行政院及所屬各機關出國報告
（出國類別： 實習 ）

報 告 題 名：油槽檢測及適用性評估

服務機關：中油公司煉製事業部
出 國 人 職 稱：安環室主任
姓 名：許世希
出國地區：美國
出國期間：92/09/22~92/09/28
報告日期：92/10/15

油槽檢測及適用性評估

一、摘要

油槽為非壓力之容器，往往為人忽略其危險性，以及輕忽其損壞後所帶來後果。近年來中油公司因油槽洩漏造成的污染防治費用，油槽使用率的降低，以及成品的損失，油槽的問題逐漸為各級主管所關心的重點。經訪Farwest 防蝕公司及參與油槽檢測及適用性評估課程後，有數點心得值得在工作上改進及運用，同時也印證目前本公司在這方面的努力與國外一致。唯仍有數點值得努力，其一為延長原油槽或腐蝕性的油槽壽命，其底板可以塗料及陰極防護共同來保護，其二為增進油槽使用的可靠性，使用先進檢測儀器全面檢測有其必要性。其他當油槽有所改變應做適用性評估。

系統識別號:C09203894

公 務 出 國 報 告 提 要

頁數: 14　含附件: 否

報告名稱:

油槽檢查及適用性評估

主辦機關:

中國石油股份有限公司

聯絡人／電話:

葉宇容／87258422

出國人員:

許世希　中國石油股份有限公司　煉製事業部　主任

出國類別: 實習

出國地區: 美國

出國期間: 民國 92 年 09 月 22 日 -民國 92 年 09 月 28 日

報告日期: 民國 92 年 10 月 15 日

分類號/目: G13／工業安全及衛生　G2／石油礦及石油工業

關鍵詞:　油槽,使用壽命,適用性,陰極防蝕

內容摘要: 油槽爲非壓力之容器，往往爲人忽略其危險性，以及輕忽其損壞後所帶來後果。近年來中油公司因油槽洩漏造成的污染防治費用，油槽使用率的降低，以及成品的損失，油槽的問題逐漸爲各級主管所關心的重點。經訪Farwest防蝕公司及參與油槽檢測及適用性評估課程後，有數點心得值得在工作上改進及運用，同時也印證目前本公司在這方面的努力與國外一致。唯仍有數點值得努力，其一爲延長原油槽或腐蝕性的油槽壽命，其底板可以塗料及陰極防護共同來保護，其二爲增進油槽使用的可靠性，使用先進檢測儀器全面檢測有其必要性。其他當油槽有所改變應做適用性評估。

二、目次

三、正文

（一）目的：本次出國實習主要目是要瞭解目前國外先進國家對於油槽的檢查及其適用性評估的最新做法，並據以修訂本公司今後對於油槽檢查之因應之道。

（二）過程：本次實習因時間短暫，扣除往返路程只四天，所以行先以電子郵件將所欲瞭解的問題寄出，在訪問 Farwest 防蝕公司時能即時得到所欲知之資料與訊息，並在對油槽實習課程時能充份掌握重點，提高學習成效。

（三）心得：本次學習心得，依次分為如下 7 項

1. 油槽壁板及頂板腐蝕問題
2. 油槽底板腐蝕問題
3. 底板內襯或油漆的選擇
4. 油槽底板陰極防蝕
5. 油槽檢測技術
6. 油槽壽命評估
7. 油槽適用性評估簡介

1. 油槽壁板及頂板腐蝕問題

油槽的腐蝕依位置分佈可分為二大類：

甲、 位於壁板較上方氣相位置，包括壁板上方、頂板及結構件。

乙、 壁板下方含水處。

基本上由於只有錐頂油槽有氣相位置，所以浮頂油槽在這位置較低腐蝕，然於此位置上的腐蝕多半是由冷凝水所造成，但假如油料中硫化氫含量較多也會加速腐蝕率，在氣液界面處腐蝕最嚴重。

在壁板下方的腐蝕較不嚴重，其油中的水含量會影響到腐蝕率，尤其含有石油腦、硫化物、或烷化酸等皆會加速腐蝕。

壁板的腐蝕率還會因溫度及進出油料的頻率而提高。

在壁板下方含水線下方以及底板可以塗裝來降低點蝕。最經濟方式以增加腐蝕裕度來對付點蝕。

各種型式油料壁板及頂壁腐蝕率如下：

由於假使局部破損會造成集中腐蝕，所以常須以陰極防蝕加以補強。

乙、 片狀玻璃塗裝：0.04~0.10 吋乾膜厚度。約可維持10~15 年壽命，但是在使用 5 年後有可能局部劣化。

丙、 層狀塗裝（FRP）：0.10 吋以上乾膜厚度。約可用 20 年，但使用 10 年後約有 10%~20%的劣化須修補，底板在使用中在各位置上常會有彎曲變化，因此造成此種厚層塗裝的龜裂，導致底板腐蝕洩漏。且由於此種重塗裝下的底板不易檢測，所以最近使用較受到考慮。

以薄膜塗裝加陰極防蝕約比片狀玻璃塗裝便宜 30%（以美國而言），層狀塗裝比片狀玻璃塗裝貴約 10%。所有防蝕方式若使用超過 10 年，其費用比更換底板來的便宜。

底板內襯選擇要領：

薄膜塗料系統

內襯系統	油料種類	使用溫度限制，°F
Coal Tar Epoxy	原油	120-170
Epoxy Phenolic	輕油、芳香煙、原油、汽油	180-220
Epoxy Amine	輕油、芳香煙、原油、汽油	160-220
Epoxy Amine Adduct	輕油、原油、汽油	160-220
Epoxy Polyamide	原油、汽油	160-180
Epoxy Polyamidoamoine	原油、汽油	160-180

厚層 FRP 塗料系統

內襯材料	油料種類	溫度限制，°F
Polyesters Isophthalic	原油、汽油	140-160
Biphenol-A	原油、汽油	160-180
Vinyl Ester	原油、汽油、芳香煙、酒精、化學品	180-220
Epoxy	原油、汽油、芳香煙	180

4. 油槽底板陰極防蝕

底板陰極防蝕可分儲油側及土壤側防蝕二類。可用犧牲陽極法及外加電流法，此部份可參考 API-651。油槽內側的防蝕若配合塗裝其電流可省 90%，效果更佳。犧牲陽極可用鋅、鋁及鎂，槽內陰極防蝕由於鎂的電位較高，恐會引起火星，造成工安事故，故不宜使用。

油槽底板外側陰極防蝕

陰極防蝕的種類

1. 犧牲陽極法：使用鎂合金或鋅為陽極，此方法適用於小油槽，陽極回填時常需用殊別回填料如石膏加硫酸鈉，其電阻係數約為 250ohm-cm。為使保護電流均勻，以分散式設立為佳。
2. 外加電流法：使用石墨、高矽鑄鐵、鉑合金、磁性氧化鐵、混合氧化金屬(mmo)做為陽極材料。回填材料可用碳粉或直接回填土。設計時要考量陽極的數量、大小及每根陽極最大輸出電流密度，地床設計時應考量干擾問題、輸出均勻問題。所需保護電流密度約為 1~2ma/ft^2 ，對於已設立的油槽可以臨時地床測試所需電流密度。整流器的規格可就上述所估電流量放大 1.1~1.5 倍，電壓伏特數則以 Dwight's 公式計算，可參考 NACE 51011 或管線腐蝕控制一書。
3. 電子絕緣：為了防止干擾其也設備、計量儀器及達到防蝕電位標準，油槽與其相連接的管線或導電裝置都以絕緣組件將之隔離。接地系統很重要，但會影響到防蝕效果，所以改以鋅地電池接地。絕緣組件間恐於雷擊時生跳電現象。所以需加裝避雷器或防止湧流裝置如 kirk cell 。

