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委託研究計畫研究報告

核四廠 RELAP5 反應器分析模式建立報告

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Design Record Files for Reactor Pressure Vessel (RPV) System of NPP4 with RELAP5 Model

by

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Abstract

This is the RELAP5 modeling report for reactor pressure vessel (RPV) system of NPP4. The contents in the report describe the functions of the internal components of the reactor pressure vessel and design record files of RELAP5 RPV model. However, part of the main steam system (MS) including the steam header and reactor internal pumps (RIP) are also included in the contents.

The contents of this report include: system description, noding diagram of RELAP5 RPV model, Modeling simplifications, references and appendix (design record files).

Keywords: reactor pressure vessel (RPV), reactor internal pumps (RIP), design record files.

National Tsing Hua University
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核四廠 RELAP5 反應器分析模式建立報告

白寶實

摘　要

本計劃為核四廠 RELAP5 分析模式建立與事故校驗數據提供，本報告是關於核四廠 RELAP5 分析模式建立部分的報告，內容將詳細地敘述反應爐壓力槽系統(RPV)中重要的內部組件和 RELAP5 反應器分析模式建立的計算書。另外，主蒸汽系統(MS)中從 RPV 至主蒸汽集管(MS Header)的部份及反應器爐內泵(RIP)也包括在本模式建立報告中。

此份報告包含下列內容：系統描述、RELAP5 RPV 模式節點圖、模式簡化說明、參考文獻及附錄(詳細的計算書)。

關鍵字：反應爐壓力槽系統、反應器爐內泵、計算書。

國立清華大學

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1. 計畫目的

上位計畫中需建立核四廠工程用系統動態模擬與分析工作平台，以支援相關工作項目審查與評估之執行，如核四廠功率測試模擬及訓練用模擬器功能評估等。本委託計畫將平行建立核四廠 RELAP5 分析模式，以提供上位計畫所建立之核四廠系統模擬與分析工作平台事故模擬校驗數據。至於該工作平台運轉暫態模擬之校驗，則將直接與電廠功率測試相比對。期使最後建立完成之核四廠系統動態模擬與分析工作平台除於計畫執行中協助相關工作項目之審查與評估，日後亦可提供相關單位使用，以充分掌握核四廠重要系統之設計特性與動態分析。

2. 計畫緣起

本委託計畫係為了支援核四廠工程用系統動態模擬與分析工作平台建立計畫，用以提供上位計畫所建立之核四廠系統模擬與分析工作平台事故模擬校驗數據。支援上位計畫相關工作項目審查與評估之執行，如核四廠功率測試模擬及訓練用模擬器功能評估等。本委託計畫將平行建立核四廠RELAP5 分析模式，以提供上位計畫所建立之核四廠系統模擬與分析工作平台計畫的事故模擬校驗數據。

3. 執行方法與進度說明

爐心熱水流的計算工具選用 RELAP5-3DK，該程式是由美國愛達荷國家工程與環境實驗室（Idaho National Engineering and Environmental Laboratory, INEEL）所發展的。

本計畫將平行建立核四廠 RELAP5 分析模式，以提供核四廠工程用系統動態模擬與分析工作平台計畫所需要的事故模擬校驗數據。本委託計畫報告內容為核四廠 RELAP5 分析模式建立，在此份報告中，除了反應爐壓力槽系統，也包括了從 RPV 至主蒸汽集管(MS Header)的部份及反應器爐內泵(RIP)。報告的主要內容包含下列章節：

(1) 系統描述－簡要地描述反應器系統的重要組件及其功能，一部分的主蒸汽系統與爐內泵亦包括在內。

(2) RELAP5 RPV 模式節點圖－為 RELAP5 RPV 模式建立時各熱水流體積與接節的示意圖。從節點圖可以很容易地了解 RELAP5 RPV 模式的編號規則與各體積相對的位置。

(3) 模式簡化說明－本章節將對 RELAP5 分析模式建立時所簡化的部分加以說明，模式簡化是考慮了計算能力與降低模式中不必要的複雜性而作的。

(4) 附錄－反應爐壓力槽系統的詳細計算書。

4. 系統描述

系統敘述將分成反應爐壓力槽系統(RPV)[1]、主蒸汽系統(MS)[2]及反應器爐內泵(RIP)[3]三個部分來敘述:

4.1 反應爐壓力槽系統(RPV)：

本系統之設計基準具有安全功能以及功率產生功能：

(1) 安全功能：

(A) 壓力槽與內部組件提供爐心灌水所需的容積,在發生壓力邊界破裂的情況下，能確保爐心有足夠的冷卻。壓力槽有穿越管能提供數種爐槽灌水的方法。

(B) 防止內部組件變形，保證控制棒及緊急爐心冷卻系統都能發揮其安全功能。

(C) 壓力槽是反應爐冷卻水壓力邊界（RCPB）的主要部份。

(D) RPV 要能支持控制爐心反應度的系統。RPV 提供控制棒與其驅動機構在結構上的支持。RPV 提供注入中子毒素進入爐心的方法。此中子毒素為控制棒無法將反應爐停機時所需的。

(E) RPV 系統在 CRD 殼故障的事故中，也要能包容控制棒與驅動機構，以防控制棒射出.

(F) RPV 系統在結構體故障的事故中，也要能包容爐內循環水泵、以免其損害在爐槽下方的 CRD 液壓管與其它組件。

(2) 發電功能：

(A) 反應爐爐心支持結構及內部組件之設計應符合：

(a) 任何預期正常運轉情況下，提供適當的冷卻水分佈，使爐心功率

運轉而不損壞燃料。

(b) 燃料填換時，方便拆除，包括爐蓋、乾燥器與為同一組件之側板蓋及汽水分離器。

(c) 方便檢查，包括 RIP。

(B) 蒸汽在進入汽機前，水份要能由蒸汽中移除。

(C) 使返回反應爐的飼水與由汽水分離器分離出來的循環飽和水充分混合，使降流區的水成為溫度均勻的過冷水，提高 RIP 的淨正壓吸水頭（NPSH）。

(D) 能提供數種停機熱移除的方式。

(3) 系統敘述：

(A) 反應爐壓力槽（簡稱壓力槽或反應爐槽，又稱 RPV），用來容納產生核反應的爐心和淹蓋爐心的冷卻水，使燃料能將爐水加熱成蒸汽，並引導出爐外至汽機作功。

(B) 沸水式反應爐使用高純度的水作為冷卻劑，水流經燃料元件的周邊吸收燃料元件所產生的熱能，使水變成蒸汽，而燃料元件也因水將熱能帶走而得以冷卻。此時、水與蒸汽一起通過汽水分離器，在汽水分離器中將水與蒸汽泡分開，水再重新回到反應爐壓力槽進行加熱與冷卻的過程。而蒸汽則再經過蒸汽乾燥器，進一步將多餘的水份除去，而成為高乾度的蒸汽，然後再經由四支主蒸汽管，引導至位於汽機廠房的汽機，推動其輪翼作功，最後經冷凝器冷凝成水後，再由反應爐凝結水泵及飼水泵打回反應爐。蒸汽產生流程見圖 4-1。

(C) 反應爐是一個有半球形頂蓋的直立圓柱形壓力槽，其設計使用壽命是 40 年，其設計壓力是 1250psig，而平常的運轉壓力是在汽水分離器上方的蒸汽空間為 1040psia。

(D) 反應爐壓力槽主要的功用是：

(a) 用來包封爐心、內部組件和反應爐冷卻水。

(b) 做為完整性的屏蔽，以防止壓力槽內放射性物質外洩到乾井。

(c) 提供可以用來產生高乾度飽和蒸汽的空間。

(d) 在壓力槽發生一次系統破管，造成冷卻水流失事故時，可以供給一個足夠冷卻爐心的淹沒水容量空間。

而反應爐壓力槽系統可分為壓力槽本體及壓力槽內部組件(Vessel Internal)兩個部分，分別敘述如下：

(1) 反應爐壓力槽本體：頂蓋（Top Head）、壓力槽凸緣（Flange）、殼環（Shell Ring）、底蓋（Bottom Head）、支持裙板（Support Skirt）、貫穿孔。

(2) 反應爐壓力槽內部組件：側板支持(Shroud Support)、甲板(Pump Deck)、爐心側板(Core Shroud)、高壓爐心灌水/備用硼液噴嘴(HPCF／SLC Sparger)、爐心底板(Core Plate)、頂部導架(Top Guide)、爐心儀殼及導管(Incore Housing 及 Guide Tube)、控制棒驅動殼(Contro1 Rod Drive Housing)、控制棒導管(Control Rod Guide Tube)、燃料墊塊(Orificed Fue1 Support)、飼水噴嘴(Feedwater Sparger)、低壓灌水/停機冷卻回水(取水)穿越管、側板蓋(Shroud Head)、汽水分離器(Steam Separator)、蒸汽乾燥器(Steam Dryer)。

以上的結構組件示意圖見圖 4-2。

4.2 主蒸汽系統(MS)：

本系統之設計基準具有安全功能以及功率產生功能：

(1)安全功能：

(A)運用主蒸汽隔離閥，提供主蒸汽管路圍阻體隔離功能，限制爐水的流失及輻射物釋放到廠外。

(B)維持反應爐冷卻水壓力邊界（Reactor Coolant Pressure Boundary RCPB）的完整。

(C)與反應器保護系統之急停功能共同提供反應爐冷卻水壓力邊界過壓之保護。

(D)當發生爐水流失事故（Loss of Coolant Accident LOCA）時，安全釋壓閥之自動洩壓功能，必要時能自動將反應爐洩壓。

(E)不論電廠正常運轉或發生事故，都能提供可靠儀器，以監測反應爐冷卻水壓力、反應爐壓力槽水位、主蒸汽隔離閥與安全釋壓閥之位置及一次系統之洩漏。

(2)發電功能：

(A)引導反應爐蒸汽通過圍阻體至汽輪機。

(B)將主蒸汽管路之凝結水滴排放到主冷凝器。當主蒸汽管路隔離後，能夠平衡主蒸汽隔離閥前後差壓，以利重新打開。

(C)將可能積聚在反應爐壓力槽頂之不凝結氣體，引導到主蒸汽管（正常運轉時）或圍阻體內之集水坑（停機時）。

(D)當停機執行水壓試驗後，在降低反應爐壓力槽水位過程中，能允許空氣進入反應爐壓力槽內。

(E)有儀器監測反應爐壓力槽溫度及安全釋壓閥排放管路、主蒸汽旁通

管路/主蒸汽洩水管路與反應爐壓力槽頂逸氣管線之洩漏情況。

(3) 系統敘述：

(A) 蒸汽系統包括主蒸汽系統、汽機旁通和抽汽系統等。反應爐產生的蒸汽，流經出口管嘴流量限流器（Outlet Nozzles/Flow Restrictors）後，由主蒸汽管引導穿過圍阻體，經汽機節流閥（四只）和控制閥（四只）至高壓汽機。每條主蒸汽管，在圍阻體內側和外側各有一主蒸汽隔離閥（Main Steam Isolation Valve，MSIV），必要時接受安全系統邏輯控制（Safety System Logic & Control SSLC）之訊號自動關閉，俾隔離一次系統，主蒸汽管上也裝有安全釋壓閥（Safety Relief Valve），有雙重功能，一為藉爐內高壓頂開，限制反應爐壓力，使其不超過 ASME 規範（核能系統設計壓力為 1250psig，ASME 規範容許過壓至 110% ，即 1375psig）；二為接受反應爐高壓力訊號而釋放爐槽壓力，二者均為保護反應爐，以免過壓情況發生。另外，安全釋壓閥尚具有自動洩壓功能（Automatic Depressurization），此功能係當發生 LOCA，必要時可將反應爐洩壓，以便緊急爐心冷卻系統（ECCS）之低壓支系統能補水。

目前 RPV 系統中附帶模擬的主蒸汽系統部分只從出口管嘴流量限流器、主蒸汽管、安全釋壓閥、主蒸汽隔離閥到主蒸汽集管(Main Steam Header)為止。汽機旁通和抽汽系統並不包含在 RPV 系統的模擬範疇中。而主蒸汽系統中的重要元件將逐一介紹。

(1) 主蒸汽管(Main Steam Line)：

(A) 總共四條 28”主蒸汽管傳送蒸汽經汽機節流閥及控制閥至汽機高壓段。節流閥上游，各主蒸汽管與主蒸汽集管(Main Steam Header)連通，此蒸汽集管之功用，可在主蒸汽隔離閥或節流閥做性能試驗

時，使進入高壓汽機之蒸汽做適當的分配。

(2) 流量限流器（Flow Restrictors）（參閱圖 4-3）：

(A) 四條主蒸汽管各置一限流器，係整件焊在反應爐壓力槽管出口管嘴上。由 308 系列不銹鋼製成。

(B) 有下列功能：

(a) 主蒸汽管發生斷裂時，限制反應爐水蒸汽流失（限制最大流量為 200% ），以保護燃料屏障。

(b) 限制蒸汽乾燥器及壓力槽內部組件在管路斷破時（大量汽水沖放）之壓力差。

(c) 提供主蒸汽流量信號至飼水流量控制系統。

(d) 提供 MSIV 因流量過高之關閉信號。

(e) 在 MSIV 關閉前，可限制放射性物質於乾井外之釋放量。

(C) 主蒸汽管發生斷裂時，限流器前後之最大差壓，保守估計約有 96.7 kg/cm^2（1373psig）。限流器必須能承受該衝力。

(D) 限流器喉部的直徑尺寸與主蒸汽管路之比約為 0.5，因而蒸汽在限流器喉部的流速，將由主蒸汽管路內 45 米/秒的流速，增為 180 米/秒。

(E) 正常運轉時，限流器前後之差壓約為 1.12 kg/cm^2（16psig）。

(3) 安全釋壓閥(Safety Relief Valve)：

(A) 功能：

(a) 安全動作：核能系統壓力過高，可能導致反應爐冷卻水壓力邊界損壞。反應爐壓力上升至設定值時，安全釋壓閥彈簧受高壓而自行開啟，限制反應爐壓力升高，使其不超過 ASME 規範。

(b) 釋放動作：防止核能系統於全功率運轉下，因 MSIV 關閉導致瞬

間過壓，信號由壓力開關控制，使安全釋壓閥所附之直流電磁閥開啟，引導氮氣至氣壓操作活塞，藉機械機構使閥開啟，壓力開關採取四選二邏輯，單一壓力傳送器故障時，不會阻止/或誤開啟安全釋壓閥。此閥容量在釋放動作時，足可維持爐壓在安全動作壓力以下，即安全動作可做為釋放動作的後備。

(c) 自動洩壓（ADS）：接受 SSLC 控制信號，使兩只電磁閥開啟，只要兩只電磁閥中之任一個開啟，即可供給氮氣至氣壓操作活塞，藉機械機構以開啟 ADS 各閥（8 安全釋壓閥兼用作 ADS 閥），洩放爐槽壓力，使低壓注水（LPFL）能發揮其功能。

十八只安全釋壓閥在四條主蒸汽管線上的分布見圖 4-4，安全釋壓閥之安全模式與釋壓模式的設定點請參考表 4-1 及表 4-2。

(4) 主蒸汽隔離閥(Main Steam Isolation Valve)：

(A) 每一條主蒸汽管裝設兩只 MSIV，在乾井內和圍阻體外，各裝一只。內側隔離閥（F0001A/B/C/D）儘量靠近乾井牆壁，外側隔離閥（F0002A/B/C/D）也是儘量靠近圍阻體外牆，穿越乾井與圍阻體處均裝有導管（Guide Tube），配置參見圖 4-4。

(B) 功能：

(a) MSIV 在接受 SSLC 之控制訊號後，約 3~4.5 秒關閉，時間的下限是考慮 MSIV 關閉太快，對爐心之衝擊較大，時間的上限是考慮 MSIV 關閉太慢，則有放射性物質洩漏至周圍環境之虞。

(b) 主蒸汽管在乾井外斷裂時，關閉 MSIV 限制爐水流失，避免燃料護套損壞。

(c) 燃料放射性物質隨爐水或蒸汽流失時，關閉 MSIV，可限制放射性物質洩漏至周圍環境。

(d) 當 MSIV 關閉到 92% 位置時，會造成反應爐急停。

4.3 反應器爐內泵(RIP)：

反應器爐內泵為反應爐再循環水系統之重要組件，而再循環水系統設計基準只具有功率產生功能：

(1) 發電功能：

(A) 提供強迫水流以增加功率。

(B) 當反應爐功率介於 65-100% 範圍時，不必抽插控制棒，僅藉本系統即可控制其功率。

(C) 當再循環水系統失效時，爐內泵（RIP）具有充分之慣性使爐心水流緩慢降低，以確保燃料熱限值不致超限。

(2) 系統敘述：十台可變速之爐水再循環泵【通稱爐內泵】是組成 RCIR 系統的主要組件，此泵馬達組由 RPV 底板支撐，RIP 自爐底周邊推動水流經爐底區向上穿過爐心底板、爐心、汽水分離器、再回到降流區環帶；其流程概要亦可參照圖 4-1。

(A) 爐內泵(RIP)：爐內泵位於 RPV 槽內、自泵甲板（Pump Deck）處分隔成上下二部份，上半部為低壓區，下半部為高壓區，為一單級混流式葉輪，由一向下延伸之長軸驅動，動葉輪則套入於擴散器（Diffuser）殼內，而擴散器（Diffuser）殼插入於泵甲板孔內。爐內泵的馬達部份裝置於馬達金屬殼（Motor Casing）之內，而馬達金屬殼則焊接在 RPV 泵管嘴（Pump Nozzle）上，構成反應爐冷卻水壓力邊界（Reactor Coolant Pressure Boundary；RCPB）而屬於 Safety Class I 的設備，故必須依 ASME SEC. III DIV.I Subsection NB Class I 的標準設計，在馬達金屬殼最底端裝有 Motor Cover 亦屬於 RCPB 的一部份，同時做為

non-rotating 止推軸承基座。而扣緊套管（Stretch Tube）是一支薄的套管猶如中空螺栓，惟頭部有一向外延伸之唇蓋，做為扣緊 Diffuser 之用，底部有一螺紋同樣做為扣緊 Diffuser 之用，以克服 RPV 內 Thermal Transient 及泵運轉所造成的震動力。結構請參照圖 4-5。

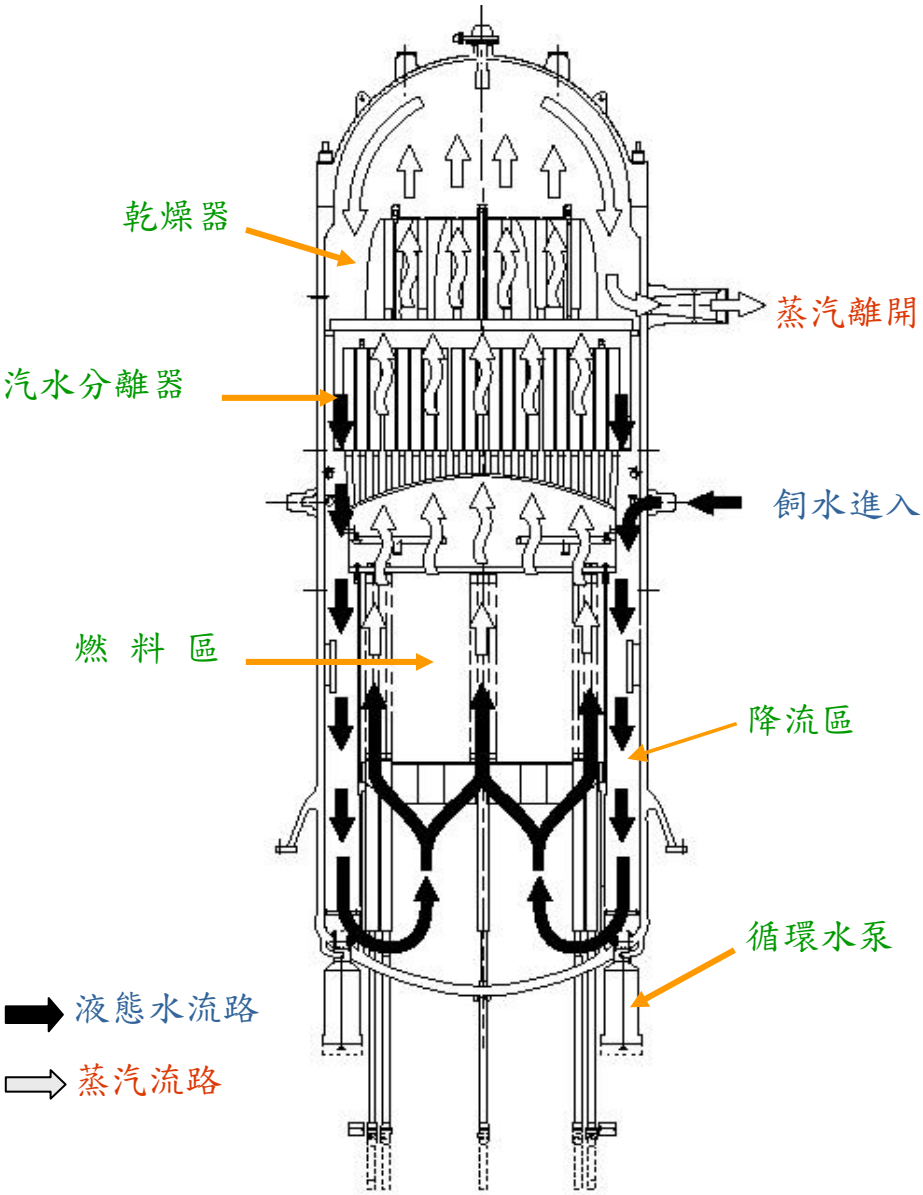
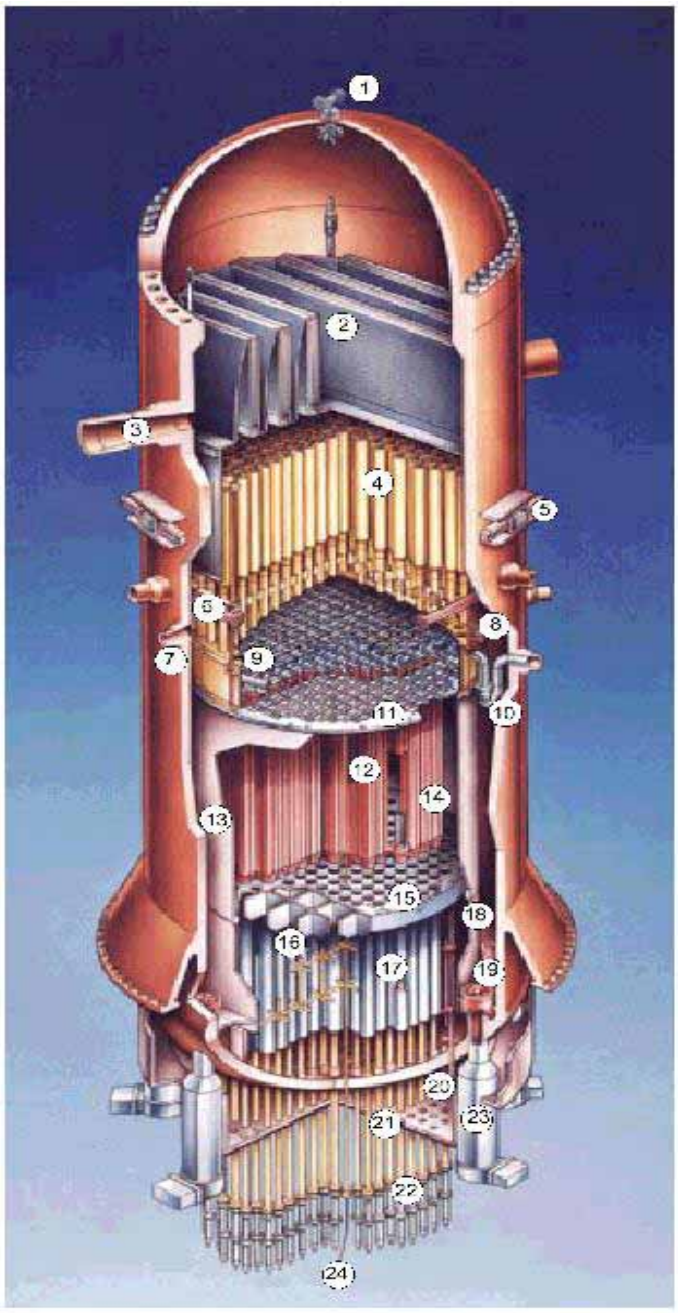


圖 4-1 蒸汽產生流程圖



Advanced Boiling Water Reactor Assembly

1. Vent and Head Spray
2. Steam Dryer
3. Steam Outlet Flow Restrictor
4. Steam Separators
5. RPV Stabilizers
6. Feedwater Spargers
7. Shutdown Cooling Outlet
8. Low pressure Flooder (LPFL) and shutdown Cooling Sparger
9. High Pressure Core Flooder (HPCF) Sparger
10. HPCF Coupling
11. Top Guide
12. Fuel Assemblies
13. Core Shroud
14. Control Rod
15. Core Plate
16. In-core Instrument Guide Tubes
17. Control Rod Guide Tubes
18. Core Differential Pressure Line
19. Reactor Internal Pumps (RIPs)
20. Thermal Insulation
22. Fine Motion Control Rod Drives
23. RIP Motor Casing
24. Local Power Range Monitor
21. Control Rod Drive Housings

