PT Filosofi Teknik Utama

Judul Dokumen	No. Dokumen	:	FTU-056/01/R-RLA/II/2024
Remaining Life Assessment Pressure Vessel	Revisi	:	0
	Tanggal Rev.	:	25 February 2024

Remaining Life Assessment Pressure Vessel

LPG Storage Tank Cap. 50 Ton (T-01)

PT Mitra Harun Gasindo

0	Issued for approval	25-Feb-24	AB	CPI	
A	Issued for review	23-Feb-24	AB	CPI	
REV.	**DESKRIPSI**	**TANGGAL**	**Prepared**	**Checked**	**Approved**
			PT Filosofi Teknik Utama		**PT Mitra Harun Gasindo**

REVISION SHEET

Revision	Date	Description of Change
A	23-Feb-2024	Issued for Review
0	25-Feb-2024	Issued for Approval

DAFTAR ISI

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DAFTAR TABEL

1. Pendahuluan

1.1 Latar Belakang

Berdasarkan pada PERMEN ESDM No. 32 tahun 2021 tentang Inspeksi Teknis dan Pemeriksaan Keselamatan Instalasi dan Peralatan Pada Kegiatan Usaha Minyak dan Gas Bumi, perihal "Pemeriksaan Peralatan Operasi MIGAS yang telah Melewati Umur Desain (Design Life) dan yang Tidak Memiliki Data". Dalam hal ini maka dilakukan penilaian sisa umur layan pada peralatan milik PT Mitra Harun Gasindo sebagai bentuk tanggung jawab keselamatan kerja dan operasi terhadap peralatan tersebut.

1.2 Tujuan

Adapun lingkup pekerjaan yang dibahas dalam laporan penilaian sisa umur layan (RLA) ini meliputi:

a) Penelaahan dokumen teknis peralatan
b) Penelahaan dokumen inspeksi dan perawatan
c) Penentuan mekanisme kerusakan
d) Fitness for Service
e) Penentuan sisa umur layan
f) Penilaian risiko
g) Rekomendasi metode dan interval inspeksi

Hasil penilaian ini digunakan sebagai pemenuhan Pemeriksaan Keselamatan untuk Sertifikat Inspeksi (COI) sesuai dengan Peraturan Menteri ESDM No. 32 Tahun 2021

1.3 Referensi

Laporan ini menguraikan tentang ketentuan inspeksi dan evaluasi data untuk menentukan integritas mekanikal dari sistem bejana tekan. Code/Standart yang digunakan sebagai referensi utama dalam pekerjaan ini adalah:

- Peraturan Menteri Energi Dan Sumber Daya Mineral Republik Indonesia No.32 Tahun 2021 tentang "Inspeksi Teknis dan Pemeriksaan Keselamatan Instalasi dan Peralatan pada Kegiatan Usaha Minyak dan Gas Bumi.
- ASME Section VIII Division 1, Rules for Construction of Pressure Vessels.
- API Publication 510, Pressure Vessel Inspection Code: Inspection, Rating, Repair, and Alteration.
- API 571, Damage Mechanisms Affecting Fixed Equipment in the Refining Industry.
- API 581 Edition 2008, Risk-Based Inspection Technology
- ASME PCC – 3, Inspection Planning Using Risk-Based Methods
- API 572, Inspection Practices for Pressure Vessels.

2. Lingkup Kerja

- **Melakukan Perhitungan Ulang**

  Menganalisa dan melakukan perhitungan ulang dengan menggunanakan Spreadsheet Excel untuk mengetahui bahwa ketebalan nominal yang digunakan dapat menahan design pressure dari bejana tekan yang mengacu sesuai standard/code konstruksi.

- **Maximum Allowable Working Pressure**

  Perhitungan aktual MAWP dilakukan menggunakan Standart ASME Section VIII Division 1. Hasil perhitungan aktual MAWP ini harus tidak boleh lebih kecil dibandingkan MAWP kondisi desain.

- **Perhitungan Sisa Umur**

  Mengetahui dan menganalisis sisa umur bejana tekan yang telah terpasang dengan membandingkan antara data design dengan data inspeksi terakhir.

- **Penentuan Metode dan Jarak Inspeksi**

  Penentuan metode pemeriksaan dan jarak inspeksi selanjutnya adalah berdasarkan ASME PCC 3 dan owner specification. .

3. Data Umum

Data umum bejana tekan dideskripsikan di bawah :

Owner/Operator	: PT Mitra Harun Gasindo
Service	: LPG Storage Tank Cap. 50 Ton
Tag No	: T-01
No Seri	: 902.03D.021
Code	: ASME Sec. VIII Div. 1 (Analisa)
Material	: SA 516 Gr. 70
Design Pressure	: 17,6 kg/cm2
Tahun Pembuatan	: 2009
Joint Eff	: 1
Size	: 3256 mm (ID) x 10980 mm (T/T)

4. Perhitungan Teknis

Perhitungan menggunakan Spreadsheet Excel sesuai ASME Code, Section VIII, Division 1 dapat dilihat pada **Lampiran C**.

