下，消防水在 800 秒時開始注入反應爐，由於有消防水注入，水位不會低於有效燃料底端的高度，過程中最大尖峰燃料護套溫度也不會超過 1088.7K。



核二廠事故模擬結果動畫展示

NUTHOS 10-1328

Scaling Consideration in a Pressure Vessel Upper Head SBLOCA

作者：A. Querol, S. Gallardo, G, Verdu

由於幾乎不可能進行全尺寸的實驗，程式分析的結果是與小尺寸的整合實驗設施所得到的數據進行比對，以驗證程式的能力。日本原子力研究開發機構的ROSA/LSTF 屬於全高全壓的實驗設施，ROSA/LSTF 實驗所得的資料庫可提供分析程式驗證其準確性。本篇論文研究小尺寸實驗設施觀察到的物理現象在放大尺寸的分析模式是否也可觀察到，實驗數據來自於 OECD/NEA ROSA-2 Test 6-1，Test 6-1 是關於 PWR 壓力容器頂部小破口喪失冷卻水事故的實驗，破口的尺寸為冷端的 1.9%。

先前的研究中已建立完成 TRACE LSTF 分析模式，放大尺寸的分析模式(scaled-up model)由這個模式修改得到，使用的標準為 power-to-volume criterion，此標準的特色為體積尺度因子的應用。前述兩個分析模式的分析結果同時與實驗數據比對，比較的參數包括系統壓力、由破口流出的質量流率、爐心出口溫度、尖峰燃料護套溫度、爐心區及降流區水位等，證實兩個分析模式都能良好的捕捉到各參數暫態變化的趨勢，確認 power-to-volume criterion 適合應用在全高全壓的實

驗設施。另外，透過靈敏度分析評估壓力容器及破口的節點分割方法(例如將方位角切割由 4 區增加至 10 區)，結果發現對分析結果沒有顯著的影響，且會消耗更多計算的時間。

Scaling of	Factor	Scaling of	Factor
Volume	K_V	Mass flow rate	Kv
Elevation change	1	Rod heat flux	1
Number of loops	1	Environment heat losses	1
Length of horizontal components	* Fr.	Fluid velocity	1
Break area	K_V	Recirculation ratio	1
Hydraulic diameter	1	Heat structures transfer area	Kv
Power	K_V	Thickness of heat structures	1
Time	1	ECC, steam line and feedwater flow	Kv
Fuel rod geometry and material	1	ECC and feedwater temperature	1
Temperature	1	Non-dimensional characteristics for pumps and valves	1
Pressure	1		

*Froude number scaling criterion in horizontal components

Power-to-Volume Criterion 體積尺度因子

NUTHOS-10-1209

Sensitive analysis and modifications to reflood-related constitutive models of RELAP5

作者：Dong Li, Xiaojing Liu (上海交通大學)

因研究者使用 RELAP5 計算程式與實驗數據相比，再泛水(reflood)過程中燃料護套溫度較實驗數據有低估及淬冷(quench front)時間有提早情況，為找到可能影響計算結果的重要參數，依據常用的理論計算，選定四個參數作靈敏度分析：壁面對蒸汽薄膜沸騰熱傳係數(wall to vapor film boiling heat transfer coefficient)、壁面對液體薄膜沸騰熱傳係數(wall to liquid film boiling heat transfer coefficient)、乾壁面表面磨擦係數(dry wall interfacial friction coefficient)及最小液滴直徑(minimum droplet diameter)。

研究以修改程式計算模式與六組 FEBA 實驗數據作比較。比較結果是瀰散流薄膜沸騰熱傳模式(dispersed flow film boiling heat transfer)及瀰散流表面摩擦模式(dispersed flow interfacial friction model)是影響計算結果主要模式，藉由改進

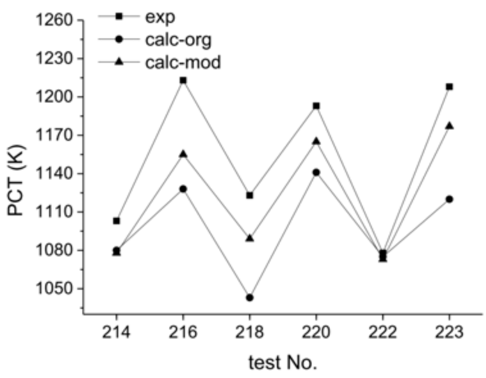
RELAP5 計算模式，可得到較原計算結果更接近實驗數據。

會議中亦討論到修改後模式的適用範圍，及是否僅適用於特定情況的問題，因目前比對的實驗數據相對 RELAP5 預設模式適用範圍小，未來該計畫若得到 OECD/NEA 持續贊助，將實驗數據比對範圍擴大則可解決此問題。

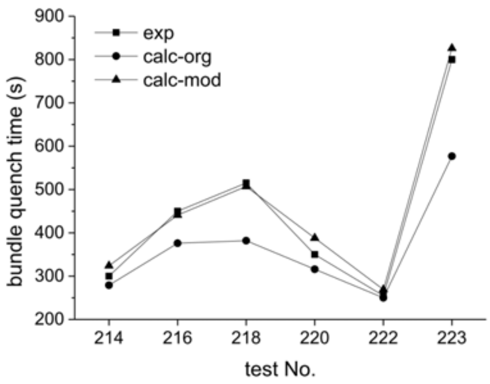
對我國熱流程式的應用上，因計算模式建立有其適用範圍、不準度及相關認證問題，建議待程式維護廠家同意或普遍取得程式使用者認可前，維持原預設計算模式。

Test No.	**Inlet velocity, cm/s**	**System pressure, Bar**	**Feed water temperature, °C**		**Bundle power, kW**	
			0-30s	End	0s	Transient
223	3.8	2.2	44	36	200	120% ANS
216	3.8	4.1	48	37	200	120% ANS
220	3.8	6.2	49	37	200	120% ANS
218	5.8	2.2	42	37	200	120% ANS
214	5.8	4.1	45	37	200	120% ANS
222	5.8	6.2	43	36	200	120% ANS

FEBA 實驗條件



燃料護套溫度比較



淬冷開始時間比較

NUTHOS-10-1352

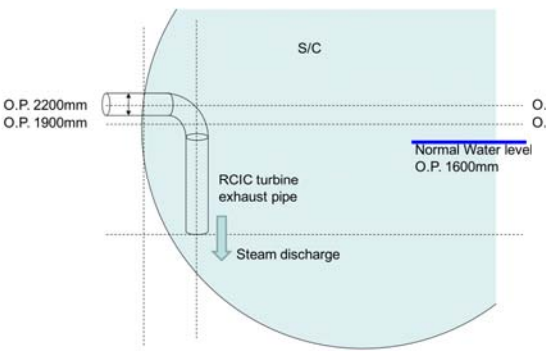
Unsolved issues relating thermal-hydraulics in the suppression chamber during Fukushima Daiichi accident

作者：Shinya Mizokami, Daichi Yamada, Takeshi Honda, Daisuke Yamauchi, Yasunori Yamanaka (東京電力公司)

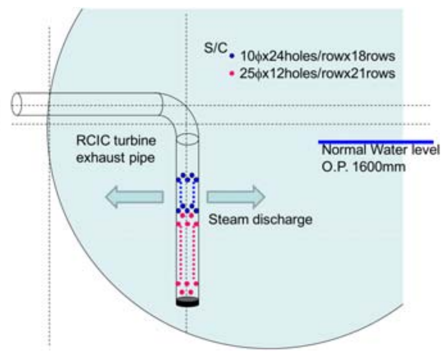
日本 311 福島事故後雖然東電公司（TEPCO）做了許多事故過程、反應爐及

圍阻體狀態調查，但仍有數十個以上未解的議題仍待解開以了解事故全貌，此篇介紹有關福島一廠 2、3 號機抑壓池(suppression chamber)的熱水力（thermal-hydraulics）現象，現象為抑壓池內可能出現熱分層（thermal stratification），我國第一核能發電廠即是使用與福島一廠 2、3 號機相同的圍阻體設計 MARK-1。

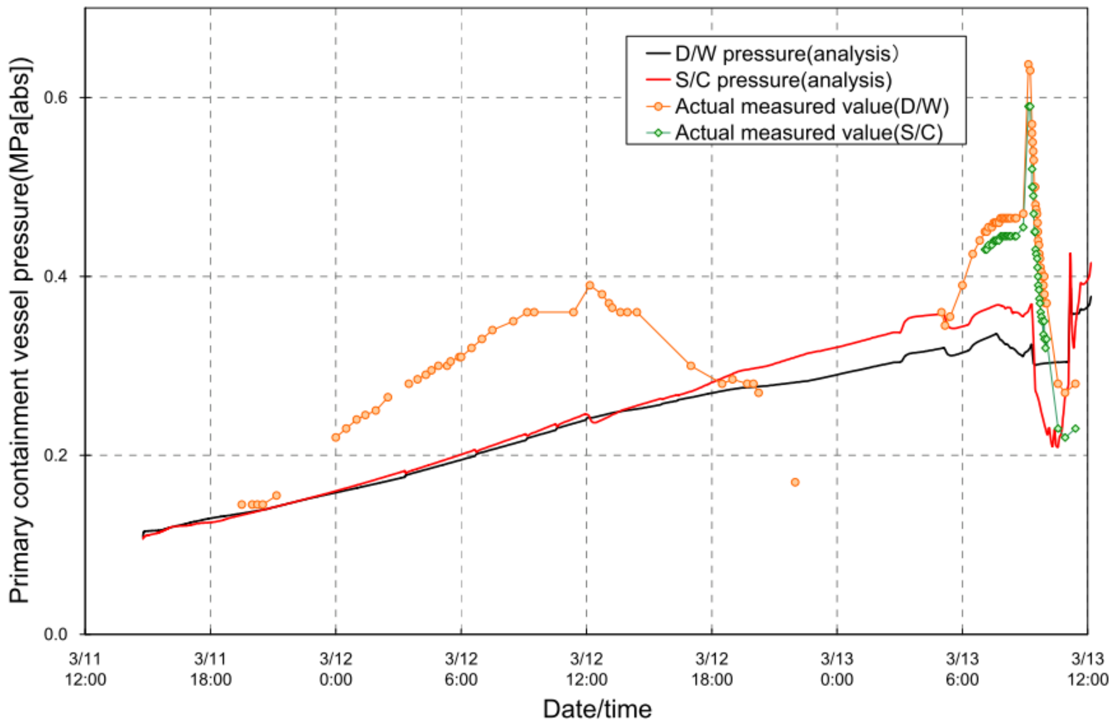
議題起因於對於福島一廠 3 號機事故期間抑壓池壓力模擬分析時，在某些時刻實際量測的壓力數據遠高於理論衰變熱造成的分析值，模擬分析係假設在抑壓池中溫度均勻分佈，然而實際情況應不是如此，並且 3 號機抑壓池壓力也高於 2 號機，經調查結果 2、3 號機 RCIC 在抑壓池排汽管設計不同，2 號機為垂直排放管，而 3 號機為垂直多孔排放管(vertical multi-hole sparger)，後續幾篇 SIET 實驗室所作小尺寸抑壓池實驗，其一為類 2 號機單一管排汽到池中實驗，結果顯示若蒸汽中挾帶即使微量不可凝結氣體，仍會顯著降低蒸汽在池中內爆(implosion)能力，另一則研究為仿效 3 號機 RCIC 排放管設計，在上部散佈 1.0cm 孔徑 432 個，在下部則散佈 2.5cm 大小孔徑 252 個，實驗結果在池水低溫度時，2.5cm 大小孔徑可以誘發 chugging phenomena，池中的液態水會被蒸汽冷凝吸入排放管內再被高速蒸汽推出，如此往復有效攪拌池水，使其溫度均勻分佈，然而當池水溫度提高到約攝氏 45 度時，則停止前述震盪現象，取代的是從上方 1.0cm 孔徑穩定釋出氣泡，使抑壓池形成穩定的熱分層，降低熱沉(heat sink)效果。



福島一廠 2 號機 RCIC 排放管



福島一廠 3 號機 RCIC 排放管



福島一廠 3 號機 PCV 壓力比較

NUTHOS-10-1098

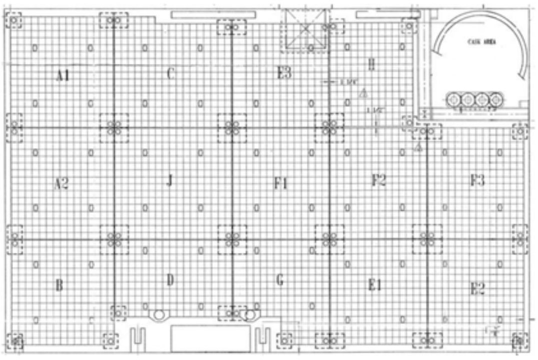
Analysisi of the loss of cooling accident for the spent fuel pool of nuclear power plant using MELCOR

作者：Zhongwei Zhang and Thomas K.S. Liang (上海交通大學)

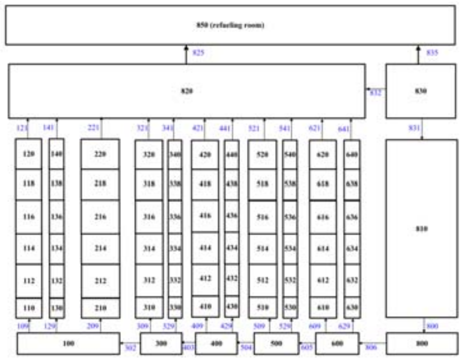
研究使用 MELCOR 程式版次 1.8.6 模擬 2011 年 3 月 11 日福島一廠 4 號機用過燃料池，用過燃料池包含 2870 束燃料，燃料總功率約 1.06MW，其中 20%功率來自最後退出的 100 束燃料，模擬節點則依燃料池幾何形狀作分節，分析假設用過燃料池失去補水及冷卻系統，分析結果顯示約 19.9 天後水位會從初始高度降到燃料貯存架(fuels storage racks)頂部，燃料護套達快速氧化閾值溫度約 1100K 則約 29.1 天，燃料護套溫度達到最高溫度 1862K 約 30.8 天，並預測總共會有 1560kg 的氫氣產生。

研究顯示 MELCOR 可以應用估算用過燃料池的嚴重事故，然而有部份仍待改善的是尚未考慮燃料貯存架對流體流動影響及與燃料匣間熱傳遞問題，另外與會專家也談到，MELCOR 並未具備計算沸騰蒸汽或氣體向上時會一併將液珠帶

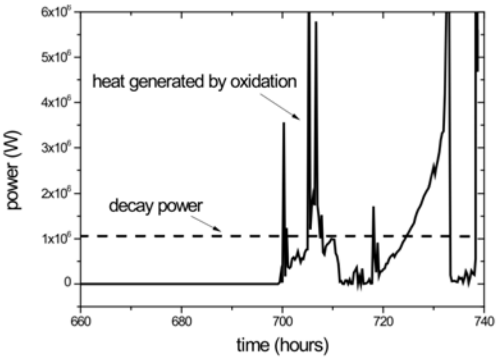
離功能，而此現象將顯著加速水位下降時間。



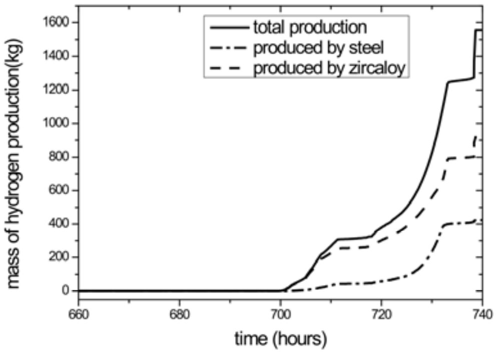
用過燃料貯存格架



MELCOR 用過燃料池節點圖



衰變熱與氧化釋能比較



氫氣產率

NUTHOS-10-1046

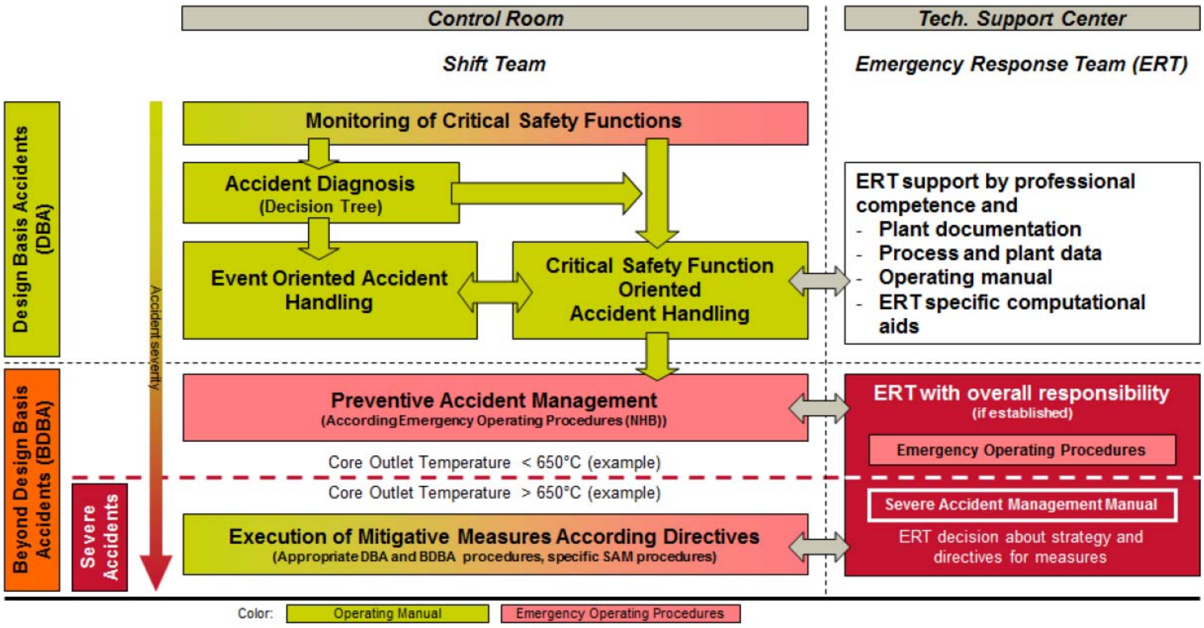
Severe accident management-optimized guidelines and strategies

作者：Matthias Braun, Micha Löffler, Hermann Plank, Dietmar Asse, Harald Dimmelmeier (AREVA GmbH)

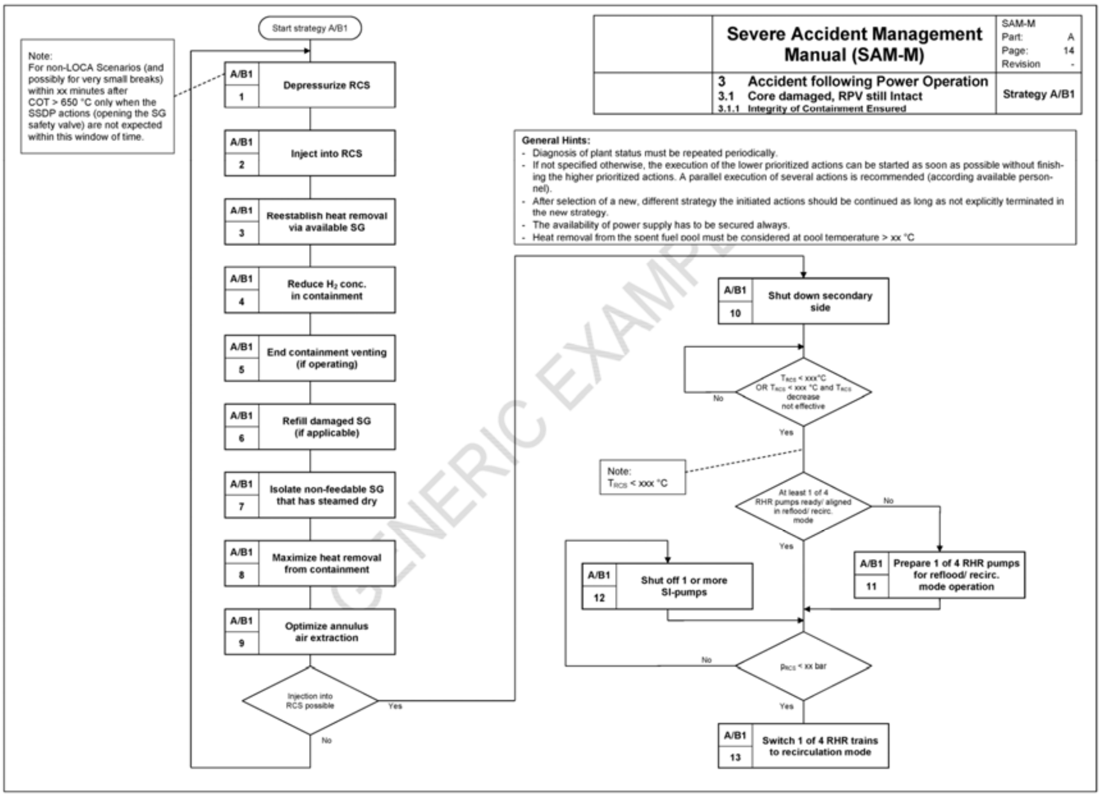
為緩和嚴重事故後果，圍阻體完整性係防護放射性物質外釋到環境的最後屏障，威脅圍阻體完整性的主要來源為高壓反應爐失效造成的圍阻體直接加熱(direct containment heating)、蒸汽爆炸(steam explosions)，以及氫氣爆炸、過壓、穿越孔過溫失效、熔渣融穿。為使嚴重事故時將可用系統發揮最大效益緩和嚴重事故，AREVA 對於德國核能電廠導入一套 SAM(sever accident management)，概念是廣泛的使用全廠數值模擬，量化各種情境下系統的啟動（包含操作系統、安全系統、嚴重事故專用系統等）對於事故的發展影響。再根據獲得的結果，發展計算系統，使運轉員了解電廠目前狀態，並預測事故發展進程，界定目前及緊接的關

鍵任務，及提供人員最佳決策。運轉員使用方法基本上為根據電廠廠內量測系統及嚴重事故專用量測系統所測得數據，套用於先前經廣泛模擬結果製成的決策矩陣，依據矩陣位置決定下一步最佳行動策略。

於會議後與作者討論若發生類福島事故如反應爐水位信號無法得到量測數值或量測儀器偏離正常運轉範圍使讀值不可信時，如何使用決策矩陣，作者答覆，在當時情況下無其他方式可提供水位量測值時，只能選擇相信電廠水位量測儀器數值。當失去廠用量測系統時，仍有 AREVA 安裝在廠內的輻射監測儀器，依據研究經驗及大量數值模擬結果，各種嚴重事故情境下，定量的爐心熔毀約會對應一定量的輻射量測值，藉測得輻射強度仍可推估爐心熔毀量並了解目前電廠狀態。



德國電廠嚴重事故管理結構圖



嚴重事故管理流程圖範例

NUTHOS-10-1130

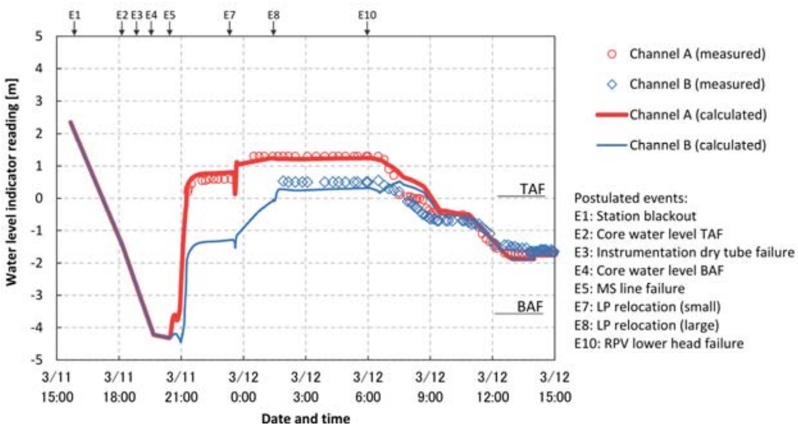
Discussion of accident progression of Fukushima Daiichi unit 1 based on behavior of fuel range water level indicator readings

作者：K. Nozaki, S. Suehiro, M. Watanabe, S. Mizokami, D. Yamauchi, D. Yamada, T. Honda (TEPCO)