為了避免迷失電流干擾，以往本公司常用的方法以鋅地電池或 kirk cell 將干擾電流導入地下，唯大量電流的處理不盡理想，因此針對此有一新產品可供選擇使用，其選擇方法如附件一。

對於電源供應的整流器的選擇也漸多元化，不管是恆電流、恆電壓、恆電位整流器皆有商業化產品可供選用如附件二。

防蝕標準

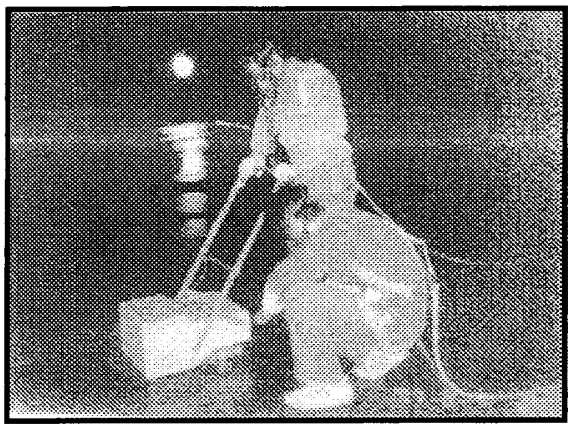
可參考 NACE RP0169。常用的標準有二，

1. -850mv(對 Cu-$CuSO_4$)
2. on-off 時的極化電位值移動達 100mv，不管是開始時形成或關電後的退化極化值皆可。

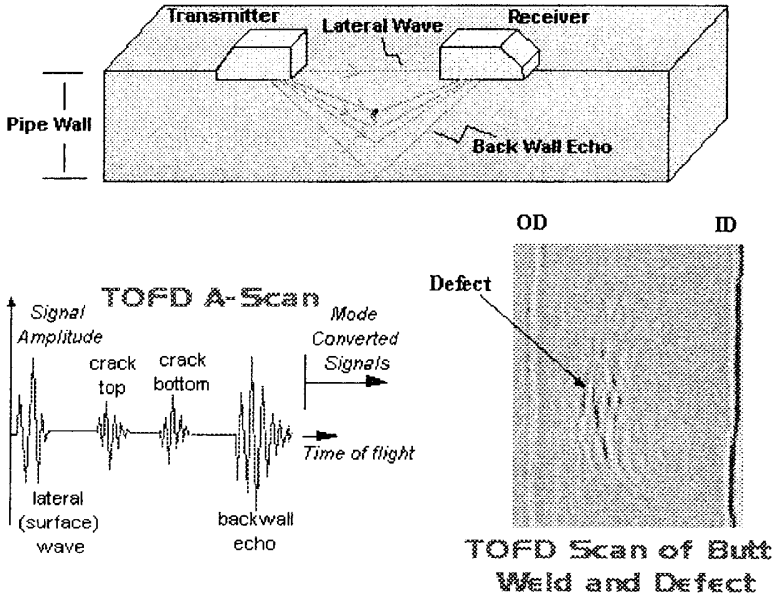
5. 油槽檢測技術

油槽檢測技術各家廠商皆依 API650 及 653 實施，但較特殊的查漏方法有：

1. 音洩檢測：利用液体流過孔洞會產生音波原理偵測腐蝕洩漏問題。
2. 底板磁通漏掃瞄器：如下圖，利用磁漏原理檢查底板厚度變化以瞭解底板內外部腐蝕問題。



3. TOFD：如下圖利用超音波繞射原理檢查銲道或母材之腐蝕問題。



目前本公司三種方法皆曾使用，以後二種較有心得唯仍未普遍使用。值得加以推廣以增進油槽檢測結果的可靠度。

6. 油槽壽命評估

油槽使用壽命長短應依各部份頂板、壁板、底板及附屬裝置來加以評估，但由於上述有關腐蝕率討論的結果，顯而易見的以底板的腐蝕洩漏影響最大，是故在API653壽命評估就以底板最小剩餘厚度與腐蝕率的結果來計算剩餘壽命，其計算方法如下：

油槽底板腐蝕率與剩餘壽命之計算要領：

1 底板最小厚度值之測量：以下述兩種方法之一測之

1.1 底板之每一塊鋼板取五點（四個角落距板邊一呎、板中心）作超音波測厚，所得諸多厚度值中最小值即為整座底板最小厚度值。

1.2 整座底板以磁通漏檢測再以超音波測厚，以測得最小厚度值。

2 腐蝕率：以下述兩種公式求得較大值為腐蝕率。

2.1 腐蝕率＝（原使用板厚－最小厚度值）÷ 使用年數

2.2 腐蝕率＝（上次開放檢查最小厚度值－本次最小厚度值）÷ 兩次

開放檢查相隔年數

3 點蝕深度量測並記錄。

4 剩餘厚度＝最小厚度值－點蝕深度。

5 剩餘壽命＝（剩餘厚度值－2.54mm 或 1.27mm）÷ 腐蝕率。

6.1 MRT＝(RT_{bc} 與 RT_{ip} 之較小值)－Or × (StPr＋UPr)

式中：

MRT＝下次檢查期限終了時，預估剩餘之最小厚度，不得低於下列數值：

一般底板之厚度：

底板/基礎無圍堵及偵測底板漏油之設施者	2.54mm(0.1")
底板/基礎有圍堵及偵測底板漏油之設施者	1.27mm(0.05")
底板塗有符合 API RP652、厚度大於 1.27mm(0.05")之重塗裝(如 FRP)者	1.27mm(0.05")

Or＝下次開放實施內部檢查之年限，但不得超過 20 年

RT_{bc}＝經過整修後，背面(土壤側)腐蝕剩餘之最小厚度(計算時，均勻腐蝕與單一的點蝕皆須列入，以下同)

RT_{ip}＝經過整修後，內部(油側)腐蝕剩餘之最小厚度

StPr＝內部(油側)未整修前之最大腐蝕速率；有塗裝之部分，若該塗裝之耐用年限可達到或超過 Or，其 StPr 方可為 0

UPr＝背面(土壤側)經過整修後之最大腐蝕速率：以油槽經歷之時間平均計算其腐蝕速率。受陰極防蝕有效保護之部分，其 UPr 可以為 0

附註：1. 對於經過磁通漏(MFL)掃瞄檢查、且未受到陰極防蝕有效保護之底板，計算 UPr 時，必須採用(MFL 設定值，經過整修後腐蝕區域最低之厚度)兩者較低之值。所謂 MFL 設定值，係指 MFL 檢測某區域時預計要檢測之最大厚度，該值應該由使用部門基於需要之開放期限事先決定

2. 背面(土壤側)經過整修後，除非腐蝕的因素已經改善，仍須以該

區域之腐蝕速率作為UPr，同時，採用貼焊之方式整修者，該處之(RT_{bc}與RT_{ip}之較小值)可加計貼焊之板厚

6.2 底板關鍵區域(離壁板內緣3吋以內之環狀帶區域)之厚度：不得低於下列兩者之較小值(經過應力分析者除外)：

6.2.1(原始底板厚度－原腐蝕裕度)之1/2

6.2.2 最下層壁板依照API 653 4.3.3.1規定計算之最小厚度之1/2，但至少需2.54mm(0.1")。此處，零星的點蝕對強度不致產生嚴重影響

6.3 底環板之厚度：

6.3.1 基於強度之要求，通常底環板之最小厚度會大於2.54mm(0.1")，零星之點蝕則對強度尚不致產生嚴重影響。除非經過應力分析，底環板需符合下列b.或c.之規定

6.3.2 內容物比重小於1.0時，底環板厚度不得低於下表數值再加上腐蝕裕度：

內容物比重小於1.0時之底環板厚度(inch)

最下層壁板之使用厚度(in.)	最下層壁板之應力=[2.34D(H-1)]/t，(D,H：ft.，t：in.)†			
	< 24,300 psi	< 27,000 psi	< 29,700 psi	< 32,400 psi
t≦0.75	0.17	0.20	0.23	0.30
0.75<t≦1.00	0.17	0.22	0.31	0.38
1.00<t≦1.25	0.17	0.26	0.38	0.48
1.25<t≦1.50	0.22	0.34	0.47	0.59
t>1.50	0.27	0.40	0.53	0.68

†D：油槽公稱直徑，ft.