5. Mekanisme Kerusakan

Bejana tekan rentan terhadap berbagai jenis kerusakan umum dan mekanisme kerusakannya adalah sebagai berikut:

Service	: Elpiji
Material	: SA 516 Gr. 70
DP/OP (Psi)	: - /
DT/OT (°F)	: - /
Aliran	: Hidrodinamis
Muatan	: Statis
Insulasi	: Tidak Ada
Kandungan CO	: Tidak Ada
Kandungan H2S	: Tidak Ada
Kandungan H2O	: Tidak Ada

Dari tabel damage mechanisms screening ASME PCC 3 - Inspection Planning Using Risk-Based Methods **(Appendix A)** ada beberapa kemungkinan jenis mekanisme kerusakan yang diduga terjadi pada bejana tekan berdasarkan parameter berikut:

- Service & Fluida
- Material
- Suhu
- Aliran
- Beban
- Insulasi

Tingkat kemungkinan (possibility) terjadinya damage mechanism (low, medium, high) berdasarkan dari banyaknya parameter yang sesuai dengan parameter screening. Dari parameter, kemungkinan jenis mekanisme kerusakan yang diduga terjadi pada bejana tekan adalah sebagai berikut:

Tabel 5.1 Mekanisme Kerusakan

No.	Mekanisme Kerusakan	Tipe	Peluang
1	External Corrosion	Penipisan	Rendah
2	General Corrosion	Penipisan	Rendah

6. Perencanaan Inspeksi

Metode perencanaan inspeksi dilakukan berdasarkan pada kemungkinan mekanisme kerusakan yang telah ditetapkan sesuai kondisi bejana tekan. Penentuan metode inspeksi dan monitoring berdasarkan ASME PCC 3 - Inspection Planning Using Risk-Based Methods **(Appendix B)**, perencanaan inspeksi yang diajukan untuk bejana tekan ini adalah sebagai berikut:

Tabel 6.1 Perencanaan Inspeksi

No	Mekanisme Kerusakan	Metode Inspeksi	Meliputi [1]	Interval Inspeksi
1.	External Corrosion	Visual Inspeksi dan UT Thickness/Scanning	Visual inspection of >95% of the exposed surface area with follow-up by UT or pit gauge as required.	4 tahun
2.	General Corrosion			

Note: 1 Ref: API 581 Edition 2008

7. Penilaian Teknis

MAWP untuk penggunaan selanjutnya dari bejana tekan didasarkan pada perhitungan yang dilakukan menggunakan ASME code edisi terbaru atau menggunakan construction code pada saat bejana tekan dibangun/dibuat.

Pada servis yang korosif, nilai dari ketebalan dinding yang digunakan untuk perhitungan adalah nilai ketebalan aktual yang didapat dari hasil inspeksi dikurangi dengan dua kali perkiraan laju korosi sebelum tanggal inspeksi selanjutnya dilakukan, sebagai berikut:

$$t = t_{actual} - 2\,(C_{rate} \text{ x } I_{internal})$$

Dari perhitungan ulang yang di lakukan pada bejana tekan, maka dapat di ambil hasil sebagai berikut:

Tabel 7.1 Perhitungan MAWP

Bagian	Ketebalan 2009 (mm)	Ketebalan 2020 (mm)	Ketebalan 2023 (mm)	Corrosion Rate (mm/yr)	Interval Inspeksi (years)[1]	Ketebalan Perhitungan (mm)	MAWP (Psi)
Head 1	14,00	13,80	13,34	0,153	4	13,03	20,89
Shell	22,00	22,33	21,21	0,373	4	20,46	15,63
Head 2	14,00	13,34	13,39	0,153 [2]	4	13,42	20,89

Note :

1. Interval 4 tahun berdasarkan re-certification planning.
2. Menggunakan Corrosion Rate Head 1

8. Perhitungan Sisa Umur

Sisa umur bejana tekan (dalam tahun) yang dihitung berdasarkan rumus dari API Publication 510 adalah sebagai berikut:

$$Remaining\ life = \frac{t_{actual} - t_{required}}{corrosion\ rate}$$

Maka dari hasil perhitungan laju korosi dan sisa umur yang telah dilakukan pada bejana tekan ini dapat dilihat dalam tabel berikut:

Tabel 8.1 Perhitungan Sisa Umur (Design Pressure 17,6 kg/cm2)

Bagian	Ketebalan 2023 (mm)	Ketebalan Dibutuhkan (mm)	Corrosion Rate (mm/yr)	Sisa Umur (years)	Catatan
Head 1	13,34	10,20	0,153	>20	Memenuhi
Shell	21,21	20,53	0,373	2	Tidak Memenuhi
Head 2	13,39	10,20	0,153	>20	Memenuhi

Tabel 8.2 Perhitungan Sisa Umur (Derating Pressure 15,6 kg/cm2)

Bagian	Ketebalan 2023 (mm)	Ketebalan Dibutuhkan (mm)	Corrosion Rate (mm/yr)	Sisa Umur (years)	Catatan
Head 1	13,34	9,04	0,153	>20	Memenuhi
Shell	21,21	18,18	0,373	8	Memenuhi
Head 2	13,39	9,04	0,153	>20	Memenuhi

9. Analisa Risiko

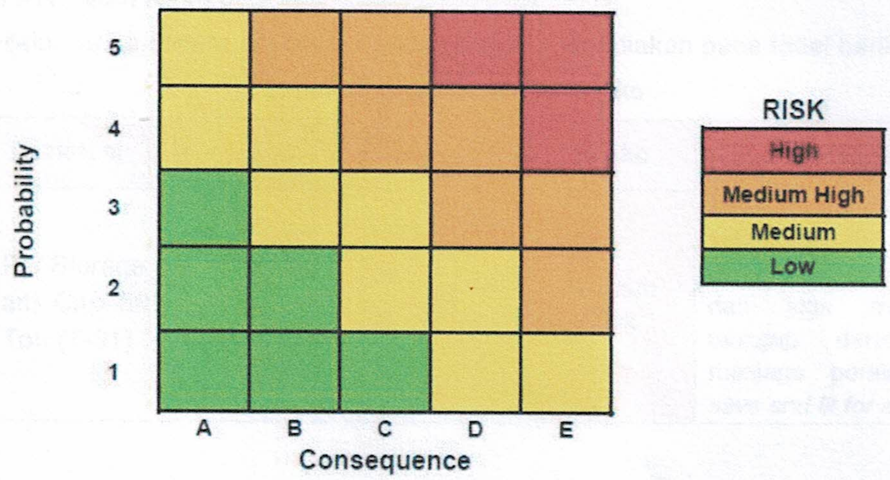
Analisis risiko merupakan aktivitas untuk mengidentifikasi dan menganalisis potensi sebab dan kemungkinan akibat risiko, baik dengan metode kualitatif, semi kuantitatif, maupun kuantitatif. Analisis risiko yang dilakukan di dalam laporan ini bersifat kualitatif.

