

# 廠內外管線安全

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- 1 管線系統建構概念及安全考量
- 2 管線劣化趨勢與劣化特徵
- 3 預防及抑制管線劣化的具體作為
- 4 交流與討論

# 洩漏

外部局部腐蝕導致洩漏



蒸氣管線  
裂紋橫貫穿透焊道



# 爆裂

管線實施性能耐壓試驗

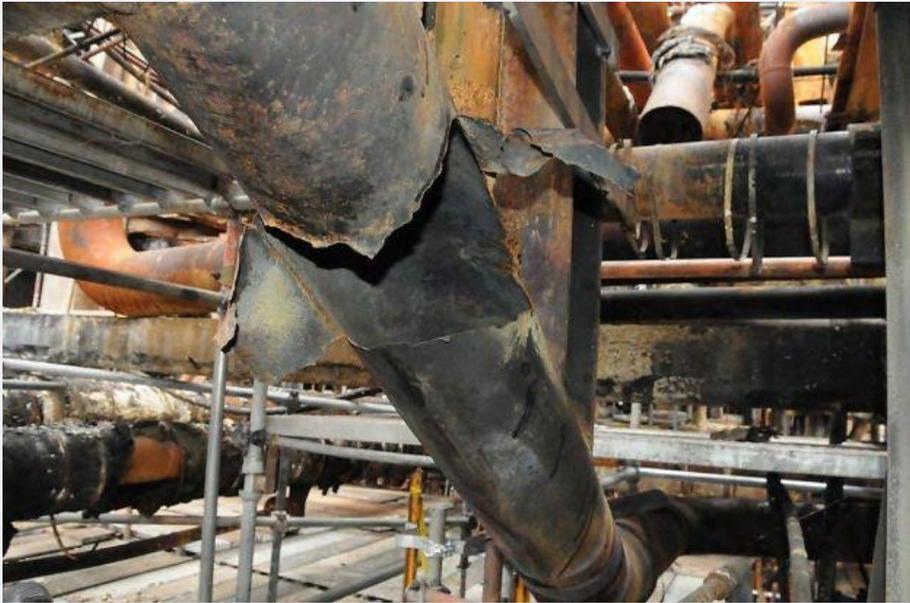
過程超壓破裂

外部腐蝕導致全面減薄



# 爆裂

內容物造成高溫硫化  
導致全面減薄



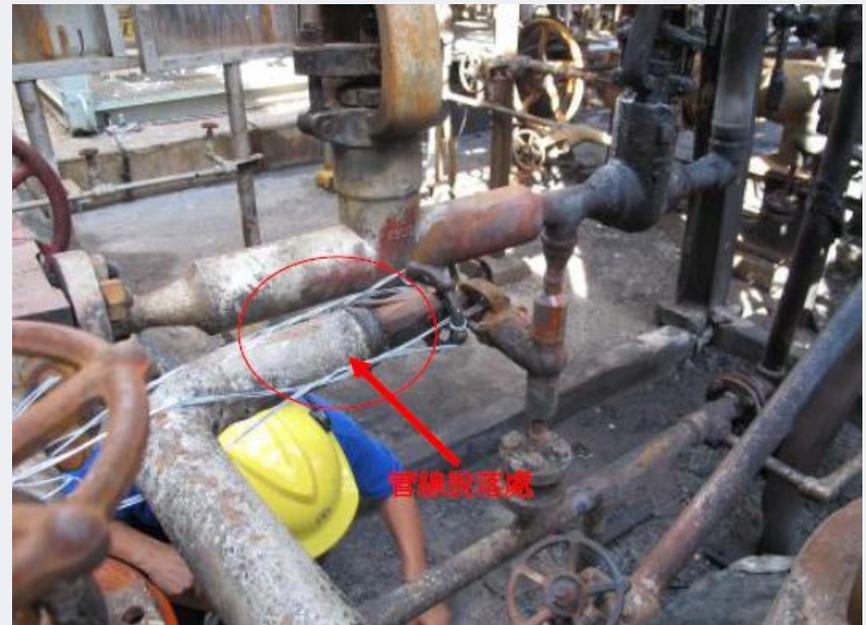
注入水流態不均沖蝕彎頭  
導致全面減薄



# 脆裂

材質及熱處理條件錯誤  
造成管線操作中脆裂

焊接條件錯誤造成焊口脫落



管線劣化分類  
操作失誤

內容物異常聚合反應  
壓力迅速臨界造成爆管



內容物異常聚合反應  
累積撐破管壁



材質變異(高溫潛變)



材質變異(高溫潛變)



短期過熱



短期過熱



管線劣化分類  
結構崩毀

震動疲勞+保溫層下方腐蝕



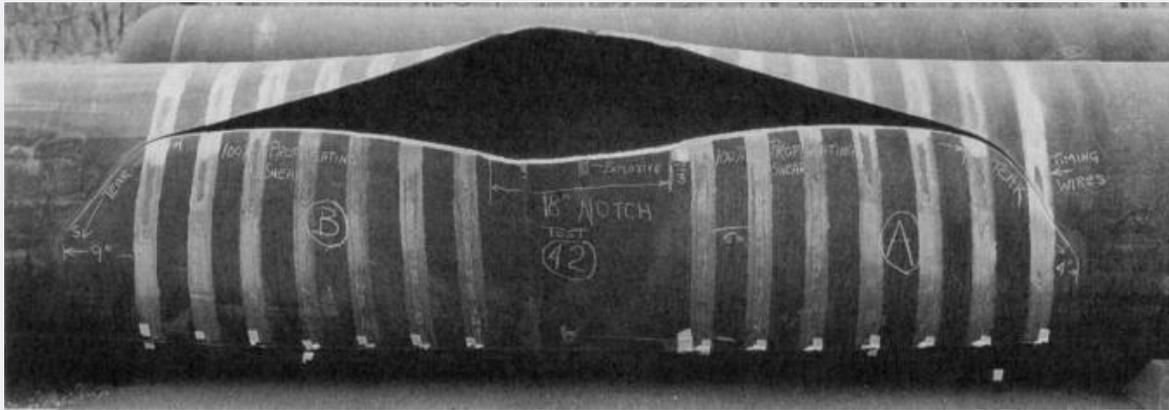
SOHIC



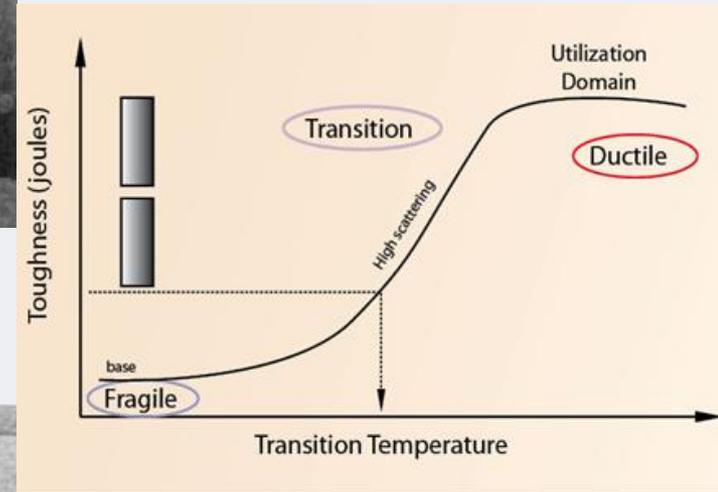
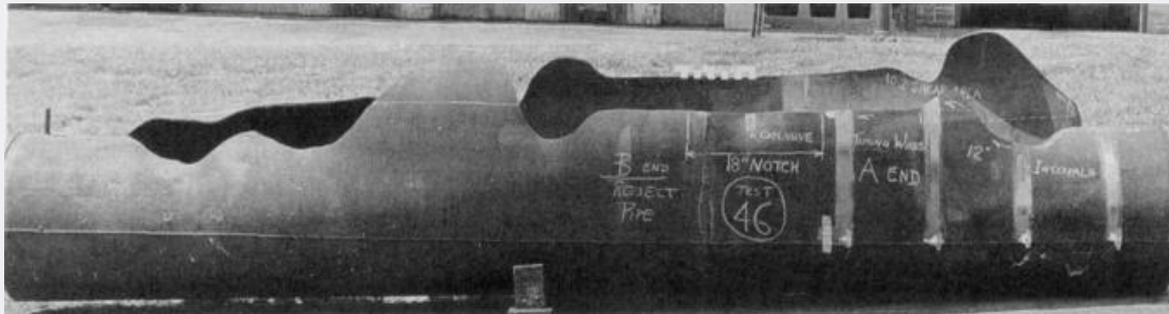
# 低溫脆裂

## ❖ API 5L X60 無縫鋼管

常溫韌性破壞(13°C)



低溫脆性破裂(-26°C)



# 劣化考量因子

- ❖ 設計理念
- ❖ 建造失誤
- ❖ 施工品質
- ❖ 操作變數
- ❖ 操作失誤
- ❖ 維修理念/保養機制
- ❖ 材料管制
- ❖ 檢查機制/檢查誤判

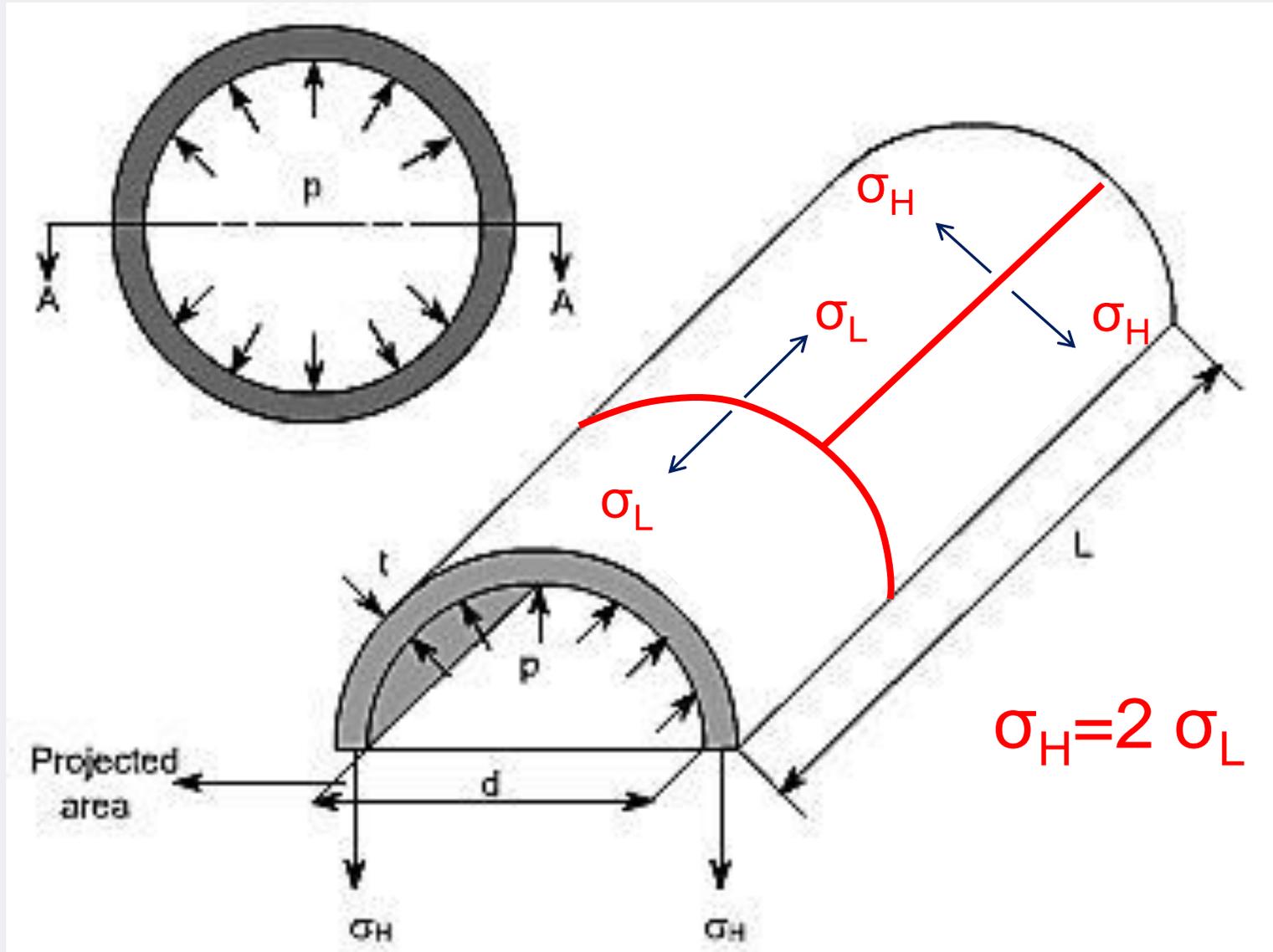
# 管線配置考量



# 管線設計考量

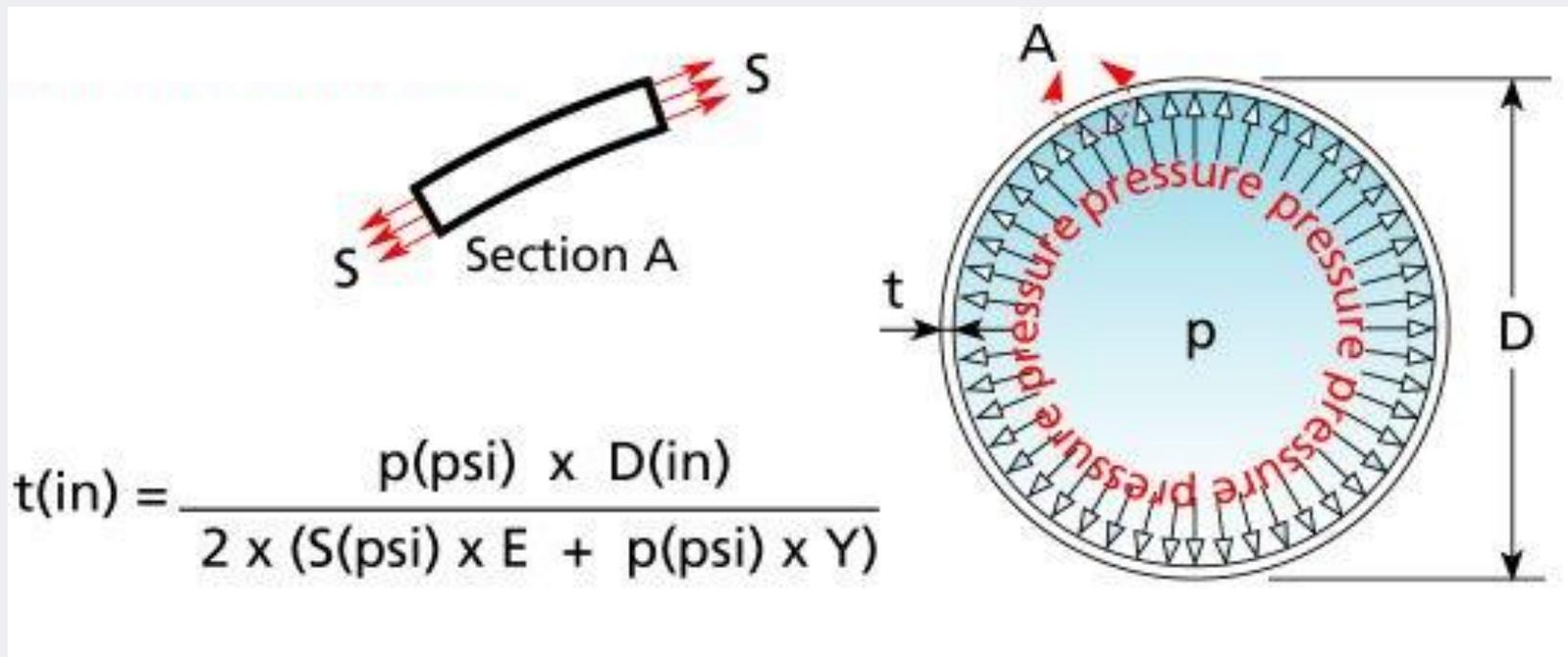


# 承受內壓之應力模式



# 承受內壓之應力模式

- ❖ 單純考量內壓條件下, 周向應力( $\sigma_H$ )為縱向應力( $\sigma_L$ )兩倍, 亦即縱向焊道受力為周向焊道兩倍, 因此縱向焊道的焊接係數為重要參數



# 承受內壓之應力模式

## ❖ Straight pipe 內壓強度計算及參數

$$t_m = t + c$$

❖ For  $t < D/6$

$$t = \frac{PD}{2(SEW + PY)}$$

or

$$t = \frac{P(d + 2c)}{2[SEW - P(1 - Y)]}$$

❖ For  $t \geq D/6$  or for  $P/SE > 0.385$ , calculation of pressure design thickness for straight pipe requires special consideration of factors such as theory of failure, effects of fatigue, and thermal stress.

# 承受內壓之應力模式

- ❖  $t_m$  : minimum required thickness
  - The minimum thickness,  $T$ , for the pipe selected, considering manufacturer's minus tolerance, shall be not less than  $t_m$ .
- ❖  $t$  : pressure design thickness for **internal pressure**
- ❖  $c$  : sum of the **mechanical**、**corrosion**、**erosion** allowances.
- ❖  $D$  : outside diameter of pipe
- ❖  $d$  : inside diameter of pipe
- ❖  $P$  : internal design gage pressure
- ❖  $S$  : allowable stress for material (Table A-1)
- ❖  $E$  : quality factor (Table A-1B)
- ❖  $W$  : weld joint strength reduction factor (Table 302.3.5)
- ❖  $Y$  : 徑/厚 形狀修正係數 (Table 304.1.1)

# 容許應力與特定應力限制

- ❖ 容許應力 (General rule for allowable stresses)
- ❖ 基本應力計算 (Bases for Design Stresses )
- ❖ 鑄造品質係數 (Casting Quality Factor,  $E_c$ )
- ❖ 焊接品質係數 (Weld Joint Quality Factor,  $E_j$ )
- ❖ 固定負荷與位移變形之應力限制 (Limits of Calculated Stresses Due to Sustained Loads and Displacement Strains )
- ❖ 偶發負荷之應力限制 (Limits of Calculated Stresses Due to Occasional Loads)

# 裕度考量

- ❖ 裕度須同時考量腐蝕、沖蝕、螺紋或刻痕深度
- ❖ 壁厚除考量內壓及外壓，尚須考量外力所造成之變形因素
- ❖ 過度增加壁厚可能引發脆性破壞風險
- ❖ 特別考量銜接設備或管線之小插管強度

# 承受內壓之應力模式



# 承受內壓之應力模式

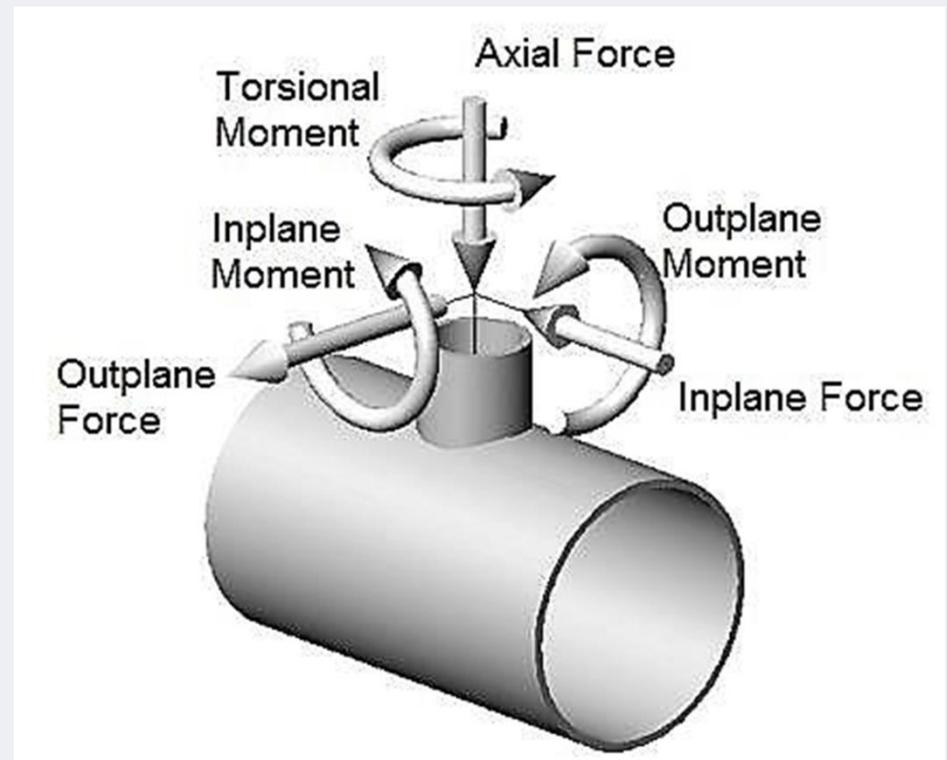
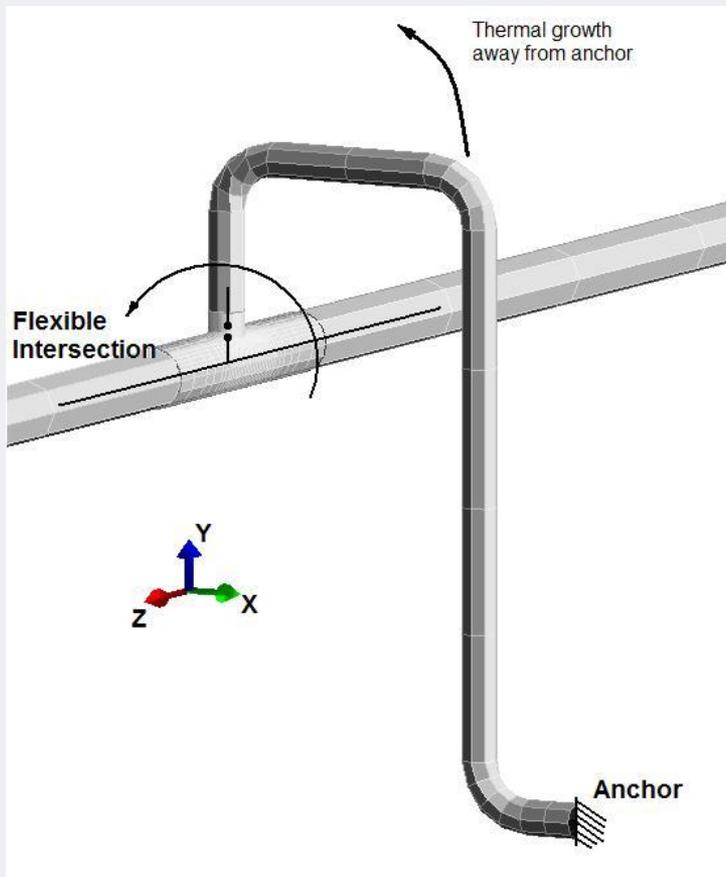


# 管線負載來源

- ❖ 內壓
- ❖ 外壓
- ❖ 流體重量
- ❖ 結構重量
- ❖ 外部結構負荷
- ❖ 外部傳導應力
- ❖ 膨脹限縮應力
- ❖ 反復作用應力

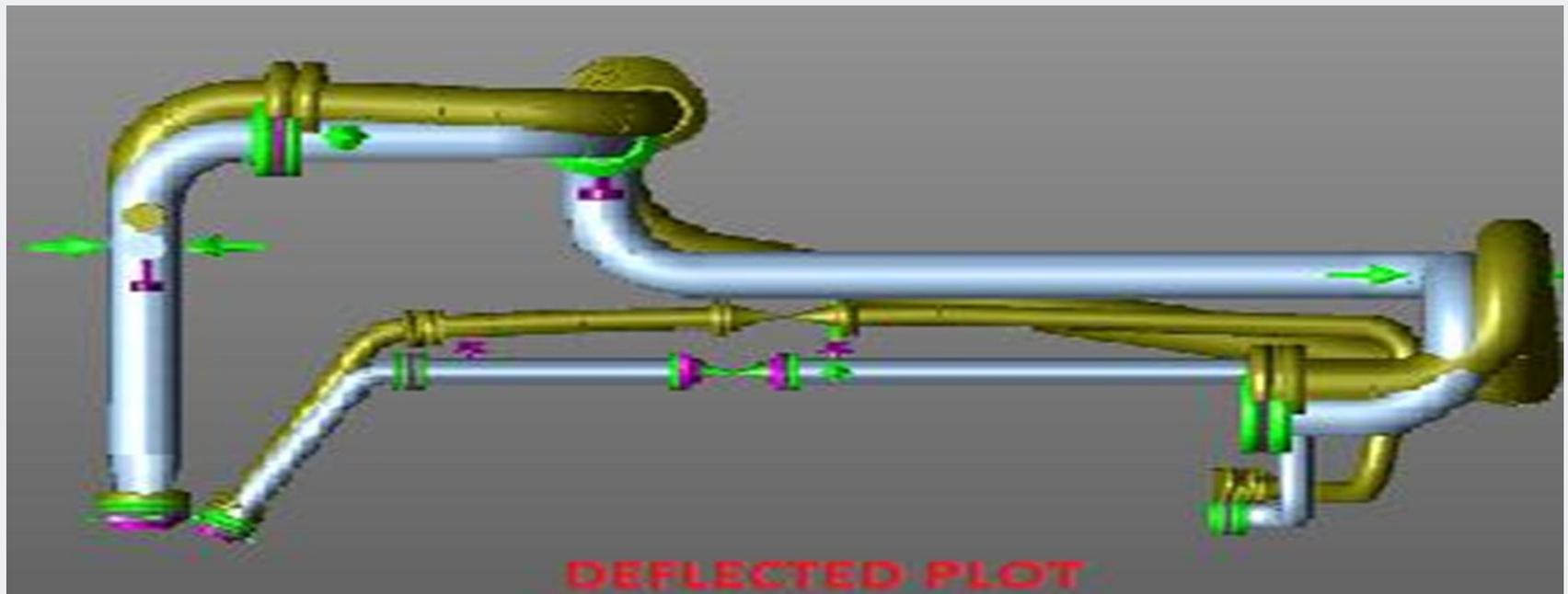
# 管線負載來源

- ❖ 額外之重量負荷及位移變形所誘發之應力多屬縱向應力, 管內有負壓之機會時, 另考慮外壓強度



# 結構應力負荷

- ❖ 顯著之側向推力及力矩應實施整體應力分析
- ❖ 傳遞至固定設備之縱向力及力矩, 須符合固定設備之設計規範, 必要時應以支撐及彈簧構件來緩衝, 改變管線配置模式也是合理的選擇



# 管線建構概念

## ❖ 管線功能與設計需求

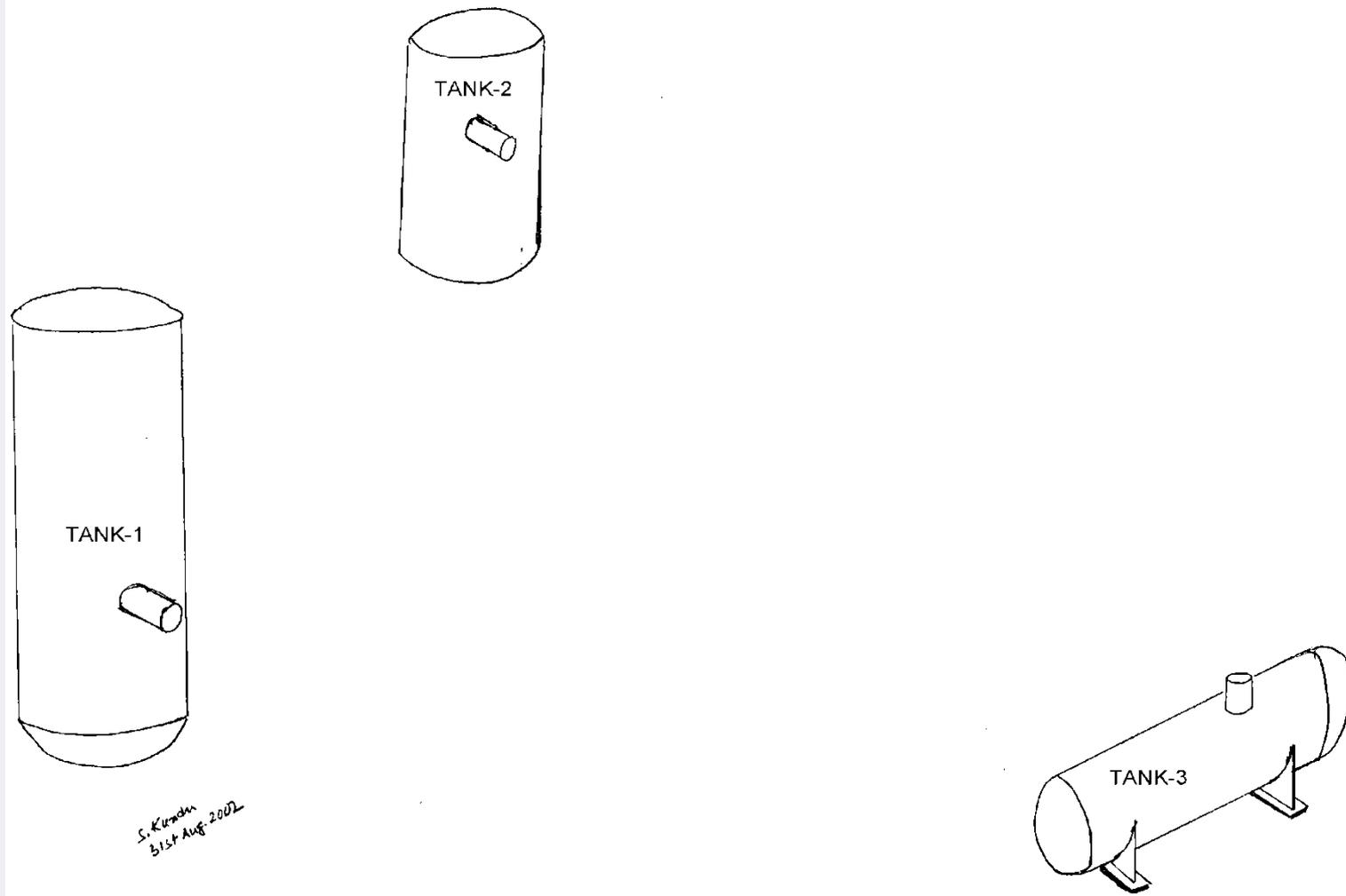
- 管線流體分類
- 基本設計條件(Design condition)
- 設計過程依循之準則(Design criteria)

## ❖ 管線構成

- 配管元件(Piping Components)
- 接頭 (Mechanical joint )
- 管線支撐構件(Pipe-Supporting Elements)

## ❖ 建構流程

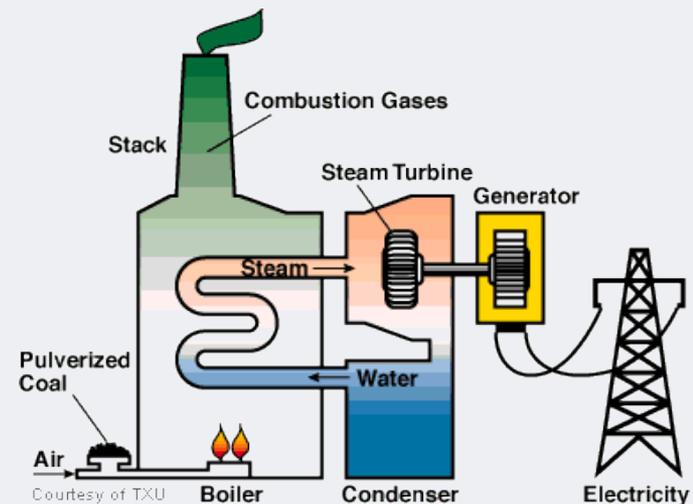
# 管線建構概念 功能設定



❖ 動力蒸氣管線

❖ B31.1 - Power Piping

- Piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems



❖ 製程管線

❖ B31.3 - Process Piping

- Piping typically found in petroleum refineries; chemical, pharmaceutical, textile, paper, semiconductor, and cryogenic plants; and related processing plants and terminals



# 管線設計規範

- ❖ 長途輸送管線(液體)
- ❖ B31.4 - Pipeline Transportation Systems for Liquids and Slurries
  - Piping transporting products that are predominately liquid between plants and terminals and within terminals, pumping, regulating, and metering stations



# 管線設計規範

## ❖ 長途輸送管線(氣體)

## ❖ B31.8 - Gas Transmission and Distribution Piping Systems

- Piping transporting products that are predominately gas between sources and terminals, including compressor, regulating, and metering stations; gas gathering pipelines



# 管線流體分類

- ❖ ASME B31.3為石化業規範製程管線通用之設計標準，亦適用於相關產業配管需求
- ❖ 設計過程需同時考量通用準則(Code Requirement)及流體條件(Fluid Service Requirement)
- ❖ 通用準則：管線系統設計通用原則, 設計過程須符合通用章節規定。
- ❖ 流體條件：依流體條件所設定之特用原則, 各類流體條件對材料(material), 元件(component), 接頭(joint), 檢查(inspection)等之要求不同, 設計過程需引用特定之規範章節。

