REPORT

TANK INSPECTION SUMMARY REPORT

API 653 Inspection of Above Ground Storage

Tank T-1253

Client	:	Chemical Specialties (S) Pte Ltd
Location	:	31 Ayer Merbau Road, Jurong Island
Project	:	Tank Inspection
Project No	:	LEADS-22-06
Report No	:	LEADS-22-0109
Date of Inspection	:	30 July 2022 to 20 August 2022

TANK INSPECTION SUMMARY REPORT

Table of Contents

TANK INSPECTION SUMMARY REPORT

Originated by	P Rajesh (API 653 Certificate: 74601)	Signature: 
Approved by	Sudhan P (General Manager)	Signature:  

TANK INSPECTION SUMMARY REPORT

1.0 Introduction

1.1 Works Brief

Leads was engaged as a third-party inspection company to carry out the inspection based on API 653 which encompasses below.

An American Petroleum Institute (API) 653 Tank External, Internal from manhole, Arc PMI, UTG & Mechanical Calculation for Tank T-1253 at CSL facility, Jurong Island, Singapore in July to August 2022 has been carried out. This inspection complied with the API 653 standard. NDT data gathered will be part of the final report.

This report is generated on data gathered from three locations: applicable codes, regulations, and laws; the observed field conditions existent during the API inspection; and material provided in written form by the facility, end-user, or client (e.g., as-builts, previous inspection reports, written transcriptions of conversations with the facility.)

This inspection report is based solely on empirically observable conditions observed during the inspection process and correspondence with the facility or end-user. Information not empirically observable or presented to us in the course of this inspection, but which may be relevant to the inspection's findings, have not been evaluated or included in this inspection. The API inspector bears no responsibility for findings which could only be ascertained by information not made available to the API inspector.

1.2 General Arrangement & Reference

This inspection report is prepared with a photo and name of each item and / or a location for reference. In addition, the report is also complemented with all the necessary equipment and personnel certification to ensure that the job was performed in line with the requirements. Please note the content of the final report and report reference numbers are number numerical in each NDT method, however they are grouped in this summary by NDT method so they may not be sequential in their grouping.

1.2.1 Reference Documents

- API 653 – Above ground Storage Tank Inspection Code
- Leads NDT Technical Procedures
- Drawings: (TNK-GA-T1253 -001 Rev 0)

TANK INSPECTION SUMMARY REPORT

1.3 Tank Suitability for Service Statement

This report contains all the details and evaluation results used to arrive at this tank suitability for service determination. Based on the above findings and the detailed report below, we have determined that:

- The tank can continue to operate. However, recommendations are provided for further follow up.

1.3.1 General Condition

T-1253 is an aboveground storage tank that contains currently non-corrosive product. The tank is 21663 mm tall with a 5180 mm internal diameter.

1.3.2 Structural Integrity

We define tank structural integrity as the capability of the tank to remain freestanding, with or without product, under the conditions of its design basis. Structural attributes include the tank bottom, shell, roof and their attachments. Ultrasonic inspections of the shell were performed.

Based on our inspection of the accessible components and engineering evaluation, Tank T-1253 is considered to have suitable structural integrity.

1.3.3 Coating Integrity

We define coating integrity as the interior wetted coating's ability to provide an impervious, completely continuous film barrier that prevents harmful environmental and service conditions corrosive agents to penetrate to the base metal, which could over time compromise hydraulic integrity.

Although corrosion and coating failures may not indicate structural failures; they present conditions which, in time, can lead to structural integrity failures. The coating inside this tank is not present, outside the integrity is not given.

Based on our inspection of the accessible components and engineering evaluation, Tank T-1253 is considered to have suitable coating integrity.

1.3.4 Hydraulic Integrity

Not Applicable as no Pressure test was conducted during this scope.

1.4 Next Inspection Schedules

API 653 recommends the interval to the next internal inspection be determined based on known corrosion rates, but in no case shall the interval exceed 20 years from the date of inspection. When corrosion rates are not known or well established, API 653 recommends that the tank be inspected within 10 years. Based on the current calculated corrosion rates, the useful life of this tank does not exceed 20 years. We recommend the following scheduled inspections:

- **API internal inspection (out-of-service)** inspection should be scheduled at the earliest possible schedule to perform full bottom cone thickness for remaining life evaluation.

- **API external inspection (in-service)** inspection be conducted in accordance with API 653 requirements

    - no later than July 2027 (5 years from July-2022 inspection) for a visual inspection, and
    - no later than July 2037 (15 years from July-2022 inspection) for a UTG inspection of the shell & roof,

  or sooner if a change in condition has occurred.

1.5 Inspector's Certification

I acknowledge that I am familiar with API Standard 653's provisions; the inspection and evaluation performed on Tank T-1253 at CSL and certify that the inspection was performed per the API Standard 653 provisions, good engineering practices, and with usual and customary care

TANK INSPECTION SUMMARY REPORT

2.0 Tank Summary

2.1 Project Scope

An out-of-service API 653 tank inspection has been performed on the tank T-1253. This tank inspection included visual inspection of the tank shell, tank appurtenances, roof, bottom plate (where accessible) and tank foundation. Following the API 653 inspection's completion, a preliminary findings report is provided detailing all tank conditions and repair recommendations.

2.2 Tank Repair Definitions

Mandatory Repairs – repairs that need to be completed before the tank can be returned to service. Mandatory Repairs consists of any failure / deficiency that hasbreached the hydraulic and/or structural integrity of the tank, and/or presents an imminent danger to personnel and/or adjacent structures.

Non-Mandatory Recommended Repairs Preceding Return-To-Service – repairs that do not meet the requirements of being a Mandatory Repair, but will help maintainor improve tank operability / serviceability, or else are required to meet current codes.Repairs noted under this category are recommended for performance prior to the tank being returned to service.

Future Non-Mandatory Recommended Repairs – repairs that do not meet the requirements of being a Mandatory Repair, but will help maintain or improve tank operability / serviceability, or else are required to meet current codes. Unlike the Non-Mandatory Recommended Repairs Preceding Return-To-Service, Future Non-Mandatory Recommended Repairs are not being recommended for performance prior to the tank being returned to service.

Recurring Maintenance Recommendations - actions that should be taken on arecurring basis

TANK INSPECTION SUMMARY REPORT

2.3 Tank Repair Recommendations

The API 653 inspection has resulted in the following repair conditions:

Mandatory Tank Repairs Preceding Return To Service	
I.1	None.
Non-Mandatory Recommended Repairs Preceding Return-To-Service	
II.1	None
Future Non-Mandatory Recommended Repairs	
III.1	Recommend to repair the damaged grouting.
III.2	Recommend to do surface preparation and repainting for Roof N4 nozzle.
Recurring Maintenance Recommendations	
IV.1	Let the fire and safety systems be checked on an annular base by a safety engineer.
IV.2	Perform proper housekeeping on a regular base.
IV.3	Perform visual and UT inspections as per Inspection Interval Recommendation.

TANK INSPECTION SUMMARY REPORT

2.4 Tank General Information:

Tank Installed in	2009 (from given drawing)
Tank Modified in	NA
Tank Coating - External	Yes
Tank Coating - Internal	No
Insulation	No
Support Type	Self-Supporting Cone Roof Tank
Does the tank has hold down bolts	Yes
Diameter of the hold down bolts	M24

2.5 Tank Design Data

DESIGN DATA		
EQUIPMENT ITEM NO		T-1253
EQUIPMENT TYPE		CONE ROOF- SELF SUPPORTING TANK
VESSEL TYPE		VERTICAL
WIND SPEED	m/s	-
WIND LOAD		-
SEISMIC LOAD		NO
		TANK
MEDIUM		CAT 4 FLAMMABLE AND NON CORROSIVE MATERIAL
DESIGN PRESSURE	kPa	10
DESIGN TEMPERATURE	°C	160
WORKING PRESSURE	kPa	ATM
OPERATING TEMPERATURE	°C	AMB
MDMT	°C	NA
MAWP	kPa	-
HYDRO TEST PRESSURE	barg	-
HYDRO TEST POSITION		VERTICAL
JOINT EFFICIENCY		0.70
INSULATION	mm	-
CORROSION ALLOWANCE	mm	1
QUANTITY	UNIT	1
FABRICATED WEIGHT	KG	-
EMPTY WEIGHT	KG	25,000
OPERATING WEIGHT	KG	421,000
SHOP HYDRO TEST WEIGHT	KG	425,000
DESIGN SPECIFIC GRAVITY		-
FLUID SPECIFIC GRAVITY		1.3
GROSS CAPACITY	m^3	400
NET CAPACITY	m^3	XXXX
YEAR BUILT		2009

TANK INSPECTION SUMMARY REPORT

3.0 Inspection Checklists and Summary

The following inspection summaries list all noted deficiencies and the governing criteria withwhich they fail to comply fully.

3.1 Tank Online Inspection

3.1.1 Diked Area and Containment – Checklist: Not Applicable

3.1.2 Tank Foundation - Checklist

1	Level survey required (base on visual planar tilt) C.1.1 & C.1.1.1:	2
2	Foundation (cracks, breaks, spalling):	2
3	Water ingress/egress/vegetation against bottom C.1.1.1	3
4	Indications of bottom leaks:	2
5	Bottom plate extension cond. (API 650 5.4.2, API 653 4.4.7.7):	2
6	Bottom plate extension welds (pitting, corrosion, undercut):	2
7	Earth grounding cables and connectors cond. (API 575. 7.2.5):	2
8	Tank settlement into pad C.1.1.2:	NE
9	Anchor bolt condition:	2

Legend:

1	Good Condition	3	Repair or alteration recommended	U/A	Un-assessable
2	Satisfactory Condition	4	Repair or alteration required	NE	None Evident
xx	Not to Code			N/A	Not applicable

TANK INSPECTION SUMMARY REPORT

3.1.3 Shell External - Checklist

1	Coating or painting on shell plates (blisters, peeling, stains):	2
2	Insulation (cracks, leaks, moisture retention):	N/A
3	Shell pitted or corroded (API 653. 4.3):	2
4	Deformation of shell (banding, peaking) (API 653. 10.5.4, 10.5.5):	2
5	Bottom course deformation:	2
6	Indication of shell leaks:	2
7	Shell misalignment (API 650. 5.6.1.4):	2
8	Weld reinforcement (API 650. 5.7.2):	2
9	Tank roundness (API 653. 10.5.3):	2
10	Seam weld undercut (API 653. 10.4.2.5):	2
11	Remnant welds (API650 3.8.1.2C) (API 652 4.3) (API 653 9.6.5):	2
12	Shell vertical seam weld spacing (API 650. 5.1.5.2):	2
13	Name plate attachment (API 650. 10.1, API 653. 13.1):	2

Legend:

1	Good Condition	3	Repair or alteration recommended	U/A	Un-assessable
2	Satisfactory Condition	4	Repair or alteration required	NE	None Evident
xx	Not to Code			N/A	Not applicable

TANK INSPECTION SUMMARY REPORT

3.1.3.1 Shell Course Remaining Life Calculations As Per API 653:

The minimum acceptable shell plate thickness for continued service was be determined by below:

$$t_{min} = \frac{2.6\,(H-1)DG}{SE}$$

- t_{min} is the minimum acceptable thickness, in inches for each course as calculated from the above equation; however, t_{min} shall not be less than 0.1 in. for any tank course.

Material - CS equivalent

H (Height of maximum liquid level, in ft.) – 68.71

D (Diameter of tank, in ft.) – 16.99

G (specific gravity of content) – 1.3

S (Max. allowable stress, lbf/in.^{2}) – 24900 (for 1st and 2nd shell course); 27400 (for rest)

E (Joint Efficiency) – 0.7

The following table consolidates the minimum thickness and remaining life of each shell course of the tank. Please refer to the UTG report (LEADS- 2022-UTG-029)

Plate No.	Original Thickness (mm)	Shell course height (mm)	Product height, H (ft)	Actual lowest Thickness (mm)	Wall loss (mm)	Years of Service	Long Term Corrosion Rate (mm/year)	Min. required thickness (mm)	Remaining Life (Years)	Next recommended UTG inspection
Shell Course #1	12	1524	68.7	11.52	0.48	13	0.037	5.67	158	15 years
Shell Course #2	10	1524	63.7	9.68	0.32	13	0.025	5.25	180	15 years
Shell Course #3	10	1524	58.7	9.67	0.33	13	0.025	4.39	208	15 years
Shell Course #4	8	1524	53.7	7.71	0.29	13	0.022	4.01	166	15 years
Shell Course #5	8	1524	48.7	7.69	0.31	13	0.024	3.63	170	15 years
Shell Course #6	8	1524	43.7	7.66	0.34	13	0.026	3.25	169	15 years
Shell Course #7	6	1800	38.7	5.73	0.27	13	0.021	2.87	138	15 years
Shell Course #8	6	1800	32.8	5.58	0.42	13	0.032	2.54	94	15 years
Shell Course #9	6	1800	26.9	5.70	0.30	13	0.023	2.54	137	15 years
Shell Course #10	6	1800	21.0	5.70	0.30	13	0.023	2.54	137	15 years
Shell Course #11	6	1800	15.1	5.90	0.10	13	0.008	2.54	437	15 years
Shell Course #12	6	1800	9.2	5.80	0.20	13	0.015	2.54	212	15 years
Shell Course #13	6	1000	3.3	5.85	0.15	13	0.012	2.54	287	15 years

TANK INSPECTION SUMMARY REPORT

3.1.4 Shell Appurtenances - Checklist

1	Leakage around reinforcement plate welds:	NE
2	Reinforcement telltale holes (API 650 5.7.5):	2
3	Reinforcement plate spacing (API 650 5.7.3):	2
4	Nozzle weld corrosion/undercut (API 650 8.5.1):	2
5	Indications of leakage around manifolds, flanges, or valves C.1.3.2:	2
6	Indications of leakage around manways and nozzles:	2
7	Indications of leakage around flange bolts and welds:	2

Legend:

1	Good Condition	3	Repair or alteration recommended	U/A	Un-assessable
2	Satisfactory Condition	4	Repair or alteration required	NE	None Evident
xx	Not to Code			N/A	Not applicable

TANK INSPECTION SUMMARY REPORT

3.1.5 Access Structure – Checklist: Not Applicable

3.1.6 Fixed Roof (Cone / Dome) - Checklist

1	Roof plate distortions:	2
2	Roof plates (corrosion, pitting, holes API 653 4.2.1.2):	2
3	Roof plates (coating or paint failure):	2
4	Remnant welds (API 652 7.3) (API 653 9.6.5):	2
5	Indications of product staining:	1
6	Rain water standing, sag of roof C.1.4.3:	2
7	Roof Nozzles & vents condition:	3

Legend:

1	Good Condition	3	Repair or alteration recommended	U/A	Un-assessable
2	Satisfactory Condition	4	Repair or alteration required	NE	None Evident
xx	Not to Code			N/A	Not applicable

3.1.6.1 ROOF PLATE REMAINING LIFE CALCULATION:

Plate No.	Original Thickness (mm)	Lowest actual thickness* (mm)	Wall loss (mm)	Years of Service	Long Term Corrosion Rate (mm/year)	Min. required thickness (mm)	Remaining Life (Years)	Next recommended UTG inspection
Roof Plate	**4.50**	**4.39**	**0.11**	**13**	**0.008**	**2.29**	**263**	**15 Years**

*Please refer to the UTG report (LEADS-2022-UTG-029).

TANK INSPECTION SUMMARY REPORT

3.2 Tank Offline Inspection

3.2.1 External floating roof – Checklist: Not Applicable

3.2.2 Fixed Roof (Internal) – Checklist: Not Accessible

3.2.3 Internal Floating Roof – Checklist: Not Applicable

3.2.4 Shell (Internal) - Checklist

1.	Shell internal coating condition:	N/A
2.	Damages / dents / scratches on the shell plates present:	2
3.	Shell corrosion (API 653 4.3.1.3):	2
4.	Seam weld undercut (API 653 10.4.2.5):	2
5.	Remnant welds (API 650 3.8.1.2C) (API 620 4.3) (API 653 9.6):	2

Legend:

1	Good Condition	3	Repair or alteration recommended	U/A	Un-assessable
2	Satisfactory Condition	4	Repair or alteration required	NE	None Evident
xx	Not to Code			N/A	Not applicable

Shell (Internal) – Comments:

- Internal inspection was not conducted.

TANK INSPECTION SUMMARY REPORT

3.2.5 Tank bottom and internal appurtenances - Checklist

1	Tank bottom plate condition (corrosion, pitting):	2
2	Remnant welds (API 620 4.3, 4.4) (API 653 9.6):	2
3	Bulges/depressions (API 653 B3.3):	2
4	Tank bottom coating condition:	N/A
5	Shell-to-bottom fillet weld (API 650 5.1.5.7):	2
6	Internal piping general (Coating, corrosion):	2
7	Heating Coil condition:	N/A

Legend:

1	Good Condition	3	Repair or alteration recommended	U/A	Un-assessable
2	Satisfactory Condition	4	Repair or alteration required	NE	None Evident
xx	Not to Code			N/A	Not applicable

Tank bottom (Internal) – Comments:

- Internal inspection was not conducted.

3.2.6 Tank bottom internal (Service Interval)

Plate No.	Original Thickness (mm)	Actual lowest Thickness (mm)	Wall loss (mm)	Years of Service	Long Term Corrosion Rate (mm/year)	Min. required thickness (mm)	Remaining Life (Years)	Next recommended UTG inspection
Bottom Cone	**10**	**NA**	**NA**	**13**	**NA**	**2.83**	**NA**	**Note**

Note: Inspection should be scheduled at the earliest possible schedule to perform full bottom cone thickness for remaining line evaluation.

TANK INSPECTION SUMMARY REPORT

4.0 NDT Inspection Reports

4.1 Visual Inspection Photographs

4.2 UTG Inspection Report

4.3 PMP REPORT

4.1 Visual Inspection Photographs

Photo 1: Tank identification

Photo 2: Tank external view in satisfactory condition.

TANK INSPECTION SUMMARY REPORT

Photo 3: Tank external view in satisfactory condition.

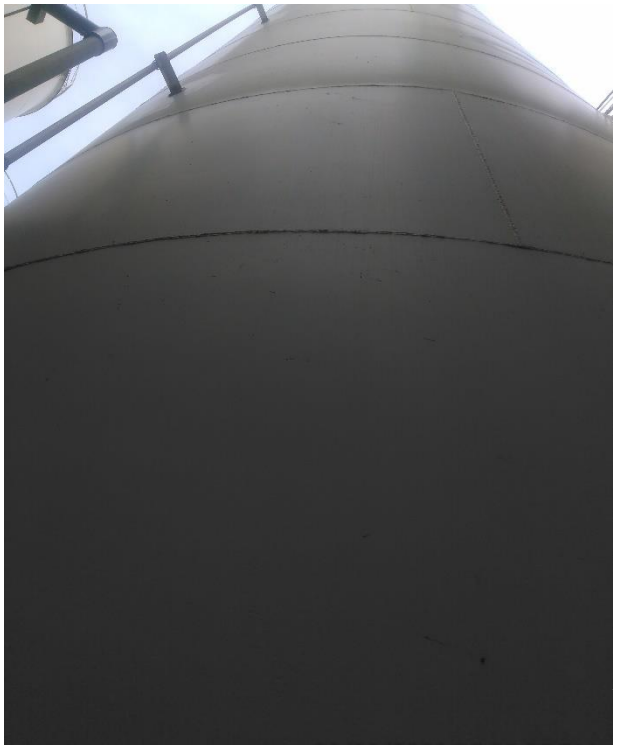


Photo 4: Tank external view in satisfactory condition.

TANK INSPECTION SUMMARY REPORT

Photo 5:

Photo 6: Bottom angle ring, bolts & grouting were in satisfactory condition.

Photo 7: Bottom angle ring, bolts & grouting were in satisfactory condition.

Photo 8: Bottom angle ring, bolts & grouting were in satisfactory condition.

Photo 9: Bottom angle ring, bolts were in satisfactory condition. Damaged grouting was noted.

Photo 10: Bottom angle ring, bolts were in satisfactory condition. Damaged grouting was noted.

TANK INSPECTION SUMMARY REPORT

Photo 11: Bottom angle ring, bolts were in satisfactory condition. Damaged grouting was noted.

Photo 12: Maintenance hole was observed in satisfactory condition

TANK INSPECTION SUMMARY REPORT

Photo 13: Manhole, reinforcement plate were observed in satisfactory condition.

Photo 14: Manhole, reinforcement plate were observed in satisfactory condition.

TANK INSPECTION SUMMARY REPORT

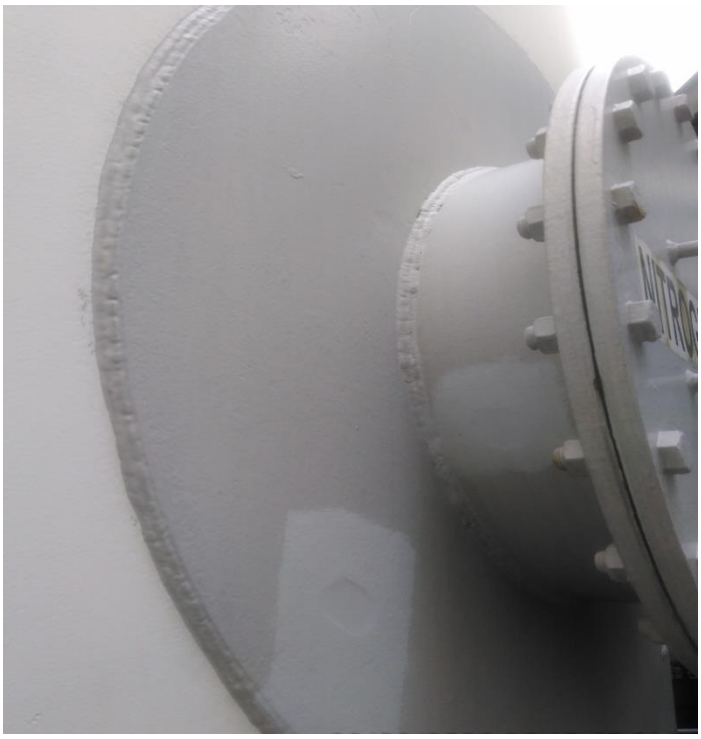


Photo 15: Manhole, reinforcement plate were observed in satisfactory condition.

Photo 16: Maintenance hole was observed in satisfactory condition.

TANK INSPECTION SUMMARY REPORT

Photo 17: Bottom cone was observed satisfactory condition.

Photo 18: Annular plate was observed with minor rusting.

Photo 19: Annular plate was observed with minor rusting.

Photo 20: Earth cable was observed satisfactory condition.

