INER-F0584

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出國報告（出國類別：其他）

赴美國 CSA 公司參訪與出席會議

服務機關：核能研究所
姓名職稱：王政德　助理研究員
　　　　　張凱嵐　助理研發師
派赴國家：美國
出國期間：101 年 6 月 2 日~101 年 6 月 15 日
報告日期：101 年 7 月 10 日

摘　要

本次公差的主要目的是受 Computer Simulation Analysis(CSA)公司邀請參加該公司所舉辦的系統熱水流技術研討會，與 RETRAN/VIPRE 使用者會議。

CSA 公司位於美國 Idaho 州 Idaho Falls 市，為一家核能工程領域的電腦模擬分析公司亦是 RETRAN-3D 程式的維護廠商，RETRAN-3D 程式用來進行核電廠系統熱水流的安全分析，INER 為該程式的使用者之一，且每年皆與該公司簽訂 RETRAN 程式維護合約。

本次參加系統熱水流技術研討會可讓我們更深入了解 RETRAN 程式的功能，以及 RETRAN-02 與 RETRAN-3D 程式在應用上的差異，討論並釐清我們在 RETRAN 程式使用上碰到的問題，有助於我們在安全分析上的應用。

RETRAN/VIPRE 使用者會議為例行會議，主要是 CSA 公司介紹 RETRAN 與 VIPRE 程式在過去一年的發展狀況，未來要進行改版的方向與新功能，各與會的 RETRAN/VIPRE 使用者成員也會報告目前 RETRAN/VIPRE 程式的應用現況。參加本會議可讓我們了解 RETRAN/VIPRE 程式的發展現狀與新功能，並可和其他使用者進行交流，可作為日後合作的契機。

目　　次

一、目　的

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二、過　程

此次公差自 101 年 6 月 2 日起至 101 年 6 月 15 日止，共計 14 天，詳細行程如下：

行程					公差地點		工作內容
月	日	星期	地點 出發	地點 抵達	國名	地名	
6	2	六	台北	舊金山	美國	舊金山	去程
6	3	日	舊金山	愛達荷福爾斯	美國	愛達荷福爾斯	路程
6	4~8	一~五			美國	愛達荷福爾斯	參加系統熱水流技術研討會
6	9~10	六~日			美國	愛達荷福爾斯	資料研讀
6	11	一	愛達荷福爾斯	Jackson Hole	美國	Jackson Hole	路程以及和 CSA 討論未來合作計畫
6	12	二			美國	Jackson Hole	參加 RETRAN/VIPRE 使用者會議
6	13	三	Jackson Hole	愛達荷福爾斯	美國	愛達荷福爾斯	參加 RETRAN/VIPRE 使用者會議與回程
6	13~15	三~五	愛達荷福爾斯	台北			回程

(一) 參加系統熱水流技術研討會

6 月 4~8 日在 Idaho Falls 參加系統熱水流技術研討會，由 CSA 的工程師介紹 RETRAN 程式的功能與使用方式，和與會者進行 RETRAN 程式在應用上的討論，並分組進行實機操作演練。本次研討會 CSA 公司提供每個與會者「Basic RETRAN Training」紙本講稿一份，但受限於智慧財產權保護，該文件只能使用於本研討會，無法列為本報告附件或以其他方式公開文件內容。

本研討會 CSA 的講師簡介如下：

Garry C. Gose

1. involved in the overall development and maintenance of the RETRAN computer code since 1977;
2. principal investigator for the implementation of the three-dimensional kinetics model in RETRAN-3D;
3. principal investigator for the implementation of the one-dimensional space dependent kinetics model and associated thermal-hydraulic feedback formulation;
4. helped develop and implement the dynamic slip model and point reactor kinetics models for RETRAN;
5. participated in numerous RETRAN training sessions;
6. co-author of SIMTRAN/SIGTRAN data interface;
7. project manager for the RETRAN-02 code maintenance project.

Mark P. Paulsen

1. involved in the overall development and maintenance of the RETRAN computer code since 1976;
2. participated in numerous RETRAN training sessions;
3. involved in the development of the semi-implicit numerical solution method for the RETRAN-3D transient and steady-state equation sets;
4. participated in the development and implementation of the two-phase unequal phase velocity, unequal phase temperature models of RETRAN-3D;
5. contributed to the development of the steady-state initialization, nonequilibrium pressurizer, steam-water separator, accumulator, control system, enthalpy transport, and transport delay time models used by RETRAN.

Craig E. Peterson

1. involved in the overall development and maintenance of the RETRAN computer code since 1976;

2. participated in the development of the steady-state initialization package and the kinetics models, many of the two-phase flow constitutive models, and component and special purpose models;
3. involved in verification and validation of many of the RETRAN models through analysis of system effects and separate effects experiments;
4. project manager and principal investigator for several PWR and BWR analyses supporting the Nuclear Safety Analysis Center;
5. worked with numerous utility engineers providing on-call support with RETRAN modeling problems, interpretation of results, and model reviews;
6. participated in a number of RETRAN training sessions.

John G. Shatford

1. participated in the development of the RETRAN-3D multidimensional kinetics model;
2. performed code development, maintenance, and validation for the RETRAN computer code series;
3. performed RETRAN-02 analysis of the Advanced Test Reactor;
4. performed containment studies using the MELCOR computer code.

John L. Westacott

1. developed and revised various RETRAN input models of BWR and PWR plants;
2. performed RETRAN analysis of various transient scenarios under utility and Nuclear Safety Analysis Center sponsorship;
3. participated in maintenance of the RETRAN code;
4. acted as principal investigator in the development of PC-based workstation environments for the mainframe codes RETRAN and ATHENA;
5. participated in the development of a steady-state flow analysis program for the EPRI CHECMATE two-phase Erosion-Corrosion Analysis Package;
6. lead engineer in development and maintenance of the thermal-hydraulics models in CORETRAN.

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研討會詳細過程如下：

6 月 4 日為研討會第一天，由 CSA 公司的工程師進行開場並邀請各個與會者自我介紹，隨後即開使進行第一天研討會的主題，首先介紹 RETRAN 的程式開發歷史與目前的最新版本，接著以 RETRAN 最新版本即 RETRAN-3D MOD4.6f95 為範例，上午講解 RETRAN 中的能量平衡計算方法，包括：Three-Equation、Four-Equation、Five-Equation 與 Noncondensable Gas，並比較其與 RETRAN-02 版本的差異處，下午說明 RETRAN 程式的基本輸入卡，包括體積卡與接節卡的設定細節並舉例教導如何建立一個簡單的基本模組，接著與會者被分為四組，並按照 CSA 工程師所指定的案例分別進行上機實際模擬，熟悉先前講述的內容。

本日的實機模擬是為了讓使用者熟悉 RETRAN 體積卡與接節卡的輸入，要建立圖 1 流體導管的 RETRAN 輸入卡。本模式要模擬一根有 36 根電熱棒棒的導管，要將導管等分為 10

等分，所以要建立 10 張體積卡與 10 張接節卡，本日的練習電熱棒不加熱，只需考慮流體的幾何。邊界條件由體積 999 與接節 1 來定義，接節 1 是 fill junction 用以提供穩定的流體；體積 999 是 time-dependent volume 有固定的壓力，用以提供管路的壓力降。本練習要建立的 RETRAN 模式如圖 2。

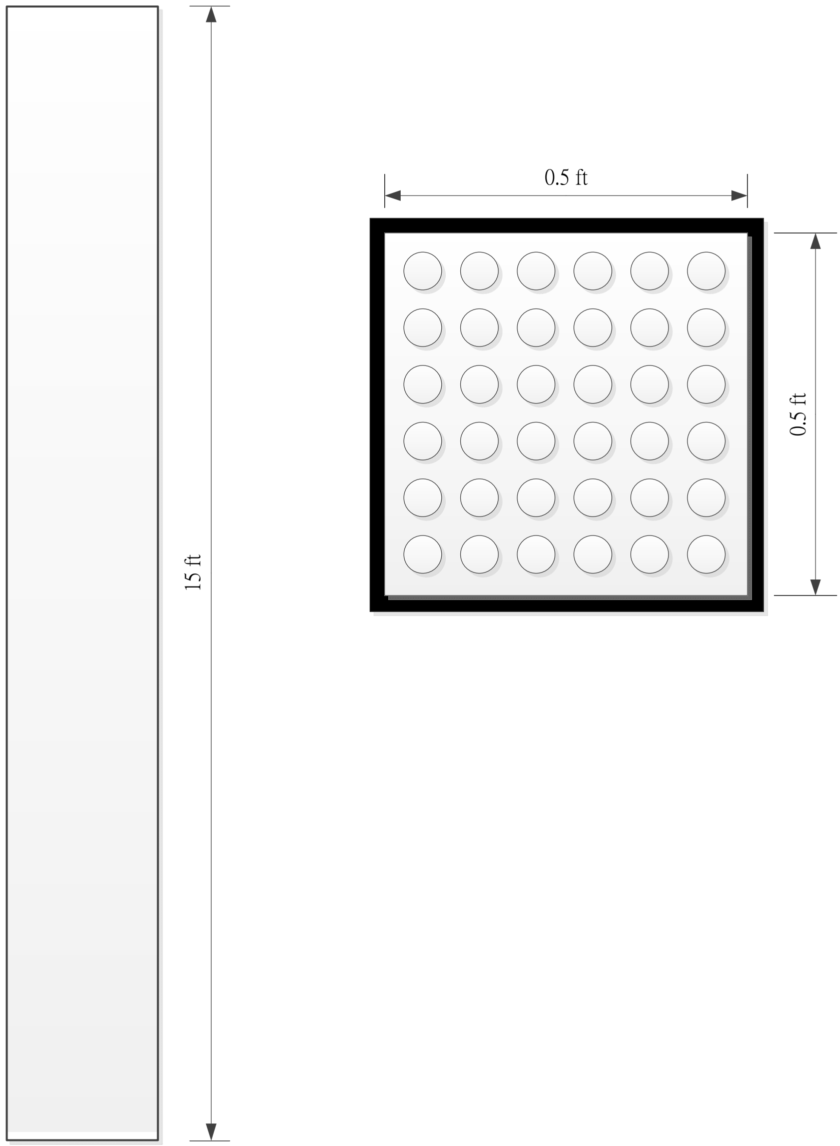

圖 1 流體管路

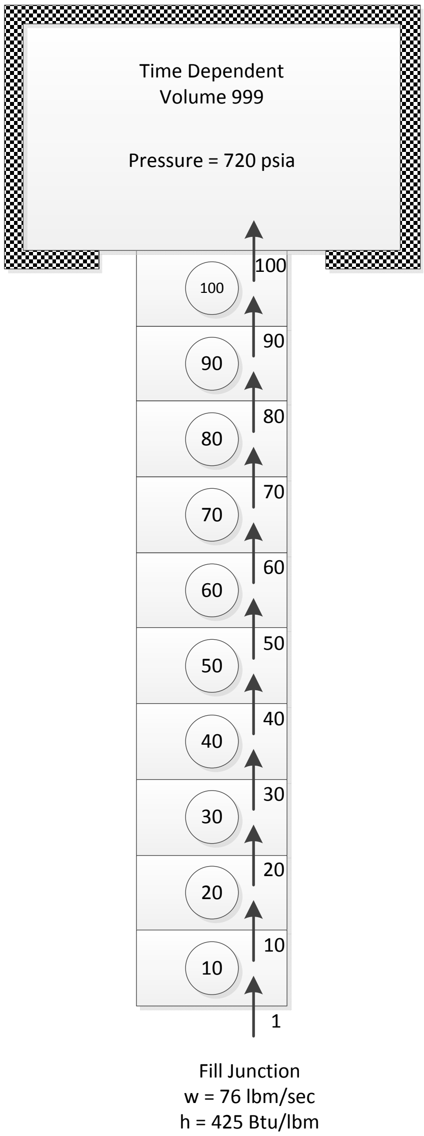

圖 2 練習 1 所要建立的 RETRAN 模式

6 月 5 日上午先講解前一日的實機模擬與問題討論，接著講解體積卡與接節卡詳細的計算原理，包括：能量守恆與動量守恆，並介紹 Constitutive Models，包括：Bubble Rise Model、Enthalpy Transport Model、Two-Phase Friction Model 與 Heat Transfer Model；接著說明 Volume Energy Sources，包括：Conduction 與 Convection，並說明如何使用 heat conductor input data、core section data、conductor geometry data、thermal conductivity、volumetric heat capacity 與 linear expansion coefficient 等相關熱計算資料設定。下午則進行跳脫卡設定、time-step 設定與邊界條件的設定說明（包括：Fills、Time-Dependent Volumes 與 Critical Flow）。隨後分組進行上機，實際模擬如何使用 RETRAN-3D 計算模組中的熱交換。

本日的實機模擬是為了讓使用者熟悉熱導體、導體幾何與爐心卡的建立，延續前一天的

問題，36 根電熱棒都會產熱必須建立熱導體，同體積卡都是在垂直方向均分為 10 等分如圖 3。電熱棒的組成如圖 4，鋼材的套管包覆著銅芯，要注意銅芯才會發熱鋼材不會發熱。本次練習要建立的卡有：熱導體卡（15 卡）、導體幾何卡（17 卡）與爐心卡（16 卡），以及兩個熱導體材料（鋼與銅）的熱傳導資料卡（17 卡）與體熱容量資料卡（18 卡），本次練習也需加入穩態計算的選項。本練習是建立核電廠爐心參數卡的極佳範例，簡單又面面俱到。

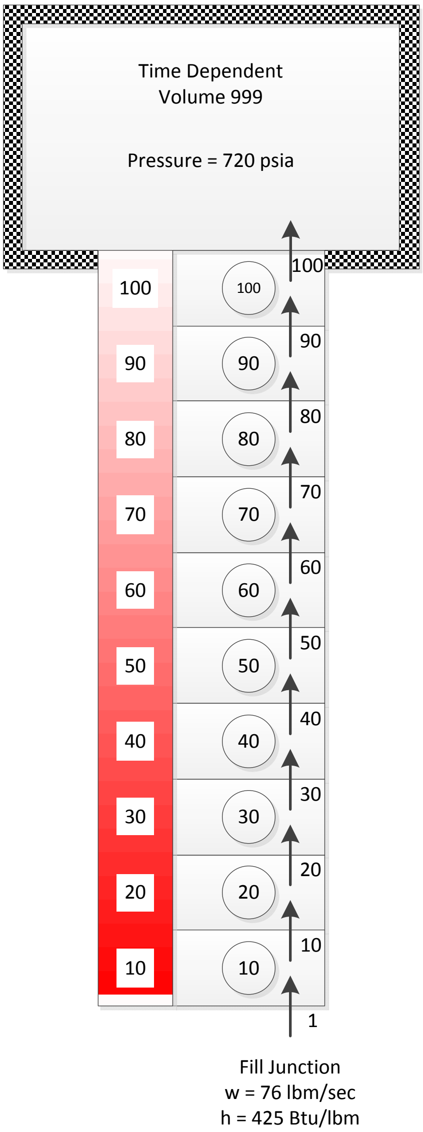

圖 3 練習 2 所要建立的 RETRAN 模式

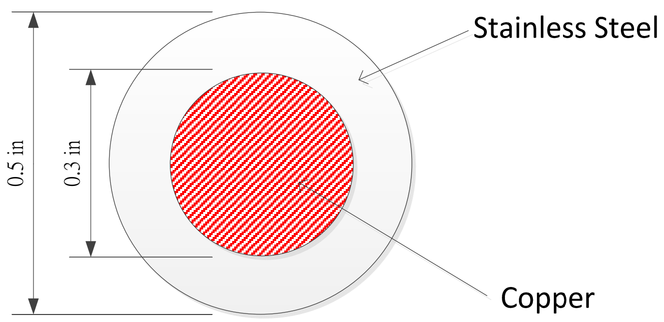

圖 4 電熱棒

6 月 6 日一開始同樣先講解前一日的實機模擬與問題討論，接著進行的研討主題為模組穩態計算，CSA 工程師講解了動量守恆方程式與能量守恆方程式中各項因子所代表的意義與設定方式，並分別配合 BWR 及 PWR 模組說明調整系統至穩態的過程中該注意的地方，隨後比較 RETRAN-02 與 RETRAN-3D 的差異，RETRAN-3D 可以利用 231 卡與 232 可設定體積與接節的初始資料，且 RETRAN-3D 提供了新功能，透過 01000X 卡的 JSST 設定可幫助使用者找出穩態無法收斂時的問題。接著討論一些針對特別目的的用法或模組，如：泵與閥等說明。隨後至 CSA 公司電腦室進行第三個例題的上機模擬。

本日的實機模擬是為了讓使用者熟悉 RETRAN 的穩態初始化程序，圖 5 是一個 BWR 電廠具有一個再循環迴路的 RETRAN 模式，使用者要輸入某些體積或接節的壓力、熱焓或流量使系統達到穩態。也可以使用 RETRAN-3D 才有的卡片—體積與接節初始條件資料卡（231 卡與 232 卡），另外還需使用功率移除卡（230 卡）來達到能量守恆的計算。圖 6 則是一個簡單的 PWR 電廠 RETRAN 模式，使用者可以藉由這兩個練習模式來熟悉 PWR 與 BWR 電廠在初始化程序上的異同。

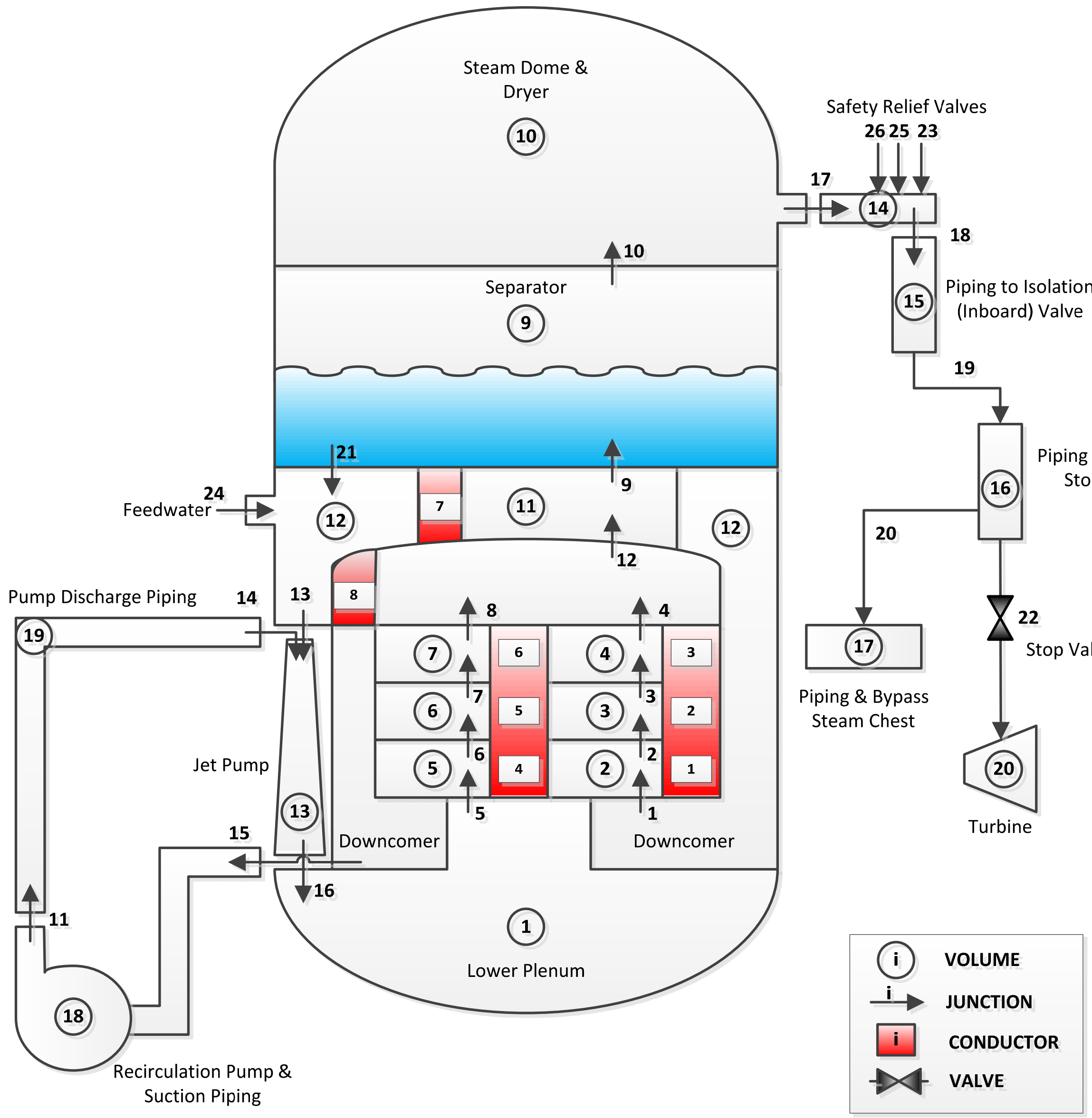

圖 5 簡單的 BWR RETRAN 模式

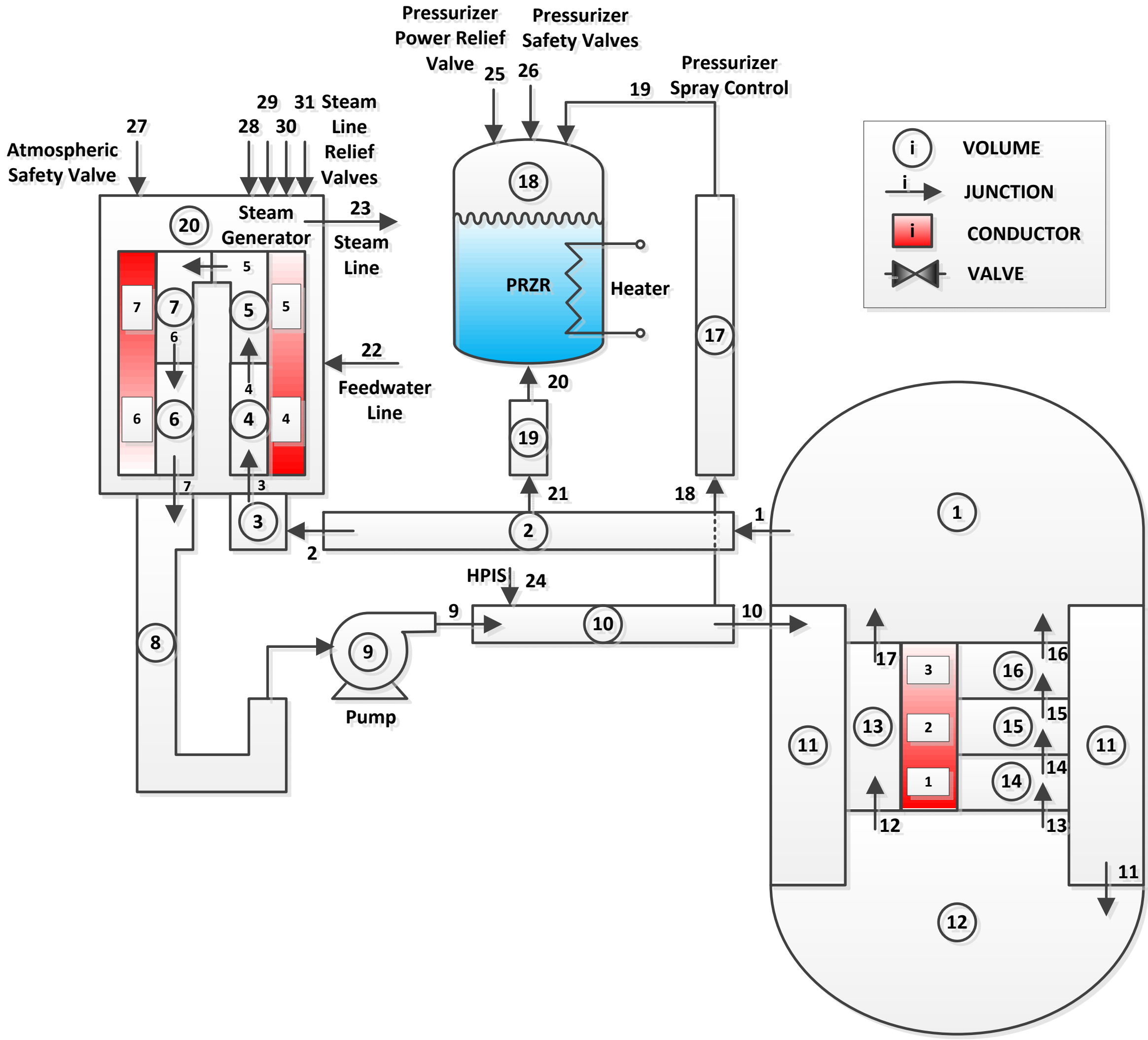

圖 6 簡單的 PWR RETRAN 模式

6 月 7 日一開始也是先講解前一日的實機模擬與問題討論，接著進入控制系統的研討，由 CSA 工程師講解如何設定控制系統相關的卡片，並以圖示說明在控制系統中的一些功能，如：LAG、DLY、LLG 與 INT 等等，並講解 PI 與 PID 控制。接著說明 RETRAN-3D 如何計算爐心功率，分別以點中子動態、一維中子動態與三維中子動態方程式切入說明。下午進行 slip modeling 的詳細講解，包括 Dynamic Model 與 Algebraic Model。而後前往 CSA 公司電腦室進行上機，按照範例的要求建立控制系統。

本日的實機模擬是為了讓使用者熟悉 RETRAN 控制系統的建立，圖 7 是一個簡單的熱流系統，包括 1 個體積與 2 個接節，該體積內包含了蒸氣與水，所以水位計算是採用混合水位，該體積有 10 ft 高、容量 1000 ft^3，2 個接節的流量由控制系統來控制。

本次練習可分為三部分，第一部分是建立控制邏輯來控控制接節 1 的流量，使體積內的

水位由初始水位 2 ft 到達 4 ft 並維持在 4 ft，並在 10 秒後停止注水。本練習可用水位差來控制住入水的流量，如一開始水位差為 2 ft 可控制注水量為 2000 lbm/sec，當水位達到 4 ft 時水位差為 0 ft，則控制注水量為 0 lbm/sec。使用者可以試著用 P、PI 或 PID 控制器來建立水位控制系統，以比較各個控制器的差異。

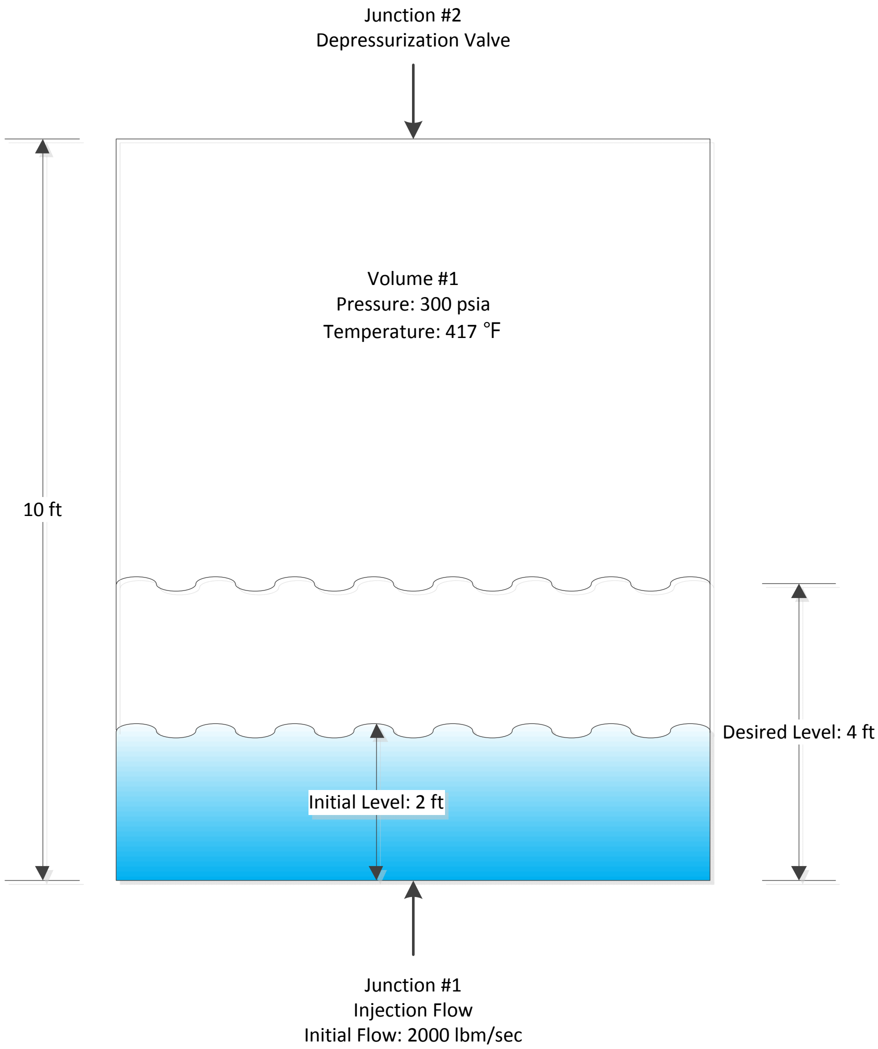

圖 7 練習 4 所要建立的模式

第二部分是接續第一部分在 10 秒時開啟洩壓閥，洩壓閥是由接節 2 來模擬，該接節為 negative fill junction。該洩壓閥是依 Volume 1 壓力作線性開啟，當壓力低於 100 psia 時全關，壓力高於 300 psia 則全開，100~300 psia 則洩壓閥的開啟面積是依壓力線性變化，全開流量為 400 lbm/sec。全部模擬時間為 20 sec。

第三部分則是要建立控制系統來記錄 Volume 1 的水位，這可讓使用者學習如何擷取所需要的數據，作圖並觀察水位的變化。使用者應建立繪製控制系統邏輯圖的習慣，在建立

RETRAN 控制系統卡時會比較容易，也比較不會出錯，而使用的控制系統卡片愈少效率愈好。

6 月 8 日一開始先講解前一日的實機模擬與問題討論，接下來的研討會內容以整個 RETRAN-3D 的變更內容為主軸，將前面幾天的討論內容全部整併進來講解，幫助參與者更熟悉 RETRAN-3D 的使用與設定，從如何建立電廠模組，到設定體積與接節，設定爐心的中子計算方法以及控制系統的模擬等等，並以 PWR 電廠模組當範例講解。最後，CSA 公司介紹了他們新開發的工具 RETRAN visualization tool，並放介紹影片當作結尾。

(二) 參加 RETRAN/VIPRE 使用者會議

6 月 12~13 日赴 Jackson Hole 參加 RETRAN/VIPRE 使用者會議，本會議為例行年會，每年舉辦一至二次，先由 CSA 介紹 RETRAN 與 VIPRE 程式目前的開發現況與本年度欲解決的問題及欲開發的新功能，接著再由與會者針對特殊主題的應用做簡報，最後並請各使用成員概略介紹在 RETRAN 與 VIPRE 程式的應用。會議中的所有簡報內容，CSA 於會議後彙整為「2012 RETRAN VIPRE User Group Meeting Summary Report」，詳細內容列於附錄。

本次會議除 INER 外其他與會人員及聯絡方式如下：

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RETRAN/VIPRE 詳細過程如下：

6 月 12 日會議第一天，早上 9 點到達會場後即與各方來參加的人員互相交流經驗，包括：美國 South Texas Project Electric Generating Station 的熱流管理者 CHARLES R. ALBURY、西班牙 IBERDROLA 的燃料設計工程師 Ignacio Collazo Nieto、日本 CSA 公司主席藪下幸久以及南韓 ICEPCO NUCLEAR FUEL 的研發師 Jin-Woo Park 等。其中尤以 IBERDROLA 的工程

師有較多的交流，由於先前所內曾與此公司合作過，且此公司所使用的申照方法亦與所內所用相似，在經過交流後得知，目前他們把重心放在三維的模組建立，並預計能將之使用在申照分析。第一天會議內容上午主要為 CSA 工程師介紹 RETRAN/VIPRE 的使用者們以及程式的發展歷史與未來規劃，而下午則由與會人員針對一些技術議題作簡報，如：Duke Energy 的 Jeff Abbott 簡報"Duke Energy Oconee SSF Analyses"，CSA 的 John Shatford 簡報"VIPRE-01 SI Units Review"，南韓 KEPCO NF 的 Jin-Woo Park 簡報"Validation of iSAM Analysis Methodology Using the Plant Startup Test"，Duke Energy 的 Adam Bingham 簡報"Steam Generator U-Tube Bundle Uncovery for Dose Calculations"，CSA 的 John Westacott 簡報"VIPRE-01 PSBT Benchmark"，CSA 的 Mark Paulsen 簡報"VIPRE-3D- A 3-D Kinetics Core Code"等。

6 月 13 日為會議第二天，本日為各使用者針對自己使用的心得或使用方法與成果作簡報，分別有 STPNOC 的 Charles Albury 簡報"Fukushima Analysis"，STPNOC 的 Charles Albury 簡報"RETRAN Analysis in Support of PRA"，STPNOC 的 Steve Smiley 簡報"RETRAN Visual Interface"，CSAJ 的 Yuki Yabushita 簡報"Station Blackout Analysis with RETRAN-3D"，本所代表則簡報 TITRAM 方法論之成果。

三、心　得

本次公差在 RETRAN 使用說明研討會過程中，學習到從基本的體積與接節卡設定到其原理、如何只憑紙本資料從無到有建立一個模組、如何透過調整控制系統的一些參數取得適合的方法模擬分析...等等，這些都是透過此次研討會始獲得的寶貴經驗。所獲得的紙本資料可作為未來規畫所內 RETRAN 訓練課程的參考，而實機演練範例更可作為用來訓練新進人員的參考。

而在 RETRAN/VIPRE 使用者會議舉行的過程中，了解到其他國家的核能技術與成果，與 RETRAN/VIPRE 程式的應用。本分組在核一、二、三廠的系統熱水流安全分析都是使用 RETRAN 程式，核一、二廠爐心熱水流安全分析也是採用 RETRAN 程式，而核三廠爐心熱水流安全分析則是採用 VIPRE 程式，本次 RETRAN/VIPRE 使用者會議可吸收到國外使用 RETRAN/VIPRE 程式進行安全分析的經驗，也可作為本分組分析模式的參考，有助於精進本分組的安全分析模式。

