(　　) 電返國報字第　　　　　號出國報告

行政院所屬各機關因公出國人員報告書

(出國類別：實習)

台中九~十號機發電計畫排煙脫硫設備相關技術研習

研習報告

服務機關：台灣電力公司
出國人:職　　稱：機械工程監
姓　　名：潘 文 川
姓名代號：721961

出國地點：日本
出國日期：91 年 07 月 09 日至 91 年 07 月 22 日
報告日期：91 年 09 月 10 日
出國計劃：91 年度第 86 號

行政院及所屬各機關出國報告提要

出國報告名稱：台中九、十號機發電計畫排煙脫硫系統相關技術研習

頁數 16 ，含附件■是□否

出國計畫主辦機關/聯絡人/電話

台灣電力公司/陳德隆/02-23667685

出國人員姓名/服務機關/單位/職稱/電話

潘文川/台灣電力公司/核能火力發電工處/機械工程監/(02) 23229535

出國類別：□1考察 □2進修 □3研究 ■4實習 □5其他

出國期間：91.07.09－91.07.22

出國地點：日本

報告日期：91.09.10

分類號/目：

關鍵詞：absorber、recirculation pump、carryover、fluoride、blinding、permeability、blistering

內容摘要

本公司台中九、十號機發電計畫共含兩部容量各為550百萬瓦之慣常燃煤汽力機組，因所建之發電廠屬於燃煤機組，因此為使未來機組運轉時，各項污染排放數值均能符合政府之法令規章，是以本公司

對於此一新建燃煤機組，規劃設置了各相關環保設備，其中有關煙氣之排放處理設施包括了脫硝、脫硫及靜電集塵等各主要設備。

為期台中九至十號機發電計畫所新建之排煙脫硫工程能如期完成並期有關之設計、製造及運轉、維護等技術能順利移轉，因此於採購合約中明定承包商須提供本公司有關人員技術訓練。

報告提要概述如下：

一、 台中九至十號機排煙脫硫系統設備內容

二、 台中九至十號機排煙脫硫系統之特性及其流程

三、 系統之製程及化學反應

四、 影響排煙脫硫系效能之主要設計參數

目　　錄

壹、前言

近年來本公司因肩負提供臺灣地區穩定電力供應之責任，並以配合國家長期經濟發展為目標，因此需持續進行電源之開發與規劃，雖然政府已開放民間設立發電廠，惟因民營發電業者尚無發電廠興建之經驗，加以相關法規繁多、土地取得困難及面對民眾可能之抗爭，是以目前除了幾家民營業者已完工發電外，其餘各民營電廠是否能如期完工加入發電，尚待時證。本公司為顧及全省供電品質，爰於民國八十五年九月向政府申設『台中九至十號機發電計畫』並於八十六年六月獲政府核定在案。

台中九至十號機發電計畫共含兩部容量各為 550 百萬瓦之慣常燃煤汽力機組，因所建之發電廠屬於燃煤機組，因此為使未來機組運轉時，各項污染排放數值均能符合政府之法令規章，是以本公司對於此一新建燃煤機組，規劃設置了各相關環保設備，其中有關煙氣之排放處理設施包括了脫硝、脫硫及靜電集塵等各主要設備。

本公司為期台中九至十號機發電計畫所新建之排煙脫硫工程能如期完成並期有關之設計、製造及運轉、維護等技術能順利移轉，因此於採購合約中明定承包商須提供本公司有關人員技術訓練。本設備之承攬廠商為日本 IHI 公司，本人即依此一合約前

往該公司研習排煙脫硫系統相關技術。

貳、台中九至十號機排煙脫硫系統基本設計參數及設計流程

一、 系統基本設計參數：詳如附件 A-1

二、 系統設計流程：詳如附件 A-2

參、研習內容

一、台中九至十號機排煙脫硫系統設備內容：

台中九至十號機排煙脫硫系統得標廠家為日本之 IHI 公司，該公司除了承攬本公司此項排煙脫硫設備工程外，同時 IHI 公司亦為本公司稍早所興建之『興達發電廠第三、四號機排煙脫硫設備』之承攬廠商，因此對於國內環保現況、各項污染排放標準及相關法規等均已熟悉、瞭解，因此對於本案之設計工作具有正面幫助。

本工程確為一龐雜之化學反應與處理系統，所含設備（子系統）約略可劃分如下：

1. 鍋爐煙氣系統
2. 石灰石漿製備系統

3. 石灰石處理系統

4. 吸收塔裝置系統

5. 回收水系統

6. 吹灰壓縮空氣系統

7. 強制氧化系統

8. 廠用壓縮空氣系統

9. 儀用壓縮空氣系統

10. 電氣系統

11. 吸收塔排放系統

12. 廢水處理系統

13. 石膏脫水系統

14. 石膏處理系統

15. 吸收塔除霧裝置清洗系統

16. 補充水系統

17. 冷卻水系統

18. 儀控系統

二、台中九至十號機排煙脫硫系統之特性及其流程：

廠家 IHI 公司所提供之本公司台中九至十號機排煙脫硫系

統屬於濕式石灰石石膏法之流程設計，此法之主要原理係由傳統濕式石灰石石膏法/廢棄石膏法（Conventional Wet Limestone Disposable Gypsum Process）演進而來。傳統製程的副產物 80%~85%為亞硫酸鈣（$CaSO_3 \cdot 1/2H_2O$）經演進後使用強制氧化（Forced Oxidation），可使 99%以上的亞硫酸鈣氧化為硫酸鈣（$CaSO_4 \cdot 2H_2O$），即為石膏。由於高純度的石膏製成率，使得演進後的副產物--石膏可達商業級規格，不僅可資源化回收利用，且省去大量廢棄物處置的問題，對製程本身而言，強制氧化除了可以減少結垢發生的機率，而強制注入系統的氧化空氣，亦可驅除吸收液中的 CO_2，使得吸收液中的石灰石溶解度增加，因而提高石灰石之利用率。另外由於石膏較亞硫酸鈣易於脫水，強制氧化法使得石膏之產率增加，故其脫水變得較為容易。

三、系統之製程化學反應：

石灰石法係將石灰石粉配製成乳液狀的吸收液後再噴入吸收塔（Absorber）。當 SO_2 與吸收液接觸時溶於水中成 HSO_3 負離子，促成吸收液之 PH 值降低，使得石灰石粉末（$CaCO_3$）溶解度大增，並與 HSO_3 負離子反應成 $CaSO_3$ 及 $CaSO_4$。由於循

環泵（Recirculation Pump）不斷自吸收塔底部的循環槽抽取乳液至吸收塔上部的噴霧塔噴灑，形成一循環迴路。此種吸收反應不斷於吸收塔及循環槽間持續進行，其反應式如下：

$SO_2 + H_2O\ .\ H_2SO_3$

$CaCO_3 + H_2SO_3\ .\ \ CaSO_3 + CO_2 + H_2O$

為使全部 $CaSO_3$ 均能氧化成 $CaSO_4$，採用強制氧化法，以空壓機或鼓風機將空氣直接打入循環槽中，使 $CaSO_3$ 氧化並結晶成穩定的 $CaSO_4$，其反應式為：

氧化：$CaSO_3 + 1/2\ O_2 \rightarrow CaSO_4$

結晶：$CaSO_3 + 1/2\ H_2O \rightarrow CaSO_3 \cdot 1/2\ H_2O$

$CaSO_4 + 2\ H_2O \rightarrow CaSO_4 \cdot 2\ H_2O$

四、影響排煙脫硫系統效能之主要設計參數：

濕式石灰石石膏法排煙脫硫系統中，影響系統脫硫效率及石膏純度之主要因素包括 PH 值、液氣比、化學劑量比、氯離子濃度、煙氣速度及粒狀物濃度等。茲將各項因子與系統效率之關係，簡述如下：

1. PH 值：

排煙脫硫系統的基本反應是 SO_2 氣體被吸收成液態之亞硫酸（H_2SO_3），亞硫酸溶解成亞硫酸根離子，而石灰石則生成鈣離子與亞硫酸氫根離子產生反應，如此即達到自煙氣中脫硫之目的。是以溶液之 PH 值愈高愈有利於 SO_2 吸收，PH 值愈低愈有利 $CaCO_3$ 之溶解。SO_2 被石灰石乳液吸收後進入反應槽，此時 PH 值會因 $CaCO_3$ 之溶解而提高，也進而增加 SO_2 之去除——參考附圖一。而提高 PH 值最有效的方法便是提高化學劑量比，亦即 $CaCO_3$ 之用量。但是相對的勢必增加系統之操作成本並容易造成結垢現象，因此排煙脫硫系統中，化學劑量比之控制就顯得非常重要。一般以石灰石為吸收劑時，PH 值均應維持在 7 以下，太低或太高之 PH 值均不利於排煙脫硫系統的操作、運轉。