TANK INSPECTION SUMMARY REPORT

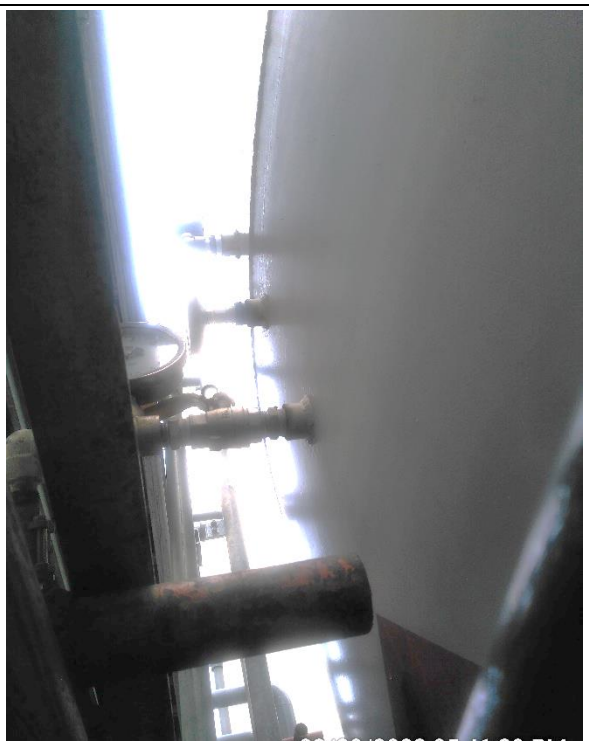


Photo 21: Shell course and nozzles were observed satisfactory condition.

Photo 22: Shell courses was observed satisfactory condition.

Photo 23: Shell courses was observed satisfactory condition

Photo 24: Remaining shell courses & nozzle was observed satisfactory condition

TANK INSPECTION SUMMARY REPORT

Photo 25: Shell courses was observed satisfactory condition

Photo 26: Roof identification was observed satisfactory condition.

TANK INSPECTION SUMMARY REPORT

Photo 27: Roof plate was observed in satisfactory condition.

Photo 28: Roof plate was observed in satisfactory condition.

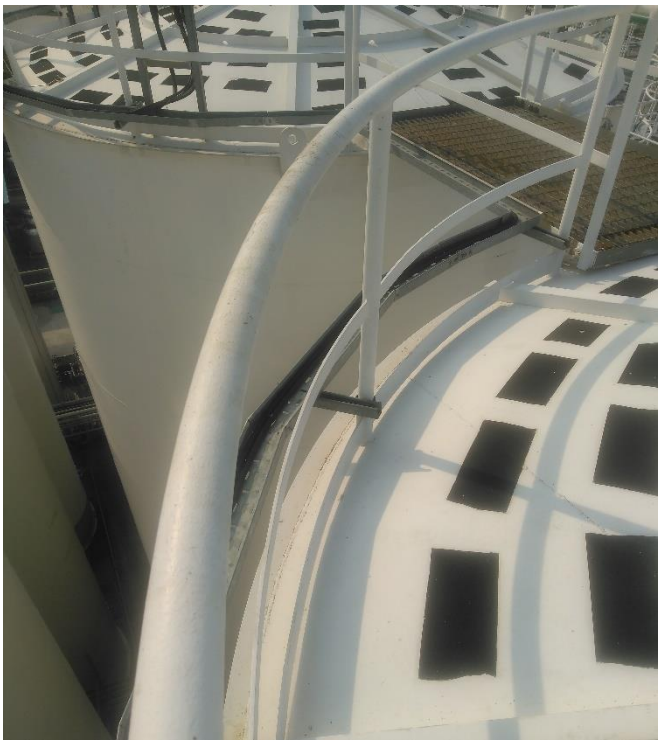


Photo 29: Roof handrail and joints were in satisfactory condition

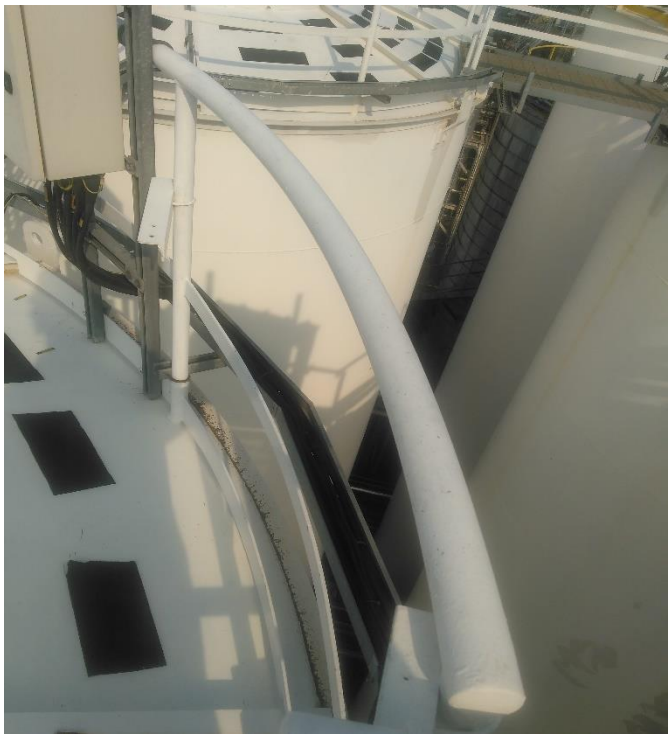


Photo 30: Roof handrail and joints were in satisfactory condition

TANK INSPECTION SUMMARY REPORT


Photo 31&32: Roof nozzles and joints were in satisfactory condition.


Photo 33&34: Roof N4 nozzle was observed with corrosion. Recommend to surface prepare and repaint.

TANK INSPECTION SUMMARY REPORT

Photo 35: Top angle ring and lifting lug were in satisfactory condition

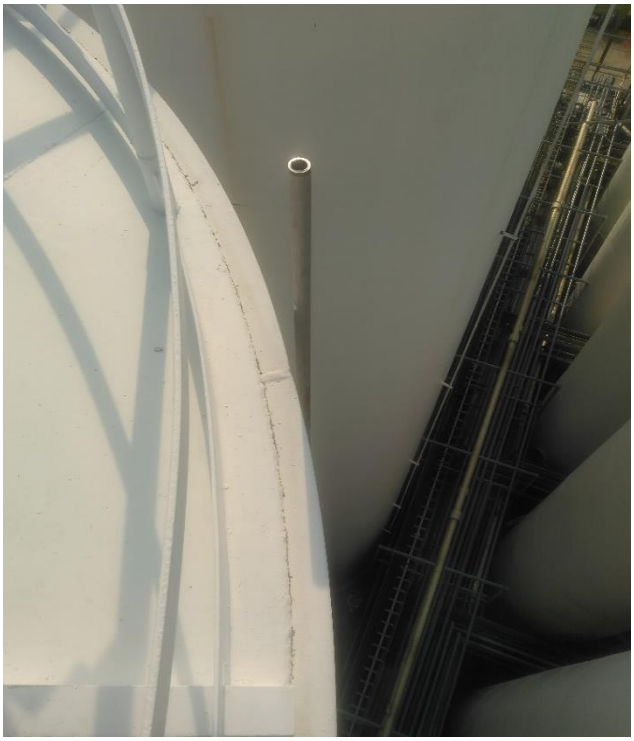


Photo 36&37: Top angle ring and lifting lug were in satisfactory condition

TANK INSPECTION SUMMARY REPORT

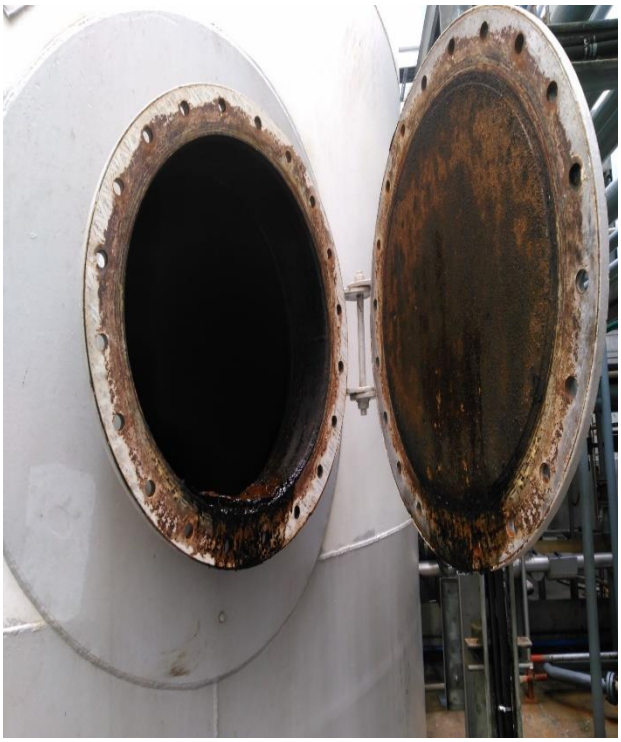


Photo 38& 39: Tank internal view from manhole were in satisfactory condition.

Photo 40&41: Tank internal view was in satisfactory condition

TANK INSPECTION SUMMARY REPORT

4.2 Ultrasonic Thickness Measurement Report

ULTRASONIC THICKNESS GAUGING

Accredited Laboratory SAC-SINGLAS LA-2016-0616-D

Client	: Chemical Specialities (Singapore) Pte Ltd	Report No	: LEADS/CSL/2022/UTG-029
Project	: API Tank Inspection	Inspection Date	: 30-07-2022
Item Description	: Tank T-1253 Shell Course	Location	: 31 Ayer Merbau Rd, Singapore 627717

Eq.Make / Model	: 38 DL PLUS	Test Mode	: Auto Echo to Echo	Procedure	: LEADS-IMSP-035 REV-02
Eq. Serial No	: 193390803	Screen Range	: 0-50mm	Standard	: API 650 12th Edition
Probe Frequency	: 5 MHZ	Material	: Carbon Steel	Drawing No.	: NA
Probe Serial No	: 1123940	Surface Cond.	: Smooth	Couplant Type	: Wallpaper paste
Probe Size Ø	: 11mm	Probe Type	: Thru-Coat Dual / D7906	Cal Block(Sr.No)	: Step Wedge(3E/2-20mm/cs/24)

S/NO	Item Description	Nominal Thk(mm)	UTG Measurement (mm)				Min	Max	Diminution		AVG	Remarks
			0°	90°	180°	270°	(mm)	(mm)	(mm)	%		
1	Shell Course-1	12 mm	11.56	11.53	11.55	11.55	11.53	11.56	-	-	11.55	
			11.58	11.52	11.54	11.52	11.52	11.58	-	-	11.54	
2	Shell Course-2	10 mm	9.73	9.70	9.72	9.69	9.69	9.73	-	-	9.71	
			9.73	9.69	9.68	9.68	9.68	9.73	-	-	9.70	
3	Shell Course-3	10 mm	9.70	9.73	9.68	9.72	9.68	9.73	-	-	9.71	
			9.71	9.72	9.67	9.72	9.67	9.72	-	-	9.71	
4	Shell Course-4	8 mm	7.83	7.90	7.75	7.86	7.75	7.90	-	-	7.84	
			7.71	7.84	7.73	7.80	7.71	7.84	-	-	7.77	
5	Shell Course-5	8 mm	7.69	7.70	7.73	7.70	7.69	7.73	-	-	7.71	
			7.70	7.70	7.74	7.76	7.70	7.76	-	-	7.73	
6	Shell Course-6	8 mm	7.68	7.70	7.72	7.74	7.68	7.74	-	-	7.71	
			7.66	7.78	7.70	7.71	7.66	7.78	-	-	7.71	
7	Shell Course-7	6 mm	5.77	5.73	5.78	5.77	5.73	5.78	-	-	5.76	
			5.73	5.73	5.75	5.76	5.73	5.76	-	-	5.74	

Leads Address : Leads Specialist Services Pte Ltd. Platinum@Pioneer, 32F Tuas Ave 11, Singapore 636855

Inspected By (Signature)	Approved By (Signature)	NDT Levell III	CLIENT REP. (Signature)
S. Nivash Kumar 01-08-2022	Chinnadurai 01-08-2022	P.Rajesh 01-08-2022	

1.The report shall not be reproduced except in full, unless the management representative of the accredited organisation has given Approval in writing.
2.The results reported herein have been performed in accordance with the terms of accreditation under the Singapore Accreditation Council"
3.Leads stand no responsibilities for changes in the quality of the same product tested in later stage with same variables but different conditions.

ULTRASONIC THICKNESS GAUGING

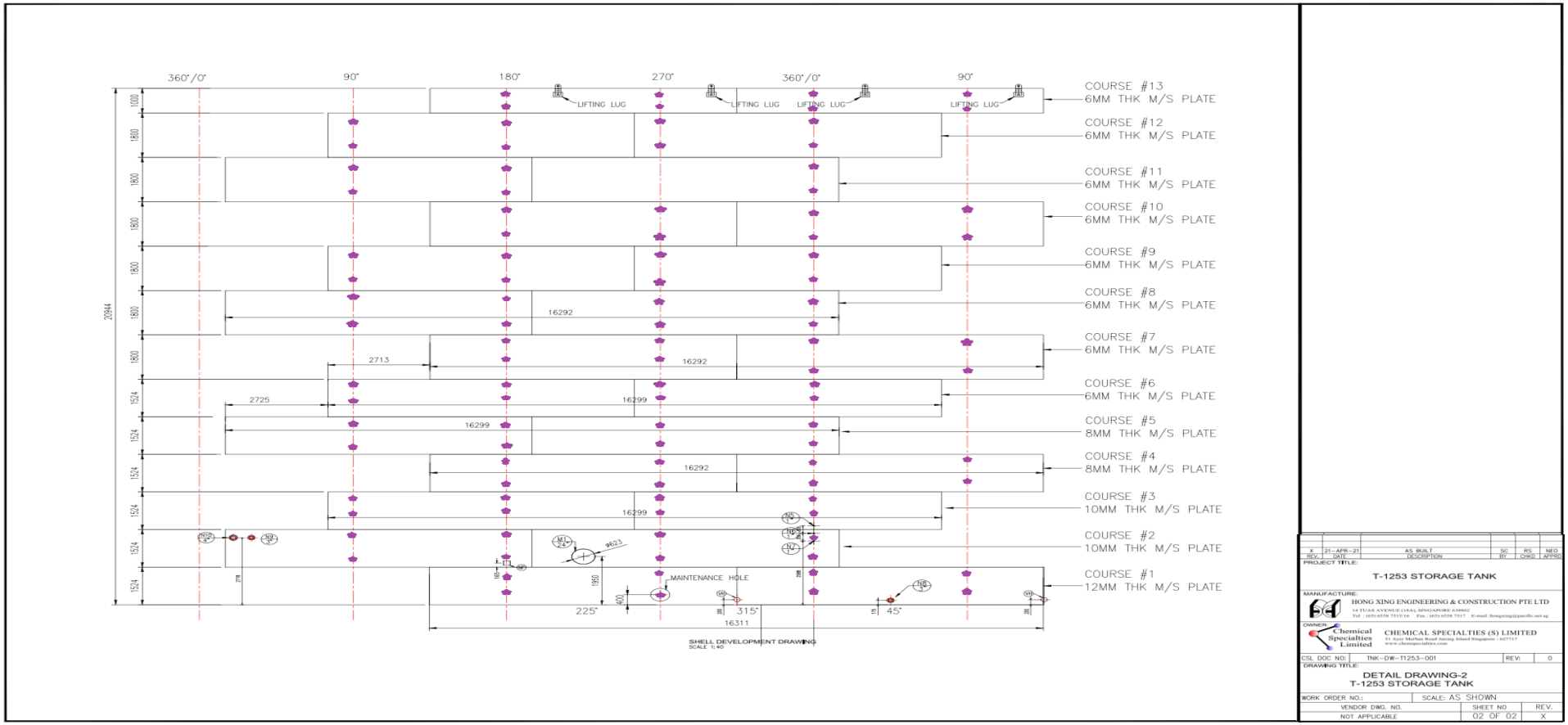
Client	: Chemical Specialities (Singapore) Pte Ltd	Report No	: LEADS/CSL/2022/UTG-029
Project	: API Tank Inspection	Inspection Date	: 30-07-2022
Item Description	: Tank T-1253	Location	: 31 Ayer Merbau Rd, Singapore 627717

Eq.Make / Model	: 38 DL PLUS	Test Mode	: Auto Echo to Echo	Procedure	: LEADS-IMSP-035 REV-02
Eq. Serial No	: 193390803	Screen Range	: 0-50mm	Standard	: API 650 12th Edition
Probe Frequency	: 5 MHZ	Material	: Carbon Steel	Drawing No.	: NA
Probe Serial No	: 1123940	Surface Cond.	: Smooth	Couplant Type	: Wallpaper paste
Probe Size Ø	: 11mm	Probe Type	: Thru-Coat Dual / D7906	Cal Block(Sr.No)	: Step Wedge(3E/2-20mm/cs/24)

S/NO	Item Description	Nominal Thk(mm)	UTG Measurement (mm)				Min	Max	Diminution		AVG	Remarks
			0°	90°	180°	270°	(mm)	(mm)	(mm)	%		
8	Shell Course-8	6 mm	5.60	5.63	5.68	5.70	5.60	5.70	-	-	5.65	
			5.58	5.64	5.68	5.72	5.58	5.72	-	-	5.66	
9	Shell Course-9	6 mm	5.77	5.73	5.75	5.72	5.72	5.77	-	-	5.74	
			5.76	5.75	5.75	5.70	5.70	5.76	-	-	5.74	
10	Shell Course-10	6 mm	5.70	5.73	5.80	5.79	5.70	5.80	-	-	5.76	
			5.74	5.72	5.78	5.78	5.72	5.78	-	-	5.76	
11	Shell Course-11	6 mm	5.92	5.97	5.95	5.93	5.92	5.97	-	-	5.94	
			5.90	5.96	5.94	5.92	5.90	5.96	-	-	5.93	
12	Shell Course-12	6 mm	5.82	5.85	5.83	5.85	5.82	5.85	-	-	5.84	
			5.80	5.88	5.84	5.84	5.80	5.88	-	-	5.84	
13	Shell Course-13	6 mm	5.98	5.86	5.94	5.92	5.86	5.98	-	-	5.93	
			5.97	5.85	5.93	5.92	5.85	5.97	-	-	5.92	
Bottom Nozzle												
14	Manhole	24"	6.44	6.35	6.39	6.43	6.35	6.44	-	-	6.40	
15	Nozzle N8	3"	5.73	5.71	5.20	5.24	5.20	5.73	-	-	5.47	
Roof Nozzle												
16	Nozzle N1	6"	6.46	6.44	6.37	6.48	6.37	6.48	-	-	6.44	
17	Nozzle 2A	8"	8.40	8.10	7.80	7.76	7.76	8.40	-	-	8.02	
18	Nozzle 2B	8"	7.64	8.33	8.05	7.90	7.64	8.33	-	-	7.98	

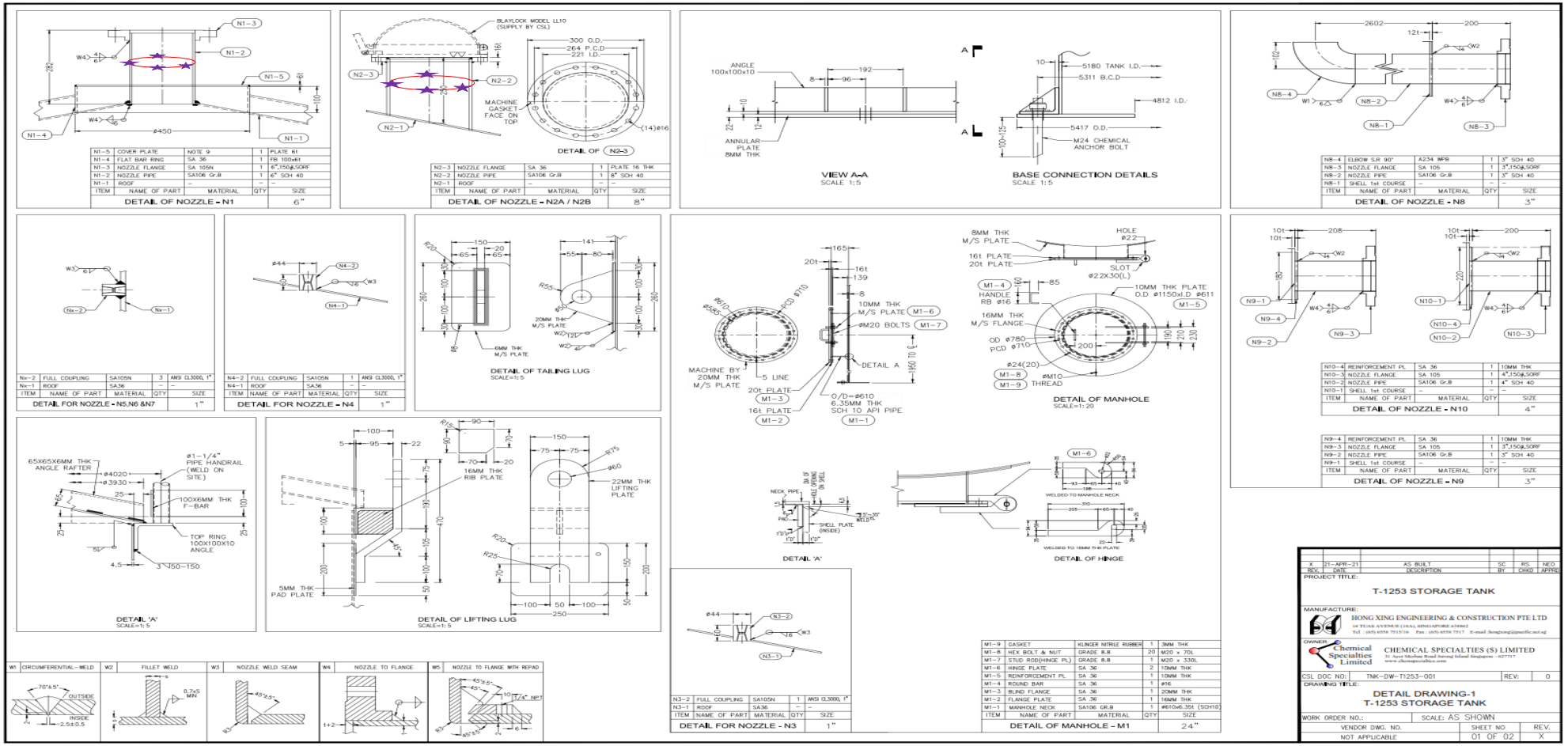
Item Description		Nominal Thk(mm)	UTG Measurement (mm)								Min (mm)	Max (mm)	AVG	Remarks
			0°	45°	90°	135°	180°	225°	270°	315°				
19	Top Cone	4.5	4.41	4.48	4.49	4.47	4.43	4.42	4.39	4.45	4.39	4.49	4.44	

Client	: Chemical Specialities (Singapore) Pte Ltd	Report No	: LEADS/CSL/2022/UTG-029
Project	: API Tank Inspection	Inspection Date	: 30-07-2022
Item Description	: T-1253	Location	: 31 Ayer Merbau Rd, Singapore 627717



UTG MEASUREMENTS

Client	: Chemical Specialities (Singapore) Pte Ltd	Report No	: LEADS/CSL/2022/UTG-029
Project	: API Tank Inspection	Inspection Date	: 30-07-2022
Item Description	: T-1253	Location	: 31 Ayer Merbau Rd, Singapore 627717



UTG MEASUREMENTS

TANK INSPECTION SUMMARY REPORT

4.3 PMP Report

POSITIVE MATERIAL IDENTIFICATION REPORT

Owner	: Chemical Specialist (S) Pte Ltd.	**Report No**	: LEADS-22-PMP-011
Client	: Hong Xing Engineering & Construction Pte Ltd	**Examination Date**	: 30-07-2022
Address	: 31 Ayer Merbau Rd, Singapore 627717	**Location**	: 31, Ayer Merbau Road
Project	: Tank T-1253	**Exposure Time**	: 5 Seconds
Equipment / Serial No	: Oxford Instrumental PMI Master smart / 57U0023	**Material**	: Carbon Steel
Acceptance Criteria	: ASME Section II Ed 2021	**Reference Procedure**	: LEADS-IMSP-064 Rev 0

S.No	Part Description	Chemical Composition (%)					Material Grade	Result
		C	Si	Mn	P	S		
1	Pre - Calibration	0.028	0.62	1.41	0.008	0.028	SS316L	Accept
2	Annual Plate	0.24	0.16	0.38	0.005	0.001	A-36	Accept
3	Bottom Shell	0.19	0.13	0.36	0.014	0.011	A-36	Accept
4	Shell - 1	0.22	0.13	0.23	0.014	0.018	A-36	Accept
5	Manual Pad	0.19	0.24	0.60	0.026	0.041	A-36	Accept
6	Manual Door	0.29	0.21	0.86	0.026	0.016	A-36	Accept
7	manual	0.22	0.18	0.85	0.020	0.012	A-36	Accept
8	Top Roof	17.00	0.17	0.29	0.017	0.025	A-36	Accept
9	Top Roof Nozzle - 1	0.20	0.19	0.31	0.017	0.034	A-36	Accept
10	Top Roof Nozzle - 2	0.15	0.17	0.30	0.010	0.020	A-36	Accept
11	Top Roof Nozzle - 3	0.16	0.17	0.31	0.010	0.024	A-36	Accept
12	Bottom Nozzle	0.06	0.28	1.55	0.010	0.020	SS304	Accept
13	Post - Calibration	0.026	0.66	1.47	0.011	0.021	SS316L	Accept
Material Specification SS 316L	**Max**	**0.035**	**1.00**	**2.00**	**0.045**	**0.030**	**SS 316L**	
Material Specification A 36		**0.25**	**0.40**	**1.35**	**0.040**	**0.050**	**A-36**	
Material Specification SS 304		**0.08**	**0.75**	**2.0**	**0.045**	**0.030**	**SS 304**	

Name & Address of the Employer : Leads Specialist Services Pte ltd, Platinum@Pioneer,32F Tuas Ave 11, Singapore 636855

Inspected By	Approved By	Reviewed By	Client Representative
V. SENTHIL INSPECTOR 01-08-2022	P. RAJESH TECHNICAL MANAGER 01-08-2022		

1.The report shall not be reproduced except in full, unless the management representative of LEADS has given Approval in writing
2. Leads stand no responsibilities for changes in the quality of the same product tested in later stage with same variables but different conditions.

