行政院原子能委員會
委託研究計畫研究報告

CFD 在核能特殊組件之分析技術發展

Development of CFD Application to the Specific Components in Nuclear Plant

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目　錄

中文摘要

　　為協助提升核能研究所應用計算流體力學於核能特殊組件之分析與模擬能力，本研究擬就計算流體力學分析技術應用於「核一廠喪失飼水加熱」以及「用過核子燃料於低雷諾數與自然對流下之流阻係數」。其中，核一廠喪失廠飼水冷之分析案中，則主要係針對核一反應爐內限流孔與爐心底板位置進行模型之精進，進而增進整體熱水流特性及爐心進口之流量與溫度分佈，而協助核研所精進其系統程式之分析精度。而在用過核子燃料之流阻計算部分，由於廠家既有之流阻模式係針對功率運轉之條件而定，故在低雷諾數與自然對流下之流阻特性實難以利用廠家所提供之既有係數進行計算，因此本研究擬藉由整合 CAD 與 CFD 之方法建立一套高精度之燃料分析模式；藉由估算低雷諾數下之流阻係數來改善未來相關與用過核子燃料相關之熱水流分析工作精確性。預期經由本研究之執行將有助於進一步釐清相關應用案中之流阻合理性，並作為未來分析之參數選擇依據。

關鍵字：計算流體力學、電腦輔助設計、核一廠喪失飼水加熱、靈敏度分析

Abstract

In order to facilitate the application of computational fluid dynamics (CFD) in the analysis and simulation of special nuclear components, the present study aims to apply computational fluid dynamics (CFD) techniques to the "loss of feedwater heating in ChinShan nuclear power plant" and the "resistance coefficient of spent nuclear fuel at low Reynolds numbers and the natural convection flow".

In the "loss of feedwater heating in ChinShan nuclear power plant" case, it is mainly for the model improvement of ChinShan nuclear vessel, thereby enhancing the overall hot water flow characteristics, the core inlet flow and temperature distribution. In other case, the "resistance coefficient of spent nuclear fuel at low Reynolds numbers and the natural convection flow", since the current flow resistance of the manufacturer is determined by the conditions of the power operation, it is difficult to calculate the flow resistance characteristic at low Reynolds number and natural convection by using the existing coefficients provided by the manufacturer, it is difficult to calculate the flow resistance characteristic at low Reynolds number and natural convection. Therefore, this study intends to establish a high-precision fuel analysis model by integrating the CAD and CFD methods. By estimating the flow resistance coefficient at low Reynolds number to improve the accuracy of the nuclear fuel analysis.

It is expected that the implementation of this study will help to further clarify the rationality of flow resistance in the relevant application and as a basis for future analysis of the parameters.

Keywords: CFD, CAD, loss of feedwater heating, sensitivity study.

壹、計畫緣起與目的

　　核能電廠之分析技術全性在歷經多年的研究與精進後，已有長足之進步，舉凡以往僅能以較為簡易之預估進行整體分析之工作，透過計算流體力學(Computational Fluid Dynamics, CFD)分析技術的發展，使得更多的細微熱流特性與其對系統之影響逐一被發現並迅速改進。例如，我國核能研究所近來於核電廠系統分析中，利用 CFD 分析工具進行了用過燃料乾式貯存、圍阻體噴灑系統熱水流分析、燃料池熱流分析與大修期間替代冷卻等案例之熱水流分析，並對電廠之實際問題提供了更佳的改善途徑。但考量分析技術的一日千里以及分析所需考量的參數靈敏度與保守度係為 CFD 應用於核能電廠熱流之關鍵，故本研究擬就核研所提出之兩項分析技術，持續進行分析模式的精進，以期透過預先建立相關分析技術之方式，來增進 CFD 於核能之應用能量。

　　依據核研所提出之兩項工作項目：(1)「核一廠喪失飼水加熱之熱流分析」；(2)「用過核子燃料束於低流速下之流阻」，並據此完成相研究報告之要求，本研究擬著手規劃如下：

　　其中，「核一廠喪失飼水加熱之熱流分析」乙案中，係針對核一廠在喪失飼水加熱之事故狀況下，致反應器熱水流特性及爐心進口溫度因為飼水冷卻能力過高而受到之影響。由於飼水溫度分佈在此事件下將與 104 年計畫研究中的高壓注水系統誤啟動狀況不同，故雖然 104 年之計劃中，核研所已針對實際的核一反應爐內注水環位置、爐心發熱功率與入口次冷度等條件進行靈敏度分析，並就額定運轉功率進行靈敏度評估；然而，在考量爐心進口溫度分布對爐心暫態事故之直接影響性，除了必需針對實際喪失飼水冷卻之熱流條

件進行模擬外，本研究更預期針對既有之核一廠 CFD 模型，依據實際之工程設計圖面進行修正與精進。而預期透過修改燃料座塊之限流孔尺寸與位置、爐心底板位置之工作，將使進入爐心燃料之流量與壓力分佈更趨於電廠實際情況，進而避免因為進一步考慮反應器模型之簡化，而忽略反應器內爐心組件對反應器內部產生的估算誤差。另外，本研究為了將以往於分析中未加以考慮的爐心燃料及上部汽液分離器、蒸汽乾燥器等大型組件忽略而可能造成流阻誤差之影響納入考慮；本期研究中更將以往忽略之流阻以適當之多孔性材質模型進行簡化並納入計算；這是因為在實際爐心出口與爐心底部之壓力降，仍將進一步影響爐心進口之流場與壓力分佈。此外，由於本研究係為 CFD 與 RETRAN 發展整合分析之技術，為使模擬資料讀取更為方便，CFD 模型亦將噴射泵與限流孔編號與 RETRAN 之後處理編碼整合，使模擬結果後處理更為順暢。然而，上述研究成果皆僅就額定運轉功率進行評估，而未更廣泛地就不同額定功率下之熱流特性與事故嚴重性進行探討。

另外，對於「用過核子燃料束於低流速下之流阻」乙項分析任務，係針對燃料廠家所提供之既有燃料束水力特性進行精進之工作；這是因為燃料廠家所提供之燃料束流阻參數往往係針對高流量之條件，在考慮可能之運轉狀況後以實際之額定運轉流量為基準，將運轉及安全分析所需區間之流阻條件進行實測並適配為回歸式。然而此回歸式對於近年常需使用之乾貯作業分析、機組大修時替代冷卻分析、燃料池喪失冷卻水之案例卻並全然適用，這是因為燃料束在低雷諾數與自然對流之條件下，其流場特性將與廠家提供之參數所有不同；例如，在低雷諾數之層流條件下，燃料棒本身之摩擦阻力

將較紊流略高。故本研究擬於計畫執行開始後，依據核研所所選定之燃料束類型，利用合適之 CAD 軟體將其工程圖面轉換為實體模型，並進行相關之流場計算與流阻預估，進而提供乙組適用於低雷諾數流場之燃料束流阻係數，以精進未來與用過核子燃料相關之分析能力。

本研究各章節所載之內容，除用以記錄各項工作之成果外，其內容可更作為滿足以下各項合約工作之佐證：

1. 核一廠模型再精進
2. 核一廠喪失飼水加熱系統之分析模式建立
3. 用過核子燃料束分析模式建立

其中工作項目 1 如本報告第二章所載，而各分析結果依其測試參數之不同，則如本報告第三章、第四章所述。另，本研究亦有一篇 Topsafe 國際議會論文產出，惟會議日期為 2017 年 2 月 12 日，尚未前往參與會議，因此僅附上會議論文摘要接受信與摘要全文，於附錄 A 所示。

一、軟體評選與所需研究資料蒐集

有鑑於安全分析結果與事故狀況研判及處置作業之決策正確性息息相關，事故期間的熱水流分析結果之保守性與完整性將直接影響安全作業之效果。而不論是「核一廠喪失飼水加熱事故之熱流分析」或是「用過核子燃料束於低流速下之流阻」分析工作，皆是希望針對既有模式或是機組運轉及熱水流參數進行精進為目的，以期能夠強化現有分析工作之精度。因此，不論是分析工具選用、模式選擇、方法論的適用性以及分析模型的正確性皆需逐一檢核，方能

確保分析結果之合理與適用性。

　　本研究擬選擇目前於核能電廠特殊組件之分析領域中，已有實例之 ANSYS FLUENT [1]分析軟體作為分析工具。這是因為該軟體已完成相關分析方法論[2,3]並通過原能會之審查，而且核研所內亦已建立相關的分析技術，故採用與該分析方法論相同之分析軟體將有利於提昇本計畫所完成之分析技術的實際應用性。除此之外，本研究團隊對此分析軟體之使用者自定函數(User Defined Function, UDF)之擴充與建立已有充足之經驗[4-8]；故透過此一擴充技術之應用，更可針對所需之分析模式進行發展，而達到預期之研究目標。以下針對本研究執行期間擬完成之核一廠喪失飼水加熱事故以及用過核子燃料束於低流速下之流阻所需資料之蒐集狀況，則如本章以下各節所述。

(一) 核一廠喪失飼水加熱事故之熱流分析資料蒐集

　　如計劃書內容所載，由於核一廠喪失飼水加熱事故分析一案只需針對反應器壓力槽內由降流區至爐心下盤區之範圍進行分析；且考量此區域之幾何形狀將直接影響分析結果，故在分析模式中將不再採行任何均質化或是過度簡化之處置方式。針對精進模型所需熱流分析之文獻、工程圖面、暫態與事故資料的蒐集與研析，以作為後續分析工作之參考依據，而所得之資料則已詳如參考文獻[9-12]所示，工程圖面應用則會在下一章節作詳細介紹。

(二) 用過核子燃料束於低流速下之流阻資料蒐集

　　依據計畫合約所載內容，本研究除「核一廠喪失飼水冷卻之熱流分析之熱流分析」之研究工作外，尚有第二項「用過核子燃料束

於低流速下之流阻」乙項分析任務。本項工作系因燃料廠家所提供之既有燃料束水力特性參數往往係針對高流量之條件，在考慮可能之運轉狀況後以實際之額定運轉流量為基準，將運轉及安全分析所需區間之流阻條件進行實測並適配為回歸式。然而此回歸式對於近年常需使用之乾貯作業分析、機組大修時替代冷分析、燃料池喪失冷卻水之案例卻並不全然適用；這是因為燃料束在低雷諾數與自然對流之條件下，其流場特性將與廠家提供之參數所有不同；例如，在低雷諾數之層流條件下，燃料棒本身之摩擦阻力將較紊流略高。

　　本研究於計畫開始執行時，即與核研所進行燃料束類型之選擇；這是因為我國電廠係有沸水式及壓水式電廠且其兩者之燃料束係具有極大差異之故。經過與核研所討論，並依據我國目前既有電廠之未來規劃與後端營運時程進行評選後；本研究先行於本年度針對核一與核二電廠皆有使用之 AREVA 廠家燃料束 ATRIUM-10(如圖 1 所示)進行模式發展與流阻分析。在下一章節將依據原計畫書所載之第三項工作項目，逐一進行實體模型建立、分析模式發展、網格測試與低雷諾數下之流阻計算，以精進未來與用過核子燃料相關之分析能力。
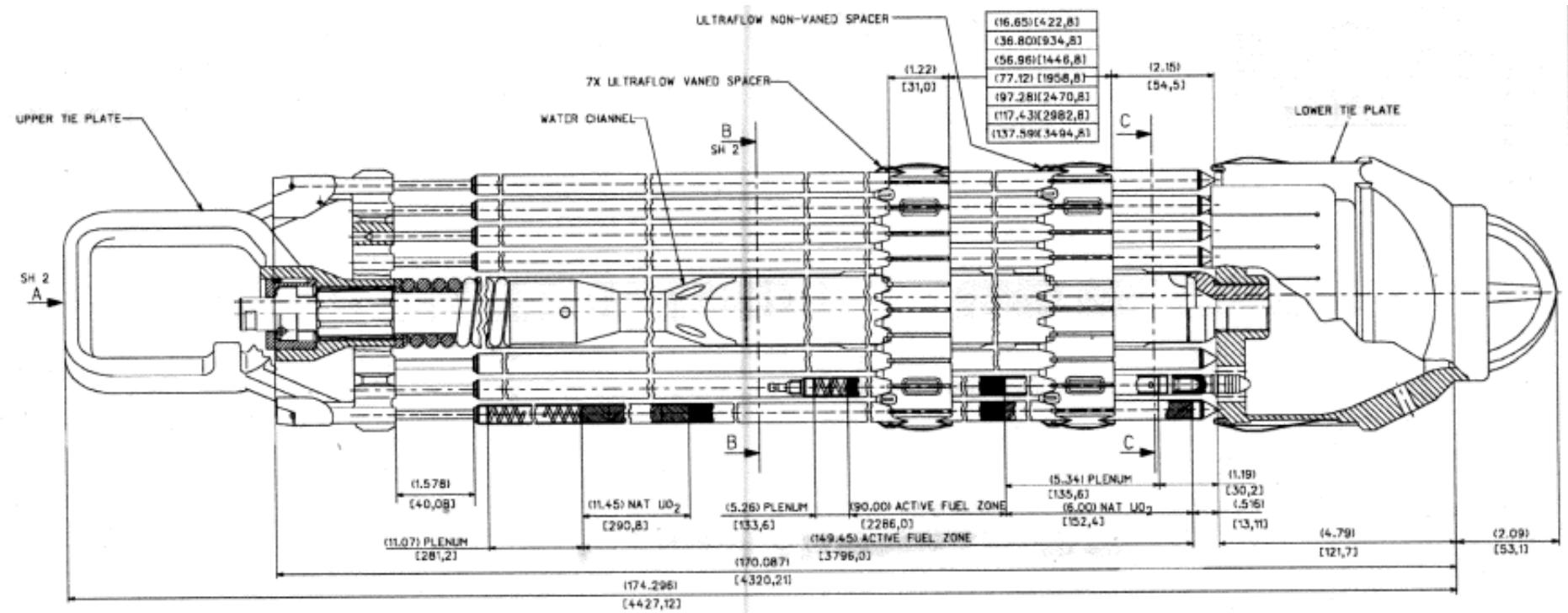
圖 1 ATRIUM-10 燃料束幾何示意圖[13]

貳、 研究方法與過程

一、 核一廠分析模型修正與精進

在「核一廠喪失飼水加熱之熱流分析」乙案中,有鑑於飼水加熱系統 (FeedWater Heating System)發生故障時,飼水加熱器無法運作,造成低溫飼水由連接爐心飼水噴灑環之管路進入降流區(Downcomer)內,再藉由其內的噴射泵與再循環迴路之吸抽效應而混合,最後流至爐心下盤區 (Lower-Plenum)並經燃料座塊之限流孔流進燃料束底端,致反應器熱水流特性及爐心進口溫度因為飼水冷卻能力過高而受到影響,是為喪失飼水加熱系統事故(Loss of FeedWater Heating, LFWH)。考量 LFWH 的低溫冷卻水在此一區間之流動與混合效應,將進一步改變爐心壓力與進口溫度之次冷度並可能造成功率上升,最終影響爐心穩定性,本分析模式即針對上述流場範圍進行模式發展。在 104 年計劃案中,核一廠降流區與爐心底盤區已建置完成,並針對重要參數進行靈敏度分析;然而,為使本分析更符合真實情況,將針對既有之核一廠 CFD 模型,依據實際之工程設計圖面進行修正與精進,修正與精進部分包括爐心底板高度位置、燃料座塊限流孔尺寸位置、增設多孔式流阻區等結構,以及讀取編碼整合等工作,將在以下各節詳述。

(一) 飼水噴灑環內飼水噴嘴孔洞修正

如圖 2 所示,根據台電訓練教材所述,飼水噴灑環共分成四個區域,每個區域內應有 36 個飼水噴嘴,因簡化模型之緣故,飼水噴嘴之幾何模型簡化為孔洞,故修正後的飼水噴灑環具有 144 個飼水噴灑孔洞,修正尺寸則詳列於表一。

(二) 爐心底板高度修正

如圖 3 與圖 4 所示，根據 AREVA 與台電提供之資料顯示，爐心底板位置略高於噴射泵出口處，因此根據工程圖資料將爐心底板位置提高至適當位置工程圖代號 111 處，修正前後之 CFD 模型如圖 5 所示，修正尺寸則詳列於表一。

(三) 燃料座塊限流孔尺寸與位置修正

根據台電工程圖與 AREVA 報告書[13]提供之資料(圖 6 與圖 7)，將燃料座塊之限流孔尺寸、數量與位置修正至符合實際設計，修正後之 CFD 模型如圖 8 所示，修正之詳細資料列於表一。

(四) 增設多孔式流阻區

本研究將以往於分析中未加以考慮的幾何組件如爐心燃料、上部汽液分離器、蒸汽乾燥器…等大型組件忽略而可能造成流阻誤差之影響納入考慮，以避免忽略之流阻造成爐心出口與爐心底部之壓力降誤差，更進一步影響爐心進口之流場與壓力分佈。根據 Darcy 定律[14]所給之流體流經多孔性材質的經驗公式，假設流體在均勻材質內壓力梯度與沿著單一方向的流動速率成正比，因此可得以下公式：

$$v = -\frac{K}{\mu} \bullet \nabla p$$

其中 v 為速度，μ 為流體動黏滯係數，∇p 為壓力梯度，K 則為多孔性材質之滲透率。因此在模型中增設一適當之多孔性材質區，以替代以往忽略之組件所產生的流阻，如圖 9 所示，詳細資料亦列於表一。

(五) 讀取編碼整合

由於本研究係為 CFD 與 RETRAN 發展整合分析之技術，為使模擬資料讀取更為方便，CFD 模型亦將噴射泵與限流孔編號和 RETRAN 之後處理編碼整合，使模擬結果後處理更為順暢。編碼名稱整合如表二所示，僅列出一項該組件變更方式，其餘同類型組件則按照修改規則更動編碼。
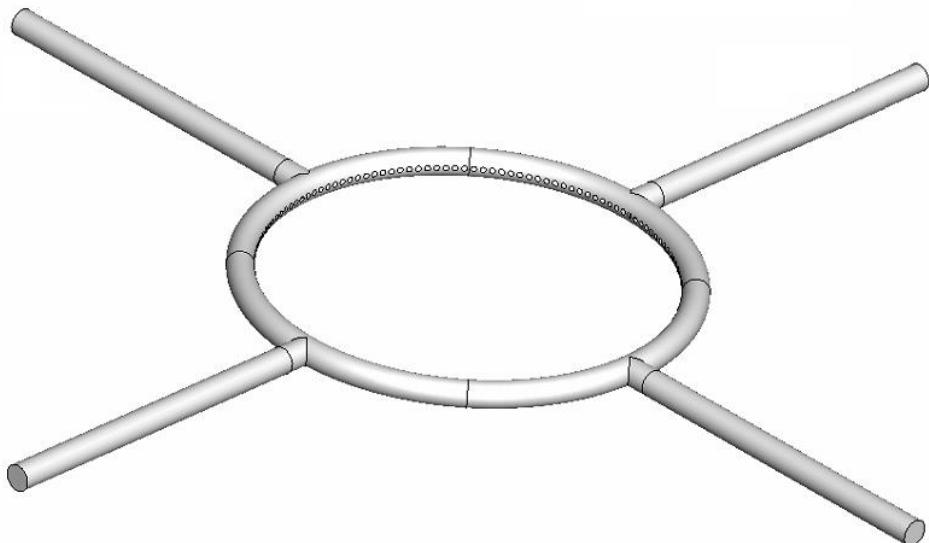

圖 2 飼水噴嘴孔洞尺寸與位置精進

圖 3 爐心底板位置精進[9]

圖 4　各組件標高位置圖[10]

圖 5 爐心底板修正前後之 CFD 模型

圖 6　核一廠限流孔配置工程圖[11]

圖 7　核一廠限流孔配置工程圖[12]
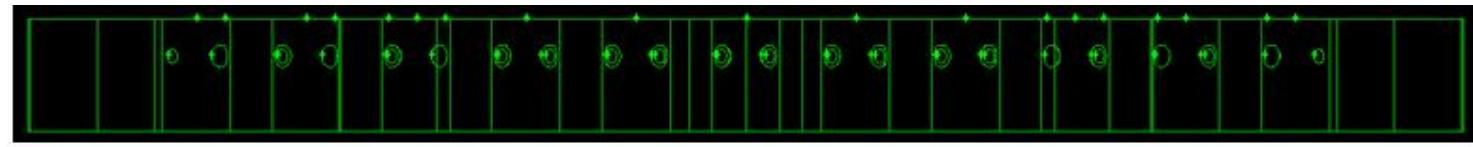
側視圖
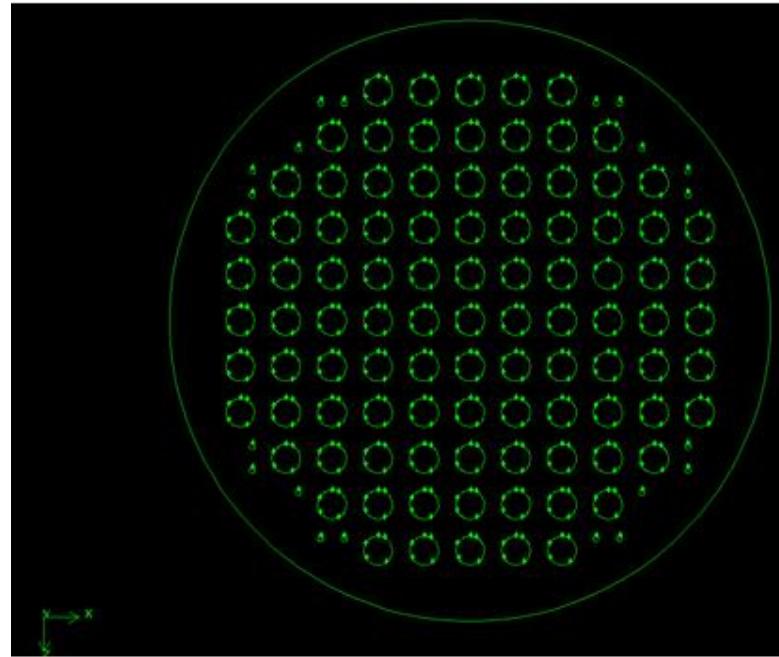
上視圖

圖 8　限流孔修正後之 CFD 模型

上視圖

側視圖

正視圖

網格圖
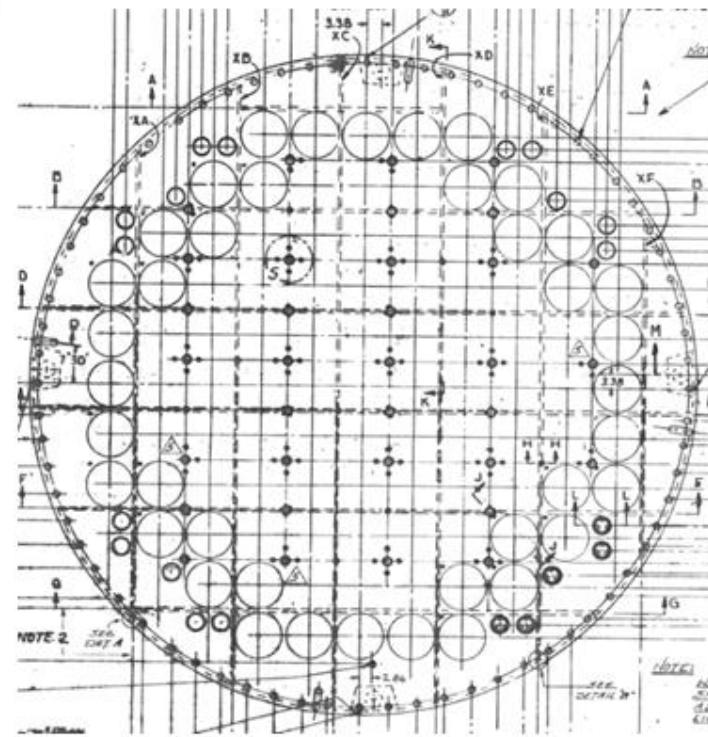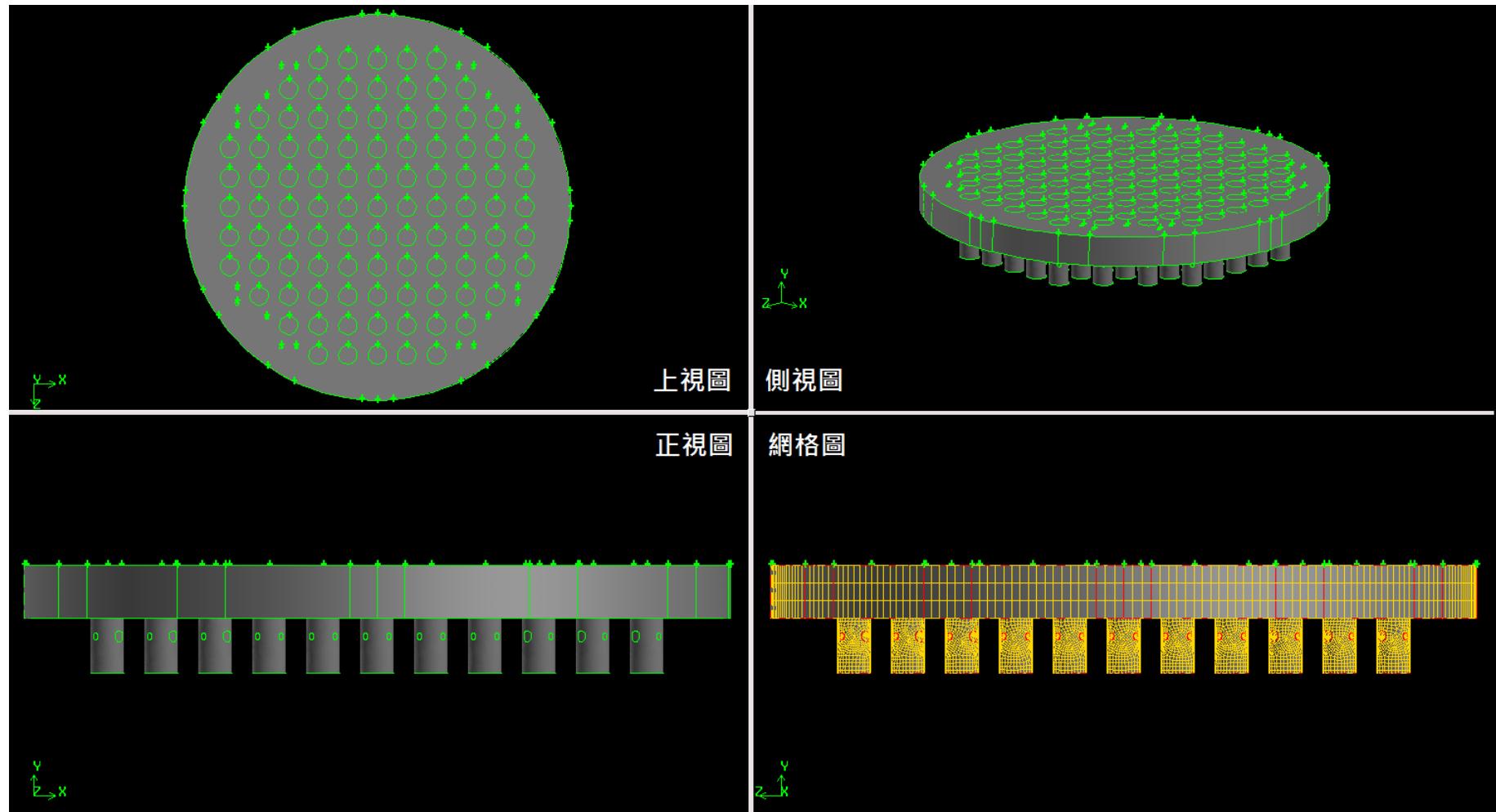
圖 9　多孔式流阻之 CFD 模型

表 1、核一廠 CFD 模型修正與精進之重要幾何參數

名稱	尺寸	參考資料
飼水噴嘴孔洞	3" (144 個,間距 2.5º)	[11]
爐心底板高度	173.965"	[9]、[10]
流孔式燃料座塊限流孔	2.430" (340 個)	[13]
外圍式燃料座塊限流孔	1.488" (68 個)	[13]
多孔性流阻區盤面高度	3cm	N/A
多孔性流阻區柱體高度	3cm	N/A

表 2、CFD 與 RETRAN 編碼名稱整合對照表

組件名稱	原始名稱	編碼整合後名稱
噴射泵	JP-1	jp--01
限流孔	o(14,01)	o_0114

(六) 模型網格建置

基於以上各小節之敘述，本報告所精進之 CFD 幾何模型則如圖 10-12 所示，圖 10 為變動較多之爐心下盤區模型，圖 11 則為整體模型與部分重要組件視圖。

而網格配置是否合適將對模擬結果有顯著的影響，且本研究使

用之模型幾何形狀複雜，網格設定需更加謹慎。由於複雜的幾何構造，使得絕大部分網格配置需使用非結構化網格，其網格種類包括三角錐形、不規則六面體型與矩形。因在 104 年計畫案中已完成網格靈敏度分析，本研究將修改區域如爐心底板、限流孔等結構進行網格重建，並連結原有模型之網格，以達到最小變更，建構完成之網格如圖 12 所示。

