



**DEHDASHT PETROCHEMICAL INDUSTRY COMPANY**  
**DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT**



DOCUMENT TITLE: Mechanical Calculation for Evaporator E-6101

POI: IFA

Contract No.: DPIC/98-12

DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0092

Rev. No.: D0

-native file to be submitted in PVElite 2018  
 -calculation for test ring to be submitted

The exchangers shall be designed to withstand to the bundle pulling force determined as follow:  
 1. 100% of the bundle weight when bundle weight is 5000 kg or less.  
 2. For bundle with weight higher than 5000 kg the force will be the greater of 5000 kg or 50% of the bundle weight.

**DOCUMENT TITLE:**

## Mechanical Calculation for Evaporator (E-6101)

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PURCHASER'S COMMENT/APPROVAL STATUS					Purchaser: NARGAN
1	AP: Approved (Released for Manufacturing)				Requisition No.: DPIC98-12-001-000-ME-MR-4150-0001-D1
<input checked="" type="checkbox"/>	AN: Approved With Minor Comments (Fabrication may Proceed)				
3	NF: Approved With Comments (Fabrication not Proceed)				Item No. (Tag No.): PK-6101
4	RJ: Rejected				
5	NR: Not be Returned				Vendor Doc. No.: DPIC9812-000-VD-1002-ME-CLN-0092-D0
	Date: 16.01.2022	Signature: A.AB			
D0	23.Dec.21	A.VOSOUGH	DR.A.NEJATI	DR.A.NEJATI	
REV	DATE ISSUE	PREPARED	CHECKED	APPROVED	



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66	x				
67	x				
68	x				
69	x				
70	x				



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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
Tag no:Evaporator E-PK1601

## **DESIGN CALCULATION**

*In Accordance with ASME Section VIII Division 1*

ASME Code Version : 2017

Analysis Performed by : SPLM Licensed User

Job File :

Date of Analysis : Dec 23,2021 11:47am

PV Elite 2019 SP1, March 2019

**Note:**

PV Elite performs all calculations internally in Imperial Units to remain compliant with the ASME Code and any built in assumptions in the ASME Code formulas. The finalized results are reflected to show the user's set of selected units.

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Tag no:Evaporator E-PK1601  
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FileName : Calculation Book for Evaporator E-PK1601 -----  
Warnings and Errors: Step: 0 11:47am Dec 23,2021

Class From To : Basic Element Checks.  
=====

Class From To: Check of Additional Element Data  
=====

There were no geometry errors or warnings.

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 Tag no:Evaporator E-PK1601

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 FileName : Calculation Book for Evaporator E-PK1601 -----  
 Input Echo: Step: 1 11:47am Dec 23,2021

**PV Elite Vessel Analysis Program: Input Data**

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 Tag no:Evaporator E-PK1601

**Exchanger Design Pressures and Temperatures**

Shell Side Design Pressure	23	bars
Channel Side Design Pressure	23	bars
Shell Side Design Temperature	125.0	°C
Channel Side Design Temperature	125.0	°C
Radiography, Shell Side	RT-1	
Radiography, Channel Side	RT-1	
Service Type, Shell Side	None	
Service Type, Channel Side	None	
MDMT (CET), Shell Side	-45.0	°C
MDMT (CET), Tube Side	-45.0	°C
User defined MAWP, Shell Side	0	bars
User defined MAWP, Channel Side	0	bars
User defined MAPnc, Shell Side	0	bars
User defined MAPnc, Channel Side	0	bars
User defined Test Pres., Shell Side	0	bars
User defined Test Pres., Channel Side	0	bars

-----

Type of Hydrotest	UG-99(b) Note [36]	
Hydrotest Position	Horizontal	
Projection of Nozzle from Vessel Top	0	mm.
Projection of Nozzle from Vessel Bottom	0	mm.
Type of Construction	Welded	
Use Higher Longitudinal Stresses (Flag)	Y	
Select t for Internal Pressure (Flag)	N	
Select t for External Pressure (Flag)	N	
Select t for Axial Stress (Flag)	N	
Select Location for Stiff. Rings (Flag)	N	
Consider Vortex Shedding	N	
Perform a Corroded Hydrotest	Y	

Load Case 1	NP+EW+WI+FW+BW
Load Case 2	NP+EW+EE+FS+BS
Load Case 3	NP+OW+WI+FW+BW
Load Case 4	NP+OW+EQ+FS+BS
Load Case 5	NP+HW+HI
Load Case 6	NP+HW+HE
Load Case 7	IP+OW+WI+FW+BW
Load Case 8	IP+OW+EQ+FS+BS
Load Case 9	EP+OW+WI+FW+BW
Load Case 10	EP+OW+EQ+FS+BS
Load Case 11	HP+HW+HI
Load Case 12	HP+HW+HE
Load Case 13	IP+WE+EW
Load Case 14	IP+WF+CW
Load Case 15	IP+VO+OW
Load Case 16	IP+VE+EW
Load Case 17	NP+VO+OW
Load Case 18	FS+BS+IP+OW
Load Case 19	FS+BS+EP+OW

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FileName : Calculation Book for Evaporator E-PK1601 -----

Input Echo: Step: 1 11:47am Dec 23,2021

Wind Design Code	ASCE-7 2010	
Wind Load Reduction Scale Factor	0.600	
Basic Wind Speed	<del>195</del> Km/hr	200
Surface Roughness Category	C: Open Terrain	
Importance Factor	1.0	
Type of Surface	Moderately Smooth	
Base Elevation	123000	mm.
Percent Wind for Hydrotest	<del>33.0</del>	20
Using User defined Wind Press. Vs Elev.	N	
Height of Hill or Escarpment H or Hh	0	mm.
Distance Upwind of Crest Lh	0	mm.
Distance from Crest to the Vessel x	0	mm.
Type of Terrain ( Hill, Escarpment )	Flat	
Damping Factor (Beta) for Wind (Ope)	0.0100	
Damping Factor (Beta) for Wind (Empty)	0.0000	
Damping Factor (Beta) for Wind (Filled)	0.0000	

Seismic Design Code	ASCE 7-2010	
Seismic Load Reduction Scale Factor	0.700	
Importance Factor	1.500	
Table Value Fa	1.000	
Table Value Fv	<del>1.300</del>	0.9
Short Period Acceleration value Ss	<del>1.163</del>	0.537
Long Period Acceleration Value Sl	0.600	
Moment Reduction Factor Tau	<del>1.000</del>	2.5
Force Modification Factor R	2.000	
Site Class	C	
Component Elevation Ratio z/h	<del>0.000</del>	1
Amplification Factor Ap	<del>1.000</del>	2.5
Force Factor	0.000	
Consider Vertical Acceleration	No	
Minimum Acceleration Multiplier	0.000	0.624
User Value of Sds (used if > 0 )	<del>0.000</del>	
User Value of Sd1 (used if > 0 )	<del>0.000</del>	0.39

20% percentage seismic for hydrotest

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

Material Database Year Current w/Addenda or Code Year

**Configuration Directives:**

Do not use Nozzle MDMT Interpretation VIII-1 01-37	No
Use Table G instead of exact equation for "A"	Yes
Shell Head Joints are Tapered	Yes
Compute "K" in corroded condition	Yes
Use Code Case 2286	No
Use the MAWP to compute the MDMT	Yes
For thickness ratios <= 0.35, MDMT will be -155F (-104C)	Yes
For PWHT & P1 Materials the MDMT can be < -55F (-48C)	No
Using Metric Material Databases, ASME II D	No
Calculate B31.3 type stress for Nozzles with Loads	Yes
Reduce the MDMT due to lower membrane stress	Yes
Consider Longitudinal Stress in MDMT calcs. (Div. 1)	No

**Complete Listing of Vessel Elements and Details:**

Element From Node 10

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FileName : Calculation Book for Evaporator E-PK1601 -----

Input Echo: Step: 1 11:47am Dec 23,2021

Element To Node	20
Element Type	Elliptical
Description	HEAD 001
Distance "FROM" to "TO"	50 mm.
Inside Diameter	1200 mm.
Element Thickness	15 mm.
Internal Corrosion Allowance	3 mm.
Nominal Thickness	18 mm.
External Corrosion Allowance	0 mm.
Design Internal Pressure	23 bars
Design Temperature Internal Pressure	125 °C
Design External Pressure	1.0342 bars
Design Temperature External Pressure	125 °C
Effective Diameter Multiplier	1.2
Material Name	SA-516 70 [Impact Tested]
Allowable Stress, Ambient	137.9 N./mm <sup>2</sup>
Allowable Stress, Operating	137.9 N./mm <sup>2</sup>
Allowable Stress, Hydrotest	235.8 N./mm <sup>2</sup>
Material Density	0.00775 kg./cm <sup>3</sup>
P Number Thickness	29.997 mm.
Yield Stress, Operating	235.2 N./mm <sup>2</sup>
UCS-66 Chart Curve Designation	Impact Tested
External Pressure Chart Name	CS-2
UNS Number	K02700
Product Form	Plate
Efficiency, Longitudinal Seam	1.0
Efficiency, Circumferential Seam	1.0
Elliptical Head Factor	2.0
Weld is pre-Heated	No

based on thermal datasheet tube side is not F.V. please recheck

1.0342 bars

Element From Node	10
Detail Type	Liquid
Detail ID	1
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Liquid	1200 mm.
Liquid Density	0.0009996 kg./cm <sup>3</sup>

to be revised

0.0009996 kg./cm<sup>3</sup>

Element From Node	20
Element To Node	30
Element Type	Cylinder
Description	S990 001
Distance "FROM" to "TO"	800 mm.
Inside Diameter	1200 mm.
Element Thickness	15 mm.
Internal Corrosion Allowance	3 mm.
Nominal Thickness	15 mm.
External Corrosion Allowance	0 mm.
Design Internal Pressure	23 bars
Design Temperature Internal Pressure	125 °C
Design External Pressure	1.0342 bars
Design Temperature External Pressure	125 °C
Effective Diameter Multiplier	1.2
Material Name	SA-516 70 [Impact Tested]
Efficiency, Longitudinal Seam	1.0
Efficiency, Circumferential Seam	1.0
Weld is pre-Heated	No

S990

1.0342 bars

Element From Node	20
Detail Type	Liquid

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FileName : Calculation Book for Evaporator E-PK1601 -----

Input Echo: Step: 1 11:47am Dec 23,2021

Detail ID 2  
 Dist. from "FROM" Node / Offset dist 0 mm.  
 Height/Length of Liquid 1200 mm.  
 Liquid Density 0.0009996 kg./cm<sup>3</sup>

Element From Node 20  
 Detail Type Nozzle  
 Detail ID T2  
 Dist. from "FROM" Node / Offset dist 400 mm.  
 Nozzle Diameter 20 in.  
 Nozzle Schedule None  
 Nozzle Class 300  
 Layout Angle 90.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 2.9969 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-516 70 [Normalized]

to be revised based on  
 thermal data sheet

Element From Node 20  
 Detail Type Nozzle  
 Detail ID T1  
 Dist. from "FROM" Node / Offset dist 400 mm.  
 Nozzle Diameter 20 in.  
 Nozzle Schedule None  
 Nozzle Class 300  
 Layout Angle 270.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 2.9969 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-516 70 [Normalized]

-----

Element From Node 30  
 Element To Node 40  
 Element Type Flange  
 Description BODY FLANGE 001  
 Distance "FROM" to "TO" 155 mm.  
 Flange Inside Diameter 1200 mm.  
 Element Thickness 110 mm.  
 Internal Corrosion Allowance 3 mm.  
 Nominal Thickness 60 mm.  
 External Corrosion Allowance 0 mm.  
 Design Internal Pressure 23 bars  
 Design Temperature Internal Pressure 125 °C  
 Design External Pressure 1.0342 bars  
 Design Temperature External Pressure 125 °C  
 Effective Diameter Multiplier 1.2  
 Material Name SA-350 LF2 [Impact Tested]  
 Allowable Stress, Ambient 137.9 N./mm<sup>2</sup>  
 Allowable Stress, Operating 137.9 N./mm<sup>2</sup>  
 Allowable Stress, Hydrotest 223.4 N./mm<sup>2</sup>  
 Material Density 0.00775 kg./cm<sup>3</sup>  
 P Number Thickness 31.75 mm.  
 Yield Stress, Operating 222.82 N./mm<sup>2</sup>  
 UCS-66 Chart Curve Designation Impact Tested  
 External Pressure Chart Name CS-2  
 UNS Number K03011  
 Class / Thickness / Grade 1::  
 Product Form Forgings  
 Perform Flange Stress Calculation (Y/N) Y

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FileName : Calculation Book for Evaporator E-PK1601 -----

Input Echo: Step: 1 11:47am Dec 23,2021

Weight of ANSI B16.5/B16.47 Flange 0 kN  
 Class of ANSI B16.5/B16.47 Flange  
 Grade of ANSI B16.5/B16.47 Flange  
 Weld is pre-Heated No  
 Element From Node 30  
 Detail Type Liquid  
 Detail ID 3  
 Dist. from "FROM" Node / Offset dist 0 mm.  
 Height/Length of Liquid 1200 mm.  
 Liquid Density 0.0009996 kg./cm<sup>3</sup>

Element From Node 40  
 Element To Node 50  
 Element Type Flange  
 Description body flange 02  
 Distance "FROM" to "TO" 155 mm.  
 Flange Inside Diameter 1200 mm.  
 Element Thickness 110 mm.  
 Internal Corrosion Allowance 3 mm.  
 Nominal Thickness 60 mm.  
 External Corrosion Allowance 0 mm.  
 Design Internal Pressure 23 bars  
 Design Temperature Internal Pressure 125 °C  
 Design External Pressure 1.0342 bars  
 Design Temperature External Pressure 125 °C  
 Effective Diameter Multiplier 1.2  
 Material Name SA-350 LF2 [Impact Tested]  
 Perform Flange Stress Calculation (Y/N) Y  
 Weight of ANSI B16.5/B16.47 Flange 0 kN  
 Class of ANSI B16.5/B16.47 Flange  
 Grade of ANSI B16.5/B16.47 Flange  
 Weld is pre-Heated No

insulation on shell  
 side to be  
 considered

Element From Node 40  
 Detail Type Liquid  
 Detail ID 4  
 Dist. from "FROM" Node / Offset dist 0 mm.  
 Height/Length of Liquid 1200 mm.  
 Liquid Density 0.0009996 kg./cm<sup>3</sup>

to be revised

Element From Node 50  
 Element To Node 60  
 Element Type Cylinder  
 Description SHELL 002  
 Distance "FROM" to "TO" 200 mm.  
 Inside Diameter 1200 mm.  
 Element Thickness 20 mm.  
 Internal Corrosion Allowance 3 mm.  
 Nominal Thickness 20 mm.  
 External Corrosion Allowance 0 mm.  
 Design Internal Pressure 23 bars  
 Design Temperature Internal Pressure 125 °C  
 Design External Pressure 1.0342 bars  
 Design Temperature External Pressure 125 °C  
 Effective Diameter Multiplier 1.2  
 Material Name SA-516 70 [Impact Tested]

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT  
Tag no:Evaporator E-PK1601

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FileName : Calculation Book for Evaporator E-PK1601 -----  
Input Echo: Step: 1 11:47am Dec 23,2021

Allowable Stress, Ambient	137.9	N./mm^2
Allowable Stress, Operating	137.9	N./mm^2
Allowable Stress, Hydrotest	235.8	N./mm^2
Material Density	0.00775	kg./cm^3
P Number Thickness	29.007	mm.
Yield Stress, Operating	235.2	N./mm^2
UCS-66 Chart Curve Designation	Impact Tested	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	

location of saddle to be changed to conical part

there is discrepancy with drawing

Element From Node	50
Detail Type	Saddle
Detail ID	Lift Sdl
Dist. from "FROM" Node / Offset dist	200 mm.
Width of Saddle	172 mm.
Height of Saddle at Bottom	972 mm.
Saddle Contact Angle	120.0
Height of Composite Ring Stiffener	0 mm.
Width of Wear Plate	332 mm.
Thickness of Wear Plate	12 mm.
Contact Angle, Wear Plate (degrees)	140.0
Friction coefficient	0.0
Moment Factor	3.0
Dimension E at base (optional)	0 mm.
Circumferential Eff. over Saddle	1.0
Circumferential Eff. at Midspan	1.0
Tangent to Tangent dist. (optional)	0 mm.

Element From Node	50
Detail Type	Liquid
Detail ID	5
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Liquid	1200 mm.
Liquid Density	0.0009996 kg./cm^3

-----

Element From Node	60
Element To Node	70
Element Type	Conical
Description	CON
Distance "FROM" to "TO"	830 mm.
Inside Diameter	1200 mm.
Element Thickness	20 mm.
Internal Corrosion Allowance	3 mm.
Nominal Thickness	20 mm.
External Corrosion Allowance	0 mm.
Design Internal Pressure	23 bars
Design Temperature Internal Pressure	125 °C
Design External Pressure	1.0342 bars
Design Temperature External Pressure	125 °C
Effective Diameter Multiplier	1.2
Material Name	SA-516 70 [Impact Tested]
Efficiency, Longitudinal Seam	1.0
Efficiency, Circumferential Seam	1.0
Cone Diameter at "To" End	1656 mm.
Design Length of Cone	830 mm.

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Half Apex Angle of Cone 28.784285 degrees  
Toriconical (Y/N) N  
Weld is pre-Heated No

Element From Node 60  
Detail Type Liquid  
Detail ID Liquid: 60  
Dist. from "FROM" Node / Offset dist 0 mm.  
Height/Length of Liquid 1200 mm.  
Liquid Density 0.0009996 kg./cm^3

Element From Node 60  
Detail Type Nozzle D2  
Detail ID ~~D4~~  
Dist. from "FROM" Node / Offset dist 400 mm.  
Nozzle Diameter 2 in.  
Nozzle Schedule None  
Nozzle Class 300  
Layout Angle 270.0  
Blind Flange (Y/N) N  
Weight of Nozzle ( Used if > 0 ) 0.1015 kN  
Grade of Attached Flange GR 1.1  
Nozzle Matl SA-350 LF2 [Impact Tested]

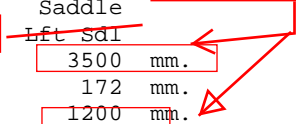
-----  
Element From Node 70  
Element To Node 80  
Element Type Cylinder  
Description SHELL 002  
Distance "FROM" to "TO" 4000 mm.  
Inside Diameter 1656 mm.  
Element Thickness 18 mm.  
Internal Corrosion Allowance 3 mm.  
Nominal Thickness 18 mm.  
External Corrosion Allowance 0 mm.  
Design Internal Pressure 23 bars  
Design Temperature Internal Pressure 125 °C  
Design External Pressure 1.0342 bars  
Design Temperature External Pressure 125 °C  
Effective Diameter Multiplier 1.2  
Material Name SA-516 70 [Impact Tested]  
Efficiency, Longitudinal Seam 1.0  
Efficiency, Circumferential Seam 1.0  
Weld is pre-Heated No

INSULATION

Element From Node 70  
Detail Type Saddle  
Detail ID Lft Sdl  
Dist. from "FROM" Node / Offset dist 3500 mm.  
Width of Saddle 172 mm.  
Height of Saddle at Bottom 1200 mm.  
Saddle Contact Angle 120.0  
Height of Composite Ring Stiffener 0 mm.  
Width of Wear Plate 350 mm.  
Thickness of Wear Plate 12 mm.  
Contact Angle, Wear Plate (degrees) 140.0  
Friction coefficient 0.30000001  
Moment Factor 3.0  
Dimension E at base (optional) 0 mm.  
Circumferential Eff. over Saddle 1.0

right saddle

there is discrepancy with drawing



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Circumferential Eff. at Midspan	1.0
Tangent to Tangent dist. (optional)	0 mm.
Element From Node	70
Detail Type	Liquid
Detail ID	Liquid: 70
Dist. from "FROM" Node / Offset dist	0 mm.
Height/Length of Liquid	1200 mm.
Liquid Density	0.0009996 kg./cm <sup>3</sup>
Element From Node	70
Detail Type	Nozzle
Detail ID	S2
Dist. from "FROM" Node / Offset dist	200 mm.
Nozzle Diameter	8 in.
Nozzle Schedule	80
Nozzle Class	300
Layout Angle	270.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.8591 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-333 6 [Impact Tested]
Element From Node	70
Detail Type	Nozzle
Detail ID	S1
Dist. from "FROM" Node / Offset dist	2800 mm.
Nozzle Diameter	8 in.
Nozzle Schedule	80
Nozzle Class	300
Layout Angle	270.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.8591 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-333 6 [Impact Tested]
Element From Node	70
Detail Type	Nozzle
Detail ID	S3
Dist. from "FROM" Node / Offset dist	600 mm.
Nozzle Diameter	8 in.
Nozzle Schedule	80
Nozzle Class	300
Layout Angle	90.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.8591 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-333 6 [Impact Tested]
Element From Node	70
Detail Type	Nozzle
Detail ID	D2
Dist. from "FROM" Node / Offset dist	600 mm.
Nozzle Diameter	2 in.
Nozzle Schedule	None
Nozzle Class	300
Layout Angle	270.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.1015 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-350 LF2 [Impact Tested]

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Element From Node 70  
 Detail Type Nozzle  
 Detail ID D1  
 Dist. from "FROM" Node / Offset dist 2400 mm.  
 Nozzle Diameter 2 in.  
 Nozzle Schedule None  
 Nozzle Class 300  
 Layout Angle 270.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.1015 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-350 LF2 [Impact Tested]

Element From Node 70  
 Detail Type Nozzle  
 Detail ID D3  
 Dist. from "FROM" Node / Offset dist 3200 mm.  
 Nozzle Diameter 2 in.  
 Nozzle Schedule None  
 Nozzle Class 300  
 Layout Angle 270.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.1015 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-350 LF2 [Impact Tested]

Element From Node 70  
 Detail Type Nozzle  
 Detail ID TT  
 Dist. from "FROM" Node / Offset dist 3800 mm.  
 Nozzle Diameter 2 in.  
 Nozzle Schedule None  
 Nozzle Class 300  
 Layout Angle 270.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.1015 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-350 LF2 [Impact Tested]

Element From Node 70  
 Detail Type Nozzle  
 Detail ID V  
 Dist. from "FROM" Node / Offset dist 200 mm.  
 Nozzle Diameter 2 in.  
 Nozzle Schedule None  
 Nozzle Class 300  
 Layout Angle 90.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.1015 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-350 LF2 [Impact Tested]

Element From Node 70  
 Detail Type Nozzle  
 Detail ID S4  
 Dist. from "FROM" Node / Offset dist 2800 mm.  
 Nozzle Diameter 8 in.  
 Nozzle Schedule 80  
 Nozzle Class 300  
 Layout Angle 90.0



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Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.8591 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-333 6 [Impact Tested]

Element From Node	70
Detail Type	Nozzle
Detail ID	LG1
Dist. from "FROM" Node / Offset dist	2200 mm.
Nozzle Diameter	2 in.
Nozzle Schedule	None
Nozzle Class	300
Layout Angle	270.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.1015 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-350 LF2 [Impact Tested]

Element From Node	70
Detail Type	Nozzle
Detail ID	LG2
Dist. from "FROM" Node / Offset dist	2200 mm.
Nozzle Diameter	2 in.
Nozzle Schedule	None
Nozzle Class	300
Layout Angle	90.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.1015 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-350 LF2 [Impact Tested]

Element From Node	70
Detail Type	Nozzle
Detail ID	LT1
Dist. from "FROM" Node / Offset dist	1000 mm.
Nozzle Diameter	2 in.
Nozzle Schedule	160
Nozzle Class	300
Layout Angle	90.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.2227 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-350 LF2 [Impact Tested]

Element From Node	70
Detail Type	Nozzle
Detail ID	LT3
Dist. from "FROM" Node / Offset dist	1500 mm.
Nozzle Diameter	2 in.
Nozzle Schedule	160
Nozzle Class	300
Layout Angle	90.0
Blind Flange (Y/N)	N
Weight of Nozzle ( Used if > 0 )	0.2227 kN
Grade of Attached Flange	GR 1.1
Nozzle Matl	SA-350 LF2 [Impact Tested]

Element From Node	70
Detail Type	Nozzle
Detail ID	LT2
Dist. from "FROM" Node / Offset dist	1000 mm.

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Input Echo: Step: 1 11:47am Dec 23,2021

Nozzle Diameter 2 in.  
 Nozzle Schedule 160  
 Nozzle Class 300  
 Layout Angle 270.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.2227 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-350 LF2 [Impact Tested]

Element From Node 70  
 Detail Type Nozzle  
 Detail ID LT4  
 Dist. from "FROM" Node / Offset dist 1500 mm.  
 Nozzle Diameter 2 in.  
 Nozzle Schedule 160  
 Nozzle Class 300  
 Layout Angle 270.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 0.2227 kN  
 Grade of Attached Flange GR 1.1  
 Nozzle Matl SA-350 LF2 [Impact Tested]

-----  
 Element From Node 80  
 Element To Node 90  
 Element Type Elliptical  
 Description HEAD 002  
 Distance "FROM" to "TO" 50 mm.  
 Inside Diameter 1656 mm.  
 Element Thickness 17 mm.  
 Internal Corrosion Allowance 3 mm.  
 Nominal Thickness 20 mm.  
 External Corrosion Allowance 0 mm.  
 Design Internal Pressure 23 bars  
 Design Temperature Internal Pressure 125 °C  
 Design External Pressure 1.0342 bars  
 Design Temperature External Pressure 125 °C  
 Effective Diameter Multiplier 1.2  
 Material Name SA-516 70 [Impact Tested]  
 Efficiency, Longitudinal Seam 1.0  
 Efficiency, Circumferential Seam 1.0  
 Elliptical Head Factor 2.0  
 Weld is pre-Heated No

Element From Node 80  
 Detail Type Liquid  
 Detail ID Liquid: 80  
 Dist. from "FROM" Node / Offset dist 0 mm.  
 Height/Length of Liquid 1200 mm.  
 Liquid Density 0.0009996 kg./cm^3

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XY Coordinate Calculations: Step: 2 11:47am Dec 23,2021

**XY Coordinate Calculations:**

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
HEAD 001		50	...	50	...
SHELL 001		850	...	800	...
BODY FLANGE 001		1005	...	155	...
body flange 02		1315.53	...	155	...
SHELL 002		1515.53	...	200	...
CON		2345.53	...	830	...
SHELL 002		6345.53	...	4000	...
HEAD 002		6395.52	...	50	...

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 Flg Calc [Int P]: New Flange Flng: 7 11:47am Dec 23,2021

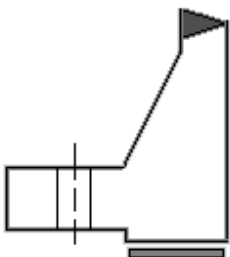
**Flange Input Data Values Description: New Flange :**

**BODY FLANGE 001**

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	23.12	bars
Design Temperature		125	°C
Internal Corrosion Allowance	ci	3.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	1200.000	mm.
Flange Outside Diameter	A	1360.000	mm.
Flange Thickness	t	110.0000	mm.
Thickness of Hub at Small End	go	15.0000	mm.
Thickness of Hub at Large End	gl	23.0000	mm.
Length of Hub	h	45.0000	mm.
Flange Material		SA-350 LF2	
Flange Material UNS number		K03011	
Flange Allowable Stress At Temperature	Sfo	137.90	N./mm^2
Flange Allowable Stress At Ambient	Sfa	137.90	N./mm^2
Bolt Material		SA-320 L7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm^2
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm^2
Diameter of Bolt Circle	C	1310.000	mm.
Nominal Bolt Diameter	a	22.2250	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		72	
Flange Face Outside Diameter	Fod	1269.000	mm.
Flange Face Inside Diameter	Fid	1200.000	mm.
Flange Facing Sketch	l, Code	Sketch 1a	
Gasket Outside Diameter	Go	1266.000	mm.
Gasket Inside Diameter	Gi	1226.000	mm.
Gasket Factor	m	3.0000	
Gasket Design Seating Stress	y	68.95	N./mm^2
Column for Gasket Seating	2, Code	Column II	
Gasket Thickness	tg	3.0000	mm.

based on drawing flat metal jacketed S.S.

gasket rib shall be considered



**ASME Code, Section VIII Division 1, 2017**

Hub Small End Required Thickness due to Internal Pressure:  
 =  $(P*(D/2+Ca))/(S*E-0.6*P)$  per UG-27 (c)(1)  
 =  $(23.12*(1200.0/2+3.0))/(137.9*1.0-0.6*23.12)+Ca$

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= 13.2120 mm.

Hub Small End Hub MAWP:

=  $(S \cdot E \cdot t) / (R + 0.6 \cdot t)$  per UG-27 (c)(1)  
 =  $(137.9 \cdot 1.0 \cdot 12.0) / (603.0 + 0.6 \cdot 12.0)$   
 = 27.117 bars

Corroded Flange Thickness, tc = T-ci	107.000	mm.
Corroded Flange ID, Bcor = B+2*Fcor	1206.000	mm.
Corroded Large Hub, glCor = g1-ci	20.000	mm.
Corroded Small Hub, g0Cor = go-ci	12.000	mm.
Code R Dimension, R = ((C-Bcor)/2)-glcor	32.000	mm.
Gasket Contact Width, N = (Go - Gi) / 2	20.000	mm.
Basic Gasket Width, bo = N / 2	10.000	mm.
Effective Gasket Width, b = Cb sqrt(bo)	7.969	mm.
Gasket Reaction Diameter, G = Go - 2 * b	1250.063	mm.

### **Basic Flange and Bolt Loads:**

Hydrostatic End Load due to Pressure [H]:

=  $0.785 \cdot G^2 \cdot Peq$   
 =  $0.785 \cdot 1250.0626^2 \cdot 23.118$   
 = 2837.167 kN

Contact Load on Gasket Surfaces [Hp]:

=  $2 \cdot b \cdot Pi \cdot G \cdot m \cdot P$   
 =  $2 \cdot 7.9687 \cdot 3.1416 \cdot 1250.0626 \cdot 3.0 \cdot 23.12$   
 = 434.062 kN

Hydrostatic End Load at Flange ID [Hd]:

=  $Pi \cdot Bcor^2 \cdot P / 4$   
 =  $3.1416 \cdot 1206.0^2 \cdot 23.1176 / 4$   
 = 2640.681 kN

Pressure Force on Flange Face [Ht]:

= H - Hd  
 = 2837 - 2641  
 = 196.486 kN

Operating Bolt Load [Wm1]:

=  $\max(H + Hp + H'p, 0)$   
 =  $\max(2837 + 434 + 0, 0)$   
 = 3271.229 kN

Gasket Seating Bolt Load [Wm2]:

=  $y \cdot b \cdot Pi \cdot G + yPart \cdot bPart \cdot lp$   
 =  $68.95 \cdot 7.9687 \cdot 3.141 \cdot 1250.063 + 0.0 \cdot 0.0 \cdot 0.0$   
 = 2157.577 kN

Required Bolt Area [Am]:

= Maximum of Wm1/Sb, Wm2/Sa  
 = Maximum of 3271/172, 2158/172  
 = 189.790 cm<sup>2</sup>

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:

=  $2a + 6t / (m + 0.5)$   
 =  $2 \cdot 22.225 + 6 \cdot 107.0 / (3.0 + 0.5)$   
 = 227.879 mm.

Actual Circumferential Bolt Spacing [Bs]:

=  $C \cdot \sin(\pi / n)$   
 =  $1310.0 \cdot \sin(3.142 / 72)$   
 = 57.141 mm.

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:

=  $\max(\sqrt{Bs / (2a + t)}, 1)$

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$$= \max(\text{sqrt}(57.141/(2 * 22.225 + 107.0)), 1)$$

$$= 1.0000$$

**Bolting Information for TEMA Imperial Thread Series (Non Mandatory):**

	Minimum	Actual	Maximum
Bolt Area, cm <sup>2</sup>	189.790	194.632	
Radial Distance between Hub and Bolts:	31.750	32.000	
Radial Distance between Bolts and Edge:	23.812	25.000	
Circ. Spacing between the Bolts:	52.400	57.141	227.879

**Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:**

$$= A_b * S_a / ( \gamma * \pi * (G_o + G_i) )$$

$$= 194.632 * 172.38 / (68.95 * 3.14 * (1266.0 + 1226.0) )$$

$$= 6.215 \text{ mm.}$$

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :

$$= 32.000 \text{ mm. [Note: Exceeds actual gasket width, 20.000 ]}$$

**Flange Design Bolt Load, Gasket Seating [W]:**

$$= S_a * ( A_m + A_b ) / 2$$

$$= 172.38 * ( 189.7901 + 194.6319 ) / 2$$

$$= 3312.96 \text{ kN}$$

**Gasket Load for the Operating Condition [HG]:**

$$= W_{m1} - H$$

$$= 3271 - 2837$$

$$= 434.06 \text{ kN}$$

**Moment Arm Calculations:**

**Distance to Gasket Load Reaction [hg]:**

$$= ( C - G ) / 2$$

$$= ( 1310.0 - 1250.0626 ) / 2$$

$$= 29.9687 \text{ mm.}$$

**Distance to Face Pressure Reaction [ht]:**

$$= ( R + g_1 + h_g ) / 2$$

$$= ( 32.0 + 20.0 + 29.9687 ) / 2$$

$$= 40.9843 \text{ mm.}$$

**Distance to End Pressure Reaction [hd]:**

$$= R + ( g_1 / 2 )$$

$$= 32.0 + ( 20.0 / 2.0 )$$

$$= 42.0000 \text{ mm.}$$

**Summary of Moments for Internal Pressure: (N-m)**

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	2641.	42.0000	1.0000	110954.
Face Pressure, Mt	196.	40.9843	1.0000	8056.
Gasket Load, Mg	434.	29.9687	1.0000	13014.
Gasket Seating, Matm	3313.	29.9687	1.0000	99325.
Total Moment for Operation, Mop				132023. N-m
Total Moment for Gasket seating, Matm				99325. N-m
Effective Hub Length, ho = sqrt(Bcor*goCor)		120.300	mm.	
Hub Ratio, h/h0 = HL / H0		0.374		
Thickness Ratio, g1/g0 = (g1Cor/goCor)		1.667		

**Flange Factors for Integral Flange:**

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 Flg Calc [Int P]: New Flange Flng: 7 11:47am Dec 23,2021

Factor F 0.861  
 Factor V 0.313  
 Factor f 1.178  
 Factors from Figure 2-7.1 K = 1.128  
 T = 1.867 U = 17.771  
 Y = 16.171 Z = 8.361  
 d = 0.98424E+06 mm.<sup>3</sup> e = 0.0072 mm.<sup>-1</sup>  
 Stress Factors ALPHA = 1.766  
 BETA = 2.021 GAMMA = 0.946  
 DELTA = 1.245 Lamda = 2.191

Longitudinal Hub Stress, Operating [SHo]:  
 = ( f \* Mop / Bcor ) / ( L \* g1<sup>2</sup> )  
 = ( 1.1782\*132023/1206.0 ) / ( 2.1905\*20.0<sup>2</sup> )  
 = 147.16 N./mm<sup>2</sup>

Longitudinal Hub Stress, Seating [SHa]:  
 = ( f \* Matm / Bcor ) / ( L \* g1<sup>2</sup> )  
 = ( 1.1782\*99325/1206.0 ) / ( 2.1905\*20.0<sup>2</sup> )  
 = 110.71 N./mm<sup>2</sup>

Radial Flange Stress, Operating [SRo]:  
 = ( Beta \* Mop / Bcor ) / ( L \* t<sup>2</sup> )  
 = ( 2.0214\*132023/1206.0 ) / ( 2.1905\*107.0<sup>2</sup> )  
 = 8.82 N./mm<sup>2</sup>

Radial Flange Stress, Seating [SRa]:  
 = ( Beta \* Matm / Bcor ) / ( L \* t<sup>2</sup> )  
 = ( 2.0214\*99325/1206.0 ) / ( 2.1905\*107.0<sup>2</sup> )  
 = 6.64 N./mm<sup>2</sup>

Tangential Flange Stress, Operating [STo]:  
 = ( Y \* Mo / ( t<sup>2</sup> \* Bcor ) ) - Z \* SRo  
 = ( 16.1715\*132023 / ( 107.0<sup>2</sup> \* 1206.0 ) ) - 8.3612\*9  
 = 80.83 N./mm<sup>2</sup>

Tangential Flange Stress, Seating [STa]:  
 = ( y \* Matm / ( t<sup>2</sup> \* Bcor ) ) - Z \* SRa  
 = ( 16.1715\*99325 / ( 107.0<sup>2</sup> \* 1206.0 ) ) - 8.3612\*7  
 = 60.81 N./mm<sup>2</sup>

Average Flange Stress, Operating [SAo]:  
 = ( SHo + max( SRo, STo ) ) / 2  
 = ( 147+max( 9, 81 ) ) / 2  
 = 113.99 N./mm<sup>2</sup>

Average Flange Stress, Seating [SAa]:  
 = ( SHa + max( SRa, STa ) ) / 2  
 = ( 111+max( 7, 61 ) ) / 2  
 = 85.76 N./mm<sup>2</sup>

Bolt Stress, Operating [BSo]:  
 = Wm1 / Ab  
 = 3271/194.6319  
 = 168.09 N./mm<sup>2</sup>

Bolt Stress, Seating [BSa]:  
 = ( Wm2 / Ab )  
 = ( 2158/194.6319 )  
 = 110.86 N./mm<sup>2</sup>

**Flange Stress Analysis Results: N./mm<sup>2</sup>**

	Operating	Gasket Seating
Actual	Allowed	Actual Allowed
-----		

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## DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

Tag no:Evaporator E-PK1601

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FileName : Calculation Book for Evaporator E-PK1601 -----

Flg Calc [Int P]: New Flange Flng: 7 11:47am Dec 23,2021

Longitudinal Hub	147.	207.	111.	207.
Radial Flange	9.	138.	7.	138.
Tangential Flange	81.	138.	61.	138.
Maximum Average	114.	138.	86.	138.
Bolting	168.	172.	111.	172.

Minimum Required Flange Thickness [Rigidity]	107.798 mm.
Estimated M.A.W.P. ( Operating )	23.707 bars
Estimated Finished Weight of Flange at given Thk.	299.6 kg.
Estimated Unfinished Weight of Forging at given Thk	386.5 kg.

Flange Rigidity Based on Required Thickness [ASME]:

## Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:

$$= 52.14 * Ma / Bsc * Cnv\_fac * V / ( Lambda * Eamb * go^2 * ho * Ki )$$

$$= 52.14 * 99325.1/1.0 * 999.68 * 0.313/( 2.107 * 202713 * 12.0^2 * 120.3 * 0.3 )$$

$$= 0.730 \quad (\text{should be } \leq 1)$$

## Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

$$= 52.14 * Mo / Bsc * Cnv\_fac * V / ( Lambda * Eop * goc^2 * ho * Ki )$$

$$= 52.14 * 132023.1/1.0 * 999.68 * 0.313/( 2.107 * 196612 * 12.0^2 * 120.3 * 0.3 )$$

$$= 1.000 \quad (\text{should be } \leq 1)$$

Flange Rigidity Based on Given Thickness [ASME]:

## Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:

$$= 52.14 * Ma / Bsc * Cnv\_fac * V / ( Lambda * Eamb * go^2 * ho * Ki )$$

$$= 52.14 * 99325.1/1.0 * 999.68 * 0.313/( 2.191 * 202713 * 12.0^2 * 120.3 * 0.3 )$$

$$= 0.702 \quad (\text{should be } \leq 1)$$

## Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

$$= 52.14 * Mo / Bsc * Cnv\_fac * V / ( Lambda * Eop * goc^2 * ho * Ki )$$

$$= 52.14 * 132023.1/1.0 * 999.68 * 0.313/( 2.191 * 196612 * 12.0^2 * 120.3 * 0.3 )$$

$$= 0.962 \quad (\text{should be } \leq 1)$$

**Minimum Design Metal Temperature Results:***Note:**This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

Note: UCS-66(b)-(c) was considered in the flange MDMT calculation.

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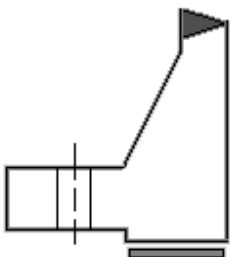
**Flange Input Data Values Description: New Flange :**

body flange 02

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	23.12	bars
Design Temperature		125	°C
Internal Corrosion Allowance	ci	3.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	1200.000	mm.
Flange Outside Diameter	A	1360.000	mm.
Flange Thickness	t	110.0000	mm.
Thickness of Hub at Small End	go	18.0000	mm.
Thickness of Hub at Large End	gl	23.0000	mm.
Length of Hub	h	45.0000	mm.
Flange Material		SA-350 LF2	
Flange Material UNS number		K03011	
Flange Allowable Stress At Temperature	Sfo	137.90	N./mm <sup>2</sup>
Flange Allowable Stress At Ambient	Sfa	137.90	N./mm <sup>2</sup>
Bolt Material		SA-320 L7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm <sup>2</sup>
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm <sup>2</sup>
Diameter of Bolt Circle	C	1310.000	mm.
Nominal Bolt Diameter	a	22.2250	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		72	
Flange Face Outside Diameter	Fod	1269.000	mm.
Flange Face Inside Diameter	Fid	1200.000	mm.
Flange Facing Sketch	l, Code	Sketch 1a	
Gasket Outside Diameter	Go	1266.000	mm.
Gasket Inside Diameter	Gi	1226.000	mm.
Gasket Factor	m	3.0000	
Gasket Design Seating Stress	y	68.95	N./mm <sup>2</sup>
Column for Gasket Seating	2, Code	Column II	
Gasket Thickness	tg	3.0000	mm.

shall be same as attached shell

based on drawing flat metal jacketed S.S.



**ASME Code, Section VIII Division 1, 2017**

Hub Small End Required Thickness due to Internal Pressure:  
 $= (P*(D/2+Ca))/(S*E-0.6*P)$  per UG-27 (c)(1)  
 $= (23.12*(1200.0/2+3.0))/(137.9*1.0-0.6*23.12)+Ca$

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 Flg Calc [Int P]: New Flange Flng: 8 11:47am Dec 23,2021

$$= 13.2120 \text{ mm.}$$

Hub Small End Hub MAWP:

$$= (S \cdot E \cdot t) / (R + 0.6 \cdot t) \text{ per UG-27 (c)(1)}$$

$$= (137.9 \cdot 1.0 \cdot 15.0) / (603.0 + 0.6 \cdot 15.0)$$

$$= 33.797 \text{ bars}$$

Corroded Flange Thickness, tc = T-ci	107.000	mm.
Corroded Flange ID, Bcor = B+2*Fcor	1206.000	mm.
Corroded Large Hub, glCor = g1-ci	20.000	mm.
Corroded Small Hub, g0Cor = go-ci	15.000	mm.
Code R Dimension, R = ((C-Bcor)/2)-glcor	32.000	mm.
Gasket Contact Width, N = (Go - Gi) / 2	20.000	mm.
Basic Gasket Width, bo = N / 2	10.000	mm.
Effective Gasket Width, b = Cb sqrt(bo)	7.969	mm.
Gasket Reaction Diameter, G = Go - 2 * b	1250.063	mm.

### **Basic Flange and Bolt Loads:**

Hydrostatic End Load due to Pressure [H]:

$$= 0.785 \cdot G^2 \cdot Peq$$

$$= 0.785 \cdot 1250.0626^2 \cdot 23.118$$

$$= 2837.167 \text{ kN}$$

Contact Load on Gasket Surfaces [Hp]:

$$= 2 \cdot b \cdot Pi \cdot G \cdot m \cdot P$$

$$= 2 \cdot 7.9687 \cdot 3.1416 \cdot 1250.0626 \cdot 3.0 \cdot 23.12$$

$$= 434.062 \text{ kN}$$

Hydrostatic End Load at Flange ID [Hd]:

$$= Pi \cdot Bcor^2 \cdot P / 4$$

$$= 3.1416 \cdot 1206.0^2 \cdot 23.1176 / 4$$

$$= 2640.681 \text{ kN}$$

Pressure Force on Flange Face [Ht]:

$$= H - Hd$$

$$= 2837 - 2641$$

$$= 196.486 \text{ kN}$$

Operating Bolt Load [Wm1]:

$$= \max( H + Hp + H'p, 0 )$$

$$= \max( 2837 + 434 + 0, 0 )$$

$$= 3271.229 \text{ kN}$$

Gasket Seating Bolt Load [Wm2]:

$$= y \cdot b \cdot Pi \cdot G + yPart \cdot bPart \cdot lp$$

$$= 68.95 \cdot 7.9687 \cdot 3.141 \cdot 1250.063 + 0.0 \cdot 0.0 \cdot 0.0$$

$$= 2157.577 \text{ kN}$$

Required Bolt Area [Am]:

$$= \text{Maximum of } Wm1/Sb, Wm2/Sa$$

$$= \text{Maximum of } 3271/172, 2158/172$$

$$= 189.790 \text{ cm}^2$$

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:

$$= 2a + 6t / (m + 0.5)$$

$$= 2 \cdot 22.225 + 6 \cdot 107.0 / (3.0 + 0.5)$$

$$= 227.879 \text{ mm.}$$

Actual Circumferential Bolt Spacing [Bs]:

$$= C \cdot \sin( pi / n )$$

$$= 1310.0 \cdot \sin( 3.142 / 72 )$$

$$= 57.141 \text{ mm.}$$

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:

$$= \max( \sqrt{ Bs / ( 2a + t ) }, 1 )$$

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 Flg Calc [Int P]: New Flange Flng: 8 11:47am Dec 23,2021

$$= \max(\text{sqrt}(57.141/(2 * 22.225 + 107.0)), 1)$$

$$= 1.0000$$

#### Bolting Information for TEMA Imperial Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm <sup>2</sup>	189.790	194.632	
Radial Distance between Hub and Bolts:	31.750	32.000	
Radial Distance between Bolts and Edge:	23.812	25.000	
Circ. Spacing between the Bolts:	52.400	57.141	227.879

#### Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:

$$= A_b * S_a / (y * \pi * (G_o + G_i))$$

$$= 194.632 * 172.38 / (68.95 * 3.14 * (1266.0 + 1226.0))$$

$$= 6.215 \text{ mm.}$$

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :

$$= 32.000 \text{ mm. [Note: Exceeds actual gasket width, 20.000 ]}$$

#### Flange Design Bolt Load, Gasket Seating [W]:

$$= S_a * (A_m + A_b) / 2$$

$$= 172.38 * (189.7901 + 194.6319) / 2$$

$$= 3312.96 \text{ kN}$$

#### Gasket Load for the Operating Condition [HG]:

$$= W_{m1} - H$$

$$= 3271 - 2837$$

$$= 434.06 \text{ kN}$$

#### Moment Arm Calculations:

##### Distance to Gasket Load Reaction [hg]:

$$= (C - G) / 2$$

$$= (1310.0 - 1250.0626) / 2$$

$$= 29.9687 \text{ mm.}$$

##### Distance to Face Pressure Reaction [ht]:

$$= (R + g_1 + h_g) / 2$$

$$= (32.0 + 20.0 + 29.9687) / 2$$

$$= 40.9843 \text{ mm.}$$

##### Distance to End Pressure Reaction [hd]:

$$= R + (g_1 / 2)$$

$$= 32.0 + (20.0 / 2.0)$$

$$= 42.0000 \text{ mm.}$$

#### Summary of Moments for Internal Pressure: (N-m)

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	2641.	42.0000	1.0000	110954.
Face Pressure, Mt	196.	40.9843	1.0000	8056.
Gasket Load, Mg	434.	29.9687	1.0000	13014.
Gasket Seating, Matm	3313.	29.9687	1.0000	99325.
Total Moment for Operation, Mop				132023. N-m
Total Moment for Gasket seating, Matm				99325. N-m
Effective Hub Length, ho = sqrt(Bcor*goCor)				134.499 mm.
Hub Ratio, h/h0 = HL / H0				0.335
Thickness Ratio, g1/g0 = (g1Cor/goCor)				1.333

#### Flange Factors for Integral Flange:

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Flg Calc [Int P]: New Flange Flng: 8 11:47am Dec 23,2021

Factor F 0.881  
 Factor V 0.400  
 Factor f 1.000  
 Factors from Figure 2-7.1 K = 1.128  
 T = 1.867 U = 17.771  
 Y = 16.171 Z = 8.361  
 d = 0.13452E+07 mm.<sup>3</sup> e = 0.0066 mm.<sup>-1</sup>  
 Stress Factors ALPHA = 1.701  
 BETA = 1.935 GAMMA = 0.911  
 DELTA = 0.911 Lamda = 1.822

Longitudinal Hub Stress, Operating [SHo]:

$$= ( f * Mop / Bcor ) / ( L * g1^2 )$$

$$= ( 1.0 * 132023 / 1206.0 ) / ( 1.8218 * 20.0^2 )$$

$$= 150.18 \text{ N./mm}^2$$

Longitudinal Hub Stress, Seating [SHa]:

$$= ( f * Matm / Bcor ) / ( L * g1^2 )$$

$$= ( 1.0 * 99325 / 1206.0 ) / ( 1.8218 * 20.0^2 )$$

$$= 112.98 \text{ N./mm}^2$$

Radial Flange Stress, Operating [SRo]:

$$= ( Beta * Mop / Bcor ) / ( L * t^2 )$$

$$= ( 1.9349 * 132023 / 1206.0 ) / ( 1.8218 * 107.0^2 )$$

$$= 10.15 \text{ N./mm}^2$$

Radial Flange Stress, Seating [SRa]:

$$= ( Beta * Matm / Bcor ) / ( L * t^2 )$$

$$= ( 1.9349 * 99325 / 1206.0 ) / ( 1.8218 * 107.0^2 )$$

$$= 7.64 \text{ N./mm}^2$$

Tangential Flange Stress, Operating [STo]:

$$= ( Y * Mo / ( t^2 * Bcor ) ) - Z * SRO$$

$$= ( 16.1715 * 132023 / ( 107.0^2 * 1206.0 ) ) - 8.3612 * 10$$

$$= 69.69 \text{ N./mm}^2$$

Tangential Flange Stress, Seating [STa]:

$$= ( y * Matm / ( t^2 * Bcor ) ) - Z * SRA$$

$$= ( 16.1715 * 99325 / ( 107.0^2 * 1206.0 ) ) - 8.3612 * 8$$

$$= 52.43 \text{ N./mm}^2$$

Average Flange Stress, Operating [SAo]:

$$= ( SHo + \max( SRO, STo ) ) / 2$$

$$= ( 150 + \max( 10, 70 ) ) / 2$$

$$= 109.93 \text{ N./mm}^2$$

Average Flange Stress, Seating [SAa]:

$$= ( SHa + \max( SRA, STa ) ) / 2$$

$$= ( 113 + \max( 8, 52 ) ) / 2$$

$$= 82.71 \text{ N./mm}^2$$

Bolt Stress, Operating [BSo]:

$$= Wm1 / Ab$$

$$= 3271 / 194.6319$$

$$= 168.09 \text{ N./mm}^2$$

Bolt Stress, Seating [BSa]:

$$= ( Wm2 / Ab )$$

$$= ( 2158 / 194.6319 )$$

$$= 110.86 \text{ N./mm}^2$$

**Flange Stress Analysis Results: N./mm<sup>2</sup>**

Actual	Operating	Gasket Seating	
	Allowed	Actual	Allowed
-----			

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FileName : Calculation Book for Evaporator E-PK1601 -----

Flg Calc [Int P]: New Flange Flng: 8 11:47am Dec 23,2021

Longitudinal Hub	150.	207.	113.	207.
Radial Flange	10.	138.	8.	138.
Tangential Flange	70.	138.	52.	138.
Maximum Average	110.	138.	83.	138.
Bolting	168.	172.	111.	172.

Minimum Required Flange Thickness [Rigidity]	99.466 mm.
Estimated M.A.W.P. ( Operating )	23.707 bars
Estimated Finished Weight of Flange at given Thk.	301.7 kg.
Estimated Unfinished Weight of Forging at given Thk	386.5 kg.

Flange Rigidity Based on Required Thickness [ASME]:

## Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:

$$= 52.14 * Ma / Bsc * Cnv\_fac * V / ( Lambda * Eamb * go^2 * ho * Ki )$$

$$= 52.14 * 99325.1/1.0 * 999.68 * 0.4/( 1.541 * 202713 * 15.0^2 * 134.499 * 0.3 )$$

$$= 0.730 \quad (\text{should be } \leq 1)$$

## Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

$$= 52.14 * Mo / Bsc * Cnv\_fac * V / ( Lambda * Eop * goc^2 * ho * Ki )$$

$$= 52.14 * 132023.1/1.0 * 999.68 * 0.4/( 1.541 * 196612 * 15.0^2 * 134.499 * 0.3 )$$

$$= 1.000 \quad (\text{should be } \leq 1)$$

Flange Rigidity Based on Given Thickness [ASME]:

## Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:

$$= 52.14 * Ma / Bsc * Cnv\_fac * V / ( Lambda * Eamb * go^2 * ho * Ki )$$

$$= 52.14 * 99325.1/1.0 * 999.68 * 0.4/( 1.822 * 202713 * 15.0^2 * 134.499 * 0.3 )$$

$$= 0.617 \quad (\text{should be } \leq 1)$$

## Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:

$$= 52.14 * Mo / Bsc * Cnv\_fac * V / ( Lambda * Eop * goc^2 * ho * Ki )$$

$$= 52.14 * 132023.1/1.0 * 999.68 * 0.4/( 1.822 * 196612 * 15.0^2 * 134.499 * 0.3 )$$

$$= 0.846 \quad (\text{should be } \leq 1)$$

**Minimum Design Metal Temperature Results:***Note:**This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

Note: UCS-66(b)(c) was considered in the flange MDMT calculation.

