







|   |   |      |       |      |      |      |      |  |         |
|---|---|------|-------|------|------|------|------|--|---------|
| OWNER:<br><br>شرکت سست و سویی توهمه ایران (سایه و شیشه) | <b>BUSHEHR PETROCHEMICAL COMPANY<br/>MEG PLANT</b>  |      |       |      |      |      |      | EPC CONTRACTOR:<br><br>Chagalesh-Enerchimi-Steam<br>Joint Venture<br>BUPC-MEG PLANT PROJECT |         |
|   | <b>AFTER COOLER MECHANICAL<br/>STRENGHT CALCULATION FOR<br/>EMERGENCY INSTRUMENT AIR<br/>COMPRESSOR</b> |      |       |      |      |      |      | <br>Contract No : 52-98/445   |         |
| MC :<br><br>شرکت سست و سویی توهمه ایران (سایه و شیشه)  | Project   | Area | Phase | Unit | Dis. | Doc. | Seq. | Contract No : 52-98/445  |         |
| Owner Document Number:<br>17811-24B   | BU  | 20   | VD    | 303  | ME   | CAL  | 0069 | Rev.:  | Page    |
|   |   |      |       |      |      |      |      | 03   | 1 of 63 |

## AFTER COOLER MECHANICAL STRENGHT CALCULATION FOR EMERGENCY INSTRUMENT AIR COMPRESSOR

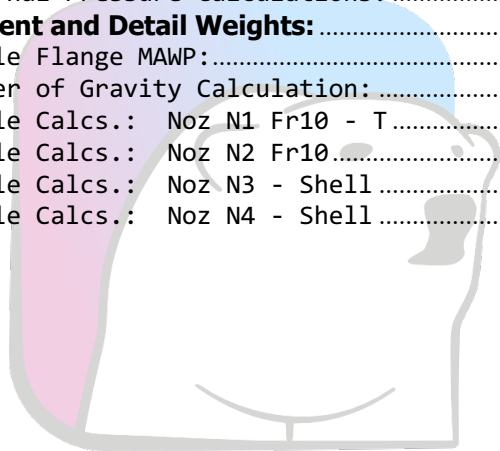
|  |  |   |              |  |  |
|--|--|---|--------------|--|--|
| <br>شرکت سست و سویی توهمه ایران (سایه و شیشه)                           |  | <br>Chagalesh-Enerchimi-Steam<br>Joint Venture<br>BUPC-MEG PLANT PROJECT |              | <b>BUSHEHR PETROCHEMICAL<br/>COMPANY<br/>MEG PLANT</b> |  |
| <b>Document Review</b>   |  |   |              |  |  |
| Issue Purpose:   |  |   | IFA          |  |  |
| Result Code: AP,AN,CM,RE,NC  |  |   | AP           |  |  |
| Next Status : IFC,IFA,IFI,AFC,AB   |  |   | AFC          |  |  |
| Responsible Department   |  |   | MECHANICAL   |  |  |
| Commented Date   |  |   | Jun /21/2022 |  |  |
| <b>Approval or review hereunder shall not be construed to relieve Vendor /<br/>Subcontractor of his responsibilities and liability under the contract.</b> |  |   |              |  |  |

|      |            |                  |          |         |          |          |
|------|------------|------------------|----------|---------|----------|----------|
|      |            |                  |          |         |          |          |
| 03   | 16/06/2022 | For approval     | KP       | LdM     | JR       |          |
| 02   | 09/05/2022 | For approval     | KP       | LdM     | JR       |          |
| 01   | 05/05/2022 | For approval     | KP       | LdM     | JR       |          |
| 00   | 17/02/2022 | For approval     | KP       | LdM     | JR       |          |
| Rev. | Date       | Purpose of Issue | Prepared | Checked | Approved | AC Code  |
|      |            |                  |          |         | Class: 1 | Phase: P |



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Strength Calculation PV-Elite  
IWS-Monje Heat Exchangers GmbH  
Wittener Str. 102, 44789 Bochum, Germany

Reference # : Project 17811  
Revision # : 00  
Client Name : Airpack Nederland BV  
Drawing # : K12-3102

**DESIGN CALCULATION**

*In Accordance with ASME Section VIII Division 1*

ASME Code Version : 2021

Analysis Performed by : IWS-Monje Heat Exchangers GmbH

Job File : Y:\Airpack\BK12-3102-L800\_Airpack-17811\_Rev00.pvdb

Date of Analysis : May 5, 2022 11:11am

**PV Elite 24, January 2022**



Strength Calculation PV-Elite  
 IWS-Monje Heat Exchangers GmbH  
 Wittener Str. 102, 44789 Bochum, Germany  
 PV Elite 24 Licensee: IWS-Monje? Heat Exchangers GmbH  
 FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
 Vessel Design Summary: Step: 20 11:11am May 5,2022

Vessel Design Summary:

### ASME Code, Section VIII Division 1, 2021

Diameter Spec : 160.000 x 141.300 mm OD  
 Vessel Design Length, Tangent to Tangent 962.85 mm

Specified Datum Line Distance 0.00 mm

Shell Side Design Temperature 210 °C  
 Channel Side Design Temperature 95 °C

Shell Side Design Pressure 2.500 MPa  
 Channel Side Design Pressure 1.000 MPa

Shop Shell Side Test Pressure 3.750 MPa  
 Shop Channel Side Test Pressure 1.500 MPa

Wind Design Code No Wind Loads  
 Earthquake Design Code No Seismic

### Materials of Construction:

| Component Type | Material     | Class | Thickness | UNS #  | Normal ized | Impact Tested |
|----------------|--------------|-------|-----------|--------|-------------|---------------|
| Shell          | SA-516 70    | ...   | ...       | K02700 | No          | No            |
| Shell          | SA-312 TP316 | ...   | ...       | S31600 | No          | No            |
| Cover          | SA-516 70    | ...   | ...       | K02700 | No          | No            |
| Flange         | SA-516 70    | ...   | ...       | K02700 | No          | No            |
| Flange         | SA-182 F316  | ...   | > 5       | S31600 | No          | No            |
| Nozzle         | SA-106 B     | ...   | ...       | K03006 | No          | No            |
| Nozzle         | SA-312 TP316 | ...   | ...       | S31600 | No          | No            |
| Nozzle Flg     | SA-182 F316  | ...   | > 5       | S31600 | No          | No            |
| Tubes          | SB-111 061   | 061   | ...       | C70600 | No          | No            |
| Tubesheet      | SB-148 M01   | M01   | ...       | C95200 | No          | No            |
| Flg Bolting    | SA-193 B7    | ...   | <= 2 1/2  | G41400 | No          | No            |

Normalized is determined based on the UCS-66 material curve selection and Figure UCS-66.  
 Impact Tested is based on material selection and material data properties.

### Element Pressures and MAWP (MPa & mm):

| Element Description or Type | Design Pressure + Stat. head | Ext. Press. | Element M.A.W.P | Total Corrosion Allowance | Str. Flg. Gov. | In Creep Range |
|-----------------------------|------------------------------|-------------|-----------------|---------------------------|----------------|----------------|
| Channel head flat           | 1.000                        | 0.10        | 26.000          | 1.0000                    | N/A            | No             |
| Channel head cylinder       | 1.000                        | 0.10        | 22.000          | 1.0000                    | N/A            | No             |
| Channel head flange         | 1.000                        | 0.10        | 2.000           | 1.0000                    | N/A            | No             |
| Shell flange ring 1         | 1.000                        | 0.10        | 2.000           | 0.0000                    | N/A            | No             |
| Main Shell                  | 2.500                        | 0.10        | 6.000           | 0.0000                    | N/A            | No             |
| Shell flange ring 2         | 1.000                        | 0.10        | 2.000           | 0.0000                    | N/A            | No             |
| Cover head                  | 1.000                        | 0.10        | 3.000           | 1.0000                    | N/A            | No             |

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 Wittener Str. 102, 44789 Bochum, Germany  
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 FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
 Vessel Design Summary: Step: 20 11:11am May 5,2022

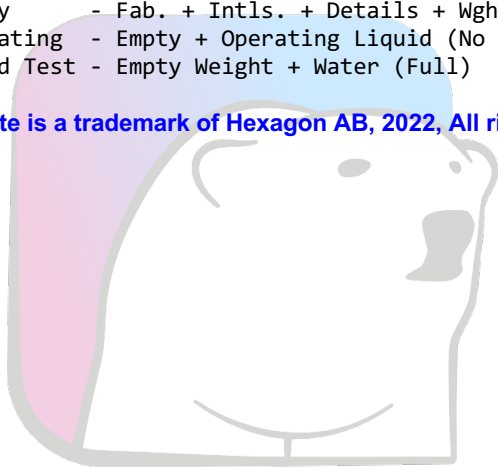
### Element Types and Properties:

| Element Type | "To" Elev<br>mm | Element Length<br>mm | Nominal Thickness<br>mm | Finished Thickness<br>mm | Reqd Thk Internal<br>mm | Reqd Thk External<br>mm | Long Eff | Circ Eff |
|--------------|-----------------|----------------------|-------------------------|--------------------------|-------------------------|-------------------------|----------|----------|
| Wld Flat     | 27.0            | 27.0                 | 27.0                    | 27.0                     | 6.1                     | ...                     | 1.00     | 1.00     |
| Cylinder     | 57.0            | 30.0                 | 13.0                    | 13.0                     | 3.5                     | 1.3                     | 1.00     | 1.00     |
| Body Flg     | 57.0            | 18.0                 | 18.0                    | 18.0                     | 14.2                    | 10.4                    | 1.00     | 1.00     |
| Body Flg     | 134.5           | 36.0                 | ...                     | 18.0                     | 12.1                    | 7.0                     | 1.00     | 1.00     |
| Cylinder     | 888.3           | 753.8                | ...                     | 3.4                      | 1.5                     | 1.0                     | 1.00     | 1.00     |
| Body Flg     | 924.3           | 36.0                 | ...                     | 18.0                     | 12.1                    | 7.0                     | 1.00     | 1.00     |
| Body Flg     | 962.8           | 25.0                 | ...                     | 25.0                     | 10.0                    | 6.9                     | 1.00     | 1.00     |

### Weights:

|  |      |    |
|--|------|----|
| Fabricated - Bare W/O Removable Internals    | 55.5 | kg |
| Shop Test - Fabricated + Water ( Full )      | 67.2 | kg |
| Shipping - Fab. + Rem. Intls.+ Shipping App. | 55.5 | kg |
| Erected - Fab. + Rem. Intls.+ Insul. (etc)   | 55.5 | kg |
| Empty - Fab. + Intls. + Details + Wghts.     | 55.5 | kg |
| Operating - Empty + Operating Liquid (No CA) | 55.5 | kg |
| Field Test - Empty Weight + Water (Full)     | 67.2 | kg |

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 FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
 Nozzle Summary: Step: 18 11:11am May 5,2022

#### Nozzle Calculation Summary (MPa & mm):

| Description     | MAWP | Ext | MAPNC | UG-45 | [tr] | Weld Path | Areas or Stresses |
|-----------------|------|-----|-------|-------|------|-----------|-------------------|
| Noz N1 Fr10 - T | 1    | ... | ...   | OK    | 4.12 | OK        | No Calc[*]        |
| Noz N2 Fr10     | 1    | ... | ...   | OK    | 4.12 | OK        | No Calc[*]        |
| Noz N3 - Shell  | 2    | ... | ...   | OK    | 1.50 | OK        | No Calc[*]        |
| Noz N4 - Shell  | 2    | ... | ...   | OK    | 1.50 | OK        | No Calc[*]        |

#### Nozzle MAWP Summary:

Minimum MAWP Nozzles : 2 Nozzle : Noz N3 - Shell [Shellside]  
 Minimum MAWP Nozzles : 1 Nozzle : Noz N1 Fr10 - T [Tubeside]

[\*] - This was a small opening and the areas were not computed.

Note: MAWPs (Internal Case) shown above are at the High Point.

Multiple output lines for the same nozzle indicates required Code calculations in both the longitudinal and circumferential planes of reinforcement where applicable.

#### Check the Spatial Relationship between the Nozzles:

| From Node | Nozzle Description | X Coordinate<br>mm | Layout Angle<br>deg | Dia. Limit<br>mm |
|-----------|--------------------|--------------------|---------------------|------------------|
| 10        | Noz N1 Fr10 - Tu   | 0.000              | 90.000              | 92.000           |
| 10        | Noz N2 Fr10        | 0.000              | 270.000             | 92.000           |
| 50        | Noz N3 - Shelli    | 206.525            | 270.000             | 104.600          |
| 50        | Noz N4 - Shello    | 826.525            | 90.000              | 104.600          |

The nozzle spacing is computed by the following:

$$= \sqrt{l_l^2 + l_c^2} \text{ where}$$

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

$l_c$  - 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!

#### Checking Multiple Nozzles on Flat Head per ASME Sec. VIII Div. 1 UG-39

Comparing Nozzles on Element: Channel head flat

#### UG-39 Average Nozzle Diameter and Ligament Checks:

| Nozzle<br>Pair Description | Avg.<br>dia.<br>mm | Head Dia.<br>/4<br>mm | Ligament<br>Width<br>mm | Min. dn<br>/4<br>mm |
|----------------------------|--------------------|-----------------------|-------------------------|---------------------|
| Noz N1 Fr10 - Tu & No      | 32                 | 40                    | 52                      | 8                   |

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 Nozzle Summary: Step: 18 11:11am May 5,2022

-----  
**UG-39 Nozzle Spacing and Average Area Checks:**

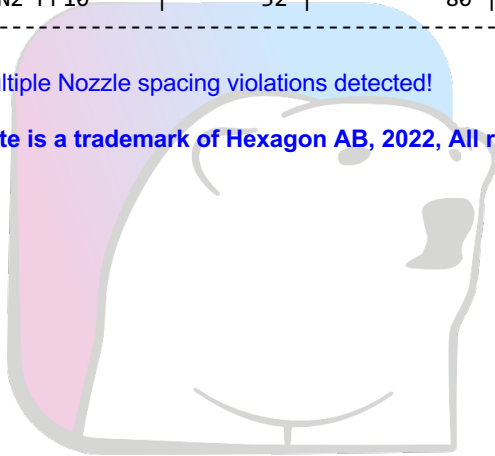
| Nozzle<br>Pair Description | Center<br>Spacing<br>mm | Avg. dia.<br>* 1.25<br>mm | Avg. Area<br>Available<br>mm^2 | Avg. Area<br>Reqd.<br>mm^2 |
|----------------------------|-------------------------|---------------------------|--------------------------------|----------------------------|
| Noz N1 Fr10 - Tu & No      | 92                      | 40                        | No Calc                        | No Calc                    |

**UG-39 Nozzle Diameter and Distance to Edge Checks:**

| Nozzle<br>Description | Nozzle<br>dia.<br>mm | Head Dia.<br>/2<br>mm | Distance<br>from Edge<br>mm | Nozzle<br>dia./4<br>mm |
|-----------------------|----------------------|-----------------------|-----------------------------|------------------------|
| Noz N1 Fr10 - Tu      | 32                   | 80                    | 27                          | 8                      |
| Noz N2 Fr10           | 32                   | 80                    | 27                          | 8                      |

No Multiple Nozzle spacing violations detected!

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## Strength Calculation PV-Elite

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PV Elite 24

Licensee: IWS-Monje? Heat Exchangers GmbH

FileName : BK12-3102-L800\_Airpack-17811\_Rev00

Nozzle Schedule:

Step: 17 11:11am May 5,2022

Nozzle Schedule:

| Description      | Nominal or Actual Size | Schd or FVC Type | Flg Type | Nozzle O/Dia mm | Wall Thk mm | Reinforcing Pad Diameter | Pad Thk mm | Cut Length mm | Flg Class |
|------------------|------------------------|------------------|----------|-----------------|-------------|--------------------------|------------|---------------|-----------|
| Noz N1 Fr10 - Tu | 40 mm                  | Actual           | None     | 40.0            | 5.000       | ...                      | ...        | 7             | ...       |
| Noz N2 Fr10      | 40 mm                  | Actual           | None     | 40.0            | 5.000       | ...                      | ...        | 7             | ...       |
| Noz N3 - Shell i | 60 mm                  | Actual           | WNF      | 60.3            | 4.000       | ...                      | ...        | 4             | 300       |
| Noz N4 - Shell o | 60 mm                  | Actual           | WNF      | 60.3            | 4.000       | ...                      | ...        | 4             | 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 |
|-------------|--------------|---------------|------------------|-------------|---------------|-------------|
| Noz N1 Fr10 | SA-106 B     | ...           | 10.000           | ...         | ...           | ...         |
| Noz N2 Fr10 | SA-106 B     | ...           | 10.000           | ...         | ...           | ...         |
| Noz N3 - Sh | SA-312 TP316 | ...           | 10.000           | ...         | ...           | ...         |
| Noz N4 - Sh | SA-312 TP316 | 3.400         | 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 |
|------------------|-----------------------------|------------------|-----------------|----------------|------------------------|
| Noz N1 Fr10 - Tu | ...                         | 90.0             | 50.00           | 0.00           | Channel head fla       |
| Noz N2 Fr10      | ...                         | 270.0            | 50.00           | 0.00           | Channel head fla       |
| Noz N3 - Shell i | 206.525                     | 270.0            | 39.00           | 0.00           | Main Shell             |
| Noz N4 - Shell o | 826.525                     | 90.0             | 39.00           | 0.00           | Main Shell             |

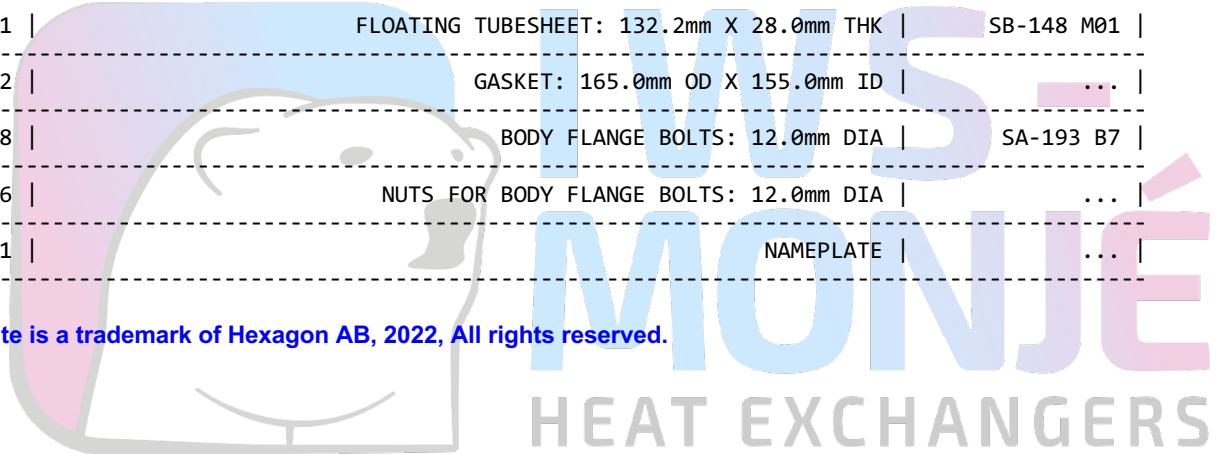
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 FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
 Bill of Material: Step: 16 11:11am May 5,2022

**Bill of Materials:**

| QTY | DESCRIPTION                                | MATERIAL     |
|-----|--|--------------|
| 1   | FLAT HEAD: 27.0mm THK X 160.0mm OD         | SA-516 70    |
| 1   | CYLINDER: 13.0mm THK X 134.0mm ID X 30.0mm | SA-516 70    |
| 1   | BODY FLANGE: 18.0mm THK X 220.0mm OD       | SA-516 70    |
| 2   | BODY FLANGE: 18.0mm THK X 220.0mm OD       | SA-182 F316  |
| 1   | CYLINDER: 3.4mm THK X 134.5mm ID X 753.8mm | SA-312 TP316 |
| 1   | BODY FLANGE: 25.0mm THK X 220.0mm OD       | SA-516 70    |
| 1   | TUBESHEET: 165.0mm X 28.0mm THK            | SB-148 M01   |
| 72  | TUBES: 830.0mm X 8.0mm DIA X 0.5mm THK     | SB-111 061   |
| 1   | FLOATING TUBESHEET: 132.2mm X 28.0mm THK   | SB-148 M01   |
| 2   | GASKET: 165.0mm OD X 155.0mm ID            | ...          |
| 8   | BODY FLANGE BOLTS: 12.0mm DIA              | SA-193 B7    |
| 16  | NUTS FOR BODY FLANGE BOLTS: 12.0mm DIA     | ...          |
| 1   | NAMEPLATE                                  | ...          |