H：最大儲油高度，ft.

t：最下層壁板之使用厚度，in.(下表同)

6.3.3 內容物比重為1.0以上時，底環板厚度不得低於下表數值再加上腐蝕裕度：

內容物比重為1.0以上時之底環板厚度(inch)

最下層壁板之使用厚度(in.)	最下層壁板之應力=[2.6D(H-1)]/t，(D,H：ft., t：in.)			
	<27,000 psi	<30,000 psi	<33,000 psi	<36,000 psi
t≦0.75	1/4	1/4	9/32	11/32
0.75<t≦1.00	1/4	9/32	3/8	7/16
1.00<t≦1.25	1/4	11/32	15/32	9/16
1.25<t≦1.50	5/16	7/16	9/16	11/16
1.50<t≦1.75	11/32	1/2	5/8	3/4

6.3.4 對於考慮地震因素而提高底環板厚度之油槽，應以底環板現有之實際厚度，依相關法規之規定，實施地震影響之評估

6.4 突出壁板填角焊道外側處之底板厚度至少須2.54mm(0.1")，同時，突出焊道外之寬度至少須10mm

6.5 另一種方法為概率原則，將區域掃瞄結果得到之實測厚度加以統計，以推估最低之剩餘厚度，再評估底板之最小厚度

在這計算公式內值的檢討的有幾點：

1. 底板平均厚度的量測：一般皆以floorscan全檢底板，檢查出底板可能腐蝕位置，再以超音波TOFD或C scan找出腐蝕範圍，其次以超音波測厚儀量測厚度，大部份廠家量測每塊底板四個角及中心共五點並以統計分析法計算剩餘厚度。目前本公司大体量測方式也是準用此方法，唯由於floorscan儀器的數量及人力尚不足無法普及至所有油槽。
2. 最大腐蝕率的計算：在API653內認為內部若有塗裝且未脫落，其內部腐蝕率為0，外部有足夠電位保護陰極防蝕系統腐蝕率亦可視為0，若二者有一無則要分別計算其腐蝕率，此點相當令人困擾，經詢大部廠家仍以上述1.所得平均厚度除以使用年限來當

做腐蝕率計算。

3. 剩餘厚度：若底板加以修補或加 patch plate 皆可計入剩餘厚度，唯用補土或其他非金屬填充物則不可計入。值的注意修補方式可用點銲、疊銲或覆面銲但在 critical zone 帶修補則要格外小心依規定實施。銲補後的底板有些廠家認為加上塗裝保護會較佳，此點倒是值得參考。

7. 油槽適用性評估簡介

油槽的適用性評估在 API653-2001 年版新增，但整個完整的 code 仍以 API579 最為完善。適用性評估主要目的是評估倘若設備經檢查現其內存有瑕疵，到底此設備是否需加以修護或暫不修護繼續使用直到下次大修時才處理。此技術可分三個等級，第一級可由檢查員或操作工程師評估，第二級可由操作工程師評估，第三級就需由專業工程師進行評估。

適用性評估基本上需具備

-破損機制的知識

-操作條件的瞭解

-材料特性的認識

-應力分析常用有限元素法

-統計分析

在 API653 code 第四章適用性評估中，規定當油槽經修護後、移位、重建、整修或變更使用目的必須做適用性評估。其考量因素包括內、外部腐蝕問題，儲存物特性，使用溫度，承受風力，地震影響，基礎沈陷，所用金屬材料特性，操作情況等。目前本公司皆尚未依此標準進行評估，爾後應朝此方向努力，以確保油槽之可用性。附件三為一評估案例可供參考。

（四）建議

1. 原油槽塗裝需從一開始就做並配合陰極防蝕，效果較佳。

2. 基礎建造時最好能設有洩漏偵測裝置，修護底板時最好亦應加

強防漏裝置及偵漏系統以防止洩漏時造成環境污染。

3. 為了延長油槽使用年限，油槽的管理及防蝕措施應加強。
4. 油槽開放後的檢查務必儘量以 floorscan 或 TOFD 超音波檢查，以求檢查完整，故應增購儀器及人力訓練。
5. 油槽經檢查、修護後結果報告，儘量能朝適用性評估方向努力。

（五）附錄

1. 各種 DEI 產品的選擇方法
2. 各種整流器目錄
3. 油槽適用性評估範例

Join the Worldwide Trend Started

DEI manufactures solid-state DC isolation and AC grounding products for connection to cathodically protected structures, such as pipelines, tanks, and underground power cable shields. These devices address concerns regarding AC fault current, induced AC voltage, lightning, stray DC currents, and over-voltage protection.

DEI developed solid-state, maintenance-free products to provide an alternative to liquid-filled polarization cells, spark-gap arresters, and zinc grounding cells, all of which are limited in ratings or application.

Product Features

- Maintenance-free
- Fail-safe design
- Higher DC blocking voltage than polarization cells
- Lower over-voltage clamping level than arresters
- Meets electrical code requirements
- Certifications: UL, C-UL

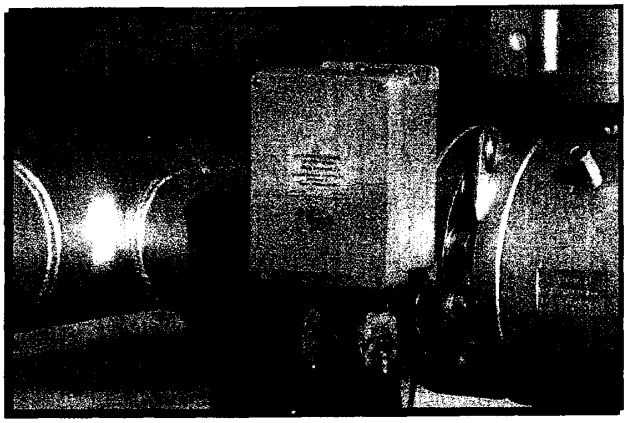
Applications

- Mitigation of induced AC voltage on pipelines: shunt AC current to ground continuously while blocking DC current
- Over-voltage protection of insulated joints from lightning and AC fault current
- Safety grounding of electrical equipment without affecting CP levels (e.g. motor-operated valves)
- DC isolation of tank farms, metering stations, etc. from power utility grounding systems
- Utility power cable sheath/casing: DC isolation, AC fault conduction
- Marine isolation: ship-to-shore
- Galvanic isolation: structural steel, piers, wells, water pipelines, tanks
- Blocking stray currents: CP, rail, telluric

Benefits

- Limit over-voltages to the lowest possible levels
- Minimize cathodic protection current requirements
- Bring cathodic protection voltages into compliance
- Comply with electrical codes for grounding
- Safely conduct AC fault current and lightning current to ground
- Comply with codes for application in explosive atmospheres
- Minimize interference by stray currents

By Dairyland Electrical Industries



Polarization Cell Replacement (PCR)

The preferred, compact product for most pipeline and related applications. Commonly used for insulated joint protection, AC mitigation, and DC isolation/AC grounding of electrical equipment on pipelines and tanks. Certified by UL and CSA for installation in safety grounding conductors, and by UL for Class I, Division 2 hazardous locations.