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Internal Pressure Calculations: Step: 7 11:47am Dec 23,2021

#### Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd bars	Nominal Thickness mm.	Total Corr Allowance mm.	Element Diameter mm.	Allowable Stress(SE) N./mm <sup>2</sup>
HEAD	001	23.118	18	3	1200	137.9
SHELL	001	23.118	15	3	1200	137.9
BODY FLANGE	001	23.118	60	3	1200	137.9
body flange	02	23.118	60	3	1200	137.9
SHELL	002	23.118	20	3	1200	137.9
CON		23.118	20	3	1656	137.9
SHELL	002	23.118	18	3	1656	137.9
HEAD	002	23.118	20	3	1656	137.9

#### Element Required Thickness and MAWP :

From	To	Design Pressure bars	M.A.W.P. Corroded bars	M.A.P. New & Cold bars	Minimum Thickness mm.	Required Thickness mm.
HEAD	001	23	27.4499	34.387	15	13.0597
SHELL	001	23	26.9995	33.9635	15	13.2122
BODY FLANGE	001	23	23.5895	23.7071	110	107.798
body flange	02	23	23.5895	23.7071	110	99.4664
SHELL	002	23	38.1104	45.0627	20	13.2122
CON		23	24.33	28.8256	20	19.0657
SHELL	002	23	24.5056	29.5906	18	17.0735
HEAD	002	23	23.1853	28.2531	17	16.8885

#### Summary of Heat Exchanger Maximum Allowable Working Pressures :

##### Note:

For Exchanger designs, the following values include MAWPs that consider the tubesheet, tubes, tube/tubesheet joint etc. These values were determined by iteration. Review the tubesheet analysis report for more information.

Shell Side MAWP = 23.589 bars  
 Shell Side MAPnc = 23.707 bars  
 Channel Side MAWP = 23.161 bars Governed by Cone Junction  
 Channel Side MAPnc = 23.707 bars

#### Internal Pressure Calculation Results :

##### ASME Code, Section VIII Division 1, 2017

##### Elliptical Head From 10 To 20 SA-516 70 at 125 °C

##### HEAD 001

Material UNS Number: K02700

##### Required Thickness due to Internal Pressure [tr]:

$$= (P \cdot D \cdot K_{cor}) / (2 \cdot S \cdot E - 0.2 \cdot P) \text{ Appendix 1-4(c)}$$

$$= (23.118 \cdot 1206.0 \cdot 0.993) / (2 \cdot 137.9 \cdot 1.0 - 0.2 \cdot 23.118)$$

$$= 10.0597 + 3.0000 = 13.0597 \text{ mm.}$$

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

Less Operating Hydrostatic Head Pressure of 0.118 bars

$$\begin{aligned}
 &= (2 * S * E * t) / (K * D + 0.2 * t) \text{ per Appendix 1-4 (c)} \\
 &= (2 * 137.9 * 1.0 * 12.0) / (0.993 * 1206.0 + 0.2 * 12.0) \\
 &= 27.568 - 0.118 = 27.450 \text{ bars}
 \end{aligned}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$\begin{aligned}
 &= (2 * S * E * t) / (K * D + 0.2 * t) \text{ per Appendix 1-4 (c)} \\
 &= (2 * 137.9 * 1.0 * 15.0) / (1.0 * 1200.0 + 0.2 * 15.0) \\
 &= 34.387 \text{ bars}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P * (K * D + 0.2 * t)) / (2 * E * t) \\
 &= (23.118 * (0.993 * 1206.0 + 0.2 * 12.0)) / (2 * 1.0 * 12.0) \\
 &= 115.641 \text{ N./mm}^2
 \end{aligned}$$

Straight Flange Required Thickness:

$$\begin{aligned}
 &= (P * R) / (S * E - 0.6 * P) + c \text{ per UG-27 (c)(1)} \\
 &= (23.118 * 603.0) / (137.9 * 1.0 - 0.6 * 23.118) + 3.0 \\
 &= 13.212 \text{ mm.}
 \end{aligned}$$

Straight Flange Maximum Allowable Working Pressure:

Less Operating Hydrostatic Head Pressure of 0.118 bars

$$\begin{aligned}
 &= (S * E * t) / (R + 0.6 * t) \text{ per UG-27 (c)(1)} \\
 &= (137.9 * 1.0 * 15.0) / (603.0 + 0.6 * 15.0) \\
 &= 33.797 - 0.118 = 33.679 \text{ bars}
 \end{aligned}$$

Factor K, corroded condition [Kcor]:

$$\begin{aligned}
 &= (2 + (\text{Inside Diameter} / (2 * \text{Inside Head Depth}))^2) / 6 \\
 &= (2 + (1206.0 / (2 * 303.0))^2) / 6 \\
 &= 0.993416
 \end{aligned}$$

Percent Elong. per UCS-79, VIII-1-01-57  $(75 * t_{nom} / R_f) * (1 - R_f / R_o)$  6.338 %

Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

**MDMT Calculations in the Knuckle Portion:**

Note: This Element/Detail was specified as being Impact Tested.

**MDMT Calculations in the Head Straight Flange:**

Note: This Element/Detail was specified as being Impact Tested.

**Cylindrical Shell From 20 To 30 SA-516 70 at 125 °C**

SHELL 001

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

$$\begin{aligned}
 &= (P * R) / (S * E - 0.6 * P) \text{ per UG-27 (c)(1)} \\
 &= (23.118 * 603.0) / (137.9 * 1.0 - 0.6 * 23.118) \\
 &= 10.2122 + 3.0000 = 13.2122 \text{ mm.}
 \end{aligned}$$

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

Less Operating Hydrostatic Head Pressure of 0.118 bars

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Internal Pressure Calculations: Step: 7 11:47am Dec 23,2021

$$\begin{aligned}
 &= (S \cdot E \cdot t) / (R + 0.6 \cdot t) \text{ per UG-27 (c)(1)} \\
 &= (137.9 \cdot 1.0 \cdot 12.0) / (603.0 + 0.6 \cdot 12.0) \\
 &= 27.117 - 0.118 = 26.999 \text{ bars}
 \end{aligned}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$\begin{aligned}
 &= (S \cdot E \cdot t) / (R + 0.6 \cdot t) \text{ per UG-27 (c)(1)} \\
 &= (137.9 \cdot 1.0 \cdot 15.0) / (600.0 + 0.6 \cdot 15.0) \\
 &= 33.964 \text{ bars}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot (R + 0.6 \cdot t)) / (E \cdot t) \\
 &= (23.118 \cdot (603.0 + 0.6 \cdot 12.0)) / (1.0 \cdot 12.0) \\
 &= 117.561 \text{ N./mm}^2
 \end{aligned}$$

% Elongation per Table UG-79-1 (50\*tnom/Rf\*(1-Rf/Ro)) 1.235 %

**Minimum Design Metal Temperature Results:**

Note: This Element/Detail was specified as being Impact Tested.

**Cylindrical Shell From 50 To 60 SA-516 70 at 125 °C**

SHELL 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

$$\begin{aligned}
 &= (P \cdot R) / (S \cdot E - 0.6 \cdot P) \text{ per UG-27 (c)(1)} \\
 &= (23.118 \cdot 603.0) / (137.9 \cdot 1.0 - 0.6 \cdot 23.118) \\
 &= 10.2122 + 3.0000 = 13.2122 \text{ mm.}
 \end{aligned}$$

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

Less Operating Hydrostatic Head Pressure of 0.118 bars

$$\begin{aligned}
 &= (S \cdot E \cdot t) / (R + 0.6 \cdot t) \text{ per UG-27 (c)(1)} \\
 &= (137.9 \cdot 1.0 \cdot 17.0) / (603.0 + 0.6 \cdot 17.0) \\
 &= 38.228 - 0.118 = 38.110 \text{ bars}
 \end{aligned}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$\begin{aligned}
 &= (S \cdot E \cdot t) / (R + 0.6 \cdot t) \text{ per UG-27 (c)(1)} \\
 &= (137.9 \cdot 1.0 \cdot 20.0) / (600.0 + 0.6 \cdot 20.0) \\
 &= 45.063 \text{ bars}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot (R + 0.6 \cdot t)) / (E \cdot t) \\
 &= (23.118 \cdot (603.0 + 0.6 \cdot 17.0)) / (1.0 \cdot 17.0) \\
 &= 83.393 \text{ N./mm}^2
 \end{aligned}$$

% Elongation per Table UG-79-1 (50\*tnom/Rf\*(1-Rf/Ro)) 1.639 %

**Minimum Design Metal Temperature Results:**

Note: This Element/Detail was specified as being Impact Tested.

**Conical Section From 60 To 70 SA-516 70 at 125 °C**

CON

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Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

$$= (P \cdot D) / (2 \cdot \cos(a) \cdot (S \cdot E - 0.6 \cdot P)) \text{ per Appendix 1-4 (e)}$$

$$= (23.118 \cdot 1662.8459) / (2 \cdot 0.8764 \cdot (137.9 \cdot 1.0 - 0.6 \cdot 23.118))$$

$$= 16.0657 + 3.0000 = 19.0657 \text{ mm.}$$

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

Less Operating Hydrostatic Head Pressure of 0.118 bars

$$= (2 \cdot S \cdot E \cdot t \cdot \cos(a)) / (D + 1.2 \cdot t \cdot \cos(a)) \text{ per App 1-4(e)}$$

$$= (2 \cdot 137.9 \cdot 1.0 \cdot 17.0 \cdot 0.876) / (1662.846 + 1.2 \cdot 17.0 \cdot 0.876)$$

$$= 24.448 - 0.118 = 24.330 \text{ bars}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$= (2 \cdot S \cdot E \cdot t \cdot \cos(a)) / (D + 1.2 \cdot t \cdot \cos(a)) \text{ per App 1-4(e)}$$

$$= (2 \cdot 137.9 \cdot 1.0 \cdot 20.0 \cdot 0.8764) / (1656.0 + 1.2 \cdot 20.0 \cdot 0.8764)$$

$$= 28.826 \text{ bars}$$

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

$$= (P \cdot (D + 1.2 \cdot t \cdot \cos(a))) / (2 \cdot E \cdot t \cdot \cos(a))$$

$$= (23.118 \cdot (1662.8459 + 1.2 \cdot 17.0 \cdot 0.8764)) / (2 \cdot 1.0 \cdot 17.0 \cdot 0.8764)$$

$$= 130.398 \text{ N./mm}^2$$

% Elongation per Table UG-79-1 ( $50 \cdot t_{nom} / R_f \cdot (1 - R_f / R_o)$ ) 1.636 %

**Minimum Design Metal Temperature Results:**

Note: This Element/Detail was specified as being Impact Tested.

### **Cylindrical Shell From 70 To 80 SA-516 70 at 125 °C**

SHELL 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

$$= (P \cdot R) / (S \cdot E - 0.6 \cdot P) \text{ per UG-27 (c)(1)}$$

$$= (23.118 \cdot 831.0) / (137.9 \cdot 1.0 - 0.6 \cdot 23.118)$$

$$= 14.0735 + 3.0000 = 17.0735 \text{ mm.}$$

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

Less Operating Hydrostatic Head Pressure of 0.118 bars

$$= (S \cdot E \cdot t) / (R + 0.6 \cdot t) \text{ per UG-27 (c)(1)}$$

$$= (137.9 \cdot 1.0 \cdot 15.0) / (831.0 + 0.6 \cdot 15.0)$$

$$= 24.624 - 0.118 = 24.506 \text{ bars}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$= (S \cdot E \cdot t) / (R + 0.6 \cdot t) \text{ per UG-27 (c)(1)}$$

$$= (137.9 \cdot 1.0 \cdot 18.0) / (828.0 + 0.6 \cdot 18.0)$$

$$= 29.591 \text{ bars}$$

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

$$= (P \cdot (R + 0.6 \cdot t)) / (E \cdot t)$$

$$= (23.118 \cdot (831.0 + 0.6 \cdot 15.0)) / (1.0 \cdot 15.0)$$

$$= 129.468 \text{ N./mm}^2$$

% Elongation per Table UG-79-1 ( $50 \cdot t_{nom} / R_f \cdot (1 - R_f / R_o)$ ) 1.075 %

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**Minimum Design Metal Temperature Results:**

Note: This Element/Detail was specified as being Impact Tested.

**Elliptical Head From 80 To 90 SA-516 70 at 125 °C**

HEAD 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

$$\begin{aligned}
 &= (P \cdot D \cdot K_{cor}) / (2 \cdot S \cdot E - 0.2 \cdot P) \text{ Appendix 1-4 (c)} \\
 &= (23.118 \cdot 1662.0 \cdot 0.995) / (2 \cdot 137.9 \cdot 1.0 - 0.2 \cdot 23.118) \\
 &= 13.8885 + 3.0000 = 16.8885 \text{ mm.}
 \end{aligned}$$

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

Less Operating Hydrostatic Head Pressure of 0.118 bars

$$\begin{aligned}
 &= (2 \cdot S \cdot E \cdot t) / (K_{cor} \cdot D + 0.2 \cdot t) \text{ per Appendix 1-4 (c)} \\
 &= (2 \cdot 137.9 \cdot 1.0 \cdot 14.0) / (0.995 \cdot 1662.0 + 0.2 \cdot 14.0) \\
 &= 23.303 - 0.118 = 23.185 \text{ bars}
 \end{aligned}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$\begin{aligned}
 &= (2 \cdot S \cdot E \cdot t) / (K \cdot D + 0.2 \cdot t) \text{ per Appendix 1-4 (c)} \\
 &= (2 \cdot 137.9 \cdot 1.0 \cdot 17.0) / (1.0 \cdot 1656.0 + 0.2 \cdot 17.0) \\
 &= 28.253 \text{ bars}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P \cdot (K_{cor} \cdot D + 0.2 \cdot t)) / (2 \cdot E \cdot t) \\
 &= (23.118 \cdot (0.995 \cdot 1662.0 + 0.2 \cdot 14.0)) / (2 \cdot 1.0 \cdot 14.0) \\
 &= 136.804 \text{ N./mm}^2
 \end{aligned}$$

Straight Flange Required Thickness:

$$\begin{aligned}
 &= (P \cdot R) / (S \cdot E - 0.6 \cdot P) + c \text{ per UG-27 (c)(1)} \\
 &= (23.118 \cdot 831.0) / (137.9 \cdot 1.0 - 0.6 \cdot 23.118) + 3.0 \\
 &= 17.073 \text{ mm.}
 \end{aligned}$$

Straight Flange Maximum Allowable Working Pressure:

Less Operating Hydrostatic Head Pressure of 0.118 bars

$$\begin{aligned}
 &= (S \cdot E \cdot t) / (R + 0.6 \cdot t) \text{ per UG-27 (c)(1)} \\
 &= (137.9 \cdot 1.0 \cdot 17.0) / (831.0 + 0.6 \cdot 17.0) \\
 &= 27.867 - 0.118 = 27.749 \text{ bars}
 \end{aligned}$$

Factor K, corroded condition [Kcor]:

$$\begin{aligned}
 &= (2 + (\text{Inside Diameter} / (2 \cdot \text{Inside Head Depth}))^2) / 6 \\
 &= (2 + (1662.0 / (2 \cdot 417.0))^2) / 6 \\
 &= 0.995212
 \end{aligned}$$

Percent Elong. per UCS-79, VIII-1-01-57  $(75 \cdot t_{nom} / R_f) \cdot (1 - R_f / R_o)$  5.145 %

Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

**MDMT Calculations in the Knuckle Portion:**

Note: This Element/Detail was specified as being Impact Tested.

**MDMT Calculations in the Head Straight Flange:**

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Note: This Element/Detail was specified as being Impact Tested.

### **Hydrostatic Test Pressure Results:**

#### **Exchanger Shell Side Hydrostatic Test Pressures:**

Pressure per UG99b	= 1.30 * M.A.W.P. * Sa/S	30.666 bars
Pressure per UG99b[36]	= 1.30 * Design Pres * Sa/S	29.900 bars
Pressure per UG99c	= 1.30 * M.A.P. - Head(Hyd)	30.657 bars
Pressure per UG100	= 1.10 * M.A.W.P. * Sa/S	25.948 bars
Pressure per PED	= max(1.43*DP, 1.25*DP*ratio)	32.890 bars
Pressure per App 27-4	= M.A.W.P.	23.589 bars

#### **Exchanger Channel Side Hydrostatic Test Pressures:**

Pressure per UG99b	= 1.30 * M.A.W.P. * Sa/S	30.109 bars
Pressure per UG99b[36]	= 1.30 * Design Pres * Sa/S	29.900 bars
Pressure per UG99c	= 1.30 * M.A.P. - Head(Hyd)	30.657 bars
Pressure per UG100	= 1.10 * M.A.W.P. * Sa/S	25.477 bars
Pressure per PED	= max(1.43*DP, 1.25*DP*ratio)	32.890 bars
Pressure per App 27-4	= M.A.W.P.	23.161 bars

#### **UG-99(b) Note 36, Test Pressure Calculation [Shell Side]:**

= Test Factor \* Design Pressure \* Stress Ratio  
 = 1.3 \* 23.0 \* 1.0  
 = 29.900 bars

#### **UG-99(b) Note 36, Test Pressure Calculation [Channel Side]:**

= Test Factor \* Design Pressure \* Stress Ratio  
 = 1.3 \* 23.0 \* 1.0  
 = 29.900 bars

### **Horizontal Test performed per: UG-99b (Note 36)**

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

### **Stresses on Elements due to Test Pressure (N./mm<sup>2</sup> & bars):**

From To	Stress	Allowable	Ratio	Pressure
HEAD 001	150.2	235.8	0.637	30.02
SHELL 001	152.6	235.8	0.647	30.02
SHELL 002	108.3	235.8	0.459	30.02
CON	169.6	235.8	0.719	30.06
SHELL 002	168.4	235.8	0.714	30.06
HEAD 002	177.9	235.8	0.754	30.06

### **Stress ratios for Nozzle and Pad Materials (N./mm<sup>2</sup>):**

Description	Pad/Nozzle	Ambient	Operating	Ratio
T2	Nozzle	137.90	137.90	1.000
T2	Pad	137.90	137.90	1.000
T1	Nozzle	137.90	137.90	1.000
T1	Pad	137.90	137.90	1.000
D4	Nozzle	137.90	137.90	1.000
S2	Nozzle	117.90	117.90	1.000
S2	Pad	137.90	137.90	1.000

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S1	Nozzle	117.90	117.90	1.000
S1	Pad	137.90	137.90	1.000
S3	Nozzle	117.90	117.90	1.000
S3	Pad	137.90	137.90	1.000
D2	Nozzle	137.90	137.90	1.000
D1	Nozzle	137.90	137.90	1.000
D3	Nozzle	137.90	137.90	1.000
TT	Nozzle	137.90	137.90	1.000
V	Nozzle	137.90	137.90	1.000
S4	Nozzle	117.90	117.90	1.000
S4	Pad	137.90	137.90	1.000
LG1	Nozzle	137.90	137.90	1.000
LG2	Nozzle	137.90	137.90	1.000
LT1	Nozzle	137.90	137.90	1.000
LT3	Nozzle	137.90	137.90	1.000
LT2	Nozzle	137.90	137.90	1.000
LT4	Nozzle	137.90	137.90	1.000

-----  
 Minimum 1.000

**Stress ratios for Pressurized Vessel Elements (N./mm<sup>2</sup>):**

Description	Ambient	Operating	Ratio
HEAD 001	137.90	137.90	1.000
SHELL 001	137.90	137.90	1.000
BODY FLANGE 001	137.90	137.90	1.000
body flange 02	137.90	137.90	1.000
SHELL 002	137.90	137.90	1.000
CON	137.90	137.90	1.000
SHELL 002	137.90	137.90	1.000
HEAD 002	137.90	137.90	1.000

-----  
 Minimum 1.000

**Stress ratios for Exchanger Materials (N./mm<sup>2</sup>):**

Description	Ambient	Operating	Ratio
Tube Material	117.90	117.90	1.000
Tubesheet Material	137.90	137.90	1.000

-----  
 Minimum 1.000

**Hoop Stress in Nozzle Wall during Pressure Test (N./mm<sup>2</sup>):**

Description	Ambient	Operating	Ratio
T2	43.65	235.80	0.185
T1	43.65	235.80	0.185
D4	8.08	223.40	0.036
S2	39.39	217.19	0.181
S1	39.39	217.19	0.181
S3	39.39	217.19	0.181
D2	8.08	223.40	0.036
D1	8.08	223.40	0.036
D3	8.08	223.40	0.036
TT	8.08	223.40	0.036
V	8.08	223.40	0.036
S4	39.39	217.19	0.181
LG1	8.08	223.40	0.036

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LG2	8.08	223.40	0.036
LT1	18.32	223.40	0.082
LT3	18.32	223.40	0.082
LT2	18.32	223.40	0.082
LT4	18.32	223.40	0.082

-----

Elements Suitable for Internal Pressure.

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**External Pressure Calculation Results :**

**External Pressure Calculations:**

From	To	Section Length mm.	Outside Diameter mm.	Corroded Thickness mm.	Factor A	Factor B N./mm <sup>2</sup>
10	20	No Calc	1230	12	0.001355	94.0922
20	30	950	1230	12	0.001708	100.056
30	40	No Calc	...	107	No Calc	No Calc
40	50	No Calc	...	107	No Calc	No Calc
50	60	5218	1240	17	0.00046617	46.6065
60	70	5218	1696	17	0.00040569	40.5597
70	80	5218	1692	15	0.00034124	34.1167
80	90	No Calc	1690	14	0.0011506	89.495

**External Pressure Calculations:**

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	20	15	6.18473	1.03419	10.1991
20	30	15	6.52984	1.03419	13.0146
30	40	110	79.2734	1.03419	No Calc
40	50	110	65.4558	1.03419	No Calc
50	60	20	10.2323	1.03419	8.51898
60	70	20	11.6968	1.03419	5.4204
70	80	18	11.6842	1.03419	4.03247
80	90	17	7.37574	1.03419	8.23707

Minimum 4.032

**External Pressure Calculations:**

From	To	Actual Length Bet. Stiffeners mm.	Allowable Length Bet. Stiffeners mm.	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	950	20495	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	No Calc	No Calc	No Calc	No Calc
50	60	5218	112034	No Calc	No Calc
60	70	5218	115500	No Calc	No Calc
70	80	5218	46275.1	No Calc	No Calc
80	90	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

**ASME Code, Section VIII Division 1, 2017**

**Elliptical Head From 10 to 20 Ext. Chart: CS-2 at 125 °C**

**HEAD 001**

Elastic Modulus from Chart: CS-2 at 125 °C : 0.200E+09 KPa.

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Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
12.000	1230.00	102.50	0.0013550	94.09

EMAP =  $B/(K0*D/t) = 94.0922/(0.9 * 102.5) = 10.1991$  bars

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
3.185	1230.00	386.22	0.0003596	35.95

EMAP =  $B/(K0*D/t) = 35.9532/(0.9 * 386.2177) = 1.0343$  bars

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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

=  $(P*D*Kcor)/(2*S*E-0.2*P)$  Appendix 1-4(c)  
 =  $(1.727*1206.0*0.993)/(2*137.9*1.0-0.2*1.727)$   
 =  $0.7504 + 3.0000 = 3.7504$  mm.

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

=  $((2*S*E*t)/(Kcor*D+0.2*t))/1.67$  per Appendix 1-4 (c)  
 =  $((2*137.9*1.0*12.0)/(0.993*1206.0+0.2*12.0))/1.67$   
 = 16.508 bars

Maximum Allowable External Pressure [MAEP]:

= min( MAEP, MAWP )  
 = min( 10.2, 16.5077 )  
 = 10.199 bars

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

### **Cylindrical Shell From 20 to 30 Ext. Chart: CS-2 at 125 °C**

SHELL 001

Elastic Modulus from Chart: CS-2 at 125 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
12.000	1230.00	950.00	102.50	0.7724	0.0017080	100.06

EMAP =  $(4*B)/(3*(D/t)) = (4*100.0556)/(3*102.5) = 13.0146$  bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.530	1230.00	950.00	348.46	0.7724	0.0002704	27.03

EMAP =  $(4*B)/(3*(D/t)) = (4*27.0303)/(3*348.4581) = 1.0342$  bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
12.000	1230.00	20495.01	102.50	16.6626	0.0001081	10.81

EMAP =  $(4*B)/(3*(D/t)) = (4*10.8077)/(3*102.5) = 1.4058$  bars

### **Cylindrical Shell From 50 to 60 Ext. Chart: CS-2 at 125 °C**

SHELL 002

Elastic Modulus from Chart: CS-2 at 125 °C : 0.200E+09 KPa.

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## Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
17.000	1240.00	5218.00	72.94	4.2081	0.0004662	46.61

EMAP =  $(4*B)/(3*(D/t)) = (4*46.6065)/(3*72.9412) = 8.519$  bars

## Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
7.232	1240.00	5218.00	171.45	4.2081	0.0001330	13.30

EMAP =  $(4*B)/(3*(D/t)) = (4*13.3003)/(3*171.4528) = 1.0343$  bars

## Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
17.000	1240.00	112033.63	72.94	50.0000	0.0002131	21.31

EMAP =  $(4*B)/(3*(D/t)) = (4*21.3074)/(3*72.9412) = 3.8947$  bars

**Cylindrical Shell From 60 to 70 Ext. Chart: CS-2 at 125 °C**

## CON

Elastic Modulus from Chart: CS-2 at 125 °C : 0.200E+09 KPa.

## Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
17.000	1696.00	5218.00	99.76	3.0767	0.0004057	40.56

EMAP =  $(4*B)/(3*(D/t)) = (4*40.5597)/(3*99.7647) = 5.4204$  bars

## Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
8.697	1696.00	5218.00	195.01	3.0767	0.0001513	15.13

EMAP =  $(4*B)/(3*(D/t)) = (4*15.1274)/(3*195.0137) = 1.0342$  bars

## Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
17.000	1696.00	115500.43	99.76	50.0000	0.0001106	11.06

EMAP =  $(4*B)/(3*(D/t)) = (4*11.06)/(3*99.7647) = 1.4781$  bars

**Cylindrical Shell From 70 to 80 Ext. Chart: CS-2 at 125 °C**

## SHELL 002

Elastic Modulus from Chart: CS-2 at 125 °C : 0.200E+09 KPa.

## Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
15.000	1692.00	5218.00	112.80	3.0839	0.0003412	34.12

EMAP =  $(4*B)/(3*(D/t)) = (4*34.1167)/(3*112.8) = 4.0325$  bars

## Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
8.684	1692.00	5218.00	194.84	3.0839	0.0001512	15.11

EMAP =  $(4*B)/(3*(D/t)) = (4*15.1136)/(3*194.8375) = 1.0342$  bars

## Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
15.000	1692.00	46275.10	112.80	27.3493	0.0000884	8.84

EMAP =  $(4*B)/(3*(D/t)) = (4*8.8357)/(3*112.8) = 1.0444$  bars

**Elliptical Head From 80 to 90 Ext. Chart: CS-2 at 125 °C**

## HEAD 002

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 External Pressure Calculations: Step: 8 11:47am Dec 23,2021

Elastic Modulus from Chart: CS-2 at 125 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
14.000	1690.00	120.71	0.0011506	89.50

EMAP =  $B / (K_0 * D / t) = 89.495 / (0.9 * 120.7143) = 8.2371$  bars

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
4.376	1690.00	386.22	0.0003596	35.95

EMAP =  $B / (K_0 * D / t) = 35.9529 / (0.9 * 386.2208) = 1.0343$  bars

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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

$$\begin{aligned}
 &= (P * D * K_{cor}) / (2 * S * E - 0.2 * P) \text{ Appendix 1-4 (c)} \\
 &= (1.727 * 1662.0 * 0.995) / (2 * 137.9 * 1.0 - 0.2 * 1.727) \\
 &= 1.0360 + 3.0000 = 4.0360 \text{ mm.}
 \end{aligned}$$

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

$$\begin{aligned}
 &= ((2 * S * E * t) / (K_{cor} * D + 0.2 * t)) / 1.67 \text{ per Appendix 1-4 (c)} \\
 &= ((2 * 137.9 * 1.0 * 14.0) / (0.995 * 1662.0 + 0.2 * 14.0)) / 1.67 \\
 &= 13.954 \text{ bars}
 \end{aligned}$$

Maximum Allowable External Pressure [MAEP]:

$$\begin{aligned}
 &= \min(\text{MAEP}, \text{MAWP}) \\
 &= \min(8.24, 13.954) \\
 &= 8.237 \text{ bars}
 \end{aligned}$$

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

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**Element and Detail Weights:**

From	To	Element Metal Wgt. kg.	Element ID Volume Cm3	Corroded Metal Wgt. kg.	Corroded ID Volume Cm3	Extra due Misc % kg.
10	20	274.398	282794	228.665	286772	54.8796
20	30	355.008	904941	284.707	914013	71.0015
30	40	299.644	176580	286.023	177090	59.9288
40	50	301.681	176580	288.06	177090	60.3362
50	60	118.823	127029	101.247	129297	23.7645
60	70	669.082	1340840	570.06	1353618	133.816
70	80	2934.72	8616848	2449.98	8679401	586.944
80	90	561.942	702273	477.651	709541	112.388
Total		5515	12327886.00	4686	12426824.00	1103

*For elements specified as shell side elements, the volume(s) shown above for those elements, reflects the displacement of the tubes.*

**Weight of Details:**

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Liqd	282.621	-100	0.36335E-04	1
20	Liqd	904.389	400	...	2
20	Nozl	366.74	400	854	T2
20	Nozl	366.74	400	854	T1
30	Liqd	176.472	77.5	...	3
40	Liqd	176.472	77.5	...	4
50	Sadl	212.848	200	770	Lft Sdl
50	Liqd	126.952	100	...	5
60	Liqd	1089.66	415	114	Liquid: 60
60	Nozl	12.4214	400	853.4	D4
70	Sadl	282.608	3500	999	Lft Sdl
70	Liqd	6683.29	2000	228	Liquid: 70
70	Nozl	105.134	200	937.537	S2
70	Nozl	105.134	2800	937.537	S1
70	Nozl	105.134	600	937.537	S3
70	Nozl	12.4214	600	853.4	D2
70	Nozl	12.4214	2400	853.4	D1
70	Nozl	12.4214	3200	853.4	D3
70	Nozl	12.4214	3800	853.4	TT
70	Nozl	12.4214	200	853.4	V
70	Nozl	105.134	2800	937.537	S4
70	Nozl	12.4214	2200	853.4	LG1
70	Nozl	12.4214	2200	853.4	LG2
70	Nozl	27.2525	1000	858.162	LT1
70	Nozl	27.2525	1500	858.162	LT3
70	Nozl	27.2525	1000	858.162	LT2
70	Nozl	27.2525	1500	858.162	LT4
80	Liqd	571.502	188	228	Liquid: 80
30	FTsh	1245.75	231	...	TUBE SHEET
30	Tube	8758.45	2261	...	

**Total Weight of Each Detail Type:**

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Saddles	495.5
Liquid	10011.4
Nozzles	1362.4
Exchanger Components	10004.2
Liquid in Tubes	1550.0
-----	
Sum of the Detail Weights	23423.4 kg.

**Weight Summation Results: (kg.)**

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	6618.4	6618.4	6618.4	6618.4	6618.4	6618.4
Saddles	495.5	495.5	495.5	495.5	495.5	495.5
Nozzles	1362.4	1362.4	1362.4	1362.4	1362.4	1362.4
Exchanger	10004.2	10004.2	10004.2	10004.2	10004.2	10004.2
Ope. Liquid	...	...	...	...	...	10011.4
Tube Ope Lqd	...	...	...	...	...	1550.0
Test Liquid	...	12320.4	...	...	...	...
Tube Tst Lqd	...	1550.0	...	...	...	...
-----						
Totals	18480.4	32350.8	18480.4	18480.4	18480.4	30041.8

**Miscellaneous Weight Percent: 20.0 %**

*Note that the above value for the miscellaneous weight percent has been applied to the shells/heads/flange/tubesheets/tubes etc. in the weight calculations for metallic components.*

**Weight Summary:**

Fabricated Wt.	- Bare Weight without Removable Internals	18480.4 kg.
Shop Test Wt.	- Fabricated Weight + Water ( Full )	32350.8 kg.
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	18480.4 kg.
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	18480.4 kg.
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	18480.4 kg.
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	30041.8 kg.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	29047.1 kg.
Field Test Wt.	- Empty Weight + Water (Full)	31455.0 kg.

**Exchanger Tube Data**

Volume of Exchanger tubes :	1550960.2 Cm3
Weight of Ope Liq in tubes :	1550.0 kg.
Weight of Water in tubes :	1550.0 kg.

**Note:**

The Corroded Weight and thickness are used in the Horizontal Vessel Analysis (Ope Case) and Earthquake Load Calculations.

Note: The Field Test weight as computed in the corroded condition.

**Outside Surface Areas of Elements:**

From	To	Surface Area cm^2
10	20	18501.5
20	30	30913.3
30	40	9678.31
40	50	9678.31

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50	60	7791.15
60	70	39848.9
70	80	212623
80	90	33844

-----  
Total 362878.469 cm^2

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Nozzle Flange MAWP: Step: 10 11:47am Dec 23,2021

**Nozzle Flange MAWP Results:**

Nozzle Description	Flange Rating		Design Temp °C	Class	Grade/Group	Equiv. Press	Max Pressure		
	Ope. bars	Ambient bars					PVP	50%	DNV bars
T2	45.85	51.10	125	300	GR 1.1	...	...	...	...
T1	45.85	51.10	125	300	GR 1.1	...	...	...	...
D4	45.85	51.10	125	300	GR 1.1	...	...	...	...
S2	45.85	51.10	125	300	GR 1.1	...	...	...	...
S1	45.85	51.10	125	300	GR 1.1	...	...	...	...
S3	45.85	51.10	125	300	GR 1.1	...	...	...	...
D2	45.85	51.10	125	300	GR 1.1	...	...	...	...
D1	45.85	51.10	125	300	GR 1.1	...	...	...	...
D3	45.85	51.10	125	300	GR 1.1	...	...	...	...
TT	45.85	51.10	125	300	GR 1.1	...	...	...	...
V	45.85	51.10	125	300	GR 1.1	...	...	...	...
S4	45.85	51.10	125	300	GR 1.1	...	...	...	...
LG1	45.85	51.10	125	300	GR 1.1	...	...	...	...
LG2	45.85	51.10	125	300	GR 1.1	...	...	...	...
LT1	45.85	51.10	125	300	GR 1.1	...	...	...	...
LT3	45.85	51.10	125	300	GR 1.1	...	...	...	...
LT2	45.85	51.10	125	300	GR 1.1	...	...	...	...
LT4	45.85	51.10	125	300	GR 1.1	...	...	...	...

**Shellside Flange Rating**

**Channelside Flange Rating**

Lowest Flange Pressure Rating was (Ope)[TubeSide ]: 45.850 bars  
 Lowest Flange Pressure Rating was (Amb)[TubeSide ]: 51.100 bars

**Selected Method for Derating ANSI B16.5 Flange MAWP: None Selected**

ANSI Ratings are per ANSI/ASME B16.5 2013 Metric Edition

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 Wind Load Calculation: Step: 11 11:47am Dec 23,2021

### Input Values:

Wind Design Code	ASCE-7 2010
Wind Load Reduction Scale Factor	0.600
Basic Wind Speed [V]	195 Km/hr
Surface Roughness Category	C: Open Terrain
Importance Factor	1.0
Type of Surface	Moderately Smooth
Base Elevation	123000 mm.
Percent Wind for Hydrotest	33.0
Using User defined Wind Press. Vs Elev.	N
Height of Hill or Escarpment H or Hh	0 mm.
Distance Upwind of Crest Lh	0 mm.
Distance from Crest to the Vessel x	0 mm.
Type of Terrain ( Hill, Escarpment )	Flat
Damping Factor (Beta) for Wind (Ope)	0.0100
Damping Factor (Beta) for Wind (Empty)	0.0000
Damping Factor (Beta) for Wind (Filled)	0.0000

### Wind Analysis Results

Static Gust-Effect Factor, Operating Case [G]:

$$\begin{aligned}
 &= \min(0.85, 0.925((1 + 1.7 * gQ * Izbar * Q) / (1 + 1.7 * gV * Izbar))) \\
 &= \min(0.85, 0.925((1 + 1.7 * 3.4 * 0.143 * 0.836) / (1 + 1.7 * 3.4 * 0.143))) \\
 &= \min(0.85, 0.856) \\
 &= 0.850
 \end{aligned}$$

Natural Frequency of Vessel (Operating)	33.000 Hz
Natural Frequency of Vessel (Empty)	33.000 Hz
Natural Frequency of Vessel (Test)	33.000 Hz

Force Coefficient [Cf]	0.559
Structure Height to Diameter ratio	4.521

*This is classified as a rigid structure. Static analysis performed.*

### Sample Calculation for the First Element

The ASCE code performs all calculations in Imperial Units only. The wind pressure is therefore computed in these units.

Value of [Alpha] and [Zg]:

Exposure Category: C from Table 26.9.1  
 Alpha = 9.5: Zg = 274320. mm.

Effective Height [z]:

$$\begin{aligned}
 &= \text{Centroid Height} + \text{Vessel Base Elevation} \\
 &= 1200.0 + 123000. = 124200.008 \text{ mm.} \\
 &= 407.48 \text{ ft. Imperial Units}
 \end{aligned}$$

Velocity Pressure coefficient evaluated at height z [Kz]:

$$\begin{aligned}
 &\text{Because } z (407.48 \text{ ft.}) > 15 \text{ ft.} \\
 &= 2.01 * ( z / Zg )^{2 / \text{Alpha}} \\
 &= 2.01 * ( 407.48 / 900.0 )^{2 / 9.5} \\
 &= 1.701
 \end{aligned}$$

Type of Hill: No Hill

Wind Directionality Factor [Kd]:

$$= 0.95 \text{ per Table 26.6-1}$$

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As there is No Hill Present: [Kzt]:  
 K1 = 0, K2 = 0, K3 = 0

Topographical Factor [Kzt]:  
 = ( 1 + K1 \* K2 \* K3 )<sup>2</sup>  
 = ( 1 + 0.0\* 0.0\* 0.0 )<sup>2</sup>  
 = 1.0

Velocity Pressure evaluated at height z, Imperial Units [qz]:  
 = max( 16, 0.00256 \* Kz \* Kzt \* Kd \* V(mph)<sup>2</sup> )  
 = max( 16, 0.00256 \* 1.701 \* 1.0 \* 0.95 \* 121.171<sup>2</sup> )  
 = 60.7 psf [296.584] Kgs/m<sup>2</sup>

Force on the first element [F]:  
 = qz \* G \* Cf \* WindArea  
 = 60.744 \* 0.85 \* 0.559 \* 4.07  
 = 117.4 lbs. [ 0.5] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m <sup>2</sup>
HEAD 001	*****	0.000	0.000	0.000	1.701	1.000	296.584
SHELL 001	*****	0.000	0.000	0.000	1.701	1.000	296.584
BODY FLANGE 001	*****	0.000	0.000	0.000	1.701	1.000	296.584
body flange 02	*****	0.000	0.000	0.000	1.701	1.000	296.584
SHELL 002	*****	0.000	0.000	0.000	1.701	1.000	296.584
CON	*****	0.000	0.000	0.000	1.701	1.000	296.584
SHELL 002	*****	0.000	0.000	0.000	1.701	1.000	296.584
HEAD 002	*****	0.000	0.000	0.000	1.701	1.000	296.584

**Wind Load Calculation:**

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm <sup>2</sup>	Wind Pressure Kgs/m <sup>2</sup>	Element Wind Load kN
10	20	124200	1476	3781.03	296.584	0.31332
20	30	124200	1476	11808	296.584	0.97847
30	40	124200	1440	2232	296.584	0.18495
40	50	124200	1440	2232	296.584	0.18495
50	60	124200	1488	2976	296.584	0.24661
60	70	124200	1761.6	14621.3	296.584	1.21159
70	80	124200	2030.4	81216	296.584	6.72997
80	90	124200	2028	6734.76	296.584	0.55808

Note:  
 The Wind Loads calculated and printed in the Wind Load calculation report have been factored by the input scalar/load reduction factor of: 0.600.

*Be sure the wind speed is in accordance with the specified wind design code.*

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 Earthquake Load Calculation: Step: 12 11:47am Dec 23,2021

**Earthquake Load Calculation:**

**Input Values:**

Seismic Design Code		ASCE 7-2010
Seismic Load Reduction Scale Factor		0.700
Importance Factor		1.500
Table Value Fa		1.000
Table Value Fv		1.300
Short Period Acceleration value Ss		1.163
Long Period Acceleration Value S1		0.600
Moment Reduction Factor Tau		1.000
Force Modification Factor R		2.000
Site Class		C
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	1.000
Force Factor		0.000
Consider Vertical Acceleration		No
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0 )		0.000
User Value of Sd1 (used if > 0 )		0.000

**Seismic Analysis Results:**

Sms = Fa \* Ss = 1.0 \* 1.163 = 1.163  
 Sml = Fv \* S1 = 1.3 \* 0.6 = 0.78  
 Sds = 2/3 \* Sms = 2/3 \* 1.163 = 0.775  
 Sd1 = 2/3 \* Sml = 2/3 \* 0.78 = 0.52

**Check Approximate Fundamental Period from 12.8-7 [Ta]:**

= Ct \* hn<sup>x</sup> where Ct = 0.020, x = 0.75 and hn = Structural Height (ft.)  
 = 0.020 \* ( 6.6535<sup>0.75</sup> )  
 = 0.083 seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

**Fundamental Period (1/Frequency) [T]:**

= ( 1/Natural Frequency ) = ( 1/33.0 )  
 = 0.030

**Check the Value of T which is the smaller of Cu\*Ta and T:**

= Minimum Value of ( 1.4 \* 0.083, 0.03 ) per 12.8.2  
 = 0.030

As the time period is < 0.06 second, use section 15.4.2.

**Compute the Base Shear per equation 15.4-5, [V]:**

= 0.3 \* Sds \* W \* I  
 = 0.3 \* 0.775 \* 285 \* 1.5  
 = 99.379 kN

Final Base Shear, V = 69.57 kN

**Earthquake Load Calculation:**

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN
10	20	600	28.4836	6.24465

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20	30	600	28.4836	6.24465
30	40	600	28.4836	6.24465
40	50	600	28.4836	6.24465
50	60	600	28.4836	6.24465
50	60	600	28.4836	6.24465
60	70	600	28.4836	6.24465
70	0	828	28.4836	8.61762
70	80	828	28.4836	8.61762
80	90	828	28.4836	8.61762

**Note:**

The Earthquake Loads calculated and printed in the Earthquake Load calculation report have been factored by the input scalar/load reduction factor of: 0.700.

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 Center of Gravity Calculation: Step: 13 11:47am Dec 23,2021

**Shop/Field Installation Options :**

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

Center of Gravity of Saddles	3985.356 mm.
Center of Gravity of Liquid	3577.988 mm.
Center of Gravity of Nozzles	2048.109 mm.
Center of Gravity of Tubesheet(s)	1081.000 mm.
Center of Gravity of Tubes	3111.000 mm.
Center of Gravity of Bare Shell New and Cold	3392.189 mm.
Center of Gravity of Bare Shell Corroded	3365.749 mm.
Vessel CG in the Operating Condition	3199.273 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	3019.945 mm.
Vessel CG in the Test Condition	3283.736 mm.

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 Horizontal Vessel Analysis (Ope.): Step: 14 11:47am Dec 23,2021

**ASME Horizontal Vessel Analysis: Stresses for the Left Saddle**  
 (per ASME Sec. VIII Div. 2 based on the Zick method.)

Horizontal Vessel Stress Calculations : Operating Case

*Warning - Distance to Saddle (a) > 0.25 \* Tangent Distance (L) - 4.15.3.2*

this part will be  
checked after  
revising relevant  
comments

**Input and Calculated Values:**

Vessel Mean Radius	Rm	611.50	mm.
Stiffened Vessel Length per 4.15.6	L	355.00	mm.
Distance from Saddle to Vessel tangent	a	352.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	332.00	mm.
Wear Plate Bearing Angle	thetal	140.00	degrees
Wear Plate Thickness	tr	12.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm <sup>2</sup>
Shell Allowable Stress used in Calculation		137.90	N./mm <sup>2</sup>
Head Allowable Stress used in Calculation		137.90	N./mm <sup>2</sup>
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		264.30	kN
Horizontal Vessel Analysis Results:	Actual	Allowable	
	N./mm <sup>2</sup>	N./mm <sup>2</sup>	
-----	-----	-----	
Long. Stress at Top of Midspan	43.05	137.90	
Long. Stress at Bottom of Midspan	50.96	137.90	
Long. Stress at Top of Saddles	19.42	137.90	
Long. Stress at Bottom of Saddles	53.70	137.90	
-----	-----	-----	
Tangential Shear in Shell	29.26	110.32	
Circ. Stress at Horn of Saddle	131.68	172.37	
Circ. Compressive Stress in Shell	3.57	137.90	
-----	-----	-----	

**Intermediate Results: Saddle Reaction Q due to Wind or Seismic**

Saddle Reaction Force due to Wind Ft [Fwt]:

$$= F_{tr} * ( F_t / \text{Num of Saddles} + Z \text{ Force Load} ) * B / E$$

$$= 3.0 * ( 10.4/2 + 0 ) * 972.0/1094.6561$$

$$= 13.9 \text{ kN}$$

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

$$= \max( F_l, \text{Friction Load, Sum of X Forces} ) * B / L_s$$

$$= \max( 2.53, 0.0, 0 ) * 972.0/4330.0$$

$$= 0.6 \text{ kN}$$

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:

$$= \max( F_l, \text{Friction Force, Sum of X Forces} ) * B / L_s$$

$$= \max( 69.57, 0.0, 0 ) * 972.0/4330.0$$

$$= 15.6 \text{ kN}$$

Saddle Reaction Force due to Earthquake Ft [Fst]:

$$= F_{tr} * ( F_t / \text{Num of Saddles} + Z \text{ Force Load} ) * B / E$$

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Horizontal Vessel Analysis (Ope.): Step: 14 11:47am Dec 23,2021

$$= 3.0 * ( 70/2 + 0 ) * 972.0/1094.6561$$

$$= 92.7 \text{ kN}$$

Load Combination Results for Q + Wind or Seismic [Q]:

$$= \text{Saddle Load} + \text{Max}( \text{Fwl}, \text{Fwt}, \text{Fsl}, \text{Fst} )$$

$$= 172 + \text{Max}( 0.6, 14, 16, 93 )$$

$$= 264.3 \text{ kN}$$

**Summary of Loads at the base of this Saddle:**

Vertical Load (including saddle weight)		266.39	kN
Transverse Shear Load Saddle	Ft	34.78	kN
Longitudinal Shear Load Saddle		69.57	kN

**Formulas and Substitutions for Horizontal Vessel Analysis:**

Note: Wear Plate is Welded to the Shell,  $k = 0.1$

**The Computed K values from Table 4.15.1:**

K1 = 0.1066	K2 = 1.1707	K3 = 0.8799	K4 = 0.4011
K5 = 0.7603	K6 = 0.0529	K7 = 0.0192	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	K6p = 0.0379
K7p = 0.0138			

The suffix 'p' denotes the values for a wear plate if it exists.

Note: Dimension a is greater than or equal to  $R_m / 2$ .

Moment per Equation 4.15.3 [M1]:

$$= -Q*a [ 1 - ( 1 - a/L + (R^2 - h^2)/(2a*L) ) / ( 1 + (4h^2)/3L ) ]$$

$$= -264*352.0 [ 1 - ( 1 - 352.0/355.0 + (611.5^2 - 0.0^2) / ( 2*352.0*355.0 ) ) / ( 1 + (4*0.0)/(3*355.0) ) ]$$

$$= 46969.6 \text{ N-m}$$

Moment per Equation 4.15.4 [M2]:

$$= Q*L/4 ( 1 + 2(R^2 - h^2)/(L^2) ) / ( 1 + (4h^2)/(3L) ) - 4a/L$$

$$= 264*355/4 ( 1 + 2(611^2 - 0^2)/(355^2) ) / ( 1 + (4*0)/(3*355) ) - 4*352/355$$

$$= 69649.5 \text{ N-m}$$

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:

$$= P * R_m / (2t) - M2 / ( \pi * R_m^2 * t )$$

$$= 23.059 * 611.5 / ( 2 * 15.0 ) - 69649.5 / ( \pi * 611.5^2 * 15.0 )$$

$$= 43.05 \text{ N./mm}^2$$

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

$$= P * R_m / (2t) + M2 / ( \pi * R_m^2 * t )$$

$$= 23.059 * 611.5 / ( 2 * 15.0 ) + 69649.5 / ( \pi * 611.5^2 * 15.0 )$$

$$= 50.96 \text{ N./mm}^2$$

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma\*3]:

$$= P * R_m / (2t) - M1 / ( K1 * \pi * R_m^2 * t )$$

$$= 23.059 * 611.5 / ( 2 * 17.0 ) - 46969.6 / ( 0.1066 * \pi * 611.5^2 * 17.0 )$$

$$= 19.42 \text{ N./mm}^2$$

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma\*4]:

$$= P * R_m / (2t) + M1 / ( K1 * \pi * R_m^2 * t )$$

$$= 23.059 * 611.5 / ( 2 * 17.0 ) + 46969.6 / ( 0.1923 * \pi * 611.5^2 * 17.0 )$$

$$= 53.70 \text{ N./mm}^2$$

Maximum Shear Force in the Saddle (4.15.5) [T]:

$$= Q(L - 2a) / ( L + ( 4 * h^2 / 3 ) )$$

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Horizontal Vessel Analysis (Ope.): Step: 14 11:47am Dec 23,2021

$$= 264(355.0 - 2 * 352.0) / (355.0 + (4 * 0.0/3))$$

$$= -259.8 \text{ kN}$$

Shear Stress in the shell no rings, not stiffened (4.15.14) [ $\tau_{u2}$ ]:

$$= K2 * T / (Rm * t)$$

$$= 1.1707 * -259.84 / (611.5 * 17.0)$$

$$= -29.26 \text{ N./mm}^2$$

Decay Length (4.15.22) [ $x1, x2$ ]:

$$= 0.78 * \sqrt{Rm * t}$$

$$= 0.78 * \sqrt{611.5 * 17.0}$$

$$= 79.527 \text{ mm.}$$

Circumferential Stress in shell, no rings (4.15.23) [ $\sigma_6$ ]:

$$= -K5 * Q * k / (t * (b + X1 + X2))$$

$$= -0.7603 * 264 * 0.1 / (17.0 * (172.0 + 79.53 + 79.53))$$

$$= -3.57 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [ $B1$ ]:

$$= \min(b + 1.56 * \sqrt{Rm * t}, 2a)$$

$$= \min(172.0 + 1.56 * \sqrt{611.5 * 17.0}, 2 * 352.0)$$

$$= 331.05 \text{ mm.}$$

Wear Plate/Shell Stress ratio (4.15.29) [ $\eta$ ]:

$$= \min(Sr/S, 1)$$

$$= \min(137.9/137.9, 1)$$

$$= 1.0000$$

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [ $\sigma_{6,r}$ ]:

$$= -K5 * Q * k / (B1(t + \eta * tr))$$

$$= -0.7603 * 264 * 0.1 / (331.055(17.0 + 1.0 * 12.0))$$

$$= -2.09 \text{ N./mm}^2$$

Circ. Comp. Stress at Horn of Saddle,  $L < 8Rm$  (4.15.28) [ $\sigma_{7,r^*}$ ]:

$$= -Q / (4(t + \eta * tr)b1) - 12 * K7 * Q * Rm / (L(t + \eta * tr)^2)$$

$$= -264 / (4(17.0 + 1.0 * 12.0)331.055) -$$

$$12 * 0.019 * 264 * 611.5 / (355.0(17.0 + 1.0 * 12.0)^2)$$

$$= -131.68 \text{ N./mm}^2$$

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:

$$= \alpha * Ls * (\text{Design Temperature} - \text{Ambient Temperature})$$

$$= 0.000012 * 4330.0 * (125.0 - 21.1)$$

$$= 5.517 \text{ mm.}$$

**Results for Vessel Ribs, Web and Base:**

Baseplate Length	Bplen	1450.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	4	
Rib Thickness	Ribtk	12.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	326.0	mm.
Friction Coefficient	mu	0.000	

Note: In the tables below  $I_o$  is  $I$  for the rectangle + Area \* Centroid Distance<sup>2</sup>

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

B	D	Y	A	AY	$I_o$
---	---	---	---	----	-------

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Shell	489.9	17.0	8.5	83.3	70797.1	0.866E+04
Wearplate	332.0	12.0	23.0	39.8	91632.0	0.304E+04
Web	12.0	324.0	191.0	38.9	742607.5	0.593E+04
BasePlate	220.0	16.0	361.0	35.2	1270719.5	0.221E+05
Totals	...	...	...	197.2	2175756.0	0.398E+05

Distance to Centroid [C1]:

$$= AY / A$$

$$= 856.597/197.211$$

$$= 110.326 \text{ mm.}$$

Angle [beta]:

$$= 180 - \text{Saddle Angle}/2$$

$$= 180 - 120.0/2$$

$$= 120.0$$

Saddle Splitting Coefficient [K1]:

$$= ( 1 + \cos(\beta) - 0.5 \cdot \sin(\beta)^2 ) / (\pi - \beta + \sin(\beta) \cos(\beta) )$$

$$= ( 1 + \cos(120.0) - 0.5 \cdot \sin(120.0)^2 ) / (\pi - 2.094 + \sin(120.0) \cos(120.0) )$$

$$= 0.2035$$

Saddle Splitting Force [Fh]:

$$= K1 \cdot Q$$

$$= 0.204 \cdot 264.302$$

$$= 53.7912 \text{ kN}$$

$$\text{Tension Stress, } St = ( Fh/As ) = 4.7222 \text{ N./mm}^2$$

$$\text{Allowed Stress, } Sa = 0.6 \cdot \text{Yield Str} = 124.1100 \text{ N./mm}^2$$

Saddle Splitting Dimension [d]:

$$= B - R \cdot \sin(\theta) / \theta$$

$$= 972.0 - 603.0 \cdot \sin(1.0472) / 1.0472$$

$$= 473.323 \text{ mm.}$$

$$\text{Bending Moment, } M = Fh \cdot d = 25470.9512 \text{ N-m}$$

$$\text{Bending Stress, } Sb = ( M \cdot C1 / I ) = 7.0660 \text{ N./mm}^2$$

$$\text{Allowed Stress, } Sa = 2/3 \cdot \text{Yield Str} = 137.9000 \text{ N./mm}^2$$

Minimum Thickness of Baseplate per Moss:

$$= ( 3( Q + \text{Saddle\_Wt} ) \text{BasePlateWidth} / ( 4 \cdot \text{BasePlateLength} \cdot \text{AllStress} ) )^{1/2}$$

$$= ( 3(264 + 2)220.0 / ( 4 \cdot 1450.0 \cdot 137.9 ) )^{1/2}$$

$$= 14.827 \text{ mm.}$$

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [ Web Length ]:

$$= 2 \cdot \cos( 90 - \text{Saddle Angle}/2 ) ( \text{Inside Radius} + \text{Shell Thk} + \text{Wear Plate Thk} )$$

$$= 2 \cdot \cos( 90 - 120.0/2 ) ( 600.0 + 20.0 + 12.0 )$$

$$= 1094.656 \text{ mm.}$$

Distance between Ribs [e]:

$$= \text{Web Length} / ( \text{Nr ribs} - 1 )$$

$$= 1094.656 / ( 4 - 1 )$$

$$= 364.885 \text{ mm.}$$

Baseplate Pressure Area [Ap]:

$$= e \cdot \text{Bpwid} / 2$$

$$= 364.8853 \cdot 220.0 / 2$$

$$= 401.374 \text{ cm}^2$$

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Axial Load [P]:  
 =  $A_p * B_p$   
 =  $401.4 * 0.08$   
 = 33.255 kN

Area of the Rib and Web [Ar]:  
 = Rib Area + Web Area  
 =  $19.2 + 21.893$   
 = 41.093 cm<sup>2</sup>

Compressive Stress [Sc]:  
 =  $P/Ar$   
 =  $33.3/41.0931$   
 = 8.093 N./mm<sup>2</sup>

#### Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	12.0	172.0	...	20.6	...	509.

