PPI NARGAN	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	PGPIC
	DOCUMENT TITLE: Mechanical Calculation for Evaporator E-6101	POI: IFA
Contract No.: DPIC/98-12	DOCUMENT No:DPIC9812-000-VD-1002-ME-CLN-0092	Rev. No.: D1

Regarding last meeting with vendor, please revise calculation as per thermal calculation comment for considering 1.1x748000 for flowrate and duty of 1750 kw and please size all equipment inside package for mentioned design duty of chiller

DOCUMENT TITLE:

Mechanical Calculation for Evaporator

(E-6101)

PURCHASER'S COMMENT/APPROVAL STATUS		Purchaser: NARGAN
1	AP: Approved (Released for Manufacturing)	Requisition No.: DPIC98-12-001-000-ME-MR-4150-0001-D1
X	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-D1
	Date: 06.03.2022 Signature: A.AB	

REV	DATE ISSUE	PREPARED	CHECKED	APPROVED
D1	06.Feb.2022	A.VOSOUGH	DR.A.NEJATI	DR.A.NEJATI
D0	23.Dec.21	A.VOSOUGH	DR.A.NEJATI	DR.A.NEJATI

KASRAVAND Engineering & Construction

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8	x	x			
9	x	x			
10	x	x			
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13	x	x			
14	x	x			
15	x	x			
16	x	x			
17	x	x			
18	x	x			
19	x	x			
20	x	x			
21	x	x			
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56	x	x			
57	x	x			
58	x	x			
59	x	x			
60	x	x			
61	x	x			
62	x	x			
63	x	x			
64	x	x			
65	x	x			
66	x	x			
67	x	x			
68	x	x			
69	x	x			
70	x	x			

	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY **DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT**	
NARGAN	**DOCUMENT TITLE: Mechanical Calculation for Evaporator E-6101**	**POI: IFA**
Contract No.: DPIC/98-12	**DOCUMENT No: DPIC9812-000-VD-1002-ME-CLN-0092**	**Rev. No.: D1**

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121	x	x			
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129	x	x			
130	x	x			
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133	x	x			
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162	x	x			
163	x	x			
164	x	x			
165	x	x			
166	x	x			
167	x	x			
168	x	x			
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206	x	x			
207	x	x			
208	x	x			
209	x	x			
210	x	x			

	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	
NARGAN	DOCUMENT TITLE: Mechanical Calculation for Evaporator E-6101	POI: IFA
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DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
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      : Feb 7,2022    1:34am

PV Elite 2018 SP2, June 2018
```

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.

Warnings and Errors: **Step: 0 1:34am Feb 7,2022**

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

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

There were no geometry errors or warnings.
```

PV Elite Vessel Analysis Program: Input Data

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
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

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	
Special Service	None	
Degree of Radiography	RT-3	
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	
Is this a Heat Exchanger	Yes	
User Defined Hydro. Press. (Used if > 0)	0	bars
User defined MAWP	0	bars
User defined MAPnc	0	bars

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

Wind Design Code		ASCE-7 2010	
Wind Load Reduction Scale Factor		0.600	
Basic Wind Speed	[V]	200	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		20.0	
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

    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                                        0.900
    Short Period Acceleration value Ss                    0.537
    Long Period Acceleration Value Sl                     0.600
    Moment Reduction Factor Tau                           2.500
    Force Modification Factor R                           3.000
    Site Class                                                C
    Component Elevation Ratio             z/h             1.000
    Amplification Factor                   Ap             2.500
    Force Factor                                          0.000
    Consider Vertical Acceleration                          Yes
    Minimum Acceleration Multiplier                       0.000
    User Value of Sds (used if > 0 )                      0.624

    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
```

<u>Complete Listing of Vessel Elements and Details:</u>

```
    Element From Node                                        10
    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^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	29.997	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	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	

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	0.000707	kg./cm^3

Element From Node	10	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	-300	mm.
Height/Length of Insulation	350	mm.
Thickness of Insulation	100	mm.
Density	0.00012	kg./cm^3

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description	SHELL 001	
Distance "FROM" to "TO"	990	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	

Element From Node	20	
Detail Type	Liquid	
Detail ID	2	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1200	mm.
Liquid Density	0.000707	kg./cm^3

Element From Node	20	
Detail Type	Insulation	
Detail ID	Ins: 20	

```
        Dist. from "FROM" Node / Offset dist                 0  mm.
        Height/Length of Insulation                        990  mm.
        Thickness of Insulation                            100  mm.
        Density                                        0.00012  kg./cm^3

        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]

        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^2
        Allowable Stress, Operating                      137.9  N./mm^2
        Allowable Stress, Hydrotest                      223.4  N./mm^2
        Material Density                               0.00775  kg./cm^3
        P Number Thickness                               31.75  mm.
        Yield Stress, Operating                         222.82  N./mm^2
        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
    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                              0.000707  kg./cm^3

        Element From Node                                 30
        Detail Type                               Insulation
        Detail ID                                    Ins: 20
        Dist. from "FROM" Node / Offset dist               0  mm.
        Height/Length of Insulation                      155  mm.
        Thickness of Insulation                          100  mm.
        Density                                      0.00012  kg./cm^3

    --------------------------------------------------------------------

    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

        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                              0.000581  kg./cm^3

        Element From Node                                 40
        Detail Type                               Insulation
        Detail ID                                    Ins: 20
        Dist. from "FROM" Node / Offset dist               0  mm.
        Height/Length of Insulation                      155  mm.
        Thickness of Insulation                          100  mm.
        Density                                      0.00012  kg./cm^3

    --------------------------------------------------------------------

    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]
        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

        Element From Node                                 50
        Detail Type                                   Saddle
        Detail ID                                    Lft Sdl
        Dist. from "FROM" Node / Offset dist             200  mm.
        Width of Saddle                                  172  mm.
        Height of Saddle at Bottom                      1374  mm.
        Saddle Contact Angle                           120.0
        Height of Composite Ring Stiffener                 0  mm.
        Width of Wear Plate                              350  mm.
        Thickness of Wear Plate                           25  mm.
        Contact Angle, Wear Plate (degrees)            140.0

        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                              0.000581  kg./cm^3

        Element From Node                                 50
        Detail Type                               Insulation
        Detail ID                                    Ins: 20
        Dist. from "FROM" Node / Offset dist               0  mm.
        Height/Length of Insulation                      200  mm.
        Thickness of Insulation                          100  mm.
        Density                                      0.00012  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.
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	0.000581	kg./cm^3

Element From Node	60	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	830	mm.
Thickness of Insulation	100	mm.
Density	0.00012	kg./cm^3

Element From Node	60	
Detail Type	Nozzle	
Detail ID	D2	
Dist. from "FROM" Node / Offset dist	380	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

        Element From Node                                     70
        Detail Type                                       Saddle
        Detail ID                                        Lft Sdl
        Dist. from "FROM" Node / Offset dist                2520  mm.
        Width of Saddle                                      172  mm.
        Height of Saddle at Bottom                          1600  mm.
        Saddle Contact Angle                               120.0
        Height of Composite Ring Stiffener                     0  mm.
        Width of Wear Plate                                  352  mm.
        Thickness of Wear Plate                               25  mm.
        Contact Angle, Wear Plate (degrees)                140.0

        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                                  0.000581  kg./cm^3

        Element From Node                                     70
        Detail Type                                   Insulation
        Detail ID                                        Ins: 20
        Dist. from "FROM" Node / Offset dist                   0  mm.
        Height/Length of Insulation                         4000  mm.
        Thickness of Insulation                              100  mm.
        Density                                          0.00012  kg./cm^3

        Element From Node                                     70
        Detail Type                                       Nozzle
        Detail ID                                             S2
        Dist. from "FROM" Node / Offset dist                 500  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                3050  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                 700  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                                            D1
        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                                            D3
        Dist. from "FROM" Node / Offset dist               3600  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               3850  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                150  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               3050  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                                         LG1
        Dist. from "FROM" Node / Offset dist             1800  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             1800  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             1200  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-333 6 [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-333 6 [Impact Tested]

        Element From Node                                  70
        Detail Type                                    Nozzle
        Detail ID                                         LT2
```

```
    Dist. from "FROM" Node / Offset dist          1200  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-333 6 [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-333 6 [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                            0.000581  kg./cm^3

    Element From Node                               80
    Detail Type                             Insulation
    Detail ID                                  Ins: 20
    Dist. from "FROM" Node / Offset dist             0  mm.
    Height/Length of Insulation                    464  mm.
    Thickness of Insulation                        100  mm.
    Density                                    0.00012  kg./cm^3
```


XY Coordinate Calculations:

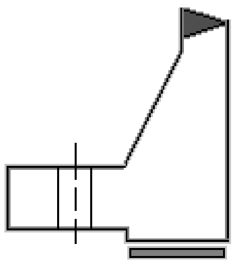
From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
HEAD 001		50	...	50	...
SHELL 001		1040	...	990	...
BODY FLANGE 001		1195	...	155	...
body flange 02		1505.53	...	155	...
SHELL 002		1705.53	...	200	...
CON		2535.52	...	830	...
SHELL 002		6535.53	...	4000	...
HEAD 002		6585.52	...	50	...

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601
Flg Calc [Int P]: New Flange Flng: 7 1:34am Feb 7,2022

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

BODY FLANGE 001

```
Description of Flange Geometry (Type)          Integral Weld Neck
Design Pressure                          P            23.08  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            g1         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                     1, 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.
```



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)
  = (23.08*(1200.0/2+3.0))/(137.9*1.0-0.6*23.08)+Ca
  = 13.1967 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 12.0)/(603.0 + 0.6 * 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,     g1Cor = g1-ci                    20.000  mm.
 Corroded Small Hub,     g0Cor = go-ci                    12.000  mm.
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor       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 * G² * Peq
  = 0.785 * 1250.0626² * 23.083
  = 2832.941 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P
  = 2 * 7.9687 * 3.1416 * 1250.0626 * 3.0 * 23.08
  = 433.415 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.1416 * 1206.0² *23.0832/4
  = 2636.748 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 2833 - 2637
  = 196.193 kN
```
Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 2833 + 433 + 0, 0 )
  = 3266.356 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 68.95*7.9687*3.141*1250.063+0.0*0.0*0.0
  = 2157.577 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 3266/172, 2158/172
  = 189.507 cm^2
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 22.225 + 6 * 107.0/(3.0 + 0.5)
  = 227.879 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 1310.0 * 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 )
  = max( 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^2	189.507	194.632	
Radial Distance between Hub and Bolts:	31.750	32.000	
Radial Distance between Bolts and the Ed	23.812	25.000	
Circumferential Spacing between the Bolt	52.400	57.141	227.879

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 194.632 * 172.38/(68.95 * 3.14 * (1266.0 + 1226.0) )
  = 6.215 mm.
```

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :
```
 = 32.000 mm.[Note: Exceeds actual gasket width, 20.000  ]
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa * ( Am + Ab ) / 2
  = 172.38 * ( 189.5074 + 194.6319 )/2
  = 3310.52 kN
```
Gasket Load for the Operating Condition [HG]:
```
  = Wm1 - H
  = 3266 - 2833
  = 433.42 kN
```

Moment Arm Calculations:
Distance to Gasket Load Reaction [hg]:
```
  = (C - G ) / 2
  = ( 1310.0 - 1250.0626 )/2
  = 29.9687 mm.
```
Distance to Face Pressure Reaction [ht]:
```
  = ( R + g1 + hg ) / 2
  = ( 32.0 + 20.0 + 29.9687 )/2
  = 40.9843 mm.
```
Distance to End Pressure Reaction [hd]:
```
  = R + ( g1 / 2 )
  = 32.0 + ( 20.0/2.0 )
  = 42.0000 mm.
```

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

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	2637.	42.0000	1.0000	110788.
Face Pressure,	Mt	196.	40.9843	1.0000	8044.
Gasket Load,	Mg	433.	29.9687	1.0000	12994.
Gasket Seating,	Matm	3311.	29.9687	1.0000	99252.

```
 Total Moment for Operation,       Mop                        131826. N-m
 Total Moment for Gasket seating, Matm                         99252. 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:
```
 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.³         e =      0.0072 mm.^-1
 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 * g1²)
  = (1.1782*131826/1206.0)/(2.1905*20.0²)
  = 146.94 N./mm^2

Longitudinal Hub Stress, Seating [SHa]:
  = (f * Matm / Bcor) / (L * g1²)
  = (1.1782*99252/1206.0)/(2.1905*20.0²)
  = 110.63 N./mm^2

Radial Flange Stress, Operating [SRo]:
  = (Beta * Mop / Bcor) / (L * t²)
  = (2.0214*131826/1206.0)/(2.1905*107.0²)
  = 8.81 N./mm^2

Radial Flange Stress, Seating [SRa]:
  = (Beta * Matm/Bcor) / (L * t²)
  = (2.0214*99252/1206.0)/(2.1905*107.0²)
  = 6.63 N./mm^2

Tangential Flange Stress, Operating [STo]:
  = (Y * Mo / (t² * Bcor)) - Z * SRo
  = (16.1715*131826/(107.0²*1206.0))-8.3612*9
  = 80.71 N./mm^2

Tangential Flange Stress, Seating [STa]:
  = (y * Matm / (t² * Bcor)) - Z * SRa
  = (16.1715*99252/(107.0²*1206.0))-8.3612*7
  = 60.76 N./mm^2

Average Flange Stress, Operating [SAo]:
  = (SHo + max(SRo, STo)) / 2
  = (147+max(9,81))/2
  = 113.82 N./mm^2

Average Flange Stress, Seating [SAa]:
  = (SHa + max(SRa, STa)) / 2
  = (111+max(7,61))/2
  = 85.70 N./mm^2

Bolt Stress, Operating [BSo]:
  = Wm1 / Ab
  = 3266/194.6319
  = 167.84 N./mm^2

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

Flange Stress Analysis Results: N./mm^2

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
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]         107.721  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 * go² * ho * Ki )
  = 52.14 * 99252.1/1.0 * 999.68 * 0.313/( 2.103 * 202713 *
    12.0² * 120.3 * 0.3 )
  = 0.730  (should be <= 1)
```

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

```
  = 52.14 * Mo / Bsc * Cnv_fac * V / ( Lambda * Eop * goc² * ho * Ki )
  = 52.14 * 131826.5/1.0 * 999.68 * 0.313/( 2.103 * 196612
    * 12.0² * 120.3 * 0.3 )
  = 1.000  (should be <= 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 * go² * ho * Ki )
  = 52.14 * 99252.1/1.0 * 999.68 * 0.313/( 2.191 * 202713 *
    12.0² * 120.3 * 0.3 )
  = 0.701  (should be <= 1)
```

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

```
  = 52.14 * Mo / Bsc * Cnv_fac * V / ( Lambda * Eop * goc² * ho * Ki )
  = 52.14 * 131826.5/1.0 * 999.68 * 0.313/( 2.191 * 196612
    * 12.0² * 120.3 * 0.3 )
  = 0.960  (should be <= 1)
```

Minimum Design Metal Temperature Results:

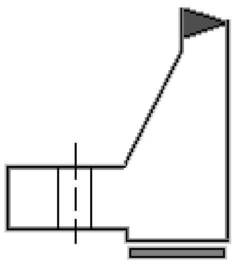
Note:
This Material was specified as being an Impact Tested (Low Temperature) Material.

```
 Impact Test Temperature provided per Specification        -46 °C
```

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

body flange 02

```
Description of Flange Geometry (Type)          Integral Weld Neck
Design Pressure                          P          23.07  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        20.0000  mm.
Thickness of Hub at Large End           g1        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                     1, 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.
```



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Hub Small End Required Thickness due to Internal Pressure:

```
= (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
= (23.07*(1200.0/2+3.0))/(137.9*1.0-0.6*23.07)+Ca
= 13.1901 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 17.0)/(603.0 + 0.6 * 17.0 )
  = 38.228 bars
```

Corroded Flange Thickness,	tc = T-ci	107.000	mm.
Corroded Flange ID,	Bcor = B+2*Fcor	1206.000	mm.
Corroded Large Hub,	g1Cor = g1-ci	20.000	mm.
Corroded Small Hub,	g0Cor = go-ci	17.000	mm.
Code R Dimension,	R = ((C-Bcor)/2)-g1cor	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 * G² * Peq
  = 0.785 * 1250.0626² * 23.068
  = 2831.121 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P
  = 2 * 7.9687 * 3.1416 * 1250.0626 * 3.0 * 23.07
  = 433.137 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.1416 * 1206.0² *23.0684/4
  = 2635.054 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 2831 - 2635
  = 196.067 kN
```
Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 2831 + 433 + 0, 0 )
  = 3264.258 kN
  = 3266.356 kN, Mating Flange Load Governs
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 68.95*7.9687*3.141*1250.063+0.0*0.0*0.0
  = 2157.577 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 3266/172, 2158/172
  = 189.507 cm^2
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 22.225 + 6 * 107.0/(3.0 + 0.5)
  = 227.879 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 1310.0 * 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 )
  = max( 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^2	189.507	194.632	
Radial Distance between Hub and Bolts:	31.750	32.000	
Radial Distance between Bolts and the Ed	23.812	25.000	
Circumferential Spacing between the Bolt	52.400	57.141	227.879

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
= Ab * Sa/(y * Pi * (Go + Gi))
= 194.632 * 172.38/(68.95 * 3.14 * (1266.0 + 1226.0))
= 6.215 mm.

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :
= 32.000 mm.[Note: Exceeds actual gasket width, 20.000]

Flange Design Bolt Load, Gasket Seating [W]:
= Sa * (Am + Ab) / 2
= 172.38 * (189.5074 + 194.6319)/2
= 3310.52 kN

Gasket Load for the Operating Condition [HG]:
= Wm1 - H
= 3266 - 2831
= 435.24 kN

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (1310.0 - 1250.0626)/2
= 29.9687 mm.

Distance to Face Pressure Reaction [ht]:
= (R + g1 + hg) / 2
= (32.0 + 20.0 + 29.9687)/2
= 40.9843 mm.

Distance to End Pressure Reaction [hd]:
= R + (g1 / 2)
= 32.0 + (20.0/2.0)
= 42.0000 mm.

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

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	2635.	42.0000	1.0000	110717.
Face Pressure,	Mt	196.	40.9843	1.0000	8039.
Gasket Load,	Mg	435.	29.9687	1.0000	13049.
Gasket Seating,	Matm	3311.	29.9687	1.0000	99252.

Total Moment for Operation, Mop 131805. N-m
Total Moment for Gasket seating, Matm 99252. N-m

Effective Hub Length, ho = sqrt(Bcor*goCor) 143.185 mm.
Hub Ratio, h/h0 = HL / H0 0.314
Thickness Ratio, g1/g0 = (g1Cor/goCor) 1.176

Flange Factors for Integral Flange:
Factor F 0.893
Factor V 0.459

```
 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 = 0.16019E+07 mm.³        e =      0.0062 mm.^-1
 Stress Factors                           ALPHA =      1.667
                 BETA =      1.890        GAMMA =      0.893
                DELTA =      0.765        Lamda =      1.658
```

Longitudinal Hub Stress, Operating [SHo]:
= (f * Mop / Bcor) / (L * g1²)
= (1.0*131805/1206.0)/(1.6578*20.0²)
= 164.76 N./mm^2

Longitudinal Hub Stress, Seating [SHa]:
= (f * Matm / Bcor) / (L * g1²)
= (1.0*99252/1206.0)/(1.6578*20.0²)
= 124.07 N./mm^2

Radial Flange Stress, Operating [SRo]:
= (Beta * Mop / Bcor) / (L * t²)
= (1.89*131805/1206.0)/(1.6578*107.0²)
= 10.88 N./mm^2

Radial Flange Stress, Seating [SRa]:
= (Beta * Matm/Bcor) / (L * t²)
= (1.89*99252/1206.0)/(1.6578*107.0²)
= 8.19 N./mm^2

Tangential Flange Stress, Operating [STo]:
= (Y * Mo / (t² * Bcor)) - Z * SRo
= (16.1715*131805/(107.0²*1206.0))-8.3612*11
= 63.36 N./mm^2

Tangential Flange Stress, Seating [STa]:
= (y * Matm / (t² * Bcor)) - Z * SRa
= (16.1715*99252/(107.0²*1206.0))-8.3612*8
= 47.71 N./mm^2

Average Flange Stress, Operating [SAo]:
= (SHo + max(SRo, STo)) / 2
= (165+max(11,63))/2
= 114.06 N./mm^2

Average Flange Stress, Seating [SAa]:
= (SHa + max(SRa, STa)) / 2
= (124+max(8,48))/2
= 85.89 N./mm^2

Bolt Stress, Operating [BSo]:
= Wm1 / Ab
= 3266/194.6319
= 167.84 N./mm^2

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

Flange Stress Analysis Results: N./mm^2

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	165.	207.	124.	207.
Radial Flange	11.	138.	8.	138.
Tangential Flange	63.	138.	48.	138.

Maximum Average	114.	138.	86.	138.
Bolting	168.	172.	111.	172.

```
Minimum Required Flange Thickness                    94.564  mm.
Estimated M.A.W.P. ( Operating )                     23.707  bars
Estimated Finished Weight of Flange at given Thk.     303.0  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 * 99252.1/1.0 * 999.68 * 0.459/(1.321 * 202713 *
17.0^2 * 143.185 * 0.3)
= 0.715 (should be <= 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 * 131804.7/1.0 * 999.68 * 0.459/(1.321 * 196612
* 17.0^2 * 143.185 * 0.3)
= 0.978 (should be <= 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 * 99252.1/1.0 * 999.68 * 0.459/(1.658 * 202713 *
17.0^2 * 143.185 * 0.3)
= 0.569 (should be <= 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 * 131804.7/1.0 * 999.68 * 0.459/(1.658 * 196612
* 17.0^2 * 143.185 * 0.3)
= 0.779 (should be <= 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

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^2
HEAD	001	23.083	18	3	1200	137.9
SHELL	001	23.083	15	3	1200	137.9
BODY FLANGE	001	23.083	60	3	1200	137.9
body flange	02	23.068	60	3	1200	137.9
SHELL	002	23.069	20	3	1200	137.9
	CON	23.069	20	3	1656	137.9
SHELL	002	23.069	18	3	1656	137.9
HEAD	002	23.069	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	27.4845	34.387	15	13.0447
SHELL	001	23	27.034	33.9635	15	13.1968
BODY FLANGE	001	23	23.6239	23.7071	110	107.721
body flange	02	23	23.6387	23.7071	110	94.5642
SHELL	002	23	38.1598	45.0627	20	13.1901
	CON	23	24.3794	28.8256	20	19.0311
SHELL	002	23	24.555	29.5906	18	17.0431
HEAD	002	23	23.2347	28.2531	17	16.8588

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      =    23.639 bars
Shell Side MAPnc     =    23.707 bars
Channel Side  MAWP   =    23.160 bars
Channel Side  MAPnc  =    23.707 bars
```

Internal Pressure Calculation Results :

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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*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
 = (23.083*1206.0*0.993)/(2*137.9*1.0-0.2*23.083)
 = 10.0447 + 3.0000 = 13.0447 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.083 bars
```
  = (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
  = (2*137.9*1.0*12.0)/(0.993*1206.0+0.2*12.0)
  = 27.568 - 0.083 = 27.484  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
  = (2*137.9*1.0*15.0)/(1.0*1200.0+0.2*15.0)
  = 34.387 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (23.083*(0.993*1206.0+0.2*12.0))/(2*1.0*12.0)
  = 115.468 N./mm^2
```

Straight Flange Required Thickness:
```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (23.083*603.0)/(137.9*1.0-0.6*23.083)+3.0
  = 13.197 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.083 bars
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 15.0)/(603.0 + 0.6 * 15.0 )
  = 33.797 - 0.083 = 33.714  bars
```

Factor K, corroded condition [Kcor]:
```
  = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
  = ( 2 + ( 1206.0/( 2 * 303.0 ))²)/6
  = 0.993416
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 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]:
```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (23.083*603.0)/(137.9*1.0-0.6*23.083)
  = 10.1968 + 3.0000 = 13.1968 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.083 bars
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*12.0)/(603.0+0.6*12.0)
```

```
   = 27.117 - 0.083 = 27.034  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
   = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
   = (137.9*1.0*15.0)/(600.0+0.6*15.0)
   = 33.964 bars
```

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

```
   = (P*(R+0.6*t))/(E*t)
   = (23.083*(603.0+0.6*12.0))/(1.0*12.0)
   = 117.386 N./mm^2
```

% 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]:

```
   = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
   = (23.069*603.0)/(137.9*1.0-0.6*23.069)
   = 10.1901 + 3.0000 = 13.1901 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.069 bars

```
   = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
   = (137.9*1.0*17.0)/(603.0+0.6*17.0)
   = 38.228 - 0.069 = 38.160  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
   = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
   = (137.9*1.0*20.0)/(600.0+0.6*20.0)
   = 45.063 bars
```

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

```
   = (P*(R+0.6*t))/(E*t)
   = (23.069*(603.0+0.6*17.0))/(1.0*17.0)
   = 83.214 N./mm^2
```

% 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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*D)/(2*cos(a)*(S*E-0.6*P)) per Appendix 1-4 (e)
  = (23.069*1662.8459)/(2*0.8764*(137.9*1.0-0.6*23.069))
  = 16.0311 + 3.0000 = 19.0311 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.069 bars
```
  = (2*S*E*t*cos(a))/(D+1.2*t*cos(a)) per App 1-4(e)
  = (2*137.9*1.0*17.0*0.876)/(1662.846+1.2*17.0*0.876)
  = 24.448 - 0.069 = 24.379  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (2*S*E*t*cos(a))/(D+1.2*t*cos(a)) per App 1-4(e)
  = (2*137.9*1.0*20.0*0.8764)/(1656.0+1.2*20.0*0.8764)
  = 28.826 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(D+1.2*t*cos(a)))/(2*E*t*cos(a))
  = (23.069*(1662.8459+1.2*17.0*0.8764))/(2*1.0*17.0*0.8764)
  = 130.119 N./mm^2
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 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*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (23.069*831.0)/(137.9*1.0-0.6*23.069)
  = 14.0431 + 3.0000 = 17.0431 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.069 bars
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*15.0)/(831.0+0.6*15.0)
  = 24.624 - 0.069 = 24.555  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*18.0)/(828.0+0.6*18.0)
  = 29.591 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(R+0.6*t))/(E*t)
  = (23.069*(831.0+0.6*15.0))/(1.0*15.0)
  = 129.191 N./mm^2
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.075 %

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]:
```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (23.069*1662.0*0.995)/(2*137.9*1.0-0.2*23.069)
  = 13.8588 + 3.0000 = 16.8588 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.069 bars
```
  = (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
  = (2*137.9*1.0*14.0)/(0.995*1662.0+0.2*14.0)
  = 23.303 - 0.069 = 23.235  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
  = (2*137.9*1.0*17.0)/(1.0*1656.0+0.2*17.0)
  = 28.253 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (23.069*(0.995*1662.0+0.2*14.0))/(2*1.0*14.0)
  = 136.511 N./mm^2
```

Straight Flange Required Thickness:
```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (23.069*831.0)/(137.9*1.0-0.6*23.069)+3.0
  = 17.043 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.069 bars
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 17.0)/(831.0 + 0.6 * 17.0 )
  = 27.867 - 0.069 = 27.798  bars
```

Factor K, corroded condition [Kcor]:
```
  = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
  = ( 2 + ( 1662.0/( 2 * 417.0 ))²)/6
  = 0.995212
```

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

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         30.730  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         26.003  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)    32.775  bars
Pressure per App 27-4  = 1.30 * M.A.W.P. * Sa/S         30.730  bars
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S         30.108  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         25.476  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)    32.775  bars
Pressure per App 27-4  = 1.30 * M.A.W.P. * Sa/S         30.108  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^2 & 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^2):

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
D2	Nozzle	137.90	137.90	1.000
S2	Nozzle	117.90	117.90	1.000
S2	Pad	137.90	137.90	1.000
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
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	117.90	117.90	1.000
LT3	Nozzle	117.90	117.90	1.000
LT2	Nozzle	117.90	117.90	1.000
LT4	Nozzle	117.90	117.90	1.000
Minimum				1.000

Stress ratios for Pressurized Vessel Elements (N./mm^2):

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^2):

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^2):

Description	Ambient	Operating	Ratio
T2	43.65	235.80	0.185
T1	43.65	235.80	0.185
D2	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
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
LG2	8.08	223.40	0.036
LT1	18.32	217.19	0.084
LT3	18.32	217.19	0.084
LT2	18.32	217.19	0.084
LT4	18.32	217.19	0.084

Elements Suitable for Internal Pressure.