圖 10 核一廠精進後爐心下盤區之 CFD 模型

Steam Separator

Feed Water Ring

Feed Water Line

Downcomer

Jet-Pumps

RECIRC Pipe

Lower-Plenum

Control Rod Guide tube
and Core Support
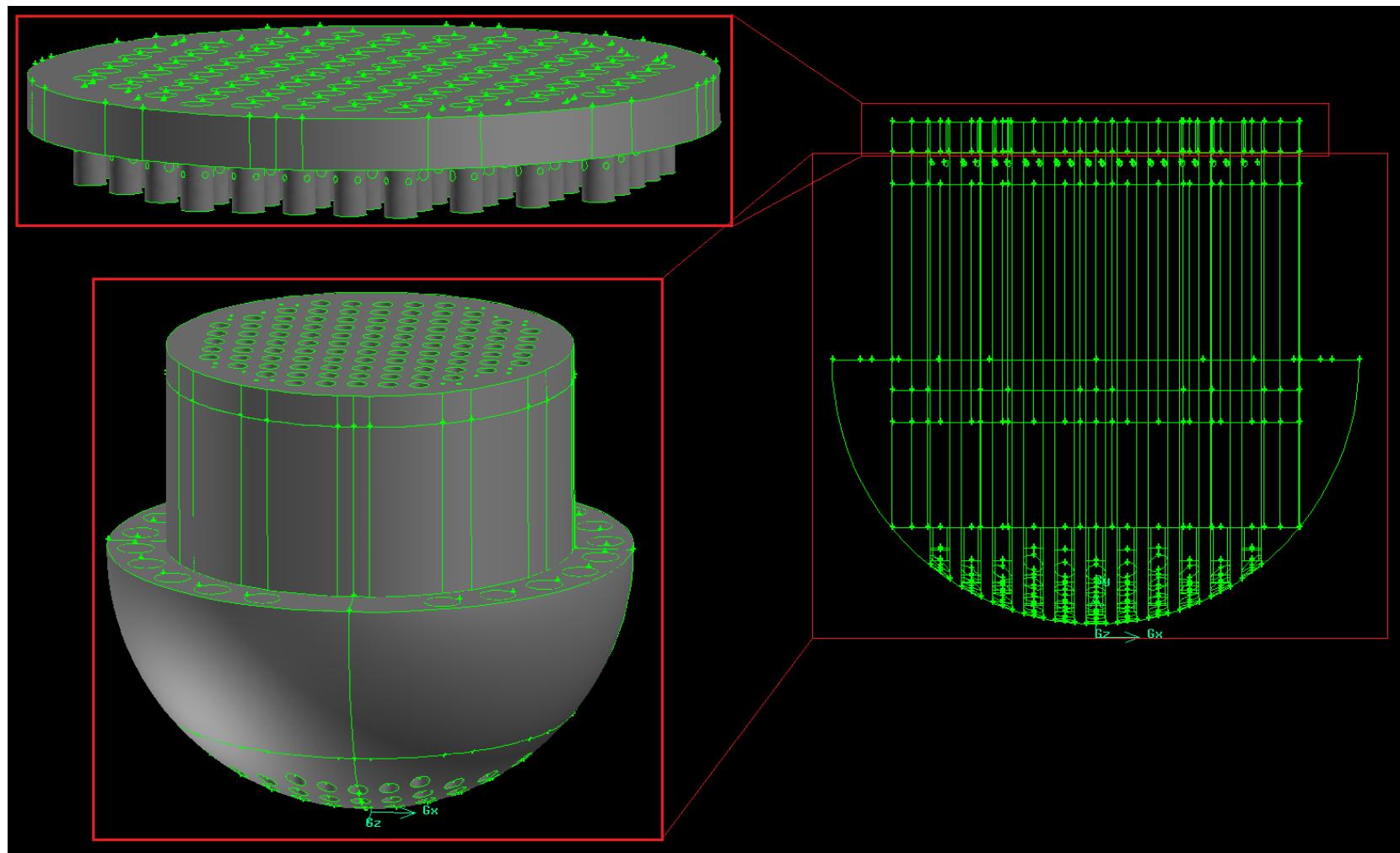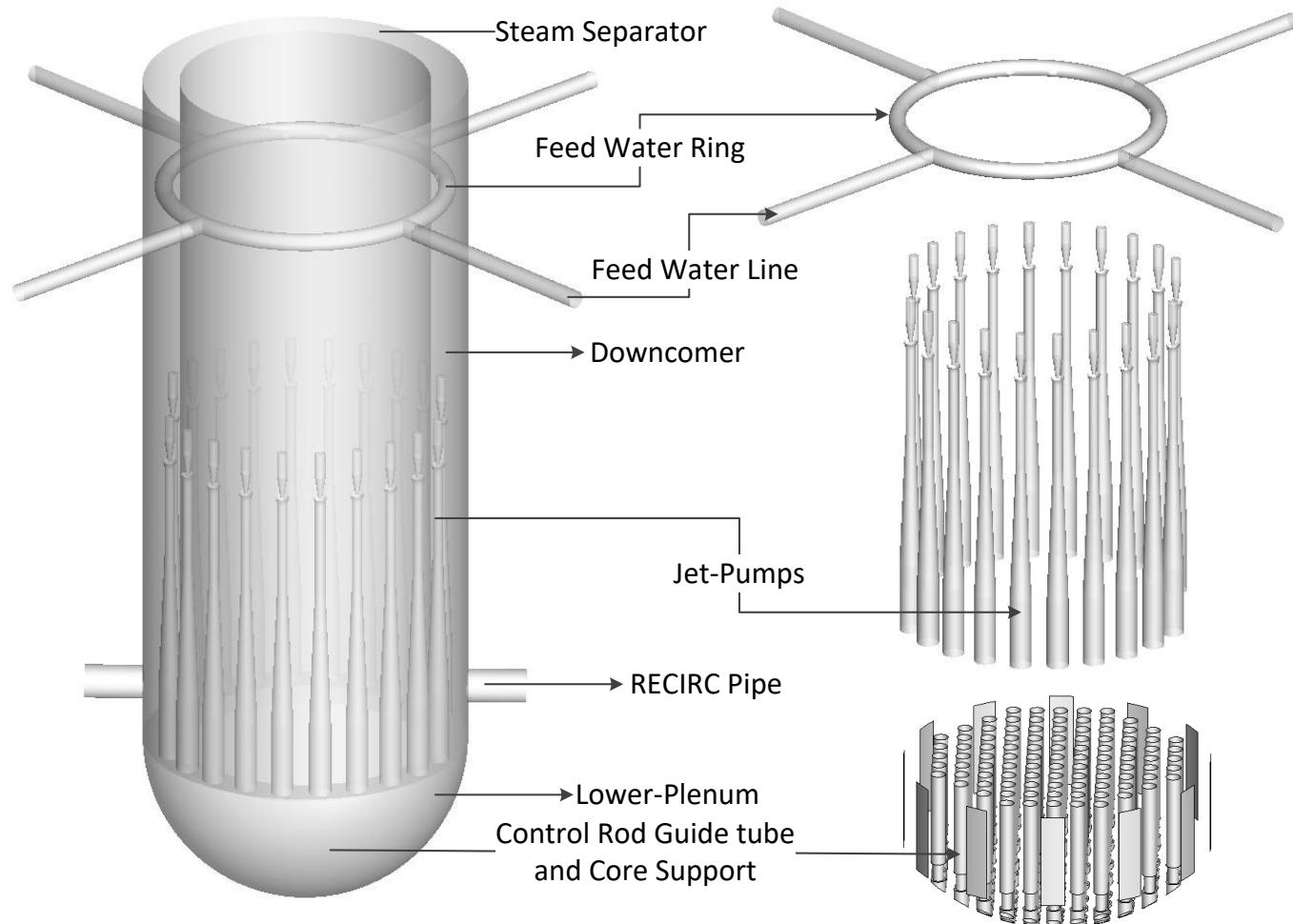
圖 11　核一廠精進後之 CFD 模型
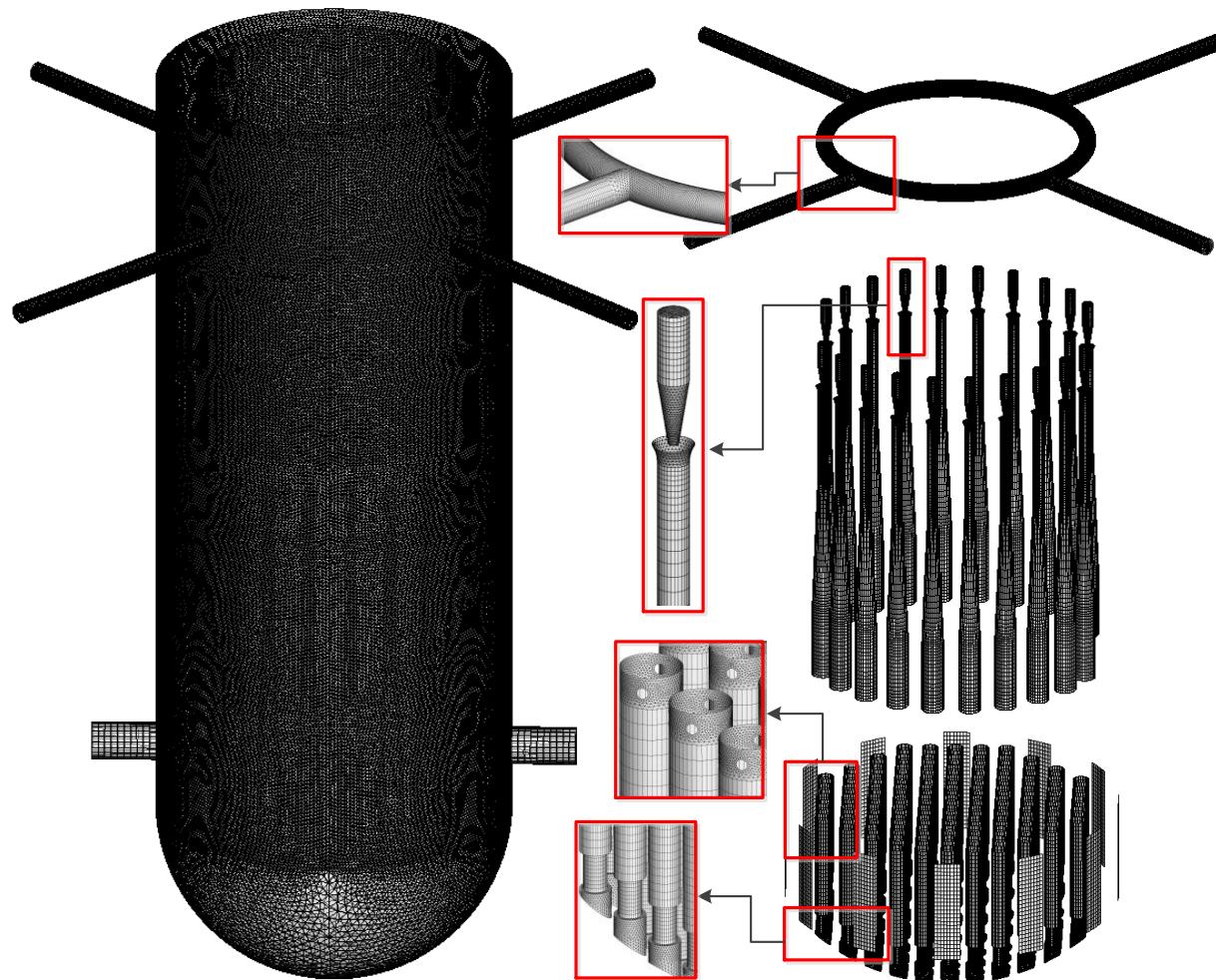
圖 12　核一廠精進後之模型網格配置

二、用過核子燃料束於低流速下之流阻分析

(一) 三維實際模式建立、分析模式發展與假設

依據國聖電廠 ATRIUM-10 之燃料資訊可以得知，該燃料棒具有 10X10(圖 13)之燃料束配置，其燃料棒外徑為 10.051mm(圖 14)且兩端具有用以固定於尾端噴嘴(圖 15)之錐狀末端與頭段提把(圖 16)之設計。而在此10x10的燃料束矩陣中並非全然用以安裝燃料棒；這是因為 BWR 之反應器於運轉期間，燃料內流動的水將會被蒸發與水蒸汽以進行發電，但隨著空泡分率的逐漸增加將導致燃料束內對快中子緩速的能力降低，因此為了確保燃料內仍能保有足夠的緩速能力，目前商用沸水式反應爐之燃料大多設置有水棒。如圖 11 與圖 17 所示，ATRIUM-10 燃料於第 4 至 7 行之位置設置了一個佔據 9 個燃料棒空間之方型水棒，其外尺寸為 35mm 且末端鎖固於尾端噴嘴(圖 15)之底部支持架上，以令液態水能直接由噴嘴流入後向上傳遞並於離開燃料發熱段後，透過其頂部漸縮段所具有的四個開孔流出，並與流經燃料束之冷卻水混和。

在瞭解上述關鍵幾何資訊後，本研究即可著手進行 ATRIUM-10 燃料束之幾何模型建立，惟鑑於本模式未來可能因為各式需求而出現不同考量，故若以傳統之前處理程式(如 gambit)直接進行模型繪

製，將致使此一模型未來之功能性減低。為此，本研究著手利用如SOLIDWORK 等 CAD 軟體，先行建構出上述之各項燃料束元件(圖18)，除進一步作為組合與模型生成之依據外，更可加速未來網格生成與測試時之網格變更作業(圖 19)。

在檢視所有燃料束之工程圖面後雖已獲得建立模式所需之各項資訊，但鑑於部分尺寸特徵係與本研究所需考量無關，故有必要進一步進行簡化，以加模式建立並減低網格成生之難度與計算負擔。而為能令後續應用時能得以瞭解其簡化考量，故以下將詳述各項簡化假設與其依據：

(1) 依據其幾何形狀，將模式設定為 1/2 對稱模型，並由對角線進行分割以節省不必要的計算資源；

(2) 考量幾何提把區不顯著影響流阻之故，忽略其幾何形狀；

(3) 因不考慮熱傳導之固，僅考慮整體護箱流固界面以外之流道區域，忽略固體區內部幾何形狀；

(4) 因影響有限，故忽略水棒彈簧、螺絲、扣環等組合元件之詳細幾何形狀。

而基於上述各項所簡化後所建立之幾何形狀則如圖 20 與圖 21 所示。
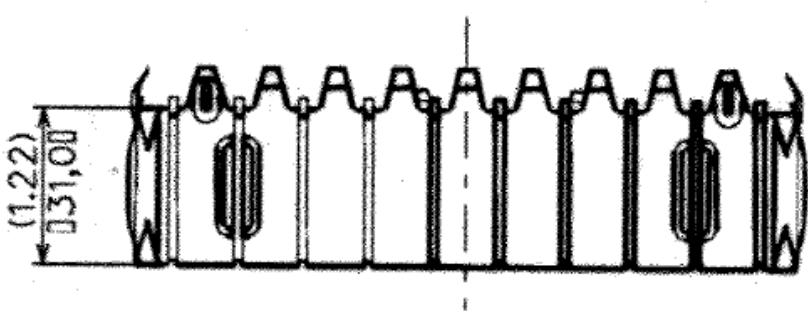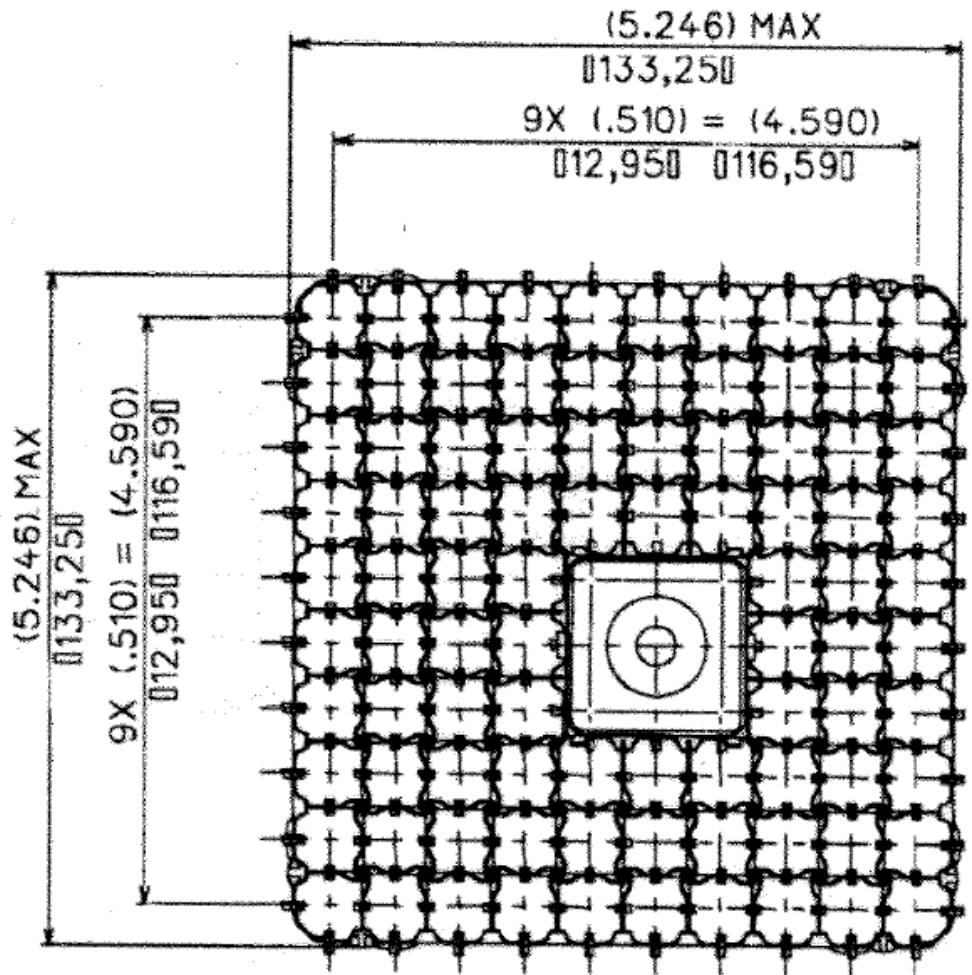
圖 11 ATRIUM-10 燃料格架幾何示意圖
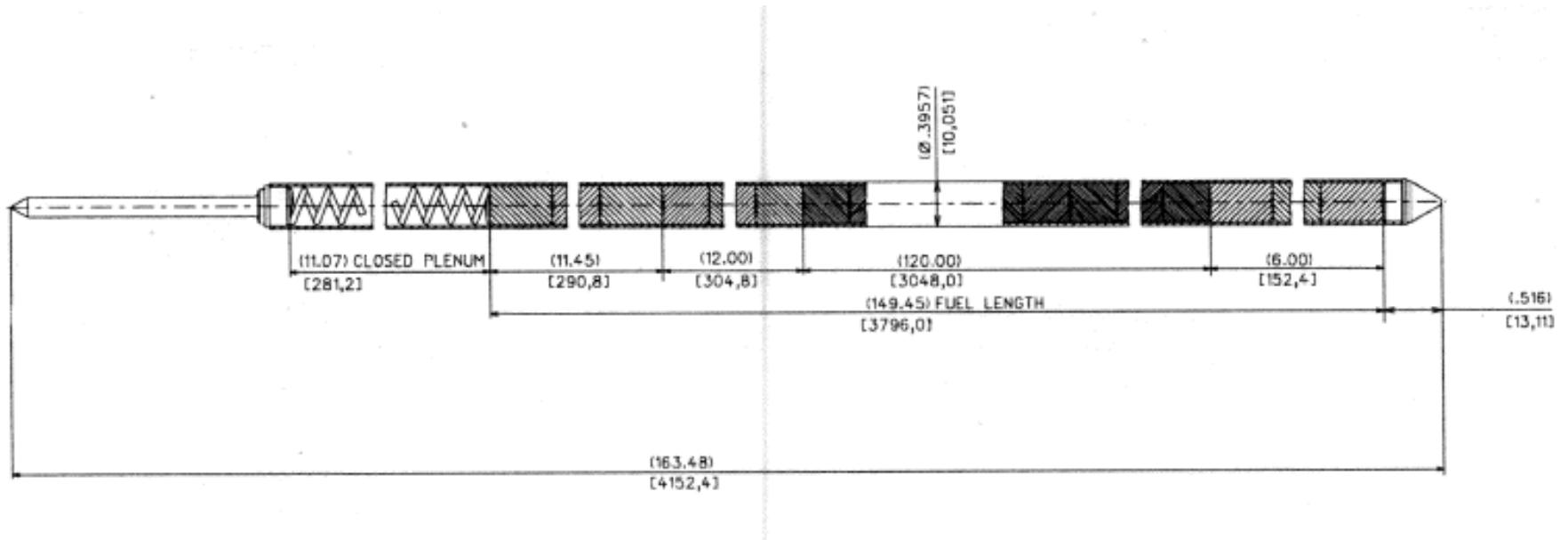
圖 14 ATRIUM-10 燃料棒幾何示意圖