Leads Specialist Services Pte Ltd
www.leads1.com / ops@leads1.com

TANK INSPECTION SUMMARY REPORT

5.0 Equipment and Personnel Certificates

5.1 Equipment Calibration

5.2 Personnel Certification

TANK INSPECTION SUMMARY REPORT

5.1 Equipment Calibration

DIGITAL ULTRASONIC THICKNESS GAUGE CALIBRATION CERTIFICATE

Calibration Certificate No : LEADS-22-UTG-04

Date of Calibration : 01/01/2022

Client : LEADS

Equipment Details

Model & Make : 38DLPLUS & OLYMPUS

Product : DIGITAL ULTRASONIC THICKNESS GAUGE

Serial No : 193390803

Ambient Temperature : (24±2) ° C

Relative Humidity : (35 to 70) % RH

Calibration Accessories

Block Serial No : 7 Step Wedge

Certificate No. : CM-47624/3

This is to certify that the above instruments having serial no. 193390803 has been calibrated Under the ambient Conditions Stated according calibration Procedure ISO 16831:2012 the UTG was calibrated by comparison with a reference Calibration block the reference Standards are traceable to National Standards.

Calibration Date: 01/01/2022

Calibrated by

Name : M. Bharath

Signature :

Date : 01-01-2022

Calibration Due Date: 31/12/2022

Approved By

Name : B. Chinnadurai

Signature :

Date : 01-01-2022

Leads Specialist Services Pte Ltd
No.2 Tuas South Avenue 2
Singapore 637601

S/No.	Reference Readings	Test Readings	Deviation	Remarks
1	20 mm	19.93	-0.07	OK
2	17 mm	17.01	+0.01	OK
3	14 mm	14.01	+0.01	OK
4	11 mm	11.04	+0.04	OK
5	8 mm	8.08	+0.08	OK
6	5 mm	5.03	+0.03	OK
7	2 mm	2.01	+0.01	OK

The expanded Uncertainty of measurement found to be 0. 06 mm at Confidence level is approximately 95% with coverage factor K = 2

POSITIVE MATERIAL IDENTIFICATION CALIBRATION CERTIFICATE

Calibration Certificate No : LEADS-20-CAL-PMI-002

Date of Calibration : 23/12/2020

Client : Leads (in house)

Equipment Details

Make : Oxford Instruments

Model : PMI Master Smart

Product : Optical Emission System

Serial No : 57U0023

This is to certify that the above instrument having serial No. 57U0023 has been calibrated. The test proved that the instrument's performance confirms in all respects of the manufacturer's specification.

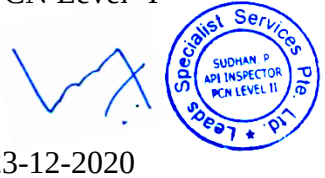
Calibration Date: 23/12/2020 **Calibration Due Date: 22/12/2021**

Calibrated & Approved By

Name : P. Sudhan

Qualification : PCN Level II

Signature :



Date : 23-12-2020

TANK INSPECTION SUMMARY REPORT

5.2 Personnel Certification

API INDIVIDUAL CERTIFICATION PROGRAMS

verifies that

Peramaiyan Rajesh

HAS MET THE ESTABLISHED AND PUBLISHED REQUIREMENTS FOR API CERTIFICATION AS AN

API 653 ABOVEGROUND STORAGE TANK INSPECTOR

IN ACCORDANCE WITH THE KNOWLEDGE DEFINED IN THE **API Standard 653**

CERTIFICATION NUMBER **74601**

ORIGINAL CERTIFICATION DATE	August 31, 2017
CURRENT CERTIFICATION DATE	August 31, 2020
EXPIRATION DATE	August 31, 2023

Manager, Individual Certification Programs

NDT CERTIFICATION

Certificate Reference No: LEADS-IMSC-NDTC-052
Date of Issue: 14/09/2020
Date of Expiry: 13/09/2025

This is to certify and authorize **Subramaniyan Nivashkumar (G2983453P)** represent Leads Specialist Services Pte. Ltd, to work in the following NDT methods, as he satisfactorily met the qualification and certification requirements of company written Practice LEADS-IMSP-029 Rev 02, which is based on ASNT RP No SNT-TC-1A 2016 Ed.

Method	NDT Level	Scope /Sectors/ Categories
Ultrasonic Test	**Level II**	**Flaw Detection**
Ultrasonic Thickness Gauging	**Level II**	**A Scan Thickness & Spot Measurement**
Magnetic Particle Inspection	**Level II**	**Electromagnetic Yoke, Visible /Fluorescent, Dry/Wet Particle**
Liquid Penetrant Inspection	**Level II**	**Visible / Fluorescent**
Radiography Test	**Level II**	**Radiography**

This record is only evidence of competence when supported by the following evidence a specified by the minimum requirements of leads specialist services pte ltd competence management system.

- Valid eye test
- Prior experience
- examination
- No interrupted services of the respective NDT Methods with the previous 6 months

This inspector has meet lead's requirements for the respective methods this record only valid during employment with leads specialist services pte ltd.

This document is un controlled if printed authorization history can be provided on demand

Authorized by	Position	Date	Signature
P. SUDHAN	Operation Manager	14/09/2020	
A.U. VASANTH	ASNT NDT Level III	14/09/2020	

LEADS SPEIALIST SERVICES PTE LTD
NO.2 TUAS SOUTH AVE 2
SINGAPORE 637601
ops@leads1.com/www.leads1.com

NDT CERTIFICATION

Certificate Reference No: LEADS-IMSC-NDTC-060
Date of Issue: 28/12/2020
Date of Expiry: 27/12/2025

This is to certify and authorize **Vaithilingam Senthil (G8568233X)** represent Leads Specialist Services Pte. Ltd, to work in the following NDT methods, as he satisfactorily met the qualification and certification requirements of company written Practice LEADS-IMSP-029 Rev 02, which is based on ASNT RP No SNT-TC-1A 2016 Ed.

Method	NDT Level	Scope /Sectors/ Categories
Magnetic Particle Inspection	**Level II**	**Electromagnetic Yoke, Visible /Fluorescent, Dry/Wet Particle**
Ultrasonic Test	**Level II**	**Flaw Detection**
Ultrasonic Thickness Gauging	**Level II**	**A Scan Thickness & Spot Measurement**
Liquid Penetrant Inspection	**Level II**	**Visible / Fluorescent**
Radiography Test	**Level II**	**Radiography**

This record is only evidence of competence when supported by the following evidence a specified by the minimum requirements of leads specialist services pte ltd competence management system.

- Valid eye test
- Prior experience
- examination
- No interrupted services of the respective NDT Methods with the previous 6 months

This inspector has meet lead's requirements for the respective methods this record only valid during employment with leads specialist services pte ltd.

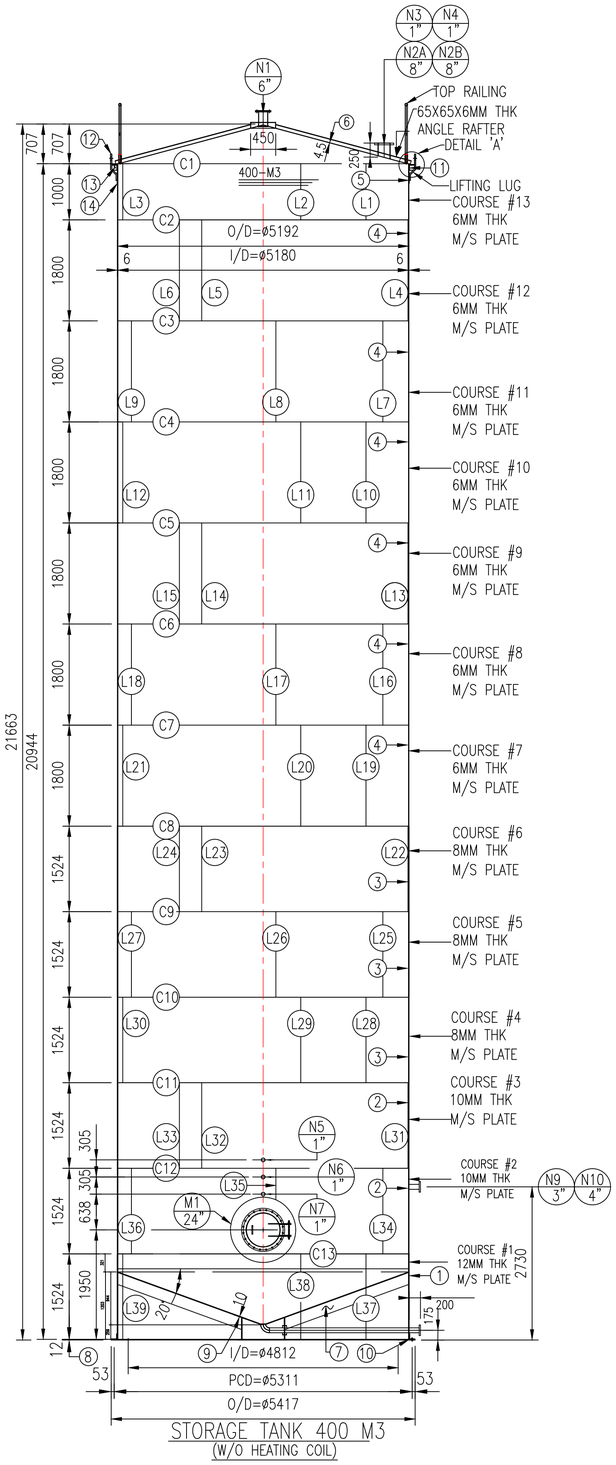
This document is un controlled if printed authorization history can be provided on demand

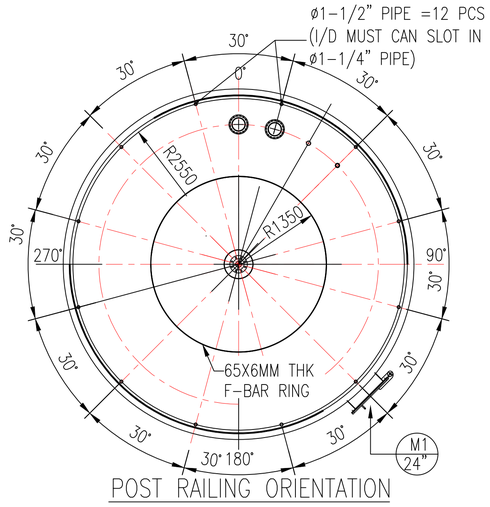
Authorized by	Position	Date	Signature
P. SUDHAN	Operation Manager	28/12/2020	
A.U. VASANTH	ASNT NDT Level III	28/12/2020	

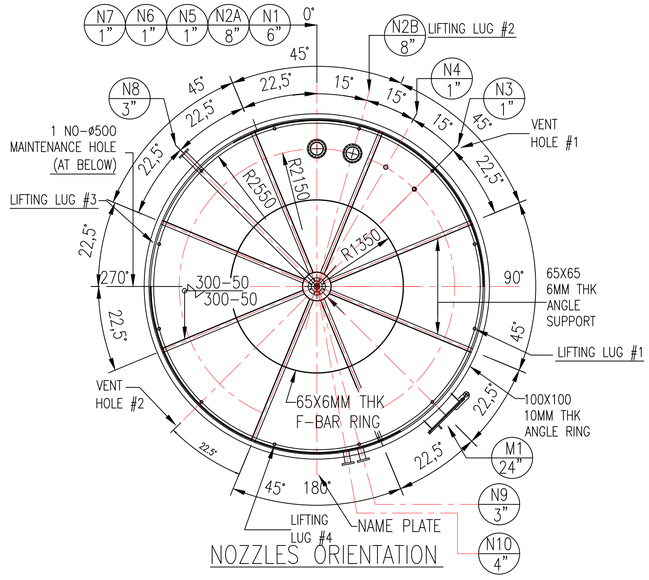
LEADS SPEIALIST SERVICES PTE LTD
NO.2 TUAS SOUTH AVE 2
SINGAPORE 637601
ops@leads1.com/www.leads1.com

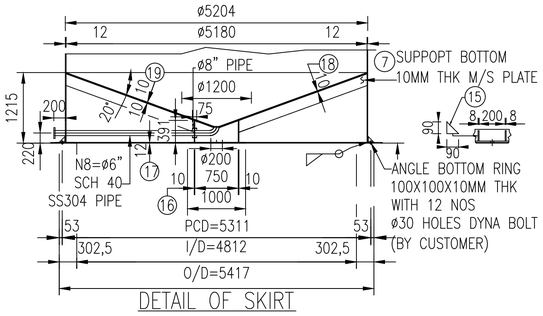
TANK INSPECTION SUMMARY REPORT

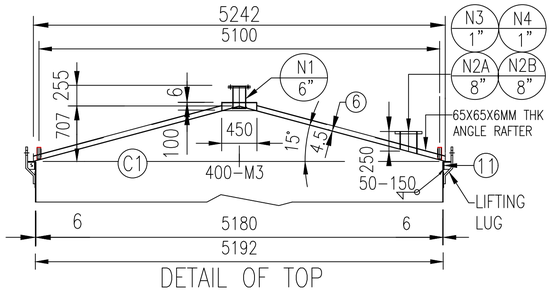
6.0 General Arrangement Drawing

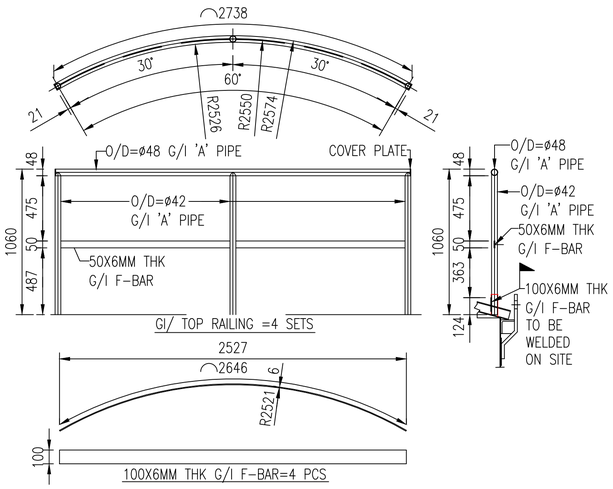


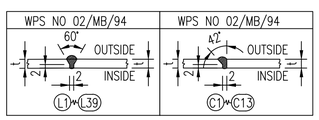












GENERAL NOTES
1. ALL DIMENSIONS ARE IN "MM" UNLESS OTHERWISE NOTED.
2. HEIGHT OF TANK FROM BOTTOM PLATE.
3. API 653 INSPECTION PERFORMED IN YEAR -.

NOZZLE LIST

MARK	SIZE	QTY	RATING	FLANGE TYPE	FACE	NECK THICK	SERVICE
N1	6"	01	ANSI 150	SO	RF	SCH 40	CLEANING
N2A/N2B	8"	02	SPECIAL	SO	RF	SCH 40	THIEF HATCH
N3	1" SOCKET	01	150 LB	NPT	–	–	NITROGEN
N4	1" SOCKET	01	150 LB	NPT	–	–	NITROGEN
N5	1" SOCKET	01	150 LB	NPT	–	–	THERMOWELL
N6	1" SOCKET	01	150 LB	NPT	–	–	TEMPERATURE
N7	1" SOCKET	01	150 LB	NPT	–	–	SAMPLING VALVE
N8	6"	01	ANSI 150	SO	RF	SCH 40	IN/OUT PRODUCT
N9	3"	01	ANSI 150	SO	RF	SCH 40	IN/OUT PRODUCT
N10	4"	01	ANSI 150	SO	RF	SCH 40	IN/OUT PRODUCT
M1	24"	01	SPECIAL	SO	RF	SCH 10	SHELL MANHOLE

DESIGN DATA

EQUIPMENT ITEM NO		T-1253
EQUIPMENT TYPE		CONE ROOF- SELF SUPPORTING TANK
VESSEL TYPE		VERTICAL
WIND SPEED	m/s	–
WIND LOAD		–
SEISMIC LOAD		NO
		TANK
MEDIUM		CAT 4 FLAMMABLE AND NON CORROSIVE MATERIAL
DESIGN PRESSURE	kPa	10
DESIGN TEMPERATURE	°C	160
WORKING PRESSURE	kPa	ATM
OPERATING TEMPERATURE	°C	AMB
MDMT	°C	NA
MAWP	kPa	–
HYDRO TEST PRESSURE	barg	–
HYDRO TEST POSITION		VERTICAL
JOINT EFFICIENCY		0.70
INSULATION	mm	–
CORROSION ALLOWANCE	mm	1
QUANTITY	UNIT	1
FABRICATED WEIGHT	KG	–
EMPTY WEIGHT	KG	25,000
OPERATING WEIGHT	KG	421,000
SHOP HYDRO TEST WEIGHT	KG	425,000
DESIGN SPECIFIC GRAVITY		–
FLUID SPECIFIC GRAVITY		1.3
GROSS CAPACITY	m³	400
NET CAPACITY	m³	XXXX
YEAR BUILT		2009

PAINTING SPECIFICATION

EXTERNAL	SWIPE BLASTING & PAINTING	TOP COAT	WHITE COLOR
INTERNAL	NA		

BILL OF MATERIAL

TOTAL=25000 KGS

ITEM	DESCRIPTION	DIMENSION	MATERIAL	Q'TY	REMARKS
22	OTHER MATERIAL				419 KGS
21	TOP RAFTER	L,65 X 65 X 6 X 2500(L)	CS	08	118 KGS
20	SLEEVE PIPE	ø1-1/2" X SCH40 X 160(L)	GI	12	8 KGS
19	PAD PLATE	10t X DIA ø1270	CS	01	100 KGS
18	PAD PLATE	10t X 100 X 2281	CS	08	143 KGS
17	BASE PLATE	10t X DIA ø1000	CS	01	62 KGS
16	CYLINDER PLATE	10 X 391 X 2388	CS	01	73 KGS
15	RIB PLATE	8 X 90 X 90	CS	24	12 KGS
14	PAD PLATE	5 X 200 X 250	CS	04	8 KGS
13	RIB PLATE	16 X 90 X 90	CS	04	4 KGS
12	LIFTING LUG	22 X 150 X 470	CS	04	48 KGS
11	ANGLE TOP RING	L,100 X 100 X 10 X 16625(L)	CS	01	250 KGS
10	ANGLE BOTTOM RING	L,100 X 100 X 10 X 16625(L)	CS	01	250 KGS
9	BOTTOM CONE	10t X DIA ø5509	CS	01	1871 KGS
8	ANNULAR PLATE	12t X I/D=ø4812XO/D=ø5417	CS	01	458 KGS
7	SUPPORT BOTTOM	10t X 200 X 2416	CS	08	304 KGS
6	TOP CONE	4.5t X DIA ø5428	CS	01	818 KGS
5	SHELL # 13	6t X 1000 X 16292	CS	01	767 KGS
4	SHELL # 7 TO 12	6t X 1800 X 16292	CS	06	8288 KGS
3	SHELL # 4-5-6	8t X 1524 X 16299	CS	03	4680 KGS
2	SHELL # 2-3	10t X 1524 X 16305	CS	02	3901 KGS
1	SHELL # 1	12t X 1524 X 16311	CS	01	2342 KGS

REV.	DATE	DESCRIPTION	BY	CHKD	APPRD
X	21-APR-21	AS BUILT	SC	RS	NEO

PROJECT TITLE:

T-1253 STORAGE TANK

MANUFACTURE:

HONG XING ENGINEERING & CONSTRUCTION PTE LTD
14 TUAS AVENUE (18A), SINGAPORE 638862
Tel : (65) 6558 7515/16 Fax : (65) 6558 7517 E-mail :hongxing@pacific.net.sg

OWNER:

Chemical Specialties Limited
CHEMICAL SPECIALTIES (S) LIMITED
31 Ayer Merbau Road Jurong Island Singapore - 627717
www.chemspecialties.com

CSL DOC NO: TNK-GA-T1253-001 REV: 0

DRAWING TITLE:

GENERAL ARRANGEMENT DRAWING T-1253 STORAGE TANK

WORK ORDER NO.: SCALE: NTS

VENDOR DWG. NO.	SHEET NO	REV.
NOT APPLICABLE	01 OF 01	X

REPORT

TANK INSPECTION SUMMARY REPORT

Mechannical calculation

Tank T-1253

Client : Chemical Specialties (S) Pte Ltd

Location : 31 Ayer Merbau Road, Jurong Island

Project : Tank Inspection

MECHANICAL CALCULATION FOR TANK T-1253

PROJECT	TANK INSPECTION - T-1253
MANUFACTURER	CHEMICAL SPECIALTIES (SINGAPORE) PTE. LTD.
END USER	CHEMICAL SPECIALTIES (SINGAPORE) PTE. LTD.
VENDOR DOCUMENT NO.	TNK-CS-T1253-001
CLIENT DOCUMENT NUMBER	TNK-CS-T1253-001

20/08/2022	0	Issued for Approval	LOK	PK	SD
Date	Rev	Description	Prepared	Checked	Approved

Table of Contents

1.0 Design Data

Inside Diameter of tank		D_i	=	5180.0 mm	=	17.0 ft		
Height of shell		Hs	=	20944.0 mm	=	68.7 ft		
Number of tanks			=	1				
Product			=	NA				
Design Code			=	API 650, 12th Ed,Add 2Jan. 2016				
Shell Design			=	1-Foot Method				
Appendixes			=	E , F , M ,P				
Data Sheet / Other main applicable specifications of client			=					
Type of tank			=	Rafter Supported Cone Roof				
High liquid levels	*(HLL)*	H_{HLL}	=	20900.00 mm	=	68.6 ft		
	(HHLL)	H_{HHLL}	=	20900.00 mm	=	68.6 ft		
Design Liquid level		H	=	20944.00 mm	=	68.7 ft		
Minimu liquid levels	*(LLL)*	H_{LLL}	=	1900.00 mm	=	6.2 ft		
	(LLLL)	H_{LLLL}	=	400.00 mm	=	1.3 ft		
Maximum Capacity	*(Volume uptill Design liquid level)*	V_{max}	=	441.38 cu.m	=	15587 cu.ft		
Net working capacity	*(Volume between HLL & LLL)*	V_{wor}	=	400 cu.m	=	14140 cu.ft		
Gross/Nominal Capacity	*(Volume Uptill shell height)*	V_{gross}	=	441.38 cu.m	=	15587 cu.ft		
Design specific gravity		G	=	1.3				
C.A for Bottom			=	1.0 mm	=	0.04 in		
C.A for Shell			=	1.0 mm	=	0.04 in		
C.A for Roof			=	1.0 mm	=	0.04 in		
C.A for curb angle			=	1.0 mm	=	0.04 in		
C.A for Anchor Bolt			=	1.0 mm	=	0.04 in		
C.A for Anchor Attachments			=	1		0.04 in		
Design pressure		P_i	=	10.000 kPa.g	=	1.45 psi.g		
External pressure		P_e	=	0.00 kPa.g	=	0.00 psi.g		
Pressure combination factor			=	0.400				
Live load on roof		L	=	1.0 kPa.g	=	21 psf	Ref:	*Data sheet*
Operating temperature		t_o	=	30.0°C				
Design temperature		t_d	=	160.00°C				
Minimum design metal temperature (MDMT)		t_{MDMT}	=	10.00°C				
Maximum filling rate			=	40.00 cu.m/hr				
Maximum empting rate			=	40.00 cu.m/hr				
Seismic and Wind design parameters as per client's specification				As per data sheet				
Seismic Use Group		SUG	=	III				
Site Class			=	D				
0.2 s (short period) spetral response acceleration		S_s	=	4.6	%g			
1.0 s (short period) spetral response acceleration		S_1	=	2	%g			
Design Level Peak Ground Acceleration Parameter		S_o	=	2	%g			
Wind Speed		V	=	79 Km/hr	=	49.15 mph		
Exposure category			=	C				
Importance Factor		I	=	1.15				

2) Shell Design

2.1) INPUTS

					References
Design code			API 650, 12th Ed,Add 2Jan. 2016		
Thickness calculation method			1-Foot Method		
Material Type			CS		
Inside dia. Of tank for first shell course	D_i	=	5.180 m		
Nominal dia. of tank for firsr shell course	D	=	5.192 m		*(API 650 5.6.1.1, note 1)*
Height of shell	H_s	=	20.944 m		
Design internal pressure	P_i	=	10.00 kPa.g		
Head due to internal pressure	H_{Pi}	=	Pi / (9.81*G) =	0.785 m	*Ref: F.2.1*
Design liquid level (pressure head included)	H	=	21.729 m		
Height of water during hydrotest		=	20.944 m		
Test pressure		=	12.50 kPa.g		*Ref: API 650 F.4.4*
Head due to test pressure		=	Pi / (9.81) =	1.276 m	
Design liquid level during hydrotest	H_t	=	22.220 m		
Density of material	ρ	=	7850 kg/m^3		
Design Specific gravity	G	=	1.30		*(Ref: API 650 5.6.3.2)*
Corrosion allowance	$C.A$	=	1.0 mm		
Joint efficiency	E	=	0.7		
Insulation Presen (Yes/No)			NO		

3.2) CALCULATION *(Ref: API 650 5.6.3)*

Design Shell Thickness $t_d = \frac{4.9 \times D \times (H-0.3) \times G}{Sd} + C.A$

Hydrostatic Test shell thickness $t_t = \frac{4.9 \times D \times (H-0.3)}{St}$

Minimum required nominal shell thickness = 6 mm *(Ref: API 650 5.6.1.1)*

Course #	Material	Plate Width	Liquid Level, Design(H_d)	Liquid level, Test(H_t)	Design Thickness, t_d	Hydrostatic test thickness, t_t	Seismic thickness, t_{sismic}	Max (t_d,t_t,t_{sismic})	t_{used}	Shell wt. (uncoroded)		Shell wt. (coroded)	
		m	m	m	mm	mm	mm	mm	mm	Kg	KN	Kg	KN
		5.6.1.2			5.6.3.2	5.6.3.2	E.6.2.4			*pi x D x H x t_{used} x r*		pi x D x H x t_{used} x r	
1	SA-36	1.524	21.73	22.22	5.87	3.26	3.69	5.87	12	2,342	23	2,147	21
2	SA-36	1.524	20.20	20.70	5.52	3.03	3.42	5.52	10	1,951	19	1,756	17
3	SA-36	1.524	18.68	19.17	5.17	2.81	3.16	5.17	10	1,951	19	1,756	17
4	SA-36	1.524	17.16	17.65	4.83	2.58	2.90	4.83	8	1,560	15	1,365	13
5	SA-36	1.524	15.63	16.12	4.48	2.35	2.64	4.48	8	1,560	15	1,365	13
6	SA-36	1.524	14.11	14.60	4.14	2.13	2.38	4.14	8	1,560	15	1,365	13
7	SA-36	1.800	12.58	13.08	3.79	1.90	2.06	3.79	6	1,381	14	1,151	11
8	SA-36	1.800	10.78	11.28	3.38	1.63	1.75	3.38	6	1,381	14	1,151	11
9	SA-36	1.800	8.98	9.48	2.97	1.37	1.44	2.97	6	1,381	14	1,151	11
10	SA-36	1.800	7.18	7.68	2.56	1.10	1.14	2.56	6	1,381	14	1,151	11
11	SA-36	1.800	7.18	7.68	2.56	1.10	1.14	2.56	6	1,381	14	1,151	11
12	SA-36	1.800	5.38	5.88	2.15	0.83	1.13	2.15	6	1,381	14	1,151	11
13	SA-36	1.000	5.38	5.88	2.15	0.83	1.13	2.15	6	767	8	639	6
Total shell plates height		20.9440								19,977	196.0	17,298	169.7
	Approx. Weight of Nozzles and their Attachments:									1,000	9.8	1000	9.8
	Approx. Weight of Staircase									400	3.9	400	3.9
	Miscellaneous weight									500	4.9	500	4.9
	Weight of Anchor chairs									114	1.1	114	1.1
	Sum of all shell atachements (excluding stiffners and curb angle)								W_{SA}	2,014	19.8	2,014	19.8
	Total weight of shell plus attachments								W_{ST}	21,992	215.7	19,312	189.5

Number of courses = *13*

Height of shell excluding top curb angle *H* = 20.944 m

Nominal thickness of thinnest shell course *t* = 6 mm

3.0 Material physical Properties

Material type		=	CS	
Density	ρ	=	7850	kg/m^3
Modulus of elasticity @ design temperature	E'	=	194200	MPa

Physical properties:

Item #	Material	Yield Stenght	Tensile Stress	Product Design Stress	Hydrostatic Test Stress
		MPa	MPa	MPa	MPa
Shell course # 1	SA-36	218.50	540.00	145.67	171.00
Shell course # 2	SA-36	218.50	540.00	145.67	171.00
Shell course # 3	SA-36	218.50	540.00	145.67	171.00
Shell course # 4	SA-36	218.50	540.00	145.67	171.00
Shell course # 5	SA-36	218.50	540.00	145.67	171.00
Shell course # 6	SA-36	218.50	540.00	145.67	171.00
Shell course # 7	SA-36	218.50	540.00	145.67	171.00
Shell course # 8	SA-36	218.50	540.00	145.67	171.00
Shell course # 9	SA-36	218.50	540.00	145.67	171.00
Shell course # 10	SA-36	218.50	540.00	145.67	171.00
Shell course # 11	SA-36	218.50	540.00	145.67	171.00
Shell course # 12	SA-36	218.50	540.00	145.67	171.00
Shell course # 13	SA-36	218.50	540.00	145.67	171.00
Bottom Plates	SA-36	218.50	540.00	145.67	171.00
Roof plates	SA-36	218.50	540.00	145.67	171.00

Temperature reduction factor for yield strenght as per M.3.3	=	0.9	*REF: API 650 M.3.3*
Annex M Modification for allowable stress as per M.3.2	=	2/3 x Temperature modified stress	*REF: API 650 M.3.2*
Temperature factor for manhole and cleanout door flange & cover and Cleanout door Flange Bottom reinforcing plate	=	1.0	*REF: API 650 M.3.5*

Material Properties As Per Section 4 of API 650

Item Name	Material	Material Group as per Table 4-4a	Material Group Selected	Applicable notes as per Table 4-4a	Maximum Thickness for selected material	Provided Thickness	Check	MDMT Provided	MDMT Rated	Check
Shell course # 1	SA-36	I/II	II	2,5	40.0	12	O.K	10.0	-24.20	O.K
Shell course # 2	SA-36	I/II	II	2,5	40.0	10	O.K	10.0	-25.47	O.K
Shell course # 3	SA-36	I/II	II	2,5	40.0	10	O.K	10.0	-25.47	O.K
Shell course # 4	SA-36	I/II	II	2,5	40.0	8	O.K	10.0	-26.74	O.K
Shell course # 5	SA-36	I/II	II	2,5	40.0	8	O.K	10.0	-26.74	O.K
Shell course # 6	SA-36	I/II	II	2,5	40.0	8	O.K	10.0	-26.74	O.K
Shell course # 7	SA-36	I/II	II	2,5	40.0	6	O.K	10.0	-28.01	O.K
Shell course # 8	SA-36	I/II	II	2,5	40.0	6	O.K	10.0	-28.01	O.K
Shell course # 9	SA-36	I/II	II	2,5	40.0	6	O.K	10.0	-28.01	O.K
Shell course # 10	SA-36	I/II	II	2,5	40.0	6	O.K	10.0	-28.01	O.K
Shell course # 11	SA-36	I/II	II	2,5	40.0	6	O.K	10.0	-28.01	O.K
Shell course # 12	SA-36	I/II	II	2,5	40.0	6	O.K	10.0	-25.47	O.K
Shell course # 13	SA-36	I/II	II	2,5	40.0	6	O.K	10.0	-39.72	O.K
Bottom Plates	SA-36	I/II	II	2,5	40.0	10	O.K	10.0	-25.47	O.K
Roof plates	SA-36	I/II	II	2,5	40.0	4.5	O.K	10.0	-34.13	O.K

4 CONICAL BOTTOM CALCULATION

Maximum liquid level		=	20,764	mm	
Minimum liquid level		=	400	mm	
Specific gravity of liquid	SG	=	1.3		
Product density		=	1300	kg/m3	
Annular plate actual thickness	t_annular	=	12.00	mm	
Annular plate actual width	w_annular	=	106.5	mm	
Material		=	SA36		
Joinf efficiency	E	=	0.85		
Shell radius	Rc	=	2590	mm	
		=	102.0	inches	
Θ - is the angle of cone elements to the horizontal, deg					
Angle Θ		=	20	deg	
	Radians	=	0.3490659		
	TAN Θ	=	0.3639702		
Height of Conical bottom	h	=	942.7	mm	
Slant Height of the Conical bottom	S	=	2756.2	mm	
Self Supported Conical bottom Area	A	=	22426608	mm2	*(PI X r X S)*
		=	22.43	m2	
		=	34761.31	inch2	
Volume of the conical bottom	V	=	6.62	m3	*(PI * (Rc^2) * h) / 3*
Weight Calculation					
Bottom Cone liquid weight		=	8608.6912	kg	*(Product density * V)*
Operating liquid height (refer section 8)		=	446,335	kg	
Total weight of the liquid on bottom cone	W_total	=	454,943	kg	
		=	1,002,978	lbs	

P = Total pressure, acting at a given level of the tank under a particular condition of loading

P = 10.00 kPA

1.450 psi

one-half the included apex angle of the conical bottom (α)		=	70	deg
	Radians	=	1.2217305	

Bottom thickness calculations due to internal pressure at the juncture between bottom and shell

Meridional unit force for conical walls T1 *API 620 Section 5.10.2.5 (b)*

$$T1 = \left(\frac{Rc}{2\cos\alpha}\right) X \left(P + \left(\frac{W\_total}{A}\right)\right)$$

T1 = ***4517.31*** lbf/inch

Latitudinal unit force for conical walls T2 *API 620 Section 5.10.2.5 (b)*

$$T2 = \left(\frac{P \times Rc}{\cos\alpha}\right)$$

T2 = ***432.41*** lbf/inch

The thickness of the tank wall at any given level shall be not less than the largest value of t as determined for the level by the methods prescribed in 5.10.3.2

5.10.3.2 If the units forces T1 and T2 are both positive indicating tension, for the governing combination of gas pressure (or partial vacuum) and liqukl head at a given level of the tank, the larger of the two shall be used for computing the thickness required at that level, as shown in the following equations:

Thickness calculatoin based on T1 *API 620 Section 5.10.3.2*

$$t1 = \left(\frac{T1}{Sts \times E} \right)$$

Maximum Allowable Stress Values for Simple Tension Sts = 16000 lbf/inch2 *API 620, Table 5-1*

t1 = ***0.3322*** Inch

Thickness calculatoin based on T1 *API 620 Section 5.10.3.2*

$$t2 = \left(\frac{T2}{Sts \times E} \right)$$

t2 = ***0.0318*** Inch

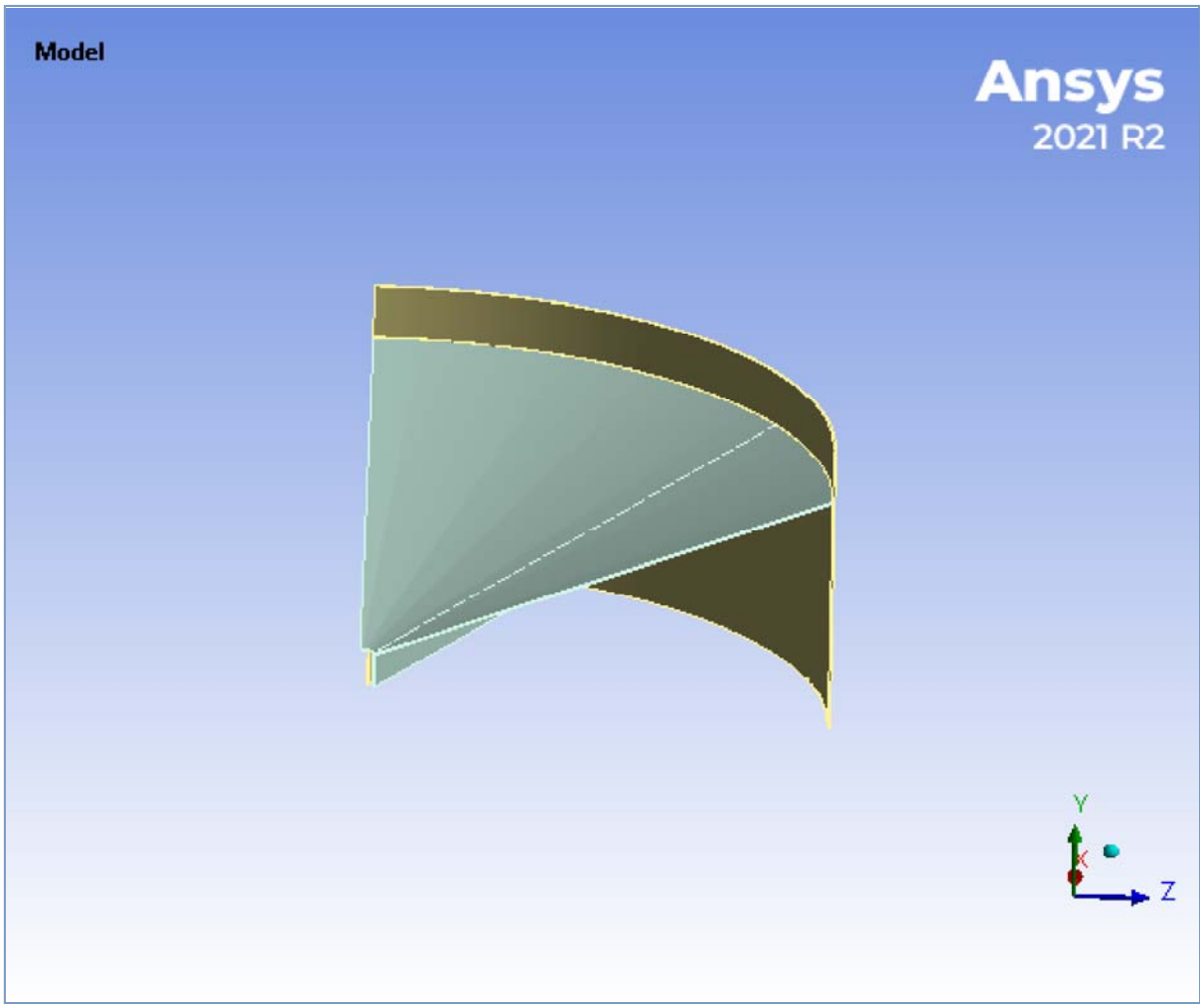
t_required	=	0.3322	Inch	*Max (t1, t2)*
	=	8.44	mm	
t_required	=	9.44	mm	*(t_required + C.A)*
Selected Thickness	=	10.0	mm	

Hence thickness of conical bottom as 10.0 mm
Therefore, use thickness satisfactory.

Actual thickness	t_actual	=	10.0 mm	
Corrosion allowance	C.A	=	1.00 mm	
Corroded plate thickness	t_corroded	=	9.0 mm	*(t_actual-C.A)*
Bottom cone new plate weight		=	1760.49 kg	*(density x A x t_actual)*
Bottom cone corroded plate weight		=	1584.44 kg	*(density x A x t_corroded)*

Note: Further investigation has been performed by FEA and confirm the thickness.

Project*



Contents

Units

TABLE 1

Unit System	Metric (mm, kg, N, s, mV, mA) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (A4)

Geometry

TABLE 2
Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	F:\Project\Ram Tank\T-1340_files\dp0\SYS\DM\SYS.scdoc
Type	SpaceClaim
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	2602. mm

Length Y	1625. mm
Length Z	2602. mm
Properties	
Volume	1.4585e+008 mm³
Mass	1144.9 kg
Scale Factor Value	1.
Statistics	
Bodies	4
Active Bodies	4
Nodes	56749
Elements	27165
Mesh Metric	None
Update Options	
Assign Default Material	No
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes
Parameters	Independent
Parameter Key	
Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	Yes
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 3
Model (A4) > Geometry > Body Groups

Object Name	*SYS*
State	Meshed
Graphics Properties	
Visible	Yes
Definition	
Suppressed	No
Assignment	Structural Steel
Coordinate System	Default Coordinate System
Bounding Box	

Length X	2602. mm
Length Y	1625. mm
Length Z	2602. mm
Properties	
Volume	1.4585e+008 mm³
Mass	1144.9 kg
Centroid X	-1202.7 mm
Centroid Y	876.08 mm
Centroid Z	1387.3 mm
Moment of Inertia Ip1	5.8684e+008 kg·mm²
Moment of Inertia Ip2	1.4603e+009 kg·mm²
Moment of Inertia Ip3	1.2122e+009 kg·mm²
Statistics	
Nodes	56749
Elements	27165
Mesh Metric	None
CAD Attributes	
PartTolerance:	0.00000001
Color:143.175.143	

TABLE 4
Model (A4) > Geometry > SYS > Parts

Object Name	*Solid*	*Solid*	*Solid*	*Solid*
State	Meshed			
Graphics Properties				
Visible	Yes			
Transparency	1			
Definition				
Suppressed	No			
Stiffness Behavior	Flexible			
Coordinate System	Default Coordinate System			
Reference Temperature	By Environment			
Treatment	None			
Material				
Assignment	Structural Steel			
Nonlinear Effects	Yes			
Thermal Strain Effects	Yes			
Bounding Box				
Length X	2590. mm	2602. mm	1263. mm	2172.2 mm
Length Y	965.23 mm	1625. mm	1154.5 mm	1153.8 mm
Length Z	2590. mm	2602. mm	2170.2 mm	1255.5 mm
Properties				
Volume	5.6324e+007 mm³	7.9517e+007 mm³	5.0046e+006 mm³	5.0006e+006 mm³
Mass	442.14 kg	624.21 kg	39.286 kg	39.254 kg
Centroid X	-1490.9 mm	-938.72 mm	-1923.2 mm	-1432.9 mm
Centroid Y	990.76 mm	812.38 mm	737.03 mm	736.65 mm
Centroid Z	1098.8 mm	1650.9 mm	1161. mm	671.52 mm
Moment of Inertia Ip1	1.674e+008 kg·mm²	1.6958e+008 kg·mm²	2.3613e+007 kg·mm²	1.1447e+005 kg·mm²
Moment of Inertia Ip2	4.3466e+008 kg·mm²	7.9422e+008 kg·mm²	2.3499e+007 kg·mm²	2.3442e+007 kg·mm²
	2.7053e+008	8.9888e+008	1.1456e+005	2.3556e+007

Moment of Inertia Ip3	kg·mm²	kg·mm²	kg·mm²	kg·mm²
Statistics				
Nodes	25074	30491	1032	
Elements	12160	14771	117	
Mesh Metric	None			

TABLE 5
Model (A4) > Materials

Object Name	*Materials*
State	Fully Defined
Statistics	
Materials	1
Material Assignments	0

Coordinate Systems

TABLE 6
Model (A4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. mm
Origin Y	0. mm
Origin Z	0. mm
Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]

Symmetry

TABLE 7
Model (A4) > Symmetry

Object Name	*Symmetry*
State	Fully Defined

TABLE 8
Model (A4) > Symmetry > Symmetry Region

Object Name	*Symmetry Region*	*Symmetry Region 2*	*Symmetry Region 3*	*Symmetry Region 4*
State	Fully Defined			
Scope				
Scoping Method	Geometry Selection			
Geometry	2 Faces	1 Face	2 Faces	1 Face
Definition				
Scope Mode	Manual			
Type	Symmetric			
Coordinate System	Global Coordinate System			
Symmetry Normal	X Axis			
Suppressed	No			