# 管線流體分類

## ❖ D類流體 (Category D Fluid Service)

- 非可燃性(nonflammable), 無毒性, 對人體無傷害性之流體
- 設計壓力小於150 psi
- 設計溫度介於  $-29^{\circ}\text{C}$  ( $-20^{\circ}\text{F}$ )到 $186^{\circ}\text{C}$  ( $366^{\circ}\text{F}$ ) 之間

## ❖ M類流體 (Category M Fluid Service)

- 微量洩漏即可造成人員重大危害之流體

# 管線流體分類

- ❖ 高壓流體 (High Pressure Fluid Service)
  - 超出Class 2500等級之溫度壓力額定範圍之流體
- ❖ 高溫流體 (Elevated Temperature Fluid Service)
  - 設計溫度達材料潛變管制點之流體
- ❖ 高純度流體 (High Purity Fluid Service)
- ❖ 一般流體 (Normal Fluid Service)
  - 不屬D類、M類、高溫類及高壓類者
- ❖ Severe Cyclic Conditions

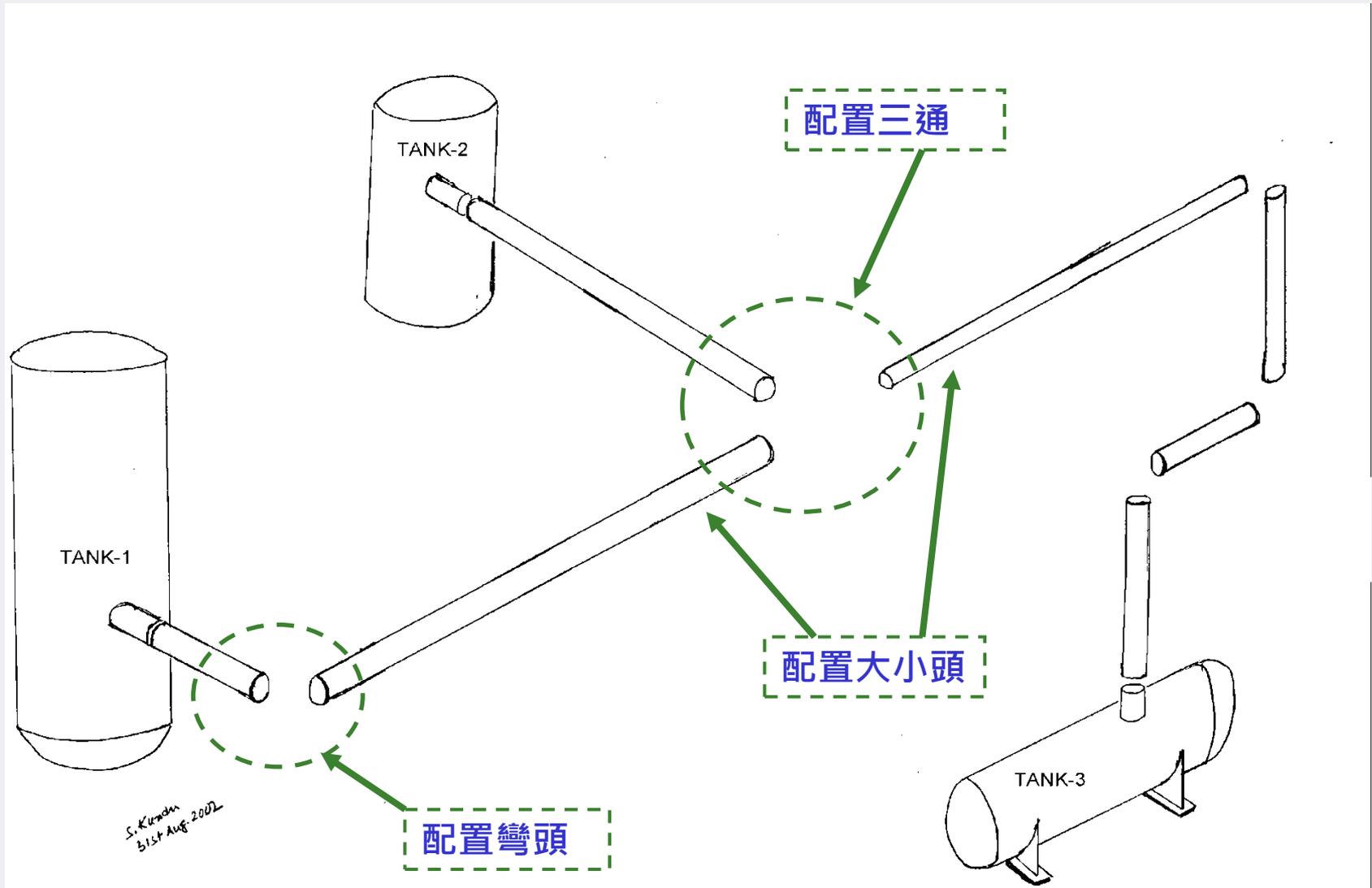
# 基本設計條件

- ❖ 設計壓力 – 流體壓力(Design Pressure)
- ❖ 設計溫度 – 流體溫度 (Design Temperature)
- ❖ 環境效應 (Ambient Effects)
- ❖ 動態負荷 (Dynamic Effects)
- ❖ 額外重量負荷 (Weight Effects)
- ❖ 熱漲冷縮 (Thermal Expansion and Contraction)
- ❖ 位移牽引 (Support, Anchor, and Terminal Movements)
- ❖ 材質韌性降低效應 (Reduced Ductility Effects)
- ❖ 週期性負荷變動 (Cyclic Effects)

# 設計過程依循之準則

- ❖ 壓力-溫度設計準則 (Pressure-Temperature Design Criteria)
- ❖ 容許應力與特定應力限制 (Allowable Stresses and Other Stress Limits)
- ❖ 裕度考量 (Allowances)

# 管線布置



# 配管元件

- ❖ 管 (Pipe & tube)
- ❖ 管配件( Pipe fitting --Elbow, Tee, Reducer, ..)
- ❖ 法蘭( Flange)
- ❖ 閥(Valve)
- ❖ 墊圈(Gasket)與螺栓(Bolt and Nut)
- ❖ 卻水器(Steam trap)
- ❖ 膨脹接頭(Expansion joint)

## 標準化元件

Table 326.1 Component Standards

Standard or Specification	Designation
<b>Bolting</b>	
Square and Hex Bolts and Screws (Inch Series) . . . . .	ASME B18.2.1
Square and Hex Nuts (Inch Series). . . . .	ASME B18.2.2
<b>Metallic Fittings, Valves, and Flanges</b>	
Cast Iron Pipe Flanges and Flanged Fittings . . . . .	ASME B16.1
Malleable Iron Threaded Fittings . . . . .	ASME B16.3
Gray Iron Threaded Fittings. . . . .	ASME B16.4
Pipe Flanges and Flanged Fittings . . . . .	ASME B16.5
Factory-Made Wrought Steel Buttwelding Fittings . . . . .	ASME B16.9
Face-to-Face and End-To-End Dimensions of Valves . . . . .	ASME B16.10
Forged Fittings, Socket-Welding and Threaded . . . . .	ASME B16.11
Ferrous Pipe Plugs, Bushings, and Locknuts With Pipe Threads . . . . .	ASME B16.14
Cast Bronze Threaded Fittings, Class 125 and 250 [Notes (1), (2)] . . . . .	ASME B16.15
Cast Copper Alloy Solder Joint Pressure Fittings . . . . .	ASME B16.18
Wrought Copper and Copper Alloy Solder Joint Pressure Fittings . . . . .	ASME B16.22
Cast Copper Alloy Pipe Flanges and Flanged Fittings: Classes 150, 300, 600, 900, 1500, and 2500. . . . .	ASME B16.24
Cast Copper Alloy Fittings for Flared Copper Tubes . . . . .	ASME B16.26
Valves-Flanged, Threaded, and Welding End. . . . .	ASME B16.34
Orifice Flanges, Class 300, 600, 900, 1500, and 2500. . . . .	ASME B16.36
Malleable Iron Threaded Pipe Unions, Class 150, 250, and 300 . . . . .	ASME B16.39
Ductile Iron Pipe Flanges and Flanged Fittings, Class 150 and 300. . . . .	ASME B16.42
Large Diameter Steel Flanges, NPS 26 Through NPS 60 . . . . .	ASME B16.47
Steel Line Blanks . . . . .	ASME B16.48

# 管(依材料類別分類)

## ❖ 鋼管

- 即為市面上通稱之鐵管，用低碳鋼製成，使用於450°F以下。

## ❖ 鑄鐵管

- 可用以輸送略有侵蝕性之流體，裝置時多埋於地下，管身頗重，抗拉力不強，管與管間之接合不易嚴密，但其抗侵蝕性稍勝於鋼或熟鐵，故用者尚多。

## ❖ 合金管

- 其種類繁多，為適合特種目的而使用，多用於高溫高壓之處，如鉻鋼管為鉻與鋼之合金，能耐強酸。不銹鋼管為合金鋼管最普通之一種。

# 管(依材料類別分類)

## ❖ 黃銅管

- 係用銅與鋅之合金製成，色黃、易傳熱，故多用於傳熱之處，如蒸汽追蹤管等。

## ❖ 鉛管

- 多用以輸送富有侵蝕性之流體，儲存酸液之槽亦常用鉛內襯。

## ❖ 塑膠管

- 質軟，重量輕，可隨意彎曲，管內清潔光滑，配管容易且對酸及鹼之抗侵蝕性特強。其缺點在於使用壓力及溫度有較多的限制，受紫外線易老化脆化，強度亦不如鋼管。

# 管(依材料類別分類)

- ❖ 橡皮管
  - 性柔，不受普通化學藥品之侵蝕，惟用久會變質。
- ❖ 水泥管
  - 直徑常在二呎以上之粗管，多埋於地下。
- ❖ 玻璃管
  - 富有耐酸性，但易於碎裂。近代所出之襯玻璃管，多用於液位計或預熱器換熱管。
- ❖ 石英管
  - 耐酸，因其性質甚脆且價格昂貴。

# 管(依生產方法分類)

## ❖ 無縫管

## ❖ 有縫焊管

- 依製程區分—電弧焊管、電阻焊管、壓接焊管
- 按焊縫區分--直縫焊管、螺旋焊管

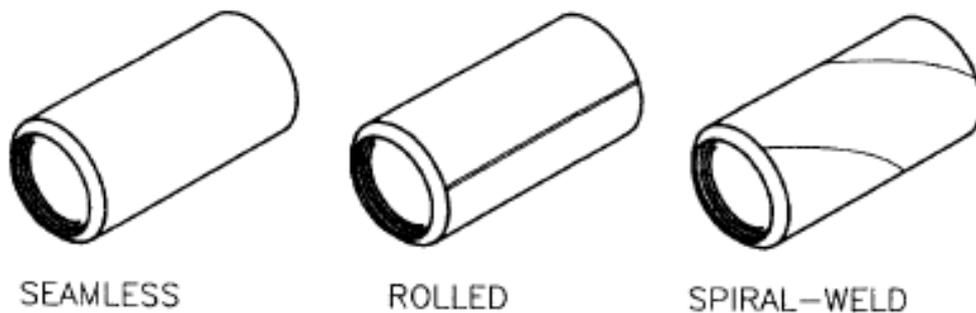
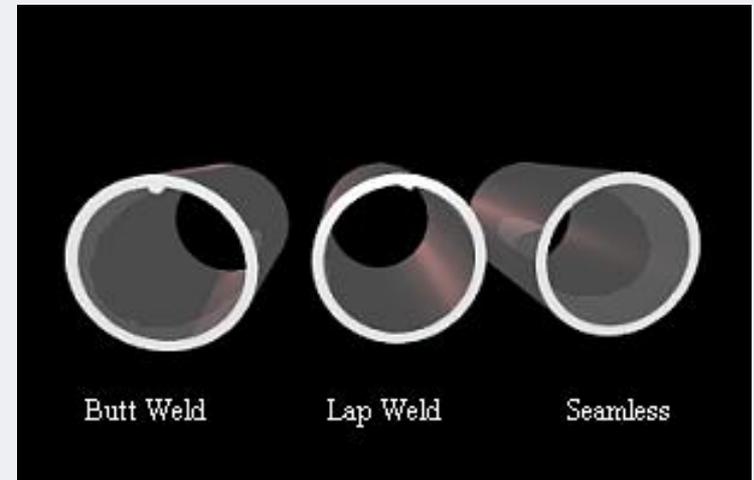
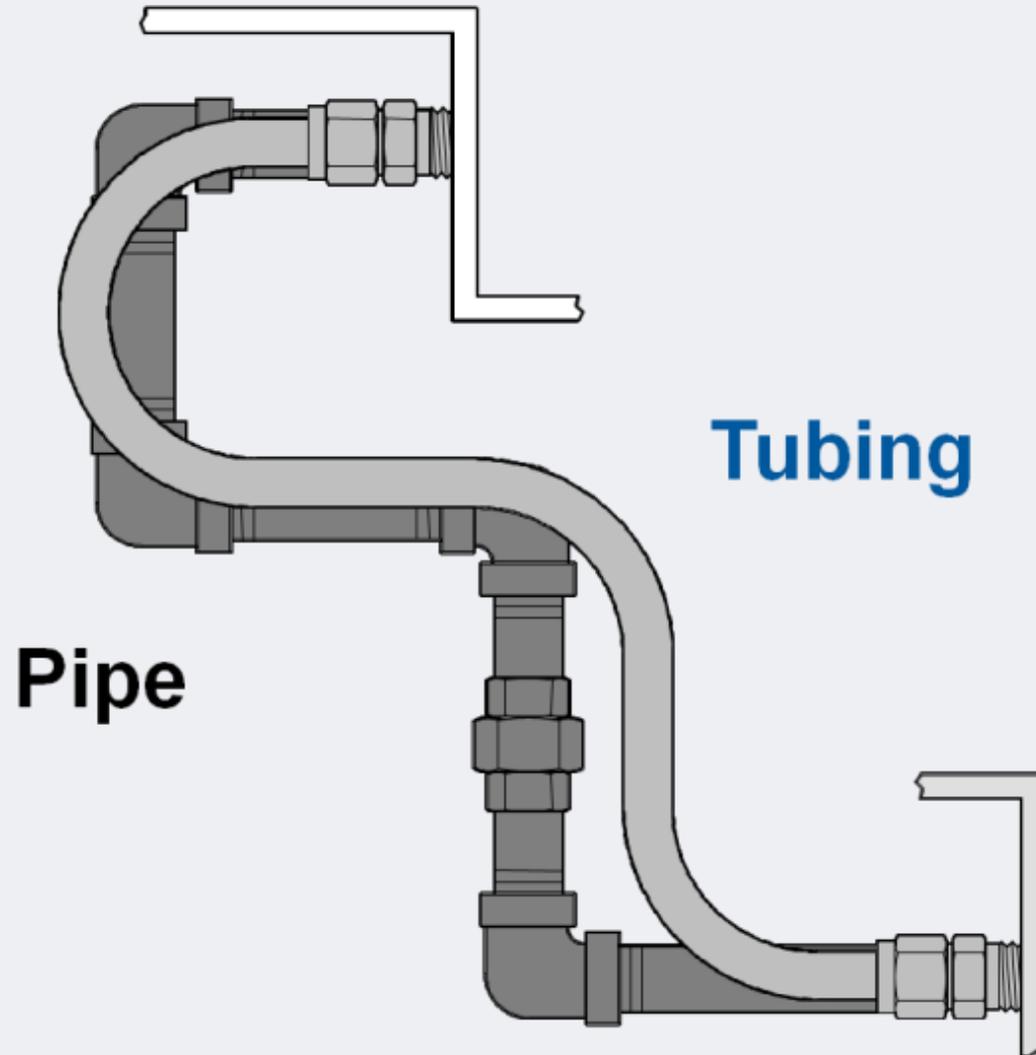


Figure 2-4. Carbon steel pipe.



# Pipe and Tube



# 管件



**Tee**



**Reduced Tee**



**Conc. Reducer**



**Ecc. Reducer**

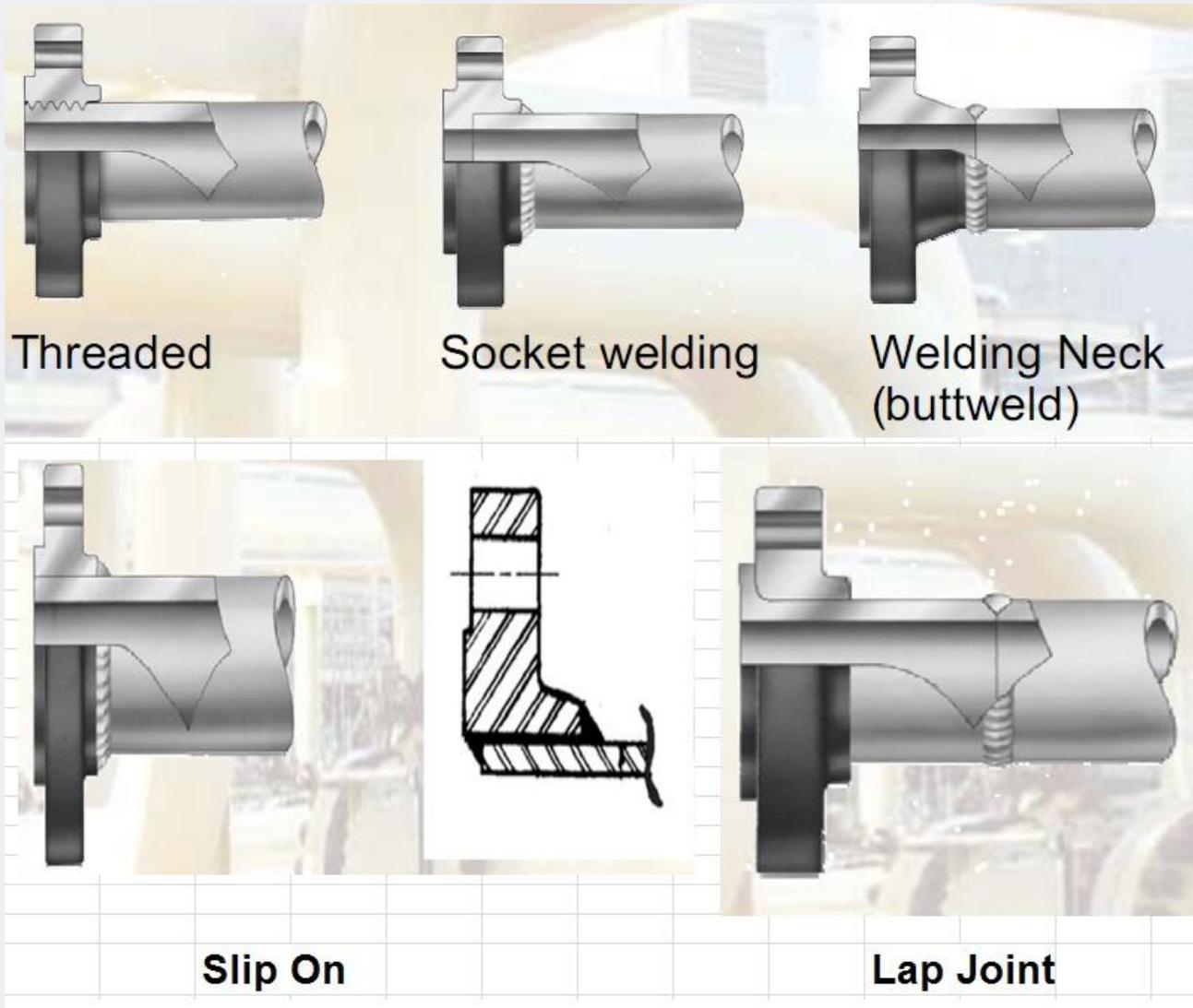


**Cap**



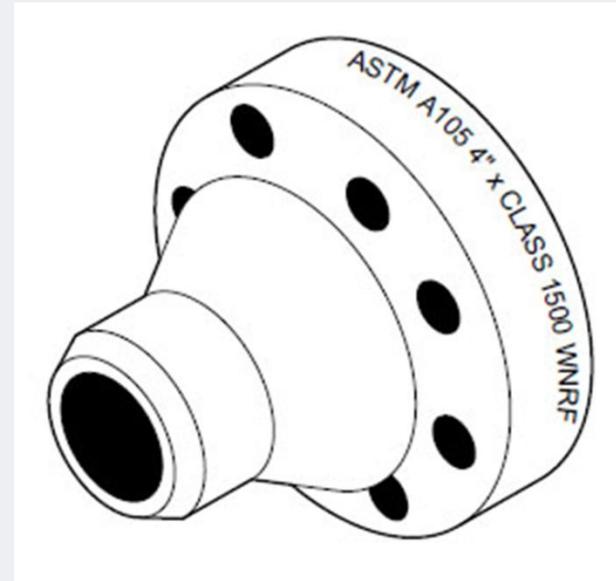
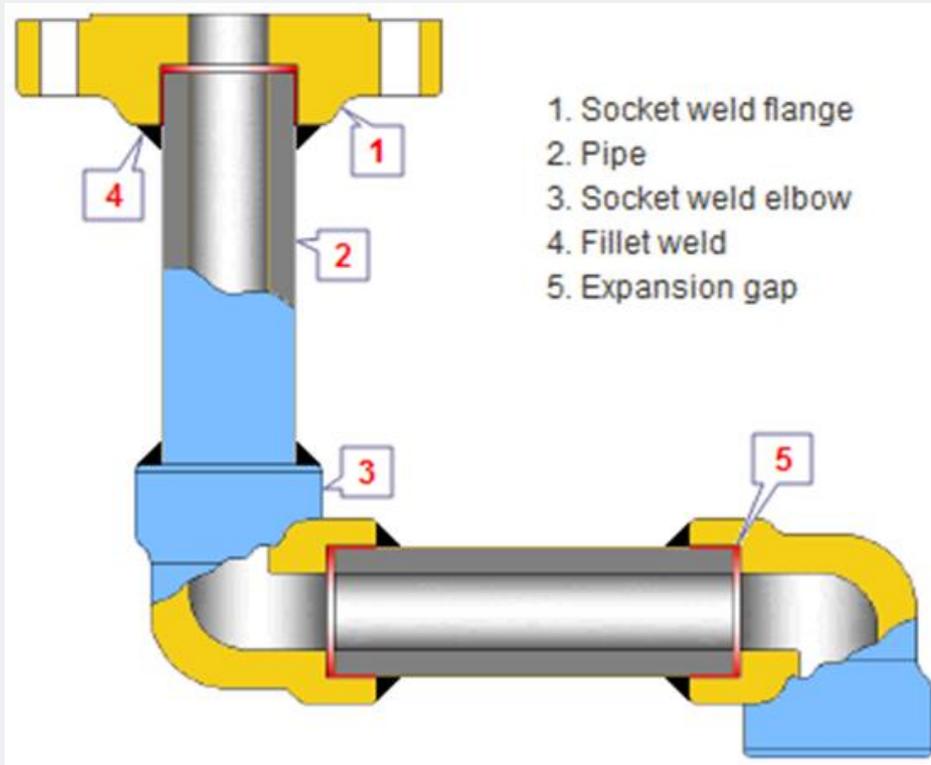
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# 法蘭



# 管線建構概念

## 標稱尺碼



# 壓力-溫度設計準則

## ❖ 標準元件

- 溫度壓力額定配置
- 溫度壓力設計依循

## ❖ 非標準元件

- 依規範計算強度

## ❖ 考量短期偏差容許條件

## ❖ 考量異質操作條件銜接點

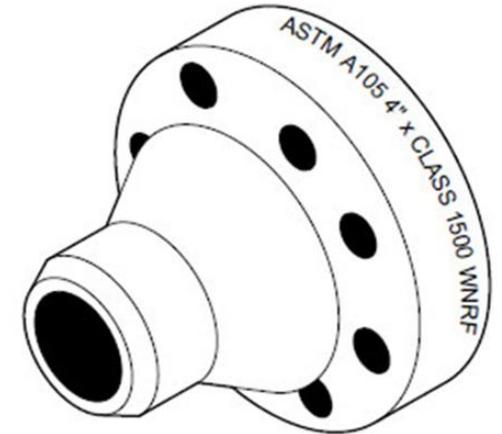
# 溫度壓力額定等級表

Table II-2-1.1 Pressure-Temperature Ratings for Group 1.1 Materials

Nominal Designation	Forgings	Castings	Plates
C-Si	A 105 (1)	A 216 Gr. WCB (1)	A 515 Gr. 70 (1)
C-Mn-Si	A 350 Gr. LF2 (1)	...	A 516 Gr. 70 (1), (2) A 537 Cl. 1 (4)
C-Mn-Si-V	A 350 Gr. LF6 Cl. 1 (3)	...	...
3½Ni	A 350 Gr. LF 3	...	...

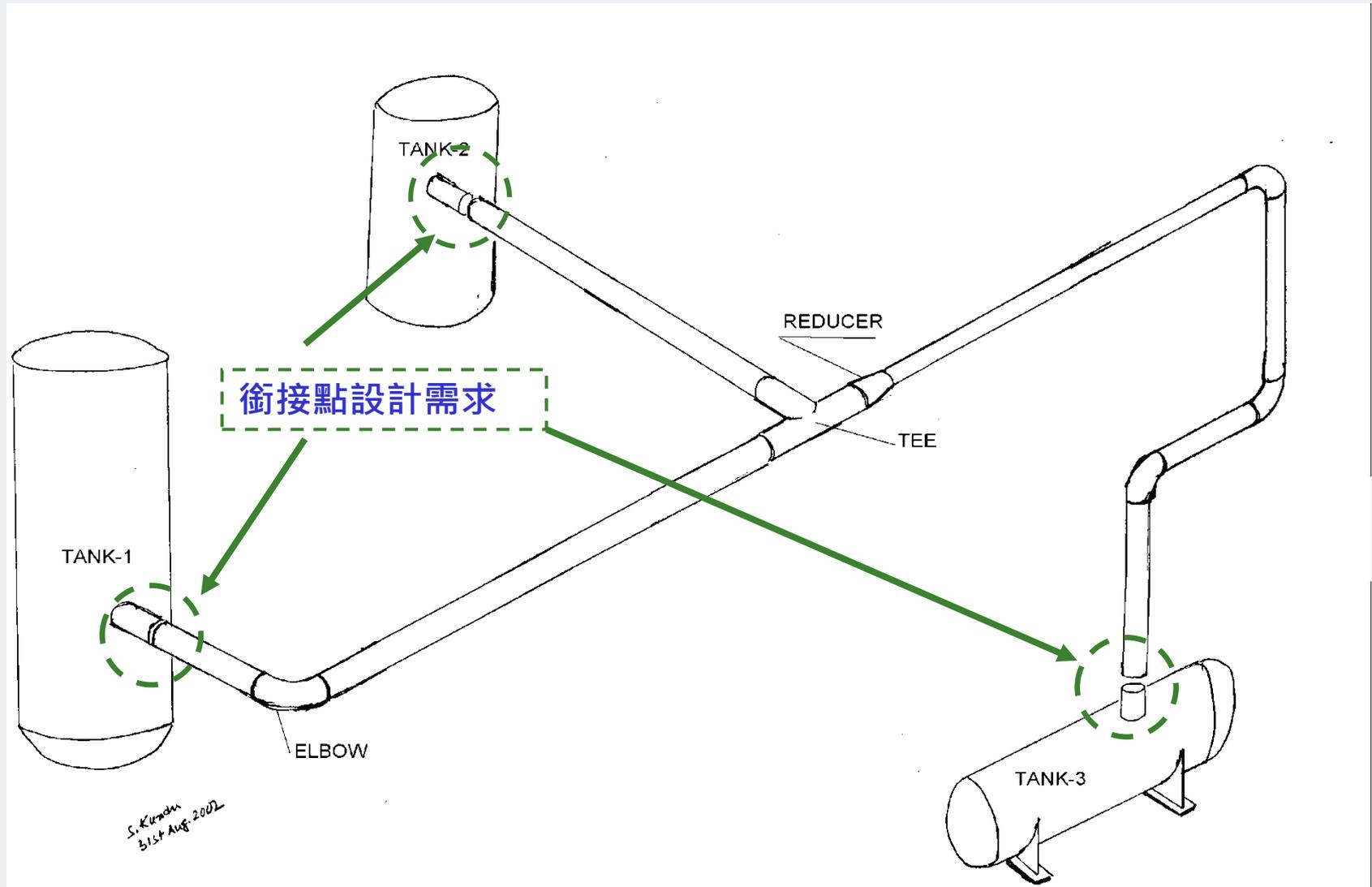
  

Working Pressures by Classes, psig							
Temp., °F	Class						
	150	300	400	600	900	1500	2500
-20 to 100	285	740	985	1,480	2,220	3,705	6,170
200	260	680	905	1,360	2,035	3,395	5,655
300	230	655	870	1,310	1,965	3,270	5,450
400	200	635	845	1,265	1,900	3,170	5,280
500	170	605	805	1,205	1,810	3,015	5,025
600	140	570	755	1,135	1,705	2,840	4,730
650	125	550	730	1,100	1,650	2,745	4,575
700	110	530	710	1,060	1,590	2,655	4,425
750	95	505	675	1,015	1,520	2,535	4,230
800	80	410	550	825	1,235	2,055	3,430
850	65	320	425	640	955	1,595	2,655
900	50	230	305	460	690	1,150	1,915
950	35	135	185	275	410	685	1,145
1,000	20	85	115	170	255	430	715

