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| **طرح نگهداشت و افزایش تولید 27 مخزن**TOTALLY REVISED04 |
| **Thermal/Mechnical Calculation Book****نگهداشت و افزایش تولید میدان نفتی بینک** |
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| **Status:** | **IFA: Issued For Approval****IFI: Issued For Information****AFC: Approved For Construction**  |

**REVISION RECORD SHEET**

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| **6** | X | X | X | X | X | **71** |  |  | X | X | X |
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| **24** |  |  | X | X | X | **89** |  |  | X |  | X |
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1. **INTRODUCTION**

Binak oilfield in Bushehr province is a part of the southern oilfields of Iran, is located 20 km northwest of Genaveh city.

With the aim of increasing production of oil from Binak oilfield, an EPC/EPD Project has been defined by NIOC/NISOC and awarded to Petro Iran Development Company (PEDCO). Also PEDCO (as General Contractor) has assigned the EPC-packages of the Project to "Hirgan Energy - Design and Inspection" JV.

**GENERAL DEFINITION**

The following terms shall be used in this document.

|  |  |
| --- | --- |
| CLIENT:  | National Iranian South Oilfields Company (NISOC)  |
| PROJECT: | Binak Oilfield Development – Manufacturing (w/Engineering & Material Supply) of Air Coolers |
| EPD/EPC CONTRACTOR (GC):  | Petro Iran Development Company (PEDCO) |
| OWNER:  | OWNER is collectively refer to National Iranian South Oil Company (NISOC) and Petro Iran Development Company (PEDCO) |
| EPC CONTRACTOR: | Joint Venture of : Hirgan Energy – Design & Inspection(D&I) Companies |
| VENDOR: | Aban Air Cooler (AAC) |
| EXECUTOR:  | Executor is the party which carries out all or part of construction and/or commissioning for the project. |
| THIRD PARTY INSPECTOR (TPI): | Third Party Inspector |
| SHALL: | Is used where a provision is mandatory. |
| SHOULD: | Is used where a provision is advisory only. |
| WILL:  | Is normally used in connection with the action by CLIENT rather than by an EPC/EPD CONTRACTOR, supplier or VENDOR. |
| MAY:  | Is used where a provision is completely discretionary. |
|  |  |
|  |  |

1. **Thermal/Mechanical Calculation Book**



















1. **Mechanical Calculation Book**

## Stationary Header Calculation @ Design Pressure for ae-2101.

**Input Echo, COMPONENT 1, Description: St.AE-2101**

 Figure Number Analyzed A8

 Design Internal Pressure P 22.0000 bars

 Design Temperature Temp 155.0000 C

 VESSEL MATERIAL DATA:

 Material Specification SA-240 316L

 Shell Allowable Stress at Design Temp S 114.3898 N./mm^2

 Shell Allowable Stress at Ambient SA 115.1465 N./mm^2

 Shell Yield Stress at Design Temperature Sy 129.8699 N./mm^2

 SHORT-SIDE VESSEL DATA:

 Short-side Length Dimension H 160.0000 mm.

 Minimum Thickness of Short-side Plates t1 20.0000 mm.

 Mid-side Joint Efficiency on Short-side E 0.8500

 Corner Joint Efficiency on Short-side EC 0.8500

 LONG-SIDE VESSEL DATA:

 Long-side Length Dimension h 122.0000 mm.

 Minimum Thickness of Long-side Plates t2 20.0000 mm.

 Mid-side Joint Efficiency on Long-side E 0.8500

 ADDITIONAL VESSEL DATA:

 Minimum Thickness of End Plate t5 20.0000 mm.

 C-Factor for End Plate Cf\_Epl 0.2000

 Long-side Plate # 1,

 Pitch Distance p 63.5000 mm.

 Uniform Hole Diameter d0 25.6500 mm.

 Depth of Holes T0 20.0000 mm.

 Long-side Plate # 2,

 Pitch Distance p 63.5000 mm.

 # 1: Hole Diameter d0 36.3000 mm.

 Hole Depth T0 2.7000 mm.

 # 2: Hole Diameter d1 28.5750 mm.

 Hole Depth T1 17.3000 mm.

 STAY PLATE MATERIAL DATA:

 Stay Material Specification SA-240 316L

 Stay Allowable Stress at Design Temp Sr 114.3898 N./mm^2

 Stay Allowable Stress at Ambient SA 115.1465 N./mm^2

 Stay Yield Stress at Design Temp Sy 129.8699 N./mm^2

 STAY PLATE DATA:

 Minimum Thickness of Stay t3 10.0000 mm.

 Minimum Thickness of Stay t4 10.0000 mm.

 The Stay(s) Are Not Welded to the End Plate

**Rectangular Vessel Results, Item number 1, Desc: St.AE-2101**

**ASME Code, Section VIII, Division 1, 2021 App. 13**

**Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):**

***Short-side 1 Calculations***

Membrane Ligament Efficiency [Em]:

 = 0.850

Bending Ligament Efficiency [Eb]:

 = 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Short-side 2 Calculations***

Membrane Ligament Efficiency [Em]:

 = 0.850

Bending Ligament Efficiency [Eb]:

 = 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Long-side 1 Calculations***

Effective Diameter [De]: 25.650 mm.

Membrane Ligament Efficiency [Em]:

 = Pitch - De / Pitch

 = 63.500 - 25.650 / 63.500

 = 0.596

Bending Ligament Efficiency [Eb]:

*As diameter holes are uniform Eb = Em*

 = 0.596

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Long-side 2 Calculations***

Effective Diameter [De]:

 = ( d0 \* T0 + d1 \* T1 + d2 \* T2 ) / ( t1 - CA )

 = ( 36.30 \* 2.70 + 28.57 \* 17.30 + 0.00 \* 0.00 ) /

 ( 20.00 - 0.00 )

 = 29.618 mm.

Membrane Ligament Efficiency [Em]:

 = Pitch - De / Pitch

 = 63.500 - 29.618 / 63.500

 = 0.534

Dist from Neutral axis of c/s to extreme fibers [Ci & Co]:

*Calculation of Xbar:*

 = (( b0 \* T0 \* ( T0/2 + T1 + T2 )) + ( b1 \* T1 \*

 ( T1/2 + T2 )) + ( b2 \* T2 \* ( T2/2 ))) /

 ( b0 \* T0 + b1 \* T1 + b2 \* T2 )

 = (( 1.07 \* 2.70 \* ( 2.70 /2 + 17.30 + 0.00 )) + ( 1.38\* 17.30 \*

 ( 17.30 /2 + 0.00 )) + ( 2.50 \* 0.00 \* ( 0.00 /2 ))) /

 ( 1.07 \* 2.70 + 1.38 \* 17.30 + 2.50 \* 0.00 )

 = 9.734 mm.

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 *Ci = Xbar*

 = 9.734 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t - CA - Xbar )

 = -( 20.000 - 0.000 - 9.734 )

 = -10.266 mm.

Moment of Inertia (Section 13-6, Equation (5)) [I]:

 = 0.085 cm\*\*4

Effective Diameter [De]:

 = Pitch - (( 6 \* I ) / (( t - CA)^2 \* (-Co)))

 = 63.50 - (( 6 \* 0.09 ) / ((20.00 - 0.00 )^2 \* (10.27 )))

 = 31.850 mm.

Bending Ligament Efficiency [Eb]:

 = Pitch - De / Pitch

 = 63.500 - 31.850 / 63.500

 = 0.498

**Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):**

 Em Eb Ci Co

 Short-side 1 0.850 0.850 10.000 -10.000

 2 0.850 0.850 10.000 -10.000

 Long-side 1 0.596 0.596 10.000 -10.000

 2 0.534 0.498 9.734 -10.266

**Moment of Inertia of a Strip of the Vessel Wall:**

 Thickness t1, I1 = 0.0667 cm\*\*4

 Thickness t2, I2 = 0.0667 cm\*\*4

**Rectangular Vessel Parameters:**

 Alpha = H / h = 1.3115

 K = (I2/I1)\*Alpha = 1.3115

**Membrane Stress Calculations per Section 13-9**

***Membrane Stresses at Short-side 1***

Membrane Stress at Short-side 1 [Sms]:

 = P \* h / ( 2 \* t1 ) \* { 3 - [( 6 + K \*

 ( 11 - alpha2) / ( 3 + 5 \* K )]}

 = 22.00 \* 122.00 / ( 2 \* 20.00 ) \* { 3- [( 6 + 1.31 \*

 ( 11 - 1.312) / ( 3 + 5 \* 1.31 )]}

 = 7.37 N./mm^2

***Membrane Stresses at Short-side 2***

Membrane Stress at Short-side 2 [Sms]:

 = P \* h / ( 2 \* t1 ) \* { 3 - [( 6 + K \*

 ( 11 - alpha2) / ( 3 + 5 \* K )]}

 = 22.00 \* 122.00 / ( 2 \* 20.00 ) \* { 3- [( 6 + 1.31 \*

 ( 11 - 1.312) / ( 3 + 5 \* 1.31 )]}

 = 7.37 N./mm^2

***Membrane Stresses at Long-side 1***

Membrane Stress at Long-side 1 at A [Sml]:

 = P \* H / 2 \* t2

 = 22.00 \* 160.00 / 2 \* 20.00

 = 8.80 N./mm^2

 *If Em( 0.596 ) < E( 0.850 ) and Eb( 0.596 ) < E( 0.850 ) then*

 Sml = Sml / Em

 = 8.80 / 0.60

 = 14.76 N./mm^2

***Membrane Stresses at Long-side 2***

Membrane Stress at Long-side 2 at A [Sml]:

 = P \* H / 2 \* t2

 = 22.00 \* 160.00 / 2 \* 20.00

 = 8.80 N./mm^2

 *If Em( 0.534 ) < E( 0.850 ) and Eb( 0.498 ) < E( 0.850 ) then*

 Sml = Sml / Em

 = 8.80 / 0.53

 = 16.49 N./mm^2

***Membrane Stresses at Stay Plate***

Membrane Stress at Stay Plate [t3]:

 = P \* h / ( 2 \* t3 ) \* [( 6 + K \* ( 11 -

 alpha2) / ( 3 + 5 \* K )]

 = 22.00 \* 122.00 / ( 2 \* 10.00 ) \* [( 6 + 1.31 \* ( 11 -

 1.312) / ( 3 + 5 \* 1.31 )]

 = 25.52 N./mm^2

Membrane Stress at Stay Plate [t4]:

 = P \* h / ( 2 \* t4 ) \* [( 6 + K \* ( 11 -

 alpha2) / ( 3 + 5 \* K )]

 = 22.00 \* 122.00 / ( 2 \* 10.00 ) \* [( 6 + 1.31 \* ( 11 -

 1.312) / ( 3 + 5 \* 1.31 )]

 = 25.52 N./mm^2

**MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-9,**

 **Equations (13-15). (N./mm^2) :**

 STRESS LOCATIONS Actual Allowable

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

 Short-side 1 7.37 97.23

 Short-side 2 7.37 97.23

 Short-side Corner 7.37 97.23

 Long-side 1 at A 14.76 114.39

 Long-side 2 at A 16.49 114.39

 Long-side Corner 8.80 97.23

 Stay Plate (t3) 25.52 114.39

 Stay Plate (t4) 25.52 114.39

**Bending Stress Calculations per Section 13-9**

***Bending Stresses at Short-side 1***

Bending Stress at Short-side 1 at N Inner[SbsNi]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 22.00 \* 10.00 / ( 24 \* 0.07 ) \* [ -3 \* 160.002 + 2 \* 122.002 \*

 (( 3 + 5 \* 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 ))]

 = -44.45 N./mm^2

Bending Stress at Short-side 1 at N Outer[SbsNo]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 22.00 \* -10.00 /( 24 \* 0.07 ) \* [ -3 \* 160.002 + 2 \* 122.002 \*

 (( 3 + 5 \* 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 ))]

 = 44.45 N./mm^2

Bending Stress at Short-side 1 at Q Inner[SbsQi]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 22.00 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 ))

 = 61.15 N./mm^2

Bending Stress at Short-side 1 at Q Outer[SbsQo]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 22.00 \* 122.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 ))

 = -61.15 N./mm^2

***Bending Stresses at Short-side 2***

Bending Stress at Short-side 2 at N Inner[SbsNi]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 22.00 \* 10.00 / ( 24 \* 0.07 ) \* [ -3 \* 160.002 + 2 \* 122.002 \*

 (( 3 + 5 \* 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 ))]

 = -44.45 N./mm^2

Bending Stress at Short-side 2 at N Outer[SbsNo]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 22.00 \* -10.00 /( 24 \* 0.07 ) \* [ -3 \* 160.002 + 2 \* 122.002 \*

 (( 3 + 5 \* 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 ))]

 = 44.45 N./mm^2

Bending Stress at Short-side 2 at Q Inner[SbsQi]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 22.00 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 ))

 = 61.15 N./mm^2

Bending Stress at Short-side 2 at Q Outer[SbsQo]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 22.00 \* 122.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 ))

 = -61.15 N./mm^2

***Bending Stresses at Long-side 1***

Bending Stress at Long-side 1 at M Inner[SblMi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 22.00 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 3 + 1.31 \*

 ( 6 - 1.312)) / ( 3 + 5 \* 1.31 )]

 = 36.89 N./mm^2

 *If Em( 0.596 ) < E( 0.850 ) and Eb( 0.596 ) < E( 0.850 ) then*

 SblMi = SblMi / Eb

 = 36.89 / 0.60

 = 61.89 N./mm^2

Bending Stress at Long-side 1 at M Outer[SblMo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 22.00 \* 122.002 \* -10.00 / ( 12 \* 0.07 ) \* [( 3 + 1.31 \*

 ( 6 - 1.312)) / ( 3 + 5 \* 1.31 )]

 = -36.89 N./mm^2

 *If Em( 0.596 ) < E( 0.850 ) and Eb( 0.596 ) < E( 0.850 ) then*

 SblMo = SblMo / Eb

 = -36.89 / 0.60

 = -61.89 N./mm^2

Bending Stress at Long-side 1 at Q Inner[SblQi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 22.00 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 )]

 = 61.15 N./mm^2

Bending Stress at Long-side 1 at Q Outer[SblQo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 22.00 \* 122.002 \* -10.00 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 )]

 = -61.15 N./mm^2

***Bending Stresses at Long-side 2***

Bending Stress at Long-side 2 at M Inner[SblMi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 22.00 \* 122.002 \* 9.73 / ( 12 \* 0.07 ) \* [( 3 + 1.31 \*

 ( 6 - 1.312)) / ( 3 + 5 \* 1.31 )]

 = 35.91 N./mm^2

 *If Em( 0.534 ) < E( 0.850 ) and Eb( 0.498 ) < E( 0.850 ) then*

 SblMi = SblMi / Eb

 = 35.91 / 0.50

 = 72.04 N./mm^2

Bending Stress at Long-side 2 at M Outer[SblMo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 22.00 \* 122.002 \* -10.27 / ( 12 \* 0.07 ) \* [( 3 + 1.31 \*

 ( 6 - 1.312)) / ( 3 + 5 \* 1.31 )]

 = -37.87 N./mm^2

 *If Em( 0.534 ) < E( 0.850 ) and Eb( 0.498 ) < E( 0.850 ) then*

 SblMo = SblMo / Eb

 = -37.87 / 0.50

 = -75.98 N./mm^2

Bending Stress at Long-side 2 at Q Inner[SblQi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 22.00 \* 122.002 \* 9.73 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 )]

 = 59.53 N./mm^2

Bending Stress at Long-side 2 at Q Outer[SblQo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 22.00 \* 122.002 \* -10.27 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 )]

 = -62.78 N./mm^2

**BENDING STRESSES: Bending Stress Calculations per Section 13-9,**

 **Equations (16-19). (N./mm^2) :**

 STRESS LOCATIONS Inner Outer Allowable

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

 Short-side 1 at N -44.45 44.45 145.85

 at Q 61.15 -61.15 145.85

 Short-side 2 at N -44.45 44.45 145.85

 at Q 61.15 -61.15 145.85

 Long-side 1 at M 61.89 -61.89 171.58

 at Q 61.15 -61.15 145.85

 Long-side 2 at M 72.04 -75.98 171.58

 at Q 59.53 -62.78 145.85

**Total Stress Calculations per Section 13-9**

***Total Stresses at Short-side 1***

Total Stress at short side 1 at N inner [STS\_Ni]:

 = Sms + SbsNi

 = 7.37 + -44.45

 = -37.08 N./mm^2

Total Stress at short side 1 at N outer [STS\_No]:

 = Sms + SbsNo

 = 7.37 + 44.45

 = 51.83 N./mm^2

Total Stress at short side 1 at Q inner [STS\_Qi]:

 = Sms + SbsQi

 = 7.37 + 61.15

 = 68.53 N./mm^2

Total Stress at short side 1 at Q outer [STS\_Qo]:

 = Sms + SbsQo

 = 7.37 + -61.15

 = -53.78 N./mm^2

***Total Stresses at Short-side 2***

Total Stress at short side 2 at N inner [STS\_Ni]:

 = Sms + SbsNi

 = 7.37 + -44.45

 = -37.08 N./mm^2

Total Stress at short side 2 at N outer [STS\_No]:

 = Sms + SbsNo

 = 7.37 + 44.45

 = 51.83 N./mm^2

Total Stress at short side 2 at Q inner [STS\_Qi]:

 = Sms + SbsQi

 = 7.37 + 61.15

 = 68.53 N./mm^2

Total Stress at short side 2 at Q outer [STS\_Qo]:

 = Sms + SbsQo

 = 7.37 + -61.15

 = -53.78 N./mm^2

***Total Stresses at Long-side 1***

Total Stress at long side 1 at M inner [STL\_Mi]:

 = Sml + SblMi

 = 14.76 + 61.89

 = 76.65 N./mm^2

Total Stress at long side 1 at M outer [STL\_Mo]:

 = Sml + SblMo

 = 14.76 + -61.89

 = -47.12 N./mm^2

Total Stress at long side 1 at Q inner [STL\_Qi]:

 = Sml + SblQi

 = 8.80 + 61.15

 = 69.95 N./mm^2

Total Stress at long side 1 at Q outer [STL\_Qo]:

 = SmlB + SblQo

 = 8.80 + -61.15

 = -52.35 N./mm^2

***Total Stresses at Long-side 2***

Total Stress at long side 2 at M inner [STL\_Mi]:

 = Sml + SblMi

 = 16.49 + 72.04

 = 88.53 N./mm^2

Total Stress at long side 2 at M outer [STL\_Mo]:

 = Sml + SblMo

 = 16.49 + -75.98

 = -59.49 N./mm^2

Total Stress at long side 2 at Q inner [STL\_Qi]:

 = Sml + SblQi

 = 8.80 + 59.53

 = 68.33 N./mm^2

Total Stress at long side 2 at Q outer [STL\_Qo]:

 = SmlB + SblQo

 = 8.80 + -62.78

 = -53.98 N./mm^2

**TOTAL STRESSES: Total Stress Calculations per Section 13-9,**

 **Equations (20-24). (N./mm^2) :**

 STRESS LOCATIONS Inner Outer Allowable

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

 Short-side 1 at N -37.08 51.83 145.85

 at Q 68.53 -53.78 145.85

 Short-side 2 at N -37.08 51.83 145.85

 at Q 68.53 -53.78 145.85

 Long-side 1 at M 76.65 -47.12 171.58

 at Q 69.95 -52.35 145.85

 Long-side 2 at M 88.53 -59.49 171.58

 at Q 68.33 -53.98 145.85

**End Plate Stresses (N./mm^2):**

 Actual Allowable

 End Plate 67.73 114.39

**Required End Plate thickness due to Internal Pressure [trEP]:**

 = d \* sqrt( Z \* C \* P / ( SE ) ) + ca

 = 160.000 \* sqrt( 2.405 \* 0.200 \* 22.000 / ( 114.390 ) ) + 0.000

 = 15.390 mm.

