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CademPVD

Software for the Mechanical Design of Process Equipment

Equipment design experience since 1987 captured, polished and ready for transfer to designers, fabricators and plant engineers.

- **Intelligent, works with minimum inputs**
- **Generates final designs at estimation stage**
- **Saves costing and quotation making time**
- **High quality documentation with all formulae and relevant code clauses**
- **Time tested, proven & established**

Pressure Vessels
Reaction Vessels
Agitator Shafts
Heat Exchangers
Process Columns
Storage Tank
Floating Roof
Chimney

ASME Sec. VIII Div. 1
TEMA
IS 2825
EN 13445
EEUA
API 650
API 620
IS 6533

"CademPVD" is an integrated software encompassing all aspects of mechanical design of various process plant equipment. It is a very intelligent software and works with minimum inputs. For any data that is not provided by the user, the software uses the best possible estimates for them wherever possible. This makes the software very easy to use, thus greatly enhancing equipment design productivity.

eg: For a body flange of an equipment, none of the parameters like the Flange OD, Flange ID, PCD, Number and Size of bolts, Gasket OD & ID, etc. need to be specified. The software evaluates all these undefined parameters by itself, meeting the requirements of the specified equipment design code.

The software performs intricate calculations like design of tube plates, at just the click of a button, even for multiple design conditions.

In the software, the user defines the main features of the equipment. Any changes to the features of the model are automatically reflected in all other dependent components.

The software provides detailed design calculations with relevant code clauses and formulae. This facilitates easy obtaining of approvals. This high quality documentation supports ISO and other certification processes at the customer's end.

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Email: software@cadem.net
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Design of Process Equipment
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Design and Drawing Review
Power Plant and High Pressure Steam Piping Engineering

Pipe Stress Analysis
Structure Analysis and Design
Wind and Seismic Analysis
Finite Element Analysis

Preparation of Plot Plans
Preparation of Equipment Layouts
Piping Engineering and Designing
3D Models and Walkthroughs
Isometrics and BOM

We are an organization engaged in design of Process Equipment, Piping Engineering and Engineering Software development since 1987.

Our flagship software product, CademPVD, encompasses all aspects of mechanical design of shell and tube heat exchangers, pressure vessels, self supported columns and chimneys etc.

We undertake design and preparation of fabrication drawings for pressure vessels, reactors with agitator shafts, heat exchangers, storage tanks, tall towers, chimneys etc. as per various international and national codes like ASME Sec. VIII Div. I, TEMA, API 620, API 650, IS 2825, IS 803, IS 6533 etc.

We have wide experience in the field of detailed piping engineering of chemical, petrochemical, dairy & brewery plants. As part of piping engineering, we undertake preparation of plot plans, equipment layouts for process plants, utilities, tankfarms, piping layouts, isometrics, piping stress analysis, bill of materials, statutory requirements like factory inspector, IBR, CCOE drawings; and valve, piping, special materials specifications, stress analysis etc.

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Email: services@cadem.net
Website: www.cadem.net

EXAMPLE NO. PV-01

DESIGN OF PRESSURE VESSEL (GAS FILTER)

This example covers design of a simple pressure vessel. This pressure vessel has a top flat cover and a bottom dished end. The top cover is of bolted type and is connected to the shell through top body flange. The pressure vessel is provided with lugs support and lifting lug.

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Customer	ABC Company Ltd.
Project / Equipment	Soap Plant / PV-01 - Gas Filter
Designed By / Revision and Date	/ R00 , 24/Aug/2018 11:17:33

Index

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Customer	ABC Company Ltd.
Project	Soap Plant
Location	Vapi Site
Plant	Refrigeration Plant
EQUIPMENT INFORMATION :	
Design Code	ASME VIII Div.1, 15
Equipment Name	PV-01 - Gas Filter
Equipment Type	Pressure Vessel
Equipment Class	N.A.
Equipment Category	N.A.
Reference Drawing No	---
Service	Other Service
Support Type	Lug Supports
DESIGN & REVIEWAL :	
Designed By	
Design Date	24/Aug/2018 11:17:33
Checked By	
Approved By	
Revision	R00
INSPECTION & APPROVAL :	
Inspection Agency	---
Reviewed By	---
EQUIPMENT DATA :	
Front end	Flat End
Front end flanged	True
Rear end	Dished End
Rear end flanged	False
Shell ID	1250 mm
Shell OD	1274 mm
Length, Shell (W.L. to W.L) / Overall	1650 / 2122.8 mm
OTHER DATA :	
Fabricated weight (corr / uncorr)	2415.5 / 2660.6 kgf
Empty weight + external weights (corr / uncorr)	2415.5 / 2660.6 kgf
Estimated operating weight (corr / uncorr)	4789.1 / 5009.7 kgf
Estimated hydrotest weight (corr / uncorr)	4701.6 / 4922.3 kgf

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VESSEL DESIGN DATA

(1) PROCESS DETAILS :

	MEDIA	DENSITY kg/m³
Operating	Process	1000
Design1		1000
Design2		
Startup		
Shutdown		
Upset		
Hydrotest	Water	1000
Pneumatic	Air	1.2

(2) PR. : kgf/mm² g

		INT.	EXT.
Operating	0.12	0.12	0.01055
Design1	0.15	0.15	0.01055
Design2			
Startup			
Shutdown			
Upset			

(3) TEST PR. : kgf/mm² g

		Based on	
	Input Pr	MAWP	MAP
Hydrotest	0.195	0.195	0.195
Pneumatic	0.165	0.165	0.165

(4) TEMPERATURE : °C

	MIN.		MAX.
	Input	MDMT	
Operating	25	25	120
Design1	15	15	150
Design2			
Startup			
Shutdown			
Upset			
Hydrotest	21.67	21.67	45
Pneumatic	21.67	10	45

(5) ALLOWANCES : mm

	INT.	EXT.
Corrosion	3	0
Polishing	0	0

(6) RADIOGRAPHY & JOINT EFFICIENCY :

	RADIOGRAPHY	JOINT EFFICIENCY
Shell	Spot	0.85
Head	Full	1.00

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Project / Equipment	Soap Plant / PV-01 - Gas Filter
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VESSEL DESIGN DATA

1. MATERIAL OF CONSTRUCTION :

	Shell side
Shell	SA-516 GR. 70 Plt. [UNS:K02700]
Head	SA-516 GR. 70 Plt. [UNS:K02700]
Body flange	SA-105 Frg. [UNS:K03504]
Body flange cover	SA-105 Frg. [UNS:K03504]
Liner	

2. NOZZLE CONNECTIONS :

	Shell side
Nozzle neck <= NPS 40	SA-106 GR. B Smls. Pipe [UNS:K03006]
Flange	SA-105 Frg. [UNS:K03504]
Cover flange	SA-105 Frg. [UNS:K03504]
Nozzle NPS > 40 & < 200	SA-106 GR. B Smls. Pipe [UNS:K03006]
Flange	SA-105 Frg. [UNS:K03504]
Cover flange	SA-105 Frg. [UNS:K03504]
Nozzle neck >= NPS 200	SA-516 GR. 70 Plt. [UNS:K02700]
Flange	SA-516 GR. 70 Plt. [UNS:K02700]
Cover flange	SA-516 GR. 70 Plt. [UNS:K02700]
Pad flange	SA-516 GR. 70 Plt. [UNS:K02700]
Pad flange cover	SA-516 GR. 70 Plt. [UNS:K02700]
Manhole flange	SA-516 GR. 70 Plt. [UNS:K02700]
Manhole cover	SA-516 GR. 70 Plt. [UNS:K02700]
Reinforcement pad	SA-516 GR. 70 Plt. [UNS:K02700]
External bolt	SA-193 GR. B7 Bolt [UNS:G41400]
External gasket	CAF with suitable binder (3 mm.)
Stiffener	SA-516 GR. 70 Plt. [UNS:K02700]
Lifting lug	IS-2062 GR. A Plt.
Support	IS-2062 GR. A Plt.
Anchor bolt	Commercial CS Bolt

3. INSULATION & CLADDING:

Mat. / Density / Thk.	Rockwool (Mineral Fibre) / 136.2 kg/m³ / 40 mm
Mat. / Thk.	Al. sheet / 1.191 mm

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Designed By / Revision and Date	/ R00 , 24/Aug/2018 11:17:33

SUMMARY OF EFFECTIVE DESIGN PRESSURES IN kgf/mm² g VS TEMPERATURE IN °C

Sr.	Item name	Temp.	Inside pr.		Liquid pr.	Effective pr.	
No.			+ve	-ve		+ve	-ve
1	Bolted Cover (Front)	120	0.12	0.01055	0	0.12	0.01055
2	Shell Flng (Front)	120	0.12	0.01055	0	0.12	0.01055
3	Main Shell	120	0.12	0.01055	0	0.12	0.01055
4	Dished End (Rear)	120	0.12	0.01055	0	0.12	0.01055
5							

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Designed By / Revision and Date	/ R00 , 24/Aug/2018 11:17:33

ITEM WISE WEIGHT SUMMARY

Sr.No.	Item name	Item size	Empty wt	Volume	Filled wt
			kgf	m³	kgf
1	Bolted Cover (Front)	Blind Cover - 1463 OD x 84.304 Thk, RF, 1413 PCD, Tgrv = 1.588	1100.8	0	1100.8
2	Shell Flng (Front)	Plate Ring - 1463 OD x 1250 ID x 1413 PCD, RF, 119.522 Thk, Trgv = 1.588	423.7	0	423.7
3	Gasket Flng (Front)	1381.943 OD x 1250 ID, 3.175 Thk	0.1	0	0.1
4	Bolt Flng (Front)	Hex Head Bolt M22 x 240.751 Lg, 56 Nos.	40.57	0	40.57
5	Main Shell	1274 OD x 12 Thk, 1650 Lg	621.4	2.025	2646.3
6	Dished End (Rear)	Elliptical D/2H = 2.0, 1274 OD x 12 Nom / 10.8 Min Thk, SF = 50	203.2	0.317	520.3
7	Bolting Plate	222 Long x 200 Wide x 16 Thk, 4 Nos.	22.5	0	22.5
8	Gusset Plate	200 Long x 190 Wide x 16 Thk, 8 Nos.	38.51	0	38.51
9	Anchor Bolt	Anchor M20 x 200 Lg, 4 Nos.	1.99	0	1.99
10	Support Pad	275 Long x 272 Wide x 12 Thk, 4 Nos.	28.42	0	28.42
11	N 01	ANSIB36.10, 150 NPS Sch.80, 156 Lg	6.697	0.00262	9.32
12	Flange [N 01]	Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 80 Pipe	8.08	0	8.08
13	Gasket [N 01]	150 NPS x 150#, 3.175 Thk	0.1	0	0.1
14	Counter Flng [N 01]	Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 80 Pipe	8.08	0	8.08
15	Reinf [N 01]	292.659 OD x 171.275 ID x 12 Thk	4.202	0	4.202
16	N 02	ANSIB36.10, 150 NPS Sch.80, 156 Lg	6.697	0.00262	9.32
17	Flange [N 02]	Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 80 Pipe	8.08	0	8.08
18	Gasket [N 02]	150 NPS x 150#, 3.175 Thk	0.1	0	0.1
19	Counter Flng [N 02]	Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 80 Pipe	8.08	0	8.08
20	Reinf [N 02]	292.659 OD x 171.275 ID x 12 Thk	4.202	0	4.202
21	N 03	ANSIB36.10, 150 NPS Sch.160, 151 Lg	10.29	0.00206	12.35
22	Flange [N 03]	Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 160 Pipe	9.203	0	9.203

23	Gasket [N 03]	150 NPS x 150#, 3.175 Thk	0.1	0	0.1
24	Bolted Cover [N 03]	Blind Cover, ANSI B16.5, RF, 150# for 150 NPS Pipe	11.56	0	11.56
25	Reinf [N 03]	263.5 OD x 171.275 ID x 12 Thk	2.992	0	2.992
26	Lifting Lugs	120 Long x 70 Wide x 14 Thk, 2 Nos.	1.862	0	1.862
27	Pad (Lifting Lugs)	70 Long x 170 Wide x 8 Thk, 2 Nos.	1.507	0	1.507
28	Insulation	4178.318 W x 3622.804 L, 40 Thk	82.44	0	82.44
29	Cladding	4182.059 W x 3622.804 L, 1.191 Thk	4.993	0	4.993
30					
31					
32					
33					
34					
35					
		∑	2660.6	∑	4922.3

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WIND LOAD CALCULATION

CODE			**Wind [IS:875, 87]**

1. DESIGN CONDITIONS (Operating Mode , Corroded Condition) :

Basic wind speed	(Section 5.2)	Vb	50 m/s
Expected life of equipment	(Section 5.3.1)		25 Years
Probability factor (Risk coeff)	(Section 5.3.1)	K1	0.902
Terrain category	(Section 5.3.2)		Category 2
Structure class	(Section 5.3.2.2)		Class B
Topography factor	(Section 5.3.3)	K3	1.3
Force coefficient (Shape factor)		Cf	0.8

3. CALCULATION OF FORCES AND MOMENTS:

Equivalent diameter		De	1862 mm
Overall length of equipment		L	2122.8 mm
Height of C.G. of equipment		Hcg	1738.9 mm
Size and height factor	(Section 5.3.2)	K2	0.98
Effective transverse cross sectional area			
= De x L		A	3952660.7 mm²
Effective wind speed			
= K1 x K2 x K3 x Vb		Vz	57.44 m/s
Wind pressure			
= 6E-08 x Vz^2		Pz	0.0002 kgf/mm²
Longitudinal force			
= Cf x A x Pz		F	626.1 kgf
Support elevation		H	474.5 mm
Turning moment			
= F x (Hcg - H)		M	791596.4 kgf-mm

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SEISMIC LOAD CALCULATION

CODE — **Seismic [IS:1893, 02]**

1. DESIGN CONDITIONS (Operating Mode , Corroded Condition) :

Weight of equipment		Wo	4789.1 kgf
Importance factor	(Table-6 , 2002)	I	1.5
Soil profile type			Stiff Soil Profile (SD)
Foundation type			RCC footings + Tie Beams
Damping factor			5
Seismic zone			Zone III
Seismic zone factor	(Table-2 , 2002)	Z	0.16
Response reduction factor	(Table-7 , 2002)	R	2.9
Spectral accelerations coeff.	(Fig. 2 , 2002)	Sa / g	2.5, Use max value
Damping correction factor	(Table-3 , 2002)	Cf	1
Seismic coefficient	(Clause-6.4.2 , 2002)		
= 0.5 x Z x I x Cf x (Sa / g) x (1 / R)			
= 0.5 x 0.16 x 1.5 x 1 x			
2.5 x (1 / 2.9)		Ah	0.103

2. CALCULATION OF FORCES AND MOMENTS:

Elevation of support	H	474.5 mm
Height of C.G. of equipment	Hcg	1381.1 mm
Seismic base shear force		
= Ah x Wo		
= 0.103 x 4789.1	Vb	433.7 kgf
Seismic moment of support		
= Vb x (Hcg - H)		
= 433.7 x (1381.1 - 474.5)	M	393227.8 kgf-mm

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Customer		ABC Company Ltd.
Project / Equipment		Soap Plant / PV-01 - Gas Filter
Designed By / Revision and Date		/ R00 , 24/Aug/2018 11:17:33
DESIGN OF FLAT BOLTED HEAD (INTERNAL)		**Bolted Cover (Front)**
CODE		**ASME VIII Div.1, 15**

1. DESIGN CONDITIONS (Operating Mode , Corroded Condition) :

Design pressure	P	0.12 kgf/mm² g
Design temperature	T	120 °C
Allowance	CA	3 mm
Groove allowance	Tg	0 mm
Radiography		Full
Joint efficiency	E	1

2. COVER DATA :

M.O.C.		SA-105 Frg. [UNS:K03504]
Code allw. stress @ design temp.	Sfo	14.06 kgf/mm²
Code allw. stress @ atm. temp.	Sfa	14.06 kgf/mm²
Young's modulus	Ey	20079.7 kgf/mm²
Self reinforced		False
Flange OD	A	1463 mm
Thickness provided		84.3 mm
Thickness available		81.3 mm

3. BOLTING DATA :

M.O.C.		SA-193 GR. B7 Bolt [UNS:G41400]
Code allw. stress @ design temp.	Sb	17.58 kgf/mm²
Code allw. stress @ atm. temp.	Sa	17.58 kgf/mm²
Bolt PCD	PCD	1413 mm
Bolt dia.	db	22 mm
No. of bolts	nb	56

4. LINER DATA :

M.O.C.		
Liner ID		mm
Liner OD		mm
Liner thk.		mm

5. GASKET DATA :

M.O.C.			CAF with suitable binder (3 mm.)
Gasket seating stress		y	1.125 kgf/mm²
Gasket factor		m	2
Inside diameter		Gi	1256 mm
Outside diameter		Go	1381.9 mm
Width of gasket		N	62.97 mm
Width of gasket	(as per Table 2-5.2)		31.75 mm
Basic gasket seating width	(as per Table 2-5.2)	b0	31.49 mm
Effective gasket width	(as per Table 2-5.2)	b	14.14 mm
Dia. at load reaction	(see Table 2-5.2)	G	1353.7 mm
Pass partition gasket width		Wp	0 mm
Pass partition gasket length		Lp	0 mm
Effective pass partition gasket width		b'	0 mm

6. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b1) :

Total joint - contact surface compression load [Hp]
= 2 x (π x b x G + b' x Lp) x m x P
= 2 x (π x 14.14 x 1353.7 + 0 x 0) x 2 x 0.12
= 28863.3 kgf
Total hydrostatic end force [H]
= 0.25 x π x G ^{2} x P
= 0.25 x π x 1353.7 ^{2} x 0.12
= 172700.1 kgf
Minimum required bolt load for operating condition [Wm1]
= Hp + H
= 28863.3 + 172700.1
= 201563.5 kgf

7. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b2) :

Minimum required bolt load for gasket seating [Wm2]
= (π x b x G + b' x Lp) x y
= (π x 14.14 x 1353.7 + 0 x 0) x 1.125
= 67643.1 kgf

8. BOLT AREAS AS PER APPENDIX 2-5 (d) :

Total required cross-sectional area of bolts [Am]
= MAX [Wm2 / Sa , Wm1 / Sb] .... For Internal '+' Pr Design
= Wm2 / Sa .... For External Pr & Self Sealing Design
= 11467.6 mm²
Actual bolt area using root diameter [Ab]
= 15255.5 mm²
Flange design bolt load for the gasket seating [W]
= 0.5 x (Am + Ab) x Sa x 1 .... average bolt area
= Ab x Sa x 1 ....full bolt area
= 234852.5 kgf (Avg. bolt area and margin factor of 1)

