PT Filosofi Teknik Utama

Judul Dokumen	No. Dokumen	:	FTU-056/02/R-RLA/II/2024
Reverse Engineering Pressure Vessel	Revisi	:	0
	Tanggal Rev.	:	29 February 2024

Reverse Engineering Pressure Vessel

Air Receiver Tank SN. 006/DPT/III/2010

PT Mitra Harun Gasindo

0	Issued for approval	29-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	29-Feb-2024	Issued for Approval

DAFTAR ISI

DAFTAR GAMBAR

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 *reverse engineering* 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 *reverse engineering* ini meliputi:

a) Kalkulasi enjiniring
b) Gambar konstruksi bejana tekan
c) Datasheet

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 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

Cakupan dokumen ini berisi ringkasan berupa data desain, asumsi, kriteria pendesainan dan juga prinsip atau filosofi desain. Ruang lingkup ini meliputi spesifikasi, penggunaan standard/code dan perhitungan.

3. Data Umum

Data umum bejana tekan dideskripsikan di bawah :

Owner/Operator	: PT Mitra Harun Gasindo
Service	: Air Receiver Tank
Tag No	: -
No Seri	: 006/DPT/III/2010
Code	: ASME Sec. VIII Div. 1 (Analisa)
Material	: JIS G 3101, SS 400 (SA 283 Gr.C)
Design Pressure	: 10 kg/cm^2
Tahun Pembuatan	: 2010
Joint Eff	: 0,85 (Spot)
Corrosion Allowance	: 1 mm
Size	: 950 mm (ID) x 1530 mm (T/T)

4. Perhitungan Teknis

Perhitungan menggunakan Software PV Elite 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	: Udara
Material	: JIS G 3101, SS 400 (SA 283 Gr.C)
DP/OP (Psi)	: - /
DT/OT (°F)	: - /
Aliran	: Hidrodinamis
Muatan	: Statis
Insulasi	: Tidak Ada
Kandungan CO	: Tidak Ada
Kandungan H2S	: Tidak Ada
Kandungan H2O	: 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.

- **Cylindrical Shell**

$$P = \frac{SEt}{R + 0.6t}$$

- **2:1 Ellipsoidal Head**

$$P = \frac{2SEt}{D + 0.2t}$$

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 10 kg/cm2)

Bagian	Ketebalan Awal (mm)	Ketebalan Aktual (mm)	Ketebalan Dibutuhkan (mm)	Corrosion Rate (mm/yr)	Sisa Umur (years)	Catatan
Bottom Head	8,00	7,61	5,30	0,127	18	Memenuhi
Shell	8,00	8,07	5,33	0,127	21	Memenuhi
Top Head	8,00	7,82	5,30	0,127	19	Memenuhi

9. Analisa Risiko

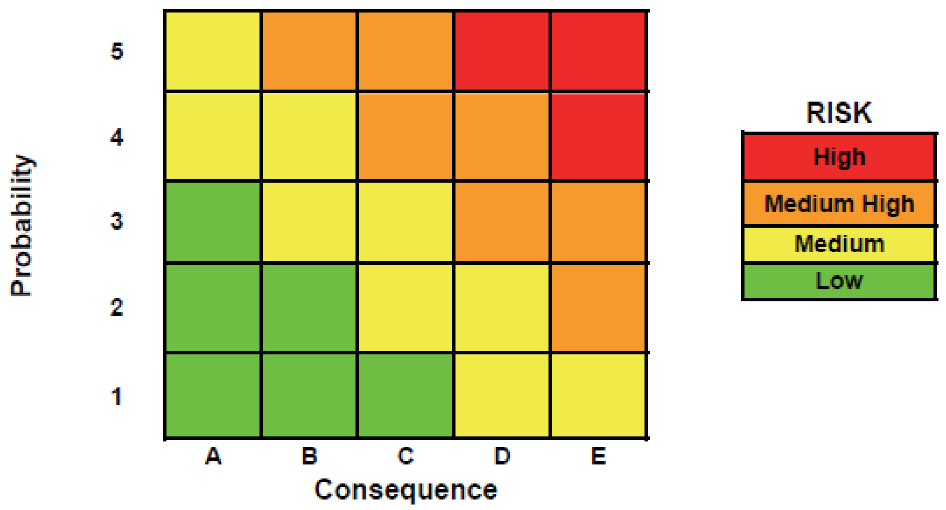
Analisis risiko merupakan aktivitas untuk mengidentifikasi dan menganalisis potensi sebab dan kemungkinan akibat risiko, baik dengan metode kualitatif, semi kuantitatif, maupun kuantitatif. Analisis risiko yang dilakukan di dalam laporan ini bersifat kualitatif.

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	Air Receiver Tank SN. 006/DPT/III/2010	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:

No	Bagian	Ketebalan Awal (mm)	Ketebalan Dibutuhkan (mm)	MAWP (kg/cm^2)	Remakrs
1	Bottom Head	8,00	5,30	16,08	Memenuhi
2	Shell	8,00	5,33	16,08	Memenuhi
3	Top Head	8,00	5,30	16,08	Memenuhi

Secara umum faktor keselamatan dan hasil perhitungan, **Air Receiver Tank SN. 006/DPT/III/2010** dalam kondisi baik untuk beroperasi dan layak untuk digunakan dengan parameter berikut:

MAWP	:	**16,08 kg/cm^2**
Sisa Umur Layan	:	**216 Bulan**

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

	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)
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				

															Operating Environment																									
	Damage/ Defect	Materials of Construction in Which Mechanism Typically Occurs													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)
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
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															

	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)
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																										

	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)
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					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)
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.