2. 液氣比：

液氣比（L/G ratio）是指循環之石灰石乳液與吸收塔出口煙氣流量之比值，其單位為 M^3/

M^3/Sec。高液氣比將提供較佳之液氣混合及接觸面積，使得 SO_2 較易為石灰石乳液吸收，亦即提高了質量傳送之效果。所以提高液氣比可以提高脫硫效率。然而提高液氣比也將會增加能源之消耗，因為在煙氣流量固定情況下，要提高液氣比值即是藉由增加石灰石乳液之循環流量來達成，而欲增加石灰石乳液流量最直接的方法即是增加循環泵之運轉能量。有關液氣比與脫硫效率之關係詳如附圖二。

3. 化學劑量比：

化學劑量比是指反應劑石灰石主要成份 $CaCO_3$ 之用量與 SO_2 之去除量兩者之莫耳數比值。理論上一莫耳之 $CaCO_3$ 可與一莫耳之 SO_2 反應，但為求反應完全，通常化學劑量比之值均大於一，化學劑量比愈高，PH 值愈高，脫硫效率愈佳，但亦將使得 $CaCO_3$ 耗用量增大因此控制系統之化學劑量比在最適當的比值是相當重要的。化學劑量比與 SO_2 去除率之關係詳如附圖三。

4. 氯離子濃度：

排煙脫硫設備之吸收系統（absorption system）中，氯離子的主要來源有二，一為含於燃煤中之氯化物隨著煤之燃燒而進入，另一則為含於系統之補充水中，隨補充水而進入系統之氯化物。燃煤所含之氯化物可分為有機及無機兩類。有機氯化物燃燒後生成鹽酸（HCL）氣；無機氯化物燃燒後則呈熔融狀態，其中部分揮發成氣體後隨煙氣溫度下降產生凝結而附着於粒狀物而被靜電集塵器所收集，其餘則隨煙氣而進入排煙脫硫系統。一般排煙脫硫系統所要求之水質品質均較高，所以通常都採用自來水，而自來水中所含之氯離子則因水源之不同而略有差異，然而大體而言，系統中氯離子之主要來源大都為來自於燃煤本身燃燒後所產生之 HCL。

氣體的 HCL 比 SO_2 更易溶解於水中，其與石灰石乳液反應後生成 $CaCL_2$。$CaCL_2$ 是一種溶解度極高的化合物，此種氯離子會漸漸累積在反應槽中，造成石灰石乳液之 PH 值降低，進而影響系統之脫硫

效率，此外氯離子濃度高亦會加速設備的腐蝕，是以系統設計時，氯離子之濃度必須維持在某一定值以下，以免影響系統之脫硫效率及避免設備受到侵蝕，為此必須將過多的氯離子排出吸收系統之外。

有關氯離子對金屬材料之腐蝕，請參考附圖四~1、附圖四~2。此外由於 HCL 氣體會與石灰石乳液起反應，因此必須提高化學劑量比藉以補充與 HCL 反應所消耗之石灰石，俾能維持石灰石乳液的 PH 值於最適當的狀況，以利於 SO_2 的吸收。

5. 煙氣速度：

煙氣速度的大小會影響吸收塔內液氣的接觸效果，提高煙氣速度可增加其擾硫之程度，使液氣之接觸面積增加，進而提高 SO_2 的去除率，然而煙氣速度若大於某一臨界值，則容易造成水氣隨煙氣逸出的現象（carryover）。水滴中含有石灰石乳液及飛灰等成份，當含有水滴的煙氣通過除霧器時，容易造成除霧器結垢與堵塞，另外煙氣速度也會影響煙氣中液滴的數量及大小，因此煙氣速度對於除

霧器之設計及效率具有極大的影響。目前大多數除霧器生產廠家都將除霧器設計為雙層，並附有清洗設備，藉以清除隨煙氣通過而附着於除霰器上之石灰石乳液，俾避免因結垢而堵塞。

目前煙氣速度之設計均傾向於採用較高之數值藉以增加 SO_2 的去除率，同時亦須加強除霰器清洗系統噴嘴及噴頭之設計，以減少 carryover 現象之發生。

6. 粒狀物濃度：

煙氣進入吸收塔後，其所含之粒狀物雖可去除一部分，惟粒狀物在吸收塔內之去除率較 SO_2 之去除率低，因此煙氣中粒狀物濃度之高低將影響石膏之純度，進口煙氣中粒狀物濃度愈高，石膏之純度則愈低。當煙氣中之粒狀物濃度因靜電集塵器故障或效率降低而過高時，會使吸收塔中之石灰石乳液產生氧化鋁（Aluminum Fluoride（ALF））的遮蔽現象（Blinding)。所謂氧化鋁遮蔽現象是指吸收乳液中氟與鋁離子之濃度達到某一比值時會反應

結合成氧化鋁。氧化鋁會吸附於 $CaCO_3$ 上而形成一種遮蔽效應，使 $CaCO_3$ 溶解於水中之數量減少，以致 $CaCO_3$ 之利用率及 SO_2 之去除率皆下降，上述造成遮蔽現象之主要元素「氟」係來自於煤燃燒後所產生之 HF 氣體，該氣體將隨著煙氣而進入吸收塔，當煙氣被洗滌後，HF 即被溶解於吸收塔中。另一項不純物「鋁」係來自於隨煙氣進入吸收塔之飛灰及含於石灰石中之不純物。欲防止此種現象產生，最簡便之方法為增設添加 NaOH 或 $Ca(OH)_2$ 進入吸收槽之設備，以便在靜電集塵器故障或降低效率時，可立即啟動此一鹼性化學物質添加設備，俾提高吸收液之 PH 值，如果能配合再排掉部分吸收乳液並加入生水等措施，即能夠加大降低氟及鋁離子濃度，使遮蔽現象得以儘早解除，恢復系統效能。

肆、心得與感想

此次前往日本 IHI 公司接受排煙脫硫系統相關技術之訓練，除了進一步了解整體系統之製程、化學反應過程及系統除硫運作主要參數間之相對關係外，本人也察覺到，在本公司目前之排煙

脫硫系統設備採購規範中，對於排煙脫硫系統之心臟 — 吸收塔，要求得標廠家所需採用之材料與 IHI 公司在其國內一般所採用之材料有極大差異，IHI 公司在其國內所設計之標準吸收塔，主要皆以碳鋼為基材，再根據吸收塔內不同區域所具有之溫度及腐蝕等特性，加上不同的內襯材料（如 Heat resistant Flake Lining、Anti-abrasion type flake lining、stainless steel 等)。而本公司所採用者，雖仍以碳鋼為基材，但所採用之內襯材料則大都為較為昂貴之高抗蝕性合金鋼材，其造價則差甚多。本人詢問 IHI 公司，何以本公司在較早期所設置之排煙脫硫系統中，採用類似 IHI 公司所採用之標準襯材，卻經常發生剝落等失敗經驗，IHI 公司認為依其判斷應是施工不良所衍生之結果，依該公司經驗，吸收塔內所採用之襯材，無須如本公司目前規範所訂，皆採用合金鋼材。前述吸收塔內，IHI 公司之標準設計與本公司台中九至十號機所採用襯材之差異詳如附表一。

另一項研習心得為 — 排煙脫硫系統中，管路橡膠襯材之選定原則。排煙脫硫系統中，許多管路皆採用橡膠作內襯，然而不同之流體具有不同之溫度、磨耗係數及腐蝕性高低等不同特性，因此其內襯材料亦須針對該等特性進行設計。目前市面上用於排煙脫硫系統之橡膠內襯，大致可分為 ” hard natural rubber “、” soft natural rubber “、 “ chloroprene rubber “ 及 ” butyl rubber “等四種，在選用上應注意以下幾點：

1. 橡膠之抗蒸氣浸透性：

大體而言，橡膠是一種具有局部可浸透之特性，橡膠內層及外層間會因為溫度的差異而衍生浸透壓力（permeability pressure)，此一壓力達到某一定值後，將使橡膠產生局部膨脹而生成泡泡（blistering)，因而破壞橡膠表面之完整性。根據廠家長期使用經驗，在上述四種橡膠中，針對抗蒸氣浸透性之強弱依序列出如下：hard natural rubber＞butyl rubber＞chloroprene rubber＞soft natural rubber。