Connections

TABLE 9
Model (A4) > Connections

Object Name	*Connections*
State	Fully Defined
Auto Detection	
Generate Automatic Connection On Refresh	Yes
Transparency	
Enabled	Yes

TABLE 10
Model (A4) > Connections > Contacts

Object Name	*Contacts*
State	Fully Defined
Definition	
Connection Type	Contact
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Auto Detection	
Tolerance Type	Slider
Tolerance Slider	0.
Tolerance Value	10.057 mm
Use Range	No
Face/Face	Yes
Face-Face Angle Tolerance	75. °
Face Overlap Tolerance	Off
Cylindrical Faces	Include
Face/Edge	No
Edge/Edge	No
Priority	Include All
Group By	Bodies
Search Across	Bodies
Statistics	
Connections	3
Active Connections	3

TABLE 11
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region*	*Contact Region 2*	*Contact Region 3*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Contact	1 Face		
Target	1 Face		
Contact Bodies	Solid		
Target Bodies	Solid		
Protected	No		
Definition			
Type	Bonded		
Scope Mode	Automatic		
Behavior	Program Controlled		

Trim Contact	Program Controlled
Trim Tolerance	10.057 mm
Suppressed	No
Advanced	
Formulation	Program Controlled
Small Sliding	Program Controlled
Detection Method	Program Controlled
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

Mesh

TABLE 12
Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	70.0 mm
Sizing	
Use Adaptive Sizing	Yes
Resolution	Default (2)
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Diagonal	4022.6 mm
Average Surface Area	9.5874e+005 mm²
Minimum Edge Length	10.0 mm
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Aggressive Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre

View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Statistics	
Nodes	56749
Elements	27165

Static Structural (A5)

TABLE 13
Model (A4) > Analysis

Object Name	*Static Structural (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 14
Model (A4) > Static Structural (A5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Quasi-Static Solution	Off
Rotordynamics Controls	
Coriolis Effect	Off
Restart Controls	
Generate Restart Points	Program Controlled
Retain Files After Full Solve	No
Combine Restart Files	Program Controlled
Nonlinear Controls	
Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled

Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Program Controlled
Advanced	
Inverse Option	No
Contact Split (DMP)	Off
Output Controls	
Stress	Yes
Surface Stress	No
Back Stress	No
Strain	Yes
Contact Data	Yes
Nonlinear Data	No
Nodal Forces	No
Volume and Energy	Yes
Euler Angles	Yes
General Miscellaneous	No
Contact Miscellaneous	No
Store Results At	All Time Points
Result File Compression	Program Controlled
Analysis Data Management	
Solver Files Directory	F:\Project\Ram Tank\T-1340_files\dp0\SYS\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Contact Summary	Program Controlled
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	nmm

TABLE 15
Model (A4) > Static Structural (A5) > Loads

Object Name	*Frictionless Support*	*Frictionless Support 2*	*Frictionless Support 3*	*Internal Design Pressure*	*Fixed Support*	*Liquid Weight*	*Frictionless Support 4*
State	Fully Defined						
Scope							
Scoping Method	Geometry Selection						
Geometry	2 Faces	1 Face	2 Faces		1 Face		
Definition							
Type	Frictionless Support			Pressure	Fixed Support	Force	Frictionless Support
Suppressed	No						
Define By				Normal To		Components	
Applied By				Surface Effect		Direct	
Loaded Area				Deformed			
Magnitude				1.e-002 MPa			

		(ramped)	
Coordinate System		Global Coordinate System	
X Component		0. N (ramped)	
Y Component		-21111 N (ramped)	
Z Component		0. N (ramped)	

FIGURE 1
Model (A4) > Static Structural (A5) > Internal Design Pressure

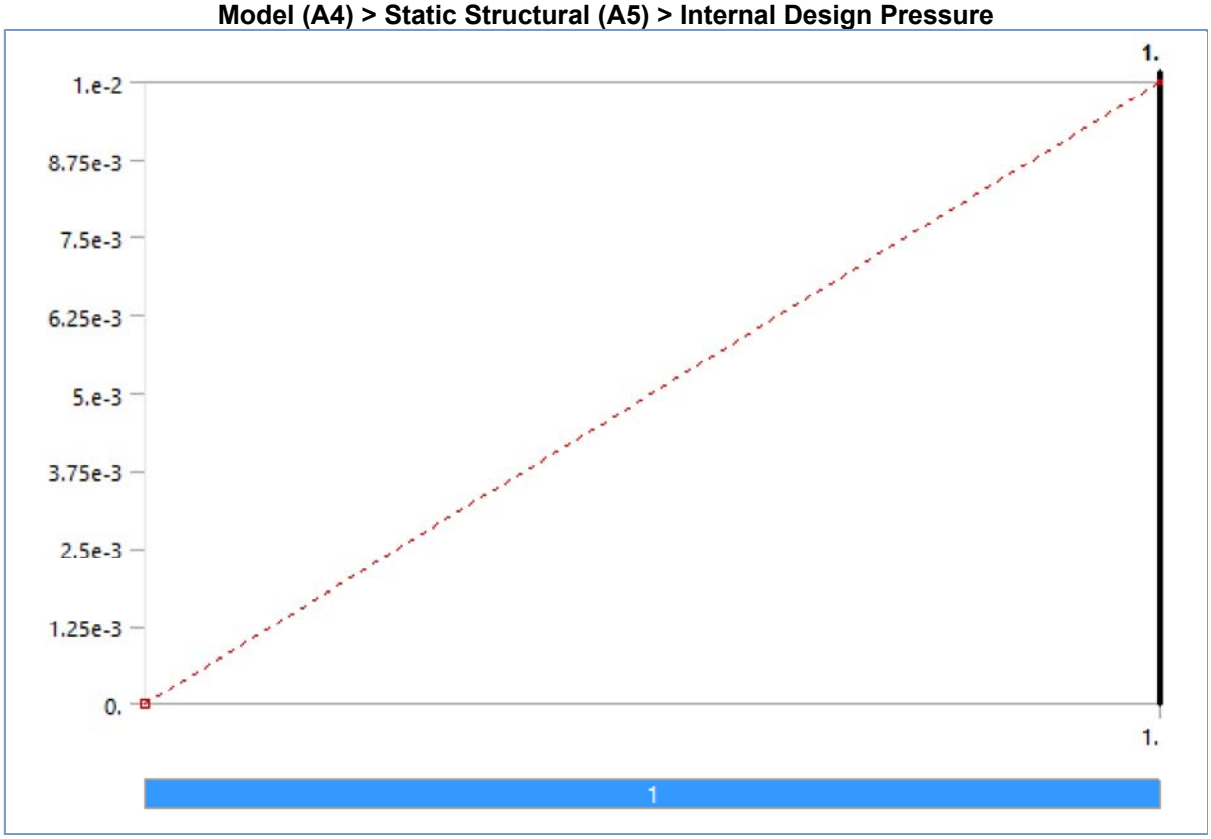
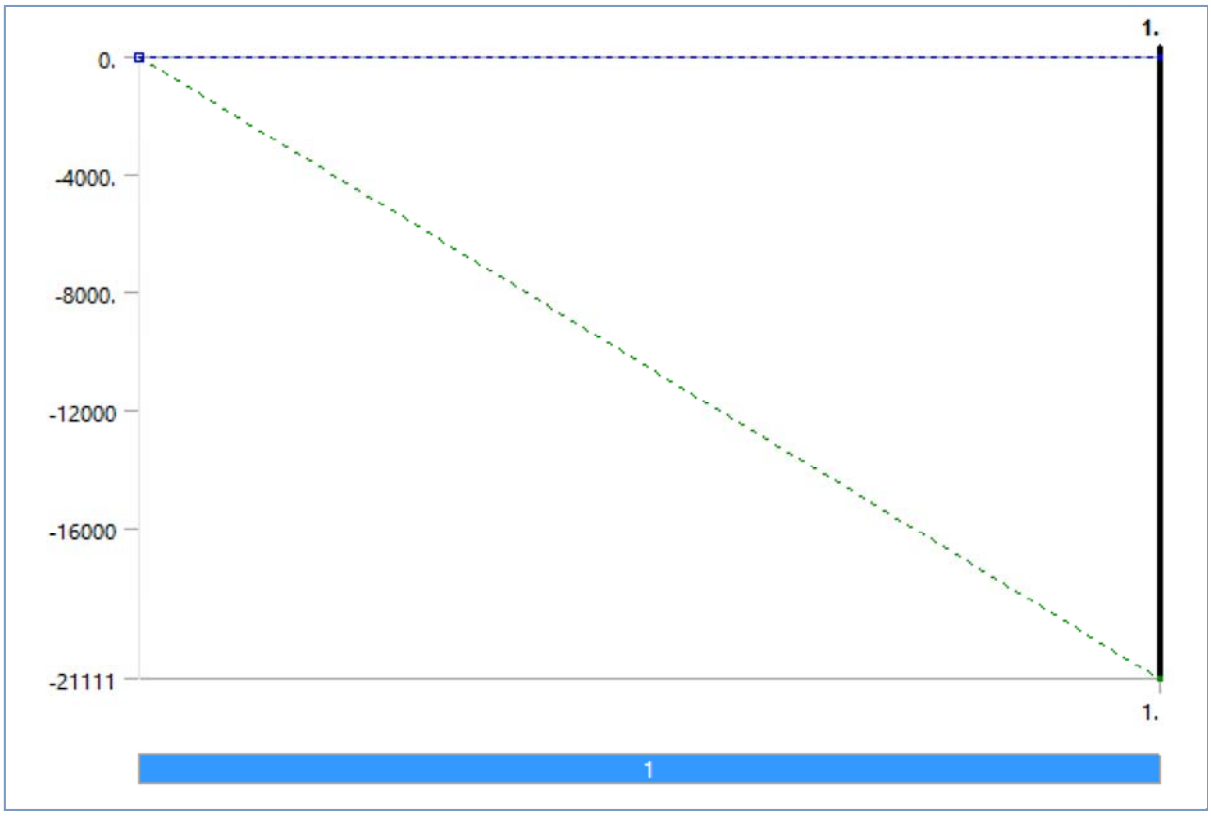


FIGURE 2
Model (A4) > Static Structural (A5) > Liquid Weight



Solution (A6)

TABLE 16
Model (A4) > Static Structural (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done
MAPDL Elapsed Time	1 m 2 s
MAPDL Memory Used	937. MB
MAPDL Result File Size	19.688 MB
Post Processing	
Beam Section Results	No
On Demand Stress/Strain	No

TABLE 17
Model (A4) > Static Structural (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Identify Element Violations	0
Update Interval	2.5 s
Display Points	All

FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 18
Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Equivalent Stress*
State	Solved
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Equivalent (von-Mises) Stress
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
Integration Point Results	
Display Option	Averaged
Average Across Bodies	No
Results	
Minimum	4.211e-002 MPa
Maximum	88.102 MPa
Average	4.2563 MPa
Minimum Occurs On	Solid
Maximum Occurs On	Solid
Information	
Time	1. s
Load Step	1
Substep	1
Iteration Number	1

FIGURE 3
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

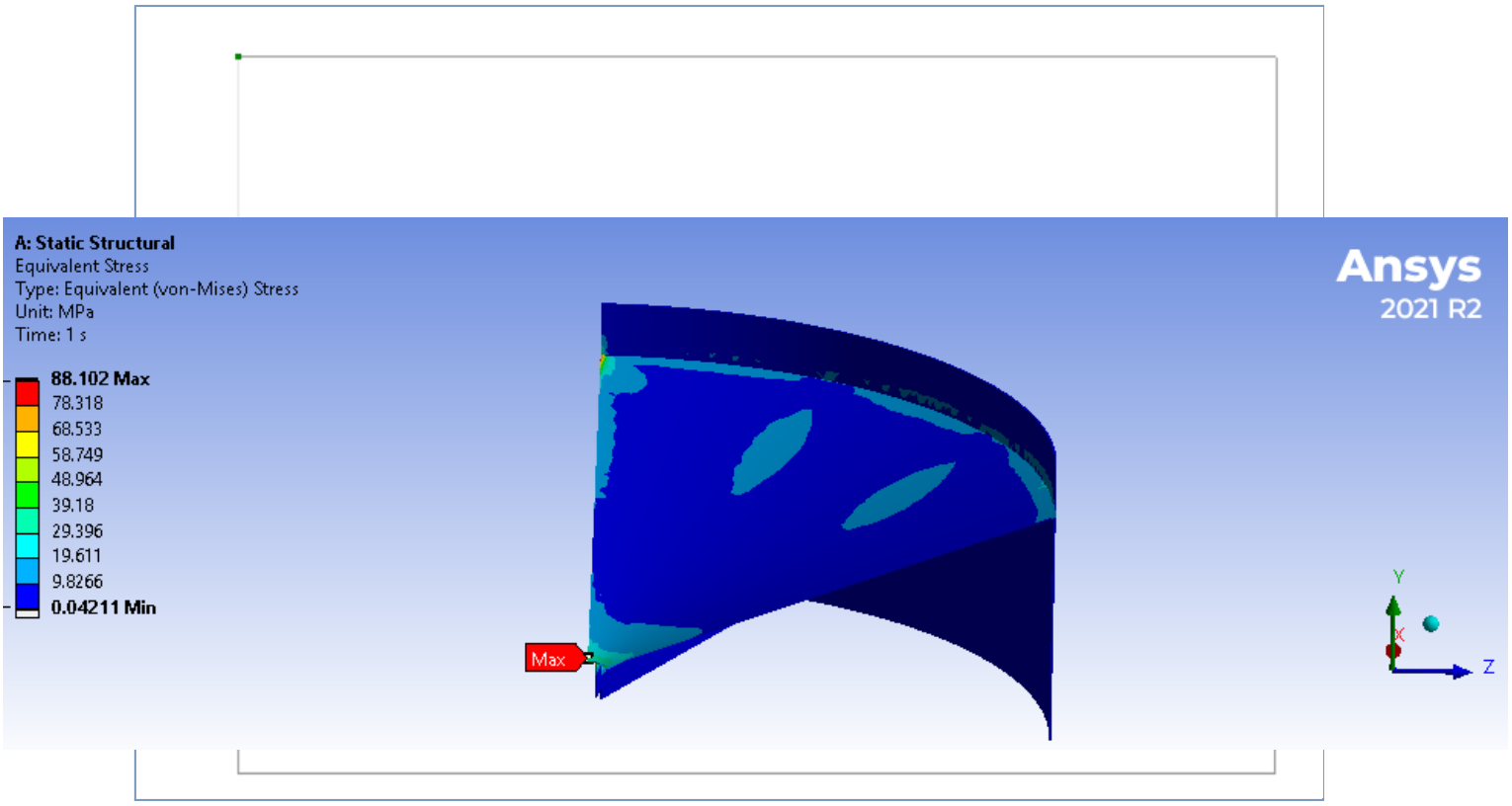


TABLE 19
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

Time [s]	Minimum [MPa]	Maximum [MPa]	Average [MPa]
1.	4.211e-002	88.102	4.2563

Material Data

Structural Steel

TABLE 20
Structural Steel > Constants

Density	7.85e-006 kg mm^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	4.34e+005 mJ kg^-1 C^-1
Thermal Conductivity	6.05e-002 W mm^-1 C^-1
Resistivity	1.7e-004 ohm mm

TABLE 21
Structural Steel > Color

Red	Green	Blue
132	139	179

TABLE 22
Structural Steel > Compressive Ultimate Strength

Compressive Ultimate Strength MPa
0

TABLE 23

Structural Steel > Compressive Yield Strength

Compressive Yield Strength MPa
218

TABLE 24
Structural Steel > Tensile Yield Strength

Tensile Yield Strength MPa
218

TABLE 25
Structural Steel > Tensile Ultimate Strength

Tensile Ultimate Strength MPa
460

TABLE 26
Structural Steel > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 27
Structural Steel > S-N Curve

Alternating Stress MPa	Cycles	Mean Stress MPa
3999	10	0
2827	20	0
1896	50	0
1413	100	0
1069	200	0
441	2000	0
262	10000	0
214	20000	0
138	1.e+005	0
114	2.e+005	0
86.2	1.e+006	0

TABLE 28
Structural Steel > Strain-Life Parameters

Strength Coefficient MPa	Strength Exponent	Ductility Coefficient	Ductility Exponent	Cyclic Strength Coefficient MPa	Cyclic Strain Hardening Exponent
920	-0.106	0.213	-0.47	1000	0.2

TABLE 29
Structural Steel > Isotropic Elasticity

Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa	Temperature C
2.e+005	0.3	1.6667e+005	76923	

TABLE 30
Structural Steel > Isotropic Relative Permeability

Relative Permeability
10000

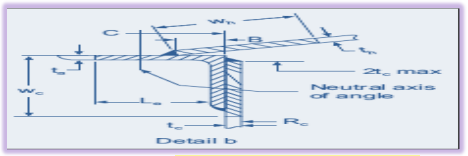
5) Rafter Supported Cone Roof

5.1) Inputs

Material Type			=	CS				
Roof Plate Material			=	SA-36				
Roof Structure Material			=	SA-36				
Internal Diameter of tank			=	5.1800	m			
Outside dia. of Tank @ curb angle			=	5.1980	m			
Outside radius of Tank @ curb angle			=	2.60	m			
Outside dia. Of roof plates			=	5.2	m			
Design Internal Pressure		*Pi*	=	10.00	kPa			
Corrosion Allowance (Shell)		*C.A*	=	1.00	mm			
Corrosion Allowance (Roof)		*C.A*	=	1.00	mm			
Corrosion Allowance (Wetted structure)		*C.A*	=	1.00	mm			
Thickness of thinest shell course			=	6.00	mm			
Slope of Roof			=	1 : 4				*Ref: API 650 5.10.4.1*
Angle of cone element to horizontal			=	15.05	degrees			
Thickness of Roof Plate Used		t	=	4.5	mm			
Corroded Thickness	*Shall not be less than 5 mm*		=	3.50	mm	<	5	Not O.K
Height of Roof		H_R	=	R/tanϴ				
		H_R	=	0.6946	m			
Slant height of Roof		L_{slant}	=	2.676	m			
Surface Area of Roof		$\pi \times (L'_{SLANT})^2$	= $\frac{Q}{r^2}$ =	22.49	m^2			
Weight of Roof	*it includes the weight of roof compression plate*		=	795	kg	=	7.79	KN
Weight of Roof(Coroded)			$Pcr = \frac{FyAr^2}{Q}$ $Q = \frac{Nr}{\pi r^2 E}$	618	kg	=	6.06	KN
Weight of parts welded to roof(nozzles, etc)			=	80.00	kg	=	0.78	KN
Overall weight of roof plate and its welded attachments		D_{LR}	=	874.54	kg	=	8.58	KN
Overall weight of roof plate and its welded attachments (Coroded)		$D_{LR\_CORRODED}$	=	697.98	kg	=	6.85	KN
Unit Load of Roof over horzontal area			=	0.41	kPa			
Live Load			=	1.00	kPa			
Gravity load		*T1*	=	$D_L + (L_r$ *or* $S) + 0.4P_e$				*Ref: API 650 5.2.2 e*
			=	1.41	kPa			
Gravity load		*T2*	=	$D_L + P_e + 0.4(L_r$ *or* $S)$				*Ref: API 650 5.2.2 e*
			=	0.81	kPa			
Maximum gravity load,		T	=	1.41	kPa			
Minimum Yield Strength of Roof Plate		Fy	=	218.50	Mpa			
Minimum Yield Strength of Structure		Fy	=	218.50	Mpa			(Temperature modification factor as per M.3.6 applied)
Minimum of above yield strenght		Fy	=	218.50	Mpa			
Product Design Stress/ least allowable tensile stress		S_d	=	145.67	MPa			
Allowable stress for structure		f	=	124.00	Mpa	=	18000	psi

5.2) Roof to Shell Joint Detail

Seleted detail of compression ring: $Pcr = AFy\left[1-\frac{Q}{4r^2}\right]$ **Detail b**



Selected size of angle				100 x 100 x 10		
Horozontal Length of curb angle		*Hz.lenght*	=	100.00	mm	
vertical length of curb angle		*V.lenght*	=	100.00	mm	
Thickness of selected curb angle leg	corroded	t'_a	=	9.00	mm	
Area of selected curb angle		A'_a	=	1710.00	mm^2	
Minimum Size required for curb angle is,			=	50 X 50 X 5		*Ref: API 650 5.1.5.9*
Minimum area required for curb angle			=	380.00	mm^2	
Selected curb angle O.K						
Neutral axis of angle		*C*	=	50.00	mm	
Roof location on the angle		*B*	=	15.00	mm	*B is less than C, therefore O.K*
Material of angle			CS	*SA-36*		
Yield strenght of angle *@ design temp*		F_y	=	218.50	MPa	
Thickness of thinnest shell course	un-corroded	t_c	=	6.00	mm	
Thickness of roof plate	un-corroded	t_h	=	4.50	mm	
Inside radius of tank shell		R_c	=	2590.00	mm	*Ref: API 650 fig F-2*
Length of the normal to the roof,		R_2	=	*(Rc / sinΘ)*		
			=	9977.10	mm	
Maximum width of participating shell		W_c	=	$0.6(R_c X t)^{1/2}$		*Ref: API 650 fig F-2*
Where, t = tc			=	74.80	mm	
Actual width of participating shell		W_c	=	25.00	mm	
Participating area of shell		A_s	=	150.00	mm^2	
Maximum width of participating roof,		W_h	=	lesser of $0.3 (X R_2 X t_h)^{1/2}$ and 300 mm		
				63.57	mm	*Ref: API 650 fig F-2*
Actual width of participating roof		W_h	=	25.00	mm	
Participating area of roof		A_r	=	112.50	mm^2	
Maximum Unstiffened length		L_e	=	$250 x t / (F_y)^{1/2}$		*Ref: API 650 fig F-2*
where t = ta			=	152.21	mm	
Actual Unstiffened length		L_e	=	2550.00	mm	*enter Hz.lenght of angle here*

length of selected angle is less than Le, therfore selection of angle O.K, Note that Unstiffened area is NOT used, instead use area of angle

Participating area of unstiffened length	A_e	=	N/A	mm^2	
Provided compression ar (As + Ar + Ae)	$A_{provided}$	=	*1972.50*	mm^2	

Frangible Roof = NO

Minimum required compression area — *Arequired =A2* = 884.07 mm^2 — Ref: API 650 F.5.1

Provided compression area at roof-shell joint is GREATER than MINIMUM REQUIRED AREA, therefore compression ring detail O.K

Minimum required roof-shell compression area — $A_{required}$ = A_2

$A_{required}$ = 884.07 mm^2

5.3) Appendix F

Tank has internal pressure: yes

Appendix F applicable

Horizontal projected Area of roof — $A_R = \frac{\pi}{4} x D^2$

A_R = 20.98 m^2

Total upward lifting force, due to internal pressure, acting on roof — $F_R = P_i \, x \, A_R$ = 209.77 KN

Total weight of coroded roof plates — W'_{RT} = 6.06 KN

Since, F_R > W'_{RT} (Roof weight)

Refere to Fig-1, of Annex-F API 650, Internal pressure exceeds the weight of corroded roof plates, therefore, Annex-F is applicable

Weight of coroded shell and roof plus attached weight — W_T = 196.58 KN

Since, F_R > W_T(Total weight)

Therefore, as per Fig-1, of Annex-F API 650, Tank needs to be mechanically anchored against internal pressure,

and shall comply to F.7. Also as per F.7.1 roof thickness needs to be checked as per API 620. For detail refere to API 620 roof thickness calculation.