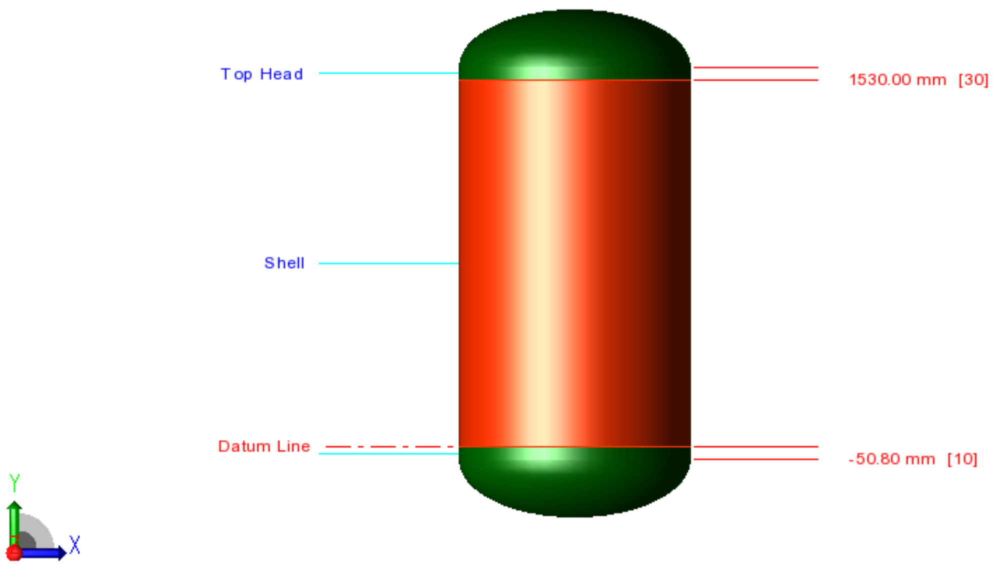
APPENDIX B
TABLE OF INSPECTION/MONITORING METHODS

	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



APPENDIX D
DATA SHEET

PV Elite Vessel Analysis Program: Input Data

Design Internal Pressure (for Hydrotest)	142.20	psig
Design Internal Temperature	200	°F
Type of Hydrotest	UG-99(b)	
Hydrotest Position	Horizontal	
Projection of Nozzle from Vessel Top	0.0000	mm
Projection of Nozzle from Vessel Bottom	0.0000	mm
Minimum Design Metal Temperature	-20	°F
Type of Construction	Welded	
Special Service	None	
Degree of Radiography	RT 1	
Use Higher Longitudinal Stresses (Flag)	Y	
Select t for Internal Pressure (Flag)	N	
Select t for External Pressure (Flag)	N	
Select t for Axial Stress (Flag)	N	
Select Location for Stiff. Rings (Flag)	N	
Consider Vortex Shedding	N	
Perform a Corroded Hydrotest	N	
Is this a Heat Exchanger	No	
User Defined Hydro. Press. (Used if > 0)	0.0000	psig
User defined MAWP	0.0000	psig
User defined MAPnc	0.0000	psig

Load Case 1	NP+EW+WI+FW+BW
Load Case 2	NP+EW+EE+FS+BS
Load Case 3	NP+OW+WI+FW+BW
Load Case 4	NP+OW+EQ+FS+BS
Load Case 5	NP+HW+HI
Load Case 6	NP+HW+HE
Load Case 7	IP+OW+WI+FW+BW
Load Case 8	IP+OW+EQ+FS+BS
Load Case 9	EP+OW+WI+FW+BW
Load Case 10	EP+OW+EQ+FS+BS
Load Case 11	HP+HW+HI
Load Case 12	HP+HW+HE

Load Case 13		IP+WE+EW	
Load Case 14		IP+WF+CW	
Load Case 15		IP+VO+OW	
Load Case 16		IP+VE+EW	
Load Case 17		NP+VO+OW	
Load Case 18		FS+BS+IP+OW	
Load Case 19		FS+BS+EP+OW	

Wind Design Code		ASCE-7 93	
Basic Wind Speed	[V]	70.000	mile/hr
Surface Roughness Category		C: Open Terrain	
Importance Factor		1.0	
Type of Surface		Moderately Smooth	
Base Elevation		0.0000	mm
Percent Wind for Hydrotest		33.0	
Using User defined Wind Press. Vs Elev.		N	
Damping Factor (Beta) for Wind (Ope)		0.0100	
Damping Factor (Beta) for Wind (Empty)		0.0000	
Damping Factor (Beta) for Wind (Filled)		0.0000	

Seismic Design Code	UBC 94
UBC Seismic Zone (1=1,2=2a,3=2b,4=3,5=4)	0.000
UBC Importance Factor	1.000
UBC Soil Type	S1
UBC Horizontal Force Factor	3.000
UBC Percent Seismic for Hydrotest	0.000