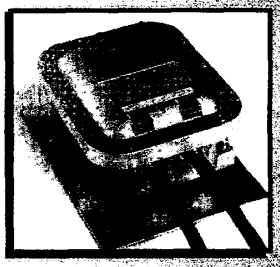
Isolator/Surge Protector (ISP)

Our most flexible product, with the greatest range of design ratings. Suitable for higher blocking voltage requirements and/or high AC fault conditions, the ISP is commonly used on power utility underground transmission cable casings. Comprehensive testing of the ISP can be performed using the DEI In-Situ Tester to verify all modes of operation and to read site parameters.

Certified Products for Hazardous Locations!

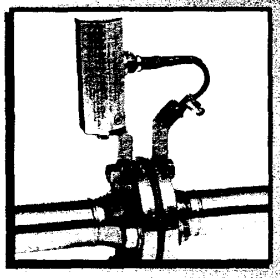
PCR for Hazardous Locations (PCRH)

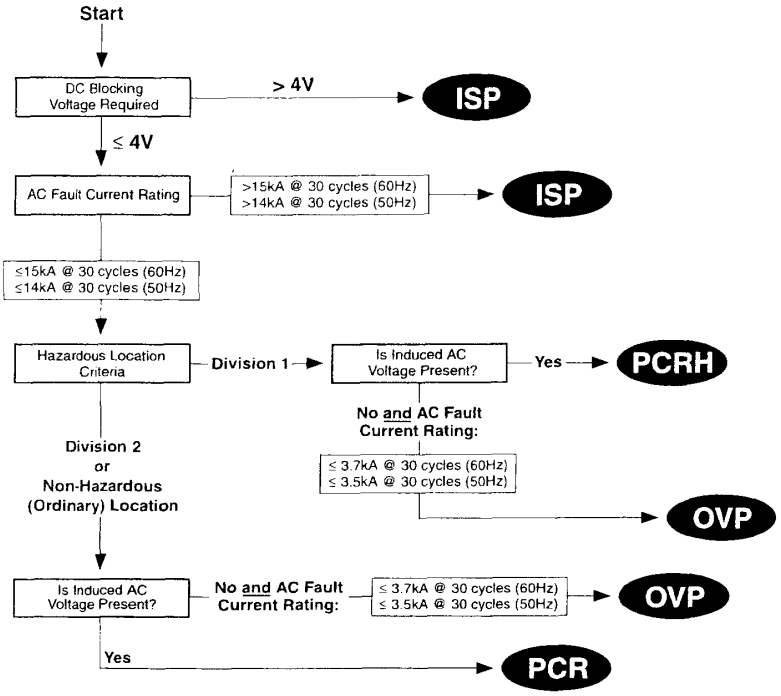
The reliable PCR, packaged in an explosion-proof housing, and tested by UL to meet Class I, Division 1 & 2 requirements. PCRH models have the same electrical ratings as the PCR. Extends the PCR for use in sites classified as Division 1 hazardous locations.



Over-Voltage Protector (OVP)

A compact product certified by UL for Class I, Division 1 & 2 locations, commonly used for insulated joint protection. Advantages over "arresters" include ratings for AC fault current, solid-state gapless design, superior over-voltage protection, and submersible, explosion-proof packaging. Provides AC and DC isolation up to the device threshold. Various mounting arrangements are available.





PCR = Polarization Cell Replacement
(Can be used for most applications)

PCRH = Polarization Cell Replacement
(Explosion-proof version of PCR)

OVP = Over-Voltage Protector
(Often used for insulated joint protection)

ISP = Isolator/Surge Protector
(Common in high power utility applications)

GD = Galvanic Decoupler
(For dissimilar metal isolation in low power applications)

Typical selection criteria is shown above. Some applications may require additional information prior to product selection. See the DEI website for "Application Notes."

	Conditions & Ratings	PCR	PCRH	OVP	ISP	GD
	DC voltage blocking level	-3/+1V, -2/+2V*+	-3/+1V -2/+2V*+	-3/+1V -2/+2V+	±10, ±17V+	-1.5/+0.5V
	Acceptable for use with induced AC voltage	Y	Y	N	Y	N
60 Hz	AC rms steady-state current rating, 60Hz	45A, 80A*	45A	N/A	30, 60, 90A+	5A
60 Hz	AC rms fault current @ 0.5 sec, kA 60Hz	3.7, 10, 15	3.7, 10, 15	3.7	3.7, 11, 14, 30+	0.5
50 Hz	AC rms steady-state current rating, 50Hz	40A, 70A*	40A	N/A	25, 50, 75A+	5A
50 Hz	AC rms fault current @ 0.5 sec, kA 50Hz	3.5, 9, 14	3.5, 9, 14	3.5	3.6, 10, 13, 28+	0.5
	Lightning surge current rating, kA, 8x20μs waveform	100	100	100	50, 75, 100*	20
	Rain-proof	Y	Y	Y	Y	Y
	Submersible	N(Y*)	N	Y	Y	N(Y*)
	Certified (UL) for Class I, Div. 1	N	Y	Y	N	N
	Certified (UL) for Class I, Div 2	Y	Y	Y	N	N
	Certified (UL, CSA) for grounding electrical equipment	Y	Y	Y	N(Y**)	Y

Optional ratings are available, and products can be customized to user requirements. Contact us regarding special applications and additional products. Reference the DEI catalog sections for full product information. Questions about ratings or applications? Contact DEI.

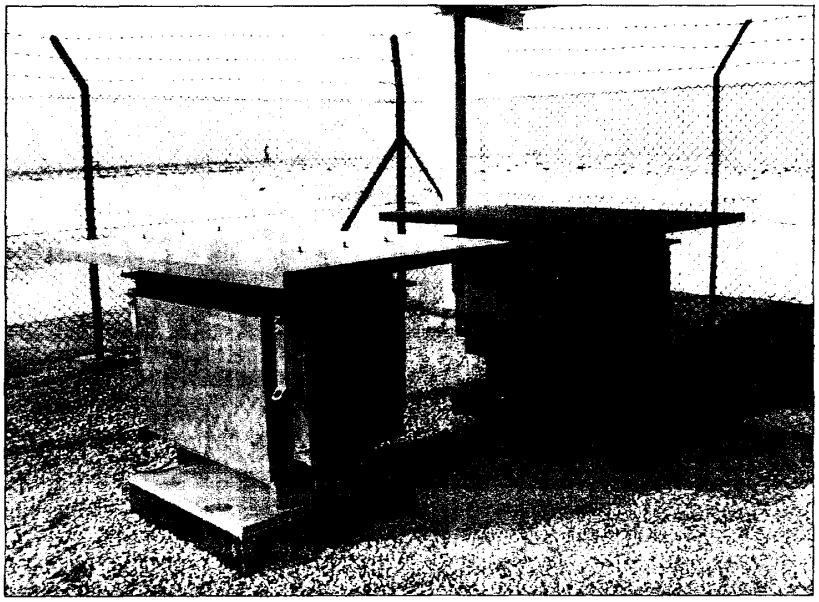
Dairyland Electrical Industries, Inc.
P.O. Box 187, Stoughton, WI 53589 USA
Website: www.dairyland.com

