تفاوت ها و شباهتها در متدولوژی های API 581 و DNV-RP-G101 در ارزیابی ریسک

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زمستان ۱۴۰۰

- **<u>DNVGL-RP-G101 :</u>**
- The objective of this recommended practice is to describe a method for establishing and maintaining a risk based inspection (RBI) plan for upstream offshore pressure systems. (onshore)

- **<u>API580/581 :</u>**
- pressurised fixed equipment (in refining, petrochemical, chemical process plants and oil and gas production facilities) (downstream)

RBI Methods

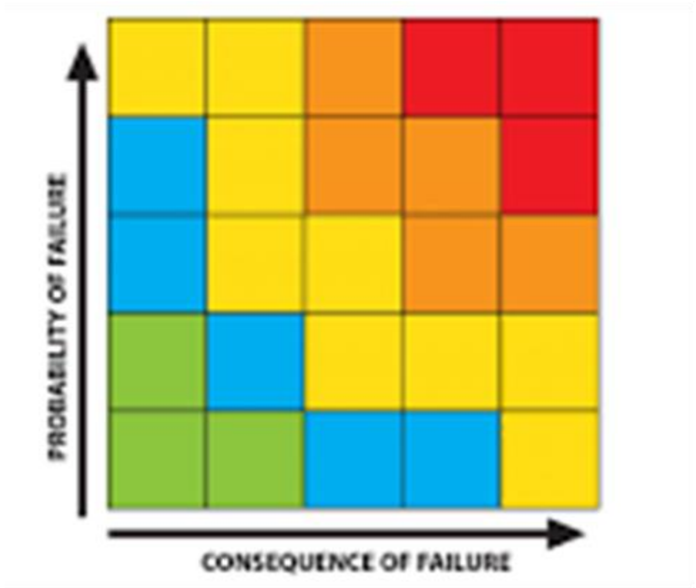
- Qualitative
- Quantitative

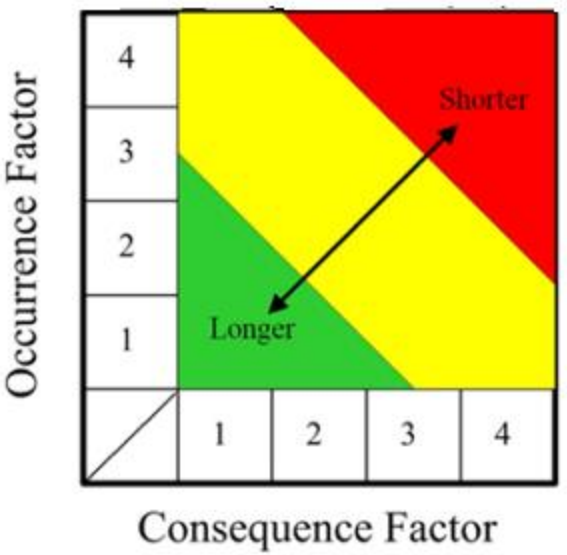
In practice: both

Semi-quantitative/semi-qualitative

RISK CALLCULATION

$$Risk = POF \times COF$$





Semi-quantitative/semi-qualitative

- the COF assessment is qualitative and the POF assessment is quantitative.

the COF and POF assessments are quantitative, whereas the risk ranking and time to inspection assessment are qualitative. (medium, high,….)

API 581

Table 4.1—Numerical Values Associated with POF and Area-based COF Categories

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

[a] POF values are based on a *gff* of 3.06E-05 and an F_{MS} of 1.0. If the suggested *gff* values in 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 4.11.4.

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DNV-RP-G101

Table 4-1 Probability of failure description

Cat.	*Annual failure probability*		*Description*
	Quantitative	*Qualitative*	
5	> 10^{-2}	Failure expected	(1) In a small population*, one or more failures can be expected annually.
			(2) Failure has occurred several times a year in location.
4	10^{-3} to 10^{-2}	High	(1) In a large population**, one or more failures can be expected annually.
			(2) Failure has occurred several times a year in operating company.
3	10^{-4} to 10^{-3}	Medium	(1) Several failures may occur during the life of the installation for a system comprising a small number of components.
			(2) Failure has occurred in operating company.
2	10^{-5} to 10^{-4}	Low	(1) Several failures may occur during the life of the installation for a system comprising a large number of components.
			(2) Failure has occurred in industry.
1	< 10^{-5}	Negligible	(1) Failure is not expected.
			(2) Failure has not occurred in industry.