Design Nozzle for Des. Press. + St. Head	Y
Consider MAP New and Cold in Noz. Design	N
Consider External Loads for Nozzle Des.	Y
Use ASME VIII-1 Appendix 1-9	N

Material Database Year	Current w/Addenda or Code Year

Configuration Directives:

Do not use Nozzle MDMT Interpretation VIII-1 01-37	No
Use Table G instead of exact equation for "A"	Yes

Shell Head Joints are Tapered	Yes
Compute "K" in corroded condition	Yes
Use Code Case 2286	No
Use the MAWP to compute the MDMT	Yes
Using Metric Material Databases, ASME II D	No

Complete Listing of Vessel Elements and Details:

Element From Node	10	
Element To Node	20	
Element Type	Elliptical	
Description	Bottom Plate	
Distance "FROM" to "TO"	50.800	mm
Inside Diameter	950.00	mm
Element Thickness	8.0000	mm
Internal Corrosion Allowance	1.0000	mm
Nominal Thickness	0.0000	mm
External Corrosion Allowance	0.0000	mm
Design Internal Pressure	142.20	psig
Design Temperature Internal Pressure	200	°F
Design External Pressure	15.000	psig
Design Temperature External Pressure	200	°F
Effective Diameter Multiplier	1.2	
Material Name	SA-283 C	
Allowable Stress, Ambient	15700.	psi
Allowable Stress, Operating	15700.	psi
Allowable Stress, Hydrotest	20410.	psi
Material Density	0.2800	lb/in^3
P Number Thickness	30.988	mm
Yield Stress, Operating	27500.	psi
UCS-66 Chart Curve Designation	A	
External Pressure Chart Name	CS-2	
UNS Number	K02401	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Elliptical Head Factor	2.0	

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description	Shell	
Distance "FROM" to "TO"	1530.0	mm
Inside Diameter	950.00	mm
Element Thickness	8.0000	mm
Internal Corrosion Allowance	1.0000	mm
Nominal Thickness	0.0000	mm
External Corrosion Allowance	0.0000	mm
Design Internal Pressure	142.20	psig
Design Temperature Internal Pressure	200	°F
Design External Pressure	15.000	psig
Design Temperature External Pressure	200	°F
Effective Diameter Multiplier	1.2	
Material Name	SA-283 C	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	

Element From Node	30	
Element To Node	40	
Element Type	Elliptical	
Description	Top Head	
Distance "FROM" to "TO"	50.800	mm
Inside Diameter	950.00	mm
Element Thickness	8.0000	mm
Internal Corrosion Allowance	1.0000	mm
Nominal Thickness	0.0000	mm
External Corrosion Allowance	0.0000	mm
Design Internal Pressure	142.20	psig
Design Temperature Internal Pressure	200	°F
Design External Pressure	15.000	psig
Design Temperature External Pressure	200	°F
Effective Diameter Multiplier	1.2	

Material Name	SA-283 C
Efficiency, Longitudinal Seam	1.0
Efficiency, Circumferential Seam	1.0
Elliptical Head Factor	2.0

XY Coordinate Calculations

From	To	X (Horiz.) mm	Y (Vert.) mm	DX (Horiz.) mm	DY (Vert.) mm
Bottom Pla		...	50.8000	...	50.8000
Shell		...	1580.80	...	1530.00
Top Head		...	1631.60	...	50.8000

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd psig	Nominal Thickness mm	Total Corr Allowance mm	Element Diameter mm	Allowable Stress(SE) psi
Bottom Pla		142.20	...	1.0000	950.00	15700.
Shell		142.20	...	1.0000	950.00	15700.
Top Head		142.20	...	1.0000	950.00	15700.

Element Required Thickness and MAWP :

From	To	Design Pressure psig	M.A.W.P. Corroded psig	M.A.P. New & Cold psig	Minimum Thickness mm	Required Thickness mm
Bottom Pla		142.200	228.863	263.976	8.00000	5.30314
Shell		142.200	228.863	261.776	8.00000	5.33484
Top Head		142.200	228.863	263.976	8.00000	5.30314
Minimum			**228.863**	**261.775**		

MAWP: 228.863 psig, limited by: Top Head.

Internal Pressure Calculation Results :

ASME Code, Section VIII, Division 1, 2015

Elliptical Head From 10 To 20 SA-283 C , UCS-66 Crv. A at 200 °F

Bottom Plate

Material UNS Number: K02401

Required Thickness due to Internal Pressure [tr]:

```
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (142.200*952.0000*0.997)/(2*15700.00*1.00-0.2*142.200)
= 4.3031 + 1.0000 = 5.3031 mm
```


Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:

```
= (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
= (2*15700.00*1.00*7.0000)/(0.997*952.0000+0.2*7.0000)
= 231.188 psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
= (2*15700.00*1.00*8.0000)/(1.000*950.0001+0.2*8.0000)
= 263.976 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:

```
= (P*(Kcor*D+0.2*t))/(2*E*t)
= (142.200*(0.997*952.0000+0.2*7.0000))/(2*1.00*7.0000)
= 9656.819 psi
```

Straight Flange Required Thickness:

```
= (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
= (142.200*476.0000)/(15700.00*1.00-0.6*142.200)+1.000
= 5.335 mm
```

Straight Flange Maximum Allowable Working Pressure:

```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (15700.00 * 1.00 * 7.0000 )/(476.0000 + 0.6 * 7.0000 )
= 228.863 psig
```

Factor K, corroded condition [Kcor]:

= (2 + (Inside Diameter/(2 * Inside Head Depth))^2)/6

= (2 + (952.000/(2 * 238.500))^2)/6

= 0.997208

```
Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro)  3.625 %
```

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 8.000 , tr = 6.930 , c = 1.0000 mm , E* = 1.00

Stress Ratio = tr * (E*)/(tg - c) = 0.990 , Temp. Reduction = 1 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve A            18 °F

Min Metal Temp. at Required thickness (UCS 66.1)          17 °F

Min Metal Temp. w/o impact per UG-20(f)                  -20 °F
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 8.000 , tr = 7.000 , c = 1.0000 mm , E* = 1.00

Stress Ratio = tr * (E*)/(tg - c) = 1.000 , Temp. Reduction = 0 °F

```
Min Metal Temp. w/o impact per UCS-66, Curve A            18 °F

Min Metal Temp. w/o impact per UG-20(f)                  -20 °F
```

Cylindrical Shell From 20 To 30 SA-283 C , UCS-66 Crv. A at 200 °F

Shell

Material UNS Number: K02401

Required Thickness due to Internal Pressure [tr]:

```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)

  = (142.200*476.0000)/(15700.00*1.00-0.6*142.200)

  = 4.3348 + 1.0000 = 5.3348 mm
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)

  = (15700.00*1.00*7.0000)/(476.0000+0.6*7.0000)

  = 228.863 psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)

  = (15700.00*1.00*8.0000)/(475.0000+0.6*8.0000)

  = 261.776 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:

```
  = (P*(R+0.6*t))/(E*t)

  = (142.200*(476.0000+0.6*7.0000))/(1.00*7.0000)

  = 9754.920 psi
```


Percent Elongation per UCS-79 (50*tnom/Rf)*(1-Rf/Ro) 0.835 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 8.000 , tr = 7.000 , c = 1.0000 mm , E* = 1.00

Stress Ratio = tr * (E*)/(tg - c) = 1.000 , Temp. Reduction = 0 °F

Min Metal Temp. w/o impact per UCS-66, Curve A	18 °F
Min Metal Temp. w/o impact per UG-20(f)	-20 °F

Elliptical Head From 30 To 40 SA-283 C , UCS-66 Crv. A at 200 °F

Top Head

Material UNS Number: K02401

Required Thickness due to Internal Pressure [tr]:

= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)

= (142.200*952.0000*0.997)/(2*15700.00*1.00-0.2*142.200)

= 4.3031 + 1.0000 = 5.3031 mm

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:

= (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)

= (2*15700.00*1.00*7.0000)/(0.997*952.0000+0.2*7.0000)

= 231.188 psig

Maximum Allowable Pressure, New and Cold [MAPNC]:

= (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)

= (2*15700.00*1.00*8.0000)/(1.000*950.0001+0.2*8.0000)

= 263.976 psig

Actual stress at given pressure and thickness, corroded [Sact]:

= (P*(Kcor*D+0.2*t))/(2*E*t)

= (142.200*(0.997*952.0000+0.2*7.0000))/(2*1.00*7.0000)

= 9656.819 psi

Straight Flange Required Thickness:

= (P*R)/(S*E-0.6*P) + c   per UG-27 (c)(1)

= (142.200*476.0000)/(15700.00*1.00-0.6*142.200)+1.000

= 5.335 mm

Straight Flange Maximum Allowable Working Pressure:

= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)

= (15700.00 * 1.00 * 7.0000)/(476.0000 + 0.6 * 7.0000)

= 228.863 psig

Factor K, corroded condition [Kcor]:

= (2 + (Inside Diameter/(2 * Inside Head Depth))^2)/6

= (2 + (952.000/(2 * 238.500))^2)/6

= 0.997208

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 3.625 %

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 8.000 , tr = 6.930 , c = 1.0000 mm , E* = 1.00

Stress Ratio = tr * (E*)/(tg - c) = 0.990 , Temp. Reduction = 1 °F

Min Metal Temp. w/o impact per UCS-66, Curve A	18 °F
Min Metal Temp. at Required thickness (UCS 66.1)	17 °F
Min Metal Temp. w/o impact per UG-20(f)	-20 °F

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 8.000 , tr = 7.000 , c = 1.0000 mm , E* = 1.00

Stress Ratio = tr * (E*)/(tg - c) = 1.000 , Temp. Reduction = 0 °F

Min Metal Temp. w/o impact per UCS-66, Curve A	18 °F
Min Metal Temp. w/o impact per UG-20(f)	-20 °F

Note: Heads and Shells Exempted to -20F (-29C) by paragraph UG-20F

Hydrostatic Test Pressure Results:

Pressure per UG99b	= 1.3 * M.A.W.P. * Sa/S	297.522	psig
Pressure per UG99b[36]	= 1.3 * Design Pres * Sa/S	184.860	psig
Pressure per UG99c	= 1.3 * M.A.P. - Head(Hyd)	338.957	psig
Pressure per UG100	= 1.1 * M.A.W.P. * Sa/S	251.749	psig
Pressure per PED	= 1.43 * MAWP	327.274	psig
Pressure per App 27-4	= 1.3 * M.A.W.P. * Sa/S	297.522	psig

UG-99(b), Test Pressure Calculation:

= Test Factor * MAWP * Stress Ratio

= 1.3 * 228.863 * 1.000

= 297.522 psig

Horizontal Test performed per: UG-99b

Please note that Nozzle, Shell, Head, Flange, etc MAWPs are all considered when determining the hydrotest pressure for those test types that are based on the MAWP of the vessel.