Phone: 608 877-9900
Fax: 608 877-9920
Email: dei@dairyland.com

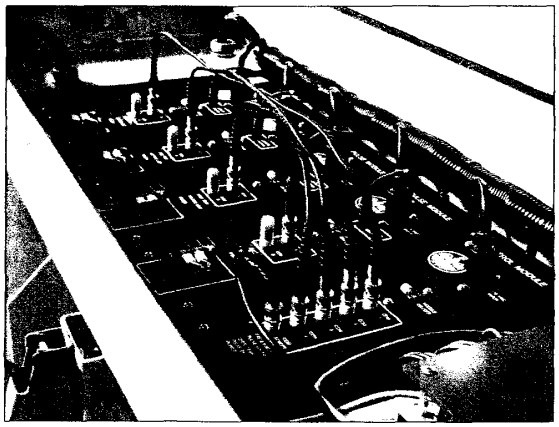
附件二

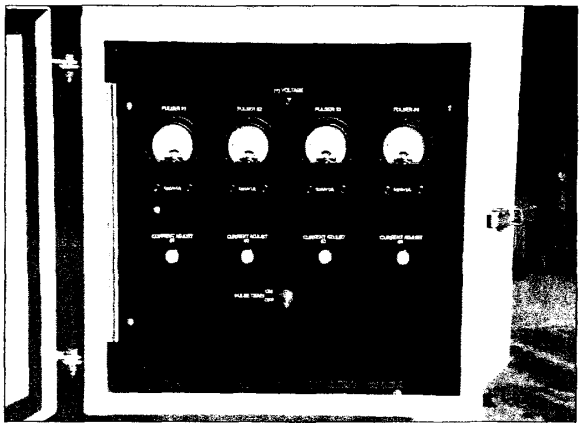
FARWEST
CORROSION
CONTROL
COMPANY

FARWEST CORROSION MODEL 3015
PULSE RECTIFIER



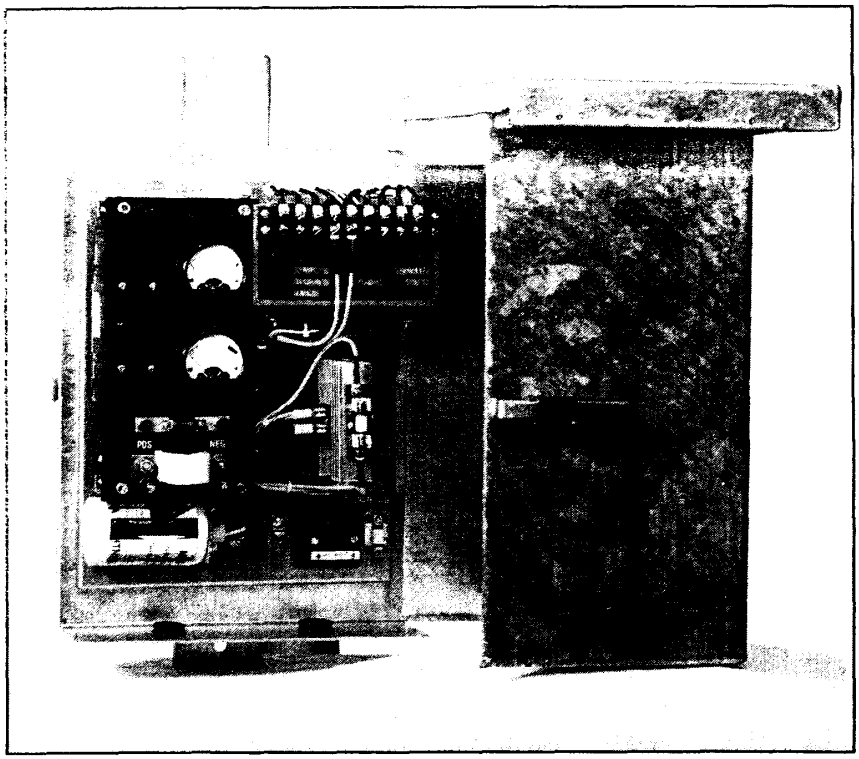
The Model 3015 Pulse Rectifier (U.S. Patent No. 6,224,742 B1, Patent Pending in Canada) by Farwest Corrosion Control Company is a new generation cathodic protection power supply (rectifier) designed to protect up to four (4) separate structures using one common anode ground bed. This feature is very attractive where multiple structures, such as well casings or pipelines, are in the same physical vicinity and can all be protected from a single common anode ground bed and power supply. Additionally, and possibly more important, is the fact that cathodic interference between structures is virtually eliminated.

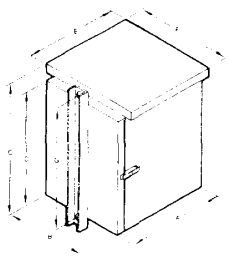




AIR COOLED SW SERIES AND UTILITY SERIES

The Universal "SW" Series rectifier is an alternate to the standard line. The "SW" rectifier features lift-off design case which permits unlimited accessibility for routine maintenance and inspection. Simplified design reduces manufacturing costs which provides an economical rectifier ideally suited to most applications. Rectifier components mounted on 11 gauge chassis panel for easy removal.

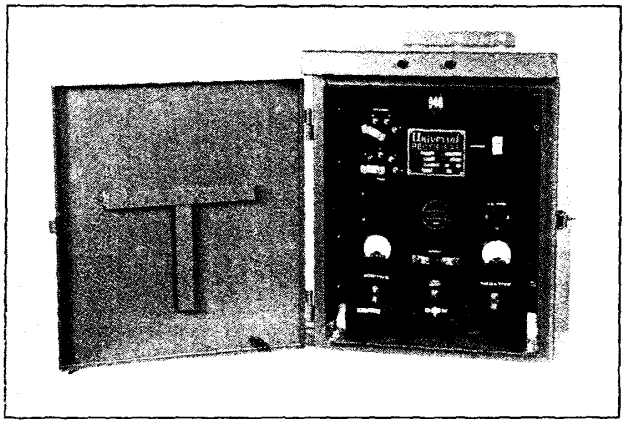




CASE SIZE	DIMENSIONS						
	A	B	C	D	E	F	G
UT	8 3/4	12	19	17	11	16	20
SW1	12	15	22	18 1/2	12	20	25
SW2	14	17	25	22	14 1/2	22	28
SW3	14	20	28	25 1/2	14 1/2	25	31

SPECIAL PURPOSE

Universal RECTIFIERS, INC.

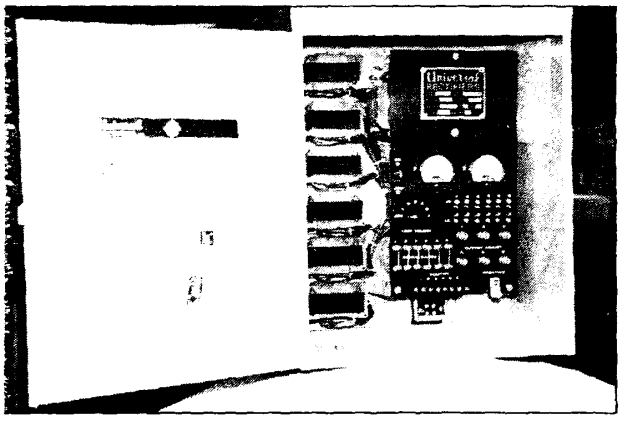


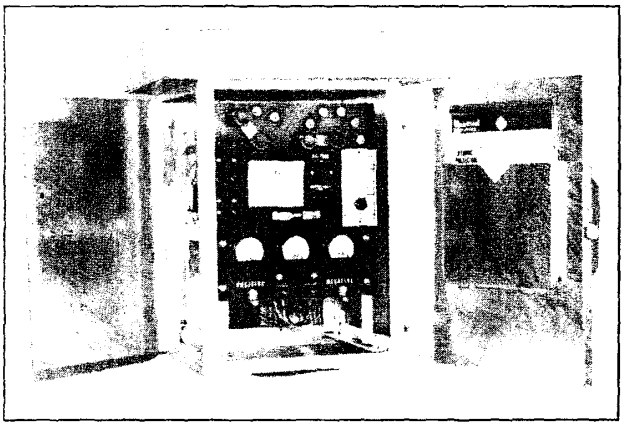
GAS STATION TYPE
STANDARD FEATURES

- 16 GA painted cabinet
- Wall mounting brackets
- 20 step output adjustment
- Sillicon with surge suppressors
- Available in many D.C. ratings
- Many options available:
  - Eapsed time meter
  - A.C/D.C. failure light