實際上，透過此兩個會議與其他參與者的互動與交流亦增廣了許多見識，透過與韓國工程師交流了解到其政府在日本福島事件後對核能產業的雖有影響但仍無撼動其大力發展核工產業的決心，最明顯的例子即是 RETRAN 使用說明研討會中有一名韓國 ICEPCO 工程師是一年前從三星公司被重金挖角過去的，其專長為設計引擎，光由此例就能了解南韓對核工產業的重視；此研討會中年紀最小的為 22 歲的 Steven Smiley，研討會首日即可看到他穿梭在會場中四處與人交流經驗的身影，從他身上可以看到積極的求知慾望，藉以警惕自己。在此兩個會議中最常被提及交流的問題莫過於各國國內的 PWR 與 BWR 數目以及未來有無新建電廠計畫，國內正在建造的龍門 ABWR 核能電廠亦有人提起並詢問商轉時程，讓我們了解到國際上有許多人其實一直在關注著全球的核能發展，最常被提及的即是中國沿海正在興建以及預計興建的眾多電廠們，從與眾人的會談中都可瞭解到他們很重視這塊市場。

這次國外公差讓人了解到福島事件後，依舊是有許多人努力在發展核工產業，他們將此視為一個轉機而不是危機，在部分國家陸續停止使用核能的情況下他們認為總有一天會發生能源不足供應的情形，到時候就是核能再次受到重視的時刻，因此他們仍積極地發展自己的

核能產業以在那個時刻到來時，仍馬上提供需求並在市場上佔到一席之地，此目標或許對台灣而言尚有一段距離，但其面對福島事件的心態值得我們借鏡。

四、建 議 事 項

經過本次 RETRAN 使用說明研討會後，深覺本分組訓練新人的方式仍停留在師傅教受徒弟的方式，尚未建立一套制式化的新進人員訓練方式，實在不妥。且本分組已將 RETRAN 列為本分組的關鍵技術，亦設有關鍵技術負責人，也參與了本次國外公差，應吸取本次研討會的經驗，逐步建立起 RETRAN 技術的訓練模式。

參加本次 RETRAN 使用說明研討會有助於釐清一些 RETRAN 使用上的問題，且研討會中一些應用分析的介紹對本分組未來分析的工作非常有幫助，也透過本次研討會取得相關的參考文件。本次研討會是 RETRAN 程式基礎使用說明，CSA 也有規劃 RETRAN 進階使用說明研討會，建議本分組也應派人參與，未來若 CSA 還有舉辦類似的研討會，也建議本分組積極派人參與，以增進 RETRAN 程式的應用能力，不再只是會修改 input deck 而已。

在參加 RETRAN/VIPRE 使用者會議時，與會者有西班牙 IBERDROLA 公司的人，該公司的分析方法與本分組的方法非常類似，且之前也有合作過。與之交流後得知該公司已發展了 3D kinetic 的方法論且已在申照中，本分組多年前也有朝此一方向發展，但在建立 RETRAN 程式所需的三維中子動態數據檔時出現了困難，當時一直無法解決，故放棄了 3D kinetic 方法論的發展，本次得知該公司開發了一個程式「SIMTAB」，可成功的將 CASMO/SIMULATE 程式的 output 轉成 RETRAN 程式所需的三維中子動態數據檔，本分組若要重新發展 3D kinetic 的方法論可與西班牙 IBERDROLA 公司洽談合作事宜。

本次國外公差充分了解到 CSA 公司對持續提升 RETRAN 程式功能投注相當大的心力，建議持續參加 RETRAN 使用者會議及持續維護與推動合作計畫，提高本所研發與創新能力，對所裡的研發績效會有一定的幫助。且與國外相同領域的人進行交流，可擴大我們的視野，增進我們的研發靈感，建議可多派員參加類似的研討會與使用者會議。

目前 RETRAN 程式的最新版本為 RETRAN-02 MOD5.3 與 RETRAN-3D MOD4.6f95，雖然 RETRAN-3D 為 RETRAN-02 的進化版本，但全球仍有相當多的使用者仍在使用 RETRAN-02，本分組在核一、二廠的安全分析即是使用 RETRAN-3D，而核三廠安全分析則是使用 RETRAN-02，這兩個程式都已取得 SER（RETRAN-02 於 1984 年取得 SER，RETRAN-3D

於 2001 取得 SER），這兩個 RETRAN 版本皆可用於認證分析。但使用 RETRAN-02 進行的分析並不是可以無條件的升級到 RETRAN-3D 版本，RETRAN-3D 的 SER 是建立在 RETRAN-02 SER 的基礎上，RETRAN-02 共有 12 個項目可完全適用於 RETRAN-3D 上，有 18 個項目不再使用於 RETRAN-3D，且有 9 個項目 RETRAN-3D 有改良而重審，這 9 個項目涵蓋在以下改良模組中：

1. Fully Implicit Steady-State Solution
2. Low Power Steam Generator Initialization
3. Implicit Pressurizer Solution
4. Colebrook Wall Friction Model – Wall Roughness
5. Control System Solution than the Single Pass Marching Scheme
6. Enthalpy Transport Model Solution
7. Improved Dynamic Slip Formulation Adding Form Losses
8. Improved Countercurrent Flow Junction Properties
9. Implicit Solution of the Heat Conduction Equation
10. Combined Heat Transfer Map (Correlations and Smoothing)
11. Wall Friction and Hydrostatic Head Losses Included in Critical Flow Pressure

而在 RETRAN-3D 有開發一些新模式，在 RETRAN-02 是無法使用的，這些 RETRAN-3D 的新模式如下：

1. Generalized Laminar Friction Model
2. Dynamic Gap Conductance Model
3. Accumulator Model
4. Dynamic Flow Regime Model
5. Horizontal Flow Regime Map and Stratified Flow Friction Model
6. Chexal-Lellouche Drift Flux Model
7. Three-Dimensional Kinetics
8. Five-Equation Nonequilibrium Model

以上這些 RETRAN-3D 版本改良或新加入的模式，無非是要使程式計算更有效率、更準確，目前核三廠認證安全分析是採保守分析的方法，RETRAN-02 程式在某些方面的計算沒有 RETRAN-3D 程式精確，分析結果會比較保守，若仍能符合安全分析的要求則沒必要進行程式改版。但若要使電廠的運轉效能提升，可能會用掉一些 Margin，這時就需要較精準的計算來得到較多的 Margin，到時就有必要建立 RETRAN-3D 的最佳估算模式。本次 RETRAN 使用說明研討會，西屋公司也有派員參加，西屋公司是核三廠的設計廠商，其主要的系統安全分析程式為 LOFTRAN，後來也同時採用 RETRAN-02，研討會期間也不時對 RETRAN-3D 的新功能提問，西屋公司應該會對使用 RETRAN-3D 程式進行評估。本分組目前核三廠的認證安全分析尚不夠齊全，應在目前現有的 RETRAN-02 安全分析模式下完成所有 RETRAN 程式可做的認證級安全分析。而 RETRAN-3D 的最佳估算模式也應著手建立，並且要完成所有 RETRAN-02 做過的安全分析，以驗證模式確實可以得到 Margin，驗證後的模式就可以應用到電廠效能提升或電廠運轉支援分析上。

本次 RETRAN 使用說明研討會較受本分組關注的議題還有 RETRAN-3D 的 3-D kinetics 的模式，由於本次是屬於基礎使用說明，並無太多相關的討論，但有一點得到確認的就是，RETRAN 程式並無法計算 cross flow，即使是採用 3-D 爐心模式也一樣無法做到，這對於 BWR 電廠並無影響（BWR 爐心沒有 cross flow），BWR 電廠還是可以應用 RETRAN-3D 的 3-D 爐心做更詳細的爐心計算，但對 PWR 電廠則沒有幫助（PWR 爐心有 cross flow），因此核三廠沒有採用 RETRAN-3D 的 3-D 爐心的必要。

由於現在電腦的效能愈來愈好，且 RETRAN 與 VIPRE 程式的 3-D 模式也不斷精進，若要得到 CPR 或 DNBR 上的 Margin，3-D 爐心計算模式有其發展的空間，可惜的是本次出差 CSA 或其他使用者並沒有對 3-D 的應用進行報告，但從間接的管道得知，西班牙已有完整的方法論且在申照中，BWR 電廠若要發展 3-D 爐心計算可以向西班牙取得相關資訊。而 PWR 的 3-D 爐心計算則在網路上可查到相關論文，爐心計算有的是交給 VIPRE 程式來做計算，這與目前核三廠分析模式的基本架構相同，但別人的作法則加入了 RETRAN 與 VIPRE 的動態連結，也須結合 Neutronics Code，這種做法可以得到 DNBR 的 Margin。目前本分組 VIPRE 程式的版本 VIPRE-W 是根據 VIPRE-01 程式改良的，而 CSA 的 VIPRE 程式版本則發展到

VIPRE-3D，與 RETRAN-3D 程式也有資料傳遞的功能，若將來要發展這種中子—系統熱水流—爐心熱水流三方動態連結的方法論時，則應評估新版 VIPRE 程式的可行性與必要性。

本次國外公差 CSA 公司展示了一套新開發的工具程式 RETRAN Visualization Tool (RVT)，該程式可配合 RETRAN 程式來使用，使用 RETRAN 模式的系統節點圖，可輕鬆的繪製暫態曲線圖（如圖 8），對於新手相當有用，可以結合系統圖並可觀察特定體積或接節的參數變化。也可以用來展示分析過程中系統暫態壓力與溫度變化的情形（如圖 9），這用於成果展示或將分析結果簡報上非常有用，可以使聽眾一目瞭然，也可以一次看到整個系統重要參數的變化情形。建議可以引進 RVT 工具程式，這會有助於新進人員的訓練，也有助於分析結果的展示，尤其是以虛擬系統的動態圖示展示給社會大眾或非本領域的外賓，可使大家更容易了解我們進行安全分析所要表達的結果。

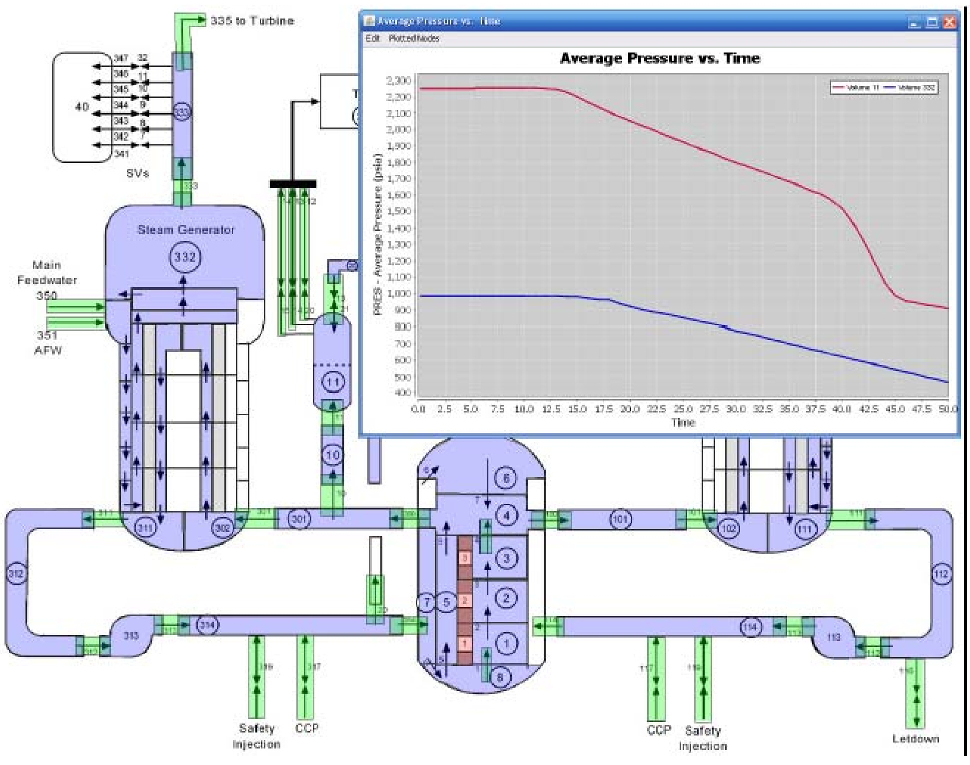

圖 8 RVT 暫態趨勢圖繪製功能

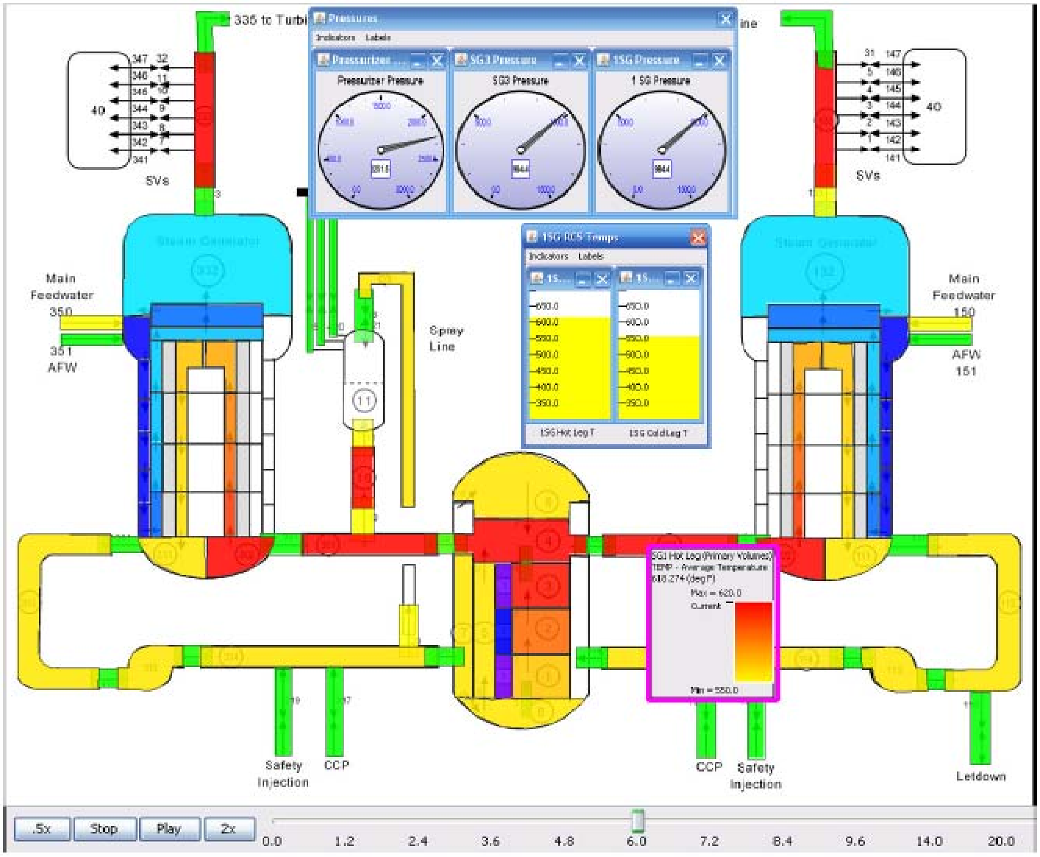

圖 9 RVT 電廠全系統暫展示功能

綜合以上所述，本次公差建議事項歸納如下：

1. 本分組應參考 RETRAN 使用說明研討會，建立起 RETRAN 技術的訓練模式。
2. 應多派員參加類似的研討會與使用者會議，持續參與 RETRAN 維護計畫並推動相關合作計畫。
3. 核三廠 RETRAN 模式不需要使用 3D Kinetics。
4. 核一、二廠 RETRAN 模式若要採用 3D Kinetics 模式，可與西班牙 IBERDROLA 公司洽談合作事宜。
5. 本分組應評估引進 RETRAN Visualization Tool 的可行性。
6. 本分組應評估引進 VIPRE-3D 程式的必要性與可行性。
7. 核三廠 RETRAN 模式若要獲得更多的 MARGIN，應與中子程式、VIPRE 程式進行動態連結。

五、附　錄

附件為「2012 RETRAN VIPRE User Group Meeting Summary Report」，記錄了本次RETRAN/VIPRE使用者會議的內容，並收錄了與會者簡報的投影片內容。

Agenda

RETRAN/VIPRE User Group Meeting
Tuesday, June 12, 2012
Virginian Convention Center
Jackson, Wyoming

8:30 Welcome/Chairman's Message

9:00 VUG Project Status – Garry Gose
- Membership
- Status
- 2012 Budget/Work Scope

10:15 Break

10:30 RUG Project Status – Mark Paulsen
- Membership
- Status
- 2012 Budget/Work Scope

12:00 Lunch

1:00 RETRAN and VIPRE Presentations

"Duke Energy Oconee SSF Analyses", Jeff Abbott, Duke Energy

"VIPRE-01 SI Units Review", John Shatford, CSA

"Validation of iSAM Analysis Methodology Using the Plant Startup Test", Jin-Woo Park, KEPCO NF

2:30 Break

2:45 RETRAN and VIPRE Presentations (Cont'd)

"Steam Generator U-Tube Bundle Uncovery for Dose Calculations", Adam Bingham, Duke Energy

"VIPRE-01 PSBT Benchmark", John Westacott, CSA

"VIPRE-3D - A 3-D Kinetics Core Code", Mark Paulsen, CSA

4:00 Adjourn

Agenda

RETRAN/VIPRE User Group Meeting
Wednesday, June 13, 2012
Virginian Convention Center
Jackson, Wyoming

8:30 Organizational Issues
- Meeting Schedule Discussion
- Steering Committee Elections

8:45 RETRAN and VIPRE Presentations (Cont'd)

"Fukushima Analysis", Charles Albury, STPNOC

" RETRAN Analysis in Support of PRA" Charles Albury, STPNOC
"RETRAN Visual Interface", Steve Smiley, STPNOC

"TPC/INER Transient Analysis Method (TITRAM) with RETRAN-3D", Kai-Lan Chang, INER

"Station Blackout Analysis with RETRAN-3D", Yuki Yabushita, CSAJ

10:00 Utility Summaries of RETRAN and VIPRE Related Work

10:30 Break

10:45 Utility Summaries of RETRAN and VIPRE Related Work (Cont'd)

11:30 Meeting Summary

12:00 Adjourn

RETRAN/VIPRE User Group Meeting
Jackson, Wyoming
June 12 & 13, 2012
Attendees

Name	Company	Email
Abbott, Jeff	Duke Energy	jeff.abbott@duke-energy.com
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RETRAN/VIPRE User Group (RVUG) Meeting
Jackson, Wyoming
June 12-13, 2012

Summary

The spring 2012 RETRAN/VIPRE User Group Meeting was held at the Virginian Lodge Convention Center Hotel in Jackson, Wyoming. Eighteen attendees represented five U.S. and two international utilities, two U.S. commercial vendors, an international fuel vendor, and CSA. The attendee list, meeting agenda, and presentations are attached.

John Lautzenheiser, the RVUG Steering Committee Chairman, welcomed the attendees to the 2012 Jackson RVUG meeting. He noted that the nuclear industry faces challenges following the Fukishima accident that requires continued maintenance and development of the codes used to evaluate the affects of Station Black Out (SBO) events.

There was some discussion regarding the computer platforms that the VUG and RUG should continue to support. Four or five years ago, the RVUG made the decision that CSA should no longer maintain the IBM, SUN and HP UNIX workstations because of the cost, which would be better spent on code development. The decision was made at that time, that code releases on the indicated platforms would be supported only as long as CSA's existing hardware and software was operational. CSA's HPUX machine recently failed. CSA's IBM and SUN workstations are very old, but are still operational.

A quick survey of the computer/operating systems used by those in attendance was taken. A summary is attached. RVUG member organizations that were not in attendance will be contacted to obtain their feedback. Several organizations suggested that if they had specific operating system requirements, they would consider a supplemental fee to help defray the additional cost of supporting their operating system. This issue will be open for discussion with RVUG member organizations (via email).

A discussion next focused on the fact that a number of organizations have made revisions to VIPRE-01 to meet the needs of their methodologies. Currently, this means they are using early versions of VIPRE-01 to which their modifications have been added. This means that they are not benefitting directly from much of the development work that has been done. Some effort will be made to evaluate these updates to determine if they can be implemented into the new code versions to the benefit of all VUG members, or in some instances similar updates may already exist in the new code version. This excludes proprietary correlations that can be implemented into the new code using the CHF dll feature. Further discussion will be held at the next RVUG meeting.

There was also some discussion that it would be useful in RETRAN-3D to be able to track impurities in both the liquid and gas phases simultaneously using the generalized transport model. This would aid in tracking fission properties that can be in both forms. This will be added as a future work scope item.

A suggestion was made that presentations for future RVUG meetings be made available to attendees in electronic form from the CSA web site prior to the meeting. They could then be downloaded to tablets or laptops prior to the meeting. Attendees could then use these during presentations rather than using hardcopies of the presentations. This will require that presentations be provided to CSA several days prior to the meeting. This will be discussed with the Steering Committees prior to the next meeting to resolve logistical problems.

CSA presented project summaries for the VIPRE and RETRAN projects. Each of these presentations summarized the project budgets, 2011 work scope tasks completed, 2012 work scope tasks, and work in progress. Member organizations then made presentations on their RETRAN- and VIPRE-related work.

Technical Presentations

Member organizations made formal and summary presentations of RETRAN and VIPRE activities. They are listed below and each presentation follows.

"Duke Energy Oconee SSF Analyses", Jeff Abbott, Duke Energy

"VIPRE-01 SI Units Review", John Shatford, CSA

"Validation of iSAM Analysis Methodology Using RETRAN Using the Plant Startup Test", Jin-Woo Park, KEPCO NF

"Fukushima Analysis", Charles Albury, STPNOC

"Steam Generator U-Tube Bundle Uncovery for Dose Calculations", Adam Bingham, Duke Energy

"VIPRE-01 PSBT Benchmark", John Westacott, CSA

"VIPRE-3D - A 3-D Kinetics Core Code", Mark Paulsen, CSA

" RETRAN Analysis in Support of PRA" Charles Albury, STPNOC
"RETRAN Visual Interface", Steve Smiley, STPNOC

"TPC/INER Transient Analysis Method (TITRAM) with RETRAN-3D", Kai-Lan Chang, INER

"Station Blackout Analysis with RETRAN-3D", Yuki Yabushita, CSAJ

Informal Utility Summaries of RETRAN- and VIPRE-Related Work

Several organizations (listed below) summarized their recent and ongoing RETRAN- and VIPRE-related activities.

- Joe Divoky, B&W
- John Lautzenheiser, Dominion
- Nobuyuki Fujita, Westinghouse
- Jeff Abbott, Duke Energy
- Charles Albury, STPNOC
- Ignacio Collazo, Iberdrola

Steering Committee

John Lautzenheiser's (Dominion) term as the RVUG Steering Committee Chairman has come to an end. We thank John for his service and look forward to his insight as he continues as a member of the RUG Steering Committee. Charlie Albury (STP) was nominated to serve as the new RVUG Steering Committee Chairmen. He was unanimously selected by those in attendance at the meeting, which was short of a majority. A ballot will be provided to members who were not in attendance.

Current members of the RUG and VUG Steering Committee are

John Lautzenheiser, Dominion (RETRAN)
Jeff Abbott, Duke Energy (RETRAN/VIPRE)
Jorge Arpa, FPL (RETRAN)
Rafael de la Fuente, Iberdrola (RETRAN)
Charlie Albury, STPNOC (RETRAN/VIPRE)
Brian Mount, Dominion (VIPRE)
Stephen Scoles, B&W (VIPRE)

Next RVUG Meeting

The RVUG membership in attendance felt that the late May to mid-June time period was good for next year's annual RVUG meeting and should avoid conflicts with 2013 outages. Suggested locations for consideration are Seattle and the bay area, possibly at EPRI Palo Alto. The RVUG members will be polled electronically to determine the location so the meeting can be scheduled.

RVUG Computer Platform Survey

Organization	Platform
Babcock & Wilcox	Windows 7, XP, & Linux
CSA of Japan	Windows XP & Linux
Dominion	Linux
Duke Energy	AIX & Windows XP (non-QA)
Iberdrola	Windows 7, XP, Linux, & HPUX
Institute of Nuclear Energy Research	Windows & (32 & 64 bit), XP (32 Bit) & HPUX
Korea Nuclear Fuel	Windows & (32 & 64 bit)
Southern Nuclear Co.	HPUX
STP Nuclear Operating Co.	Windows 7, XP, & Linux
Westinghouse	HP, Linux, & Windows XP
Wolf Creek Nuclear Operating Corp.	Linux

VIPRE-01 Project Status

Garry Gose
Computer Simulation & Analysis, Inc.
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RETRAN/VIPRE User Group Meeting
Jackson Hole, Wyoming
June 12-13, 2012

Overview

- 2012 VUG Membership
- 2012 VUG Budget and Expenses
- VIPRE Code Maintenance
- 2011 VUG Task Summary
- 2012 VUG Work Scope

2012 VUG Members

- APS
- Babcock and Wilcox
- Dominion
- Duke Energy
- Eletrobras (Brazil)
- First Energy Nuclear
- NextEra Energy (FPL)
- MHI Ltd.
- NEL/NFI
- NRI
- Southern Nuclear Co
- STP Nuclear
- TVA*
- WCNOC

*New Member for 2012

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2012 VUG Budget/Expense

Projected Funding	
• 2012 Membership	$ 185.5k
• 2011 Carry Over	$ 6.9k
Total 2012 Funds	$ 192.4k
Costs	
• EPRI Royalties	$ 18.5k
2012 Available Project Funds	$ 173.9k

2011 Total Project Funding $175.5k

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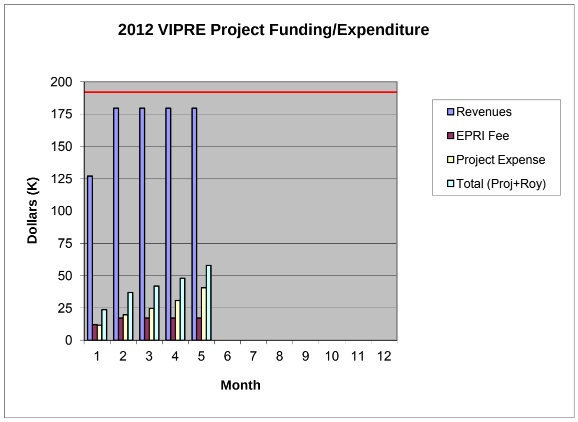
2012 VUG Budget/Expense



VIPRE Maintenance

- Project Management
- Trouble Reports
- User Support
- Code Transmittals
- Support for QA Audits

VIPRE Maintenance (Cont'd)

- Project Management
  - Quarterly Trouble and Project Reports
  - Web Page Updates
  - Invoices
  - Develop - Prioritize 2012 Work Scope Items
  - Marketing VIPRE-01 and VUG
  - Interaction with EPRI
  - VUG Meetings

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VIPRE Maintenance (Cont'd)

- VIPRE-01 Trouble Reports
- 7 Reported Since MOD02.4F95 Release
- All Have Been Resolved - Modifications
  - Dynamic Memory Allocation (2)
  - CHF_DLL Issues (1)
  - Input Edit Processing (1)
  - Model Errors (3)

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VIPRE Maintenance (Cont'd)

- VIPRE-01 Trouble Reports
  - TR 259
    - B&W Reported. Problem with SI Option Use.
  - TR 260
    - CSA Reported. Large BWR problem with dynamic memory allocation.
  - TR 261
    - Duke Reported. Problems with missing CHF_DLL Parameters.
  - TR 262
    - CSA Reported. Problems with Editing Heated Hollow Tube Outer Surface Geometry

VIPRE Maintenance (Cont'd)

- VIPRE-01 Trouble Reports
  - TR 263
    - CSA Reported. Problem with Incorrect Viscosity Units in Chexal-Lellouche Drift Flux Model.
  - TR 264
    - CSA Reported. Large PWR problem with Dynamic Memory Allocation.
  - TR 265
    - CSA Reported. Problems with Dynamic Gap Model when Gap Closure Occurs.

VIPRE Maintenance (Cont'd)

- TR-259 – Problems with SI Usage
  - Reported by B&W
  - VIPRE-01 MOD02.4F95 (and Older)
  - SI Input Related Problem
    - ***nunits*** =1 on **VIPRE.1** Combined with:
    - ***isp*** =2 on **OPER.1** (Inlet Channel Flow Fraction Specification)
    - ***ig***=1 through 4 (Various Units)
- Corrected in mod_276

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VIPRE Maintenance (Cont'd)

- TR-263 – Problem with Chexal-Lellouche Viscosity Units
  - Only Effects VIPRE-01 MOD002.4f95
  - Mismatch Between VIPRE-01 Internal Viscosity Units (lbm/hr-ft) and RETRAN C-L Drift Flux Routines (lbm/hr-sec)
  - Effects Void Fraction Distribution
  - Older VIPRE-01 EPRI Drift Flux Model is not Affected
- Corrected in mod_273

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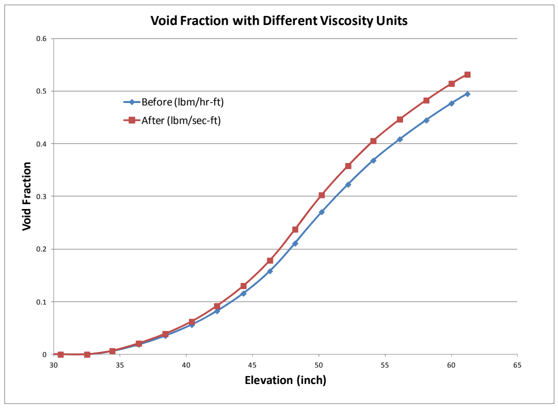
VIPRE Maintenance (Cont'd)

- TR-263



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VIPRE Maintenance (Cont'd)

- TR 265
- Problem with Dynamic Gap Model – Incorrect Implementation
- The Documentation and the Model is Incorrect
  - Incorrect Calculation of Fuel Surface Roughness to Wavelength Values in the Dynamic Gap Model
    - $(R_1/\lambda_1) = \exp[0.5285 * \ln(R_1 - 5.738)]$
  - Should Be
    - $(R_1/\lambda_1) = \exp[0.5285 * \ln(R_1) - 5.738]$
- Corrected in mod_280

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VIPRE Maintenance (Cont'd)

- TR 265
  - The error will occur if the dynamic gap model is selected and gap closure (including effects of roughness) is predicted. This can be seen by examination of the interfacial contact pressure given in the dynamic gap conductance edit for a given rod.
  - In the limited test cases that CSA has examined, gap conductance values are significantly higher (factors of 40 or more) than the corrected value. This will impact fuel surface and clad temperatures. In general, the temperatures will be lower than the corrected values.

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VIPRE Maintenance (Cont'd)

- TR 265
  - VIPRE-01 users that activate the dynamic gap model should review and evaluate their results if the code indicates a gap closure. VIPRE-01 will edit dynamic gap conductance parameters for rods that use this model.
  - A key indicator for closure is a significant increase in interfacial contact pressure and a reduction in gap width.
  - CSA has classified this error as significant but not reportable. The reason is that a competent user would notice the clearly incorrect values of gap conductance that are computed. In addition, to the best of CSA's knowledge, no VUG member uses the dynamic gap model for licensing work.