**End Plate MAWP at given Thickness [MAWPEP]:**

 = ((T-ca)/d)^2 \* ((SE)/(C\*Z)) per UG-34 (c)(3)

 = ((20.0000-0.0000)/160.0000)^2\*((114)/(.20\*2.41))

 = 37.154 bars

 *where Z is:*

 = min( 3.4 - 2.4( d/D ), 2.5 )

 = min( 3.4 - 2.4( 160.000 / 386.000 ), 2.5 )

 = 2.405

**SUMMARY OF RESULTS:**

 MEMBRANE STRESS SUMMARY,

 High Stress (Highest % of Allowable) 25.52 N./mm^2

 High Stress Percentage 22.31 %

 M.A.W.P. for Membrane Stresses 98.63 bars

 BENDING STRESS SUMMARY,

 High Stress (Highest % of Allowable) -75.98 N./mm^2

 High Stress Percentage 44.28 %

 M.A.W.P. for Bending Stresses 49.68 bars

 TOTAL STRESS SUMMARY,

 High Stress (Highest % of Allowable) 88.53 N./mm^2

 High Stress Percentage 51.60 %

 M.A.W.P. for Total Stresses 42.64 bars

**Rectangular Vessel Results For Item 1 : A8**

**SUMMARY OF RESULTS:**

 MEMBRANE STRESS SUMMARY,

 High Stress (Highest % of Allowable) 25.52 N./mm^2

 High Stress Percentage 22.31 %

 M.A.W.P. for Membrane Stresses 98.63 bars

 BENDING STRESS SUMMARY,

 High Stress (Highest % of Allowable) -75.98 N./mm^2

 High Stress Percentage 44.28 %

 M.A.W.P. for Bending Stresses 49.68 bars

 TOTAL STRESS SUMMARY,

 High Stress (Highest % of Allowable) 88.53 N./mm^2

 High Stress Percentage 51.60 %

 M.A.W.P. for Total Stresses 42.64 bars

## Stationary Header Calculation @ test Pressure for ae-2101.

**Input Echo, COMPONENT 1, Description: St.AE-2101-Test**

 Figure Number Analyzed A8

 Design Internal Pressure P 28.6000 bars

 Design Temperature Temp 25.0000 C

 VESSEL MATERIAL DATA:

 Material Specification SA-240 316L

 Shell Allowable Stress at Design Temp S 155.0000 N./mm^2

 Shell Allowable Stress at Ambient SA 155.0000 N./mm^2

 Shell Yield Stress at Design Temperature Sy 172.3750 N./mm^2

 SHORT-SIDE VESSEL DATA:

 Short-side Length Dimension H 160.0000 mm.

 Minimum Thickness of Short-side Plates t1 20.0000 mm.

 Mid-side Joint Efficiency on Short-side E 0.8500

 Corner Joint Efficiency on Short-side EC 0.8500

 LONG-SIDE VESSEL DATA:

 Long-side Length Dimension h 122.0000 mm.

 Minimum Thickness of Long-side Plates t2 20.0000 mm.

 Mid-side Joint Efficiency on Long-side E 0.8500

 ADDITIONAL VESSEL DATA:

 Minimum Thickness of End Plate t5 20.0000 mm.

 C-Factor for End Plate Cf\_Epl 0.2000

 Long-side Plate # 1,

 Pitch Distance p 63.5000 mm.

 Uniform Hole Diameter d0 25.6500 mm.

 Depth of Holes T0 20.0000 mm.

 Long-side Plate # 2,

 Pitch Distance p 63.5000 mm.

 # 1: Hole Diameter d0 36.3000 mm.

 Hole Depth T0 2.7000 mm.

 # 2: Hole Diameter d1 28.5750 mm.

 Hole Depth T1 17.3000 mm.

 STAY PLATE MATERIAL DATA:

 Stay Material Specification SA-240 316L

 Stay Allowable Stress at Design Temp Sr 114.3898 N./mm^2

 Stay Allowable Stress at Ambient SA 115.1465 N./mm^2

 Stay Yield Stress at Design Temp Sy 129.8699 N./mm^2

 STAY PLATE DATA:

 Minimum Thickness of Stay t3 10.0000 mm.

 Minimum Thickness of Stay t4 10.0000 mm.

 The Stay(s) Are Not Welded to the End Plate

**Rectangular Vessel Results, Item number 1, Desc: St.AE-2101-Test**

**ASME Code, Section VIII, Division 1, 2021 App. 13**

**Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):**

***Short-side 1 Calculations***

Membrane Ligament Efficiency [Em]:

 = 0.850

Bending Ligament Efficiency [Eb]:

 = 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Short-side 2 Calculations***

Membrane Ligament Efficiency [Em]:

 = 0.850

Bending Ligament Efficiency [Eb]:

 = 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Long-side 1 Calculations***

Effective Diameter [De]: 25.650 mm.

Membrane Ligament Efficiency [Em]:

 = Pitch - De / Pitch

 = 63.500 - 25.650 / 63.500

 = 0.596

Bending Ligament Efficiency [Eb]:

*As diameter holes are uniform Eb = Em*

 = 0.596

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Long-side 2 Calculations***

Effective Diameter [De]:

 = ( d0 \* T0 + d1 \* T1 + d2 \* T2 ) / ( t1 - CA )

 = ( 36.30 \* 2.70 + 28.57 \* 17.30 + 0.00 \* 0.00 ) /

 ( 20.00 - 0.00 )

 = 29.618 mm.

Membrane Ligament Efficiency [Em]:

 = Pitch - De / Pitch

 = 63.500 - 29.618 / 63.500

 = 0.534

Dist from Neutral axis of c/s to extreme fibers [Ci & Co]:

*Calculation of Xbar:*

 = (( b0 \* T0 \* ( T0/2 + T1 + T2 )) + ( b1 \* T1 \*

 ( T1/2 + T2 )) + ( b2 \* T2 \* ( T2/2 ))) /

 ( b0 \* T0 + b1 \* T1 + b2 \* T2 )

 = (( 1.07 \* 2.70 \* ( 2.70 /2 + 17.30 + 0.00 )) + ( 1.38\* 17.30 \*

 ( 17.30 /2 + 0.00 )) + ( 2.50 \* 0.00 \* ( 0.00 /2 ))) /

 ( 1.07 \* 2.70 + 1.38 \* 17.30 + 2.50 \* 0.00 )

 = 9.734 mm.

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 *Ci = Xbar*

 = 9.734 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t - CA - Xbar )

 = -( 20.000 - 0.000 - 9.734 )

 = -10.266 mm.

Moment of Inertia (Section 13-6, Equation (5)) [I]:

 = 0.085 cm\*\*4

Effective Diameter [De]:

 = Pitch - (( 6 \* I ) / (( t - CA)^2 \* (-Co)))

 = 63.50 - (( 6 \* 0.09 ) / ((20.00 - 0.00 )^2 \* (10.27 )))

 = 31.850 mm.

Bending Ligament Efficiency [Eb]:

 = Pitch - De / Pitch

 = 63.500 - 31.850 / 63.500

 = 0.498

**Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):**

 Em Eb Ci Co

 Short-side 1 0.850 0.850 10.000 -10.000

 2 0.850 0.850 10.000 -10.000

 Long-side 1 0.596 0.596 10.000 -10.000

 2 0.534 0.498 9.734 -10.266

**Moment of Inertia of a Strip of the Vessel Wall:**

 Thickness t1, I1 = 0.0667 cm\*\*4

 Thickness t2, I2 = 0.0667 cm\*\*4

**Rectangular Vessel Parameters:**

 Alpha = H / h = 1.3115

 K = (I2/I1)\*Alpha = 1.3115

**Membrane Stress Calculations per Section 13-9**

***Membrane Stresses at Short-side 1***

Membrane Stress at Short-side 1 [Sms]:

 = P \* h / ( 2 \* t1 ) \* { 3 - [( 6 + K \*

 ( 11 - alpha2) / ( 3 + 5 \* K )]}

 = 28.60 \* 122.00 / ( 2 \* 20.00 ) \* { 3- [( 6 + 1.31 \*

 ( 11 - 1.312) / ( 3 + 5 \* 1.31 )]}

 = 9.59 N./mm^2

***Membrane Stresses at Short-side 2***

Membrane Stress at Short-side 2 [Sms]:

 = P \* h / ( 2 \* t1 ) \* { 3 - [( 6 + K \*

 ( 11 - alpha2) / ( 3 + 5 \* K )]}

 = 28.60 \* 122.00 / ( 2 \* 20.00 ) \* { 3- [( 6 + 1.31 \*

 ( 11 - 1.312) / ( 3 + 5 \* 1.31 )]}

 = 9.59 N./mm^2

***Membrane Stresses at Long-side 1***

Membrane Stress at Long-side 1 at A [Sml]:

 = P \* H / 2 \* t2

 = 28.60 \* 160.00 / 2 \* 20.00

 = 11.44 N./mm^2

 *If Em( 0.596 ) < E( 0.850 ) and Eb( 0.596 ) < E( 0.850 ) then*

 Sml = Sml / Em

 = 11.44 / 0.60

 = 19.19 N./mm^2

***Membrane Stresses at Long-side 2***

Membrane Stress at Long-side 2 at A [Sml]:

 = P \* H / 2 \* t2

 = 28.60 \* 160.00 / 2 \* 20.00

 = 11.44 N./mm^2

 *If Em( 0.534 ) < E( 0.850 ) and Eb( 0.498 ) < E( 0.850 ) then*

 Sml = Sml / Em

 = 11.44 / 0.53

 = 21.44 N./mm^2

***Membrane Stresses at Stay Plate***

Membrane Stress at Stay Plate [t3]:

 = P \* h / ( 2 \* t3 ) \* [( 6 + K \* ( 11 -

 alpha2) / ( 3 + 5 \* K )]

 = 28.60 \* 122.00 / ( 2 \* 10.00 ) \* [( 6 + 1.31 \* ( 11 -

 1.312) / ( 3 + 5 \* 1.31 )]

 = 33.17 N./mm^2

Membrane Stress at Stay Plate [t4]:

 = P \* h / ( 2 \* t4 ) \* [( 6 + K \* ( 11 -

 alpha2) / ( 3 + 5 \* K )]

 = 28.60 \* 122.00 / ( 2 \* 10.00 ) \* [( 6 + 1.31 \* ( 11 -

 1.312) / ( 3 + 5 \* 1.31 )]

 = 33.17 N./mm^2

**MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-9,**

 **Equations (13-15). (N./mm^2) :**

 STRESS LOCATIONS Actual Allowable

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

 Short-side 1 9.59 131.75

 Short-side 2 9.59 131.75

 Short-side Corner 9.59 131.75

 Long-side 1 at A 19.19 155.00

 Long-side 2 at A 21.44 155.00

 Long-side Corner 11.44 131.75

 Stay Plate (t3) 33.17 114.39

 Stay Plate (t4) 33.17 114.39

**Bending Stress Calculations per Section 13-9**

***Bending Stresses at Short-side 1***

Bending Stress at Short-side 1 at N Inner[SbsNi]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 28.60 \* 10.00 / ( 24 \* 0.07 ) \* [ -3 \* 160.002 + 2 \* 122.002 \*

 (( 3 + 5 \* 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 ))]

 = -57.79 N./mm^2

Bending Stress at Short-side 1 at N Outer[SbsNo]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 28.60 \* -10.00 /( 24 \* 0.07 ) \* [ -3 \* 160.002 + 2 \* 122.002 \*

 (( 3 + 5 \* 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 ))]

 = 57.79 N./mm^2

Bending Stress at Short-side 1 at Q Inner[SbsQi]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 28.60 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 ))

 = 79.50 N./mm^2

Bending Stress at Short-side 1 at Q Outer[SbsQo]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 28.60 \* 122.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 ))

 = -79.50 N./mm^2

***Bending Stresses at Short-side 2***

Bending Stress at Short-side 2 at N Inner[SbsNi]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 28.60 \* 10.00 / ( 24 \* 0.07 ) \* [ -3 \* 160.002 + 2 \* 122.002 \*

 (( 3 + 5 \* 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 ))]

 = -57.79 N./mm^2

Bending Stress at Short-side 2 at N Outer[SbsNo]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 28.60 \* -10.00 /( 24 \* 0.07 ) \* [ -3 \* 160.002 + 2 \* 122.002 \*

 (( 3 + 5 \* 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 ))]

 = 57.79 N./mm^2

Bending Stress at Short-side 2 at Q Inner[SbsQi]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 28.60 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 ))

 = 79.50 N./mm^2

Bending Stress at Short-side 2 at Q Outer[SbsQo]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 28.60 \* 122.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 ))

 = -79.50 N./mm^2

***Bending Stresses at Long-side 1***

Bending Stress at Long-side 1 at M Inner[SblMi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 28.60 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 3 + 1.31 \*

 ( 6 - 1.312)) / ( 3 + 5 \* 1.31 )]

 = 47.96 N./mm^2

 *If Em( 0.596 ) < E( 0.850 ) and Eb( 0.596 ) < E( 0.850 ) then*

 SblMi = SblMi / Eb

 = 47.96 / 0.60

 = 80.45 N./mm^2

Bending Stress at Long-side 1 at M Outer[SblMo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 28.60 \* 122.002 \* -10.00 / ( 12 \* 0.07 ) \* [( 3 + 1.31 \*

 ( 6 - 1.312)) / ( 3 + 5 \* 1.31 )]

 = -47.96 N./mm^2

 *If Em( 0.596 ) < E( 0.850 ) and Eb( 0.596 ) < E( 0.850 ) then*

 SblMo = SblMo / Eb

 = -47.96 / 0.60

 = -80.45 N./mm^2

Bending Stress at Long-side 1 at Q Inner[SblQi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 28.60 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 )]

 = 79.50 N./mm^2

Bending Stress at Long-side 1 at Q Outer[SblQo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 28.60 \* 122.002 \* -10.00 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 )]

 = -79.50 N./mm^2

***Bending Stresses at Long-side 2***

Bending Stress at Long-side 2 at M Inner[SblMi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 28.60 \* 122.002 \* 9.73 / ( 12 \* 0.07 ) \* [( 3 + 1.31 \*

 ( 6 - 1.312)) / ( 3 + 5 \* 1.31 )]

 = 46.68 N./mm^2

 *If Em( 0.534 ) < E( 0.850 ) and Eb( 0.498 ) < E( 0.850 ) then*

 SblMi = SblMi / Eb

 = 46.68 / 0.50

 = 93.65 N./mm^2

Bending Stress at Long-side 2 at M Outer[SblMo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 28.60 \* 122.002 \* -10.27 / ( 12 \* 0.07 ) \* [( 3 + 1.31 \*

 ( 6 - 1.312)) / ( 3 + 5 \* 1.31 )]

 = -49.23 N./mm^2

 *If Em( 0.534 ) < E( 0.850 ) and Eb( 0.498 ) < E( 0.850 ) then*

 SblMo = SblMo / Eb

 = -49.23 / 0.50

 = -98.78 N./mm^2

Bending Stress at Long-side 2 at Q Inner[SblQi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 28.60 \* 122.002 \* 9.73 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 )]

 = 77.38 N./mm^2

Bending Stress at Long-side 2 at Q Outer[SblQo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 28.60 \* 122.002 \* -10.27 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

 1.312 \* 1.31 ) / ( 3 + 5 \* 1.31 )]

 = -81.62 N./mm^2

**BENDING STRESSES: Bending Stress Calculations per Section 13-9,**

 **Equations (16-19). (N./mm^2) :**

 STRESS LOCATIONS Inner Outer Allowable

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

 Short-side 1 at N -57.79 57.79 197.62

 at Q 79.50 -79.50 197.62

 Short-side 2 at N -57.79 57.79 197.62

 at Q 79.50 -79.50 197.62

 Long-side 1 at M 80.45 -80.45 232.50

 at Q 79.50 -79.50 197.62

 Long-side 2 at M 93.65 -98.78 232.50

 at Q 77.38 -81.62 197.62

**Total Stress Calculations per Section 13-9**

***Total Stresses at Short-side 1***

Total Stress at short side 1 at N inner [STS\_Ni]:

 = Sms + SbsNi

 = 9.59 + -57.79

 = -48.20 N./mm^2

Total Stress at short side 1 at N outer [STS\_No]:

 = Sms + SbsNo

 = 9.59 + 57.79

 = 67.37 N./mm^2

Total Stress at short side 1 at Q inner [STS\_Qi]:

 = Sms + SbsQi

 = 9.59 + 79.50

 = 89.08 N./mm^2

Total Stress at short side 1 at Q outer [STS\_Qo]:

 = Sms + SbsQo

 = 9.59 + -79.50

 = -69.91 N./mm^2

***Total Stresses at Short-side 2***

Total Stress at short side 2 at N inner [STS\_Ni]:

 = Sms + SbsNi

 = 9.59 + -57.79

 = -48.20 N./mm^2

Total Stress at short side 2 at N outer [STS\_No]:

 = Sms + SbsNo

 = 9.59 + 57.79

 = 67.37 N./mm^2

Total Stress at short side 2 at Q inner [STS\_Qi]:

 = Sms + SbsQi

 = 9.59 + 79.50

 = 89.08 N./mm^2

Total Stress at short side 2 at Q outer [STS\_Qo]:

 = Sms + SbsQo

 = 9.59 + -79.50

 = -69.91 N./mm^2

***Total Stresses at Long-side 1***

Total Stress at long side 1 at M inner [STL\_Mi]:

 = Sml + SblMi

 = 19.19 + 80.45

 = 99.65 N./mm^2

Total Stress at long side 1 at M outer [STL\_Mo]:

 = Sml + SblMo

 = 19.19 + -80.45

 = -61.26 N./mm^2

Total Stress at long side 1 at Q inner [STL\_Qi]:

 = Sml + SblQi

 = 11.44 + 79.50

 = 90.94 N./mm^2

Total Stress at long side 1 at Q outer [STL\_Qo]:

 = SmlB + SblQo

 = 11.44 + -79.50

 = -68.06 N./mm^2

***Total Stresses at Long-side 2***

Total Stress at long side 2 at M inner [STL\_Mi]:

 = Sml + SblMi

 = 21.44 + 93.65

 = 115.09 N./mm^2

Total Stress at long side 2 at M outer [STL\_Mo]:

 = Sml + SblMo

 = 21.44 + -98.78

 = -77.33 N./mm^2

Total Stress at long side 2 at Q inner [STL\_Qi]:

 = Sml + SblQi

 = 11.44 + 77.38

 = 88.82 N./mm^2

Total Stress at long side 2 at Q outer [STL\_Qo]:

 = SmlB + SblQo

 = 11.44 + -81.62

 = -70.18 N./mm^2

**TOTAL STRESSES: Total Stress Calculations per Section 13-9,**

 **Equations (20-24). (N./mm^2) :**

 STRESS LOCATIONS Inner Outer Allowable

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

 Short-side 1 at N -48.20 67.37 197.62

 at Q 89.08 -69.91 197.62

 Short-side 2 at N -48.20 67.37 197.62

 at Q 89.08 -69.91 197.62

 Long-side 1 at M 99.65 -61.26 232.50

 at Q 90.94 -68.06 197.62

 Long-side 2 at M 115.09 -77.33 232.50

 at Q 88.82 -70.18 197.62

**End Plate Stresses (N./mm^2):**

 Actual Allowable

 End Plate 88.05 155.00

**Required End Plate thickness due to Internal Pressure [trEP]:**

 = d \* sqrt( Z \* C \* P / ( SE ) ) + ca

 = 160.000 \* sqrt( 2.405 \* 0.200 \* 28.600 / ( 155.000 ) ) + 0.000

 = 15.074 mm.

**End Plate MAWP at given Thickness [MAWPEP]:**

 = ((T-ca)/d)^2 \* ((SE)/(C\*Z)) per UG-34 (c)(3)

 = ((20.0000-0.0000)/160.0000)^2\*((155)/(.20\*2.41))

 = 50.344 bars

 *where Z is:*

 = min( 3.4 - 2.4( d/D ), 2.5 )

 = min( 3.4 - 2.4( 160.000 / 386.000 ), 2.5 )

 = 2.405

**SUMMARY OF RESULTS:**

 MEMBRANE STRESS SUMMARY,

 High Stress (Highest % of Allowable) 33.17 N./mm^2

 High Stress Percentage 29.00 %

 M.A.W.P. for Membrane Stresses 98.63 bars

 BENDING STRESS SUMMARY,

 High Stress (Highest % of Allowable) -98.78 N./mm^2

 High Stress Percentage 42.48 %

 M.A.W.P. for Bending Stresses 67.32 bars

 TOTAL STRESS SUMMARY,

 High Stress (Highest % of Allowable) 115.09 N./mm^2

 High Stress Percentage 49.50 %

 M.A.W.P. for Total Stresses 57.77 bars

**Rectangular Vessel Results For Item 1 : A8**

**SUMMARY OF RESULTS:**

 MEMBRANE STRESS SUMMARY,

 High Stress (Highest % of Allowable) 33.17 N./mm^2

 High Stress Percentage 29.00 %

 M.A.W.P. for Membrane Stresses 98.63 bars

 BENDING STRESS SUMMARY,

 High Stress (Highest % of Allowable) -98.78 N./mm^2

 High Stress Percentage 42.48 %

 M.A.W.P. for Bending Stresses 67.32 bars

 TOTAL STRESS SUMMARY,

 High Stress (Highest % of Allowable) 115.09 N./mm^2

 High Stress Percentage 49.50 %

 M.A.W.P. for Total Stresses 57.77 bars

## floating Header Calculation @ Design Pressure for ae-2101.

**Input Echo, COMPONENT 1, Description: Fl.AE-2101**

 Figure Number Analyzed A7

 Design Internal Pressure P 22.0000 bars

 Design Temperature Temp 155.0000 C

 VESSEL MATERIAL DATA:

 Material Specification SA-240 316L

 Shell Allowable Stress at Design Temp S 114.3898 N./mm^2

 Shell Allowable Stress at Ambient SA 115.1465 N./mm^2

 Shell Yield Stress at Design Temperature Sy 129.8699 N./mm^2

 SHORT-SIDE VESSEL DATA:

 Short-side Length Dimension H 100.0000 mm.

 Minimum Thickness of Short-side Plates t1 20.0000 mm.

 Mid-side Joint Efficiency on Short-side E 0.8500

 Corner Joint Efficiency on Short-side EC 0.8500

 LONG-SIDE VESSEL DATA:

 Long-side Length Dimension h 122.0000 mm.

 Minimum Thickness of Long-side Plates t2 20.0000 mm.

 Mid-side Joint Efficiency on Long-side E 0.8500

 ADDITIONAL VESSEL DATA:

 Minimum Thickness of End Plate t5 20.0000 mm.

 C-Factor for End Plate Cf\_Epl 0.2000

 Long-side Plate # 1,

 Pitch Distance p 63.5000 mm.

 Uniform Hole Diameter d0 25.6500 mm.

 Depth of Holes T0 20.0000 mm.

 Long-side Plate # 2,

 Pitch Distance p 63.5000 mm.

 # 1: Hole Diameter d0 36.3000 mm.

 Hole Depth T0 2.7000 mm.

 # 2: Hole Diameter d1 28.5750 mm.

 Hole Depth T1 17.3000 mm.

 STAY PLATE MATERIAL DATA:

 Stay Material Specification SA-240 316L

 Stay Allowable Stress at Design Temp Sr 114.3898 N./mm^2

 Stay Allowable Stress at Ambient SA 115.1465 N./mm^2

 Stay Yield Stress at Design Temp Sy 129.8699 N./mm^2

 STAY PLATE DATA:

 Minimum Thickness of Stay t3 10.0000 mm.

 The Stay(s) Are Not Welded to the End Plate

**Rectangular Vessel Results, Item number 1, Desc: Fl.AE-2101**

**ASME Code, Section VIII, Division 1, 2021 App. 13**

**Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):**

***Short-side 1 Calculations***

Membrane Ligament Efficiency [Em]:

 = 0.850

Bending Ligament Efficiency [Eb]:

 = 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Short-side 2 Calculations***

Membrane Ligament Efficiency [Em]:

 = 0.850

Bending Ligament Efficiency [Eb]:

 = 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Long-side 1 Calculations***

Effective Diameter [De]: 25.650 mm.

Membrane Ligament Efficiency [Em]:

 = Pitch - De / Pitch

 = 63.500 - 25.650 / 63.500

 = 0.596

Bending Ligament Efficiency [Eb]:

*As diameter holes are uniform Eb = Em*

 = 0.596

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Long-side 2 Calculations***

Effective Diameter [De]:

 = ( d0 \* T0 + d1 \* T1 + d2 \* T2 ) / ( t1 - CA )

 = ( 36.30 \* 2.70 + 28.57 \* 17.30 + 0.00 \* 0.00 ) /

 ( 20.00 - 0.00 )

 = 29.618 mm.

Membrane Ligament Efficiency [Em]:

 = Pitch - De / Pitch

 = 63.500 - 29.618 / 63.500

 = 0.534

Dist from Neutral axis of c/s to extreme fibers [Ci & Co]:

*Calculation of Xbar:*

 = (( b0 \* T0 \* ( T0/2 + T1 + T2 )) + ( b1 \* T1 \*

 ( T1/2 + T2 )) + ( b2 \* T2 \* ( T2/2 ))) /

 ( b0 \* T0 + b1 \* T1 + b2 \* T2 )

 = (( 1.07 \* 2.70 \* ( 2.70 /2 + 17.30 + 0.00 )) + ( 1.38\* 17.30 \*

 ( 17.30 /2 + 0.00 )) + ( 2.50 \* 0.00 \* ( 0.00 /2 ))) /

 ( 1.07 \* 2.70 + 1.38 \* 17.30 + 2.50 \* 0.00 )

 = 9.734 mm.

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 *Ci = Xbar*

 = 9.734 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t - CA - Xbar )

 = -( 20.000 - 0.000 - 9.734 )

 = -10.266 mm.

Moment of Inertia (Section 13-6, Equation (5)) [I]:

 = 0.085 cm\*\*4

Effective Diameter [De]:

 = Pitch - (( 6 \* I ) / (( t - CA)^2 \* (-Co)))

 = 63.50 - (( 6 \* 0.09 ) / ((20.00 - 0.00 )^2 \* (10.27 )))

 = 31.850 mm.

Bending Ligament Efficiency [Eb]:

 = Pitch - De / Pitch

 = 63.500 - 31.850 / 63.500

 = 0.498

**Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):**

 Em Eb Ci Co

 Short-side 1 0.850 0.850 10.000 -10.000

 2 0.850 0.850 10.000 -10.000

 Long-side 1 0.596 0.596 10.000 -10.000

 2 0.534 0.498 9.734 -10.266

**Moment of Inertia of a Strip of the Vessel Wall:**

 Thickness t1, I1 = 0.0667 cm\*\*4

 Thickness t2, I2 = 0.0667 cm\*\*4

**Rectangular Vessel Parameters:**

 Alpha = H / h = 0.8197

 K = (I2/I1)\*Alpha = 0.8197

**Membrane Stress Calculations per Section 13-9**

***Membrane Stresses at Short-side 1***

Membrane Stress at Short-side 1 [Sms]:

 = p \* h / ( 4 \* t1 ) \* { 4 - [( 2 + K \*

 ( 5 - alpha2)) / ( 1 + 2 \* K )]}

 = 22.00 \* 122.00 / ( 4 \* 20.00 ) \* { 4 - [( 2 + 0.82 \*

 ( 5 - 0.822)) / ( 1 + 2 \* 0.82 )]}

 = 6.37 N./mm^2

***Membrane Stresses at Short-side 2***

Membrane Stress at Short-side 2 [Sms]:

 = p \* h / ( 4 \* t1 ) \* { 4 - [( 2 + K \*

 ( 5 - alpha2)) / ( 1 + 2 \* K )]}

 = 22.00 \* 122.00 / ( 4 \* 20.00 ) \* { 4 - [( 2 + 0.82 \*

 ( 5 - 0.822)) / ( 1 + 2 \* 0.82 )]}

 = 6.37 N./mm^2

***Membrane Stresses at Long-side 1***

Membrane Stress at Long-side 1 at A [Sml]:

 = P \* H / 2 \* t2

 = 22.00 \* 100.00 / 2 \* 20.00

 = 5.50 N./mm^2

 *If Em( 0.596 ) < E( 0.850 ) and Eb( 0.596 ) < E( 0.850 ) then*

 Sml = Sml / Em

 = 5.50 / 0.60

 = 9.23 N./mm^2

***Membrane Stresses at Long-side 2***

Membrane Stress at Long-side 2 at A [Sml]:

 = P \* H / 2 \* t2

 = 22.00 \* 100.00 / 2 \* 20.00

 = 5.50 N./mm^2

 *If Em( 0.534 ) < E( 0.850 ) and Eb( 0.498 ) < E( 0.850 ) then*

 Sml = Sml / Em

 = 5.50 / 0.53

 = 10.31 N./mm^2

***Membrane Stresses at Stay Plate***

Membrane Stress at Stay Plate [Smsp]:

 = P \* h / ( 2 \* t3 ) \* [( 2 + K \* ( 5 -

 alpha2)) / ( 1 + 2 \* K )]

 = 22.00 \* 122.00 / ( 2 \* 10.00 ) \* [( 2 + 0.82 \* ( 5 -

 0.822)) / ( 1 + 2 \* 0.82 )]

 = 28.21 N./mm^2

**MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-9,**

 **Equations (1-3). (N./mm^2) :**

 STRESS LOCATIONS Actual Allowable

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

 Short-side 1 6.37 97.23

 Short-side 2 6.37 97.23

 Short-side Corner 6.37 97.23

 Long-side 1 at A 9.23 114.39

 Long-side 2 at A 10.31 114.39

 Long-side Corner 5.50 97.23

 Stay Plate (t3) 28.21 114.39

**Bending Stress Calculations per Section 13-9**

***Bending Stresses at Short-side 1***

Bending Stress at Short-side 1 at N Inner[SbsNi]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 1 + 2 \* Alpha2 \* K ) / ( 1 + 2 \* K ))]

 = 22.00 \* 10.00 / ( 24 \* 0.07 ) \* [ -3 \* 100.002 + 2 \* 122.002 \*

 (( 1 + 2 \* 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 ))]

 = -8.66 N./mm^2

Bending Stress at Short-side 1 at N Outer[SbsNo]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 1 + 2 \* Alpha2 \* K ) / ( 1 + 2 \* K ))]

 = 22.00 \* -10.00 / ( 24 \* 0.07 ) \* [ -3 \* 100.002 + 2 \* 122.002 \*

 (( 1 + 2 \* 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 ))]

 = 8.66 N./mm^2

Bending Stress at Short-side 1 at Q Inner[SbsQi]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 1 + 2 \*

 Alpha2 \* K ) / ( 1 + 2 \* K ))

 = 22.00 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 1 + 2 \*

 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 ))

 = 32.59 N./mm^2

Bending Stress at Short-side 1 at Q Outer[SbsQo]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 1 + 2 \*

 Alpha2 \* K ) / ( 1 + 2 \* K ))

 = 22.00 \* 122.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 1 + 2 \*

 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 ))

 = -32.59 N./mm^2

***Bending Stresses at Short-side 2***

Bending Stress at Short-side 2 at N Inner[SbsNi]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 1 + 2 \* Alpha2 \* K ) / ( 1 + 2 \* K ))]

 = 22.00 \* 10.00 / ( 24 \* 0.07 ) \* [ -3 \* 100.002 + 2 \* 122.002 \*

 (( 1 + 2 \* 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 ))]

 = -8.66 N./mm^2

Bending Stress at Short-side 2 at N Outer[SbsNo]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 1 + 2 \* Alpha2 \* K ) / ( 1 + 2 \* K ))]

 = 22.00 \* -10.00 / ( 24 \* 0.07 ) \* [ -3 \* 100.002 + 2 \* 122.002 \*

 (( 1 + 2 \* 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 ))]

 = 8.66 N./mm^2

Bending Stress at Short-side 2 at Q Inner[SbsQi]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 1 + 2 \*

 Alpha2 \* K ) / ( 1 + 2 \* K ))

 = 22.00 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 1 + 2 \*

 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 ))

 = 32.59 N./mm^2

Bending Stress at Short-side 2 at Q Outer[SbsQo]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 1 + 2 \*

 Alpha2 \* K ) / ( 1 + 2 \* K ))

 = 22.00 \* 122.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 1 + 2 \*

 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 ))

 = -32.59 N./mm^2

***Bending Stresses at Long-side 1***

Bending Stress at Long-side 1 at M Inner[SblMi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 1 + K \*

 ( 3 - Alpha2)) / ( 1 + 2 \* K )]

 = 22.00 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 1 + 0.82 \*

 ( 3 - 0.822)) / ( 1 + 2 \* 0.82 )]

 = 45.10 N./mm^2

 *If Em( 0.596 ) < E( 0.850 ) and Eb( 0.596 ) < E( 0.850 ) then*

 SblMi = SblMi / Eb

 = 45.10 / 0.60

 = 75.67 N./mm^2

Bending Stress at Long-side 1 at M Outer[SblMo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 1 + K \*

 ( 3 - Alpha2)) / ( 1 + 2 \* K )]

 = 22.00 \* 122.002 \* -10.00 / ( 12 \* 0.07 ) \* [( 1 + 0.82 \*

 ( 3 - 0.822)) / ( 1 + 2 \* 0.82 )]

 = -45.10 N./mm^2

 *If Em( 0.596 ) < E( 0.850 ) and Eb( 0.596 ) < E( 0.850 ) then*

 SblMo = SblMo / Eb

 = -45.10 / 0.60

 = -75.67 N./mm^2

Bending Stress at Long-side 1 at Q Inner[SblQi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 1 + 2 \*

 Alpha2 \* K ) / ( 1 + 2 \* K )]

 = 22.00 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 1 + 2 \*

 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 )]

 = 32.59 N./mm^2

Bending Stress at Long-side 1 at Q Outer[SblQo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 1 + 2 \*

 Alpha2 \* K ) / ( 1 + 2 \* K )]

 = 22.00 \* 122.002 \* -10.00 / ( 12 \* 0.07 ) \* [( 1 + 2 \*

 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 )]

 = -32.59 N./mm^2

***Bending Stresses at Long-side 2***

Bending Stress at Long-side 2 at M Inner[SblMi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 1 + K \*

 ( 3 - Alpha2)) / ( 1 + 2 \* K )]

 = 22.00 \* 122.002 \* 9.73 / ( 12 \* 0.07 ) \* [( 1 + 0.82 \*

 ( 3 - 0.822)) / ( 1 + 2 \* 0.82 )]