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 FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
 MDMT Summary: Step: 19 11:11am May 5,2022

### Minimum Design Metal Temperature Results Summary (°C):

| Description   | Notes | Curve | Basic MDMT | Reduced MDMT | UG-20(f) MDMT | Thickness ratio | Gov Thk mm | E*   | PWHT reqd |
|---------------|-------|-------|------------|--------------|---------------|-----------------|------------|------|-----------|
| Main Shell    | [16]  |       | -196       |              |               |                 |            |      |           |
| Noz N3 - Shel | [15]  |       | -196       |              |               |                 |            |      |           |
| Nozzle Flg    | [5]   |       | -196       |              |               |                 |            |      |           |
| Noz N4 - Shel | [15]  |       | -196       |              |               |                 |            |      |           |
| Nozzle Flg    | [5]   |       | -196       |              |               |                 |            |      |           |
| Nozl. Bolting | [22]  |       | -48        |              |               | 1.000           | 63.500     | 1.00 | No        |
| Tubesheet: SS | [13]  |       | -18        |              |               |                 |            |      | No        |

Warmest MDMT: -18

|                |      |   |      |      |     |       |        |      |    |
|----------------|------|---|------|------|-----|-------|--------|------|----|
| Shell flange   | [11] |   | -196 |      |     |       |        |      |    |
| Shell flange   | [11] |   | -196 |      |     |       |        |      |    |
| Cover head     | [11] | B | -29  | -48  | -29 | 0.381 | 6.250  | 1.00 | No |
| Channel head   | [12] | B | -21  | -104 | -29 | 0.196 | 13.000 | 1.00 | No |
| Channel head c | [8]  | B | -21  | -104 | -29 | 0.208 | 13.000 | 1.00 | No |
| Noz N1 Fr10 -  | [1]  | B | -29  | -104 | -29 | 0.042 | 5.000  | 1.00 | No |
| Noz N2 Fr10    | [1]  | B | -29  | -104 | -29 | 0.042 | 5.000  | 1.00 | No |
| Tubesheet: CS  | [14] |   | -18  |      |     |       |        |      | No |
| Bolting        | [21] |   | -48  |      |     |       |        |      |    |

Warmest MDMT: -18 -48

| Exchanger Side | Computed MDMT | Required MDMT | Pass/Fail |
|----------------|---------------|---------------|-----------|
| Shell          | -18.0         | -10.0         | Pass      |
| Channel/Tube   | -18.0         | -10.0         | Pass      |

#### Notes:

- [ ! ] - This was an impact tested material.
- [ 1 ] - Governing Nozzle Weld.
- [ 4 ] - ASME Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
- [ 5 ] - ASME Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-b).
- [ 6 ] - MDMT Calculations at the Shell/Head Joint.
- [ 7 ] - MDMT Calculations for the Straight Flange.
- [ 8 ] - Cylinder/Cone/Flange Junction MDMT.
- [ 9 ] - Calculations in the Spherical Portion of the Head.
- [10] - Calculations in the Knuckle Portion of the Head.
- [11] - Calculated (Body Flange) Flange MDMT.
- [12] - Calculated Flat Head MDMT per UCS-66.3
- [13] - Tubesheet MDMT, shell side, if applicable
- [14] - Tubesheet MDMT, tube side, if applicable
- [15] - Nozzle Material
- [16] - Shell or Head Material
- [17] - Impact Testing required
- [18] - Impact Testing not required, see UCS-66(b)(3)
- [20] - Cylinder/Cone Junction MDMT based on Longitudinal Stress considerations
- [21] - Body Flange Bolting Material
- [22] - Nozzle Flange Bolting Material
- [23] - Stiffening Ring to Shell Weld

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FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
MDMT Summary: Step: 19 11:11am May 5,2022

[24] - Saddle to Shell Weld

UG-84(b)(2) was not considered.

UCS-66(g) was not considered.

UCS-66(i) was not considered.

Notes:

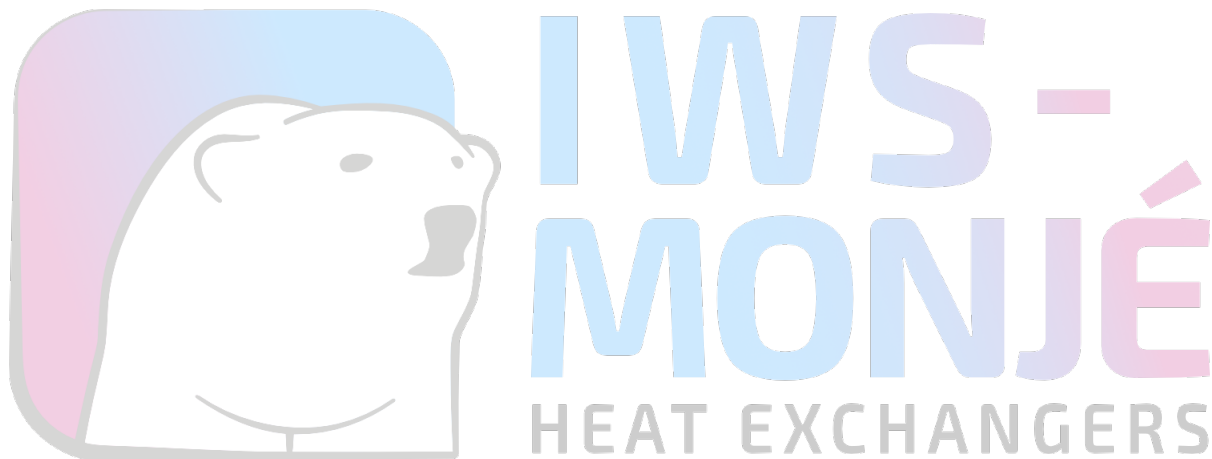
Impact test temps were not entered in and not considered in the analysis.

UCS-66(i) applies to impact tested materials not by specification and

UCS-66(g) applies to materials impact tested per UG-84.1 General Note (c).

The Basic MDMT includes the (30F) PWHT credit if applicable.

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FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
Warnings and Errors: Step: 0 11:11am May 5,2022

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

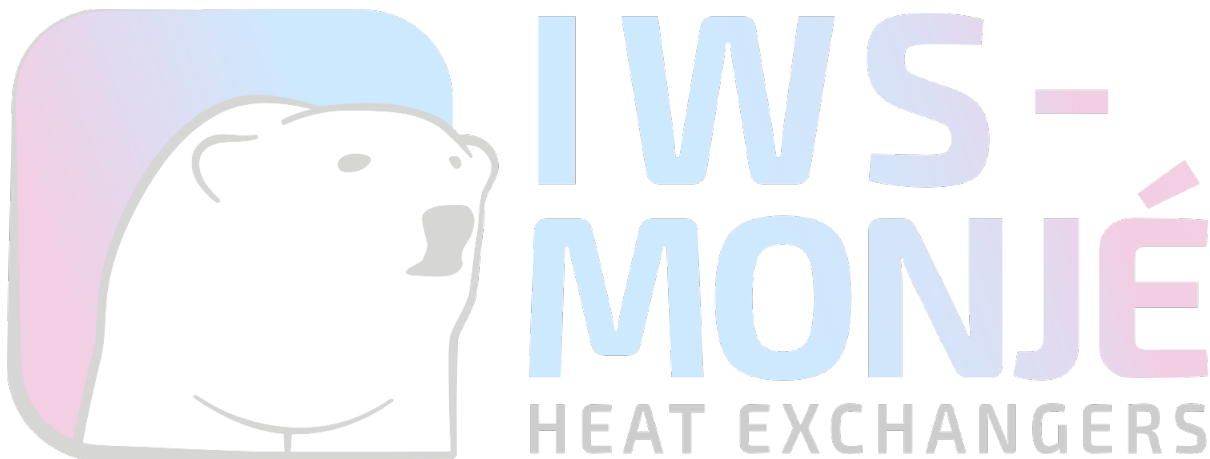
Class From To: Check of Additional Element Data  
-----

Please insure the C factor entered is in accordance with Figure UG-34.

There were no geometry errors or warnings.

*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 set of selected units for this analysis.*

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**Units used in this Analysis (SI\_ASME\_Unicode):**

| Name           | System Unit | Constant    | User Unit |
|----------------|-------------|-------------|-----------|
| Length         | Feet        | 304.8000    | mm        |
| Force          | Pounds      | 4.4480      | N         |
| Mass           | Pounds      | 0.4536      | kg        |
| Area           | sq. inches  | 645.1600    | mm^2      |
| Moment         | ft. lbs.    | 1356.3000   | N-mm      |
| Stress         | lbs./sq.in. | 0.0069      | MPa       |
| Temperature    | Degrees F   | 0.5556      | °C        |
| Pressure       | psig        | 0.0069      | MPa       |
| Elast. Modulus | lbs./sq.in. | 0.0069      | MPa       |
| Pipe Density   | lbs./cu.in. | 0.0277      | kg/cm^3   |
| Ins. Density   | lbs./cu.ft. | 0.1602E-04  | kg/cm^3   |
| Fluid Density  | lbs./cu.ft. | 0.1602E-04  | kg/cm^3   |
| Wind Speed     | miles/hr    | 1.6093      | km/hr     |
| Tray Weight    | lbs./sq.ft. | 0.0005      | kgs/cm^2  |
| Inertia        | in.**4      | 416231.0000 | mm^4      |
| G Load         | G's         | 1.0000      | g's       |
| Wind Load      | lbs./sq.ft. | 0.0479      | kPa       |
| Elevation      | Feet        | 304.8000    | mm        |
| Volume         | in.**3      | 0.0164      | ltr       |
| Diameter       | inches      | 25.4000     | mm        |
| Thickness      | inches      | 25.4000     | mm        |

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

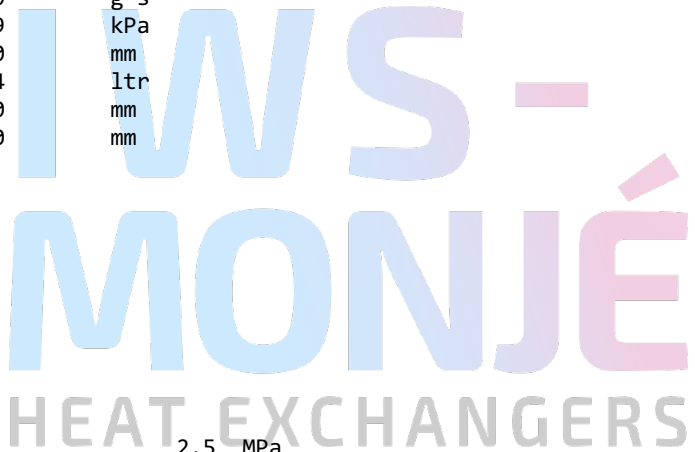
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**Exchanger Design Pressures and Temperatures**

|                                       |                 |
|---------------------------------------|-----------------|
| Shell Side Design Pressure            | 2.5 MPa         |
| Channel Side Design Pressure          | 1 MPa           |
| Shell Side Design Temperature         | 210.0 °C        |
| Channel Side Design Temperature       | 95.0 °C         |
| Radiography, Shell Side               | RT-3            |
| Radiography, Channel Side             | RT-1            |
| Service Type, Shell Side              | Air/Water/Steam |
| Service Type, Channel Side            | Air/Water/Steam |
| MDMT (CET), Shell Side                | -10.0 °C        |
| MDMT (CET), Tube Side                 | -10.0 °C        |
| User defined MAWP, Shell Side         | 2.5 MPa         |
| User defined MAWP, Channel Side       | 1 MPa           |
| User defined MAPnc, Shell Side        | 2.5 MPa         |
| User defined MAPnc, Channel Side      | 1 MPa           |
| User defined Test Pres., Shell Side   | 3.75 MPa        |
| User defined Test Pres., Channel Side | 1.5 MPa         |

---

|   |      |
|---|------|
| Projection of Nozzle from Vessel Top    | 0 mm |
| Projection of Nozzle from Vessel Bottom | 0 mm |



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Input Echo: Step: 1 11:11am May 5,2022

|   |        |
|---|--------|
| Type of Construction                    | Welded |
| Use Higher Longitudinal Stresses (Flag) | N      |
| 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      |

**Shop Pressure Test:**

|                        |                       |
|------------------------|-----------------------|
| Type of Pressure Test  | User Entered Pressure |
| Pressure Test Position | Horizontal            |

|              |                |
|--------------|----------------|
| 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    |
| Load Case 20 | BL+IP+OW       |

|                  |               |
|------------------|---------------|
| Wind Design Code | No Wind Loads |
|------------------|---------------|

|                     |            |
|---------------------|------------|
| Seismic Design Code | No Seismic |
|---------------------|------------|

|  |   |
|--|---|
| 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 |

|                             |                                |
|-----------------------------|--------------------------------|
| Perform Blast Load Analysis | No                             |
| Material Database Year      | Current w/Addenda or Code Year |

**Configuration Directives:**

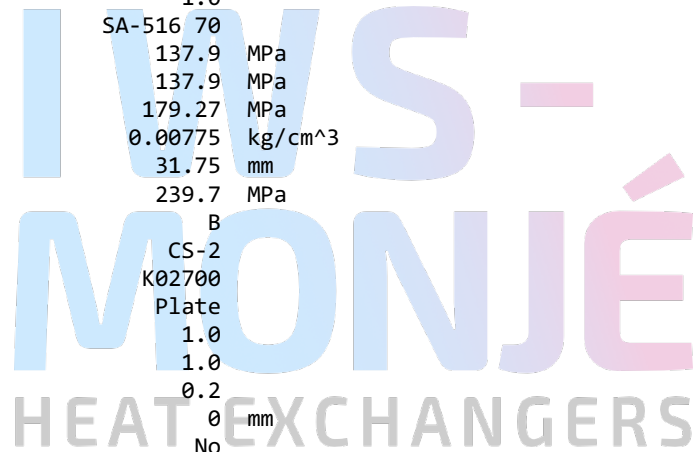
|   |     |
|---|-----|
| Do not use Nozzle MDMT Interpretation VIII-1 01-37            | No  |
| Use Table G instead of exact equation for "A"                 | Yes |
| Shell Head Joints are Tapered                                 | Yes |
| Compute "K" in corroded condition                             | Yes |
| Use Code Case 2286  | No  |
| Use the MAWP to compute the MDMT                              | Yes |
| For thickness ratios $\leq 0.35$ , 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  |

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Calculate B31.3 type stress for Nozzles with Loads Yes  
 Reduce the MDMT due to lower membrane stress Yes  
 Consider Longitudinal Stress in MDMT Calculations Yes

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

Element From Node 10  
 Element To Node 20  
 Element Type Flat  
 Description Channel head flat  
 Distance "FROM" to "TO" 27 mm  
 Element Outside Diameter 160 mm  
 Element Thickness 27 mm  
 Internal Corrosion Allowance 1 mm  
 Nominal Thickness 27 mm  
 External Corrosion Allowance 0 mm  
 Design Internal Pressure 1 MPa  
 Design Temperature Internal Pressure 95 °C  
 Design External Pressure 0.1013 MPa  
 Design Temperature External Pressure 95 °C  
 Effective Diameter Multiplier 1.0  
 Material Name SA-516 70  
 Allowable Stress, Ambient 137.9 MPa  
 Allowable Stress, Operating 137.9 MPa  
 Allowable Stress, Hydrotest 179.27 MPa  
 Material Density 0.00775 kg/cm<sup>3</sup>  
 P Number Thickness 31.75 mm  
 Yield Stress, Operating 239.7 MPa  
 UCS-66 Chart Curve Designation B  
 External Pressure Chart Name CS-2  
 UNS Number K02700  
 Product Form Plate  
 Efficiency, Longitudinal Seam 1.0  
 Efficiency, Circumferential Seam 1.0  
 Flat Head Attachment Factor 0.2  
 Small diameter if Non-Circular 0 mm  
 Weld is pre-Heated No



Element From Node 10  
 Detail Type Nozzle  
 Detail ID Noz N1 Fr10 - Tu  
 Dist. from "FROM" Node / Offset dist 46 mm  
 Nozzle Diameter 40 mm  
 Nozzle Schedule 40  
 Nozzle Class None  
 Layout Angle 90.0  
 Blind Flange (Y/N) N  
 Weight of Nozzle ( Used if > 0 ) 3.0184 N  
 Grade of Attached Flange None  
 Nozzle Matl SA-106 B

Element From Node 10  
 Detail Type Nozzle  
 Detail ID Noz N2 Fr10  
 Dist. from "FROM" Node / Offset dist 46 mm  
 Nozzle Diameter 40 mm  
 Nozzle Schedule 40

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|                                  |          |
|----------------------------------|----------|
| Nozzle Class                     | None     |
| Layout Angle                     | 270.0    |
| Blind Flange (Y/N)               | N        |
| Weight of Nozzle ( Used if > 0 ) | 0 N      |
| Grade of Attached Flange         | None     |
| Nozzle Matl                      | SA-106 B |

-----

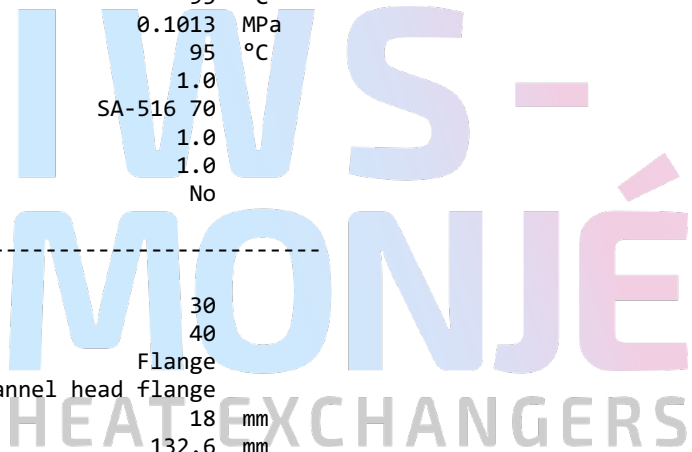
|                                      |                       |
|--------------------------------------|-----------------------|
| Element From Node                    | 20                    |
| Element To Node                      | 30                    |
| Element Type                         | Cylinder ! Atype      |
| Description                          | Channel head cylinder |
| Distance "FROM" to "TO"              | 30 mm                 |
| Element Outside Diameter             | 160 mm                |
| Element Thickness                    | 13 mm                 |
| Internal Corrosion Allowance         | 1 mm                  |
| Nominal Thickness                    | 13 mm                 |
| External Corrosion Allowance         | 0 mm                  |
| Design Internal Pressure             | 1 MPa                 |
| Design Temperature Internal Pressure | 95 °C                 |
| Design External Pressure             | 0.1013 MPa            |
| Design Temperature External Pressure | 95 °C                 |
| Effective Diameter Multiplier        | 1.0                   |
| Material Name                        | SA-516 70             |
| Efficiency, Longitudinal Seam        | 1.0                   |
| Efficiency, Circumferential Seam     | 1.0                   |
| Weld is pre-Heated                   | No                    |

-----

|   |                     |
|---|---------------------|
| Element From Node                       | 30                  |
| Element To Node                         | 40                  |
| Element Type                            | Flange              |
| Description                             | Channel head flange |
| Distance "FROM" to "TO"                 | 18 mm               |
| Flange Inside Diameter                  | 132.6 mm            |
| Element Thickness                       | 18 mm               |
| Internal Corrosion Allowance            | 1 mm                |
| Nominal Thickness                       | 18 mm               |
| External Corrosion Allowance            | 0 mm                |
| Design Internal Pressure                | 1 MPa               |
| Design Temperature Internal Pressure    | 95 °C               |
| Design External Pressure                | 0.1013 MPa          |
| Design Temperature External Pressure    | 95 °C               |
| Effective Diameter Multiplier           | 1.0                 |
| Material Name                           | SA-516 70           |
| Perform Flange Stress Calculation (Y/N) | Y                   |
| Weld is pre-Heated                      | No                  |