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dynamic gap conductance model results for rod no. 1

cladding axial expansion, inches....... 0.160
fuel column axial expansion, inches.... 0.199
fill gas pressure, psia................ 22.52

node no.	axial range (inches)	gas gap thickness (inches)	fuel pellet diametral expansion (inches)	cladding diametral expansion (inches)	interfacial contact pressure (psig)
21	43.0- 48.0	0.225E-03	0.792E-03	0.243E-03	0.00
20	39.0- 43.0	0.225E-03	0.792E-03	0.243E-03	0.00
19	36.0- 39.0	0.225E-03	0.792E-03	0.243E-03	0.00
18	34.0- 36.0	0.225E-03	0.792E-03	0.243E-03	0.00
17	32.0- 34.0	0.224E-03	0.795E-03	0.243E-03	0.00
16	30.0- 32.0	0.212E-03	0.150E-02	0.921E-03	3329.38
15	28.0- 30.0	0.212E-03	0.176E-02	0.118E-02	4611.18
14	26.0- 28.0	0.212E-03	0.204E-02	0.146E-02	6014.39
13	24.0- 26.0	0.212E-03	0.235E-02	0.178E-02	7555.31
12	22.0- 24.0	0.212E-03	0.252E-02	0.194E-02	8378.16
11	20.0- 22.0	0.212E-03	0.252E-02	0.194E-02	8370.49
10	18.0- 20.0	0.212E-03	0.252E-02	0.194E-02	8362.06
9	16.0- 18.0	0.212E-03	0.251E-02	0.194E-02	8352.94
8	14.0- 16.0	0.212E-03	0.235E-02	0.177E-02	7529.11
7	12.0- 14.0	0.212E-03	0.203E-02	0.146E-02	5975.67
6	10.0- 12.0	0.212E-03	0.175E-02	0.117E-02	4567.38
5	8.0- 10.0	0.212E-03	0.148E-02	0.906E-03	3256.46
4	6.0- 8.0	0.225E-03	0.793E-03	0.243E-03	0.00
3	3.0- 6.0	0.225E-03	0.793E-03	0.243E-03	0.00
2	0.0- 3.0	0.225E-03	0.793E-03	0.243E-03	0.00

****

Contact Pressure

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Incorrect

gap conductance (btu) (hr-ft2-f)	fuel temperatures (deg f) outside	average	center line	fuel enthalpy cal/gm
3400.752	543.9	543.9	543.9	16.509
3400.820	543.9	543.9	543.9	16.510
3400.962	544.0	544.0	544.0	16.512
3401.003	544.0	544.0	544.0	16.513
3410.219	544.7	545.5	546.1	16.570
96717.656	599.5	812.7	996.3	27.054
133473.313	614.0	905.6	1162.5	30.796
174095.359	628.0	1003.7	1342.3	34.794
219118.109	641.5	1107.5	1536.7	39.066
243321.000	647.9	1161.3	1639.1	41.298
243061.000	647.7	1160.6	1638.0	41.270
242772.391	647.4	1159.9	1636.8	41.239
242459.000	647.1	1159.0	1635.5	41.205
218191.438	640.3	1104.9	1532.7	38.959
172841.453	626.6	1000.2	1336.7	34.651
132137.594	612.9	901.8	1156.3	30.645
94623.961	598.5	807.2	986.7	26.833
3401.585	544.2	544.2	544.2	16.523
3401.615	544.3	544.3	544.3	16.523
3401.636	544.3	544.3	544.3	16.524

Corrected Mod_280

gap conductance (btu) (hr-ft2-f)	fuel temperatures (deg f) outside	average	center line	fuel enthalpy cal/gm
3418.229	543.9	543.9	543.9	16.509
3418.299	543.9	543.9	543.9	16.510
3418.441	544.0	544.0	544.0	16.512
3418.481	544.0	544.0	544.0	16.513
3427.797	544.7	545.5	546.1	16.569
4371.368	645.4	865.4	1054.9	29.158
4640.667	671.5	974.5	1241.6	33.579
4923.388	695.5	1088.5	1442.4	38.249
5220.219	717.8	1207.6	1658.3	43.186
5373.303	728.2	1268.9	1771.6	45.746
5372.261	727.9	1268.2	1770.4	45.716
5371.145	727.6	1267.4	1769.1	45.682
5369.960	727.2	1266.5	1767.7	45.645
5217.091	716.5	1204.8	1654.1	43.070
4917.365	693.9	1084.6	1436.4	38.090
4632.689	670.0	970.3	1234.8	33.408
4355.946	643.6	858.9	1044.1	28.897
3419.073	544.2	544.2	544.2	16.523
3419.109	544.3	544.3	544.3	16.523
3419.127	544.3	544.3	544.3	16.524

Lower Gap Conductance
Elevated Fuel Enthalpy
Higher Fuel Center Line Temp
Higher Cladding Surface Temp

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VIPRE Maintenance (Cont'd)

- Code Transmittals – University Update
  - Colorado School of Mines
    - Reactor Design Course
  - Oregon State
    - Teaching Seminars
    - Masters Thesis
  - Nanyang Technological University (Singapore)
    - Research
  - MIT*
    - Thesis: *Analysis of quasi steady-state and transient DNB prediction methodologies applied to reactivity insertion accident simulation of pressurized water reactors.*

*New 2012

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VIPRE Maintenance (Cont'd)

- Code Transmittals – University Update
  - Penn State
    - Heat Transfer Correlation Studies
  - Texas A&M
    - Teaching Seminars, Graduate Student Research

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VIPRE Maintenance (Cont'd)

- NUPIC QA Audits
  - Approximately 30 Month Cycle
  - 2011 Audit – May 2011 - 4 Days 4 Auditors
  - Support for VIPRE-01 Specific Issues
    - Code Maintenance Procedures
    - Trouble Reports/Corrective Action
    - Software Design/Control
    - Part 21 Evaluation

VIPRE-01 2011 Tasks

- Code Transmittal VIPRE-01 MOD02.4F95
- Review SI Input Output Option
- PSBT Benchmark
- DNBR Search for Limiting Rod Location

VIPRE-01 2011 Tasks (Cont'd)

- Code Transmittal - VIPRE-01 MOD02.4F95
  - Final Step in a VUG Directed Multi-Year Project
  - Code Transmittal Sent February 2012
  - 13 Modifications
    - 10 Error Corrections for Trouble Reports Since MOD02.3
    - 3 Model Enhancements
      - CHF-DLL
      - Chexal-Lellouche Drift Flux
      - Error Summary File

VIPRE-01 2011 Tasks (Cont'd)

- VIPRE-01 MOD02.4 F95 - Platform Support
  - Windows XP Windows 7
    - 32 Bit exe
  - Red Hat Linux with Intel Visual Fortran Version 11.1
  - HPUX
  - AIX
  - Solaris

VIPRE-01 2011 Tasks (Cont'd)

- Comprehensive Review of SI Option
  - Several Trouble Reports Filed on SI Usage
  - SI Option is Relatively Unused by US VUG
  - Concern that Numbers may not be Correct
    - Code Does Not Always Fail
  - See Separate JGS Presentation " VIPRE-01 SI Units Review"

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VIPRE-01 2011 Tasks (Cont'd)

- PSBT Benchmark
  - NUPEC PWR Subchannel Tests (PSBT)
  - OECD/NEA/NRC Sponsored International Benchmark
  - Void Fraction, Pressure Drop, Fluid Temperature, DNB
  - Steady-State and Transient Conditions
  - Subchannels and Full Bundles
  - Comparisons with Experiments and Other Codes
  - See Separate JLW Discussion " VIPRE-01 PSBT Benchmark"

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VIPRE-01 2011 Tasks (Cont'd)

- MDNBR Search (Duke Sponsored Request)
  - MDNBR Search Requires Specification of Correct Limiting Rod for Search to Converge (May Change with Iterations)
  - Request Model Modifications to have VIPRE-01 Detect the Limiting Rod
- VUG and Duke Codes are Different for this Option (NDNB=5, OPER.1)
  - Duke Model Adjust all Individual Rod Powers and Modifies Lumped Rod Power to Maintain Power Level
  - VUG Code Adjusts Power of Limiting Rod or Specified Rod Only
    - No Convergence Issues with VUG Version
- Mutual Decision to Drop the Task – Apply Remaining Funds to 2012

2012 VUG Work Scope Task Selection

- Candidate Development Tasks
  - New Tasks
  - Tasks from Prior Year with Lower Priority
  - Suggestions from VUG Members
- CSA Prepares Detailed Scope
- Task Selection
  - Steering Committee Members Prioritize from Task Candidates, Costs, and Funding

2012 VUG Candidate Tasks

- New Code Version - VIPRE-01 MOD02.5
- Input Error Message Improvement
- CHF_DLL Enhancements
- Multiple ABETA Channel
- Revise Volume 3 Programmers
- B&W Suggestions

2012 VUG Candidate Tasks (Cont'd)

- New Code Version VIPRE-01 MOD02.5
  - Include Error Corrections
  - 2012 Development Tasks
    See Candidates Below

2012 VUG Candidate Tasks (Cont'd)

- Input Error Message Improvement – Prior Year
  - Provide More Useful Input Error Reporting
    - Description of the Error
    - Location of Error
    - Possible Corrective Action

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2012 VUG Candidate Tasks (Cont'd)

- CHF_DLL Enhancements - New Item
  - Take Advantage of Duke 2011 Study
  - Survey Users for Additional Data Linkage Requirements
  - Provide Additional Data Linkage for 'Real' CHF Correlations

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2012 VUG Candidate Tasks (Cont'd)

- Multiple ABETA per Channel - Prior Year
  - Add Capability for More than a Single Value
    - Turbulent Mixing Factor
    - Supports Assemblies with Multiple Grid Designs
  - Is this a DOA Task? i.e., Permanent Removal

2012 VUG Candidate Tasks (Cont'd)

- Revise/Replace VIPRE-01 Programmer's Volume 3
  - Many of the long standing VUG members have been involved in gradual transition of the VIPRE-01 code from mainframe to laptop and are familiar with the shortcomings of Volume 3.
  - For these organizations, local code maintenance procedures have evolved over time to adapt to the older and obsolete methods.
  - But for recent or new VUG members or new members of an organization staff, Volume 3 is not helpful.

2012 VUG Candidate Tasks (Cont'd)

- Replace VIPRE-01 (VOL 3) – Prior Year
  - Manual is Dated
    - 4 Out of 7 Sections are Obsolete
  - Update the Manual for the Current Code
    - Remove VAX/CDC/IBM mainframe discussion
    - Remove CALCOMP Plotting Discussion
    - Show New Code Methods, Structure, Support
    - Full Electronic Format Going Forward

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2012 VUG Candidate Tasks (Cont'd)

- Recent Additional Suggestions – B&W
  - Extend CHF DLL to Friction and Heat Transfer
    - Phased Effort. Phase 1 Feasibility and Options
      - Implementation Plan is the Deliverable
    - Combine with CHF DLL Enhancement Task
  - Add Local Heat Flux Multiplier – Performance Factor or Penalty for CHF Calculation Only
  - Vary a 'Standard' Profile by Applying Hot Channel Factors

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2012 VUG Candidate Tasks (Cont'd)

- Recent Additional Suggestions – B&W
  - Generate EXCEL Readable File Output
  - Goal is to Provide a File with Fixed Formats
    - Allows Parametric Studies for Cases that may have different VIPRE-01 Output File Lengths or Structures
  - Option to Provide Delimited Result File with Minimal Header Information

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2012 VUG Work Scope

- Summary
  - Proposed Budget is 3% Higher than 2011
  - VUG Members Identify Development Tasks
  - Steering Committee to Finalize
    - Mid 2012

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Summary

- New Members in 2012
  - TVA
- VIPRE VUG Membership is Increasing
- Actively Supported Code is Helpful
- Code Modernization Helps Market VIPRE-01 to New Organizations
- VIPRE-01 Use in Universities is Active

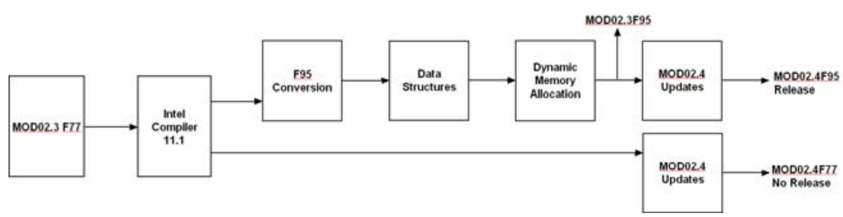
- Spares

2011 VUG Tasks (Cont'd)

- F95 VIPRE-01 MOD02.4 (Cont'd)
  - Modifications Independently Validated for Versions
    - MOD02.4 F77
    - MOD02.4 F95
  - Test Cases for V&V
    - Standard VIPRE-01 Transmittal Problems
    - Additional PWR and BWR Cases
      - Steady-State and Transient
      - Large and Small
      - Different Solution Options
      - British and SI
      - Restart

VIPRE-01 2011 Tasks (Cont'd)

- VIPRE-01 MOD02.4 F95 Development Path



VIPRE Maintenance (Cont'd)

- TR 261
  - Problem with data sharing several parameters between VIPRE-01 and the CHF DLL
    - Wetted Perimeter, Axial Flux Factor
  - Reported By Duke During Evaluation
  - Mod_274

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VIPRE Maintenance (Cont'd)

- TR 260
  - Large BWR Test Case – Terminates No Error Message
  - Dynamic Memory Allocation Problem For Temporary Space and Space for Rod Edits
  - Mod_275
- TR 264
  - Large PWR Test Case – Terminates No Error Message
  - Dynamic Memory Allocation Problem
  - Mod_278

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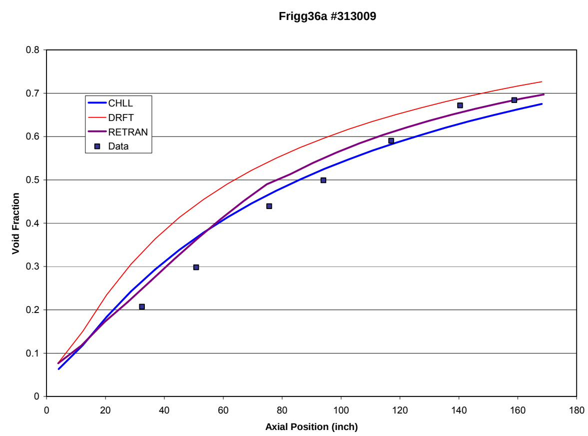
VIPRE Maintenance (Cont'd)

- TR 262
  - PSBT Model Using the VIPRE general rod to model a hollow tube heated rod.
  - The input reflection does not print the geometry for the outside surface.
  - Mod_272

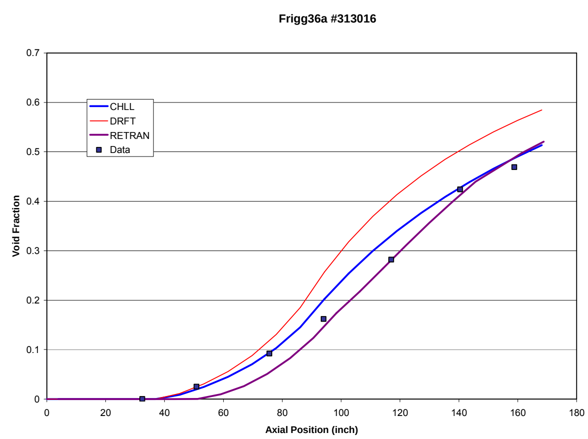
Chexal-Lellouche Drift Flux (Cont'd)

- Test Cases
  - Single Channel, Single Rod, Uniform Heat Flux
  - Frigg36a Void Cases
  - Compare with Data and/or RETRAN

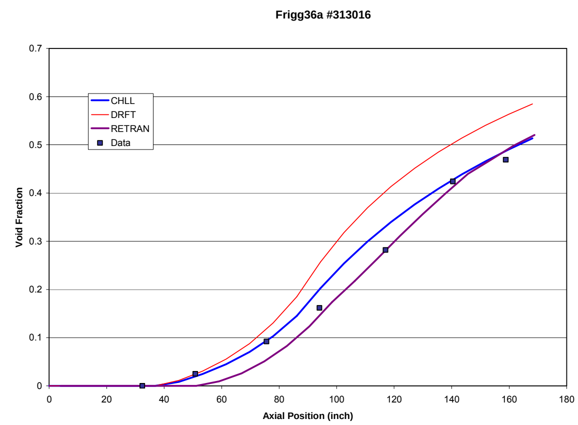
Chexal-Lellouche Drift Flux (Cont’d)



Chexal-Lellouche Drift Flux (Cont’d)



Chexal-Lellouche Drift Flux (Cont'd)



2010 VUG Tasks (Cont'd)

- F95 VIPRE-01 MOD02.4 (Cont'd)
  - Modifications Independently Validated for Versions
    - MOD02.4 F77
    - MOD02.4 F95
  - Test Cases for V&V
    - Standard VIPRE-01 Transmittal Problems
    - Additional PWR and BWR Cases
      - Steady-State and Transient
      - Large and Small
      - Different Solution Options
      - British and SI
      - Restart

RETRAN Project Status

Presented by

Mark P. Paulsen
CSA Inc.
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RETRAN/VIPRE User Group Meeting
June 12-13, 2012
Jackson, Wyoming

RUG Status

- 2012 Membership
- Financial Summary
- Trouble Report Status
- 2011 Task Summary
- 2012 Development Plan
- Other Issues

2012 Membership

- APS
- Areva Solar ??
- B&W
- Dominion
- Duke
- Eletrobras Termonuclear
- Florida Power & Light
- Iberdrola
- INER
- Pacific Gas & Electric
- Southern Nuclear
- South Texas Project Nuclear
- Westinghouse
- Wolf Creek

2012 Membership Changes

- Dropped Membership
  - TEPCO/TEPSYS
- Reinstated Membership
  - Westinghouse

2012 Financial Summary

2011 Revenue	$372.0k
Planned 2012 Revenue	$389.3k
EPRI Royalties	$38.9k
Maintenance and Development Funding	$350.0k
• Net Increase from 2011 - $17.3k	
• Year To Date Expense	$207.0k
Available for Development	$143.0k

RETRAN-02 Trouble Reports

- 5 Trouble Reports not Resolved at Release of MOD005.2
- 25 Reports Received After Release of MOD005.2
- Status Summary
  - 2 Closed (not Reproducible or Obsolete)
  - 4 Not Code Errors
  - 7 Code/Model Limitations
    - Recently Reported Error Resolved by Existing Modification
  - 3 Documentation Errors
    - Documents Corrected (Revision 6.1 for Volumes 1 and 3)
  - 13 Corrections Available
    - MOD_414 Resolves 2 Trouble Reports
    - Validation Complete for Individual Modifications
    - Available Upon Request
- All Trouble Reports Resolved/Closed
- Quarterly Summary Report on Web Page
- One 10CFR21 Indeterminate Error

10CFR21 Indeterminate Error Notification

- RETRAN-02 TR-460
  - After Draining, Pressurizer Level Fails to Reestablish with Insurge
  - Could Underestimate the Pressure Due to Single Vapor Region
    - Complicated by Initial Interpretation of Error
      - Heat Transfer Regime
      - Not a Significant Safety Concern
    - Could Not Definitively Evaluate Effect of Error for all Uses
    - Triggered 5-Day Notification Requirement

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10CFR21 Indeterminate Error Notification (Cont'd)

- Notification Process
  - RUG Members Notified by Letter
  - Available on Web Site
    - Notification
    - Trouble Report and Letter
- Recent Audits Scrutinized 10CFR21
  - Related Procedures
  - Trouble Reports and Evaluation

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RETRAN-3D Trouble Reports

- No Unresolved Trouble Reports at Release of MOD004.6f95
- 44 Trouble Reports Filed Since Release of MOD004.6f95
  - TR-459 Through TR-502
  - All Trouble Reports Resolved
- Significant Trouble Reports
  - TR-489 – Pressurizer Vapor Region Fails to Reestablish
  - TR-493 – Pressurizer Wall Heat Transfer – Conductor Numbering
  - TR-501 – Compiler Diagnostic Message Option
- Quarterly Summary Report on Web Page

Trouble Report TR-489

- Problem Description
  - Pressurizer Fills and the Vapor Region Disappears
  - Subsequent Depressurization Causes Liquid Region to Flash
  - Vapor Region Doesn't Re-establish Until Void Fraction is ~12%
- Effect of Error
  - Indicated Level for Reported Problem – Control System Calc.
  - Minimal Affect on Pressure if Depressurization Continues Until Vapor Region Forms
  - Slight Under Prediction of Pressure if Insurge Occurs Before Vapor Region Re-establishes
    - Low Probability of Occurring

Trouble Report TR-493

- Problem Description
  - Affects MOD004.5f95 and Later
  - Implicit Pressurizer Model Only
  - Using Heat Conductor
  - Wrong Conductor Index Used when Pressurizer Volume Number is Different than Sequential Number
- Affect of Error
  - Incorrect Wall Heat Flux Results
  - Affects Pressure Response
  - Low Probability of Occurrence

Trouble Report TR-501

- Problem Description
  - Compile Diagnostic Warning Messages Turned Off
  - When Turned On, the Compilation Fails and the Error Messages are Written to Build Log
- Affect of Error
  - None on Results
  - Most Deal with Unused Variables
  - Variables through Call Statements
- Benefit to Correcting
  - Will Allow Use of Compile Diagnostics
  - Help Prevent Future Errors
  - Some Errors not Detected Until UNIX Compilation

2011 Development Tasks

- Continue Preparation of a RETRAN-3D User Guidelines Manual
  - Some Editing and Merging
- Add Enhanced Steady-State Error Messages
- Develop a Pressurizer Thermal Stratification Model
  - Validation Included In Volume 4
- Investigate Code Failures During Long Two-Phase Transients
  - Work not Begun in 2011

Enhanced Steady-State Error Messages

- New and Improved Error Messages for
  - Input Processing
  - Memory Allocation
  - Steady State Errors
  - Transient Solution Errors
- Final Step in Completing Error Message Enhancement
- Old Input Error Messages were Scattered Throughout the Output File and were Sometime Difficult to Resolve
  - Description of Error was Vague
  - No Specific Instructions were Available for Resolution
- Now, All Error Messages are Combined in a Single File "ERRLOG"
- Error Message Document Is Created Which Describes in Detail, Input Error and Resolution

Enhanced Steady-State Error Messages (Cont'd)

- Revised and Organized Error Messages Generated During Steady-State Initialization
  - Processed Similar Way as Input Error Messages
  - Includes Warning
- New Error Messages with Error Number and Detail Description Linked with Error Resolution Document Makes Resolving Error Easy
  - Error/Warning Resolution Documented in Volume 3 Appendix C
  - Has Detail Information on Error Description And Resolution
- New Scheme Generates Error Log Even for Warnings

Enhanced Steady-State Error Messages (Cont'd)

Error number	Error Description
926	The enthalpy cannot be computed for a volume with no flow.

User Recommendations

The mixture energy equation is used to compute the volume enthalpies. It requires that there be flow through the volume. Enthalpy in this volume will be propagated from adjacent volume(known enthalpy), if the area of the junction connecting the volumes is greater than zero. This was not possible for the offending volume.

1. The enthalpy was not supplied for the volume but must be specified using the volume initial condition data cards 231XXX or the volume data cards 05XXXY (not recommended).
2. Another possibility is that there must be flow through the volume. If so, review the time dependent junction areas and the junction initial condition summary edit to make sure that the area is open. Make any necessary revisions to the flow initial conditions. If the time dependent area is incorrectly zero, review and revise as necessary the setting for valves and trips.

Pressurizer Thermal Stratification Model

- Thermal Stratification can Influence Rate of Depressurization
- Default Pressurizer is a Single Volume Two-Region Model
  - Mixes Incoming Fluid in Liquid Region
- New Model Option Accounts for Thermal Stratification in the Liquid Region
  - Uses Detailed Nodalization for Pressurizer Vessel
  - Applies Temperature Transport Delay in Each Node
  - Accounts for Stratification in Liquid Region

Pressurizer Thermal Stratification Model (Cont'd)

- Pressurizer Model to Vapor Region
  - Lower Boundary is Node Containing the Mixture Level
  - Pressurizer Volume is Associated with Top Node
  - All Other Nodes in Pressurizer Domain will be Deactivated
  - Pressurizer Domain will Move During a Transient
- In Surge Transients
  - As Liquid in Liquid Region is Adequate to Fill Bottom Node
    - Pressurizer Domain is Shifted Up 1 Node
    - Bottom Node is Activated
    - Mass and Energy Moved from Liquid Region to Activated Node
    - Update Geometry and Connection Information for New Domain Boundary

Pressurizer Thermal Stratification Model (Cont'd)

- Out Surge Transients
  - As Liquid in Liquid Region of Pressurizer is Depleted
    - Pressurizer Domain is Shifted Down 1 Node
    - New Interior Node is Deactivated
    - Mass and Energy Moved from Deactivated Node to Liquid Region
    - Update Geometry and Connection Information for New Domain Boundary
- Nodes Moved Into or Out of Pressurizer Domain
  - Subcooled or Saturated Liquid
  - Essentially Incompressible
  - No Change to Vapor Region
  - Pressure Behavior Should Be Continuous

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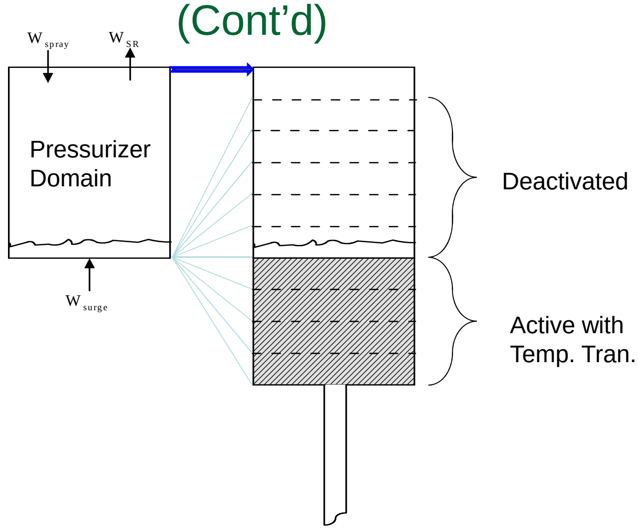
Pressurizer Thermal Stratification Model (Cont'd)



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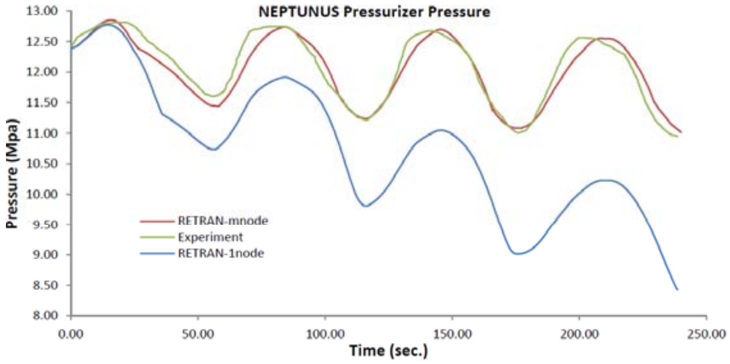
Pressurizer Thermal Stratification Model Results (Cont'd)



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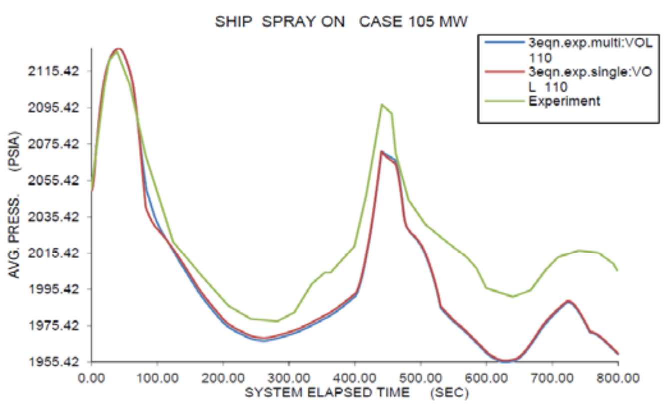
Pressurizer Thermal Stratification Model Results (Cont'd)



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Plot Option Enhancement

- Originally Requested via RETRAN Configuration File
- Now Request Plot File via Input File
  - No Plot File Unless Requested
- Plot File Large
  - Binary or ASCII Form
- User Control of Plot File Content
  - Short Form
  - Long Form – Same As Current
  - User can Add any Minor Edit Variables to Short or Long Form

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2012 Development Work Scope

- Procedure for Selection Development Tasks
  - Task Previously Requested by Members
  - Members Ask to Provide Recommendations
- Proposed Development Task List Prepared
  - Task Summaries Prepared
  - Cost Estimates Prepared
- List Provided to Steering Committee
  - Tasks Ranked
  - Included Rankings of Members that Responded
- Steering Committee Held Telephone Conference Call
  - Selected Tasks Based on Rankings

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2012 Development Work Scope (Cont'd)

Priority	Task Description
7.0	Preparation of User Guidelines - Phase 2
4.0	Prepare and Distribute MOD004.7f95
5.4	Investigate Code Errors for Long Two-Phase Transients
4.4	Water Packing Mitigation
4.6	Automatic Nodalization for Pressurizer Stratification Model
3.4	Add Automatic Subnodalization – e.g. RELAP5 Pipe Component
4.0	Revise Implicit Pressurizer Solution
3.0	Improved Generalized Transport

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Additional Tasks Completed

- RETRAN-02 MOD005.3 Release
  - Driven by TR-460
- Pressurizer Stratification Validation
  - Included in Volume 4
- Enhance User Control of Plot File
  - Request
  - Content

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New RETRAN-02 Release - MOD005.3

- Released 2/03/2012
- Error Corrections
  - All Trouble Reports Resolved
- Significant Corrections
  - TR-439 – Mod_408 – Actinide Contribution to Decay Heat
  - TR-440 – Mod_414 – Kinetic Energy for Small Valve Area
  - TR-445 – Mod_409 – Generalized Transport B Concentration
  - TR-451 – Mod_413 – Wrong Heat Transfer Mode
  - TR-458 – Mod_418 – Decay Heat for 1-D Kinetics
  - TR-460 – Mod_419 – No Pressurizer Liquid Region on Refill
- Two CD-ROM Transmittal Formats
  - Windows Only CD-ROM
  - IBM AIX/Linux/Windows CD-ROM

New RETRAN-02 Release - MOD005.3 (Cont'd)

- Windows Only CD-ROM
  - Used for Organization with No Access to Source Code
  - Executable Version Only
    - Windows 7
    - 32-bit Application
  - Requires License File
    - Contains Organization Name
    - Included with Transmittal
    - Can Lock Installation to a Given Computer
    - Can Use Expiration or Use Controls

New RETRAN-02 Release - MOD005.3 (Cont'd)

- UNIX/Linux/Windows CD-ROM
  - IBM AIX and Linux Platforms
    - Executables Available
    - Procedures Install from Source Code
    - Standard Fortran 95 Source Code
  - Windows Platforms
    - Executable Only
    - Same Installation as Windows Only CD-ROM
    - No Procedures for Installation from Source Code

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New Code Release - MOD004.7f95

- New Models/Features
  - PC License Enforcement – 32- and 64-Bit
  - Pressurizer Stratification Model
  - Enhanced Steady-State Error Messages
  - Plot File Request Via Input
  - Revised Volume 4
- Error Corrections
  - 44 Trouble Reports Resolved
- 2012 Development Items If Completed

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New Code Release - MOD004.7f95 (Cont'd)

- Release Schedule - Fall 2012
- Two CD-ROM Transmittal Formats
  - Windows Only CD-ROM
    - Used for Organization with No Access to Source Code
    - Executable Version Only
      - Windows XP and 7
      - 32-bit and 64-bit Applications
    - Requires License File
      - Contains Organization Name
      - Generally Included with Transmittal
      - Can Lock Installation to a Given Computer
      - Can Use Expiration or Use Controls
      - Previous 16-bit dll Problem Eliminated

New Code Release - MOD004.7f95 (Cont'd)

- UNIX/Linux/Windows CD-ROM
  - UNIX/Linux Platforms
    - Executables Available
    - Procedures Install from Source Code
    - Standard Fortran 95 Source Code
    - SLIB77 use No Longer Required to Extract Source
  - Windows Platforms
    - Executable Only
    - Same Installation as Windows Only CD-ROM
    - No Procedures for Installation from Source Code

New Code Release - MOD004.7f95 (Cont'd)

- Updated Documentation
  - Theory and Numerics – Volume 1- Revision 9
  - Programmer's Manual – Volume 2- Revision 9
  - User's Manual – Volume 3 – Revision 9
  - Applications Manual – Volume 4 – Revision 9

Develop User Guidelines

- Drafts Completed with Some In-House Review
  - 1.0 Geometric Modeling
  - 2.0 Modeling of Physical Phenomena
  - 3.0 Component Modeling
- Preliminary Drafts Prepared
  - 4.0 Component Modeling
  - 5.0 Data Requirements
  - 6.0 System Transients
- Some Available from RETRAN-02 – Needs Major Revision
  - 7.0 Code Limitations
  - 8.0 Steady-State Initialization

Develop User Guidelines (Cont'd)

- Update Sections 4.0 Through 6.0 for RETRAN-3D Specific Guidelines
- Add Tech Tips from News Letters
- Prepare a Draft Document
  - Could be Useful to New Users
  - User Comments are Needed

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Code Failures During Two-Phase Transients

- Two Know Problems are Contributors
  - Pressure Search Failures
    - Two-Phase Volume Transitions to Single Phase During Time Step
    - Pressure and Flow Spikes Occur
    - Indicates a Water Packing Event
  - Mass Depletion in Two-Phase Volume
    - Inlet and Exit Flows Accelerate
    - Junction Velocity Head is Large
    - Momentum Flux Problem
- May be Other Causes

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Water Packing

- Occurs when Volume Transitions from Two-Phase to Single Phase Liquid
  - Problem Because Slip Allows Volumes to Refill
    - Countercurrent Flow – Fill from Above
    - Cocurrent Flow – Fill from Below
  - Finer Nodalization Increases the Number of Refill Events
- Some Water Packing Events Cause a Pressure and Associated Flow Spikes
  - Short Term
  - Return to Near Pre-spike Value
- Other Water Packing Events Cause Failures

Water Packing (Cont'd)

- Numerical Pressure and Flow Perturbations Created when a Fluid Volume Transitions from Two-Phase to Single-Phase Liquid
  - Occurs as Volumes Fill
- Small Error in Mass Leads to Large Pressure Change
  - Leads to Pressure and Flow Spikes in Vicinity of Packing Event
  - Perturbations may be Insignificant or Catastrophic
- Smaller Time-Step Size Helps — Not a Cure
- Sometime Larger Time-Step Sizes Help
- Common Problem to Most TH Codes
- Problem has been Addressed - Not Resolved

Historical Approaches to Mitigating Water Packing

- Modify the Partial Derivatives Used to Linearize Pressure
  - Makes System Stiff - Forces Flow to Respond Quickly
  - Pressure Still Spikes
  - Approach Used by RELAP4 WREM
- Select Time-Step Size that Just Takes the Volume Single Phase
  - Attempted with RETRAN-3D
  - Calculated Time-Step Size is not Sufficiently Accurate
  - Volume Still Packs
  - Volume Stays Two-Phase

Historical Approaches to Mitigating Water Packing (Cont'd)

- Other Explicit Algorithms to Adjust Flow Rate and Mass Inventory
  - Mass is not Conserved
  - Flow Adjustment not Accurate
  - Volume Still Packs Occasionally
  - Volume Remains Two-Phase
- These Approaches Are Unacceptable
  - Lack Robustness
  - Don't Conserve Mass

Implicit Water Packing Mitigation Scheme

- New Approach to Mitigating Effects of Water Packing
  - Conserves Mass
  - Eliminates Pressure Spikes
  - Iterative Method
- Water Packing Mitigation Scheme was Developed ~15 Years Ago – MOD002.0
  - Budget Limitations Prevented Completion and Validation
  - Original Work Retrieved from Archives
  - Prepare a Design Document
  - Coding Changes Need to be Implemented into MOD004.6
  - Additional Development may be Necessary

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Implicit Water Packing Mitigation Scheme (Cont'd)

- RETRAN-3D Balance Equations
  - Mixture Momentum > Junction Flow
  - Mixture Continuity > Volume Mass
  - Mixture Energy > Volume Internal Energy
  - Water Properties > P = f(M,U)
- What Should Occur When a Volume Fills
  - There Should be No Significant Pressure Change
  - The Volume Should be Liquid Full
  - Time Rate of Change of Mass ~0 After Filling
- Balance Equation Solution Should be Revised to Account for Known Conditions
  - Only for Filling Volume

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Implicit Water Packing Mitigation Scheme (Cont'd)

- Detect a Water Packing Event for Time Step Just Solved
- Resolve the Time Advancement with a Reduced Time-Step Size
  - Estimate Time-Step Size Need to Fill Packed Volume with Liquid
  - Accurate Value for Time-Step Size is not Required
- Solve Revised Balance Equations for Packed Volume (Fully Implicit)
  - Inlet Mixture Momentum > Volume Pressure
  - Mixture Continuity > Inlet Junction Flow
    - Liquid Specific Volume > Mass Required to Fill Volume
  - Mixture Energy > Volume Internal Energy

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Implicit Water Packing Mitigation Scheme (Cont'd)

- Check Convergence
  - Is Quality = 0
  - If Not, Perform Another Newton-Raphson Iteration for TS
- Once Converged, Adjust Exit Flow so dM/dt = 0
  - Exit "To" Volume Should be Two-Phase
  - Instantaneous Adjustment
  - No Affect on Mass
- Testing Required
  - Vertical Channel Refill
  - SBO and/or OTSG SLB Transients - Problems in Past