 = 43.90 N./mm^2

 *If Em( 0.534 ) < E( 0.850 ) and Eb( 0.498 ) < E( 0.850 ) then*

 SblMi = SblMi / Eb

 = 43.90 / 0.50

 = 88.08 N./mm^2

Bending Stress at Long-side 2 at M Outer[SblMo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 1 + K \*

 ( 3 - Alpha2)) / ( 1 + 2 \* K )]

 = 22.00 \* 122.002 \* -10.27 / ( 12 \* 0.07 ) \* [( 1 + 0.82 \*

 ( 3 - 0.822)) / ( 1 + 2 \* 0.82 )]

 = -46.31 N./mm^2

 *If Em( 0.534 ) < E( 0.850 ) and Eb( 0.498 ) < E( 0.850 ) then*

 SblMo = SblMo / Eb

 = -46.31 / 0.50

 = -92.90 N./mm^2

Bending Stress at Long-side 2 at Q Inner[SblQi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 1 + 2 \*

 Alpha2 \* K ) / ( 1 + 2 \* K )]

 = 22.00 \* 122.002 \* 9.73 / ( 12 \* 0.07 ) \* [( 1 + 2 \*

 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 )]

 = 31.72 N./mm^2

Bending Stress at Long-side 2 at Q Outer[SblQo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 1 + 2 \*

 Alpha2 \* K ) / ( 1 + 2 \* K )]

 = 22.00 \* 122.002 \* -10.27 / ( 12 \* 0.07 ) \* [( 1 + 2 \*

 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 )]

 = -33.46 N./mm^2

**BENDING STRESSES: Bending Stress Calculations per Section 13-9,**

 **Equations (4-7). (N./mm^2) :**

 STRESS LOCATIONS Inner Outer Allowable

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

 Short-side 1 at N -8.66 8.66 145.85

 at Q 32.59 -32.59 145.85

 Short-side 2 at N -8.66 8.66 145.85

 at Q 32.59 -32.59 145.85

 Long-side 1 at M 75.67 -75.67 171.58

 at Q 32.59 -32.59 145.85

 Long-side 2 at M 88.08 -92.90 171.58

 at Q 31.72 -33.46 145.85

**Total Stress Calculations per Section 13-9**

***Total Stresses at Short-side 1***

Total Stress at short side 1 at N inner [STS\_Ni]:

 = Sms + SbsNi

 = 6.37 + -8.66

 = -2.29 N./mm^2

Total Stress at short side 1 at N outer [STS\_No]:

 = Sms + SbsNo

 = 6.37 + 8.66

 = 15.03 N./mm^2

Total Stress at short side 1 at Q inner [STS\_Qi]:

 = Sms + SbsQi

 = 6.37 + 32.59

 = 38.96 N./mm^2

Total Stress at short side 1 at Q outer [STS\_Qo]:

 = Sms + SbsQo

 = 6.37 + -32.59

 = -26.22 N./mm^2

***Total Stresses at Short-side 2***

Total Stress at short side 2 at N inner [STS\_Ni]:

 = Sms + SbsNi

 = 6.37 + -8.66

 = -2.29 N./mm^2

Total Stress at short side 2 at N outer [STS\_No]:

 = Sms + SbsNo

 = 6.37 + 8.66

 = 15.03 N./mm^2

Total Stress at short side 2 at Q inner [STS\_Qi]:

 = Sms + SbsQi

 = 6.37 + 32.59

 = 38.96 N./mm^2

Total Stress at short side 2 at Q outer [STS\_Qo]:

 = Sms + SbsQo

 = 6.37 + -32.59

 = -26.22 N./mm^2

***Total Stresses at Long-side 1***

Total Stress at long side 1 at M inner [STL\_Mi]:

 = Sml + SblMi

 = 9.23 + 75.67

 = 84.90 N./mm^2

Total Stress at long side 1 at M outer [STL\_Mo]:

 = Sml + SblMo

 = 9.23 + -75.67

 = -66.44 N./mm^2

Total Stress at long side 1 at Q inner [STL\_Qi]:

 = Sml + SblQi

 = 5.50 + 32.59

 = 38.09 N./mm^2

Total Stress at long side 1 at Q outer [STL\_Qo]:

 = Sml + SblQo

 = 5.50 + -32.59

 = -27.09 N./mm^2

***Total Stresses at Long-side 2***

Total Stress at long side 2 at M inner [STL\_Mi]:

 = Sml + SblMi

 = 10.31 + 88.08

 = 98.39 N./mm^2

Total Stress at long side 2 at M outer [STL\_Mo]:

 = Sml + SblMo

 = 10.31 + -92.90

 = -82.59 N./mm^2

Total Stress at long side 2 at Q inner [STL\_Qi]:

 = Sml + SblQi

 = 5.50 + 31.72

 = 37.22 N./mm^2

Total Stress at long side 2 at Q outer [STL\_Qo]:

 = Sml + SblQo

 = 5.50 + -33.46

 = -27.96 N./mm^2

**TOTAL STRESSES: Total Stress Calculations per Section 13-9,**

 **Equations (8-12). (N./mm^2) :**

 STRESS LOCATIONS Inner Outer Allowable

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

 Short-side 1 at N -2.29 15.03 145.85

 at Q 38.96 -26.22 145.85

 Short-side 2 at N -2.29 15.03 145.85

 at Q 38.96 -26.22 145.85

 Long-side 1 at M 84.90 -66.44 171.58

 at Q 38.09 -27.09 145.85

 Long-side 2 at M 98.39 -82.59 171.58

 at Q 37.22 -27.96 145.85

**End Plate Stresses (N./mm^2):**

 Actual Allowable

 End Plate 30.85 114.39

**Required End Plate thickness due to Internal Pressure [trEP]:**

 = d \* sqrt( Z \* C \* P / ( SE ) ) + ca

 = 110.000 \* sqrt( 2.318 \* 0.200 \* 22.000 / ( 114.390 ) ) + 0.000

 = 10.387 mm.

**End Plate MAWP at given Thickness [MAWPEP]:**

 = ((T-ca)/d)^2 \* ((SE)/(C\*Z)) per UG-34 (c)(3)

 = ((20.0000-0.0000)/110.0000)^2\*((114)/(.20\*2.32))

 = 81.562 bars

 *where Z is:*

 = min( 3.4 - 2.4( d/D ), 2.5 )

 = min( 3.4 - 2.4( 110.000 / 244.000 ), 2.5 )

 = 2.318

**SUMMARY OF RESULTS:**

 MEMBRANE STRESS SUMMARY,

 High Stress (Highest % of Allowable) 28.21 N./mm^2

 High Stress Percentage 24.66 %

 M.A.W.P. for Membrane Stresses 89.21 bars

 BENDING STRESS SUMMARY,

 High Stress (Highest % of Allowable) -92.90 N./mm^2

 High Stress Percentage 54.14 %

 M.A.W.P. for Bending Stresses 40.63 bars

 TOTAL STRESS SUMMARY,

 High Stress (Highest % of Allowable) 98.39 N./mm^2

 High Stress Percentage 57.34 %

 M.A.W.P. for Total Stresses 38.37 bars

**Rectangular Vessel Results For Item 1 : A7**

**SUMMARY OF RESULTS:**

 MEMBRANE STRESS SUMMARY,

 High Stress (Highest % of Allowable) 28.21 N./mm^2

 High Stress Percentage 24.66 %

 M.A.W.P. for Membrane Stresses 89.21 bars

 BENDING STRESS SUMMARY,

 High Stress (Highest % of Allowable) -92.90 N./mm^2

 High Stress Percentage 54.14 %

 M.A.W.P. for Bending Stresses 40.63 bars

 TOTAL STRESS SUMMARY,

 High Stress (Highest % of Allowable) 98.39 N./mm^2

 High Stress Percentage 57.34 %

 M.A.W.P. for Total Stresses 38.37 bars

## floating Header Calculation @ test Pressure for ae-2101.

**Input Echo, COMPONENT 1, Description: Fl.AE-2101-Test**

 Figure Number Analyzed A7

 Design Internal Pressure P 28.6000 bars

 Design Temperature Temp 25.0000 C

 VESSEL MATERIAL DATA:

 Material Specification SA-240 316L

 Shell Allowable Stress at Design Temp S 155.0000 N./mm^2

 Shell Allowable Stress at Ambient SA 155.0000 N./mm^2

 Shell Yield Stress at Design Temperature Sy 172.3750 N./mm^2

 SHORT-SIDE VESSEL DATA:

 Short-side Length Dimension H 100.0000 mm.

 Minimum Thickness of Short-side Plates t1 20.0000 mm.

 Mid-side Joint Efficiency on Short-side E 0.8500

 Corner Joint Efficiency on Short-side EC 0.8500

 LONG-SIDE VESSEL DATA:

 Long-side Length Dimension h 122.0000 mm.

 Minimum Thickness of Long-side Plates t2 20.0000 mm.

 Mid-side Joint Efficiency on Long-side E 0.8500

 ADDITIONAL VESSEL DATA:

 Minimum Thickness of End Plate t5 20.0000 mm.

 C-Factor for End Plate Cf\_Epl 0.2000

 Long-side Plate # 1,

 Pitch Distance p 63.5000 mm.

 Uniform Hole Diameter d0 25.6500 mm.

 Depth of Holes T0 20.0000 mm.

 Long-side Plate # 2,

 Pitch Distance p 63.5000 mm.

 # 1: Hole Diameter d0 36.3000 mm.

 Hole Depth T0 2.7000 mm.

 # 2: Hole Diameter d1 28.5750 mm.

 Hole Depth T1 17.3000 mm.

 STAY PLATE MATERIAL DATA:

 Stay Material Specification SA-240 316L

 Stay Allowable Stress at Design Temp Sr 114.3898 N./mm^2

 Stay Allowable Stress at Ambient SA 115.1465 N./mm^2

 Stay Yield Stress at Design Temp Sy 129.8699 N./mm^2

 STAY PLATE DATA:

 Minimum Thickness of Stay t3 10.0000 mm.

 The Stay(s) Are Not Welded to the End Plate

**Rectangular Vessel Results, Item number 1, Desc: Fl.AE-2101-Test**

**ASME Code, Section VIII, Division 1, 2021 App. 13**

**Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):**

***Short-side 1 Calculations***

Membrane Ligament Efficiency [Em]:

 = 0.850

Bending Ligament Efficiency [Eb]:

 = 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Short-side 2 Calculations***

Membrane Ligament Efficiency [Em]:

 = 0.850

Bending Ligament Efficiency [Eb]:

 = 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Long-side 1 Calculations***

Effective Diameter [De]: 25.650 mm.

Membrane Ligament Efficiency [Em]:

 = Pitch - De / Pitch

 = 63.500 - 25.650 / 63.500

 = 0.596

Bending Ligament Efficiency [Eb]:

*As diameter holes are uniform Eb = Em*

 = 0.596

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Long-side 2 Calculations***

Effective Diameter [De]:

 = ( d0 \* T0 + d1 \* T1 + d2 \* T2 ) / ( t1 - CA )

 = ( 36.30 \* 2.70 + 28.57 \* 17.30 + 0.00 \* 0.00 ) /

 ( 20.00 - 0.00 )

 = 29.618 mm.

Membrane Ligament Efficiency [Em]:

 = Pitch - De / Pitch

 = 63.500 - 29.618 / 63.500

 = 0.534

Dist from Neutral axis of c/s to extreme fibers [Ci & Co]:

*Calculation of Xbar:*

 = (( b0 \* T0 \* ( T0/2 + T1 + T2 )) + ( b1 \* T1 \*

 ( T1/2 + T2 )) + ( b2 \* T2 \* ( T2/2 ))) /

 ( b0 \* T0 + b1 \* T1 + b2 \* T2 )

 = (( 1.07 \* 2.70 \* ( 2.70 /2 + 17.30 + 0.00 )) + ( 1.38\* 17.30 \*

 ( 17.30 /2 + 0.00 )) + ( 2.50 \* 0.00 \* ( 0.00 /2 ))) /

 ( 1.07 \* 2.70 + 1.38 \* 17.30 + 2.50 \* 0.00 )

 = 9.734 mm.

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 *Ci = Xbar*

 = 9.734 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t - CA - Xbar )

 = -( 20.000 - 0.000 - 9.734 )

 = -10.266 mm.

Moment of Inertia (Section 13-6, Equation (5)) [I]:

 = 0.085 cm\*\*4

Effective Diameter [De]:

 = Pitch - (( 6 \* I ) / (( t - CA)^2 \* (-Co)))

 = 63.50 - (( 6 \* 0.09 ) / ((20.00 - 0.00 )^2 \* (10.27 )))

 = 31.850 mm.

Bending Ligament Efficiency [Eb]:

 = Pitch - De / Pitch

 = 63.500 - 31.850 / 63.500

 = 0.498

**Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):**

 Em Eb Ci Co

 Short-side 1 0.850 0.850 10.000 -10.000

 2 0.850 0.850 10.000 -10.000

 Long-side 1 0.596 0.596 10.000 -10.000

 2 0.534 0.498 9.734 -10.266

**Moment of Inertia of a Strip of the Vessel Wall:**

 Thickness t1, I1 = 0.0667 cm\*\*4

 Thickness t2, I2 = 0.0667 cm\*\*4

**Rectangular Vessel Parameters:**

 Alpha = H / h = 0.8197

 K = (I2/I1)\*Alpha = 0.8197

**Membrane Stress Calculations per Section 13-9**

***Membrane Stresses at Short-side 1***

Membrane Stress at Short-side 1 [Sms]:

 = p \* h / ( 4 \* t1 ) \* { 4 - [( 2 + K \*

 ( 5 - alpha2)) / ( 1 + 2 \* K )]}

 = 28.60 \* 122.00 / ( 4 \* 20.00 ) \* { 4 - [( 2 + 0.82 \*

 ( 5 - 0.822)) / ( 1 + 2 \* 0.82 )]}

 = 8.28 N./mm^2

***Membrane Stresses at Short-side 2***

Membrane Stress at Short-side 2 [Sms]:

 = p \* h / ( 4 \* t1 ) \* { 4 - [( 2 + K \*

 ( 5 - alpha2)) / ( 1 + 2 \* K )]}

 = 28.60 \* 122.00 / ( 4 \* 20.00 ) \* { 4 - [( 2 + 0.82 \*

 ( 5 - 0.822)) / ( 1 + 2 \* 0.82 )]}

 = 8.28 N./mm^2

***Membrane Stresses at Long-side 1***

Membrane Stress at Long-side 1 at A [Sml]:

 = P \* H / 2 \* t2

 = 28.60 \* 100.00 / 2 \* 20.00

 = 7.15 N./mm^2

 *If Em( 0.596 ) < E( 0.850 ) and Eb( 0.596 ) < E( 0.850 ) then*

 Sml = Sml / Em

 = 7.15 / 0.60

 = 12.00 N./mm^2

***Membrane Stresses at Long-side 2***

Membrane Stress at Long-side 2 at A [Sml]:

 = P \* H / 2 \* t2

 = 28.60 \* 100.00 / 2 \* 20.00

 = 7.15 N./mm^2

 *If Em( 0.534 ) < E( 0.850 ) and Eb( 0.498 ) < E( 0.850 ) then*

 Sml = Sml / Em

 = 7.15 / 0.53

 = 13.40 N./mm^2

***Membrane Stresses at Stay Plate***

Membrane Stress at Stay Plate [Smsp]:

 = P \* h / ( 2 \* t3 ) \* [( 2 + K \* ( 5 -

 alpha2)) / ( 1 + 2 \* K )]

 = 28.60 \* 122.00 / ( 2 \* 10.00 ) \* [( 2 + 0.82 \* ( 5 -

 0.822)) / ( 1 + 2 \* 0.82 )]

 = 36.67 N./mm^2

**MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-9,**

 **Equations (1-3). (N./mm^2) :**

 STRESS LOCATIONS Actual Allowable

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

 Short-side 1 8.28 131.75

 Short-side 2 8.28 131.75

 Short-side Corner 8.28 131.75

 Long-side 1 at A 12.00 155.00

 Long-side 2 at A 13.40 155.00

 Long-side Corner 7.15 131.75

 Stay Plate (t3) 36.67 114.39

**Bending Stress Calculations per Section 13-9**

***Bending Stresses at Short-side 1***

Bending Stress at Short-side 1 at N Inner[SbsNi]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 1 + 2 \* Alpha2 \* K ) / ( 1 + 2 \* K ))]

 = 28.60 \* 10.00 / ( 24 \* 0.07 ) \* [ -3 \* 100.002 + 2 \* 122.002 \*

 (( 1 + 2 \* 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 ))]

 = -11.26 N./mm^2

Bending Stress at Short-side 1 at N Outer[SbsNo]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 1 + 2 \* Alpha2 \* K ) / ( 1 + 2 \* K ))]

 = 28.60 \* -10.00 / ( 24 \* 0.07 ) \* [ -3 \* 100.002 + 2 \* 122.002 \*

 (( 1 + 2 \* 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 ))]

 = 11.26 N./mm^2

Bending Stress at Short-side 1 at Q Inner[SbsQi]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 1 + 2 \*

 Alpha2 \* K ) / ( 1 + 2 \* K ))

 = 28.60 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 1 + 2 \*

 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 ))

 = 42.37 N./mm^2

Bending Stress at Short-side 1 at Q Outer[SbsQo]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 1 + 2 \*

 Alpha2 \* K ) / ( 1 + 2 \* K ))

 = 28.60 \* 122.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 1 + 2 \*

 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 ))

 = -42.37 N./mm^2

***Bending Stresses at Short-side 2***

Bending Stress at Short-side 2 at N Inner[SbsNi]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 1 + 2 \* Alpha2 \* K ) / ( 1 + 2 \* K ))]

 = 28.60 \* 10.00 / ( 24 \* 0.07 ) \* [ -3 \* 100.002 + 2 \* 122.002 \*

 (( 1 + 2 \* 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 ))]

 = -11.26 N./mm^2

Bending Stress at Short-side 2 at N Outer[SbsNo]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 1 + 2 \* Alpha2 \* K ) / ( 1 + 2 \* K ))]

 = 28.60 \* -10.00 / ( 24 \* 0.07 ) \* [ -3 \* 100.002 + 2 \* 122.002 \*

 (( 1 + 2 \* 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 ))]

 = 11.26 N./mm^2

Bending Stress at Short-side 2 at Q Inner[SbsQi]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 1 + 2 \*