Stresses on Elements due to Test Pressure:

From To	Stress	Allowable	Ratio	Pressure
Bottom Plate	17775.4	20410.0	0.871	298.87
Shell	17924.9	20410.0	0.878	298.87
Top Head	17775.4	20410.0	0.871	298.87

Stress ratios for Vessel Elements:

Description	Ambient	Operating	ratio
Bottom Plate	15700.00	15700.00	1.000
Shell	15700.00	15700.00	1.000
Top Head	15700.00	15700.00	1.000
Minimum			1.000

Elements Suitable for Internal Pressure.

External Pressure Calculation Results :

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Elliptical Head From 10 to 20 Ext. Chart: CS-2 at 200 °F

Bottom Plate

Elastic Modulus from Chart: CS-2 at 200 °F : 0.290E+08 psi

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
7.000	966.00	138.00	0.0010064	12399.87

EMAP = B/(K0*D/t) = 12399.8711/(0.9000 *138.0000) = 99.8379 psig

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
2.501	966.00	386.22	0.0003596	5214.32

EMAP = B/(K0*D/t) = 5214.3184/(0.9000 *386.2229) = 15.0009 psig

*Check the requirements of UG-33(a)(1) using P = 1.67 * External Design pressure for this head.*

Material UNS Number: K02401

Required Thickness due to Internal Pressure [tr]:

= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)

= (25.050*952.0000*0.997)/(2*15700.00*1.00-0.2*25.050)

= 0.7575 + 1.0000 = 1.7575 mm

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:

= ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)

= ((2*15700.00*1.00*7.0000)/(0.997*952.0000+0.2*7.0000))/1.67

= 138.436 psig

Maximum Allowable External Pressure [MAEP]:

= min(MAEP, MAWP)

= min(99.84 , 138.4359)

= 99.838 psig

Thickness requirements per UG-33(a)(1) do not govern the required thickness of this head.

Cylindrical Shell From 20 to 30 Ext. Chart: CS-2 at 200 °F

Shell

Elastic Modulus from Chart: CS-2 at 200 °F : 0.290E+08 psi

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
7.000	966.00	1789.93	138.00	1.8529	0.0004322	6267.06

EMAP = (4*B)/(3*(D/t)) = (4*6267.0625)/(3*138.0000) = 60.5513 psig

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
4.003	966.00	1789.93	241.33	1.8529	0.0001872	2715.03

EMAP = (4*B)/(3*(D/t)) = (4*2715.0261)/(3*241.3271) = 15.0005 psig

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
7.000	966.00	6569.47	138.00	6.8007	0.0001071	1553.30

EMAP = (4*B)/(3*(D/t)) = (4*1553.3014)/(3*138.0000) = 15.0077 psig

Elliptical Head From 30 to 40 Ext. Chart: CS-2 at 200 °F

Top Head

Elastic Modulus from Chart: CS-2 at 200 °F : 0.290E+08 psi

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
7.000	966.00	138.00	0.0010064	12399.87

EMAP = B/(K0*D/t) = 12399.8711/(0.9000 *138.0000) = 99.8379 psig

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
2.501	966.00	386.22	0.0003596	5214.32

EMAP = B/(K0*D/t) = 5214.3184/(0.9000 *386.2229) = 15.0009 psig

*Check the requirements of UG-33(a)(1) using P = 1.67 * External Design pressure for this head.*

Material UNS Number: K02401

Required Thickness due to Internal Pressure [tr]:

= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)

= (25.050*952.0000*0.997)/(2*15700.00*1.00-0.2*25.050)

= 0.7575 + 1.0000 = 1.7575 mm

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:

= ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)

= ((2*15700.00*1.00*7.0000)/(0.997*952.0000+0.2*7.0000))/1.67

= 138.436 psig

Maximum Allowable External Pressure [MAEP]:

= min(MAEP, MAWP)

= min(99.84 , 138.4359)

= 99.838 psig

Thickness requirements per UG-33(a)(1) do not govern the required thickness of this head.