2. 橡膠之耐磨耗性：

橡膠材料抗磨耗性的大小，主要係依據橡膠本身之彈性（elasticity)對輸送溶液分子碰撞能量所具之吸收能力而定，橡膠內襯之彈性愈大，其抗磨耗性則愈高。茲依上述四種橡膠所具之抗磨耗性依序列出如下：

soft natural rubber > chloroprene rubber > butyl rubber>hard natural rubber。

3. 橡膠之抗腐蝕性（抗氟化物(fluoride)、抗硫氧化物(SO_x)、抗氯化物(chloride)）：

基本上，橡膠材料對於氟化物、硫氧化物、氯化物所造成之腐蝕均有極佳的抵抗性，惟其濃度愈高則對橡膠之破壞及侵蝕則越強，然而上述三種元素之化合物若以塩類型態存在於溶液中，對橡膠襯材則不構成任何傷害。上述四種橡膠所具之抗腐蝕性依序列出如下：

hard natural rubber > butyl rubber > chloroprene rubber>soft natural rubber。

4. 橡膠之耐熱性：

橡膠受熱產生劣化現象，主要是因為橡膠受熱時，其內部溶解之氧滲入橡膠之分子中，使橡膠本身產生氧化而造成劣化現象。因此若橡膠中未飽和分子越多，則受熱時其內部分子受氧化程度越高，橡膠劣化程度也越大。上述四種橡膠所具之耐熱性依序列出如下：

hard natural rubber＞butyl rubber＞chloroprene rubber＞soft natural rubber。

綜合以上所述，四種橡膠中，最適用於排煙脫硫系統之橡膠內襯應屬於 butyl rubber。雖然 butyl rubber 之抗磨耗性與其他型式之橡膠相比略顯偏低，惟此一缺陷則可透過增加厚度予以彌補。

伍、建議

台灣電力公司自民國 35 年成立迄今，已超過半個世紀，這期間電力的裝置容量由當年的 27.5 萬千瓦擴充到目前的 3,125 萬千瓦，成長近 120 倍，而年發電量亦由當初的 472 百萬度增加到現在的 158,058 百萬度，成長近 330 倍，這種豐碩的成果與傲人的成就可是由一群無怨無悔、默默奉獻歲月的台電前輩、同仁們胼手胝足，一點一滴所累積創造出來的；台電今日的規模與成就不僅對台灣地區提供質優、價廉、可靠的電力，更擠身世界排名前 14 的大電力事業，受到世界各國電力業的重視。

然而隨著國內政治民主化與經濟自由化的風起雲湧，台電的經營環境與從前相比，其差異與困難度已越來越大，台電得面對電力市場開放民營後的競爭，公司轉民營化的腳步亦已迫在眉

睫；衡諸於此，本處主要工作乃是負責公司新設電廠之興建，而對上述開放民營電廠之設立及未來電業法修正後對電業經營權之限制等，本處未來所將面臨之競爭與工作權之維護勢必愈益艱辛，因此如何提升本處同仁未來之工作效率、充實專業智能及如何改變過去吃大鍋飯的任事心態，應為本處亟需思索及創造的工作新環境。

總公司為因應電業自由化及台電民營化之衝擊，規劃部門已為公司構建了一個發展願景，那就是「成為電力事業的領導者及國內最具聲望的集團」。在此一宏願下，本處必當配合公司新事業之開發與發展，在工作內容及人員組織方面做調整；儘管改革的過程將充滿艱困與挑戰，但卻也將伴隨著希望與成就，相信只要本處同仁各盡本份，大家同心戮力合作下定能使本處展現企業經營的活力，拉大與競爭者的距離，進而建立電力事業領導者的角色，與公司規劃之發展相互暉映，共創台電新紀元。

5.0 DESIGN CRITERIA

5.1 General Description

This section specifies the operating conditions and design and performance criteria for the flue gas desulfurization plant.

The flue gas desulfurization (FGD) system shall be designed for utility power plant operation and shall be designed and arranged to treat the flue gas from a coal-fired steam generator after it emerges from the combustion air preheater, selective catalytic reduction and electrostatic precipitator.

The FGD plant shall be designed and furnished that allow continuous operation of the power plant unit under any trouble on the FGD plant.

The flue gas absorber system shall be designed to operate satisfactorily and reliably for extended periods at 30 percent of steam generator MCR.

The flue gas desulfurization system shall be designed for pressurized operation.

The FGD system shall be designed for continuous operation at the conditions as specified in Sections 5.3 and 5.4.4 while treating 100 percent of the flue gas generated by operation of the steam generator at any condition up to its maximum continuous rating (MCR).

Flue gas reheat shall be accomplished by a flue gas reheater. The flue gas reheater shall reheat treated flue gas leaving the absorber with heat removed from flue gas before it enters into the absorber.

The Specifications are based on a one absorber designed to treat 100 percent of the design flue gas flow. More than one module may be provided if required by the CONTRACTOR's design to comply with any of the requirements of the contract documents.

Each FGD system shall be capable of independent operation. Each system shall be provided with dampers as specified in Section 8.21.

Each FGD system will discharge to a separate 6.7 meter diameter flue gas stack which is 250 meters high. The stack contains flues for two systems.

The product of flue gas absorbing reaction shall be forced oxidized to produce calcium sulfate (gypsum).

Slurry shall be discharged from an appropriate point in the system and transferred to the gypsum dewatering equipment provided as specified in Section 8.4. The dewatered gypsum filter cake will be washed and dewatered to produce a saleable gypsum product. The gypsum product shall be stored in gypsum storage building until sold or removed for disposal. The gypsum storage building shall be designed to have an effective capacity at minimum 15,000 tonnes. The building shall have two entrance/exits for gypsum removing trucks. The building shall be a steel frame structure enclosed as required for noise abatement. Stairs and platforms shall be provided for access to all equipment. Access hatches, if required, and monorail beam shall be furnished for the installation and maintenance of heavy equipment. All equipment and materials shall be of industrial grade and quality, suitable for frequent stop/start operation in a seacoast environment.

The gypsum filter cake wash water shall be returned to the absorber system.

Each absorber system shall be designed to remove sufficient sulfur dioxide from the flue gas so that the overall sulfur dioxide emission, including any leakage in the regenerative flue gas reheater, at the inlet of stack should be no more than 35 ppmvd with 6% O_2.

The FGD system shall be completely protected from erosion, corrosion, cementation, or plugging. The CONTRACTOR shall provide all special coatings, washers, soot blowers, strainers, screens, grinders, comminutors, or other devices as required to provide this protection.

5.2 Site Conditions

The Taichung Steam Power Station of the Taiwan Power Company will supply necessary power to the FGD systems. The FGD layout of Taichung Units 9 and 10 is shown on the attached Drawing No. 1528-M-X-020. The layout is to illustrate the general concepts only, and modifications may be made to accommodate the design of the equipment offered by the CONTRACTOR.

5.2.1 The plant site is located near Taichung Harbor at the seacoast in a sub-torrid zone with severe salt wind conditions and dust-laden atmosphere. The climatic conditions are as follows:

a.	Grade elevation, MSL	8.25 meters
b.	Daily Maximum Humidity	100%
c.	Daily Average Humidity	79%
d.	Daily Ambient Outdoor Air Temperature, °C	
	Average	22.6
	Maximum	35
	Minimum	5.6
e.	Indoor Ambient Air Temperature, °C	3 to 11°C higher than outdoor temperature

5.2.2 Rainfall shall be computed on the following intensities for rainfall events having a once in ten year period:

Duration, hour	Intensity, mm/h
0	146
0.5	100
1	77
2	52

5.2.3 The site is subject to earthquakes and typhoons. The seismic loads for structures and major equipment shall be derived from the latest edition of ROC "Regulations Concerning Building Technology" (RCBT). To avoid any significant variations among different loading analysis methods, the total seismic forces shall be in no case lower than the following:

0.15 W horizontal

Where W = total dead load plus normal operating live load which would reasonably be estimated to be on the structure at the time of an earthquake.

The wind loads act on all outside surfaces shall be derived from a typhoon gust speed of 60 meters per second (134 mph) at 10 meters above grade.

Wind pressure 2.4 kPa (50 psf) of flat surface not exceeding 30 meters (100 ft) above grade and 3.6 kPa (75 psf) of flat surface at a height exceeding 30 meters above grade shall be assumed. The seismic forces or the wind pressure shall be used in design of all the equipment and structures, whichever is greater and more critical.