Establishing internal pressure *(MAWP)* — $P = \frac{A \, x \, Fy \, x \, \tan\theta}{200 \, x \, D^2} + \frac{0.00127 \, x \, DLR}{D^2}$ — Ref: API 650 F.4.1

P = 21.99 kPa

Design pressure LESS *than P(MAWP)* hence condition SATISFIED

Where,

$A(A_{provided})$ = Provided compression area

F_y = Temperature corrected specified yield strenght

D_{LR} = Nominal weight of roof plates plus attached structure

Calculated Failure pressure — $P_f = 1.6 \, x \, P - \frac{0.000746 \, x \, DLR}{D^2}$ — Ref: API 650 F.7

P_f = 35.00 kPa

Design pressure LESS than P_f hence condition SATISFIED

Minimum required participating compression area against internal pressure — $A_2 = \frac{200D^2\left(P_i - \frac{0.00127DLR}{D^2}\right)}{F_v(\tan\theta)}$ — Ref: API 650 F.5.1

A_2 = 884.07 mm^2

Hydrostatic Test Pressure — Pt = 12.50 kPa — Ref: API 650 F.4.4

5.4 Thickness calculation of roof plates as per F.6

Minimum roof thickness required for internal pressure $t = \frac{(P \times R_t)}{\cos\alpha \times S_d \times E} + C_a$

where, t = 1.94 mm

P = is the internal design pressure - minus effect of of corroded roof plate

P = (F_R - W'_{RT}) / Area = 9.60 kPa

R_t = is the nominal tank radius

R_t = 2.60 m

a = is the half apex angle of cone roof(degrees)

a = 75.0 degrees

cosα = is the cosine of half appex angle expressed as a decimal quantity

cosα = 0.26 , where α is a in radians.

S_d = 146 MPa

E = 0.7

C_a = Corrosion allowance

C_a = 1 mm

5.5) Calculations for Roof support structure

Dia of Compression Ring		=	1.35	m			
Developed Radius of Roof		=	2.68	m			
Maximum Rafter length		=	1.983	m			
Maximum Allowable Roof Plate Span	*b*	=	$t_{roof\_corroded}$ x (1.5 x F_y / p)				*Ref: API 650 5.10.4.4*
Where, p = T		=	1.69	m	≤	2.1	

As per 5.10.4.4 Maximum Allowable Roof Plate Span should not be less than 2100 mm, Therefore,

	b_{max}	=	1.69	m	=	66.46	in
More than 1 bay present		=	NO				
Number of bays		=	1.00				

Rafters along bev 1 (Ring 1)

Developed radius of ring 1	R_1	=	2.68	m			
Rafers length	L_1	=	1.983	m			
Minimum number Rafters at shell periphery	N_{min}	=	π x Di / b_{max}				
		=	9.64				
Actual number of rafters	$N_{rafters}$	=	8.00				
Actual rafter Spacing	b_1	=	2.03	m	=	80.09	in
	b_1	>	b_{max}	Not O.K			
Spacing on Compression ring	b_2	=	0.530	m			
Average width of roof plate	$(b_1 + b_2)/2$	=	1.282	m			
Angle btw rafters		=	37.18	degrees			

Selection of Rafter Size

Corroded properties of Rafter:				*Section used*	=	L65x65x6				
Height of web				*H'*	=	65.00	mm			
Flange-flange inner face height				*H*	=	53.00	mm			
Width of Flange				*B*	=	65.00	mm			
Thickness of flange				*h*	=	6.00	mm			
Thickness of Web				*b*	=	6.00	mm			
Unit weight of *(Uncoroded)*					=	6.85	kg/m	=	0.38	lbs/in
Cross sectional area	A	=		*2xBxh + bxH*	=	1098.00	mm^2			
Area moment of area	Ixx	=	$H^3 b/12 + 2[h^3 B/12 + hB(H+h)^2/4]$		=	7.56E+05	mm^4	=	1.82	in^4
Center of gravity	Ycog	=	*H/2 +h*		=	32.5	mm			
Section modulus	S_{xx}	=		$I_{xx}/Ycog$	=	**23248.415**	mm^3	=	1.42	in^3
Weight of Rafters					=	108.67	Kg	=	1.07	KN

Checking for section modulus

Maximum Rafter Length				*L1*	=	1.983	m	=	78.07	in
Average width of roof plate				*(b1+b2)/2*	=	1.28	m	=	50.5	in
Total Design Load				*T*	=	1.41	kPa	=	0.20	psi
U.D.L Load(including unit weight of selected rafter)	w	=	Tx(b1+b2)/2 + unit weight of rafterx9.81/1000		=	1.87	KN/m	=	10.70	Lbs/in
Maximum bending moment	M_{max}	=		$w \times L_{eff}^2 / 8$	=	0.92	m-KN	=	8151	Lbs-in
Required section modulus		z	=	*M/f*	=	7427.43	mm^3	=	0.45	in^3
Provided section modulus		$z_{provided}$	=	S_{xx}	=	23248.42	mm^3	=	1.42	in^3

Selection of Rafter size O.K

Checking for deflection in rafter

Maximum Rafter Span				=	1.98	m			
Total Load on Rafter+Self weight	(U.D.L)		*w*	=	1.87	KN/m	=	10.70	Lbs/in
Allowable deflection			*L1 x 1000/360*	=	5.51	mm			

Deflection in beam both ends fixed with Uniformly Distributed load

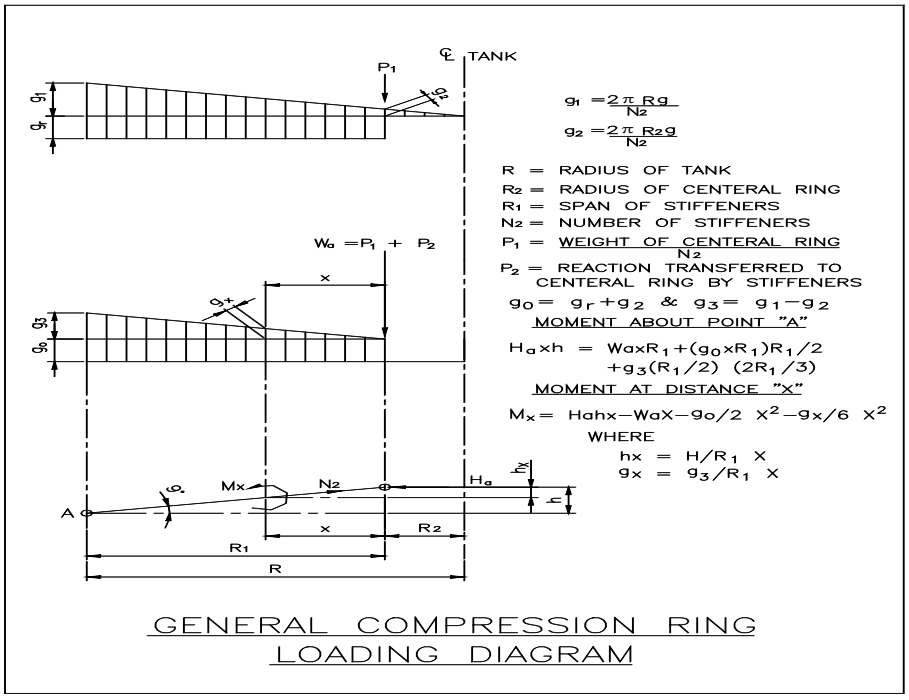
Induce Deflection as given by. Eq. 4.17

(Ref. Chapter-4, Roof Design 4.3 "Process equipment design Vessel Design By Brownell Yong")

=	0.51	mm	=	0.020	in

Induced deflection in rafters is less than allowable, therefore rafter is O.K

Design of Central Ring



GENERAL COMPRESSION RING LOADING DIAGRAM

Live Load on roof L_r =		*Lr*	=	1.00	KN/m^2	(Total weight of roof (D_{LR})+ rafter)/developed ared of roof		
Load of roof plate D_r =		*Dr*	=	0.43	KN/m2			
	g =	*Lr + Dr*	=	1.43	KN/m2			
I.R of tank		*R*	=	2.60	m			
Radius of central compression ring		R_2	=	0.68	m	=	2.21	ft
Span of Rafter			=	1.98	m			
Unit weight of one Rafter		g_r	=	6.85	kg/m	=	0.07	KN/m
Total weight of Rafter			=	108.67	kg	=	1.07	KN
Total weight of Rafter/area			=	0.05	KN/m2			
Weight of Central Ring		*Wr*	=	0.097706	KN			
Number of rafter		N_2	=	8.00				
Height of Roof at center		*h*	=	0.69	m			
Radius of tank - radius of compression ring		$R_1 = R - R_2$	=	1.92	m			
	g_1 =	*2π x R xg / N2*	=	2.92	kN/m			
	g_2 =	*2π x R_2 xg / N2*	=	0.76	kN/m			

Calculation of load transferred at joint of stiffener and central ring , Wa = $P_1 + P_2$				0.52	KN			
Weight of Central Ring ,Wr per stiffener	$P_1 = Wr/N$	=		0.01221	KN			
Load transferred to central ring by rafters,	$P_2 = g_2 \times R_2$	=		0.51	KN			
	$g_0 = g_r + g_2$	=		0.82	KN/m			
	$g_3 = g_1 - g_2$	=		2.16	KN/m			
Considering the equilibrium and taking Moments about point A.	Ha	=	$\frac{W_a \times R_1 + \frac{(g_0 \times R_1)R_1}{2} + g_3(\frac{R_1}{2})(\frac{R_1}{3})}{h}$					
		=		5.57	KN			
Therefore, Radial Load transferred to ring through stiffeners,	Ha	=		5.57	KN	=	1.25	kips
Moment transferred to Ring	M	=		(Ha R_2/2) (cot 180/N_2 - N_2/π)				
		=		0.06	Kip ft	=	0.08	KNm
Thrust	T	=		Ha/2 (cot 180/N_2)				
		=		1.51	Kips	=	6.72	KN

Design of compression ring

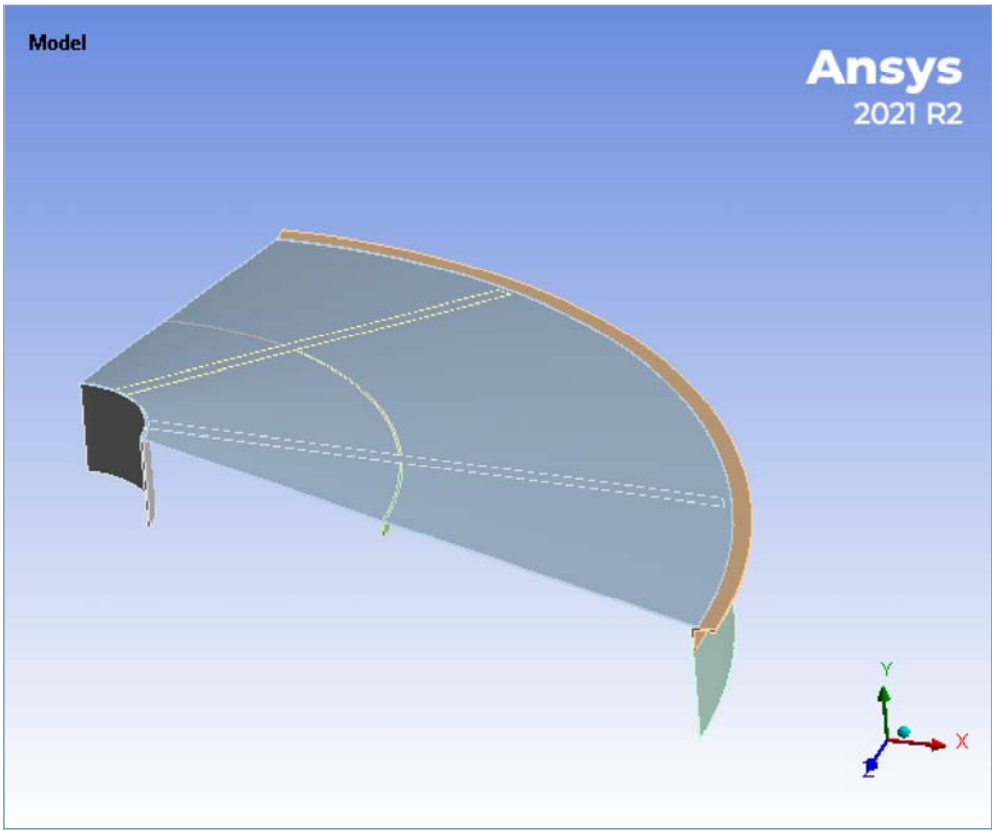
	Location of Centroid	C	=	50	mm			
			=	50.00	mm			
	Moment of Inertia	I						
			=	2.07E+06	mm^4			
		A	=	105730.865	mm^2	=	0.10573	m^2
	Section Modulus		=	23248.4	mm^3	=	2.3E-05	m^3
		f_b = M / Z	=	3257.44	KN/m^2			
Allowable Bending Stress		Fb = 0.6 Fy	=	131100	KN/m^2			
		fc = T / A	=	63.5327597	KN/m^2			
Allowable Compression Stress		Fc = 0.5 Fy	=	109250	KN/m^2			
		f_b / Fb + fc / Fc	=	0.03				
		As fb/Fb+fc/Fc<1 Ok						

Selection of Columns

Load supprted by central column	P =(T*Ar + weight of rafters+weight of column)/2	=	20.37	KN			
Length of Central columns	*L*	=	21.64	m	=	851.91	m
Minimum radius of gyration	r	=	L/180				
	r	=	120.21	mm	=	4.733	in
Selected column: combo section IPE 180							
unit weight of column		=	18.8	kg/m	=	1.05275	lb/in
Minimum Moment of inertia of combo section	I	=	13853099.9	mm^4	=	33.2822	
Cross section area of combo section	A	=	4780	mm^2	=	7.40901	
Radius of gyration of combo section	*I/A^0.5*	=	53.8	mm	=	2.12	in
Allowable compressive stress for column	*f*	=	$\frac{Sd}{1+\left(\frac{L^2}{Sd\ x\ r^2}\right)}$				
		=	44.32	Mpa	=	6429	psi
Actual Induced Stress	f_{actual}	=	P/a				
			4.26	Mpa			
Since f_{actual} < f, central column provided is O.K.							
Total weight of rafters and colum		=	1015.5	kg			

Note: As per manual calculation as thickess has shown not adequate so to confirm the thickness FEA been carried out and found the thickness is adequate.

Project*



Contents

Units

TABLE 1

Unit System	Metric (mm, t, N, s, mV, mA) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (B4)

Geometry

TABLE 2
Model (B4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	F:\Project\Ram Tank\T-1341.scdoc
Type	SpaceClaim
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	2696. mm
Length Y	1104.3 mm
Length Z	2696. mm
Properties	
Volume	5.4487e+007 mm³
Mass	0.42772 t
Scale Factor Value	1.
Statistics	
Bodies	9
Active Bodies	9
Nodes	155110
Elements	21434
Mesh Metric	None

Update Options	
Assign Default Material	No
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes
Parameters	Independent
Parameter Key	
Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	Yes
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 3
Model (B4) > Geometry > Parts

Object Name	*Solid1*	*Solid2*	*Solid3*	*Solid4*	*Solid5*	*Solid6*	*Solid7*	*Solid8*	*Solid9*
State	Meshed								
Graphics Properties									
Visible	Yes								
Transparency	1								
Definition									
Suppressed	No								
Stiffness Behavior	Flexible								
Coordinate System	Default Coordinate System								
Reference Temperature	By Environment								
Treatment	None								
Material									
Assignment	Structural Steel								
Nonlinear Effects	Yes								
Thermal Strain Effects	Yes								
Bounding Box									
Length X	385. mm	2622.3 mm	110.25 mm	2696. mm	2596. mm	902.79 mm	2059.4 mm	732.69 mm	519.3 mm
Length Y	393.67 mm	604.31 mm	65. mm	100. mm	500. mm	656.41 mm		65. mm	
Length Z	385. mm	2622.3 mm	513.75 mm	2696. mm	2596. mm	2065.3 mm	905.22 mm	735.92 mm	112.53 mm
Properties									
Volume	2.3418e+006 mm³	2.7361e+007 mm³	3.3062e+005 mm³	7.8333e+006 mm³	1.2219e+007 mm³	1.697e+006 mm³		6.6863e+005 mm³	3.3802e+005 mm³
Mass	1.8383e-002 t	0.21479 t	2.5954e-003 t	6.1491e-002 t	9.5921e-002 t	1.3321e-002 t		5.2488e-003 t	2.6535e-003 t
Centroid X	241.86 mm	1132.3 mm	1318.8 mm	1670.7 mm	1650.4 mm	585.71 mm	1379.9 mm	935.89 mm	262.05 mm
Centroid Y	401.63 mm	227.18 mm	306.37 mm	-28.517 mm	-250. mm	283.68 mm	283.69 mm	306.53 mm	306.68 mm
						-	-		

Centroid Z	-241.86 mm	-1132.3 mm	-256.73 mm	-1670.7 mm	-1650.4 mm	1365.7 mm	551.57 mm	-928.07 mm	-1317.4 mm
Moment of Inertia Ip1	717.5 t·mm²	70583 t·mm²	59.103 t·mm²	3390.2 t·mm²	6985.2 t·mm²	5778.3 t·mm²	10.739 t·mm²	470.3 t·mm²	1.078 t·mm²
Moment of Inertia Ip2	502.48 t·mm²	2.069e+005 t·mm²	58.408 t·mm²	80424 t·mm²	1.2206e+005 t·mm²	5784.6 t·mm²		473.36 t·mm²	62.013 t·mm²
Moment of Inertia Ip3	256.32 t·mm²	1.3718e+005 t·mm²	1.0301 t·mm²	77150 t·mm²	1.1907e+005 t·mm²	10.741 t·mm²	5778.2 t·mm²	6.5785 t·mm²	62.729 t·mm²
Statistics									
Nodes	4296	87446	491	13316	33816	6916		959	954
Elements	574	12324	54	1794	4624	924		108	
Mesh Metric	None								
CAD Attributes									
PartTolerance:	0.00000001								
Color:143.175.143									

TABLE 4
Model (B4) > Materials

Object Name	*Materials*
State	Fully Defined
Statistics	
Materials	1
Material Assignments	0

Coordinate Systems

TABLE 5
Model (B4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. mm
Origin Y	0. mm
Origin Z	0. mm
Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]

Symmetry

TABLE 6
Model (B4) > Symmetry

Object Name	*Symmetry*
State	Fully Defined

TABLE 7
Model (B4) > Symmetry > Symmetry Region

Object Name	*Symmetry Region*	*Symmetry Region 2*	*Symmetry Region 3*	*Symmetry Region 4*
State	Fully Defined			
Scope				
Scoping Method	Geometry Selection			
Geometry	5 Faces	1 Face	4 Faces	1 Face
Definition				
Scope Mode	Manual			
Type	Symmetric			
Coordinate System	Global Coordinate System			
Symmetry Normal	X Axis			
Suppressed	No			

Connections

TABLE 8
Model (B4) > Connections

Object Name	*Connections*
State	Fully Defined
Auto Detection	
Generate Automatic Connection On Refresh	Yes
Transparency	
Enabled	Yes

TABLE 9
Model (B4) > Connections > Contacts

Object Name	*Contacts*
State	Fully Defined
Definition	
Connection Type	Contact
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Auto Detection	
Tolerance Type	Slider
Tolerance Slider	0.
Tolerance Value	9.9236 mm
Use Range	No
Face/Face	Yes
Face-Face Angle Tolerance	75. °
Face Overlap Tolerance	Off
Cylindrical Faces	Include
Face/Edge	No
Edge/Edge	No
Priority	Include All
Group By	Bodies
Search Across	Bodies
Statistics	
Connections	21
Active Connections	21

TABLE 10
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region*	*Contact Region 2*	*Contact Region 3*	*Contact Region 4*	*Contact Region 5*	*Contact Region 6*	*Contact Region 7*	*Contact Region 8*	*Contact Region 9*	*Contact Region 10*	*Contact Region 11*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	1 Face	2 Faces		1 Face							3 Faces
Target	1 Face	2 Faces			1 Face				2 Faces	1 Face	3 Faces
Contact Bodies	Solid1			Solid2							Solid3
Target Bodies	Solid2	Solid6	Solid7	Solid3	Solid4	Solid5	Solid6	Solid7	Solid8	Solid9	Solid7
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	9.9236 mm										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration	Program Controlled										

Tolerance	
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 11
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 12*	*Contact Region 13*	*Contact Region 14*	*Contact Region 15*	*Contact Region 16*	*Contact Region 17*	*Contact Region 18*	*Contact Region 19*	*Contact Region 20*	*Contact Region 21*
State	Fully Defined									
Scope										
Scoping Method	Geometry Selection									
Contact	1 Face						3 Faces	1 Face		
Target	1 Face						3 Faces	1 Face		
Contact Bodies	Solid3	Solid4			Solid5		Solid6		Solid7	Solid8
Target Bodies	Solid8	Solid5	Solid6	Solid7	Solid6	Solid7	Solid8	Solid9	Solid8	Solid9
Protected	No									
Definition										
Type	Bonded									
Scope Mode	Automatic									
Behavior	Program Controlled									
Trim Contact	Program Controlled									
Trim Tolerance	9.9236 mm									
Suppressed	No									
Advanced										
Formulation	Program Controlled									
Small Sliding	Program Controlled									
Detection Method	Program Controlled									
Penetration Tolerance	Program Controlled									
Elastic Slip Tolerance	Program Controlled									
Normal Stiffness	Program Controlled									
Update Stiffness	Program Controlled									
Pinball Region	Program Controlled									
Geometric Modification										
Contact Geometry Correction	None									
Target Geometry Correction	None									

Mesh

TABLE 12
Model (B4) > Mesh

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting

Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	30.0 mm
Sizing	
Use Adaptive Sizing	Yes
Resolution	Default (2)
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Diagonal	3969.4 mm
Average Surface Area	2.9313e+005 mm²
Minimum Edge Length	5.0 mm
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Aggressive Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Statistics	
Nodes	155110
Elements	21434

Static Structural (B5)

TABLE 13
Model (B4) > Analysis

Object Name	*Static Structural (B5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 14
Model (B4) > Static Structural (B5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled

Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Quasi-Static Solution	Off
Rotordynamics Controls	
Coriolis Effect	Off
Restart Controls	
Generate Restart Points	Program Controlled
Retain Files After Full Solve	No
Combine Restart Files	Program Controlled
Nonlinear Controls	
Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Program Controlled
Advanced	
Inverse Option	No
Contact Split (DMP)	Off
Output Controls	
Stress	Yes
Surface Stress	No
Back Stress	No
Strain	Yes
Contact Data	Yes
Nonlinear Data	No
Nodal Forces	No
Volume and Energy	Yes
Euler Angles	Yes
General Miscellaneous	No
Contact Miscellaneous	No
Store Results At	All Time Points
Result File Compression	Program Controlled
Analysis Data Management	
Solver Files Directory	F:\Project\Ram Tank\T-1340_files\dp0\SYS-1\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Contact Summary	Program Controlled
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	nmm

TABLE 15
Model (B4) > Static Structural (B5) > Loads

Object Name	*Internal Design pressure*	*Frictionless Support*	*Frictionless Support 2*	*Frictionless Support 3*	*Frictionless Support 4*	*Live Load*
State	Fully Defined					
Scope						
Scoping Method	Geometry Selection					
Geometry	18 Faces	5 Faces	1 Face	4 Faces	1 Face	2 Faces
Definition						
Type	Pressure	Frictionless Support				Pressure
Define By	Normal To					Normal To
Applied By	Surface Effect					Surface Effect
Loaded Area	Deformed					Deformed
Magnitude	1.e-002 MPa (ramped)					1.e-003 MPa (ramped)

Suppressed	No

FIGURE 1
Model (B4) > Static Structural (B5) > Internal Design pressure

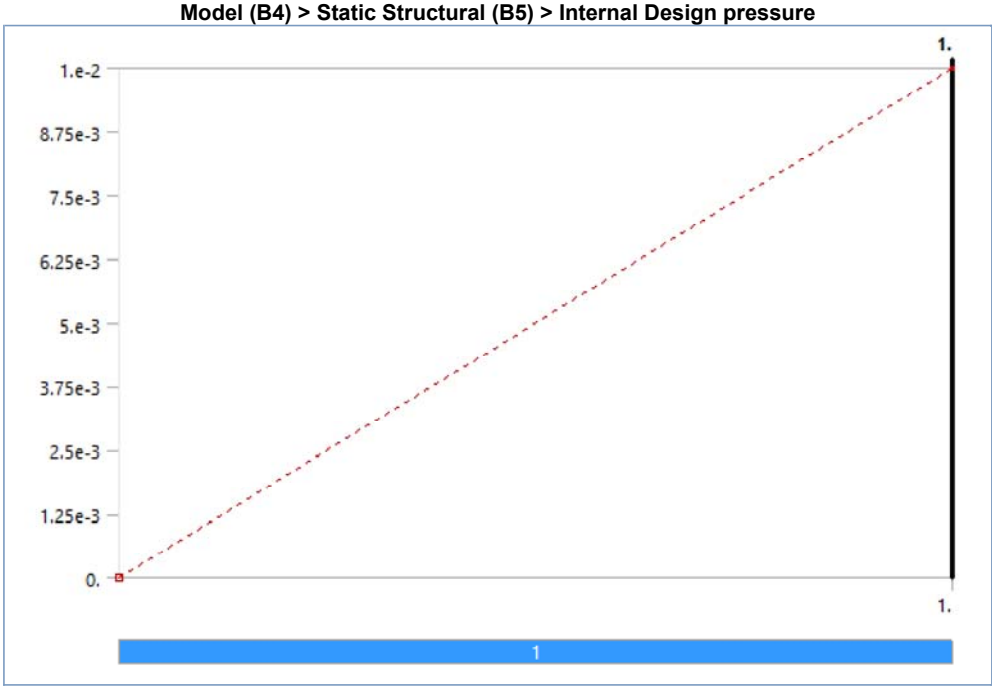
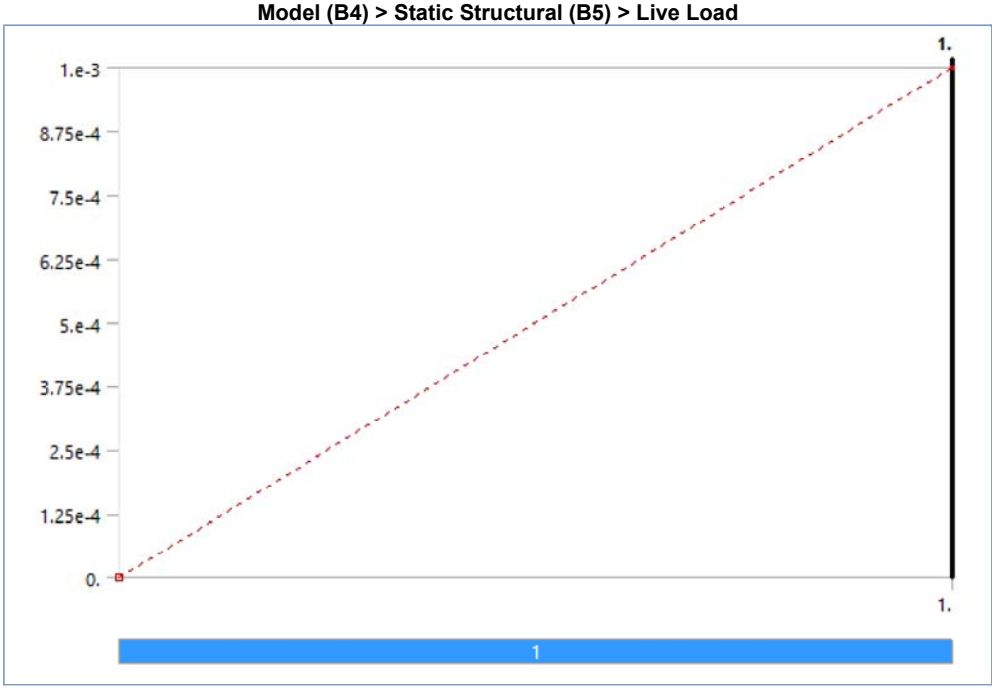


FIGURE 2
Model (B4) > Static Structural (B5) > Live Load



Solution (B6)

TABLE 16
Model (B4) > Static Structural (B5) > Solution

Object Name	*Solution (B6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.

Information	
Status	Done
MAPDL Elapsed Time	7 m 4 s
MAPDL Memory Used	2.0166 GB
MAPDL Result File Size	41.188 MB
Post Processing	
Beam Section Results	No
On Demand Stress/Strain	No

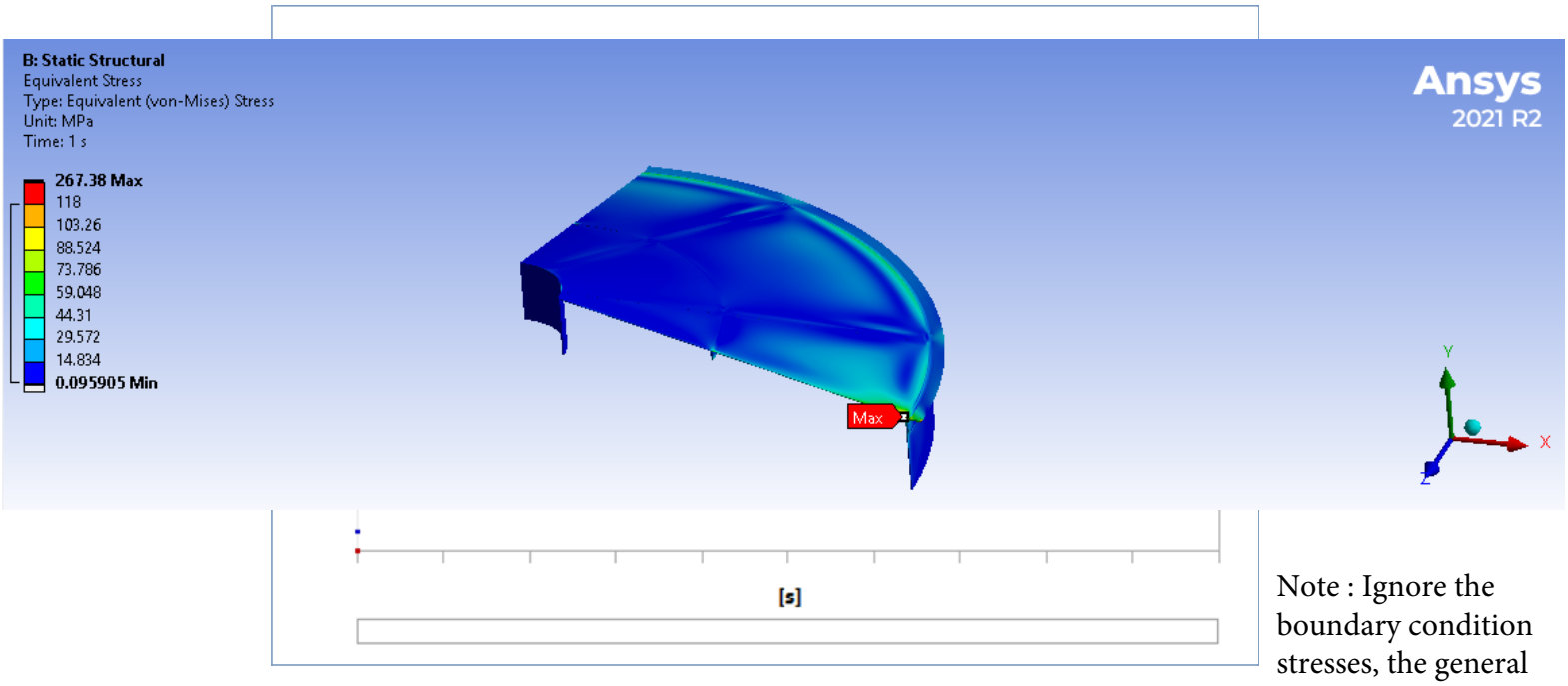
TABLE 17
Model (B4) > Static Structural (B5) > Solution (B6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Identify Element Violations	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 18
Model (B4) > Static Structural (B5) > Solution (B6) > Results

Object Name	*Equivalent Stress*	*Total Deformation*
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Definition		
Type	Equivalent (von-Mises) Stress	Total Deformation
By	Time	
Display Time	Last	
Calculate Time History	Yes	
Identifier		
Suppressed	No	
Integration Point Results		
Display Option	Averaged	
Average Across Bodies	No	
Results		
Minimum	9.5905e-002 MPa	0. mm
Maximum	267.38 MPa	1.949 mm
Average	10.676 MPa	0.75107 mm
Minimum Occurs On	Solid7	Solid5
Maximum Occurs On	Solid2	
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	

FIGURE 3
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress



Note : Ignore the boundary condition stresses, the general stress is below the allowable stress.

TABLE 19
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress

Time [s]	Minimum [MPa]	Maximum [MPa]	Average [MPa]
1.	9.5905e-002	267.38	10.676

FIGURE 4
Model (B4) > Static Structural (B5) > Solution (B6) > Total Deformation

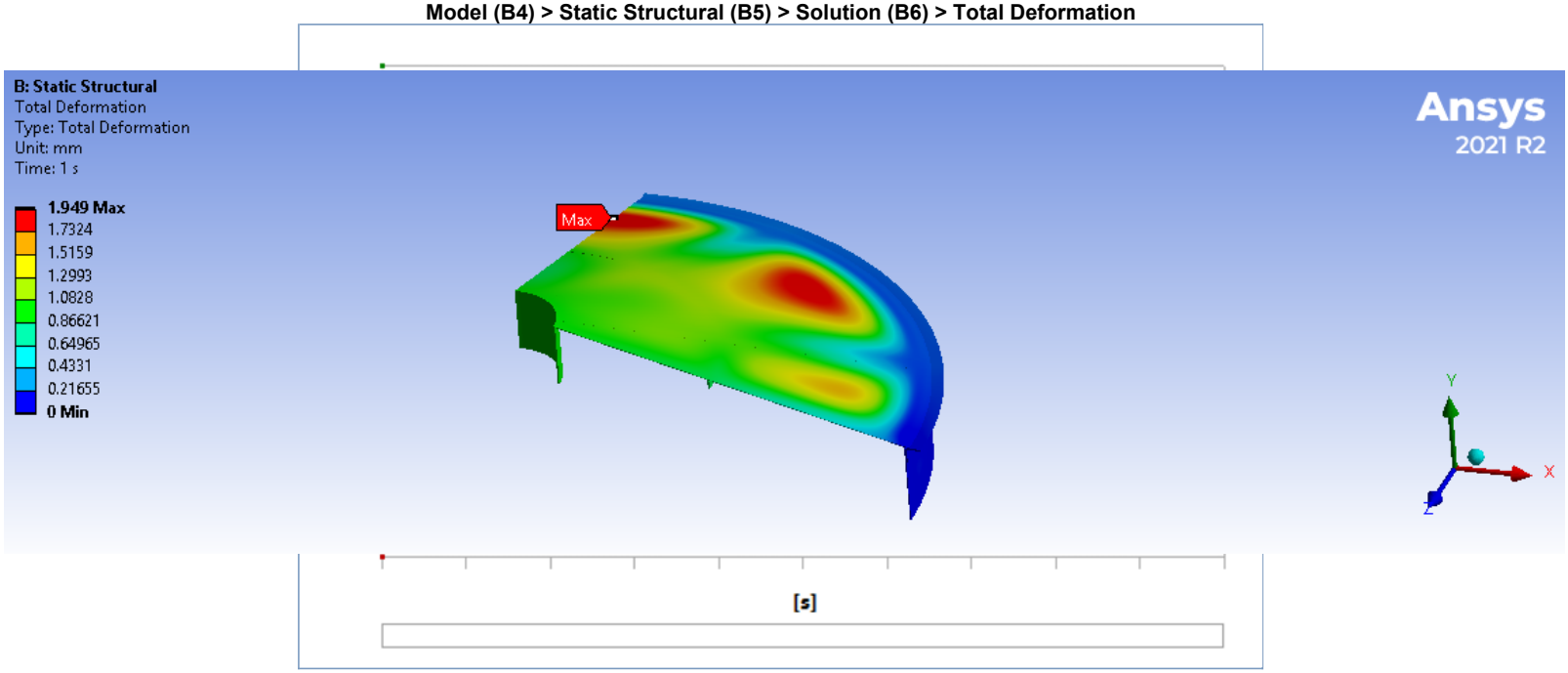


TABLE 20
Model (B4) > Static Structural (B5) > Solution (B6) > Total Deformation

Time [s]	Minimum [mm]	Maximum [mm]	Average [mm]
1.	0.	1.949	0.75107

Material Data

Structural Steel

TABLE 21
Structural Steel > Constants

Density	7.85e-009 tonne mm^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	4.34e+008 mJ tonne^-1 C^-1
Thermal Conductivity	6.05e-002 W mm^-1 C^-1
Resistivity	1.7e-004 ohm mm

TABLE 22
Structural Steel > Color

Red	Green	Blue
132	139	179

TABLE 23
Structural Steel > Compressive Ultimate Strength

Compressive Ultimate Strength MPa
0

TABLE 24
Structural Steel > Compressive Yield Strength

Compressive Yield Strength MPa
218

TABLE 25
Structural Steel > Tensile Yield Strength

Tensile Yield Strength MPa
218

TABLE 26
Structural Steel > Tensile Ultimate Strength

Tensile Ultimate Strength MPa
460

TABLE 27
Structural Steel > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 28
Structural Steel > S-N Curve

Alternating Stress MPa	Cycles	Mean Stress MPa
3999	10	0
2827	20	0
1896	50	0
1413	100	0
1069	200	0
441	2000	0
262	10000	0
214	20000	0
138	1.e+005	0
114	2.e+005	0
86.2	1.e+006	0

TABLE 29
Structural Steel > Strain-Life Parameters

Strength Coefficient MPa	Strength Exponent	Ductility Coefficient	Ductility Exponent	Cyclic Strength Coefficient MPa	Cyclic Strain Hardening Exponent
920	-0.106	0.213	-0.47	1000	0.2

TABLE 30
Structural Steel > Isotropic Elasticity

Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa	Temperature C
2.e+005	0.3	1.6667e+005	76923	

TABLE 31
Structural Steel > Isotropic Relative Permeability

Relative Permeability
10000

6.0 Design of Shell for Intermediate Wind Girder

6.1 INPUTS:

Inside dia. of tank	D_i	=	5.180	m	
Height of shell	H	=	20.944	m	
Design Wind speed	V	=	79.00	Km/h	*(Ref: API 650 5.2.1 k)*
Nominal dia. of Tank	D	=	5.192	m	
Nominal thickness of thinnest shell course	$t_{uniform}$	=	6	mm	
Buckling in coroded condition			NO		*(Ref: API 650 5.9.7.1 note 1)*

Factors for caclutating velocity pressure, including vacuum	K_Z	K_{Zt}	K_d	V (mph)	I	G	Vacuum(lbf/ft2)
Factors as per API 650 5.9.7.1 Note 2	1.04	1	0.95	120	1	0.85	5
Factors as per ASCE 7	1.04	1	0.95	49.09	1.15	0.85	0.00

(Ref: API 650 5.9.7.1 note 2)

6.2 CALCULATION

The velocity pressure + internal vacuum		=	$0.00256 K_Z K_{Zt} K_d V^2 I G$ + internal vacuum		
The velocity pressure, including internal vacuum, as per API 650	p_1	=	35.96	lbf/ft^2	*(Using API 650 5.9.7.1 note2 factors)*
		=	1.72	kPa	
The velocity pressure, including internal vacuum, as per client's specs	p_2	=	5.96	lbf/ft^2	*(using clien's specs)*
		=	0.29	kPa	
	p_1/p_2	=	1.00		*(Using API 650 5.9.7.1 note 2.d)*

As modified total pressure is less than or equal to 1.72 kPa, therefore ratio p1/p2 will not be taken into account

Max. height of the unstiffened shell	H_1	=	$9.47\, t_{tc} \times \sqrt{(t/D)^3 \times (190/V)^2}$		*(Ref: API 650 5.9.7.1)*
		=	398.45	m	*(Annex M reduction factor is included)*
Appendix M temperature factore		=	0.976		(Ref: API 650 Annex M.6)
Coroded thickness of thinnest shell course	t	=	6.00	mm	

Height of tranformed shell:

Course Number		Actual Shell Course Height W (m)	Thickness $t_{uactual}$ (mm)	Transformed shell course height $W_{tr} = W\sqrt{(t_{uniform}/t_{actual})^5}$ (mm)
1		1524	12	269.41
2		1524	10	424.97
3		1524	10	424.97
4		1524	8	742.40
5		1524	8	742.40
6		1524	8	742.40
7		1800	6	1800.00
8		1800	6	1800.00
9		1800	6	1800.00
10		1800	6	1800.00
11		1800	6	1800.00
12		1800	6	1800.00
13		1000	6	1000.00
Top Angle		100.00	9.00	36.29
	Sum =	16344 mm	Sum =	*15182.85*
	=	16.344 m	H_T =	15.18

Since, H_T < H_1 , therefore wind girders are NOT REQUIRED.

7.0 Seismic Analysis

7.1 Inputs

0.2 s (short period) spetral response acceleration	S_S	=	0.046		*As per data sheet*
1 s spetral response acceleration	S_1	=	0.02		*As per data sheet*
Design Level Peak Ground Acceleration Parameter	S_0	=	0.02		*As per data sheet*
Seismic User Group as per	*SUG*	=	*III*		*Table E-5, API 650*
Site Class		=	D		*As per data sheet*
Maximum design product level	*H*	=	20.94	m	
Nominal tank diameter	*D*	=	5.192	m	
	D/H	=	0.248		
Thickness of bottom shell course (coroded)	t_s	=	11.0	mm	*Ref: API 650 E.2.2*
Thickness of Annulas plate(coroded)	*ta*	=	-1.000	mm	*Ref: API 650 E.2.2*
Specific gravity	*G*	=	1.3		
Weight of product	W_p	=	5,655	KN	
Total weight of tank shell and appurtenances	W_s	=	216.80	KN	*(Un-corroded)*
Total weight of fixed tank roof including permanent attachment	W_r	=	FALSE	KN	*(Un-corroded)*
Weight of the bottom	*Wf*	=	17.77	KN	*(Un-corroded)*
Height from bottom of the tank shell to shell's center of gravity	X_s	=	10.47	m	
Height from bottom of the tank shell to roof center of gravity	X_r	=	21.1755	m	
Minimum yield strenght of bottom annular plate	F_y	=	253.46	MPa	
Product design stress of lowest shell course	S_d	=	145.67	MPa	
Internal design pressure	P_i	=	10.000	kPa.g	

7.2 Determining Spectral Acceleration Parameters

Regional-dependent transition period for longer period	T_L	=	4	sec	*Ref: API 650 E.4.6.1*
Acceleration-based site coeficient (at 0.2 sec period)	F_a	=	1.6		*Ref: API 650 Table E-1*
Velocity based site coefficient (at 1.0 sec period)	F_v	=	2.4		*Ref: API 650 Table E-1*
Scaling factor	*Q*	=	0.67		*Ref: API 650 E.4.6.1*
Spectral response accelration at one second,	S_{D1}	=	($Q \times F_V \times S_1$)		
		=	0.0322		
Spectral response accelration at short periods	S_{DS}	=	($Q \times F_a \times S_s$)		
(T = 0.2 seconds),		=	0.04931		

Spectral response accelration at zero second,	S_{D0}	=	$(Q \times S_0)$			
		=	0.013			
	T_S	=	S_{D1}/S_{DS}			
		=	0.652			
	T_O	=	$0.2 \times S_{D1}/S_{DS}$			
		=	0.130			

7.3 Determining Spectral Acceleration Coefficients

Assuming Tank is			Self-anchored			
Force reduction factor for the convective mode	R_{wi}	=	3.5			*Ref: API 650 Table E-4*
Force reduction factor for the impulsive mode	R_{wc}	=	2			*Ref: API 650 Table E-4*
Importance factor	I	=	1.5			*Ref: API 650 Table E-5*
Impulsive design response spectrum aceleration coeficient	A_i	=	*SDS(I/ Rwi)*			*Ref: API 650 E.4.6.1*
		=	0.021	≥	0.007	
Convective(sloshing) period	Tc	=	$1.8 \times K_s \times \sqrt{D}$			
		=	2.371	Sec		
Where,	K_s	=	$\frac{0.578}{\sqrt{tanh\frac{3.68\ x\ H}{D}}}$			
		=	0.578			
Cofficient to adjust the spectral acceleration from 5% - 0.5% damping	K	=	1.5			*Ref: API 650 E.2.2*
Since,	Tc	≤	T_L			
	Ac	=	*KSD1 x (TL/Tc^2) x (I/Rwc)*			Ref: API 650 Eq E.4.6.1-4
Convective design response spectrum aceleration coeficient	Ac	=	0.01526	≤	A_i	Condition satisfied

7.4 Seismic Overturning Moment

Ref: API 650 E.6.1.5

Type of foundation			Slab			
Seismic overturning moment at the base of tank shell	Ms	=	$\sqrt{[Ai(WiXis + WsXs + WrXr]2 + [Ac(WcXcs)]2}$			
		=	**1200.50**	KN-m		*Ref: API 650 E.6.1.5-2*
Where,						
Effective impulsive weight	W_i	=	$W_i = \left[1.0 - 0.218\frac{D}{H}\right]W_p$	With D/H	< 1.333	
						Ref: API 650 E.6.1.1
		=	5349.38	KN		
Center of action for effective impulsive weight for slab moment	Xis	=	*[0.5 - 0.06 x D/H] x H*	With D/H	< 1.333	
		=	10.160	m		*Ref: API 650 E.6.1.2.2*
Effective convective(sloshing) weight	W_c	=	$0.230\frac{D}{H}\tanh\left(\frac{3.67H}{D}\right)W_p$			*Ref: API 650 E.6.1.1*
		=	322.43	KN		

