WHEN TRUST MATTERS

石化產業關鍵性設備量化RBI

SY-12-TC 量化RBI與資產完整性管理課程

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講師簡介

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NACE THE WORLDWIDE CORROSION AUTHORITY

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機械製造組

資訊管理系
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資訊完整性管理系統導入
推廣及深入探討 RBI 的應用

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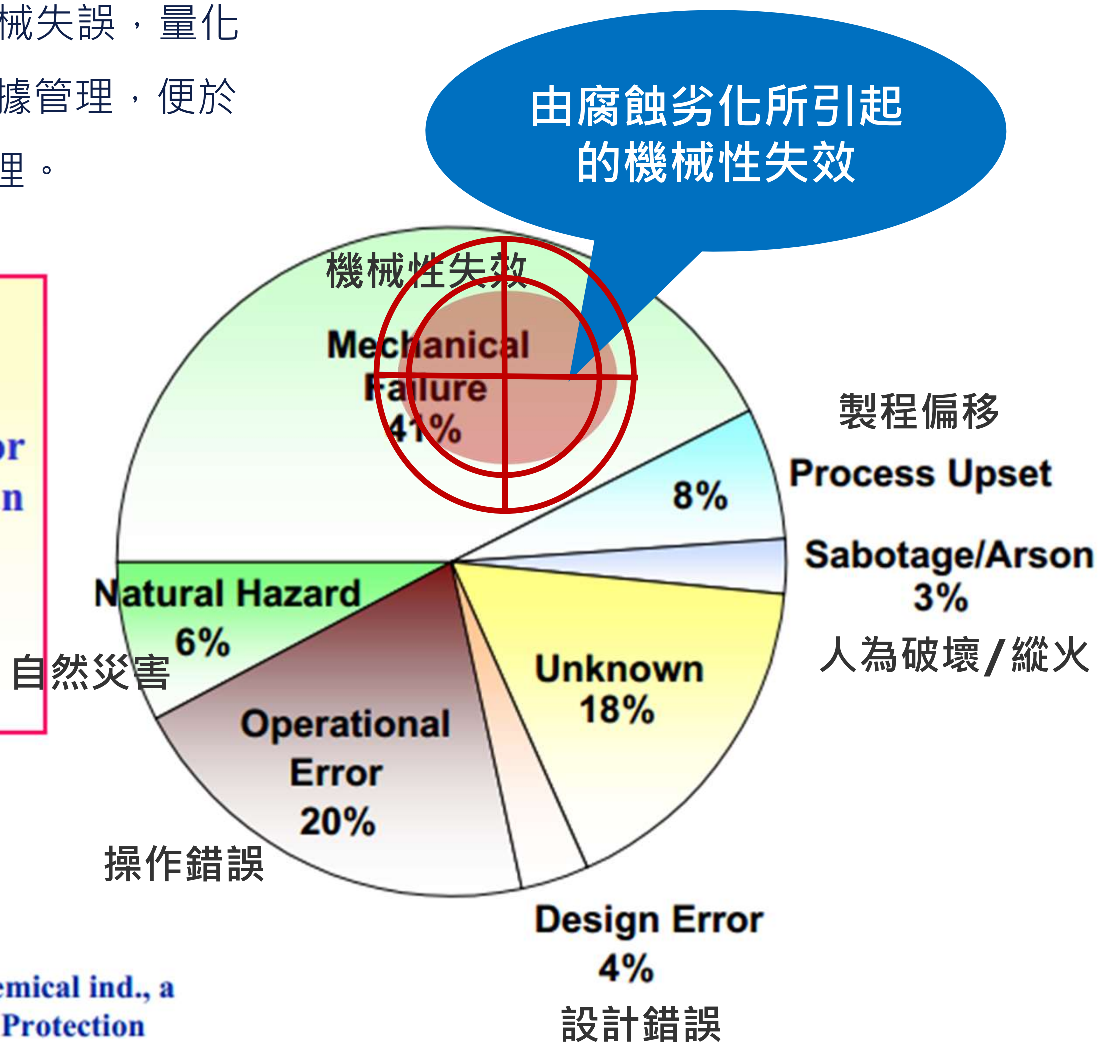
石化廠洩漏原因分析

- 針對腐蝕劣化所引起的機械失誤，量化RBI 可以提供科學化的數據管理，便於PDCA永續追蹤及比較管理。

About half of the containment losses in a refinery, petrochemical or chemical process plant can be influenced by maintenance and inspection



Large property losses in the HC-chemical ind., a 30 year review, 14th edition, M&M Protection Consultants, 1992

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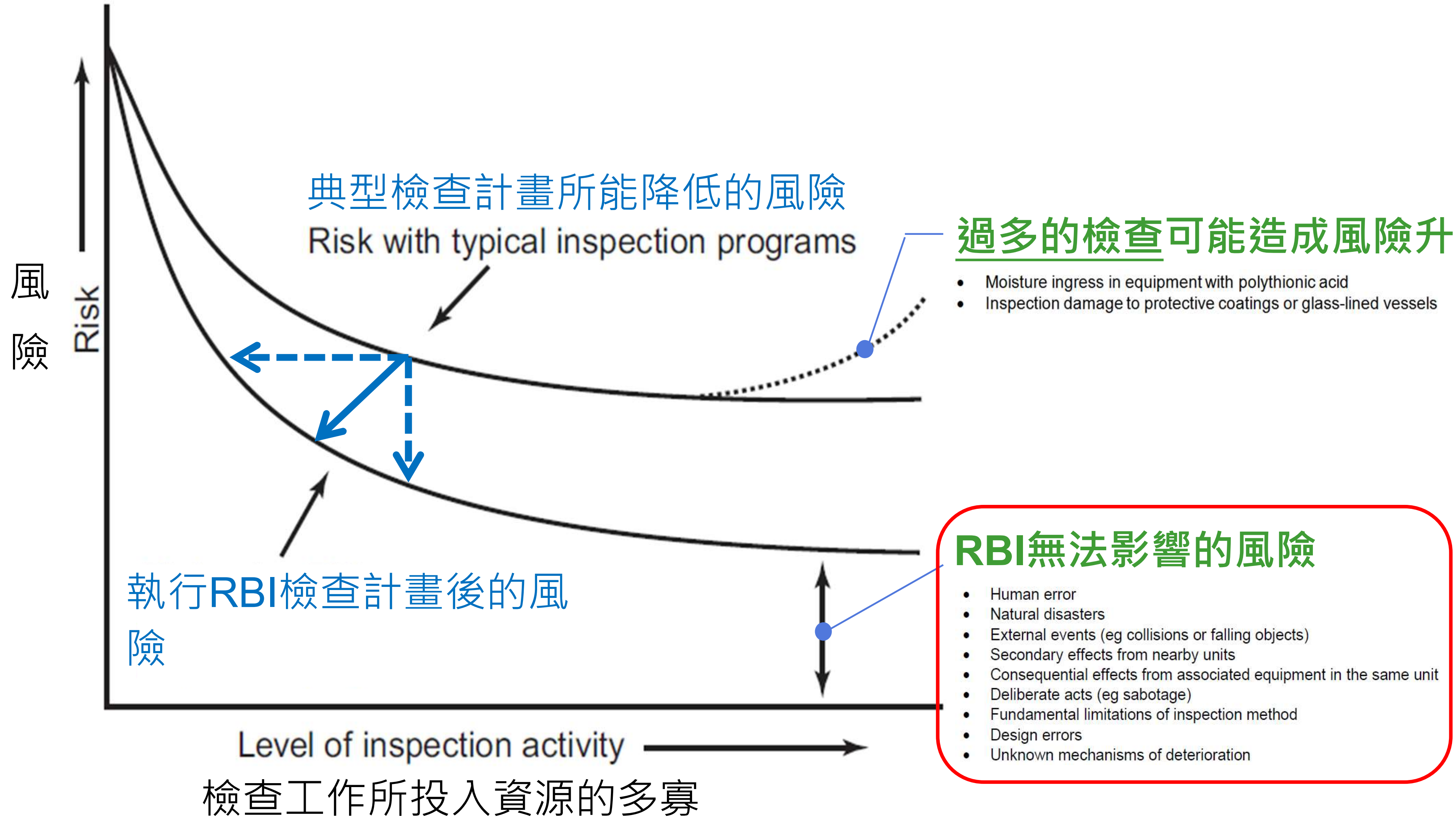
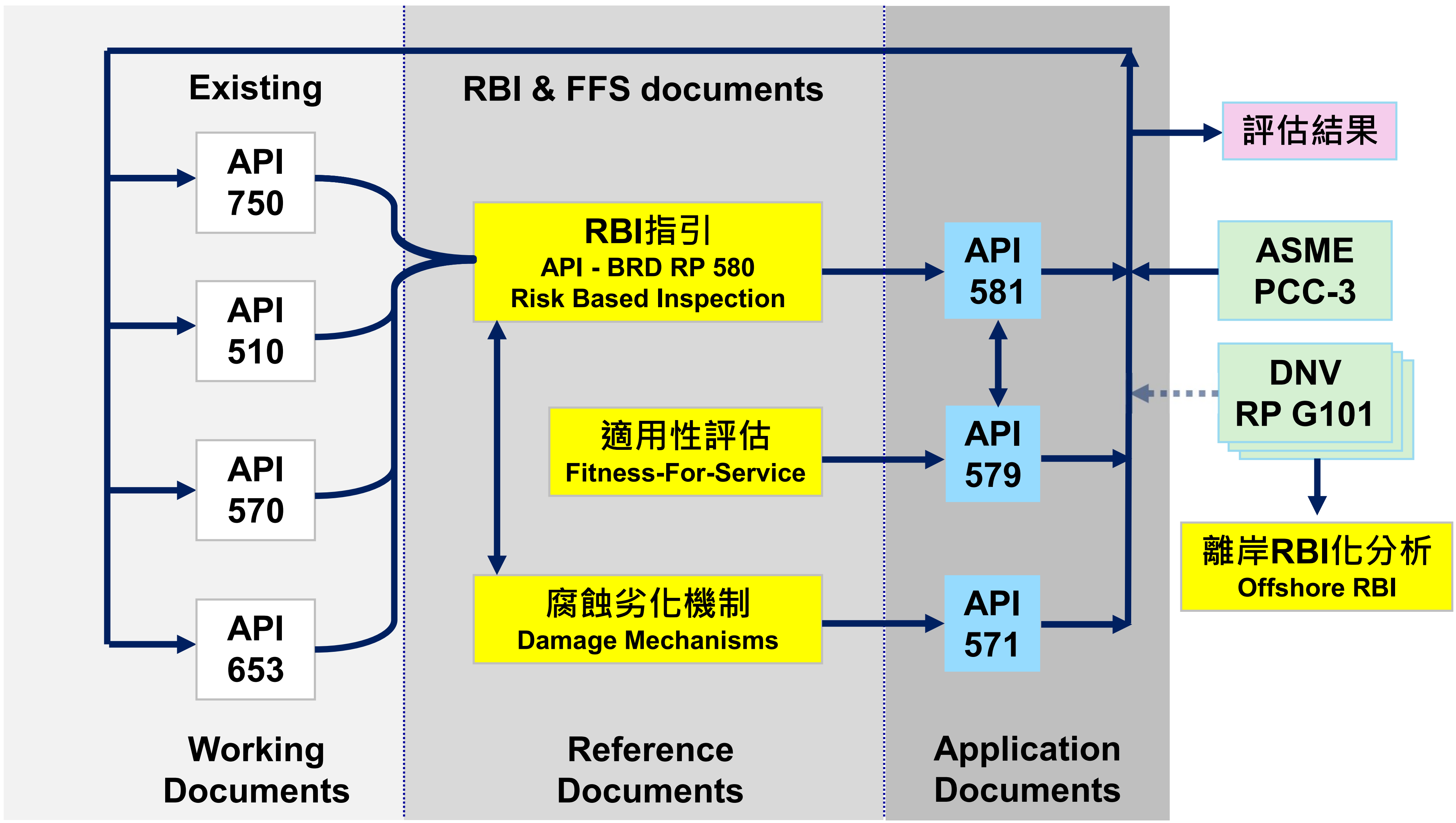
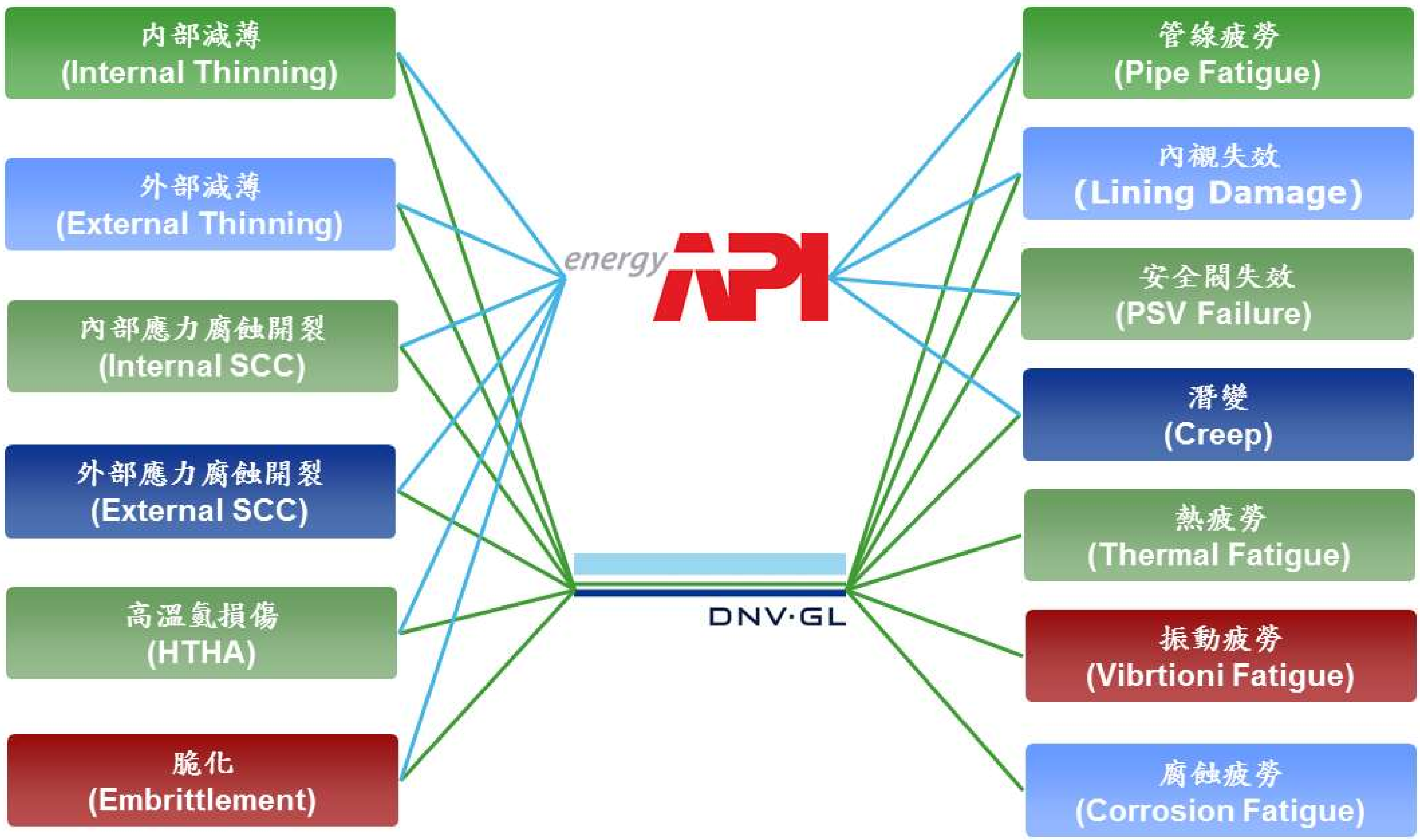
API RBI風險管理概念