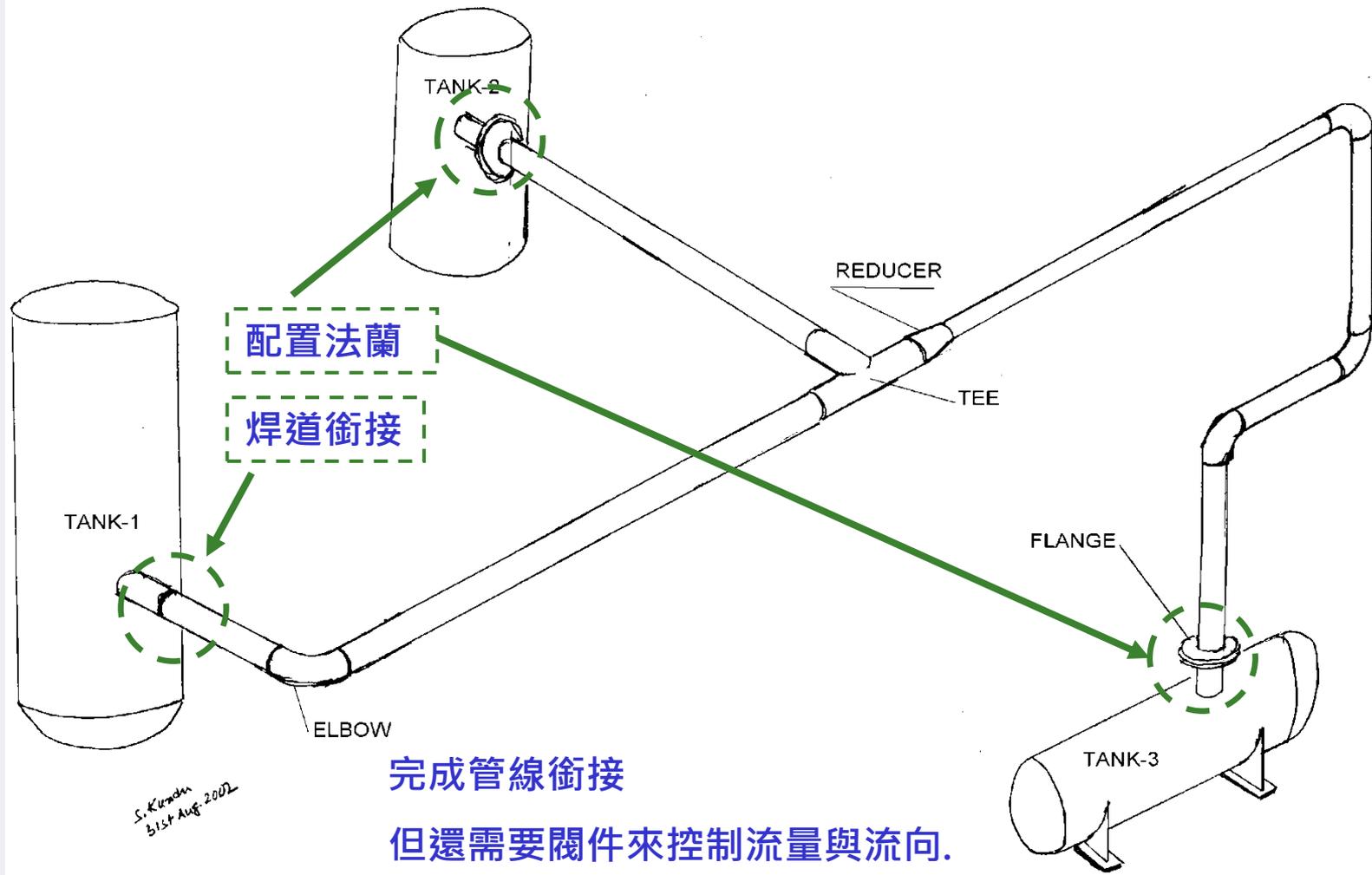


# 管線系統基本架構

## 銜接點設計



# 管線系統基本架構 銜接點設計



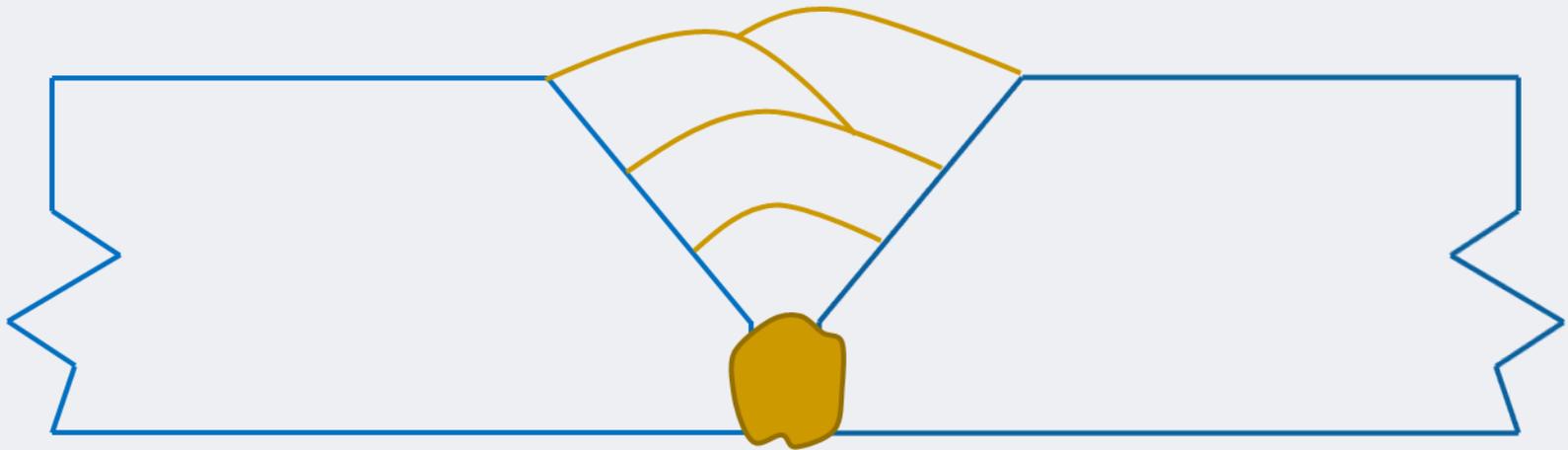
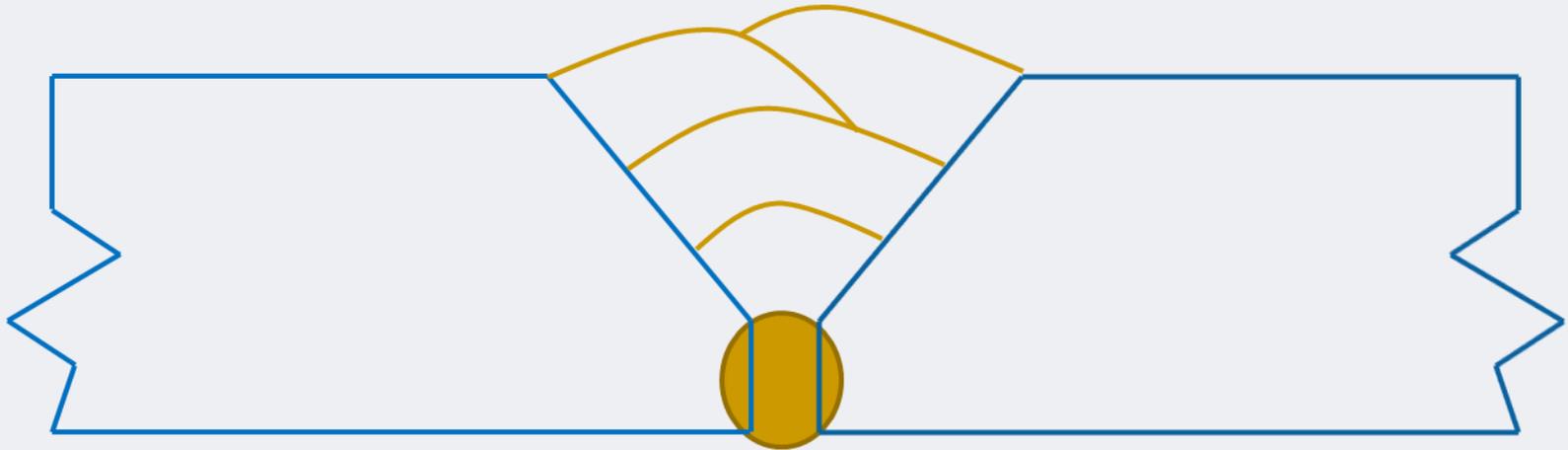
# 管線焊接風險

- ❖ 焊接方法組合
- ❖ 焊接檢定
  - 焊接程序與程序檢定紀錄(WPS/PQR)
  - 焊工手藝檢定
- ❖ 預熱需求
- ❖ 焊後熱處理需求
- ❖ 焊接檢查

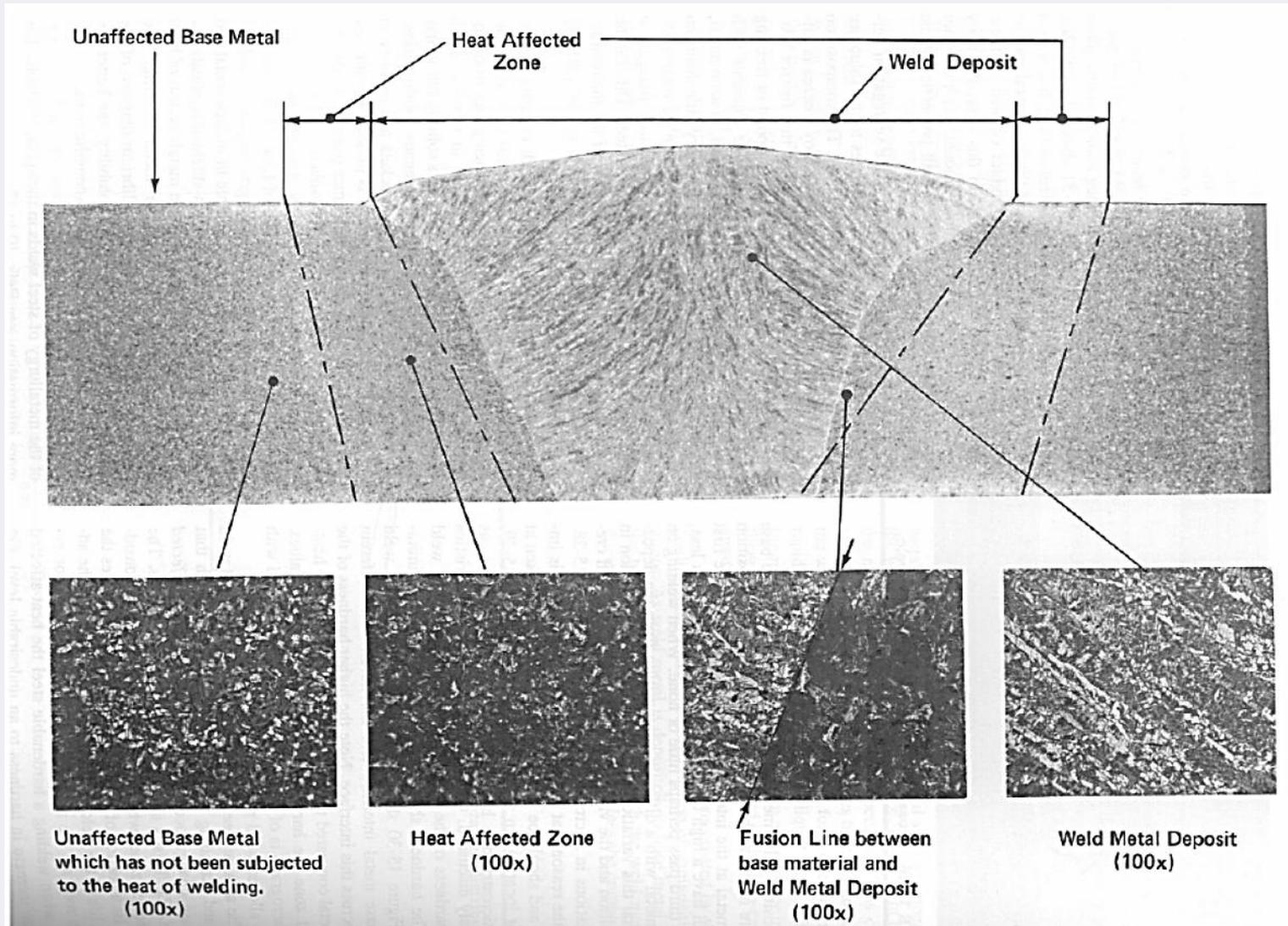
# 焊接方法組合



# 焊接方法組合



# 焊接冶金變化



# 焊接檢定

2013

ASME Boiler and  
Pressure Vessel Code  
AN INTERNATIONAL CODE

IX

Welding, Brazing, and  
Fusing Qualifications

Qualification Standard for Welding,  
Brazing, and Fusing Procedures;  
Welders; Brazers; and Welding,  
Brazing, and Fusing Operators

$\beta$

# 焊接檢定

## ❖ 焊接程序

- 確認焊接工件之機械性質符合設計要求

## ❖ 焊工手藝

- 確認焊工在特定姿勢、管徑、厚度、焊材組合下，能妥善完成焊接工作

# 焊接程序與程序檢定紀錄(WPS/PQR)

- ❖ WPS, Welding Procedure Specification
- ❖ 由焊接承商(Manufacturer/Contractor)依其機具設備、焊接知識、管理體系及施工能力等，對完成某特定之焊接工作所提出之詳細焊接過程指導書
- ❖ WPS所定之各項必要變數需參照檢定合格之程序檢定紀錄(PQR)所得之結果以確認其可行
- ❖ 每件特定之焊接工程均應有WPS與之對應

# 焊接程序與程序檢定紀錄(WPS/PQR)

- ❖ PQR, Procedure Qualification Record(s)
- ❖ 測試特定之焊接方法、條件及步驟所組成之焊接程序之可行性
- ❖ 由技藝純熟之焊工，依程序所設定之變數完成焊接試片，進行機械性能或其他必要之試驗，以確認此項程序可達成預期之目的
- ❖ 詳細測量及記錄焊接過程之各項數據，並參照規範定義各項變數之合格範圍，作為焊接程序書撰寫之參考及依據

# 焊工手藝檢定

- ❖ WPQ, Welder or Welding Operator Performance Qualifications
- ❖ 測驗焊工是否熟悉焊接基本知識
- ❖ 測驗焊工使用焊接機具之熟練程度
- ❖ 測驗焊工在特定焊接姿勢下之焊接穩定度
- ❖ 焊工依據某份合格WPS之內容，測驗其是否熟悉焊接基本知識、熟練使用焊接機具及在特定焊接姿勢下之焊接能力

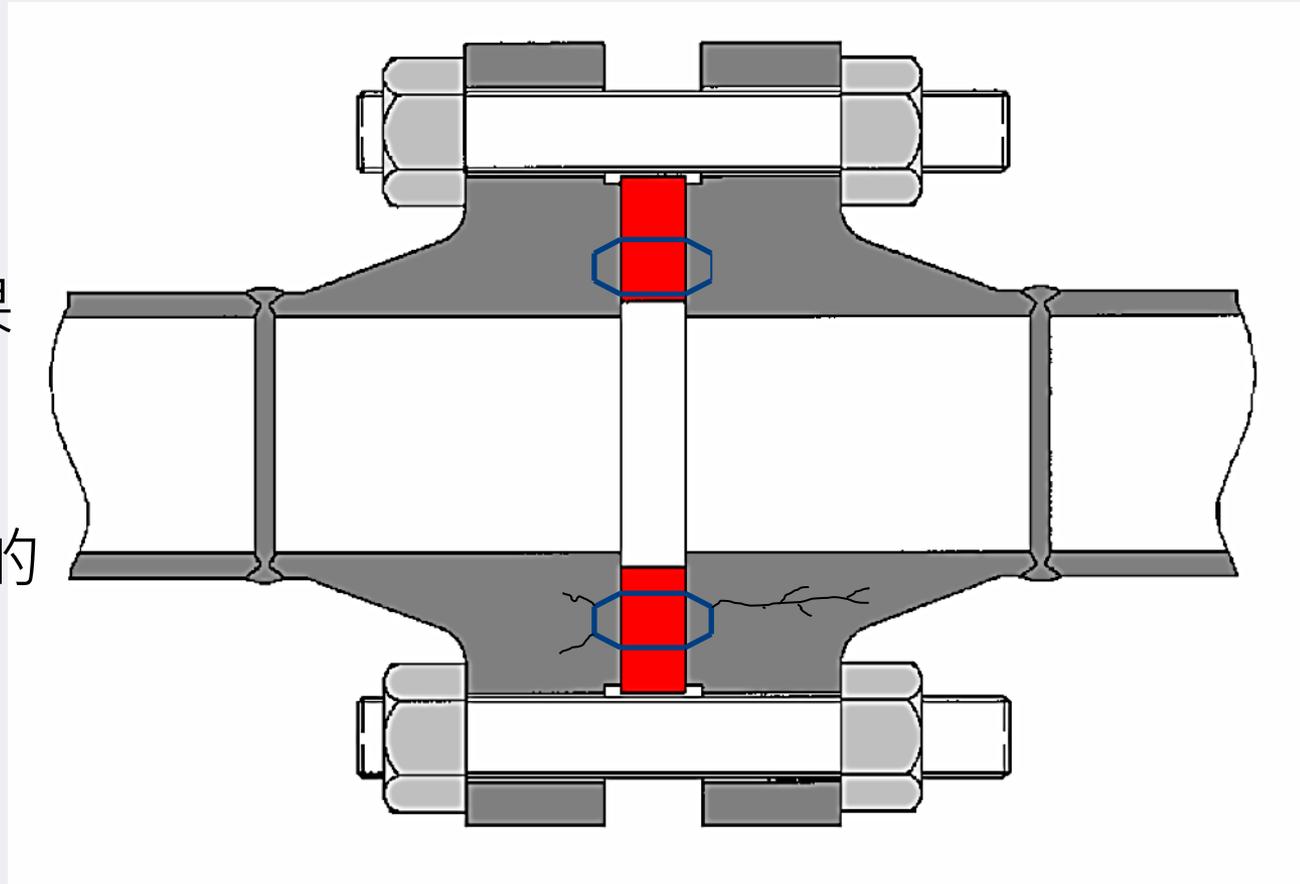
# 法蘭接頭風險探討

## 墊片

在2個接合面間提供且保持密封效果

## 螺栓

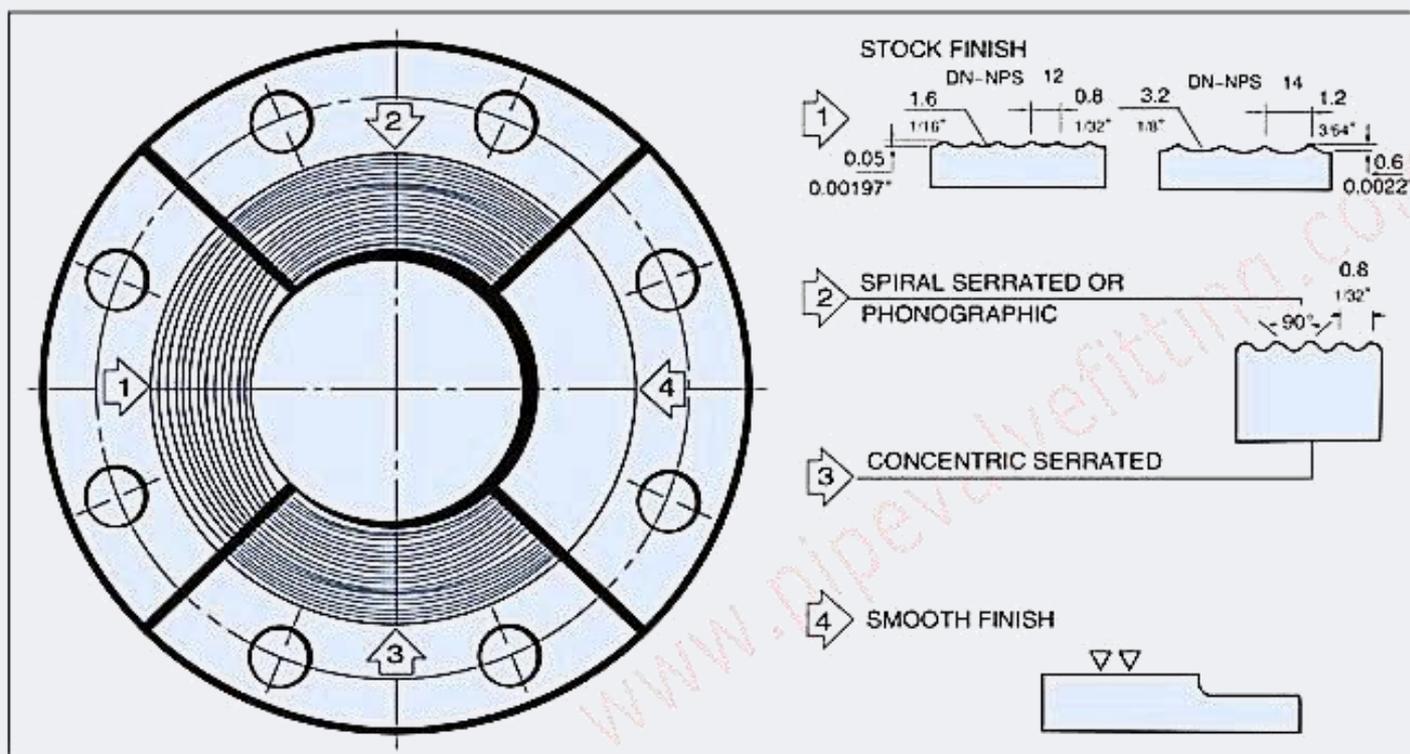
提供接合面必要的夾緊力



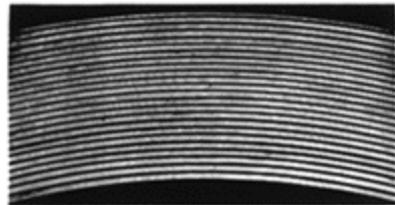
# 法蘭接頭風險探討

## STANDARD FINISH

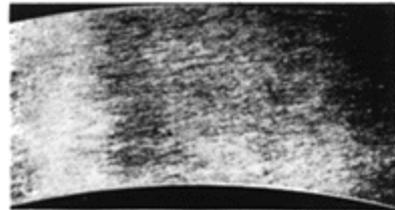
STANDARD FINISHES for Face of Flange (ANSI B16.5)



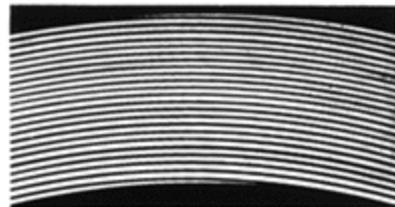
# 法蘭接頭風險探討



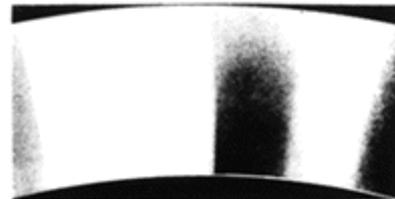
SERRATED FINISH



SMOOTH FACE

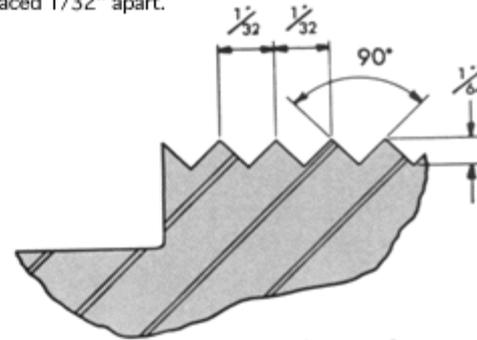


PHONOGRAPHIC FINISH



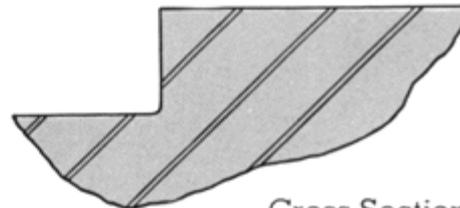
MIRROR GROUND FINISH

Concentric triangular grooves, 90 degree included angle, 1/64" deep and spaced 1/32" apart.



Cross-Section  
Serrated Face and  
Phonographic Finish

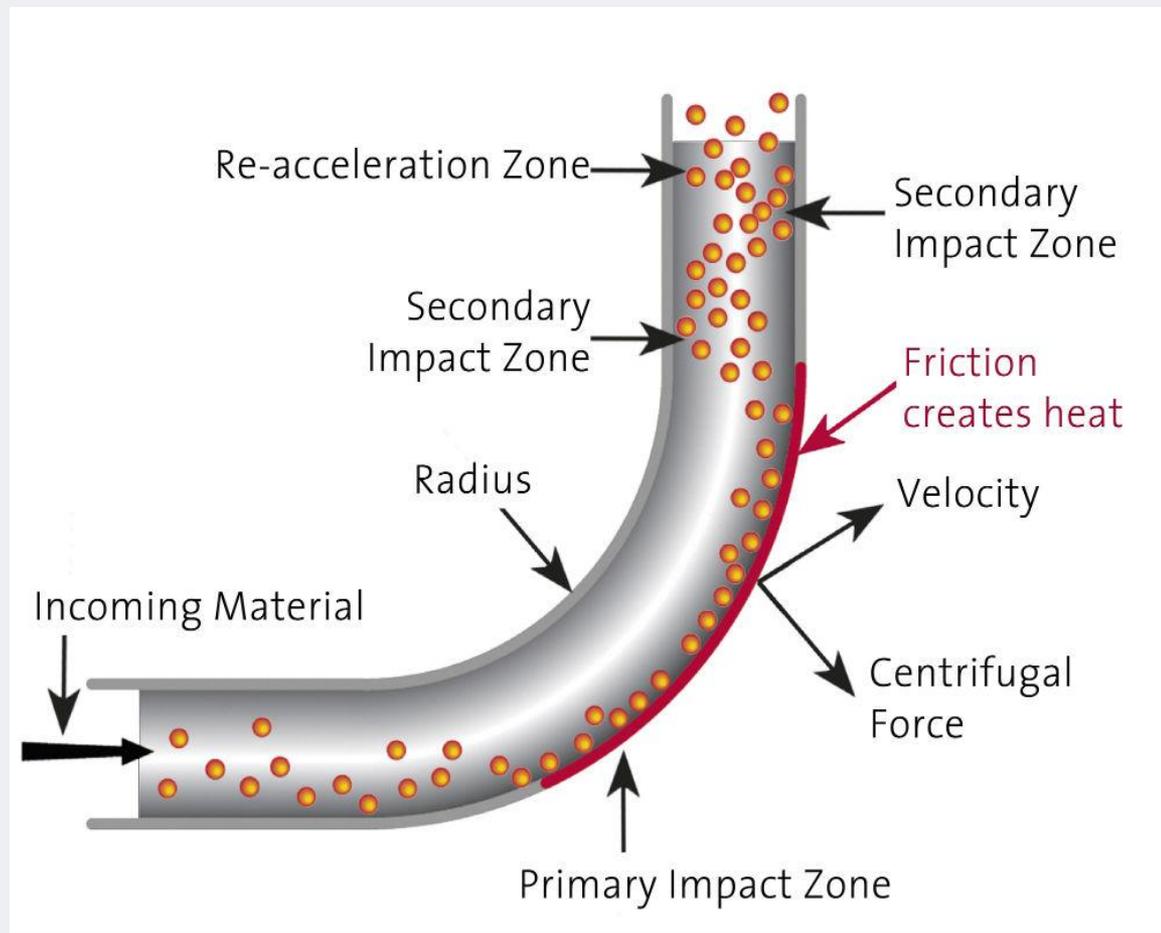
Continuous triangular grooves, 90 degree included angle, 1/64" deep and spaced 1/32" apart.



Cross-Section  
Smooth Face and  
Mirror Ground Finish

# 彎頭風險探討

- ❖ 直管與彎管
- ❖ 水平與垂直
- ❖ 高速與低速
- ❖ 流動與停滯
- ❖ 高溫與低溫
- ❖ 高壓與低壓

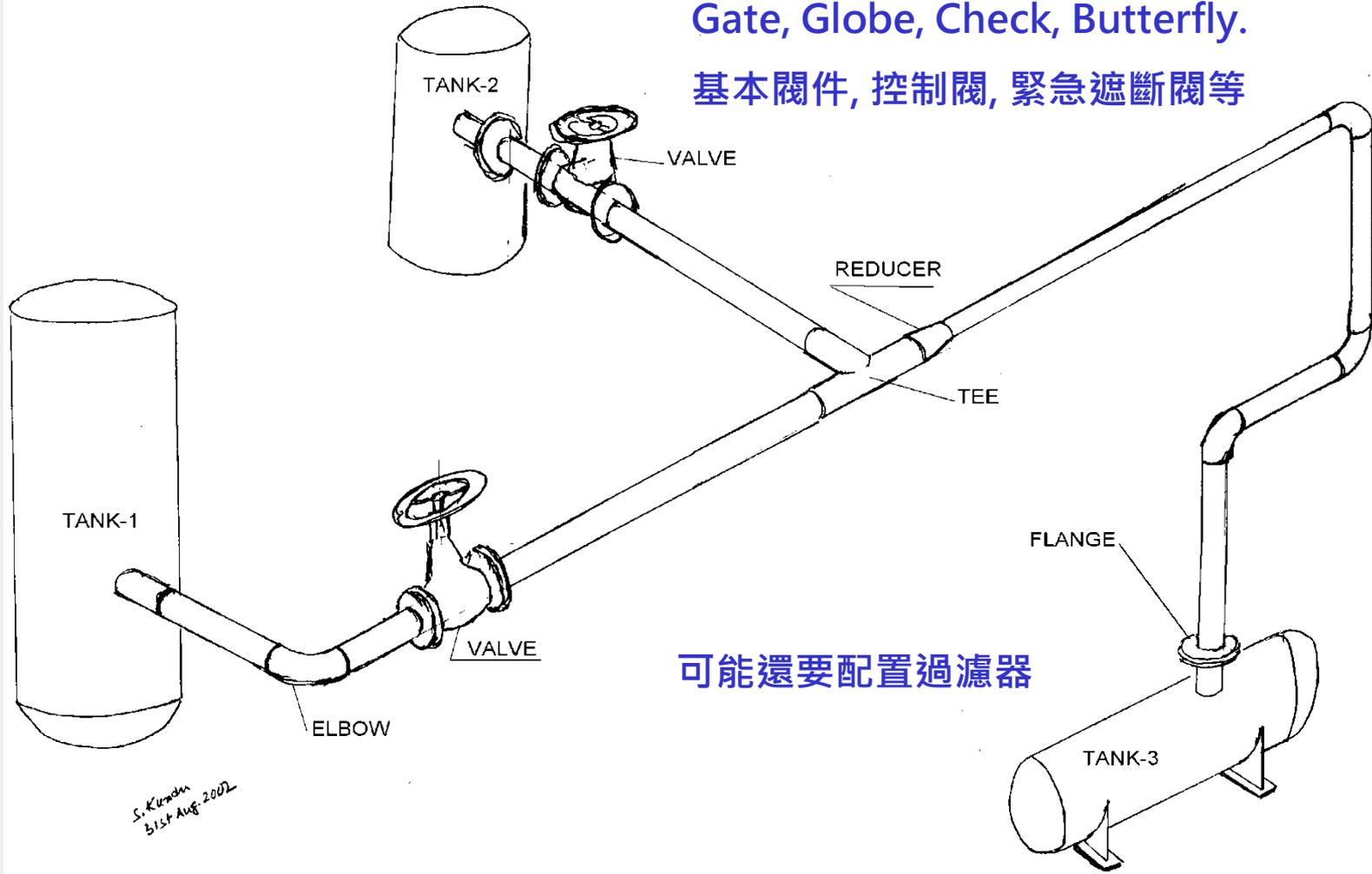


# 流向與流量控制

閥件型式依實際需求而定

Gate, Globe, Check, Butterfly.