Center of action for effective convective weight for slab moment — Xcs = $\left[1-\frac{\cosh\frac{3.67\,x\,H}{D}-1}{\frac{3.67\,x\,H}{D}\sinh\left(\frac{3.67\,x\,H}{D}\right)}\right]x\,(H)$ *Ref: API 650 E.6.1.2*

= 19.53 m

7.5 Seismic Base Shear *Ref: API 650 E.6.1*

Design base shear due to impulsive component from effective weight of tank and contents — Vi = $A_i (W_s + W_r + W_f + W_i)$ *Ref: API 650 E.6.1-2*

= 118.01 KN

Design base shear due to convective component of effective sloshing weight — V_c = 4.92 KN

Total seismic base shear — V = $\sqrt{V_i^2 + V_c^2}$ *Ref: API 650 E.6.1-1*

= **118.11** KN

7.6 Resistance to seismic overtuning forces *Ref: API 650 E.6.2.1*

Vertical earthquake acceleration coefficient, 0.47 x S_{DS} — A_v = 0.023 *Ref: API 650 E.2.2*

Force resisting uplift in annulus region — W_a' = $99 \times t_a \times \sqrt{Fy \times H \times G(1 - 0.4*A_v)}$

Wa' = -8.19 KN/m

Wa" = 201.1 x H x D x G_e

Wa" = 28.16 KN/m

W_a = lesser of (Wa' and Wa")

W_a = -8.19 KN/m

so now, the thikness,ta, corespondingwith final Wa is — t'a = -1.0000 mm

Anchorage Ratio — J = $\frac{M_{rw}}{D^2[w_t(1-0.4Av)+wa\ -0.4wint]}$

= -212.620 J ≤0.785

No calculated uplift under the design seismic overturning moment. The tank is self-anchored

Where,

Roof load acting on shell per unit cercumferential length w_{rs} = 0.00 KN/m

Tank and roof weight acting at base per unit cercumferential length w_t = 13.29 KN/m

Uplift load due to product pressure per unit cercumferential length w_{int} = 12.98 KN/m

7.6.1 Minimum Anchorage Resistance

Ref: API 650 E.6.2.1.2

Calculated design uplift load on anchors per unit $W_{AB} = \left(\frac{1.273\ x\ Mrw}{D^2} - wt\ x\ (1 - 0.4\ x\ Av)\right)$

circumferential length = 48.72 KN/m

Anchor seismic load $P_{AB} = W_{AB}(\ x\ D / n_a)$

= *66.22* KN

Where, n_a = 12

7.6.2 Shell Compression in: Self-Anchored Tank

Ref: API 650 E.6.2.2

The maximum longitudal shell compression stress at the bottom $\sigma_c = \left(w_t(1 + 0.4Av) + \frac{1.273\ x\ Mrw}{D^2}\right)\frac{1}{1000ts}$

of shell when there is no calculated up *J ≤ 0.785*

= 6.373 Mpa

when GHD^2/t^2 = 6.065785 < 44 F_c = 109.47 MPa < 126.73 O.K

Seismic allowable longitudal stress

Since, *Fc* > σ_c Shell compression O.K

7.7 Dynamic Liquid Hoop Forces

Ref: API 650 E.6.1.4

For *D/H <1.333* and Y ≥3.894

Impulsive hoop membrane force in tank shell N_i = $2.6\ x\ A_i\ x\ G\ x\ D^2$

1.93 N/mm

Convective hoop membrane force in tank shell $N_c = \frac{1.85\ x\ Ac\ x\ G\ x\ D^2\left[\frac{3.68(H\ -Y)}{D}\right]}{cosh\left[\frac{3.68\ x\ H}{D}\right]}$

= 0.00000 N/mm

Product hudrostatic membrane hoop load at the base of tank N_h = 4.9 x (Y -0.3) x D x G

= 708.72 N/mm

Total hoop stress, including lateral and vertical seismic acceleration $\sigma_T = \sigma_h + \sigma_s = \frac{Nh \pm \sqrt{N_i^2 + N_c^2 + ((A_v\ x\ Nh)/2.5)^2}}{t}$

= 65.05 Mpa

Allowable seismic hoop stress = *lesser of 1.333 x S_d and 0.9 x F_y*

= 194.17 Mpa

Since, *σT* 65.05 < 194.17 Total hoop stress is O.K

Minimum required thickness for seismic hoop stress $t_{seismic} = \frac{Nh \pm \sqrt{N_i^2 + N_c^2 + ((A_v \times Nh)/2.5)^2}}{Allowable\ seismic\ hoop\ stress}$

$= 3.69$ mm

Summary of dynamic hoop stresses

Course No.	Design liquid height	Ni	*Nc*	*Nh*	σ_T	Allowable hoop stress	Required thickness
	Y(m)	N/mm	N/mm	N/mm	Mpa	Mpa	$t_{seismic}$
1	21.729	1.93	0.00	708.72	65.05	194.17	3.69
2	20.205	1.93	0.00	658.32	73.86	194.17	3.42
3	18.681	1.93	0.00	607.91	68.21	194.17	3.16
4	17.157	1.93	0.00	557.51	80.43	194.17	2.90
5	15.633	1.93	0.00	507.11	73.17	194.17	2.64
6	14.109	1.93	0.00	456.70	65.91	194.17	2.38
7	12.285	1.93	0.00	396.38	80.10534	194.17	2.06
8	10.485	1.93	0.00	336.85	68.10306	194.17	1.75
9	8.685	1.93	0.00	277.315104	56.11	194.17	1.44
10	6.885	1.93	0.01	217.783632	44.11	194.17	1.14
11	6.885	0.00	0.01	217.783632	43.96	194.17	1.13
12	5.085	0.00	0.03	158.25216	-156.78	194.17	0.82
13	-0.300	0.00	1.22	-19.843824	21.08	194.17	-0.10

8.0 Wind Loads(Overturning Stability)

8.1 Inputs

Roof Type				*Rafter Supported Cone Roof*		
Nominal diameter	*(2 m has been added to tank dia, so to accommodate wind loads)*	D_W	=	7.19	m	
Design wind speed		V	=	79.00	Km/h	
Height of shell		H_S	=	20.94	m	
Height of roof above shell	*(1.1 m has been added to troof height, so to accommodate wind loads)*	H_R	=	1.795	m	
Height of tank		H_T	=	22.739	m	
Horizontal projected area of roof	$\frac{\pi}{4}(internal\ diameter)^2$	A_R	=	21.07	m^2	
Vertical projected area of shell (including roof height above shell)		A_s	=	$D_W \times H_T$ =	163.54	m^2
Internal pressure		P_i	=	10.00	kPa	
Weight of shell	(nominal plate weight only)	Ws	=	195.98	KN	
Weight of liquid present		w_L	=	0.00		
Weight of roof	(nominal plate weight+welded structure and nozzles)	W_R	=	6.85	KN	
Pressure combination factor		F_P	=	0.40		*(Ref: API 650, 5.2.2)*

8.2 Calculation

8.2.1 Wind pressures *(Ref: API 650, 5.2.1.K.1)*

Wind pressure on vertical projected area of tank	*(Horizontal Wind Pressure)*	P_{WS}	=	$0.86 \times (V/190)^2$	
			=	0.15	kPa
Wind pressure on horizontal projected area of roof	*(Vertical Wind Pressure)*	P_{WR}	=	$1.44 \times (V/190)^2$	
			=	0.25	kPa

8.2.2 Uplift pressure on roof *(Ref: API 650, 5.2.1.K.2)*

Wind plus internal pressure on roof	$P_{WR} + P_{DESIGN}$		=	10.25	kPa
1.6 times the Design pressure determined as per F.4.1		$P_{F.4.1}$	=	35.19	kPa
	As "$P_{WR} + P_{DESIGN}$" is		≤	$P_{F.4.1}$	

Requirement of API 650, 5.2.1.K.2 is Satisfied.

8.2.3 Overturning Moments about Shell-Bottom joint

Overturning moment about shell-bottom joint from horizontal wind pressure,	M_{WS}	=	$P_{WS} \times A_S \times H_T/2$	
		=	276.43	KN-m
Overturning moment about shell-bottom joint from vertical wind pressure	M_{WV}	=	$P_{WR} \times A_R \times D_W/2$	
		=	18.87	KN-m
Combined Moment due to wind pressure	M_W	=	295.30	KN-m
Moment about shell-bottom joint from design internal pressure	M_{pi}	=	$P_i \times A_R \times D_W/2$	
		=	757.83	KN-m

Moment about shell-bottom joint from nominal weight of shell

M_{DL} = $0.5 \times D_W \times W_S$

Note: Only shell weight is considered to get more stringent result

= 704.74 KN-m

Moment about shell-bottom joint from liquid weight — M_F = 0 KN-m — *Zero liquid weight will give worst case scenario*

Force about shell-bottom joint from nominal weight of roof plus any attached structure

M_{DLR} = $0.5 \times D_W \times W_R$

= 24.62 KN-m

9.2.4 Wind shear force

Wind force on shell — $F1$ = $P_{WS} \times Dw \times H_s$

= 22.40 KN

Wind force on roof — $F2$ = $P_{WR} \times 0.5 \times Dw \times H_R$

= 1.61 KN

Total wind force on tank — $F1 + F2$ = 24.00 KN

For tank to be structurally stable without anchorage, the following uplift criteria shall satisfy:

Criteria 1: $0.6\ Mw + Mpi < MDL / 1.5 + M_{DLR}$

Criteria 2: $Mw + F_p\ Mpi < (MDL + MF) / 2 + M_{DLR}$

Criteria 3: $Mws + Fp\ (MPi) < MDL / 1.5 + MDLR$

For Criteria 1:	$0.6\ M_w + M_{pi}$	<	$M_{DL} / 1.5 + M_{DLR}$	
	935	>	494.45	Not satisfied
For Criteria 2:	$M_w + 0.4\ M_{pi}$	<	$(MDL + MF) / 2 + M_{DLR}$	
	598.43	>	376.99	Not satisfied
For Criteria 3:	$M_{ws} + F_p\ (M_{Pi})$	<	$M_{DL} / 1.5 + M_{DLR}$	
	579.56	>	494.45	Not satisfied

Since, All criterias are not satisfied

Therefore the tank, Needs to be mechanically anchored against wind load

9.0 Anchor Bolts

Need to be Anchored against Wind loads (5.11) *(YES/NO)*	YES
Needs to be anchored against internal pressure (Appendix F) *(YES/NO)*	YES
Needs to be anchored against seismic loads (Appendix E) *(YES/NO)*	YES
Anchorage to be Provided (YES/NO)	YES

Material of anchor bolt used			A 36 Gr.36 Class 8.8				
Minimum yield strenght of the anchor bolt			660	Mpa			Ref: API 650 Table 5.21a
Corrosion Allowance for anchor bolt			1.5	mm			
Minimum nominal anchor bolt diameter including C.A		=	26.5	mm			Ref: API 650 5.12.5
Selected bolt size			M27				O.K
Root diameter of anchor bolt		=	21.46	mm	corroded		
Root area		=	361.53	mm^2	corroded		Ref: API 650 5.12.4
Number of anchor bolts		=	12		>	6	
Specing between anchors	Spacing b/w anchors is satisfactory	=	1.36	m	<	3 m	Ref: API 650 5.12.3

Table 5-21a - (SI) Uplift Loads

Uplift Load case	Net Uplift Formula, U(N)	Uplift Load, U (N)	Load/bolt t_b (N)	Stress/ bolt (Mpa)	*Allowable Anchor Bolt Stress (Mpa)	Remarks
Design Pressure	$[(P_i \times D^2 \times 785] - W_1$	14,246	1187	*3*	104	O.K
Test pressure	$[(P_t \times D^2 \times 785] - W_3$	39,132	3261	*9*	*139*	O.K
Wind load	$P_{WR} \times D^2 \times 785 + [4 \times M_{WH}/D] - W_2$	20,872	1739	*5*	*200*	O.K
Seismic Load	$[4 \times M_{rw}/D] - W_2 x(1 - 0.4 X A_v)$	729,347	60779	*168*	*200*	O.K
Design pressure + Wind	$[(F_p \times P_i + P_{WR}) \times D^2 \times 785] + 4 \times [M_{ws}/D] - W_1$	102,356	8530	*24*	*139*	O.K
Design pressure + Seismic	$[(F_p \times P_i \times D^2 \times 785] + 4 \times [M_{rw}/D] - W_1(1 - 0.4 \times A_v)$	813,992	67833	*188*	*200*	O.K
Frangibilty Pressure	$[(3 \times P_f \times D^2 \times 785] - W_3$	N/A	N/A	*N/A*	*250*	N/A

Governing Uplift Load case		=	Design pressure + Seismic		
Governing Uplift Load		=	813,992	N	
Where,					
Vertical earthquake acceleration coefficient, 0.47 x S_{DS}	A_v	=	0.023		
Tank Diameter	D	=	5.192	m	
Minimum yield strenght of the bottom shell course	F_{ty}	=	218.50	Mpa	Ref:: API 650, Table 5.21a
Minimum yield strenght of the anchor bolt	Fy	=	250	Mpa	
Tank height	H	=	20.944	m	
Overturning moment about shell-bottom joint from horizontal wind pressure,	M_{WS}	=	276.43	KN-m	
Seismic overturning moment at the base of tank shell	M_{rw}	=	1200.50	KN-m	
Design pressure	P	=	10.000	kPa(g)	

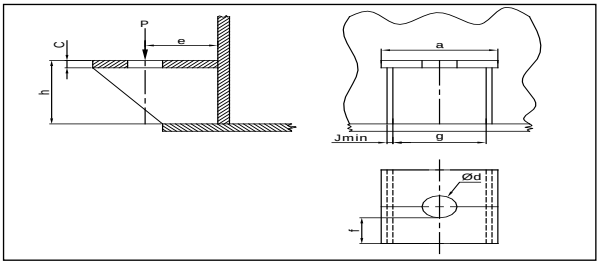
Tank Falling under F.1.3 of API 650				*NO*	
Test pressure	*(to be filled with water)*	*Pt*	=	12.500	kPa(g)
Wind uplift pressure on roof		P_{WR}	=	0.25	kPa
Wind pressure on shell		P_{WS}	=	0.15	kPa
Roof plate thickness		t_h	=	4.5	mm
Roof plate thickness (coroded)		t_{h_c}		3.5	mm
Dead load of shell + Dead load of roof plates & other dead loads acting on shell *(corroded)*		W_1	=	197366	N
Dead load of shell + other dead loads acting on shell, including roof plates weight acting on shell *(corroded)*		W_2	=	197366	N
Un-corroded shell +Roof & other dead load acting on shell *(Un-corroded)*		W_3	=	225382	N

10.0

Anchor Chair

Reference: *AISI: Steel Plate Engineering Data - Volume 2 - Part VII*

Top-plate width along the Shell		a	=	11.811	in	=	300	mm
Top-plate width along the radial direction (including R.P thickness)		b	=	e + lenght of anchor hole/2 + f				
			=	9.41	in	=	239.0	mm
Top-plate thickness		c_{actual}	=	0.79	in	=	20	mm
Height of Chair		h	=	9.84	in	=	250	mm
Nominal Anchor bolt diameter		d	=	1.18	in	=	30	mm
Root diameter of anchor bolt		d_R	=	0.88	in		22.31	mm
Maximum Allowable anchor bolt load(root area of bolt X yield strenght of anchor bolt)		P1	=	21.32	kips	=	96.91	kN
3 x Anchor bolt load(Governing uplift load/Bolt)		P2	=	14.00	kips	=	63.62	KN
3xSeismic load P_{AB}		P3	=	-1.83	kips	=	-8.33	KN
Design Load	*P = lesser of P1 and Max(P2 & P3)*		=	19.88	kips	=	90.38	kN
Maximum Load on upwind side		P	=	19.88	kips	=	90.383	kN
Calculated gusset plate thickness		j_{cal}	=	0.56	in	=	14.30	mm
Actual gusset plate thickness		j_{actual}	=	0.79	in	=	20	mm
For taper gusset;								
Top width of gusset		k1	=	9.41	in	=	239	mm
Bottom width of gusset	Q =	k2	=	3.94	in	=	100	mm
Average width of gusset		k	=	6.67	in	=	169.50	mm
Bolt Circle diameter		B.C.D	=	209.1	in	=	5311	mm
Corrosion allowance for anchor attachments			=	1.6	mm			
Weight of anchor chairs			=	114	kg			



Bottom plate thickness		m	=	0.24	in	=	6.00	mm
Shell plate thickness	Without R.P	t	=	0.20	in	=	5.00	mm

	Nominal dia. of tank	D	=	204.41	in	=	5192	mm
	Outside dia. of tank	D_o	=	204.61	in	=	5197	mm
	Mean Inside radius of tank	R	=	102.20	in	=	2596.0	mm
	Height of shell	H_s	=	824.57	in	=	20944	mm
	radial projection of Annular/bottom plate from OD of tank	Q	=	3.94	in	=	100.0	mm
	Radius of gyration of shell	r	=	1/4 x $\sqrt{(D_o^2+D_i^2)}$				
			=	72.30	in			
	Size of hole for anchor bolt :	width	=	1.42	in	=	36	mm
		length	=	1.77	in	=	45	mm
10.1	Minimum Anchor bolt eccentricity	e_{min1}	=	0.866 x d + 0.572				
			=	1.59	in			
		e_{min2}	=	Q + length of anchor bolt hole/2				
			=	4.82	in			
		e_{min}	=	max. of e_{min1} and e_{min2}				
			=	4.82	in	=	122.50	mm
	Actual anchor bolt eccentricity	e_{actual}	=	5.96	in	=	151.5	mm
	e_{actual} is greater than $e_{min,}$ therefore selection O.K.							
10.2	Distance form outside of top-plate to the hole edge	f_{min}	=	d/2 +1/8				
			=	0.72	in	=	18.2	mm
		f_{actual}	=	2.56	in	=	65.0	mm
	f_{actual} is greater than f_{min} therefore selection O.K.							
10.3	Minimum Distance b/w vertical plates	g_{min}	=	d + 1				
			=	2.18	in	=	55.40	mm
	Used distance b/w vertical plates	g_{used}	=	5.91	in	=	150	mm
	g_{used} is greater than g_{min} therefore selection O.K.							
10.4	TOP PLATE:							
	Maximum Recommended Stress as per AISI	S_1	=	25	ksi		172.4	Mpa
	allowable stress of top plate of anchor chair	S_2	=	22	ksi	=	155.0	Mpa
	Maximum Stress for anchor chair top plate	S_{max}	=	22	ksi		155.0	Mpa

Considering Top-plate as a beam with partially fixed ends, with a portion of the total anchor bolt load distributed along part of span,

so, thickness calculated on Max. stress is,	c_{cal}	=	$\sqrt{(P/(S_{max} \times f_{actual}) \times (0.375 g_{used} - 0.22 d_R))}$					
		=	0.899	in		=	22.83	mm
Since,	0.787	<	0.899					

Used Top plate thickness is less than calculated, so increase Top plate thickness

10.5 Stress above the top of chair

Calculated max. stress, which is combination of bending & direct stress, S =

$$\frac{P\ x\ e}{t^2}\left[\frac{1.32\ x\ Z}{\frac{1.43\ x\ a\ x\ h^2}{R\ x\ t}+(4\ x\ a\ x\ h^2)^{0.333}}+\frac{0.031}{\sqrt{R\ x\ t}}\right]$$

Where, reduction factor,Z, is Z =

$$\frac{1.0}{\frac{0.177\ x\ a\ x\ m}{\sqrt{R\ x\ t}}\left(\frac{m}{t}\right)^2+1.0}$$

= 0.86

S = 56.78 Ksi > 25 Ksi

Actual calculated stress at Top-plate is more than used Max. recommended stress.

10.6 CHAIR HEIGHT

Used height of chair h = 9.843 in

Condition 1: Bottom thickness less than 0.375 in and governing case is seismic, than height of chair shall be greater or equal to 12 inch

Condition 2 : Bottom thickness less than 0.375 in and wind speed is greater than 100 mph, than height of chair shall be greater or equal to 12 inch.

Conclusion: As all the criteria of either of above conditions are not met, therefore

Minimum recommended chair height h_{min} = 6 in

Max. Recommended chair height h_{max} = 3a

= 35.43 in

Since, 9.843 > 6 O.K, as actual chair height exceeds the minimum required

9.84 < 35.43 O.K, as chair height is less the maximum recommended height

Used Chair height is satisfactory

10.7 VERTICAL SIDE PLATES / GUSSET PLATES:

Requirement 1

Min. recommended gusset plate thickness j_{min} = Max{ 0.5, [0.04x(h-c)] } *whichever is greater*

= 0.6 in = 14.300 mm

Actual gusset plate thickness j_{actual} = 0.8 in = 20 mm Satisfactory

Requirement 2

j x k >= P/25

5.25 > 0.80 Satisfactory

Gusset plate used is satisfactory

Requirement 3

L/r <= 86.6

Since, radius of gyration for gusset r = $\sqrt{(j^2/12)}$ Ref: Brownell & Young: Eq.10.42

= 0.23 in

And, height of gusset is L = 9.84 in

Then, 43.301 < 86.60

Gusset plate used is satisfactory

10.7 Loads on Weld :

Verical load

W_V = P/(a + 2h)

= 0.63 kips/in

W_H = Pxe/(a x h + 0.667 x h^2)

= 0.66 kips/in

W = $\sqrt{W_v^2 + W_H^2}$

= 0.91 kips/in

For weld size 0.24 in the allowable load therefore is,

9.6w ≥ W

Since, 2.27 ≥ 0.91

Weld size is O.K

11

Weight Summary

Part No.	Part List	Thicknesses / Size (mm)	Kg	KN	Part No.	Part List	Size
1	Shell Plates	12, 10, 10, 8, 8, 8, 6, 6, 6, 6, 6,	19,977	195.98			*Size M27 & Quantity 12 B.C.D 5310.625 mm*
2	Top compression Angle	100 x 100 x 10	244	2.39			
3	Intermediate Winder Girders/ Vacuum Stiffeners	N/A	0	0.00			
4	Staircase / Ladder (~)	-	400	3.92			
4	Shell Nozzles (~)	-	1,000	9.81			
5	Weight of anchor chairs		114	1.12			
	Total weight of Shell		22,235	213			
6	Roof plates	4.5	795	8			
7	Weight of roof support structure		109	1			
8	Roof appurtenanaces (~)	-	80	1			
	Total weight of Roof		983	10			
9	Bottom Plates(sketch plates)	10	1,760	17			
10	Annular Plates	N/A	0.00	0			
	Total Weight of Bottom		1,760	17			
	Total Empty Weight of Tank		24,979	245			
	weight of during hydrotest (full tank Ht)		466,406	4,575			
	weight of tank during operation with lquid uptill Design liquid level		598,819	5,874			