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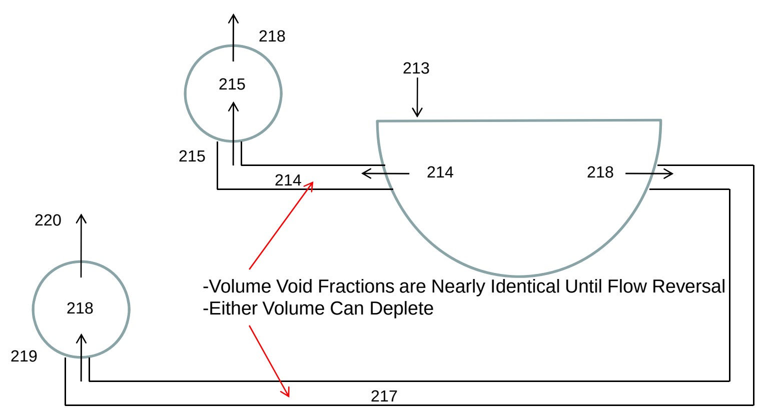
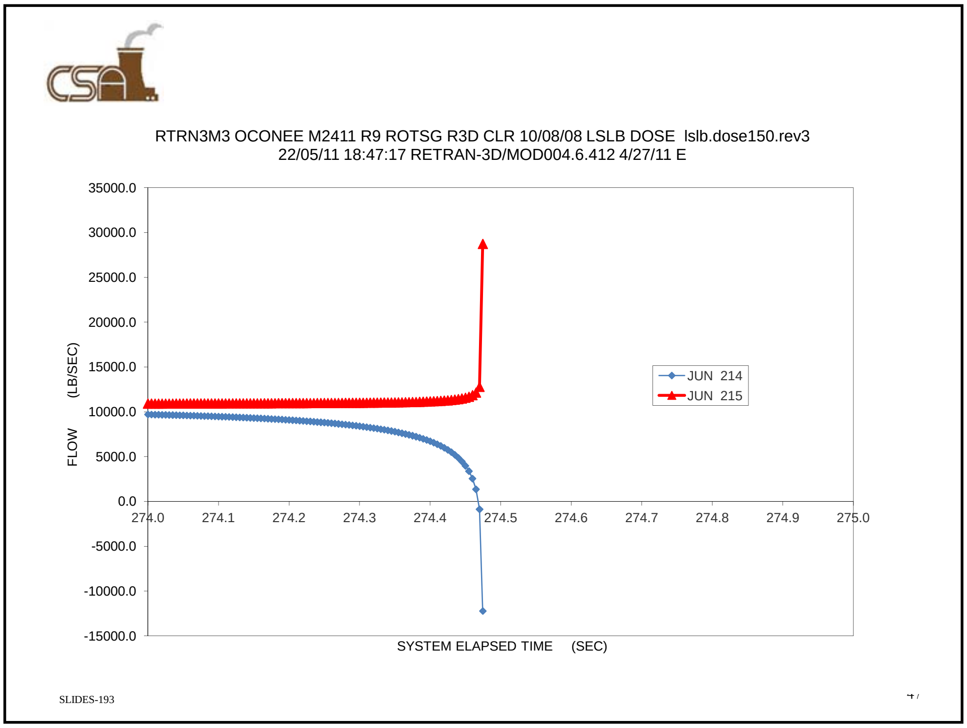
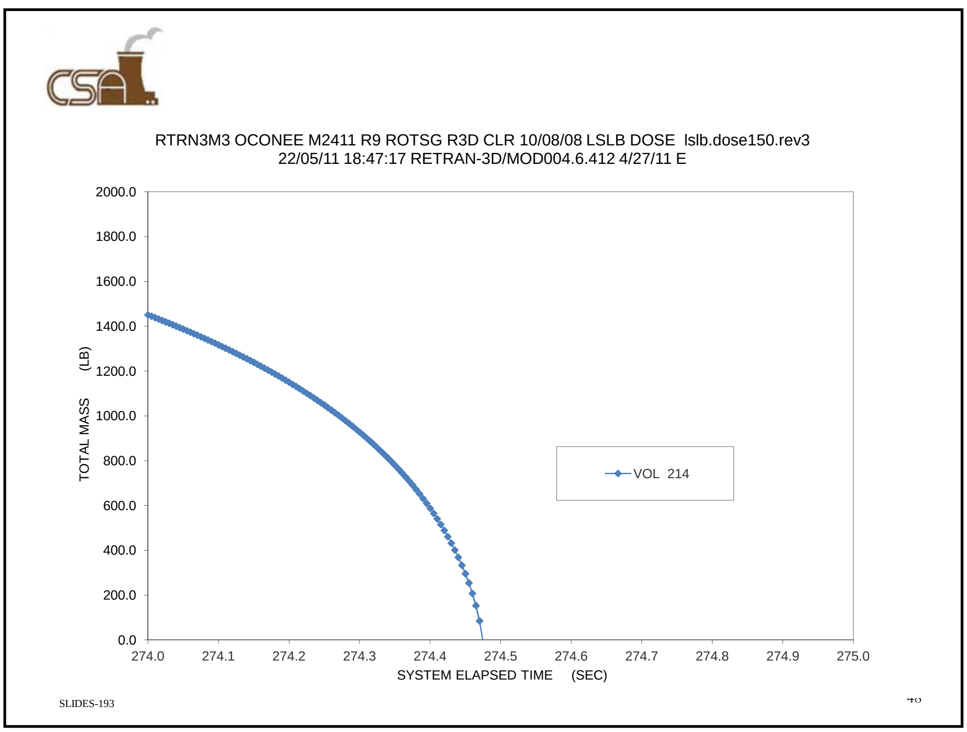
Momentum Flux Model Limitation

- Problem Fails with Negative of Zero Mass and/or Energy
- The Two-Phase Volume Rapidly Empties
  - Initiated by Flow Reversal at Inlet
  - Both the Inlet and Exit Flows Accelerate
  - Velocity Head Terms Extremely Large and Increase Rapidly
- Results for OTSG Model
  - Noding Diagram
  - Key Junction Flows
  - Volume Mass
  - Velocity Heads for Key Junctions

Momentum Flux Model Limitation (Cont'd)




RTRN3M3 OCONEE M2411 R9 ROTSG R3D CLR 10/08/08 LSLB DOSE lslb.dose150.rev3
22/05/11 18:47:17 RETRAN-3D/MOD004.6.412 4/27/11 E
FLOW (LB/SEC)
35000.0
30000.0
25000.0
20000.0
15000.0
10000.0
5000.0
0.0
-5000.0
-10000.0
-15000.0
274.0
274.1
274.2
274.3
274.4
274.5
274.6
274.7
274.8
274.9
275.0
SYSTEM ELAPSED TIME (SEC)
JUN 214
JUN 215
SLIDES-193


RTRN3M3 OCONEE M2411 R9 ROTSG R3D CLR 10/08/08 LSLB DOSE lslb.dose150.rev3
22/05/11 18:47:17 RETRAN-3D/MOD004.6.412 4/27/11 E
TOTAL MASS (LB)
2000.0
1800.0
1600.0
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
274.0
274.1
274.2
274.3
274.4
274.5
274.6
274.7
274.8
274.9
275.0
SYSTEM ELAPSED TIME (SEC)
VOL 214
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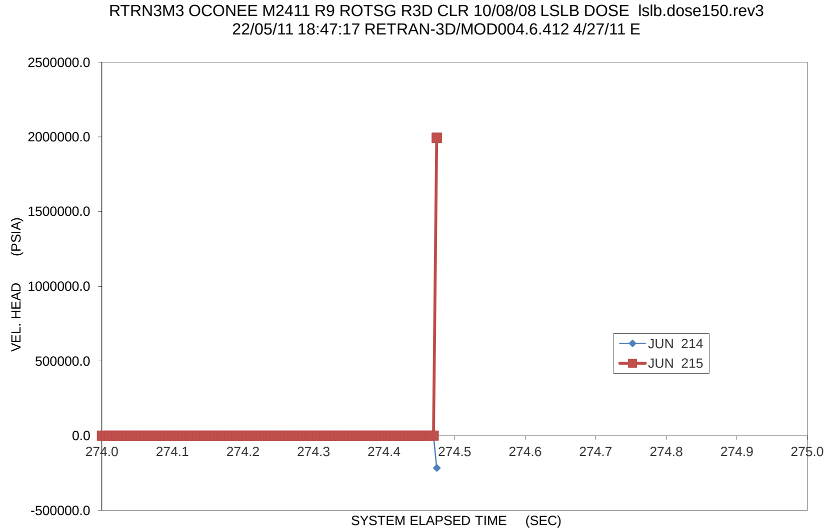

Momentum Flux Model Limitation (Cont'd)

- Momentum Flux Terms
  - $$\left(\frac{1}{\bar{\rho} A^2}\right)_K \overline{W}_K^2 \cos\theta_{j1} - \left(\frac{1}{\bar{\rho} A^2}\right)_L \overline{W}_L^2 \left|\cos\theta_{j2}\right| + \frac{1}{2\rho_j}\left[\frac{\sum_{j\varepsilon Out_k} \left|W_j\right|^2 \left|\cos\theta_{j1}\right|}{A_K^2} - \frac{\sum_{j\varepsilon In_L} \left|W_j\right|^2 \left|\cos\theta_{j2}\right|}{A_L^2}\right]$$
- Velocity Head has Mass in the Denominator
  - As Mass Goes to Zero
    - Velocity Head Becomes Infinite
    - Flows Accelerate
- Form of Model Becomes Numerically Unstable
  - Originates from RELAP4
    - Explicit
  - RETRAN-02 Uses Similar Formulation
    - Explicit
  - RETRAN-3D Formulation
    - Implicit Scheme Probably Exacerbates Problem

Momentum Flux Model Limitation (Cont'd)

- Alternate Momentum Flux Formulation has been Developed
  - Resolves Mass Depletion Problem Described
  - Testing with Other Problems Identified Significant Differences with Current Model
    - Have Not Evaluated Yet
  - Additional Testing Required
    - Standard Test Problems
    - SBO and/or OTSG SLB Transients
      - Cases that have Experienced Problems in the Past

Eliminating Code Failures During Two-Phase Transients

- Add Enhancements for Two Know Problems
  - Water Packing
  - Momentum Flux
- Evaluate Two-Phase Test Cases
- Identify Additional Problems
  - Resolve as Funding Permits

Automatic Pressurizer Thermal Stratification Model Nodalization

- Current Implementation Requires User to Define Finer Nodalization
- Automatic Nodalization
  - Expand Single Node Description
  - Define N Equal Size Subnodes
    - Volumes
    - Junctions
    - Heat Conductors

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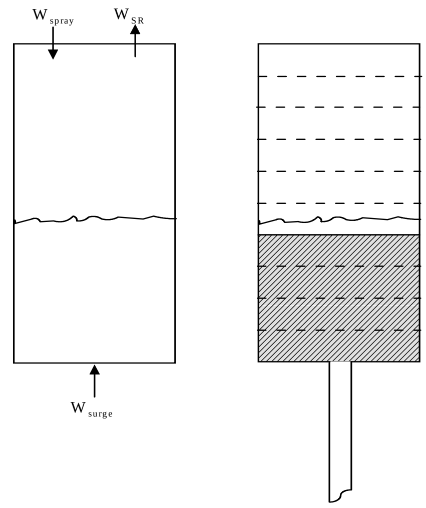
Automatic Pressurizer Thermal Stratification Model Nodalization (Cont'd)



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Revise Implicit Pressurizer Solution

- Currently have Explicit and Implicit Solutions
- NRC Approved Implicit
- Explicit Used Extensively
- Implicit Method More Robust
  - Required for Some Transients
  - Runtime Penalty Due to Implementation Method
- Revise Implicit Solution
  - Augmented Matrix – Runtime ~ Same as Explicit
  - Remove Explicit – Only One Solution - Approved

Improved Generalized Transport

- Solution Suffers from Numerical Diffusion
  - Related SER Condition
- Revise Solution
  - Higher Order Solution
  - Mitigate Undesirable Numerical Diffusion
- Perform Validation

Linux gfortran Compiler

- Discussed Last RVUG – Nothing Done
- All Linux Computers have Access to gfortran
  - No Additional Cost for Compiler
  - Some Testing Done at MOD004.5f95
    - Problems Encountered with 3-D Kinetics Samples
    - Cause may have been Identified
- Current Linux Installation Procedures Apply
  - Compiler Options
- Further Testing Beneficial for Linux Users
  - Compare Results with Intel Compiler Version
  - Compare Run Times

Duke Energy Oconee SSF Analyses

Jeff Abbott

RETRAN/VIPRE User's Group Meeting

June 12-13, 2012

Oconee SSF

- SSF = Standby Shutdown Facility
- Originally licensed in 1982 to augment existing Systems to keep plant ≥ 525 °F Tavg and 1% subcritical for up to 72 hours
  - To mitigate fires, floods, and security events
  - No T&H analyses submitted to support design basis
- NRC insisted Duke add SSF to Tech Specs
- During Tech Spec LAR/RAI responses, applicability extended down to Tavg ≥ 250 °F
- SSF also credited for SBO mitigation
  - No T&H analyses submitted to support

ONS SSF

- SSF consists of
  - Independent power source (diesel generator)
  - Independent RC makeup system (positive displacement pump) for RCP seal cooling
  - Independent letdown system
  - Independent means of EFW (called Auxiliary Service Water, or ASW) which pumps lake water into the SGs
  - Independent control of pressurizer heaters
  - Manually activated

Duke Energy®

RETRAN-02 Analysis Evolution

- Duke first performed an SSF analysis in 1986 to bound a fire, flood, and security event
  - Used RETRAN-02, Mod 2
  - Demonstrate sufficient ASW flow available for DHR removal
- Analysis updated over the years to model reduced pressurizer heater capacity, reduced makeup flow, and increased pressurizer ambient heat losses
  - 2002 first analyzed water solid pressurizer condition
- Analysis always performed at EOC 100%FP conditions

Duke Energy®

RETRAN-02 Analysis Evolution

- 2006 Duke determined extraction steam loads not automatically isolated on turbine trip (no MSIVs)
  - Leads to an overcooling event if not isolated
  - Duke first analyzed lower decay heat conditions
    - Defined as ≥ 4 EFPD, 100 %FP
- 2011 NRC questioned use of R2 for natural circulation and water solid pressurizer
  - "unsteady" natural circulation – see plots
  - NRC neither approved or disapproved use of R2 for this condition
  - NRC requires submittal prior to approval

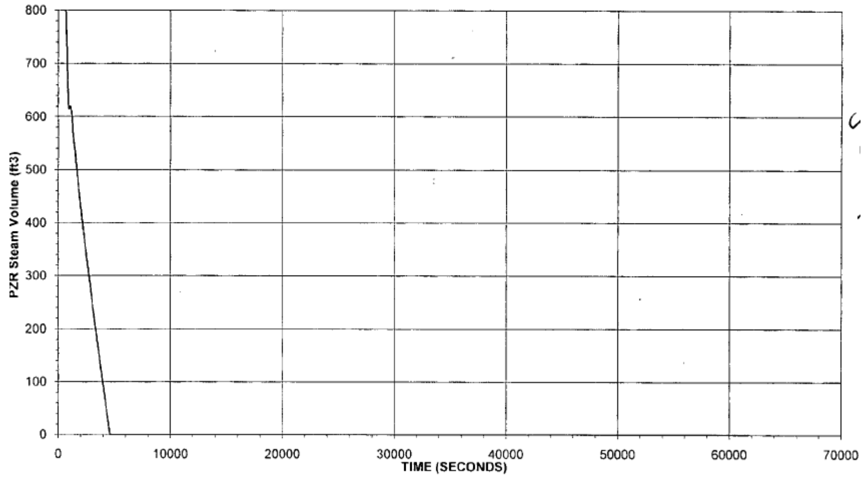
Duke Energy®

RETRAN-02 Analysis Evolution

- 2012 special team formed by Duke issued a corrective action stating SSF unanalyzed at
  - < 4EFPD
  - < 100 %FP
  - < MODE 1
- Safety Analysis reran RETRAN-02 for low decay heat conditions
- Safety Analysis converted RETRAN-02 to RETRAN-3D and reran for low decay heat conditions (more later)

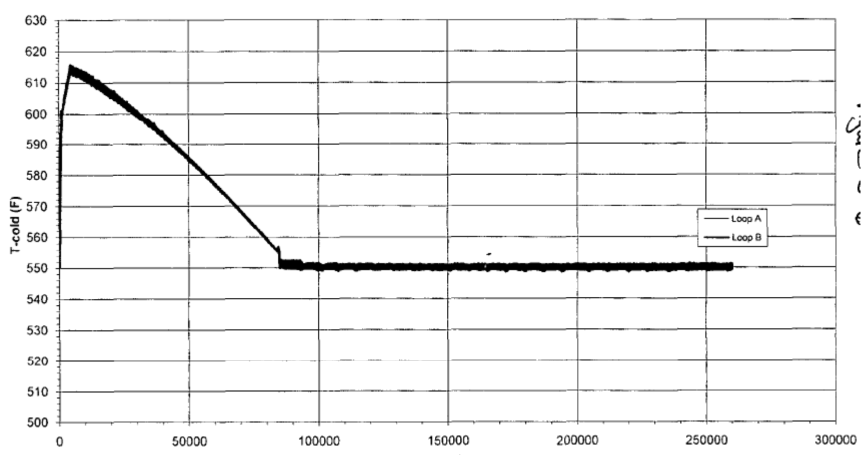
Duke Energy®

Water Solid



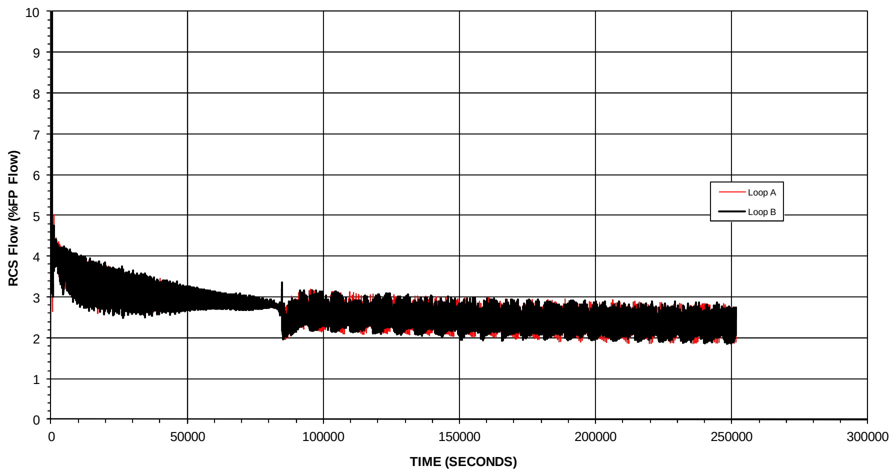
Duke Energy

Water Solid



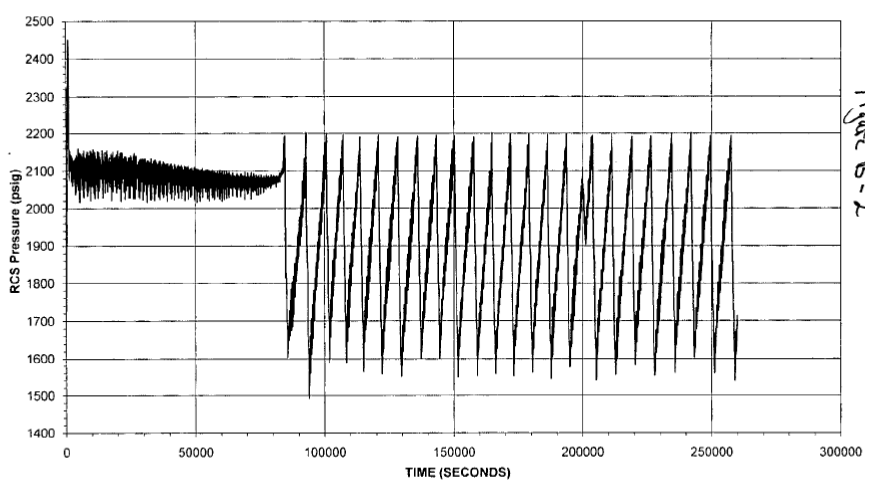
Duke Energy

Water Solid



Duke Energy

Water Solid



Duke Energy

RETRAN-3D Low Decay Heat Analysis

- R3D results similar to R2
- Acceptance criteria used are for Appendix R Fire (abbreviated list)
  - Pressurizer level remains on-scale
  - Maintain MODE 3 (Tavg ≥ 250 °F) for 60 hours
  - Keep reactor subcritical
- Other acceptance criteria as defined for the SSF over the years (abbreviated list)
  - Keep RCS intact
  - Assure natural circulation for adequate core cooling
  - Do not intentionally cool the plant below 525 °F

Duke Energy

RETRAN-3D Low Decay Heat Analysis

- 0 EFPD, 100 %FP case results follow
  - Not ultimately used in the end to justify operability
  - Illustrates the problem extreme
- 0 EFPD, < 100 %FP cases difficult to maintain pressurizer level on-scale
  - Turbine Driven EFW flow on loss of RCPs overcools RCS
  - Requires fast, manual , operator action to stop EFW flow

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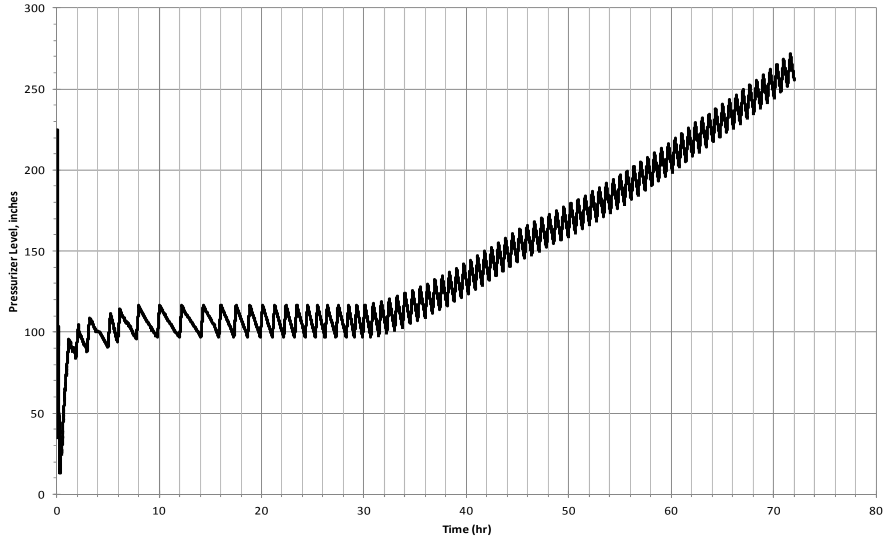
Low Decay Heat – R3D



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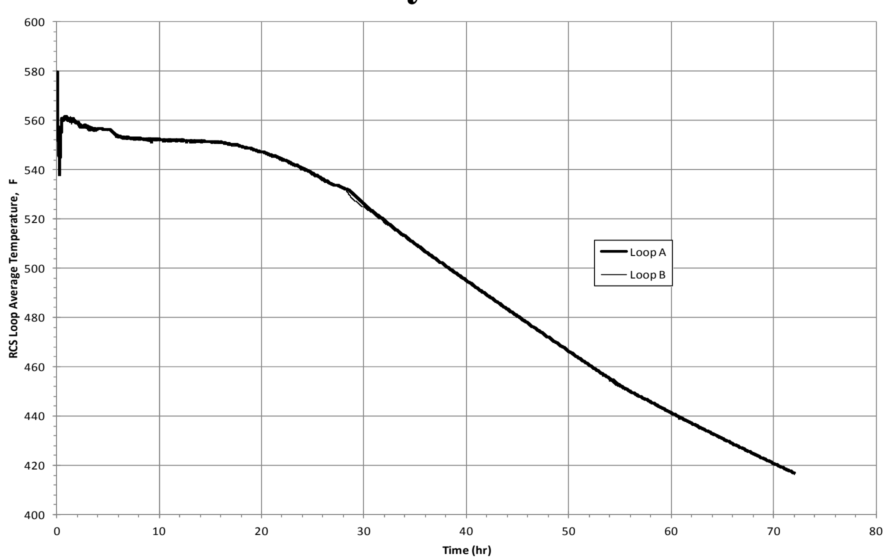
Low Decay Heat – R3D



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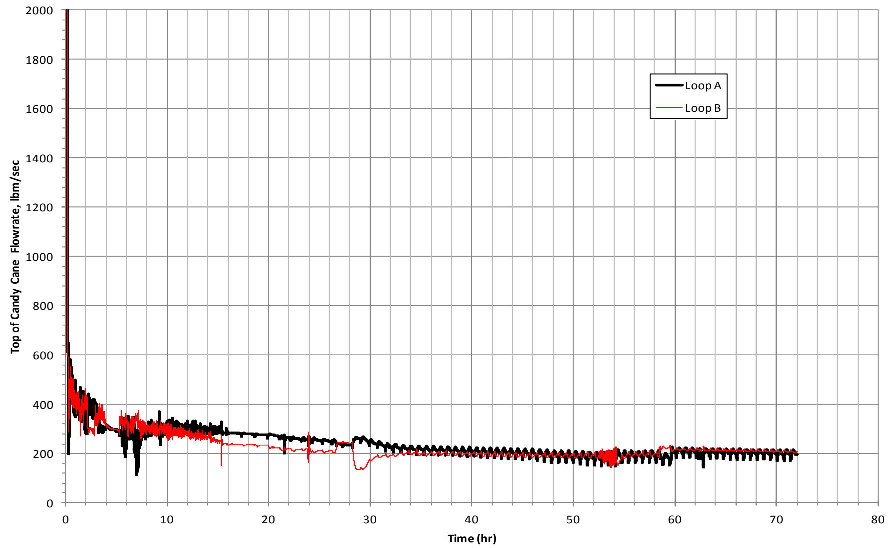
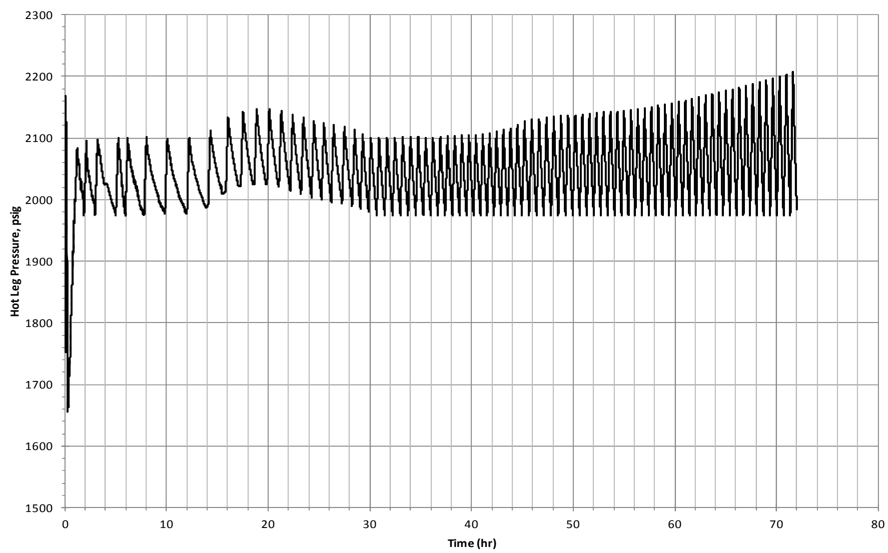
Low Decay Heat – R3D



Duke Energy

Low Decay Heat – R3D



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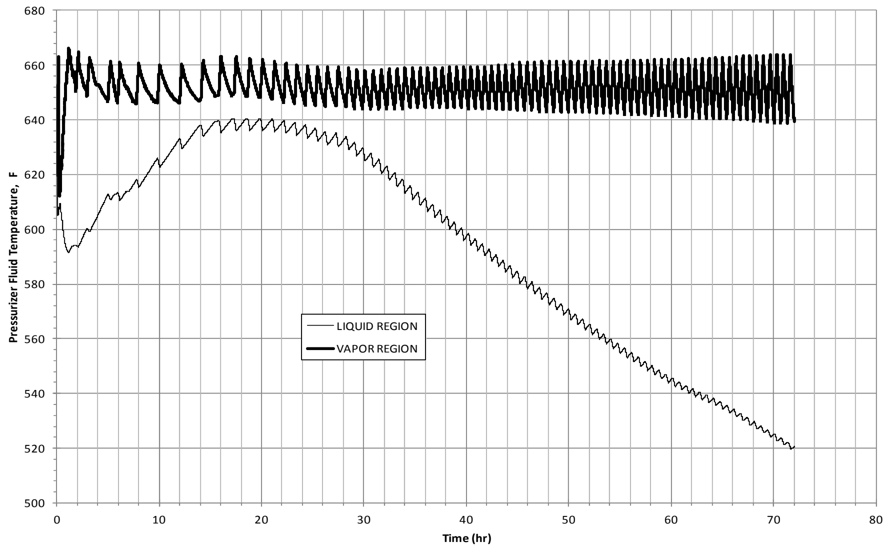
Low Decay Heat – R3D



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Low Decay Heat Results

- **Ultimately chose 1.3 days operation at >98%FP as minimum acceptable time for decay heat buildup based on RETRAN-02**
- **Issues with subcooled water overwhelming pzr heaters**
  - **Need pressurizer thermal-stratification model**
  - **Need to have high degree of confidence in such modeling (i.e., benchmark data)**
- **RETRAN results questionable if lose natural circulation**
  - **Depends on when flow stagnates (early overheating, late overcooling)**
  - **Depends on RCS ambient heat loss modeling**
  - **Operator actions keyed off Tcold response, pressure response, pressurizer level response and those responses are impacted by presence of natural circulation**

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Low Decay Heat Results

- If lose natural circulation
  - Pressurizer expected to stay on-scale due to makeup and letdown control
- RCS ambient heat loss modeling becomes more and more important with lower and lower decay heat
- Need ability to intentionally cool the plant down
  - SSF not designed to cool plant down so operators attempt to keep temperatures elevated
  - Impossible to do with low decay heat
- Even if plant cools down naturally, no safety concerns
  - Core will remain covered
  - Pressure boundary will remain intact

Duke Energy®

VIPRE-01 SI Units Review

John Shatford
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RETRAN/VIPRE User Group Meeting
Jackson Hole, Wyoming
June 12-13, 2012

SI Units Code Review

- Review SI Units Input/Output Option
  - Several Recent Trouble Reports Filed on SI Usage
    - Internal Conversion Errors
  - SI Option is Relatively Unused by US VUG
  - Concern that Values May be Incorrect and the Code Does not Fail
  - Comprehensive Review Undertaken
    - Test Matrix for All Options
  - SI Support is Important for International Members

SI Units Code Review (Cont'd)

- VIPRE-01 SI Units Options
  - NUNITS (Word 4) on ***vipre.1*** card = 1
  - User Supplies Input Data in SI Units
  - VIPRE-01 Converts SI Data into British Units Internally
  - All Calculations Within VIPRE-01 are Performed Using the Internal Working Units
  - Calculated Results are Converted to SI Units Before Output Edits are Printed

SLIDES-190 3

SI Units Code Review (Cont'd)

- VIPRE-01 SI Units Options (Cont'd)
  - NUNITS (Word 4) on ***vipre.1*** card = -1
  - User Supplies Input Data in British Units
  - All Calculations within VIPRE-01 are Performed Using the Internal Working Units (British)
  - Results are Converted to SI Units Before Output Edits are Printed

SLIDES-190 4

SI Units Code Review (Cont'd)

- Review VIPRE-01 MOD02.4f95 and Determine if SI Implementation is Correct
  - Two Arrays Contain Conversion Factors for Unit Conversion
    - convi() Converts SI Input into Working Units
    - convf() Converts Working Units to SI Output
- Visually Examine Code for Correct Use of NUNITS, CONVF() and CONVI()
- Verify Conversion Factors are Correct

SI Units Code Review (Cont'd)

- One Current Trouble Report Already Filed for Problem in SI Usage
  - TR-259 (mod_276) Address Issues with Flow Specification in SI Units
- Modifications From This Evaluation Will Be Included in mod_276
- 5 Subroutines Required Modification
  - *mkase, oper, reslt2, setin*, and *state*

SI Units Code Review (Cont'd)

- Subroutine mkase
  - Revised logic for all input flow specification combinations (IG=1,2,3,4, ISP=1,2,3)
  - Revised logic for enthalpy/temperature forcing functions input options
  - Added logic for pressure forcing functions in absolute SI units
  - Added logic for power forcing functions in absolute SI units
- Subroutine reslt2
  - A block of fuel rod edits in working units if direct solution 3 (idirect==3) selected
  - Logic revised to change write statements to print SI units
  - Added logic to generate AOA file in SI units
- Subroutine oper
  - Revised Logic for BWR inlet enthalpy balance input (OPER.7 cards) so that units for "qsys" are correct.
- Subroutine setin
  - Logic revised so rod temperature convergence "terror" in SI converted to working units. (convert K to oF)
- Subroutine state
  - Logic revised so error message variables "hfmsi" and "hfmaxsi" are converted to SI units

SI Units Code Review (Cont'd)

- Standard Test Cases
  - Cases 1 - 6 are VIPRE-01 Standard Test Case Set
  - Cases 7 – 12 are SI Output Versions of 1 – 6 (NUNITS = -1)
  - Create New SI Input/Output Versions (NUNITS = 1)
  - Cases 17, 18, 20, 23, 24, and 25 Develop SI Input/Output (NUNITS = 1) and SI Output (NUNITS = -1) Cases
- RESTART Test Cases
  - Case 13 Standard RESTART Test Case
  - Case 14 is SI Output Version (NUNITS = -1)
  - Create SI Input/Output (NUNITS = 1) Version

SI Units Code Review (Cont'd)

- Test Cases from Trouble Report 259
  - 16 SI Input Test Cases
    - All Possible Combination of Flow Specifications
    - Mass Flow, Mass Flux, and Volumetric Flow
    - Relative and Absolute Forcing Functions
- Create New Test Cases
  - 7 SI Input Test Cases
    - Power as Heat Rate (NPOW=0) and Average Heat Flux (NPOW = 2)
    - Absolute and Relative Pressure Forcing Functions
    - Absolute and Relative Enthalpy Forcing Functions
    - Absolute and Relative Temperature Forcing Functions

SLIDES-190

9

SI Units Code Review (Cont'd)