基本閥件, 控制閥, 緊急遮斷閥等



可能還要配置過濾器

# 閥的基本功能

基本功能	說明原理	相關閥類
開、關	主要用於截斷或接通流體	閘閥、球形閥、球閥、塞閥、蝶閥
調整流量	用於調節流體之流量	球形閥、針閥、塞閥、蝶閥
防止逆流	阻止流體倒流	止回閥（逆止閥）
改變流向	改變流體方向及分離、分配流體	球閥、塞閥
控制流體壓力	限制流體壓力	減壓閥、安全閥

## 閥的基本功能

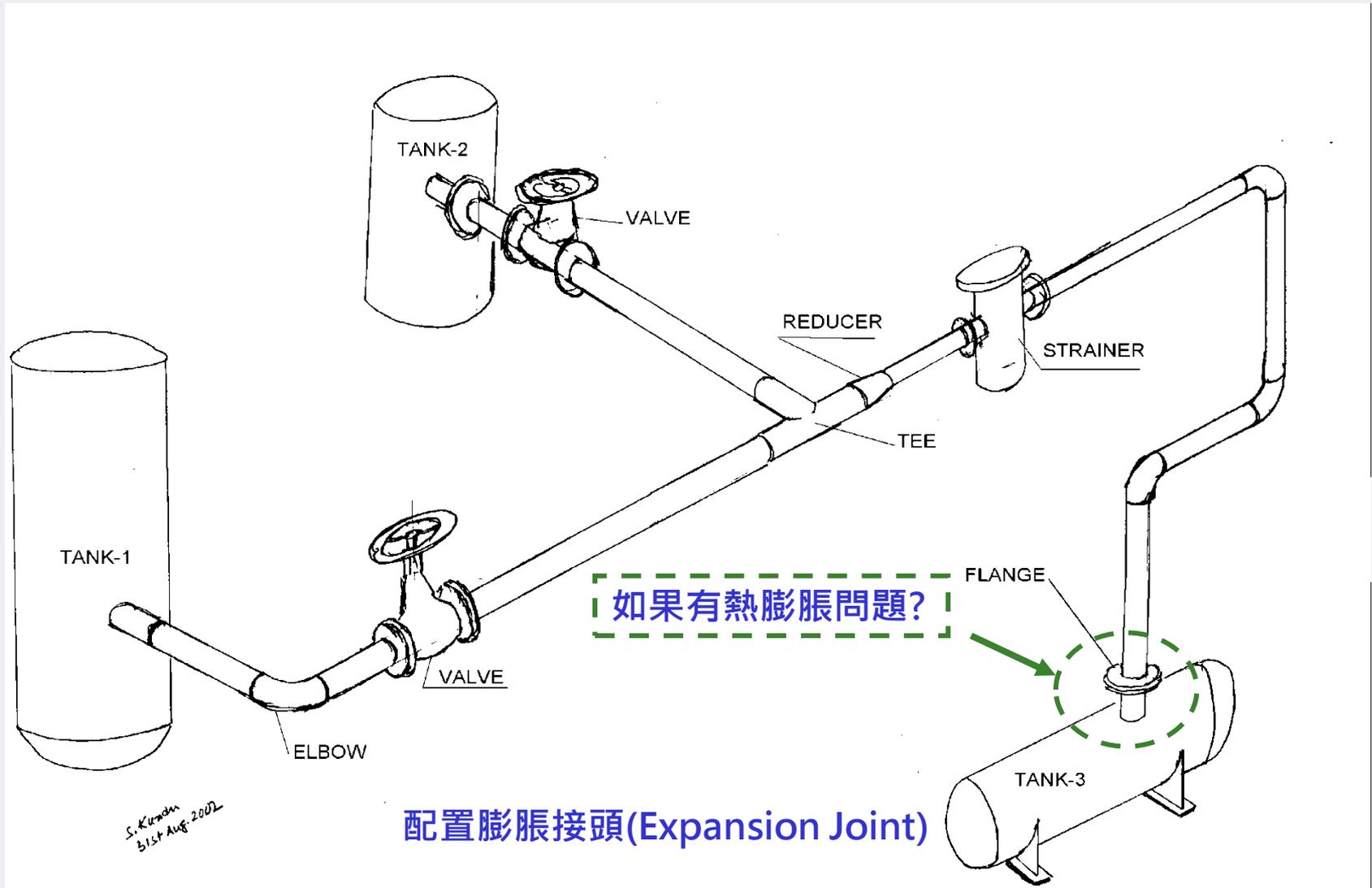
用途	開-關	節流	液流轉向	時常操作	低壓下降	快開	自由排閥
閘閥	√				√	√	√
球型閥	√	√		√			
塞閥	√	√	√	√	√	√	√
球閥	√		√	√	√	√	
蝶形閥	√	√		√	√	√	√
針閥		√					

# 閥的分類

- ❖ 閘閥 (Gate valve)
- ❖ 球閥 (Globe valve)
- ❖ 止回閥 (Check valve)
- ❖ 球塞閥 (Ball valve)
- ❖ 塞閥 (Plug valve)
- ❖ 蝶閥 (Butterfly valve)
- ❖ 針閥 (Needle valve)
- ❖ 減壓閥 調壓閥 (Regulator)
- ❖ 直通閥 刀閥 (Conductic Valve ,Slide Valve )
- ❖ 安全閥 Safety (relief Valve)

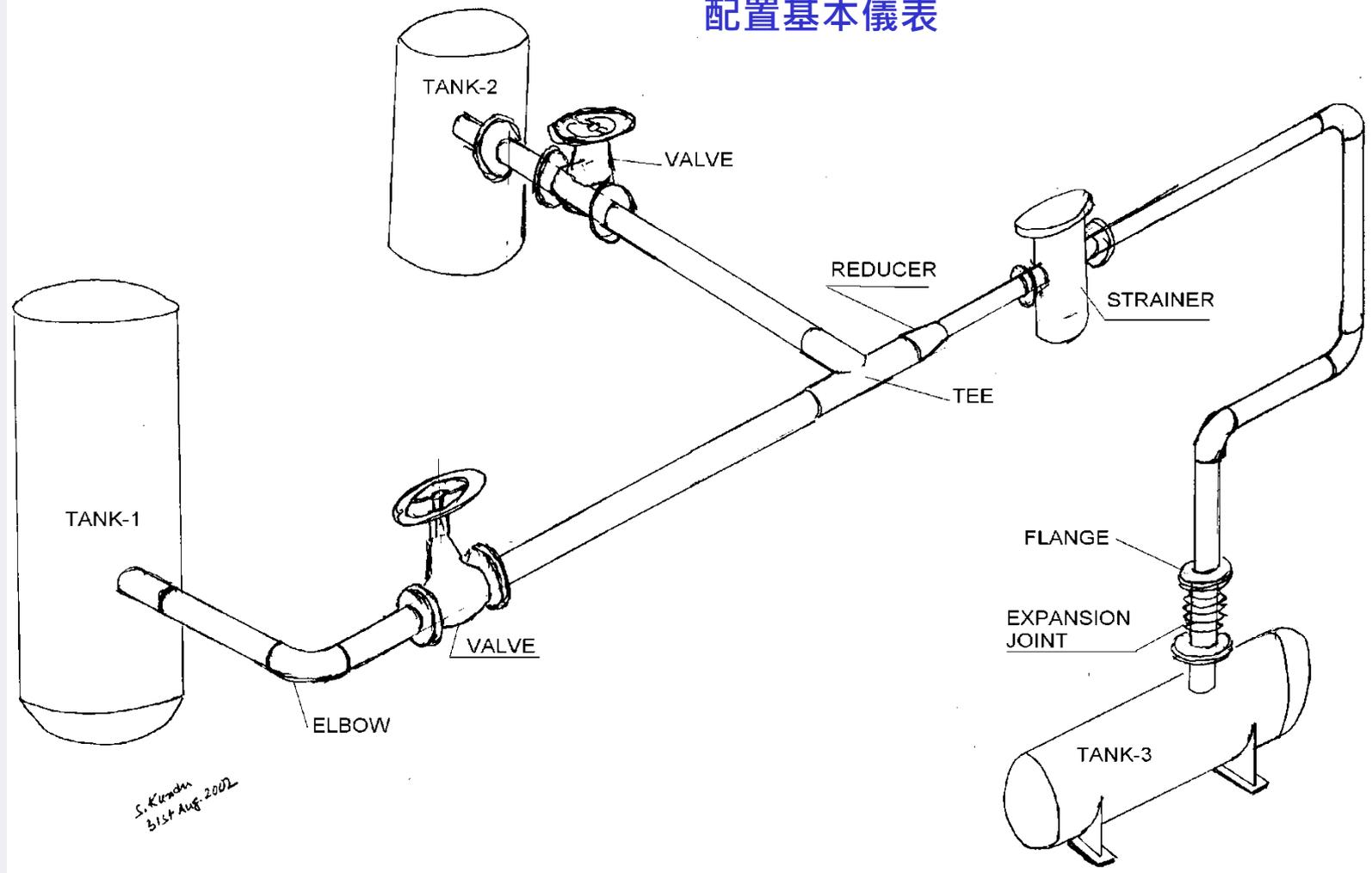
管線系統基本架構

# 流體特性考量



# 儀表需求

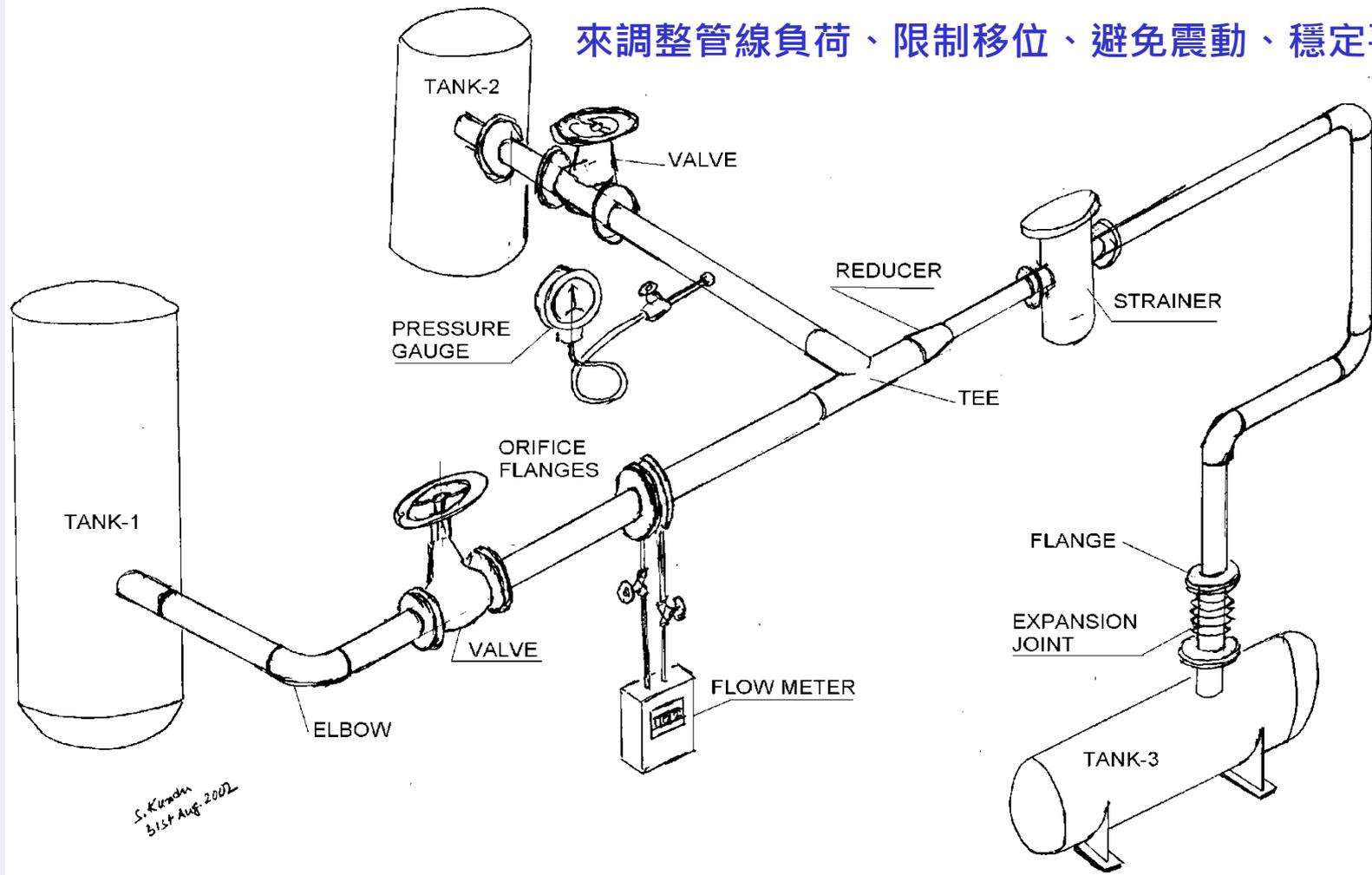
為了解溫度、壓力、流量等操作資訊, 必須配置基本儀表



# 儀表需求

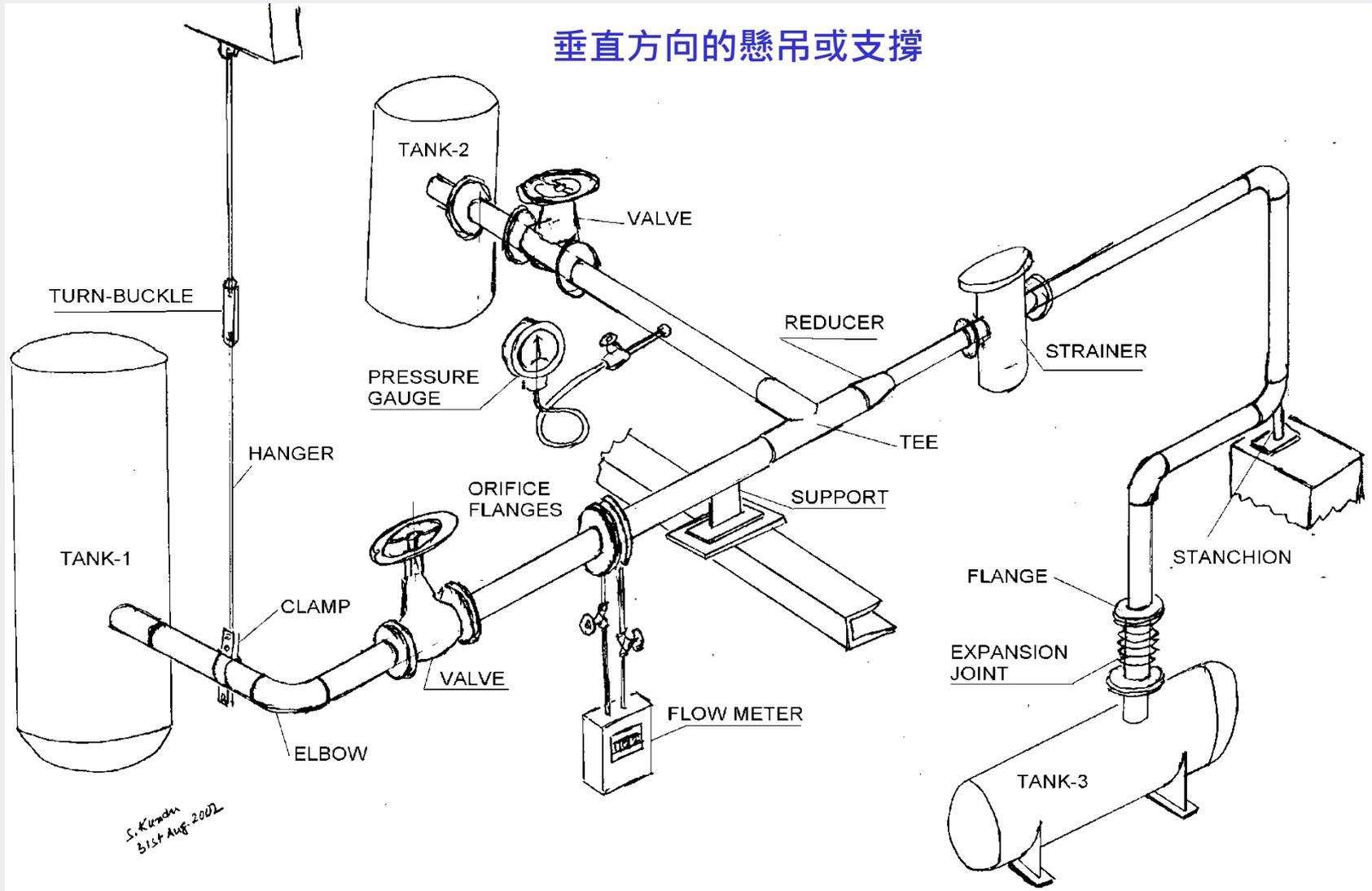
管線需要有輔助支撐,

來調整管線負荷、限制移位、避免震動、穩定平衡

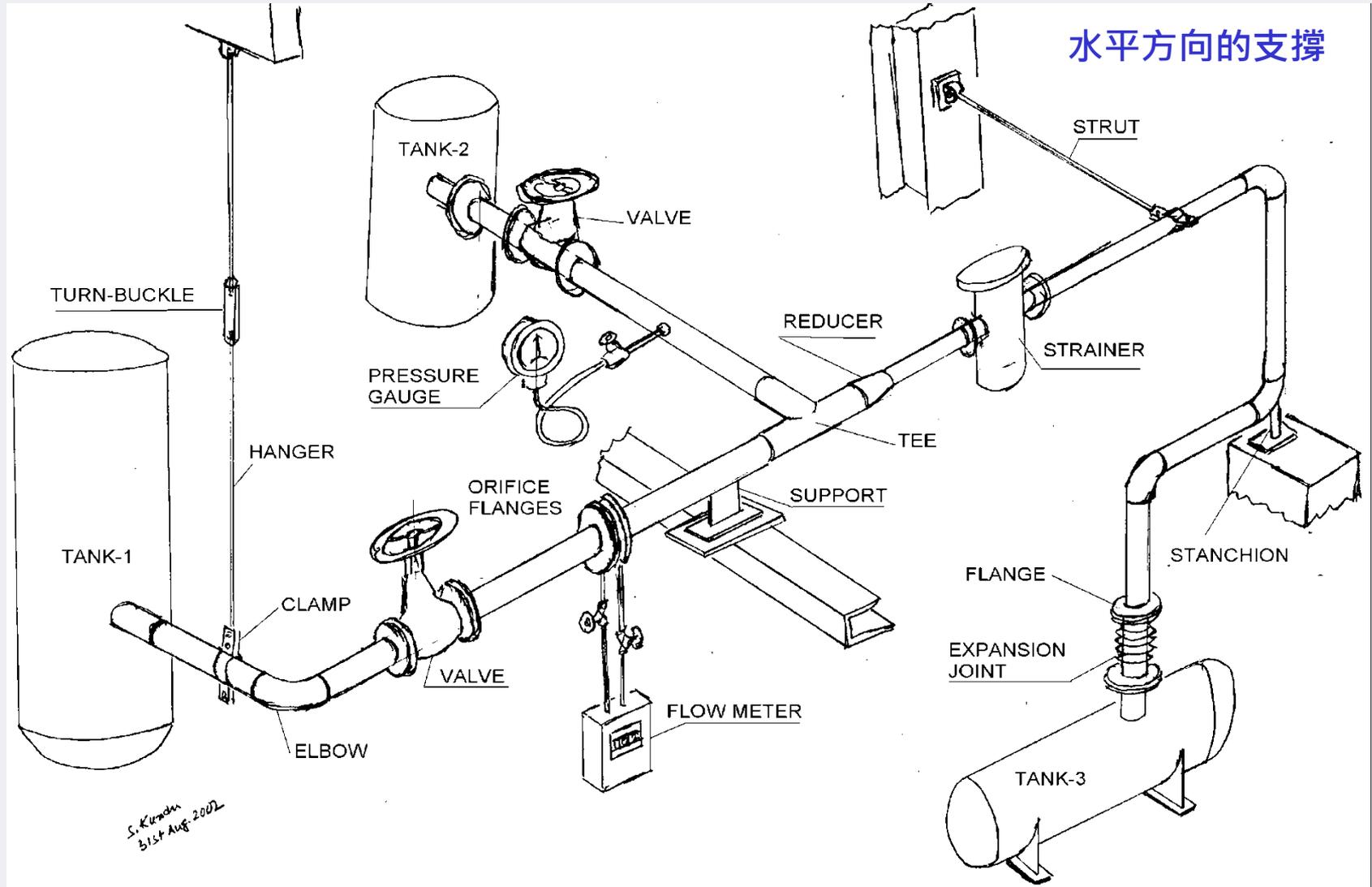


# 垂直方向結構支撐

垂直方向的懸吊或支撐

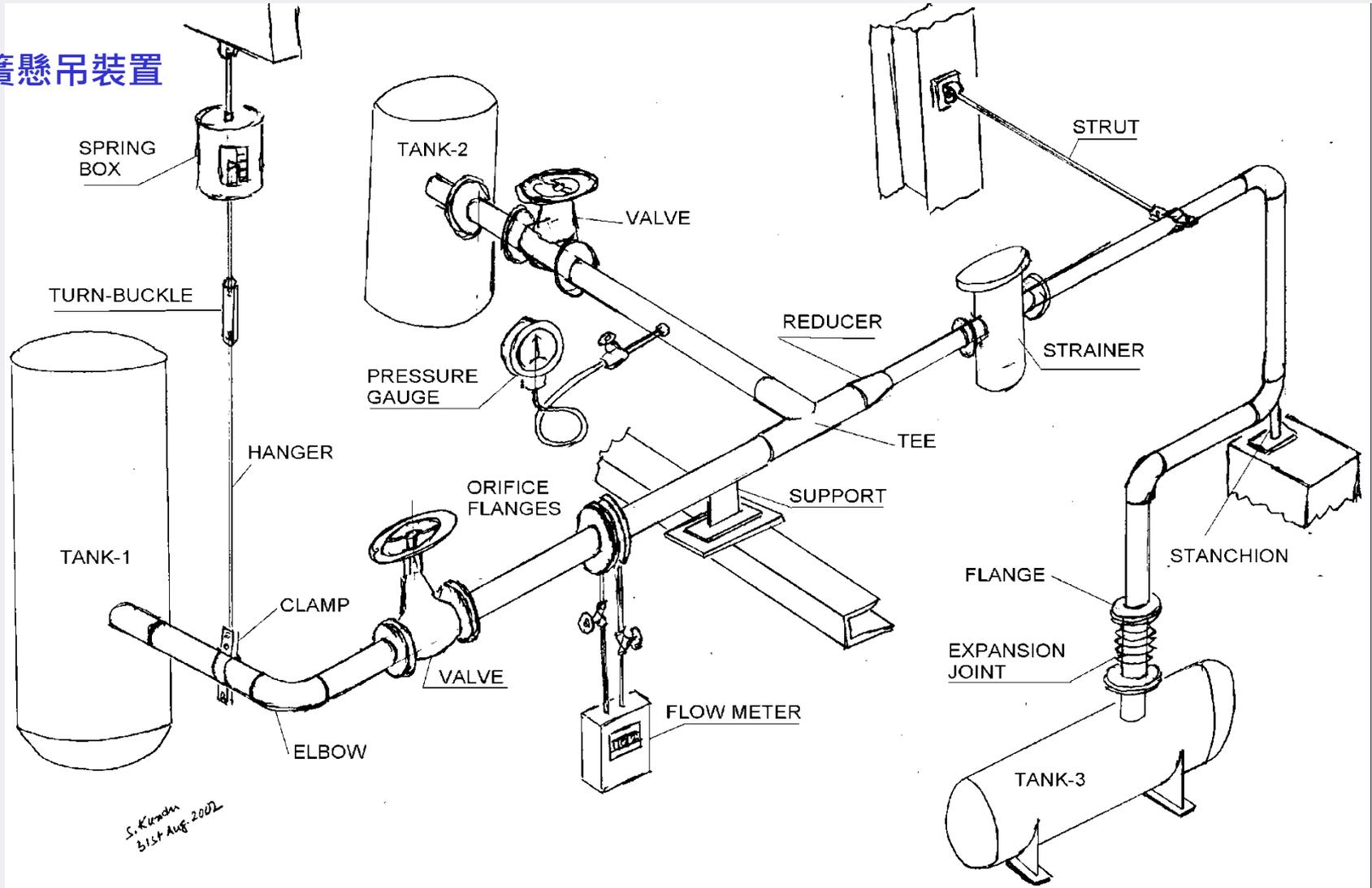


# 水平方向結構支撐



# 平衡式結構支撐

## 彈簧懸吊裝置



# 管線支撐構件(Pipe-Supporting Elements)

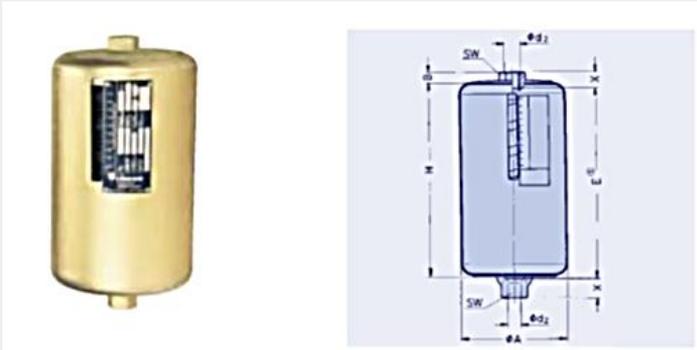
## ❖ Hanging type fixtures

- Hanger Rods, Spring Hangers, Sway Braces, Counterweights, Turnbuckles, Struts, Chains, Guides, and Anchors

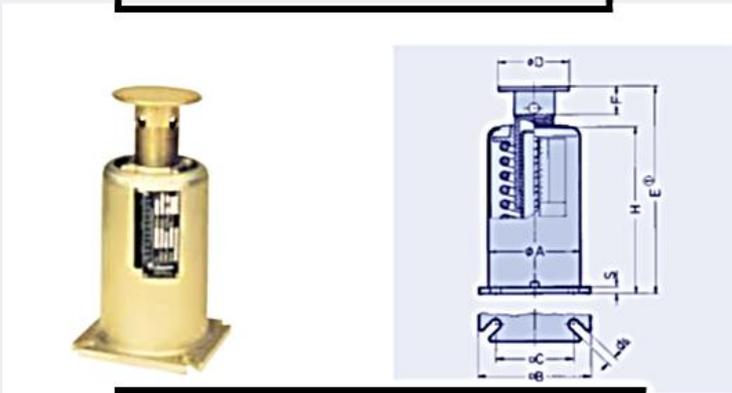
## ❖ Bearing type fixtures

- Saddles, Bases, Rollers, Brackets, and Sliding Supports

# 管線支撐構件(Pipe-Supporting Elements)



Spring hanger



Spring support

## Spring Hangers

Type B

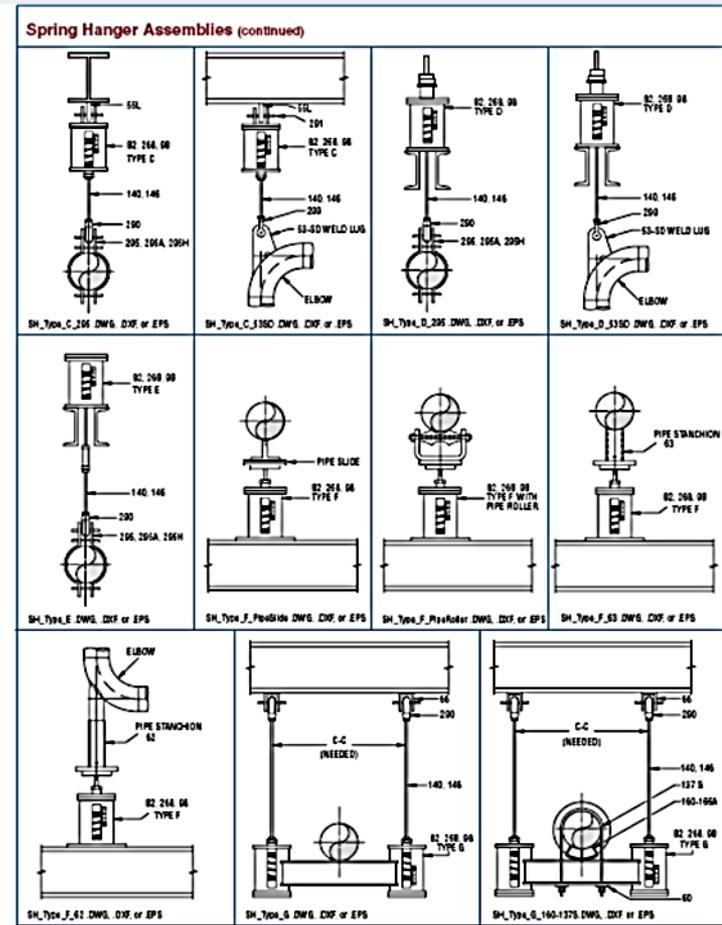
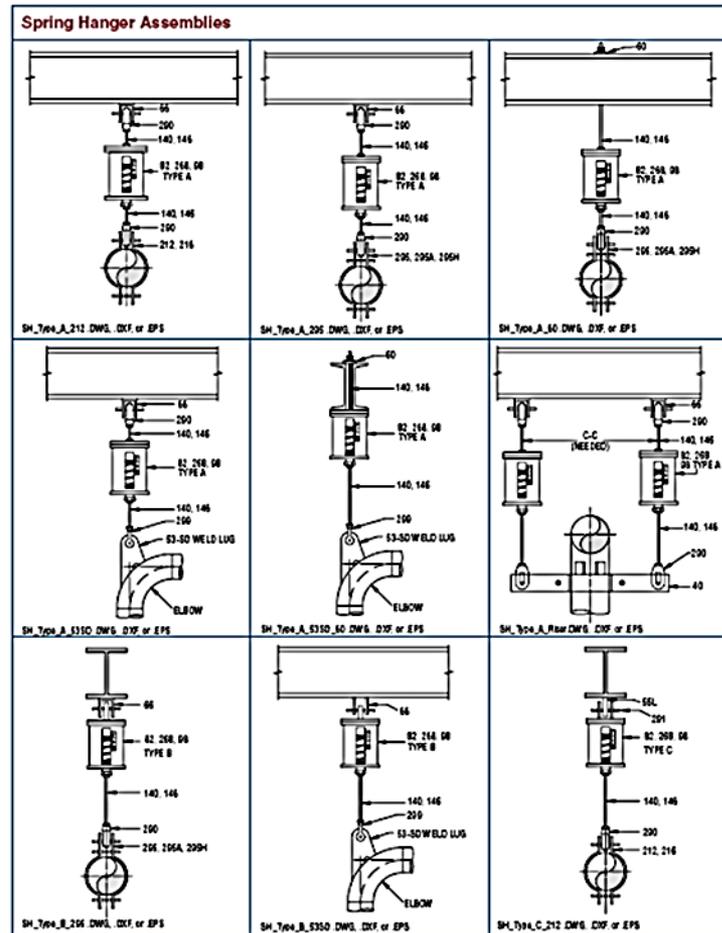
Type E

Type F

Type G

Variable Spring Hanger Installation (Anvil International)  
[Note that springs are always in compression.]

# 管線支撐構件(Pipe-Supporting Elements)



# 建造品質管理

- ❖ 材質確認 (Positive Material Identify, PMI)
- ❖ 焊接管制
- ❖ 配管元件品質
- ❖ 檢驗(Examination)、檢查(Inspection)、性能測試(Testing)
- ❖ 管線配置合理性