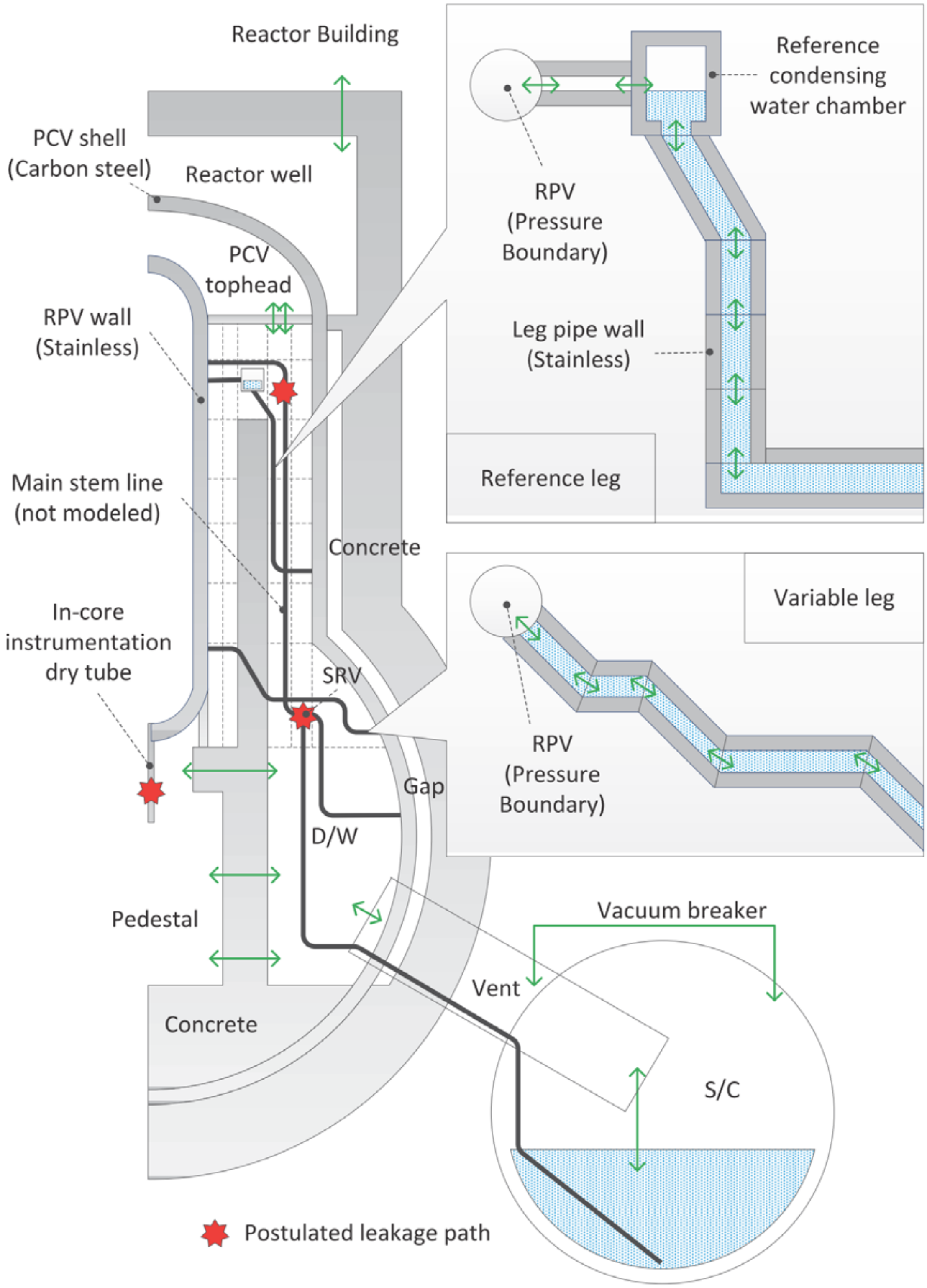
福島一廠 1 號機在事故後，有許多事件有待釐清與調查，其中一項為反應爐水位量測儀器數據無法反應實際水位。由於事故過程中 1 號機水位及壓力量測系統僅有部份時間點有量測數據，因此研究以熱流分析程式 GOTHIC 試圖重建完整的水位及圍阻體壓力變化，並推測各時間點事故變化可能的原因。研究以假設的反應爐壓力、圍阻體溫度、RPV 洩漏到圍阻體氣體流量等作為模擬的邊界條件。

水位量測儀器並未正確指示反應爐水位，可能原因為某些情況下圍阻體溫度上升，水位量測儀器內的水蒸發，溫度上升的主因推測並非由 RPV 的直接加熱，因為 RPV 與乾井間裝置有絕熱層，而是 1.在事故初期有部份的冷卻劑從 RPV 洩漏到圍組體，同一時間因為 RPV 進行洩壓，使得水位量測儀器的飽和壓力下降，雙重原因下使水位儀器內液體更容易蒸發。2.事故後期 RPV 底部可能破裂，使熔渣直接對圍阻體加熱，同樣使得水位儀器內液體蒸發。

模擬結果能近似重現反應爐壓力及水位紀錄值的變化，及水位量測儀器 A 及 B 通道的差異（原因推測為反應爐冷卻劑洩漏位置造成的差異）。



福島一廠 1 號機水位儀器讀值及模擬比較



GOTHIC 電廠模擬節點圖

表一、NUTHOS-10 專題會議領域表

A: Thermal-hydraulics and safety
- A-1) Thermal-hydraulics and safety of water-cooled reactors
- A-2) Thermal-hydraulics and safety of liquid-metal cooled reactors
- A-3) Thermal-hydraulics and safety of gas-cooled reactors
- A-4) Thermal-hydraulics and safety of fusion systems
- A-5) Thermal-hydraulics and safety of advanced reactors
- A-6) Cross-cutting thermal-hydraulic issues of innovative nuclear systems

B: Advances in experiments and numerical methods
- B-1) Advances in experimental thermal-hydraulics
- B-2) Advances in numerical thermal-hydraulics
- B-3) Multi-scale thermal-hydraulics codes
- B-4) Verification and validation of numerical codes
- B-5) CFD Application to nuclear engineering

C: Plant operation and safety
- C-1) Plant operation and maintenance experiences
- C-2) Plant monitoring and diagnostics
- C-3) Plant simulator and operator training
- C-4) Plant life extension and license renewal
- C-5) Multi-physical phenomena in nuclear operation
- C-6) Advances in materials and water chemistry
- C-7) Advances in digital instrumentation and control
- C-8) Advances in nuclear safety systems and analysis

D: Severe accident and PRA methodology
- D-1) Severe accident mitigation measures
- D-2) Severe accident management guidelines
- D-3) PRA application to design, operation and maintenance
- D-4) Uncertainty analysis

E: Others
- E-1) Licensing issues in thermal-hydraulic and safety Lessons-learned from Fukushima Dai-ichi Accident
- E-1) Others

OG: Organized session

- OG-1) Reactor dynamics and instability
- OG-2) Corrosion residual unidentified deposit (CRUD)
- OG-3) Nuclear policy and regulatory
- OG-4) Unique innovative NPP concepts

表二、NUTHOS-10 各國參與人數及投稿篇數表

國家	參與人數	投稿篇數
日本	106	72
韓國	52	29
德國	25	26
中國	30	23
瑞典	9	13
美國	19	13
瑞士	9	12
台灣	19	12
印度	4	7
法國	6	6
義大利	5	6
俄羅斯	4	5
西班牙	3	4
阿根廷	1	2
加拿大	2	2
墨西哥	2	2
比利時	1	1
立陶宛	1	1
斯洛維尼亞	1	1
泰國	1	1
越南	2	
香港	1	
拉脫維亞	1	
挪威	1	
英國	1	
國際原子能總署	1	
總計	307	238

四、 專業技術討論

參加國際學術會議，除了可以了解目前最新的研究趨勢與發表論文，接受國際同儕的審議外，更重要的是參與專業技術討論與認識同行專家。其中，認識同行專家尤其重要，同行專家可以提供寶貴資訊與諮詢意見，並可就某一雙方共同有興趣的議題進行深入討論，對於提升我國的學術水準將有莫大助益。而在會議上積極參與專業討論更是認識同行專家最有效的途徑之一。以下簡述在這次會議中我們所參與的討論：

12 月 15 日第一個 Plenary lecture 是由美國北卡大學的 Nam Dinh 教授演講，講題為 Perspectives on Nuclear Power Safety，他以非常宏觀的角度有系統的檢視目前核能安全的概念與做法，並提出未來核能安全的需求，內容非常豐富精彩。在 Nam Dinh 教授演講當下，我們並未於公開場合與他進行專業技術對話，然而，透過邀約，第二天(12 月 16 日)午餐時，我們與 Nam Dinh 教授以及瑞典的 Pavel Kudinov 博士就嚴重事故的模擬、緊急應變之事故評估需求以及 SAMG(嚴重事故應變指引)的評估進行了非常深入的討論。討論時，Nam Dinh 教授以及瑞典的 Pavel Kudinov 博士承諾提供相關論文與報告給我們參考，會議還沒結束，就已經收到這兩位專家提供的五篇論文與報告，收穫非常豐碩。

12 月 15 日下午聆聽韓國核燃料公司(KEPCO Nuclear Fuel)演講，其論文題目為「Application of the Monte Carlo Thermal Design Analysis to Evaluate Uncertainties of the PWR Core using the THALES Subchannel Code」，在這一篇論文中，韓國核燃料公司利用蒙地卡羅方法來處理運轉參數所伴隨的不準度以及臨界熱通率經驗公式所伴隨的不準度並據以決定偏離核沸騰比限制值(DNBR limition)。韓國核燃料公司使用 3000 次之次流道分析(subchannel analysis)來獲得偏離核沸騰比限制值。相較於目前做法，此論文所建議的做法需要耗費非常龐大的電腦計算，是否具實用價值尚待未來進一步觀察。針對此論文，我們基於過去之審查經驗，提出一項提問：「請問在計算偏離核沸騰比限制值時，介於燃料棒與護套間之間隙熱傳係

數是否為一個重要參數？如果是，其不準度在蒙地卡羅方法中是何處理的？」主講者沒回答間隙熱傳係數是否為一個重要參數，僅表示在計算時這個參數係假設為常數，換言之，沒有考慮其不準度。另一位曾任職於西屋公司的專家提問「如採用蒙地卡羅方法，相較於目前方法，偏離核沸騰比限制值有多少改進？」主講者遲疑了一陣子回答說 5%之改進。在演講後之休息時間，美國核管會之專家表示他同意我們的看法，依據他的經驗，間隙熱傳係數確實是一個很重要的參數，其不準度不該沒納入考慮。曾任職於西屋公司的專家也參與討論，他認為目前方法能夠再改進的空間已經相當有限，主講者所說的 5%之改進，值得存疑。

12 月 15 日下午聆聽墨西哥一所大學演講，其論文題目為 Natural Convection Effects During a Severe Accident，針對此論文，我們提出一項提問：「發生嚴重事故時，燃料溫度非常高，在此情況下，輻射熱傳相當重要，從論文所提出之公式看來，輻射熱傳並未處理，請說明在何處處理？」，主講者有些尷尬，表示該論文並未將輻射熱傳納入考慮。

12 月 16 日早上 Panel Discussion；Nuclear Safety Research Perspective in Each Country 由各參與國家簡介其核能安全之簡介。我國是由清華大學潘欽教授進行簡報，由於大會指示演講內容要聚焦於創新，因此，潘欽教授的演講係以斷然處置指引為主軸搭配研發計畫。在潘欽教授的演講中採用了我們提供的若干素材。在 Panel Discussion 這一時段，由於主席對與談者之演講時間沒做控制，各國代表講完後，已經沒有時間進行討論。

在 Panel Discussion 後分場次在不同會議室同時進行 5 場 Keynote lecture。我們聆聽 KL-1. Keynote lecture 1，其講題為 Fukushima Daiichi Nuclear Accident; based on the Final Report of the AESJ Investigation Committee。在聽完此項演講後，我們提出兩項提問。在第一項提問中我們先比較了福島一廠與福島二廠在事故過程中設備毀損情況之異同，再簡述福島二廠採用之策略，接著表示，如果福島一廠三號機採用了福島二廠之策略或是採用了剛剛潘欽教授所介紹的斷然處置指引，依照我們的意見，福島一廠三號機的爐心熔毀應該是有機會可以避免的，這是我們的

看法希望聽一聽您的看法。主講者 Naoto Sekimura 教授並未從熱流觀點討論避免爐心熔毀的可能性，僅表示當時情況很危急也很混亂加上福島一廠一號機氫氣爆炸造成設備受損以及輻射外釋，因此，是否能避免爐心熔毀很難斷定。主講者的答覆看似合理，但是如進一步檢視，實存有可議之處。首先，讓我們從地理位置談起：氫氣爆炸確實造成設備受損以及輻射外釋，然而受影響最大者應該是臨近氫氣爆炸之機組，福島一廠一號機於 3 月 12 日下午 3 點 36 分率先發生氫氣爆炸，福島一廠三號機於 3 月 13 日上午 10 點 40 分開始爐心熔毀，一號機之臨近機組為二號機，因此，受爆炸影響最大者為二號機而非三號機。其次從時間點加以檢視，福島二廠之一、二、四號機在 3 月 12 日上午 0 點左右就已經將替代注水打入爐心，如果，福島一廠三號機採用福島二廠之策略，可望於 3 月 12 日上午將替代注水打入爐心，而此時一號機之氫氣爆炸尚未發生(一號機之氫氣爆炸實際發生於 3 月 12 日下午)，不致於妨礙爐心熔毀的救援。從以上之討論，我們覺得福島一廠三號機甚至二號機如採用了福島二廠之策略或是我國首創之斷然處置指引，其爐心熔毀應該是有機會可以避免的。

12 月 16 日下午我們發表一篇論文，主講者為黃議輝先生，論文題目為 Multi-Dimensional Modeling and Simulation of Upper Plenum in URG Analysis of Lungmen Nuclear Power Plant using RELAP5-3D，講完後有三人提問，其中一位為日本專家，他對於論文假設情境下 RELAP5-3D 之適用性提出質疑，在燃料底部有複雜的流道通往 lower plenum，他問我們是否有模擬並懷疑 RELAP5-3D 之適用性。當天晚上在正式晚宴上，我們找到 Michio Murase 博士並簡短討論，他提到以往他們有做一些相關實驗，我們向他索取實驗結果報告，他爽快答應並已經提供給我們。

12 月 17 日上午 KL-6. Keynote lecture 是由美國 Ohio State University 之 Tunc Aldemir 教授演講，講題為 Recent Trends in Nuclear Reactor Safety Assessment and Available Tools，演講內容強調 dynamic PRA，在演講休息時間與一位在美國從事 PRA 三十餘年之專家討論，我們一致認為演講題目範圍很廣，內容之範圍卻很

窄，不是十分相稱。該專家並表示 dynamic PRA 在美國之 PRA 業界並非主流。

12 月 17 日下午聆聽清華大學一篇演講，講題為 MELCOR/SNAP analysis of Chinshan (BWR/4) nuclear power plant spent fuel pool for the similar Fukushima accident， 在聽完此項演講後，有一位專家提出一項 comment，他表示 MELCOR 並不適合用來模擬類福島事故下用過燃料池的熱流分析，因為 MELCOR 在計算輻射熱傳時其 view factor 之適切性存在爭議，此外，水位低燃料棒裸露時，空氣之 convection 將扮演相當重要的角色，MELCOR 在模擬此情境時準確度也值得存疑。會後與清華大學教授討論，教授表示，MELCOR 之發展者在說明該程式之應用範圍時，將用過燃料池的熱流分析也納入。另外，會後查了一下 2013 美國核管會所舉辦之 RIC 會議，在會議中 Hossein Esmaili 發表一篇簡報標題為 Spent Fuel Pool Modeling and Analysis with MELCOR 該簡報之結論為 MELCOR modeling approach is the right tool for SFP accident analysis since all severe accident phenomena are represented in an integral manner。所以，MELCOR 大體上應該適合用來模擬類福島事故下用過燃料池的熱流分析(或許部分模式需要進一步精進)。該項 comment 所質疑之議題值得未來進一步追蹤。

12 月 18 日上午廖主任擔任 Thermal Hydraulics and Safety of Water-Cooled Reactors 11 之共同主席。聆聽日本三菱重工與關西電力所共同發表的論文，講題為 Study on PWR Safety System Using SG Secondary-side Depressurization，在聽完此項演講後，我們提出一項提問:「雖然非均勻案例之整體冷卻速率較均勻案例低，但是，非均勻案例之護套尖峰溫度反而較均勻案例低。請問這項意外的結果對緊急運轉程序書之影響為何？」論文作者表示，此項結果是最近才獲得，尚未考慮其對緊急運轉程序書之影響。此時段我們也發表一篇論文，主講者為吳文雄先生，論文題目為 The Assessment of the Fukushima Like Accident for Kuosheng BWR/6 with TRACE，講完後有人提問，如何驗證計算之結果。我們的答覆是 TRACE 為美國核管會所發展之程式，該程式透過 CAMP 國際合作案，由世界各國進行為數眾多之各式各樣驗證比對，包括 Separate Effects 驗證比對、Integrated Effects 驗證比

對等，其適用性已經獲得完整足夠的驗證。此外，本論文中所使用的核二廠 TRACE 分析模式已被用來模擬核二廠起動測試，透過模擬數據與實際紀錄數據比對，驗證該模式的準確度。比對後說明核二廠 TRACE 分析模式可良好的捕捉電廠暫態行為，模擬的結果也已在其它國際會議上發表。

五、 心得與建議

1. 核能熱水流運轉及安全專題會議 (International Topical Meeting on Nuclear Thermal-Hydraulics, Operation and Safety)，目的在提供各國核能產業與學術機構交流研發技術成果與工程實務經驗之平台。各國的研究重點除了針對福島事故相關現象及嚴重事故發展外，也積極使用 CFD 分析軟體，對系統各組件細部的熱水流現象作詳細的模擬，希望可作為法制分析工具。
2. 對於本次會議後有部份研究議題可再進一步探討，例如嚴重事故期間，水位指示器讀值可能變得相當不可信，此部份會議中並未提出良好對策，以及核一廠 RCIC 蒸汽排放管設計與福島 2、3 號機的差異，事故期間是否同樣會出現熱分層現象，也值得後續探討，其他福島事故相關待解決議題的調查研究，亦需持續關心及掌握，以了解是否以有相關改善措施可供借鏡。
3. 關於 TRACE 程式的應用，會議論文大多著墨於分析模式的驗證，驗證的方式是將程式模擬的結果與實驗數據進行比對，實驗設施包括了單通道的熱流實驗以及系統整合的 ROSA/LSTF 喪失冷卻水事故實驗。比對結果可確認分析模式節點切割的有效性，以及程式選項是否適切，另外也可驗證得到尺寸放大分析模式的方法。我國電廠的 TRACE 分析模式是使用起動測試的數據來評估程式模擬的結果，尚無關於 separate effect 及 integral effect 的研究，未來若要進行相關分析，可參照會議論文的成果。
4. 另外值得注意的是，使用最佳估算方法加上考量不準度是進行安全分析的方法之一，近來的國際會議皆把不準度分析獨立為技術專題報告的其中一項，在 NUTHOS-10 關於不準度分析約有十篇論文發表。顯見在電腦硬體快速發展的今日，大量案例需要耗費長時間計算的情形已漸漸獲得改善，相關程式的發展也越來越多，此研究趨勢可提供本中心未來技術發展參考。
5. 參加國際會議，除掌握國際最新趨勢與發表論文，接受國際同儕的審議外，更重要的是參與專業技術討論與認識同行專家，同行專家可以提供寶貴資訊

與諮詢意見，並可就某一雙方共同有興趣的議題進行深入討論,對於提升我國的學術水準將有莫大助益。未來經費許可情況下，建議持續派員參與此類國際技術專題會議。

六、 附件

（一） 會議日程表

Day	Time	Room A1	Room A2	Room B1	Room B2	Room B3+B4	Room B6+B7
Dec. 15 (Mon.)	9:00 - 9:30	Opening Session					
	9:30 - 10:30	Plenary 1					
	10:30 - 10:50	Coffee break					
	10:50 - 11:50	Plenary 2					
	11:50 - 13:00	Lunch					
	13:00 - 15:00	A-1-1 Thermal Hydraulics and Safety of Water-Cooled Reactors 1	A-1-2 Thermal Hydraulics and Safety of Water-Cooled Reactors 2	D-1-1 Severe Accident Mitigation Measures 1	B-1-1 Advances in Experimental Thermal-Hydraulics 1	B-2-1 Advances in Numerical Thermal-Hydraulics 1	D-3-1 Methodology and Application of PRA for Internal, Seismic and Tsunami Events 1
	15:00 - 15:30	Coffee break					
	15:30 - 17:50	A-1-3 Thermal Hydraulics and Safety of Water-Cooled Reactors 3	A-1-4 Thermal Hydraulics and Safety of Water-Cooled Reactors 4	D-1-2 Severe Accident Mitigation Measures related to Fukushima Dai-ich Accident	B-1-2 Advances in Experimental Thermal-Hydraulics 2	B-2-2 Advances in Numerical Thermal-Hydraulics 2	D-4-1 Uncertainty Analysis 1
Dec. 16 (Tue.)	9:00 - 10:30	Plenary 3					
	10:30 - 11:00	Coffee break					
	11:00 - 12:00	Keynote Lecture 1	Keynote Lecture 2	Keynote Lecture 3		Keynote Lecture 4	Keynote Lecture 5
	12:00 - 13:00	Lunch					
	13:00 - 15:00	A-1-5 Thermal Hydraulics and Safety of Water-Cooled Reactors 5	A-2-1 Thermal Hydraulics and Safety of SFR Plant Systems	D-1-3 Severe Accident Mitigation Measures 2	B-1-3 Advances in Experimental Thermal-Hydraulics 3	A-5-1 Gas and Super-Critical Fluid Heat Transfer and Diffusion	D-4-2 Uncertainty Analysis 2
	15:00 - 15:30	Coffee break					
	15:30 - 17:50	A-1-6 Thermal Hydraulics and Safety of Water-Cooled Reactors 6	A-2-2 Safty Assessment of Severe Accidents in SFRs	A-1-7 Thermal Hydraulics and Safety of Water-Cooled Reactors 7	OG-1 Reactor Dynamics, Instability and Fuel Cladding Coatings & Deposits	A-5-2 Heat Transfer and Safety in PWR and ADS	D-3-2 PRA for External Events other than Earthquakes and Tsunami
	9:00 - 10:00	Keynote Lecture 6	Keynote Lecture 7	Keynote Lecture 8		Keynote Lecture 9	Keynote Lecture 10
	10:00 - 10:30	Coffee break					
	10:30 - 12:00	A-1-8 Thermal Hydraulics and Safety of	B-5-1 CFD for Reactor	D-2 Severe Accident	B-4-1 Verification and Validaiton	A-6-1 Cross-Cutting Thermal-Hydraulics of	D-3-3 Methodology and Application of PRA for

		Water-Cooled Reactors 8	Application	Management Guidelines	of Numerical Codes 1	Innovatie Nuclear Systems	Internal, Seismic and Tsunami Events 2
	12:00 - 13:00	Lunch					
Dec. 17 (Wed.)	13:00 - 15:00	A-1-9 Thermal Hydraulics and Safety of Water-Cooled Reactors 9	A-2-3 Thermal Hydraulics in Liquid Metal Systems 1	E-1 Licensing Issues in Thermal-Hydraulic and Safety Lessons-Learned from Fukushima Dai-ichi Accident 1	B-4-2 Verification and Validaiton of Numerical Codes 2	A-6-2 Cross-Cutting Thermal-Hydraulics of Liquid Metal and Fusion Sytems	C-1 Plant Operation & Maintenance Management
	15:00 - 15:30	Coffee break					
	15:30 - 17:50	A-1-10 Thermal Hydraulics and Safety of Water-Cooled Reactors 10	A-2-4 Severe Accident Phenomena in SFRs	E-2 Licensing Issues in Thermal-Hydraulic and Safety Lessons-Learned from Fukushima Dai-ichi Accident 2	B-4-3 Verification and Validaiton of Numerical Codes 3	A-3 Thermal-Hydraulics and Safety of Gas-Cooled Reactors	C-8 Advances in Nuclear Safety Systems and Analysis
Dec. 18 (Thu.)	9:00 - 11:00	A-1-11 Thermal Hydraulics and Safety of Water-Cooled Reactors 11	A-2-5 Thermal Hydraulics in Liquid Metal Systems 2	D-1-4 Severe Accident Mitigation Measures 3	B-5-2 CFD for Component Application	OG-4 Unique Innovative NPP Concepts	C-2 Plant Monitoring
	11:00 - 11:20	Coffee break					
	11:20 - 12:00	Closing Session					

Dec. 15 (Mon.)