- Three Stages of Testing to Check the Validity and Accuracy of the SI Unit Edits
  - Compvip Program ("Cv4") is Used to Compare the SI Output Cases Against the SI Input/Output Cases
    - Use 1% Tolerance Reasonable to Demonstrate that SI Unit Input is Correct and the Internal Conversions are Correct
  - Line-by-Line File Comparison of SI Output Cases with SI Input/Output Cases Using the ExamDiff Program
  - SI Output Edits Converted to British Units in Excel Spreadsheet and Compared to the Base Case Edits in British Units

SLIDES-190

10

SI Units Code Review (Cont'd)

- Each Type of Edit was Examined
  - Geometry Data Edit
  - Operating Conditions Edit
  - Channel Inlet Conditions Edit
  - Channel Exit Summary
  - Bundle Average Results Edit
  - Cell Edge Values Edit
  - Rod Geometry Description
  - Rod Edit (Idrect = 2)
  - Rod Edit (Idrect = 3)
  - Cross Flow Results
  - CHF Calculation Edit
  - Dynamic Gap Conductance Edit

SI Units Code Review (Cont'd)

- Testing Complete
  - SI Input Tested Successfully
  - SI RESTART Case Tested Successfully
  - SI CHF DLL Test Completed Successfully
  - SI BOA AOA Case Tested Successfully
  - SI VBC file is not Currently Implemented
  - SI Binary Forcing Function File is not Implemented

SI Units Code Review (Cont'd)

- Review Documentation
  - Table of Unit Conversion Factors (Page 2-8 User's Manual)
  - Table Defines SI Units Assumed for VIPRE-01 Input
  - Some Code Manual Changes were Suggested to Clarify the Input Required for SI Units
  - Documentation has been Marked up to add SI Units Everywhere Input Units are Described

SI Units Code Review (Cont'd)

British unit	SI unit to be used	conversion factor (British=SI*factor)
inches	meters	39.370
$in.^2$	m^2	1.5500e+3
$in.^3$	m^3	6.10237e+4
psi	n/m^2	1.45038e-4
lbm/ft^3	kg/m^3	0.06242796
ft^3/lbm	m^3/kg	16.0185796
ft/sec	m/s	3.28084
Btu/sec	w	9.47817e-4
Btu/lbm	j/kg	4.29923e-4
lbm/sec	kg/s	2.204623
lbf/ft	n/m	0.06852
kw/ft	kw/m	0.3048
$Btu/hr\text{-}ft^2$	w/m^2	0.316998
lbm/hr-ft	$n.s/m^2$	2.419099e+3
Btu/hr-ft-°F	w/m-°K	0.577789
Btu/lbm-°F	j/kg-°K	2.388459e-4
$Btu/hr\text{-}ft^2\text{-}°F$	$w/m^2\text{-}°K$	0.176113
$mlbm/hr\text{-}ft^2$	$kg/s\text{-}m^2$	7.373585e-4
Btu/sec-ft	j/s-m	2.88895e-4

SI Units Code Review (Cont'd)

- Observations
  - Input with SI Units is More Sensitive to the Number of Significant Figures Specified
    - Channel Height of 144.0 inches Becomes 3.658 m
    - Operating Pressure of 2244.4 psia Becomes 1.547E+07 n/m2
  - User Needs to Provide More Significant Digits to get the Correct Modeling
  - However, User must be Mindful of Rule 3 on Page 2-3 of the User's Manual
    - Maximum Number of Digits for any Input Item is 10 Including the Decimal Point

Validation of iSAM Using the Plant Startup Test

RETRAN/VIPRE User Group Meeting

June 12, 2012

Jinwoo Park, Chansu Jang (KEPCO NF)

KEPCO NF

SINCE 1982

I. Overview

- **PURPOSE OF ANALYSIS**

  Validation of KNF safety analysis method(iSAM*)

- **OBJECT UNIT & TEST CASE**

  Yonggwang unit 3, natural circulation and turbine trip

- **VALIDATION METHODOLOGY**

  Comparison with Yonggwang unit 3 measured plant data

*** iSAM**

• Acronym of "Integrated Non-LOCA Safety Analysis Methodology"

• Using RETRAN model for the analysis of Non-LOCA transients

II. Analysis Methods

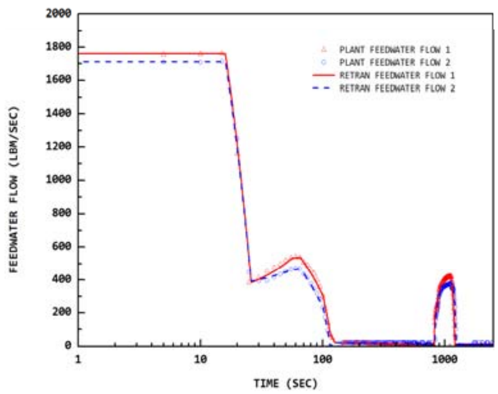
- **Initial Conditions**

Parameters	Values
Core Power, % of nominal	98.61
Core Inlet Temperature, ˚F	565.3
Pressurizer Pressure, psia	2252.03
Pressurizer Level, %	51.8
SG Level, %	43.8
RCS Flow Rate, gpm	347.707
FW Flow Rate, lbm/sec	1736.0
FW Enthalpy, Btu/lbm	432.2

- **Core physics parameter : BOC (Beginning-Of-Cycle)**
  - Small negative moderator temperature coefficient
  - Minimum doppler feedback
  - Maximum delayed neutron fraction

II. Analysis Methods

- Forcing Functions

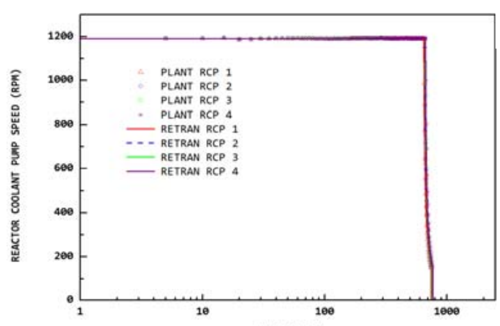


- Because of the irregularity of the measured data, main feedwater flow rate and steam bypass dump valve flow rate profile obtained from the plant test are directly used in RETRAN model

II. Analysis Methods

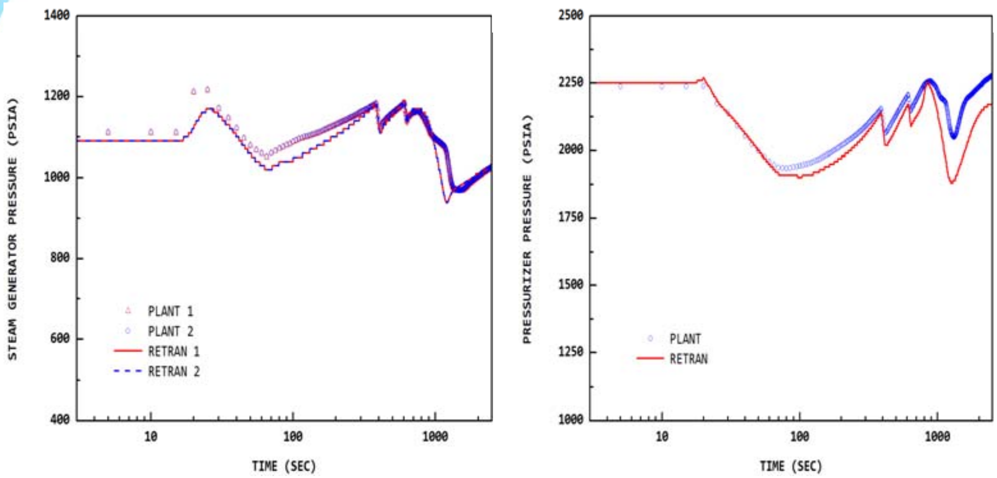
- Sequence of events

Events	Plant (sec)
Turbine trip	15
Reactor trip	16
Steam bypass valve open	20, 400, 625
RCPs trip	650, 660, 665, 670

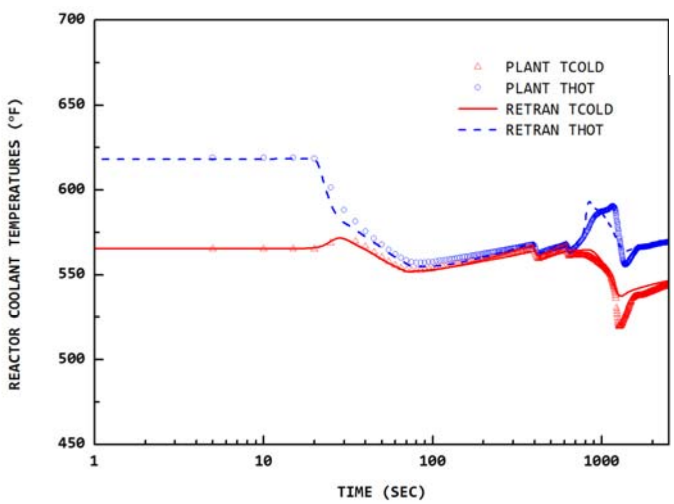


- To simulate the natural circulation and turbine trip test, the manual trips of turbine and reactor coolant pumps are considered in RETRAN model

III. Results of Comparison



III. Results of Comparison



III. Results of Comparison

Estimation of power-to-flow ratio

- Power-to-flow ratio is considered as the important parameter to check the cooling effect by the natural circulation
- If power-to-flow ratio is less than one, RCP's coastdown can be cooled down by natural circulation
- Power-to-flow ratio normally estimated as the ratio of the enthalpy difference between cold legs and hot legs on nominal condition
- Predicted power-to-flow ratio during stable natural circulation phase is 0.37

IV. Conclusion

- In order to validate the applicability of the iSAM, Yonggwang unit. 3 natural circulation and turbine trip test is simulated with KNF standard RETRAN model.
- The results of the simulation were compared with measured plant data.
- Comparison results show that principal behaviors predicted by RETRAN model are quite similar to the measured plant data.
- Estimated power-to-flow ratio 0.37 is close to the plant data 0.45


THANK YOU

Steam Generator U-Tube Bundle Uncovery for Dose Calculations

Presented by Adam Bingham to RETRAN / VIPRE User Group
June 12th, 2012

Overview

- Background on Steam Generator U-Tube Bundle Uncovery Issue
- Supporting Work
- Current Analysis of Non-SGTR* Events
- Summary and Questions

*SGTR = Steam Generator Tube Rupture

Steam Generator U-Tube Bundle Uncovery Background

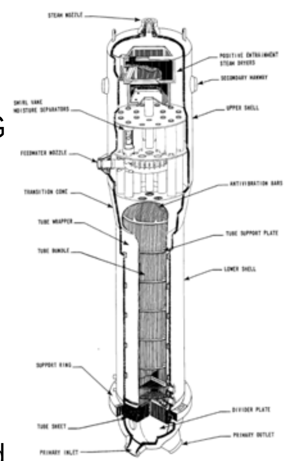
- In 1987, W* notified utilities of potential for increased radioactivity release following reactor trip due to SG* U-tube bundle uncovery
  - Issue identified following SGTR event at North Anna 1 in July 1987
  - Current analyses that resulted in secondary steaming to environment did not consider possibility of SG tube rupture / leakage site being uncovered
- The W Owners Group (WOG) initiated a program in 1988 to investigate U-tube bundle uncovery effects and develop generic resolution

*W = Westinghouse *SG = Steam Generator

3

WOG Investigation

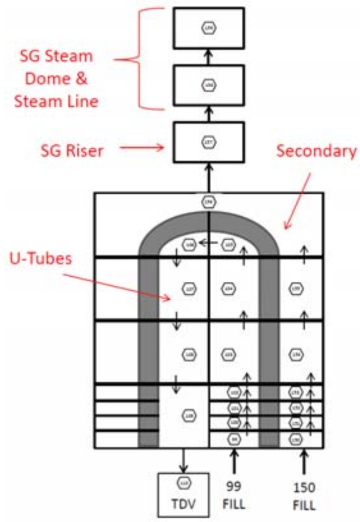
- WOG program investigation included experimental testing and computational analysis
- Developed analytical methodology for predicting SG two-phase mixture level for representative plant
- Generic analyses developed for SGTR and Non-SGTR events:
  - Locked Rotor
  - Rod Ejection
  - Single Uncontrolled Rod Withdrawal (Rod Control Cluster Assembly Withdrawal)
- Duke pursued deterministic approach for SGTR and Non-SGTR FSAR analyses



4

Determination of SG Two-Phase Mixture Level

- Developed special SG RETRAN model
  - Based on existing SG model for accident analyses
  - Separated from primary system model
  - Primary system and auxiliary feedwater conditions supplied as boundary conditions through TDV* and fill junctions based on separate transient analysis
  - Removed downcomer and recirculation junctions / volumes (non-recirculation conditions)
  - Finer nodalization of lower tube bundle region and primary U-tube inlet volumes
  - Dynamic Slip option used to calculate bubble velocity



*TDV = Time-Dependent Volume

Determination of SG Two-Phase Mixture Level

- Parameters of interest:
  - Onset of boiling location (length of tube bundle required to heat AFW* to saturation)
  - Bubble velocity
- Several non-SGTR scenarios investigated
  - Primary side forced and natural circulation flow
- Model initialized with no flow and conditions near those of separate transient analysis major edit of interest
  - Primary and secondary flows ramped up to major edit values
  - Model stabilizes at near SS* at conditions with minimal U-tube bundle uncovery
- Results from various transient conditions provide a representative bubble velocity and boiling length for forced and natural circulation flow
  - Used to calculate bubble lifetime in two-phase mixture
  - Translates to swelled two-phase mixture volume when given the SG steaming rate

*AFW = Auxiliary Feedwater *SS = Steady-state

Determination of SG Two-Phase Mixture Level

- Swelled two-phase mixture volume is translated to mixture level based on SG geometry
- Two different mixture level coverage criteria assuming rupture / leakage occurs at top of U-tube bundle
  - SGTR – considers primary fluid jetting effect for large tube ruptures immersed in secondary mixture, based on WOG investigation from experimental testing
  - Non-SGTR (TS* leakage) – small primary leakage conditions (100-150 GPD*/SG), insufficient flow for significant primary fluid jetting => lower mixture level required to provide U-tube bundle coverage
- Given the mixture level required for U-tube bundle coverage and the bubble lifetime, approximation for onset of tube bundle uncovery and uncovery duration can be made for SGTR and non-SGTR events

*TS = Tech Spec *GPD = Gallon Per Day

7

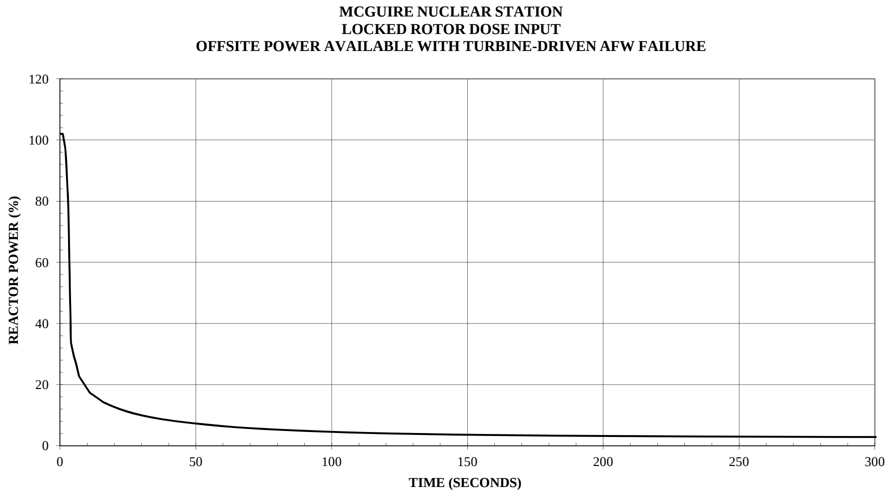
Analysis of Non-SGTR Events

- Equations and transient parameters necessary for calculating SG swelled two-phase mixture level implemented in RETRAN control system
  - Reduces need for external calculations
  - Finer tracking of two-phase mixture level => margin gain (rod ejection)
  - Accounts for increased SG mixture swelling due to increased steaming following opening of steam line PORV / SV*
  - Credits shock wave effect on SG bubble presence following main steam PORV / SV closure – neglects mixture swelling for determinate time period to model bubble collapse
- Additional control system implemented to initiate controlled RCS cooldown
  - Extends transient analysis to assess long-term response of key dose parameters
    - Secondary steaming rate and total steamed mass
    - Primary-to-secondary leakage
    - SG liquid mass

*PORV = Power Operated Relief Valve *SV = Safety Valve *RCS = Reactor Coolant System

8

Analysis of Non-SGTR Events – Locked Rotor



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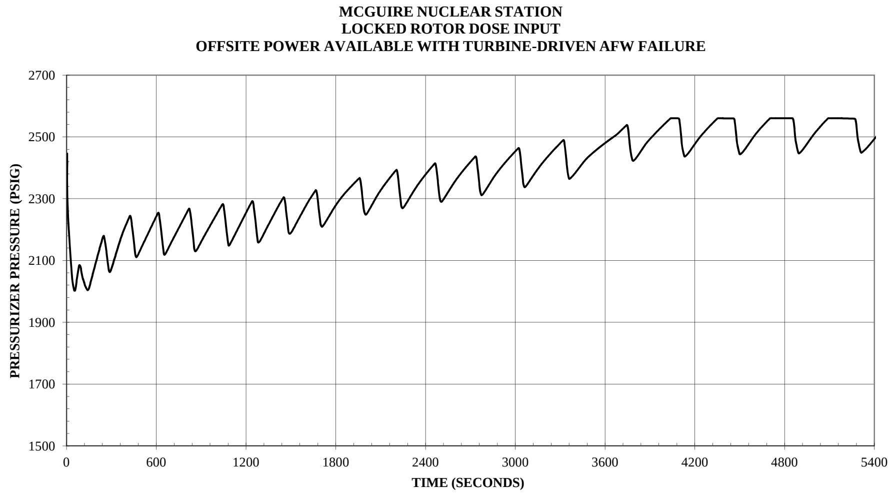
Analysis of Non-SGTR Events – Locked Rotor



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Analysis of Non-SGTR Events – Locked Rotor

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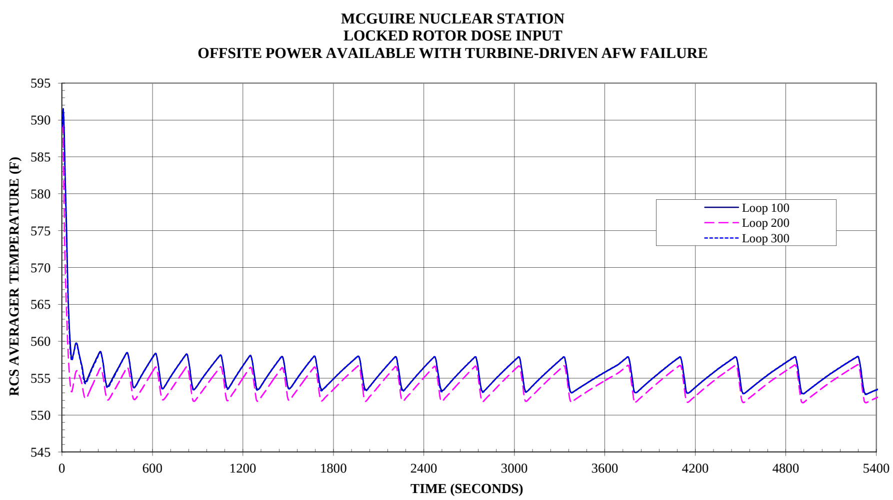
Analysis of Non-SGTR Events – Locked Rotor



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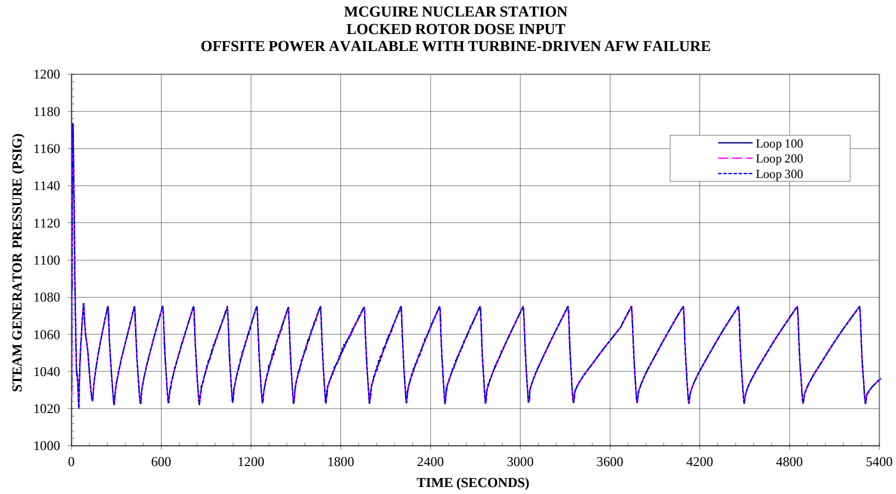
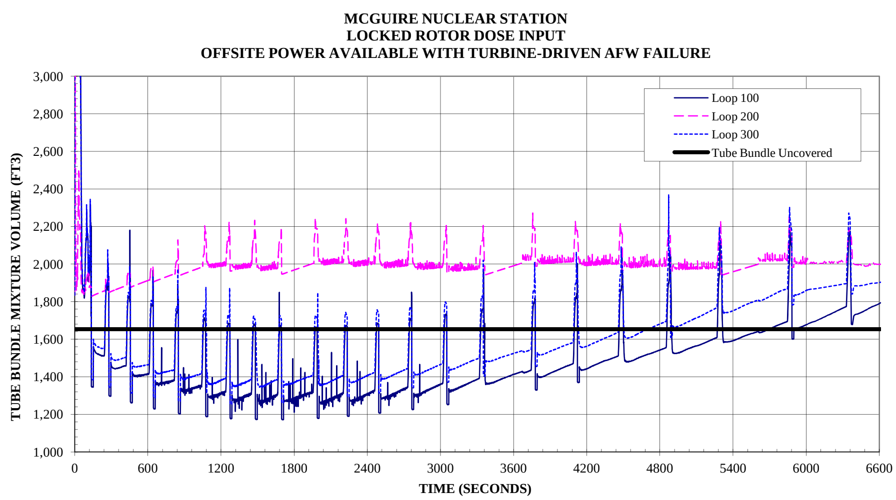
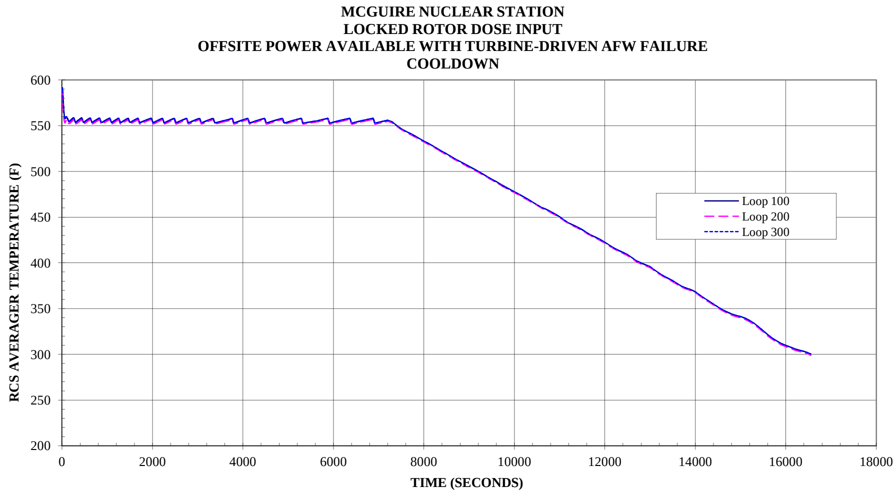
Analysis of Non-SGTR Events – Locked Rotor



Analysis of Non-SGTR Events – Locked Rotor



Analysis of Non-SGTR Events – Locked Rotor



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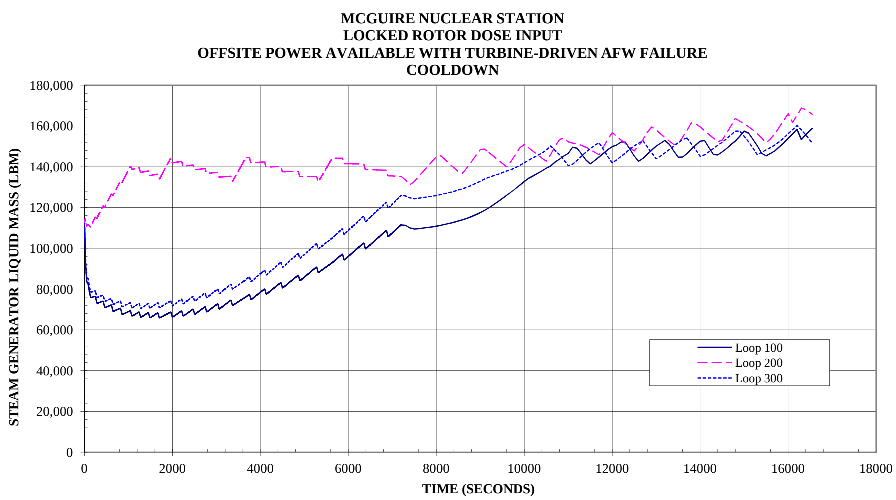
Analysis of Non-SGTR Events – Locked Rotor



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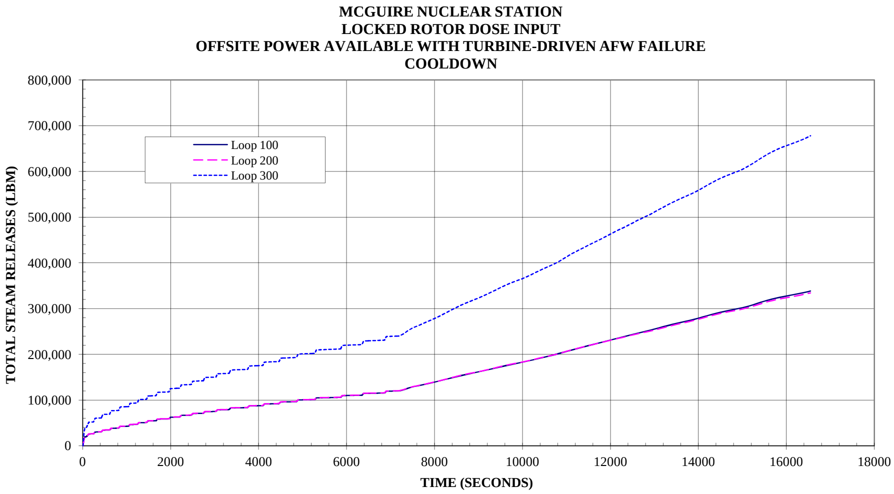
Analysis of Non-SGTR Events – Locked Rotor



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Summary

- History of U-tube bundle uncovery issue
- WOG Program evaluations
  - Insights gained through analytical and experimental evaluations
- Development of Duke Energy U-tube bundle uncovery methodology for SGTR and Non-SGTR events
  - Two-phase mixture level calculation
- Results from recent application and enhancement of methodology for Non-SGTR events
  - Separate two-phase mixture level criterion for U-tube bundle coverage
  - Multiple control system implementations for tracking SG two-phase mixture level and key dose parameters for RCS cooldown scenarios

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QUESTIONS?

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VIPRE-01 PSBT Benchmark

Presented by

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RETRAN/VIPRE User Group Meeting
Jackson Hole, WY
June 12-13, 2012

PSBT Benchmark

- NUPEC PWR Subchannel Benchmark Tests (PSBT)
- OECD/NEA/NRC Sponsored International Benchmark
- Steady-State and Transient Conditions
- Subchannels and Full Bundles
- Comparisons with Experiments and Other Codes
- Results will be Published by the OECD Benchmark Team

PSBT Benchmark (Cont'd)

- NUPEC PSBT Benchmark Exercise Definitions

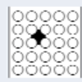
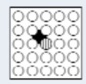
Phase I – Void Distribution Benchmark
  Exercise 1 – Steady-State Single Subchannel Benchmark
  Exercise 2 – Steady-State Bundle Benchmark
  Exercise 3 – Transient Bundle Benchmark
  Exercise 4 – Pressure Drop Benchmark

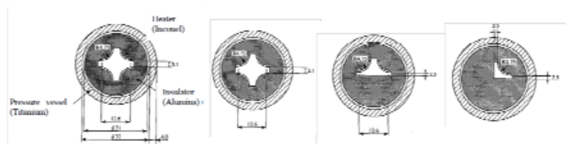
Phase II – DNB Benchmark
  Exercise 1 – Steady-State Fluid Temperature Benchmark
  Exercise 2 – Steady-State DNB Benchmark
  Exercise 3 – Transient DNB Benchmark

PSBT Benchmark (Cont'd)

- PSBT Benchmark – Phase 1
  - Generate Models and Results for Phase 1 Exercises
  - Steady State and Transient
  - Void Fraction Comparisons
  - Expands VIPRE-01 Validation Base for PWR Conditions
  - Contributions to VIPRE-01 Applications Manual
  - Submit Results to the OECD Benchmark Organization
  - Phased Effort – DNB Tests in Phase 2 (2012 Proposed)

Single Subchannel Benchmark

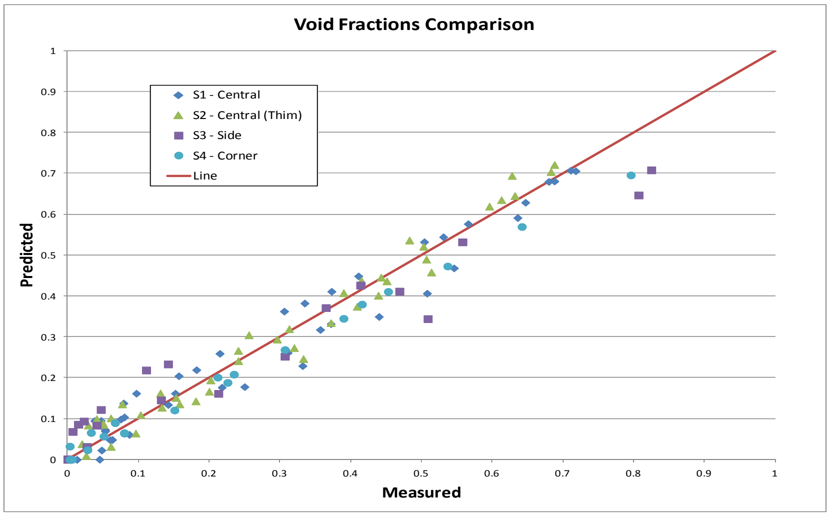
Item	Data			
Assembly (Subjected subchannel)	 S1	 S2	 S3	 S4
Subchannel type	Center (Typical)	Center (Thimble)	Side	Corner
Number of heaters	4×1/4	3×1/4	2×1/4	1×1/4
Axial heated length (mm)	1555	1555	1555	1555
Axial power shape	Uniform	Uniform	Uniform	Uniform



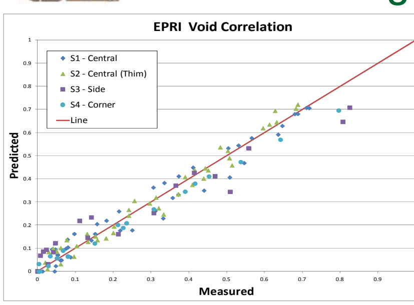
Single Subchannel Benchmark (Cont'd)

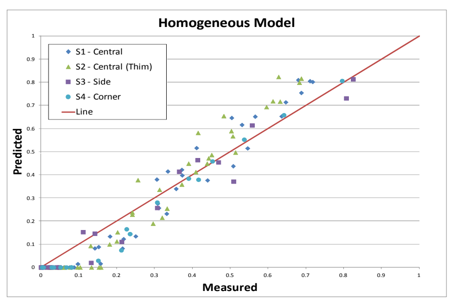
- Void Fraction
  - Heated Length 1555 mm 61.22 inch
  - Measurement 1400 mm 55.12 inch

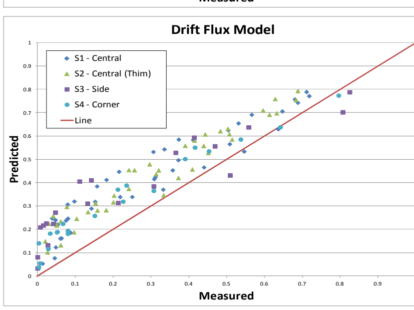
PSBT Single Subchannel

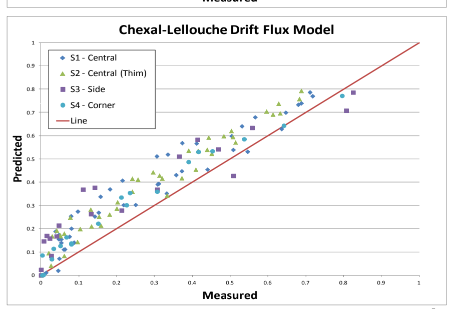


PSBT Single Subchannel Results

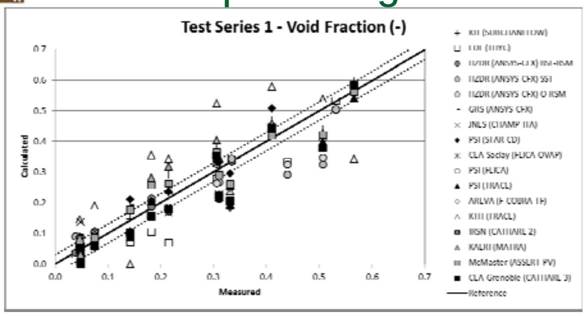


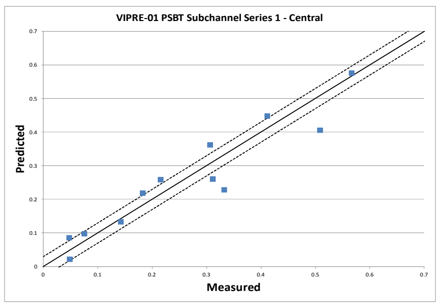






Compare Single Subchannel





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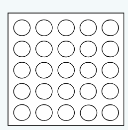
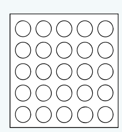
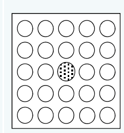
PSBT Steady-State Bundle Tests

