EXAMPLE OF RBI

API Recommended Practice 580/581

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API 581 APPLICATION EXAMPLES

Background

- **Large Refinery** in the middle east **commissioned in 2013**
- Last/best **technology in materials and process control** applied to project
- **Inspection team** in place since construction, mostly dealing with **QA/QC**
- Initial RBI @ Project phase using an **internationally recognized RBI software** based on API 581
- **First** maintenance **turnaround** scheduled for **2018**

Examples:

1. Unit material review of a **Coker Naphtha Hydrotreater** Unit (KNHT) using API 571 for **damage mechanism** and API 581 Annex 2.B for the determination of **corrosion rates** (no piping included)
2. **Massive RBI analysis** of the Refinery's Train affected by **internal corrosion** using API 581 V3 (Thinning)

EXAMPLE 1 BACKGROUND

Unit material review and RBI of a Coker Naphtha Hydrofiner

- **RBI database** existed and fully inputted with **design & process data** and consequence of failure, while the **corrosion rates** were determined based on **expert-advice**
- **Original scope** asked for **100% vessel opening** at first mechanical turnaround to check consistency with **design assumptions** and identify **materials/corrosion issues**
- **A baseline inspection** using thickness monitoring was scheduled during the first in-service cycle based on inspector judgment **to adjust corrosion rates and reassess RBI** (near 90K TML's for Train 1)
- **Scope** was considered **excessive by management** and an alternative method of scope definition was requested
- **Purpose** of the exercise was to determine the **first in-service inspection** date & scope for the unit example's equipment and establish a quick evaluation tool to reassess the scope of vessels inspection

EXAMPLE 1 METHOD

1. **Identify** equipment into the standard **damage mechanism** diagram of API 571
2. Check **local unit's corrosion concern** areas and corrosion control program against NACE Corrosion control manual
3. Identify **active and inactive damage mechanism** (Thinning & SCC)
4. Determine **theoretical corrosion rate** using API 581 Annex 2.B and the material & process information
5. **Recalculate the risk** using the RBI software and revised data
6. Determine **minimum inspection effectiveness** to control the risk for the period **2014 to 2023** (maximizing non-intrusive on-stream)

➢ Exercise lasts **4 days covering 47 vessels** using a team formed with the local RBI leader and deputy, and an external RBI expert

***SCC**: Stress corrosion cracking*

EXAMPLE 1 EXAMPLE OF CORROSION RATE ESTIMATION

- Drum D2, affected by Sour water corrosion (additionally to HIC-SOHIC)
- Use of API 581's Table 2.B.7.1/2 and 7M
- Gas concentration into Water: 0,51 wt%
- Corrosion rate @ max. fluid speed: 0,38 mm/yr.