27
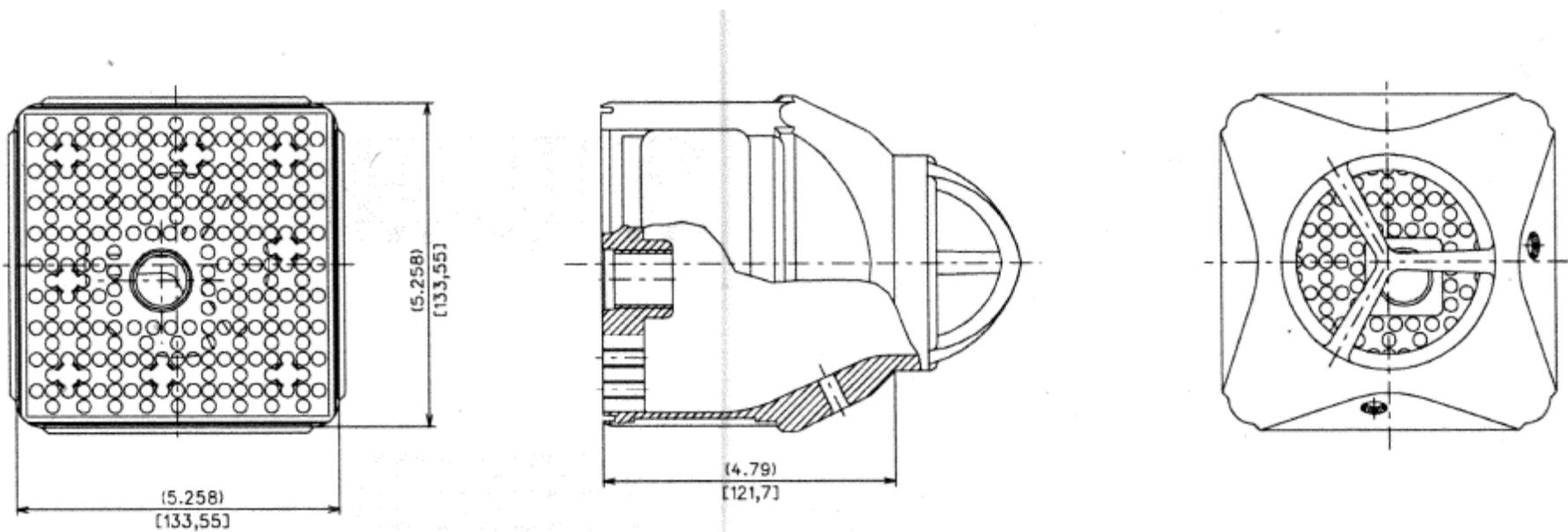
圖 15　ATRIUM-10 燃料束噴嘴幾何示意圖

圖 16 ATRIUM-10 燃料束提把幾何示意圖

圖 17 ATRIUM-10 燃料水棒幾何示意圖
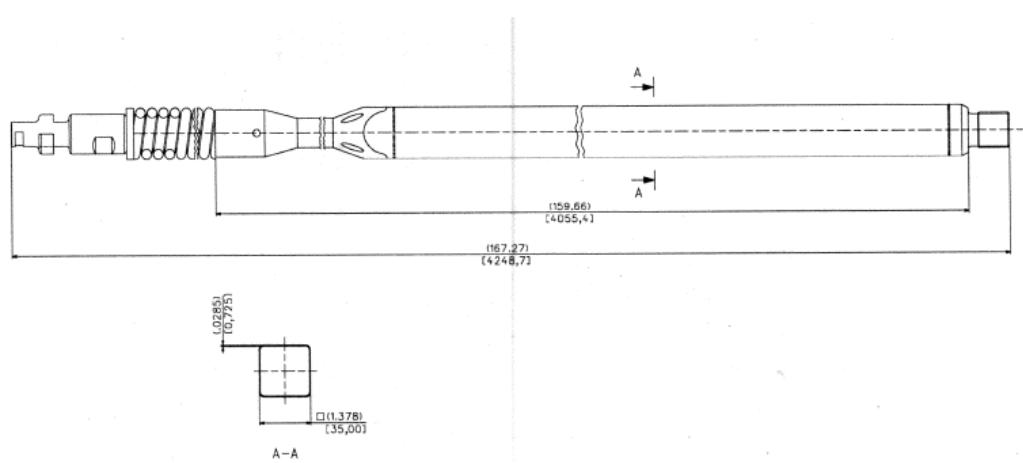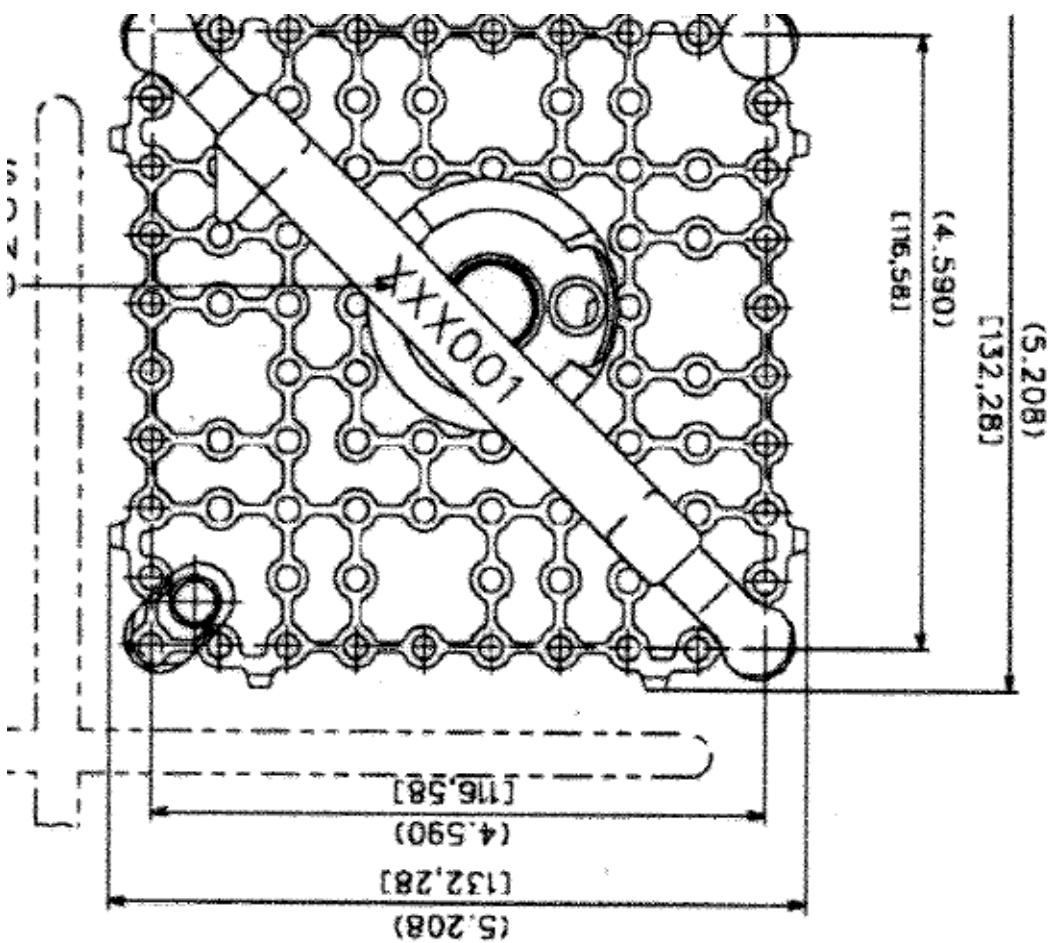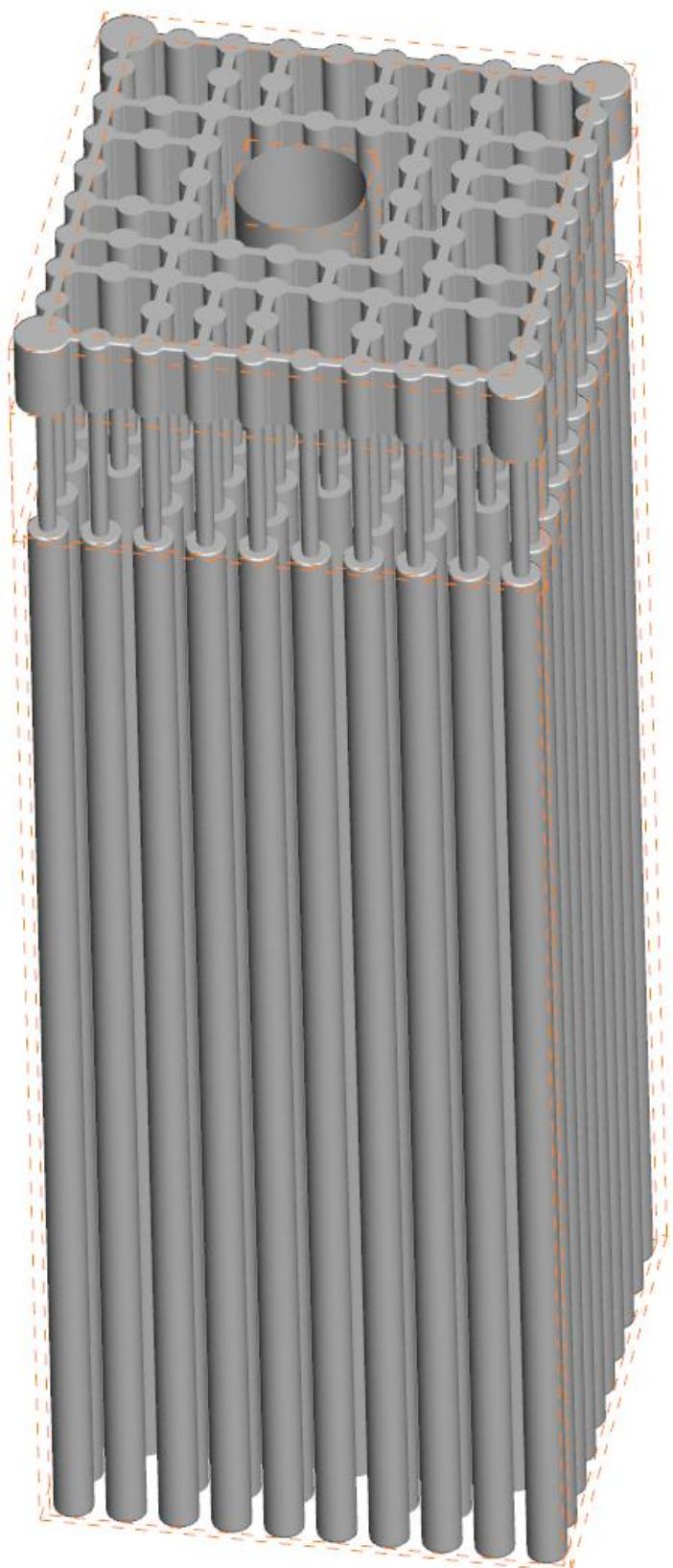
圖 18 ATRIUM-10 燃料 3D 模型示意圖
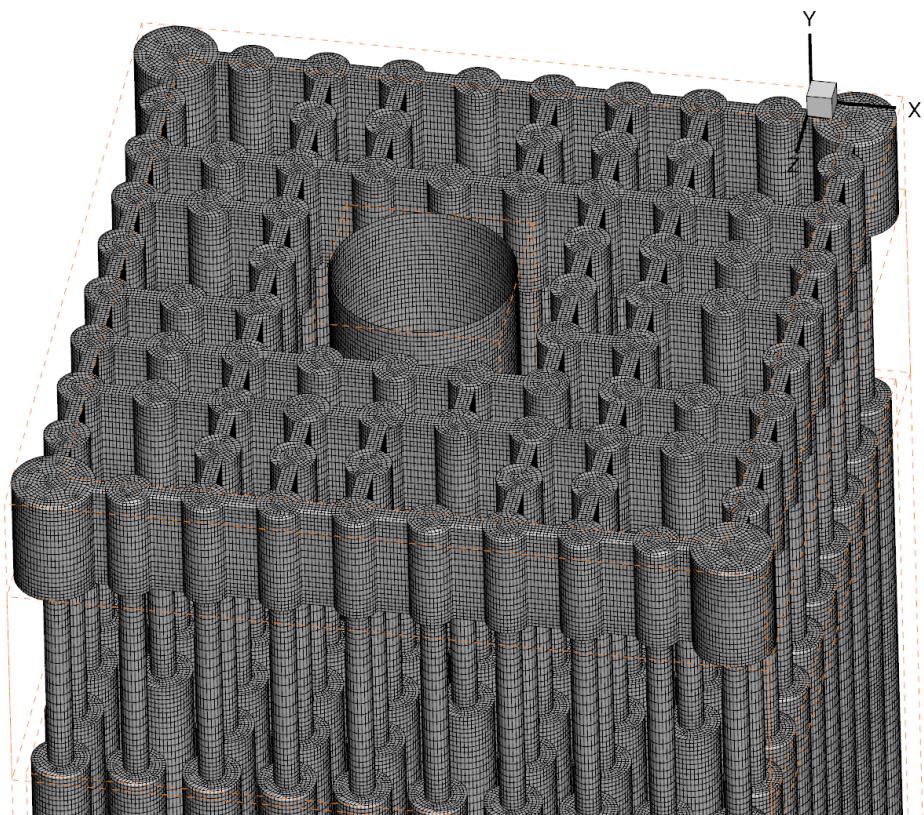
圖 19 ATRIUM-10 燃料 3D 網格示意圖
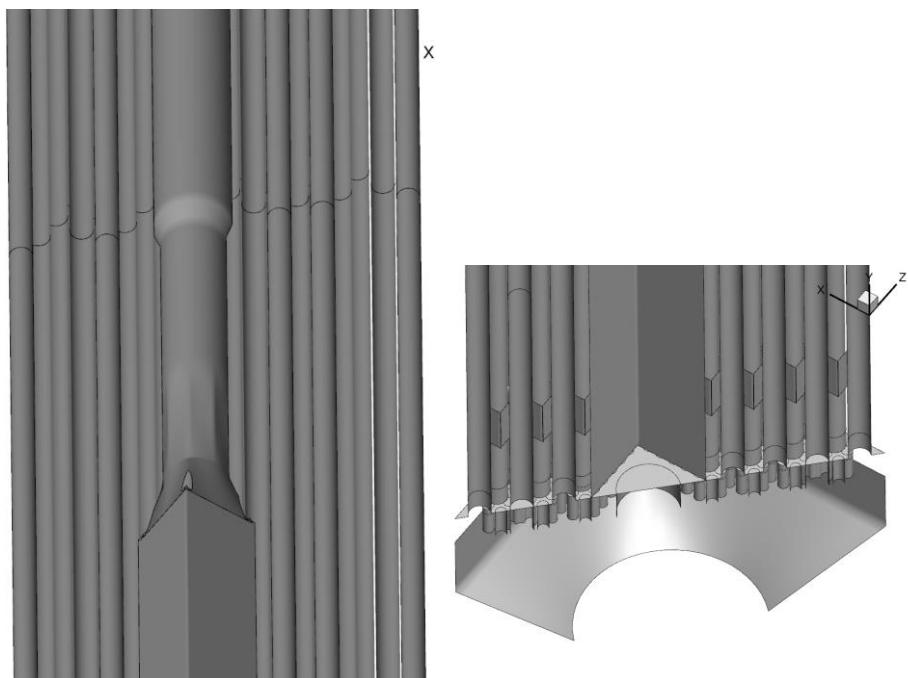
圖 20 1/2 對稱模式之水棒與噴嘴幾何模型
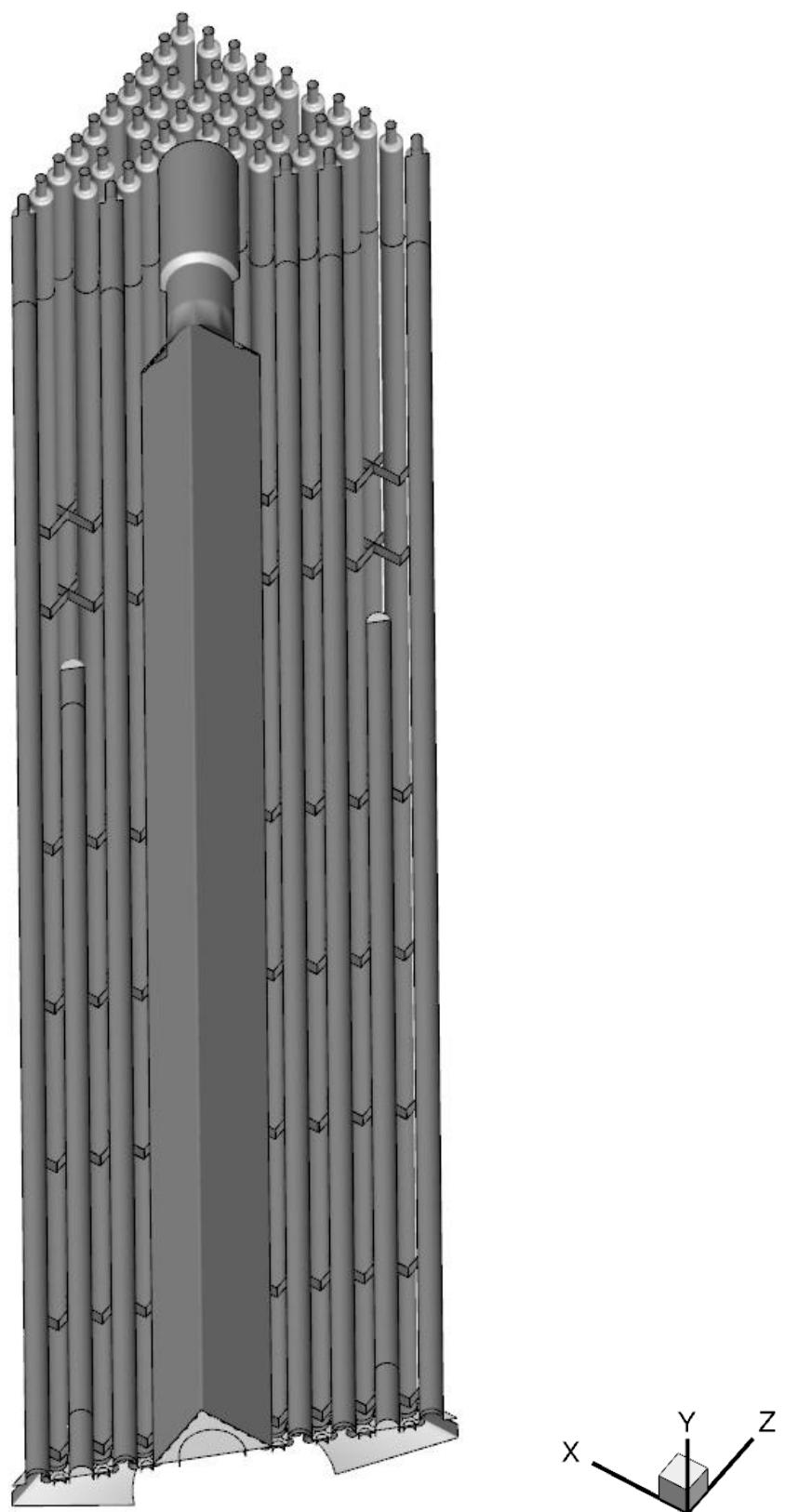
圖 21 整體 1/2 對稱 ATRIUM-10 燃料模型(X:Y:Z=1:0.2:1)

(二) 網格生成與測試

　　為能確保分析模式於後續計算中不致因為網格分佈之故，而造成不必要的計算誤差，本研究進行以下之網格生成與測試作業。其中，整體之網格生成方式是盡可能採用六面體或三角柱沿軸線堆疊之方式進行生成，且依據以下條件進行設定來減少可能存在的扭曲：

(1) 圓周最少點數為 12 點，主要用以燃料棒表面；

(2) 最大軸向網格長度為 1cm，主要用於燃料棒沿軸向之網格生成；

(3) 為確保網格變化不至過劇，網格之變化率控制在 1.02~1.05 左右。

　　此外，針對 CFD 進行分析時，可能因網格影響所造成的計算不準度，本分析採用 ASME V&V 20-2009 導則[15]來進行分析，此方法之估算流程依續為：

　　計算代表網格大小(Representative Grid size, h)；

　　對於非結構性網格而言：$h = \left[\left(\sum_{i=1}^{N} \Delta V_i\right)/N\right]^{1/3}$；

　　其中 ΔV_i 為網格 i 之體積，N 為網格數目。

計算格點加密因子 (Grid Refinement Factor, r)

$$r_{i+1,i} = \frac{h_{i+1}}{h_i} > 1.3$$

其中，$r_{i+1,i}$為標準網格(較粗)對較細網格的加密因子，而本研究於 FLUENT 中採用 ADAPT 指令直接進行網格加密，故各維度之網格數將以倍增方式增加，故其值可定為 2。

計算準確度等級 (Order of Accuracy, p)

由前面得到之格點加密因子與各格點之變數可算出準確度等級

$p = \left[\frac{1}{ln(r_{21})}\right]\left[ln\left|\frac{\varphi_3 - \varphi_2}{\varphi_2 - \varphi_1}\right| + q(p)\right]$，

其中，$q(p)$為超越函數，可定義為：$q(p) = ln\left(\frac{r_{21}^p - s}{r_{32}^p - s}\right)$，

而s定義為：$1 \cdot sign\left(\frac{\varphi_3 - \varphi_2}{\varphi_2 - \varphi_1}\right)$；

其中，$sign$則為邏輯函數，係用以判斷實數的正負值，其定義為：

$$sign = \begin{cases} -1 : x < 0, \\ 0 : x = 0, \\ 1 : x > 0, \end{cases}$$

而φ_i則是第 i 組格點分佈下之計算結果。

計算格點收斂指標 (Grid Convergence Index, GCI)

$$GCI_{fine}^{21} = \frac{Fs}{r_{21}^p - 1}\left|\frac{\varphi_2 - \varphi_1}{\varphi_1}\right|$$

其中 Fs 係數，是用修正利用不同格點分佈進行評估時所需導入之修正係數，當採用三格點進行誤差評估時，其值為 1.25；而採用二格點分佈時其值為 2；由於本研究選用三種網格，故其值可定義

為 2。

不準度 (Uncertainty, Unum)

$$u_{mesh} = \frac{GCI}{k} = \frac{U_{mesh}}{k} \text{ ,}$$

其中 k 為分佈係數因子，與誤差分佈有關；在 95%信心水準且為常態分佈之條件下，其 k 值為 1.15。

針對以上 ASME 校驗報告所述之方法，本評估選用整體燃料束進出口之壓力差作為不準度測試標的，其壓力分佈值與網格數目分佈則分別如

表 3 與 22-24 所示。

表 3、不同網格之計算結果

網格類型	Mesh size/in	ΔP (pa)
粗化網格	962,700	75.51
標準網格	7,701,609	81.8
加密網格	61,612,872	82.16

而計算所得則如下所示：

$$r21 = \frac{h_{original}}{h_{fine\_1}} = 2.0 \text{ ,}$$

$r32 = \frac{h_{fine\_1}}{h_{fine\_2}} = 2.0$,

$p = \left[\frac{1}{ln(r_{21})}\right]\left[ln\left|\frac{\varphi_3-\varphi_2}{\varphi_2-\varphi_1}\right| + q(p)\right] = 2.94419$,

$ln\left|\frac{\varphi_3-\varphi_2}{\varphi_2-\varphi_1}\right| = 2.86061$,

$q(p) = ln\left(\frac{r_{21}^p-s}{r_{32}^p-s}\right) = -0.25902$,

$s = 1 \cdot sign\left(\frac{\varphi_3-\varphi_2}{\varphi_2-\varphi_1}\right) = 1$,

$GCI_{fine}^{21} = \frac{Fs}{r_{21}^p-1}\left|\frac{\varphi_2-\varphi_1}{\varphi_1}\right| = 0.0044$ 。

經上述計算後，網格不準度(u_{mesh})可量化為：0.0044/1.15=0.38%，

為確保分析結果之嚴謹性，本研究擬將此分析模式之標準網格來進

行後續求解，以減少不必要的不準度。
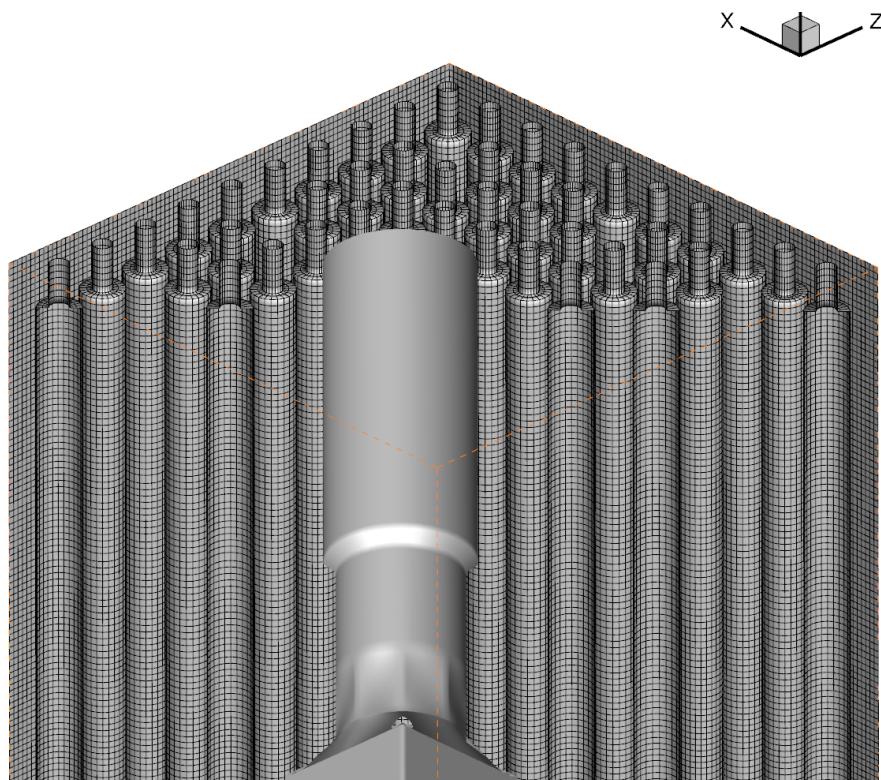
圖 2 粗化之模型網格分佈
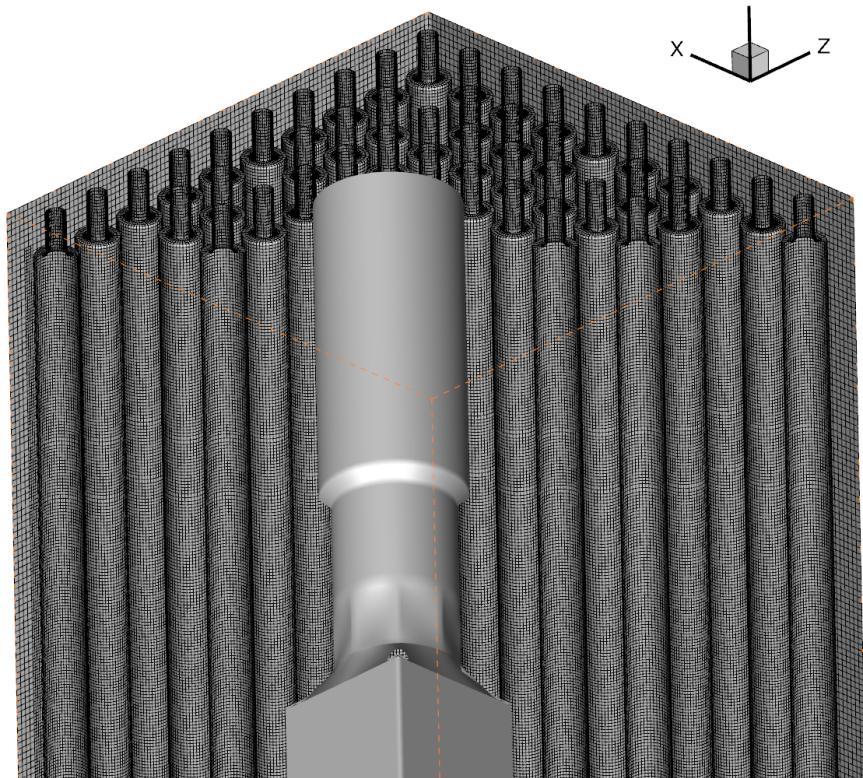
圖 3 標準之模型網格分佈
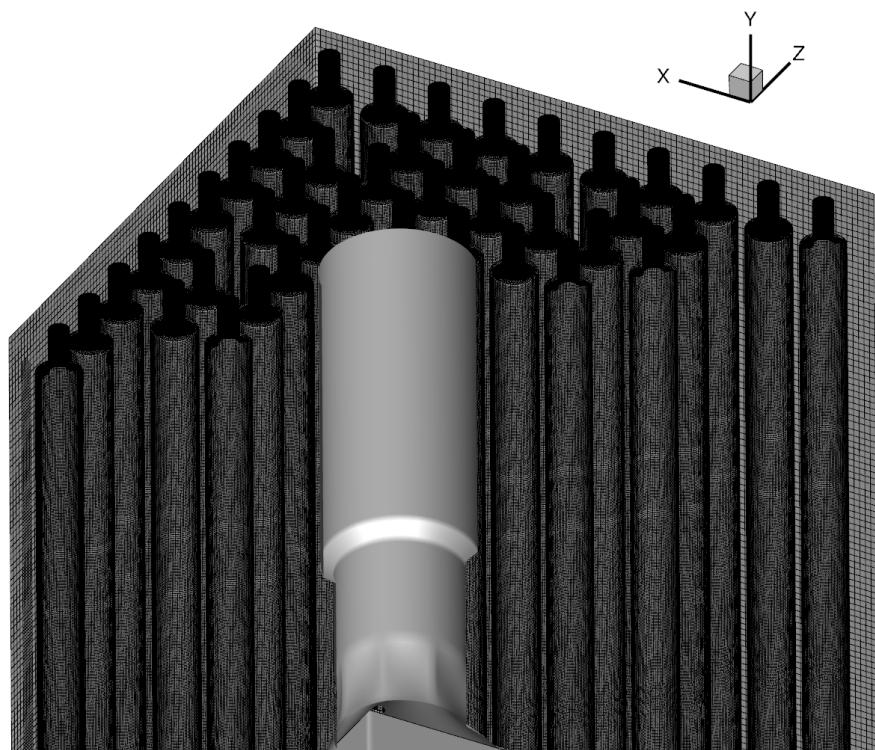
圖 4 加密後之模型網格分佈

三、數值分析設定與邊界條件

(一) 數值分析設定

　　本計畫將沿用 104 年計畫案中所選用的 FLUENT 分析工具與數值分析設定進行模擬，該分析工具將以有限體積法(Finite Volume Method, FVM)來進行離散，利用將計算域分割為數量龐大的控制體積以簡化其邊界條件，再針對每個控制體積之各個統御方程式以數值方法進行求解，即可獲得所需之分析結果。本次模擬相關分析設定與收斂條件如表 4 所示。

表 4、本研究模擬相關分析設定與收斂條件

Pressure-Velocity Coupling	
Scheme	Simple-C
Spatial Discretization	
Gradient	Least Squares Cell Based
Pressure	Standard
Momentum	Second Order Upwind
Turbulent Kinetic Energy	Second Order Upwind
Specific Dissipation Rate	Second Order Upwind
收斂條件(殘差值)	Energy : 10^{-5} Others : 10^{-4}

(二) 邊界條件設定

表 5 為核一廠提供之正常運轉狀態與 RETRAN 分析喪失飼水加熱案例提供之進口邊界條件，FLUENT 將利用下表分別進行穩態與暫態邊界條件之設計與求解，UDF 之內容則詳列於附錄 B 至 D。

表 5、模擬核一廠各組件運轉時之設定狀態

邊界條件	溫度(K)	質量流率(kg/s)
穩態		
汽水分離器	560	5682
飼水流體	485.011	243
噴射泵驅動流	取決於 RECIRC 迴路	取決於 RECIRC 迴路
RECIRC 迴路	UDF 計算取得	UDF 計算取得
暫態		
飼水流體	RETRAN 資料提供	RETRAN 資料提供

叁、模擬結果

以下將各別針對核一廠喪失飼水加熱事故之熱流分析以及用過核子燃料束於低流速下之流阻的模擬結果進行結果分析。

一、核一廠喪失飼水加熱事故之模擬結果

由圖 25 飼水管路切面速度分布顯示,由於飼水進入飼水環時撞擊壁面(A 點),使 A 點處流向呈現散射狀,而遠離飼水環末端的出口流向較一致(B 點)。圖 26 可以更清楚地解釋,從飼水管線注入的冷卻水打到飼水環管壁後往兩側移動,並從兩側的飼水噴嘴孔洞流出,由於流出的流體方向與從汽水分離器來的工作流體流向不同,因此造成該處流速減緩,並且有較好的混合效應。受到流場的影響,降流區內的溫度場亦呈現一對稱現象,飼水與汽水分離器的飽和水約有 65K 的溫差,當兩者在降流區內混合,在飼水噴嘴出口處可以發現一個明顯的溫度降(圖 27),而在降流區內工作流體均勻混合,在進入噴射泵進口與再循環管路進口前即均勻混合至溫差小於 4K,其溫度混合情形如圖 28 所示。圖 29 則能進一步解釋降流區內的熱水流現象,流線圖顯示 B 點位置之飼水噴嘴孔洞注入降流區的工作流體因流向較一致,撞擊降流區內壁後,部分水流往上而造成 12.85m 高度處明顯的溫度差,而 A 點則因先行撞擊飼水環內壁導致

流速下降且流向紊亂後才流出飼水噴嘴孔洞，造成降流區內對應飼水管路位置混合後溫度較高(45 度、135 度、225 度、315 度)，而遠離飼水管路之相對應位置處(0 度、90 度、180 度、270 度)則在降流區內呈現明顯的溫度梯度。在降流區內混合後的工作流體經由噴射泵與再循環管路的抽吸，並透過噴射泵的驅動流進一步均勻混合後從 20 支噴射泵出口注入爐心下盤區。

在爐心下盤區，由於幾何形狀並未有太多改變，因此如同 104 年計畫案模擬結果所述，在爐心下盤區內並無較強的橫向穿越水流，每支噴射泵注入水流之間的混合效應並不高，大多沿著碗型幾何形狀改變流向後，往上直接抵達爐心進口區，熱水流現象則沿著軸向高度呈現極相似的分布，圖 30 至 33 分別為爐心下盤區內之速度與溫度分布情況，與 104 年計畫案之模擬結果並無太大差異。

而喪失飼水加熱器主要原因有兩種，第一種為飼水旁通飼水加熱器，造成進入反應器壓力槽的飼水溫度突然降低；第二種原因則為飼水加熱器內的蒸氣管路關閉，由於此時飼水加熱器上有餘溫，使得進入反應器壓力槽的飼水溫度緩慢降低。一旦事故發生造成飼水加熱器喪失功能，當過冷的工作流體進入爐心後，會造成爐心內水中的空泡變少，進而增加次冷度，並因為正的空泡反應度增加而

使水位降低，最終影響爐心穩定性。在事故發生第 23 秒，溫度驟降 40K 的過冷飼水從飼水管線注入，並透過飼水噴嘴孔洞進入反應器降流區，444K 的飼水與從汽水分離器分離出之 560K 熱水混合，造成降流區內一明顯的溫度梯度，如圖 34 所示，透過降流區混合、再循環迴路與噴射泵的抽吸，在注入爐心下盤區之噴射泵出口溫度仍無法達到均勻分布，出口最大溫差可達到 10K(圖 35)。

進一步將降流區內 20 支噴射泵之分析結果與 INER 提供之 RETRAN 結果進行比較，可發現流量與溫度分布趨勢皆與 RETRAN 十分吻合(圖 36 與 37)，確保本分析結果具一定可信度外，並可提供 RETRAN 分析無法取得之重要組件局部熱水流現象。

而在爐心下盤區，由於幾何結構與混合空間等限制，導致混合不均勻的狀況無法改善，在事故第 50 秒即可明顯地看出爐心下盤區內接進碗型底部有明顯局部過冷的區域(圖 38)，亦可看出控制棒導管間無強烈的橫向穿越水流混合效應，其軸向溫度分布沿著高度方向有相同的趨勢。而徑向溫度分佈則為一顯著的非均勻溫度分布，由此可推論爐心進口區亦會形成一較大溫差的溫度分布，這對反應器穩定性分析將是一個重要的問題。