9.1 Risk Matriks

Analisa risiko dapat dirumuskan sebagai perkalian antara Probability of Failure (PoF) dan Consequence of Failure (CoF) dengan rumus sebagai berikut:

Risk = Probability of Failure (PoF) x Consequence of Failure (CoF)

Matrik risiko ditunjukkan pada gambar berikut:



Gambar 9-1 Risk Matrix based on API 581 2016

9.2 Probability of Failure (POF)

Kriteria Probability of Failure (PoF) ditunjukan pada table berikut:

Tabel 9.1 Probability of Failure (POF) Kriteria

Category	Probability Range
1	≤ 3.06E-05
2	3.06E-05 < 3.06E-04
3	3.06E-04 < 3.06E-03
4	3.06E-03 < 3.06E-02
5	> 3.06E-02

Ref: API 518 2016 (Table 4.1M – Numerical Values Associated with POF

9.3 Consequence of Failure (COF)

Kriteria Consequence of Failure (CoF) ditunjukan pada table berikut:

Tabel 9.2 Consequence of Failure (COF) Kriteria

Category	Consequence Range (m2)
1	CA ≤ 9.29
2	9.29 < CA ≤ 92.9
3	92.9 < CA ≤ 929
4	929 < CA ≤ 9290
5	CA > 9,290

Ref: API 518 2016 (Table 4.1M – Numerical Values Associated with Area Based COF Categories

9.4 Hasil Penilaian Resiko

Hasil penilaian risiko secara *qualitative* pada peralatan disediakan pada tabel berikut.

Tabel 9.3 Hasil Penilaian Resiko

No	Deskripsi	Kategori		Risiko	Keterangan
		PoF	CoF		
1	LPG Storage Tank Cap. 50 Ton (T-01)	3	2	Medium Risk	Tidak pernah terjadi kebocoran ataupun kegagalan pada peralatan dan juga management tanggap darurat untuk menjaga peralatan tetap *save and fit for service.*

10. Kesimpulan dan Rekomendasi

10.1 Kesimpulan

Hasil penilaian integritas pada peralatan sesuai dengan parameter teknis berdasarkan peraturan, kode/standar dan dokumen perusahaan antara lain:

- LPG Storage Tank Cap. 50 Ton (T-01) dalam kondisi derating dengan **MAWP 15,6 kg/cm2**
- Sisa umur layan pada LPG Storage Tank Cap. 50 Ton (T-01) adalah **8 Tahun**,
- Kategori risiko pada LPG Storage Tank Cap. 50 Ton (T-01) adalah **Medium Risk**

10.2 Rekomendasi

Disarankan untuk merawat kondisi bejan tekan untuk tetap layak beroperasi dengan saran:

- Melakukan inspeksi dan perawatan secara berkala untuk mengetahui indikasi kebocoran, korosi ekstenal, kerusakan peralatan dan keadaan tidak normal lain pada peralatan proses sesuai kaidah keteknikan yang baik.
- Melakukan pengecatan coating pada bagian yang terindikasi korosi untuk mencegah korosi luar (API RP 572 – 9.3.12).
- Menandai titik pengambilan ketebalan pada bejana tekan, agar pada pengambilan ketebalan selanjutnya dilakukan pada titik yang sama.
- Melakukan kegiatan operasional dengan memperhatikan SOP dan manajemen risiko
- Melakukan pengecekan mekanisme kerusakan lain seperti korosi dan retak
- Memastikan tekanan operasi tidak melebihi MAWP peralatan bejana tekan.