-----

|                         |                     |
|-------------------------|---------------------|
| Element From Node       | 40                  |
| Element To Node         | 50                  |
| Element Type            | Flange              |
| Description             | Shell flange ring 1 |
| Distance "FROM" to "TO" | 36 mm               |



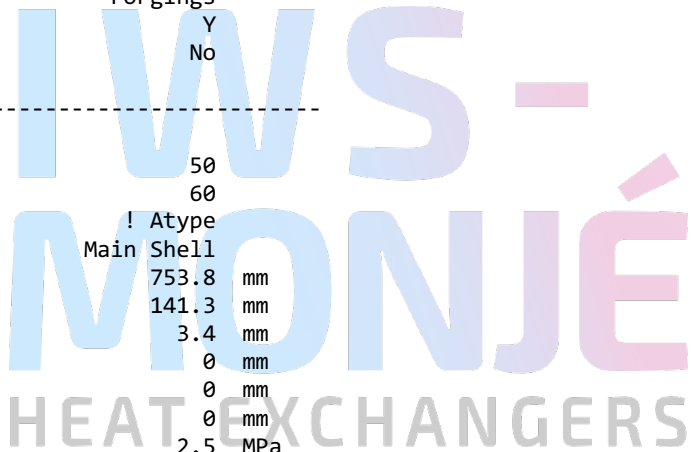
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|   |             |         |
|---|-------------|---------|
| Flange Inside Diameter                  | 133         | mm      |
| Element Thickness                       | 18          | mm      |
| Internal Corrosion Allowance            | 0           | mm      |
| Nominal Thickness                       | 0           | mm      |
| External Corrosion Allowance            | 0           | mm      |
| Design Internal Pressure                | 1           | MPa     |
| Design Temperature Internal Pressure    | 210         | °C      |
| Design External Pressure                | 0.1013      | MPa     |
| Design Temperature External Pressure    | 210         | °C      |
| Effective Diameter Multiplier           | 1.0         |         |
| Material Name                           | SA-182 F316 |         |
| Allowable Stress, Ambient               | 137.9       | MPa     |
| Allowable Stress, Operating             | 131.56      | MPa     |
| Allowable Stress, Hydrotest             | 179.27      | MPa     |
| Material Density                        | 0.008027    | kg/cm^3 |
| P Number Thickness                      | 0           | mm      |
| Yield Stress, Operating                 | 146.59      | MPa     |
| External Pressure Chart Name            | HA-2        |         |
| UNS Number                              | S31600      |         |
| Class / Thickness / Grade               | :: > 5      |         |
| Product Form                            | Forgings    |         |
| Perform Flange Stress Calculation (Y/N) | Y           |         |
| Weld is pre-Heated                      | No          |         |

---

|                                      |                       |         |
|--------------------------------------|-----------------------|---------|
| Element From Node                    | 50                    |         |
| Element To Node                      | 60                    |         |
| Element Type                         | Cylinder              |         |
| Description                          | ! Atype<br>Main Shell |         |
| Distance "FROM" to "TO"              | 753.8                 | mm      |
| Element Outside Diameter             | 141.3                 | mm      |
| Element Thickness                    | 3.4                   | mm      |
| Internal Corrosion Allowance         | 0                     | mm      |
| Nominal Thickness                    | 0                     | mm      |
| External Corrosion Allowance         | 0                     | mm      |
| Design Internal Pressure             | 2.5                   | MPa     |
| Design Temperature Internal Pressure | 210                   | °C      |
| Design External Pressure             | 0.1013                | MPa     |
| Design Temperature External Pressure | 210                   | °C      |
| Effective Diameter Multiplier        | 1.0                   |         |
| Material Name                        | SA-312 TP316          |         |
| Allowable Stress, Ambient            | 137.9                 | MPa     |
| Allowable Stress, Operating          | 132.2                 | MPa     |
| Allowable Stress, Hydrotest          | 179.3                 | MPa     |
| Material Density                     | 0.008027              | kg/cm^3 |
| P Number Thickness                   | 0                     | mm      |
| Yield Stress, Operating              | 146.6                 | MPa     |
| External Pressure Chart Name         | HA-2                  |         |
| UNS Number                           | S31600                |         |
| Product Form                         | Smls. & wld. pipe     |         |
| Efficiency, Longitudinal Seam        | 1.0                   |         |
| Efficiency, Circumferential Seam     | 1.0                   |         |
| Weld is pre-Heated                   | No                    |         |

|                   |        |
|-------------------|--------|
| Element From Node | 50     |
| Detail Type       | Nozzle |



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FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----

Input Echo: Step: 1 11:11am May 5,2022

|                                      |                  |
|--------------------------------------|------------------|
| Detail ID                            | Noz N3 - Shell i |
| Dist. from "FROM" Node / Offset dist | 72 mm            |
| Nozzle Diameter                      | 60.3 mm          |
| Nozzle Schedule                      | 40               |
| Nozzle Class                         | 300              |
| Layout Angle                         | 270.0            |
| Blind Flange (Y/N)                   | N                |
| Weight of Nozzle ( Used if > 0 )     | 0 N              |
| Grade of Attached Flange             | GR 2.2           |
| Nozzle Matl                          | SA-312 TP316     |

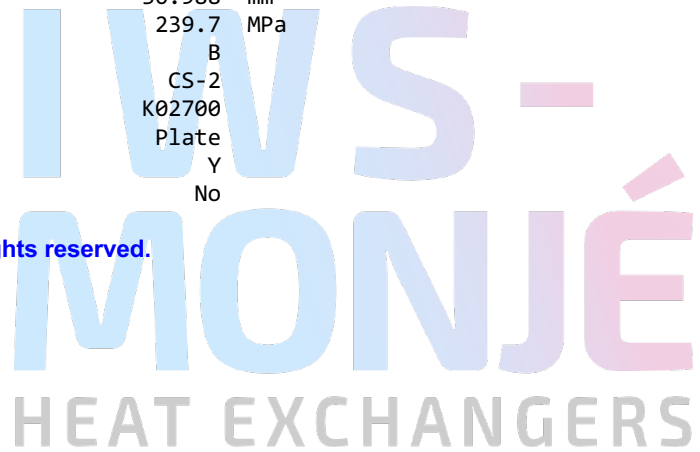
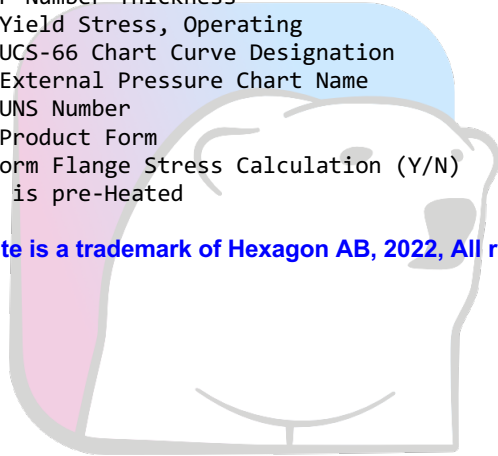
|                                      |                  |
|--------------------------------------|------------------|
| Element From Node                    | 50               |
| Detail Type                          | Nozzle           |
| Detail ID                            | Noz N4 - Shell o |
| Dist. from "FROM" Node / Offset dist | 692 mm           |
| Nozzle Diameter                      | 60.3 mm          |
| Nozzle Schedule                      | 40               |
| Nozzle Class                         | 300              |
| Layout Angle                         | 90.0             |
| Blind Flange (Y/N)                   | N                |
| Weight of Nozzle ( Used if > 0 )     | 0 N              |
| Grade of Attached Flange             | GR 2.2           |
| Nozzle Matl                          | SA-312 TP316     |

|   |                             |
|---|-----------------------------|
| Element From Node                       | 60                          |
| Element To Node                         | 70                          |
| Element Type                            | Flange                      |
| Description                             | Shell flange ring 2         |
| Distance "FROM" to "TO"                 | 36 mm                       |
| Flange Inside Diameter                  | 133 mm                      |
| Element Thickness                       | 18 mm                       |
| Internal Corrosion Allowance            | 0 mm                        |
| Nominal Thickness                       | 0 mm                        |
| External Corrosion Allowance            | 0 mm                        |
| Design Internal Pressure                | 1 MPa                       |
| Design Temperature Internal Pressure    | 210 °C                      |
| Design External Pressure                | 0.1013 MPa                  |
| Design Temperature External Pressure    | 210 °C                      |
| Effective Diameter Multiplier           | 1.0                         |
| Material Name                           | SA-182 F316                 |
| Allowable Stress, Ambient               | 137.9 MPa                   |
| Allowable Stress, Operating             | 131.6 MPa                   |
| Allowable Stress, Hydrotest             | 179.3 MPa                   |
| Material Density                        | 0.008027 kg/cm <sup>3</sup> |
| P Number Thickness                      | 0 mm                        |
| Yield Stress, Operating                 | 146.6 MPa                   |
| External Pressure Chart Name            | HA-2                        |
| UNS Number                              | S31600                      |
| Class / Thickness / Grade               | :: > 5                      |
| Product Form                            | Forgings                    |
| Perform Flange Stress Calculation (Y/N) | Y                           |
| Weld is pre-Heated                      | No                          |

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|   |            |                    |
|---|------------|--------------------|
| Element From Node                       | 70         |                    |
| Element To Node                         | 80         |                    |
| Element Type                            | Flange     |                    |
| Description                             | Cover head |                    |
| Distance "FROM" to "TO"                 | 25         | mm                 |
| Flange Outside Diameter                 | 220        | mm                 |
| Element Thickness                       | 25         | mm                 |
| Internal Corrosion Allowance            | 1          | mm                 |
| Nominal Thickness                       | 0          | mm                 |
| External Corrosion Allowance            | 0          | mm                 |
| Design Internal Pressure                | 1          | MPa                |
| Design Temperature Internal Pressure    | 95         | °C                 |
| Design External Pressure                | 0.1013     | MPa                |
| Design Temperature External Pressure    | 95         | °C                 |
| Effective Diameter Multiplier           | 1.0        |                    |
| Material Name                           | SA-516     | 70                 |
| Allowable Stress, Ambient               | 137.9      | MPa                |
| Allowable Stress, Operating             | 137.9      | MPa                |
| Allowable Stress, Hydrotest             | 179.3      | MPa                |
| Material Density                        | 0.00775    | kg/cm <sup>3</sup> |
| P Number Thickness                      | 30.988     | mm                 |
| Yield Stress, Operating                 | 239.7      | MPa                |
| UCS-66 Chart Curve Designation          | B          |                    |
| External Pressure Chart Name            | CS-2       |                    |
| UNS Number                              | K02700     |                    |
| Product Form                            | Plate      |                    |
| Perform Flange Stress Calculation (Y/N) | Y          |                    |
| Weld is pre-Heated                      | No         |                    |

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 FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
 XY Coordinate Calculations: Step: 2 11:11am May 5,2022

XY Coordinate Calculations:

| From            | To | X (Horiz.)<br>mm | Y (Vert.)<br>mm | DX (Horiz.)<br>mm | DY (Vert.)<br>mm |
|-----------------|----|------------------|-----------------|-------------------|------------------|
| Channel head fl |    | 27               | ...             | 27                | ...              |
| Channel head cy |    | 57               | ...             | 30                | ...              |
| Channel head fl |    | 57               | ...             | -18               | ...              |
| Shell flange ri |    | 134.525          | ...             | 36                | ...              |
| Main Shell      |    | 888.325          | ...             | 753.8             | ...              |
| Shell flange ri |    | 924.325          | ...             | 36                | ...              |
| Cover head      |    | 962.85           | ...             | 25                | ...              |

PV Elite includes an 1/8 inch (3.175mm) raised face and gasket thicknesses for girth flanges and tubesheet thicknesses where applicable in the Tangent to Tangent length calculation. The calculated dimensions are based on the given element lengths. Due to variability in manufacturing (weld gaps etc.), the Tangent to Tangent length may not be exact.

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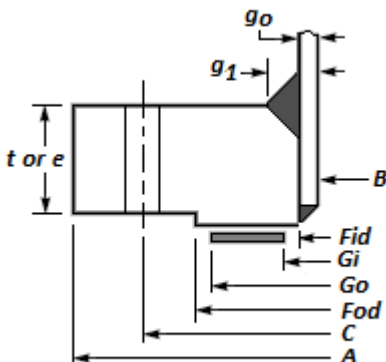
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 Wittener Str. 102, 44789 Bochum, Germany  
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 FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
 Flg Calc [Int P]: Channel Fla. Flng: 37 11:11am May 5,2022

**Flange Input Data Values****Description: Channel Fla. :**

## Channel head flange

|   |     |                    |     |
|---|-----|--------------------|-----|
| Flange Type                                 |     | Integral Ring      |     |
| Design Pressure                             | P   | 1.00               | MPa |
| Design Temperature                          |     | 95                 | °C  |
| Internal Corrosion Allowance                | ci  | 1.0000             | mm  |
| External Corrosion Allowance                | ce  | 0.0000             | mm  |
| Use Corrosion Allowance in Thickness Calcs. |     | Yes                |     |
| Attached Shell Inside Diameter              | B   | 132.6000           | mm  |
| Integral Ring Inside Diameter               |     | 158.6000           | mm  |
| Flange Outside Diameter                     | A   | 220.000            | mm  |
| Flange Thickness                            | t   | 18.0000            | mm  |
| Flange Material                             |     | SA-516 70          |     |
| Flange Material UNS number                  |     | K02700             |     |
| Flange Allowable Stress At Temperature      | Sfo | 137.90             | MPa |
| Flange Allowable Stress At Ambient          | Sfa | 137.90             | MPa |
| Bolt Material                               |     | SA-193 B7          |     |
| Bolt Allowable Stress At Temperature        | Sb  | 172.38             | MPa |
| Bolt Allowable Stress At Ambient            | Sa  | 172.38             | MPa |
| Length of Weld Leg at Back of Ring          | tw  | 0.0000             | mm  |
| Diameter of Bolt Circle                     | C   | 179.600            | mm  |
| Nominal Bolt Diameter                       | a   | 12.0000            | mm  |
| Type of Threads                             |     | TEMA Thread Series |     |
| Number of Bolts                             |     | 4                  |     |
| Flange Face Outside Diameter                | Fod | 165.000            | mm  |
| Flange Face Inside Diameter                 | Fid | 155.000            | mm  |
| Flange Facing Sketch                        |     | 1, Code Sketch 1a  |     |
| Gasket Outside Diameter                     | Go  | 165.000            | mm  |
| Gasket Inside Diameter                      | Gi  | 155.000            | mm  |
| Gasket Factor                               | m   | 0.0000             |     |
| Gasket Design Seating Stress                | y   | 0.00               | MPa |
| Column for Gasket Seating                   |     | 2, Code Column II  |     |
| Gasket Thickness                            | tg  | 2.0000             | mm  |

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|  |         |    |
|--|---------|----|
| Corroded Flange Thickness, $t_c = T - c_i$             | 17.000  | mm |
| Corroded Flange ID, $B_{cor} = B + 2 * F_{cor}$        | 134.600 | mm |
| Corroded Large Hub, $g1_{cor} = g1 - c_i$              | 0.000   | mm |
| Corroded Small Hub, $g0_{cor} = g0 - c_i$              | 0.000   | mm |
| Code R Dimension, $R = ((C - B_{cor}) / 2) - g1_{cor}$ | 22.500  | mm |
| Gasket Contact Width, $N = (G_o - G_i) / 2$            | 5.000   | mm |
| Basic Gasket Width, $b_o = N / 2$                      | 2.500   | mm |
| Effective Gasket Width, $b = b_o$                      | 2.500   | mm |
| Gasket Reaction Diameter, $G = G_o$ (Self-Energizing)  | 165.000 | mm |

### Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:  
 $= 0.785 * G^2 * P_{eq}$   
 $= 0.785 * 165.0^2 * 1.$   
 $= 21380.648 \text{ N}$

Contact Load on Gasket Surfaces [Hp]:  
 $= 2 * b * \pi * G * m * P$   
 $= 2 * 2.5 * \pi * 165.0 * 0.0 * 1.$   
 $= 0.000 \text{ N}$

Hydrostatic End Load at Flange ID [Hd]:  
 $= \pi * B_{cor}^2 * P / 4$   
 $= \pi * 134.6^2 * 1. / 4$   
 $= 14227.976 \text{ N}$

Pressure Force on Flange Face [Ht]:  
 $= H - H_d$   
 $= 21381 - 14228$   
 $= 7152.672 \text{ N}$

Operating Bolt Load [Wm1]:  
 $= \max( H + H_p + H'p, 0 )$   
 $= \max( 21381 + 0 + 0, 0 )$   
 $= 21380.648 \text{ N}$

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Gasket Seating Bolt Load [Wm2]:  
 $= y * b * pi * G + yPart * bPart * lp$   
 $= 0.0 * 2.5 * pi * 165.0 + 0.0 * 0.0 * 0.0$   
 $= 0.000 \text{ N}$

Required Bolt Area [Am]:  
 $= \max( Wm1/Sb, Wm2/Sa )$   
 $= \max( 21381/172, 0/172 )$   
 $= 124.046 \text{ mm}^2$

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:  
 $= 2a + 6t / (m + 0.5)$   
 $= 2 * 12.7 + 6 * 17.0 / (0.0 + 0.5)$   
 $= 229.400 \text{ mm}$

Actual Circumferential Bolt Spacing [Bs]:  
 $= C * \sin( pi / n )$   
 $= 179.6 * \sin( pi / 4 )$   
 $= 126.996 \text{ mm}$

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:  
 $= \max( \sqrt{ Bs / ( 2a + t ) }, 1 )$   
 $= \max( \sqrt{ 126.996 / ( 2 * 12.7 + 17.0 ) }, 1 )$   
 $= 1.7307$

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

|   |   |         |         |         |
|---|---|---------|---------|---------|
| Distance Across Corners for Nuts        |   | 24.613  | mm      |         |
| Circular Wrench End Diameter            | a | 38.100  | mm      |         |
|   |   | Minimum | Actual  | Maximum |
| Bolt Area:                              |   | 124.046 | 325.161 |         |
| Radial Distance between Hub and Bolts:  |   | 15.875  | 23.500  |         |
| Radial Distance between Bolts and Edge: |   | 15.875  | 20.200  |         |
| Circ. Spacing between the Bolts:        |   | 31.750  | 126.996 | 229.400 |

Flange Design Bolt Load, Gasket Seating [W]:  
 $= Sa( Am + Ab ) / 2$   
 $= 172.38( 124.0462 + 325.1606 ) / 2$   
 $= 38712.72 \text{ N}$

Gasket Load for the Operating Condition [HG]:  
 $= Wm1 - H$   
 $= 21381 - 21381$   
 $= 0.00 \text{ N}$

**Moment Arm Calculations:**

Distance to Gasket Load Reaction [hg]:  
 $= ( C - G ) / 2$   
 $= ( 179.6 - 165.0 ) / 2$   
 $= 7.3000 \text{ mm}$

Distance to Face Pressure Reaction [ht]:  
 $= ( R + g1 + hg ) / 2$

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$$= ( 22.5 + 0.0 + 7.3 )/2$$

$$= 14.9000 \text{ mm}$$

Distance to End Pressure Reaction [hd]:

$$= R + ( g1 / 2 )$$

$$= 22.5 +( 0.0/2.0 )$$

$$= 22.5000 \text{ mm}$$

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

| Loading              | Force  | Distance | Bolt Corr | Moment  |
|----------------------|--------|----------|-----------|---------|
| End Pressure, Md     | 14228. | 22.5000  | 1.7307    | 554261. |
| Face Pressure, Mt    | 7153.  | 14.9000  | 1.7307    | 184520. |
| Gasket Load, Mg      | 0.     | 7.3000   | 1.7307    | 0.      |
| Gasket Seating, Matm | 38713. | 7.3000   | 1.7307    | 489289. |

Total Moment for Operation, Mop 738781. N-mm  
 Total Moment for Gasket seating, Matm 489289. N-mm