API-RBI相關標準間之關連性



API 581中所涵蓋的腐蝕形態



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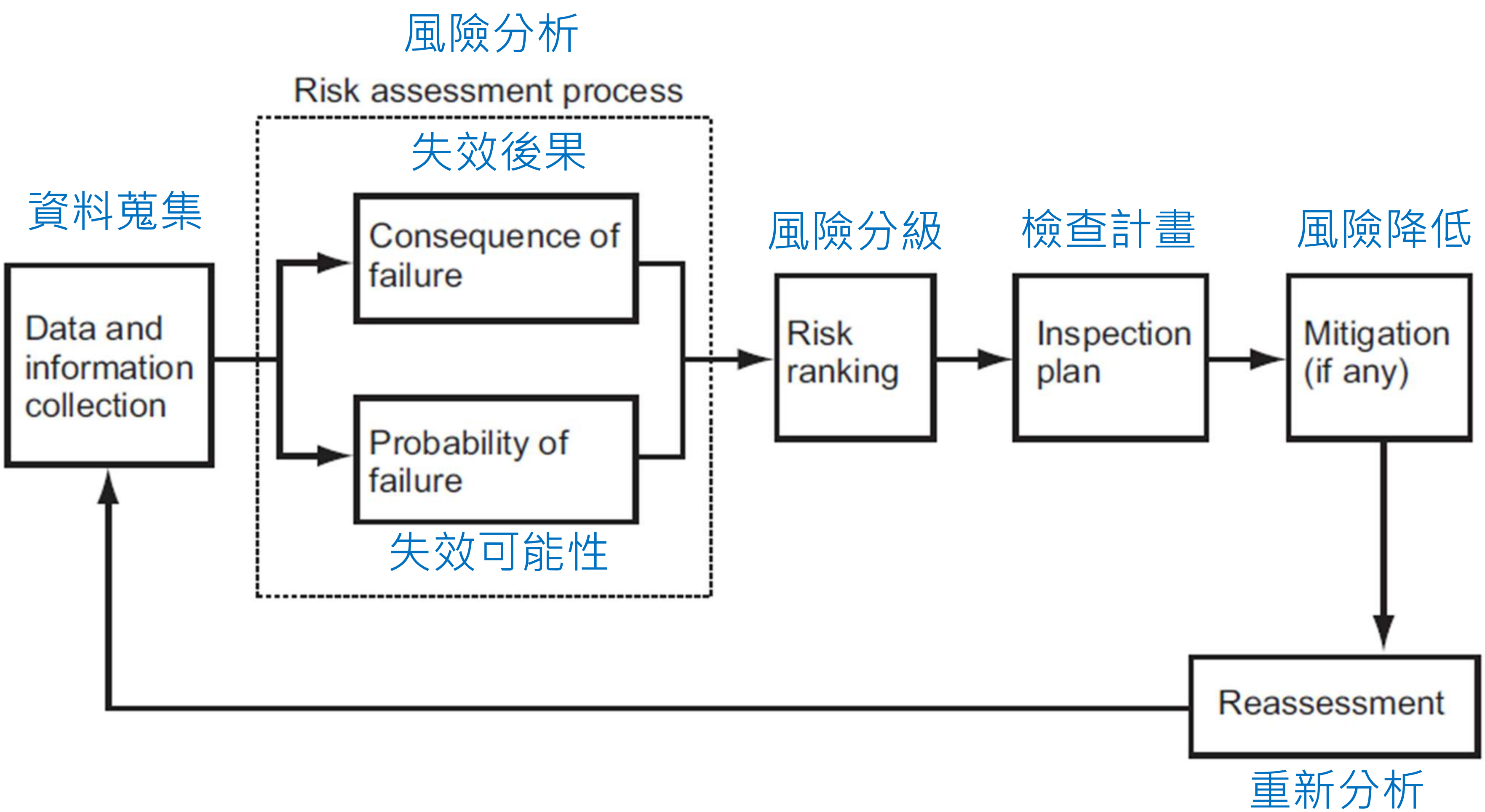
RBI評估流程

- **資料收集往往是最難的部份 - 資料完整性.資料正確性.資料及時性**

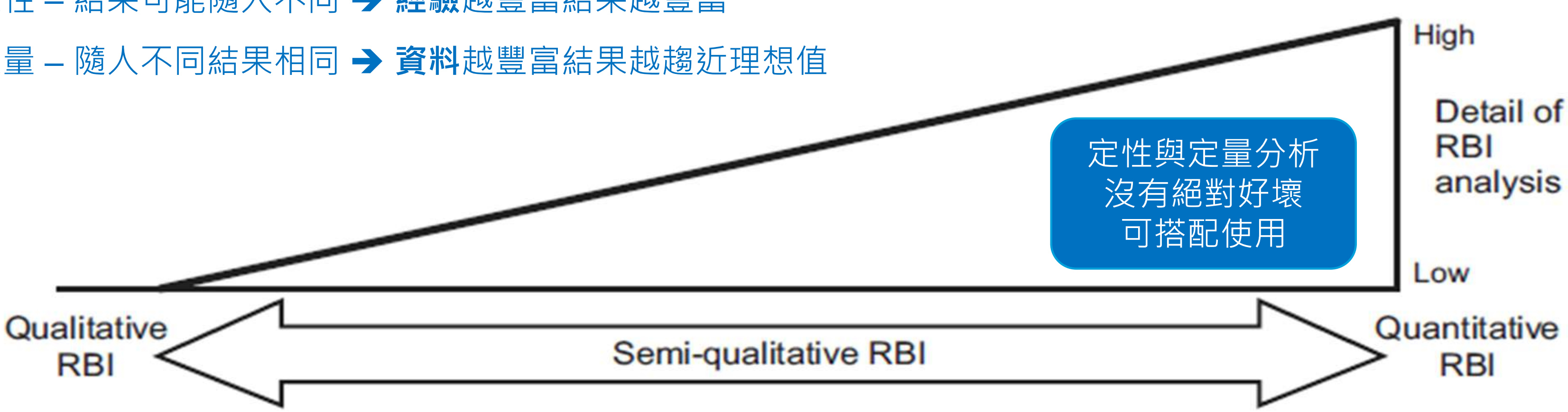


RBI的評估方式

定性分析 (Qualitative)	半定量分析 (Semi-Quantitative)	全定量分析 (Quantitative)
• 多依賴管理/技術人員經驗 • 較多的假設 • 初步篩選(Screening) • 資料或資源不足時使用 • 執行時間短 • 結果較為粗略	• 評估採定性分析，但是評估項目部份採數據分析 • 評估採定量分析，但是評估項目部份是定性方式或是部份採簡化的定量評估 • 結果可做比較管理	• PoF和CoF皆採RBI量化計算方法 • 需大量而詳細的資料和技術人員配合 • 執行時間較長，結果較詳細具體 • 量化數據易於追蹤管理

