NARGAN	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	PGPIC
	DOCUMENT TITLE: Mechanical Calculation for Economizer	POI: IFA
Contract No.: DPIC/98-12	DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0030	Rev. No.: D1

DOCUMENT TITLE:

Mechanical Calculation for Economizer

(E-PK6101-3)

PURCHASER'S COMMENT/APPROVAL STATUS		Purchaser: NARGAN
1	AP: Approved (Released for Manufacturing)	Requisition No.: DPIC98-12-001-000-ME-MR-4150-0001-D1
2	AN: Approved With Minor Comments (Fabrication may Proceed)	
3	NF: Approved With Comments (Fabrication not Proceed)	Item No. (Tag No.): (E-PK6101-3)
4	RJ: Rejected	
5	NR: Not be Returned	Vendor Doc. No.: DPIC9812-000-VD-1002-ME-CLN-0030-D1
Date:	Signature:	

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

KASRAVAND Engineering & Construction

	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	
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15	x	x			
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162	x	x			
163	x				
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DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3   ECONOMIZER

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 6,2022    11:20pm

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 11:20pm Feb 6,2022

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:E-PK6101-3 ECONOMIZER

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	33.0	
Using User defined Wind Press. Vs Elev.	N	
Height of Hill or Escarpment H or Hh	0	mm.

Input Echo: Step: 1 11:20pm Feb 6,2022

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		1.250	
Table Value Fa		1.000	
Table Value Fv		1.300	
Short Period Acceleration value Ss		0.900	
Long Period Acceleration Value Sl		0.537	
Moment Reduction Factor Tau		1.000	
Force Modification Factor R		3.000	
Site Class		B	
Component Elevation Ratio	z/h	0.000	
Amplification Factor	Ap	0.000	
Force Factor		0.000	
Consider Vertical Acceleration		Yes	
Minimum Acceleration Multiplier		0.000	
User Value of Sds (used if > 0)		0.390	
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

Complete Listing of Vessel Elements and Details:

Element From Node	10	
Element To Node	20	
Element Type	Elliptical	
Description	HEAD 1	
Distance "FROM" to "TO"	50	mm.
Inside Diameter	581	mm.
Element Thickness	10	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	12	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	125	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	125	°C
Effective Diameter Multiplier	1.2	

```
    Material Name                                   SA-516 70 [Normalized]
        Allowable Stress, Ambient                       137.9  N./mm^2
        Allowable Stress, Operating                     137.9  N./mm^2
        Allowable Stress, Hydrotest                    235.81  N./mm^2
        Material Density                              0.00775  kg./cm^3
        P Number Thickness                             30.988  mm.
        Yield Stress, Operating                        235.23  N./mm^2
        UCS-66 Chart Curve Designation                      D
        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                           581  mm.
        Liquid Density                              0.0005998  kg./cm^3

        Element From Node                                  10
        Detail Type                                Insulation
        Detail ID                                     Ins: 40
        Dist. from "FROM" Node / Offset dist          -145.25  mm.
        Height/Length of Insulation                    195.25  mm.
        Thickness of Insulation                            80  mm.
        Density                                       0.00024  kg./cm^3

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

    Element From Node                                      20
    Element To Node                                        30
    Element Type                                     Cylinder
    Description                                    CHANNEL 01
    Distance "FROM" to "TO"                               407  mm.
    Inside Diameter                                       581  mm.
    Element Thickness                                      10  mm.
    Internal Corrosion Allowance                            3  mm.
    Nominal Thickness                                      10  mm.
    External Corrosion Allowance                            0  mm.
    Design Internal Pressure                               23  bars
    Design Temperature Internal Pressure                  125  °C
    Design External Pressure                              1.1  bars
    Design Temperature External Pressure                  125  °C
    Effective Diameter Multiplier                         1.2
    Material Name                                   SA-516 70 [Normalized]
    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                           581  mm.
        Liquid Density                               0.000531  kg./cm^3

        Element From Node                                  20
        Detail Type                                Insulation
        Detail ID                                     Ins: 40
```

```
        Dist. from "FROM" Node / Offset dist                 0  mm.
        Height/Length of Insulation                        407  mm.
        Thickness of Insulation                             80  mm.
        Density                                        0.00024  kg./cm^3

        Element From Node                                   20
        Detail Type                                     Nozzle
        Detail ID                                           T4
        Dist. from "FROM" Node / Offset dist               203  mm.
        Nozzle Diameter                                   0.75  in.
        Nozzle Schedule                                   None
        Nozzle Class                                       300
        Layout Angle                                      90.0
        Blind Flange (Y/N)                                   N
        Weight of Nozzle ( Used if > 0 )               0.04826  kN
        Grade of Attached Flange                        GR 1.1
        Nozzle Matl                                SA-350 LF2 [Impact Tested]

        Element From Node                                   20
        Detail Type                                     Nozzle
        Detail ID                                           T1
        Dist. from "FROM" Node / Offset dist               203  mm.
        Nozzle Diameter                                      4  in.
        Nozzle Schedule                                    120
        Nozzle Class                                       300
        Layout Angle                                     270.0
        Blind Flange (Y/N)                                   N
        Weight of Nozzle ( Used if > 0 )                0.2988  kN
        Grade of Attached Flange                        GR 1.1
        Nozzle Matl                                  SA-333 6 [Impact Tested]

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

    Element From Node                                       30
    Element To Node                                         40
    Element Type                                      Flange
    Description                                 BODY FLANGE 01
    Distance "FROM" to "TO"                                 88  mm.
    Flange Inside Diameter                                 581  mm.
    Element Thickness                                       62  mm.
    Internal Corrosion Allowance                             3  mm.
    Nominal Thickness                                       79  mm.
    External Corrosion Allowance                             0  mm.
    Design Internal Pressure                                23  bars
    Design Temperature Internal Pressure                   125  °C
    Design External Pressure                               1.1  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                               581  mm.
        Liquid Density                                  0.0005998  kg./cm^3

        Element From Node                                      30
        Detail Type                                    Insulation
        Detail ID                                         Ins: 40
        Dist. from "FROM" Node / Offset dist                    0  mm.
        Height/Length of Insulation                            88  mm.
        Thickness of Insulation                                80  mm.
        Density                                           0.00024  kg./cm^3

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

    Element From Node                                          40
    Element To Node                                            50
    Element Type                                         Cylinder
    Description                                             SHELL
    Distance "FROM" to "TO"                                  5880  mm.
    Inside Diameter                                           581  mm.
    Element Thickness                                          10  mm.
    Internal Corrosion Allowance                                3  mm.
    Nominal Thickness                                          10  mm.
    External Corrosion Allowance                                0  mm.
    Design Internal Pressure                                   23  bars
    Design Temperature Internal Pressure                      125  °C
    Design External Pressure                                  1.1  bars
    Design Temperature External Pressure                      125  °C
    Effective Diameter Multiplier                             1.2
    Material Name                                      SA-516 70 [Normalized]
        Allowable Stress, Ambient                           137.9  N./mm^2
        Allowable Stress, Operating                         137.9  N./mm^2
        Allowable Stress, Hydrotest                        235.81  N./mm^2
        Material Density                                  0.00775  kg./cm^3
        P Number Thickness                                 30.988  mm.
        Yield Stress, Operating                            235.23  N./mm^2
        UCS-66 Chart Curve Designation                          D
        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                                      40
        Detail Type                                        Saddle
        Detail ID                                    Fixed Saddle
        Dist. from "FROM" Node / Offset dist                  940  mm.
        Width of Saddle                                       150  mm.
        Height of Saddle at Bottom                            600  mm.
        Saddle Contact Angle                                120.0
        Height of Composite Ring Stiffener                      0  mm.
        Width of Wear Plate                                   225  mm.
        Thickness of Wear Plate                                10  mm.
        Contact Angle, Wear Plate (degrees)                 132.0

        Element From Node                                      40
```

Detail Type	Saddle	
Detail ID	Sliding Saddle	
Dist. from "FROM" Node / Offset dist	4940	mm.
Width of Saddle	150	mm.
Height of Saddle at Bottom	600	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.
Width of Wear Plate	225	mm.
Thickness of Wear Plate	10	mm.
Contact Angle, Wear Plate (degrees)	132.0	

Element From Node	40	
Detail Type	Liquid	
Detail ID	4	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	581	mm.
Liquid Density	0.0005998	kg./cm^3

Element From Node	40	
Detail Type	Insulation	
Detail ID	Ins: 40	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	5880	mm.
Thickness of Insulation	80	mm.
Density	0.00024	kg./cm^3

Element From Node	40	
Detail Type	Nozzle	
Detail ID	S2	
Dist. from "FROM" Node / Offset dist	196	mm.
Nozzle Diameter	6	in.
Nozzle Schedule	80	
Nozzle Class	300	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.5568	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]

Element From Node	40	
Detail Type	Nozzle	
Detail ID	S1	
Dist. from "FROM" Node / Offset dist	5680	mm.
Nozzle Diameter	6	in.
Nozzle Schedule	80	
Nozzle Class	300	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.5568	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]

Element From Node	40	
Detail Type	Nozzle	
Detail ID	S3	
Dist. from "FROM" Node / Offset dist	146	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)	0.1175	kN
Grade of Attached Flange	GR 1.1	

```
        Nozzle Matl                                  SA-350 LF2 [Impact Tested]

        Element From Node                                    40
        Detail Type                                      Weight
        Detail ID                                 WEIGHT BAFFLE
        Dist. from "FROM" Node / Offset dist               2940  mm.
        Miscellaneous Weight                             1.4709  kN
        Offset from Element Centerline                        0  mm.

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

    Element From Node                                        50
    Element To Node                                          60
    Element Type                                         Flange
    Description                                 BODY FLANGE 002
    Distance "FROM" to "TO"                                  88  mm.
    Flange Inside Diameter                                  581  mm.
    Element Thickness                                        62  mm.
    Internal Corrosion Allowance                              3  mm.
    Nominal Thickness                                        79  mm.
    External Corrosion Allowance                              0  mm.
    Design Internal Pressure                                 23  bars
    Design Temperature Internal Pressure                    125  °C
    Design External Pressure                                1.1  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                                    50
        Detail Type                                      Liquid
        Detail ID                                             5
        Dist. from "FROM" Node / Offset dist                  0  mm.
        Height/Length of Liquid                             581  mm.
        Liquid Density                                0.0005998  kg./cm^3

        Element From Node                                    50
        Detail Type                                  Insulation
        Detail ID                                       Ins: 40
        Dist. from "FROM" Node / Offset dist                  0  mm.
        Height/Length of Insulation                          88  mm.
        Thickness of Insulation                              80  mm.
        Density                                         0.00024  kg./cm^3

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

    Element From Node                                        60
    Element To Node                                          70
```

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for ECONOMIZER E-PK6101-3
Input Echo: Step: 1 11:20pm Feb 6,2022

```
    Element Type                                          Cylinder
    Description                                        CHANNEL 002
    Distance "FROM" to "TO"                                    407  mm.
    Inside Diameter                                            581  mm.
    Element Thickness                                           10  mm.
    Internal Corrosion Allowance                                 3  mm.
    Nominal Thickness                                           10  mm.
    External Corrosion Allowance                                 0  mm.
    Design Internal Pressure                                    23  bars
    Design Temperature Internal Pressure                       125  °C
    Design External Pressure                                   1.1  bars
    Design Temperature External Pressure                       125  °C
    Effective Diameter Multiplier                              1.2
    Material Name                                      SA-516 70 [Normalized]
        Allowable Stress, Ambient                            137.9  N./mm^2
        Allowable Stress, Operating                          137.9  N./mm^2
        Allowable Stress, Hydrotest                         235.81  N./mm^2
        Material Density                                   0.00775  kg./cm^3
        P Number Thickness                                  30.988  mm.
        Yield Stress, Operating                             235.23  N./mm^2
        UCS-66 Chart Curve Designation                           D
        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                                       60
        Detail Type                                         Liquid
        Detail ID                                                5
        Dist. from "FROM" Node / Offset dist                     0  mm.
        Height/Length of Liquid                                581  mm.
        Liquid Density                                   0.0005998  kg./cm^3

        Element From Node                                       60
        Detail Type                                     Insulation
        Detail ID                                          Ins: 40
        Dist. from "FROM" Node / Offset dist                     0  mm.
        Height/Length of Insulation                            407  mm.
        Thickness of Insulation                                 80  mm.
        Density                                            0.00024  kg./cm^3

        Element From Node                                       60
        Detail Type                                         Nozzle
        Detail ID                                               T2
        Dist. from "FROM" Node / Offset dist                   200  mm.
        Nozzle Diameter                                          6  in.
        Nozzle Schedule                                         80
        Nozzle Class                                           300
        Layout Angle                                          90.0
        Blind Flange (Y/N)                                       N
        Weight of Nozzle ( Used if > 0 )                    0.5568  kN
        Grade of Attached Flange                            GR 1.1
        Nozzle Matl                                       SA-333 6 [Impact Tested]

        Element From Node                                       60
        Detail Type                                         Nozzle
        Detail ID                                               T3
        Dist. from "FROM" Node / Offset dist                   203  mm.
        Nozzle Diameter                                          1  in.
        Nozzle Schedule                                       None
        Nozzle Class                                           300
```

```
    Layout Angle                                   270.0
    Blind Flange (Y/N)                                 N
    Weight of Nozzle ( Used if > 0 )             0.05845  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                                 Elliptical
  Description                                   HEAD 002
  Distance "FROM" to "TO"                             50  mm.
  Inside Diameter                                    581  mm.
  Element Thickness                                   10  mm.
  Internal Corrosion Allowance                         3  mm.
  Nominal Thickness                                   12  mm.
  External Corrosion Allowance                         0  mm.
  Design Internal Pressure                            23  bars
  Design Temperature Internal Pressure               125  °C
  Design External Pressure                           1.1  bars
  Design Temperature External Pressure               125  °C
  Effective Diameter Multiplier                      1.2
  Material Name                               SA-516 70 [Normalized]
  Efficiency, Longitudinal Seam                      1.0
  Efficiency, Circumferential Seam                   1.0
  Elliptical Head Factor                             2.0
  Weld is pre-Heated                                  No

    Element From Node                                 70
    Detail Type                                   Liquid
    Detail ID                                          6
    Dist. from "FROM" Node / Offset dist               0  mm.
    Height/Length of Liquid                          581  mm.
    Liquid Density                             0.0005998  kg./cm^3

    Element From Node                                 70
    Detail Type                               Insulation
    Detail ID                                    Ins: 40
    Dist. from "FROM" Node / Offset dist               0  mm.
    Height/Length of Insulation                   195.25  mm.
    Thickness of Insulation                           80  mm.
    Density                                      0.00024  kg./cm^3
```

XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
HEAD 1		50	...	50	...
CHANNEL 01		457	...	407	...
BODY FLANGE 01		545	...	88	...
SHELL		6493.18	...	5880	...
BODY FLANGE 002		6587.35	...	88	...
CHANNEL 002		7056.35	...	407	...
HEAD 002		7106.35	...	50	...

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER
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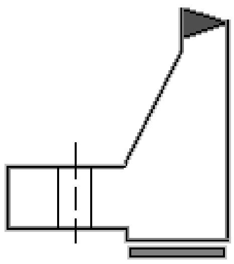
FileName : Calculation Book for ECONOMIZER E-PK6101-3
Flg Calc [Int P]: FLANGE Flng: 3 11:20pm Feb 6,2022

Flange Input Data Values **Description: FLANGE :**

BODY FLANGE 01

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	23.03	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	581.000	mm.
Flange Outside Diameter	A	715.000	mm.
Flange Thickness	t	62.0000	mm.
Thickness of Hub at Small End	go	10.0000	mm.
Thickness of Hub at Large End	g1	17.0000	mm.
Length of Hub	h	26.0000	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	673.000	mm.
Nominal Bolt Diameter	a	19.0500	mm.
Type of Threads		UNC Thread Series	
Number of Bolts		32	
Flange Face Outside Diameter	Fod	647.000	mm.
Flange Face Inside Diameter	Fid	581.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	641.000	mm.
Gasket Inside Diameter	Gi	611.000	mm.
Gasket Factor	m	3.7800	
Gasket Design Seating Stress	y	62.05	N./mm^2
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.0000	mm.
Length of Partition Gasket	lp	559.0000	mm.
Width of Partition Gasket	tp	6.4000	mm.
Partition Gasket Factor	mPart	3.7500	
Partition Gasket Design Seating Stress	yPart	62.05	N./mm^2



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)
  = (23.03*(581.0/2+3.0))/(137.9*1.0-0.6*23.03)+Ca
  = 7.9524 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 7.0)/(293.5 + 0.6 * 7.0 )
  = 32.423 bars
```

```
 Corroded Flange Thickness, tc = T-ci                      59.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor                 587.000  mm.
 Corroded Large Hub,     g1Cor = g1-ci                     14.000  mm.
 Corroded Small Hub,     g0Cor = go-ci                      7.000  mm.
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor        29.000  mm.

 Gasket Contact Width,       N = (Go - Gi) / 2             15.000  mm.
 Basic Gasket Width,        bo = N / 2                      7.500  mm.
 Effective Gasket Width,     b = Cb sqrt(bo)                6.901  mm.
 Gasket Reaction Diameter,   G = Go - 2 * b               627.198  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.785 * 627.1979² * 23.034
  = 711.639 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 6.9011 * 3.1416 * 627.1979 * 3.78 * 23.03
    + 2.0 * 559.0 * 3.2 * 3.75 * 23.0342
  = 267.687 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.1416 * 587.0² *23.0342/4
  = 623.343 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 712 - 623
  = 88.296 kN
```
Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 712 + 268 + 0, 0 )
  = 979.326 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 62.05*6.9011*3.141*627.198+62.05*3.2*559.0
  = 954.707 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 979/172, 955/172
  = 56.819 cm^2
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 19.05 + 6 * 59.0/(3.78 + 0.5)
  = 120.810 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 673.0 * sin( 3.142/32 )
```

```
  = 65.966 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 65.966/( 2 * 19.05 + 59.0 )), 1 )
  = 1.0000
```

Bolting Information for UNC Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm^2	56.819	62.348	
Radial Distance between Hub and Bolts:	28.575	29.000	
Radial Distance between Bolts and the Ed	20.637	21.000	
Circumferential Spacing between the Bolt	44.450	65.966	120.810

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 62.348 * 172.38/(62.05 * 3.14 * (641.0 + 611.0) )
  = 4.403 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa * ( Am + Ab ) / 2
  = 172.38 * ( 56.8185 + 62.3483 )/2
  = 1026.98 kN
```
Gasket Load for the Operating Condition [HG]:
```
  = Wm1 - H
  = 979 - 712
  = 267.69 kN
```

Moment Arm Calculations:
Distance to Gasket Load Reaction [hg]:
```
  = (C - G ) / 2
  = ( 673.0 - 627.1979 )/2
  = 22.9011 mm.
```
Distance to Face Pressure Reaction [ht]:
```
  = ( R + g1 + hg ) / 2
  = ( 29.0 + 14.0 + 22.9011 )/2
  = 32.9505 mm.
```
Distance to End Pressure Reaction [hd]:
```
  = R + ( g1 / 2 )
  = 29.0 + ( 14.0/2.0 )
  = 36.0000 mm.
```

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

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	623.	36.0000	1.0000	22449.
Face Pressure, Mt	88.	32.9505	1.0000	2911.
Gasket Load, Mg	268.	22.9011	1.0000	6133.
Gasket Seating, Matm	1027.	22.9011	1.0000	23529.

```
Total Moment for Operation,      Mop                          31493. N-m
Total Moment for Gasket seating, Matm                         23529. N-m

Effective Hub Length, ho = sqrt(Bcor*goCor)        64.101  mm.
Hub Ratio,          h/h0 = HL / H0                  0.406
Thickness Ratio,   g1/g0 = (g1Cor/goCor)            2.000
```

Flange Factors for Integral Flange:

```
 Factor F                                                0.847
 Factor V                                                0.257
 Factor f                                                1.586
 Factors from Figure 2-7.1                       K =     1.218
                    T =      1.832               U =    10.940
                    Y =      9.955               Z =     5.135
                    d = 0.13358E+06 mm.³          e =     0.0132 mm.^-1
 Stress Factors                              ALPHA =     1.779
                 BETA =      2.039           GAMMA =     0.972
                DELTA =      1.537           Lamda =     2.509
```

Longitudinal Hub Stress, Operating [SHo]:
```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1.5858*31493/587.0)/(2.5089*14.0²)
  = 172.96 N./mm^2
```
Longitudinal Hub Stress, Seating [SHa]:
```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.5858*23529/587.0)/(2.5089*14.0²)
  = 129.22 N./mm^2
```

Radial Flange Stress, Operating [SRo]:
```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (2.0393*31493/587.0)/(2.5089*59.0²)
  = 12.52 N./mm^2
```
Radial Flange Stress, Seating [SRa]:
```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (2.0393*23529/587.0)/(2.5089*59.0²)
  = 9.36 N./mm^2
```

Tangential Flange Stress, Operating [STo]:
```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (9.9551*31493/(59.0²*587.0))-5.1351*13
  = 89.08 N./mm^2
```
Tangential Flange Stress, Seating [STa]:
```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (9.9551*23529/(59.0²*587.0))-5.1351*9
  = 66.55 N./mm^2
```

Average Flange Stress, Operating [SAo]:
```
  = ( SHo + max( SRo, STo ) ) / 2
  = (173+max(13,89))/2
  = 131.02 N./mm^2
```
Average Flange Stress, Seating [SAa]:
```
  = ( SHa + max( SRa, STa ) ) / 2
  = (129+max(9,67))/2
  = 97.88 N./mm^2
```

Bolt Stress, Operating [BSo]:
```
  = Wm1 / Ab
  = 979/62.3483
  = 157.09 N./mm^2
```
Bolt Stress, Seating [BSa]:
```
  = ( Wm2 / Ab )
  = (955/62.3483)
  = 153.14 N./mm^2
```

Flange Stress Analysis Results: N./mm^2

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	173.	207.	129.	207.

Radial Flange	13.	138.	9.	138.
Tangential Flange	89.	138.	67.	138.
Maximum Average	131.	138.	98.	138.
Bolting	157.	172.	153.	172.

Minimum Required Flange Thickness	60.173	mm.
Estimated M.A.W.P. (Operating)	24.244	bars
Estimated Finished Weight of Flange at given Thk.	70.6	kg.
Estimated Unfinished Weight of Forging at given Thk	93.0	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 * 23528.5/1.0 * 999.68 * 0.257/(2.356 * 202713 * 7.0² * 64.101 * 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 * 31492.8/1.0 * 999.68 * 0.257/(2.356 * 196612 * 7.0² * 64.101 * 0.3)
= 0.967 (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 * 23528.5/1.0 * 999.68 * 0.257/(2.509 * 202713 * 7.0² * 64.101 * 0.3)
= 0.658 (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 * 31492.8/1.0 * 999.68 * 0.257/(2.509 * 196612 * 7.0² * 64.101 * 0.3)
= 0.908 (should be <= 1)

Minimum Design Metal Temperature Results:

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

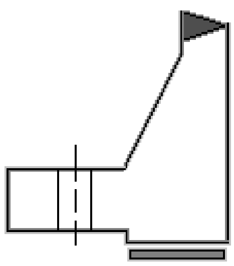
Impact Test Temperature provided per Specification -46 °C

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for ECONOMIZER E-PK6101-3
Flg Calc [Int P]: New Flange Flng: 4 11:20pm Feb 6,2022

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

BODY FLANGE 002

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	23.03	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	581.000	mm.
Flange Outside Diameter	A	715.000	mm.
Flange Thickness	t	62.0000	mm.
Thickness of Hub at Small End	go	10.0000	mm.
Thickness of Hub at Large End	g1	17.0000	mm.
Length of Hub	h	26.0000	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	673.000	mm.
Nominal Bolt Diameter	a	19.0500	mm.
Type of Threads		UNC Thread Series	
Number of Bolts		32	
Flange Face Outside Diameter	Fod	647.000	mm.
Flange Face Inside Diameter	Fid	581.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	641.000	mm.
Gasket Inside Diameter	Gi	611.000	mm.
Gasket Factor	m	3.7800	
Gasket Design Seating Stress	y	62.05	N./mm^2
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.0000	mm.
Length of Partition Gasket	lp	559.0000	mm.
Width of Partition Gasket	tp	6.4000	mm.
Partition Gasket Factor	mPart	3.7500	
Partition Gasket Design Seating Stress	yPart	62.05	N./mm^2



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)
  = (23.03*(581.0/2+3.0))/(137.9*1.0-0.6*23.03)+Ca
  = 7.9524 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 7.0)/(293.5 + 0.6 * 7.0 )
  = 32.423 bars
```

```
 Corroded Flange Thickness, tc = T-ci                    59.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor               587.000  mm.
 Corroded Large Hub,     g1Cor = g1-ci                   14.000  mm.
 Corroded Small Hub,     g0Cor = go-ci                    7.000  mm.
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor      29.000  mm.

 Gasket Contact Width,       N = (Go - Gi) / 2           15.000  mm.
 Basic Gasket Width,        bo = N / 2                    7.500  mm.
 Effective Gasket Width,     b = Cb sqrt(bo)              6.901  mm.
 Gasket Reaction Diameter,   G = Go - 2 * b             627.198  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.785 * 627.1979² * 23.034
  = 711.639 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 6.9011 * 3.1416 * 627.1979 * 3.78 * 23.03
    + 2.0 * 559.0 * 3.2 * 3.75 * 23.0342
  = 267.687 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.1416 * 587.0² *23.0342/4
  = 623.343 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 712 - 623
  = 88.296 kN
```
Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 712 + 268 + 0, 0 )
  = 979.326 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 62.05*6.9011*3.141*627.198+62.05*3.2*559.0
  = 954.707 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 979/172, 955/172
  = 56.819 cm^2
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 19.05 + 6 * 59.0/(3.78 + 0.5)
  = 120.810 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 673.0 * sin( 3.142/32 )
```

```
  = 65.966 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 65.966/( 2 * 19.05 + 59.0 )), 1 )
  = 1.0000
```

Bolting Information for UNC Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm^2	56.819	62.348	
Radial Distance between Hub and Bolts:	28.575	29.000	
Radial Distance between Bolts and the Ed	20.637	21.000	
Circumferential Spacing between the Bolt	44.450	65.966	120.810

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 62.348 * 172.38/(62.05 * 3.14 * (641.0 + 611.0) )
  = 4.403 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa * ( Am + Ab ) / 2
  = 172.38 * ( 56.8185 + 62.3483 )/2
  = 1026.98 kN
```
Gasket Load for the Operating Condition [HG]:
```
  = Wm1 - H
  = 979 - 712
  = 267.69 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
```
  = (C - G ) / 2
  = ( 673.0 - 627.1979 )/2
  = 22.9011 mm.
```
Distance to Face Pressure Reaction [ht]:
```
  = ( R + g1 + hg ) / 2
  = ( 29.0 + 14.0 + 22.9011 )/2
  = 32.9505 mm.
```
Distance to End Pressure Reaction [hd]:
```
  = R + ( g1 / 2 )
  = 29.0 + ( 14.0/2.0 )
  = 36.0000 mm.
```

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

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	623.	36.0000	1.0000	22449.
Face Pressure, Mt	88.	32.9505	1.0000	2911.
Gasket Load, Mg	268.	22.9011	1.0000	6133.
Gasket Seating, Matm	1027.	22.9011	1.0000	23529.