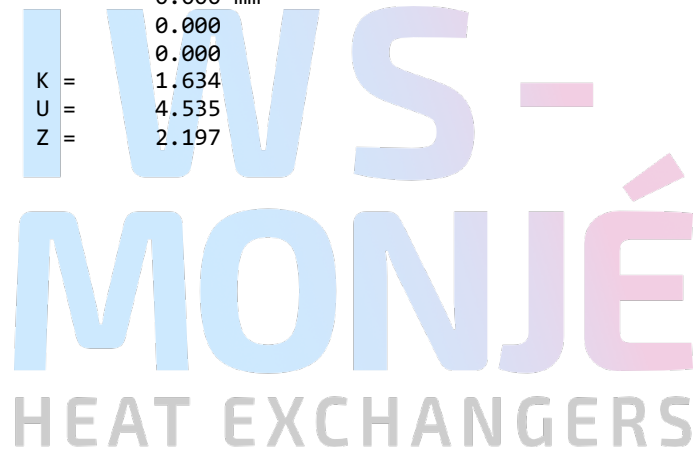
Effective Hub Length, ho = sqrt(Bcor\*goCor) 0.000 mm  
 Hub Ratio, h/h0 = Defined as 0 0.000  
 Thickness Ratio, g1/g0 = Defined as 0.0 0.000  
 Factors from Figure 2-7.1  
 K = 1.634  
 U = 4.535  
 Z = 2.197  
 T = 1.653  
 Y = 4.126

Tangential Flange Stress, Operating [Sto]:  
 = ( Y \* Mop )/( t<sup>2</sup> \* Bcor )  
 = ( 4.1264\*738781)/(17.0<sup>2</sup>\*134.6)  
 = 78.34 MPa

Tangential Flange Stress, Seating [STa]:  
 = ( Y \* Matm )/( t<sup>2</sup> \* Bcor )  
 = ( 4.1264\*489289)/(17.0<sup>2</sup>\*134.6)  
 = 51.89 MPa

Bolt Stress, Operating [BSo]:  
 = Wm1 / Ab  
 = 21381/325.1606  
 = 65.76 MPa

Bolt Stress, Seating [BSa]:  
 = ( Wm2 / Ab )  
 = ( 0/325.1606 )  
 = 0.00 MPa



**Flange Stress Analysis Results: MPa**

|                   | Actual | Operating Allowed | Gasket Seating Actual | Gasket Seating Allowed |
|-------------------|--------|-------------------|-----------------------|------------------------|
| Tangential Flange | 78.34  | 137.90            | 51.89                 | 137.90                 |
| Bolting           | 65.76  | 172.38            | 0.00                  | 172.38                 |

Minimum Required Flange Thickness 14.249 mm  
 Estimated M.A.W.P. ( Operating ) 2 MPa

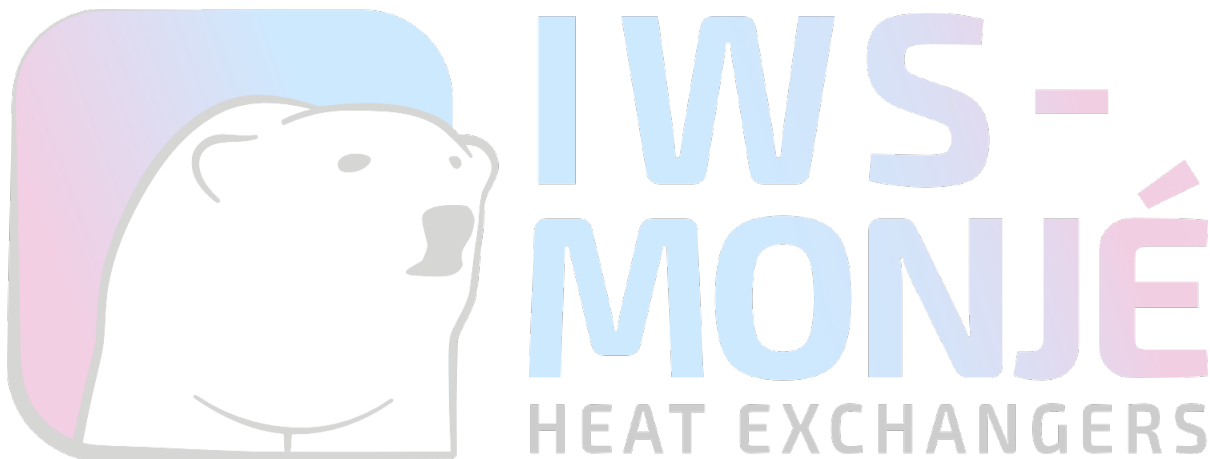
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Estimated Finished Weight of Flange at given Thk. 3.4 kg  
Estimated Unfinished Weight of Forging at given Thk 3.4 kg

**Required Fillet Weld Leg size for Slip on Flanges:**

= max( tn, ( 6 mm or 1/4 inch ) ) no hub size given  
= max( 12.0, 6.0 )  
= 12.000 mm

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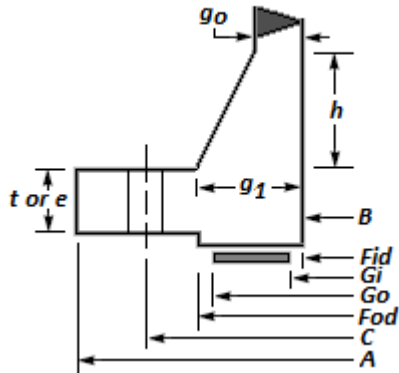
### Flange Input Data Values

Description: Shell Fl. 1 :

#### Shell flange ring 1

| Flange Type                                 | Integral Weld Neck |                    |     |
|---|--------------------|--------------------|-----|
| Design Pressure                             | P                  | 1.00               | MPa |
| Design Temperature                          |                    | 210                | °C  |
| Internal Corrosion Allowance                | ci                 | 0.0000             | mm  |
| External Corrosion Allowance                | ce                 | 0.0000             | mm  |
| Use Corrosion Allowance in Thickness Calcs. |                    | Yes                |     |
| Flange Inside Diameter                      | B                  | 133.000            | mm  |
| Flange Outside Diameter                     | A                  | 220.000            | mm  |
| Flange Thickness                            | t                  | 18.0000            | mm  |
| Thickness of Hub at Small End               | go                 | 3.4000             | mm  |
| Thickness of Hub at Large End               | g1                 | 4.5000             | mm  |
| Length of Hub                               | h                  | 18.0000            | mm  |
| Flange Material                             |                    | SA-182 F316        |     |
| Flange Material UNS number                  |                    | S31600             |     |
| Flange Allowable Stress At Temperature      | Sfo                | 131.56             | MPa |
| Flange Allowable Stress At Ambient          | Sfa                | 137.90             | MPa |
| Bolt Material                               |                    | SA-193 B7          |     |
| Bolt Allowable Stress At Temperature        | Sb                 | 172.38             | MPa |
| Bolt Allowable Stress At Ambient            | Sa                 | 172.38             | MPa |
| Diameter of Bolt Circle                     | C                  | 179.600            | mm  |
| Nominal Bolt Diameter                       | a                  | 12.0000            | mm  |
| Type of Threads                             |                    | TEMA Thread Series |     |
| Number of Bolts                             |                    | 4                  |     |
| Flange Face Outside Diameter                | Fod                | 165.000            | mm  |
| Flange Face Inside Diameter                 | Fid                | 155.000            | mm  |
| Flange Facing Sketch                        |                    | 1, Code Sketch 1a  |     |
| Gasket Outside Diameter                     | Go                 | 165.000            | mm  |
| Gasket Inside Diameter                      | Gi                 | 155.000            | mm  |
| Gasket Factor                               | m                  | 0.0000             |     |
| Gasket Design Seating Stress                | y                  | 0.00               | MPa |
| Column for Gasket Seating                   |                    | 2, Code Column II  |     |
| Gasket Thickness                            | tg                 | 2.0000             | mm  |

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Hub Small End Required Thickness due to Internal Pressure:

$$= (P \cdot (D/2 + C_a)) / (S \cdot E - 0.6 \cdot P) \text{ per UG-27 (c)(1)}$$

$$= (1 \cdot (133.0/2 + 0.0)) / (131.56 \cdot 1.0 - 0.6 \cdot 1.0) + C_a$$

$$= 0.5078 \text{ mm}$$

Hub Small End Hub MAWP:

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

$$= (131.56 \cdot 1.0 \cdot 3.4) / (66.5 + 0.6 \cdot 3.4)$$

$$= 6.526 \text{ MPa}$$

|                           |                                 |            |
|---------------------------|---------------------------------|------------|
| Corroded Flange ID,       | $B_{cor} = B + 2 \cdot F_{cor}$ | 133.000 mm |
| Corroded Large Hub,       | $g1_{cor} = g1 - c_i$           | 4.500 mm   |
| Corroded Small Hub,       | $g0_{cor} = g0 - c_i$           | 3.400 mm   |
| Code R Dimension,         | $R = (C - B) / 2 - g1$          | 18.800 mm  |
| Gasket Contact Width,     | $N = (G_o - G_i) / 2$           | 5.000 mm   |
| Basic Gasket Width,       | $b_o = N / 2$                   | 2.500 mm   |
| Effective Gasket Width,   | $b = b_o$                       | 2.500 mm   |
| Gasket Reaction Diameter, | $G = G_o$ (Self-Energizing)     | 165.000 mm |

### Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

$$= 0.785 \cdot G^2 \cdot P_{eq}$$

$$= 0.785 \cdot 165.0^2 \cdot 1.$$

$$= 21380.648 \text{ N}$$

Contact Load on Gasket Surfaces [Hp]:

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

$$= 2 \cdot 2.5 \cdot \pi \cdot 165.0 \cdot 0.0 \cdot 1.$$

$$= 0.000 \text{ N}$$

Hydrostatic End Load at Flange ID [Hd]:

$$= \pi \cdot B_{cor}^2 \cdot P / 4$$

$$= \pi \cdot 133.0^2 \cdot 1.0 / 4$$

$$= 13891.725 \text{ N}$$

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Pressure Force on Flange Face [Ht]:

$$\begin{aligned}
 &= H - H_d \\
 &= 21381 - 13892 \\
 &= 7488.922 \text{ N}
 \end{aligned}$$

Operating Bolt Load [Wm1]:

$$\begin{aligned}
 &= \max( H + H_p + H'p, 0 ) \\
 &= \max( 21381 + 0 + 0, 0 ) \\
 &= 21380.648 \text{ N}
 \end{aligned}$$

Gasket Seating Bolt Load [Wm2]:

$$\begin{aligned}
 &= y * b * \pi * G + y_{Part} * b_{Part} * l_p \\
 &= 0.0 * 2.5 * \pi * 165.0 + 0.0 * 0.0 * 0.0 \\
 &= 0.000 \text{ N}
 \end{aligned}$$

Required Bolt Area [Am]:

$$\begin{aligned}
 &= \max( Wm1/S_b, Wm2/S_a ) \\
 &= \max( 21381/172, 0/172 ) \\
 &= 124.046 \text{ mm}^2
 \end{aligned}$$

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

$$\begin{aligned}
 &= 2a + 6t / (m + 0.5) \\
 &= 2 * 12.7 + 6 * 18.0 / (0.0 + 0.5) \\
 &= 241.400 \text{ mm}
 \end{aligned}$$

Actual Circumferential Bolt Spacing [Bs]:

$$\begin{aligned}
 &= C * \sin( \pi / n ) \\
 &= 179.6 * \sin( \pi / 4 ) \\
 &= 126.996 \text{ mm}
 \end{aligned}$$

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

$$\begin{aligned}
 &= \max( \sqrt{ Bs / ( 2a + t ) }, 1 ) \\
 &= \max( \sqrt{ 126.996 / ( 2 * 12.7 + 18.0 ) }, 1 ) \\
 &= 1.7106
 \end{aligned}$$

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

|   | Minimum | Actual  | Maximum |
|---|---------|---------|---------|
| Bolt Area:                              | 124.046 | 325.161 |         |
| Radial Distance between Hub and Bolts:  | 20.637  | 18.800  |         |
| Radial Distance between Bolts and Edge: | 15.875  | 20.200  |         |
| Circ. Spacing between the Bolts:        | 31.750  | 126.996 | 241.400 |

Flange Design Bolt Load, Gasket Seating [W]:

$$\begin{aligned}
 &= S_a ( A_m + A_b ) / 2 \\
 &= 172.38 ( 124.0462 + 325.1606 ) / 2 \\
 &= 38712.72 \text{ N}
 \end{aligned}$$

Gasket Load for the Operating Condition [HG]:

$$\begin{aligned}
 &= Wm1 - H \\
 &= 21381 - 21381 \\
 &= 0.00 \text{ N}
 \end{aligned}$$

**Moment Arm Calculations:**

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Distance to Gasket Load Reaction [hg]:

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

$$= (179.6 - 165.0) / 2$$

$$= 7.3000 \text{ mm}$$

Distance to Face Pressure Reaction [ht]:

$$= (R + g1 + hg) / 2$$

$$= (18.8 + 4.5 + 7.3) / 2$$

$$= 15.3000 \text{ mm}$$

Distance to End Pressure Reaction [hd]:

$$= R + (g1 / 2)$$

$$= 18.8 + (4.5 / 2)$$

$$= 21.0500 \text{ mm}$$

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

| Loading                                     | Force       | Distance | Bolt Corr | Moment                   |
|---|-------------|----------|-----------|--------------------------|
| End Pressure, Md                            | 13892.      | 21.0500  | 1.7106    | 500421.                  |
| Face Pressure, Mt                           | 7489.       | 15.3000  | 1.7106    | 196082.                  |
| Gasket Load, Mg                             | 0.          | 7.3000   | 1.7106    | 0.                       |
| Gasket Seating, Matm                        | 38713.      | 7.3000   | 1.7106    | 483619.                  |
| Total Moment for Operation, Mop             |             |          |           | 696503. N-mm             |
| Total Moment for Gasket seating, Matm       |             |          |           | 483619. N-mm             |
| Effective Hub Length, ho = sqrt(Bcor*goCor) |             |          | 21.265 mm |                          |
| Hub Ratio, h/h0 = HL / H0                   |             |          | 0.846     |                          |
| Thickness Ratio, g1/g0 = (g1Cor/goCor)      |             |          | 1.324     |                          |
| Flange Factors for Integral Flange:         |             |          |           |                          |
| Factor F                                    |             |          | 0.835     |                          |
| Factor V                                    |             |          | 0.330     |                          |
| Factor f                                    |             |          | 1.000     |                          |
| Factors from Figure 2-7.1                   |             |          |           |                          |
| T =   | 1.645       |          | K =       | 1.654                    |
| Y =   | 4.032       |          | U =       | 4.431                    |
| e =   | 0.0393 1/mm |          | Z =       | 2.152                    |
|   |             |          | d =       | 3305.564 mm <sup>3</sup> |
| Stress Factors                              |             |          |           |                          |
| Beta =                                      | 1.942       |          | Alpha =   | 1.707                    |
| Delta =                                     | 1.764       |          | Gamma =   | 1.038                    |
|   |             |          | Lambda =  | 2.802                    |

Longitudinal Hub Stress, Operating [SHo]:

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

$$= (1.0 * 696503 / 133.0) / (2.8021 * 4.5^2)$$

$$= 92.26 \text{ MPa}$$

Longitudinal Hub Stress, Seating [SHa]:

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

$$= (1.0 * 483619 / 133.0) / (2.8021 * 4.5^2)$$

$$= 64.06 \text{ MPa}$$

Radial Flange Stress, Operating [SRo]:

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

$$= (1.9424 * 696503 / 133.0) / (2.8021 * 18.0^2)$$

$$= 11.20 \text{ MPa}$$

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Radial Flange Stress, Seating [SRa]:

$$= ( \text{beta} * \text{Matm}/\text{Bcor} ) / ( \text{L} * \text{t}^2 )$$

$$= ( 1.9424*483619/133.0 ) / ( 2.8021*18.0^2 )$$

$$= 7.78 \text{ MPa}$$

Tangential Flange Stress, Operating [STo]:

$$= ( \text{Y} * \text{Mo} / ( \text{t}^2 * \text{Bcor} ) ) - \text{Z} * \text{SRo}$$

$$= ( 4.0324*696503 / ( 18.0^2 * 133.0 ) ) - 2.152 * 11$$

$$= 41.05 \text{ MPa}$$

Tangential Flange Stress, Seating [STa]:

$$= ( \text{y} * \text{Matm} / ( \text{t}^2 * \text{Bcor} ) ) - \text{Z} * \text{SRa}$$

$$= ( 4.0324*483619 / ( 18.0^2 * 133.0 ) ) - 2.152 * 8$$

$$= 28.50 \text{ MPa}$$

Average Flange Stress, Operating [SAo]:

$$= ( \text{SHo} + \max( \text{SRo}, \text{STo} ) ) / 2$$

$$= ( 92 + \max( 11, 41 ) ) / 2$$

$$= 66.66 \text{ MPa}$$

Average Flange Stress, Seating [SAa]:

$$= ( \text{SHa} + \max( \text{SRa}, \text{STa} ) ) / 2$$

$$= ( 64 + \max( 8, 29 ) ) / 2$$

$$= 46.28 \text{ MPa}$$

Bolt Stress, Operating [BSo]:

$$= \text{Wm1} / \text{Ab}$$

$$= 21381 / 325.1606$$

$$= 65.76 \text{ MPa}$$

Bolt Stress, Seating [BSa]:

$$= ( \text{Wm2} / \text{Ab} )$$

$$= ( 0 / 325.1606 )$$

$$= 0.00 \text{ MPa}$$

**Flange Stress Analysis Results: MPa**

|                   | Operating |         | Gasket Seating |         |
|-------------------|-----------|---------|----------------|---------|
|                   | Actual    | Allowed | Actual         | Allowed |
| Longitudinal Hub  | 92.26     | 197.34  | 64.06          | 206.85  |
| Radial Flange     | 11.20     | 131.56  | 7.78           | 137.90  |
| Tangential Flange | 41.05     | 131.56  | 28.50          | 137.90  |
| Maximum Average   | 66.66     | 131.56  | 46.28          | 137.90  |
| Bolting           | 65.76     | 172.38  | 0.00           | 172.38  |

|   |           |
|---|-----------|
| Minimum Required Flange Thickness                   | 12.141 mm |
| Estimated M.A.W.P. ( Operating )                    | 2 MPa     |
| Estimated Finished Weight of Flange at given Thk.   | 3.7 kg    |
| Estimated Unfinished Weight of Forging at given Thk | 7.0 kg    |

SA-182 F316, Min Metal Temp without impact per UHA-51: -196 °C

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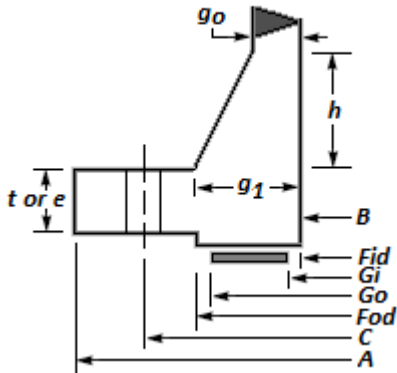
### Flange Input Data Values

Description: Shell Fl. 2 :