定性 – 結果可能隨人不同 ➔ **經驗**越豐富結果越豐富

定量 – 隨人不同結果相同 ➔ **資料**越豐富結果越趨近理想值



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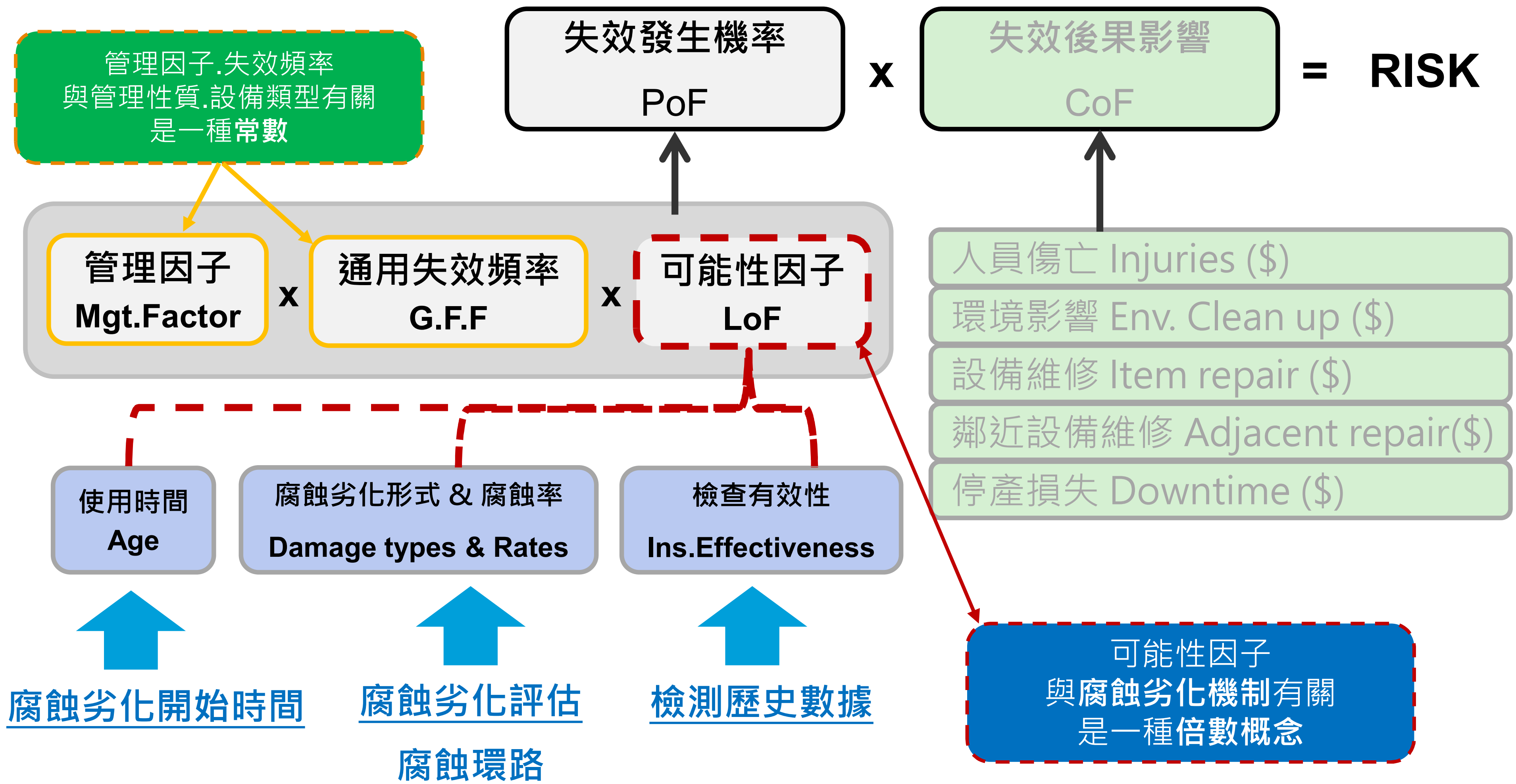
失效發生機率(PoF)計算

- 在失效可能性計算上著重在可能性因子 ➔ 會隨時間而異動



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管理因子

Table 4.4 – Management Systems Evaluation

Table	Title	Questions	Points
2.A.1	Leadership and Administration	6	70
2.A.2	Process Safety Information	10	80
2.A.3	Process Hazard Analysis	9	100
2.A.4	Management of Change	6	80
2.A.5	Operating Procedures	7	80
2.A.6	Safe Work Practices	7	85
2.A.7	Training	8	100
2.A.8	Mechanical Integrity	20	120
2.A.9	Pre-Startup Safety Review	5	60
2.A.10	Emergency Response	6	65
2.A.11	Incident Investigation	9	75
2.A.12	Contractors	5	45
2.A.13	Audits	4	40
Total		**101**	**1000**

註：擷取自 API 581 2008年第二版

$$pscore = \frac{Score}{1000} \cdot 100 \ [\text{unit is } \%]$$

$$F_{MS} = 10^{(-0.02 \cdot pscore + 1)}$$

$$F_{management} = \begin{cases} 10 & S_{management} = 0 \\ 1 & S_{management} = 50 \\ 0.1 & S_{management} = 100 \\ 10 \times e^{-0.046071 \times S_{management}} & S_{management} = other\ value \end{cases}$$

(DNV)

Score	Pscore (%)	FMS	DNV management score
0	0	10	0
500	50	1	50
800	80	0.251189	80
1000	100	0.1	100

通用失效頻率

Table 3.1—Suggested Component Generic Failure Frequencies

Equipment Type	Component Type	GFF As a Function of Hole Size (failures/yr)				gff_{total} (failures/yr)
		Small	Medium	Large	Rupture	
Compressor	COMPC	8.00E-06	2.00E-05	2.00E-06	0	3.00E-05
Compressor	COMPR	8.00E-06	2.00E-05	2.00E-06	6.00E-07	3.06E-05
Heat exchanger	HEXSS, HEXTS	8.00E-06	2.00E-05	2.00E-06	6.00E-07	3.06E-05
Pipe	PIPE-1, PIPE-2	2.80E-05	0	0	2.60E-06	3.06E-05
Pipe	PIPE-4, PIPE-6	8.00E-06	2.00E-05	0	2.60E-06	3.06E-05
Pipe	PIPE-8, PIPE-10, PIPE-12, PIPE-16, PIPEGT16	8.00E-06	2.00E-05	2.00E-06	6.00E-07	3.06E-05
Pump	PUMP2S, PUMPR, PUMP1S	8.00E-06	2.00E-05	2.00E-06	6.00E-07	3.06E-05

保溫對於腐蝕率之影響

$$C_r = C_{rB} \cdot F_{INS} \cdot F_{CM} \cdot F_{IC} \cdot \max\left[F_{EQ},\ F_{IF}\right]$$

F_{EQ}：設計階段有考慮水的蓄積
F_{IF}：管線是否有水或土壤介面

Table 16.3 – Corrosion Rate Adjustment Factor for Insulation Type

Insulation Type	Adjustment Factor, F_{INS}
Unknown/Unspecified	1.25
Foamglass	0.75
Pearlite	1.0
Fiberglass	1.25
Mineral Wool	1.25
Calcium Silicate	1.25
Asbestos	1.25

F_{INS} 保溫材質

不同保溫材的選擇
對於CUI的計算程度也不同

Complexity	A_3	
	API 581 Method	Other Methods
Below Average	0.75	0.5
Average	1.00	1.00
Above Average	1.25	2.00

F_{CM} 保溫複雜度

Condition of Insulation	A_2	
	API 581 Method	Other Methods
Above Average	0.75	0.25
Average	1.0	0.50
Below Average or None	1.25	1.00

F_{IC} 保溫品質

施工品質與複雜度
也會影響CUI的計算程度

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油漆對損傷因子之影響

d) STEP 4 – Determine the time in-service, age_{tk}, since the last known inspection thickness, t_{rde} (see Section 4.5.5. The t_{rde} is the starting thickness with respect to wall loss associated with external corrosion. If no measured thickness is available, set $t_{rde} = t$ and $age_{tk} = age$.

e) STEP 5 – Determine the in-service time, age_{coat}, since the coat
(2.35).

$$age_{coat} = Calculation\ Date - Coating\ Installation\ Date$$

f) STEP 6 – Determine coating adjustment, $Coat_{adj}$, using Equations

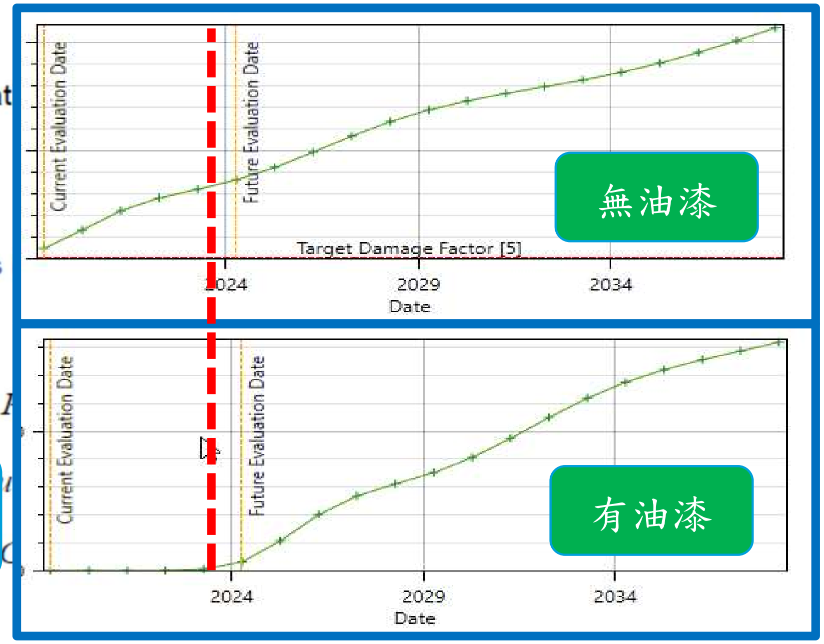
If $age_{tk} \geq age_{coat}$:

$Coat_{adj} = 0$ No Coating or P

$Coat_{adj} = \min[5,\ age_{coat}]$

$Coat_{adj} = \min[15,\ age_{coat}]$

高品質的油漆
可以延長較久的壽命



If $age_{tk} < age_{coat}$:

$Coat_{adj} = 0$ No Coating or Poor Coating Quality (2.39)

$Coat_{adj} = \min[5,\ age_{coat}] - \min[5,\ age_{coat} - age_{tk}]$ Medium Coating Quality (2.40)

$Coat_{adj} = \min[15,\ age_{coat}] - \min[15,\ age_{coat} - age_{tk}]$ High Coating Quality (2.41)

g) STEP 7 – Determine the in-service time, age, over which external corrosion may have occurred using Equation (2.42).