9. CHECK FOR GASKET CRUSHING :

Minimum gasket width required [Nmin]
= Ab x Sb / (2 x π x y x G)
= 15255.5 x 17.58 / (2 x π x 1.125 x 1353.7)
= 28.03 mm

10. DESIGN CALCULATION AS PER UG 34

Self reinforced		False
Factor C is user input		False
Factor C taken from fig. UG 34 or user input	C	0.3
Factor, 2 $^{0.5}$ for self reinf. cover, otherwise 1	F	1

Required thickness for bolting condition [t]
= G x F x SQRT [1.9 x W x 0.5 x (PCD - G) / (Sfa x E x G ^{3})]
= 1353.7 x 1 x SQRT [1.9 x 234852.5 x 0.5 x (1413 - 1353.7) / (14.06 x 1 x 1353.7 ^{3})]
= 26.37 mm
Required thickness for operating condition [t]
= G x F x SQRT { [C x P / (Sfo x E)] + 1.9 x Wm1 x 0.5 x (PCD - G) / (Sfo x E x G ^{3}) }
= 1353.7 x 1 x SQRT { [0.3 x 0.12 / (14.06 x 1)] + 1.9 x 201563.5 x 0.5 x (1413 - 1353.7) /
(14.06 x 1 x 1353.7 ^{3}) }
= 72.72 mm

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DESIGN OF FLAT BOLTED HEAD (EXTERNAL)			**Bolted Cover (Front)**
CODE			**ASME VIII Div.1, 15**

1. DESIGN CONDITIONS (Operating Mode , Corroded Condition) :

Design pressure		P	0.01055 kgf/mm² g
Design temperature		T	120 °C
Allowance		CA	3 mm
Groove allowance		Tg	0 mm
Radiography			Full
Joint efficiency		E	1

2. COVER DATA :

M.O.C.			SA-105 Frg. [UNS:K03504]
Code allw. stress @ design temp.		Sfo	14.06 kgf/mm²
Code allw. stress @ atm. temp.		Sfa	14.06 kgf/mm²
Young's modulus		Ey	20079.7 kgf/mm²
Self reinforced			False
Flange OD		A	1463 mm
Thickness provided			84.3 mm
Thickness available			81.3 mm

3. BOLTING DATA :

M.O.C.			SA-193 GR. B7 Bolt [UNS:G41400]
Code allw. stress @ design temp.		Sb	17.58 kgf/mm²
Code allw. stress @ atm. temp.		Sa	17.58 kgf/mm²
Bolt PCD		PCD	1413 mm
Bolt dia.		db	22 mm
No. of bolts		nb	56

4. LINER DATA :

M.O.C.			
Liner ID			mm
Liner OD			mm
Liner thk.			mm

5. GASKET DATA :

M.O.C.			CAF with suitable binder (3 mm.)
Gasket seating stress		y	1.125 kgf/mm²
Gasket factor		m	2
Inside diameter		Gi	1256 mm
Outside diameter		Go	1381.9 mm
Width of gasket		N	62.97 mm
Width of gasket	(as per Table 2-5.2)		31.75 mm
Basic gasket seating width	(as per Table 2-5.2)	b0	31.49 mm
Effective gasket width	(as per Table 2-5.2)	b	14.14 mm
Dia. at load reaction	(see Table 2-5.2)	G	1353.7 mm
Pass partition gasket width		Wp	0 mm
Pass partition gasket length		Lp	0 mm
Effective pass partition gasket width		b'	0 mm

6. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b1) :

Total joint - contact surface compression load [Hp]
= 2 x (π x b x G + b' x Lp) x m x P
= 2 x (π x 14.14 x 1353.7 + 0 x 0) x 2 x 0.01055
= 2536.6 kgf
Total hydrostatic end force [H]
= 0.25 x π x G ^{2} x P
= 0.25 x π x 1353.7 ^{2} x 0.01055
= 15177.5 kgf
Minimum required bolt load for operating condition [Wm1]
= Hp + H
= 2536.6 + 15177.5
= 17714.1 kgf

7. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b2) :

Minimum required bolt load for gasket seating [Wm2]
= (π x b x G + b' x Lp) x y
= (π x 14.14 x 1353.7 + 0 x 0) x 1.125
= 67643.1 kgf

8. BOLT AREAS AS PER APPENDIX 2-5 (d) :

Total required cross-sectional area of bolts [Am]
= MAX [Wm2 / Sa , Wm1 / Sb] .... For Internal '+' Pr Design
= Wm2 / Sa .... For External Pr & Self Sealing Design
= 3848.4 mm²
Actual bolt area using root diameter [Ab]
= 15255.5 mm²
Flange design bolt load for the gasket seating [W]
= 0.5 x (Am + Ab) x Sa x 1 .... average bolt area
= Ab x Sa x 1 ....full bolt area
= 167892.3 kgf (Avg. bolt area and margin factor of 1)

9. CHECK FOR GASKET CRUSHING :

Minimum gasket width required [Nmin]
= Ab x Sb / (2 x π x y x G)
= 15255.5 x 17.58 / (2 x π x 1.125 x 1353.7)
= 28.03 mm

10. DESIGN CALCULATION AS PER UG 34

Self reinforced		False
Factor C is user input		False
Factor C taken from fig. UG 34 or user input	C	0.3
Factor, 2 $^{0.5}$ for self reinf. cover, otherwise 1	F	1

Required thickness for bolting condition [t]
= G x F x SQRT [1.9 x W x 0.5 x (PCD - G) / (Sfa x E x G ^{3})]
= 1353.7 x 1 x SQRT [1.9 x 167892.3 x 0.5 x (1413 - 1353.7) / (14.06 x 1 x 1353.7 ^{3})]
= 26.37 mm
Required thickness for operating condition [t]
= G x F x SQRT { [C x P / (Sfo x E)] + 1.9 x Wm1 x 0.5 x (PCD - G) / (Sfo x E x G ^{3}) }
= 1353.7 x 1 x SQRT { [0.3 x 0.01055 / (14.06 x 1)] + 1.9 x 17714.1 x 0.5 x (1413 - 1353.7) /
(14.06 x 1 x 1353.7 ^{3}) }
= 31.77 mm

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Project / Equipment		Soap Plant / PV-01 - Gas Filter
Designed By / Revision and Date		/ R00 , 24/Aug/2018 11:17:33
FLANGE DESIGN (INTERNAL)		**Shell Flng (Front)**
CODE		**ASME VIII Div.1, 15**

1. DESIGN CONDITIONS (Operating Mode , Corroded Condition) :

Design pressure	P	0.12 kgf/mm² g
Design temperature	T	120 °C
Allowance	CA	3 mm
Groove allowance	Tg	0 mm

2. FLANGE DATA :

M.O.C.		SA-105 Frg. [UNS:K03504]
Code allw. stress @ design temp.	Sfo	14.06 kgf/mm²
Code allw. stress @ atm. temp.	Sfa	14.06 kgf/mm²
Inside diameter	B	1256 mm
Outside diameter	A	1463 mm
Hub length	h	12 mm
Thickness (hub end)	g1	21 mm
Thickness (pipe end)	g0	9 mm
Thickness provided		119.5 mm
Thickness available		116.5 mm

3. BOLTING DATA :

M.O.C.		SA-193 GR. B7 Bolt [UNS:G41400]
Code allw. stress @ design temp.	Sb	17.58 kgf/mm²
Code allw. stress @ atm. temp.	Sa	17.58 kgf/mm²
Bolt PCD	C	1413 mm
Bolt dia.	db	22 mm
No. of bolts	nb	56

4. LINER DATA :

M.O.C.		
Liner ID		mm
Liner OD		mm
Liner thk.		mm

5. GASKET DATA :

5a. Flange gasket data :

M.O.C.			CAF with suitable binder (3 mm.)
Gasket type			Ring Gasket
Gasket confinement type			Unconfined
Flange face type			Raised Face
Flange gasket surface finish			Serrated (Normal)
Counter flange face type			Raised Face
Counter gasket surface finish			Serrated (Normal)
Applicable gasket sketch in Table 2-5.2			Type 1B
Applicable gasket column in Table 2-5.2			1
Gasket seating stress	(refer to Note 1, Table 2-5.1)	y	1.125 kgf/mm²
Gasket factor	(from Table 2-5.1)	m	2
Inside diameter		Gi	1256 mm
Outside diameter		Go	1381.9 mm
Width of gasket	(as per Table 2-5.2)	N	62.97 mm

Width of gasket	(as per Table 2-5.2)	w	62.97 mm
Width of raised face or gasket contact width			31.75 mm
	(as per Table 2-5.2)		
Basic gasket seating width	(as per Table 2-5.2)	b0	31.49 mm
Effective gasket width	(as per Table 2-5.2)	b	14.14 mm
Dia. at load reaction	(see Table 2-5.2)	G	1353.7 mm

5b. Partition groove gasket data (For H.E. body flange) :

M.O.C.			--
Gasket seating stress	(refer to Note 1, Table 2-5.1)	y'	0 kgf/mm²
Gasket factor	(from Table 2-5.1)	m'	0
Pass partition gasket width		Wp	0 mm
Pass partition gasket length		Lp	0 mm
Effective pass partition gasket width		b'	0 mm

6. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b1)

Total joint - contact surface compression load [Hp]
= 2 x (π x b x G x m + b' x Lp x m') x P
= 2 x (π x 14.14 x 1353.7 x 2 + 0 x 0 x 0) x 0.12
= 28863.3 kgf
Total hydrostatic end force [H]
= 0.25 x π x G ² x P
= 0.25 x π x 1353.7 ² x 0.12
= 172700.1 kgf
Minimum required bolt load for operating condition [Wm1a]
= Hp + H
= 28863.3 + 172700.1
= 201563.5 kgf
Minimum required bolt load for operating condition [Wm1b]
(from mating flange)
= 201563.5 kgf
Governing bolt load for operating condition [Wm1]
= MAX [Wm1a , Wm1b]
= MAX [201563.5 , 201563.5]
= 201563.5 kgf

7. BOLT LOAD CALCULATION AS PER APPENDIX 2-5 (b2)

Minimum required bolt load for gasket seating [Wm2]
= (π x b x G x y + b' x Lp x y')
= (π x 14.14 x 1353.7 x 1.125 + 0 x 0 x 0)
= 67643.1 kgf

8. BOLT AREAS AS PER APPENDIX 2-5 (d)

Total required cross-sectional area of bolts [Am]
= MAX [Wm2 / Sa , Wm1 / Sb] .... For Internal '+' Pr Design
= Wm2 / Sa .... For External Pr & Self Sealing Design
= 11467.6 mm²
Actual bolt area using root diameter [Ab]
= 15255.5 mm²
Flange design bolt load for the gasket seating [W]
= 0.5 x (Am + Ab) x Sa x 1 .... average bolt area
= Ab x Sa x 1 ....full bolt area
= 234852.5 kgf (Avg. bolt area and margin factor of 1)

9. CHECK FOR GASKET CRUSHING

Minimum gasket width required [Nmin]
= Ab x Sb / (2 x π x y x G)
= 15255.5 x 17.58 / (2 x π x 1.125 x 1353.7)
= 28.03 mm

10. BOLT SPACING CORRECTION FACTOR

As per Brownell & Young or IS 2825,
= SQRT [Bolt spacing / (2 x db + t)]
As per TEMA or BS 5500,
= SQRT [Bolt spacing / Bmax] .... where,

Bmax = maximum recommended bolt spacing = 2 x db + 6 x t / (m + 0.5)
Code Select, Cf = 1 (min. equal to 1)

INTEGRAL FLANGE DESIGN **Shell Flng (Front)**

11. LOADS AND FORCES DURING OPERATING CONDITION AS PER APPENDIX 2-3

Hydrostatic end force on area inside of flange [HD]
= 0.25 x π x B ^{2} x P
= 0.25 x π x 1256 ^{2} x 0.12
= 148679.3 kgf
Gasket load (difference between flange design bolt load and total hydrostatic end force) [HG]
= Wm1 - H
= 201563.5 - 172700.1
= 28863.3 kgf
Difference between total hydrostatic end force and hydrostatic end force on area inside of flange [HT]
= H - HD
= 172700.1 - 148679.3
= 24020.9 kgf

12. MOMENT ARMS FOR FLANGE LOADS AS PER TABLE 2-6

Radial distance from the bolt circle to intersection of hub and back of flange, as per Appendix 2-3 [R]
= 0.5 x (C - B) - g1
= 0.5 x (1413 - 1256) - 21
= 57.5 mm
Radial distance from the bolt circle to the circle on which HD acts [hD]
= R + 0.5 x g1
= 57.5 + 0.5 x 21
= 68 mm
Radial distance from gasket load reaction to the bolt circle [hG]
= 0.5 x (C - G)
= 0.5 x (1413 - 1353.7)
= 29.67 mm
Radial distance from the bolt circle to the circle on which HT acts [hT]
= 0.5 x (R + g1 + hG)
= 0.5 x (57.5 + 21 + 29.67)
= 54.08 mm

13. FLANGE MOMENTS UNDER OPERATING CONDITION AS PER APPENDIX 2-6

Component of moment due to HD [MD]
= HD x hD
= 148679.3 x 68
= 10110190 kgf-mm
Component of moment due to HG [MG]
= HG x hG
= 28863.3 x 29.67
= 856321.7 kgf-mm
Component of moment due to HT [MT]
= HT x hT
= 24020.9 x 54.08
= 1299146.8 kgf-mm
Total moment acting on the flange for operating condition [MO]
= MD + MG + MT
= 10110190 + 856321.7 + 1299146.8
= 12265658.5 kgf-mm

14. LOADS AND FORCES DURING GASKET SEATING AS PER APPENDIX 2-3

Gasket load for seating condition [HG]
= W
= 234852.5 kgf

15. MOMENT UNDER GASKET SEATING AS PER APPENDIX 2-6

Total moment acting on the flange for gasket seating [MO']
= W x hG
= 234852.5 x 29.67
= 6967639.1 kgf-mm

16. SHAPE CONSTANTS

A / B K 1.165

Flange factors from Fig. 2-7.1	T	1.853
	Z	6.606
	Y	12.8
	U	14.06
h0		106.3
F / h0	e	0.00849
Factor from Fig. 2-7.2	F	0.903
Factor from Fig. 2-7.3	V	0.417
g1 / g0		2.333
h / h0		0.113
(U / V) x h0 x $g0^2$	d	290617.3
Factor from Fig. 2-7.6	f	4.354

17. STRESS FORMULA FACTORS

Assumed thickness [t]
= 106.2 mm
Factor [α]
= t x e + 1
= 106.2 x 0.00849 + 1
= 1.902
Factor [β]
= 1.333 x t x e + 1
= 1.333 x 106.2 x 0.00849 + 1
= 2.202
Factor [γ]
= α / T
= 1.902 / 1.853
= 1.026
Factor [δ]
= t^3 / d
= 106.2^3 / 290617.3
= 4.12
Factor [λ]
= $\gamma + \delta$
= 1.026 + 4.12
= 5.147

18. FLANGE STRESSES AS PER APPENDIX 2-7 & 2-8

Equivalent moment [Mmax]
= MAX [MO , MO' x Sfo / Sfa]
= MAX [12265658.5 , 6967639.1 x 14.06 / 14.06]
= 12265658.5 kgf-mm
Corrected equivalent moment per unit length [M]
= Mmax x (Cf / B)
= 12265658.5 x (1 / 1256)
= 9765.7 kgf
Longitudinal hub stress [SH]
= f x M / (λ x $g1^2$)
= 4.354 x 9765.7 / (5.147 x 21^2)
= 18.73 kgf/mm² .... < 1.5 x Sfo
Radial flange stress [SR]
= β x M / (λ x t^2)
= 2.202 x 9765.7 / (5.147 x 106.2^2)
= 0.371 kgf/mm² .... < Sfo
Tangential flange stress [ST]
= (M x Y / t^2) - Z x SR
= (9765.7 x 12.8 / 106.2^2) - 6.606 x 0.371
= 8.633 kgf/mm² .... < Sfo
Average stress

= MAX [0.5 x (SH + SR) , 0.5 x (SH + ST)]
= MAX [0.5 x (18.73 + 0.371) , 0.5 x (18.73 + 8.633)]
= 13.68 kgf/mm² .... < Sfo

19. FLANGE RIGIDITY CHECKING AS PER APPENDIX 2-14

Modulus of elasticity for flange	Efo	20079.7 kgf/mm²
Rigidity factor	KI	0.3

Rigidity index [J]
= 52.14 x V x Mmax / (λ x Efo x $g0^2$ x KI x h0)
= 52.14 x 0.417 x 12265658.5 / (5.147 x 20079.7 x 9^2 x 0.3 x 106.3)
= 0.998
Since J < 1.0, design is safe

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FLANGE DESIGN (EXTERNAL)		**Shell Flng (Front)**
CODE		**ASME VIII Div.1, 15**

1. DESIGN CONDITIONS (Operating Mode , Corroded Condition) :

Design pressure	P	0.01055 kgf/mm² g
Design temperature	T	120 °C
Allowance	CA	3 mm
Groove allowance	Tg	0 mm

2. FLANGE DATA :

M.O.C.		SA-105 Frg. [UNS:K03504]
Code allw. stress @ design temp.	Sfo	14.06 kgf/mm²
Code allw. stress @ atm. temp.	Sfa	14.06 kgf/mm²
Inside diameter	B	1256 mm
Outside diameter	A	1463 mm
Hub length	h	12 mm
Thickness (hub end)	g1	21 mm
Thickness (pipe end)	g0	9 mm
Thickness provided		119.5 mm
Thickness available		116.5 mm

3. BOLTING DATA :

M.O.C.		SA-193 GR. B7 Bolt [UNS:G41400]
Code allw. stress @ design temp.	Sb	17.58 kgf/mm²
Code allw. stress @ atm. temp.	Sa	17.58 kgf/mm²
Bolt PCD	C	1413 mm
Bolt dia.	db	22 mm
No. of bolts	nb	56

4. LINER DATA :

M.O.C.		
Liner ID		mm
Liner OD		mm
Liner thk.		mm

5. GASKET DATA :

5a. Flange gasket data :

M.O.C.			CAF with suitable binder (3 mm.)
Gasket type			Ring Gasket
Gasket confinement type			Unconfined
Flange face type			Raised Face
Flange gasket surface finish			Serrated (Normal)
Counter flange face type			Raised Face
Counter gasket surface finish			Serrated (Normal)
Applicable gasket sketch in Table 2-5.2			Type 1B
Applicable gasket column in Table 2-5.2			1
Gasket seating stress	(refer to Note 1, Table 2-5.1)	y	1.125 kgf/mm²
Gasket factor	(from Table 2-5.1)	m	2
Inside diameter		Gi	1256 mm
Outside diameter		Go	1381.9 mm
Width of gasket	(as per Table 2-5.2)	N	62.97 mm