APPENDIX A
DAMAGE MECHANISM AND DEFECTS SCREENING TABLE

Mechanism	Damage/ Defect Mode [Note (1)]	Materials of Construction in Which Mechanism Typically Occurs													Operating Environment: Temperature (T) Range in Which Mech. May Occur					Operating Environment: Processes in Which Mechanism May Be Suspected. Process Contains:															Flow Req.		Type of Loading			
		Damage Mechanism	Manufacturing Defect	Carbon Steel	Low Alloy Steel	300 Series Stainless Steel	400 Series Stainless Steel	Duplex Stainless Steel	Fe-Ni Alloys (0.6–1.3 Fe:Ni Ratios)	Ni-Based Alloys (>50% Ni)	Cu Alloys	Ti	Al Alloys	Cast Iron	T>1,000°F	800<T<1,000°F	250<T<800°F	32<T<250°F	T<32°F	Water, Steam, Air	Hydrogen	Carbon	Sodium	Carbonate	Sulfur	Amines	Ammonia	Chloride	HF	Phenol	Crude Oil	Phosphoric Acid	Particulates	Other	Motionless–Static	Hydrodynamic	Static Stress [Note (2)]	Impact	Thermal Gradients or Shock	Cyclic Stress (e.g., Vibratory)
885°F embrittlement	Metallurgical damage	X					X	X								X	X																							
Abrasive wear	Metal loss	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X														X			X				
Acid dew point corrosion	Metal loss	X		X	X	X	X	X	X					X			X	X		X								X	X			X		X	X					
Adhesive wear	Metal loss	X		X	X	X	X	X	X	X	X	X	X	X			X	X																						X
Amine corrosion	Metal loss	X		X	X						X						X	X								X														
Amine cracking	Cracking	X		X							X						X	X								X														
Ammonia grooving	Metal loss	X									X						X	X		X						X	X									X				
Ammonia stress corrosion cracking	Cracking	X		X							X						X	X									X										X			
Ammonium bisulfide corrosion (alkaline sour water)	Metallurgical damage	X		X	X						X		X	X				X		X					X		X									X				
Brittle fracture	Cracking	X	X	X	X		X							X			X	X	X																		X	X	X	X
Carbonate stress corrosion cracking	Cracking	X		X	X												X	X						X													X			
Carburization	Metallurgical damage	X		X	X	X	X	X	X	X					X	X						X																		
Metal dusting (catastrophic carburization)	Metal loss	X			X	X				X					X							X																		
Caustic stress corrosion cracking	Cracking	X		X	X	X	X	X									X	X		X			X											X			X			
Caustic corrosion (caustic gouging)	Metal loss	X		X	X						X		X				X	X		X			X											X		X				
Cavitation	Metal loss	X		X	X	X	X	X	X	X	X	X	X	X			X	X		X														X		X				

	Damage/ Defect	Materials of Construction in Which Mechanism Typically Occurs													Operating Environment: Temperature (T) Range in Which Mech. May Occur					Operating Environment: Processes in Which Mechanism May Be Suspected. Process Contains:															Operating Environment: Flow Req.		Operating Environment: Type of Loading			
Mechanism	Mode [Note (1)]	Damage Mechanism	Manufacturing Defect	Carbon Steel	Low Alloy Steel	300 Series Stainless Steel	400 Series Stainless Steel	Duplex Stainless Steel	Fe-Ni Alloys (0.6–1.3 Fe:Ni Ratios)	Ni-Based Alloys (>50% Ni)	Cu Alloys	Ti	Al Alloys	Cast Iron	$T>1{,}000°F$	$800<T<1{,}000°F$	$250<T<800°F$	$32<T<250°F$	$T<32°F$	Water, Steam, Air	Hydrogen	Carbon	Sodium	Carbonate	Sulfur	Amines	Ammonia	Chloride	HF	Phenol	Crude Oil	Phosphoric Acid	Particulates	Other	Motionless–Static	Hydrodynamic	Static Stress [Note (2)]	Impact	Thermal Gradients or Shock	Cyclic Stress (e.g., Vibratory)
Chelant corrosion	Metal loss	X		X	X												X			X																X				
Chloride stress corrosion cracking	Cracking	X				X		X	X								X	X		X								X						X			X			X
CO_2 corrosion	Metal loss	X		X	X												X	X				X																		
Cold cracking	Weld defects		X	X	X	X	X	X	X	X	X		X																											
Corrosion under insulation (CUI)	Metal loss	X		X	X	X	X	X			X	X	X	X				X	X	X															X					
Corrosion–fatigue	Cracking	X		X	X	X	X	X	X	X	X	X	X	X			X	X	X	X				X	X	X	X	X	X	X	X	X		X						X
Creep	Cracking	X		X	X	X	X	X	X	X	X	X	X	X	X	X																					X			
Creep fatigue	Cracking			X	X	X	X	X	X	X	X	X	X	X	X	X																					X			
Crevice corrosion	Metal loss	X		X	X	X	X	X	X	X	X	X	X	X			X	X		X															X					
Decarburization	Metallurgical damage	X		X	X										X					X	X				X									X						
Dissimilar metal weld cracking (DMW)	Cracking	X		X	X	X	X	X	X	X	X				X	X																								
Dissolved O_2 attack	Metal loss	X		X	X													X		X														X						
Electrical discharge	Metal loss	X		X	X	X	X	X	X	X	X	X	X	X			X	X																						
Erosion	Metal loss	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X				
Erosion–droplets	Metal loss	X		X	X	X	X	X	X	X	X	X	X	X			X	X		X	X	X	X	X	X	X	X	X	X	X	X	X		X		X				
Erosion–solids	Metal loss	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X													X			X				
Erosion/corrosion	Metal loss	X		X	X	X	X	X	X	X	X	X	X	X			X	X		X	X	X	X	X	X	X	X	X	X	X	X	X		X		X				
Fatigue	Cracking	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																					X
Fatigue, contact	Cracking	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																					X