$$age = age_{tk} - Coat_{adj}$$

腐蝕作用時間 = 運轉時間 - 油漆可以提供保護時間

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損傷狀態(Damage State) - 減薄

❑ 實際可能的損傷狀態

Thinning DF calculations are based on the probability of three damage states being present. The three damage states used in Section 4.5.7 are defined as:

a) Damage State 1 – Damage is no worse than expected, or a factor of 1 applied to the expected corrosion rate

b) Damage State 2 – Damage is somewhat worse than expected, or a factor of 2 applied to the expected corrosion rate

c) Damage State 3 – Damage considerably worse than expected, or a factor of 4 applied to the expected corrosion rate

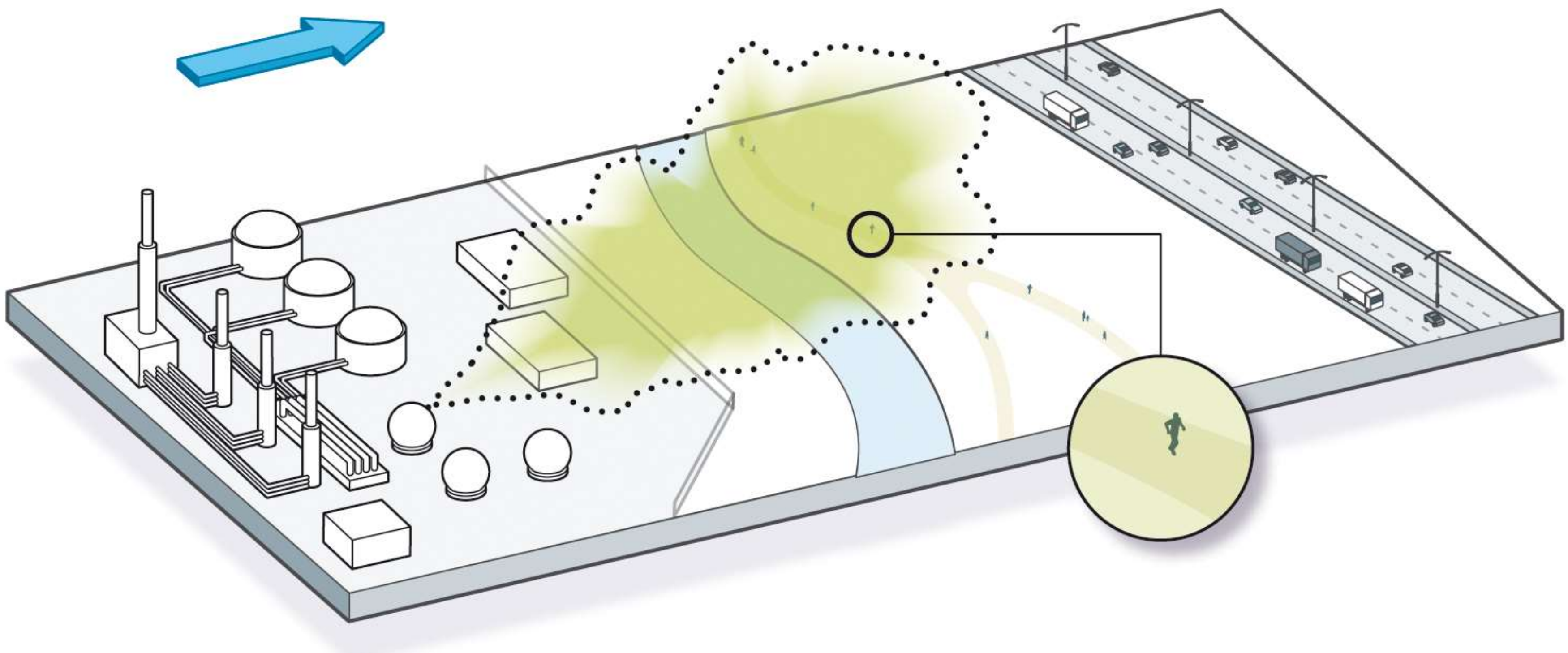
❑ 可能會出現的三種損傷狀態

- 實際的損傷**沒有**比預期的糟 ➔ 1倍腐蝕率
- 實際的損傷比預期的**糟一點** ➔ 2倍腐蝕率
- 實際的損傷比預期的**糟很多** ➔ 4倍腐蝕率

Consequence Analysis Dispersion Modeling

- The computer modeling necessary to determine consequence areas associated with cloud dispersion (flash fires, VCEs, toxic releases) requires specific input regarding meteorological and release conditions.
- Level 1 consequence analysis, meteorological conditions representative of the Gulf Coast annual averages were used.
- The meteorological input assumptions were as follows:
  - a) Atmospheric Temperature 70°F (21°C)
  - b) Relative Humidity 75%
  - c) Wind Speed 8 mph (12.9 km/h)
  - d) Stability Class D
  - e) Surface Roughness Parameter 30.5 mm (1.2 inch) for typical for processing plants

Dispersion



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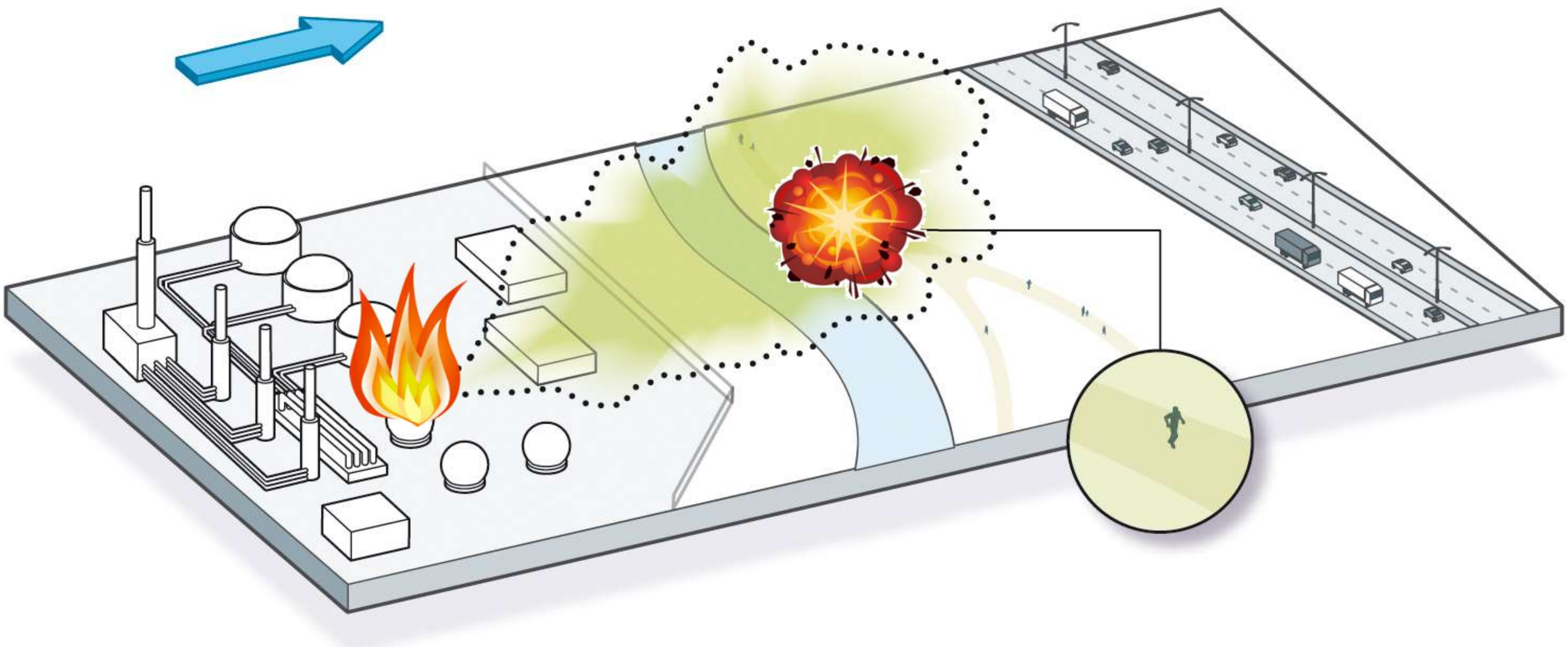
Effects (Fire, Explosion, Toxic)



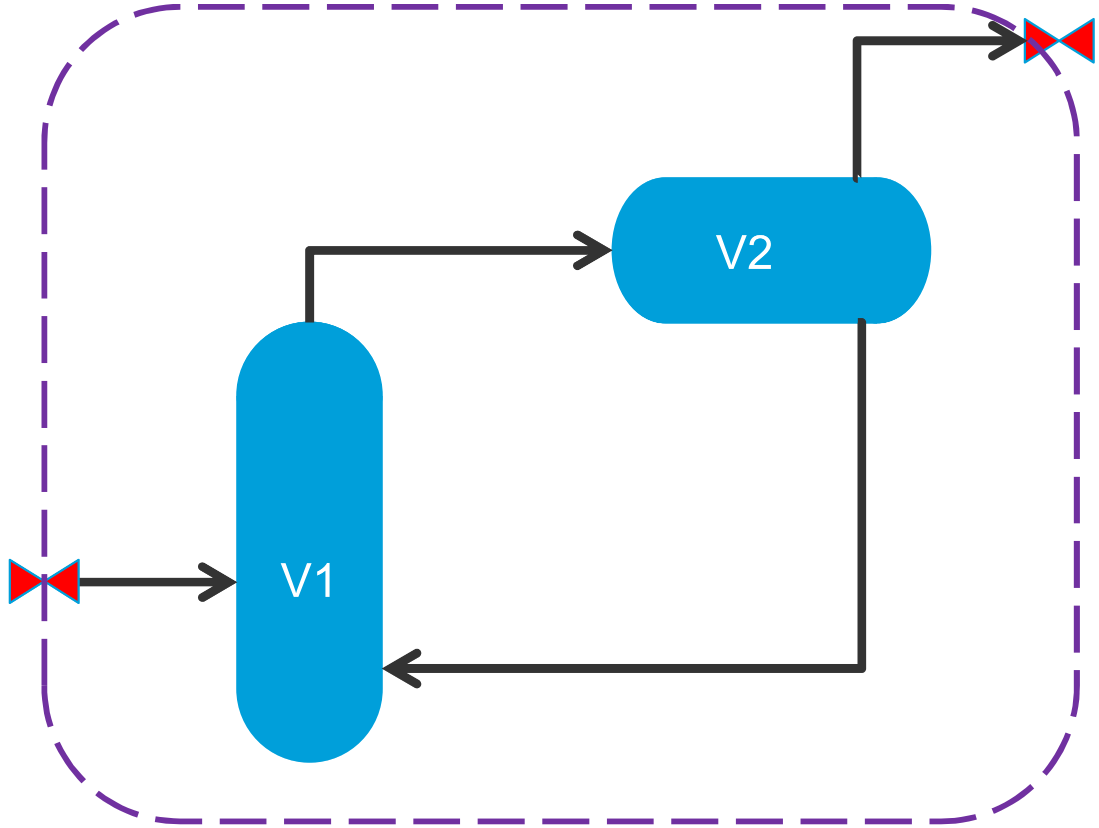
物流環路(Inventory group)