Width of gasket	(as per Table 2-5.2)	w	62.97 mm
Width of raised face or gasket contact width	(as per Table 2-5.2)		31.75 mm
Basic gasket seating width	(as per Table 2-5.2)	b0	31.49 mm
Effective gasket width	(as per Table 2-5.2)	b	14.14 mm
Dia. at load reaction	(see Table 2-5.2)	G	1353.7 mm

5b. Partition groove gasket data (For H.E. body flange) :

M.O.C.			--
Gasket seating stress	(refer to Note 1, Table 2-5.1)	y'	0 kgf/mm²
Gasket factor	(from Table 2-5.1)	m'	0
Pass partition gasket width		Wp	0 mm
Pass partition gasket length		Lp	0 mm
Effective pass partition gasket width		b'	0 mm

6. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b1)

Total joint - contact surface compression load [Hp]
= 2 x (π x b x G x m + b' x Lp x m') x P
= 2 x (π x 14.14 x 1353.7 x 2 + 0 x 0 x 0) x 0.01055
= 2536.6 kgf
Total hydrostatic end force [H]
= 0.25 x π x G ² x P
= 0.25 x π x 1353.7 ² x 0.01055
= 15177.5 kgf
Minimum required bolt load for operating condition [Wm1a]
= Hp + H
= 2536.6 + 15177.5
= 17714.1 kgf
Minimum required bolt load for operating condition [Wm1b]
(from mating flange)
= 17714.1 kgf
Governing bolt load for operating condition [Wm1]
= MAX [Wm1a , Wm1b]
= MAX [17714.1 , 17714.1]
= 17714.1 kgf

7. BOLT LOAD CALCULATION AS PER APPENDIX 2-5 (b2)

Minimum required bolt load for gasket seating [Wm2]
= (π x b x G x y + b' x Lp x y')
= (π x 14.14 x 1353.7 x 1.125 + 0 x 0 x 0)
= 67643.1 kgf

8. BOLT AREAS AS PER APPENDIX 2-5 (d)

Total required cross-sectional area of bolts [Am]
= MAX [Wm2 / Sa , Wm1 / Sb] .... For Internal '+' Pr Design
= Wm2 / Sa .... For External Pr & Self Sealing Design
= 3848.4 mm²
Actual bolt area using root diameter [Ab]
= 15255.5 mm²
Flange design bolt load for the gasket seating [W]
= 0.5 x (Am + Ab) x Sa x 1 .... average bolt area
= Ab x Sa x 1 ....full bolt area
= 167892.3 kgf (Avg. bolt area and margin factor of 1)

9. CHECK FOR GASKET CRUSHING

Minimum gasket width required [Nmin]
= Ab x Sb / (2 x π x y x G)
= 15255.5 x 17.58 / (2 x π x 1.125 x 1353.7)
= 28.03 mm

10. BOLT SPACING CORRECTION FACTOR

As per Brownell & Young or IS 2825,
= SQRT [Bolt spacing / (2 x db + t)]
As per TEMA or BS 5500,
= SQRT [Bolt spacing / Bmax] .... where,

Bmax = maximum recommended bolt spacing = 2 x db + 6 x t / (m + 0.5)
Code Select, Cf = 1 (min. equal to 1)

INTEGRAL FLANGE DESIGN **Shell Flng (Front)**

11. LOADS AND FORCES DURING OPERATING CONDITION AS PER APPENDIX 2-3

Hydrostatic end force on area inside of flange [HD]
= 0.25 x π x B ^{2} x P
= 0.25 x π x 1256 ^{2} x 0.01055
= 13066.4 kgf
Difference between total hydrostatic end force and hydrostatic end force on area inside of flange [HT]
= H - HD
= 15177.5 - 13066.4
= 2111 kgf

12. MOMENT ARMS FOR FLANGE LOADS AS PER APPENDIX TABLE 2-6

Radial distance from the bolt circle to intersection of hub and back of flange, as per Appendix 2-3 [R]
= 0.5 x (C - B) - g1
= 0.5 x (1413 - 1256) - 21
= 57.5 mm
Radial distance from the bolt circle to the circle on which HD acts [hD]
= R + 0.5 x g1
= 57.5 + 0.5 x 21
= 68 mm
Radial distance from gasket load reaction to the bolt circle [hG]
= 0.5 x (C - G)
= 0.5 x (1413 - 1353.7)
= 29.67 mm
Radial distance from the bolt circle to the circle on which HT acts [hT]
= 0.5 x (R + g1 + hG)
= 0.5 x (57.5 + 21 + 29.67)
= 54.08 mm

13. FLANGE MOMENTS UNDER OPERATING CONDITION AS PER APPENDIX 2-6

Component of moment due to HD [MD]
= HD x (hD - hG)
= 13066.4 x (68 - 29.67)
= 500860.4 kgf-mm
Component of moment due to HT [MT]
= HT x (hT - hG)
= 2111 x (54.08 - 29.67)
= 51542.9 kgf-mm
Total moment acting on the flange for operating condition [MO]
= MD + MT
= 500860.4 + 51542.9
= 552403.2 kgf-mm

14. LOADS AND FORCES DURING GASKET SEATING AS PER APPENDIX 2-3

Gasket load for seating condition [HG]
= W
= 167892.3 kgf

15. MOMENT UNDER GASKET SEATING AS PER APPENDIX 2-6

Total moment acting on the flange for gasket seating [MO']
= W x hG
= 167892.3 x 29.67
= 4981054.6 kgf-mm

16. SHAPE CONSTANTS

A / B	K	1.165
Flange factors from Fig. 2-7.1	T	1.853
	Z	6.606
	Y	12.8
	U	14.06
h0		106.3
F / h0	e	0.00849

Factor from Fig. 2-7.2	F	0.903
Factor from Fig. 2-7.3	V	0.417
g1 / g0		2.333
h / h0		0.113
(U / V) x h0 x g0 ^{2}	d	290617.3
Factor from Fig. 2-7.6	f	4.354

17. STRESS FORMULA FACTORS

Assumed thickness [t]
= 70.88 mm
Factor [α]
= t x e + 1
= 70.88 x 0.00849 + 1
= 1.602
Factor [β]
= 1.333 x t x e + 1
= 1.333 x 70.88 x 0.00849 + 1
= 1.803
Factor [γ]
= α / T
= 1.602 / 1.853
= 0.865
Factor [δ]
= t ^{3} / d
= 70.88 ^{3} / 290617.3
= 1.225
Factor [λ]
= γ + δ
= 0.865 + 1.225
= 2.09

18. FLANGE STRESSES AS PER APPENDIX 2-7 & 2-8

Equivalent moment [Mmax]
= MAX [MO , MO' x Sfo / Sfa]
= MAX [552403.2 , 4981054.6 x 14.06 / 14.06]
= 4981054.6 kgf-mm
Corrected equivalent moment per unit length [M]
= Mmax x (Cf / B)
= 4981054.6 x (1 / 1256)
= 3965.8 kgf
Longitudinal hub stress [SH]
= f x M / (λ x g1 ^{2})
= 4.354 x 3965.8 / (2.09 x 21 ^{2})
= 18.74 kgf/mm² .... < 1.5 x Sfo
Radial flange stress [SR]
= β x M / (λ x t ^{2})
= 1.602 x 3965.8 / (2.09 x 70.88 ^{2})
= 0.681 kgf/mm² .... < Sfo
Tangential flange stress [ST]
= (M x Y / t ^{2}) - Z x SR
= (3965.8 x 12.8 / 70.88 ^{2}) - 6.606 x 0.681
= 5.603 kgf/mm² .... < Sfo
Average stress
= MAX [0.5 x (SH + SR) , 0.5 x (SH + ST)]
= MAX [0.5 x (18.74 + 0.681) , 0.5 x (18.74 + 5.603)]
= 12.17 kgf/mm² .... < Sfo

19. FLANGE RIGIDITY CHECKING AS PER APPENDIX AS PER 2-14

Modulus of elasticity for flange	Efo	20079.7 kgf/mm²
Rigidity factor	KI	0.3

Rigidity index [J]

$= 52.14 \times V \times Mmax / (\lambda \times Efo \times g0^2 \times KI \times h0)$

$= 52.14 \times 0.417 \times 4981054.6 / (2.09 \times 20079.7 \times 9^2 \times 0.3 \times 106.3)$

$= 0.998$

Since $J < 1.0$, design is safe

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Designed By / Revision and Date	/ R00 , 24/Aug/2018 11:17:33
DESIGN OF SHELL (INTERNAL AND EXTERNAL PRESSURE)	**Main Shell**
CODE	**ASME VIII Div.1, 15**

1. DESIGN CONDITIONS (Operating Mode , Corroded Condition)

Design pressure (internal)	Pi	0.12 kgf/mm² g
Design pressure (external)	Pe	0.01055 kgf/mm² g
Design temperature	T	120 °C
Material of construction		SA-516 GR. 70 Plt. [UNS:K02700]
Max. allowable stress at design temp.	S	14.06 kgf/mm²
Radiography		Spot
Joint efficiency long. seam	Ec	0.85
Outside diameter	OD	1274 mm
Inside radius (corroded)	R	628 mm
Shell length	L	1650 mm
Design length	L1	1650 mm
Nominal thickness		12 mm
Nominal thickness required as per TEMA		N.A. mm
Internal allowance, corrosion + polishing		3 mm
External allowance, corrosion + polishing		0 mm
Thickness undertolerance		0 mm
Available thickness		9 mm

2. DESIGN CALCULATION AS PER UG-27

Thickness of shell under internal pressure [ti]
= Pi x R / (S x E - 0.6 x Pi)
= 0.12 x 628 / (14.06 x 0.85 - 0.6 x 0.12)
= 6.343 mm

3. DESIGN CALCULATION OF SHELL THICKNESS UNDER EXTERNAL PRESSURE AS PER UG-28

Assumed te	4.506 mm
L1 / OD	1.295
OD / te	282.7
Factor A (Refer to Fig. G in Subpart 3 of Sec. II, Part D)	0.00021
Factor B (CS-2)	2.302 kgf/mm²

Allowable external pressure [Pa]
= 4 x B / (3 x (OD / te))
= 4 x 2.302 / (3 x 282.7)
= 0.01086 kgf/mm² g
Since Pa > Pe, design is safe
Since available thickness is more than design thickness, design is safe.

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DESIGN OF ELLIPSOIDAL HEAD (INT. & EXT. PRESSURE)	**Dished End (Rear)**
CODE	**ASME VIII Div.1, 15**

1. DESIGN CONDITIONS (Operating Mode , Corroded Condition) :

Design pressure (internal)	Pi	0.12 kgf/mm² g
Design pressure (external)	Pe	0.01055 kgf/mm² g
Design temperature	T	120 °C
Material of construction		SA-516 GR. 70 Plt. [UNS:K02700]
Max. allowable stress @ design temp.	S	14.06 kgf/mm²
Radiography		Full
Joint efficiency	E	1
Outside diameter of head	OD	1274 mm
Inside diameter of shell	ID	1256 mm
Head shape		Elliptical D/2H = 2.0
Nominal thickness		12 mm
Nominal thickness required as per TEMA		N.A mm
Internal allowance, corrosion + polishing		3 mm
External allowance, corrosion + polishing		0 mm
Thinning allowance / Under tolerance		1.2 mm
Available thickness		7.8 mm

2. DESIGN CALCULATION AS PER UG 32 d / APPENDIX 1-4 (c) :

Factor [K]
= 1
Thickness for internal pressure [t]
= K x Pi x ID / (2 x S x E - 0.2 x Pi)
= 1 x 0.12 x 1256 / (2 x 14.06 x 1 - 0.2 x 0.12)
= 5.364 mm

3. DESIGN CALCULATION AS PER UG 33 d :

Thickness for equivalent internal pressure [t]
= K x 1.67 x Pe x ID / (2 x S x 1.0 - 0.2 x 1.67 x Pe)
= 1 x 1.67 x 0.01055 x 1256 / (2 x 14.06 x 1.0 - 0.2 x 1.67 x 0.01055)
= 0.787 mm
Factor [Ko]
= 0.88
Assumed head thickness, [te]
= 3.211 mm
Factor [A]
= 0.125 x te / (Ko x OD)
= 0.125 x 3.211 / (0.88 x 1274)
= 0.00036
Factor with reference to chart (CS-2) [B]
= 3.777 kgf/mm²
Allowable external pressure [Pa]
= B / (Ko x OD / te)
= 3.777 x 3.211 / (0.88 x 1274)
= 0.01082 kgf/mm²
Since Pa > Pe, design is safe

Since available thickness is more than design thickness, design is safe.

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Project / Equipment	Soap Plant / PV-01 - Gas Filter
Designed By / Revision and Date	/ R00 , 24/Aug/2018 11:17:33
LUG SUPPORT DESIGN	**Lug Support**
CODE	**P V Design Manual, D.R. Moss**
	Operating Mode , Corroded Condition

1. LUG DATA :

M.O.C		IS-2062 GR. A Plt.
No. of support	N	4
Base plate width	b1	222 mm
Base plate depth	Lb	200 mm
Thickness of base plate	tb	16 mm
Allowable bending stress	Sb	22.15 kgf/mm²

2. BOLT DATA :

M.O.C		Commercial CS Bolt
No. of bolt / lug	Nb	1
Bolt diameter	db	20 mm
PCD	D	1598 mm
Diameter of bolt hole		24 mm
Allowable tensile stress	Fs	10.69 kgf/mm²

3. GUSSET DATA :

Thickness	tg	16 mm
Height	h	190 mm
Gusset angle	θ	51.71
Gusset depth at top	Lc	50 mm
Number of gussets	n	2
Distance between gussets	b	180 mm

4. SHELL DATA :

Material		SA-516 GR. 70 Plt. [UNS:K02700]
OD diameter	OD	1274 mm
Inside diameter	ID	1256 mm
Thickness available	ts	9 mm

5. PAD DATA :

Material		SA-516 GR. 70 Plt. [UNS:K02700]
Thickness	tp	12 mm
Width	W	275 mm
Length	L	272 mm

6. LOAD AND MOMENT (Wind) :

Max. overturning moment	M	791596.4 kgf-mm
Design weight of vessel	Wt	2415.5 kgf

7. DESIGN OF ANCHOR BOLTS :

Total uplift force on bolts [T]

= [4 x M / (D x N)] - Wt / N

= [4 x 791596.4 / (1598 x 4)] - 2415.5 / 4

= -108.5 kgf

Required area of bolts [Am]

= MAX [(T / Fs) , 0]

= MAX [(-108.5 / 10.69) , 0]

= 0 mm²

Available area of bolts [Ab]

= Ar x Nb .... where, Ar = 217.1 mm², is root area of bolt

= 217.1 x 1

= 217.1 mm²

Since Ab > Am, bolts provided are sufficient

8. GUSSET DESIGN :

Reaction force at each support [Q]

= [4 x M / (D x N)] + Wt / N

= [4 x 791596.4 / (1598 x 4)] + 2415.5 / 4

= 1099.2 kgf

Maximum axial force in gusset [P1]

= Q / n

= 1099.2 / 2

= 549.6 kgf

Allowable compr. stress in gusset [Sg]

= 18000 / [1 + 12 x (h' / tg) ^{2} / 18000] .... where, h' = 242.1 mm

= 18000 / [1 + 12 x (242.1 / 16) ^{2} / 18000]

= 15616.8 psi

= 10.98 kgf/mm²

Required thickness of gusset [tg']

= 2 x P1 x (3 x a - Lb) / [Sg x Lb ^{2} x (sin θ) ^{2}]

= 2 x 549.6 x (3 x 150 - 200) / [10.98 x (200) ^{2} x (sin 51.71) ^{2}]

= 1.016 mm

9. BASE PLATE DESIGN :

Bending moment [Mb]

= Q x b1 / 6

= 1099.2 x 222 / 6

= 40671.8 kgf-mm

Bearing pressure [bp]

= Q / (w x b1) .... where, w = 120 mm

= 1099.2 / (120 x 222)

= 0.04126 kgf/mm²

Bending moment due to bearing pressure [Mb']

= bp x b ^{2} / 10

= 0.04126 x 180 ^{2} / 10

= 133.7 kgf-mm

Required thickness of base plate between chairs [tb']

= SQRT { 6 x MAX [Mb , Mb'] / [(Lb - db) x Sb] }

= SQRT { 6 x MAX [40671.8 , 133.7] / [(200 - 20) x 22.15] }

= 7.912 mm

10. CHECK FOR COMPRESSION PLATE :

Equivalent radial load [f]

= Q x a / (n x h)

= 1099.2 x 150 / (2 x 190)

= 433.9 kgf

Angle between supports [α]

= 2 x π / N

= 2 x π / 4

= 1.571 rad

Internal bending moment coefficient [Kr]

= 0.5 x [1 / (0.5 x α) - cot (0.5 x α)]
= 0.5 x [1 / (0. 5 x 1.571) - cot (0.5 x 1.571)]
= 0.137
Internal bending moment [Mc]
= 0.5 x Kr x f x OD
= 0.5 x 0.137 x 433.9 x 1274
= 37761.8 kgf-mm
Bending stress induced [fb]
= Mo / Zc
= 37761.8 / 13224.4
= 2.855 kgf/mm² .... < Sb = 22.15 kgf/mm²
Since, induced stress fb < allow. stress Sb in shell material, design is safe.