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601
External Pressure Calculations: Step: 7 1:34am Feb 7,2022

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length mm.	Outside Diameter mm.	Corroded Thickness mm.	Factor A	Factor B N./mm^2
10	20	No Calc	1230	12	0.001355	94.0922
20	30	1140	1230	12	0.0014054	95.0759
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	6.81561	1.03419	12.3669
30	40	110	79.2734	1.03419	No Calc
40	50	110	58.547	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	1140	24339.1	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.

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 * 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	1140.00	102.50	0.9268	0.0014054	95.08

EMAP = (4*B)/(3*(D/t)) = (4*95.0759)/(3*102.5) = 12.3669 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.816	1230.00	1140.00	322.36	0.9268	0.0002501	25.01

EMAP = (4*B)/(3*(D/t)) = (4*25.0064)/(3*322.3596) = 1.0342 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
12.000	1230.00	24339.10	102.50	19.7879	0.0001069	10.69

EMAP = (4*B)/(3*(D/t)) = (4*10.6869)/(3*102.5) = 1.3901 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.

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

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/(K0*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/(K0*D/t) = 35.9529/( 0.9 *386.2208 ) = 1.0343 bars
```

*Check the requirements of UG-33(a)(1) using P = 1.67 * 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*1662.0*0.995)/(2*137.9*1.0-0.2*1.727)
= 1.0360 + 3.0000 = 4.0360 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*14.0)/(0.995*1662.0+0.2*14.0))/1.67
= 13.954 bars
```

Maximum Allowable External Pressure [MAEP]:

```
= min( MAEP, MAWP )
= min( 8.24, 13.954 )
= 8.237 bars
```

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

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	439.322	1119864	352.324	1131091	87.8643
30	40	299.644	176580	286.023	177090	59.9288
40	50	303.042	176580	289.421	177090	60.6084
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		5600	12542809.00	4755	12643901.00	1120

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	199.87	-100	-0.00004	1
10	Insl	31.0015	-125	...	Ins: 20
20	Liqd	791.485	495	...	2
20	Insl	49.6345	495	...	Ins: 20
20	Nozl	366.74	400	854	T2
20	Nozl	366.74	400	854	T1
30	Liqd	124.81	77.5	...	3
30	Insl	5.87196	77.5	...	Ins: 20
40	Liqd	102.566	77.5	...	4
40	Insl	5.93855	77.5	...	Ins: 20
50	Sadl	707.36	200	964.5	Lft Sdl
50	Liqd	73.785	100	...	5
50	Insl	10.1026	100	...	Ins: 20
60	Liqd	633.315	415	114	Liquid: 60
60	Insl	55.5007	415	...	Ins: 20
60	Nozl	12.4214	380	853.4	D2
70	Sadl	908.635	2520	1192.5	Lft Sdl
70	Liqd	3884.36	2000	228	Liquid: 70
70	Insl	270.206	2000	...	Ins: 20
70	Nozl	105.134	500	937.537	S2
70	Nozl	105.134	3050	937.537	S1
70	Nozl	105.134	700	937.537	S3
70	Nozl	12.4214	2200	853.4	D1
70	Nozl	12.4214	3600	853.4	D3
70	Nozl	12.4214	3850	853.4	TT
70	Nozl	12.4214	150	853.4	V
70	Nozl	105.134	3050	937.537	S4
70	Nozl	12.4214	1800	853.4	LG1
70	Nozl	12.4214	1800	853.4	LG2
70	Nozl	27.2525	1200	858.162	LT1
70	Nozl	27.2525	1500	858.162	LT3
70	Nozl	27.2525	1200	858.162	LT2
70	Nozl	27.2525	1500	858.162	LT4
80	Liqd	332.159	188	228	Liquid: 80
80	Insl	54.7541	232	...	Ins: 20
30	FTsh	1245.75	231	...	TUBE SHEET

30	Tube	11050.1	2261	...

Total Weight of Each Detail Type

Total Weight of Saddles	1616.0
Total Weight of Liquid	6142.3
Total Weight of Insulation	483.0
Total Weight of Nozzles	1350.0
Total Weight of Exchanger Components	12295.8
Total Weight of Liquid in Tubes	900.5
Sum of the Detail Weights	22787.6 kg.

Weight Summation: kg.

Fabricated	Shop Test	Shipping	Erected	Empty	Operating
6721.2	21983.0	6721.2	21983.0	6721.2	22466.0
1616.0	12535.2	1616.0	...	1616.0	6142.3
1350.0	...	1350.0	...	...	...
...	1286.4	...	483.0	...	...
...	...	...	...	483.0	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	1350.0	900.5
12295.8	...	12295.8	...	...	...
...	...	...	...	12295.8	...
21983.0	35804.5	22466.0	22466.0	22466.0	29508.8

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.

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

Weight Summary

Fabricated Wt.	- Bare Weight W/O Removable Internals	21983.0 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	35804.5 kg.
Shipping Wt.	- Fab. Wt + Rem. Intls.+ Shipping App.	22466.0 kg.
Erected Wt.	- Fab. Wt + Rem. Intls.+ Insul. (etc)	22466.0 kg.
Ope. Wt. no Liq	- Fab. Wt + Intls. + Details + Wghts.	22466.0 kg.
Operating Wt.	- Empty Wt + Operating Liq. Uncorroded	29508.8 kg.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	28494.1 kg.
Field Test Wt.	- Empty Weight + Water (Full)	35373.8 kg.

Exchanger Tube Data

Volume of Exchanger tubes :	1287149.9 Cm3
Weight of Ope Liq in tubes :	900.5 kg.
Weight of Water in tubes :	1286.4 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	38255.2
30	40	9678.31
40	50	9678.31
50	60	7791.15
60	70	39848.9
70	80	212623
80	90	33844

Total 370220.344 cm^2

Nozzle Flange MAWP Results:

Nozzle Description	Flange Rating Ope. bars	Ambient bars	Design Temp °C	Class	Grade/ Group	Equiv. Press	Max Pressure PVP	50%	DNV bars
T2	45.8	51.1	125	300	GR 1.1	...	...	...	...
T1	45.8	51.1	125	300	GR 1.1	...	...	...	...
D2	45.8	51.1	125	300	GR 1.1	...	...	...	...
S2	45.8	51.1	125	300	GR 1.1	...	...	...	...
S1	45.8	51.1	125	300	GR 1.1	...	...	...	...
S3	45.8	51.1	125	300	GR 1.1	...	...	...	...
D1	45.8	51.1	125	300	GR 1.1	...	...	...	...
D3	45.8	51.1	125	300	GR 1.1	...	...	...	...
TT	45.8	51.1	125	300	GR 1.1	...	...	...	...
V	45.8	51.1	125	300	GR 1.1	...	...	...	...
S4	45.8	51.1	125	300	GR 1.1	...	...	...	...
LG1	45.8	51.1	125	300	GR 1.1	...	...	...	...
LG2	45.8	51.1	125	300	GR 1.1	...	...	...	...
LT1	45.8	51.1	125	300	GR 1.1	...	...	...	...
LT3	45.8	51.1	125	300	GR 1.1	...	...	...	...
LT2	45.8	51.1	125	300	GR 1.1	...	...	...	...
LT4	45.8	51.1	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 Flange MAWP: None Selected

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

The PVP Method is based on the paper PVP 2013-97814. PV Elite uses the maximum loads from each load category to determine ME and FE. In many cases, the computed maximum allowable pressure will be greater than the flange rating. In these cases, the minimum of the rating from the table and the PVP method will be used. SA-193 B8 Cl. 2 bolts or ones with higher allowable stresses at the specified bolt size shall be used. Note that ANSI pipe nominal sizes up to 24 inch (600mm) are addressed.

How the 50% Stress Method Works:
If the computed stress/allowable stress is < 0.5 on the pipe wall, then the allowable pressure is the table rating from the ANSI/ASME standard. If the stress ratio is >= 0.5, then the full equivalent pressure is subtracted from the flange rating.

The DNV Method:
minimum(table rating, 1.5 * Operating rating - equivalent pressure)

Input Values:

Wind Design Code		ASCE-7 2010	
Wind Load Reduction Scale Factor		0.600	
Basic Wind Speed	[V]	200	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		20.0	
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]:
= 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

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]	0.553
Structure Height to Diameter ratio		4.205

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]:
= Centroid Height + Vessel Base Elevation
= 1600.0 + 123000. = 124600. mm.
= 408.793 ft. Imperial Units

Velocity Pressure coefficient evaluated at height z [Kz]:
Because z (408.793 ft.) > 15 ft.
$= 2.01 * (z / Zg)^{2 / Alpha}$
$= 2.01 * (408.793/900.0)^{2/9.5}$
= 1.702

Type of Hill: No Hill

Wind Directionality Factor [Kd]:
= 0.95 per Table 26.6-1

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Wind Load Calculation: Step: 10 1:34am Feb 7,2022

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

Topographical Factor [Kzt]:
= (1 + K1 * K2 * K3)²
= (1 + 0.0* 0.0* 0.0)²
= 1.0

Velocity Pressure evaluated at height z, Imperial Units [qz]:
= max(16, 0.00256 * Kz * Kzt * Kd * V(mph)²)
= max(16, 0.00256 * 1.702 * 1.0 * 0.95 * 124.278²)
= 63.9 psf [312.199] Kgs/m^2

Force on the first element [F]:
= qz * G * Cf * WindArea
= 63.943 * 0.85 * 0.553 * 5.941
= 178.7 lbs. [0.8] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m^2
HEAD 001	*******	0.000	0.000	0.000	1.702	1.000	312.199
SHELL 001	*******	0.000	0.000	0.000	1.702	1.000	312.199
BODY FLANGE 001	*******	0.000	0.000	0.000	1.702	1.000	312.199
body flange 02	*******	0.000	0.000	0.000	1.702	1.000	312.199
SHELL 002	*******	0.000	0.000	0.000	1.702	1.000	312.199
CON	*******	0.000	0.000	0.000	1.702	1.000	312.199
SHELL 002	*******	0.000	0.000	0.000	1.702	1.000	312.199
HEAD 002	*******	0.000	0.000	0.000	1.702	1.000	312.199

Wind Load Calculation:

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm^2	Wind Pressure Kgs/m^2	Element Wind Load kN
10	20	124600	1716	5518.95	312.199	0.47687
20	30	124600	1716	16988.4	312.199	1.46791
30	40	124600	1680	2604	312.199	0.225
40	50	124600	1680	2604	312.199	0.225
50	60	124600	1728	3456	312.199	0.29862
60	70	124600	2001.6	16613.3	312.199	1.43549
70	80	124600	2270.4	90816	312.199	7.84708
80	90	124600	2268	9016.18	312.199	0.77905

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.

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		0.900
Short Period Acceleration value Ss		0.537
Long Period Acceleration Value Sl		0.600
Moment Reduction Factor Tau		2.500
Force Modification Factor R		3.000
Site Class		C
Component Elevation Ratio	z/h	1.000
Amplification Factor	Ap	2.500
Force Factor		0.000
Consider Vertical Acceleration		Yes
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0)		0.624

Seismic Analysis Results:

```
Sms = Fa * Ss = 1.0 * 0.537 = 0.537
Sm1 = Fv * S1 = 0.9 * 0.6 = 0.54
Sds = 2/3 * Sms = 2/3 * 0.537 = 0.358

Sds = Max( 0.8*Sds, SdsUser )
    = Max( 0.286, 0.624 )
    = 0.624

Sd1 = 2/3 * Sm1 = 2/3 * 0.54 = 0.36

Sd1 = Max( 0.8*Sd1, Sd1User )
    = Max( 0.288, 0.39 )
    = 0.390
```

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

= Ct * hn^x where Ct = 0.020, x = 0.75 and hn = Structural Height (ft.)
= 0.020 * ($7.9659^{0.75}$)
= 0.095 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 * 0.095, 0.03 ) per 12.8.2
= 0.030
```

Compute the Seismic Force per equation 13.3-1, [Fp]:

```
= 0.4 * Ap * Sds * W * ( 1 + 2*(z/h) ) / ( R / Ie )
= 0.4 * 2.5 * 0.624 * 279 * ( 1 + 2*1.0 )/( 3.0/1.5 )
= 261.530 kN
```

Check the Maximum value of Fp per equation 13.3-2:

```
= 1.6 * Sds * I * W
= 1.6 * 0.624 * 1.5 * 279 = 418.45 kN
```

Check the Minimum value of Fp per equation 13.3-3:
= 0.3 * 0.62 * 1.5 * 279
= 78.459 kN

Compute the Total Base Shear V = Fp, [V]:
= 261.530 kN

Vertical load per 12.4-4, [YEq]:
= 0.2 * Sds * W
= 0.2 * 0.624 * 279 = 34.87 kN

Final Base Shear, V = 183.07 kN
Final Vertical Load, YEq = 24.41 kN

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN
10	20	600	27.9413	16.4337
20	30	600	27.9413	16.4337
30	40	600	27.9413	16.4337
40	50	600	27.9413	16.4337
50	60	600	27.9413	16.4337
50	60	600	27.9413	16.4337
60	70	600	27.9413	16.4337
70	0	828	27.9413	22.6785
70	80	828	27.9413	22.6785
80	90	828	27.9413	22.6785

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.

Shop/Field Installation Options :

Insulation is installed in the Shop.

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

Center of Gravity of Saddles	3589.149 mm.
Center of Gravity of Liquid	3583.260 mm.
Center of Gravity of Insulation	3660.804 mm.
Center of Gravity of Nozzles	2199.080 mm.
Center of Gravity of Tubesheet(s)	1271.000 mm.
Center of Gravity of Tubes	3301.000 mm.
Center of Gravity of Bare Shell New and Cold	3520.615 mm.
Center of Gravity of Bare Shell Corroded	3497.506 mm.
Vessel CG in the Operating Condition	3282.684 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	3216.387 mm.
Vessel CG in the Test Condition	3428.823 mm.

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*

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       350.00  mm.
Wear Plate Bearing Angle                      theta1       140.00  degrees
Wear Plate Thickness                              tr        25.0   mm.
Wear Plate Allowable Stress                       Sr       137.90  N./mm^2

Shell Allowable Stress used in Calculation                 137.90  N./mm^2
Head Allowable Stress used in Calculation                  137.90  N./mm^2
Circumferential Efficiency in Plane of Saddle                1.00
Circumferential Efficiency at Mid-Span                       1.00

Saddle Force Q, Operating Case                             508.39  kN

Horizontal Vessel Analysis Results:          Actual |    Allowable |
                                            N./mm^2 |      N./mm^2 |
----------------------------------------------------------------
Long. Stress at Top    of Midspan             39.35 |       137.90 |
Long. Stress at Bottom of Midspan             54.55 |       137.90 |
Long. Stress at Top    of Saddles             -0.99 |      -409.94 |
Long. Stress at Top    of Saddles              0.99 |       137.90 |
Long. Stress at Bottom of Saddles             64.94 |       137.90 |
----------------------------------------------------------------
Tangential Shear in Shell                     56.29 |       110.32 |
Circ. Stress at Horn of Saddle               123.58 |       172.37 |
Circ. Compressive Stress in Shell              6.87 |       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 * ( 12.8/2 + 0 ) * 1374.0/1059.149
  = 24.8 kN
```

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

```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 2.66, 0.0, 0 ) * 1374.0/3350.0
  = 1.1 kN
```

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

```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 183.07, 0.0, 0 ) * 1374.0/3350.0
  = 75.1 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
```

```
  = 3.0 * ( 183/2 + 0 ) * 1374.0/1059.149
  = 356.2 kN
```

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

```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 152 + Max( 1, 25, 75, 356 )
  = 508.4 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	515.32	kN
Transverse Shear Load Saddle	91.54	kN
Longitudinal Shear Load Saddle	183.07	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 Rm / 2.

Moment per Equation 4.15.3 [M1]:

```
  = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -508*352.0[1-(1-352.0/355.0+(611.5²-0.0²)/
    (2*352.0*355.0))/(1+(4*0.0)/(3*355.0))]
  = 90346.4 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 508*355/4(1+2(611²-0²)/(355²))/(1+(4*0)/
    (3*355))-4*352/355
  = 133971.2 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 23.034 * 611.5/(2*15.0) - 133971.2/(pi*611.5²*15.0)
  = 39.35 N./mm^2
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 23.034 * 611.5/(2 * 15.0) + 133971.2/(pi * 611.5² * 15.0 )
  = 54.55 N./mm^2
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 23.034*611.5/(2*17.0)-90346.4/(0.1066*pi*611.5²*17.0)
  = -0.99 N./mm^2
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 23.034*611.5/(2*17.0)+90346.4/(0.1923*pi*611.5²*17.0)
  = 64.94 N./mm^2
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 508( 355.0 - 2 * 352.0)/(355.0 + ( 4 * 0.0/3))
```

```
  = -499.8 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * -499.8/( 611.5 * 17.0 )
  = -56.29 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 611.5 * 17.0 )
  = 79.527 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 508 * 0.1/( 17.0 * ( 172.0 + 79.53 + 79.53 ) )
  = -6.87 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 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 * 508 * 0.1/( 331.055( 17.0 + 1.0 * 25.0 ) )
  = -2.78 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)
  = -508/(4(17.0+ 1.0* 25.0)331.055) -
     12*0.019*508*611.5/(355.0(17.0+1.0*25.0)²)
  = -123.58 N./mm^2
```

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
```
  = Alpha * Ls * ( Design Temperature - Ambient Temperature )
  = 0.000012 * 3350.0 * ( 125.0 - 21.1 )
  = 4.268 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1450.0000	mm.
Baseplate Thickness	Bpthk	25.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	5	
Rib Thickness	Ribtk	30.0000	mm.
Web Thickness	Webtk	30.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	508.	17.	8.	86.	73398.	83.2
Wearplate	350.	25.	29.	88.	258125.	807.
Web	30.	704.	394.	211.	8321278.	0.415E+06
BasePlate	220.	25.	758.	55.	4171750.	0.316E+06
Totals	...	...	...	440.	12824552.	0.732E+06

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```
Value  C1 = Sumof(Ay)/Sumof(A)              =      291.      mm.
Value   I = Sumof(Io) - C1*Sumof(Ay)        =    0.359E+06  cm**4
Value  As = Sumof(A) - Ashell               =      354.      cm^2

K1 = (1+cos(beta)-0.5*sin(beta)² )/(pi-beta+sin(beta)*cos(beta)) = 0.2035

Fh = K1 * Q = 0.2035 * 508.387 = 103.4678 kN

Tension Stress, St = ( Fh/As )       =          2.9255  N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str =        124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin( theta )/ theta
  = 1374.0 - 603.0 * sin( 1.0472 )/1.0472
  = 875.323 mm.

Bending Moment, M  = Fh * d          =      90604.4766  N-m

Bending Stress, Sb = ( M * C1 / I  ) =          7.3594  N./mm^2
Allowed Stress, Sa = 2/3 * Yield Str =        137.9000  N./mm^2
```

Minimum Thickness of Baseplate per Moss:
```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(508 + 7)220.0/( 4 * 1450.0 * 137.9 ))½
  = 20.622 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 1122.3689/( 5 - 1 )
  = 280.592 mm.
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 280.5922 * 220.0/2
  = 308.651 cm^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 308.7 * 0.16
  = 49.189 kN
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 42.6 + 42.089
  = 84.689 cm^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 49.2/84.6888
  = 5.809 N./mm^2
```

Check of Outside Ribs:
Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	30.0	172.0	...	51.6	...	0.127E+04

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * rl / 2
  = 183.1/( 2 * 1450.0 ) * 280.592 * 1025.0/2
```

```
  = 9081.711 N-m
```

Compressive Allowable, KL/R < Cc (26.4469 < 138.1347) per AISC E2-1 [Sca]:

```
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 26.45 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(26.45)/(8* 138.13)-( 26.45³)/(8*138.13³)
  = 116.863 N./mm^2
```

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

```
  = Sc/Sca + ( Rm * Distance Side/I )/Sba
  = 5.81/116.86 + ( 9081.71 * 86.0/12721121 )/137.9
  = 0.495
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	30.0	142.0	0.0	42.6	0.0	0.127E+04
Web	280.6	30.0	0.0	84.2	0.0	63.1
Values	...	...	...	126.8	...	0.133E+04

```
 Compressive Allowable, KL/R < Cc ( 21.6551 < 138.1347 ) per AISC E2-1 [Sca]:
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 21.66 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(21.66)/(8* 138.13)-( 21.66³)/(8*138.13³)
  = 118.441 N./mm^2
```

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

```
  = Sc/Sca + ( Rm * Distance Center/I )/Sba
  = 7.37/118.44 + ( 12422.01 * 86.0/1328.494 )/137.9
  = 0.645
```

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^2
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	75.0	mm.
Nominal Bolt Diameter	Bnd	30.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	5.0297	cm^2
Saddle Load QO (Weight)	QO	159.1	kN
Saddle Load QL (Wind/Seismic contribution)	QL	75.1	kN
Maximum Transverse Force	Ft	91.5	kN
Maximum Longitudinal Force	Fl	183.1	kN
Saddle Bolted to Steel Foundation		No	

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]:

```
  = Fl / (Stba * Nbolts)
  = 183.07/(172.38 * 4.0)
  = 2.6554 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 1374.0 * 91.54 + 0.0
  = 125820.93 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 125820.93/159.08
  = 790.58 mm. > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 1450.0/2 - 75.0
   = 650.00 mm.
```

Modular Ratio Of Steel/Concrete (n1):
```
  = ES / EC
  = 203402.5/21526.32
  = 9.45

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (790.58 - 0.5*1450.0)
    = 196.75 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 9.45 * 10.06/220.0 * (650.0 + 790.58)
    = 373440.44 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -373440.44 * (0.5 * 1450.0 + 650.0)
    = -513480572.95 mm.³
```

Iteratively Solving for the Effective Bearing Length:
```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + 196.75 * Y² + 373440.44 * Y + -0.5E+09 = 0
 Y  = 601.53 mm.