Room A1

Dec. 15 (Mon.), 09:00 - 09:30, Room A1 **OP. Opening Session**
Chairs: Ken-ichiro Sugiyama (Hokkaido University, Japan), Koji Okamoto (University of Tokyo, Japan)

NUTHOS10-OP01	**Opening Remark** Reiko Fujita (President of Atomic Energy Society of Japan, Japan)

Dec. 15 (Mon.), 09:30 - 10:30, Room A1 **PL-1. Plenary Lecture 1**
Chairs: Akira Yamaguchi (Osaka University, Japan), Chul-hwa Song (KAERI , Korea)

NUTHOS10-PL01	**Perspectives on Nuclear Power Safety** Nam Dinh (North Carolina State University, United States), Richard Denning (Ohio State University, United States), Pavel Kudinov (Royal Institute of Technology, Sweden)

Dec. 15 (Mon.), 10:50 - 11:50, Room A1 **PL-2. Plenary Lecture 2**
Chairs: Chul-hwa Song (KAERI , Korea), Akira Yamaguchi (Osaka University, Japan)

NUTHOS10-PL02	**Challenges for the decommissioning of Fukushima Daiichi Nuclear Power Station** Hajimu Yamana (Nuclear Damage Compensation and Decommissioning Facilitation Corporation, Japan)

Dec. 15 (Mon.), 13:00 - 15:00, Room A1 **A-1-1. Thermal Hydraulics and Safety of Water-Cooled Reactors 1**
Chairs: Michio Murase (Institute of Nuclear Safety System, Inc., Japan), Kwon-yeong Lee (Korea Atomic Energy Research Institute, Korea)

NUTHOS10-1003	**The Best-Estimate Plus Uncertainty (BEPU) Challenge in the Licensing of Current Generation of Reactors**

	Alessandro Petruzzi (GRNSPG - NINE, Italy), Francesco D'Auria (GRNSPG - University of Pisa, Italy)
NUTHOS10-1005	**An investigation of pressure drop for helical coils and orifices** Kwon-yeong Lee, Seo Yoon Jung, Hyungoo Lee, Jae-kwang Seo, Juhyeon Yoon (Korea Atomic Energy Research Institute, Korea)
NUTHOS10-1020	**Numerical Simulation of Countercurrent Flow in a Scaled Model of a Pressurizer Surge Line** Michio Murase, Yoichi Utanohara, Takayoshi Kusunoki (Institute of Nuclear Safety system, Inc., Japan), Dirk Lucas (Helmholtz-Zentrum Dresden-Rossendorf, Germany), Akio Tomiyama (Kobe University, Japan)
NUTHOS10-1048	**Reactor Inlet Header Critical Break identification and Analysis For KAPP-3&4 Using Computer Code RELAP-5/Mod.3.2** P Krishna Kumar, Rammohan P H (Nuclear Power Corporation of India Ltd, India)
NUTHOS10-1292	**Possibility of air ingress into a BWR containment during a LOCA in case of activation of containment venting system** Ignacio Gallego-Marcos, Walter Villanueva, Pavel Kudinov (Royal Institute of Technology, Sweden)

Dec. 15 (Mon.), 15:30 - 17:50, Room A1 **A-1-3. Thermal Hydraulics and Safety of Water-Cooled Reactors 3**
Chairs: Yoichi Utanohara (Institute of Nuclear Safety System, Inc., Japan), Eugenijus Ušpuras (LIETUVOS ENERGETIKOS INSTTTUTAS, Lithuania)

NUTHOS10-1034	**Study On Prediction Of Surface Temperature For Vertical Tubes With Non-uniform Axial Heating** Sohei Yamada, Shinichi Morooka (Waseda University, Japan)
NUTHOS10-1054	**Prediction of Post-Dryout Heat Transfer in Channels with Flow Obstacles** Henryk Anglart (Royal Institute of Technology, Sweden)
NUTHOS10-1060	**Experimental study on the local void fraction distribution in the ERVC upward channel** Yongchun Li, Xiaojing Liu, Xu Cheng, Yanhua Yang (Shanghai Jiao Tong University, China)
NUTHOS10-1063	**Study on pressure drop prediction of Tight Lattice Fuel Assembly using CFD** Kojiro Tada, Shinichi Morooka, Hideaki Katoh (Waseda University, Japan)
NUTHOS10-1071	**WEIGHTED RESIDUAL PROCEDURE WITH NODALIZATION SCHEME TO ANALYZE FLOW INSTABILITIES IN NATURAL CIRCULATION LOOP** Subhanker Paul, Vikas Pandey, Ashish Mani Mishra, Suneet Singh (Indian Institute of Technology Bombay-India, India)
NUTHOS10-1100	**Ex-vessel fuel coolant interaction experiment in the DISCO facility in the LACOMECO project** Alexei Miassoedov, Giancarlo Albrecht, Leonhard Meyer (Karlsruhe Institute of Technology, Germany), Renaud Meignen (Institut de Radioprotection et de Sûreté Nucléaire, France)

Room A2

Dec. 15 (Mon.), 13:00 - 15:00, Room A2 **A-1-2. Thermal Hydraulics and Safety of Water-Cooled Reactors 2**
Chairs: Koichi Hata (Kyoto University, Japan), Dirk Lucas (Helmholtz-Zentrum Dresden - Rossendorf, Germany)

NUTHOS10-1025	**Wash-down tests of silver aerosol from stainless steel and painted surfaces** Benjamin Von Laufenberg, Meryll Colombet, Martin Freitag (Becker Technologies GmbH, Germany)
NUTHOS10-1032	**MECHANISM OF SUBCOOLED WATER FLOW BOILING CRITICAL HEAT FLUX IN A CIRCULAR TUBE AT HIGH LIQUID REYNOLDS NUMBER** Koichi Hata (Kyoto University, Japan), Katsuya Fukuda (Kobe Univ., Japan), Suguru Masuzaki (National Institute for Fusion Science, Japan)
NUTHOS10-1055	**The Impact of Vertical Vibration on the Nonlinear Behaviors of a Single Nuclear-Coupled Boiling Channel** Jin-der Lee, Chin Pan, Shaw-wen Chen (National Tsing Hua University, Taiwan)
NUTHOS10-1072	**Conceptual Design of REMISE (Inherently Safe Modular Reactor)** José Héctor González (INVAP, Argentina)
NUTHOS10-1112	**Application of the Monte Carlo Thermal Design Analysis to Evaluate Uncertainties of the PWR Core using the THALES Subchannel Code** Byeong Il Jang, Hong ju Kim, Beom jun Jang, Chong kuk Chun, Sung won Han (KEPCO Nuclear Fuel, Korea)

Dec. 15 (Mon.), 15:30 - 17:50, Room A2 **A-1-4. Thermal Hydraulics and Safety of Water-Cooled Reactors 4**
Chairs: A. Tomiyama (Kobe University, Japan), Yong Hoon Jeong (Korea Advanced Inst of Sci & Tech, Korea)

NUTHOS10-1033	**Condensation Experiments for Counter-current Flow Limitation at Lower End of an Inverted U-Tube** Takayoshi Kusunoki (Institute of Nuclear Safety System, Incorporated , Japan), Yuki Fujii, Takahiro Nozoe, Shigeo Hosokawa, Akio Tomiyama (Kobe University, Japan), Michio Murase (Institute of Nuclear Safety System, Incorporated , Japan)
NUTHOS10-1049	**Severe accident analysis of a representative BWR plant with MAAP and MELCOR - Station blackout in a BWR-5 with advanced Mark-II containment -**

	Satoshi Nishimura (Central Research Institute of Electric Power Industry, Japan), Ryoji Hiwatari (Central Research Institute of Electris Power Industry, Japan), Masahiro Furuya, Yoshihisa Nishi (Central Research Institute of Electric Power Industry, Japan)
NUTHOS10-1094	**Comparison and Analysis on Two kinds of Passive Residual Heat Removal System Designs under Blackout Accident for Integral Small Modular Reactor** Guoxu Zhang, Heng Xie (Tsinghua University, China)
NUTHOS10-1101	**Natural Convection Effects During a Severe Accident** Ricardo Cazarez-Ramirez (Universidad Autónoma Metropolitana-Iztapalapa, Mexico), Marco-antonio Polo-Labarrios, Fabiola-belen Garcia-Barron (Universidad Nacional Autónoma de México, Mexico), Erick-gilberto Espinosa-Martínez, Gilberto Espinosa-Paredes (Universidad Autónoma Metropolitana-Iztapalapa, Mexico)
NUTHOS10-1125	**Experimental Investigations on the Coolability of Stratified Debris Beds Consisting of Prototypical Particles** Simon Leininger, Rudi Kulenovic, Eckart Laurien (University of Stuttgart, Institute of Nuclear Technology and Energy Systems, Germany)
NUTHOS10-1164	**A Mechanistic Model to Predict the Critical Heat Flux on a Downward Facing Curved Surface** Hae Min Park (Korea Advanced Institute of Sciense and Technology, Korea), Yong Hoon Jeong (Korea Advanced Institute of Science and Technology, Korea)

Room B1

Dec. 15 (Mon.), 13:00 - 15:00, Room B1 **D-1-1. Severe Accident Mitigation Measures 1**
Chairs: Alexei Miassoedov (Karlsruhe Institute of Technology , Germany), H. Kikura (Tokyo Inst of Tech , Japan)

NUTHOS10-1043	**Noble Gas Control Room Accident Filtration System for severe accident conditions N-CRAFT - System Design** Axel Hill (AREVA, Germany)
NUTHOS10-1044	**Nuclide Specific Activity Monitoring of Containment Atmosphere and Semi Passive Effluent Monitoring during Containment Venting** Axel Hill (AREVA, Germany)
NUTHOS10-1045	**Multi-functional Combustible Gas Measurement of Containment Atmosphere** Axel Hill (AREVA, Germany)
NUTHOS10-1106	**Technical Bases for Experimentation on Source Term Mitigation: The EU-PASSAM Project** Luis E. Herranz (CENTRO INVESTIGACIONES ENERGÉTICAS MEDIOAMBIENTALES Y TECNOLOGICAS, Spain)
NUTHOS10-1132	**Feasibility Studies on Severe Accident Mitigation Measures against Containment Over-pressurization** Sangwon Lee (Korea Hydro and Nuclear Power, Korea)

Dec. 15 (Mon.), 15:30 - 17:50, Room B1 **D-1-2. Severe Accident Mitigation Measures related to Fukushima Dai-ich Accident**
Chairs: Marco Pellegrini (The Institute of Applied Energy, Japan), Shinya Mizokami (Tokyo Electric Power Company, Japan)

NUTHOS10-1352	**Unsolved issues relating thermal-hydraulics in the suppression chamber during Fukushima Daiichi accident** Shinya Mizokami, Daichi Yamada, Takeshi Honda, Daisuke Yamauchi, Yasunori Yamanaka (Tokyo Electric Power Company, Japan)
NUTHOS10-1306	**Suppression pool testing at the SIET laboratory (1) Experimental Investigation of Critical Phenomena Expected in the Fukushima Daiichi** Andrea Achilli, Gustavo Cattadori, Marco Rigamonti (SIET, Italy), Lucio Araneo, Hisashi Ninokata, Marco Ricotti (Politecnico di Milano, Italy), Marco Pellegrini, Masanori Naitoh, Shunsuke Uchida (The Institute of Applied Energy, Japan)
NUTHOS10-1307	**Suppression pool testing at the SIET labs (2) Steam chugging investigation under the presence of non-condensable gas** Lucio Araneo, Hisashi Ninokata, Marco Ricotti (Politecnico di Milano, Italy), Marco Pellegrini (The Institute of Applied Energy, Japan), Andrea Achilli (SIET, Italy)
NUTHOS10-1274	**Suppression pool testing at the SIET labs (3) Experiments on Steam Direct Contact Condensation in a Vertical Multi-holes Sparger** Marco Pellegrini, Masanori Naitoh (The Institute of Applied Energy, Japan), Lucio Araneo, Hisashi Ninokata, Marco Ricotti (Politecnico di Milano, Italy), Andrea Achilli (SIET, Italy)
NUTHOS10-1233	**Suppression pool testing at the SIET laboratory (4) Release of fission products into the environments under severe accident conditions** Shunsuke Uchida, Masanori Naitoh, Marcl Pellegrini (Institute of Applied Energy, Japan), Yukio Hanamoto (KAKEN, Japan), Hiroaki Sasaki (Fukushima Prefectural Government, Japan), Andrea Achilli (SIET, Italy), Hitoshi Mimura (Tohoku University, Japan)

Room B2	
Dec. 15 (Mon.), 13:00 - 15:00, Room B2 **B-1-1. Advances in Experimental Thermal-Hydraulics 1** **Chairs: Tomio Okawa (The University of Electro-Communications, Japan), Minggang Lang (Tsinghua University, China)**	
NUTHOS10-1022	**Local Gas- and Liquid-phase Measurements for Air-water Two-phase Flows in a Rectangular Channel** Xinquan Zhou (The Ohio State University, United States), Matthew Williams, Yang Liu (Virginia Tech, United States), Xiaodong Sun (The Ohio State University, United States), Yucheng Fu (Virginia Tech, United States)
NUTHOS10-1036	**Simultaneous Measurement of Diameter and Velocity of Liquid Droplets in Annular-mist Flow Using Shadowgraph Technique** Shota Ueda, Ryoji Matsue , Tatsuya Hazuku, Yutaka Fukuhara, Tomoji Takamasa (Tokyo University of Marine Science and Technology, Japan)
NUTHOS10-1087	**Experimental Study on Two-dimensional Film Flow with Lateral Air Injection** Jin-hwa Yang, Hyoung-kyu Cho (Seoul National University, Korea), Dong-jin Euh (Korea Atomic Energy Research Institute, Korea), Goon-cherl Park (Seoul National University, Korea)
NUTHOS10-1091	**Characteristics of void fraction and interfacial area concentration of downward bubbly flow in mini pipes** Tomohito Fukazawa, Tatsuya Hazuku, Tomoji Takamasa, Yutaka Fukuhara (Tokyo University of Marine Science and Technology, Japan)
NUTHOS10-1207	**An Experimental Study on Liquid Film Dynamics in an Inclined Rectangular Channel** Youjia Zhang, Weimin Ma (KTH ROYAL INSTITUTE OF TECHNOLOGY, Sweden)
Dec. 15 (Mon.), 15:30 - 17:50, Room B2 **B-1-2. Advances in Experimental Thermal-Hydraulics 2** **Chairs: Ivan Otic (Karlsruhe Institut of Technology, Germany), Tatsuya Hazuku (Tokyo University of Marine Science and Technology, Japan)**	
NUTHOS10-1065	**A Study on the Effects of Heated Surface Wettability on Nucleation Characteristics in Subcooled Flow Boiling** Tomoyuki Kajihara, Tomio Okawa, Kazuhiro Kaiho (The University of Electro-Communications, Japan)
NUTHOS10-1117	**Investigation on the mechanisms of bubble lift-off from a vertical heated surface in subcooled pool boiling** Naoki Miyano, Tomio Okawa (The University of Electro-Communications, Japan), Takafumi Suginaka (AdvanceSoft Corporation, Japan)
NUTHOS10-1346	**Experimental study on the critical heat flux and heat transfer coefficient in nanofluid pool boiling** Tomio Okawa, Muhamad Zuhairi Bin Sulaiman, Daisuke Matsuo (The University of Electro-Communications, Japan)
NUTHOS10-1012	**Experiment of Critical Heat Flux for Single Fuel Pin with and without Wire Spacer** Dan Tri Le, Noriaki Inaba, Minoru Takahashi (Tokyo Institute of Technology, Japan)
NUTHOS10-1381	**A Fundamental Study on Cesium Transfer to Sodium Coolant** Masaaki Inoue, Yusuke Ichiryu, Ken-ichiro Sugiyama (Hokkaido University, Japan), Hiroshi Endo (Central Research Institute of Electric Power Industry, Japan)

Room B3+B4	
Dec. 15 (Mon.), 13:00 - 15:00, Room B3+B4 **B-2-1. Advances in Numerical Thermal-Hydraulics 1** **Chairs: G.H. Su (Xi'an Jiaotong University, China), Hiroyuki Yoshida (Japan Atomic Energy Agency, Japan)**	
NUTHOS10-1074	**Linear and nonlinear analysis of the dynamic behaviour of natural circulation with internally heated fluids** Alessandro Pini, Antonio Cammi, Lelio Luzzi (POLITECNICO DI MILANO, Italy), Daniel E. Ruiz (Princeton University , United States)
NUTHOS10-1122	**Application of Minimal Energy Dissipation Principle to Turbulence Modeling** Vladimir Kriventsev (Karlsruhe Institute of Technology, Germany)
NUTHOS10-1280	**One equation subgrid model for turbulent convection** Ivan Otic (Karlsruhe Institut of Technology, Germany)
NUTHOS10-1209	**Sensitive analysis and modifications to reflood-related constitutive models of RELAP5** Dong Li, Xiaojing Liu (Shanghai Jiao Tong University, China)
NUTHOS10-1342	**Improvement of the Critical Heat Flux models of COBRA-TF and Assessment against the Post-Dryout Experiments Performed at the Royal Institute of Technology** Agustin Abarca, Rafael Miró, Teresa Barrachina (Institute for Industrial, Radiophysical and Environmental Safety, Spain), Gumersindo Verdu (Universitat Politècnica de Valéncia, Spain)
Dec. 15 (Mon.), 15:30 - 17:50, Room B3+B4 **B-2-2. Advances in Numerical Thermal-Hydraulics 2** **Chairs: Dirk Lucas (Helmholtz-Zentrum Dresden - Rossendorf, Germany), Koji Morita (Kyushu University, Japan)**	

NUTHOS10-1178	**Interfacial Area Transport Equation of Gas-Liquid Two-Phase Flow Across a Horizontal Tube** Atsushi Ishikawa (IHI Corporation, Japan), Tetsuya Kono, Kenji Yoshida, Isao Kataoka (Osaka University, Japan)
NUTHOS10-1302	**Advanced Subgrid Modeling for Multiphase CFD in CASL VERA Tools** Emilio Baglietto, Lindsey Gilman, Rosie Sugrue (Massachusetts Institute of Technology, United States)
NUTHOS10-1137	**Development of a Hybrid Particle-Mesh Method for Simulations of Multiphase Flows with Phase Change** Xiaoxing Liu, Liancheng Guo, Koji Morita (Kyushu University, Japan)
NUTHOS10-1348	**Simulation of Two-phase Natural Circulation Flows at a Core Catcher Experiment Facility Using the CUPID Code** Dong Hun Lee, Byong Jo Yun (Pusan National University, Korea), Han Young Yoon, Ik Kyu Park (Korea Atomic Energy Research Institute, Korea), Jae Jun Jeong (Pusan National University, Korea), Kwang Soon Ha (Korea Atomic Energy Research Institute, Korea)
NUTHOS10-1170	**Assessment of Multi-Scale Thermal-Hydraulic Simulation for a PWR Steam Generator with CUPID/MARS coupling** Jae Ryong Lee, Ik Kyu Park, Seung Jun Lee (Korea Atomic Energy Research Institute, Korea), Hyoung Kyu Cho (Seoul National University, Korea), Han Young Yoon (Korea Atomic Energy Research Institute, Korea)
NUTHOS10-1359	**Thermal Hydraulics Analysis of Steam Generator's Secondary Side** Ye Yi, Daogang Lu (North China Electric Power University, China)

Room B6+B7

Dec. 15 (Mon.), 13:00 - 15:00, Room B6+B7 **D-3-1. Methodology and Application of PRA for Internal, Seismic and Tsunami Events 1**
Chairs: Marko Cepin (University of Ljubljana, Slovenia), Hitoshi Muta (Tokyo City University, Japan)

NUTHOS10-1186	**Amendment of Standard for Procedures of Level-1 Probabilistic Risk Assessment of Nuclear Power Plants during Power Operation** Takashi Takata (Osaka University, Japan), Yukihiro Kirimoto (Central Reserch Institute of Electric power Industry, Japan), Naoyuki Murata (Japan Nuclear Safety Institute, Japan)
NUTHOS10-1282	**Loss of Offsite Power and Power System Reliability** Marko Cepin (University of Ljubljana, Slovenia)
NUTHOS10-1169	**Study of risk reduction by improving operation of Reactor Core Isolation Cooling system** Yamato Watanabe, Ayuko Tazai, Shohei Yamagishi, Ken Muramatsu, Hitoshi Muta (Tokyo City University, Japan)
NUTHOS10-1184	**Study of Hydraulic Behaviors during Multiple Steam Generator Tube Rupture Events in PWR** Shohei Yamagishi (Tokyo city Univercity, Japan), Keita Fujiwara, Mingxi Wei (Tokyo city university, Japan), Ken Muramatsu, Hitoshi Muta (Tokyo City Univercity, Japan)
NUTHOS10-1305	**Study on risk indicator for appropriate plant maintenance considering aging effect** Akihiro Mano, Takashi Takata, Akira Yamaguchi (Graduate School of Engineering, Osaka University, Japan)

Dec. 15 (Mon.), 15:30 - 17:50, Room B6+B7 **D-4-1. Uncertainty Analysis 1**
Chairs: Saidur Rahman (Paul Scherrer Institut , Switzerland), Hidemasa Yamano (Japan Atomic Energy Agency, Japan)

NUTHOS10-1206	**Uncertainty and Sensitivity Analysis of QUENCH Experiments Using ASTEC and RELAP/SCDAPSIM Codes** Eugenijus Uspuras, Virginijus Vileiniskis, Tadas Kaliatka, Algirdas Kaliatka, Antanas Sutas (Lithuanian Energy Institute, Lithuania)
NUTHOS10-1013	**Uncertainty and Sensitivity Analysis on the Iodine Model in the Containment Code COCOSYS** Gunter Weber (Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH, Germany), Friedhelm Funke (AREVA GmbH, Germany), Bernhard Krzykacz-Hausmann, Walter Klein-Hessling (Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH, Germany)
NUTHOS10-1173	**Treatment of Epistemic and Aleatory Uncertainties in DET Simulations: Computational Framework with ADS-TRACE** Saidur Rahman, Durga Rao Karanki, Vinh Dang, Omar Zerkak (Paul Scherrer Institut , Switzerland)
NUTHOS10-1002	**Uncertainties in Predictions by System Thermal-Hydraulic Codes: the CASUALIDAD Method** Alessandro Petruzzi (GRNSPG - NINE, Italy), Francesco D'Auria (GRNSPG - University of Pisa, Italy)
NUTHOS10-1241	**An Assessmt of Conservatism Embeded in Licensing Calculations of Loss of Coolant Accident via RELAP5-3D/K Simulation of Experiment L2-3 of Loss of Fluid Test** Wei Ting Chen, Min Lee, Feijan Tsai (National Tsing Hua University, Taiwan)

Dec. 16 (Tue.)