Notes:
* Small population = 20 to 50 components.
** Large population = More than 50 components

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PoF Ranking	PoF Description	A	B	C	D	E
5	(1) In a small population, one or more failures can be expected annually. (2) Failure has occurred several times a year in the location.	YELLOW	RED	RED	RED	RED
4	(1) In a large population, one or more failures can be expected annually. (2) Failure has occurred several times a year in operating company.	YELLOW	YELLOW	RED	RED	RED
3	(1) Several failures may occur during the life of the installation for a system comprising a small number of components. (2) Failure has occurred in the operating company.	GREEN	YELLOW	YELLOW	RED	RED
2	(1) Several failures may occur during the life of the installation for a system comprising a large number of components. (2) Failure has occurred in industry.	GREEN	GREEN	YELLOW	YELLOW	RED
1	(1) Several failures may occur during the life of the installation for a system comprising a large number of components. (2) Failure has occurred in industry.	GREEN	GREEN	GREEN	YELLOW	YELLOW
CoF Types	Safety	No Injury	Minor Injury Absence < 2 days	Major Injury Absence > 2 days	Single Fatality	Multiple Fatalities
	Envirnoment	No pollution	Minor local effect. Can be cleaned up easily.	Significant local effect. Will take more than 1 man week to remove.	Pollution has significant effect upon the surrounding ecosystem (e.g. population of birds or fish).	Pollution that can cause massive and irreparable damage to ecosystem.
	Business	No downtime or asset damage	< € 10.000 damage or downtime < one shift	< € 100.000 damage or downtime < 4 shifts	< € 1.000.000 damage or downtime < one month	< € 10.000.000 damage or downtime one year
CoF Ranking		A	B	C	D	E

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Table C-1 Factors to consider in consequence assessment

Ignited leak		
Safety consequence	*Economic consequence*	*Environmental consequence*
Consider loss of life due to: — burns to personnel — direct blast effects to personnel — indirect blast effects to personnel (missiles, falling objects) — injuries sustained during escape and evacuation.	Consider the costs of: — repair of damage to equipment and structure — replacement of equipment and structural items — deferred production — damage to reputation.	Consider the effects of: — toxic gas release — smoke.
Unignited leak		
Safety consequence	Economic consequence	Environmental consequence
Consider loss of life due to: — toxic gas release — asphyxiating gas release — impingement of high pressure fluids on personnel.	Consider the costs of: — deferred production — repairs.	Consider the effects of: — hydrocarbon liquids spilled into the sea.

API 581

- consequence area or in financial consequence.

1. Affected area
2. Financial

- Consequences from flammable and explosive events, toxic releases, and nonflammable and nontoxic events are considered based on the process fluid and operating conditions.