# 設計階段操作條件及材料規格設定

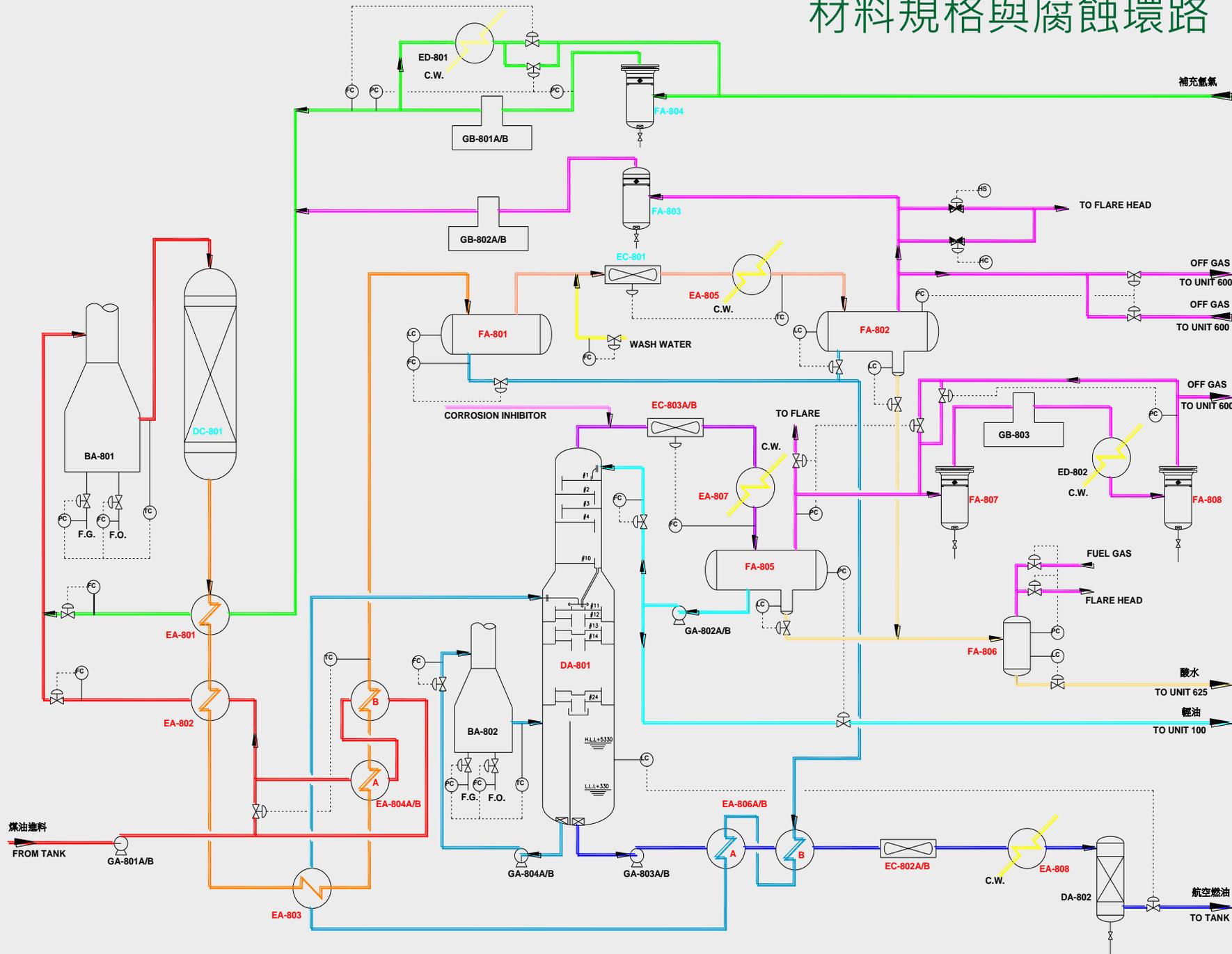
## ❖ 材料規格配置

- 製程設計者依內容物性質、溫度及壓力所提出之基本腐蝕考量規格
- 包含設備管線材料類別、腐蝕裕度、熱處理條件
- 材料規格配置必須與腐蝕環路一併檢討

## ❖ 管線材料等級分類規範

- 管線材質、厚度、接面、腐蝕裕度、保溫、管件、配件、閥等，採購、選用及焊裝/組建標準

# 材料規格與腐蝕環路



# 腐蝕與劣化

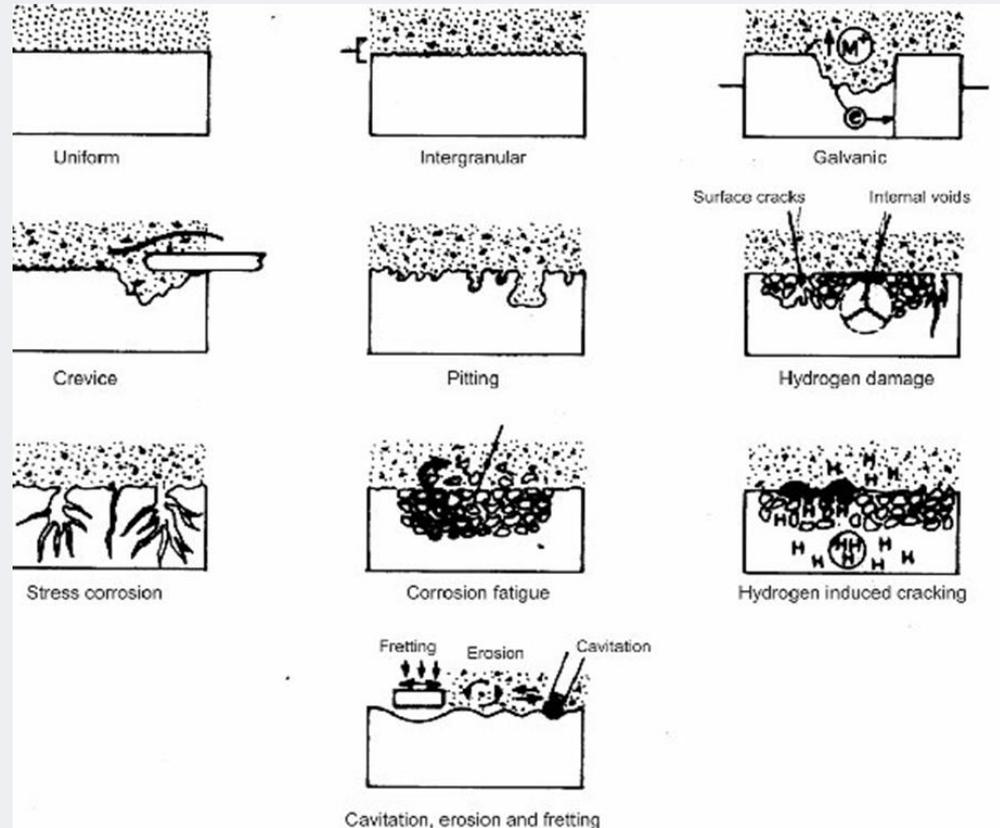
## ❖ 均勻腐蝕

## ❖ 局部腐蝕

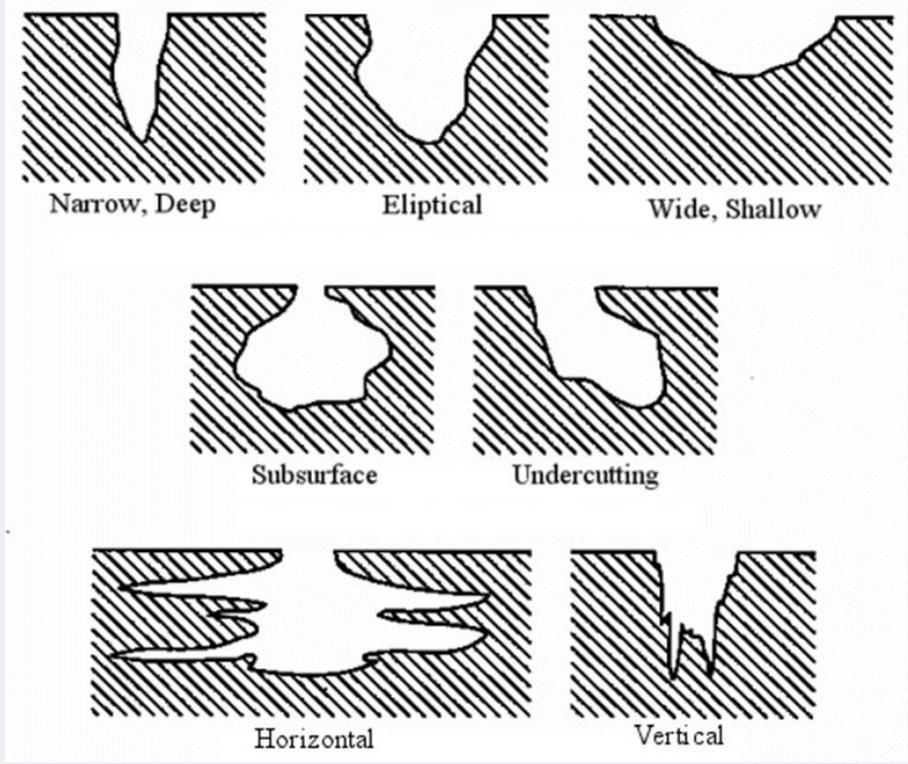
- 容易預知的位置
- 不容易預知的位置
- 起始自內部
- 起始自外部

## ❖ 裂紋

## ❖ 材料性質改變



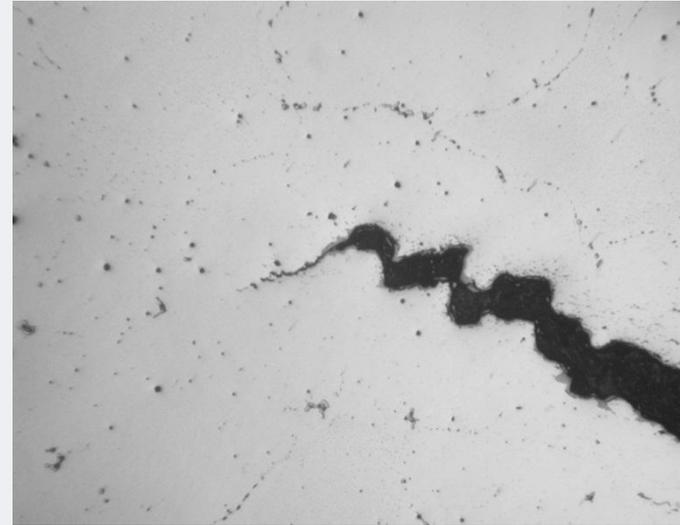
# 腐蝕與劣化



# 腐蝕與劣化

## ❖ 裂紋

- 明顯開口
- 微隙開口
- 未開口



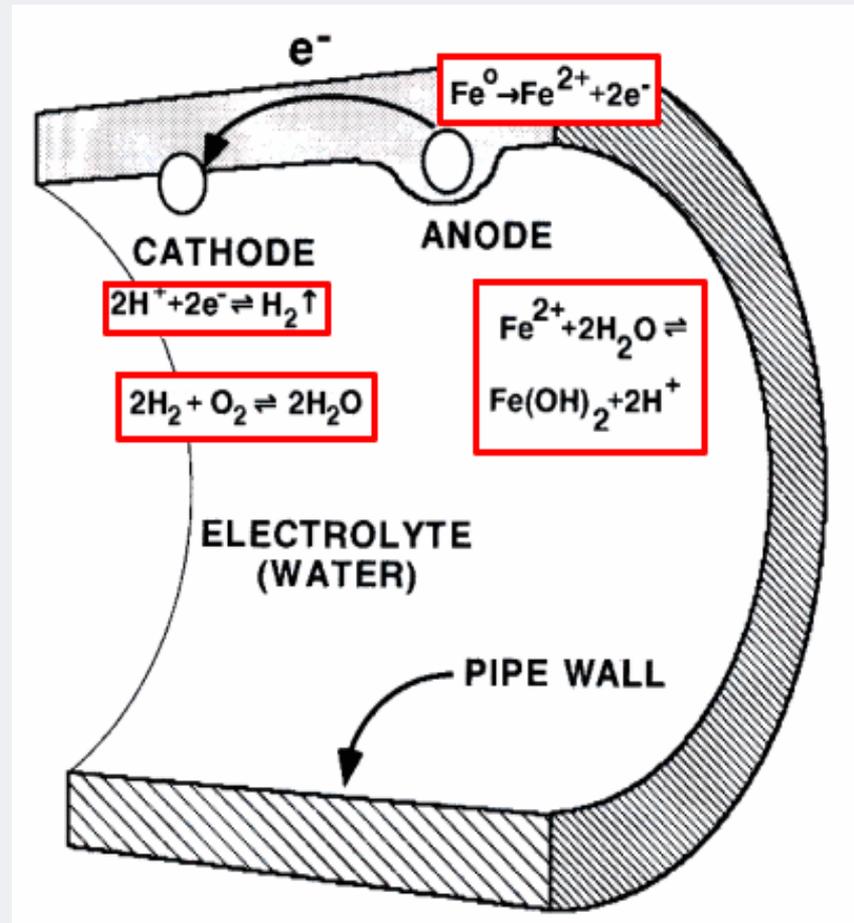
## ❖ 材料性質改變

- 外觀
- 顏色
- 尺寸



# 腐蝕及劣化分類

- ❖ 電化學腐蝕
- ❖ 化學腐蝕
- ❖ 物理性攻擊
- ❖ 材料本質劣化
- ❖ 微生物腐蝕



# 劣化趨勢與剩餘壽命

- ❖ 設計階段操作條件及材料規格設定
- ❖ 建廠階段可能殘留之瑕疵
- ❖ 操作初期常出現的劣化現象
- ❖ 穩定期
- ❖ 逐漸老化特徵
- ❖ 預防老化的具體措施

# 建廠階段可能殘留之瑕疵

- ❖ 材料誤用(管材、管件、焊材...)
- ❖ 焊接檢查遺漏
- ❖ 焊後熱處理效果未達成
- ❖ 安裝不當
- ❖ 管線配置不當

# 操作初期常出現的劣化現象

## ❖ 異常減薄

- 嚴重全面腐蝕 --- 操作條件偏差
- 嚴重局部腐蝕 --- 流體特性所致
- 材料厚度等級誤用 --- 配管失誤

## ❖ 局部沖蝕

- 流體通路配置不當

# 操作初期常出現的劣化現象

## ❖ 水槌現象

- 設計失誤、安裝不當、管線配置不當

## ❖ 表面裂紋

- 局部殘留應力、內容物

## ❖ 應力腐蝕

- 張應力、溫度、內容物

## ❖ 操作變數偏差

# 逐漸老化特徵

## ❖ 腐蝕

- 腐蝕裕度消耗殆盡
- 局部腐蝕普遍出現

## ❖ 材質老化/劣化

## ❖ 維護保養面

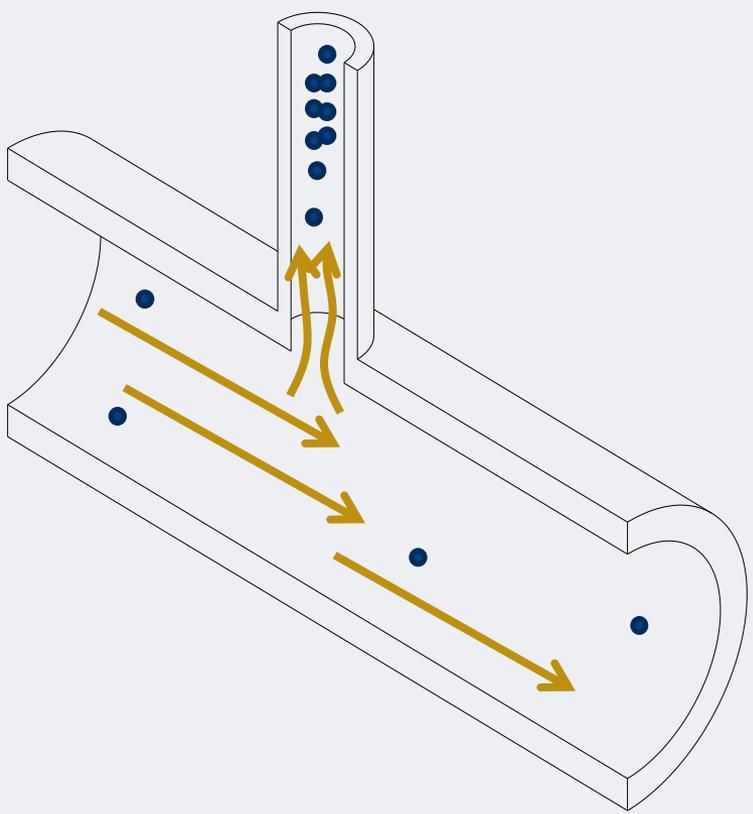
- 保溫層劣化/漆膜劣化
- 機件磨耗

# 典型老化特徵

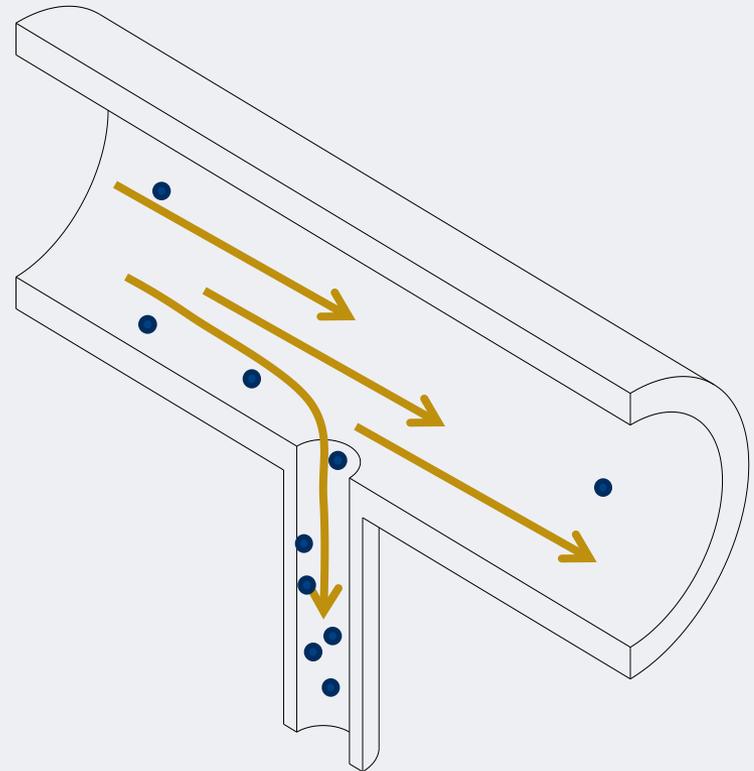
- ❖ 異常腐蝕
- ❖ 流體滯留區腐蝕
- ❖ 包覆層下方腐蝕
- ❖ 流態急速改變部位沖蝕
- ❖ 管線支撐部位腐蝕
- ❖ 管線配置不當誘發劣化
- ❖ 漆膜或包布劣化
- ❖ 土壤/空氣介面腐蝕
- ❖ 材質劣化

典型老化特徵  
**流體滯留區**

排氣孔滯留區



排液孔滯留區



# 流體滯留區

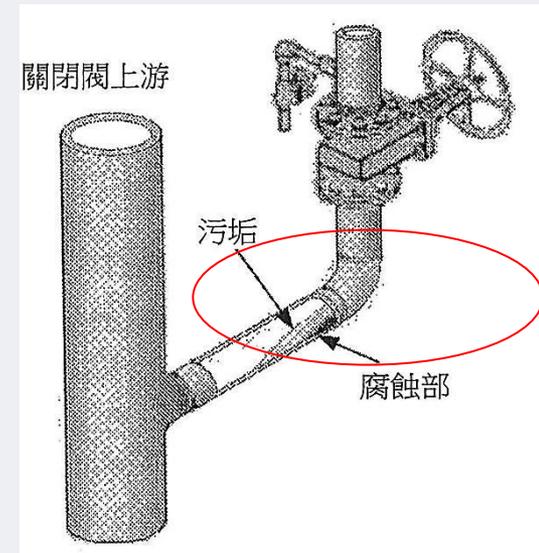
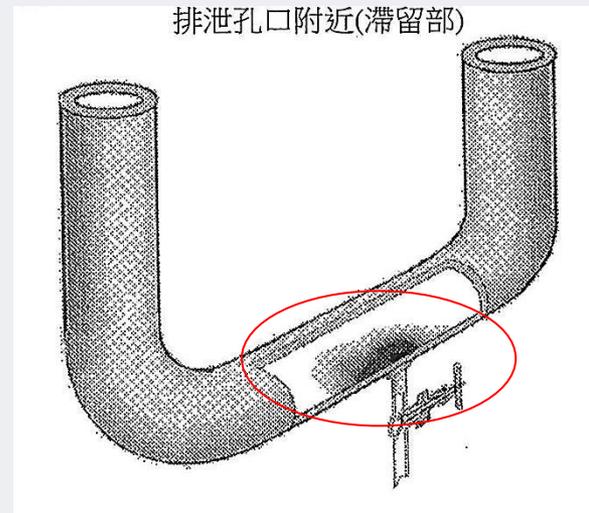
- ❖ 流體局部停滯(deadleg)
- ❖ 流體不流動區
- ❖ 流體流不到但其蒸氣會到達處
- ❖ 容易累積污、酸、鹼之位置
- ❖ 滯留區於腐蝕環路規劃過程極容易被忽視

# 流體滯留區

- ❖ 滯留區腐蝕率可能會遠高於正常流體區段
- ❖ 內容物僅具微量腐蝕因子仍可能因累積效應而造成滯留區嚴重腐蝕。
- ❖ 容易在特定點發生(與流體特性、配管過程及操作習慣相關)

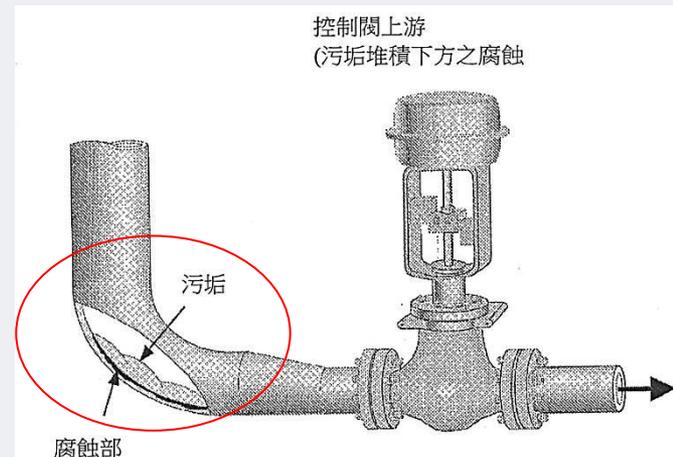
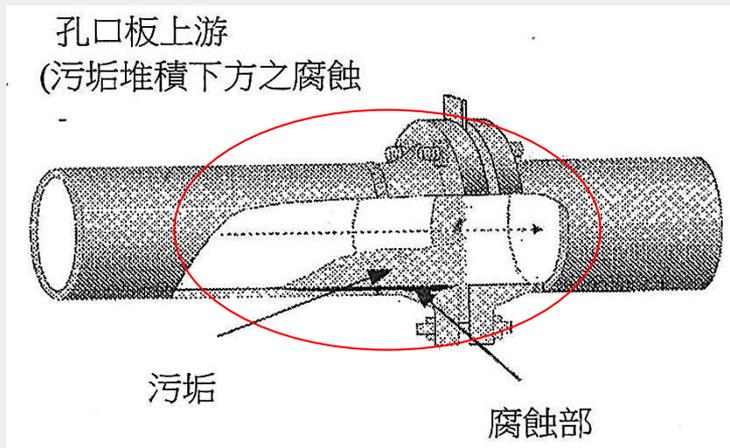
# 常見之管線流體滯留區

- ❖ 儀器金屬導管
- ❖ 取樣管
- ❖ VENT、DRAIN
- ❖ 液位計連通管
- ❖ 釋壓閥連接導管
- ❖ 釋壓閥後存在酸氣之管線



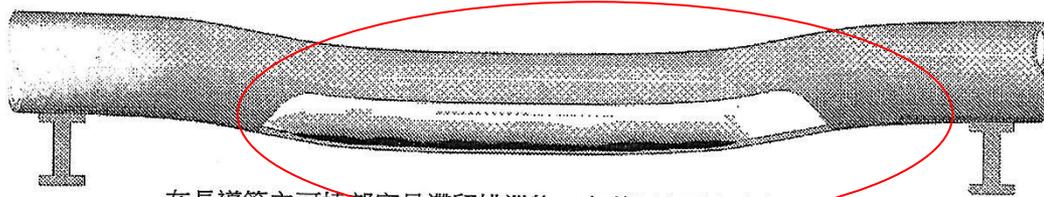
# 常見之管線流體滯留區

- ❖ 關斷閥前管線
- ❖ 管線支撐管另一端未盲封者
- ❖ 管線cap(如air cooler 分配管之header)
- ❖ 設備或控制閥等之旁通管線
- ❖ 備用台之管線系統(pump or compressor)



# 常見之管線流體滯留區

- ❖ 停用設備關斷點和製程仍連通之管段其內容物具腐蝕性者
- ❖ 僅供特殊時機才使用之管線
- ❖ 長跨距管線



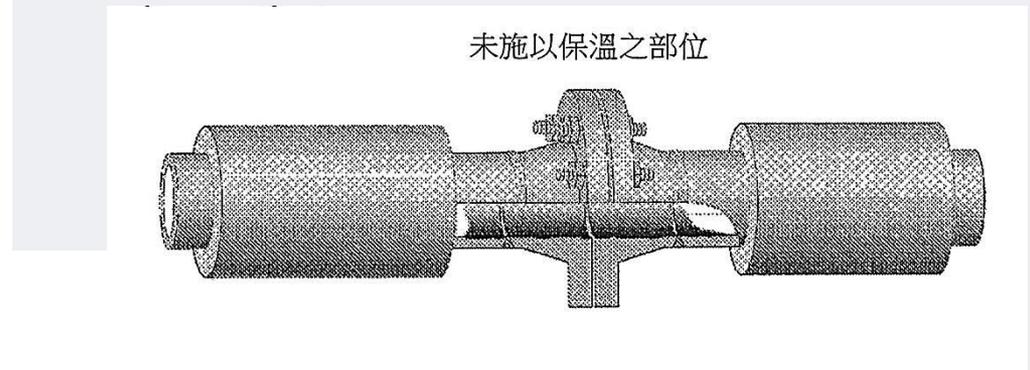
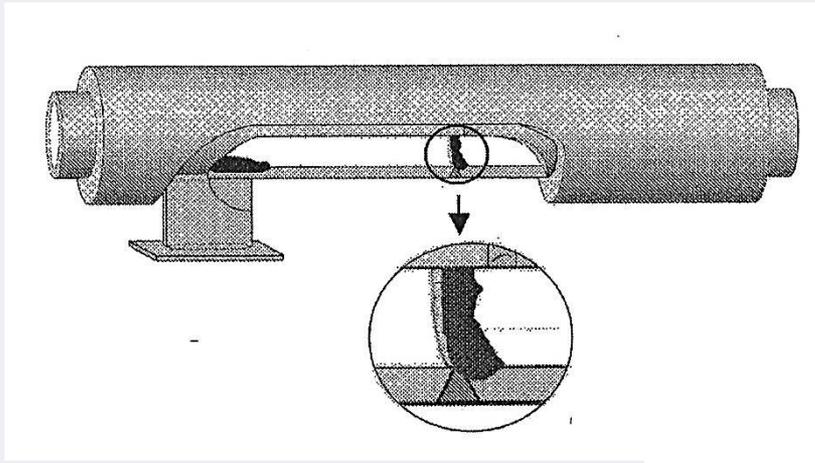
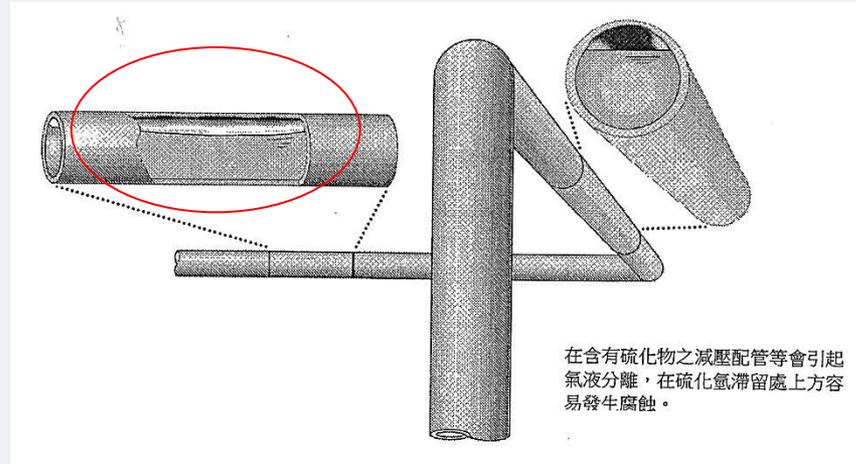
在長導管之可撓部容易滯留排泄物，在其下方引起腐蝕



# 常見之管線流體滯留區

❖ 蒸發點

❖ 局部凝結點



# 流體滯留區風險排序

- ❖ 向下管段 > 水平管段 > 向上管段。
- ❖ 存在水溶液之酸性因子管段(例如硫化氫、鹽酸、硫酸.....)
- ❖ 存在水溶液易積污之管段
- ❖ 存在酸性因子大修進行steam purge之管線從未排放之drain
- ❖ 位於高溫管線最高點之vent
- ❖ 溫度大幅低於正常流體區段者
- ❖ 可能有結晶物或水冷凝析出者

# 保溫層下方腐蝕

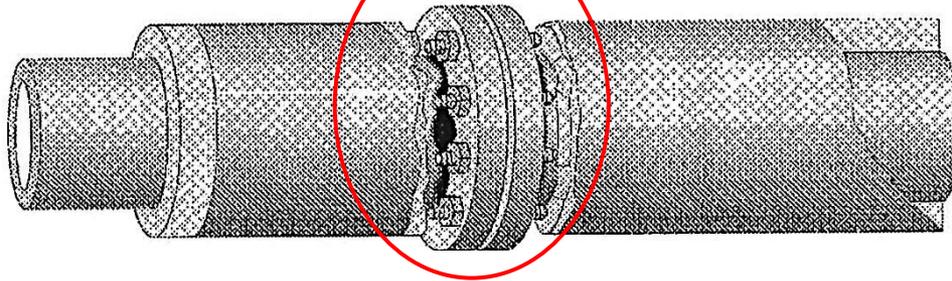
- ❖ 操作溫度介於 -4~175°C 範圍的碳鋼管線系統
- ❖ 正常操作溫度超過 175°C，但只間歇性操作的碳鋼管線
- ❖ 操作溫度介於 65~204°C 範圍的不鏽鋼管線，易遭受應力腐蝕龜裂
- ❖ 暴露在冷卻水塔溢出水氣的區域
- ❖ 在蒸氣排放裝置附近

# 保溫層下方腐蝕

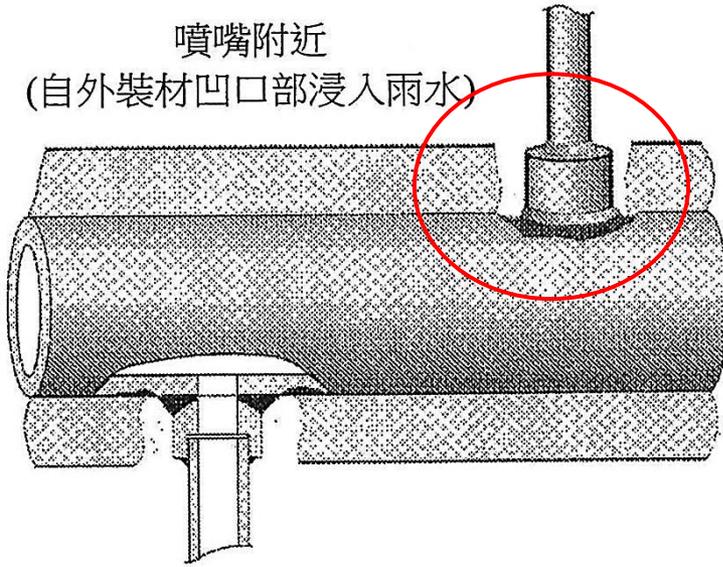
- ❖ 暴露於製程液體溢濺、溼氣和酸氣侵入的區域
- ❖ 暴露在經常灑水或淋雨(deluge)的區域
- ❖ 保溫鋁皮搭接錯誤區

# 保溫層下方腐蝕

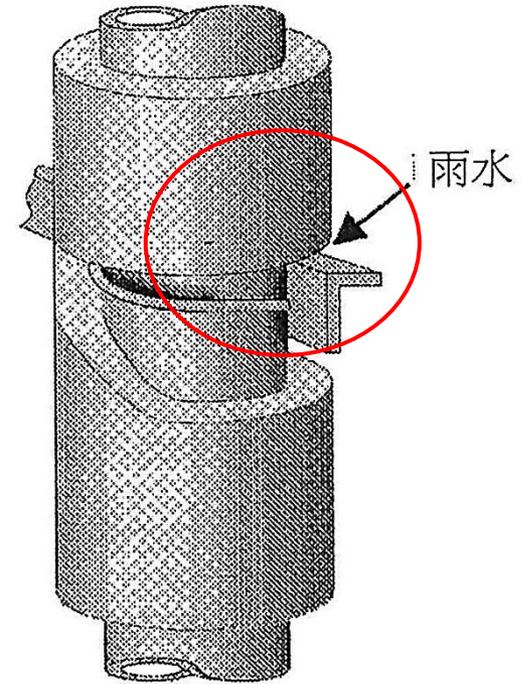
凸緣部(自外裝材端部浸入雨水)



噴嘴附近  
(自外裝材凹口部浸入雨水)

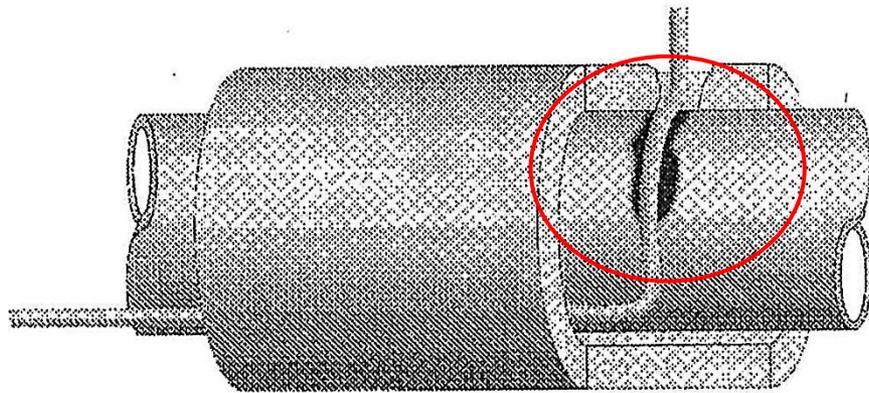


支撐安裝部  
(自外裝材凹口部浸入雨水)

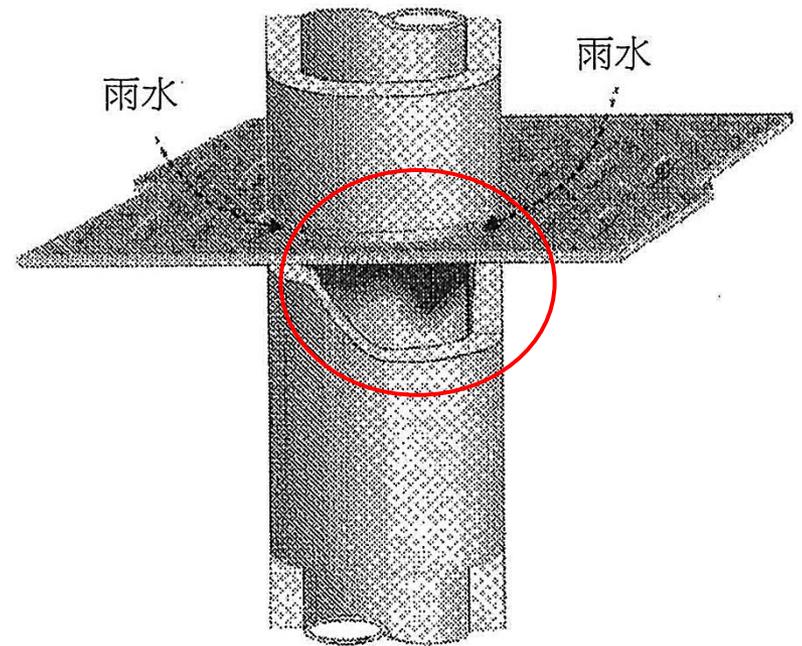


# 保溫層下方腐蝕

抱線入口-• 出口  
(自外裝材凹口部浸入雨水)

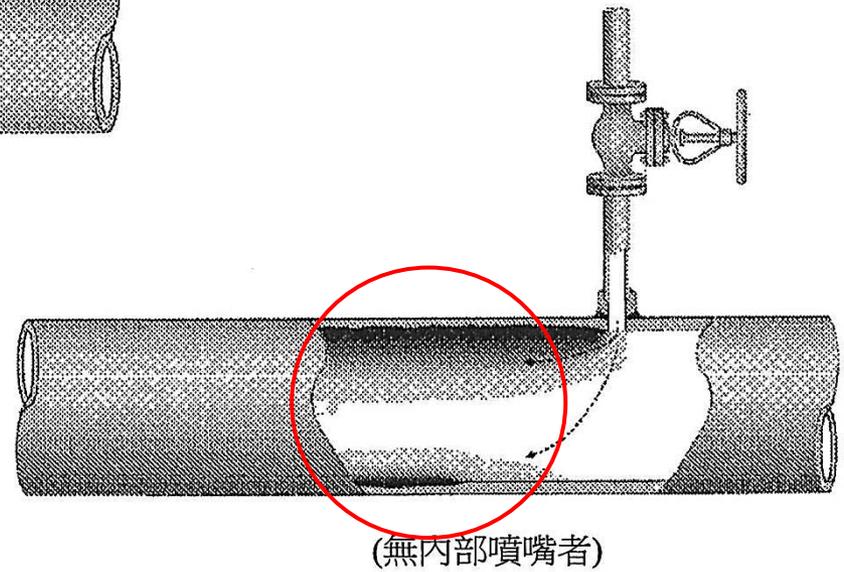
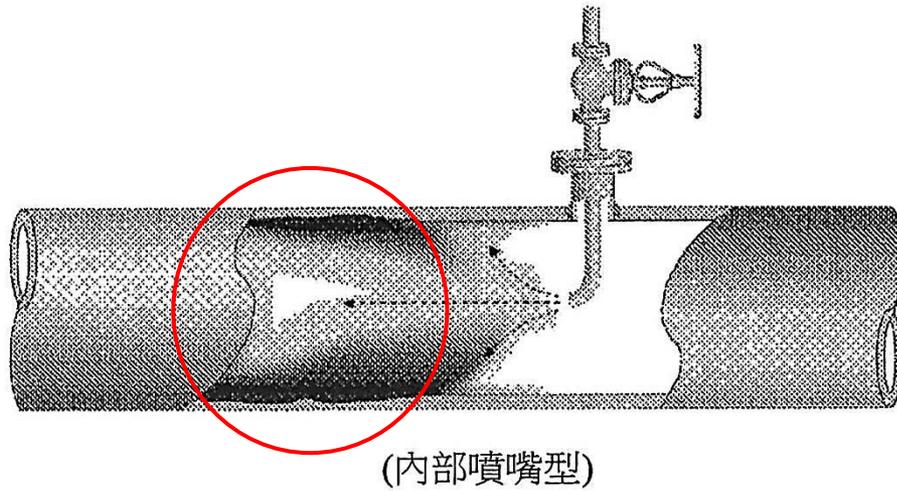