 Alpha2 \* K ) / ( 1 + 2 \* K ))

 = 28.60 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 1 + 2 \*

 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 ))

 = 42.37 N./mm^2

Bending Stress at Short-side 2 at Q Outer[SbsQo]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 1 + 2 \*

 Alpha2 \* K ) / ( 1 + 2 \* K ))

 = 28.60 \* 122.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 1 + 2 \*

 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 ))

 = -42.37 N./mm^2

***Bending Stresses at Long-side 1***

Bending Stress at Long-side 1 at M Inner[SblMi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 1 + K \*

 ( 3 - Alpha2)) / ( 1 + 2 \* K )]

 = 28.60 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 1 + 0.82 \*

 ( 3 - 0.822)) / ( 1 + 2 \* 0.82 )]

 = 58.64 N./mm^2

 *If Em( 0.596 ) < E( 0.850 ) and Eb( 0.596 ) < E( 0.850 ) then*

 SblMi = SblMi / Eb

 = 58.64 / 0.60

 = 98.37 N./mm^2

Bending Stress at Long-side 1 at M Outer[SblMo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 1 + K \*

 ( 3 - Alpha2)) / ( 1 + 2 \* K )]

 = 28.60 \* 122.002 \* -10.00 / ( 12 \* 0.07 ) \* [( 1 + 0.82 \*

 ( 3 - 0.822)) / ( 1 + 2 \* 0.82 )]

 = -58.64 N./mm^2

 *If Em( 0.596 ) < E( 0.850 ) and Eb( 0.596 ) < E( 0.850 ) then*

 SblMo = SblMo / Eb

 = -58.64 / 0.60

 = -98.37 N./mm^2

Bending Stress at Long-side 1 at Q Inner[SblQi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 1 + 2 \*

 Alpha2 \* K ) / ( 1 + 2 \* K )]

 = 28.60 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 1 + 2 \*

 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 )]

 = 42.37 N./mm^2

Bending Stress at Long-side 1 at Q Outer[SblQo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 1 + 2 \*

 Alpha2 \* K ) / ( 1 + 2 \* K )]

 = 28.60 \* 122.002 \* -10.00 / ( 12 \* 0.07 ) \* [( 1 + 2 \*

 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 )]

 = -42.37 N./mm^2

***Bending Stresses at Long-side 2***

Bending Stress at Long-side 2 at M Inner[SblMi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 1 + K \*

 ( 3 - Alpha2)) / ( 1 + 2 \* K )]

 = 28.60 \* 122.002 \* 9.73 / ( 12 \* 0.07 ) \* [( 1 + 0.82 \*

 ( 3 - 0.822)) / ( 1 + 2 \* 0.82 )]

 = 57.08 N./mm^2

 *If Em( 0.534 ) < E( 0.850 ) and Eb( 0.498 ) < E( 0.850 ) then*

 SblMi = SblMi / Eb

 = 57.08 / 0.50

 = 114.51 N./mm^2

Bending Stress at Long-side 2 at M Outer[SblMo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 1 + K \*

 ( 3 - Alpha2)) / ( 1 + 2 \* K )]

 = 28.60 \* 122.002 \* -10.27 / ( 12 \* 0.07 ) \* [( 1 + 0.82 \*

 ( 3 - 0.822)) / ( 1 + 2 \* 0.82 )]

 = -60.20 N./mm^2

 *If Em( 0.534 ) < E( 0.850 ) and Eb( 0.498 ) < E( 0.850 ) then*

 SblMo = SblMo / Eb

 = -60.20 / 0.50

 = -120.77 N./mm^2

Bending Stress at Long-side 2 at Q Inner[SblQi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 1 + 2 \*

 Alpha2 \* K ) / ( 1 + 2 \* K )]

 = 28.60 \* 122.002 \* 9.73 / ( 12 \* 0.07 ) \* [( 1 + 2 \*

 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 )]

 = 41.24 N./mm^2

Bending Stress at Long-side 2 at Q Outer[SblQo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 1 + 2 \*

 Alpha2 \* K ) / ( 1 + 2 \* K )]

 = 28.60 \* 122.002 \* -10.27 / ( 12 \* 0.07 ) \* [( 1 + 2 \*

 0.822 \* 0.82 ) / ( 1 + 2 \* 0.82 )]

 = -43.50 N./mm^2

**BENDING STRESSES: Bending Stress Calculations per Section 13-9,**

 **Equations (4-7). (N./mm^2) :**

 STRESS LOCATIONS Inner Outer Allowable

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

 Short-side 1 at N -11.26 11.26 197.62

 at Q 42.37 -42.37 197.62

 Short-side 2 at N -11.26 11.26 197.62

 at Q 42.37 -42.37 197.62

 Long-side 1 at M 98.37 -98.37 232.50

 at Q 42.37 -42.37 197.62

 Long-side 2 at M 114.51 -120.77 232.50

 at Q 41.24 -43.50 197.62

**Total Stress Calculations per Section 13-9**

***Total Stresses at Short-side 1***

Total Stress at short side 1 at N inner [STS\_Ni]:

 = Sms + SbsNi

 = 8.28 + -11.26

 = -2.98 N./mm^2

Total Stress at short side 1 at N outer [STS\_No]:

 = Sms + SbsNo

 = 8.28 + 11.26

 = 19.54 N./mm^2

Total Stress at short side 1 at Q inner [STS\_Qi]:

 = Sms + SbsQi

 = 8.28 + 42.37

 = 50.65 N./mm^2

Total Stress at short side 1 at Q outer [STS\_Qo]:

 = Sms + SbsQo

 = 8.28 + -42.37

 = -34.09 N./mm^2

***Total Stresses at Short-side 2***

Total Stress at short side 2 at N inner [STS\_Ni]:

 = Sms + SbsNi

 = 8.28 + -11.26

 = -2.98 N./mm^2

Total Stress at short side 2 at N outer [STS\_No]:

 = Sms + SbsNo

 = 8.28 + 11.26

 = 19.54 N./mm^2

Total Stress at short side 2 at Q inner [STS\_Qi]:

 = Sms + SbsQi

 = 8.28 + 42.37

 = 50.65 N./mm^2

Total Stress at short side 2 at Q outer [STS\_Qo]:

 = Sms + SbsQo

 = 8.28 + -42.37

 = -34.09 N./mm^2

***Total Stresses at Long-side 1***

Total Stress at long side 1 at M inner [STL\_Mi]:

 = Sml + SblMi

 = 12.00 + 98.37

 = 110.37 N./mm^2

Total Stress at long side 1 at M outer [STL\_Mo]:

 = Sml + SblMo

 = 12.00 + -98.37

 = -86.38 N./mm^2

Total Stress at long side 1 at Q inner [STL\_Qi]:

 = Sml + SblQi

 = 7.15 + 42.37

 = 49.52 N./mm^2

Total Stress at long side 1 at Q outer [STL\_Qo]:

 = Sml + SblQo

 = 7.15 + -42.37

 = -35.22 N./mm^2

***Total Stresses at Long-side 2***

Total Stress at long side 2 at M inner [STL\_Mi]:

 = Sml + SblMi

 = 13.40 + 114.51

 = 127.91 N./mm^2

Total Stress at long side 2 at M outer [STL\_Mo]:

 = Sml + SblMo

 = 13.40 + -120.77

 = -107.37 N./mm^2

Total Stress at long side 2 at Q inner [STL\_Qi]:

 = Sml + SblQi

 = 7.15 + 41.24

 = 48.39 N./mm^2

Total Stress at long side 2 at Q outer [STL\_Qo]:

 = Sml + SblQo

 = 7.15 + -43.50

 = -36.35 N./mm^2

**TOTAL STRESSES: Total Stress Calculations per Section 13-9,**

 **Equations (8-12). (N./mm^2) :**

 STRESS LOCATIONS Inner Outer Allowable

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

 Short-side 1 at N -2.98 19.54 197.62

 at Q 50.65 -34.09 197.62

 Short-side 2 at N -2.98 19.54 197.62

 at Q 50.65 -34.09 197.62

 Long-side 1 at M 110.37 -86.38 232.50

 at Q 49.52 -35.22 197.62

 Long-side 2 at M 127.91 -107.37 232.50

 at Q 48.39 -36.35 197.62

**End Plate Stresses (N./mm^2):**

 Actual Allowable

 End Plate 40.11 155.00

**Required End Plate thickness due to Internal Pressure [trEP]:**

 = d \* sqrt( Z \* C \* P / ( SE ) ) + ca

 = 110.000 \* sqrt( 2.318 \* 0.200 \* 28.600 / ( 155.000 ) ) + 0.000

 = 10.174 mm.

**End Plate MAWP at given Thickness [MAWPEP]:**

 = ((T-ca)/d)^2 \* ((SE)/(C\*Z)) per UG-34 (c)(3)

 = ((20.0000-0.0000)/110.0000)^2\*((155)/(.20\*2.32))

 = 110.518 bars

 *where Z is:*

 = min( 3.4 - 2.4( d/D ), 2.5 )

 = min( 3.4 - 2.4( 110.000 / 244.000 ), 2.5 )

 = 2.318

**SUMMARY OF RESULTS:**

 MEMBRANE STRESS SUMMARY,

 High Stress (Highest % of Allowable) 36.67 N./mm^2

 High Stress Percentage 32.06 %

 M.A.W.P. for Membrane Stresses 89.21 bars

 BENDING STRESS SUMMARY,

 High Stress (Highest % of Allowable) -120.77 N./mm^2

 High Stress Percentage 51.95 %

 M.A.W.P. for Bending Stresses 55.06 bars

 TOTAL STRESS SUMMARY,

 High Stress (Highest % of Allowable) 127.91 N./mm^2

 High Stress Percentage 55.02 %

 M.A.W.P. for Total Stresses 51.99 bars

**SUMMARY OF RESULTS:**

 MEMBRANE STRESS SUMMARY,

 High Stress (Highest % of Allowable) 36.67 N./mm^2

 High Stress Percentage 32.06 %

 M.A.W.P. for Membrane Stresses 89.21 bars

 BENDING STRESS SUMMARY,

 High Stress (Highest % of Allowable) -120.77 N./mm^2

 High Stress Percentage 51.95 %

 M.A.W.P. for Bending Stresses 55.06 bars

 TOTAL STRESS SUMMARY,

 High Stress (Highest % of Allowable) 127.91 N./mm^2

 High Stress Percentage 55.02 %

 M.A.W.P. for Total Stresses 51.99 bars

## Stationary Header Calculation @ Design Pressure for ae-2102.

**Input Echo, COMPONENT 1, Description: St.AE-2102**

 Figure Number Analyzed A8

 Design Internal Pressure P 62.0000 bars

 Design Temperature Temp 175.0000 C

 VESSEL MATERIAL DATA:

 Material Specification SA-240 316L

 Shell Allowable Stress at Design Temp S 111.9078 N./mm^2

 Shell Allowable Stress at Ambient SA 115.1465 N./mm^2

 Shell Yield Stress at Design Temperature Sy 126.1469 N./mm^2

 SHORT-SIDE VESSEL DATA:

 Short-side Length Dimension H 110.0000 mm.

 Minimum Thickness of Short-side Plates t1 20.0000 mm.

 Mid-side Joint Efficiency on Short-side E 0.8500

 Corner Joint Efficiency on Short-side EC 0.8500

 LONG-SIDE VESSEL DATA:

 Long-side Length Dimension h 130.0000 mm.

 Minimum Thickness of Long-side Plates t2 28.0000 mm.

 Mid-side Joint Efficiency on Long-side E 0.8500

 ADDITIONAL VESSEL DATA:

 Minimum Thickness of End Plate t5 20.0000 mm.

 C-Factor for End Plate Cf\_Epl 0.2000

 Long-side Plate # 1,

 Pitch Distance p 70.5000 mm.

 Uniform Hole Diameter d0 25.6500 mm.

 Depth of Holes T0 28.0000 mm.

 Long-side Plate # 2,

 Pitch Distance p 70.5000 mm.

 # 1: Hole Diameter d0 36.3000 mm.

 Hole Depth T0 2.7000 mm.

 # 2: Hole Diameter d1 28.5750 mm.

 Hole Depth T1 25.3000 mm.

 STAY PLATE MATERIAL DATA:

 Stay Material Specification SA-240 316L

 Stay Allowable Stress at Design Temp Sr 114.3898 N./mm^2

 Stay Allowable Stress at Ambient SA 115.1465 N./mm^2

 Stay Yield Stress at Design Temp Sy 129.8699 N./mm^2

 STAY PLATE DATA:

 Minimum Thickness of Stay t3 10.0000 mm.

 Minimum Thickness of Stay t4 10.0000 mm.

 The Stay(s) Are Not Welded to the End Plate

**Rectangular Vessel Results, Item number 1, Desc: St.AE-2102**

**ASME Code, Section VIII, Division 1, 2021 App. 13**

**Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):**

***Short-side 1 Calculations***

Membrane Ligament Efficiency [Em]:

 = 0.850

Bending Ligament Efficiency [Eb]:

 = 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Short-side 2 Calculations***

Membrane Ligament Efficiency [Em]:

 = 0.850

Bending Ligament Efficiency [Eb]:

 = 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Long-side 1 Calculations***

Effective Diameter [De]: 25.650 mm.

Membrane Ligament Efficiency [Em]:

 = Pitch - De / Pitch

 = 70.500 - 25.650 / 70.500

 = 0.636

Bending Ligament Efficiency [Eb]:

*As diameter holes are uniform Eb = Em*

 = 0.636

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 28.000 - 0.000 / 2

 = 14.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 28.000 - 0.000 ) / 2

 = -14.000 mm.

***Long-side 2 Calculations***

Effective Diameter [De]:

 = ( d0 \* T0 + d1 \* T1 + d2 \* T2 ) / ( t1 - CA )

 = ( 36.30 \* 2.70 + 28.57 \* 25.30 + 0.00 \* 0.00 ) /

 ( 28.00 - 0.00 )

 = 29.320 mm.

Membrane Ligament Efficiency [Em]:

 = Pitch - De / Pitch

 = 70.500 - 29.320 / 70.500

 = 0.584

Dist from Neutral axis of c/s to extreme fibers [Ci & Co]:

*Calculation of Xbar:*

 = (( b0 \* T0 \* ( T0/2 + T1 + T2 )) + ( b1 \* T1 \*

 ( T1/2 + T2 )) + ( b2 \* T2 \* ( T2/2 ))) /

 ( b0 \* T0 + b1 \* T1 + b2 \* T2 )

 = (( 1.35 \* 2.70 \* ( 2.70 /2 + 25.30 + 0.00 )) + ( 1.65\* 25.30 \*

 ( 25.30 /2 + 0.00 )) + ( 2.78 \* 0.00 \* ( 0.00 /2 ))) /

 ( 1.35 \* 2.70 + 1.65 \* 25.30 + 2.78 \* 0.00 )

 = 13.771 mm.

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 *Ci = Xbar*

 = 13.771 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t - CA - Xbar )

 = -( 28.000 - 0.000 - 13.771 )

 = -14.229 mm.

Moment of Inertia (Section 13-6, Equation (5)) [I]:

 = 0.289 cm\*\*4

Effective Diameter [De]:

 = Pitch - (( 6 \* I ) / (( t - CA)^2 \* (-Co)))

 = 70.50 - (( 6 \* 0.29 ) / ((28.00 - 0.00 )^2 \* (14.23 )))

 = 31.084 mm.

Bending Ligament Efficiency [Eb]:

 = Pitch - De / Pitch

 = 70.500 - 31.084 / 70.500

 = 0.559

**Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):**

 Em Eb Ci Co

 Short-side 1 0.850 0.850 10.000 -10.000

 2 0.850 0.850 10.000 -10.000

 Long-side 1 0.636 0.636 14.000 -14.000

 2 0.584 0.559 13.771 -14.229

**Moment of Inertia of a Strip of the Vessel Wall:**

 Thickness t1, I1 = 0.0667 cm\*\*4

 Thickness t2, I2 = 0.1829 cm\*\*4

**Rectangular Vessel Parameters:**

 Alpha = H / h = 0.8462

 K = (I2/I1)\*Alpha = 2.3218

**Membrane Stress Calculations per Section 13-9**

***Membrane Stresses at Short-side 1***

Membrane Stress at Short-side 1 [Sms]:

 = P \* h / ( 2 \* t1 ) \* { 3 - [( 6 + K \*

 ( 11 - alpha2) / ( 3 + 5 \* K )]}

 = 62.00 \* 130.00 / ( 2 \* 20.00 ) \* { 3- [( 6 + 2.32 \*

 ( 11 - 0.852) / ( 3 + 5 \* 2.32 )]}

 = 19.24 N./mm^2

***Membrane Stresses at Short-side 2***

Membrane Stress at Short-side 2 [Sms]:

 = P \* h / ( 2 \* t1 ) \* { 3 - [( 6 + K \*

 ( 11 - alpha2) / ( 3 + 5 \* K )]}

 = 62.00 \* 130.00 / ( 2 \* 20.00 ) \* { 3- [( 6 + 2.32 \*

 ( 11 - 0.852) / ( 3 + 5 \* 2.32 )]}

 = 19.24 N./mm^2

***Membrane Stresses at Long-side 1***

Membrane Stress at Long-side 1 at A [Sml]:

 = P \* H / 2 \* t2

 = 62.00 \* 110.00 / 2 \* 28.00

 = 12.18 N./mm^2

 *If Em( 0.636 ) < E( 0.850 ) and Eb( 0.636 ) < E( 0.850 ) then*

 Sml = Sml / Em

 = 12.18 / 0.64

 = 19.14 N./mm^2

***Membrane Stresses at Long-side 2***

Membrane Stress at Long-side 2 at A [Sml]:

 = P \* H / 2 \* t2

 = 62.00 \* 110.00 / 2 \* 28.00

 = 12.18 N./mm^2

 *If Em( 0.584 ) < E( 0.850 ) and Eb( 0.559 ) < E( 0.850 ) then*

 Sml = Sml / Em

 = 12.18 / 0.58

 = 20.85 N./mm^2

***Membrane Stresses at Stay Plate***

Membrane Stress at Stay Plate [t3]:

 = P \* h / ( 2 \* t3 ) \* [( 6 + K \* ( 11 -

 alpha2) / ( 3 + 5 \* K )]