```
Total Moment for Operation,      Mop                          31493. N-m
Total Moment for Gasket seating, Matm                         23529. N-m

Effective Hub Length, ho = sqrt(Bcor*goCor)        64.101  mm.
Hub Ratio,          h/h0 = HL / H0                  0.406
Thickness Ratio,   g1/g0 = (g1Cor/goCor)            2.000
```

Flange Factors for Integral Flange:

```
 Factor F                                                   0.847
 Factor V                                                   0.257
 Factor f                                                   1.586
 Factors from Figure 2-7.1                          K =     1.218
                    T =      1.832                  U =    10.940
                    Y =      9.955                  Z =     5.135
                    d = 0.13358E+06 mm.³             e =     0.0132 mm.^-1
 Stress Factors                                 ALPHA =     1.779
                 BETA =      2.039              GAMMA =     0.972
                DELTA =      1.537              Lamda =     2.509
```

Longitudinal Hub Stress, Operating [SHo]:
```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1.5858*31493/587.0)/(2.5089*14.0²)
  = 172.96 N./mm^2
```
Longitudinal Hub Stress, Seating [SHa]:
```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.5858*23529/587.0)/(2.5089*14.0²)
  = 129.22 N./mm^2
```

Radial Flange Stress, Operating [SRo]:
```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (2.0393*31493/587.0)/(2.5089*59.0²)
  = 12.52 N./mm^2
```
Radial Flange Stress, Seating [SRa]:
```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (2.0393*23529/587.0)/(2.5089*59.0²)
  = 9.36 N./mm^2
```

Tangential Flange Stress, Operating [STo]:
```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (9.9551*31493/(59.0²*587.0))-5.1351*13
  = 89.08 N./mm^2
```
Tangential Flange Stress, Seating [STa]:
```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (9.9551*23529/(59.0²*587.0))-5.1351*9
  = 66.55 N./mm^2
```

Average Flange Stress, Operating [SAo]:
```
  = ( SHo + max( SRo, STo ) ) / 2
  = (173+max(13,89))/2
  = 131.02 N./mm^2
```
Average Flange Stress, Seating [SAa]:
```
  = ( SHa + max( SRa, STa ) ) / 2
  = (129+max(9,67))/2
  = 97.88 N./mm^2
```

Bolt Stress, Operating [BSo]:
```
  = Wm1 / Ab
  = 979/62.3483
  = 157.09 N./mm^2
```
Bolt Stress, Seating [BSa]:
```
  = ( Wm2 / Ab )
  = (955/62.3483)
  = 153.14 N./mm^2
```

Flange Stress Analysis Results: N./mm^2

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	173.	207.	129.	207.

Radial Flange	13.	138.	9.	138.
Tangential Flange	89.	138.	67.	138.
Maximum Average	131.	138.	98.	138.
Bolting	157.	172.	153.	172.

```
Minimum Required Flange Thickness                    60.173  mm.
Estimated M.A.W.P. ( Operating )                     24.244  bars
Estimated Finished Weight of Flange at given Thk.      70.6  kg.
Estimated Unfinished Weight of Forging at given Thk    93.0  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 * 23528.5/1.0 * 999.68 * 0.257/( 2.356 * 202713 *
    7.0² * 64.101 * 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 * 31492.8/1.0 * 999.68 * 0.257/( 2.356 * 196612
    * 7.0² * 64.101 * 0.3 )
  = 0.967   (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 * 23528.5/1.0 * 999.68 * 0.257/( 2.509 * 202713 *
    7.0² * 64.101 * 0.3 )
  = 0.658   (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 * 31492.8/1.0 * 999.68 * 0.257/( 2.509 * 196612
    * 7.0² * 64.101 * 0.3 )
  = 0.908   (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
```

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER
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FileName : Calculation Book for ECONOMIZER E-PK6101-3
Internal Pressure Calculations: Step: 5 11:20pm Feb 6,2022

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 1		23.034	12	3	581	137.9
CHANNEL 01		23.03	10	3	581	137.9
BODY FLANGE 01		23.034	79	3	581	137.9
SHELL		23.034	10	3	581	137.9
BODY FLANGE 002		23.034	79	3	581	137.9
CHANNEL 002		23.034	10	3	581	137.9
HEAD 002		23.034	12	3	581	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 1		23	No Calc	No Calc	10	7.8451
CHANNEL 01		23	No Calc	No Calc	10	7.95159
BODY FLANGE 01		23	No Calc	No Calc	62	60.1726
SHELL		23	No Calc	No Calc	10	7.95245
BODY FLANGE 002		23	No Calc	No Calc	62	60.1726
CHANNEL 002		23	No Calc	No Calc	10	7.95245
HEAD 002		23	No Calc	No Calc	10	7.8451

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      =     44.133 bars
Shell Side MAPnc     =     51.100 bars
Channel Side   MAWP  =     25.277 bars
Channel Side   MAPnc =     25.277 bars
```

Note:
PV Elite could not compute the MAWP of one of the Flanges.
Please check the reported MAWP by entering it as the design pressure and performing an extra analysis.

Internal Pressure Calculation Results :

ASME Code, Section VIII Division 1, 2017

Elliptical Head From 10 To 20 SA-516 70 , UCS-66 Crv. D at 125 °C

HEAD 1

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)

```
  = (23.034*587.0*0.987)/(2*137.9*1.0-0.2*23.034)
  = 4.8451 + 3.0000 = 7.8451 mm.
```

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

```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (23.034*(0.987*587.0+0.2*7.0))/(2*1.0*7.0)
  = 95.519 N./mm^2
```

Straight Flange Required Thickness:

```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (23.034*293.5)/(137.9*1.0-0.6*23.034)+3.0
  = 7.952 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.034 bars

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 9.0)/(293.5 + 0.6 * 9.0 )
  = 41.520 - 0.034 = 41.485  bars
```

Factor K, corroded condition [Kcor]:

```
  = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
  = ( 2 + ( 587.0/( 2 * 148.25 ))²)/6
  = 0.986578
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 8.590 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 10.0, tr = 4.845, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.692, Temp. Reduction = 17 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D            -48 °C
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 12.0, tr = 4.952, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.55, Temp. Reduction = 27 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D            -48 °C
```

Cylindrical Shell From 20 To 30 SA-516 70 , UCS-66 Crv. D at 125 °C

CHANNEL 01

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (23.03*293.5)/(137.9*1.0-0.6*23.03)
  = 4.9516 + 3.0000 = 7.9516 mm.
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (23.03*(293.5+0.6*7.0))/(1.0*7.0)
  = 97.951 N./mm^2
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.692 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.707, Temp. Reduction = 16 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D          -48 °C
```

Cylindrical Shell From 40 To 50 SA-516 70 , UCS-66 Crv. D at 125 °C

SHELL

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (23.034*293.5)/(137.9*1.0-0.6*23.034)
  = 4.9524 + 3.0000 = 7.9524 mm.
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (23.034*(293.5+0.6*7.0))/(1.0*7.0)
  = 97.967 N./mm^2
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.692 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.707, Temp. Reduction = 16 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D          -48 °C
```

Cylindrical Shell From 60 To 70 SA-516 70 , UCS-66 Crv. D at 125 °C

CHANNEL 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (23.034*293.5)/(137.9*1.0-0.6*23.034)
  = 4.9524 + 3.0000 = 7.9524 mm.
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (23.034*(293.5+0.6*7.0))/(1.0*7.0)
  = 97.967 N./mm^2
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.692 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.707, Temp. Reduction = 16 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D          -48 °C
```

Elliptical Head From 70 To 80 SA-516 70 , UCS-66 Crv. D 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)
  = (23.034*587.0*0.987)/(2*137.9*1.0-0.2*23.034)
  = 4.8451 + 3.0000 = 7.8451 mm.
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (23.034*(0.987*587.0+0.2*7.0))/(2*1.0*7.0)
  = 95.519 N./mm^2
```

Straight Flange Required Thickness:
```
  = (P*R)/(S*E-0.6*P) + c     per UG-27 (c)(1)
  = (23.034*293.5)/(137.9*1.0-0.6*23.034)+3.0
  = 7.952 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.034 bars
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 9.0)/(293.5 + 0.6 * 9.0 )
  = 41.520 - 0.034 = 41.485  bars
```

Factor K, corroded condition [Kcor]:
```
  = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
  = ( 2 + ( 587.0/( 2 * 148.25 ))²)/6
  = 0.986578
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 8.590 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 10.0, tr = 4.845, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.692, Temp. Reduction = 17 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D            -48 °C
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 12.0, tr = 4.952, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.55, Temp. Reduction = 27 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D            -48 °C
```

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

Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

```
 Pressure per UG99b      = 1.30 * M.A.W.P. * Sa/S         57.373  bars
 Pressure per UG99b[36]  = 1.30 * Design Pres * Sa/S      29.900  bars
 Pressure per UG99c      = 1.30 * M.A.P. - Head(Hyd)      66.430  bars
 Pressure per UG100      = 1.10 * M.A.W.P. * Sa/S         48.547  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         57.373  bars
```

Exchanger Channel Side Hydrostatic Test Pressures:

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Internal Pressure Calculations: Step: 5 11:20pm Feb 6,2022

```
Pressure per UG99b      = 1.30 * M.A.W.P. * Sa/S        32.860  bars
Pressure per UG99b[36]  = 1.30 * Design Pres * Sa/S     29.900  bars
Pressure per UG99c      = 1.30 * M.A.P. - Head(Hyd)     32.803  bars
Pressure per UG100      = 1.10 * M.A.W.P. * Sa/S        27.804  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        32.860  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 1	124.2	235.8	0.527	29.96
CHANNEL 01	127.4	235.8	0.540	29.96
SHELL	127.4	235.8	0.540	29.96
CHANNEL 002	127.4	235.8	0.540	29.96
HEAD 002	124.2	235.8	0.527	29.96

Stress ratios for Nozzle and Pad Materials (N./mm^2):

Description	Pad/Nozzle	Ambient	Operating	Ratio
T4	Nozzle	137.90	137.90	1.000
T1	Nozzle	117.90	117.90	1.000
T1	Pad	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	137.90	137.90	1.000
T2	Nozzle	117.90	117.90	1.000
T2	Pad	137.90	137.90	1.000
T3	Nozzle	137.90	137.90	1.000
Minimum				1.000

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

Description	Ambient	Operating	Ratio
HEAD 1	137.90	137.90	1.000
CHANNEL 01	137.90	137.90	1.000
BODY FLANGE 01	137.90	137.90	1.000
SHELL	137.90	137.90	1.000
BODY FLANGE 002	137.90	137.90	1.000
CHANNEL 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
T4	5.13	223.40	0.023
T1	24.22	217.19	0.112
S2	36.99	217.19	0.170
S1	36.99	217.19	0.170
S3	8.05	223.40	0.036
T2	36.99	217.19	0.170
T3	5.96	223.40	0.027

Elements Suitable for Internal Pressure.

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	601	7	0.0016177	98.7135
20	30	505.417	601	7	0.0020537	104.349
30	40	No Calc	...	59	No Calc	No Calc
40	50	5880	601	7	0.00016747	16.7432
50	60	No Calc	...	59	No Calc	No Calc
60	70	505.417	601	7	0.0020537	104.349
70	80	No Calc	601	7	0.0016177	98.7135

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	10	4.60484	1.1	12.7742
20	30	10	4.83369	1.1	16.2041
30	40	62	49.4792	1.1	No Calc
40	50	10	8.13291	1.1	2.60002
50	60	62	49.4792	1.1	No Calc
60	70	10	4.83369	1.1	16.2041
70	80	10	4.60484	1.1	12.7742
Minimum					2.600

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	505.417	12031.9	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	5880	131539	No Calc	No Calc
50	60	No Calc	No Calc	No Calc	No Calc
60	70	505.417	12031.9	No Calc	No Calc
70	80	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

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

HEAD 1

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
7.000	601.00	85.86	0.0016177	98.71

EMAP = B/(K0*D/t) = 98.7135/(0.9 *85.8571) = 12.7742 bars

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
1.605	601.00	374.49	0.0003709	37.08

EMAP = B/(K0*D/t) = 37.0789/(0.9 *374.4927) = 1.1001 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)
= (1.837*587.0*0.987)/(2*137.9*1.0-0.2*1.837)
= 0.3858 + 3.0000 = 3.3858 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*7.0)/(0.987*587.0+0.2*7.0))/1.67
= 19.913 bars

Maximum Allowable External Pressure [MAEP]:
= min(MAEP, MAWP)
= min(12.77, 19.9128)
= 12.774 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

CHANNEL 01

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
7.000	601.00	505.42	85.86	0.8410	0.0020537	104.35

EMAP = (4*B)/(3*(D/t)) = (4*104.3486)/(3*85.8571) = 16.2041 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.834	601.00	505.42	327.75	0.8410	0.0002705	27.04

EMAP = (4*B)/(3*(D/t)) = (4*27.043)/(3*327.7541) = 1.1001 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
7.000	601.00	12031.87	85.86	20.0198	0.0001535	15.35

EMAP = (4*B)/(3*(D/t)) = (4*15.3457)/(3*85.8571) = 2.383 bars

Cylindrical Shell From 40 to 50 Ext. Chart: CS-2 at 125 °C

SHELL

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
7.000	601.00	5880.00	85.86	9.7837	0.0001675	16.74

EMAP = (4*B)/(3*(D/t)) = (4*16.7432)/(3*85.8571) = 2.6 bars

Results for Required Thickness (Tca):
```
     Tca          OD         SLEN        D/t        L/D   Factor A         B
   5.133      601.00      5880.00     117.09     9.7837  0.0000966      9.66
 EMAP = (4*B)/(3*(D/t)) = (4*9.6607)/(3*117.0875) = 1.1 bars
```

Results for Maximum Stiffened Length (Slen):
```
     Tca          OD         SLEN        D/t        L/D   Factor A         B
   7.000      601.00    131538.89      85.86    50.0000  0.0001516     15.15
 EMAP = (4*B)/(3*(D/t)) = (4*15.1537)/(3*85.8571) = 2.3532 bars
```

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

CHANNEL 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
   7.000      601.00       505.42      85.86     0.8410  0.0020537    104.35
 EMAP = (4*B)/(3*(D/t)) = (4*104.3486)/(3*85.8571) = 16.2041 bars
```

Results for Required Thickness (Tca):
```
     Tca          OD         SLEN        D/t        L/D   Factor A         B
   1.834      601.00       505.42     327.75     0.8410  0.0002705     27.04
 EMAP = (4*B)/(3*(D/t)) = (4*27.043)/(3*327.7541) = 1.1001 bars
```

Results for Maximum Stiffened Length (Slen):
```
     Tca          OD         SLEN        D/t        L/D   Factor A         B
   7.000      601.00     12031.87      85.86    20.0198  0.0001535     15.35
 EMAP = (4*B)/(3*(D/t)) = (4*15.3457)/(3*85.8571) = 2.383 bars
```

Elliptical Head From 70 to 80 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
   7.000      601.00        85.86   0.0016177         98.71
 EMAP = B/(K0*D/t) = 98.7135/( 0.9 *85.8571 ) = 12.7742 bars
```

Results for Required Thickness (Tca):
```
     Tca          OD          D/t    Factor A             B
   1.605      601.00       374.49   0.0003709         37.08
 EMAP = B/(K0*D/t) = 37.0789/( 0.9 *374.4927 ) = 1.1001 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)
  = (1.837*587.0*0.987)/(2*137.9*1.0-0.2*1.837)
  = 0.3858 + 3.0000 = 3.3858 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*7.0)/(0.987*587.0+0.2*7.0))/1.67
```

```
  = 19.913 bars
```

Maximum Allowable External Pressure [MAEP]:

```
  = min( MAEP, MAWP )
  = min( 12.77, 19.9128 )
  = 12.774 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	47.807	38935.4	35.8552	40014.4	2.39035
20	30	58.5682	107923	41.2058	110164	2.92841
30	40	88.5944	28277.5	84.1151	28420.6	4.42972
40	50	846.145	841010	595.307	873380	42.3073
50	60	88.5944	28277.5	84.1151	28420.6	4.42972
60	70	58.5682	107923	41.2058	110164	2.92841
70	80	47.807	38935.4	35.8552	40014.4	2.39035
Total		1236	1191281.88	917	1230577.00	61

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	23.347	-48.4167	-0.00002	1
10	Insl	13.6455	-47.625	...	Ins: 40
20	Liqd	57.2924	203.5	...	2
20	Insl	16.717	203.5	...	Ins: 40
20	Nozl	5.16718	203	300.025	T4
20	Nozl	31.9986	203	347.65	T1
30	Liqd	16.9561	44	...	3
30	Insl	4.53732	44	...	Ins: 40
40	Sadl	60.6827	940	435.25	Fixed Saddle
40	Sadl	60.6827	4940	435.25	Sliding Saddle
40	Liqd	504.298	2940	...	4
40	Insl	241.513	2940	...	Ins: 40
40	Nozl	59.6222	196	374.637	S2
40	Nozl	59.6222	5680	374.637	S1
40	Nozl	12.585	146	315.9	S3
40	Wght	150	2940	...	WEIGHT BAFFLE
50	Liqd	16.9561	44	...	5
50	Insl	4.53732	44	...	Ins: 40
60	Liqd	64.7144	203.5	...	5
60	Insl	16.717	203.5	...	Ins: 40
60	Nozl	59.6222	200	374.637	T2
60	Nozl	6.25877	203	303.2	T3
70	Liqd	23.347	98.4167	-0.00002	6
70	Insl	13.6455	97.625	...	Ins: 40
30	FTsh	140.973	125	...	TUBE SHEET
30	Tube	2317.4	3094	...	
30	RTsh	140.973	6063	...	

Total Weight of Each Detail Type

Total Weight of Saddles	121.4
Total Weight of Liquid	706.9
Total Weight of Insulation	311.3
Total Weight of Nozzles	234.9
Total Weight of Weights	150.0

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```
 Total Weight of Exchanger Components                2599.3
 Total Weight of Liquid in Tubes                      313.4
 ---------------------------------------------------------------
 Sum of the Detail Weights                           4437.2 kg.
```

Weight Summation: kg.

Fabricated	Shop Test	Shipping	Erected	Empty	Operating
1297.9	4403.5	1297.9	4403.5	1297.9	4714.8
121.4	1190.6	121.4	...	121.4	706.9
234.9	...	234.9	...	...	...
...	447.7	...	311.3	...	...
...	...	...	...	311.3	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	234.9	313.4
2599.3	...	2599.3	...	...	...
150.0	...	150.0	...	...	...
...	...	...	...	2599.3	...
...	...	...	...	150.0	...
4403.5	6041.8	4403.5	4714.8	4714.8	5735.1

Miscellaneous Weight Percent: 5.0 %

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

Weight Summary

```
 Fabricated Wt.   - Bare Weight W/O Removable Internals       4403.5 kg.
 Shop Test Wt.    - Fabricated Weight + Water ( Full )        6041.8 kg.
 Shipping Wt.     - Fab. Wt + Rem. Intls.+ Shipping App.      4403.5 kg.
 Erected  Wt.     - Fab. Wt + Rem. Intls.+ Insul. (etc)       4714.8 kg.
 Ope. Wt. no Liq  - Fab. Wt + Intls. + Details + Wghts.       4714.8 kg.
 Operating Wt.    - Empty Wt + Operating Liq. Uncorroded      5735.1 kg.
 Oper. Wt. + CA   - Corr Wt. + Operating Liquid               5400.8 kg.
 Field Test Wt.   - Empty Weight + Water (Full)               6058.0 kg.
```

Exchanger Tube Data

```
 Volume of Exchanger tubes    :                    448017.0 Cm3
 Weight of Ope Liq in tubes   :                       313.4 kg.
 Weight of Water in tubes     :                       447.7 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	4917.99
20	30	7684.56
30	40	3640.82
40	50	111020

50	60	3640.82
60	70	7684.56
70	80	4917.99

Total 143506.844 cm^2

Nozzle Flange MAWP Results:

Nozzle Description	Flange Rating Ope. bars	Flange Rating Ambient bars	Design Temp °C	Class	Grade/ Group	Equiv. Press	Max Pressure PVP	Max Pressure 50%	Max Pressure DNV bars
T4	45.8	51.1	125	300	GR 1.1	...	...	...	...
T1	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	...	...	...	...
T2	45.8	51.1	125	300	GR 1.1	...	...	...	...
T3	45.8	51.1	125	300	GR 1.1	...	...	...	...

Shellside Flange Rating

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

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)

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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		33.0	
Using User defined Wind Press. Vs Elev.		N	
Height of Hill or Escarpment	H or Hh	0	mm.
Distance Upwind of Crest	Lh	0	mm.
Distance from Crest to the Vessel	x	0	mm.
Type of Terrain (Hill, Escarpment)		Flat	
Damping Factor (Beta) for Wind (Ope)		0.0100	
Damping Factor (Beta) for Wind (Empty)		0.0000	
Damping Factor (Beta) for Wind (Filled)		0.0000	

Wind Analysis Results

Static Gust-Effect Factor, Operating Case [G]:
```
  = 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]	0.616
Structure Height to Diameter ratio		9.906

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
  = 600.0 + 123000. = 123600.008 mm.
  = 405.512 ft. Imperial Units
```

Velocity Pressure coefficient evaluated at height z [Kz]:
Because z (405.512 ft.) > 15 ft.
$= 2.01 * (z / Zg)^{2 / Alpha}$
$= 2.01 * (405.512/900.0)^{2/9.5}$
= 1.699

Type of Hill: No Hill

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

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

Topographical Factor [Kzt]:
= (1 + K1 * K2 * K3)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 * 1.699 * 1.0 * 0.95 * 124.278²)
= 63.8 psf [311.67] Kgs/m^2

Force on the first element [F]:
= qz * G * Cf * WindArea
= 63.834 * 0.85 * 0.616 * 2.005
= 67.0 lbs. [0.3] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m^2
HEAD 1	*******	0.000	0.000	0.000	1.699	1.000	311.670
CHANNEL 01	*******	0.000	0.000	0.000	1.699	1.000	311.670
BODY FLANGE 01	*******	0.000	0.000	0.000	1.699	1.000	311.670
SHELL	*******	0.000	0.000	0.000	1.699	1.000	311.670
BODY FLANGE 002	*******	0.000	0.000	0.000	1.699	1.000	311.670
CHANNEL 002	*******	0.000	0.000	0.000	1.699	1.000	311.670
HEAD 002	*******	0.000	0.000	0.000	1.699	1.000	311.670

Wind Loads on Masses/Equipment/Piping

ID	Wind Area cm^2	Elevation mm.	Pressure Kgs/m^2	Force kN
WEIGHT BAFFLE	0.00	125940.00	311.67	0.00

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	123600	913.2	1862.66	311.67	0.17888
20	30	123600	913.2	3716.72	311.67	0.35694
30	40	123600	889.2	782.496	311.67	0.075149
40	50	123600	913.2	53696.2	311.67	5.15683
50	60	123600	889.2	782.496	311.67	0.075149
60	70	123600	913.2	3716.72	311.67	0.35694
70	80	123600	913.2	1862.66	311.67	0.17888

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		1.250
Table Value Fa		1.000
Table Value Fv		1.300
Short Period Acceleration value Ss		0.900
Long Period Acceleration Value Sl		0.537
Moment Reduction Factor Tau		1.000
Force Modification Factor R		3.000
Site Class		B
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	0.000
Force Factor		0.000
Consider Vertical Acceleration		Yes
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0)		0.390

Seismic Analysis Results:

```
Sms = Fa * Ss = 1.0 * 0.9 = 0.9
Sm1 = Fv * S1 = 1.3 * 0.537 = 0.698
Sds = 2/3 * Sms = 2/3 * 0.9 = 0.6

Sds = Max( 0.8*Sds, SdsUser )
    = Max( 0.48, 0.39 )
    = 0.480

Sd1 = 2/3 * Sm1 = 2/3 * 0.698 = 0.465

Sd1 = Max( 0.8*Sd1, Sd1User )
    = Max( 0.372, 0.624 )
    = 0.624
```

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 * ($2.9216^{0.75}$)
= 0.045 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 * 0.045, 0.03) per 12.8.2
= 0.030

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

Compute the Base Shear per equation 15.4-5, [V]:
= 0.3 * Sds * W * I
= 0.3 * 0.48 * 53 * 1.25
= 9.533 kN

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

= 0.2 * 0.48 * 53 = 5.08 kN

Final Base Shear, V = 6.67 kN
Final Vertical Load, YEq = 3.56 kN

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN
10	20	290.5	5.88444	0.74144
20	30	290.5	5.88444	0.74144
30	40	290.5	5.88444	0.74144
40	Sadl	290.5	5.88444	0.74144
Sadl	50	290.5	5.88444	0.74144
40	50	290.5	5.88444	0.74144
50	60	290.5	5.88444	0.74144
60	70	290.5	5.88444	0.74144
70	80	290.5	5.88444	0.74144

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

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Shop/Field Installation Options :

Insulation is installed in the Field.

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

Center of Gravity of Saddles	3553.176 mm.
Center of Gravity of Liquid	3586.333 mm.
Center of Gravity of Insulation	3552.272 mm.
Center of Gravity of Nozzles	3804.880 mm.
Center of Gravity of Added Weights (Operating)	3553.176 mm.
Center of Gravity of Added Weights (Empty)	3553.176 mm.
Center of Gravity of Tubesheet(s)	3551.000 mm.
Center of Gravity of Tubes	3551.000 mm.
Center of Gravity of Bare Shell New and Cold	3548.732 mm.
Center of Gravity of Bare Shell Corroded	3547.492 mm.
Vessel CG in the Operating Condition	3566.223 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	3564.007 mm.
Vessel CG in the Test Condition	3560.619 mm.

