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出國報告（出國類別：實習）

赴美國 True North Consulting 公司實習報告

服務機關：核能研究所
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派赴國家：美國
出國期間：102 年 9 月 8 日~102 年 10 月 7 日
報告日期：102 年 11 月 4 日

摘 要

本所於執行「核一廠中幅度功率提昇案」時，發現核一廠在 88 年更換兩部機組之低壓汽機轉子後，一號機的發電量始終低於二號機約 8 MWe，而在分別執行完小幅度功率提昇(Measurement Uncertainty Recapture Power Uprate, MUR PU)以及中幅度功率提昇(Stretch Power Uprate, SPU)後，其發電差異也都維持在 10 MWe 左右。爲了釐清前述現象之肇因，以及精進本所電廠效能評估相關人員於電廠熱效率分析之技術，因此指派蔡員至美國 True North Consulting 公司參加核電廠熱效率評估實習，以利後續對核一廠進行熱功性能評估工作。本報告中則探討實習課程內容與初步的實習成果。

目　　次

一、目的

美國 True North Consulting 公司(以下簡稱 TNC 公司)位於美國科羅拉多州的蒙特羅斯(Montrose)(圖 1 與圖 2)，該公司專長於提供電廠工程諮詢、熱效率改善、次系統工程諮詢、客製化效能監控軟體等技術服務。本次實習的主要目的爲精進本所從事電廠效能評估相關人員於電廠熱效率分析之技術，其技術將應用於釐清目前核一廠兩部機組發電量差異之肇因，此外，相關技術對於現有電廠效率損失之評估亦有所助益。

圖 1　True North Consulting 公司所在位置

圖 2　True North Consulting 公司外觀

二、過程

(一)行程

此次公差行程，由 102 年 9 月 8 日起至 102 年 10 月 7 日止，共計 30 天，詳細行程如表 1：

表 1　赴美國公差行程表

行程					公差地點		工作內容
月	日	星期	地點		國名	地名	
			出發	抵達			
9	8	日	台北	丹佛	美國	丹佛	去程
9	9	一	丹佛	蒙特羅斯	美國	蒙特羅斯	1. 去程 2. 討論 TSM 軟體實習事宜
9 10	10- 4	二 五			美國	蒙特羅斯	1. 電廠熱功性能訓練課程 2. 各種熱功性能分析軟體(TSM、CIM、PEPSE)實習 3. 核一廠一號機、二號機熱功性能分析實習。 4. 資料整理
10	5	六	蒙特羅斯	洛杉磯	美國	洛杉磯	回程
10	6- 7	一	洛杉磯	台北			回程

由於至蒙特羅斯並無直航班機，因此本次行程於 9 月 8 日先抵達美國洛杉磯國際機場，並接著轉機至丹佛住宿一晚，於 9 月 9 日再搭美國聯合航空班機至蒙特羅斯，並於當天與 TNC 公司的熱效率評估部門經理 Mr. Frank Todd 討論實習細節。實習過程中主要由 Mr. Christopher J. Seip (熱效率評估部門工程師) 擔任專人指導，此外，Mr. Frank Todd、Mr. Greg Alder 以及 Mr. Richard Duggan (熱效率評估部門資深工程師) 於實習過程中，亦提供相關之訓練課程指導。至於回程則按照與去程相反之路徑返回台灣。

(二)出國紀要

本次實習於 9 月 10 日開始，展開爲期約一個月實習課程。整個實習課程之綱要如表 2 所示，以下小節則針對各個實習課程進行說明:

表 2　赴美國實習課程表

項次	課程名稱	課程日期	講師
1	熱功性能訓練 (Thermal Performance Training)	9/10 ~ 9/13	Mr. Frank Todd
2	TP-PLUS TSM 軟體使用訓練	9/16 ~ 9/17	Mr. Christopher J. Seip
3	TP-PLUS CIM 軟體使用訓練	9/18 ~ 9/19 9/26 ~ 9/30	Mr. Richard Duggan
4	PEPSE 軟體使用訓練	9/20 ~ 9/25	Mr. Christopher J. Seip
5	熱功性能評估訓練 (Thermal Performance Assessment Training)	10/1 ~ 10/4	Mr. Frank Todd Mr. Christopher J. Seip Mr. Greg Alder

1. 熱功性能訓練(Thermal Performance Training)

由於電廠的熱功性能分析，需考量電廠每個設備之個別性能以及其運轉條件對於系統整體熱效率之影響。因此，實習一開始由 Mr. Frank Todd 針對熱功性能分析所牽涉到的相關課題進行爲期 4 天(9 月 10 日至 9 月 13 日)的訓練課程，該課程除了加強熱功性能分析之整體概念外，亦有利於後續各實習課程之銜接，本課程之細部課程表詳附錄 1，主要課程大綱如下:

(1) Introduction
(2) Thermodynamic Fundamentals – 1 Introduction
(3) Thermodynamic Fundamentals – 2 Heat Balance Diagrams
(4) Thermal Dynamic Program Development Overview
(5) Power Plant Component Evaluation – Introduction Turbines & Condensers
(6) Power Plant Component Evaluation – Feed Water Heaters Pumps & Control Valves
(7) Power Plant Component Evaluation – Cooling Towers
(8) Power Plant Component Evaluation – Nuclear Component
(9) Power Plant Cycle & Component Evaluation – Cycle Isolation Monitoring
(10) Power Plant Cycle & Component Evaluation – Power Calculation
(11) Thermal Performance Resources & Tools – Introduction
(12) Thermal Performance Resources & Tools – Instrumentation
(13) Thermal Performance Resources & Tools – Measuring & Delivering Electricity
(14) Thermal Power Testing Overview – Introduction

(15) Thermal Power Testing Overview – Test Procedure Example
(16) Thermal Power Testing Overview – Instrumentation Validation and Uncertainty
(17) Thermal Power Testing Overview – Cooling Tower Testing
(18) Exercises
(19) Exercise Answers

課程大綱第(1)~(3)項主要介紹電廠熱功分析中所會用到的基本熱力學公式以及圖表，課程大綱第(4)項則是敘述電廠運轉數據的架構，資料蒐集與過濾的方法、主要參數之趨勢追蹤、主要效能評估參數之定義等。課程大綱第(5)~(8)項，則針對核電廠中重要的設備組件，如汽輪機組、冷凝器、飼水加熱器、反應爐、各主要閥件與泵浦、冷卻塔及其他重要組件進行基本原理介紹，此外，對於各組件在熱功性能分析中的主要分析參數、參數變動對於系統效能之影響、以及其參數計算過程均有詳細的介紹，並提供相關的計算練習以加強學員之理解。課程大綱第(9)項主要在介紹電廠蒸汽管線洩漏對於電廠功率輸出之衝擊，同時亦介紹TNC 公司所開發的 Cycle Isolation Monitoring (CIM)軟體之功能以及有關蒸汽洩漏量計算之理論基礎。課程大綱第(10)項，則係整合前述各組件之性能分析，來進行全廠一般支援系統(Balance of Plant, BOP)之效能分析，同時對於各參數之靈敏度分析(Sensitivity)亦有所著墨。課程大綱第(11)項，除了介紹一般常用的商用熱功性能分析軟體 PEPSE 之分析功能外，亦介紹了 TNC 公司自己開發的熱功性能分析軟體 TSM 之相關功能。課程大綱第(12)項，除了對於實際應用於電廠中的各式溫度、壓力與流量感測器介紹其基本運作原理外，課堂中講師更分享了在電廠中實際量測的實務經驗。課程大綱第(13)項，則是對於發電機端以及電力輸出的各種主要參數與計算公式進行介紹。課程大綱第(14)~(17)項，則係針對核電廠各種主要的性能測試，如汽機更新後的效能驗證試驗、飼水加熱器試驗、冷卻水塔試驗、大修後試驗，以及容量試驗等進行介紹。其中，課程對於汽機更新後之效能驗證試驗有較為深入的探討，包含試驗的準則、儀控需求、試驗程序、各種校正曲線、效能之計算，以及可接受準則等，均有理論與實務上的介紹。最後，課程大綱第(18)~(19)項，則提供本課程中的計算練習，以加深學員之理解與印象。

2. TP-PLUS TSM 軟體訓練

在接受完電廠熱功性能分析訓練課程，對於電廠熱功性能各項目有較深刻的認識後，接著於 9 月 16 日至 9 月 17 日間進行 TP-PLUS TSM (以下簡稱 TSM) 軟體訓練。TSM 軟體為本次實習目標所採用的主要分析軟體，該軟體係 TNC 公司自行開發的電廠熱功性能分析軟體。有別於一般常見的熱功性能分析軟體(如PEPSE)，TSM 並非用於系統 BOP 模型的建置工作，它的主要功用為利用電廠的

運轉資料來分析電廠的潛在發電功率損失。該軟體係以 Microsoft Excel 建置，介面簡單且十分容易上手，其軟體畫面如圖 3 所示，上課情形則如圖 4 所示。

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Chin Shan Nuclear Power Plant

Thermal Performance Summary

Current Statistics		Unit 1 Report	Unit 2 Report
Report Date		2013/3/20	2013/3/20
Gross Dependable Capacity	MWe	662.7	662.4
Gross Generation	MWe	651.8	661.2
MW Deviation	MWe	-10.9	-1.3
Accounted MW Loss	MWe	-1.1	#NAME?
Unaccounted MW Loss	MWe	-9.8	#NAME?
Core Thermal Power	%	100.0%	99.9%
Average Condenser Back Pressure	$mmHg_a$	50.4	50.3
Circulating Water Inlet Temperature	°C	21.4	21.5
Condensate Temperature	°C	39.1	37.0

Contact True North Consulting | Weekly Report | Unit 1 TSM | Unit 2 TSM

TP-Plus | Edit Mode | Compare MWe Loss | Compare Critical Parameters | TRUE NORTH

圖 3　TP-PLUS TSM 軟體畫面(資料來源:本次實習課程操作資料)

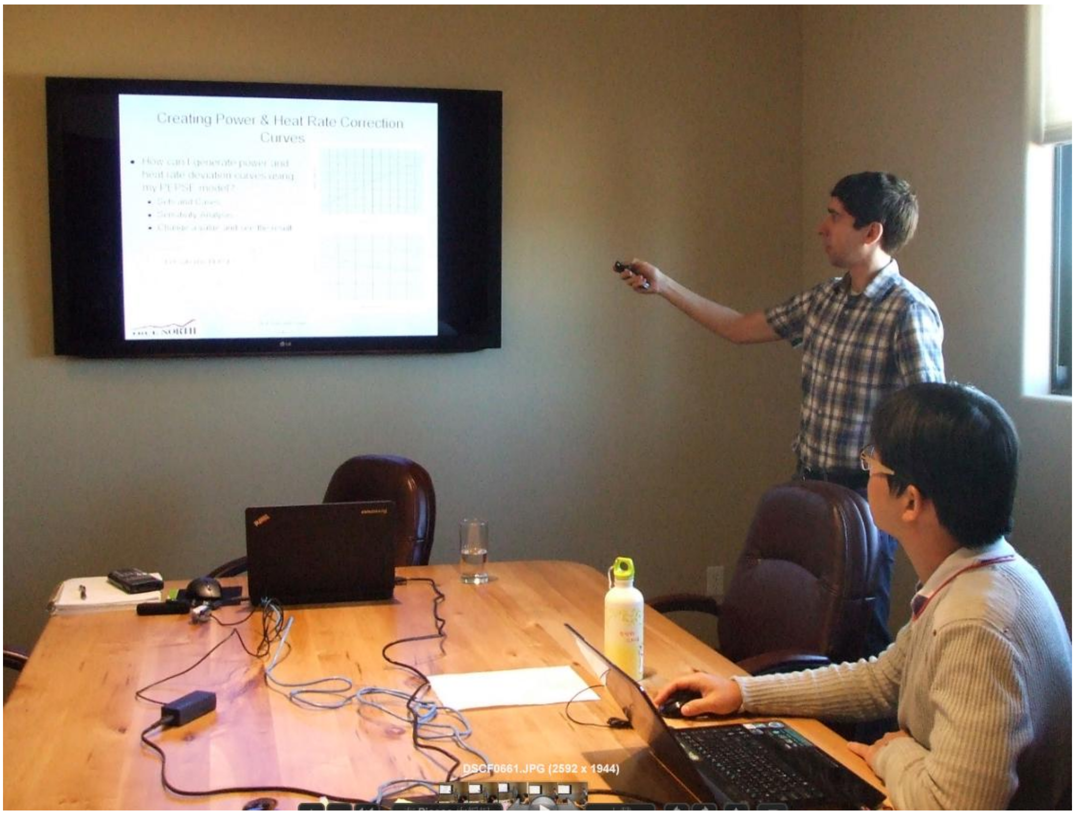


圖 4　TP-PLUS TSM 軟體上課照片

整個 TSM 軟體訓練的細部課程表如附錄 2 中的“TSM Software Training”部分，至於課程大綱則介紹如下:

(1) Introduction
(2) Software Installation
(3) System Use
(4) Data Management
(5) System Tables

TSM 軟體訓練課程講師由 Mr. Christopher J. Seip 擔任，主要教學內容爲介紹 TSM 軟體之各項表單與功能，並進行操作練習。此外，對於軟體之運作架構、輸入數據之前處理、各主要參數之計算原理、效能分析方法等均有介紹。

3. TP-PLUS CIM 軟體訓練

TP-Plus CIM(Cycle Isolation Monitoring)是由 TNC 公司開發的系統環路隔離度監測軟體。該軟體藉由輸入欲監測的閥件規格、閥件洩漏對於系統熱功率之損失因子(Loss Factor, LF)以及現場量測閥件下游管路之表面溫度等資料，即可自動計算出蒸汽之洩漏量以及該洩漏量所導致的發電輸出損失。本課程的訓練時間爲 9 月 18 日至 9 月 19 日，講師由 Mr. Richard Duggan 擔任，上課情況如圖 5 所示:

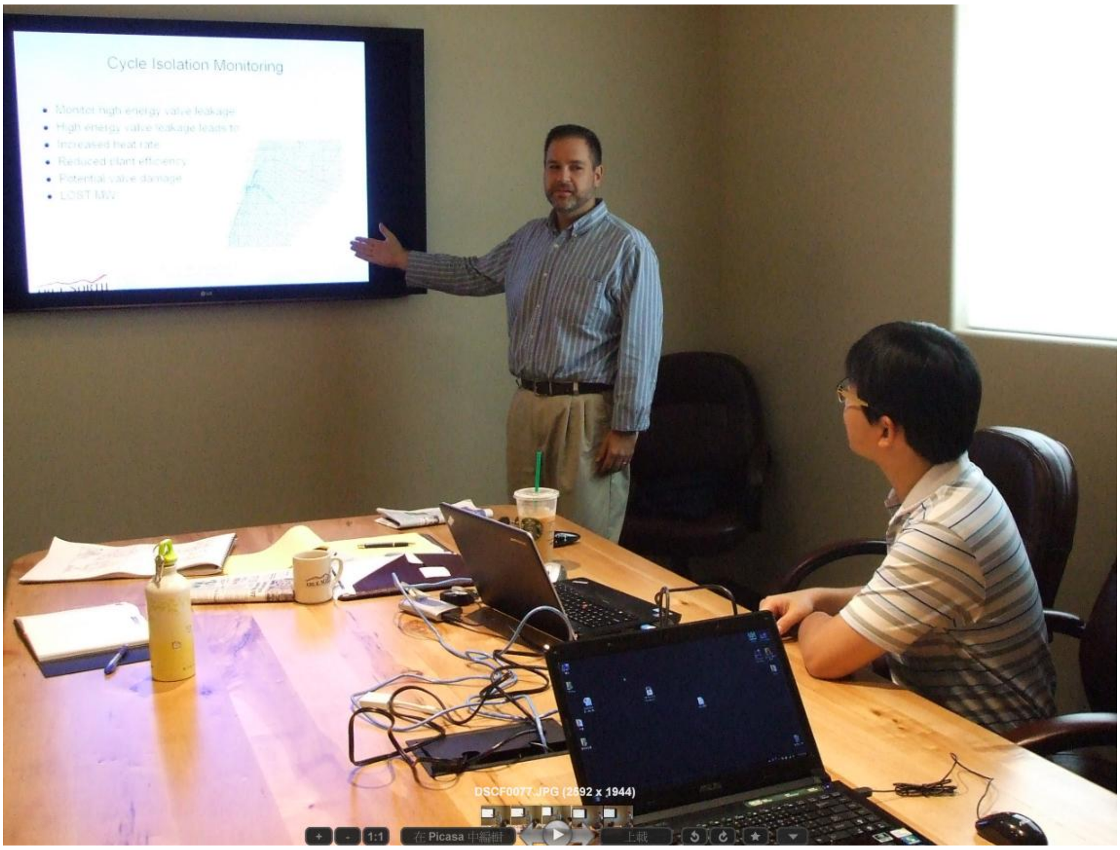


圖 5　TP-PLUS CIM 軟體上課照片

TP-Plus CIM 之細部課程表如附錄 3 所示，課程大綱則說明如下:

(1) Use of the TP-Plus software
(2) Review of valve construction and design
(3) Drawing Review
(4) Loss Factor Calculation
(5) Distance Correction

整個課程首先針對 TP-Plus CIM 的使用介面(圖 6)進行介紹，接著針對常見的主要洩漏監測閥件種類、電廠 P & ID 圖中相關閥件之判讀、閥件洩漏判斷方式、主要量測參數、主要量測方法、洩漏量計算方法、現場巡查資料收集、軟體資料輸入以及結果輸出等課題進行介紹。此外，課程最後亦以核二廠部分洩水閥件資料爲例，探討相關閥件的洩漏狀況。

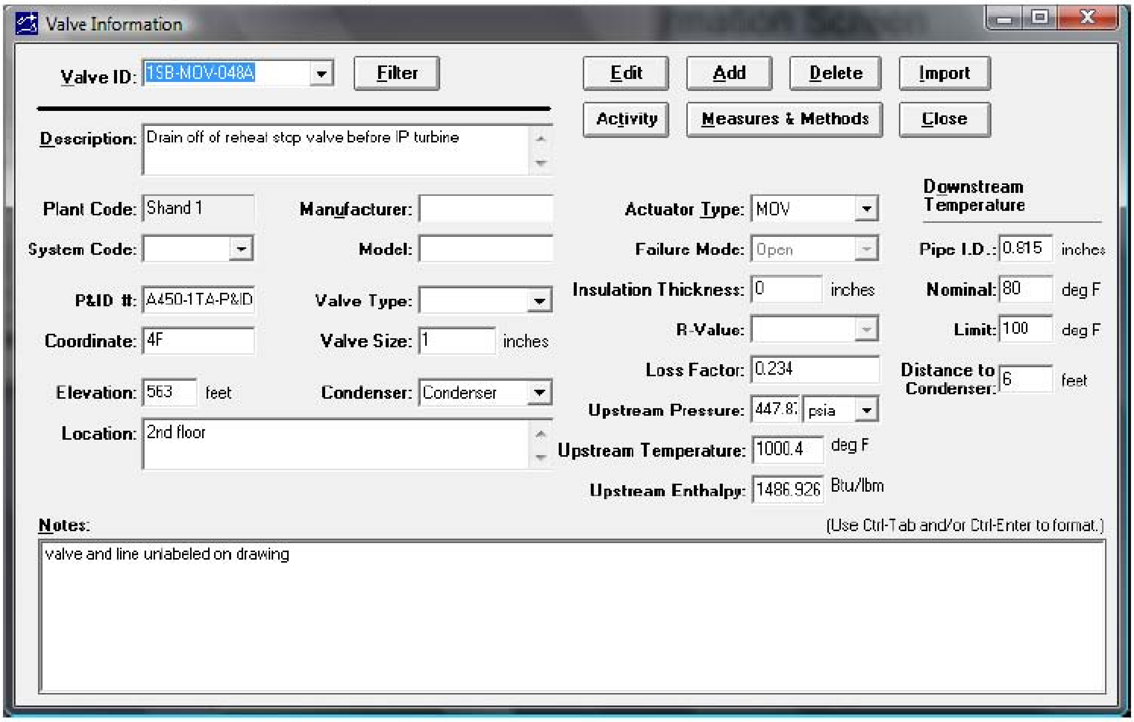


圖 6 TP-PLUS CIM 閥件資料輸入畫面(資料來源:本次實習課程教材)

4. PEPSE 軟體訓練

由於使用 TSM 軟體進行熱功性能分析時，部分的校正曲線需藉由 PEPSE 軟體來獲得，因此，本次實習中 TNC 公司亦進行 PEPSE 軟體之使用訓練。本訓練的實施日期爲 9 月 20 日至 9 月 25 日，講師由 Mr. Christopher J. Seip 擔任，整個 PEPSE 軟體訓練的細部課程表如附錄 2 中“PEPSE Software Training”部分，至於課程大綱則介紹如下:

(1) Introduction
(2) General

(3) Potential Dangers and Pitfalls
(4) Heat Rate and Power
(5) Condensers
(6) Cooling Towers
(7) Feedwater Heaters
(8) Pumps, Valves, Sources and Sinks
(9) Boilers and Components
(10) Combustion Turbines and HRSG Components
(11) Nuclear Applications
(12) Testing
(13) Special Options Overview
(14) Tips for PEPSE Model Review

課程大綱(1)~(3)項主要爲介紹 PEPSE 軟體的基本指令、電廠模型之建立、資料之輸入以及 PEPSE 軟體的使用限制等。課程(4)~(11)，則著重在詳細介紹 PEPSE 內建模組，如冷凝器、汽機、飼水加熱器、泵浦與閥件等常用組件之細部設定與使用方式，並以核一廠之相關資料實際建置電廠熱平衡模型。由於本次實習的目標主要爲核電廠之熱功性能分析，因此，諸如項目(9)、(10)與火力電廠相關之項目，以及項目(6)等不適用我國核電廠之設備項目則僅以簡略之方式進行介紹。PEPSE 軟體操作畫面則如圖 7 所示。

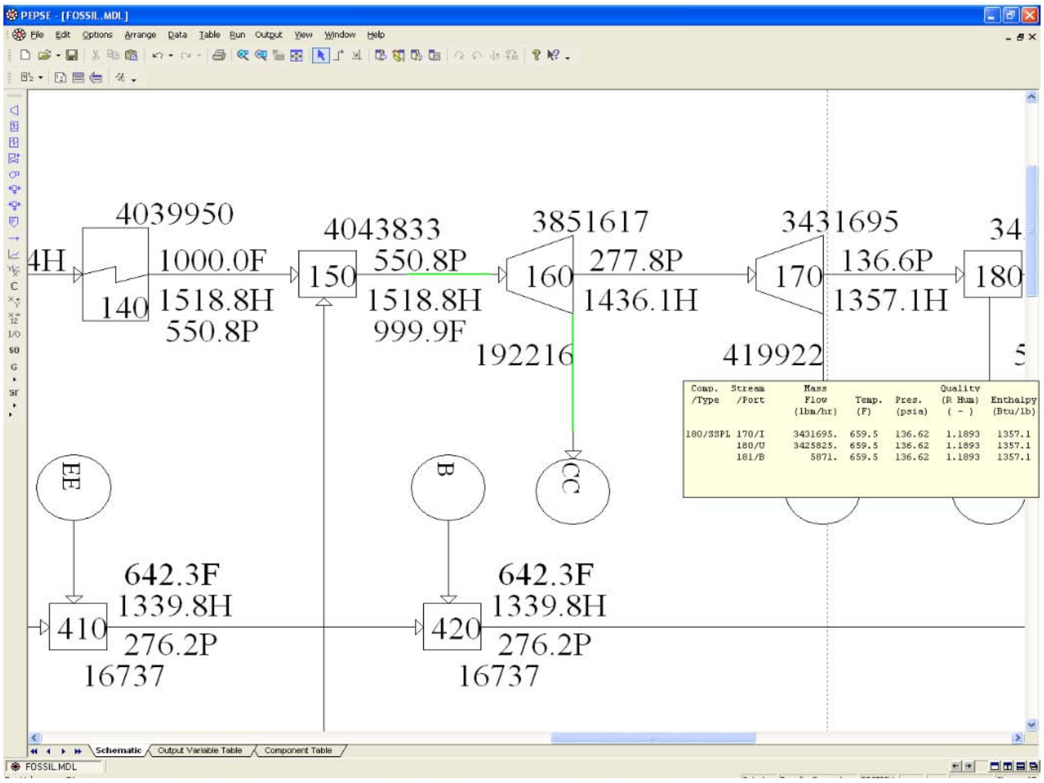


圖 7　PEPSE 軟體畫面(資料來源:本次實習教材)

5. 核一廠一、二號機熱功性能分析實習

在接受完前述的熱功性能分析相關基礎訓練課程後，爲了探討本次實習的目標，即核一廠兩部機組之發電量差異，接著由 Mr. Frank Todd、Mr. Greg Alder、Mr. Christopher J. Seip 進行核一廠一、二號機熱功性能分析之實習課程，課程實施日期爲 9 月 26 日至 10 月 4 日，整個訓練的細部課程表如附錄 2 中的"Using TSM for thermal Performance Assessments"部分，至於課程大綱則介紹如下:

(1) Data Preparation and Filtering
(2) Correction Curve Preparation
(3) Correction Curve Practicing (PEPSE Software)
(4) Correction Curve Summary
(5) Methods to predict Condenser Back Pressure
(6) Establishing Baseline Plant Parameters from actual plant data
(7) Evaluating Plant Performance using TSM software
(8) Case Study of Chinshan NPP
(9) Advanced model analysis
(10) Summary of the evaluation