API 581 POF

$$P_f(t) = gff \cdot F_{MS} \cdot D_f(t)$$

Generic Failure Frequency Method

$$P_f(t) = gff \times F_{MS} \times D_f(t)$$

- Generic failure frequency
- Management system factor
- Damage factor

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

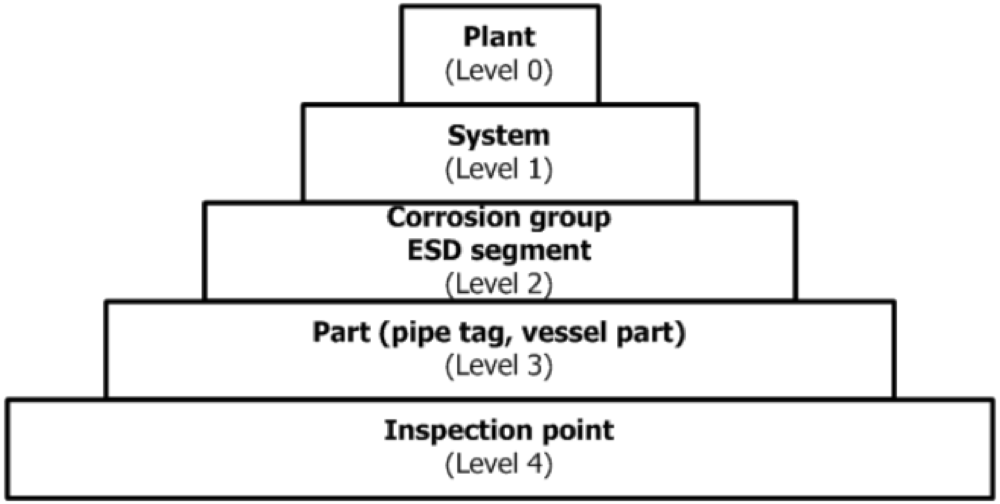
G101 POF

- (POF) is the probability of an event occurring per unit time (e.g. annual probability).
- It is estimated on the basis of the component degradation. PoF is related to the extent of, and uncertainty in, the
degradation related to the component's resistance to its loading.
- (limit state functions)

G101 POF

- It must be noted that QRA analyses are usually based upon generic failure frequencies.
- **RBI** should not be
  based on these generic data, since the failure frequency should be specific to the degradation mechanisms of specific components.
- Therefore, these generic failure frequencies should be removed and replaced with the specific probability of failure calculated using this recommended practice.

G101
Generic RBI Process



API 581:Damage Mechanism

6 Scc Damage Factor – Caustic Cracking
7 Scc Damage Factor – Amine Cracking
8 Scc Damage Factor – Sulfide Stress Cracking
9 Scc Damage Factor – Hic/Sohic-H2s
10 Scc Damage Factor – Alkaline Carbonate Stress Corrosion Cracking
11 Scc Damage Factor – Polythionic Acid Stress Corrosion Cracking
12 Scc Damage Factor – Chloride Stress Corrosion Cracking
13 Scc Damage Factor – Hydrogen Stress Cracking-Hf
14 Scc Damage Factor – Hic/Sohic-Hf
15 External Corrosion Damage Factor – Ferritic Component
16 Corrosion Under Insulation Damage Factor – Ferritic Component
17 External Chloride Stress Corrosion Cracking Damage Factor – AusteniticComponent
18 External Chloride Stress Corrosion Cracking Under Insulation Damage Factor –Austenitic Com
19 High Temperaure Hydrogen Attack Damage Factor
20 Brittle Fracture Damage Factor
21 Low Alloy Steel Embrittlement Damage Factor
22 885°F Embrittlement Damage Factor

API 581
Thinning Damage Factor

- material specification
- corrosion rate
- Therefore by using these 2 factors, can model.
- General/ related to corrosion rate not damage mechanism.

- **G101:**
- CO_2 Corrosion, erosion
- CO_2 module for this is separated from corrosion rate.

API 581: Hole Size

Table 4.4M – Release Hole Sizes and Areas Used in Level 1 and 2 Consequence Analyses

Release Hole Number	Release Hole Size	Range of Hole Diameters (mm)	Release Hole Diameter, d_n (mm)
1	Small	0 – 6.4	$d_1 = 6.4$
2	Medium	> 6.4 – 51	$d_2 = 25$
3	Large	> 51 – 152	$d_3 = 102$
4	Rupture	> 152	$d_4 = \min[D, 406]$

G101

Table A-2 Hole size category and the corresponding hole diameters

Small holes	hole diameter ≤ 5 mm
Medium holes	5 mm < hole diameter < 25 mm
Large holes	25 mm ≤ hole diameter
Rupture (full release)	component diameter < hole diameter

- **API 581:**
  Hole size and distribution is independent of D.M
- **G101:**
  hole size related to degradation mechanism and damage mechanism

Table A-3 Hole size distribution for "insignificant" systems

	% distribution		
Equivalent hole diameter	*Carbon steels*	*Stainless steel and nickel-based alloys*	*Titanium-based alloys*
Small hole	0	0	100
Medium hole	0	100	0
Large hole	100	0	0
Rupture	0	0	0