Warning: CG of Vessel is too near or Outside the Lift Points!

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

Input and Calculated Values:

```
Vessel Mean Radius                              Rm      297.00  mm.
Stiffened Vessel Length per 4.15.6               L     5880.00  mm.
Distance from Saddle to Vessel tangent           a      992.00  mm.

Saddle Width                                     b      150.00  mm.
Saddle Bearing Angle                         theta      120.00  degrees

Wear Plate Width                                b1      225.00  mm.
Wear Plate Bearing Angle                    theta1      132.00  degrees
Wear Plate Thickness                            tr        10.0  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                           39.17  kN
```

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	39.03	137.90
Long. Stress at Bottom of Midspan	58.64	137.90
Long. Stress at Top of Saddles	79.11	137.90
Long. Stress at Bottom of Saddles	32.05	137.90
Tangential Shear in Shell	14.61	110.32
Circ. Stress at Horn of Saddle	13.35	172.38
Circ. Compressive Stress in Shell	1.92	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 * ( 6.4/2 + 0 ) * 600.0/514.4191
  = 11.2 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 0.62, 0.0, 0 ) * 600.0/4000.0
  = 0.1 kN
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 6.67, 0.0, 0 ) * 600.0/4000.0
  = 1.0 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 7/2 + 0 ) * 600.0/514.4191
  = 11.7 kN
```

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Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 27 + Max( 0.1, 11, 1, 12 )
  = 39.2 kN
```

Summary of Loads at the base of this Saddle:
```
 Vertical Load (including saddle weight)              39.76  kN
 Transverse Shear Load Saddle                          3.34  kN
 Longitudinal Shear Load Saddle                        6.67  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  = 0.0529     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0434
 K7p = 0.0434
```

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)]
  = -39*992.0[1-(1-992.0/5880.0+(297.0²-0.0²)/
    (2*992.0*5880.0))/(1+(4*0.0)/(3*5880.0))]
  = -6263.5 N-m
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 39*5880/4(1+2(297²-0²)/(5880²))/(1+(4*0)/
    (3*5880))-4*992/5880
  = 19023.0 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 23.017 * 297.0/(2*7.0) - 19023.0/(pi*297.0²*7.0)
  = 39.03 N./mm^2
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 23.017 * 297.0/(2 * 7.0) + 19023.0/(pi * 297.0² * 7.0 )
  = 58.64 N./mm^2
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 23.017*297.0/(2*7.0)--6263.5/(0.1066*pi*297.0²*7.0)
  = 79.11 N./mm^2
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 23.017*297.0/(2*7.0)+-6263.5/(0.1923*pi*297.0²*7.0)
  = 32.05 N./mm^2
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 39( 5880.0 - 2 * 992.0)/(5880.0 + ( 4 * 0.0/3))
  = 26.0 kN
```

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

```
  = K2 * T / ( Rm * t )
  = 1.1707 * 25.95/( 297.0 * 7.0 )
  = 14.61 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 297.0 * 7.0 )
  = 35.565 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 39 * 0.1/( 7.0 * ( 150.0 + 35.56 + 35.56 ) )
  = -1.92 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 150.0 + 1.56 * sqrt( 297.0 * 7.0 ), 2 * 992.0 )
  = 221.13 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 * 39 * 0.1/( 221.13( 7.0 + 1.0 * 10.0 ) )
  = -0.79 N./mm^2
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27) [sigma7,r]:
```
  = -Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)²)
  = -39/(4(7.0 + 1.0 * 10.0)221.13) -
     3 * 0.053 * 39/(2(7.0 + 1.0 * 10.0)²)
  = -13.35 N./mm^2
```

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
```
  = Alpha * Ls * ( Design Temperature - Ambient Temperature )
  = 0.000012 * 4000.0 * ( 125.0 - 21.1 )
  = 5.096 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	545.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	180.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	296.	7.	3.	21.	7245.	3.38
Wearplate	225.	10.	12.	22.	27000.	34.3
Web	10.	273.	154.	27.	420506.	0.817E+04
BasePlate	180.	16.	298.	29.	859680.	0.257E+05
Totals	...	...	...	99.	1314431.	0.339E+05

```
Value  C1 = Sumof(Ay)/Sumof(A)          =     132.      mm.
Value   I = Sumof(Io) - C1*Sumof(Ay)    =    0.165E+05  cm**4
Value  As = Sumof(A) - Ashell           =     78.6      cm^2
```

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

Fh = K1 * Q = 0.2035 * 39.166 = 7.9712 kN

Tension Stress, St = ( Fh/As )       =         1.0136  N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str =       124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin( theta )/ theta
  = 600.0 - 293.5 * sin( 1.0472 )/1.0472
  = 357.277 mm.

Bending Moment, M  = Fh * d          =      2849.0820  N-m

Bending Stress, Sb = ( M * C1 / I  ) =         2.2859  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(39 + 0.6)180.0/( 4 * 545.0 * 137.9 ))½
  = 8.452 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 542.9979/( 4 - 1 )
  = 180.999 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 181.0 * 180.0/2
  = 162.899 cm^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 162.9 * 0.04
  = 6.504 kN
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 14.0 + 9.05
  = 23.050 cm^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 6.5/23.05
  = 2.822 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	10.0	150.0	...	15.0	...	281.

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * rl / 2
  = 6.7/( 2 * 545.0 ) * 181.0 * 427.25/2
  = 236.808 N-m
```

Compressive Allowable, KL/R < Cc (12.2313 < 138.1347) per AISC E2-1 [Sca]:

```
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.23 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(12.23)/(8* 138.13)-( 12.23³)/(8*138.13³)
  = 121.215 N./mm^2
```

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

```
  = Sc/Sca + ( Rm * Distance Side/I )/Sba
  = 2.82/121.21 + ( 236.81 * 75.0/2812500 )/137.9
  = 0.069
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	0.0	14.0	0.0	281.
Web	181.0	10.0	0.0	18.1	0.0	1.51
Values	...	...	...	32.1	...	283.

```
 Compressive Allowable, KL/R < Cc ( 9.5652 < 138.1347 ) per AISC E2-1 [Sca]:
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 9.57 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(9.57)/(8* 138.13)-( 9.57³)/(8*138.13³)
  = 121.916 N./mm^2
```

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

```
  = Sc/Sca + ( Rm * Distance Center/I )/Sba
  = 4.0/121.92 + ( 314.65 * 75.0/282.675 )/137.9
  = 0.093
```

<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	72.0	mm.
Nominal Bolt Diameter	Bnd	24.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	3.1275	cm^2
Saddle Load QO (Weight)	QO	28.1	kN
Saddle Load QL (Wind/Seismic contribution)	QL	1.0	kN
Maximum Transverse Force	Ft	3.3	kN
Maximum Longitudinal Force	Fl	11.4	kN
Saddle Bolted to Steel Foundation		Yes	

<u>Bolt Area Calculation per Dennis R. Moss</u>

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)
  = 11.37/(172.38 * 4.0)
  = 0.1650 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
```

```
  = 600.0 * 3.34 + 0.0
  = 2002.70 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 2002.7/28.09
  = 71.28 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, 0.165, 0.0]
  = 0.1650 cm^2
```

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

Input and Calculated Values:

Vessel Mean Radius	Rm	297.00	mm.
Stiffened Vessel Length per 4.15.6	L	5880.00	mm.
Distance from Saddle to Vessel tangent	a	992.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	225.00	mm.
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	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		39.51	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	38.94	137.90
Long. Stress at Bottom of Midspan	58.72	137.90
Long. Stress at Top of Saddles	79.38	137.90
Long. Stress at Bottom of Saddles	31.90	137.90
Tangential Shear in Shell	14.74	110.32
Circ. Stress at Horn of Saddle	13.47	172.38
Circ. Compressive Stress in Shell	1.94	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 * ( 6.4/2 + 0 ) * 600.0/514.4191
  = 11.2 kN
```

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


```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 0.62, 11.37, 0 ) * 600.0/4000.0
  = 1.7 kN
```

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

```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 6.67, 11.37, 0 ) * 600.0/4000.0
  = 1.7 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 7/2 + 0 ) * 600.0/514.4191
  = 11.7 kN
```

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

```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 28 + Max( 2, 11, 2, 12 )
  = 39.5 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	40.11	kN
Transverse Shear Load Saddle	3.34	kN
Longitudinal Shear Load Saddle	11.37	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 = 0.0529	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	K6p = 0.0434
K7p = 0.0434			

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)]
  = -40*992.0[1-(1-992.0/5880.0+(297.0²-0.0²)/
    (2*992.0*5880.0))/(1+(4*0.0)/(3*5880.0))]
  = -6318.8 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 40*5880/4(1+2(297²-0²)/(5880²))/(1+(4*0)/
    (3*5880))-4*992/5880
  = 19190.8 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 23.017 * 297.0/(2*7.0) - 19190.8/(pi*297.0²*7.0)
  = 38.94 N./mm^2
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 23.017 * 297.0/(2 * 7.0) + 19190.8/(pi * 297.0² * 7.0 )
  = 58.72 N./mm^2
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
```

```
  = 23.017*297.0/(2*7.0)--6318.8/(0.1066*pi*297.0²*7.0)
  = 79.38 N./mm^2
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 23.017*297.0/(2*7.0)+-6318.8/(0.1923*pi*297.0²*7.0)
  = 31.90 N./mm^2
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 40( 5880.0 - 2 * 992.0)/(5880.0 + ( 4 * 0.0/3))
  = 26.2 kN
```

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

```
  = K2 * T / ( Rm * t )
  = 1.1707 * 26.18/( 297.0 * 7.0 )
  = 14.74 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 297.0 * 7.0 )
  = 35.565 mm.
```

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

```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 40 * 0.1/( 7.0 * ( 150.0 + 35.56 + 35.56 ) )
  = -1.94 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 150.0 + 1.56 * sqrt( 297.0 * 7.0 ), 2 * 992.0 )
  = 221.13 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 * 40 * 0.1/( 221.13( 7.0 + 1.0 * 10.0 ) )
  = -0.80 N./mm^2
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27) [sigma7,r]:

```
  = -Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)²)
  = -40/(4(7.0 + 1.0 * 10.0)221.13) -
     3 * 0.053 * 40/(2(7.0 + 1.0 * 10.0)²)
  = -13.47 N./mm^2
```

Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	545.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	180.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

B	D	Y	A	AY	Io

Shell	296.	7.	3.	21.	7245.	3.38
Wearplate	225.	10.	12.	22.	27000.	34.3
Web	10.	273.	154.	27.	420506.	0.817E+04
BasePlate	180.	16.	298.	29.	859680.	0.257E+05
Totals	...	...	...	99.	1314431.	0.339E+05

```
Value  C1 = Sumof(Ay)/Sumof(A)          =     132.      mm.
Value   I = Sumof(Io) - C1*Sumof(Ay)    =    0.165E+05  cm**4
Value  As = Sumof(A) - Ashell           =     78.6      cm^2

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

Fh = K1 * Q = 0.2035 * 39.512 = 8.0415 kN

Tension Stress, St = ( Fh/As )       =          1.0225  N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str =        124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin( theta )/ theta
  = 600.0 - 293.5 * sin( 1.0472 )/1.0472
  = 357.277 mm.

Bending Moment, M  = Fh * d          =       2874.2144  N-m

Bending Stress, Sb = ( M * C1 / I  ) =          2.3060  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(40 + 0.6)180.0/( 4 * 545.0 * 137.9 ))½
  = 8.488 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 542.9979/( 4 - 1 )
  = 180.999 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 181.0 * 180.0/2
  = 162.899 cm^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 162.9 * 0.04
  = 6.561 kN
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 14.0 + 9.05
  = 23.050 cm^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 6.6/23.05
  = 2.847 N./mm^2
```

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

	B	D	Y	A	AY	Io
Rib+Web	10.0	150.0	...	15.0	...	281.

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * rl / 2
  = 11.4/( 2 * 545.0 ) * 181.0 * 427.25/2
  = 403.598 N-m
```

Compressive Allowable, KL/R < Cc (12.2313 < 138.1347) per AISC E2-1 [Sca]:
```
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.23 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(12.23)/(8* 138.13)-( 12.23³)/(8*138.13³)
  = 121.215 N./mm^2
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * Distance Side/I )/Sba
  = 2.85/121.21 + ( 403.6 * 75.0/2812500 )/137.9
  = 0.102
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	0.0	14.0	0.0	281.
Web	181.0	10.0	0.0	18.1	0.0	1.51
Values	...	...	...	32.1	...	283.

```
 Compressive Allowable, KL/R < Cc ( 9.5652 < 138.1347 ) per AISC E2-1 [Sca]:
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 9.57 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(9.57)/(8* 138.13)-( 9.57³)/(8*138.13³)
  = 121.916 N./mm^2
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * Distance Center/I )/Sba
  = 4.03/121.92 + ( 536.27 * 75.0/282.675 )/137.9
  = 0.136
```

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	72.0	mm.
Nominal Bolt Diameter	Bnd	24.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	3.1275	cm^2
Saddle Load QO (Weight)	QO	28.4	kN
Saddle Load QL (Wind/Seismic contribution)	QL	1.7	kN
Maximum Transverse Force	Ft	3.3	kN
Maximum Longitudinal Force	Fl	11.4	kN
Saddle Bolted to Steel Foundation		Yes	

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)
  = 11.37/(172.38 * 4.0)
  = 0.1650 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 600.0 * 3.34 + 0.0
  = 2002.70 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 2002.7/28.43
  = 70.41 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, 0.165, 0.0]
  = 0.1650 cm^2
```

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

Input and Calculated Values:

```
Vessel Mean Radius                               Rm      297.00  mm.
Stiffened Vessel Length per 4.15.6                L     5880.00  mm.
Distance from Saddle to Vessel tangent            a      992.00  mm.

Saddle Width                                      b      150.00  mm.
Saddle Bearing Angle                          theta      120.00  degrees

Wear Plate Width                                 b1      225.00  mm.
Wear Plate Bearing Angle                     theta1      132.00  degrees
Wear Plate Thickness                             tr        10.0  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                 32.60  kN

Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                        N./mm^2 |      N./mm^2 |
----------------------------------------------------------------
Long. Stress at Top    of Midspan         55.34 |       235.81 |
Long. Stress at Bottom of Midspan         71.66 |       235.81 |
Long. Stress at Top    of Saddles         88.70 |       235.81 |
Long. Stress at Bottom of Saddles         49.53 |       235.81 |
----------------------------------------------------------------
Tangential Shear in Shell                 12.16 |       188.65 |
Circ. Stress at Horn of Saddle            11.11 |       353.71 |
Circ. Compressive Stress in Shell          1.60 |       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 * ( 2.1/2 + 0 ) * 600.0/514.4191
  = 3.7 kN
```

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

```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 0.21, 0.0, 0 ) * 600.0/4000.0
  = 0.0 kN
```

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

```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 1.33, 0.0, 0 ) * 600.0/4000.0
  = 0.2 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 1/2 + 0 ) * 600.0/514.4191
  = 2.3 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 29 + Max( 0.0, 4, 0.2, 2 )
  = 32.6 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	33.20	kN
Transverse Shear Load Saddle	1.05	kN
Longitudinal Shear Load Saddle	1.33	kN

Hydrostatic Test Pressure at center of Vessel: 29.929 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  = 0.0529     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0434
 K7p = 0.0434
```

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)]
  = -33*992.0[1-(1-992.0/5880.0+(297.0²-0.0²)/
    (2*992.0*5880.0))/(1+(4*0.0)/(3*5880.0))]
  = -5213.5 N-m
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 33*5880/4(1+2(297²-0²)/(5880²))/(1+(4*0)/
    (3*5880))-4*992/5880
  = 15833.9 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 29.929 * 297.0/(2*7.0) - 15833.9/(pi*297.0²*7.0)
  = 55.34 N./mm^2
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 29.929 * 297.0/(2 * 7.0) + 15833.9/(pi * 297.0² * 7.0 )
  = 71.66 N./mm^2
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 29.929*297.0/(2*7.0)--5213.5/(0.1066*pi*297.0²*7.0)
  = 88.70 N./mm^2
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 29.929*297.0/(2*7.0)+-5213.5/(0.1923*pi*297.0²*7.0)
  = 49.53 N./mm^2
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 33( 5880.0 - 2 * 992.0)/(5880.0 + ( 4 * 0.0/3))
  = 21.6 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
 = K2 * T / ( Rm * t )
 = 1.1707 * 21.6/( 297.0 * 7.0 )
 = 12.16 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:
```
 = 0.78 * sqrt( Rm * t )
 = 0.78 * sqrt( 297.0 * 7.0 )
 = 35.565 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
 = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
 = - 0.7603 * 33 * 0.1/( 7.0 * ( 150.0 + 35.56 + 35.56 ) )
 = -1.60 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:
```
 = min( b + 1.56 * sqrt( Rm * t ), 2a  )
 = min( 150.0 + 1.56 * sqrt( 297.0 * 7.0 ), 2 * 992.0 )
 = 221.13 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 * 33 * 0.1/( 221.13( 7.0 + 1.0 * 10.0 ) )
 = -0.66 N./mm^2
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27) [sigma7,r]:
```
 = -Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)²)
 = -33/(4(7.0 + 1.0 * 10.0)221.13) -
    3 * 0.053 * 33/(2(7.0 + 1.0 * 10.0)²)
 = -11.11 N./mm^2
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	545.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	180.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	296.	7.	3.	21.	7245.	3.38
Wearplate	225.	10.	12.	22.	27000.	34.3
Web	10.	273.	154.	27.	420506.	0.817E+04
BasePlate	180.	16.	298.	29.	859680.	0.257E+05
Totals	...	...	...	99.	1314431.	0.339E+05

```
Value  C1 = Sumof(Ay)/Sumof(A)          =     132.      mm.
Value   I = Sumof(Io) - C1*Sumof(Ay)    =    0.165E+05  cm**4
Value  As = Sumof(A) - Ashell           =     78.6      cm^2

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

Fh = K1 * Q = 0.2035 * 32.6 = 6.6349 kN
```

```
Tension Stress, St = ( Fh/As )       =          0.8437  N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str =        124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin( theta )/ theta
  = 600.0 - 293.5 * sin( 1.0472 )/1.0472
  = 357.277 mm.
```

```
Bending Moment, M  = Fh * d          =       2371.4509  N-m

Bending Stress, Sb = ( M * C1 / I  ) =          1.9026  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(33 + 0.6)180.0/( 4 * 545.0 * 137.9 ))½
  = 7.722 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 542.9979/( 4 - 1 )
  = 180.999 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 181.0 * 180.0/2
  = 162.899 cm^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 162.9 * 0.03
  = 5.413 kN
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 14.0 + 9.05
  = 23.050 cm^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 5.4/23.05
  = 2.349 N./mm^2
```

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

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	10.0	150.0	...	15.0	...	281.

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * rl / 2
  = 1.3/( 2 * 545.0 ) * 181.0 * 427.25/2
  = 47.362 N-m
```

Compressive Allowable, KL/R < Cc (12.2313 < 138.1347) per AISC E2-1 [Sca]:

```
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.23 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(12.23)/(8* 138.13)-( 12.23³)/(8*138.13³)
  = 121.215 N./mm^2
```

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

= Sc/Sca + (Rm * Distance Side/I)/Sba
= 2.35/121.21 + (47.36 * 75.0/2812500)/137.9
= 0.029

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	0.0	14.0	0.0	281.
Web	181.0	10.0	0.0	18.1	0.0	1.51
Values	...	...	...	32.1	...	283.

Compressive Allowable, KL/R < Cc (9.5652 < 138.1347) per AISC E2-1 [Sca]:
= $(1-(Klr)^2/(2*Cc^2))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$
= $(1-(9.57)^2/(2 * 138.13^2)) * 207/$
$(5/3+3*(9.57)/(8* 138.13)-(9.57^3)/(8*138.13^3)$
= 121.916 N./mm^2

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

= Sc/Sca + (Rm * Distance Center/I)/Sba
= 3.33/121.92 + (62.93 * 75.0/282.675)/137.9
= 0.039

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	72.0	mm.
Nominal Bolt Diameter	Bnd	24.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	3.1275	cm^2
Saddle Load QO (Weight)	QO	29.5	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.2	kN
Maximum Transverse Force	Ft	1.1	kN
Maximum Longitudinal Force	Fl	1.3	kN
Saddle Bolted to Steel Foundation		Yes	

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)
= 1.33/(172.38 * 4.0)
= 0.0194 cm^2

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 600.0 * 1.05 + 0.0
= 631.76 N-m

Eccentricity (e):
= Rmom / QO

```
  = 631.76/29.51
  = 21.40 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, 0.0194, 0.0]
  = 0.0194 cm^2
```

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

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm      297.00  mm.
 Stiffened Vessel Length per 4.15.6               L     5880.00  mm.
 Distance from Saddle to Vessel tangent           a      992.00  mm.

 Saddle Width                                     b      150.00  mm.
 Saddle Bearing Angle                         theta      120.00  degrees

 Wear Plate Width                                b1      225.00  mm.
 Wear Plate Bearing Angle                    theta1      132.00  degrees
 Wear Plate Thickness                            tr        10.0  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                32.82  kN

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                         N./mm^2 |      N./mm^2 |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan         55.28 |       235.81 |
 Long. Stress at Bottom of Midspan         71.71 |       235.81 |
 Long. Stress at Top    of Saddles         88.87 |       235.81 |
 Long. Stress at Bottom of Saddles         49.43 |       235.81 |
 ----------------------------------------------------------------
 Tangential Shear in Shell                 12.25 |       188.65 |
 Circ. Stress at Horn of Saddle            11.19 |       353.71 |
 Circ. Compressive Stress in Shell          1.61 |       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 * ( 2.1/2 + 0 ) * 600.0/514.4191
  = 3.7 kN
```

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

```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 0.21, 0.0, 0 ) * 600.0/4000.0
  = 0.0 kN
```

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

```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 1.33, 0.0, 0 ) * 600.0/4000.0
  = 0.2 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 1/2 + 0 ) * 600.0/514.4191
  = 2.3 kN
```

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

```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 29 + Max( 0.0, 4, 0.2, 2 )
  = 32.8 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	33.42	kN
Transverse Shear Load Saddle	1.05	kN
Longitudinal Shear Load Saddle	1.33	kN

Hydrostatic Test Pressure at center of Vessel: 29.929 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 = 0.0529	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	K6p = 0.0434
K7p = 0.0434			

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)]
  = -33*992.0[1-(1-992.0/5880.0+(297.0²-0.0²)/
    (2*992.0*5880.0))/(1+(4*0.0)/(3*5880.0))]
  = -5248.8 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 33*5880/4(1+2(297²-0²)/(5880²))/(1+(4*0)/
    (3*5880))-4*992/5880
  = 15941.0 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 29.929 * 297.0/(2*7.0) - 15941.0/(pi*297.0²*7.0)
  = 55.28 N./mm^2
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 29.929 * 297.0/(2 * 7.0) + 15941.0/(pi * 297.0² * 7.0 )
  = 71.71 N./mm^2
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 29.929*297.0/(2*7.0)--5248.8/(0.1066*pi*297.0²*7.0)
  = 88.87 N./mm^2
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 29.929*297.0/(2*7.0)+-5248.8/(0.1923*pi*297.0²*7.0)
  = 49.43 N./mm^2
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 33( 5880.0 - 2 * 992.0)/(5880.0 + ( 4 * 0.0/3))
  = 21.7 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 21.75/( 297.0 * 7.0 )
  = 12.25 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 297.0 * 7.0 )
  = 35.565 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 33 * 0.1/( 7.0 * ( 150.0 + 35.56 + 35.56 ) )
  = -1.61 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 150.0 + 1.56 * sqrt( 297.0 * 7.0 ), 2 * 992.0 )
  = 221.13 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 * 33 * 0.1/( 221.13( 7.0 + 1.0 * 10.0 ) )
  = -0.66 N./mm^2
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27) [sigma7,r]:
```
  = -Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)²)
  = -33/(4(7.0 + 1.0 * 10.0)221.13) -
     3 * 0.053 * 33/(2(7.0 + 1.0 * 10.0)²)
  = -11.19 N./mm^2
```

Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	545.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	180.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	296.	7.	3.	21.	7245.	3.38
Wearplate	225.	10.	12.	22.	27000.	34.3
Web	10.	273.	154.	27.	420506.	0.817E+04
BasePlate	180.	16.	298.	29.	859680.	0.257E+05

```
 Totals             ... |         ... |         ... |         99. |    1314431. |   0.339E+05 |

 Value  C1 = Sumof(Ay)/Sumof(A)            =     132.      mm.
 Value   I = Sumof(Io) - C1*Sumof(Ay)      =    0.165E+05  cm**4
 Value  As = Sumof(A) - Ashell             =     78.6      cm^2

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

 Fh = K1 * Q = 0.2035 * 32.821 = 6.6797 kN

 Tension Stress, St = ( Fh/As )       =          0.8494  N./mm^2
 Allowed Stress, Sa = 0.6 * Yield Str =        124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin( theta )/ theta
  = 600.0 - 293.5 * sin( 1.0472 )/1.0472
  = 357.277 mm.

 Bending Moment, M  = Fh * d          =       2387.4902  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =          1.9155  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(33 + 0.6)180.0/( 4 * 545.0 * 137.9 ))½
  = 7.748 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 542.9979/( 4 - 1 )
  = 180.999 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 181.0 * 180.0/2
  = 162.899 cm^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 162.9 * 0.03
  = 5.450 kN
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 14.0 + 9.05
  = 23.050 cm^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 5.5/23.05
  = 2.365 N./mm^2
```

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

	B	D	Y	A	AY	Io
Rib+Web	10.0	150.0	...	15.0	...	281.

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * rl / 2
  = 1.3/( 2 * 545.0 ) * 181.0 * 427.25/2
  = 47.362 N-m
```

Compressive Allowable, KL/R < Cc (12.2313 < 138.1347) per AISC E2-1 [Sca]:

```
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.23 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(12.23)/(8* 138.13)-( 12.23³)/(8*138.13³)
  = 121.215 N./mm^2
```

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

```
  = Sc/Sca + ( Rm * Distance Side/I )/Sba
  = 2.36/121.21 + ( 47.36 * 75.0/2812500 )/137.9
  = 0.029
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	0.0	14.0	0.0	281.
Web	181.0	10.0	0.0	18.1	0.0	1.51
Values	...	...	...	32.1	...	283.