本課程需應用到的軟體包含 TSM 以及 PEPSE，由於 TSM 軟體需要套用一定格式的電廠運轉數據，因此，課程的一開始爲進行電廠的運轉數據處理。在本次實習中，係利用核一廠自 2008 年 8 月至 2013 年 9 月之實際運轉數據來進行分析，由於原始的電廠資料所包含的欄位高達 334 個，且其資料包含全載運轉、部分負載運轉以及大修時的停機資料，因此，爲了將資料整理成 TSM 所需要的格式與條件，須對資料進行初步篩選。而在完成初步的資料篩選後，接著課程大綱(2)~(5)爲學習如何利用 PEPSE 軟體來獲得各種校正曲線，此校正曲線係用來評估不同運轉條件之參數對於電廠熱耗率之影響，以判斷實際運轉效能與基準線數值(Baseline value)之差異。在校正曲線的實際操作過程中，係以核一廠完成中幅度功率提昇後之熱平衡圖來建立 PEPSE 模型，並且參考實際運轉數據之範圍，來訂定各種參數之變化限值，利用 PEPSE 軟體求出相對應的功率輸出變化，即可繪製各參數之單位變化量對於熱耗率影響之關係圖。課程(5)則是學習如何從歷史運轉數據中，挑選出基準線數值，而此基準線數值將作爲判斷電廠運轉效能差異之基礎。在 TSM 軟體中輸入篩選過的運轉數據、校正曲線公式、基準線數值以及部分設備之設計資料後，TSM 軟體即可分析核一廠兩部機組於指定日期下的主要運轉參數差異以及其對於運轉效率之影響。課程(7)~(9)即是以核一廠爲案例，探討兩部機組各主要參數之運轉差異及其影響。課程(10)則是將本次實習過程中，針對核一廠之分析案例進行回顧與總結。

三、心得

本次針對電廠熱功效率分析之相關課程，內容十分豐富，以下將本次實習內容，分爲熱功性能訓練、分析軟體訓練以及核一廠熱功性能分析實習三個部分來進行心得說明。

(一)熱功性能訓練

熱功性能分析訓練課程中，在每個章節除了基礎介紹外，亦提供了相對應的計算練習。此外，每一章節的結尾，均會以提問的方式來對整個章節進行回顧(各章節之回顧如附錄 4)，此一方式除了增進學員之理解外，亦可增進學員對於該章節之印象。例如附錄 4-3、4-4 針對冷凝器對於熱功性能之影響回顧，其舉例之問題如下:

1. Tube Sheet fouling results in the following changes (Increase or Decrease)
   - Circulating water flow through condenser.   Answer: Decrease
   - Differential pressure across tubes.   Answer: Increase
   - Temperature rise tube inlet to tube outlet.   Answer: Increase
   - Condenser pressure.   Answer: Increase
   - Condensate sub-cooling.   Answer: Decrease
   - Cleanliness factor if you do not measure flow.   Answer: Decrease
   - Cleanliness factor if you do measure flow.   Answer: Remain the Same
   - Electric output.   Answer: Could go either way
2. What can cause tube side air binding?   Answer: Failure of air venting system and tide level changes
3. Shell side tube fouling will cause tube side temperature rise to? (increase or decrease)   Answer: stay the same or slightly increase
4. When does air in-leakage become a thermal performance problem?   Answer: When it overcomes the air removal capacity
5. When might it be a good idea to turn off a circulator?   Answer: In the winter when the plant is operating on the flat portion of the correction curve.
6. List at least two alternate parameters to give an indication of condenser pressure. Answer: Exhaust hood temperature; Condenser hotwell (if there is no sub-cooling) temperature.
7. What should you watch out for when measuring condenser outlet temperature? Answer: Stratification if the sensor is near the tube sheet.
8. List at least two major causes of condenser tube leaks.   Answer: Vibration; Impingement from damaged spargers

問題1探討了冷凝器管側內壁結垢對於冷凝器重要參數的影響，例如當管側內壁結垢時，將會造成管段壓降、循環海水出口溫昇以及冷凝器背壓上升，相反地則會降

低循環海水流量以及冷凝水次冷度。不過對於冷凝器洗淨因素(cleanliness)而言，因為其定義為$C_f=U_{actual}/U_{ideal}$ (C_f: 洗淨因素、U_{actual}:實際熱傳系數，U_{ideal}:設計熱傳系數)，在沒有量測循環海水流量下，因U_{actual}會降低而U_{ideal}不變，因此C_f 會顯示為降低的狀況，不過如果有量測循環海水流量，則U_{ideal}同樣會降低，因此C_f 計算後將與原本相同。至於對發電功率輸出之影響，則有可能造成上升或下降，而其原因主要係考慮冷凝器當時的操作點，如當時冷凝器操作在choke Point左側(如圖8)，則管側結垢所造成的冷凝器背壓上升可能微幅提升發電出力，反之，如操作在choke Point右側，則會降低發電出力。當結垢是發生在管側之外壁，如問題3所述時，則對於海水溫昇可能無影響，亦可能造成其微幅上昇。

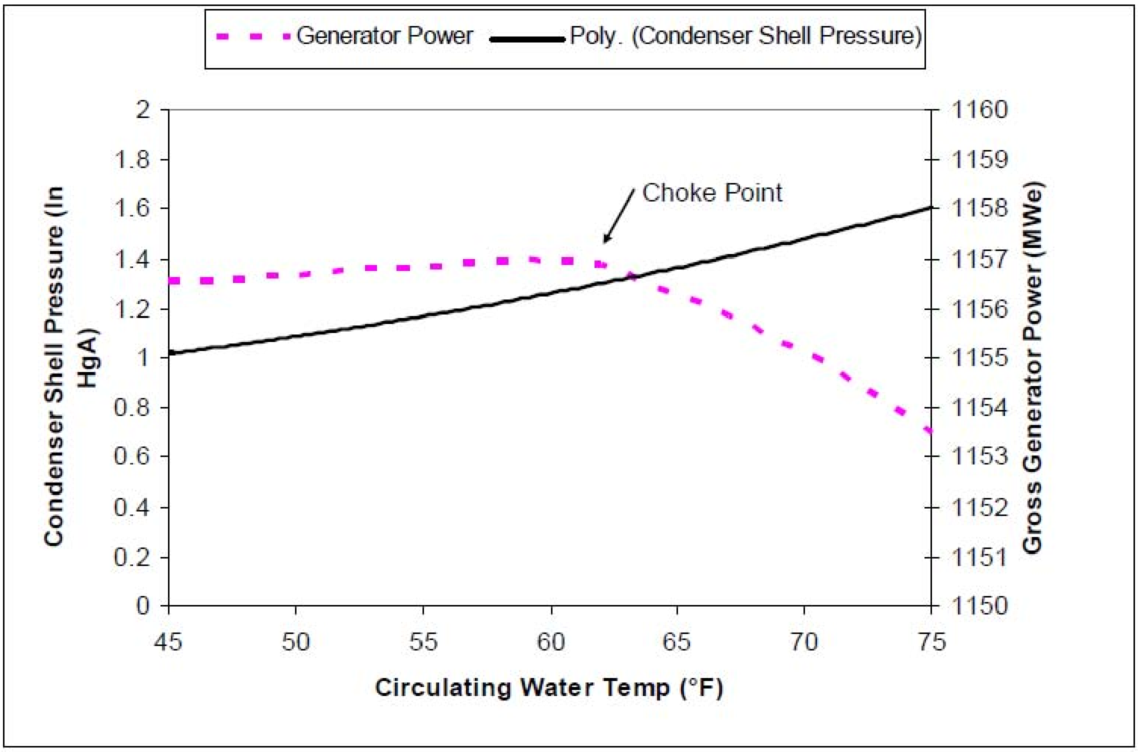


圖8　循環海水溫度對於冷凝器壓力與電力輸出之關係

除了上述舉例的冷凝器組件外，對於飼水加熱器、汽機、發電機、閥件等，亦有相對應的回顧章節來探討該組件參數之變動對於其上下游組件之影響，以及對於整體功率輸出。而藉此一問一答的方式，講師誘導著學員從單一設備的運轉參數，逐步考量至整個系統之影響，對於學員整合所學甚有幫助。

(二)分析軟體訓練

分析軟體之訓練，包含 TP-PLUS TSM、TP-PLUS CIM、PEPSE 以及之訓練，以下則僅針對 TNC 公司開發的 TP-PLUS TSM、TP-PLUS CIM 之使用心得進行說明。

1. TP-PLUS TSM

基本上，TSM 軟體並非泛用型的軟體，亦即 TNC 公司必須針對個別電廠的組態來進行 TSM 軟體的客製化。不過由於整個軟體是以 Excel 搭配巨集功能撰寫，因此其軟體運作流程以及相關的計算公式均十分透明，使用者如有一定 excel 與巨集使用經驗，對於程式參數之調整並不困難，TSM 之軟體架構則如圖 9 所示:

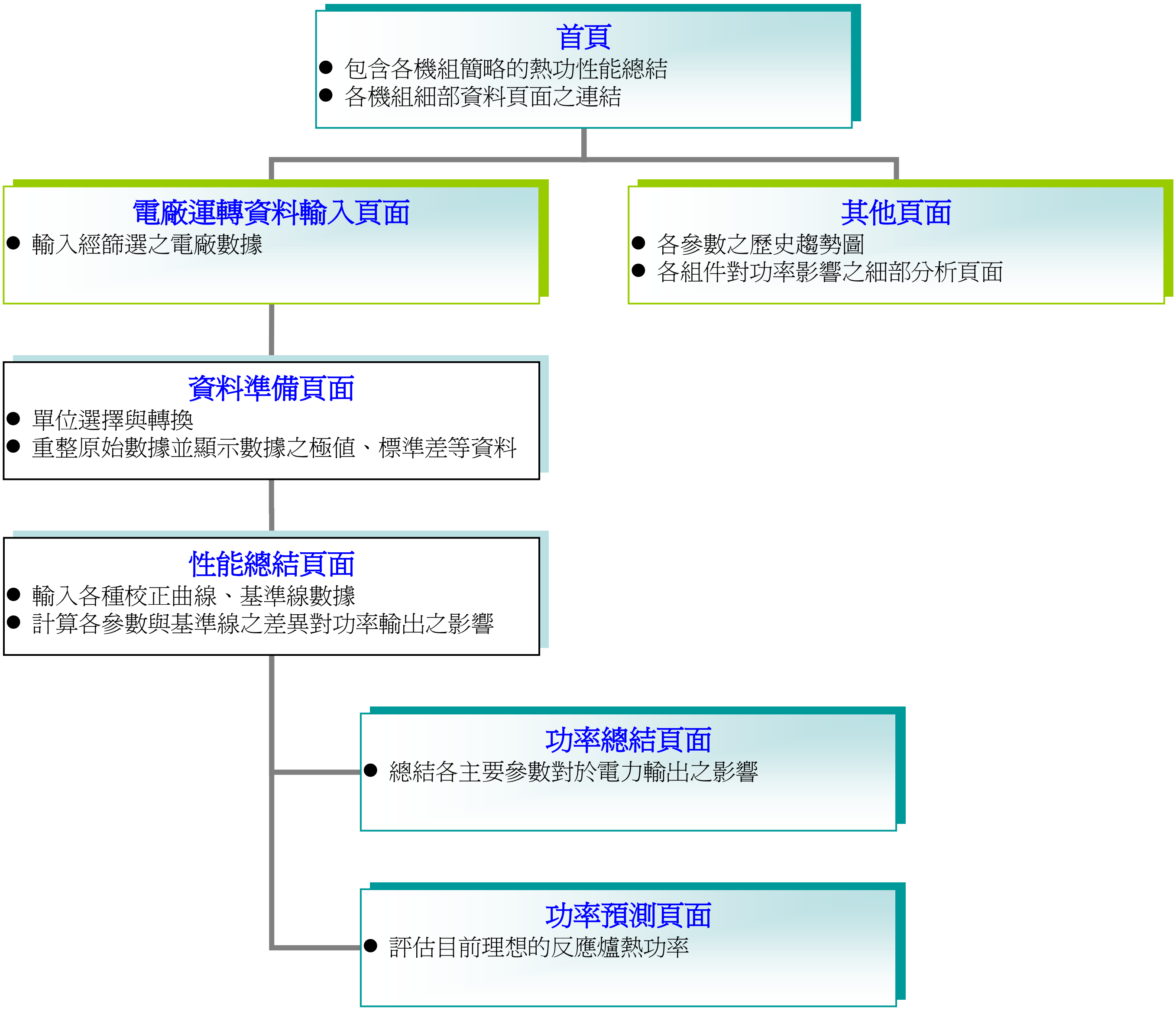


圖 9　TSM 之軟體架構

在本次實習中，TSM 軟體係根據核一廠之架構進行客製化，因此，在 TSM 首頁之顯示即爲核一廠一號機與二號機之簡略的熱功性能比較表(如圖 3)，其呈現的資料包含預期最佳發電量(Gross Dependable Capacity)、實際發電量(Gross Generation)、發電偏差(MW Deviation)、已知發電損失(Accounted MW loss)、未知發電損失(Unaccounted MW loss)、爐心熱功率、冷凝器背壓、海水溫度、冷凝水溫度等基本資訊，另外，使用者可由此首頁連結至各機組的細部資料。在各機組