❑ Inventory group

➢ 為了計算遭遇失效時可能洩漏的最大量

$$mass_{inv} = \sum_{i=1}^{N} mass_{comp,i}$$

腐蝕環路 ➔ 失效可能性
物流環路 ➔ 失效後果



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計算洩漏量的四種模型

- 計算洩漏後果的四種模型 – 小破孔. 中破孔. 大破孔. 毀損

Release Hole Number	Release Hole Size	Range of Hole Diameters (inch)	Release Hole Diameter, d_n (inch)
1	Small	0 – ¼	$d_1 = 0.25$
2	Medium	> ¼ – 2	$d_2 = 1$
3	Large	> 2 – 6	$d_3 = 4$
4	Rupture	> 6	$d_4 = \min[D, 16]$

$$A_n = \frac{\pi d_n^2}{4}$$

- 氣體洩漏量(Vapor)

$$W_n = \frac{C_d}{C_2} \cdot A_n \cdot P_s \sqrt{\left(\frac{k \cdot MW \cdot g_c}{R \cdot T_s}\right)\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

>背壓

$$W_n = \frac{C_d}{C_2} \cdot A_n \cdot P_s \sqrt{\left(\frac{MW \cdot g_c}{R \cdot T_s}\right)\left(\frac{2 \cdot k}{k-1}\right)\left(\frac{P_{atm}}{P_s}\right)^{\frac{2}{k}}\left(1-\left(\frac{P_{atm}}{P_s}\right)^{\frac{k-1}{k}}\right)}$$

≤背壓

- 液體洩漏量(Liquid)

$$W_n = C_d \cdot K_{v,n} \cdot \rho_l \cdot \frac{A_n}{C_1} \sqrt{\frac{2 \cdot g_c \cdot (P_s - P_{atm})}{\rho_l}}$$

$$mass_{add,n} = 180 \cdot \min[W_n, \ W_{max8}]$$

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洩漏類型

- **確認洩漏類型** (Continuous or Instantaneous)

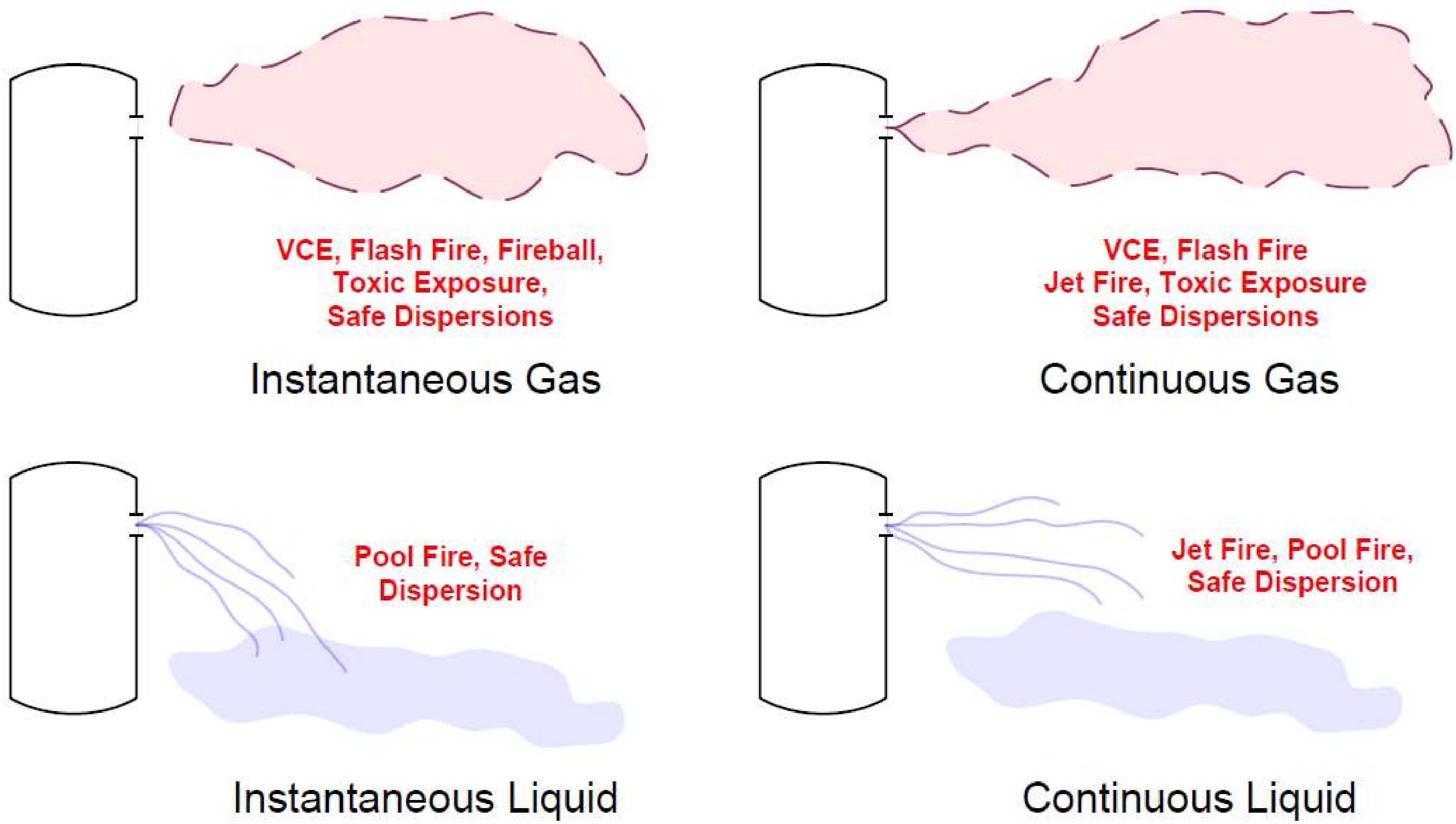
瞬間洩漏 Instantaneous Release

  - An instantaneous or puff release is one that occurs so rapidly that the fluid disperses as a single large cloud or pool
  - 3分鐘內洩漏量 > 4,536 kgs (10,000 lbs)

連續洩漏 Continuous Release

  - A continuous or plume release is one that occurs over a longer period of time, allowing the fluid to disperse in the shape of an elongated ellipse (depending on weather conditions)
  - 洩漏孔徑 ≤ ¼ inch (6.35mm)
  - 3分鐘內洩漏量 ≤ 4,536 kgs (10,000 lbs)

洩漏類型


VCE, Flash Fire, Fireball,
Toxic Exposure,
Safe Dispersions
Instantaneous Gas
VCE, Flash Fire
Jet Fire, Toxic Exposure
Safe Dispersions
Continuous Gas
Pool Fire, Safe
Dispersion
Instantaneous Liquid
Jet Fire, Pool Fire,
Safe Dispersion
Continuous Liquid

燃燒爆炸後果計算

- **計算燃燒爆炸後果**
  Determine Flammable and Explosive Consequence
  - 計算後果影響面積 Consequence Area Equations
    - 引燃機率及引燃時間點為決定後果分析事件樹路徑的主要參數
    - Level-1中使用查表法得出a、b常數，以計算後果影響面積