Figure 1 - Advanced Boiling Water Reactor

圖 4-2 壓力槽本體及壓力槽內部組件結構示意圖

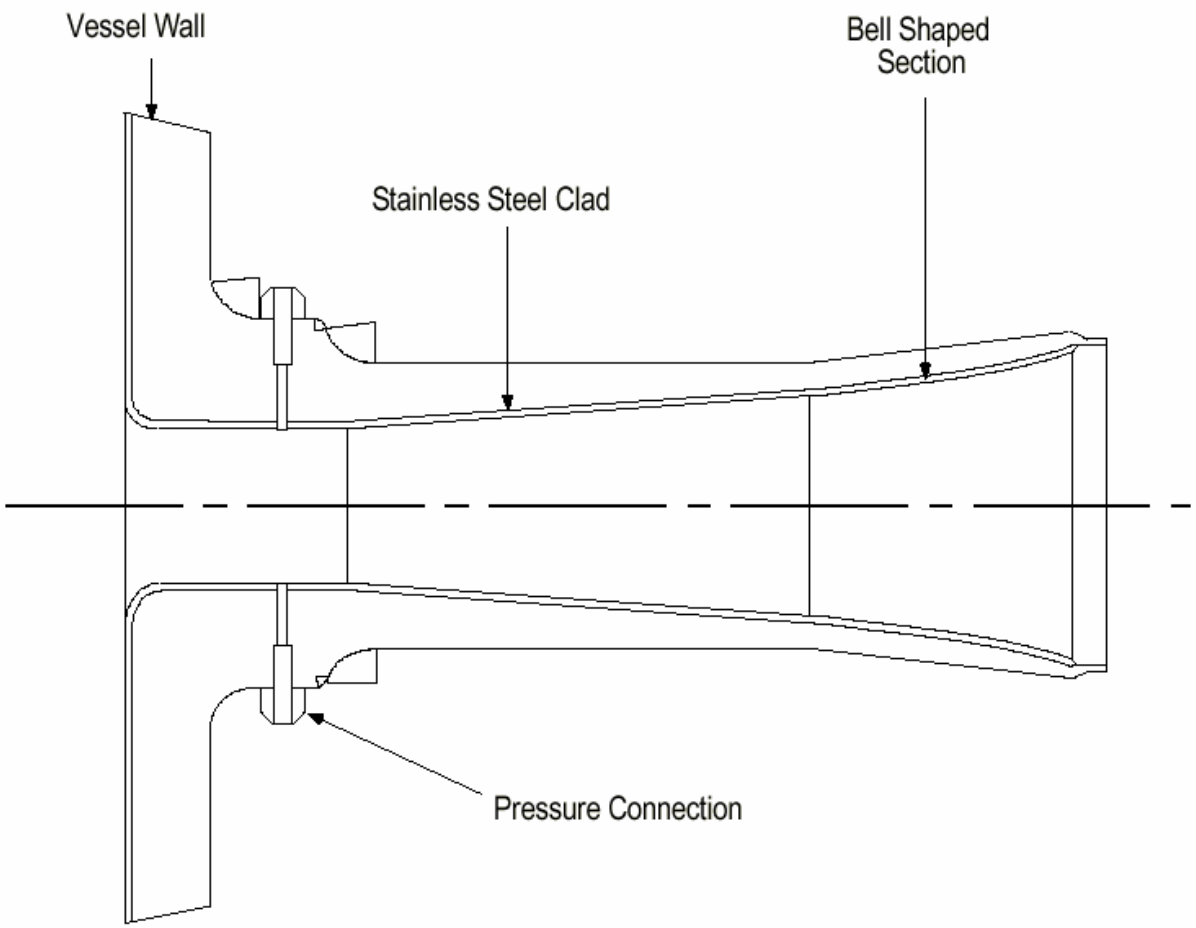


Figure 2 - Main Steamline Nozzle And Flow Restrictor

圖 4-3 出口管嘴流量限流器（Outlet Nozzles/Flow Restrictors）

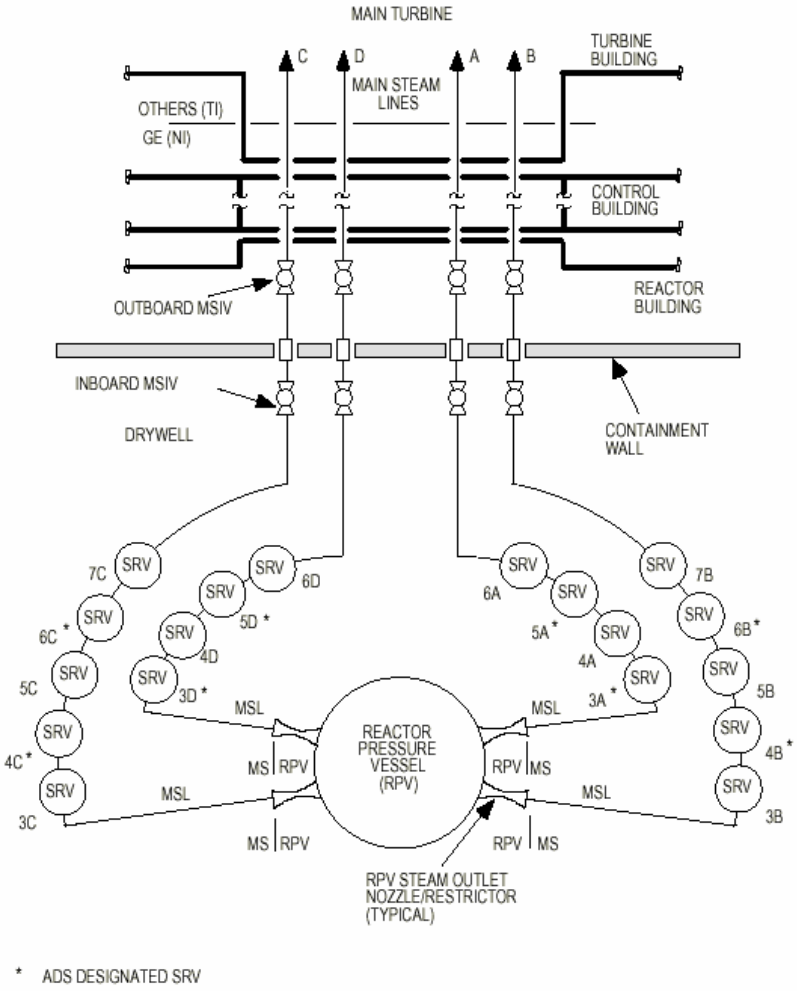


Figure 4 - Safety Relief Valves and Steamline

圖 4-4 十八只安全釋壓閥在四條主蒸汽管線上的分布圖

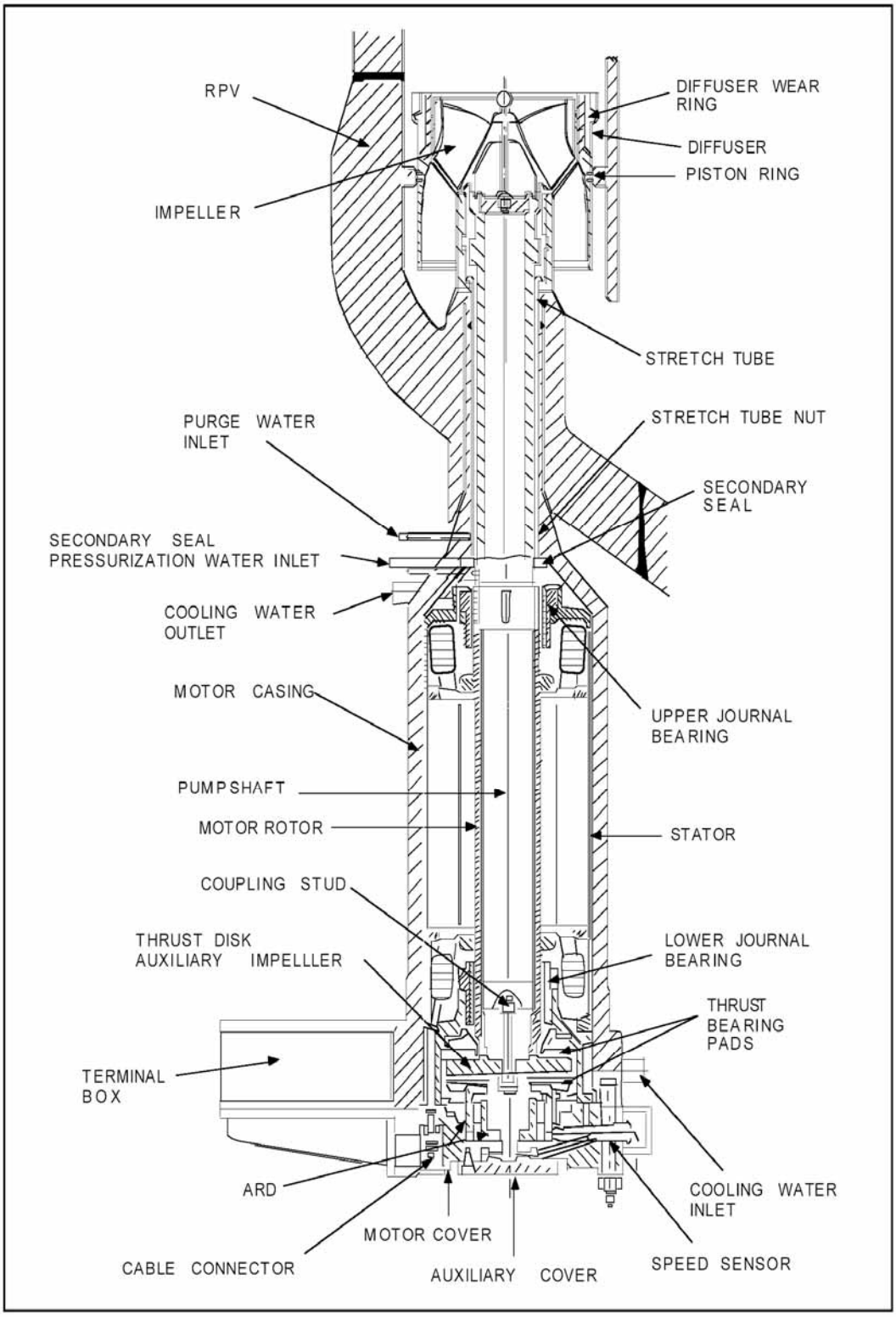

RPV
IMPELLER
DIFFUSER WEAR RING
DIFFUSER
PISTON RING
STRETCH TUBE
PURGE WATER INLET
STRETCH TUBE NUT
SECONDARY SEAL
SECONDARY SEAL PRESSURIZATION WATER INLET
COOLING WATER OUTLET
MOTOR CASING
UPPER JOURNAL BEARING
PUMPSHAFT
MOTOR ROTOR
STATOR
COUPLING STUD
THRUST DISK AUXILIARY IMPELLLER
LOWER JOURNAL BEARING
THRUST BEARING PADS
TERMINAL BOX
ARD
COOLING WATER INLET
MOTOR COVER
CABLE CONNECTOR
AUXILIARY COVER
SPEED SENSOR

圖 4-5 爐內泵剖視圖

表 4-1 安全模式的設定點

Safety Mode SRV Opened	安全模式(Safety Mode)
7B、7C	8.00 MpaG（1160psig）
4A、4D、5B、5C	8.07 MpaG（1170psig）
3B、3C、6A、6D	8.14 MpaG（1180psig）
5A、5D、6B、6C	8.20 MpaG（1190psig）
3A、3D、4B、4C	8.27 MpaG（1200psig）

表 4-2 釋壓模式的設定點

Relief Mode SRV Opened	釋壓模式(Relief Mode)
7B	7.58 MpaG（1100psig）
7C	7.65 MpaG（1110psig）
4A、4D、5B、5C	7.72 MpaG（1120psig）
3B、3C、6A、6D	7.79 MpaG（1130psig）
5A、5D、6B、6C	7.86 MpaG（1140psig）
3A、3D、4B、4C	7.93 MpaG（1150psig）

5. 核四廠 RELAP5-3DK 輸入模式的節點圖

本章為 RELAP5-3D 建立模式時所用的節點圖，圖上標示出在建立 RELAP5-3D RPV 系統輸入模式時的各個體積與節點連接示意圖及標號。反應爐壓力槽(RPV)的 RELAP5-3DK 輸入模式中各熱水流控制體積的幾何大小與內部組件的相關標高均由參考文獻四[(4)]而來。另外主蒸汽系統(MS)中的安全釋壓閥與主蒸汽隔離閥是由 RELAP5-3D 的閥門接節組件模擬。而爐內泵(RIP)在模式中將以 RELAP5-3D 的幫浦組件建立，其操作參數亦由製造廠家的設計資料決定。爐內泵(RIP)的相關參數由參考文獻五[(5)]和參考文獻六[(6)]的廠家資料及參考文獻七[(7)]的設計資料提供。圖 5-1 和圖 5-2 標示出在建立 RELAP5-3DK RPV 系統輸入模式時的各控制體積及接節連接相關位置的示意圖，RPV 系統模式與 BOP 系統的交界在主蒸汽集管處(Steam Header)進行銜接。

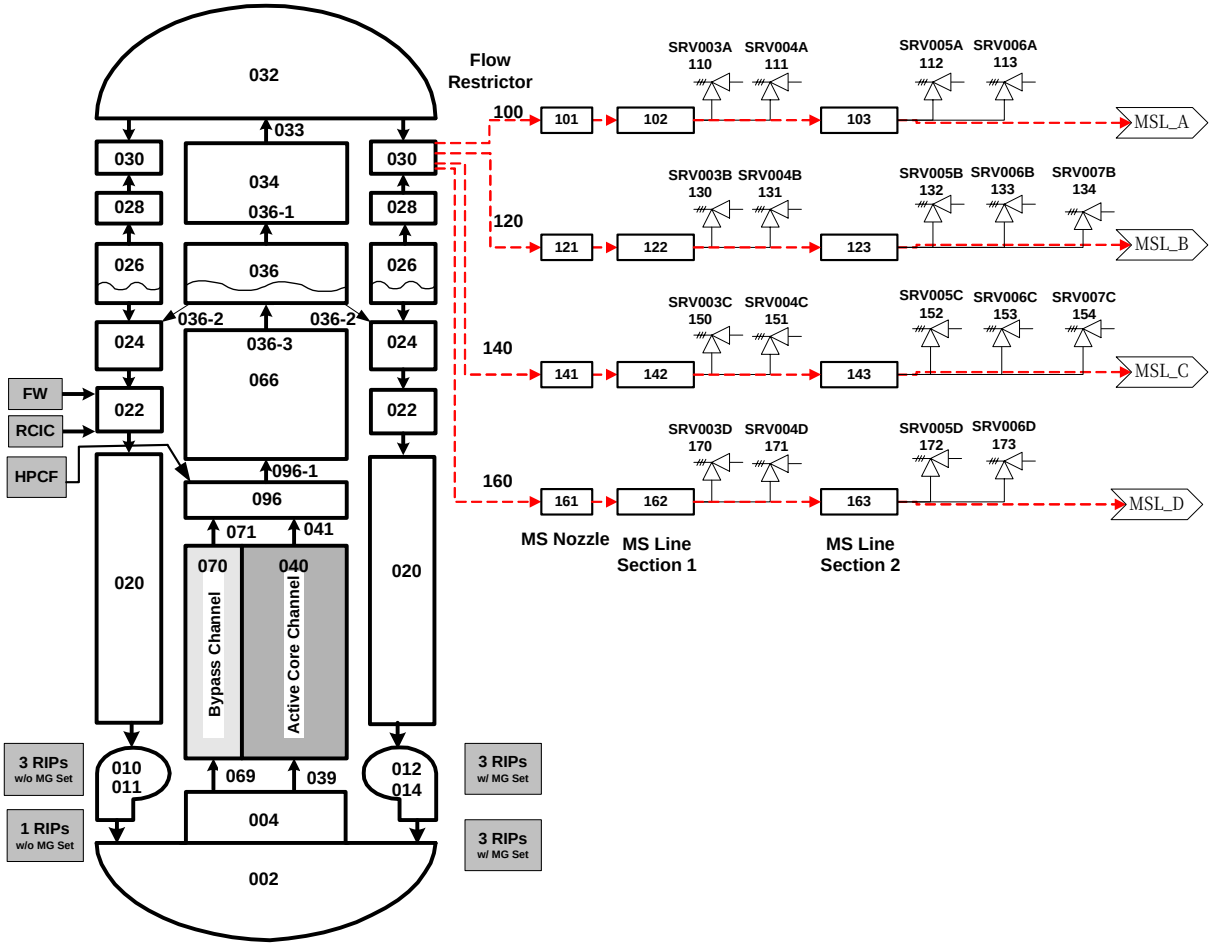


圖 5-1 RPV 系統模式節點示意圖-1

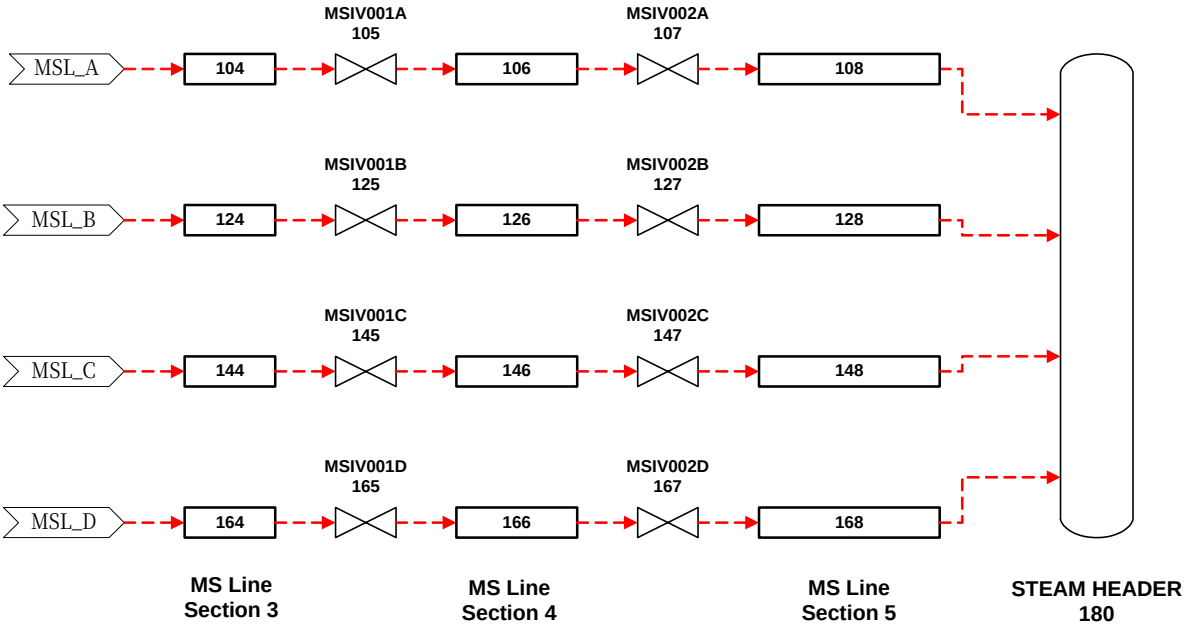


圖 5-2 RPV 系統模式節點示意圖-2

6. 模式簡化說明

RPV 系統模式之簡化如下：

(1) RELAP5-3D 模式中各熱水流體積原則上是按照內部組件作區分的，體積與高度均參照設計數據設定，但是各熱水流體積是 1D 的，3D 的效應不考慮模擬。

(2) 爐心燃料的熱結構模擬簡化至與爐心熱水流體積的區分數目相同，目前規劃的爐心將區分為 9 個，爐心中央有一個通道，外圍分成兩圈，每圈共有 4 個熱水流通道，共計 9 個爐心的熱水流通道，因此配合的熱結構數目也是 9 組，每一組所包括的燃料元件數目由熱水流通道的區分決定。

(3) 爐心燃料的熱結構軸向功率分布由 Chopped cosine 計算，徑向分布則依各區熱結構的燃料束數目來均分，總額定功率為 3926MW。

(4) 爐內泵(RIP)總計有十台可變速之爐水再循環泵，模式簡化為四群組來模擬，首先依有無與馬達發電機組連接（Motor／Generator，M/G Set）分成三群組，與馬達發電機組連接的有兩群各三個爐內泵，而最後未與馬達發電機組連接的四台再分成兩群，分別是三台和一台。

(5) 水位偵測儀器的功能以 RELAP5-3D 模式的控制變數(Control Variable)對熱水流體積的參數計算來模擬。

7. 結論與建議

在此份報告中，已完成了核四廠 RELAP5 反應爐壓力槽模式的建立。

模式建立完成後，接下來的工作將以適當的數據來作驗証及修正，來確保模式建立的正確性。驗証工作包括搜集在不同額定功率的初始狀態和重要的設定點，或事件前後的系統重要參數值，作為模式比對或修正的依據。

參考文獻

1. “進步型沸水式反應器(ABWR)訓練教材(上冊):第一篇 第二章反應爐壓力槽內部組件(Reactor Pressure Vessel and Internal) ”,台灣電力公司。
2. “進步型沸水式反應器(ABWR)訓練教材(上冊):第三篇 第一章 主蒸汽系統 (Main Steam System) ”，台灣電力公司。
3. “進步型沸水式反應器(ABWR)訓練教材(上冊):第一篇 第四章 再循環水系統(Reactor Recirculation System-RCIR) ”，台灣電力公司。
4. “Reactor Weights and Volumes Design Requirements”, 31113-0A51-6006, Rev 0, General Electric Company.
5. “INSTRUCTION BOOK FOR PACKAGE 62.2610 RIP PUMPS AND MOTORS”,E KK090400-a 33/119,TOSHIBA CORPORATION.
6. “INSTRUCTION BOOK FOR PACKAGE 62.2610 RIP PUMPS AND MOTORS”, EME000097-c 23/133,TOSHIBA CORPORATION.
7. Project Design Manual”, 31113-0A23-1000,Chapter 3, 3.14.8.1.4 System Performance Requirements, Rev 20, General Electric Company.

附錄

以下所附為進步型沸水式反應器(ABWR)的計算書。

Reactor Pressure Vessel Hydraulic Volume and Junction

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

D M Y
日期： / /
撰寫：
審查：

The Development of RELAP5-3DK Code Input Deck of RPV Model
Hydraulic Volumes and Junctions

Ref. No.

The data of the hydraulic volumes are derived from the reference document; 31113-0A51-6006,Reactor Weights and Volumes Design Requirements. The RELAP5 noding diagram of the Lungmen RPV model is shown on the attachment of this document. From the attached noding diagram, the distribution of the volumes in the Lungmen model can be easily understood. The reference zero point is the RVZ(Reactor Vessel Zero),located at the lowest point of the reactor vessel inside cladding. Most of the elevation data are estimated from reference 1 and the RPV outline drawing(1/2). **1** **2**

Lower Plenum Region Volume 002:

Volume 002 is inside the shroud diameter,from RVZ to the top of the CRD housing. The volume 002 is defined to have these zones: **1**

Zone A (CRD housings)= $5.81m^3$

Zone B (RVZ to the top of the CRD housing)= $18.58m^3$

Zone T_3 (Volume inside internal pumps)= $0.32m^3$

Volume(002) = Zone A+ Zone B+ Zone T_3

= $24.71m^3$

Elevation (RVZ to the top of the CRD housing) = 0.0 ~1.3969m **1**

Height = (1.3969m-0.0m) = 1.3969m

Inclination angle = Vertical = 90°

ε (Roughness)= $1.5*10^{-4}$

Junction Area (A_{002}) of branch Volume 002 (Zone A & Zone T_3 are not included, because there are no flows in these zones.)

A_{002} = Zone B / Elevation change= $18.58m^3$ /1.3969m = $13.30m^2$

RELAP 5-3D Input Deck is listed on next page:

Ref. 1. GE: 31113-0A51-6006,Reactor Weights and Volumes Design Requirements.

2. BABCOCK-HITACHI K.K. 6711-001-01-06 RPV OUTLINE DRAWING (1/2)

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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```
**************************************************
*     lower plenum region      ( Branch Volume 002)              *
**************************************************
*
0020000      loplnv02     branch
*            ---------    ---------
*
*            number         jun. i.c.
*            of jun.        control
*
0020001      1              0
*                                                    horiz.        vert.
*                  area          length        volume       angle         angle
*
0020101   0.0   1.3969   24.71   0.0   90.0 *CRD Housing 5.81m3 & RIP Casing 0.32m3
*
*                   elev.                                hydraulic     volume
*                  change             rough.         diam.          control
*
0020102            1.3969             1.5000e-4      0.0            00
*
0020200   0   7263102.      1209080.      2579174.      0.
*
*            from           to            junction     forward      reverse      junct.
*            connect.       connect.      area         loss coef.   l.c.         flags
*
0021101      002010000   004000000   13.30      2.0578       2.0578       01000 *Correctio
*
0021201     1.33872      1.718843 0. * 13502.4
*
**************************************
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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Core Entrance Region Volume 004:

Volume 004 inside the shroud diameter, from the top of the CRD housing to the bottom of active fuel channel(BAF). The volume 004 is defined to have these zones listed below: **1**

Zone C (Top of the CRD housing to Pump Deck)= 9.15m^3

Zone D (Top of the Pump Deck to the core support mounting flange)= 58.85m^3

Zone E (Shroud Volume: Top of the core support mounting flange to BAF)= 10.34m^3

Volume(004) = Zone C+ Zone D+ Zone E

= 78.34m^3

Elevation (Top of the CRD housing to BAF) = 1.3969m~5.3411m **2**

Height = (5.3411m -1.3969m) = 3.9442m

Inclination angle = Vertical = 90°

ε (Roughness)= 1.5*10^{-4}

RELAP 5-3D Input Deck is listed below:

```
**************************************
*     Core Entrance region     ( branch Volume 004)          *
**************************************
0040000     loplnv04     branch
*           ---------    ---------
*
*           number       jun. i.c.
*           of jun.      control
*
0040001     0            0
*
*                 area         length       volume       angle        angle
*
0040101           0.0          3.9442       78.34        0.0          90.0 *Elv & Vol
*
*           elev.                     hydraulic    volume
*           change       rough.       diam.        control
*
0040102     3.9442       1.5000e-4    0.0          00
*
0040200 0          7241526.    1209080. 2579401. 0
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model
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Reactor Pressure Vessel Fuel Channels
Volume 041~049

Ref. No.

There are 872 fuel channel boxes in the core of RPV. Total hydraulic volume in these channels are to be divided into 9 divisions. The thermo-hydraulic volume data of each section is generated from reference 1. **1**

Sum of all channel volumes:
Zone F (BAF to TAF) = 34.78m^3
Elevation (BAF to TAF) = 5.3411m~9.1511m **2**
Height = (9.1511m-5.3411m) = 3.81m
There are 872 channels.
34.78m^3/872 channels = 0.039885m^3/channel
A(channel) = 0.039885m^3/3.81m = 0.010469m^2/channel

In the RELAP5 model, the core of Lungmen plant is divided into 9 parts in radial direction. These hydraulic volumes are numbered as 41 to 49. The radial distribution of these volumes are shown on the attached core mapping figure.

1.Central fuel channels:
Hydraulic volume No.= 041
The hydraulic volume 041 is the centermost volume in the core. There are 4 channels in this pipe volume.

Volume(041) = 4 channels*0.039885m^3/channel = 0.15954m^3
Area(041) = 4 channels*0.010469m^2/channel = 0.041876 m^2

The axial nodes are 13. Length of the first 12 nodes is 12 inches and the last node is 6 inches. The fuel channels are modeled as a pipe volume in RELAP5.

Each fuel assembly contains 78 full length rods, 14 partial length rods and 2 water rods. The full length rod has 150” active fuel length and the partial length rod has 84” active fuel length for GE14 fuel. By reference 3(”GNF-DB-0003.21 Rev5. page 19 of 24 Fig 3A.”), total length of the partial length rod is 96” including gas plenum. **3**

Ref. 3. GNF-DB-0003.21 Rev5. page 19 of 24 Fig 3A

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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審查：

Reactor Pressure Vessel Fuel Channels

Volume 041~049

Ref. No.

From previous page; Area(041) = 0.041876 m^2 (Axial averaged value)

The area of the channel varies because of the existence of the partial length rod. The variation in area can be estimated as following equations :

Let variables x,y are the cross-sections of each region.

x = 92 fuel rods + 2 water rods (Partial length rods exist)

y = 78 full length fuel rods + 2 water rods (No PLR)

Length of PLR = 96”

Eq(1) x*(96/150)+y*(54/150) = 0.010469m^2 (Axial averaged channel area)

Eq(2) y-x = Sum of cross-sections of 14 fuel rods

By reference 4;(874611M002-1 Amendment2 Figure 1: Lattice Geometry) **4**

Cladding Outside Diameter = 0.404” = 1.03cm

Cross-sections of 14 fuel rods = 14*[π *D^2/4] = 1.166520*$10^{-3}m^2$

Inserting the value into Eq(2) and solving Eq(1) & Eq(2), values of variables x,y are gained.

x = 0.010049052m^2/channel(92 rods + 2 water rods)

y = 0.011215572m^2/channel(78 rods + 2 water rods)

Core Pipe Volume 041 :

Pipe 041 is axially divided into 13 nodes, the geometry data of the sub-volume of each node is estimated by the result in previous calculation.

Fuel length 0”~96” → 92 fuel rods

Fuel length 96”~150” → 78 fuel rods

There are twelve 12” nodes and one 6” node.

For sub-volume 041-1~041-8 :

Junction flow area = 4x = 4*0.010049052m^2 = 0.040196208m^2

Length of sub-volume = 12” = 0.3048m

Volume of sub-volume = 0.3048m*0.040196208m^2 = 0.012251804m^3

Elevation for sub-volume 041-1~041-8 = 12”*8 = 96”

Ref. 4. 874611 M002-1 Amendment2 Figure 1: Lattice Geometry

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model
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Core Pipe Volume 041(continued)
For sub-volume 041-9~041-12 :
Elevation : 96”~144” (96” = End of PLR)
Junction flow area = 4y = 4*0.011215572m^2 = 0.044862288m^2
Length of sub-volume = 12” = 0.3048m
Volume of sub-volume = 0.3048m*0.044862288m^2 = 0.013674025m^3

For sub-volume 041-13 :
Elevation : 144”~150” (150” = End of FLR)
Junction flow area = 4y = 0.044862288m^2
Length of sub-volume = 6” = 0.1524m
Volume of sub-volume = 0.1524m*0.044862288m^2 = 6.837012691*$10^{-3}$$m^3$

RELAP5 Input for Pipe 041:

Pipe 041
No. of vol = 13
Volume flow area = 0.0
Junction flow area :

area	Jun No.
0.040196208m^2	8
0.044862288m^2	12

Volume of volume :

Volume	Vol No.
0.012251804m^3	8
0.013674025m^3	12
6.837012691*$10^{-3}$$m^3$	13

Length of Volume :

Length	Vol No.
0.3048m	12
0.1524m	13

Horizontal angle	Vol No.
0.0	13

Vertical angle	Vol No.
90.0	13

Elevation change	Vol No.
0.3048m	12
0.1524m	13

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model
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Core Pipe Volume 041(continued)

Ref. No.

Hydraulic Diameter :
By Reference 4; Lattice geometry : **4**
Fuel Rod Cladding O.D = 0.404" = 1.03cm
Water Rod O.D = 0.98" = 2.49cm
Channel Box inside perimeter = 2 π *R(Corner inside radius)+4*[B(Inside width)-2R]
Where R = 0.450" = 1.143cm
B = 5.278" = 13.406cm
Channel Box inside perimeter = 2 π *1.143+4*[13.406-1.143] = 51.66cm = 0.5166m

For sub-volume 041-1~041-8 (W/PLR) :
Total wetted perimeter P = 92*[π *(1.03/100)]+2*[π *(2.49/100)]+0.5166
= 2.9770+0.1565+0.5166 = 3.6501m
Hydraulic Diameter = 4x/P = 4*0.010049052m^2/3.6501m = 0.011012358m

For sub-volume 041-9~041-13 (W/o PLR) :
Total wetted perimeter P = 78*[π *(1.03/100)]+2*[π *(2.49/100)]+0.5166
= 2.5240+0.1565+0.5166 = 3.1971m
Hydraulic Diameter = 4y/P = 4*0.011215572m^2/3.1971m = 0.014032181m

Hydraulic Dia	Vol No.
0.011012358m	8
0.014032181m	13

RELAP5 Input Deck listed below :

```
*
0410000     corev041     pipe
*           ---------    ---------
*
*           number
*           of vol.
*
0410001     13
*
```

RELAP5 Input Deck for Core Pipe Volume 041(continued)

Ref. No.

```
*
*              volume        volume
*              flow area     number
*
0410101        0.0             13
*
*              junction      junction
*              flow area     number
*
0410201        0.040196208       8 *w/ 14 PLR
*
0410202        0.044862288       12 *w/o 14 PLR
*
*              length         volume
*              of vol.        number
*
0410301        0.3048          12
*
0410302        0.1524          13
*
*              volume         volume
*              of vol.        number
*
0410401      0.012251804      8 *w/ 14 PLR
*
0410402      0.013674025      12 *w/o 14 PLR
*
0410403      6.837012691e-3 13 *w/o 14 PLR
*
*              horiz.         volume
*              angle           number
*
0410501        0.0             13
```

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RELAP5 Input Deck for Core Pipe Volume 041(continued)

```
*
*              vert.          volume
*              angle           number
*
0410601        90.0             13
*
*              elev.          volume
*              change          number
*
0410701        0.3048           12
*
0410702        0.1524           13
*
*                                      hydr.           volume
*                            rough.    diam.           number
*
0410801          0.0      0.011012358      8
*
0410802          0.0      0.014032181      13
*
*              forward        reverse        junction
*              loss coef.  loss coef.  number
*
0410901        0.355        0.355          12
*
*              vol cntrl.  volume
*              flags           number
*
0411001      00110             13
*
* Pipe 041 I.C
*
0411201 0      7221902.    1224402.    2579609.          0.              0.    1
*
0411202 0      7219342.    1245849.    2579648.        .1720096          0.    2
*
```

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RELAP5 Input Deck for Core Pipe Volume 041(continued)

```
*
0411203 0       7216812.    1259158.    2579882.        .375859     0.  3
*
0411204 0       7214271.    1265018.    2875834.        .533791     0.  4
*
0411205 0       7211524.    1267741.    2884987.        .644351     0.  5
*
0411206 0       7208590.    1268871.    2737892.        .733708     0.  6
*
0411207 0       7205354.    1268744.    2682194.        .76132      0.  7
*
0411208 0       7202596.    1268404.    2640614.         .776285    0.  8
*
0411209 0       7200866.    1268210.    2615546.         .788186    0.  9
*
0411210 0       7198601.    1268026.    2598220.         .799627    0.  10
*
0411211 0       7196297.    1267860.    2585788.         .807354    0.  11
*
0411212 0       7194061.    1267681.    2580208.         .812196    0.  12
*
0411213 0       7192235.    1267564.    2580021.         .775814    0.  13
*
*Pipe 041 I.C ends
*
*               junction    junction
*               flags        number
*
0411101         01000          12
*
*               jun. i.c.
*               contrl
*
0411300         0
*
```

RELAP5 Input Deck for Core Pipe Volume 041(continued)

Ref. No.