圖 25　飼水管路切面速度分布

流線正視剖面圖　　　　　　　　　　　　　　　流線側視剖面圖
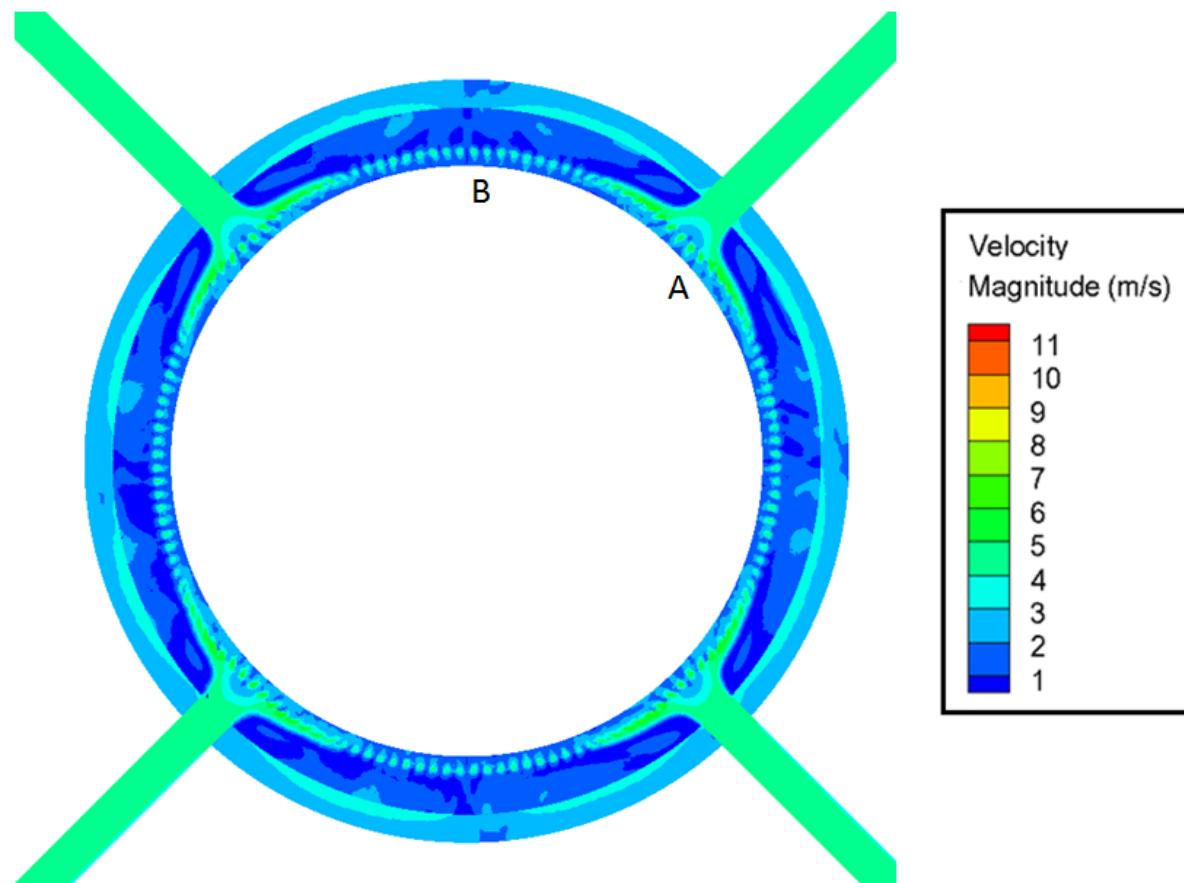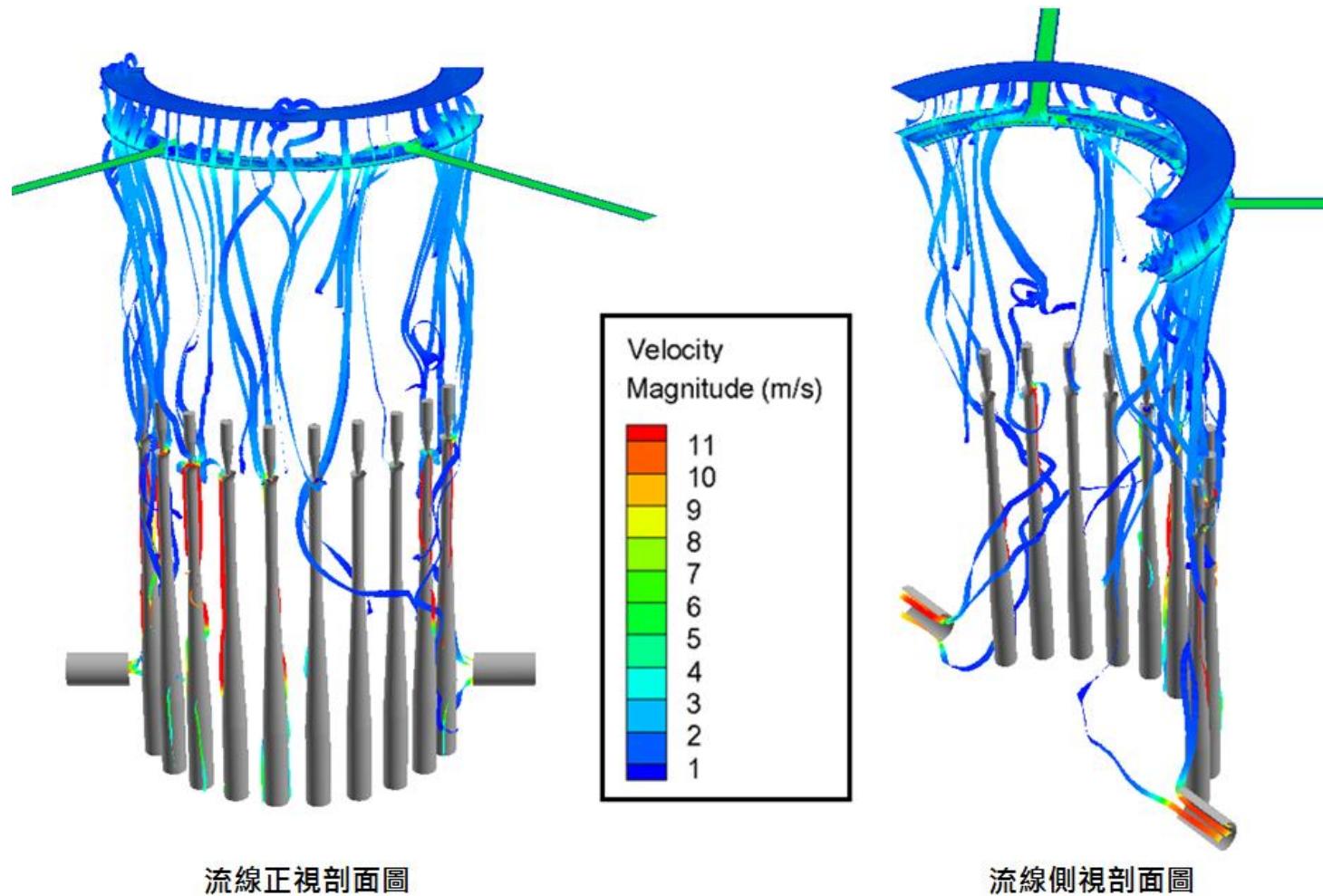
圖 26　降流區流線剖面視圖
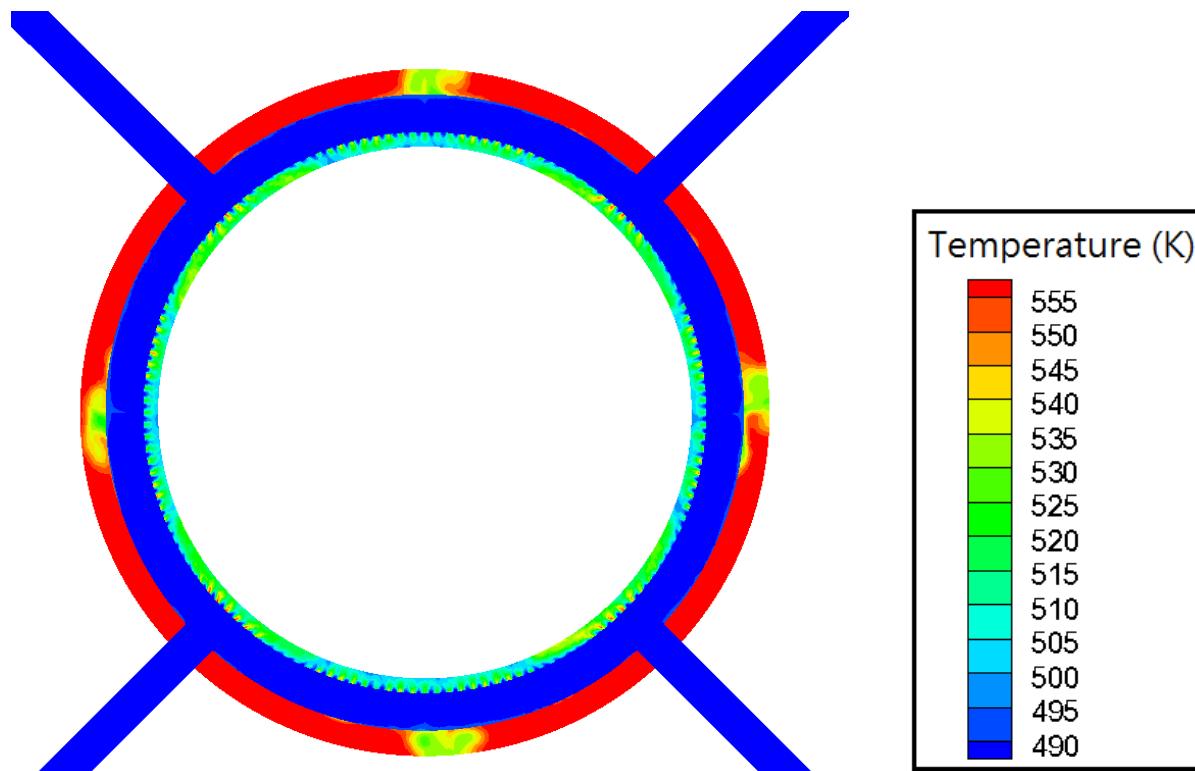
圖 27　飼水管路切面溫度分布
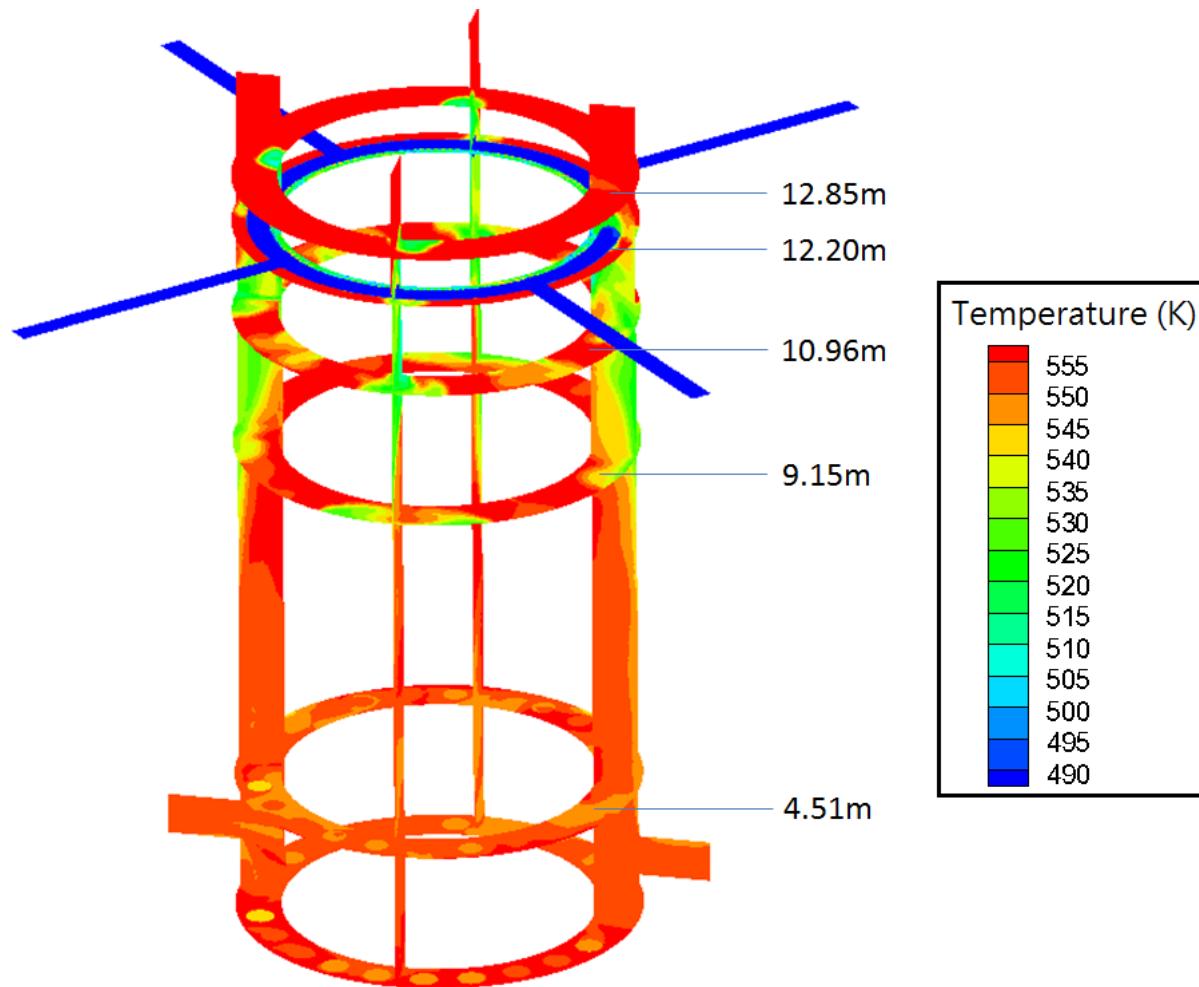
圖 28　降流區內不同高度切面溫度分布
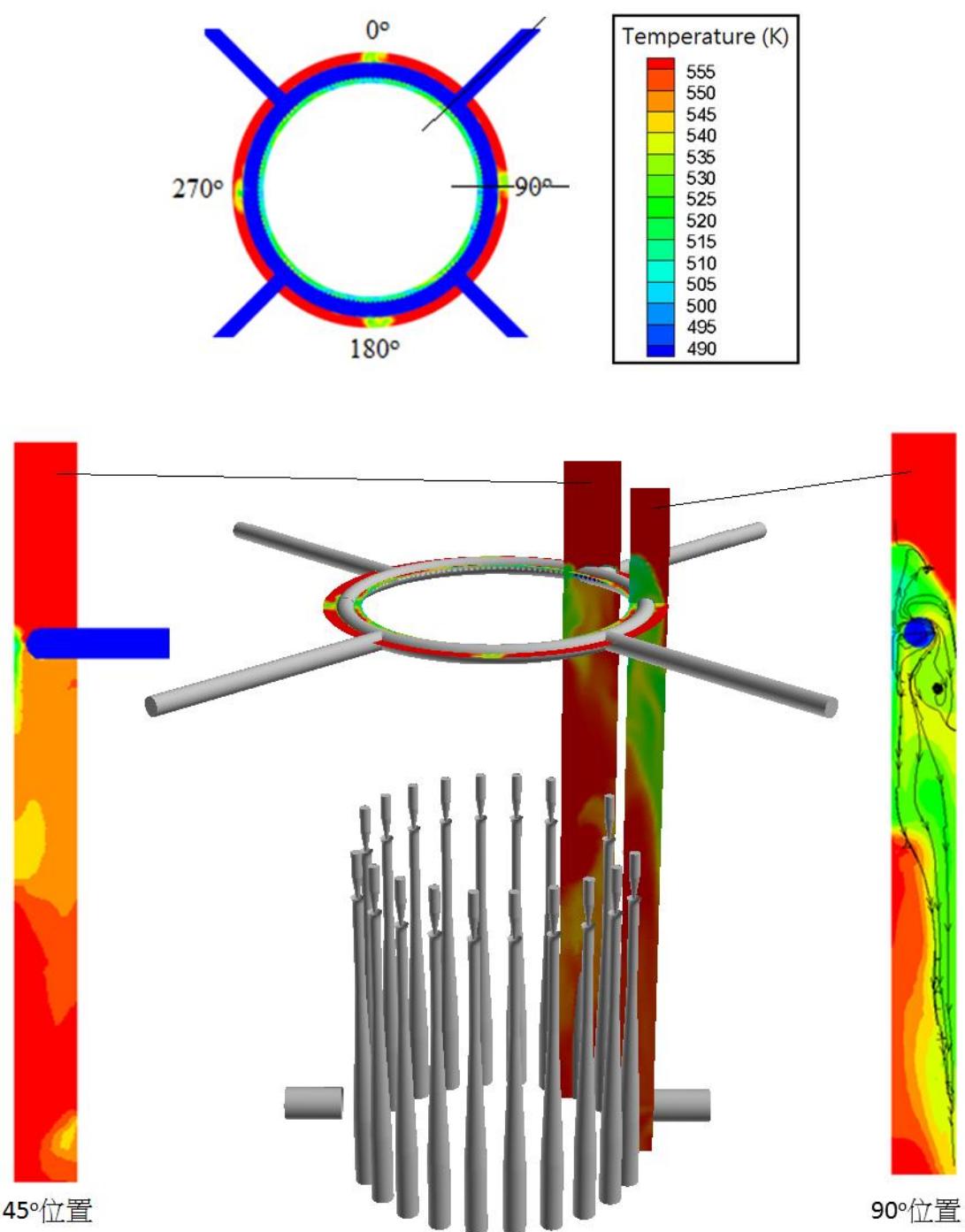
圖 29　降流區內局部區域溫度分布圖
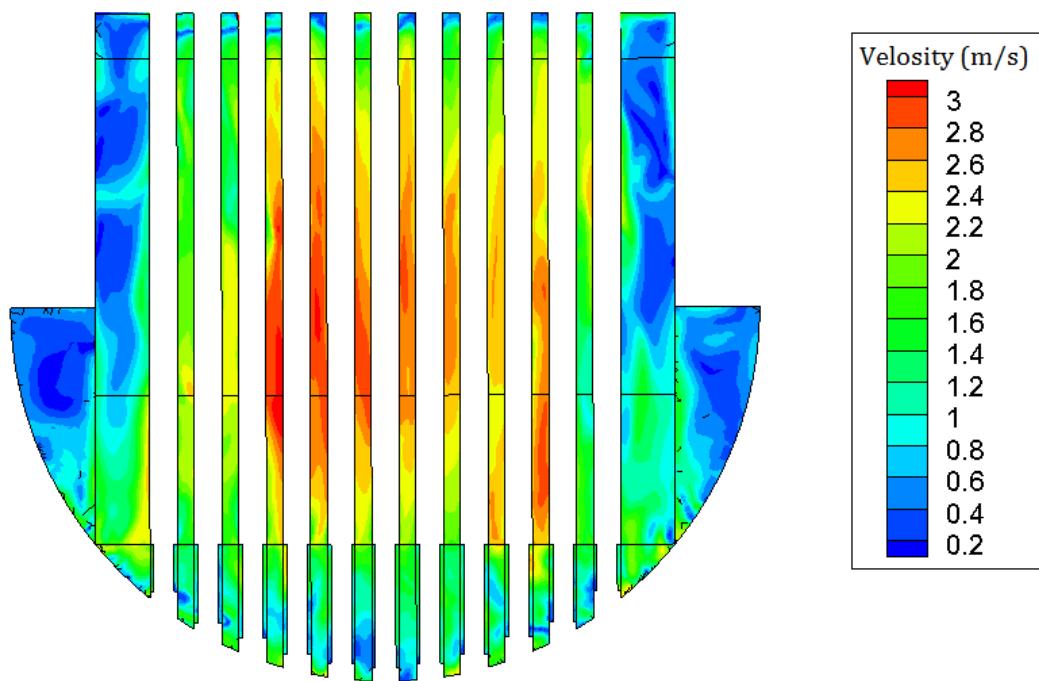
圖 30　爐心下盤區內速度分布圖
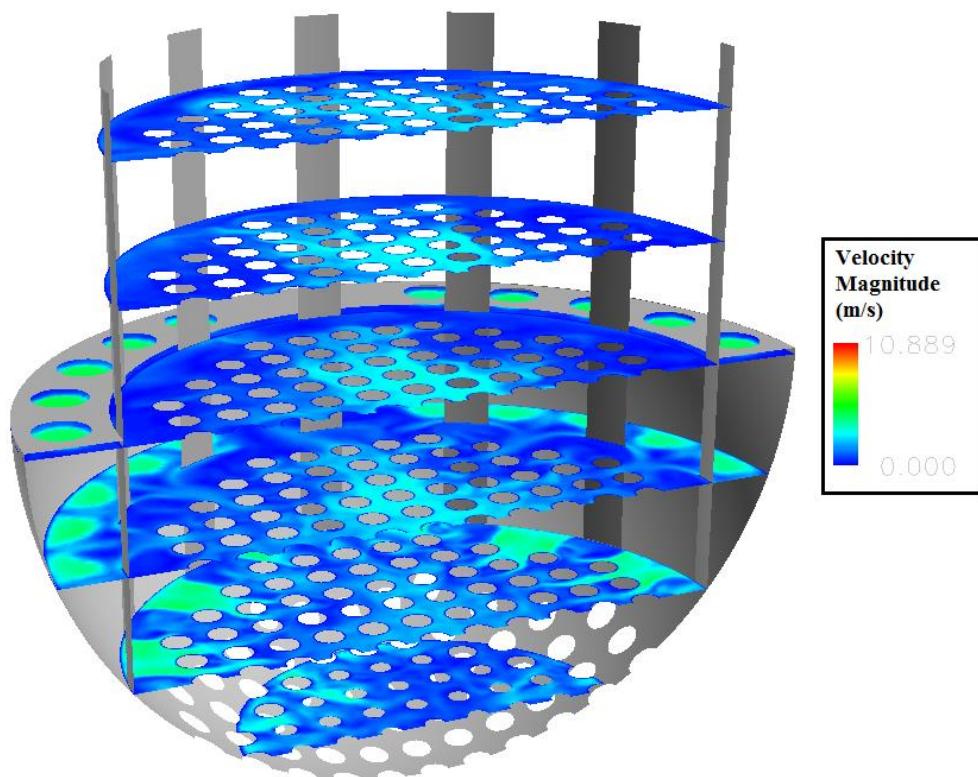
圖 31　爐心下盤區內不同高度之徑向截面速度分布圖
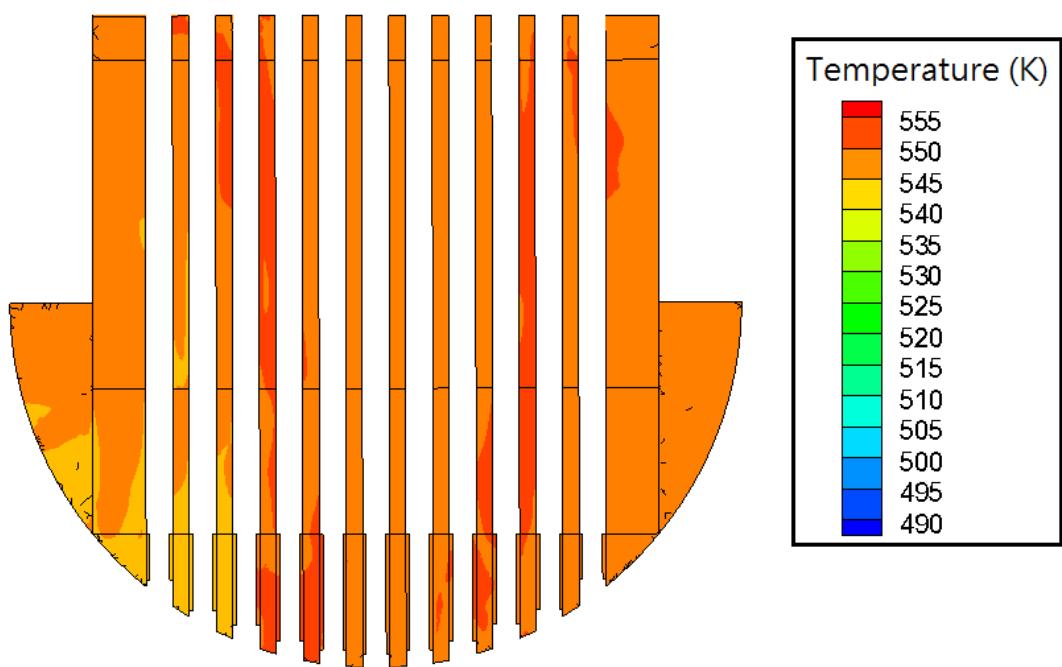
圖 32　爐心下盤區內溫度分布圖
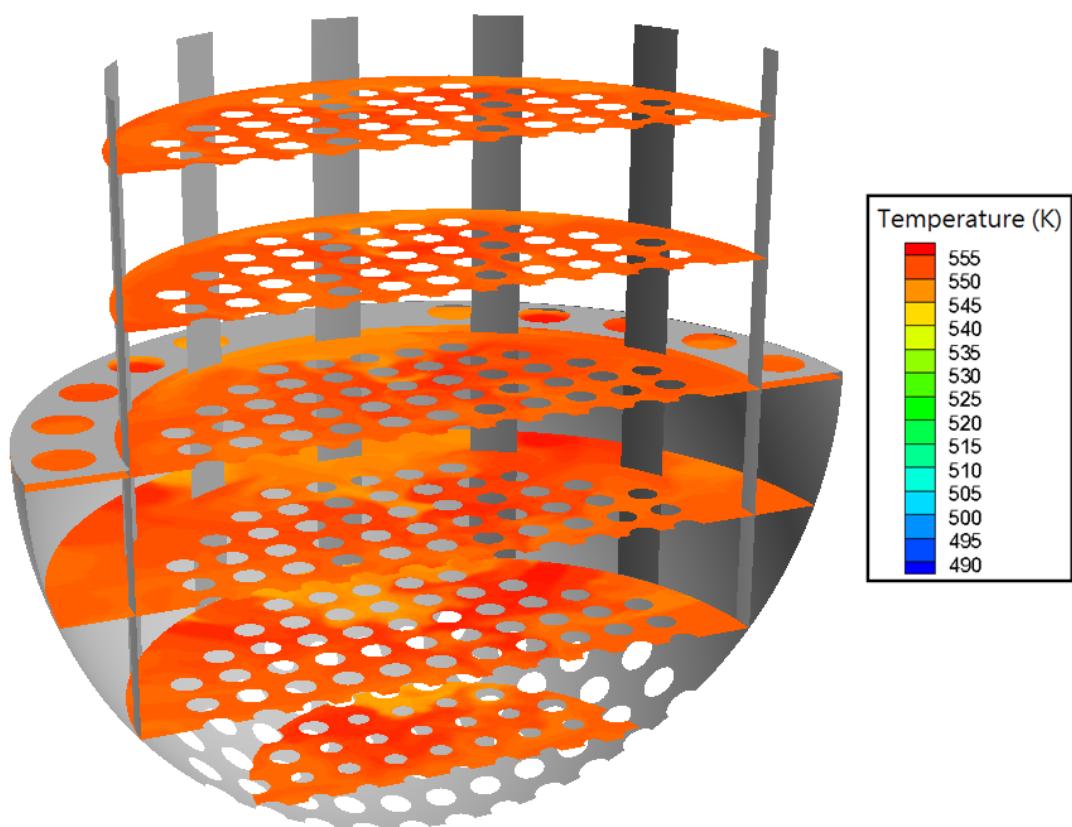
圖 33　爐心下盤區內不同高度之徑向截面溫度分布圖