Item	Data		
Assembly			
	B5	B6	B7
Rods array	5×5	5×5	5×5
Number of heated rods	25	25	24
Number of thimble rods	0	0	1
Heated rod outer diameter (mm)	9.50	9.50	9.50
Thimble rod outer diameter (mm)	-	-	12.24
Heated rods pitch (mm)	12.60	12.60	12.60
Axial heated length (mm)	3658	3658	3658
Flow channel inner width (mm)	64.9	64.9	64.9
Radial power shape	A	A	B
Axial power shape	Uniform	Cosine	Cosine
Number of MV spacers	7	7	7
Number of NMV spacers	2	2	2
Number of simple spacers	8	8	8
MV spacer location (mm)	471, 925, 1378, 1832, 2285, 2739, 3247		
NMV spacer location (mm)	2.5, 3755		
Simple spacer location (mm)	237, 698, 1151, 1605, 2059, 2512, 2993, 3501		

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PBST Steady-State Bundle Tests

- S5 Test Repeated – Series S8
- Radial Power Distribution

0.85	0.85	0.85	0.85	0.85
0.85	1.00	1.00	1.00	0.85
0.85	1.00	1.00	1.00	0.85
0.85	1.00	1.00	1.00	0.85
0.85	0.85	0.85	0.85	0.85

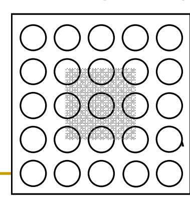
Series S5,S6, & S8

0.85	0.85	0.85	0.85	0.85
0.85	1.00	1.00	1.00	0.85
0.85	1.00	0.00	1.00	0.85
0.85	1.00	1.00	1.00	0.85
0.85	0.85	0.85	0.85	0.85

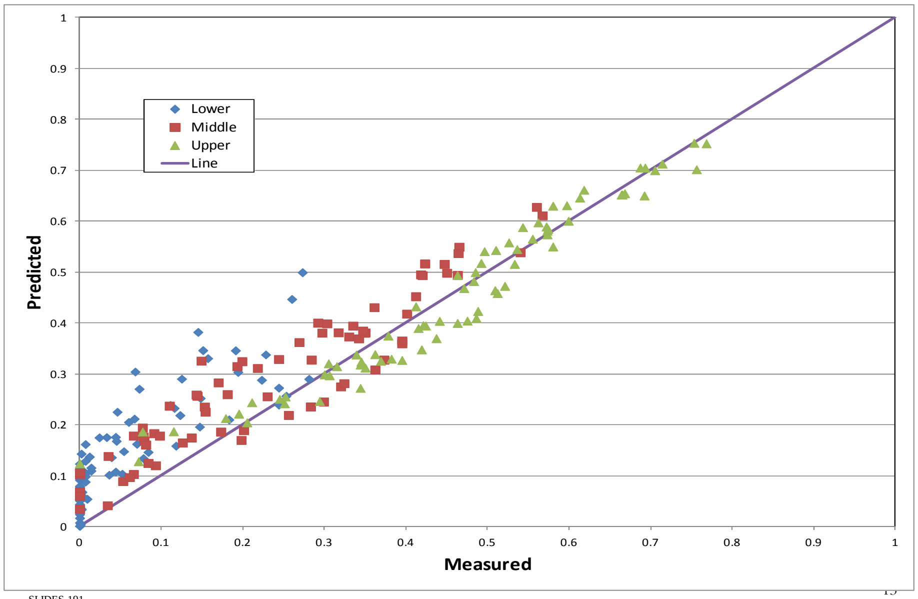
Series S7 – Thimble Rod

Void Fraction Measurements

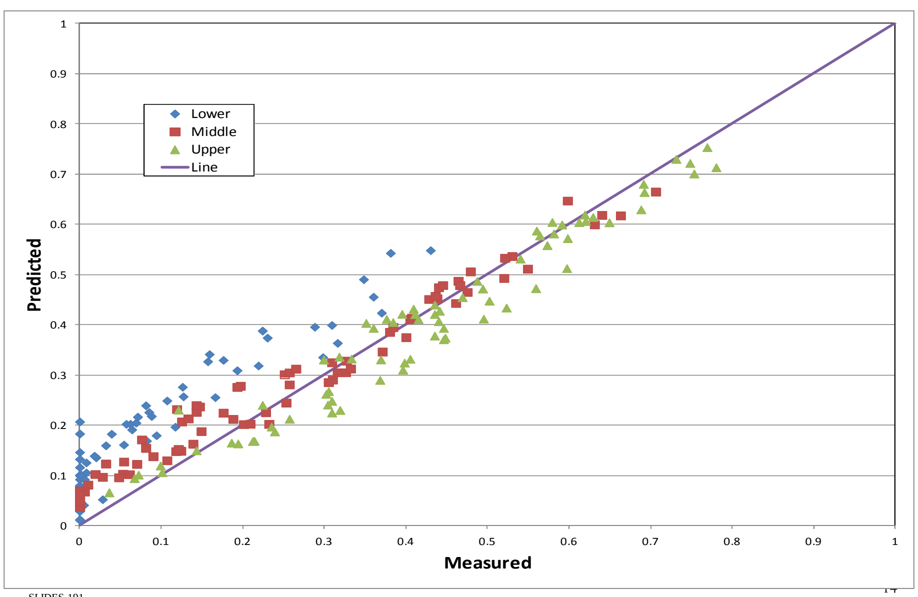
- Chordal Densitometer Measurements
- Three Axial Locations
  - lower 2216 mm = 87.2 inch
  - middle 2669 mm = 105.1 inch
  - upper 3177 mm = 125.1 inch
- Averaged Over Four Central Subchannels



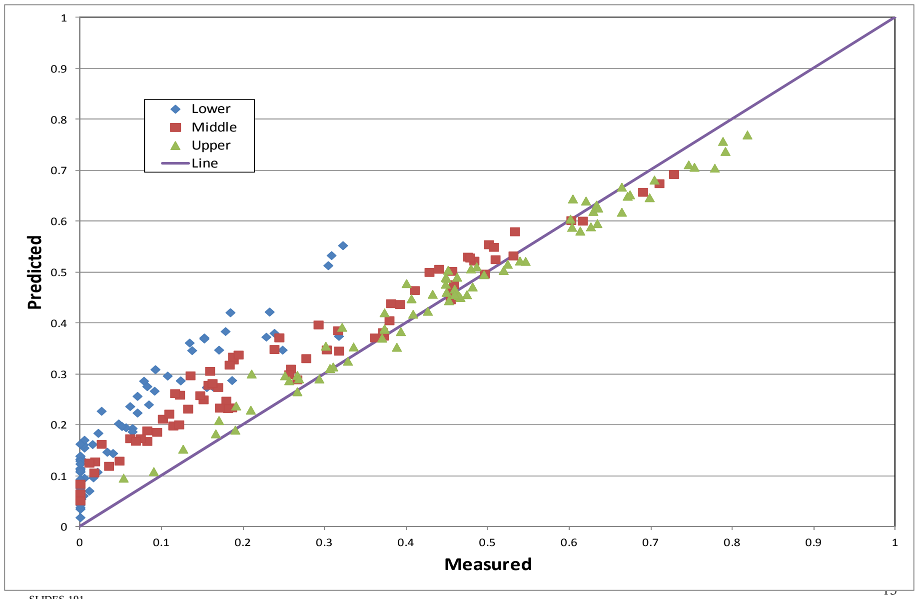
Bundle Series S5



Bundle Series S6



Bundle Series S7



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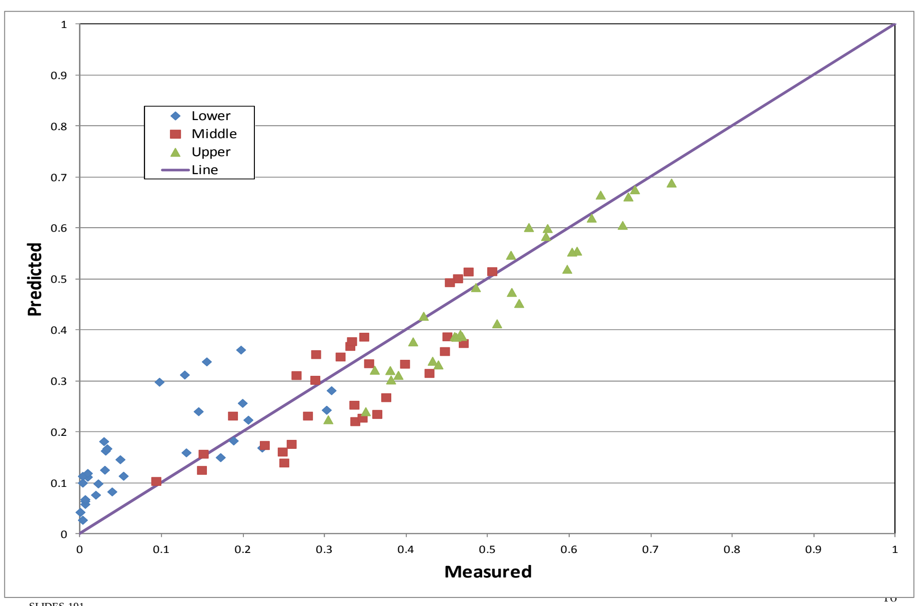
Bundle Series S8



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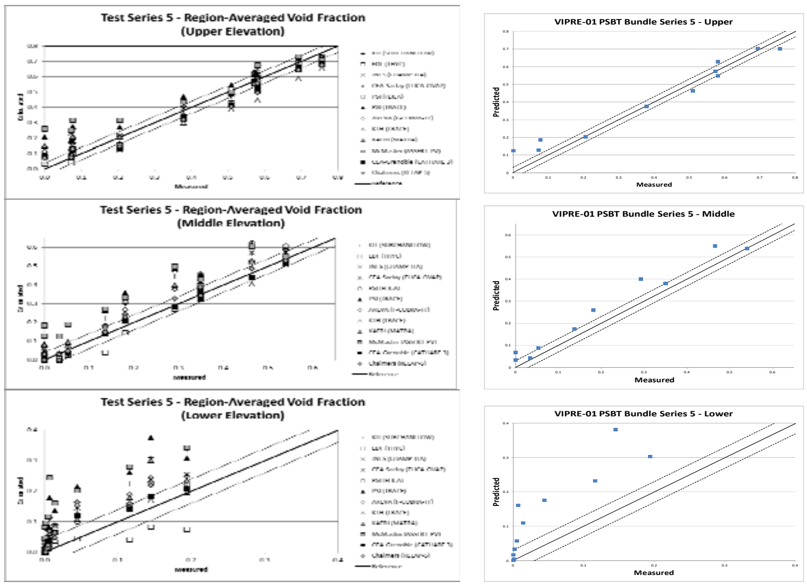
Compare Bundle



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PSBT Transient Bundle Tests

- Four Transients
  - Power Increase
  - Flow Reduction
  - Depressurization
  - Temperature Increase
- Three Bundle Configurations
- Total of 12 cases

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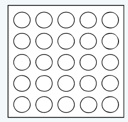
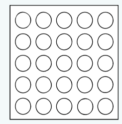
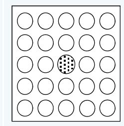
PSBT Transient Bundle Tests

Item	Data		
Assembly	 T5	 T6	 T7
Rods array	5×5	5×5	5×5
Number of heated rods	25	25	24
Number of thimble rods	0	0	1
Heated rod outer diameter (mm)	9.50	9.50	9.50
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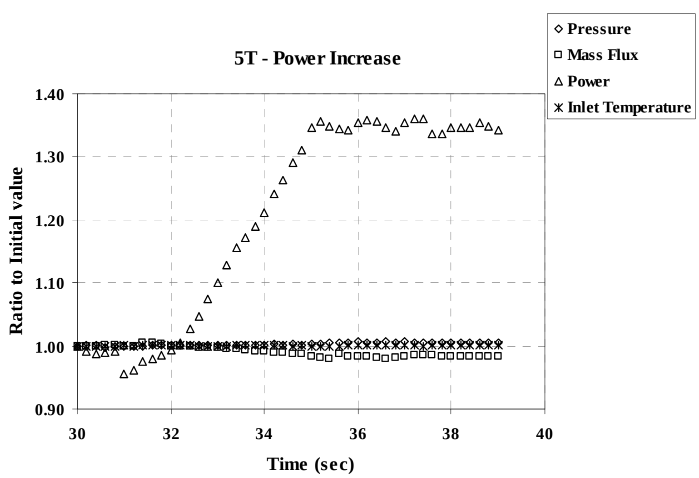
Power Increase Transient Boundary Conditions



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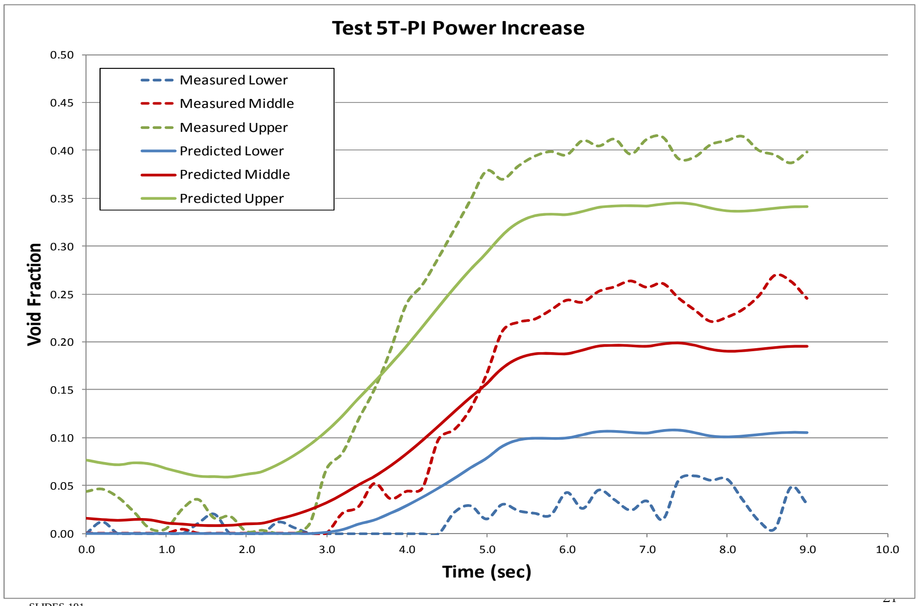
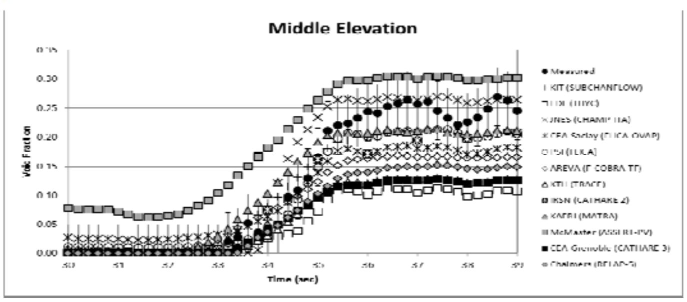
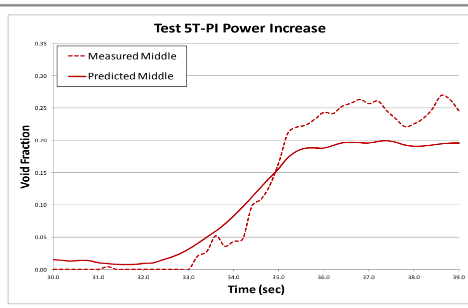
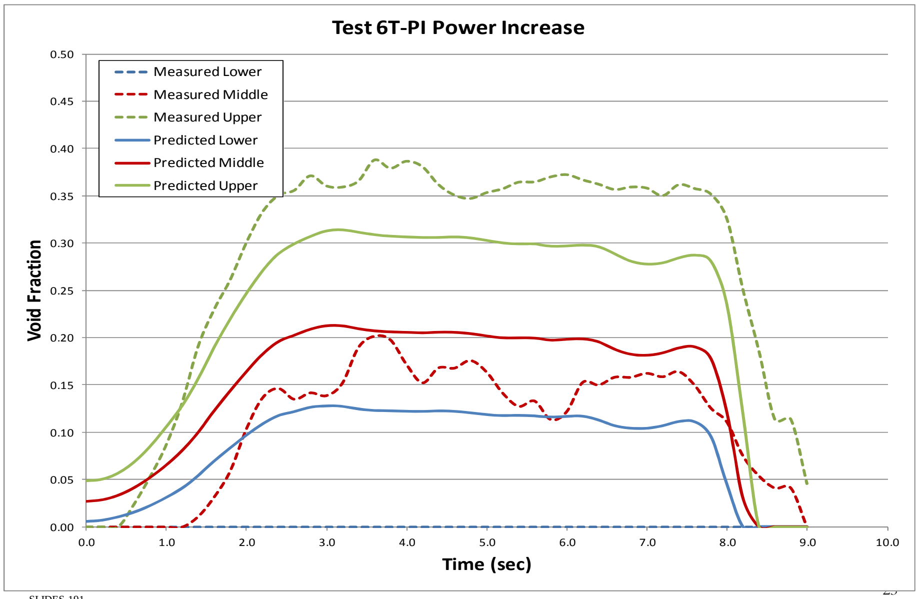


Test 5T-PI Power Increase







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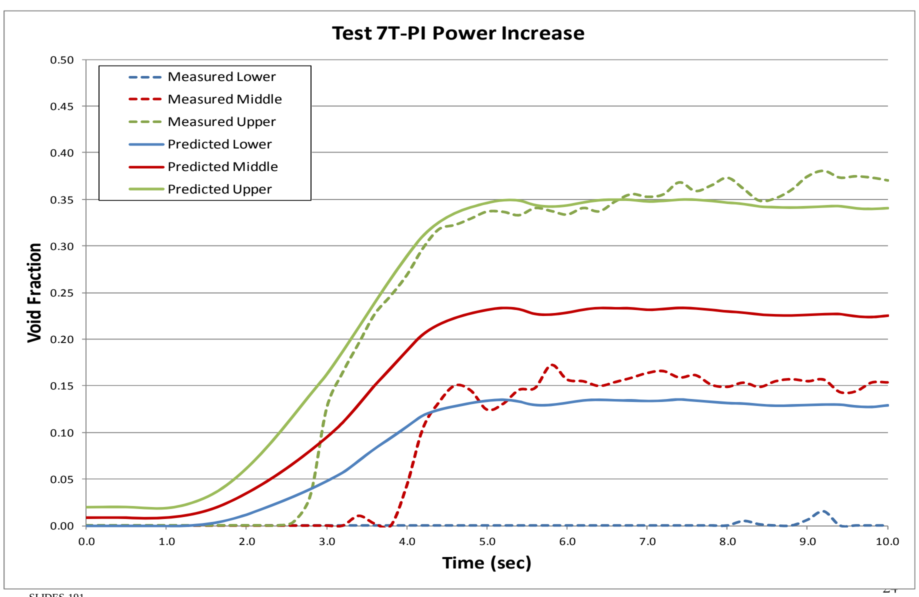

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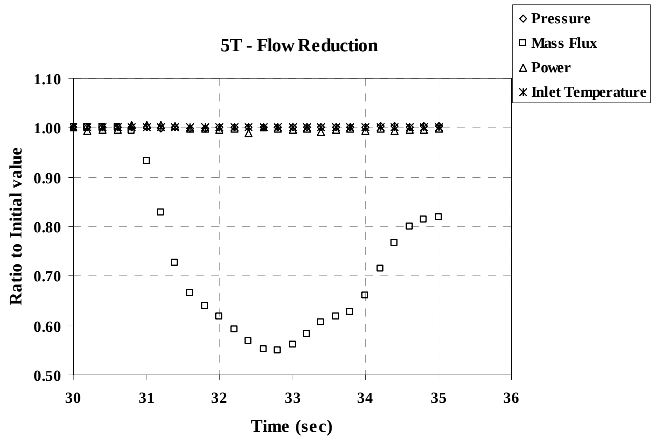
Flow Reductions Transient Boundary Conditions



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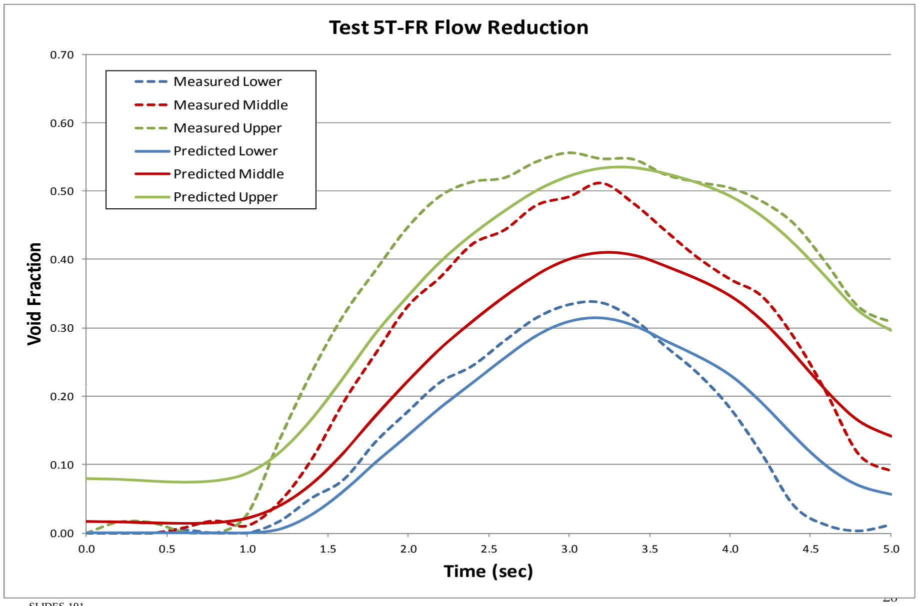

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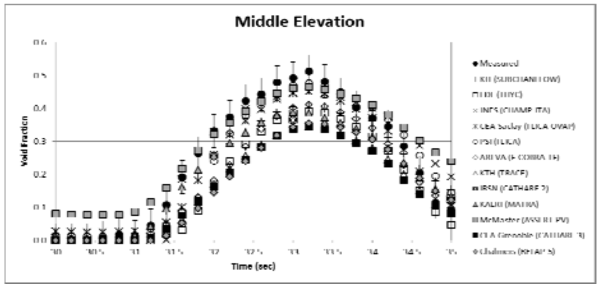
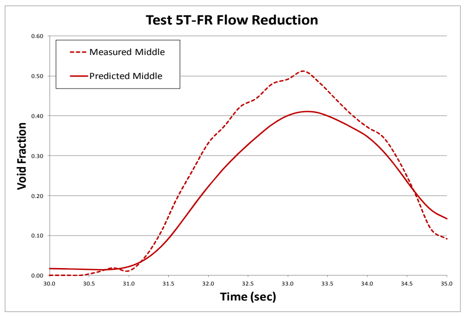
Test 5T-FR Flow Reduction





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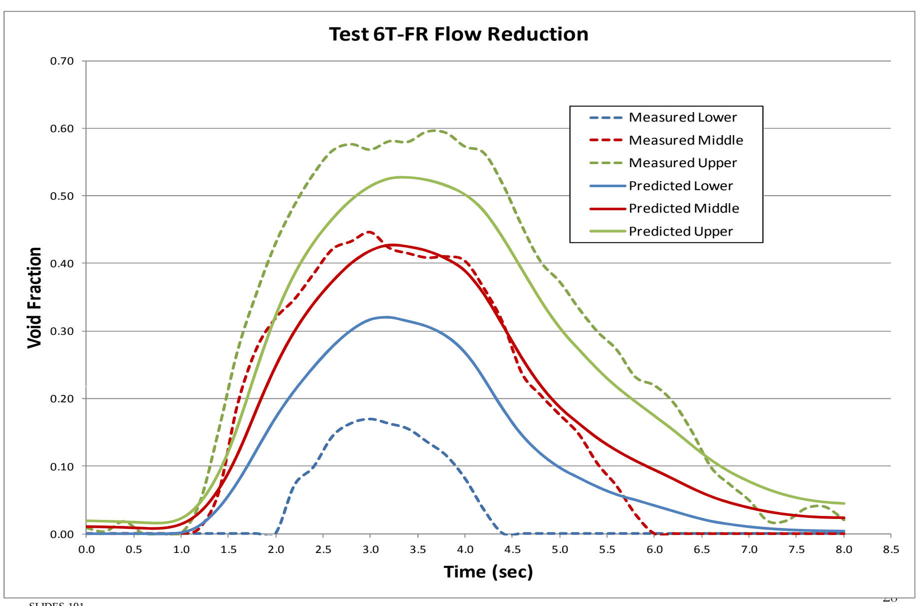

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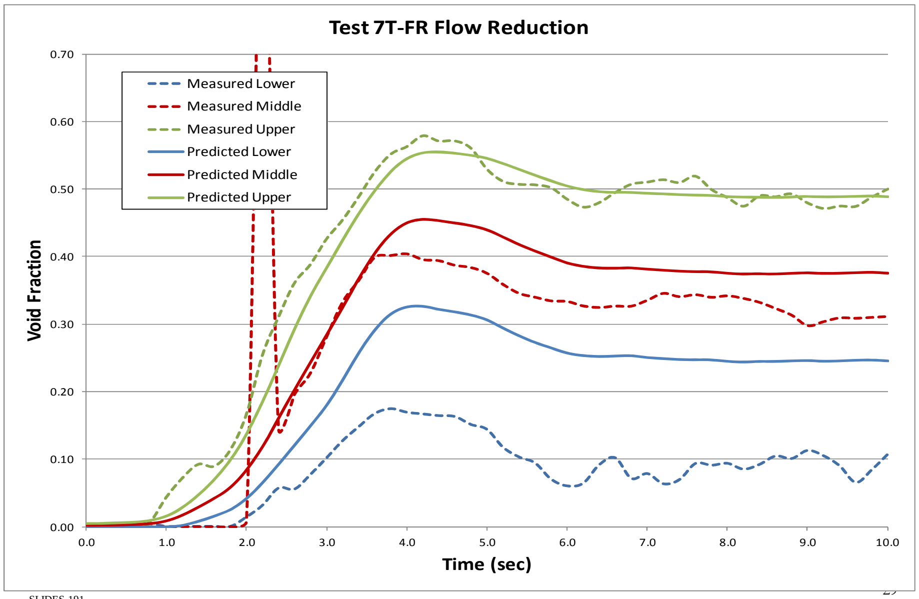
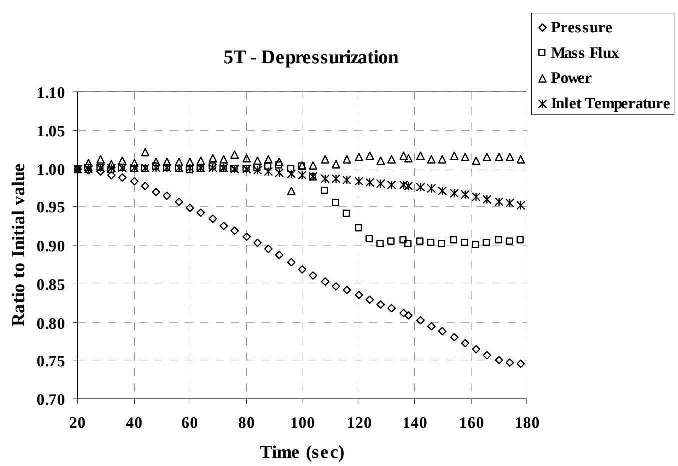
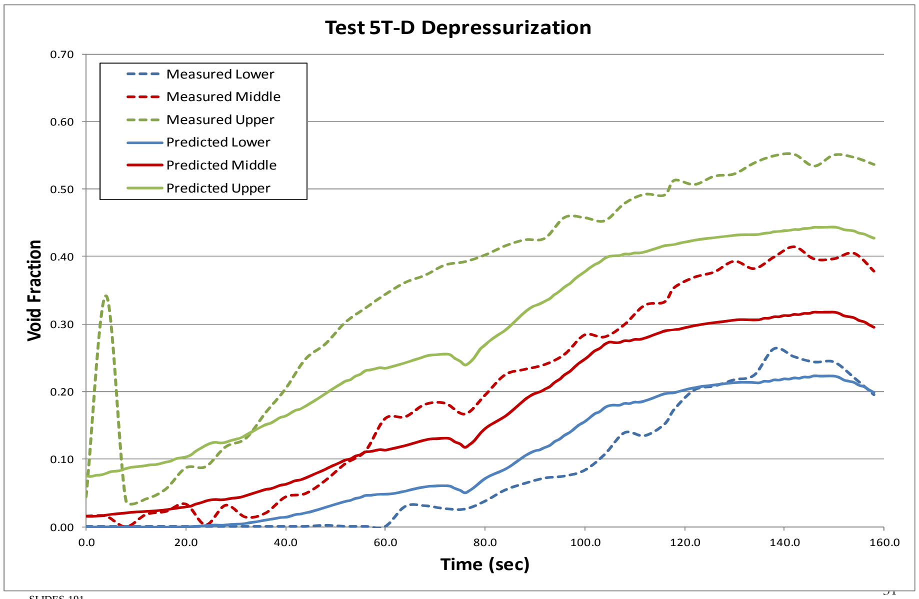


Depressurization Transient Boundary Conditions





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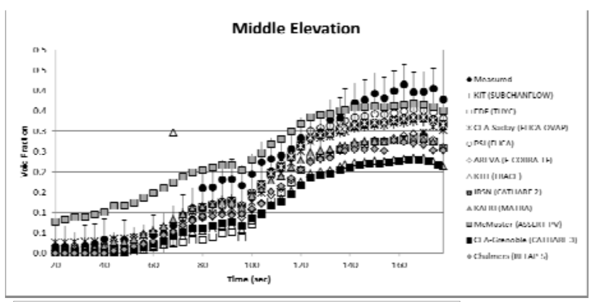
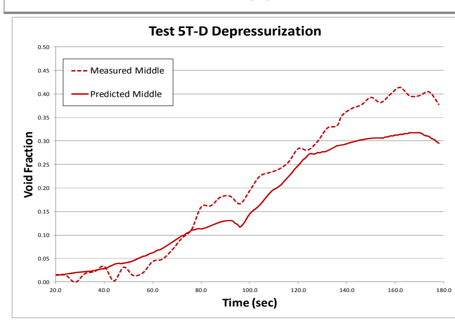
Test 5T-D Depressurization





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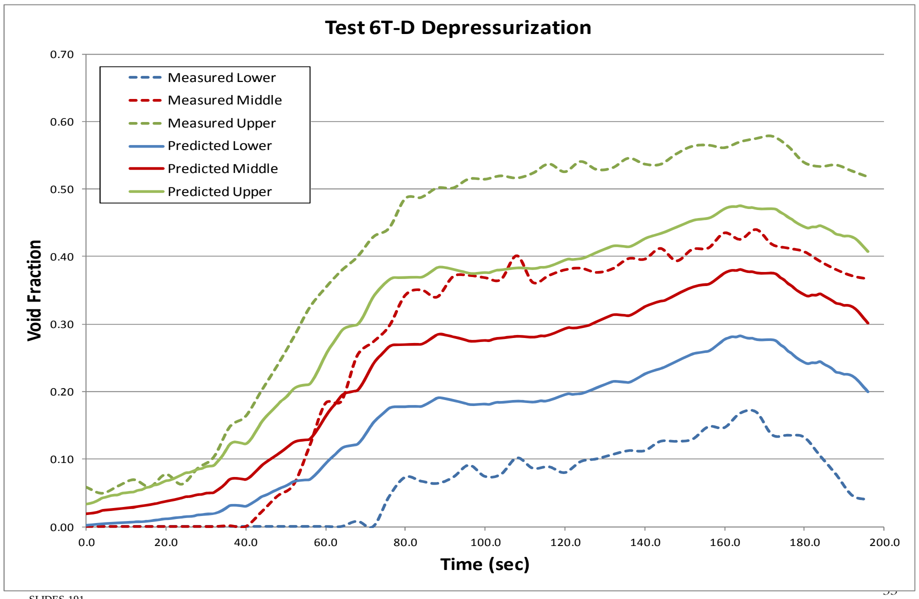

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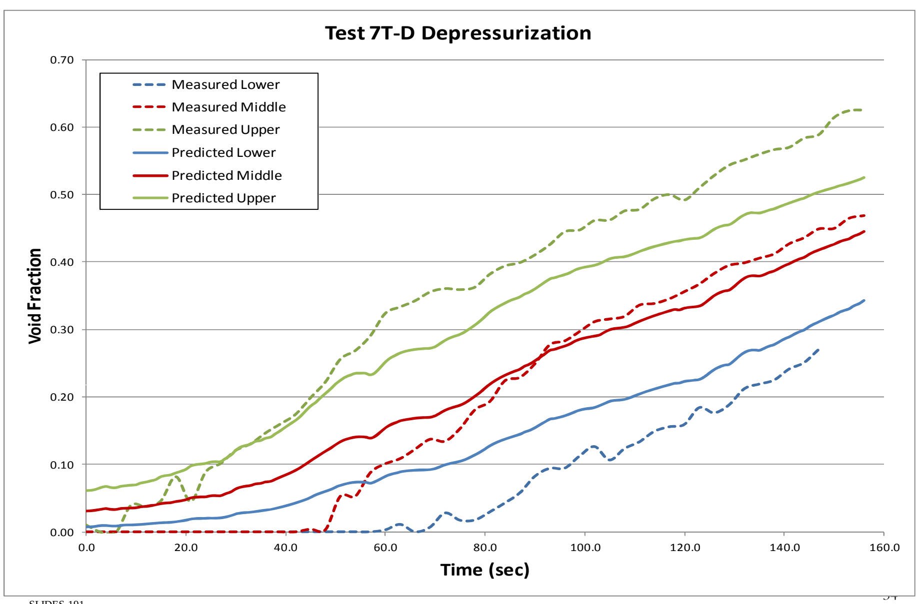