 = 62.00 \* 130.00 / ( 2 \* 10.00 ) \* [( 6 + 2.32 \* ( 11 -

 0.852) / ( 3 + 5 \* 2.32 )]

 = 82.42 N./mm^2

Membrane Stress at Stay Plate [t4]:

 = P \* h / ( 2 \* t4 ) \* [( 6 + K \* ( 11 -

 alpha2) / ( 3 + 5 \* K )]

 = 62.00 \* 130.00 / ( 2 \* 10.00 ) \* [( 6 + 2.32 \* ( 11 -

 0.852) / ( 3 + 5 \* 2.32 )]

 = 82.42 N./mm^2

**MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-9,**

 **Equations (13-15). (N./mm^2) :**

 STRESS LOCATIONS Actual Allowable

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

 Short-side 1 19.24 95.12

 Short-side 2 19.24 95.12

 Short-side Corner 19.24 95.12

 Long-side 1 at A 19.14 111.91

 Long-side 2 at A 20.85 111.91

 Long-side Corner 12.18 95.12

 Stay Plate (t3) 82.42 114.39

 Stay Plate (t4) 82.42 114.39

**Bending Stress Calculations per Section 13-9**

***Bending Stresses at Short-side 1***

Bending Stress at Short-side 1 at N Inner[SbsNi]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 62.00 \* 10.00 / ( 24 \* 0.07 ) \* [ -3 \* 110.002 + 2 \* 130.002 \*

 (( 3 + 5 \* 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 ))]

 = -39.25 N./mm^2

Bending Stress at Short-side 1 at N Outer[SbsNo]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 62.00 \* -10.00 /( 24 \* 0.07 ) \* [ -3 \* 110.002 + 2 \* 130.002 \*

 (( 3 + 5 \* 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 ))]

 = 39.25 N./mm^2

Bending Stress at Short-side 1 at Q Inner[SbsQi]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 62.00 \* 130.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 ))

 = 101.42 N./mm^2

Bending Stress at Short-side 1 at Q Outer[SbsQo]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 62.00 \* 130.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 ))

 = -101.42 N./mm^2

***Bending Stresses at Short-side 2***

Bending Stress at Short-side 2 at N Inner[SbsNi]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 62.00 \* 10.00 / ( 24 \* 0.07 ) \* [ -3 \* 110.002 + 2 \* 130.002 \*

 (( 3 + 5 \* 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 ))]

 = -39.25 N./mm^2

Bending Stress at Short-side 2 at N Outer[SbsNo]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 62.00 \* -10.00 /( 24 \* 0.07 ) \* [ -3 \* 110.002 + 2 \* 130.002 \*

 (( 3 + 5 \* 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 ))]

 = 39.25 N./mm^2

Bending Stress at Short-side 2 at Q Inner[SbsQi]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 62.00 \* 130.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 ))

 = 101.42 N./mm^2

Bending Stress at Short-side 2 at Q Outer[SbsQo]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 62.00 \* 130.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 ))

 = -101.42 N./mm^2

***Bending Stresses at Long-side 1***

Bending Stress at Long-side 1 at M Inner[SblMi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 62.00 \* 130.002 \* 14.00 / ( 12 \* 0.18 ) \* [( 3 + 2.32 \*

 ( 6 - 0.852)) / ( 3 + 5 \* 2.32 )]

 = 69.84 N./mm^2

 *If Em( 0.636 ) < E( 0.850 ) and Eb( 0.636 ) < E( 0.850 ) then*

 SblMi = SblMi / Eb

 = 69.84 / 0.64

 = 109.79 N./mm^2

Bending Stress at Long-side 1 at M Outer[SblMo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 62.00 \* 130.002 \* -14.00 / ( 12 \* 0.18 ) \* [( 3 + 2.32 \*

 ( 6 - 0.852)) / ( 3 + 5 \* 2.32 )]

 = -69.84 N./mm^2

 *If Em( 0.636 ) < E( 0.850 ) and Eb( 0.636 ) < E( 0.850 ) then*

 SblMo = SblMo / Eb

 = -69.84 / 0.64

 = -109.79 N./mm^2

Bending Stress at Long-side 1 at Q Inner[SblQi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 62.00 \* 130.002 \* 14.00 / ( 12 \* 0.18 ) \* [( 3 + 5 \*

 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 )]

 = 51.74 N./mm^2

Bending Stress at Long-side 1 at Q Outer[SblQo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 62.00 \* 130.002 \* -14.00 / ( 12 \* 0.18 ) \* [( 3 + 5 \*

 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 )]

 = -51.74 N./mm^2

***Bending Stresses at Long-side 2***

Bending Stress at Long-side 2 at M Inner[SblMi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 62.00 \* 130.002 \* 13.77 / ( 12 \* 0.18 ) \* [( 3 + 2.32 \*

 ( 6 - 0.852)) / ( 3 + 5 \* 2.32 )]

 = 68.70 N./mm^2

 *If Em( 0.584 ) < E( 0.850 ) and Eb( 0.559 ) < E( 0.850 ) then*

 SblMi = SblMi / Eb

 = 68.70 / 0.56

 = 122.88 N./mm^2

Bending Stress at Long-side 2 at M Outer[SblMo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 62.00 \* 130.002 \* -14.23 / ( 12 \* 0.18 ) \* [( 3 + 2.32 \*

 ( 6 - 0.852)) / ( 3 + 5 \* 2.32 )]

 = -70.99 N./mm^2

 *If Em( 0.584 ) < E( 0.850 ) and Eb( 0.559 ) < E( 0.850 ) then*

 SblMo = SblMo / Eb

 = -70.99 / 0.56

 = -126.97 N./mm^2

Bending Stress at Long-side 2 at Q Inner[SblQi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 62.00 \* 130.002 \* 13.77 / ( 12 \* 0.18 ) \* [( 3 + 5 \*

 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 )]

 = 50.90 N./mm^2

Bending Stress at Long-side 2 at Q Outer[SblQo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 62.00 \* 130.002 \* -14.23 / ( 12 \* 0.18 ) \* [( 3 + 5 \*

 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 )]

 = -52.59 N./mm^2

**BENDING STRESSES: Bending Stress Calculations per Section 13-9,**

 **Equations (16-19). (N./mm^2) :**

 STRESS LOCATIONS Inner Outer Allowable

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

 Short-side 1 at N -39.25 39.25 142.68

 at Q 101.42 -101.42 142.68

 Short-side 2 at N -39.25 39.25 142.68

 at Q 101.42 -101.42 142.68

 Long-side 1 at M 109.79 -109.79 167.86

 at Q 51.74 -51.74 142.68

 Long-side 2 at M 122.88 -126.97 167.86

 at Q 50.90 -52.59 142.68

**Total Stress Calculations per Section 13-9**

***Total Stresses at Short-side 1***

Total Stress at short side 1 at N inner [STS\_Ni]:

 = Sms + SbsNi

 = 19.24 + -39.25

 = -20.01 N./mm^2

Total Stress at short side 1 at N outer [STS\_No]:

 = Sms + SbsNo

 = 19.24 + 39.25

 = 58.49 N./mm^2

Total Stress at short side 1 at Q inner [STS\_Qi]:

 = Sms + SbsQi

 = 19.24 + 101.42

 = 120.66 N./mm^2

Total Stress at short side 1 at Q outer [STS\_Qo]:

 = Sms + SbsQo

 = 19.24 + -101.42

 = -82.18 N./mm^2

***Total Stresses at Short-side 2***

Total Stress at short side 2 at N inner [STS\_Ni]:

 = Sms + SbsNi

 = 19.24 + -39.25

 = -20.01 N./mm^2

Total Stress at short side 2 at N outer [STS\_No]:

 = Sms + SbsNo

 = 19.24 + 39.25

 = 58.49 N./mm^2

Total Stress at short side 2 at Q inner [STS\_Qi]:

 = Sms + SbsQi

 = 19.24 + 101.42

 = 120.66 N./mm^2

Total Stress at short side 2 at Q outer [STS\_Qo]:

 = Sms + SbsQo

 = 19.24 + -101.42

 = -82.18 N./mm^2

***Total Stresses at Long-side 1***

Total Stress at long side 1 at M inner [STL\_Mi]:

 = Sml + SblMi

 = 19.14 + 109.79

 = 128.93 N./mm^2

Total Stress at long side 1 at M outer [STL\_Mo]:

 = Sml + SblMo

 = 19.14 + -109.79

 = -90.64 N./mm^2

Total Stress at long side 1 at Q inner [STL\_Qi]:

 = Sml + SblQi

 = 12.18 + 51.74

 = 63.92 N./mm^2

Total Stress at long side 1 at Q outer [STL\_Qo]:

 = SmlB + SblQo

 = 12.18 + -51.74

 = -39.57 N./mm^2

***Total Stresses at Long-side 2***

Total Stress at long side 2 at M inner [STL\_Mi]:

 = Sml + SblMi

 = 20.85 + 122.88

 = 143.73 N./mm^2

Total Stress at long side 2 at M outer [STL\_Mo]:

 = Sml + SblMo

 = 20.85 + -126.97

 = -106.11 N./mm^2

Total Stress at long side 2 at Q inner [STL\_Qi]:

 = Sml + SblQi

 = 12.18 + 50.90

 = 63.08 N./mm^2

Total Stress at long side 2 at Q outer [STL\_Qo]:

 = SmlB + SblQo

 = 12.18 + -52.59

 = -40.41 N./mm^2

**TOTAL STRESSES: Total Stress Calculations per Section 13-9,**

 **Equations (20-24). (N./mm^2) :**

 STRESS LOCATIONS Inner Outer Allowable

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

 Short-side 1 at N -20.01 58.49 142.68

 at Q 120.66 -82.18 142.68

 Short-side 2 at N -20.01 58.49 142.68

 at Q 120.66 -82.18 142.68

 Long-side 1 at M 128.93 -90.64 167.86

 at Q 63.92 -39.57 142.68

 Long-side 2 at M 143.73 -106.11 167.86

 at Q 63.08 -40.41 142.68

**End Plate Stresses (N./mm^2):**

 Actual Allowable

 End Plate 93.78 111.91

**Required End Plate thickness due to Internal Pressure [trEP]:**

 = d \* sqrt( Z \* C \* P / ( SE ) ) + ca

 = 110.000 \* sqrt( 2.500 \* 0.200 \* 62.000 / ( 111.908 ) ) + 0.000

 = 18.309 mm.

**End Plate MAWP at given Thickness [MAWPEP]:**

 = ((T-ca)/d)^2 \* ((SE)/(C\*Z)) per UG-34 (c)(3)

 = ((20.0000-0.0000)/110.0000)^2\*((111)/(.20\*2.50))

 = 73.984 bars

 *where Z is:*

 = min( 3.4 - 2.4( d/D ), 2.5 )

 = min( 3.4 - 2.4( 110.000 / 410.000 ), 2.5 )

 = 2.500

**SUMMARY OF RESULTS:**

 MEMBRANE STRESS SUMMARY,

 High Stress (Highest % of Allowable) 82.42 N./mm^2

 High Stress Percentage 72.06 %

 M.A.W.P. for Membrane Stresses 86.04 bars

 BENDING STRESS SUMMARY,

 High Stress (Highest % of Allowable) -126.97 N./mm^2

 High Stress Percentage 75.64 %

 M.A.W.P. for Bending Stresses 81.97 bars

 TOTAL STRESS SUMMARY,

 High Stress (Highest % of Allowable) 143.73 N./mm^2

 High Stress Percentage 85.63 %

 M.A.W.P. for Total Stresses 72.41 bars

**Rectangular Vessel Results For Item 1 : A8**

**SUMMARY OF RESULTS:**

 MEMBRANE STRESS SUMMARY,

 High Stress (Highest % of Allowable) 82.42 N./mm^2

 High Stress Percentage 72.06 %

 M.A.W.P. for Membrane Stresses 86.04 bars

 BENDING STRESS SUMMARY,

 High Stress (Highest % of Allowable) -126.97 N./mm^2

 High Stress Percentage 75.64 %

 M.A.W.P. for Bending Stresses 81.97 bars

 TOTAL STRESS SUMMARY,

 High Stress (Highest % of Allowable) 143.73 N./mm^2

 High Stress Percentage 85.63 %

 M.A.W.P. for Total Stresses 72.41 bars

## Stationary Header Calculation @ test Pressure for ae-2102.

**Input Echo, COMPONENT 1, Description: St.AE-2102-Test**

 Figure Number Analyzed A8

 Design Internal Pressure P 80.6000 bars

 Design Temperature Temp 25.0000 C

 VESSEL MATERIAL DATA:

 Material Specification SA-240 316L

 Shell Allowable Stress at Design Temp S 155.1000 N./mm^2

 Shell Allowable Stress at Ambient SA 155.1000 N./mm^2

 Shell Yield Stress at Design Temperature Sy 172.3750 N./mm^2

 SHORT-SIDE VESSEL DATA:

 Short-side Length Dimension H 110.0000 mm.

 Minimum Thickness of Short-side Plates t1 20.0000 mm.

 Mid-side Joint Efficiency on Short-side E 0.8500

 Corner Joint Efficiency on Short-side EC 0.8500

 LONG-SIDE VESSEL DATA:

 Long-side Length Dimension h 130.0000 mm.

 Minimum Thickness of Long-side Plates t2 28.0000 mm.

 Mid-side Joint Efficiency on Long-side E 0.8500

 ADDITIONAL VESSEL DATA:

 Minimum Thickness of End Plate t5 20.0000 mm.

 C-Factor for End Plate Cf\_Epl 0.2000

 Long-side Plate # 1,

 Pitch Distance p 70.5000 mm.

 Uniform Hole Diameter d0 25.6500 mm.

 Depth of Holes T0 28.0000 mm.

 Long-side Plate # 2,

 Pitch Distance p 70.5000 mm.

 # 1: Hole Diameter d0 36.3000 mm.

 Hole Depth T0 2.7000 mm.

 # 2: Hole Diameter d1 28.5750 mm.

 Hole Depth T1 25.3000 mm.

 STAY PLATE MATERIAL DATA:

 Stay Material Specification SA-240 316L

 Stay Allowable Stress at Design Temp Sr 116.9000 N./mm^2

 Stay Allowable Stress at Ambient SA 116.9000 N./mm^2

 Stay Yield Stress at Design Temp Sy 129.8699 N./mm^2

 STAY PLATE DATA:

 Minimum Thickness of Stay t3 10.0000 mm.

 Minimum Thickness of Stay t4 10.0000 mm.

 The Stay(s) Are Not Welded to the End Plate

**Rectangular Vessel Results, Item number 1, Desc: St.AE-2102-Test**

**ASME Code, Section VIII, Division 1, 2021 App. 13**

**Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):**

***Short-side 1 Calculations***

Membrane Ligament Efficiency [Em]:

 = 0.850

Bending Ligament Efficiency [Eb]:

 = 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Short-side 2 Calculations***

Membrane Ligament Efficiency [Em]:

 = 0.850

Bending Ligament Efficiency [Eb]:

 = 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Long-side 1 Calculations***

Effective Diameter [De]: 25.650 mm.

Membrane Ligament Efficiency [Em]:

 = Pitch - De / Pitch

 = 70.500 - 25.650 / 70.500

 = 0.636

Bending Ligament Efficiency [Eb]:

*As diameter holes are uniform Eb = Em*

 = 0.636

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 28.000 - 0.000 / 2

 = 14.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 28.000 - 0.000 ) / 2

 = -14.000 mm.

***Long-side 2 Calculations***

Effective Diameter [De]:

 = ( d0 \* T0 + d1 \* T1 + d2 \* T2 ) / ( t1 - CA )

 = ( 36.30 \* 2.70 + 28.57 \* 25.30 + 0.00 \* 0.00 ) /

 ( 28.00 - 0.00 )

 = 29.320 mm.

Membrane Ligament Efficiency [Em]:

 = Pitch - De / Pitch

 = 70.500 - 29.320 / 70.500

 = 0.584

Dist from Neutral axis of c/s to extreme fibers [Ci & Co]:

*Calculation of Xbar:*

 = (( b0 \* T0 \* ( T0/2 + T1 + T2 )) + ( b1 \* T1 \*

 ( T1/2 + T2 )) + ( b2 \* T2 \* ( T2/2 ))) /

 ( b0 \* T0 + b1 \* T1 + b2 \* T2 )

 = (( 1.35 \* 2.70 \* ( 2.70 /2 + 25.30 + 0.00 )) + ( 1.65\* 25.30 \*

 ( 25.30 /2 + 0.00 )) + ( 2.78 \* 0.00 \* ( 0.00 /2 ))) /

 ( 1.35 \* 2.70 + 1.65 \* 25.30 + 2.78 \* 0.00 )

 = 13.771 mm.

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 *Ci = Xbar*

 = 13.771 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t - CA - Xbar )

 = -( 28.000 - 0.000 - 13.771 )

 = -14.229 mm.

Moment of Inertia (Section 13-6, Equation (5)) [I]:

 = 0.289 cm\*\*4

Effective Diameter [De]:

 = Pitch - (( 6 \* I ) / (( t - CA)^2 \* (-Co)))

 = 70.50 - (( 6 \* 0.29 ) / ((28.00 - 0.00 )^2 \* (14.23 )))

 = 31.084 mm.