事故發生第23秒　　　　　　　　　　　　　　　　正常運轉情況
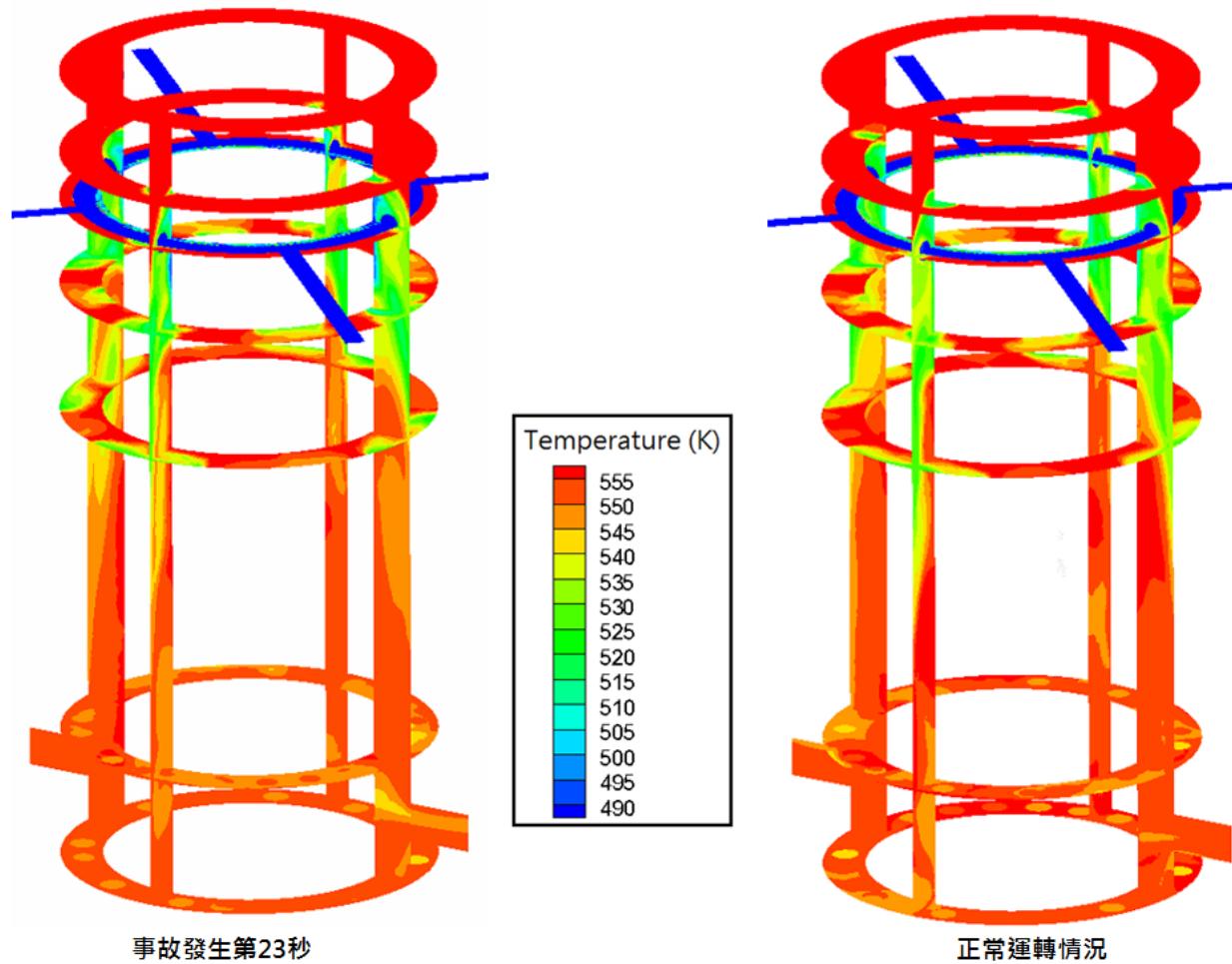
圖 34　降流區內溫度分布比較圖
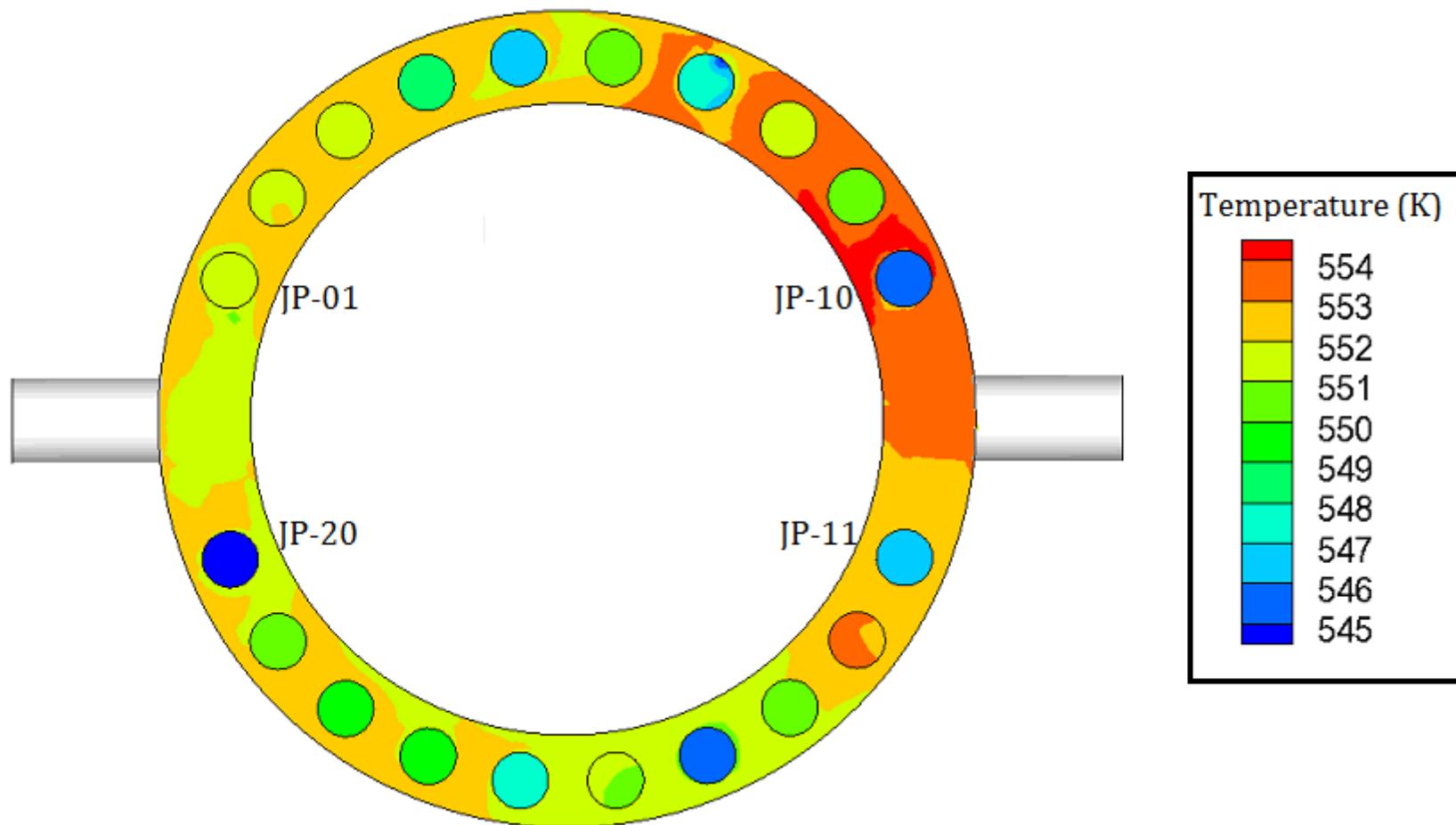
圖 35　事故發生後第 23 秒噴射泵溫度分布圖
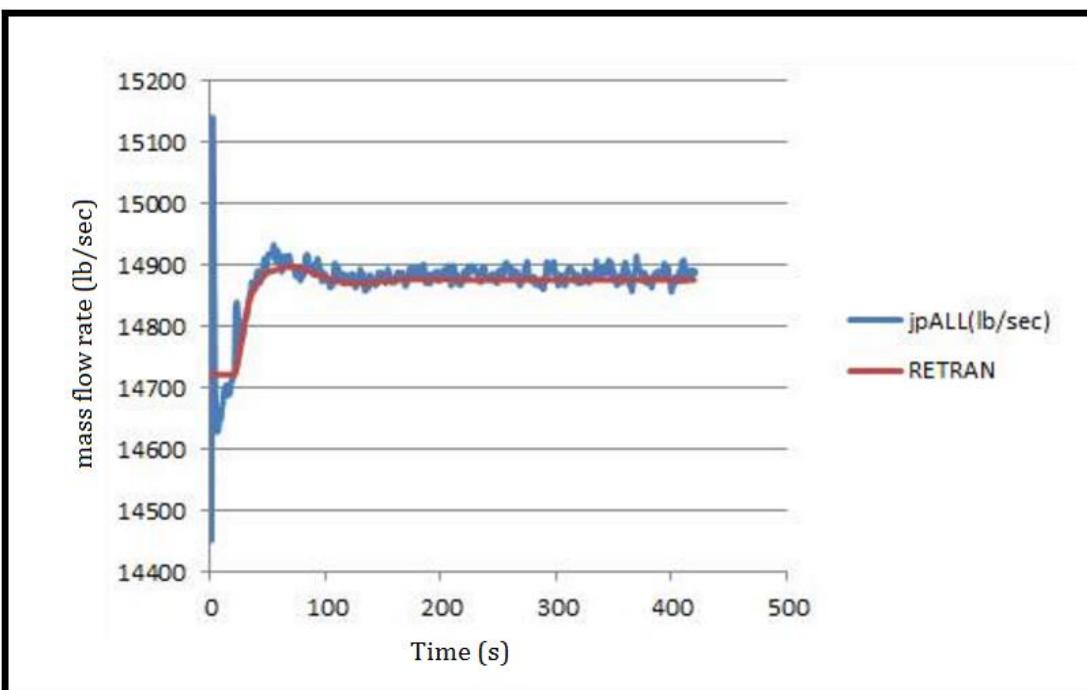
圖 36 噴射泵流量比較圖
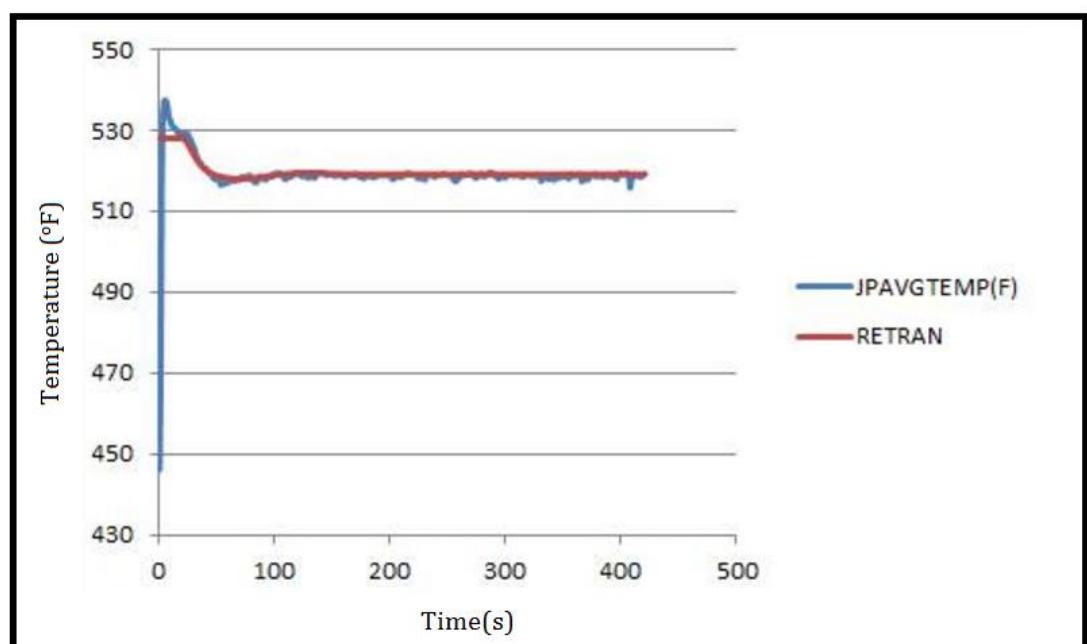
圖 37 噴射泵溫度比較圖
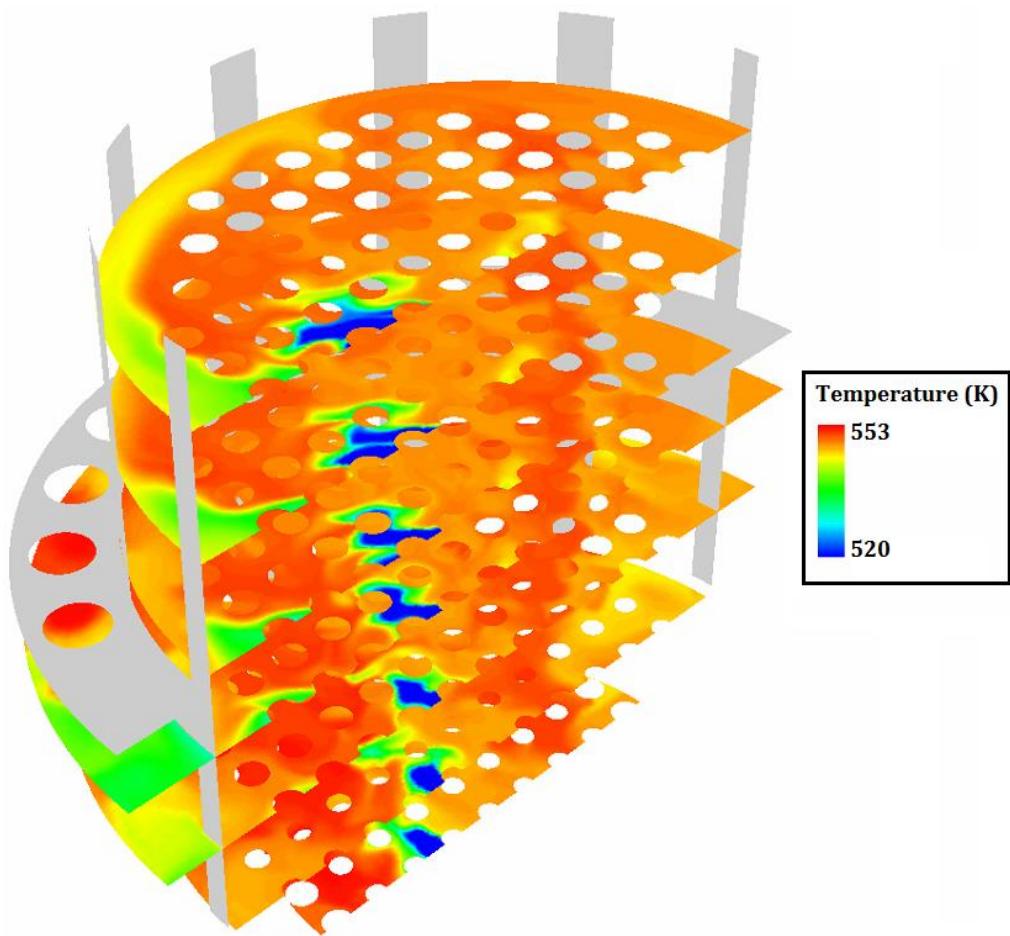
圖 38　事故發生後爐心下盤區溫度分布圖

二、用過核子燃料束於低流速下之流阻模擬結果

(一) 流場研析

　　如圖 3 所示，當冷卻劑由燃料束底部流入燃料束時，將會沿著燃料匣內的空間，分別流經燃料束或經由水棒向上流動；相較於燃料束所具有的緊密排列，水棒內的空間使得其內部流動的冷卻劑具有更低的壓損。而也因為整體分析處於低雷諾數、低流速之條件下，燃料束表面之壓力分佈並未因為所在位置與是否受格架影響而有顯著差異(圖 5)。

　　此一現象是因為沿著流場方向的速度分佈並未明顯在兩根燃料束相鄰處或是四根燃料束所組成的次通道間存在過於明顯的速度差異(圖 6)，故不致因為速度分佈所造成的側向流而影響其壓力分佈。整體而言，流場除了位於水棒出口(0.15m)是半長棒(3m)及燃料底座之處因為存在較大的幾何變化而導致速度分佈出現變化之外，並無其它區域在存在的顯著速度差，這也意味著在低流速下整體壓力分佈主要係來自於元件表面之摩擦壓損，而非源自於幾何形狀變化所造成的形阻。

　　此一陳述可以透過圖 72 所示之壓力沿軸線分佈之變化趨勢來加進一步加以探討；例如，水棒之壓力減除於中段呈現較為平緩的

線性下降趨勢之外，於頂部與底部則分別因為幾何形狀之改變及底部燃料匣噴嘴底部燃料支持板而呈現壓降現象；此外，在 0.5m 處的壓力上升，則是流道面積放寬後速度下降時，流體因白努力定律而造成的升壓現象。而在燃料束的部分則可發現，其壓力係逐步呈現近似線性下降之趨勢，且在無格架區之壓降因僅有摩擦流阻之故而使壓降明顯低於具有格架區間之壓力變化。

最後，透過以上對內部流場的探討可以得知，本研究所建立的分析模式確實能夠掌握燃料束內之流動特性，並求取其壓降以建立低雷諾數下燃料束流阻係數回歸式。
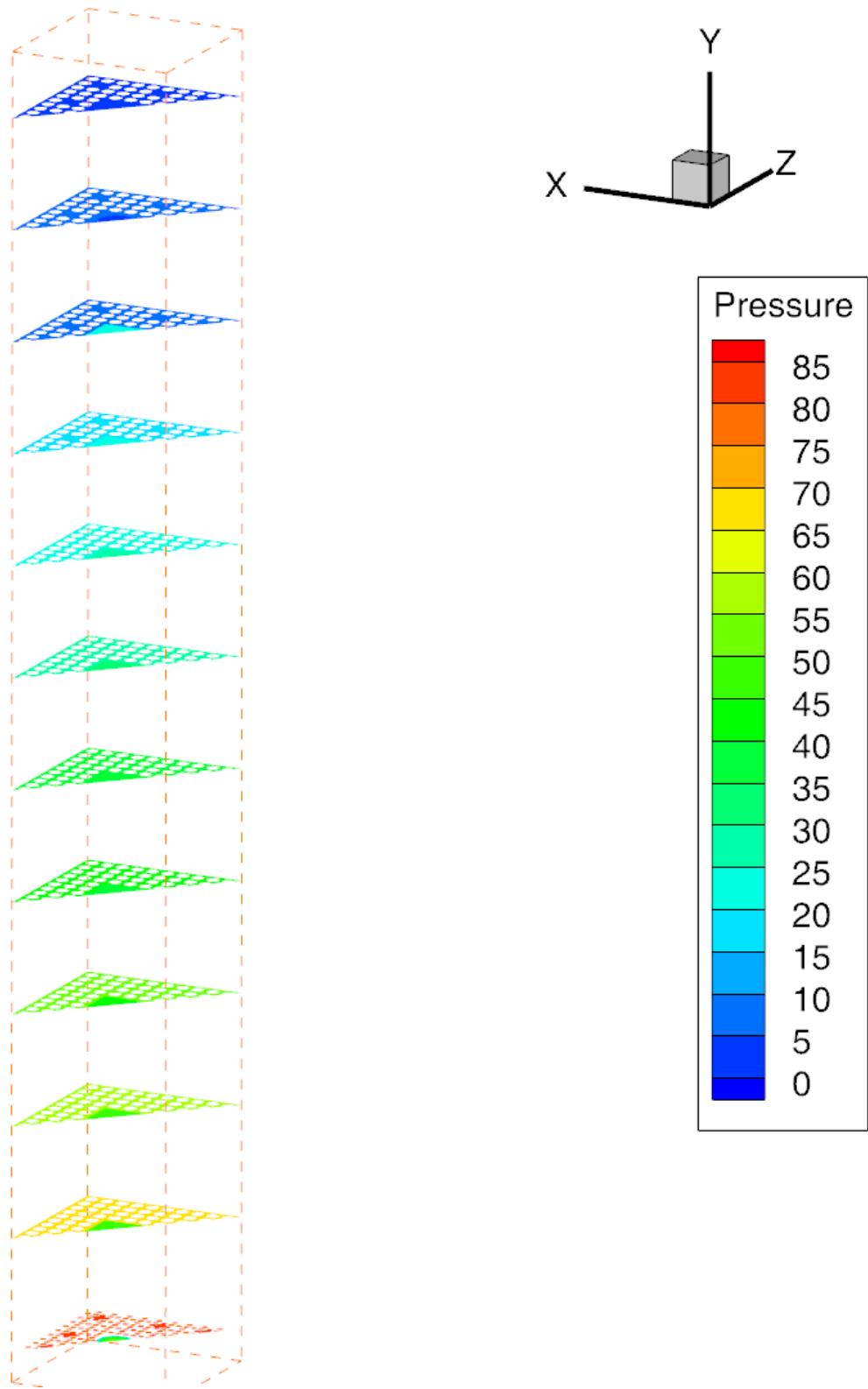
圖 39 整體流道截面之壓力分佈
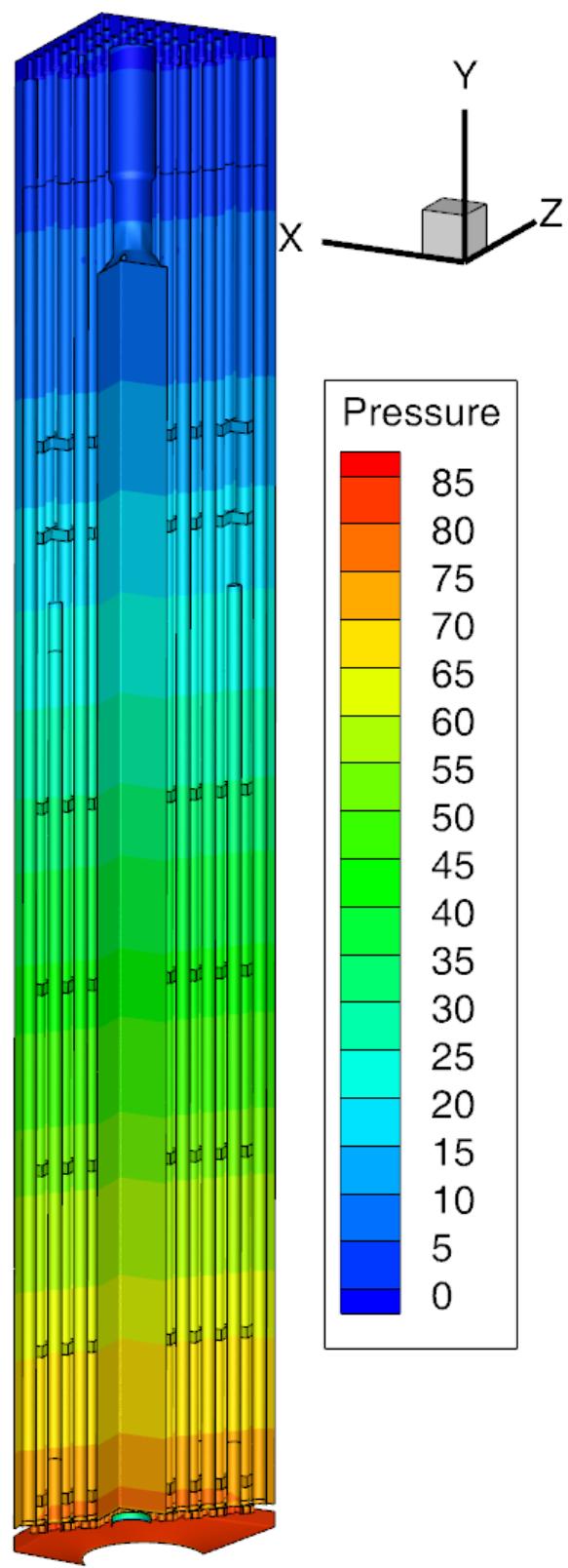
圖 5　整體燃料組件表面壓力分佈
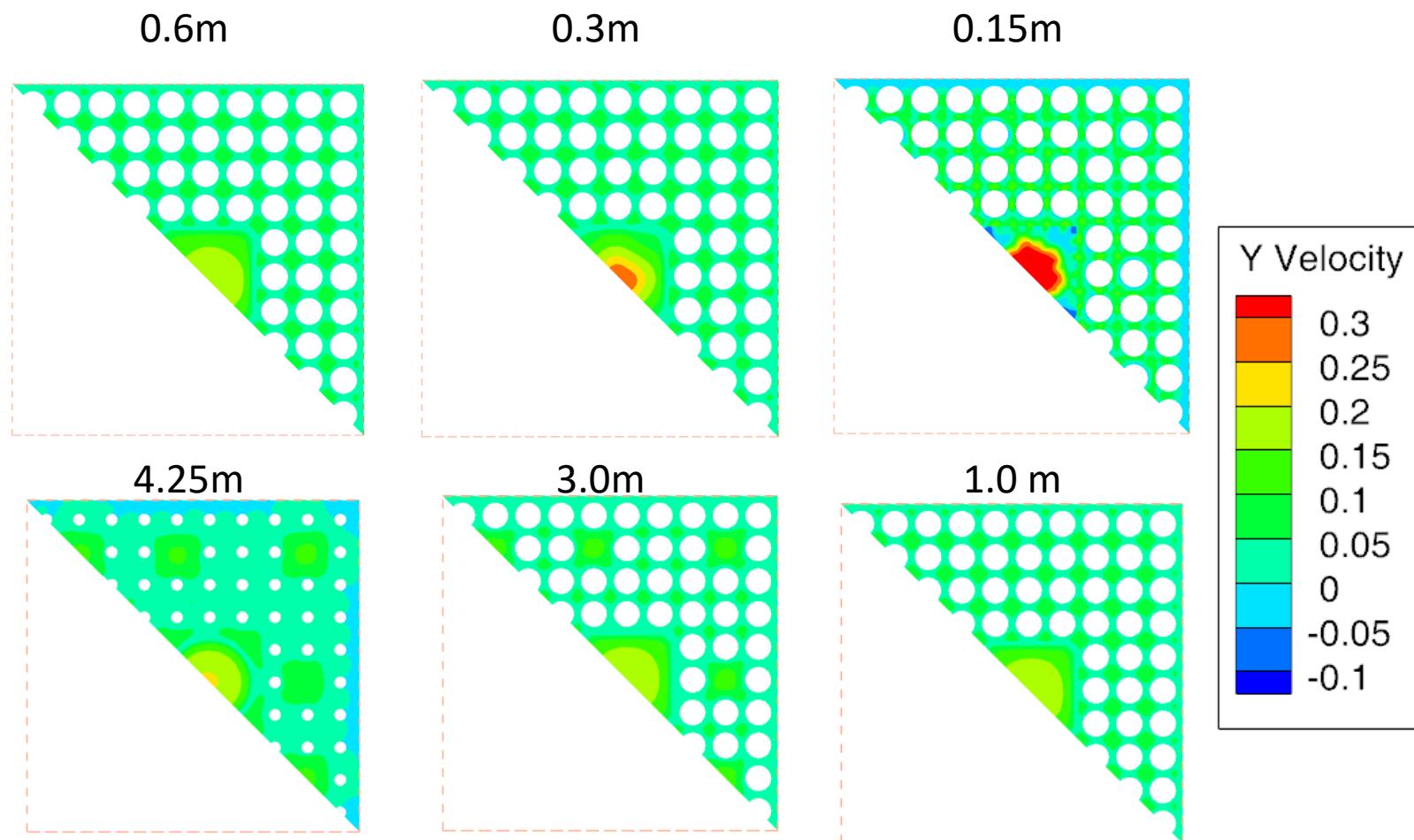
圖 6 不同流道高度之軸向速度分佈
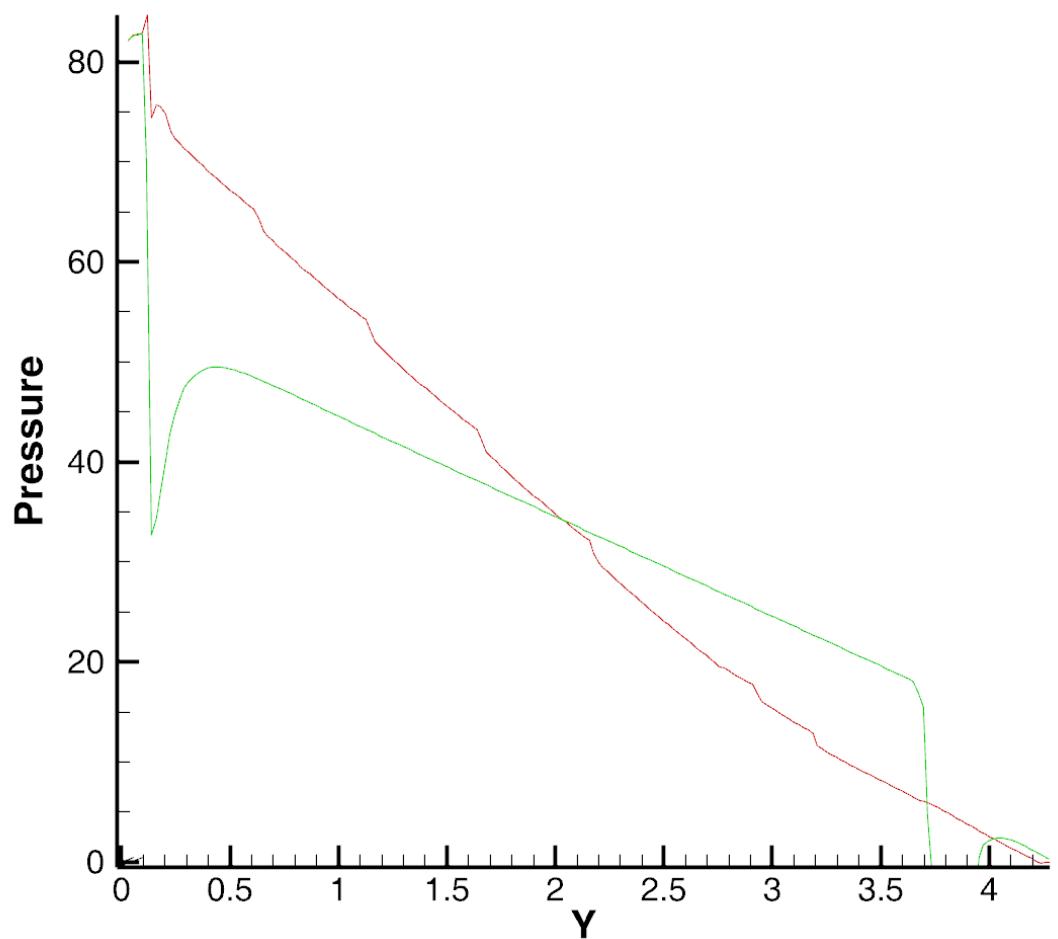
圖 7　　不同流道高度之壓力變化趨勢

(二) 低雷諾數下流阻計算

本研究所建立之 ATRIUM-10 燃料在經過檢驗與測試後，即可於不同進口流量條件下進行計算，進而求取在不同流量下之壓損結果，以作為後續建立流阻-流量關係式之依據。在將低雷諾數範圍之進口流速設定至所建立之分析模式後，即可利用 FLUENT 進行計算，而所獲流阻結果則如圖 8 所示。

若更進一步與 NED-CM-02A16804-CCS-001-01 所載之流阻特性(如圖 9)相比後可以發現，本研究分析所獲之 ATRIUM-10 燃料流阻係較原計算書略高。這是因為既有計算書中之分析模式係單純考慮流燃料束與水棒之效應，而未將進口噴嘴、格架與半長棒等效應納入考量之中。