#### Shell flange ring 2

| Flange Type                                 | Integral Weld Neck |                    |     |
|---|--------------------|--------------------|-----|
| Design Pressure                             | P                  | 1.00               | MPa |
| Design Temperature                          |                    | 210                | °C  |
| Internal Corrosion Allowance                | ci                 | 0.0000             | mm  |
| External Corrosion Allowance                | ce                 | 0.0000             | mm  |
| Use Corrosion Allowance in Thickness Calcs. |                    | Yes                |     |
| Flange Inside Diameter                      | B                  | 133.000            | mm  |
| Flange Outside Diameter                     | A                  | 220.000            | mm  |
| Flange Thickness                            | t                  | 18.0000            | mm  |
| Thickness of Hub at Small End               | go                 | 3.4000             | mm  |
| Thickness of Hub at Large End               | g1                 | 4.5000             | mm  |
| Length of Hub                               | h                  | 18.0000            | mm  |
| Flange Material                             |                    | SA-182 F316        |     |
| Flange Material UNS number                  |                    | S31600             |     |
| Flange Allowable Stress At Temperature      | Sfo                | 131.60             | MPa |
| Flange Allowable Stress At Ambient          | Sfa                | 137.90             | MPa |
| Bolt Material                               |                    | SA-193 B7          |     |
| Bolt Allowable Stress At Temperature        | Sb                 | 172.38             | MPa |
| Bolt Allowable Stress At Ambient            | Sa                 | 172.38             | MPa |
| Diameter of Bolt Circle                     | C                  | 179.600            | mm  |
| Nominal Bolt Diameter                       | a                  | 12.0000            | mm  |
| Type of Threads                             |                    | TEMA Thread Series |     |
| Number of Bolts                             |                    | 4                  |     |
| Flange Face Outside Diameter                | Fod                | 165.000            | mm  |
| Flange Face Inside Diameter                 | Fid                | 155.000            | mm  |
| Flange Facing Sketch                        |                    | 1, Code Sketch 1a  |     |
| Gasket Outside Diameter                     | Go                 | 165.000            | mm  |
| Gasket Inside Diameter                      | Gi                 | 155.000            | mm  |
| Gasket Factor                               | m                  | 0.0000             |     |
| Gasket Design Seating Stress                | y                  | 0.00               | MPa |
| Column for Gasket Seating                   |                    | 2, Code Column II  |     |
| Gasket Thickness                            | tg                 | 2.0000             | mm  |

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Hub Small End Required Thickness due to Internal Pressure:

$$\begin{aligned}
 &= (P \cdot (D/2 + Ca)) / (S \cdot E - 0.6 \cdot P) \text{ per UG-27 (c)(1)} \\
 &= (1. \cdot (133.0 / 2 + 0.0)) / (131.6 \cdot 1.0 - 0.6 \cdot 1.) + Ca \\
 &= 0.5076 \text{ mm}
 \end{aligned}$$

Hub Small End Hub MAWP:

$$\begin{aligned}
 &= (S \cdot E \cdot t) / (R + 0.6 \cdot t) \text{ per UG-27 (c)(1)} \\
 &= (131.6 \cdot 1.0 \cdot 3.4) / (66.5 + 0.6 \cdot 3.4) \\
 &= 6.528 \text{ MPa}
 \end{aligned}$$

|                           |                          |            |
|---------------------------|--------------------------|------------|
| Corroded Flange ID,       | Bcor = B + 2 * Fcor      | 133.000 mm |
| Corroded Large Hub,       | g1Cor = g1 - ci          | 4.500 mm   |
| Corroded Small Hub,       | g0Cor = go - ci          | 3.400 mm   |
| Code R Dimension,         | R = (C - B) / 2 - g1     | 18.800 mm  |
| Gasket Contact Width,     | N = (Go - Gi) / 2        | 5.000 mm   |
| Basic Gasket Width,       | bo = N / 2               | 2.500 mm   |
| Effective Gasket Width,   | b = bo                   | 2.500 mm   |
| Gasket Reaction Diameter, | G = Go (Self-Energizing) | 165.000 mm |

### Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

$$\begin{aligned}
 &= 0.785 \cdot G^2 \cdot Peq \\
 &= 0.785 \cdot 165.0^2 \cdot 1. \\
 &= 21380.648 \text{ N}
 \end{aligned}$$

Contact Load on Gasket Surfaces [Hp]:

$$\begin{aligned}
 &= 2 \cdot b \cdot \pi \cdot G \cdot m \cdot P \\
 &= 2 \cdot 2.5 \cdot \pi \cdot 165.0 \cdot 0.0 \cdot 1. \\
 &= 0.000 \text{ N}
 \end{aligned}$$

Hydrostatic End Load at Flange ID [Hd]:

$$\begin{aligned}
 &= \pi \cdot Bcor^2 \cdot P / 4 \\
 &= \pi \cdot 133.0^2 \cdot 1. / 4 \\
 &= 13891.725 \text{ N}
 \end{aligned}$$

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Pressure Force on Flange Face [Ht]:

$$= H - H_d$$

$$= 21381 - 13892$$

$$= 7488.922 \text{ N}$$

Operating Bolt Load [Wm1]:

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

$$= \max( 21381 + 0 + 0, 0 )$$

$$= 21380.648 \text{ N}$$

Gasket Seating Bolt Load [Wm2]:

$$= y * b * \pi * G + y_{Part} * b_{Part} * l_p$$

$$= 0.0 * 2.5 * \pi * 165.0 + 0.0 * 0.0 * 0.0$$

$$= 0.000 \text{ N}$$

Required Bolt Area [Am]:

$$= \max( Wm1/S_b, Wm2/S_a )$$

$$= \max( 21381/172, 0/172 )$$

$$= 124.046 \text{ mm}^2$$

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

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

$$= 2 * 12.7 + 6 * 18.0 / (0.0 + 0.5)$$

$$= 241.400 \text{ mm}$$

Actual Circumferential Bolt Spacing [Bs]:

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

$$= 179.6 * \sin( \pi / 4 )$$

$$= 126.996 \text{ mm}$$

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

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

$$= \max( \sqrt{ 126.996 / ( 2 * 12.7 + 18.0 ) }, 1 )$$

$$= 1.7106$$

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

|   | Minimum | Actual  | Maximum |
|---|---------|---------|---------|
| Bolt Area:                              | 124.046 | 325.161 |         |
| Radial Distance between Hub and Bolts:  | 20.637  | 18.800  |         |
| Radial Distance between Bolts and Edge: | 15.875  | 20.200  |         |
| Circ. Spacing between the Bolts:        | 31.750  | 126.996 | 241.400 |

Flange Design Bolt Load, Gasket Seating [W]:

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

$$= 172.38 ( 124.0462 + 325.1606 ) / 2$$

$$= 38712.72 \text{ N}$$

Gasket Load for the Operating Condition [HG]:

$$= Wm1 - H$$

$$= 21381 - 21381$$

$$= 0.00 \text{ N}$$

**Moment Arm Calculations:**

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Distance to Gasket Load Reaction [hg]:

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

$$= (179.6 - 165.0) / 2$$

$$= 7.3000 \text{ mm}$$

Distance to Face Pressure Reaction [ht]:

$$= (R + g1 + hg) / 2$$

$$= (18.8 + 4.5 + 7.3) / 2$$

$$= 15.3000 \text{ mm}$$

Distance to End Pressure Reaction [hd]:

$$= R + (g1 / 2)$$

$$= 18.8 + (4.5 / 2.0)$$

$$= 21.0500 \text{ mm}$$

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

| Loading                                     | Force       | Distance | Bolt Corr | Moment                   |
|---|-------------|----------|-----------|--------------------------|
| End Pressure, Md                            | 13892.      | 21.0500  | 1.7106    | 500421.                  |
| Face Pressure, Mt                           | 7489.       | 15.3000  | 1.7106    | 196082.                  |
| Gasket Load, Mg                             | 0.          | 7.3000   | 1.7106    | 0.                       |
| Gasket Seating, Matm                        | 38713.      | 7.3000   | 1.7106    | 483619.                  |
| Total Moment for Operation, Mop             |             |          |           | 696503. N-mm             |
| Total Moment for Gasket seating, Matm       |             |          |           | 483619. N-mm             |
| Effective Hub Length, ho = sqrt(Bcor*goCor) |             |          | 21.265 mm |                          |
| Hub Ratio, h/h0 = HL / H0                   |             |          | 0.846     |                          |
| Thickness Ratio, g1/g0 = (g1Cor/goCor)      |             |          | 1.324     |                          |
| Flange Factors for Integral Flange:         |             |          |           |                          |
| Factor F                                    |             |          | 0.835     |                          |
| Factor V                                    |             |          | 0.330     |                          |
| Factor f                                    |             |          | 1.000     |                          |
| Factors from Figure 2-7.1                   |             |          |           |                          |
| T =   | 1.645       |          | K =       | 1.654                    |
| Y =   | 4.032       |          | U =       | 4.431                    |
| e =   | 0.0393 1/mm |          | Z =       | 2.152                    |
|   |             |          | d =       | 3305.564 mm <sup>3</sup> |
| Stress Factors                              |             |          |           |                          |
| Beta =                                      | 1.942       |          | Alpha =   | 1.707                    |
| Delta =                                     | 1.764       |          | Gamma =   | 1.038                    |
|   |             |          | Lambda =  | 2.802                    |

Longitudinal Hub Stress, Operating [SHo]:

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

$$= (1.0 * 696503 / 133.0) / (2.8021 * 4.5^2)$$

$$= 92.26 \text{ MPa}$$

Longitudinal Hub Stress, Seating [SHa]:

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

$$= (1.0 * 483619 / 133.0) / (2.8021 * 4.5^2)$$

$$= 64.06 \text{ MPa}$$

Radial Flange Stress, Operating [SRo]:

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

$$= (1.9424 * 696503 / 133.0) / (2.8021 * 18.0^2)$$

$$= 11.20 \text{ MPa}$$

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Radial Flange Stress, Seating [SRa]:

$$= ( \text{beta} * \text{Matm}/\text{Bcor} ) / ( \text{L} * \text{t}^2 )$$

$$= ( 1.9424*483619/133.0 ) / ( 2.8021*18.0^2 )$$

$$= 7.78 \text{ MPa}$$

Tangential Flange Stress, Operating [STo]:

$$= ( \text{Y} * \text{Mo} / ( \text{t}^2 * \text{Bcor} ) ) - \text{Z} * \text{SRo}$$

$$= ( 4.0324*696503 / ( 18.0^2 * 133.0 ) ) - 2.152 * 11$$

$$= 41.05 \text{ MPa}$$

Tangential Flange Stress, Seating [STa]:

$$= ( \text{y} * \text{Matm} / ( \text{t}^2 * \text{Bcor} ) ) - \text{Z} * \text{SRa}$$

$$= ( 4.0324*483619 / ( 18.0^2 * 133.0 ) ) - 2.152 * 8$$

$$= 28.50 \text{ MPa}$$

Average Flange Stress, Operating [SAo]:

$$= ( \text{SHo} + \max( \text{SRo}, \text{STo} ) ) / 2$$

$$= ( 92 + \max( 11, 41 ) ) / 2$$

$$= 66.66 \text{ MPa}$$

Average Flange Stress, Seating [SAa]:

$$= ( \text{SHa} + \max( \text{SRa}, \text{STa} ) ) / 2$$

$$= ( 64 + \max( 8, 29 ) ) / 2$$

$$= 46.28 \text{ MPa}$$

Bolt Stress, Operating [BSo]:

$$= \text{Wm1} / \text{Ab}$$

$$= 21381 / 325.1606$$

$$= 65.76 \text{ MPa}$$

Bolt Stress, Seating [BSa]:

$$= ( \text{Wm2} / \text{Ab} )$$

$$= ( 0 / 325.1606 )$$

$$= 0.00 \text{ MPa}$$

**Flange Stress Analysis Results: MPa**

|                   | Operating |         | Gasket Seating |         |
|-------------------|-----------|---------|----------------|---------|
|                   | Actual    | Allowed | Actual         | Allowed |
| Longitudinal Hub  | 92.26     | 197.40  | 64.06          | 206.85  |
| Radial Flange     | 11.20     | 131.60  | 7.78           | 137.90  |
| Tangential Flange | 41.05     | 131.60  | 28.50          | 137.90  |
| Maximum Average   | 66.66     | 131.60  | 46.28          | 137.90  |
| Bolting           | 65.76     | 172.38  | 0.00           | 172.38  |

|   |           |
|---|-----------|
| Minimum Required Flange Thickness                   | 12.141 mm |
| Estimated M.A.W.P. ( Operating )                    | 2 MPa     |
| Estimated Finished Weight of Flange at given Thk.   | 3.7 kg    |
| Estimated Unfinished Weight of Forging at given Thk | 7.0 kg    |

SA-182 F316, Min Metal Temp without impact per UHA-51: -196 °C

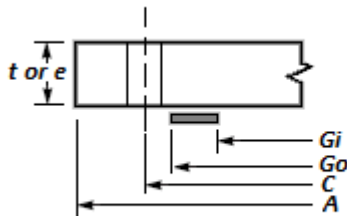
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 Flg Calc [Int P]: Cover head Flng: 40 11:11am May 5,2022

**Flange Input Data Values** Description: Cover head :

Cover head

|   |     |                    |     |
|---|-----|--------------------|-----|
| Flange Type                                 |     | Blind              |     |
| Design Pressure                             | P   | 1.00               | MPa |
| Design Temperature                          |     | 95                 | °C  |
| Internal Corrosion Allowance                | ci  | 1.0000             | mm  |
| External Corrosion Allowance                | ce  | 0.0000             | mm  |
| Use Corrosion Allowance in Thickness Calcs. |     | Yes                |     |
| Flange Outside Diameter                     | A   | 220.000            | mm  |
| Flange Thickness                            | t   | 25.0000            | mm  |
| Flange Material                             |     | SA-516 70          |     |
| Flange Material UNS number                  |     | K02700             |     |
| Flange Allowable Stress At Temperature      | Sfo | 137.90             | MPa |
| Flange Allowable Stress At Ambient          | Sfa | 137.90             | MPa |
| Bolt Material                               |     | SA-193 B7          |     |
| Bolt Allowable Stress At Temperature        | Sb  | 172.38             | MPa |
| Bolt Allowable Stress At Ambient            | Sa  | 172.38             | MPa |
| Diameter of the Load Reaction, Long Span    | D   | 0.000              | mm  |
| Diameter of the Load Reaction, Short Span   | d   | 0.000              | mm  |
| Perimeter along the Center of the Bolts     | L   | 564.230            | mm  |
| Diameter of Bolt Circle                     | C   | 179.600            | mm  |
| Nominal Bolt Diameter                       | a   | 12.0000            | mm  |
| Type of Threads                             |     | TEMA Thread Series |     |
| Number of Bolts                             |     | 4                  |     |
| Flange Face Outside Diameter                | Fod | 165.000            | mm  |
| Flange Face Inside Diameter                 | Fid | 155.000            | mm  |
| Flange Facing Sketch                        |     | 1, Code Sketch 1a  |     |
| Gasket Outside Diameter                     | Go  | 165.000            | mm  |
| Gasket Inside Diameter                      | Gi  | 155.000            | mm  |
| Gasket Factor                               | m   | 0.0000             |     |
| Gasket Design Seating Stress                | y   | 0.00               | MPa |
| Column for Gasket Seating                   |     | 2, Code Column II  |     |
| Gasket Thickness                            | tg  | 2.0000             | mm  |



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Gasket Contact Width,  $N = (G_o - G_i) / 2$  5.000 mm  
 Basic Gasket Width,  $b_o = N / 2$  2.500 mm  
 Effective Gasket Width,  $b = b_o$  2.500 mm  
 Gasket Reaction Diameter,  $G = G_o$  (Self-Energizing) 165.000 mm

### Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

$$= 0.785 * G^2 * P_{eq}$$

$$= 0.785 * 165.0^2 * 1.$$

$$= 21380.648 \text{ N}$$

Contact Load on Gasket Surfaces [Hp]:

$$= 2 * b * \pi * G * m * P$$

$$= 2 * 2.5 * \pi * 165.0 * 0.0 * 1.$$

$$= 0.000 \text{ N}$$

Operating Bolt Load [Wm1]:

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

$$= \max( 21381 + 0 + 0, 0 )$$

$$= 21380.648 \text{ N}$$

Gasket Seating Bolt Load [Wm2]:

$$= y * b * \pi * G + y_{Part} * b_{Part} * l_p$$

$$= 0.0 * 2.5 * \pi * 165.0 + 0.0 * 0.0 * 0.0$$

$$= 0.000 \text{ N}$$

Required Bolt Area [Am]:

$$= \max( W_{m1}/S_b, W_{m2}/S_a )$$

$$= \max( 21381/172, 0/172 )$$

$$= 124.046 \text{ mm}^2$$

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

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

$$= 2 * 12.7 + 6 * 24.0/(0.0 + 0.5)$$

$$= 313.400 \text{ mm}$$

Actual Circumferential Bolt Spacing [Bs]:

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

$$= 179.6 * \sin( \pi / 4 )$$

$$= 126.996 \text{ mm}$$

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

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

$$= \max( \sqrt{ 126.996 / ( 2 * 12.7 + 24.0 ) }, 1 )$$

$$= 1.6034$$

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

|   | Minimum | Actual  | Maximum |
|---|---------|---------|---------|
| Bolt Area:                              | 124.046 | 325.161 |         |
| Radial Distance between Bolts and Edge: | 15.875  | 20.200  |         |
| Circ. Spacing between the Bolts:        | 31.750  | 126.996 | 313.400 |

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Flange Design Bolt Load, Gasket Seating [W]:

$$= Sa( A_m + A_b ) / 2$$

$$= 172.38( 124.0462 + 325.1606 )/2$$

$$= 38712.72 \text{ N}$$

Gasket Load for the Operating Condition [HG]:

$$= W_{m1}$$

$$= 21380.65 \text{ N}$$

### Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

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

$$= ( 179.6 - 165.0 )/2$$

$$= 7.3000 \text{ mm}$$

Tangential Flange Stress, Flat Head (UG-34), Operating [STo]:

$$= 1.9 * W_{m1} * hg * Bsc / (t^2 * G) + C * Z * Peq * G^2 / t^2$$

$$= 1.9 * 21381 * 7.3 * 1.6034 / (24.0^2 * 165.0) + 0.3 * 1.0 * 1. * 165.0^2 / 24.0^2$$

$$= 19.18 \text{ MPa}$$

Tangential Flange Stress, Flat Head (UG-34), Seating [STa]:

$$= 1.9 * W * hg * Bsc / (t^2 * G)$$

$$= 1.9 * 38713 * 7.3 * 1.603 / (24.0^2 * 165.0)$$

$$= 9.06 \text{ MPa}$$

Bolt Stress, Operating [BSo]:

$$= W_{m1} / A_b$$

$$= 21381 / 325.1606$$

$$= 65.76 \text{ MPa}$$

Bolt Stress, Seating [BSa]:

$$= ( W_{m2} / A_b )$$

$$= ( 0 / 325.1606 )$$

$$= 0.00 \text{ MPa}$$

### Flange Stress Analysis Results: MPa

|                   | Actual | Operating Allowed | Actual | Gasket Seating Allowed |
|-------------------|--------|-------------------|--------|------------------------|
| Tangential Flange | 19.18  | 137.90            | 9.06   | 137.90                 |
| Bolting           | 65.76  | 172.38            | 0.00   | 172.38                 |

|   |          |
|---|----------|
| Reqd. Blind Flange Thickness at Center              | 9.951 mm |
| Reqd. Blind Flange Thickness at Gasket              | 7.151 mm |
| Estimated M.A.W.P. ( Operating )                    | 3 MPa    |
| Estimated Finished Weight of Flange at given Thk.   | 7.4 kg   |
| Estimated Unfinished Weight of Forging at given Thk | 7.4 kg   |

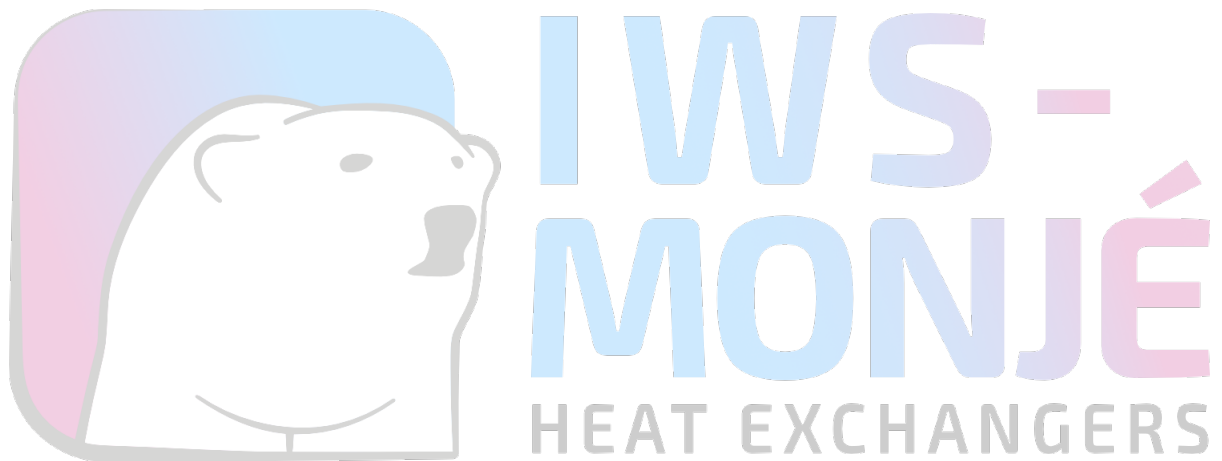
### Minimum Design Metal Temperature Results:

Thickness Ratio = 0.381, Temperature Reduction per Fig. UCS 66.1 = 56 °C

|  |        |
|--|--------|
| Min Metal Temp. w/o impact per UCS-66, Curve B   | -29 °C |
| Min Metal Temp. at Required thickness (UCS 66.1) | -48 °C |

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 Internal Pressure Calculations: Step: 7 11:11am May 5,2022

### Internal Pressure Results Summary:

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

| From             | To | Int. Press<br>+ Liq. Hd<br>MPa | Nominal<br>Thickness<br>mm | Total Corr<br>Allowance<br>mm | Element<br>Diameter<br>mm | Allowable<br>Stress(SE)<br>MPa |
|------------------|----|--------------------------------|----------------------------|-------------------------------|---------------------------|--------------------------------|
| Channel head fla |    | 1                              | 27                         | 1                             | 160                       | 137.9                          |
| Channel head cyl |    | 1                              | 13                         | 1                             | 160                       | 137.9                          |
| Channel head fla |    | 1                              | 18                         | 1                             | 132.6                     | 137.9                          |
| Shell flange rin |    | 1                              | ...                        | ...                           | 133                       | 131.56                         |
| Main Shell       |    | 2.5                            | ...                        | ...                           | 141.3                     | 132.2                          |
| Shell flange rin |    | 1                              | ...                        | ...                           | 133                       | 131.6                          |
| Cover head       |    | 1                              | ...                        | 1                             | 220                       | 137.9                          |

#### Element Required Thickness and MAWP :

| From             | To | Design<br>Pressure<br>MPa | M.A.W.P.<br>Corroded<br>MPa | M.A.P.<br>New<br>& Cold<br>MPa | Minimum<br>Thickness<br>mm | Required<br>Thickness<br>mm |
|------------------|----|---------------------------|-----------------------------|--------------------------------|----------------------------|-----------------------------|
| Channel head fla |    | 1                         | 25.958                      | 27.9932                        | 27                         | 6.10314                     |
| Channel head cyl |    | 1                         | 22.0053                     | 23.9666                        | 13                         | 3.5                         |
| Channel head fla |    | 1                         | 1.76016                     | 1.95811                        | 18                         | 14.2494                     |
| Shell flange rin |    | 1                         | 1.97362                     | 2.06878                        | 18                         | 12.1412                     |
| Main Shell       |    | 2.5                       | 6.48694                     | 6.76663                        | 3.4                        | 1.5                         |
| Shell flange rin |    | 1                         | 1.97425                     | 2.06878                        | 18                         | 12.1412                     |
| Cover head       |    | 1                         | 2.62127                     | 2.62127                        | 25                         | 9.95133                     |

#### 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 = 2 MPa  
 Shell Side MAPnc = 2 MPa  
 Channel Side MAWP = 1 MPa  
 Channel Side MAPnc = 1 MPa

Elements Suitable for Design Internal Pressure.

#### Internal Pressure Calculation Results:

ASME Code, Section VIII Division 1, 2021

Welded Flat Head From 10 To 20 SA-516 70 , UCS-66 Crv. B at 95 °C

Channel head flat

Longitudinal Joint: User Defined

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 Internal Pressure Calculations: Step: 7 11:11am May 5,2022

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:  
 $= d * \sqrt{Z * C * P / (S * E)}$  per UG-34 (c)(3)  
 $= 134.0 * \sqrt{1.0 * 0.2 * 1. / (137.9 * 1.0)}$   
 $= 5.1031 + 1.0000 = 6.1031 \text{ mm}$

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:  
 $= (t/d)^2 * ((S * E) / (C * Z))$  per UG-34 (c)(3)  
 $= ((26.0) / 134.0)^2 * ((137.9 * 1.0) / (0.2 * 1.0))$   
 $= 26 \text{ MPa}$

Maximum Allowable Pressure, New and Cold [MAPNC]:  
 $= (t/d)^2 * ((S * E) / (C * Z))$  per UG-34 (c)(3)  
 $= (27.0 / 134.0)^2 * ((137.9 * 1.0) / (0.2 * 1.0))$   
 $= 28 \text{ MPa}$

Actual stress at given pressure and thickness, corroded [Sact]:  
 $= (Z * C * P) / (((t/d)^2) * E)$   
 $= (1.0 * 0.2 * 1.0) / (((26.0) / 134.0)^2 * 1.0)$   
 $= 5.312 \text{ MPa}$

#### Minimum Design Metal Temperature Results:

$t_g = 13.0$ ,  $t_{g\_sr} = 27.0$ ,  $t_r = 5.103$ ,  $c = 1.0 \text{ mm}$ ,  $E * = 1.0$   
 Thickness Ratio =  $t_r * E * / (t_{g\_sr} - c) = 0.196$ , Temp. Reduction =  $78 \text{ }^\circ\text{C}$

|  |         |
|--|---------|
| Min Metal Temp. w/o impact per UCS-66, Curve B   | -21 °C  |
| Min Metal Temp. at Required thickness (UCS 66.1) | -104 °C |
| Min Metal Temp. w/o impact per UG-20(f)          | -29 °C  |

#### Cylindrical Shell From 20 To 30 SA-516 70 , UCS-66 Crv. B at 95 °C

Channel head cylinder

Longitudinal Joint: User Defined

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:  
 $= (P * R_o) / (S * E + 0.4 * P)$  per Appendix 1-1 (a)(1)  
 $= (1. * 80.0) / (137.9 * 1.0 + 0.4 * 1.0)$   
 $= 0.5785 + 1.0000 = 1.5785 \text{ mm}$

*Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 2.5000 mm per UG-16 will be used.*

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:  
 $= (S * E * t) / (R_o - 0.4 * t)$  per Appendix 1-1 (a)(1)  
 $= (137.9 * 1.0 * 12.0) / (80.0 - 0.4 * 12.0)$   
 $= 22 \text{ MPa}$

Maximum Allowable Pressure, New and Cold [MAPNC]:  
 $= (S * E * t) / (R_o - 0.4 * t)$  per Appendix 1-1 (a)(1)  
 $= (137.9 * 1.0 * 13.0) / (80.0 - 0.4 * 13.0)$   
 $= 24 \text{ MPa}$

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 Internal Pressure Calculations: Step: 7 11:11am May 5,2022

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

$$\begin{aligned}
 &= (P*(Ro-0.4*t))/(E*t) \\
 &= (1.*((80.0-0.4*12.0))/(1.0*12.0)) \\
 &= 6.267 \text{ MPa}
 \end{aligned}$$

% Elongation per Table UG-79-1 ( $50*t_{nom}/R_f*(1-R_f/R_o)$ ) 8.844 %  
 Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

#### Minimum Design Metal Temperature Results:

Govern. thk,  $t_g = 13.0$ ,  $t_r = 2.5$ ,  $c = 1.0$  mm,  $E* = 1.0$   
 Thickness Ratio =  $t_r * E*/(t_g - c) = 0.208$ , Temp. Reduction = 78 °C

|  |         |
|--|---------|
| Min Metal Temp. w/o impact per UCS-66, Curve B   | -21 °C  |
| Min Metal Temp. at Required thickness (UCS 66.1) | -104 °C |
| Min Metal Temp. w/o impact per UG-20(f)          | -29 °C  |

#### Cylindrical Shell From 50 To 60 SA-312 TP316 at 210 °C

Main Shell

Longitudinal Joint: User Defined

Material UNS Number: S31600

Required Thickness due to Internal Pressure [tr]:

$$\begin{aligned}
 &= (P*Ro) / (S*E+0.4*P) \text{ per Appendix 1-1 (a)(1)} \\
 &= (2.5*70.65)/(132.2*1.0+0.4*2.5) \\
 &= 1.3260 + 0.0000 = 1.3260 \text{ mm}
 \end{aligned}$$

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm per UG-16 will be used.

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

$$\begin{aligned}
 &= (S*E*t)/(Ro-0.4*t) \text{ per Appendix 1-1 (a)(1)} \\
 &= (132.2*1.0*3.4)/(70.65-0.4*3.4) \\
 &= 6 \text{ MPa}
 \end{aligned}$$

Maximum Allowable Pressure, New and Cold [MAPNC]:

$$\begin{aligned}
 &= (S*E*t)/(Ro-0.4*t) \text{ per Appendix 1-1 (a)(1)} \\
 &= (137.9*1.0*3.4)/(70.65-0.4*3.4) \\
 &= 7 \text{ MPa}
 \end{aligned}$$

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

$$\begin{aligned}
 &= (P*(Ro-0.4*t))/(E*t) \\
 &= (2.5*((70.65-0.4*3.4))/(1.0*3.4)) \\
 &= 50.949 \text{ MPa}
 \end{aligned}$$

SA-312 TP316, Min Metal Temp without impact per UHA-51: -196 °C

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

#### Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

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|                        |                               |           |
|------------------------|-------------------------------|-----------|
| Pressure per UG99b     | = 1.30 * M.A.W.P. * Sa/S      | 3.390 MPa |
| Pressure per UG99b[35] | = 1.30 * Design Pres * Sa/S   | 3.390 MPa |
| Pressure per UG99c     | = 1.30 * M.A.P. - Head(Hyd)   | 3.248 MPa |
| Pressure per UG100     | = 1.10 * M.A.W.P. * Sa/S      | 2.869 MPa |
| Pressure per PED       | = max(1.43*DP, 1.25*DP*ratio) | 3.575 MPa |
| Pressure per App 27-4  | = M.A.W.P.                    | 2.500 MPa |

**User defined Hydrostatic Test Pressures:**

|  |           |
|--|-----------|
| Shell Side Test Pressure at High Point   | 3.750 MPa |
| Channel Side Test Pressure at High Point | 1.500 MPa |

**Exchanger Channel Side Hydrostatic Test Pressures:**

|                        |                               |           |
|------------------------|-------------------------------|-----------|
| Pressure per UG99b     | = 1.30 * M.A.W.P. * Sa/S      | 1.300 MPa |
| Pressure per UG99b[35] | = 1.30 * Design Pres * Sa/S   | 1.300 MPa |
| Pressure per UG99c     | = 1.30 * M.A.P. - Head(Hyd)   | 1.298 MPa |
| Pressure per UG100     | = 1.10 * M.A.W.P. * Sa/S      | 1.100 MPa |
| Pressure per PED       | = max(1.43*DP, 1.25*DP*ratio) | 1.430 MPa |
| Pressure per App 27-4  | = M.A.W.P.                    | 1.000 MPa |

**Horizontal Test performed per: User Hydro Pressure**

*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 (MPa):**

| From To              | Stress | Allowable | Ratio | Pressure |
|----------------------|--------|-----------|-------|----------|
| Channel head flat    | 7.4    | 179.3     | 0.041 | 1.50     |
| Channel head cylinde | 8.6    | 179.3     | 0.048 | 1.50     |
| Main Shell           | 76.5   | 179.3     | 0.426 | 3.75     |

**Stress ratios for Nozzle and Pad Materials (MPa):**

| Description      | Pad/Nozzle | Ambient | Operating | Ratio |
|------------------|------------|---------|-----------|-------|
| Noz N1 Fr10 - Tu | Nozzle     | 117.90  | 117.90    | 1.000 |
| Noz N2 Fr10      | Nozzle     | 117.90  | 117.90    | 1.000 |
| Noz N3 - Shell i | Nozzle     | 117.22  | 112.32    | 1.044 |
| Noz N4 - Shell o | Nozzle     | 117.22  | 112.32    | 1.044 |
| Minimum          |            |         |           | 1.000 |

**Stress ratios for Pressurized Vessel Elements (MPa):**

| Description          | Ambient | Operating | Ratio |
|----------------------|---------|-----------|-------|
| Channel head flat    | 137.90  | 137.90    | 1.000 |
| Channel head cylinde | 137.90  | 137.90    | 1.000 |
| Channel head flange  | 137.90  | 137.90    | 1.000 |
| Shell flange ring 1  | 137.90  | 131.56    | 1.048 |
| Main Shell           | 137.90  | 132.20    | 1.043 |

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|                     |        |        |       |
|---------------------|--------|--------|-------|
| Shell flange ring 2 | 137.90 | 131.60 | 1.048 |
| Cover head          | 137.90 | 137.90 | 1.000 |

-----  
 Minimum 1.000

#### Stress ratios for Exchanger Materials (MPa):

| Description        | Ambient | Operating | Ratio |
|--------------------|---------|-----------|-------|
| Tube Material      | 68.95   | 59.71     | 1.155 |
| Tubesheet Material | 115.15  | 97.91     | 1.176 |

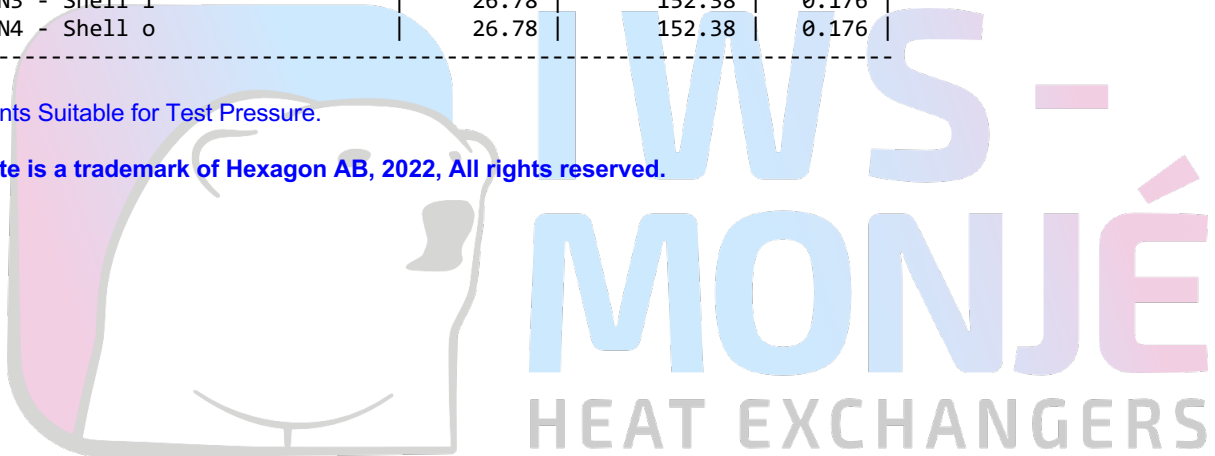
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 Minimum 1.155

#### Hoop Stress in Nozzle Wall during Pressure Test (MPa):

| Description      | Ambient | Operating | Ratio |
|------------------|---------|-----------|-------|
| Noz N1 Fr10 - Tu | 5.41    | 153.28    | 0.035 |
| Noz N2 Fr10      | 5.41    | 153.28    | 0.035 |
| Noz N3 - Shell i | 26.78   | 152.38    | 0.176 |
| Noz N4 - Shell o | 26.78   | 152.38    | 0.176 |

Elements Suitable for Test Pressure.

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 External Pressure Calculations: Step: 8 11:11am May 5,2022

### External Pressure Calculation Results :

#### External Pressure Calculations:

| From | To | Section Length<br>mm | Outside Diameter<br>mm | Corroded Thickness<br>mm | Factor A   | Factor B<br>MPa |
|------|----|----------------------|------------------------|--------------------------|------------|-----------------|
| 10   | 20 | No Calc              | ...                    | 26                       | No Calc    | No Calc         |
| 20   | 30 | 30                   | 160                    | 12                       | 0.096675   | 122.731         |
| 30   | 40 | No Calc              | ...                    | 17                       | No Calc    | No Calc         |
| 40   | 50 | No Calc              | ...                    | 18                       | No Calc    | No Calc         |
| 50   | 60 | 753.8                | 141.3                  | 3.4                      | 0.00082629 | 58.4069         |
| 60   | 70 | No Calc              | ...                    | 18                       | No Calc    | No Calc         |
| 70   | 80 | No Calc              | ...                    | 24                       | No Calc    | No Calc         |

#### External Pressure Calculations:

| From | To | External Actual T.<br>mm | External Required T.<br>mm | External Design Pressure<br>MPa | External M.A.W.P.<br>MPa |
|------|----|--------------------------|----------------------------|---------------------------------|--------------------------|
| 10   | 20 | 27                       | No Calc                    | 0.1013                          | No Calc                  |
| 20   | 30 | 13                       | 1.25164                    | 0.1013                          | 12.2731                  |
| 30   | 40 | 18                       | 10.4394                    | 0.1013                          | No Calc                  |
| 40   | 50 | 18                       | 6.9596                     | 0.1013                          | No Calc                  |
| 50   | 60 | 3.4                      | 0.95704                    | 0.1013                          | 1.87387                  |
| 60   | 70 | 18                       | 6.9596                     | 0.1013                          | No Calc                  |
| 70   | 80 | 25                       | 6.9342                     | 0.1013                          | No Calc                  |

Minimum

2

#### External Pressure Calculations:

| From | To | Actual Length<br>Bet. Stiffeners<br>mm | Allowable Length<br>Bet. Stiffeners<br>mm | Ring Inertia<br>Required<br>mm <sup>4</sup> | Ring Inertia<br>Available<br>mm <sup>4</sup> |
|------|----|--|---|---|--|
| 10   | 20 | No Calc                                | No Calc                                   | No Calc                                     | No Calc                                      |
| 20   | 30 | 30                                     | 3634.68                                   | No Calc                                     | No Calc                                      |
| 30   | 40 | No Calc                                | No Calc                                   | No Calc                                     | No Calc                                      |
| 40   | 50 | No Calc                                | No Calc                                   | No Calc                                     | No Calc                                      |
| 50   | 60 | 753.8                                  | 55631.4                                   | No Calc                                     | No Calc                                      |
| 60   | 70 | No Calc                                | No Calc                                   | No Calc                                     | No Calc                                      |
| 70   | 80 | No Calc                                | No Calc                                   | No Calc                                     | No Calc                                      |

Elements Suitable for External Pressure.

**ASME Code, Section VIII Division 1, 2021**

### Welded Flat Head

Channel head flat

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Note: This element's required thickness was computed in the internal Pressure Report using the maximum of the Internal and External pressures.