The moving equipment exposed to wind shall be designed to operate normally under the monsoon with a wind velocity of 20 meters per second. The above wind velocities are considered to be taken at 10 m (30 ft) above grade level.

5.3 Operating Conditions

The FGD systems shall be designed for operation under the following conditions:

5.3.1 There will be two (2) additional power generating units Taichung Units 9 and 10 in the Taichung Power Station. The capacity of each unit is 550 MW. The site has been selected and is to be constructed in the western side of the existing Units 1 through 8.

5.3.2 To meet the power system peak and off-peak loads, as well as to improve quality of the Taipower system, power units were specially designed for Daily Shutdown and Startup (DSS) and Auto Generation Control (AGC). Weekend Shutdown (WES) and start-up will be executed in case of need. Each unit will be operated under the condition of governor free mode at a certain range.

5.3.3 The steam generators to be supplied are of balanced draft, single reheat, drum type with natural circulation design to burn pulverized coal. Each steam generator has a maximum continuous rating (MCR) of 1,830,000 kilograms per hour (4.034 million pounds per hour) of steam at 17.4 MPa gauge (2,524 psig), with a gross heat input of 5,358 million kJ/h (5,079 million Btu/h) for burning coal.

5.3.4 The particulate collection system consists of an electrostatic precipitator designed to limit the particulate content in the flue gas stream to the FGD system to the amount as specified in Section 5.4.4.

The contingency that the electrostatic precipitators may operate at reduced efficiency for short periods of time shall be considered in design of the absorber.

It is anticipated, during start-up of the generating unit, that the electrostatic precipitator will not be fully energized. Therefore, the particulate loading may exceed the expected quantity. The Bidder shall state as part of the Proposal Data the particulate removal efficiency anticipated for an inlet grain loading of 10,000 mg/Nm^3.

Particulate content at the FGD system inlet will exceed the maximum specified in the event of failure of the electrostatic precipitators. The Bidder shall state as part of the Proposal Data the capability of the absorber system to handle fly ash and his recommendations regarding absorber operation during failure of the electrostatic precipitators. The maximum allowable inlet particulate grain loading and duration shall be stated as part of the Proposal Data.

The FGD system shall be guaranteed to be capable of continuous operation during periods of reduced particulate collector efficiency without undue problems caused by erosion or corrosion within the FGD system. The FGD system is not required to meet performance guarantees during this condition.

5.3.5 The flue gas desulfurization (FGD) system and auxiliary equipment shall be suitable for automatic operation at all loads from start-up to the maximum continuous rating of the steam generating unit.

The FGD system shall be designed for safe and reliable operation under the following steam generator operating conditions in any combination.

Daily start-up following an overnight shutdown of approximately 8 hours duration

Weekly start-up following weekend shutdown of approximately 48 hours duration

Continuous load following from 30 to 100 percent of maximum continuous rating

Operation at 30 percent of maximum continuous rating over extended periods of time

Continuous operation at maximum continuous rating

5.3.6 Air and Flue

Combustion air is supplied to each boiler by two motor-driven, axial flow forced draft fans located on ground elevation. Two (2) Ljungstrom regenerative type air preheaters are also provided to heat up the combustion air before it enters into the furnace. Primary air fans are also equipped for the intended purposes.

The steam generators are also equipped with high dust type selective catalytic reduction (SCR) system installed immediate downstream of the economizers. After it passes through the SCR, flue gas is diverted to the air preheaters, it is then discharged to the electrostatic precipitators for further treatment.

Two (2) motor-driven induced draft fans are furnished with each boiler and located between the electrostatic precipitators and the chimney. FGD systems are intended for insertion in between the I.D. fans and the chimney.

5.4 Raw Materials

5.4.1 Fuel analysis

Primary fuel for the steam generator will be raw, unwashed coal delivered directly from the mine.

5.4.1.1 Coal

The FGD system shall be designed and guaranteed to operate as specified with any coal whose properties are defined by the ranges stated in the following tabulated data.

5.4.1.1.1 The average coal analysis is as follows:

As Received	Proximate, wt %	Ultimate, wt %

Surface Moisture	6.50	-
Air Dried Basis	Proximate, wt %	Ultimate, wt %
Inherent Moisture	2.50	-
Ash	14.5	-
Volatile Matter	28.0	-
Fixed Carbon	51.0	-
Carbon	-	70.2
Hydrogen	-	4.90
Nitrogen	-	1.60
Oxygen	-	7.90
Sulfur	0.60	-
High Heating Value, as received		26460 kJ/kg (6300 kcal/kg)

5.4.1.1.2 The FGD systems shall be designed to permit troublefree operation when steam generators are burning any coal within the range of the following design coal guidelines Specification:

Proximate	Design Coal Range, wt, %
Total Moisture (A.R.)	20 Max
Ash (A.D.)	19 Max.
Volatile Matter (A.D.)	24 - 42
Fixed Carbon (A. D.)	60 Max.
Ultimate (Air Dried Basis)	
Inherent Moisture	1 - 10

Ash	19 Max.
Sulfur	0.3 - 1.5
Nitrogen	0.4 - 2.0
Carbon	51.6 - 84.7
Hydrogen	3.4 - 6.0
Oxygen	1.2 - 23.2
Chlorine	0.05
Fluorine	0.015
High Heating Value, as received	23940 kJ/kg (5700 kcal/kg)

5.4.2 Ash

The maximum range of ash constituent based on the TPC selected coal is as follows:

Ash Constituents (Air Dried Basis)	Range Weight, %
SiO_2	24 - 81.5
Al_2O_3	14 - 39.0
Fe_2O_3	19.0 Max.
CaO	0.1 - 28
MgO	0.2 - 8.5
K_2O	3.2 Max.
Na_2O	2.0 Max. for bituminous type ash
Na_2O	6.0 Max. for lignitic type ash

TiO_2	0.6 -3.10
SO_3	11.0 Max
P_2O_5	3.8 Max.

5.4.3 Ignition Oil

The characteristics of a distillate fuel oil to be used for steam generator ignition are as follows:

	Product of Kaohsiung Plant (K)	Product of Miaoli Plant (M)
Gravity, degrees API	32, Minimum	29 - 34
Corrosion Flash Point, C.O.C.	0	Passive
P. M.	60°C (140°F) Min.	93°C(200°F) Min.
Viscosity, SSU at 38°C (100°F)	2.7-5.8 mm^2/s (35 - 45 SSU)	2.7-5.5 mm^2/s (35 - 44 SSU)
Diesel Index	50 Minimum	50 Minimum
Heating Value (Minimum)	44190 kJ/kg (19,000 Btu/lb)	44430 kJ/kg (19,100 Btu/lb)
ASTM Distillation End Point (Maximum)	385°C (725°F)	393°C (740°F)

5.4.4 Flue Gas Conditions

5.4.4.1 The FGD system shall be designed to operate under the following conditions:

Steam Generator Operating Conditions

		30 Percent of MCR	60 Percent of MCR	70 percent of MCR	100 percent MCR
a.	Fuel Heat Input to Steam Generator, Million kJ/h	1886	3468	3928	5361
b.	Total Flue Gas Flow, kg/h	1019600 to 1029000	1874000 to 1892000	2123000 to 2143000	2897400 to 2924000
c.	Percent of Total Flue Gas Flow to be Treated by Absorber System	100	100	100	100
d.	Flue Gas Temperature at I.D. Fan Inlet, °C(°F)	108 (226)	123 (254)	126 (259)	132 (270) (160°C MAX.)
e.	Flue Gas Density at Specific Nominal Temperature, kg/m³	0.9580 to 0.9574	0.9281 to 0.9274	0.9190 to 0.9183	0.8962 to 0.8956
f.	Dry Flue Gas Volumetric Flow to I.D. Fan Inlet, Nm³/h	7.2×10^5	1.3×10^6	1.5×10^6	2.0×10^6
g.	Particulate content in (Influent) Flue Gas Stream, mg/Nm³	40~50	40~50	40~50	40~50
h.	Particulate Content in Treated (Exiting) Flue Gas Stream, mg/Nm³	20	20	20	20

i.	Nitrogen Oxides Content in (Influent) Flue Gas Stream, ppm	35	35	35	35
j.	Design Sulfur Dioxide Concentration in Untreated (Influent) Flue Gas, ppm dry basis, base on 6 percent of O2	210 to 1050	210 to 1050	210 to 1050	210 to 1050
k.	Maximum Leakage Rate for Leakage Type Flue Gas Reheater, percent (Volumetric Flow)	3	3	3	3

Limitations, if any, on removal of sulfur dioxide during start-up, at loads below 30 percent of the steam generator maximum continuous rating while firing coal, shall be stated in the Proposal Data.