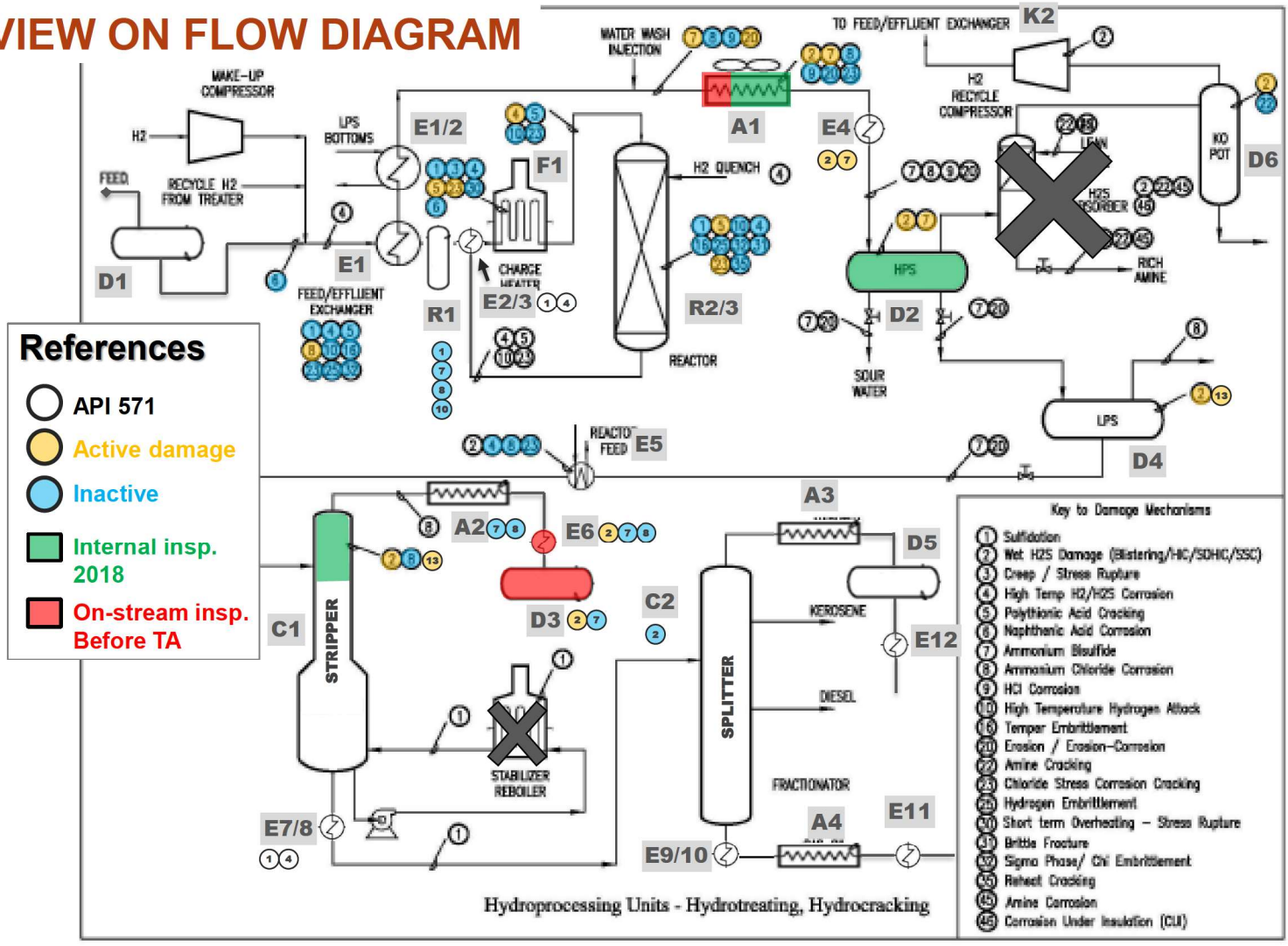
Equipment	API-571 DM	Inspection required at?	Equipment	API-571 DM	Inspection required at?
D1	4,6	Not required	**AI's** (Bundle)	7	CR=0,13, insp. 2018 (Internal, IRIS/EC)
EIABCD tube side	8	CR=0,13, HIC-SOHIC removed, insp >2028	**E4** (shell side)	2,7	CR0,13, insp >2028
E14 (tube side)	8	CR=0,13, insp >2028	**D2**	2,7	CR=0,38, HIC-SOHIC (Sens. Low, insp 2024) Finally insp. 2018 (Highly, internal WFMT)
R1	8	CR=0,13, insp >2028	**D4**	2,13	CR=0,13, HIC-SOHIC (sens very low) insp. >2028
E2/E3 (tube side)	8	CR=0,13, insp >2028	**D6**	2	HIC-SOHIC sens. Med insp. 2023 (Fairly, on stream)
F1 (tubes)	1,3,4	No required	**E5**	2,13	2048
	5,23	Prevention (PTA, etc)	**C1** top section	2	HIC-SOHIC, send med. insp. 2018 (Highly, internal WFMT)
R2/R3	1	CR=0,51 Base & 0,03 Clad. 0,3 if clad is gone, insp >2028	**A2's**	2	HIC-SOHIC sens low insp. 2025 (On-stream)
	4	CR=0,2 Base & 0,03 Clad. 0,3 if clad is gone, insp >2028	**E6**	2	HIC-SOHIC sens low insp. 2018 (On-stream)
	5,23	Prevention (PTA, etc)	**D3**	2	HIC-SOHIC sens low insp. 2018 (On-stream)
E1's/E2 (shell side)	1,4	CR=0,03/0,05, insp >2028	**C2, A3's, D5, E12/7/8/9/10/11, A2's**	Clean service	Not required
A1's (Headers)	2,7	HIC-SOHIC (API 932B), insp 2018 (on stream)			

EXAMPLE 1 RESULTS

- Summary by equipment type and inspection needs
- Globally, 20% of equipment require inspection during the period 2014-2023 (two unit cycles)

EQP-Type	Net-count	Assessed	Internal insp. TA 2018	On-stream insp. before TA 2018	On-stream insp. Period 2018-2023
Reactor	3	3			
Drum	6	6	1	1	1
Column	2	2	1		
Furnace	1	1			
Exchanger	19	19		1	
Airfin	16	16		4	
Total	**47**	**47**	**2 (4%)**	**6 (13%)**	**2 (4%)**