	Damage/ Defect	Materials of Construction in Which Mechanism Typically Occurs													Operating Environment: Temperature (T) Range in Which Mech. May Occur					Operating Environment: Processes in Which Mechanism May Be Suspected. Process Contains:															Operating Environment: Flow Req.		Operating Environment: Type of Loading			
Mechanism	Mode [Note (1)]	Damage Mechanism	Manufacturing Defect	Carbon Steel	Low Alloy Steel	300 Series Stainless Steel	400 Series Stainless Steel	Duplex Stainless Steel	Fe-Ni Alloys (0.6–1.3 Fe:Ni Ratios)	Ni-Based Alloys (>50% Ni)	Cu Alloys	Ti	Al Alloys	Cast Iron	$T>1{,}000°F$	$800<T<1{,}000°F$	$250<T<800°F$	$32<T<250°F$	$T<32°F$	Water, Steam, Air	Hydrogen	Carbon	Sodium	Carbonate	Sulfur	Amines	Ammonia	Chloride	HF	Phenol	Crude Oil	Phosphoric Acid	Particulates	Other	Motionless–Static	Hydrodynamic	Static Stress [Note (2)]	Impact	Thermal Gradients or Shock	Cyclic Stress (e.g., Vibratory)
Fatigue, thermal	Cracking	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X																						X	
Fatigue, vibration	Cracking	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																					X
Filiform corrosion	Metal loss	X																X		X														X	X					
Flow-accelerated corrosion (FAC)	Metal loss	X		X													X	X																		X				
Flue gas dew point corrosion	Metal loss	X		X	X	X	X	X	X	X								X		X								X	X							X				
Fretting	Metal loss	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X	X																					X
Fuel ash corrosion	Metal loss	X		X	X	X	X	X	X	X	X		X	X	X	X							X		X															
Galvanic corrosion	Metal loss	X		X	X	X	X	X	X	X	X	X	X	X			X	X		X														X						
Graphitization	Metallurgical damage	X		X	X										X	X																								
High temp H_2/H_2S corrosion	Metal loss	X		X	X	X	X				X		X				X				X				X															
Hot cracking	Weld defects		X	X	X	X	X	X	X	X	X		X																											
Hot tensile	Metallurgical damage	X		X	X	X	X	X	X	X	X	X	X	X	X	X																					X			
Hydrochloric acid corrosion	Metal loss	X		X	X	X	X			X	X	X	X	X				X										X												
Hydrofluoric acid corrosion	Metal loss	X		X	X	X	X				X	X	X					X											X											
Hydrogen damage (HTHA)	Cracking	X		X	X										X	X					X													X						
Hydrogen embrittlement	Metallurgical damage	X	X	X	X		X					X						X							X									X						
Hydrogen-induced crack (HIC)	Cracking	X		X	X							X						X							X															

Mechanism	Damage/ Defect Mode [Note (1)]	Materials of Construction in Which Mechanism Typically Occurs													Operating Environment – Temperature (T) Range in Which Mech. May Occur					Operating Environment – Processes in Which Mechanism May Be Suspected. Process Contains:															Flow Req.		Type of Loading			
		Damage Mechanism	Manufacturing Defect	Carbon Steel	Low Alloy Steel	300 Series Stainless Steel	400 Series Stainless Steel	Duplex Stainless Steel	Fe-Ni Alloys (0.6–1.3 Fe:Ni Ratios)	Ni-Based Alloys (>50% Ni)	Cu Alloys	Ti	Al Alloys	Cast Iron	$T>1,000^\circ F$	$800<T<1,000^\circ F$	$250<T<800^\circ F$	$32<T<250^\circ F$	$T<32^\circ F$	Water, Steam, Air	Hydrogen	Carbon	Sodium	Carbonate	Sulfur	Amines	Ammonia	Chloride	HF	Phenol	Crude Oil	Phosphoric Acid	Particulates	Other	Motionless–Static	Hydrodynamic	Static Stress [Note (2)]	Impact	Thermal Gradients or Shock	Cyclic Stress (e.g., Vibratory)
Intergranular corrosion	Metal loss/ cracking	X				X		X	X	X							X	X		X					X									X						
Knife-line attack	Cracking		X			X												X		X														X						
Lack-of-fusion	Weld defects		X	X	X	X	X	X	X	X	X	X	X	X																										
Lack-of-penetration	Weld defects		X	X	X	X	X	X	X	X	X	X	X																											
Liquid (molten) slag attack	Metal loss	X		X	X	X				X					X																			X	X					
Liquid metal embrittlement	Cracking	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																							
Microbiological induced corrosion (MIC)	Metal loss	X		X	X	X	X			X	X							X	X	X														X	X					
Napthenic acid corrosion	Metal loss	X		X	X	X	X			X							X	X													X									
Oxidation corrosion	Metal loss	X		X	X	X	X	X	X	X					X					X														X						
Phenol (carbolic acid)	Metal loss	X		X	X												X													X					X					
Phosphate attack	Metal loss	X		X	X												X	X		X																X				
Phosphoric acid corrosion	Metal loss	X		X	X							X	X				X	X		X												X								
Pitting corrosion	Metal loss	X		X	X	X	X	X	X	X	X	X	X				X	X		X					X									X						
Polythionic acid cracking	Cracking	X				X			X									X		X					X												X			
Porosity	Weld defects		X	X	X	X	X	X	X	X	X	X	X	X																										