Rib dimension [D]:  
 = Saddle Width - Web Thickness  
 =  $172.0 - 12.0$   
 = 160.000 mm.

Distance to Centroid from Datum [ytot]:  
 =  $AY / A$   
 =  $0.0/41.093$   
 = 0.000 mm.

Distance to Centroid [C1]:  
 = Saddle Width / 2  
 =  $172.0/2$   
 = 86.000 mm.

Radius of Gyration [r]:  
 =  $\sqrt{\text{Total Inertia} / \text{Total Area}}$   
 =  $\sqrt{508.8/41.093}$   
 = 35.189 mm.

Length of Outer Rib [L]:  
 = Saddle Height -  $\cos(\theta/2) * (\text{radius} + \text{shlthk} + \text{wpdthk}) - \text{bpthk}$   
 =  $972.0 - \cos(120.0/2) * (600.0 + 20.0 + 12.0) - 16.0$   
 = 640.000 mm.

Intermediate Term [Cc]:  
 =  $\sqrt{2 * \pi^2 * \text{Elastic Modulus} / \text{Yield Stress}}$   
 =  $\sqrt{2 * \pi^2 * 0.19994E+09/206.9}$   
 = 138.135

Slenderness ratio [KL/r]:  
 =  $KL/r$   
 =  $1 * 640.0/35.189$   
 = 18.187

Bending Moment [Rm]:  
 =  $F_l / (2 * B_{plen}) * e * L / 2$

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$$= 69.6 / ( 2 * 1450.0 ) * 364.885 * 640.0 / 2$$

$$= 2802.062 \text{ N-m}$$

Compressive Allowable,  $KL/r < Cc$  ( 18.1875 < 138.1347 ) per AISC E2-1 [Sca]:

$$= ( 1 - (KL/r)^2 / (2 * Cc^2) ) Fy / ( 5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r)^3 / (8 * Cc^3) )$$

$$= ( 1 - ( 18.19 )^2 / ( 2 * 138.13^2 ) ) 207 / ( 5/3 + 3 * (18.19) / (8 * 138.13) - ( 18.19^3 ) / (8 * 138.13^3) )$$

$$= 119.5 \text{ N./mm}^2$$

**AISC Unity Check of Outside Ribs ( must be <= 1 )**

$$= Sc / Sca + ( Rm * C1 / I ) / Sba$$

$$= 8.09 / 119.51 + ( 2802.06 * 86.0 / 5088449 ) / 137.9$$

$$= 0.411$$

**Check of Inside Ribs:**

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	12.0	160.0	0.0	19.2	0.0	509.
Web	364.9	12.0	0.0	43.8	0.0	5.25
Totals	...	...	...	63.0	...	514.

Distance to Centroid from Datum [ytot]:

$$= AY / A$$

$$= 0.0 / 62.986$$

$$= 0.000 \text{ mm.}$$

Distance to Centroid [C1]:

$$= \text{Saddle Width} / 2$$

$$= 172.0 / 2$$

$$= 86.000 \text{ mm.}$$

Length of Inner Rib [L]:

$$= \text{Saddle Height} - \sqrt{ (Ro + Wpdthk)^2 - (Pitch/2)^2 } - Bpdthk$$

$$= 972.0 - \sqrt{ (632.0 + 12.0)^2 - (364.885/2)^2 } - 16.0$$

$$= 350.906 \text{ mm.}$$

Radius of Gyration [r]:

$$= \sqrt{ \text{Total Inertia} / \text{Total Area} }$$

$$= \sqrt{ 513.9 / 62.986 }$$

$$= 28.565 \text{ mm.}$$

Slenderness ratio [KL/r]:

$$= KL/r$$

$$= 1 * 350.906 / 28.565$$

$$= 12.285$$

Unit Force [Force,u]:

$$= F1 / ( 2 * \text{Baseplate Length} )$$

$$= 69.565 / ( 2 * 1450.0 )$$

$$= 0.024 \text{ kN/mm.}$$

Moment at base of inner Rib [Mbase,c]:

$$= \text{Unit Force} * e * L$$

$$= 0.024 * 364.885 * 350.906$$

$$= 3072.689 \text{ N-m}$$

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:

$$= \text{Bending Moment} / \text{Section Modulus}$$

$$= 3072.689 / 59758.879$$

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$$= 51.402 \text{ N./mm}^2$$

Compressive Allowable,  $KL/r < Cc$  ( 12.2847 < 138.1347 ) per AISC E2-1 [Sca]:

$$= ( 1 - (KL/r)^2 / (2 * Cc^2) ) Fy / ( 5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r)^3 / (8 * Cc^3) )$$

$$= ( 1 - ( 12.28 )^2 / ( 2 * 138.13^2 ) ) 207 / ( 5/3 + 3 * (12.28) / (8 * 138.13) - ( 12.28^3 ) / (8 * 138.13^3) )$$

$$= 121.2 \text{ N./mm}^2$$

#### AISC Unity Check of Inside Ribs ( must be $\leq 1$ )

$$= Sc/Sca + ( Mbase,c * C1/I ) / Sba$$

$$= 10.12/121.2 + ( 3072.69 * 86.0/513.926 ) / 137.9$$

$$= 0.456$$

#### Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm <sup>2</sup>
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	75.0	mm.
Nominal Bolt Diameter	Bnd	22.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	2.7242	cm <sup>2</sup>
Saddle Load QO (Weight)	QO	173.7	kN
Saddle Load QL (Wind/Seismic contribution)	QL	15.6	kN
Maximum Transverse Force	Ft	34.8	kN
Maximum Longitudinal Force	F1	69.6	kN
Saddle Bolted to Steel Foundation		No	

there is discrepancy with drawing

#### Shear Stress in a Single Bolt [taub]:

$$= \text{Shear Force} / ( 2 * \text{Bolt Area} * \text{Number of Bolts} )$$

$$= 70 / ( 2 * 2.72 * 4 )$$

$$= 31.9 \text{ N./mm}^2. \text{ Must be less than } 103.4 \text{ N./mm}^2.$$

#### Bolt Area Calculation per Dennis R. Moss

##### Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

$$= 0.0 \text{ (} QO > QL \text{ --> No Uplift in Longitudinal direction)}$$

##### Bolt Area due to Shear Load [Bltarears]:

$$= F1 / ( Stba * Nbolts )$$

$$= 69.57 / ( 172.38 * 4.0 )$$

$$= 1.0090 \text{ cm}^2$$

##### Bolt Area due to Transverse Load:

##### Moment on Baseplate Due to Transverse Load [Rmom]:

$$= B * Ft + \text{Sum of X Moments}$$

$$= 972.0 * 34.78 + 0.0$$

$$= 33822.50 \text{ N-m}$$

##### Eccentricity (e):

$$= Rmom / QO$$

$$= 33822.5 / 173.73$$

$$= 194.60 \text{ mm.} < Bplen/6 \text{ --> No Uplift in Transverse direction}$$

##### Bolt Area due to Transverse Load [Bltareart]:

$$= 0 \text{ (No Uplift)}$$

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Required Area of a Single Bolt [Bltarear]:  
 = max[Bltarearl, Bltarears, Bltareart]  
 = max[0.0, 1.009, 0.0]  
 = 1.0090 cm<sup>2</sup>

**ASME Horizontal Vessel Analysis: Stresses for the Right Saddle**  
 (per ASME Sec. VIII Div. 2 based on the Zick method.)

*Warning - Distance to Saddle (a) > 0.25 \* Tangent Distance (L) - 4.15.3.2*

**Input and Calculated Values:**

Vessel Mean Radius	Rm	838.50	mm.
Stiffened Vessel Length per 4.15.6	L	355.00	mm.
Distance from Saddle to Vessel tangent	a	466.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	350.00	mm.
Wear Plate Bearing Angle	thetal	140.00	degrees
Wear Plate Thickness	tr	12.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm <sup>2</sup>
Inside Depth of Head	h2	417.00	mm.
Shell Allowable Stress used in Calculation		137.90	N./mm <sup>2</sup>
Head Allowable Stress used in Calculation		137.90	N./mm <sup>2</sup>
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		192.59	kN
Horizontal Vessel Analysis Results:	Actual	Allowable	
	N./mm <sup>2</sup>	N./mm <sup>2</sup>	
-----			
Long. Stress at Top of Midspan	65.21	137.90	
Long. Stress at Bottom of Midspan	63.57	137.90	
Long. Stress at Top of Saddles	77.06	137.90	
Long. Stress at Bottom of Saddles	57.37	137.90	
-----			
Tangential Shear in Shell	11.35	110.32	
Circ. Stress at Horn of Saddle	137.19	172.37	
Circ. Compressive Stress in Shell	2.81	137.90	
-----			

**Intermediate Results: Saddle Reaction Q due to Wind or Seismic**

Saddle Reaction Force due to Wind Ft [Fwt]:  
 = Ftr \* ( Ft/Num of Saddles + Z Force Load ) \* B / E  
 = 3.0 \* ( 10.4/2 + 0 ) \* 1200.0/1486.0997  
 = 12.6 kN

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:  
 = max( Fl, Friction Load, Sum of X Forces ) \* B / Ls  
 = max( 4.71, 33.33, 0 ) \* 1200.0/4330.0  
 = 9.2 kN

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:  
 = max( Fl, Friction Force, Sum of X Forces ) \* B / Ls

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$$= \max(69.57, 33.33, 0) * 1200.0/4330.0$$

$$= 19.3 \text{ kN}$$

Saddle Reaction Force due to Earthquake Ft [Fst]:

$$= F_{tr} * (F_t / \text{Num of Saddles} + Z \text{ Force Load}) * B / E$$

$$= 3.0 * (70/2 + 0) * 1200.0/1486.0997$$

$$= 84.3 \text{ kN}$$

Load Combination Results for Q + Wind or Seismic [Q]:

$$= \text{Saddle Load} + \max(F_{wl}, F_{wt}, F_{sl}, F_{st})$$

$$= 108 + \max(9, 13, 19, 84)$$

$$= 192.6 \text{ kN}$$

#### **Summary of Loads at the base of this Saddle:**

Vertical Load (including saddle weight)	195.36	kN
Transverse Shear Load Saddle	34.78	kN
Longitudinal Shear Load Saddle	69.57	kN

#### **Formulas and Substitutions for Horizontal Vessel Analysis:**

Note: Wear Plate is Welded to the Shell,  $k = 0.1$

The Computed K values from Table 4.15.1:

$K_1 = 0.1066$	$K_2 = 1.1707$	$K_3 = 0.8799$	$K_4 = 0.4011$
$K_5 = 0.7603$	$K_6 = 0.0529$	$K_7 = 0.0176$	$K_8 = 0.3405$
$K_9 = 0.2711$	$K_{10} = 0.0581$	$K_{1p} = 0.1923$	$K_{6p} = 0.0379$
$K_{7p} = 0.0126$			

The suffix 'p' denotes the values for a wear plate if it exists.

Note: Dimension a is greater than or equal to  $R_m / 2$ .

Moment per Equation 4.15.3 [M1]:

$$= -Q * a [1 - (1 - a/L + (R^2 - h^2)/(2a * L)) / (1 + (4h^2)/3L)]$$

$$= -193 * 466.0 [1 - (1 - 466.0/355.0 + (838.5^2 - 417.0^2) / (2 * 466.0 * 355.0)) / (1 + (4 * 417.0) / (3 * 355.0))]$$

$$= -44763.2 \text{ N-m}$$

Moment per Equation 4.15.4 [M2]:

$$= Q * L / 4 (1 + 2(R^2 - h^2)/(L^2)) / (1 + (4h^2)/(3L)) - 4a/L$$

$$= 193 * 355 / 4 (1 + 2(838^2 - 417^2)/(355^2)) / (1 + (4 * 417) / (3 * 355)) - 4 * 466 / 355$$

$$= -27160.3 \text{ N-m}$$

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:

$$= P * R_m / (2t) - M_2 / (\pi * R_m^2 * t)$$

$$= 23.036 * 838.5 / (2 * 15.0) - 27160.3 / (\pi * 838.5^2 * 15.0)$$

$$= 65.21 \text{ N./mm}^2$$

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

$$= P * R_m / (2t) + M_2 / (\pi * R_m^2 * t)$$

$$= 23.036 * 838.5 / (2 * 15.0) + 27160.3 / (\pi * 838.5^2 * 15.0)$$

$$= 63.57 \text{ N./mm}^2$$

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma\*3]:

$$= P * R_m / (2t) - M_1 / (K_1 * \pi * R_m^2 * t)$$

$$= 23.036 * 838.5 / (2 * 15.0) - 44763.2 / (0.1066 * \pi * 838.5^2 * 15.0)$$

$$= 77.06 \text{ N./mm}^2$$

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma\*4]:

$$= P * R_m / (2t) + M_1 / (K_{1p} * \pi * R_m^2 * t)$$

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$$= 23.036 * 838.5 / (2 * 15.0) + -44763.2 / (0.1923 * \pi * 838.5^2 * 15.0)$$

$$= 57.37 \text{ N./mm}^2$$

Maximum Shear Force in the Saddle (4.15.5) [T]:

$$= Q(L-2a) / (L + (4 * h^2 / 3))$$

$$= 193(355.0 - 2 * 466.0) / (355.0 + (4 * 417.0 / 3))$$

$$= -122.0 \text{ kN}$$

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:

$$= K2 * T / (Rm * t)$$

$$= 1.1707 * -121.98 / (838.4999 * 15.0)$$

$$= -11.35 \text{ N./mm}^2$$

Decay Length (4.15.22) [x1,x2]:

$$= 0.78 * \sqrt{Rm * t}$$

$$= 0.78 * \sqrt{838.5 * 15.0}$$

$$= 87.477 \text{ mm.}$$

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:

$$= -K5 * Q * k / (t * (b + X1 + X2))$$

$$= -0.7603 * 193 * 0.1 / (15.0 * (172.0 + 87.48 + 87.48))$$

$$= -2.81 \text{ N./mm}^2$$

Effective reinforcing plate width (4.15.1) [B1]:

$$= \min(b + 1.56 * \sqrt{Rm * t}, 2a)$$

$$= \min(172.0 + 1.56 * \sqrt{838.5 * 15.0}, 2 * 466.0)$$

$$= 346.95 \text{ mm.}$$

Wear Plate/Shell Stress ratio (4.15.29) [eta]:

$$= \min(Sr/S, 1)$$

$$= \min(137.9/137.9, 1)$$

$$= 1.0000$$

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:

$$= -K5 * Q * k / (B1(t + eta * tr))$$

$$= -0.7603 * 193 * 0.1 / (346.953(15.0 + 1.0 * 12.0))$$

$$= -1.56 \text{ N./mm}^2$$

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r\*]:

$$= -Q / (4(t + eta * tr)b1) - 12 * K7 * Q * Rm / (L(t + eta * tr)^2)$$

$$= -193 / (4(15.0 + 1.0 * 12.0)346.953) -$$

$$12 * 0.018 * 193 * 838.5 / (355.0(15.0 + 1.0 * 12.0)^2)$$

$$= -137.19 \text{ N./mm}^2$$

#### Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1450.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	4	
Rib Thickness	Ribtk	12.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	372.0	mm.
Friction Coefficient	mu	0.300	

Note: In the tables below I<sub>o</sub> is I for the rectangle + Area \* Centroid Distance<sup>2</sup>

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

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	B	D	Y	A	AY	Io
Shell	524.2	15.0	7.5	78.6	58969.0	0.841E+04
Wearplate	350.0	12.0	21.0	42.0	88200.0	0.340E+04
Web	12.0	326.0	190.0	39.1	743279.8	0.591E+04
BasePlate	220.0	16.0	361.0	35.2	1270719.8	0.220E+05
Totals	...	...	...	194.9	2161168.5	0.398E+05

## Distance to Centroid [C1]:

$$= AY / A$$

$$= 850.854/194.945$$

$$= 110.860 \text{ mm.}$$

## Angle [beta]:

$$= 180 - \text{Saddle Angle}/2$$

$$= 180 - 120.0/2$$

$$= 120.0$$

## Saddle Splitting Coefficient [K1]:

$$= ( 1 + \cos(\beta) - 0.5 \cdot \sin(\beta)^2 ) / (\pi - \beta + \sin(\beta)\cos(\beta) )$$

$$= ( 1 + \cos(120.0) - 0.5 \cdot \sin(120.0)^2 ) / (\pi - 2.094 + \sin(120.0)\cos(120.0) )$$

$$= 0.2035$$

## Saddle Splitting Force [Fh]:

$$= K1 \cdot Q$$

$$= 0.204 \cdot 192.59$$

$$= 39.1963 \text{ kN}$$

$$\text{Tension Stress, } St = ( Fh/As ) = 3.3700 \text{ N./mm}^2$$

$$\text{Allowed Stress, } Sa = 0.6 \cdot \text{Yield Str} = 124.1100 \text{ N./mm}^2$$

## Saddle Splitting Dimension [d]:

$$= B - R \cdot \sin(\theta) / \theta$$

$$= 1200.0 - 831.0 \cdot \sin(1.0472) / 1.0472$$

$$= 512.768 \text{ mm.}$$

$$\text{Bending Moment, } M = Fh \cdot d = 20106.7695 \text{ N-m}$$

$$\text{Bending Stress, } Sb = ( M \cdot C1 / I ) = 5.6047 \text{ N./mm}^2$$

$$\text{Allowed Stress, } Sa = 2/3 \cdot \text{Yield Str} = 137.9000 \text{ N./mm}^2$$

## Minimum Thickness of Baseplate per Moss:

$$= ( 3( Q + \text{Saddle\_Wt} ) \text{BasePlateWidth} / ( 4 \cdot \text{BasePlateLength} \cdot \text{AllStress} ) )^{1/2}$$

$$= ( 3(193 + 3)220.0 / ( 4 \cdot 1450.0 \cdot 137.9 ) )^{1/2}$$

$$= 12.697 \text{ mm.}$$

## Calculation of Axial Load, Intermediate Values and Compressive Stress:

## Web Length Dimension [Web Length]:

$$= 2 \cdot \cos( 90 - \text{Saddle Angle}/2 ) ( \text{Inside Radius} + \text{Shell Thk} + \text{Wear Plate Thk} )$$

$$= 2 \cdot \cos( 90 - 120.0/2 ) ( 828.0 + 18.0 + 12.0 )$$

$$= 1486.100 \text{ mm.}$$

## Distance between Ribs [e]:

$$= \text{Web Length} / ( \text{Nr ribs} - 1 )$$

$$= 1486.0997 / ( 4 - 1 )$$

$$= 495.367 \text{ mm.}$$

## Baseplate Pressure Area [Ap]:

$$= e \cdot \text{Bpwid} / 2$$

$$= 495.3665 \cdot 220.0/2$$

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$$= 544.903 \text{ cm}^2$$

Axial Load [P]:

$$\begin{aligned} &= A_p * B_p \\ &= 544.9 * 0.06 \\ &= 32.898 \text{ kN} \end{aligned}$$

Area of the Rib and Web [Ar]:

$$\begin{aligned} &= \text{Rib Area} + \text{Web Area} \\ &= 19.2 + 29.722 \\ &= 48.922 \text{ cm}^2 \end{aligned}$$

Compressive Stress [Sc]:

$$\begin{aligned} &= P / A_r \\ &= 32.9 / 48.922 \\ &= 6.725 \text{ N./mm}^2 \end{aligned}$$

### Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	12.0	172.0	...	20.6	...	509.

Rib dimension [D]:

$$\begin{aligned} &= \text{Saddle Width} - \text{Web Thickness} \\ &= 172.0 - 12.0 \\ &= 160.000 \text{ mm.} \end{aligned}$$

Distance to Centroid from Datum [ytot]:

$$\begin{aligned} &= AY / A \\ &= 0.0 / 48.922 \\ &= 0.000 \text{ mm.} \end{aligned}$$

Distance to Centroid [C1]:

$$\begin{aligned} &= \text{Saddle Width} / 2 \\ &= 172.0 / 2 \\ &= 86.000 \text{ mm.} \end{aligned}$$

Radius of Gyration [r]:

$$\begin{aligned} &= \sqrt{\text{Total Inertia} / \text{Total Area}} \\ &= \sqrt{508.8 / 48.922} \\ &= 32.251 \text{ mm.} \end{aligned}$$

Intermediate Term [Cc]:

$$\begin{aligned} &= \sqrt{2 * \pi^2 * \text{Elastic Modulus} / \text{Yield Stress}} \\ &= \sqrt{2 * \pi^2 * 0.19994\text{E}+09 / 206.9} \\ &= 138.135 \end{aligned}$$

Slenderness ratio [KL/r]:

$$\begin{aligned} &= KL / r \\ &= 1 * 353.914 / 32.251 \\ &= 10.974 \end{aligned}$$

Bending Moment [Rm]:

$$\begin{aligned} &= F_1 / (2 * B_{pln}) * e * L / 2 \\ &= 69.6 / (2 * 1450.0) * 495.367 * 353.91 / 2 \\ &= 2103.616 \text{ N-m} \end{aligned}$$

Compressive Allowable,  $KL/r < C_c$  (  $10.9738 < 138.1347$  ) per AISC E2-1 [Sca]:

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$$= ( 1-(K1r)^2/(2*Cc^2))Fy/(5/3+3*(K1r)/(8*Cc)-(K1r^3)/(8*Cc^3))$$

$$= ( 1-( 10.97 )^2/(2 * 138.13^2 ))207/$$

$$( 5/3+3*(10.97)/(8* 138.13)-( 10.97^3)/(8*138.13^3))$$

$$= 121.6 \text{ N./mm}^2$$

#### AISC Unity Check of Outside Ribs ( must be <= 1 )

$$= Sc/Sca + ( Rm * C1 / I )/Sba$$

$$= 6.73/121.55 + ( 2103.62 * 86.0/5088449 )/137.9$$

$$= 0.313$$

#### Check of Inside Ribs:

##### Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	12.0	160.0	0.0	19.2	0.0	509.
Web	495.4	12.0	0.0	59.4	0.0	7.13
Totals	...	...	...	78.6	...	516.

##### Distance to Centroid from Datum [ytot]:

$$= AY / A$$

$$= 0.0/78.644$$

$$= 0.000 \text{ mm.}$$

##### Distance to Centroid [C1]:

$$= \text{Saddle Width} / 2$$

$$= 172.0/2$$

$$= 86.000 \text{ mm.}$$

##### Length of Inner Rib [L]:

$$= \text{Saddle Height} - \sqrt{ (Ro + Wpdthk)^2 - (Pitch/2)^2 } - Bpthk$$

$$= 1200.0 - \sqrt{ (858.0 + 12.0)^2 - (495.367/2)^2 } - 16.0$$

$$= 362.527 \text{ mm.}$$

##### Radius of Gyration [r]:

$$= \sqrt{ \text{Total Inertia} / \text{Total Area} }$$

$$= \sqrt{ 515.8/78.644 }$$

$$= 25.610 \text{ mm.}$$

##### Slenderness ratio [KL/r]:

$$= KL/r$$

$$= 1 * 362.527/25.61$$

$$= 14.156$$

##### Unit Force [Force,u]:

$$= F1 / ( 2 * \text{Baseplate Length} )$$

$$= 69.565/( 2 * 1450.0 )$$

$$= 0.024 \text{ kN/mm.}$$

##### Moment at base of inner Rib [Mbase,c]:

$$= \text{Unit Force} * e * L$$

$$= 0.024 * 495.367 * 362.527$$

$$= 4309.621 \text{ N-m}$$

##### Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:

$$= \text{Bending Moment} / \text{Section Modulus}$$

$$= 4309.621/59977.363$$

$$= 71.831 \text{ N./mm}^2$$

##### Compressive Allowable, KL/r < Cc ( 14.1557 < 138.1347 ) per AISC E2-1 [Sca]:

$$= ( 1-(K1r)^2/(2*Cc^2))Fy/(5/3+3*(K1r)/(8*Cc)-(K1r^3)/(8*Cc^3))$$

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$$= ( 1 - ( 14.16 )^2 / ( 2 * 138.13^2 ) ) 207 /$$

$$( 5/3 + 3 * ( 14.16 ) / ( 8 * 138.13 ) - ( 14.16^3 ) / ( 8 * 138.13^3 ) )$$

$$= 120.7 \text{ N./mm}^2$$

#### AISC Unity Check of Inside Ribs ( must be <= 1 )

$$= Sc/Sca + ( Mbase,c * C1/I ) / Sba$$

$$= 8.09/120.69 + ( 4309.62 * 86.0/515.805 ) / 137.9$$

$$= 0.588$$

#### Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm <sup>2</sup>
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	75.0	mm.
Nominal Bolt Diameter	Bnd	22.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	2.7242	cm <sup>2</sup>
Saddle Load QO (Weight)	QO	111.1	kN
Saddle Load QL (Wind/Seismic contribution)	QL	19.3	kN
Maximum Transverse Force	Ft	34.8	kN
Maximum Longitudinal Force	F1	69.6	kN
Saddle Bolted to Steel Foundation		No	

#### Shear Stress in a Single Bolt [taub]:

$$= \text{Shear Force} / ( 2 * \text{Bolt Area} * \text{Number of Bolts} )$$

$$= 70 / ( 2 * 2.72 * 4 )$$

$$= 31.9 \text{ N./mm}^2. \text{ Must be less than } 103.4 \text{ N./mm}^2.$$

#### Bolt Area Calculation per Dennis R. Moss

##### Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

$$= 0.0 \text{ ( } QO > QL \text{ --> No Uplift in Longitudinal direction)}$$

##### Bolt Area due to Shear Load [Bltarears]:

$$= F1 / ( Stba * Nbolts )$$

$$= 69.57 / ( 172.38 * 4.0 )$$

$$= 1.0090 \text{ cm}^2$$

##### Bolt Area due to Transverse Load:

##### Moment on Baseplate Due to Transverse Load [Rmom]:

$$= B * Ft + \text{Sum of X Moments}$$

$$= 1200.0 * 34.78 + 0.0$$

$$= 41756.17 \text{ N-m}$$

##### Eccentricity (e):

$$= Rmom / QO$$

$$= 41756.17 / 111.1$$

$$= 375.68 \text{ mm.} > Bplen/6 \text{ --> Uplift in Transverse direction}$$

$$f = Bplen / 2 - Edgedis$$

$$= 1450.0/2 - 75.0$$

$$= 650.00 \text{ mm.}$$

##### Modular Ratio Of Steel/Concrete (n1):

$$= ES / EC$$

$$= 203402.5 / 21526.32$$

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$$= 9.45$$

$$\begin{aligned} K1 &= 3 (e - 0.5 * Bplen) \\ &= 3 (375.68 - 0.5*1450.0) \\ &= -1047.95 \text{ mm.} \end{aligned}$$

$$\begin{aligned} K2 &= 6 * n1 * At / Bpwid * (f + e) \\ &= 6 * 9.45 * 5.45/220.0 * (650.0 + 375.68) \\ &= 144011.04 \text{ mm.}^2 \end{aligned}$$

$$\begin{aligned} K3 &= -K2 * (0.5 * Bplen + f) \\ &= -144011.05 * (0.5 * 1450.0 + 650.0) \\ &= -198015174.66 \text{ mm.}^3 \end{aligned}$$

Iteratively Solving for the Effective Bearing Length:

$$\begin{aligned} Y^3 + K1 * Y^2 + K2 * Y + K3 &= 0 \\ Y^3 + -1047.95 * Y^2 + 144011.05 * Y + -0.2E+09 &= 0 \\ Y &= 1083.68 \text{ mm.} \end{aligned}$$

$$\begin{aligned} \text{Num} &= (Bplen / 2 - Y / 3 - e) \\ &= (1450.0/2 - 1083.68/3 - 375.68) \\ &= -11.91 \end{aligned}$$

$$\begin{aligned} \text{Denom} &= (Bplen / 2 - Y / 3 + f) \\ &= (1450.0/2 - 1083.68/3 + 650.0) \\ &= 1013.77 \end{aligned}$$

Total Bolt Tension Force [Tforce]:

$$\begin{aligned} &= - QO * \text{Num} / \text{Denom} \\ &= - 111.1 * -11.91/1013.77 \\ &= 1.31 \text{ kN} \end{aligned}$$

Bolt Area Required due to Transverse Load [Bltareart]:

$$\begin{aligned} &= Tforce / (\text{Stba} * \text{Nbt}) \\ &= 1.31 / (172.38 * 2.0) \\ &= 0.0379 \text{ cm}^2 \end{aligned}$$

Required Area of a Single Bolt [Bltarear]:

$$\begin{aligned} &= \max[\text{Bltarearl}, \text{Bltarears}, \text{Bltareart}] \\ &= \max[0.0, 1.009, 0.0379] \\ &= 1.0090 \text{ cm}^2 \end{aligned}$$

### **Baseplate Thickness Calculation per D. Moss:**

Bearing Pressure (fc)

$$\begin{aligned} &= 2(QO + Tforce) / (Y * Bpwid) \\ &= 2(111.1 + 1.31)/(1083.68 * 220.0) \\ &= 9.43 \text{ bars} \end{aligned}$$

Distance from Baseplate Edge to the Web [ADIST]:

$$\begin{aligned} &= (Bplen - \text{Weblngth}) / 2 \\ &= (1450.0 - 1399.2)/2 \\ &= 25.4000 \text{ mm.} \end{aligned}$$

Overturning Moment due To Bolt Tension [Mt]:

$$\begin{aligned} &= Tforce * \text{Adist} \\ &= 1.31 * 25.4 \\ &= 33.16 \text{ N-m} \end{aligned}$$

Equivalent Bearing Pressure (f1):

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$$\begin{aligned}
 &= f_c * (Y - A_{dist}) / Y \\
 &= 9.43 * (1083.68 - 25.4) / 1083.68 \\
 &= 9.21 \text{ bars}
 \end{aligned}$$

Overturning Moment due to Bearing Pressure [Mc]:

$$\begin{aligned}
 &= (A_{dist}^2 * B_{pwid} / 6) * (f_1 + 2 * f_c) \\
 &= (25.4^2 * 220.0 / 6) * (9.21 + 2 * 9.43) \\
 &= 66.43 \text{ N-m}
 \end{aligned}$$

Baseplate Required Thickness [Treq]:

$$\begin{aligned}
 &= (6 * \max(M_t, M_c) / (B_{pwid} * S_{ba}))^{1/2} \\
 &= (6 * \max(33.16, 66.43) / (220.0 * 162.38))^{1/2} \\
 &= 3.3396 \text{ mm.}
 \end{aligned}$$

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**ASME Horizontal Vessel Analysis: Stresses for the Left Saddle**  
 (per ASME Sec. VIII Div. 2 based on the Zick method.)

Horizontal Vessel Stress Calculations : Test Case

*Warning - Distance to Saddle (a) > 0.25 \* Tangent Distance (L) - 4.15.3.2*

**Input and Calculated Values:**

Vessel Mean Radius	Rm	611.50	mm.
Stiffened Vessel Length per 4.15.6	L	355.00	mm.
Distance from Saddle to Vessel tangent	a	352.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	332.00	mm.
Wear Plate Bearing Angle	thetal	140.00	degrees
Wear Plate Thickness	tr	12.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm <sup>2</sup>
Shell Allowable Stress used in Calculation		235.81	N./mm <sup>2</sup>
Head Allowable Stress used in Calculation		235.81	N./mm <sup>2</sup>
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		189.83	kN
Horizontal Vessel Analysis Results:	Actual	Allowable	
	N./mm <sup>2</sup>	N./mm <sup>2</sup>	
-----			
Long. Stress at Top of Midspan	58.23	235.81	
Long. Stress at Bottom of Midspan	63.91	235.81	
Long. Stress at Top of Saddles	38.05	235.81	
Long. Stress at Bottom of Saddles	62.67	235.81	
-----			
Tangential Shear in Shell	21.02	188.65	
Circ. Stress at Horn of Saddle	94.58	353.71	
Circ. Compressive Stress in Shell	2.56	235.81	
-----			

**Intermediate Results: Saddle Reaction Q due to Wind or Seismic**

Saddle Reaction Force due to Wind Ft [Fwt]:

$$\begin{aligned}
 &= F_{tr} * ( F_t / \text{Num of Saddles} + Z \text{ Force Load} ) * B / E \\
 &= 3.0 * ( 3.4/2 + 0 ) * 972.0/1094.6561 \\
 &= 4.6 \text{ kN}
 \end{aligned}$$

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

$$\begin{aligned}
 &= \max( F_l, \text{Friction Load, Sum of X Forces} ) * B / L_s \\
 &= \max( 0.83, 0.0, 0 ) * 972.0/4330.0 \\
 &= 0.2 \text{ kN}
 \end{aligned}$$

Load Combination Results for Q + Wind or Seismic [Q]:

$$\begin{aligned}
 &= \text{Saddle Load} + \max( F_{wl}, F_{wt}, F_{sl}, F_{st} ) \\
 &= 185 + \max( 0.2, 5, 0, 0 ) \\
 &= 189.8 \text{ kN}
 \end{aligned}$$

**Summary of Loads at the base of this Saddle:**

Vertical Load (including saddle weight) 191.92 kN

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Transverse Shear Load Saddle Ft 1.72 kN  
 Longitudinal Shear Load Saddle 0.83 kN

Hydrostatic Test Pressure at center of Vessel: 29.960 bars

### **Formulas and Substitutions for Horizontal Vessel Analysis:**

Note: Wear Plate is Welded to the Shell,  $k = 0.1$

#### **The Computed K values from Table 4.15.1:**

K1 = 0.1066      K2 = 1.1707      K3 = 0.8799      K4 = 0.4011  
 K5 = 0.7603      K6 = 0.0529      K7 = 0.0192      K8 = 0.3405  
 K9 = 0.2711      K10 = 0.0581      K1\* = 0.1923      K6p = 0.0379  
 K7p = 0.0138

The suffix 'p' denotes the values for a wear plate if it exists.

Note: Dimension a is greater than or equal to  $R_m / 2$ .

#### Moment per Equation 4.15.3 [M1]:

$$\begin{aligned}
 &= -Q \cdot a \left[ 1 - \left( 1 - \frac{a}{L} + \frac{(R^2 - h^2)}{(2a \cdot L)} \right) / \left( 1 + \frac{(4h^2)}{3L} \right) \right] \\
 &= -190 \cdot 352.0 \left[ 1 - \left( 1 - \frac{352.0}{355.0} + \frac{(611.5^2 - 0.0^2)}{(2 \cdot 352.0 \cdot 355.0)} \right) / \left( 1 + \frac{(4 \cdot 0.0^2)}{3 \cdot 355.0} \right) \right] \\
 &= 33735.3 \text{ N-m}
 \end{aligned}$$

#### Moment per Equation 4.15.4 [M2]:

$$\begin{aligned}
 &= \frac{Q \cdot L}{4} \left( 1 + 2 \frac{(R^2 - h^2)}{(L^2)} \right) / \left( 1 + \frac{(4h^2)}{3L} \right) - 4 \frac{a}{L} \\
 &= \frac{190 \cdot 355}{4} \left( 1 + 2 \frac{(611^2 - 0^2)}{(355^2)} \right) / \left( 1 + \frac{(4 \cdot 0)}{3 \cdot 355} \right) - 4 \cdot \frac{352}{355} \\
 &= 50024.8 \text{ N-m}
 \end{aligned}$$

#### Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 29.96 \cdot 611.5 / (2 \cdot 15.0) - 50024.8 / (\pi \cdot 611.5^2 \cdot 15.0) \\
 &= 58.23 \text{ N./mm}^2
 \end{aligned}$$

#### Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M2 / (\pi \cdot R_m^2 \cdot t) \\
 &= 29.96 \cdot 611.5 / (2 \cdot 15.0) + 50024.8 / (\pi \cdot 611.5^2 \cdot 15.0) \\
 &= 63.91 \text{ N./mm}^2
 \end{aligned}$$

#### Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma\*3]:

$$\begin{aligned}
 &= P \cdot R_m / (2t) - M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 29.96 \cdot 611.5 / (2 \cdot 17.0) - 33735.3 / (0.1066 \cdot \pi \cdot 611.5^2 \cdot 17.0) \\
 &= 38.05 \text{ N./mm}^2
 \end{aligned}$$

#### Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma\*4]:

$$\begin{aligned}
 &= P \cdot R_m / (2t) + M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t) \\
 &= 29.96 \cdot 611.5 / (2 \cdot 17.0) + 33735.3 / (0.1923 \cdot \pi \cdot 611.5^2 \cdot 17.0) \\
 &= 62.67 \text{ N./mm}^2
 \end{aligned}$$

#### Maximum Shear Force in the Saddle (4.15.5) [T]:

$$\begin{aligned}
 &= \frac{Q(L - 2a)}{(L + (4 \cdot h^2 / 3))} \\
 &= \frac{190(355.0 - 2 \cdot 352.0)}{(355.0 + (4 \cdot 0.0 / 3))} \\
 &= -186.6 \text{ kN}
 \end{aligned}$$

#### Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:

$$\begin{aligned}
 &= K2 \cdot T / (R_m \cdot t) \\
 &= 1.1707 \cdot -186.62 / (611.5 \cdot 17.0) \\
 &= -21.02 \text{ N./mm}^2
 \end{aligned}$$

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Decay Length (4.15.22) [x1,x2]:  
 $= 0.78 * \text{sqrt}( Rm * t )$   
 $= 0.78 * \text{sqrt}( 611.5 * 17.0 )$   
 $= 79.527 \text{ mm.}$

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:  
 $= -K5 * Q * k / ( t * ( b + X1 + X2 ) )$   
 $= - 0.7603 * 190 * 0.1 / ( 17.0 * ( 172.0 + 79.53 + 79.53 ) )$   
 $= -2.56 \text{ N./mm}^2$

Effective reinforcing plate width (4.15.1) [B1]:  
 $= \text{min}( b + 1.56 * \text{sqrt}( Rm * t ), 2a )$   
 $= \text{min}( 172.0 + 1.56 * \text{sqrt}( 611.5 * 17.0 ), 2 * 352.0 )$   
 $= 331.05 \text{ mm.}$

Wear Plate/Shell Stress ratio (4.15.29) [eta]:  
 $= 1.0000$  Materials are the same, test case

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:  
 $= -K5 * Q * k / ( B1( t + eta * tr ) )$   
 $= - 0.7603 * 190 * 0.1 / ( 331.055( 17.0 + 1.0 * 12.0 ) )$   
 $= -1.50 \text{ N./mm}^2$

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r\*]:  
 $= -Q / ( 4( t + eta * tr ) b1 ) - 12 * k7 * Q * Rm / ( L( t + eta * tr )^2 )$   
 $= -190 / ( 4( 17.0 + 1.0 * 12.0 ) 331.055 ) -$   
 $12 * 0.019 * 190 * 611.5 / ( 355.0( 17.0 + 1.0 * 12.0 )^2 )$   
 $= -94.58 \text{ N./mm}^2$

#### Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1450.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	4	
Rib Thickness	Ribtck	12.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	206.9	N. /
Height of Web at Center	Hw,c	326.0	mm.
Friction Coefficient	mu	0.000	

Note: In the tables below I<sub>o</sub> is I for the rectangle + Area \* Centroid Distance<sup>2</sup>

#### Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	I <sub>o</sub>
Shell	489.9	17.0	8.5	83.3	70797.1	0.866E+04
Wearplate	332.0	12.0	23.0	39.8	91632.0	0.304E+04
Web	12.0	324.0	191.0	38.9	742607.5	0.593E+04
BasePlate	220.0	16.0	361.0	35.2	1270719.5	0.221E+05
Totals	...	...	...	197.2	2175756.0	0.398E+05

Distance to Centroid [C1]:  
 $= AY / A$   
 $= 856.597 / 197.211$   
 $= 110.326 \text{ mm.}$

Angle [beta]:  
 $= 180 - \text{Saddle Angle} / 2$   
 $= 180 - 120.0 / 2$

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$$= 120.0$$

Saddle Splitting Coefficient [K1]:

$$= ( 1 + \cos(\beta) - 0.5 \cdot \sin(\beta)^2 ) / (\pi - \beta + \sin(\beta) \cos(\beta) )$$

$$= ( 1 + \cos(120.0) - 0.5 \cdot \sin(120.0)^2 ) / (\pi - 2.094 + \sin(120.0) \cos(120.0) )$$

$$= 0.2035$$

Saddle Splitting Force [Fh]:

$$= K1 \cdot Q$$

$$= 0.204 \cdot 189.831$$

$$= 38.6348 \text{ kN}$$

$$\text{Tension Stress, } St = ( Fh / As ) = 3.3917 \text{ N./mm}^2$$

$$\text{Allowed Stress, } Sa = 0.6 \cdot \text{Yield Str} = 124.1100 \text{ N./mm}^2$$

Saddle Splitting Dimension [d]:

$$= B - R \cdot \sin(\theta) / \theta$$

$$= 972.0 - 603.0 \cdot \sin(1.0472) / 1.0472$$

$$= 473.323 \text{ mm.}$$

$$\text{Bending Moment, } M = Fh \cdot d = 18294.1660 \text{ N-m}$$

$$\text{Bending Stress, } Sb = ( M \cdot C1 / I ) = 5.0751 \text{ N./mm}^2$$

$$\text{Allowed Stress, } Sa = 2/3 \cdot \text{Yield Str} = 137.9000 \text{ N./mm}^2$$

**Minimum Thickness of Baseplate per Moss:**

$$= ( 3( Q + \text{Saddle\_Wt} ) \text{BasePlateWidth} / ( 4 \cdot \text{BasePlateLength} \cdot \text{AllStress} ) )^{1/2}$$

$$= ( 3(190 + 2)220.0 / ( 4 \cdot 1450.0 \cdot 137.9 ) )^{1/2}$$

$$= 12.585 \text{ mm.}$$

**Calculation of Axial Load, Intermediate Values and Compressive Stress:**

Web Length Dimension [ Web Length ]:

$$= 2 \cdot \cos( 90 - \text{Saddle Angle}/2 ) ( \text{Inside Radius} + \text{Shell Thk} + \text{Wear Plate Thk} )$$

$$= 2 \cdot \cos( 90 - 120.0/2 ) ( 600.0 + 20.0 + 12.0 )$$

$$= 1094.656 \text{ mm.}$$

Distance between Ribs [e]:

$$= \text{Web Length} / ( \text{Nr ribs} - 1 )$$

$$= 1094.656 / ( 4 - 1 )$$

$$= 364.885 \text{ mm.}$$

Baseplate Pressure Area [Ap]:

$$= e \cdot \text{Bpwid} / 2$$

$$= 364.8853 \cdot 220.0 / 2$$

$$= 401.374 \text{ cm}^2$$

Axial Load [P]:

$$= Ap \cdot Bp$$

$$= 401.4 \cdot 0.06$$

$$= 23.885 \text{ kN}$$

Area of the Rib and Web [Ar]:

$$= \text{Rib Area} + \text{Web Area}$$

$$= 19.2 + 21.893$$

$$= 41.093 \text{ cm}^2$$

Compressive Stress [Sc]:

$$= P / Ar$$

$$= 23.9 / 41.0931$$

$$= 5.813 \text{ N./mm}^2$$

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### Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	12.0	172.0	...	20.6	...	509.

Rib dimension [D]:

$$\begin{aligned}
 &= \text{Saddle Width} - \text{Web Thickness} \\
 &= 172.0 - 12.0 \\
 &= 160.000 \text{ mm.}
 \end{aligned}$$

Distance to Centroid from Datum [ytot]:

$$\begin{aligned}
 &= AY / A \\
 &= 0.0/41.093 \\
 &= 0.000 \text{ mm.}
 \end{aligned}$$

Distance to Centroid [C1]:

$$\begin{aligned}
 &= \text{Saddle Width} / 2 \\
 &= 172.0/2 \\
 &= 86.000 \text{ mm.}
 \end{aligned}$$

Radius of Gyration [r]:

$$\begin{aligned}
 &= \sqrt{\text{Total Inertia} / \text{Total Area}} \\
 &= \sqrt{508.8/41.093} \\
 &= 35.189 \text{ mm.}
 \end{aligned}$$

Length of Outer Rib [L]:

$$\begin{aligned}
 &= \text{Saddle Height} - \cos(\text{theta}/2) (\text{radius} + \text{shlthk} + \text{wpdthk}) - \text{bpthk} \\
 &= 972.0 - \cos(120.0/2) (600.0 + 20.0 + 12.0) - 16.0 \\
 &= 640.000 \text{ mm.}
 \end{aligned}$$

Intermediate Term [Cc]:

$$\begin{aligned}
 &= \sqrt{2 * \pi^2 * \text{Elastic Modulus} / \text{Yield Stress}} \\
 &= \sqrt{2 * \pi^2 * 0.19994\text{E}+09/206.9} \\
 &= 138.135
 \end{aligned}$$

Slenderness ratio [KL/r]:

$$\begin{aligned}
 &= KL/r \\
 &= 1 * 640.0/35.189 \\
 &= 18.187
 \end{aligned}$$

Bending Moment [Rm]:

$$\begin{aligned}
 &= F1 / (2 * \text{Bplen}) * e * L / 2 \\
 &= 0.8 / (2 * 1450.0) * 364.885 * 640.0/2 \\
 &= 33.613 \text{ N-m}
 \end{aligned}$$

Compressive Allowable,  $KL/r < Cc$  (  $18.1875 < 138.1347$  ) per AISC E2-1 [Sca]:

$$\begin{aligned}
 &= (1 - (KL/r)^2 / (2 * Cc^2)) Fy / (5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r)^3 / (8 * Cc^3)) \\
 &= (1 - (18.19)^2 / (2 * 138.13^2)) 207 / \\
 &\quad (5/3 + 3 * (18.19) / (8 * 138.13) - (18.19^3) / (8 * 138.13^3)) \\
 &= 119.5 \text{ N./mm}^2
 \end{aligned}$$

AISC Unity Check of Outside Ribs ( must be  $\leq 1$  )

$$\begin{aligned}
 &= Sc/Sca + (Rm * C1 / I) / Sba \\
 &= 5.81/119.51 + (33.61 * 86.0/5088449) / 137.9 \\
 &= 0.053
 \end{aligned}$$

Check of Inside Ribs:

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Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	12.0	160.0	0.0	19.2	0.0	509.
Web	364.9	12.0	0.0	43.8	0.0	5.25
Totals	...	...	...	63.0	...	514.

Distance to Centroid from Datum [ytot]:

$$= AY / A$$

$$= 0.0/62.986$$

$$= 0.000 \text{ mm.}$$

Distance to Centroid [C1]:

$$= \text{Saddle Width} / 2$$

$$= 172.0/2$$

$$= 86.000 \text{ mm.}$$

Length of Inner Rib [L]:

$$= \text{Saddle Height} - \sqrt{(\text{Ro} + \text{Wpdthk})^2 - (\text{Pitch}/2)^2} - \text{Bpthk}$$

$$= 972.0 - \sqrt{(632.0 + 12.0)^2 - (364.885/2)^2} - 16.0$$

$$= 350.906 \text{ mm.}$$

Radius of Gyration [r]:

$$= \sqrt{\text{Total Inertia} / \text{Total Area}}$$

$$= \sqrt{513.9/62.986}$$

$$= 28.565 \text{ mm.}$$

Slenderness ratio [KL/r]:

$$= KL/r$$

$$= 1 * 350.906/28.565$$

$$= 12.285$$

Unit Force [Force,u]:

$$= F1 / (2 * \text{Baseplate Length})$$

$$= 0.834 / (2 * 1450.0)$$

$$= 0.000 \text{ kN/mm.}$$

Moment at base of inner Rib [Mbase,c]:

$$= \text{Unit Force} * e * L$$

$$= 0. * 364.885 * 350.906$$

$$= 36.859 \text{ N-m}$$

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:

$$= \text{Bending Moment} / \text{Section Modulus}$$

$$= 36.859/59758.879$$

$$= 0.617 \text{ N./mm}^2$$

Compressive Allowable,  $KL/r < Cc$  ( 12.2847 < 138.1347 ) per AISC E2-1 [Sca]:

$$= (1 - (KL/r)^2 / (2 * Cc^2)) Fy / (5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r)^3 / (8 * Cc^3))$$

$$= (1 - (12.28)^2 / (2 * 138.13^2)) 207 /$$

$$(5/3 + 3 * (12.28) / (8 * 138.13) - (12.28^3) / (8 * 138.13^3))$$

$$= 121.2 \text{ N./mm}^2$$

AISC Unity Check of Inside Ribs ( must be  $\leq 1$  )

$$= Sc/Sca + (Mbase,c * C1/I) / Sba$$

$$= 7.27/121.2 + (36.86 * 86.0/513.926) / 137.9$$

$$= 0.064$$

**Input Data for Base Plate Bolting Calculations:**

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Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm <sup>2</sup>
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	75.0	mm.
Nominal Bolt Diameter	Bnd	22.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	2.7242	cm <sup>2</sup>
Saddle Load QO (Weight)	QO	187.3	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.2	kN
Maximum Transverse Force	Ft	1.7	kN
Maximum Longitudinal Force	F1	1.6	kN
Saddle Bolted to Steel Foundation		No	

#### Shear Stress in a Single Bolt [taub]:

= Shear Force / ( 2 \* Bolt Area \* Number of Bolts )  
 = 2 / ( 2 \* 2.72 \* 4 )  
 = 0.8 N./mm<sup>2</sup>. Must be less than 103.4 N./mm<sup>2</sup>.

#### **Bolt Area Calculation per Dennis R. Moss**

#### Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

= 0.0 (QO > QL --> No Uplift in Longitudinal direction)

#### Bolt Area due to Shear Load [Bltarears]:

= F1 / (Stba \* Nbolts)  
 = 1.55 / (172.38 \* 4.0)  
 = 0.0225 cm<sup>2</sup>

#### **Bolt Area due to Transverse Load:**

#### Moment on Baseplate Due to Transverse Load [Rmom]:

= B \* Ft + Sum of X Moments  
 = 972.0 \* 1.72 + 0.0  
 = 1669.90 N-m

#### Eccentricity (e):

= Rmom / QO  
 = 1669.9 / 187.34  
 = 8.91 mm. < Bplen/6 --> No Uplift in Transverse direction

#### Bolt Area due to Transverse Load [Bltareart]:

= 0 (No Uplift)

#### Required Area of a Single Bolt [Bltarear]:

= max[Bltarearl, Bltarears, Bltareart]  
 = max[0.0, 0.0225, 0.0]  
 = 0.0225 cm<sup>2</sup>

#### **ASME Horizontal Vessel Analysis: Stresses for the Right Saddle**

(per ASME Sec. VIII Div. 2 based on the Zick method.)

*Warning - Distance to Saddle (a) > 0.25 \* Tangent Distance (L) - 4.15.3.2*

#### **Input and Calculated Values:**

Vessel Mean Radius	Rm	838.50	mm.
Stiffened Vessel Length per 4.15.6	L	355.00	mm.

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Distance from Saddle to Vessel tangent	a	466.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	350.00	mm.
Wear Plate Bearing Angle	thetal	140.00	degrees
Wear Plate Thickness	tr	12.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm <sup>2</sup>
Inside Depth of Head	h2	417.00	mm.
Shell Allowable Stress used in Calculation		235.81	N./mm <sup>2</sup>
Head Allowable Stress used in Calculation		235.81	N./mm <sup>2</sup>
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		131.28	kN

Horizontal Vessel Analysis Results:	Actual N./mm <sup>2</sup>	Allowable N./mm <sup>2</sup>
-----		
Long. Stress at Top of Midspan	84.36	235.81
Long. Stress at Bottom of Midspan	83.25	235.81
Long. Stress at Top of Saddles	92.44	235.81
Long. Stress at Bottom of Saddles	79.02	235.81
-----		
Tangential Shear in Shell	7.74	188.65
Circ. Stress at Horn of Saddle	93.51	353.71
Circ. Compressive Stress in Shell	1.92	235.81
-----		

**Intermediate Results: Saddle Reaction Q due to Wind or Seismic**

Saddle Reaction Force due to Wind Ft [Fwt]:

$$= F_{tr} * ( F_t / \text{Num of Saddles} + Z \text{ Force Load} ) * B / E$$

$$= 3.0 * ( 3.4/2 + 0 ) * 1200.0/1486.0997$$

$$= 4.2 \text{ kN}$$

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

$$= \max( F_l, \text{Friction Load, Sum of X Forces} ) * B / L_s$$

$$= \max( 1.55, 0.0, 0 ) * 1200.0/4330.0$$

$$= 0.4 \text{ kN}$$

Load Combination Results for Q + Wind or Seismic [Q]:

$$= \text{Saddle Load} + \max( F_{wl}, F_{wt}, F_{sl}, F_{st} )$$

$$= 127 + \max( 0.4, 4, 0, 0 )$$

$$= 131.3 \text{ kN}$$

**Summary of Loads at the base of this Saddle:**

Vertical Load (including saddle weight)		134.05	kN
Transverse Shear Load Saddle	Ft	1.72	kN
Longitudinal Shear Load Saddle		1.55	kN

Hydrostatic Test Pressure at center of Vessel: 29.982 bars

**Formulas and Substitutions for Horizontal Vessel Analysis:**

Note: Wear Plate is Welded to the Shell, k = 0.1

The Computed K values from Table 4.15.1:

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K1 = 0.1066      K2 = 1.1707      K3 = 0.8799      K4 = 0.4011  
 K5 = 0.7603      K6 = 0.0529      K7 = 0.0176      K8 = 0.3405  
 K9 = 0.2711      K10 = 0.0581      K1\* = 0.1923      K6p = 0.0379  
 K7p = 0.0126

The suffix 'p' denotes the values for a wear plate if it exists.