連續洩漏 Continuous Release

$$CA_n^{CONT} = a\left(rate_n\right)^b$$

瞬間洩漏 Instantaneous Release

$$CA_n^{INST} = a\left(mass_n\right)^b$$

事件樹

- API RBI Level 1 後果分析事件樹 Consequence Analysis Event Tree

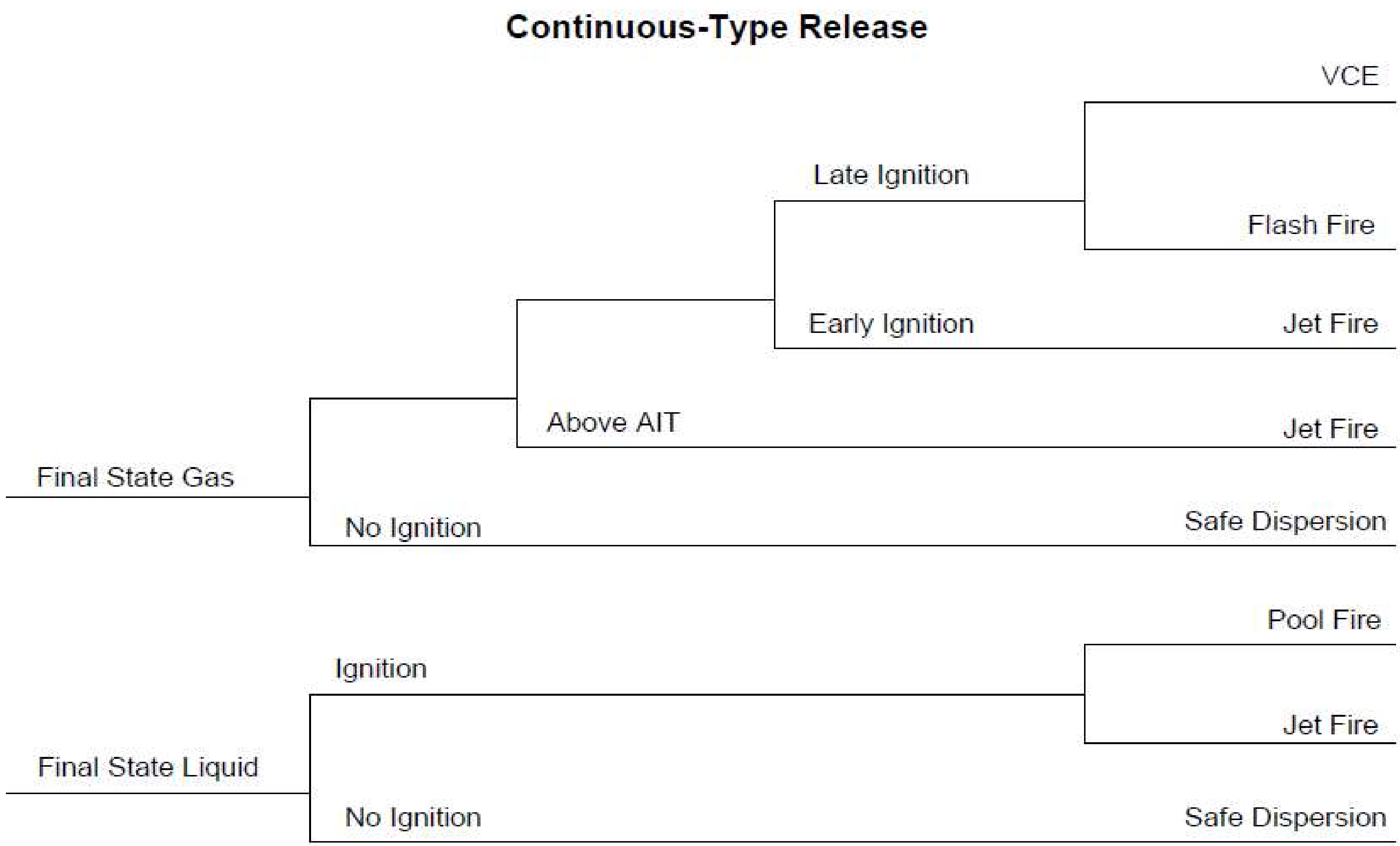


Figure 3.A.3.1 – API RBI Level 1 Consequence Analysis Event Tree

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後果面積常數表

Table 4.8 – Component Damage Flammable Consequence Equation Constants

Fluid	Continuous Releases Constants								Instantaneous Releases Constants							
	Auto-Ignition Not Likely (CAINL)				Auto-Ignition Likely (CAIL)				Auto-Ignition Not Likely (IAINL)				Auto-Ignition Likely (IAIL)			
	Gas		Liquid		Gas		Liquid		Gas		Liquid		Gas		Liquid	
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
C_1-C_2	43.0	0.98			280.0	0.95			41.0	0.67			1079	0.62		
C_3-C_4	49.48	1.00			313.6	1.00			27.96	0.72			522.9	0.63		
C_5	25.17	0.99	536.0	0.89	304.7	1.00			13.38	0.73	1.49	0.85	275.0	0.61		
C_6-C_8	29.0	0.98	182.0	0.89	312.4	1.00	525.0	0.95	13.98	0.66	4.35	0.78	275.7	0.61	57.0	0.55
C_9-C_{12}	12.0	0.98	130.0	0.90	391.0	0.95	560.0	0.95	7.1	0.66	3.3	0.76	281.0	0.61	6.0	0.53
C_{13}-C_{16}			64.0	0.90			1023	0.92			0.46	0.88			9.2	0.88
C_{17}-C_{25}			20.0	0.90			861.0	0.92			0.11	0.91			5.6	0.91
C_{25} +			11.0	0.91			544.0	0.90			0.03	0.99			1.4	0.99
H_2	64.5	0.992			420.0	1.00			61.5	0.657			1430	0.618		
H_2S	32.0	1.00			203.0	0.89			148.0	0.63			357.0	0.61		
HF																
Aromatics	17.87	1.097	103.0	1.00	374.5	1.055			11.46	0.667	70.12	1.00	512.6	0.713	701.2	1.00
Styrene	17.87	1.097	103.0	1.00	374.5	1.055			11.46	0.667	70.12	1.00	512.6	0.713	701.2	1.00
CO	0.107	1.752							69.68	0.667						
DEE	39.84	1.134	737.4	1.106	320.7	1.033	6289	0.649	155.7	0.667	5.105	0.919			5.672	0.919
Methanol	0.026	0.909	1751	0.934					28.11	0.667	1.919	0.900				
PO	14.62	1.114	1295	0.960					65.58	0.667	3.404	0.869				
EEA	0.002	1.035	117.0	1.00					8.014	0.667	69.0	1.00				
EE	12.62	1.005	173.1	1.00					38.87	0.667	72.21	1.00				
EG	7.721	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]				
EO	[illegible]	[illegible]							[illegible]	[illegible]						
Pyrophoric	12.0	0.98	130.0	0.90	391.0	0.95	560.0	0.95	7.1	0.66	3.3	0.76	281.0	0.61	6.0	0.53

Component Damage Flammable Consequence Equation Constants

Table 4.9 – Personnel Injury Flammable Consequence Equation Constants

Fluid	Continuous Releases Constants								Instantaneous Releases Constants							
	Auto-Ignition Not Likely (CAINL)				Auto-Ignition Likely (CAIL)				Auto-Ignition Not Likely (IAINL)				Auto-Ignition Likely (IAIL)			
	Gas		Liquid		Gas		Liquid		Gas		Liquid		Gas		Liquid	
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
C_1-C_2	110.0	0.96			745.0	0.92			79.0	0.67			3100	0.63		
C_3-C_4	125.2	1.00			836.7	1.00			57.72	0.75			1769	0.63		
C_5	62.05	1.00	1545	0.89	811.0	1.00			28.45	0.76	4.34	0.85	959.6	0.63		
C_6-C_8	68.0	0.96	516.0	0.89	828.7	1.00	1315	0.92	26.72	0.67	12.7	0.78	962.8	0.63	224.0	0.54
C_9-C_{12}	29.0	0.96	373.0	0.89	981.0	0.92	1401	0.92	13.0	0.66	9.5	0.76	988.0	0.63	20.0	0.54
C_{13}-C_{16}			183.0	0.89			2850	0.90			1.3	0.88			26.0	0.88
C_{17}-C_{25}			57.0	0.89			2420	0.90			0.32	0.91			16.0	0.91
C_{25} +			33.0	0.89			1604	0.90			0.081	0.99			4.1	0.99
H_2	165.0	0.933			1117	1.00			118.5	0.652			4193	0.621		
H_2S	52.0	1.00			375.0	0.94			271.0	0.63			1253	0.63		
HF																
Aromatics	64.14	0.963	353.5	0.883	1344	0.937	487.7	0.268	18.08	0.686	0.14	0.935	512.6	0.713	1.404	0.935
Styrene	64.14	0.963	353.5	0.883	1344	0.937	487.7	0.268	18.08	0.686	0.14	0.935	512.6	0.713	1.404	0.935
CO	27.0	0.991							105.3	0.692						
DEE	128.1	1.025	971.9	1.219	1182	0.997	2658	0.864	199.1	0.682	47.13	0.814	821.7	0.657	52.36	0.814
Methanol	0.016	1.008	4484	0.902					37.71	0.688	6.255	0.871				
PO	38.76	1.047	1955	0.840					83.68	0.682	15.21	0.834				
EEA	0.017	0.946	443.1	0.835					11.41	0.687	0.153	0.924				
EE	35.56	0.969	46.56	0.800					162.0	0.660	0.152	0.927				
EG	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]				
EO	49.43	1.105							[illegible]	[illegible]						
Pyrophoric	29.0	0.96	373.0	0.89	981.0	0.92	1401	0.92	13.0	0.66	9.5	0.76	988.0	0.63	20.0	0.54

Personnel Injury Flammable Consequence Equation Constants

DNV

停產損失的計算(Outage Cost)

- 設備本身的損毀成本

$$Outage_{cmd} = \left(\frac{\sum_{n=1}^{4} gff_n \cdot Outage_n}{gff_{total}} \right) \cdot Outage_{mult}$$

- 周遭設備的損毀成本

$$Outage_{affa} = 10^{1.242+0.585 \cdot \log_{10}\left[FC_{affa} \cdot (10)^{-6}\right]}$$

- 停產損失

$$FC_{prod} = \left(Outage_{cmd} + Outage_{affa}\right)\left(prodcost\right)$$

Table 4.17 – Estimated Equipment Outage

Equipment Type	Component Type	Estimated Outage in Days, $Outage_n$			
		Small	Medium	Large	Rupture
Compressor	COMPC, COMPR	NA	3	7	NA
Heat Exchanger	HEXSS, HEXTS	2	3	3	10
	HEXTUBE	NA	NA	NA	NA
Pipe	PIPE-1, PIPE-2	0	NA	NA	1
	PIPE-4	0	1	NA	2
	PIPE-6	0	1	2	3
	PIPE-8	0	2	2	3
	PIPE-10	0	2	2	4
	PIPE-12	1	3	4	4
	PIPE-16	1	3	4	5
	PIPEGT16	1	4	5	7
Pump	PUMP2S, PUMPR, PUMP1S	0	0	0	NA
Tank	TANKBOTTOM	5	NA	NA	50
	COURSE-1 through 10	2	3	3	14
Vessel/FinFan	KODRUM	2	3	3	10
	FINFAN	0	0	2	3
	FILTER	0	1	2	3
	DRUM	2	3	3	10
	REACTOR	4	6	6	21
	COLTOP, COLMID, COLBTM	3	4	5	21

Notes:
1. The outage day values li ... reflect their specific requirements
2. NA – Not applicable me ... Refer to Part 3, Annex 3.A Section 3.A.

API-581中對於各式設備復原所需的時間

DNV 計算模組–失效後果

- **後果計算**
  - 採用最新版DNV Phast軟體屬性系統
  - 採用最新版DNV Phast軟體的後果計算模組（Phast軟體是目前世界上最好的後果計算軟體）
  - 後果類型考慮經濟後果、安全後果、環境後果等，使用總成本、停產損失、設備損傷面積、火災死亡面積、毒性影響面積、安全面積、潛在人員傷亡、環境後果等8種後果指標表徵後果
  - 可同時呈現多種後果
  - 包含API 581第3版環境後果計算模組
  - 包含API 581第3版非毒性非易燃性後果計算模組

DNV

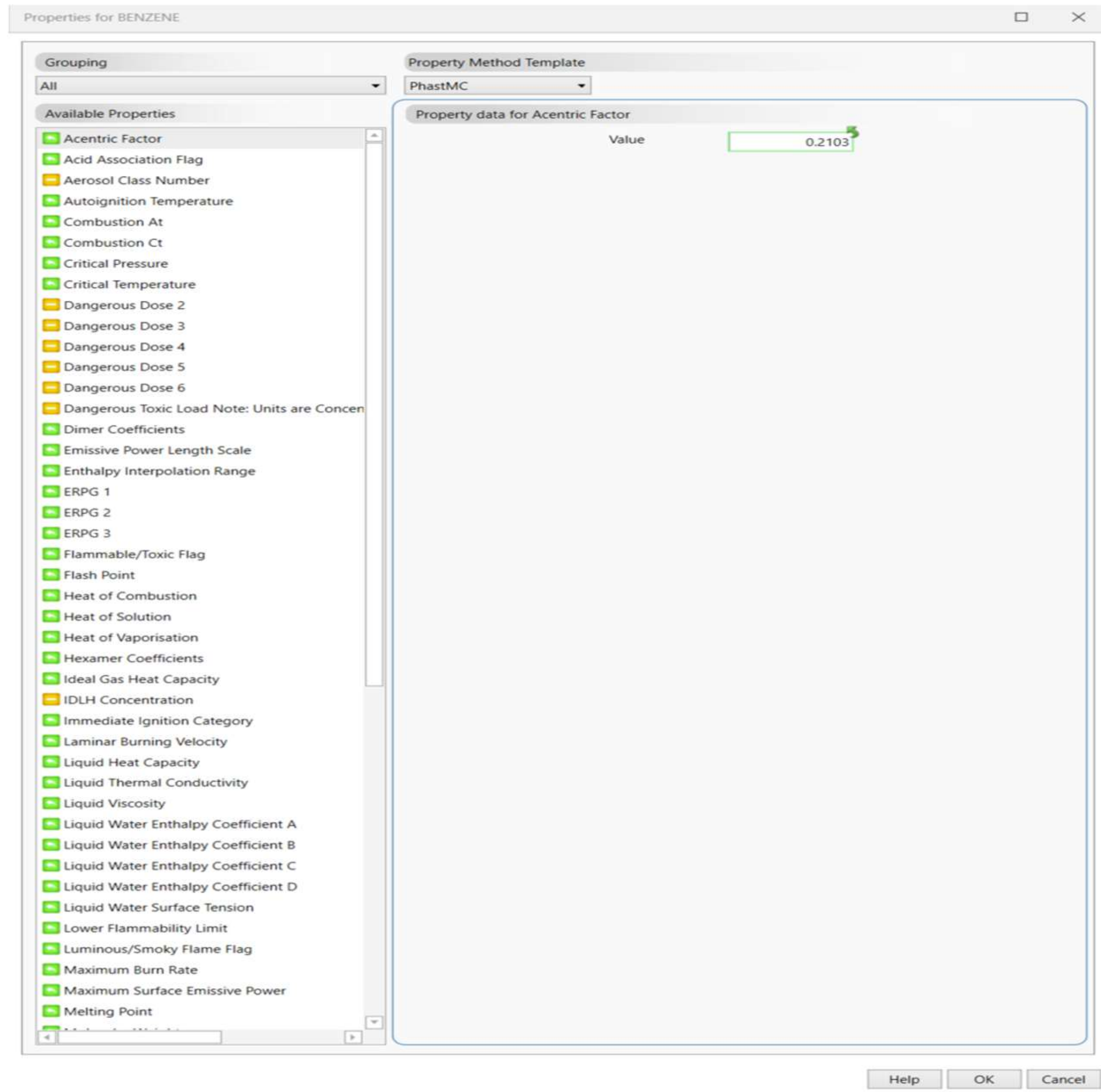
化學品屬性值

Table 4.2—Properties of the Representative Fluids Used in Level 1 Consequence Analysis