Mechanism	Damage/ Defect Mode [Note (1)]	Materials of Construction in Which Mechanism Typically Occurs													Operating Environment – Temperature (T) Range in Which Mech. May Occur					Operating Environment – Processes in Which Mechanism May Be Suspected. Process Contains:															Flow Req.		Type of Loading			
		Damage Mechanism	Manufacturing Defect	Carbon Steel	Low Alloy Steel	300 Series Stainless Steel	400 Series Stainless Steel	Duplex Stainless Steel	Fe-Ni Alloys (0.6–1.3 Fe:Ni Ratios)	Ni-Based Alloys (>50% Ni)	Cu Alloys	Ti	Al Alloys	Cast Iron	$T>1,000^\circ F$	$800<T<1,000^\circ F$	$250<T<800^\circ F$	$32<T<250^\circ F$	$T<32^\circ F$	Water, Steam, Air	Hydrogen	Carbon	Sodium	Carbonate	Sulfur	Amines	Ammonia	Chloride	HF	Phenol	Crude Oil	Phosphoric Acid	Particulates	Other	Motionless–Static	Hydrodynamic	Static Stress [Note (2)]	Impact	Thermal Gradients or Shock	Cyclic Stress (e.g., Vibratory)
Selective leaching (dealloying)	Metal loss	X									X			X			X	X		X				X										X						
Sensitization	Metallurgical damage	X	X			X			X						X	X																								
Sigma phase	Metallurgical damage	X				X	X								X																									
Sigma and chi phase	Metallurgical damage	X				X	X								X																									
Sliding wear	Metal loss	X		X	X	X	X	X	X	X	X	X	X	X			X	X																						X
Softening (over aging)	Metallurgical damage	X		X	X	X	X	X	X	X	X	X	X	X	X	X																								
Sour water corrosion (acidic)	Metal loss	X		X	X								X				X	X		X	X				X															
Spheroidization	Metallurgical damage	X		X	X										X	X																								
Strain aging	Metallurgical damage	X		X														X																						
Stray current corrosion	Metal loss	X		X	X	X	X	X	X	X	X	X	X	X			X	X																						
Sulfidization	Metal loss	X		X	X		X		X	X	X				X	X									X															
Sulfide-stress cracking (SSC)	Cracking	X		X	X		X										X	X																			X			X
Sulfuric acid corrosion	Metal loss	X		X	X	X	X	X	X	X	X	X	X	X			X	X		X																X				
Temper embrittlement	Metallurgical damage	X	X		X										X	X	X																							

	Damage/ Defect	Materials of Construction in Which Mechanism Typically Occurs													Operating Environment																									
															Temperature (T) Range in Which Mech. May Occur					Processes in Which Mechanism May Be Suspected. Process Contains:															Flow Req.		Type of Loading			
Mechanism	Mode [Note (1)]	Damage Mechanism	Manufacturing Defect	Carbon Steel	Low Alloy Steel	300 Series Stainless Steel	400 Series Stainless Steel	Duplex Stainless Steel	Fe-Ni Alloys (0.6–1.3 Fe:Ni Ratios)	Ni-Based Alloys (>50% Ni)	Cu Alloys	Ti	Al Alloys	Cast Iron	T>1,000°F	800<T<1,000°F	250<T<800°F	32<T<250°F	T<32°F	Water, Steam, Air	Hydrogen	Carbon	Sodium	Carbonate	Sulfur	Amines	Ammonia	Chloride	HF	Phenol	Crude Oil	Phosphoric Acid	Particulates	Other	Motionless—Static	Hydrodynamic	Static Stress [Note (2)]	Impact	Thermal Gradients or Shock	Cyclic Stress (e.g., Vibratory)
Under deposit corrosion	Metal loss	X		X	X	X	X	X	X	X	X	X	X	X			X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X							
Uniform corrosion	Metal loss	X		X	X	X	X	X	X	X	X	X	X	X			X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
Weld decay	Metal loss	X				X											X	X		X														X						
Weld metal crater cracking	Weld defects		X	X	X	X	X	X	X	X	X		X																											
Weld metal fusion line cracking	Weld defects		X	X	X	X	X	X	X	X	X		X																											
Weld metal longitudinal cracking	Weld defects		X	X	X	X	X	X	X	X	X		X																											
Weld metal root cracking	Weld defects		X	X	X	X	X	X	X	X	X		X																											
Weld metal toe cracking	Weld defects		X	X	X	X	X	X	X	X	X		X																											
Weld metal transverse cracking	Weld defects		X	X	X	X	X	X	X	X	X		X																											
Weld metal underbead cracking	Weld defects		X	X	X	X	X	X	X	X	X		X																											

GENERAL NOTE: This table does not include misapplication of materials, and damage issues rarely experienced or not typical of process environments.

NOTES:

(1) Manufacturing, weld, and casting defects can become a factor and also can lead to other damage mechanisms.

(2) Static stress can include residual tensile stress.

APPENDIX B
TABLE OF INSPECTION/MONITORING METHODS

	Damage/Defect			Common Examination Methods Used to Identify [Note (1)]															
				Surface					Subsurface					Other Methods					
Mechanism	Mode [Note (2)]	Damage Mechanism	Manufacturing Defect	Visual (Including Borescope)—VT [Note (3)]	Liquid Penetrant—PT [Note (3)]	Fluorescent Liquid Penetrant—FPT [Note (3)]	Magnetic Particle—MT [Note (4)]	Wet Fluorescent Magnetic Particle—WFMT [Note (4)]	Ultrasonics for Thickness—UTT	Ultrasonics—Straight Beam—UTS	Ultrasonics—Shear Wave—UTSW	Ultrasonics—Shear Wave Adv. Techniques—UTSWA	Radiography—RT	Eddy-Current—ET	Acoustic Emission—AE	Dimensional Measurements	Hardness Tests	In-Place Metallography (Replication)	Boat/Plug Sample
Dissimiliar metal weld cracking (DMW)	Cracking	X		X	X	X	X	X			X	X							
Dissolved O_2 Attack	Metal loss	X		X										X					X
Electrical discharge	Metal loss	X		X															
Erosion	Metal loss	X		X					X	X	X	X				X			
Erosion—droplets	Metal loss	X		X					X	X	X	X				X			
Erosion—solids	Metal loss	X		X					X	X	X	X				X			
Erosion/corrosion	Metal loss	X		X					X	X	X	X				X			
Fatigue	Cracking	X		X	X	X	X	X		X	X	X		X	X				X
Fatigue, contact	Cracking	X		X	X	X		X							X				
Fatigue, thermal	Cracking	X		X	X	X	X	X		X	X	X		X	X				X
Fatigue, vibration	Cracking	X		X	X	X	X	X		X	X	X		X	X				X
Filiform, corrosion	Metal loss	X		X															X
Flow-accelerated corrosion (FAC)	Metal loss	X		X					X					X					
Flue gas dew point corrosion	Metal loss	X		X					X										
Fretting	Metal loss	X		X	X	X													X
Fuel ash corrosion	Metal loss	X																	
Galvanic corrosion	Metal loss	X		X															X
Graphitization	Metallurgical damage	X															X	X	X
High temp H_2/H_2S corrosion	Metal loss	X		X					X				X						
Hot cracking	Weld Defects		X	X	X	X	X	X					X		X				X
Hot tensile	Metallurgical damage	X		X												X		X	X
Hydrochloric acid corrosion	Metal loss	X		X					X										
Hydrofluoric acid corrosion	Metal loss	X		X					X				X						