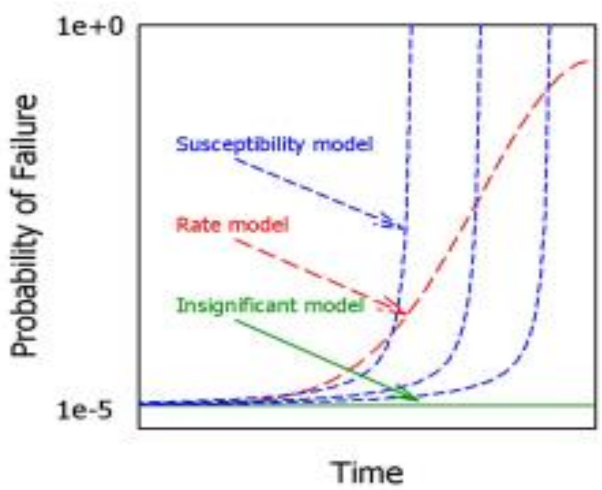
G101

Degradation modelling and probability of failure evaluation

- insignificant model
- unknown model
- rate model (model that we can predict it by time)
- susceptibility model

G101

Rate Model/ (thinning)
susceptibility model (no useful Inspection) (Incubation - Growth)
(All of cracking mechanism = No inspection plan, susceptibility model)



G101

Susceptibility model

- Since the mechanism is such that the damage can be triggered at any time and thereafter proceed rapidly, the onset and development of the damage are difficult to follow by inspection.
- However, it is beneficial to monitor key process parameters.

G101

Rate model

Since the degradation increases with time, the development of degradation can be measured by inspection, thus the inspection results can be used to adjust the rate model to suit the actual situation.

API 581

cracking , we have inspection effectiveness

Table 6.1 – Data Required for Determination of the Damage Factor – Caustic Cracking

Required Data	Comments
Susceptibility (Low, Medium, High)	The susceptibility is determined by expert advice or using the proceduresin this section.
NaOH Concentration (%)	Determine the concentration of the caustic solution being handled in this component. Take into account whether heating or flashing of water produces higher concentration.
Maximum Process Temperature, °C (°F)	Determine the maximum process temperature in this component. Consider local heating due to mixing if at a caustic injection point.
Steam out? (Yes or No)	Determine whether the component has been steamed out prior to water flushing to remove residual caustic.
Time since last SCC inspection (years)	Use inspection history to determine years since the last SCC inspection.
Inspection Effectiveness Category	The effectiveness category that has been performed on the component.
Number of Inspections	The number of inspections in each effectiveness category that have been performed.

API 581

Fatigue, high temperature hydrogen attack = no inspection plan

lining damage factor = no inspection plan

Table 5.3 – Data Required for Determination of the Lining Damage Factor

Required Data	Comments
Type of Lining	See Tables 5.4 and 5.5, as applicable
Age of Lining (years)	Age of lining, or years since last A or B effective inspection (i.e. since last thorough visual inspection or other appropriate method)
Lining Condition	Condition of lining based on Table 5.6
On-Line Monitoring for Lining Failure	On-line monitoring, see Section 5.5.2.c
Damage factor	Thinning DF determined as in Section 4.0

G101

- water corrosion mechanism

Table A-6 Water categories - definition and description

Water categories	*Description*
Raw seawater	*Seawater:* Untreated, normal oxygen, bacteria, marine flora etc.
Seawater + biocide/ chlorination	*Seawater:* Treated with UV/filtered or bactericide, chlorinated.
Seawater low oxygen	*Seawater:* Deoxygenated (max. 50 ppb O_2). No other treatment.
Seawater low oxygen + biocide	*Seawater:* Deoxygenated (max. 50 ppb O_2), treated with UV/filtered or bactericide. No chlorination.
Seawater low oxygen + chlorination	*Seawater:* Deoxygenated (max. 50 ppb O_2) and chlorinated.
Seawater low oxygen + biocide + chlorination	*Seawater:* Deoxygenated (max. 50 ppb O_2), treated with UV/filtered or bactericide, chlorinated.
Fresh water	*Desalinated water:* Typically prepared by condensation of seawater. Basis for plant water for steam generation etc., low salt content, normal oxygen.
Closed loop	*Closed loop systems:* Desalinated systems that have intrinsically "low" oxygen content.
Exposed drains	*Seawater:* Open systems that collect water from drains, sluices, deluge, etc., and are assumed to contain untreated (raw) seawater.
Sanitary drains	*Fresh water:* Drains from sanitary systems. Fresh water with high bacteria and organic matter content.