站台貫穿部  
(自外裝材端部浸入雨水)



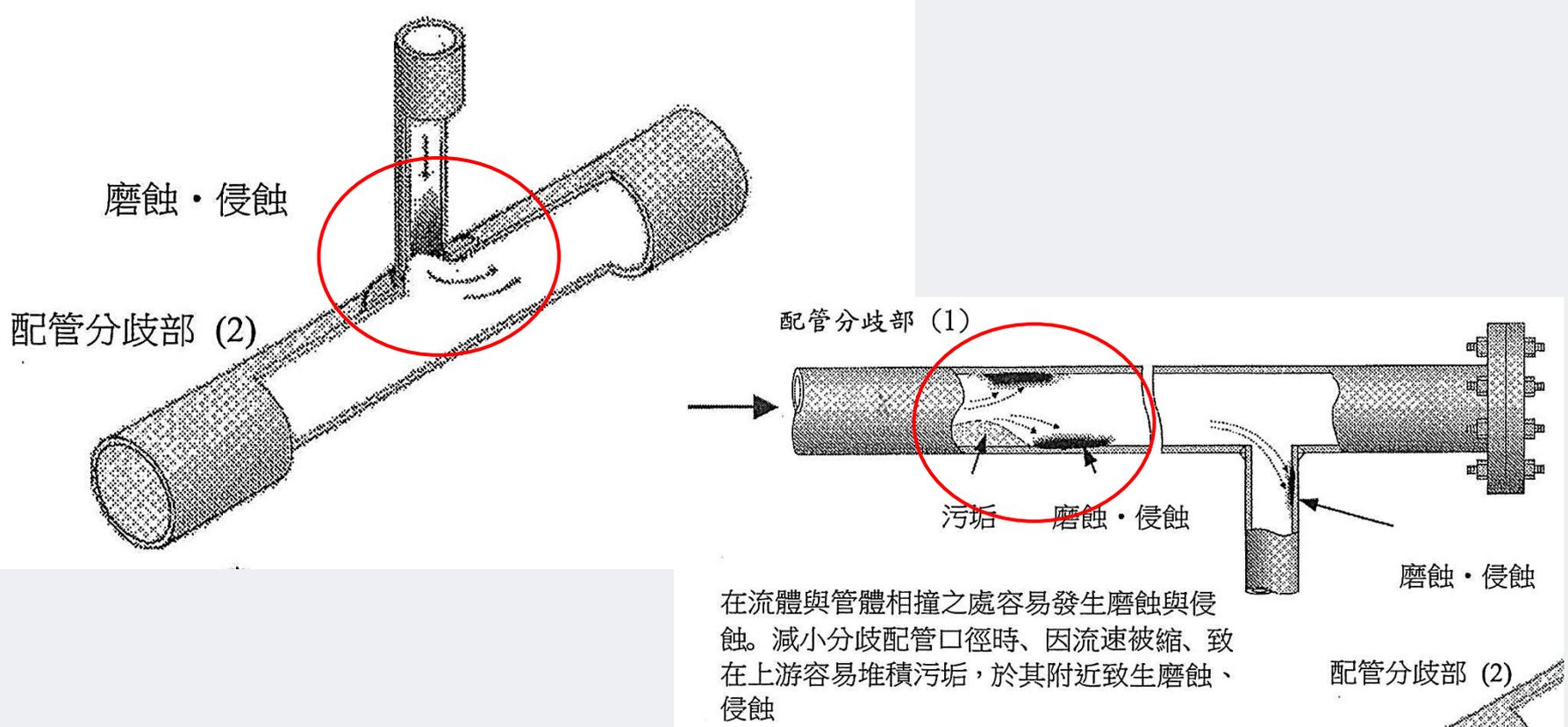
# 流態急速改變部位沖蝕

## ❖ 注入點



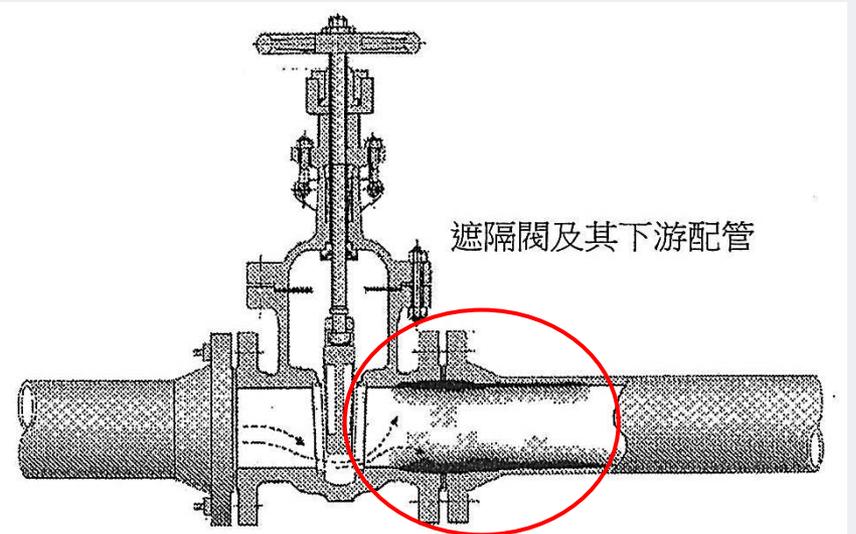
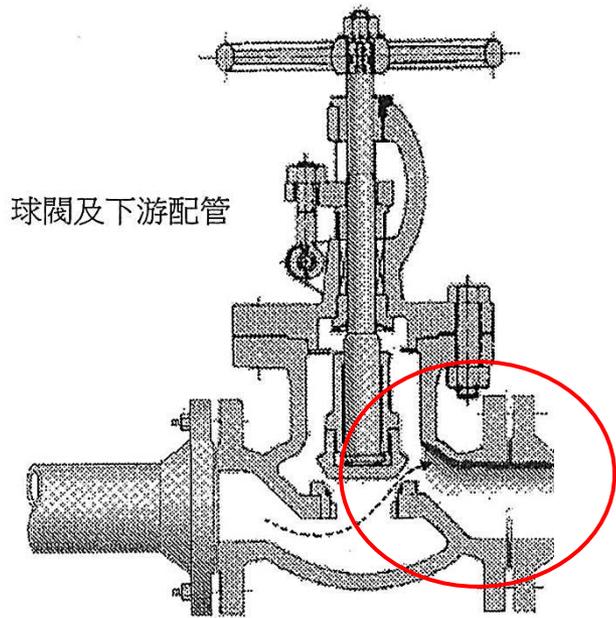
# 流態急速改變部位沖蝕

## ❖ 分歧點/匯合點



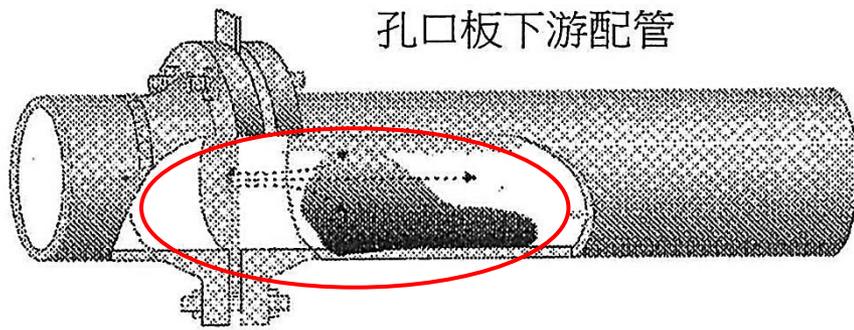
# 流態急速改變部位沖蝕

## ❖ 閥體後端

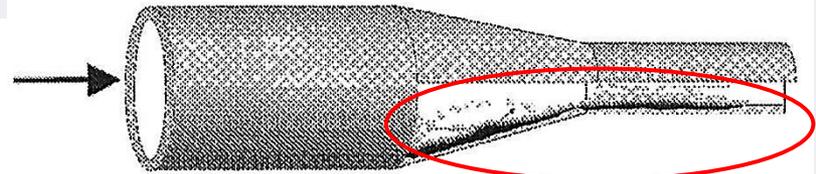


# 流態急速改變部位沖蝕

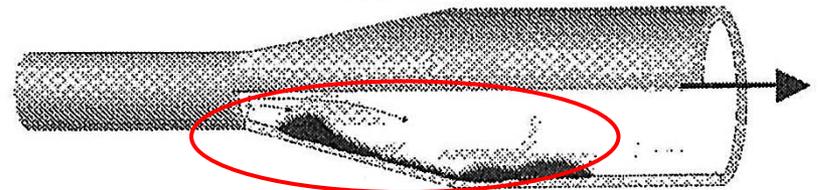
## ❖ 流動急變點



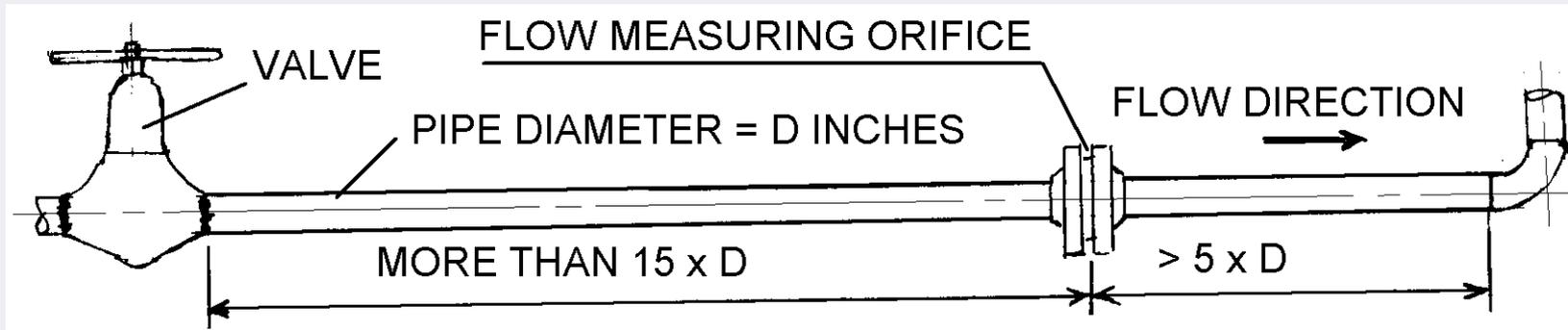
縮流管及其上游



擴張管及其下游



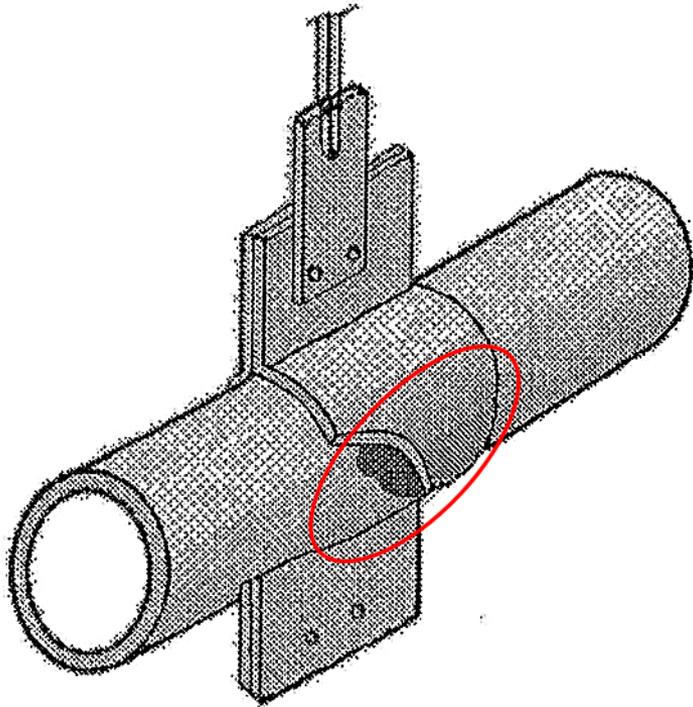
# 流態急速改變部位沖蝕



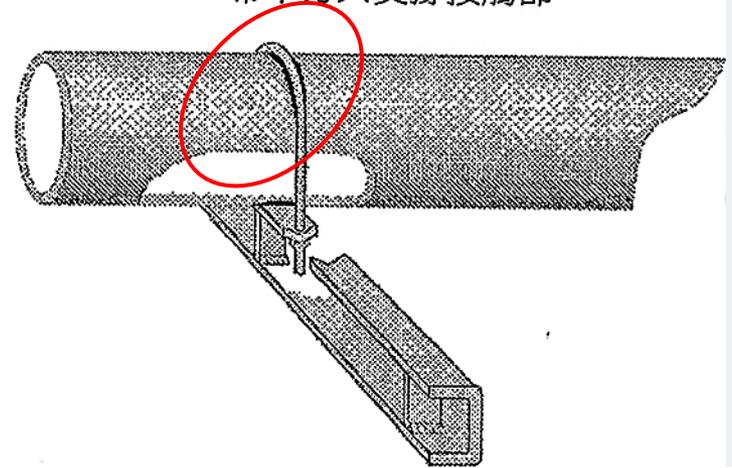
**Example of Straight length requirement for Flow Orifice**

# 管線支撐部位腐蝕

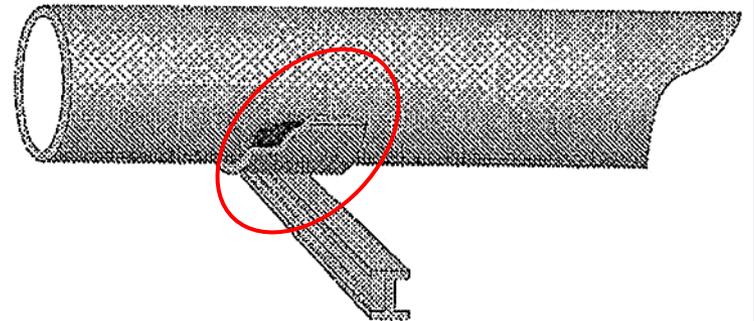
懸吊架支撐部



U帶下方與支撐接觸部



支撐滑板接觸部



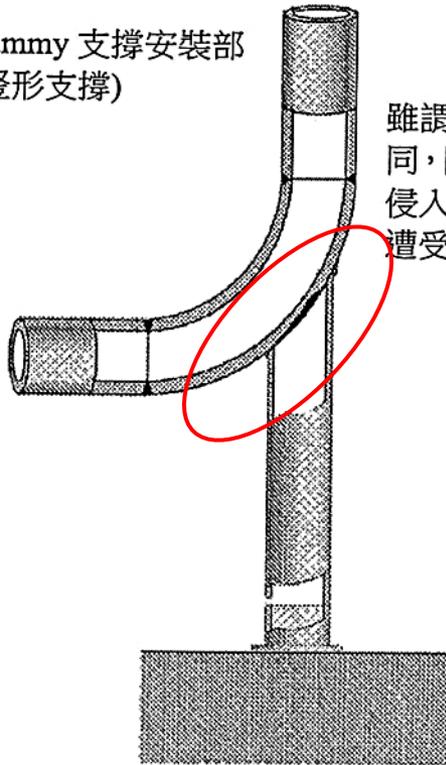
典型老化特徵

# 管線支撐部位腐蝕



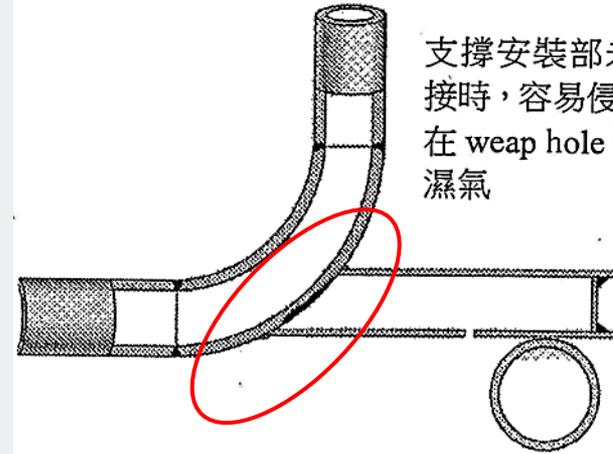
# 管線支撐部位腐蝕

dummy 支撐安裝部  
(豎形支撐)



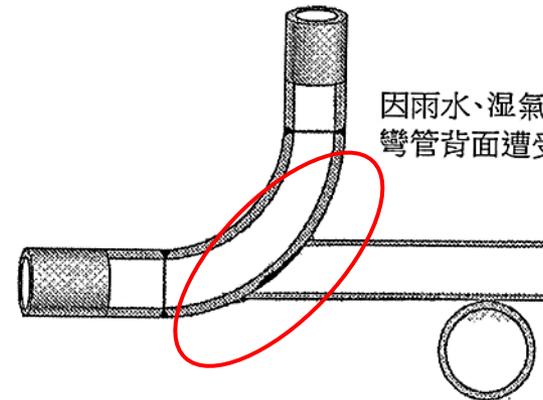
雖謂豎型，與上圖相同，因雨水或濕氣之侵入，致使彎管背面遭受腐蝕。

dummy 支撐安裝部(置端板)



支撐安裝部未施全周熔接時，容易侵入雨水，另在 weap hole 也容易侵入濕氣

dummy 支撐安裝部(未置端板)

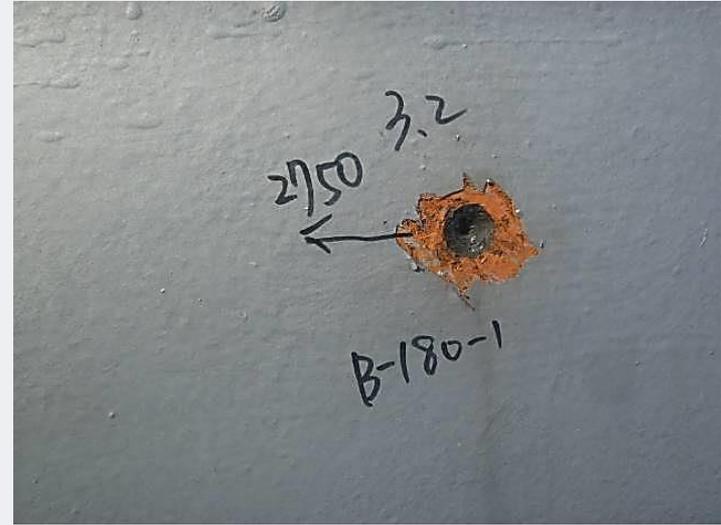


因雨水、濕氣之浸入致使彎管背面遭受腐蝕

# 管線支撐部位腐蝕



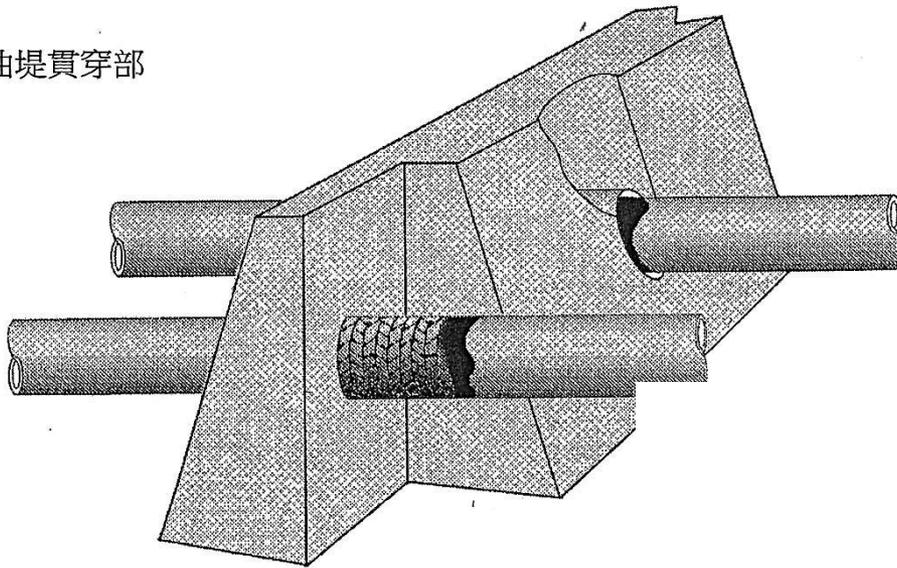
# 漆膜或包布劣化



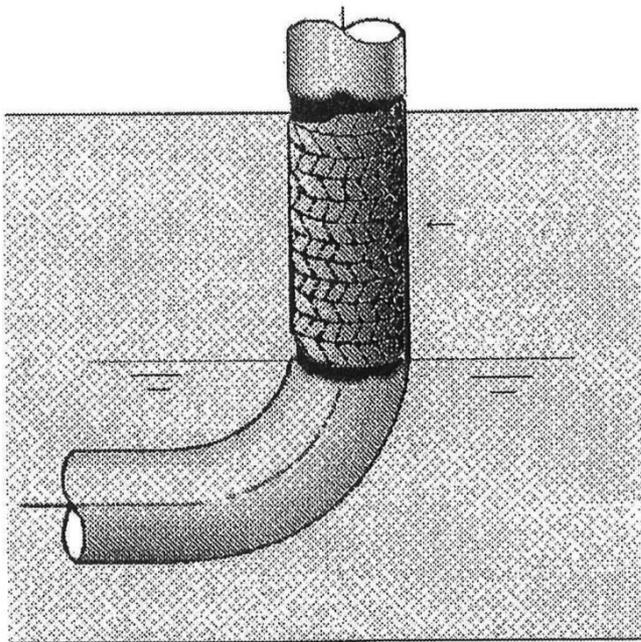
# 土壤/空氣介面腐蝕

## ❖ 管線穿牆

防油堤貫穿部



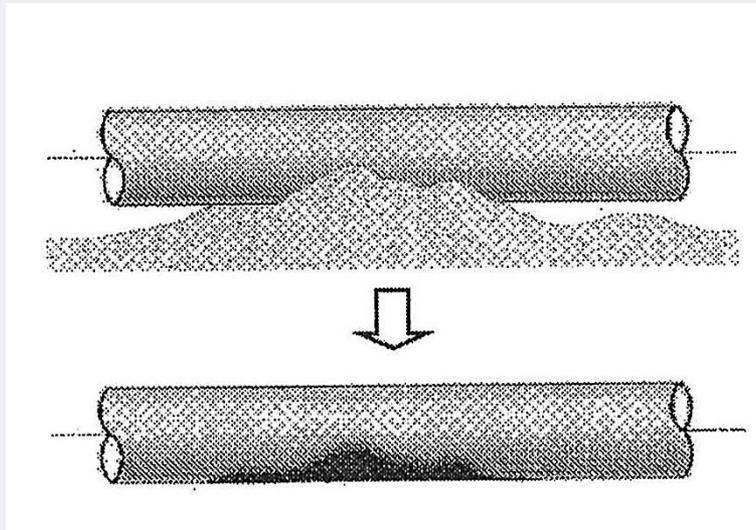
# 土壤/空氣介面腐蝕



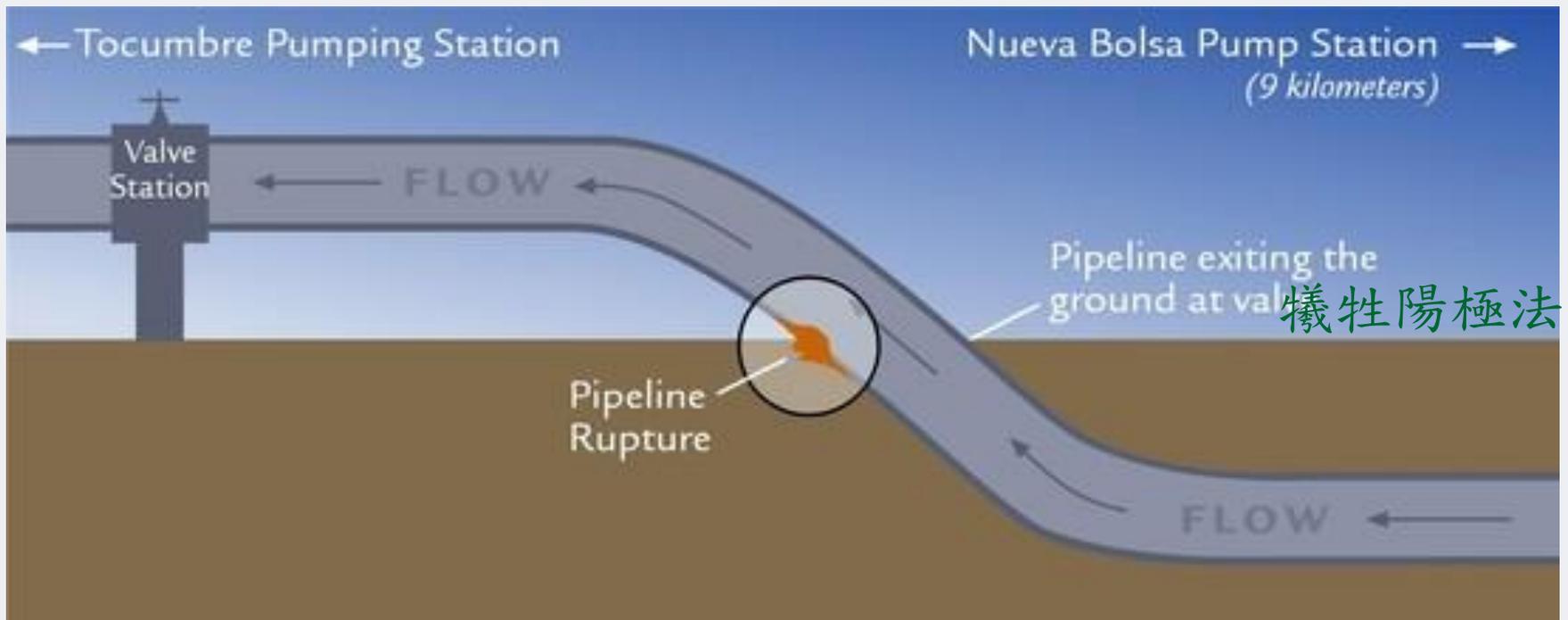
在地表面附近及防蝕帶端邊容易遭受腐蝕，尤其僅在地中部分捲繞防蝕帶者更應加留意，另外在地下水位附近也易受腐蝕