```
 Compressive Allowable, KL/R < Cc ( 9.5652 < 138.1347 ) per AISC E2-1 [Sca]:
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 9.57 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(9.57)/(8* 138.13)-( 9.57³)/(8*138.13³)
  = 121.916 N./mm^2
```

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

```
  = Sc/Sca + ( Rm * Distance Center/I )/Sba
  = 3.35/121.92 + ( 62.93 * 75.0/282.675 )/137.9
  = 0.040
```

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	72.0	mm.
Nominal Bolt Diameter	Bnd	24.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	3.1275	cm^2
Saddle Load QO (Weight)	QO	29.7	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.2	kN
Maximum Transverse Force	Ft	1.1	kN
Maximum Longitudinal Force	Fl	1.3	kN
Saddle Bolted to Steel Foundation		Yes	

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)
  = 1.33/(172.38 * 4.0)
  = 0.0194 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
= B * Ft + Sum of X Moments
= 600.0 * 1.05 + 0.0
= 631.76 N-m
```

Eccentricity (e):

```
= Rmom / QO
= 631.76/29.73
= 21.24 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, 0.0194, 0.0]
= 0.0194 cm^2
```

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
T4	...	OK	...	OK	6.22	OK	Passed
T1	...	OK	...	OK	7.95	OK	Passed
S2	...	OK	...	OK	7.94	OK	Passed
S1	...	OK	...	OK	7.94	OK	Passed
S3	...	OK	...	OK	7.80	OK	Passed
T2	...	OK	...	OK	7.94	OK	Passed
T3	...	OK	...	OK	6.42	OK	Passed

MAWP Summary:
Minimum MAWP Nozzles : 0.000 Nozzle : T3

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	T4	253.000	90.000	61.550
20	T1	253.000	270.000	201.662
40	S2	809.175	90.000	310.145
40	S1	6293.175	90.000	310.145
40	S3	759.175	270.000	113.600
60	T2	6849.351	90.000	310.145
60	T3	6852.351	270.000	68.000

The nozzle spacing is computed by the following:
= 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 !

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for ECONOMIZER E-PK6101-3
Nozzle Calcs.: T4 Nozl: 8 11:20pm Feb 6,2022

INPUT VALUES, Nozzle Description: T4 From : 20

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Normalized]		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	581.00	mm.
Design Length of Section	L	505.4167	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		253.00	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		0.7500	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	14.2500	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	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

Nozzle Sketch (may not represent actual weld type/configuration)

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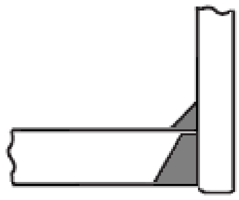
FileName : Calculation Book for ECONOMIZER E-PK6101-3
Nozzle Calcs.: T4 Nozl: 8 11:20pm Feb 6,2022



Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: T4

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation          0.750  in.
Actual Thickness Used in Calculation                0.561  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*293.5)/(138*1.0-0.6*23.0)
 = 4.9450 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
 = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
 = 12.525(exp([23.0/(137.9*1.0]-1)
 = 0.2107 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2845 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)            Dl    61.5500  mm.
Parallel to Vessel Wall                        Rn+tn+t    30.7750  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:

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

Weld Strength Reduction Factor [fr2]:

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

Weld Strength Reduction Factor [fr3]:

```
 = min( fr2, fr4 )
 = min( 1.0, 1.0 )
 = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.239	0.230	NA
Area in Shell	A1	0.750	1.886	NA
Area in Nozzle Wall	A2	3.864	3.838	NA

Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.630	0.630	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	5.244	6.354	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)
  = (25.05*4.945*1.0+2*11.25*4.945*1.0*(1-1.0))
  = 1.239 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 )
  = 36.5( 1.0 * 7.0 - 1.0 * 4.945 ) - 2 * 11.25
    ( 1.0 * 7.0 - 1.0 * 4.945 ) * ( 1 - 1.0 )
  = 0.750 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 11.25 - 0.21 )1.0
  = 3.864 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = ( Wo² - Area Lost )*fr2 + ( (Wi-can/0.707)² - Area Lost)*fr2
  = ( 8.0² - 0.01 ) * 1.0 + ( 0.0² -0.0 ) * 1.0
  = 0.630 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 3.2845 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 7.9450 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 7.9450 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                     tb3 = 6.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 6.22, max( 7.945, 4.5 ) ]
  = 6.2200 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.2845, 6.22 )
  = 6.2200 mm.
```

Available Nozzle Neck Thickness = 14.2500 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: D

Govrn. thk, tg = 10.0, tr = 4.945, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.706, Temp. Reduction = 16 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D            -48 °C
```

```
 Governing MDMT of all the sub-joints of this Junction   :   -48 °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: T4

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                         Required Thickness    Actual Thickness
 Nozzle Weld           4.9000 = 0.7 * tmin.  5.6560 = 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, (1.2387 - 0.7501 + 2 * 11.25 * 1.0 *
    (1.0 * 7.0 - 4.945 ) )138)
  = 13.11 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.8638 + 0.0 + 0.63 - 0.0 * 1.0 ) * 138
  = 61.96 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.8638 + 0.0 + 0.63 + ( 1.575 ) ) * 138
  = 83.68 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.8638 + 0.0 + 0.63 + 0.0 + ( 1.575 ) ) * 138
  = 83.68 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 ) * 47.55 * 8.0 * 0.49 * 138
  = 40. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 18.15) * ( 14.25 - 3.0 ) * 0.7 * 138
  = 62. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 47.55 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 53. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 40 + 62 ) = 102 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 40 + 0 + 53 + 0 ) = 94 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 40 + 53 + 0 ) = 94 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 102 kN , must exceed W = 13 kN  or W1 = 61 kN
 Path 2-2 = 93 kN , must exceed W = 13 kN  or W2 = 83 kN
 Path 3-3 = 93 kN , must exceed W = 13 kN  or W3 = 83 kN

 Nozzle is O.K. for the External Pressure                1.100   bars
```

The Drop for this Nozzle is : 0.9745 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 210.9745 mm.

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FileName : Calculation Book for ECONOMIZER E-PK6101-3
Nozzle Calcs.: T1 Nozl: 9 11:20pm Feb 6,2022

INPUT VALUES, Nozzle Description: T1 From : 20

Pressure for Reinforcement Calculations	P	23.030	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Normalized]		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	581.00	mm.
Design Length of Section	L	505.4167	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		253.00	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		4.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	120	
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	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		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	230.0000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		57.8500	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

```
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Tag no:E-PK6101-3     ECONOMIZER
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for ECONOMIZER E-PK6101-3
Nozzle Calcs.: T1                      Nozl:     9  11:20pm   Feb 6,2022
```
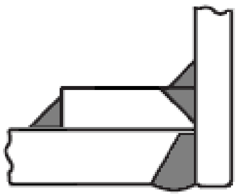

Nozzle Sketch (may not represent actual weld type/configuration)



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             4.500  in.
 Actual Thickness Used in Calculation                    0.383  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)
  = (23.03*293.5)/(138*1.0-0.6*23.03)
  = 4.9516 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)
  = (23.03*57.15)/(118*1.0+0.4*23.03)
  = 1.1077 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4740 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
 Parallel to Vessel Wall (Diameter Limit)             Dl   201.6618  mm.
 Parallel to Vessel Wall, opening length               d   100.8309  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000  mm.
```

Note: The Pad diameter is greater than the Diameter Limit. The excess will not be considered.

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	5.089	0.942	NA
Area in Shell	A1	2.025	5.108	NA
Area in Nozzle Wall	A2	1.684	1.873	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.545	0.545	NA
Area in Element	A5	6.552	6.552	NA
TOTAL AREA AVAILABLE	Atot	10.806	14.079	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:	125.4341	10.0000	mm.
Based on given Pad Diameter:	230.0000	1.2745	mm.
Based on Shell or Nozzle Thickness:	125.7377	9.7345	mm.

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (100.8309*4.9516*1.0+2*6.7345*4.9516*1.0*(1-0.86))
  = 5.089 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 )
  = 100.831( 1.0 * 7.0 - 1.0 * 4.952 ) - 2 * 6.735
    ( 1.0 * 7.0 - 1.0 * 4.9516 ) * ( 1 - 0.855 )
  = 2.025 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 17.5 ) * ( 6.73 - 1.11 ) * 0.855
  = 1.684 cm^2
```

Area Available in Welds [A41 + A42 + A43]:

```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.6375 ) * 0.86 + (0.0 ) * 0.86 + 0.0² * 1.0
  = 0.545 cm^2
```

Area Available in Element, also see UG-37(h) [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
  = ( 201.6618 - 114.3 )10.0 * 1.0 * 0.75
  = 6.552 cm^2
```

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

```
 Wall Thickness for Internal/External pressures        ta = 4.1077 mm.
 Wall Thickness per UG16(b),                         tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure        trb1 = 7.9516 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 7.9516 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                        tb3 = 8.2578 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 8.258, max( 7.9516, 4.5 ) ]
  = 7.9516 mm.
```

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

```
  = max( ta, tb )
  = max( 4.1077, 7.9516 )
  = 7.9516 mm.
```

Available Nozzle Neck Thickness = 9.7345 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  :     51.4,  Allowable :    117.9 N./mm^2  Passed
 Expansion  :      0.0,  Allowable :    243.4 N./mm^2  Passed
 Occasional :      8.1,  Allowable :    156.8 N./mm^2  Passed
 Shear      :     24.8,  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: B

Govrn. thk, tg = 9.735, tr = 1.108, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.164, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
```

Shell to Pad Weld Junction at Pad OD, min(Curve:B, Curve:D)

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.707, Temp. Reduction = 16 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -45 °C
```

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: D

Govrn. thk, tg = 9.735, tr = 1.108, c = 3.0 mm., E* = 1.0

Thickness Ratio = tr * (E*)/(tg - c) = 0.164, 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

Governing MDMT of the Nozzle                       :   -104 °C
Governing MDMT of the Reinforcement Pad            :    -45 °C
Governing MDMT of all the sub-joints of this Junction  :  -45 °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 = 23.03/51.10 = 0.451

Note:
Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: T1

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.7345  mm.
Intermediate Calc. for pad/shell Welds   TminPad      7.0000  mm.
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
Nozzle Weld           4.7142 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
Pad Weld              3.5000 = 0.5*TminPad  5.6560 = 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, (5.0894 - 2.0255 + 2 * 6.7345 * 0.855 *
    (1.0 * 7.0 - 4.9516 ) )138)
 = 45.50 kN
```

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

Weld Load [W1]:
```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 1.6838 + 6.5521 + 0.5451 - 0.0 * 0.86 ) * 138
 = 121.08 kN
```

Weld Load [W2]:
```
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 1.6838 + 0.0 + 0.5472 + ( 0.8061 ) ) * 138
 = 41.88 kN
```

Weld Load [W3]:
```
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = ( 1.6838 + 0.0 + 0.5451 + 6.5521 + ( 0.8061 ) ) * 138
 = 132.20 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 ) * 114.3 * 8.0 * 0.49 * 118
 = 83. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 230.0 * 8.0 * 0.49 * 138
  = 195. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 53.7827) * ( 9.7345 - 3.0 ) * 0.7 * 118
  = 94. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 114.3 * 10.0 * 0.74 * 138
  = 183. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 114.3 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 128. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 195 + 94 ) = 289 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 83 + 183 + 128 + 0 ) = 394 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 195 + 128 + 0 ) = 324 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 289 kN , must exceed W = 45 kN  or W1 = 121 kN
 Path 2-2 = 394 kN , must exceed W = 45 kN  or W2 = 41 kN
 Path 3-3 = 323 kN , must exceed W = 45 kN  or W3 = 132 kN

 Nozzle is O.K. for the External Pressure            1.100  bars
```

The Drop for this Nozzle is : 5.6770 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 215.6770 mm.

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    581.000  mm.
 Vessel Thickness                               Tv     10.000  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    114.300  mm.
 Nozzle Thickness                               Tn      9.735  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	10.000	mm.
Diameter of Reinforcing Pad	Dpad	230.000	mm.
Design Internal Pressure	Dp	23.030	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	4.0	kN
Longitudinal Shear	(SUS)	Vl	4.0	kN
Circumferential Shear	(SUS)	Vc	4.0	kN
Circumferential Moment	(SUS)	Mc	1700.0	N-m
Longitudinal Moment	(SUS)	Ml	1700.0	N-m
Torsional Moment	(SUS)	Mt	2100.0	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))
= 114.3 + 2 * 1.65 * sqrt(297.0 (10.0 - 3.0))
= 264.767 mm.

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	4.0	kN
Circumferential Shear	VC	4.0	kN
Longitudinal Shear	VL	4.0	kN
Circumferential Moment	MC	1700.0	N-m
Longitudinal Moment	ML	1700.0	N-m
Torsional Moment	MT	2100.0	N-m

Dimensionless Parameters used : Gamma = 17.76

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.166	4C	3.000	(A,B)
N(PHI) / (P/Rm)	0.166	3C	2.539	(C,D)
M(PHI) / (P)	0.166	2C1	0.077	(A,B)
M(PHI) / (P)	0.166	1C	0.107	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.166	3A	0.597	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.166	1A	0.095	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.166	3B	1.885	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.166	1B	0.044	(A,B,C,D)
N(x) / (P/Rm)	0.166	3C	2.539	(A,B)
N(x) / (P/Rm)	0.166	4C	3.000	(C,D)
M(x) / (P)	0.166	1C1	0.112	(A,B)
M(x) / (P)	0.166	2C	0.077	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.166	4A	0.893	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.166	2A	0.052	(A,B,C,D)


```
N(x)    / ( ML/(Rm**2 * Beta) )   0.166   4B        0.568   (A,B,C,D)
M(x)    / ( ML/(Rm    * Beta) )   0.166   2B        0.069   (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
Circ. Memb. P	-2.3	-2.3	-2.3	-2.3	-2.0	-2.0	-2.0	-2.0
Circ. Bend. P	-6.4	6.4	-6.4	6.4	-8.9	8.9	-8.9	8.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-4.0	-4.0	4.0	4.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-67.0	67.0	67.0	-67.0
Circ. Memb. ML	-12.5	-12.5	12.5	12.5	0.0	0.0	0.0	0.0
Circ. Bend. ML	-31.1	31.1	31.1	-31.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-52.3	22.7	34.9	-14.6	-81.8	69.9	60.0	-56.1
Long. Memb. P	-2.0	-2.0	-2.0	-2.0	-2.3	-2.3	-2.3	-2.3
Long. Bend. P	-9.3	9.3	-9.3	9.3	-6.4	6.4	-6.4	6.4
Long. Memb. MC	0.0	0.0	0.0	0.0	-5.9	-5.9	5.9	5.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-36.6	36.6	36.6	-36.6
Long. Memb. ML	-3.8	-3.8	3.8	3.8	0.0	0.0	0.0	0.0
Long. Bend. ML	-48.7	48.7	48.7	-48.7	0.0	0.0	0.0	0.0
Tot. Long. Str.	-63.7	52.3	41.2	-37.7	-51.2	34.7	33.8	-26.7
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Tot. Shear	7.3	7.3	4.7	4.7	4.7	4.7	7.3	7.3
Str. Int.	67.3	54.0	43.7	38.6	82.5	70.6	61.9	57.8

Dimensionless Parameters used : Gamma = 42.43

Dimensionless Loads for Cylindrical Shells at Pad edge:

```
-------------------------------------------------------------------
Curves read for 1979              Beta  Figure    Value  Location
-------------------------------------------------------------------
N(PHI) / ( P/Rm )                 0.339   4C        4.173   (A,B)
N(PHI) / ( P/Rm )                 0.339   3C        1.862   (C,D)
M(PHI) / ( P )                    0.339   2C1       0.012   (A,B)
M(PHI) / ( P )                    0.339   1C   !    0.063   (C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )    0.339   3A        1.336   (A,B,C,D)
M(PHI) / ( MC/(Rm    * Beta) )    0.339   1A        0.064   (A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )    0.339   3B        2.607   (A,B,C,D)
M(PHI) / ( ML/(Rm    * Beta) )    0.339   1B        0.010   (A,B,C,D)

N(x)    / ( P/Rm )                0.339   3C        1.862   (A,B)
N(x)    / ( P/Rm )                0.339   4C        4.173   (C,D)
M(x)    / ( P )                   0.339   1C1       0.030   (A,B)
M(x)    / ( P )                   0.339   2C   !    0.032   (C,D)
N(x)    / ( MC/(Rm**2 * Beta) )   0.339   4A        4.079   (A,B,C,D)
M(x)    / ( MC/(Rm    * Beta) )   0.339   2A        0.025   (A,B,C,D)
N(x)    / ( ML/(Rm**2 * Beta) )   0.339   4B        1.423   (A,B,C,D)
M(x)    / ( ML/(Rm    * Beta) )   0.339   2B        0.016   (A,B,C,D)
```

Note - The ! mark next to the figure name denotes curve value exceeded.

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (N./mm^2)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-8.0	-8.0	-8.0	-8.0	-3.6	-3.6	-3.6	-3.6
Circ. Bend. P	-5.9	5.9	-5.9	5.9	-30.9	30.9	-30.9	30.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-10.9	-10.9	10.9	10.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-131.6	131.6	131.6	-131.6
Circ. Memb. ML	-21.2	-21.2	21.2	21.2	0.0	0.0	0.0	0.0
Circ. Bend. ML	-20.1	20.1	20.1	-20.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-55.3	-3.2	27.3	-1.0	-177.0	148.1	107.9	-93.4
Long. Memb. P	-3.6	-3.6	-3.6	-3.6	-8.0	-8.0	-8.0	-8.0
Long. Bend. P	-14.7	14.7	-14.7	14.7	-15.9	15.9	-15.9	15.9
Long. Memb. MC	0.0	0.0	0.0	0.0	-33.1	-33.1	33.1	33.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-52.3	52.3	52.3	-52.3
Long. Memb. ML	-11.6	-11.6	11.6	11.6	0.0	0.0	0.0	0.0
Long. Bend. ML	-32.6	32.6	32.6	-32.6	0.0	0.0	0.0	0.0
Tot. Long. Str.	-62.4	32.1	25.8	-9.9	-109.4	27.1	61.5	-11.3
Shear VC	1.6	1.6	-1.6	-1.6	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.6	-1.6	1.6	1.6
Shear MT	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Tot. Shear	5.2	5.2	2.0	2.0	2.0	2.0	5.2	5.2
Str. Int.	65.1	36.8	28.7	10.3	177.0	148.1	108.5	93.7

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)	38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Circ. Pl (SUS)	-14.8	-14.8	10.1	10.1	-5.9	-5.9	2.0	2.0
Circ. Q (SUS)	-37.5	37.5	24.7	-24.7	-75.9	75.9	58.0	-58.0
Long. Pm (SUS)	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Long. Pl (SUS)	-5.7	-5.7	1.8	1.8	-8.2	-8.2	3.6	3.6
Long. Q (SUS)	-58.0	58.0	39.4	-39.4	-43.0	43.0	30.2	-30.2
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q (SUS)	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Pm (SUS)	38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Pm+Pl (SUS)	24.0	26.3	48.8	51.1	32.8	35.1	40.7	43.0
Pm+Pl+Q (Total)	46.1	75.9	75.0	45.7	44.9	111.3	99.8	19.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	40.95	137.90	Passed
Pm+Pl (SUS)	51.14	206.85	Passed
Pm+Pl+Q (TOTAL)	111.28	413.70	Passed

WRC 107/537 Stress Summations:

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	95.4	97.7	95.4	97.7	95.4	97.7	95.4	97.7
Circ. Pl (SUS)	-29.2	-29.2	13.1	13.1	-14.4	-14.4	7.3	7.3
Circ. Q (SUS)	-26.0	26.0	14.1	-14.1	-162.5	162.5	100.6	-100.6
Long. Pm (SUS)	47.7	47.7	47.7	47.7	47.7	47.7	47.7	47.7
Long. Pl (SUS)	-15.1	-15.1	8.0	8.0	-41.2	-41.2	25.1	25.1
Long. Q (SUS)	-47.2	47.2	17.9	-17.9	-68.2	68.2	36.4	-36.4
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.6	1.6	-1.6	-1.6	-1.6	-1.6	1.6	1.6
Shear Q (SUS)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Pm (SUS)	95.4	97.7	95.4	97.7	95.4	97.7	95.4	97.7
Pm+Pl (SUS)	66.3	68.6	108.6	110.9	81.0	83.3	102.8	105.1
Pm+Pl+Q (Total)	55.8	96.2	122.8	96.8	81.7	245.8	203.6	37.2

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	97.73	137.90	Passed
Pm+Pl (SUS)	110.93	206.85	Passed
Pm+Pl+Q (TOTAL)	245.85	413.70	Passed

INPUT VALUES, Nozzle Description: S2 From : 40

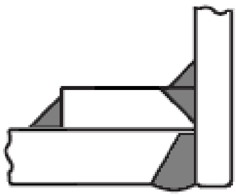
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	581.00	mm.
Design Length of Section	L	5880.0005	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		809.18	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		6.0000	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	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		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	290.0000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		60.8625	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             6.625  in.
Actual Thickness Used in Calculation                    0.378  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*293.5)/(138*1.0-0.6*23.0)
  = 4.9450 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*84.1375)/(118*1.0+0.4*23.0)
  = 1.6287 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5944 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)            Dl    310.1452  mm.
Parallel to Vessel Wall, opening length              d    155.0726  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     17.5000  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	7.763	4.029	NA
Area in Shell	A1	3.147	2.860	NA
Area in Nozzle Wall	A2	1.488	1.798	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.185	1.185	NA
Area in Element	A5	12.172	12.172	NA
TOTAL AREA AVAILABLE	Atot	17.993	18.015	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:	187.6997	10.0000	mm.
Based on given Pad Diameter:	290.0000	1.5958	mm.
Based on Shell or Nozzle Thickness:	188.5066	9.6012	mm.

Area Required [A]:
```
= ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
= (155.0726*4.945*1.0+2*6.6012*4.945*1.0*(1-0.86))
= 7.763 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 )
= 155.073( 1.0 * 7.0 - 1.0 * 4.945 ) - 2 * 6.601
  ( 1.0 * 7.0 - 1.0 * 4.945 ) * ( 1 - 0.855 )
= 3.147 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
= ( 2 * Tlwp ) * ( tn - trn ) * fr2
= ( 2 * 17.5 ) * ( 6.6 - 1.63 ) * 0.855
= 1.488 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
= (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
= ( 0.6375 ) * 0.86 + (0.0 ) * 0.86 + 203.2² * 1.0
= 1.185 cm^2
```

Area Available in Element [A5]:
```
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= ( 290.0 - 168.275 ) * 10.0 * 1.0
= 12.172 cm^2
```

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

```
Wall Thickness for Internal/External pressures         ta = 4.6287 mm.
Wall Thickness per UG16(b),                         tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure        trb1 = 7.9450 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 7.9450 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                        tb3 = 9.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:


```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.22, max( 7.945, 4.5 ) ]
  = 7.9450 mm.
```

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

```
  = max( ta, tb )
  = max( 4.6287, 7.945 )
  = 7.9450 mm.
```

Available Nozzle Neck Thickness = 9.6012 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   :     55.9,  Allowable :    117.9 N./mm^2  Passed
 Expansion   :      0.0,  Allowable :    238.8 N./mm^2  Passed
 Occasional  :     13.0,  Allowable :    156.8 N./mm^2  Passed
 Shear       :     24.1,  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: B

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.247, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

Shell to Pad Weld Junction at Pad OD, min(Curve:B, Curve:D)

Govrn. thk, tg = 10.0, tr = 4.945, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.706, Temp. Reduction = 16 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)            -45 °C
```

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: D

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.247, 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

Governing MDMT of the Nozzle                          :  -104 °C
Governing MDMT of the Reinforcement Pad               :   -45 °C
Governing MDMT of all the sub-joints of this Junction :   -45 °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: S2

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.6012  mm.
Intermediate Calc. for pad/shell Welds   TminPad      7.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.6208 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	3.5000 = 0.5*TminPad	5.6560 = 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, (7.763 - 3.1474 + 2 * 6.6012 * 0.855 *
     (1.0 * 7.0 - 4.945 ) )138)
  = 66.84 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.488 + 12.1725 + 1.1851 - 0.0 * 0.86 ) * 138
  = 204.70 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.488 + 0.0 + 0.5472 + ( 0.7902 ) ) * 138
  = 38.96 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.488 + 0.0 + 1.1851 + 12.1725 + ( 0.7902 ) ) * 138
  = 215.60 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 ) * 168.275 * 8.0 * 0.49 * 118
  = 122. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 290.0 * 8.0 * 0.49 * 138
  = 246. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 80.8369) * ( 9.6012 - 3.0 ) * 0.7 * 118
  = 138. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 168.275 * 10.0 * 0.74 * 138
  = 270. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 168.275 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 189. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 246 + 138 ) = 385 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 122 + 270 + 189 + 0 ) = 581 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 246 + 189 + 0 ) = 435 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 384 kN , must exceed W = 66 kN  or W1 = 204 kN
 Path 2-2 = 580 kN , must exceed W = 66 kN  or W2 = 38 kN
 Path 3-3 = 435 kN , must exceed W = 66 kN  or W3 = 215 kN

 Nozzle is O.K. for the External Pressure              1.100  bars
```

The Drop for this Nozzle is : 12.4512 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.4512 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    581.000  mm.
 Vessel Thickness                                 Tv     10.000  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    168.275  mm.
 Nozzle Thickness                                 Tn      9.601  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      10.000  mm.
 Diameter  of Reinforcing Pad                   Dpad     290.000  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           6.0  kN
 Longitudinal Shear       (SUS)                   Vl          6.0  kN
 Circumferential Shear    (SUS)                   Vc          6.0  kN
 Circumferential Moment   (SUS)                   Mc       3800.0  N-m
 Longitudinal Moment      (SUS)                   Ml       3800.0  N-m
 Torsional Moment         (SUS)                   Mt       4700.0  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 ) )
  = 168.275 + 2 * 1.65 * sqrt( 297.0 ( 10.0 - 3.0 ) )
  = 318.742 mm.
```