而在獲得上述所載之分析結果後，仍需進行相關轉換，方能將計算所得之流阻轉換為對應之流阻係以供後續應用；為此本研究採用 FLUENT 中所包含的多孔性介質模式進行流阻係數之建立，此一模式是藉由在動量方程式額外增加一額外力源($\vec{F}$)來進行數值處理，以描述流體流經結構時受摩擦或形阻之影響；其方程式如下所示，藉由此式之應用，即可計算不同流速下之壓力降。

$$F = (\frac{\mu V}{K} + C_2\frac{\rho V^2}{2})$$

上式中$\frac{\mu V}{K}$與$C_2\frac{\rho V^2}{2}$分別代表黏滯壓降項以及慣性壓降項，

C_2＝單位長度之形狀阻力係數。

$\frac{1}{K}$為單位長度之黏滯阻力係數；

μ為流體黏滯係數；

$\vec{V}$為流體速度；

ρ為流體密度；

而經轉換後所得之流阻係則如表 6 所示。
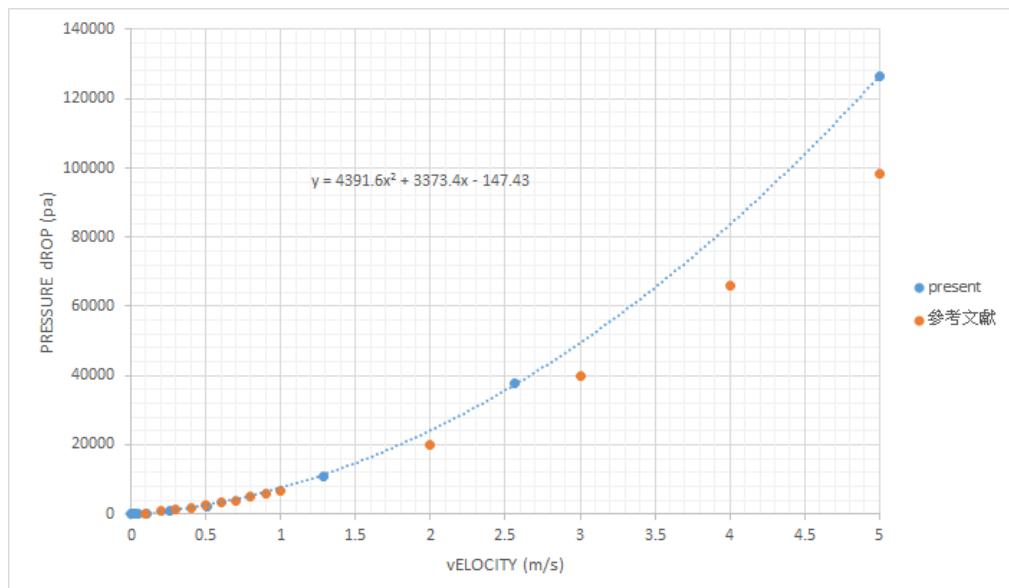
圖 8 考慮格架與提把等結構重新計算之

ATRIUM-10 燃料流阻係數
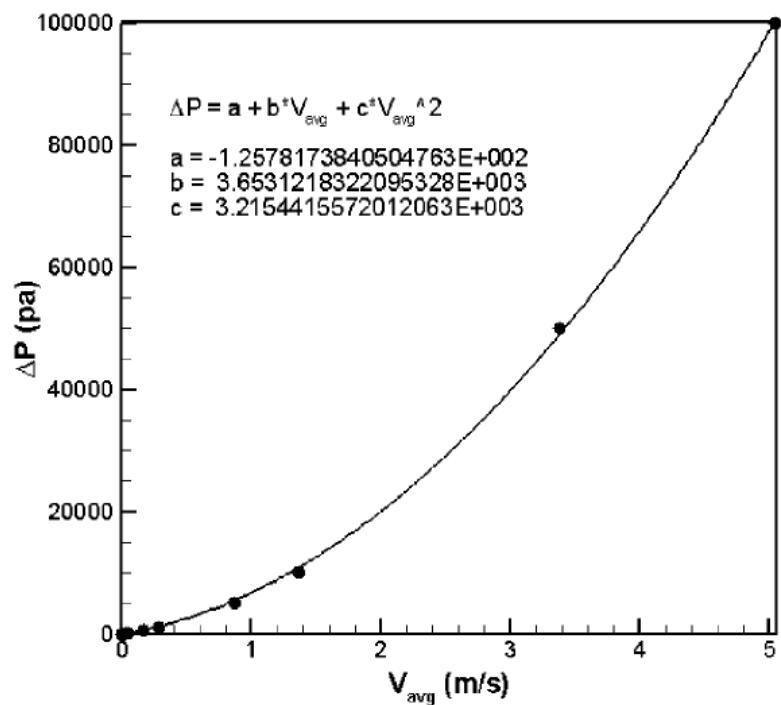
圖 9　既有 ATRIUM-10 燃料流阻係數

表 6、ATRIUM-10 燃料軸向流阻係數

	孔隙率 α	黏滯阻力係數 (viscous losses term，$1/m^2$)	慣性阻力係數C2 (inertial loss term，1/m)
ATRIUM-10	0.59	3.3633E6	8.79903

肆、主要發現與結論

本研究已於年度工作執行之同時，將計算流體力學分析技術應用於核一廠喪失飼水加熱之熱流分析與用過核子燃料束於低流速下之流阻之應用案例進行分析，並針對各項參數對熱流特性之影響靈敏度進行探討。其中，核一廠喪失飼水加熱之熱流分析將基於核研所既有之模型與分析模式進行延伸，除修正模型使其更符合真實電廠設計外，主要係將核一廠雷傳輸入模式與計算流體力學軟體(Computational Fluid Dynamic, CFD)進行整合分析，將雷傳程式之分析結果作為 CFD 邊界參數以進行暫態分析，以進一步釐清反應器內熱水流現象。其結果顯示，事故發生造成飼水進口溫度驟降，幾何結構與混合空間之限制將使爐心下盤區呈現不均勻溫度分布之現象，可預期將進一步影響燃料進口溫度。

而用過核子燃料束於低流速下之流阻之應用案例中，已成功建立用過燃料束模型，並針對網格尺寸進行靈敏度分析以評估其對分析結果之影響。由結果顯示，用過燃料束在低流速下整體壓力分佈主要係來自於元件表面之摩擦壓損，而非源自於幾何形狀變化所造成的形阻，並根據流場探討結果可得知本分析模式確實能夠掌握燃料束內之流動特性，並求取其壓降以建立低雷諾數下燃料束流阻係

數回歸式，亦同時完成在不同進口流量下用過燃料束之壓損結果，以作為後續建立流阻-流量關係式之依據。預期經由本研究之執行，將有助於進一步釐清相關應用案中之分析結果，並可作為未來分析之參數選擇的依據。

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附錄 A

摘要接受信

Subject: Abstract TopSafe2017-A0016 for TopSafe 2017 has been accepted
Date: Thu, 27 Oct 2016 12:22:27 +0200 (CEST)
From: "TopSafe2017" <TopSafe2017@euronuclear.org>
To: "s100011801" <s100011801@m100.nthu.edu.tw>

Dear Ms. Ku,

We are pleased to inform you that the TopSafe 2017 Programme Committee has approved your abstract.

Title: The Improvement of Downcomer and Lower-Plenum Model of Chinshan Nuclear Power Plant by Using CFD Simulation (TopSafe2017-A0016)

Presentation type: poster presentation

Session: Poster

Please note that a draft full paper of a minimum of 1000 words must be submitted by 15 December 2016.

Members of the TopSafe 2017 Programme Committee will screen this draft full paper and will come back to you in case they would like to ask for modifications.

Please carefully read the "Instructions for Authors" at www.topsafe2017.org before composing your Full Paper. You can find these instructions under 'Authors resources'. Your document will be published as received. Therefore, we highly recommend respecting our standard layout.

Deadline for submission of your final full paper is 20 January 2017.

Full papers which will not be submitted by the mentioned deadlines will be withdrawn from the programme.

To submit your draft full paper and your full paper please log in at:
https://oass.euronuclear.org/TopSafe2017/index_html

For oral presentations:
The presentation must be exclusively held in English! The time frame for all oral presentations is 15 minutes. Your presentation should in no case exceed the 15 minutes maximum. To simplify the introduction of you and your work the chairperson should have a short resume of your C.V.. Please submit your C.V. according the template provided on the TopSafe 2017 website.

The standard visual aid for you as a presenter will be a PowerPoint projection. Your presentation will be transferred to an on-site laptop.

Your Powerpoint presentation and CV should be in our hands by 3 February 2017 at the very latest. You can now log in and upload your presentation at: https://oass.euronuclear.org/TopSafe2017/index_html

For poster presentations:
Posters will be on displays throughout the conference. They should be hung up preferably on Monday morning 13 February 2017 before the beginning of the first session or during the first coffee break and must be taken off at the end of the conference. Please respect those indications and stick to the PORTRAIT format!

At least one author per paper is requested to attend personally the whole poster session to permit proper presentation and discussion of the poster.

To download the instructions for authors, the programme, to register or for any other additional organisational information regarding the conference you may consult our website: www.topsafe2017.org.

The Improvement of Downcomer and Lower-Plenum Model of Chinshan Nuclear Power Plant by Using CFD Simulation

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Jong-Rong Wang[2,3], and Chunkuan Shin[2,3]
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Abstract—In the past study, a commercial CFD model was established to investigate thermal-hydraulic phenomena in downcomer and lower-plenum of boiling water reactors (BWRs). The analyses of BWRs under steady operations as well as transient status were completed by using CFD code, FLUENT. Owing to model simplification, flow resistance caused by ignored components, such as fuel assembly, separator, and steam dryer, was not considered. However, the flow resistance has certain effects on follow-up calculations on flow velocity and pressure field. As the result, the reliability of the simplified model decreased.

This study focused on the improvement of the vessel model with considering the flow resistance caused by ignored components in the previous research, and the effects of the flow resistance was represented via an added porous zone at the outlet of the simplified model. The porous zone was generated to reach the purpose of approaching actual flow field and pressure distribution under operating conditions. The results showed that the pressure distribution and the flow field at the core inlet region were more approaching to the actual status in the improved model. We expected the results of the steady state of the improved model could be utilized on the initialization of transient events, and facilitated the safety analysis under different transient events afterwards.

Keywords—CFD, porous zone, sensitivity study.

附錄 B

LFWH_trans0814_v2

```
#include "udf.h"
#include "extfile_trans0814.h"
#include "mem.h"
/*本程式重要邏輯*/
/*1．利用c語言之全域變數使資料能於udf之間傳輸，fluent手冊有誤；主要作法是在要用的所有程
式裡宣告extern real 在.h中宣告為 real */
/*2．利用fleunt之function PRF_GRHIGH1(x)讀到各node之間的最大值，作為所有node的input，以
防止其中有一個node的input因為平行處理的切割而出現空值*/
/* 汽液分離器進口程式*/


DEFINE_PROFILE(mass_sp_vel,thread, position)
{
  real ro_avg, flow_flux;
  extern real j8m;
  face_t f;
#if !PR_HOST


    begin_f_loop(f, thread)
  {
     F_PROFILE(f, thread, position) =j8m/F_R(f,thread)/8.3782587;
  }
  end_f_loop(f, thread)


#endif /* !PR_HOST*/



#if !RP_NODE


    begin_f_loop(f, thread)
  {
     F_PROFILE(f, thread, position) =j8m/F_R(f,thread)/8.3782587;
  }
```

```
      end_f_loop(f, thread)


#endif /* !RP_NODE*/


#if !PARALLEL


        begin_f_loop(f, thread)
  {
      F_PROFILE(f, thread, position) =j8m/F_R(f,thread)/8.3782587;
  }
  end_f_loop(f, thread)


#endif /* !PARRLLEL*/
}


DEFINE_PROFILE(mass_sp_temp,thread, position)
{
  real Tfluid;
extern real j8t;
  face_t f;


#if !PR_HOST
Tfluid=PRF_GRHIGH1(j8t);
begin_f_loop(f, thread)
  {
      F_PROFILE(f, thread, position) =j8t;
  }
  end_f_loop(f, thread)
#endif /* !PR_HOST*/


#if !RP_NODE
Tfluid=PRF_GRHIGH1(j8t);
begin_f_loop(f, thread)
  {
      F_PROFILE(f, thread, position) =j8t;
  }
  end_f_loop(f, thread)
```

```c
#endif /* !RP_NODE*/


#if !PARALLEL
Tfluid=PRF_GRHIGH1(j8t);
begin_f_loop(f, thread)
  {
      F_PROFILE(f, thread, position) =j8t;
  }
  end_f_loop(f, thread)
#endif /* !PARRLLEL*/
}
/* 汽液分離器進口程式*/


/* 飼水進口程式*/

DEFINE_PROFILE(fw_vel,thread, position)
{
  real ro_avg, flow_flux;
  extern real j600m;
  face_t f;
#if !PR_HOST

      begin_f_loop(f, thread)
  {
      F_PROFILE(f, thread, position) =j600m/F_R(f,thread)/0.24578486;
  }
  end_f_loop(f, thread)


#endif /* !PR_HOST*/


#if !RP_NODE

      begin_f_loop(f, thread)
  {
```

```
            F_PROFILE(f, thread, position) =j600m/F_R(f,thread)/0.24578486;
    }
    end_f_loop(f, thread)


#endif /* !RP_NODE*/


#if !PARALLEL


            begin_f_loop(f, thread)
    {
        F_PROFILE(f, thread, position) =j600m/F_R(f,thread)/0.24578486;
    }
    end_f_loop(f, thread)


#endif /* !PARRLLEL*/
}



DEFINE_PROFILE(fw_temp,thread, position)
{
    real Tfluid;
extern real  j600t;
    face_t f;


#if !PR_HOST
Tfluid=PRF_GRHIGH1(j600t);
begin_f_loop(f, thread)
    {
        F_PROFILE(f, thread, position) =j600t;
    }
    end_f_loop(f, thread)
#endif /* !PR_HOST*/


#if !RP_NODE
Tfluid=PRF_GRHIGH1(j600t);
begin_f_loop(f, thread)
    {
```

```c
            F_PROFILE(f, thread, position) =j600t;
    }
    end_f_loop(f, thread)
#endif /* !RP_NODE*/


#if !PARALLEL
Tfluid=PRF_GRHIGH1(j600t);
begin_f_loop(f, thread)
    {
        F_PROFILE(f, thread, position) =j600t;
    }
    end_f_loop(f, thread)
#endif /* !PARRLLEL*/
}
/* 飼水進口程式*/


DEFINE_PROFILE(jp_1_vel,thread, position)
{
    real ro_avg, flow_flux;
    extern real j13m;
    face_t f;
#if !PR_HOST

        begin_f_loop(f, thread)
    {
        F_PROFILE(f, thread, position) =j13m/F_R(f,thread)/0.2212372;
    }
    end_f_loop(f, thread)

#endif /* !PR_HOST*/


#if !RP_NODE

        begin_f_loop(f, thread)
```

```
    {
        F_PROFILE(f, thread, position) =j13m/F_R(f,thread)/0.2212372;
    }
    end_f_loop(f, thread)


#endif /* !RP_NODE*/


#if !PARALLEL


            begin_f_loop(f, thread)
    {
        F_PROFILE(f, thread, position) =j13m/F_R(f,thread)/0.2212372;
    }
    end_f_loop(f, thread)


#endif /* !PARRLLEL*/
}



DEFINE_PROFILE(jp_2_vel,thread, position)
{
    real ro_avg, flow_flux;
    extern real j12m;
    face_t f;
#if !PR_HOST


            begin_f_loop(f, thread)
    {
        F_PROFILE(f, thread, position) =j12m/F_R(f,thread)/0.2212372;
    }
    end_f_loop(f, thread)


#endif /* !PR_HOST*/



#if !RP_NODE
```

```
            begin_f_loop(f, thread)
    {
        F_PROFILE(f, thread, position) =j12m/F_R(f,thread)/0.2212372;
    }
    end_f_loop(f, thread)


#endif /* !RP_NODE*/


#if !PARALLEL


            begin_f_loop(f, thread)
    {
        F_PROFILE(f, thread, position) =j12m/F_R(f,thread)/0.2212372;
    }
    end_f_loop(f, thread)
#endif /* !PARRLLEL*/
}




DEFINE_PROFILE(recirc_1_vel,thread, position)
{
    real ro_avg, flow_flux;
    extern real j13m, j13q;
    face_t f;
#if !PR_HOST
flow_flux=0;
ro_avg=0;
begin_f_loop(f, thread)
    {
        flow_flux+=F_FLUX(f,thread);
        ro_avg+=F_FLUX(f,thread)*F_R(f,thread);
    }
    end_f_loop(f, thread)


        begin_f_loop(f, thread)
    {
```

```
            F_PROFILE(f, thread, position) =-j13m/(ro_avg/flow_flux)/0.22117029;
  }
  end_f_loop(f, thread)


#endif /* !PR_HOST*/



#if !RP_NODE
flow_flux=0;
ro_avg=0;
begin_f_loop(f, thread)
  {
    flow_flux+=F_FLUX(f,thread);
     ro_avg+=F_FLUX(f,thread)*F_R(f,thread);
  }
  end_f_loop(f, thread)


      begin_f_loop(f, thread)
  {
     F_PROFILE(f, thread, position) =-j13m/(ro_avg/flow_flux)/0.22117029;
  }
  end_f_loop(f, thread)


#endif /* !RP_NODE*/

#if !PARALLEL
flow_flux=0;
ro_avg=0;
begin_f_loop(f, thread)
  {
    flow_flux+=F_FLUX(f,thread);
     ro_avg+=F_FLUX(f,thread)*F_R(f,thread);
  }
  end_f_loop(f, thread)


      begin_f_loop(f, thread)
  {
```

```c
        F_PROFILE(f, thread, position) =-j13m/(ro_avg/flow_flux)/0.22117029;
    }
  end_f_loop(f, thread)


#endif /* !PARRLLEL*/
}

DEFINE_PROFILE(recirc_2_vel,thread, position)
{
  real ro_avg, flow_flux;
  extern real j12m, j12q;
  face_t f;
#if !PR_HOST
flow_flux=0;
ro_avg=0;
begin_f_loop(f, thread)
  {
    flow_flux+=F_FLUX(f,thread);
     ro_avg+=F_FLUX(f,thread)*F_R(f,thread);
  }
  end_f_loop(f, thread)


      begin_f_loop(f, thread)
  {
      F_PROFILE(f, thread, position) =-j12m/(ro_avg/flow_flux)/0.22117029;
  }
  end_f_loop(f, thread)


#endif /* !PR_HOST*/


#if !RP_NODE
      flow_flux=0;
ro_avg=0;
begin_f_loop(f, thread)
  {
    flow_flux+=F_FLUX(f,thread);
```

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```c
        ro_avg+=F_FLUX(f,thread)*F_R(f,thread);
    }
    end_f_loop(f, thread)


        begin_f_loop(f, thread)
    {
        F_PROFILE(f, thread, position) =-j12m/(ro_avg/flow_flux)/0.22117029;
    }
    end_f_loop(f, thread)


#endif /* !RP_NODE*/


#if !PARALLEL
        flow_flux=0;
ro_avg=0;
begin_f_loop(f, thread)
    {
        flow_flux+=F_FLUX(f,thread);
        ro_avg+=F_FLUX(f,thread)*F_R(f,thread);
    }
    end_f_loop(f, thread)


        begin_f_loop(f, thread)
    {
        F_PROFILE(f, thread, position) =-j12m/(ro_avg/flow_flux)/0.22117029;
    }
    end_f_loop(f, thread)


#endif /* !PARRLLEL*/
}



DEFINE_PROFILE(recirc_1_temp,thread, position)
{
    real   flow_flux,power_flux;
extern real rercic_1;   /*define the temp_out is a enternal variable*/
```

```
      face_t f;

#if !PR_HOST
rercic_1=0;
flow_flux=0;
power_flux=0;
begin_f_loop(f, thread)
  {
     flow_flux+=F_FLUX(f,thread);
      power_flux+=F_FLUX(f,thread)*F_T(f,thread);
  }
  end_f_loop(f, thread)
       if (abs(flow_flux) >0.)
rercic_1=power_flux/(flow_flux);
       else
           rercic_1=0.0;

#endif /* !PR_HOST*/


#if !RP_NODE
rercic_1=0;
flow_flux=0;
power_flux=0;
begin_f_loop(f, thread)
  {
     flow_flux+=F_FLUX(f,thread);
      power_flux+=F_FLUX(f,thread)*F_T(f,thread);
  }
  end_f_loop(f, thread)
       if (abs(flow_flux) >0.)
rercic_1=power_flux/(flow_flux);
       else
           rercic_1=0.0;
#endif /* !RP_NODE*/


#if !PARALLEL
```

```
rercic_1=0;
flow_flux=0;
power_flux=0;
begin_f_loop(f, thread)
  {
    flow_flux+=F_FLUX(f,thread);
     power_flux+=F_FLUX(f,thread)*F_T(f,thread);
  }
  end_f_loop(f, thread)
      if (abs(flow_flux) >0.)
rercic_1=power_flux/(flow_flux);
     else
          rercic_1=0.0;
#endif /* !PARRLLEL*/
}


DEFINE_PROFILE(recirc_2_temp,thread, position)
{
  real   flow_flux,power_flux;
extern real rercic_2;   /*define the temp_out is a enternal variable*/
  face_t f;

#if !PR_HOST
  rercic_2=0;
  flow_flux=0;
power_flux=0;
begin_f_loop(f, thread)
  {
    flow_flux+=F_FLUX(f,thread);
     power_flux+=F_FLUX(f,thread)*F_T(f,thread);
  }
  end_f_loop(f, thread)
      if (abs(flow_flux) >0.)
rercic_2=power_flux/(flow_flux);
     else
          rercic_2=0.0;
```

```
#endif /* !PR_HOST*/


#if !RP_NODE
   rercic_2=0;
   flow_flux=0;
power_flux=0;
begin_f_loop(f, thread)
  {
    flow_flux+=F_FLUX(f,thread);
     power_flux+=F_FLUX(f,thread)*F_T(f,thread);
  }
  end_f_loop(f, thread)
       if (abs(flow_flux) >0.)
rercic_2=power_flux/(flow_flux);
       else
             rercic_2=0.0;


#endif /* !RP_NODE*/


#if !PARALLEL
   rercic_2=0;
   flow_flux=0;
power_flux=0;
begin_f_loop(f, thread)
  {
    flow_flux+=F_FLUX(f,thread);
     power_flux+=F_FLUX(f,thread)*F_T(f,thread);
  }
  end_f_loop(f, thread)
       if (abs(flow_flux) >0.)
rercic_2=power_flux/(flow_flux);
       else
             rercic_2=0.0;


#endif /* !PARRLLEL*/
}
```

```
/*for cavity inlet temp*/

DEFINE_PROFILE(jp_1_temp,thread, position)
{
  real Tfluid, CP_v;
extern real rercic_1, j13q ,j13m;
  face_t f;

#if !PR_HOST
Tfluid=PRF_GRHIGH1(rercic_1);

begin_f_loop(f, thread)
  {
      CP_v=2390.+(1054.22*((F_T(f, thread)-470.)/120.));   /*此處CP的計算使用470K~590K數
值之內差*/
       F_PROFILE(f, thread, position) =Tfluid+j13q*0.293/CP_v/j13m;
  }
  end_f_loop(f, thread)
#endif /* !PR_HOST*/

#if !RP_NODE
Tfluid=PRF_GRHIGH1(rercic_1);

begin_f_loop(f, thread)
  {
      CP_v=2390.+(1054.22*((F_T(f, thread)-470.)/120.));   /*此處CP的計算使用470K~590K數
值之內差*/
       F_PROFILE(f, thread, position) =Tfluid+j13q*0.293/CP_v/j13m;
  }
  end_f_loop(f, thread)
#endif /* !RP_NODE*/


#if !PARALLEL
Tfluid=PRF_GRHIGH1(rercic_1);
```

```
begin_f_loop(f, thread)
    {
        CP_v=2390.+(1054.22*((F_T(f, thread)-470.)/120.));   /*此處CP的計算使用470K~590K數
值之內差*/
        F_PROFILE(f, thread, position) =Tfluid+j13q*0.293/CP_v/j13m;


    }
    end_f_loop(f, thread)
#endif /* !PARRLLEL*/
}




DEFINE_PROFILE(jp_2_temp,thread, position)
{
    real Tfluid, CP_v;
extern real rercic_2, j12m, j12q;
    face_t f;

#if !PR_HOST
    Tfluid=PRF_GRHIGH1(rercic_2);

begin_f_loop(f, thread)
    {
        CP_v=2390.+(1054.22*((F_T(f, thread)-470.)/120.));   /*此處CP的計算使用470K~590K數
值之內差*/
        F_PROFILE(f, thread, position) =Tfluid+j12q*0.293/CP_v/j12m;



    }
    end_f_loop(f, thread)
#endif /* !PR_HOST*/

#if !RP_NODE
```

```c
    Tfluid=PRF_GRHIGH1(rercic_2);

begin_f_loop(f, thread)
  {
      CP_v=2390.+(1054.22*((F_T(f, thread)-470.)/120.));   /*此處CP的計算使用470K~590K數
值之內差*/
       F_PROFILE(f, thread, position) =Tfluid+j12q*0.293/CP_v/j12m;
  }
  end_f_loop(f, thread)
#endif /* !RP_NODE*/


#if !PARALLEL
  Tfluid=PRF_GRHIGH1(rercic_2);

begin_f_loop(f, thread)
  {
      CP_v=2390.+(1054.22*((F_T(f, thread)-470.)/120.));   /*此處CP的計算使用470K~590K數
值之內差*/
       F_PROFILE(f, thread, position) =Tfluid+j12q*0.293/CP_v/j12m;
  }
  end_f_loop(f, thread)
#endif /* !PARRLLEL*/
}