LUG SUPPORT DESIGN	**Lug Support**
CODE	**P V Design Manual, D.R. Moss**
	Operating Mode , Corroded Condition

1. LUG DATA :

M.O.C		IS-2062 GR. A Plt.
No. of support	N	4
Base plate width	b1	222 mm
Base plate depth	Lb	200 mm
Thickness of base plate	tb	16 mm
Allowable bending stress	Sb	22.15 kgf/mm²

2. BOLT DATA :

M.O.C		Commercial CS Bolt
No. of bolt / lug	Nb	1
Bolt diameter	db	20 mm
PCD	D	1598 mm
Diameter of bolt hole		24 mm
Allowable tensile stress	Fs	10.69 kgf/mm²

3. GUSSET DATA :

Thickness	tg	16 mm
Height	h	190 mm
Gusset angle	θ	51.71
Gusset depth at top	Lc	50 mm
Number of gussets	n	2
Distance between gussets	b	180 mm

4. SHELL DATA :

Material		SA-516 GR. 70 Plt. [UNS:K02700]
OD diameter	OD	1274 mm
Inside diameter	ID	1256 mm
Thickness available	ts	9 mm

5. PAD DATA :

Material		SA-516 GR. 70 Plt. [UNS:K02700]
Thickness	tp	12 mm
Width	W	275 mm
Length	L	272 mm

6. LOAD AND MOMENT (Seismic) :

Max. overturning moment	M	393227.8 kgf-mm
Design weight of vessel	Wt	4789.1 kgf

7. DESIGN OF ANCHOR BOLTS :

Total uplift force on bolts [T]

= [4 x M / (D x N)] - Wt / N

= [4 x 393227.8 / (1598 x 4)] - 4789.1 / 4

= -951.2 kgf

Required area of bolts [Am]

= MAX [(T / Fs) , 0]

= MAX [(-951.2 / 10.69) , 0]

= 0 mm²
Available area of bolts [Ab]
= Ar x Nb .... where, Ar = 217.1 mm², is root area of bolt
= 217.1 x 1
= 217.1 mm²
Since Ab > Am, bolts provided are sufficient

8. GUSSET DESIGN :

Reaction force at each support [Q]
= [4 x M / (D x N)] + Wt / N
= [4 x 393227.8 / (1598 x 4)] + 4789.1 / 4
= 1443.3 kgf
Maximum axial force in gusset [P1]
= Q / n
= 1443.3 / 2
= 721.7 kgf
Allowable compr. stress in gusset [Sg]
= 18000 / [1 + 12 x (h' / tg) ^{2} / 18000] .... where, h' = 242.1 mm
= 18000 / [1 + 12 x (242.1 / 16) ^{2} / 18000]
= 15616.8 psi
= 10.98 kgf/mm²
Required thickness of gusset [tg']
= 2 x P1 x (3 x a - Lb) / [Sg x Lb ^{2} x (sin θ) ^{2}]
= 2 x 721.7 x (3 x 150 - 200) / [10.98 x (200) ^{2} x (sin 51.71) ^{2}]
= 1.334 mm

9. BASE PLATE DESIGN :

Bending moment [Mb]
= Q x b1 / 6
= 1443.3 x 222 / 6
= 53403.7 kgf-mm
Bearing pressure [bp]
= Q / (w x b1) .... where, w = 120 mm
= 1443.3 / (120 x 222)
= 0.05418 kgf/mm²
Bending moment due to bearing pressure [Mb']
= bp x b ^{2} / 10
= 0.05418 x 180 ^{2} / 10
= 175.5 kgf-mm
Required thickness of base plate between chairs [tb']
= SQRT { 6 x MAX [Mb , Mb'] / [(Lb - db) x Sb] }
= SQRT { 6 x MAX [53403.7 , 175.5] / [(200 - 20) x 22.15] }
= 9.067 mm

10. CHECK FOR COMPRESSION PLATE :

Equivalent radial load [f]
= Q x a / (n x h)
= 1443.3 x 150 / (2 x 190)
= 569.7 kgf
Angle between supports [α]
= 2 x π / N
= 2 x π / 4
= 1.571 rad
Internal bending moment coefficient [Kr]

= 0.5 x [1 / (0.5 x α) - cot (0.5 x α)]
= 0.5 x [1 / (0. 5 x 1.571) - cot (0.5 x 1.571)]
= 0.137
Internal bending moment [Mc]
= 0.5 x Kr x f x OD
= 0.5 x 0.137 x 569.7 x 1274
= 49582.7 kgf-mm
Bending stress induced [fb]
= Mo / Zc
= 49582.7 / 13224.4
= 3.749 kgf/mm^2 .... < Sb = 22.15 kgf/mm^2
Since, induced stress fb < allow. stress Sb in shell material, design is safe.

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NOZZLE NECK THICKNESS AND REINFORCEMENT DESIGN		**N 01**
CODE		**ASME VIII Div.1, 15**
		Operating Mode , Corroded Condition
DESIGN CONDITIONS		
Design pressure (internal)	Pi	0.12 kgf/mm² g
Design pressure (external)	Pe	0.01055 kgf/mm² g
Design temperature	T	120 °C
NOZZLE DATA		
M.O.C.		SA-106 GR. B Smls. Pipe [UNS:K03006]
Allowable stress @ design temperature	Sn	12.02 kgf/mm²
Outside diameter	OD	168.3 mm
Inside diameter	ID	152.3 mm
Maximum chord length	D	152.3 mm
Neck thickness (provided)	tnp	10.97 mm
Internal allowance , corrosion + polishing	CAI	3 mm
External allowance , corrosion + polishing	CAE	0
Neck thickness (tnp - CAI - CAE)	tn	7.973 mm
Max. under tolerance on thickness	Alw	1.372 mm
Available neck thickness (tn - Alw)	tc	6.601 mm
Nozzle projection outward (from vessel outer face)	Lo	150 mm
Total length of nozzle (Lo + tvp + Addn for curvature)	L	156 mm
Connection type		Pipe Nozzle
Application type		Process Opening
Reinforcement calculation method		Isolated Opening
Design as large opening		False
SHELL DATA (Main Shell)		
M.O.C.		SA-516 GR. 70 Plt. [UNS:K02700]
Allowable stress @ design temperature	Sv	14.06 kgf/mm²
Inside radius	R	628 mm
Thickness	t	9 mm
Min. thickness for external pressure	tr2	4.506 mm
WELD DATA		
Nozzle outside weld	W1	10.86 mm

CALCULATION OF NOZZLE NECK THICKNESS AS PER UG-45

Neck thickness for internal pressure , [ta_1]
Formula in Appendix 1-1 , [ta_1]
= (0.5 x Pi x OD) / (Sn x E + 0.4 x Pi)
= (0.5 x 0.12 x 168.3) / (12.02 x 1.0 + 0.4 x 0.12)
= 0.836 mm
Neck thickness for external pressure , [ta_2]
Neck thickness for external pressure as per UG-28
Assumed neck thickness , [ta_2] = 0.552 mm
L / OD = 0.891
OD / ta_2 = 304.7
Factor A = 0.00028
Factor B = 2.99 kgf/mm²

Allowable external pressure , [Pa]
= 4 x B / (3 x OD / ta_2)
= 4 x 2.99 / (3 x 304.7)
= 0.01309 kgf/mm² g
Shell thickness for internal pressure as per UG-37 & UG-27 , [tr1 = tb_1]
= Pi x R / (Sv x E - 0.6 x Pi)
= 0.12 x 628 / (14.06 x 1.0 - 0.6 x 0.12)
= 5.387 mm
Shell thickness considering internal pressure equal to external pressure as per UG-27 , [tb_2]
= Pe x R / (Sv x E - 0.6 x Pe)
= 0.01055 x 628 / (14.06 x 1.0 - 0.6 x 0.01055)
= 0.471 mm
Nozzle minimum thickness required as per Table UG-45 , [tb_3]
= 6.223 mm
Minimum thickness of vessel wall required as per UG-16(b) , [t_min]
= 1.6 mm
Neck thk as per UG-45 , [tUG_45]
Thickness , [ta]
= MAX [ta_1 , ta_2 , t_min]
= MAX [0.836 , 0.552 , 1.6]
= 1.6 mm
Thickness , [tb]
= MIN [tb_3 , MAX (tb_1 , tb_2 , t_min)]
= MIN [6.223 , MAX (5.387 , 5.387 , 1.6)]
= 5.387 mm
Thickness , [tUG_45]
= MAX [ta , tb] .... for Process Nozzle
= ta .... for Access Opening
= 5.387 mm .... Process Opening
Since available neck thickness, tc >= tUG_45 , selected neck thickness is adequate.

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NOZZLE NECK THICKNESS AND REINFORCEMENT DESIGN	**N 02**
CODE	**ASME VIII Div.1, 15**
	Operating Mode , Corroded Condition

DESIGN CONDITIONS

Design pressure (internal)	Pi	0.12 kgf/mm² g
Design pressure (external)	Pe	0.01055 kgf/mm² g
Design temperature	T	120 °C

NOZZLE DATA

M.O.C.		SA-106 GR. B Smls. Pipe [UNS:K03006]
Allowable stress @ design temperature	Sn	12.02 kgf/mm²
Outside diameter	OD	168.3 mm
Inside diameter	ID	152.3 mm
Maximum chord length	D	152.3 mm
Neck thickness (provided)	tnp	10.97 mm
Internal allowance , corrosion + polishing	CAI	3 mm
External allowance , corrosion + polishing	CAE	0
Neck thickness (tnp - CAI - CAE)	tn	7.973 mm
Max. under tolerance on thickness	Alw	1.372 mm
Available neck thickness (tn - Alw)	tc	6.601 mm
Nozzle projection outward (from vessel outer face)	Lo	150 mm
Total length of nozzle (Lo + tvp + Addn for curvature)	L	156 mm
Connection type		Pipe Nozzle
Application type		Process Opening
Reinforcement calculation method		Isolated Opening
Design as large opening		False

SHELL DATA (Main Shell)

M.O.C.		SA-516 GR. 70 Plt. [UNS:K02700]
Allowable stress @ design temperature	Sv	14.06 kgf/mm²
Inside radius	R	628 mm
Thickness	t	9 mm
Min. thickness for external pressure	tr2	4.506 mm

WELD DATA

Nozzle outside weld	W1	10.86 mm

CALCULATION OF NOZZLE NECK THICKNESS AS PER UG-45

Neck thickness for internal pressure , [ta_1]
Formula in Appendix 1-1 , [ta_1]
= (0.5 x Pi x OD) / (Sn x E + 0.4 x Pi)
= (0.5 x 0.12 x 168.3) / (12.02 x 1.0 + 0.4 x 0.12)
= 0.836 mm
Neck thickness for external pressure , [ta_2]
Neck thickness for external pressure as per UG-28
Assumed neck thickness , [ta_2] = 0.552 mm
L / OD = 0.891
OD / ta_2 = 304.7
Factor A = 0.00028
Factor B = 2.99 kgf/mm²

Allowable external pressure , [Pa]
= 4 x B / (3 x OD / ta_2)
= 4 x 2.99 / (3 x 304.7)
= 0.01309 kgf/mm^2 g
Shell thickness for internal pressure as per UG-37 & UG-27 , [tr1 = tb_1]
= Pi x R / (Sv x E - 0.6 x Pi)
= 0.12 x 628 / (14.06 x 1.0 - 0.6 x 0.12)
= 5.387 mm
Shell thickness considering internal pressure equal to external pressure as per UG-27 , [tb_2]
= Pe x R / (Sv x E - 0.6 x Pe)
= 0.01055 x 628 / (14.06 x 1.0 - 0.6 x 0.01055)
= 0.471 mm
Nozzle minimum thickness required as per Table UG-45 , [tb_3]
= 6.223 mm
Minimum thickness of vessel wall required as per UG-16(b) , [t_min]
= 1.6 mm
Neck thk as per UG-45 , [tUG_45]
Thickness , [ta]
= MAX [ta_1 , ta_2 , t_min]
= MAX [0.836 , 0.552 , 1.6]
= 1.6 mm
Thickness , [tb]
= MIN [tb_3 , MAX (tb_1 , tb_2 , t_min)]
= MIN [6.223 , MAX (5.387 , 5.387 , 1.6)]
= 5.387 mm
Thickness , [tUG_45]
= MAX [ta , tb] .... for Process Nozzle
= ta .... for Access Opening
= 5.387 mm .... Process Opening
Since available neck thickness, tc >= tUG_45 , selected neck thickness is adequate.

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NOZZLE NECK THICKNESS AND REINFORCEMENT DESIGN		**N 03**
CODE		**ASME VIII Div.1, 15**
		Operating Mode , Corroded Condition
DESIGN CONDITIONS		
Design pressure (internal)	Pi	0.12 kgf/mm² g
Design pressure (external)	Pe	0.01055 kgf/mm² g
Design temperature	T	120 °C
NOZZLE DATA		
M.O.C.		SA-106 GR. B Smls. Pipe [UNS:K03006]
Allowable stress @ design temperature	Sn	12.02 kgf/mm²
Outside diameter	OD	168.3 mm
Inside diameter	ID	137.7 mm
Maximum chord length	D	137.7 mm
Neck thickness (provided)	tnp	18.26 mm
Internal allowance , corrosion + polishing	CAI	3 mm
External allowance , corrosion + polishing	CAE	0
Neck thickness (tnp - CAI - CAE)	tn	15.26 mm
Max. under tolerance on thickness	Alw	2.283 mm
Available neck thickness (tn - Alw)	tc	12.98 mm
Nozzle projection outward (from vessel outer face)	Lo	150 mm
Nozzle projection inward (from vessel inner face)	Li	0 mm
Total length of nozzle (Lo + Li + tvp + Addn for curvature)	L	151 mm
Connection type		Pipe Nozzle
Application type		Process Opening
Reinforcement calculation method		Isolated Opening
Design as large opening		False
HEAD DATA (Dished End (Rear))		
Allowable stress @ design temperature	Sv	14.06 kgf/mm²
Inside diameter of head @ head skirt	Dsf	1256 mm
D / 2 H for Ellispoidal head		2
Factor from Table UG-37	K1	0.9
Inside diameter of equivalent sphere, K1 x Dsk x 2	ID1	2260.8 mm
Thickness	t	7.8 mm
Min. thickness for external pressure	tr2	3.211 mm
WELD DATA		
Nozzle outside weld	W1	11.88 mm

CALCULATION OF NOZZLE NECK THICKNESS AS PER UG-45

Neck thickness for internal pressure , [ta_1]
Formula in Appendix 1-1 , [ta_1]
= (0.5 x Pi x OD) / (Sn x E + 0.4 x Pi)
= (0.5 x 0.12 x 168.3) / (12.02 x 1.0 + 0.4 x 0.12)
= 0.836 mm
Neck thickness for external pressure , [ta_2]
Neck thickness for external pressure as per UG-28

Assumed neck thickness , [ta_2] = 0.538 mm
L / OD = 0.891
OD / ta_2 = 312.9
Factor A = 0.00027
Factor B = 2.878 kgf/mm²
Allowable external pressure , [Pa]
= 4 x B / (3 x OD / ta_2)
= 4 x 2.878 / (3 x 312.9)
= 0.01226 kgf/mm² g
Head thickness for internal pressure as per UG-37 & UG-27(d) , [tr1 = tb_1]
= 0.5 x Pi x ID1 / (2 x Sv x E - 0.2 x Pi)
= 0.5 x 0.12 x 2260.8 / (2 x 14.06 x 1.0 - 0.2 x 0.12)
= 4.828 mm
Head thickness considering internal pressure equal to external pressure per UG-27(d) , [tb_2]
= 0.5 x Pe x ID1 / (2 x Sv x E - 0.2 x Pe)
= 0.5 x 0.01055 x 2260.8 / (2 x 14.06 x 1.0 - 0.2 x 0.01055)
= 0.424 mm
Nozzle minimum thickness required as per Table UG-45 , [tb_3]
= 6.223 mm
Minimum thickness of vessel wall required as per UG-16(b) , [t_min]
= 1.6 mm
Neck thk as per UG-45 , [tUG_45]
Thickness , [ta]
= MAX [ta_1 , ta_2 , t_min]
= MAX [0.836 , 0.538 , 1.6]
= 1.6 mm
Thickness , [tb]
= MIN [tb_3 , MAX (tb_1 , tb_2 , t_min)]
= MIN [6.223 , MAX (4.828 , 0.424 , 1.6)]
= 4.828 mm
Thickness , [tUG_45]
= MAX [ta , tb] .... for Process Nozzle
= ta .... for Access Opening
= 4.828 mm .... Process Opening
Since available neck thickness, tc >= tUG_45 , selected neck thickness is adequate.

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DESIGN OF LIFTING LUG	**Lifting Lugs**
CODE	**P V Design Manual, D.R. Moss**
	Design Mode 1 , Uncorroded Condition

1. LIFTING LUG DATA :

Material		IS-2062 GR. A Plt.
Length of lug	LL	70 mm
Width of lug	A	120 mm
Thickness of lug plate	TL	14 mm
Straight length	B1	10 mm
Radius at tip	R3	35 mm
Pin Hole diameter	D1	40 mm
Lug to vessel weld size	W1	6.216 mm
Min yield stress	Sy	24.61 kgf/mm²
Allowable tensile stress (2 / 3 x Sy)	St	16.4 kgf/mm²
Allowable bending stress (1.5 x St)	Sb	22.15 kgf/mm²
Allowable shear stress (0.6 x St)	Ss	9.843 kgf/mm²

2. DESIGN LOADS :

Total design lift weight	Wt	2660.6 kgf
Number of lifting lugs	N	2
Jirk load factor	j	1.5

3. CALCULATION OF REFERENCE DIMENSIONS :

Dimension [L1]
= LL - B1 - R3
= 70 - 10 - 35
= 25 mm

Dimension [LT]
= LL - R3
= 70 - 35
= 35 mm

Angle [θ1]
= ATAN (2 x L1 / A)
= ATAN (2 x 25 / 120)
= 0.395 radians

Dimension [L2]
= L1 / SIN (θ1)
= 25 / SIN (0.395)
= 65 mm

Angle [θ2]
= ASIN (R3 / L2)
= ASIN (35 / 65)
= 0.569 radians

Angle [θ3]
= θ1 + θ2
= 0.395 + 0.569
= 0.963 radians

Dimension [L3]
= R3 / SIN (θ3)
= 35 / SIN (0.963)
= 42.62 mm

4. DESIGN OF LUG PLATE :

Effective design load on each lug [P]
= j x Wt / N
= 1.5 x 2660.6 / 2
= 1998.1 kgf

Required min. thickness of lug plate for shear [t2]
= P / [(R3 - 0.5 x D1) x ss]
= 1998.1 / [(35 - 0.5 x 40) x 9.843]
= 13.53 mm

Required min. thickness of lug plate for bending [t1]

Required min. thickness of lug plate for tension [t3]

= 6 x P x LT / (A ^{2} x Sb)

= 6 x 1998.1 x 35 / (120 ^{2} x 22.15)

= 1.316 mm

= P / [(2 x L3 - D1) x ss]

= 1998.1 / [(2 x 42.62 - 40) x 16.4]

= 2.692 mm

5. CALCULATION OF STRESSES IN LUG PLATE WELDS :

Bending stress in weld [f1]

= 6 x P x LT / [2 x LL^2]

= 6 x 1998.1 x 35 / (2 x 70 ^{2})

= 42.82 kgf/mm

Max. shear stress in weld [f2]

= P / [2 x A]

= 1998.1 / (2 x 120)

= 8.326 kgf/mm

Min. Size of lug plate weld [w1]

= MAX (f1 , 2 x f2) / (0.707 x Ss)