WRC 107 Stress Calculation for SUStained loads:

```
 Radial Load                                     P           6.0  kN
 Circumferential Shear                           VC          6.0  kN
 Longitudinal Shear                              VL          6.0  kN
 Circumferential Moment                          MC       3800.0  N-m
 Longitudinal Moment                             ML       3800.0  N-m
 Torsional Moment                                MT       4700.0  N-m

 Dimensionless Parameters used :    Gamma =    17.76
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

```
 -------------------------------------------------------------------
 Curves read for 1979                 Beta  Figure     Value   Location
 -------------------------------------------------------------------
 N(PHI) / ( P/Rm )                   0.244   4C         2.697   (A,B)
 N(PHI) / ( P/Rm )                   0.244   3C         1.952   (C,D)
 M(PHI) / ( P )                      0.244   2C1        0.045   (A,B)
 M(PHI) / ( P )                      0.244   1C         0.074   (C,D)
 N(PHI) / ( MC/(Rm**2 * Beta) )      0.244   3A         0.734   (A,B,C,D)
 M(PHI) / ( MC/(Rm     * Beta) )     0.244   1A         0.085   (A,B,C,D)
 N(PHI) / ( ML/(Rm**2 * Beta) )      0.244   3B         1.941   (A,B,C,D)
 M(PHI) / ( ML/(Rm     * Beta) )     0.244   1B         0.032   (A,B,C,D)

 N(x)   / ( P/Rm )                   0.244   3C         1.952   (A,B)
 N(x)   / ( P/Rm )                   0.244   4C         2.697   (C,D)
 M(x)   / ( P )                      0.244   1C1        0.077   (A,B)
 M(x)   / ( P )                      0.244   2C         0.045   (C,D)
 N(x)   / ( MC/(Rm**2 * Beta) )      0.244   4A         1.267   (A,B,C,D)
 M(x)   / ( MC/(Rm     * Beta) )     0.244   2A         0.044   (A,B,C,D)
 N(x)   / ( ML/(Rm**2 * Beta) )      0.244   4B         0.709   (A,B,C,D)
 M(x)   / ( ML/(Rm     * Beta) )     0.244   2B         0.051   (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	-3.2	-3.2	-3.2	-3.2	-2.3	-2.3	-2.3	-2.3
Circ. Bend.	P	-5.6	5.6	-5.6	5.6	-9.2	9.2	-9.2	9.2
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-7.4	-7.4	7.4	7.4
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-91.0	91.0	91.0	-91.0
Circ. Memb.	ML	-19.5	-19.5	19.5	19.5	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-33.9	33.9	33.9	-33.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-62.2	16.8	44.6	-11.9	-109.9	90.5	86.9	-76.7
Long. Memb.	P	-2.3	-2.3	-2.3	-2.3	-3.2	-3.2	-3.2	-3.2
Long. Bend.	P	-9.6	9.6	-9.6	9.6	-5.6	5.6	-5.6	5.6
Long. Memb.	MC	0.0	0.0	0.0	0.0	-12.7	-12.7	12.7	12.7
Long. Bend.	MC	0.0	0.0	0.0	0.0	-47.2	47.2	47.2	-47.2
Long. Memb.	ML	-7.1	-7.1	7.1	7.1	0.0	0.0	0.0	0.0
Long. Bend.	ML	-55.1	55.1	55.1	-55.1	0.0	0.0	0.0	0.0
Tot. Long. Str.		-74.1	55.2	50.4	-40.7	-68.7	37.0	51.2	-32.1
Shear	VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear	MT	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Tot. Shear		7.5	7.5	4.9	4.9	4.9	4.9	7.5	7.5
Str. Int.		77.7	56.7	53.2	41.5	110.4	91.0	88.4	77.9

Dimensionless Parameters used : Gamma = 42.43

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.427	4C	3.340	(A,B)
N(PHI) / (P/Rm)	0.427	3C	1.296	(C,D)
M(PHI) / (P)	0.427	2C1	0.008	(A,B)
M(PHI) / (P)	0.427	1C !	0.063	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.427	3A	1.071	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.427	1A	0.061	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.427	3B	1.851	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.427	1B	0.006	(A,B,C,D)
N(x) / (P/Rm)	0.427	3C	1.296	(A,B)
N(x) / (P/Rm)	0.427	4C	3.340	(C,D)
M(x) / (P)	0.427	1C1	0.019	(A,B)
M(x) / (P)	0.427	2C !	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.427	4A	4.057	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.427	2A	0.024	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.427	4B	1.123	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.427	2B	0.010	(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	-9.6	-9.6	-9.6	-9.6	-3.7	-3.7	-3.7	-3.7
Circ. Bend. P	-5.6	5.6	-5.6	5.6	-46.4	46.4	-46.4	46.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-15.4	-15.4	15.4	15.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-222.1	222.1	222.1	-222.1
Circ. Memb. ML	-26.7	-26.7	26.7	26.7	0.0	0.0	0.0	0.0
Circ. Bend. ML	-22.7	22.7	22.7	-22.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-64.6	-8.0	34.1	-0.1	-287.6	249.3	187.3	-164.0
Long. Memb. P	-3.7	-3.7	-3.7	-3.7	-9.6	-9.6	-9.6	-9.6
Long. Bend. P	-13.7	13.7	-13.7	13.7	-23.9	23.9	-23.9	23.9
Long. Memb. MC	0.0	0.0	0.0	0.0	-58.4	-58.4	58.4	58.4
Long. Bend. MC	0.0	0.0	0.0	0.0	-89.1	89.1	89.1	-89.1
Long. Memb. ML	-16.2	-16.2	16.2	16.2	0.0	0.0	0.0	0.0
Long. Bend. ML	-38.1	38.1	38.1	-38.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-71.7	31.9	36.8	-11.9	-181.1	44.9	114.1	-16.5
Shear VC	1.9	1.9	-1.9	-1.9	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.9	-1.9	1.9	1.9
Shear MT	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Tot. Shear	7.0	7.0	3.2	3.2	3.2	3.2	7.0	7.0
Str. Int.	76.0	42.3	38.9	13.4	287.7	249.4	188.0	164.3

(Stress Intensity Values at)

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)	38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Circ. Pl (SUS)	-22.7	-22.7	16.4	16.4	-9.7	-9.7	5.1	5.1
Circ. Q (SUS)	-39.5	39.5	28.2	-28.2	-100.2	100.2	81.8	-81.8
Long. Pm (SUS)	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Long. Pl (SUS)	-9.4	-9.4	4.8	4.8	-15.9	-15.9	9.6	9.6
Long. Q (SUS)	-64.6	64.6	45.5	-45.5	-52.8	52.8	41.6	-41.6
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q (SUS)	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Pm (SUS)	38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Pm+Pl (SUS)	16.2	18.4	55.0	57.3	29.0	31.3	43.8	46.1
Pm+Pl+Q (Total)	56.5	77.4	84.8	51.3	72.3	131.8	126.5	38.0

(Stress Intensity Values at)

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	40.89	137.90	Passed
Pm+Pl (SUS)	57.30	206.85	Passed
Pm+Pl+Q (TOTAL)	131.75	413.70	Passed

WRC 107/537 Stress Summations:

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Circ. Pl (SUS)	-36.3	-36.3	17.0	17.0	-19.2	-19.2	11.7	11.7
Circ. Q (SUS)	-28.3	28.3	17.1	-17.1	-268.5	268.5	175.7	-175.7
Long. Pm (SUS)	47.7	47.7	47.7	47.7	47.7	47.7	47.7	47.7
Long. Pl (SUS)	-19.9	-19.9	12.4	12.4	-68.1	-68.1	48.8	48.8
Long. Q (SUS)	-51.8	51.8	24.4	-24.4	-113.0	113.0	65.3	-65.3
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.9	1.9	-1.9	-1.9	-1.9	-1.9	1.9	1.9
Shear Q (SUS)	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Pm (SUS)	95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Pm+Pl (SUS)	59.1	61.4	112.4	114.7	96.6	98.9	107.3	109.6
Pm+Pl+Q (Total)	56.5	93.2	129.7	97.7	192.5	347.0	283.0	98.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	97.61	137.90	Passed
Pm+Pl (SUS)	114.68	206.85	Passed
Pm+Pl+Q (TOTAL)	346.96	413.70	Passed

INPUT VALUES, Nozzle Description: S1 From : 40

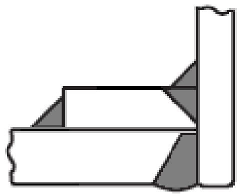
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	581.00	mm.
Design Length of Section	L	5880.0005	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		6293.18	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		6.0000	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	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		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	290.0000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		60.8625	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            6.625  in.
Actual Thickness Used in Calculation                   0.378  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*293.5)/(138*1.0-0.6*23.0)
= 4.9450 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*84.1375)/(118*1.0+0.4*23.0)
= 1.6287 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5944 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl   310.1452  mm.
Parallel to Vessel Wall, opening length              d   155.0726  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp    17.5000  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	7.763	4.029	NA
Area in Shell	A1	3.147	2.860	NA
Area in Nozzle Wall	A2	1.488	1.798	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.185	1.185	NA
Area in Element	A5	12.172	12.172	NA
TOTAL AREA AVAILABLE	Atot	17.993	18.015	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:	187.6997	10.0000	mm.
Based on given Pad Diameter:	290.0000	1.5958	mm.
Based on Shell or Nozzle Thickness:	188.5066	9.6012	mm.

Area Required [A]:
```
= ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
= (155.0726*4.945*1.0+2*6.6012*4.945*1.0*(1-0.86))
= 7.763 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 )
= 155.073( 1.0 * 7.0 - 1.0 * 4.945 ) - 2 * 6.601
  ( 1.0 * 7.0 - 1.0 * 4.945 ) * ( 1 - 0.855 )
= 3.147 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
= ( 2 * Tlwp ) * ( tn - trn ) * fr2
= ( 2 * 17.5 ) * ( 6.6 - 1.63 ) * 0.855
= 1.488 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
= (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
= ( 0.6375 ) * 0.86 + (0.0 ) * 0.86 + 203.2² * 1.0
= 1.185 cm^2
```

Area Available in Element [A5]:
```
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= ( 290.0 - 168.275 ) * 10.0 * 1.0
= 12.172 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures          ta = 4.6287 mm.
Wall Thickness per UG16(b),                          tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure         trb1 = 7.9450 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 7.9450 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                         tb3 = 9.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.22, max( 7.945, 4.5 ) ]
  = 7.9450 mm.
```

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

```
  = max( ta, tb )
  = max( 4.6287, 7.945 )
  = 7.9450 mm.
```

Available Nozzle Neck Thickness = 9.6012 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   :     55.9,  Allowable :    117.9 N./mm^2  Passed
 Expansion   :      0.0,  Allowable :    238.8 N./mm^2  Passed
 Occasional  :     13.0,  Allowable :    156.8 N./mm^2  Passed
 Shear       :     24.1,  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: B

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.247, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

Shell to Pad Weld Junction at Pad OD, min(Curve:B, Curve:D)

Govrn. thk, tg = 10.0, tr = 4.945, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.706, Temp. Reduction = 16 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)            -45 °C
```

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: D

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.247, 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

Governing MDMT of the Nozzle                             :  -104 °C
Governing MDMT of the Reinforcement Pad                  :   -45 °C
Governing MDMT of all the sub-joints of this Junction    :   -45 °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: S1

```
Intermediate Calc. for nozzle/shell Welds   Tmin       6.6012  mm.
Intermediate Calc. for pad/shell Welds    TminPad      7.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.6208 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
Pad Weld             3.5000 = 0.5*TminPad  5.6560 = 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, (7.763 - 3.1474 + 2 * 6.6012 * 0.855 *
     (1.0 * 7.0 - 4.945 ) )138)
  = 66.84 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.488 + 12.1725 + 1.1851 - 0.0 * 0.86 ) * 138
  = 204.70 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.488 + 0.0 + 0.5472 + ( 0.7902 ) ) * 138
  = 38.96 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.488 + 0.0 + 1.1851 + 12.1725 + ( 0.7902 ) ) * 138
  = 215.60 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 ) * 168.275 * 8.0 * 0.49 * 118
  = 122. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 290.0 * 8.0 * 0.49 * 138
  = 246. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 80.8369) * ( 9.6012 - 3.0 ) * 0.7 * 118
  = 138. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 168.275 * 10.0 * 0.74 * 138
  = 270. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 168.275 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 189. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 246 + 138 ) = 385 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 122 + 270 + 189 + 0 ) = 581 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 246 + 189 + 0 ) = 435 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 384 kN , must exceed W = 66 kN  or W1 = 204 kN
 Path 2-2 = 580 kN , must exceed W = 66 kN  or W2 = 38 kN
 Path 3-3 = 435 kN , must exceed W = 66 kN  or W3 = 215 kN

 Nozzle is O.K. for the External Pressure               1.100   bars
```

The Drop for this Nozzle is : 12.4512 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.4512 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    581.000  mm.
 Vessel Thickness                               Tv     10.000  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    168.275  mm.
 Nozzle Thickness                               Tn      9.601  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     10.000  mm.
 Diameter  of Reinforcing Pad                 Dpad    290.000  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	6.0	kN
Longitudinal Shear	(SUS)	Vl	6.0	kN
Circumferential Shear	(SUS)	Vc	6.0	kN
Circumferential Moment	(SUS)	Mc	3800.0	N-m
Longitudinal Moment	(SUS)	Ml	3800.0	N-m
Torsional Moment	(SUS)	Mt	4700.0	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 ) )
  = 168.275 + 2 * 1.65 * sqrt( 297.0 ( 10.0 - 3.0 ) )
  = 318.742 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	6.0	kN
Circumferential Shear	VC	6.0	kN
Longitudinal Shear	VL	6.0	kN
Circumferential Moment	MC	3800.0	N-m
Longitudinal Moment	ML	3800.0	N-m
Torsional Moment	MT	4700.0	N-m

Dimensionless Parameters used : Gamma = 17.76

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.244	4C	2.697	(A,B)
N(PHI) / (P/Rm)	0.244	3C	1.952	(C,D)
M(PHI) / (P)	0.244	2C1	0.045	(A,B)
M(PHI) / (P)	0.244	1C	0.074	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.244	3A	0.734	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.244	1A	0.085	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.244	3B	1.941	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.244	1B	0.032	(A,B,C,D)
N(x) / (P/Rm)	0.244	3C	1.952	(A,B)
N(x) / (P/Rm)	0.244	4C	2.697	(C,D)
M(x) / (P)	0.244	1C1	0.077	(A,B)
M(x) / (P)	0.244	2C	0.045	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.244	4A	1.267	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.244	2A	0.044	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.244	4B	0.709	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.244	2B	0.051	(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	-3.2	-3.2	-3.2	-3.2	-2.3	-2.3	-2.3	-2.3
Circ. Bend. P	-5.6	5.6	-5.6	5.6	-9.2	9.2	-9.2	9.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-7.4	-7.4	7.4	7.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-91.0	91.0	91.0	-91.0
Circ. Memb. ML	-19.5	-19.5	19.5	19.5	0.0	0.0	0.0	0.0
Circ. Bend. ML	-33.9	33.9	33.9	-33.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-62.2	16.8	44.6	-11.9	-109.9	90.5	86.9	-76.7
Long. Memb. P	-2.3	-2.3	-2.3	-2.3	-3.2	-3.2	-3.2	-3.2
Long. Bend. P	-9.6	9.6	-9.6	9.6	-5.6	5.6	-5.6	5.6
Long. Memb. MC	0.0	0.0	0.0	0.0	-12.7	-12.7	12.7	12.7
Long. Bend. MC	0.0	0.0	0.0	0.0	-47.2	47.2	47.2	-47.2
Long. Memb. ML	-7.1	-7.1	7.1	7.1	0.0	0.0	0.0	0.0
Long. Bend. ML	-55.1	55.1	55.1	-55.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-74.1	55.2	50.4	-40.7	-68.7	37.0	51.2	-32.1
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Tot. Shear	7.5	7.5	4.9	4.9	4.9	4.9	7.5	7.5
Str. Int.	77.7	56.7	53.2	41.5	110.4	91.0	88.4	77.9

Dimensionless Parameters used : Gamma = 42.43

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.427	4C	3.340	(A,B)
N(PHI) / (P/Rm)	0.427	3C	1.296	(C,D)
M(PHI) / (P)	0.427	2C1	0.008	(A,B)
M(PHI) / (P)	0.427	1C !	0.063	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.427	3A	1.071	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.427	1A	0.061	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.427	3B	1.851	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.427	1B	0.006	(A,B,C,D)
N(x) / (P/Rm)	0.427	3C	1.296	(A,B)
N(x) / (P/Rm)	0.427	4C	3.340	(C,D)
M(x) / (P)	0.427	1C1	0.019	(A,B)
M(x) / (P)	0.427	2C !	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.427	4A	4.057	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.427	2A	0.024	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.427	4B	1.123	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.427	2B	0.010	(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	-9.6	-9.6	-9.6	-9.6	-3.7	-3.7	-3.7	-3.7
Circ. Bend. P	-5.6	5.6	-5.6	5.6	-46.4	46.4	-46.4	46.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-15.4	-15.4	15.4	15.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-222.1	222.1	222.1	-222.1
Circ. Memb. ML	-26.7	-26.7	26.7	26.7	0.0	0.0	0.0	0.0
Circ. Bend. ML	-22.7	22.7	22.7	-22.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-64.6	-8.0	34.1	-0.1	-287.6	249.3	187.3	-164.0
Long. Memb. P	-3.7	-3.7	-3.7	-3.7	-9.6	-9.6	-9.6	-9.6
Long. Bend. P	-13.7	13.7	-13.7	13.7	-23.9	23.9	-23.9	23.9
Long. Memb. MC	0.0	0.0	0.0	0.0	-58.4	-58.4	58.4	58.4
Long. Bend. MC	0.0	0.0	0.0	0.0	-89.1	89.1	89.1	-89.1
Long. Memb. ML	-16.2	-16.2	16.2	16.2	0.0	0.0	0.0	0.0
Long. Bend. ML	-38.1	38.1	38.1	-38.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-71.7	31.9	36.8	-11.9	-181.1	44.9	114.1	-16.5
Shear VC	1.9	1.9	-1.9	-1.9	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.9	-1.9	1.9	1.9
Shear MT	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Tot. Shear	7.0	7.0	3.2	3.2	3.2	3.2	7.0	7.0
Str. Int.	76.0	42.3	38.9	13.4	287.7	249.4	188.0	164.3

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)	38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Circ. Pl (SUS)	-22.7	-22.7	16.4	16.4	-9.7	-9.7	5.1	5.1
Circ. Q (SUS)	-39.5	39.5	28.2	-28.2	-100.2	100.2	81.8	-81.8
Long. Pm (SUS)	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Long. Pl (SUS)	-9.4	-9.4	4.8	4.8	-15.9	-15.9	9.6	9.6
Long. Q (SUS)	-64.6	64.6	45.5	-45.5	-52.8	52.8	41.6	-41.6
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q (SUS)	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Pm (SUS)	38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Pm+Pl (SUS)	16.2	18.4	55.0	57.3	29.0	31.3	43.8	46.1
Pm+Pl+Q (Total)	56.5	77.4	84.8	51.3	72.3	131.8	126.5	38.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	40.89	137.90	Passed
Pm+Pl (SUS)	57.30	206.85	Passed
Pm+Pl+Q (TOTAL)	131.75	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)	95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Circ. Pl (SUS)	-36.3	-36.3	17.0	17.0	-19.2	-19.2	11.7	11.7
Circ. Q (SUS)	-28.3	28.3	17.1	-17.1	-268.5	268.5	175.7	-175.7
Long. Pm (SUS)	47.7	47.7	47.7	47.7	47.7	47.7	47.7	47.7
Long. Pl (SUS)	-19.9	-19.9	12.4	12.4	-68.1	-68.1	48.8	48.8
Long. Q (SUS)	-51.8	51.8	24.4	-24.4	-113.0	113.0	65.3	-65.3
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.9	1.9	-1.9	-1.9	-1.9	-1.9	1.9	1.9
Shear Q (SUS)	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Pm (SUS)	95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Pm+Pl (SUS)	59.1	61.4	112.4	114.7	96.6	98.9	107.3	109.6
Pm+Pl+Q (Total)	56.5	93.2	129.7	97.7	192.5	347.0	283.0	98.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	97.61	137.90	Passed
Pm+Pl (SUS)	114.68	206.85	Passed
Pm+Pl+Q (TOTAL)	346.96	413.70	Passed

INPUT VALUES, Nozzle Description: S3 From : 40

Pressure for Reinforcement Calculations	P	23.034	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Normalized]		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	581.00	mm.
Design Length of Section	L	5880.0005	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		759.18	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

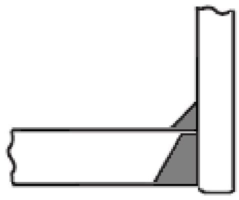
Type of Element Connected to the Shell : Nozzle

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	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	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:E-PK6101-3 ECONOMIZER
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for ECONOMIZER E-PK6101-3
Nozzle Calcs.: S3 Nozl: 12 11:20pm Feb 6,2022



Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: S3

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)
= (23.03*293.5)/(138*1.0-0.6*23.03)
= 4.9524 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)
= 0.4792 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3963 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)          Dl   113.6000  mm.
Parallel to Vessel Wall, opening length            d    56.8000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
= min( 1, Sn/Sv )
= min( 1, 137.9/137.9 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:
```
= min( 1, Sn/Sv )
= min( 1, 137.9/137.9 )
= 1.000
```

Weld Strength Reduction Factor [fr3]:
```
= min( fr2, fr4 )
= min( 1.0, 1.0 )
= 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.813	1.458	NA
Area in Shell	A1	1.163	1.061	NA
Area in Nozzle Wall	A2	4.592	4.621	NA

Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	6.395	6.322	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*4.9524*1.0+2*13.6*4.9524*1.0*(1-1.0))
  = 2.813 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 )
  = 56.8( 1.0 * 7.0 - 1.0 * 4.952 ) - 2 * 13.6
    ( 1.0 * 7.0 - 1.0 * 4.9524 ) * ( 1 - 1.0 )
  = 1.163 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 13.6 - 0.48 )1.0
  = 4.592 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 8.0² * 1.0 + ( 0.0 )² * 1.0
  = 0.640 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 3.4792 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 7.9524 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 7.9524 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( 7.9524, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.4792, 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   :     16.5,  Allowable :    137.9 N./mm^2  Passed
 Expansion   :      0.0,  Allowable :    328.2 N./mm^2  Passed
 Occasional  :      1.9,  Allowable :    183.4 N./mm^2  Passed
 Shear       :      8.1,  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 (UCS-66(a)1(b)), Curve: D

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.707, Temp. Reduction = 16 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve D           -48 °C

Governing MDMT of all the sub-joints of this Junction  :  -48 °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: S3

```
Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.9000 = 0.7 * tmin.  5.6560 = 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, (2.813 - 1.163 + 2 * 13.6 * 1.0 *
     (1.0 * 7.0 - 4.9524 ) )138)
  = 30.43 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.5923 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
  = 72.15 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.5923 + 0.0 + 0.64 + ( 1.904 ) ) * 138
  = 98.40 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.5923 + 0.0 + 0.64 + 0.0 + ( 1.904 ) ) * 138
  = 98.40 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 * 8.0 * 0.49 * 138
  = 71. 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 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 94. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 71 + 145 ) = 216 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 71 + 0 + 94 + 0 ) = 166 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 71 + 94 + 0 ) = 166 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 216 kN , must exceed W = 30 kN  or W1 = 72 kN
 Path 2-2 = 165 kN , must exceed W = 30 kN  or W2 = 98 kN
 Path 3-3 = 165 kN , must exceed W = 30 kN  or W3 = 98 kN

 Nozzle is O.K. for the External Pressure           1.100  bars
```

The Drop for this Nozzle is : 3.0522 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 213.0522 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     581.000  mm.
 Vessel Thickness                                 Tv      10.000  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       23.034  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        500.0  N-m
 Longitudinal Moment     (SUS)                    Ml        400.0  N-m
 Torsional Moment        (SUS)                    Mt        400.0  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( 297.0 ( 10.0 - 3.0 ) )
 = 234.467 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       500.0  N-m
Longitudinal Moment                          ML       400.0  N-m
Torsional Moment                             MT       400.0  N-m

Dimensionless Parameters used :   Gamma =   42.43
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.124	4C	7.046	(A,B)
N(PHI) / (P/Rm)	0.124	3C	5.702	(C,D)
M(PHI) / (P)	0.124	2C1	0.068	(A,B)
M(PHI) / (P)	0.124	1C	0.101	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.124	3A	1.535	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.124	1A	0.090	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.124	3B	4.748	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.124	1B	0.039	(A,B,C,D)
N(x) / (P/Rm)	0.124	3C	5.702	(A,B)
N(x) / (P/Rm)	0.124	4C	7.046	(C,D)
M(x) / (P)	0.124	1C1	0.106	(A,B)
M(x) / (P)	0.124	2C	0.068	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.124	4A	2.341	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.124	2A	0.047	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.124	4B	1.458	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.124	2B	0.060	(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	-6.8	-6.8	-6.8	-6.8	-5.5	-5.5	-5.5	-5.5
Circ. Bend.	P	-16.6	16.6	-16.6	16.6	-24.7	24.7	-24.7	24.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-10.0	-10.0	10.0	10.0

Circ. Memb. MC	0.0	0.0	0.0	0.0	-149.4	149.4	149.4	-149.4
Circ. Memb. ML	-24.8	-24.8	24.8	24.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	-52.5	52.5	52.5	-52.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-100.7	37.4	54.0	-17.8	-189.7	158.6	129.3	-120.2
Long. Memb. P	-5.5	-5.5	-5.5	-5.5	-6.8	-6.8	-6.8	-6.8
Long. Bend. P	-25.9	25.9	-25.9	25.9	-16.6	16.6	-16.6	16.6
Long. Memb. MC	0.0	0.0	0.0	0.0	-15.3	-15.3	15.3	15.3
Long. Bend. MC	0.0	0.0	0.0	0.0	-78.9	78.9	78.9	-78.9
Long. Memb. ML	-7.6	-7.6	7.6	7.6	0.0	0.0	0.0	0.0
Long. Bend. ML	-80.6	80.6	80.6	-80.6	0.0	0.0	0.0	0.0
Tot. Long. Str.	-119.6	93.3	56.9	-52.6	-117.6	73.4	70.8	-53.7
Shear VC	2.2	2.2	-2.2	-2.2	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-2.2	-2.2	2.2	2.2
Shear MT	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Tot. Shear	7.3	7.3	3.0	3.0	3.0	3.0	7.3	7.3
Str. Int.	122.1	94.3	58.7	52.8	189.8	158.7	130.2	121.0

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)	95.4	97.8	95.4	97.8	95.4	97.8	95.4	97.8
Circ. Pl (SUS)	-31.6	-31.6	18.1	18.1	-15.5	-15.5	4.6	4.6
Circ. Q (SUS)	-69.0	69.0	35.9	-35.9	-174.1	174.1	124.7	-124.7
Long. Pm (SUS)	47.7	47.7	47.7	47.7	47.7	47.7	47.7	47.7
Long. Pl (SUS)	-13.1	-13.1	2.1	2.1	-22.1	-22.1	8.5	8.5
Long. Q (SUS)	-106.4	106.4	54.7	-54.7	-95.5	95.5	62.3	-62.3
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	2.2	2.2	-2.2	-2.2	-2.2	-2.2	2.2	2.2
Shear Q (SUS)	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Pm (SUS)	95.4	97.8	95.4	97.8	95.4	97.8	95.4	97.8
Pm+Pl (SUS)	64.0	66.3	113.6	115.9	80.0	82.3	100.1	102.4
Pm+Pl+Q (Total)	72.6	146.0	149.6	85.0	94.6	256.4	225.2	25.2

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	97.75	137.90	Passed
Pm+Pl (SUS)	115.89	206.85	Passed
Pm+Pl+Q (TOTAL)	256.44	413.70	Passed

INPUT VALUES, Nozzle Description: T2 From : 60

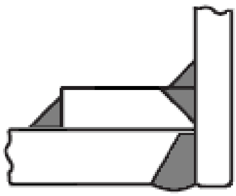
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	581.00	mm.
Design Length of Section	L	505.4167	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		6849.35	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		6.0000	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	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		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	290.0000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		60.8625	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              6.625  in.
 Actual Thickness Used in Calculation                     0.378  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*293.5)/(138*1.0-0.6*23.0)
   = 4.9450 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*84.1375)/(118*1.0+0.4*23.0)
   = 1.6287 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5944 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   310.1452  mm.
 Parallel to Vessel Wall, opening length              d   155.0726  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp    17.5000  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	7.763	1.439	NA
Area in Shell	A1	3.147	7.913	NA
Area in Nozzle Wall	A2	1.488	1.798	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.185	1.185	NA
Area in Element	A5	12.172	12.172	NA
TOTAL AREA AVAILABLE	Atot	17.993	23.068	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:	187.6997	10.0000	mm.
Based on given Pad Diameter:	290.0000	1.5958	mm.
Based on Shell or Nozzle Thickness:	188.5066	9.6012	mm.