5.4.5 Limestone

5.4.5.1 Limestone is expected to have an available calcium carbonate content of 95 percent. For calculation of material mass balances, limestone with 95 percent available calcium carbonate shall be assumed.

5.4.5.2 The maximum or minimum allowable percentages of the various constituents of the limestone shall be stated in the Proposal Data.

5.4.5.3 The FGD system shall be guaranteed for operation with any limestone defined by the ranges stated in the Specification.

5.4.5.4 The limestone reagent delivered to the plant site will be in powdered form, it is 90 percent through 325 mesh, and is expected to have composition of the following range:

Limestone Constituent	Range, wt %

SiO_2	0.16 -4.10
Fe_2O_3	Trace - 1.15
Al_2O_3	Trace - 1.15
CaO*	52.05 - 55.74
MgO**	0.41 - 5.05
P_2O_5	0.03 - 0.17
Ig Loss	41.49 - 44.16
Na_2O	Trace - 0.15

* Equivalent CaO of the $CaCO_3$ content.
** No credit allowed for MgO beneficial impact.

5.4.5.5 The following tabulated data are the chemical analysis for main limestone mines of Taiwan, R.O.C., wt, %.

Region	Ig Loss	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	P_2O_5	Na_2O
I-Lan	42.24	0.46	0.14	0.10	55.22	1.16	-	-
Kaa-Nah-Ahn	41.82	0.38	0.14	0.06	55.26	1.00	-	-
Central-Cross-High-Way	41.92	0.70	0.10	Tr	55.74	1.14	-	-
San Chan Brook of Hua Lien	41.64	0.06	0.14	0.12	55.50	1.36	-	-
Chier-Wan	42.99	0.37	0.51	0.09	53.36	1.49	0.05	-
Sha-Po-Dang	42.14	0.67	0.26	0.15	51.02	2.02	0.11	-
Tumg-Mern	43.56	0.30	0.14	0.18	53.17	2.38	0.11	-
Muh-Guah-Brook	43.69	0.16	0.13	0.21	54.16	2.18	0.10	-
Jy-Yaa-Can-Brook	42.82	3.49	0.49	1.12	52.30	0.41	0.03	-

Ta-Kang-Shan of Kaohsiung	43.04	2.07	Tr	0.40	53.19	1.17	0.10	
Shou-Shan	43.24	0.56	-	2.29	55.58	0.67	-	-
Hsiao-Caang	41.77	3.75	-	1.64	51.41	1.45	-	-
Tun-Pih-Guang-Chirng of Taiwan	42.79	3.11	-	0.24	53.58	1.40	-	-
Guan-Tzyy-Lin	43.75	1.43	-	0.64	48.94	5.05	-	-
Jeeng-Tour-Shan	44.16	0.53	-	0.31	52.70	1.40	-	-
Kung-Tien	44.08	0.55	-	0.47	53.50	1.14	-	0.15
Kung-Tien	43.82	0.31	-	0.47	53.39	0.92	-	0.09
Chyh-Ke-Shan of Hsin-Chu	42.16	3.87	0.88	0.18	52.11	0.79	0.05	-
Chyh-Ke-Shan	41.49	4.10	-	0.80	52.05	1.48	-	-
Chu-Tour-Jiaan of Tao-Yuan	41.98	3.42	0.49	0.21	53.31	0.55	0.17	-

NOTE: "Tr" means "Trace".

5.4.6 Water Supply

Makeup water and pump seal water will be supplied from the raw water storage tank through the raw water supply system. Circulating water will be supplied from the circulating water system. Closed cooling water makeup will be supplied from the demineralized water system.

5.4.6.1 Raw Water

Raw water quality is expected to be variable but the following analysis is considered typical (all constituents expressed in mg/L as calcium carbonate unless otherwise specified).

Constituent	Concentration mg/L

Calcium	62.5
Magnesium	42.1
Sodium as Na^+	8.3
Bicarbonate	177
Chloride as Cl^-	9.86
Sulfate as $SO_4^=$	27.7
Silica as SiO_2	13.1
Iron as Fe	ND
Manganese as Mn	ND
Chlorine as Cl_2	2
pH	7.8
Turbidity as NTU	0.7

5.4.6.2 Circulating Water

Circulating water is provided from the sea. Circulating water quality is expected to be variable but the following analysis and temperatures are considered typical.

Item	Range
pH	7.2 - 8.2
Salinity, %	17.3 - 33.7
Suspended Solid, ppm	0.01 - 0.04
Total Hardness, ppm	3420 - 6300
$CaCO_3$ Hardness, ppm	432 - 744

Fe, ppm as Fe	0.03 - 0.07
Dissolved Oxygen, ppm	5.3 - 9.0
Total Alkalinity, ppm as $CaCO_3$	114 - 130

Temperature of circulating water

Month	Mean Seawater Temperature Range, °C
January	20.5 - 21.5
February	20 - 21
March	21 - 22
April	23 - 25
May	25 - 26.5
June	26.5 - 27
July	27 - 28
August	28 - 28.5
September	26 - 28
October	24 - 26
November	22.5 - 24
December	21.5 - 22.5

5.4.6.3 Closed Cooling Water

Closed cooling water makeup is provided from the demineralized water system. Demineralized water quality will be within the limits listed below:

Content	Concentration

Total Dissolve Silica	0.01 mg/L SiO_2 Maximum
Specific Conductivity	0.5 micro ohms/cm at 25°C Maximum
Carbon Dioxide	Trace
Sodium	0.01 mg/L Na Maximum

5.4.7 Power Source

5.4.7.1 Two (2) 6900 V, 3 phase, 60 Hz power supply sources shall be furnished by the CONTRACTOR as shown on the Dwg. No. 1528-E-X-602, one as the normal supply from secondary of the FGD main auxiliary transformer which will be connected to unit generator, the other as the start-up and standby supply from secondary of the FGD start-up transformer which will be connected to parallel 161 kV buses in the switchyard, for each of the two (2) FGD systems.

5.4.7.2 The two (2) power supply sources will operate within a ±10% voltage variation and a frequency variation of 60 Hz ±5%.

5.4.8 Emergency Operation

Should an unscheduled outage of a regenerative air heater occur, the flue gas desulfurization system will experience a rapid flue gas temperature increase to approximately 400°C. This temperature excursion would persist for approximately 30 minutes.

The flue gas desulfurization system shall be designed to withstand a temperature excursion of the above magnitude and duration without damage or increased maintenance.