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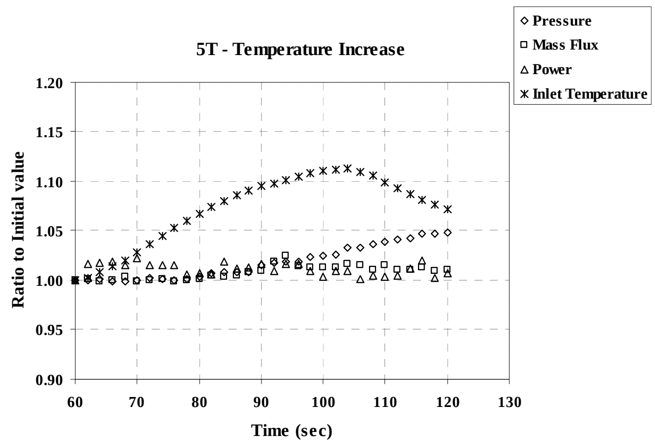
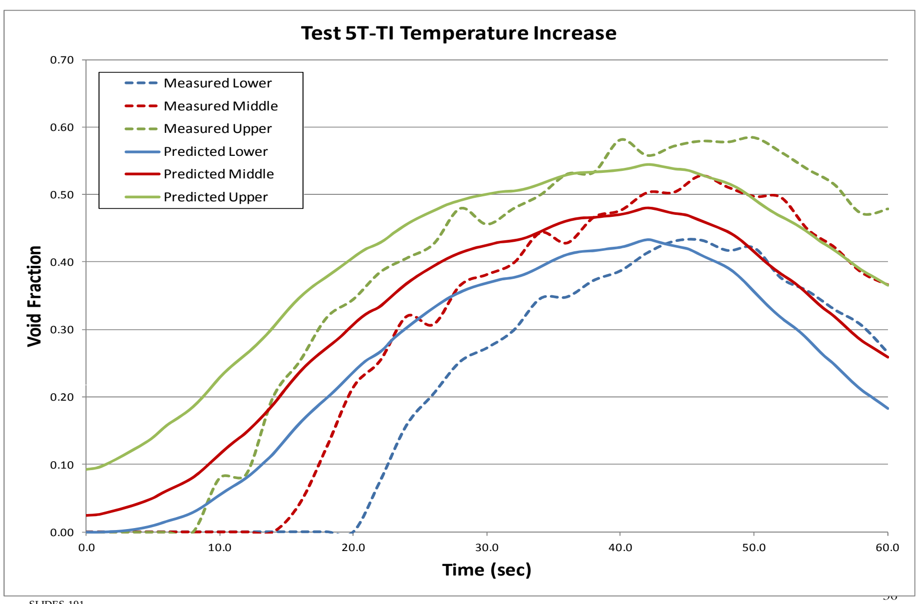
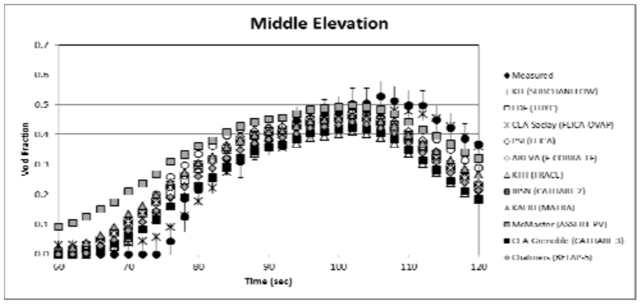
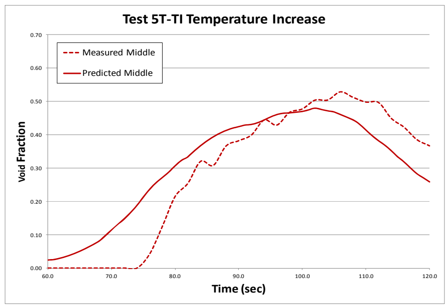
Temperature Increase Transient Boundary Conditions





Test 5T-TI Temperature Increase





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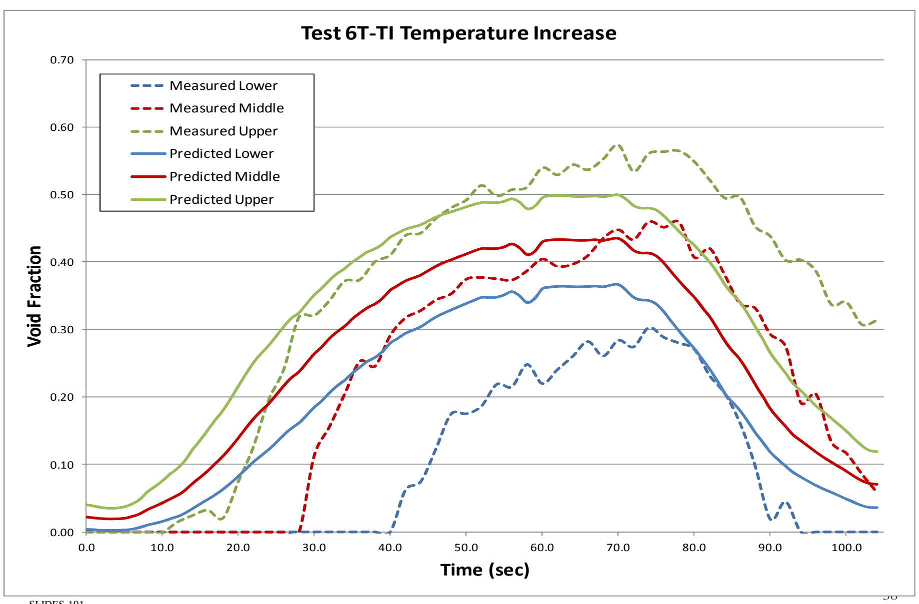

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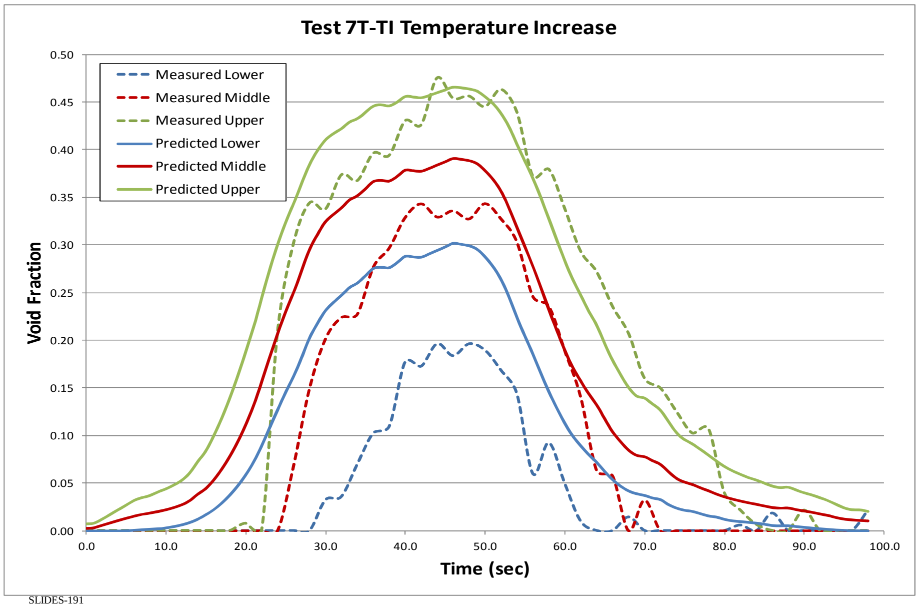

Conclusions

- PSBT Benchmarks Completed for
  - Exercise I-1 Steady-State Single Subchannel
  - Exercise I-2 Steady-State Bundle
  - Exercise I-3 Transient Bundle

Conclusions (Cont'd)

- Steady-State Void Fraction Predictions
  - Generally Compare Well with Data
  - Slightly Over Predicted Void in Subcooled and Low Void Fraction Region
  - Slightly Under Predicted Void in Higher Void Fraction Region
  - Compare Well with Other Codes
  - Drift Flux Models Tend to Overpredict Void and have More Scatter

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Conclusions (Cont'd)

- Transient Void Fraction Predictions
  - Transient Trends Predicted Well
  - In General;
    - Code Tends to Over Predict at Lower Elevations
    - Agrees Fairly Well with Middle Elevation
    - Code Tends to Under Predict at Upper Elevations
  - Code Predictions Show Slight Time Shifts as Compared to Data
  - Consistent with Other Code Predictions

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VIPRE-3D – A 3-D Kinetics Core Code

Presented by Mark P. Paulsen

for
Hiral Kidakia
CSA Inc.
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RETRAN/VIPRE User Group Meeting
June 12-13, 2012
Jackson, Wyoming

3-D Kinetics Linkage

- VIPRE-01
  - Models 3-D Thermal-Hydraulics Behavior
  - Does Not Model 3-D Kinetics in the Core
- Linked RETRAN-3D 3-D Kinetics with VIPRE-01
  - Extends VIPRE-01 to Model 3-D Kinetics
- B&W Project

Code Coupling for VIPRE-3D

- VIPRE-01 Defines the Steady-State and Transient Thermal-Hydraulic Data
  - Fuel Temperature, Moderator Density and Temperature, Time-Step Size During Transient
- 3-D Kinetics Model Defines Total Power and Power Distribution
- FORTRAN Interface Routines Written to Accommodate Flow of Information Between 3-D Kinetics and VIPRE-01

Running VIPRE-3D

- VIPRE-3D Uses VIPRE-01 Input File
  - First Input Field '*VIP3D' Activates 3-D Kinetics
  - Without *VIP3D Standard VIPRE-01 Calculation Takes Place
  - Binary Cross-Section File (BXF File) Required i.e., TAPE68 File from RETRAN-3D
  - Core Data Interface File (CDI File) Required i.e., TAPE78 from RETRAN-3D

CDI File

- Contains
  - Neutronics Channel Information, Symmetry Information, Mesh Size
  - Iteration, Control and Convergence Parameters
  - The Control Rod Layout and Motion Data
  - Decay Heat Data, Thermal-Hydraulic Channel and Neutronics Channel Mapping Data
- CDI File Additions
  - Decay Heat, Rod Motion Data, Added to End of CDI File
  - Revised File can still be Use for RETRAN-3D

CDI File (Cont'd)

- Unnecessary Blocks in CDI File Skipped by VIPRE-3D
  - Example: PAR2 Block Used for Core Symmetry and Neutronic Mesh, Not Required by VIPRE-3D
- Parameters Within Some Blocks Ignored by VIPRE-3D
  - Example: PAR1 Block - Power Input, Flux Equation, Precursor Equation Time Differencing

Input Processing

- VIPRE-3D
  - Reads the Input File and Sets Up Necessary Flags for Processing 3-D Kinetics
  - Reads CDI File
    - Geometry, Mapping and Solution Options for the 3-D Kinetics
  - Reads BXF File
    - Cross-Section Information
    - Must Have Method to Generate BXF File, e.g. BXFGEN
  - VIPRE-01 Error Checking to Test Geometry and Model Options
  - Additional Error Checking to Match VIPRE-01 and 3-D Kinetics Geometry

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Steady-State

- Begins with 3-D Kinetics
- Cross Section Values Calculated from Reference Feed Back Values Using BXF File
  - Moderator Temperature and Density, Fuel Temperature
- Perform Eigenvalue Iteration
  - Nodal Power Fractions are Evaluated
- Interface Routine Passes Power Fraction to VIPRE-01
- For Each Converged Kinetics Steady-State Solution, a VIPRE-01 Steady-State Calculation is Performed

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Steady State (Cont'd)

- Reactivity Feedback Values from VIPRE-01 Thermal-Hydraulics Returned To 3-D Kinetics
  - Eigenvalue Calculation
  - Power Distribution Calculation
- Kinetics Iterations Continue Until Nodal Power Densities Converge
- Steady-State Channel and Rod Edits Along with T-H Edits
- Steady-State Kinetics Edits – Nodal Power Fractions, Reactivities, etc.

Transient Solution

- Interface Routines Pass Information Back and Forth Between VIPRE and 3D-Kinetics
- Coupling is Explicit
- VIPRE-01
  - Selects Time-Step Size
  - Performs T-H Calculation
  - Passes Feedback Parameters to 3-D Kinetics

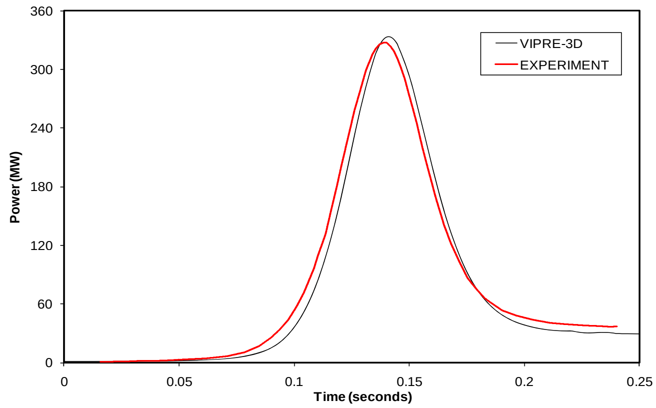
Transient Solution (Cont'd)

- 3-D Kinetics
  - Evaluates the New Cross Section Values, Power Distribution and Magnitude Using the Same Time-Step Size
  - Passes the Power Fraction Back to VIPRE-01 to Complete the Solution for the Current Time Step

VIPRE-3D Validation

- SPERT-81 Power Excursion Transient Test
  - Demonstrates VIPRE-3D Calculation Compares Well with Data
  - Steady-State Core Power for Test 81 is About 1 Mw - Hot-Standby Condition
  - Reactivity Insertion is $1.17
- RETRAN-3D PWR Rod Ejection Transient
  - Demonstrates VIPRE-01 and RETAN-3D Linkage Works Properly
  - RETRAN-3D Sample Problem Converted to VIPRE-01 Input
  - Added New Information to End of CDI File
  - RETRAN-3D BXF File Unchanged

SPERT-81 Power Comparison



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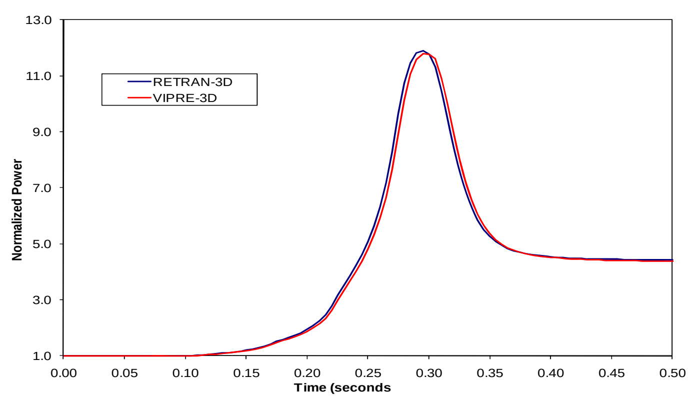
PWR Rod Eject Transient



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Summary

- Coupling RETRAN-3D 3-D Kinetics with VIPRE-01 Successfully Demonstrated
- Excellent Agreement with RETRAN-3D Results and Data
- Does Not Affect Base VIPRE-01 Functionality

FUKUSHIMA ANALYSIS

Presented by Charlie Albury

STPNOC

Jackson Hole, WY

June 12, 2012

FUKUSHIMA ANALYSIS

- Background
- Status of generic analysis
- Analysis opportunities

Background

- INPO IER 11-4
- NRC Bulletin 2011-01(May 11, 2011)
- NRC ORDER EA-12-049 (March 12, 2012)
- JLD-ISG-12-01 (Draft)
- NEI 12-06 (FLEX) (DRAFT)
- WCAP 1701-P (DRAFT)

Generic Analysis Acceptance Criteria

- Prevent Core Damage (keep the core covered)
- No re-criticality (assume no stuck rods)

Selected General Assumptions

- Steam flow to TDAFW (except CE) not considered
- Reactor vessel voiding not considered (cool down will not be stopped)
- Battery power sufficient during event for key parameters
- Instrument air available for controls
- 21 GPM RCP leakage/pump

Status of Generic Analysis Westinghouse

- W coping study based on Vogtle
- NOTRUMP used in the analysis
- Core uncovery in 55 hours (with SG depressurization)

Status of Generic Analysis Westinghouse Issues

- Cool down and Re-criticality
- Accumulator gas injection
- Impact of TDAFW on cool down
- Impact of SG dry out and seal failure
- RCS make up strategy
- Cycle specific checks for shutdown margin
- Loss of natural circulation strategy

Status of Generic Analysis CE Plants

- Core uncovery in 66 hours (using CETs)
- CENTS code used in analysis

Status of Generic Analysis CE Issues

- Pump size for blind feeding a steam generator
- Monitoring SIT Tank levels
- Asymmetric cool down rate analysis

Status of Generic Analysis B&W

- Core exceeded 10CFR50.46 in 23 hours (no SG Depressurization)
- RELAP5/MOD 2 B&W used in analysis

Status of Generic Analysis B&W Issues

- Natural circulation management
- Reactivity management for Raised Loop plants when using EFW.
- Modeling ambient heat losses.

Analysis Opportunities

- Generic Analysis is Generic
- Funding restraints are limiting generic analysis efforts
- Additional plant specific analysis may be required

RETRAN Analysis in Support of PRA

Presented by Charlie Albury (STPNOC)
Work performed by John Shatford (CSA)
RETRAN Visual Interface by Steve Smiley (STPNOC)
Jackson Hole WY
June 12, 2012

1

RETRAN Analysis in Support of PRA Introduction

- Define the problem from a PRA prospective
- Identify cases considered
- Discuss RETRAN nodalization and assumptions
- Discuss results
- Show results with the RVI tool

2

RETRAN Analysis in Support of PRA

- Problem Statement: Determine the core damage frequency assuming operator action, in combination with the loss of offsite power and emergency diesels

- PRA is used to determine core melt frequency due to a loss of all AC power.

3

RETRAN Analysis in Support of PRA

The following are types of events considered in the PRA

- Plant Centered
- Switchyard Centered
- Grid related
- Weather Related

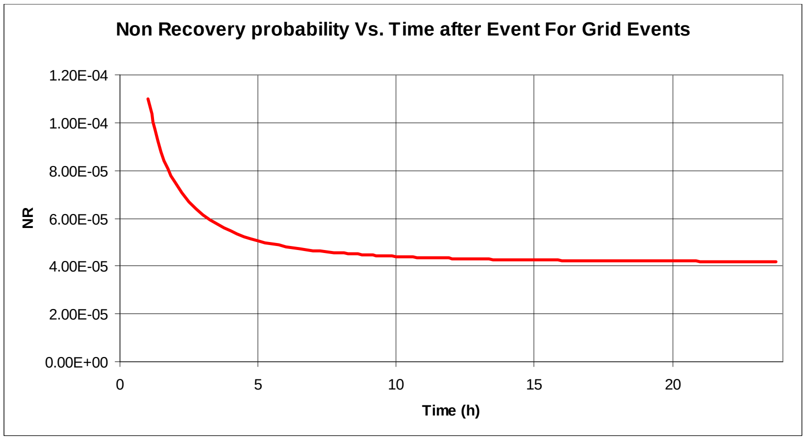
4

RETRAN Analysis in Support of PRA

- Operator Actions can help mitigate the event (e.g. SG depressurization)
- The longer the time the operator has to respond, the higher the probability the operator will complete actions to mitigate the event as shown on the following slide

5

RETRAN Analysis in Support of PRA



6

RETRAN Analysis in Support of PRA

- The PRA considers a combination of the the following failures"
  - Seal Leakage (3, 21, 76, 182, 480 gpm/pump)
  - Loss of AFW
  - Failure of Pressurizer PORV to close
  - Failure to depressurize the steam generators thus reducing RCS pressure

7

RETRAN Analysis in Support of PRA CASES CONSIDERED

Case	Seal Leakage After 13 min (gpm/pump)	AFW Flow	Pressurizer PORV Closes	Depressurizer steam generator
1	3	Yes	Yes	No
3	76	Yes	Yes	No
5	480	Yes	Yes	No
6	3	No	Yes	No
8	76	No	Yes	No
10	480	No	Yes	No
11	3	Yes	No	No
13	76	Yes	No	No
15	480	Yes	No	No
16	3	No	No	No
18	76	No	No	No
20	480	No	No	No

RETRAN Analysis in Support of PRA CASES CONSIDERED

Case	Seal Leakage After 13 min (gpm/pump)	AFW Flow	Pressurizer PORV Closes	Depressurizer steam generator
21	0	Yes	Yes	Yes
22	21	Yes	Yes	Yes
23	76	Yes	Yes	Yes
25	480	Yes	Yes	Yes
26	0	Yes	No	Yes
28	76	Yes	No	Yes
30	480	Yes	No	Yes

9

RETRAN Analysis in Support of PRA Assumptions

- Plant is at full power, steady state nominal conditions, at which time a loss of all AC power occurs.
- RCP seal leakage is 3 gpm per pump for the first 13 minutes, than increases to the value based on the table for the remainder of the event. The leak rate is based on choked flow at normal operating temperature and pressure conditions and decreases with RCS pressure.
- No credit is taken for RCS charging and RCS letdown fails closed at 0 seconds.
- Turbine driven auxiliary feedwater pump starts in 60 seconds feeding steam generator D. Operators maintain narrow range between 22% and 50%.
- The Main Steam Isolation Valves fail closed due to loss of instrument air 20 minutes into the event.
- Operators cross connect the turbine driven auxiliary feedwater pump to a A, B and C steam generators 30 minutes into the event and control level between 22% and 50%.

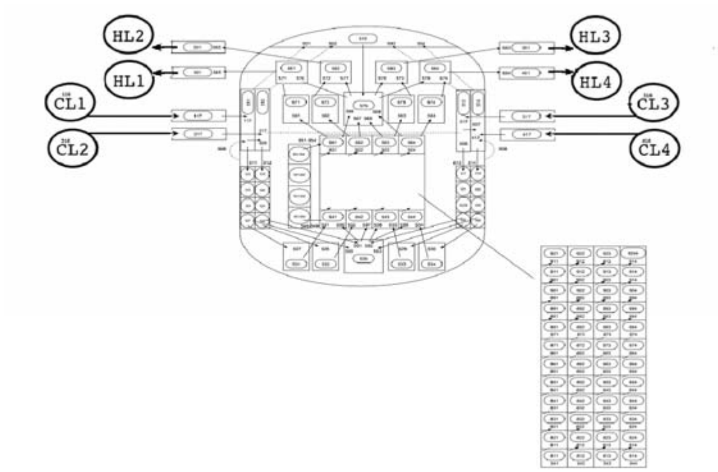
10

RETRAN Analysis in Support of PRA Assumptions

- The pressurizer PORVs operate as designed for 8 hours unless failed open as shown on the case matrix above. No other RCS pressure controls are operable.
- At 8 hours into the event, DC power is lost, which results in a loss of steam generator water level indication and pressurizer power operated relief valve control. The pressurizer power operated relief valves fail closed at this time. Operators continue to feed the steam generators at a rate equivalent to the steam generator boil rate at 8 hours. The water level in all steam generators is 50% narrow range at 8 hours.
- Credit is taken for accumulator injection.
- No credit is taken for the pressurizer heaters.
- The steam generator PORVs fail closed at the initiation of the event and do not open.
- Cases are run to simulate 24 hours of the event or until core damage occurs (core exit thermal couple greater than 1,200ºF), whichever comes first.

RETRAN Analysis in Support of PRA TYPICAL CHAPTER 15 RV NODALIZATION

RETRAN Analysis in Support of PRA
SBLOCAR RV NODALIZATION



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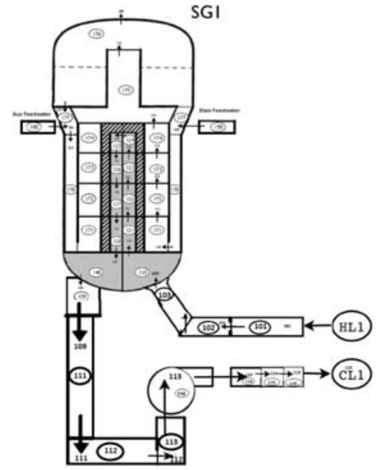
RETRAN Analysis in Support of PRA
TYPICAL CHAPTER 15 LOOP NODALIZATION

14

RETRAN Analysis in Support of PRA
SBLOCA LOOP NODALIZATION



15

RETRAN Analysis in Support of PRA
Results

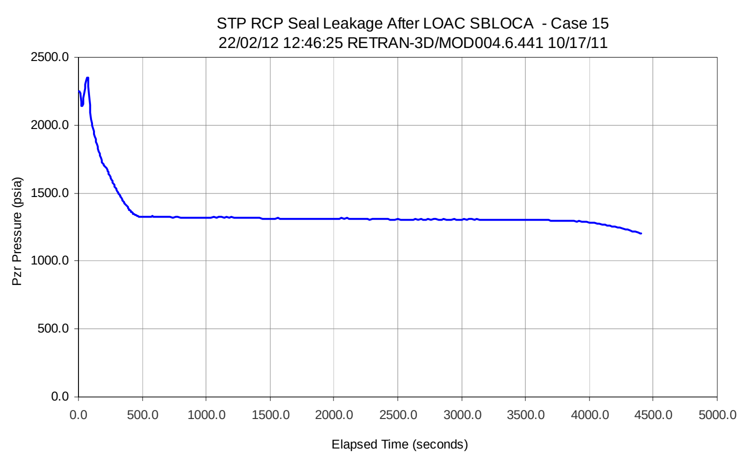
Case	Seal Leakage After 13 min (gpm/pump)	AFW Flow	Pressurizer PORV Closes	Depressurizer steam generator	Transient duration seconds (core top reaches 1200 degrees)	(hours)
1	3	Yes	Yes	No	86400	24.00
3	76	Yes	Yes	No	48929	13.59
5	480	Yes	Yes	No	9471	2.63
6	3	No	Yes	No	9254	2.57
8	76	No	Yes	No	9015	2.50
10	480	No	Yes	No	7705	2.14
11	3	Yes	No	No	7850	2.18
13	76	Yes	No	No	6807	1.89
15	480	Yes	No	No	4527	1.26
16	3	No	No	No	7378	2.05
18	76	No	No	No	6621	1.84
20	480	No	No	No	4450	1.24

RETRAN Analysis in Support of PRA Results

Case	Seal Leakage after 13 min (gpm/pump)	AFW Flow	Pressurizer PORV Closes	Depressurizer steam generator	Transient duration seconds (core top reaches 1200 degrees)	(hours)
21	0	Yes	Yes	Yes		
22	21	Yes	Yes	Yes		
23	76	Yes	Yes	Yes	86400	24.00
25	480	Yes	Yes	Yes	22365	6.21
26	0	Yes	No	Yes	21011	5.84
28	76	Yes	No	Yes	20068	5.57
30	480	Yes	No	Yes	12899	3.58

17

RETRAN Analysis in Support of PRA Case 15 Results



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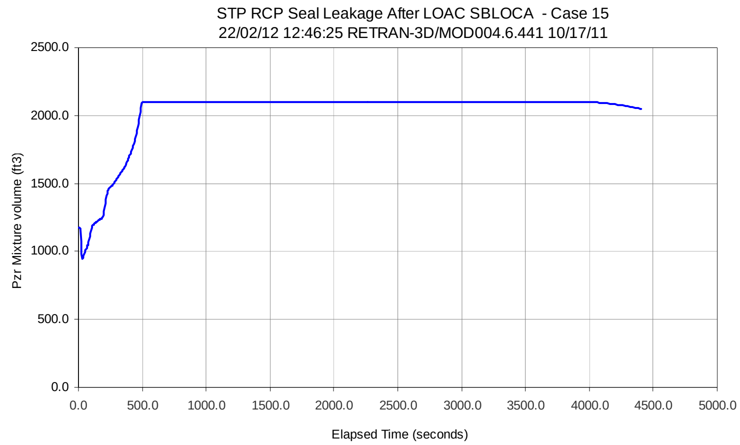
RETRAN Analysis in Support of PRA
Case 15 Results



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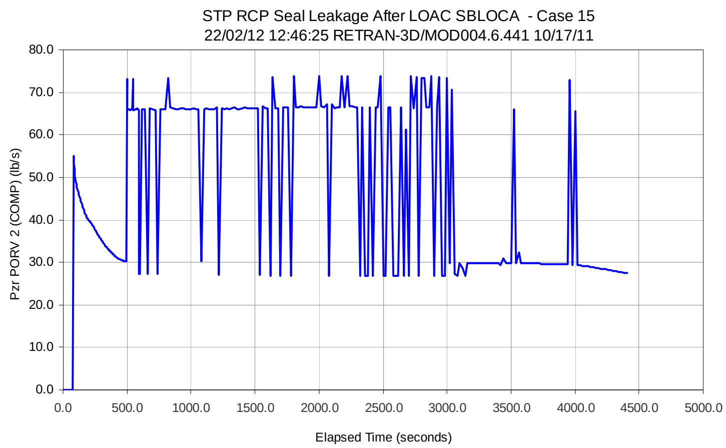
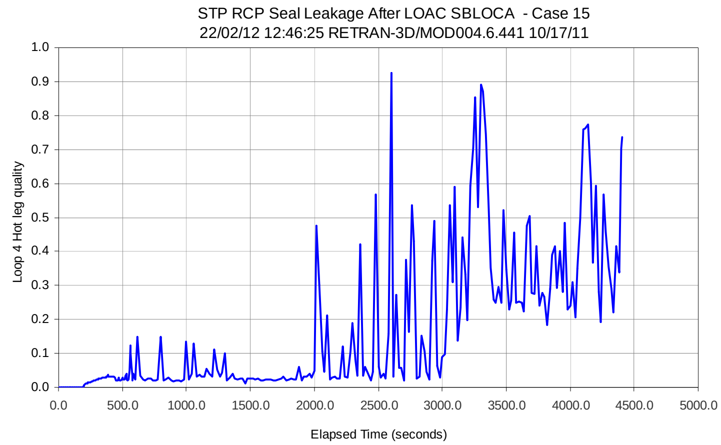
RETRAN Analysis in Support of PRA
Case 15 Results



20

RETRAN Analysis in Support of PRA Case 15 Results



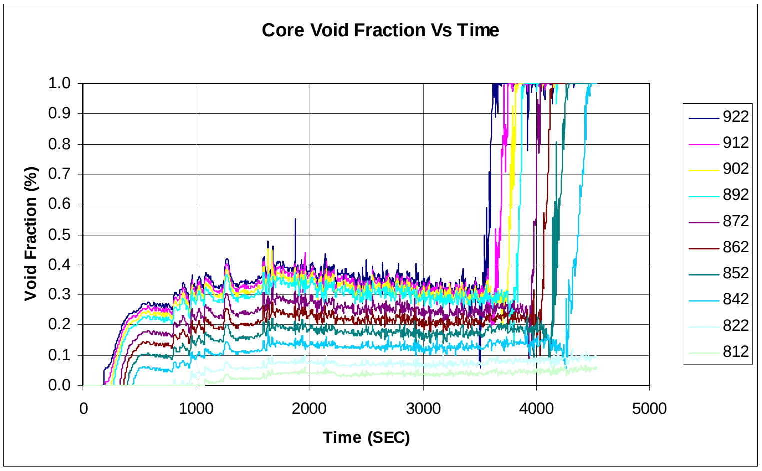
21

RETRAN Analysis in Support of PRA Case 15 Results Core Nodalization

921	922	923	924
911	912	913	914
901	902	903	904
891	892	893	894
881	882	883	884
871	872	873	874
861	862	863	864
851	852	853	854
841	842	843	844
831	832	833	834
821	822	823	824
811	812	813	814

22

RETRAN Analysis in Support of PRA Case 15 Results



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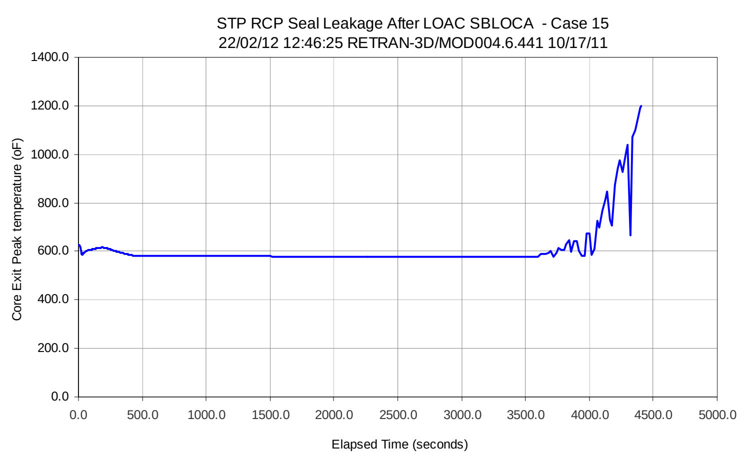
RETRAN Analysis in Support of PRA Case 15 Results



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RETRAN Analysis in Support of PRA
RVI Demo

- Show Demo

25

RETRAN Analysis in Support of PRA
Future Improvements

- Improve PRA results by assuming different SBO times
- Code modifications to improve solution methods
- Five equation model

26

TPC/INER Transient Analysis Method (TITRAM) With RETRAN-3D

Kai-Lan Chang

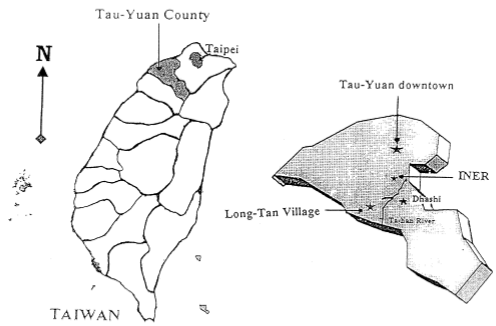
Institute of Nuclear Energy Research

Outline

- Introduction
- TPC/INER Transient Analysis Method (TITRAM)
  - TITRAM BWR Methodology
  - TITRAM PWR Methodology
  - Chinshan RETRAN model
  - Kuosheng RETRAN model
  - Maanshan RETRAN model
- Conclusions

Introduction

- Institute of Nuclear Energy Research (INER)
  - ➢ Located at Longtan Township, Taoyuan County, Taiwan
  - ➢ Founded in 1968
  - ➢ Main programs
    - ➢ Nuclear technology research
    - ➢ Development of carbon-free energy
    - ➢ Development of low-carbon energy
    - ➢ Industrial radiation applications



Introduction (continued)

- Chinshan nuclear power station is the first nuclear power plant (NPP) of Taiwan Power Company (TPC).
  - ➢ two units of GE designed BWR/4
  - ➢ 1775 MW rated thermal power (1804 MWt after MUR now)
- Kuosheng nuclear power station is the second NPP of TPC.
  - ➢ two units of GE designed BWR/6
  - ➢ 2894 MW rated thermal power (2943 MWt after MUR now)


Chinshan Nuclear Power Plant

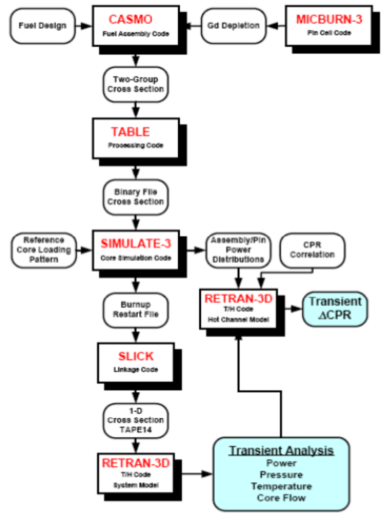
Introduction (continued)

- Maanshan nuclear power station is the third NPP of TPC.
  - two units of Westinghouse designed PWR
  - 2775 MW rated thermal power (2822 MWt after MUR now)
- Lungmen nuclear power station is the fourth NPP of TPC.
  - two units of GE designed ABWR
  - 3926 MW rated thermal power
  - Under construction

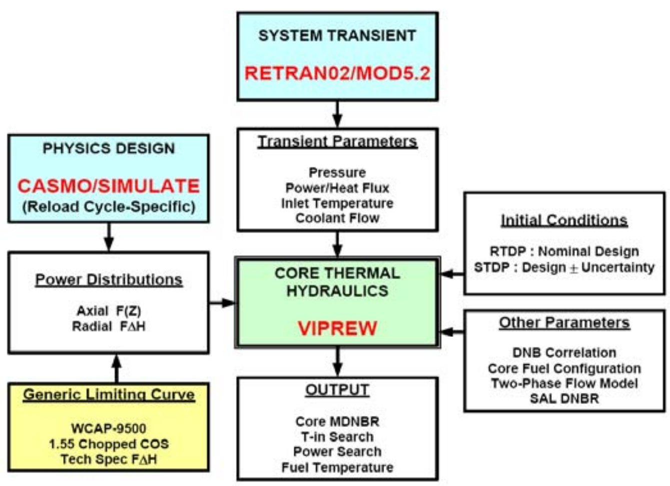
TPC/INER Transient Analysis Method (TITRAM)

- TPC/INER Transient Analysis Method (TITRAM) is an independent licensing safety analysis method
  - Developed by TPC and INER
  - Including neutronics/thermal hydraulics non-LOCA transient safety analysis methods for both BWR (Chinshan & Kuosheng) and PWR (Maanshan) nuclear power plants.
  - Conservative assumptions are implemented in the TITRAM in order to comply with regulation requirements in the calculations of thermal hydraulics transient responses of the NSSS system as well as the containment.
  - The topical reports described in detail the computer codes, plant specific models and qualifications, conservative transient safety analysis assumptions, uncertainty qualifications, and thermal hydraulics limits determination.