Area Required [A]:
```
= ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
= (155.0726*4.945*1.0+2*6.6012*4.945*1.0*(1-0.86))
= 7.763 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 )
= 155.073( 1.0 * 7.0 - 1.0 * 4.945 ) - 2 * 6.601
  ( 1.0 * 7.0 - 1.0 * 4.945 ) * ( 1 - 0.855 )
= 3.147 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
= ( 2 * Tlwp ) * ( tn - trn ) * fr2
= ( 2 * 17.5 ) * ( 6.6 - 1.63 ) * 0.855
= 1.488 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
= (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
= ( 0.6375 ) * 0.86 + (0.0 ) * 0.86 + 203.2² * 1.0
= 1.185 cm^2
```

Area Available in Element [A5]:
```
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= ( 290.0 - 168.275 ) * 10.0 * 1.0
= 12.172 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures        ta = 4.6287 mm.
Wall Thickness per UG16(b),                         tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure        trb1 = 7.9450 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 7.9450 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                        tb3 = 9.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.22, max( 7.945, 4.5 ) ]
  = 7.9450 mm.
```

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

```
  = max( ta, tb )
  = max( 4.6287, 7.945 )
  = 7.9450 mm.
```

Available Nozzle Neck Thickness = 9.6012 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   :     55.9,  Allowable :    117.9 N./mm^2  Passed
 Expansion   :      0.0,  Allowable :    238.8 N./mm^2  Passed
 Occasional  :     13.0,  Allowable :    156.8 N./mm^2  Passed
 Shear       :     24.1,  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: B

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.247, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

Shell to Pad Weld Junction at Pad OD, min(Curve:B, Curve:D)

Govrn. thk, tg = 10.0, tr = 4.945, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.706, Temp. Reduction = 16 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)            -45 °C
```

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: D

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.247, 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

Governing MDMT of the Nozzle                          :    -104 °C
Governing MDMT of the Reinforcement Pad               :     -45 °C
Governing MDMT of all the sub-joints of this Junction :     -45 °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: T2

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.6012  mm.
Intermediate Calc. for pad/shell Welds   TminPad      7.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.6208 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	3.5000 = 0.5*TminPad	5.6560 = 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, (7.763 - 3.1474 + 2 * 6.6012 * 0.855 *
  (1.0 * 7.0 - 4.945 ) )138)
= 66.84 kN
```

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

Weld Load [W1]:
```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 1.488 + 12.1725 + 1.1851 - 0.0 * 0.86 ) * 138
= 204.70 kN
```

Weld Load [W2]:
```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 1.488 + 0.0 + 0.5472 + ( 0.7902 ) ) * 138
= 38.96 kN
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 1.488 + 0.0 + 1.1851 + 12.1725 + ( 0.7902 ) ) * 138
= 215.60 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 ) * 168.275 * 8.0 * 0.49 * 118
= 122. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 290.0 * 8.0 * 0.49 * 138
  = 246. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 80.8369) * ( 9.6012 - 3.0 ) * 0.7 * 118
  = 138. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 168.275 * 10.0 * 0.74 * 138
  = 270. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 168.275 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 189. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 246 + 138 ) = 385 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 122 + 270 + 189 + 0 ) = 581 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 246 + 189 + 0 ) = 435 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 384 kN , must exceed W = 66 kN  or W1 = 204 kN
 Path 2-2 = 580 kN , must exceed W = 66 kN  or W2 = 38 kN
 Path 3-3 = 435 kN , must exceed W = 66 kN  or W3 = 215 kN

 Nozzle is O.K. for the External Pressure                1.100  bars
```

The Drop for this Nozzle is : 12.4512 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.4512 mm.

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    581.000  mm.
 Vessel Thickness                               Tv     10.000  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    168.275  mm.
 Nozzle Thickness                               Tn      9.601  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     10.000  mm.
 Diameter  of Reinforcing Pad                 Dpad    290.000  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	6.0	kN
Longitudinal Shear	(SUS)	Vl	6.0	kN
Circumferential Shear	(SUS)	Vc	6.0	kN
Circumferential Moment	(SUS)	Mc	3800.0	N-m
Longitudinal Moment	(SUS)	Ml	3800.0	N-m
Torsional Moment	(SUS)	Mt	4700.0	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 ) )
  = 168.275 + 2 * 1.65 * sqrt( 297.0 ( 10.0 - 3.0 ) )
  = 318.742 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	6.0	kN
Circumferential Shear	VC	6.0	kN
Longitudinal Shear	VL	6.0	kN
Circumferential Moment	MC	3800.0	N-m
Longitudinal Moment	ML	3800.0	N-m
Torsional Moment	MT	4700.0	N-m

Dimensionless Parameters used : Gamma = 17.76

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.244	4C	2.697	(A,B)
N(PHI) / (P/Rm)	0.244	3C	1.952	(C,D)
M(PHI) / (P)	0.244	2C1	0.045	(A,B)
M(PHI) / (P)	0.244	1C	0.074	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.244	3A	0.734	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.244	1A	0.085	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.244	3B	1.941	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.244	1B	0.032	(A,B,C,D)
N(x) / (P/Rm)	0.244	3C	1.952	(A,B)
N(x) / (P/Rm)	0.244	4C	2.697	(C,D)
M(x) / (P)	0.244	1C1	0.077	(A,B)
M(x) / (P)	0.244	2C	0.045	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.244	4A	1.267	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.244	2A	0.044	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.244	4B	0.709	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.244	2B	0.051	(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	-3.2	-3.2	-3.2	-3.2	-2.3	-2.3	-2.3	-2.3
Circ. Bend.	P	-5.6	5.6	-5.6	5.6	-9.2	9.2	-9.2	9.2
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-7.4	-7.4	7.4	7.4
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-91.0	91.0	91.0	-91.0
Circ. Memb.	ML	-19.5	-19.5	19.5	19.5	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-33.9	33.9	33.9	-33.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-62.2	16.8	44.6	-11.9	-109.9	90.5	86.9	-76.7
Long. Memb.	P	-2.3	-2.3	-2.3	-2.3	-3.2	-3.2	-3.2	-3.2
Long. Bend.	P	-9.6	9.6	-9.6	9.6	-5.6	5.6	-5.6	5.6
Long. Memb.	MC	0.0	0.0	0.0	0.0	-12.7	-12.7	12.7	12.7
Long. Bend.	MC	0.0	0.0	0.0	0.0	-47.2	47.2	47.2	-47.2
Long. Memb.	ML	-7.1	-7.1	7.1	7.1	0.0	0.0	0.0	0.0
Long. Bend.	ML	-55.1	55.1	55.1	-55.1	0.0	0.0	0.0	0.0
Tot. Long. Str.		-74.1	55.2	50.4	-40.7	-68.7	37.0	51.2	-32.1
Shear	VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear	MT	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Tot. Shear		7.5	7.5	4.9	4.9	4.9	4.9	7.5	7.5
Str. Int.		77.7	56.7	53.2	41.5	110.4	91.0	88.4	77.9

Dimensionless Parameters used : Gamma = 42.43

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.427	4C	3.340	(A,B)
N(PHI) / (P/Rm)	0.427	3C	1.296	(C,D)
M(PHI) / (P)	0.427	2C1	0.008	(A,B)
M(PHI) / (P)	0.427	1C !	0.063	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.427	3A	1.071	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.427	1A	0.061	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.427	3B	1.851	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.427	1B	0.006	(A,B,C,D)
N(x) / (P/Rm)	0.427	3C	1.296	(A,B)
N(x) / (P/Rm)	0.427	4C	3.340	(C,D)
M(x) / (P)	0.427	1C1	0.019	(A,B)
M(x) / (P)	0.427	2C !	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.427	4A	4.057	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.427	2A	0.024	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.427	4B	1.123	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.427	2B	0.010	(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	-9.6	-9.6	-9.6	-9.6	-3.7	-3.7	-3.7	-3.7
Circ. Bend. P	-5.6	5.6	-5.6	5.6	-46.4	46.4	-46.4	46.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-15.4	-15.4	15.4	15.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-222.1	222.1	222.1	-222.1
Circ. Memb. ML	-26.7	-26.7	26.7	26.7	0.0	0.0	0.0	0.0
Circ. Bend. ML	-22.7	22.7	22.7	-22.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-64.6	-8.0	34.1	-0.1	-287.6	249.3	187.3	-164.0
Long. Memb. P	-3.7	-3.7	-3.7	-3.7	-9.6	-9.6	-9.6	-9.6
Long. Bend. P	-13.7	13.7	-13.7	13.7	-23.9	23.9	-23.9	23.9
Long. Memb. MC	0.0	0.0	0.0	0.0	-58.4	-58.4	58.4	58.4
Long. Bend. MC	0.0	0.0	0.0	0.0	-89.1	89.1	89.1	-89.1
Long. Memb. ML	-16.2	-16.2	16.2	16.2	0.0	0.0	0.0	0.0
Long. Bend. ML	-38.1	38.1	38.1	-38.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-71.7	31.9	36.8	-11.9	-181.1	44.9	114.1	-16.5
Shear VC	1.9	1.9	-1.9	-1.9	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.9	-1.9	1.9	1.9
Shear MT	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Tot. Shear	7.0	7.0	3.2	3.2	3.2	3.2	7.0	7.0
Str. Int.	76.0	42.3	38.9	13.4	287.7	249.4	188.0	164.3

(Column header: Stress Intensity Values at)

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)	38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Circ. Pl (SUS)	-22.7	-22.7	16.4	16.4	-9.7	-9.7	5.1	5.1
Circ. Q (SUS)	-39.5	39.5	28.2	-28.2	-100.2	100.2	81.8	-81.8
Long. Pm (SUS)	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Long. Pl (SUS)	-9.4	-9.4	4.8	4.8	-15.9	-15.9	9.6	9.6
Long. Q (SUS)	-64.6	64.6	45.5	-45.5	-52.8	52.8	41.6	-41.6
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q (SUS)	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Pm (SUS)	38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Pm+Pl (SUS)	16.2	18.4	55.0	57.3	29.0	31.3	43.8	46.1
Pm+Pl+Q (Total)	56.5	77.4	84.8	51.3	72.3	131.8	126.5	38.0

(Column header: Stress Intensity Values at)

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	40.89	137.90	Passed
Pm+Pl (SUS)	57.30	206.85	Passed
Pm+Pl+Q (TOTAL)	131.75	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)	95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Circ. Pl (SUS)	-36.3	-36.3	17.0	17.0	-19.2	-19.2	11.7	11.7
Circ. Q (SUS)	-28.3	28.3	17.1	-17.1	-268.5	268.5	175.7	-175.7
Long. Pm (SUS)	47.7	47.7	47.7	47.7	47.7	47.7	47.7	47.7
Long. Pl (SUS)	-19.9	-19.9	12.4	12.4	-68.1	-68.1	48.8	48.8
Long. Q (SUS)	-51.8	51.8	24.4	-24.4	-113.0	113.0	65.3	-65.3
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.9	1.9	-1.9	-1.9	-1.9	-1.9	1.9	1.9
Shear Q (SUS)	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Pm (SUS)	95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Pm+Pl (SUS)	59.1	61.4	112.4	114.7	96.6	98.9	107.3	109.6
Pm+Pl+Q (Total)	56.5	93.2	129.7	97.7	192.5	347.0	283.0	98.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	97.61	137.90	Passed
Pm+Pl (SUS)	114.68	206.85	Passed
Pm+Pl+Q (TOTAL)	346.96	413.70	Passed

INPUT VALUES, Nozzle Description: T3 From : 60

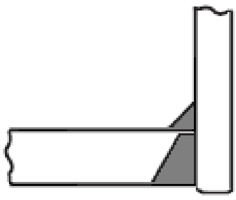
Pressure for Reinforcement Calculations	P	23.034	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	581.00	mm.
Design Length of Section	L	505.4167	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		6852.35	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		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	14.3000	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	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	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: T3

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

```
Actual Inside Diameter Used in Calculation              1.000  in.
Actual Thickness Used in Calculation                    0.563  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)
  = (23.03*293.5)/(138*1.0-0.6*23.03)
  = 4.9524 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 15.7(exp([23.03/(137.9*1.0]-1)
  = 0.2645 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3056 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]

```
Parallel to Vessel Wall (Diameter Limit)            Dl    68.0000  mm.
Parallel to Vessel Wall                        Rn+tn+t    34.0000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    17.5000  mm.
```

Weld Strength Reduction Factor [fr1]:

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

Weld Strength Reduction Factor [fr2]:

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

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1.0, 1.0 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.555	0.288	NA
Area in Shell	A1	0.749	1.891	NA
Area in Nozzle Wall	A2	3.862	3.848	NA

Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.630	0.630	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	5.242	6.369	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)
= (31.4*4.9524*1.0+2*11.3*4.9524*1.0*(1-1.0))
= 1.555 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 )
= 36.6( 1.0 * 7.0 - 1.0 * 4.952 ) - 2 * 11.3
  ( 1.0 * 7.0 - 1.0 * 4.9524 ) * ( 1 - 1.0 )
= 0.749 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 17.5 )( 11.3 - 0.26 )1.0
= 3.862 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
= ( Wo² - Area Lost )*fr2 + ( (Wi-can/0.707)² - Area Lost)*fr2
= ( 8.0² - 0.01 ) * 1.0 + ( 0.0² -0.0 ) * 1.0
= 0.630 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures       ta = 3.3056 mm.
Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure      trb1 = 7.9524 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 7.9524 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( 7.9524, 4.5 ) ]
= 6.4200 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
= max( ta, tb )
= max( 3.3056, 6.42 )
= 6.4200 mm.
```

Available Nozzle Neck Thickness = 14.3000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle-Shell/Head Weld (UCS-66(a)1(b)), Curve: D

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.707, Temp. Reduction = 16 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -48 °C

```
Governing MDMT of all the sub-joints of this Junction   :   -48 °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: T3

```
Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
Nozzle Weld           4.9000 = 0.7 * tmin.  5.6560 = 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, (1.5551 - 0.7494 + 2 * 11.3 * 1.0 *
     (1.0 * 7.0 - 4.9524 ) )138)
  = 17.49 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.8624 + 0.0 + 0.63 - 0.0 * 1.0 ) * 138
  = 61.95 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.8624 + 0.0 + 0.63 + ( 1.582 ) ) * 138
  = 83.76 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.8624 + 0.0 + 0.63 + 0.0 + ( 1.582 ) ) * 138
  = 83.76 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 ) * 54.0 * 8.0 * 0.49 * 138
  = 46. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 21.35) * ( 14.3 - 3.0 ) * 0.7 * 138
  = 73. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 54.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 61. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 46 + 73 ) = 119 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 46 + 0 + 61 + 0 ) = 106 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 46 + 61 + 0 ) = 106 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 119 kN , must exceed W = 17 kN  or W1 = 61 kN
 Path 2-2 = 106 kN , must exceed W = 17 kN  or W2 = 83 kN
 Path 3-3 = 106 kN , must exceed W = 17 kN  or W3 = 83 kN

 Nozzle is O.K. for the External Pressure              1.100  bars
```

The Drop for this Nozzle is : 1.2575 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 211.2574 mm.

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
T4	0.750 in	Actual	LWN	1.872	14.250	...	...	210.97	300
T3	1.000 in	Actual	LWN	2.126	14.300	...	...	211.26	300
S3	2.000 in	Actual	LWN	3.307	16.600	...	...	213.05	300
T1	4.000 in	120	WNF	4.500	11.125	230.00	10.00	215.68	300
S2	6.000 in	80	WNF	6.625	10.973	290.00	10.00	222.45	300
S1	6.000 in	80	WNF	6.625	10.973	290.00	10.00	222.45	300
T2	6.000 in	80	WNF	6.625	10.973	290.00	10.00	222.45	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.):

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
T4	SA-350 LF2	10.000	8.000	...	...	...
T3	SA-350 LF2	10.000	8.000	...	...	...
S3	SA-350 LF2	10.000	8.000	...	...	...
T1	SA-333 6	10.000	8.000	8.000	10.000	...
S2	SA-333 6	10.000	8.000	8.000	10.000	...
S1	SA-333 6	10.000	8.000	8.000	10.000	...
T2	SA-333 6	10.000	8.000	8.000	10.000	...

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
T4	203.000	90.0	200.00	0.00	CHANNEL 01
T3	6802.351	270.0	200.00	0.00	CHANNEL 002

S3	709.175	270.0	200.00	0.00	SHELL
T1	203.000	270.0	200.00	0.00	CHANNEL 01
S2	759.175	90.0	200.00	0.00	SHELL
S1	6243.176	90.0	200.00	0.00	SHELL
T2	6799.351	90.0	200.00	0.00	CHANNEL 002

Input Echo, Tubesheet Number 1, Description: TUBE SHEET

Shell Data:

Main Shell Description: SHELL

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	10.0000	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	581.000	mm.
Shell Circumferential Joint Efficiency	Esw	1.000	
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: CHANNEL 01

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	10.0000	mm.
Channel Corrosion Allowance	cac	3.0000	mm.
Inside Diameter of Channel	Dc	581.000	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	241	
Tube Wall Thickness	et	2.7700	mm.
Tube Outside Diameter	D	25.4000	mm.
Total Straight Tube Length	Lt	6000.00	mm.
Straight Tube Length (bet. inner tubsht faces)	L	5876.00	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	32.0000	mm.
Tube Layout Pattern		Triangular	

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	270.770	mm.
Largest Center-to-Center Tube Distance	Ul	40.0000	mm.
Length of Expanded Portion of Tube	ltx	0.0000	mm.
Tube-side pass partition groove depth	hg	5.0000	mm.
Area of Tube Layout	Ap	226.8	cm^2

Tubesheet Data:

Tubesheet TYPE: Fixed Tubesheet Exchanger, Conf B

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	62.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	3.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	3.0000	mm.
Tubesheet Outside Diameter	A	715.000	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	644.00	mm.
Step 1 Depth on the Tubeside	ht1	6.00	mm.
Step 2 Diameter on the Tubeside	dt2	578.00	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	0.00	mm.
Step 1 Depth on the Shellside	hs1	0.00	mm.
Step 2 Diameter on the Shellside	ds2	578.00	mm.
Step 2 Depth on the Shellside	hs2	5.00	mm.
Calculated Tubesheet Diameter as per UHX-10(b)		644.00	mm.

Note: Tubesheet diameter is now: 644.000 mm. per UHX-10(b).

Area of the Untubed Lanes	AL	226.8	cm^2

Additional Data for Fixed/Floating Tubesheet Exchangers:

Unsupported Tube Span under consideration	l	600.000	mm.
Tube End condition corresponding to Span (l)	k	1.00	
Ignore Radial Thermal Exp. effects (UHX-13.8/14.6)		YES	

Note: The Metal temperatures at the Rim are set to ambient (21 °C)

Tubesheet Metal Temp. at Rim	T'	21.11	°C
Shell Metal Temp. at Tubesheet	T'S	21.11	°C
Channel Metal Temp. at Tubesheet	T'C	21.11	°C
Perform Differential Pressure Design		N	
Run Multiple Load Cases		YES	

Shell Side Min. Design Pressure	Psd,min	1.0342	bars
Channel Side Min. Design Pressure	Ptd,min	1.0314	bars
Mean Shell Metal Temp. along Shell len.	Tsm	28.02	°C
Mean Tube Metal Temp. along Tube length	Ttm	20.44	°C
Junction Stress Reduction option	Perform Plastic Calculation		

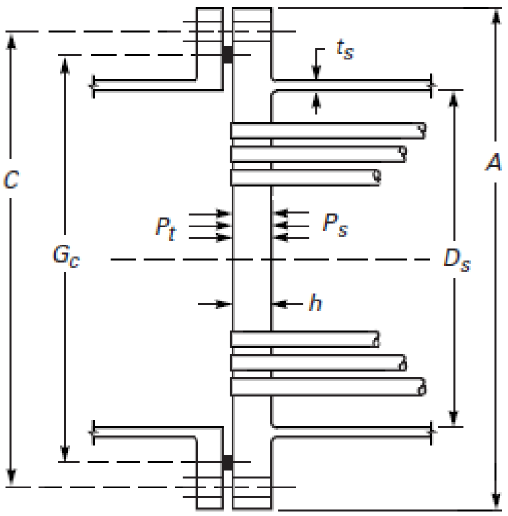
Additional Data for Gasketed Tubesheets:

Tubesheet Gasket on which Side		Channel	
Flange Outside Diameter	A	715.000	mm.
Flange Inside Diameter	B	581.000	mm.
Flange Face Outside Diameter	Fod	647.000	mm.
Flange Face Inside Diameter	Fid	581.000	mm.
Gasket Outside Diameter	Go	641.000	mm.
Gasket Inside Diameter	Gi	611.000	mm.
Small end Hub thk.	g0	10.0000	mm.
Large end Hub thk.	g1	17.0000	mm.
Gasket Factor,	m	3.78	
Gasket Design Seating Stress	y	62.05	N./mm^2
Flange Facing Sketch	Code Sketch 1a		
Column for Gasket Seating	Code Column II		
Gasket Thickness	tg	3.0000	mm.
Full face Gasket Flange Option	Program Selects		
Length of Partition Gasket	lp	559.000	mm.
Width of Partition Gasket	wp	6.4000	mm.
Partition Gasket Factor,	mPart	3.7500	
Partition Gasket Design Seating Stress	yPart	62.05	N./mm^2
Partition Gasket Facing Sketch	Code Sketch 1a		
Partition Gasket Column for Gasket Seating	Code Column II		

Bolting Information:

Diameter of Bolt Circle	C	673.000	mm.
Nominal Bolt Diameter	dB	19.0500	mm.
Type of Thread Series	UNC Thread Series		
Number of Bolts	n	32	

Tubesheet Integral With Shell and Gasketed With Channel, Extended as a Flange



Configuration b:

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.

 Tubesheet Integral with                                 Shell
 Tubesheet Extended as Flange                              Yes
 Thickness of Extended Portion of Tubesheet     Tf     46.0000  mm.
 Is Bolt Load Transferred to the Tubesheet                 Yes

 Is Exchanger in Creep range (skip EP, Use 3S for Sps)      NO
```

ASME TubeSheet Results per Part UHX, 2017

Elasticity/Expansion Material Properties:

Shell - TE-1 Carbon & Low Alloy Steels, Group 1
Shell - TM-1 Carbon Steels with C<= 0.3%

```
 -----------------------------------------------------------------
 Th. Exp. Coeff. Metal Temp. along Len    28.0 °C    0.0000115937 /°C
 Elastic Mod. at Design Temperature      125.0 °C      0.19660E+09 KPa.
 Th. Exp. Coeff. Metal Temp. at Tubsht    21.1 °C    0.0000115190 /°C
 Elastic Mod. at Metal Temp. along Len    28.0 °C      0.20231E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

Channel - TE-1 Carbon & Low Alloy Steels, Group 1
Channel - TM-1 Carbon Steels with C<= 0.3%

```
 -----------------------------------------------------------------
 Th. Exp. Coeff. Metal Temp. at Tubsht    21.1 °C    0.0000115190 /°C
 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 - TE-1 Carbon & Low Alloy Steels, Group 1
Tubes - TM-1 Carbon Steels with C<= 0.3%

```
 -----------------------------------------------------------------
 Th. Exp. Coeff. Metal Temp. along Len    20.4 °C    0.0000115094 /°C
 Elastic Mod. at Design Temperature      125.0 °C      0.19660E+09 KPa.
 Elastic Mod. at Metal Temp. along Len    20.4 °C      0.20275E+09 KPa.
 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 - TE-1 Carbon & Low Alloy Steels, Group 1
TubeSheet - TM-1 Carbon Steels with C<= 0.3%

```
 -----------------------------------------------------------------
 Th. Exp. Coeff. Metal Temp. at Rim       21.1 °C    0.0000115190 /°C
 Elastic Mod. at Design Temperature      125.0 °C      0.19660E+09 KPa.
 Elastic Mod. at Metal Temp. at Rim       21.1 °C      0.20270E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

Note:
The Elasticity and Alpha values are taken from Tables in ASME II D.
Please insure these properties are consistent with the
type of Material for the tubes, shell, channel etc.