的細部資料中，首先須將篩選過後的電廠運轉資料由“電廠運轉資料輸入頁面(ImportRawData)”將其匯入(如圖 10)：

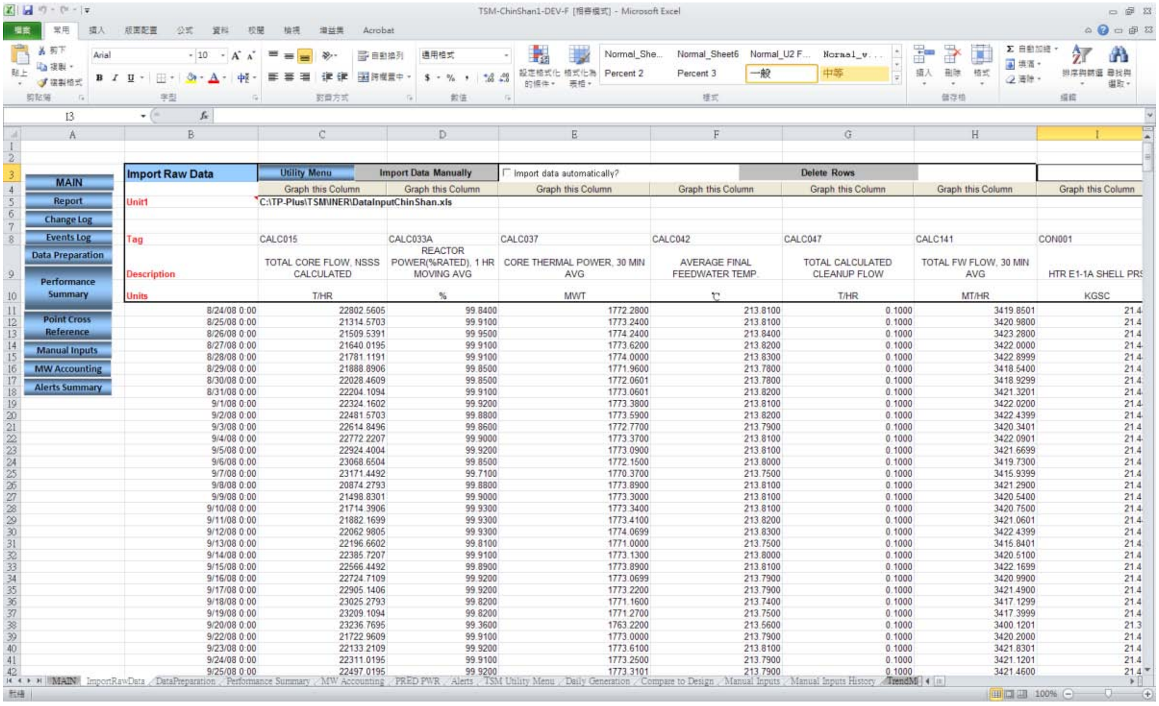


圖 10　TSM 軟體-電廠數據輸入頁面

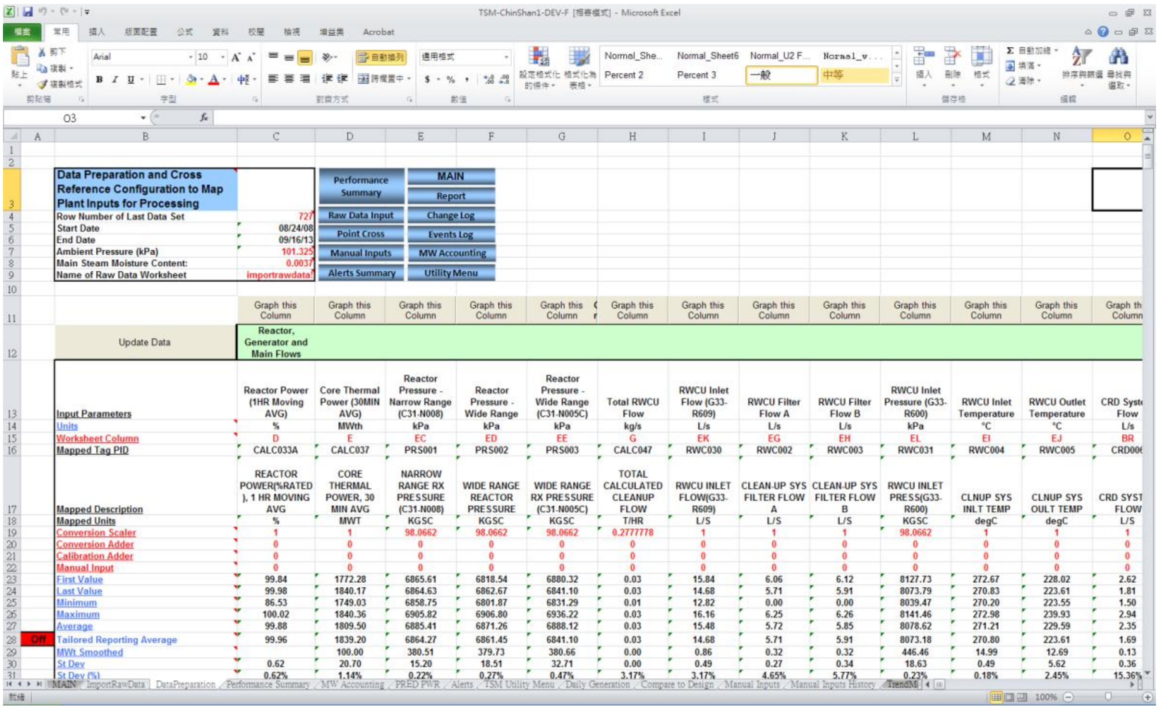
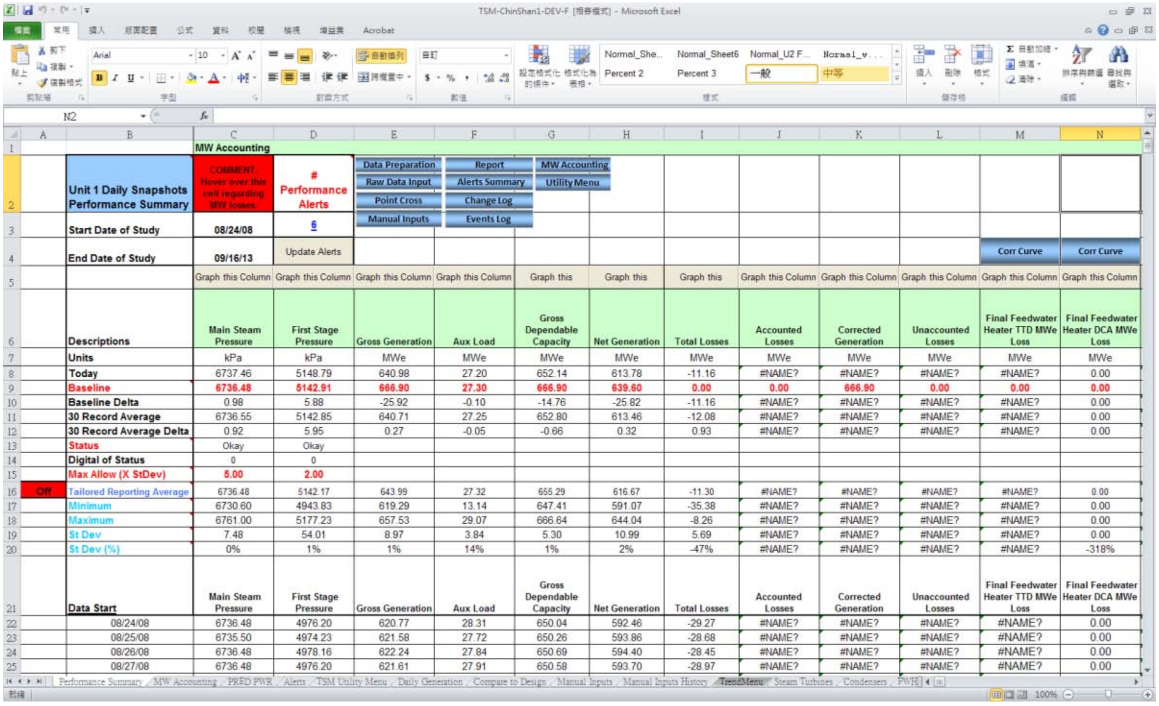


圖 11　TSM 軟體-資料準備頁面

接著至“資料準備頁面(DataPreparation)”進行資料轉換工作(圖 11)，此處主要的工作係將匯入之運轉資料單位轉換爲 TSM 軟體計算所使用之單位(此部分須以人工點選之方式指定所有資料點對應之單位)，此外，由於資料準備頁面已將原始輸入資料之欄位，依所屬設備類別進行重新排列，因此，在初次使用時，必須爲 TSM 軟體建立點位參照表(Point Cross)，由於此部分需要耗費許多時間，因此 TNC 公司在進行 TSM 軟體客製化時，即幫客戶完成此項工作。不過值得注意的是，如果電廠量測之資料有增減或變更時，此一點位參照表之修正爲此軟體可否繼續使用之關鍵。除了資料轉換工作外，此一頁面亦顯示運轉數據的最大值、最小值與標準差等資料，除了有助於判斷參數的變動幅度外，對於後續校正曲線所應求取的範圍亦提供了重要的參考。在完成了資料準備頁面後，接著進入“性能總結頁面(Performance Summary)”(如圖 12)。



	Unit 1 Daily Snapshots Performance Summary	COMMENT: Hover over this cell regarding MW losses	# Performance Alerts										
	Start Date of Study	08/24/08	6										
	End Date of Study	09/16/13	Update Alerts									Corr Curve	Corr Curve
		Graph this Column	Graph this Column	Graph this Column	Graph this Column	Graph this	Graph this	Graph this	Graph this Column	Graph this Column	Graph this Column	Graph this Column	Graph this Column
	Descriptions	Main Steam Pressure	First Stage Pressure	Gross Generation	Aux Load	Gross Dependable Capacity	Net Generation	Total Losses	Accounted Losses	Corrected Generation	Unaccounted Losses	Final Feedwater Heater TTD MWe Loss	Final Feedwater Heater DCA MWe Loss
	Units	kPa	kPa	MWe	MWe	MWe	MWe	MWe	MWe	MWe	MWe	MWe	MWe
	Today	6737.46	5148.79	640.98	27.20	652.14	613.78	-11.16	#NAME?	#NAME?	#NAME?	#NAME?	0.00
	Baseline	6736.48	5142.91	666.90	27.30	666.90	639.60	0.00	0.00	666.90	0.00	0.00	0.00
	Baseline Delta	0.98	5.88	-25.92	-0.10	-14.76	-25.82	-11.16	#NAME?	#NAME?	#NAME?	#NAME?	0.00
	30 Record Average	6736.55	5142.85	640.71	27.25	652.80	613.46	-12.08	#NAME?	#NAME?	#NAME?	#NAME?	0.00
	30 Record Average Delta	0.92	5.95	0.27	-0.05	-0.66	0.32	0.93	#NAME?	#NAME?	#NAME?	#NAME?	0.00
	Status	Okay	Okay										
	Digital of Status	0	0										
	Max Allow (X StDev)	5.00	2.00										
Off	Tailored Reporting Average	6736.48	5142.17	643.99	27.32	655.29	616.67	-11.30	#NAME?	#NAME?	#NAME?	#NAME?	0.00
	Minimum	6730.60	4943.83	619.29	13.14	647.41	591.07	-35.38	#NAME?	#NAME?	#NAME?	#NAME?	0.00
	Maximum	6761.00	5177.23	657.53	29.07	666.64	644.04	-8.26	#NAME?	#NAME?	#NAME?	#NAME?	0.00
	St Dev	7.48	54.01	8.97	3.84	5.30	10.99	5.69	#NAME?	#NAME?	#NAME?	#NAME?	0.00
	St Dev (%)	0%	1%	1%	14%	1%	2%	-47%	#NAME?	#NAME?	#NAME?	#NAME?	-318%
	Data Start	Main Steam Pressure	First Stage Pressure	Gross Generation	Aux Load	Gross Dependable Capacity	Net Generation	Total Losses	Accounted Losses	Corrected Generation	Unaccounted Losses	Final Feedwater Heater TTD MWe Loss	Final Feedwater Heater DCA MWe Loss
	08/24/08	6736.48	4976.20	620.77	28.31	650.04	592.46	-29.27	#NAME?	#NAME?	#NAME?	#NAME?	0.00
	08/25/08	6735.50	4974.23	621.58	27.72	650.26	593.86	-28.68	#NAME?	#NAME?	#NAME?	#NAME?	0.00
	08/26/08	6736.48	4978.16	622.24	27.84	650.69	594.40	-28.45	#NAME?	#NAME?	#NAME?	#NAME?	0.00
	08/27/08	6736.48	4976.20	621.61	27.91	650.58	593.70	-28.97	#NAME?	#NAME?	#NAME?	#NAME?	0.00