	Damage/Defect		Common Examination Methods Used to Identify [Note (1)]																
			Surface					Subsurface					Other Methods						
Mechanism	Mode [Note (2)]	Damage Mechanism	Manufacturing Defect	Visual (Including Borescope)—VT [Note (3)]	Liquid Penetrant—PT [Note (3)]	Fluorescent Liquid Penetrant—FPT [Note (3)]	Magnetic Particle—MT [Note (4)]	Wet Fluorescent Magnetic Particle—WFMT [Note (4)]	Ultrasonics for Thickness—UTT	Ultrasonics—Straight Beam—UTS	Ultrasonics—Shear Wave—UTSW	Ultrasonics—Shear Wave Adv. Techniques—UTSWA	Radiography—RT	Eddy-Current—ET	Acoustic Emission—AE	Dimensional Measurements	Hardness Tests	In-Place Metallography (Replication)	Boat/Plug Sample
Hydrogen damage (HTHA)	Cracking	X								X	X	X			X				X
Hydrogen embrittlement	Metallurgical damage	X	X																X
Hydrogen-induced crack (HIC)	Cracking	X				X		X		X	X	X		X	X			X	X
Intergranular corrosion	Metal loss	X																X	X
Knife-line attack	Cracking		X	X						X	X	X			X				
Lack-of-fusion	Weld defects		X							X	X	X	X						X
Lack-of-penetration	Weld defects		X	X	X		X			X	X	X	X						X
Liquid (molten) slag attack	Metal loss	X		X					X	X									X
Liquid metal embrittlement	Cracking	X	X		X	X	X	X		X	X	X			X			X	X
Microbiological induced corrosion (MIC)	Metal loss	X		X					X	X									X
Napthenic acid corrosion	Metal loss	X		X					X				X						
Oxidation corrosion	Metal loss	X		X					X	X									X
Phenol (carbolic acid)	Metal loss	X		X					X				X						
Phosphate attack	Metal loss	X							X										X
Phosphoric acid corrosion	Metal loss	X		X					X				X						
Pitting corrosion	Metal loss	X		X	X					X				X					X
Polythionic acid cracking	Cracking	X			X	X				X	X	X							
Porosity	Weld defects		X							X	X	X	X						X
Selective leaching (dealloying)	Metal loss	X																X	X
Sensitization	Metallurgical damage	X																X	X
Sigma Phase	Metallurgical damage	X																X	X
Sigma and chi phase	Metallurgical damage	X																X	X

	Damage/Defect		Common Examination Methods Used to Identify [Note (1)]															
			Surface					Subsurface					Other Methods					
Mechanism	Mode [Note (2)]	Damage Mechanism	Manufacturing Defect	Visual (Including Borescope)—VT [Note (3)]	Liquid Penetrant—PT [Note (3)]	Fluorescent Liquid Penetrant—FPT [Note (3)]	Magnetic Particle—MT [Note (4)]	Wet Fluorescent Magnetic Particle—WFMT [Note (4)]	Ultrasonics for Thickness—UTT	Ultrasonics—Straight Beam—UTS	Ultrasonics—Shear Wave—UTSW	Ultrasonics—Shear Wave Adv. Techniques—UTSWA	Radiography—RT	Eddy-Current—ET	Acoustic Emission—AE	Dimensional Measurements	Hardness Tests	In-Place Metallography (Replication)	Boat/Plug Sample
Sliding wear	Metal loss	X		X					X							X			
Softening (over aging)	Metallurgical damage	X															X		X
Sour water corrosion (acidic)	Metal loss	X		X					X				X						
Spheroidization	Metallurgical damage	X															X	X	X
Strain aging	Metallurgical damage	X															X		X
Stray current corrosion	Metal loss	X		X					X	X	X	X							
Sulfidation	Metal loss	X																X	X
Sulfide-stress cracking (SSC)	Cracking	X			X	X	X	X		X	X	X		X	X			X	X
Sulfuric acid corrosion	Metal loss	X		X					X				X						
Temper embrittlement	Metallurgical damage	X	X																X
Under deposit corrosion	Metal loss	X							X	X									X
Uniform corrosion	Metal loss	X		X					X	X	X	X				X			
Weld decay	Metal loss	X		X						X	X	X							X
Weld metal crater cracking	Weld defects		X	X	X	X	X	X		X	X	X			X				X
Weld metal fusion line cracking	Weld defects		X	X	X	X	X	X		X	X	X	X		X				X
Weld metal longitudinal cracking	Weld defects		X	X	X	X	X	X		X	X	X	X		X				X
Weld metal root cracking	Weld defects		X							X	X	X	X		X				X
Weld metal toe cracking	Weld defects		X	X	X	X	X	X		X	X	X	X		X				X
Weld metal transverse cracking	Weld defects		X	X	X	X	X	X		X	X	X	X		X				X
Weld metal underbead cracking	Weld defects		X							X	X	X	X		X				X