External Pressure Calculations

From	To	Section Length mm	Outside Diameter mm	Corroded Thickness mm	Factor A	Factor B psi
10	20	No Calc	966.000	7.00000	0.0010064	12399.9
20	30	1789.93	966.000	7.00000	0.00043221	6267.06
30	40	No Calc	966.000	7.00000	0.0010064	12399.9

External Pressure Calculations

From	To	External Actual T. mm	External Required T. mm	External Des. Press. psig	External M.A.W.P. psig
10	20	8.00000	3.50115	15.0000	99.8379
20	30	8.00000	5.00287	15.0000	60.5513
30	40	8.00000	3.50115	15.0000	99.8379
Minimum					**60.551**

External Pressure Calculations

From	To	Actual Len. Bet. Stiff. mm	Allow. Len. Bet. Stiff. mm	Ring Inertia Required in**4	Ring Inertia Available in**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	1789.93	6569.47	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

Element and Detail Weights

From	To	Element Metal Wgt. lbf	Element ID Volume in^3	Corroded Metal Wgt. lbf	Corroded ID Volume in^3	Extra due Misc % lbf
10	20	171.047	9046.06	149.666	9098.66	...
20	30	629.440	66180.1	551.335	66459.0	...
30	40	171.047	9046.06	149.666	9098.66	...
Total		**971**	**84272**	**850**	**84656**	**0**

Weight Summation: lbf

Fabricated	Shop Test	Shipping	Erected	Empty	Operating
971.5	971.5	971.5	971.5	971.5	971.5
...	3043.2	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
971.5	4014.7	971.5	971.5	971.5	971.5

Note:

The shipping total has been modified because some items have been specified as being installed in the shop.

Weight Summary

Fabricated Wt.	- Bare Weight W/O Removable Internals	971.5 lbf
Shop Test Wt.	- Fabricated Weight + Water (Full)	4014.7 lbf
Shipping Wt.	- Fab. Wt + Rem. Intls.+ Shipping App.	971.5 lbf
Erected Wt.	- Fab. Wt + Rem. Intls.+ Insul. (etc)	971.5 lbf
Ope. Wt. no Liq	- Fab. Wt + Intls. + Details + Wghts.	971.5 lbf
Operating Wt.	- Empty Wt + Operating Liq. Uncorroded	971.5 lbf
Field Test Wt.	- Empty Weight + Water (Full)	4014.7 lbf
Mass of the Upper 1/3 of the Vertical Vessel		327.3 lbf

Outside Surface Areas of Elements

From	To	Surface Area in²
10	20	1806.83
20	30	7196.99
30	40	1806.83

Total 10810.652 in² [75.1 Square Feet]

Element and Detail Weights

From	To	Total Ele. Empty Wgt. lbm	Total. Ele. Oper. Wgt. lbm	Total. Ele. Hydro. Wgt. lbm	Total Dtl. Offset Mom. ft-lb	Oper. Wgt. No Liquid lbm
10	20	171.047	171.047	497.710	...	171.047
20	30	629.440	629.440	3019.28	...	629.440
30	40	171.047	171.047	497.710	...	171.047

Cumulative Vessel Weight

From	To	Cumulative Ope Wgt. No Liquid lbm	Cumulative Oper. Wgt. lbm	Cumulative Hydro. Wgt. lbm
10	20	971.533	971.533	4014.70
20	30	800.487	800.487	3516.99
30	40	171.047	171.047	497.710

Note: The cumulative operating weights no liquid in the column above are the cumulative operating weights minus the operating liquid weight minus any weights absent in the empty condition.

Cumulative Vessel Moment

From	To	Cumulative Empty Mom. ft-lb	Cumulative Oper. Mom. ft-lb	Cumulative Hydro. Mom. ft-lb
10	20	...	...	...
20	30	...	...	...
30	40	...	...	...

Shop/Field Installation Options :

Note : The CG is computed from the first Element From Node

Center of Gravity of Bare Shell New and Cold	815.800 mm
Center of Gravity of Bare Shell Corroded	815.800 mm
Vessel CG in the Operating Condition	815.800 mm
Vessel CG in the Fabricated (Shop/Empty) Condition	815.800 mm

Minimum Design Metal Temperature Results Summary :

Description	Notes	Curve	Basic MDMT °F	Reduced MDMT °F	UG-20(f) MDMT °F	Thickness ratio	Gov Thk mm	E*
Bottom Plate	[10]	A	18	17	-20	0.990	8.000	1.000
Bottom Plate	[7]	A	18	18	-20	1.000	8.000	1.000
Shell	[8]	A	18	18	-20	1.000	8.000	1.000
Top Head	[10]	A	18	17	-20	0.990	8.000	1.000
Top Head	[7]	A	18	18	-20	1.000	8.000	1.000

Required Minimum Design Metal Temperature -20 °F

Warmest Computed Minimum Design Metal Temperature -20 °F

Notes:

[!] - This was an impact tested material.

[1] - Governing Nozzle Weld.

[4] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(c).

[5] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(b).

[6] - MDMT Calculations at the Shell/Head Joint.

[7] - MDMT Calculations for the Straight Flange.

[8] - Cylinder/Cone/Flange Junction MDMT.

[9] - Calculations in the Spherical Portion of the Head.

[10] - Calculations in the Knuckle Portion of the Head.

[11] - Calculated (Body Flange) Flange MDMT.

[12] - Calculated Flat Head MDMT per UCS-66.3

[13] - Tubesheet MDMT, shell side, if applicable

[14] - Tubesheet MDMT, tube side, if applicable

[15] - Nozzle Material

[16] - Shell or Head Material

[17] - Impact Testing required

UG-84(b)(2) was not considered.