圖 12　TSM 軟體-性能總結頁面

雖然名爲“性能總結頁面”，然而，此一頁面仍有眾多參數需要使用者進行輸入，包括:校正曲線、基準線數值(Baseline value)、最高可容忍偏差等。其中校正曲線可由電廠的熱平衡套件(Thermal Kit)中獲得，或是在 PEPSE 軟體中建立電廠模型並藉由改變目標參數之數值來獲得該參數變動對功率影響之關係。在本次實習中，係採用後者的方式來建立校正曲線，而此一練習亦使得吾人對於校正曲線的產生原理與方式有了更加深刻的認識，TSM 軟體所需獲得的校正曲線如下:

(1)　第一級飼水加熱器終端溫度(Final Feed Water Heater TTD)對功率輸出之影響

(2)　第一級飼水加熱器洩水終端溫度(Final Feed Water Heater DCA)對功率輸出之

影響

(3) 冷凝器背壓(Condenser Backpressure)對功率輸出之影響
(4) 冷凝器次冷度(Condenser Subcooling)對功率輸出之影響
(5) 節流蒸汽壓力(Throttle Steam Pressure)對功率輸出之影響
(6) 汽水分離再熱器終端溫度(MSR TTD)對功率輸出之影響
(7) 功率因素(Power Factor)對功率輸出之影響
(8) 發電機氫氣壓力(Generator H_2 Pressure)對功率輸出之影響
(9) 其它校正曲線(如海水溫度對冷凝器背壓影響之預測曲線等)

至於基準線數值的選用，TNC 公司則建議從歷史運轉數據中挑出具代表性之數值，而非採用額定熱功率下的設計熱平衡數值。其主要原因則是爲了避免過度高估個別參數對於功率損失之影響。不過基準線參數的選用十分仰賴經驗判斷，而此點則不利於客戶端之使用。不過其資料點選用之判斷準則，主要有以下幾點原則:

(1) 需要用到電廠每日之連續運轉數據(Continuous data)，其取數間隔最好介於 10 ~ 60 分鐘之間。
(2) 首先以爐心熱功率來過濾資料，將資料限縮至運轉在 99.9%爐心熱功率的範圍。
(3) 接著以高壓汽機第一級壓力(First stage pressure)來挑選適用的資料，挑選原則爲在 2 標準差內且數值爲最高的資料，接著以此資料檢視高壓汽機第一級抽汽壓力(1st extraction pressure)，看看是否同爲最高值(如否則另挑選其他資料點)。
(4) 而除了以上的挑選參數外，尚應注意汽機的其他參數，不過所檢視的參數不應離 condenser 太近，以免受季節性背壓變動之影響。
(5) 最後以所挑選的某天資料的當日平均值當作 baseline 之數值。

至於本頁面設定中，最高可容忍偏差則是用來做爲警報顯示頁面中，那些參數超出預計範圍內之依據。而在完成以上主要的參數設定後，TSM 軟體即會計算出個別機組的熱功性能分析結果，並顯示於“功率總結頁面(MW Accounting)”。在功率總結頁面中，除了顯示主要運轉參數對於發電輸出之衝擊外，亦可由此頁面連結進入各主要設備觀看細部參數之影響與趨勢，而此功能對於熱功問題之分析提供了方便的診斷工具。

總而言之，雖然 TSM 軟體初次使用時，仍需仰賴使用者處理大量的參數設定，然而，當所有重要參數完成設定後，往後只需要匯入更新的運轉數據資料即可進行完整的熱功性能分析，此則爲其實用之優點。

2. TP-PLUS CIM

在提升電廠效率的眾多方法中，以降低現有管路的洩漏量屬於相對便宜且有效的方法。然而電廠內部管線與閥件數量龐雜，因此，如何以有效的方法診斷出蒸汽洩漏量，以及該洩漏量是否具有更換閥件之經濟效益便是 TP-Plus CIM 軟體之功能。該軟體藉由輸入閥件規格、閥件洩漏對於系統熱功率之損失因子(Loss Factor, LF)以及現場量測閥件下游管路之表面溫度等資料，即可自動計算出蒸汽之洩漏量以及該洩漏量所導致的熱功率損失量。

在判斷閥件是否有洩漏之狀況發生，依據 TNC 公司之經驗，在現場實務上最簡易的判斷方式為量測靠近閥件上下游管線的表面溫度並加以比較。當閥件靠上游處與下游處之溫度均接近於室溫時，則表示無洩漏情形發生。當閥件靠上游處溫度顯著高於室溫，而靠下游處溫度卻接近室溫時，則此一閥件可能僅有微幅洩漏之情形。而當閥件靠上游處溫度與靠下游處溫度均顯著高於室溫時，則此一閥件應有較大幅度之洩漏。此外，當閥件上游管線溫度顯著高於室溫時，則由圖 13 中閥件上下游管線表面溫度分佈情形亦可瞭解閥件洩漏之程度。當閥件無洩漏時，則上游高溫流體透過閥件以熱傳導方式將熱量傳遞至下游管線，將造成溫度呈現急遽降溫之情形，而延伸至下游管線一定距離後(一般取 L/D=10 處)，其管路表面溫度即降至一般室溫。如果閥件有大幅度的洩漏時，則下游管路除了經由上游高溫流體透過閥件以熱傳導方式傳遞的熱量外，由洩漏流體帶來的熱量亦十分可觀，也因此導致閥件下游管路表面溫度降低之趨勢較不劇烈。

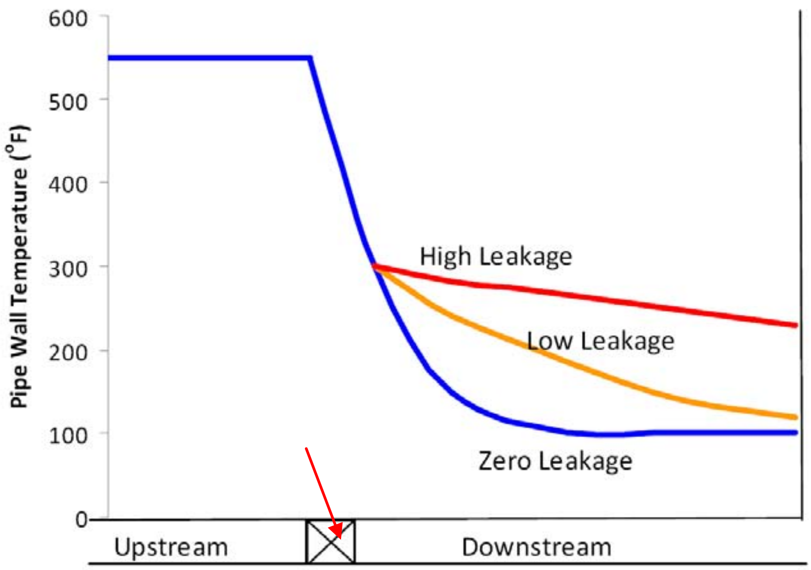


圖 13　以閥件上下游溫度判斷洩漏程度之示意圖

不過上述的閥件洩漏程度判斷方法仍要注意一些例外情形，例如：(1)當高壓流體通過閥件後如產生膨脹時，有時可能伴隨吸熱之反應，導致判斷洩漏之準則

失效。(2)由周遭設備或管線傳來之熱量或冷卻效果。(3)閥體下游管線表面溫度量測位置不適當(應至少距離閥體 L/D=10 的位置)。

CIM 軟體之使用，除了需要蒐集大量電廠閥件資料以外，更需要對相關閥件之上下游溫度進行定期的現場巡察與資料紀錄。然而，對於 BWR 電廠而言，許多重要的閥件在正常運轉時均位於高輻射區，因此無法由人員進行現場巡查，此時則需在欲監測之閥件上下游管路壁面裝設溫度感測器，並藉由資料擷取系統定期來蒐集此溫度資料。因此，在不增加額外量測設備的前提下，CIM 軟體較適用於火力電廠或是 PWR 電廠之洩漏偵測應用。不過，在本次實習中，亦嘗試利用核二廠一號機之部分閥件資料來進行分析練習，經實際操作結果，相關結論如下:

(1) 洩水控制閥 1LV-275 與 1LV-305 經 CIM 軟體分析雖顯示有微幅洩漏，然而其溫度資料卻顯示閥件下游溫度高於上游(不符物理現象)，且根據電廠 P&ID 圖檢視其上下游管線配置，顯示其下游溫度量測受周圍管線影響之機率頗高，因此該閥件初步判斷應無洩漏。
(2) 依 TNC 公司經驗判斷，可提高前述兩閥件的下游溫度限值設定至 175^{o}F，亦即下游量測溫度超過此一設定時才啓動洩漏量計算。
(3) 爲了確認上述判斷正確，建議可進一步監控其鄰近閥件 HV149、HV156、HV150、HV157、101HB06、101JB06、251HB04 以及 251JB04 之上下游溫度，以確認前述之判斷準確性。

(三)核一廠熱功性能分析實習

在利用核一廠運轉數據進行熱功性能分析之前，須先進行資料之篩選，而其篩選條件如下:

1. 將原始資料中 334 個資料欄位刪減至 TSM 所需的 248 欄。
2. 將反應爐功率低於 99.5%額定熱功率之資料剔除。
3. 將高壓汽機第一級壓力(First Stage Pressure)運轉值偏離平均值過大者之資料點剔除。
4. 以冷凝器熱交換量爲指標(循環海水入出口溫差)，考慮季節因素後，將偏離平均值過大者之資料點剔除。

經過此一步驟篩選後的資料，可剔除異常運轉狀況下的資料，且其分析出來的結果也會較具代表性。在利用 PEPSE 軟體獲得各種校正曲線的過程中，TNC 公司亦提供了一個以 excel 寫成的介面程式來輔助曲線的獲得。利用此程式，使用者只要設定特定參數欲變化的範圍(一次僅變動一項參數)，例如高壓汽機第一級壓力由 70 kg/cm^2 以 0.5 kg/cm^2 之增幅增加至 80 kg/cm^2，則此軟體會自動呼叫 PEPSE 軟體進行運算，並求出不同高壓汽機第一級壓力的功率輸出值，在經過後製作圖後即可獲得高壓汽機

第一級壓力變化對於功率影響之校正曲線圖。此一小程式對於本所將來執行電廠汽機轉子更換時，驗證廠商所提供的 Thermal Kit 之正確性將有相當的助益。經比較本次實習所獲得的各種校正曲線與電廠的 Thermal Kit 比較，其差異很小，因此亦可證明本次實習所建立的電廠熱平衡模型之可信度。

在前述的校正曲線中，需特別提到的一個校正曲線爲冷凝器背壓對於熱耗率之關係圖，有別於其他校正曲線係由改變 PEPSE 模型參數獲得，TSM 軟體中所採用的冷凝器背壓對熱耗率校正曲線是由電廠的歷史運轉數據而來。由於循環海水入口溫度爲環境因素，非人力可控制項目，因此，對於冷凝器效能造成的發電損失評估，TNC 公司首先利用海水入口溫度來推測出預期可達到的最小冷凝器背壓(同樣由歷史運轉數據推測獲得)，此即爲冷凝器現實運轉上可達到的最小背壓，而在此背壓下計算得到的發電輸出會比利用 PEPSE 模型推估來的保守，最後，此值與經由實際量測的發電輸出相減，即爲冷凝器偏離預期背壓所造成的發電損失。

探討核一廠兩部機組之熱功性能差異爲本次實習的主要目的之一，根據歷史運轉數據顯示，核一廠兩部機組之發電量差異，在 1999 年進行低壓汽機轉子更換前，一號機之平均輸出約比二號機高 2 MWe，不過，在 1999 年兩部機組更換低壓汽機轉子後，一號機之電力輸出反而低於二號機約 8 MWe。而在 2009 年於兩部機組加裝超音波飼水流量計並執行小幅度功率提昇後，一號機之電力輸出更低於二號機約 13 MWe。如要探討兩部機組發電量差異之肇因，則勢必需要發電量差異發生點 1999 年前後之運轉數據。然而，由於目前所獲得的 1999 年運轉數據資料有限，且 TSM 所需的部分資料點係 2000 年之後才有新增，因此將先以近期較完整之運轉數據(2008~2013 年)來進行初步分析。