CONSTANT CURRENT MULTIPLE OUTPUT CIRCUIT TYPE

- Constant current - maintains preset current
- Stepless, infinite adjustment of individual output circuits
- Very rugged due to current limiting feature can be operated into a D.C. short circuit indefinitely
- Precise control of individual anodes and/or structure current
- Eliminates anode resistor boxes and bond boxes





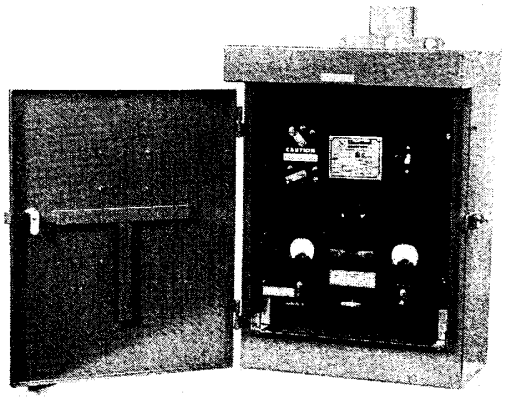
AUTOMATIC POTENTIAL CONTROL

- Solid state
- Standard Automatic operation
- IR Free operation
- Current Limit
- Voltage Limit
- Manual or automatic operation

SPECIAL PURPOSE

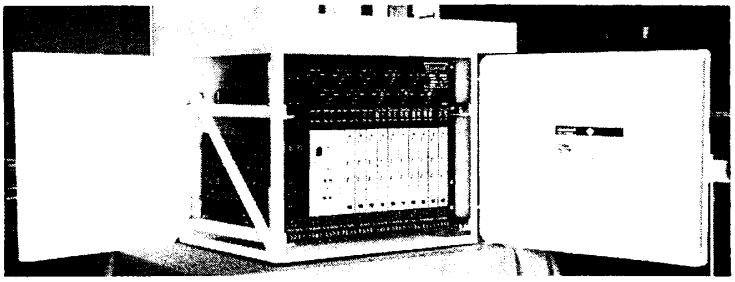
UNDERWRITERS LABORATORY APPROVED (U.L.)

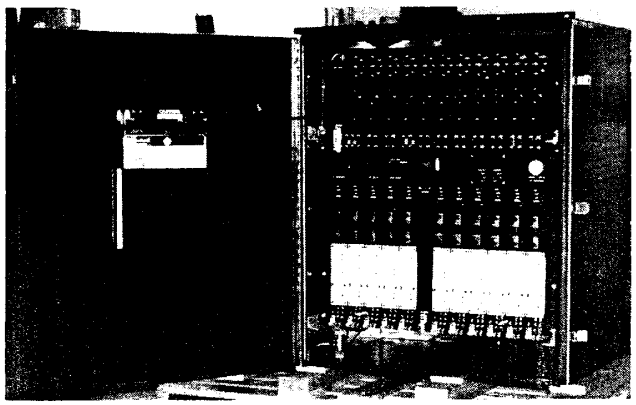
- File E150287
- Thirty-five ratings available
- manual tap adjust, automatic and solid state
- Suitable for service station, pipeline, etc.

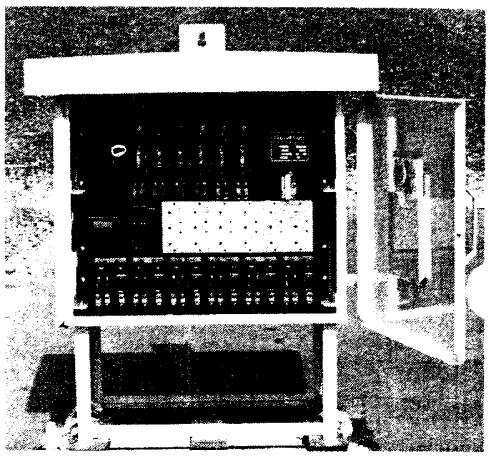


BRIDGE DECK AND CONCRETE REINFORCEMENT BAR CATHODIC PROTECTION RECTIFIERS

- Stepless, precise output adjustment
- Constant current, constant voltage models
- Patent pending IR drop free models
- Multiple output circuits with individual control
- Many options available
- Any style enclosure available
- Custom designs to suit any requirement