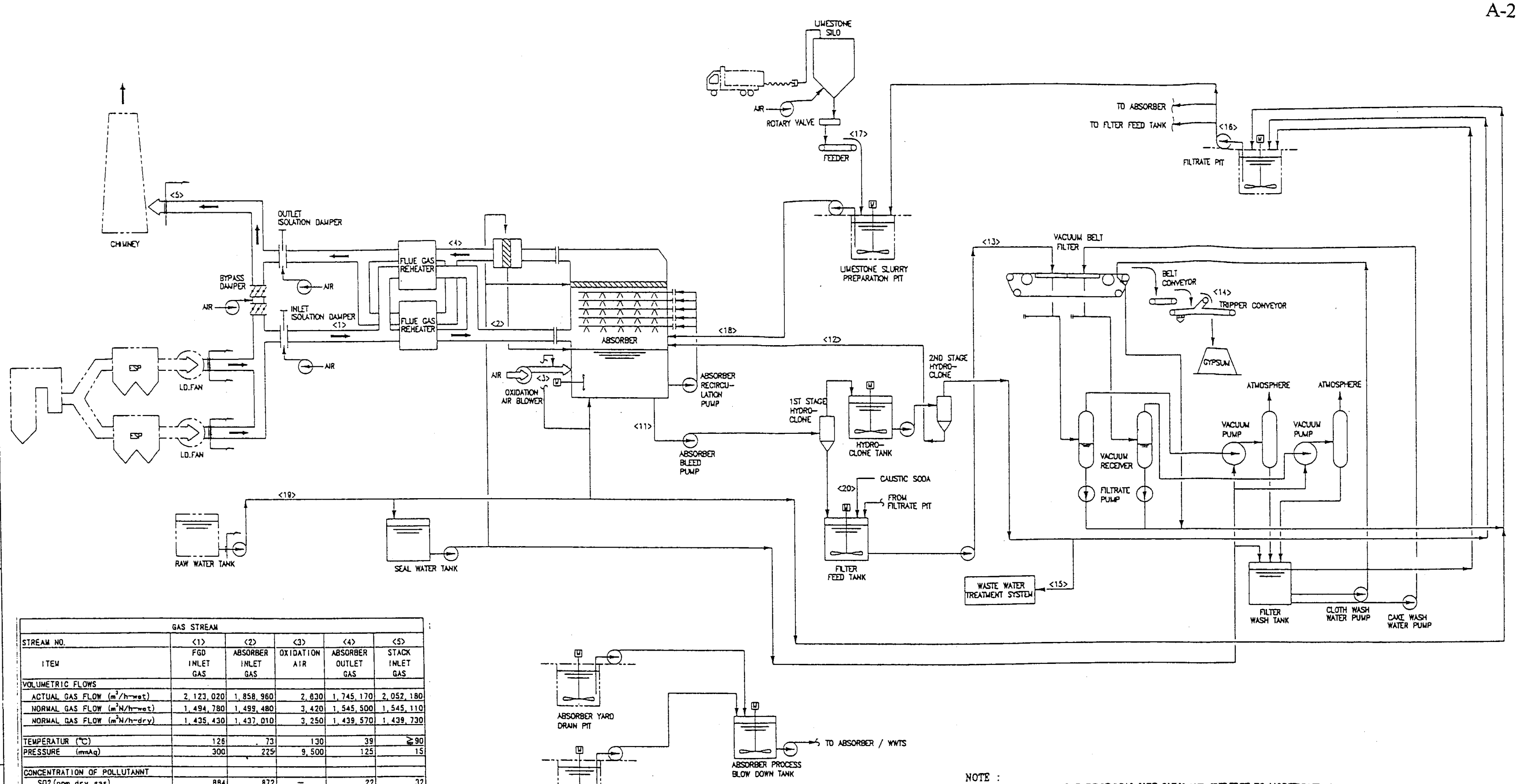
5.5 Model Test

A three-dimensional model of not less than 1/12 scale, shall be constructed and tested by the CONTRACTOR.

A description of the model test proposed shall be included as part of the Proposal Data.

The arrangement used for modeling shall have prior approval of the Engineer.

A-2



GAS STREAM					
STREAM NO.	<1>	<2>	<3>	<4>	<5>
ITEM	FGD INLET GAS	ABSORBER INLET GAS	OXIDATION AIR	ABSORBER OUTLET GAS	STACK INLET GAS
VOLUMETRIC FLOWS					
ACTUAL GAS FLOW (m^3/h-wet)	2,123,020	1,858,960	2,630	1,745,170	2,052,180
NORMAL GAS FLOW (m^3N/h-wet)	1,494,780	1,499,480	3,420	1,545,500	1,545,110
NORMAL GAS FLOW (m^3N/h-dry)	1,435,430	1,437,010	3,250	1,439,570	1,439,730
TEMPERATUR (℃)	126	73	130	39	≧90
PRESSURE (mmAq)	300	225	9,500	125	15
CONCENTRATION OF POLLUTANNT					
SO2 (ppm dry gas)	884	872	–	22	32
SO2 (kg/h)	3627	3585	–	89	132
HCL (ppm dry gas)	30	30	–	0	0
HF (ppm dry gas)	11	11	–	0	0
DUST CONC. (mg/m^3N)	.50	45	–	13	18

* is based on the actual 02 Content

LIQUID STREAM										
STREAM NO.	<11>	<12>	<13>	<14>	<15>	<16>	<17>	<18>	<19>	<20>
ITEM	ABSORBER BLEED	ABSORBER RETURN	FILTER FEED	PRODUCT GYPSUM	WASTE WATER	FILTRATE WATER	LIMESTONE	LIMESTONE SLURRY	TOTAL RAW WATER	CAUSTIC SODA
TEMPERATURE (°C)	45	45	45	35	35	25	25	30	25	25
SLURRY CONCENTRATION (wt%)	20	8	35	90	3	1	-	20	0	45 (NaOH)
pH	4-6	4-6	4-6	-	4-6	4-6	-	7-8	7	14
LIQUID FLOW (m^3/h)	58.4	32.7	22.8	5.3	4.9	41.3	-	27.5	42.8	0.1
MASS FLOW										
$CaSO_4 \cdot 2H_2O$ (kg/h)	10,880	1,260	9,420	9,300	100	310	0	180	0	0
$CaCO_3$ (kg/h)	320	110	140	130	30	60	5,660	5,700	0	0
INERT (kg/h)	1,520	1,190	280	280	20	30	300	320	0	40 (NaOH)
CaF_2 (kg/h)	140	110	30	30	2	3	0	2	0	0
FLY ASH (kg/h)	230	180	40	40	3	5	0	3	0	0
F (mg/l)	40	40	30	0	40	20	-	20	0	0
CL (mg/l)	20,000	20,000	12,190	100	20,000	10,780	-	10,780	10	10
H_2O (kg/h)	52,330	31,220	18,410	1,090	4,850	41,190	0	24,810	42,820	90
TOTAL (kg/h)	65,420	34,070	28,320	10,870	5,000	41,590	5,960	31,010	42,820	130

NOTE :
1. THIS DRAWING IS FOR PROPOSAL USE ONLY AND SUBJECT TO MODIFICATION.
THESE FLUE GAS CONSTITUENTS AND FLOW RATES ARE INCLUDED ONLY FOR THE REFFERENCE OF OBTAINING MATERIAL BALANCE AND ARE NOT TO UTILIZED AS A BASIS OF DESIGN OF GUARANTEE
(Gas flow rate : 70%MCR, Total Flue Gas : 2,123,020m3/hr, Gas Temperature : 126℃, Limestone Purity : 95%)
2. FIGURES ON THE TABLE SHOW THE DAILY AVERAGE OF THE MATERIAL BALANCE FLOW FOR 1 FGD UNIT.
3. ⌉ LINE SHOWS DELIVERY POINT. ---- LINE SHOWS TPC'S SCOPE.

REV.	DATE	DESCRIPTION	DRAWN	DESIGNED	CHECKED	APPROVED
0	'00.1.21	FOR PROPOSAL				

SCALE: —

1ST ANGLE PROJECTION / 3RD ANGLE PROJECTION

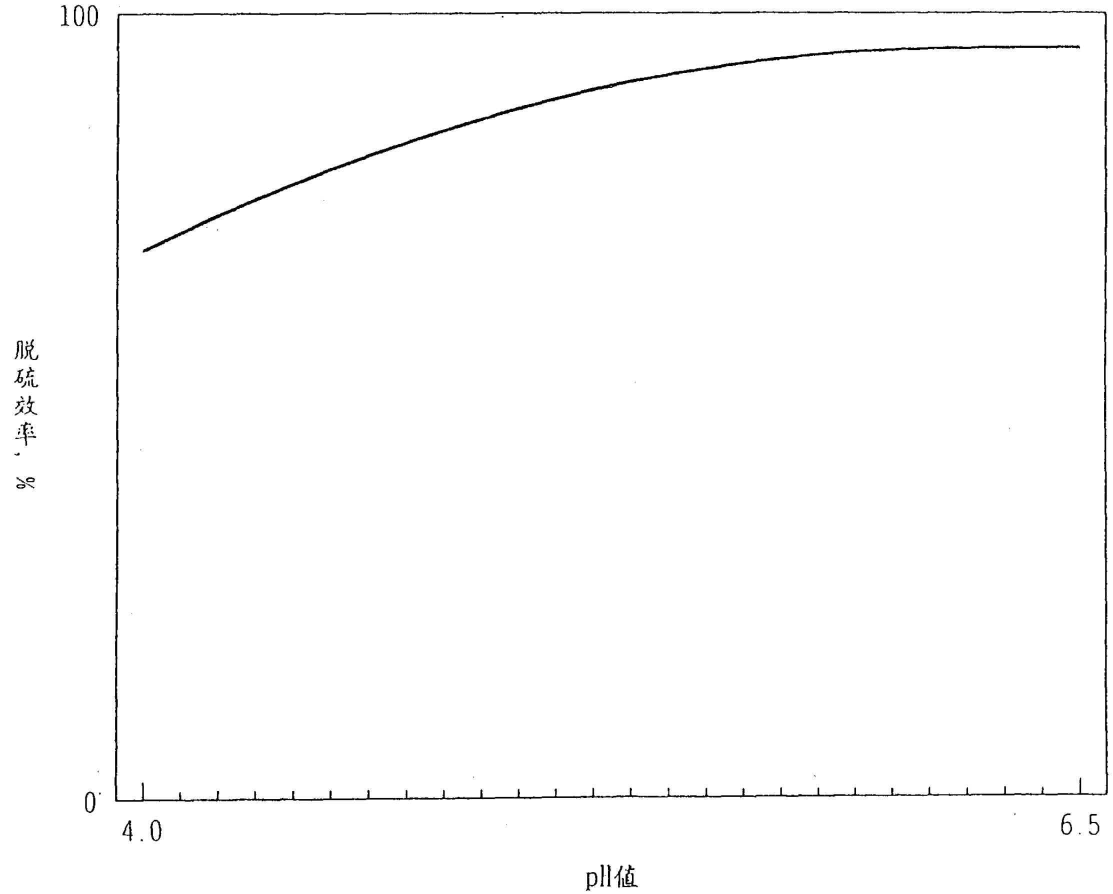
Taiwan Power Company Specification No. 1528-CS-007
Taichung Fossil Power Priojact Units Nos. 9 & 10
550 MW x 2 Flue Gas Desulfurization Project