Bending Ligament Efficiency [Eb]:

 = Pitch - De / Pitch

 = 70.500 - 31.084 / 70.500

 = 0.559

**Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):**

 Em Eb Ci Co

 Short-side 1 0.850 0.850 10.000 -10.000

 2 0.850 0.850 10.000 -10.000

 Long-side 1 0.636 0.636 14.000 -14.000

 2 0.584 0.559 13.771 -14.229

**Moment of Inertia of a Strip of the Vessel Wall:**

 Thickness t1, I1 = 0.0667 cm\*\*4

 Thickness t2, I2 = 0.1829 cm\*\*4

**Rectangular Vessel Parameters:**

 Alpha = H / h = 0.8462

 K = (I2/I1)\*Alpha = 2.3218

**Membrane Stress Calculations per Section 13-9**

***Membrane Stresses at Short-side 1***

Membrane Stress at Short-side 1 [Sms]:

 = P \* h / ( 2 \* t1 ) \* { 3 - [( 6 + K \*

 ( 11 - alpha2) / ( 3 + 5 \* K )]}

 = 80.60 \* 130.00 / ( 2 \* 20.00 ) \* { 3- [( 6 + 2.32 \*

 ( 11 - 0.852) / ( 3 + 5 \* 2.32 )]}

 = 25.01 N./mm^2

***Membrane Stresses at Short-side 2***

Membrane Stress at Short-side 2 [Sms]:

 = P \* h / ( 2 \* t1 ) \* { 3 - [( 6 + K \*

 ( 11 - alpha2) / ( 3 + 5 \* K )]}

 = 80.60 \* 130.00 / ( 2 \* 20.00 ) \* { 3- [( 6 + 2.32 \*

 ( 11 - 0.852) / ( 3 + 5 \* 2.32 )]}

 = 25.01 N./mm^2

***Membrane Stresses at Long-side 1***

Membrane Stress at Long-side 1 at A [Sml]:

 = P \* H / 2 \* t2

 = 80.60 \* 110.00 / 2 \* 28.00

 = 15.83 N./mm^2

 *If Em( 0.636 ) < E( 0.850 ) and Eb( 0.636 ) < E( 0.850 ) then*

 Sml = Sml / Em

 = 15.83 / 0.64

 = 24.89 N./mm^2

***Membrane Stresses at Long-side 2***

Membrane Stress at Long-side 2 at A [Sml]:

 = P \* H / 2 \* t2

 = 80.60 \* 110.00 / 2 \* 28.00

 = 15.83 N./mm^2

 *If Em( 0.584 ) < E( 0.850 ) and Eb( 0.559 ) < E( 0.850 ) then*

 Sml = Sml / Em

 = 15.83 / 0.58

 = 27.11 N./mm^2

***Membrane Stresses at Stay Plate***

Membrane Stress at Stay Plate [t3]:

 = P \* h / ( 2 \* t3 ) \* [( 6 + K \* ( 11 -

 alpha2) / ( 3 + 5 \* K )]

 = 80.60 \* 130.00 / ( 2 \* 10.00 ) \* [( 6 + 2.32 \* ( 11 -

 0.852) / ( 3 + 5 \* 2.32 )]

 = 107.15 N./mm^2

Membrane Stress at Stay Plate [t4]:

 = P \* h / ( 2 \* t4 ) \* [( 6 + K \* ( 11 -

 alpha2) / ( 3 + 5 \* K )]

 = 80.60 \* 130.00 / ( 2 \* 10.00 ) \* [( 6 + 2.32 \* ( 11 -

 0.852) / ( 3 + 5 \* 2.32 )]

 = 107.15 N./mm^2

**MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-9,**

 **Equations (13-15). (N./mm^2) :**

 STRESS LOCATIONS Actual Allowable

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

 Short-side 1 25.01 131.84

 Short-side 2 25.01 131.84

 Short-side Corner 25.01 131.84

 Long-side 1 at A 24.89 155.10

 Long-side 2 at A 27.11 155.10

 Long-side Corner 15.83 131.84

 Stay Plate (t3) 107.15 116.90

 Stay Plate (t4) 107.15 116.90

**Bending Stress Calculations per Section 13-9**

***Bending Stresses at Short-side 1***

Bending Stress at Short-side 1 at N Inner[SbsNi]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 80.60 \* 10.00 / ( 24 \* 0.07 ) \* [ -3 \* 110.002 + 2 \* 130.002 \*

 (( 3 + 5 \* 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 ))]

 = -51.03 N./mm^2

Bending Stress at Short-side 1 at N Outer[SbsNo]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 80.60 \* -10.00 /( 24 \* 0.07 ) \* [ -3 \* 110.002 + 2 \* 130.002 \*

 (( 3 + 5 \* 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 ))]

 = 51.03 N./mm^2

Bending Stress at Short-side 1 at Q Inner[SbsQi]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 80.60 \* 130.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 ))

 = 131.85 N./mm^2

Bending Stress at Short-side 1 at Q Outer[SbsQo]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 80.60 \* 130.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 ))

 = -131.85 N./mm^2

***Bending Stresses at Short-side 2***

Bending Stress at Short-side 2 at N Inner[SbsNi]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 80.60 \* 10.00 / ( 24 \* 0.07 ) \* [ -3 \* 110.002 + 2 \* 130.002 \*

 (( 3 + 5 \* 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 ))]

 = -51.03 N./mm^2

Bending Stress at Short-side 2 at N Outer[SbsNo]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 80.60 \* -10.00 /( 24 \* 0.07 ) \* [ -3 \* 110.002 + 2 \* 130.002 \*

 (( 3 + 5 \* 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 ))]

 = 51.03 N./mm^2

Bending Stress at Short-side 2 at Q Inner[SbsQi]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 80.60 \* 130.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 ))

 = 131.85 N./mm^2

Bending Stress at Short-side 2 at Q Outer[SbsQo]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 80.60 \* 130.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 ))

 = -131.85 N./mm^2

***Bending Stresses at Long-side 1***

Bending Stress at Long-side 1 at M Inner[SblMi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 80.60 \* 130.002 \* 14.00 / ( 12 \* 0.18 ) \* [( 3 + 2.32 \*

 ( 6 - 0.852)) / ( 3 + 5 \* 2.32 )]

 = 90.80 N./mm^2

 *If Em( 0.636 ) < E( 0.850 ) and Eb( 0.636 ) < E( 0.850 ) then*

 SblMi = SblMi / Eb

 = 90.80 / 0.64

 = 142.73 N./mm^2

Bending Stress at Long-side 1 at M Outer[SblMo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 80.60 \* 130.002 \* -14.00 / ( 12 \* 0.18 ) \* [( 3 + 2.32 \*

 ( 6 - 0.852)) / ( 3 + 5 \* 2.32 )]

 = -90.80 N./mm^2

 *If Em( 0.636 ) < E( 0.850 ) and Eb( 0.636 ) < E( 0.850 ) then*

 SblMo = SblMo / Eb

 = -90.80 / 0.64

 = -142.73 N./mm^2

Bending Stress at Long-side 1 at Q Inner[SblQi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 80.60 \* 130.002 \* 14.00 / ( 12 \* 0.18 ) \* [( 3 + 5 \*

 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 )]

 = 67.27 N./mm^2

Bending Stress at Long-side 1 at Q Outer[SblQo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 80.60 \* 130.002 \* -14.00 / ( 12 \* 0.18 ) \* [( 3 + 5 \*

 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 )]

 = -67.27 N./mm^2

***Bending Stresses at Long-side 2***

Bending Stress at Long-side 2 at M Inner[SblMi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 80.60 \* 130.002 \* 13.77 / ( 12 \* 0.18 ) \* [( 3 + 2.32 \*

 ( 6 - 0.852)) / ( 3 + 5 \* 2.32 )]

 = 89.31 N./mm^2

 *If Em( 0.584 ) < E( 0.850 ) and Eb( 0.559 ) < E( 0.850 ) then*

 SblMi = SblMi / Eb

 = 89.31 / 0.56

 = 159.75 N./mm^2

Bending Stress at Long-side 2 at M Outer[SblMo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 80.60 \* 130.002 \* -14.23 / ( 12 \* 0.18 ) \* [( 3 + 2.32 \*

 ( 6 - 0.852)) / ( 3 + 5 \* 2.32 )]

 = -92.28 N./mm^2

 *If Em( 0.584 ) < E( 0.850 ) and Eb( 0.559 ) < E( 0.850 ) then*

 SblMo = SblMo / Eb

 = -92.28 / 0.56

 = -165.06 N./mm^2

Bending Stress at Long-side 2 at Q Inner[SblQi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 80.60 \* 130.002 \* 13.77 / ( 12 \* 0.18 ) \* [( 3 + 5 \*

 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 )]

 = 66.17 N./mm^2

Bending Stress at Long-side 2 at Q Outer[SblQo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 80.60 \* 130.002 \* -14.23 / ( 12 \* 0.18 ) \* [( 3 + 5 \*

 0.852 \* 2.32 ) / ( 3 + 5 \* 2.32 )]

 = -68.37 N./mm^2

**BENDING STRESSES: Bending Stress Calculations per Section 13-9,**

 **Equations (16-19). (N./mm^2) :**

 STRESS LOCATIONS Inner Outer Allowable

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

 Short-side 1 at N -51.03 51.03 197.75

 at Q 131.85 -131.85 197.75

 Short-side 2 at N -51.03 51.03 197.75

 at Q 131.85 -131.85 197.75

 Long-side 1 at M 142.73 -142.73 232.65

 at Q 67.27 -67.27 197.75

 Long-side 2 at M 159.75 -165.06 232.65

 at Q 66.17 -68.37 197.75

**Total Stress Calculations per Section 13-9**

***Total Stresses at Short-side 1***

Total Stress at short side 1 at N inner [STS\_Ni]:

 = Sms + SbsNi

 = 25.01 + -51.03

 = -26.01 N./mm^2

Total Stress at short side 1 at N outer [STS\_No]:

 = Sms + SbsNo

 = 25.01 + 51.03

 = 76.04 N./mm^2

Total Stress at short side 1 at Q inner [STS\_Qi]:

 = Sms + SbsQi

 = 25.01 + 131.85

 = 156.86 N./mm^2

Total Stress at short side 1 at Q outer [STS\_Qo]:

 = Sms + SbsQo

 = 25.01 + -131.85

 = -106.83 N./mm^2

***Total Stresses at Short-side 2***

Total Stress at short side 2 at N inner [STS\_Ni]:

 = Sms + SbsNi

 = 25.01 + -51.03

 = -26.01 N./mm^2

Total Stress at short side 2 at N outer [STS\_No]:

 = Sms + SbsNo

 = 25.01 + 51.03

 = 76.04 N./mm^2

Total Stress at short side 2 at Q inner [STS\_Qi]:

 = Sms + SbsQi

 = 25.01 + 131.85

 = 156.86 N./mm^2

Total Stress at short side 2 at Q outer [STS\_Qo]:

 = Sms + SbsQo

 = 25.01 + -131.85

 = -106.83 N./mm^2

***Total Stresses at Long-side 1***

Total Stress at long side 1 at M inner [STL\_Mi]:

 = Sml + SblMi

 = 24.89 + 142.73

 = 167.61 N./mm^2

Total Stress at long side 1 at M outer [STL\_Mo]:

 = Sml + SblMo

 = 24.89 + -142.73

 = -117.84 N./mm^2

Total Stress at long side 1 at Q inner [STL\_Qi]:

 = Sml + SblQi

 = 15.83 + 67.27

 = 83.10 N./mm^2

Total Stress at long side 1 at Q outer [STL\_Qo]:

 = SmlB + SblQo

 = 15.83 + -67.27

 = -51.44 N./mm^2

***Total Stresses at Long-side 2***

Total Stress at long side 2 at M inner [STL\_Mi]:

 = Sml + SblMi

 = 27.11 + 159.75

 = 186.85 N./mm^2

Total Stress at long side 2 at M outer [STL\_Mo]:

 = Sml + SblMo

 = 27.11 + -165.06

 = -137.95 N./mm^2

Total Stress at long side 2 at Q inner [STL\_Qi]:

 = Sml + SblQi

 = 15.83 + 66.17

 = 82.00 N./mm^2

Total Stress at long side 2 at Q outer [STL\_Qo]:

 = SmlB + SblQo

 = 15.83 + -68.37

 = -52.53 N./mm^2

**TOTAL STRESSES: Total Stress Calculations per Section 13-9,**

 **Equations (20-24). (N./mm^2) :**

 STRESS LOCATIONS Inner Outer Allowable

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

 Short-side 1 at N -26.01 76.04 197.75

 at Q 156.86 -106.83 197.75

 Short-side 2 at N -26.01 76.04 197.75

 at Q 156.86 -106.83 197.75

 Long-side 1 at M 167.61 -117.84 232.65

 at Q 83.10 -51.44 197.75

 Long-side 2 at M 186.85 -137.95 232.65

 at Q 82.00 -52.53 197.75

**End Plate Stresses (N./mm^2):**

 Actual Allowable

 End Plate 121.91 155.10

**Required End Plate thickness due to Internal Pressure [trEP]:**

 = d \* sqrt( Z \* C \* P / ( SE ) ) + ca

 = 110.000 \* sqrt( 2.500 \* 0.200 \* 80.600 / ( 155.100 ) ) + 0.000

 = 17.732 mm.

**End Plate MAWP at given Thickness [MAWPEP]:**

 = ((T-ca)/d)^2 \* ((SE)/(C\*Z)) per UG-34 (c)(3)

 = ((20.0000-0.0000)/110.0000)^2\*((155)/(.20\*2.50))

 = 102.540 bars

 *where Z is:*

 = min( 3.4 - 2.4( d/D ), 2.5 )

 = min( 3.4 - 2.4( 110.000 / 410.000 ), 2.5 )

 = 2.500

**SUMMARY OF RESULTS:**

 MEMBRANE STRESS SUMMARY,

 High Stress (Highest % of Allowable) 107.15 N./mm^2

 High Stress Percentage 91.66 %

 M.A.W.P. for Membrane Stresses 87.93 bars

 BENDING STRESS SUMMARY,

 High Stress (Highest % of Allowable) -165.06 N./mm^2

 High Stress Percentage 70.95 %

 M.A.W.P. for Bending Stresses 113.61 bars

 TOTAL STRESS SUMMARY,

 High Stress (Highest % of Allowable) 186.85 N./mm^2

 High Stress Percentage 80.31 %

 M.A.W.P. for Total Stresses 100.35 bars

**Rectangular Vessel Results For Item 1 : A8**

**SUMMARY OF RESULTS:**

 MEMBRANE STRESS SUMMARY,

 High Stress (Highest % of Allowable) 107.15 N./mm^2

 High Stress Percentage 91.66 %

 M.A.W.P. for Membrane Stresses 87.93 bars

 BENDING STRESS SUMMARY,

 High Stress (Highest % of Allowable) -165.06 N./mm^2

 High Stress Percentage 70.95 %

 M.A.W.P. for Bending Stresses 113.61 bars

 TOTAL STRESS SUMMARY,

 High Stress (Highest % of Allowable) 186.85 N./mm^2

 High Stress Percentage 80.31 %

 M.A.W.P. for Total Stresses 100.35 bars

## floating Header Calculation @ Design Pressure for ae-2102.

**Input Echo, COMPONENT 1, Description: Fl.AE-2102**

 Figure Number Analyzed A8

 Design Internal Pressure P 62.0000 bars

 Design Temperature Temp 175.0000 C

 VESSEL MATERIAL DATA:

 Material Specification SA-240 316L

 Shell Allowable Stress at Design Temp S 111.9078 N./mm^2

 Shell Allowable Stress at Ambient SA 115.1465 N./mm^2

 Shell Yield Stress at Design Temperature Sy 126.1469 N./mm^2

 SHORT-SIDE VESSEL DATA:

 Short-side Length Dimension H 100.0000 mm.

 Minimum Thickness of Short-side Plates t1 20.0000 mm.

 Mid-side Joint Efficiency on Short-side E 0.8500

 Corner Joint Efficiency on Short-side EC 0.8500

 LONG-SIDE VESSEL DATA:

 Long-side Length Dimension h 60.0000 mm.

 Minimum Thickness of Long-side Plates t2 20.0000 mm.

 Mid-side Joint Efficiency on Long-side E 0.8500

 ADDITIONAL VESSEL DATA:

 Minimum Thickness of End Plate t5 20.0000 mm.

 C-Factor for End Plate Cf\_Epl 0.2000

 Long-side Plate # 1,

 Pitch Distance p 70.5000 mm.

 Uniform Hole Diameter d0 25.6500 mm.

 Depth of Holes T0 20.0000 mm.

 Long-side Plate # 2,

 Pitch Distance p 70.5000 mm.

 # 1: Hole Diameter d0 36.3000 mm.

 Hole Depth T0 2.7000 mm.

 # 2: Hole Diameter d1 28.5750 mm.

 Hole Depth T1 17.3000 mm.

 STAY PLATE MATERIAL DATA:

 Stay Material Specification SA-240 316L

 Stay Allowable Stress at Design Temp Sr 114.3898 N./mm^2

 Stay Allowable Stress at Ambient SA 115.1465 N./mm^2

 Stay Yield Stress at Design Temp Sy 129.8699 N./mm^2

 STAY PLATE DATA:

 Minimum Thickness of Stay t3 10.0000 mm.

 Minimum Thickness of Stay t4 10.0000 mm.

 The Stay(s) Are Not Welded to the End Plate

**Rectangular Vessel Results, Item number 1, Desc: Fl.AE-2102**

**ASME Code, Section VIII, Division 1, 2021 App. 13**

**Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):**

***Short-side 1 Calculations***

Membrane Ligament Efficiency [Em]:

 = 0.850

Bending Ligament Efficiency [Eb]:

 = 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Short-side 2 Calculations***

Membrane Ligament Efficiency [Em]:

 = 0.850

Bending Ligament Efficiency [Eb]:

 = 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Long-side 1 Calculations***

Effective Diameter [De]: 25.650 mm.

Membrane Ligament Efficiency [Em]:

 = Pitch - De / Pitch

 = 70.500 - 25.650 / 70.500

 = 0.636

Bending Ligament Efficiency [Eb]:

*As diameter holes are uniform Eb = Em*

 = 0.636

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Long-side 2 Calculations***

Effective Diameter [De]:

 = ( d0 \* T0 + d1 \* T1 + d2 \* T2 ) / ( t1 - CA )

 = ( 36.30 \* 2.70 + 28.57 \* 17.30 + 0.00 \* 0.00 ) /

 ( 20.00 - 0.00 )

 = 29.618 mm.

Membrane Ligament Efficiency [Em]:

 = Pitch - De / Pitch

 = 70.500 - 29.618 / 70.500

 = 0.580

Dist from Neutral axis of c/s to extreme fibers [Ci & Co]:

*Calculation of Xbar:*

 = (( b0 \* T0 \* ( T0/2 + T1 + T2 )) + ( b1 \* T1 \*

 ( T1/2 + T2 )) + ( b2 \* T2 \* ( T2/2 ))) /

 ( b0 \* T0 + b1 \* T1 + b2 \* T2 )

 = (( 1.35 \* 2.70 \* ( 2.70 /2 + 17.30 + 0.00 )) + ( 1.65\* 17.30 \*

 ( 17.30 /2 + 0.00 )) + ( 2.78 \* 0.00 \* ( 0.00 /2 ))) /

 ( 1.35 \* 2.70 + 1.65 \* 17.30 + 2.78 \* 0.00 )

 = 9.779 mm.