Note: Dimension a is greater than or equal to  $R_m / 2$ .

Moment per Equation 4.15.3 [M1]:

$$= -Q \cdot a \left[ 1 - \left( 1 - \frac{a}{L} + \frac{(R^2 - h^2)}{(2a \cdot L)} \right) / \left( 1 + \frac{(4h^2)}{(3L)} \right) \right]$$

$$= -131 \cdot 466.0 \left[ 1 - \left( 1 - \frac{466.0}{355.0} + \frac{(838.5^2 - 417.0^2)}{(2 \cdot 466.0 \cdot 355.0)} \right) / \left( 1 + \frac{(4 \cdot 417.0^2)}{(3 \cdot 355.0)} \right) \right]$$

$$= -30512.2 \text{ N-m}$$

Moment per Equation 4.15.4 [M2]:

$$= \frac{Q \cdot L}{4} \left( 1 + 2 \frac{(R^2 - h^2)}{(L^2)} \right) / \left( 1 + \frac{(4h^2)}{(3L)} \right) - 4a/L$$

$$= \frac{131 \cdot 355}{4} \left( 1 + 2 \frac{(838.5^2 - 417.0^2)}{(355.0^2)} \right) / \left( 1 + \frac{(4 \cdot 417.0^2)}{(3 \cdot 355.0)} \right) - 4 \cdot 466 / 355$$

$$= -18513.5 \text{ N-m}$$

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:

$$= P \cdot R_m / (2t) - M2 / (\pi \cdot R_m^2 \cdot t)$$

$$= 29.982 \cdot 838.5 / (2 \cdot 15.0) - -18513.5 / (\pi \cdot 838.5^2 \cdot 15.0)$$

$$= 84.36 \text{ N./mm}^2$$

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

$$= P \cdot R_m / (2t) + M2 / (\pi \cdot R_m^2 \cdot t)$$

$$= 29.982 \cdot 838.5 / (2 \cdot 15.0) + -18513.5 / (\pi \cdot 838.5^2 \cdot 15.0)$$

$$= 83.25 \text{ N./mm}^2$$

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma\*3]:

$$= P \cdot R_m / (2t) - M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t)$$

$$= 29.982 \cdot 838.5 / (2 \cdot 15.0) - -30512.2 / (0.1066 \cdot \pi \cdot 838.5^2 \cdot 15.0)$$

$$= 92.44 \text{ N./mm}^2$$

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma\*4]:

$$= P \cdot R_m / (2t) + M1 / (K1 \cdot \pi \cdot R_m^2 \cdot t)$$

$$= 29.982 \cdot 838.5 / (2 \cdot 15.0) + -30512.2 / (0.1923 \cdot \pi \cdot 838.5^2 \cdot 15.0)$$

$$= 79.02 \text{ N./mm}^2$$

Maximum Shear Force in the Saddle (4.15.5) [T]:

$$= \frac{Q(L - 2a)}{(L + (4h^2/3))}$$

$$= \frac{131(355.0 - 2 \cdot 466.0)}{(355.0 + (4 \cdot 417.0/3))}$$

$$= -83.1 \text{ kN}$$

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:

$$= K2 \cdot T / (R_m \cdot t)$$

$$= 1.1707 \cdot -83.15 / (838.4999 \cdot 15.0)$$

$$= -7.74 \text{ N./mm}^2$$

Decay Length (4.15.22) [x1,x2]:

$$= 0.78 \cdot \sqrt{R_m \cdot t}$$

$$= 0.78 \cdot \sqrt{838.5 \cdot 15.0}$$

$$= 87.477 \text{ mm.}$$

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:

$$= -K5 \cdot Q \cdot k / (t \cdot (b + X1 + X2))$$

$$= -0.7603 \cdot 131 \cdot 0.1 / (15.0 \cdot (172.0 + 87.48 + 87.48))$$

$$= -1.92 \text{ N./mm}^2$$

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Effective reinforcing plate width (4.15.1) [B1]:  
 $= \min( b + 1.56 * \text{sqrt}( R_m * t ), 2a )$   
 $= \min( 172.0 + 1.56 * \text{sqrt}( 838.5 * 15.0 ), 2 * 466.0 )$   
 $= 346.95 \text{ mm.}$

Wear Plate/Shell Stress ratio (4.15.29) [eta]:  
 $= 1.0000$  Materials are the same, test case

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:  
 $= -K5 * Q * k / ( B1( t + \text{eta} * \text{tr} ) )$   
 $= - 0.7603 * 131 * 0.1 / ( 346.953( 15.0 + 1.0 * 12.0 ) )$   
 $= -1.07 \text{ N./mm}^2$

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r\*]:  
 $= -Q / ( 4( t + \text{eta} * \text{tr} ) b1 ) - 12 * K7 * Q * R_m / ( L( t + \text{eta} * \text{tr} )^2 )$   
 $= -131 / ( 4( 15.0 + 1.0 * 12.0 ) 346.953 ) -$   
 $12 * 0.018 * 131 * 838.5 / ( 355.0( 15.0 + 1.0 * 12.0 )^2 )$   
 $= -93.51 \text{ N./mm}^2$

#### Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1450.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs ( inc. outside ribs )	Nribs	4	
Rib Thickness	Ribtk	12.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	372.0	mm.
Friction Coefficient	mu	0.300	

Note: In the tables below I<sub>o</sub> is I for the rectangle + Area \* Centroid Distance<sup>2</sup>

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	I <sub>o</sub>
Shell	524.2	15.0	7.5	78.6	58969.0	0.841E+04
Wearplate	350.0	12.0	21.0	42.0	88200.0	0.340E+04
Web	12.0	326.0	190.0	39.1	743279.8	0.591E+04
BasePlate	220.0	16.0	361.0	35.2	1270719.8	0.220E+05
Totals	...	...	...	194.9	2161168.5	0.398E+05

Distance to Centroid [C1]:

$= AY / A$   
 $= 850.854 / 194.945$   
 $= 110.860 \text{ mm.}$

Angle [beta]:

$= 180 - \text{Saddle Angle} / 2$   
 $= 180 - 120.0 / 2$   
 $= 120.0$

Saddle Splitting Coefficient [K1]:

$= ( 1 + \cos(\text{beta}) - 0.5 * \sin(\text{beta})^2 ) / ( \pi - \text{beta} + \sin(\text{beta}) \cos(\text{beta}) )$   
 $= ( 1 + \cos(120.0) - 0.5 * \sin(120.0)^2 ) / ( \pi - 2.094 + \sin(120.0) \cos(120.0) )$   
 $= 0.2035$

Saddle Splitting Force [Fh]:

$= K1 * Q$

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$$= 0.204 * 131.276$$

$$= 26.7176 \text{ kN}$$

$$\text{Tension Stress, } St = ( Fh/As ) = 2.2971 \text{ N./mm}^2$$

$$\text{Allowed Stress, } Sa = 0.6 * \text{Yield Str} = 124.1100 \text{ N./mm}^2$$

Saddle Splitting Dimension [d]:

$$= B - R * \sin(\text{theta}) / \text{theta}$$

$$= 1200.0 - 831.0 * \sin(1.0472) / 1.0472$$

$$= 512.768 \text{ mm.}$$

$$\text{Bending Moment, } M = Fh * d = 13705.4990 \text{ N-m}$$

$$\text{Bending Stress, } Sb = ( M * C1 / I ) = 3.8204 \text{ N./mm}^2$$

$$\text{Allowed Stress, } Sa = 2/3 * \text{Yield Str} = 137.9000 \text{ N./mm}^2$$

**Minimum Thickness of Baseplate per Moss:**

$$= ( 3( Q + \text{Saddle\_Wt} ) \text{BasePlateWidth} / ( 4 * \text{BasePlateLength} * \text{AllStress} ) )^{1/2}$$

$$= ( 3(131 + 3)220.0 / ( 4 * 1450.0 * 137.9 ) )^{1/2}$$

$$= 10.518 \text{ mm.}$$

**Calculation of Axial Load, Intermediate Values and Compressive Stress:**

Web Length Dimension [ Web Length ]:

$$= 2 * \cos( 90 - \text{Saddle Angle}/2 ) ( \text{Inside Radius} + \text{Shell Thk} + \text{Wear Plate Thk} )$$

$$= 2 * \cos( 90 - 120.0/2 ) ( 828.0 + 18.0 + 12.0 )$$

$$= 1486.100 \text{ mm.}$$

Distance between Ribs [e]:

$$= \text{Web Length} / ( \text{Nr ribs} - 1 )$$

$$= 1486.0997 / ( 4 - 1 )$$

$$= 495.367 \text{ mm.}$$

Baseplate Pressure Area [Ap]:

$$= e * \text{Bpwid} / 2$$

$$= 495.3665 * 220.0 / 2$$

$$= 544.903 \text{ cm}^2$$

Axial Load [P]:

$$= Ap * Bp$$

$$= 544.9 * 0.04$$

$$= 22.424 \text{ kN}$$

Area of the Rib and Web [Ar]:

$$= \text{Rib Area} + \text{Web Area}$$

$$= 19.2 + 29.722$$

$$= 48.922 \text{ cm}^2$$

Compressive Stress [Sc]:

$$= P / Ar$$

$$= 22.4 / 48.922$$

$$= 4.584 \text{ N./mm}^2$$

**Check of Outside Ribs:**

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	12.0	172.0	...	20.6	...	509.

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**Rib dimension [D]:**

= Saddle Width - Web Thickness  
 = 172.0 - 12.0  
 = 160.000 mm.

**Distance to Centroid from Datum [ytot]:**

= AY / A  
 = 0.0/48.922  
 = 0.000 mm.

**Distance to Centroid [C1]:**

= Saddle Width / 2  
 = 172.0/2  
 = 86.000 mm.

**Radius of Gyration [r]:**

= sqrt( Total Inertia / Total Area )  
 = sqrt( 508.8/48.922 )  
 = 32.251 mm.

**Intermediate Term [Cc]:**

= sqrt( 2 \* pi<sup>2</sup> \* Elastic Modulus / Yield Stress )  
 = sqrt( 2 \* pi<sup>2</sup> \* 0.19994E+09/206.9 )  
 = 138.135

**Slenderness ratio [KL/r]:**

= KL/r  
 = 1 \* 353.914/32.251  
 = 10.974

**Bending Moment [Rm]:**

= F1 / ( 2 \* Bplen ) \* e \* L / 2  
 = 1.6 / ( 2 \* 1450.0 ) \* 495.367 \* 353.91/2  
 = 46.984 N-m

**Compressive Allowable, KL/r < Cc ( 10.9738 < 138.1347 ) per AISC E2-1 [Sca]:**

= ( 1 - (KL/r)<sup>2</sup> / (2 \* Cc<sup>2</sup>) ) Fy / ( 5/3 + 3 \* (KL/r) / (8 \* Cc) - (KL/r)<sup>3</sup> / (8 \* Cc<sup>3</sup>) )  
 = ( 1 - ( 10.97 )<sup>2</sup> / (2 \* 138.13<sup>2</sup>) ) 207 /  
 ( 5/3 + 3 \* (10.97) / (8 \* 138.13) - ( 10.97<sup>3</sup> ) / (8 \* 138.13<sup>3</sup>) )  
 = 121.6 N./mm<sup>2</sup>

**AISC Unity Check of Outside Ribs ( must be <= 1 )**

= Sc/Sca + ( Rm \* C1 / I ) / Sba  
 = 4.58/121.55 + ( 46.98 \* 86.0/5088449 ) / 137.9  
 = 0.043

**Check of Inside Ribs:**

**Inertia of Saddle, Inner Ribs - Axial Direction**

	B	D	Y	A	AY	Io
Rib	12.0	160.0	0.0	19.2	0.0	509.
Web	495.4	12.0	0.0	59.4	0.0	7.13
Totals	...	...	...	78.6	...	516.

**Distance to Centroid from Datum [ytot]:**

= AY / A  
 = 0.0/78.644  
 = 0.000 mm.

**Distance to Centroid [C1]:**

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$$\begin{aligned}
 &= \text{Saddle Width} / 2 \\
 &= 172.0 / 2 \\
 &= 86.000 \text{ mm.}
 \end{aligned}$$

Length of Inner Rib [L]:

$$\begin{aligned}
 &= \text{Saddle Height} - \sqrt{(\text{Ro} + \text{Wpdthk})^2 - (\text{Pitch}/2)^2} - \text{Bpthk} \\
 &= 1200.0 - \sqrt{(858.0 + 12.0)^2 - (495.367/2)^2} - 16.0 \\
 &= 362.527 \text{ mm.}
 \end{aligned}$$

Radius of Gyration [r]:

$$\begin{aligned}
 &= \sqrt{\text{Total Inertia} / \text{Total Area}} \\
 &= \sqrt{515.8 / 78.644} \\
 &= 25.610 \text{ mm.}
 \end{aligned}$$

Slenderness ratio [KL/r]:

$$\begin{aligned}
 &= KL/r \\
 &= 1 * 362.527 / 25.61 \\
 &= 14.156
 \end{aligned}$$

Unit Force [Force,u]:

$$\begin{aligned}
 &= F1 / (2 * \text{Baseplate Length}) \\
 &= 1.554 / (2 * 1450.0) \\
 &= 0.001 \text{ kN/mm.}
 \end{aligned}$$

Moment at base of inner Rib [Mbase,c]:

$$\begin{aligned}
 &= \text{Unit Force} * e * L \\
 &= 0.001 * 495.367 * 362.527 \\
 &= 96.255 \text{ N-m}
 \end{aligned}$$

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:

$$\begin{aligned}
 &= \text{Bending Moment} / \text{Section Modulus} \\
 &= 96.255 / 59977.363 \\
 &= 1.604 \text{ N./mm}^2
 \end{aligned}$$

Compressive Allowable,  $KL/r < Cc$  (  $14.1557 < 138.1347$  ) per AISC E2-1 [Sca]:

$$\begin{aligned}
 &= (1 - (KL/r)^2 / (2 * Cc^2)) Fy / (5/3 + 3 * (KL/r) / (8 * Cc) - (KL/r)^3 / (8 * Cc^3)) \\
 &= (1 - (14.16)^2 / (2 * 138.13^2)) 207 / \\
 &\quad (5/3 + 3 * (14.16) / (8 * 138.13) - (14.16^3) / (8 * 138.13^3)) \\
 &= 120.7 \text{ N./mm}^2
 \end{aligned}$$

**AISC Unity Check of Inside Ribs ( must be  $\leq 1$  )**

$$\begin{aligned}
 &= Sc/Sca + (Mbase,c * C1/I) / Sba \\
 &= 5.51 / 120.69 + (96.25 * 86.0 / 515.805) / 137.9 \\
 &= 0.057
 \end{aligned}$$

### Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm <sup>2</sup>
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	75.0	mm.
Nominal Bolt Diameter	Bnd	22.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm <sup>2</sup>
Area Available in a Single Bolt	BltArea	2.7242	cm <sup>2</sup>
Saddle Load Q0 (Weight)	Q0	129.9	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.4	kN
Maximum Transverse Force	Ft	1.7	kN
Maximum Longitudinal Force	F1	1.6	kN

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Saddle Bolted to Steel Foundation No

Shear Stress in a Single Bolt [ $\tau_{\text{aub}}$ ]:  
 = Shear Force / ( 2 \* Bolt Area \* Number of Bolts )  
 = 2 / ( 2 \* 2.72 \* 4 )  
 = 0.8 N./mm<sup>2</sup>. Must be less than 103.4 N./mm<sup>2</sup>.

### **Bolt Area Calculation per Dennis R. Moss**

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:  
 = 0.0 (QO > QL --> No Uplift in Longitudinal direction)

Bolt Area due to Shear Load [Bltarears]:  
 = F1 / (Stba \* Nbolts)  
 = 1.55 / (172.38 \* 4.0)  
 = 0.0225 cm<sup>2</sup>

### **Bolt Area due to Transverse Load:**

Moment on Baseplate Due to Transverse Load [Rmom]:  
 = B \* Ft + Sum of X Moments  
 = 1200.0 \* 1.72 + 0.0  
 = 2061.61 N-m

Eccentricity (e):  
 = Rmom / QO  
 = 2061.61 / 129.89  
 = 15.87 mm. < Bplen/6 --> No Uplift in Transverse direction

Bolt Area due to Transverse Load [Bltareart]:  
 = 0 (No Uplift)

Required Area of a Single Bolt [Bltarear]:  
 = max[Bltarearl, Bltarears, Bltareart]  
 = max[0.0, 0.0225, 0.0]  
 = 0.0225 cm<sup>2</sup>

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### Conical Reinforcement Calculations, ASME VIII Div. 1, App. 1

#### Conical Section From 60 To 70 SA-516 70

CON

Elastic Modulus Data from ASME Section II Part D at 125 °C

Elastic Modulus of Cone Material	0.197E+09 KPa. at 124 °C
Elastic Modulus of Small Cylinder Material	0.197E+09 KPa. at 124 °C
Elastic Modulus of Large Cylinder Material	0.197E+09 KPa. at 124 °C
Elastic Modulus of Large End Reinforcement	0.197E+09 KPa. at 124 °C
Elastic Modulus of Small End Reinforcement	0.197E+09 KPa. at 124 °C

Elastic Modulus Data from ASME Section II Part D at 125 °C

Elastic Modulus of Cone Material	0.197E+09 KPa. at 124 °C
Elastic Modulus of Small Cylinder Material	0.197E+09 KPa. at 124 °C
Elastic Modulus of Large Cylinder Material	0.197E+09 KPa. at 124 °C
Elastic Modulus of Large End Reinforcement	0.197E+09 KPa. at 124 °C
Elastic Modulus of Small End Reinforcement	0.197E+09 KPa. at 124 °C

Axial Force on Small End of Cone	0.00 kN
Axial Force on Large End of Cone	0.00 kN
Moment on Small End of Cone	0.00 N-m
Moment on Large End of Cone	0.00 N-m

Note: Axial forces and moments are not computed for Horizontal geometries.

Please compute them manually and input them as Miscellaneous Load on the ends of the cone.

Note: Neither end of Cone is a Line of Support

Maximum Centroid Reinforcement Distance Large End	28.1625 mm.
Maximum Centroid Reinforcement Distance Small End	25.6661 mm.

Note: No ring was found close enough to the large end to be considered.

Note: No ring was found close enough to the small end to be considered.

#### Reinforcement Calculations for Cone / Large Cylinder:

##### Required Area of Reinforcement for Large End Under Internal Pressure

Large end ratio of pressure to allowable stress	0.01677
Large end max. half apex angle w/o reinforcement	30.000 degrees
Large end actual half apex angle	28.784 degrees

##### Required Area of Reinforcement for Large End Under External Pressure

Large end ratio of pressure to allowable stress	0.00075
Large end max. half apex angle w/o reinforcement	1.875 degrees
Large end actual half apex angle	28.784 degrees

Intermediate Value [k]:

$$= \max( Y / ( S_{rl} * E_{rl} ), 1 )$$

$$= \max( 0.27111E+11 / ( 137.9 * 0.19660E+09 ), 1 )$$

$$= 1.0000$$

where [Y] is:

$$= \text{Large End All. Stress} * \text{Large End Elastic Modulus (Ext. temp.)}$$

$$= 137.9 * 0.19660E+09$$

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$$= 27111170048.0 \text{ N./mm}^2$$

Allowable Stress of Large End Material (Ext. Temp) 137.9 N./mm<sup>2</sup>  
 Allowable Stress of Cone Material (Ext. Temp) 137.9 N./mm<sup>2</sup>

**Required Area of Reinforcement, Large End, External [Arl]:**

$$= (k*QL*Rl*\tan(\text{angle})/(Ss*E1))*(1-1/4((P*Rl-QL)/QL)*(\text{delta}/\alpha))$$

$$= (1.0*0.0437*846.0*0.549/(138*1.0))*$$

$$(1-1/4((1.03*846.0-0.044)/0.044))*(1.875/28.784)$$

$$= 1.451 \text{ cm}^2$$

**Force per Length, Cone Large End External Pressure [QL]:**

$$= P_{\text{ext}}(Rl/2) + F_{\text{axial}}/(\pi(Dl - Tl)) + \text{Moment}/(\pi(Rl - Tl/2)(Rl - Tl/2))$$

$$= 1.034(846.0/2) + 0.0/(\pi(1692.0 - 18.0)) +$$

$$0.0/(\pi(846.0 - 18.0/2)(846.0 - 18.0/2))$$

$$= 0.044 \text{ kN/mm.}$$

**Available Area of Reinforcement, Large End, External [Ael]:**

$$= 0.55*(Dl*ts)^{1/2} * (ts + tc/\cos(\alpha))$$

$$= 0.55 * (1692.0 * 15.0)^{1/2} * (15.0 + 17.0/0.876)$$

$$= 30.1387 \text{ cm}^2$$

**Summary of Reinforcement Area, Large End, External Pressure:**

Area of reinforcement required per App. 1-8(1)	1.4505	cm <sup>2</sup>
Area of reinforcement in shell per App. 1-8(2)	30.1387	cm <sup>2</sup>
Area of reinforcement in stiffening ring	0.0000	cm <sup>2</sup>

**Reinforcement Calculations for Cone / Small Cylinder:**

**Required Area of Reinforcement for Small End under Internal Pressure**

Small end ratio of pressure to allowable stress	0.01677	
Small end max. half apex angle w/o reinforcement	11.368	degrees
Small end actual half apex angle	28.784	degrees

**Intermediate Value [k]:**

$$= \max(Y / (Sr * Ers), 1)$$

$$= \max(0.27111E+11 / (137.9 * 0.19660E+09), 1)$$

$$= 1.0000$$

**where [Y] is:**

$$= \text{Small End All. Stress} * \text{Small End Elastic Modulus (Int. temp.)}$$

$$= 137.9 * 0.19660E+09$$

$$= 27111170048.0 \text{ N./mm}^2$$

**Decay Length, Cone Small End:**

$$= 1.4 * \sqrt{Rs(ts - ca)}$$

$$= 1.4 * \sqrt{603.0(20.0 - 3.0)}$$

$$= 141.746 \text{ mm.}$$

**Required Area of Reinforcement, Small End, Internal [Ars]:**

$$= k*QS*Rs/(Ss*E1)*(1-\text{delta}/\alpha)*\tan(\alpha)$$

$$= 1.0 * 0.697 * 603.0 / (138 * 1.0) *$$

$$(1 - 11.37/28.78) * 0.5494$$

$$= 10.13 \text{ cm}^2$$

**Force per Length, Cone Small End [QS]:**

$$= P(Rs/2) - F_{\text{axial}}/(\pi(Ds + Ts)) + \text{Moment}/(\pi(Rs + Ts/2)(Rs + Ts/2))$$

$$= 23.118(603.0/2) - 0.0/(\pi(1206.0 + 20.0)) +$$

$$0.0/(\pi(603.0 + 20.0/2)(603.0 + 20.0/2))$$

$$= 0.697 \text{ kN/mm.}$$

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**Area of Reinforcement Available in Small End Shell [Aes]:**

$$= 0.78(Rs*Ts)^{1/2} * ((Ts-t) + (Tc-Tr) / \cos(\alpha))$$

$$= 0.78(603.0*17.0)^{1/2} * ((17.0-10.212) + (17.0-11.652) / 0.88)$$

$$= 10.1795 \text{ cm}^2$$

**Summary of Reinforcement Area, Small End, Internal Pressure:**

Area of reinforcement required per App. 1-5(3)	10.1322	cm <sup>2</sup>
Area of reinforcement in shell per App. 1-5(4)	10.1795	cm <sup>2</sup>
Area of reinforcement in stiffening ring	0.0000	cm <sup>2</sup>

**Required Area of Reinforcement for Small End Under External Pressure**

Allowable Stress of Small End Material (Ext. Temp)	137.9	N./mm <sup>2</sup>
Allowable Stress of Cone Material (Ext. Temp)	137.9	N./mm <sup>2</sup>

**Intermediate Value [k]:**

$$= \max(Y / (Srs * Ers), 1)$$

$$= \max(0.27111E+11 / (137.9 * 0.19660E+09), 1)$$

$$= 1.0000$$

**where [Y] is:**

$$= \text{Small End All. Stress} * \text{Small End Elastic Modulus (Ext. temp.)}$$

$$= 137.9 * 0.19660E+09$$

$$= 27111170048.0 \text{ N./mm}^2$$

**Area of Reinforcement Required in Small End Shell [Ars]:**

$$= k * QS * Rs * \tan(\alpha) / (Ss * E1)$$

$$= (1.0 * 0.0321 * 620.0 * 0.5494) / (138 * 1.0)$$

$$= 0.792 \text{ cm}^2$$

**Force per Length, Cone Small End [QS]:**

$$= P_{ext}(Rs/2) + F_{axial} / (\pi(Ds - Ts)) + \text{Moment} / (\pi(Rs - Ts/2)(Rs - Ts/2))$$

$$= 1.034(620.0/2) + 0.0 / (\pi(1240.0 - 20.0)) +$$

$$0.0 / (\pi(620.0 - 20.0/2)(620.0 - 20.0/2))$$

$$= 0.032 \text{ kN/mm.}$$

**Area of Reinforcement Available in Small End Shell [Aes]:**

$$= 0.55*(Ds*ts)^{1/2} * [(ts-t) + (tc-tr) / \cos(\alpha)]$$

$$= 0.55*(1240.0*17.0)^{1/2} * [(17.0-7.232) + (17.0-3.633) / 0.876]$$

$$= 19.9791 \text{ cm}^2$$

**Summary of Reinforcement Area, Small End, External Pressure:**

Area of reinforcement required per App. 1-8(3)	0.7920	cm <sup>2</sup>
Area of reinforcement in shell per App. 1-8(4)	19.9791	cm <sup>2</sup>
Area of reinforcement in stiffening ring	0.0000	cm <sup>2</sup>

Note: The following calculations are only required per 1-5(g)(1) and do include external loads due to wind or seismic. These discontinuity stresses are computed at the shell/cone junction and do not include effects of local stiffening from a junction ring.

**Results for Discontinuity Stresses per Bednar p. 236 2nd Edition**

Stress Type	Stress	Allowable	Location
Tensile Stress	196.23	413.70	Small Cyl. Long.
Compres. Stress	-113.07	-413.70	Small Cyl. Long.
Membrane Stress	168.29	-206.85	Small End Tang.
Tensile Stress	202.10	413.70	Cone Longitudinal
Compres. Stress	-107.21	-413.70	Cone Longitudinal
Compres Stress	180.01	-206.85	Cone Tangential

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Tensile Stress	371.50	413.70	Large Cyl. Long.
Compres. Stress	-242.27	-413.70	Large Cyl. Long.
Membrane Stress	-20.95	-206.85	Large End Tang.
Tensile Stress	303.98	413.70	Cone Longitudinal
Compres. Stress	-173.87	-413.70	Cone Longitudinal
Compres Stress	-20.08	-206.85	Cone Tangential

Note: An asterisk (\*) denotes that this stress was not applicable for this combination of loads.

**Maximum Allowable Pressure Calculations for Cone to Shell Junction:**

Pressure Case	Pressure bars	Reason for Failure at this Pressure
MAWP	23.161	Small End Reinforcement
MAPnc	28.825	Small End Reinforcement

These pressures were determined by iteration.

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#### Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
T2	24.91	OK	...	OK	11.33	OK	Passed
T1	24.79	OK	...	OK	11.33	OK	Passed
D4	24.33	OK	...	OK	7.80	OK	Passed
S2	24.51	OK	...	OK	10.16	OK	Passed
S1	24.51	OK	...	OK	10.16	OK	Passed
S3	24.51	OK	...	OK	10.16	OK	Passed
D2	24.51	OK	...	OK	7.80	OK	Passed
D1	24.51	OK	...	OK	7.80	OK	Passed
D3	24.51	OK	...	OK	7.80	OK	Passed
TT	24.51	OK	...	OK	7.80	OK	Passed
V	24.51	OK	...	OK	7.80	OK	Passed
S4	24.51	OK	...	OK	10.16	OK	Passed
LG1	24.51	OK	...	OK	7.80	OK	Passed
LG2	24.51	OK	...	OK	7.80	OK	Passed
LT1	24.51	OK	...	OK	6.42	OK	Passed
LT3	24.51	OK	...	OK	6.42	OK	Passed
LT2	24.51	OK	...	OK	6.42	OK	Passed
LT4	24.51	OK	...	OK	6.42	OK	Passed

#### MAWP Summary:

Minimum MAWP Nozzles : 24.330 Nozzle : D4

Note: MAWPs (Internal Case) shown above are at the High Point.

#### Check the Spatial Relationship between the Nozzles

From Node	Nozzle Description	X Coordinate mm.	Layout Angle deg	Dia. Limit mm.
20	T2	450.000	90.000	948.000
20	T1	450.000	270.000	948.000
60	D4	1915.525	270.000	118.000
70	S2	2545.525	270.000	405.700
70	S1	5145.525	270.000	405.700
70	S3	2945.525	90.000	405.700
70	D2	2945.525	270.000	114.000
70	D1	4745.525	270.000	114.000
70	D3	5545.525	270.000	114.000
70	TT	6145.525	270.000	114.000
70	V	2545.525	90.000	114.000
70	S4	5145.525	90.000	405.700
70	LG1	4545.525	270.000	114.000
70	LG2	4545.525	90.000	114.000
70	LT1	3345.525	90.000	115.034
70	LT3	3845.525	90.000	115.034
70	LT2	3345.525	270.000	115.034
70	LT4	3845.525	270.000	115.034

#### The nozzle spacing is computed by the following:

$$= \text{Sqrt}(l^2 + lc^2) \text{ where}$$

l - Arc length along the inside vessel surface in the long. direction.

lc - Arc length along the inside vessel surface in the circ. direction

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If any interferences/violations are found, they will be noted below.

[No interference violations have been detected !](#)

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Nozzle Calcs.: T2 Nozl: 19 11:47am Dec 23,2021

**Input, Nozzle Desc: T2 From: 20**

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1200.00	mm.
Design Length of Section	L	949.9999	mm.
Shell Finished (Minimum) Thickness	t	15.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		450.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

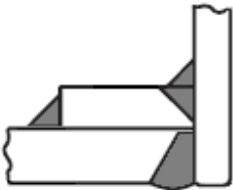
**Type of Element Connected to the Shell : Nozzle**

Material [Normalized]		SA-516 70	
Material UNS Number		K02700	
Material Specification/Type		Plate	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		20.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	<del>20.0000</del>	mm.
Flange Material		SA-350 LF2	
Flange Type	Weld Neck Flange		
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	18.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	15.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	748.0000	mm.
Thickness of Pad	te	20.0000	mm.
Weld leg size between Pad and Shell	Wp	12.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	15.0000	mm.
Reinforcing Pad Width		120.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

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The Pressure Design option was Design Pressure + static head.

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle With Pad, no Inside projection**

**Reinforcement CALCULATION, Description: T2**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	20.000 in.
Actual Thickness Used in Calculation	0.787 in.

Nozzle input data check completed without errors.

Req'd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 $= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 $= (23.0 \cdot 603.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$   
 $= 10.1595 \text{ mm.}$

Req'd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 $= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 $= (23.0 \cdot 254.0) / (138 \cdot 1.0 + 0.4 \cdot 23.0)$   
 $= 4.2086 \text{ mm.}$

Required Nozzle thickness under External Pressure per UG-28 : 0.9797 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	D1	948.0001	mm.
Parallel to Vessel Wall, opening length	d	474.0000	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		30.0000	mm.

Weld Strength Reduction Factor [fr1]:  
 $= \min( 1, S_n / S_v )$   
 $= \min( 1, 137.9 / 137.9 )$   
 $= 1.000$

Weld Strength Reduction Factor [fr2]:  
 $= \min( 1, S_n / S_v )$   
 $= \min( 1, 137.9 / 137.9 )$   
 $= 1.000$

Weld Strength Reduction Factor [fr4]:  
 $= \min( 1, S_p / S_v )$   
 $= \min( 1, 137.9 / 137.9 )$   
 $= 1.000$

Weld Strength Reduction Factor [fr3]:

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= min( fr2, fr4 )  
 = min( 1.0, 1.0 )  
 = 1.000

**Results of Nozzle Reinforcement Area Calculations: (cm^2)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	48.156	8.366	NA
Area in Shell	A1	8.724	40.149	NA
Area in Nozzle Wall	A2	7.675	9.612	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		4.040	4.040	NA
Area in Element	A5	36.000	36.000	NA
TOTAL AREA AVAILABLE	Atot	56.439	89.801	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.  
 The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS: Diameter Thickness  
 Based on given Pad Thickness: 692.7844 20.0000 mm.  
 Based on given Pad Diameter: 748.0001 15.3987 mm.  
 Based on Shell or Nozzle Thickness: 754.3792 15.0000 mm.

Area Required [A]:  
 = ( d \* tr\*F + 2 \* tn \* tr\*F \* (1-fr1) ) UG-37(c)  
 = ( 474.0\*10.1595\*1.0+2\*17.0\*10.1595\*1.0\*(1-1.0) )  
 = 48.156 cm^2

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:  
 = d( E1\*t - F\*tr ) - 2 \* tn( E1\*t - F\*tr ) \* ( 1 - fr1 )  
 = 474.0( 1.0 \* 12.0 - 1.0 \* 10.16 ) - 2 \* 17.0  
 ( 1.0 \* 12.0 - 1.0 \* 10.1595 ) \* ( 1 - 1.0 )  
 = 8.724 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:  
 = ( 2 \* Tlwp ) \* ( tn - trn ) \* fr2  
 = ( 2 \* 30.0 ) \* ( 17.0 - 4.21 ) \* 1.0  
 = 7.675 cm^2

Area Available in Welds [A41 + A42 + A43]:  
 = (Wo^2 - Ar Lost)\*Fr3+((Wi-can/0.707)^2 - Ar Lost)\*fr2 + Wp^2\*fr4  
 = ( 2.6 ) \* 1.0 + ( 0.0 ) \* 1.0 + 304.8^2 \* 1.0  
 = 4.040 cm^2

Area Available in Element, also see UG-37(h) [A5]:  
 = (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) \* fr4 \* 0.75  
 = ( 748.0 - 508.0 )20.0 \* 1.0 \* 0.75  
 = 36.000 cm^2

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**

Wall Thickness for Internal/External pressures ta = 7.2086 mm.  
 Wall Thickness per UG16(b), tr16b = 4.5000 mm.  
 Wall Thickness, shell/head, internal pressure trb1 = 13.1595 mm.  
 Wall Thickness tbt1 = max(trb1, tr16b) = 13.1595 mm.

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Wall Thickness, shell/head, external pressure trb2 = 3.4525 mm.  
 Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.  
 Wall Thickness per table UG-45 tb3 = 11.3312 mm.

Determine Nozzle Thickness candidate [tb]:

= min[ tb3, max( tb1, tb2 ) ]  
 = min[ 11.331, max( 13.1595, 4.5 ) ]  
 = 11.3312 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

= max( ta, tb )  
 = max( 7.2086, 11.3312 )  
 = 11.3312 mm.

Available Nozzle Neck Thickness = 20.0000 mm. --&gt; OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME****B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	:	32.6,	Allowable	:	137.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	312.2 N./mm <sup>2</sup>	Passed
Occasional	:	15.5,	Allowable	:	183.4 N./mm <sup>2</sup>	Passed
Shear	:	11.0,	Allowable	:	96.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

**Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:****Nozzle Neck to Flange Weld, Curve: D**

Govrn. thk, tg = 20.0, tr = 4.209, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.248$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-40 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

**Nozzle Neck to Pad Weld for the Nozzle, Curve: D**

Govrn. thk, tg = 20.0, tr = 4.209, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.248$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-40 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

**Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D**

Govrn. thk, tg = 20.0, tr = 4.209, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.248$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-40 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

**Shell to Pad Weld Junction at Pad OD, Curve: D**

Govrn. thk, tg = 15.0, tr = 10.16, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.847$ , Temp. Reduction = 9 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-47 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C

**Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: D**

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 Govern. thk, tg = 15.0, tr = 10.16, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.847$ , Temp. Reduction = 9 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -47 °C  
 Min Metal Temp. at Required thickness (UCS 66.1) -48 °C

Governing MDMT of the Nozzle : -48 °C  
 Governing MDMT of the Reinforcement Pad : -48 °C  
 Governing MDMT of all the sub-joints of this Junction : -48 °C

#### ANSI Flange MDMT including Temperature reduction per UCS-66.1:

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c) -29 °C  
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b) -48 °C  
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-c) -104 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :  
 Design Pressure/Ambient Rating =  $23.00 / 51.10 = 0.450$

#### Note:

Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

#### Weld Size Calculations, Description: T2

Intermediate Calc. for nozzle/shell Welds Tmin 17.0000 mm.  
 Intermediate Calc. for pad/shell Welds TminPad 12.0000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	$11.9000 = 0.7 * t_{min}$	$12.7260 = 0.7 * W_o$ mm.
Pad Weld	$6.0000 = 0.5 * T_{minPad}$	$8.4840 = 0.7 * W_p$ mm.

#### Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

##### Weld Load [W]:

$$= \max( 0, (A - A1 + 2 * t_n * f_{r1} * (E1 * t - tr)) * S_v )$$

$$= \max( 0, (48.1563 - 8.7237 + 2 * 17.0 * 1.0 * (1.0 * 12.0 - 10.1595) ) * 138 )$$

$$= 552.36 \text{ kN}$$

Note: F is always set to 1.0 throughout the calculation.

##### Weld Load [W1]:

$$= (A2 + A5 + A4 - (W_i - C_{an} / .707)^2 * f_{r2}) * S_v$$

$$= ( 7.6749 + 36.0 + 4.04 - 0.0 * 1.0 ) * 138$$

$$= 657.93 \text{ kN}$$

##### Weld Load [W2]:

$$= (A2 + A3 + A4 + (2 * t_n * t * f_{r1})) * S_v$$

$$= ( 7.6749 + 0.0 + 3.24 + ( 4.08 ) ) * 138$$

$$= 206.76 \text{ kN}$$

##### Weld Load [W3]:

$$= (A2 + A3 + A4 + A5 + (2 * t_n * t * f_{r1})) * S$$

$$= ( 7.6749 + 0.0 + 4.04 + 36.0 + ( 4.08 ) ) * 138$$

$$= 714.19 \text{ kN}$$

#### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

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$$= (\pi/2) * Dlo * Wo * 0.49 * Snw$$

$$= ( 3.1416/2.0 ) * 508.0 * 18.0 * 0.49 * 138$$

$$= 970. \text{ kN}$$

Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= ( 3.1416/2.0 ) * 748.0 * 12.0 * 0.49 * 138$$

$$= 953. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn$$

$$= ( 3.1416 * 245.5 ) * ( 20.0 - 3.0 ) * 0.7 * 138$$

$$= 1266. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgp * 0.74 * Seg$$

$$= ( 3.1416/2 ) * 508.0 * 15.0 * 0.74 * 138$$

$$= 1221. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng$$

$$= ( 3.1416/2.0 ) * 508.0 * ( 15.0 - 3.0 ) * 0.74 * 138$$

$$= 977. \text{ kN}$$

#### Strength of Failure Paths:

$$\text{PATH11} = ( \text{SPEW} + \text{SNW} ) = ( 953 + 1266 ) = 2218 \text{ kN}$$

$$\text{PATH22} = ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} )$$

$$= ( 970 + 1221 + 977 + 0 ) = 3169 \text{ kN}$$

$$\text{PATH33} = ( \text{Spew} + \text{Tngw} + \text{Sinw} )$$

$$= ( 953 + 977 + 0 ) = 1930 \text{ kN}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 2218 kN , must exceed W = 552 kN or W1 = 657 kN  
 Path 2-2 = 3168 kN , must exceed W = 552 kN or W2 = 206 kN  
 Path 3-3 = 1929 kN , must exceed W = 552 kN or W3 = 714 kN

#### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 24.907 bars

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 56.4156 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 221.4156 mm.

#### Percent Elongation Calculations:

% Elongation per Table UG-79-1 (50\*tnom/Rf\*(1-Rf/Ro)) 4.098 %

#### Input Echo, WRC107/537 Item 1, Description: T2 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1200.000	mm.
Vessel Thickness	Tv	15.000	mm.
Design Temperature	T1	125.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>

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Note:  
 Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

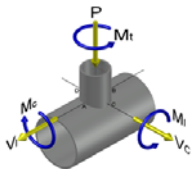
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	508.000	mm.
Nozzle Thickness	Tn	20.000	mm.
Nozzle Material		SA-516 70	
Nozzle UNS Number		K02700	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	20.000	mm.
Diameter of Reinforcing Pad	Dpad	748.000	mm.
Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	20.0	kN
Longitudinal Shear (SUS)	Vl	20.0	kN
Circumferential Shear (SUS)	Vc	20.0	kN
Circumferential Moment (SUS)	Mc	28000.0	N-m
Longitudinal Moment (SUS)	Ml	42500.1	N-m
Torsional Moment (SUS)	Mt	52500.1	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979
Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

Note:  
 WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:  
 = NozzleOD + 2 \* 1.65 \* sqrt( Rmean( t - ca ) )  
 = 508.0 + 2 \* 1.65 \* sqrt( 609.0 ( 15.0 - 3.0 ) )  
 = 790.107 mm.

WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	20.0	kN
Circumferential Shear	VC	20.0	kN

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Longitudinal Shear	VL	20.0	kN
Circumferential Moment	MC	28000.0	N-m
Longitudinal Moment	ML	42500.1	N-m
Torsional Moment	MT	52500.1	N-m

Dimensionless Parameters used : Gamma = 19.34

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.359	4C	2.373	(A,B)
N(PHI) / ( P/Rm )	0.359	3C	1.389	(C,D)
M(PHI) / ( P )	0.359	2C1	0.023	(A,B)
M(PHI) / ( P )	0.359	1C !	0.057	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.359	3A	0.798	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.359	1A	0.075	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.359	3B	1.693	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.359	1B	0.019	(A,B,C,D)
N(x) / ( P/Rm )	0.359	3C	1.389	(A,B)
N(x) / ( P/Rm )	0.359	4C	2.373	(C,D)
M(x) / ( P )	0.359	1C1	0.045	(A,B)
M(x) / ( P )	0.359	2C !	0.030	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.359	4A	1.812	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.359	2A	0.034	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.359	4B	0.768	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.359	2B	0.032	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-2.4	-2.4	-2.4	-2.4	-1.4	-1.4	-1.4	-1.4
Circ. Bend.	P	-2.7	2.7	-2.7	2.7	-6.7	6.7	-6.7	6.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-5.1	-5.1	5.1	5.1
Circ. Memb.	ML	-16.3	-16.3	16.3	16.3	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-20.9	20.9	20.9	-20.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-42.4	4.9	32.1	-4.2	-68.5	55.5	52.3	-44.9
Long. Memb.	P	-1.4	-1.4	-1.4	-1.4	-2.4	-2.4	-2.4	-2.4
Long. Bend.	P	-5.3	5.3	-5.3	5.3	-3.5	3.5	-3.5	3.5
Long. Memb.	MC	0.0	0.0	0.0	0.0	-11.5	-11.5	11.5	11.5
Long. Bend.	MC	0.0	0.0	0.0	0.0	-24.9	24.9	24.9	-24.9
Long. Memb.	ML	-7.4	-7.4	7.4	7.4	0.0	0.0	0.0	0.0
Long. Bend.	ML	-35.6	35.6	35.6	-35.6	0.0	0.0	0.0	0.0
Tot. Long. Str.		-49.7	32.1	36.4	-24.4	-42.3	14.5	30.5	-12.2
Shear	VC	0.8	0.8	-0.8	-0.8	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-0.8	-0.8	0.8	0.8

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Shear MT	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Tot. Shear	4.8	4.8	3.3	3.3	3.3	3.3	4.8	4.8	
Str. Int.	52.1	32.9	38.1	24.9	68.9	55.8	53.3	45.6	

WARNING: Ratio of Pad Radius/Rm (.614) is not between 0.01 and 0.571.

Dimensionless Parameters used : Gamma = 50.75

**Dimensionless Loads for Cylindrical Shells at Pad edge:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.537	4C !	2.960	(A,B)
N(PHI) / ( P/Rm )	0.537	3C !	1.042	(C,D)
M(PHI) / ( P )	0.537	2C1 !	0.004	(A,B)
M(PHI) / ( P )	0.537	1C !	0.065	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta ) )	0.537	3A !	0.947	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta ) )	0.537	1A !	0.057	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta ) )	0.537	3B !	1.547	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta ) )	0.537	1B !	0.003	(A,B,C,D)
N(x) / ( P/Rm )	0.537	3C !	1.042	(A,B)
N(x) / ( P/Rm )	0.537	4C !	2.960	(C,D)
M(x) / ( P )	0.537	1C1 !	0.010	(A,B)
M(x) / ( P )	0.537	2C !	0.033	(C,D)
N(x) / ( MC/(Rm**2 * Beta ) )	0.537	4A !	4.440	(A,B,C,D)
M(x) / ( MC/(Rm * Beta ) )	0.537	2A !	0.023	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta ) )	0.537	4B !	0.987	(A,B,C,D)
M(x) / ( ML/(Rm * Beta ) )	0.537	2B !	0.006	(A,B,C,D)

nozzle pro to be submitted WRC is not applicable for this size

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-8.1	-8.1	-8.1	-8.1	-2.9	-2.9	-2.9	-2.9
Circ. Bend. P		-3.5	3.5	-3.5	3.5	-54.4	54.4	-54.4	54.4
Circ. Memb. MC		0.0	0.0	0.0	0.0	-11.1	-11.1	11.1	11.1
Circ. Memb. ML		-27.5	-27.5	27.5	27.5	0.0	0.0	0.0	0.0
Circ. Bend. ML		-18.6	18.6	18.6	-18.6	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-57.7	-13.5	34.4	4.3	-271.5	243.6	157.0	-140.6
Long. Memb. P		-2.9	-2.9	-2.9	-2.9	-8.1	-8.1	-8.1	-8.1
Long. Bend. P		-8.7	8.7	-8.7	8.7	-27.9	27.9	-27.9	27.9
Long. Memb. MC		0.0	0.0	0.0	0.0	-52.0	-52.0	52.0	52.0
Long. Bend. MC		0.0	0.0	0.0	0.0	-81.4	81.4	81.4	-81.4
Long. Memb. ML		-17.5	-17.5	17.5	17.5	0.0	0.0	0.0	0.0
Long. Bend. ML		-31.0	31.0	31.0	-31.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-60.1	19.4	37.0	-7.6	-169.4	49.2	97.4	-9.6

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Shear VC	1.4	1.4	-1.4	-1.4	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.4	-1.4	1.4	1.4
Shear MT	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Tot. Shear	6.4	6.4	3.6	3.6	3.6	3.6	6.4	6.4
Str. Int.	65.4	35.2	39.5	13.9	271.6	243.7	157.7	140.9

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		42.2	44.5	42.2	44.5	42.2	44.5	42.2	44.5
Circ. Pl (SUS)		-18.7	-18.7	13.9	13.9	-6.5	-6.5	3.7	3.7
Circ. Q (SUS)		-23.6	23.6	18.2	-18.2	-62.0	62.0	48.6	-48.6
Long. Pm (SUS)		21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1
Long. Pl (SUS)		-8.8	-8.8	6.0	6.0	-13.9	-13.9	9.1	9.1
Long. Q (SUS)		-40.9	40.9	30.4	-30.4	-28.4	28.4	21.3	-21.3
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.8	0.8	-0.8	-0.8	-0.8	-0.8	0.8	0.8
Shear Q (SUS)		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Pm (SUS)		42.2	44.5	42.2	44.5	42.2	44.5	42.2	44.5
Pm+Pl (SUS)		23.5	25.8	56.2	58.5	35.8	38.1	45.9	48.2
Pm+Pl+Q (Total)		30.1	56.5	75.0	44.0	27.8	100.2	95.0	13.4

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	44.52	137.90	Passed
Pm+Pl (SUS)	58.48	206.85	Passed
Pm+Pl+Q (TOTAL)	100.21	413.70	Passed

Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		114.4	116.7	114.4	116.7	114.4	116.7	114.4	116.7
Circ. Pl (SUS)		-35.6	-35.6	19.4	19.4	-13.9	-13.9	8.2	8.2
Circ. Q (SUS)		-22.1	22.1	15.0	-15.0	-257.6	257.6	148.8	-148.8

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Long. Pm (SUS)	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2
Long. Pl (SUS)	-20.4	-20.4	14.7	14.7	-60.1	-60.1	43.9	43.9	43.9
Long. Q (SUS)	-39.7	39.7	22.3	-22.3	-109.3	109.3	53.5	53.5	-53.5
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.4	1.4	-1.4	-1.4	-1.4	-1.4	1.4	1.4	1.4
Shear Q (SUS)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Pm (SUS)	114.4	116.7	114.4	116.7	114.4	116.7	114.4	116.7	116.7
Pm+Pl (SUS)	78.9	81.2	133.9	136.2	103.4	105.7	122.8	125.1	125.1
Pm+Pl+Q (Total)	61.0	104.7	149.1	121.3	157.3	360.4	271.8	271.8	72.5

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	116.74	137.90	Passed
Pm+Pl (SUS)	136.16	206.85	Passed
Pm+Pl+Q (TOTAL)	360.40	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.*

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Nozzle Calcs.: T1 Nozl: 20 11:47am Dec 23,2021

**Input, Nozzle Desc: T1 From: 20**

Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1200.00	mm.
Design Length of Section	L	949.9999	mm.
Shell Finished (Minimum) Thickness	t	15.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		450.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

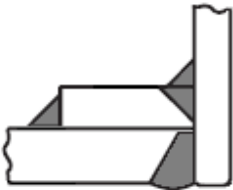
**Type of Element Connected to the Shell : Nozzle**

Material [Normalized]		SA-516 70	
Material UNS Number		K02700	
Material Specification/Type		Plate	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		<del>20.0000</del>	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	20.0000	mm.
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	18.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	15.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	748.0000	mm.
Thickness of Pad	te	20.0000	mm.
Weld leg size between Pad and Shell	Wp	12.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	15.0000	mm.
Reinforcing Pad Width		120.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

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The Pressure Design option was Design Pressure + static head.

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle With Pad, no Inside projection**

**Reinforcement CALCULATION, Description: T1**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	20.000 in.
Actual Thickness Used in Calculation	0.787 in.

Nozzle input data check completed without errors.

Req'd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 $= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 $= (23.12 \cdot 603.0) / (138 \cdot 1.0 - 0.6 \cdot 23.12)$   
 $= 10.2120 \text{ mm.}$

Req'd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 $= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 $= (23.12 \cdot 254.0) / (138 \cdot 1.0 + 0.4 \cdot 23.12)$   
 $= 4.2299 \text{ mm.}$

Required Nozzle thickness under External Pressure per UG-28 : 0.9797 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	D1	948.0001	mm.
Parallel to Vessel Wall, opening length	d	474.0000	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		30.0000	mm.

Weld Strength Reduction Factor [fr1]:  
 $= \min( 1, S_n / S_v )$   
 $= \min( 1, 137.9 / 137.9 )$   
 $= 1.000$

Weld Strength Reduction Factor [fr2]:  
 $= \min( 1, S_n / S_v )$   
 $= \min( 1, 137.9 / 137.9 )$   
 $= 1.000$

Weld Strength Reduction Factor [fr4]:  
 $= \min( 1, S_p / S_v )$   
 $= \min( 1, 137.9 / 137.9 )$   
 $= 1.000$

Weld Strength Reduction Factor [fr3]:

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= min( fr2, fr4 )  
 = min( 1.0, 1.0 )  
 = 1.000

#### Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	48.405	8.366	NA
Area in Shell	A1	8.475	40.149	NA
Area in Nozzle Wall	A2	7.662	9.612	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		4.040	4.040	NA
Area in Element	A5	36.000	36.000	NA
TOTAL AREA AVAILABLE	Atot	56.177	89.801	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.

The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS: Diameter Thickness  
 Based on given Pad Thickness: 696.1868 20.0000 mm.  
 Based on given Pad Diameter: 748.0001 15.6822 mm.  
 Based on Shell or Nozzle Thickness: 758.9158 15.0000 mm.

Area Required [A]:

= ( d \* tr\*F + 2 \* tn \* tr\*F \* (1-fr1) ) UG-37(c)  
 = ( 474.0\*10.212\*1.0+2\*17.0\*10.212\*1.0\*(1-1.0) )  
 = 48.405 cm<sup>2</sup>

#### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

= d( E1\*t - F\*tr ) - 2 \* tn( E1\*t - F\*tr ) \* ( 1 - fr1 )  
 = 474.0( 1.0 \* 12.0 - 1.0 \* 10.212 ) - 2 \* 17.0  
 ( 1.0 \* 12.0 - 1.0 \* 10.212 ) \* ( 1 - 1.0 )  
 = 8.475 cm<sup>2</sup>

Area Available in Nozzle Wall Projecting Outward [A2]:

= ( 2 \* Tlwp ) \* ( tn - trn ) \* fr2  
 = ( 2 \* 30.0 ) \* ( 17.0 - 4.23 ) \* 1.0  
 = 7.662 cm<sup>2</sup>

Area Available in Welds [A41 + A42 + A43]:

= (Wo<sup>2</sup> - Ar Lost)\*Fr3+((Wi-can/0.707)<sup>2</sup> - Ar Lost)\*fr2 + Wp<sup>2</sup>\*fr4  
 = ( 2.6 ) \* 1.0 + ( 0.0 ) \* 1.0 + 304.8<sup>2</sup> \* 1.0  
 = 4.040 cm<sup>2</sup>

Area Available in Element, also see UG-37(h) [A5]:

= (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) \* fr4 \* 0.75  
 = ( 748.0 - 508.0 )20.0 \* 1.0 \* 0.75  
 = 36.000 cm<sup>2</sup>

#### UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

Wall Thickness for Internal/External pressures ta = 7.2299 mm.  
 Wall Thickness per UG16(b), tr16b = 4.5000 mm.  
 Wall Thickness, shell/head, internal pressure trb1 = 13.2120 mm.  
 Wall Thickness tbl = max(trb1, tr16b) = 13.2120 mm.