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)
  = (24.03*(25.4/2-0.0)/(117.9*1.0+0.4*24.03)
  = 0.2568 + 0.0000 = 0.2568 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     25.40   5876.00      9.17   50.0000  0.0130823        122.73
EMAWP = (2.167/(D/T)-0.0833)*B = 187.7951 bars
```

Results for Reqd Thickness for Ext. Pressure (Tca):

```
    TCA        ODCA     SLEN       D/T       L/D   Factor A        B
  0.6452     25.40   5876.00     39.37   50.0000  0.0007098         70.96
EMAWP = (4*B)/(3*(D/T)) = ( 4 *70.9602 )/( 3 *39.3677 ) = 24.0319 bars
```

Summary of Tube Required Thickness Results:

```
Total Required Thickness including Corrosion all.            0.6452  mm.
Allowable Internal Pressure at Corroded thickness           281.73  bars
Required Internal Design Pressure                            24.03  bars
Allowable External Pressure at Corroded thickness           187.80  bars
Required External Design Pressure                            24.03  bars
Required Thickness due to Shell Side pressure                0.6452  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            15.000  mm.
Basic Gasket Width,        b0 = N / 2.0                   7.500  mm.
Effective Gasket Width,     b = SQRT(b0) * 2.5            6.899  mm.
Gasket Reaction Diameter,   G = Go-2.0*b                627.203  mm.
```

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

```
= 2a + 6t/(m + 0.5)
= 2 * 19.05 + 6 * 46.0/(3.78 + 0.5)
= 102.586 mm.
```

Actual Circumferential Bolt Spacing [Bs]:

```
= C * sin( pi / n )
= 673.0 * sin( 3.142/32 )
= 65.966 mm.
```

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

```
= max( sqrt( Bs/( 2a + t )), 1 )
= max( sqrt( 65.966/( 2 * 19.05 + 46.0 )), 1 )
= 1.0000
```

Bolting Information for UNC Thread Series (Non Mandatory):

```
Distance Across Corners for Nuts                    35.128  mm.
Circular Wrench End Diameter                   a    52.388  mm.
```

	Minimum	Actual	Maximum
Bolt Area, cm^2	56.730	62.348	
Radial Distance between Hub and Bolts:	20.637	36.000	
Radial Distance between Bolts and the Ed	20.637	21.000	

```
 Circumferential Spacing between the Bolt    44.450     65.966    102.586
 ---------------------------------------------------------------------------

 Flange Design Bolt Load, Seating Condition    W  :      1026.22  kN
 Flange Design Bolt Load, Operating Condition  Wm1:       977.80  kN
```

Results for ASME Fixed Tubesheet Calculations for Configuration b,

Results for Tubesheet Calculations Original Thickness :

UHX-13.5.1 Step 1:

Compute the Tube Expansion Depth Ratio [rho]:
```
  = ltx / h  ( modified for corrosion if present )
  = 0.0/62.0 = 0.0 ( must be 0 <= rho <= 1 )
```

Compute the Effective Tube Hole Diameter [d*]:
```
  = Max( dt - 2tt*( Et/E )( StT/S )( rho ), dt - 2tt)
  = Max( 25.4 -2*2.77 *(.19660E+09/.19660E+09)*
    ( 117/137 )*(0.0 ), 25.4 -2*2.77 )
  = 25.4000 mm.
```

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
```
  = 2 * ro + dt = 2 * 270.77 + 25.4 = 566.94 mm.
```

Determine the Basic Ligament Efficiency for Shear [mu]:
```
  = (p - dt)/p = (32.0 - 25.4 )/32.0 = 0.2062
```

Compute the Equivalent Outer Tube Limit Radius [ao]:
```
  = Do/2 = 566.94/2 = 283.47 mm.
```

Compute the Effective Tube Pitch [p*]:
```
  = p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
  = 32.0/sqrt( 1 - 4 * min( 226.77 *100.0, 4*566.94 *32.0 )/( 3.141 * 566.94²) )
  = 33.5420 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:
```
  = (p* - d*)/p* = (33.542 - 25.4 )/33.542 = 0.2427
```

Compute the Ratio [Rhos]:
```
  = as/ao = 290.5/283.47 = 1.0248
```

Compute the Ratio [Rhoc]:
```
  = ac/ao = 313.6014/283.47 = 1.106295
```

Compute Parameter [xt]:
```
  = 1 - Nt * (( dt - 2 * tt )/( 2 * ao ))²
  = 1 - 241 * ((25.4 - 2 * 2.77 )/(2 * 283.47 ))² = 0.7043
```

Determine Parameter [xs]:
```
  = 1 - Nt*( dt/(2*ao) )²
  = 1 - 241 *( 25.4/(2*283.47 ) )² = 0.5163
```

Determine the Value [h'g]:
```
  = Max(( hg - CATC ), 0 )  (For pressure only cases)
  = Max(( 5.0 - 0.0 ), 0 ) = 5.0 mm.
```

UHX-13.5.2 Step 2:

Determine the Axial Shell Stiffness [Ks]:
```
  = pi * ts( Ds + ts )Es/L
```

```
  = 3.1416 * 10.0 ( 581.0 + 10.0 ).19660E+09/5876.0
  = 621211456.0000 KPa. * mm.
```

Determine the Axial Tube Stiffness [Kt]:
```
  = pi * tt( Dt - tt )Et/L
  = 3.1416 * 2.77 ( 25.4 - 2.77 ).19660E+09/5876.0
  = 6588953.0000 KPa. * mm.
```

Compute the Stiffness Factor [Ks,t]:
```
  = Ks/( Nt * Kt ) = 0.62121E+09/( 241 * 6588953 ) = 0.39121
```

Rigidty Ratio [J]:
```
  = 1 / ( 1 + Ks/Kj )
  = 1/(1 + 0.62121E+09/0.0 ) = 1. (= 1 if No Exp. Jt.)
```

Compute Shell Coefficient [betas]:
```
  = (( 12 * (1-nus²))^0.25 )/((Ds + ts) * ts )^0.5
  = (( 12 * (1 - 0.3²) )^0.25 )/(( 581.0 + 10.0 ) * 10.0 )^0.5
  = 0.0236 1/mm.
```

Determine Shell Coefficient [ks]:
```
  = betas * Es * ts³ / ( 6 * (1 - nus²) )
  = 0.024 * 0.19660E+09 * 10.0³/( 6 * (1 - 0.3²) )
  = 8514383.0000 bars*mm.²
```

Determine Shell Coefficient [Lambdas]:
```
  = (6*Ds*ks)/(h³) * (1 + h*betas + 0.5*(h*betas)²)
  = 6*581.0 *8514383/(62.0³) * ( 1 + 62.0 * 0.024 + 1.075 )
  = 440960.5312 bars
```

Determine Shell Coefficient [deltaS]:
```
  = Ds²/(4 * Es * Ts) * ( 1 - nus/2 )
  = 581.0²/( 4 * 0.19660E+09 * 10.0 ) * ( 1 - 0.3/2 )
  = 0.0364839621 mm./N./mm^2
```

Intermediate parameters for Tubesheet Gasketed on the Channel Side:
betac, kc, deltaC, Lambdac = 0

UHX-13.5.3 Step 3:

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.
```
   h/p =   1.937500 ;  mu* =   0.242740
  E*/E =   0.209541 ;  nu* =   0.401441 ;  E* = 41195736. KPa.
```

Compute the Tube Bundle Stiffness Factor [Xa]:
```
  = ((24 *(1 - nu*²)*Nt * Et* tt* (dt - tt)* ao²) /
    ( E* * L * H³ ) )^0.25
  = ((24 *(1 - 0.401²)*241 *.19660E+09*2.77 *
    (25.4 - 2.77 )*283.47²)/( 41195736 *
    5876.0 * 62.0³ ))^0.25
  = 3.0209
```

Values from Table UHX-13.1
```
  Zd =       0.053417 ;  Zv =       0.102619 ;  Zm =       0.487516
  Za =   0.225057E+01 ;  Zw =       0.102619
```

UHX-13.5.4 Step 4:

Compute the Diameter Ratio [K]:
```
  = A/Do = 644.0/566.94 = 1.1359
```

Compute Coefficient [F]:

```
  = (1 - nu*) / (E*) * ( Lambdas + Lambdac + E * ln(K) )
  = (1 - 0.4 )/(41195736 ) * ( 440960.53 + 0.0 +
    0.19660E+09 * ln(1.14 ) )
  = 1.0048
```

Compute Parameter [Phi]:

```
  = (1 + nu*) * F = (1 + 0.4014 ) * 1.0048 = 1.4081
```

Compute Parameter [Q1]:

```
  = (Rhos - 1 - Phi * Zv)/(1 + Phi * Zm)
  = (1.0248 - 1 - 1.4081 * 0.1026 )/(1 + 1.4081 * 0.4875 )
  = -0.070975378
```

Compute Parameter [Qz1]:

```
  = (Zd + Q1*Zw)/2 *Xa^4
  = ( 0.05342 + -0.07098 * 0.10262 )/2 *3.02093^4 = 1.9211
```

Compute Parameter [Qz2]:

```
  = (Zv + Q1*Zm)/2 *Xa^4
  = ( 0.10262 + -0.07098 * 0.48752 )/2 *3.02093^4 = 2.8324
```

Compute Parameter [U]:

```
  = (Zw + (Rhos - 1)*Zm)*Xa^4 / (1 + Phi*Zm)
  = ( 0.1026 + (1.0248 - 1)* 0.4875 )*3.02093^4/(1 + 1.4081 * 0.4875 )
  = 5.6648
```

UHX-13.5.5 Step 5:

Determine factor [gamab]:

```
  = ( Gc - C ) / Do (config b)
  = (627.2029 - 673.0 )/566.94 = -0.08078
```

Compute Parameter [gamma]:

```
  = 0.000 mm. (For Pressure only cases)
```

Calculate Parameter [OmegaS]:

```
  = rhos * ks * Betas * deltaS( 1 + h * Betas )
  = 1.0248 * 8514383 * 0.0236 * 0.036484 ( 1 + 62.0 * 0.0236 )
  = 1856.4623 mm.^2
```

Calculate Parameter [Omega*S]:

```
  = Ao^2 * ( Rhos^2 - 1 ) * ( Rhos - 1 ) / 4 - OmegaS
  = 283.47^2 * ( 1.025^2 - 1 ) * ( 1.025 - 1 )/4 - 1856.462
  = -1831.4454 mm.^2
```

Calculate Parameter [OmegaC]:

```
  = rhoc * kc * Betac * deltaC( 1 + h * Betac )
  = 1.1063 * 0.0 * 0.0 * 0. ( 1 + 62.0 * 0.0 )
  = 0.0000 mm.^2
```

Calculate Parameter [Omega*C]:

```
  = ao^2[( Rhoc^2+1 )*( Rhoc-1 )/4 -(Rhos-1)/2]- OmegaC
  = 283.47^2[( 1.10629^2+1 )*( 1.10629 -1 )/4 -(1.0248 -1)/2]- 0.
  = 3752.3599 mm.^2
```

Compute the Pressure [P*S]:
= 0 For Pressure only cases or Configurations d,e,f,A,B,C,D

Compute the Pressure [P*C]:
= 0 For Pressure only cases or Configurations b,c,d,B,C,D

UHX-13.5.6 Step 6:

Compute the Pressure [P's]:

```
  = Ps * {xs + 2( 1 - xs )nut + [2/Kst(Ds/Do)^2]nus -
    [(rhos^2-1)/(J*Kst)]-[(1-J)/(2J*Kst)][(Dj^2-(Ds)^2)/Do^2]}
  = 23.0 * { 0.516 + 2( 1 - 0.516 ) 0.3 +
    [2/0.391 (581.0/566.94 )^2] 0.3 -
    [(1.025^2-1)/( 1.0 * 0.391 )] -
    [(1 - 1.0 )/(2 * 1.0 * 0.391 )][(0.0^2-(581.0 )^2)/566.94^2]}
  = 52.6442 bars
```

Compute the Pressure [P't]:

```
  = [ xt + 2(1 - xt)nut + 1/(J * Kst) ]*Pt
  = [ 0.704 + 2(1 - 0.704 ) 0.3 +
    1/(1. * 0.391 ) ]* 23.0
  = 79.0717 bars
```

Compute the Pressure [Pgama]:

```
  = Nt * Kt * gama / ( pi * ao^2 )
  = 241 * 6588953 * 0.0/(3.142 * 283.47^2) = 0.0 bars
```

Compute the Pressure [Pw]:

```
  = -gamab * U * W* / (2 * pi * ao^2)
  = --0.081 * 5.665 * 977.8/(2 * 3.142 * 283.47^2)
  = 8.8624 bars
```

Calculate the Pressure [Prim]:

```
  = -( U/ao^2)(Omega*S * Ps - Omega*C * Pt )
  = -( 5.665/283.47^2)(-2.839 * 23.0 - 5.816 * 23.0 )
  = 9.0537 bars
```

Calculate the Pressure [POmega]:

```
  = U/ao^2(OmegaS * P*s - OmegaC * P*c )
  = 5.665/283.47^2( 2.8775 * 0.0 - 0.0 * 0.0 )
  = 0.0000 bars
```

Determine the Effective Pressure [Pe]:

```
  = J * Kst / (1 + J * Kst *(Qz1 + (Rhos - 1) * Qz2)) *
    (P's - P't + Pgama + Pw + Prim )
  = 0.1000E+01 * 0.391/(1 + 1.0 * 0.391 *(1.921 + (1.025 -
    1) * 2.832 )) * (52.644 - 79.072 + 0.0 + 8.862 + 9.054 )
  = -1.8717 bars
```

UHX-13.5.7 Step 7:

Determine Factor [Q2]:

```
  = [((Omega*S*Ps - Omega*C*Pt) - (Omegas*P*s - Omegac P*c))CNV_FAC +
    W* * gamab/(2*pi)]/(1 + Phi*Zm)
  = [( ( -1831.445 * 23.0 - 3752.36 * 23.0 ) -
    ( 1856.462 * 0.0 - 0.0 * 0.0 )) * 0. +
    977.8 * -0.081/(2*3.141)]/(1 + 1.4081 * 0.48752 )
  = -15.069016457 kN
```

Calculate Factor [Q3]:

```
  = Q1 + 2 * Q2 / ( Pe * ao^2 )
  = -0.071 + 2 * -15.069/( -1.872 * 283.47^2 )
  = 1.932976
```

Fm Value from Table UHX-13.1 = 0.990604

The Tubesheet Bending Stress - Original Thickness [Sigma]:

```
  = (1.5 * Fm / mu* ) * (2 * ao/(H - h'g)^2 * Pe
  = (1.5 * 0.9906/0.2427 ) * (2 * 283.47/(62.0 - 5.0 ))^2 * -1.87
```

```
  = -113.3509 N./mm^2
```

The Allowable Tubesheet Bending Stress [Sigma allowed]:
```
  = 1.5 * S = 1.5 * 137.9 = 206.85 N./mm^2
```

The Tubesheet Bending Stress - Final Thickness [Sigmaf]:
```
  = (1.5 * Fm/mu*) * (2 * ao/( h - h'g)² * Pe
  = (1.5 * 12.1082/0.2427 ) * (2 * 283.47/(45.39 - 5.0 ))² * 0.14
  = 206.8445 N./mm^2
```

Reqd Tubesheet Thickness, for Bending Stress (Including CA) [HReqB]:
```
  = h + Cats + Catc = 45.3899 + 0.0 + 0.0 = 45.3899 mm.
```

UHX-13.5.8 Step 8:

Shear Stress check [Tau_limit]:
```
  = 1.6 * S * MU * h / ao
  = 1.6 * 137.9 * 0.206 * 62.0/283.47
  = 9.9532 N./mm^2
```

The Shear Stress is not required to be computed; [Pe] <= Tau_limit

Note: Tubesheet Shear Stress is probably low, use the following req. thk:
```
  Tubesheet thickness (Incl. Corr.)= 3.8100 mm.
  Tubesheet Shear Stress            = 31.9994 N./mm^2
```

Reqd Tubesheet Thickness for Given Loadings (Including CA) [Hreqd] :
```
  = Max( HreqB, HreqS ) = Max( 45.3899, 3.81 ) = 45.3899 mm.
```

UHX-13.5.9 Step 9:

The Ftmin and Ftmax Coefficients from Table UHX-13.2:
```
  Ftmin = -6.5552, Ftmax = 10.4845
```

First Extreme Tube Axial Stress from among all the tubes [Sigmat1]:
```
  = ( (Ps * xs - Pt * xt) - Pe * Ftmin ) / ( Xt - Xs )
  = ( (23.0 * 0.5163 - 23.0 * 0.7043 ) - (-1.872 ) * -6.555 )/
    ( 0.7043 - 0.5163 ) )
  = -8.8265 N./mm^2
```

Second Extreme value of Tube Axial Stress from among all the tubes [Sigmat2]:
```
  = ( (Ps * xs - Pt * xt) - Pe * Ftmax ) / ( Xt - Xs )
  = ( (23.0 * 0.5163 - 23.0 * 0.7043 ) - (-1.872 ) * 10.485 )/
    ( 0.7043 - 0.5163 ) )
  = 8.1382 N./mm^2
```

Maximum Tube Axial Stress [Sigmat,max]:
```
  = MAX( abs(Sigmat1), abs(Sigmat2) ) = 8.826 N./mm^2
```

The Allowable Tube Stress, [SigmatA]:
```
  = Sot = 117.9045 N./mm^2
```

Check for Buckling as some of the Tubes are in Compression

Determine the Factor of Safety [Fs]:
```
  = Max( (3.25 - 0.25*(Zd + Q3*Zw)*Xa^4 ), 1.25 )
  = Max((3.25 - 0.25*( 0.053 + 1.933 * 0.103 )*3.021^4), 1.25 )
  = 1.2500 (Should be <= 2 )
```

Determine the Factor [rt]:
```
  = ( ( dt² + (dt - 2*tt)² ).5 )/4
```

= ($(25.4^2 + (25.4 - 2*2.77)^2)^{.5}$)/4 = 8.0606 mm.

Determine the Factor [Ct]:
= $(2 * PI^2 * Et/Syt)^{0.5}$
= $(2 * 3.14^2 * 0.19660E+09/216)^{0.5}$ = 133.8224

Determine the Factor [Ft]:
= k * L/r = 1.0 * 600.0/8.061 = 74.4359

The Buckling Allowable Stress [Stb]:
= Sy,t/Fs*(1 - Ft/(2*Ct))
= 216/1.25 *(1 - 74.436/(2*133.822))
= 117.905 N./mm^2 (Never greater than Sot)

Note: The Axial Compressive stress in Tubes is within limits.

The Largest tube-to-tubesheet Joint Load [Wt]:
= Sigmat,max * Tube Area = 8.83 * 1.9693 = 1.74 kN

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
= 3.1415 * t * (do - t) * Sa
= 3.1415 * 2.77 * (25.4 - 2.77) * 117.9 = 23.217 kN

Fillet Weld Strength [Ff]:
= 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
= 0.55 * 3.1415 * 2.0 * (25.4 + 0.67*2.0) * 117.9
= 10.8943 kN

Groove Weld Strength [Fg]:
= 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
= 0.85 * 3.1415 * 2.0 * (25.4 + 0.67*2.0) * 117.9
= 16.8366 kN

Max. Allow. Tube-Tubesheet Joint load, Lmax
= Ft = 23.2171 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)
= 3.3717 mm.

Minimum Required Fillet Weld Leg	afr	1.6859	mm.
Minimum Required Groove Weld Leg	agr	1.6859	mm.

Tube-Tubesheet Jt allowable, 23.22 is >= tube strength 23.22 kN
Note: This tube-tubesheet joint is a Full Strength joint

UHX-13.5.10 Step 10:

Shell Axial Membrane Allowable Stress:
= Ss * Esw = 137.9 * 1.0 = 137.9 N./mm^2

Axial Membrane Stress in Shell [Sigmas,m]:
= ao^2/((Ds+ts)*ts)* [Pe + $(Rhos^2-1)$(Ps-Pt)]+ as^2*Pt/((Ds+ts)*ts)

```
  = 283.47²/((581.0 +10.0 )*10.0 )* [-1.87 + (1.025²-1)
    (23.0 -23.0 )] + 290.5²*23.0/((581.0 +10.0 )
    * 10.0 )
  = 30.2992 N./mm^2
```

UHX-13.5.11 Step 11:

Note:
For a given Shell thickness of 10.0 mm., the minimum Shell
length adjacent to the tubesheet should be 137.202 mm.

The Shell Membrane Stress due to Joint Interaction [Sigmas,m]:

```
  = ao²/((Ds+ts)*ts)[Pe + (Rhos²-1)(Ps-Pt)]+ as²*Pt/((Ds+ts)*ts)
  = 283.47²/((581.0 +10.0 )*10.0 )[-1.87 + (1.025²-1)
    (23.0 -23.0 )] + 290.5²*23.0/((581.0 +10.0 )
    * 10.0 )
  = 30.2992 N./mm^2
```

The Shell Bending Stress due to Joint Interaction [Sigmasb]:

```
  = 6*ks/ts² {betas[deltaS*Ps + as²*PstarS/(Es*ts)] +
    6(1 - nu*²)/(E*)(ao/h)³(1 + h*betas/2)[Pe(Zv + Zm*Q1) +
    2/ao² * Zm * Q2 ]}
  = 6 * 8514383/10.0² { 0.024 [ 0.036 * 23.0 + 290.5²
    * 0.0/(.19660E+1 ) ] +
    6(1 - 0.4²)/(41195736 )(283.47/62.0 )³(1 + 62.0 *
    0.02/2)[ -1.9 ( 0.103 + 0.488 * -0.071 ) +
    2/283.47² * 0.488 * -15.069 ] }
  = -100.8277 N./mm^2
```

Shell Stress Summation vs. Allowable

```
  abs(Sigmasm) + abs(Sigmasb) <= 1.5 * Ss
  abs(30.3 ) + abs(-100.8 ) <= 206.85 N./mm^2
  131.13 must be < or = 206.85 N./mm^2
```

Computations Completed for ASME Tubesheet Configuration b

Stress/Force Summary for Loadcase D3 un-corr. (Psd,max + Ptd,max):

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet Bend. Stress	113.4	<=	206.9 N./mm^2	Ok
Tubesheet Shear Stress	2.1	<=	110.3 N./mm^2	Ok
Maximum Tube Stress	8.8	<=	117.9 N./mm^2	Ok
Minimum Tube Stress (Buckling)	-8.8	<=	-117.9 N./mm^2	Ok
Maximum Force on any one Tube	1.7	<=	23.2 kN	Ok
Axial Membrane Stress in Shell	30.3	<=	137.9 N./mm^2	Ok
Shell Stress (jt. inter.)	131.1	<=	206.9 N./mm^2	Ok

Thickness Results for Loadcase D3 un-corr. (Psd,max + Ptd,max):

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	45.390	62.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.686	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.686	2.000	Ok

Fixed Tubesheet results per ASME UHX-13 2017

Results for 16 Load Cases:

	--Reqd. Thk. + CA		---- Tubesheet	Stresses			Case		Pass/
Case#	Tbsht	Extnsn	Bend	Allwd	Shear	Allwd	Type		Fail
D1uc	43.480	22.721	125	207	16	110	Ps+Pt-Th	D1	Ok
D2uc	25.729	...	55	207	14	110	Ps+Pt-Th	D2	Ok
D3uc	45.390	...	113	207	2	110	Ps+Pt-Th	D3	Ok
D4uc	7.089	...	3	207	...	110	Ps+Pt-Th	D4	Ok
O1uc	11.066	...	127	446	23	110	Ps+Pt+Th	O1	Ok
O2uc	19.129	...	79	446	8	110	Ps+Pt+Th	O2	Ok
O3uc	19.360	...	106	446	10	110	Ps+Pt+Th	O3	Ok
O4uc	7.318	...	55	446	6	110	Ps+Pt+Th	O4	Ok
D1c	52.094	22.721	153	207	18	110	Ps+Pt-Th-c	D1	Ok
D2c	23.287	...	52	207	15	110	Ps+Pt-Th-c	D2	Ok
D3c	50.809	...	135	207	3	110	Ps+Pt-Th-c	D3	Ok
D4c	9.810	...	3	207	...	110	Ps+Pt-Th-c	D4	Ok
O1c	31.953	...	159	446	24	110	Ps+Pt+Th-c	O1	Ok
O2c	28.747	...	98	446	10	110	Ps+Pt+Th-c	O2	Ok
O3c	32.964	...	137	446	9	110	Ps+Pt+Th-c	O3	Ok
O4c	24.552	...	73	446	4	110	Ps+Pt+Th-c	O4	Ok
Max:	52.0941	22.721	mm.	0.737		0.214	(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

[(+-)Th]:
With or Without Thermal Expansion, Tt,mx & Ts,mx

[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)

[O1, O2, O3, O4]:
Operating Load Cases using the Maximum and Minimum Operating Pressures and
Operating Temperatures

Shell Axial Membrane Stress Summary:

	---- Shell Stresses		----	:	---- Shell Band Stress ----			:	Pass
Case#	Ten	Allwd	Cmp	Allwd	Ten	Allwd	Cmp	Allwd	Fail
D1uc	11	137	...	...	...	...	...	...	Ok
D2uc	18	137	...	...	...	...	...	...	Ok
D3uc	30	137	...	...	...	...	...	...	Ok
D4uc	1	137	-1	-117	...	...	...	...	Ok
O1uc	3	470	...	...	...	...	...	...	Ok
O2uc	11	470	...	...	...	...	...	...	Ok
O3uc	21	470	...	...	...	...	...	...	Ok
O4uc	7	470	-7	-117	...	...	...	...	Ok
D1c	16	137	...	...	...	...	...	...	Ok
D2c	25	137	...	...	...	...	...	...	Ok
D3c	43	137	...	...	...	...	...	...	Ok

D4c	2	137	-2	-111	...	...	...	...	Ok
O1c	7	470	...	...	...	...	...	...	Ok
O2c	19	470	...	...	...	...	...	...	Ok
O3c	33	470	...	...	...	...	...	...	Ok
O4c	6	470	-6	-111	...	...	...	...	Ok
Max RATIO		0.313		0.059		...		...	