G101:

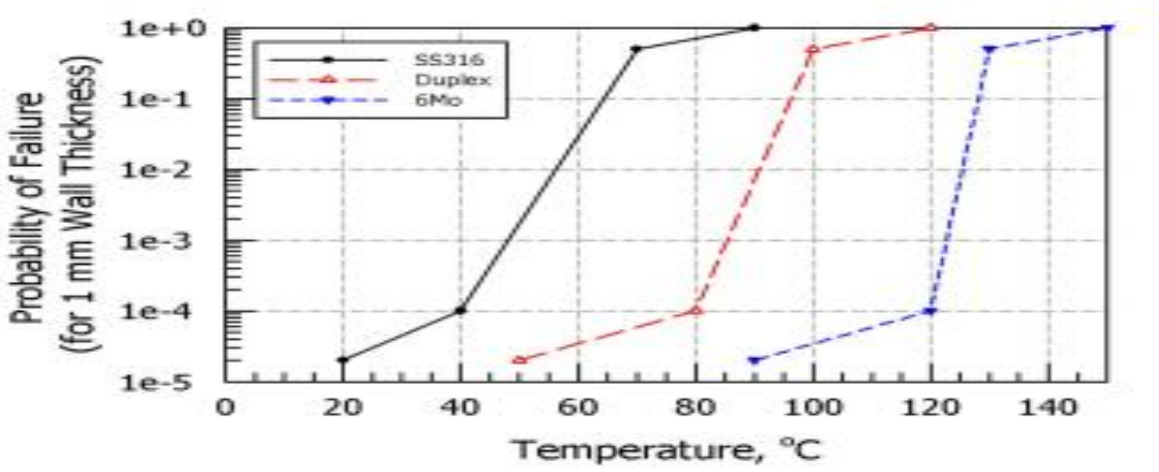
External corrosion of stainless steel

External corrosion of stainless steel - uninsulated

API 581 :

doesn't have it.

- **External local corrosion of stainless steel – insulated**



API 581:

External Chloride Stress Corrosion Cracking Damage Factor – Austenitic Component (Uninsulation)

External Chloride Stress Corrosion Cracking Under Insulation Damage Factor –

Austenitic Component

G101: JUST for under insulation we have ESCC

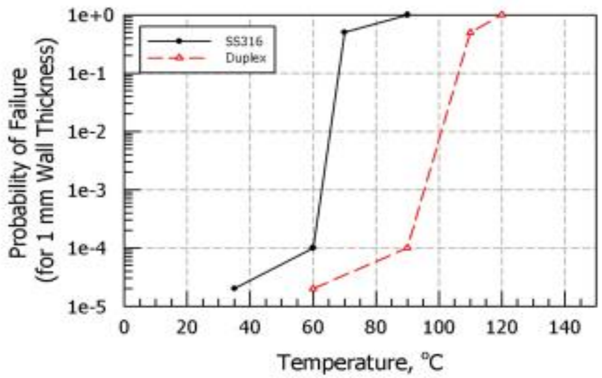


Figure A-6 PoF for ESCC of stainless steel under insulation

G101:
External corrosion of copper-nickel alloys/

API 581:
No external corrosion of copper-nickel alloys

A.10.1.1 External corrosion of copper-nickel alloys - uninsulated

Most of the copper-nickel alloys are resistant to corrosion in marine environment, hence, no external degradation is expected. So a fixed probability of failure of 10^{-5} should be assigned.

A.10.2 External corrosion of copper-nickel alloys - insulated

Most of the copper-nickel alloys are resistant to corrosion under insulation, hence, no external degradation is expected. So a fixed probability of failure of 10^{-5} should be assigned.

Thanks for your attention

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