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Wall Thickness, shell/head, external pressure trb2 = 3.4525 mm.  
 Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.  
 Wall Thickness per table UG-45 tb3 = 11.3312 mm.

Determine Nozzle Thickness candidate [tb]:

= min[ tb3, max( tb1, tb2 ) ]  
 = min[ 11.331, max( 13.212, 4.5 ) ]  
 = 11.3312 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

= max( ta, tb )  
 = max( 7.2299, 11.3312 )  
 = 11.3312 mm.

Available Nozzle Neck Thickness = 20.0000 mm. --> OK

### Stresses on Nozzle due to External and Pressure Loads per the ASME

#### B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	:	32.7,	Allowable	:	137.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	312.1 N./mm <sup>2</sup>	Passed
Occasional	:	15.6,	Allowable	:	183.4 N./mm <sup>2</sup>	Passed
Shear	:	11.0,	Allowable	:	96.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

### Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

#### Nozzle Neck to Flange Weld, Curve: D

Govrn. thk, tg = 20.0, tr = 4.23, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.249$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-40 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

#### Nozzle Neck to Pad Weld for the Nozzle, Curve: D

Govrn. thk, tg = 20.0, tr = 4.23, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.249$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-40 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

#### Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D

Govrn. thk, tg = 20.0, tr = 4.23, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.249$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-40 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

#### Shell to Pad Weld Junction at Pad OD, Curve: D

Govrn. thk, tg = 15.0, tr = 10.212, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.851$ , Temp. Reduction = 8 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-47 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C

#### Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: D

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-----  
 Govrn. thk, tg = 15.0, tr = 10.212, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.851$ , Temp. Reduction = 8 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-47 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C
Governing MDMT of the Nozzle	: -48 °C
Governing MDMT of the Reinforcement Pad	: -48 °C
Governing MDMT of all the sub-joints of this Junction	: -48 °C

#### ANSI Flange MDMT including Temperature reduction per UCS-66.1:

Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)	-29 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)	-48 °C
Flange MDMT with Temp reduction per UCS-66(b)(1)(-c)	-104 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :  
 Design Pressure/Ambient Rating =  $23.12 / 51.10 = 0.452$

#### Note:

Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

#### Weld Size Calculations, Description: T1

Intermediate Calc. for nozzle/shell Welds	Tmin	17.0000 mm.
Intermediate Calc. for pad/shell Welds	TminPad	12.0000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	$11.9000 = 0.7 * t_{min}$	$12.7260 = 0.7 * W_o$ mm.
Pad Weld	$6.0000 = 0.5 * T_{minPad}$	$8.4840 = 0.7 * W_p$ mm.

#### Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

##### Weld Load [W]:

$$= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv )$$

$$= \max( 0, (48.405 - 8.475 + 2 * 17.0 * 1.0 * (1.0 * 12.0 - 10.212) ) 138 )$$

$$= 558.97 \text{ kN}$$

Note: F is always set to 1.0 throughout the calculation.

##### Weld Load [W1]:

$$= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv$$

$$= ( 7.662 + 36.0 + 4.04 - 0.0 * 1.0 ) * 138$$

$$= 657.76 \text{ kN}$$

##### Weld Load [W2]:

$$= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv$$

$$= ( 7.662 + 0.0 + 3.24 + ( 4.08 ) ) * 138$$

$$= 206.58 \text{ kN}$$

##### Weld Load [W3]:

$$= (A2+A3+A4+A5+(2*tn*t*fr1))*S$$

$$= ( 7.662 + 0.0 + 4.04 + 36.0 + ( 4.08 ) ) * 138$$

$$= 714.01 \text{ kN}$$

#### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

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$$= (\pi/2) * Dlo * Wo * 0.49 * Snw$$

$$= ( 3.1416/2.0 ) * 508.0 * 18.0 * 0.49 * 138$$

$$= 970. \text{ kN}$$

Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * DP * WP * 0.49 * SEW$$

$$= ( 3.1416/2.0 ) * 748.0 * 12.0 * 0.49 * 138$$

$$= 953. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn$$

$$= ( 3.1416 * 245.5 ) * ( 20.0 - 3.0 ) * 0.7 * 138$$

$$= 1266. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * Dlo * Wgpw * 0.74 * Seg$$

$$= ( 3.1416/2 ) * 508.0 * 15.0 * 0.74 * 138$$

$$= 1221. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng$$

$$= ( 3.1416/2.0 ) * 508.0 * ( 15.0 - 3.0 ) * 0.74 * 138$$

$$= 977. \text{ kN}$$

#### Strength of Failure Paths:

$$\text{PATH11} = ( \text{SPEW} + \text{SNW} ) = ( 953 + 1266 ) = 2218 \text{ kN}$$

$$\text{PATH22} = ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} )$$

$$= ( 970 + 1221 + 977 + 0 ) = 3169 \text{ kN}$$

$$\text{PATH33} = ( \text{Spew} + \text{Tngw} + \text{Sinw} )$$

$$= ( 953 + 977 + 0 ) = 1930 \text{ kN}$$

#### Summary of Failure Path Calculations:

Path 1-1 = 2218 kN , must exceed W = 558 kN or W1 = 657 kN  
 Path 2-2 = 3168 kN , must exceed W = 558 kN or W2 = 206 kN  
 Path 3-3 = 1929 kN , must exceed W = 558 kN or W3 = 714 kN

#### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 24.907 bars

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 56.4156 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 221.4156 mm.

#### Percent Elongation Calculations:

% Elongation per Table UG-79-1 (50\*tnom/Rf\*(1-Rf/Ro)) 4.098 %

#### Input Echo, WRC107/537 Item 1, Description: T1 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1200.000	mm.
Vessel Thickness	Tv	15.000	mm.
Design Temperature	T1	125.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>

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Note:  
 Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

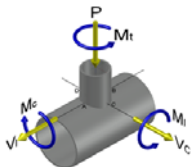
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	508.000	mm.
Nozzle Thickness	Tn	20.000	mm.
Nozzle Material		SA-516 70	
Nozzle UNS Number		K02700	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	20.000	mm.
Diameter of Reinforcing Pad	Dpad	748.000	mm.
Design Internal Pressure	Dp	23.118	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	20.0	kN
Longitudinal Shear (SUS)	Vl	20.0	kN
Circumferential Shear (SUS)	Vc	20.0	kN
Circumferential Moment (SUS)	Mc	28000.0	N-m
Longitudinal Moment (SUS)	Ml	42500.1	N-m
Torsional Moment (SUS)	Mt	52500.1	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979
Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

Note:  
 WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:  
 = NozzleOD + 2 \* 1.65 \* sqrt( Rmean( t - ca ) )  
 = 508.0 + 2 \* 1.65 \* sqrt( 609.0 ( 15.0 - 3.0 ) )  
 = 790.107 mm.

WRC 107 Stress Calculation for SUSTained loads:

Radial Load	P	20.0	kN
Circumferential Shear	VC	20.0	kN

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Longitudinal Shear	VL	20.0	kN
Circumferential Moment	MC	28000.0	N-m
Longitudinal Moment	ML	42500.1	N-m
Torsional Moment	MT	52500.1	N-m

Dimensionless Parameters used : Gamma = 19.34

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.359	4C	2.373	(A,B)
N(PHI) / ( P/Rm )	0.359	3C	1.389	(C,D)
M(PHI) / ( P )	0.359	2C1	0.023	(A,B)
M(PHI) / ( P )	0.359	1C !	0.057	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.359	3A	0.798	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.359	1A	0.075	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.359	3B	1.693	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.359	1B	0.019	(A,B,C,D)
N(x) / ( P/Rm )	0.359	3C	1.389	(A,B)
N(x) / ( P/Rm )	0.359	4C	2.373	(C,D)
M(x) / ( P )	0.359	1C1	0.045	(A,B)
M(x) / ( P )	0.359	2C !	0.030	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.359	4A	1.812	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.359	2A	0.034	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.359	4B	0.768	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.359	2B	0.032	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-2.4	-2.4	-2.4	-2.4	-1.4	-1.4	-1.4	-1.4
Circ. Bend.	P	-2.7	2.7	-2.7	2.7	-6.7	6.7	-6.7	6.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-5.1	-5.1	5.1	5.1
Circ. Memb.	ML	-16.3	-16.3	16.3	16.3	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-20.9	20.9	20.9	-20.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-42.4	4.9	32.1	-4.2	-68.5	55.5	52.3	-44.9
Long. Memb.	P	-1.4	-1.4	-1.4	-1.4	-2.4	-2.4	-2.4	-2.4
Long. Bend.	P	-5.3	5.3	-5.3	5.3	-3.5	3.5	-3.5	3.5
Long. Memb.	MC	0.0	0.0	0.0	0.0	-11.5	-11.5	11.5	11.5
Long. Bend.	MC	0.0	0.0	0.0	0.0	-24.9	24.9	24.9	-24.9
Long. Memb.	ML	-7.4	-7.4	7.4	7.4	0.0	0.0	0.0	0.0
Long. Bend.	ML	-35.6	35.6	35.6	-35.6	0.0	0.0	0.0	0.0
Tot. Long. Str.		-49.7	32.1	36.4	-24.4	-42.3	14.5	30.5	-12.2
Shear	VC	0.8	0.8	-0.8	-0.8	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-0.8	-0.8	0.8	0.8

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Shear MT	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Tot. Shear	4.8	4.8	3.3	3.3	3.3	3.3	4.8	4.8	
Str. Int.	52.1	32.9	38.1	24.9	68.9	55.8	53.3	45.6	

WARNING: Ratio of Pad Radius/Rm (.614) is not between 0.01 and 0.571.

Dimensionless Parameters used : Gamma = 50.75

**Dimensionless Loads for Cylindrical Shells at Pad edge:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.537	4C !	2.960	(A,B)
N(PHI) / ( P/Rm )	0.537	3C !	1.042	(C,D)
M(PHI) / ( P )	0.537	2C1 !	0.004	(A,B)
M(PHI) / ( P )	0.537	1C !	0.065	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.537	3A !	0.947	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.537	1A !	0.057	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.537	3B !	1.547	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.537	1B !	0.003	(A,B,C,D)
N(x) / ( P/Rm )	0.537	3C !	1.042	(A,B)
N(x) / ( P/Rm )	0.537	4C !	2.960	(C,D)
M(x) / ( P )	0.537	1C1 !	0.010	(A,B)
M(x) / ( P )	0.537	2C !	0.033	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.537	4A !	4.440	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.537	2A !	0.023	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.537	4B !	0.987	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.537	2B !	0.006	(A,B,C,D)

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P		-8.1	-8.1	-8.1	-8.1	-2.9	-2.9	-2.9	-2.9
Circ. Bend. P		-3.5	3.5	-3.5	3.5	-54.4	54.4	-54.4	54.4
Circ. Memb. MC		0.0	0.0	0.0	0.0	-11.1	-11.1	11.1	11.1
Circ. Memb. ML		-27.5	-27.5	27.5	27.5	0.0	0.0	0.0	0.0
Circ. Bend. ML		-18.6	18.6	18.6	-18.6	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-57.7	-13.5	34.4	4.3	-271.5	243.6	157.0	-140.6
Long. Memb. P		-2.9	-2.9	-2.9	-2.9	-8.1	-8.1	-8.1	-8.1
Long. Bend. P		-8.7	8.7	-8.7	8.7	-27.9	27.9	-27.9	27.9
Long. Memb. MC		0.0	0.0	0.0	0.0	-52.0	-52.0	52.0	52.0
Long. Bend. MC		0.0	0.0	0.0	0.0	-81.4	81.4	81.4	-81.4
Long. Memb. ML		-17.5	-17.5	17.5	17.5	0.0	0.0	0.0	0.0
Long. Bend. ML		-31.0	31.0	31.0	-31.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-60.1	19.4	37.0	-7.6	-169.4	49.2	97.4	-9.6

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Shear VC	1.4	1.4	-1.4	-1.4	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.4	-1.4	1.4	1.4
Shear MT	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Tot. Shear	6.4	6.4	3.6	3.6	3.6	3.6	6.4	6.4
Str. Int.	65.4	35.2	39.5	13.9	271.6	243.7	157.7	140.9

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		42.4	44.8	42.4	44.8	42.4	44.8	42.4	44.8
Circ. Pl (SUS)		-18.7	-18.7	13.9	13.9	-6.5	-6.5	3.7	3.7
Circ. Q (SUS)		-23.6	23.6	18.2	-18.2	-62.0	62.0	48.6	-48.6
Long. Pm (SUS)		21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2
Long. Pl (SUS)		-8.8	-8.8	6.0	6.0	-13.9	-13.9	9.1	9.1
Long. Q (SUS)		-40.9	40.9	30.4	-30.4	-28.4	28.4	21.3	-21.3
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.8	0.8	-0.8	-0.8	-0.8	-0.8	0.8	0.8
Shear Q (SUS)		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Pm (SUS)		42.4	44.8	42.4	44.8	42.4	44.8	42.4	44.8
Pm+Pl (SUS)		23.8	26.1	56.4	58.7	36.0	38.3	46.1	48.5
Pm+Pl+Q (Total)		30.2	56.6	75.2	44.1	27.7	100.4	95.3	13.3

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	44.75	137.90	Passed
Pm+Pl (SUS)	58.71	206.85	Passed
Pm+Pl+Q (TOTAL)	100.44	413.70	Passed

Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		115.0	117.3	115.0	117.3	115.0	117.3	115.0	117.3
Circ. Pl (SUS)		-35.6	-35.6	19.4	19.4	-13.9	-13.9	8.2	8.2
Circ. Q (SUS)		-22.1	22.1	15.0	-15.0	-257.6	257.6	148.8	-148.8

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Nozzle Calcs.: T1 Nozl: 20 11:47am Dec 23,2021

Long. Pm (SUS)	57.5	57.5	57.5	57.5	57.5	57.5	57.5	57.5
Long. Pl (SUS)	-20.4	-20.4	14.7	14.7	-60.1	-60.1	43.9	43.9
Long. Q (SUS)	-39.7	39.7	22.3	-22.3	-109.3	109.3	53.5	-53.5
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.4	1.4	-1.4	-1.4	-1.4	-1.4	1.4	1.4
Shear Q (SUS)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Pm (SUS)	115.0	117.3	115.0	117.3	115.0	117.3	115.0	117.3
Pm+Pl (SUS)	79.5	81.8	134.4	136.8	103.7	106.0	123.4	125.7
Pm+Pl+Q (Total)	61.2	105.3	149.7	121.9	156.7	361.0	272.4	72.2

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	117.34	137.90	Passed
Pm+Pl (SUS)	136.76	206.85	Passed
Pm+Pl+Q (TOTAL)	361.00	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.*

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Nozzle Calcs.: D4 Nozl: 21 11:47am Dec 23,2021

Input, Nozzle Desc: ~~D4~~ D2 From: 60

Pressure for Reinforcement Calculations	P	23.051	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cone at Nozzle Location	D	1419.76	mm.
Equivalent Length of Conical Section	Le	5217.9990	mm.
Cone Half Apex Angle	Alpha	28.78	Degrees
Shell Finished (Minimum) Thickness	t	20.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1915.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	20.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

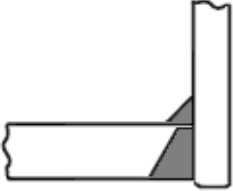
**Nozzle Sketch (may not represent actual weld type/configuration)**

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Nozzle Calcs.: D4 Nozl: 21 11:47am Dec 23,2021



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: D4**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation 2.000 in.  
 Actual Thickness Used in Calculation 0.654 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Conical Transition, Tr [Int. Press]  
 =  $(P \cdot D) / (2 \cdot \cos(a) \cdot (S_v \cdot E - 0.6 \cdot P))$  Appendix 1-4(e)  
 =  $(23.05 \cdot (1426.605 + 2 \cdot 0.0)) / (2 \cdot 0.8764 \cdot (138 \cdot 1.0 - 0.6 \cdot 23.05))$   
 = 13.7432 mm.

Reqd Cone thickness at Nozzle Location under External Pres. : 11.6968 mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 =  $(P \cdot R) / (S_n \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.05 \cdot 28.4) / (138 \cdot 1.0 - 0.6 \cdot 23.05)$   
 = 0.4796 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	D1	118.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	59.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	mm.

**Weld Strength Reduction Factor [fr1]:**

= min( 1, Sn/Sv )  
 = min( 1, 137.9/137.9 )  
 = 1.000

**Weld Strength Reduction Factor [fr2]:**

= min( 1, Sn/Sv )  
 = min( 1, 137.9/137.9 )  
 = 1.000

**Weld Strength Reduction Factor [fr3]:**

= min( fr2, fr4 )  
 = min( 1.0, 1.0 )  
 = 1.000

**Results of Nozzle Reinforcement Area Calculations: (cm^2)**

AREA AVAILABLE, A1 to A5 | Design | External | Mapnc |

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Nozzle Calcs.: D4 Nozl: 21 11:47am Dec 23,2021

Area Required	Ar	7.806	2.470	NA
Area in Shell	A1	1.993	5.082	NA
Area in Nozzle Wall	A2	8.922	9.015	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	11.915	15.096	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)} \\
 &= ( 56.8 * 13.7432 * 1.0 + 2 * 13.6 * 13.7432 * 1.0 * (1 - 1.0) ) \\
 &= 7.806 \text{ cm}^2
 \end{aligned}$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 61.2( 1.0 * 17.0 - 1.0 * 13.743 ) - 2 * 13.6 \\
 &\quad ( 1.0 * 17.0 - 1.0 * 13.7432 ) * ( 1 - 1.0 ) \\
 &= 1.993 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp )( tn - trn ) fr2 \\
 &= ( 2 * 34.0 )( 13.6 - 0.48 ) 1.0 \\
 &= 8.922 \text{ cm}^2
 \end{aligned}$$

Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2 \\
 &= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0 \\
 &= 1.000 \text{ cm}^2
 \end{aligned}$$

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

Wall Thickness for Internal/External pressures	ta = 3.4796 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 16.7432 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 16.7432 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6107 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 7.8000 mm.

Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 7.8, \max( 16.7432, 4.5 ) ] \\
 &= 7.8000 \text{ mm.}
 \end{aligned}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$\begin{aligned}
 &= \max( ta, tb ) \\
 &= \max( 3.4796, 7.8 ) \\
 &= 7.8000 \text{ mm.}
 \end{aligned}$$

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

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 Nozzle Calcs.: D4 Nozl: 21 11:47am Dec 23,2021

-----  
**Note:**

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C  
 Calculated Minimum Design Metal Temperature -104 °C  
 Governing MDMT of all the sub-joints of this Junction : -104 °C

**Weld Size Calculations, Description: D4**

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 mm.

**Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

**Weld Load [W]:**

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (7.8061 - 1.9932 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 17.0 - 13.7432) )138) \\
 &= 92.37 \text{ kN}
 \end{aligned}$$

**Note:** F is always set to 1.0 throughout the calculation.

**Weld Load [W1]:**

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.9219 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 136.81 \text{ kN}
 \end{aligned}$$

**Weld Load [W2]:**

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.9219 + 0.0 + 1. + ( 4.624 ) ) * 138 \\
 &= 200.57 \text{ kN}
 \end{aligned}$$

**Weld Load [W3]:**

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.9219 + 0.0 + 1. + 0.0 + ( 4.624 ) ) * 138 \\
 &= 200.57 \text{ kN}
 \end{aligned}$$

**Strength of Connection Elements for Failure Path Analysis**

**Shear, Outward Nozzle Weld [Sonw]:**

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138 \\
 &= 89. \text{ kN}
 \end{aligned}$$

**Shear, Nozzle Wall [Snw]:**

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= ( 3.1416 * 35.2 ) * ( 16.6 - 3.0 ) * 0.7 * 138 \\
 &= 145. \text{ kN}
 \end{aligned}$$

**Tension, Shell Groove Weld [Tngw]:**

$$\begin{aligned}
 &= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng \\
 &= ( 3.1416/2.0 ) * 84.0 * ( 20.0 - 3.0 ) * 0.74 * 138 \\
 &= 229. \text{ kN}
 \end{aligned}$$

**Strength of Failure Paths:**

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 Nozzle Calcs.: D4 Noz1: 21 11:47am Dec 23,2021

PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 89 + 0 + 229 + 0 ) = 318 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 89 + 229 + 0 ) = 318 kN

**Summary of Failure Path Calculations:**

Path 1-1 = 234 kN , must exceed W = 92 kN or W1 = 136 kN  
 Path 2-2 = 318 kN , must exceed W = 92 kN or W2 = 200 kN  
 Path 3-3 = 318 kN , must exceed W = 92 kN or W3 = 200 kN

**Maximum Allowable Pressure for this Nozzle at this Location:**

Converged Max. Allow. Pressure in Operating case 24.381 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 1.2436 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 171.2436 mm.

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Nozzle Calcs.: S2 Nozl: 22 11:47am Dec 23,2021

**Input, Nozzle Desc: S2 From: 70**

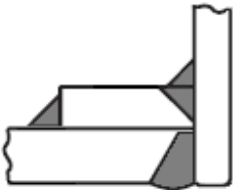
Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516	70
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2545.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-333	6
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		8.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350	LF2
Flange Type		Weld Neck	Flange
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516	70
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	379.0750	mm.
Thickness of Pad	te	18.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	18.0000	mm.
Reinforcing Pad Width		80.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle With Pad, no Inside projection**

**Reinforcement CALCULATION, Description: S2**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	8.625 in.
Actual Thickness Used in Calculation	0.438 in.

Nozzle input data check completed without errors.

Req'd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 $= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 $= (23.12 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.12)$   
 $= 14.0733 \text{ mm.}$

Req'd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 $= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 $= (23.12 \cdot 109.5375) / (118 \cdot 1.0 + 0.4 \cdot 23.12)$   
 $= 2.1311 \text{ mm.}$

Required Nozzle thickness under External Pressure per UG-28 : 0.5985 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	D1	405.7000	mm.
Parallel to Vessel Wall, opening length	d	202.8500	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		37.5000	mm.

Weld Strength Reduction Factor [fr1]:  
 $= \min( 1, S_n / S_v )$   
 $= \min( 1, 117.9 / 137.9 )$   
 $= 0.855$

Weld Strength Reduction Factor [fr2]:  
 $= \min( 1, S_n / S_v )$   
 $= \min( 1, 117.9 / 137.9 )$   
 $= 0.855$

Weld Strength Reduction Factor [fr4]:  
 $= \min( 1, S_p / S_v )$   
 $= \min( 1, 137.9 / 137.9 )$   
 $= 1.000$

Weld Strength Reduction Factor [fr3]:

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Nozzle Calcs.: S2 Nozl: 22 11:47am Dec 23,2021

= min( fr2, fr4 )  
 = min( 0.855, 1.0 )  
 = 0.855

#### Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	28.879	8.910	NA
Area in Shell	A1	1.858	12.663	NA
Area in Nozzle Wall	A2	3.836	4.818	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		2.810	2.810	NA
Area in Element	A5	28.800	28.800	NA
TOTAL AREA AVAILABLE	Atot	37.304	49.092	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.

The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS: Diameter Thickness  
 Based on given Pad Thickness: 332.2690 18.0000 mm.  
 Based on given Pad Diameter: 379.0750 12.7343 mm.  
 Based on Shell or Nozzle Thickness: 402.4264 11.1125 mm.

Area Required [A]:

= ( d \* tr\*F + 2 \* tn \* tr\*F \* (1-fr1) ) UG-37(c)  
 = ( 202.85\*14.0733\*1.0+2\*8.1125\*14.0733\*1.0\*(1-0.86) )  
 = 28.879 cm<sup>2</sup>

#### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

= d( E1\*t - F\*tr ) - 2 \* tn( E1\*t - F\*tr ) \* ( 1 - fr1 )  
 = 202.85( 1.0 \* 15.0 - 1.0 \* 14.073 ) - 2 \* 8.113  
 ( 1.0 \* 15.0 - 1.0 \* 14.0733 ) \* ( 1 - 0.855 )  
 = 1.858 cm<sup>2</sup>

Area Available in Nozzle Wall Projecting Outward [A2]:

= ( 2 \* Tlwp ) \* ( tn - trn ) \* fr2  
 = ( 2 \* 37.5 ) \* ( 8.11 - 2.13 ) \* 0.855  
 = 3.836 cm<sup>2</sup>

Area Available in Welds [A41 + A42 + A43]:

= (Wo<sup>2</sup> - Ar Lost)\*Fr3+((Wi-can/0.707)<sup>2</sup> - Ar Lost)\*fr2 + Trapfr4  
 = ( 1. ) \* 0.86 + (0.0 ) \* 0.86 + 195.5274<sup>2</sup> \* 1.0  
 = 2.810 cm<sup>2</sup>

Area Available in Element [A5]:

= (min(Dp,DL)-(Nozzle OD))\*(min(tp,Tlwp,te)) \* fr4  
 = ( 379.075 - 219.075 ) \* 18.0 \* 1.0  
 = 28.800 cm<sup>2</sup>

#### UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

Wall Thickness for Internal/External pressures ta = 5.1311 mm.  
 Wall Thickness per UG16(b), tr16b = 4.5000 mm.  
 Wall Thickness, shell/head, internal pressure trb1 = 17.0733 mm.  
 Wall Thickness tbl = max(trb1, tr16b) = 17.0733 mm.

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Wall Thickness, shell/head, external pressure trb2 = 3.6235 mm.  
 Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.  
 Wall Thickness per table UG-45 tb3 = 10.1600 mm.

Determine Nozzle Thickness candidate [tb]:

= min[ tb3, max( tb1, tb2 ) ]  
 = min[ 10.16, max( 17.0733, 4.5 ) ]  
 = 10.1600 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

= max( ta, tb )  
 = max( 5.1311, 10.16 )  
 = 10.1600 mm.

Available Nozzle Neck Thickness = 11.1125 mm. --> OK

### Stresses on Nozzle due to External and Pressure Loads per the ASME

#### B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	:	50.5,	Allowable	:	117.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	244.2 N./mm <sup>2</sup>	Passed
Occasional	:	13.9,	Allowable	:	156.8 N./mm <sup>2</sup>	Passed
Shear	:	20.4,	Allowable	:	82.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

### Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

#### Nozzle Neck to Flange Weld (Impact tested) :

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

#### Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

#### Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D

Govrn. thk, tg = 11.113, tr = 2.131, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.263$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C

Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

#### Shell to Pad Weld Junction at Pad OD, Curve: D

Govrn. thk, tg = 18.0, tr = 14.073, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.938$ , Temp. Reduction = 3 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -43 °C

Min Metal Temp. at Required thickness (UCS 66.1) -46 °C

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**Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :**  
 -----

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C
Governing MDMT of the Nozzle	: -104 °C
Governing MDMT of the Reinforcement Pad	: -46 °C
Governing MDMT of all the sub-joints of this Junction	: -46 °C

**ANSI Flange MDMT including Temperature reduction per UCS-66.1:**

MDMT of ANSI B16.5/47 flange per Matl. Specification	-46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)	-85 °C
Flange MDMT with Temp reduction per UCS-66(i)(3)	-104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

Design Pressure/Ambient Rating = 23.12/51.10 = 0.452

*Note:*

*Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.*

**Weld Size Calculations, Description: S2**

Intermediate Calc. for nozzle/shell Welds	Tmin	8.1125 mm.
Intermediate Calc. for pad/shell Welds	TminPad	15.0000 mm.

**Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	5.6788 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm.
Pad Weld	7.5000 = 0.5*TminPad	9.8980 = 0.7 * Wp mm.

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

**Weld Load [W]:**

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (28.8788 - 1.858 + 2 * 8.1125 * 0.855 * \\
 &\quad (1.0 * 15.0 - 14.0733) )138) \\
 &= 374.36 \text{ kN}
 \end{aligned}$$

*Note: F is always set to 1.0 throughout the calculation.*

**Weld Load [W1]:**

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 3.8356 + 28.8 + 2.8103 - 0.0 * 0.86 ) * 138 \\
 &= 488.76 \text{ kN}
 \end{aligned}$$

**Weld Load [W2]:**

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 3.8356 + 0.0 + 0.855 + ( 2.0809 ) ) * 138 \\
 &= 93.37 \text{ kN}
 \end{aligned}$$

**Weld Load [W3]:**

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 3.8356 + 0.0 + 2.8103 + 28.8 + ( 2.0809 ) ) * 138 \\
 &= 517.45 \text{ kN}
 \end{aligned}$$

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### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$= (\pi/2) * D_{lo} * W_o * 0.49 * S_{nw}$$

$$= ( 3.1416/2.0 ) * 219.075 * 10.0 * 0.49 * 118$$

$$= 199. \text{ kN}$$

Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * D_P * W_P * 0.49 * S_{EW}$$

$$= ( 3.1416/2.0 ) * 379.075 * 14.0 * 0.49 * 138$$

$$= 563. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * ( D_{lr} + D_{lo} ) / 4 ) * ( Thk - Can ) * 0.7 * S_n$$

$$= ( 3.1416 * 105.4813 ) * ( 11.1125 - 3.0 ) * 0.7 * 118$$

$$= 222. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= ( \pi/2 ) * D_{lo} * W_{gpn} * 0.74 * S_{eg}$$

$$= ( 3.1416/2 ) * 219.075 * 18.0 * 0.74 * 138$$

$$= 632. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * D_{lo} * (W_{gnvi-Cas}) * 0.74 * S_{ng}$$

$$= ( 3.1416/2.0 ) * 219.075 * ( 18.0 - 3.0 ) * 0.74 * 138$$

$$= 527. \text{ kN}$$

### Strength of Failure Paths:

$$\text{PATH11} = ( \text{SPEW} + \text{SNW} ) = ( 563 + 222 ) = 785 \text{ kN}$$

$$\text{PATH22} = ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} )$$

$$= ( 199 + 632 + 527 + 0 ) = 1358 \text{ kN}$$

$$\text{PATH33} = ( \text{Spew} + \text{Tngw} + \text{Sinw} )$$

$$= ( 563 + 527 + 0 ) = 1090 \text{ kN}$$

### Summary of Failure Path Calculations:

Path 1-1 = 785 kN , must exceed W = 374 kN or W1 = 488 kN  
 Path 2-2 = 1357 kN , must exceed W = 374 kN or W2 = 93 kN  
 Path 3-3 = 1089 kN , must exceed W = 374 kN or W3 = 517 kN

### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 24.623 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 7.2775 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 175.2774 mm.

### Input Echo, WRC107/537 Item 1, Description: S2 :

Diameter Basis for Vessel	Vbasis	ID
Cylindrical or Spherical Vessel	Cylsph	Cylindrical
Internal Corrosion Allowance	Cas	3.0000 mm.
Vessel Diameter	Dv	1656.000 mm.
Vessel Thickness	Tv	18.000 mm.
Design Temperature	T1	125.0 °C
Vessel Material		SA-516 70
Vessel UNS Number		K02700

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Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>

Note:

Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	219.075	mm.
Nozzle Thickness	Tn	11.113	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm <sup>2</sup>
Thickness of Reinforcing Pad	Tpad	18.000	mm.
Diameter of Reinforcing Pad	Dpad	379.075	mm.
Design Internal Pressure	Dp	23.118	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

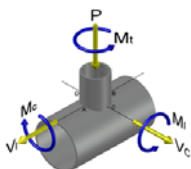
Radial Load (SUS)	P	8.0	kN
Longitudinal Shear (SUS)	Vl	8.0	kN
Circumferential Shear (SUS)	Vc	8.0	kN
Circumferential Moment (SUS)	Mc	6800.0	N-m
Longitudinal Moment (SUS)	Ml	6800.0	N-m
Torsional Moment (SUS)	Mt	8400.0	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

Note:

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:

$$\begin{aligned}
 &= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) ) \\
 &= 219.075 + 2 * 1.65 * \text{sqrt}( 838.5 ( 18.0 - 3.0 ) ) \\
 &= 589.168 \text{ mm.}
 \end{aligned}$$

WRC 107 Stress Calculation for SUSTained loads:





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Nozzle Calcs.: S2 Noz1: 22 11:47am Dec 23,2021

Tot. Shear	3.4	3.4	1.6	1.6	1.6	1.6	3.4	3.4
Str. Int.	55.3	33.5	28.8	14.0	99.4	79.6	66.1	57.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		57.1	59.4	57.1	59.4	57.1	59.4	57.1	59.4
Circ. Pl (SUS)		-7.6	-7.6	5.0	5.0	-3.0	-3.0	0.7	0.7
Circ. Q (SUS)		-22.7	22.7	14.2	-14.2	-44.2	44.2	32.4	-32.4
Long. Pm (SUS)		28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5
Long. Pl (SUS)		-2.9	-2.9	0.6	0.6	-3.9	-3.9	1.3	1.3
Long. Q (SUS)		-36.7	36.7	24.7	-24.7	-25.5	25.5	16.9	-16.9
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.7	0.7	-0.7	-0.7	-0.7	-0.7	0.7	0.7
Shear Q (SUS)		3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Pm (SUS)		57.1	59.4	57.1	59.4	57.1	59.4	57.1	59.4
Pm+Pl (SUS)		49.5	51.8	62.1	64.4	54.1	56.4	57.8	60.1
Pm+Pl+Q (Total)		38.7	75.8	76.5	50.3	12.1	100.7	90.6	28.7

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	59.40	137.90	Passed
Pm+Pl (SUS)	64.36	206.85	Passed
Pm+Pl+Q (TOTAL)	100.73	413.70	Passed

Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl (SUS)		-21.6	-21.6	12.3	12.3	-9.9	-9.9	4.4	4.4
Circ. Q (SUS)		-28.0	28.0	16.1	-16.1	-89.5	89.5	61.4	-61.4
Long. Pm (SUS)		63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl (SUS)		-10.1	-10.1	4.5	4.5	-19.7	-19.7	10.4	10.4
Long. Q (SUS)		-43.2	43.2	18.3	-18.3	-42.1	42.1	27.6	-27.6

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Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.9	0.9	-0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q (SUS)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2	129.2
Pm+Pl (SUS)	105.3	107.6	139.3	141.6	117.1	119.4	131.3	133.6	
Pm+Pl+Q (Total)	77.5	135.9	155.4	125.5	27.7	208.8	192.8	72.7	

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	141.57	206.85	Passed
Pm+Pl+Q (TOTAL)	208.84	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.*

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**Input, Nozzle Desc: S1 From: 70**

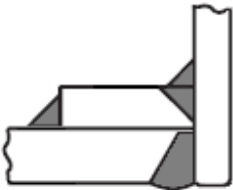
Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516	70
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		5145.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-333	6
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		8.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350	LF2
Flange Type		Weld Neck	Flange
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516	70
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	379.0750	mm.
Thickness of Pad	te	18.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	18.0000	mm.
Reinforcing Pad Width		80.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle With Pad, no Inside projection**

**Reinforcement CALCULATION, Description: S1**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	8.625 in.
Actual Thickness Used in Calculation	0.438 in.

Nozzle input data check completed without errors.

Req'd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 $= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 $= (23.12 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.12)$   
 $= 14.0733 \text{ mm.}$

Req'd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 $= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 $= (23.12 \cdot 109.5375) / (118 \cdot 1.0 + 0.4 \cdot 23.12)$   
 $= 2.1311 \text{ mm.}$

Required Nozzle thickness under External Pressure per UG-28 : 0.5985 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	D1	405.7000	mm.
Parallel to Vessel Wall, opening length	d	202.8500	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		37.5000	mm.

Weld Strength Reduction Factor [fr1]:  
 $= \min(1, S_n / S_v)$   
 $= \min(1, 117.9 / 137.9)$   
 $= 0.855$

Weld Strength Reduction Factor [fr2]:  
 $= \min(1, S_n / S_v)$   
 $= \min(1, 117.9 / 137.9)$   
 $= 0.855$

Weld Strength Reduction Factor [fr4]:  
 $= \min(1, S_p / S_v)$   
 $= \min(1, 137.9 / 137.9)$   
 $= 1.000$

Weld Strength Reduction Factor [fr3]:

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$$= \min( fr2, fr4 )$$

$$= \min( 0.855, 1.0 )$$

$$= 0.855$$

**Results of Nozzle Reinforcement Area Calculations: (cm^2)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	28.879	8.910	NA
Area in Shell	A1	1.858	12.663	NA
Area in Nozzle Wall	A2	3.836	4.818	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		2.810	2.810	NA
Area in Element	A5	28.800	28.800	NA
TOTAL AREA AVAILABLE	Atot	37.304	49.092	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.  
 The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness
Based on given Pad Thickness:	332.2690	18.0000 mm.
Based on given Pad Diameter:	379.0750	12.7343 mm.
Based on Shell or Nozzle Thickness:	402.4264	11.1125 mm.

Area Required [A]:

$$= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)}$$

$$= ( 202.85 * 14.0733 * 1.0 + 2 * 8.1125 * 14.0733 * 1.0 * (1 - 0.86) )$$

$$= 28.879 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:

$$= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 )$$

$$= 202.85( 1.0 * 15.0 - 1.0 * 14.073 ) - 2 * 8.113$$

$$( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 0.855 )$$

$$= 1.858 \text{ cm}^2$$

Area Available in Nozzle Wall Projecting Outward [A2]:

$$= ( 2 * Tlwp ) * ( tn - trn ) * fr2$$

$$= ( 2 * 37.5 ) * ( 8.11 - 2.13 ) * 0.855$$

$$= 3.836 \text{ cm}^2$$

Area Available in Welds [A41 + A42 + A43]:

$$= ( Wo^2 - Ar \text{ Lost} ) * Fr3 + ( ( Wi - can / 0.707 )^2 - Ar \text{ Lost} ) * fr2 + Trapfr4$$

$$= ( 1. ) * 0.86 + ( 0.0 ) * 0.86 + 195.5274^2 * 1.0$$

$$= 2.810 \text{ cm}^2$$

Area Available in Element [A5]:

$$= ( \min( Dp, DL ) - ( \text{Nozzle OD} ) ) * ( \min( tp, Tlwp, te ) ) * fr4$$

$$= ( 379.075 - 219.075 ) * 18.0 * 1.0$$

$$= 28.800 \text{ cm}^2$$

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**

Wall Thickness for Internal/External pressures	ta = 5.1311 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0733 mm.
Wall Thickness	tbl = max(trb1, tr16b) = 17.0733 mm.

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Wall Thickness, shell/head, external pressure trb2 = 3.6235 mm.  
 Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.  
 Wall Thickness per table UG-45 tb3 = 10.1600 mm.

Determine Nozzle Thickness candidate [tb]:  
 = min[ tb3, max( tb1, tb2) ]  
 = min[ 10.16, max( 17.0733, 4.5 ) ]  
 = 10.1600 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 5.1311, 10.16 )  
 = 10.1600 mm.

Available Nozzle Neck Thickness = 11.1125 mm. --> OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME  
 B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	: 50.5,	Allowable	: 117.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0,	Allowable	: 244.2 N./mm <sup>2</sup>	Passed
Occasional	: 13.9,	Allowable	: 156.8 N./mm <sup>2</sup>	Passed
Shear	: 20.4,	Allowable	: 82.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

**Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:**

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C

**Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D**

Govrn. thk, tg = 11.113, tr = 2.131, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.263, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-48 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C

**Shell to Pad Weld Junction at Pad OD, Curve: D**

Govrn. thk, tg = 18.0, tr = 14.073, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.938, Temp. Reduction = 3 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-43 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-46 °C

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**Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :**  
 -----

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C
Governing MDMT of the Nozzle	: -104 °C
Governing MDMT of the Reinforcement Pad	: -46 °C
Governing MDMT of all the sub-joints of this Junction	: -46 °C

**ANSI Flange MDMT including Temperature reduction per UCS-66.1:**

MDMT of ANSI B16.5/47 flange per Matl. Specification	-46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)	-85 °C
Flange MDMT with Temp reduction per UCS-66(i)(3)	-104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

Design Pressure/Ambient Rating = 23.12/51.10 = 0.452

*Note:*

*Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.*

**Weld Size Calculations, Description: S1**

Intermediate Calc. for nozzle/shell Welds	Tmin	8.1125 mm.
Intermediate Calc. for pad/shell Welds	TminPad	15.0000 mm.

**Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	5.6788 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm.
Pad Weld	7.5000 = 0.5*TminPad	9.8980 = 0.7 * Wp mm.

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

**Weld Load [W]:**

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (28.8788 - 1.858 + 2 * 8.1125 * 0.855 * \\
 &\quad (1.0 * 15.0 - 14.0733) )138) \\
 &= 374.36 \text{ kN}
 \end{aligned}$$

*Note: F is always set to 1.0 throughout the calculation.*

**Weld Load [W1]:**

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 3.8356 + 28.8 + 2.8103 - 0.0 * 0.86 ) * 138 \\
 &= 488.76 \text{ kN}
 \end{aligned}$$

**Weld Load [W2]:**

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 3.8356 + 0.0 + 0.855 + ( 2.0809 ) ) * 138 \\
 &= 93.37 \text{ kN}
 \end{aligned}$$

**Weld Load [W3]:**

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 3.8356 + 0.0 + 2.8103 + 28.8 + ( 2.0809 ) ) * 138 \\
 &= 517.45 \text{ kN}
 \end{aligned}$$

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### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$= (\pi/2) * D_{lo} * W_o * 0.49 * S_{nw}$$

$$= (3.1416/2.0) * 219.075 * 10.0 * 0.49 * 118$$

$$= 199. \text{ kN}$$

Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * D_P * W_P * 0.49 * S_{EW}$$

$$= (3.1416/2.0) * 379.075 * 14.0 * 0.49 * 138$$

$$= 563. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * (D_{lr} + D_{lo}) / 4) * (Thk - Can) * 0.7 * S_n$$

$$= (3.1416 * 105.4813) * (11.1125 - 3.0) * 0.7 * 118$$

$$= 222. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * D_{lo} * W_{gpn} * 0.74 * S_{eg}$$

$$= (3.1416/2) * 219.075 * 18.0 * 0.74 * 138$$

$$= 632. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * D_{lo} * (W_{gnvi-Cas}) * 0.74 * S_{ng}$$

$$= (3.1416/2.0) * 219.075 * (18.0 - 3.0) * 0.74 * 138$$

$$= 527. \text{ kN}$$

### Strength of Failure Paths:

$$\text{PATH11} = (S_{PEW} + S_{NW}) = (563 + 222) = 785 \text{ kN}$$

$$\text{PATH22} = (S_{onw} + T_{pgw} + T_{ngw} + S_{inw})$$

$$= (199 + 632 + 527 + 0) = 1358 \text{ kN}$$

$$\text{PATH33} = (S_{pew} + T_{ngw} + S_{inw})$$

$$= (563 + 527 + 0) = 1090 \text{ kN}$$

### Summary of Failure Path Calculations:

Path 1-1 = 785 kN , must exceed W = 374 kN or W1 = 488 kN  
 Path 2-2 = 1357 kN , must exceed W = 374 kN or W2 = 93 kN  
 Path 3-3 = 1089 kN , must exceed W = 374 kN or W3 = 517 kN

### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 24.623 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 7.2775 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 175.2774 mm.

### Input Echo, WRC107/537 Item 1, Description: S1 :

Diameter Basis for Vessel	Vbasis	ID
Cylindrical or Spherical Vessel	Cylsph	Cylindrical
Internal Corrosion Allowance	Cas	3.0000 mm.
Vessel Diameter	Dv	1656.000 mm.
Vessel Thickness	Tv	18.000 mm.
Design Temperature	T1	125.0 °C
Vessel Material		SA-516 70
Vessel UNS Number		K02700

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Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>

Note:

Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	219.075	mm.
Nozzle Thickness	Tn	11.113	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm <sup>2</sup>
Thickness of Reinforcing Pad	Tpad	18.000	mm.
Diameter of Reinforcing Pad	Dpad	379.075	mm.
Design Internal Pressure	Dp	23.118	bars
Include Pressure Thrust		No	

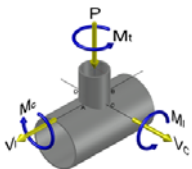
External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	8.0	kN
Longitudinal Shear (SUS)	Vl	8.0	kN
Circumferential Shear (SUS)	Vc	8.0	kN
Circumferential Moment (SUS)	Mc	6800.0	N-m
Longitudinal Moment (SUS)	Ml	6800.0	N-m
Torsional Moment (SUS)	Mt	8400.0	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979
Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

Note:

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:

$$\begin{aligned}
 &= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) ) \\
 &= 219.075 + 2 * 1.65 * \text{sqrt}( 838.5 ( 18.0 - 3.0 ) ) \\
 &= 589.168 \text{ mm.}
 \end{aligned}$$

WRC 107 Stress Calculation for SUSTained loads:





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Nozzle Calcs.: S1 Noz1: 23 11:47am Dec 23,2021

Tot. Shear	3.4	3.4	1.6	1.6	1.6	1.6	3.4	3.4
Str. Int.	55.3	33.5	28.8	14.0	99.4	79.6	66.1	57.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		57.1	59.4	57.1	59.4	57.1	59.4	57.1	59.4
Circ. Pl (SUS)		-7.6	-7.6	5.0	5.0	-3.0	-3.0	0.7	0.7
Circ. Q (SUS)		-22.7	22.7	14.2	-14.2	-44.2	44.2	32.4	-32.4
Long. Pm (SUS)		28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5
Long. Pl (SUS)		-2.9	-2.9	0.6	0.6	-3.9	-3.9	1.3	1.3
Long. Q (SUS)		-36.7	36.7	24.7	-24.7	-25.5	25.5	16.9	-16.9
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.7	0.7	-0.7	-0.7	-0.7	-0.7	0.7	0.7
Shear Q (SUS)		3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Pm (SUS)		57.1	59.4	57.1	59.4	57.1	59.4	57.1	59.4
Pm+Pl (SUS)		49.5	51.8	62.1	64.4	54.1	56.4	57.8	60.1
Pm+Pl+Q (Total)		38.7	75.8	76.5	50.3	12.1	100.7	90.6	28.7

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	59.40	137.90	Passed
Pm+Pl (SUS)	64.36	206.85	Passed
Pm+Pl+Q (TOTAL)	100.73	413.70	Passed

Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl (SUS)		-21.6	-21.6	12.3	12.3	-9.9	-9.9	4.4	4.4
Circ. Q (SUS)		-28.0	28.0	16.1	-16.1	-89.5	89.5	61.4	-61.4
Long. Pm (SUS)		63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl (SUS)		-10.1	-10.1	4.5	4.5	-19.7	-19.7	10.4	10.4
Long. Q (SUS)		-43.2	43.2	18.3	-18.3	-42.1	42.1	27.6	-27.6

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Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.9	0.9	-0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q (SUS)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2	129.2
Pm+Pl (SUS)	105.3	107.6	139.3	141.6	117.1	119.4	131.3	133.6	
Pm+Pl+Q (Total)	77.5	135.9	155.4	125.5	27.7	208.8	192.8	72.7	

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	141.57	206.85	Passed
Pm+Pl+Q (TOTAL)	208.84	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.*

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**Input, Nozzle Desc: S3 From: 70**

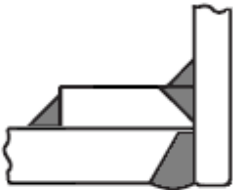
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2945.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		8.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	379.0750	mm.
Thickness of Pad	te	18.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	18.0000	mm.
Reinforcing Pad Width		80.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle With Pad, no Inside projection**

**Reinforcement CALCULATION, Description: S3**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	8.625 in.
Actual Thickness Used in Calculation	0.438 in.

Nozzle input data check completed without errors.

Req'd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 $= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 $= (23.0 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$   
 $= 14.0010 \text{ mm.}$

Req'd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 $= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 $= (23.0 \cdot 109.5375) / (118 \cdot 1.0 + 0.4 \cdot 23.0)$   
 $= 2.1204 \text{ mm.}$

Required Nozzle thickness under External Pressure per UG-28 : 0.5985 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	D1	405.7000	mm.
Parallel to Vessel Wall, opening length	d	202.8500	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		37.5000	mm.

Weld Strength Reduction Factor [fr1]:  
 $= \min( 1, S_n / S_v )$   
 $= \min( 1, 117.9 / 137.9 )$   
 $= 0.855$

Weld Strength Reduction Factor [fr2]:  
 $= \min( 1, S_n / S_v )$   
 $= \min( 1, 117.9 / 137.9 )$   
 $= 0.855$

Weld Strength Reduction Factor [fr4]:  
 $= \min( 1, S_p / S_v )$   
 $= \min( 1, 137.9 / 137.9 )$   
 $= 1.000$

Weld Strength Reduction Factor [fr3]:

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= min( fr2, fr4 )  
 = min( 0.855, 1.0 )  
 = 0.855

#### Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	28.730	8.910	NA
Area in Shell	A1	2.003	12.663	NA
Area in Nozzle Wall	A2	3.842	4.818	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		2.810	2.810	NA
Area in Element	A5	28.800	28.800	NA
TOTAL AREA AVAILABLE	Atot	37.456	49.092	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.

The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS: Diameter Thickness  
 Based on given Pad Thickness: 330.6005 18.0000 mm.  
 Based on given Pad Diameter: 379.0750 12.5466 mm.  
 Based on Shell or Nozzle Thickness: 399.7238 11.1125 mm.

Area Required [A]:

= ( d \* tr\*F + 2 \* tn \* tr\*F \* (1-fr1) ) UG-37(c)  
 = ( 202.85\*14.001\*1.0+2\*8.1125\*14.001\*1.0\*(1-0.86) )  
 = 28.730 cm<sup>2</sup>

#### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

= d( E1\*t - F\*tr ) - 2 \* tn( E1\*t - F\*tr ) \* ( 1 - fr1 )  
 = 202.85( 1.0 \* 15.0 - 1.0 \* 14.001 ) - 2 \* 8.113  
 ( 1.0 \* 15.0 - 1.0 \* 14.001 ) \* ( 1 - 0.855 )  
 = 2.003 cm<sup>2</sup>

Area Available in Nozzle Wall Projecting Outward [A2]:

= ( 2 \* Tlwp ) \* ( tn - trn ) \* fr2  
 = ( 2 \* 37.5 ) \* ( 8.11 - 2.12 ) \* 0.855  
 = 3.842 cm<sup>2</sup>

Area Available in Welds [A41 + A42 + A43]:

= (Wo<sup>2</sup> - Ar Lost)\*Fr3+((Wi-can/0.707)<sup>2</sup> - Ar Lost)\*fr2 + Trapfr4  
 = ( 1. ) \* 0.86 + (0.0 ) \* 0.86 + 195.5274<sup>2</sup> \* 1.0  
 = 2.810 cm<sup>2</sup>

Area Available in Element [A5]:

= (min(Dp,DL)-(Nozzle OD))\*(min(tp,Tlwp,te)) \* fr4  
 = ( 379.075 - 219.075 ) \* 18.0 \* 1.0  
 = 28.800 cm<sup>2</sup>

#### UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

Wall Thickness for Internal/External pressures ta = 5.1204 mm.  
 Wall Thickness per UG16(b), tr16b = 4.5000 mm.  
 Wall Thickness, shell/head, internal pressure trb1 = 17.0010 mm.  
 Wall Thickness tbt = max(trb1, tr16b) = 17.0010 mm.

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Wall Thickness, shell/head, external pressure trb2 = 3.6235 mm.  
 Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.  
 Wall Thickness per table UG-45 tb3 = 10.1600 mm.

Determine Nozzle Thickness candidate [tb]:

= min[ tb3, max( tb1, tb2 ) ]  
 = min[ 10.16, max( 17.001, 4.5 ) ]  
 = 10.1600 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

= max( ta, tb )  
 = max( 5.1204, 10.16 )  
 = 10.1600 mm.

Available Nozzle Neck Thickness = 11.1125 mm. --> OK

### Stresses on Nozzle due to External and Pressure Loads per the ASME

#### B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	: 50.5,	Allowable	: 117.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0,	Allowable	: 244.3 N./mm <sup>2</sup>	Passed
Occasional	: 13.8,	Allowable	: 156.8 N./mm <sup>2</sup>	Passed
Shear	: 20.4,	Allowable	: 82.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

### Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

#### Nozzle Neck to Flange Weld (Impact tested) :

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

#### Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

#### Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D

Govrn. thk, tg = 11.113, tr = 2.12, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.261, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C

Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

#### Shell to Pad Weld Junction at Pad OD, Curve: D

Govrn. thk, tg = 18.0, tr = 14.001, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio = tr \* (E\*)/(tg - c) = 0.933, Temp. Reduction = 4 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -43 °C

Min Metal Temp. at Required thickness (UCS 66.1) -46 °C

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**Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :**  
 -----

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C
Governing MDMT of the Nozzle	: -104 °C
Governing MDMT of the Reinforcement Pad	: -46 °C
Governing MDMT of all the sub-joints of this Junction	: -46 °C

**ANSI Flange MDMT including Temperature reduction per UCS-66.1:**

MDMT of ANSI B16.5/47 flange per Matl. Specification	-46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)	-86 °C
Flange MDMT with Temp reduction per UCS-66(i)(3)	-104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

*Note:*

*Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.*

**Weld Size Calculations, Description: S3**

Intermediate Calc. for nozzle/shell Welds	Tmin	8.1125 mm.
Intermediate Calc. for pad/shell Welds	TminPad	15.0000 mm.

**Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	5.6788 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm.
Pad Weld	7.5000 = 0.5*TminPad	9.8980 = 0.7 * Wp mm.