-----  
**Cylindrical Shell From 50 to 60 Ext. Chart: HA-2 at 210 °C**

**Main Shell**

Elastic Modulus from Chart: HA-2 at 210 °C: 178099 MPa

| Results for Maximum Allowable Ext. Pressure |           |        |       |        |           |          | MAEP |
|---|-----------|--------|-------|--------|-----------|----------|------|
| Tca   | Outer Dia | Slen   | Do/t  | L/D    | Factor A  | Factor B |      |
| 3.400                                       | 141.30    | 753.80 | 41.56 | 5.3347 | 0.0008263 | 58.41    |      |

$$MAEP = (4*B)/(3*(Do/t)) = (4*58.4069)/(3*41.5588) = 1.8739 \text{ MPa}$$

| Results for Required Thickness |           |        |        |        |           |          | Tca |
|--------------------------------|-----------|--------|--------|--------|-----------|----------|-----|
| Tca                            | Outer Dia | Slen   | Do/t   | L/D    | Factor A  | Factor B |     |
| 0.957                          | 141.30    | 753.80 | 147.64 | 5.3347 | 0.0001260 | 11.22    |     |

$$MAEP = (4*B)/(3*(Do/t)) = (4*11.2178)/(3*147.6435) = 0.1013 \text{ MPa}$$

| Results for Maximum Stiffened Length |           |          |       |         |           |          | Slen |
|--------------------------------------|-----------|----------|-------|---------|-----------|----------|------|
| Tca                                  | Outer Dia | Slen     | Do/t  | L/D     | Factor A  | Factor B |      |
| 3.400                                | 141.30    | 55631.38 | 41.56 | 50.0000 | 0.0006433 | 54.15    |      |

$$MAEP = (4*B)/(3*(Do/t)) = (4*54.1462)/(3*41.5588) = 1.7372 \text{ MPa}$$

-----  
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 Element and Detail Weights: Step: 9 11:11am May 5,2022

Element and Detail Weights:

| From  | To | Element Metal Wgt. kg | Element ID Volume ltr | Corroded Metal Wgt. kg | Corroded ID Volume ltr | Extra due Misc % |
|-------|----|-----------------------|-----------------------|------------------------|------------------------|------------------|
| 10    | 20 | 4.20749               | ...                   | 4.05166                | ...                    | ...              |
| 20    | 30 | 1.39592               | 0.42315               | 1.29731                | 0.43588                | ...              |
| 30    | 40 | 3.37665               | ...                   | 3.37665                | ...                    | ...              |
| 40    | 50 | 3.73074               | 0.50023               | 3.73074                | 0.50023                | ...              |
| 50    | 60 | 8.9129                | 7.98337               | 8.9129                 | 7.98337                | ...              |
| 60    | 70 | 3.73074               | 0.50023               | 3.73074                | 0.50023                | ...              |
| 70    | 80 | 7.36555               | ...                   | 7.36555                | ...                    | ...              |
| Total |    | 32                    | 9.41                  | 32                     | 9.42                   | 0                |

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 | Z Offset, Dtl. Cent. mm | Description      |
|------|------|---------------------|-------------------------|-------------------------|-------------------------|------------------|
| 10   | Noz1 | 0.30781             | ...                     | 100                     | ...                     | Noz N1 Fr10 - Tu |
| 10   | Noz1 | 0.32816             | ...                     | -100                    | ...                     | Noz N2 Fr10      |
| 50   | Noz1 | 4.92907             | 72                      | -97.4                   | ...                     | Noz N3 - Shell i |
| 50   | Noz1 | 4.92907             | 692                     | 97.4                    | ...                     | Noz N4 - Shell o |
| 30   | FTsh | 3.79983             | 36                      | ...                     | ...                     | Tubesheet fix    |
| 30   | Tube | 6.29457             | 437                     | ...                     | ...                     | Tubes            |
| 30   | FlTs | 2.16206             | 852                     | ...                     | ...                     |                  |

#### Total Weight of Each Detail Type:

|                           |         |
|---------------------------|---------|
| Nozzles                   | 10.5    |
| Exchanger Components      | 12.3    |
| -----                     |         |
| Sum of the Detail Weights | 22.8 kg |

#### Weight Summation Results: (kg)

|               | Fabricated | Shop Test | Shipping | Erected | Empty | Operating |
|---------------|------------|-----------|----------|---------|-------|-----------|
| Main Elements | 32.7       | 32.7      | 32.7     | 32.7    | 32.7  | 32.7      |
| Nozzles       | 10.5       | 10.5      | 10.5     | 10.5    | 10.5  | 10.5      |
| Exchanger     | 12.3       | 12.3      | 12.3     | 12.3    | 12.3  | 12.3      |
| Test Liquid   | ...        | 9.4       | ...      | ...     | ...   | ...       |
| Tube Tst Lqd  | ...        | 2.3       | ...      | ...     | ...   | ...       |
| -----         |            |           |          |         |       |           |
| Totals        | 55.5       | 67.2      | 55.5     | 55.5    | 55.5  | 55.5      |

#### Weight Summary:

Fabricated Wt. - Bare Weight without Removable Internals 55.5 kg

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Element and Detail Weights: Step: 9 11:11am May 5,2022

|                 |   |         |
|-----------------|---|---------|
| Shop Test Wt.   | - Fabricated Weight + Water ( Full )                | 67.2 kg |
| Shipping Wt.    | - Fab. Weight + removable Intls.+ Shipping App.     | 55.5 kg |
| Erected Wt.     | - Fab. Wt + or - loose items (trays,platforms etc.) | 55.5 kg |
| Ope. Wt. no Liq | - Fab. Weight + Internals. + Details + Weights      | 55.5 kg |
| Operating Wt.   | - Empty Weight + Operating Liq. Uncorroded          | 55.5 kg |
| Oper. Wt. + CA  | - Corr Wt. + Operating Liquid                       | 55.2 kg |
| Field Test Wt.  | - Empty Weight + Water (Full)                       | 67.2 kg |

**Exchanger Tube Data**

|                              |         |
|------------------------------|---------|
| Volume of Exchanger tubes :  | 2.3 ltr |
| Weight of Ope Liq in tubes : | 0.0 kg  |
| Weight of Water in tubes :   | 2.3 kg  |

**Note:**

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

**Outside Surface Areas of Elements:**

| From  | To | Surface Area<br>mm <sup>2</sup> |
|-------|----|---------------------------------|
| 10    | 20 | ...                             |
| 20    | 30 | 15079.6                         |
| 30    | 40 | 36644.5                         |
| 40    | 50 | 44591                           |
| 50    | 60 | 334617                          |
| 60    | 70 | 44591                           |
| 70    | 80 | 55292                           |
| Total |    | 530815.312 mm <sup>2</sup>      |

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 Nozzle Flange MAWP: Step: 10 11:11am May 5,2022

**Nozzle Flange MAWP Results: (MPa & °C)**

| Nozzle Description | Flange Rating |         | Design Temp | Class | Grade/Group | Equiv. Press | Max Pressure |     |     |
|--------------------|---------------|---------|-------------|-------|-------------|--------------|--------------|-----|-----|
|                    | Ope.          | Ambient |             |       |             |              | UG-44(b)     | 50% | DNV |
| Noz N3 - Shell     | 3.52          | 4.96    | 210         | 300   | GR 2.2      | ...          | ...          | ... | ... |
| Noz N4 - Shell     | 3.52          | 4.96    | 210         | 300   | GR 2.2      | ...          | ...          | ... | ... |

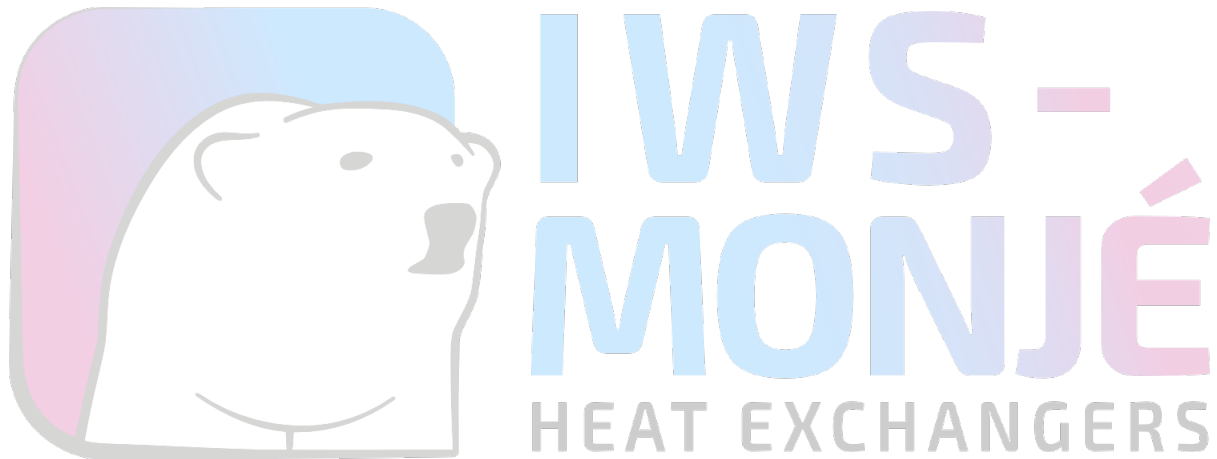
**Shellside Flange Rating**

Lowest Flange Pressure Rating was (Ope)[ShellSide]: 3.524 MPa  
 Lowest Flange Pressure Rating was (Amb)[ShellSide]: 4.960 MPa

**Channelside Flange Rating**

Pressure Ratings are per ASME B16.5 2017 Metric Edition

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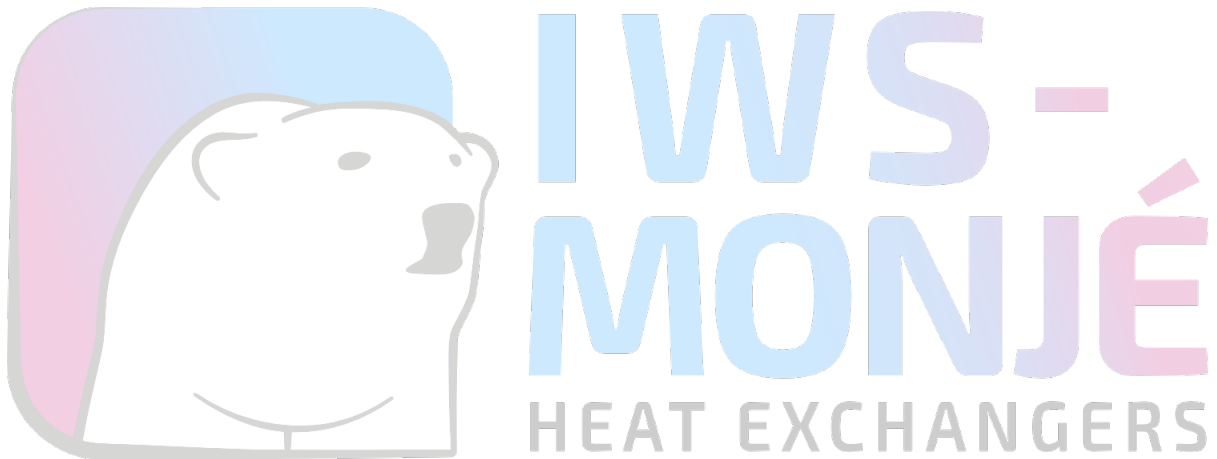
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 Center of Gravity Calculation: Step: 11 11:11am May 5,2022

**Shop/Field Installation Options :**

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

|  |            |
|--|------------|
| Center of Gravity of the Nozzles                   | 485.222 mm |
| Center of Gravity of the Tubesheet(s)              | 406.920 mm |
| Center of Gravity of the Tubes                     | 512.000 mm |
| Center of Gravity of Bare Shell New and Cold       | 478.350 mm |
| Center of Gravity of Bare Shell Corroded           | 481.907 mm |
| Vessel CG in the Operating Condition               | 477.871 mm |
| Vessel CG in the Fabricated (Shop/Empty) Condition | 475.792 mm |

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 FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
 Nozzle Calcs.: Noz N1 Fr10 - T Nozl: 17 11:11am May 5,2022

**Input, Nozzle Desc: Noz N1 Fr10 - Tube inlet****From: 10**

|   |      |           |     |
|---|------|-----------|-----|
| Pressure for Reinforcement Calculations       | P    | 1.0000    | MPa |
| Temperature for Internal Pressure             | Temp | 95        | °C  |
| Parent Material                               |      | SA-516 70 |     |
| Parent Allowable Stress at Temperature        | Sv   | 137.90    | MPa |
| Parent Allowable Stress At Ambient            | Sva  | 137.90    | MPa |
| Outside Diameter of Flat Head                 | D    | 160.00    | mm  |
| Large Diameter of Flat Head                   | Dl   | 160.0000  | mm  |
| Flat Head Attachment Factor                   | F    | 0.20      |     |
| Head Finished (Minimum) Thickness             | t    | 27.0000   | mm  |
| Head Internal Corrosion Allowance             | c    | 1.0000    | mm  |
| Head External Corrosion Allowance             | co   | 0.0000    | mm  |
| Distance from Head Centerline                 | L1   | 46.0000   | mm  |
| User Entered Minimum Design Metal Temperature |      | -10.00    | °C  |

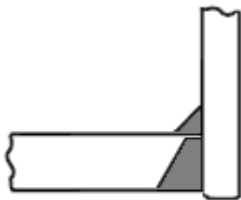
**Type of Element Connected to the Parent : Nozzle**

|   |      |            |     |
|---|------|------------|-----|
| Material                                    |      | SA-106 B   |     |
| Material UNS Number                         |      | K03006     |     |
| Material Specification/Type                 |      | Smls. pipe |     |
| Allowable Stress at Temperature             | Sn   | 117.90     | MPa |
| Allowable Stress At Ambient                 | Sna  | 117.90     | MPa |
| Diameter Basis (for tr calc only)           |      | Outside    |     |
| Layout Angle                                |      | 90.00      | deg |
| Diameter                                    |      | 40.0000    | mm  |
| Size and Thickness Basis                    |      | Actual     |     |
| Actual Thickness                            | tn   | 5.0000     | mm  |
| Corrosion Allowance                         | can  | 1.0000     | mm  |
| Joint Efficiency of Shell Seam at Nozzle    | E1   | 1.00       |     |
| Joint Efficiency of Nozzle Neck             | En   | 1.00       |     |
| Outside Projection                          | ho   | 50.0000    | mm  |
| Weld leg size between Nozzle and Pad/Shell  | Wo   | 10.0000    | mm  |
| Groove weld depth between Nozzle and Vessel | Wgnv | 0.0000     | mm  |
| Inside Projection                           | h    | 0.0000     | mm  |
| Weld leg size, Inside Element to Shell      | Wi   | 0.0000     | mm  |

The Pressure Design option was Design Pressure + static head.

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

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 FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
 Nozzle Calcs.: Noz N1 Fr10 - T Nozl: 17 11:11am May 5,2022



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

**Reinforcement CALCULATION, Description: Noz N1 Fr10 - Tube inlet**

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

Actual Outside Diameter Used in Calculation 40.000 mm.  
 Actual Thickness Used in Calculation 5.000 mm

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Welded Flat Head, tr [Int. Press]  
 $= d \cdot \sqrt{Z \cdot C \cdot P / (S_v \cdot E)}$  per UG-34 (c)(3)  
 $= 134.0 \cdot \sqrt{1.0 \cdot 0.2 \cdot 1. / (138 \cdot 1.0)}$   
 $= 5.1031$  mm

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]  
 $= P \cdot R_o / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 $= 1. \cdot 20.0 / (118 \cdot 1.0 + 0.4 \cdot 1.)$   
 $= 0.1691$  mm

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

|   |         |         |    |
|---|---------|---------|----|
| Parallel to Vessel Wall (Diameter Limit)        | D1      | 92.0000 | mm |
| Parallel to Vessel Wall                         | Rn+tn+t | 46.0000 | mm |
| Normal to Vessel Wall (Thickness Limit), no pad | Tlnp    | 10.0000 | mm |

*Taking a UG-36(c)(3)(a) exemption for nozzle: Noz N1 Fr10 - T.  
 This calculation is valid for nozzles that meet all the requirements of  
 paragraph UG-36. Please check the Code carefully, especially for nozzles  
 that are not isolated or do not meet Code spacing requirements. To force  
 the computation of areas for small nozzles go to Tools->Configuration  
 and check the box to force the UG-37 small nozzle area calculation.*

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

|  |                        |          |    |
|--|------------------------|----------|----|
| Wall Thickness for Internal/External pressures | ta                     | = 1.1691 | mm |
| Wall Thickness per UG16(b),                    | tr16b                  | = 3.5000 | mm |
| Wall Thickness, shell/head, internal pressure  | trb1                   | = 6.1031 | mm |
| Wall Thickness                                 | tb1 = max(trb1, tr16b) | = 6.1031 | mm |
| Wall Thickness                                 | tb2 = max(trb2, tr16b) | = 3.5000 | mm |
| Wall Thickness per table UG-45                 | tb3                    | = 4.1200 | mm |

Determine Nozzle Thickness candidate [tb]:

$= \min[ tb3, \max( tb1, tb2 ) ]$   
 $= \min[ 4.12, \max( 6.1031, 3.5 ) ]$   
 $= 4.1200$  mm

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 Nozzle Calcs.: Noz N1 Fr10 - T Nozl: 17 11:11am May 5,2022

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

$$= \max( t_a, t_b )$$

$$= \max( 1.1691, 4.12 )$$

$$= 4.1200 \text{ mm}$$

Available Nozzle Neck Thickness = 5.0000 mm --> OK

### Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk,  $t_g = 5.0$ ,  $t_r = 0.169$ ,  $c = 1.0$  mm,  $E^* = 1.0$   
 Thickness Ratio =  $t_r * E^* / (t_g - c) = 0.042$ , 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

Gov. MDMT of the nozzle to shell joint welded assembly : -104 °C

#### Weld Size Calculations, Description: Noz N1 Fr10 - T

Intermediate Calc. for nozzle/shell Welds  $T_{min} = 4.0000$  mm

#### Results Per UW-16.1:

|             | Required Thickness       | Actual Thickness        |
|-------------|--------------------------|-------------------------|
| Nozzle Weld | $2.8000 = 0.7 * t_{min}$ | $7.0700 = 0.7 * W_o$ mm |

Skipping the nozzle attachment weld strength calculations. Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a) (small nozzles) do not require a weld strength check.

#### Maximum Allowable Pressure for this Nozzle at this Location:

Converged Maximum Allowable Pressure in the Operating case: 1 MPa

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 77.0508 mm

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 FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
 Nozzle Calcs.: Noz N2 Fr10 Nozl: 18 11:11am May 5,2022

**Input, Nozzle Desc: Noz N2 Fr10****From: 10**

|   |      |           |     |
|---|------|-----------|-----|
| Pressure for Reinforcement Calculations       | P    | 1.0000    | MPa |
| Temperature for Internal Pressure             | Temp | 95        | °C  |
| Parent Material                               |      | SA-516 70 |     |
| Parent Allowable Stress at Temperature        | Sv   | 137.90    | MPa |
| Parent Allowable Stress At Ambient            | Sva  | 137.90    | MPa |
| Outside Diameter of Flat Head                 | D    | 160.00    | mm  |
| Large Diameter of Flat Head                   | Dl   | 160.0000  | mm  |
| Flat Head Attachment Factor                   | F    | 0.20      |     |
| Head Finished (Minimum) Thickness             | t    | 27.0000   | mm  |
| Head Internal Corrosion Allowance             | c    | 1.0000    | mm  |
| Head External Corrosion Allowance             | co   | 0.0000    | mm  |
| Distance from Head Centerline                 | L1   | 46.0000   | mm  |
| User Entered Minimum Design Metal Temperature |      | -10.00    | °C  |

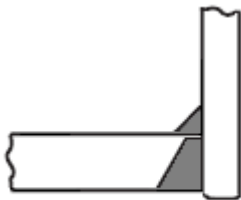
**Type of Element Connected to the Parent : Nozzle**

|   |      |            |     |
|---|------|------------|-----|
| Material                                    |      | SA-106 B   |     |
| Material UNS Number                         |      | K03006     |     |
| Material Specification/Type                 |      | Smls. pipe |     |
| Allowable Stress at Temperature             | Sn   | 117.90     | MPa |
| Allowable Stress At Ambient                 | Sna  | 117.90     | MPa |
| Diameter Basis (for tr calc only)           |      | Outside    |     |
| Layout Angle                                |      | 270.00     | deg |
| Diameter                                    |      | 40.0000    | mm  |
| Size and Thickness Basis                    |      | Actual     |     |
| Actual Thickness                            | tn   | 5.0000     | mm  |
| Corrosion Allowance                         | can  | 1.0000     | mm  |
| Joint Efficiency of Shell Seam at Nozzle    | E1   | 1.00       |     |
| Joint Efficiency of Nozzle Neck             | En   | 1.00       |     |
| Outside Projection                          | ho   | 50.0000    | mm  |
| Weld leg size between Nozzle and Pad/Shell  | Wo   | 10.0000    | mm  |
| Groove weld depth between Nozzle and Vessel | Wgnv | 0.0000     | mm  |
| Inside Projection                           | h    | 0.0000     | mm  |
| Weld leg size, Inside Element to Shell      | Wi   | 0.0000     | mm  |

The Pressure Design option was Design Pressure + static head.