Room A1

Dec. 16 (Tue.), 09:00 - 10:30, Room A1 **PL-3. Panel Discussion; Perspective of Nuclear Thermal Hydraulic and Safety Research in the Post Fukushima Daiichi Accident Era**
Chair: Akira Yamaguchi (Osaka University, Japan)

NUTHOS10-PL03	**Keynote; Prof. Hisashi Ninokata (POLIMI, Italy)** **Panelists; Prof. Emilio Baglietto (MIT, USA), Dr. Chul-Hwa Song (KAERI, Korea), Prof. Marco Enrico Ricotti (POLIMI, Italy), Prof. Chin Pan (NTHU, Taiwan), Prof. Bao-Wen Yang (XJTU, China)**

Dec. 16 (Tue.), 11:00 - 12:00, Room A1 **KL-1. Keynote lecture 1**
Chair: Koji Okamoto (University of Tokyo, Japan)

NUTHOS10-KL01	**Fukushima Daiichi Nuclear Accident; based on the Final Report of the AESJ Investigation Committee** Naoto Sekimura (The University of Tokyo, Japan)

Dec. 16 (Tue.), 13:00 - 15:00, Room A1 **A-1-5. Thermal Hydraulics and Safety of Water-Cooled Reactors 5**
Chairs: Michitsugu Mori (Hokkaido Univ., Japan), Jinbiao Xiong (Shanghai Jiao Tong University, China)

NUTHOS10-1098	**Analysis of the loss of cooling accident for the spent fuel pool of nuclear power plant using MELCOR** Zhongwei Zhang, Kuoshing Liang (Shanghai Jiao Tong University, China)
NUTHOS10-1108	**RELAP5 Code Study of ROSA/LSTF Validation Tests for PWR Safety System Using SG Secondary-side Depressurization** Takeshi Takeda (Japan Atomic Energy Agency, Japan), Akira Ohnuki (Mitsubishi Heavy Industries, LTD, Japan), Hiroaki Nishi (The Kansai Electric Power Co., Inc., Japan)
NUTHOS10-1126	**The effect of nodalization on the Wet Well's performance during an SBO accident** Luis Enrique HErranz, Joan Fontanet, Elena Fernandez, Claudia Lopez (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Spain)
NUTHOS10-1149	**Analysis of Flow Characteristics of the ECBD SLAB Model** Tae-soon Kwon, Kihwan Kim (Korea Atomic Energy Research Institute, Korea), Dong-jin Euh (KAERI, Korea)
NUTHOS10-1166	**Monitoring of heavy water flow in a "cannelloni" spallation target through fluctuation analysis of measured temperatures** Sergejs Dementjevs (Paul Scherrer Institute, Switzerland), Normunds Jekabsons, Arturs Orbidans (Engineering Research Institute "Ventspils International Radio Astronomy Centre" of Ventspils University College, Latvia), Michael Wohlmuther (Paul Scherrer Institute, Switzerland)

Dec. 16 (Tue.), 15:30 - 17:50, Room A1 **A-1-6. Thermal Hydraulics and Safety of Water-Cooled Reactors 6**
Chairs: Hiroaki Suzuki (The Institute of Applied Energy, Japan), John Kickhofel (ETH Zürich, Switzerland)

NUTHOS10-1086	**Accident Analysis for the TEPCO Fukushima Daiichi Unit 2 by the SAMPSON Code with Improved Models** Hiroaki Suzuki, Atsuo Takahashi, Marco Pellegrini, Hideo Mizouchi, Masanori Naitoh (The Institute of Applied Energy, Japan)
NUTHOS10-1120	**Numerical Simulation of MCCI experiments by MPS Method - Validation against SURC-2 and SURC-4 experiments** Xin Li, Yoshiaki Oka (Waseda University, Japan)
NUTHOS10-1134	**Effect of the Flow Blockage of the LSSBP on the APR+ Reactor Core Flow Distributions** Kihwan Kim, Hae-seob Choi, Dong-jin Euh, Tae-soon Kwon (Korea Atomic Energy Research Institute, Korea)
NUTHOS10-1135	**Analysis of RCS injection strategy with RNS on Severe Accident Mitigation** Wei Zhu, Yabing Li, Lili Tong, Xuewu Cao (Shanghai Jiao Tong University, China)
NUTHOS10-1143	**Study of Condenser Pressure Response in Loss of Turbine/Generator and Offsite Power Event for Lungmen Nuclear Power Station** Un Chi Juan, C Y Yang, W S Huang (Nuclear Information Center, Taiwan), L C Wang, S C Chiang, C C Liu (Taiwan Power Company, Taiwan)
NUTHOS10-1246	**The Influence of Density Stratification and T-junction Geometry on Turbulent Penetration** John Kickhofel (ETH Zürich, Switzerland), Cosimo Trinca (University of Palermo, Italy), Horst-michael Prasser (ETH Zürich, Switzerland)

Room A2

Dec. 16 (Tue.), 11:00 - 12:00, Room A2 **KL-2. Keynote lecture 2**
Chair: Takashi Takata (Osaka University, Japan)

NUTHOS10-KL02	**GIF's Activities and Safety Approaches for Generation IV Reactors** Yutaka Sagayama (Japan Atomic Energy Agency, Japan)

Dec. 16 (Tue.), 13:00 - 15:00, Room A2 **A-2-1. Thermal Hydraulics and Safety of SFR Plant Systems** **Chairs: Yasushi Okano (Japan Atomic Energy Agency, Japan), Katrien Van Tichelen (Belgian Nuclear Research Centre, Belgium)**	
NUTHOS10-1097	**Evaluation of Gas Entrainment Flow Rate using Numerical Simulation with Interface-Tracking Method** Kei Ito (Japan Atomic Energy Agency, Japan), Yasuo Koizumi (Shinshu University, Japan), Shuji Ohno (Japan Atomic Energy Agency, Japan), Takumi Kawamura (NESI.Inc, Japan)
NUTHOS10-1297	**Numerical and Experimental Study on the Formation of Sodium Frozen Seal** Vadakanchery Vinod (Indira Gandhi Centre for Atomic Research, India), Bekkenti Nagaraju, R Punniamoorthy, V Suresh Kumar, S Chandramouli, G Padmakumar, K.k Rajan (Indira Gandhi Centre for Atomic Research India, India)
NUTHOS10-1252	**Analysis of Self-wastage Phenomena of Micro Leak Caused by Sodium-water reaction in Sodium-cooled Fast Breeder Reactor through Simulant Experiment** Sunghyon Jang, Takashi Takata, Akira Yamaguchi (Osaka University, Japan)
NUTHOS10-1315	**Investigation of Multi-dimensional Effect in Sodium Leak and Fire Behavior** Shuji Ohno (Japan Atomic Energy Agency, Japan)
NUTHOS10-1067	**Experimental Study and Kinetic Analysis on Sodium-Concrete Reaction in Sodium-Cooled Fast Reactor** Shin Kikuchi, Hiroshi Seino, Shuji Ohno (Japan Atomic Energy Agency, Japan)

Dec. 16 (Tue.), 15:30 - 17:50, Room A2 **A-2-2. Safty Assessment of Severe Accidents in SFRs** **Chairs: Vladimir Kriventsev (Karlsruhe Institute of Technology, Germany), Koji Morita (Kyushu University, Japan)**	
NUTHOS10-1226	**Identification of the Accident Sequences for the Evaluation of the Effectiveness of Severe Accident Measures on Prototype Sodium-Cooled Fast Reactor** Yuichi Onoda, Kenichi Kurisaka, Takaaki Sakai (Japan Atomic Energy Agency, Japan)
NUTHOS10-1220	**Development of the evaluation methodology for the material relocation behavior in the core disruptive accident of sodium-cooled fast reactors** Yoshiharu Tobita, Kenji Kamiyama, Hirotaka Tagami, Ken-ichi Matsuba, Tohru Suzuki, Mikio Isozaki, Hidemasa Yamano (Japan Atomic Energy Agency, Japan), Koji Morita (Kyu-syu university, Japan), Liancheng Guo (Kyusyu University, Japan)
NUTHOS10-1069	**State of the art of CATHARE model for transient safety analysis of ASTRID SFR** Romain Lavastre (CEA, France)
NUTHOS10-1084	**Phenomenological Investigation of Sodium Boiling in a SFR Core during a postulated ULOF Transient with CATHARE 2 System Code: a Stabilized Boiling Case** Nicolas Alpy, Marine Anderhuber, Philippe Marsault (French Commission for Atomic Energy and Alternative Energy, France), Antoine Gerschenfeld (French Commission for Atomic Energy, France), Dominique Kadri, Pierre Sciora, Romain Lavastre, Pascal Bazin, Jorge Perez-Manes (French Commission for Atomic Energy and Alternative Energy, France)
NUTHOS10-1187	**PRELIMINARY RESULT OF VALIDATION STUDY IN SAS-SFR (SAS4A) CODE IN SIMULATED TOP AND UNDERCOOLED OVERPOWER CONDITIONS** Kenichi Kawada (Japan Atomic Energy Agency, Japan), Katsuhiko Takahashi (NESI Inc., Japan), Yoshiharu Tobita (Japan Atomic Energy Agency, Japan)
NUTHOS10-1294	**Local flow blockage analysis with checkerboard configuration in a wire wrapped fuel subassembly using the ASFRE code** Masahiro Nishimura (Japan Atomic Energy Agency, Japan), Yoshitaka Fukano (Japan Atomic Enerfy Agency, Japan)

Room B1

Dec. 16 (Tue.), 11:00 - 12:00, Room B1 **KL-3. Keynote lecture 3** **Chair: H. Kikura (Tokyo Inst of Tech , Japan)**	
NUTHOS10-KL03	**The facts obtained from the activities towards the decommissioning of Fukushima Dai-ichi NPS** Takafumi Anegawa (Tokyo Electric Power Company, Japan)

Dec. 16 (Tue.), 13:00 - 15:00, Room B1 **D-1-3. Severe Accident Mitigation Measures 2** **Chairs: Min Lee (NHTU, Taiwan), Nobuyoshi Tsuzuki (Tokyo Institute of Technology, Japan)**	
NUTHOS10-1171	**An Experimental Study on In-vessel Retention Strategy by External Reactor Vessel Cooling with Liquid Metal** Seong Dae Park, In Cheol Bang (Ulsan National Institute of Science and Technology, Korea)
NUTHOS10-1229	**Experimental Investigation of the Focusing Effect of the Metallic Layer Heat Transfer in a Severe Accident Condition** Je-young Moon , Bum-jin Chung (Kyung Hee University, Korea)
NUTHOS10-1047	**Core melt stabilization in nuclear power plants – Implementations in new builds and retrofitting in existing plants**

	Manfred Fischer, Werner Schmidt, Matthias Braun, Harald Dimmelmeier (AREVA, Germany)
NUTHOS10-1333	**PLINIUS-2 : A versatile platform for severe accident mitigation device and simulation model assessments** Christophe Journeau (CEA, France), Laurence Buffe, Nathalie Cassiaut-Louis, Jean-françois Haquet, Pascal Piluso, Eric Pluyette, Christophe Suteau, Guy Willermoz, Frederic Serre (Commissariat a l'Energie Atomique et aux Energies Alternatives, France)

Dec. 16 (Tue.), 15:30 - 17:50, Room B1 **A-1-7. Thermal Hydraulics and Safety of Water-Cooled Reactors 7**
Chairs: Shoji Mori (yokohama national university, Japan), Suleiman Al Issa (Technichal university Munich, Germany)

NUTHOS10-1140	**The Effect of Heater Orientation on the Critical Heat Flux in a Saturated Pool Boiling with Honeycomb Porous Plate on Nanoparticle Deposited Surface** Mt Aznam Suazlan, Shoji Mori, Kunito Okuyama (Yokohama National University, Japan)
NUTHOS10-1146	**Multi-Dimensional Modeling and Simulation of Upper Plenum in URG Analysis of Lungmen Nuclear Power Plant using RELAP5-3D** Yi-huei Huang, Keng-yen Chiang (Atomic Energy Council, Taiwan), Lih-yih Liao (Institute of Nuclear Energy Research, Taiwan)
NUTHOS10-1211	**Experimental investigation and CFD validation of countercurrent flow limitation (CCFL) in a large-diameter hot-leg PWR geometry** Suleiman Al Issa, Rafael Macian (Technical university Munich, Germany)
NUTHOS10-1239	**Experimental study of dryout characteristics at low mass flux in helically-coiled tubes** Kyung Won Hwang (Pohang University of Science and Technology, Korea), Dong Eok Kim (Kyungpook National University, Korea), Jin Man Kim (Pohang University of Science and Technology, Korea), Moo Hwan Kim (Korea Institute of Nuclear Safety , Korea), Hyun Sun Park (Pohang University of Science and Technology, Korea), Kiyofumi Moriyama (POSTECH, Japan)
NUTHOS10-1248	**Development of a Numerical Code for Comparison of Different Theories of Subcooled Flow Boiling CHF in Vertical Round Tubes** Nishant Ashok Mistry (Veermata Jijabai Technological Institute, India), Dinesh Chandraker, Arnab Dasgupta (Bhabha Atomic Research Center, India), Amod Velingkar, Bhavesh Jain, Swati Kulkarni, Mandar Tendolkar (Veermata Jijabai Technological Institute, India)
NUTHOS10-1320	**A Prediction Method of the Effect of Radial Heat Flux Distribution on Critical Heat Flux in CANDU Fuel Bundles** Lan Qin Yuan, Jun Yang, Noel Harrison (Canadian Nuclear Laboratories, Canada)

Room B2

Dec. 16 (Tue.), 13:00 - 15:00, Room B2 **B-1-3. Advances in Experimental Thermal-Hydraulics 3**
Chairs: Xu Cheng (SJTU , China), Masahiro Furuya (Central Research Institute of Electric Power Industry, Japan)

NUTHOS10-1139	**Comparison of Counterpart Test Results with the VISTA-ITL and FESTA on SBLOCA Scenarios for an Integral Type Reactor SMART** Hyun-sik Park (Korea Atomic Energy Research Institute, Korea), Sung-uk Ryu, Hyobong Ryu, Yung-joo Ko, Hwang Bae, Sung-jae Yi (KAERI, Korea)
NUTHOS10-1159	**Flow measurement in a Joule-heating cavity with sloping bottom by using Ultrasonic Velocity Profiler** Jiaju Zhou (Tokyo Institute of Technolopgy, Japan), Hiromasa Tanaka, Nobuyoshi Tsuzuki, Hiroshige Kikura (Tokyo Institute of Technology, Japan), Hideki Hideki (Muroran Institute of Technology, Japan)
NUTHOS10-1210	**Infrared Film Thickness Measurement: Comparison with Cold Neutron Imaging** Julien Dupont, Guillaume Mignot, Robert Zboray (Paul Scherrer Institute, Switzerland), Horst-michael Prasser (Swiss Federal Institute of Technology Zürich, Switzerland)
NUTHOS10-1330	**Researches of Local Mass-transfer characteristics of Coolant in VVER-1000 FA with Mixing Grids** Maksim Aleksandrovich Legchanov, Sergei Mikhailovich Dmitriev, Sergei Sergeevich Borodin, Alexander Evgenievich Khrobostov, Dmitriy Nikolaevich Solntsev, Andrei Vladislavovich Varentsov (Nizhny Novgorod State Technical University n.a. R.E. Alekseev, Russian Federation)

Dec. 16 (Tue.), 15:30 - 17:50, Room B2 **OG-1. Reactor Dynamics, Instability and Fuel Cladding Coatings & Deposits**
Chairs: Masahiro Furuya (Central Research Institute of Electric Power Industry, Japan), Michael Philip Short (Massachusetts Institute of Technology, United States)

NUTHOS10-1021	**Towards a stability monitor in Laguna Verde Nuclear Power Plant based on the empirical mode decomposition** Alfonso Prieto-Guerrero, Gilberto Espinosa-Paredes (Universidad Autónoma Metropolitana Unidad Iztapalapa, Mexico)
NUTHOS10-1105	**A Comparative study of Two-Phase Flow Instability analysis of Uniformly Heated Channel having different Inclinations** Ashish Mani Mishra (Indian Institute of Technology Bombay, Mumbai , India), Subhanker Paul (Indian

	Institute of Technology-Bombay , India), Vikas Pandey, Suneet Singh (Indian Institute of Technology Bombay, Mumbai, India)
NUTHOS10-1115	**Non Linear Dynamics of Boiling Water Reactor Dynamical System** Vikas Pandey, Subhanker Paul, Ashish Mani Mishra, Suneet Singh (Indian Institute of Technology, Bombay, India)
NUTHOS10-1298	**Mechanical Property of Surface Modification Layer and Oxide Layer of Zircaloy 2** Masahiro Furuya, Shoichi Kitajima, Takeshi Sonoda, Takashi Sawabe, Takanari Ogata (Central Research Institute of Electric Power Industry, Japan)
NUTHOS10-1364	**The Development of CRUD-Resistant Materials** Abdulla Abdulaziz Alhajri, Leigh Lin, Rasheed Auguste, Pavlina Karafilis, Gabrielle Ledoux (Massachusetts Institute of Technology, United States), Vikash Mishra (University of Arkansas, United States), Ekaterina Paramonova, Michael Philip Short (Massachusetts Institute of Technology, United States)
NUTHOS10-1365	**Three Dimensional Multiphysics Modeling And Validation Of CRUD-Induced Localized Corrosion (CILC) In PWRs** Andrew Dykhuis, Michael Philip Short (Massachusetts Institute of Technology, United States)

Room B3+B4

Dec. 16 (Tue.), 11:00 - 12:00, Room B3+B4 **KL-4. Keynote lecture 4**
Chair: Xiaodong Sun (Ohio State University, USA, United States)

NUTHOS10-KL04	**Progress and Challenges in Predictive Simulation of Thermal Hydraulic Phenomena** Emilio Baglietto (MIT, United States)

Dec. 16 (Tue.), 13:00 - 15:00, Room B3+B4 **A-5-1. Gas and Super-Critical Fluid Heat Transfer and Diffusion**
Chairs: Allen Ho (Energy Technology International, United States), Kenji Kamiyama (Japan Atomic Energy Agency , Japan)

NUTHOS10-1199	**OSU Tritium Control and Mitigation Strategy for FHRs** In Hun Kim, Xiao Wu, Xiaodong Sun, Richard Christensen (Ohio State University, United States), Piyush Sabharwall (Idaho National Laboratory, United States)
NUTHOS10-1204	**Computer simulation of tritium removal facility design** Xiao Wu, Inhun Kim, David Arcilesi, Xiaodong Sun, Richard Christensen (the Ohio State University, United States), Piyush Sabharwall (Idaho National Laboratory, United States)
NUTHOS10-1007	**Design and Thermal-hydraulic Transient Analysis of Helium-cooled Solid Target for ADS** Tianji Peng, Zhiwei Zhou (Tsinghua University, China), Long Gu (Chinese Academy of Sciences, China)

Dec. 16 (Tue.), 15:30 - 17:50, Room B3+B4 **A-5-2. Heat Transfer and Safety in PWR and ADS**
Chairs: Lien H Peter (United States Nuclear Regulatory Commission, United States), Byongjo Yun (Pusan National University, Korea)

NUTHOS10-1116	**On the prediction of single-phase forced convection heat transfer in narrow rectangular channels** Alberto Ghione (Chalmers University of Technology (Gothenburg, Sweden) and CEA Grenoble (France), Sweden), Brigitte Noel (CEA Grenoble , France), Christophe Demazière, Paolo Vinai (Chalmers University of Technology, Sweden)
NUTHOS10-1231	**Experimental Study on a Heat Pipe towards In-Core Decay Heat Removal Control Rod** Kyung Mo Kim, In Cheol Bang (Ulsan National Institute of Science and Technology, Korea), Jae Young Lee (Handong Global University, Korea), Dong Wook Jerng (Chung Ang University, Korea)
NUTHOS10-1009	**Experimental study for Convective Heat Transfer of Staged Tube Bundles** Young-jong Chung (kaeri, Korea)
NUTHOS10-1061	**Study of a Loss of Feedwater Transient for an Integral Pressurized Water Reactor with a Helical Coil Steam Generator** Lien H Peter (United States Nuclear Regulatory Commission, United States)
NUTHOS10-1121	**Measurement and Analysis of Heat Transfer Characteristics between LBE with Other Coolants in KYLIN-II Loop** Yang Li (Institute of Nuclear Energy Safety Technology, China)
NUTHOS10-1119	**Comparison of the Transient Behavior of Lead-based Advanced Critical and Sub-critical Reactors** Gang Wang, Zhixing Gu, Zhen Wang, Ming Jin, Yunqing Bai (Institute of Nuclear Energy Safety Technology, Chinese Academy of Sciences, China)

Room B6+B7

Dec. 16 (Tue.), 11:00 - 12:00, Room B6+B7 **KL-5. Keynote lecture 5**
Chair: Tomio Okawa (The University of Electro-Communications, Japan)

NUTHOS10-	**Recent efforts and R&D activities for enhancing nuclear safety in Korea**

KL05	Chul-hwa Song, Won-pil Baek (Korea Atomic Energy Research Institute, Korea)

Dec. 16 (Tue.), 13:00 - 15:00, Room B6+B7 **D-4-2. Uncertainty Analysis 2**
Chairs: James C. Lin (ABSG Consulting Inc., United States), Takahiro Kuramoto (Nuclear Engineering, Ltd., Japan)

NUTHOS10-1319	**Sensitivity Analysis of the Oskarshamn-2 Stability Event Using the URANIE Software** Javier Jimenez Escalante, Nico Trost, Victor Hugo Sanchez Espinosa (Karlsruhe Institute of Technology, Germany)
NUTHOS10-1249	**Calibration of Thermal Hydraulic Models for Best Estimate Safety Analysis Using Flooding Experimental Data** Jaeseok Heo, Seung-wook Lee, Kyung Doo Kim (Korea Atomic Energy Research Institute, Korea)
NUTHOS10-1089	**The best-estimate calculation with uncertainty evaluation for PSBT benchmark using TRACE code** Cong Khanh Le, Teawan Kim (KEPCO International Nuclear Graduate School, Korea)
NUTHOS10-1293	**Sensitivity Study of Steam Explosion Characteristics to Uncertain Input Parameters Using TEXAS-V Code** Dmitry Grishchenko, Pavel Kudinov, Simone Basso, Sevostian Bechta (KTH Royal Institute of Technology, Sweden)
NUTHOS10-1300	**Formation of Decontamination Cost Calculation Model for Severe Accident Consequence Assessment** Kampanart Silva (Thailand Institute of Nuclear Technology, Thailand), Koji Okamoto (The University of Tokyo, Japan), Yuki Ishiwatari (The University of Tokyo/Hitachi GE Nuclear Energy, Ltd., Japan), Jiraporn Promping (Thailand Institute of Nuclear Technology, Thailand)

Dec. 16 (Tue.), 15:30 - 17:50, Room B6+B7 **D-3-2. PRA for External Events other than Earthquakes and Tsunami**
Chairs: John C Lai (United States Nuclear Regulatory Commission, United States), Kampanart Silva (Thailand Institute of Nuclear Technology, Thailand)

NUTHOS10-1014	**Development of Margin Assessment Methodology of Decay Heat Removal Function Against External Hazards (1) Project Overview and Snow PRA Methodology** Hidemasa Yamano, Hiroyuki Nishino, Kenichi Kurisaka, Yasushi Okano, Takaaki Sakai (Japan Atomic Energy Agency, Japan), Takahiro Yamamoto, Yoshihiro Ishizuka, Nobuo Geshi, Ryuta Furukawa, Futoshi Nanayama (National Institute of Advanced Industrial Science and Technology, Japan), Takashi Takata, Emiko Azuma (Osaka University, Japan)
NUTHOS10-1068	**Development of Margin Assessment Methodology of Decay Heat Removal Function Against External Hazards (2) Tornado PRA Methodology** Hiroyuki Nishino, Kenichi Kurisaka, Hidemasa Yamano (Japan Atomic Energy Agency, Japan)
NUTHOS10-1018	**Development of Margin Assessment Methodology of Decay Heat Removal Function against External Hazards (3) Forest Fire Hazard Assessment Methodology** Yasushi Okano, Hidemasa Yamano (Japan Atomic Energy Agency, Japan)
NUTHOS10-1291	**Development of Margin Assessment Methodology of Decay Heat Removal Function against External Hazards (4) Event Sequence Assessment Based on Continuous Markov Chain Monte Carlo Method with Plant Dynamics Analysis** Takashi Takata, Emiko Azuma (Osaka University, Japan)
NUTHOS10-1057	**River Flooding due to Intense Precipitation** James C. Lin (ABSG Consulting Inc., United States)
NUTHOS10-1311	**A Study of Risk Evaluation Methodology Selection for the External Hazards** Takahiro Kuramoto (Nuclear Engineering, Ltd., Japan), Akira Yamaguchi (Osaka University, Japan), Yoshiyuki Narumiya (The Kansai Electric Power Company, Japan), Yutaka Mamizuka (Nuclear Engineering, Ltd., Japan)

Dec. 17 (Wed.)