VIEW ON FLOW DIAGRAM



EXAMPLE 2 BACKGROUND

Full RBI analysis of Refinery's Train 2

- **Train 2** of the Refinery includes Distillation, Mild Hydrocracker, Diesel & Naphtha Hydrotreaters, Sulphur Recovery, Amine, Hydrogen, LPG and FCC/Coker (shared with Train 1).
- RBI database was **fully inputted with design & process data** of **1425** component on vessels and **454 piping** circuits
- The **corrosion rates** were determined based on **expert-advice** at project Phase
- **Purpose** of study was to determine the **number of equipment needing inspection** for internal corrosion during the first two unit cycles **2013-2023**

Unit type	Piping	Vessels
Hydrotreating	106	371
FCC-Coker	115	352
Treating	106	241
Distillation	44	199
Gas Plant	25	100
Alkylation	17	90
Hydrogen	23	50
LPG	18	22
Total Items	**454**	**1425**

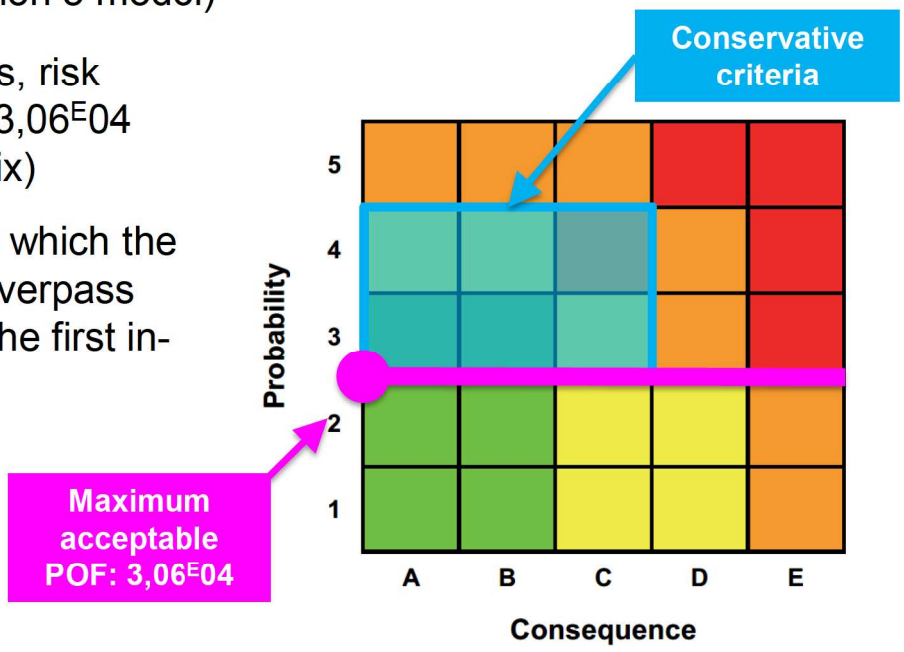
EXAMPLE 2 NEW THINNING MODEL OF API 581

- Version 3 of document released in 2018 contains a new model for assessing POF related to metal loss.
- In general terms this model includes:
  - Determination of **furnished thickness**, corrosion rate, effectiveness of past inspection and time in service
  - Determination **of minimum required thickness through FFS** or code calculation
  - Calculate **ar/t** factor including clad (if exist)
  - Calculate **strength ratio using flow stress** and the average of tensile & yield stress of the material
  - Calculate the **inspection effectiveness factor** and the posterior probability depending on those factors (Bayesian approach)
  - Determine the **damage factor** using affecting the previous calculated parameters by a standard normal cumulative distribution function
  - Affect the calculated damage factor by the on-line monitoring, dead-legs, etc. as in version 2.