Tube, Shell and Channel Stress Summary:

	---- Tube Stresses				Tube Loads		Shell Stress		Channel Stress		Pass
Case#	Ten	Allwd	Cmp	Allwd	Ld	Allwd	Stress	Allwd	Stress	Allwd	Fail
D1uc	15	117	-15	-85	3	23	275	470	...	...	Ok
D2uc	6	117	-5	-78	1	23	182	206	...	...	Ok
D3uc	9	117	-9	-117	2	23	131	206	...	...	Ok
D4uc	...	117	...	-117	...	23	2	206	...	...	Ok
O1uc	20	235	-15	-79	4	46	314	470	...	...	Ok
O2uc	5	235	...	...	1	46	33	470	...	...	Ok
O3uc	16	235	-9	-114	3	46	176	470	...	...	Ok
O4uc	10	235	-4	-106	2	46	141	470	...	...	Ok
D1c	18	117	-18	-101	3	23	332	470	...	...	Ok
D2c	8	117	-7	-78	2	23	254	470	...	...	Ok
D3c	11	117	-10	-117	2	23	129	206	...	...	Ok
D4c	...	117	...	-117	...	23	2	206	...	...	Ok
O1c	24	235	-18	-93	5	46	365	470	...	...	Ok
O2c	4	235	...	...	1	46	91	470	...	...	Ok
O3c	18	235	-11	-117	3	46	171	470	...	...	Ok
O4c	10	235	-5	-117	2	46	154	470	...	...	Ok
Max RATIO		0.149		0.196		0.149		0.879		...	

Summary of Thickness Comparisons for 16 Load Cases:

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	52.094	62.000	Ok
Tubesheet Thickness Flanged Extension :	22.721	46.000	Ok
Tube Thickness :	0.645	2.770	Ok
Tube-Tubesheet Fillet Weld Leg :	1.686	2.000	Ok
Tube-Tubesheet Groove Weld Leg :	1.686	2.000	Ok

Min Shell length of thk, (10.000) adj. to tubesheet: 137.202 mm.

Note: This is a full strength Tube to Tubesheet Joint.

Summary of Axial Differential Expansion between Shell and Tubes :

Due to Thermal Expansion Shell Compresses by : -0.517 mm.
Due to Pressure Shell Compresses by : -0.083 mm.
Due to Pressure + Thermal Shell Compresses by : -0.599 mm.

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	30.656	1.000	93.613	1.000
Tubesheet Shear Stress	131.633	1.000	178.646	1.000
Tube Tensile Stress	157.026	1.000	378.619	1.000
Tube Compressive Stress	80.553	0.625	303.073	1.000
Tube-Tubesheet Joint load	157.026	1.000	378.620	1.000
Shell Stress (Axial, Junction)	30.656	1.000	44.133	1.000
Tube Pressure Stress	281.725	1.000	187.794	1.000

Tubesheet Extension Stress	25.277	...	No Calc	No Calc
Minimum MAWP	25.277		44.133	

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	36.997	1.000	93.613	1.000
Tubesheet Shear Stress	162.333	1.000	187.178	1.000
Tube Tensile Stress	187.847	1.000	483.423	1.000
Tube Compressive Stress	150.580	1.000	413.832	1.000
Tube-Tubesheet Joint load	187.847	1.000	483.415	1.000
Shell Stress (Axial, Junction)	36.997	1.000	69.170	1.000
Tube Pressure Stress	281.725	1.000	187.794	1.000
Tubesheet Extension Stress	25.277	...	No Calc	No Calc
Minimum MAPnc	25.277		69.170	

Tubesheet MDMT Calculations:

Note: The loading conditions from this case will be used to determine the tubesheet MDMT.

Shell Side MDMT calculation:

Governing thickness on the shell side per figure UCS-66.3 (e):
= max(tubesheet thk/4, min(tubesheet thk, shell thickness))
= max(62.0/4, min(62.0, 10.0))
= 15.500 mm.

Thickness Ratio = 0.91, Temperature Reduction per Fig. UCS 66.1 = 5 °C

Min Metal Temp. w/o impact per UCS-66, Curve D	-46 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C

Channel Side MDMT calculation:

Governing thickness for the channel side:
= tubesheet thickness/4
= 62.0/4
= 15.500 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(23.0/25.28, 23.0/69.17)
= 0.910

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
SHELL	[8]	D	-48	-48	-29	0.707	10.000	1.00	No
S2	[1]	B	-29	-45	-29	0.706	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
S1	[1]	B	-29	-45	-29	0.706	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
S3	[1]	D	-48	-48		0.707	10.000	1.00	No
Nozzle Flg	[5]	!	-46	-48					
Tubesheet: SS	[13]	D	-46	-48	-29	0.910	15.500	1.00	No
Warmest MDMT:			-29	-45					
BODY FLANGE 0	[11]	!	-46	-46		0.950	10.000	1.00	No
BODY FLANGE 0	[11]	!	-46	-46		0.950	10.000	1.00	No
HEAD 1	[10]	D	-48	-48	-29	0.692	10.000	1.00	No
HEAD 1	[7]	D	-48	-48	-29	0.550	12.000	1.00	No
CHANNEL 01	[8]	D	-48	-48	-29	0.707	10.000	1.00	No
CHANNEL 002	[8]	D	-48	-48	-29	0.707	10.000	1.00	No
HEAD 002	[10]	D	-48	-48	-29	0.692	10.000	1.00	No
HEAD 002	[7]	D	-48	-48	-29	0.550	12.000	1.00	No
T4	[1]	D	-48	-48		0.706	10.000	1.00	No
Nozzle Flg	[5]	!	-46	-48					
T1	[1]	B	-29	-45	-29	0.707	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T2	[1]	B	-29	-45	-29	0.706	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T3	[1]	D	-48	-48		0.707	10.000	1.00	No
Nozzle Flg	[5]	!	-46	-48					
Tubesheet: CS	[14]	!	-46	-46		0.910	15.500	1.00	No
Warmest MDMT:			-29	-45					

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.

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for ECONOMIZER E-PK6101-3
Vessel Design Summary: Step: 24 11:20pm Feb 6,2022

ASME Code, Section VIII Division 1, 2017

Diameter Spec : 581.000 mm. ID		
Vessel Design Length, Tangent to Tangent	7106.35	mm.
Specified Datum Line Distance	50.00	mm.
Shell Material	SA-516 70	[Normalized]
Nozzle Material	SA-350 LF2	[Impact Tested]
Nozzle Material	SA-333 6	[Impact Tested]
Re-Pad Material	SA-516 70	
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
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 1	23.034	1.10No Calc	70	3.0000	No
CHANNEL 01	23.030	1.10No Calc	70	3.0000	N/A
BODY FLANGE 01	23.034	1.10No Calc	70	3.0000	N/A
SHELL	23.034	1.10No Calc	70	3.0000	N/A
BODY FLANGE 002	23.034	1.10No Calc	70	3.0000	N/A
CHANNEL 002	23.034	1.10No Calc	70	3.0000	N/A
HEAD 002	23.034	1.10No Calc	70	3.0000	No

Liquid Level: 581.00 mm. Dens.: 0.001 kg./cm^3 Sp. Gr.: 0.600

Element Types and Properties:

Element Type	"To" Elev mm.	Length mm.	Element Thk mm.	R e q d Int.	T h k Ext.	Joint Eff Long	Circ
Ellipse	0.0	50.0	12.0	7.8	4.6	1.00	1.00
Cylinder	407.0	407.0	10.0	8.0	4.8	1.00	1.00
Body Flg	495.0	88.0	79.0	60.2	49.5	1.00	1.00
Cylinder	6443.2	5880.0	10.0	8.0	8.1	1.00	1.00
Body Flg	6537.4	88.0	79.0	60.2	49.5	1.00	1.00
Cylinder	7006.4	407.0	10.0	8.0	4.8	1.00	1.00
Ellipse	7056.4	50.0	12.0	7.8	4.6	1.00	1.00

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

Saddle Parameters:

Saddle Width	150.000	mm.
Saddle Bearing Angle	120.000	deg.
Centerline Dimension	600.000	mm.
Wear Pad Width	225.000	mm.
Wear Pad Thickness	10.000	mm.
Wear Pad Bearing Angle	132.000	deg.
Distance from Saddle to Tangent	992.000	mm.
Baseplate Length	545.000	mm.

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3   ECONOMIZER
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for ECONOMIZER E-PK6101-3
Vessel Design Summary: Step: 24 11:20pm Feb 6,2022

Baseplate Thickness	16.000	mm.
Baseplate Width	180.000	mm.
Number of Ribs (including outside ribs)	4	
Rib Thickness	10.000	mm.
Web Thickness	10.000	mm.
Height of Center Web	273.000	mm.
Number of Bolts in Baseplate	4	

Baseplate Sketch

```
|------------------- 545.000 mm. --------------------|
------------------------------------------------------ ---
|                                                     |
|                                                     | 180.000 mm.
|                                                     |
------------------------------------------------------ ---
```

Baseplate Plan View

```
------------------------------------------------------ ---
|                                                     | 16.000 mm.
------------------------------------------------------ ---
```

Baseplate Side View

Summary of Maximum Saddle Loads, Operating Case :

Maximum Vertical Saddle Load	40.11	kN
Maximum Transverse Saddle Shear Load	3.34	kN
Maximum Longitudinal Saddle Shear Load	11.37	kN

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	33.42	kN
Maximum Transverse Saddle Shear Load	1.05	kN
Maximum Longitudinal Saddle Shear Load	1.33	kN

Weights:

Fabricated - Bare W/O Removable Internals	4403.5	kg.
Shop Test - Fabricated + Water (Full)	6041.8	kg.
Shipping - Fab. + Rem. Intls.+ Shipping App.	4403.5	kg.
Erected - Fab. + Rem. Intls.+ Insul. (etc)	4714.8	kg.
Empty - Fab. + Intls. + Details + Wghts.	4714.8	kg.
Operating - Empty + Operating Liquid (No CA)	5735.1	kg.
Field Test - Empty Weight + Water (Full)	6058.0	kg.

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: Tue Feb 06 23:18:11 2018.

```
Model Notes
Model Notes

  Input Echo:

  Model Type                  : Cylindrical Shell

  Parent Geometry
         Parent Outside Diam.   :     601.000 mm.
         Thickness              :       8.000 mm.
         Fillet Along Shell     :       6.000 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.   :     168.300 mm.
         Thickness              :       6.600 mm.
```

```
        Length                 :     200.000 mm.
        Nozzle Weld Length     :       6.000 mm.
        RePad Width            :      60.000 mm.
        RePad Thickness        :      10.000 mm.
        RePad Weld Leg         :       6.000 mm.
        Nozzle Tilt Angle      :       0.000 deg.
        Distance from Top      :     203.000 mm.
        Distance from Bottom   :     204.000 mm.

   Nozzle Properties
        Cold Allowable         :       160.7 MPa
        Hot  Allowable         :       144.1 MPa
        Material DB # 7002618.
        Ultimate Tensile (Amb) :       413.7 MPa
        Yield Strength (Amb)   :       241.3 MPa
        Yield Strength (Hot)   :       216.5 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:	6000.0	6000.0	6000.0	4700.0	3800.0	3800.0
OPER:	6000.0	6000.0	6000.0	4700.0	3800.0	3800.0
OCC:	6000.0	6000.0	6000.0	4700.0	3800.0	3800.0

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:	6000.0	6000.0	6000.0	4700.0	3800.0	3800.0
OPER:	6000.0	6000.0	6000.0	4700.0	3800.0	3800.0
OCC:	6000.0	6000.0	6000.0	4700.0	3800.0	3800.0

The "top" or "positive" end of this model is "free" in
the axial and translational directions.

Stresses ARE nodally AVERAGED.

Vessel Centerline Vector : 0.000 1.000 0.000

```
    Nozzle Orientation Vector     :  1.000    0.000    0.000
```

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```
  Load Case Report
  FE/Pipe Version 10.0          Jobname: NOZZLE                $P
  Released Nov 2017             11:17pm  FEB  6,2018



  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
```

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```
Solution Data
FE/Pipe Version 10.0          Jobname: NOZZLE               $P
Released Nov 2017             11:17pm  FEB  6,2018
```

Solution Data

```
Maximum Solution Row Size =     558
Number of Nodes           =    2082
Number of Elements        =     686
Number of Solution Cases  =       9
```

Summation of Loads per Case

Case #	FX	FY	FZ
1	6000.	6001.	5999.
2	2223.	640963.	5999.
3	2223.	640963.	5999.
4	8223.	646963.	11999.
5	462333.	0.	0.
6	0.	3.	0.
7	0.	0.	-3.
8	0.	0.	0.
9	-3777.	634962.	0.

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```
ASME Code Stress Output Plots
FE/Pipe Version 10.0          Jobname: NOZZLE               $P
Released Nov 2017             11:18pm  FEB  6,2018
```

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
FE/Pipe Version 10.0 Jobname: NOZZLE $P
Released Nov 2017 11:18pm FEB 6,2018

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
FE/Pipe Version 10.0          Jobname: NOZZLE              $P
Released Nov 2017             11:18pm  FEB  6,2018



ASME Overstressed Areas                          $X


             *** NO OVERSTRESSED NODES IN THIS MODEL ***
```

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```
Highest Primary Stress Ratios
FE/Pipe Version 10.0          Jobname: NOZZLE              $P
Released Nov 2017             11:18pm  FEB  6,2018



Highest Primary Stress Ratios                    $X


Pad/Header at Junction

       Pl            SPL     Primary Membrane Load Case 2
       92            235     Plot Reference:
      MPa            MPa     1) Pl < SPL (SUS,Membrane) Case 2

             39%


Branch at Junction

       Pl            SPL     Primary Membrane Load Case 2
      122            216     Plot Reference:
      MPa            MPa     1) Pl < SPL (SUS,Membrane) Case 2

             56%


Branch Transition

       Pl            SPL     Primary Membrane Load Case 2
       66            216     Plot Reference:
      MPa            MPa     1) Pl < SPL (SUS,Membrane) Case 2

             30%


Pad Outer Edge Weld
```

```
  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
      235           497     Plot Reference:
      MPa           MPa     4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

          47%
```

Header Outside Pad Area

```
       Pl           SPL     Primary Membrane Load Case 2
       92           235     Plot Reference:
      MPa           MPa     1) Pl < SPL (SUS,Membrane) Case 2

          39%
```

Branch removed from Junction

```
       Pl           SPL     Primary Membrane Load Case 2
       67           216     Plot Reference:
      MPa           MPa     1) Pl < SPL (SUS,Membrane) Case 2

          30%
```

Table of Contents

```
Highest Secondary Stress Ratios
FE/Pipe Version 10.0          Jobname: NOZZLE                 $P
Released Nov 2017             11:18pm  FEB  6,2018
```

Highest Secondary Stress Ratios $X

Pad/Header at Junction

```
  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
      190           497     Plot Reference:
      MPa           MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

          38%
```

Branch at Junction

```
  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
      426           458     Plot Reference:
      MPa           MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

          92%
```

Branch Transition

```
  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
      138           458     Plot Reference:
      MPa           MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

          30%
```

Pad Outer Edge Weld

```
  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
      282           497     Plot Reference:
      MPa           MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5
```



```
          56%


 Header Outside Pad Area

   Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
       148           497     Plot Reference:
       MPa           MPa     18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

          29%


 Branch removed from Junction

   Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
       142           458     Plot Reference:
       MPa           MPa     18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

          30%
```

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```
 Highest Fatigue Stress Ratios
 FE/Pipe Version 10.0          Jobname: NOZZLE                 $P
 Released Nov 2017             11:18pm  FEB  6,2018



 Highest Fatigue Stress Ratios                           $X


 Pad/Header at Junction

 Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
        64     0.000 Life     Stress Concentration Factor = 1.350
       MPa     0.221 Stress   Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 2.3176E8
 Allowable                    "B31" Fatigue Stress Allowable = 413.6
     289.9                    Markl Fatigue Stress Allowable = 287.5
       MPa                    WRC 474 Mean Cycles to Failure = 4,630,829.
                              WRC 474 99% Probability Cycles = 1,075,784.
       22%                    WRC 474 95% Probability Cycles = 1,493,590.
                              BS5500 Allowed Cycles(Curve F) = 803,995.
                              Membrane-to-Bending Ratio = 2.816
                              Bending-to-PL+PB+Q Ratio = 0.262
                              Plot Reference:
                              22) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4


 Branch at Junction

 Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
        54     0.000 Life     Stress Concentration Factor = 1.350
       MPa     0.188 Stress   Strain Concentration Factor = 1.000
                              Cycles Allowed for this Stress = 6.8014E9
 Allowable                    "B31" Fatigue Stress Allowable = 381.0
     289.9                    Markl Fatigue Stress Allowable = 287.5
       MPa                    WRC 474 Mean Cycles to Failure = 17,936,688.
                              WRC 474 99% Probability Cycles = 4,166,851.
       18%                    WRC 474 95% Probability Cycles = 5,785,148.
                              BS5500 Allowed Cycles(Curve F) = 1,317,435.
                              Membrane-to-Bending Ratio = 0.224
                              Bending-to-PL+PB+Q Ratio = 0.817
                              Plot Reference:
                              23) Pl+Pb+Q+F < Sa (EXP,Outside) Case 4


 Branch Transition
```

```
Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
       26     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.088 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 381.0
    289.9                    Markl Fatigue Stress Allowable = 287.5
      MPa                    WRC 474 Mean Cycles to Failure = 69,291,424.
                             WRC 474 99% Probability Cycles = 16,097,027.
       8%                    WRC 474 95% Probability Cycles = 22,348,696.
                             BS5500 Allowed Cycles(Curve F) = 5,119,459.
                             Membrane-to-Bending Ratio = 0.527
                             Bending-to-PL+PB+Q Ratio = 0.655
                             Plot Reference:
                             22) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4
```

Pad Outer Edge Weld

```
Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
      122     0.049 Life     Stress Concentration Factor = 1.350
      MPa     0.422 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 143,391.
Allowable                    "B31" Fatigue Stress Allowable = 413.6
    289.9                    Markl Fatigue Stress Allowable = 287.5
      MPa                    WRC 474 Mean Cycles to Failure = 1,147,895.
                             WRC 474 99% Probability Cycles = 266,666.
      42%                    WRC 474 95% Probability Cycles = 370,233.
                             BS5500 Allowed Cycles(Curve F) = 115,710.
                             Membrane-to-Bending Ratio = 0.661
                             Bending-to-PL+PB+Q Ratio = 0.602
                             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
       50     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.173 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 3.2198E10
Allowable                    "B31" Fatigue Stress Allowable = 413.6
    289.9                    Markl Fatigue Stress Allowable = 287.5
      MPa                    WRC 474 Mean Cycles to Failure = 6,905,774.
                             WRC 474 99% Probability Cycles = 1,604,274.
      17%                    WRC 474 95% Probability Cycles = 2,227,332.
                             BS5500 Allowed Cycles(Curve F) = 679,651.
                             Membrane-to-Bending Ratio = 1.749
                             Bending-to-PL+PB+Q Ratio = 0.364
                             Plot Reference:
                             22) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4
```

Branch removed from Junction

```
Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
       18     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.062 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 381.0
    289.9                    Markl Fatigue Stress Allowable = 287.5
      MPa                    WRC 474 Mean Cycles to Failure = 1.8734E8
                             WRC 474 99% Probability Cycles = 43,520,172.
       6%                    WRC 474 95% Probability Cycles = 60,422,280.
                             BS5500 Allowed Cycles(Curve F) = 18,924,234.
                             Membrane-to-Bending Ratio = 7.450
                             Bending-to-PL+PB+Q Ratio = 0.118
                             Plot Reference:
                             22) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4
```

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```
Highest Occasional Stress Ratios
FE/Pipe Version 10.0         Jobname: NOZZLE              $P
Released Nov 2017            11:18pm  FEB  6,2018



Highest Occasional Stress Ratios                       $X


Pad/Header at Junction

      Pl           SPL     Primary Membrane Load Case 5
     109           235     Plot Reference:
     MPa           MPa     16) Pl < SPL (OCC,Membrane) Case 5

          46%

      Qb        3(Smh)     Primary Bending Load Case 5
     123           497     Plot Reference:
     MPa           MPa     17) Qb < 3(Smh) (OCC,Bending) Case 5

          24%

 Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
     149           497     Plot Reference:
     MPa           MPa     18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

          29%

 Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
     190           497     Plot Reference:
     MPa           MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

          38%


Branch at Junction

      Pl           SPL     Primary Membrane Load Case 5
     199           216     Plot Reference:
     MPa           MPa     16) Pl < SPL (OCC,Membrane) Case 5

          92%

      Qb        3(Smh)     Primary Bending Load Case 5
     363           458     Plot Reference:
     MPa           MPa     17) Qb < 3(Smh) (OCC,Bending) Case 5

          79%

 Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
     354           458     Plot Reference:
     MPa           MPa     18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

          77%

 Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
     426           458     Plot Reference:
     MPa           MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

          92%


Branch Transition

      Pl           SPL     Primary Membrane Load Case 5
     110           216     Plot Reference:
     MPa           MPa     16) Pl < SPL (OCC,Membrane) Case 5

          50%

      Qb        3(Smh)     Primary Bending Load Case 5
```

```
     61           458     Plot Reference:
    MPa           MPa     17) Qb < 3(Smh) (OCC,Bending) Case 5

          13%

  Pl+Pb+Q         SPS     Primary+Secondary (Inner) Load Case 5
    122           458     Plot Reference:
    MPa           MPa     18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

          26%

  Pl+Pb+Q         SPS     Primary+Secondary (Outer) Load Case 5
    138           458     Plot Reference:
    MPa           MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

          30%


Pad Outer Edge Weld

     Pl           SPL     Primary Membrane Load Case 5
    129           235     Plot Reference:
    MPa           MPa     16) Pl < SPL (OCC,Membrane) Case 5

          54%

     Qb        3(Smh)     Primary Bending Load Case 5
    191           497     Plot Reference:
    MPa           MPa     17) Qb < 3(Smh) (OCC,Bending) Case 5

          38%

  Pl+Pb+Q         SPS     Primary+Secondary (Inner) Load Case 5
    147           497     Plot Reference:
    MPa           MPa     18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

          29%

  Pl+Pb+Q         SPS     Primary+Secondary (Outer) Load Case 5
    282           497     Plot Reference:
    MPa           MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

          56%


Header Outside Pad Area

     Pl           SPL     Primary Membrane Load Case 5
    102           235     Plot Reference:
    MPa           MPa     16) Pl < SPL (OCC,Membrane) Case 5

          43%

     Qb        3(Smh)     Primary Bending Load Case 5
    116           497     Plot Reference:
    MPa           MPa     17) Qb < 3(Smh) (OCC,Bending) Case 5

          23%

  Pl+Pb+Q         SPS     Primary+Secondary (Inner) Load Case 5
    148           497     Plot Reference:
    MPa           MPa     18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

          29%

  Pl+Pb+Q         SPS     Primary+Secondary (Outer) Load Case 5
    112           497     Plot Reference:
    MPa           MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

          22%


Branch removed from Junction
```

```
       Pl           SPL     Primary Membrane Load Case 5
      111           216     Plot Reference:
      MPa           MPa     16) Pl < SPL (OCC,Membrane) Case 5

            51%

       Qb        3(Smh)     Primary Bending Load Case 5
       37           458     Plot Reference:
      MPa           MPa     17) Qb < 3(Smh) (OCC,Bending) Case 5

             7%

  Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 5
      142           458     Plot Reference:
      MPa           MPa     18) Pl+Pb+Q < SPS (OCC,Inside) Case 5

            30%

  Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 5
       98           458     Plot Reference:
      MPa           MPa     19) Pl+Pb+Q < SPS (OCC,Outside) Case 5

            21%
```

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Stress Intensification Factors
FE/Pipe Version 10.0          Jobname: NOZZLE              $P
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Stress Intensification Factors                       $X


Branch/Nozzle Sif Summary

                 Peak      Primary    Secondary      SSI
Axial   :        4.825      3.574       7.148       1.436
Inplane :        2.732      2.024       4.048       1.398
Outplane:        4.296      3.182       6.364       1.398
Torsion :        0.667      0.931       0.989       0.817
Pressure:        1.417      1.050       2.100       1.084

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 :      168.300  mm.
Pipe Thk:        6.600  mm.
Z approx:   135535.625  cu.mm.
Z exact :   130437.461  cu.mm.

  (SSI = SIF^x)        Axial   Inpl    Outpl   Tors    Pres
SIF/SSI Exponents:     0.809   0.701   0.794   0.176   0.140

SIF/SSI exponent based on relationship between primary and
peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor =        8.692
      Header Pressure i-factor =        2.873
```

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
	2.962	Inplane
	3.675	Outplane
	1.000	Torsional
B31.1 (Branch)		
Peak Stress Sif	0.000	Axial
	3.675	Inplane
	3.675	Outplane
	3.675	Torsional
WRC 330 (Branch)		
Peak Stress Sif	0.000	Axial
	4.454	Inplane
	3.675	Outplane
	4.454	Torsional

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Allowable Loads
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Allowable Loads $X

SECONDARY Load Type (Range):		Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force	(N)	201489.	54556.	81834.
Inplane Moment	(mm. N)	13843928.	2650550.	5622666.
Outplane Moment	(mm. N)	8804816.	1685765.	3576047.
Torsional Moment	(mm. N)	56667544.	15343557.	23015336.
Pressure	(MPa)	5.45	2.30	2.30

PRIMARY Load Type:		Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force	(N)	203085.	50102.	75153.
Inplane Moment	(mm. N)	13953564.	2434135.	5163580.
Outplane Moment	(mm. N)	8874546.	1548124.	3284067.
Torsional Moment	(mm. N)	30319114.	7479818.	11219728.
Pressure	(MPa)	5.96	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 =  168.300  mm.
  Wall Thickness   =    6.600  mm.

  Axial Translational Stiffness   =       567645.   N /mm.
  Inplane Rotational Stiffness    =     91352064.  mm. N /deg
  Outplane Rotational Stiffness   =     41939760.  mm. N /deg
  Torsional Rotational Stiffness  =   1333581440.  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    0.22282E+13    N mm.^2
  The value of (d) to use is: 161.700  mm..
  The resulting bending stiffness is in units of force x length per radian.

  Axial Flexibility Factor     (k) =     1.407
  Inplane Flexibility Factor   (k) =     2.633
  Outplane Flexibility Factor  (k) =     5.734
  Torsional Flexibility Factor (k) =     0.180
```

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