```
*
**core pipe 041
*
0411301 1.726713 2.07496      0.        1 * 52.2513
*
0411302 2.082083 2.420026     0.        2 * 52.2513
*
0411303 2.709995 3.41916      0.        3 * 52.2513
*
0411304 3.573414 5.1313       0.        4 * 52.2513
*
0411305 4.56007   6.36206      0.        5 * 52.2513
*
0411306 5.83368   6.99794      0.        6 * 52.2513
*
0411307 6.2528    8.08873      0.        7 * 52.2513
*
0411308 6.42665   9.00473      0.        8 * 52.2513
*
0411309 5.87038   8.84342      0.        9 * 52.2513
*
0411310 6.00782   9.49699      0.        10 * 52.2513
*
0411311 6.08964   9.9787       0.        11 * 52.2513
*
0411312 6.1653    10.19958     0.        12 * 52.2513
*
***core pipe 041 ends
```

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Reactor Pressure Vessel Fuel Channels

Core Entrance Junction 051

The core entrance junction 051 connects the core entrance volume 004 and fuel channel pipe volume 041. The Junction area is assumed to be equal to the channel flow area in the lower part of the pipe 041.

Junction flow area = 0.040196208m^2

RELAP5 Input for Single junction 051:

```
*
0510000      conj051     sngljun
*            ---------   ---------
*
*            from          to          junction    forward     reverse     junct.
*            connect.      connect.    area        loss coef.  l.c.        flags
*
0510101   004010000   041000000   0.040196208   2.7      2.7       01000
*
0510201 0 1.714168 1.918256 0. * 52.2513
*
```

Core Exit Junction 061

The core exit junction 061 connects the fuel channel pipe volume 041 and upper plenum volume 071. The Junction area is assumed to be equal to the channel flow area in the upper part of the pipe 041.

Junction flow area = 0.044862288m^2

RELAP5 Input for Single junction 061:

```
*
0610000      conj061     sngljun
*            ---------   ---------
*
*            from          to          junction    forward     reverse     junct.
*            connect.      connect.    area        loss coef.  l.c.        flags
*
0610101      041010000   071000000   0.044862288   0.5      0.5       01000
*
0610201 0    5.153          10.74213        0. * 52.2513
*
```

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Reactor Pressure Vessel Fuel Channels
Volume 041~049
Pipe Volume 042

Pipe 042 is one of the volumes that surrounding the central pipe volume 041. Because of the symmetry, pipe volume 042、043、044 & 045 are identical. There are 27 control cells in volume 042. The geometry data can be calculated from the data of pipe volume 041.

For pipe volume 042(043、044、045):
All geometry data can be calculated by scaling the value of volume 041 27 times.

For sub-volume 042-1~042-8(W/ PLR):
Junction flow area = 27*[4x] = 27*[4*0.010049052m^2] = 1.085297616m^2
Length of sub-volume = 12” = 0.3048m
Volume of sub-volume = 0.3048m*1.085297616m^2 = 0.330798713m^3
Elevation for sub-volume 042-1~042-8 = 12”*8 = 96”

For sub-volume 042-9~042-12(No PLR):
Elevation : 96”~144” (96” = End of PLR)
Junction flow area = 27*[4y] = 27*[4*0.011215572m^2] = 1.211281776m^2
Length of sub-volume = 12” = 0.3048m
Volume of sub-volume = 0.3048m*1.211281776m^2 = 0.369198685m^3

For sub-volume 042-13(No PLR):
Elevation : 144”~150” (150” = End of FLR)
Junction flow area = 27*[4y] = 1.211281776m^2
Length of sub-volume = 6” = 0.1524m
Volume of sub-volume = 0.1524m*1.211281776m^2 = 0.184599342m^3

RELAP5 Input for Pipe 042、043、044 & 045:

Pipe 042
No. of vol = 13
Volume flow area = 0.0

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Core Pipe Volume 042(continued)

Junction flow area :

area	Jun No.
1.085297616m^2	8
1.211281776m^2	12

Volume of volume :

Volume	Vol No.
0.330798713m^3	8
0.369198685m^3	12
0.184599342m^3	13

Length of Volume :

Length	Vol No.
0.3048m	12
0.1524m	13

Horizontal angle	Vol No.
0.0	13

Vertical angle	Vol No.
90.0	13

Elevation change	Vol No.
0.3048m	12
0.1524m	13

Hydraulic Dia	Vol No.
0.011012358m	8
0.014032181m	13

RELAP5 Input Deck listed below :

```
*
0420000     corev042    pipe
*           ---------   ---------
*
*           number
*           of vol.
*
0420001     13
*
```

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RELAP5 Input Deck for Core Pipe Volume 042(continued)

Ref. No.

```
*
*              volume        volume
*              flow area     number
*
0420101        0.0             13
*
*              junction      junction
*              flow area     number
*
0420201        1.085297616       8 *w/ 14 PLR
*
0420202        1.211281776      12 *w/o 14 PLR
*
*              length         volume
*              of vol.        number
*
0420301        0.3048          12
*
0420302        0.1524          13
*
*              volume         volume
*              of vol.        number
*
0420401      0.330798713       8 *w/ 14 PLR
*
0420402      0.369198685      12 *w/o 14 PLR
*
0420403      0.184599342      13 *w/o 14 PLR
*
*              horiz.         volume
*              angle           number
*
0420501        0.0             13
*
```

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RELAP5 Input Deck for Core Pipe Volume 042(continued)

```
*
*              vert.          volume
*              angle           number
*
0420601        90.0            13
*
*              elev.          volume
*              change          number
*
0420701        0.3048          12
*
0420702        0.1524          13
*
*                                        hydr.          volume
*                              rough.    diam.          number
*
0420801          0.0      0.011012358      8
*
0420802          0.0      0.014032181      13
*
*              forward        reverse        junction
*              loss coef. loss coef. number
*
0420901        0.355        0.355          12
*
*              vol cntrl. volume
*              flags          number
*
0421001      00110            13
*
* Pipe 042 I.C
*
0421201 0      7221718.     1222808.     2579611.          0.              0.    1
*
0421202 0      7219090.     1243978.     2579646.        .1277345          0.    2
*
```

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RELAP5 Input Deck for Core Pipe Volume 042(continued)

Ref. No.

```
*
0421203 0       7216493.    1257662.    2579778.        .3037155        0.  3
*
0421204 0       7213880.    1264474.    2579988.        .446372         0.  4
*
0421205 0       7211244.    1267771.    2580115.        .546603         0.  5
*
0421206 0       7208572.    1268580.    2580196.        .618423         0.  6
*
0421207 0       7205841.    1268592.    2580239.        .668711         0.  7
*
0421208 0       7203084.    1268440.    2580252.         .705789        0.  8
*
0421209 0       7201066.    1268318.    2580326.         .729789        0.  9
*
0421210 0       7198734.    1268165.    2580334.         .749852        0.  10
*
0421211 0       7196397.    1267944.    2580199.         .763286        0.  11
*
0421212 0       7194144.    1267719.    2580062.         .77051         0.  12
*
0421213 0       7192380.    1267592.    2580020.         .716113        0.  13
*
*Pipe 042 I.C ends
*
*               junction    junction
*               flags        number
*
0421101         01000         12
*
*               jun. i.c.
*               contrl
*
0421300         0
*
```

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RELAP5 Input Deck for Core Pipe Volume 042(continued)

Ref. No.

```
*
***core pipe jun 042
*
0421301 1.787674 2.724664       0.          1 * 1461.708
*
0421302 2.05156   2.60239        0.          2 * 1461.708
*
0421303 2.534484 3.50534        0.          3 * 1461.708
*
0421304 3.1139    4.44667       0.          4 * 1461.708
*
0421305 3.695555 5.46517        0.          5 * 1461.708
*
0421306 4.253065 6.51755        0.          6 * 1461.708
*
0421307 4.74622   7.50502       0.          7 * 1461.708
*
0421308 5.19309   8.34204       0.          8 * 1461.708
*
0421309 4.92874   8.22397       0.          9 * 1461.708
*
0421310 5.19622   8.83771       0.          10 * 1461.708
*
0421311 5.39193   9.28082       0.          11 * 1461.708
*
0421312 5.51137   9.4839        0.          12 * 1461.708
*
***core pipe jun 042 ends
*
```

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Reactor Pressure Vessel Fuel Channels

Core Entrance Junction 052(053、054、055)

The core entrance junction 052 connects the core entrance volume 004 and fuel channel pipe volume 042. The Junction area is assumed to be equal to the channel flow area in the lower part of the pipe 042.

Junction flow area = 1.085297616m^2

RELAP5 Input for Single junction 052:

```
*
0520000     conj052     sngljun
*           ---------   ---------
*
*           from          to          junction    forward     reverse     junct.
*           connect.      connect.    area        loss coef.  l.c.        flags
*
0520101   004010000   042000000   1.085297616   2.6     2.6     01000
*
0520201 0 1.776043 2.102015 0. * 1461.708
*
```

Core Exit Junction 062(063、064、065)

The core exit junction 062 connects the fuel channel pipe volume 042 and upper plenum volume 071. The Junction area is assumed to be equal to the channel flow area in the upper part of the pipe 042.

Junction flow area = 1.211281776m^2

RELAP5 Input for Single junction 062:

```
*
0620000     conj062     sngljun
*           ---------   ---------
*
*           from          to          junction    forward     reverse     junct.
*           connect.      connect.    area        loss coef.  l.c.        flags
*
0620101     042010000   071000000   1.211281776   0.5     0.5     01000
*
0620201 0   4.447535      10.26416      0. * 1461.708
*
```

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Reactor Pressure Vessel Fuel Channels
Volume 041~049
Pipe Volume 046

Pipe 046 is one of the 4 peripheral volumes in the core. All 4 volumes are symmetrical, so pipe volume 046、047、048 & 049 are identical. There are 109 channel boxes in each peripheral. volume. The geometry data can be evaluated by previous result.

For pipe volume 046(047、048、049):
All geometry data can be calculated by scaling the single channel box data 109 times.

For sub-volume 046-1~046-8(W/ PLR):
Junction flow area = 109*x = 109*0.010049052m^2 = 1.095346668m^2
Length of sub-volume = 12” = 0.3048m
Volume of sub-volume = 0.3048m*1.095346668m^2 = 0.333861664m^3
Elevation for sub-volume 042-1~042-8 = 12”*8 = 96”

For sub-volume 046-9~046-12(No PLR):
Elevation : 96”~144” (96” = End of PLR)
Junction flow area = 109*y = 109*0.011215572m^2 = 1.222497348m^2
Length of sub-volume = 12” = 0.3048m
Volume of sub-volume = 0.3048m*1.222497348m^2 = 0.372617191m^3

For sub-volume 046-13(No PLR):
Elevation : 144”~150” (150” = End of FLR)
Junction flow area = 1.222497348m^2
Length of sub-volume = 6” = 0.1524m
Volume of sub-volume = 0.1524m*1.222497348m^2 = 0.186308595m^3

RELAP5 Input for Pipe 046、047、048 & 049:

Pipe 046
No. of vol = 13
Volume flow area = 0.0
Junction flow area :

area	Jun No.
1.095346668m^2	8
1.222497348m^2	12

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Core Pipe Volume 046(continued)

Volume of volume :

Volume	Vol No.
0.333861664m^3	8
0.372617191m^3	12
0.186308595m^3	13

Length of Volume :

Length	Vol No.
0.3048m	12
0.1524m	13

Horizontal angle	Vol No.
0.0	13

Vertical angle	Vol No.
90.0	13

Elevation change	Vol No.
0.3048m	12
0.1524m	13

Hydraulic Dia	Vol No.
0.011012358m	8
0.014032181m	13

RELAP5 Input Deck listed below :

```
*
0460000     corev046     pipe
*           ---------    ---------
*
*           number
*           of vol.
*
0460001     13
*
*           volume       volume
*           flow area    number
*
0460101     0.0          13
```

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RELAP5 Input Deck for Core Pipe Volume 046(continued)

Ref. No.

```
*
*              junction      junction
*              flow area     number
*
0460201        1.095346668       8 *w/ 14 PLR
*
0460202        1.222497348      12 *w/o 14 PLR
*
*              length         volume
*              of vol.        number
*
0460301        0.3048          12
*
0460302        0.1524          13
*
*              volume          volume
*              of vol.        number
*
0460401      0.333861664      8 *w/ 14 PLR
*
0460402      0.372617191      12 *w/o 14 PLR
*
0460403      0.186308595      13 *w/o 14 PLR
*
*              horiz.         volume
*              angle           number
*
0460501        0.0             13
*
*              vert.          volume
*              angle           number
*
0460601        90.0            13
*
```

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RELAP5 Input Deck for Core Pipe Volume 046(continued)

```
*
*              elev.          volume
*              change         number
*
0460701        0.3048         12
*
0460702        0.1524         13
*
*                                      hydr.          volume
*                              rough.  diam.          number
*
0460801          0.0     0.011012358    8
*
0460802          0.0     0.014032181    13
*
*              forward        reverse        junction
*              loss coef.     loss coef.     number
*
0460901        0.355          0.355          12
*
*              vol cntrl.     volume
*              flags          number
*
0461001      00110            13
*
*
* Pipe 046 I.C
*
0461201 0      7219326.   1219654.   2579636.      0.          0.   1
*
0461202 0      7216706.   1240181.   2579692.      .0701934    0.   2
*
0461203 0      7214140.   1254153.   2579698.      .1989535    0.   3
*
0461204 0      7211622.   1261992.   2579828.      .327184     0.   4
*
```

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RELAP5 Input Deck for Core Pipe Volume 046(continued)

```
*
0461205 0       7209169.    1266107.    2579955.        .4307315        0.   5
*
0461206 0       7206757.    1267962.    2580039.        .510861         0.   6
*
0461207 0       7204361.    1268319.    2580073.        .567827         0.   7
*
0461208 0       7202008.    1268245.    2580068.         .606448        0.   8
*
0461209 0       7200266.    1268136.    2580093.         .629611        0.   9
*
0461210 0       7198328.    1.268+6     2580085.         .648625        0.   10
*
0461211 0       7196415.    1267852.    2580058.         .661055        0.   11
*
0461212 0       7194560.    1267691.    2580011.         .668038        0.   12
*
0461213 0       7193133.    1267589.    2579972.         .58068         0.   13
*
*Pipe 046 I.C ends
*
*               junction    junction
*               flags        number
*
0461101         01000          12
*
*               jun. i.c.
*               contrl
*
0461300         0
*
*
***core pipe jun 046
*
0461301 1.72216    2.430597        0.          1 * 1423.318
*
```

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RELAP5 Input Deck for Core Pipe Volume 046(continued)

```
*
0461302 1.863067 2.02277      0.        2 * 1423.318
*
0461303 2.150473 2.883843     0.        3 * 1423.318
*
0461304 2.527197 3.509044     0.        4 * 1423.318
*
0461305 2.935055 4.16899      0.        5 * 1423.318
*
0461306 3.346585 4.87282      0.        6 * 1423.318
*
0461307 3.71154   5.52815      0.         7 * 1423.318
*
0461308 4.008916 6.0233       0.        8 * 1423.318
*
0461309 3.76174   5.82769      0.         9 * 1423.318
*
0461310 3.91928   6.1427       0.         10 * 1423.318
*
0461311 4.02971   6.35928      0.         11 * 1423.318
*
0461312 4.098234 6.44862      0.        12 * 1423.318
*
***core pipe jun 046 ends
*
```

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Ref. No.

Reactor Pressure Vessel Fuel Channels

Core Entrance Junction 056(057、058、059)

The core entrance junction 056 connects the core entrance volume 004 and fuel channel pipe volume 046. The Junction area is assumed to be equal to the channel flow area in the lower part of the pipe 046.

Junction flow area = 1.095346668m^2

RELAP5 Input for Single junction 056:

```
*
0560000      conj056     sngljun
*            ---------   ---------
*
*            from          to          junction    forward     reverse     junct.
*            connect.      connect.    area        loss coef.  l.c.        flags
*
0560101   004010000   046000000   1.095346668   5.0      5.0       01000
*
0560201 0 1.71353   2.03365   0. * 1423.318
*
```

Core Exit Junction 066(067、068、069)

The core exit junction 066 connects the fuel channel pipe volume 046 and upper plenum volume 071. The Junction area is assumed to be equal to the channel flow area in the upper part of the pipe 046.

Junction flow area = 1.222497348m^2

RELAP5 Input for Single junction 066:

```
*
0660000      conj066     sngljun
*            ---------   ---------
*
*            from          to          junction    forward     reverse     junct.
*            connect.      connect.    area        loss coef.  l.c.        flags
*
0660101      046010000   071000000   1.222497348   0.5      0.5       01000
*
0660201 0    3.27202        7.52083          0. * 1423.318
*
```

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Reactor Pressure Vessel Bypass Channels
Core Bypass Volume 070

Ref. No.

Core Bypass Channels Volume 070 :

Volume 070 is defined as the bypass volume from bottom of active fuel to top of active fuel. By reference 1, the Volume 070 equals the zone G. To match the fuel channel volumes in axial direction, volume 070 also has the same numbers of axial nodes as fuel channel volume 041~049.

Zone G (Bypass free volume) = 26.96m^3 **1**
Volume(070) = Zone G = 26.96m^3
Elevation (BAF to TAF) = 5.3411m~9.1511m
Height = (9.1511m-5.3411m) = 3.81m
Inclination angle = Vertical = 90°
Junction Area (A_{070}) of branch Volume 070 :
A_{070} = Zone G / Elevation change= 26.96m^3 /3.81m = 7.0761m^2

For sub-volume 070-1~070-12(12” node):
Junction flow area = 7.0761m^2
Length of sub-volume = 12” = 0.3048m
Volume of sub-volume = (26.96m^3/3.81m)*0.3048m = 2.1568m^3

For sub-volume 070-1~070-12(6” node):
Junction flow area = 7.0761m^2
Length of sub-volume = 6” = 0.1524m
Volume of sub-volume = (26.96m^3/3.81m)*0.1524m = 1.0784m^3

RELAP5 Input for Pipe 070:

Pipe 070
No. of vol = 13
Volume flow area = 0.0
Junction flow area :

area	Jun No.
7.0761m^2	12

Volume of volume :

Volume	Vol No.
2.1568m^3	12
1.0784m^3	13

Ref. No.

Core Bypass Volume 070(continued)

Length of Volume :

Length	Vol No.
0.3048m	12
0.1524m	13

Horizontal angle	Vol No.
0.0	13

Vertical angle	Vol No.
90.0	13

Elevation change	Vol No.
0.3048m	12
0.1524m	13

Hydraulic Dia	Vol No.
0.0	13

RELAP5 Input Deck listed below :

```
*
**************************************
*       core bypass region (070 Pipe : 13 nodes)       *
**************************************
*
0700000       cobyv070      pipe
*             ---------     ---------
*
*             number
*             of vol.
*
0700001       13
*
*             volume        volume
*             flow area     number
*
0700101       0.0           13
*
```

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RELAP5 Input Deck for Core Pipe Volume 070(continued)

Ref. No.

```
*
*              junction     junction
*              flow area    number
*
0700201        7.0761       12 *from GE data (1.0784/0.1524)=7.0761
*
*              length        volume
*              of vol.      number
*
0700301        0.3048         12
*
0700302        0.1524         13
*
*              volume         volume
*              of vol.      number
*
0700401      2.1568      12 *from GE data (26.96/12.5)=2.1568
*
0700402      1.0784      13 *from GE data 2.1568*0.5=1.0768
*
*              horiz.       volume
*              angle         number
*
0700501        0.0            13
*
*              vert.        volume
*              angle         number
*
0700601        90.0           13
*
*              elev.        volume
*              change        number
*
0700701        0.3048         12
*
0700702        0.1524         13
*
```

RELAP5 Input Deck for Core Pipe Volume 070(continued)

Ref. No.

```
*
*                          hydr.          volume
*                rough.    diam.          number
*
0700801          0.0       0.0            13
*
*                forward   reverse        junction
*                loss coef. loss coef.    number
*
0700901          5.15      5.15           12
*
*                vol cntrl. volume
*                flags      number
*
0701001     00010          13
*
*Pipe 070 I.C
*
0701201 0       7224699.    1209387.    2579579.    0.      0.   1
*
0701202 0       7222179.    1210258.    2579606.    0.      0.   2
*
0701203 0       7219660.    1211634.    2579632.    0.      0.   3
*
0701204 0       7217142.    1213121.    2579659.    0.      0.   4
*
0701205 0       7214626.    1214588.    2579686.    0.      0.   5
*
0701206 0       7212110.    1216024.    2579712.    0.      0.   6
*
0701207 0       7209596.    1217425.    2579739.    0.      0.   7
*
0701208 0       7207084.    1218791.    2579766.    0.      0.   8
*
0701209 0       7204573.    1220110.    2579792.    0.      0.   9
*
```

RELAP5 Input Deck for Core Pipe Volume 070(continued)

Ref. No.

```
*
0701210 0       7202064.      1221394.      2579819.      0.      0. 10
*
0701211 0       7199555.      1222643.      2579846.      0.      0. 11
*
0701212 0       7197048.      1223856.      2579872.      0.      0. 12
*
0701213 0       7195104.      1224454.      2579892.      0.      0.   13
*
*Pipe 070 I.C ends
*
*               junction      junction
*               flags         number
*
0701101         01000           12
*
*               jun. i.c.
*               contrl
*
0701300         0
*
***bypass region jun 070
*
0701301 .356011     .443856   0.       1 * 1910.04
*
0701302 .356162     .44405    0.       2 * 1910.04
*
0701303 .356393     .4443455  0.       3 * 1910.04
*
0701304 .356642     .444665   0.       4 * 1910.04
*
0701305 .356889     .444982   0.       5 * 1910.04
*
0701306 .357132     .445294   0.       6 * 1910.04
*
0701307 .35737      .445599   0.       7 * 1910.04
*
```

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RELAP5 Input Deck for Core Pipe Volume 070(continued)

Ref. No.

```
*
*
0701308 .3576026    .445897    0.       8 * 1910.04
*
0701309 .357828     .4461865 0.        9 * 1910.04
*
0701310 .358049     .446469    0.       10 * 1910.04
*
0701311 .358264     .446745    0.       11 * 1910.04
*
0701312 .358474     .447014    0.       12 * 1910.04
*
***bypass region    ends
*
```

Ref. No.

Bypass Entrance Junction 040

The bypass entrance junction 040 connects the core entrance volume 004 and bypass channel pipe volume 070. The Junction area is assumed to be equal to the channel flow area of the pipe 070.

Junction flow area = 7.0761m^2

RELAP5 Input for Single junction 040:

```
*
0400000     cbyj040     sngljun
*           ---------   ---------
*
*           from        to          junction    forward     reverse     junct.
*           connect.    connect.    area        loss coef.  l.c.        flags
*
0400101     004010000   070000000   7.0761   26.0    26.0    01000 *from Vol 070 GE da
*
0400201 0 .355951   .443779   0. * 1910.04
*
```

Bypass Exit Junction 060

The bypass exit junction 060 connects the bypass channel pipe volume 070 and upper plenum volume 071. The Junction area is assumed to be equal to the channel flow area of the pipe 070.

Junction flow area = 7.0761m^2

RELAP5 Input for Single junction 060:

```
*
0600000     conj060     sngljun
*           ---------   ---------
*
*           from        to          junction    forward     reverse     junct.
*           connect.    connect.    area        loss coef.  l.c.        flags
*
0600101     070010000   071000000   7.0761   0.5     0.5     01000
*
0600201  0      .3585776        1.899203        0. * 1910.04
*
```

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Ref. No.

Upper Plenum Region Volume 071

Volume 071 is the volume which is inside the shroud diameter, extends from TAF to the shroud head dome. The volume 071 is defined to have these zones: **1**

In-Shroud volume :

Zone H (TAF to Top of the fuel channel)= 5.15m^3(In-channel+Bypass)

Zone J (Top of the fuel channel to Bottom of the shroud head)= 31.12m^3

Zone K (Shroud head dome: Exclude volume of stand pipe holes)= 11.30m^3

Volume(071) = Zone H+ Zone J+ Zone K

= 47.57m^3

Elevation (TAF to Shroud head dome)= 9.1511m~11.51m **1**

Height = (11.51m-9.1511m) = 2.3589m

Inclination angle = Vertical = 90°

ε (Roughness)= 0.0

Upper plenum volume 071 is a branch volume. Branch volume 071 also has 1 junction connecting the exit of volume 071 and the entrance of stand pipe volume 072

Junction Area (A_{071}) of branch Volume 071

A_{071} = 47.57m^3 /2.3589m = 20.1662m^2

RELAP 5-3D Input Deck is listed below:

```
*
**************************************
*       Upper Plenum      Volume 071 branch
**************************************
0710000       uppcv71      branch
*             ---------    ---------
*
*             number         jun. i.c.
*             of jun.        control
*
0710001       1              0
*
*                                                    horiz.        vert.
*             area           length         volume   angle         angle
*
0710101       0.0            2.3589      47.57    0.0             90.0 *Vol & Elv
*
```

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RELAP5 Input Deck for Upper Plenum Volume 071(continued)

Ref. No.

```
*
*                    elev.                              hydraulic   volume
*                    change          rough.      diam.           control
*
0710102              2.3589     0.0      0.0        00
*
0710200    0         7190440.   1262071.    2579950.        .643111
*
*                    from            to              junction    forward     reverse
*                    connect.        connect.        area        loss coef.  l.c.
*
0711101      071010000   072000000       20.1662         0.0     0.0     01000
*
0711201   4.13875    8.48089     0. * 13502.4
*
```

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Standpipe Region Volume 072

Ref. No.

Volume 072 is the standpipe volume which includes volume of the standpipe penetration into the shroud head, extends from bottom of the shroud head to the bottom of the steam separator swirler. The volume 072 is defined to have this zone listed below: **1**

Zone L (Steam separator standpipe: Includes volume of the standpipe penetration into the shroud head)= $10.76m^3$

Elevation (Shroud head dome to Bottom of the swirler)= 11.51m~12.67m **1**

Height = (12.67m-11.51m) = 1.160m

Inclination angle = Vertical = 90°

ε (Roughness)= 0.0

Standpipe volume 072 is a single volume. Volume 072 has 0 junction in itself.

RELAP 5-3D Input Deck is listed below:

```
*
**************************************
* Stand Pipe Volume 072 single volume
**************************************
*
0720000     stdpip72     snglvol
*           ---------    ---------
*
*                                                 horiz.       vert.
*           area          length       volume     angle        angle
*
0720101     0.000       1.1600       10.76     0.0          90.0 *Vol & Elv
*
*           elev.                    hydraulic   volume
*           change        rough.     diam.       control
*
0720102     1.1600    0.0      0.0          00
*
0720200     0         7183048.   1263070.        2579926.       .735046
*
*********************************************************************************
*
```

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Steam Separator Region Volume 036 *Ref. No.*

Volume 036 is the steam separator volume. By the figure 2 and table 2a of reference 1, steam separator volume is the summation of these sub-zones:

Zone N_1 (From votex barrel to Top of the separator)= $12.28m^3$ **1**

Zone R_4 (From vortex barrel to Top of the separator: Excluding N_1)= $10.43m^3$

Zone R_5 (Volume of discharge channel)= $9.52m^3+0.47m^3= 9.99m^3$

Volume(036) = Zone N_1+ Zone R_4+ Zone R_5= $12.28m^3+10.43m^3+9.99m^3$

$= 32.7m^3$

Elevation (Bottom of the swirler to Top of separator)= 12.67m~14.521m

Height = (14.521m-12.67m) = 1.851m

Inclination angle = Vertical = 90°

ε (Roughness)= 0.0

Steam separator volume 036 has 3 junctions in the separator component of RELAP5. **5**
The 3 junctions, N=1 is the vapor outlet, N=2 is the liquid fall back, N=3 is the separator inlet. Table 2a of reference 1 shows the fluid state of each regions in the separator, Zone N_1 is saturated **1**
steam, Zone R_4 and Zone R_5 are mainly saturated water. The area of each junction can be estimated by the volume data. The Zone N_1 is vapor outlet region, Zone R_4 and Zone R_5 are belonging the liquid fall back region. By reference 6, O.D of standpipe is 6” and O.D of cyclone **6**
separator is 10”. Total number of the cyclone separators is 349.

Junction 1 and 2 of separator 036 can be estimated:

Junction 1 Area (A_{036-1})

= 349*[π *(O.D of cyclone separator)^2]/4*[(Zone N_1)/Volume 036]

= 349*[π *(0.254m)^2]/4*[($12.28m^3/32.7m^3$)]

= $17.6841m^2$*0.3755= $6.6404m^2$

Junction 2 Area (A_{036-2})

= 349*[π *(O.D of cyclone separator)^2]/4*[(Zone R_4 +Zone R_5)/Volume 036]

= 349*[π *(0.254m)^2]/4*[($20.42m^3/32.7m^3$)]

= $17.6841m^2$*0.6245= $11.0437m^2$

Junction 3 Area (A_{036-3})

= 349*[π *(O.D of standpipe)^2]/4 = 349*[π *(0.1524m)^2]/4

= $6.3663m^2$

RELAP 5-3D Input Deck is listed on next page:

Ref. 5. “RELAP5-3D CODE MANUAL VOLUME II: USER’S GUIDE AND INPUT REQUIREMENTS” INEEL.

Ref. 6. “進步型沸水式反應器(ABWR)訓練教材(上冊):第一篇 第二章 反應爐壓力槽內部組件” 臺灣電力公司

Ref. No.