 Num = (Bplen / 2 - Y / 3 - e)
     = (1450.0/2 - 601.53/3 - 790.58)
     = -266.09

 Denom = (Bplen / 2 - Y / 3 + f)
       = (1450.0/2 - 601.53/3 + 650.0)
       = 1174.49
```

Total Bolt Tension Force [Tforce]:
```
  = - QO * Num / Denom
  = - 159.08 * -266.09/1174.49
  = 36.04 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:
```
  = Tforce / (Stba * Nbt)
  = 36.04/( 172.38 * 2.0 )
  = 1.0456 cm^2
```

Required Area of a Single Bolt [Bltarear]:
```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0.0, 2.6554, 1.0456]
  = 2.6554 cm^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(159.08 + 36.04)/(601.53 * 220.0)
  = 29.49 bars
```

Distance from Baseplate Edge to the Web [ADIST]:
```
  = (Bplen - Weblngth) / 2
  = (1450.0 - 1399.2)/2
  = 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:
```
  = Tforce * Adist
  = 36.04 * 25.4
  = 915.85 N-m
```

Equivalent Bearing Pressure (f1):
```
  = fc * (Y - Adist) / Y
  = 29.49 * (601.53 - 25.4)/601.53
  = 28.25 bars
```

Overturning Moment due to Bearing Pressure [Mc]:
```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (25.4² * 220.0/6) * (28.25 + 2 * 29.49)
  = 206.42 N-m
```

Baseplate Required Thickness [Treq]:
```
  = (6 * max(Mt,Mc) / (Bpwid * Sba))½
  = (6 *max(915.85,206.42/(220.0 * 162.38))½
  = 12.4006 mm.
```

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      352.00  mm.
 Wear Plate Bearing Angle                     theta1      140.00  degrees
 Wear Plate Thickness                             tr        25.0  mm.
 Wear Plate Allowable Stress                      Sr      137.90  N./mm^2

 Inside Depth of Head                             h2      417.00  mm.

 Shell Allowable Stress used in Calculation               137.90  N./mm^2
 Head Allowable Stress used in Calculation                137.90  N./mm^2
 Circumferential Efficiency in Plane of Saddle              1.00
 Circumferential Efficiency at Mid-Span                     1.00

 Saddle Force Q, Operating Case                           438.36  kN

 Horizontal Vessel Analysis Results:        Actual |     Allowable |
                                           N./mm^2 |       N./mm^2 |
```


Long. Stress at Top of Midspan	66.21	137.90
Long. Stress at Bottom of Midspan	62.48	137.90
Long. Stress at Top of Saddles	93.18	137.90
Long. Stress at Bottom of Saddles	48.37	137.90
Tangential Shear in Shell	25.84	110.32
Circ. Stress at Horn of Saddle	144.84	172.37
Circ. Compressive Stress in Shell	6.40	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 * ( 12.8/2 + 0 ) * 1600.0/1452.3246
= 21.1 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 4.96, 43.42, 0 ) * 1600.0/3350.0
= 20.7 kN
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
```
= max( Fl, Friction Force, Sum of X Forces ) * B / Ls
= max( 183.07, 43.42, 0 ) * 1600.0/3350.0
= 87.4 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
= Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0 * ( 183/2 + 0 ) * 1600.0/1452.3246
= 302.5 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
= Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
= 136 + Max( 21, 21, 87, 303 )
= 438.4 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	447.27	kN
Transverse Shear Load Saddle	91.54	kN
Longitudinal Shear Load Saddle	183.07	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 = 0.0176	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 Rm / 2.

Moment per Equation 4.15.3 [M1]:
```
= -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -438*466.0[1-(1-466.0/355.0+(838.5²-417.0²)/
  (2*466.0*355.0))/(1+(4*417.0)/(3*355.0))]
= -101886.1 N-m
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 438*355/4(1+2(838²-417²)/(355²))/(1+(4*417)/
    (3*355))-4*466/355
  = -61820.0 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 23.021 * 838.5/(2*15.0) - -61820.0/(pi*838.5²*15.0)
  = 66.21 N./mm^2
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 23.021 * 838.5/(2 * 15.0) + -61820.0/(pi * 838.5² * 15.0 )
  = 62.48 N./mm^2
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 23.021*838.5/(2*15.0)--101886.1/(0.1066*pi*838.5²*15.0)
  = 93.18 N./mm^2
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 23.021*838.5/(2*15.0)+-101886.1/(0.1923*pi*838.5²*15.0)
  = 48.37 N./mm^2
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 438( 355.0 - 2 * 466.0)/(355.0 + ( 4 * 417.0/3))
  = -277.6 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * -277.64/( 838.4999 * 15.0 )
  = -25.84 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 838.5 * 15.0 )
  = 87.477 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 438 * 0.1/( 15.0 * ( 172.0 + 87.48 + 87.48 ) )
  = -6.40 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 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 * 438 * 0.1/( 346.953( 15.0 + 1.0 * 25.0 ) )
  = -2.40 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)
  = -438/(4(15.0+ 1.0* 25.0)346.953) -
     12*0.018*438*838.5/(355.0(15.0+1.0*25.0)²)
  = -144.84 N./mm^2
```

Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	1450.0000	mm.
Baseplate Thickness	Bpthk	25.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	5	
Rib Thickness	Ribtk	30.0000	mm.
Web Thickness	Webtk	30.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	526.	15.	8.	79.	59194.	59.2
Wearplate	352.	25.	27.	88.	242000.	711.
Web	30.	704.	392.	211.	8279038.	0.412E+06
BasePlate	220.	25.	756.	55.	4160749.	0.315E+06
Totals	...	...	...	433.	12740981.	0.727E+06

```
Value  C1 = Sumof(Ay)/Sumof(A)          =    294.      mm.
Value   I = Sumof(Io) - C1*Sumof(Ay)    =    0.353E+06 cm**4
Value  As = Sumof(A) - Ashell           =    354.      cm^2

K1 = (1+cos(beta)-0.5*sin(beta)² )/(pi-beta+sin(beta)*cos(beta)) = 0.2035

Fh = K1 * Q = 0.2035 * 438.357 = 89.2151 kN

Tension Stress, St = ( Fh/As )       =        2.5190  N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str =      124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin( theta )/ theta
  = 1600.0 - 831.0 * sin( 1.0472 )/1.0472
  = 912.768 mm.

Bending Moment, M  = Fh * d         =     81465.7500  N-m

Bending Stress, Sb = ( M * C1 / I  ) =        6.7956  N./mm^2
Allowed Stress, Sa = 2/3 * Yield Str =      137.9000  N./mm^2
```

Minimum Thickness of Baseplate per Moss:

```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(438 + 9)220.0/( 4 * 1450.0 * 137.9 ))½
  = 19.212 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 1513.8124/( 5 - 1 )
  = 378.453 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 378.4531 * 220.0/2
```

```
  = 416.298 cm^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 416.3 * 0.14
  = 57.206 kN
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 42.6 + 56.768
  = 99.368 cm^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 57.2/99.368
  = 5.757 N./mm^2
```

<u>Check of Outside Ribs:</u>
Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	30.0	172.0	...	51.6	...	0.127E+04

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * rl / 2
  = 183.1/( 2 * 1450.0 ) * 378.453 * 1139.44/2
  = 13616.718 N-m
```

Compressive Allowable, KL/R < Cc (31.8458 < 138.1347) per AISC E2-1 [Sca]:
```
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 31.85 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(31.85)/(8* 138.13)-( 31.85³)/(8*138.13³)
  = 114.955 N./mm^2
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * Distance Side/I )/Sba
  = 5.76/114.95 + ( 13616.72 * 86.0/12721121 )/137.9
  = 0.717
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	30.0	142.0	0.0	42.6	0.0	0.127E+04
Web	378.5	30.0	0.0	113.5	0.0	85.2
Values	...	...	...	156.1	...	0.135E+04

```
 Compressive Allowable, KL/R < Cc ( 23.8353 < 138.1347 ) per AISC E2-1 [Sca]:
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 23.84 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(23.84)/(8* 138.13)-( 23.84³)/(8*138.13³)
  = 117.737 N./mm^2
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * Distance Center/I )/Sba
  = 7.02/117.74 + ( 16754.38 * 86.0/1350.513 )/137.9
  = 0.833
```

<u>**Input Data for Base Plate Bolting Calculations:**</u>

```
 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^2
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	75.0	mm.
Nominal Bolt Diameter	Bnd	30.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	5.0297	cm^2
Saddle Load QO (Weight)	QO	144.7	kN
Saddle Load QL (Wind/Seismic contribution)	QL	87.4	kN
Maximum Transverse Force	Ft	91.5	kN
Maximum Longitudinal Force	Fl	183.1	kN
Saddle Bolted to Steel Foundation		No	

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]:
```
  = Fl / (Stba * Nbolts)
  = 183.07/(172.38 * 4.0)
  = 2.6554 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 1600.0 * 91.54 + 0.0
  = 146516.38 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 146516.38/144.74
  = 1011.88 mm. > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 1450.0/2 - 75.0
   = 650.00 mm.
```

Modular Ratio Of Steel/Concrete (n1):
```
  = ES / EC
  = 203402.5/21526.32
  = 9.45

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (1011.88 - 0.5*1450.0)
    = 860.64 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 9.45 * 10.06/220.0 * (650.0 + 1011.88)
    = 430807.07 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -430807.06 * (0.5 * 1450.0 + 650.0)
    = -592359683.58 mm.³
```

Iteratively Solving for the Effective Bearing Length:
```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + 860.64 * Y² + 430807.06 * Y + -0.6E+09 = 0
 Y  = 517.66 mm.
```

```
 Num = (Bplen / 2 - Y / 3 - e)
     = (1450.0/2 - 517.66/3 - 1011.88)
     = -459.43

 Denom = (Bplen / 2 - Y / 3 + f)
       = (1450.0/2 - 517.66/3 + 650.0)
       = 1202.45
```

Total Bolt Tension Force [Tforce]:

```
  = - QO * Num / Denom
  = - 144.74 * -459.43/1202.45
  = 55.30 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:

```
  = Tforce / (Stba * Nbt)
  = 55.3/( 172.38 * 2.0 )
  = 1.6042 cm^2
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0.0, 2.6554, 1.6042]
  = 2.6554 cm^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)

```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(144.74 + 55.3)/(517.66 * 220.0)
  = 35.13 bars
```

Distance from Baseplate Edge to the Web [ADIST]:

```
  = (Bplen - Weblngth) / 2
  = (1450.0 - 1399.2)/2
  = 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:

```
  = Tforce * Adist
  = 55.3 * 25.4
  = 1405.23 N-m
```

Equivalent Bearing Pressure (f1):

```
  = fc * (Y - Adist) / Y
  = 35.13 * (517.66 - 25.4)/517.66
  = 33.41 bars
```

Overturning Moment due to Bearing Pressure [Mc]:

```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (25.4² * 220.0/6) * (33.41 + 2 * 35.13)
  = 245.33 N-m
```

Baseplate Required Thickness [Treq]:

```
  = (6 * max(Mt,Mc) / (Bpwid * Sba))½
  = (6 *max(1405.23,245.33/(220.0 * 162.38))½
  = 15.3605 mm.
```

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	350.00	mm.
Wear Plate Bearing Angle	theta1	140.00	degrees
Wear Plate Thickness	tr	25.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm^2
Shell Allowable Stress used in Calculation		235.81	N./mm^2
Head Allowable Stress used in Calculation		235.81	N./mm^2
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		169.83	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	58.53	235.81
Long. Stress at Bottom of Midspan	63.61	235.81
Long. Stress at Top of Saddles	39.72	235.81
Long. Stress at Bottom of Saddles	61.74	235.81
Tangential Shear in Shell	18.80	188.65
Circ. Stress at Horn of Saddle	41.28	353.71
Circ. Compressive Stress in Shell	2.29	235.81

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 * ( 2.6/2 + 0 ) * 1374.0/1059.149
= 5.0 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 0.53, 0.0, 0 ) * 1374.0/3350.0
= 0.2 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
= Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
= 165 + Max( 0.2, 5, 0, 0 )
= 169.8 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	176.76	kN
Transverse Shear Load Saddle	1.28	kN

```
 Longitudinal Shear Load Saddle                          0.53  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 Rm / 2.

Moment per Equation 4.15.3 [M1]:

```
  = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -170*352.0[1-(1-352.0/355.0+(611.5²-0.0²)/
    (2*352.0*355.0))/(1+(4*0.0)/(3*355.0))]
  = 30180.5 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 170*355/4(1+2(611²-0²)/(355²))/(1+(4*0)/
    (3*355))-4*352/355
  = 44753.4 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 29.96 * 611.5/(2*15.0) - 44753.4/(pi*611.5²*15.0)
  = 58.53 N./mm^2
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 29.96 * 611.5/(2 * 15.0) + 44753.4/(pi * 611.5² * 15.0 )
  = 63.61 N./mm^2
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 29.96*611.5/(2*17.0)-30180.5/(0.1066*pi*611.5²*17.0)
  = 39.72 N./mm^2
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 29.96*611.5/(2*17.0)+30180.5/(0.1923*pi*611.5²*17.0)
  = 61.74 N./mm^2
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 170( 355.0 - 2 * 352.0)/(355.0 + ( 4 * 0.0/3))
  = -167.0 kN
```

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

```
  = K2 * T / ( Rm * t )
  = 1.1707 * -166.96/( 611.5 * 17.0 )
  = -18.80 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
```

```
  = 0.78 * sqrt( 611.5 * 17.0 )
  = 79.527 mm.
```

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

```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 170 * 0.1/( 17.0 * ( 172.0 + 79.53 + 79.53 ) )
  = -2.29 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 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 * 170 * 0.1/( 331.055( 17.0 + 1.0 * 25.0 ) )
  = -0.93 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)
  = -170/(4(17.0+ 1.0* 25.0)331.055) -
     12*0.019*170*611.5/(355.0(17.0+1.0*25.0)²)
  = -41.28 N./mm^2
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1450.0000	mm.
Baseplate Thickness	Bpthk	25.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	5	
Rib Thickness	Ribtk	30.0000	mm.
Web Thickness	Webtk	30.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	508.	17.	8.	86.	73398.	83.2
Wearplate	350.	25.	29.	88.	258125.	807.
Web	30.	704.	394.	211.	8321278.	0.415E+06
BasePlate	220.	25.	758.	55.	4171750.	0.316E+06
Totals	...	...	...	440.	12824552.	0.732E+06

```
 Value  C1 = Sumof(Ay)/Sumof(A)          =     291.      mm.
 Value   I = Sumof(Io) - C1*Sumof(Ay)    =    0.359E+06  cm**4
 Value  As = Sumof(A) - Ashell           =     354.      cm^2

 K1 = (1+cos(beta)-0.5*sin(beta)² )/(pi-beta+sin(beta)*cos(beta)) = 0.2035

 Fh = K1 * Q = 0.2035 * 169.828 = 34.5637 kN

 Tension Stress, St = ( Fh/As )       =        0.9773  N./mm^2
 Allowed Stress, Sa = 0.6 * Yield Str =      124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin( theta )/ theta
  = 1374.0 - 603.0 * sin( 1.0472 )/1.0472
  = 875.323 mm.
```

```
 Bending Moment, M  = Fh * d          =      30266.6797  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =          2.4584  N./mm^2
 Allowed Stress, Sa = 2/3 * Yield Str =        137.9000  N./mm^2
```

Minimum Thickness of Baseplate per Moss:

```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(170 + 7)220.0/( 4 * 1450.0 * 137.9 ))½
  = 12.078 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 1122.3689/( 5 - 1 )
  = 280.592 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 280.5922 * 220.0/2
  = 308.651 cm^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 308.7 * 0.05
  = 16.432 kN
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 42.6 + 42.089
  = 84.689 cm^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 16.4/84.6888
  = 1.940 N./mm^2
```

<u>Check of Outside Ribs:</u>

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	30.0	172.0	...	51.6	...	0.127E+04

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * rl / 2
  = 0.5/( 2 * 1450.0 ) * 280.592 * 1025.0/2
  = 26.410 N-m
```

Compressive Allowable, KL/R < Cc (26.4469 < 138.1347) per AISC E2-1 [Sca]:

```
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 26.45 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(26.45)/(8* 138.13)-( 26.45³)/(8*138.13³)
  = 116.863 N./mm^2
```

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

```
  = Sc/Sca + ( Rm * Distance Side/I )/Sba
  = 1.94/116.86 + ( 26.41 * 86.0/12721121 )/137.9
  = 0.018
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	30.0	142.0	0.0	42.6	0.0	0.127E+04
Web	280.6	30.0	0.0	84.2	0.0	63.1
Values	...	...	...	126.8	...	0.133E+04

```
Compressive Allowable, KL/R < Cc ( 21.6551 < 138.1347 ) per AISC E2-1 [Sca]:
 = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
 = ( 1-( 21.66 )²/(2 * 138.13² )) * 207/
   ( 5/3+3*(21.66)/(8* 138.13)-( 21.66³)/(8*138.13³)
 = 118.441 N./mm^2
```

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

```
 = Sc/Sca + ( Rm * Distance Center/I )/Sba
 = 2.46/118.44 + ( 36.12 * 86.0/1328.494 )/137.9
 = 0.022
```

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^2
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	75.0	mm.
Nominal Bolt Diameter	Bnd	30.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	5.0297	cm^2
Saddle Load QO (Weight)	QO	171.8	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.2	kN
Maximum Transverse Force	Ft	1.3	kN
Maximum Longitudinal Force	Fl	1.0	kN
Saddle Bolted to Steel Foundation		No	

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]:

```
 = Fl / (Stba * Nbolts)
 = 0.99/(172.38 * 4.0)
 = 0.0144 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
 = B * Ft + Sum of X Moments
 = 1374.0 * 1.28 + 0.0
 = 1753.25 N-m
```

Eccentricity (e):

```
 = Rmom / QO
 = 1753.25/171.8
 = 10.20 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, 0.0144, 0.0]
= 0.0144 cm^2

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	352.00	mm.
Wear Plate Bearing Angle	theta1	140.00	degrees
Wear Plate Thickness	tr	25.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm^2
Inside Depth of Head	h2	417.00	mm.
Shell Allowable Stress used in Calculation		235.81	N./mm^2
Head Allowable Stress used in Calculation		235.81	N./mm^2
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		179.34	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	84.57	235.81
Long. Stress at Bottom of Midspan	83.04	235.81
Long. Stress at Top of Saddles	95.60	235.81
Long. Stress at Bottom of Saddles	77.27	235.81
Tangential Shear in Shell	10.57	188.65
Circ. Stress at Horn of Saddle	59.26	353.71
Circ. Compressive Stress in Shell	2.62	235.81

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 * (2.6/2 + 0) * 1600.0/1452.3246
= 4.2 kN

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
= max(Fl, Friction Load, Sum of X Forces) * B / Ls
= max(0.99, 0.0, 0) * 1600.0/3350.0
= 0.5 kN

Load Combination Results for Q + Wind or Seismic [Q]:
= Saddle Load + Max(Fwl, Fwt, Fsl, Fst)
= 175 + Max(0.5, 4, 0, 0)
= 179.3 kN

Summary of Loads at the base of this Saddle:

```
Vertical Load (including saddle weight)         188.25  kN
Transverse Shear Load Saddle                      1.28  kN
Longitudinal Shear Load Saddle                    0.99  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:

```
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 Rm / 2.

Moment per Equation 4.15.3 [M1]:

```
= -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -179*466.0[1-(1-466.0/355.0+(838.5²-417.0²)/
  (2*466.0*355.0))/(1+(4*417.0)/(3*355.0))]
= -41683.5 N-m
```

Moment per Equation 4.15.4 [M2]:

```
= Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 179*355/4(1+2(838²-417²)/(355²))/(1+(4*417)/
  (3*355))-4*466/355
= -25291.7 N-m
```

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

```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 29.982 * 838.5/(2*15.0) - -25291.7/(pi*838.5²*15.0)
= 84.57 N./mm^2
```

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

```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 29.982 * 838.5/(2 * 15.0) + -25291.7/(pi * 838.5² * 15.0 )
= 83.04 N./mm^2
```

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

```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 29.982*838.5/(2*15.0)--41683.5/(0.1066*pi*838.5²*15.0)
= 95.60 N./mm^2
```

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

```
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 29.982*838.5/(2*15.0)+-41683.5/(0.1923*pi*838.5²*15.0)
= 77.27 N./mm^2
```

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

```
= Q(L-2a)/(L+(4*h2/3))
= 179( 355.0 - 2 * 466.0)/(355.0 + ( 4 * 417.0/3))
= -113.6 kN
```

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

```
= K2 * T / ( Rm * t )
= 1.1707 * -113.59/( 838.4999 * 15.0 )
= -10.57 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 838.5 * 15.0 )
  = 87.477 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 179 * 0.1/( 15.0 * ( 172.0 + 87.48 + 87.48 ) )
  = -2.62 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 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 * 179 * 0.1/( 346.953( 15.0 + 1.0 * 25.0 ) )
  = -0.98 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)
  = -179/(4(15.0+ 1.0* 25.0)346.953) -
     12*0.018*179*838.5/(355.0(15.0+1.0*25.0)²)
  = -59.26 N./mm^2
```

Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	1450.0000	mm.
Baseplate Thickness	Bpthk	25.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	5	
Rib Thickness	Ribtk	30.0000	mm.
Web Thickness	Webtk	30.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	526.	15.	8.	79.	59194.	59.2
Wearplate	352.	25.	27.	88.	242000.	711.
Web	30.	704.	392.	211.	8279038.	0.412E+06
BasePlate	220.	25.	756.	55.	4160749.	0.315E+06
Totals	...	...	...	433.	12740981.	0.727E+06

```
Value  C1 = Sumof(Ay)/Sumof(A)         =     294.      mm.
Value   I = Sumof(Io) - C1*Sumof(Ay)   =    0.353E+06  cm**4
Value  As = Sumof(A) - Ashell          =     354.      cm^2

K1 = (1+cos(beta)-0.5*sin(beta)² )/(pi-beta+sin(beta)*cos(beta)) = 0.2035

Fh = K1 * Q = 0.2035 * 179.34 = 36.4996 kN

Tension Stress, St = ( Fh/As )       =          1.0306  N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str =        124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin( theta )/ theta
  = 1600.0 - 831.0 * sin( 1.0472 )/1.0472
  = 912.768 mm.

 Bending Moment, M  = Fh * d          =      33329.1797  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =          2.7802  N./mm^2
 Allowed Stress, Sa = 2/3 * Yield Str =        137.9000  N./mm^2
```

Minimum Thickness of Baseplate per Moss:

```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(179 + 9)220.0/( 4 * 1450.0 * 137.9 ))½
  = 12.464 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 1513.8124/( 5 - 1 )
  = 378.453 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 378.4531 * 220.0/2
  = 416.298 cm^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 416.3 * 0.06
  = 23.404 kN
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 42.6 + 56.768
  = 99.368 cm^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 23.4/99.368
  = 2.355 N./mm^2
```

<u>Check of Outside Ribs:</u>

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	30.0	172.0	...	51.6	...	0.127E+04

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * rl / 2
  = 1.0/( 2 * 1450.0 ) * 378.453 * 1139.44/2
  = 73.728 N-m
```

Compressive Allowable, KL/R < Cc (31.8458 < 138.1347) per AISC E2-1 [Sca]:

```
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 31.85 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(31.85)/(8* 138.13)-( 31.85³)/(8*138.13³)
  = 114.955 N./mm^2
```

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

```
  = Sc/Sca + ( Rm * Distance Side/I )/Sba
  = 2.36/114.95 + ( 73.73 * 86.0/12721121 )/137.9
  = 0.024
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	30.0	142.0	0.0	42.6	0.0	0.127E+04
Web	378.5	30.0	0.0	113.5	0.0	85.2
Values	...	...	...	156.1	...	0.135E+04

```
Compressive Allowable, KL/R < Cc ( 23.8353 < 138.1347 ) per AISC E2-1 [Sca]:
 = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
 = ( 1-( 23.84 )²/(2 * 138.13² )) * 207/
   ( 5/3+3*(23.84)/(8* 138.13)-( 23.84³)/(8*138.13³)
 = 117.737 N./mm^2
```

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

```
 = Sc/Sca + ( Rm * Distance Center/I )/Sba
 = 2.87/117.74 + ( 90.72 * 86.0/1350.513 )/137.9
 = 0.029
```

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^2
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	75.0	mm.
Nominal Bolt Diameter	Bnd	30.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	5.0297	cm^2
Saddle Load QO (Weight)	QO	184.0	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.5	kN
Maximum Transverse Force	Ft	1.3	kN
Maximum Longitudinal Force	Fl	1.0	kN
Saddle Bolted to Steel Foundation		No	

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]:

```
 = Fl / (Stba * Nbolts)
 = 0.99/(172.38 * 4.0)
 = 0.0144 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
 = B * Ft + Sum of X Moments
 = 1600.0 * 1.28 + 0.0
 = 2041.63 N-m
```

Eccentricity (e):

```
 = Rmom / QO
 = 2041.63/184.03
 = 11.09 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, 0.0144, 0.0]
= 0.0144 cm^2

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     0.01673
 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 / ( Srl * Erl ), 1 )
  = max( 0.27111E+11/( 137.9 * 0.19660E+09 ), 1 )
  = 1.0000
```

where [Y] is:

```
  = Large End All. Stress * Large End Elastic Modulus (Ext. temp.)
  = 137.9 * 0.19660E+09
  = 27111170048.0 N./mm^2^2
```

Allowable Stress of Large End Material (Ext. Temp)	137.9	N./mm^2
Allowable Stress of Cone Material (Ext. Temp)	137.9	N./mm^2

Required Area of Reinforcement, Large End, External [Arl]:

```
= (k*QL*Rl*tan(angle)/(Ss*E1))*(1-1/4((P*Rl-QL)/QL)*(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 cm^2
```