PROCESS FLOW DIAGRAM
(FLUE GAS FLOW RATE : 70% MCR)

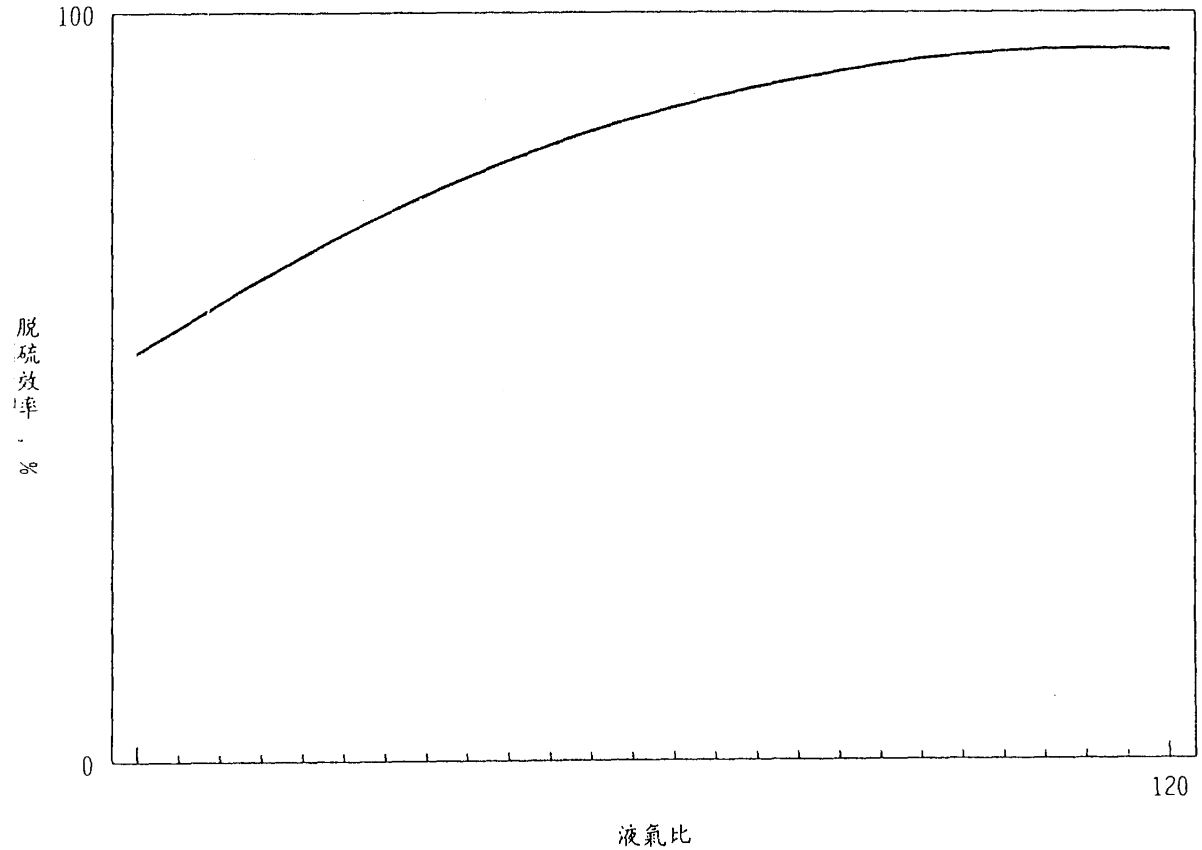
IHI AIR POLLUTION CONTROL DESIGN DEPARTMENT

JOB NO. 99000937-0507
DRAWING NO. K012-012
REV. 0

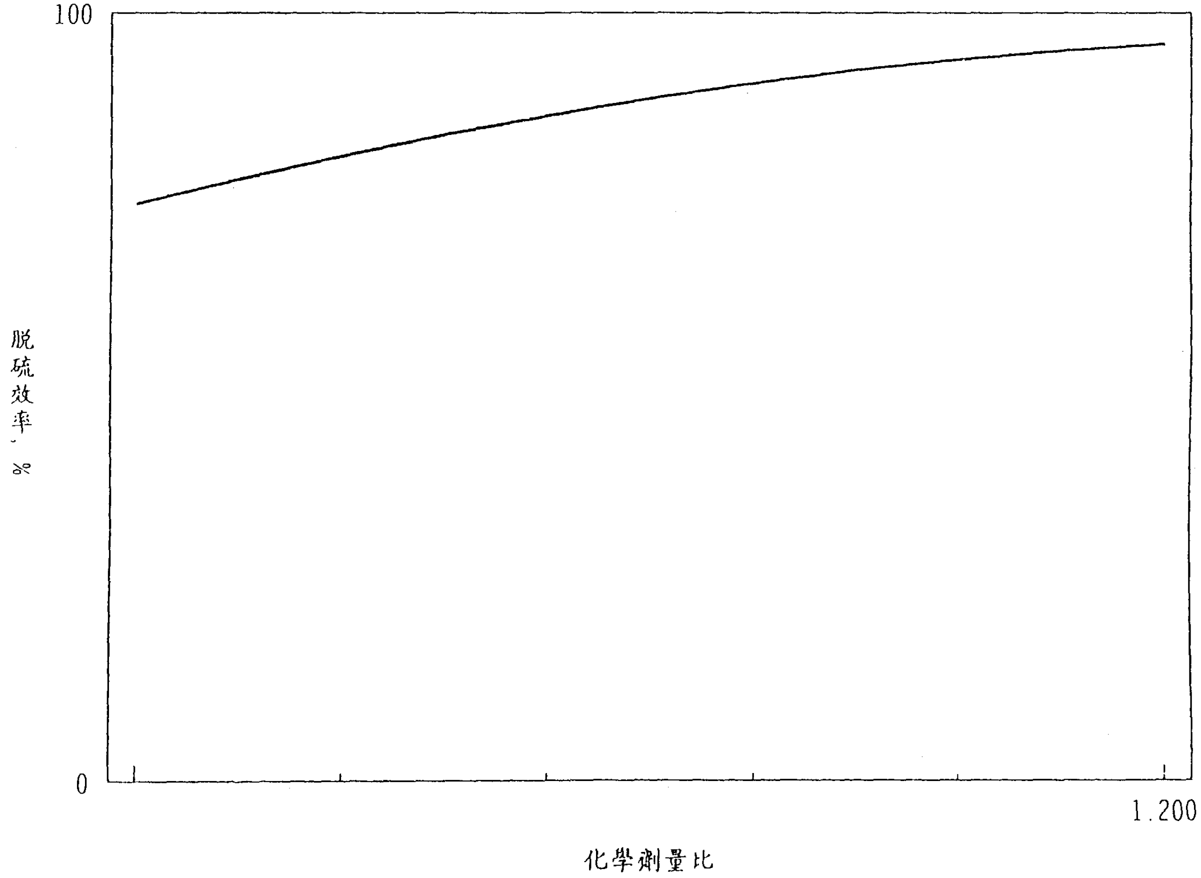
Ishikawajima-Harima Heavy Industries Co., Ltd.