```
*
**************************************
* Steam Separator Volume 036 separator
**************************************
*
0360000     sepsv36     separatr
*           ---------   ---------
*
*           number      jun. i.c.
*           of jun.     control
*
0360001     3           0
*
*                                                horiz.      vert.
*           area        length      volume       angle       angle
*
0360101     0.000       1.8510      32.70  0.0          90.0 *Vol & Elv
*
*           elev.                   hydraulic    volume
*           change      rough.      diam.        control
*
0360102     1.8510  0.0  0.0        00010
*
0360200 0          7182262.   1263555.       2579943.          .614132
*
*           from        to          junction     forward     reverse     junct.
*           connect.    connect.    area         loss coef.  l.c.        flags
*
0361101  036010000  034000000   6.6404  25.0    25.0    01000  0.1
0362101  036000000  024000000  11.0437  0.03    0.03    01000  0.1
0363101  072010000  036000000   6.3663  0.01    0.01    01000 *from Vol 072 GE
*
0361201  -.2270979      8.515785      0.   * 2126.5
0362201   1.395618      1.576602      0. * 11375.88
0363201   9.132120      12.104095     0.   * 13502.4
*
```

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Steam Dryer Region Volume 034

Ref. No.

Volume 034 is the steam dryer volume which connects the separator volume 036 and steam dome volume 032. By table 2a of reference 1, steam dryer volume contains these sub-zones: 1

Zone N_2 (From Top of the separator to Bottom of steam dryers)

= $0.14m^3$ + $22.44m^3$= $22.58m^3$ (In dryer volume of Zone N_2)

Zone P (From Bottom of steam dryers to Vessel flange)

= $33.68m^3$ (In dryer volume of Zone P)

Volume(034) = Zone N_2+ Zone P= $22.58m^3$+$33.68m^3$= $56.26m^3$

Elevation (Top of the separator to Vessel flange)= 14.521m~17.703m 2

Height = (17.703m-14.521m) = 3.1820m

Inclination angle = Vertical = 90°

ε (Roughness)= $1.5*10^{-4}$

Steam dryer volume 034 is a single volume. Volume 034 has 0 junction in itself.

RELAP 5-3D Input Deck is listed below:

```
*
**************************************
* Steam Dryer Volume 034 single volume
**************************************
*
0340000     dryev34     snglvol
*           ---------   ---------
*
*                                                 horiz.      vert.
*           area          length       volume     angle       angle
*
0340101     0.000         3.1820       56.26      0.0         90.0 *Vol & Elv
*
*           elev.                      hydraulic  volume
*           change        rough.       diam.      control
*
0340102     3.1820        1.5000e-4    0.0        00
*
0340200  0          7171576.  1266498.    2579928.    .99999
*
**************************************
```

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Steam Dryer Exit Junction 033

Ref. No.

The steam dryer exit junction 033 connects the steam dryer single volume 034 and steam dome volume 032. The Junction area is calculated from the data of steam dryer 034.

Junction Area (A_{033}):

A_{033}= Volume(034)/Height(034)= 56.26m^3/3.182m= 17.6807m^2

RELAP5 Input for Single junction 033:

```
*
************************************
*
0330000      domej29     sngljun
*            ---------   ---------
*
*            from          to            junction    forward     reverse     junct.
*            connect.      connect.      area        loss coef.  l.c.        flags
*
0330101      034010000   032000000   17.6807     0.0         0.0         01100 *from Vol 034
*
0330201   0     3.106867 3.202526    0.    * 2126.49
*
************************************
```

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Steam Dome Region Volume 032

Ref. No.

Volume 032 is the steam dome volume which is the highest volume in the reactor pressure vessel. Bottom of volume 032 connects with the steam dryer volume 034. Steam flows upward to the steam dome volume 032 and then turns down to the dryer downcomer volume 030. By table 1a of reference 1, steam dome volume only refers to a single zone:

Zone Q (Volume in side vessel head)= 78.96m^3
Elevation (Vessel flange to Top of vessel head)= 17.703m~21.060m
Height = (21.060m-17.703m) = 3.3570m
Inclination angle = Vertical = 90°
ε (Roughness)= 0.0

1 & 2

Steam dome volume 032 is a branch volume and it has 1 junction in itself to connect with dryer downcomer volume 030. The junction area of volume 032 is identical with volume 030.

RELAP 5-3D Input Deck is listed below:

```
*
**************************************
* Steam Dome Volume 032 branch
**************************************
*
0320000     domev32     branch
*           ---------   ---------
*
*           number       jun. i.c.
*           of jun.      control
*
0320001     1            0
*                                                 horiz.      vert.
*           area         length      volume       angle       angle
*
0320101     0.000        3.3570      78.96        0.0         90.0 *Vol & Elv
*
*           elev.                    hydraulic    volume
*           change       rough.      diam.        control
*
```

RELAP5 Input Deck for Steam Dome Volume 032(continued)

Ref. No.

```
*
0320200 0          7170564.   1266448.    2580026.    .999986
*
*                      from          to              junction   forward   reverse
*                      connect.      connect.        area       loss coef.  l.c.
*
0321101        032000000     030000000   19.3462   0.4        0.6         01000 *from Vol 030
*
0321201        2.830964 2.733054   0.    * 2126.454
*
```

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Steam Dryer Downcomer 028 & 030

Ref. No.

The steam dryer downcomer is the area besides the steam dryer and the steam flows downward through this area from the steam dome. In RELAP5 model, this area is divided into 2 volumes, volume 030 is from vessel flange to the center of the steam line and volume 028 is from the center of the steam line to the dryer bottom. The volume of these two volumes is determined by the height ratio. By table 2a of reference 1, steam dryer downcomer volume contains these sub-zones: **1**

Zone N_2 (From Top of the separator to Bottom of steam dryers)
= $0.03m^3$ + $2.42m^3$= $4.45m^3$ (Outside dryer volume of Zone N_2)
Zone P (From Bottom of steam dryers to Vessel flange)
= $57.11m^3$ (Outside dryer volume of Zone P)
Volume(030)+Volume(028) = Zone N_2+ Zone P= $4.45m^3$+$57.11m^3$= $61.56m^3$
Elevation(030 & 028) = (Vessel flange to Bottom of steam dryer) = 17.703m ~ 14.521m
Height(030 & 028) = (17.703m-14.521m) = 3.1820m = Height(034)

Elevation(030) = [Vessel flange to Center of MSL] = 17.703m ~ 15.544m **1 & 2**
Height(030) = (17.703m-15.544m) = 2.1590m
Elevation change(030) = (15.544m-17.703m) = -2.1590m (Downward direction)
Volume(030) = $61.56m^3$*[Height(030)/ Height(030 & 028)]
= $61.56m^3$*[2.1590m/3.1820m] = $41.7687m^3$

Elevation(028) = [Center of MSL to Bottom of steam dryers] = 15.544m~14.521m
Height(028) = (15.544m-14.521m) = 1.0230m
Elevation change(028) = (14.521m-15.544m) = -1.0230m (Downward direction)
Volume(028) = Volume(030 & 028)-Volume(030) = $61.56m^3$-$41.7687m^3$= $19.7913m^3$
Inclination angle = Vertical = -90° (Flow downward)

Steam dryer downcomer volume 030 is a branch volume and it has 1 junction in itself to connect with the lower dryer downcomer volume 028. Steam dryer downcomer volume 028 is a single volume and it has no junction in it.

Junction Area (A_{030}) of branch Volume 030
A_{030} = $41.7687m^3$ /2.1590m = $19.3463m^2$

RELAP 5-3D Input Deck is listed on next page:

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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Ref. No.

RELAP5 Input for Volume 030 :

```
*
**************************************
*       Dryer downcomer 2      Volume 030 branch
**************************************
0300000       drydnv30      branch
*             ---------     ---------
*
*             number        jun. i.c.
*             of jun.       control
*
0300001       1             0
*
*                                                   horiz.        vert.
*             area          length        volume    angle         angle
*
0300101       0.000         2.1590        41.7686   0.0           -90.0 *Vol & Elv
*
*             elev.                       hydraulic  volume
*             change        rough.        diam.      control
*
0300102     -2.1590     0.0    0.0       00
*
0300200    0          7171362.    1266488.     2580070.     .999984
*
*             from          to            junction   forward     reverse     junct.
*             connect.      connect.      area       loss coef.  l.c.        flags
*
0301101       028000000     030010000     19.3462    0.0         0.0         01100 *from Vol 30
*
0301201       -.128934      -5.73204-5    0.    * -.0702644
*
```

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Ref. No.

RELAP5 Input for Volume 028 :

```
*
**************************************
*       Dryer downcomer 1      Volume 028 single volume
**************************************
0280000       drydnv28      snglvol
*             ---------     ---------
*
*                                                    horiz.        vert.
*                      area          length        volume        angle         angle
*
0280101               0.000         1.0230      19.7913         0.0         -90.0 *Vol & Elv
*
*                     elev.                              hydraulic    volume
*                   change           rough.        diam.          control
*
0280102       -1.0230       0.0          0.0      00
*
0280200    0          7172108.    1266525.      2580137.      .999983
*
**************************************
```

Steam Dryer Downcomer Exit Junction 027

The steam dryer downcomer exit junction 027 connects the steam dryer downcomer volume 028 and separator downcomer volume 026. The Junction area is assumed to be equal to the area of volume 028.

Junction Area (A_{027}) of Single Junction 027

A_{027} = 19.7913m^3 /1.0230m = 19.3463m^2

RELAP5 Input for Single junction 027 :

```
*
0270000    sepdnj27    sngljun
0270101    026000000    028010000    19.3463    0.0    0.0    1100
0270201    0    -.1180221    -3.2133-5    0.      * -.0521042
*
```

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Steam Separator Downcomer 026

Ref. No. **1**

The steam separator downcomer is the area excluding the cyclone separators. The normal narrow range water level also falls in this region. Figure 1、2 and table 2a of reference 1 indicate the related zones of the separator downcomer. Because the normal narrow range water level falls in this volume 026, the volume 026 is modeled as a pipe component with 10 sections for more accurate water level calculation. The elevation of volume 026 extends from bottom of the steam dryer to the top of standpipes.

Zone M_1 (From bottom of steam dryer to normal water surface)
= $0.11m^3$ + $18.59m^3$= $18.70m^3$ (Inside the steam dryer skirt)
Zone M_2 (From bottom of steam dryer to normal water surface)
= $0.05m^3$ + $8.95m^3$= $9.00m^3$ (Outside the steam dryer skirt)
Zone R_3 (From normal water surface to top of standpipes)
= $14.00m^3$ + $0.69m^3$ = $14.69m^3$ (In Dryer)
Zone R_3 (From normal water surface to top of standpipes)
= $6.91m^3$ + $0.34m^3$ = $7.25m^3$ (Outside Dryer)
Volume(026) = Zone M_1 + Zone M_2 + Zone R_3(In Dryer) + Zone R_3(Outside Dryer)
= $18.70m^3$+$9.00m^3$+$14.69m^3$+$7.25m^3$= $49.64m^3$
Elevation(Bottom of steam dryer to top of standpipes) = 14.521m ~ 12.670m
Elevation change(026) = (12.670m-14.521m) = -1.851m
Height(026) = 1.851m

For sub-volume 026-1~026-10:
Length of sub-volume = 1.851m/10 = 0.1851m
Volume of sub-volume = $49.64m^3$/10 = $4.964m^3$
Inclination angle = Vertical = -90° (Flow downward)

RELAP5 Input for Pipe 026:

Pipe 026
No. of vol = 10
Volume flow area = 0.0
Volume of volume :

Volume	Vol No.
$4.964m^3$	10

Length of Volume :

Length	Vol No.
0.1851m	10

Ref. No.

RELAP5 Input for Pipe 026(Continued):

Horizontal angle	Vol No.
0.0	10
Vertical angle	Vol No.
-90.0	10
Elevation change	Vol No.
-0.1851m	10
Hydraulic Dia	Vol No.
0.0m	10

RELAP5 Input Deck listed below:

```
*
0260000  sepdnv26  pipe
0260001  10
0260101  0.0  10
0260301  0.1851  10
0260401  4.964  10
0260501  0.0  10
0260601  -90.0  10
0260701  -0.1851  10
0260801  0.0  0.0  10
0260901  0.0  0.0  9
0261001  0  10
0261101  1000  9
0261201  0  7172331.  1266536.  2580136.  .999986  0. 1
0261202  0  7172399.  1266539.  2580136.  .999986  0. 2
0261203  0  7172467.  1266542.  2580135.  .999987  0. 3
0261204  0  7172535.  1266546.  2580134.  .999982  0. 4
0261205  0  7172604.  1266549.  2580274.  1.  0. 5
0261206  0  7172765.  1266545.  2580294.  .85227  0. 6
0261207  0  7173562.  1266355.  2580122.  0.  0. 7
0261208  0  7174900.  1266337.  2580107.  0.  0. 8
0261209  0  7176238.  1266414.  2580093.  0.  0. 9
0261210  0  7177575.  1266520.  2580079.  0.  0. 10
*
```

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RELAP5 Input Deck (Continued):

```
*
0261300   0
0261301   .1053722     1.925413-5   0.   1 * .0481162
0261302   .1039843     1.544233-5   0.   2 * .04424385
0261303   .1108758     1.172259-5   0.   3 * .0404647
0261304   .082802       8.07296-6    0. 4 * .0367563
0261305   4.81946       5.8915-6     0. 5 * .00593037
0261306   1.921854-5    -.855719     0. 6 * .0561106
0261307   2.830786-6 2.830823-6 0.     7 * .0559507
0261308   2.825464-6 2.8255-6    0.     8 * .0558461
0261309   2.81663-6     2.81666-6    0.   9 * .0556694
*
```

Steam Separator Downcomer Exit Junction 025

Steam separator downcomer exit junction 025 is a single junction connecting the steam separator downcomer volume 026 and upper downcomer volume 024. The junction area is given by the volume area of volume 024.

Junction Area (A_{025}) of single Junction 025

A_{025} = 18.2845m^2

RELAP5 Input for Single junction 025:

```
**************************************
*
0250000      dncj25     sngljun
*            ---------  ---------
*
*            from          to          junction    forward     reverse     junct.
*            connect.      connect.    area        loss coef.  l.c.        flags
*
0250101      026010000  024000000  18.2845  0.0       0.0       01000 *from Vol 24
*
0250201   0      4.111254-6   4.11132-6    0. * .0553983
*
**************************************
```

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Upper Downcomer Volume 022、023、024

Ref. No.

The upper downcomer is the area excluding the volume in the standpipes. Figure 1、2 and table 2a of reference 1 indicate the related zones of the upper downcomer. For more accurate water level calculation, volume 022 and 023 are divided into thin layers. The total elevation of the upper downcomer region extends from top of standpipes to the top of shroud head. The volume of these volumes is determined by the height ratio. **1**

Zone R_1 (From top of standpipes to the top of shroud head)
= $0.35m^3$ + $19.88m^3$ + $0.98m^3$
= $21.21m^3$ (Excluding the volume in the standpipes)
Volume(024)+Volume(023)+Volume(022) = Zone R_1= $21.21m^3$
Elevation(024、023 & 022) = (Top of standpipes to top of shroud head) **1**
= 12.670m~11.510m
Elevation change(024、023 & 022) = (11.510m-12.670m) = -1.160m
Height(024、023 & 022) = 1.160m

Height(024) = 0.5* Height(024、023 & 022)
= 0.5*1.160m = 0.580m
Elevation change(024) = -0.580m (Downward direction)
Volume(024) = $21.21m^3$*[Height(024)/ Height(024、023 & 022)]
= $21.21m^3$*[0.580m/1.160m] = $10.6050m^3$

Height(023) = 0.4* Height(024、023 & 022)
= 0.4*1.160m = 0.4640m
Elevation change(023) = -0.4640m (Downward direction)
Volume(023) = $21.21m^3$*[Height(023)/ Height(024、023 & 022)]
= $21.21m^3$*[0.4640m/1.160m] = $8.4840m^3$
Volume 023 is equally divided into 4 pieces, so the geometry data for each sub-volume:
Sub-volume 023-1~023-4:
Length of sub-volume = 0.4640m/4 = 0.1160m
Volume of sub-volume = $8.4840m^3/4$ = $2.1210m^3$
Inclination angle = Vertical = -90° (Flow downward)

Height(022) = 0.1* Height(024、023 & 022)
= 0.1*1.160m = 0.1160m
Elevation change(022) = -0.1160m (Downward direction)
Volume(022) = $21.21m^3$*[Height(022)/ Height(024、023 & 022)]
= $21.21m^3$*[0.1160m/1.160m] = $2.1210m^3$

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Ref. No.

Upper Downcomer Volume 022、023、024(Continued)

Volume Area (A_{024}) of Single Volume 024

A_{024} = 10.6050m^3 /0.58m = 18.2845m^2= A_{025}

RELAP5 Input for Single volume 024:

```
*
**************************************
*       Upper downcomer 3      Volume 024 single volume
**************************************
0240000       dncv24     snglvol
*             ---------  ---------
*
*                                                    horiz.        vert.
*                      area          length        volume        angle         angle
*
0240101                0.000         0.5800    10.605    0.0           -90.0 *Vol & Elv
*
*                      elev.                              hydraulic    volume
*                    change            rough.        diam.         control
*
0240102       -0.5800       0.0          0.0      00
*
0240200 0           7180080.    1263565. 2580052. 0.
*
**************************************
```

RELAP5 Input for Pipe 023:

Pipe 023
No. of vol = 4
Volume flow area = 0.0
Volume of volume :

Volume	Vol No.
2.1210m^3	4

Length of Volume :

Length	Vol No.
0.1160m	4

Ref. No.

RELAP5 Input for Pipe 023(Continued):

Horizontal angle	Vol No.
0.0	4
Vertical angle	Vol No.
-90.0	4
Elevation change	Vol No.
-0.1160m	4
Hydraulic Dia	Vol No.
0.0m	4

RELAP5 Input for Pipe Volume 023

```
*
0230000  dncv23   pipe
0230001  4
0230101  0.0   4
0230301  0.116   4
0230401  2.121   4
0230501  0.0   4
0230601  -90.0   4
0230701  -0.116   4
0230801  0.0   3.658   4
0230901  0.0   0.0   3
0231001  0   4
0231101  1000   3
0231201  0   7182181.    1263567.    2580030.    0.          0.    1
0231202  0   7183020.    1263569.    2580021.    0.          0.    2
0231203  0   7183860.    1263571.    2580012.    0.          0.    3
0231204  0   7184700.    1263573.    2580003.    0.          0.    4
0231300  0
0231301  .842957   1.073153 0.   1 * 11375.93
0231302  .842956   1.073153 0.   2 * 11375.93
0231303  .842956   1.073153 0.   3 * 11375.93
*
```

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Ref. No.

Upper Downcomer Volume 022、023、024(Continued)

RELAP5 Input for Branch Volume 022

```
*
************************************
*New Noding 022 & 023 on Feb.09.2004
************************************
**
0220000  dncv22  branch
0220001  1  0
0220101  0.0  0.116  2.121  0.0  -90.0  -0.116  0.0  3.658  0
0220200  0  7185488.  1209072.  2579995.  0.
0221101  023010000  022000000  0.0  0.0  0.0  1000
0221201  .842956  1.073153 0. * 11375.93
*
```

Upper Downcomer to Downcomer Single Junction 019

Upper downcomer exit junction 019 is a single junction connecting the upper downcomer volume 022 and downcomer volume 020. The junction area is given by the volume area of volume 020.

Junction Area (A_{019}) of single Junction 019

A_{019} = 15.7246m^2 = Volume 020 area

RELAP5 Input for Single junction 019:

```
*
0190000  dncj19  sngljun
0190101  022010000  020000000  15.7246  35.0  35.0  1000
0190201  0  1.157777  1.48283  0.  * 13502.4
*
```

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Downcomer Volume 020、018

Ref. No.

The downcomer volume is the region that water flows downward to the inlet of the reactor internal pumps. The downcomer volume is bounded between the vessel wall and core shroud. The total elevation of the downcomer region extends from top of the shroud head to the top of the RIP deck, but the lowest elevation is slightly shifted up to the edge of the RIP diffuser in the final model. **1** **7**

Zone S (From top of the shroud head dome to the top of the internal pump deck)
= 147.89m^3 (Volume in the vessel, outside the shroud.) **1**

Volume(020)+Volume(018) = Zone S = 147.89m^3

Elevation(020 & 018) = (Top of shroud head dome to top of RIP diffuser)
= 11.510m~2.105m

Elevation change(020 & 018) = (2.105m-11.510m) = -9.405m **7**

Height(020 & 018) = 9.405m

Now the downcomer is divided into 10 equal size partitions. Volume 020 is modeled as a pipe volume and has nine partitions in it. Volume 018 is modeled as a branch volume for connecting the RIPs on it and has the last one of the ten partitions in it.

Height(020) = 0.9* Height(020 & 018)
= 0.9*9.405m = 8.4645m

Elevation change(020) = -8.4645m(Downward direction)

Volume(020) = 0.9*147.89m^3
= 133.101m^3

Volume 020 is equally divided into 9 pieces, so the geometry data for each sub-volume:

Sub-volume 020-1~020-9:

Length of sub-volume = 8.4645m/9 = 0.9405m

Volume of sub-volume = 133.101m^3/9 = 14.789m^3

Inclination angle = Vertical = -90° (Flow downward)

Junction area for single junction 019 = 14.789m^3/0.9405m = A_{019} = 15.7246m^2

The RELAP5 Input for pipe 020 is listed on next page.

Ref. 7. TOSHIBA CORPORATION TOKYO,JAPAN:"INSTRUCTION BOOK FOR PACKAGE 62.2610 (B31-RIP) RIP PUMPS AND MOTORS" E KK090400-a page 18/119, Figure 2.3

Ref. No.

RELAP5 Input for pipe 020:

Pipe 020
No. of vol = 9
Volume flow area = 0.0
Volume of volume :

Volume	Vol No.
$14.789m^3$	9

Length of Volume :

Length	Vol No.
0.9405m	9

Horizontal angle	Vol No.
0.0	9

Vertical angle	Vol No.
-90.0	9

Elevation change	Vol No.
-0.9405m	9

Hydraulic Dia	Vol No.
0.0m	9

RELAP5 Input for Pipe Volume 020

```
*
0200000   dncv20   pipe
0200001   9
0200101   0.0   9
0200301   0.9405   9
0200401   14.789   9
0200501   0.0   9
0200601   -90.0   9
0200701   -0.9405   9
0200801   0.0   0.0   9
0200901   0.0   0.0   8
0201001   0   9
0201101   1000   8
*
```

RELAP5 Input for Pipe Volume 020(Continued)

Ref. No.

```
*
0201201  0  7171320.   1209074.   2580145.   0.        0.   1
0201202  0  7178311.   1209077.   2580071.   0.        0.   2
0201203  0  7185302.   1209077.   2579997.   0.        0.   3
0201204  0  7192294.   1209077.   2579922.   0.        0.   4
0201205  0  7199284.   1209078.   2579848.   0.        0.   5
0201206  0  7206276.   1209078.   2579774.   0.        0.   6
0201207  0  7213268.   1209078.   2579700.   0.        0.   7
0201208  0  7220259.   1209078.   2579626.   0.        0.   8
0201209  0  7227250.   1209078.   2579552.   0.        0.   9
0201300  0
0201301  1.132424  1.44979   0.   1 * 13502.4
0201302  1.132416  1.449778  0.   2 * 13502.4
0201303  1.132406  1.449766  0.   3 * 13502.4
0201304  1.132397  1.449753  0.   4 * 13502.4
0201305  1.132387  1.44974   0.   5 * 13502.4
0201306  1.132377  1.449728  0.   6 * 13502.4
0201307  1.132367  1.449715  0.   7 * 13502.4
0201308  1.132358  1.449703  0.   8 * 13502.4
*
```

The downcomer volume 018 is a branch volume and it has 1 junction in itself to connect with the downcomer pipe volume 020. There are also RIP inlet junctions connecting to this branch volume 018 but they are not part of the input for branch 018.

Height(018) = 0.1* Height(020 & 018)

= 0.1*9.405m = 0.9405m

Elevation change(022) = -0.9405m (Downward direction)

Volume(018) = 0.1*147.89m^3 = 14.789m^3

RELAP5 Input for branch volume 018 is listed on next page:

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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審查：

Ref. No.

RELAP5 Input for branch volume 018:

```
*
0180000  dncv18  branch
0180001  1  0
0180101  0.0  0.9405  14.789  0.0  -90.0  -0.9405  0.0  1.461  0
0180200  0  7234242.  1209078.  2579478.  0.
0181101  020010000  018000000  0.0  0.0  0.0  1000
0181201  1.132348  1.44969  0.  * 13502.4
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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Reactor Internal Pump Volume 010、011、012 & 014 — *Ref. No.*

The reactor internal pumps connect the downcomer and lower plenum. These pumps are used to force water flowing down to the lower plenum. There are totally 10 RIPs and these 10 RIPs in RELAP model are divided into 4 groups. The pump volume 010 and 011 include 4 RIPs and there are no motor-generator sets connecting to them. There is 3 RIPs in pump volume 010 and the remaining 1 RIP is in volume 011. The left 2 groups share the rest 6 RIPs which with motor-generator sets on them equally. So volume 012 and 014 each own 3 RIPs themself. By table 2a and figure 3 of reference 1, the 10 RIPs are defined to including the following zones: **1**

Zone T_1 (Volume in the internal pumps including impeller and diffuser)
= $1.16m^3$

Zone T_2 (Volume in the lower plenum),
= $8.04m^3$ (Upstream the shroud support legs to the pump deck)

Volume(010、011、012 & 014) = Zone T_1+ Zone T_2= $1.16m^3$+$8.04m^3$= $9.20m^3$

Because all 10 RIPs locate on the same pump deck plane, they all have the same elevation. **7 & 1**

Elevation(010、011、012 & 014) = (Top of RIP diffuser to top of the lower plenum)
= 2.105m~1.3969m

Height(010、011、012 & 014) = 2.105m-1.3969m = 0.7081m

Elevation change(010、011、012 & 014) = -0.7081m (Downward direction)

Inclination angle = Vertical = -90° (Flow downward)

There are 2 junctions for a pump component in RELAP5, one attached to the inlet end and the other attached to the exit end. Area of each inlet and outlet junction is determined by the drawing of reference 7. The result is only for 1 RIP. Actual area applied in the model should be multiplied by the number of RIPs in each group. The necessary homologous curve for a pump component will be derived from the performance curve of reference 8. **7** **8**

Diffuser inlet: D_{in} = 524mm

Inlet Junction area $A_{in} = \pi D_{in}^2/4$ = $0.21565m^2$

Diffuser outlet annulus: D_{out1} = 636mm D_{out2} = 345mm

Outlet Junction area $A_{out} = \pi /4*[D_{out1}^2 - D_{out2}^2]$= $0.22421m^2$

The 4 groups of RIP are in 1,3,3,3 configuration.

Junction area of each group can easily be calculated by the number of RIPs.

Ref. 8. GE:"Project Design Manual, 31113-0A23-1000 Rev 20" Chapter 3,Figure 3.14-14

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Reactor Internal Pump Volume 010、011、012 & 014

Homologous curve from reference 8 is tabled below: *Ref. No.*

h	v	B	alpha	HAN(v/alpha)	HAN(h/alpha2)	
1.198352761	0.147880208	0.177839233	1	0.147880208	1.198352761	**8**
1.232889571	0.295760417	0.365929288	1	0.295760417	1.232889571	
1.223199387	0.443640625	0.544579646	1	0.443640625	1.223199387	
1.194625767	0.591520833	0.709144543	1	0.591520833	1.194625767	
1.149653374	0.739401042	0.853060472	1	0.739401042	1.149653374	
1.084555215	0.88728125	0.965707965	1	0.88728125	1.084555215	
1	1	1	1	1	1	
0.860687117	1.183041667	1.021828908	1	1.183041667	0.860687117	
0.682039877	1.296938448	0.888076327	1	1.296938448	0.682039877	

BAN(v/alpha)	BAN(B/alpha2)	HVN(alpha/v)	HVN(h/v2)	BVN(alpha/v)	BVN(B/v2)	
0.147880208	0.177839233	6.762230142	54.79798325	6.762230142	8.132189143	
0.295760417	0.365929288	3.38111506	14.09431843	3.38111506	4.183281316	
0.443640625	0.544579646	2.254076709	6.214907052	2.254076709	2.766933926	
0.591520833	0.709144543	1.690557533	3.41422225	1.690557533	2.026724305	
0.739401042	0.853060472	1.352446025	2.10284277	1.352446025	1.560341653	
0.88728125	0.965707965	1.127038355	1.377618793	1.127038355	1.22665718	
1	1	1	1	1	1	
1.183041667	1.021828908	0.845278766	0.614957667	0.845278766	0.730092863	
1.296938448	0.888076327	0.771046615	0.405481493	0.771046615	0.527972817	**9**

Basic operation condition is coming from Table 3.14-13 of reference 9 and the moment of inertia of the RIP is coming from reference 10. **10**

Total moment of inertia = 22 kg-m^2

Ref. 9. GE:“Project Design Manual, 31113-0A23-1000 Rev 20” Chapter 3,Table 3.14-13

Ref 10. TOSHIBA CORPORATION TOKYO,JAPAN:”INSTRUCTION BOOK FOR PACKAGE 62.2610 (B31-RIP) RIP PUMPS AND MOTORS” EME000097-c page 23/133

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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Reactor Internal Pump Volume 010、011、012 & 014

Ref. No.

RELAP5 Input for Pump Volume 010:

Length(010) = 0.7081m

Elevation change(010) = -0.7081m (Downward direction)

Volume(010) = 3/10*9.20m^3 = 2.76m^3

Inlet junction area = 3*0.21565m^2 = 0.64695m^2

Outlet junction area = 3*0.22421m^2 = 0.67263m^2 **9**

Pump Speed = 0.9*Rated (Rated speed =1450 RPM)

= 0.9*1450*2 π /60 = 136.66rad/sec **9**

Pump flow rate = 6912m^3/h = 1.92m^3/sec(1 RIP)

Pump 010 flow rate = 3*1.92m^3/sec= 5.76m^3/sec **9**

Rated head = 32.6m **10**

Moment of Inertia = 22kg-m^2/RIP **9**

Pump 010 moment of Inertia = 3*22kg-m^2/ RIP = 66kg-m^2

Torque can be calculated by the following relation:

Q(Flow rate)*H(Head) = ω(Angular speed)* τ (Torque)

(1.92m^3/sec)*(32.6m*9.80665m/sec^2*755.73kg/m^3) = 136.66 rad/sec* τ (Torque)

τ (Torque) = 3394.43 N-m/RIP

Pump 010 Torque = 3* τ = 10183.29 N-m

Pump 010 homologous table is coming from the table in previous page.