Force per Length, Cone Large End External Pressure [QL]:

```
= Pext( Rl/2 ) + Faxial/(pi(Dl - Tl)) + 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 kN/mm.
```

Available Area of Reinforcement, Large End, External [Ael]:

```
= 0.55*( Dl*ts )½ * ( ts + tc/cos(alpha) )
= 0.55 * ( 1692.0 * 15.0 )½ * ( 15.0 + 17.0/0.876 )
= 30.1387 cm^2
```

<u>Summary of Reinforcement Area, Large End, External Pressure:</u>

Area of reinforcement required per App. 1-8(1)	1.4505	cm^2
Area of reinforcement in shell per App. 1-8(2)	30.1387	cm^2
Area of reinforcement in stiffening ring	0.0000	cm^2

<u>Reinforcement Calculations for Cone / Small Cylinder:</u>

Required Area of Reinforcement for Small End under Internal Pressure

Small end ratio of pressure to allowable stress	0.01673	
Small end max. half apex angle w/o reinforcement	11.355	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:

```
= Small End All. Stress * Small End Elastic Modulus (Int. temp.)
= 137.9 * 0.19660E+09
= 27111170048.0 N./mm^2^2
```

Decay Length, Cone Small End:

```
= 1.4 * sqrt( Rs( ts - ca ) )
= 1.4 * sqrt( 603.0( 20.0 - 3.0 ) )
= 141.746 mm.
```

Required Area of Reinforcement, Small End, Internal [Ars]:

```
= k*QS*Rs/(Ss*E1)*(1-delta/alpha)*tan(alpha)
= 1.0 * 0.6955 * 603.0/( 138 * 1.0 ) *
  ( 1 - 11.36/28.78 ) 0.5494
= 10.12 cm^2
```

Force per Length, Cone Small End [QS]:

```
= P( Rs/2 ) - Faxial/(pi(Ds + Ts)) + Moment/(pi(Rs + Ts/2)(Rs + Ts/2))
= 23.069( 603.0/2 ) - 0.0/(pi(1206.0 + 20.0)) +
  0.0/(pi(603.0 + 20.0/2)(603.0 + 20.0/2))
= 0.695 kN/mm.
```

Area of Reinforcement Available in Small End Shell [Aes]:

```
= 0.78(Rs*Ts)½*((Ts-t)+(Tc-Tr)/cos(alpha) ))
```

```
  = 0.78*(603.0*17.0)½*(( 17.0-10.19 )+( 17.0-11.627 )/0.88)
  = 10.2196 cm^2
```

Summary of Reinforcement Area, Small End, Internal Pressure:

Area of reinforcement required per App. 1-5(3)	10.1179	cm^2
Area of reinforcement in shell per App. 1-5(4)	10.2196	cm^2
Area of reinforcement in stiffening ring	0.0000	cm^2

Required Area of Reinforcement for Small End Under External Pressure

Allowable Stress of Small End Material (Ext. Temp)	137.9	N./mm^2
Allowable Stress of Cone Material (Ext. Temp)	137.9	N./mm^2

Intermediate Value [k]:

```
  = max( Y / ( Srs * Ers ), 1 )
  = max( 0.27111E+11/( 137.9 * 0.19660E+09 ), 1 )
  = 1.0000
```

where [Y] is:

```
  = Small End All. Stress * Small End Elastic Modulus (Ext. temp.)
  = 137.9 * 0.19660E+09
  = 27111170048.0 N./mm^2^2
```

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 cm^2
```

Force per Length, Cone Small End [QS]:

```
  = Pext( Rs/2 ) + Faxial/(pi(Ds - Ts)) + 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 kN/mm.
```

Area of Reinforcement Available in Small End Shell [Aes]:

```
  = 0.55*(Ds*ts)½*[(ts-t)+(tc-tr)/cos(alpha))]
  = 0.55*(1240.0*17.0)½*[(17.0-7.232)+(17.0-3.633)/0.876]
  = 19.9791 cm^2
```

Summary of Reinforcement Area, Small End, External Pressure:

Area of reinforcement required per App. 1-8(3)	0.7920	cm^2
Area of reinforcement in shell per App. 1-8(4)	19.9791	cm^2
Area of reinforcement in stiffening ring	0.0000	cm^2

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	195.82	413.70	Small Cyl. Long.
Compres. Stress	-112.83	-413.70	Small Cyl. Long.
Membrane Stress	167.93	-206.85	Small End Tang.
Tensile Stress	201.66	413.70	Cone Longitudinal
Compres. Stress	-106.98	-413.70	Cone Longitudinal
Compres Stress	179.63	-206.85	Cone Tangential
Tensile Stress	370.71	413.70	Large Cyl. Long.
Compres. Stress	-241.75	-413.70	Large Cyl. Long.
Membrane Stress	-20.90	-206.85	Large End Tang.

Tensile Stress	303.33	413.70	Cone Longitudinal
Compres. Stress	-173.50	-413.70	Cone Longitudinal
Compres Stress	-20.03	-206.85	Cone Tangential

Note: An asterisk (*) denotes that this stress was not applicable
for this combination of loads.

Maximum Allowable Working Pressure for Cone to Shell Junction:
= 23.2 bars, determined by iteration

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	24.82	OK	...	OK	11.33	OK	Passed
D2	24.38	OK	...	OK	7.80	OK	Passed
S2	24.56	OK	...	OK	10.16	OK	Passed
S1	24.56	OK	...	OK	10.16	OK	Passed
S3	24.56	OK	...	OK	10.16	OK	Passed
D1	24.56	OK	...	OK	7.80	OK	Passed
D3	24.56	OK	...	OK	7.80	OK	Passed
TT	24.56	OK	...	OK	7.80	OK	Passed
V	24.56	OK	...	OK	7.80	OK	Passed
S4	24.56	OK	...	OK	10.16	OK	Passed
LG1	24.56	OK	...	OK	7.80	OK	Passed
LG2	24.56	OK	...	OK	7.80	OK	Passed
LT1	24.56	OK	...	OK	6.42	OK	Passed
LT3	24.56	OK	...	OK	6.42	OK	Passed
LT2	24.56	OK	...	OK	6.42	OK	Passed
LT4	24.56	OK	...	OK	6.42	OK	Passed

MAWP Summary:

Minimum MAWP Nozzles : 24.379 Nozzle : D2

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	D2	2085.525	270.000	118.000
70	S2	3035.526	270.000	405.700
70	S1	5585.525	270.000	405.700
70	S3	3235.525	90.000	405.700
70	D1	4735.525	270.000	114.000
70	D3	6135.525	270.000	114.000
70	TT	6385.525	270.000	114.000
70	V	2685.526	90.000	114.000
70	S4	5585.525	90.000	405.700
70	LG1	4335.525	270.000	114.000
70	LG2	4335.525	90.000	114.000
70	LT1	3735.525	90.000	115.034
70	LT3	4035.525	90.000	115.034
70	LT2	3735.525	270.000	115.034
70	LT4	4035.525	270.000	115.034

The nozzle spacing is computed by the following:

$= \mathrm{Sqrt}(ll^2 + lc^2)$ where

ll - Arc length along the inside vessel surface in the long. direction.

lc - Arc length along the inside vessel surface in the circ. direction

If any interferences/violations are found, they will be noted below.

No interference violations have been detected !

INPUT VALUES, Nozzle Description: T2 From : 20

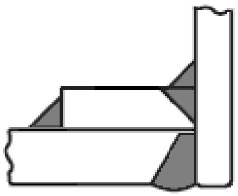
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1200.00	mm.
Design Length of Section	L	1140.0000	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^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		20.0000	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^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
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	

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.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]

```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.0*603.0)/(138*1.0-0.6*23.0)
  = 10.1595 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]

```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (23.0*254.0)/(138*1.0+0.4*23.0)
  = 4.2086 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)            Dl    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, 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 [fr4]:

```
  = min( 1, Sp/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
Area Required	Ar	48.156	9.043	NA
Area in Shell	A1	8.724	38.794	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	88.446	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]:
```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = (2.6 ) * 1.0 + (0.0 ) * 1.0 + 304.8² * 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                tb1 = max(trb1, tr16b) = 13.1595 mm.
 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. --> 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^2  Passed
Expansion  :     0.0,  Allowable :    312.2 N./mm^2  Passed
Occasional :    15.5,  Allowable :    183.4 N./mm^2  Passed
Shear      :    11.0,  Allowable :     96.5 N./mm^2  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

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

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 * tmin. 12.7260 = 0.7 * Wo mm.
Pad Weld               6.0000 = 0.5*TminPad  8.4840 = 0.7 * Wp 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, (48.1563 - 8.7237 + 2 * 17.0 * 1.0 *
     (1.0 * 12.0 - 10.1595 ) )138)
  = 552.36 kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 7.6749 + 36.0 + 4.04 - 0.0 * 1.0 ) * 138
  = 657.93 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 7.6749 + 0.0 + 3.24 + ( 4.08 ) ) * 138
  = 206.76 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 7.6749 + 0.0 + 4.04 + 36.0 + ( 4.08 ) ) * 138
  = 714.19 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 ) * 508.0 * 18.0 * 0.49 * 138
  = 970. 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. 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. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 508.0 * 15.0 * 0.74 * 138
  = 1221. 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. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 953 + 1266 ) = 2218 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 970 + 1221 + 977 + 0 ) = 3169 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 953 + 977 + 0 ) = 1930 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                                       125.00  °C
 Vessel Material                                        SA-516 70
 Vessel Cold S.I. Allowable                      Smc      137.90  N./mm^2
 Vessel Hot  S.I. Allowable                      Smh      137.90  N./mm^2

 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 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
 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. MC	0.0	0.0	0.0	0.0	-55.3	55.3	55.3	-55.3
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
Shear MT	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)

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601
Nozzle Calcs.: T2 Nozl: 18 1:34am Feb 7,2022

```
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	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.	MC	0.0	0.0	0.0	0.0	-203.2	203.2	203.2	-203.2
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
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^2)

Type of Stress	Load	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

Stress Summation Comparison (N./mm^2):

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

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm^2)

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
Long. Pm (SUS)	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
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)	114.4	116.7	114.4	116.7	114.4	116.7	114.4	116.7
Pm+Pl (SUS)	78.9	81.2	133.9	136.2	103.4	105.7	122.8	125.1
Pm+Pl+Q (Total)	61.0	104.7	149.1	121.3	157.3	360.4	271.8	72.5

Stress Summation Comparison (N./mm^2):

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

INPUT VALUES, Nozzle Description: T1 From : 20

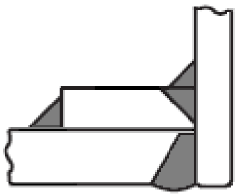
Pressure for Reinforcement Calculations	P	23.083	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1200.00	mm.
Design Length of Section	L	1140.0000	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^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		20.0000	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^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
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	

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.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
```
   = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
   = (23.08*603.0)/(138*1.0-0.6*23.08)
   = 10.1967 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
```
   = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
   = (23.08*254.0)/(138*1.0+0.4*23.08)
   = 4.2237 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)            Dl    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, 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 [fr4]:
```
   = min( 1, Sp/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
Area Required	Ar	48.332	9.043	NA
Area in Shell	A1	8.548	38.794	NA
Area in Nozzle Wall	A2	7.666	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	56.254	88.446	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:	695.1907	20.0000	mm.
Based on given Pad Diameter:	748.0001	15.5992	mm.
Based on Shell or Nozzle Thickness:	757.5876	15.0000	mm.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (474.0*10.1967*1.0+2*17.0*10.1967*1.0*(1-1.0))
  = 48.332 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 * 10.197 ) - 2 * 17.0
    ( 1.0 * 12.0 - 1.0 * 10.1967 ) * ( 1 - 1.0 )
  = 8.548 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 30.0 ) * ( 17.0 - 4.22 ) * 1.0
  = 7.666 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = (2.6 ) * 1.0 + (0.0 ) * 1.0 + 304.8² * 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 = 7.2237 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 13.1967 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 13.1967 mm.
 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(13.1967, 4.5)]
= 11.3312 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(7.2237, 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	:	32.6,	Allowable :	137.9 N./mm^2	Passed
Expansion	:	0.0,	Allowable :	312.1 N./mm^2	Passed
Occasional	:	15.5,	Allowable :	183.4 N./mm^2	Passed
Shear	:	11.0,	Allowable :	96.5 N./mm^2	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 = 4.224, 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 = 4.224, 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 = 4.224, 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 = 10.197, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.85, 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

Govrn. thk, tg = 15.0, tr = 10.197, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.85, 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 = 23.08/51.10 = 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 * tmin. 12.7260 = 0.7 * Wo mm.
 Pad Weld              6.0000 = 0.5*TminPad  8.4840 = 0.7 * Wp 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, (48.3322 - 8.5478 + 2 * 17.0 * 1.0 *
     (1.0 * 12.0 - 10.1967 ) )138)
  = 557.03 kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 7.6658 + 36.0 + 4.04 - 0.0 * 1.0 ) * 138
  = 657.81 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 7.6658 + 0.0 + 3.24 + ( 4.08 ) ) * 138
  = 206.64 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 7.6658 + 0.0 + 4.04 + 36.0 + ( 4.08 ) ) * 138
  = 714.07 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 ) * 508.0 * 18.0 * 0.49 * 138
  = 970. 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. 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. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 508.0 * 15.0 * 0.74 * 138
  = 1221. 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. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 953 + 1266 ) = 2218 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 970 + 1221 + 977 + 0 ) = 3169 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 953 + 977 + 0 ) = 1930 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 2218 kN , must exceed W = 557 kN  or W1 = 657 kN
 Path 2-2 = 3168 kN , must exceed W = 557 kN  or W2 = 206 kN
 Path 3-3 = 1929 kN , must exceed W = 557 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                                         125.00  °C
 Vessel Material                                         SA-516 70
 Vessel Cold S.I. Allowable                       Smc       137.90  N./mm^2
 Vessel Hot  S.I. Allowable                       Smh       137.90  N./mm^2

 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 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	23.083	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
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. MC	0.0	0.0	0.0	0.0	-55.3	55.3	55.3	-55.3
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
Shear MT	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	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
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.	MC	0.0	0.0	0.0	0.0	-203.2	203.2	203.2	-203.2
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
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^2)

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Pm	(SUS)	42.4	44.7	42.4	44.7	42.4	44.7	42.4	44.7
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	44.7	42.4	44.7	42.4	44.7	42.4	44.7
Pm+Pl (SUS)	23.7	26.0	56.3	58.6	35.9	38.2	46.1	48.4
Pm+Pl+Q (Total)	30.1	56.6	75.1	44.1	27.7	100.4	95.2	13.4

Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	44.68	137.90	Passed
Pm+Pl (SUS)	58.64	206.85	Passed
Pm+Pl+Q (TOTAL)	100.38	413.70	Passed

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	114.9	117.2	114.9	117.2	114.9	117.2	114.9	117.2
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
Long. Pm (SUS)	57.4	57.4	57.4	57.4	57.4	57.4	57.4	57.4
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)	114.9	117.2	114.9	117.2	114.9	117.2	114.9	117.2
Pm+Pl (SUS)	79.3	81.6	134.3	136.6	103.6	105.9	123.2	125.5
Pm+Pl+Q (Total)	61.2	105.2	149.5	121.7	156.9	360.8	272.2	72.3

Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	117.17	137.90	Passed
Pm+Pl (SUS)	136.58	206.85	Passed
Pm+Pl+Q (TOTAL)	360.83	413.70	Passed

INPUT VALUES, Nozzle Description: D2 From : 60

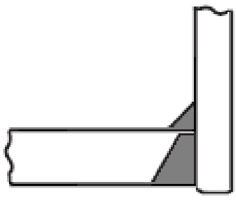
Pressure for Reinforcement Calculations	P	23.030	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cone at Nozzle Location	D	1408.77	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		2085.52	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^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
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)



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 Conical Transition, Tr [Int. Press]
```
= (P*D)/(2*cos(a)*(Sv*E-0.6*P)) Appendix 1-4(e)
= (23.03*(1415.6171+2*0.0))/( 2*0.8764*(138*1.0-0.6*23.03))
= 13.6246 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*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
= (23.03*28.4)/(138*1.0-0.6*23.03)
= 0.4791 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    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
Area Required	Ar	7.739	2.470	NA

Area in Shell	A1	2.066	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	11.988	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]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*13.6246*1.0+2*13.6*13.6246*1.0*(1-1.0))
  = 7.739 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 )
  = 61.2( 1.0 * 17.0 - 1.0 * 13.625 ) - 2 * 13.6
    ( 1.0 * 17.0 - 1.0 * 13.6246 ) * ( 1 - 1.0 )
  = 2.066 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34.0 )( 13.6 - 0.48 )1.0
  = 8.922 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 1.0 + ( 0.0 )² * 1.0
  = 1.000 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures        ta = 3.4791 mm.
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure       trb1 = 16.6246 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 16.6246 mm.
 Wall Thickness, shell/head, external pressure       trb2 = 3.6060 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( 16.6246, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.4791, 7.8 )
  = 7.8000 mm.
```

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) :

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
```

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)            -48 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
```
Design Pressure/Ambient Rating = 23.03/51.10 = 0.451
```

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]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (7.7388 - 2.0657 + 2 * 13.6 * 1.0 *
     (1.0 * 17.0 - 13.6246 ) )138)
  = 90.88 kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.9222 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 136.82 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.9222 + 0.0 + 1. + ( 4.624 ) ) * 138
  = 200.57 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.9222 + 0.0 + 1. + 0.0 + ( 4.624 ) ) * 138
  = 200.57 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 ) * 84.0 * 10.0 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:


```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 20.0 - 3.0 ) * 0.74 * 138
  = 229. kN
```

Strength of Failure Paths:

```
  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 = 90 kN  or W1 = 136 kN
 Path 2-2 = 318 kN , must exceed W = 90 kN  or W2 = 200 kN
 Path 3-3 = 318 kN , must exceed W = 90 kN  or W3 = 200 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       24.409   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 : 1.2533 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 171.2533 mm.

INPUT VALUES, Nozzle Description: S2 From : 70

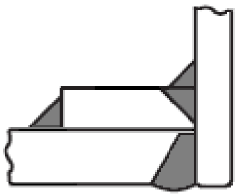
Pressure for Reinforcement Calculations	P	23.068	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
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		3035.53	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^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
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^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
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.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.07*831.0)/(138*1.0-0.6*23.07)
  = 14.0430 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (23.07*109.5375)/(118*1.0+0.4*23.07)
  = 2.1266 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)            Dl   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, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr4]:
```
  = min( 1, Sp/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = 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	28.817	8.910	NA
Area in Shell	A1	1.919	12.663	NA
Area in Nozzle Wall	A2	3.838	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	37.367	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:	331.5703	18.0000	mm.
Based on given Pad Diameter:	379.0750	12.6557	mm.
Based on Shell or Nozzle Thickness:	401.2946	11.1125	mm.

Area Required [A]:
```
 = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
 = (202.85*14.043*1.0+2*8.1125*14.043*1.0*(1-0.86))
 = 28.817 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 * 14.043 ) - 2 * 8.113
   ( 1.0 * 15.0 - 1.0 * 14.043 ) * ( 1 - 0.855 )
 = 1.919 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
 = ( 2 * Tlwp ) * ( tn - trn ) * fr2
 = ( 2 * 37.5 ) * ( 8.11 - 2.13 ) * 0.855
 = 3.838 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
 = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Trapfr4
 = ( 1. ) * 0.86 + (0.0 ) * 0.86 + 195.5274² * 1.0
 = 2.810 cm^2
```

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^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures        ta = 5.1266 mm.
Wall Thickness per UG16(b),                         tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure        trb1 = 17.0430 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 17.0430 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 = 10.1600 mm.
```


Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 10.16, max( 17.043, 4.5 ) ]
  = 10.1600 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

```
  = max( ta, tb )
  = max( 5.1266, 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^2  Passed
 Expansion  :      0.0,  Allowable :    244.3 N./mm^2  Passed
 Occasional :     13.9,  Allowable :    156.8 N./mm^2  Passed
 Shear      :     20.4,  Allowable :     82.5 N./mm^2  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 = 2.127, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.262, 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 = 14.043, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.936, 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
```

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)           -48 °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 = 23.07/51.10 = 0.451
```

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]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (28.8166 - 1.9187 + 2 * 8.1125 * 0.855 *
    (1.0 * 15.0 - 14.043 ) )138)
  = 372.72 kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.8384 + 28.8 + 2.8103 - 0.0 * 0.86 ) * 138
  = 488.80 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.8384 + 0.0 + 0.855 + ( 2.0809 ) ) * 138
  = 93.41 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.8384 + 0.0 + 2.8103 + 28.8 + ( 2.0809 ) ) * 138
  = 517.49 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 ) * 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 = 372 kN  or W1 = 488 kN
 Path 2-2 = 1357 kN , must exceed W = 372 kN  or W2 = 93 kN
 Path 3-3 = 1089 kN , must exceed W = 372 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                                    125.00   °C
 Vessel Material                                    SA-516 70
 Vessel Cold S.I. Allowable                   Smc      137.90   N./mm^2
 Vessel Hot  S.I. Allowable                   Smh      137.90   N./mm^2

 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 Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	18.000	mm.
Diameter of Reinforcing Pad	Dpad	379.075	mm.
Design Internal Pressure	Dp	23.068	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:
= NozzleOD + 2 * 1.65 * sqrt(Rmean(t - ca))
= 219.075 + 2 * 1.65 * sqrt(838.5 (18.0 - 3.0))
= 589.168 mm.

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	8.0	kN
Circumferential Shear	VC	8.0	kN
Longitudinal Shear	VL	8.0	kN
Circumferential Moment	MC	6800.0	N-m
Longitudinal Moment	ML	6800.0	N-m
Torsional Moment	MT	8400.0	N-m

Dimensionless Parameters used : Gamma = 25.68

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.113	4C	4.590	(A,B)
N(PHI) / (P/Rm)	0.113	3C	3.985	(C,D)
M(PHI) / (P)	0.113	2C1	0.097	(A,B)
M(PHI) / (P)	0.113	1C	0.134	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.113	3A	0.723	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.113	1A	0.098	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.113	3B	2.471	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.113	1B	0.047	(A,B,C,D)
N(x) / (P/Rm)	0.113	3C	3.985	(A,B)

	Beta	Figure	Value	Location
N(x) / (P/Rm)	0.113	4C	4.590	(C,D)
M(x) / (P)	0.113	1C1	0.136	(A,B)
M(x) / (P)	0.113	2C	0.097	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.113	4A	1.032	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.113	2A	0.054	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.113	4B	0.691	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.113	2B	0.078	(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	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-1.3	-1.3	-1.3	-1.3	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P	-4.3	4.3	-4.3	4.3	-5.9	5.9	-5.9	5.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-1.8	-1.8	1.8	1.8
Circ. Memb. MC	0.0	0.0	0.0	0.0	-38.3	38.3	38.3	-38.3
Circ. Memb. ML	-6.3	-6.3	6.3	6.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-18.5	18.5	18.5	-18.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-30.3	15.1	19.1	-9.2	-47.1	41.2	33.1	-31.7
Long. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.3	-1.3	-1.3	-1.3
Long. Bend. P	-6.0	6.0	-6.0	6.0	-4.3	4.3	-4.3	4.3
Long. Memb. MC	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Long. Bend. MC	0.0	0.0	0.0	0.0	-21.2	21.2	21.2	-21.2
Long. Memb. ML	-1.8	-1.8	1.8	1.8	0.0	0.0	0.0	0.0
Long. Bend. ML	-30.7	30.7	30.7	-30.7	0.0	0.0	0.0	0.0
Tot. Long. Str.	-39.5	33.8	25.3	-24.0	-29.4	21.5	18.3	-15.6
Shear VC	0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Tot. Shear	4.1	4.1	2.7	2.7	2.7	2.7	4.1	4.1
Str. Int.	41.1	34.6	26.3	24.5	47.5	41.5	34.1	32.7

Dimensionless Parameters used : Gamma = 55.90

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.198	4C	7.314	(A,B)
N(PHI) / (P/Rm)	0.198	3C	4.343	(C,D)
M(PHI) / (P)	0.198	2C1	0.028	(A,B)
M(PHI) / (P)	0.198	1C !	0.066	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.198	3A	2.187	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.198	1A	0.069	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.198	3B	5.207	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.198	1B	0.020	(A,B,C,D)
N(x) / (P/Rm)	0.198	3C	4.343	(A,B)
N(x) / (P/Rm)	0.198	4C	7.314	(C,D)
M(x) / (P)	0.198	1C1	0.058	(A,B)
M(x) / (P)	0.198	2C !	0.034	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.198	4A	4.611	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.198	2A	0.032	(A,B,C,D)

```
N(x)   / ( ML/(Rm**2 * Beta) )   0.198   4B   2.241   (A,B,C,D)
M(x)   / ( ML/(Rm    * Beta) )   0.198   2B   0.028   (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	-4.7	-4.7	-4.7	-4.7	-2.8	-2.8	-2.8	-2.8
Circ. Bend. P	-6.0	6.0	-6.0	6.0	-14.0	14.0	-14.0	14.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-7.1	-7.1	7.1	7.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-75.4	75.4	75.4	-75.4
Circ. Memb. ML	-17.0	-17.0	17.0	17.0	0.0	0.0	0.0	0.0
Circ. Bend. ML	-22.0	22.0	22.0	-22.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-49.6	6.4	28.4	-3.8	-99.4	79.6	65.7	-57.0
Long. Memb. P	-2.8	-2.8	-2.8	-2.8	-4.7	-4.7	-4.7	-4.7
Long. Bend. P	-12.4	12.4	-12.4	12.4	-7.2	7.2	-7.2	7.2
Long. Memb. MC	0.0	0.0	0.0	0.0	-15.0	-15.0	15.0	15.0
Long. Bend. MC	0.0	0.0	0.0	0.0	-34.8	34.8	34.8	-34.8
Long. Memb. ML	-7.3	-7.3	7.3	7.3	0.0	0.0	0.0	0.0
Long. Bend. ML	-30.8	30.8	30.8	-30.8	0.0	0.0	0.0	0.0
Tot. Long. Str.	-53.3	33.1	22.9	-13.8	-61.7	22.4	37.9	-17.2
Shear VC	0.9	0.9	-0.9	-0.9	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Shear MT	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
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^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	57.0	59.3	57.0	59.3	57.0	59.3	57.0	59.3
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)	57.0	59.3	57.0	59.3	57.0	59.3	57.0	59.3

Pm+Pl (SUS)	49.4	51.7	61.9	64.2	54.0	56.3	57.7	60.0
Pm+Pl+Q (Total)	38.6	75.7	76.4	50.2	12.0	100.6	90.4	28.6

Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	59.27	137.90	Passed
Pm+Pl (SUS)	64.24	206.85	Passed
Pm+Pl+Q (TOTAL)	100.60	413.70	Passed

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm^2)

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
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)	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
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
Shear Pm (SUS)	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
Shear Q (SUS)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pm (SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Pm+Pl (SUS)	105.1	107.4	139.0	141.3	116.8	119.1	131.0	133.3
Pm+Pl+Q (Total)	77.2	135.6	155.1	125.2	27.4	208.6	192.5	72.4

Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.97	137.90	Passed
Pm+Pl (SUS)	141.30	206.85	Passed
Pm+Pl+Q (TOTAL)	208.57	413.70	Passed

INPUT VALUES, Nozzle Description: S1 From : 70

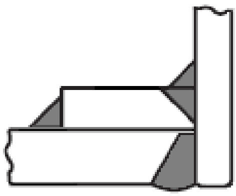
```
 Pressure for Reinforcement Calculations        P       23.068  bars
 Temperature for Internal Pressure           Temp          125  °C
 Design External Pressure                    Pext         1.03  bars
 Temperature for External Pressure         Tempex          125  °C

 Shell Material  [Impact Tested]                    SA-516 70
 Shell Allowable Stress at Temperature         Sv       137.90  N./mm^2
 Shell Allowable Stress At Ambient            Sva       137.90  N./mm^2

 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                     5585.52  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^2
 Allowable Stress At Ambient                  Sna       117.90  N./mm^2

 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^2
 Pad Allowable Stress At Ambient              Spa       137.90  N./mm^2
 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.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (23.07*831.0)/(138*1.0-0.6*23.07)
= 14.0430 mm.