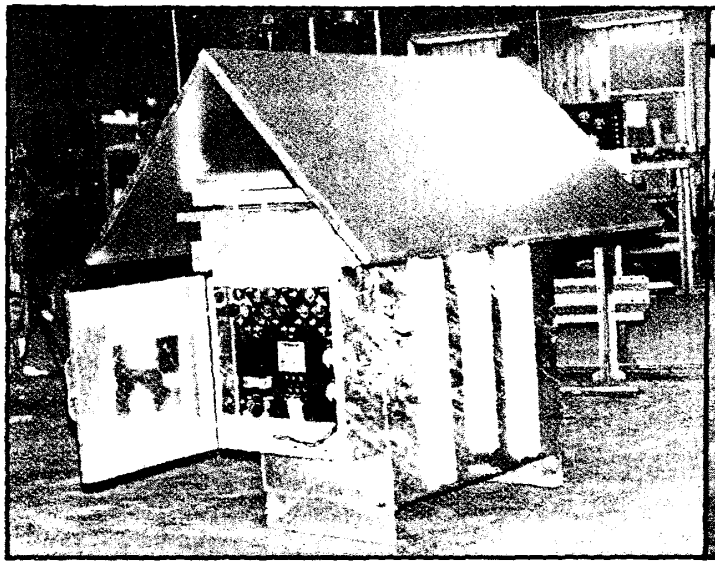


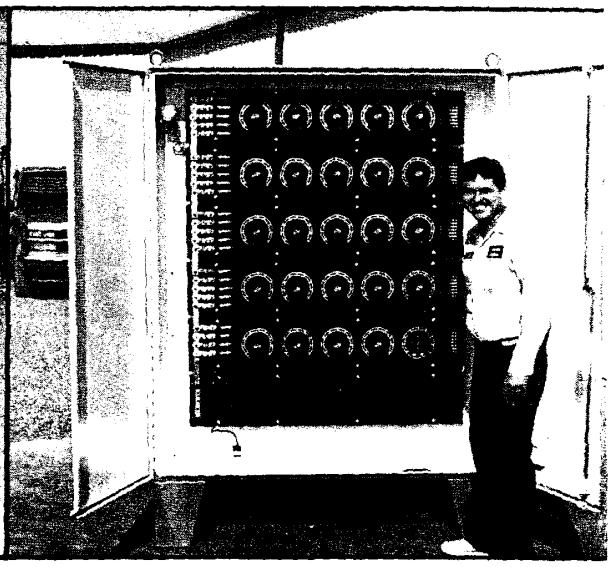


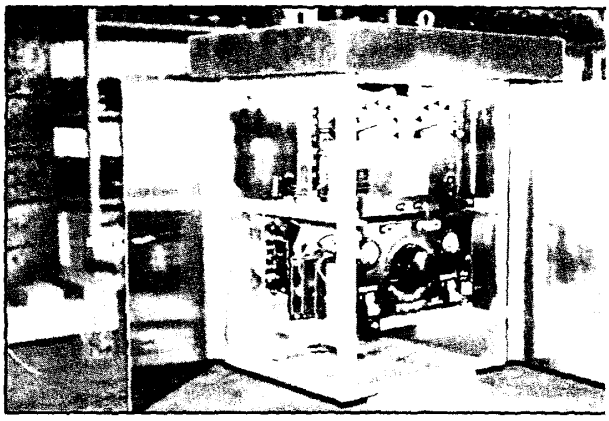


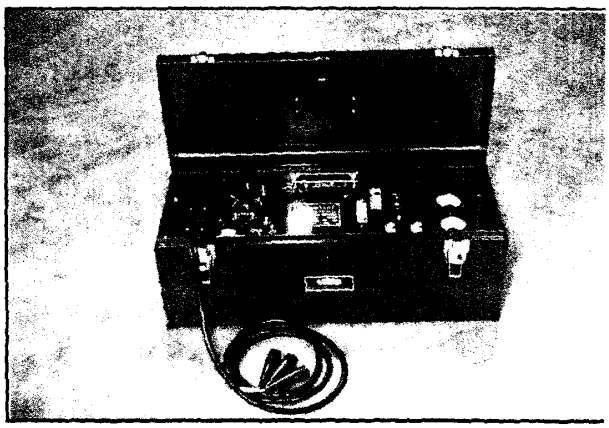
CUSTOM UNITS

Universal RECTIFIERS, INC.









Universal is a unique, versatile manufacturing facility. Not governed by mass production techniques, our facilities are flexible to meet all demands. We welcome unusual designs.

- Constant Current
- Automatic potential control
- Multi-units in common case
- Test rectifiers
- Export units

附件三

Aboveground Storage Tank Suitability Evaluation

On

Western Equipment

Process Tank

By

Danny Wang, P.E.
California Registered Professional Engineer
DOT Certified Design Engineer & Inspector
ASNT UT Level III
November 30, 2000

Table of Content

1. Introduction

CONAM Inspection Company has inspected an above ground tank at Western Equipment Company located at Oakland, California on November 23, 2000. This inspection was performed in accordance with API 653 out of service inspection checklist, with the additional requirements as supplied by the customer. This inspection provides the basis for the evaluation of tank in accordance with API 653 and applicable standards to determine any recommended repairs.

CONAM Inspection Company has review the inspection information and evaluated the condition of the tank based upon the information contained herewith. The information appears to be a reasonable sample of tank condition, but is not judged to represent the condition of the tank with absolute certainty. Accordingly, CONAM Inspection Company has applied ordinary skill in making the evaluation and shall not be held liable for errors of omission or commission. CONAM Inspection Company makes no warranty of mechantability or fitness for a particular purpose or any other warranty of any kind, expressed or implied. The tank owner must satisfy itself as to the adequacy and accuracy of the evaluation and judge the value of the recommendations presented.

2. General Tank Information

Owner:	Western Equipment
Owner Address:	Oakland, California
Tank Location:	Oakland, California
Tank Material:	Stainless Steel
Tank Number:	Unknown
Tank Diameter:	11'6"
Tank Height:	14'
Product Stored:	Paint
Specific Gravity:	1.2 (assumed)
Max. Operation Temperature:	Ambient
Nominal Capacity:	Unknown
Type of Roof:	Fixed Roof
Type of Construction:	Welded
Foundation:	On Concrete Pad (assumed)
Manufacturer:	Unknown
Year Built:	Unknown
Code:	Unknown

3. References

1. API-653 Tank Inspection, Repair, Alteration, and Reconstruction, Second Edition, 1995, American Petroleum Institute.

2. API-650 Weld Steel Tanks For Oil Storage, Ninth Edition, July, 1993, American Petroleum Institute.

3. API-579 Fitness-For-Service

4. Conam Tank Inspection Report, November 23, 2000

4. Evaluation Parameters

Variables	Values	Reference
D, Tank Diameter, feet	11'6"	Inspection Data
H_T, Tank Height, feet	14'	Inspection Data
H_L, Maximum Liquid Height, feet	13'	Assumed
G_p, Product Specific Gravity	2	17 lb/gal Info. from client
E, Weld Joint Efficiency	0.7	API-653
Y, Min. Yield Strength, Psi	35,000 Psi	Material Handbook
T, Tensile Strength, Psi	80,000 Psi	Material Handbook
CA, corrosion Allowance, inches	0	Unknow
Width of bottom shell course 1, feet	60"	Inspection Data
Width of shell course 2, feet	48"	Inspection Data
Width of shell course 3, feet	60"	Inspection Data

H_{LC}, Liquid height at the bottom of each course, feet

Course Number (Bottom to Top)	H_{LC}	W	t_1	t_2	
1	13'	4'	0.125"	0.125"	Inspection Data
2	8'	4'	0.125"	0.125"	Inspection Data
3	4'	4'	0.125"	0.125"	Inspection Data

t_1: lowest average measured thickness in a vertical plane in a course, in inches

t_2: lowest measured thickness in a course, in inches

P_w, wind Load or Pressure, Psi	18 Psf	API 650
V, wind velocity, mph	100 mph	API 650
$t_{r\ ave}$, roof average measured thickness, inches	0.125"	Inspection Data
t, as order thickness of top shell thickness	N/A	
Z, seismic zone factor	4	API 650
I, importance factor	1	API 650
D/H_L	0.88	
w_1/w_T	0.84	API 650
w_2/w_T	0.20	API 650
X_1/H_L	0.42	API 650
X_2/H_L	0.74	API 650
K	0.59	API 650
C_1, lateral force coefficient	0.6	API 650
S, site coefficient	1.5	API 650

5. **Minimum Shell Thickness Evaluation:** API 653

$$t_{min} = \frac{2.6\ D\ (H-1)\ G}{S\ E}$$

Parameter please see API 653

Maximum allowable Stress, S = 28 Ksi for course 1 and 2
Maximum allowable Stress, S = 30.8 Ksi for course 3

t_{min} = 0.1" for all the shell course

Criteria for continues operation from API 653

1. The value of t_1 shall be greater than or equal to t_{min}.
2. The value of t_2 shall be greater than or equal to 60% of t_{min}.

Any corrosion allwance for service until the time of the next inspection shall be added to the required thickness (t_{min} and 0.60 t_{min}) in 1 and 2 above.

Corrosion allowance:
0.125"- 0.1" = 0.025" for all courses

Therefore shell thickness as measured are accept for maximum liquid height 13'.

5.1. Minimum Bottom Head Thickness Evaluation

API 653 Code required minimum 0.1 " for tank bottom without leak detection system.

Current tank bottom thickness as measured are accept for maximum liquid height 13'.

6. Wind load (overturn stability) calculation:

Wind moment M = $D H_T P_w (H/2)$
= 20,286 ft-lbs

M = Overturning moment due to wind load or pressure, in ft-lbs
H_T = Tank Height
P_w = Wind load or pressure

Steel density = 0.283 lb/in^3

Shell weight for course 1and 3 = 920 lb

Shell weight for course 2 = 736 lb

Head weight (Top and Bottom)= 1,058 lb

Total tank weight = 3,634 lb

Dead load resisting moment , in ft-lbs

2/3 (weight) (D/2) = 13,930 ft-lbs

Since wind moment larger than above Dead load resisting moment therefore tank required anchors to resist wind load or pressure overturn. Anchors shall be spaced a maximum of 10 feet apart.

7. Intermediate Wind Girders Requirement

The maximum height of the unstiffened shell shall be calculated as follow:

$H_1 = 6\,(100t)\,\sqrt{(100t/D)^3}$

$= 85$ ft

H_1 = Maximum height of unstiffened shell, in feet

Transformed tank height (course 1and 3):

$W_{tr} = W\,\sqrt{(t_{uniform}/t_{actual})^5}$

$= 5'$

Transformed tank height (course 2):

$W_{tr} = W\,\sqrt{(t_{uniform}/t_{actual})^5}$

$= 4'$

The sum of the transposed height = 14'

Intermediate wind girder is not required since H_1 is greater than height of transformed shell.