Room A1

Dec. 17 (Wed.), 09:00 - 10:00, Room A1 **KL-6. Keynote lecture 6**
Chair: Takahiro Kuramoto (Nuclear Engineering, Ltd., Japan)

NUTHOS10-KL06	**Recent Trends in Nuclear Reactor Safety Assessment and Available Tools** Tunc Aldemir (The Ohio State University, United States)

Dec. 17 (Wed.), 10:30 - 12:00, Room A1 **A-1-8. Thermal Hydraulics and Safety of Water-Cooled Reactors 8**
Chairs: Kazuaki Kito (Hitachi Ltd., Japan), Xiaojing Liu (Shanghai Jiao Tong University, China)

NUTHOS10-1153	**Effect of flow obstacle on droplet sizes in vertical annular air-water flow in a small diameter pipe.** Yasuteru Sibamoto (Japan Atomc Energy Agency, Japan), Hoamin Sun (Japan Atomic Energy Agency, Japan), Taisuke Yonomoto (Japan Atomc Energy Agency, Japan)
NUTHOS10-	**Development of sub-channel/system coupled code and its application to a supercritical water-cooled test**

1158	**loop** Xiaojing Liu, Ting Yang, Xu Cheng (Shanghai Jiao Tong University, China)
NUTHOS10-1182	**Post-test Analysis of OECD/NEA ROSA-2 Test 4 using TRACE** Ivor Clifford, Omar Zerkak, Andreas Pautz (Paul Scherrer Institut, Switzerland)
NUTHOS10-1253	**An experimental study of the nitrogen gas effect during the reflood phase of a LBLOCA** Yusun Park, Hyun-sik Park , Kyoung-ho Kang, Nam-hyun Choi, Kyoung-ho Min, Ki-yong Choi (Korea Atomic Energy Research Institute, Korea)

Dec. 17 (Wed.), 13:00 - 15:00, Room A1 **A-1-9. Thermal Hydraulics and Safety of Water-Cooled Reactors 9**
Chairs: Masaya Ohtsuka (Hitachi Ltd., Japan), Chin Pan (National Tsing Hua University, Taiwan)

NUTHOS10-1174	**THE QUENCHING OF STEEL ROD WITH VARIOUS POWER INPUT IN DI WATER** Yuan-hong Ho, Jian-chiuan Wang, Pan Chin, Ming-xi Ho (National Tsing Hua University, Taiwan)
NUTHOS10-1177	**Numerical study by large-eddy simulation on effects and mechanism of air-cooling enhancing technologies** Akinori Tamura, Toshinori Kawamura, Naoyuki Ishida, Kazuaki Kitou (Hitachi, Ltd., Japan)
NUTHOS10-1262	**Transverse Diffusion in Annular Liquid Film in BWR Subchannel with Spacers** Abhishek Saxena (Eidgenössische Technische Hochschule Zürich, Switzerland), Juan Pablo Calvo Sanchez (ETH Zürich, Switzerland), Horst-michael Prasser (Eidgenössische Technische Hochschule Zürich, Switzerland)
NUTHOS10-1271	**Experimental study for the effects of ballooned rod bundle on the convective heat transfer by single-phase steam flow** Jongrok Kim, Jong-kuk Park, Young-jung Youn, Hae Seob Choi, Sang-ki Moon (Korea Atomic Energy Research Institute, Korea)
NUTHOS10-1362	**Numerical Analysis of Transient Thermal-hydraulic Behavior of Supercritical Water Flow Subjected to Sharp Pressure Variations** Goutam Dutta (Indian Institute of Information Technology Design & Manufacturing Jabalpur, India), Jin Jiang, Rohit Maitri, Chao Zhang (Western University, Canada)

Dec. 17 (Wed.), 15:30 - 17:50, Room A1 **A-1-10. Thermal Hydraulics and Safety of Water-Cooled Reactors 10**
Chairs: Masanori Naitoh (The Institute of Applied Energy, Japan), Hyoung Kyu Cho (Seoul National University, Korea)

NUTHOS10-1191	**Boiling heat transfer correlation outside horizontal tube in a condenser** Hideaki Hosoi, Naoyuki Ishida, Naohisa Watahiki, Kiyoshi Fujimoto, Kazuaki Kito (Hitachi, Ltd., Japan)
NUTHOS10-1265	**Accident Analysis of Fukushima Daiichi NPP Unit-1 with SAMPSON Code** Masanori Naitoh, Hideo Mizouchi, Hiroaki Suzuki, Hidetoshi Okada, Marco Pellegrini (The Institute of Applied Energy, Japan)
NUTHOS10-1275	**Molten Core Relocation Analysis of Fukushima Daiichi Unit 3 by the SAMPSON Code** Marco Pellegrini, Hideo Mizouchi, Hiroaki Suzuki, Masanori Naitoh (The Institute of Applied Energy, Japan), Alessandro Costa (Politecnico di Milano, Italy)
NUTHOS10-1290	**Simulation of Large Scale Erosion of a Stratified Helium Layer by a Vertical Air Jet using the GOTHIC Code** Ante Hultgren, Ignacio Gallego-Marcos, Walter Villanueva, Pavel Kudinov (Royal Institute of Technology, Sweden)
NUTHOS10-1343	**A condensation heat transfer model for nearly horizontal heat exchanger tubes of the passive auxiliary feedwater System in APR+** Taehwan Ahn, Jae-jun Jeong, Byong-jo Yun (Pusan National University, Korea), Kyong-ho Kang, Yu-sun Park (Korea Atomic Energy Research Institute, Korea), Jong Cheon (KHNP, Korea)
NUTHOS10-1350	**Analysis of the ATLAS Main Steam Line Break Experiment Using the MARS Code** Tae Wook Ha, Jae Jun Jeong, Byong Jo Yun (Pusan National Univ., Korea)

Room A2

Dec. 17 (Wed.), 09:00 - 10:00, Room A2 **KL-7. Keynote lecture 7**
Chair: Michio Murase (Institute of Nuclear Safety System, Inc., Japan)

NUTHOS10-KL07	**Qualification of multiphase CFD for nuclear reactor safety - status and perspective** Dirk Lucas (Helmholtz-Zentrum Dresden – Rossendorf, Insitute of Fluid Dynamics, Germany)

Dec. 17 (Wed.), 10:30 - 12:00, Room A2 **B-5-1. CFD for Reactor Application**
Chairs: Jan-patrice Simoneau (Electricité de France, France), Abhishek Saxena (Eidgenössische Technische Hochschule Zürich, Switzerland)

NUTHOS10-1017	**Advanced CFD simulation for the assessment of nuclear safety issues at EDF: some examples** Christophe Vare (Electricité de France, China)
NUTHOS10-	**A synthesis of some challenges to be met by CFD for PWR safety and design**

1027	Jan-patrice Simoneau (Electricité de France, France)
NUTHOS10-1179	**Assessment of CFD URANS models for buoyancy driven mixing flows based on ROCOM experiments** Riccardo Puragliesi, Omar Zerkak, Andreas Pautz (Paul Scherrer Institute, Switzerland)
NUTHOS10-1203	**Implementation into a CFD code of Neutron Kinetics and Fuel Pin Models for Nuclear Reactor Transient Analyses** Zhao Chen (University of Science and Technology of China，Karlsruhe Institute of Technology, China), Xue-nong Chen, Andrei Rineiski (Karlsruhe Institute of Technology, Germany), Pengcheng Zhao, Hongli Chen (University of Science and Technology of China, China)

Dec. 17 (Wed.), 13:00 - 15:00, Room A2 **A-2-3. Thermal Hydraulics in Liquid Metal Systems 1**
Chairs: Nicolas Alpy (French Commission for Atomic Energy and Alternative Energy, France), Shuji Ohno (Japan Atomic Energy Agency, Japan)

NUTHOS10-1163	**Investigation on Thermal Striping Phenomena in Five Jets Modelled Water Test (FIWAT) simulating Sodium-cooled Fast Reactor** Kosuke Aizawa, Jun Kobayashi (Japan Atomic Energy Agency, Japan), Takamitsu Onojima (Japan Atomic Enery Agency, Japan), Masaaki Tanaka, Shuji Ohno, Hideki Kamide (Japan Atomic Energy Agency, Japan)
NUTHOS10-1183	**COMPLOT AND E-SCAPE: FACILITIES FOR LIQUID-METAL, POOL-TYPE REACTOR THERMAL HYDRAULIC INVESTIGATIONS AND THEIR ASSOCIATED R&D PROGRAM IN THE FRAME OF THE MYRRHA PROJECT** Katrien Van Tichelen, Matteo Greco, Graham Kennedy, Fabio Mirelli (Belgian Nuclear Research Centre, Belgium)
NUTHOS10-1031	**Heat transfer experiments in rod bundles cooled by lead-bismuth eutectic (LBE)** Julio Pacio, Markus Daubner, Frank Fellmoser, Karsten Litfin, Luca Marocco, Thomas Wetzel (Karlsruhe Institute of Technology, Germany)
NUTHOS10-1303	**CFD Activities in Support of Thermal-hydraulic Modeling of SFR Fuel Bundles** Emilio Baglietto (Massachusetts Institute of Technology, United States), Joseph William Fricano (FrepoliSolutions, United States), Eugeny Sosnovsky (Massachusetts Institute of Technology, United States)
NUTHOS10-1355	**Validation of SOCRAT-BN Code on Rod Bundle Experiments** Uliya U Vinogradova, Nikolay Ryzhov , Vladimir Semenov, Ruslan Chalyy (Nuclear Safety Institute, Russian Federation)

Dec. 17 (Wed.), 15:30 - 17:50, Room A2 **A-2-4. Severe Accident Phenomena in SFRs**
Chairs: In Cheol Bang (Ulsan National Institute of Science and Technology, Korea), Satoshi Nishimura (Central Research Institute of Electric Power Industry, Japan)

NUTHOS10-1050	**An experimental study on heat transfer from a mixture of solid-fuel and liquid-steel during core disruptive accidents in sodium-cooled fast reactors** Kenji Kamiyama, Kensuke Konishi, Ikken Sato, Jun-ichi Toyooka, Ken-ichi Matsuba, Tohru Suzuki, Yoshiharu Tobita (Japan Atomic Energy Agency, Japan), Alexander V. Pakhnits, Vladimir A. Vityuk, Alexander D. Vurim, Valery A. Gaidaichuk, Alexander A. Kolodeshnikov, Yuri S. Vassiliev (National Nuclear Center of the Republic of Kazakhstan, Kazakhstan)
NUTHOS10-1026	**Validation and improvement of a numerical model for freezing and blockage formation of solid-liquid flow of molten fuel in the core disruptive accident of FBR** Mitsuhiro Aoyagi, Kenji Kamiyama, Yoshiharu Tobita, Tohru Suzuki (Japan Atomic Energy Agency, Japan)
NUTHOS10-1095	**Distance for fragmentation of a simulated molten-core material discharged into a sodium pool** Ken-ichi Matsuba, Mikio Isozaki, Kenji Kamiyama, Tohru Suzuki, Yoshiharu Tobita (Japan Atomic Energy Agency, Japan)
NUTHOS10-1040	**Characteristics of Pressure Buildup from Local Fuel-Coolant Interactions in a Simulated Molten Fuel Pool: II. Numerical Analyses using SIMMER-III** Songbai Cheng, Ken-ichi Matsuba, Mikio Isozaki, Kenji Kamiyama, Tohru Suzuki, Yoshiharu Tobita (Japan Atomic Energy Agency, Japan)
NUTHOS10-1299	**Validation of New Empirical Model for Self-Leveling Behavior of Cylindrical Particle Beds Based on Experimental Database** Koji Morita, Tatsuya Matsumoto, Shohei Taketa, Shinpei Nishi (Kyushu University, Japan), Songbai Cheng, Tohru Suzuki, Yoshiharu Tobita (Japan Atomic Energy Agency, Japan)
NUTHOS10-1141	**Numerical simulation for debris bed behavior in Sodium Cooled Fast Reactor** Hirotaka Tagami, Yoshiharu Tobita (Japan Atomic Energy Agency, Japan)

Room B1

Dec. 17 (Wed.), 09:00 - 10:00, Room B1 **KL-8. Keynote lecture 8**
Chair: Masahiro Furuya (Central Research Institute of Electric Power Industry, Japan)

NUTHOS10-	**V&V for Engineering Simulation**

KL08	Seiichi Koshizuka (The University of Tokyo, Japan)

Dec. 17 (Wed.), 10:30 - 12:00, Room B1 **D-2. Severe Accident Management Guidelines**
Chairs: Chris Allison (INNOVATIVE SYSTEMS SOFTWARE, United States), Jun Sugimoto (Kyoto University, Japan)

NUTHOS10-1363	**The Technical Requirements Concerning Severe Accident Management in Nuclear Power Plants** Koji Okamoto (University of Tokyo, Japan), Tomoyuki Sugiyama (Japan Atomic Energy Agency, Japan), Shinya Kamata (Japan Nuclear Safety Institute, Japan)
NUTHOS10-1046	**Severe accident management – Optimized guidelines and strategies** Matthias Braun, Micha Loeffler, Hermann Plank, Dietmar Asse, Harald Dimmelmeier (AREVA, Germany)
NUTHOS10-1080	**Requirement Analysis of Computerized Procedures of AP1000 Severe Accident Management Guidelines** Gang Chen, Haidan Wang, Yiqiang Xiong, Yixue Chen, Yanhua Yang (State Nuclear Power Software Development Center, China)
NUTHOS10-1304	**Analysis of Severe Accident in OPR1000 PWR Plant at Low Power and Shutdown States with MAAP 5 Code** Hyeong Taek Kim (Korea Hydro & Nuclear Power Co., Korea), Haecheol Oh, Sangwon Lee (Korea Hydro & Nuclear Power Co, Korea)

Dec. 17 (Wed.), 13:00 - 15:00, Room B1 **E-1. Licensing Issues in Thermal-Hydraulic and Safety Lessons-Learned from Fukushima Dai-ichi Accident 1**
Chairs: Shinya Mizokami (Tokyo Electric Power Company, Japan), Christophe Journeau (CEA, France)

NUTHOS10-1128	**SUMMARY OF SEVERE ACCIDENT ASSESMENT FOR ATUCHA 2 NUCLEAR POWER PLANT USING RELAP/SCDAPSIM Mod3.6** Analia Noemi Bonelli (Nucleoeléctrica Argentina S.A., Argentina), Larry J Siefken, Chris M Allison (Innovative Systems Software, United States), Oscar Alberto Mazzantini (Nucleoeléctrica Argentina S.A., Argentina)
NUTHOS10-1185	**The accident progression analysis in Fukushima Dai-ichi Unit 1 based on update of forensic investigation** Takeshi Sakai (Hitachi-GE Nuclear Energy,Ltd., Japan), Tomohiro Kiguchi, Tadashi Fujii, Kohei Hisamochi (Hitachi-GE Nuclear Energy,Ltd, Japan), Shinya Mizokami, Daichi Yamada, Daisuke Yamauchi (Tokyo Electric Power Company, Inc., Japan)
NUTHOS10-1156	**The accident progression analysis in Fukushima Dai-ichi Unit 3 based on update of forensic investigation** Daichi Yamada, Shinya Mizokami, Takeshi Honda (Tokyo Electric Power Company, Japan), Hiromasa Yanagisawa (Toshiba Corporation Power Systems Company, Japan), Yasunori Yamanaka (Tokyo Electric Power Company, Japan), Noriyuki Katagiri (Toshiba Corporation Power Systems Company, Japan)
NUTHOS10-1075	**TRACE/FRAPTRAN analysis of Kuosheng (BWR/6) nuclear power plant for the similar Fukushima accident** Jong-rong Wang, Hao-tzu Lin (Institute of Nuclear Energy Research, Atomic Energy Council, R.O.C., Taiwan), Hsiung-chih Chen, Jung-hua Yang, Chunkuan Shih (Institute of Nuclear Engineering and Science, National Tsing Hua University, Taiwan)
NUTHOS10-1076	**MELCOR/SNAP analysis of Chinshan (BWR/4) nuclear power plant spent fuel pool for the similar Fukushima accident** Jong-rong Wang, Hao-tzu Lin, Te-chuan Wang (Institute of Nuclear Energy Research, Atomic Energy Council, R.O.C., Taiwan), Hsiung-chih Chen, Jung-hua Yang , Chunkuan Shih (Institute of Nuclear Engineering and Science, National Tsing Hua University, Taiwan)

Dec. 17 (Wed.), 15:30 - 17:50, Room B1 **E-2. Licensing Issues in Thermal-Hydraulic and Safety Lessons-Learned from Fukushima Dai-ichi Accident 2**
Chairs: Malgorzata Sneve (Norwegian Radiation Protection Authority, Norway), Analia Noemi Bonelli (Nucleoeléctrica Argentina S.A., Argentina)

NUTHOS10-1130	**Discussion of Accident Progression of Fukushima Daiichi Unit 1 based on Behavior of Fuel Range Water Level Indicator Readings** Kenichiro Nozaki, Shoichi Suehiro, Manabu Watanabe (TEPCO Systems Corporation, Japan), Shinya Mizokami, Daisuke Yamauchi, Daichi Yamada, Takeshi Honda (Tokyo Electric Power Company, Japan)
NUTHOS10-1243	**Assessment of RELAP/SCDAPSIM/MOD3.5 against the BWR core degradation experiment CORA-17** Hiroshi Madokoro (The University of Tokyo, Japan), Siegfried Hagen (Formerly Karlsruhe Institute of Technology, Germany), Larry Siefken, Judith Hohorst, Chris Allison (Innovative Systems Software, United States), Koji Okamoto (The University of Tokyo, Japan)
NUTHOS10-1340	**Study on the disappearing of thermal stratification at the suppression chamber** Daisuke Yamauchi, Nejdet Erkan, Byeongnam Jo, Koji Okamoto (The University of Tokyo, Japan)
NUTHOS10-1039	**A Comparison of United States and Japanese Regulatory Requirements at the Time of Fukushima Accident and Updates of USNRC Post-Fukushima Activities**

	John C Lai (United States Nuclear Regulatory Commission, United States)
NUTHOS10-1351	**Canadian Regulatory Requirements and Practices for Qualification of Computer Codes Used in Safety Analysis** Janusz E. Kowalski (Canadian Nuclear Safety Commission, Canada)

Room B2

Dec. 17 (Wed.), 10:30 - 12:00, Room B2 **B-4-1. Verification and Validaiton of Numerical Codes 1**
Chairs: Aaron Simon Epiney (Paul Scherrer Institute, Switzerland), S. Koshizuka (Univ. Tokyo, Japan)

NUTHOS10-1004	**Supporting Qualified Database for V&V and Uncertainty Evaluation of Best-Estimate System Codes** Alessandro Petruzzi (GRNSPG - NINE, Italy), Francesco D'Auria (GRNSPG - University of Pisa, Italy)
NUTHOS10-1053	**Simulation of thermal hydraulics accidental transients: evaluation of MAAP5.02 versus CATHAREv2.5** Jeremy Bittan (EDF, France)
NUTHOS10-1192	**Assessment of TRACE against single-tube post-dryout heat transfer experiments** Yacine Aounallah (Paul Scherrer Institut, Switzerland)
NUTHOS10-1255	**Loss of Pump Transient Experiments of the KYLIN-II Thermal-hydraulics Mixed Circulation LBE Loop and Comparative RELAP Analysis** Ming Jin, Liuli Chen, Jiayue Chen, Qungying Huang (Institute of Nuclear Energy Safety Technology, Chinese Academy of Sciences, China)

Dec. 17 (Wed.), 13:00 - 15:00, Room B2 **B-4-2. Verification and Validaiton of Numerical Codes 2**
Chairs: Tatjana Jevremovic (The University of Utah, United States), Yoshiyuki Kondo (Mitsubishi Heavy Industries, Ltd., Japan)

NUTHOS10-1205	**Sensitivity Analysis of a Bottom Reflood Simulation using Morris Screening Method** Damar Wicaksono (École polytechnique fédérale de Lausanne, Switzerland), Omar Zerkak (Paul Scherrer Institut, Switzerland), Andreas Pautz (École polytechnique fédérale de Lausanne, Switzerland)
NUTHOS10-1208	**Exploring Variability in Reflood Simulation Results: Application of Functional Data Analysis** Damar Wicaksono (École polytechnique fédérale de Lausanne, Switzerland), Omar Zerkak (Paul Scherrer Institut, Switzerland), Andreas Pautz (École polytechnique fédérale de Lausanne, Switzerland)
NUTHOS10-1024	**EXPERIMENTAL STUDY ON HYDROGEN BEHAVIOR IN CONTAINMENT BUILDINGS FILLED WITH STEAM DURING SEVERE ACCIDENTS** Wen Sheng Hsu, Hungpei Chen (National Tsing Hua University, Taiwan), Hui-chen Lin, Yao-hui Hsieh (National Tsing Hua University, Taiwan, Taiwan)
NUTHOS10-1194	**Assessment of the integral code ASTEC with respect to the late in-vessel phase of core degradation** Christophe D'Alessandro, Joerg Starflinger (Institut für Kernenergetik und Energiesysteme, University of Stuttgart, Germany)
NUTHOS10-1155	**Development of the Three Dimensional Flow Model in the SPACE Code** Myung Taek Oh, Chan Eok Park (KEPCO Engineering & Construction Company, INC., Korea)

Dec. 17 (Wed.), 15:30 - 17:50, Room B2 **B-4-3. Verification and Validaiton of Numerical Codes 3**
Chairs: Damar Wicaksono (École polytechnique fédérale de Lausanne, Switzerland), Aaron Simon Epiney (Paul Scherrer Institute, Switzerland)

NUTHOS10-1070	**3D AGENT Methodology Validation for Prismatic High-Temperature Gas-Cooled Reactor** Hermilo Hernandez, Sarah Obadina, Victor Bautista, Tatjana Jevremovic (The University of Utah, United States)
NUTHOS10-1196	**Uncertainty- and Sensitivity Analysis of COBRA-TF for the Simulation of Selected OECD/NRC BFBT Void Experiments** Aaron Simon Epiney, Omar Zerkak, Andreas Pautz (Paul Scherrer Institute, Switzerland)
NUTHOS10-1360	**Evaluation and Validation of Turbulent Models Used in Numerical Simulation of IRWST Experimental Model** Yu Hao Zhang, Dao Gang Lu (North China Electric Power University, China), Zheng Du, Xiao Liang Fu (State Nuclear Power Software Development Center, China)
NUTHOS10-1092	**DEVELOPMENT AND VALIDATION OF COUPLED PARCS/RELAP5 MODEL FOR FORSMARK-2 NPP AT UPRATED POWER** Alexander Agung, József Bánáti (Chalmers University of Technology, Sweden)

Room B3+B4

Dec. 17 (Wed.), 09:00 - 10:00, Room B3+B4 **KL-9. Keynote lecture 9**
Chair: Marco Pellegrini (The Institute of Applied Energy, Japan)

NUTHOS10-KL09	**SMR-iPWR concepts: thermal hydraulics R&Ds and other key aspects** Marco Enrico Ricotti (Politecnico di Milano, Italy)

Dec. 17 (Wed.), 10:30 - 12:00, Room B3+B4 **A-6-1. Cross-Cutting Thermal-Hydraulics of Innovatie Nuclear Systems**
Chairs: Vladimir Kriventsev (Karlsruhe Institute of Technology, Germany), Katrien Van Tichelen (Belgian Nuclear Research Centre, Belgium)

NUTHOS10-1041	**CFD analysis on Supercritical Pressure Water Heat Transfer in a 2x2 Rod Bundle** Jinbiao Xiong, Xu Cheng (Shanghai Jiao Tong University, China)
NUTHOS10-1124	**Geometric Size Optimization and Behavior Analysis of a Dual-cooled Annular Fuel** Yang Bin Deng, Ying Wei Wu, Da Lin Zhang, Wen Xi Tian, Sui Zheng Qiu, Guang Hui Su, Wei Xu Zhang, Jun Mei Wu (Xi'an Jiaotong University, China)
NUTHOS10-1123	**Coupled Thermal-Hydraulic and Neutronic Simulations of Phenix Control Rod Withdrawal Tests with SIMMER-IV** Vladimir Kriventsev, Fabrizio Gabrielli, Andrei Rineiski (Karlsruhe Institute of Technology, Germany)
NUTHOS10-1145	**FLUENT-based Neutronics and Thermal-Hydraulics Coupling Calculation for a Liqui-Fuel Molten Salt Reator** Dalin Zhang (Xi'an Jiaotong University, China), Zhi-gang Zhai (Xi'an Modnut Network Technologies Co. Ltd., China), Andrei Rineiski, Shisheng Wang (Karlsruhe Institute of Technology, Germany), Zhangpeng Guo, Chenglong Wang, Suizheng Qiu (Xi'an Jiaotong University, China)

Dec. 17 (Wed.), 13:00 - 15:00, Room B3+B4 **A-6-2. Cross-Cutting Thermal-Hydraulics of Liquid Metal and Fusion Sytems**
Chairs: Takashi Takata (Osaka University, Japan), Hongli Chen (University of Science and Technology of China, China)

NUTHOS10-1269	**Validation of a CFD code Star-CCM+ for liquid Lead-Bismuth Eutectic (LBE) thermal-hydraulics using TALL-3D experiment.** Marti Jeltsov, Kaspar Kööp, Walter Villanueva, Dmitry Grishchenko, Pavel Kudinov (Royal Institute of Technology, Sweden)
NUTHOS10-1103	**Multi-Scale Uncertainty and Sensitivity Analysis of the TALL-3D Experiment Using Thermal-Hydraulic Coupled Codes** Clotaire Geffray (Technische Universitaet Muenchen, Germany), Angel Papukchiev (Gesellschaft fuer Anlagen- und Reaktorsicherheit mbH, Germany), Rafael Macián-Juan (Technische Universitaet Muenchen, Germany)
NUTHOS10-1052	**A Study of Different Approaches for Multi-Scale Sensitivity Analysis of the TALL-3D Experiment Using Thermal-Hydraulic Computer Codes** Clotaire Geffray, Rafael Macián-Juan (Technische Universitaet Muenchen, Germany)
NUTHOS10-1078	**Numerical Study on Flow Distribution Characteristics of Water-Cooled Solid Breeder Blanket Module** Mufei Wang, Lili Tong, Xuewu Cao (Shanghai Jiao Tong University, China)
NUTHOS10-1221	**Thermal-hydraulic Design and Analysis of Helium Cooled Solid Breeder Blanket for Chinese Fusion Engineering Test Reactor** Hongli Chen (University of Science and Technology of China, China), Minyou Ye (University of Science and Technology of China; Institute of Plasma Physics, Chinese Academy of Sciences, China), Min Li, Zhongliang Lv, Guangming Zhou, Qianwen Liu, Shuai Wang (University of Science and Technology of China, China)

Dec. 17 (Wed.), 15:30 - 17:50, Room B3+B4 **A-3. Thermal-Hydraulics and Safety of Gas-Cooled Reactors**
Chairs: Bum-jin Chung (Kyung Hee University, Korea), Andrei Rineiski (Karlsruher Institut für Technologie , Germany)