以 2013 年 9 月 16 日之資料爲分析目標，兩部機組的發電損失分析總結如圖 14 所示。由圖中可發現，以海水入口溫度修正冷凝器之預期背壓後，兩部機組的預期最高電力輸出(Gross Dependable Capacity)相近，分別爲 652.1 MWe (一號機)與 651.7 MWe (二號機)，不過實際量測到的電力輸出(Gross Generation)則分別爲 641 MWe (一號機)以及 648.7 MWe (二號機)，因此，由各項運轉參數與基準線之差異所造成的發電損失(負號代表損失，正號代表增益)分別爲-11.2 MWe (一號機)以及 -3.1MWe (二號機)。由此結果可以明顯的看出二號機相對來講運轉的效率較高(接近預期之電力輸出)。在 TSM 軟體分析發電損失時，會將其歸類爲已知發電損失(Accounted MW loss)與未知發電損失(Unaccounted MW loss)，而所謂已知的發電損失係指 TSM 軟體可由相關的校正曲線計算而得的發電損失來源，除此之外的其他的發電損失來源，則歸類爲未知的發電損失。而由圖 11 中顯示的數值換算，一號機的總發電損失中，有約 83% 爲未知來源，二號機則較爲特別，其未知的損失爲正值，表示某些參數的運轉狀態是優於基準值的。

圖 14 除了總發電損失外，對於各主要參數對發電損失之影響亦顯示其中。對於

一號機而言，在已知發電損失(-1.8 MWe)中，其主要的負面因素為冷凝器效率(-0.9 MWe)以及其它損失(-1.3 MWe)，不過舉凡最終飼水加熱器的終端溫度(Final Feedwater Heater TTD)、蒸汽節流壓力(Throttle Steam Pressure)、汽水分離及再熱器的終端溫度(MSR TTD)以及反應爐熱功率之運轉狀況則對於發電輸出有正面之幫助。對於二號機而言，在已知發電損失(-4.2 MWe)中，其主要的負面因素為冷凝器效率(-2.6 MWe)、冷凝水次冷度(-0.1 MWe)以及反應爐熱功率(-0.3 MWe)，不過最終飼水加熱器的終端溫度以及蒸汽節流壓力則對於發電輸出有正面之幫助。

Print Page

Chin Shan Nuclear Plant
Thermal Performance MWe Loss Comparison

Station Summary

Current Statistics				Unit 1	Unit 2
Report Date				2013/9/16	2013/9/16
Gross Dependable Capacity			MWe	652.1	651.7
Gross Generation			MWe	641.0	648.7
MW Deviation			MWe	-11.2	-3.1
Accounted MW Loss			MWe	-1.8	-4.2
Unaccounted MW Loss			MWe	-9.3	1.1
Core Thermal Power			%	100.0%	100.0%
Average Condenser Back Pressure			$mmHg_a$	66.5	69.0
Circulating Water Inlet Temperature			°C	27.5	27.6
Condensate Temperature			°C	44.8	43.4
Losses		**Unit 1 Value**	**Unit 2 Value**	**Unit 1 Loss Mwe**	**Unit 2 Loss Mwe**
Final Feedwater Heater TTD	°C	1.4	1.3	0.1	0.2
Final Feedwater Heater DCA	°C	9.4	4.1	0.0	0.0
Throttle Steam Pressure	kPa	6634.2	6629.3	0.2	0.2
Condenser Efficiency	$mmHg_a$	66.5	69.0	-0.9	-2.6
Condenser Subcooling	°C	0.0	0.8	0.0	-0.1
MSR TTD	°C	12.3	20.3	0.1	0.0
Core Thermal Power	MWth	1840.2	1839.2	0.1	-0.3
Miscellaneous Losses	MWe			-1.3	-1.6
Other Losses (from Manual Input)	MWe			0.0	0.0
			Accounted MW Deviations (-Loss +Gains)	-1.8	-4.2
			Unaccounted MWe	-9.3	1.1
Contact True North Consulting				Unit 1 Report	Unit 2 Report

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圖 14　核一廠熱功性能分析結果-分析總結

總而言之，在已知的發電損失因素中，無論是一號機或是二號機，主要都是由冷凝器效率及部分雜項設備之運轉狀況所造成，因此可再藉由探討冷凝器等設備之運轉狀況來尋求改善之方法。不過在未知的發電損失中一號機則高達-9.3 MWe，經排除已列入考量之各運轉參數後，目前初步評估主要的肇因可能位於汽機本身之效率。為了確認此一初步評估之推論，未來除了將繼續蒐集 1999 年低壓汽機更換前後之資料外，亦將與 TNC 公司密切保持合作以持續進行相關分析驗證。

四、建議事項

(一)TNC 公司規模雖然不大，其員工僅 20 多人，然而在分析電廠熱功性能之領域，無論是在核電廠或是傳統的火力電廠都有多年的實務經驗，因此，本次實習所參與的相關訓練課程，其教材內容不但豐富且易於學習，而且講師授課時對於實務之應用亦有不少著墨。經過本次實習後，吾人亦深感獲益良多。因此，建議爾後可持續選派同仁參加該公司之熱功性能訓練課程。

(二)該公司所開發的 TP-PLUS CIM 軟體，係用以監測電廠閥件蒸汽洩漏量之軟體，藉由量化由閥件洩漏的蒸汽量對於電廠功率輸出之影響，可判斷閥件之更換是否具有經濟性。由於我國電廠之平均年齡已高，勢必面臨閥件老化與洩漏率增加之議題，雖然本所已有引進一套軟體作爲評估核二廠閥件洩漏之影響，然而對於 BWR 電廠而言，如未在閥件上下游設置溫度自動量測系統，則該軟體可監控之閥件數量將有所限制，不過對於 PWR 電廠或是火力電廠，因大部分閥件所在區域較無輻射問題，因此，建議國內可引進該軟體作爲監測傳統火力電廠或是核三廠之閥件洩漏偵測，以提高電廠運轉效率。

(三)該公司所開發的 TP-PLUS TSM 軟體，係利用電廠的運轉數據來分析電廠各主要運轉參數對於發電損失之影響。該軟體之操作介面簡單易懂，且所提供的發電損失比較結果表亦非常實用。本所目前已引進一套 TSM 軟體進行核一廠熱功性能分析，惟利用該軟體來判斷各種發電損失之肇因上，仍有賴豐富的實務經驗，因此建議與 TNC 公司持續保持合作關係，俾吸收其相關實務經驗來發揮該軟體之最大效用。

五、附錄

附錄 1	Thermal Performance Training 課程表
附錄 2	Thermal Performance Assessment Training 課程表
附錄 3	TP-PLUS CIM 課程表
附錄 4	熱功性能訓練課程各章節回顧部分

附錄 1　Thermal Performance Training 課程表

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Course Title: Thermal Performance Training

Date: Sep. 10^{th} – Sep. 13^{th}, 2013.

Location: True North Consulting
150 Merchant Dr.
Montrose, CO 81401

Teachers: Frank Todd

Course Outline:

This document certifies that Yu-Ching Tsai has completed the True North Consulting, LLC, Thermal Performance training course. Specifically, Mr. Tsai was trained as follows

Date	Training Content
Sep. 10^{th} (Tue.) 08::00 AM ~ 05:00 PM	**1-Introduction** • *Company Background* • *Resources (cards, websites, what we do)* • *Instructor Backgrounds* • *Student Introduction (pass around sign up)* • *Class Layout and Overview - Schedule* • *Class Purpose – Why? – Talk about purpose* **2-Thermodynamic Fundamentals** • *Introduction* • *Terminology* • *First Law* • *Cycles (Carnot, Rankine)* • *Second Law* • *Foundation Tools to Understand the Thermodynamic Process* • *Assumptions* • *Mass Conservation* • *Pressure Equation* • *Fluid Flow* • *Energy Conservation* • *Properties of steam – Steam Tables/Mollier Diagram* • *Equations specific to component types*

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Date	Training Content
	3-Heat Balance Diagrams • *Introduction* • *Purpose of the Heat Balance* • *Thermal Kit Heat Balance Diagrams Examples* • *Limitations of the Heat Balance Diagrams* • *Heat Balance Diagram Errors* • *Description of Heat Balance Sections* **Simple Heat Rate Exercise** **4-Thermal Performance Program Development** • *Elements of a thermal performance program* • *Data flow* • *Setting up a program* **5-Power Plant Cycle & Component Evaluation** • *Introduction to Component Evaluation* • *Operation Losses* • *Equipment Losses* **6-Power Plant Cycle & Component Evaluation Steam Turbines** • *Purpose* • *Principle of Operation:* • *Components* • *Parameters* • *Identifying and Correcting Poor Performance* • *Operation Losses* • *Equipment Losses* **Steam Turbine Exercises** **7-Power Plant Cycle & Component Evaluation Condensers** • *Purpose* • *Principle of Operation* • *Components* • *Parameters* • *Identifying and Correcting Poor Performance* • *Operation Losses*

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Date	Training Content
	• *Equipment Losses*
Sep. 11th (Wen.) 08::00 AM ~ 05:00 PM	**Condenser Exercise** **8-Power Plant Cycle & Component Evaluation- Feedwater Heaters and Pumps** • *Purpose* • *Principle of Operation* • *Components* • *Parameters* • *Identifying and Correcting Poor Performance* • *Operation Losses* • *Equipment Losses* **Feedwater Heater Exercise** **Pump Exercise** **9-Power Plant Cycle & Component Evaluation Cooling Towers** • *Purpose* • *Principle of Operation* • *Components* • *Parameters* • *Identifying and Correcting Poor Performance* • *Operation Losses* • *Equipment Losses* **10-Power Plant Cycle & Component Evaluation-4 Nuclear Power Plant Component Evaluation** • *Reactors* • *Purpose* • *Principle of Operation* • *Components* • *Parameters* • *Identifying and Correcting Poor Performance* • *Operation Losses* • *Equipment Losses* • *Moisture Separator/Reheater*

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Date	Training Content
	• *Purpose* • *Principle of Operation* • *Components* • *Parameters* • *Identifying and Correcting Poor Performance* • *Operation Losses* • *Equipment Losses* **MSR Exercises** **11-Power Plant Cycle & Component Evaluation Cycle Isolation Monitoring** • *High Energy Valve Leakage Leads To:* • *Reduced Plant Efficiency* • *Potential Valve Damage* • *Selection Criteria (handout)* • *Performed Monthly* • *Calculations to determine impact*
Sep. 12th (Thu.) 08::00 AM ~05:00 PM	**Cycle Isolation Exercises** **12-Power Plant Cycle & Component Evaluation: Power Calculation** • *Thermal Power Evaluation* • *Preventing Overpowers & Identifying power calculation errors* **Power Calculation Exercises** **13-Thermal Performance Resources & Tools-1 Software and Documentation** • *Introduction to Thermal Performance Resources & Tools* • *Off-Line Computer Modeling* • *Simulation of Plant Problems* • *Evaluate Based on Plant Data* • *Run with Model* • *Compare* • *Show – Limits of Models, Data Reconciliation* • *On-Line Computer Modeling* • *Thermal Performance References*

Date	Training Content
	14-Thermal Performance Resources & Tools-2 Instrumentation • *Instrumentation* • *Temperature* • *Types of Instruments* • *Failure Modes* • *Troubleshooting* • *Usage* • *Calibration* • *Pressure* • *Types of Instruments* • *Failure Modes* • *Trouble shooting* • *Usage* • *Calibration* • *Flow* • *Flow Theory Discussion* • *ypes of Instruments & Methods* • *Failure Modes* • *Trouble shooting* • *Usage* • *Calibration* • *Quality of Steam* • *Types of Instruments & Methods* • *Failure Modes* • *Trouble shooting* • *Usage* • *Calibration* **15-Thermal Performance Resources & Tools-3 Power System and Electric Power Metering** • *Power System* • *Generators* • *Iso-Phase* • *Switchyard* • *Measurement of Electrical Power* • *Basic Electrical Concepts Necessary to Understand Power Factor* • *Resistance*

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Date	Training Content
	• *Inductance* • *Capacitance* • *Impendence* • *Power Triangle and Power Factor* • *How a Megawatt Meter works* • *Uncertainties of Power Measurement* • *Failure Modes of Metering* **Electric Aspect Exercises** **16-Thermal Performance Resources & Tools-4 Uncertainty and Data Validation** • *Instrumentation Data Validation & Analysis* • *Sensitivity/uncertainty analysis* • *Location of sensors (show examples)* • *Data Validation* **Uncertainty Exercise**
Sep. 13th (Fri.) 08:00 AM ~ 05:00 PM	**17-Thermal Plant Testing Overview-1: Testing** • *Introduction to Thermal Plant Testing* • *Why Do Performance Testing?* • *What Should Be Tested? When?* • *Types of Thermal Plant Testing* • *Tools for the Test* • *ASME Performance Test Codes* • *PTC – 1&2 General Instructions; Definitions and Values* • *The Turbine Testing Codes PTC-6* • *PTC 19 Series – Instrumentation and Uncertainty* • *Test Organization* • *Data Requirements* • *Developing a Test Plan* • *Accounting* • *Written Test Procedures* • *Test Notebook* **18-Thermal Plant Testing Overview-2: Steam Turbine Testing Procedure** • *Test Procedure Development*