DEFINE_PROFILE(wall,t,i)
{
  face_t f;
  int index;/*注意下行中retran[1616]的數字要與暫態資料量相符*/
  real retran[6736]=
  {
1.2585380E+04,5.4559797E+02,0.0000000E+00,5.2798037E+02,0.0000000E+00,5.2798037E+02,2.
1372715E+03,4.1323232E+02,3.0807600E+03,5.2799080E+02,3.0807600E+03,5.2799080E+02,7.47
41696E+06,7.4741696E+06,6.9473346E+02,3.5171915E+03,
```

85

1.2585043E+04,5.4559809E+02,0.0000000E+00,5.2797971E+02,0.0000000E+00,5.2797971E+02,2.1372358E+03,4.1323232E+02,3.0807603E+03,5.2799075E+02,3.0807603E+03,5.2799075E+02,7.4741698E+06,7.4741698E+06,6.9478889E+02,3.5173532E+03,

1.2585035E+04,5.4559832E+02,0.0000000E+00,5.2797923E+02,0.0000000E+00,5.2797923E+02,2.1372129E+03,4.1323232E+02,3.0807601E+03,5.2799061E+02,3.0807601E+03,5.2799061E+02,7.4741716E+06,7.4741716E+06,6.9492032E+02,3.5175010E+03,

1.2585043E+04,5.4559851E+02,0.0000000E+00,5.2797893E+02,0.0000000E+00,5.2797893E+02,2.1371915E+03,4.1323232E+02,3.0807608E+03,5.2799042E+02,3.0807608E+03,5.2799042E+02,7.4741728E+06,7.4741728E+06,6.9508707E+02,3.5175895E+03,

1.2585056E+04,5.4559864E+02,0.0000000E+00,5.2797875E+02,0.0000000E+00,5.2797875E+02,2.1371713E+03,4.1323232E+02,3.0807616E+03,5.2799023E+02,3.0807616E+03,5.2799023E+02,7.4741740E+06,7.4741740E+06,6.9525681E+02,3.5176376E+03,

1.2585068E+04,5.4559872E+02,0.0000000E+00,5.2797866E+02,0.0000000E+00,5.2797866E+02,2.1371531E+03,4.1323232E+02,3.0807624E+03,5.2799005E+02,3.0807624E+03,5.2799005E+02,7.4741755E+06,7.4741755E+06,6.9540962E+02,3.5176586E+03,

1.2585076E+04,5.4559877E+02,0.0000000E+00,5.2797862E+02,0.0000000E+00,5.2797862E+02,2.1371378E+03,4.1323232E+02,3.0807631E+03,5.2798988E+02,3.0807631E+03,5.2798988E+02,7.4741773E+06,7.4741773E+06,6.9553550E+02,3.5176632E+03,

1.2585084E+04,5.4559880E+02,0.0000000E+00,5.2797863E+02,0.0000000E+00,5.2797863E+02,2.1371251E+03,4.1323232E+02,3.0807637E+03,5.2798974E+02,3.0807637E+03,5.2798974E+02,7.4741791E+06,7.4741791E+06,6.9563115E+02,3.5176588E+03,

1.2585092E+04,5.4559882E+02,0.0000000E+00,5.2797866E+02,0.0000000E+00,5.2797866E+02,2.1371138E+03,4.1323232E+02,3.0807642E+03,5.2798963E+02,3.0807642E+03,5.2798963E+02,7.4741807E+06,7.4741807E+06,6.9569717E+02,3.5176500E+03,

1.2585102E+04,5.4559883E+02,0.0000000E+00,5.2797870E+02,0.0000000E+00,5.2797870E+02,2.1371029E+03,4.1323232E+02,3.0807646E+03,5.2798954E+02,3.0807646E+03,5.2798954E+02,7.4741821E+06,7.4741821E+06,6.9573594E+02,3.5176386E+03,

1.2585111E+04,5.4559884E+02,0.0000000E+00,5.2797876E+02,0.0000000E+00,5.2797876E+02,2.1370921E+03,4.1323232E+02,3.0807649E+03,5.2798948E+02,3.0807649E+03,5.2798948E+02,7.4741833E+06,7.4741833E+06,6.9575052E+02,3.5176253E+03,

1.2585119E+04,5.4559885E+02,0.0000000E+00,5.2797882E+02,0.0000000E+00,5.2797882E+02,2.1370818E+03,4.1323232E+02,3.0807650E+03,5.2798944E+02,3.0807650E+03,5.2798944E+02,7.4741844E+06,7.4741844E+06,6.9574423E+02,3.5176109E+03,

1.2585125E+04,5.4559886E+02,0.0000000E+00,5.2797889E+02,0.0000000E+00,5.2797889E+02,2.1370722E+03,4.1323232E+02,3.0807651E+03,5.2798941E+02,3.0807651E+03,5.2798941E+02,7.4741853E+06,7.4741853E+06,6.9572046E+02,3.5175962E+03,

1.2585132E+04,5.4559887E+02,0.0000000E+00,5.2797896E+02,0.0000000E+00,5.2797896E+02,2.

1370635E+03,4.1323232E+02,3.0807650E+03,5.2798940E+02,3.0807650E+03,5.2798940E+02,7.47
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1370552E+03,4.1323232E+02,3.0807650E+03,5.2798941E+02,3.0807650E+03,5.2798941E+02,7.47
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1370474E+03,4.1323232E+02,3.0807649E+03,5.2798943E+02,3.0807649E+03,5.2798943E+02,7.47
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1370398E+03,4.1323232E+02,3.0807647E+03,5.2798945E+02,3.0807647E+03,5.2798945E+02,7.47
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1.2725642E+04,5.4563382E+02,0.0000000E+00,5.1959190E+02,0.0000000E+00,5.1959190E+02,2.1874452E+03,3.4121152E+02,3.1081267E+03,5.2176103E+02,3.1081267E+03,5.2176103E+02,7.5220643E+06,7.5220643E+06,5.4017543E+03,5.2760061E+03,

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2834633E+03,3.4121152E+02,3.1213043E+03,5.1801604E+02,3.1213043E+03,5.1801604E+02,7.57
42328E+06,7.5742328E+06,3.4765102E+03,5.5270291E+03,

1.2617797E+04,5.4588546E+02,0.0000000E+00,5.1785066E+02,0.0000000E+00,5.1785066E+02,2.
2824902E+03,3.4121152E+02,3.1213866E+03,5.1799165E+02,3.1213866E+03,5.1799165E+02,7.57

45780E+06,7.5745780E+06,3.3821863E+03,5.5266535E+03,

1.2618683E+04,5.4588284E+02,0.0000000E+00,5.1784788E+02,0.0000000E+00,5.1784788E+02,2.2812095E+03,3.4121152E+02,3.1214572E+03,5.1797058E+02,3.1214572E+03,5.1797058E+02,7.5748873E+06,7.5748873E+06,3.2893641E+03,5.5255660E+03,

1.2619777E+04,5.4588020E+02,0.0000000E+00,5.1784868E+02,0.0000000E+00,5.1784868E+02,2.2796430E+03,3.4121152E+02,3.1215144E+03,5.1795287E+02,3.1215144E+03,5.1795287E+02,7.5751639E+06,7.5751639E+06,3.1979108E+03,5.5237672E+03,

1.2621057E+04,5.4587759E+02,0.0000000E+00,5.1785301E+02,0.0000000E+00,5.1785301E+02,2.2778157E+03,3.4121152E+02,3.1215580E+03,5.1793857E+02,3.1215580E+03,5.1793857E+02,7.5754082E+06,7.5754082E+06,3.1077192E+03,5.5212915E+03,

1.2622529E+04,5.4587504E+02,0.0000000E+00,5.1786077E+02,0.0000000E+00,5.1786077E+02,2.2757454E+03,3.4121152E+02,3.1215882E+03,5.1792769E+02,3.1215882E+03,5.1792769E+02,7.5756193E+06,7.5756193E+06,3.0187097E+03,5.5181855E+03,

1.2624198E+04,5.4587260E+02,0.0000000E+00,5.1787187E+02,0.0000000E+00,5.1787187E+02,2.2734419E+03,3.4121152E+02,3.1216056E+03,5.1792022E+02,3.1216056E+03,5.1792022E+02,7.5757963E+06,7.5757963E+06,2.9308228E+03,5.5144882E+03,

1.2626052E+04,5.4587027E+02,0.0000000E+00,5.1788623E+02,0.0000000E+00,5.1788623E+02,2.2709148E+03,3.4121152E+02,3.1216101E+03,5.1791614E+02,3.1216101E+03,5.1791614E+02,7.5759394E+06,7.5759394E+06,2.8440137E+03,5.5102272E+03,

1.2628067E+04,5.4586806E+02,0.0000000E+00,5.1790374E+02,0.0000000E+00,5.1790374E+02,2.2681786E+03,3.4121152E+02,3.1216013E+03,5.1791542E+02,3.1216013E+03,5.1791542E+02,7.5760494E+06,7.5760494E+06,2.7582521E+03,5.5054274E+03,

1.2630226E+04,5.4586592E+02,0.0000000E+00,5.1792427E+02,0.0000000E+00,5.1792427E+02,2.2652524E+03,3.4121152E+02,3.1215794E+03,5.1791802E+02,3.1215794E+03,5.1791802E+02,7.5761266E+06,7.5761266E+06,2.6735242E+03,5.5001204E+03,

1.2632513E+04,5.4586386E+02,0.0000000E+00,5.1794766E+02,0.0000000E+00,5.1794766E+02,2.2621562E+03,3.4121152E+02,3.1215445E+03,5.1792388E+02,3.1215445E+03,5.1792388E+02,7.5761712E+06,7.5761712E+06,2.5898342E+03,5.4943444E+03,

1.2634921E+04,5.4586184E+02,0.0000000E+00,5.1797375E+02,0.0000000E+00,5.1797375E+02,2.2589072E+03,3.4121152E+02,3.1214971E+03,5.1793290E+02,3.1214971E+03,5.1793290E+02,7.5761834E+06,7.5761834E+06,2.5072031E+03,5.4881397E+03,

1.2637551E+04,5.4585986E+02,0.0000000E+00,5.1800238E+02,0.0000000E+00,5.1800238E+02,2.2553768E+03,3.4121152E+02,3.1214378E+03,5.1794499E+02,3.1214378E+03,5.1794499E+02,7.5761635E+06,7.5761635E+06,2.4256656E+03,5.4815704E+03,

1.2640670E+04,5.4585785E+02,0.0000000E+00,5.1803451E+02,0.0000000E+00,5.1803451E+02,2.2512102E+03,3.4121152E+02,3.1213663E+03,5.1796014E+02,3.1213663E+03,5.1796014E+02,7.5761124E+06,7.5761124E+06,2.3451819E+03,5.4743779E+03,

1.2643848E+04,5.4585581E+02,0.0000000E+00,5.1807010E+02,0.0000000E+00,5.1807010E+02,2.2469795E+03,3.4121152E+02,3.1212827E+03,5.1797844E+02,3.1212827E+03,5.1797844E+02,7.5760301E+06,7.5760301E+06,2.2656010E+03,5.4664360E+03,

1.2647072E+04,5.4585376E+02,0.0000000E+00,5.1810859E+02,0.0000000E+00,5.1810859E+02,2.2426987E+03,3.4121152E+02,3.1211869E+03,5.1799989E+02,3.1211869E+03,5.1799989E+02,7.5759168E+06,7.5759168E+06,2.1868691E+03,5.4579611E+03,

1.2650326E+04,5.4585170E+02,0.0000000E+00,5.1814950E+02,0.0000000E+00,5.1814950E+02,2.2383847E+03,3.4121152E+02,3.1210790E+03,5.1802440E+02,3.1210790E+03,5.1802440E+02,7.5757727E+06,7.5757727E+06,2.1090217E+03,5.4491075E+03,

1.2653599E+04,5.4584963E+02,0.0000000E+00,5.1819238E+02,0.0000000E+00,5.1819238E+02,2.2340543E+03,3.4121152E+02,3.1209596E+03,5.1805183E+02,3.1209596E+03,5.1805183E+02,7.5755980E+06,7.5755980E+06,2.0321535E+03,5.4399898E+03,

1.2656878E+04,5.4584754E+02,0.0000000E+00,5.1823687E+02,0.0000000E+00,5.1823687E+02,2.2297234E+03,3.4121152E+02,3.1208296E+03,5.1808199E+02,3.1208296E+03,5.1808199E+02,7.5753934E+06,7.5753934E+06,1.9563967E+03,5.4306946E+03,

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1.2666647E+04,5.4584110E+02,0.0000000E+00,5.1837662E+02,0.0000000E+00,5.1837662E+02,2.2168752E+03,3.4121152E+02,3.1203852E+03,5.1818650E+02,3.1203852E+03,5.1818650E+02,7.5746114E+06,7.5746114E+06,1.7373699E+03,5.4023683E+03,

1.2669849E+04,5.4583888E+02,0.0000000E+00,5.1842435E+02,0.0000000E+00,5.1842435E+02,2.2126861E+03,3.4121152E+02,3.1202226E+03,5.1822519E+02,3.1202226E+03,5.1822519E+02,7.5743004E+06,7.5743004E+06,1.6676524E+03,5.3929373E+03,

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1.2682151E+04,5.4582965E+02,0.0000000E+00,5.1861480E+02,0.0000000E+00,5.1861480E+02,2.

1967119E+03,3.4121152E+02,3.1195271E+03,5.1839262E+02,3.1195271E+03,5.1839262E+02,7.57

28597E+06,7.5728597E+06,1.4091778E+03,5.3562071E+03,

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1929630E+03,3.4121152E+02,3.1193471E+03,5.1843646E+02,3.1193471E+03,5.1843646E+02,7.57

24615E+06,7.5724615E+06,1.3502599E+03,5.3474116E+03,

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1893286E+03,3.4121152E+02,3.1191663E+03,5.1848066E+02,3.1191663E+03,5.1848066E+02,7.57

20529E+06,7.5720529E+06,1.2938125E+03,5.3388176E+03,

1.2690650E+04,5.4582246E+02,0.0000000E+00,5.1875199E+02,0.0000000E+00,5.1875199E+02,2.

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16358E+06,7.5716358E+06,1.2399048E+03,5.3304448E+03,

1.2693052E+04,5.4582097E+02,0.0000000E+00,5.1879582E+02,0.0000000E+00,5.1879582E+02,2.

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12287E+06,7.5712287E+06,1.1885489E+03,5.3222686E+03,

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07914E+06,7.5707914E+06,1.1398824E+03,5.3144465E+03,

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03592E+06,7.5703592E+06,1.0938518E+03,5.3068326E+03,

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99292E+06,7.5699292E+06,1.0504795E+03,5.2994846E+03,

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94936E+06,7.5694936E+06,1.0097984E+03,5.2924943E+03,

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90646E+06,7.5690646E+06,9.7180994E+02,5.2857137E+03,

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1650513E+03,3.4121152E+02,3.1177768E+03,5.1882577E+02,3.1177768E+03,5.1882577E+02,7.56

86472E+06,7.5686472E+06,9.3647184E+02,5.2792846E+03,

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82319E+06,7.5682319E+06,9.0380256E+02,5.2732028E+03,

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1.2725324E+04,5.4577914E+02,0.0000000E+00,5.1940468E+02,0.0000000E+00,5.1940468E+02,2.1441145E+03,3.4121152E+02,3.1157439E+03,5.1935420E+02,3.1157439E+03,5.1935420E+02,7.5625851E+06,7.5625851E+06,7.0236869E+02,5.2177166E+03,

1.2725523E+04,5.4577853E+02,0.0000000E+00,5.1940741E+02,0.0000000E+00,5.1940741E+02,2.1443300E+03,3.4121152E+02,3.1157150E+03,5.1936465E+02,3.1157150E+03,5.1936465E+02,7.5624205E+06,7.5624205E+06,7.0832450E+02,5.2177066E+03,

1.2725212E+04,5.4577769E+02,0.0000000E+00,5.1940885E+02,0.0000000E+00,5.1940885E+02,2.1446469E+03,3.4121152E+02,3.1156803E+03,5.1937367E+02,3.1156803E+03,5.1937367E+02,7.5622911E+06,7.5622911E+06,7.1531377E+02,5.2177548E+03,

1.2724903E+04,5.4577775E+02,0.0000000E+00,5.1940902E+02,0.0000000E+00,5.1940902E+02,2.1450337E+03,3.4121152E+02,3.1156521E+03,5.1938133E+02,3.1156521E+03,5.1938133E+02,7.5621752E+06,7.5621752E+06,7.2325573E+02,5.2180817E+03,

1.2724593E+04,5.4577796E+02,0.0000000E+00,5.1940811E+02,0.0000000E+00,5.1940811E+02,2.1454973E+03,3.4121152E+02,3.1156314E+03,5.1938762E+02,3.1156314E+03,5.1938762E+02,7.5620698E+06,7.5620698E+06,7.3209584E+02,5.2186401E+03,

1.2724258E+04,5.4577817E+02,0.0000000E+00,5.1940620E+02,0.0000000E+00,5.1940620E+02,2.1460270E+03,3.4121152E+02,3.1156167E+03,5.1939261E+02,3.1156167E+03,5.1939261E+02,7.5619768E+06,7.5619768E+06,7.4174147E+02,5.2193926E+03,

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1.2723412E+04,5.4577858E+02,0.0000000E+00,5.1939959E+02,0.0000000E+00,5.1939959E+02,2.

1472720E+03,3.4121152E+02,3.1156011E+03,5.1939890E+02,3.1156011E+03,5.1939890E+02,7.56

18326E+06,7.5618326E+06,7.6307879E+02,5.2213814E+03,

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1479898E+03,3.4121152E+02,3.1155997E+03,5.1940030E+02,3.1155997E+03,5.1940030E+02,7.56

17807E+06,7.5617807E+06,7.7460661E+02,5.2226045E+03,

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17124E+06,7.5617124E+06,7.9903012E+02,5.2254910E+03,

1.2721131E+04,5.4577976E+02,0.0000000E+00,5.1937613E+02,0.0000000E+00,5.1937613E+02,2.

1504494E+03,3.4121152E+02,3.1156210E+03,5.1939812E+02,3.1156210E+03,5.1939812E+02,7.56

16952E+06,7.5616952E+06,8.1179520E+02,5.2271272E+03,

1.2720475E+04,5.4578018E+02,0.0000000E+00,5.1936843E+02,0.0000000E+00,5.1936843E+02,2.

1513468E+03,3.4121152E+02,3.1156357E+03,5.1939543E+02,3.1156357E+03,5.1939543E+02,7.56

16891E+06,7.5616891E+06,8.2484302E+02,5.2288714E+03,

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16937E+06,7.5616937E+06,8.3811085E+02,5.2307123E+03,

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17083E+06,7.5617083E+06,8.5153864E+02,5.2326416E+03,

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17323E+06,7.5617323E+06,8.6506917E+02,5.2346501E+03,

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17651E+06,7.5617651E+06,8.7864750E+02,5.2367270E+03,

1.2716815E+04,5.4578286E+02,0.0000000E+00,5.1932185E+02,0.0000000E+00,5.1932185E+02,2.

1562357E+03,3.4121152E+02,3.1157556E+03,5.1936960E+02,3.1157556E+03,5.1936960E+02,7.56

18063E+06,7.5618063E+06,8.9222078E+02,5.2388610E+03,

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1572613E+03,3.4121152E+02,3.1157875E+03,5.1936234E+02,3.1157875E+03,5.1936234E+02,7.56

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19121E+06,7.5619121E+06,9.1915301E+02,5.2432592E+03,

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1807407E+03,3.4121152E+02,3.1170856E+03,5.1903803E+02,3.1170856E+03,5.1903803E+02,7.56
50974E+06,7.5650974E+06,1.1434973E+03,5.2980833E+03,

1.2697012E+04,5.4580451E+02,0.0000000E+00,5.1900282E+02,0.0000000E+00,5.1900282E+02,2.
1807824E+03,3.4121152E+02,3.1170999E+03,5.1903411E+02,3.1170999E+03,5.1903411E+02,7.56

51481E+06,7.5651481E+06,1.1420027E+03,5.2983368E+03,

1.2696975E+04,5.4580468E+02,0.0000000E+00,5.1900126E+02,0.0000000E+00,5.1900126E+02,2.

1807984E+03,3.4121152E+02,3.1171127E+03,5.1903056E+02,3.1171127E+03,5.1903056E+02,7.56

51950E+06,7.5651950E+06,1.1402332E+03,5.2985273E+03,

1.2696958E+04,5.4580483E+02,0.0000000E+00,5.1900002E+02,0.0000000E+00,5.1900002E+02,2.

1807900E+03,3.4121152E+02,3.1171241E+03,5.1902737E+02,3.1171241E+03,5.1902737E+02,7.56

52382E+06,7.5652382E+06,1.1382072E+03,5.2986572E+03,

1.2696959E+04,5.4580495E+02,0.0000000E+00,5.1899910E+02,0.0000000E+00,5.1899910E+02,2.

1807581E+03,3.4121152E+02,3.1171341E+03,5.1902454E+02,3.1171341E+03,5.1902454E+02,7.56

52778E+06,7.5652778E+06,1.1359433E+03,5.2987290E+03,

1.2696979E+04,5.4580505E+02,0.0000000E+00,5.1899849E+02,0.0000000E+00,5.1899849E+02,2.

1807041E+03,3.4121152E+02,3.1171427E+03,5.1902206E+02,3.1171427E+03,5.1902206E+02,7.56

53137E+06,7.5653137E+06,1.1334600E+03,5.2987450E+03,

1.2697016E+04,5.4580513E+02,0.0000000E+00,5.1899817E+02,0.0000000E+00,5.1899817E+02,2.

1806290E+03,3.4121152E+02,3.1171499E+03,5.1901992E+02,3.1171499E+03,5.1901992E+02,7.56

53460E+06,7.5653460E+06,1.1307755E+03,5.2987080E+03,

1.2697069E+04,5.4580520E+02,0.0000000E+00,5.1899813E+02,0.0000000E+00,5.1899813E+02,2.

1805342E+03,3.4121152E+02,3.1171558E+03,5.1901812E+02,3.1171558E+03,5.1901812E+02,7.56

53748E+06,7.5653748E+06,1.1279080E+03,5.2986204E+03,

1.2697138E+04,5.4580524E+02,0.0000000E+00,5.1899836E+02,0.0000000E+00,5.1899836E+02,2.

1804210E+03,3.4121152E+02,3.1171605E+03,5.1901664E+02,3.1171605E+03,5.1901664E+02,7.56

54002E+06,7.5654002E+06,1.1248753E+03,5.2984850E+03,

1.2697220E+04,5.4580527E+02,0.0000000E+00,5.1899885E+02,0.0000000E+00,5.1899885E+02,2.

1802905E+03,3.4121152E+02,3.1171639E+03,5.1901546E+02,3.1171639E+03,5.1901546E+02,7.56

54222E+06,7.5654222E+06,1.1216948E+03,5.2983044E+03,

1.2697317E+04,5.4580528E+02,0.0000000E+00,5.1899958E+02,0.0000000E+00,5.1899958E+02,2.

1801441E+03,3.4121152E+02,3.1171662E+03,5.1901459E+02,3.1171662E+03,5.1901459E+02,7.56

54409E+06,7.5654409E+06,1.1183838E+03,5.2980815E+03,

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54564E+06,7.5654564E+06,1.1149590E+03,5.2978190E+03,

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54689E+06,7.5654689E+06,1.1114368E+03,5.2975196E+03,

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54784E+06,7.5654784E+06,1.1078333E+03,5.2971862E+03,

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1.2703525E+04,5.4580025E+02,0.0000000E+00,5.1909346E+02,0.0000000E+00,5.1909346E+02,2.1721084E+03,3.4121152E+02,3.1168185E+03,5.1909815E+02,3.1168185E+03,5.1909815E+02,7.5647065E+06,7.5647065E+06,1.0098052E+03,5.2798463E+03,

1.2703546E+04,5.4580022E+02,0.0000000E+00,5.1909405E+02,0.0000000E+00,5.1909405E+02,2.1720889E+03,3.4121152E+02,3.1168145E+03,5.1909923E+02,3.1168145E+03,5.1909923E+02,7.5646930E+06,7.5646930E+06,1.0099585E+03,5.2797624E+03,

1.2703561E+04,5.4580019E+02,0.0000000E+00,5.1909456E+02,0.0000000E+00,5.1909456E+02,2.1720761E+03,3.4121152E+02,3.1168108E+03,5.1910022E+02,3.1168108E+03,5.1910022E+02,7.5646805E+06,7.5646805E+06,1.0101887E+03,5.2796946E+03,

1.2703571E+04,5.4580016E+02,0.0000000E+00,5.1909497E+02,0.0000000E+00,5.1909497E+02,2.1720697E+03,3.4121152E+02,3.1168075E+03,5.1910111E+02,3.1168075E+03,5.1910111E+02,7.5646688E+06,7.5646688E+06,1.0104913E+03,5.2796424E+03,

1.2703576E+04,5.4580014E+02,0.0000000E+00,5.1909531E+02,0.0000000E+00,5.1909531E+02,2.1720694E+03,3.4121152E+02,3.1168046E+03,5.1910192E+02,3.1168046E+03,5.1910192E+02,7.5646580E+06,7.5646580E+06,1.0108619E+03,5.2796052E+03,

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1.2703573E+04,5.4580011E+02,0.0000000E+00,5.1909575E+02,0.0000000E+00,5.1909575E+02,2.

1720860E+03,3.4121152E+02,3.1167997E+03,5.1910328E+02,3.1167997E+03,5.1910328E+02,7.56

46391E+06,7.5646391E+06,1.0117886E+03,5.2795736E+03,

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1721023E+03,3.4121152E+02,3.1167978E+03,5.1910384E+02,3.1167978E+03,5.1910384E+02,7.56

46309E+06,7.5646309E+06,1.0123358E+03,5.2795779E+03,

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1722140E+03,3.4121152E+02,3.1167932E+03,5.1910526E+02,3.1167932E+03,5.1910526E+02,7.56

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1722520E+03,3.4121152E+02,3.1167928E+03,5.1910544E+02,3.1167928E+03,5.1910544E+02,7.56

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1741748E+03,3.4121152E+02,3.1168724E+03,5.1908626E+02,3.1168724E+03,5.1908626E+02,7.56
47694E+06,7.5647694E+06,1.0404288E+03,5.2841115E+03,

1.2701949E+04,5.4580192E+02,0.0000000E+00,5.1907313E+02,0.0000000E+00,5.1907313E+02,2.
1741884E+03,3.4121152E+02,3.1168738E+03,5.1908589E+02,3.1168738E+03,5.1908589E+02,7.56

47738E+06,7.5647738E+06,1.0404805E+03,5.2841528E+03,

1.2701938E+04,5.4580194E+02,0.0000000E+00,5.1907290E+02,0.0000000E+00,5.1907290E+02,2.1742001E+03,3.4121152E+02,3.1168751E+03,5.1908554E+02,3.1168751E+03,5.1908554E+02,7.5647779E+06,7.5647779E+06,1.0405091E+03,5.2841897E+03,

1.2701929E+04,5.4580197E+02,0.0000000E+00,5.1907269E+02,0.0000000E+00,5.1907269E+02,2.1742100E+03,3.4121152E+02,3.1168763E+03,5.1908522E+02,3.1168763E+03,5.1908522E+02,7.5647818E+06,7.5647818E+06,1.0405157E+03,5.2842223E+03,

1.2701921E+04,5.4580199E+02,0.0000000E+00,5.1907251E+02,0.0000000E+00,5.1907251E+02,2.1742180E+03,3.4121152E+02,3.1168774E+03,5.1908492E+02,3.1168774E+03,5.1908492E+02,7.5647855E+06,7.5647855E+06,1.0405013E+03,5.2842508E+03,

1.2701914E+04,5.4580201E+02,0.0000000E+00,5.1907235E+02,0.0000000E+00,5.1907235E+02,2.1742244E+03,3.4121152E+02,3.1168785E+03,5.1908463E+02,3.1168785E+03,5.1908463E+02,7.5647889E+06,7.5647889E+06,1.0404668E+03,5.2842751E+03,

1.2701909E+04,5.4580203E+02,0.0000000E+00,5.1907221E+02,0.0000000E+00,5.1907221E+02,2.1742291E+03,3.4121152E+02,3.1168794E+03,5.1908438E+02,3.1168794E+03,5.1908438E+02,7.5647922E+06,7.5647922E+06,1.0404134E+03,5.2842954E+03,

1.2701905E+04,5.4580205E+02,0.0000000E+00,5.1907209E+02,0.0000000E+00,5.1907209E+02,2.1742322E+03,3.4121152E+02,3.1168803E+03,5.1908414E+02,3.1168803E+03,5.1908414E+02,7.5647953E+06,7.5647953E+06,1.0403420E+03,5.2843118E+03,

1.2701902E+04,5.4580207E+02,0.0000000E+00,5.1907199E+02,0.0000000E+00,5.1907199E+02,2.1742338E+03,3.4121152E+02,3.1168811E+03,5.1908392E+02,3.1168811E+03,5.1908392E+02,7.5647981E+06,7.5647981E+06,1.0402539E+03,5.2843245E+03,

1.2701900E+04,5.4580209E+02,0.0000000E+00,5.1907191E+02,0.0000000E+00,5.1907191E+02,2.1742339E+03,3.4121152E+02,3.1168818E+03,5.1908373E+02,3.1168818E+03,5.1908373E+02,7.5648007E+06,7.5648007E+06,1.0401500E+03,5.2843336E+03,

1.2701900E+04,5.4580210E+02,0.0000000E+00,5.1907185E+02,0.0000000E+00,5.1907185E+02,2.1742326E+03,3.4121152E+02,3.1168824E+03,5.1908356E+02,3.1168824E+03,5.1908356E+02,7.5648031E+06,7.5648031E+06,1.0400314E+03,5.2843393E+03,

1.2701900E+04,5.4580212E+02,0.0000000E+00,5.1907181E+02,0.0000000E+00,5.1907181E+02,2.1742300E+03,3.4121152E+02,3.1168829E+03,5.1908340E+02,3.1168829E+03,5.1908340E+02,7.5648053E+06,7.5648053E+06,1.0398993E+03,5.2843416E+03,

1.2701902E+04,5.4580213E+02,0.0000000E+00,5.1907178E+02,0.0000000E+00,5.1907178E+02,2.1742261E+03,3.4121152E+02,3.1168834E+03,5.1908327E+02,3.1168834E+03,5.1908327E+02,7.5648072E+06,7.5648072E+06,1.0397547E+03,5.2843408E+03,

1.2701904E+04,5.4580214E+02,0.0000000E+00,5.1907177E+02,0.0000000E+00,5.1907177E+02,2.1742211E+03,3.4121152E+02,3.1168837E+03,5.1908316E+02,3.1168837E+03,5.1908316E+02,7.5648090E+06,7.5648090E+06,1.0395987E+03,5.2843369E+03,

1.2701908E+04,5.4580215E+02,0.0000000E+00,5.1907178E+02,0.0000000E+00,5.1907178E+02,2.1742149E+03,3.4121152E+02,3.1168840E+03,5.1908307E+02,3.1168840E+03,5.1908307E+02,7.5648106E+06,7.5648106E+06,1.0394323E+03,5.2843303E+03,

1.2701912E+04,5.4580216E+02,0.0000000E+00,5.1907180E+02,0.0000000E+00,5.1907180E+02,2.1742078E+03,3.4121152E+02,3.1168843E+03,5.1908299E+02,3.1168843E+03,5.1908299E+02,7.5648119E+06,7.5648119E+06,1.0392566E+03,5.2843209E+03,

1.2701917E+04,5.4580217E+02,0.0000000E+00,5.1907184E+02,0.0000000E+00,5.1907184E+02,2.1741996E+03,3.4121152E+02,3.1168844E+03,5.1908293E+02,3.1168844E+03,5.1908293E+02,7.5648131E+06,7.5648131E+06,1.0390725E+03,5.2843090E+03,

1.2701923E+04,5.4580218E+02,0.0000000E+00,5.1907189E+02,0.0000000E+00,5.1907189E+02,2.1741906E+03,3.4121152E+02,3.1168845E+03,5.1908289E+02,3.1168845E+03,5.1908289E+02,7.5648141E+06,7.5648141E+06,1.0388812E+03,5.2842947E+03,

1.2701930E+04,5.4580218E+02,0.0000000E+00,5.1907195E+02,0.0000000E+00,5.1907195E+02,2.1741808E+03,3.4121152E+02,3.1168845E+03,5.1908287E+02,3.1168845E+03,5.1908287E+02,7.5648149E+06,7.5648149E+06,1.0386836E+03,5.2842782E+03,

1.2701937E+04,5.4580219E+02,0.0000000E+00,5.1907203E+02,0.0000000E+00,5.1907203E+02,2.1741702E+03,3.4121152E+02,3.1168845E+03,5.1908286E+02,3.1168845E+03,5.1908286E+02,7.5648155E+06,7.5648155E+06,1.0384806E+03,5.2842597E+03,

1.2701945E+04,5.4580219E+02,0.0000000E+00,5.1907211E+02,0.0000000E+00,5.1907211E+02,2.1741590E+03,3.4121152E+02,3.1168844E+03,5.1908287E+02,3.1168844E+03,5.1908287E+02,7.5648160E+06,7.5648160E+06,1.0382732E+03,5.2842393E+03,

1.2701953E+04,5.4580220E+02,0.0000000E+00,5.1907221E+02,0.0000000E+00,5.1907221E+02,2.1741472E+03,3.4121152E+02,3.1168843E+03,5.1908289E+02,3.1168843E+03,5.1908289E+02,7.5648163E+06,7.5648163E+06,1.0380623E+03,5.2842171E+03,

1.2701962E+04,5.4580220E+02,0.0000000E+00,5.1907232E+02,0.0000000E+00,5.1907232E+02,2.1741349E+03,3.4121152E+02,3.1168841E+03,5.1908292E+02,3.1168841E+03,5.1908292E+02,7.5648164E+06,7.5648164E+06,1.0378487E+03,5.2841934E+03,

1.2701971E+04,5.4580220E+02,0.0000000E+00,5.1907243E+02,0.0000000E+00,5.1907243E+02,2.1741221E+03,3.4121152E+02,3.1168838E+03,5.1908297E+02,3.1168838E+03,5.1908297E+02,7.5648164E+06,7.5648164E+06,1.0376333E+03,5.2841683E+03,

1.2701981E+04,5.4580220E+02,0.0000000E+00,5.1907255E+02,0.0000000E+00,5.1907255E+02,2.1741089E+03,3.4121152E+02,3.1168835E+03,5.1908303E+02,3.1168835E+03,5.1908303E+02,7.5648162E+06,7.5648162E+06,1.0374169E+03,5.2841420E+03,

1.2701991E+04,5.4580221E+02,0.0000000E+00,5.1907268E+02,0.0000000E+00,5.1907268E+02,2.1740953E+03,3.4121152E+02,3.1168832E+03,5.1908310E+02,3.1168832E+03,5.1908310E+02,7.5648159E+06,7.5648159E+06,1.0372002E+03,5.2841145E+03,

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1740815E+03,3.4121152E+02,3.1168828E+03,5.1908318E+02,3.1168828E+03,5.1908318E+02,7.56
48155E+06,7.5648155E+06,1.0369841E+03,5.2840861E+03,

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1740675E+03,3.4121152E+02,3.1168824E+03,5.1908327E+02,3.1168824E+03,5.1908327E+02,7.56
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1.2702022E+04,5.4580221E+02,0.0000000E+00,5.1907311E+02,0.0000000E+00,5.1907311E+02,2.
1740534E+03,3.4121152E+02,3.1168819E+03,5.1908337E+02,3.1168819E+03,5.1908337E+02,7.56
48143E+06,7.5648143E+06,1.0365560E+03,5.2840269E+03,

1.2702032E+04,5.4580221E+02,0.0000000E+00,5.1907326E+02,0.0000000E+00,5.1907326E+02,2.
1740391E+03,3.4121152E+02,3.1168815E+03,5.1908348E+02,3.1168815E+03,5.1908348E+02,7.56
48136E+06,7.5648136E+06,1.0363454E+03,5.2839965E+03,

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1740106E+03,3.4121152E+02,3.1168804E+03,5.1908372E+02,3.1168804E+03,5.1908372E+02,7.56
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1739964E+03,3.4121152E+02,3.1168799E+03,5.1908384E+02,3.1168799E+03,5.1908384E+02,7.56
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1739683E+03,3.4121152E+02,3.1168788E+03,5.1908411E+02,3.1168788E+03,5.1908411E+02,7.56
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1739409E+03,3.4121152E+02,3.1168776E+03,5.1908440E+02,3.1168776E+03,5.1908440E+02,7.56
48060E+06,7.5648060E+06,1.0349854E+03,5.2837785E+03,

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1739277E+03,3.4121152E+02,3.1168770E+03,5.1908455E+02,3.1168770E+03,5.1908455E+02,7.56
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1739147E+03,3.4121152E+02,3.1168764E+03,5.1908469E+02,3.1168764E+03,5.1908469E+02,7.56

48033E+06,7.5648033E+06,1.0346463E+03,5.2837179E+03,

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1.2702205E+04,5.4580218E+02,0.0000000E+00,5.1907597E+02,0.0000000E+00,5.1907597E+02,2.1738152E+03,3.4121152E+02,3.1168710E+03,5.1908603E+02,3.1168710E+03,5.1908603E+02,7.5647903E+06,7.5647903E+06,1.0334687E+03,5.2834790E+03,

1.2702212E+04,5.4580218E+02,0.0000000E+00,5.1907609E+02,0.0000000E+00,5.1907609E+02,2.1738064E+03,3.4121152E+02,3.1168704E+03,5.1908616E+02,3.1168704E+03,5.1908616E+02,7.5647889E+06,7.5647889E+06,1.0333751E+03,5.2834569E+03,

1.2702219E+04,5.4580218E+02,0.0000000E+00,5.1907621E+02,0.0000000E+00,5.1907621E+02,2.1737982E+03,3.4121152E+02,3.1168699E+03,5.1908630E+02,3.1168699E+03,5.1908630E+02,7.5647875E+06,7.5647875E+06,1.0332890E+03,5.2834359E+03,

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1.2702251E+04,5.4580218E+02,0.0000000E+00,5.1907680E+02,0.0000000E+00,5.1907680E+02,2.1737591E+03,3.4121152E+02,3.1168670E+03,5.1908703E+02,3.1168670E+03,5.1908703E+02,7.5647796E+06,7.5647796E+06,1.0329241E+03,5.2833329E+03,

1.2702255E+04,5.4580218E+02,0.0000000E+00,5.1907688E+02,0.0000000E+00,5.1907688E+02,2.1737544E+03,3.4121152E+02,3.1168666E+03,5.1908713E+02,3.1168666E+03,5.1908713E+02,7.5647784E+06,7.5647784E+06,1.0328873E+03,5.2833196E+03,

1.2702258E+04,5.4580219E+02,0.0000000E+00,5.1907695E+02,0.0000000E+00,5.1907695E+02,2.1737501E+03,3.4121152E+02,3.1168662E+03,5.1908723E+02,3.1168662E+03,5.1908723E+02,7.5647773E+06,7.5647773E+06,1.0328569E+03,5.2833074E+03,

1.2702262E+04,5.4580219E+02,0.0000000E+00,5.1907702E+02,0.0000000E+00,5.1907702E+02,2.1737463E+03,3.4121152E+02,3.1168658E+03,5.1908733E+02,3.1168658E+03,5.1908733E+02,7.5647762E+06,7.5647762E+06,1.0328328E+03,5.2832963E+03,

1.2702264E+04,5.4580219E+02,0.0000000E+00,5.1907708E+02,0.0000000E+00,5.1907708E+02,2.1737430E+03,3.4121152E+02,3.1168655E+03,5.1908742E+02,3.1168655E+03,5.1908742E+02,7.5647752E+06,7.5647752E+06,1.0328146E+03,5.2832862E+03,

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1.2702272E+04,5.4580221E+02,0.0000000E+00,5.1907728E+02,0.0000000E+00,5.1907728E+02,2.

1737342E+03,3.4121152E+02,3.1168643E+03,5.1908773E+02,3.1168643E+03,5.1908773E+02,7.56
47715E+06,7.5647715E+06,1.0327973E+03,5.2832566E+03,

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1737331E+03,3.4121152E+02,3.1168641E+03,5.1908779E+02,3.1168641E+03,5.1908779E+02,7.56
47707E+06,7.5647707E+06,1.0328056E+03,5.2832517E+03,

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47700E+06,7.5647700E+06,1.0328184E+03,5.2832478E+03,

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47681E+06,7.5647681E+06,1.0328815E+03,5.2832413E+03,

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1737352E+03,3.4121152E+02,3.1168630E+03,5.1908809E+02,3.1168630E+03,5.1908809E+02,7.56
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1.2702268E+04,5.4580228E+02,0.0000000E+00,5.1907739E+02,0.0000000E+00,5.1907739E+02,2.
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47654E+06,7.5647654E+06,1.0331387E+03,5.2832529E+03,

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1738254E+03,3.4121152E+02,3.1168653E+03,5.1908756E+02,3.1168653E+03,5.1908756E+02,7.56

47696E+06,7.5647696E+06,1.0342911E+03,5.2834293E+03,

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1738283E+03,3.4121152E+02,3.1168655E+03,5.1908753E+02,3.1168655E+03,5.1908753E+02,7.56

47700E+06,7.5647700E+06,1.0343233E+03,5.2834363E+03,

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1738311E+03,3.4121152E+02,3.1168656E+03,5.1908749E+02,3.1168656E+03,5.1908749E+02,7.56

47704E+06,7.5647704E+06,1.0343536E+03,5.2834431E+03,

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47708E+06,7.5647708E+06,1.0343822E+03,5.2834496E+03,

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47711E+06,7.5647711E+06,1.0344089E+03,5.2834559E+03,

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47715E+06,7.5647715E+06,1.0344339E+03,5.2834620E+03,

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1738411E+03,3.4121152E+02,3.1168662E+03,5.1908734E+02,3.1168662E+03,5.1908734E+02,7.56

47719E+06,7.5647719E+06,1.0344570E+03,5.2834679E+03,

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47722E+06,7.5647722E+06,1.0344784E+03,5.2834735E+03,

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47726E+06,7.5647726E+06,1.0344979E+03,5.2834788E+03,

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1.2702182E+04,5.4580258E+02,0.0000000E+00,5.1907620E+02,0.0000000E+00,5.1907620E+02,2.

1738510E+03,3.4121152E+02,3.1168668E+03,5.1908718E+02,3.1168668E+03,5.1908718E+02,7.56

47736E+06,7.5647736E+06,1.0345461E+03,5.2834932E+03,

1.2702181E+04,5.4580259E+02,0.0000000E+00,5.1907618E+02,0.0000000E+00,5.1907618E+02,2.

1738526E+03,3.4121152E+02,3.1168670E+03,5.1908715E+02,3.1168670E+03,5.1908715E+02,7.56

47739E+06,7.5647739E+06,1.0345587E+03,5.2834974E+03,

1.2702179E+04,5.4580260E+02,0.0000000E+00,5.1907616E+02,0.0000000E+00,5.1907616E+02,2.
1738540E+03,3.4121152E+02,3.1168671E+03,5.1908712E+02,3.1168671E+03,5.1908712E+02,7.56
47743E+06,7.5647743E+06,1.0345697E+03,5.2835014E+03,

1.2702178E+04,5.4580261E+02,0.0000000E+00,5.1907614E+02,0.0000000E+00,5.1907614E+02,2.
1738554E+03,3.4121152E+02,3.1168672E+03,5.1908709E+02,3.1168672E+03,5.1908709E+02,7.56
47746E+06,7.5647746E+06,1.0345790E+03,5.2835051E+03,

1.2702177E+04,5.4580262E+02,0.0000000E+00,5.1907612E+02,0.0000000E+00,5.1907612E+02,2.
1738566E+03,3.4121152E+02,3.1168673E+03,5.1908707E+02,3.1168673E+03,5.1908707E+02,7.56
47749E+06,7.5647749E+06,1.0345868E+03,5.2835085E+03,

1.2702176E+04,5.4580262E+02,0.0000000E+00,5.1907610E+02,0.0000000E+00,5.1907610E+02,2.
1738577E+03,3.4121152E+02,3.1168674E+03,5.1908704E+02,3.1168674E+03,5.1908704E+02,7.56
47752E+06,7.5647752E+06,1.0345931E+03,5.2835117E+03,

1.2702175E+04,5.4580263E+02,0.0000000E+00,5.1907608E+02,0.0000000E+00,5.1907608E+02,2.
1738587E+03,3.4121152E+02,3.1168675E+03,5.1908702E+02,3.1168675E+03,5.1908702E+02,7.56
47754E+06,7.5647754E+06,1.0345978E+03,5.2835146E+03,

1.2702174E+04,5.4580264E+02,0.0000000E+00,5.1907607E+02,0.0000000E+00,5.1907607E+02,2.
1738596E+03,3.4121152E+02,3.1168675E+03,5.1908700E+02,3.1168675E+03,5.1908700E+02,7.56
47757E+06,7.5647757E+06,1.0346012E+03,5.2835172E+03,

1.2702174E+04,5.4580265E+02,0.0000000E+00,5.1907605E+02,0.0000000E+00,5.1907605E+02,2.
1738604E+03,3.4121152E+02,3.1168676E+03,5.1908698E+02,3.1168676E+03,5.1908698E+02,7.56
47759E+06,7.5647759E+06,1.0346032E+03,5.2835196E+03,

1.2702173E+04,5.4580265E+02,0.0000000E+00,5.1907604E+02,0.0000000E+00,5.1907604E+02,2.
1738610E+03,3.4121152E+02,3.1168677E+03,5.1908696E+02,3.1168677E+03,5.1908696E+02,7.56
47762E+06,7.5647762E+06,1.0346039E+03,5.2835217E+03,

1.2702172E+04,5.4580266E+02,0.0000000E+00,5.1907603E+02,0.0000000E+00,5.1907603E+02,2.
1738616E+03,3.4121152E+02,3.1168678E+03,5.1908694E+02,3.1168678E+03,5.1908694E+02,7.56
47764E+06,7.5647764E+06,1.0346034E+03,5.2835236E+03,

1.2702172E+04,5.4580267E+02,0.0000000E+00,5.1907602E+02,0.0000000E+00,5.1907602E+02,2.
1738620E+03,3.4121152E+02,3.1168678E+03,5.1908692E+02,3.1168678E+03,5.1908692E+02,7.56
47766E+06,7.5647766E+06,1.0346016E+03,5.2835252E+03,

1.2702172E+04,5.4580267E+02,0.0000000E+00,5.1907601E+02,0.0000000E+00,5.1907601E+02,2.
1738624E+03,3.4121152E+02,3.1168679E+03,5.1908690E+02,3.1168679E+03,5.1908690E+02,7.56
47768E+06,7.5647768E+06,1.0345987E+03,5.2835266E+03,

1.2702171E+04,5.4580268E+02,0.0000000E+00,5.1907600E+02,0.0000000E+00,5.1907600E+02,2.
1738626E+03,3.4121152E+02,3.1168679E+03,5.1908689E+02,3.1168679E+03,5.1908689E+02,7.56
47770E+06,7.5647770E+06,1.0345948E+03,5.2835277E+03,

1.2702171E+04,5.4580269E+02,0.0000000E+00,5.1907599E+02,0.0000000E+00,5.1907599E+02,2.1738628E+03,3.4121152E+02,3.1168680E+03,5.1908688E+02,3.1168680E+03,5.1908688E+02,7.5647772E+06,7.5647772E+06,1.0345899E+03,5.2835287E+03,

1.2702171E+04,5.4580269E+02,0.0000000E+00,5.1907599E+02,0.0000000E+00,5.1907599E+02,2.1738629E+03,3.4121152E+02,3.1168680E+03,5.1908686E+02,3.1168680E+03,5.1908686E+02,7.5647773E+06,7.5647773E+06,1.0345840E+03,5.2835294E+03,

1.2702171E+04,5.4580270E+02,0.0000000E+00,5.1907598E+02,0.0000000E+00,5.1907598E+02,2.1738629E+03,3.4121152E+02,3.1168681E+03,5.1908685E+02,3.1168681E+03,5.1908685E+02,7.5647775E+06,7.5647775E+06,1.0345772E+03,5.2835299E+03,

1.2702171E+04,5.4580271E+02,0.0000000E+00,5.1907598E+02,0.0000000E+00,5.1907598E+02,2.1738628E+03,3.4121152E+02,3.1168681E+03,5.1908684E+02,3.1168681E+03,5.1908684E+02,7.5647776E+06,7.5647776E+06,1.0345697E+03,5.2835302E+03,

1.2702171E+04,5.4580271E+02,0.0000000E+00,5.1907598E+02,0.0000000E+00,5.1907598E+02,2.1738626E+03,3.4121152E+02,3.1168681E+03,5.1908684E+02,3.1168681E+03,5.1908684E+02,7.5647778E+06,7.5647778E+06,1.0345614E+03,5.2835303E+03,

1.2702171E+04,5.4580272E+02,0.0000000E+00,5.1907598E+02,0.0000000E+00,5.1907598E+02,2.1738624E+03,3.4121152E+02,3.1168681E+03,5.1908683E+02,3.1168681E+03,5.1908683E+02,7.5647779E+06,7.5647779E+06,1.0345523E+03,5.2835303E+03,

1.2702171E+04,5.4580272E+02,0.0000000E+00,5.1907598E+02,0.0000000E+00,5.1907598E+02,2.1738621E+03,3.4121152E+02,3.1168682E+03,5.1908682E+02,3.1168682E+03,5.1908682E+02,7.5647780E+06,7.5647780E+06,1.0345427E+03,5.2835300E+03,

1.2702171E+04,5.4580273E+02,0.0000000E+00,5.1907598E+02,0.0000000E+00,5.1907598E+02,2.1738618E+03,3.4121152E+02,3.1168682E+03,5.1908682E+02,3.1168682E+03,5.1908682E+02,7.5647781E+06,7.5647781E+06,1.0345325E+03,5.2835296E+03,

1.2702171E+04,5.4580274E+02,0.0000000E+00,5.1907598E+02,0.0000000E+00,5.1907598E+02,2.1738613E+03,3.4121152E+02,3.1168682E+03,5.1908681E+02,3.1168682E+03,5.1908681E+02,7.5647781E+06,7.5647781E+06,1.0345218E+03,5.2835291E+03,

1.2702172E+04,5.4580274E+02,0.0000000E+00,5.1907598E+02,0.0000000E+00,5.1907598E+02,2.1738609E+03,3.4121152E+02,3.1168682E+03,5.1908681E+02,3.1168682E+03,5.1908681E+02,7.5647782E+06,7.5647782E+06,1.0345107E+03,5.2835284E+03,

1.2702172E+04,5.4580275E+02,0.0000000E+00,5.1907599E+02,0.0000000E+00,5.1907599E+02,2.1738604E+03,3.4121152E+02,3.1168682E+03,5.1908681E+02,3.1168682E+03,5.1908681E+02,7.5647782E+06,7.5647782E+06,1.0344992E+03,5.2835276E+03,

1.2702172E+04,5.4580275E+02,0.0000000E+00,5.1907599E+02,0.0000000E+00,5.1907599E+02,2.1738598E+03,3.4121152E+02,3.1168682E+03,5.1908681E+02,3.1168682E+03,5.1908681E+02,7.5647783E+06,7.5647783E+06,1.0344873E+03,5.2835267E+03,

1.2702173E+04,5.4580276E+02,0.0000000E+00,5.1907599E+02,0.0000000E+00,5.1907599E+02,2.

1738592E+03,3.4121152E+02,3.1168682E+03,5.1908681E+02,3.1168682E+03,5.1908681E+02,7.56
47783E+06,7.5647783E+06,1.0344752E+03,5.2835256E+03