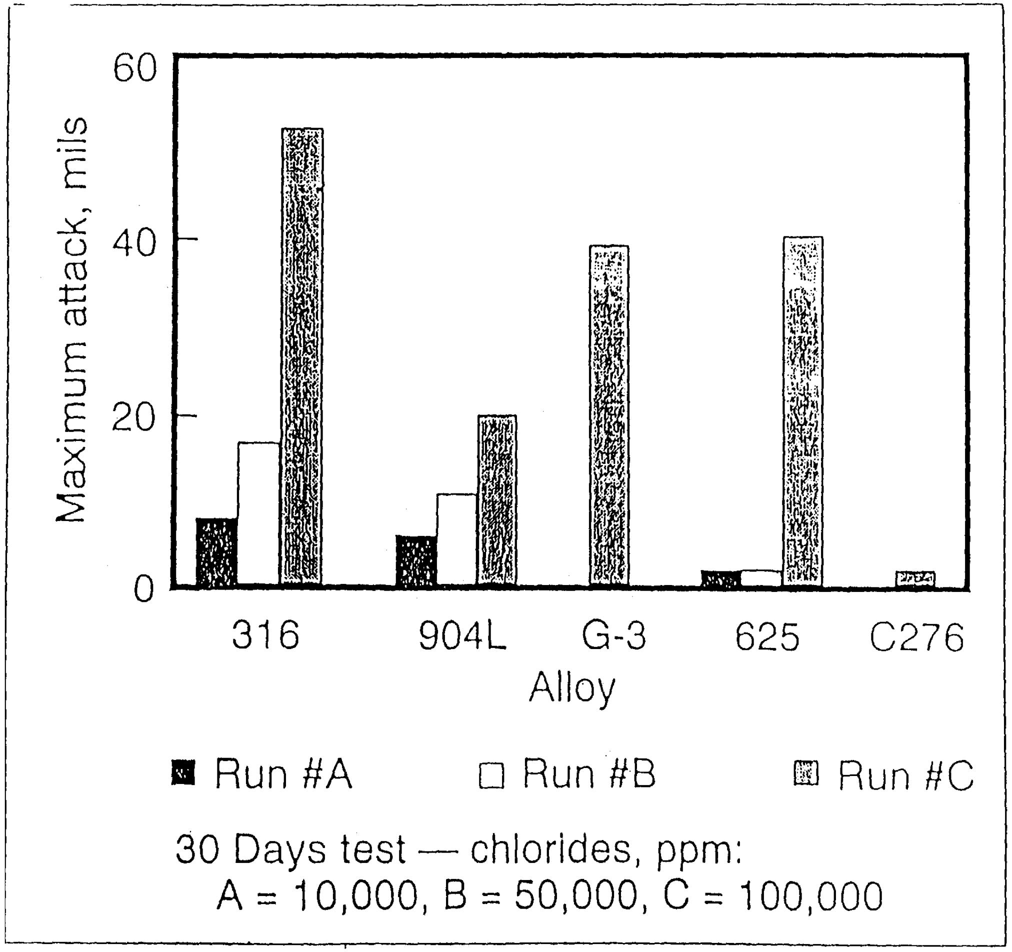
圖一　pH值與脫硫效率之關係圖



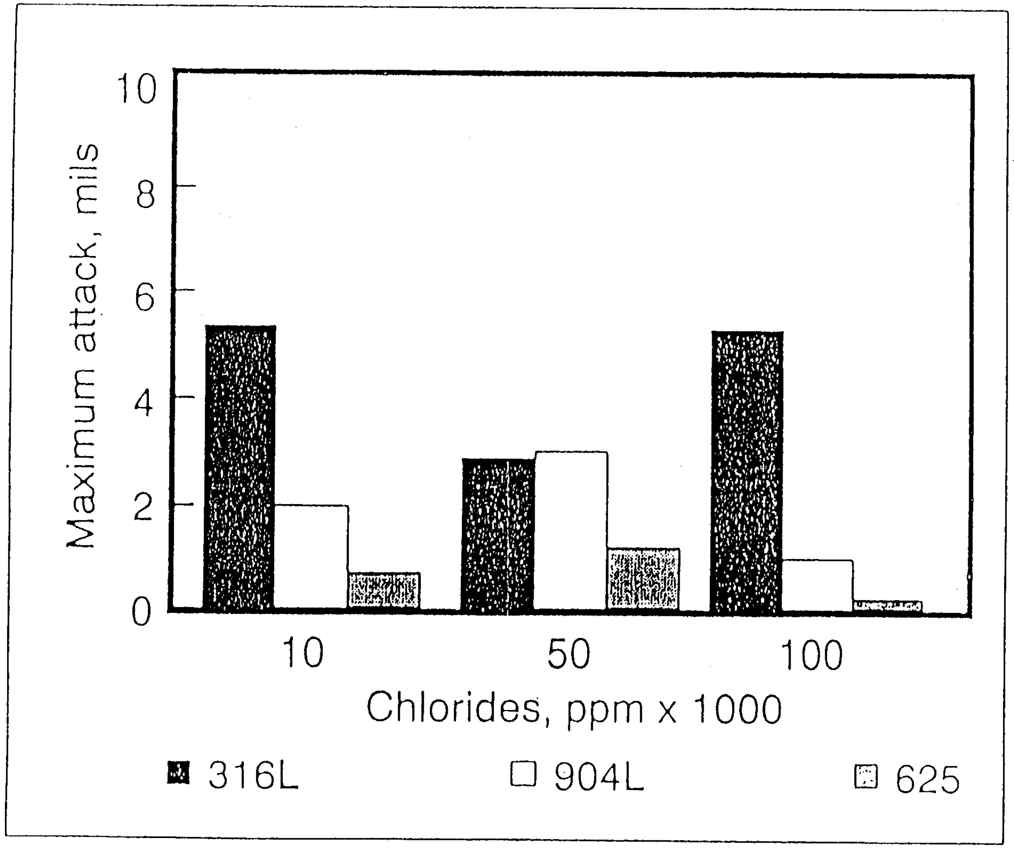
圖二　液氣比與脫硫效率之關係圖



圖三　化學劑量比與脫硫效率之關係圖



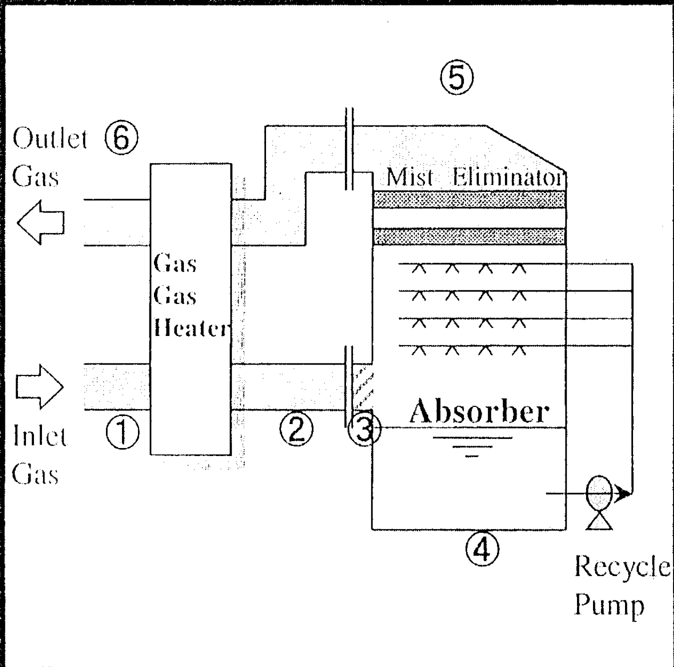
圖四~1　不同氯離子濃度對不同金屬材料的腐蝕測試結果



圖四~2　不同氯離子濃度對不同金屬材料的腐蝕測試結果

附表一

ABSORBER & DUCT MATERIAL



No	Temp.	IHI Standard Specification	Taichung #9,10 & Hsinta #3,4
①	140～160℃	Carbon Steel (SS41)	ASTM A588 (S-TEN)
②	90～100℃	Carbon Steel (SS41) + Heat resistant Flake Lining	ASTM A36(C.S.) + Hastelloy C-276 clad
③	90～100℃	Carbon Steel (SS41) + Heat resistant Flake Lining	Hastelloy C-276 solid
④	40～50℃	Carbon Steel (SS41) + Flake Lining (Spray Zone : anti-abrasion type flake lining or Stainless Steel-clad)	Hastelloy C-276 solid (Taichung #9,10) 6% Molybdenum Stainless Steel solid (Hsinta #3,4)
⑤	40～50℃	Carbon Steel (SS41) + Flake Lining	ASTM A36(C.S.) + Hastelloy C-276 clad
⑥	85～95℃	Carbon Steel (SS41)	ASTM A36(C.S.) + Hastelloy C-276 clad