# 土壤/空氣介面腐蝕

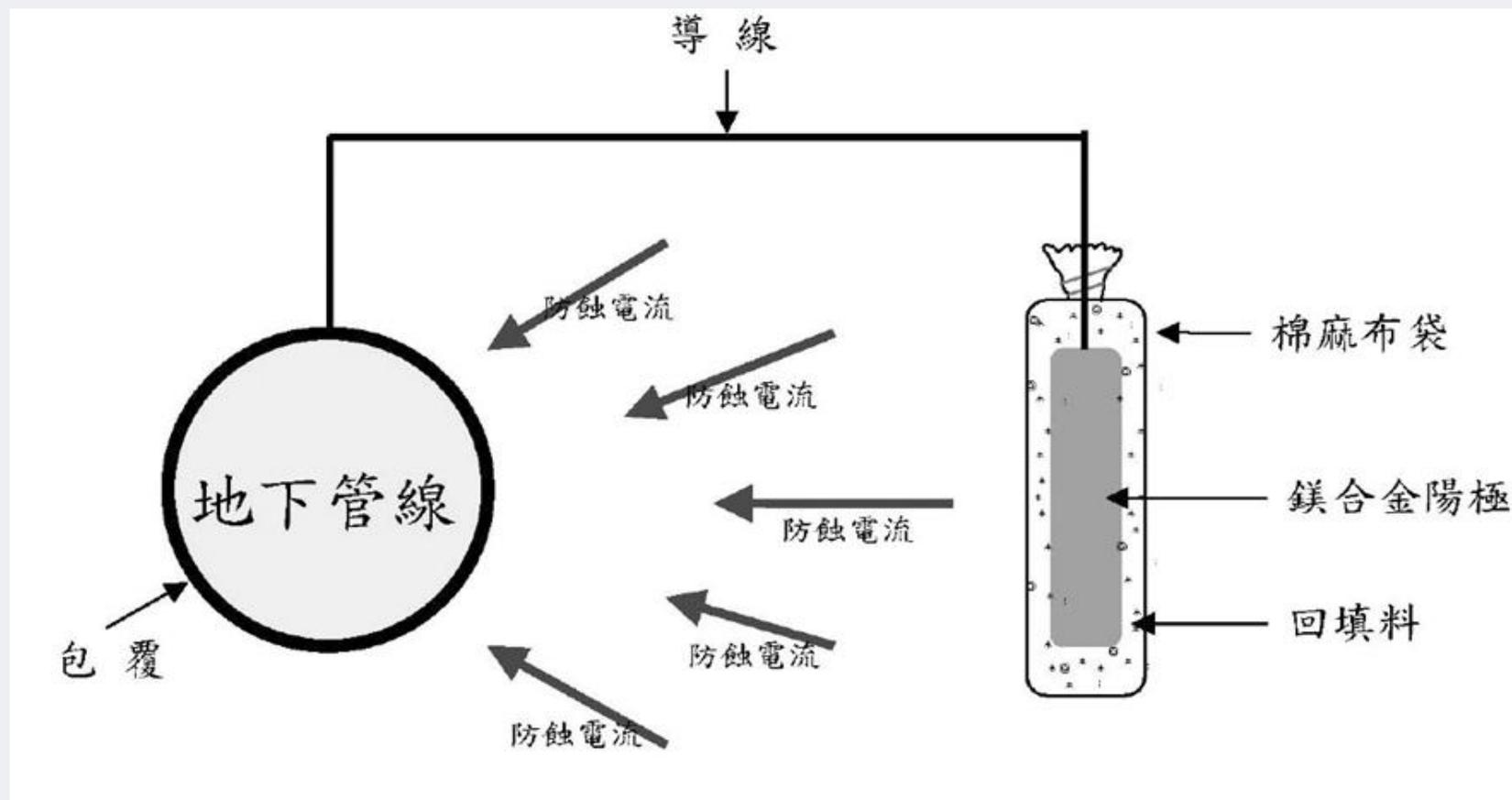


# 土壤/空氣介面腐蝕



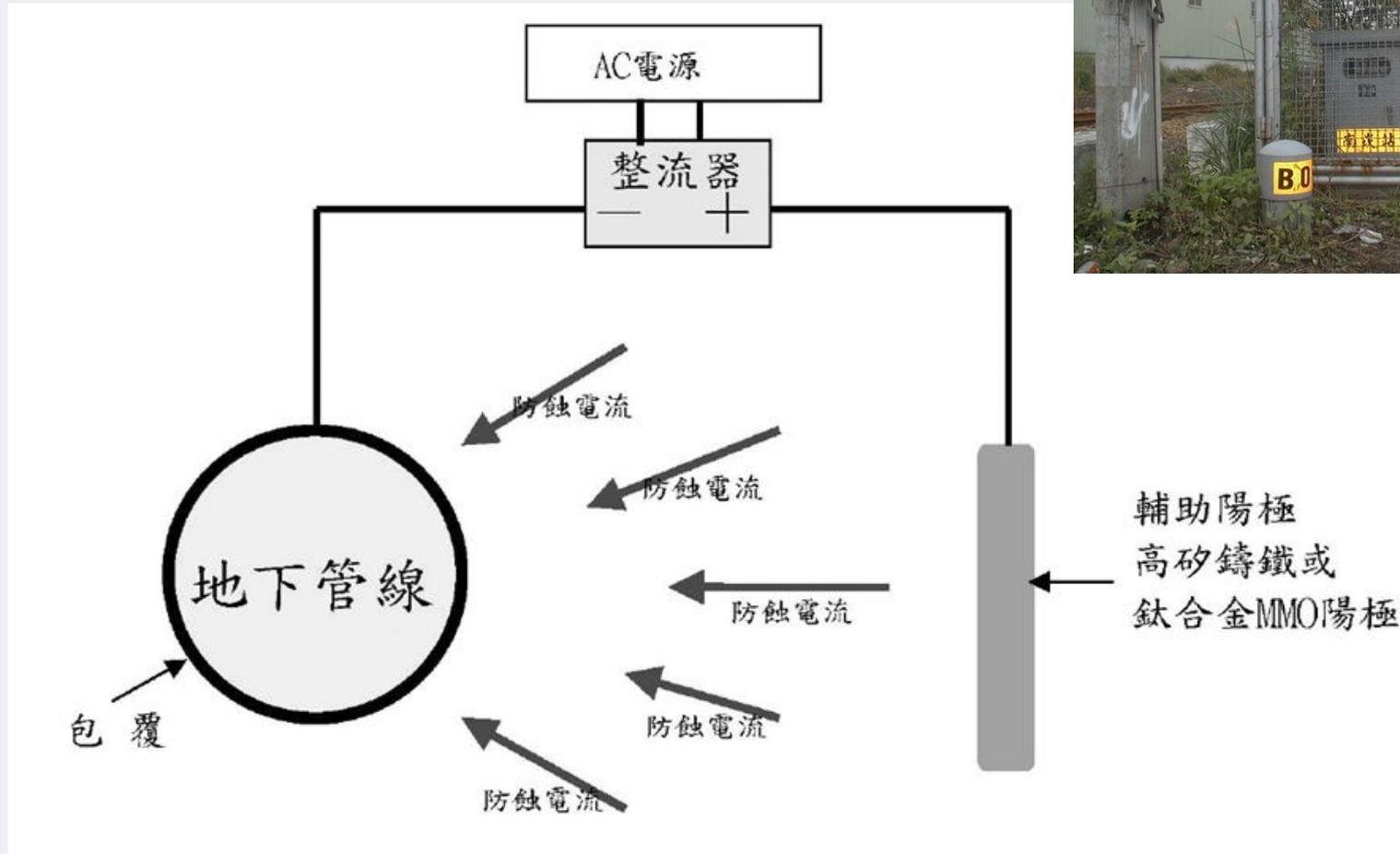
# 管線陰極防蝕裝置

## ❖ 犧牲陽極法



# 管線陰極防蝕裝置

## ❖ 外加電流法

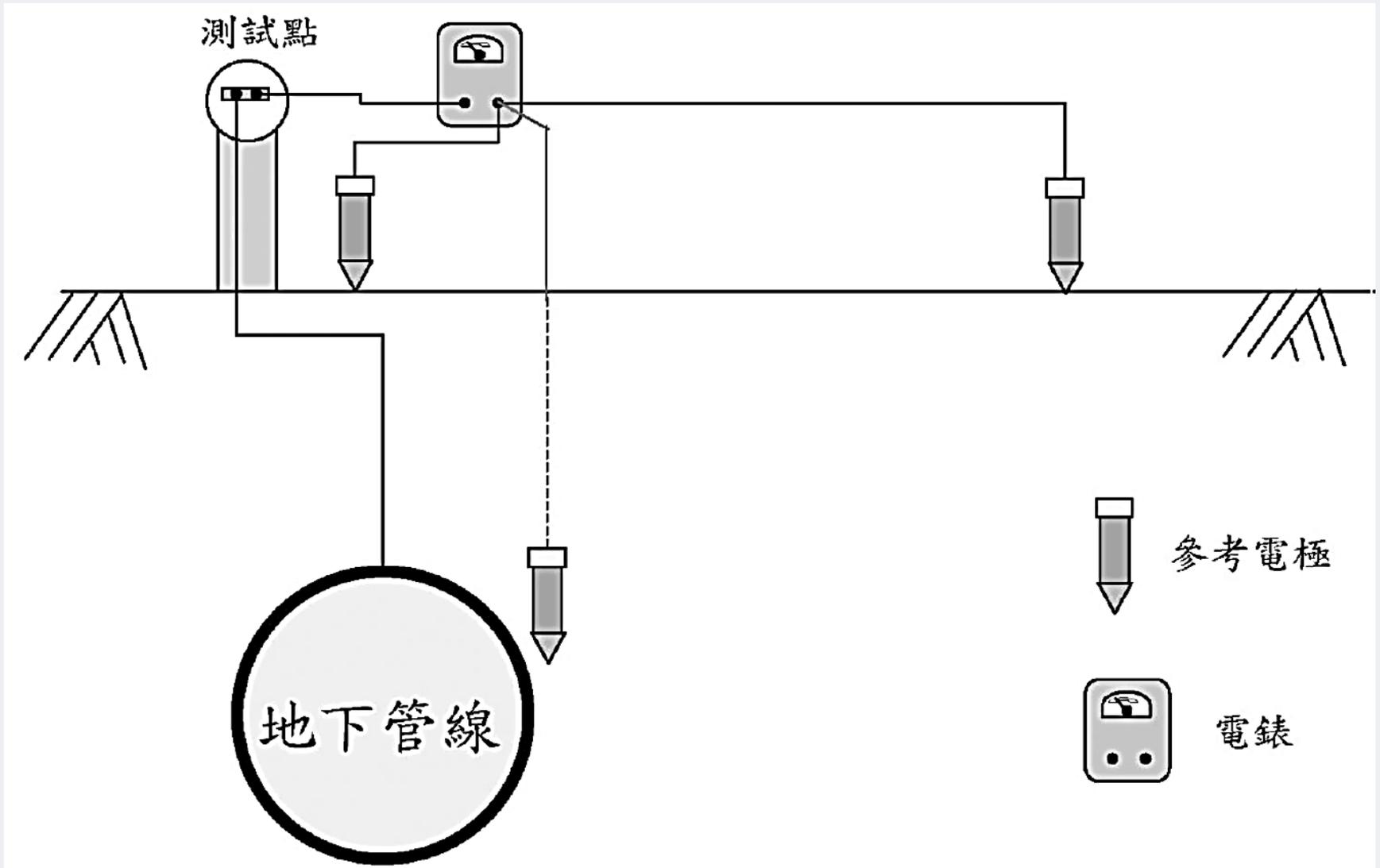


# 管線陰極防蝕裝置

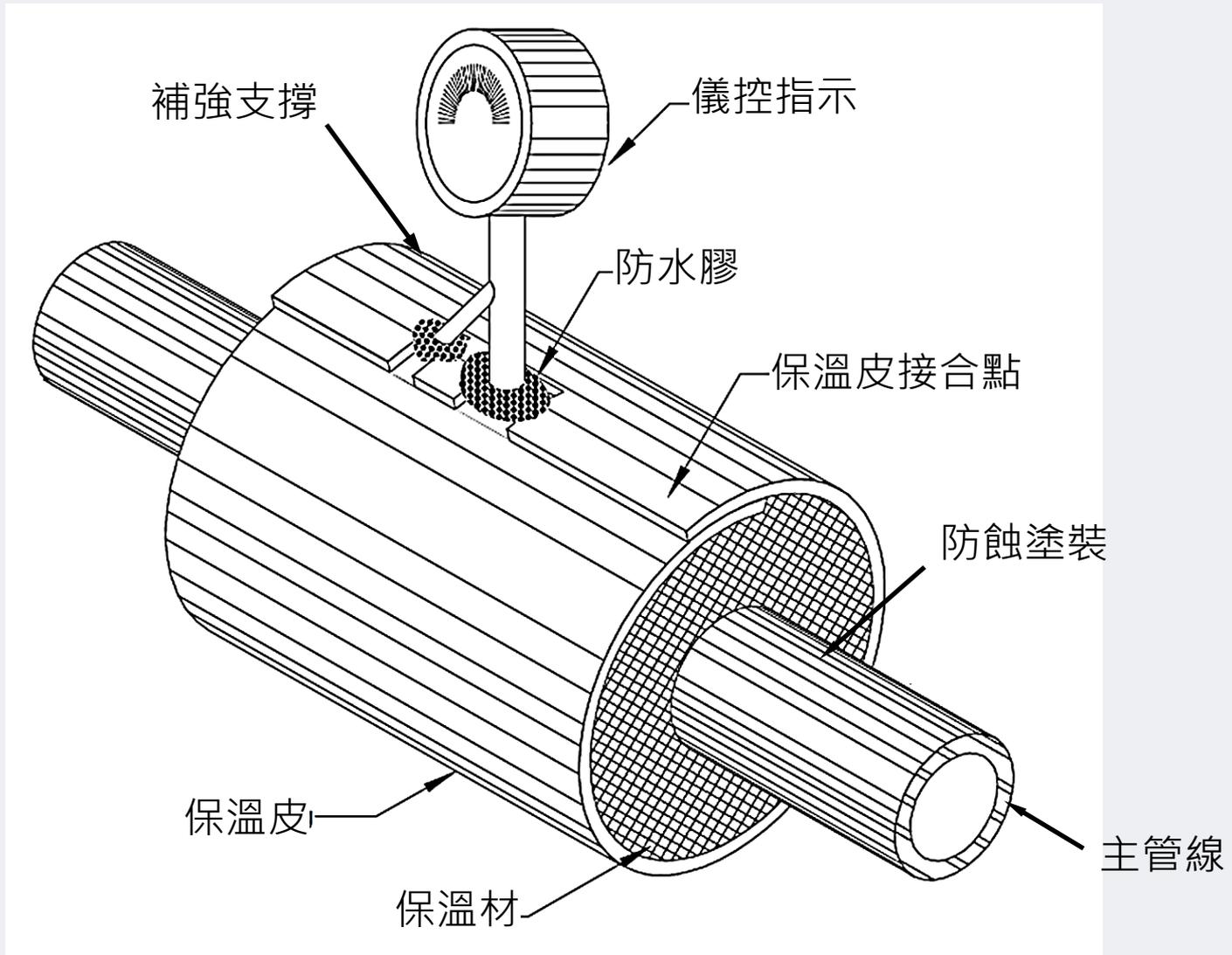


管線露頭處

# 管線陰極防蝕電位量測



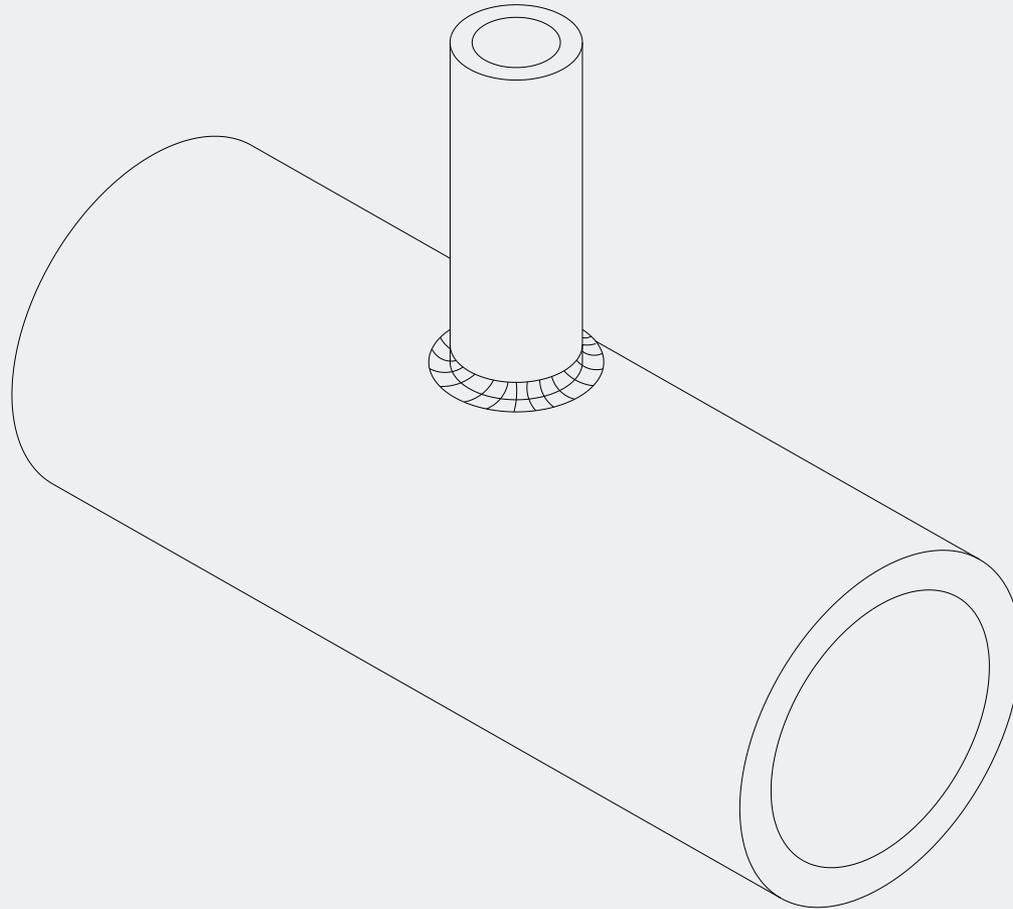
# 小管徑輔助管線的風險



# 流程功能

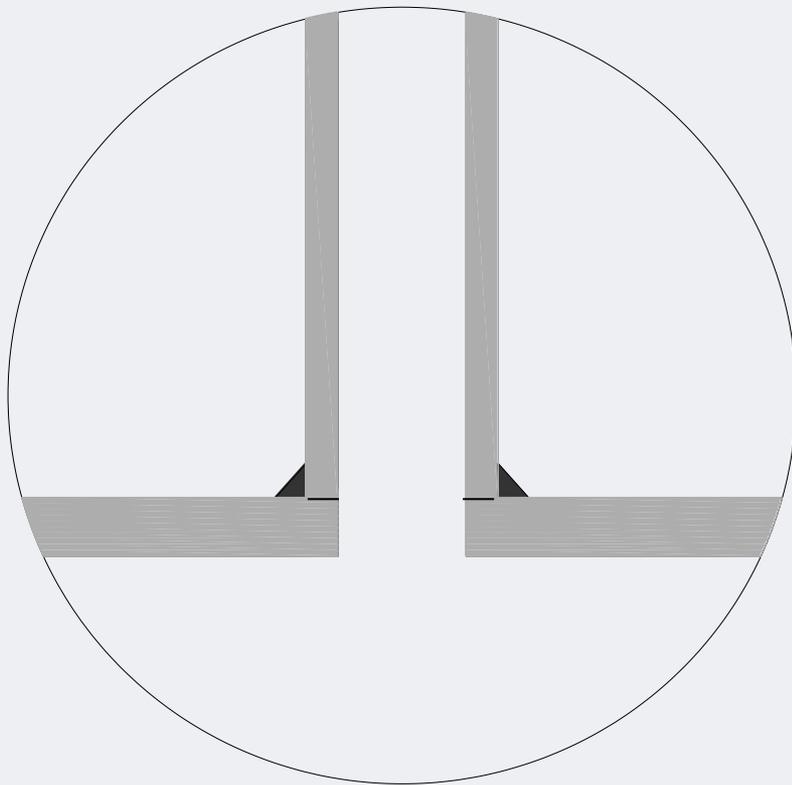
- ❖ 儀控銜接點
- ❖ 取樣點
- ❖ 平衡回流銜接
- ❖ 化學品注入點
- ❖ 排氣/排液專用
- ❖ 停爐吹噓銜接點
- ❖ 預留孔
- ❖ 其他理由.....

# 銜接點設計

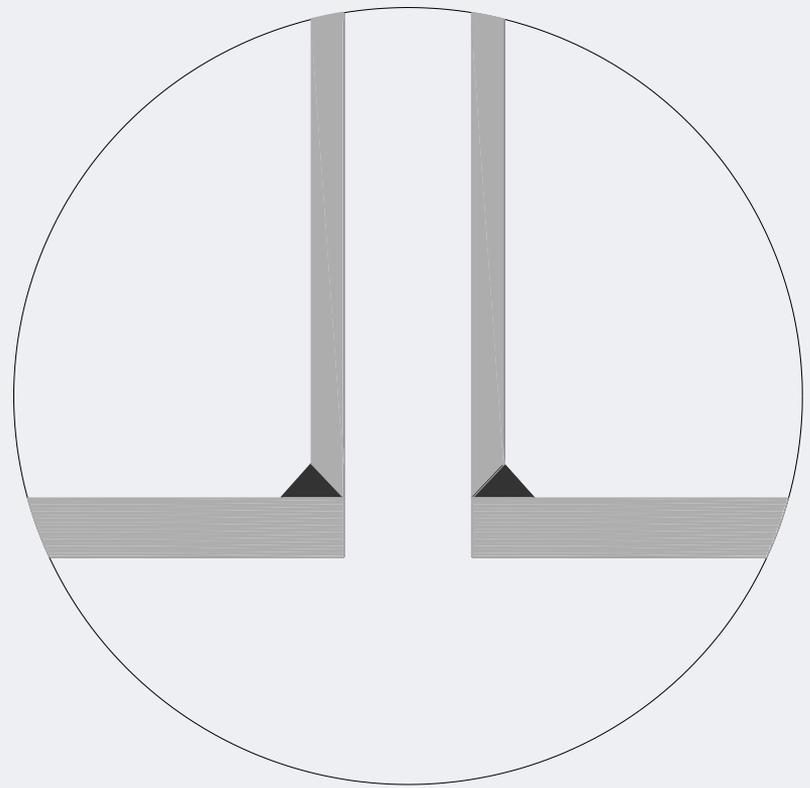


# 銜接點設計

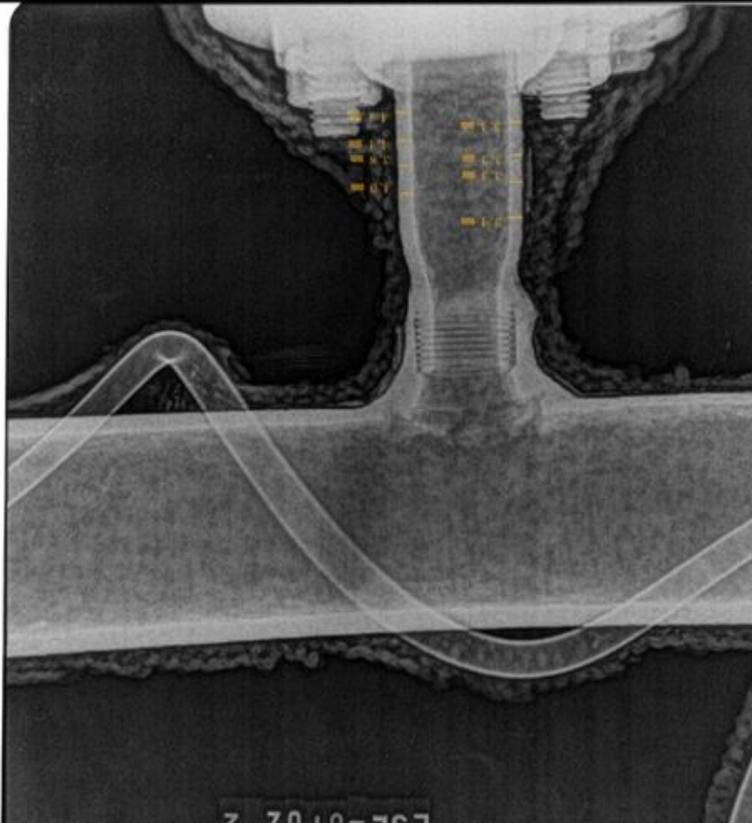
填角封焊



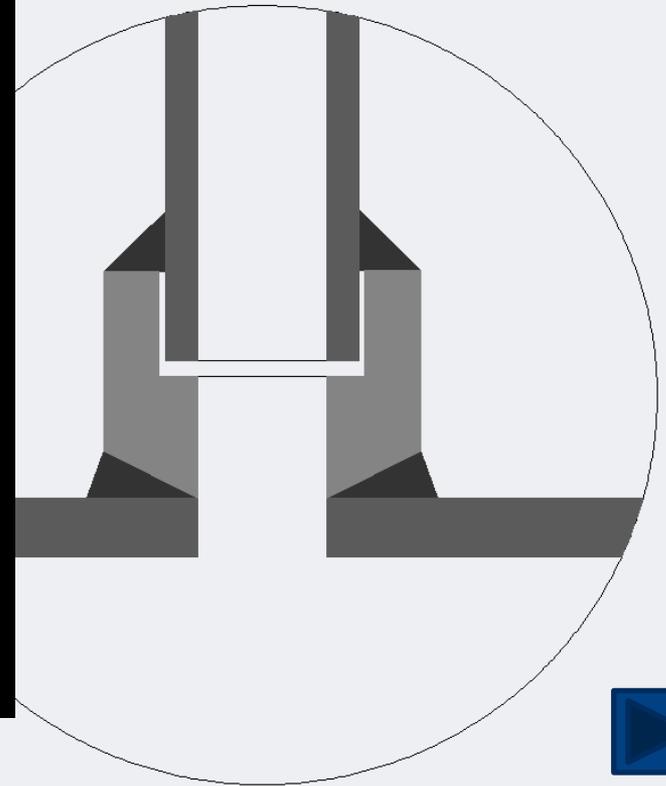
強力封焊



# 銜接點設計

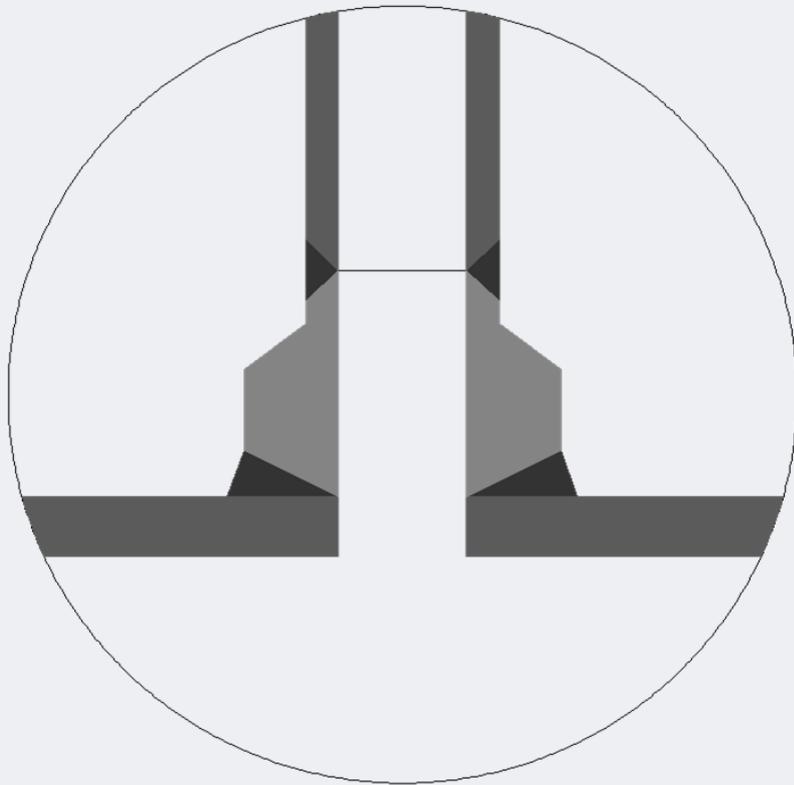


(Socket)



# 銜接點設計

騎接(Weldolet)



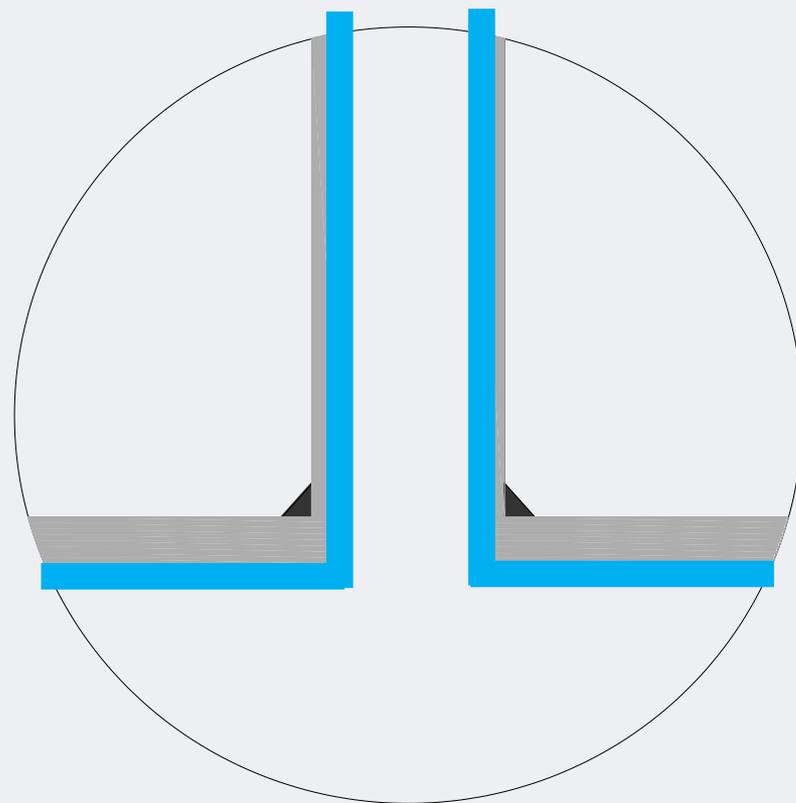
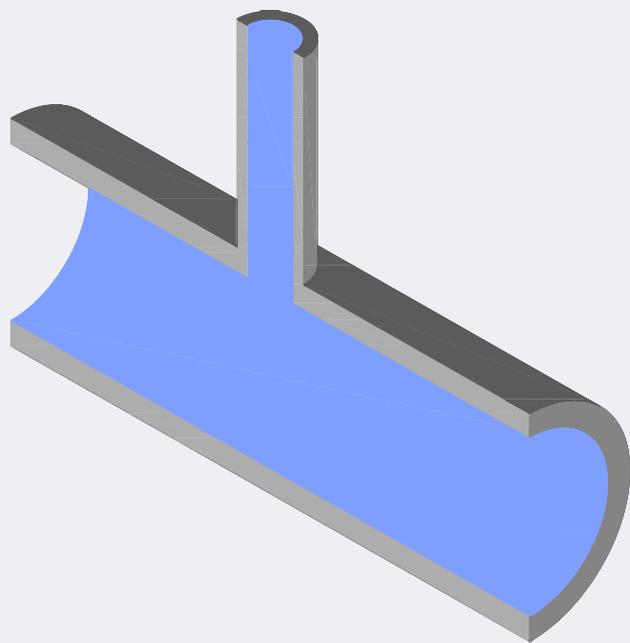
三通(Tee)



# 銜接點施工

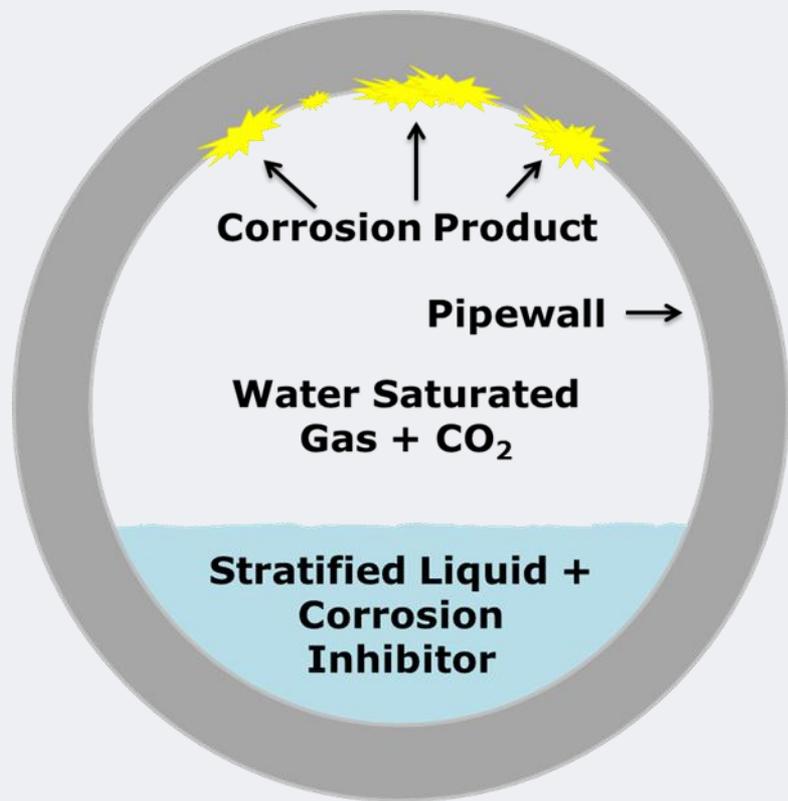
- ❖ 材料管制
- ❖ 特定管徑及姿勢下之焊接技藝
- ❖ 銜接對心
- ❖ 熱處理效果
- ❖ 焊道檢查效果

# 腐蝕特性(內部均勻腐蝕)



# 腐蝕特性(內部局部腐蝕)

## 局部腐蝕特徵

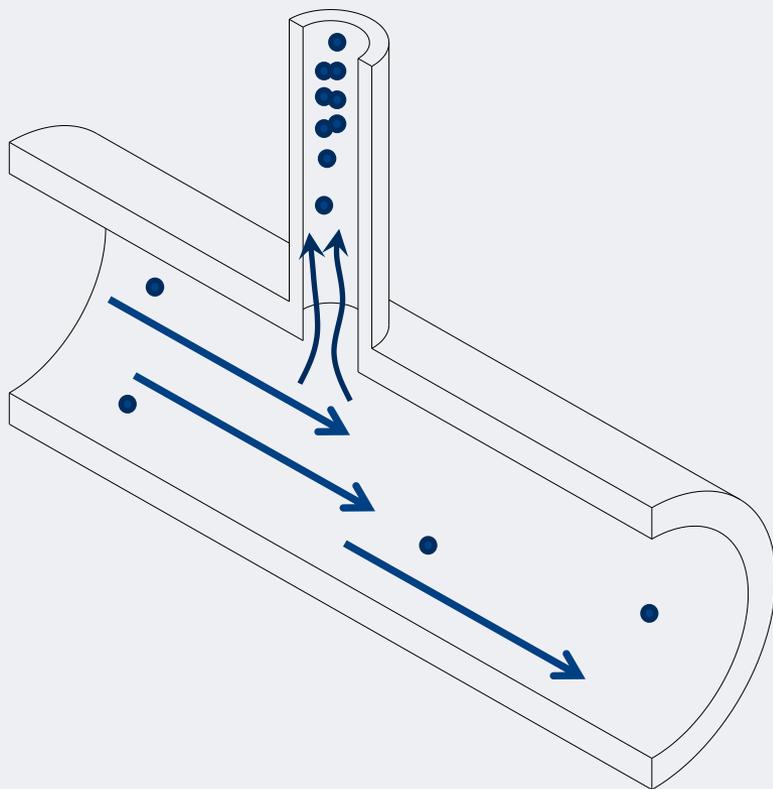


## 局部腐蝕及沉積物

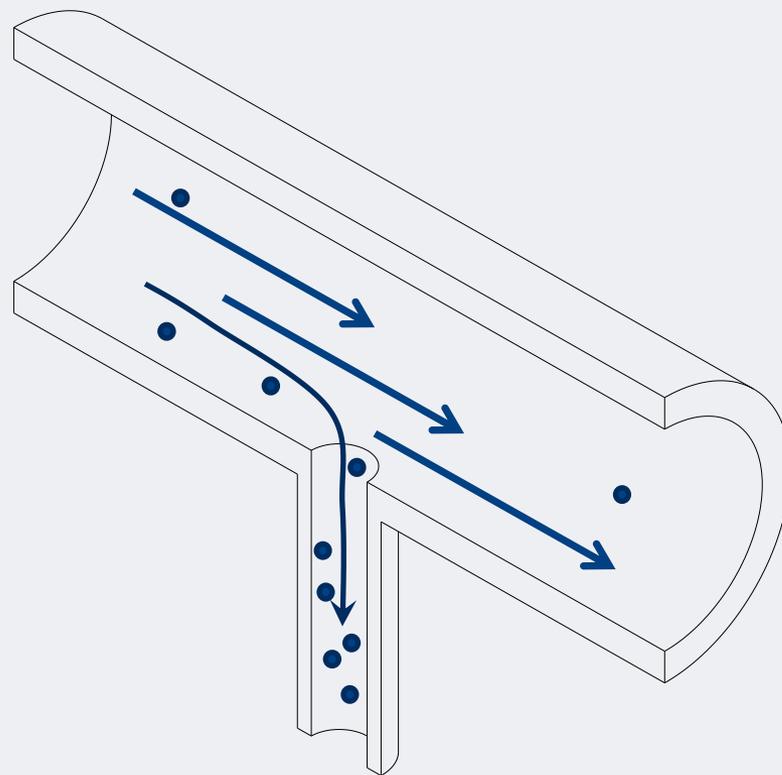


# 腐蝕特性(內部局部腐蝕)

排氣孔滯留區

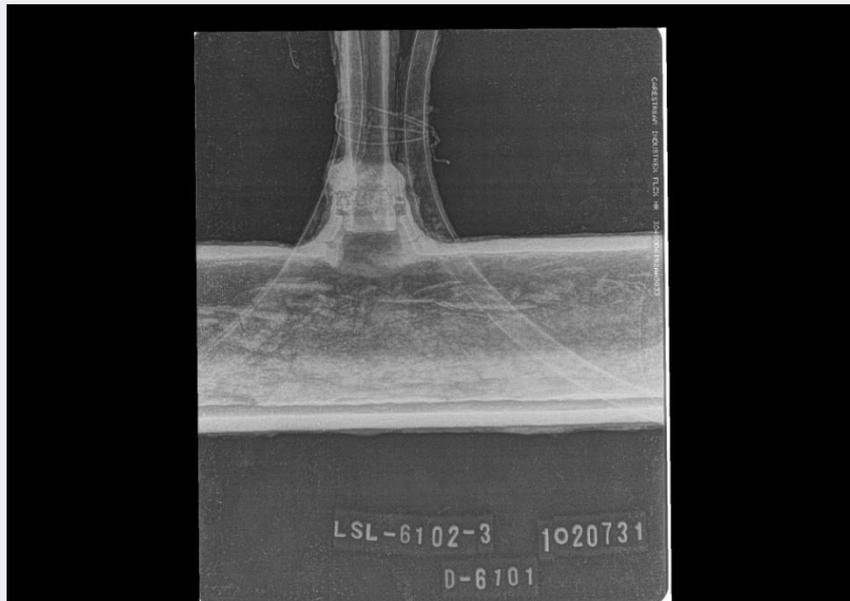


排液孔滯留區

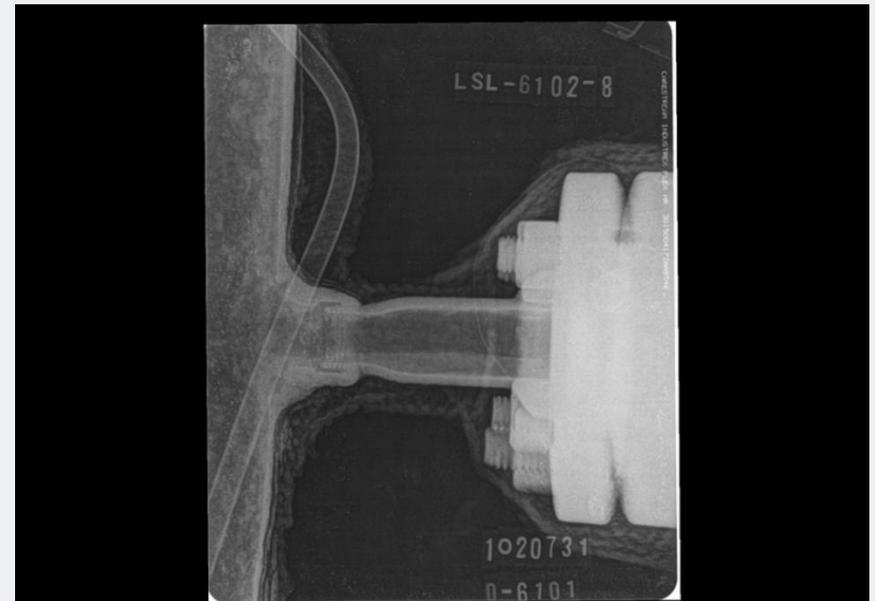


管線風險探討(從小管徑輔助管線的風險談起)  
腐蝕特性(內部局部腐蝕)