UCS-66(g) was not considered.

UCS-66(i) was not considered.

Notes:

Impact test temps were not entered in and not considered in the analysis.

UCS-66(i) applies to impact tested materials not by specification and

UCS-66(g) applies to materials impact tested per UG-84.1 General Note (c).

The Basic MDMT includes the (30F) PWHT credit if applicable.

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Diameter Spec : 950.000 mm ID

Vessel Design Length, Tangent to Tangent	1631.60	mm
Distance of Bottom Tangent above Grade	0.00	mm
Distance of Base above Grade	0.00	mm
Specified Datum Line Distance	50.80	mm
Shell Material	SA-283 C	
Internal Design Temperature	200	°F
Internal Design Pressure	142.200	psig
External Design Temperature	200	°F
External Design Pressure	15.000	psig
Maximum Allowable Working Pressure	228.863	psig
External Max. Allowable Working Pressure	60.551	psig
Hydrostatic Test Pressure	297.522	psig
Required Minimum Design Metal Temperature	-20	°F
Warmest Computed Minimum Design Metal Temperature	-20	°F
Wind Design Code	ASCE-93	
Earthquake Design Code	UBC-94	

Element Pressures and MAWP: psig

Element Desc	Design Pres. + Stat. head	External Pressure	M.A.W.P	Corrosion Allowance
Bottom Plate	142.200	15.000	228.863	1.0000
Shell	142.200	15.000	228.863	1.0000
Top Head	142.200	15.000	228.863	1.0000

Element Type	"To" Elev mm	Length mm	Element Thk mm	R e q d T h k Int.	Ext.	Joint Eff Long	Circ

Ellipse	0.0	50.8	8.0	5.3	3.5	1.00	1.00
Cylinder	1530.0	1530.0	8.0	5.3	5.0	1.00	1.00
Ellipse	1580.8	50.8	8.0	5.3	3.5	1.00	1.00

Element thicknesses are shown as Nominal if specified, otherwise are Minimum

Weights:

Fabricated	- Bare W/O Removable Internals	971.5	lbm
Shop Test	- Fabricated + Water (Full)	4014.7	lbm
Shipping	- Fab. + Rem. Intls.+ Shipping App.	971.5	lbm
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	971.5	lbm
Empty	- Fab. + Intls. + Details + Wghts.	971.5	lbm
Operating	- Empty + Operating Liquid (No CA)	971.5	lbm
Field Test	- Empty Weight + Water (Full)	4014.7	lbm

MECHANICAL DATA SHEET
PRESSURE VESSEL

Date : -
Revision : -

TEKHNICAL SPECIFICATION

Equipment Title	:	Air Receiver Tank	Tag No.	:	-
Quantity	:	1 unit	Doc. No.	:	-
Company	:	PT Mitra Harun Gasindo	Serial No.	:	006/DPT/III/2010
Location	:	SPBE Bogor	Service	:	Air

DESIGN DATA

Design Code	:	ASME Sect. VIII Div. 1, 2015 Ed.	Joint Eff.	:	Spot (0,85)
Company Design Spec.	:	None.	Corr. Allow.	:	1 mm
Design Pressure	:	10 kg/cm2	Head Type	:	Hemispherical
Operating Pressure	:	8 kg/cm2	Insulation	:	No
Design Temperature	:	131 ^{o}F	Fire Proofing	:	N/A
Operating Temperature	:	100 ^{o}F	Year Built	:	2010
Dimensi	:		Position	:	Vertical
Vessel	:		Liquid Density	:	N/A
- OD / ID	:	950 mm (ID)	Sour Service	:	No
- Length	:	1530 mm (S/S)	Inspection	:	-

MATERIAL SPECIFICATION

- Shell	:	JIS G 3101, SS 400	- Support	:	
- Head	:		Leg	:	N/A
Top	:	JIS G 3101, SS 400	Skirt	:	N/A
Bottom	:	JIS G 3101, SS 400	Saddle	:	N/A
- Nozzle	:		- Base Plate	:	N/A
Neck	:	SA 106 Gr.B	- Earthing Lug	:	N/A
Plate	:	N/A	- Internal Attach.	:	
- Manhole Neck	:	SA 106 Gr.B	Ladder	:	N/A
- Flange	:	N/A	Bolt / Nut	:	N/A
- Fitting	:	N/A	- External Attach.	:	
- Reinforcement Pad	:	N/A	Ladder	:	N/A
- Name Plate / Bracket	:	N/A	Bolt / Nut	:	N/A
- Lifting Lug / Pad	:	N/A			
- Gasket	:	N/A			