Fluid	MW	Liquid Density (lb/ft³)	NBP (°F)	Ambient State	Ideal Gas Specific Heat Eq.	C_p Ideal Gas Constant *A*	Ideal Gas Constant *B*	Ideal Gas Constant *C*	Ideal Gas Constant *D*	Ideal Gas Constant *E*	AIT (°F)
C_1-C_2	23	15.639	−193	Gas	Note 1	12.3	1.150E-01	−2.87E-05	−1.30E-09	N/A	1036
C_3-C_4	51	33.61	−6.3	Gas	Note 1	2.632	0.3188	−1.347E-04	1.466E-08	N/A	696
C_5	72	39.03	97	Liquid	Note 1	−3.626	0.4873	−2.6E-04	5.3E-08	N/A	544
C_6-C_8	100	42.702	210	Liquid	Note 1	−5.146	6.762E-01	−3.65E-04	7.658E-08	N/A	433
C_9-C_{12}	149	45.823	364	Liquid	Note 1	−8.5	1.01E+00	−5.56E-04	1.180E-07	N/A	406
C_{13}-C_{16}	205	47.728	502	Liquid	Note 1	−11.7	1.39E+00	−7.72E-04	1.670E-07	N/A	396
C_{17}-C_{25}	280	48.383	651	Liquid	Note 1	−22.4	1.94E+00	−1.12E-03	−2.53E-07	N/A	396
C_{25+}	422	56.187	981	Liquid	Note 1	−22.4	1.94E+00	−1.12E-03	−2.53E-07	N/A	396
Pyrophoric	149	45.823	364	Liquid	Note 1	−8.5	1.01E+00	−5.56E-04	1.180E-07	N/A	Note 4
Aromatic	104	42.7	293	Liquid	Note 2	8.93E+04	2.15E+05	7.72E+02	9.99E+04	2.44E+03	914
Styrene	104	42.7	293	Liquid	Note 2	8.93E+04	2.15E+05	7.72E+02	9.99E+04	2.44E+03	914
Water	18	62.3	212	Liquid	Note 3	2.76E+05	−2.09E+03	8.125	−1.41E-02	9.37E-06	N/A
Steam	18	62.3	212	Gas	Note 2	3.34E+04	2.68E+04	2.61e+03	8.90E+03	1.17E+03	N/A
Acid/Caustic-LP	18	62.3	212	Liquid	Note 2	2.76E+05	−2.09E+03	8.125	−1.41E-02	9.37E-06	N/A

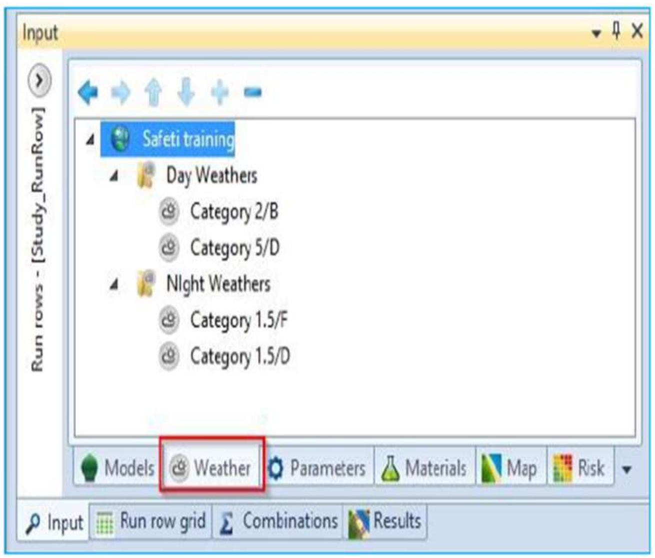
(擷取自 API 581)

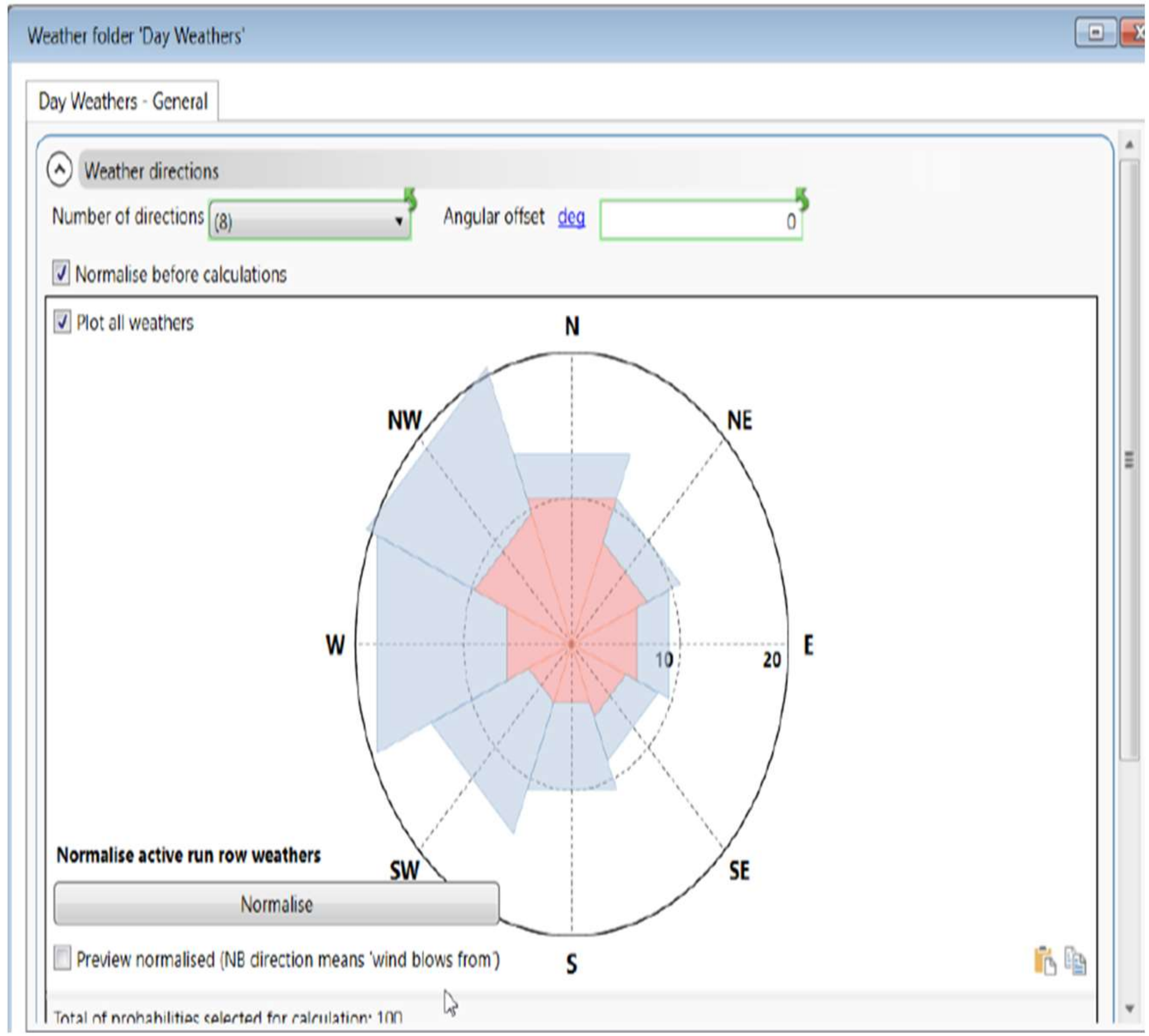
DNV Synergi Onshore RBI 化學品資料庫



考慮天候影響

- Day Weathers:
  - Category 5/D and Category 2/B
  - 8 wind directions
- Night Weathers:
  - Category 1.5/F and Category 1.5/D
  - 8 wind directions





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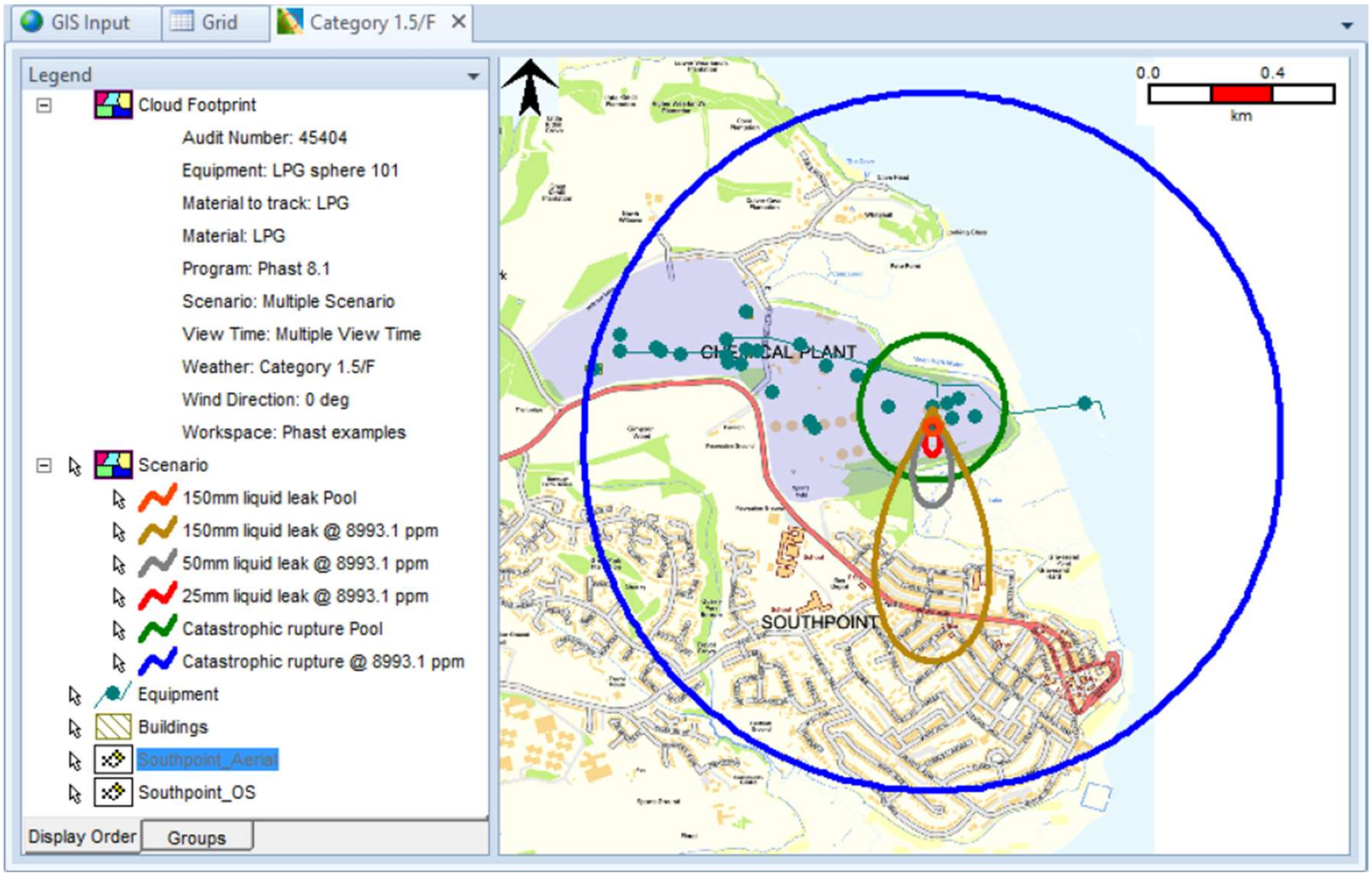
後果影響範圍 (Phast)