```c
    };
    extern real j8m,j8t,j400m, j400t,j500m,j500t,j600m,j600t,j12m, j12t,j13m, j13t,j12q,
j13q,con51, con52; /*j12t&j13t 用不到,放入只是為了簡化資料輸入轉換的工作*/
    /*注意,目前除了j12q、j13q con51 con52仍是用英制(but/hr),其它需於此udf中轉成公制*/
#if !PR_HOST
    index=N_TIME-1;
        j8m=retran[index*16+0]*0.45359237;
        j8t=(retran[index*16+1]-32)/9.*5.+273.15;
        j400m=retran[index*16+2]*0.45359237;
        j400t=(retran[index*16+3]-32)/9.*5.+273.15;
        j500m=retran[index*16+4]*0.45359237;
        j500t=(retran[index*16+5]-32)/9.*5.+273.15;
        j600m=retran[index*16+6]*0.45359237;
        j600t=(retran[index*16+7]-32)/9.*5.+273.15;
        j12m=retran[index*16+8]*0.45359237;
        j12t=(retran[index*16+9]-32)/9.*5.+273.15;
        j13m=retran[index*16+10]*0.45359237;
        j13t=(retran[index*16+11]-32)/9.*5.+273.15;
        j12q=retran[index*16+12]-retran[index+12];
        j13q=retran[index*16+13]-retran[index+13];
        con51=retran[index*16+14];
        con52=retran[index*16+15];
#endif /* !PR_HOST*/
#if !RP_NODE
    index=N_TIME-1;
        j8m=retran[index*16+0]*0.45359237;
        j8t=(retran[index*16+1]-32)/9.*5.+273.15;
        j400m=retran[index*16+2]*0.45359237;
        j400t=(retran[index*16+3]-32)/9.*5.+273.15;
        j500m=retran[index*16+4]*0.45359237;
        j500t=(retran[index*16+5]-32)/9.*5.+273.15;
        j600m=retran[index*16+6]*0.45359237;
        j600t=(retran[index*16+7]-32)/9.*5.+273.15;
        j12m=retran[index*16+8]*0.45359237;
```

```
        j12t=(retran[index*16+9]-32)/9.*5.+273.15;
        j13m=retran[index*16+10]*0.45359237;
        j13t=(retran[index*16+11]-32)/9.*5.+273.15;
         j12q=retran[index*16+12]-retran[index+12];
         j13q=retran[index*16+13]-retran[index+13];
         con51=retran[index*16+14];
         con52=retran[index*16+15];


#endif /* !RP_NODE*/
#if !PARALLEL
   index=N_TIME-1;
        j8m=retran[index*16+0]*0.45359237;
        j8t=(retran[index*16+1]-32)/9.*5.+273.15;
        j400m=retran[index*16+2]*0.45359237;
        j400t=(retran[index*16+3]-32)/9.*5.+273.15;
        j500m=retran[index*16+4]*0.45359237;
        j500t=(retran[index*16+5]-32)/9.*5.+273.15;
        j600m=retran[index*16+6]*0.45359237;
        j600t=(retran[index*16+7]-32)/9.*5.+273.15;
        j12m=retran[index*16+8]*0.45359237;
        j12t=(retran[index*16+9]-32)/9.*5.+273.15;
        j13m=retran[index*16+10]*0.45359237;
        j13t=(retran[index*16+11]-32)/9.*5.+273.15;
         j12q=retran[index*16+12]-retran[index+12];
         j13q=retran[index*16+13]-retran[index+13];
         con51=retran[index*16+14];
         con52=retran[index*16+15];


#endif /* !PARRLLEL*/
}
```

附錄 C

extfile_trans0814

```
/* extfile.h
   Header file that contains the external variable declaration for
   volume  */


 real
rercic_2,rercic_1,j8m,j8t,j400m,j400t,j500m,j500t,j600m,j600t,j12m,j12t,j13m,j13t,j12q
,j13q,con51,con52;
```

附錄 D

Jet-Pump.c

```c
#include <udf.h>
 real MJP1[421]=

  {
413.0666809082,
326.3579101562,
321.0173034668,
307.5032958984,
297.3935241699,
289.4401245117,
283.8507080078,
287.2659912109,
284.8008117676,
287.7175292969,
296.3175354004,
297.6595153809,
289.2878112793,
279.1041564941,
274.3890380859,
286.1222229004,
299.8766784668,
308.1109924316,
314.0970764160,
313.7276611328,
310.4779052734,
314.3295288086,
316.7553100586,
306.8313903809,
296.6226196289,
297.8337402344,
304.1250915527,
305.1626281738,
```

303.2226562500,

301.5214538574,

307.9545593262,

296.6928100586,

297.6777954102,

305.4465332031,

302.0891723633,

303.5141906738,

307.6730346680,

304.7698669434,

305.2008361816,

307.6646118164,

312.2106018066,

302.1304931641,

295.0678405762,

300.4559326172,

305.4530944824,

306.1307067871,

311.7238464355,

311.2301940918,

300.5154724121,

300.3254089355,

294.9004211426,

298.5279846191,

304.4056396484,

308.2414245605,

308.9651184082,

315.5549316406,

314.1866760254,

305.1500244141,

299.6817626953,

301.3420104980,

306.5887756348,

304.8813781738,

298.9572753906,

305.9981384277,

309.8601684570,

306.1230773926,

302.7181701660,

308.5161132812,

305.2914123535,

296.7590332031,

296.0934753418,

296.7260742188,

299.9962768555,

296.9165649414,

292.6705627441,

300.3601074219,

304.5277709961,

302.6087341309,

300.0222778320,

285.4369506836,

276.8054809570,

288.5116882324,

302.0780639648,

310.5999145508,

312.9721374512,

312.5473937988,

311.9107055664,

308.0333862305,

325.7108764648,

332.8321228027,

335.9859619141,

332.5013427734,

333.7884216309,

324.6588134766,

308.1458435059,

300.0551147461,

300.9734802246,

302.5968627930,

297.5284729004,

307.8698730469,

312.3447265625,

307.9054260254,

317.8560180664,

319.8342285156,

320.7813415527,

319.2579650879,

323.2377014160,

320.1287536621,

310.5867309570,

299.2576293945,

299.1072692871,

312.2298278809,

316.6038513184,

316.8911743164,

308.1024780273,

303.2912902832,

304.2585144043,

305.7385864258,

297.7686767578,

300.8628845215,

304.8452758789,

306.6133117676,

305.2666320801,

311.5539855957,

316.5277099609,

311.5317077637,

318.0693664551,

317.5680541992,

313.5215759277,

309.0600891113,

307.4252929688,

305.4765625000,

316.7678833008,

321.5791320801,

318.5670776367,

321.7465515137,

326.6211853027,

320.7984313965,

312.9338073730,

304.8275146484,

302.2018432617,

302.5981140137,

300.7713928223,

297.0481262207,

300.3267211914,

306.2807922363,

308.6179809570,

307.8139953613,

303.3892211914,

301.6270141602,

298.5530395508,

301.4265441895,

298.7424621582,

293.6414489746,

296.9594726562,

309.1371459961,

308.9330444336,

310.3220214844,

320.9402770996,

322.7087097168,

329.6543273926,

329.4833068848,

330.8347167969,

338.5202941895,

338.9606933594,

334.1957702637,

332.6296081543,

324.9040832520,

316.9577636719,

313.8995056152,

316.2251586914,

314.3447265625,

322.0126342773,

330.4769287109,

331.3041687012,

325.8958740234,

317.4710693359,

303.8621826172,

297.9824829102,

296.1604919434,

303.3266601562,

306.4691162109,

311.1526489258,

322.5455322266,

324.8806762695,

319.4925231934,

311.2976684570,

300.5209960938,

303.4821166992,

294.7719421387,

293.5421447754,

293.0712890625,

296.6499633789,

298.4014282227,

298.6011657715,

299.4833068848,

301.3288574219,

299.0025329590,

292.9275207520,

291.8115234375,

290.4216918945,

298.3817443848,

304.2197570801,

300.5233764648,

295.9208679199,

302.1153564453,

306.5271606445,

307.9630737305,

306.5380249023,

313.7500610352,

316.3907165527,

299.0316467285,

296.4185180664,

300.7223510742,

294.7338867188,

297.6352539062,

300.7776184082,

306.3455200195,

305.9098510742,

305.6818542480,

301.1197204590,

308.0666503906,

308.2240600586,

304.2214660645,

303.4303588867,

306.4281616211,

306.2767944336,

315.8268737793,

317.5952148438,

315.1491088867,

306.5415954590,

292.5543212891,

289.2420654297,

289.1956176758,

290.6029663086,

298.8447875977,

299.5834960938,

300.3887634277,

307.0400390625,

306.8403625488,

305.1284179688,

306.6665039062,

307.8930969238,

309.2055053711,

308.4380187988,

305.9452209473,

311.1340637207,

319.7749023438,

316.1598510742,

311.3017883301,

307.9494934082,

313.6158752441,

315.8036499023,

319.8055419922,

322.6976928711,

327.5531921387,

330.0814514160,

330.7543945312,

329.0117492676,

316.6713256836,

300.8808898926,

302.8599243164,

298.3752136230,

295.1193237305,

309.1203002930,

307.1749572754,

297.5987854004,

302.2038574219,

305.7335510254,

310.8834533691,

311.1208190918,

307.4714965820,

311.0030822754,

310.3283996582,

310.6437988281,

309.3616333008,

301.3576354980,

300.1160583496,

302.7118835449,

307.2509765625,

317.8715820312,

315.9887390137,

310.4831542969,

312.9618835449,

314.5558166504,

311.9319763184,

306.6300048828,

310.1999206543,

315.0173034668,

314.7652282715,

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311.3652343750,

307.1312561035,

304.6244506836,

304.3390502930,

308.6628723145,

308.2032165527,

304.7149963379,

304.0281677246
   };

```
DEFINE_PROFILE(mass_jp1,t,i)
{
  face_t f;
  int index;
#if !PR_HOST

  begin_f_loop(f,t)
    {
         index=N_TIME;
F_PROFILE(f,t,i)=MJP1[index-1];
      }
  end_f_loop(f,t)
```

```
#endif /* !PR_HOST*/


#if !RP_NODE

  begin_f_loop(f,t)
    {
          index=N_TIME;
F_PROFILE(f,t,i)=MJP1[index-1];
        }
  end_f_loop(f,t)


#endif /* !RP_NODE*/

#if !PARALLEL

  begin_f_loop(f,t)
    {
          index=N_TIME;
F_PROFILE(f,t,i)=MJP1[index-1];
        }
  end_f_loop(f,t)

#endif /* !PARRLLEL*/
}
```