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
= (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= (23.07*109.5375)/(118*1.0+0.4*23.07)
= 2.1266 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)	Dl	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, Sn/Sv)
= min(1, 117.9/137.9)
= 0.855

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 117.9/137.9)
= 0.855

Weld Strength Reduction Factor [fr4]:
= min(1, Sp/Sv)
= min(1, 137.9/137.9)
= 1.000

Weld Strength Reduction Factor [fr3]:
= 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	28.817	8.910	NA
Area in Shell	A1	1.919	12.663	NA
Area in Nozzle Wall	A2	3.838	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	37.367	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:	331.5703	18.0000	mm.
Based on given Pad Diameter:	379.0750	12.6557	mm.
Based on Shell or Nozzle Thickness:	401.2946	11.1125	mm.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (202.85*14.043*1.0+2*8.1125*14.043*1.0*(1-0.86))
  = 28.817 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 * 14.043 ) - 2 * 8.113
    ( 1.0 * 15.0 - 1.0 * 14.043 ) * ( 1 - 0.855 )
  = 1.919 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 37.5 ) * ( 8.11 - 2.13 ) * 0.855
  = 3.838 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Trapfr4
  = ( 1. ) * 0.86 + (0.0 ) * 0.86 + 195.5274² * 1.0
  = 2.810 cm^2
```

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^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures        ta = 5.1266 mm.
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure       trb1 = 17.0430 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 17.0430 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 = 10.1600 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
= min[ 10.16, max( 17.043, 4.5 ) ]
= 10.1600 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

```
= max( ta, tb )
= max( 5.1266, 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^2  Passed
Expansion  :      0.0,  Allowable :    244.3 N./mm^2  Passed
Occasional :     13.9,  Allowable :    156.8 N./mm^2  Passed
Shear      :     20.4,  Allowable :     82.5 N./mm^2  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 = 2.127, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.262, 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 = 14.043, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.936, 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
```

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)          -48 °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 = 23.07/51.10 = 0.451
```

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]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (28.8166 - 1.9187 + 2 * 8.1125 * 0.855 *
    (1.0 * 15.0 - 14.043 ) )138)
  = 372.72 kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.8384 + 28.8 + 2.8103 - 0.0 * 0.86 ) * 138
  = 488.80 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.8384 + 0.0 + 0.855 + ( 2.0809 ) ) * 138
  = 93.41 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.8384 + 0.0 + 2.8103 + 28.8 + ( 2.0809 ) ) * 138
  = 517.49 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 ) * 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 = 372 kN  or W1 = 488 kN
 Path 2-2 = 1357 kN , must exceed W = 372 kN  or W2 = 93 kN
 Path 3-3 = 1089 kN , must exceed W = 372 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                                       125.00   °C
 Vessel Material                                       SA-516 70
 Vessel Cold S.I. Allowable                      Smc      137.90   N./mm^2
 Vessel Hot  S.I. Allowable                      Smh      137.90   N./mm^2

 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 Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	18.000	mm.
Diameter of Reinforcing Pad	Dpad	379.075	mm.
Design Internal Pressure	Dp	23.068	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:

```
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 219.075 + 2 * 1.65 * sqrt( 838.5 ( 18.0 - 3.0 ) )
= 589.168 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	8.0	kN
Circumferential Shear	VC	8.0	kN
Longitudinal Shear	VL	8.0	kN
Circumferential Moment	MC	6800.0	N-m
Longitudinal Moment	ML	6800.0	N-m
Torsional Moment	MT	8400.0	N-m

Dimensionless Parameters used : Gamma = 25.68

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.113	4C	4.590	(A,B)
N(PHI) / (P/Rm)	0.113	3C	3.985	(C,D)
M(PHI) / (P)	0.113	2C1	0.097	(A,B)
M(PHI) / (P)	0.113	1C	0.134	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.113	3A	0.723	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.113	1A	0.098	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.113	3B	2.471	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.113	1B	0.047	(A,B,C,D)
N(x) / (P/Rm)	0.113	3C	3.985	(A,B)

N(x) / (P/Rm)	0.113	4C	4.590	(C,D)
M(x) / (P)	0.113	1C1	0.136	(A,B)
M(x) / (P)	0.113	2C	0.097	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.113	4A	1.032	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.113	2A	0.054	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.113	4B	0.691	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.113	2B	0.078	(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	-1.3	-1.3	-1.3	-1.3	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P	-4.3	4.3	-4.3	4.3	-5.9	5.9	-5.9	5.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-1.8	-1.8	1.8	1.8
Circ. Memb. MC	0.0	0.0	0.0	0.0	-38.3	38.3	38.3	-38.3
Circ. Memb. ML	-6.3	-6.3	6.3	6.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-18.5	18.5	18.5	-18.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-30.3	15.1	19.1	-9.2	-47.1	41.2	33.1	-31.7
Long. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.3	-1.3	-1.3	-1.3
Long. Bend. P	-6.0	6.0	-6.0	6.0	-4.3	4.3	-4.3	4.3
Long. Memb. MC	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Long. Bend. MC	0.0	0.0	0.0	0.0	-21.2	21.2	21.2	-21.2
Long. Memb. ML	-1.8	-1.8	1.8	1.8	0.0	0.0	0.0	0.0
Long. Bend. ML	-30.7	30.7	30.7	-30.7	0.0	0.0	0.0	0.0
Tot. Long. Str.	-39.5	33.8	25.3	-24.0	-29.4	21.5	18.3	-15.6
Shear VC	0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Tot. Shear	4.1	4.1	2.7	2.7	2.7	2.7	4.1	4.1
Str. Int.	41.1	34.6	26.3	24.5	47.5	41.5	34.1	32.7

Dimensionless Parameters used : Gamma = 55.90

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.198	4C	7.314	(A,B)
N(PHI) / (P/Rm)	0.198	3C	4.343	(C,D)
M(PHI) / (P)	0.198	2C1	0.028	(A,B)
M(PHI) / (P)	0.198	1C !	0.066	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.198	3A	2.187	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.198	1A	0.069	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.198	3B	5.207	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.198	1B	0.020	(A,B,C,D)
N(x) / (P/Rm)	0.198	3C	4.343	(A,B)
N(x) / (P/Rm)	0.198	4C	7.314	(C,D)
M(x) / (P)	0.198	1C1	0.058	(A,B)
M(x) / (P)	0.198	2C !	0.034	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.198	4A	4.611	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.198	2A	0.032	(A,B,C,D)

```
 N(x)    / ( ML/(Rm**2 * Beta) )    0.198   4B        2.241    (A,B,C,D)
 M(x)    / ( ML/(Rm    * Beta) )    0.198   2B        0.028    (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	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-4.7	-4.7	-4.7	-4.7	-2.8	-2.8	-2.8	-2.8
Circ. Bend. P	-6.0	6.0	-6.0	6.0	-14.0	14.0	-14.0	14.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-7.1	-7.1	7.1	7.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-75.4	75.4	75.4	-75.4
Circ. Memb. ML	-17.0	-17.0	17.0	17.0	0.0	0.0	0.0	0.0
Circ. Bend. ML	-22.0	22.0	22.0	-22.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-49.6	6.4	28.4	-3.8	-99.4	79.6	65.7	-57.0
Long. Memb. P	-2.8	-2.8	-2.8	-2.8	-4.7	-4.7	-4.7	-4.7
Long. Bend. P	-12.4	12.4	-12.4	12.4	-7.2	7.2	-7.2	7.2
Long. Memb. MC	0.0	0.0	0.0	0.0	-15.0	-15.0	15.0	15.0
Long. Bend. MC	0.0	0.0	0.0	0.0	-34.8	34.8	34.8	-34.8
Long. Memb. ML	-7.3	-7.3	7.3	7.3	0.0	0.0	0.0	0.0
Long. Bend. ML	-30.8	30.8	30.8	-30.8	0.0	0.0	0.0	0.0
Tot. Long. Str.	-53.3	33.1	22.9	-13.8	-61.7	22.4	37.9	-17.2
Shear VC	0.9	0.9	-0.9	-0.9	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Shear MT	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
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^2)

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	57.0	59.3	57.0	59.3	57.0	59.3	57.0	59.3
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)	57.0	59.3	57.0	59.3	57.0	59.3	57.0	59.3

Pm+Pl (SUS)	49.4	51.7	61.9	64.2	54.0	56.3	57.7	60.0
Pm+Pl+Q (Total)	38.6	75.7	76.4	50.2	12.0	100.6	90.4	28.6

Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	59.27	137.90	Passed
Pm+Pl (SUS)	64.24	206.85	Passed
Pm+Pl+Q (TOTAL)	100.60	413.70	Passed

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
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)	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
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
Shear Pm (SUS)	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
Shear Q (SUS)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pm (SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Pm+Pl (SUS)	105.1	107.4	139.0	141.3	116.8	119.1	131.0	133.3
Pm+Pl+Q (Total)	77.2	135.6	155.1	125.2	27.4	208.6	192.5	72.4

Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.97	137.90	Passed
Pm+Pl (SUS)	141.30	206.85	Passed
Pm+Pl+Q (TOTAL)	208.57	413.70	Passed

INPUT VALUES, Nozzle Description: S3 From : 70

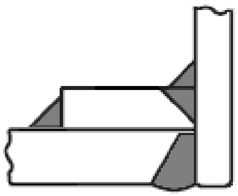
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
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		3235.53	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^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
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^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
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.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]

```
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (23.0*831.0)/(138*1.0-0.6*23.0)
= 14.0010 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]

```
= (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= (23.0*109.5375)/(118*1.0+0.4*23.0)
= 2.1204 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)              Dl   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, Sn/Sv )
= min( 1, 117.9/137.9 )
= 0.855
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 117.9/137.9 )
= 0.855
```

Weld Strength Reduction Factor [fr4]:

```
= min( 1, Sp/Sv )
= min( 1, 137.9/137.9 )
= 1.000
```

Weld Strength Reduction Factor [fr3]:

```
= 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	28.730	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^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 * 14.001 ) - 2 * 8.113
  ( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 0.855 )
= 2.003 cm^2
```

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^2
```

Area Available in Welds [A41 + A42 + A43]:
```
= (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Trapfr4
= ( 1. ) * 0.86 + (0.0 ) * 0.86 + 195.5274² * 1.0
= 2.810 cm^2
```

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^2
```

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                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 = 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^2  Passed
 Expansion  :      0.0,  Allowable :    244.3 N./mm^2  Passed
 Occasional :     13.8,  Allowable :    156.8 N./mm^2  Passed
 Shear      :     20.4,  Allowable :     82.5 N./mm^2  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
```

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)            -48 °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]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (28.7304 - 2.003 + 2 * 8.1125 * 0.855 *
    (1.0 * 15.0 - 14.001 ) )138)
  = 370.45 kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.8425 + 28.8 + 2.8103 - 0.0 * 0.86 ) * 138
  = 488.85 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.8425 + 0.0 + 0.855 + ( 2.0809 ) ) * 138
  = 93.47 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.8425 + 0.0 + 2.8103 + 28.8 + ( 2.0809 ) ) * 138
  = 517.54 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 ) * 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       24.555   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                                        125.00   °C
 Vessel Material                                        SA-516 70
 Vessel Cold S.I. Allowable                       Smc      137.90   N./mm^2
 Vessel Hot  S.I. Allowable                       Smh      137.90   N./mm^2

 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 Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
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:
= NozzleOD + 2 * 1.65 * sqrt(Rmean(t - ca))
= 219.075 + 2 * 1.65 * sqrt(838.5 (18.0 - 3.0))
= 589.168 mm.

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	8.0	kN
Circumferential Shear	VC	8.0	kN
Longitudinal Shear	VL	8.0	kN
Circumferential Moment	MC	6800.0	N-m
Longitudinal Moment	ML	6800.0	N-m
Torsional Moment	MT	8400.0	N-m

Dimensionless Parameters used : Gamma = 25.68

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.113	4C	4.590	(A,B)
N(PHI) / (P/Rm)	0.113	3C	3.985	(C,D)
M(PHI) / (P)	0.113	2C1	0.097	(A,B)
M(PHI) / (P)	0.113	1C	0.134	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.113	3A	0.723	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.113	1A	0.098	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.113	3B	2.471	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.113	1B	0.047	(A,B,C,D)
N(x) / (P/Rm)	0.113	3C	3.985	(A,B)

```
N(x)   / ( P/Rm )                  0.113   4C        4.590   (C,D)
M(x)   / ( P )                     0.113   1C1       0.136   (A,B)
M(x)   / ( P )                     0.113   2C        0.097   (C,D)
N(x)   / ( MC/(Rm**2 * Beta) )     0.113   4A        1.032   (A,B,C,D)
M(x)   / ( MC/(Rm    * Beta) )     0.113   2A        0.054   (A,B,C,D)
N(x)   / ( ML/(Rm**2 * Beta) )     0.113   4B        0.691   (A,B,C,D)
M(x)   / ( ML/(Rm    * Beta) )     0.113   2B        0.078   (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	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-1.3	-1.3	-1.3	-1.3	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P	-4.3	4.3	-4.3	4.3	-5.9	5.9	-5.9	5.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-1.8	-1.8	1.8	1.8
Circ. Memb. MC	0.0	0.0	0.0	0.0	-38.3	38.3	38.3	-38.3
Circ. Memb. ML	-6.3	-6.3	6.3	6.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-18.5	18.5	18.5	-18.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-30.3	15.1	19.1	-9.2	-47.1	41.2	33.1	-31.7
Long. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.3	-1.3	-1.3	-1.3
Long. Bend. P	-6.0	6.0	-6.0	6.0	-4.3	4.3	-4.3	4.3
Long. Memb. MC	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Long. Bend. MC	0.0	0.0	0.0	0.0	-21.2	21.2	21.2	-21.2
Long. Memb. ML	-1.8	-1.8	1.8	1.8	0.0	0.0	0.0	0.0
Long. Bend. ML	-30.7	30.7	30.7	-30.7	0.0	0.0	0.0	0.0
Tot. Long. Str.	-39.5	33.8	25.3	-24.0	-29.4	21.5	18.3	-15.6
Shear VC	0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Tot. Shear	4.1	4.1	2.7	2.7	2.7	2.7	4.1	4.1
Str. Int.	41.1	34.6	26.3	24.5	47.5	41.5	34.1	32.7

Dimensionless Parameters used : Gamma = 55.90

Dimensionless Loads for Cylindrical Shells at Pad edge:

```
-------------------------------------------------------------------
Curves read for 1979               Beta  Figure    Value   Location
-------------------------------------------------------------------
N(PHI) / ( P/Rm )                  0.198   4C        7.314   (A,B)
N(PHI) / ( P/Rm )                  0.198   3C        4.343   (C,D)
M(PHI) / ( P )                     0.198   2C1       0.028   (A,B)
M(PHI) / ( P )                     0.198   1C  !     0.066   (C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )     0.198   3A        2.187   (A,B,C,D)
M(PHI) / ( MC/(Rm    * Beta) )     0.198   1A        0.069   (A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )     0.198   3B        5.207   (A,B,C,D)
M(PHI) / ( ML/(Rm    * Beta) )     0.198   1B        0.020   (A,B,C,D)

N(x)   / ( P/Rm )                  0.198   3C        4.343   (A,B)
N(x)   / ( P/Rm )                  0.198   4C        7.314   (C,D)
M(x)   / ( P )                     0.198   1C1       0.058   (A,B)
M(x)   / ( P )                     0.198   2C  !     0.034   (C,D)
N(x)   / ( MC/(Rm**2 * Beta) )     0.198   4A        4.611   (A,B,C,D)
M(x)   / ( MC/(Rm    * Beta) )     0.198   2A        0.032   (A,B,C,D)
```



```
 N(x)    / ( ML/(Rm**2 * Beta) )    0.198   4B        2.241    (A,B,C,D)
 M(x)    / ( ML/(Rm    * Beta) )    0.198   2B        0.028    (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	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-4.7	-4.7	-4.7	-4.7	-2.8	-2.8	-2.8	-2.8
Circ. Bend. P	-6.0	6.0	-6.0	6.0	-14.0	14.0	-14.0	14.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-7.1	-7.1	7.1	7.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-75.4	75.4	75.4	-75.4
Circ. Memb. ML	-17.0	-17.0	17.0	17.0	0.0	0.0	0.0	0.0
Circ. Bend. ML	-22.0	22.0	22.0	-22.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-49.6	6.4	28.4	-3.8	-99.4	79.6	65.7	-57.0
Long. Memb. P	-2.8	-2.8	-2.8	-2.8	-4.7	-4.7	-4.7	-4.7
Long. Bend. P	-12.4	12.4	-12.4	12.4	-7.2	7.2	-7.2	7.2
Long. Memb. MC	0.0	0.0	0.0	0.0	-15.0	-15.0	15.0	15.0
Long. Bend. MC	0.0	0.0	0.0	0.0	-34.8	34.8	34.8	-34.8
Long. Memb. ML	-7.3	-7.3	7.3	7.3	0.0	0.0	0.0	0.0
Long. Bend. ML	-30.8	30.8	30.8	-30.8	0.0	0.0	0.0	0.0
Tot. Long. Str.	-53.3	33.1	22.9	-13.8	-61.7	22.4	37.9	-17.2
Shear VC	0.9	0.9	-0.9	-0.9	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Shear MT	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
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^2)

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
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

Stress Summation Comparison (N./mm^2):

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

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm^2)

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
Shear Pm (SUS)	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
Shear Q (SUS)	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
Pm+Pl (SUS)	104.7	107.0	138.6	140.9	116.4	118.7	130.7	133.0
Pm+Pl+Q (Total)	76.9	135.2	154.7	124.9	27.0	208.2	192.1	72.0

Stress Summation Comparison (N./mm^2):

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

INPUT VALUES, Nozzle Description: D1 From : 70

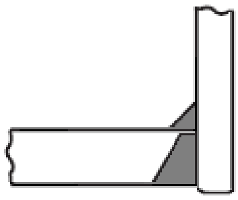
Pressure for Reinforcement Calculations	P	23.068	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
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		4735.53	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^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
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: 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*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.07*831.0)/(138*1.0-0.6*23.07)
  = 14.0430 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (23.07*28.4)/(138*1.0-0.6*23.07)
  = 0.4799 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, 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
Area Required	Ar	7.976	2.466	NA
Area in Shell	A1	0.547	3.613	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	10.469	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*14.043*1.0+2*13.6*14.043*1.0*(1-1.0))
  = 7.976 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 * 14.043 ) - 2 * 13.6
    ( 1.0 * 15.0 - 1.0 * 14.043 ) * ( 1 - 1.0 )
  = 0.547 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34.0 )( 13.6 - 0.48 )1.0
  = 8.922 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 1.0 + ( 0.0 )² * 1.0
  = 1.000 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

```
 Wall Thickness for Internal/External pressures      ta = 3.4799 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 17.0430 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 17.0430 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( 17.043, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

```
  = max( ta, tb )
  = max( 3.4799, 7.8 )
  = 7.8000 mm.
```

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^2  Passed
 Expansion  :       0.0,  Allowable :     329.9 N./mm^2  Passed
 Occasional :       1.9,  Allowable :     183.4 N./mm^2  Passed
 Shear      :       9.6,  Allowable :      96.5 N./mm^2  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
```

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)             -48 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
Design Pressure/Ambient Rating = 23.07/51.10 = 0.451

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]:
```
  = max( 0,  (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0,  (7.9764 - 0.5474 + 2 * 13.6 * 1.0 *
    (1.0 * 15.0 - 14.043 ) )138)
  = 106.03 kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.9216 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 136.81 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.9216 + 0.0 + 1. + ( 4.08 ) ) * 138
  = 193.07 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.9216 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138
  = 193.07 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 ) * 84.0 * 10.0 * 0.49 * 138
```



```
  = 89. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
  = 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                                    125.00  °C
 Vessel Material                                    SA-516 70
 Vessel Cold S.I. Allowable                   Smc      137.90  N./mm^2
 Vessel Hot  S.I. Allowable                   Smh      137.90  N./mm^2

 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 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      23.068  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)
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)

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
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)

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Pm (SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
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)	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
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
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)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Pm+Pl (SUS)	122.3	124.6	127.7	130.0	124.4	126.7	125.7	128.0
Pm+Pl+Q (Total)	97.7	149.8	136.9	120.9	84.6	166.5	145.7	108.4

Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result

Pm (SUS)	128.97	137.90	Passed
Pm+Pl (SUS)	130.01	206.85	Passed
Pm+Pl+Q (TOTAL)	166.50	413.70	Passed

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601
Nozzle Calcs.: D3 Nozl: 25 1:34am Feb 7,2022

INPUT VALUES, Nozzle Description: D3 From : 70

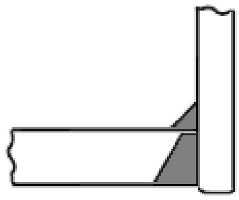
Pressure for Reinforcement Calculations	P	23.068	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
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		6135.53	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^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
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*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.07*831.0)/(138*1.0-0.6*23.07)
  = 14.0430 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (23.07*28.4)/(138*1.0-0.6*23.07)
  = 0.4799 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, 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
Area Required	Ar	7.976	2.466	NA
Area in Shell	A1	0.547	3.613	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	10.469	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*14.043*1.0+2*13.6*14.043*1.0*(1-1.0))
  = 7.976 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 * 14.043 ) - 2 * 13.6
    ( 1.0 * 15.0 - 1.0 * 14.043 ) * ( 1 - 1.0 )
  = 0.547 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34.0 )( 13.6 - 0.48 )1.0
  = 8.922 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 1.0 + ( 0.0 )² * 1.0
  = 1.000 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]

```
 Wall Thickness for Internal/External pressures        ta = 3.4799 mm.
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure       trb1 = 17.0430 mm.
 Wall Thickness                  tbl = max(trb1, tr16b) = 17.0430 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( 17.043, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

```
  = max( ta, tb )
  = max( 3.4799, 7.8 )
  = 7.8000 mm.
```