RELAP5 Input for Pump Volume 010:

```
*
**************************************
*    010 Reactor Internal pump*4 (w/o MG set)        *
**************************************
*
0100000      pmpv10     pump
*            ---------  ---------
*
*                                                  horiz.       vert.
*            area          length       volume      angle        angle
*
0100101          0.0   0.7081       3.68        0.0          -90.0 *Elv
*
```

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Ref. No.

RELAP5 Input for Pump Volume 010(Continued):

```
*
*              elev.          volume
*              change         control
*
0100102       -0.7081          0
*
0100108    018010000       0.64695       1.79        1.79      00000 *correction by TOSHIBA
*
0100109    002010000       0.67263       6.047       6.047     00000 *correction by TOSHIBA
*
0100200       0            7296577.    1209078. 2578822. 0
*
0100201    0    8.89898      6.95339 0. * 4348.10
0100202    0    15.409       17.0736    0. * 4348.09
*
*                                       trip    reverse
*
0100301       0    -1    -3     -1    -1    404      0 *L3 trip
*
*              rated      speed      rated       rated       rated         moment
*              speed      ratio      flow        head        torque        of inertia
*
0100302      136.66    1.0        5.76      32.6    10183.29      66.0 *100% of Rated Core flow
*
*             rated         rated           tf2             tfo          tf1         tf3
*            density     motor tor        coef            coef         coef        coef
*
0100303    0.0    10183.29      0.0 0.0    0.0         0.0
*
*
*010 Pump table input
*
```

RELAP5 Input for Pump Volume 010(Continued):

Ref. No.

```
*
**************************
*
** Head Tables
*
**************************
*New from PDM Figure 3.14-14
*     Table 1 = HAN
*            Curve       curve        indep.      depend.
*             type       regime         var          var
0101100      1            1
0101101 0.00000     1.19835
0101102 0.14788     1.19835
0101103 0.29576     1.23289
0101104 0.44364     1.33432
0101105 0.59152     1.19463
0101106 0.73940     1.14965
0101107 0.88728     1.08455
0101108 1.00000     1.00000
*
**************************
*     Table 2 = HVN
*            Curve       curve        indep.      depend.
*             type       regime         var          var
0101200      1            2
0101201 0.00000    -0.5500
0101202 0.15000    -0.4000
0101203 0.30000    -0.2328
0101204 0.45000    -0.1000
0101205 0.60000     0.25000
0101206 0.77105     0.40548
0101207 0.84528     0.61496
0101208 1.00000     1.00000
*
*New from PDM Figure 3.14-14
**************************
*
```

RELAP5 Input for Pump Volume 010(Continued):

Ref. No.

```
*
****************************
*
** Torque Tables
*
****************************
*New from PDM Figure 3.14-14
*     Table 3 = BAN
*            Curve       curve        indep.      depend.
*             type        regime        var           var
0101300   2             1
0101301 0.00000     0.17784
0101302 0.14788     0.17784
0101303 0.29576     0.36593
0101304 0.44364     0.54458
0101305 0.59152     0.70914
0101306 0.73940     0.85306
0101307 0.88728     0.96571
0101308 1.00000     1.00000
******************************
*
**************************
*     Table 4 = BVN
*            Curve       curve        indep.      depend.
*             type        regime        var           var
0101400   2             2
0101401 0.00000     -0.4300
0101402 0.15000     -0.3200
0101403 0.30000     -0.1200
0101404 0.45000     0.11000
0101405 0.60000     0.30000
0101406 0.77105     0.52797
0101407 0.84528     0.73009
0101408 1.00000     1.00000
**************************
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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RELAP5 Input for Pump Volume 010(Continued):

Ref. No.

```
*
*****************************
*     Table 5 = HAD
*             Curve       curve        indep.      depend.
*               type        regime       var           var
*
0101500       1             3
0101501 -1.000    500.00000
0101502 -0.909    537.19008
0101503 -0.800    400.00
0101504 -0.667    368.05556
0101505 -0.571    316.32653
0101506 -0.500    293.75
0101507 -0.333    227.77778
0101508 -0.250    201.56250
0101509 -0.200    189.00
0101510 -0.167    181.25000
0101511 -0.143    176.02041
0101512    0.000    1.5007
*****************************
*
*****************************
*     Table 6 = HVD
*             Curve       curve        indep.      depend.
*               type        regime       var           var
*
0101600       1             4
0101601 -1.000    500.00000
0101602 -0.750    375.00000
0101603 -0.500    312.50
0101604 -0.375    260.93750
0101605 -0.275    223.43750
0101606 -0.125    187.50
0101607    0.000 -2.127
*****************************
*
```

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Reactor Internal Pump Volume 010、011、012 & 014

Ref. No.

Pump Volume 012 & 014 also have 3 RIPs in each group as the pump 010. Except the trip point setting points are different. All 4 groups share the same homologous curve of pump volume 010, so it is not necessary to list the table for the rest 3 groups.

RELAP5 Input for Pump Volume 012:

```
*
**************************************
*    012 Reactor Internal pump*3 (w/ MG set)        *
**************************************
*
0120000      pmpv12     pump
*            ---------  ---------
*
*                                                    horiz.       vert.
*            area          length       volume       angle        angle
*
0120101         0.0 0.7081        2.76   0.0          -90.0 *Elv
*
*            elev.         volume
*            change        control
*
0120102      -0.7081       0
*
0120108   018010000       0.64695   1.79       1.79    00000 *By TOSHIBA data
*
0120109   002010000       0.67263     6.047      6.047     00000 *By TOSHIBA data
*
*
0120200   0           7296577.    1209078. 2578822. 0.
*

*
0120201   0   8.8686      9.6110   0. * 4350.93
0120202   0   8.5294      8.5294   0. * 4350.93
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model
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Ref. No.

RELAP5 Input for Pump Volume 012(Continued):

```
*
*                                    trip    reverse
*
0120301     010    -1    -3    -1    -1    403      0 *L2 trip
*
*             rated      speed      rated       rated       rated         moment
*             speed      ratio      flow        head        torque        of inertia
*
0120302    136.66    1.0        5.76    32.6      10183.29      66.0 *100% of Rated Core flow
*
*           rated         rated          tf2            tfo          tf1         tf3
*          density     motor tor       coef           coef         coef        coef
*
0120303    0.0      10183.29      0.0    0.0    0.0         0.0
*
```

RELAP5 Input for Pump Volume 014:

```
*
**************************************
*    014 Reactor Internal pump*3 (w/ MG set)        *
**************************************
*
0140000       pmpv14      pump
*             ---------   ---------
*
*                                                      horiz.        vert.
*             area           length         volume       angle         angle
*
0140101           0.0    0.7081       2.76    0.0          -90.0 *Elv
*
*             elev.          volume
*             change         control
*
0140102       -0.7081         0
*
```

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Ref. No.

RELAP5 Input for Pump Volume 014(Continued):

```
*
0140108   018010000      0.64695      1.79       1.79     000000 *from TOSHIBA data
*
0140109   002010000      0.67263      6.047      6.047    000000 *from TOSHIBA data
*
0140200   0          7296577.   1209078. 2578822. 0.
*
0140201   0   8.8686      9.6110   0. * 4350.93
0140202   0   8.5294      8.5294   0. * 4350.93
*
*                                          trip   reverse
*
0140301      010   -1   -3   -1   -1 476     0   *L2+6.0 sec trip
*
*            rated     speed     rated      rated      rated       moment
*            speed     ratio     flow       head       torque      of inertia
*
0140302   136.66   1.     5.76      32.6     10183.29   66.0 *100% of Rated Core flow
*
*           rated       rated          tf2          tfo         tf1        tf3
*          density    motor tor       coef         coef        coef       coef
*
0140303   0.0   10183.29   0.0   0.0   0.0       0.0
*
```

Ref. No.

Reactor Internal Pump Volume 010、011、012 & 014

Pump Volume 011 only has 1 RIP in it.

RELAP5 Input for Pump Volume 011:

Length(011) = 0.7081m

Elevation change(011) = -0.7081m (Downward direction)

Volume(010) = 1/10*9.20m^3 = 0.92m^3

Inlet junction area = 0.21565m^2

Outlet junction area = 0.22421m^2

Pump Speed = 0.9*Rated (Rated speed =1450 RPM)

= 0.9*1450*2 π /60 = 136.66rad/sec

Pump flow rate = 6912m^3/h = 1.92m^3/sec(1 RIP)

Rated head = 32.6m

Moment of Inertia = 22kg-m^2/RIP

Torque can be calculated by the following relation:

Q(Flow rate)*H(Head) = ω(Angular speed)* τ (Torque)

(1.92m^3/sec)*(32.6m*9.80665m/sec^2*755.73kg/m^3) = 136.66 rad/sec* τ (Torque)

τ (Torque) = 3394.43 N-m/RIP

RELAP5 Input for Pump Volume 011:

```
*
**************************************
*   011 Reactor Internal pump*1 (w/o MG set)       *
**************************************
*
0110000     pmpv11     pump
*           ---------  ---------
*
*                                                  horiz.      vert.
*           area         length       volume       angle       angle
*
0110101     0.0          0.7081       0.92   0.0         -90.0 *Elv
*
*           elev.        volume
*           change       control
*
0110102     -0.7081      0
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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Ref. No.

RELAP5 Input for Pump Volume 011(Continued):

```
*
0110108   018010000      0.21565   1.79      1.79    00000 *By TOSHIBA data
*
0110109   002010000      0.22421    6.047     6.047   00000 *By TOSHIBA data
*
0110200   0          7296577.   1209078. 2578822. 0.
*


*
0110201   0   8.8686      9.6110   0. * 1450.31
0110202   0   8.5294      8.5294   0. * 1450.31
*
*                                      trip   reverse
*
0110301    010   -1   -3   -1   -1   403     0 *L2 trip
*
*            rated     speed     rated      rated      rated       moment
*            speed     ratio     flow       head       torque      of inertia
*
0110302   136.66   1.     1.92   32.6     3394.43     22.0 *100% of Rated Core flow
*
*           rated       rated          tf2           tfo         tf1       tf3
*          density    motor tor       coef          coef        coef      coef
*
0110303   0.0     3394.43     0.0   0.0   0.0         0.0
*
```

Main Steam Line Side: Flow Restrictor to Main Steam Header

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model(Flow Restrictor to Main Steam Header)

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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The Development of RELAP5-3D Code Input Deck of RPV Model
(Main Steam Line Side: Flow Restrictor to Main Steam Header)
Hydraulic Volumes and Junctions

Ref. No.

Part of the main steam system is also included in RELAP5 RPV model. The main steam system of the RELAP5 RPV model ranges from the flow restrictor of the RPV steam outlet to the main steam header. The main steam system till the steam header consists of by 4 flow restrictors、4 main steam lines、18 SRVs and 4 MSIVs. The nodding diagram of the main steam system is shown on the attachment figure in the report.

Flow Restrictors Junction 100(120、140 & 160):

Junction 100、120、140 & 160 are the flow restrictors on each main steam lines. The junction area can be estimated by reference 1. The ratio of diameter of the flow restrictor versus the diameter of main steam line is 0.5 and diameter of the main steam line is 700mm. **1**

Junction 100、120、140 & 160 can be estimated:

Junction 100 Area (A_{100})

= [π *(0.5*Diameter of MSL)^2]/4

= [π *(0.350m)^2]/4 = 0.0962m^2

RELAP 5-3D Input Deck is listed here:

```
*
**************************************
* MSL_A Flow Restrictor Jun 100
**************************************
*
*
1000000       ms_aj100      sngljun
*             ---------     ---------
*
*             from          to            junct.    forward   reverse   junct
*             connect.      connect.      area      l.c.      l.c.      flags
1000101       030010000     101000000     0.0962    0.353     0.353     01000
*
1000201   0   141.6526   147.157     0. * 531.584
*
```

Ref. 1. “進步型沸水式反應器(ABWR)訓練教材(上冊):第三篇 第一章 主蒸汽系統”臺灣電力公司

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model(Flow Restrictor to Main Steam Header)

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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The Development of RELAP5-3D Code Input Deck of RPV Model
(Main Steam Line Side: Flow Restrictor to Main Steam Header)
Hydraulic Volumes and Junctions

Ref. No.

Flow Restrictors Nozzle Volume 101(121、141 & 161):

Volume 101、121、141 & 161 are the flow restrictor nozzles on each main steam lines. The volume can be estimated by reference 1. The ratio of diameter of the flow restrictor versus the diameter of main steam line is 0.5 and diameter of the main steam line is 700mm. Total length of the nozzle is estimated as 2.15m. **1**

D_1 = 350 mm , D_2 = 700 mm , L = 2.15m

Volume(101) = 1/2*[π *(D_1^2+D_2^2)/4]*L= 1/2*[π *(0.35m_1^2+0.70m^2)/4]*2.15m
= 0.5171m^3

Elevation = 0.0m

Length = 2.15m

Inclination angle = Horizontal = 0°

ε (Roughness)= 0.0

RELAP 5-3D Input Deck is listed below:

```
*
**************************************
*   MSL_A   Nozzle Single Volume 101   *
**************************************
*
1010000     ms_av101     snglvol
*           ---------    ---------
*                                                 horiz.       vert.
*           area         length       volume      angle        angle
*
1010101     0.0          2.1500       0.5171      0.0          0.0
*
*           elev.                     hydraulic   volume
*           change       rough.       diam.       control
*
1010102     0.0          0.0          0.0         00
*
1010200     0          6962295.    1256163.     2579893.     .999556
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model(Flow Restrictor to Main Steam Header)

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

D M Y

日期： / /

撰寫：

審查：

The Development of RELAP5-3D Code Input Deck of RPV Model
(Main Steam Line Side: Flow Restrictor to Main Steam Header)
Hydraulic Volumes and Junctions

Ref. No.

Volume 102(122、142 & 162):

Branch Volume 102 is the main steam line section that extends from the end of restrictor nozzle to the first group of safety relief valves. The radius of the first group of SRVs is estimated to be 9.0m from the center line of RPV. The length of Volume 102 can be calculated by reference 1 & 2. Branch Volume 102 has 2 SRVs on the exit of itself. **1**

R_1(First group of SRVs)= 9.0m **1**

R_2(RPV Inside Radius)= 7.112m/2 = 3.556m **2**

L_{101}= 2.15m

L_{102}= R_1-(R_2+L_{101}) = 9.0m-(3.556m+2.150m)= 3.294m≒3.30m

A_{102}= [π *(Diameter of MSL)^2]/4

= [π *(0.700m)^2]/4 = 0.38485m^2

Volume(102) = A_{102}* L_{102} = 0.38485m^2*3.30m = 1.2700m^3

Elevation = 0.0m

Length = 3.30m

Inclination angle = Horizontal = 0°

ε (Roughness)= 0.0

RELAP 5-3D Input Deck is listed here:

```
*
****************************************
* MSL_A MS Line section_1 Branch 102 *
****************************************
*
*
1020000     ms_ab102     branch
*           ---------    ---------
*
*           number       jun. i.c.
*           of jun.      control
*
1020001     1            0
```

Ref. 2. BABCOCK-HITACHI K.K. 6711-001-01-06 RPV OUTLINE DRAWING (1/2)

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model(Flow Restrictor to Main Steam Header)

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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撰寫：

審查：

RELAP 5-3D Input Deck for Volume 102(Continued):

Ref. No.

```
*
*                                                    horiz.      vert.
*            area          length        volume      angle       angle
*
1020101      0.0           3.3000        1.2700      0.0         0.0
*
*            elev.                       hydraulic   volume
*            change        rough.        diam.       control
*
1020102    0.0           0.0         0.0       00
*
1020200 0  6986900.   1257309.    2580758.    .999522
*
*            from          to            junction    forward     reverse     junct.
*            connect.      connect.      area        loss coef.  l.c.        flags
*
1021101      101010000     102000000   0.38485   0.5     1.0     01000
*
1021201    16.272        37.7831     0. * 531.6
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model(Flow Restrictor to Main Steam Header)

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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日期： / /

撰寫：

審查：

The Development of RELAP5-3D Code Input Deck of RPV Model
(Main Steam Line Side: Flow Restrictor to Main Steam Header)
Hydraulic Volumes and Junctions

Ref. No.

Volume 103(123、143 & 163):

Branch Volume 103 is the main steam line section that connects the first group of safety relief valves and the second group of safety relief valves on main steam line A. The radius of the second group of SRVs is estimated to be 12.0m from the center line of RPV. The length of Volume 103 can be calculated by reference 1 & 2. Branch Volume 103 has 2 SRVs on the exit of itself. **1**

R_1(First group of SRVs)= 9.0m

R_2(Second group of SRVs)= 12.0m

L_{103}= R_2-R_1 = 12.0m-9.0m = 3.0m

A_{103}= [π *(Diameter of MSL)^2]/4

= [π *(0.700m)^2]/4 = 0.38485m^2

Volume(103) = A_{103}* L_{103} = 0.38485m^2*3.0m = 1.1546m^3

Elevation = 0.0m

Length = 3.0m

Inclination angle = Horizontal = 0°

ε (Roughness)= 0.0

RELAP 5-3D Input Deck is listed here:

```
*
****************************************
* MSL_A MS Line section_2 Branch 103 *
****************************************
*
*
1030000     ms_ab103     branch
*           ---------    ---------
*
*           number       jun. i.c.
*           of jun.      control
*
1030001     2            0
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model(Flow Restrictor to Main Steam Header)

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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日期： / /

撰寫：

審查：

RELAP 5-3D Input Deck for Volume 103(Continued):

Ref. No.

```
*
*                                                  horiz.      vert.
*            area          length       volume     angle       angle
*
1030101      0.0           3.0000       1.1546     0.0         0.0
*
*            elev.                      hydraulic  volume
*            change        rough.       diam.      control
*
1030102    0.0           0.0          0.0        00
*
1030200 0  6973248.    1256688.     2580801.   .999496
*
*            from          to           junction   forward     reverse     junct.
*            connect.      connect.     area       loss coef.  l.c.        flags
*
1031101      102010000     103000000    0.38485    0.5         1.0         01000
*
1032101      103010000     104000000    0.38485    0.5         1.0         01000
*
1031201    16.16897      37.6863      0. * 531.615
*
1032201    16.36082      37.7556      0. * 531.618
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model(Flow Restrictor to Main Steam Header)

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

D M Y

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The Development of RELAP5-3D Code Input Deck of RPV Model
(Main Steam Line Side: Flow Restrictor to Main Steam Header)
Hydraulic Volumes and Junctions

Ref. No.

Junction 110(Safety Relief Valve):

Junction 110 is one of the 18 SRVs. The distribution of these SRVs along each main steam line is shown in the reference 1. The other number for each individual junction of SRVs is on the attachment figure in the report. The junction area is evaluated from the value of the reference 3. **1** **3**

Junction 110 Area (A_{110}) = $0.095m^2/8$ = $0.012m^2$(1 SRV)

RELAP 5-3D Input Deck is listed here:

```
*
1100000     srv003a     valve
*           ---------   ---------
*           from        to          junction    forward     reverse     junct.
*           connect.    connect.    area        l.c.        l.c.        flags
*
1100101     102010000   200000000   0.012       18.5        18.5        01100
*
*         Control Liquid   vapor int
*           flag    vel      vel     vel
*
1100201     0       0.       0.      0. * 0.
*
*           valve type
*
1100300     srvvlv
*
*           control   Valveopen
*           var       table no.
*
1100301     0595    * temp set for test
20505950    srvctrl   constant 0.0
*
```

Ref. 3. GE:“Project Design Manual, 31113-0A23-1000 Rev 20” Chapter 3,Table 3.15-3 ADS Description

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model(Flow Restrictor to Main Steam Header)

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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The Development of RELAP5-3D Code Input Deck of RPV Model
(Main Steam Line Side: Flow Restrictor to Main Steam Header)
Hydraulic Volumes and Junctions

Ref. No.

Volume 104(124、144 & 164):

Single Volume 104 is the main steam line section that extends from the second group of SRVs to the inboard MSIV on main steam line A. The MSIV is modeled as a junction component in RELAP5 and the junction of MSIV only needs the value of flow area. Thus half of the physical volume of MSIV will be counted in volume 104 and the other half will be counted in the next section of steam pipe. The piping length of main steam line A before the primary containment wall is derived from the diagonal diagram of GE. For modeling convenience, the other three main steam lines are assumed to have same length as line A. **4**

L11(MS Nozzle end to MSIV 001A) = 11.954m (MSIV 001A not included) **4**

L12(MSIV 001A)= 1.829m **4**

L_{102}= 3.3m

L_{103}= 3.0m

L_{104}= (L11+0.5*L12)-L_{102}-L_{103}

= 11.954m+0.5*1.829m-3.3m-3.0m = 6.5685m

A_{104}= [π *(Diameter of MSL)^2]/4

= [π *(0.700m)^2]/4 = 0.38485m^2

Volume(104) = A_{104}* L_{104} = 0.38485m^2*6.5685m = 2.5279m^3

Elevation = 0.0m

Length = 6.5685m

Inclination angle = Horizontal = 0°

ε (Roughness)= 0.0

RELAP 5-3D Input Deck is listed here:

```
*
**********************************************************
*    MSL_A MS Line section_3 to MSIV 001A Single Volume 104 *
**********************************************************
*
1040000      ms_av104     snglvol
*            ---------    ---------
*
```

Ref. 4. GE: 31113-1B21-L-A-001

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model(Flow Restrictor to Main Steam Header)

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

D M Y

日期： / /

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審查：

RELAP 5-3D Input Deck for Volume 104(Continued):

Ref. No.

```
*                                                    horiz.      vert.
*            area          length        volume      angle       angle
*
1040101      0.0           6.5685        2.5279      0.0         0.0
*
*            elev.                       hydraulic   volume
*            change        rough.        diam.       control
*
1040102      0.0           0.0           0.0         00
*
1040200      0      6.959+6      1255974.      2581069.      .999451
*
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model(Flow Restrictor to Main Steam Header)

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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Ref. No.

The Development of RELAP5-3D Code Input Deck of RPV Model
(Main Steam Line Side: Flow Restrictor to Main Steam Header)
Hydraulic Volumes and Junctions

Junction 105(Main Steam Isolation Valve-MSIV 001A):

Junction 105 is one of the 8 MSIVs. The distribution of these MSIVs along each main steam line is shown in the reference 1. The other number for each individual junction of MSIVs is also on the attachment figure in the report. The junction area of MSIV is set to equal the cross section of main steam line.

A_{105}= [π *(Diameter of MSL)^2]/4
= [π *(0.700m)^2]/4 = 0.38485m^2

RELAP 5-3D Input Deck is listed here:

```
*
*******************************
* MSL_A MSIV 001A    Valve 105 *
*******************************
*
1050000       msiv001a      valve
*             ---------     ---------
*
*             from             to             junction     forward     reverse     junct.
*             connect.      connect.       area         l.c.         l.c.         flags
*
1050101       104010000     106000000      0.38485      1.0          1.0          01100
*
1050201    0    16.62225      37.8343      0. * 531.618
*
*             valve type
*
1050300       srvvlv
*
*            control    Valveopen
*             var         table no.
*
1050301       596       *temp set for test
20505960 msivcrl    constant 1.0
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model(Flow Restrictor to Main Steam Header)

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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The Development of RELAP5-3D Code Input Deck of RPV Model
(Main Steam Line Side: Flow Restrictor to Main Steam Header)
Hydraulic Volumes and Junctions

Ref. No.

Volume 106(126、146 & 166):

Single Volume 106 is the main steam line section that locates between the inboard MSIV and the outboard MSIV on main steam line A. Thus half of the physical volume of 2 MSIVs will be counted in volume 106 and the other half will be counted in the next section of steam pipe. The piping length of main steam line A between 2 MSIVs is derived from the diagonal diagram of GE. **4**

L13(MSIV 001A to MSIV 002A) = 6.011m (MSIV 001A not included) **4**

L12(MSIV 001A)= 1.829m **4**

L_{106}= (L13+2*0.5*L12)

= 6.011m+1.829m= 7.84m

A_{106}= [π *(Diameter of MSL)^2]/4

= [π *(0.700m)^2]/4 = 0.38485m^2

Volume(106) = A_{106}* L_{106} = 0.38485m^2*7.84m = 3.017224m^3

Elevation = 0.0m

Length = 7.84m

Inclination angle = Horizontal = 0°

ε (Roughness)= 0.0

RELAP 5-3D Input Deck is listed here:

```
*
**********************************************************
*   MSL_A MS Line section_4 Between MSIV 001A & MSIV 002A   *
*                                                Single Volume 106 *
**********************************************************
*
1060000     ms_av106    snglvol
*           ---------   ---------
*                                                  horiz.      vert.
*           area        length      volume       angle       angle
*
1060101     0.0         7.8400      3.017224     0.0         0.0
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model(Flow Restrictor to Main Steam Header)

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

D M Y

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撰寫：

審查：

RELAP 5-3D Input Deck for Volume 106(Continued):

Ref. No.

```
*
*
*              elev.                        hydraulic   volume
*              change       rough.          diam.       control
*
1060102     0.0             0.0         0.0       00
*
1060200     0   6931062.    1254594.    2581251.     .999393
*
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model(Flow Restrictor to Main Steam Header)

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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The Development of RELAP5-3D Code Input Deck of RPV Model
(Main Steam Line Side: Flow Restrictor to Main Steam Header)
Hydraulic Volumes and Junctions

Ref. No.

Volume 108(128、148 & 168):

Single Volume 108 is the main steam line section that extends from the outboard MSIV to the main steam header. The last half of the physical volume of outboard MSIV will be counted in this volume 108. The piping length of main steam line A from MSIV 002A to MSL header is derived from the diagonal diagrams of GE and SW.

L12(MSIV 002A)= 1.829m **4**

L14(MSIV 002A to MSL Header) = 79.296m **5&6**

L_{108}= (L14+0.5*L12)

= 79.296m+0.5*1.829m= 80.2105m

A_{108}= [π *(Diameter of MSL)^2]/4

= [π *(0.700m)^2]/4 = 0.38485m^2

Volume(108) = A_{108}* L_{108} = 0.38485m^2*80.2105m = 30.8690m^3

Elevation = 0.0m

Length = 80.2105m

Inclination angle = Horizontal = 0°

ε (Roughness)= 0.0

RELAP 5-3D Input Deck is listed here:

```
*
**************************************************
*   MSL_A MS Line section_5 MSIV 002A to MS Header *
*                                    Single Volume 108 *
**************************************************
*
1080000     ms_av108     snglvol
*           ---------    ---------
*                                                 horiz.      vert.
*           area         length      volume       angle       angle
*
1080101     0.0          80.2105     30.8691      0.0         0.0
*
```

Ref. 5. GE: 31113-1B21-L-I-002

Ref. 6. SW: 06888-1B21-L-SA-5001

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model(Flow Restrictor to Main Steam Header)

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

D M Y

日期： / /

撰寫：

審查：

RELAP 5-3D Input Deck for Volume 108(Continued):

Ref. No.

```
*
*              elev.                        hydraulic    volume
*              change        rough.         diam.        control
*
1080102     0.0              0.0         0.0        00
*
1080200     0     6894044.   1252738.    2582187.     .999285
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model(Flow Restrictor to Main Steam Header)

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(Main Steam Line Side: Flow Restrictor to Main Steam Header)
Hydraulic Volumes and Junctions

Ref. No.

Volume 180(Main Steam Line Header):

Branch Volume 180 is the main steam line header that collects four main steam lines together before steam entering the turbine. It is a cylindrical structure. The geometry sizing data of the header is derived from the diagonal diagram of SW. 7

D1(Diameter of MSL Header)= 1.5m

H1(Height of MSL Header) = 9.0m

Volume(180) = [π *$D1^2$]/4*H1 = [π *$(1.5m)^2$]/4*9.0m

= $15.9043m^3$

No. of Junctions = 4 (MSL A,B,C & D)

Junction area =(MSL cross section) = $0.38485m^2$

Elevation = 0.0m

Length = 1.5m

Inclination angle = Horizontal = 0°

ε (Roughness)= 0.0

RELAP 5-3D Input Deck is listed here:

```
*
****************************************
*    MSL_A,B,C,D-->MS Header Branch 180 *
****************************************
*
*
1800000      ms_hb180     branch
*            ---------    ---------
*
*            number       jun. i.c.
*            of jun.      control
*
1800001      4            0
*
```

Ref. 7. SW: 06888-1B21-L-SA-5005

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model(Flow Restrictor to Main Steam Header)

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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撰寫：

審查：

RELAP 5-3D Input Deck for Volume 180(Continued):

Ref. No.

```
*                                                  horiz.      vert.
*            area          length       volume     angle       angle
*
1800101      0.0           1.500        15.9043    0.0         0.0
*
*            elev.                      hydraulic  volume
*            change        rough.       diam.      control
*
1800102    0.0           0.0          0.0        00
*
1800200 0    6896512.    1252743.     2582249.     .99881
*
*            from          to           junction   forward     reverse     junct.
*            connect.      connect.     area       loss coef.  l.c.        flags
*
1801101      108010000     180000000    0.38485    0.5     1.0    01000
*
1802101      128010000     180000000    0.38485    0.5     1.0    01000
*
1803101      148010000     180000000    0.38485    0.5     1.0    01000
*
1804101      168010000     180000000    0.38485    0.5     1.0    01000
*
1801201    17.61453      38.1996      0. * 531.619
*
1802201    17.61453      38.1996      0. * 531.619
*
1803201    17.61453      38.1996      0. * 531.619
*
1804201    17.61453      38.1996      0. * 531.619
*
```

Reactor Pressure Vessel Fuel Heat Structures

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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The Development of RELAP5-3DK Code Input Deck of RPV Model -Fuel Assembly Heat Structures(Fuel Rods)-

Ref. No.

The number of fuel assemblies in Lungmen power plant is 872. For simplicity, the Lungmen RPV model uses 9 active heat structures to represent all the assemblies. The number of assemblies in each heat structure consists with the corresponding fuel hydraulic channel. First, geometry data of single assembly is calculated, the result will be the basis of all fuel heat structures.

Fuel Assembly Data:
Full Length Rod : 78 (150” active length)
Partial Length Rod : 14 (84” active length)

Fuel Rod geometry : 1

Cladding :
Outside Diameter = 0.404” = 1.02616 cm = $1.02616*10^{-2}$ m
Inside Diameter = 0.352” = 0.89408 cm = $8.9408*10^{-3}$ m

Pellet :
Diameter = 0.345” = 0.8763 cm = $8.763*10^{-3}$ m

Active Fuel Length :
Full Length Rod = 150” = 3.81 m
Partial Length Rod = 84” = 2.1336 m

***Ref. 1.* 874611M002-1 Amendment2 Figure 1: Lattice Geometry**

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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審查：

Ref. No.