= MAX (42.82 , 2 x 8.326) / (0.707 x 9.843)

= 6.153 mm

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Project / Equipment Soap Plant / PV-01 - Gas Filter

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FOUNDATION LOAD DATA

Sr. No.	Mode	Condition	Weight (kgf) Empty	Weight (kgf) Filled	Wind Shear (kgf) Tran.	Wind Shear (kgf) Long.	Wind Moment (kgf-m) Tran.	Wind Moment (kgf-m) Long.	Seismic Shear (kgf)	Seismic Moment (kgf-m)
1	Operating	Corroded	2415.5	4789.1	626.1	626.1	791.6	791.6	433.7	393.2
2	Design1	Corroded	2415.5	4789.1	626.1	626.1	791.6	791.6	433.7	393.2
3	Operating	Uncorroded	2660.6	5009.7	626.1	626.1	751.5	751.5	451.6	404.1
4	Design1	Uncorroded	2660.6	5009.7	626.1	626.1	751.5	751.5	451.6	404.1

CENTER OF GRAVITY DATA

Sr. No.	Mode	Condition	Empty		Operating / Filled	
			Wt (kgf)	C.G. (mm)	Wt (kgf)	C.G. (mm)
1	Operating	Corroded	2415.5	1738.9	4789.1	1381.1
2	Design1	Corroded	2415.5	1738.9	4789.1	1381.1
3	Operating	Uncorroded	2660.6	1674.9	5009.7	1369.2
4	Design1	Uncorroded	2660.6	1674.9	5009.7	1369.2

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Project / Equipment	Soap Plant / PV-01 - Gas Filter
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Index

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Customer	ABC Company Ltd.
Project	Soap Plant
Location	Vapi Site
Plant	Refrigeration Plant
EQUIPMENT INFORMATION :	
Design Code	ASME VIII Div.1, 15
Equipment Name	PV-01 - Gas Filter
Equipment Type	Pressure Vessel
Equipment Class	N.A.
Equipment Category	N.A.
Reference Drawing No	---
Service	Other Service
Support Type	Lug Supports
DESIGN & REVIEWAL :	
Designed By	
Design Date	24/Aug/2018 11:17:33
Checked By	
Approved By	
Revision	R00
INSPECTION & APPROVAL :	
Inspection Agency	---
Reviewed By	---
EQUIPMENT DATA :	
Front end	Flat End
Front end flanged	True
Rear end	Dished End
Rear end flanged	False
Shell ID	1250 mm
Shell OD	1274 mm
Length, Shell (W.L. to W.L) / Overall	1650 / 2122.8 mm
OTHER DATA :	
Fabricated weight (corr / uncorr)	2415.5 / 2660.6 kgf
Empty weight + external weights (corr / uncorr)	2415.5 / 2660.6 kgf
Estimated operating weight (corr / uncorr)	4789.1 / 5009.7 kgf
Estimated hydrotest weight (corr / uncorr)	4701.6 / 4922.3 kgf

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Project / Equipment	Soap Plant / PV-01 - Gas Filter
Designed By / Revision and Date	/ R00 , 24/Aug/2018 11:17:33

VESSEL DESIGN DATA

(1) PROCESS DETAILS :

	MEDIA	**DENSITY kg/m³**
Operating	Process	1000
Design1		1000
Design2		
Startup		
Shutdown		
Upset		
Hydrotest	Water	1000
Pneumatic	Air	1.2

(2) PR. : kgf/mm² g

		INT.	**EXT.**
Operating	0.12	0.12	0.01055
Design1	0.15	0.15	0.01055
Design2			
Startup			
Shutdown			
Upset			

(3) TEST PR. : kgf/mm² g

		Based on	
	Input Pr	**MAWP**	**MAP**
Hydrotest	0.195	0.195	0.195
Pneumatic	0.165	0.165	0.165

(4) TEMPERATURE : °C

	MIN.		**MAX.**
	Input	**MDMT**	
Operating	25	25	120
Design1	15	15	150
Design2			
Startup			
Shutdown			
Upset			
Hydrotest	21.67	21.67	45
Pneumatic	21.67	10	45

(5) ALLOWANCES : mm

	INT.	**EXT.**
Corrosion	3	0
Polishing	0	0

(6) RADIOGRAPHY & JOINT EFFICIENCY :

	RADIOGRAPHY	**JOINT EFFICIENCY**
Shell	Spot	0.85
Head	Full	1.00

VESSEL DESIGN DATA

1. MATERIAL OF CONSTRUCTION :

	Shell side
Shell	SA-516 GR. 70 Plt. [UNS:K02700]
Head	SA-516 GR. 70 Plt. [UNS:K02700]
Body flange	SA-105 Frg. [UNS:K03504]
Body flange cover	SA-105 Frg. [UNS:K03504]
Liner	

2. NOZZLE CONNECTIONS :

	Shell side
Nozzle neck <= NPS 40	SA-106 GR. B Smls. Pipe [UNS:K03006]
Flange	SA-105 Frg. [UNS:K03504]
Cover flange	SA-105 Frg. [UNS:K03504]
Nozzle NPS > 40 & < 200	SA-106 GR. B Smls. Pipe [UNS:K03006]
Flange	SA-105 Frg. [UNS:K03504]
Cover flange	SA-105 Frg. [UNS:K03504]
Nozzle neck >= NPS 200	SA-516 GR. 70 Plt. [UNS:K02700]
Flange	SA-516 GR. 70 Plt. [UNS:K02700]
Cover flange	SA-516 GR. 70 Plt. [UNS:K02700]
Pad flange	SA-516 GR. 70 Plt. [UNS:K02700]
Pad flange cover	SA-516 GR. 70 Plt. [UNS:K02700]
Manhole flange	SA-516 GR. 70 Plt. [UNS:K02700]
Manhole cover	SA-516 GR. 70 Plt. [UNS:K02700]
Reinforcement pad	SA-516 GR. 70 Plt. [UNS:K02700]
External bolt	SA-193 GR. B7 Bolt [UNS:G41400]
External gasket	CAF with suitable binder (3 mm.)
Stiffener	SA-516 GR. 70 Plt. [UNS:K02700]
Lifting lug	IS-2062 GR. A Plt.
Support	IS-2062 GR. A Plt.
Anchor bolt	Commercial CS Bolt

3. INSULATION & CLADDING:

Mat. / Density / Thk.	Rockwool (Mineral Fibre) / 136.2 kg/m³ / 40 mm
Mat. / Thk.	Al. sheet / 1.191 mm

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Project / Equipment	Soap Plant / PV-01 - Gas Filter
Designed By / Revision and Date	/ R00 , 24/Aug/2018 11:17:33

SUMMARY OF EFFECTIVE DESIGN PRESSURES IN kgf/mm² g VS TEMPERATURE IN °C

Sr.	Item name	Temp.	Inside pr.		Liquid pr.	Effective pr.	
No.			+ve	-ve		+ve	-ve
1	Bolted Cover (Front)	150	0.15	0.01055	0	0.15	0.01055
2	Shell Flng (Front)	150	0.15	0.01055	0	0.15	0.01055
3	Main Shell	150	0.15	0.01055	0	0.15	0.01055
4	Dished End (Rear)	150	0.15	0.01055	0	0.15	0.01055
5							

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Project / Equipment	Soap Plant / PV-01 - Gas Filter
Designed By / Revision and Date	/ R00 , 24/Aug/2018 11:17:33

ITEM WISE WEIGHT SUMMARY

Sr.No.	Item name	Item size	Empty wt	Volume	Filled wt
			kgf	m^3	kgf
1	Bolted Cover (Front)	Blind Cover - 1463 OD x 84.304 Thk, RF, 1413 PCD, Tgrv = 1.588	1100.8	0	1100.8
2	Shell Flng (Front)	Plate Ring - 1463 OD x 1250 ID x 1413 PCD, RF, 119.522 Thk, Trgv = 1.588	423.7	0	423.7
3	Gasket Flng (Front)	1381.943 OD x 1250 ID, 3.175 Thk	0.1	0	0.1
4	Bolt Flng (Front)	Hex Head Bolt M22 x 240.751 Lg, 56 Nos.	40.57	0	40.57
5	Main Shell	1274 OD x 12 Thk, 1650 Lg	621.4	2.025	2646.3
6	Dished End (Rear)	Elliptical D/2H = 2.0, 1274 OD x 12 Nom / 10.8 Min Thk, SF = 50	203.2	0.317	520.3
7	Bolting Plate	222 Long x 200 Wide x 16 Thk, 4 Nos.	22.5	0	22.5
8	Gusset Plate	200 Long x 190 Wide x 16 Thk, 8 Nos.	38.51	0	38.51
9	Anchor Bolt	Anchor M20 x 200 Lg, 4 Nos.	1.99	0	1.99
10	Support Pad	275 Long x 272 Wide x 12 Thk, 4 Nos.	28.42	0	28.42
11	N 01	ANSIB36.10, 150 NPS Sch.80, 156 Lg	6.697	0.00262	9.32
12	Flange [N 01]	Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 80 Pipe	8.08	0	8.08
13	Gasket [N 01]	150 NPS x 150#, 3.175 Thk	0.1	0	0.1
14	Counter Flng [N 01]	Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 80 Pipe	8.08	0	8.08
15	Reinf [N 01]	292.659 OD x 171.275 ID x 12 Thk	4.202	0	4.202
16	N 02	ANSIB36.10, 150 NPS Sch.80, 156 Lg	6.697	0.00262	9.32
17	Flange [N 02]	Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 80 Pipe	8.08	0	8.08
18	Gasket [N 02]	150 NPS x 150#, 3.175 Thk	0.1	0	0.1
19	Counter Flng [N 02]	Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 80 Pipe	8.08	0	8.08
20	Reinf [N 02]	292.659 OD x 171.275 ID x 12 Thk	4.202	0	4.202
21	N 03	ANSIB36.10, 150 NPS Sch.160, 151 Lg	10.29	0.00206	12.35
22	Flange [N 03]	Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 160 Pipe	9.203	0	9.203

23	Gasket [N 03]	150 NPS x 150#, 3.175 Thk	0.1	0	0.1
24	Bolted Cover [N 03]	Blind Cover, ANSI B16.5, RF, 150# for 150 NPS Pipe	11.56	0	11.56
25	Reinf [N 03]	263.5 OD x 171.275 ID x 12 Thk	2.992	0	2.992
26	Lifting Lugs	120 Long x 70 Wide x 14 Thk, 2 Nos.	1.862	0	1.862
27	Pad (Lifting Lugs)	70 Long x 170 Wide x 8 Thk, 2 Nos.	1.507	0	1.507
28	Insulation	4178.318 W x 3622.804 L, 40 Thk	82.44	0	82.44
29	Cladding	4182.059 W x 3622.804 L, 1.191 Thk	4.993	0	4.993
30					
31					
32					
33					
34					
35					
			∑ 2660.6		∑ 4922.3

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Project / Equipment	Soap Plant / PV-01 - Gas Filter
Designed By / Revision and Date	/ R00 , 24/Aug/2018 11:17:33

WIND LOAD CALCULATION

CODE			**Wind [IS:875, 87]**

1. DESIGN CONDITIONS (Design Mode 1 , Corroded Condition) :

Basic wind speed	(Section 5.2)	Vb	50 m/s
Expected life of equipment	(Section 5.3.1)		25 Years
Probability factor (Risk coeff)	(Section 5.3.1)	K1	0.902
Terrain category	(Section 5.3.2)		Category 2
Structure class	(Section 5.3.2.2)		Class B
Topography factor	(Section 5.3.3)	K3	1.3
Force coefficient (Shape factor)		Cf	0.8

3. CALCULATION OF FORCES AND MOMENTS:

Equivalent diameter		De	1862 mm
Overall length of equipment		L	2122.8 mm
Height of C.G. of equipment		Hcg	1738.9 mm
Size and height factor	(Section 5.3.2)	K2	0.98
Effective transverse cross sectional area			
= De x L		A	3952660.7 mm²
Effective wind speed			
= K1 x K2 x K3 x Vb		Vz	57.44 m/s
Wind pressure			
= 6E-08 x Vz^2		Pz	0.0002 kgf/mm²
Longitudinal force			
= Cf x A x Pz		F	626.1 kgf
Support elevation		H	474.5 mm
Turning moment			
= F x (Hcg - H)		M	791596.4 kgf-mm

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Project / Equipment	Soap Plant / PV-01 - Gas Filter
Designed By / Revision and Date	/ R00 , 24/Aug/2018 11:17:33

SEISMIC LOAD CALCULATION

CODE — **Seismic [IS:1893, 02]**

1. DESIGN CONDITIONS (Design Mode 1 , Corroded Condition) :

Weight of equipment		Wo	4789.1 kgf
Importance factor	(Table-6 , 2002)	I	1.5
Soil profile type			Stiff Soil Profile (SD)
Foundation type			RCC footings + Tie Beams
Damping factor			5
Seismic zone			Zone III
Seismic zone factor	(Table-2 , 2002)	Z	0.16
Response reduction factor	(Table-7 , 2002)	R	2.9
Spectral accelerations coeff.	(Fig. 2 , 2002)	Sa / g	2.5, Use max value
Damping correction factor	(Table-3 , 2002)	Cf	1
Seismic coefficient	(Clause-6.4.2 , 2002)		
= 0.5 x Z x I x Cf x (Sa / g) x (1 / R)			
= 0.5 x 0.16 x 1.5 x 1 x			
2.5 x (1 / 2.9)		Ah	0.103

2. CALCULATION OF FORCES AND MOMENTS:

Elevation of support	H	474.5 mm
Height of C.G. of equipment	Hcg	1381.1 mm
Seismic base shear force		
= Ah x Wo		
= 0.103 x 4789.1	Vb	433.7 kgf
Seismic moment of support		
= Vb x (Hcg - H)		
= 433.7 x (1381.1 - 474.5)	M	393227.8 kgf-mm

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Customer		ABC Company Ltd.
Project / Equipment		Soap Plant / PV-01 - Gas Filter
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DESIGN OF FLAT BOLTED HEAD (INTERNAL)		**Bolted Cover (Front)**
CODE		**ASME VIII Div.1, 15**

1. DESIGN CONDITIONS (Design Mode 1 , Corroded Condition) :

Design pressure	P	0.15 kgf/mm² g
Design temperature	T	150 °C
Allowance	CA	3 mm
Groove allowance	Tg	0 mm
Radiography		Full
Joint efficiency	E	1

2. COVER DATA :

M.O.C.		SA-105 Frg. [UNS:K03504]
Code allw. stress @ design temp.	Sfo	14.06 kgf/mm²
Code allw. stress @ atm. temp.	Sfa	14.06 kgf/mm²
Young's modulus	Ey	19888.4 kgf/mm²
Self reinforced		False
Flange OD	A	1463 mm
Thickness provided		84.3 mm
Thickness available		81.3 mm

3. BOLTING DATA :

M.O.C.		SA-193 GR. B7 Bolt [UNS:G41400]
Code allw. stress @ design temp.	Sb	17.58 kgf/mm²
Code allw. stress @ atm. temp.	Sa	17.58 kgf/mm²
Bolt PCD	PCD	1413 mm
Bolt dia.	db	22 mm
No. of bolts	nb	56

4. LINER DATA :

M.O.C.		
Liner ID		mm
Liner OD		mm
Liner thk.		mm

5. GASKET DATA :

M.O.C.			CAF with suitable binder (3 mm.)
Gasket seating stress		y	1.125 kgf/mm²
Gasket factor		m	2
Inside diameter		Gi	1256 mm
Outside diameter		Go	1381.9 mm
Width of gasket		N	62.97 mm
Width of gasket	(as per Table 2-5.2)		31.75 mm
Basic gasket seating width	(as per Table 2-5.2)	b0	31.49 mm
Effective gasket width	(as per Table 2-5.2)	b	14.14 mm
Dia. at load reaction	(see Table 2-5.2)	G	1353.7 mm
Pass partition gasket width		Wp	0 mm
Pass partition gasket length		Lp	0 mm
Effective pass partition gasket width		b'	0 mm

6. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b1) :

Total joint - contact surface compression load [Hp]
= 2 x (π x b x G + b' x Lp) x m x P
= 2 x (π x 14.14 x 1353.7 + 0 x 0) x 2 x 0.15
= 36079.2 kgf
Total hydrostatic end force [H]
= 0.25 x π x G ^{2} x P
= 0.25 x π x 1353.7 ^{2} x 0.15
= 215875.2 kgf
Minimum required bolt load for operating condition [Wm1]
= Hp + H
= 36079.2 + 215875.2
= 251954.3 kgf

7. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b2) :

Minimum required bolt load for gasket seating [Wm2]
= (π x b x G + b' x Lp) x y
= (π x 14.14 x 1353.7 + 0 x 0) x 1.125
= 67643.1 kgf

8. BOLT AREAS AS PER APPENDIX 2-5 (d) :

Total required cross-sectional area of bolts [Am]
= MAX [Wm2 / Sa , Wm1 / Sb] .... For Internal '+' Pr Design
= Wm2 / Sa .... For External Pr & Self Sealing Design
= 14334.5 mm²
Actual bolt area using root diameter [Ab]
= 15255.5 mm²
Flange design bolt load for the gasket seating [W]
= 0.5 x (Am + Ab) x Sa x 1 .... average bolt area
= Ab x Sa x 1 ....full bolt area
= 260047.9 kgf (Avg. bolt area and margin factor of 1)

9. CHECK FOR GASKET CRUSHING :

Minimum gasket width required [Nmin]
= Ab x Sb / (2 x π x y x G)
= 15255.5 x 17.58 / (2 x π x 1.125 x 1353.7)
= 28.03 mm

10. DESIGN CALCULATION AS PER UG 34

Self reinforced		False
Factor C is user input		False
Factor C taken from fig. UG 34 or user input	C	0.3
Factor, 2 $^{0.5}$ for self reinf. cover, otherwise 1	F	1

Required thickness for bolting condition [t]
= G x F x SQRT [1.9 x W x 0.5 x (PCD - G) / (Sfa x E x G ^{3})]
= 1353.7 x 1 x SQRT [1.9 x 260047.9 x 0.5 x (1413 - 1353.7) / (14.06 x 1 x 1353.7 ^{3})]
= 27.75 mm
Required thickness for operating condition [t]
= G x F x SQRT { [C x P / (Sfo x E)] + 1.9 x Wm1 x 0.5 x (PCD - G) / (Sfo x E x G ^{3}) }
= 1353.7 x 1 x SQRT { [0.3 x 0.15 / (14.06 x 1)] + 1.9 x 251954.3 x 0.5 x (1413 - 1353.7) /
(14.06 x 1 x 1353.7 ^{3}) }
= 81.3 mm