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^2  Passed
 Expansion   :      0.0,  Allowable :    329.9 N./mm^2  Passed
 Occasional  :      1.9,  Allowable :    183.4 N./mm^2  Passed
 Shear       :      9.6,  Allowable :     96.5 N./mm^2  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
```

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)            -48 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
```
Design Pressure/Ambient Rating = 23.07/51.10 = 0.451
```

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]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (7.9764 - 0.5474 + 2 * 13.6 * 1.0 *
     (1.0 * 15.0 - 14.043 ) )138)
  = 106.03 kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.9216 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 136.81 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.9216 + 0.0 + 1. + ( 4.08 ) ) * 138
  = 193.07 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.9216 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138
  = 193.07 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 ) * 84.0 * 10.0 * 0.49 * 138
```



```
  = 89. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
  = 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                                      125.00  °C
 Vessel Material                                      SA-516 70
 Vessel Cold S.I. Allowable                     Smc      137.90  N./mm^2
 Vessel Hot  S.I. Allowable                     Smh      137.90  N./mm^2

 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 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      23.068  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)
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)

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	-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)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
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)	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
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
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)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Pm+Pl (SUS)	122.3	124.6	127.7	130.0	124.4	126.7	125.7	128.0
Pm+Pl+Q (Total)	97.7	149.8	136.9	120.9	84.6	166.5	145.7	108.4

Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result

Pm (SUS)	128.97	137.90	Passed
Pm+Pl (SUS)	130.01	206.85	Passed
Pm+Pl+Q (TOTAL)	166.50	413.70	Passed

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601
Nozzle Calcs.: TT Nozl: 26 1:34am Feb 7,2022

INPUT VALUES, Nozzle Description: TT From : 70

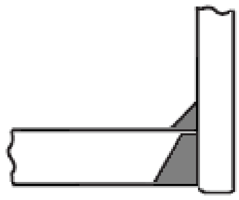
Pressure for Reinforcement Calculations	P	23.068	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
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		6385.52	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^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
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: 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*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.07*831.0)/(138*1.0-0.6*23.07)
  = 14.0430 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (23.07*28.4)/(138*1.0-0.6*23.07)
  = 0.4799 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, 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
Area Required	Ar	7.976	2.466	NA
Area in Shell	A1	0.547	3.613	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	10.469	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*14.043*1.0+2*13.6*14.043*1.0*(1-1.0))
  = 7.976 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 * 14.043 ) - 2 * 13.6
    ( 1.0 * 15.0 - 1.0 * 14.043 ) * ( 1 - 1.0 )
  = 0.547 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34.0 )( 13.6 - 0.48 )1.0
  = 8.922 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 1.0 + ( 0.0 )² * 1.0
  = 1.000 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 3.4799 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 17.0430 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 17.0430 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( 17.043, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.4799, 7.8 )
  = 7.8000 mm.
```

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^2  Passed
 Expansion  :       0.0,  Allowable :    329.9 N./mm^2  Passed
 Occasional :       1.9,  Allowable :    183.4 N./mm^2  Passed
 Shear      :       9.6,  Allowable :     96.5 N./mm^2  Passed
```

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601
Nozzle Calcs.: TT                       Nozl:    26   1:34am   Feb 7,2022
```

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
```

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)            -48 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

```
Design Pressure/Ambient Rating = 23.07/51.10 = 0.451
```

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]:

```
 = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
 = max( 0, (7.9764 - 0.5474 + 2 * 13.6 * 1.0 *
   (1.0 * 15.0 - 14.043 ) )138)
 = 106.03 kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:

```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 8.9216 + 0.0 + 1. - 0.0 * 1.0 ) * 138
 = 136.81 kN
```

Weld Load [W2]:

```
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 8.9216 + 0.0 + 1. + ( 4.08 ) ) * 138
 = 193.07 kN
```

Weld Load [W3]:

```
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = ( 8.9216 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138
 = 193.07 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 ) * 84.0 * 10.0 * 0.49 * 138
```

```
  = 89. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
  = 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                                     125.00  °C
 Vessel Material                                     SA-516 70
 Vessel Cold S.I. Allowable                    Smc      137.90  N./mm^2
 Vessel Hot  S.I. Allowable                    Smh      137.90  N./mm^2

 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 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      23.068  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)
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)

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	-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)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
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)	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
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
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)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Pm+Pl (SUS)	122.3	124.6	127.7	130.0	124.4	126.7	125.7	128.0
Pm+Pl+Q (Total)	97.7	149.8	136.9	120.9	84.6	166.5	145.7	108.4

Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result

Pm (SUS)	128.97	137.90	Passed
Pm+Pl (SUS)	130.01	206.85	Passed
Pm+Pl+Q (TOTAL)	166.50	413.70	Passed

INPUT VALUES, Nozzle Description: V From : 70

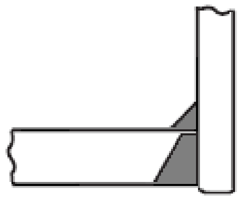
```
Pressure for Reinforcement Calculations         P       23.000  bars
Temperature for Internal Pressure            Temp          125  °C
Design External Pressure                     Pext         1.03  bars
Temperature for External Pressure          Tempex          125  °C

Shell Material   [Impact Tested]                     SA-516 70
Shell Allowable Stress at Temperature          Sv       137.90  N./mm^2
Shell Allowable Stress At Ambient             Sva       137.90  N./mm^2

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                      2685.53  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^2
Allowable Stress At Ambient                   Sna       137.90  N./mm^2

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*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.0*831.0)/(138*1.0-0.6*23.0)
  = 14.0010 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (23.0*28.4)/(138*1.0-0.6*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, 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
Area Required	Ar	7.953	2.466	NA
Area in Shell	A1	0.571	3.613	NA
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]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*14.001*1.0+2*13.6*14.001*1.0*(1-1.0))
  = 7.953 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 * 14.001 ) - 2 * 13.6
    ( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 1.0 )
  = 0.571 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34.0 )( 13.6 - 0.48 )1.0
  = 8.923 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 1.0 + ( 0.0 )² * 1.0
  = 1.000 cm^2
```

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]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 17.001, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:

```
  = max( ta, tb )
  = max( 3.4785, 7.8 )
  = 7.8000 mm.
```

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^2  Passed
 Expansion   :      0.0,  Allowable :    329.9 N./mm^2  Passed
 Occasional  :      1.9,  Allowable :    183.4 N./mm^2  Passed
 Shear       :      9.6,  Allowable :     96.5 N./mm^2  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
```

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)            -48 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
```
Design Pressure/Ambient Rating = 23.00/51.10 = 0.450
```

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]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (7.9526 - 0.5714 + 2 * 13.6 * 1.0 *
     (1.0 * 15.0 - 14.001 ) )138)
  = 105.52 kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.9226 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 136.82 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.9226 + 0.0 + 1. + ( 4.08 ) ) * 138
  = 193.08 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.9226 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138
  = 193.08 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 ) * 84.0 * 10.0 * 0.49 * 138
```

```
  = 89. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
  = 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       24.555   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                                        125.00  °C
 Vessel Material                                        SA-516 70
 Vessel Cold S.I. Allowable                      Smc       137.90  N./mm^2
 Vessel Hot  S.I. Allowable                      Smh       137.90  N./mm^2

 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 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:

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601
Nozzle Calcs.: V Nozl: 27 1:34am Feb 7,2022

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)
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)

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	-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)

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)	-24.8	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
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)	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
Pm+Pl (SUS)	122.0	124.3	127.3	129.6	124.0	126.3	125.3	127.6
Pm+Pl+Q (Total)	97.3	149.4	136.6	120.5	84.2	166.1	145.4	108.0

Stress Summation Comparison (N./mm^2):

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

INPUT VALUES, Nozzle Description: 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^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
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		5585.52	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

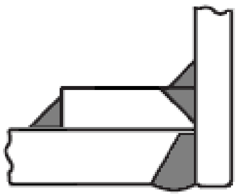
Type of Element Connected to the Shell : Nozzle

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^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
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^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
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.

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601
Nozzle Calcs.: S4                      Nozl:    28    1:34am    Feb 7,2022
```

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.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]

```
   = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
   = (23.0*831.0)/(138*1.0-0.6*23.0)
   = 14.0010 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]

```
   = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
   = (23.0*109.5375)/(118*1.0+0.4*23.0)
   = 2.1204 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)            Dl    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, Sn/Sv )
   = min( 1, 117.9/137.9 )
   = 0.855
```

Weld Strength Reduction Factor [fr2]:

```
   = min( 1, Sn/Sv )
   = min( 1, 117.9/137.9 )
   = 0.855
```

Weld Strength Reduction Factor [fr4]:

```
   = min( 1, Sp/Sv )
   = min( 1, 137.9/137.9 )
   = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
   = 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	28.730	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^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 * 14.001 ) - 2 * 8.113
    ( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 0.855 )
  = 2.003 cm^2
```

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^2
```

Area Available in Welds [A41 + A42 + A43]:
```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Trapfr4
  = ( 1. ) * 0.86 + (0.0 ) * 0.86 + 195.5274² * 1.0
  = 2.810 cm^2
```

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^2
```

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                  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 = 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^2	Passed
Expansion	:	0.0,	Allowable :	244.3 N./mm^2	Passed
Occasional	:	13.8,	Allowable :	156.8 N./mm^2	Passed
Shear	:	20.4,	Allowable :	82.5 N./mm^2	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

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)            -48 °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]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (28.7304 - 2.003 + 2 * 8.1125 * 0.855 *
    (1.0 * 15.0 - 14.001 ) )138)
  = 370.45 kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.8425 + 28.8 + 2.8103 - 0.0 * 0.86 ) * 138
  = 488.85 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.8425 + 0.0 + 0.855 + ( 2.0809 ) ) * 138
  = 93.47 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.8425 + 0.0 + 2.8103 + 28.8 + ( 2.0809 ) ) * 138
  = 517.54 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 ) * 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       24.555   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                                         125.00   °C
 Vessel Material                                         SA-516 70
 Vessel Cold S.I. Allowable                        Smc      137.90   N./mm^2
 Vessel Hot  S.I. Allowable                        Smh      137.90   N./mm^2

 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 Cold S.I. Allowable                  SNmc      117.90  N./mm^2
 Nozzle Hot  S.I. Allowable                  SNmh      117.90  N./mm^2

 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:

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 219.075 + 2 * 1.65 * sqrt( 838.5  ( 18.0 - 3.0 ) )
  = 589.168 mm.
```

WRC 107 Stress Calculation for SUStained loads:

```
 Radial Load                                    P         8.0  kN
 Circumferential Shear                         VC         8.0  kN
 Longitudinal Shear                            VL         8.0  kN
 Circumferential Moment                        MC      6800.0  N-m
 Longitudinal Moment                           ML      6800.0  N-m
 Torsional Moment                              MT      8400.0  N-m

 Dimensionless Parameters used :    Gamma =    25.68
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.113	4C	4.590	(A,B)
N(PHI) / (P/Rm)	0.113	3C	3.985	(C,D)
M(PHI) / (P)	0.113	2C1	0.097	(A,B)
M(PHI) / (P)	0.113	1C	0.134	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.113	3A	0.723	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.113	1A	0.098	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.113	3B	2.471	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.113	1B	0.047	(A,B,C,D)
N(x) / (P/Rm)	0.113	3C	3.985	(A,B)

N(x) / (P/Rm)	0.113	4C	4.590	(C,D)
M(x) / (P)	0.113	1C1	0.136	(A,B)
M(x) / (P)	0.113	2C	0.097	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.113	4A	1.032	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.113	2A	0.054	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.113	4B	0.691	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.113	2B	0.078	(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	-1.3	-1.3	-1.3	-1.3	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P	-4.3	4.3	-4.3	4.3	-5.9	5.9	-5.9	5.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-1.8	-1.8	1.8	1.8
Circ. Memb. MC	0.0	0.0	0.0	0.0	-38.3	38.3	38.3	-38.3
Circ. Memb. ML	-6.3	-6.3	6.3	6.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-18.5	18.5	18.5	-18.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-30.3	15.1	19.1	-9.2	-47.1	41.2	33.1	-31.7
Long. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.3	-1.3	-1.3	-1.3
Long. Bend. P	-6.0	6.0	-6.0	6.0	-4.3	4.3	-4.3	4.3
Long. Memb. MC	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Long. Bend. MC	0.0	0.0	0.0	0.0	-21.2	21.2	21.2	-21.2
Long. Memb. ML	-1.8	-1.8	1.8	1.8	0.0	0.0	0.0	0.0
Long. Bend. ML	-30.7	30.7	30.7	-30.7	0.0	0.0	0.0	0.0
Tot. Long. Str.	-39.5	33.8	25.3	-24.0	-29.4	21.5	18.3	-15.6
Shear VC	0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Tot. Shear	4.1	4.1	2.7	2.7	2.7	2.7	4.1	4.1
Str. Int.	41.1	34.6	26.3	24.5	47.5	41.5	34.1	32.7

Dimensionless Parameters used : Gamma = 55.90

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.198	4C	7.314	(A,B)
N(PHI) / (P/Rm)	0.198	3C	4.343	(C,D)
M(PHI) / (P)	0.198	2C1	0.028	(A,B)
M(PHI) / (P)	0.198	1C !	0.066	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.198	3A	2.187	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.198	1A	0.069	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.198	3B	5.207	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.198	1B	0.020	(A,B,C,D)
N(x) / (P/Rm)	0.198	3C	4.343	(A,B)
N(x) / (P/Rm)	0.198	4C	7.314	(C,D)
M(x) / (P)	0.198	1C1	0.058	(A,B)
M(x) / (P)	0.198	2C !	0.034	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.198	4A	4.611	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.198	2A	0.032	(A,B,C,D)

```
N(x)    / ( ML/(Rm**2 * Beta) )   0.198   4B      2.241   (A,B,C,D)
M(x)    / ( ML/(Rm    * Beta) )   0.198   2B      0.028   (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	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-4.7	-4.7	-4.7	-4.7	-2.8	-2.8	-2.8	-2.8
Circ. Bend. P	-6.0	6.0	-6.0	6.0	-14.0	14.0	-14.0	14.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-7.1	-7.1	7.1	7.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-75.4	75.4	75.4	-75.4
Circ. Memb. ML	-17.0	-17.0	17.0	17.0	0.0	0.0	0.0	0.0
Circ. Bend. ML	-22.0	22.0	22.0	-22.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-49.6	6.4	28.4	-3.8	-99.4	79.6	65.7	-57.0
Long. Memb. P	-2.8	-2.8	-2.8	-2.8	-4.7	-4.7	-4.7	-4.7
Long. Bend. P	-12.4	12.4	-12.4	12.4	-7.2	7.2	-7.2	7.2
Long. Memb. MC	0.0	0.0	0.0	0.0	-15.0	-15.0	15.0	15.0
Long. Bend. MC	0.0	0.0	0.0	0.0	-34.8	34.8	34.8	-34.8
Long. Memb. ML	-7.3	-7.3	7.3	7.3	0.0	0.0	0.0	0.0
Long. Bend. ML	-30.8	30.8	30.8	-30.8	0.0	0.0	0.0	0.0
Tot. Long. Str.	-53.3	33.1	22.9	-13.8	-61.7	22.4	37.9	-17.2
Shear VC	0.9	0.9	-0.9	-0.9	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Shear MT	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
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^2)

Type of Stress Load	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

Stress Summation Comparison (N./mm^2):

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

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (N./mm^2)

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
Shear Pm (SUS)	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
Shear Q (SUS)	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
Pm+Pl (SUS)	104.7	107.0	138.6	140.9	116.4	118.7	130.7	133.0
Pm+Pl+Q (Total)	76.9	135.2	154.7	124.9	27.0	208.2	192.1	72.0

Stress Summation Comparison (N./mm^2):

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

INPUT VALUES, Nozzle Description: LG1 From : 70

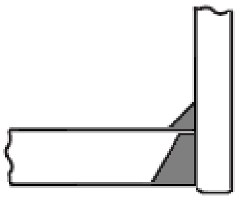
Pressure for Reinforcement Calculations	P	23.068	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
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		4335.53	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^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
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: 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*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.07*831.0)/(138*1.0-0.6*23.07)
  = 14.0430 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (23.07*28.4)/(138*1.0-0.6*23.07)
  = 0.4799 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, 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
Area Required	Ar	7.976	2.466	NA
Area in Shell	A1	0.547	3.613	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	10.469	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*14.043*1.0+2*13.6*14.043*1.0*(1-1.0))
  = 7.976 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 * 14.043 ) - 2 * 13.6
    ( 1.0 * 15.0 - 1.0 * 14.043 ) * ( 1 - 1.0 )
  = 0.547 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34.0 )( 13.6 - 0.48 )1.0
  = 8.922 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 1.0 + ( 0.0 )² * 1.0
  = 1.000 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 3.4799 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 17.0430 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 17.0430 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( 17.043, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.4799, 7.8 )
  = 7.8000 mm.
```

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) :

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
```

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)            -48 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

```
 Design Pressure/Ambient Rating = 23.07/51.10 = 0.451
```

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]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (7.9764 - 0.5474 + 2 * 13.6 * 1.0 *
     (1.0 * 15.0 - 14.043 ) )138)
  = 106.03 kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.9216 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 136.81 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.9216 + 0.0 + 1. + ( 4.08 ) ) * 138
  = 193.07 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.9216 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138
  = 193.07 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 ) * 84.0 * 10.0 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
  = 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.

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601
Nozzle Calcs.: LG2 Nozl: 30 1:34am Feb 7,2022

INPUT VALUES, Nozzle Description: LG2 From : 70

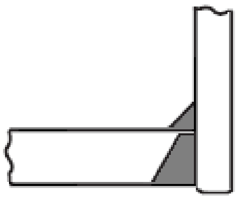
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
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		4335.53	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^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
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: 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*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.0*831.0)/(138*1.0-0.6*23.0)
  = 14.0010 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (23.0*28.4)/(138*1.0-0.6*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, 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
Area Required	Ar	7.953	2.466	NA
Area in Shell	A1	0.571	3.613	NA
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]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*14.001*1.0+2*13.6*14.001*1.0*(1-1.0))
  = 7.953 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 * 14.001 ) - 2 * 13.6
    ( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 1.0 )
  = 0.571 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34.0 )( 13.6 - 0.48 )1.0
  = 8.923 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 1.0 + ( 0.0 )² * 1.0
  = 1.000 cm^2
```

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]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 17.001, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.4785, 7.8 )
  = 7.8000 mm.
```

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) :

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
```

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)            -48 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

```
Design Pressure/Ambient Rating = 23.00/51.10 = 0.450
```

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]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (7.9526 - 0.5714 + 2 * 13.6 * 1.0 *
    (1.0 * 15.0 - 14.001 ) )138)
  = 105.52 kN
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.9226 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 136.82 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.9226 + 0.0 + 1. + ( 4.08 ) ) * 138
  = 193.08 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.9226 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138
  = 193.08 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 ) * 84.0 * 10.0 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
  = 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       24.555  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.

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601
Nozzle Calcs.: LT1 Nozl: 31 1:34am Feb 7,2022

INPUT VALUES, Nozzle Description: 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^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
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		3735.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

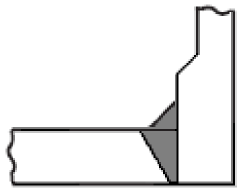
Type of Element Connected to the Shell : Nozzle

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^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
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)

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601
Nozzle Calcs.: LT1                      Nozl:    31    1:34am    Feb 7,2022
```



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.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]

```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.0*831.0)/(138*1.0-0.6*23.0)
  = 14.0010 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]

```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (23.0*30.1625)/(118*1.0+0.4*23.0)
  = 0.5839 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, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr3]:

```
  = 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	7.836	2.430	NA
Area in Shell	A1	0.590	3.731	NA
Area in Nozzle Wall	A2	10.527	10.720	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.855	0.855	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	11.972	15.306	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*(1-0.86))
  = 7.836 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 - 0.855 )
  = 0.590 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 37.5 )( 17.0 - 0.58 ) 0.855
  = 10.527 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.855 + ( 0.0 )² * 0.855
  = 0.855 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 = 3.5839 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 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.5839, 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 :   117.9 N./mm^2  Passed
Expansion  :     0.0,  Allowable :   232.7 N./mm^2  Passed
Occasional :     5.8,  Allowable :   156.8 N./mm^2  Passed
Shear      :    33.9,  Allowable :    82.5 N./mm^2  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)            -48 °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, (7.8355 - 0.5901 + 2 * 17.0 * 0.855 *
     (1.0 * 15.0 - 14.001 ) )138)
  = 103.91 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
  = ( 10.5268 + 0.855 - 0.0 * 0.86 ) * 138
  = 156.94 kN
```

Weld Load [W2]:
```
   = ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 )) * Sv
  = ( 10.5268 + 0.0 + 0.855 + ( 4.3605 ) ) * 138
  = 217.07 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+(2*(Hub Thickness)* t * fr1 )) * Sv
  = ( 10.5268 + 0.0 + 0.855 + 0.0 ) * 138
  = 217.07 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 * 118
  = 55. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 27.8398) * ( 20.0 - 3.0 ) * 0.7 * 118
  = 123. 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 ) = ( 55 + 123 ) = 177 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 55 + 0 + 145 + 0 ) = 200 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 55 + 145 + 0 ) = 200 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 177 kN , must exceed W = 103 kN  or W1 = 156 kN
 Path 2-2 = 199 kN , must exceed W = 103 kN  or W2 = 217 kN
 Path 3-3 = 199 kN , must exceed W = 103 kN  or W3 = 217 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case       24.555   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.

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                                         125.00  °C
 Vessel Material                                        SA-516 70
 Vessel Cold S.I. Allowable                       Smc       137.90  N./mm^2
 Vessel Hot  S.I. Allowable                       Smh       137.90  N./mm^2

 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-333 6
 Nozzle Cold S.I. Allowable                      SNmc       117.90  N./mm^2
 Nozzle Hot  S.I. Allowable                      SNmh       117.90  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".

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
   = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
   = 85.034 + 2 * 1.65 * sqrt( 838.5 ( 18.0 - 3.0 ) )
   = 455.127 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
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	-7.7	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
Long. Bend. MC	0.0	0.0	0.0	0.0	-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
Long. Bend. ML	-27.6	27.6	27.6	-27.6	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
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	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
Str. Int.	41.4	36.4	16.9	18.6	42.0	37.3	20.0	21.9

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm^2)

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

Stress Summation Comparison (N./mm^2):

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

INPUT VALUES, Nozzle Description: 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^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
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		4035.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

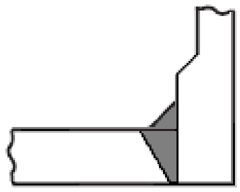
Type of Element Connected to the Shell : Nozzle

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^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
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)

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601
Nozzle Calcs.: LT3                    Nozl:   32   1:34am   Feb 7,2022
```



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*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
   = (23.0*831.0)/(138*1.0-0.6*23.0)
   = 14.0010 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
```
   = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
   = (23.0*30.1625)/(118*1.0+0.4*23.0)
   = 0.5839 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, 117.9/137.9 )
   = 0.855
```

Weld Strength Reduction Factor [fr2]:
```
   = min( 1, Sn/Sv )
   = min( 1, 117.9/137.9 )
   = 0.855
```

Weld Strength Reduction Factor [fr3]:
```
   = 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	7.836	2.430	NA
Area in Shell	A1	0.590	3.731	NA
Area in Nozzle Wall	A2	10.527	10.720	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.855	0.855	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	11.972	15.306	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*(1-0.86))
  = 7.836 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 - 0.855 )
  = 0.590 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 37.5 )( 17.0 - 0.58 ) 0.855
  = 10.527 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 10.0² * 0.855 + ( 0.0 )² * 0.855
  = 0.855 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 = 3.5839 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 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.5839, 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 :    117.9 N./mm^2  Passed
Expansion   :     0.0,  Allowable :    232.7 N./mm^2  Passed
Occasional  :     5.8,  Allowable :    156.8 N./mm^2  Passed
Shear       :    33.9,  Allowable :     82.5 N./mm^2  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)            -48 °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, (7.8355 - 0.5901 + 2 * 17.0 * 0.855 *
    (1.0 * 15.0 - 14.001 ) )138)
  = 103.91 kN
```

For hub type nozzles, A2 includes the area of the hub.

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601
Nozzle Calcs.: LT3                        Nozl:    32    1:34am    Feb 7,2022
```

Note: F is always set to 1.0 throughout the calculation.