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Date	Training Content
	• *Introduction* • *Scope* • *References* • *Test Preparations and Logistics* • *Cycle Isolation and Leakage* • *Test Conduct* • *Test Instrumentation* • *Data Recording* • *Calculation* • *Acceptance of Test Results and Test Report* • *Evaluation of Test Data* • *Test Repeatability* • *Exercise – Assuring Repeatability* **19-Thermal Plant Testing Overview: Exercise** • *Exercise – Calculate Turbine Test Results* **20-Thermal Plant Testing Overview: Cooling Tower Testing** • *Cooling Tower Testing: Applicable Codes* • *Cooling Tower Testing Introduction* • *Testing Requirements* • *Consistency of Test Conditions* • *Duration of Test* • *Frequency of Test Data* • *Test Set Up* • *Performance Method of Testing* • *Performance Method Procedure* • *Cooling Tower Test Example Calculation* • *Using Performance Method* **Cooling Tower Test Exercise**

Digitally signed by Frank Todd
DN: cn=Frank Todd, o=True North Consulting, ou=Thermal Performance, email=ftodd@truenorthconsulting.com, c=US
Date: 2013.10.03 14:38:19 -0600

Frank Todd, TNC Thermal Performance Manager

Yu-Ching, Tsai 蔡毓蓉

Yu-Ching Tsai, INER

附錄 2　Thermal Performance Assessment Training 課程表

Course Title: Thermal Performance Assessment Training

Date: Sep. 16th – Sep. 17th, Sep. 20th – Oct. 4th

Location: True North Consulting
150 Merchant Dr.
Montrose, CO 81401

Teachers: Frank Todd, Greg Alder, Christopher Seip

Course Outline:

This document certifies that Yu-Ching Tsai has completed the True North Consulting, LLC, Thermal Performance Assessment training course. Specifically, Mr. Tsai was trained in

1. **TSM Software Training** *(by Christopher Seip)*

Date	Training Content
Sep. 16th (Mon.) 08::00 AM ~ 05:00 PM	**1. Introduction** **2. Software Installation** • *installation of TP-Steam Software* • *installation of TP-Plus Startup Software* • *installation of TP-Plus TSM Plant Specific System Model Files* • *Application* **3. System Use** • *TP-Plus Main Menu Screen* • *Main TSM Menu and Navigation* • *MW and Heat Rate Accounting Reports* • *Component Reports* • *Power Predictor* • *Printing* • *Tailored Reporting*
Sep. 17th (Tue.) 08::00 AM ~ 05:30 PM	**4. Data Management** • *Data Input* – *DataInput File* – *Input Raw Data* – *Point Cross Reference Worksheet* – *Data Preparation*

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Date	Training Content
	– *Graphing* – *Documentation* • *System Menus* – *Utility Menu* – *Manual Input* – *Change Log* – *Event Log* – *Trend Summary Menu* 5. **System Tables**

2. **PEPSE Software Training** *(by Christopher Seip)*

Date	Training Content
Sep. 20th (Fri.) 08::00 AM ~ 05:00 PM	1. **Introduction** • *Company Background* • *Resources (cards, website, what we do)* • *Instructor Backgrounds* • *Student Introductions (pass around sign up)* • *Class Layout and Overview – Schedule* • *Class Purpose – Why? – Talk About Purpose* 2. **General** • *It's Been Months. How Do I Get Back Into Using PEPSE?* • *What are Cases and Sets?* • *Documenting Model Changes.* • *Can I Just Use a Sub Model?* • *Using Stream Features Effectively.* • *Practical Use of Controls.* • *Understanding Modeling of Leakages.* • *What is a Back-up Demand Splitter?* • *How Do I Perform a Sensitivity Analysis?* • *Generator Modeling Basics.* • *Modeling and Calculating Power and Heat Rate Impacts for Plant Changes.* • *How Can I Use EXCEL, PI and PEPSE Together?* • *How to Know What Is In an Inherited Model* • *Unique PEPSE Applications.* • *Bring Your Problem and We Will Show You How to Solve It!* 3. **Potential Dangers and Pitfalls** • *Dangers of Infrequent Use.*

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Date	Training Content
	• *Being Careful with the "Quick Studies"!* • *Changing and Forgetting Changes! Hardwiring Data (setting pressures, temperatures, etc.)* • *I've Inherited Ten PEPSE Models. Which One Do I Use?* • *Is PEPSE a Black Box?* • *Overcoming Fears of Making Model Changes.* • *Common Model User Errors and Their Impacts.*
Sep. 23th (Mon.) 08::00 AM ~ 05:00 PM	**4. Heat Rate and Power** • *Defining a Plant Heat Rate Calculation With and Without Operations.* • *How Does PEPSE Account for Auxiliary Power?* • *CTP Calculations and Using Special Option 4 (nuclear only).* • *How Do I Create and Update Power and Heat Rate Correction Curves?* • *How Do I Correct My Plant's Thermal Kit?* **5. Condensers** • *Setting Up and Using an HEI Condenser Model.* • *Building Condenser Curves.* • *Parallels and Series Modeling.* • *Useful Condenser Model Tutorials.* • *How to Analyze a Condenser Change Out or Retubing.* **6. Cooling Towers** • *Setting Up a Model for the Performance of Cooling Towers.* • *Testing of Cooling Towers Using PEPSE.* • *Useful Cooling Tower Model Tutorials.*
Sep. 24th (Tue.) 08::00 AM ~ 05:30 PM	**7. Feedwater Heaters** • *Taking Heater(s) Out of Service.* • *Modeling Heater Bypass (partial up to full tube side bypass).* • *How Do I Split Out a Heater Train?* • *Modeling Alternate Drains.* • *Simplified Design Mode Heaters – It's Easy!* • *Using Tuning Factors.* • *Useful Feedwater Heater Model Tutorials.* • *How to Evaluate Heater Modifications or Replacement.* **8. Pumps, Valves, Sources and Sinks** • *How Do I "Close the Loop" On a Cycle Model?* • *Modeling Pump and Driver Efficiencies.* • *Modeling Sliding Pressure.* • *Useful Control Valve Tutorials.* • *Plant Test Data.* • *Modeling to Detect and Quantify Excessive Spill Strip Leakage.*

Date	Training Content
	• *Understanding and Modeling Exhaust Loss Curves.* • *Useful Steam Turbine Model Tutorials.* **9. Boilers and Components (break out session)** • *Setting Up Boiler Efficiency without Building a Boiler Model.* • *Common and Easy Boiler Studies.* • *Setting Up and Using a Basic Boiler Model.* • *Design Mode: Radiant and Convective Stages.* • *Air Heater Modeling – It's Easy!* • *Acid Dew Point Impacts.* • *Modeling Auxiliary Boiler Equipment.* **10. Combustion Turbines and HRSG Components (break out session)** • *How Do I Use Correction Curves?* • *Water Wash Modeling.* • *Using HRSG Pinch and Approach.* • *Common and Easy CCGT Studies.*
Sep. 25th (Wen.) 08:00 AM ~ 05:00 PM	**11. Nuclear Applications (break out session)** • *Modeling MSRs (scavenging steam, TD, etc).* • *Steam Generator Modeling.* • *Am I Using the Right Moisture Removal Curves?* • *Useful Nuclear Applications Tutorials.* **12. Testing** • *Verifying Test Data.* • *Analyzing Plant Test Data.* • *Should I Use Special Option 6?* • *How to evaluate turbine modifications or replacement.* **13. Special Options Overview** **Tips for PEPSE Model Review**

3. Using TSM for Thermal Performance Assessments

3-A. Construction of Load Correction Curves *(by Christopher Seip)*

Date	Training Content
Sep. 26th (Thu.) 08:00 AM ~ 05:00 PM	**1. Data Preparation and Filtering** • *Using Chinshan NPP Unit 1 data for practicing*

	2. Correction Curve Preparation • *Introduction* • *Curve generation software* **3. Correction Curve Practicing (PEPSE Software)** • *FWH TTD vs. Gross Power* • *FWH DCA vs. Gross Power* • *Condenser Backpressure vs. Gross Power* • *Condenser Subcooling vs. Gross Power*
Sep. 27th (Fri.) 08::00 AM ~ 05:00 PM	**4. Correction Curve practicing (PEPSE Software)** • *Throttle Steam Pressure vs. Gross Power* • *MSR TTD vs. Gross Power* • *Power Factor vs. Gross Power* • *Generator H2 Pressure vs. Gross Power* • *Other Correction Curves* **5. Correction Curve Summary**
Sep. 30th (Mon.) 08::00 AM ~ 05:00 PM	**6. Methods to predict Condenser Back Pressure** • *Introduction* • *Use 1 Empirical data of Chinshan NPP Unit 1 for Curve Fitting* **7. Establishing Baseline Plant Parameters from actual plant data** • *Use 100% OLTP BOP*

3-B. Thermal Performance Assessments *(by Christopher Seip)*

Date	Training Content
Oct. 1st (Tue.) 08::00 AM ~ 05:00 PM	**8. Evaluating Plant Performance using TSM software** • *Import the filtered operating data* • *Point Cross Reference Worksheet for Chinshan NPP Unit 1* • *Import all correction curve* • *Preliminary result overview*

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3-C. Identifying Possible Performance Problems *(by Christopher Seip, Greg Alder, Frank Todd)*

Date	Training Content
Oct. 2th (Wen.) 8:00 AM ~ 05:00 PM	**9. Case Study of Chinshan NPP** • *Plotted plant parameters versus time* • *Evaluated percent changes in Unit 1 for pre and post outage of 2013.*
Oct. 3th (Thu.) 08::00 AM ~ 05:00 PM	**10. Advanced model analysis** • *True North model review.* • *Comparison between True North model and INER model.*
Oct. 4th (Fri.) 08::00 AM ~ 05:00 PM	**11. Summary of the evaluation** • *Preliminary evaluation result of percent changes in Unit 1 for pre and post outage of 2013.* • *Overview of the TSM training course.* • *Delivery of beta TSM and Training Materials.*

Digitally signed by Frank Todd

Frank Todd, TNC Thermal Performance Manager

Greg Alder Digitally signed by Greg Alder
DN: cn=Greg Alder, o=True North Consulting, ou,
c=US

Greg Aider, TNC Senior Engineer

Christopher Seip, TNC Jr. Engineer

Yu-Ching Tsai, INER

附錄 3　TP-Plus CIM Training 課程表

TRUE NORTH
CONSULTING, LLC

Course Title: CIM Software Training

Date: Sep. 18th – Sep. 19th, 2013.

Location: True North Consulting
150 Merchant Dr.
Montrose, CO 81401

Teachers: Richard Duggan

Course Outline:

This document certifies that Yu-Ching Tsai has completed the True North Consulting, LLC, TP-Plus Cycle Isolation Monitoring Training course. Specifically, Mr. Tsai was trained in

- **Operation of CIM software** *(by Richard Duggan)*

Date	Training Content
Sep. 18th (Wen.) 08::00 AM ~ 05:00 PM	1. Use of the TP-Plus software • Valve Information • Walkdown Entry • Report Generation 2. Review of valve construction and design • Types of valves • Leak Paths

- **CIM Evaluation of Kuosheng NPP** *(by Richard Duggan)*

Date	Training Content
Sep. 19th (Thu.) 08::00 AM ~ 05:00 PM	3. Drawing Review • Identification of valves of interest • Review of systems of interest

	4. Loss Factor Calculation • PEPSE modeling • Leak Rates 5. Distance Correction • Demonstration of relationship of distance to flow rates

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Yu-Ching, Tsai 蔡毓擎

Yu-Ching Tsai, INER

附錄 4 熱功性能訓練課程各章節回顧部分

附錄 4-1　Thermodynamics Fundamentals 章節回顧

Review

- What are two ways to increase the efficiency of the Carnot cycle? Raise Thot or decrease Tcold
- How does the MS pressure affect Rankine cycle efficiency? Why?
  Increase; because it raises Thot.
- How does MS quality affect Rankine cycle efficiency?
  Increase quality increases efficiency
- How does the condenser pressure affect Rankine cycle efficiency? Why?
  Lower pressure increases efficiency- lower tcold (unless you're choked)
- We do not want to change this without doing work: Entropy
  - Enthalpy? or
  - Entropy?
- Why do feedwater heaters help the cycle if they steal steam from the cycle?
  - Because they add reversibility to the cycle or yes
  - Because they make the cycle more stable

Thermal Performance Training
Thermodynamic Fundamentals -1 Introduction
Slide 34

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附錄 4-2　Introduction Turbines & Condensers 章節回顧-Turbine 部分

Steam Turbine Review - Answers

- How do the following affect throttle flow (increase or decrease)?
  - Deposits – decrease
  - Erosion – increase
  - Foreign object or obstruction - decrease
  - Internal Leakage - increase
- How do the following affect section efficiency (increase or decrease)?
  - Deposits - decrease
  - Erosion - decrease
  - Foreign object or obstruction - decrease
  - Internal Leakage - decrease

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Power Plant Component Evaluation 1 – Slide 48
Introduction Turbines and Condensers

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附錄 4-3　Introduction Turbines & Condensers 章節回顧-Condenser 部分 I