APPENDIX C
ENGINEERING CALCULATION

PRESSURE VESSEL CALCULATION

(ASME SECT. VIII DIV. 1 & API 510 LATEST EDITION)

ITEM NO : T-01
EQUIPMENT : Pressure Vessel
OWNER : PT Mitra Harun Gasindo

PRESSURE VESSEL DATA

Design Press.	(P) :	15,60	kg/cm^2	Actual Thick. Shell	(t_{act}) :	21,21	mm
Inside Diameter	(ID) :	3256	mm	Nominal Thick. Shell	(t_{nom}) :	22,00	mm
Inside Radius	(R_i) :	1628	mm	Prev. Actual Thick. Shell	(t_{prev}) :	22,33	mm
Material(Shell)	:	SA 516 Gr 70		Actual Thick. Head	(t_{act}) :	13,34	mm
Allow. Stress (Shell)	(S) :	1406,14	kg/cm^2	Nominal Thick.Head	(t_{nom}) :	14,00	mm
Material(Head)	:	SA 516 Gr 70		Prev. Actual Thick. Head	(t_{prev}) :	13,80	mm
Allow. Stress (Head)	(S) :	1406,14	kg/cm^2	Year Built	:	2009	
Joint Eff. (Shell)	(E) :	1		Last of Inspection	:	2020	
Joint Eff. (Head)	(E) :	1		Date of inspection	:	2023	
Corrosion Allowance	(CA) :	0	mm	Year of Recertification (Next Insp.)	(T) :	4	years

FORMULA

Shell Calculation

Minimum Thickness of Shell

$$t_{req} = \frac{P\,IR}{SE - 0.6P} = \frac{15{,}6 \quad x \quad 1628}{(\ 1406{,}1 \quad x \quad 1{,}0\ ) - (\ 0{,}6 \quad x \quad 15{,}6\ )} = 18{,}18 \text{ mm}$$

Minimum Required Thickness of Shell

$$t_{min\ req} = t_{req} + CA = 18{,}182 + 0 = 18{,}18 \text{ mm}$$

Result : Thickness is ***Satisfactory***

Head Calculation

Minimum Thickness of Head (Hemispherical)

$$t_{req} = \frac{P\,L}{2SE - 0.2P} = \frac{15{,}6 \quad x \quad 1628}{2(\ 1406{,}14 \quad x \quad 1\ ) - (\ 0{,}2 \quad x \quad 15{,}6\ )} = 9{,}04 \text{ mm}$$

Minimum Required Thickness of Head

$$t_{min\ req} = t_{req} + CA = 9{,}04 + 0 = 9{,}04 \text{ mm}$$

Result : Thickness is ***Satisfactory***

Corrosion Rate Short Term (CR)

Corrosion Rate for Shell

$$CR = \frac{\text{tprev - tact}}{\text{years between tprev and tact}} = \frac{22{,}33 - 21{,}21}{3} = 0{,}373 \text{ mm/year}$$

Corrosion Rate for Head

$$CR = \frac{\text{tprev - tact}}{\text{years between tprev and tact}} = \frac{13{,}80 - 13{,}34}{3} = 0{,}153 \text{ mm/year}$$

Conclusion

Corrosion rate (CR) = mm/year

PRESSURE VESSEL CALCULATION

(ASME SECT. VIII DIV. 1 & API 510 LATEST EDITION)

ITEM NO : T-01
EQUIPMENT : Pressure Vessel
OWNER : PT Mitra Harun Gasindo

Maximum Allowable Working Pressure (MAWP)

Maximum Allowable Working Pressure (MAWP) for **Shell**

$$MAWP = \frac{S\,E\,[\,t_{act} - (2\,CR\,T)]}{(Ri\,) + 0.6\,[t_{act} - (2\,CR\,T)]}$$

$$= \frac{(\;1406{,}14 \;\; x \;\; 1{,}00\;)\,\{\;21{,}21 \;-\; [(\,2\,x \;\; 1{,}493\;)]\}}{[\;1628\;] + 0{,}6\;\{\;21{,}21 - [(\,2\,x\;\;1{,}493\;)]\}}$$

$$= 15{,}63 \quad kg/cm^2$$

Maximum Allowable Working Pressure (MAWP) for **Head**

$$MAWP = \frac{2\,S\,E\,[\,t_{act} - (2\,CR\,T)]}{[ID] + 0.2\,[t_{act} - (2\,CR\,T)]}$$

$$= \frac{2\,(\;1406{,}1 \;\; x \;\; 1{,}00\;)\,\{\;13{,}34 \;-\, [\;(\;2 \;\; x \;\; 0{,}613\;)]\}}{(\;1628\;) + (\;0{,}2\;)\;\{\;13{,}34 - [\;(\;2 \;\; x \;\; 0{,}613\;)]\}}$$

$$= 20{,}89 \quad kg/cm^2$$

Conclusion

MAWP calc. = 15,63 kg/cm^2 (***Satisfactory***)

Remaining Life (RL)

$$\text{Remaining Life Shell} = \frac{t_{act} - t_{req}}{CR} = \frac{21{,}21 \;-\; 18{,}18}{0{,}373} = 8 \text{ years}$$

$$\text{Remaining Life Head} = \frac{t_{act} - t_{req}}{CR} = \frac{13{,}34 \;-\; 9{,}04}{0{,}153} = 28 \text{ years}$$

Conclusion

Base on above calculation, Remaining life of pressure vessel is **8** years