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

**Weld Load [W]:**

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (28.7304 - 2.003 + 2 * 8.1125 * 0.855 * \\
 &\quad (1.0 * 15.0 - 14.001) )138) \\
 &= 370.45 \text{ kN}
 \end{aligned}$$

*Note: F is always set to 1.0 throughout the calculation.*

**Weld Load [W1]:**

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 3.8425 + 28.8 + 2.8103 - 0.0 * 0.86 ) * 138 \\
 &= 488.85 \text{ kN}
 \end{aligned}$$

**Weld Load [W2]:**

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 3.8425 + 0.0 + 0.855 + ( 2.0809 ) ) * 138 \\
 &= 93.47 \text{ kN}
 \end{aligned}$$

**Weld Load [W3]:**

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 3.8425 + 0.0 + 2.8103 + 28.8 + ( 2.0809 ) ) * 138 \\
 &= 517.54 \text{ kN}
 \end{aligned}$$

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### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$= (\pi/2) * D_{lo} * W_o * 0.49 * S_{nw}$$

$$= (3.1416/2.0) * 219.075 * 10.0 * 0.49 * 118$$

$$= 199. \text{ kN}$$

Shear, Pad Element Weld [Spew]:

$$= (\pi/2) * D_P * W_P * 0.49 * S_{EW}$$

$$= (3.1416/2.0) * 379.075 * 14.0 * 0.49 * 138$$

$$= 563. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * (D_{lr} + D_{lo}) / 4) * (Thk - Can) * 0.7 * S_n$$

$$= (3.1416 * 105.4813) * (11.1125 - 3.0) * 0.7 * 118$$

$$= 222. \text{ kN}$$

Tension, Pad Groove Weld [Tpgw]:

$$= (\pi/2) * D_{lo} * W_{gpn} * 0.74 * S_{eg}$$

$$= (3.1416/2) * 219.075 * 18.0 * 0.74 * 138$$

$$= 632. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * D_{lo} * (W_{gnvi-Cas}) * 0.74 * S_{ng}$$

$$= (3.1416/2.0) * 219.075 * (18.0 - 3.0) * 0.74 * 138$$

$$= 527. \text{ kN}$$

### Strength of Failure Paths:

$$\text{PATH11} = (S_{PEW} + S_{NW}) = (563 + 222) = 785 \text{ kN}$$

$$\text{PATH22} = (S_{onw} + T_{pgw} + T_{ngw} + S_{inw})$$

$$= (199 + 632 + 527 + 0) = 1358 \text{ kN}$$

$$\text{PATH33} = (S_{pew} + T_{ngw} + S_{inw})$$

$$= (563 + 527 + 0) = 1090 \text{ kN}$$

### Summary of Failure Path Calculations:

Path 1-1 = 785 kN , must exceed W = 370 kN or W1 = 488 kN  
 Path 2-2 = 1357 kN , must exceed W = 370 kN or W2 = 93 kN  
 Path 3-3 = 1089 kN , must exceed W = 370 kN or W3 = 517 kN

### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 24.506 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 7.2775 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 175.2774 mm.

### Input Echo, WRC107/537 Item 1, Description: S3 :

Diameter Basis for Vessel	Vbasis	ID
Cylindrical or Spherical Vessel	Cylsph	Cylindrical
Internal Corrosion Allowance	Cas	3.0000 mm.
Vessel Diameter	Dv	1656.000 mm.
Vessel Thickness	Tv	18.000 mm.
Design Temperature	T1	125.0 °C
Vessel Material		SA-516 70
Vessel UNS Number		K02700

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Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>

Note:

Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	219.075	mm.
Nozzle Thickness	Tn	11.113	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm <sup>2</sup>
Thickness of Reinforcing Pad	Tpad	18.000	mm.
Diameter of Reinforcing Pad	Dpad	379.075	mm.
Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

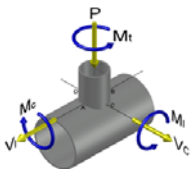
External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	8.0	kN
Longitudinal Shear (SUS)	Vl	8.0	kN
Circumferential Shear (SUS)	Vc	8.0	kN
Circumferential Moment (SUS)	Mc	6800.0	N-m
Longitudinal Moment (SUS)	Ml	6800.0	N-m
Torsional Moment (SUS)	Mt	8400.0	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979
Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

Note:

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:

$$\begin{aligned}
 &= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) ) \\
 &= 219.075 + 2 * 1.65 * \text{sqrt}( 838.5 ( 18.0 - 3.0 ) ) \\
 &= 589.168 \text{ mm.}
 \end{aligned}$$

WRC 107 Stress Calculation for SUSTained loads:





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Nozzle Calcs.: S3 Noz1: 24 11:47am Dec 23,2021

Tot. Shear	3.4	3.4	1.6	1.6	1.6	1.6	3.4	3.4
Str. Int.	55.3	33.5	28.8	14.0	99.4	79.6	66.1	57.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		56.8	59.1	56.8	59.1	56.8	59.1	56.8	59.1
Circ. Pl (SUS)		-7.6	-7.6	5.0	5.0	-3.0	-3.0	0.7	0.7
Circ. Q (SUS)		-22.7	22.7	14.2	-14.2	-44.2	44.2	32.4	-32.4
Long. Pm (SUS)		28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.4
Long. Pl (SUS)		-2.9	-2.9	0.6	0.6	-3.9	-3.9	1.3	1.3
Long. Q (SUS)		-36.7	36.7	24.7	-24.7	-25.5	25.5	16.9	-16.9
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.7	0.7	-0.7	-0.7	-0.7	-0.7	0.7	0.7
Shear Q (SUS)		3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Pm (SUS)		56.8	59.1	56.8	59.1	56.8	59.1	56.8	59.1
Pm+Pl (SUS)		49.2	51.5	61.8	64.1	53.8	56.1	57.5	59.8
Pm+Pl+Q (Total)		38.5	75.5	76.3	50.0	11.9	100.4	90.3	28.5

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	59.09	137.90	Passed
Pm+Pl (SUS)	64.06	206.85	Passed
Pm+Pl+Q (TOTAL)	100.43	413.70	Passed

Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl (SUS)		-21.6	-21.6	12.3	12.3	-9.9	-9.9	4.4	4.4
Circ. Q (SUS)		-28.0	28.0	16.1	-16.1	-89.5	89.5	61.4	-61.4
Long. Pm (SUS)		63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl (SUS)		-10.1	-10.1	4.5	4.5	-19.7	-19.7	10.4	10.4
Long. Q (SUS)		-43.2	43.2	18.3	-18.3	-42.1	42.1	27.6	-27.6

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Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.9	0.9	-0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q (SUS)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6	128.6
Pm+Pl (SUS)	104.7	107.0	138.6	140.9	116.4	118.7	130.7	133.0	133.0
Pm+Pl+Q (Total)	76.9	135.2	154.7	124.9	27.0	208.2	192.1	72.0	72.0

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.59	137.90	Passed
Pm+Pl (SUS)	140.91	206.85	Passed
Pm+Pl+Q (TOTAL)	208.18	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.*

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Nozzle Calcs.: D2 Noz1: 25 11:47am Dec 23,2021

**Input, Nozzle Desc: D2 From: 70**

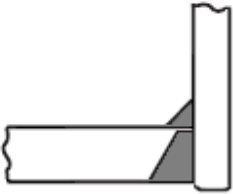
Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516	70
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2945.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-350	LF2
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350	LF2
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: D2**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation 2.000 in.  
 Actual Thickness Used in Calculation 0.654 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 =  $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.12 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.12)$   
 = 14.0733 mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 =  $(P \cdot R) / (S_n \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.12 \cdot 28.4) / (138 \cdot 1.0 - 0.6 \cdot 23.12)$   
 = 0.4810 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	Dl	114.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	57.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	mm.

Weld Strength Reduction Factor [fr1]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr2]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr3]:  
 =  $\min(fr2, fr4)$   
 =  $\min(1.0, 1.0)$   
 = 1.000

**Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.994	2.466	NA
Area in Shell	A1	0.530	3.613	NA

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Area in Nozzle Wall	A2	8.921	9.015	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	10.451	13.627	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)} \\
 &= ( 56.8 * 14.0733 * 1.0 + 2 * 13.6 * 14.0733 * 1.0 * (1 - 1.0) ) \\
 &= 7.994 \text{ cm}^2
 \end{aligned}$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 57.2( 1.0 * 15.0 - 1.0 * 14.073 ) - 2 * 13.6 \\
 &\quad ( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 1.0 ) \\
 &= 0.530 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp )( tn - trn ) fr2 \\
 &= ( 2 * 34.0 )( 13.6 - 0.48 ) 1.0 \\
 &= 8.921 \text{ cm}^2
 \end{aligned}$$

Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2 \\
 &= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0 \\
 &= 1.000 \text{ cm}^2
 \end{aligned}$$

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

Wall Thickness for Internal/External pressures	ta = 3.4810 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0733 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0733 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 7.8000 mm.

Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 7.8, \max( 17.0733, 4.5 ) ] \\
 &= 7.8000 \text{ mm.}
 \end{aligned}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$\begin{aligned}
 &= \max( ta, tb ) \\
 &= \max( 3.481, 7.8 ) \\
 &= 7.8000 \text{ mm.}
 \end{aligned}$$

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME

B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	: 14.9,	Allowable	: 137.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0,	Allowable	: 329.9 N./mm <sup>2</sup>	Passed
Occasional	: 1.9,	Allowable	: 183.4 N./mm <sup>2</sup>	Passed

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Shear : 9.6, Allowable : 96.5 N./mm<sup>2</sup> Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

### Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

#### Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C  
 Calculated Minimum Design Metal Temperature -104 °C  
 Governing MDMT of all the sub-joints of this Junction : -104 °C

#### Weld Size Calculations, Description: D2

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.

#### Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

##### Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv ) \\
 &= \max( 0, (7.9936 - 0.5301 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 15.0 - 14.0733 ) )138 ) \\
 &= 106.39 \text{ kN}
 \end{aligned}$$

*Note: F is always set to 1.0 throughout the calculation.*

##### Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.9209 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 136.80 \text{ kN}
 \end{aligned}$$

##### Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.9209 + 0.0 + 1. + ( 4.08 ) ) * 138 \\
 &= 193.06 \text{ kN}
 \end{aligned}$$

##### Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.9209 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138 \\
 &= 193.06 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

##### Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138 \\
 &= 89. \text{ kN}
 \end{aligned}$$

##### Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
 \end{aligned}$$

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= 145. kN

Tension, Shell Groove Weld [Tngw]:

= (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.1416/2.0 ) \* 84.0 \* ( 18.0 - 3.0 ) \* 0.74 \* 138  
 = 202. kN

**Strength of Failure Paths:**

PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 89 + 0 + 202 + 0 ) = 291 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 89 + 202 + 0 ) = 291 kN

**Summary of Failure Path Calculations:**

Path 1-1 = 234 kN , must exceed W = 106 kN or W1 = 136 kN  
 Path 2-2 = 291 kN , must exceed W = 106 kN or W2 = 193 kN  
 Path 3-3 = 291 kN , must exceed W = 106 kN or W3 = 193 kN

**Maximum Allowable Pressure for this Nozzle at this Location:**

Converged Max. Allow. Pressure in Operating case 24.623 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 1.0659 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

**Input Echo, WRC107/537 Item 1, Description: D2 :**

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	mm.
Design Temperature	T1	125.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2

**Note:**

Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-350 LF2	
Nozzle UNS Number		K03011	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm^2

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Design Internal Pressure	Dp	23.118	bars
Include Pressure Thrust		No	

**External Forces and Moments in WRC 107/537 Convention:**

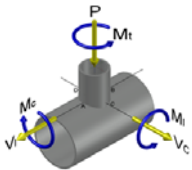
Radial Load	(SUS)	P	2.0	kN
Longitudinal Shear	(SUS)	Vl	2.0	kN
Circumferential Shear	(SUS)	Vc	2.0	kN
Circumferential Moment	(SUS)	Mc	400.0	N-m
Longitudinal Moment	(SUS)	Ml	400.0	N-m
Torsional Moment	(SUS)	Mt	500.0	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

**Note:**

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".

**Stress Attenuation Diameter (for Insert Plates) per WRC 297:**

$$\begin{aligned}
 &= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) ) \\
 &= 84.0 + 2 * 1.65 * \text{sqrt}( 838.5 ( 18.0 - 3.0 ) ) \\
 &= 454.093 \text{ mm.}
 \end{aligned}$$

**WRC 107 Stress Calculation for Sustained loads:**

Radial Load	P	2.0	kN
Circumferential Shear	VC	2.0	kN
Longitudinal Shear	VL	2.0	kN
Circumferential Moment	MC	400.0	N-m
Longitudinal Moment	ML	400.0	N-m
Torsional Moment	MT	500.0	N-m

Dimensionless Parameters used : Gamma = 55.90

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.044	4C	10.449	(A,B)
N(PHI) / ( P/Rm )	0.044	3C	10.482	(C,D)
M(PHI) / ( P )	0.044	2C1	0.147	(A,B)
M(PHI) / ( P )	0.044	1C	0.187	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.763	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.111	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.059	(A,B,C,D)
N(x) / ( P/Rm )	0.044	3C	10.482	(A,B)

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N(x)	/ ( P/Rm )	0.044	4C	10.449	(C,D)
M(x)	/ ( P )	0.044	1C1	0.194	(A,B)
M(x)	/ ( P )	0.044	2C	0.146	(C,D)
N(x)	/ ( MC/(Rm**2 * Beta) )	0.044	4A	1.005	(A,B,C,D)
M(x)	/ ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N(x)	/ ( ML/(Rm**2 * Beta) )	0.044	4B	0.781	(A,B,C,D)
M(x)	/ ( ML/(Rm * Beta) )	0.044	2B	0.096	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.8	29.8	29.8	-29.8
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-17.0	17.0	17.0	-17.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend.	P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb.	MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend.	MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb.	ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend.	ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear	VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear	MT	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear		4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.		41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl	(SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q	(SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm	(SUS)	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl	(SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q	(SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1

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Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2	129.2
-----									
Pm+Pl (SUS)	122.6	124.9	128.0	130.3	124.6	126.9	125.9	128.3	128.3
-----									
Pm+Pl+Q (Total)	98.0	150.0	137.2	121.2	84.9	166.8	146.0	108.7	108.7

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	130.29	206.85	Passed
Pm+Pl+Q (TOTAL)	166.77	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.*

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**Input, Nozzle Desc: D1 From: 70**

Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516	70
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		4745.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-350	LF2
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350	LF2
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

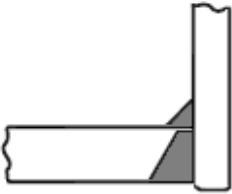
**Nozzle Sketch (may not represent actual weld type/configuration)**

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**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: D1**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation 2.000 in.  
 Actual Thickness Used in Calculation 0.654 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 =  $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.12 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.12)$   
 = 14.0733 mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 =  $(P \cdot R) / (S_n \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.12 \cdot 28.4) / (138 \cdot 1.0 - 0.6 \cdot 23.12)$   
 = 0.4810 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	Dl	114.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	57.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	mm.

Weld Strength Reduction Factor [fr1]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr2]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr3]:  
 =  $\min(fr2, fr4)$   
 =  $\min(1.0, 1.0)$   
 = 1.000

**Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.994	2.466	NA
Area in Shell	A1	0.530	3.613	NA

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Area in Nozzle Wall	A2		8.921		9.015		NA
Area in Inward Nozzle	A3		0.000		0.000		NA
Area in Welds	A41+A42+A43		1.000		1.000		NA
Area in Element	A5		0.000		0.000		NA
TOTAL AREA AVAILABLE	Atot		10.451		13.627		NA

## The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

## The area available without a pad is Sufficient.

## Area Required [A]:

$$= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) UG-37(c)$$

$$= ( 56.8 * 14.0733 * 1.0 + 2 * 13.6 * 14.0733 * 1.0 * (1 - 1.0) )$$

$$= 7.994 \text{ cm}^2$$

## Reinforcement Areas per Figure UG-37.1

## Area Available in Shell [A1]:

$$= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 )$$

$$= 57.2( 1.0 * 15.0 - 1.0 * 14.073 ) - 2 * 13.6$$

$$( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 1.0 )$$

$$= 0.530 \text{ cm}^2$$

## Area Available in Nozzle Projecting Outward [A2]:

$$= ( 2 * tlnp )( tn - trn ) fr2$$

$$= ( 2 * 34.0 )( 13.6 - 0.48 ) 1.0$$

$$= 8.921 \text{ cm}^2$$

## Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2$$

$$= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0$$

$$= 1.000 \text{ cm}^2$$

## UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

Wall Thickness for Internal/External pressures	ta = 3.4810 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0733 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0733 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 7.8000 mm.

## Determine Nozzle Thickness candidate [tb]:

$$= \min[ tb3, \max( tb1, tb2 ) ]$$

$$= \min[ 7.8, \max( 17.0733, 4.5 ) ]$$

$$= 7.8000 \text{ mm.}$$

## Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$= \max( ta, tb )$$

$$= \max( 3.481, 7.8 )$$

$$= 7.8000 \text{ mm.}$$

Available Nozzle Neck Thickness = 16.6000 mm. --&gt; OK

## Stresses on Nozzle due to External and Pressure Loads per the ASME

## B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	: 14.9,	Allowable	: 137.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0,	Allowable	: 329.9 N./mm <sup>2</sup>	Passed
Occasional	: 1.9,	Allowable	: 183.4 N./mm <sup>2</sup>	Passed

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Shear : 9.6, Allowable : 96.5 N./mm<sup>2</sup> Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

### Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

#### Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C  
 Calculated Minimum Design Metal Temperature -104 °C  
 Governing MDMT of all the sub-joints of this Junction : -104 °C

#### Weld Size Calculations, Description: D1

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.

#### Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

##### Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv ) \\
 &= \max( 0, (7.9936 - 0.5301 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 15.0 - 14.0733) ) 138 ) \\
 &= 106.39 \text{ kN}
 \end{aligned}$$

*Note: F is always set to 1.0 throughout the calculation.*

##### Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.9209 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 136.80 \text{ kN}
 \end{aligned}$$

##### Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.9209 + 0.0 + 1. + ( 4.08 ) ) * 138 \\
 &= 193.06 \text{ kN}
 \end{aligned}$$

##### Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.9209 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138 \\
 &= 193.06 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

##### Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138 \\
 &= 89. \text{ kN}
 \end{aligned}$$

##### Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= ( 3.1416 * 35.2 ) * ( 16.6 - 3.0 ) * 0.7 * 138
 \end{aligned}$$

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= 145. kN

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng$$

$$= ( 3.1416/2.0 ) * 84.0 * ( 18.0 - 3.0 ) * 0.74 * 138$$

$$= 202. kN$$

**Strength of Failure Paths:**

PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 89 + 0 + 202 + 0 ) = 291 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 89 + 202 + 0 ) = 291 kN

**Summary of Failure Path Calculations:**

Path 1-1 = 234 kN , must exceed W = 106 kN or W1 = 136 kN  
 Path 2-2 = 291 kN , must exceed W = 106 kN or W2 = 193 kN  
 Path 3-3 = 291 kN , must exceed W = 106 kN or W3 = 193 kN

**Maximum Allowable Pressure for this Nozzle at this Location:**

Converged Max. Allow. Pressure in Operating case 24.623 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 1.0659 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

**Input Echo, WRC107/537 Item 1, Description: D1 :**

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	mm.
Design Temperature	T1	125.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2

Note:

Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-350 LF2	
Nozzle UNS Number		K03011	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm^2

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Design Internal Pressure Dp 23.118 bars  
 Include Pressure Thrust No

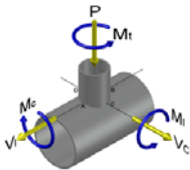
External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS) P 2.0 kN  
 Longitudinal Shear (SUS) VL 2.0 kN  
 Circumferential Shear (SUS) Vc 2.0 kN  
 Circumferential Moment (SUS) Mc 400.0 N-m  
 Longitudinal Moment (SUS) ML 400.0 N-m  
 Torsional Moment (SUS) Mt 500.0 N-m

Use Interactive Control No  
 WRC107 Version Version March 1979

Include Pressure Stress Indices per Div. 2 No  
 Compute Pressure Stress per WRC-368 No  
 Local Loads applied at end of Nozzle/Attachment No

*Note:*  
 WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:  
 = NozzleOD + 2 \* 1.65 \* sqrt( Rmean( t - ca ) )  
 = 84.0 + 2 \* 1.65 \* sqrt( 838.5 ( 18.0 - 3.0 ) )  
 = 454.093 mm.

WRC 107 Stress Calculation for Sustained loads:

Radial Load P 2.0 kN  
 Circumferential Shear VC 2.0 kN  
 Longitudinal Shear VL 2.0 kN  
 Circumferential Moment MC 400.0 N-m  
 Longitudinal Moment ML 400.0 N-m  
 Torsional Moment MT 500.0 N-m

Dimensionless Parameters used : Gamma = 55.90

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.044	4C	10.449	(A,B)
N(PHI) / ( P/Rm )	0.044	3C	10.482	(C,D)
M(PHI) / ( P )	0.044	2C1	0.147	(A,B)
M(PHI) / ( P )	0.044	1C	0.187	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.763	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.111	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.059	(A,B,C,D)
N(x) / ( P/Rm )	0.044	3C	10.482	(A,B)

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N(x) / ( P/Rm )	0.044	4C	10.449	(C,D)
M(x) / ( P )	0.044	1C1	0.194	(A,B)
M(x) / ( P )	0.044	2C	0.146	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.044	4A	1.005	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.044	4B	0.781	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.044	2B	0.096	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm^2)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.8	29.8	29.8	-29.8
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-17.0	17.0	17.0	-17.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend.	P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb.	MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend.	MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb.	ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend.	ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear	VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear	MT	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear		4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.		41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm^2)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl	(SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q	(SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm	(SUS)	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl	(SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q	(SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1

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Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2	129.2
-----									
Pm+Pl (SUS)	122.6	124.9	128.0	130.3	124.6	126.9	125.9	128.3	128.3
-----									
Pm+Pl+Q (Total)	98.0	150.0	137.2	121.2	84.9	166.8	146.0	108.7	108.7

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	130.29	206.85	Passed
Pm+Pl+Q (TOTAL)	166.77	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.*

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**Input, Nozzle Desc: D3 From: 70**

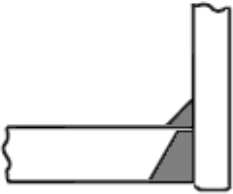
Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516	70
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		5545.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-350	LF2
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350	LF2
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: D3**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation 2.000 in.  
 Actual Thickness Used in Calculation 0.654 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 =  $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.12 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.12)$   
 = 14.0733 mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 =  $(P \cdot R) / (S_n \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.12 \cdot 28.4) / (138 \cdot 1.0 - 0.6 \cdot 23.12)$   
 = 0.4810 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	Dl	114.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	57.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	mm.

Weld Strength Reduction Factor [fr1]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr2]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr3]:  
 =  $\min(fr2, fr4)$   
 =  $\min(1.0, 1.0)$   
 = 1.000

**Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.994	2.466	NA
Area in Shell	A1	0.530	3.613	NA

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Area in Nozzle Wall	A2	8.921	9.015	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	10.451	13.627	NA

## The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

## The area available without a pad is Sufficient.

## Area Required [A]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)} \\
 &= ( 56.8 * 14.0733 * 1.0 + 2 * 13.6 * 14.0733 * 1.0 * (1 - 1.0) ) \\
 &= 7.994 \text{ cm}^2
 \end{aligned}$$

## Reinforcement Areas per Figure UG-37.1

## Area Available in Shell [A1]:

$$\begin{aligned}
 &= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 57.2( 1.0 * 15.0 - 1.0 * 14.073 ) - 2 * 13.6 \\
 &\quad ( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 1.0 ) \\
 &= 0.530 \text{ cm}^2
 \end{aligned}$$

## Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp )( tn - trn ) fr2 \\
 &= ( 2 * 34.0 )( 13.6 - 0.48 ) 1.0 \\
 &= 8.921 \text{ cm}^2
 \end{aligned}$$

## Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2 \\
 &= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0 \\
 &= 1.000 \text{ cm}^2
 \end{aligned}$$

## UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

Wall Thickness for Internal/External pressures	ta = 3.4810 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0733 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0733 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 7.8000 mm.

## Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 7.8, \max( 17.0733, 4.5 ) ] \\
 &= 7.8000 \text{ mm.}
 \end{aligned}$$

## Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$\begin{aligned}
 &= \max( ta, tb ) \\
 &= \max( 3.481, 7.8 ) \\
 &= 7.8000 \text{ mm.}
 \end{aligned}$$

Available Nozzle Neck Thickness = 16.6000 mm. --&gt; OK

## Stresses on Nozzle due to External and Pressure Loads per the ASME

## B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	: 14.9,	Allowable	: 137.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0,	Allowable	: 329.9 N./mm <sup>2</sup>	Passed
Occasional	: 1.9,	Allowable	: 183.4 N./mm <sup>2</sup>	Passed

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 FileName : Calculation Book for Evaporator E-PK1601 -----  
 Nozzle Calcs.: D3 Noz1: 27 11:47am Dec 23,2021

Shear : 9.6, Allowable : 96.5 N./mm<sup>2</sup> Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

### Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

#### Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C  
 Calculated Minimum Design Metal Temperature -104 °C  
 Governing MDMT of all the sub-joints of this Junction : -104 °C

#### Weld Size Calculations, Description: D3

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.

#### Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

##### Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv ) \\
 &= \max( 0, (7.9936 - 0.5301 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 15.0 - 14.0733) )138 ) \\
 &= 106.39 \text{ kN}
 \end{aligned}$$

*Note: F is always set to 1.0 throughout the calculation.*

##### Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.9209 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 136.80 \text{ kN}
 \end{aligned}$$

##### Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.9209 + 0.0 + 1. + ( 4.08 ) ) * 138 \\
 &= 193.06 \text{ kN}
 \end{aligned}$$

##### Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.9209 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138 \\
 &= 193.06 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

##### Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138 \\
 &= 89. \text{ kN}
 \end{aligned}$$

##### Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
 \end{aligned}$$

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= 145. kN

Tension, Shell Groove Weld [Tngw]:

= (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.1416/2.0 ) \* 84.0 \* ( 18.0 - 3.0 ) \* 0.74 \* 138  
 = 202. kN

**Strength of Failure Paths:**

PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 89 + 0 + 202 + 0 ) = 291 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 89 + 202 + 0 ) = 291 kN

**Summary of Failure Path Calculations:**

Path 1-1 = 234 kN , must exceed W = 106 kN or W1 = 136 kN  
 Path 2-2 = 291 kN , must exceed W = 106 kN or W2 = 193 kN  
 Path 3-3 = 291 kN , must exceed W = 106 kN or W3 = 193 kN

**Maximum Allowable Pressure for this Nozzle at this Location:**

Converged Max. Allow. Pressure in Operating case 24.623 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 1.0659 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

**Input Echo, WRC107/537 Item 1, Description: D3 :**

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	mm.
Design Temperature	T1	125.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2

Note:

Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-350 LF2	
Nozzle UNS Number		K03011	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm^2

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Design Internal Pressure Dp 23.118 bars  
 Include Pressure Thrust No

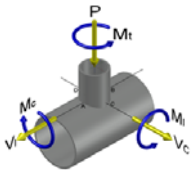
External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS) P 2.0 kN  
 Longitudinal Shear (SUS) VL 2.0 kN  
 Circumferential Shear (SUS) Vc 2.0 kN  
 Circumferential Moment (SUS) Mc 400.0 N-m  
 Longitudinal Moment (SUS) ML 400.0 N-m  
 Torsional Moment (SUS) Mt 500.0 N-m

Use Interactive Control No  
 WRC107 Version Version March 1979

Include Pressure Stress Indices per Div. 2 No  
 Compute Pressure Stress per WRC-368 No  
 Local Loads applied at end of Nozzle/Attachment No

*Note:*  
 WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:  
 = NozzleOD + 2 \* 1.65 \* sqrt( Rmean( t - ca ) )  
 = 84.0 + 2 \* 1.65 \* sqrt( 838.5 ( 18.0 - 3.0 ) )  
 = 454.093 mm.

WRC 107 Stress Calculation for Sustained loads:

Radial Load P 2.0 kN  
 Circumferential Shear VC 2.0 kN  
 Longitudinal Shear VL 2.0 kN  
 Circumferential Moment MC 400.0 N-m  
 Longitudinal Moment ML 400.0 N-m  
 Torsional Moment MT 500.0 N-m

Dimensionless Parameters used : Gamma = 55.90

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.044	4C	10.449	(A,B)
N(PHI) / ( P/Rm )	0.044	3C	10.482	(C,D)
M(PHI) / ( P )	0.044	2C1	0.147	(A,B)
M(PHI) / ( P )	0.044	1C	0.187	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.763	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.111	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.059	(A,B,C,D)
N(x) / ( P/Rm )	0.044	3C	10.482	(A,B)

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N(x)	/ ( P/Rm )	0.044	4C	10.449	(C,D)
M(x)	/ ( P )	0.044	1C1	0.194	(A,B)
M(x)	/ ( P )	0.044	2C	0.146	(C,D)
N(x)	/ ( MC/(Rm**2 * Beta) )	0.044	4A	1.005	(A,B,C,D)
M(x)	/ ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N(x)	/ ( ML/(Rm**2 * Beta) )	0.044	4B	0.781	(A,B,C,D)
M(x)	/ ( ML/(Rm * Beta) )	0.044	2B	0.096	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.8	29.8	29.8	-29.8
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-17.0	17.0	17.0	-17.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend.	P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb.	MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend.	MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb.	ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend.	ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear	VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear	MT	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear		4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.		41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl	(SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q	(SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm	(SUS)	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl	(SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q	(SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1

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Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2	129.2
-----									
Pm+Pl (SUS)	122.6	124.9	128.0	130.3	124.6	126.9	125.9	128.3	128.3
-----									
Pm+Pl+Q (Total)	98.0	150.0	137.2	121.2	84.9	166.8	146.0	108.7	108.7

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	130.29	206.85	Passed
Pm+Pl+Q (TOTAL)	166.77	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.*

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Nozzle Calcs.: TT Nozl: 28 11:47am Dec 23,2021

**Input, Nozzle Desc: TT From: 70**

Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516	70
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		6145.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-350	LF2
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350	LF2
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

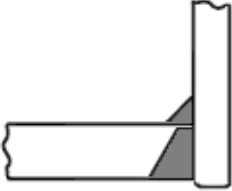
**Nozzle Sketch (may not represent actual weld type/configuration)**

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**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: TT**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation 2.000 in.  
 Actual Thickness Used in Calculation 0.654 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 =  $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.12 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.12)$   
 = 14.0733 mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 =  $(P \cdot R) / (S_n \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.12 \cdot 28.4) / (138 \cdot 1.0 - 0.6 \cdot 23.12)$   
 = 0.4810 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	Dl	114.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	57.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	mm.

Weld Strength Reduction Factor [fr1]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr2]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr3]:  
 =  $\min(fr2, fr4)$   
 =  $\min(1.0, 1.0)$   
 = 1.000

**Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.994	2.466	NA
Area in Shell	A1	0.530	3.613	NA

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Nozzle Calcs.: TT Nozl: 28 11:47am Dec 23,2021

Area in Nozzle Wall	A2	8.921	9.015	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	10.451	13.627	NA

## The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

## The area available without a pad is Sufficient.

## Area Required [A]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)} \\
 &= ( 56.8 * 14.0733 * 1.0 + 2 * 13.6 * 14.0733 * 1.0 * (1 - 1.0) ) \\
 &= 7.994 \text{ cm}^2
 \end{aligned}$$

## Reinforcement Areas per Figure UG-37.1

## Area Available in Shell [A1]:

$$\begin{aligned}
 &= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 57.2( 1.0 * 15.0 - 1.0 * 14.073 ) - 2 * 13.6 \\
 &\quad ( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 1.0 ) \\
 &= 0.530 \text{ cm}^2
 \end{aligned}$$

## Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp )( tn - trn ) fr2 \\
 &= ( 2 * 34.0 )( 13.6 - 0.48 ) 1.0 \\
 &= 8.921 \text{ cm}^2
 \end{aligned}$$

## Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2 \\
 &= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0 \\
 &= 1.000 \text{ cm}^2
 \end{aligned}$$

## UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

Wall Thickness for Internal/External pressures	ta = 3.4810 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0733 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0733 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 7.8000 mm.

## Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 7.8, \max( 17.0733, 4.5 ) ] \\
 &= 7.8000 \text{ mm.}
 \end{aligned}$$

## Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$\begin{aligned}
 &= \max( ta, tb ) \\
 &= \max( 3.481, 7.8 ) \\
 &= 7.8000 \text{ mm.}
 \end{aligned}$$

Available Nozzle Neck Thickness = 16.6000 mm. --&gt; OK

## Stresses on Nozzle due to External and Pressure Loads per the ASME

## B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	: 14.9,	Allowable	: 137.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0,	Allowable	: 329.9 N./mm <sup>2</sup>	Passed
Occasional	: 1.9,	Allowable	: 183.4 N./mm <sup>2</sup>	Passed

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 Nozzle Calcs.: TT Noz1: 28 11:47am Dec 23,2021

Shear : 9.6, Allowable : 96.5 N./mm<sup>2</sup> Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

### Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

#### Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C  
 Calculated Minimum Design Metal Temperature -104 °C  
 Governing MDMT of all the sub-joints of this Junction : -104 °C

#### Weld Size Calculations, Description: TT

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.

#### Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

##### Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv ) \\
 &= \max( 0, (7.9936 - 0.5301 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 15.0 - 14.0733) )138 ) \\
 &= 106.39 \text{ kN}
 \end{aligned}$$

*Note: F is always set to 1.0 throughout the calculation.*

##### Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.9209 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 136.80 \text{ kN}
 \end{aligned}$$

##### Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.9209 + 0.0 + 1. + ( 4.08 ) ) * 138 \\
 &= 193.06 \text{ kN}
 \end{aligned}$$

##### Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.9209 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138 \\
 &= 193.06 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

##### Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138 \\
 &= 89. \text{ kN}
 \end{aligned}$$

##### Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
 \end{aligned}$$

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= 145. kN

Tension, Shell Groove Weld [Tngw]:

= (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.1416/2.0 ) \* 84.0 \* ( 18.0 - 3.0 ) \* 0.74 \* 138  
 = 202. kN

#### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 89 + 0 + 202 + 0 ) = 291 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 89 + 202 + 0 ) = 291 kN

#### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 106 kN or W1 = 136 kN  
 Path 2-2 = 291 kN , must exceed W = 106 kN or W2 = 193 kN  
 Path 3-3 = 291 kN , must exceed W = 106 kN or W3 = 193 kN

#### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 24.623 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 1.0659 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

#### Input Echo, WRC107/537 Item 1, Description: TT :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	mm.
Design Temperature	T1	125.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>

Note:

Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-350 LF2	
Nozzle UNS Number		K03011	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm <sup>2</sup>

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Design Internal Pressure Dp 23.118 bars  
 Include Pressure Thrust No

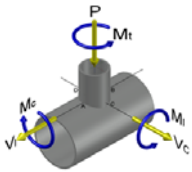
External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS) P 2.0 kN  
 Longitudinal Shear (SUS) VL 2.0 kN  
 Circumferential Shear (SUS) Vc 2.0 kN  
 Circumferential Moment (SUS) Mc 400.0 N-m  
 Longitudinal Moment (SUS) ML 400.0 N-m  
 Torsional Moment (SUS) Mt 500.0 N-m

Use Interactive Control No  
 WRC107 Version Version March 1979

Include Pressure Stress Indices per Div. 2 No  
 Compute Pressure Stress per WRC-368 No  
 Local Loads applied at end of Nozzle/Attachment No

*Note:*  
 WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) )$$

$$= 84.0 + 2 * 1.65 * \text{sqrt}( 838.5 ( 18.0 - 3.0 ) )$$

$$= 454.093 \text{ mm.}$$

WRC 107 Stress Calculation for Sustained loads:

Radial Load P 2.0 kN  
 Circumferential Shear VC 2.0 kN  
 Longitudinal Shear VL 2.0 kN  
 Circumferential Moment MC 400.0 N-m  
 Longitudinal Moment ML 400.0 N-m  
 Torsional Moment MT 500.0 N-m

Dimensionless Parameters used : Gamma = 55.90

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.044	4C	10.449	(A,B)
N(PHI) / ( P/Rm )	0.044	3C	10.482	(C,D)
M(PHI) / ( P )	0.044	2C1	0.147	(A,B)
M(PHI) / ( P )	0.044	1C	0.187	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.763	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.111	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.059	(A,B,C,D)
N(x) / ( P/Rm )	0.044	3C	10.482	(A,B)

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N(x) / ( P/Rm )	0.044	4C	10.449	(C,D)
M(x) / ( P )	0.044	1C1	0.194	(A,B)
M(x) / ( P )	0.044	2C	0.146	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.044	4A	1.005	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.044	4B	0.781	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.044	2B	0.096	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm^2)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.8	29.8	29.8	-29.8
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-17.0	17.0	17.0	-17.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend.	P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb.	MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend.	MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb.	ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend.	ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear	VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear	MT	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear		4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.		41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm^2)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl	(SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q	(SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm	(SUS)	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl	(SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q	(SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1

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Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2	129.2
-----									
Pm+Pl (SUS)	122.6	124.9	128.0	130.3	124.6	126.9	125.9	128.3	128.3
-----									
Pm+Pl+Q (Total)	98.0	150.0	137.2	121.2	84.9	166.8	146.0	108.7	108.7

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	130.29	206.85	Passed
Pm+Pl+Q (TOTAL)	166.77	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.*

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**Input, Nozzle Desc: V From: 70**

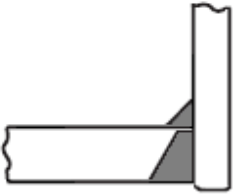
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2545.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		ID	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: V**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation 2.000 in.  
 Actual Thickness Used in Calculation 0.654 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 =  $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.0 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$   
 = 14.0010 mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 =  $(P \cdot R) / (S_n \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.0 \cdot 28.4) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$   
 = 0.4785 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	Dl	114.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	57.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	mm.

Weld Strength Reduction Factor [fr1]:  
 =  $\min(1, S_n/S_v)$   
 =  $\min(1, 137.9/137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr2]:  
 =  $\min(1, S_n/S_v)$   
 =  $\min(1, 137.9/137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr3]:  
 =  $\min(fr2, fr4)$   
 =  $\min(1.0, 1.0)$   
 = 1.000

**Results of Nozzle Reinforcement Area Calculations: (cm^2)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.953	2.466	NA
Area in Shell	A1	0.571	3.613	NA

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Area in Nozzle Wall	A2		8.923		9.015		NA
Area in Inward Nozzle	A3		0.000		0.000		NA
Area in Welds	A41+A42+A43		1.000		1.000		NA
Area in Element	A5		0.000		0.000		NA
TOTAL AREA AVAILABLE	Atot		10.494		13.627		NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)} \\
 &= ( 56.8 * 14.001 * 1.0 + 2 * 13.6 * 14.001 * 1.0 * (1 - 1.0) ) \\
 &= 7.953 \text{ cm}^2
 \end{aligned}$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 57.2( 1.0 * 15.0 - 1.0 * 14.001 ) - 2 * 13.6 \\
 &\quad ( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 1.0 ) \\
 &= 0.571 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp )( tn - trn ) fr2 \\
 &= ( 2 * 34.0 )( 13.6 - 0.48 ) 1.0 \\
 &= 8.923 \text{ cm}^2
 \end{aligned}$$

Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2 \\
 &= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0 \\
 &= 1.000 \text{ cm}^2
 \end{aligned}$$

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

Wall Thickness for Internal/External pressures	ta = 3.4785 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0010 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0010 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 7.8000 mm.

Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 7.8, \max( 17.001, 4.5 ) ] \\
 &= 7.8000 \text{ mm.}
 \end{aligned}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$\begin{aligned}
 &= \max( ta, tb ) \\
 &= \max( 3.4785, 7.8 ) \\
 &= 7.8000 \text{ mm.}
 \end{aligned}$$

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME

B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	: 14.9,	Allowable	: 137.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0,	Allowable	: 329.9 N./mm <sup>2</sup>	Passed
Occasional	: 1.9,	Allowable	: 183.4 N./mm <sup>2</sup>	Passed

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Shear : 9.6, Allowable : 96.5 N./mm<sup>2</sup> Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

### Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

#### Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C  
 Calculated Minimum Design Metal Temperature -104 °C  
 Governing MDMT of all the sub-joints of this Junction : -104 °C

#### Weld Size Calculations, Description: V

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.

#### Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

##### Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv ) \\
 &= \max( 0, (7.9526 - 0.5714 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 15.0 - 14.001 ) )138 ) \\
 &= 105.52 \text{ kN}
 \end{aligned}$$

*Note: F is always set to 1.0 throughout the calculation.*

##### Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.9226 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 136.82 \text{ kN}
 \end{aligned}$$

##### Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.9226 + 0.0 + 1. + ( 4.08 ) ) * 138 \\
 &= 193.08 \text{ kN}
 \end{aligned}$$

##### Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.9226 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138 \\
 &= 193.08 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

##### Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138 \\
 &= 89. \text{ kN}
 \end{aligned}$$

##### Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
 \end{aligned}$$

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 Nozzle Calcs.: V Nozl: 29 11:47am Dec 23,2021

= 145. kN

Tension, Shell Groove Weld [Tngw]:

= (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.1416/2.0 ) \* 84.0 \* ( 18.0 - 3.0 ) \* 0.74 \* 138  
 = 202. kN

#### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 89 + 0 + 202 + 0 ) = 291 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 89 + 202 + 0 ) = 291 kN

#### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 105 kN or W1 = 136 kN  
 Path 2-2 = 291 kN , must exceed W = 105 kN or W2 = 193 kN  
 Path 3-3 = 291 kN , must exceed W = 105 kN or W3 = 193 kN

#### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 24.506 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 1.0659 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

#### Input Echo, WRC107/537 Item 1, Description: V :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	mm.
Design Temperature	T1	125.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>

Note:

Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-350 LF2	
Nozzle UNS Number		K03011	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm <sup>2</sup>

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Nozzle Calcs.: V Nozl: 29 11:47am Dec 23,2021

Design Internal Pressure Dp 23.000 bars  
 Include Pressure Thrust No

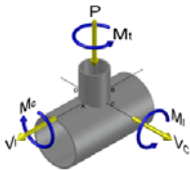
External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS) P 2.0 kN  
 Longitudinal Shear (SUS) VL 2.0 kN  
 Circumferential Shear (SUS) Vc 2.0 kN  
 Circumferential Moment (SUS) Mc 400.0 N-m  
 Longitudinal Moment (SUS) ML 400.0 N-m  
 Torsional Moment (SUS) Mt 500.0 N-m

Use Interactive Control No  
 WRC107 Version Version March 1979

Include Pressure Stress Indices per Div. 2 No  
 Compute Pressure Stress per WRC-368 No  
 Local Loads applied at end of Nozzle/Attachment No

*Note:*  
 WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) )$$

$$= 84.0 + 2 * 1.65 * \text{sqrt}( 838.5 ( 18.0 - 3.0 ) )$$

$$= 454.093 \text{ mm.}$$

WRC 107 Stress Calculation for Sustained loads:

Radial Load P 2.0 kN  
 Circumferential Shear VC 2.0 kN  
 Longitudinal Shear VL 2.0 kN  
 Circumferential Moment MC 400.0 N-m  
 Longitudinal Moment ML 400.0 N-m  
 Torsional Moment MT 500.0 N-m

Dimensionless Parameters used : Gamma = 55.90

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.044	4C	10.449	(A,B)
N(PHI) / ( P/Rm )	0.044	3C	10.482	(C,D)
M(PHI) / ( P )	0.044	2C1	0.147	(A,B)
M(PHI) / ( P )	0.044	1C	0.187	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.763	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.111	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.059	(A,B,C,D)
N(x) / ( P/Rm )	0.044	3C	10.482	(A,B)

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Nozzle Calcs.: V Noz1: 29 11:47am Dec 23,2021

N(x) / ( P/Rm )	0.044	4C	10.449	(C,D)
M(x) / ( P )	0.044	1C1	0.194	(A,B)
M(x) / ( P )	0.044	2C	0.146	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.044	4A	1.005	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.044	4B	0.781	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.044	2B	0.096	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.8	29.8	29.8	-29.8
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-17.0	17.0	17.0	-17.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend.	P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb.	MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend.	MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb.	ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend.	ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear	VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear	MT	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear		4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.		41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl	(SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q	(SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm	(SUS)	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl	(SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q	(SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1

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Nozzle Calcs.: V Nozl: 29 11:47am Dec 23,2021

Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	128.6	126.3	128.6
-----									
Pm+Pl (SUS)	122.0	124.3	127.3	129.6	124.0	126.3	125.3	127.6	127.6
-----									
Pm+Pl+Q (Total)	97.3	149.4	136.6	120.5	84.2	166.1	145.4	108.0	108.0

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.59	137.90	Passed
Pm+Pl (SUS)	129.63	206.85	Passed
Pm+Pl+Q (TOTAL)	166.12	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.*

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Nozzle Calcs.: S4 Nozl: 30 11:47am Dec 23,2021

**Input, Nozzle Desc: S4 From: 70**

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		5145.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

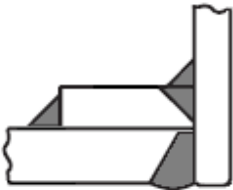
**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type	Smls. & wld. pipe		
Allowable Stress at Temperature	Sn	117.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	117.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		8.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm <sup>2</sup>
Pad Allowable Stress At Ambient	Spa	137.90	N./mm <sup>2</sup>
Diameter of Pad along vessel surface	Dp	379.0750	mm.
Thickness of Pad	te	18.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	18.0000	mm.
Reinforcing Pad Width		80.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

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The Pressure Design option was Design Pressure + static head.

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Insert/Set-in Nozzle With Pad, no Inside projection**

**Reinforcement CALCULATION, Description: S4**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	8.625 in.
Actual Thickness Used in Calculation	0.438 in.

Nozzle input data check completed without errors.

Req'd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 $= (P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 $= (23.0 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$   
 $= 14.0010 \text{ mm.}$

Req'd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 $= (P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 $= (23.0 \cdot 109.5375) / (118 \cdot 1.0 + 0.4 \cdot 23.0)$   
 $= 2.1204 \text{ mm.}$

Required Nozzle thickness under External Pressure per UG-28 : 0.5985 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	D1	405.7000	mm.
Parallel to Vessel Wall, opening length	d	202.8500	mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp		37.5000	mm.

Weld Strength Reduction Factor [fr1]:  
 $= \min(1, S_n / S_v)$   
 $= \min(1, 117.9 / 137.9)$   
 $= 0.855$

Weld Strength Reduction Factor [fr2]:  
 $= \min(1, S_n / S_v)$   
 $= \min(1, 117.9 / 137.9)$   
 $= 0.855$

Weld Strength Reduction Factor [fr4]:  
 $= \min(1, S_p / S_v)$   
 $= \min(1, 137.9 / 137.9)$   
 $= 1.000$

Weld Strength Reduction Factor [fr3]:

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= min( fr2, fr4 )  
 = min( 0.855, 1.0 )  
 = 0.855

#### Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)

AREA AVAILABLE, A1 to A5	Design	External	Mapnc
Area Required Ar	28.730	8.910	NA
Area in Shell A1	2.003	12.663	NA
Area in Nozzle Wall A2	3.842	4.818	NA
Area in Inward Nozzle A3	0.000	0.000	NA
Area in Welds A41+A42+A43	2.810	2.810	NA
Area in Element A5	28.800	28.800	NA
TOTAL AREA AVAILABLE Atot	37.456	49.092	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.

The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS: Diameter Thickness  
 Based on given Pad Thickness: 330.6005 18.0000 mm.  
 Based on given Pad Diameter: 379.0750 12.5466 mm.  
 Based on Shell or Nozzle Thickness: 399.7238 11.1125 mm.

Area Required [A]:

= ( d \* tr\*F + 2 \* tn \* tr\*F \* (1-fr1) ) UG-37(c)  
 = ( 202.85\*14.001\*1.0+2\*8.1125\*14.001\*1.0\*(1-0.86) )  
 = 28.730 cm<sup>2</sup>

#### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

= d( E1\*t - F\*tr ) - 2 \* tn( E1\*t - F\*tr ) \* ( 1 - fr1 )  
 = 202.85( 1.0 \* 15.0 - 1.0 \* 14.001 ) - 2 \* 8.113  
 ( 1.0 \* 15.0 - 1.0 \* 14.001 ) \* ( 1 - 0.855 )  
 = 2.003 cm<sup>2</sup>

Area Available in Nozzle Wall Projecting Outward [A2]:

= ( 2 \* Tlwp ) \* ( tn - trn ) \* fr2  
 = ( 2 \* 37.5 ) \* ( 8.11 - 2.12 ) \* 0.855  
 = 3.842 cm<sup>2</sup>

Area Available in Welds [A41 + A42 + A43]:

= (Wo<sup>2</sup> - Ar Lost)\*Fr3+((Wi-can/0.707)<sup>2</sup> - Ar Lost)\*fr2 + Trapfr4  
 = ( 1. ) \* 0.86 + (0.0 ) \* 0.86 + 195.5274<sup>2</sup> \* 1.0  
 = 2.810 cm<sup>2</sup>

Area Available in Element [A5]:

= (min(Dp,DL)-(Nozzle OD))\*(min(tp,Tlwp,te)) \* fr4  
 = ( 379.075 - 219.075 ) \* 18.0 \* 1.0  
 = 28.800 cm<sup>2</sup>

#### UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

Wall Thickness for Internal/External pressures ta = 5.1204 mm.  
 Wall Thickness per UG16(b), tr16b = 4.5000 mm.  
 Wall Thickness, shell/head, internal pressure trb1 = 17.0010 mm.  
 Wall Thickness tbt = max(trb1, tr16b) = 17.0010 mm.

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Nozzle Calcs.: S4 Noz1: 30 11:47am Dec 23,2021

Wall Thickness, shell/head, external pressure trb2 = 3.6235 mm.  
 Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.  
 Wall Thickness per table UG-45 tb3 = 10.1600 mm.

Determine Nozzle Thickness candidate [tb]:

= min[ tb3, max( tb1, tb2 ) ]  
 = min[ 10.16, max( 17.001, 4.5 ) ]  
 = 10.1600 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

= max( ta, tb )  
 = max( 5.1204, 10.16 )  
 = 10.1600 mm.

Available Nozzle Neck Thickness = 11.1125 mm. --> OK

### Stresses on Nozzle due to External and Pressure Loads per the ASME

#### B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	: 50.5,	Allowable	: 117.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0,	Allowable	: 244.3 N./mm <sup>2</sup>	Passed
Occasional	: 13.8,	Allowable	: 156.8 N./mm <sup>2</sup>	Passed
Shear	: 20.4,	Allowable	: 82.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

### Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

#### Nozzle Neck to Flange Weld (Impact tested) :

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

#### Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

#### Nozzle Neck to Pad Weld for Reinforcement pad, Curve: D

Govrn. thk, tg = 11.113, tr = 2.12, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.261$ , Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C

Min Metal Temp. at Required thickness (UCS 66.1) -104 °C

#### Shell to Pad Weld Junction at Pad OD, Curve: D

Govrn. thk, tg = 18.0, tr = 14.001, c = 3.0 mm., E\* = 1.0  
 Thickness Ratio =  $tr * (E^*) / (tg - c) = 0.933$ , Temp. Reduction = 4 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -43 °C

Min Metal Temp. at Required thickness (UCS 66.1) -46 °C

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**Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :**  
 -----

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification	-46 °C
Calculated Minimum Design Metal Temperature	-104 °C
Governing MDMT of the Nozzle	: -104 °C
Governing MDMT of the Reinforcement Pad	: -46 °C
Governing MDMT of all the sub-joints of this Junction	: -46 °C

**ANSI Flange MDMT including Temperature reduction per UCS-66.1:**

MDMT of ANSI B16.5/47 flange per Matl. Specification	-46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)	-86 °C
Flange MDMT with Temp reduction per UCS-66(i)(3)	-104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

*Note:*

*Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.*

Weld Size Calculations, Description: S4

Intermediate Calc. for nozzle/shell Welds	Tmin	8.1125 mm.
Intermediate Calc. for pad/shell Welds	TminPad	15.0000 mm.

**Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	5.6788 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm.
Pad Weld	7.5000 = 0.5*TminPad	9.8980 = 0.7 * Wp mm.

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv) \\
 &= \max( 0, (28.7304 - 2.003 + 2 * 8.1125 * 0.855 * \\
 &\quad (1.0 * 15.0 - 14.001) )138) \\
 &= 370.45 \text{ kN}
 \end{aligned}$$

*Note: F is always set to 1.0 throughout the calculation.*

Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 3.8425 + 28.8 + 2.8103 - 0.0 * 0.86 ) * 138 \\
 &= 488.85 \text{ kN}
 \end{aligned}$$

Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 3.8425 + 0.0 + 0.855 + ( 2.0809 ) ) * 138 \\
 &= 93.47 \text{ kN}
 \end{aligned}$$

Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 3.8425 + 0.0 + 2.8103 + 28.8 + ( 2.0809 ) ) * 138 \\
 &= 517.54 \text{ kN}
 \end{aligned}$$

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**Strength of Connection Elements for Failure Path Analysis**

Shear, Outward Nozzle Weld [Sonw]:  
 = (pi/2) \* Dlo \* Wo \* 0.49 \* Snw  
 = ( 3.1416/2.0 ) \* 219.075 \* 10.0 \* 0.49 \* 118  
 = 199. kN

Shear, Pad Element Weld [Spew]:  
 = (pi/2) \* DP \* WP \* 0.49 \* SEW  
 = ( 3.1416/2.0 ) \* 379.075 \* 14.0 \* 0.49 \* 138  
 = 563. kN

Shear, Nozzle Wall [Snw]:  
 = (pi \* ( Dlr + Dlo )/4 ) \* ( Thk - Can ) \* 0.7 \* Sn  
 = ( 3.1416 \* 105.4813 ) \* ( 11.1125 - 3.0 ) \* 0.7 \* 118  
 = 222. kN

Tension, Pad Groove Weld [Tpgw]:  
 = ( pi/2 ) \* Dlo \* Wgpn \* 0.74 \* Seg  
 = ( 3.1416/2 ) \* 219.075 \* 18.0 \* 0.74 \* 138  
 = 632. kN

Tension, Shell Groove Weld [Tngw]:  
 = (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.1416/2.0 ) \* 219.075 \* ( 18.0 - 3.0 ) \* 0.74 \* 138  
 = 527. kN

**Strength of Failure Paths:**

PATH11 = ( SPEW + SNW ) = ( 563 + 222 ) = 785 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 199 + 632 + 527 + 0 ) = 1358 kN  
 PATH33 = ( Spew + Tngw + Sinw )  
 = ( 563 + 527 + 0 ) = 1090 kN

**Summary of Failure Path Calculations:**

Path 1-1 = 785 kN , must exceed W = 370 kN or W1 = 488 kN  
 Path 2-2 = 1357 kN , must exceed W = 370 kN or W2 = 93 kN  
 Path 3-3 = 1089 kN , must exceed W = 370 kN or W3 = 517 kN

**Maximum Allowable Pressure for this Nozzle at this Location:**

Converged Max. Allow. Pressure in Operating case 24.506 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 7.2775 mm.  
 The Cut Length for this Nozzle is, Drop + Ho + H + T : 175.2774 mm.