Weld Load [W1]:
```
  = (A2+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 10.5268 + 0.855 - 0.0 * 0.86 ) * 138
  = 156.94 kN
```

Weld Load [W2]:
```
   = ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 )) * Sv
  = ( 10.5268 + 0.0 + 0.855 + ( 4.3605 ) ) * 138
  = 217.07 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+(2*(Hub Thickness)* t * fr1 )) * Sv
  = ( 10.5268 + 0.0 + 0.855 + 0.0 ) * 138
  = 217.07 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 * 118
  = 55. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 27.8398) * ( 20.0 - 3.0 ) * 0.7 * 118
  = 123. 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 ) = ( 55 + 123 ) = 177 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 55 + 0 + 145 + 0 ) = 200 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 55 + 145 + 0 ) = 200 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 177 kN , must exceed W = 103 kN  or W1 = 156 kN
 Path 2-2 = 199 kN , must exceed W = 103 kN  or W2 = 217 kN
 Path 3-3 = 199 kN , must exceed W = 103 kN  or W3 = 217 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case       24.555   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.

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                                         125.00  °C
 Vessel Material                                         SA-516 70
 Vessel Cold S.I. Allowable                        Smc      137.90  N./mm^2
 Vessel Hot  S.I. Allowable                        Smh      137.90  N./mm^2

 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-333 6
 Nozzle Cold S.I. Allowable                       SNmc      117.90  N./mm^2
 Nozzle Hot  S.I. Allowable                       SNmh      117.90  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".

Stress Attenuation Diameter (for Insert Plates) per WRC 297:

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 85.034 + 2 * 1.65 * sqrt( 838.5  ( 18.0 - 3.0 ) )
  = 455.127 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
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	-7.7	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
Long. Bend. MC	0.0	0.0	0.0	0.0	-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
Long. Bend. ML	-27.6	27.6	27.6	-27.6	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
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	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
Str. Int.	41.4	36.4	16.9	18.6	42.0	37.3	20.0	21.9

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm^2)

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

Stress Summation Comparison (N./mm^2):

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

INPUT VALUES, Nozzle Description: LT2 From : 70

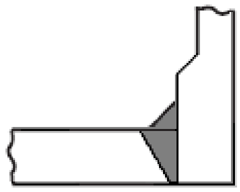
```
Pressure for Reinforcement Calculations         P       23.068  bars
Temperature for Internal Pressure            Temp          125  °C
Design External Pressure                     Pext         1.03  bars
Temperature for External Pressure          Tempex          125  °C

Shell Material  [Impact Tested]                    SA-516 70
Shell Allowable Stress at Temperature          Sv     137.90  N./mm^2
Shell Allowable Stress At Ambient             Sva     137.90  N./mm^2

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                    3735.53  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^2
Allowable Stress At Ambient                   Sna     117.90  N./mm^2

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*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (23.07*831.0)/(138*1.0-0.6*23.07)
= 14.0430 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]

```
= (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= (23.07*30.1625)/(118*1.0+0.4*23.07)
= 0.5856 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, 117.9/137.9 )
= 0.855
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 117.9/137.9 )
= 0.855
```

Weld Strength Reduction Factor [fr3]:

```
= 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	7.859	2.430	NA
Area in Shell	A1	0.565	3.731	NA
Area in Nozzle Wall	A2	10.526	10.720	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.855	0.855	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	11.946	15.306	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*14.043*1.0+2*17.0*14.043*1.0*(1-0.86))
= 7.859 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 * 14.043) - 2 * 17.0
(1.0 * 15.0 - 1.0 * 14.043) * (1 - 0.855)
= 0.565 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 37.5)(17.0 - 0.59) 0.855
= 10.526 cm^2

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo^2 * fr2 + (Wi-can/0.707 $)^2$ * fr2
= 10.0^2 * 0.855 + (0.0 $)^2$ * 0.855
= 0.855 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	= 3.5856 mm.
Wall Thickness per UG16(b),	tr16b	= 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1	= 17.0430 mm.
Wall Thickness	tb1 = max(trb1, tr16b)	= 17.0430 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(17.043, 4.5)]
= 6.4200 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.5856, 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 :    117.9 N./mm^2  Passed
Expansion  :     0.0,  Allowable :    232.7 N./mm^2  Passed
Occasional :     5.8,  Allowable :    156.8 N./mm^2  Passed
Shear      :    33.9,  Allowable :     82.5 N./mm^2  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)             -48 °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 = 23.07/51.10 = 0.451
```

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, (7.8591 - 0.5653 + 2 * 17.0 * 0.855 *
      (1.0 * 15.0 - 14.043 ) )138)
  = 104.41 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
  = ( 10.5257 + 0.855 - 0.0 * 0.86 ) * 138
  = 156.93 kN
```

Weld Load [W2]:
```
    = ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 )) * Sv
  = ( 10.5257 + 0.0 + 0.855 + ( 4.3605 ) ) * 138
  = 217.05 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+(2*(Hub Thickness)* t * fr1 )) * Sv
  = ( 10.5257 + 0.0 + 0.855 + 0.0 ) * 138
  = 217.05 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 * 118
  = 55. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 27.8398) * ( 20.0 - 3.0 ) * 0.7 * 118
  = 123. 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 ) = ( 55 + 123 ) = 177 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 55 + 0 + 145 + 0 ) = 200 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 55 + 145 + 0 ) = 200 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 177 kN , must exceed W = 104 kN  or W1 = 156 kN
 Path 2-2 = 199 kN , must exceed W = 104 kN  or W2 = 217 kN
 Path 3-3 = 199 kN , must exceed W = 104 kN  or W3 = 217 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.

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		125.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2
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-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Design Internal Pressure	Dp	23.068	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 ) )
  = 85.034 + 2 * 1.65 * sqrt( 838.5 ( 18.0 - 3.0 ) )
  = 455.127 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
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	-7.7	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
Long. Bend. MC	0.0	0.0	0.0	0.0	-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
Long. Bend. ML	-27.6	27.6	27.6	-27.6	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
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	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
Str. Int.	41.4	36.4	16.9	18.6	42.0	37.3	20.0	21.9

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl

Circ. Pm (SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
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)	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
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)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Pm+Pl (SUS)	122.3	124.6	127.7	130.0	124.4	126.7	125.7	128.0
Pm+Pl+Q (Total)	98.0	149.4	136.7	121.1	85.0	166.1	145.4	108.7

Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.97	137.90	Passed
Pm+Pl (SUS)	130.02	206.85	Passed
Pm+Pl+Q (TOTAL)	166.06	413.70	Passed

INPUT VALUES, Nozzle Description: LT4 From : 70

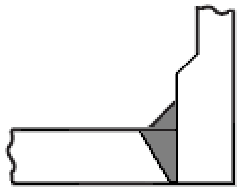
Pressure for Reinforcement Calculations	P	23.068	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
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		4035.53	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^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
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*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.07*831.0)/(138*1.0-0.6*23.07)
  = 14.0430 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (23.07*30.1625)/(118*1.0+0.4*23.07)
  = 0.5856 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, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr3]:
```
  = 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	7.859	2.430	NA
Area in Shell	A1	0.565	3.731	NA
Area in Nozzle Wall	A2	10.526	10.720	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.855	0.855	NA
Area in Element	A5	0.000	0.000	NA
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	11.946	15.306	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*14.043*1.0+2*17.0*14.043*1.0*(1-0.86))
= 7.859 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 * 14.043) - 2 * 17.0
(1.0 * 15.0 - 1.0 * 14.043) * (1 - 0.855)
= 0.565 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 37.5)(17.0 - 0.59) 0.855
= 10.526 cm^2

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo^2 * fr2 + (Wi-can/0.707 $)^2$ * fr2
= 10.0^2 * 0.855 + (0.0 $)^2$ * 0.855
= 0.855 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	= 3.5856 mm.
Wall Thickness per UG16(b),	tr16b	= 4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1	= 17.0430 mm.
Wall Thickness	tb1 = max(trb1, tr16b)	= 17.0430 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(17.043, 4.5)]
= 6.4200 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.5856, 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 :    117.9 N./mm^2  Passed
Expansion   :      0.0,  Allowable :    232.7 N./mm^2  Passed
Occasional  :      5.8,  Allowable :    156.8 N./mm^2  Passed
Shear       :     33.9,  Allowable :     82.5 N./mm^2  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)            -48 °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 = 23.07/51.10 = 0.451
```

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, (7.8591 - 0.5653 + 2 * 17.0 * 0.855 *
     (1.0 * 15.0 - 14.043 ) )138)
  = 104.41 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
  = ( 10.5257 + 0.855 - 0.0 * 0.86 ) * 138
  = 156.93 kN
```

Weld Load [W2]:
```
    = ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 )) * Sv
  = ( 10.5257 + 0.0 + 0.855 + ( 4.3605 ) ) * 138
  = 217.05 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+(2*(Hub Thickness)* t * fr1 )) * Sv
  = ( 10.5257 + 0.0 + 0.855 + 0.0 ) * 138
  = 217.05 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 * 118
  = 55. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 27.8398) * ( 20.0 - 3.0 ) * 0.7 * 118
  = 123. 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 ) = ( 55 + 123 ) = 177 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 55 + 0 + 145 + 0 ) = 200 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 55 + 145 + 0 ) = 200 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 177 kN , must exceed W = 104 kN  or W1 = 156 kN
 Path 2-2 = 199 kN , must exceed W = 104 kN  or W2 = 217 kN
 Path 3-3 = 199 kN , must exceed W = 104 kN  or W3 = 217 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.

Input Echo, WRC107/537 Item 1, Description: LT4 :

```
 Diameter Basis for Vessel                  Vbasis      ID
 Cylindrical or Spherical Vessel            Cylsph      Cylindrical
```

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601
Nozzle Calcs.: LT4 Nozl: 34 1:34am Feb 7,2022

Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	mm.
Design Temperature		125.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2
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-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Design Internal Pressure	Dp	23.068	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 ) )
  = 85.034 + 2 * 1.65 * sqrt( 838.5 ( 18.0 - 3.0 ) )
  = 455.127 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
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	-7.7	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
Long. Bend. MC	0.0	0.0	0.0	0.0	-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
Long. Bend. ML	-27.6	27.6	27.6	-27.6	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
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	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
Str. Int.	41.4	36.4	16.9	18.6	42.0	37.3	20.0	21.9

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (N./mm^2)

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl

Circ. Pm (SUS)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
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)	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
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)	126.7	129.0	126.7	129.0	126.7	129.0	126.7	129.0
Pm+Pl (SUS)	122.3	124.6	127.7	130.0	124.4	126.7	125.7	128.0
Pm+Pl+Q (Total)	98.0	149.4	136.7	121.1	85.0	166.1	145.4	108.7

Stress Summation Comparison (N./mm^2):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.97	137.90	Passed
Pm+Pl (SUS)	130.02	206.85	Passed
Pm+Pl+Q (TOTAL)	166.06	413.70	Passed

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia in	Wall Thk mm.	Reinforcing Pad Diameter mm.	Reinforcing Pad Thk mm.	Cut Length mm.	Flg Class
D2	2.000 in	Actual	LWN	3.307	16.600	...	...	171.25	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.

Nozzle Material and Weld Fillet Leg Size Details (mm.):

		Shl Grve	Noz Shl/Pad	Pad OD	Pad Grve	Inside

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601
Nozzle Schedule: Step: 33 1:34am Feb 7,2022

Description	Material	Weld	Weld	Weld	Weld	Weld
D2	SA-350 LF2	20.000	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-333 6	18.000	10.000	...	...	...
LT3	SA-333 6	18.000	10.000	...	...	...
LT2	SA-333 6	18.000	10.000	...	...	...
LT4	SA-333 6	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
D2	2035.525	270.0	150.00	0.00	CON
D1	4685.525	270.0	150.00	0.00	SHELL 002
D3	6085.525	270.0	150.00	0.00	SHELL 002
TT	6335.525	270.0	150.00	0.00	SHELL 002
V	2635.526	90.0	150.00	0.00	SHELL 002
LG1	4285.525	270.0	150.00	0.00	SHELL 002
LG2	4285.525	90.0	150.00	0.00	SHELL 002
LT1	3685.525	90.0	150.00	0.00	SHELL 002
LT3	3985.525	90.0	150.00	0.00	SHELL 002
LT2	3685.525	270.0	150.00	0.00	SHELL 002
LT4	3985.525	270.0	150.00	0.00	SHELL 002
S2	2985.525	270.0	150.00	0.00	SHELL 002
S1	5535.525	270.0	150.00	0.00	SHELL 002
S3	3185.525	90.0	150.00	0.00	SHELL 002
S4	5535.525	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

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
```

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^2
Shell Allowable Stress at Ambient                      137.90  N./mm^2
```

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^2
Channel Allowable Stress at Ambient                    137.90  N./mm^2
```

Tube Data:

```
Number of Tube Holes                           Nt        1740
Tube Wall Thickness                            et      2.7700  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^2
Tube Allowable Stress At Ambient                       117.90  N./mm^2
Tube Yield Stress At design Temperature       Syt      216.71  N./mm^2
Tube Pitch (Center to Center Spacing)           P     24.0000  mm.
Tube Layout Pattern                                    Square

Fillet Weld Leg                                af      2.0000  mm.
```


Groove Weld Leg	ag	2.0000	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	57.8000	mm.
Length of Expanded Portion of Tube	ltx	0.0000	mm.
Tube-side pass partition groove depth	hg	5.0000	mm.

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.

Additional Data for Stepped Tubesheets:

Is the Tubesheet Stepped?		YES	
Is the Tubesheet Flat on Tubeside?		NO	
Step 1 Diameter on the Tubeside	dt1	1266.00	mm.
Step 1 Depth on the Tubeside	ht1	6.00	mm.
Step 2 Diameter on the Tubeside	dt2	1197.00	mm.
Step 2 Depth on the Tubeside	ht2	5.00	mm.
Is the Tubesheet Flat on Shellside?		NO	
Step 1 Diameter on the Shellside	ds1	1266.00	mm.
Step 1 Depth on the Shellside	hs1	6.00	mm.
Step 2 Diameter on the Shellside	ds2	1197.00	mm.
Step 2 Depth on the Shellside	hs2	5.00	mm.
Calculated Tubesheet Diameter as per UHX-10(b)		1360.00	mm.

Note: Tubesheet diameter is now: 1360.000 mm. per UHX-10(b).

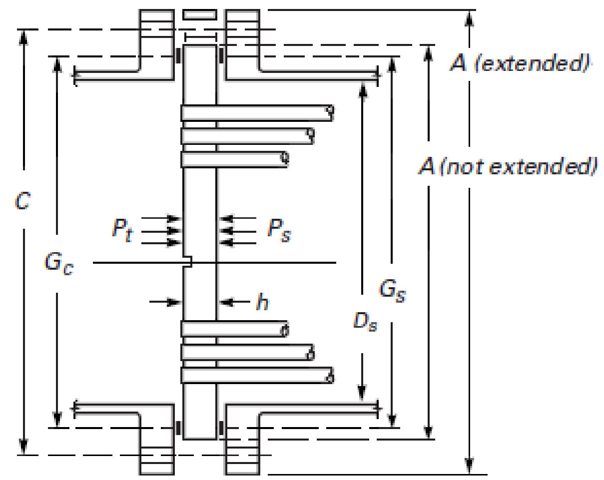
Dimension G for the Channel Side	Gc	1250.063	mm.
Area of the Untubed Lanes	AL	255.9	cm^2
Junction Stress Reduction option		Increase Tubesheet thickness	
Perform Differential Pressure Design		NO	
Run Multiple Load Cases		YES	
Channel Side Min. Design Pressure	Ptd,min	1.0342	bars

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.
Gasket Outside Diameter	Go	1266.000	mm.
Gasket Inside Diameter	Gi	1226.000	mm.

Small end Hub thk.	g0	20.0000	mm.
Large end Hub thk.	g1	23.0000	mm.
Gasket Factor,	m	3.00	
Gasket Design Seating Stress	y	68.95	N./mm^2
Flange Facing Sketch	Code Sketch 1a		
Column for Gasket Seating	Code Column II		

Tubesheet Gasketed With Shell and Channel



Configuration d:

Gasket Thickness tg 3.0000 mm.
Full face Gasket Flange Option Program Selects

Bolting Information:

Diameter of Bolt Circle	C	1310.000	mm.
Nominal Bolt Diameter	dB	22.2250	mm.
Type of Thread Series	TEMA Thread Series		
Number of Bolts	n	72	
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
Weld between Flange and Shell/Channel		0.0000	mm.
Alternate Flange Operating Bolt Load, Wm1		3266.36	kN
Alternate Flange Seating Bolt Load, Wm2		2157.58	kN
Alternate Flange Design Bolt Load, W		3310.52	kN
Tubesheet Integral with		None	
Tubesheet Extended as Flange		Yes	
Thickness of Extended Portion of Tubesheet	Tf	118.0000	mm.
Is Bolt Load Transferred to the Tubesheet		Yes	

ASME TubeSheet Results per Part UHX, 2017

Elasticity/Expansion Material Properties :

Shell - 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.

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) 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 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
   2.7700     19.05   4641.89      6.88   50.0000  0.0232575        122.73
 EMAWP = (2.167/(D/T)-0.0833)*B = 284.4698 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 *70.9667 )/( 3 *39.3659 ) = 24.0352 bars
```

Summary of Tube Required Thickness Results:

```
 Total Required Thickness including Corrosion all.          0.4839  mm.
 Allowable Internal Pressure at Corroded thickness          388.00  bars
 Required Internal Design Pressure                           23.00  bars
 Allowable External Pressure at Corroded thickness          284.47  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.
```

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

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

```
  = 2 * 22.225 + 6 * 118.0/(3.0 + 0.5)
  = 246.736 mm.
```

Actual Circumferential Bolt Spacing [Bs]:

```
  = C * sin( pi / n )
  = 1310.0 * 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 )
  = max( sqrt( 57.141/( 2 * 22.225 + 118.0 )), 1 )
  = 1.0000
```

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^2                          188.817    194.632
 ---------------------------------------------------------------------

 Flange Design Bolt Load, Seating Condition    W  :     3310.52  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 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 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 (Configurations d, e, f)
  = 1250.0685/1182.83 = 1.0568
```

Compute the Ratio [Rhoc]:

```
  = Gc / Do (Configurations d)
  = 1250.0626/1182.83 = 1.0568
```

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:

```
  = Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
  = 1182.83²/16 * [ (1.057 - 1) * (1.057² + 1) * 23.0 -
    (1.057 - 1) * (1.057² + 1) * 23.0 ]
  = 22.5152 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 ( must be 0 <= rho <= 1 )
```

Compute the Effective Tube Hole Diameter [d*]:

```
= max( dt - 2tt*( Et/E )( St/S )( rho ), dt - 2tt)
= max( 19.05 -2*2.77 *(.19660E+09/.19522E+09)*
     ( 117/137 )*(0.0 ), 19.05 -2*2.77 )
= 19.0500 mm.
```

Compute the Effective Tube Pitch [p*]:

```
= p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
= 24.0/sqrt( 1 - 4 * min( 255.94 *100.0, 4*1182.83 *24.0 )
   (3.141* 1182.83²) )
= 24.2845 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. 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 + 3266.4 * (1250.063 - 1250.063 )/(2 * pi * 1182.83 )
= 22.5152 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*) - Do²/32 * F * (Ps - Pt) ) / (1 + F)
= ((22.52 ) - 1182.83²/32 * 0.369 * (23.0 - 23.0 ) )/(1 + 0.37 )
= 16.4477 bars*mm.²
```

Maximum Bending Moment acting on Center of Tubesheet [Mo]:

```
= Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
= 16.45 + 1182.83²/64 * (3 + 0.336 )(23.0 - 23.0 )
= 16.4477 bars*mm.²
```

Maximum Bending Moment acting on Tubesheet [M]:

```
= Max( abs(Mp), abs(Mo) )
= Max( abs(16.448 ), abs(16.448 ) )
= 16.4477 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 N./mm^2
```

The Allowable Tubesheet Bending Stress [SigmaAll]:
```
  = 2 * S = 2 * 137.9 = 275.8 N./mm^2
```

Tubesheet Bending Stress at Final Thickness [Sigma]:
```
  = 6 * M / ( (mu*) * ( h - hg')²
  = 6 * 16.473/( ( 0.2155 ) * ( 0.508 - 5.0 )²
  = 2.2726 N./mm^2
```

Required Tubesheet Thickness, for Bending Stress [HreqB]:
```
  = H + CATS + CATC = 0.508 + 0.0 + 0.0 = 0.508 mm.
```

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
```
  = Max( HreqB, HreqS ) = Max( 0.508, 0.0 ) = 0.508 mm.
```

UHX-12.5.9 Step 9:

```
  abs(Ps - Pt) = abs(23.0 - 23.0 ) = 0.0 bars
```

Shear Stress check [Tau_limit]:
```
  = 3.2 * S * MU * h / Do
  = 3.2 * 137.9 * 0.206 * 140.0/1182.83 = 107.72 bars
```

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
```
  = 1/(4* Mu) * (Do/h) * [Ps - Pt]
  = 1/(4*0.206)*(1182.83/140.0)*[23.0-23.0]N./mm^2
  = 0.00 N./mm^2
```

Note: Analysis Completed for Tubesheet Configuration d.

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
```
  = 3.1415 * t * ( do - t ) * Sa
  = 3.1415 * 2.77 * ( 19.05 - 2.77 ) * 117.9 = 16.702 kN
```

Fillet Weld Strength [Ff]:
```
  = 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
  = 0.55 * 3.1415 * 2.0 * (19.05 + 0.67*2.0 ) * 117.9
  = 8.3072  kN
```

Groove Weld Strength [Fg]:
```
  = 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
  = 0.85 * 3.1415 * 2.0 * (19.05 + 0.67*2.0 ) * 117.9
  = 12.8384  kN
```

```
 Max. Allow. Tube-Tubesheet Joint load, Lmax
  = Ft = 16.7023 kN
```

Design Strength Ratio [fd]:
```
  = 1.0000
```

Weld Strength Factor [fw]:
```
  = Sot / ( Min(Sot, S) ) = 1.0000
```

Min Weld Length [ar]:
```
  = 2 *( ( (0.75 * do)² + 1.07*t*(do - t)* fw * fd ) )½ - 0.75 * do)
```

= 3.1983 mm.

Minimum Required Fillet Weld Leg	afr	1.5991	mm.
Minimum Required Groove Weld Leg	agr	1.5991	mm.

Tube-Tubesheet Jt allowable, 16.7 is >= tube strength 16.7 kN
Note: This tube-tubesheet joint is a Full Strength joint

Stress/Force summary for loadcase D3 un-corr. (Psd,max + Ptd,max):

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	0.0	<=	275.8 N./mm^2	Ok
Tubesheet shear stress	0.0	<=	110.3 N./mm^2	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 :	1.599	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.599	2.000	Ok

U-Tube Tubesheet results per ASME UHX-12 2017

Results for 8 Load Cases:

Case#	--Reqd. Thk. + CA Tbsht	Extnsn	---- Tubesheet Stresses Bend	Allwd	Shear	Allwd	Case Type	Pass/ Fail
D1uc	131.418	33.068	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	33.068	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	33.068 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 :	33.068	118.000	Ok
Tube Thickness :	0.484	2.770	Ok
Tube-Tubesheet Fillet Weld Leg :	1.599	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.599	2.000	Ok

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	387.995	1.000	284.469	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	387.995	1.000	284.469	1.000
Tubesheet Extension Stress	23.707	...	No Calc	No Calc
Minimum MAPnc	23.707		26.233	

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

MDMT Summary: Step: 35 1:34am Feb 7,2022

Minimum Design Metal Temperature Results Summary :

Description	Notes	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		0.997	20.000	1.00	No
SHELL 002	[8]	!	-45			0.614	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		0.977	15.000	1.00	No
HEAD 001	[10]	!	-45			0.840	15.000	1.00	No
HEAD 001	[7]	!	-45			0.682	18.000	1.00	No
SHELL 001	[8]	!	-45			0.853	15.000	1.00	No
CON	[8]	!	-45			0.947	20.000	1.00	No
SHELL 002	[8]	!	-45			0.940	18.000	1.00	No
HEAD 002	[10]	!	-45			0.994	17.000	1.00	No
HEAD 002	[7]	!	-45			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	0.850	15.000	1.00	No
Nozzle Flg	[4]	D	-29	-104					
D2	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-48					
S2	[1]	D	-43	-46	-29	0.936	18.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
S1	[1]	D	-43	-46	-29	0.936	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					
D1	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-48					
D3	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-48					
TT	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-48					
V	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-48					
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	-48					
LG2	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-48					
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		0.936	18.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
LT4	[1]	!	-46	-46		0.936	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	-46					

Exchanger Side	Computed MDMT °C	Required MDMT °C	Pass/Fail

Shell	-45	-45	Pass
Channel/Tube	-45	-45	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)

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.

ASME Code, Section VIII Division 1, 2017

```
Diameter Spec : 1200.000 x 1656.000 mm. ID
Vessel Design Length, Tangent to Tangent          6585.52  mm.

Specified Datum Line Distance                       50.00  mm.