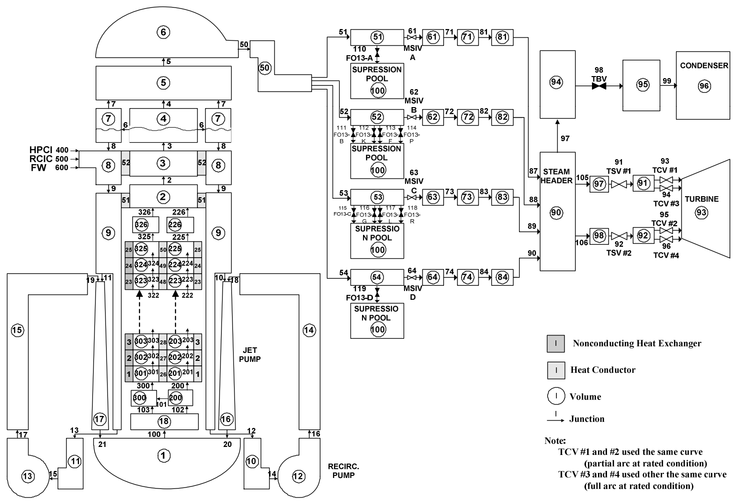
TITRAM BWR Methodology



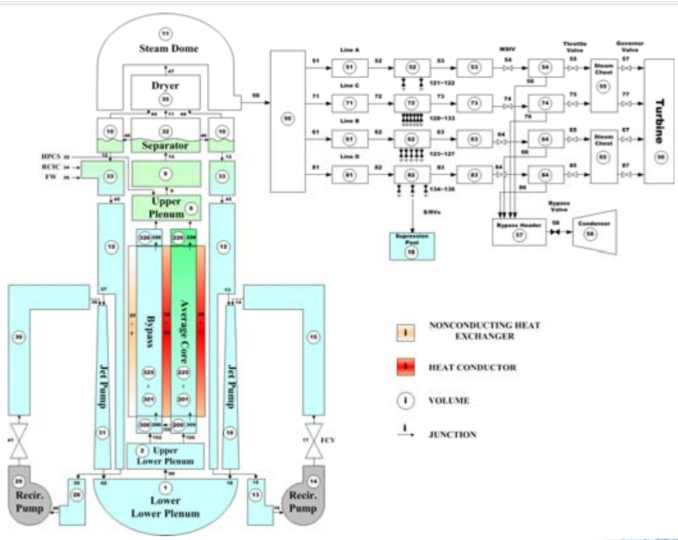
TITRAM PWR Methodology



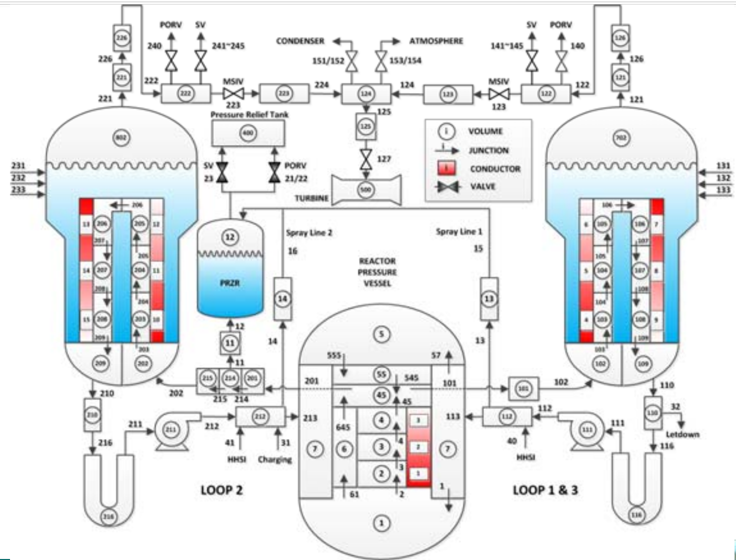
Chinshan RETRAN model



Kuosheng RETRAN model



Maanshan RETRAN model



Conclusions

- Past and future works:
  - In TITRAM I & II, 23 topic reports have been got SER in the past.
  - In TITRAM II, 6 topic reports are under review now.
  - In TITRAM II & III, 40 topic reports will be draft for submittal to the nuclear authority's review in the future.
    Ex: Fast Off-rated Transient Analysis Methods for the Chinshan and Kuosheng, MCPRp Methodology, SLMCPR Calculation Method for the Chinshan and Kuosheng, Containment Analysis Methods…etc.
- TPC/INER transient analysis team use the methods and models for both reload licensing and operational support applications.
- The development of TITRAM would enhance the applicability of the method and contribute to operational supports for existing nuclear power plants.

Thanks for your attention !

Station BlackOut Analysis with RETRAN-3D

June 12, 2012

CSA of Japan Co.,Ltd

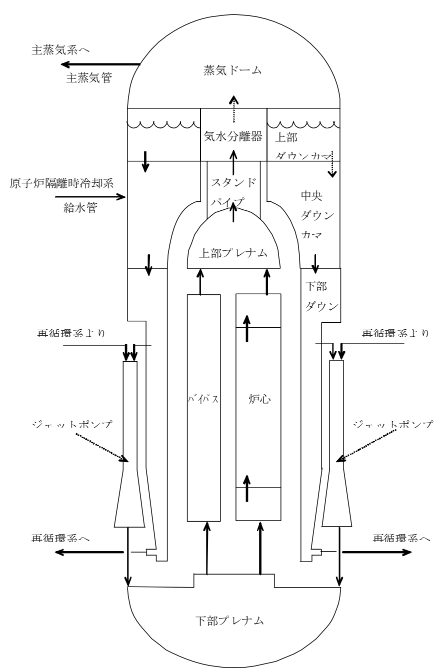
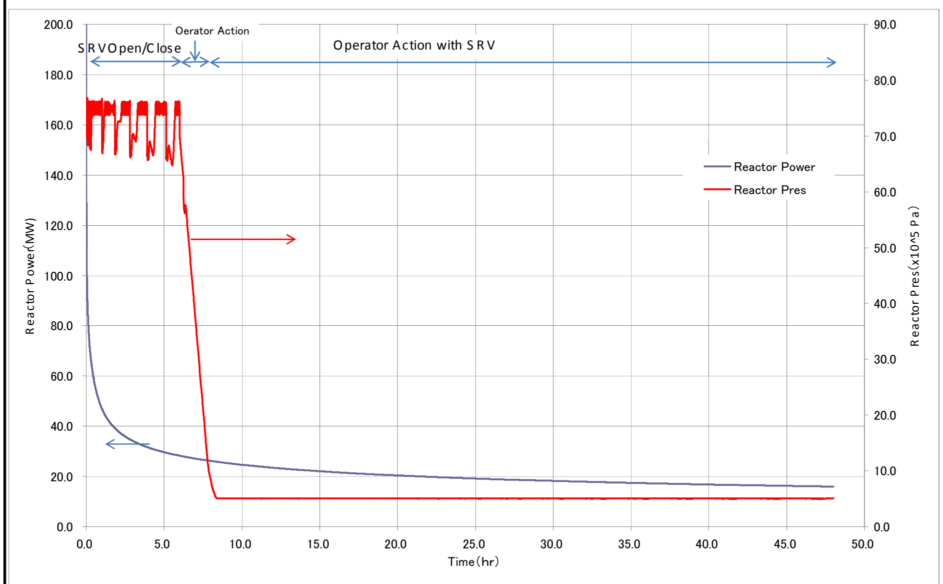


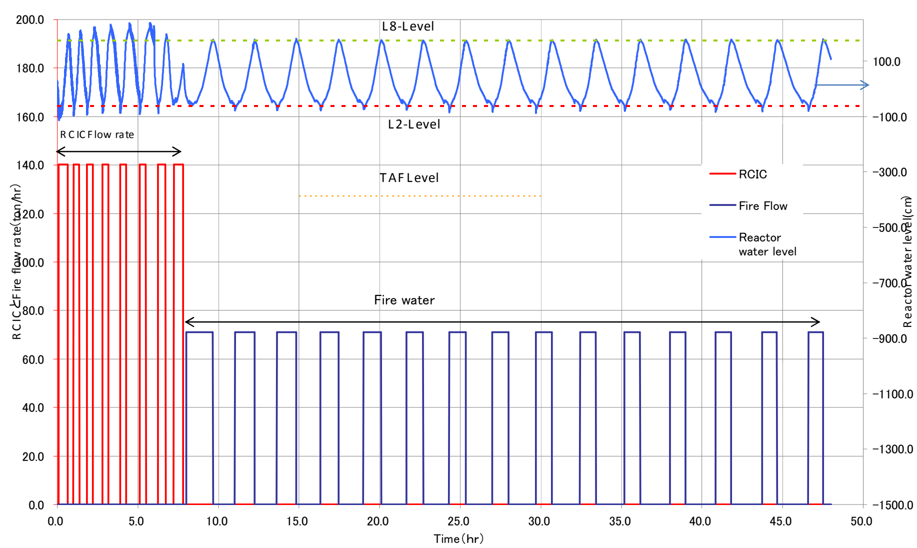
Table 1 Analysis Conditions

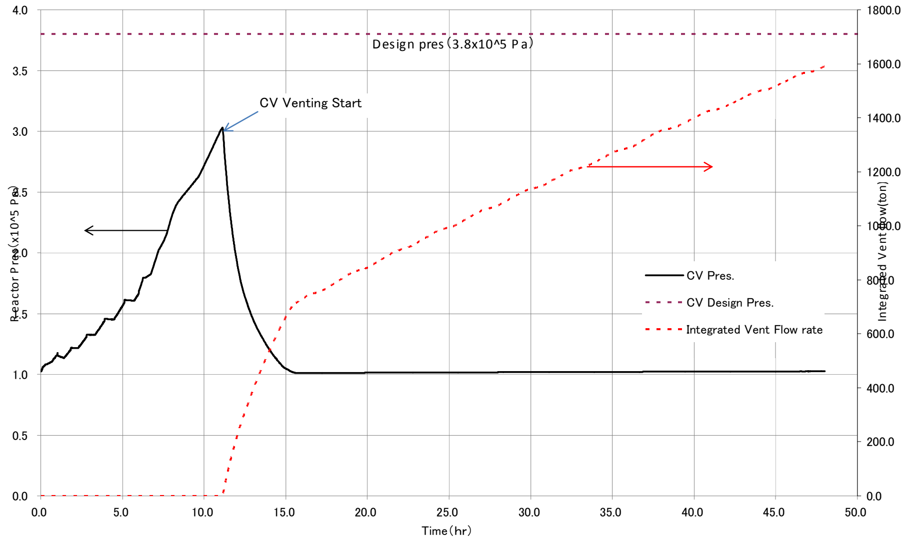
Term	Value
Rated Reactor Power	3227.14 MWt
Plant Type	BWR-5
Initiated Event	Station Black Out
Battery	8 hour
CV Vent	Pcv > 0.3MPa
RCIC	1.1 – 8.0 (MPa) L2 level – L8 level 140 ton/hr
Fire Water	P < 0.7 MPa 71 ton/hr
HPCS	Not available
LPCS	Not available
LPCI	Not available

Table 2 Event

Time (hr)	Event
0.0	Station Black Out starts SRV actvated RCIC
6.0	Operator starts depressurizing action
8.0	P = 0.7MPa Buttery stop Alternative feedwater with Fire water starts
11.0	Pcv = 0.3MPa : CV Vent starts


SRV Open/Close
Oerator Action
Operator Action with SRV
Reactor Power
Reactor Pres
Reactor Power(MW)
Reactor Pres(x10^5 Pa)
Time(hr)


L8-Level
L2-Level
RCIC Flow rate
TAF Level
RCIC
Fire Flow
Reactor water level
Fire water
RCIC・Fire flow rate(ton/hr)
Reactor water level(cm)
Time(hr)



Design pres（3.8x10^5 Pa）
CV Venting Start
Reactor Pres（x10^5 Pa）
Integrated Vent Flow(ton)
Time（hr）
CV Pres.
CV Design Pres.
Integrated Vent Flow rate

B&W mPower™ VIPRE-01 Update

- Models
  - Best Estimate
    - B&W mPower Core
    - CHF Test Articles
    - Unconventional Models
  - Licensing
- Users
  - Four Regular Users
  - One+ Occasional User(s)
- Upcoming Efforts
  - VIPRE Code Topical Report
  - TH Methodology Topical Report
  - CHF Correlation Topical Report
- VIPRE-3D

B&W mPower™ RETRAN-3D Update

- Models
  - 3D Kinetics
    - Primary Loop with Necessary Portions of Secondary
    - Control System
    - Cross Sections from CASMO/SIMULATE via BXFGEN
  - Point Kinetics
- Users
  - One Regular User
  - One+ Occasional User(s)
- Example Uses
  - RELAP Benchmarking
  - System Trade Studies
  - Reactivity Transients
    - Startup
    - Sequence Exchanges
    - AOOs

RETRAN Activities at Dominion

Nuclear Safety Analysis
Nuclear Analysis and Fuel

RETRAN User Group Meeting
Jackson, WY
June 12-13, 2012

Dominion

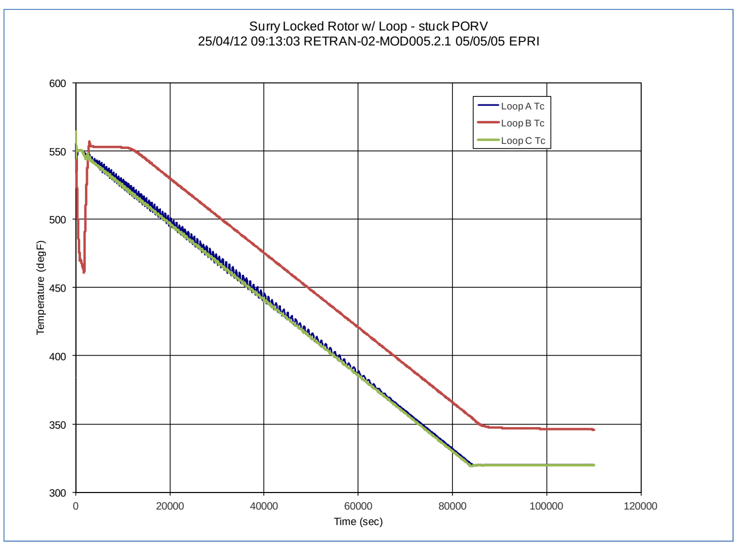
Surry Cooldown Analyses

- Surry 3-Loop PWR
- Locked Rotor:Dose- Long term steam releases
- Cooldown to RHR Entry / 350 F
- FSAR Statement – stuck open PORV
- Spreadsheet inadequate for asymmetry

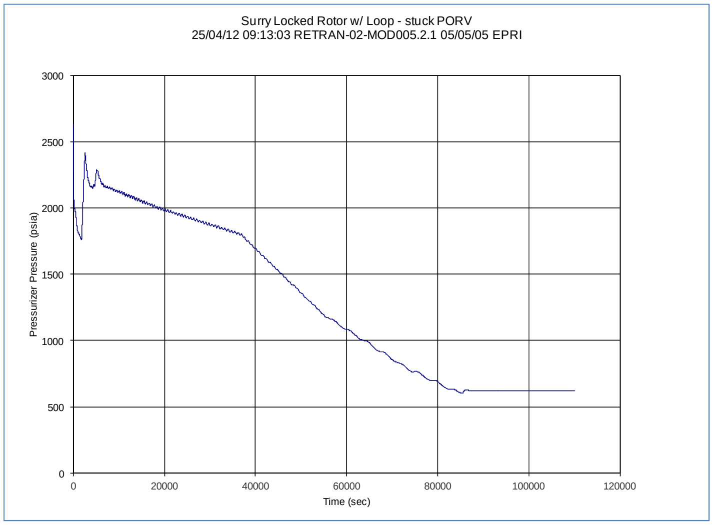
EOP Procedure Considerations

- 25 F/hr with 3 CRDMs; 10 F/hr <3 CRDMs
- Emergency Power for 2 of the 3 CRDM
- Hold point 6 hr – reduce risk of RV head flashing
- Borate to CSD concentration prior to cooldown
- Implications at other sites

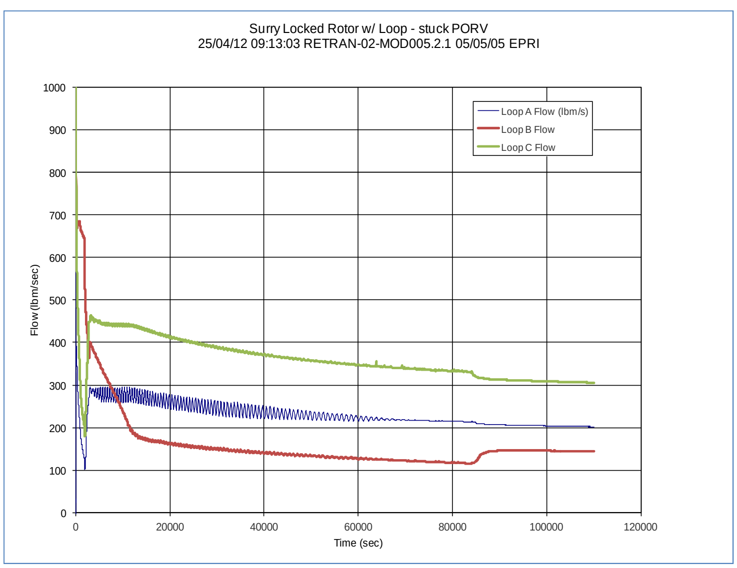
RCS Temperature



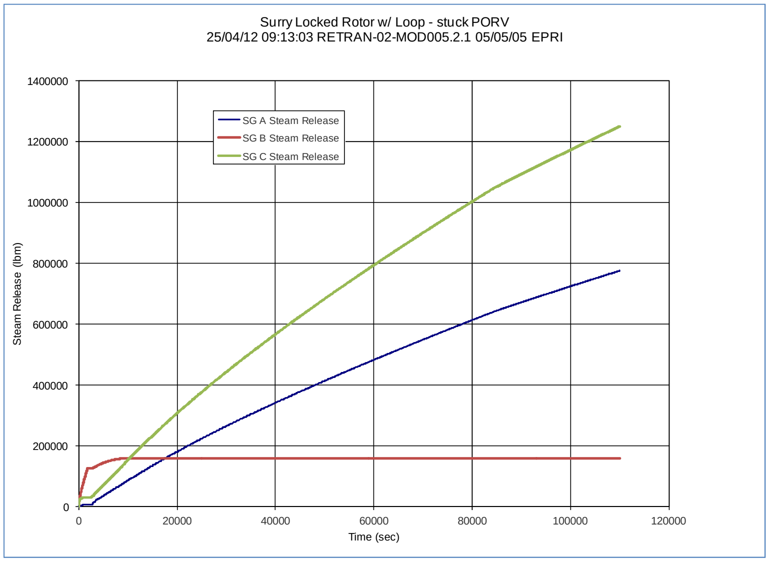
RCS Pressure



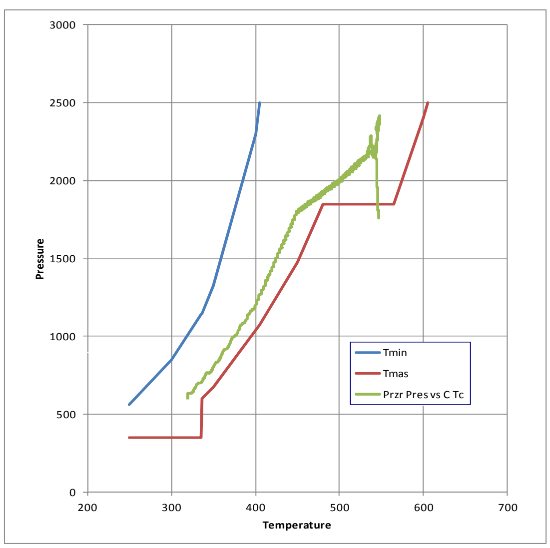
RCS Flows



Integrated SG PORV Flow



EOP P-T Limit Curve

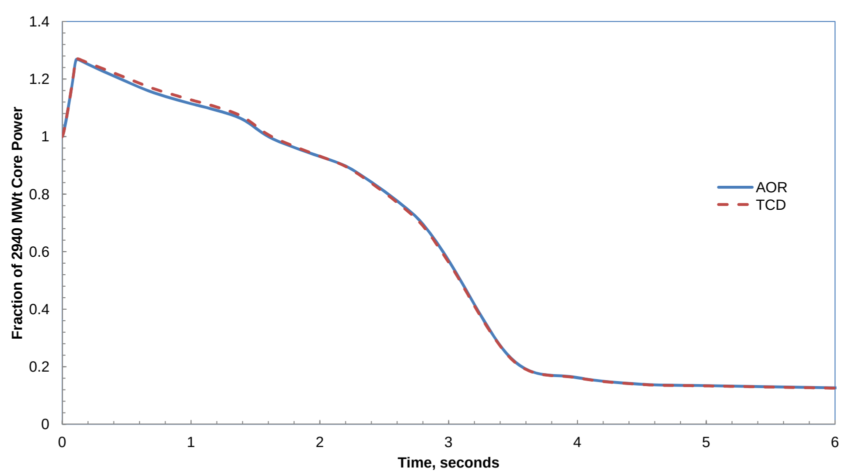


North Anna -Control Rod Ejection

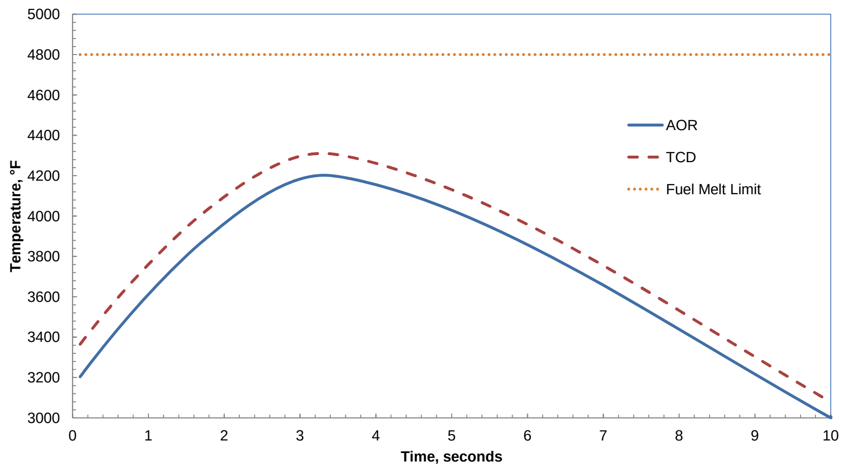
- Sensitivity Study performed in support of RFA-2 transition at North Anna in response to NRC question on Thermal Conductivity Degradation (TCD)
- All parameters held constant except
  - Initial fuel temperature
  - Doppler feedback modeling
  - Fuel properties not changed since they were not from PAD.
- Results are reported for EOC, HFP case

  Assume fuel in second cycle without crediting any peaking factor reductions

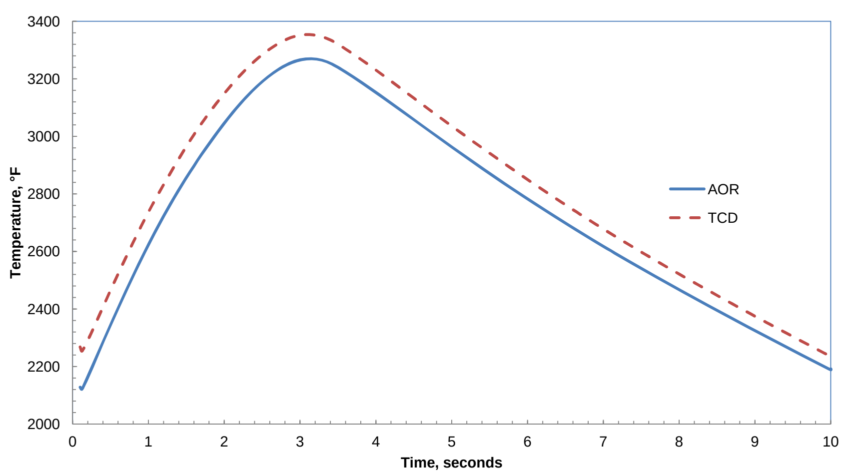
Normalized Nuclear Power



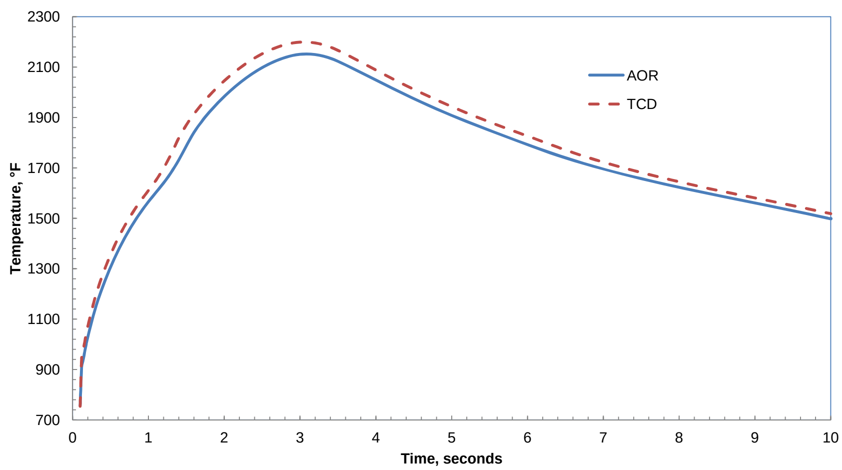
Centerline Temperature



Fuel Average Temperature



Cladding Temperature



Numerical Results (max)

Parameter	Delta T In (°F)	Delta T Results (°F)
Fuel Centerline Temperature	138	109
Average Fuel Temperature		84
Cladding Surface Temperature		47

Other Analyses

- MSLB Analysis North Anna/Surry
  -RFA-2/IFBA

- SGTR North Anna – corrected SG PORV flows

Westinghouse RETRAN Activities

Nobuyuki Fujita
Transient & Design Analysis

- **UFSAR License Analyses for Westinghouse & CE design PWRs**
- **SG Divider-plate Crack Open Analysis (French PWR issue)**
- **Appendix R FSS Analyses (spurious open valves scenarios)**
- **Small Modular Reactor – Safety Analyses**
- **Mid-Loop Loss of SDC Analysis (RETRAN-3D @Customer site)**

Jackson Hole, WY
June 13, 2012

Duke Energy RETRAN/VIPRE Update

Jeff Abbott
RETRAN/VIPRE User's Group Meeting
June 12-13, 2012

Duke Energy

RETRAN-02 Usage

- Completed CNS-1 and CNS-2 RCS flow reduction analyses
- McGuire tube bundle uncovery analyses for input to dose analyses
- McGuire MUR Uprate analyses
- Oconee SSF Analyses
  - Low Decay heat conditions
  - Pressurizer Overfill conditions
- Evaluated pressurizer drain/refill Trouble Report

Duke Energy

Catawba RCS Flow Reduction

- Catawba is a 4-loop 3411 MWt Westinghouse plant
- Indicated RCS flow decreased over past 4-5 cycles
- Reanalyzed a limited subset of Chapter 15 analyses for a 1% flow reduction Tech Spec change
  - LSLB at HZP, UCBW at Power, Locked Rotor
  - Remaining Chapter 15 analyses credit tradeoff between RCS flow and Bypass flow
  - Flow decrease stopped with RCP maintenance, LAR package being assembled to reduce TS flow requirement

Duke Energy®

McGuire Tube Bundle Uncovery

- Subject of a presentation

Duke Energy®

McGuire MUR Uprate

- McGuire going to uprate ~1.7%
- Most Chapter 15 and 6 analyses already analyzed for 1.7% uprate in anticipation of the uprate
  - HZP UCBW needs revision for high flux trip setpoint impact
- Non-UFSAR event remaining to revise
  - Loss of feedwater feed and bleed cooling (for EP guidance)

Duke Energy

Oconee SSF

- SSF = Standby Shutdown Facility
- SSF included in Oconee Tech Specs
- Summer of 2011 NRC sent SIT to Oconee for water solid operation
  - Pressurizer heater breakers not environmentally qualified for SSF events – thus could lose heaters leading to water solid condition in pzr
  - RETRAN-02 was used to justify acceptability of water solid operation
  - NRC questioned RETRAN's ability to model natural circulation with a water solid pressurizer
  - Solicited help from CSA (Peterson) to answer NRC questions
  - NRC ultimately rejected water solid operation, unless we submit for review, but not RETRAN's ability to model it

Duke Energy

Oconee SSF (cont.)

- As result of Summer 2011 SIT, special team created to thoroughly review SSF
- SSF in Tech Specs required operable down to MODE 3 (RCS Tavg ≥ 250 °F, 1% subcritical)
- No analyses ever submitted to NRC for their review and approval (1980's-1990's)
  - RETRAN-02 was used to analyze an event that assumed a LOOP occurred at time 0 from 100%FP conditions – never submitted
- SSF team identified that no analyses exist below 100% FP nor in MODES 2 and 3
- RETRAN-02 used to investigate low decay conditions

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RETRAN-3D Usage

- Oconee SSF analyses also run using RETRAN-3D for comparisons to RETRAN-02
  - Results similar
  - REALLY REALLY REALLY need a pressurizer thermal-stratification model
- Continuing work to upgrade to Mod 4.6
  - Concern about accumulator model in R3D not licensed (no update from last year)
- Adding MSIVs to RETRAN-3D models for HELB mitigation
  - Revising ONS SGTR to possibly credit MSIV for intentional SG overfill – would require adding MSIVs to Tech Specs

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VIPRE Update

- Summer 2011 an intern installed VIPRE-01, Mod 2.4 to exercise new .dll capability for CHF correlations
  - Learned some things
  - Haven't had resources to build on his experience
- Update on benchmark of gap modeling during a rod ejection event (McGuire/Catawba)
  - Anatech finished FALCON modeling, confirmed thermal expansion was main driver for gap closure for the power excursions Duke predicts
  - Dynamic gap model appropriate to use in this situation
  - Decided not to pursue licensing change at this time to use dynamic gap model

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South Texas Update

Charlie Albury

June 12, 2012

Jackson Hole, WY

South Texas Update
Past Activities

- Appendix R analysis with RETRAN 02
- Maintain indicate pressurizer and steam generator water level and no SI.
- Address spurious actuation of the following during control room evacuation:
  - Pressurizer PORV Opening
  - Pressurizer Spray Valve Opening
  - Startup feedwater pump starting
  - Feedwater isolation valve opening
  - Main steam isolation valve opening
  - Letdown isolation opening
- PRA support analysis with RETRAN 3D

South Texas Update
Future Activities Activities

- Additional analysis to support EOP changes for Loss of all AC events
- Revise Chapter 6 LOCA containment analysis addressing NSAL 11-05

Summary of R3D Activities

RVUG Meeting, Jackson Hole

June 12-13, 2012

IBERDROLA
Engineering & Construction

Present activities (1) :

- Using the R3D Mod 4.2 version with the current R3D 1D-kinetics RLA Licensed Methodology for the Reload no.18 of Cofrentes NPP.

- Using the R3D Mod 4.2 version in the current R3D 1D-kinetics Order Statistics Methodology to verify the conservatism of RLA Methodology results.

  - Tolerance interval 95/95%.
  - This methodology has been submitted and accepted by Spanish Nuclear Regulatory Body (CSN).

Present activities (2) :

- Conducting the assessment and the update of the Licensed R03 1D-kinetics TLFW Methodology for Cofrentes NPP to R3D Mod 4.2.

- Develop an Order Statistics Methodology (Wilks) to verify the conservatism.

- Completing the assessment and the update of the present R03 1D-kinetics ATWS Licensed Methodology for Cofrentes NPP to R3D Mod 4.2.

Near future activities (1) :

- To update the 3D-kinetics RIA Methodology developed with version Mod 4.2 for the CRDA in Cofrentes NPP to a newer version of R3D

- To improve a preliminar Order Statistics Methodology (Wilks) to verify the conservatism for the updated R3D 3D-kinetics RIA Methodology.

- To submit both to Spanish Nuclear Regulatory Body (CSN).

Near future activities (2) :

- To test and check the compatibility of our licensed methodologies with the new version of RETRAN, (mod 4.7). Adapting our procedures to use the new R3D versions based on f95.

- Useful feedback to CSA.
- Prepare the way to a future migration.