主管線內部沉積



插管內部沉積



# 腐蝕特性(外部腐蝕)

排氣管CUI

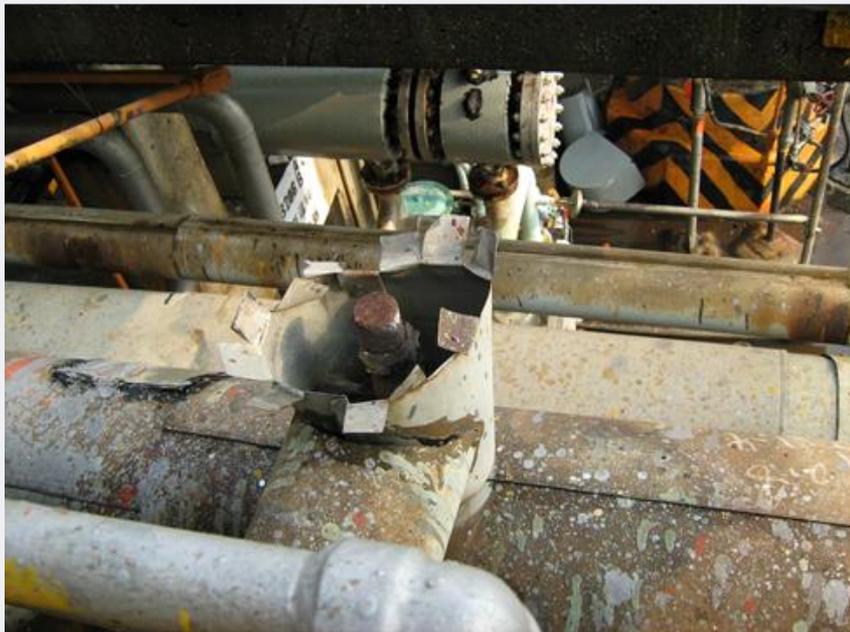


排氣管CUI



# 腐蝕特性(外部腐蝕)

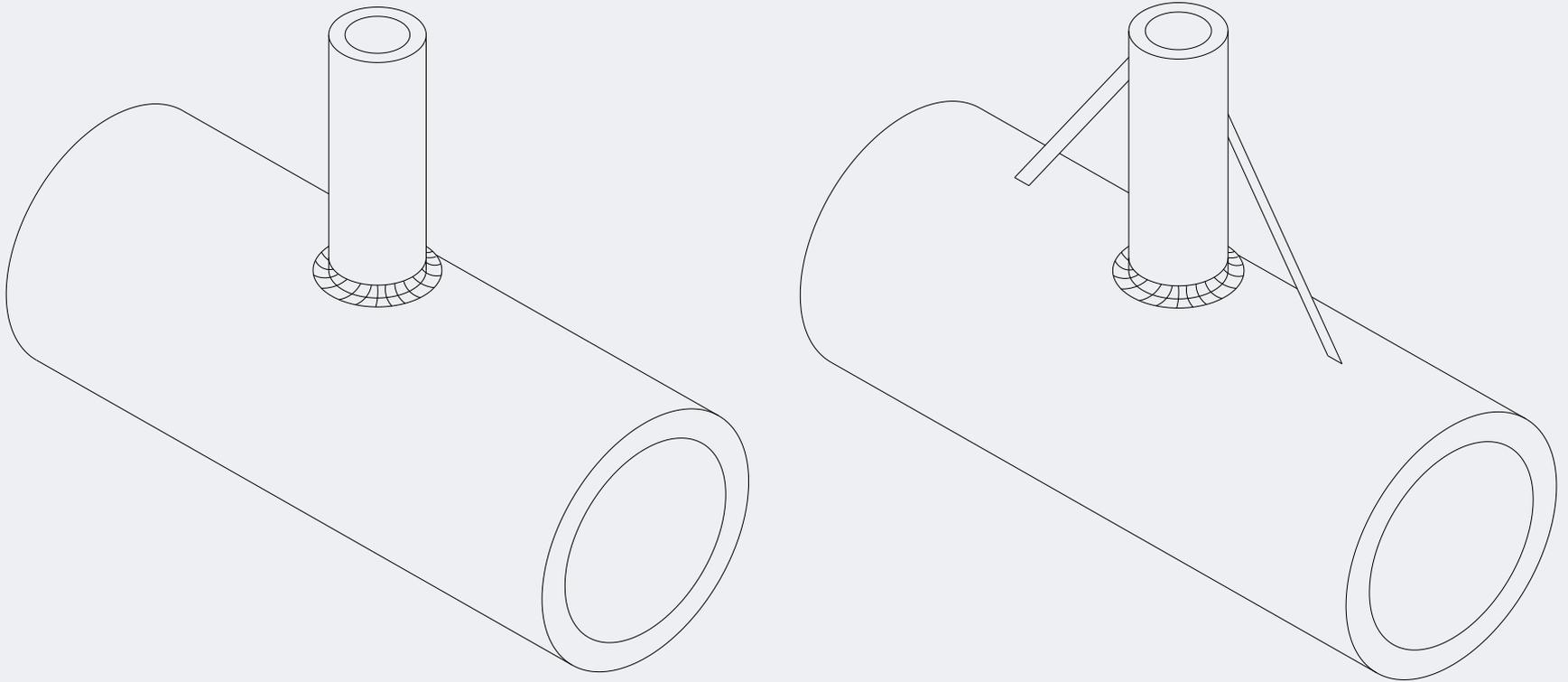
取樣管CUI



取樣管CUI



# 結構穩定度



# 結構穩定度



# 結構穩定度

排液管補強支撐龜裂



補強措施



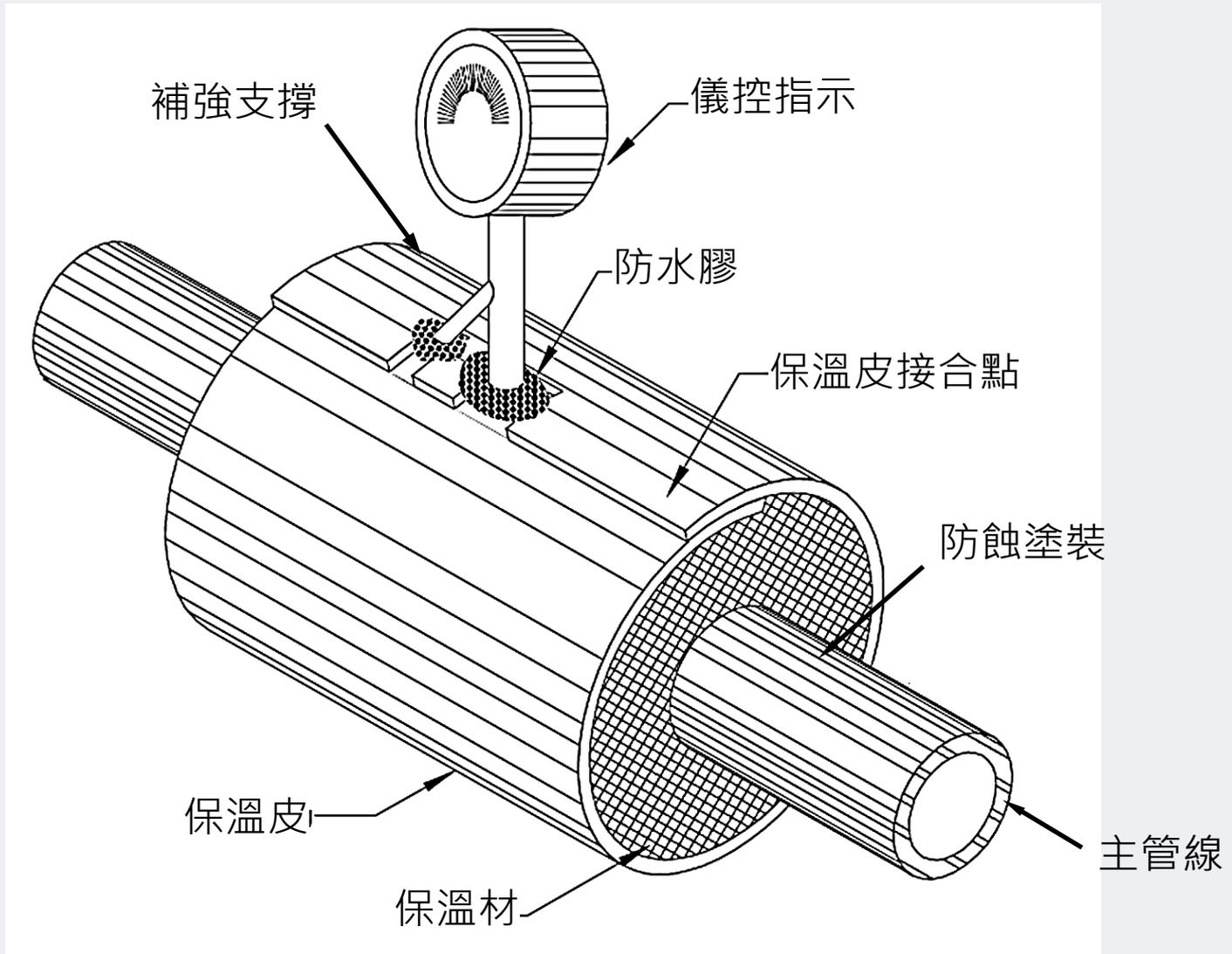
# 安全設計與裝置

- ❖ 搬運機扯斷丙烯系統小型排水閥
- ❖ 丙烯洩漏蒸發擴散形成蒸氣雲造成爆炸

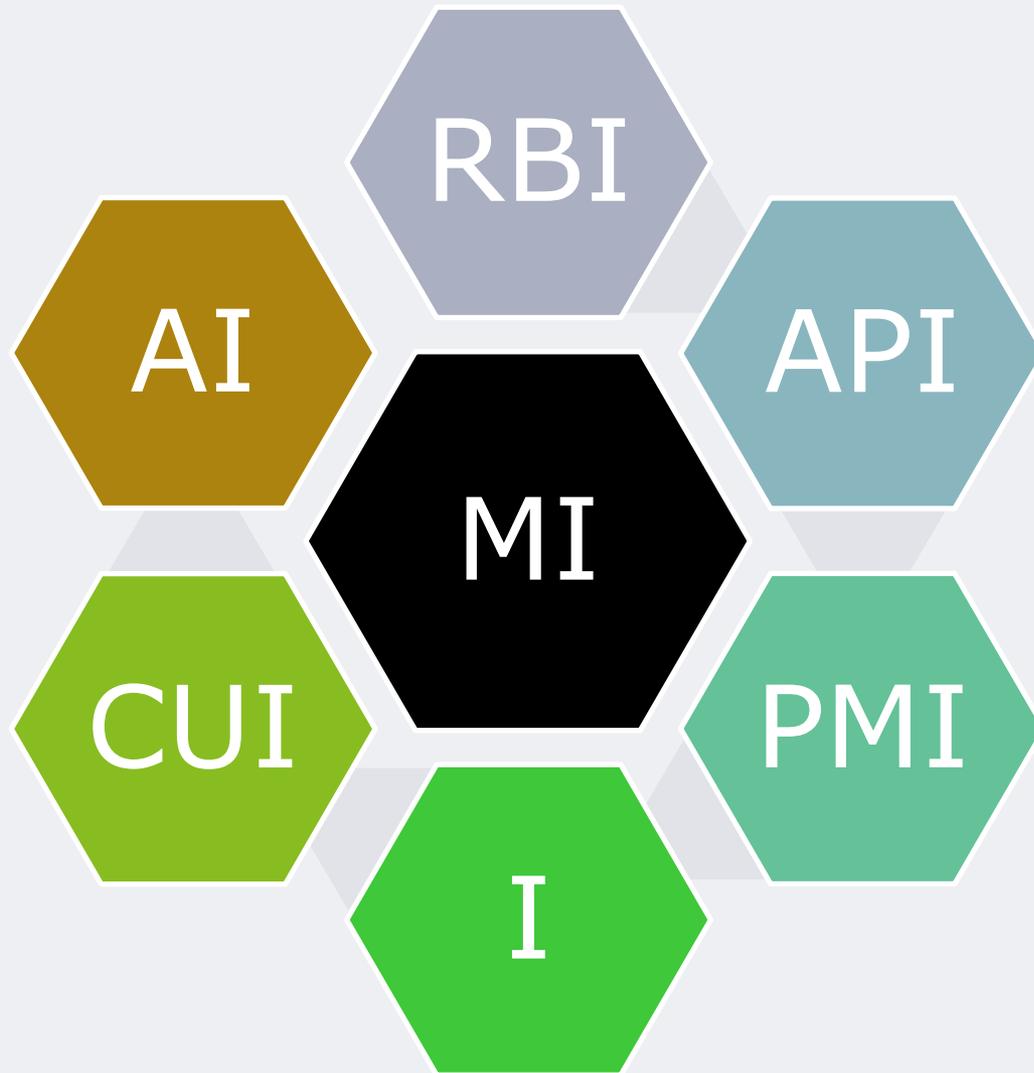


# 機械完整性管理

PMI  
CUI  
RBI  
MI



# 7個I



# 機械完整性考量面

1	<b>MOC</b>	11	Flare Systems
2	<b>PMI</b>	12	Training and Certification
3	Temporary Repairs	13	<b>Inspection Procedures</b>
4	Temporary Installations	14	Welding QA/QC
5	<b>Materials Degradation</b>	15	Qualified Suppliers
6	<b>Materials and Corrosion</b>	16	Fabrication QA/QC
7	<b>Environmental Cracking</b>	17	<b>Inspection Scheduling</b>
8	<b>Furnace Monitoring</b>	18	<b>Remaining Life Calculations</b>
9	<b>Brittle Fracture</b>	19	<b>Equipment Overdue</b>
10	<b>Record Keeping</b>	20	<b>Piping Inspection</b>

# 機械完整性考量面

21	<b>Injection Points</b>	31	Hot Spots
22	<b>Deadlegs</b>	32	Bull Plugs
23	<b>Thickness Measurements</b>	33	<b>Fatigue Failures</b>
24	<b>Small Bore Piping Inspection</b>	34	Flange Gaskets
25	Critical Check Valves	35	<b>Fitness for Service</b>
26	<b>Failure Reporting</b>	36	Cast Iron
27	<b>Inspection Recommendation Tracking</b>	37	Heat Tracing
28	<b>Risk Management</b>	38	<b>Soil-to-Air Interfaces</b>
29	<b>Corrosion Under Insulation</b>	39	Bundle Classification
30	<b>External Corrosion Prevention</b>	40	Wire Wrapping/Boxing

# 機械完整性考量面

41	Relief Valve Preopping	51	<b>Tank Bottom Inspection</b>
42	Hydrotesting Safety	52	Water Drop Out Points
43	<b>On-Stream Inspection</b>	53	Inspection Staffing
44	<b>NDE Specialists</b>	54	<b>ERW Pipe and Tubing</b>
45	<b>Carbon -1/2 Molly Equipment</b>	55	Process Contamination
46	Knowledge Transfer	56	<b>Inspection of Tank Roofs</b>
47	<b>Localized Corrosion</b>	57	Inspection of Inaccessible Locations
48	Hot Tapping	58	<b>External Chloride Cracking CUI</b>
49	Gray Zone Equipment	59	Process Creep
50	Pressure Relief Device Auditing	60	<b>Mixed Metallurgy Piping Systems</b>

## 機械完整性考量面

61	Third Party Equipment	69	Flange Bolting Procedures
62	<b>Corrosive Mix Points</b>	70	Valve Quality
63	<b>Dummy Leg Corrosion</b>	71	Surface Cleaning
64	Corporate Failure Memory	72	Bad Actor Pumps
65	<b>Ammonium Salts</b>	73	Plugged Vents on AST's
66	Hydrotest Water Quality	74	PWHT Problems
67	<b>Pipe Rack Inspections</b>	75	<b>Risk Based T/A Planning</b>
68	Total Cost of Ownership	76	<b>Failure Analysis</b>

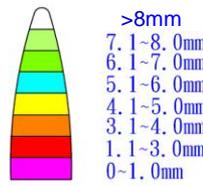
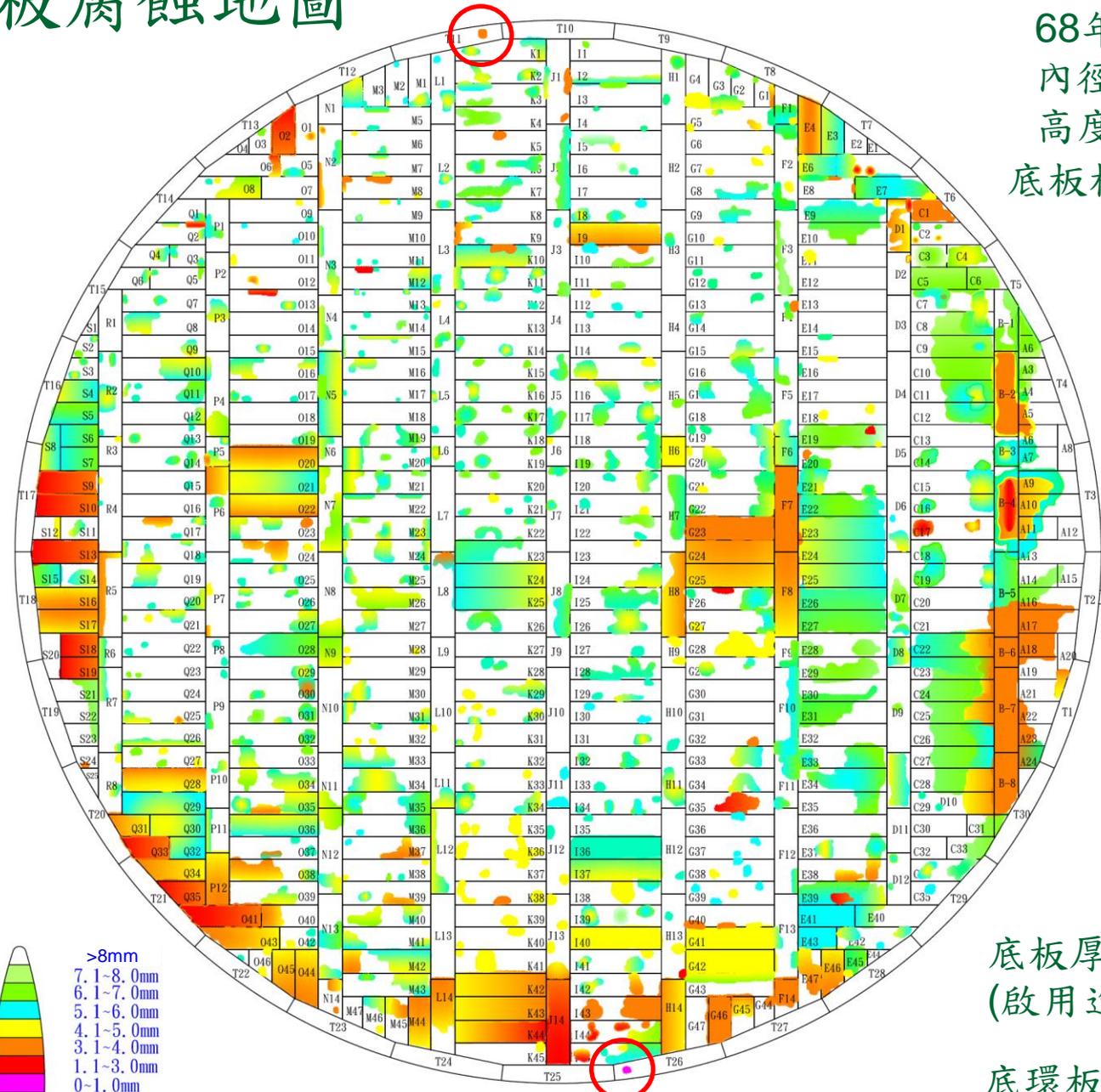
# 油槽底板腐蝕地圖

北

13萬公秉原油槽  
 68年10月啟用  
 內徑：110M  
 高度：15.24M  
 底板材質：A283C

西

東



36" 清掃孔

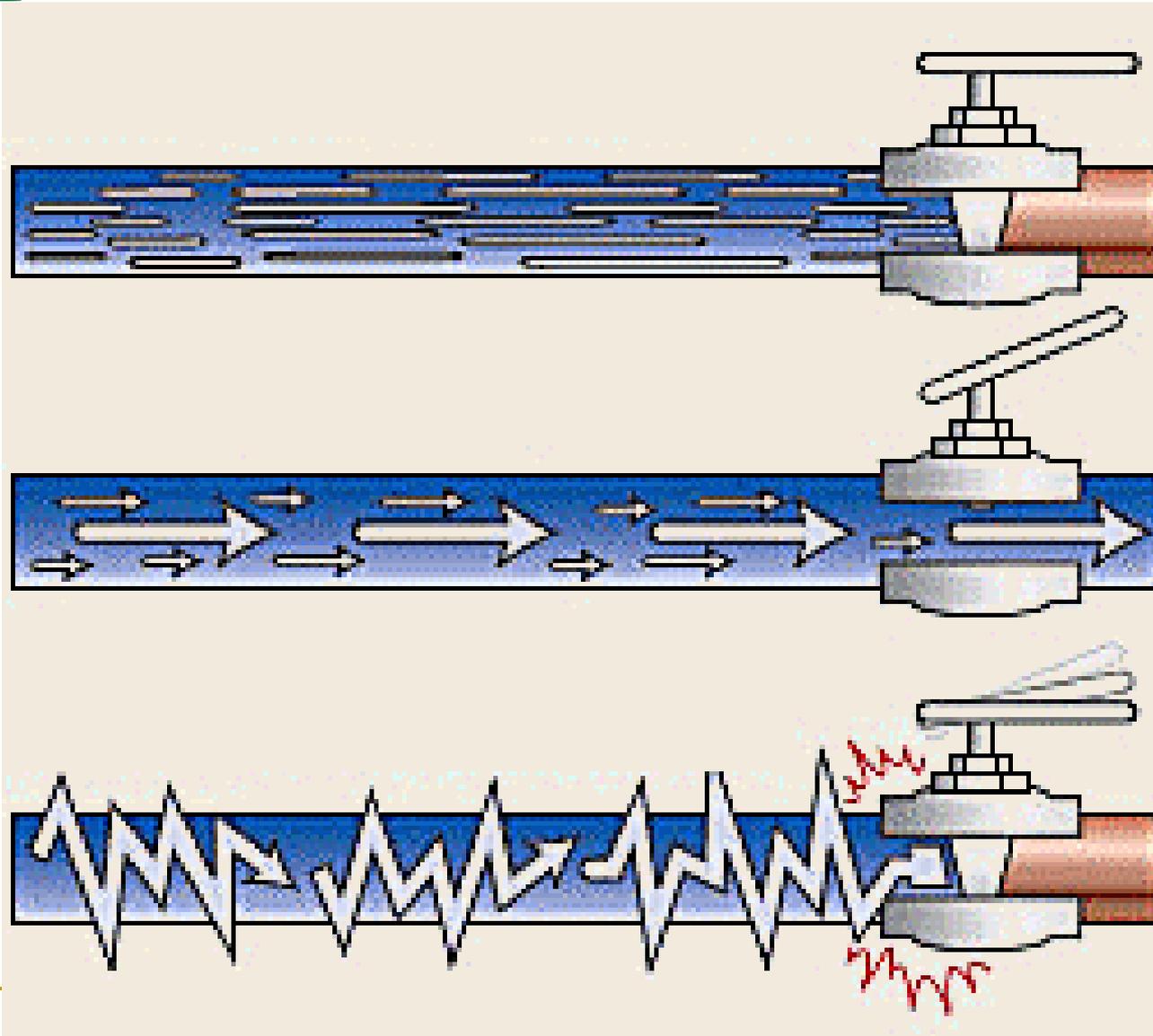
底板厚度：9.5mm  
 (啟用迄今不曾更換)

底環板厚度：14.3mm  
 (87年更新)

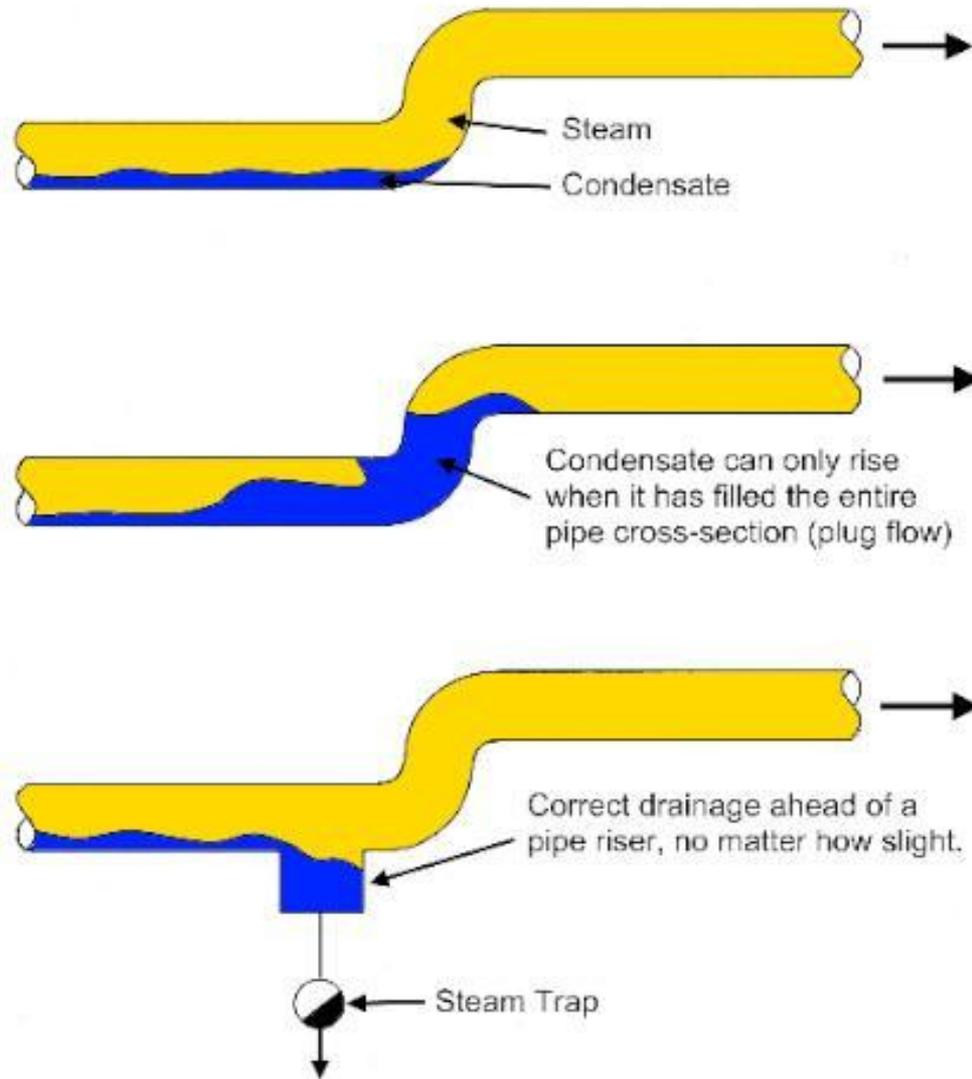
南

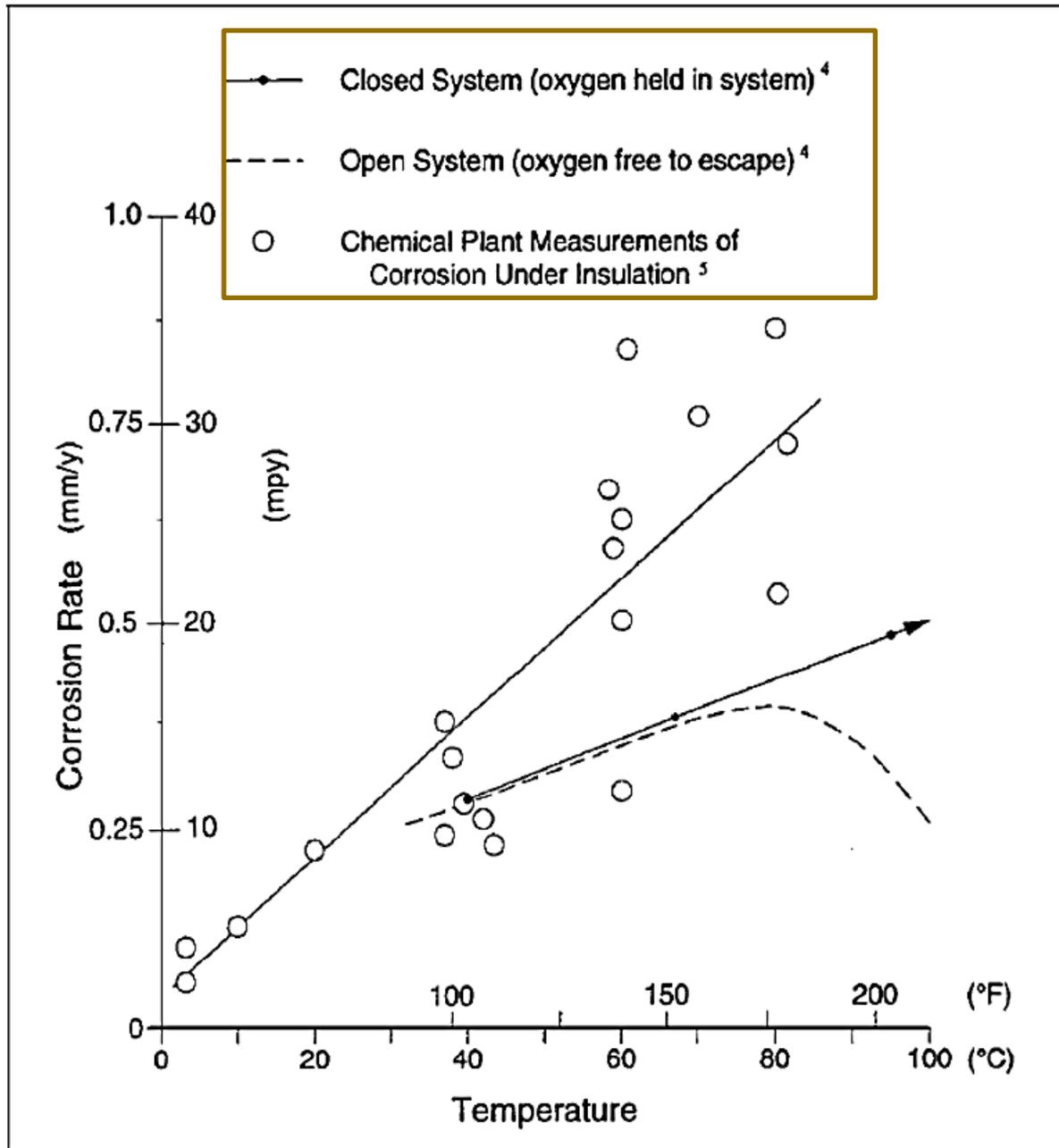
剩餘厚度等級

# 水槌



# 水槌





Effect of Temperature on Steel Corrosion in Water