NUTHOS10-1216	**An Experimental Study of Coolant Flow Mixing within Scaled Model of the Upper Plenum of VHTR.** Jaehyung Park, Kyle McVay, Saya Lee, Yassin Hassan, N.K. Anand (Texas A&M University, United States)
NUTHOS10-1279	**EXPERIMENTAL INVESTIGATION OF TURBULENT CONVECTIVE HEAT TRANSFER AND PRESSURE FOR SMOOTH AND ROUGHNED ANNULAR GAS FLOWS IN HEXAGONAL CHANNELS** Rodrigo Gomez (Karlsruhe Institute of Technologie, Germany)
NUTHOS10-1227	**Force Convection Heat Transfer Correlation for Finned Plates in a Duct** Myeong-seon Chae, Je-young Moon , Bum-jin Chung (Kyung Hee University, Korea)
NUTHOS10-1118	**CFD Simulation and Some Analysis of Reverse U-shape Slot Experiment** Peng Liu, Yanhua Zheng, Lei Shi (Tsinghua University, China)
NUTHOS10-1015	**New Reactor Cavity Cooling System Using Novel Shape for HTGRs and VHTRs** Kuniyoshi Takamatsu (Japan Atomic Energy Agency, Japan), Rui Hu (Argonne National Laboratory, United States)
NUTHOS10-1082	**Loss-of-water accident analysis of the pebble-bed modular high temperature gas-cooled reactor** Yanhua Zheng, Lei Shi, Fubing Chen (Tsinghua University, China)

Room B6+B7

Dec. 17 (Wed.), 09:00 - 10:00, Room B6+B7 **KL-10. Keynote lecture 10**
Chair: Michitsugu Mori (Hokkaido Univ., Japan)

NUTHOS10-KL10	**Thermal Hydraulic R&D of Chinese Advanced Reactors** Guanghui Su (Xi'an Jiaotong University, China)

Dec. 17 (Wed.), 10:30 - 12:00, Room B6+B7 **D-3-3. Methodology and Application of PRA for Internal, Seismic and Tsunami Events 2**
Chairs: Gerben J. Dirksen (AREVA GmbH, Germany), Yasushi Okano (Japan Atomic Energy Agency, Japan)

NUTHOS10-1010	**Level 2 PSA Applications – Focus on Advanced Containment Systems** Gerben J Dirksen, Heiko Kollasko (AREVA GmbH, Germany)
NUTHOS10-1318	**The evaluation of a group motion for FBR core subassemblies under the seismic condition over Design Basis Earthquake Ground Motion** Masahiko Ariyoshi, Akira Yamaguchi, Takashi Takata (Osaka University, Japan), Hiroshi Endo (Central Research Institute of Electric Industry, Japan)
NUTHOS10-1011	**Seismic Level 2 PSA** Gerben J. Dirksen, Manuel Pellissetti (AREVA GmbH, Germany), Paul Duncan-Whiteman (AREVA Inc., United States)
NUTHOS10-1237	**Evaluation of Safety Issues on Newly Regulated Nuclear Power Plant by Tsunami-Level 1 PRA** Yutaro Tsuji, Shuichiro Miwa, Michitsugu Mori (Hokkaido University, Japan)

Dec. 17 (Wed.), 13:00 - 15:00, Room B6+B7 **C-1. Plant Operation & Maintenance Management**
Chairs: Mark J. Harper (International Atomic Energy Agency, Austria), Y. Narumiya (KANSAI Electric Power Company, Japan)

NUTHOS10-1066	**CONTROL ROOM UNFILTERED IN-LEAKAGE LIMIT ANALYSIS OF DESIGN-BASIS LOCA FOR LUNGMEN ABWR PLANT** Chih-ming Harris Tsai, Chin-jang Chang, Yng-ruey Yuann (Institute of Nuclear Energy Research, Taiwan)
NUTHOS10-1110	**Transient Analysis for a System with a Tilted Disc Check Valve** Jae Sik Jeung, Dae Gwan Cho, Kyu Kwang Lee (KEPCO Engineering & Construction Company, Korea)
NUTHOS10-1157	**Control Room Dose Analysis for Maanshan PWR Plant during Design Basis Loss of Coolant Accident** Cheng-der Wang (Institute of Nuclear Energy Research, Taiwan)
NUTHOS10-1030	**An Investigation into the Electrochemical Behavior of Hydrogen Peroxide on TiO2 Treated Type 304 Stainless Steels in High Temperature Water** Tsung-kuang Yeh, Mei-ya Wang, Tsung-han Li (National Tsing Hua University, Taiwan)

Dec. 17 (Wed.), 15:30 - 17:50, Room B6+B7 **C-8. Advances in Nuclear Safety Systems and Analysis**
Chairs: Alexander Georgievich Tyapin (ATOMENERGOPROJECT, Russian Federation), Takashi Takata (Osaka University, Japan)

NUTHOS10-1035	**IMPACT OF FOUNDATION PROPERTIES ON SEISMIC RESPONSE** Alexander Georgievich Tyapin (ATOMENERGOPROJECT, Russian Federation)
NUTHOS10-1073	**Study on Transient Hydrogen Behavior and Effect on Passive Containment Cooling System of the Advanced PWR** Yan Wang (tsinghua university, China)
NUTHOS10-1202	**Interaction between Retrofittable and Existing Emergency Cooling Systems in BWRs** Jeanne Venker (RWE Technology GmbH, Germany), Dominik Von Lavante (TÜV Rheinland, Germany), Michael Buck (University of Stuttgart, Germany), Detlef Gitzel (RWE Power AG, Germany), Jörg Starflinger (University of Stuttgart, Germany)
NUTHOS10-1308	**Numerical quantification of effectiveness in the countermeasure against severe accident** Yuki Nishikawa, Akira Yamaguchi, Takashi Takata (Osaka-University, Japan)
NUTHOS10-1312	**Study on human reliability considering dependence among tasks in operation under accumulative stress condition** Masaki Kibashi, Akira Yamaguchi, Takashi Takata (Graduate School of Engineering, Osaka University, Japan)
NUTHOS10-1368	**Feasibility Study of Helical Coil Tube Condensation Heat Exchanger for a Passive Auxiliary Feedwater System** Kwanghee Seo, Taewan Kim (KEPCO International Nuclear Graduate School, Korea)

Dec. 18 (Thu.)

Room A1

Dec. 18 (Thu.), 09:00 - 11:00, Room A1 **A-1-11. Thermal Hydraulics and Safety of Water-Cooled Reactors 11**
Chairs: Y. Yamamoto (Toshiba, Japan), L. Y. Liao (INER, Taiwan), Masato Fukuta (Toshiba Corp., Japan)

NUTHOS10-	**Study on PWR Safety System Using SG Secondary-side Depressurization**

1195	Takahiro Morimoto, Akira Ohnuki (Mitsubishi Heavy Industries, Ltd., Japan), Hiroaki Nishi (The Kansai Electric Power Co., Inc, Japan)
NUTHOS10-1295	**The Assessment of the Fukushima Like Accident for Kuosheng BWR/6 with TRACE** Wen-hsiung Wu (Atomic Energy Council, Taiwan), Jong-rong Wang, Lih-yih Liao, Hao-tzu Lin (Institute of Nuclear Energy Research, Taiwan), Chunkuan Shih, Shao-wen Chen (National Tsing Hua University, Taiwan)
NUTHOS10-1313	**Simultaneous Visual Acquisition of Photography and Radiography for Melt Jet Breakup** Louis Manickam (The Royal institute of technology (KTH), Sweden), Sachin Thakre (The Royal institute of technology Sweden, Sweden), Weimin Ma, Sevostian Bechta (The Royal institute of technology, Sweden)
NUTHOS10-1328	**Scaling considerations in a Pressure Vessel Upper Head SBLOCA** Andrea Querol (Universitat Politècnica de València, Spain), Sergio Gallardo (Univeristat Politècnica de València, Spain), Gumersindo Verdú (Universitat Politècnica de València, Spain)
NUTHOS10-1335	**Pool boiling heat transfer of downward-facing oxidized metal heaters in atmospheric saturated water** Hong Hyun Son, Uiju Jeong, Gwang Hyeok Seo, Gyoodong Jeun, Sung Joong Kim (Hanyang University, Korea)

Dec. 18 (Thu.), 11:20 - 12:00, Room A1 **CL. Closing Session**
Chair: Xiaodong Sun (Ohio State University, USA, United States)

NUTHOS10-CL01	**Closing Remark**

Room A2

Dec. 18 (Thu.), 09:00 - 11:00, Room A2 **A-2-5. Thermal Hydraulics in Liquid Metal Systems 2**
Chairs: Emilio Baglietto (Massachusetts Institute of Technology, United States), Kei Ito (Japan Atomic Energy Agency, Japan)

NUTHOS10-1081	**Optimization of the flow path in a conceptual pool type reactor under natural circulation with lead coolant** Roman Thiele, Henryk Anglart (Royal Institute of Technology, Sweden)
NUTHOS10-1356	**Validation of SOCRAT-BN Code on the Base of Reactor Experiments** Nikita Rtishchev , Ruslan Chalyy, Vladimir Semenov, Aleksey Fokin, Artem Tarasov (Nuclear Safety Institute, Russian Federation), Sergey Shepelev, Sergey Osipov, Valeriy Gorbunov, Artem Anfimov (OKBM, Russian Federation)
NUTHOS10-1114	**An Investigation of Thermal-hydraulics Behavior of MONJU Reactor Upper Plenum under 40%-Rated Steady State** Kei Honda, Hiroaki Ohira, Takero Mori (Japan Atomic Energy Agency, Japan)
NUTHOS10-1296	**Numerical Study on Structural Integrity of Inner Barrel Caused by Thermal Stratification in Upper Plenum of Monju** Atsushi Kodama, Takashi Takata, Akira Yamaguchi (Graduate School of Engineering, Osaka University, Japan)
NUTHOS10-1085	**Influence of Piping Layout upon the characteristics of flow separation and pressure fluctuation in the primary cold-leg of sodium cooled fast reactor** Jun Mizutani, Shinji Ebara, Hidetoshi Hashizume (Tohoku University, Japan), Hidemasa Yamano (Japan Atomic Energy Agency, Japan)

Room B1

Dec. 18 (Thu.), 09:00 - 11:00, Room B1 **D-1-4. Severe Accident Mitigation Measures 3**
Chairs: Luis E. Herranz (CENTRO INVESTIGACIONES ENERGÉTICAS MEDIOAMBIENTALES Y TECNOLOGICAS, Spain), Jun Sugimoto (Kyoto University, Japan)

NUTHOS10-1257	**Experiments and Characterization of the Two-Phase Flow Driven Particulate Debris Spreading in the Pool** Alexander Konovalenko, Simone Basso, Pavel Kudinov (Royal Institute of Technology, Sweden)
NUTHOS10-1323	**A Numerical Simulation of Jet Breakup in Melt Coolant Interactions** Sachin S Thakre, Louis Manickam, Weimin Ma (Royal Institute of Technology, Sweden)
NUTHOS10-1190	**Validation and application of the MEWA 3D code for the investigation of multidimensional effects on debris coolability** Ana Kate Hartmann, Michael Buck, Jörg Starflinger (Institute for Nuclear Technology and Energy Systems, University of Stuttgart, Germany)
NUTHOS10-1281	**Simulation of In-vessel Debris Bed Coolability and Remelting** Sergey Yakush (Institute for Problems in Mechanics of Russian Academy of Sciences, Russian Federation), Walter Villanueva, Simone Basso, Pavel Kudinov (Royal Institute of Technology , Sweden)

NUTHOS10-1316	**Investigation of Steam Explosion in Stratified Melt-Coolant Configuration** Pavel Kudinov, Dmitry Grishchenko, Alexander Konovalenko, Aram Karbojian, Sevostian Bechta (Royal Institute of Technology, Sweden)

Room B2

Dec. 18 (Thu.), 09:00 - 11:00, Room B2 **B-5-2. CFD for Component Application**
Chairs: Henryk Anglart (Royal Institute of Technology, Sweden), Riccardo Puragliesi (Paul Scherrer Institute, Switzerland)

NUTHOS10-1059	**Numerical Simulation of Long-period Fluid Temperature Fluctuation Downstream from a Mixing Tee** Yoichi Utanohara, Akira Nakamura, Koji Miyoshi (Institute of Nuclear Safety System, Inc., Japan), Naoto Kasahara (University of Tokyo, Japan)
NUTHOS10-1138	**A Study on Thermal Sizing of In-Vessel Once Through Steam Generator for Sizing Configuration of Reactor Vessel** Kunwoo Yi, Youngjin Kim, Sungje Hong, Byungjin Lee, Kyongin Ju, Inyoung Im, Eunkee Kim, Cheolsoo Maeng (KEPCO Engineering & Construction Company. Inc, Korea)
NUTHOS10-1181	**A study on improvement of RANS analysis for erosion of density stratified layer of multicomponent gas by buoyant jet in a containment vessel** Satoshi Abe, Masahiro Ishigaki, Yasuteru Sibamoto, Taisuke Yonomoto (Japan Atomic Energy Agency, Japan)
NUTHOS10-1189	**Two-phase CFD modeling of flow causing the heater vibration** Antonín Povolný (Tokyo Institute of Technology, Japan), Dušan Kobylka (Czech Technical University in Prague, Czech Republic), Hiroshige Kikura (Tokyo Institute of Technology, Japan)

Room B3+B4

Dec. 18 (Thu.), 09:00 - 11:00, Room B3+B4 **OG-4. Unique Innovative NPP Concepts**
Chair: Marco Enrico Ricotti (Politecnico di Milano, Italy)

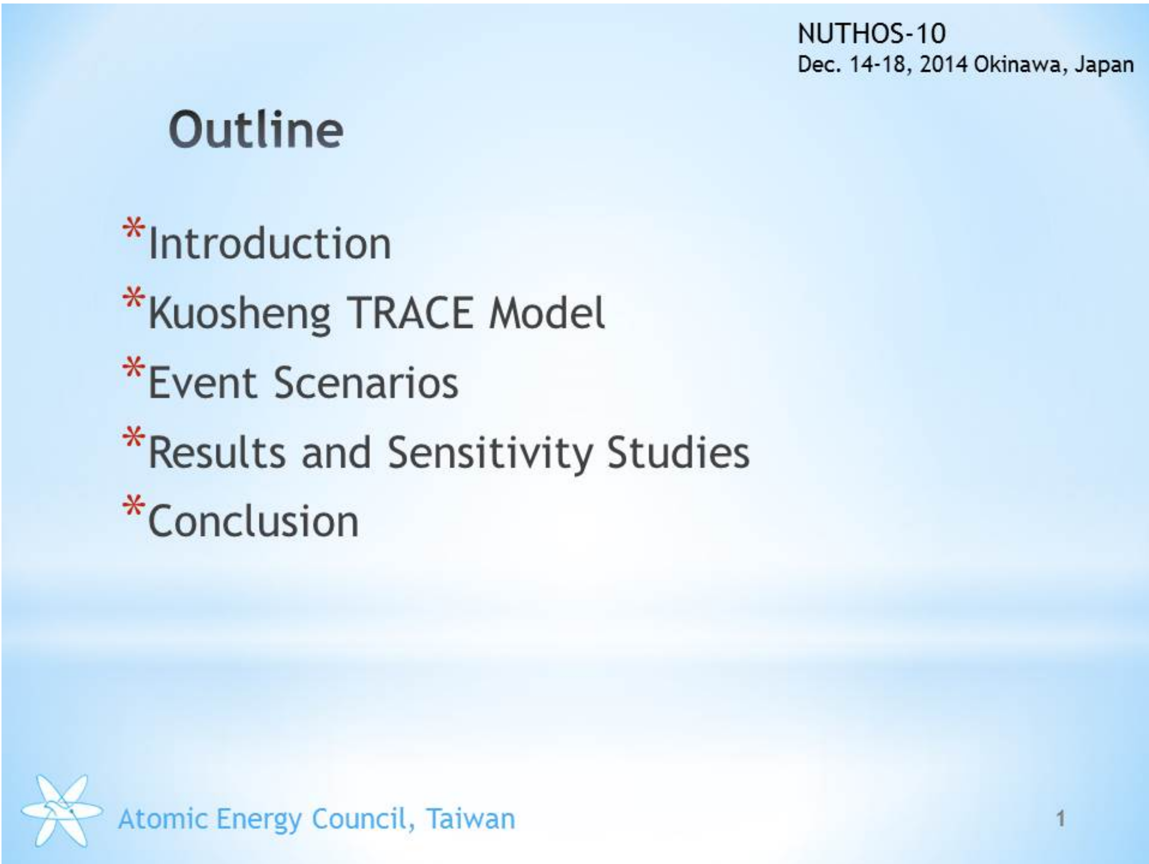
NUTHOS10-1104	**Spar-type Platform Design for the Offshore Floating Nuclear Power Plant** Jacob Matthew Jurewicz, Jacopo Buongiorno, Neil Todreas, Michael Golay (Massachusetts Institute of Technology, United States)
NUTHOS10-1366	**CFD investigation of Flexblue® hull** G. Haratyk, JJ. Ingremeau, V. Gourmel (DCNS, France), M. Santinello, M. E. Ricotti, H. Ninokata (Politecnico di Milano, Italy)
NUTHOS10-1367	**Concept Design and Safety Features of Nuclear Power Plants Mounted on Gravity Based Structures** Kang-heon Lee, Phill-seung Lee, Min-gil Kim, Jeong-ik Lee (Korea Advanced Institute of Science and Technology, Korea)

Room B6+B7

Dec. 18 (Thu.), 09:00 - 11:00, Room B6+B7 **C-2. Plant Monitoring**
Chairs: Ivan Otic (Karlsruhe Institut of Technology, Germany), Yoshiyuki Kondo (Mitsubishi Heavy Industries, Ltd., Japan)

NUTHOS10-1006	**On the METAL:LIC target design optimization and failure diagnostics by means of liquid metal loop vibrations monitoring.** Sergejs Dementjevs, Filippo Barbagallo, Michael Wohlmuther, Knud Thomsen (Paul Scherrer Institut, Switzerland), Raimonds Nikoluskins, Anatolijs Ziks (IPUL, Latvia)
NUTHOS10-1037	**Plant Monitoring and Diagnostic Systems related to Safety and Operation** Benedikt Heinz, Gerit Gloth (AREVA GmbH, Germany)
NUTHOS10-1038	**AREVA Fatigue Concept** Juergen Rudolph, Benoît Jouan, Steffen Bergholz, Benedikt Heinz (AREVA GmbH, Germany)
NUTHOS10-1051	**Safety features of selected Emergency Buildings designed by AREVA for European NPP** Thorsten Borrmann, Michael Drechsler (AREVA GmbH, Germany)
NUTHOS10-1160	**Development of the clamp-on ultrasound flow meter for steam in pipe** Tatsuya Kawaguchi, Keisuke Tsukada, Hiroshige Kikura (Tokyo institute of technology, Japan), Katsuhiko Tanaka, Shuichi Umezawa (Tokyo Electric Power Company, Japan)

（二） 吳文雄技士專題研究簡報：



NUTHOS-10
Dec. 14-18, 2014 Okinawa, Japan

Outline

* Introduction
* Kuosheng TRACE Model
* Event Scenarios
* Results and Sensitivity Studies
* Conclusion

Atomic Energy Council, Taiwan

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NUTHOS-10
Dec. 14-18, 2014 Okinawa, Japan

Introduction

* In order to cope with the Fukushima like accident, the Taiwan Power Company has proposed an emergency procedure which is named Ultimate Response Guideline (URG)

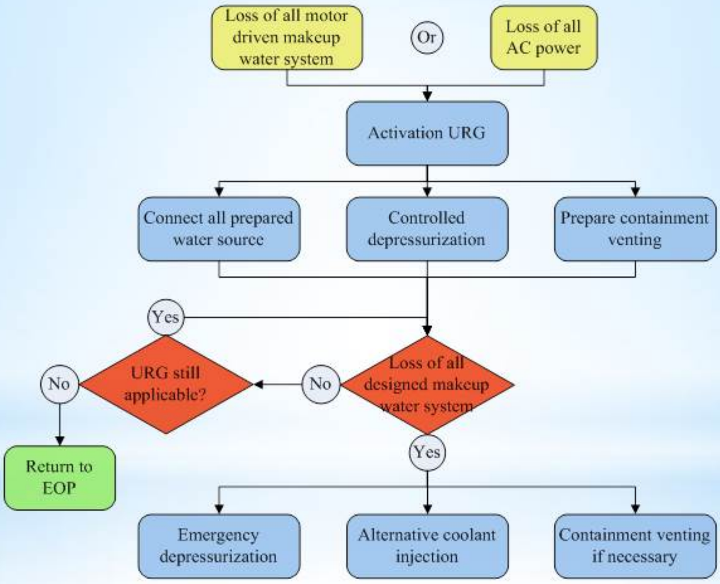
* DIVing Plan
  * Two Step Depressurization
  * Cooling Water Injection
  * Containment Venting

Atomic Energy Council, Taiwan

3

Introduction

Ultimate Response Guideline Flowchart



Introduction

Kuosheng Nuclear Power Plant

- Two BWR/6 units
- Rated Thermal Power:2943MWt
- Rated Core Flow:38.33×10^6kg/hr

NUTHOS-10
Dec. 14-18, 2014 Okinawa, Japan

Introduction

* The Fukushima like accident for Kuosheng nuclear power plant is analyzed by TRACE
  * Verify the effectiveness of URG
  * Discuss some issues related to URG

Atomic Energy Council, Taiwan

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NUTHOS-10
Dec. 14-18, 2014 Okinawa, Japan

Outline

* Introduction
* Kuosheng TRACE Model
* Event Scenarios
* Results and Sensitivity Studies
* Conclusion

Atomic Energy Council, Taiwan

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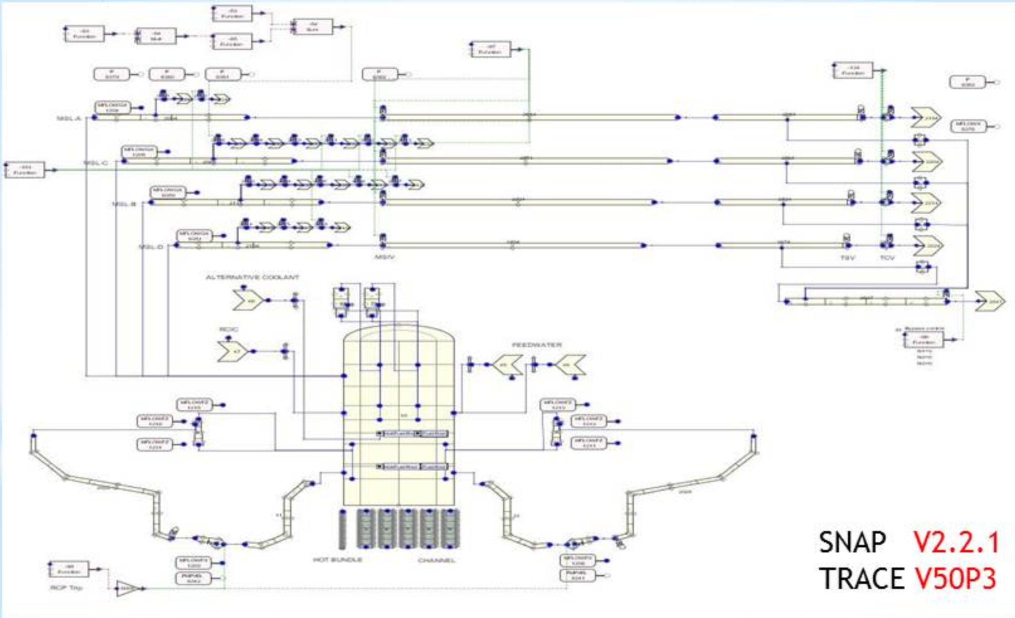
Kuosheng TRACE model