Condenser Review Answers

- Tube Sheet fouling results in the following changes (Increase or Decrease)
  - Circulating water flow through condenser-Decrease
  - Differential pressure across tubes- Increase
  - Temperature rise tube inlet to tube outlet.- Increase
  - Condenser pressure- Increase
  - Condensate sub-cooling - Decrease
  - Cleanliness factor if you do not measure flow -Decrease
  - Cleanliness factor if you do measure flow – Remain the Same
  - Electric output – Could go either way
- What can cause tube side air binding ? Failure of air venting system and tide level changes
- Shell side tube fouling will cause tube side temperature rise to? (increase or decrease) – stay the same or slightly increase

附錄 4-4　Introduction Turbines & Condensers 章節回顧-Condenser 部分 II

Condenser Review

- When does air in-leakage become a thermal performance problem. – When it overcomes the air removal capacity
- When might it be a good idea to turn off a circulator? – In the winter when the plant is operating on the flat portion of the correction curve.
- List at least two alternate parameters to give an indication of condenser pressure – Exhaust hood temperature; Condenser hot-well (if there is no sub-cooling) temperature.
- What should you watch out for when measuring condenser outlet temperature? – Stratification if the sensor is near the tube sheet.
- List at least two major causes of condenser tube leaks –Vibration; Impingement from damaged spargers

附錄 4-5　Feed Water Heaters Pumps & Control Valves 章節回顧

Feedwater Heater Review- Answers

- How do the following affect heater parameters?
  - Heater level increase- TTD Increase; DCA Decrease
  - Heater level decrease-TTD Decrease; DCA Increase (heater damage)
  - Divider plate leakage-TTD Increase
  - Isolation of running vents – Slow TTD Increase
  - Tube leak in heater- Small leak none; Large leak-TTD Increase ;DCA Decrease
  - Tube leak in downstream heater – Level control valve increase; Level Increase
  - Damage to extraction line expansion bellows – Heater Pressure Decrease
  - Failure of Normal level control valve – Level Increase
  - Failure of High level control valve –Level Decrease, damage to drain cooler.
- What general effect do the following have on turbine cycle performance?
  - Heater emergency drains to the condenser - Decrease
  - 2 DEG F increase final feed temperature - Increase
  - Decrease top (highest pressure) feed water heater level - Increase
  - Decrease heater drain flow with an increase in condensate flow - Decrease

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Power Plant Component Evaluation - 2
Feedwater Heaters, Pumps and Control Valves　Slide 29
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附錄 4-6　Cooling Tower 章節回顧-I

Cooling Tower Review

- What are the parameters measured for cooling tower performance? Wetbulb; dry bulb; hot water temperature; cold water temperature; wind speed; circulating water flow; fan horse power.
- What affect will an increase in humidity have on Natural Draft cooling tower air flow parameters? Increase flow
- What are the two means of heat transfer in a cooling tower? Sensible heat transfer (temperature difference) and latent heat transfer (evaporation)
- Why does uneven spray flow affect a natural draft cooling tower? Lower flow resistance in one area of tower such that more air flow passes through areas of low heat transfer.
- Why is it important to maintain Biocide treatment of cooling tower? To prevent clogging of fill.
- What is the tradeoff between high performance fill and high flow fill? High performance fill can result in fill clogging.

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Power Plant Component Evaluation – 3
Cooling Towers　Slide 44
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附錄 4-7　Cooling Tower 章節回顧-II

Cooling Tower Review

- What is the impact (increase or decrease) on cooling tower outlet water temperature (cold water temp) resulting from following:
  - Increasing the approach at a constant Wet Bulb - increase
  - Increasing the wet bulb temperature at a constant approach - increase
  - Decrease in range at constant Q – could go either way depending on the tower design
  - Decreasing the fan power (mechanical draft) – increase due to less air flow
- What causes the cooling tower plume to be visible? - atmospheric temperature is at or near saturation.

Thermal Performance Training
Power Plant Component Evaluation – 3
Cooling Towers Slide 45

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附錄 4-8　Nuclear Component 章節回顧

Nuclear Components Review Answers

- A decrease in Moisture Separator Drain Flow at a constant steam flow is indicative of what problem? Failure of Chevrons or Moisture Removal equipment; Blockage of flow distribution plate; blockage of drain channel.
- If Steam Generator Pressure is decreasing what is happening to the turbine cycle? Control Valves are opening; Temperature into cycle is decreasing; MWe loss is dependant on starting valve position.
- MSR Second Stage Drain Flow is increasing at a constant power and TTD is increasing; what could cause this to happen? First Stage Re-heater Tube Leak; Moisture Separation Failure
- What happens if Scavenging (or excess) steam flow is decreased or isolated? Condensation in tubes causing chug flow and increased re-heater TTD. Could result in damage to reheater tubes.
- What affect does the Moisture separator efficiency have on first stage pressure and why? Increased MSR First Stage TTD=> Increased Second Stage Heating Steam Flow => Reduced First Stage Pressure
- What happens when quenching flow is lost to the second stage re-heater drains? Flashing in re-heater drain line; control valve vapor lock; High Level Dump open on re-heater drain tank; lost generation; damage to re-heater drain line.

Thermal Performance Training
Power Plant Component Evaluation – 4 Nuclear Components
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附錄 4-9　Cycle Isolation 章節回顧

Review

•What are the two most common methods used to determine cycle isolation leakage? Temperature and Acoustic

•List at least 4 types of valves that should be included in a cycle isolation program. FWH dump vlaves, turbine drain valves, turbine bypass valves, steam line drain valves, feedwater vents, reheater dump valves.

•Where should the downstream temperature be measured for the Grashoff or the ASME figure 14 Method? At least 10 L/D downstream of the valve.

•Why is upstream temperature an unreliable method to quantify leakage? Because a very small leakage will result in a high temperature.

•List two situations where it would be difficult to determine leakage based on down stream temperature, how should these situations be handled? Valve is close to sink; many valve drain into a header; use temperature limits, use acoustics as a back up.

•Why is it important to have a flat black surface if using an infrared temperature meter? Because emissivity is different based on the reflectivity of the surface.

附錄 4-10　Power Calculation 章節回顧

Power Calculation Review

- At 1000 psia an increase in steam pressure causes enthalpy to increase or decrease? Decrease
- Which parameter has the most influence on reactor power? Feed Flow
- Which turbine parameter is the most consistent with reactor power? First Stage Pressure
- If the final feedwater heater bypass valve fails open what happens to reactor power? Reactor Power Increases
- What is the difference between a PWR and BWR when it comes to controlling reactor power? PWR-Turbine Drives Reactor BWR- Reactor Drives Turbine
- Describe one method to detect an over power condition. First Stage Pressure Higher than design value
- In a PWR why is primary differential temperature often a poor indicator of reactor power? Unknown mass flow; Temperature Stratification; Sensitivity to Error.
- If using first stage pressure as an alternate indication of reactor power what other parameters could have an influence on it other than reactor power? Second stage reheater flow; turbine bypass flow; Final Feed Temperature.
- List at least five alternate indications of reactor power.

  First stage pressure; Steam flow; First extraction pressure; Final feed Temperature; Primary differential temperature; Thermal performance indicator; Heatrate; Megawatts electric; HP exhaust pressure; Condensate flow; Drain flow + condensate flow; Drain flow; Feed pump suction or discharge flow ;Feed pump steam flow; Feed pump amps;2nd stage reheat flow; First stage reheat flow; Condensate pump amps

附錄 4-11　Thermal Performance Resources & Tools 章節回顧-I

Review Answers

- What are the benefits of on-line modeling? Find lost power; Reduction in heat rate; Resolve cycle isolation problems; Monitoring of plant degradation and performance; Optimization of plant processes; Assist in preventing overpower
- What are the limitations of off-line modeling?
  - Calculations are dependant on input quality
    - Validation of plant data is critical
    - Results are only as good as the user input
    - Model development
    - Data quality
    - Engineering units
    - Location of sensors in relation to plant components
    - User assumptions
    - Realistic inputs
- Why is data validation important for on-line modeling? Garbage in = garbage out
- Where can information regarding relative instrument and component locations be found? PID
- Where can information regarding expected plant parameter values be found? Heat Balance or Thermal Kit.
- List at least four pieces of information that can be found in a thermal kit. Heat Balance; Correction Curves; Moisture Removal Curves; Exhaust loss Curves.
- Where can information regarding actual pipe lengths be found? Isometrics

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Performance Software and Documentation
Slide 35

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附錄 4-12　Thermal Performance Resources & Tools 章節回顧-II

Instrumentation Review

- What happens to an RTD if it looses power? Fails off scale low.
- What happens to a thermocouple if the leads are shorted together? Measures temperature where leads are shorted.
- When measuring temperature what affect does thermal stratification have on the reading? Cause error either high or low depending on location of probe.
- List at least 4 pressure measurement failure modes. Line leakage (low pressure); Loss of water leg (inaccurate water leg); Instrument bias; Drifting due to temperature; Bypass valve leakage (DP instruments); Low pressure cross connected tubing; Low pressure loop seal or incorrect slope; Turbulence affects on pressure tap; Improper placement (near significant disturbance areas)
- Define Wet-Bulb Temperature. Temperature at which water will evaporate.
- What do close coupled out of plane bends introduce to the flow velocity profile? Swirl.
- What two types of ultrasonic flow measurement devices are available? Explain the basic differences between these devices. Cross-correlation and time of flight.
- What are the two major sources of tracer testing error? Hideout and improper mixing.

Thermal Performance Resources & Tools -2
Instrumentation
Slide 75

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附錄 4-13　Thermal Performance Resources & Tools 章節回顧-III

Thermal Performance Resources & Tools Measuring Electricity Review

- What are the three components of Impedance? Resistance, Inductance, & Capacitance
- Which impedance component causes voltage to lag current? Capacitance
- Which impedance component causes current to lag voltage? Inductance
- Which impedance component causes voltage and current to be "in phase"? Resistance
- The resistance – reactance- impedance diagram is expanded to address real, reactive, and apparent power in a diagram known as the …………… …………? Power Triangle
- Power factor represents the ratio of which two components of the Power Triangle? Real Power (MW) to Total Apparent Power(MVA)
- How are power triangle components affected by generator operation during synchronized and un-synchronized operation? Unsynched-more steam = more speed, less steam = lower speed. More excitation =greater terminal voltage at generator output, Less excitation = lower voltage at generator terminals. Synched – More steam = greater KW output, Less steam = lower kw output to grid. More excitation = increased Var output to grid, lower excitation = less output var to grid or possibly intake of vars to machine.
- How are real and reactive power components measured? Watt & Var Meters (New meters are integrated to measure both)
- What are the typical components in a "metering loop"? Instrument transformers(CT/PT), wiring, metering device (Watt/Var), possibly transducers, panel meters, etc.

Thermal Performance Resources & Tools -3
Measuring & Delivering Electricity
Slide 55

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附錄 4-14　Power System 章節回顧

Power System Review

- What are the major components of a Power System? Generator, Exciter, Isophase bus Duct, Generator Circuit Breaker, Main Station Transformers, Switchyard, Grid
- What are the three requirements for connection to a Power System Grid? Same Voltage Magnitude, Same Frequency, Same Phase Relationship
- What limits the operational range of a generator? Cooling -- typically(Rotor-Hydrogen, Stator-Water)
- Which component of power is affected by the prime mover (steam)? MW
- What is the purpose of the excitation system? Terminal voltage – unsynched, Vars in or out in a synched condition
- What is the P&ID equivalent electrical drawing? Single Line Diagram
- State two sources of losses between a Station's gross and net output metering? Transformer Losses, House Loads

Thermal Performance Resources & Tools -3
Measuring & Delivering Electricity
Slide 57

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附錄 4-15　Thermal Power Testing Overview 章節回顧-I

Data Validation Review - Answers

- What are the two types of error we deal with when calculating instrument uncertainty? Systematic and Random
- How is random uncertainty calculated? With average and standard deviation
- Why do we have to be concerned with instrument location? Proximity to heat, vibration, etc.
- Instrument drift is what kind of error? Both Systematic and Random
- What can be done to improve (reduce) random error? Increase sample size　Add redundant instrument
- What is the purpose of the plant walk down when developing an uncertainty analysis for a power plant? To determine instrument location
- Where would we find an acceptable method for power plant testing uncertainty? ASME PTCs

Thermal Plant Testing Overview -3
Instrumentation Validation and Uncertainty
Slide 23

附錄 4-16　Thermal Power Testing Overview 章節回顧-I

Review Answers

- What are the benefits of on-line modeling? Find lost power; Reduction in heat rate; Resolve cycle isolation problems; Monitoring of plant degradation and performance; Optimization of plant processes; Assist in preventing overpower
- What are the limitations of off-line modeling?
  - Calculations are dependant on input quality
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- Where can information regarding actual pipe lengths be found? Isometrics

Thermal Performance Resources & Tools-1
Performance Software and Documentation
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