All 9 heat structures of fuels are axial divided into twelve 12” sections and one 6” section. The geometry data of single fuel assembly are calculated below.

For one assembly :

Elevation 0~84” (w/ 14 PLR)
12” per section = 0.3048 m
Total No of fuel rods =78 FLR + 14 PLR = 92
Total length of fuels in the 12” section
=92*0.3048m = 28.0416m/Assembly

Elevation 84”~144” (w/o 14 PLR) :
Total No of fuel rods =78 FLR = 78
Total length of fuels in the 12” section
= 78*0.3048m = 23.7744m/Assembly
Inside Diameter = 0.352” = 0.89408 cm = $8.9408*10^{-3}$ m

Elevation 144”~150” (w/o 14 PLR) :
Total No of fuel rods =78 FLR = 78
Total length of fuels in the 6” section
= 78*0.1524m = 11.8872m/Assembly

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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Ref. No.

For the hydraulic volume 041, the heat structure 1010 has 4 assemblies in itself. The necessary geometry data can be derived from single assembly.

Heat structure 1010 for volume 041: (w/ 4 Assemblies)

Elevation 0~84” (w/ 14 PLR)
Total length of fuels in the 12” section (By the result on page 2)
= 4*28.0416m/Assembly = 112.1664m

Elevation 84”~144” (w/o 14 PLR) :
Total length of fuels in the 12” section (By the result on page 2)
= 4*23.7744m/Assembly = 95.0976m

Elevation 144”~150” (w/o 14 PLR) :
Total length of fuels in the 6” section (By the result on page 2)
Total length of fuels in the 6” section
= 4*11.8872m/Assembly = 47.5488m

RELAP 5-3D Input Deck for Heat Structure 1010 is listed below :

```
**************************************
* 1010->4 Assemblies
**************************************
*
*   num. of      num.of      geom.      s.s.      l.bound
*   heat str.   heat str. type      flag       coordin.
*
*
11010000     13      7       2          1         0.0
*
*              mesh loc.   mesh format
*              flag          flag
*
11010100      0              1
*
*     heat structure mesh interval data
*     --------------------------------
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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審查：

Ref. No.

```
*
*                    interval number                right bond.
*
11010101                    4                        4.3815e-3       * fuel interval
11010102                    1                        4.4704e-3       * gap interval
11010103                    1                        5.1308e-3       * clad interval
*
*                 ** fuel **                 ** gap **                 ** clad **
*              comp.          interval     comp.          interval     comp.          interval
*
11010201       1              4            -2             5            -3             6
*
*   power source distribution data
*   ------------------------------
*
*              rel. power     interval         rel. power     interval
*
11010301         1.0          4
11010302         0.0          6
*
*initial temperature flag
*
*                 flag
11010400           -1
*
*              init. temp.          mesh pt.
*
11010401   732.25   715.74   668.03   594.32   575.56   569.49
+ 566.60
11010402   889.34   855.42   760.07   620.89   587.99   582.62
+ 572.35
11010403   919.94   882.47   777.55   625.83   590.44   579.07
+ 573.63
11010404   911.34   874.95   831.14   772.90   703.09 624.92
+ 596.11
```

Ref. No.

```
11010405  924.85  915.23  886.87  841.16  780.55  708.01
+ 627.01
11010406  933.85  923.95  894.78  847.80  785.57  711.19
+ 574.52
11010407  937.50  927.48  897.95  850.42  787.48  712.30
+ 574.30
11010408  973.89  962.74  929.89  877.28  807.76  725.15
+ 575.35
11010409  968.07  957.11  924.84  873.09  804.70  723.34
+ 575.53
11010410  926.92  917.23  888.68  842.66  781.67  708.70
+ 574.30
11010411  831.33  824.49  804.25  771.40  727.35  673.67
+ 571.69
11010412  651.98  649.91  643.76  633.60  619.58  601.93
+ 565.80
11010413  614.86  613.67  610.13  604.25  596.12  585.79
+ 564.25
*
*    boundary condition data
*    ----------------------
*
*          vol. increment      type        code        length      number
*          bdry                b.c.        s.a.                    heat sr.
*
11010501    0       0           0           1         112.1164      7
11010502    0       0           0           1          95.0976      12
11010503    0       0           0           1          47.5488      13
*
11010601    041010000   0       1           1         112.1164      1
11010602    041020000   0       1           1         112.1164      2
11010603    041030000   0       1           1         112.1164      3
11010604    041040000   0       1           1         112.1164      4
11010605    041050000   0       1           1         112.1164      5
11010606    041060000   0       1           1         112.1164      6
11010607    041070000   0       1           1         112.1164      7
11010608    041080000   0       1           1          95.0976      8
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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```
11010609    041090000   0    1          1        95.0976      9
11010610    041100000   0    1          1        95.0976      10
11010611    041110000   0    1          1        95.0976      11
11010612    041120000   0    1          1        95.0976      12
11010613    041130000   0    1          1        47.5488      13
*
*     source data
*     -----------
11010701    100   1.973589E-04      0.0   8.33042E-06     1
11010702    100   5.117951E-04      0.0   2.16026E-05     2
11010703    100   6.561612E-04      0.0   2.76962E-05     3
11010704    100   6.751752E-04      0.0   2.84988E-05     4
11010705    100   6.799288E-04      0.0   2.86994E-05     5
11010706    100   6.683090E-04      0.0   2.8209E-05      6
11010707    100   6.070415E-04      0.0   2.56229E-05     7
11010708    100   5.121472E-04      0.0   2.16175E-05     8
11010709    100   4.792248E-04      0.0   2.02278E-05     9
11010710    100   4.239432E-04      0.0   1.78944E-05     10
11010711    100   3.223588E-04      0.0   1.36066E-05     11
11010712    100   1.600350E-04      0.0   6.755E-06       12
11010713    100   3.045771E-05      0.0   1.2856E-06      13
*
*
*           diam        len.                                          number
*           heat        chan                                          heat sr.
*
*
11010901          0.012513 0.1524   3.6576   0.0  0.0  0.0  0.0  1.0  1
11010902          0.012513 0.4572   3.3528   0.0  0.0  0.0  0.0  1.0  2
11010903          0.012513 0.7620   3.0480   0.0  0.0  0.0  0.0  1.0  3
11010904          0.012513 1.0668   2.7432   0.0  0.0  0.0  0.0  1.0  4
11010905          0.012513 1.3716   2.4384   0.0  0.0  0.0  0.0  1.0  5
11010906          0.012513 1.6764   2.1336   0.0  0.0  0.0  0.0  1.0  6
11010907          0.012513 1.9812   1.8288   0.0  0.0  0.0  0.0  1.0  7
```

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```
11010908        0.012513 2.2860   1.5240   0.0  0.0  0.0  0.0  1.0  8
11010909        0.012513 2.5908   1.2192   0.0  0.0  0.0  0.0  1.0  9
11010910        0.012513 2.8956   0.9144   0.0  0.0  0.0  0.0  1.0  10
11010911        0.012513 3.2004   0.6096   0.0  0.0  0.0  0.0  1.0  11
11010912        0.012513 3.5052   0.3048   0.0  0.0  0.0  0.0  1.0  12
11010913        0.012513 3.7338   0.0762   0.0  0.0  0.0  0.0  1.0  13
*
*
**************************************
```

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The hydraulic volumes 042、043、044 and 045 have the same geometry data because of the symmetry. The heat structure 2010、3010、4010 and 5010 are located in each corresponding volume and are consisted of by 108 assemblies. The necessary geometry data for these heat structures can be derived from single assembly.

Heat structure 2010、3010、4010 and 5010 for volume 042、043、044 and 045 (w/ 108 Assemblies)

Elevation 0~84” (w/ 14 PLR)
Total length of fuels in the 12” section (By the result on page 2)
= 108*28.0416m/Assembly = 3028.4928m

Elevation 84”~144” (w/o 14 PLR) :
Total length of fuels in the 12” section (By the result on page 2)
= 108*23.7744m/Assembly = 2567.6352m

Elevation 144”~150” (w/o 14 PLR) :
Total length of fuels in the 6” section (By the result on page 2)
Total length of fuels in the 6” section
= 108*11.8872m/Assembly = 1283.8176m

RELAP 5-3D Input Deck for Heat Structure 2010 is listed below :
(Heat Structures 3010、4010 and 5010 are the same as 2010.)

```
**************************************
* Fuel Heat Structures for Volume 042 *27 control cells
**************************************
* 2010->108 Assemblies
**************************************
*
*   num. of      num.of      geom.      s.s.      l.bound
*   heat str.   heat str. type      flag      coordin.
*
*
12010000    13      7       2          1         0.0
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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```
*
*              mesh loc.    mesh format
*              flag         flag
*
12010100       0              1
*
*     heat structure mesh interval data
*     ---------------------------------
*
*
*                      interval number              right bond.
*
12010101                     4                      4.3815e-3       * fuel interval
12010102                     1                      4.4704e-3       * gap interval
12010103                     1                      5.1308e-3       * clad interval
*
*                  ** fuel **                ** gap **                ** clad **
*              comp.         interval     comp.         interval     comp.         interval
*
12010201       1              4            -2             5           -3             6
*
*    power source distribution data
*    ------------------------------
*
*              rel. power     interval         rel. power     interval
*
12010301         1.0          4
12010302         0.0          6
*
*initial temperature flag
*
*                flag
12010400           -1
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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```
*
*              init. temp.          mesh pt.
*
12010401   732.25   728.10   715.74   695.52   668.03   634.03
+ 566.60
12010402   889.34   880.77   855.42   814.58   760.07   694.54
+ 572.35
12010403   919.94   910.45   882.47   837.38   777.55   705.90
+ 573.63
12010404   911.34   902.13   874.95   831.14   772.90   703.09
+ 573.84
12010405   924.85   915.23   886.87   841.16   780.55   708.01
+ 574.33
12010406   933.85   923.95   894.78   847.80   785.57   711.19
+ 574.52
12010407   937.50   927.48   897.95   850.42   787.48   712.30
+ 574.30
12010408   973.89   962.74   929.89   877.28   807.76   725.15
+ 575.35
12010409   968.07   957.11   924.84   873.09   804.70   723.34
+ 575.53
12010410   926.92   917.23   888.68   842.66   781.67   708.70
+ 574.30
12010411   831.33   824.49   804.25   771.40   727.35   673.67
+ 571.69
12010412   651.98   649.91   643.76   633.60   619.58   601.93
+ 565.80
12010413   614.86   613.67   610.13   604.25   596.12   585.79
+ 564.25
*
```

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```
*
*     boundary condition data
*     -----------------------
*
*              vol. increment        type          code          length        number
*              bdry                    b.c.          s.a.                        heat sr.
*
12010501     0        0              0             1          3028.4928       7
12010502     0        0              0             1          2567.6532       12
12010503     0        0              0             1          1283.8176       13
*
12010601     042010000    0        1             1          3028.4928       1
12010602     042020000    0        1             1          3028.4928       2
12010603     042030000    0        1             1          3028.4928       3
12010604     042040000    0        1             1          3028.4928       4
12010605     042050000    0        1             1          3028.4928       5
12010606     042060000    0        1             1          3028.4928       6
12010607     042070000    0        1             1          3028.4928       7
12010608     042080000    0        1             1          2567.6532       8
12010609     042090000    0        1             1          2567.6532       9
12010610     042100000    0        1             1          2567.6532       10
12010611     042110000    0        1             1          2567.6532       11
12010612     042120000    0        1             1          2567.6532       12
12010613     042130000    0        1             1          1283.8176       13
*
*     source data
*     -----------
12010701     100    4.946869E-03    0.0    0.000208805     1
12010702     100    1.271244E-02    0.0    0.000536586     2
12010703     100    1.598396E-02    0.0    0.000674675     3
12010704     100    1.625095E-02    0.0    0.000685944     4
12010705     100    1.618123E-02    0.0    0.000683001     5
12010706     100    1.591961E-02    0.0    0.000671959     6
12010707     100    1.481917E-02    0.0    0.00062551      7
```

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```
12010708    100   1.298092E-02   0.0   0.000547918    8
12010709    100   1.211455E-02   0.0   0.000511349    9
12010710    100   1.041403E-02   0.0   0.000439571   10
12010711    100   7.599199E-03   0.0   0.000320758   11
12010712    100   3.710075E-03   0.0   0.0001566     12
12010713    100   6.909322E-04   0.0   2.91639E-05   13
*
*          diam        len.                                          number
*          heat        chan                                          heat sr.
*
*
12010901          0.012513 0.1524  3.6576   0.0  0.0  0.0  0.0  1.0  1
12010902          0.012513 0.4572  3.3528   0.0  0.0  0.0  0.0  1.0  2
12010903          0.012513 0.7620  3.0480   0.0  0.0  0.0  0.0  1.0  3
12010904          0.012513 1.0668  2.7432   0.0  0.0  0.0  0.0  1.0  4
12010905          0.012513 1.3716  2.4384   0.0  0.0  0.0  0.0  1.0  5
12010906          0.012513 1.6764  2.1336   0.0  0.0  0.0  0.0  1.0  6
12010907          0.012513 1.9812  1.8288   0.0  0.0  0.0  0.0  1.0  7
12010908          0.012513 2.2860  1.5240   0.0  0.0  0.0  0.0  1.0  8
12010909          0.012513 2.5908  1.2192   0.0  0.0  0.0  0.0  1.0  9
12010910          0.012513 2.8956  0.9144   0.0  0.0  0.0  0.0  1.0  10
12010911          0.012513 3.2004  0.6096   0.0  0.0  0.0  0.0  1.0  11
12010912          0.012513 3.5052  0.3048   0.0  0.0  0.0  0.0  1.0  12
12010913          0.012513 3.7338  0.0762   0.0  0.0  0.0  0.0  1.0  13
*
```

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The hydraulic volumes 046、047、048 and 049 have the same geometry data because of the symmetry. The heat structure 6010、7010、8010 and 9010 are located in each corresponding volume and are consisted of by 109 assemblies. The necessary geometry data for these heat structures can be derived from single assembly.

Heat structure 6010、7010、8010 and 9010 for volume 046、047、048 and 049 (w/ 109 Assemblies)

Elevation 0~84” (w/ 14 PLR)
Total length of fuels in the 12” section (By the result on page 2)
= 109*28.0416m/Assembly = 3056.5344m

Elevation 84”~144” (w/o 14 PLR) :
Total length of fuels in the 12” section (By the result on page 2)
= 109*23.7744m/Assembly = 2591.4096m

Elevation 144”~150” (w/o 14 PLR) :
Total length of fuels in the 6” section (By the result on page 2)
Total length of fuels in the 6” section
= 109*11.8872m/Assembly = 1295.7048m

RELAP 5-3D Input Deck for Heat Structure 6010 is listed below :
(Heat Structures 7010、8010 and 9010 are the same as 6010.)

```
**************************************
* Fuel Heat Structures for Volume 046 *24 control cells
**************************************
* 6010-> 109 Assemblies
**************************************
*
*   num. of      num.of      geom.      s.s.      l.bound
*   heat str.   heat str. type      flag       coordin.
*
*
16010000     13      7       2          1         0.0
*
```

```
*              mesh loc.    mesh format
*              flag           flag
*
16010100       0              1
*
*     heat structure mesh interval data
*     ---------------------------------
*
*
*                      interval number              right bond.
*
16010101                     4                      4.3815e-3       * fuel interval
16010102                     1                      4.4704e-3       * gap interval
16010103                     1                      5.1308e-3       * clad interval
*
*                  ** fuel **                ** gap **                ** clad **
*              comp.          interval     comp.          interval     comp.          interval
*
16010201       1              4            -2             5            -3             6
*
*    power source distribution data
*    ------------------------------
*
*              rel. power     interval          rel. power     interval
*
16010301         1.0          4
16010302         0.0          6
*
*initial temperature flag
*
*                 flag
16010400            -1
*
*              init. temp.          mesh pt.
*
16010401    732.25    728.10    715.74    695.52    668.03    634.03
+ 566.60
```

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```
16010402  889.34  880.77  855.42  814.58  760.07  694.54
+ 572.35
16010403  919.94  910.45  882.47  837.38  777.55  705.90
+ 573.63
16010404  911.34  902.13  874.95  831.14  772.90  703.09
+ 573.84
16010405  924.85  915.23  886.87  841.16  780.55  708.01
+ 574.33
16010406  933.85  923.95  894.78  847.80  785.57  711.19
+ 574.52
16010407  937.50  927.48  897.95  850.42  787.48  712.30
+ 574.30
16010408  973.89  962.74  929.89  877.28  807.76  725.15
+ 575.35
16010409  968.07  957.11  924.84  873.09  804.70  723.34
+ 575.53
16010410  926.92  917.23  888.68  842.66  781.67  708.70
+ 574.30
16010411  831.33  824.49  804.25  771.40  727.35  673.67
+ 571.69
16010412  651.98  649.91  643.76  633.60  619.58  601.93
+ 565.80
16010413  614.86  613.67  610.13  604.25  596.12  585.79
+ 564.25
*
*    boundary condition data
*    ----------------------
*
*          vol. increment      type        code        length      number
*          bdry                b.c.        s.a.                    heat sr.
*
16010501    0       0           0           1       3056.5344       7
16010502    0       0           0           1       2591.4096       12
16010503    0       0           0           1       1295.7048       13
```

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```
*
16010601    046010000    0    1          1    3056.5344    1
16010602    046020000    0    1          1    3056.5344    2
16010603    046030000    0    1          1    3056.5344    3
16010604    046040000    0    1          1    3056.5344    4
16010605    046050000    0    1          1    3056.5344    5
16010606    046060000    0    1          1    3056.5344    6
16010607    046070000    0    1          1    3056.5344    7
16010608    046080000    0    1          1    2591.4096    8
16010609    046090000    0    1          1    2591.4096    9
16010610    046100000    0    1          1    2591.4096    10
16010611    046110000    0    1          1    2591.4096    11
16010612    046120000    0    1          1    2591.4096    12
16010613    046130000    0    1          1    1295.7048    13
*
*     source data
*     -----------
16010701    100    3.710471E-03    0.0    0.000156617    1
16010702    100    9.404566E-03    0.0    0.000396962    2
16010703    100    1.151975E-02    0.0    0.000486243    3
16010704    100    1.148167E-02    0.0    0.000484636    4
16010705    100    1.125276E-02    0.0    0.000474973    5
16010706    100    1.114951E-02    0.0    0.000470615    6
16010707    100    9.978551E-03    0.0    0.000421189    7
16010708    100    7.785025E-03    0.0    0.000328602    8
16010709    100    6.693301E-03    0.0    0.000282521    9
16010710    100    5.317027E-03    0.0    0.000224429    10
16010711    100    3.703693E-03    0.0    0.000156331    11
16010712    100    1.757876E-03    0.0    7.4199E-05     12
16010713    100    3.165049E-04    0.0    1.33595E-05    13
*
```

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```
*          diam        len.                                          number
*          heat        chan                                          heat sr.
*
*
16010901          0.012513 0.1524   3.6576   0.0  0.0  0.0  0.0  1.0  1
16010902          0.012513 0.4572   3.3528   0.0  0.0  0.0  0.0  1.0  2
16010903          0.012513 0.7620   3.0480   0.0  0.0  0.0  0.0  1.0  3
16010904          0.012513 1.0668   2.7432   0.0  0.0  0.0  0.0  1.0  4
16010905          0.012513 1.3716   2.4384   0.0  0.0  0.0  0.0  1.0  5
16010906          0.012513 1.6764   2.1336   0.0  0.0  0.0  0.0  1.0  6
16010907          0.012513 1.9812   1.8288   0.0  0.0  0.0  0.0  1.0  7
16010908          0.012513 2.2860   1.5240   0.0  0.0  0.0  0.0  1.0  8
16010909          0.012513 2.5908   1.2192   0.0  0.0  0.0  0.0  1.0  9
16010910          0.012513 2.8956   0.9144   0.0  0.0  0.0  0.0  1.0  10
16010911          0.012513 3.2004   0.6096   0.0  0.0  0.0  0.0  1.0  11
16010912          0.012513 3.5052   0.3048   0.0  0.0  0.0  0.0  1.0  12
16010913          0.012513 3.7338   0.0762   0.0  0.0  0.0  0.0  1.0  13
*
*
*
**************************************
```

Ref. No.

Reactor Pressure Vessel Channel Box Heat Structures

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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The Development of RELAP5-3DK Code Input Deck of RPV Model -Fuel Assembly Heat Structures(Channel Boxes)-

The fuel channel boxes surround the fuel rods of each assembly. Because the hydraulic volume of the reactor core is now divided into 9 volumes in RELAP5 model. The heat structures of the fuel channel boxes also need to be modified to fit both the hydraulic volumes and fuel rod heat structures.

For a single channel box :
From reference document :
874611M002-1 Amendment2 Figure 1: Lattice Geometry **1**

Corner thickness A_1 = 0.1” = 0.254 cm = $2.54*0^{-3}$ m

Side thickness A_2 = 0.065” = 0.1651 cm = $1.651*10^{-3}$ m

Inside width B = 5.278” = 13.40612 cm = $1.340612*10^{-1}$ m

Corner Inside Radius C = 0.450” = 1.143 cm = $1.143*10^{-2}$ m

Inside perimeter of a channel box :
= (B-2C)*4+2* π *C
= (5.278”-2*0.45”)*4+2* π *0.45”
= 20.339” = 51.6611 cm = $5.1661*10^{-1}$ m

Average thickness of a channel box :
= [A_1*2 π C+(B-2C)*4*A_2]/[(B-2C)*4+2 π C]
= [(0.1”*2 π *0.45”)+(5.278”-2*0.45”)*4*0.065”]/ 20.339”
= 0.0699” = $1.7755*10^{-3}$ m

Ref. 1. **874611M002-1 Amendment2 Figure 1: Lattice Geometry**

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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The whole core is divided into 9 areas and the channel boxes are the heat structures located between core hydraulic volume and bypass region. The heat structures of channel boxes must be modeled as 9 pieces for each corresponding hydraulic volume.

For volume 041 :
Volume 041 has 4 fuel assemblies.

Elevation 0~144” : Twelve 12” nodes
Total length of each node
= 4*0.3048 m = 1.2192 m

Surface Area of a 12” node
= Perimeter*Total length
= $5.1661*10^{-1}$ m*1.2192 m
= 0.629851 m^2

Elevation 144”~150” : One 6” node
Total length of the node
= 4*0.1524 m = 0.6096 m

Surface Area of a 6” node
= $5.1661*10^{-1}$ m*0.6096 m
= 0.314925 m^2

Volume 042、043、044 and 045 are identical in geometry because of the radial symmetry.

There are 108 fuel assemblies in volume 042 (043、044 and 045)

Elevation 0~144” : Twelve 12” nodes
Total length of each node
= 108*0.3048 m = 32.9184 m

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Volume 042 continued ;

Surface Area of a 12” node
= Perimeter*Total length
= $5.1661*10^{-1}$ m*32.9184 m
= 17.005975 m^2

Elevation 144”~150” : One 6” node
Total length of the node
= 108*0.1524 m = 16.4592 m

Surface Area of a 6” node
= $5.1661*10^{-1}$ m*16.4592 m
= 8.502987 m^2

Volume 046、047、048 and 049 are identical in geometry because of the radial symmetry.

There are 109 fuel assemblies in volume 046 (047、048 and 049)

Elevation 0~144” : Twelve 12” nodes
Total length of each node
= 109*0.3048 m = 33.2232 m

Surface Area of a 12” node
= Perimeter*Total length
= $5.1661*10^{-1}$ m*33.2232 m
= 17.163437 m

Elevation 144”~150” : One 6” node
Total length of the node
= 109*0.1524 m = 16.6116 m

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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Volume 046 continued ;

Surface Area of a 6” node
= 5.1661*10^{-1} m*16.6116 m
= 8.581719 m^2

The RELAP5-3D Input of the channel boxes ;

Channel box of volume 041 :
Card No. 10411000
1CCCG000 CCC = Hydraulic volume No. G = 1
No of heat structures in axial direction = 13
No of mesh points = 2
Geometry type = 1
S.S flag = 1
Left boundary coordination = (Cell Area)$^{1/2}$ = (0.041876 m^2)$^{1/2}$ = 0.2046363 m **2**
Interval No. = 1
Right boundary coordination = 0.2046363 m+ Average thickness of a channel box
= 0.2046363 m + 1.7755*10^{-3} m
= 0.2064118 m
Heat Structure composition : Zr → 003
No Power source
Relative Power = 0.0
Boundary condition :
Left boundary vol No. = 041
Right boundary vol No. = 070
Surface Area of each 12” node = 0.629851 m^2
Surface Area of the last 6” node = 0.314925 m^2

Ref. 2. **The hydraulic volume calculation sheet page x**

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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The RELAP5 input of channel box 041 :

```
**************************************
* Channel boxes of Volume 041
* (4 Assemblies)
**************************************
*
*          num. of       num. of      geom.      s.s.      l. bound.
*          heat str.     mesh pts. type        flag       coord.
*
10411000    13            2            1            1       0.204363
*
*                 mesh loc.            mesh format
*                 flag                  flag
*
10411100            0                      1
*
*       heat structure mesh interval data
*       ___________________________________
*
*
*                          interval number                    right    bound.
*
10411101                        1                              0.2064118
*
*                               heat struc. comp               interval
*
10411201                              003                            1
*
*      power source distribution data
*      ______________________________
*
*          relative power              interval
*
10411301         0.0                         1
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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Ref. No.

```
*
*          initial temp.          mesh pt.
*
10411400    -1
*
10411401    552.27    552.16
*
10411402    555.38    554.45
*
10411403    558.23    556.58
*
10411404    560.66    558.43
*
10411405    561.40    559.04
*
10411406    561.47    559.18
*
10411407    561.50    559.27
*
10411408    561.51    559.35
*
10411409    561.46    559.39
*
10411410    561.46    559.46
*
10411411    561.46    559.52
*
10411412    561.45    559.57
*
10411413    561.43    559.62
*
*
*          boundary condition data
*          ______________________
*
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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Ref. No.

```
*
*
*           bdry.                          b.c.    s.a.          heat
*           vol.          increment        type    code          length          number
*
10411501    041010000     0                  1       1           0.629851          1
10411502    041020000     0                  1       1           0.629851          2
10411503    041030000     0                  1       1           0.629851          3
10411504    041040000     0                  1       1           0.629851          4
10411505    041050000     0                  1       1           0.629851          5
10411506    041060000     0                  1       1           0.629851          6
10411507    041070000     0                  1       1           0.629851          7
10411508    041080000     0                  1       1           0.629851          8
10411509    041090000     0                  1       1           0.629851          9
10411510    041100000     0                  1       1           0.629851         10
10411511    041110000     0                  1       1           0.629851         11
10411512    041120000     0                  1       1           0.629851         12
10411513    041130000     0                  1       1           0.314925         13
*
10411601    070010000     0                  1       1           0.629851          1
10411602    070020000     0                  1       1           0.629851          2
10411603    070030000     0                  1       1           0.629851          3
10411604    070040000     0                  1       1           0.629851          4
10411605    070050000     0                  1       1           0.629851          5
10411606    070060000     0                  1       1           0.629851          6
10411607    070070000     0                  1       1           0.629851          7
10411608    070080000     0                  1       1           0.629851          8
10411609    070090000     0                  1       1           0.629851          9
10411610    070100000     0                  1       1           0.629851         10
10411611    070110000     0                  1       1           0.629851         11
10411612    070120000     0                  1       1           0.629851         12
10411613    070130000     0                  1       1           0.314925         13
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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Ref. No.

```
*
*                source data
*                ___________
*
*
*
*                 source          int. source          right       left       heat str.
*                 type            multiplier           dir.heat    dir.heat   number
*
10411701            0                 0.0                  0.0         0.0        13
*
*
*              heat              chan.                                              heat
*              diam.             len.                                               number
*
10411801      0.0         0.1524    3.6576    0.0    0.0    0.0    0.0    1.0      1
10411802      0.0         0.4572    3.3528    0.0    0.0    0.0    0.0    1.0      2
10411803      0.0         0.7620    3.0480    0.0    0.0    0.0    0.0    1.0      3
10411804      0.0         1.0668    2.7432    0.0    0.0    0.0    0.0    1.0      4
10411805      0.0         1.3716    2.4384    0.0    0.0    0.0    0.0    1.0      5
10411806      0.0         1.6764    2.1336    0.0    0.0    0.0    0.0    1.0      6
10411807      0.0         1.9812    1.8288    0.0    0.0    0.0    0.0    1.0      7
10411808      0.0         2.2860    1.5240    0.0    0.0    0.0    0.0    1.0      8
10411809      0.0         2.5908    1.2192    0.0    0.0    0.0    0.0    1.0      9
10411810      0.0         2.8956    0.9144    0.0    0.0    0.0    0.0    1.0      10
10411811      0.0         3.2004    0.6096    0.0    0.0    0.0    0.0    1.0      11
10411812      0.0         3.5052    0.3048    0.0    0.0    0.0    0.0    1.0      12
10411813      0.0         3.7338    0.0762    0.0    0.0    0.0    0.0    1.0      13
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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Ref. No.