System



NUTHOS-10
Dec. 14-18, 2014 Okinawa, Japan

Outline

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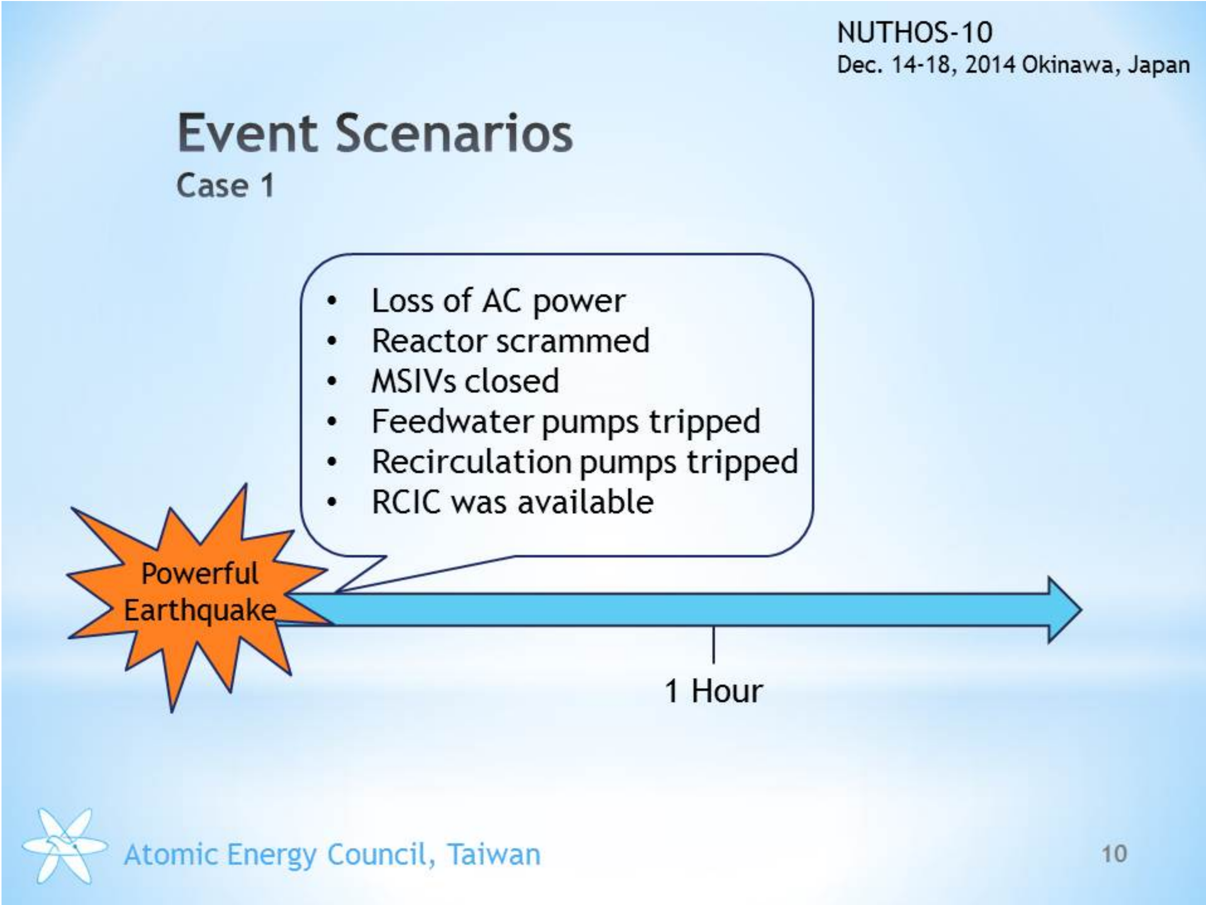
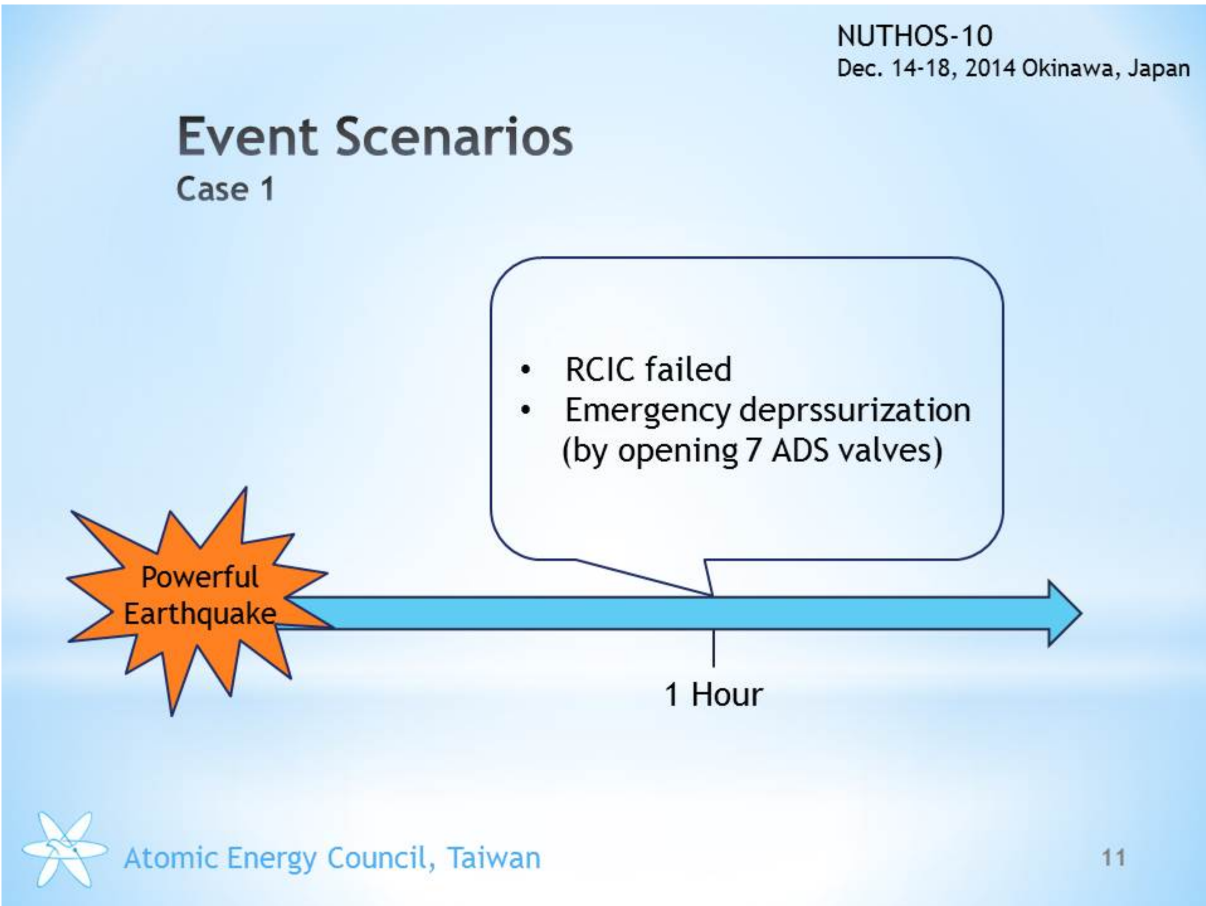
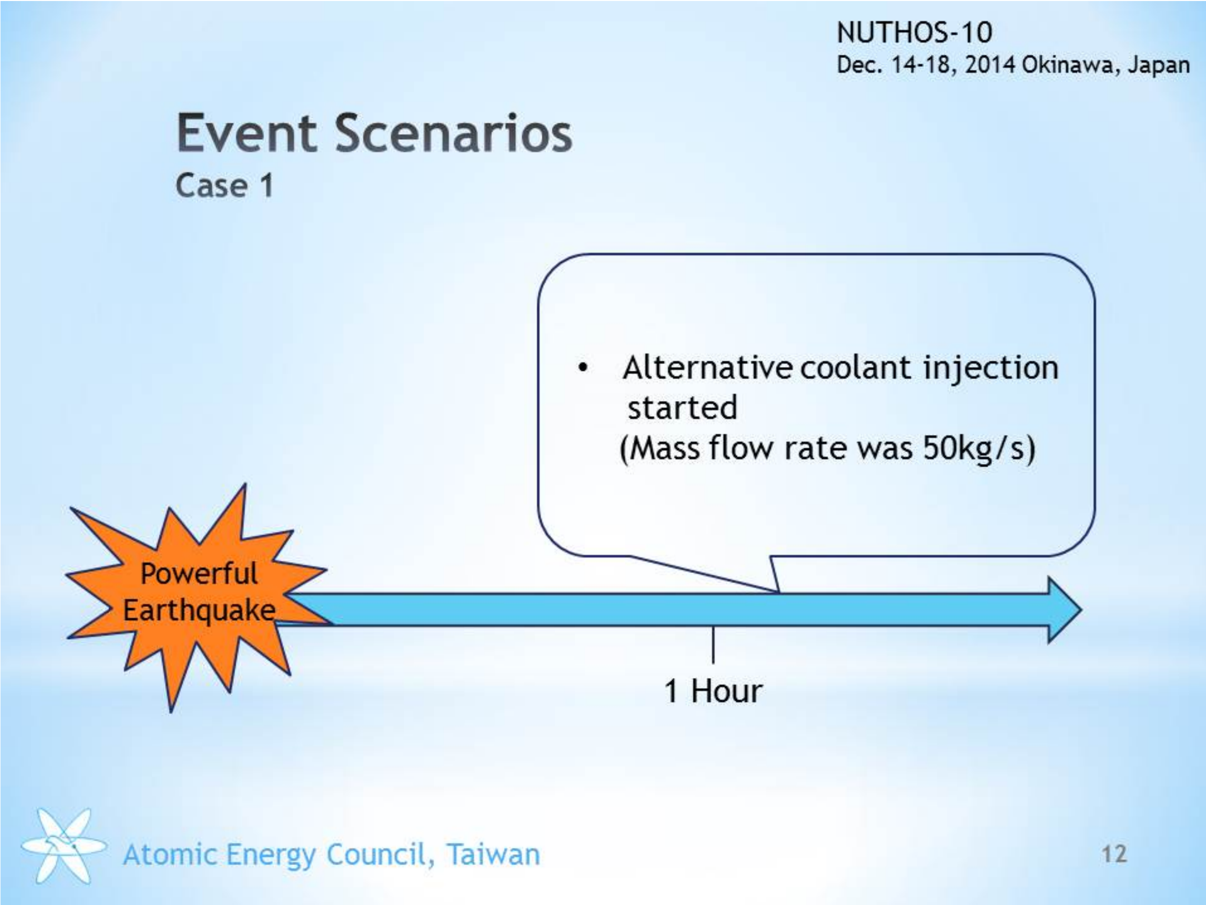
* Event Scenarios
* Results and Sensitivity Studies
* Conclusion


NUTHOS-10
Dec. 14-18, 2014 Okinawa, Japan
Event Scenarios
Case 1
• Loss of AC power
• Reactor scrammed
• MSIVs closed
• Feedwater pumps tripped
• Recirculation pumps tripped
• RCIC was available
Powerful Earthquake
1 Hour
Atomic Energy Council, Taiwan
10


NUTHOS-10
Dec. 14-18, 2014 Okinawa, Japan
Event Scenarios
Case 1
• RCIC failed
• Emergency deprssurization (by opening 7 ADS valves)
Powerful Earthquake
1 Hour
Atomic Energy Council, Taiwan
11


NUTHOS-10
Dec. 14-18, 2014 Okinawa, Japan
Event Scenarios
Case 1
• Alternative coolant injection started
(Mass flow rate was 50kg/s)
Powerful Earthquake
1 Hour
Atomic Energy Council, Taiwan
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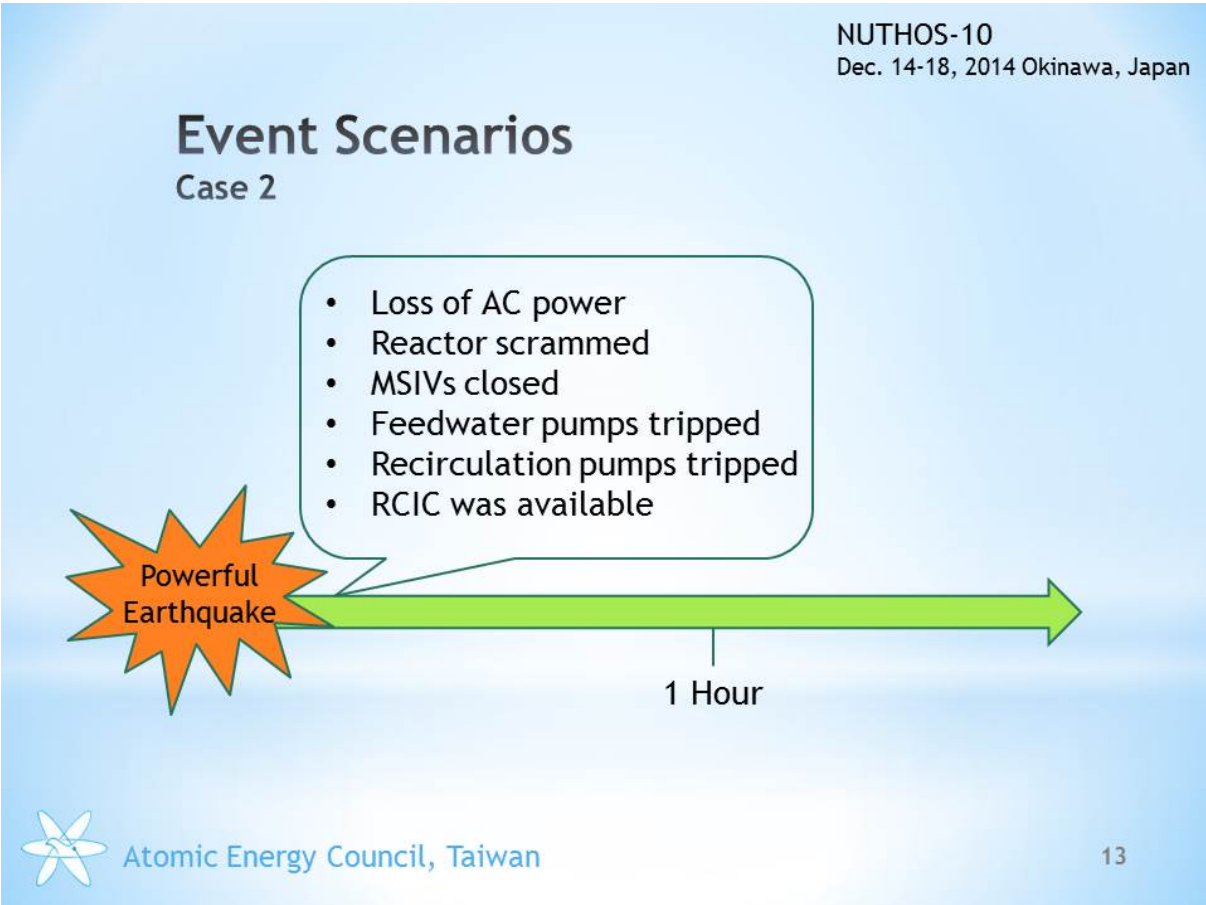
NUTHOS-10
Dec. 14-18, 2014 Okinawa, Japan
Event Scenarios
Case 2
• Loss of AC power
• Reactor scrammed
• MSIVs closed
• Feedwater pumps tripped
• Recirculation pumps tripped
• RCIC was available
Powerful Earthquake
1 Hour
Atomic Energy Council, Taiwan
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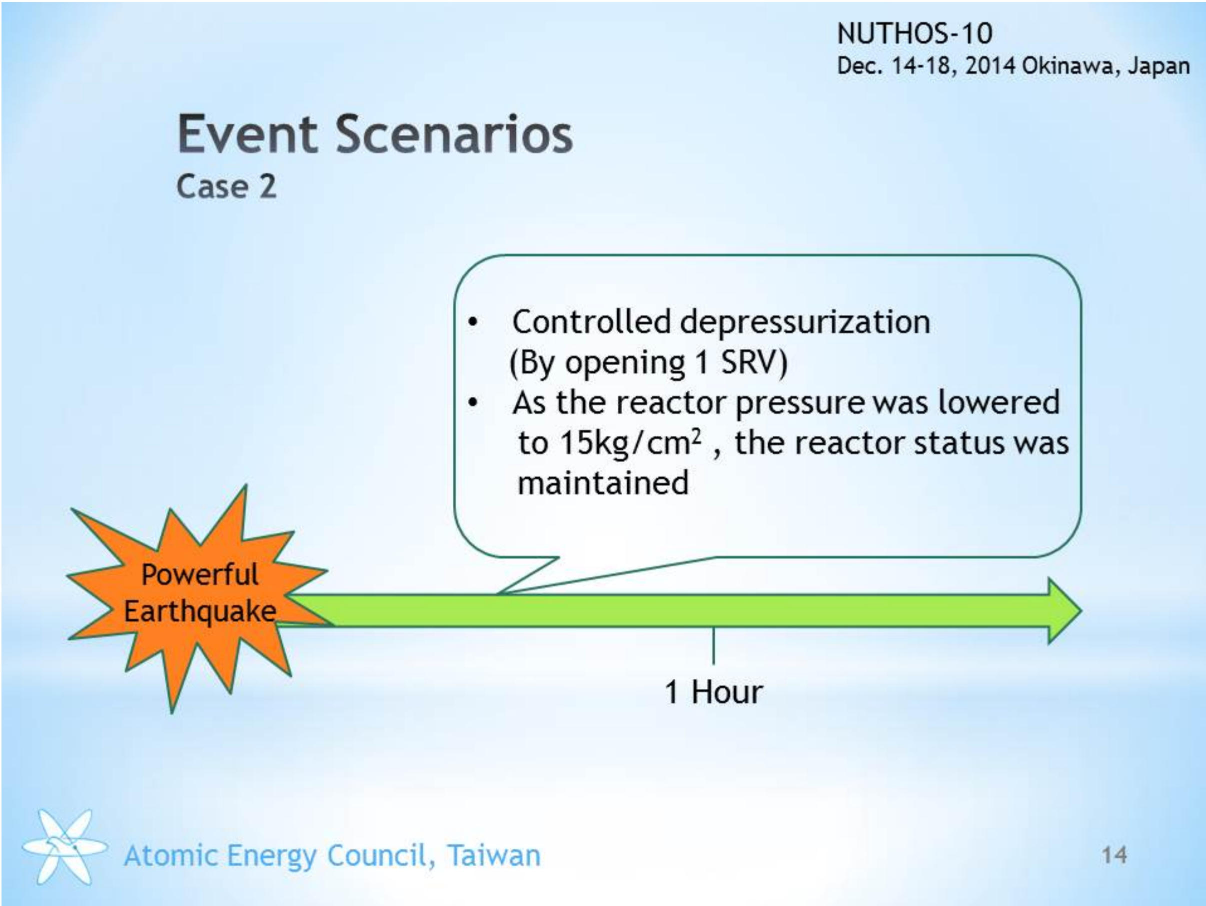
NUTHOS-10
Dec. 14-18, 2014 Okinawa, Japan
Event Scenarios
Case 2
• Controlled depressurization (By opening 1 SRV)
• As the reactor pressure was lowered to 15kg/cm2 , the reactor status was maintained
Powerful Earthquake
1 Hour
Atomic Energy Council, Taiwan
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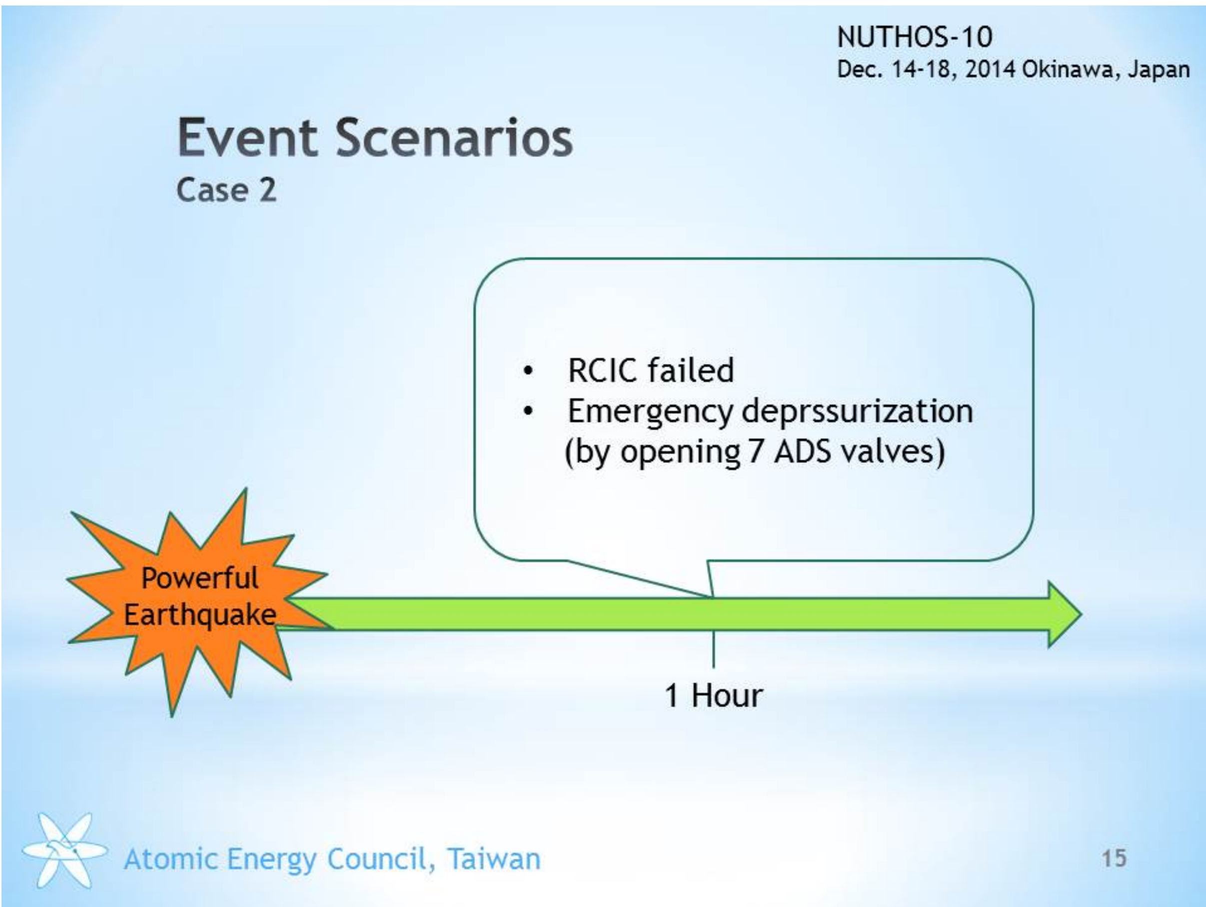
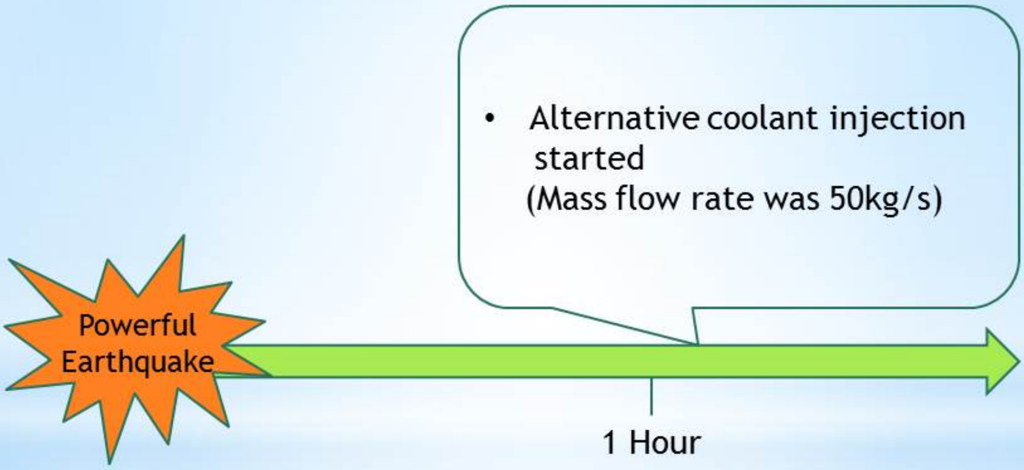

NUTHOS-10
Dec. 14-18, 2014 Okinawa, Japan
Event Scenarios
Case 2
• RCIC failed
• Emergency deprssurization (by opening 7 ADS valves)
Powerful Earthquake
1 Hour
Atomic Energy Council, Taiwan
15

Event Scenarios

Case 2

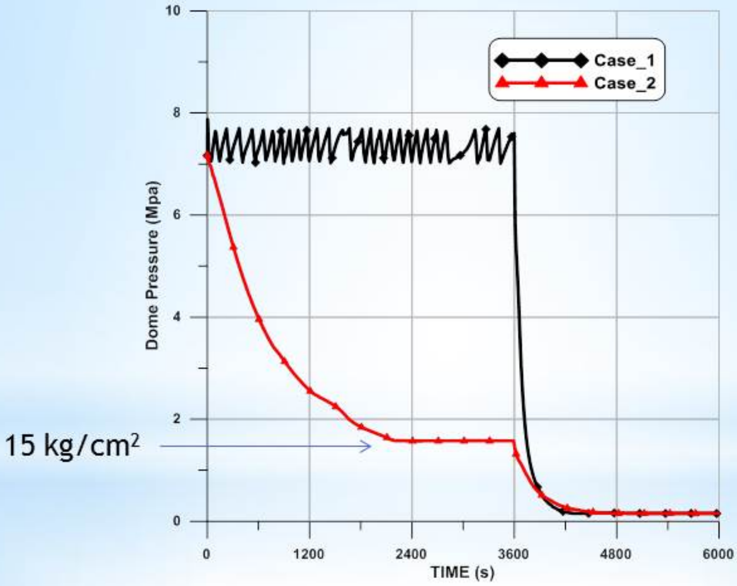


Outline

* Introduction
* Kuosheng TRACE Model
* Event Scenarios
* Results and Sensitivity Studies
* Conclusion