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Project / Equipment			Soap Plant / PV-01 - Gas Filter
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DESIGN OF FLAT BOLTED HEAD (EXTERNAL)			**Bolted Cover (Front)**
CODE			**ASME VIII Div.1, 15**

1. DESIGN CONDITIONS (Design Mode 1 , Corroded Condition) :

Design pressure		P	0.01055 kgf/mm² g
Design temperature		T	150 °C
Allowance		CA	3 mm
Groove allowance		Tg	0 mm
Radiography			Full
Joint efficiency		E	1

2. COVER DATA :

M.O.C.			SA-105 Frg. [UNS:K03504]
Code allw. stress @ design temp.		Sfo	14.06 kgf/mm²
Code allw. stress @ atm. temp.		Sfa	14.06 kgf/mm²
Young's modulus		Ey	19888.4 kgf/mm²
Self reinforced			False
Flange OD		A	1463 mm
Thickness provided			84.3 mm
Thickness available			81.3 mm

3. BOLTING DATA :

M.O.C.			SA-193 GR. B7 Bolt [UNS:G41400]
Code allw. stress @ design temp.		Sb	17.58 kgf/mm²
Code allw. stress @ atm. temp.		Sa	17.58 kgf/mm²
Bolt PCD		PCD	1413 mm
Bolt dia.		db	22 mm
No. of bolts		nb	56

4. LINER DATA :

M.O.C.			
Liner ID			mm
Liner OD			mm
Liner thk.			mm

5. GASKET DATA :

M.O.C.			CAF with suitable binder (3 mm.)
Gasket seating stress		y	1.125 kgf/mm²
Gasket factor		m	2
Inside diameter		Gi	1256 mm
Outside diameter		Go	1381.9 mm
Width of gasket		N	62.97 mm
Width of gasket	(as per Table 2-5.2)		31.75 mm
Basic gasket seating width	(as per Table 2-5.2)	b0	31.49 mm
Effective gasket width	(as per Table 2-5.2)	b	14.14 mm
Dia. at load reaction	(see Table 2-5.2)	G	1353.7 mm
Pass partition gasket width		Wp	0 mm
Pass partition gasket length		Lp	0 mm
Effective pass partition gasket width		b'	0 mm

6. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b1) :

Total joint - contact surface compression load [Hp]
= 2 x (π x b x G + b' x Lp) x m x P
= 2 x (π x 14.14 x 1353.7 + 0 x 0) x 2 x 0.01055
= 2536.7 kgf
Total hydrostatic end force [H]
= 0.25 x π x G^2 x P
= 0.25 x π x 1353.7^2 x 0.01055
= 15177.9 kgf
Minimum required bolt load for operating condition [Wm1]
= Hp + H
= 2536.7 + 15177.9
= 17714.6 kgf

7. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b2) :

Minimum required bolt load for gasket seating [Wm2]
= (π x b x G + b' x Lp) x y
= (π x 14.14 x 1353.7 + 0 x 0) x 1.125
= 67643.1 kgf

8. BOLT AREAS AS PER APPENDIX 2-5 (d) :

Total required cross-sectional area of bolts [Am]
= MAX [Wm2 / Sa , Wm1 / Sb] .... For Internal '+' Pr Design
= Wm2 / Sa .... For External Pr & Self Sealing Design
= 3848.4 mm²
Actual bolt area using root diameter [Ab]
= 15255.5 mm²
Flange design bolt load for the gasket seating [W]
= 0.5 x (Am + Ab) x Sa x 1 .... average bolt area
= Ab x Sa x 1 ....full bolt area
= 167892.3 kgf (Avg. bolt area and margin factor of 1)

9. CHECK FOR GASKET CRUSHING :

Minimum gasket width required [Nmin]
= Ab x Sb / (2 x π x y x G)
= 15255.5 x 17.58 / (2 x π x 1.125 x 1353.7)
= 28.03 mm

10. DESIGN CALCULATION AS PER UG 34

Self reinforced		False
Factor C is user input		False
Factor C taken from fig. UG 34 or user input	C	0.3
Factor, $2^{0.5}$ for self reinf. cover, otherwise 1	F	1

Required thickness for bolting condition [t]
= G x F x SQRT [1.9 x W x 0.5 x (PCD - G) / (Sfa x E x G^3)]
= 1353.7 x 1 x SQRT [1.9 x 167892.3 x 0.5 x (1413 - 1353.7) / (14.06 x 1 x 1353.7^3)]
= 27.75 mm
Required thickness for operating condition [t]
= G x F x SQRT { [C x P / (Sfo x E)] + 1.9 x Wm1 x 0.5 x (PCD - G) / (Sfo x E x G^3) }
= 1353.7 x 1 x SQRT { [0.3 x 0.01055 / (14.06 x 1)] + 1.9 x 17714.6 x 0.5 x (1413 - 1353.7) /
(14.06 x 1 x 1353.7^3) }
= 34.04 mm

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Designed By / Revision and Date		/ R00 , 24/Aug/2018 11:17:33
FLANGE DESIGN (INTERNAL)		**Shell Flng (Front)**
CODE		**ASME VIII Div.1, 15**

1. DESIGN CONDITIONS (Design Mode 1 , Corroded Condition) :

Design pressure	P	0.15 kgf/mm² g
Design temperature	T	150 °C
Allowance	CA	3 mm
Groove allowance	Tg	0 mm

2. FLANGE DATA :

M.O.C.		SA-105 Frg. [UNS:K03504]
Code allw. stress @ design temp.	Sfo	14.06 kgf/mm²
Code allw. stress @ atm. temp.	Sfa	14.06 kgf/mm²
Inside diameter	B	1256 mm
Outside diameter	A	1463 mm
Hub length	h	12 mm
Thickness (hub end)	g1	21 mm
Thickness (pipe end)	g0	9 mm
Thickness provided		119.5 mm
Thickness available		116.5 mm

3. BOLTING DATA :

M.O.C.		SA-193 GR. B7 Bolt [UNS:G41400]
Code allw. stress @ design temp.	Sb	17.58 kgf/mm²
Code allw. stress @ atm. temp.	Sa	17.58 kgf/mm²
Bolt PCD	C	1413 mm
Bolt dia.	db	22 mm
No. of bolts	nb	56

4. LINER DATA :

M.O.C.		
Liner ID		mm
Liner OD		mm
Liner thk.		mm

5. GASKET DATA :

5a. Flange gasket data :

M.O.C.			CAF with suitable binder (3 mm.)
Gasket type			Ring Gasket
Gasket confinement type			Unconfined
Flange face type			Raised Face
Flange gasket surface finish			Serrated (Normal)
Counter flange face type			Raised Face
Counter gasket surface finish			Serrated (Normal)
Applicable gasket sketch in Table 2-5.2			Type 1B
Applicable gasket column in Table 2-5.2			1
Gasket seating stress	(refer to Note 1, Table 2-5.1)	y	1.125 kgf/mm²
Gasket factor	(from Table 2-5.1)	m	2
Inside diameter		Gi	1256 mm
Outside diameter		Go	1381.9 mm
Width of gasket	(as per Table 2-5.2)	N	62.97 mm

Width of gasket	(as per Table 2-5.2)	w	62.97 mm
Width of raised face or gasket contact width (as per Table 2-5.2)			31.75 mm
Basic gasket seating width	(as per Table 2-5.2)	b0	31.49 mm
Effective gasket width	(as per Table 2-5.2)	b	14.14 mm
Dia. at load reaction	(see Table 2-5.2)	G	1353.7 mm

5b. Partition groove gasket data (For H.E. body flange) :

M.O.C.			--
Gasket seating stress	(refer to Note 1, Table 2-5.1)	y'	0 kgf/mm²
Gasket factor	(from Table 2-5.1)	m'	0
Pass partition gasket width		Wp	0 mm
Pass partition gasket length		Lp	0 mm
Effective pass partition gasket width		b'	0 mm

6. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b1)

Total joint - contact surface compression load [Hp]
= 2 x (π x b x G x m + b' x Lp x m') x P
= 2 x (π x 14.14 x 1353.7 x 2 + 0 x 0 x 0) x 0.15
= 36079.2 kgf
Total hydrostatic end force [H]
= 0.25 x π x G ² x P
= 0.25 x π x 1353.7 ² x 0.15
= 215875.2 kgf
Minimum required bolt load for operating condition [Wm1a]
= Hp + H
= 36079.2 + 215875.2
= 251954.3 kgf
Minimum required bolt load for operating condition [Wm1b]
(from mating flange)
= 251954.3 kgf
Governing bolt load for operating condition [Wm1]
= MAX [Wm1a , Wm1b]
= MAX [251954.3 , 251954.3]
= 251954.3 kgf

7. BOLT LOAD CALCULATION AS PER APPENDIX 2-5 (b2)

Minimum required bolt load for gasket seating [Wm2]
= (π x b x G x y + b' x Lp x y')
= (π x 14.14 x 1353.7 x 1.125 + 0 x 0 x 0)
= 67643.1 kgf

8. BOLT AREAS AS PER APPENDIX 2-5 (d)

Total required cross-sectional area of bolts [Am]
= MAX [Wm2 / Sa , Wm1 / Sb] .... For Internal '+' Pr Design
= Wm2 / Sa .... For External Pr & Self Sealing Design
= 14334.5 mm²
Actual bolt area using root diameter [Ab]
= 15255.5 mm²
Flange design bolt load for the gasket seating [W]
= 0.5 x (Am + Ab) x Sa x 1 .... average bolt area
= Ab x Sa x 1 ....full bolt area
= 260047.9 kgf (Avg. bolt area and margin factor of 1)

9. CHECK FOR GASKET CRUSHING

Minimum gasket width required [Nmin]
= Ab x Sb / (2 x π x y x G)
= 15255.5 x 17.58 / (2 x π x 1.125 x 1353.7)
= 28.03 mm

10. BOLT SPACING CORRECTION FACTOR

As per Brownell & Young or IS 2825,
= SQRT [Bolt spacing / (2 x db + t)]
As per TEMA or BS 5500,
= SQRT [Bolt spacing / Bmax] .... where,

Bmax = maximum recommended bolt spacing = 2 x db + 6 x t / (m + 0.5)
Code Select, Cf = 1 (min. equal to 1)

INTEGRAL FLANGE DESIGN **Shell Flng (Front)**

11. LOADS AND FORCES DURING OPERATING CONDITION AS PER APPENDIX 2-3

Hydrostatic end force on area inside of flange [HD]
= 0.25 x π x B ^{2} x P
= 0.25 x π x 1256 ^{2} x 0.15
= 185849.1 kgf
Gasket load (difference between flange design bolt load and total hydrostatic end force) [HG]
= Wm1 - H
= 251954.3 - 215875.2
= 36079.2 kgf
Difference between total hydrostatic end force and hydrostatic end force on area inside of flange [HT]
= H - HD
= 215875.2 - 185849.1
= 30026.1 kgf

12. MOMENT ARMS FOR FLANGE LOADS AS PER TABLE 2-6

Radial distance from the bolt circle to intersection of hub and back of flange, as per Appendix 2-3 [R]
= 0.5 x (C - B) - g1
= 0.5 x (1413 - 1256) - 21
= 57.5 mm
Radial distance from the bolt circle to the circle on which HD acts [hD]
= R + 0.5 x g1
= 57.5 + 0.5 x 21
= 68 mm
Radial distance from gasket load reaction to the bolt circle [hG]
= 0.5 x (C - G)
= 0.5 x (1413 - 1353.7)
= 29.67 mm
Radial distance from the bolt circle to the circle on which HT acts [hT]
= 0.5 x (R + g1 + hG)
= 0.5 x (57.5 + 21 + 29.67)
= 54.08 mm

13. FLANGE MOMENTS UNDER OPERATING CONDITION AS PER APPENDIX 2-6

Component of moment due to HD [MD]
= HD x hD
= 185849.1 x 68
= 12637737.5 kgf-mm
Component of moment due to HG [MG]
= HG x hG
= 36079.2 x 29.67
= 1070402.1 kgf-mm
Component of moment due to HT [MT]
= HT x hT
= 30026.1 x 54.08
= 1623933.5 kgf-mm
Total moment acting on the flange for operating condition [MO]
= MD + MG + MT
= 12637737.5 + 1070402.1 + 1623933.5
= 15332073.2 kgf-mm

14. LOADS AND FORCES DURING GASKET SEATING AS PER APPENDIX 2-3

Gasket load for seating condition [HG]
= W
= 260047.9 kgf

15. MOMENT UNDER GASKET SEATING AS PER APPENDIX 2-6

Total moment acting on the flange for gasket seating [MO']
= W x hG
= 260047.9 x 29.67
= 7715141.1 kgf-mm

16. SHAPE CONSTANTS

A / B K 1.165

Flange factors from Fig. 2-7.1	T	1.853
	Z	6.606
	Y	12.8
	U	14.06
h0		106.3
F / h0	e	0.00849
Factor from Fig. 2-7.2	F	0.903
Factor from Fig. 2-7.3	V	0.417
g1 / g0		2.333
h / h0		0.113
(U / V) x h0 x $g0^2$	d	290617.3
Factor from Fig. 2-7.6	f	4.354

17. STRESS FORMULA FACTORS

Assumed thickness [t]
= 116.5 mm
Factor [α]
= t x e + 1
= 116.5 x 0.00849 + 1
= 1.99
Factor [β]
= 1.333 x t x e + 1
= 1.333 x 116.5 x 0.00849 + 1
= 2.319
Factor [γ]
= α / T
= 1.99 / 1.853
= 1.074
Factor [δ]
= t^3 / d
= 116.5^3 / 290617.3
= 5.444
Factor [λ]
= $\gamma + \delta$
= 1.074 + 5.444
= 6.518

18. FLANGE STRESSES AS PER APPENDIX 2-7 & 2-8

Equivalent moment [Mmax]
= MAX [MO , MO' x Sfo / Sfa]
= MAX [15332073.2 , 7715141.1 x 14.06 / 14.06]
= 15332073.2 kgf-mm
Corrected equivalent moment per unit length [M]
= Mmax x (Cf / B)
= 15332073.2 x (1 / 1256)
= 12207.1 kgf
Longitudinal hub stress [SH]
= f x M / (λ x $g1^2$)
= 4.354 x 12207.1 / (6.518 x 21^2)
= 18.49 kgf/mm² .... < 1.5 x Sfo
Radial flange stress [SR]
= β x M / (λ x t^2)
= 2.319 x 12207.1 / (6.518 x 116.5^2)
= 0.32 kgf/mm² .... < Sfo
Tangential flange stress [ST]
= (M x Y / t^2) - Z x SR
= (12207.1 x 12.8 / 116.5^2) - 6.606 x 0.32
= 9.391 kgf/mm² .... < Sfo
Average stress

= MAX [0.5 x (SH + SR) , 0.5 x (SH + ST)]
= MAX [0.5 x (18.49 + 0.32) , 0.5 x (18.49 + 9.391)]
= 13.94 kgf/mm² .... < Sfo

19. FLANGE RIGIDITY CHECKING AS PER APPENDIX 2-14

Modulus of elasticity for flange	Efo	19888.4 kgf/mm²
Rigidity factor	KI	0.3

Rigidity index [J]
= 52.14 x V x Mmax / (λ x Efo x g0 ^{2} x KI x h0)
= 52.14 x 0.417 x 15332073.2 / (6.518 x 19888.4 x 9 ^{2} x 0.3 x 106.3)
= 0.995
Since J < 1.0, design is safe

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FLANGE DESIGN (EXTERNAL)	**Shell Flng (Front)**
CODE	**ASME VIII Div.1, 15**

1. DESIGN CONDITIONS (Design Mode 1 , Corroded Condition) :

Design pressure	P	0.01055 kgf/mm² g
Design temperature	T	150 °C
Allowance	CA	3 mm
Groove allowance	Tg	0 mm

2. FLANGE DATA :

M.O.C.		SA-105 Frg. [UNS:K03504]
Code allw. stress @ design temp.	Sfo	14.06 kgf/mm²
Code allw. stress @ atm. temp.	Sfa	14.06 kgf/mm²
Inside diameter	B	1256 mm
Outside diameter	A	1463 mm
Hub length	h	12 mm
Thickness (hub end)	g1	21 mm
Thickness (pipe end)	g0	9 mm
Thickness provided		119.5 mm
Thickness available		116.5 mm

3. BOLTING DATA :

M.O.C.		SA-193 GR. B7 Bolt [UNS:G41400]
Code allw. stress @ design temp.	Sb	17.58 kgf/mm²
Code allw. stress @ atm. temp.	Sa	17.58 kgf/mm²
Bolt PCD	C	1413 mm
Bolt dia.	db	22 mm
No. of bolts	nb	56

4. LINER DATA :

M.O.C.		
Liner ID		mm
Liner OD		mm
Liner thk.		mm

5. GASKET DATA :

5a. Flange gasket data :

M.O.C.			CAF with suitable binder (3 mm.)
Gasket type			Ring Gasket
Gasket confinement type			Unconfined
Flange face type			Raised Face
Flange gasket surface finish			Serrated (Normal)
Counter flange face type			Raised Face
Counter gasket surface finish			Serrated (Normal)
Applicable gasket sketch in Table 2-5.2			Type 1B
Applicable gasket column in Table 2-5.2			1
Gasket seating stress	(refer to Note 1, Table 2-5.1)	y	1.125 kgf/mm²
Gasket factor	(from Table 2-5.1)	m	2
Inside diameter		Gi	1256 mm
Outside diameter		Go	1381.9 mm
Width of gasket	(as per Table 2-5.2)	N	62.97 mm

Width of gasket	(as per Table 2-5.2)	w	62.97 mm
Width of raised face or gasket contact width (as per Table 2-5.2)			31.75 mm
Basic gasket seating width	(as per Table 2-5.2)	b0	31.49 mm
Effective gasket width	(as per Table 2-5.2)	b	14.14 mm
Dia. at load reaction	(see Table 2-5.2)	G	1353.7 mm

5b. Partition groove gasket data (For H.E. body flange) :

M.O.C.			--
Gasket seating stress	(refer to Note 1, Table 2-5.1)	y'	0 kgf/mm²
Gasket factor	(from Table 2-5.1)	m'	0
Pass partition gasket width		Wp	0 mm
Pass partition gasket length		Lp	0 mm
Effective pass partition gasket width		b'	0 mm

6. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b1)