8. Overturning Moment Due to Seismic Forces

$M = ZI(C_1W_sX_s + C_1W_rH_t + C_1W_1X_1 + C_2W_2X_2)$

M= Overturning moment due to seismic forces applied to bottom of shell, in ft-lbs
Z = Seismic zone factor
I = importance factor
C1, C2 = Lateral earthquake force coefficients
W_S = Total weight of Shell, lb
X_s = Height from the bottom of the tank of shell to shell's center of gravity, ft.
W_r = Total weight of roof, lb
H_T = Height of Tank, in ft.
W_1 = Weight of the effective mass of tank shell contents that move in unison with the tank shell, in lb.
X_1 = Height from the bottom of tank shell to the centroid of lateral seismic force applied to W_1, in ft.
W_2 = Weight of the effective mass of the tank contents that move in the first sloshing mode, in lb.
X_2 = Height from the bottom of tank shell to the centroid of lateral seismic force applied to W2₁, in ft.

Find the total weight of product and tank itself, W_T = 171,487 + 3634 = 175,121 lbs

Ratio	Value	Result		
W_1/W_T	0.84	W_1 = 147,101 lbs		
W_2/W_T	0.20	W_2 = 35,024 lbs		
X_1/H_L	0.42	X1 = 5.46'		
X_2/H_L	0.74	X_2 = 9.62'		
K	0.59			
C_1, lateral force coefficient			0.6	API 650
S, site coefficient			1.5	API 650

Find C_2

$T = k (\sqrt{D}) = 2.0$
Therefore $C_2 = 0.75\ S/T = 0.5652$
X_s = 7'
ZI = 0.4
W_s = 2576 lb, W_r = 529 lb

$C_1W_sX_s$ = 10,819
$C_1W_rH_t$ = 4443.6
$C_1W_1X_1$ = 481,903
$C_2W_2X_2$ = 190,433
Total = 687,599

M = 275,039 ft-lbs

Resistance to Seismic Overturning Moment:

$W_L = 7.9\ t_b\ (\sqrt{F_{by}}\ G\ H)$

W_L = Maximum weight of tank contents that may be used to resist shell overturnung moment (unanchored tank) in pounds per foot of shell circumference.
t_b = Thickness of the bottom plate under the shell, inches (shall not exceed the thickness of the bottom shell course or 0.25", whichever is greater), in inches.
F_{by} = Minimum specified yield strength of the bottom plate under the shell, psi

t_b = 0.20"
W_L = 942 lbs/ft

1.25 G H D = 402.5

Tank require anchorage because of W_L is larger than 1.25 GHD.

The spacing between anchors shall not exceed 6 feet. Anchor bolts shall have a minimum diameter of 1 inch.

9. Shell Compression Due to Seismic Moment

For anchored tank, the maximum longitudinal compressive force at the bottom of the shell may be determined as follows:

$b = Wt + 1.273M/D^2$
$= 86 + 2647$ lb/ft
$= 2733$

The maximum longitudinal compressive stress in the shell, b/12t shall not exceed the maximum allowable stress.

b/12t = 1822 Psi, It is lower than maximum allowable stress.

$GHD^2/t^2 = 236992$, it is small than 1,000,000 therefore

$Fa = 1{,}000{,}000\ t/2.5D + 600\sqrt{(GH)}$
$= 4348 + 3172$
$= 7522$ Psi

Fa is small than the 0.5 x Minimum specified Yield strength

Therefore tank shell is stable in compression.
However this tank has 4 carbon steel channels to protect buckling. The dent was discovered at the bottom of shell need to monitoring for any leak or crack develops at future operation.
According to visual inspection, the coating failures at 4 carbon steel channels need to repair to prevent further corrosion. Galvanic corrosion will happen where carbon steel contacts with stainless.

10. Conclusion:

A. Tank is in the good condition. Shell and tank bottom thickness, as measured 0.125" are acceptable for maximum liquid height 13'.

B. Intermediate wind girder is not required.

C. Anchorage is required due to wind load and seismic overturn, the spacing between anchors shall not exceed 6 feet. Anchor bolts shall have a minimum diameter of 1 inch.

D. Tank shell is stable in compression stress.

E. Repair coating failure on four carbon steel channels to minimize further galvanic corrosion.

F. Monitoring the bottom shell dent for any sign of leakage and crack development in the future operation.

I, the undersigned, holding a valid Registration as a Professional Engineer issued by the State of California, reviewed the inspection data provided and performed the suitability for service evaluation for tank D4 in accordance with API standard 653, "Tank Inspection, Repair, Alteration and Reconstruction."

By signing this suitability evaluation, the undersigned makes no any warranty, expressed or implied, concerning the work described in the inspection or the suitability evaluation. Furthermore, the undersigned shall not be liable in any manner for any personal injury, property damage or loss of any kind arising from or connected with the inspection conducted or suitability evaluation performed. The undersigned shall not be held responsible or liable for errors of omission and/or commission.

The tank owner and/or operator must satisfy himself as to the adequacy and accuracy of the inspection conducted and the suitability evaluation performed, including but not limited to, the calculations, conclusions, recommendations, limitations, and disclaimers contained therein, prior to making a decision to returning the tank to service and/or continuing the current service.

Danny Wang, P.E.
ASNT UT level III, # NM-1263

API 653 Formula
Shell Stress Calculation for tanks with Annular Plates

$$S = \frac{2.34D(H-1)}{t}$$

S = Allowable Stress in psi.

D = Diameter of Tank in Feet.

H = Height of product above point of consideration in feet.

T = Thickness of Shell Plate.

API 653 Formula
Length of area to be measured in a corroded area of the Shell

$$L=3.7\sqrt{Dt_2}$$

L = The maximum vertical length in inches over which hoop stresses are assumed to average out around local discontinuities. **CAN NOT EXCEED 40".**

D = Diameter of Tank in Feet.
t_2 = Least thickness. in inches, within the area of corrosion-exclusive of pits.

API 653 Formula Shell Plumbness Calculation

$$P = H/100$$

P = maximum out of plumbness allowed, with a maximum allowed of 5 inches.

H = Top of shell to bottom of shell.

* Note: The maximum out of plumbness in any one-shell course shall not exceed the values specified for mill tolerances in ASTM A6 or A20 whichever is applicable

API 653 Formula
Shell Stress Calculation to determine allowable stress for shell courses during Reconstruction

$$S = \frac{2.6D(H-1)G}{tE}$$

S = Shell stress in psi.

D = Diameter of tank in feet.

H = Height of product above point of consideration in feet.

T = Thickness of shell plate in inches.

E = Original joint efficiency for the tank. Use Table 2-1 to establish value. (Note: New joints made during reconstruction shall be consistent with the design method used, i.e., if current API 650 is used, the new joints will have an E=1.

Fill Height Calculation-For in-service Tanks

$$H = \frac{SEt}{2.6Dg}$$

S = Allowable stress in psi

E = Original joint efficiency for the tank. Use Table 2-1 if original E is unknown. E=1.0 when evaluating the retirement thickness in a corroded plate away from welds or joints by at least the greater of 1" or twice the plate thickness.

T = Thickness of plate in inches, minus the corrosion allowance.

D = Diameter of the tank in feet.

G = Specific gravity of product stored in the tank (S.G. of water=1.0).

API 653 Formula Internal Bottom Settlement for Bulges

$$B = 0.37R$$

B = Maximum height of bulge or depth of local depression in inches.

R = Radius of inscribed circle in bulged area or local depression in feet.