**Input Echo, WRC107/537 Item 1, Description: S4 :**

Diameter Basis for Vessel	Vbasis	ID
Cylindrical or Spherical Vessel	Cylsph	Cylindrical
Internal Corrosion Allowance	Cas	3.0000 mm.
Vessel Diameter	Dv	1656.000 mm.
Vessel Thickness	Tv	18.000 mm.
Design Temperature	T1	125.0 °C
Vessel Material		SA-516 70
Vessel UNS Number		K02700

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Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>

**Note:**

Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
Make sure that material properties at this temperature are not  
time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	219.075	mm.
Nozzle Thickness	Tn	11.113	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm <sup>2</sup>
Thickness of Reinforcing Pad	Tpad	18.000	mm.
Diameter of Reinforcing Pad	Dpad	379.075	mm.
Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

**External Forces and Moments in WRC 107/537 Convention:**

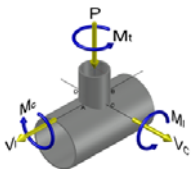
Radial Load (SUS)	P	8.0	kN
Longitudinal Shear (SUS)	Vl	8.0	kN
Circumferential Shear (SUS)	Vc	8.0	kN
Circumferential Moment (SUS)	Mc	6800.0	N-m
Longitudinal Moment (SUS)	Ml	6800.0	N-m
Torsional Moment (SUS)	Mt	8400.0	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

**Note:**

WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".

**Stress Attenuation Diameter (for Insert Plates) per WRC 297:**

$$\begin{aligned}
 &= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) ) \\
 &= 219.075 + 2 * 1.65 * \text{sqrt}( 838.5 ( 18.0 - 3.0 ) ) \\
 &= 589.168 \text{ mm.}
 \end{aligned}$$

**WRC 107 Stress Calculation for SUSTained loads:**





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Nozzle Calcs.: S4 Noz1: 30 11:47am Dec 23,2021

Tot. Shear	3.4	3.4	1.6	1.6	1.6	1.6	3.4	3.4
Str. Int.	55.3	33.5	28.8	14.0	99.4	79.6	66.1	57.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		56.8	59.1	56.8	59.1	56.8	59.1	56.8	59.1
Circ. Pl (SUS)		-7.6	-7.6	5.0	5.0	-3.0	-3.0	0.7	0.7
Circ. Q (SUS)		-22.7	22.7	14.2	-14.2	-44.2	44.2	32.4	-32.4
Long. Pm (SUS)		28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.4
Long. Pl (SUS)		-2.9	-2.9	0.6	0.6	-3.9	-3.9	1.3	1.3
Long. Q (SUS)		-36.7	36.7	24.7	-24.7	-25.5	25.5	16.9	-16.9
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		0.7	0.7	-0.7	-0.7	-0.7	-0.7	0.7	0.7
Shear Q (SUS)		3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Pm (SUS)		56.8	59.1	56.8	59.1	56.8	59.1	56.8	59.1
Pm+Pl (SUS)		49.2	51.5	61.8	64.1	53.8	56.1	57.5	59.8
Pm+Pl+Q (Total)		38.5	75.5	76.3	50.0	11.9	100.4	90.3	28.5

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	59.09	137.90	Passed
Pm+Pl (SUS)	64.06	206.85	Passed
Pm+Pl+Q (TOTAL)	100.43	413.70	Passed

Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Reinforcing Pad Edge (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl (SUS)		-21.6	-21.6	12.3	12.3	-9.9	-9.9	4.4	4.4
Circ. Q (SUS)		-28.0	28.0	16.1	-16.1	-89.5	89.5	61.4	-61.4
Long. Pm (SUS)		63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl (SUS)		-10.1	-10.1	4.5	4.5	-19.7	-19.7	10.4	10.4
Long. Q (SUS)		-43.2	43.2	18.3	-18.3	-42.1	42.1	27.6	-27.6

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Nozzle Calcs.: S4 Nozl: 30 11:47am Dec 23,2021

Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.9	0.9	-0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q (SUS)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6	128.6
Pm+Pl (SUS)	104.7	107.0	138.6	140.9	116.4	118.7	130.7	133.0	133.0
Pm+Pl+Q (Total)	76.9	135.2	154.7	124.9	27.0	208.2	192.1	72.0	72.0

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.59	137.90	Passed
Pm+Pl (SUS)	140.91	206.85	Passed
Pm+Pl+Q (TOTAL)	208.18	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.*

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Nozzle Calcs.: LG1 Nozl: 31 11:47am Dec 23,2021

**Input, Nozzle Desc: LG1 From: 70**

Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		4545.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

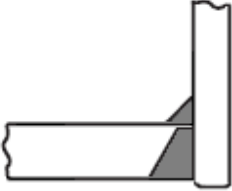
**Nozzle Sketch (may not represent actual weld type/configuration)**

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Nozzle Calcs.: LG1 Nozl: 31 11:47am Dec 23,2021



**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: LG1**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation 2.000 in.  
 Actual Thickness Used in Calculation 0.654 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 =  $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.12 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.12)$   
 = 14.0733 mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 =  $(P \cdot R) / (S_n \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.12 \cdot 28.4) / (138 \cdot 1.0 - 0.6 \cdot 23.12)$   
 = 0.4810 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	Dl	114.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	57.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	mm.

Weld Strength Reduction Factor [fr1]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr2]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr3]:  
 =  $\min(fr2, fr4)$   
 =  $\min(1.0, 1.0)$   
 = 1.000

**Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.994	2.466	NA
Area in Shell	A1	0.530	3.613	NA

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Area in Nozzle Wall	A2	8.921	9.015	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	10.451	13.627	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)} \\
 &= ( 56.8 * 14.0733 * 1.0 + 2 * 13.6 * 14.0733 * 1.0 * (1 - 1.0) ) \\
 &= 7.994 \text{ cm}^2
 \end{aligned}$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 57.2( 1.0 * 15.0 - 1.0 * 14.073 ) - 2 * 13.6 \\
 &\quad ( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 1.0 ) \\
 &= 0.530 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp )( tn - trn ) fr2 \\
 &= ( 2 * 34.0 )( 13.6 - 0.48 ) 1.0 \\
 &= 8.921 \text{ cm}^2
 \end{aligned}$$

Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2 \\
 &= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0 \\
 &= 1.000 \text{ cm}^2
 \end{aligned}$$

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**

Wall Thickness for Internal/External pressures	ta = 3.4810 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0733 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0733 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 7.8000 mm.

Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 7.8, \max( 17.0733, 4.5 ) ] \\
 &= 7.8000 \text{ mm.}
 \end{aligned}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$\begin{aligned}
 &= \max( ta, tb ) \\
 &= \max( 3.481, 7.8 ) \\
 &= 7.8000 \text{ mm.}
 \end{aligned}$$

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME**

**B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	: 14.9,	Allowable	: 137.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0,	Allowable	: 329.9 N./mm <sup>2</sup>	Passed
Occasional	: 1.9,	Allowable	: 183.4 N./mm <sup>2</sup>	Passed

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Shear : 9.6, Allowable : 96.5 N./mm<sup>2</sup> Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

### Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

#### Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C  
 Calculated Minimum Design Metal Temperature -104 °C  
 Governing MDMT of all the sub-joints of this Junction : -104 °C

#### Weld Size Calculations, Description: LG1

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.

#### Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

##### Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv ) \\
 &= \max( 0, (7.9936 - 0.5301 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 15.0 - 14.0733) )138 ) \\
 &= 106.39 \text{ kN}
 \end{aligned}$$

*Note: F is always set to 1.0 throughout the calculation.*

##### Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.9209 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 136.80 \text{ kN}
 \end{aligned}$$

##### Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.9209 + 0.0 + 1. + ( 4.08 ) ) * 138 \\
 &= 193.06 \text{ kN}
 \end{aligned}$$

##### Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.9209 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138 \\
 &= 193.06 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

##### Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138 \\
 &= 89. \text{ kN}
 \end{aligned}$$

##### Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
 \end{aligned}$$

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= 145. kN

Tension, Shell Groove Weld [Tngw]:

= (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.1416/2.0 ) \* 84.0 \* ( 18.0 - 3.0 ) \* 0.74 \* 138  
 = 202. kN

#### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 89 + 0 + 202 + 0 ) = 291 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 89 + 202 + 0 ) = 291 kN

#### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 106 kN or W1 = 136 kN  
 Path 2-2 = 291 kN , must exceed W = 106 kN or W2 = 193 kN  
 Path 3-3 = 291 kN , must exceed W = 106 kN or W3 = 193 kN

#### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 24.623 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 1.0659 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

#### Input Echo, WRC107/537 Item 1, Description: LG1 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	mm.
Design Temperature	T1	125.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>

Note:

Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-350 LF2	
Nozzle UNS Number		K03011	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm <sup>2</sup>

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Design Internal Pressure Dp 23.118 bars  
 Include Pressure Thrust No

External Forces and Moments in WRC 107/537 Convention:

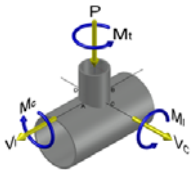
Radial Load (SUS)	P	2.0	kN
Longitudinal Shear (SUS)	VL	2.0	kN
Circumferential Shear (SUS)	Vc	2.0	kN
Circumferential Moment (SUS)	Mc	400.0	N-m
Longitudinal Moment (SUS)	ML	400.0	N-m
Torsional Moment (SUS)	Mt	500.0	N-m

??

Use Interactive Control No  
 WRC107 Version Version March 1979

Include Pressure Stress Indices per Div. 2 No  
 Compute Pressure Stress per WRC-368 No  
 Local Loads applied at end of Nozzle/Attachment No

*Note:*  
 WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:  
 = NozzleOD + 2 \* 1.65 \* sqrt( Rmean( t - ca ) )  
 = 84.0 + 2 \* 1.65 \* sqrt( 838.5 ( 18.0 - 3.0 ) )  
 = 454.093 mm.

WRC 107 Stress Calculation for Sustained loads:

Radial Load	P	2.0	kN
Circumferential Shear	VC	2.0	kN
Longitudinal Shear	VL	2.0	kN
Circumferential Moment	MC	400.0	N-m
Longitudinal Moment	ML	400.0	N-m
Torsional Moment	MT	500.0	N-m

Dimensionless Parameters used : Gamma = 55.90

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.044	4C	10.449	(A,B)
N(PHI) / ( P/Rm )	0.044	3C	10.482	(C,D)
M(PHI) / ( P )	0.044	2C1	0.147	(A,B)
M(PHI) / ( P )	0.044	1C	0.187	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.763	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.111	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.059	(A,B,C,D)
N(x) / ( P/Rm )	0.044	3C	10.482	(A,B)

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N(x) / ( P/Rm )	0.044	4C	10.449	(C,D)
M(x) / ( P )	0.044	1C1	0.194	(A,B)
M(x) / ( P )	0.044	2C	0.146	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.044	4A	1.005	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.044	4B	0.781	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.044	2B	0.096	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.8	29.8	29.8	-29.8
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-17.0	17.0	17.0	-17.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend.	P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb.	MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend.	MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb.	ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend.	ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear	VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear	MT	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear		4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.		41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl	(SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q	(SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm	(SUS)	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl	(SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q	(SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1

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Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2	129.2
-----									
Pm+Pl (SUS)	122.6	124.9	128.0	130.3	124.6	126.9	125.9	128.3	128.3
-----									
Pm+Pl+Q (Total)	98.0	150.0	137.2	121.2	84.9	166.8	146.0	108.7	108.7

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	130.29	206.85	Passed
Pm+Pl+Q (TOTAL)	166.77	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.*

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Nozzle Calcs.: LG2 Nozl: 32 11:47am Dec 23,2021

**Input, Nozzle Desc: LG2 From: 70**

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		4545.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

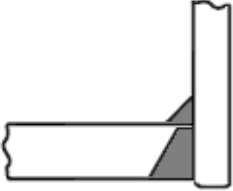
**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		ID	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

**Nozzle Sketch (may not represent actual weld type/configuration)**

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**Insert/Set-in Nozzle No Pad, no Inside projection**

**Reinforcement CALCULATION, Description: LG2**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation 2.000 in.  
 Actual Thickness Used in Calculation 0.654 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 =  $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.0 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$   
 = 14.0010 mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 =  $(P \cdot R) / (S_n \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.0 \cdot 28.4) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$   
 = 0.4785 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	Dl	114.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	57.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	mm.

Weld Strength Reduction Factor [fr1]:  
 =  $\min(1, S_n/S_v)$   
 =  $\min(1, 137.9/137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr2]:  
 =  $\min(1, S_n/S_v)$   
 =  $\min(1, 137.9/137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr3]:  
 =  $\min(fr2, fr4)$   
 =  $\min(1.0, 1.0)$   
 = 1.000

**Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.953	2.466	NA
Area in Shell	A1	0.571	3.613	NA

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Area in Nozzle Wall	A2	8.923	9.015	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	10.494	13.627	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)} \\
 &= ( 56.8 * 14.001 * 1.0 + 2 * 13.6 * 14.001 * 1.0 * (1 - 1.0) ) \\
 &= 7.953 \text{ cm}^2
 \end{aligned}$$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 57.2( 1.0 * 15.0 - 1.0 * 14.001 ) - 2 * 13.6 \\
 &\quad ( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 1.0 ) \\
 &= 0.571 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp )( tn - trn ) fr2 \\
 &= ( 2 * 34.0 )( 13.6 - 0.48 ) 1.0 \\
 &= 8.923 \text{ cm}^2
 \end{aligned}$$

Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2 \\
 &= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0 \\
 &= 1.000 \text{ cm}^2
 \end{aligned}$$

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

Wall Thickness for Internal/External pressures	ta = 3.4785 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0010 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0010 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 7.8000 mm.

Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 7.8, \max( 17.001, 4.5 ) ] \\
 &= 7.8000 \text{ mm.}
 \end{aligned}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$\begin{aligned}
 &= \max( ta, tb ) \\
 &= \max( 3.4785, 7.8 ) \\
 &= 7.8000 \text{ mm.}
 \end{aligned}$$

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME

B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained	: 14.9,	Allowable	: 137.9 N./mm <sup>2</sup>	Passed
Expansion	: 0.0,	Allowable	: 329.9 N./mm <sup>2</sup>	Passed
Occasional	: 1.9,	Allowable	: 183.4 N./mm <sup>2</sup>	Passed

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Shear : 9.6, Allowable : 96.5 N./mm<sup>2</sup> Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

### Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

#### Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C  
 Calculated Minimum Design Metal Temperature -104 °C  
 Governing MDMT of all the sub-joints of this Junction : -104 °C

#### Weld Size Calculations, Description: LG2

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 mm.

#### Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.

#### Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)

##### Weld Load [W]:

$$\begin{aligned}
 &= \max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv ) \\
 &= \max( 0, (7.9526 - 0.5714 + 2 * 13.6 * 1.0 * \\
 &\quad (1.0 * 15.0 - 14.001 ) )138 ) \\
 &= 105.52 \text{ kN}
 \end{aligned}$$

*Note: F is always set to 1.0 throughout the calculation.*

##### Weld Load [W1]:

$$\begin{aligned}
 &= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv \\
 &= ( 8.9226 + 0.0 + 1. - 0.0 * 1.0 ) * 138 \\
 &= 136.82 \text{ kN}
 \end{aligned}$$

##### Weld Load [W2]:

$$\begin{aligned}
 &= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv \\
 &= ( 8.9226 + 0.0 + 1. + ( 4.08 ) ) * 138 \\
 &= 193.08 \text{ kN}
 \end{aligned}$$

##### Weld Load [W3]:

$$\begin{aligned}
 &= (A2+A3+A4+A5+(2*tn*t*fr1))*S \\
 &= ( 8.9226 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138 \\
 &= 193.08 \text{ kN}
 \end{aligned}$$

#### Strength of Connection Elements for Failure Path Analysis

##### Shear, Outward Nozzle Weld [Sonw]:

$$\begin{aligned}
 &= (\pi/2) * Dlo * Wo * 0.49 * Snw \\
 &= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138 \\
 &= 89. \text{ kN}
 \end{aligned}$$

##### Shear, Nozzle Wall [Snw]:

$$\begin{aligned}
 &= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn \\
 &= (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
 \end{aligned}$$

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= 145. kN

Tension, Shell Groove Weld [Tngw]:

= (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.1416/2.0 ) \* 84.0 \* ( 18.0 - 3.0 ) \* 0.74 \* 138  
 = 202. kN

#### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 89 + 0 + 202 + 0 ) = 291 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 89 + 202 + 0 ) = 291 kN

#### Summary of Failure Path Calculations:

Path 1-1 = 234 kN , must exceed W = 105 kN or W1 = 136 kN  
 Path 2-2 = 291 kN , must exceed W = 105 kN or W2 = 193 kN  
 Path 3-3 = 291 kN , must exceed W = 105 kN or W3 = 193 kN

#### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 24.506 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 1.0659 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

#### Input Echo, WRC107/537 Item 1, Description: LG2 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	mm.
Design Temperature	T1	125.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>

Note:

Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-350 LF2	
Nozzle UNS Number		K03011	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm <sup>2</sup>

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Design Internal Pressure Dp 23.000 bars  
 Include Pressure Thrust No

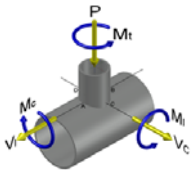
External Forces and Moments in WRC 107/537 Convention:

Radial Load (SUS)	P	2.0	kN
Longitudinal Shear (SUS)	VL	2.0	kN
Circumferential Shear (SUS)	Vc	2.0	kN
Circumferential Moment (SUS)	Mc	400.0	N-m
Longitudinal Moment (SUS)	ML	400.0	N-m
Torsional Moment (SUS)	Mt	500.0	N-m

Use Interactive Control No  
 WRC107 Version Version March 1979

Include Pressure Stress Indices per Div. 2 No  
 Compute Pressure Stress per WRC-368 No  
 Local Loads applied at end of Nozzle/Attachment No

*Note:*  
 WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".



Stress Attenuation Diameter (for Insert Plates) per WRC 297:  
 = NozzleOD + 2 \* 1.65 \* sqrt( Rmean( t - ca ) )  
 = 84.0 + 2 \* 1.65 \* sqrt( 838.5 ( 18.0 - 3.0 ) )  
 = 454.093 mm.

WRC 107 Stress Calculation for Sustained loads:

Radial Load	P	2.0	kN
Circumferential Shear	VC	2.0	kN
Longitudinal Shear	VL	2.0	kN
Circumferential Moment	MC	400.0	N-m
Longitudinal Moment	ML	400.0	N-m
Torsional Moment	MT	500.0	N-m

Dimensionless Parameters used : Gamma = 55.90

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.044	4C	10.449	(A,B)
N(PHI) / ( P/Rm )	0.044	3C	10.482	(C,D)
M(PHI) / ( P )	0.044	2C1	0.147	(A,B)
M(PHI) / ( P )	0.044	1C	0.187	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.763	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.111	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.059	(A,B,C,D)
N(x) / ( P/Rm )	0.044	3C	10.482	(A,B)

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Nozzle Calcs.: LG2 Noz1: 32 11:47am Dec 23,2021

N(x)	/ ( P/Rm )	0.044	4C	10.449	(C,D)
M(x)	/ ( P )	0.044	1C1	0.194	(A,B)
M(x)	/ ( P )	0.044	2C	0.146	(C,D)
N(x)	/ ( MC/(Rm**2 * Beta) )	0.044	4A	1.005	(A,B,C,D)
M(x)	/ ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N(x)	/ ( ML/(Rm**2 * Beta) )	0.044	4B	0.781	(A,B,C,D)
M(x)	/ ( ML/(Rm * Beta) )	0.044	2B	0.096	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm^2)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.8	29.8	29.8	-29.8
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-17.0	17.0	17.0	-17.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend.	P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb.	MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend.	MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb.	ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend.	ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear	VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear	MT	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear		4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.		41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm^2)**

		Stress Intensity Values at							
Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl	(SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q	(SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm	(SUS)	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl	(SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q	(SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1

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Nozzle Calcs.: LG2 Nozl: 32 11:47am Dec 23,2021

Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6	128.6
-----									
Pm+Pl (SUS)	122.0	124.3	127.3	129.6	124.0	126.3	125.3	127.6	127.6
-----									
Pm+Pl+Q (Total)	97.3	149.4	136.6	120.5	84.2	166.1	145.4	108.0	108.0

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.59	137.90	Passed
Pm+Pl (SUS)	129.63	206.85	Passed
Pm+Pl+Q (TOTAL)	166.12	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.*

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FileName : Calculation Book for Evaporator E-PK1601 -----

Nozzle Calcs.: LT1 Nozl: 33 11:47am Dec 23,2021

**Input, Nozzle Desc: LT1 From: 70**

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3345.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

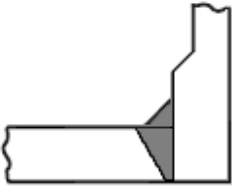
pipe material to be considered

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Hub Height of Integral Nozzle	h	99.8228	mm.
Height of Beveled Transition	L'	23.8228	mm.
Hub Thickness of Integral Nozzle ( tn or x+tp )		20.0000	mm.
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Hub Nozzle (Set-in)**

**Reinforcement CALCULATION, Description: LT1**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation 2.375 in.  
 Actual Thickness Used in Calculation 0.301 in.

Nozzle input data check completed without errors.

Req'd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 =  $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.0 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$   
 = 14.0010 mm.

Req'd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 =  $(P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 =  $(23.0 \cdot 30.1625) / (138 \cdot 1.0 + 0.4 \cdot 23.0)$   
 = 0.4998 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.2826 mm.

**Intermediate Hub Nozzle Calculations:**

Check to determine use of Sketch (e-1) or (e-2):  
 = 2.5 \* Corroded Hub Thickness  
 = 2.5 \* 17.0 Note: less than the hub height, use (e-2)  
 = 42.5000 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	Dl	115.0342	mm.
Parallel to Vessel Wall	Rn+tn+t	57.5171	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	37.5000	mm.

Weld Strength Reduction Factor [fr1]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr2]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr3]:  
 =  $\min(fr2, fr4)$   
 =  $\min(1.0, 1.0)$   
 = 1.000

**Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.145	2.216	NA
Area in Shell	A1	0.639	4.042	NA
Area in Nozzle Wall	A2	12.375	12.538	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	14.015	17.580	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

$$= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) UG-37(c)$$

$$= ( 51.0342 * 14.001 * 1.0 + 2 * 17.0 * 14.001 * 1.0 * (1 - 1.0) )$$

$$= 7.145 \text{ cm}^2$$

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:

$$= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 )$$

$$= 64.0( 1.0 * 15.0 - 1.0 * 14.001 ) - 2 * 17.0$$

$$( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 1.0 )$$

$$= 0.639 \text{ cm}^2$$

Area Available in Nozzle Projecting Outward [A2]:

$$= ( 2 * tlnp )( tn - trn ) fr2$$

$$= ( 2 * 37.5 )( 17.0 - 0.5 ) 1.0$$

$$= 12.375 \text{ cm}^2$$

Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2$$

$$= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0$$

$$= 1.000 \text{ cm}^2$$

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**

Wall Thickness for Internal/External pressures	ta = 3.4998 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0010 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0010 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:

$$= \min[ tb3, \max( tb1, tb2 ) ]$$

$$= \min[ 6.42, \max( 17.001, 4.5 ) ]$$

$$= 6.4200 \text{ mm.}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$= \max( ta, tb )$$

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 Nozzle Calcs.: LT1 Nozl: 33 11:47am Dec 23,2021

= max( 3.4998, 6.42 )  
 = 6.4200 mm.

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME  
 B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	:	62.0,	Allowable	:	137.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	282.7 N./mm <sup>2</sup>	Passed
Occasional	:	5.8,	Allowable	:	183.4 N./mm <sup>2</sup>	Passed
Shear	:	33.9,	Allowable	:	96.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

**Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:**

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

**Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

Governing MDMT of all the sub-joints of this Junction : -46 °C

**ANSI Flange MDMT including Temperature reduction per UCS-66.1:**

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C

Flange MDMT with Temp reduction per UCS-66(i)(2) -86 °C

Flange MDMT with Temp reduction per UCS-66(i)(3) -104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

*Note:*

*Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.*

**Weld Size Calculations, Description: LT1**

Intermediate Calc. for nozzle/shell Welds Tmin 15.0000 mm.

**Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:

= max( 0, (A-A1+2\*tn\*fr1\*(E1\*t-tr))Sv )  
 = max( 0, (7.1453 - 0.6394 + 2 \* 17.0 \* 1.0 \*  
 (1.0 \* 15.0 - 14.001 ) )138 )

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 Nozzle Calcs.: LT1 Noz1: 33 11:47am Dec 23,2021

$$= 94.39 \text{ kN}$$

For hub type nozzles, A2 includes the area of the hub.

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:

$$= (A2+A4-(Wi-Can/.707)^2*fr2)*Sv$$

$$= ( 12.3752 + 1. - 0.0 * 1.0 ) * 138$$

$$= 184.43 \text{ kN}$$

Weld Load [W2]:

$$= ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 ) ) * Sv$$

$$= ( 12.3752 + 0.0 + 1. + ( 5.1 ) ) * 138$$

$$= 254.75 \text{ kN}$$

Weld Load [W3]:

$$= (A2+A3+A4+(2*(Hub Thickness)* t * fr1 ) ) * Sv$$

$$= ( 12.3752 + 0.0 + 1. + 0.0 ) * 138$$

$$= 254.75 \text{ kN}$$

### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$= (\pi/2) * Dlo * Wo * 0.49 * Snw$$

$$= ( 3.1416/2.0 ) * 60.325 * 10.0 * 0.49 * 138$$

$$= 64. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn$$

$$= ( 3.1416 * 27.8398 ) * ( 20.0 - 3.0 ) * 0.7 * 138$$

$$= 144. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng$$

$$= ( 3.1416/2.0 ) * 60.325 * ( 18.0 - 3.0 ) * 0.74 * 138$$

$$= 145. \text{ kN}$$

### Strength of Failure Paths:

$$\text{PATH11} = ( \text{SONW} + \text{SNW} ) = ( 64 + 144 ) = 208 \text{ kN}$$

$$\text{PATH22} = ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} )$$

$$= ( 64 + 0 + 145 + 0 ) = 209 \text{ kN}$$

$$\text{PATH33} = ( \text{Sonw} + \text{Tngw} + \text{Sinw} )$$

$$= ( 64 + 145 + 0 ) = 209 \text{ kN}$$

### Summary of Failure Path Calculations:

Path 1-1 = 207 kN , must exceed W = 94 kN or W1 = 184 kN  
 Path 2-2 = 209 kN , must exceed W = 94 kN or W2 = 254 kN  
 Path 3-3 = 209 kN , must exceed W = 94 kN or W3 = 254 kN

### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 24.506 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 0.5496 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 168.5495 mm.

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 Nozzle Calcs.: LT1 Nozl: 33 11:47am Dec 23,2021

**Input Echo, WRC107/537 Item 1, Description: LT1 :**

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	mm.
Design Temperature	T1	125.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2

**Note:**  
 Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	85.034	mm.
Nozzle Thickness	Tn	20.000	mm.
Nozzle Material		SA-350 LF2	
Nozzle UNS Number		K03011	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm^2
Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

**External Forces and Moments in WRC 107/537 Convention:**

Radial Load (SUS)	P	2.0	kN
Longitudinal Shear (SUS)	Vl	2.0	kN
Circumferential Shear (SUS)	Vc	2.0	kN
Circumferential Moment (SUS)	Mc	400.0	N-m
Longitudinal Moment (SUS)	Ml	400.0	N-m
Torsional Moment (SUS)	Mt	500.0	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979
Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

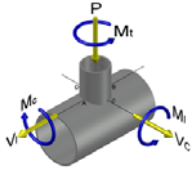
**Note:**  
 WRC Bulletin 537 provides equations for the dimensionless curves  
 found in bulletin 107. As noted in the foreword to bulletin 537,  
 "537 is equivalent to WRC 107". Where 107 is printed in the  
 results below, "537" can be interchanged with "107".

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**Stress Attenuation Diameter (for Insert Plates) per WRC 297:**

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) )$$

$$= 85.034 + 2 * 1.65 * \text{sqrt}( 838.5 ( 18.0 - 3.0 ) )$$

$$= 455.127 \text{ mm.}$$

**WRC 107 Stress Calculation for SUSTained loads:**

Radial Load	P	2.0	kN
Circumferential Shear	VC	2.0	kN
Longitudinal Shear	VL	2.0	kN
Circumferential Moment	MC	400.0	N-m
Longitudinal Moment	ML	400.0	N-m
Torsional Moment	MT	500.0	N-m

Dimensionless Parameters used : Gamma = 55.90

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.044	4C	10.441	(A,B)
N(PHI) / ( P/Rm )	0.044	3C	10.458	(C,D)
M(PHI) / ( P )	0.044	2C1	0.146	(A,B)
M(PHI) / ( P )	0.044	1C	0.186	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.776	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.153	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.058	(A,B,C,D)
-----				
N(x) / ( P/Rm )	0.044	3C	10.458	(A,B)
N(x) / ( P/Rm )	0.044	4C	10.441	(C,D)
M(x) / ( P )	0.044	1C1	0.192	(A,B)
M(x) / ( P )	0.044	2C	0.145	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.044	4A	1.024	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.044	4B	0.794	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.044	2B	0.096	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-9.9	9.9	-9.9	9.9
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.5	29.5	29.5	-29.5
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-16.7	16.7	16.7	-16.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-28.9	20.1	10.0	-7.9	-41.7	37.0	18.5	-20.5

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Long. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-10.3	10.3	-10.3	10.3	-7.7	7.7	-7.7	7.7	7.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9	0.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-17.7	17.7	17.7	-17.7	-17.7
Long. Memb. ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0	0.0
Long. Bend. ML	-27.6	27.6	27.6	-27.6	0.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-40.2	35.5	16.3	-18.3	-27.9	22.9	9.2	-10.7	-10.7
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0	1.0
Shear MT	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Tot. Shear	3.9	3.9	1.9	1.9	1.9	1.9	3.9	3.9	3.9
Str. Int.	41.4	36.4	16.9	18.6	42.0	37.3	20.0	21.9	21.9

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl (SUS)		-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)		-24.5	24.5	9.0	-9.0	-39.4	39.4	19.5	-19.5
Long. Pm (SUS)		63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl (SUS)		-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)		-37.8	37.8	17.3	-17.3	-25.4	25.4	9.9	-9.9
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)		2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Pm (SUS)		126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Pm+Pl (SUS)		121.9	124.2	127.3	129.6	124.0	126.3	125.3	127.6
Pm+Pl+Q (Total)		97.6	149.0	136.4	120.7	84.7	165.7	145.0	108.3

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.59	137.90	Passed
Pm+Pl (SUS)	129.64	206.85	Passed
Pm+Pl+Q (TOTAL)	165.68	413.70	Passed

Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.

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**Input, Nozzle Desc: LT3 From: 70**

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3845.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

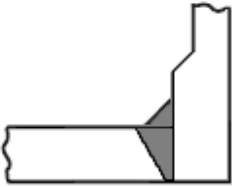
pipe material to be considered

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Hub Height of Integral Nozzle	h	99.8228	mm.
Height of Beveled Transition	L'	23.8228	mm.
Hub Thickness of Integral Nozzle ( tn or x+tp )		20.0000	mm.
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Hub Nozzle (Set-in)**

**Reinforcement CALCULATION, Description: LT3**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation 2.375 in.  
 Actual Thickness Used in Calculation 0.301 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 =  $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.0 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.0)$   
 = 14.0010 mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 =  $(P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 =  $(23.0 \cdot 30.1625) / (138 \cdot 1.0 + 0.4 \cdot 23.0)$   
 = 0.4998 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.2826 mm.

**Intermediate Hub Nozzle Calculations:**

Check to determine use of Sketch (e-1) or (e-2):  
 = 2.5 \* Corroded Hub Thickness  
 = 2.5 \* 17.0 Note: less than the hub height, use (e-2)  
 = 42.5000 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	Dl	115.0342	mm.
Parallel to Vessel Wall	Rn+tn+t	57.5171	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	37.5000	mm.

Weld Strength Reduction Factor [fr1]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr2]:  
 =  $\min(1, S_n / S_v)$   
 =  $\min(1, 137.9 / 137.9)$   
 = 1.000

Weld Strength Reduction Factor [fr3]:  
 =  $\min(fr2, fr4)$   
 =  $\min(1.0, 1.0)$   
 = 1.000

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### Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.145	2.216	NA
Area in Shell	A1	0.639	4.042	NA
Area in Nozzle Wall	A2	12.375	12.538	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	14.015	17.580	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{ UG-37(c)} \\
 &= ( 51.0342 * 14.001 * 1.0 + 2 * 17.0 * 14.001 * 1.0 * (1 - 1.0) ) \\
 &= 7.145 \text{ cm}^2
 \end{aligned}$$

### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d ( E1 * t - F * tr ) - 2 * tn ( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 64.0 ( 1.0 * 15.0 - 1.0 * 14.001 ) - 2 * 17.0 \\
 &\quad ( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 1.0 ) \\
 &= 0.639 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp ) ( tn - trn ) fr2 \\
 &= ( 2 * 37.5 ) ( 17.0 - 0.5 ) 1.0 \\
 &= 12.375 \text{ cm}^2
 \end{aligned}$$

Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2 \\
 &= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0 \\
 &= 1.000 \text{ cm}^2
 \end{aligned}$$

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

### UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

Wall Thickness for Internal/External pressures	ta = 3.4998 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0010 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0010 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 6.42, \max( 17.001, 4.5 ) ] \\
 &= 6.4200 \text{ mm.}
 \end{aligned}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$= \max( ta, tb )$$

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= max( 3.4998, 6.42 )  
 = 6.4200 mm.

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME  
 B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	:	62.0,	Allowable	:	137.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	282.7 N./mm <sup>2</sup>	Passed
Occasional	:	5.8,	Allowable	:	183.4 N./mm <sup>2</sup>	Passed
Shear	:	33.9,	Allowable	:	96.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

**Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:**

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

**Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

Governing MDMT of all the sub-joints of this Junction : -46 °C

**ANSI Flange MDMT including Temperature reduction per UCS-66.1:**

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C

Flange MDMT with Temp reduction per UCS-66(i)(2) -86 °C

Flange MDMT with Temp reduction per UCS-66(i)(3) -104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

*Note:*

*Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.*

**Weld Size Calculations, Description: LT3**

Intermediate Calc. for nozzle/shell Welds Tmin 15.0000 mm.

**Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:

= max( 0, (A-A1+2\*tn\*fr1\*(E1\*t-tr))Sv )  
 = max( 0, (7.1453 - 0.6394 + 2 \* 17.0 \* 1.0 \*  
 (1.0 \* 15.0 - 14.001 ) )138 )

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$$= 94.39 \text{ kN}$$

For hub type nozzles, A2 includes the area of the hub.

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:

$$= (A2+A4-(Wi-Can/.707)^2*fr2)*Sv$$

$$= ( 12.3752 + 1. - 0.0 * 1.0 ) * 138$$

$$= 184.43 \text{ kN}$$

Weld Load [W2]:

$$= ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 ) ) * Sv$$

$$= ( 12.3752 + 0.0 + 1. + ( 5.1 ) ) * 138$$

$$= 254.75 \text{ kN}$$

Weld Load [W3]:

$$= (A2+A3+A4+(2*(Hub Thickness)* t * fr1 ) ) * Sv$$

$$= ( 12.3752 + 0.0 + 1. + 0.0 ) * 138$$

$$= 254.75 \text{ kN}$$

### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$= (\pi/2) * Dlo * Wo * 0.49 * Snw$$

$$= ( 3.1416/2.0 ) * 60.325 * 10.0 * 0.49 * 138$$

$$= 64. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn$$

$$= ( 3.1416 * 27.8398 ) * ( 20.0 - 3.0 ) * 0.7 * 138$$

$$= 144. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng$$

$$= ( 3.1416/2.0 ) * 60.325 * ( 18.0 - 3.0 ) * 0.74 * 138$$

$$= 145. \text{ kN}$$

### Strength of Failure Paths:

$$\text{PATH11} = ( \text{SONW} + \text{SNW} ) = ( 64 + 144 ) = 208 \text{ kN}$$

$$\text{PATH22} = ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} )$$

$$= ( 64 + 0 + 145 + 0 ) = 209 \text{ kN}$$

$$\text{PATH33} = ( \text{Sonw} + \text{Tngw} + \text{Sinw} )$$

$$= ( 64 + 145 + 0 ) = 209 \text{ kN}$$

### Summary of Failure Path Calculations:

Path 1-1 = 207 kN , must exceed W = 94 kN or W1 = 184 kN  
 Path 2-2 = 209 kN , must exceed W = 94 kN or W2 = 254 kN  
 Path 3-3 = 209 kN , must exceed W = 94 kN or W3 = 254 kN

### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 24.506 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 0.5496 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 168.5495 mm.

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**Input Echo, WRC107/537 Item 1, Description: LT3 :**

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	mm.
Design Temperature	T1	125.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm <sup>2</sup>
Vessel Hot S.I. Allowable	Smh	137.90	N./mm <sup>2</sup>

**Note:**

Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
Make sure that material properties at this temperature are not  
time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	85.034	mm.
Nozzle Thickness	Tn	20.000	mm.
Nozzle Material		SA-350 LF2	
Nozzle UNS Number		K03011	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm <sup>2</sup>
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm <sup>2</sup>
Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

**External Forces and Moments in WRC 107/537 Convention:**

Radial Load (SUS)	P	2.0	kN
Longitudinal Shear (SUS)	Vl	2.0	kN
Circumferential Shear (SUS)	Vc	2.0	kN
Circumferential Moment (SUS)	Mc	400.0	N-m
Longitudinal Moment (SUS)	Ml	400.0	N-m
Torsional Moment (SUS)	Mt	500.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979
Include Pressure Stress Indices per Div. 2		No
Compute Pressure Stress per WRC-368		No
Local Loads applied at end of Nozzle/Attachment		No

**Note:**

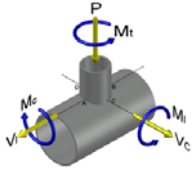
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".

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**Stress Attenuation Diameter (for Insert Plates) per WRC 297:**

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) )$$

$$= 85.034 + 2 * 1.65 * \text{sqrt}( 838.5 ( 18.0 - 3.0 ) )$$

$$= 455.127 \text{ mm.}$$

**WRC 107 Stress Calculation for SUSTained loads:**

Radial Load	P	2.0	kN
Circumferential Shear	VC	2.0	kN
Longitudinal Shear	VL	2.0	kN
Circumferential Moment	MC	400.0	N-m
Longitudinal Moment	ML	400.0	N-m
Torsional Moment	MT	500.0	N-m

Dimensionless Parameters used : Gamma = 55.90

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.044	4C	10.441	(A,B)
N(PHI) / ( P/Rm )	0.044	3C	10.458	(C,D)
M(PHI) / ( P )	0.044	2C1	0.146	(A,B)
M(PHI) / ( P )	0.044	1C	0.186	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.776	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.153	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.058	(A,B,C,D)
-----				
N(x) / ( P/Rm )	0.044	3C	10.458	(A,B)
N(x) / ( P/Rm )	0.044	4C	10.441	(C,D)
M(x) / ( P )	0.044	1C1	0.192	(A,B)
M(x) / ( P )	0.044	2C	0.145	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.044	4A	1.024	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.044	4B	0.794	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.044	2B	0.096	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-9.9	9.9	-9.9	9.9
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.5	29.5	29.5	-29.5
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-16.7	16.7	16.7	-16.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-28.9	20.1	10.0	-7.9	-41.7	37.0	18.5	-20.5

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Long. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-10.3	10.3	-10.3	10.3	-7.7	7.7	-7.7	7.7	7.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9	0.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-17.7	17.7	17.7	-17.7	-17.7
Long. Memb. ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0	0.0
Long. Bend. ML	-27.6	27.6	27.6	-27.6	0.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-40.2	35.5	16.3	-18.3	-27.9	22.9	9.2	-10.7	-10.7
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0	1.0
Shear MT	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Tot. Shear	3.9	3.9	1.9	1.9	1.9	1.9	3.9	3.9	3.9
Str. Int.	41.4	36.4	16.9	18.6	42.0	37.3	20.0	21.9	21.9

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl (SUS)		-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)		-24.5	24.5	9.0	-9.0	-39.4	39.4	19.5	-19.5
Long. Pm (SUS)		63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl (SUS)		-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)		-37.8	37.8	17.3	-17.3	-25.4	25.4	9.9	-9.9
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)		2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Pm (SUS)		126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Pm+Pl (SUS)		121.9	124.2	127.3	129.6	124.0	126.3	125.3	127.6
Pm+Pl+Q (Total)		97.6	149.0	136.4	120.7	84.7	165.7	145.0	108.3

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.59	137.90	Passed
Pm+Pl (SUS)	129.64	206.85	Passed
Pm+Pl+Q (TOTAL)	165.68	413.70	Passed

Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.

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**Input, Nozzle Desc: LT2 From: 70**

Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516	70
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3345.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

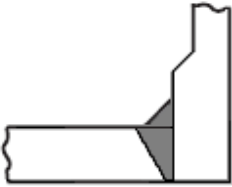
pipe material to be considered

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-350	LF2
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-350	LF2
Flange Type		Weld Neck	Flange
Hub Height of Integral Nozzle	h	99.8228	mm.
Height of Beveled Transition	L'	23.8228	mm.
Hub Thickness of Integral Nozzle ( tn or x+tp )		20.0000	mm.
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Hub Nozzle (Set-in)**

**Reinforcement CALCULATION, Description: LT2**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation 2.375 in.  
 Actual Thickness Used in Calculation 0.301 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 =  $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.12 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.12)$   
 = 14.0733 mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 =  $(P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 =  $(23.12 \cdot 30.1625) / (138 \cdot 1.0 + 0.4 \cdot 23.12)$   
 = 0.5023 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.2826 mm.

**Intermediate Hub Nozzle Calculations:**

Check to determine use of Sketch (e-1) or (e-2):  
 = 2.5 \* Corroded Hub Thickness  
 = 2.5 \* 17.0 Note: less than the hub height, use (e-2)  
 = 42.5000 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	Dl	115.0342	mm.
Parallel to Vessel Wall	Rn+tn+t	57.5171	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	37.5000	mm.

Weld Strength Reduction Factor [fr1]:  
 = min( 1, Sn/Sv )  
 = min( 1, 137.9/137.9 )  
 = 1.000

Weld Strength Reduction Factor [fr2]:  
 = min( 1, Sn/Sv )  
 = min( 1, 137.9/137.9 )  
 = 1.000

Weld Strength Reduction Factor [fr3]:  
 = min( fr2, fr4 )  
 = min( 1.0, 1.0 )  
 = 1.000

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### Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.182	2.216	NA
Area in Shell	A1	0.593	4.042	NA
Area in Nozzle Wall	A2	12.373	12.538	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	13.966	17.580	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{UG-37(c)} \\
 &= ( 51.0342 * 14.0733 * 1.0 + 2 * 17.0 * 14.0733 * 1.0 * (1 - 1.0) ) \\
 &= 7.182 \text{ cm}^2
 \end{aligned}$$

### Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 64.0( 1.0 * 15.0 - 1.0 * 14.073 ) - 2 * 17.0 \\
 &\quad ( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 1.0 ) \\
 &= 0.593 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp )( tn - trn ) fr2 \\
 &= ( 2 * 37.5 )( 17.0 - 0.5 ) 1.0 \\
 &= 12.373 \text{ cm}^2
 \end{aligned}$$

Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2 \\
 &= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0 \\
 &= 1.000 \text{ cm}^2
 \end{aligned}$$

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

### UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

Wall Thickness for Internal/External pressures	ta = 3.5023 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0733 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0733 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 6.42, \max( 17.0733, 4.5 ) ] \\
 &= 6.4200 \text{ mm.}
 \end{aligned}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$= \max( ta, tb )$$

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= max( 3.5023, 6.42 )  
 = 6.4200 mm.

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME  
 B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	:	62.1,	Allowable	:	137.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	282.7 N./mm <sup>2</sup>	Passed
Occasional	:	5.8,	Allowable	:	183.4 N./mm <sup>2</sup>	Passed
Shear	:	33.9,	Allowable	:	96.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

**Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:**

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

**Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

Governing MDMT of all the sub-joints of this Junction : -46 °C

**ANSI Flange MDMT including Temperature reduction per UCS-66.1:**

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C

Flange MDMT with Temp reduction per UCS-66(i)(2) -85 °C

Flange MDMT with Temp reduction per UCS-66(i)(3) -104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

Design Pressure/Ambient Rating = 23.12/51.10 = 0.452

*Note:*

*Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.*

**Weld Size Calculations, Description: LT2**

Intermediate Calc. for nozzle/shell Welds Tmin 15.0000 mm.

**Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:

= max( 0, (A-A1+2\*tn\*fr1\*(E1\*t-tr))Sv )  
 = max( 0, (7.1822 - 0.5931 + 2 \* 17.0 \* 1.0 \*  
 (1.0 \* 15.0 - 14.0733 ) )138 )

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$$= 95.20 \text{ kN}$$

For hub type nozzles, A2 includes the area of the hub.

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:

$$= (A2+A4-(Wi-Can/.707)^2*fr2)*Sv$$

$$= ( 12.3733 + 1. - 0.0 * 1.0 ) * 138$$

$$= 184.40 \text{ kN}$$

Weld Load [W2]:

$$= ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 ) ) * Sv$$

$$= ( 12.3733 + 0.0 + 1. + ( 5.1 ) ) * 138$$

$$= 254.72 \text{ kN}$$

Weld Load [W3]:

$$= (A2+A3+A4+(2*(Hub Thickness)* t * fr1 ) ) * Sv$$

$$= ( 12.3733 + 0.0 + 1. + 0.0 ) * 138$$

$$= 254.72 \text{ kN}$$

### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

$$= (\pi/2) * Dlo * Wo * 0.49 * Snw$$

$$= ( 3.1416/2.0 ) * 60.325 * 10.0 * 0.49 * 138$$

$$= 64. \text{ kN}$$

Shear, Nozzle Wall [Snw]:

$$= (\pi * ( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn$$

$$= ( 3.1416 * 27.8398 ) * ( 20.0 - 3.0 ) * 0.7 * 138$$

$$= 144. \text{ kN}$$

Tension, Shell Groove Weld [Tngw]:

$$= (\pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng$$

$$= ( 3.1416/2.0 ) * 60.325 * ( 18.0 - 3.0 ) * 0.74 * 138$$

$$= 145. \text{ kN}$$

### Strength of Failure Paths:

$$\text{PATH11} = ( \text{SONW} + \text{SNW} ) = ( 64 + 144 ) = 208 \text{ kN}$$

$$\text{PATH22} = ( \text{Sonw} + \text{Tpgw} + \text{Tngw} + \text{Sinw} )$$

$$= ( 64 + 0 + 145 + 0 ) = 209 \text{ kN}$$

$$\text{PATH33} = ( \text{Sonw} + \text{Tngw} + \text{Sinw} )$$

$$= ( 64 + 145 + 0 ) = 209 \text{ kN}$$

### Summary of Failure Path Calculations:

Path 1-1 = 207 kN , must exceed W = 95 kN or W1 = 184 kN  
 Path 2-2 = 209 kN , must exceed W = 95 kN or W2 = 254 kN  
 Path 3-3 = 209 kN , must exceed W = 95 kN or W3 = 254 kN

### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 24.623 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 0.5496 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 168.5495 mm.

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**Input Echo, WRC107/537 Item 1, Description: LT2 :**

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	mm.
Design Temperature	T1	125.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2

**Note:**  
 Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	85.034	mm.
Nozzle Thickness	Tn	20.000	mm.
Nozzle Material		SA-350 LF2	
Nozzle UNS Number		K03011	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm^2
Design Internal Pressure	Dp	23.118	bars
Include Pressure Thrust		No	

**External Forces and Moments in WRC 107/537 Convention:**

Radial Load (SUS)	P	2.0	kN
Longitudinal Shear (SUS)	Vl	2.0	kN
Circumferential Shear (SUS)	Vc	2.0	kN
Circumferential Moment (SUS)	Mc	400.0	N-m
Longitudinal Moment (SUS)	Ml	400.0	N-m
Torsional Moment (SUS)	Mt	500.0	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979
Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

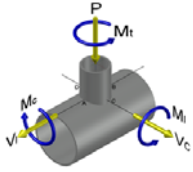
**Note:**  
 WRC Bulletin 537 provides equations for the dimensionless curves  
 found in bulletin 107. As noted in the foreword to bulletin 537,  
 "537 is equivalent to WRC 107". Where 107 is printed in the  
 results below, "537" can be interchanged with "107".

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**Stress Attenuation Diameter (for Insert Plates) per WRC 297:**

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) )$$

$$= 85.034 + 2 * 1.65 * \text{sqrt}( 838.5 ( 18.0 - 3.0 ) )$$

$$= 455.127 \text{ mm.}$$

**WRC 107 Stress Calculation for SUSTained loads:**

Radial Load	P	2.0	kN
Circumferential Shear	VC	2.0	kN
Longitudinal Shear	VL	2.0	kN
Circumferential Moment	MC	400.0	N-m
Longitudinal Moment	ML	400.0	N-m
Torsional Moment	MT	500.0	N-m

Dimensionless Parameters used : Gamma = 55.90

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.044	4C	10.441	(A,B)
N(PHI) / ( P/Rm )	0.044	3C	10.458	(C,D)
M(PHI) / ( P )	0.044	2C1	0.146	(A,B)
M(PHI) / ( P )	0.044	1C	0.186	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.776	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.153	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.058	(A,B,C,D)
-----				
N(x) / ( P/Rm )	0.044	3C	10.458	(A,B)
N(x) / ( P/Rm )	0.044	4C	10.441	(C,D)
M(x) / ( P )	0.044	1C1	0.192	(A,B)
M(x) / ( P )	0.044	2C	0.145	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.044	4A	1.024	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.044	4B	0.794	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.044	2B	0.096	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-9.9	9.9	-9.9	9.9
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.5	29.5	29.5	-29.5
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-16.7	16.7	16.7	-16.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-28.9	20.1	10.0	-7.9	-41.7	37.0	18.5	-20.5

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Long. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-10.3	10.3	-10.3	10.3	-7.7	7.7	-7.7	7.7	7.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9	0.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-17.7	17.7	17.7	-17.7	-17.7
Long. Memb. ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0	0.0
Long. Bend. ML	-27.6	27.6	27.6	-27.6	0.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-40.2	35.5	16.3	-18.3	-27.9	22.9	9.2	-10.7	-10.7
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0	1.0
Shear MT	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Tot. Shear	3.9	3.9	1.9	1.9	1.9	1.9	3.9	3.9	3.9
Str. Int.	41.4	36.4	16.9	18.6	42.0	37.3	20.0	21.9	21.9

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl (SUS)		-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)		-24.5	24.5	9.0	-9.0	-39.4	39.4	19.5	-19.5
Long. Pm (SUS)		63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl (SUS)		-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)		-37.8	37.8	17.3	-17.3	-25.4	25.4	9.9	-9.9
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)		2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Pm (SUS)		126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Pm+Pl (SUS)		122.6	124.9	128.0	130.3	124.6	126.9	125.9	128.3
Pm+Pl+Q (Total)		98.3	149.7	137.0	121.4	85.3	166.3	145.7	109.0

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	130.29	206.85	Passed
Pm+Pl+Q (TOTAL)	166.34	413.70	Passed

Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.

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Nozzle Calcs.: LT4 Nozl: 36 11:47am Dec 23,2021

**Input, Nozzle Desc: LT4 From: 70**

Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516	70
Shell Allowable Stress at Temperature	Sv	137.90	N./mm <sup>2</sup>
Shell Allowable Stress At Ambient	Sva	137.90	N./mm <sup>2</sup>
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.

Distance from Bottom/Left Tangent		3845.53	mm
User Entered Minimum Design Metal Temperature		-45.00	°C

pipe material to be considered

**Type of Element Connected to the Shell : Nozzle**

Material [Impact Tested]		SA-350	LF2
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm <sup>2</sup>
Allowable Stress At Ambient	Sna	137.90	N./mm <sup>2</sup>

Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		2.0000	in.

Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	

Flange Material		SA-350	LF2
Flange Type		Weld Neck	Flange

Hub Height of Integral Nozzle	h	99.8228	mm.
Height of Beveled Transition	L'	23.8228	mm.
Hub Thickness of Integral Nozzle ( tn or x+tp )		20.0000	mm.

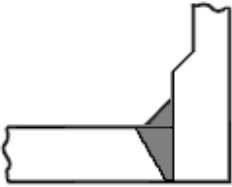
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	

Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.

Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

**Nozzle Sketch (may not represent actual weld type/configuration)**



**Hub Nozzle (Set-in)**

**Reinforcement CALCULATION, Description: LT4**

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation 2.375 in.  
 Actual Thickness Used in Calculation 0.301 in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]  
 =  $(P \cdot R) / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $(23.12 \cdot 831.0) / (138 \cdot 1.0 - 0.6 \cdot 23.12)$   
 = 14.0733 mm.

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]  
 =  $(P \cdot R_o) / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 =  $(23.12 \cdot 30.1625) / (138 \cdot 1.0 + 0.4 \cdot 23.12)$   
 = 0.5023 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.2826 mm.