```
*
10411901    0.0         0.1524    3.6576    0.0     0.0     0.0     0.0     1.0     1
10411902    0.0         0.4572    3.3528    0.0     0.0     0.0     0.0     1.0     2
10411903    0.0         0.7620    3.0480    0.0     0.0     0.0     0.0     1.0     3
10411904    0.0         1.0668    2.7432    0.0     0.0     0.0     0.0     1.0     4
10411905    0.0         1.3716    2.4384    0.0     0.0     0.0     0.0     1.0     5
10411906    0.0         1.6764    2.1336    0.0     0.0     0.0     0.0     1.0     6
10411907    0.0         1.9812    1.8288    0.0     0.0     0.0     0.0     1.0     7
10411908    0.0         2.2860    1.5240    0.0     0.0     0.0     0.0     1.0     8
10411909    0.0         2.5908    1.2192    0.0     0.0     0.0     0.0     1.0     9
10411910    0.0         2.8956    0.9144    0.0     0.0     0.0     0.0     1.0     10
10411911    0.0         3.2004    0.6096    0.0     0.0     0.0     0.0     1.0     11
10411912    0.0         3.5052    0.3048    0.0     0.0     0.0     0.0     1.0     12
10411913    0.0         3.7338    0.0762    0.0     0.0     0.0     0.0     1.0     13
*

The input of channel box 10411000 finished.
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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Channel box of volume 042 (043、044 and 045):
Card No. 10421000 (10431000、10441000 & 10451000)
1CCCG000 CCC = Hydraulic volume No. G = 1
No of heat structures in axial direction = 13
No of mesh points = 2
Geometry type = 1
S.S flag = 1
Left boundary coordination = (Volume Area)$^{1/2}$
= (108 channels*0.010469 m^2/channel)$^{1/2}$ = 1.063321 m **2**
Interval No. = 1
Right boundary coordination = 1.063321 m+ Average thickness of a channel box
= 1.063321 m + 1.7755*10^{-3} m
= 1.0650965 m
Heat Structure composition : Zr → 003
No Power source
Relative Power = 0.0
Boundary condition :
Left boundary vol No. = 042 (043、044 and 045)
Right boundary vol No. = 070
Surface Area of each 12” node = 17.005975 m^2
Surface Area of the last 6” node = 8.502987 m^2

The RELAP5 input of channel box 042 (Same as 043、044 and 045):

```
************************************
* Channel boxes of Volume 042
* (108 Assemblies)
************************************
*
*         num. of      num. of     geom.     s.s.     l. bound.
*         heat str.    mesh pts. type       flag     coord.
*
10421000  13           2           1         1        1.063321
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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```
*
*
*                mesh loc.          mesh format
*                flag                flag
*
10421100          0                    1
*
*      heat structure mesh interval data
*      ____________________________________
*
*
*                      interval number                right    bound.
*
10421101                    1                          1.0650965
*
*                           heat struc. comp           interval
*
10421201                        003                        1
*
*     power source distribution data
*     ______________________________
*
*          relative power            interval
*
10421301        0.0                      1
*
*          initial temp.          mesh pt.
*
10421400    -1
*
10421401    552.27    552.16
*
10421402    555.38    554.45
*
10421403    558.23    556.58
*
10421404    560.66    558.43
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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Ref. No.

```
*
10421405   561.40   559.04
*
10421406   561.47   559.18
*
10421407   561.50   559.27
*
10421408   561.51   559.35
*
10421409   561.46   559.39
*
10421410   561.46   559.46
*
10421411   561.46   559.52
*
10421412   561.45   559.57
*
10421413   561.43   559.62
*
*        boundary condition data
*        ______________________
*
*
*            bdry.                          b.c.     s.a.          heat
*            vol.          increment        type     code          length          number
*
10421501   042010000        0                1        1          17.005975          1
10421502   042020000        0                1        1          17.005975          2
10421503   042030000        0                1        1          17.005975          3
10421504   042040000        0                1        1          17.005975          4
10421505   042050000        0                1        1          17.005975          5
10421506   042060000        0                1        1          17.005975          6
10421507   042070000        0                1        1          17.005975          7
10421508   042080000        0                1        1          17.005975          8
10421509   042090000        0                1        1          17.005975          9
10421510   042100000        0                1        1          17.005975          10
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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```
*
10421511  042110000       0                1        1          17.005975          11
10421512  042120000       0                1        1          17.005975          12
10421513  042130000       0                1        1           8.502987          13
*
10421601  070010000       0                1        1          17.005975           1
10421602  070020000       0                1        1          17.005975           2
10421603  070030000       0                1        1          17.005975           3
10421604  070040000       0                1        1          17.005975           4
10421605  070050000       0                1        1          17.005975           5
10421606  070060000       0                1        1          17.005975           6
10421607  070070000       0                1        1          17.005975           7
10421608  070080000       0                1        1          17.005975           8
10421609  070090000       0                1        1          17.005975           9
10421610  070100000       0                1        1          17.005975          10
10421611  070110000       0                1        1          17.005975          11
10421612  070120000       0                1        1          17.005975          12
10421613  070130000       0                1        1           8.502987          13
*
*
*                source data
*                ___________
*
*
*                  source          int. source          right        left       heat str.
*                  type              multiplier         dir.heat     dir.heat   number
*
10421701             0                 0.0                0.0          0.0        13

*              heat              chan.                                                heat
*              diam.             len.                                                 number
*
10421801       0.0         0.1524      3.6576      0.0    0.0    0.0    0.0    1.0     1
10421802       0.0         0.4572      3.3528      0.0    0.0    0.0    0.0    1.0     2
10421803       0.0         0.7620      3.0480      0.0    0.0    0.0    0.0    1.0     3
10421804       0.0         1.0668      2.7432      0.0    0.0    0.0    0.0    1.0     4
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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審查：

Ref. No.

```
*
10421805  0.0       1.3716    2.4384    0.0       0.0       0.0       0.0       1.0       5
10421806  0.0       1.6764    2.1336    0.0       0.0       0.0       0.0       1.0       6
10421807  0.0       1.9812    1.8288    0.0       0.0       0.0       0.0       1.0       7
10421808  0.0       2.2860    1.5240    0.0       0.0       0.0       0.0       1.0       8
10421809  0.0       2.5908    1.2192    0.0       0.0       0.0       0.0       1.0       9
10421810  0.0       2.8956    0.9144    0.0       0.0       0.0       0.0       1.0       10
10421811  0.0       3.2004    0.6096    0.0       0.0       0.0       0.0       1.0       11
10421812  0.0       3.5052    0.3048    0.0       0.0       0.0       0.0       1.0       12
10421813  0.0       3.7338    0.0762    0.0       0.0       0.0       0.0       1.0       13
*
10421901  0.0       0.1524    3.6576    0.0       0.0       0.0       0.0       1.0       1
10421902  0.0       0.4572    3.3528    0.0       0.0       0.0       0.0       1.0       2
10421903  0.0       0.7620    3.0480    0.0       0.0       0.0       0.0       1.0       3
10421904  0.0       1.0668    2.7432    0.0       0.0       0.0       0.0       1.0       4
10421905  0.0       1.3716    2.4384    0.0       0.0       0.0       0.0       1.0       5
10421906  0.0       1.6764    2.1336    0.0       0.0       0.0       0.0       1.0       6
10421907  0.0       1.9812    1.8288    0.0       0.0       0.0       0.0       1.0       7
10421908  0.0       2.2860    1.5240    0.0       0.0       0.0       0.0       1.0       8
10421909  0.0       2.5908    1.2192    0.0       0.0       0.0       0.0       1.0       9
10421910  0.0       2.8956    0.9144    0.0       0.0       0.0       0.0       1.0       10
10421911  0.0       3.2004    0.6096    0.0       0.0       0.0       0.0       1.0       11
10421912  0.0       3.5052    0.3048    0.0       0.0       0.0       0.0       1.0       12
10421913  0.0       3.7338    0.0762    0.0       0.0       0.0       0.0       1.0       13
*
```

The input of channel box 10421000 finished.

Ref. No.

Channel box of volume 046 (047、048 and 049):
Card No. 10461000 (10471000、10481000 & 10491000)
1CCCG000 CCC = Hydraulic volume No. G = 1
No of heat structures in axial direction = 13
No of mesh points = 2
Geometry type = 1
S.S flag = 1
Left boundary coordination = (Volume Area)$^{1/2}$
= (109 channels*0.010469 m^2/channel)$^{1/2}$ = 1.068233 m **2**
Interval No. = 1
Right boundary coordination = 1.068233 m+ Average thickness of a channel box
= 1.068233 m + 1.7755*10^{-3} m
= 1.0700085 m
Heat Structure composition : Zr → 003
No Power source
Relative Power = 0.0
Boundary condition :
Left boundary vol No. = 046 (047、048 and 049)
Right boundary vol No. = 070
Surface Area of each 12” node = 17.163437 m^2
Surface Area of the last 6” node = 8.581719 m^2

The RELAP5 input of channel box 046 (Same as 047、048 and 049):

```
**************************************
* Channel boxes of Volume 046
* (109 Assemblies)
**************************************
*
*          num. of       num. of      geom.      s.s.      l. bound.
*          heat str.     mesh pts.    type       flag      coord.
*
10461000    13            2            1          1         1.068233
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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Ref. No.

```
*
*              mesh loc.          mesh format
*              flag               flag
*
10461100          0                  1
*
*     heat structure mesh interval data
*     ___________________________________
*
*
*                    interval number              right   bound.
*
10461101                  1                        1.0700085
*
*                        heat struc. comp          interval
*
10461201                    003                      1
*
*    power source distribution data
*    ______________________________
*
*        relative power          interval
*
10461301       0.0                  1
*
*        initial temp.        mesh pt.
*
10461400   -1
*
10461401   552.27   552.16
*
10461402   555.38   554.45
*
10461403   558.23   556.58
*
10461404   560.66   558.43
*
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

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Ref. No.

```
*
10461405   561.40   559.04
*
10461406   561.47   559.18
*
10461407   561.50   559.27
*
10461408   561.51   559.35
*
10461409   561.46   559.39
*
10461410   561.46   559.46
*
10461411   561.46   559.52
*
10461412   561.45   559.57
*
10461413   561.43   559.62
*
*        boundary condition data
*        ______________________
*
*
*            bdry.                                b.c.     s.a.          heat
*            vol.          increment              type     code          length          number
*
10461501   046010000          0                     1        1          17.163437            1
10461502   046020000          0                     1        1          17.163437            2
10461503   046030000          0                     1        1          17.163437            3
10461504   046040000          0                     1        1          17.163437            4
10461505   046050000          0                     1        1          17.163437            5
10461506   046060000          0                     1        1          17.163437            6
10461507   046070000          0                     1        1          17.163437            7
10461508   046080000          0                     1        1          17.163437            8
10461509   046090000          0                     1        1          17.163437            9
10461510   046100000          0                     1        1          17.163437           10
```

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱： 核四廠 RELAP5 分析模式建立與事故校驗數據提供

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```
*
10461511  046110000  0          1        1        17.163437        11
10461512  046120000  0          1        1        17.163437        12
10461513  046130000  0          1        1         8.581719        13
*
10461601  070010000  0          1        1        17.163437        1
10461602  070020000  0          1        1        17.163437        2
10461603  070030000  0          1        1        17.163437        3
10461604  070040000  0          1        1        17.163437        4
10461605  070050000  0          1        1        17.163437        5
10461606  070060000  0          1        1        17.163437        6
10461607  070070000  0          1        1        17.163437        7
10461608  070080000  0          1        1        17.163437        8
10461609  070090000  0          1        1        17.163437        9
10461610  070100000  0          1        1        17.163437        10
10461611  070110000  0          1        1        17.163437        11
10461612  070120000  0          1        1        17.163437        12
10461613  070130000  0          1        1         8.581719        13
*
*               source data
*               ___________
*
*
*                 source          int. source          right       left       heat str.
*                 type            multiplier           dir.heat    dir.heat   number
*
10461701            0               0.0                  0.0         0.0        13
*
*
*             heat          chan.                                                  heat
*             diam.         len.                                                   number
*
10461801    0.0       0.1524    3.6576    0.0   0.0   0.0   0.0   1.0     1
10461802    0.0       0.4572    3.3528    0.0   0.0   0.0   0.0   1.0     2
10461803    0.0       0.7620    3.0480    0.0   0.0   0.0   0.0   1.0     3
```

Ref. No.