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

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 FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
 Nozzle Calcs.: Noz N2 Fr10 Nozl: 18 11:11am May 5,2022



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

**Reinforcement CALCULATION, Description: Noz N2 Fr10**

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

Actual Outside Diameter Used in Calculation 40.000 mm.  
 Actual Thickness Used in Calculation 5.000 mm

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Welded Flat Head, tr [Int. Press]  
 $= d \cdot \sqrt{Z \cdot C \cdot P / (S_v \cdot E)}$  per UG-34 (c)(3)  
 $= 134.0 \cdot \sqrt{1.0 \cdot 0.2 \cdot 1. / (138 \cdot 1.0)}$   
 $= 5.1031 \text{ mm}$

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]  
 $= P \cdot R_o / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 $= 1. \cdot 20.0 / (118 \cdot 1.0 + 0.4 \cdot 1.)$   
 $= 0.1691 \text{ mm}$

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

|   |         |            |
|---|---------|------------|
| Parallel to Vessel Wall (Diameter Limit)        | D1      | 92.0000 mm |
| Parallel to Vessel Wall                         | Rn+tn+t | 46.0000 mm |
| Normal to Vessel Wall (Thickness Limit), no pad | Tlnp    | 10.0000 mm |

*Taking a UG-36(c)(3)(a) exemption for nozzle: Noz N2 Fr10.  
 This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation.*

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

|  |                        |             |
|--|------------------------|-------------|
| Wall Thickness for Internal/External pressures | ta                     | = 1.1691 mm |
| Wall Thickness per UG16(b),                    | tr16b                  | = 3.5000 mm |
| Wall Thickness, shell/head, internal pressure  | trb1                   | = 6.1031 mm |
| Wall Thickness                                 | tb1 = max(trb1, tr16b) | = 6.1031 mm |
| Wall Thickness                                 | tb2 = max(trb2, tr16b) | = 3.5000 mm |
| Wall Thickness per table UG-45                 | tb3                    | = 4.1200 mm |

Determine Nozzle Thickness candidate [tb]:  
 $= \min[ tb3, \max( tb1, tb2 ) ]$   
 $= \min[ 4.12, \max( 6.1031, 3.5 ) ]$   
 $= 4.1200 \text{ mm}$

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 Nozzle Calcs.: Noz N2 Fr10 Nozl: 18 11:11am May 5,2022

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 1.1691, 4.12 )  
 = 4.1200 mm

Available Nozzle Neck Thickness = 5.0000 mm --> OK

**Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:**

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

Govrn. thk, tg = 5.0, tr = 0.169, c = 1.0 mm, E\* = 1.0  
 Thickness Ratio = tr \* E\*/(tg - c) = 0.042, 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

Gov. MDMT of the nozzle to shell joint welded assembly : -104 °C

Weld Size Calculations, Description: Noz N2 Fr10

Intermediate Calc. for nozzle/shell Welds Tmin 4.0000 mm

**Results Per UW-16.1:**

|             |                      |                      |
|-------------|----------------------|----------------------|
|             | Required Thickness   | Actual Thickness     |
| Nozzle Weld | 2.8000 = 0.7 * tmin. | 7.0700 = 0.7 * Wo mm |

Skipping the nozzle attachment weld strength calculations. Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a) (small nozzles) do not require a weld strength check.

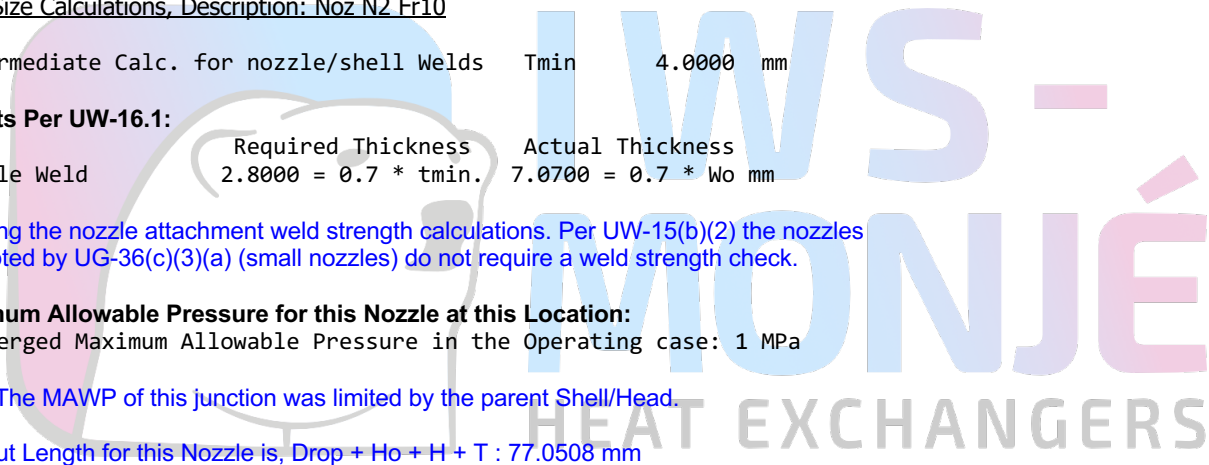
**Maximum Allowable Pressure for this Nozzle at this Location:**

Converged Maximum Allowable Pressure in the Operating case: 1 MPa

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Cut Length for this Nozzle is, Drop + Ho + H + T : 77.0508 mm

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 FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
 Nozzle Calcs.: Noz N3 - Shell Nozl: 19 11:11am May 5,2022

**Input, Nozzle Desc: Noz N3 - Shell inlet****From: 50**

|   |        |        |     |
|---|--------|--------|-----|
| Pressure for Reinforcement Calculations | P      | 2.5000 | MPa |
| Temperature for Internal Pressure       | Temp   | 210    | °C  |
| Design External Pressure                | Pext   | 0.10   | MPa |
| Temperature for External Pressure       | Tempex | 210    | °C  |

|  |     |              |     |
|--|-----|--------------|-----|
| Parent Material                        |     | SA-312 TP316 |     |
| Parent Allowable Stress at Temperature | Sv  | 132.20       | MPa |
| Parent Allowable Stress At Ambient     | Sva | 137.90       | MPa |

|                                      |    |          |    |
|--------------------------------------|----|----------|----|
| Inside Diameter of Cylindrical Shell | D  | 134.50   | mm |
| Design Length of Section             | L  | 753.8000 | mm |
| Shell Finished (Minimum) Thickness   | t  | 3.4000   | mm |
| Shell Internal Corrosion Allowance   | c  | 0.0000   | mm |
| Shell External Corrosion Allowance   | co | 0.0000   | mm |

|                                   |  |        |    |
|-----------------------------------|--|--------|----|
| Distance from Bottom/Left Tangent |  | 206.52 | mm |
|-----------------------------------|--|--------|----|

|   |  |        |    |
|---|--|--------|----|
| User Entered Minimum Design Metal Temperature |  | -10.00 | °C |
|---|--|--------|----|

**Type of Element Connected to the Parent : Nozzle**

|                                 |     |              |     |
|---------------------------------|-----|--------------|-----|
| Material                        |     | SA-312 TP316 |     |
| Material UNS Number             |     | S31600       |     |
| Material Specification/Type     |     | Wld. pipe    |     |
| Allowable Stress at Temperature | Sn  | 132.14       | MPa |
| Allowable Stress At Ambient     | Sna | 137.90       | MPa |

Note: The allowables above have been divided by 0.85, see UG-37 [S].

|                                   |  |         |     |
|-----------------------------------|--|---------|-----|
| Diameter Basis (for tr calc only) |  | Outside |     |
| Layout Angle                      |  | 270.00  | deg |
| Diameter                          |  | 60.3000 | mm  |

|                          |    |        |    |
|--------------------------|----|--------|----|
| Size and Thickness Basis |    | Actual |    |
| Actual Thickness         | tn | 4.0000 | mm |

|             |  |                  |  |
|-------------|--|------------------|--|
| Flange Type |  | Weld Neck Flange |  |
|-------------|--|------------------|--|

|  |     |        |    |
|--|-----|--------|----|
| Corrosion Allowance                      | can | 0.0000 | mm |
| Joint Efficiency of Shell Seam at Nozzle | E1  | 1.00   |    |
| Joint Efficiency of Nozzle Neck          | En  | 1.00   |    |

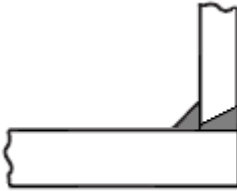
|   |      |         |    |
|---|------|---------|----|
| Outside Projection                          | ho   | 39.0000 | mm |
| Weld leg size between Nozzle and Pad/Shell  | Wo   | 10.0000 | mm |
| Groove weld depth between Nozzle and Vessel | Wgnv | 0.0000  | mm |

|              |  |        |  |
|--------------|--|--------|--|
| Flange Class |  | 300    |  |
| Flange Grade |  | GR 2.2 |  |

The Pressure Design option was Design Pressure + static head.

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

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 FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
 Nozzle Calcs.: Noz N3 - Shell Nozl: 19 11:11am May 5,2022



### Abutting/Set-on Nozzle No Pad

#### Reinforcement CALCULATION, Description: Noz N3 - Shell inlet

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

Actual Outside Diameter Used in Calculation 60.300 mm.  
 Actual Thickness Used in Calculation 4.000 mm

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]  
 =  $P \cdot R / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 =  $2.5 \cdot 67.25 / (132 \cdot 1.0 - 0.6 \cdot 2.5)$   
 = 1.2863 mm

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]  
 =  $P \cdot R_o / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 =  $2.5 \cdot 30.15 / (132 \cdot 1.0 + 0.4 \cdot 2.5)$   
 = 0.5661 mm

Required Nozzle thickness under External Pressure per UG-28 : 0.1670 mm

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

|   |      |             |
|---|------|-------------|
| Parallel to Vessel Wall (Diameter Limit)        | D1   | 104.6000 mm |
| Parallel to Vessel Wall, opening length         | d    | 52.3000 mm  |
| Normal to Vessel Wall (Thickness Limit), no pad | Tlnp | 8.5000 mm   |

*Taking a UG-36(c)(3)(a) exemption for nozzle: Noz N3 - Shell.*

*This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation.*

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

|  |                        |             |
|--|------------------------|-------------|
| Wall Thickness for Internal/External pressures | ta                     | = 0.5661 mm |
| Wall Thickness per UG16(b),                    | tr16b                  | = 1.5000 mm |
| Wall Thickness, shell/head, internal pressure  | trb1                   | = 1.2863 mm |
| Wall Thickness                                 | tb1 = max(trb1, tr16b) | = 1.5000 mm |
| Wall Thickness                                 | tb2 = max(trb2, tr16b) | = 1.5000 mm |
| Wall Thickness per table UG-45                 | tb3                    | = 3.4200 mm |

Determine Nozzle Thickness candidate [tb]:

= min[ tb3, max( tb1,tb2) ]

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 FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
 Nozzle Calcs.: Noz N3 - Shell Nozl: 19 11:11am May 5,2022

$$= \min[ 3.42, \max( 1.5, 1.5 ) ]$$

$$= 1.5000 \text{ mm}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 $= \max( t_a, t_b )$   
 $= \max( 0.5661, 1.5 )$   
 $= 1.5000 \text{ mm}$

Available Nozzle Neck Thickness = 4.0000 mm --> OK

SA-312 TP316, Min Metal Temp without impact per UHA-51: -196 °C

Weld Size Calculations, Description: Noz N3 - Shell

Intermediate Calc. for nozzle/shell welds  $t_{min}$  3.4000 mm

**Results Per UW-16.1:**

|             | Required Thickness       | Actual Thickness           |
|-------------|--------------------------|----------------------------|
| Nozzle Weld | $2.3800 = 0.7 * t_{min}$ | $7.0700 = 0.7 * t_{no}$ mm |

Skipping the nozzle attachment weld strength calculations. Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a) (small nozzles) do not require a weld strength check.

**Maximum Allowable Pressure for this Nozzle at this Location:**

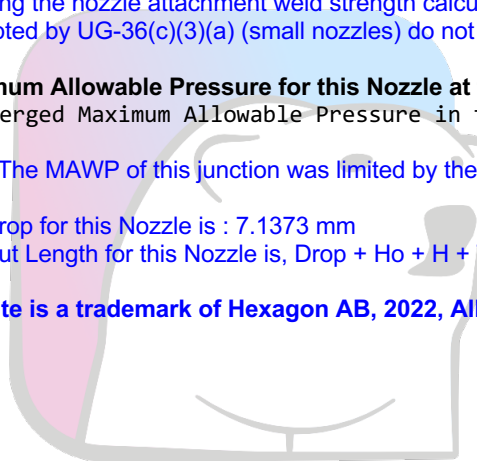
Converged Maximum Allowable Pressure in the Operating case: 2 MPa

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 7.1373 mm

The Cut Length for this Nozzle is, Drop + Ho + H + T : 49.5373 mm

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 FileName : BK12-3102-L800\_Airpack-17811\_Rev00 -----  
 Nozzle Calcs.: Noz N4 - Shell Nozl: 20 11:11am May 5,2022

**Input, Nozzle Desc: Noz N4 - Shell outlet****From: 50**

|   |        |        |     |
|---|--------|--------|-----|
| Pressure for Reinforcement Calculations | P      | 2.5000 | MPa |
| Temperature for Internal Pressure       | Temp   | 210    | °C  |
| Design External Pressure                | Pext   | 0.10   | MPa |
| Temperature for External Pressure       | Tempex | 210    | °C  |

|  |     |              |     |
|--|-----|--------------|-----|
| Parent Material                        |     | SA-312 TP316 |     |
| Parent Allowable Stress at Temperature | Sv  | 132.20       | MPa |
| Parent Allowable Stress At Ambient     | Sva | 137.90       | MPa |

|                                      |    |          |    |
|--------------------------------------|----|----------|----|
| Inside Diameter of Cylindrical Shell | D  | 134.50   | mm |
| Design Length of Section             | L  | 753.8000 | mm |
| Shell Finished (Minimum) Thickness   | t  | 3.4000   | mm |
| Shell Internal Corrosion Allowance   | c  | 0.0000   | mm |
| Shell External Corrosion Allowance   | co | 0.0000   | mm |

|                                   |  |        |    |
|-----------------------------------|--|--------|----|
| Distance from Bottom/Left Tangent |  | 826.53 | mm |
|-----------------------------------|--|--------|----|

|   |  |        |    |
|---|--|--------|----|
| User Entered Minimum Design Metal Temperature |  | -10.00 | °C |
|---|--|--------|----|

**Type of Element Connected to the Parent : Nozzle**

|                                 |     |              |     |
|---------------------------------|-----|--------------|-----|
| Material                        |     | SA-312 TP316 |     |
| Material UNS Number             |     | S31600       |     |
| Material Specification/Type     |     | Wld. pipe    |     |
| Allowable Stress at Temperature | Sn  | 132.14       | MPa |
| Allowable Stress At Ambient     | Sna | 137.90       | MPa |

Note: The allowables above have been divided by 0.85, see UG-37 [S].

|                                   |  |         |     |
|-----------------------------------|--|---------|-----|
| Diameter Basis (for tr calc only) |  | Outside |     |
| Layout Angle                      |  | 90.00   | deg |
| Diameter                          |  | 60.3000 | mm  |

|                          |    |        |    |
|--------------------------|----|--------|----|
| Size and Thickness Basis |    | Actual |    |
| Actual Thickness         | tn | 4.0000 | mm |

|             |  |                  |  |
|-------------|--|------------------|--|
| Flange Type |  | Weld Neck Flange |  |
|-------------|--|------------------|--|

|  |     |        |    |
|--|-----|--------|----|
| Corrosion Allowance                      | can | 0.0000 | mm |
| Joint Efficiency of Shell Seam at Nozzle | E1  | 1.00   |    |
| Joint Efficiency of Nozzle Neck          | En  | 1.00   |    |

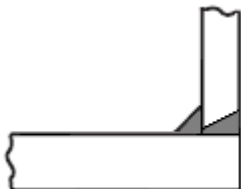
|   |      |         |    |
|---|------|---------|----|
| Outside Projection                          | ho   | 39.0000 | mm |
| Weld leg size between Nozzle and Pad/Shell  | Wo   | 10.0000 | mm |
| Groove weld depth between Nozzle and Vessel | Wgnv | 3.4000  | mm |

|              |  |        |  |
|--------------|--|--------|--|
| Flange Class |  | 300    |  |
| Flange Grade |  | GR 2.2 |  |

The Pressure Design option was Design Pressure + static head.

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

Strength Calculation PV-Elite  
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 Nozzle Calcs.: Noz N4 - Shell Nozl: 20 11:11am May 5,2022



### Abutting/Set-on Nozzle No Pad

#### Reinforcement CALCULATION, Description: Noz N4 - Shell outlet

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

Actual Outside Diameter Used in Calculation 60.300 mm.  
 Actual Thickness Used in Calculation 4.000 mm

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Int. Press]  
 $= P \cdot R / (S_v \cdot E - 0.6 \cdot P)$  per UG-27 (c)(1)  
 $= 2.5 \cdot 67.25 / (132 \cdot 1.0 - 0.6 \cdot 2.5)$   
 $= 1.2863$  mm

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]  
 $= P \cdot R_o / (S_n \cdot E + 0.4 \cdot P)$  per Appendix 1-1 (a)(1)  
 $= 2.5 \cdot 30.15 / (132 \cdot 1.0 + 0.4 \cdot 2.5)$   
 $= 0.5661$  mm

Required Nozzle thickness under External Pressure per UG-28 : 0.1670 mm

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

|   |      |             |
|---|------|-------------|
| Parallel to Vessel Wall (Diameter Limit)        | D1   | 104.6000 mm |
| Parallel to Vessel Wall, opening length         | d    | 52.3000 mm  |
| Normal to Vessel Wall (Thickness Limit), no pad | Tlnp | 8.5000 mm   |

*Taking a UG-36(c)(3)(a) exemption for nozzle: Noz N4 - Shell.*

*This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation.*

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

|  |                        |             |
|--|------------------------|-------------|
| Wall Thickness for Internal/External pressures | ta                     | = 0.5661 mm |
| Wall Thickness per UG16(b),                    | tr16b                  | = 1.5000 mm |
| Wall Thickness, shell/head, internal pressure  | trb1                   | = 1.2863 mm |
| Wall Thickness                                 | tb1 = max(trb1, tr16b) | = 1.5000 mm |
| Wall Thickness                                 | tb2 = max(trb2, tr16b) | = 1.5000 mm |
| Wall Thickness per table UG-45                 | tb3                    | = 3.4200 mm |

Determine Nozzle Thickness candidate [tb]:

= min[ tb3, max( tb1,tb2) ]

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 Nozzle Calcs.: Noz N4 - Shell Nozl: 20 11:11am May 5,2022

$$= \min[ 3.42, \max( 1.5, 1.5 ) ]$$

$$= 1.5000 \text{ mm}$$

Minimum Wall Thickness of Nozzle Necks [tUG-45]:  
 = max( ta, tb )  
 = max( 0.5661, 1.5 )  
 = 1.5000 mm

Available Nozzle Neck Thickness = 4.0000 mm --> OK

SA-312 TP316, Min Metal Temp without impact per UHA-51: -196 °C

Weld Size Calculations, Description: Noz N4 - Shell

Intermediate Calc. for nozzle/shell welds Tmin 3.4000 mm

**Results Per UW-16.1:**

|             | Required Thickness   | Actual Thickness     |
|-------------|----------------------|----------------------|
| Nozzle Weld | 2.3800 = 0.7 * tmin. | 7.0700 = 0.7 * Wo mm |

Skipping the nozzle attachment weld strength calculations. Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a) (small nozzles) do not require a weld strength check.

**Maximum Allowable Pressure for this Nozzle at this Location:**

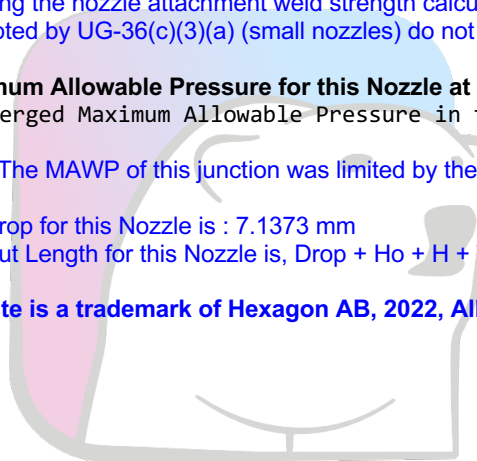
Converged Maximum Allowable Pressure in the Operating case: 2 MPa

Note: The MAWP of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 7.1373 mm

The Cut Length for this Nozzle is, Drop + Ho + H + T : 49.5373 mm

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