Results

Dome Pressure



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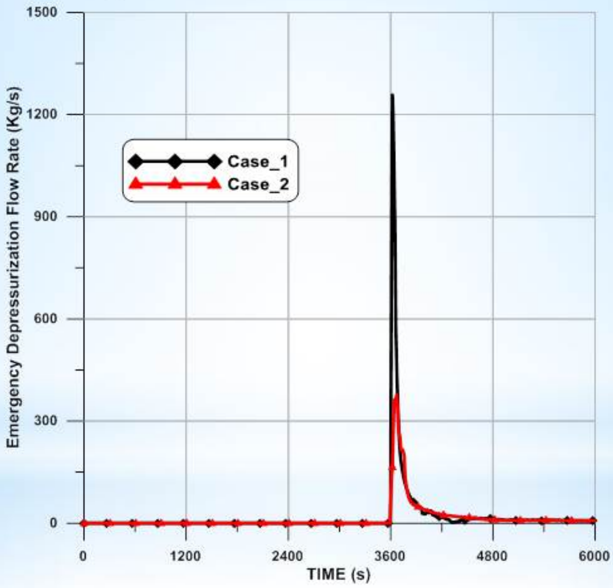
Results

Emergency Depressurization Flow Rate



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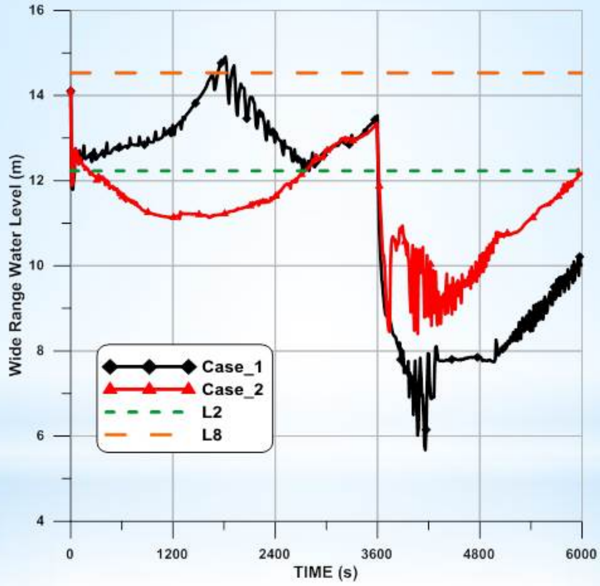
Results

Wide Range Water Level



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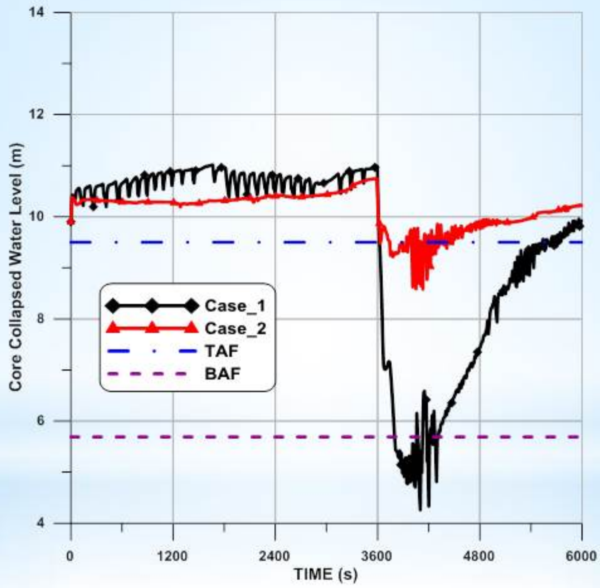
Results

Core Collapsed Water Level



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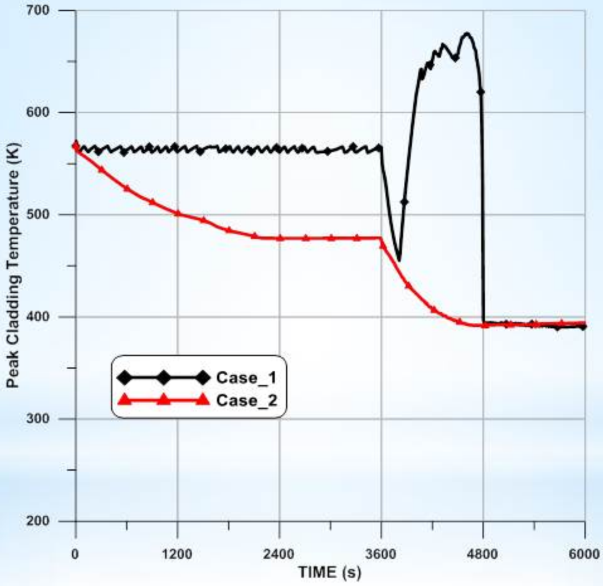
Results

Peak Cladding Temperature

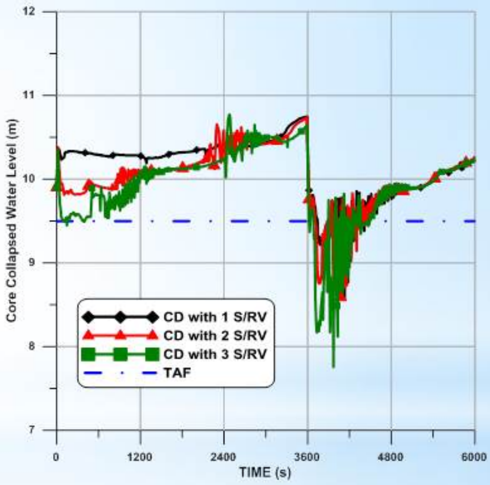


Sensitivity Studies

Number of S/RV Opened (Controlled Depressurization)

* 1 SRV was opened for the controlled depressurization in the base case

* Effectiveness of different numbers of SRV opened was investigated



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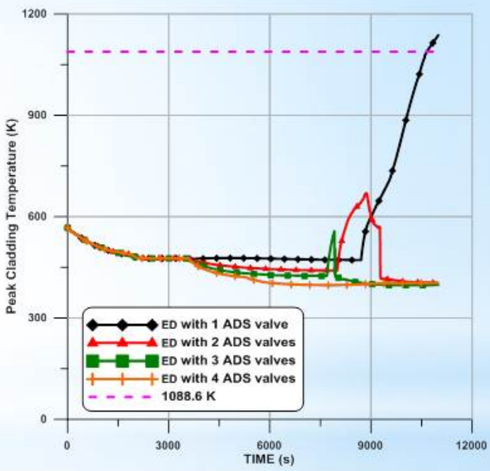
Sensitivity Studies

Number of ADS Valve Opened (Emergency Depressurization)

* 7 ADS Valves were opened for the emergency depressurization in the base case
* Effectiveness of different numbers of ADS valves opened was investigated



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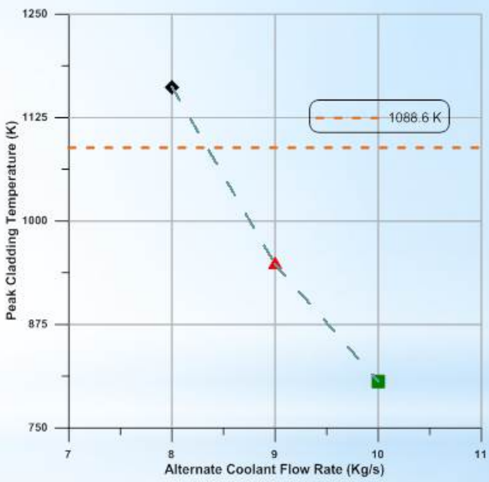
Sensitivity Studies

Minimum required mass flow rate of the alternative coolant

* With the URG activation, the minimum mass flow rate of the alternative coolant required to keep the PCT less than 1088.6K was estimated



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Conclusion

* The effectiveness of URG has been verified by the simulation of Fukushima like accidents

* If the mass flow rate of alternative makeup water is large enough, performing the emergency depressurization directly may not result in core melt

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Conclusion

* If the DIVing plan is performed in advance, reactor will be brought to a relatively safe state, the risk of the emergency depressurization is minimized and the requirement of alternative coolant is reduced

* Opening 1 SRV for the controlled depressurization and opening 7 ADS valves for the emergency depressurization are suitable strategies

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Thanks for Listening!

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（三）　黃議輝技士專題研究簡報：

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Multi-Dimensional Modeling and Simulation of Upper Plenum in URG Analysis of Lungmen Nuclear Power Plant using RELAP5-3D

NUTHOS-10

December 14-18, 2014

Okinawa Convention Center, Okinawa, Japan

Yi-Huei Huang

Atomic Energy Council. Taiwan

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Outline:

- URG Introduction
- Model Description
- Results
- Conclusion

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●URG Introduction

- The Ultimate Response Guideline (URG) proposed by the Taiwan Power Company (TPC) is the ultimate measure to prevent core damage in response to Fukushima-like accident (Prolonged Station Blackout, SBO)
- Also named as DIVing plan, abbreviated from system Depressurization, water Injection and containment Venting.
- Perform orderly depressurization at the earlier stage before the emergency depressurization and alternative coolant injection.

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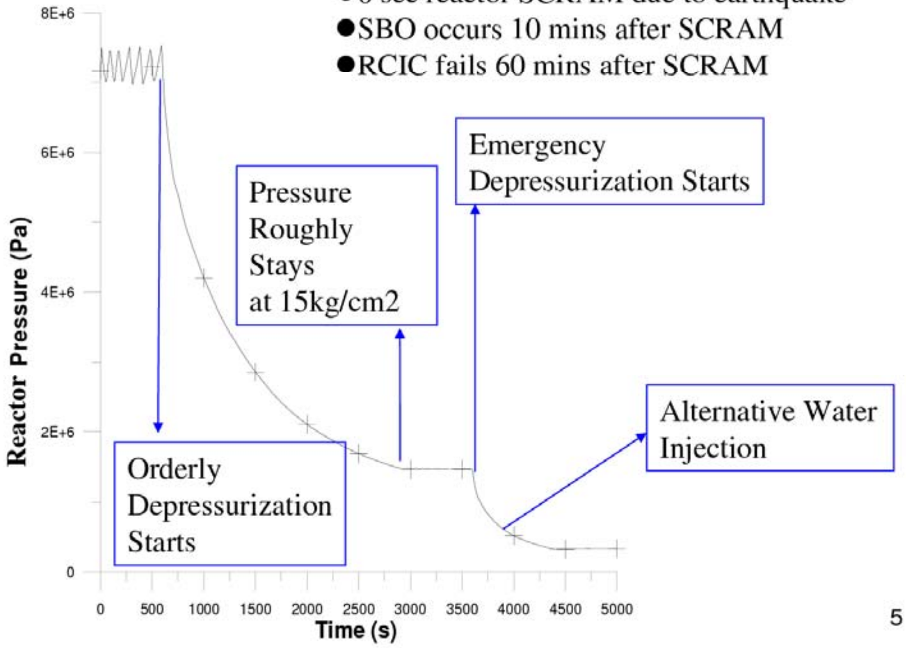
●URG Introduction

Assumptions:

- ●0 sec reactor SCRAM due to earthquake
- ●SBO occurs 10 mins after SCRAM
- ●RCIC fails 60 mins after SCRAM



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Outline:

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●Model Description

- URG is an effective countermeasure against the Fukushima like accident. And this study is the improvement research of URG by individually investigates the cooling effectiveness of alternative coolant injection via different pathways as follows,

  (a) Downcomer flooding

  (b) upper plenum spray (1D&3D simulation)

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●Model Description

- In downcomer flooding system, core cooling is achieved via single phase vapor cooling that water reaches core bottom, evaporates into steam, and flows up taking away the decay heat generated in fuel bundles.
- As to spray system core cooling, water is sprinkled into channel of the core from the top, flows down and evaporates taking away the heat.

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●Model Description

- In Lungmen Nuclear Power Station, an Advanced Boiling Water Reactor (ABWR) in Taiwan, AC-Independent Water Addition (ACIWA) system will add coolant from fire protection system to reactor pressure vessel during SBO after RCIC failure.

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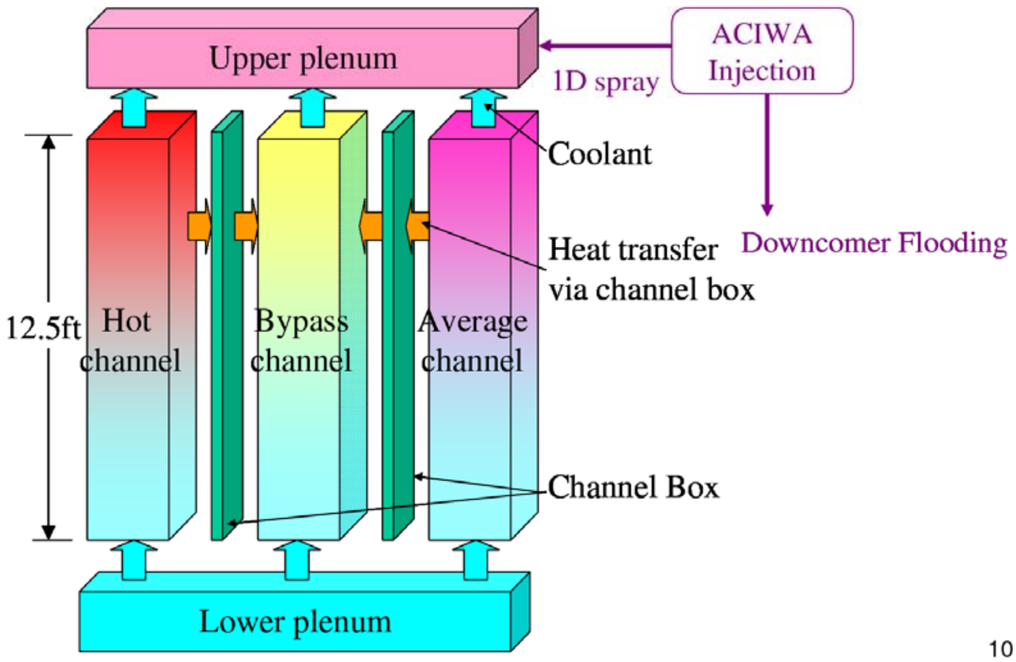
●One-Dimensional Upper Plenum Model



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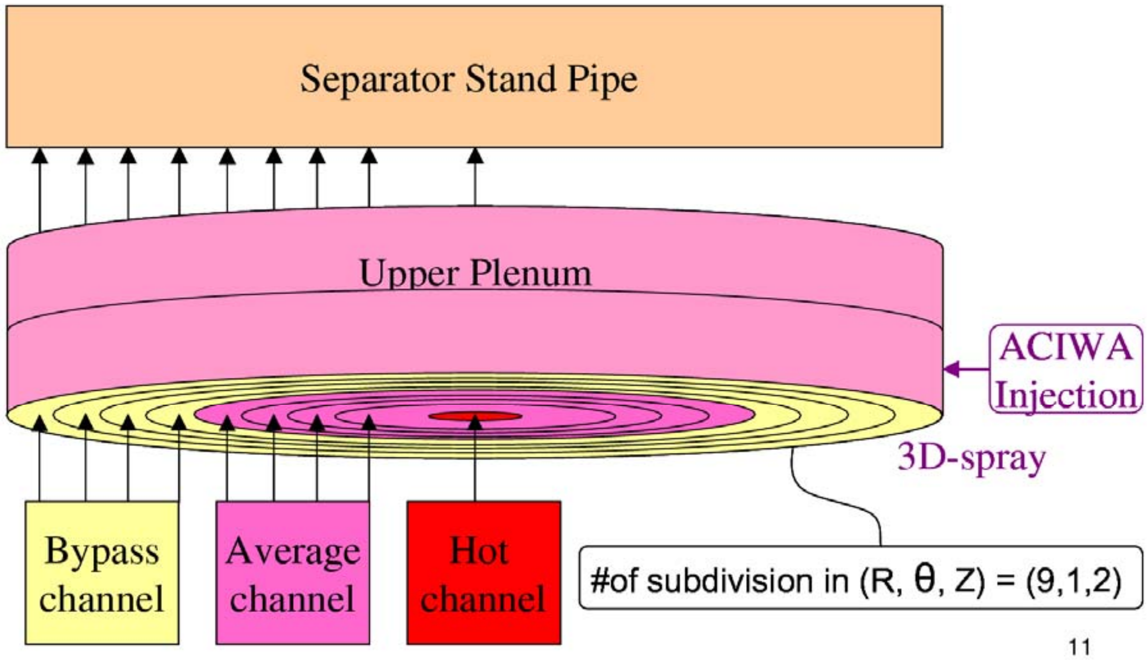
●Multi-Dimensional Upper Plenum Model



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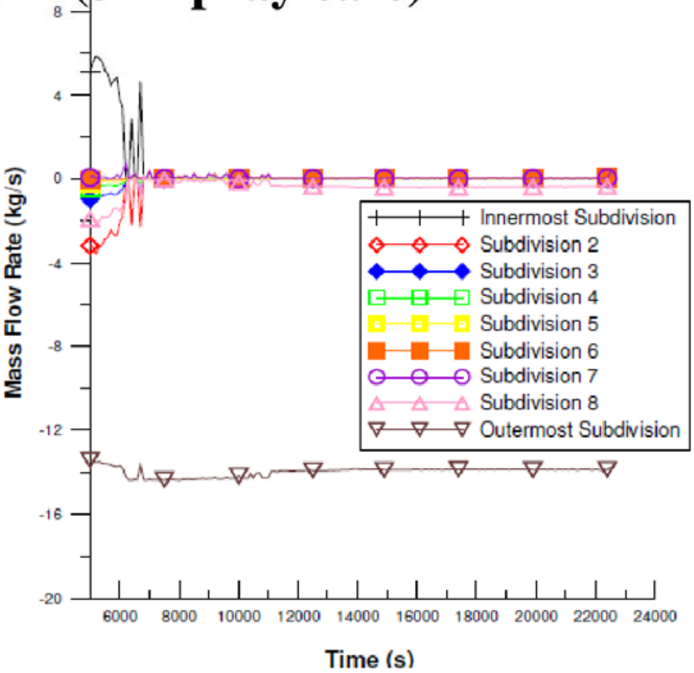
● Liquid mass flow rate from core to upper plenum (3D spray case)



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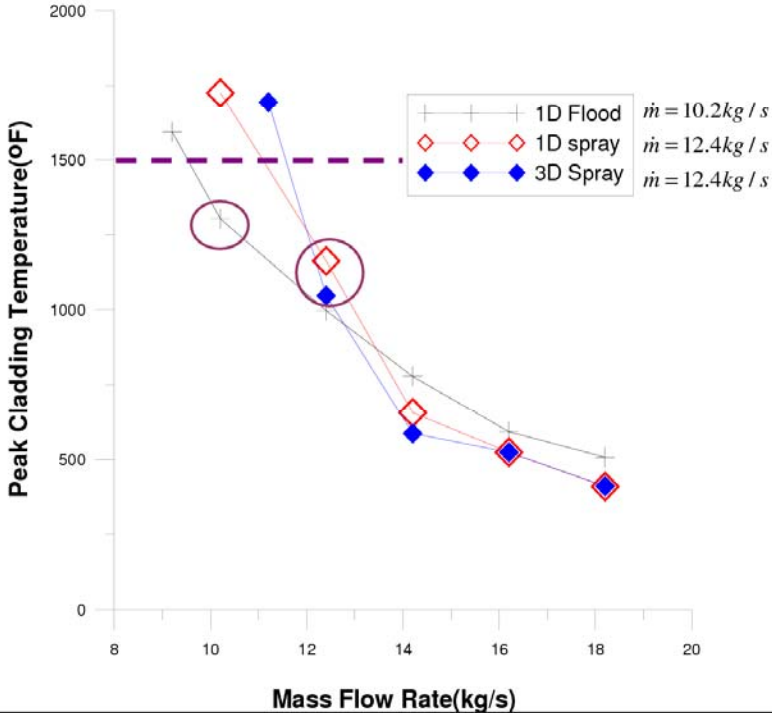
● Sensitivity Study of ACIWA Mass Flow Rate



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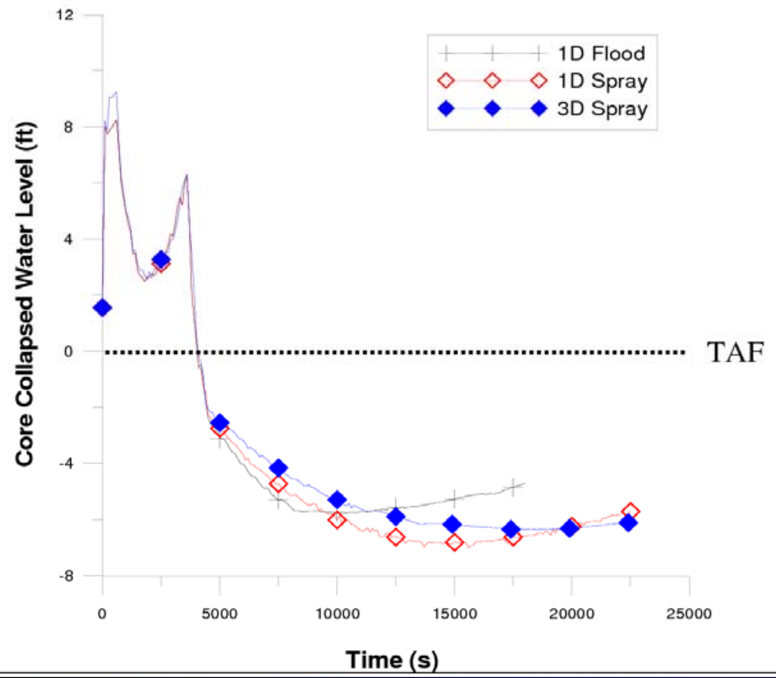
● Core Collapsed Water Level Comparison



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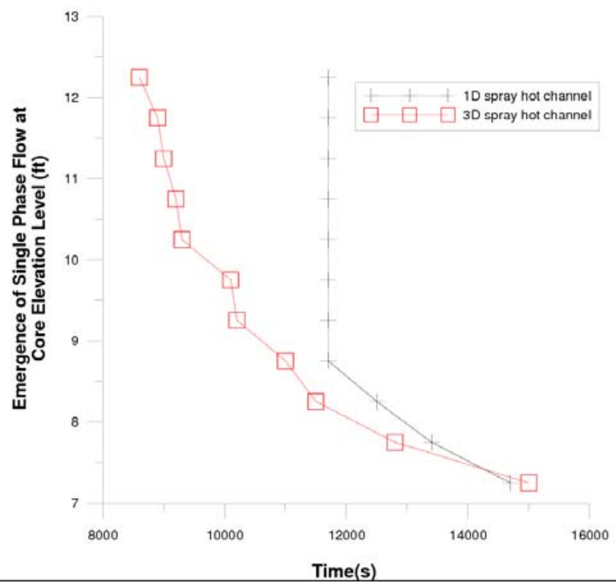
● Core Elevation Level Undergoing Flow Regime Changing from Annular Flow to Single Phase Vapor Flow for the Spray Cases.



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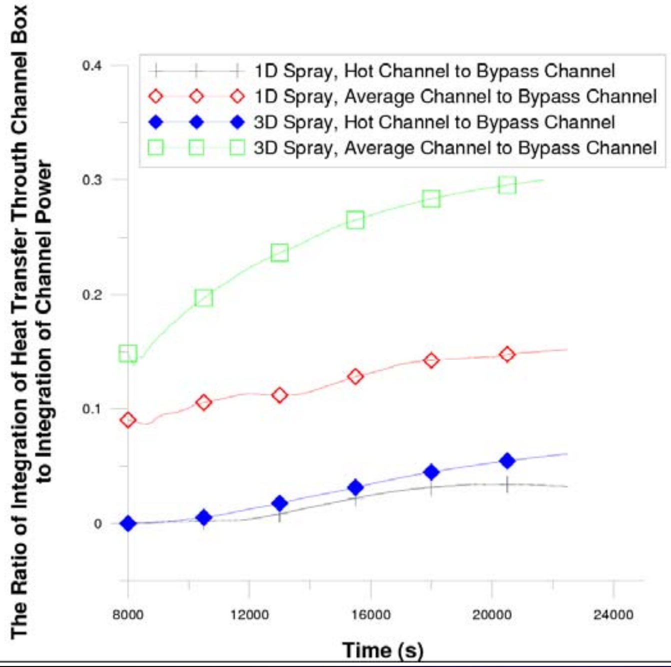
●Partial Heat Removal due to Bypass Channel Heat Transfer



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Outline:

- URG Introduction
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●Conclusion

- Spray cooling is more effective than flooding cooling, but this is not the case when mass flow rates are small.
- This is because in the spray system water evaporates at upper section of core so that less water is able to reach to core bottom comparing to the flood system. That is, when sprinkled from top, the flow rate is so small that liquid water is not able to reach the hot spot of fuel cladding.

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●Conclusion

- It shows that the employment of 3D upper plenum model does not necessarily predict more conservative PCT than 1D at different flow rates.

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Thank you for your attention

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