```
*
10461804  0.0       1.0668    2.7432    0.0       0.0       0.0       0.0       1.0       4
10461805  0.0       1.3716    2.4384    0.0       0.0       0.0       0.0       1.0       5
10461806  0.0       1.6764    2.1336    0.0       0.0       0.0       0.0       1.0       6
10461807  0.0       1.9812    1.8288    0.0       0.0       0.0       0.0       1.0       7
10461808  0.0       2.2860    1.5240    0.0       0.0       0.0       0.0       1.0       8
10461809  0.0       2.5908    1.2192    0.0       0.0       0.0       0.0       1.0       9
10461810  0.0       2.8956    0.9144    0.0       0.0       0.0       0.0       1.0       10
10461811  0.0       3.2004    0.6096    0.0       0.0       0.0       0.0       1.0       11
10461812  0.0       3.5052    0.3048    0.0       0.0       0.0       0.0       1.0       12
10461813  0.0       3.7338    0.0762    0.0       0.0       0.0       0.0       1.0       13
*
10461901  0.0       0.1524    3.6576    0.0       0.0       0.0       0.0       1.0       1
10461902  0.0       0.4572    3.3528    0.0       0.0       0.0       0.0       1.0       2
10461903  0.0       0.7620    3.0480    0.0       0.0       0.0       0.0       1.0       3
10461904  0.0       1.0668    2.7432    0.0       0.0       0.0       0.0       1.0       4
10461905  0.0       1.3716    2.4384    0.0       0.0       0.0       0.0       1.0       5
10461906  0.0       1.6764    2.1336    0.0       0.0       0.0       0.0       1.0       6
10461907  0.0       1.9812    1.8288    0.0       0.0       0.0       0.0       1.0       7
10461908  0.0       2.2860    1.5240    0.0       0.0       0.0       0.0       1.0       8
10461909  0.0       2.5908    1.2192    0.0       0.0       0.0       0.0       1.0       9
10461910  0.0       2.8956    0.9144    0.0       0.0       0.0       0.0       1.0       10
10461911  0.0       3.2004    0.6096    0.0       0.0       0.0       0.0       1.0       11
10461912  0.0       3.5052    0.3048    0.0       0.0       0.0       0.0       1.0       12
10461913  0.0       3.7338    0.0762    0.0       0.0       0.0       0.0       1.0       13
*
```

The input of channel box 10461000 finished.

Reactor Pressure Vessel Passive Heat Structures

主題： The Development of RELAP5-3DK Code Input Deck of Reactor Pressure Vessel Passive Heat Structures

計畫名稱：核四廠 RELAP5 分析模式建立與事故校驗數據提供

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審查：

Reactor Pressure Vessel Passive Heat Structures

Most of heat structure information is derived from the weight data listed in GE 31113-0A51-6006, “Reactor Weights and Volume Design Requirements”.

Lower Plenum Heat Structures

Heat Structure No.:002-1

The Heat Structure 002-1 is attached to the hydraulic Volume 002. From Table 3a, Table 4a of Ref.1, Lower Plenum contains the following components: *1*

1. Bottom Head (RVZ –2120 mm) *1*
   Ref 1, Table 4a: 110.59 t = $1.1059*10^5$ kg
2. Shroud Support *1*
   Ref 1, Table 4a: 22.27 t = $2.227*10^4$ kg
3. FMCRD *1*
   Ref 1, Table 3a: 97.39 t = $9.739*10^4$ kg
4. CRD Housings *1*
   Ref 1, Table 3a: 51.53 t = $5.153*10^4$ kg
5. In-core Housings *1*
   Ref 1, Table 3a: 2.45 t = $2.45*10^3$ kg
6. Reactor Internal Pumps
   Ref 1, Table 3a: 67.17 t = $6.717*10^4$ kg

Ref. *No.*

Ref. **1. GE 31113-0A51-6006, “Reactor Weights and Volume Design Requirements”**
2. RPV OUTLINE DRAWING
3. 0820-2 反應爐壓力槽與內部組件 RPV-賴昇亨.ppt, Fig 20

主題： The Development of RELAP5-3DK Code Input Deck of Reactor Pressure Vessel Passive Heat Structures

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撰寫：

審查：

By Ref.2, RPV OUTLINE DRAWING and RELAP5-3D Noding Diagram, the hydraulic Volume 002 can be assumed to represent the whole Lower Plenum — *Ref. No. 2*

Total weight of Heat Structure 002-1 is equal to the sum of item 1~6 of Lower Plenum.

$\sum_{i=1-6} W_i$ =1.1059*10^5 kg + 2.227*10^4 kg + 9.739*10^4 kg + 5.153*10^4 kg + 2.45*10^3 kg + 6.717*10^4 kg = 35.14*10^4 kg

Density of Metal =7800 kg/m^3 (Iron assumed)

Surface area is estimated from Ref.2.

$V_{HT\,002-1}$ = 35.14*10^4 kg / (7800 kg/m^3) = 45.0513 m^3

$S.A_{Bottom\_Head\,1}$ = $2\pi rh_1$ (r = 4866mm, h_1 =1420.5 mm (RVZ to top of Shroud Support Leg)) — *2*

= 2π *4.866m*1.4205m = 43.4303 m^2

$S.A_{Bottom\_Head\,2}$ = πDh_2 ($\not\phi$ = 7061 mm, h_2 =2210 mm -1420.5 mm=789.5 mm) — *2*

= π *7.061 m*0.7895 m = 17.5133 m^2

$S.A_{Shroud\_Support}$ = $2\pi Dh_s$ ($\not\phi$ = 5301.5 mm, h_s =2438 mm -4866 mm*(1-cos33^0)=1653 mm) — *2*

= 2π *5.3015 m*1.653 m = 55.0619 m^2

$S.A_{CRD\_Housings}$ = $205\pi\not\phi L_{avg}$ (L_{avg} =(1/2)(1397 mm +1397 mm - 4866 mm*(1-cos33^0)) = 1004.5 mm, $\not\phi$ = 152.4 mm) — *2 & 3*

= 205*π *1.0045 m*0.1524 m= 98.5913 m^2

Others (FMCRD, In core Housings, RIPS) are ignored.

$S.A_{Total}$ = 43.4303 m^2 + 17.5133 m^2 + 55.0619 m^2 + 98.5913 m^2 = 214.5968 m^2

RELAP5-3D Input:

Geometry = 1

Wall thickness = 45.0573 m^3 / 214.5968 m^2 = 0.2099 m

Left boundary coordination = 7061 mm /2 =3530.5 mm = 3.5305 m

Right boundary coordination = 3.5305 m + 0.2099 m = 3.7404 m

Material = Carbon Steel = 999

Ref. 1. _____

主題： The Development of RELAP5-3DK Code Input Deck of Reactor Pressure Vessel Passive Heat Structures

計畫名稱：核四廠 RELAP5 分析模式建立與事故校驗數據提供

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撰寫：

審查：

Lower Core Shroud Heat Structures *Ref. No.*

Heat Structure No.= 004-1

The Heat Structure 004-1 is attached to hydraulic Volume 004. The Heat Structure 004-1 contains the lower part of core shroud.

1. Core Shroud (Top of shroud support 2438 mm to 9350 mm) (from Ref.3 Fig.12) *3*
   Lower Region: 2438 mm to 4695 mm, thickness=60 mm
   Upper Region: 4695 mm to 9350 mm, thickness=50 mm *1*
   $\not\phi_{shroud}$ =5436 mm (from Ref.1 Table 3a)
   W_{shroud} =57.29 t
2. Core Plate (from Ref.1 Table 3a & Ref.3 Fig.13) *1 & 3*
   W_{Core_Plate} =17.05 t
   205 Holes for Guide Tubes, $\not\phi$ =280 mm, thickness= 648 mm
3. Guide Tubes (from Ref.1 Table 3a & Ref.3 Fig.21) *1 & 3*
   W_{Guide_Tubes} =45.95 t
   205 Guide Tubes, L=4000 mm, D= 280 mm
4. Orifice Fuel Supports (from Ref.1 Table 3a) *1*
   $W_{Fuel\_Supports}$ =6.03 t

Since hydraulic Volume 004 ranges from 1396.6 mm to BAF 5341.1 mm, the Heat Structure 004-1 contains part of Core Shroud and whole components of list 2,3,4.

V_L =(4.695 m-2.438 m)*0.06 m * π *5.436 m=2.3127 m^3

V_U =(9.350 m-4.695 m)*0.05 m * π *5.436 m=3.9748 m^3

$$V_{Core\_Shroud\_004} = V_L + \frac{5.3411 - 4.695}{9.350 - 4.695} * V_U = 2.3127 + 0.5517 = 2.8644 \ m^3$$

$$W_{Core\_Shroud\_004} = 57.29 * \frac{2.8644}{2.3127 - 3.9748} = 26.10 \text{ t}$$

$$W_{HT\_004-1} = W_{Core\_Shroud\_004} + W_{Core\_Shroud\_004} + W_{Core\_Shroud\_004} + W_{Core\_Shroud\_004}$$

$$= 26.10 \text{ t} + 17.05 \text{ t} + 45.95 \text{ t} + 6.03 \text{ t} = 95.13 \text{ t}$$

Ref. 1. _____

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撰寫：

審查：

Ref. No.

Density of Metal = 7800 kg/m^3 (steel assumed)

V_{HT_004-1} = W_{HT_004-1} / ρ = 95.13 *1000 kg/(7800 kg/m^3) = 12.1962 m^3

Surface Area is derived from Ref3. Neglect the contribution of Core Plate and Orifice Fuel Supports.

$S.A_{Core\_Shroud\_004-1}$ = $\pi \phi h_{Core\_Shroud\_004-1}$ = π *5.436 m *(5.3411 m -2.438 m) = 49.5783 m^2

$S.A_{205\_Guide\_Tubes}$ = $205\pi DL$ =205* π *0.28 m *4.0 m =721.3097 m^2

$S.A_{Total}$ = 49.5783 m^2 +721.3097 m^2 = 770.888 m^2

RELAP5-3D Input:

Geometry = 1

Wall thickness = 12.1962 m^3 / 770.888 m^2 = 0.0158 m

Left boundary coordination = 5436 mm /2 =2718 mm = 2.718 m

Right boundary coordination = 2.178 m + 0.0158 m = 2.7338 m

Material = Carbon Steel = 801

Left boundary volume = 004

Right boundary volume = 020

Ref. 1. _____

2. _____

3. _____

主題： The Development of RELAP5-3DK Code Input Deck of Reactor Pressure Vessel Passive Heat Structures

計畫名稱：核四廠 RELAP5 分析模式建立與事故校驗數據提供

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撰寫：

審查：

Upper Core Shroud Heat Structures *Ref. No.*

Heat Structure No.= 070-2

The Heat Structure 070-2 represents the upper region of Core Shroud Which separates the hydraulic Volume 020 and Volume 070.

Heat Structure 070-2:

(3) Upper Region of Core Shroud (from Ref.1 Table 3a) *1*

From Heat Structure 004-1, $W_{Core\_Shroud\_004}$ = 26.10 t

$W_{Core\_Shroud\_004}$ = 57.29 t – 26.10 t = 31.19 t

Density of Metal = 7800 kg/m^3 (steel assumed)

V_{HT_070-2} = W_{HT_070-2} / ρ = 31.19 *1000 kg/(7800 kg/m^3) = 3.9987 m^3 *3*

Surface Area is derived from Ref3.

$S.A_{Core\_Shroud}$ = $\pi \phi h_{Core\_Shroud\_070}$ = π *5.436 m *(9.350 m –5.3411 m) = 68.4628 m^2

RELAP5-3D Input:

Geometry = 2

Wall thickness = 3.9987 m^3 / 68.4628 m^2 = 0.0584 m

Left boundary coordination = 5436 mm /2 =2718 mm = 2.718 m

Right boundary coordination = 2.178 m + 0.0584 m = 2.7764 m

Height of 070-2 = 9.350 m -5.3411 m = 4.0089 m

Left boundary volume = 070

Right boundary volume = 020

Material = Stainless Steel = 801

Ref. 1. _____

2. _____

3. _____

主題： The Development of RELAP5-3DK Code Input Deck of Reactor Pressure Vessel Passive Heat Structures

計畫名稱：核四廠 RELAP5 分析模式建立與事故校驗數據提供

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撰寫：

審查：

Control Rod Heat Structures

Heat Structure No.= 070-3

The Heat Structure 070-3 is the Control Rod Heat Structures. All Control Rods are assumed to be full in the core.

Heat Structure 070-3:

1. Upper Region of Core Shroud (205 Rods Full in) (from Ref.1 Table 3a) *1*

   $W_{Control\_Rods}$ = 16.37 t

2. Incores ($W_{Incores}$ =1.13 t) *4*

   Cruciform Control Blades of Control Rod. (Neglect Incores)

   Surface Area is derived from Ref.4, Fig5.4.

   $P_{\text{Control Brade}}$ = 249 mm*4= 996 mm=0.996 m

   $h_{\text{Control Blade}}$ = 173.75″ = 4.4133 m

   $S.A_{070\text{-}3}$ = 205*0.996 m*4.4133 m =901.1076 m^2

Density of Metal = 7800 kg/ m^3 (steel assumed)

W_{HT_070-3} = 16.37 t+1.13 t =17.5 t

V_{HT_070-3} = 17.5*1000 kg/ (7800 kg/ m^3) = 2.2436 m^3

RELAP5-3D Input:

Geometry = 1

Wall thickness = 2.2436 m^3 / 901.1076 m^2 = 0.00249 m

Left boundary coordination = 249 mm = 0.249 m

Right boundary coordination = 0.2515 m

Left boundary volume = 070

Right boundary volume = 0

Material = Stainless Steel = 801

Ref. No.

Ref. 4. CRD_FIG-R1.ppt

主題： The Development of RELAP5-3DK Code Input Deck of Reactor Pressure Vessel Passive Heat Structures

計畫名稱：核四廠 RELAP5 分析模式建立與事故校驗數據提供

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撰寫：

審查：

Upper Plenum Heat Structures

Ref. No.

Heat Structure No.= 096-1

The Heat Structure 069-1 includes the top guide, shroud dome HPCF components. The Heat Structure 069-1 located in hydraulic Volume 096.

Bases from Ref.1 and Ref.3, Heat Structure 096-1 will have following parts: *1 & 3*

1. Shroud Head Dome (8.71 t)
2. Shroud Head Flange (4.58 t)
3. Lift Rods (0.59 t)
4. Shroud Head Bolt Ring (2.99 t)
5. Shroud Head Bolt (9.24 t)
6. Top Guide (20.32 t)
7. HPCF Sparkers & Nozzles (0.54 t)
8. HPCF Piping (0.32 t)

$W_{Total} = \sum_{i=1to8} W_i$ = 8.71 t+4.58 t+0.59 t+2.99 t+ 9.24 t +20.32 t +0.54 t +0.32 t = 47.29 t

Density of Metal = 7800 kg/m^3 (Stainless Steel assumed)

V_{HT_096-1} = 6.0628 m^3

From Ref.3 Fig.15, Surface Area of Heat Structure 096-1 can be evaluated. *3*

$S.A_{Total}$ = $S.A_{Inside\_Shroud}$ (other components are ignored for simplicity)

= $\pi \phi_{096} h_{Vol\_096}$ = π *6.223 m*2.3588 m = 46.1148 m^2

RELAP5-3D Input:

Geometry = 1

Wall thickness = 6.0628 m^3 / 46.1148 m^2 = 0.1315 m

Left boundary coordination = 6.223 m/2 = 3.1115 m

Right boundary coordination = 3.1115 m + 0.1315 m = 3.243 m

Left boundary volume = 096 , Right boundary volume = 020,Material = Stainless Steel = 801

Ref. 1. _____

主題： The Development of RELAP5-3DK Code Input Deck of Reactor Pressure Vessel Passive Heat Structures

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審查：

Stand Pipe Heat Structures

Heat Structure No.= 066-1

Ref. No.

The Heat Structure 066-1 represents the metal of Stand Pipes. Inside Stand Pipes is hydraulic Volume 066 and outside Stand Pipes are Volume 024 and 022.

From Ref.1, Stand Pipes will be: *1*

1. Stand Pipes (4.26 t)

W_{066-1} = 4.26 t

Based on Ref.3 page50, there are 349 Stand Pipes and outer diameter 6″. *3*

$S.A_{Total}$ = 349* $\pi \phi_{066} h_{Vol\_066}$

=349* π *0.1524 m*1.16m = 193.8288 m^2

Density of Metal = 7800 kg/ m^3 (stainless steel assumed)

V_{HT_066-1} = 4.26 t/ (7800 kg/ m^3) = 0.5462 m^3

RELAP5-3D Input:

Geometry = 1

Wall thickness = 0.5462 m^3 / 193.8288 m^2 = 0.002818 m

Left boundary coordination = 0.1524 m/2 = 0.0762 m

Right boundary coordination = 0.0762 m + 0.002818 m = 0.0790 m

Left boundary volume = 066

Right boundary volume = 022, 024

Material = Stainless Steel = 801

Heated Diameter = 0.1524 m

Ref. 1. _____

2. _____

3. _____

主題： The Development of RELAP5-3DK Code Input Deck of Reactor Pressure Vessel Passive Heat Structures

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撰寫：

審查：

Steam Separators Heat Structures

Heat Structure No.= 036-1

The Heat Structure 036-1 is the metal part of the Steam Separators. Inside cyclone separator is hydraulic Volume 036, outside cyclone separators is Volume 026.

From Ref.1 Table 3a, Heat Structures of Separators will have the following components: *1*

1. Separators (38.65 t)
2. Guides Rods (0.73 t)

$W_{036-1} = W_1 + W_2$ = 38.65+0.73 = 39.38 t

By Ref.3 page50, there are 349 cyclone separators having 10″ outer diameter. *3*

Surface area is evaluated by above information.

$S.A_{Total}$ = 349* $\pi \phi_{036} h_{Vol\_036}$

=349* π *0.254 m*1.8510m = 515.4843 m^2

Density of Metal = 7800 kg/ m^3 (stainless steel)

V_{HT_036-1} = 39.38 t/ (7800 kg/ m^3) = 5.0487 m^3

RELAP5-3D Input:

Geometry = 1

Wall thickness = 5.0487 m^3 / 515.4843 m^2 = 0.0097941 m

Left boundary coordination = 0.254 m/2 = 0.127 m

Right boundary coordination = 0.127 m + 0.0097941 m = 0.1368 m

Left boundary volume = 036

Right boundary volume = 026

Material = Stainless Steel = 801

Heated Diameter = 0.254 m

Ref.

Ref. 1. _____

2. _____

3. _____

主題： The Development of RELAP5-3DK Code Input Deck of Reactor Pressure Vessel Passive Heat Structures

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撰寫：

審查：

Steam Dryer Heat Structures

Ref. No.

Heat Structure No.= 034-1

The Heat Structure 036-1 is used to model the metal of the steam dryer. In Dryer skirt is Volume 034. Volume 028 & 030 are outside Dryer skirts.

From Ref.1 Table 3a: *1*

1. Steam Dryer (49.99 t)

W_{034-1} = 49.99 t

By Ref.3 Fig.18, the Surface Area of Steam Dryer is roughly estimated. *3*

$S.A_{Total}$ = 2 sides* 6 panels * A_{Panel}

= 2*6*(D*h)

= 2*6*(6.630 m*2.261 m)

= 2*6*14.9904

= 179.8848 m^2

Density of Metal = 7800 kg/m^3 (stainless steel)

V_{HT_034-1} = 49.99t/ (7800 kg/m^3) = 6.4090 m^3

RELAP5-3D Input:

Geometry = 1

Wall thickness = 6.0490 m^3 / 179.8848 m^2 = 0.0357 m

Left boundary coordination = 6.630 m/2 = 3.315 m

Right boundary coordination = 3.315 m + 0.0357 m = 3.3507 m

Left boundary volume = 036

Right boundary volume = 030, 028

Material = Stainless Steel = 801

Ref. 1. _____

2. _____

3. _____

主題： The Development of RELAP5-3DK Code Input Deck of Reactor Pressure Vessel Passive Heat Structures

計畫名稱：核四廠 RELAP5 分析模式建立與事故校驗數據提供

日期： D / M / Y

撰寫：

審查：

Steam Dome Heat Structures

Heat Structure No.= 032-1

Ref. No.

The Heat Structure 032-1 is used to model the metal of the Steam Dome hydraulic Volume 032. From Ref.1 Table 4a, Vessel Head and Lifting Lugs weights totally are 106.87 t: *1*

1. Steam Dome (106.87 t)

W_{032-1} = 106.87 t

In Ref.2, Inner Surface Area of Steam Dome is estimated as a hemi-sphere. *2*

$S.A_{Total} = 2\pi r^2$

$= 2\pi(3.360)^2$

$= 70.9346\ m^2$

Density of Metal = 7800 kg/m^3 (carbon steel)

V_{HT_032-1} = 106.87 t / (7800 kg/m^3) = 13.7013 m^3

RELAP5-3D Input:

Geometry = 1

Wall thickness = 13.7013 m^3 / 70.9346 m^2 = 0.1932 m

Left boundary coordination = r = 3.360 m

Right boundary coordination = 3.360 m + 0.1932 m = 3.5532 m

Left boundary volume = 032

Right boundary volume = 0

Material = Carbon Steel = 999

Ref. 1. _____

2. _____

3. _____

主題： The Development of RELAP5-3DK Code Input Deck of Reactor Pressure Vessel Passive Heat Structures

計畫名稱：核四廠 RELAP5 分析模式建立與事故校驗數據提供

日期： D / M / Y

撰寫：

審查：

Vessel Flange to Main Steam Nozzle Heat Structures

Ref. No.

Heat Structure No.= 030-1

The Heat Structure 030-1 extends from Vessel Flange to Main Steam Nozzle and is attached to hydraulic Volume 030.

From Ref.1 Table 4a & Ref.2, Heat Structure 030-1 has the following components: *1 & 2*

1. Vessel Flange (42.18 t)
2. Studs, Nuts and Washers (26.26 t)

W_{030-1} = 42.18+26.26 = 68.44 t

By Ref.2, Inner Surface Area of Area can be estimated as a cylinder. *2*

$S.A_{030-1} = \pi \phi h_{030}$

$= \pi$ *6.720 m*2.1590 m

= 45.5797 m^2

Density of Metal = 7800 kg/m^3 (carbon steel)

V_{HT_030-1} = 68.44 t/ (7800 kg/m^3) = 8.7744 m^3

RELAP5-3D Input:

Geometry = 1

Wall thickness = 8.7744 m^3 / 45.5797 m^2 = 0.1925 m

Left boundary coordination = 6.720 m/2 = 3.36 m

Right boundary coordination = 3.36 m + 0.1925 m = 3.5525 m

Left boundary volume = 030

Right boundary volume = 0

Material = Stainless Steel = 999

Ref. 1. _____

2. _____

3. _____

主題： The Development of RELAP5-3DK Code Input Deck of Reactor Pressure Vessel Passive Heat Structures

計畫名稱：核四廠 RELAP5 分析模式建立與事故校驗數據提供

日期： D / M / Y

撰寫：

審查：

Dryer Downcomer of Vessel Wall Heat Structures

Heat Structure No.= 028-1

The Heat Structure 028-1 is formed by Vessel Wall metal. The Heat Structure 028-1 is attached to hydraulic Volume 028 which is located between Dryer and Vessel Wall.

From Ref.2, Vessel cylinder region is extended from 2120 mm to 17703 mm. From Ref.1 Table 4a, Vessel cylinder weights 526.89 ton. So the weight of Vessel cylinder can be calculated. *Ref. 2 1*

1. Vessel cylinder (526.89 t)

$$W_{028-1} = \frac{h_{028}}{h_{Vessel\_cylinder}} * W_{Vessel\_cylinder}$$

$$= \frac{1.0230m}{17.703m - 2.120m} * 526.89t$$

$$= \frac{1.0230m}{15.583m} * 526.89t$$

= 34.5895 t *2*

By Ref.2, Vessel cylinder inner Surface Area can be estimated.

$$S.A_{028-1} = \pi \phi h_{028}$$

$$= \pi * 7.112\ m * 1.0230\ m$$

$$= 22.8569\ m^2$$

Density of Metal = 7800 kg/m^3 (carbon steel)

V_{HT_036-1} = 34.5895 t/ (7800 kg/m^3) = 4.4346 m^3

RELAP5-3D Input:

Geometry = 1

Wall thickness = 4.4346 m^3 / 22.8569 m^2 = 0.1940 m

Left boundary coordination = 7.112 m/2 = 3.556 m

Right boundary coordination = 3.556 m + 0.1940 m = 3.75 m

Left boundary volume = 028

Right boundary volume = 0, Material = Stainless Steel = 999

Ref. 1. _____

2. _____

主題： The Development of RELAP5-3DK Code Input Deck of Reactor Pressure Vessel Passive Heat Structures

計畫名稱：核四廠 RELAP5 分析模式建立與事故校驗數據提供

日期： D / M / Y

撰寫：

審查：

Separator Downcomer of Vessel Wall Heat Structures

Ref. No.

Heat Structure No.= 026-1

The Heat Structure 026-1 is formed by Vessel Wall metal. The Heat Structure 026-1 is attached to hydraulic Volume 026 which is located between Sepataro and Vessel Wall.

From Ref.1 Table 4a, Vessel cylinder total weights 526.89 ton, and the weight of Heat Structure 026-1 can be calculated in the same way as Heat Structure 028-1 . 1 & 2

1. Vessel cylinder (526.89 t)

$$W_{026-1} = \frac{h_{026}}{h_{Vessel\_cylinder}} * W_{Vessel\_cylinder}$$

$$= \frac{1.8510m}{17.703m - 2.120m} * 526.89t$$

$$= \frac{1.8510m}{15.583m} * 526.89t$$

$$= \underline{62.5857\ t}$$ 2

By Ref.2, Vessel cylinder inner Surface Area can be estimated.

$$S.A_{026-1} = \pi \phi h_{026}$$

$$= \pi * 7.112\ m * 1.8510\ m$$

$$= \underline{41.3569\ m^2}$$

Density of Metal = 7800 kg/m^3 (carbon steel)

V_{HT_026-1} = 62.5857 t/ (7800 kg/m^3) = $\underline{8.0238\ m^3}$

RELAP5-3D Input:

Geometry = 1

Wall thickness = 8.0238 m^3 / 41.3569 m^2 = 0.1940 m

Left boundary coordination = 7.112 m/2 = 3.556 m

Right boundary coordination = 3.556 m + 0.1940 m = 3.75 m

Left boundary volume = 026 , Right boundary volume = 0

Material = Stainless Steel = 999

Ref. 1. _____

2. _____

主題： The Development of RELAP5-3DK Code Input Deck of Reactor Pressure Vessel Passive Heat Structures

計畫名稱：核四廠 RELAP5 分析模式建立與事故校驗數據提供

日期： D / M / Y

撰寫：

審查：

Upper Downcomer 1 Heat Structures

Ref. No.

Heat Structure No.= 024-1

The Heat Structure 024-1 is the vessel wall that surrounds the region where stand pipes exist. From Ref.1, Vessel cylinder has uniform geometry and total weights 526.89 ton. Heat Structure 024-1 can be calculated in the same way as Heat Structure 026-1. *1 & 2*

1. Vessel cylinder (526.89 t)

$$W_{024-1} = \frac{h_{024}}{h_{Vessel\_cylinder}} * W_{Vessel\_cylinder}$$

$$= \frac{0.58m}{17.703m - 2.120m} * 526.89t$$

$$= \frac{0.58m}{15.583m} * 526.89t$$

$$= 19.6109\ t$$

By Ref.2, Vessel cylinder inner Surface Area can be estimated. *2*

$$S.A_{024-1} = \pi \phi h_{024}$$

$$= \pi * 7.112\ m * 0.58m$$

$$= 12.9589\ m^2$$

Density of Metal = 7800 kg/m^3 (carbon steel)

V_{HT_026-1} = 19.6109 t/ (7800 kg/m^3) = 2.5142 m^3

RELAP5-3D Input:

Geometry = 1

Wall thickness = 2.5142 m^3 / 12.9589 m^2 = 0.1940 m

Left boundary coordination = 7.112 m/2 = 3.556 m

Right boundary coordination = 3.556 m + 0.1940 m = 3.75 m

Left boundary volume = 024

Right boundary volume = 0

Material = Stainless Steel = 999

Ref. 1. _____

2. _____

主題： The Development of RELAP5-3DK Code Input Deck of Reactor Pressure Vessel Passive Heat Structures

計畫名稱：核四廠 RELAP5 分析模式建立與事故校驗數據提供

日期： D / M / Y

撰寫：

審查：

Upper Downcomer 2 & FW Spargers Heat Structures

Ref. No.

Heat Structure No.= 022-1

The Heat Structure 022-1 contains part of the vessel cylinder and Feed Water Sparters.

From Ref.1 Table 3a, Table 4a and Ref.2, the weight of Heat Structure 022-1 can be calculated. *1 & 2*

1. Vessel cylinder (526.89 t)

$$W_1 = \frac{h_{022}}{h_{Vessel\_cylinder}} * W_{Vessel\_cylinder}$$

$$= \frac{0.58m}{17.703m - 2.120m} * 526.89t$$

$$= \frac{0.58m}{15.583m} * 526.89t$$

$$= 19.6109\ t$$

By the sizing data of Ref.2, Inner Surface Area of Vessel cylinder is as the following: *2*

$$S.A_{022-1} = \pi \phi h_{022}$$

$$= \pi * 7.112\ m * 0.58m$$

$$= 12.9589\ m^2$$ (To ignore the surface area of FW sparger)

2. Feed Water Spargers (0.91 t, from Ref.1 Table 3a) *1*

$W_{022-1} = W_1 + W_2 = 19.6109\ t + 0.91\ t = 20.5209\ t$

Density of Metal = 7800 kg/m^3 (carbon steel)

$V_{HT\_022-1} = 20.5209\ t / (7800\ kg/m^3) = 2.6309\ m^3$

RELAP5-3D Input:

Geometry = 1

Wall thickness = 2.6309 m^3 / 12.9589 m^2 = 0.2030 m

Left boundary coordination = 7.112 m/2 = 3.556 m

Right boundary coordination = 3.556 m + 0.2030 m = 3.759 m

Left boundary volume = 022

Right boundary volume = 0, Material = Stainless Steel = 999

Ref. 1. _____

2. _____

主題： The Development of RELAP5-3DK Code Input Deck of Reactor Pressure Vessel Passive Heat Structures

計畫名稱：核四廠 RELAP5 分析模式建立與事故校驗數據提供

日期： D / M / Y

撰寫：

審查：

Downcomer and LPFL Spargers Heat Structures

Ref. No.

Heat Structure No.= 020-1

The Heat Structure 020-1 is consisted of by the rest part of vessel cylinder, Support Skirt and LPFL Spargers. From Ref.1 and Ref.2: 1&2

1. Vessel cylinder (526.89 t)

$$W_{020-1,wall} = W_{Vessel\_cylinder} - W_{028-1} - W_{026-1} - W_{024-1} - W_{022-1,wall}$$

= 526.89 t – 34.5895 t – 62.5857 t – 19.6109 t -19.6109 t

= 390.493 t

2. Support Skirt (34.84 t) 1

3. LPFL Spargers (0.35 t, from Ref.1 Table 4a and 3a)

$$W_{020-1} = W_{020-1,wall} + W_2 + W_3$$

= 390.493 t + 34.84 t + 0.35 t

= 425.683 t

Including the S.A of LPFL Sparger and Support Skirt outside the vessel, surface area can be calculated as:

$$S.A_{020-1} = \pi \phi h_{020} = \pi * 7.112\ \text{m} * 9.405\text{m} = 210.1360\ m^2$$

Density of Metal = 7800 kg/m^3 (carbon steel)

$$V_{HT\_020-1} = 425.683\ \text{t} / (7800\ \text{kg}/m^3) = 54.5747\ m^3$$

RELAP5-3D Input:

Geometry = 1, Wall thickness = 54.5747 m^3 / 210.1360 m^2 = 0.2597 m

Left boundary coordination = 7.112 m/2 = 3.556 m

Right boundary coordination = 3.556 m + 0.2597 m = 3.8157 m

Left boundary volume = 020, Right boundary volume = 0, Material = Stainless Steel = 999

Ref. 1.

參考文獻附圖

以下所附為計算書中部分參考文獻的附圖。

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱：核四廠 RELAP5 分析模式建立與事故校驗數據提供

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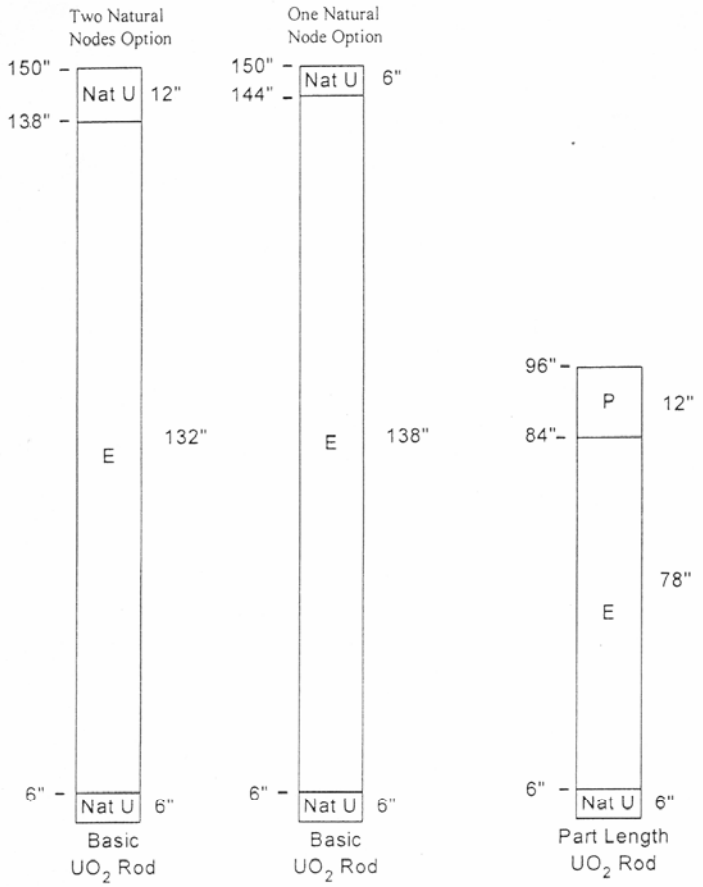
審查：

GNF
Global Nuclear Fuel

Figure 3A - GE14 BWR / 4-6 and ABWR UO_2 Rods



Legend
E = U235 enriched zone
Nat U = Natural UO_2
P = Plenum

E allowed values are listed in section 4.1.5.

Ref. 3. GNF-DB-0003.21 Rev5. page 19 of 24 Fig 3A

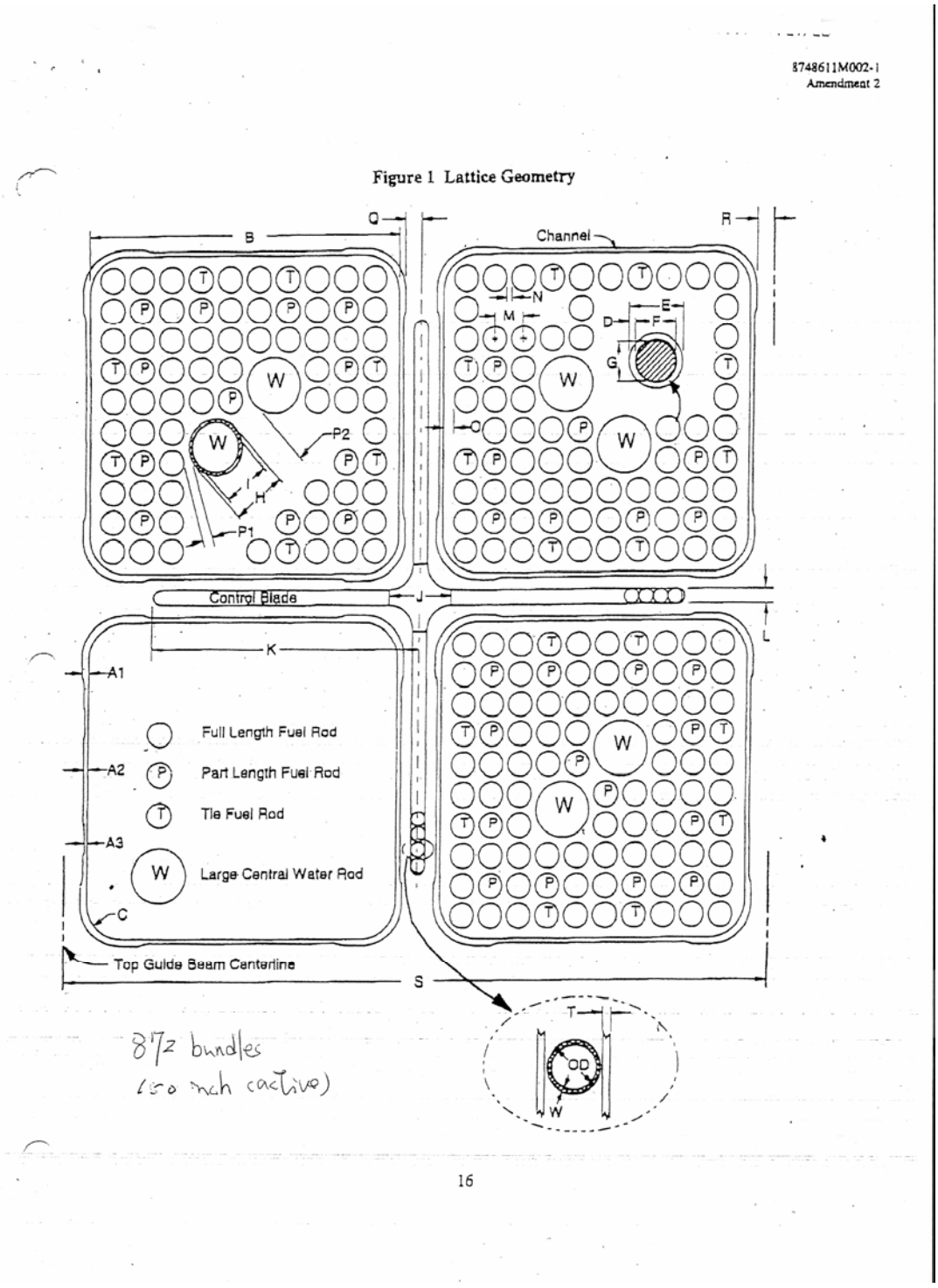
主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱：核四廠 RELAP5 分析模式建立與事故校驗數據提供

日期： D M Y / /

撰寫：

審查：



Ref. 4. 874611 M002-1 Amendment2 Figure 1: Lattice Geometry

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱：核四廠 RELAP5 分析模式建立與事故校驗數據提供

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日期： / /
撰寫：
審查：

8748611M002-1
Amendment 2

Figure 1 Lattice Geometry (cont'd)

(English units)

GE14 Fuel Design Type: Lattice Type: Plant Type: Channel Type (Thickness):		D BWR/2-4 100/65	C BWR/4 100/65	C BWR/4-5 120/75	S BWR/6 120/75	N ABWR 120/75
Features	Ref	Nominal Dimensions (inches) (Refer to Figure A1 for Dimensions)				
Channel Dimensions:						
Corner Thickness:	A1	0.100	0.100	0.120	0.120	0.120
Side Thickness:	A2	0.065	0.065	0.075	0.075	0.075
Groove Thickness:	A3	0.050	0.050	N/A	N/A	N/A
Inside Width:	B	5.278	5.278	5.278	5.278	5.278
Corner Inside Radius:	C	0.450	0.450	0.450	0.450	0.450
Fuel Rod Dimensions:						
Total Cladding Thickness:	D	0.026	0.026	0.026	0.026	0.026
Outside Diameter:	E	0.404	0.404	0.404	0.404	0.404
Inside Diameter:	F	0.352	0.352	0.352	0.352	0.352
Pellet Diameter:	G	0.345	0.345	0.345	0.345	0.345
Water Rod Dimensions:						
Outside Diameter:	H	0.980	0.980	0.980	0.980	0.980
Inside Diameter:	I	0.920	0.920	0.920	0.920	0.920
Control Blade Dimensions (1):						
Tie Rod Span:	J	1.58	1.58	1.58	1.55	1.55
Wing Length:	K	4.905	4.905	4.905	4.902	4.902
Wing Thickness:	L	0.312	0.260	0.260	0.328	0.328
Sheath Thickness:	T	0.056	0.030	0.030	0.045	0.045
Number of Absorber Tubes / Wing:	NT	21	19	19	18	18
Absorber Tube Outside Diameter:	OD	0.188	0.188	0.188	0.220	0.220
Absorber Tube Wall Thickness:	W	0.025	0.025	0.025	0.027	0.027
Bundle Lattice Dimensions (2):						
Rod Pitch:	M	0.510	0.510	0.510	0.510	0.510
Rod to Rod Gap:	N	0.106	0.106	0.106	0.106	0.106
Rod to Channel Gap:	O	0.142	0.142	0.142	0.142	0.142
Water Rod to Fuel Rod Gap:	P1	0.114	0.114	0.114	0.114	0.114
Water Rod to Water Rod Gap:	P2	0.462	0.462	0.462	0.462	0.462
Fuel Cell Dimensions:						
One Half of Wide Gap:	Q	0.315	0.261	0.241	0.241	0.291
One Half of Narrow Gap:	R	0.207	0.261	0.241	0.241	0.291
Fuel Cell Width:	S	12.000	12.000	12.000	12.000	12.200

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Ref. 4. 874611 M002-1 Amendment2 Figure 1: Lattice Geometry(Continued)

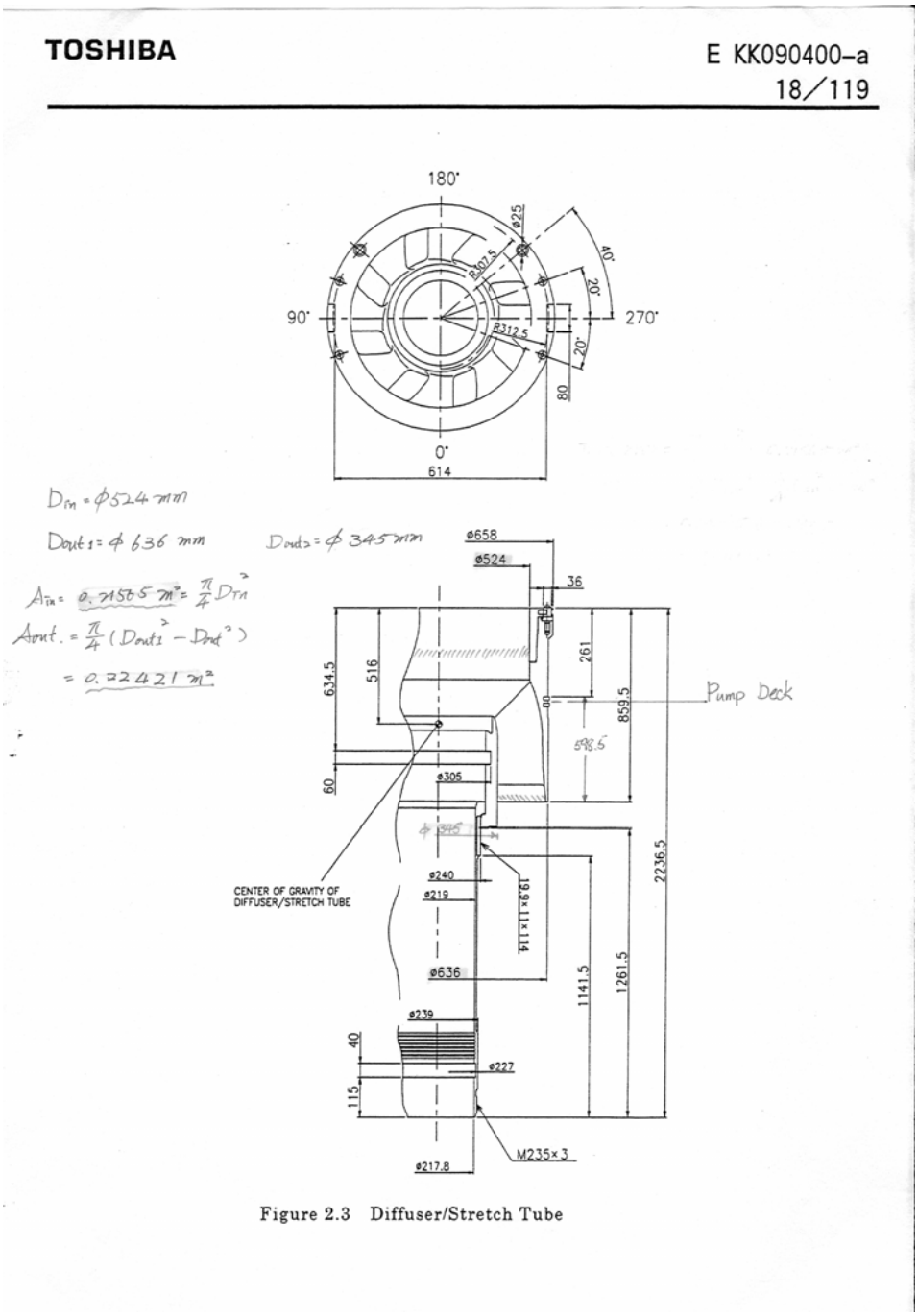

Figure 2.3 Diffuser/Stretch Tube

Ref. 7. TOSHIBA CORPORATION TOKYO,JAPAN:“INSTRUCTION BOOK FOR PACKAGE 62.2610 (B31-RIP) RIP PUMPS AND MOTORS” E KK090400-a page 18/119, Figure 2.3

主題： The Development of RELAP5-3DK Code Input Deck of RPV Model

計畫名稱：核四廠 RELAP5 分析模式建立與事故校驗數據提供

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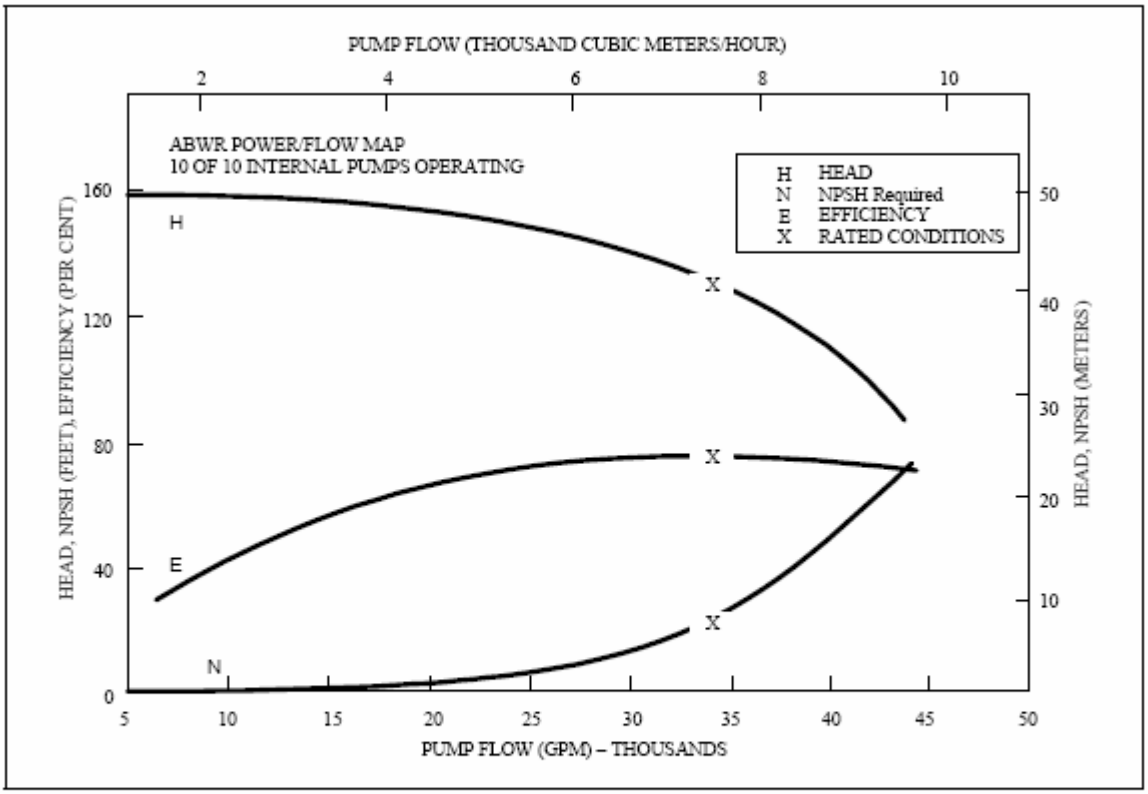

Figure 3.14-14 Expected Pump Performance vs. Flow

Design Basis: DRF A23-00005

Ref. 8. GE:“Project Design Manual, 31113-0A23-1000 Rev 20” Chapter 3,Figure 3.14-14,