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量化 RBI 在關鍵性設備的應用

失效可能性與失效後果等級

Table 4.2—Numerical Values Associated with POF and Financial-based COF Categories

Category	Probability Category [a, b, c]		Consequence Category [d]	
	Probability Range	**DF Range**	**Category**	**Range ($)**
1	$P_f(t,I_E) \le$ 3.06E-05	$D_{f\text{-}total} \le 1$	A	$CA_f^{fin} \le 10{,}000$
2	3.06E-05 < $P_f(t,I_E) \le$ 3.06E-04	$1 < D_{f\text{-}total} \le 10$	B	$10{,}000 < CA_f^{fin} \le 100{,}000$
3	3.06E-04 < $P_f(t,I_E) \le$ 3.06E-03	$10 < D_{f\text{-}total} \le 100$	C	$100{,}000 < CA_f^{fin} \le 1{,}000{,}000$
4	3.06E-03 < $P_f(t,I_E) \le$ 3.06E-02	$100 < D_{f\text{-}total} \le 1000$	D	$1{,}000{,}000 < CA_f^{fin} \le 10{,}000{,}000$
5	$P_f(t,I_E)$ > 3.06E-02	$D_{f\text{-}total} > 1000$	E	$CA_f^{fin} > 10{,}000{,}000$

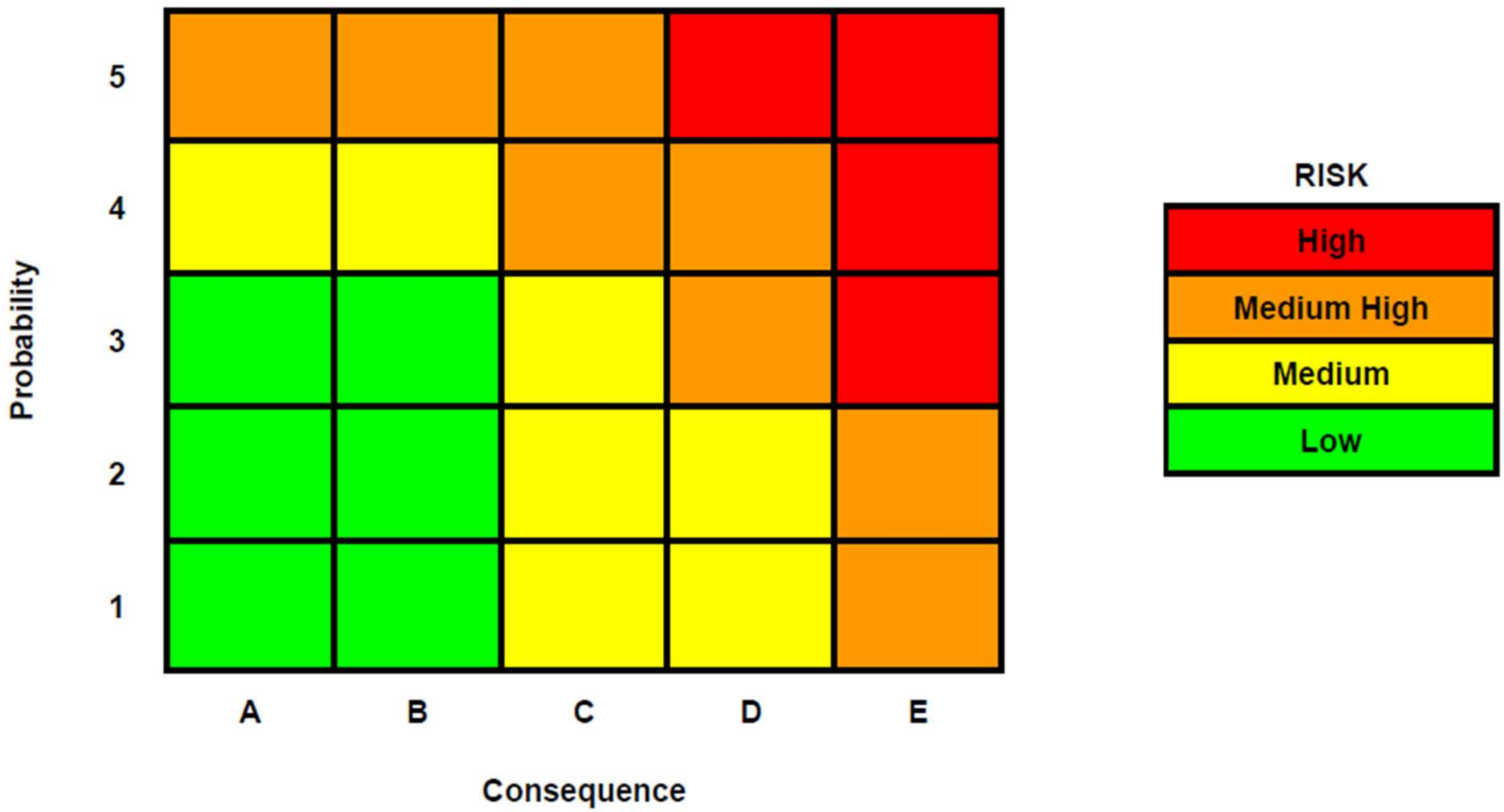
[a] POF values are based on a *gff* of 3.06E-05 and an F_{MS} of 1.0. If the suggested *gff* values of Part 2, Table 3.1 are used, the probability range does not apply to AST shell course, AST bottoms and centrifugal compressors.

[b] In terms of POF, see Part 1, Section 4.1.

[c] In terms of the total DF, see Part 2, Section 3.4.2.

[d] In terms of consequence area, see Part 3, Section 4.12.1.

風險矩陣


Probability
5
4
3
2
1
A
B
C
D
E
Consequence
RISK
High
Medium High
Medium
Low

評估日期與檢查日期

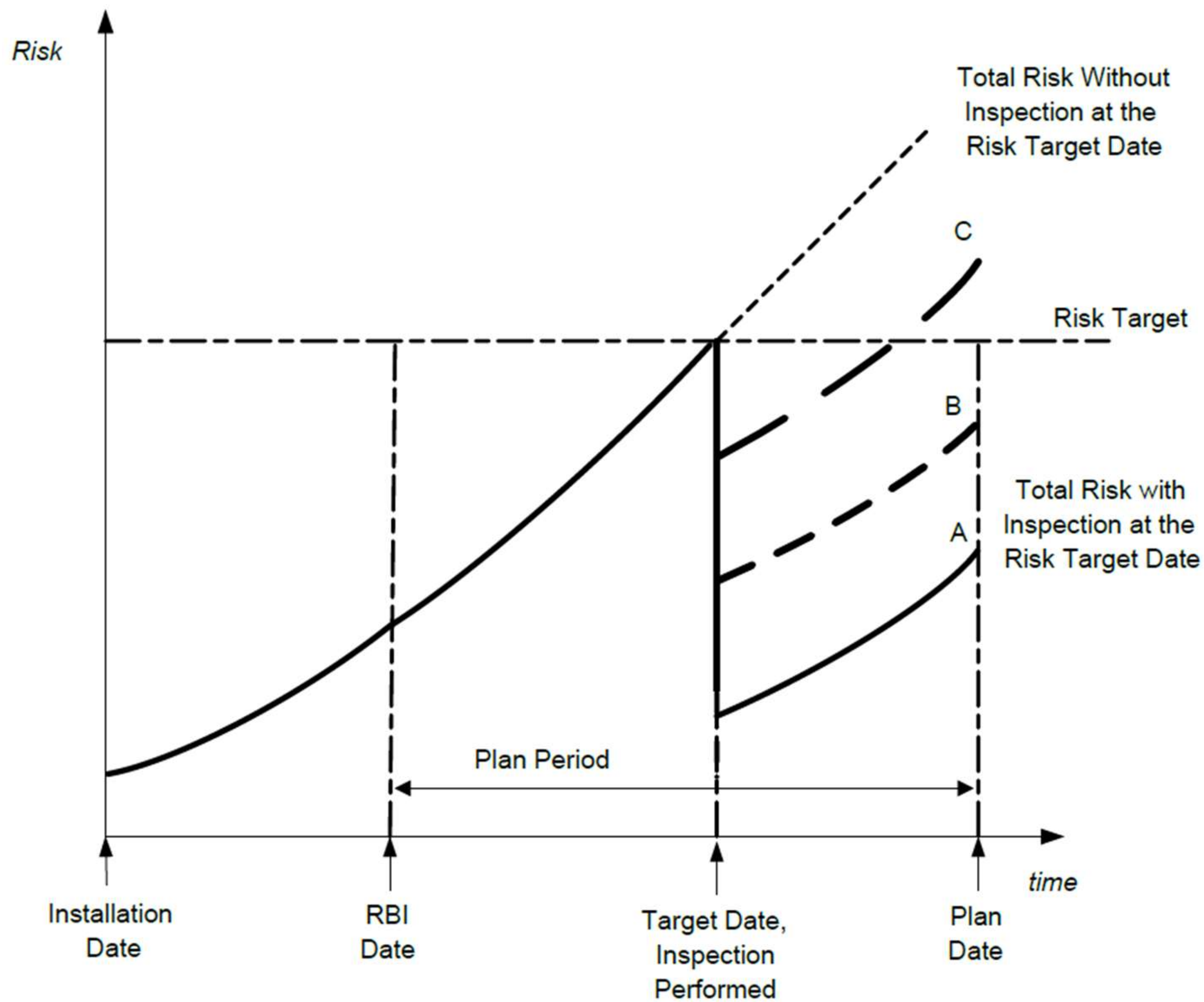


Figure 4.6—Case 1: Inspection Planning when the Risk Target is Exceeded During the Plan Period

如何訂立 Risk Target

- 基於大修頻率
- 基於法規規定
- 風險可承受程度

基於 RBI 的檢查

ALARP (As Low As Reasonably Practical)

基於腐蝕劣化機制來進行 NDT 或是其他技術分析

配合 risk target 的檢查有效性

依風險排序結果依序進行風險減緩措施(例如:NDT)

RBI 風險管理

- 資料收集
- 腐蝕環路
- API 571
- API 581

- 定性
- 定量

- 檢查資料回饋
- Re-RBI
- 第三方驗證
- 管理系統

- 迴避
- 預防
- 轉移、承受

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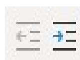

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