Total joint - contact surface compression load [Hp]
= 2 x (π x b x G x m + b' x Lp x m') x P
= 2 x (π x 14.14 x 1353.7 x 2 + 0 x 0 x 0) x 0.01055
= 2536.7 kgf
Total hydrostatic end force [H]
= 0.25 x π x G ² x P
= 0.25 x π x 1353.7 ² x 0.01055
= 15177.9 kgf
Minimum required bolt load for operating condition [Wm1a]
= Hp + H
= 2536.7 + 15177.9
= 17714.6 kgf
Minimum required bolt load for operating condition [Wm1b]
(from mating flange)
= 17714.6 kgf
Governing bolt load for operating condition [Wm1]
= MAX [Wm1a , Wm1b]
= MAX [17714.6 , 17714.6]
= 17714.6 kgf

7. BOLT LOAD CALCULATION AS PER APPENDIX 2-5 (b2)

Minimum required bolt load for gasket seating [Wm2]
= (π x b x G x y + b' x Lp x y')
= (π x 14.14 x 1353.7 x 1.125 + 0 x 0 x 0)
= 67643.1 kgf

8. BOLT AREAS AS PER APPENDIX 2-5 (d)

Total required cross-sectional area of bolts [Am]
= MAX [Wm2 / Sa , Wm1 / Sb] .... For Internal '+' Pr Design
= Wm2 / Sa .... For External Pr & Self Sealing Design
= 3848.4 mm²
Actual bolt area using root diameter [Ab]
= 15255.5 mm²
Flange design bolt load for the gasket seating [W]
= 0.5 x (Am + Ab) x Sa x 1 .... average bolt area
= Ab x Sa x 1 ....full bolt area
= 167892.3 kgf (Avg. bolt area and margin factor of 1)

9. CHECK FOR GASKET CRUSHING

Minimum gasket width required [Nmin]
= Ab x Sb / (2 x π x y x G)
= 15255.5 x 17.58 / (2 x π x 1.125 x 1353.7)
= 28.03 mm

10. BOLT SPACING CORRECTION FACTOR

As per Brownell & Young or IS 2825,
= SQRT [Bolt spacing / (2 x db + t)]
As per TEMA or BS 5500,
= SQRT [Bolt spacing / Bmax] .... where,

Bmax = maximum recommended bolt spacing = 2 x db + 6 x t / (m + 0.5)

Code Select, Cf = 1 (min. equal to 1)

INTEGRAL FLANGE DESIGN **Shell Flng (Front)**

11. LOADS AND FORCES DURING OPERATING CONDITION AS PER APPENDIX 2-3

Hydrostatic end force on area inside of flange [HD]

= 0.25 x π x B ^{2} x P

= 0.25 x π x 1256 ^{2} x 0.01055

= 13066.8 kgf

Difference between total hydrostatic end force and hydrostatic end force on area inside of flange [HT]

= H - HD

= 15177.9 - 13066.8

= 2111.1 kgf

12. MOMENT ARMS FOR FLANGE LOADS AS PER APPENDIX TABLE 2-6

Radial distance from the bolt circle to intersection of hub and back of flange, as per Appendix 2-3 [R]

= 0.5 x (C - B) - g1

= 0.5 x (1413 - 1256) - 21

= 57.5 mm

Radial distance from the bolt circle to the circle on which HD acts [hD]

= R + 0.5 x g1

= 57.5 + 0.5 x 21

= 68 mm

Radial distance from gasket load reaction to the bolt circle [hG]

= 0.5 x (C - G)

= 0.5 x (1413 - 1353.7)

= 29.67 mm

Radial distance from the bolt circle to the circle on which HT acts [hT]

= 0.5 x (R + g1 + hG)

= 0.5 x (57.5 + 21 + 29.67)

= 54.08 mm

13. FLANGE MOMENTS UNDER OPERATING CONDITION AS PER APPENDIX 2-6

Component of moment due to HD [MD]

= HD x (hD - hG)

= 13066.8 x (68 - 29.67)

= 500874.5 kgf-mm

Component of moment due to HT [MT]

= HT x (hT - hG)

= 2111.1 x (54.08 - 29.67)

= 51544.3 kgf-mm

Total moment acting on the flange for operating condition [MO]

= MD + MT

= 500874.5 + 51544.3

= 552418.8 kgf-mm

14. LOADS AND FORCES DURING GASKET SEATING AS PER APPENDIX 2-3

Gasket load for seating condition [HG]

= W

= 167892.3 kgf

15. MOMENT UNDER GASKET SEATING AS PER APPENDIX 2-6

Total moment acting on the flange for gasket seating [MO']

= W x hG

= 167892.3 x 29.67

= 4981054.6 kgf-mm

16. SHAPE CONSTANTS

A / B	K	1.165
Flange factors from Fig. 2-7.1	T	1.853
	Z	6.606
	Y	12.8
	U	14.06
h0		106.3
F / h0	e	0.00849

Factor from Fig. 2-7.2	F	0.903
Factor from Fig. 2-7.3	V	0.417
g1 / g0		2.333
h / h0		0.113
(U / V) x h0 x g0 ^{2}	d	290617.3
Factor from Fig. 2-7.6	f	4.354

17. STRESS FORMULA FACTORS

Assumed thickness [t]
= 71.38 mm
Factor [α]
= t x e + 1
= 71.38 x 0.00849 + 1
= 1.606
Factor [β]
= 1.333 x t x e + 1
= 1.333 x 71.38 x 0.00849 + 1
= 1.808
Factor [γ]
= α / T
= 1.606 / 1.853
= 0.867
Factor [δ]
= t ^{3} / d
= 71.38 ^{3} / 290617.3
= 1.251
Factor [λ]
= γ + δ
= 0.867 + 1.251
= 2.118

18. FLANGE STRESSES AS PER APPENDIX 2-7 & 2-8

Equivalent moment [Mmax]
= MAX [MO , MO' x Sfo / Sfa]
= MAX [552418.8 , 4981054.6 x 14.06 / 14.06]
= 4981054.6 kgf-mm
Corrected equivalent moment per unit length [M]
= Mmax x (Cf / B)
= 4981054.6 x (1 / 1256)
= 3965.8 kgf
Longitudinal hub stress [SH]
= f x M / (λ x g1 ^{2})
= 4.354 x 3965.8 / (2.118 x 21 ^{2})
= 18.49 kgf/mm² .... < 1.5 x Sfo
Radial flange stress [SR]
= β x M / (λ x t ^{2})
= 1.606 x 3965.8 / (2.118 x 71.38 ^{2})
= 0.665 kgf/mm² .... < Sfo
Tangential flange stress [ST]
= (M x Y / t ^{2}) - Z x SR
= (3965.8 x 12.8 / 71.38 ^{2}) - 6.606 x 0.665
= 5.571 kgf/mm² .... < Sfo
Average stress
= MAX [0.5 x (SH + SR) , 0.5 x (SH + ST)]
= MAX [0.5 x (18.49 + 0.665) , 0.5 x (18.49 + 5.571)]
= 12.03 kgf/mm² .... < Sfo

19. FLANGE RIGIDITY CHECKING AS PER APPENDIX AS PER 2-14

Modulus of elasticity for flange	Efo	19888.4 kgf/mm²
Rigidity factor	KI	0.3

Rigidity index [J]

$= 52.14 \times V \times Mmax / (\lambda \times Efo \times g0^2 \times KI \times h0)$

$= 52.14 \times 0.417 \times 4981054.6 / (2.118 \times 19888.4 \times 9^2 \times 0.3 \times 106.3)$

= 0.994

Since J < 1.0, design is safe

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DESIGN OF SHELL (INTERNAL AND EXTERNAL PRESSURE)	**Main Shell**
CODE	**ASME VIII Div.1, 15**

1. DESIGN CONDITIONS (Design Mode 1 , Corroded Condition)

Design pressure (internal)	Pi	0.15 kgf/mm² g
Design pressure (external)	Pe	0.01055 kgf/mm² g
Design temperature	T	150 °C
Material of construction		SA-516 GR. 70 Plt. [UNS:K02700]
Max. allowable stress at design temp.	S	14.06 kgf/mm²
Radiography		Spot
Joint efficiency long. seam	Ec	0.85
Outside diameter	OD	1274 mm
Inside radius (corroded)	R	628 mm
Shell length	L	1650 mm
Design length	L1	1650 mm
Nominal thickness		12 mm
Nominal thickness required as per TEMA		N.A. mm
Internal allowance, corrosion + polishing		3 mm
External allowance, corrosion + polishing		0 mm
Thickness undertolerance		0 mm
Available thickness		9 mm

2. DESIGN CALCULATION AS PER UG-27

Thickness of shell under internal pressure [ti]
= Pi x R / (S x E - 0.6 x Pi)
= 0.15 x 628 / (14.06 x 0.85 - 0.6 x 0.15)
= 7.941 mm

3. DESIGN CALCULATION OF SHELL THICKNESS UNDER EXTERNAL PRESSURE AS PER UG-28

Assumed te	4.506 mm
L1 / OD	1.295
OD / te	282.7
Factor A (Refer to Fig. G in Subpart 3 of Sec. II, Part D)	0.00021
Factor B (CS-2)	2.298 kgf/mm²

Allowable external pressure [Pa]
= 4 x B / (3 x (OD / te))
= 4 x 2.298 / (3 x 282.7)
= 0.01084 kgf/mm² g
Since Pa > Pe, design is safe
Since available thickness is more than design thickness, design is safe.

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DESIGN OF ELLIPSOIDAL HEAD (INT. & EXT. PRESSURE)	**Dished End (Rear)**
CODE	**ASME VIII Div.1, 15**

1. DESIGN CONDITIONS (Design Mode 1 , Corroded Condition) :

Design pressure (internal)	Pi	0.15 kgf/mm² g
Design pressure (external)	Pe	0.01055 kgf/mm² g
Design temperature	T	150 °C
Material of construction		SA-516 GR. 70 Plt. [UNS:K02700]
Max. allowable stress @ design temp.	S	14.06 kgf/mm²
Radiography		Full
Joint efficiency	E	1
Outside diameter of head	OD	1274 mm
Inside diameter of shell	ID	1256 mm
Head shape		Elliptical D/2H = 2.0
Nominal thickness		12 mm
Nominal thickness required as per TEMA		N.A mm
Internal allowance, corrosion + polishing		3 mm
External allowance, corrosion + polishing		0 mm
Thinning allowance / Under tolerance		1.2 mm
Available thickness		7.8 mm

2. DESIGN CALCULATION AS PER UG 32 d / APPENDIX 1-4 (c) :

Factor [K]
= 1
Thickness for internal pressure [t]
= K x Pi x ID / (2 x S x E - 0.2 x Pi)
= 1 x 0.15 x 1256 / (2 x 14.06 x 1 - 0.2 x 0.15)
= 6.706 mm

3. DESIGN CALCULATION AS PER UG 33 d :

Thickness for equivalent internal pressure [t]
= K x 1.67 x Pe x ID / (2 x S x 1.0 - 0.2 x 1.67 x Pe)
= 1 x 1.67 x 0.01055 x 1256 / (2 x 14.06 x 1.0 - 0.2 x 1.67 x 0.01055)
= 0.787 mm
Factor [Ko]
= 0.88
Assumed head thickness, [te]
= 3.211 mm
Factor [A]
= 0.125 x te / (Ko x OD)
= 0.125 x 3.211 / (0.88 x 1274)
= 0.00036
Factor with reference to chart (CS-2) [B]
= 3.771 kgf/mm²
Allowable external pressure [Pa]
= B / (Ko x OD / te)
= 3.771 x 3.211 / (0.88 x 1274)
= 0.0108 kgf/mm²
Since Pa > Pe, design is safe

Since available thickness is more than design thickness, design is safe.

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LUG SUPPORT DESIGN	**Lug Support**
CODE	**P V Design Manual, D.R. Moss**
	Design Mode 1 , Corroded Condition

1. LUG DATA :

M.O.C		IS-2062 GR. A Plt.
No. of support	N	4
Base plate width	b1	222 mm
Base plate depth	Lb	200 mm
Thickness of base plate	tb	16 mm
Allowable bending stress	Sb	22.15 kgf/mm²

2. BOLT DATA :

M.O.C		Commercial CS Bolt
No. of bolt / lug	Nb	1
Bolt diameter	db	20 mm
PCD	D	1598 mm
Diameter of bolt hole		24 mm
Allowable tensile stress	Fs	10.69 kgf/mm²

3. GUSSET DATA :

Thickness	tg	16 mm
Height	h	190 mm
Gusset angle	θ	51.71
Gusset depth at top	Lc	50 mm
Number of gussets	n	2
Distance between gussets	b	180 mm

4. SHELL DATA :

Material		SA-516 GR. 70 Plt. [UNS:K02700]
OD diameter	OD	1274 mm
Inside diameter	ID	1256 mm
Thickness available	ts	9 mm

5. PAD DATA :

Material		SA-516 GR. 70 Plt. [UNS:K02700]
Thickness	tp	12 mm
Width	W	275 mm
Length	L	272 mm

6. LOAD AND MOMENT (Wind) :

Max. overturning moment	M	791596.4 kgf-mm
Design weight of vessel	Wt	2415.5 kgf

7. DESIGN OF ANCHOR BOLTS :

Total uplift force on bolts [T]

= [4 x M / (D x N)] - Wt / N

= [4 x 791596.4 / (1598 x 4)] - 2415.5 / 4

= -108.5 kgf

Required area of bolts [Am]

= MAX [(T / Fs) , 0]

= MAX [(-108.5 / 10.69) , 0]

= 0 mm²

Available area of bolts [Ab]

= Ar x Nb .... where, Ar = 217.1 mm², is root area of bolt

= 217.1 x 1

= 217.1 mm²

Since Ab > Am, bolts provided are sufficient

8. GUSSET DESIGN :

Reaction force at each support [Q]

= [4 x M / (D x N)] + Wt / N

= [4 x 791596.4 / (1598 x 4)] + 2415.5 / 4

= 1099.2 kgf

Maximum axial force in gusset [P1]

= Q / n

= 1099.2 / 2

= 549.6 kgf

Allowable compr. stress in gusset [Sg]

= 18000 / [1 + 12 x (h' / tg) ^{2} / 18000] .... where, h' = 242.1 mm

= 18000 / [1 + 12 x (242.1 / 16) ^{2} / 18000]

= 15616.8 psi

= 10.98 kgf/mm²

Required thickness of gusset [tg']

= 2 x P1 x (3 x a - Lb) / [Sg x Lb ^{2} x (sin θ) ^{2}]

= 2 x 549.6 x (3 x 150 - 200) / [10.98 x (200) ^{2} x (sin 51.71) ^{2}]

= 1.016 mm

9. BASE PLATE DESIGN :

Bending moment [Mb]

= Q x b1 / 6

= 1099.2 x 222 / 6

= 40671.8 kgf-mm

Bearing pressure [bp]

= Q / (w x b1) .... where, w = 120 mm

= 1099.2 / (120 x 222)

= 0.04126 kgf/mm²

Bending moment due to bearing pressure [Mb']

= bp x b ^{2} / 10

= 0.04126 x 180 ^{2} / 10

= 133.7 kgf-mm

Required thickness of base plate between chairs [tb']

= SQRT { 6 x MAX [Mb , Mb'] / [(Lb - db) x Sb] }

= SQRT { 6 x MAX [40671.8 , 133.7] / [(200 - 20) x 22.15] }

= 7.912 mm

10. CHECK FOR COMPRESSION PLATE :

Equivalent radial load [f]

= Q x a / (n x h)

= 1099.2 x 150 / (2 x 190)

= 433.9 kgf

Angle between supports [α]

= 2 x π / N

= 2 x π / 4

= 1.571 rad

Internal bending moment coefficient [Kr]

= 0.5 x [1 / (0.5 x α) - cot (0.5 x α)]
= 0.5 x [1 / (0. 5 x 1.571) - cot (0.5 x 1.571)]
= 0.137
Internal bending moment [Mc]
= 0.5 x Kr x f x OD
= 0.5 x 0.137 x 433.9 x 1274
= 37761.8 kgf-mm
Bending stress induced [fb]
= Mo / Zc
= 37761.8 / 13224.4
= 2.855 kgf/mm^2 .... < Sb = 22.15 kgf/mm^2
Since, induced stress fb < allow. stress Sb in shell material, design is safe.

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LUG SUPPORT DESIGN	**Lug Support**
CODE	**P V Design Manual, D.R. Moss**
	Design Mode 1 , Corroded Condition

1. LUG DATA :

M.O.C		IS-2062 GR. A Plt.
No. of support	N	4
Base plate width	b1	222 mm
Base plate depth	Lb	200 mm
Thickness of base plate	tb	16 mm
Allowable bending stress	Sb	22.15 kgf/mm^2

2. BOLT DATA :

M.O.C		Commercial CS Bolt
No. of bolt / lug	Nb	1
Bolt diameter	db	20 mm
PCD	D	1598 mm
Diameter of bolt hole		24 mm
Allowable tensile stress	Fs	10.69 kgf/mm^2

3. GUSSET DATA :

Thickness	tg	16 mm
Height	h	190 mm
Gusset angle	θ	51.71
Gusset depth at top	Lc	50 mm
Number of gussets	n	2
Distance between gussets	b	180 mm

4. SHELL DATA :

Material		SA-516 GR. 70 Plt. [UNS:K02700]
OD diameter	OD	1274 mm
Inside diameter	ID	1256 mm
Thickness available	ts	9 mm

5. PAD DATA :

Material		SA-516 GR. 70 Plt. [UNS:K02700]
Thickness	tp	12 mm
Width	W	275 mm
Length	L	272 mm

6. LOAD AND MOMENT (Seismic) :

Max. overturning moment	M	393227.8 kgf-mm
Design weight of vessel	Wt	4789.1 kgf

7. DESIGN OF ANCHOR BOLTS :

Total uplift force on bolts [T]

= [4 x M / (D x N)] - Wt / N

= [4 x 393227.8 / (1598 x 4)] - 4789.1 / 4

= -951.2 kgf

Required area of bolts [Am]

= MAX [(T / Fs) , 0]

= MAX [(-951.2 / 10.69) , 0]

= 0 mm²
Available area of bolts [Ab]
= Ar x Nb .... where, Ar = 217.1 mm², is root area of bolt
= 217.1 x 1
= 217.1 mm²
Since Ab > Am, bolts provided are sufficient

8. GUSSET DESIGN :

Reaction force at each support [Q]
= [4 x M / (D x N)] + Wt / N
= [4 x 393227.8 / (1598 x 4)] + 4789.1 / 4
= 1443.3 kgf
Maximum axial force in gusset [P1]
= Q / n
= 1443.3 / 2
= 721.7 kgf
Allowable compr. stress in gusset [Sg]
= 18000 / [1 + 12 x (h' / tg) ^{2} / 18000] .... where, h' = 242.1 mm
= 18000 / [1 + 12 x (242.1 / 16) ^{2} / 18000]
= 15616.8 psi
= 10.98 kgf/mm²
Required thickness of gusset [tg']
= 2 x P1 x (3 x a - Lb) / [Sg x Lb ^{2} x (sin θ) ^{2}]
= 2 x 721.7 x (3 x 150 - 200) / [10.98 x (200) ^{2} x (sin 51.71) ^{2}]
= 1.334 mm

9. BASE PLATE DESIGN :

Bending moment [Mb]
= Q x b1 / 6
= 1443.3 x 222 / 6
= 53403.7 kgf-mm
Bearing pressure [bp]
= Q / (w x b1) .... where, w = 120 mm
= 1443.3 / (120 x 222)
= 0.05418 kgf/mm²
Bending moment due to bearing pressure [Mb']
= bp x b ^{2} / 10
= 0.05418 x 180 ^{2} / 10
= 175.5 kgf-mm
Required thickness of base plate between chairs [tb']
= SQRT { 6 x MAX [Mb , Mb'] / [(Lb - db) x Sb] }
= SQRT { 6 x MAX [53403.7 , 175.5] / [(200 - 20) x 22.15] }
= 9.067 mm

10. CHECK FOR COMPRESSION PLATE :

Equivalent radial load [f]
= Q x a / (n x h)
= 1443.3 x 150 / (2 x 190)
= 569.7 kgf
Angle between supports [α]
= 2 x π / N
= 2 x π / 4
= 1.571 rad
Internal bending moment coefficient [Kr]

= 0.5 x [1 / (0.5 x α) - cot (0.5 x α)]
= 0.5 x [1 / (0. 5 x 1.571) - cot (0.5 x 1.571)]
= 0.137
Internal bending moment [Mc]
= 0.5 x Kr x f x OD
= 0.5 x 0.137 x 569.7 x 1274
= 49582.7 kgf-mm
Bending stress induced [fb]
= Mo / Zc
= 49582.7 / 13224.4
= 3.749 kgf/mm^2 .... < Sb = 22.15 kgf/mm^2
Since, induced stress fb < allow. stress Sb in shell material, design is safe.