Shell Material                                      SA-516 70 [Impact Tested]
Nozzle Material                                    SA-350 LF2 [Impact Tested]
Nozzle Material                                      SA-333 6 [Impact Tested]
Re-Pad Material                                     SA-516 70 [Normalized]

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
```

Element Pressures and MAWP (bars):

Element Description	Design Pres. + Stat. head	External Pressure	M.A.W.P	Corrosion Allowance	Str. Flange Governing
HEAD 001	23.083	1.034	27.484	3.0000	No
SHELL 001	23.083	1.034	27.034	3.0000	N/A
BODY FLANGE 001	23.083	1.034	23.624	3.0000	N/A
body flange 02	23.068	1.034	23.639	3.0000	N/A
SHELL 002	23.069	1.034	38.160	3.0000	N/A
CON	23.069	1.034	24.379	3.0000	N/A
SHELL 002	23.069	1.034	24.555	3.0000	N/A
HEAD 002	23.069	1.034	23.235	3.0000	No

Liquid Level: 1200.00 mm. Dens.: 0.001 kg./cm^3 Sp. Gr.: 0.581

Element Types and Properties:

Element Type	"To" Elev mm.	Length mm.	Element Thk mm.	Reqd Int.	Thk Ext.	Joint Eff Long	Joint Eff Circ
Ellipse	0.0	50.0	18.0	13.0	6.2	1.00	1.00
Cylinder	990.0	990.0	15.0	13.2	6.8	1.00	1.00
Body Flg	1145.0	155.0	110.0	107.7	79.3	1.00	1.00
Body Flg	1455.5	155.0	110.0	94.6	58.5	1.00	1.00
Cylinder	1655.5	200.0	20.0	13.2	10.2	1.00	1.00
Conical	2485.5	830.0	20.0	19.0	11.7	1.00	1.00
Cylinder	6485.5	4000.0	18.0	17.0	11.7	1.00	1.00
Ellipse	6535.5	50.0	20.0	16.9	7.4	1.00	1.00

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

Saddle Parameters:

```
Saddle Width                                         172.000  mm.
Saddle Bearing Angle                                 120.000  deg.
Centerline Dimension                                1374.000  mm.
Wear Pad Width                                       350.000  mm.
```

Vessel Design Summary: Step: 36 1:34am Feb 7,2022

Wear Pad Thickness	25.000	mm.
Wear Pad Bearing Angle	140.000	deg.
Distance from Saddle to Tangent	352.000	mm.

Baseplate Length	1450.000	mm.
Baseplate Thickness	25.000	mm.
Baseplate Width	220.000	mm.
Number of Ribs (including outside ribs)	5	
Rib Thickness	30.000	mm.
Web Thickness	30.000	mm.
Height of Center Web	720.000	mm.
Number of Bolts in Baseplate	4	

Baseplate Sketch

```
|------------------ 1450.000 mm. ------------------|
------------------------------------------------------ ---
|                                                 |
|                                                 | 220.000 mm.
|                                                 |
------------------------------------------------------ ---
```

Baseplate Plan View

```
------------------------------------------------------ ---
|                                                 | 25.000 mm.
------------------------------------------------------ ---
```

Baseplate Side View

Maximum Tensile Bolt Load	28.	kN

Summary of Maximum Saddle Loads, Operating Case :

Maximum Vertical Saddle Load	515.32	kN
Maximum Transverse Saddle Shear Load	91.54	kN
Maximum Longitudinal Saddle Shear Load	183.07	kN

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	188.25	kN
Maximum Transverse Saddle Shear Load	1.28	kN
Maximum Longitudinal Saddle Shear Load	0.99	kN

Weights:

Fabricated - Bare W/O Removable Internals	21983.0	kg.
Shop Test - Fabricated + Water (Full)	35804.5	kg.
Shipping - Fab. + Rem. Intls.+ Shipping App.	22466.0	kg.
Erected - Fab. + Rem. Intls.+ Insul. (etc)	22466.0	kg.
Empty - Fab. + Intls. + Details + Wghts.	22466.0	kg.
Operating - Empty + Operating Liquid (No CA)	29508.8	kg.
Field Test - Empty Weight + Water (Full)	35373.8	kg.

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601
Vessel Design Summary:                Step:   36   1:10am   Feb 7,2022
```

Tabular Results

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Wed Feb 07 01:05:45 2018.

```
Model Notes
Model Notes

  Input Echo:

  Model Type                   : Cylindrical Shell

  Parent Geometry
         Parent Outside Diam.   :    1230.000 mm.
         Thickness              :      12.000 mm.

  Parent Properties:
         Cold Allowable         :       174.4 MPa
         Hot  Allowable         :       156.5 MPa
         Material DB # 7005218.
         Ultimate Tensile (Amb) :       482.6 MPa
         Yield Strength (Amb)   :       262.0 MPa
         Yield Strength (Hot)   :       235.1 MPa
         Elastic Modulus (Amb)  :    202720.0 MPa
         Poissons Ratio         :       0.300
         Expansion Coefficient  :  0.1227E-04 mm./mm./deg.
         Weight Density         :  0.0000E+00  N /cu.mm.(NOT USED)

  Nozzle Geometry
         Nozzle Outside Diam.   :     508.000 mm.
         Thickness              :      17.000 mm.
         Length                 :     200.000 mm.
```

```
        RePad Width           :     120.000 mm.
        RePad Thickness       :      20.000 mm.
        Nozzle Tilt Angle     :       0.000 deg.
        Distance from Top     :     495.000 mm.
        Distance from Bottom  :     495.000 mm.

    Nozzle Properties
        Cold Allowable        :       174.4 MPa
        Hot  Allowable        :       156.5 MPa
        Material DB # 7005218.
        Ultimate Tensile (Amb) :      482.6 MPa
        Yield Strength (Amb)  :       262.0 MPa
        Yield Strength (Hot)  :       235.1 MPa
        Elastic Modulus (Amb) :    202720.0 MPa
        Poissons Ratio        :       0.300
        Expansion Coefficient  :  0.1227E-04 mm./mm./deg.
        Weight Density        :  0.0000E+00  N /cu.mm. (NOT USED)

    Design Operating Cycles       :       7000.
    Ambient Temperature (Deg.)    :       21.10
```

Uniform thermal expansion produces no stress in this geometry.
Any thermal loads will come through operating forces and
moments applied through the nozzle.

```
    Nozzle Inside  Temperature    :      125.00 deg.
    Nozzle Outside Temperature    :      125.00 deg.
    Vessel Inside  Temperature    :      125.00 deg.
    Vessel Outside Temperature    :      125.00 deg.

    Nozzle Pressure               :       2.300 MPa
    Vessel Pressure               :       2.300 MPa

    Operating Pressure            :         2.3 MPa
```

The operating pressure is used for secondary and peak stress
cases. The design pressure is used for primary cases. The ratio
of the operating/design pressure = 1.000

User Defined Load Input Echo:
Loads are given at the End of Nozzle
Loads are defined in Global Coordinates

Forces(N) Moments (N-m)

Load Case	FX	FY	FZ	MX	MY	MZ
WEIGHT:	20000.0	20000.0	20000.0	52500.0	42500.0	42500.0
OPER:	20000.0	20000.0	20000.0	52500.0	42500.0	42500.0
OCC:	20000.0	20000.0	20000.0	52500.0	42500.0	42500.0

FEA Model Loads:
These are the actual loads applied to the FEA model.
These are the User Defined Loads translated to the
end of the nozzle and reported in global coordinates.

Forces(N) Moments (N-m)

Load Case	FX	FY	FZ	MX	MY	MZ
WEIGHT:	20000.0	20000.0	20000.0	52500.0	42500.0	42500.0
OPER:	20000.0	20000.0	20000.0	52500.0	42500.0	42500.0
OCC:	20000.0	20000.0	20000.0	52500.0	42500.0	42500.0

The "top" or "positive" end of this model is "free" in
the axial and translational directions.

Stresses ARE nodally AVERAGED.

No weld dimensions have been given for the nozzle
connection to the shell. This will produce conservative
results for external loads and may tend to produce more
realistic inside surface pressure stresses.

```
No pad weld dimensions have been given for the pad
connection to the shell. Few correlations have been
performed to investigate the sensitivity of peak stresses
to this value. Reasonable lengths have been assumed.

Vessel Centerline  Vector     :  0.000    1.000    0.000
Nozzle Orientation Vector     :  1.000    0.000    0.000
```

Table of Contents

```
Load Case Report
FE/Pipe Version 10.0          Jobname: NOZZLE                 $P
Released Nov 2017             1:05am   FEB  7,2018



Load Case Report                                   $X

Inner and outer element temperatures are the same
throughout the model.  No thermal ratcheting
calculations will be performed.

THE  10  LOAD CASES ANALYZED ARE:

  1   WEIGHT ONLY    (Wgt Only)

      Weight ONLY case run to get the stress range
      between the installed and the operating states.

      /-------- Loads in Case   1
        Loads due to Weight

  2   SUSTAINED      (Wgt+Pr)

      Sustained case run to satisfy local primary
      membrane and bending stress limits.

      /-------- Loads in Case   2
        Loads due to Weight
        Pressure Case    1

  3   OPERATING

      Case run to compute the operating stresses used in
      secondary, peak and range calculations as needed.

      /-------- Loads in Case   3
        Pressure Case    1
        Loads from (Operating)

  4   RANGE          (Fatigue Calc Performed)

      Case run to get the RANGE of stresses.
      as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

      /-------- Combinations in Range Case   4
        Plus  Stress Results from CASE   3
        Minus Stress Results from CASE   1

  5   OCCASIONAL

      Occasional load case established per the
      requirements of the Code.

      /-------- Loads in Case   5
        Loads due to Weight
        Pressure Case    1
        Loads from (Occasional)
```

```
   6   Program Generated -- Force Only

       Case run to compute sif's and flexibilities.
       /-------- Loads in Case   6
         Loads from (Axial)

   7   Program Generated -- Force Only

       Case run to compute sif's and flexibilities.
       /-------- Loads in Case   7
         Loads from (Inplane)

   8   Program Generated -- Force Only

       Case run to compute sif's and flexibilities.
       /-------- Loads in Case   8
         Loads from (Outplane)

   9   Program Generated -- Force Only

       Case run to compute sif's and flexibilities.
       /-------- Loads in Case   9
         Loads from (Torsion)

  10   Program Generated -- Force Only

       Case run to compute sif's and flexibilities.
       /-------- Loads in Case  10
         Pressure Case    1
```

Table of Contents

```
Solution Data
FE/Pipe Version 10.0          Jobname: NOZZLE               $P
Released Nov 2017             1:05am   FEB  7,2018
```

Solution Data

```
Maximum Solution Row Size =     594
Number of Nodes           =    1968
Number of Elements        =     648
Number of Solution Cases  =       9
```

Summation of Loads per Case

Case #	FX	FY	FZ
1	20000.	20002.	19999.
2	-9632.	2699605.	19999.
3	-9632.	2699605.	19999.
4	10368.	2719607.	39998.
5	3616029.	0.	0.
6	0.	20.	0.
7	0.	0.	-12.
8	0.	0.	0.
9	-29632.	2679603.	0.

Table of Contents

```
ASME Code Stress Output Plots
FE/Pipe Version 10.0          Jobname: NOZZLE               $P
Released Nov 2017             1:05am   FEB  7,2018
```

ASME Code Stress Output Plots $X

1) Pl < SPL (SUS,Membrane) Case 2
2) Qb < SPS (SUS,Bending) Case 2
3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
8) Membrane < User (OPE,Membrane) Case 3
9) Bending < User (OPE,Bending) Case 3
10) S1+S2+S3 < 4S (OPE,S1+S2+S3) Case 3
11) Pl+Pb+Q+F < Sa (SIF,Outside) Case 6
12) Pl+Pb+Q+F < Sa (SIF,Outside) Case 7
13) Pl+Pb+Q+F < Sa (SIF,Outside) Case 8
14) Pl+Pb+Q+F < Sa (SIF,Outside) Case 9
15) Pl+Pb+Q+F < Sa (SIF,Outside) Case 10
16) Pl < SPL (OCC,Membrane) Case 5
17) Qb < 3(Smh) (OCC,Bending) Case 5
18) Pl+Pb+Q < SPS (OCC,Inside) Case 5
19) Pl+Pb+Q < SPS (OCC,Outside) Case 5
20) Pl+Pb+Q < SPS (EXP,Inside) Case 4
21) Pl+Pb+Q < SPS (EXP,Outside) Case 4
22) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4
23) Pl+Pb+Q+F < Sa (EXP,Outside) Case 4

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Stress Results - Notes
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Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.

- Using 2013-2015 ASME Section VIII Division 2

- Use Polished Bar fatigue curve.

- Ratio between Operating and Design Pressure = 1.000000
  Assume pressure increases all other stresses.

- Assume free end displacements of attached pipe
  (e.g. thermal loads) are secondary within the limits
  of nozzle reinforcement.

- Use Equivalent Stress (Von Mises).

- Include S1+S2+S3 evaluation for operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Assume bending stress not local primary for S1+S2+S3.

- Use local tensor values for averaged and not
  averaged stresses.

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```
ASME Overstressed Areas
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ASME Overstressed Areas                                 $X


             *** NO OVERSTRESSED NODES IN THIS MODEL ***
```

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```
Highest Primary Stress Ratios
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Highest Primary Stress Ratios                           $X


Pad/Header at Junction

       Pl            SPL     Primary Membrane Load Case 2
      153            235     Plot Reference:
      MPa            MPa     1) Pl < SPL (SUS,Membrane) Case 2

            64%


Branch at Junction

       Pl            SPL     Primary Membrane Load Case 2
      160            235     Plot Reference:
      MPa            MPa     1) Pl < SPL (SUS,Membrane) Case 2

            68%


Branch Transition

       Pl            SPL     Primary Membrane Load Case 2
```

```
      66           235     Plot Reference:
     MPa           MPa     1) Pl < SPL (SUS,Membrane) Case 2

          28%


  Pad Outer Edge Weld

    Pl+Pb+Q        SPS     Primary+Secondary (Outer) Load Case 2
     393           497     Plot Reference:
     MPa           MPa     4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

          78%


  Header Outside Pad Area

      Pl           SPL     Primary Membrane Load Case 2
     129           235     Plot Reference:
     MPa           MPa     1) Pl < SPL (SUS,Membrane) Case 2

          54%
```

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```
  Highest Secondary Stress Ratios
  FE/Pipe Version 10.0         Jobname: NOZZLE              $P
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  Highest Secondary Stress Ratios                      $X


  Pad/Header at Junction

    Pl+Pb+Q        SPS     Primary+Secondary (Outer) Load Case 5
     218           497     Plot Reference:
     MPa           MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

          43%


  Branch at Junction

    Pl+Pb+Q        SPS     Primary+Secondary (Outer) Load Case 5
     400           497     Plot Reference:
     MPa           MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

          80%


  Branch Transition

    Pl+Pb+Q        SPS     Primary+Secondary (Inner) Load Case 5
     121           497     Plot Reference:
     MPa           MPa     18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

          24%


  Pad Outer Edge Weld

    Pl+Pb+Q        SPS     Primary+Secondary (Outer) Load Case 5
     476           497     Plot Reference:
     MPa           MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

          95%
```

```
 Header Outside Pad Area

   Pl+Pb+Q          SPS     Primary+Secondary (Inner) Load Case 5
       181          497     Plot Reference:
       MPa          MPa     18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

           36%
```

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```
 Highest Fatigue Stress Ratios
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 Highest Fatigue Stress Ratios                            $X


 Pad/Header at Junction

 Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
        97     0.019 Life     Stress Concentration Factor = 1.350
       MPa     0.336 Stress   Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 371,369.
 Allowable                    "B31" Fatigue Stress Allowable = 413.6
     289.9                    Markl Fatigue Stress Allowable = 287.5
       MPa                    WRC 474 Mean Cycles to Failure = 836,769.
                              WRC 474 99% Probability Cycles = 194,389.
       33%                    WRC 474 95% Probability Cycles = 269,885.
                              BS5500 Allowed Cycles(Curve F) = 173,074.
                              Membrane-to-Bending Ratio = 3.861
                              Bending-to-PL+PB+Q Ratio = 0.206
                              Plot Reference:
                              22) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4


 Branch at Junction

 Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
        96     0.017 Life     Stress Concentration Factor = 1.350
       MPa     0.331 Stress   Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 401,575.
 Allowable                    "B31" Fatigue Stress Allowable = 413.6
     289.9                    Markl Fatigue Stress Allowable = 287.5
       MPa                    WRC 474 Mean Cycles to Failure = 1,409,810.
                              WRC 474 99% Probability Cycles = 327,512.
       33%                    WRC 474 95% Probability Cycles = 454,709.
                              BS5500 Allowed Cycles(Curve F) = 241,319.
                              Membrane-to-Bending Ratio = 1.861
                              Bending-to-PL+PB+Q Ratio = 0.350
                              Plot Reference:
                              22) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4


 Branch Transition

 Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
        47     0.000 Life     Stress Concentration Factor = 1.000
       MPa     0.164 Stress   Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 9.7250E10
 Allowable                    "B31" Fatigue Stress Allowable = 413.6
     289.9                    Markl Fatigue Stress Allowable = 287.5
       MPa                    WRC 474 Mean Cycles to Failure = 5,483,744.
                              WRC 474 99% Probability Cycles = 1,273,924.
       16%                    WRC 474 95% Probability Cycles = 1,768,682.
                              BS5500 Allowed Cycles(Curve F) = 808,979.
                              Membrane-to-Bending Ratio = 0.275
```

Bending-to-PL+PB+Q Ratio = 0.785
Plot Reference:
23) Pl+Pb+Q+F < Sa (EXP,Outside) Case 4

Pad Outer Edge Weld

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 4
198	0.294 Life	Stress Concentration Factor = 1.350
MPa	0.683 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 23,811.
Allowable		"B31" Fatigue Stress Allowable = 413.6
289.9		Markl Fatigue Stress Allowable = 287.5
MPa		WRC 474 Mean Cycles to Failure = 195,969.
		WRC 474 99% Probability Cycles = 45,525.
68%		WRC 474 95% Probability Cycles = 63,206.
		BS5500 Allowed Cycles(Curve F) = 27,296.
		Membrane-to-Bending Ratio = 0.515
		Bending-to-PL+PB+Q Ratio = 0.660
		Plot Reference:
		23) Pl+Pb+Q+F < Sa (EXP,Outside) Case 4

Header Outside Pad Area

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 4
75	0.001 Life	Stress Concentration Factor = 1.000
MPa	0.258 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 10,560,117.
Allowable		"B31" Fatigue Stress Allowable = 413.6
289.9		Markl Fatigue Stress Allowable = 287.5
MPa		WRC 474 Mean Cycles to Failure = 1,502,322.
		WRC 474 99% Probability Cycles = 349,003.
25%		WRC 474 95% Probability Cycles = 484,547.
		BS5500 Allowed Cycles(Curve F) = 205,556.
		Membrane-to-Bending Ratio = 1.650
		Bending-to-PL+PB+Q Ratio = 0.377
		Plot Reference:
		22) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4

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Highest Occasional Stress Ratios
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Highest Occasional Stress Ratios $X

Pad/Header at Junction

Pl	SPL	Primary Membrane Load Case 5
169	235	Plot Reference:
MPa	MPa	16) Pl < SPL (OCC,Membrane) Case 5
71%		
Qb	3(Smh)	Primary Bending Load Case 5
128	497	Plot Reference:
MPa	MPa	17) Qb < 3(Smh) (OCC,Bending) Case 5
25%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 5
192	497	Plot Reference:
MPa	MPa	18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

```
          38%

   Pl+Pb+Q          SPS     Primary+Secondary (Outer) Load Case 5
       218          497     Plot Reference:
       MPa          MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

          43%


 Branch at Junction

        Pl          SPL     Primary Membrane Load Case 5
       199          235     Plot Reference:
       MPa          MPa     16) Pl < SPL (OCC,Membrane) Case 5

          84%

        Qb       3(Smh)     Primary Bending Load Case 5
       367          497     Plot Reference:
       MPa          MPa     17) Qb < 3(Smh) (OCC,Bending) Case 5

          73%

   Pl+Pb+Q          SPS     Primary+Secondary (Inner) Load Case 5
       377          497     Plot Reference:
       MPa          MPa     18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

          75%

   Pl+Pb+Q          SPS     Primary+Secondary (Outer) Load Case 5
       400          497     Plot Reference:
       MPa          MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

          80%


 Branch Transition

        Pl          SPL     Primary Membrane Load Case 5
        84          235     Plot Reference:
       MPa          MPa     16) Pl < SPL (OCC,Membrane) Case 5

          35%

        Qb       3(Smh)     Primary Bending Load Case 5
        75          497     Plot Reference:
       MPa          MPa     17) Qb < 3(Smh) (OCC,Bending) Case 5

          15%

   Pl+Pb+Q          SPS     Primary+Secondary (Inner) Load Case 5
       121          497     Plot Reference:
       MPa          MPa     18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

          24%

   Pl+Pb+Q          SPS     Primary+Secondary (Outer) Load Case 5
       118          497     Plot Reference:
       MPa          MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

          23%


 Pad Outer Edge Weld

        Pl          SPL     Primary Membrane Load Case 5
       162          235     Plot Reference:
       MPa          MPa     16) Pl < SPL (OCC,Membrane) Case 5

          69%

        Qb       3(Smh)     Primary Bending Load Case 5
       356          497     Plot Reference:
       MPa          MPa     17) Qb < 3(Smh) (OCC,Bending) Case 5
```

```
          71%

   Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
       252           497     Plot Reference:
       MPa           MPa     18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

          50%

   Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
       476           497     Plot Reference:
       MPa           MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

          95%


 Header Outside Pad Area

        Pl           SPL     Primary Membrane Load Case 5
       144           235     Plot Reference:
       MPa           MPa     16) Pl < SPL (OCC,Membrane) Case 5

          61%

        Qb        3(Smh)     Primary Bending Load Case 5
       145           497     Plot Reference:
       MPa           MPa     17) Qb < 3(Smh) (OCC,Bending) Case 5

          29%

   Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
       181           497     Plot Reference:
       MPa           MPa     18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

          36%

   Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
       152           497     Plot Reference:
       MPa           MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

          30%
```

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```
 Stress Intensification Factors
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 Stress Intensification Factors                        $X


 Branch/Nozzle Sif Summary

                  Peak      Primary    Secondary      SSI
 Axial    :      7.327      5.588      10.855       2.240
 Inplane  :      3.994      2.959       5.918       2.247
 Outplane:       8.011      5.934      11.868       2.286
 Torsion :       0.800      1.051       1.186       1.267
 Pressure:       1.681      1.245       2.491       1.596

 The above stress intensification factors are to be used
 in a beam-type analysis of the piping system.  Inplane,
 Outplane and Torsional sif's should be used with the
 matching branch pipe whose diameter and thickness is given
 below.  The axial sif should be used to intensify the
 axial stress in the branch pipe calculated by F/A.  The
 pressure sif should be used to intensify the nominal
```

```
pressure stress in the PARENT or HEADER, calculated
from PDo/2T. B31 calculations use mean diameters and
Section VIII calculations use outside diameters. SSIs are
based on peak stress factors and correlated test results.

Pipe OD :      508.000  mm.
Pipe Thk:       17.000  mm.
Z approx:  3218855.250  cu.mm.
Z exact :  3114867.000  cu.mm.

  (SSI = SIF^x)        Axial   Inpl    Outpl   Tors    Pres
SIF/SSI Exponents:     0.864   0.783   0.856  -0.224   0.422

SIF/SSI exponent based on relationship between primary and
peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor =       11.933
      Header Pressure i-factor =        3.396

The B31.3 pressure i-factors should be used with with
F/A, where F is the axial force due to pressure, and
A is the area of the pipe wall. This is equivalent to
finding the pressure stress from (ip)(PD/4T).

B31.3   (Branch)
Peak Stress Sif ....    0.000         Axial
                        5.513         Inplane
                        6.879         Outplane
                        1.000         Torsional
B31.1  (Branch)
Peak Stress Sif ....    0.000         Axial
                        6.879         Inplane
                        6.879         Outplane
                        6.879         Torsional
WRC 330  (Branch)
Peak Stress Sif ....    0.000         Axial
                        4.855         Inplane
                        6.879         Outplane
                        4.855         Torsional
```

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```
Allowable Loads
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Allowable Loads                                    $X


SECONDARY                     Maximum      Conservative        Realistic
Load Type (Range):          Individual     Simultaneous       Simultaneous
                              Occuring       Occuring           Occuring
Axial Force        ( N      )   1037814.       175056.           262584.
Inplane   Moment (mm.   N )  226131072.      35770668.         75881040.
Outplane  Moment (mm.   N )  112755640.      13422793.         28474042.
Torsional Moment (mm.   N ) 1128424320.     119076232.        178614352.
Pressure         (MPa     )       3.37           2.30              2.30


PRIMARY                       Maximum      Conservative        Realistic
Load Type:                  Individual     Simultaneous       Simultaneous
                              Occuring       Occuring           Occuring
Axial Force        ( N      )   1103191.       155554.           233331.
Inplane   Moment (mm.   N )  247503200.      29003524.         61525764.
Outplane  Moment (mm.   N )  123412416.      14462014.         30678564.
Torsional Moment (mm.   N )  696742336.     110850176.        166275264.
Pressure         (MPa     )       3.68           2.30              2.30
```

```
NOTES:

1) Maximum Individual Occuring Loads are the maximum
   allowed values of the respective loads if all other
   load components are zero, i.e. the listed axial force
   may be applied if the inplane, outplane and torsional
   moments, and the pressure are zero.

2) The Conservative Allowable Simultaneous loads are
   the maximum loads that can be applied simultaneously.
   A conservative stress combination equation is used
   that typically produces stresses within 50-70% of the
   allowable stress.

3) The Realistic Allowable Simultaneous loads are the
   maximum loads that can be applied simultaneously.  A
   more realistic stress combination equation is used
   based on experience at Paulin Research.  Stresses are
   typically produced within 80-105% of the allowable.

4) Secondary allowable loads are limits for expansion
   and operating piping loads.

5) Primary allowable loads are limits for weight,
   primary and sustained type piping loads.
```

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```
Flexibilities
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Flexibilities                                          $X


  The following stiffnesses should be used in a piping,
  "beam-type" analysis of the intersection.  The stiff-
  nesses should be inserted at the surface of the
  branch/header or nozzle/vessel junction.  The general
  characteristics used for the branch pipe should be:

  Outside Diameter =  508.000  mm.
  Wall Thickness   =   17.000  mm.

  Axial Translational Stiffness    =       1143422.   N /mm.
  Inplane Rotational Stiffness     =    1253046784.  mm. N /deg
  Outplane Rotational Stiffness    =     478415680.  mm. N /deg
  Torsional Rotational Stiffness   =   10465922048.  mm. N /deg


  Intersection Flexibility Factors for Branch/Nozzle
:

  Find axial stiffness: K = 3EI/(kd)^3   N /mm.
  Find bending and torsional stiffnesses: K = EI/(kd)  mm. N per radian.
  The EI product is   0.16061E+15    N mm.^2
  The value of (d) to use is: 491.000  mm..
  The resulting bending stiffness is in units of force x length per radian.

  Axial Flexibility Factor     (k) =     1.527
  Inplane Flexibility Factor   (k) =     4.556
  Outplane Flexibility Factor  (k) =    11.933
  Torsional Flexibility Factor (k) =     0.545
```

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