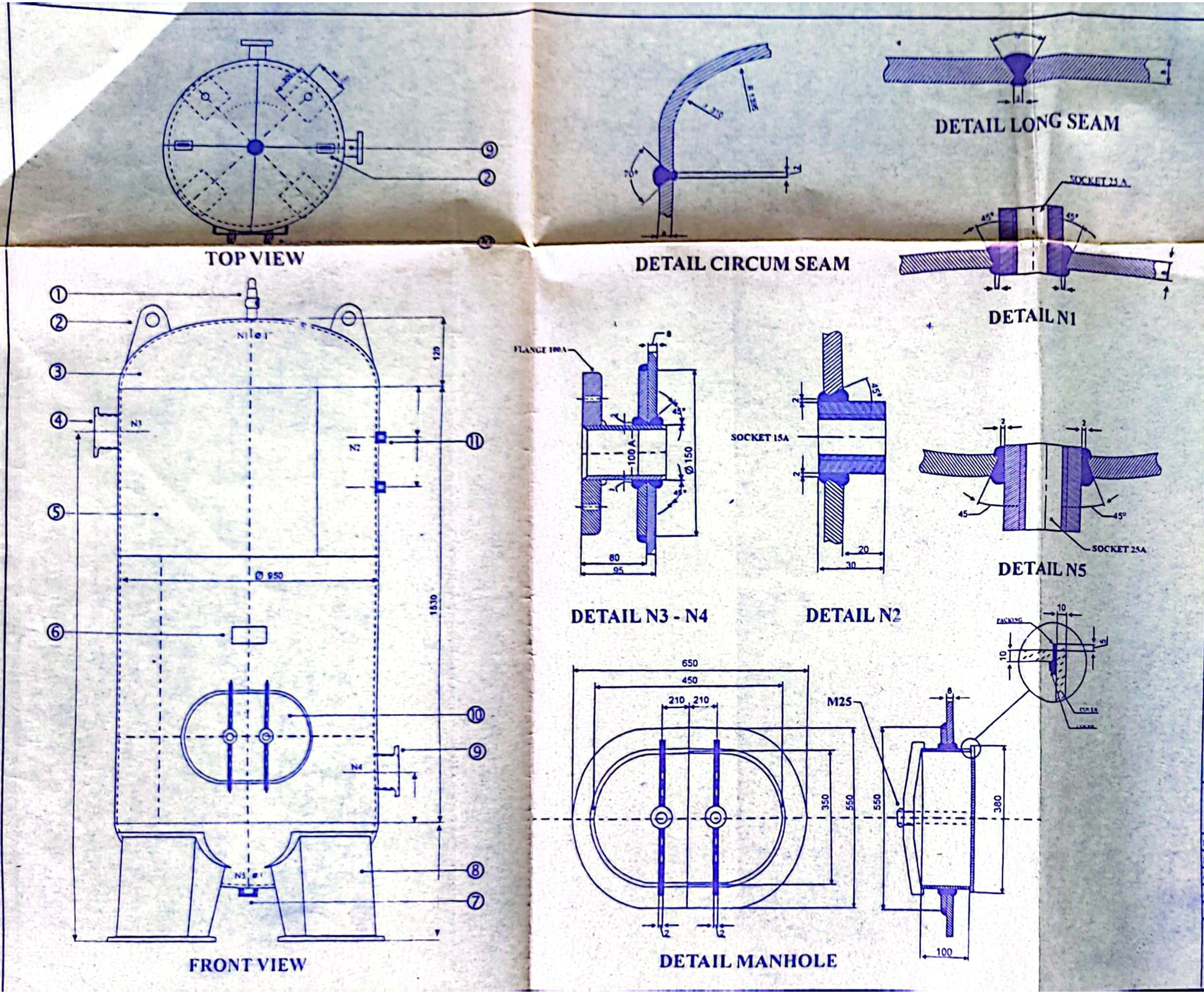
NOZZLE DATA

Mark	Qty	Size (inch)	Type	Rating	Face	Service
N1	1	-	Weld Neck	#150	Raise Face	-
N2	1	-	Weld Neck	#150	Raise Face	-
N3	1	-	Weld Neck	#150	Raise Face	-
N4	1	-	Weld Neck	#150	Raise Face	-
N5	1	-	Weld Neck	#150	Raise Face	-
MW	1	-	Weld Neck	#150	Raise Face	-

NOTE

1. All dimensions are in milimeter and inch, unless otherwise specified.

APPENDIX E
DRAWING



MARK	DESCRIPTION	QTY	SIZE	MATERIAL
1	SAFETY VALVE	1	25A	
2	LIFTING LUG	2	STD	SS 41
3	HEAD PLATE	1	THK-6	SS 41
4	AIR INLET	1	100A	FLANGE
5	SHELL PLATE	1	THK-6	SS 41
6	NAME PLATE	1	[illegible]	SS 41
7	DRAIN	1	25A	SOCK DRAT
8	FOOT STAND	4	STD	SS 41
9	AIR OUTLET	1	100A	FLANGE
10	MANHOLE	1	[illegible]	SS 41
11	PRESSURE GAUGE	1	15A	YAMAMOTO
12				

Fabricator

PT. DAYA PERKASA TEKNIK

Jl. Agung Karya II Blok D 12 Komplek Indofica
Sunter Agung Podomoro
Telp : (021) 6510518 - 6510716 - 687080
Fax : (021) 682133
JAKARTA

NO	DESCRIPTION	DATE	DRWN	CHKD	APPD

PRODUCT

TITLE

PRESSURE VESSEL
STANDARD

SUB TITLE

AIR RECEIVER TANK 1.000 L

DSGN		SCALE	ISSUED
DRWN		NTS	
CHKD			FILE NAME
APPD		CONTRACT NO	ART 1000 L
ACCD			
		DRAWING NO	SHEET / REV