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NOZZLE NECK THICKNESS AND REINFORCEMENT DESIGN	**N 01**
CODE	**ASME VIII Div.1, 15**
	Design Mode 1 , Corroded Condition

DESIGN CONDITIONS

Design pressure (internal)	Pi	0.15 kgf/mm² g
Design pressure (external)	Pe	0.01055 kgf/mm² g
Design temperature	T	150 °C

NOZZLE DATA

M.O.C.		SA-106 GR. B Smls. Pipe [UNS:K03006]
Allowable stress @ design temperature	Sn	12.02 kgf/mm²
Outside diameter	OD	168.3 mm
Inside diameter	ID	152.3 mm
Maximum chord length	D	152.3 mm
Neck thickness (provided)	tnp	10.97 mm
Internal allowance , corrosion + polishing	CAI	3 mm
External allowance , corrosion + polishing	CAE	0
Neck thickness (tnp - CAI - CAE)	tn	7.973 mm
Max. under tolerance on thickness	Alw	1.372 mm
Available neck thickness (tn - Alw)	tc	6.601 mm
Nozzle projection outward (from vessel outer face)	Lo	150 mm
Total length of nozzle (Lo + tvp + Addn for curvature)	L	156 mm
Connection type		Pipe Nozzle
Application type		Process Opening
Reinforcement calculation method		Isolated Opening
Design as large opening		False

SHELL DATA (Main Shell)

M.O.C.		SA-516 GR. 70 Plt. [UNS:K02700]
Allowable stress @ design temperature	Sv	14.06 kgf/mm²
Inside radius	R	628 mm
Thickness	t	9 mm
Min. thickness for external pressure	tr2	4.506 mm

WELD DATA

Nozzle outside weld	W1	10.86 mm

CALCULATION OF NOZZLE NECK THICKNESS AS PER UG-45

Neck thickness for internal pressure , [ta_1]
Formula in Appendix 1-1 , [ta_1]
= (0.5 x Pi x OD) / (Sn x E + 0.4 x Pi)
= (0.5 x 0.15 x 168.3) / (12.02 x 1.0 + 0.4 x 0.15)
= 1.045 mm
Neck thickness for external pressure , [ta_2]
Neck thickness for external pressure as per UG-28
Assumed neck thickness , [ta_2] = 0.552 mm
L / OD = 0.891
OD / ta_2 = 304.7
Factor A = 0.00028
Factor B = 2.985 kgf/mm²

Allowable external pressure , [Pa]
= 4 x B / (3 x OD / ta_2)
= 4 x 2.985 / (3 x 304.7)
= 0.01306 kgf/mm² g
Shell thickness for internal pressure as per UG-37 & UG-27 , [tr1 = tb_1]
= Pi x R / (Sv x E - 0.6 x Pi)
= 0.15 x 628 / (14.06 x 1.0 - 0.6 x 0.15)
= 6.742 mm
Shell thickness considering internal pressure equal to external pressure as per UG-27 , [tb_2]
= Pe x R / (Sv x E - 0.6 x Pe)
= 0.01055 x 628 / (14.06 x 1.0 - 0.6 x 0.01055)
= 0.471 mm
Nozzle minimum thickness required as per Table UG-45 , [tb_3]
= 6.223 mm
Minimum thickness of vessel wall required as per UG-16(b) , [t_min]
= 1.6 mm
Neck thk as per UG-45 , [tUG_45]
Thickness , [ta]
= MAX [ta_1 , ta_2 , t_min]
= MAX [1.045 , 0.552 , 1.6]
= 1.6 mm
Thickness , [tb]
= MIN [tb_3 , MAX (tb_1 , tb_2 , t_min)]
= MIN [6.223 , MAX (6.742 , 6.223 , 1.6)]
= 6.223 mm
Thickness , [tUG_45]
= MAX [ta , tb] .... for Process Nozzle
= ta .... for Access Opening
= 6.223 mm .... Process Opening
Since available neck thickness, tc >= tUG_45 , selected neck thickness is adequate.

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NOZZLE NECK THICKNESS AND REINFORCEMENT DESIGN		**N 02**
CODE		**ASME VIII Div.1, 15**
		Design Mode 1 , Corroded Condition
DESIGN CONDITIONS		
Design pressure (internal)	Pi	0.15 kgf/mm² g
Design pressure (external)	Pe	0.01055 kgf/mm² g
Design temperature	T	150 °C
NOZZLE DATA		
M.O.C.		SA-106 GR. B Smls. Pipe [UNS:K03006]
Allowable stress @ design temperature	Sn	12.02 kgf/mm²
Outside diameter	OD	168.3 mm
Inside diameter	ID	152.3 mm
Maximum chord length	D	152.3 mm
Neck thickness (provided)	tnp	10.97 mm
Internal allowance , corrosion + polishing	CAI	3 mm
External allowance , corrosion + polishing	CAE	0
Neck thickness (tnp - CAI - CAE)	tn	7.973 mm
Max. under tolerance on thickness	Alw	1.372 mm
Available neck thickness (tn - Alw)	tc	6.601 mm
Nozzle projection outward (from vessel outer face)	Lo	150 mm
Total length of nozzle (Lo + tvp + Addn for curvature)	L	156 mm
Connection type		Pipe Nozzle
Application type		Process Opening
Reinforcement calculation method		Isolated Opening
Design as large opening		False
SHELL DATA (Main Shell)		
M.O.C.		SA-516 GR. 70 Plt. [UNS:K02700]
Allowable stress @ design temperature	Sv	14.06 kgf/mm²
Inside radius	R	628 mm
Thickness	t	9 mm
Min. thickness for external pressure	tr2	4.506 mm
WELD DATA		
Nozzle outside weld	W1	10.86 mm

CALCULATION OF NOZZLE NECK THICKNESS AS PER UG-45

Neck thickness for internal pressure , [ta_1]
Formula in Appendix 1-1 , [ta_1]
= (0.5 x Pi x OD) / (Sn x E + 0.4 x Pi)
= (0.5 x 0.15 x 168.3) / (12.02 x 1.0 + 0.4 x 0.15)
= 1.045 mm
Neck thickness for external pressure , [ta_2]
Neck thickness for external pressure as per UG-28
Assumed neck thickness , [ta_2] = 0.552 mm
L / OD = 0.891
OD / ta_2 = 304.7
Factor A = 0.00028
Factor B = 2.985 kgf/mm²

Allowable external pressure , [Pa]
= 4 x B / (3 x OD / ta_2)
= 4 x 2.985 / (3 x 304.7)
= 0.01306 kgf/mm^2 g
Shell thickness for internal pressure as per UG-37 & UG-27 , [tr1 = tb_1]
= Pi x R / (Sv x E - 0.6 x Pi)
= 0.15 x 628 / (14.06 x 1.0 - 0.6 x 0.15)
= 6.742 mm
Shell thickness considering internal pressure equal to external pressure as per UG-27 , [tb_2]
= Pe x R / (Sv x E - 0.6 x Pe)
= 0.01055 x 628 / (14.06 x 1.0 - 0.6 x 0.01055)
= 0.471 mm
Nozzle minimum thickness required as per Table UG-45 , [tb_3]
= 6.223 mm
Minimum thickness of vessel wall required as per UG-16(b) , [t_min]
= 1.6 mm
Neck thk as per UG-45 , [tUG_45]
Thickness , [ta]
= MAX [ta_1 , ta_2 , t_min]
= MAX [1.045 , 0.552 , 1.6]
= 1.6 mm
Thickness , [tb]
= MIN [tb_3 , MAX (tb_1 , tb_2 , t_min)]
= MIN [6.223 , MAX (6.742 , 6.223 , 1.6)]
= 6.223 mm
Thickness , [tUG_45]
= MAX [ta , tb] .... for Process Nozzle
= ta .... for Access Opening
= 6.223 mm .... Process Opening
Since available neck thickness, tc >= tUG_45 , selected neck thickness is adequate.

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NOZZLE NECK THICKNESS AND REINFORCEMENT DESIGN	**N 03**
CODE	**ASME VIII Div.1, 15**
	Design Mode 1 , Corroded Condition

DESIGN CONDITIONS

Design pressure (internal)	Pi	0.15 kgf/mm² g
Design pressure (external)	Pe	0.01055 kgf/mm² g
Design temperature	T	150 °C

NOZZLE DATA

M.O.C.		SA-106 GR. B Smls. Pipe [UNS:K03006]
Allowable stress @ design temperature	Sn	12.02 kgf/mm²
Outside diameter	OD	168.3 mm
Inside diameter	ID	137.7 mm
Maximum chord length	D	137.7 mm
Neck thickness (provided)	tnp	18.26 mm
Internal allowance , corrosion + polishing	CAI	3 mm
External allowance , corrosion + polishing	CAE	0
Neck thickness (tnp - CAI - CAE)	tn	15.26 mm
Max. under tolerance on thickness	Alw	2.283 mm
Available neck thickness (tn - Alw)	tc	12.98 mm
Nozzle projection outward (from vessel outer face)	Lo	150 mm
Nozzle projection inward (from vessel inner face)	Li	0 mm
Total length of nozzle (Lo + Li + tvp + Addn for curvature)	L	151 mm
Connection type		Pipe Nozzle
Application type		Process Opening
Reinforcement calculation method		Isolated Opening
Design as large opening		False

HEAD DATA (Dished End (Rear))

Allowable stress @ design temperature	Sv	14.06 kgf/mm²
Inside diameter of head @ head skirt	Dsf	1256 mm
D / 2 H for Ellispoidal head		2
Factor from Table UG-37	K1	0.9
Inside diameter of equivalent sphere, K1 x Dsk x 2	ID1	2260.8 mm
Thickness	t	7.8 mm
Min. thickness for external pressure	tr2	3.211 mm

WELD DATA

Nozzle outside weld	W1	11.88 mm

CALCULATION OF NOZZLE NECK THICKNESS AS PER UG-45

Neck thickness for internal pressure , [ta_1]
Formula in Appendix 1-1 , [ta_1]
= (0.5 x Pi x OD) / (Sn x E + 0.4 x Pi)
= (0.5 x 0.15 x 168.3) / (12.02 x 1.0 + 0.4 x 0.15)
= 1.045 mm
Neck thickness for external pressure , [ta_2]
Neck thickness for external pressure as per UG-28

Assumed neck thickness , [ta_2] = 0.538 mm
L / OD = 0.891
OD / ta_2 = 312.9
Factor A = 0.00027
Factor B = 2.872 kgf/mm^2
Allowable external pressure , [Pa]
= 4 x B / (3 x OD / ta_2)
= 4 x 2.872 / (3 x 312.9)
= 0.01224 kgf/mm^2 g
Head thickness for internal pressure as per UG-37 & UG-27(d) , [tr1 = tb_1]
= 0.5 x Pi x ID1 / (2 x Sv x E - 0.2 x Pi)
= 0.5 x 0.15 x 2260.8 / (2 x 14.06 x 1.0 - 0.2 x 0.15)
= 6.036 mm
Head thickness considering internal pressure equal to external pressure per UG-27(d) , [tb_2]
= 0.5 x Pe x ID1 / (2 x Sv x E - 0.2 x Pe)
= 0.5 x 0.01055 x 2260.8 / (2 x 14.06 x 1.0 - 0.2 x 0.01055)
= 0.424 mm
Nozzle minimum thickness required as per Table UG-45 , [tb_3]
= 6.223 mm
Minimum thickness of vessel wall required as per UG-16(b) , [t_min]
= 1.6 mm
Neck thk as per UG-45 , [tUG_45]
Thickness , [ta]
= MAX [ta_1 , ta_2 , t_min]
= MAX [1.045 , 0.538 , 1.6]
= 1.6 mm
Thickness , [tb]
= MIN [tb_3 , MAX (tb_1 , tb_2 , t_min)]
= MIN [6.223 , MAX (6.036 , 0.424 , 1.6)]
= 6.036 mm
Thickness , [tUG_45]
= MAX [ta , tb] .... for Process Nozzle
= ta .... for Access Opening
= 6.036 mm .... Process Opening
Since available neck thickness, tc >= tUG_45 , selected neck thickness is adequate.

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DESIGN OF LIFTING LUG	**Lifting Lugs**
CODE	**P V Design Manual, D.R. Moss**
	Design Mode 1 , Uncorroded Condition

1. LIFTING LUG DATA :

Material		IS-2062 GR. A Plt.
Length of lug	LL	70 mm
Width of lug	A	120 mm
Thickness of lug plate	TL	14 mm
Straight length	B1	10 mm
Radius at tip	R3	35 mm
Pin Hole diameter	D1	40 mm
Lug to vessel weld size	W1	6.216 mm
Min yield stress	Sy	24.61 kgf/mm²
Allowable tensile stress (2 / 3 x Sy)	St	16.4 kgf/mm²
Allowable bending stress (1.5 x St)	Sb	22.15 kgf/mm²
Allowable shear stress (0.6 x St)	Ss	9.843 kgf/mm²

2. DESIGN LOADS :

Total design lift weight	Wt	2660.6 kgf
Number of lifting lugs	N	2
Jirk load factor	j	1.5

3. CALCULATION OF REFERENCE DIMENSIONS :

Dimension [L1]
= LL - B1 - R3
= 70 - 10 - 35
= 25 mm

Dimension [LT]
= LL - R3
= 70 - 35
= 35 mm

Angle [θ1]
= ATAN (2 x L1 / A)
= ATAN (2 x 25 / 120)
= 0.395 radians

Dimension [L2]
= L1 / SIN (θ1)
= 25 / SIN (0.395)
= 65 mm

Angle [θ2]
= ASIN (R3 / L2)
= ASIN (35 / 65)
= 0.569 radians

Angle [θ3]
= θ1 + θ2
= 0.395 + 0.569
= 0.963 radians

Dimension [L3]
= R3 / SIN (θ3)
= 35 / SIN (0.963)
= 42.62 mm

4. DESIGN OF LUG PLATE :

Effective design load on each lug [P]
= j x Wt / N
= 1.5 x 2660.6 / 2
= 1998.1 kgf

Required min. thickness of lug plate for shear [t2]
= P / [(R3 - 0.5 x D1) x ss]
= 1998.1 / [(35 - 0.5 x 40) x 9.843]
= 13.53 mm

Required min. thickness of lug plate for bending [t1]

Required min. thickness of lug plate for tension [t3]

= 6 x P x LT / (A ^{2} x Sb)

= 6 x 1998.1 x 35 / (120 ^{2} x 22.15)

= 1.316 mm

= P / [(2 x L3 - D1) x ss]

= 1998.1 / [(2 x 42.62 - 40) x 16.4]

= 2.692 mm

5. CALCULATION OF STRESSES IN LUG PLATE WELDS :

Bending stress in weld [f1]

= 6 x P x LT / [2 x LL^{2}]

= 6 x 1998.1 x 35 / (2 x 70 ^{2})

= 42.82 kgf/mm

Max. shear stress in weld [f2]

= P / [2 x A]

= 1998.1 / (2 x 120)

= 8.326 kgf/mm

Min. Size of lug plate weld [w1]

= MAX (f1 , 2 x f2) / (0.707 x Ss)

= MAX (42.82 , 2 x 8.326) / (0.707 x 9.843)

= 6.153 mm

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Project / Equipment Soap Plant / PV-01 - Gas Filter

Designed By / Revision and Date / R00 , 24/Aug/2018 11:17:33

FOUNDATION LOAD DATA

Sr. No.	Mode	Condition	Weight (kgf)		Wind				Seismic	
					Shear (kgf)		Moment (kgf-m)		Shear	Moment
			Empty	Filled	Tran.	Long.	Tran.	Long.	(kgf)	(kgf-m)
1	Operating	Corroded	2415.5	4789.1	626.1	626.1	791.6	791.6	433.7	393.2
2	Design1	Corroded	2415.5	4789.1	626.1	626.1	791.6	791.6	433.7	393.2
3	Operating	Uncorroded	2660.6	5009.7	626.1	626.1	751.5	751.5	451.6	404.1
4	Design1	Uncorroded	2660.6	5009.7	626.1	626.1	751.5	751.5	451.6	404.1

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Designed By / Revision and Date / R00 , 24/Aug/2018 11:17:33

CENTER OF GRAVITY DATA

Sr. No.	Mode	Condition	Empty		Operating / Filled	
			Wt (kgf)	C.G. (mm)	Wt (kgf)	C.G. (mm)
1	Operating	Corroded	2415.5	1738.9	4789.1	1381.1
2	Design1	Corroded	2415.5	1738.9	4789.1	1381.1
3	Operating	Uncorroded	2660.6	1674.9	5009.7	1369.2
4	Design1	Uncorroded	2660.6	1674.9	5009.7	1369.2