***FFS**: Fitness-for-service, **ar/t:** Aging factor (Period.Corrosion rate / Thickness)*

EXAMPLE 2 METHOD

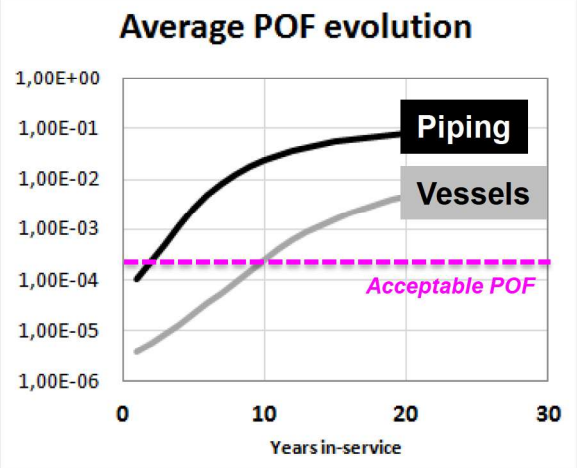
1. Obtain **process and physical data** from RBI database including the corrosion rate determined by the expert
2. Recalculate parameters and **probability of failure** of each year in service for 30 years period (Version 3 model)
3. No consequence analysis, risk target was set to POF < $3{,}06^{E}04$ (Level 2 of the Risk Matrix)
4. Identify the **early date** at which the POF of the component overpass $3{,}06^{E}04$ and set that as the first in-service inspection date



EXAMPLE 2 RESULTS

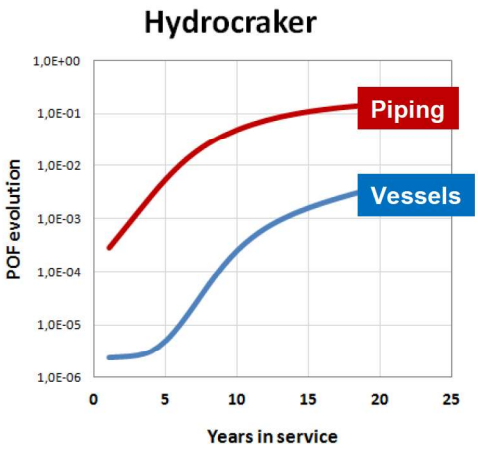
- Only **6% of Vessels** should receive **first in-service inspection before 2023** (the bottom of a HDS stripper must have been inspected following 1 year of operation)
- **Piping** should **receive more attention with 16%** of circuits inspected by 2023 (which 88 during the first Refinery cycle)
- As per piping, most of inspection should be ***on-stream non-intrusive***

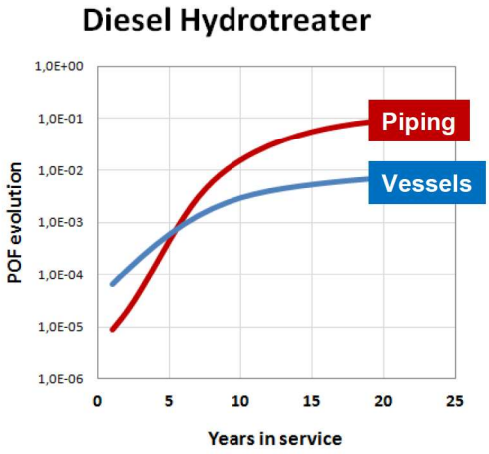
First in-service inspection	Piping		Vessels	
≤ 2023	309	16%	115	6%
2024 to 2028	60	3%	296	16%
> 2028	85	5%	1014	54%
Total	**454**		**1425**	

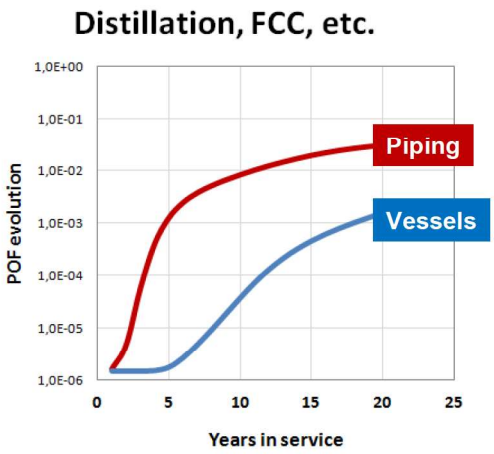


EXAMPLE 2 SUMMARY

- Assessment **result is in line with industry experience**
- A **partial independent check** of those two assessment by a recognized international RBI expert body **confirmed the results**
- The validity of this type of assessment is extremely **conditioned to the integrity operation management**
- Piping, Hydro treating units the main concern for corrosion (also in line with the history)







WHY TURNAROUND INSPECTION SHOULD BE MINIMIZED?

- A required inspection…

	Feasible	Effective	Opportune	Low cost
On-Stream, Non-Intrusive	Highly	Highly	Fully	Low
Intrusive	Poorly	Fully	Fairly	High
Issues	*Manhole, NDT*	*Integrity*	*Integrity, discovery work*	*Budget*

REFERENCES

- API 571 Damage Mechanism affecting Refining Industry
- API 581 Recommended practice version 2008 & 2016