**Intermediate Hub Nozzle Calculations:**

Check to determine use of Sketch (e-1) or (e-2):  
 = 2.5 \* Corroded Hub Thickness  
 = 2.5 \* 17.0 Note: less than the hub height, use (e-2)  
 = 42.5000 mm.

**UG-40, Limits of Reinforcement : [Internal Pressure]**

Parallel to Vessel Wall (Diameter Limit)	Dl	115.0342	mm.
Parallel to Vessel Wall	Rn+tn+t	57.5171	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	37.5000	mm.

Weld Strength Reduction Factor [fr1]:  
 = min( 1, Sn/Sv )  
 = min( 1, 137.9/137.9 )  
 = 1.000

Weld Strength Reduction Factor [fr2]:  
 = min( 1, Sn/Sv )  
 = min( 1, 137.9/137.9 )  
 = 1.000

Weld Strength Reduction Factor [fr3]:  
 = min( fr2, fr4 )  
 = min( 1.0, 1.0 )  
 = 1.000

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**Results of Nozzle Reinforcement Area Calculations: (cm<sup>2</sup>)**

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.182	2.216	NA
Area in Shell	A1	0.593	4.042	NA
Area in Nozzle Wall	A2	12.373	12.538	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds A41+A42+A43		1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	13.966	17.580	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

$$\begin{aligned}
 &= ( d * tr * F + 2 * tn * tr * F * (1 - fr1) ) \text{UG-37(c)} \\
 &= ( 51.0342 * 14.0733 * 1.0 + 2 * 17.0 * 14.0733 * 1.0 * (1 - 1.0) ) \\
 &= 7.182 \text{ cm}^2
 \end{aligned}$$

**Reinforcement Areas per Figure UG-37.1**

Area Available in Shell [A1]:

$$\begin{aligned}
 &= d( E1 * t - F * tr ) - 2 * tn( E1 * t - F * tr ) * ( 1 - fr1 ) \\
 &= 64.0( 1.0 * 15.0 - 1.0 * 14.073 ) - 2 * 17.0 \\
 &\quad ( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 1.0 ) \\
 &= 0.593 \text{ cm}^2
 \end{aligned}$$

Area Available in Nozzle Projecting Outward [A2]:

$$\begin{aligned}
 &= ( 2 * tlnp )( tn - trn ) fr2 \\
 &= ( 2 * 37.5 )( 17.0 - 0.5 ) 1.0 \\
 &= 12.373 \text{ cm}^2
 \end{aligned}$$

Area Available in Inward Weld + Outward Weld [A41 + A43]:

$$\begin{aligned}
 &= Wo^2 * fr2 + ( Wi - can / 0.707 )^2 * fr2 \\
 &= 10.0^2 * 1.0 + ( 0.0 )^2 * 1.0 \\
 &= 1.000 \text{ cm}^2
 \end{aligned}$$

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

**UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]**

Wall Thickness for Internal/External pressures	ta = 3.5023 mm.
Wall Thickness per UG16(b),	tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 = 17.0733 mm.
Wall Thickness	tb1 = max(trb1, tr16b) = 17.0733 mm.
Wall Thickness, shell/head, external pressure	trb2 = 3.6235 mm.
Wall Thickness	tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45	tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:

$$\begin{aligned}
 &= \min[ tb3, \max( tb1, tb2 ) ] \\
 &= \min[ 6.42, \max( 17.0733, 4.5 ) ] \\
 &= 6.4200 \text{ mm.}
 \end{aligned}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

$$= \max( ta, tb )$$

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= max( 3.5023, 6.42 )  
 = 6.4200 mm.

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

**Stresses on Nozzle due to External and Pressure Loads per the ASME  
 B31.3 Piping Code (see 319.4.4 and 302.3.5):**

Sustained	:	62.1,	Allowable	:	137.9 N./mm <sup>2</sup>	Passed
Expansion	:	0.0,	Allowable	:	282.7 N./mm <sup>2</sup>	Passed
Occasional	:	5.8,	Allowable	:	183.4 N./mm <sup>2</sup>	Passed
Shear	:	33.9,	Allowable	:	96.5 N./mm <sup>2</sup>	Passed

*Note : The number of cycles on this nozzle was assumed to be 7000 or less for the determination of the expansion stress allowable.*

**Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:**

**Nozzle Neck to Flange Weld (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

**Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :**

*Note:*

*This Material was specified as being an Impact Tested (Low Temperature) Material.*

Impact Test Temperature provided per Specification -46 °C

Governing MDMT of all the sub-joints of this Junction : -46 °C

**ANSI Flange MDMT including Temperature reduction per UCS-66.1:**

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C

Flange MDMT with Temp reduction per UCS-66(i)(2) -85 °C

Flange MDMT with Temp reduction per UCS-66(i)(3) -104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

Design Pressure/Ambient Rating = 23.12/51.10 = 0.452

*Note:*

*Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.*

**Weld Size Calculations, Description: LT4**

Intermediate Calc. for nozzle/shell Welds Tmin 15.0000 mm.

**Results Per UW-16.1:**

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.

**Weld Strength and Weld Loads per UG-41.1, Sketch (a) or (b)**

Weld Load [W]:

= max( 0, (A-A1+2\*tn\*fr1\*(E1\*t-tr))Sv )  
 = max( 0, (7.1822 - 0.5931 + 2 \* 17.0 \* 1.0 \*  
 (1.0 \* 15.0 - 14.0733 ) )138 )

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= 95.20 kN

For hub type nozzles, A2 includes the area of the hub.

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:

= (A2+A4-(Wi-Can/.707)<sup>2</sup>\*fr2)\*Sv  
 = ( 12.3733 + 1. - 0.0 \* 1.0 ) \* 138  
 = 184.40 kN

Weld Load [W2]:

= ( A2 + A3 + A4 + (2(Hub Thickness) \* t \* fr1 ) ) \* Sv  
 = ( 12.3733 + 0.0 + 1. + ( 5.1 ) ) \* 138  
 = 254.72 kN

Weld Load [W3]:

= (A2+A3+A4+(2\*(Hub Thickness)\* t \* fr1 ) ) \* Sv  
 = ( 12.3733 + 0.0 + 1. + 0.0 ) \* 138  
 = 254.72 kN

### Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

= (pi/2) \* Dlo \* Wo \* 0.49 \* Snw  
 = ( 3.1416/2.0 ) \* 60.325 \* 10.0 \* 0.49 \* 138  
 = 64. kN

Shear, Nozzle Wall [Snw]:

= (pi \* ( Dlr + Dlo )/4 ) \* ( Thk - Can ) \* 0.7 \* Sn  
 = ( 3.1416 \* 27.8398 ) \* ( 20.0 - 3.0 ) \* 0.7 \* 138  
 = 144. kN

Tension, Shell Groove Weld [Tngw]:

= (pi/2) \* Dlo \* (Wgnvi-Cas) \* 0.74 \* Sng  
 = ( 3.1416/2.0 ) \* 60.325 \* ( 18.0 - 3.0 ) \* 0.74 \* 138  
 = 145. kN

### Strength of Failure Paths:

PATH11 = ( SONW + SNW ) = ( 64 + 144 ) = 208 kN  
 PATH22 = ( Sonw + Tpgw + Tngw + Sinw )  
 = ( 64 + 0 + 145 + 0 ) = 209 kN  
 PATH33 = ( Sonw + Tngw + Sinw )  
 = ( 64 + 145 + 0 ) = 209 kN

### Summary of Failure Path Calculations:

Path 1-1 = 207 kN , must exceed W = 95 kN or W1 = 184 kN  
 Path 2-2 = 209 kN , must exceed W = 95 kN or W2 = 254 kN  
 Path 3-3 = 209 kN , must exceed W = 95 kN or W3 = 254 kN

### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 24.623 bars

Note: The MAWP of this junction was limited by the parent Shell/Head.

Nozzle is O.K. for the External Pressure 1.034 bars

The Drop for this Nozzle is : 0.5496 mm.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 168.5495 mm.

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**Input Echo, WRC107/537 Item 1, Description: LT4 :**

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	mm.
Design Temperature	T1	125.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2

**Note:**  
 Using 2 \* Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	85.034	mm.
Nozzle Thickness	Tn	20.000	mm.
Nozzle Material		SA-350 LF2	
Nozzle UNS Number		K03011	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm^2
Design Internal Pressure	Dp	23.118	bars
Include Pressure Thrust		No	

**External Forces and Moments in WRC 107/537 Convention:**

Radial Load (SUS)	P	2.0	kN
Longitudinal Shear (SUS)	Vl	2.0	kN
Circumferential Shear (SUS)	Vc	2.0	kN
Circumferential Moment (SUS)	Mc	400.0	N-m
Longitudinal Moment (SUS)	Ml	400.0	N-m
Torsional Moment (SUS)	Mt	500.0	N-m

Use Interactive Control	No
WRC107 Version	Version March 1979
Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

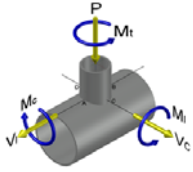
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**Stress Attenuation Diameter (for Insert Plates) per WRC 297:**

$$= \text{NozzleOD} + 2 * 1.65 * \text{sqrt}( \text{Rmean}( t - ca ) )$$

$$= 85.034 + 2 * 1.65 * \text{sqrt}( 838.5 ( 18.0 - 3.0 ) )$$

$$= 455.127 \text{ mm.}$$

**WRC 107 Stress Calculation for SUSTAINED loads:**

Radial Load	P	2.0	kN
Circumferential Shear	VC	2.0	kN
Longitudinal Shear	VL	2.0	kN
Circumferential Moment	MC	400.0	N-m
Longitudinal Moment	ML	400.0	N-m
Torsional Moment	MT	500.0	N-m

Dimensionless Parameters used : Gamma = 55.90

**Dimensionless Loads for Cylindrical Shells at Attachment Junction:**

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / ( P/Rm )	0.044	4C	10.441	(A,B)
N(PHI) / ( P/Rm )	0.044	3C	10.458	(C,D)
M(PHI) / ( P )	0.044	2C1	0.146	(A,B)
M(PHI) / ( P )	0.044	1C	0.186	(C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )	0.044	3A	0.776	(A,B,C,D)
M(PHI) / ( MC/(Rm * Beta) )	0.044	1A	0.103	(A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )	0.044	3B	3.153	(A,B,C,D)
M(PHI) / ( ML/(Rm * Beta) )	0.044	1B	0.058	(A,B,C,D)
N(x) / ( P/Rm )	0.044	3C	10.458	(A,B)
N(x) / ( P/Rm )	0.044	4C	10.441	(C,D)
M(x) / ( P )	0.044	1C1	0.192	(A,B)
M(x) / ( P )	0.044	2C	0.145	(C,D)
N(x) / ( MC/(Rm**2 * Beta) )	0.044	4A	1.024	(A,B,C,D)
M(x) / ( MC/(Rm * Beta) )	0.044	2A	0.062	(A,B,C,D)
N(x) / ( ML/(Rm**2 * Beta) )	0.044	4B	0.794	(A,B,C,D)
M(x) / ( ML/(Rm * Beta) )	0.044	2B	0.096	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

**Stresses in the Vessel at the Attachment Junction (N./mm^2)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-9.9	9.9	-9.9	9.9
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.5	29.5	29.5	-29.5
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-16.7	16.7	16.7	-16.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-28.9	20.1	10.0	-7.9	-41.7	37.0	18.5	-20.5

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Long. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-10.3	10.3	-10.3	10.3	-7.7	7.7	-7.7	7.7	7.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9	0.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-17.7	17.7	17.7	-17.7	-17.7
Long. Memb. ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0	0.0
Long. Bend. ML	-27.6	27.6	27.6	-27.6	0.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-40.2	35.5	16.3	-18.3	-27.9	22.9	9.2	-10.7	-10.7
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0	1.0
Shear MT	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Tot. Shear	3.9	3.9	1.9	1.9	1.9	1.9	3.9	3.9	3.9
Str. Int.	41.4	36.4	16.9	18.6	42.0	37.3	20.0	21.9	21.9

**WRC 107/537 Stress Summations:**

**Vessel Stress Summation at Attachment Junction (N./mm<sup>2</sup>)**

Type of Stress	Load	Stress Intensity Values at							
		Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)		126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl (SUS)		-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)		-24.5	24.5	9.0	-9.0	-39.4	39.4	19.5	-19.5
Long. Pm (SUS)		63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl (SUS)		-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)		-37.8	37.8	17.3	-17.3	-25.4	25.4	9.9	-9.9
Shear Pm (SUS)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)		1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)		2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Pm (SUS)		126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Pm+Pl (SUS)		122.6	124.9	128.0	130.3	124.6	126.9	125.9	128.3
Pm+Pl+Q (Total)		98.3	149.7	137.0	121.4	85.3	166.3	145.7	109.0

**Vessel Stress Summation Comparison (N./mm<sup>2</sup>):**

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	130.29	206.85	Passed
Pm+Pl+Q (TOTAL)	166.34	413.70	Passed

Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 \* Smh.

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Nozzle Schedule: Step: 35 11:47am Dec 23,2021

**Nozzle Schedule:**

Flg	Nominal or	Schd	Flg	Nozzle	Wall	Reinforcing Pad	Cut			
Class	Actual	or FVC	Type	O/Dia	Thk	Diameter	Thk	Length		
Description	Size	Type		in	mm.	mm.	mm.	mm.		
D4	2.000 in	Actual	LWN	3.307	16.600	...	...	171.24	300	
D2	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300	
D1	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300	
D3	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300	
TT	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300	
V	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300	
LG1	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300	
LG2	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300	
LT1	2.000 in	160	WNF	2.375	8.738	...	...	168.55		
300										
LT3	2.000 in	160	WNF	2.375	8.738	...	...	168.55		
300										
LT2	2.000 in	160	WNF	2.375	8.738	...	...	168.55		
300										
LT4	2.000 in	160	WNF	2.375	8.738	...	...	168.55		
300										
S2	8.000 in	80	WNF	8.625	12.700	379.08	18.00	175.28		
300										
S1	8.000 in	80	WNF	8.625	12.700	379.08	18.00	175.28		
300										
S3	8.000 in	80	WNF	8.625	12.700	379.08	18.00	175.28		
300										
S4	8.000 in	80	WNF	8.625	12.700	379.08	18.00	175.28		
300										
T2	20.000 in	Actual	WNF	20.000	20.000	748.00	20.00	221.42	300	
T1	20.000 in	Actual	WNF	20.000	20.000	748.00	20.00	221.42	300	

*General Notes for the above table:*

The Cut Length is the Outside Projection + Inside Projection + Drop + In Plane Shell Thickness. This value does not include weld gaps, nor does it account for shrinkage.

In the case of Oblique Nozzles, the Outside Diameter must be increased. The Re-Pad WIDTH around the nozzle is calculated as follows:  
 Width of Pad = (Pad Outside Dia. (per above) - Nozzle Outside Dia.)/2

For hub nozzles, the thickness and diameter shown are those of the smaller and thinner section.

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**Nozzle Material and Weld Fillet Leg Size Details (mm.):**

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
D4	SA-350 LF2	20.000	10.000	...	...	...
D2	SA-350 LF2	18.000	10.000	...	...	...
D1	SA-350 LF2	18.000	10.000	...	...	...
D3	SA-350 LF2	18.000	10.000	...	...	...
TT	SA-350 LF2	18.000	10.000	...	...	...
V	SA-350 LF2	18.000	10.000	...	...	...
LG1	SA-350 LF2	18.000	10.000	...	...	...
LG2	SA-350 LF2	18.000	10.000	...	...	...
LT1	SA-350 LF2	18.000	10.000	...	...	...
LT3	SA-350 LF2	18.000	10.000	...	...	...
LT2	SA-350 LF2	18.000	10.000	...	...	...
LT4	SA-350 LF2	18.000	10.000	...	...	...
S2	SA-333 6	18.000	10.000	14.000	18.000	...
S1	SA-333 6	18.000	10.000	14.000	18.000	...
S3	SA-333 6	18.000	10.000	14.000	18.000	...
S4	SA-333 6	18.000	10.000	14.000	18.000	...
T2	SA-516 70	15.000	18.000	12.000	15.000	...
T1	SA-516 70	15.000	18.000	12.000	15.000	...

Note: The Outside projections below do not include the flange thickness.

**Nozzle Miscellaneous Data:**

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
D4	1865.525	270.0	150.00	0.00	CON
D2	2895.525	270.0	150.00	0.00	SHELL 002
D1	4695.525	270.0	150.00	0.00	SHELL 002
D3	5495.525	270.0	150.00	0.00	SHELL 002
TT	6095.525	270.0	150.00	0.00	SHELL 002
V	2495.525	90.0	150.00	0.00	SHELL 002
LG1	4495.525	270.0	150.00	0.00	SHELL 002
LG2	4495.525	90.0	150.00	0.00	SHELL 002
LT1	3295.525	90.0	150.00	0.00	SHELL 002
LT3	3795.525	90.0	150.00	0.00	SHELL 002
LT2	3295.525	270.0	150.00	0.00	SHELL 002
LT4	3795.525	270.0	150.00	0.00	SHELL 002
S2	2495.525	270.0	150.00	0.00	SHELL 002
S1	5095.525	270.0	150.00	0.00	SHELL 002
S3	2895.525	90.0	150.00	0.00	SHELL 002
S4	5095.525	90.0	150.00	0.00	SHELL 002
T2	400.000	90.0	150.00	0.00	SHELL 001
T1	400.000	270.0	150.00	0.00	SHELL 001

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**Input Echo, Tubesheet Number 1, Description: TUBE SHEET**

**Shell Data:**

**Main Shell Description: SHELL 002**

Shell Maximum Design Pressure	Psd,max	23.00	bars
Shell Maximum Operating Pressure	Psox,max	23.00	bars
Shell Minimum Operating Pressure	Psox,min	0.00	bars
Shell Thickness	ts	20.0000	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	1200.000	mm.
Shell Temperature for Internal Pressure	Ts	125.00	°C
Shell Material		SA-516 70	

two load cases to be considered for tubesheet design:  
 case 1: shell side and tube side without full vacuum  
 case 2: shell side with F.V. and tube side without F.V.

**Note:**

Using 2 \* Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.  
 Make sure that material properties at this temperature are not time-dependent for Material: SA-516 70

Shell Material UNS Number		K02700	
Shell Allowable Stress at Temperature	Ss	137.90	N./mm <sup>2</sup>
Shell Allowable Stress at Ambient		137.90	N./mm <sup>2</sup>

**Channel Description: SHELL 001**

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	23.00	bars
Channel Maximum Operating Pressure	Ptox,max	23.00	bars
Channel Minimum Operating Pressure	Ptox,min	0.00	bars
Channel Thickness	tc	15.0000	mm.
Channel Corrosion Allowance	cac	3.0000	mm.
Inside Diameter of Channel	Dc	1200.000	mm.
Channel Design Temperature	TEMPC	125.00	°C
Channel Material		SA-516 70	

**Note:**

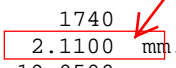
Using 2 \* Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.  
 Make sure that material properties at this temperature are not time-dependent for Material: SA-516 70

Channel Material UNS Number		K02700	
Channel Allowable Stress at Temperature	Sc	137.90	N./mm <sup>2</sup>
Channel Allowable Stress at Ambient		137.90	N./mm <sup>2</sup>

**Tube Data:**

Number of Tube Holes	Nt	1740	
Tube Wall Thickness	et	2.1100	mm.
Tube Outside Diameter	D	19.0500	mm.
Total Straight Tube Length	Lt	4200.00	mm.
Straight Tube Length (bet. inner tubsht faces)	L	4060.00	mm.
Design Temperature of the Tubes		125.00	°C
Tube Material		SA-334 6	
Tube Material UNS Number		K03006	
Is this a Welded Tube		No	
Tube Material Specification used	Smls. & wld. tube		
Tube Allowable Stress at Temperature		117.90	N./mm <sup>2</sup>
Tube Allowable Stress At Ambient		117.90	N./mm <sup>2</sup>
Tube Yield Stress At design Temperature	Syt	216.71	N./mm <sup>2</sup>
Tube Pitch (Center to Center Spacing)	P	24.0000	mm.
Tube Layout Pattern		Square	

TO BE RECHECKED



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Fillet Weld Leg	af	1.5000	mm.
Groove Weld Leg	ag	1.5000	mm.
Tube-Tubesheet Joint Weld Type		Full Strength	
Method for Tube-Tubesheet Jt. Allow.		UW-20	
Tube-Tubesheet Joint Classification		f	
Radius to Outermost Tube Hole Center	ro	581.890	mm.
Largest Center-to-Center Tube Distance	Ul	<del>57.8000</del>	mm.
Length of Expanded Portion of Tube	ltx	0.0000	mm.
Tube-side pass partition groove depth	hg	5.0000	mm.

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**Tubesheet Data:**

Tubesheet TYPE: U-tube, Gasketed both Sides, Conf. d

Tubesheet Design Metal Temperature	T	125.00	°C
Tubesheet Material		SA-350 LF2	

**Note:**

Using 2 \* Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.  
 Make sure that material properties at this temperature are not  
 time-dependent for Material: SA-350 LF2

Tubesheet Material UNS Number		K03011	
Tubesheet Allowable Stress at Temperature	S	137.90	N./mm^2
Tubesheet Allowable Stress at Ambient	Tt	137.90	N./mm^2
Thickness of Tubesheet	h	140.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	3.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	3.0000	mm.
Tubesheet Outside Diameter	A	1360.000	mm.

these data is not correct to be revised

**Additional Data for Stepped Tubesheets:**

Is the Tubesheet Stepped?		YES	
Is the Tubesheet Flat on Tubeside?		NO	
Step 1 Diameter on the Tubeside	dt1	406.00	mm.
Step 1 Depth on the Tubeside	ht1	7.00	mm.
Step 2 Diameter on the Tubeside	dt2	337.00	mm.
Step 2 Depth on the Tubeside	ht2	6.00	mm.
Is the Tubesheet Flat on Shellside?		NO	
Step 1 Diameter on the Shellside	ds1	406.00	mm.
Step 1 Depth on the Shellside	hs1	7.00	mm.
Step 2 Diameter on the Shellside	ds2	337.00	mm.
Step 2 Depth on the Shellside	hs2	6.00	mm.
Calculated Tubesheet Diameter as per UHX-10(b)		1360.00	mm.

tubesheet extended as flange to be considered

Note: Tubesheet diameter is now: 1360.000 mm. per UHX-10(b).

Dimension G for the Channel Side	Gc	1250.063	mm.
Area of the Untubed Lanes	AL	255.9	cm^2

Junction Stress Reduction option		Increase Tubesheet thickness	
Perform Differential Pressure Design		NO	
Run Multiple Load Cases		YES	
Channel Side Min. Design Pressure	Ptd,min	1.0342	bars

**Additional Data for Gasketed Tubesheets:**

Tubesheet Gasket on which Side		Both	
Flange Outside Diameter	A	1360.000	mm.
Flange Inside Diameter	B	1200.000	mm.
Flange Face Outside Diameter	Fod	1269.000	mm.
Flange Face Inside Diameter	Fid	1200.000	mm.

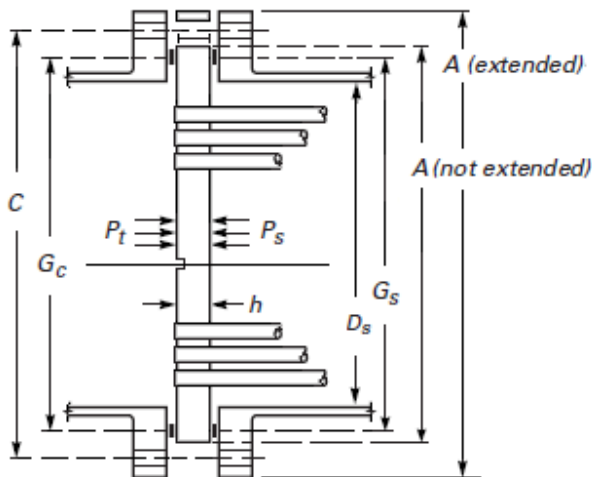
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Gasket Outside Diameter	Go	1266.000	mm.
Gasket Inside Diameter	Gi	1226.000	mm.
Small end Hub thk.	g0	18.0000	mm.
Large end Hub thk.	g1	23.0000	mm.
Gasket Factor,	m	3.00	
Gasket Design Seating Stress	y	68.95	N./mm <sup>2</sup>
Flange Facing Sketch	Code	Sketch 1a	

**Tubesheet Gasketed With Shell and Channel**



**Configuration d:**

Column II

Gasket Thickness  
 Full face Gasket Flange Option

Column for Gasket Seating

tg 3.0000 mm.  
 Program Selects

Code

**Bolting Information:**

Diameter of Bolt Circle  
 Nominal Bolt Diameter  
 Type of Thread Series  
 Number of Bolts  
 Bolt Material  
 Bolt Allowable Stress At Temperature  
 Bolt Allowable Stress At Ambient  
 Weld between Flange and Shell/Channel

C 1310.000 mm.  
 dB 22.2250 mm.  
 TEMA Thread Series  
 n 72  
 SA-320 L7  
 Sb 172.38 N./mm<sup>2</sup>  
 Sa 172.38 N./mm<sup>2</sup>  
 0.0000 mm.

Alternate Flange Operating Bolt Load, Wm1  
 Alternate Flange Seating Bolt Load, Wm2  
 Alternate Flange Design Bolt Load, W

3271.23 kN  
 2157.58 kN  
 3312.96 kN

Tubesheet Integral with  
 Tubesheet Extended as Flange  
 Thickness of Extended Portion of Tubesheet  
 Is Bolt Load Transferred to the Tubesheet

None  
 Yes  
 Tf 118.0000 mm.  
 Yes

**ASME TubeSheet Results per Part UHX, 2017**

**Elasticity/Expansion Material Properties :**

Shell - TM-1 Carbon Steels with C<= 0.3%

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Elastic Mod. at Design Temperature 125.0 °C 0.19660E+09 KPa.  
 Elastic Mod. at Ambient Temperature 21.1 °C 0.20270E+09 KPa.

Channel - TM-1 Carbon Steels with C<= 0.3%

Elastic Mod. at Design Temperature 125.0 °C 0.19660E+09 KPa.  
 Elastic Mod. at Ambient Temperature 21.1 °C 0.20270E+09 KPa.

Tubes - TM-1 Carbon Steels with C<= 0.3%

Elastic Mod. at Tubsht. Design Temp. 125.0 °C 0.19660E+09 KPa.  
 Elastic Mod. at Ambient Temperature 21.1 °C 0.20270E+09 KPa.

TubeSheet - TM-1 Carbon Steels with C> 0.3%

Elastic Mod. at Design Temperature 125.0 °C 0.19522E+09 KPa.  
 Elastic Mod. at Ambient Temperature 21.1 °C 0.20132E+09 KPa.

**Tube Required Thickness under Internal Pressure (Tubeside pressure):**

Thickness Due to Internal Pressure:

$$= (P*(D/2-CAE)) / (S*E+0.4*P) \text{ per Appendix 1-1 (a)(1)}$$

$$= (23.0*(19.05/2-0.0))/(117.9*1.0+0.4*23.0)$$

$$= 0.1844 + 0.0000 = 0.1844 \text{ mm.}$$

**Tube Required Thickness under External Pressure (Shellside pressure) :**

External Pressure Chart CS-2 at 125.00 °C  
 Elastic Modulus for Material 199943392.00 KPa.

**Results for Max. Allowable External Pressure (Emawp):**

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
2.1100	19.05	4641.89	9.03	50.0000	0.0134948	122.73

EMAWP = (2.167/(D/T)-0.0833)\*B = 192.3322 bars

**Results for Reqd Thickness for Ext. Pressure (Tca):**

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
0.4839	19.05	4641.89	39.37	50.0000	0.0007098	70.97

EMAWP = (4\*B)/(3\*(D/T)) = ( 4 \*70.9657 )/( 3 \*39.3662 ) = 24.0347 bars

**Summary of Tube Required Thickness Results:**

Total Required Thickness including Corrosion all.	0.4839	mm.
Allowable Internal Pressure at Corroded thickness	286.56	bars
Required Internal Design Pressure	23.00	bars
Allowable External Pressure at Corroded thickness	192.33	bars
Required External Design Pressure	24.03	bars
Required Thickness due to Shell Side pressure	0.4839	mm.

**Detailed Results for load Case D3 un-corr. (Psd,max + Ptd,max)**

**Intermediate Calculations For Tubesheets Extended As Flanges:**

**ASME Code, Section VIII Division 1, 2017**

Gasket Contact Width,	N = (Goc-Gic) / 2	20.000	mm.
Basic Gasket Width,	b0 = N / 2.0	10.000	mm.
Effective Gasket Width,	b = SQRT(b0) * 2.5	7.966	mm.
Gasket Reaction Diameter,	G = Go-2.0*b	1250.068	mm.

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**Bolting Information for TEMA Imperial Thread Series (Non Mandatory):**

Distance Across Corners for Nuts		40.361	mm.
Circular Wrench End Diameter	a	60.325	mm.
-----			
		Minimum	Actual
		Maximum	
-----			
Bolt Area, cm <sup>2</sup>		188.817	194.632
-----			
Flange Design Bolt Load, Seating Condition	W :	3312.96	kN
Flange Design Bolt Load, Operating Condition	Wm1:	3254.46	kN

**Results for ASME U-tube Tubesheet Calculations for Configuration d,**  
**Per Edition 2017, Original Thickness :**

Minimum Required Thickness for Shear [HreqS]:  
 $= 1/(4 * \mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc$   
 $= 1/(4 * 0.206) * (1182.83/(0.8 * 137.9)) * [23.0 - 23.0] + 0.0$   
 $= 0.0000 \text{ mm.}$

**UHX-12.5.1 Step 1:**

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:  
 $= 2 * ro + dt$   
 $= 2 * 581.89 + 19.05 = 1182.83 \text{ mm.}$

Determine the Basic Ligament Efficiency for Shear [ $\mu$ ]:  
 $= (p - dt) / p$   
 $= (24.0 - 19.05) / 24.0 = 0.206$

**UHX-12.5.2 Step 2:**

Compute the Ratio [Rhos]:  
 $= Gs / Do \text{ (Configurations d, e, f)}$   
 $= 1250.0685 / 1182.83 = 1.0568$

Compute the Ratio [Rhoc]:  
 $= Gc / Do \text{ (Configurations d)}$   
 $= 1250.0626 / 1182.83 = 1.0568$

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:  
 $= Do^2/16 * [(Rhos-1)*(Rhos^2+1)* Ps - (Rhoc-1) * (Rhoc^2+1) * Pt]$   
 $= 1182.83^2/16 * [(1.057 - 1) * (1.057^2 + 1) * 23.0 -$   
 $(1.057 - 1) * (1.057^2 + 1) * 23.0]$   
 $= 22.5152 \text{ bars*mm.}^2$

**UHX-12.5.3 Step 3, Determination of Effective Elastic Properties :**

Compute the Ratio [ $\rho$ ]:  
 $= ltx/h = 0.0/140.0 = 0.0 \text{ ( must be } 0 \leq \rho \leq 1 \text{ )}$

Compute the Effective Tube Hole Diameter [d\*]:  
 $= \max( dt - 2tt*( Et/E )( St/S )( \rho ), dt - 2tt)$   
 $= \max( 19.05 - 2*2.11 * (.19660E+09/.19522E+09) *$   
 $( 117/137 )*(0.0) , 19.05 - 2*2.11 )$   
 $= 19.0500 \text{ mm.}$

Compute the Effective Tube Pitch [p\*]:  
 $= p / \sqrt{ 1 - 4 * \min( AL * CNV_factor, 4*Do*p ) / (Pi * Do^2) }$   
 $= 24.0 / \sqrt{ 1 - 4 * \min( 255.94 * 100.0, 4*1182.83 * 24.0 ) }$

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$$(3.141 * 1182.83^2) \\ = 24.2845 \text{ mm.}$$

Compute the Effective Ligament Efficiency for Bending [ $\mu^*$ ]:

$$= (p^* - d^*)/p^* = (24.2845 - 19.05) / 24.2845 = 0.21555$$

E\*/E,  $\nu^*$  for Square pattern from Fig. UHX-11.4.

$$h/p = 5.833333 ; \mu^* = 0.215548 \\ E^*/E = 0.251278 ; \nu^* = 0.335866 ; E^* = 49054772. \text{ KPa.}$$

Note: As  $h/p$  (5.833) is > 2, data values for  $h/p = 2$  were used.

**Skip Step 4 for Configuration d :**

**UHX-12.5.5 Step 5:**

Diameter ratio [K]:

$$= A/Do = 1360.0/1182.83 = 1.1498$$

Determine Coefficient [F]:

$$= (1 - \nu^*)/E^* * ( E * \ln(K) ) \\ = (1 - 0.34) / 49054772 * ( 0.19522E+09 * \ln(1.15) ) \\ = 0.3689$$

**UHX-12.5.6 Step 6:**

Moment Acting on Unperforated Tubesheet Rim [M\*]

$$= Mts + W^* * (Gc - Gs) / (2 * \pi * Do) \\ = 22.5 + 3271.2 * (1250.063 - 1250.063) / (2 * \pi * 1182.83) \\ = 22.5152 \text{ bars*mm.}^2$$

Note:  $W^*$  is the maximum of the bolt loads between the shell and channel sides.

**UHX-12.5.7 Step 7:**

Maximum Bending Moment acting on Periphery of Tubesheet [Mp]:

$$= ((M^*) - Do^2/32 * F * (Ps - Pt) ) / (1 + F) \\ = ((22.52) - 1182.83^2/32 * 0.369 * (23.0 - 23.0) ) / (1 + 0.37) \\ = 16.4477 \text{ bars*mm.}^2$$

Maximum Bending Moment acting on Center of Tubesheet [Mo]:

$$= Mp + Do^2/64 * (3 + r\nu^*) (Ps - Pt) \\ = 16.45 + 1182.83^2/64 * (3 + 0.336) (23.0 - 23.0) \\ = 16.4477 \text{ bars*mm.}^2$$

Maximum Bending Moment acting on Tubesheet [M]:

$$= \text{Max}( \text{abs}(Mp), \text{abs}(Mo) ) \\ = \text{Max}( \text{abs}(16.448), \text{abs}(16.448) ) \\ = 16.4477 \text{ bars*mm.}^2$$

**UHX-12.5.8 Step 8:**

Tubesheet Bending Stress at Original Thickness:

$$= 6 * M / ( (\mu^*) * ( h - hg' )^2 ) \\ = 6 * 16.448 / ( ( 0.2155 ) * ( 140.0 - 5.0 )^2 ) \\ = 0.0025 \text{ N./mm}^2$$

The Allowable Tubesheet Bending Stress [ $\sigma_{All}$ ]:

$$= 2 * S = 2 * 137.9 = 275.8 \text{ N./mm}^2$$

Tubesheet Bending Stress at Final Thickness [ $\sigma$ ]:

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$$\begin{aligned}
 &= 6 * M / ( (\mu^*) * ( h - hg' )^2 ) \\
 &= 6 * 16.473 / ( ( 0.2155 ) * ( 0.508 - 5.0 )^2 ) \\
 &= 2.2726 \text{ N./mm}^2
 \end{aligned}$$

Required Tubesheet Thickness, for Bending Stress [HreqB]:

$$= H + CATS + CATC = 0.508 + 0.0 + 0.0 = 0.508 \text{ mm.}$$

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:

$$= \text{Max}( HreqB, HreqS ) = \text{Max}( 0.508, 0.0 ) = 0.508 \text{ mm.}$$

#### UHX-12.5.9 Step 9:

$$\text{abs}(Ps - Pt) = \text{abs}(23.0 - 23.0) = 0.0 \text{ bars}$$

Shear Stress check [Tau\_limit]:

$$\begin{aligned}
 &= 3.2 * S * MU * h / Do \\
 &= 3.2 * 137.9 * 0.206 * 140.0 / 1182.83 = 107.72 \text{ bars}
 \end{aligned}$$

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:

$$\begin{aligned}
 &= 1 / (4 * \mu) * (Do/h) * [Ps - Pt] \\
 &= 1 / (4 * 0.206) * (1182.83 / 140.0) * [23.0 - 23.0] \text{ N./mm}^2 \\
 &= 0.00 \text{ N./mm}^2
 \end{aligned}$$

Note: Analysis Completed for Tubesheet Configuration d.

#### Tube Weld Size Results per UW-20:

Tube Strength [Ft]:

$$\begin{aligned}
 &= 3.1415 * t * ( do - t ) * Sa \\
 &= 3.1415 * 2.11 * ( 19.05 - 2.11 ) * 117.9 = 13.239 \text{ kN}
 \end{aligned}$$

Fillet Weld Strength [Ff]:

$$\begin{aligned}
 &= 0.55 * 3.1415 * af * (do + 0.67*af) * Sw \text{ (but not } > Ft) \\
 &= 0.55 * 3.1415 * 1.5 * (19.05 + 0.67*1.5) * 117.9 \\
 &= 6.1280 \text{ kN}
 \end{aligned}$$

Groove Weld Strength [Fg]:

$$\begin{aligned}
 &= 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw \text{ (but not } > Ft) \\
 &= 0.85 * 3.1415 * 1.5 * (19.05 + 0.67*1.5) * 117.9 \\
 &= 9.4706 \text{ kN}
 \end{aligned}$$

Max. Allow. Tube-Tubesheet Joint load, Lmax

$$= Ft = 13.2385 \text{ kN}$$

Design Strength Ratio [fd]:

$$= 1.0000$$

Weld Strength Factor [fw]:

$$= Sot / ( \text{Min}(Sot, S) ) = 1.0000$$

Min Weld Length [ar]:

$$\begin{aligned}
 &= 2 * ( ( 0.75 * do )^2 + 1.07 * t * (do - t) * fw * fd )^{1/2} - 0.75 * do \\
 &= 2.5620 \text{ mm.}
 \end{aligned}$$

Minimum Required Fillet Weld Leg afr 1.2810 mm.

Minimum Required Groove Weld Leg agr 1.2810 mm.

Tube-Tubesheet Jt allowable, 13.24 is  $\geq$  tube strength 13.24 kN

Note: This tube-tubesheet joint is a Full Strength joint

#### Stress/Force summary for loadcase D3 un-corr. (Psd,max + Ptd,max):

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Stress Description	Actual	Allowable	Pass/Fail
Tubesheet bend. stress	0.0 <=	275.8 N./mm <sup>2</sup>	Ok
Tubesheet shear stress	0.0 <=	110.3 N./mm <sup>2</sup>	Ok

**Thickness results for loadcase D3 un-corr. (Psd,max + Ptd,max):**

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	0.508	140.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	1.500	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	1.500	Ok

**U-Tube Tubesheet results per ASME UHX-12 2017**

**Results for 8 Load Cases:**

Case#	--Reqd. Thk. + CA Tbsht Extnsn	----- Tubesheet Bend Allwd	Stresses Shear Allwd	Case Type	Pass/ Fail
D1uc	131.418 33.080	242 276	24 110	Ps+Pt D1	Ok
D2uc	134.225 ...	253 276	25 110	Ps+Pt D2	Ok
D3uc	0.508 ...	... 276	... 110	Ps+Pt D3	Ok
D4uc	31.855 ...	11 276	1 110	Ps+Pt D4	Ok
D1c	134.407 33.080	253 276	25 110	Ps+Pt-c D1	Ok
D2c	137.218 ...	264 276	26 110	Ps+Pt-c D2	Ok
D3c	6.508 ...	... 276	... 110	Ps+Pt-c D3	Ok
D4c	34.828 ...	11 276	1 110	Ps+Pt-c D4	Ok
Max:	137.2176 33.080 mm.	0.958	0.233 (Str. Ratio)		

**Load Case Definitions:**

[Ps & Pt]:  
 Shell-side and Tube-side Design or Operating Pressures  
 derived from Psd,min Ptd,max, Psox,min, Ptox,max etc. per the  
 Load Case Tables

[c]:  
 With or Without Corrosion Allowance

[D1, D2, D3]:  
 Design Load Cases using the Maximum and Minimum Design Pressures

[D4]:  
 Design Load Case using the Minimum (Vacuum) Pressures (if specified)

**Summary of Thickness Comparisons for 8 Load Cases:**

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	137.218	140.000	Ok
Tubesheet Thickness Flanged Extension :	33.080	118.000	Ok
Tube Thickness :	0.484	2.110	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	1.500	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	1.500	Ok

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Note: This is a full strength Tube to Tubesheet Joint.

**Tubesheet MAWP used to Compute Hydrotest Pressure:**

Stress / Force Condition	Tubeside MAWP	0 shellside Stress Rat.	Shellside MAWP	0 tubeside Stress Rat.
Tubesheet Bending Stress	25.080	1.000	25.080	1.000
Tubesheet Shear Stress	103.101	1.000	103.101	1.000
Tube Pressure Stress	286.561	1.000	192.331	1.000
Tubesheet Extension Stress	23.707	...	No Calc	No Calc
Minimum MAWP	23.707		25.080	

**Tubesheet MAPnc used to Compute Hydrotest Pressure:**

Stress / Force Condition	Tubeside MAPnc	0 shellside Stress Rat.	Shellside MAPnc	0 tubeside Stress Rat.
Tubesheet Bending Stress	26.233	1.000	26.233	1.000
Tubesheet Shear Stress	107.717	1.000	107.717	1.000
Tube Pressure Stress	286.561	1.000	192.331	1.000
Tubesheet Extension Stress	23.707	...	No Calc	No Calc
Minimum MAPnc	23.707		26.233	

(\*) All load cases were analyzed to compute the MAWP for determining the test pressure.

**Tubesheet MDMT Calculations:**

Note: The loading conditions from this case will be used to determine the tubesheet MDMT.

**Determine the governing MDMT considering the governing condition:**

Governing thickness on the shell side per figure UCS-66.3 (c):  
 = tubesheet thickness/4  
 = 140.0/4  
 = 35.000 mm.

Note:  
 This Material was specified as being an Impact Tested (Low Temperature) Material.

Impact Test Temperature provided per Specification -46 °C

where the MDMT reduction ratio per UCS 66 (b)(1)(b) is:  
 = max( pt/Tubeside MAPnc, ps/Shellside MAPnc ), must be <= 1  
 = max( 23.0/23.71, 23.0/26.23 )  
 = 0.970

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**Minimum Design Metal Temperature Results Summary :**

Description	Curve	Basic MDMT °C	Reduced MDMT °C	UG-20(f) MDMT °C	Thickness ratio	Gov Thk mm.	E*	PWHT reqd
body flange 0[11]	!	-46	-46		0.617	18.000	1.00	No
SHELL 002 [8]	!	-45	-66		0.613	20.000	1.00	No
Tubesheet: SS[13]	!	-46	-46		0.970	35.000	1.00	No
Warmest MDMT:		-45	-46					
BODY FLANGE 0[11]	!	-46	-46		0.854	15.000	1.00	No
HEAD 001 [10]	!	-45	-54		0.840	15.000	1.00	No
HEAD 001 [7]	!	-45	-63		0.682	18.000	1.00	No
SHELL 001 [8]	!	-45	-53		0.853	15.000	1.00	No
CON [8]	!	-45	-48		0.947	20.000	1.00	No
SHELL 002 [8]	!	-45	-48		0.940	18.000	1.00	No
HEAD 002 [10]	!	-45	-45		0.994	17.000	1.00	No
HEAD 002 [7]	!	-45	-54		0.829	20.000	1.00	No
T2 [1]	D	-47	-48	-29	0.847	15.000	1.00	No
Nozzle Flg [4]	D	-29	-104					
T1 [1]	D	-47	-48	-29	0.851	15.000	1.00	No
Nozzle Flg [4]	D	-29	-104					
D4 [1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg [5]	!	-46	-46					
S2 [1]	D	-43	-46	-29	0.938	18.000	1.00	No
Nozzle Flg [4]	!	-46	-104					
S1 [1]	D	-43	-46	-29	0.938	18.000	1.00	No
Nozzle Flg [4]	!	-46	-104					
S3 [1]	D	-43	-46	-29	0.933	18.000	1.00	No
Nozzle Flg [4]	!	-46	-104					
D2 [1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg [5]	!	-46	-46					
D1 [1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg [5]	!	-46	-46					
D3 [1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg [5]	!	-46	-46					
TT [1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg [5]	!	-46	-46					
V [1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg [5]	!	-46	-46					
S4 [1]	D	-43	-46	-29	0.933	18.000	1.00	No
Nozzle Flg [4]	!	-46	-104					
LG1 [1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg [5]	!	-46	-46					
LG2 [1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg [5]	!	-46	-46					
LT1 [1]	!	-46	-46		0.933	18.000	1.00	No
Nozzle Flg [4]	!	-46	-104					
LT3 [1]	!	-46	-46		0.933	18.000	1.00	No
Nozzle Flg [4]	!	-46	-104					
LT2 [1]	!	-46	-46		0.938	18.000	1.00	No
Nozzle Flg [4]	!	-46	-104					
LT4 [1]	!	-46	-46		0.938	18.000	1.00	No
Nozzle Flg [4]	!	-46	-104					
Tubesheet: CS[14]	!	-46	-46		0.970	35.000	1.00	No
Warmest MDMT:		-29	-45					

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Exchanger Side	Computed MDMT °C	Required MDMT °C	Pass/Fail
-----			
Shell	-46.0	-45.0	Pass
Channel/Tube	-45.0	-45.0	Pass

**Notes:**

- [ ! ] - This was an impact tested material.
- [ 1 ] - Governing Nozzle Weld.
- [ 4 ] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
- [ 5 ] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-b).
- [ 6 ] - MDMT Calculations at the Shell/Head Joint.
- [ 7 ] - MDMT Calculations for the Straight Flange.
- [ 8 ] - Cylinder/Cone/Flange Junction MDMT.
- [ 9 ] - Calculations in the Spherical Portion of the Head.
- [10] - Calculations in the Knuckle Portion of the Head.
- [11] - Calculated (Body Flange) Flange MDMT.
- [12] - Calculated Flat Head MDMT per UCS-66.3
- [13] - Tubesheet MDMT, shell side, if applicable
- [14] - Tubesheet MDMT, tube side, if applicable
- [15] - Nozzle Material
- [16] - Shell or Head Material
- [17] - Impact Testing required
- [18] - Impact Testing not required, see UCS-66(b)(3)
- [20] - Cylinder/Cone Junction MDMT based on Longitudinal Stress considerations
- [21] - Bolting Material

UG-84(b)(2) was not considered.  
 UCS-66(g) was not considered.  
 UCS-66(i) was not considered.

**Notes:**

Impact test temps were not entered in and not considered in the analysis.  
 UCS-66(i) applies to impact tested materials not by specification and  
 UCS-66(g) applies to materials impact tested per UG-84.1 General Note (c).  
 The Basic MDMT includes the (30F) PWHT credit if applicable.

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Vessel Design Summary: Step: 38 11:47am Dec 23,2021

**ASME Code, Section VIII Division 1, 2017**

Diameter Spec : 1200.000 x 1656.000 mm. ID  
 Vessel Design Length, Tangent to Tangent 6395.52 mm.  
 Specified Datum Line Distance 50.00 mm.  
 Shell Side Design Temperature 125 °C  
 Channel Side Design Temperature 125 °C  
 Shell Side Design Pressure 23.000 bars  
 Channel Side Design Pressure 23.000 bars  
 Shell Side Hydrostatic Test Pressure 29.900 bars  
 Channel Side Hydrostatic Test Pressure 29.900 bars  
 Wind Design Code ASCE-2010  
 Earthquake Design Code ASCE 7-2010

**Materials of Construction:**

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-516 70	...	...	K02700	No	Yes
Head	SA-516 70	...	...	K02700	No	Yes
Cone	SA-516 70	...	...	K02700	No	Yes
Flange	SA-350 LF2	1	...	K03011	No	Yes
Nozzle	SA-516 70	...	...	K02700	Yes	No
Nozzle	SA-350 LF2	1	...	K03011	No	Yes
Nozzle	SA-333 6	...	...	K03006	No	Yes
Re-Pad	SA-516 70	...	...	K02700	Yes	No
Nozzle Flg	SA-350 LF2	1	...	K03011	No	No
Tubes	SA-334 6	...	...	K03006	No	Yes
Tubesheet	SA-350 LF2	1	...	K03011	No	Yes
Flg Bolting	SA-320 L7	...	<= 2 1/2	G41400	No	No
Hrz Bolting	SA-193 B7	...	2 1/2 < t <= 4	G41400	No	No

Normalized is determined based on the UCS-66 material curve selection and Figure UCS-66.  
 Impact Tested is based on material selection and material data properties.

**Element Pressures and MAWP (bars & mm.):**

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Corrosion Allowance	Str. Flg. Gov.	In Creep Range
HEAD 001	23.118	1.03	27.450	3.0000	No	No
SHELL 001	23.118	1.03	26.999	3.0000	N/A	No
BODY FLANGE 001	23.118	1.03	23.589	3.0000	N/A	No
body flange 02	23.118	1.03	23.589	3.0000	N/A	No
SHELL 002	23.118	1.03	38.110	3.0000	N/A	No
CON	23.118	1.03	24.330	3.0000	N/A	No
SHELL 002	23.118	1.03	24.506	3.0000	N/A	No
HEAD 002	23.118	1.03	23.185	3.0000	No	No

Liquid Level: 1200.00 mm. Dens.: 0.001 kg./cm^3 Sp. Gr.: 1.000

**Element Types and Properties:**

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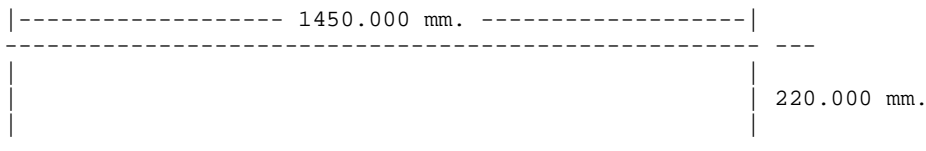
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Element Type	"To" Elev mm.	Element Length mm.	Nominal Thickness mm.	Finished Thickness mm.	Reqd Thk Internal mm.	Reqd Thk External mm.	Long Eff	Circ Eff
Ellipse	0.0	50.0	18.0	15.0	13.1	6.2	1.00	1.00
Cylinder	800.0	800.0	15.0	15.0	13.2	6.5	1.00	1.00
Body Flg	955.0	155.0	60.0	110.0	107.8	79.3	1.00	1.00
Body Flg	1265.5	155.0	60.0	110.0	99.5	65.5	1.00	1.00
Cylinder	1465.5	200.0	20.0	20.0	13.2	10.2	1.00	1.00
Conical	2295.5	830.0	20.0	20.0	19.1	11.7	1.00	1.00
Cylinder	6295.5	4000.0	18.0	18.0	17.1	11.7	1.00	1.00
Ellipse	6345.5	50.0	20.0	17.0	16.9	7.4	1.00	1.00

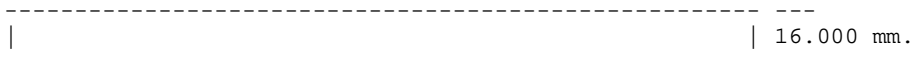
**Saddle Parameters:**

Saddle Width	172.000 mm.
Saddle Bearing Angle	120.000 deg.
Centerline Dimension	972.000 mm.
Wear Pad Width	332.000 mm.
Wear Pad Thickness	12.000 mm.
Wear Pad Bearing Angle	140.000 deg.
Distance from Saddle to Tangent	352.000 mm.
Baseplate Length	1450.000 mm.
Baseplate Thickness	16.000 mm.
Baseplate Width	220.000 mm.
Number of Ribs (including outside ribs)	4
Rib Thickness	12.000 mm.
Web Thickness	12.000 mm.
Height of Center Web	326.000 mm.
Number of Bolts in Baseplate	4

**Baseplate Sketch**



**Baseplate Plan View**



**Baseplate Side View**

Maximum Tensile Bolt Load 1. kN

**Summary of Maximum Saddle Loads, Operating Case :**

Maximum Vertical Saddle Load	266.39 kN
Maximum Transverse Saddle Shear Load	34.78 kN
Maximum Longitudinal Saddle Shear Load	69.57 kN

**Summary of Maximum Saddle Loads, Operating Case, Un-Factored :**

Maximum Vertical Saddle Load	306.10 kN
Maximum Transverse Saddle Shear Load	92.66 kN
Maximum Longitudinal Saddle Shear Load	99.38 kN

**Summary of Maximum Saddle Loads, Hydrotest Case :**

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY  
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Maximum Vertical Saddle Load 191.92 kN  
 Maximum Transverse Saddle Shear Load 1.72 kN  
 Maximum Longitudinal Saddle Shear Load 1.55 kN

**Local Stress Analysis Results:**

Description	Analysis Type	Max Stress Ratio	Pass Fail
T2	WRC-107/537	0.871	Passed
T1	WRC-107/537	0.873	Passed
S2	WRC-107/537	0.937	Passed
S1	WRC-107/537	0.937	Passed
S3	WRC-107/537	0.932	Passed
D2	WRC-107/537	0.937	Passed
D1	WRC-107/537	0.937	Passed
D3	WRC-107/537	0.937	Passed
TT	WRC-107/537	0.937	Passed
V	WRC-107/537	0.932	Passed
S4	WRC-107/537	0.932	Passed
LG1	WRC-107/537	0.937	Passed
LG2	WRC-107/537	0.932	Passed
LT1	WRC-107/537	0.932	Passed
LT3	WRC-107/537	0.932	Passed
LT2	WRC-107/537	0.937	Passed
LT4	WRC-107/537	0.937	Passed

**Weights:**

Fabricated - Bare W/O Removable Internals 18480.4 kg.  
 Shop Test - Fabricated + Water ( Full ) 32350.8 kg.  
 Shipping - Fab. + Rem. Intls.+ Shipping App. 18480.4 kg.  
 Erected - Fab. + Rem. Intls.+ Insul. (etc) 18480.4 kg.  
 Empty - Fab. + Intls. + Details + Wghts. 18480.4 kg.  
 Operating - Empty + Operating Liquid (No CA) 30041.8 kg.  
 Field Test - Empty Weight + Water (Full) 31455.0 kg.

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