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 *Ci = Xbar*

 = 9.779 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t - CA - Xbar )

 = -( 20.000 - 0.000 - 9.779 )

 = -10.221 mm.

Moment of Inertia (Section 13-6, Equation (5)) [I]:

 = 0.104 cm\*\*4

Effective Diameter [De]:

 = Pitch - (( 6 \* I ) / (( t - CA)^2 \* (-Co)))

 = 70.50 - (( 6 \* 0.10 ) / ((20.00 - 0.00 )^2 \* (10.22 )))

 = 31.848 mm.

Bending Ligament Efficiency [Eb]:

 = Pitch - De / Pitch

 = 70.500 - 31.848 / 70.500

 = 0.548

**Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):**

 Em Eb Ci Co

 Short-side 1 0.850 0.850 10.000 -10.000

 2 0.850 0.850 10.000 -10.000

 Long-side 1 0.636 0.636 10.000 -10.000

 2 0.580 0.548 9.779 -10.221

**Moment of Inertia of a Strip of the Vessel Wall:**

 Thickness t1, I1 = 0.0667 cm\*\*4

 Thickness t2, I2 = 0.0667 cm\*\*4

**Rectangular Vessel Parameters:**

 Alpha = H / h = 1.6667

 K = (I2/I1)\*Alpha = 1.6667

**Membrane Stress Calculations per Section 13-9**

***Membrane Stresses at Short-side 1***

Membrane Stress at Short-side 1 [Sms]:

 = P \* h / ( 2 \* t1 ) \* { 3 - [( 6 + K \*

 ( 11 - alpha2) / ( 3 + 5 \* K )]}

 = 62.00 \* 60.00 / ( 2 \* 20.00 ) \* { 3- [( 6 + 1.67 \*

 ( 11 - 1.672) / ( 3 + 5 \* 1.67 )]}

 = 11.73 N./mm^2

***Membrane Stresses at Short-side 2***

Membrane Stress at Short-side 2 [Sms]:

 = P \* h / ( 2 \* t1 ) \* { 3 - [( 6 + K \*

 ( 11 - alpha2) / ( 3 + 5 \* K )]}

 = 62.00 \* 60.00 / ( 2 \* 20.00 ) \* { 3- [( 6 + 1.67 \*

 ( 11 - 1.672) / ( 3 + 5 \* 1.67 )]}

 = 11.73 N./mm^2

***Membrane Stresses at Long-side 1***

Membrane Stress at Long-side 1 at A [Sml]:

 = P \* H / 2 \* t2

 = 62.00 \* 100.00 / 2 \* 20.00

 = 15.50 N./mm^2

 *If Em( 0.636 ) < E( 0.850 ) and Eb( 0.636 ) < E( 0.850 ) then*

 Sml = Sml / Em

 = 15.50 / 0.64

 = 24.37 N./mm^2

***Membrane Stresses at Long-side 2***

Membrane Stress at Long-side 2 at A [Sml]:

 = P \* H / 2 \* t2

 = 62.00 \* 100.00 / 2 \* 20.00

 = 15.50 N./mm^2

 *If Em( 0.580 ) < E( 0.850 ) and Eb( 0.548 ) < E( 0.850 ) then*

 Sml = Sml / Em

 = 15.50 / 0.58

 = 26.73 N./mm^2

***Membrane Stresses at Stay Plate***

Membrane Stress at Stay Plate [t3]:

 = P \* h / ( 2 \* t3 ) \* [( 6 + K \* ( 11 -

 alpha2) / ( 3 + 5 \* K )]

 = 62.00 \* 60.00 / ( 2 \* 10.00 ) \* [( 6 + 1.67 \* ( 11 -

 1.672) / ( 3 + 5 \* 1.67 )]

 = 32.34 N./mm^2

Membrane Stress at Stay Plate [t4]:

 = P \* h / ( 2 \* t4 ) \* [( 6 + K \* ( 11 -

 alpha2) / ( 3 + 5 \* K )]

 = 62.00 \* 60.00 / ( 2 \* 10.00 ) \* [( 6 + 1.67 \* ( 11 -

 1.672) / ( 3 + 5 \* 1.67 )]

 = 32.34 N./mm^2

**MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-9,**

 **Equations (13-15). (N./mm^2) :**

 STRESS LOCATIONS Actual Allowable

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

 Short-side 1 11.73 95.12

 Short-side 2 11.73 95.12

 Short-side Corner 11.73 95.12

 Long-side 1 at A 24.37 111.91

 Long-side 2 at A 26.73 111.91

 Long-side Corner 15.50 95.12

 Stay Plate (t3) 32.34 114.39

 Stay Plate (t4) 32.34 114.39

**Bending Stress Calculations per Section 13-9**

***Bending Stresses at Short-side 1***

Bending Stress at Short-side 1 at N Inner[SbsNi]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 62.00 \* 10.00 / ( 24 \* 0.07 ) \* [ -3 \* 100.002 + 2 \* 60.002 \*

 (( 3 + 5 \* 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 ))]

 = -51.88 N./mm^2

Bending Stress at Short-side 1 at N Outer[SbsNo]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 62.00 \* -10.00 /( 24 \* 0.07 ) \* [ -3 \* 100.002 + 2 \* 60.002 \*

 (( 3 + 5 \* 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 ))]

 = 51.88 N./mm^2

Bending Stress at Short-side 1 at Q Inner[SbsQi]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 62.00 \* 60.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 ))

 = 64.37 N./mm^2

Bending Stress at Short-side 1 at Q Outer[SbsQo]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 62.00 \* 60.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 ))

 = -64.37 N./mm^2

***Bending Stresses at Short-side 2***

Bending Stress at Short-side 2 at N Inner[SbsNi]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 62.00 \* 10.00 / ( 24 \* 0.07 ) \* [ -3 \* 100.002 + 2 \* 60.002 \*

 (( 3 + 5 \* 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 ))]

 = -51.88 N./mm^2

Bending Stress at Short-side 2 at N Outer[SbsNo]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 62.00 \* -10.00 /( 24 \* 0.07 ) \* [ -3 \* 100.002 + 2 \* 60.002 \*

 (( 3 + 5 \* 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 ))]

 = 51.88 N./mm^2

Bending Stress at Short-side 2 at Q Inner[SbsQi]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 62.00 \* 60.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 ))

 = 64.37 N./mm^2

Bending Stress at Short-side 2 at Q Outer[SbsQo]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 62.00 \* 60.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 ))

 = -64.37 N./mm^2

***Bending Stresses at Long-side 1***

Bending Stress at Long-side 1 at M Inner[SblMi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 62.00 \* 60.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 3 + 1.67 \*

 ( 6 - 1.672)) / ( 3 + 5 \* 1.67 )]

 = 20.61 N./mm^2

 *If Em( 0.636 ) < E( 0.850 ) and Eb( 0.636 ) < E( 0.850 ) then*

 SblMi = SblMi / Eb

 = 20.61 / 0.64

 = 32.39 N./mm^2

Bending Stress at Long-side 1 at M Outer[SblMo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 62.00 \* 60.002 \* -10.00 / ( 12 \* 0.07 ) \* [( 3 + 1.67 \*

 ( 6 - 1.672)) / ( 3 + 5 \* 1.67 )]

 = -20.61 N./mm^2

 *If Em( 0.636 ) < E( 0.850 ) and Eb( 0.636 ) < E( 0.850 ) then*

 SblMo = SblMo / Eb

 = -20.61 / 0.64

 = -32.39 N./mm^2

Bending Stress at Long-side 1 at Q Inner[SblQi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 62.00 \* 60.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 )]

 = 64.37 N./mm^2

Bending Stress at Long-side 1 at Q Outer[SblQo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 62.00 \* 60.002 \* -10.00 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 )]

 = -64.37 N./mm^2

***Bending Stresses at Long-side 2***

Bending Stress at Long-side 2 at M Inner[SblMi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 62.00 \* 60.002 \* 9.78 / ( 12 \* 0.07 ) \* [( 3 + 1.67 \*

 ( 6 - 1.672)) / ( 3 + 5 \* 1.67 )]

 = 20.15 N./mm^2

 *If Em( 0.580 ) < E( 0.850 ) and Eb( 0.548 ) < E( 0.850 ) then*

 SblMi = SblMi / Eb

 = 20.15 / 0.55

 = 36.76 N./mm^2

Bending Stress at Long-side 2 at M Outer[SblMo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 62.00 \* 60.002 \* -10.22 / ( 12 \* 0.07 ) \* [( 3 + 1.67 \*

 ( 6 - 1.672)) / ( 3 + 5 \* 1.67 )]

 = -21.06 N./mm^2

 *If Em( 0.580 ) < E( 0.850 ) and Eb( 0.548 ) < E( 0.850 ) then*

 SblMo = SblMo / Eb

 = -21.06 / 0.55

 = -38.42 N./mm^2

Bending Stress at Long-side 2 at Q Inner[SblQi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 62.00 \* 60.002 \* 9.78 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 )]

 = 62.95 N./mm^2

Bending Stress at Long-side 2 at Q Outer[SblQo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 62.00 \* 60.002 \* -10.22 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 )]

 = -65.79 N./mm^2

**BENDING STRESSES: Bending Stress Calculations per Section 13-9,**

 **Equations (16-19). (N./mm^2) :**

 STRESS LOCATIONS Inner Outer Allowable

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

 Short-side 1 at N -51.88 51.88 142.68

 at Q 64.37 -64.37 142.68

 Short-side 2 at N -51.88 51.88 142.68

 at Q 64.37 -64.37 142.68

 Long-side 1 at M 32.39 -32.39 167.86

 at Q 64.37 -64.37 142.68

 Long-side 2 at M 36.76 -38.42 167.86

 at Q 62.95 -65.79 142.68

**Total Stress Calculations per Section 13-9**

***Total Stresses at Short-side 1***

Total Stress at short side 1 at N inner [STS\_Ni]:

 = Sms + SbsNi

 = 11.73 + -51.88

 = -40.15 N./mm^2

Total Stress at short side 1 at N outer [STS\_No]:

 = Sms + SbsNo

 = 11.73 + 51.88

 = 63.61 N./mm^2

Total Stress at short side 1 at Q inner [STS\_Qi]:

 = Sms + SbsQi

 = 11.73 + 64.37

 = 76.11 N./mm^2

Total Stress at short side 1 at Q outer [STS\_Qo]:

 = Sms + SbsQo

 = 11.73 + -64.37

 = -52.64 N./mm^2

***Total Stresses at Short-side 2***

Total Stress at short side 2 at N inner [STS\_Ni]:

 = Sms + SbsNi

 = 11.73 + -51.88

 = -40.15 N./mm^2

Total Stress at short side 2 at N outer [STS\_No]:

 = Sms + SbsNo

 = 11.73 + 51.88

 = 63.61 N./mm^2

Total Stress at short side 2 at Q inner [STS\_Qi]:

 = Sms + SbsQi

 = 11.73 + 64.37

 = 76.11 N./mm^2

Total Stress at short side 2 at Q outer [STS\_Qo]:

 = Sms + SbsQo

 = 11.73 + -64.37

 = -52.64 N./mm^2

***Total Stresses at Long-side 1***

Total Stress at long side 1 at M inner [STL\_Mi]:

 = Sml + SblMi

 = 24.37 + 32.39

 = 56.76 N./mm^2

Total Stress at long side 1 at M outer [STL\_Mo]:

 = Sml + SblMo

 = 24.37 + -32.39

 = -8.03 N./mm^2

Total Stress at long side 1 at Q inner [STL\_Qi]:

 = Sml + SblQi

 = 15.50 + 64.37

 = 79.88 N./mm^2

Total Stress at long side 1 at Q outer [STL\_Qo]:

 = SmlB + SblQo

 = 15.50 + -64.37

 = -48.87 N./mm^2

***Total Stresses at Long-side 2***

Total Stress at long side 2 at M inner [STL\_Mi]:

 = Sml + SblMi

 = 26.73 + 36.76

 = 63.49 N./mm^2

Total Stress at long side 2 at M outer [STL\_Mo]:

 = Sml + SblMo

 = 26.73 + -38.42

 = -11.68 N./mm^2

Total Stress at long side 2 at Q inner [STL\_Qi]:

 = Sml + SblQi

 = 15.50 + 62.95

 = 78.45 N./mm^2

Total Stress at long side 2 at Q outer [STL\_Qo]:

 = SmlB + SblQo

 = 15.50 + -65.79

 = -50.29 N./mm^2

**TOTAL STRESSES: Total Stress Calculations per Section 13-9,**

 **Equations (20-24). (N./mm^2) :**

 STRESS LOCATIONS Inner Outer Allowable

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

 Short-side 1 at N -40.15 63.61 142.68

 at Q 76.11 -52.64 142.68

 Short-side 2 at N -40.15 63.61 142.68

 at Q 76.11 -52.64 142.68

 Long-side 1 at M 56.76 -8.03 167.86

 at Q 79.88 -48.87 142.68

 Long-side 2 at M 63.49 -11.68 167.86

 at Q 78.45 -50.29 142.68

**End Plate Stresses (N./mm^2):**

 Actual Allowable

 End Plate 68.20 111.91

**Required End Plate thickness due to Internal Pressure [trEP]:**

 = d \* sqrt( Z \* C \* P / ( SE ) ) + ca

 = 100.000 \* sqrt( 2.200 \* 0.200 \* 62.000 / ( 111.908 ) ) + 0.000

 = 15.614 mm.

**End Plate MAWP at given Thickness [MAWPEP]:**

 = ((T-ca)/d)^2 \* ((SE)/(C\*Z)) per UG-34 (c)(3)

 = ((20.0000-0.0000)/100.0000)^2\*((111)/(.20\*2.20))

 = 101.728 bars

 *where Z is:*

 = min( 3.4 - 2.4( d/D ), 2.5 )

 = min( 3.4 - 2.4( 100.000 / 200.000 ), 2.5 )

 = 2.200

**SUMMARY OF RESULTS:**

 MEMBRANE STRESS SUMMARY,

 High Stress (Highest % of Allowable) 32.34 N./mm^2

 High Stress Percentage 28.27 %

 M.A.W.P. for Membrane Stresses 219.31 bars

 BENDING STRESS SUMMARY,

 High Stress (Highest % of Allowable) -65.79 N./mm^2

 High Stress Percentage 46.11 %

 M.A.W.P. for Bending Stresses 134.45 bars

 TOTAL STRESS SUMMARY,

 High Stress (Highest % of Allowable) 79.88 N./mm^2

 High Stress Percentage 55.98 %

 M.A.W.P. for Total Stresses 110.75 bars

**Rectangular Vessel Results For Item 1 : A8**

**SUMMARY OF RESULTS:**

 MEMBRANE STRESS SUMMARY,

 High Stress (Highest % of Allowable) 32.34 N./mm^2

 High Stress Percentage 28.27 %

 M.A.W.P. for Membrane Stresses 219.31 bars

 BENDING STRESS SUMMARY,

 High Stress (Highest % of Allowable) -65.79 N./mm^2

 High Stress Percentage 46.11 %

 M.A.W.P. for Bending Stresses 134.45 bars

 TOTAL STRESS SUMMARY,

 High Stress (Highest % of Allowable) 79.88 N./mm^2

 High Stress Percentage 55.98 %

 M.A.W.P. for Total Stresses 110.75 bars

## floating Header Calculation @ test Pressure for ae-2102.

**Input Echo, COMPONENT 1, Description: Fl.AE-2102-Test**

 Figure Number Analyzed A8

 Design Internal Pressure P 80.6000 bars

 Design Temperature Temp 25.0000 C

 VESSEL MATERIAL DATA:

 Material Specification SA-240 316L

 Shell Allowable Stress at Design Temp S 155.0000 N./mm^2

 Shell Allowable Stress at Ambient SA 155.0000 N./mm^2

 Shell Yield Stress at Design Temperature Sy 172.3750 N./mm^2

 SHORT-SIDE VESSEL DATA:

 Short-side Length Dimension H 100.0000 mm.

 Minimum Thickness of Short-side Plates t1 20.0000 mm.

 Mid-side Joint Efficiency on Short-side E 0.8500

 Corner Joint Efficiency on Short-side EC 0.8500

 LONG-SIDE VESSEL DATA:

 Long-side Length Dimension h 60.0000 mm.

 Minimum Thickness of Long-side Plates t2 20.0000 mm.

 Mid-side Joint Efficiency on Long-side E 0.8500

 ADDITIONAL VESSEL DATA:

 Minimum Thickness of End Plate t5 20.0000 mm.

 C-Factor for End Plate Cf\_Epl 0.2000

 Long-side Plate # 1,

 Pitch Distance p 70.5000 mm.

 Uniform Hole Diameter d0 25.6500 mm.

 Depth of Holes T0 20.0000 mm.

 Long-side Plate # 2,

 Pitch Distance p 70.5000 mm.

 # 1: Hole Diameter d0 36.3000 mm.

 Hole Depth T0 2.7000 mm.

 # 2: Hole Diameter d1 28.5750 mm.

 Hole Depth T1 17.3000 mm.

 STAY PLATE MATERIAL DATA:

 Stay Material Specification SA-240 316L

 Stay Allowable Stress at Design Temp Sr 114.3898 N./mm^2

 Stay Allowable Stress at Ambient SA 115.1465 N./mm^2

 Stay Yield Stress at Design Temp Sy 129.8699 N./mm^2

 STAY PLATE DATA:

 Minimum Thickness of Stay t3 10.0000 mm.

 Minimum Thickness of Stay t4 10.0000 mm.

 The Stay(s) Are Not Welded to the End Plate

**Rectangular Vessel Results, Item number 1, Desc: Fl.AE-2102-Test**

**ASME Code, Section VIII, Division 1, 2021 App. 13**

**Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):**

***Short-side 1 Calculations***

Membrane Ligament Efficiency [Em]:

 = 0.850

Bending Ligament Efficiency [Eb]:

 = 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Short-side 2 Calculations***

Membrane Ligament Efficiency [Em]:

 = 0.850

Bending Ligament Efficiency [Eb]:

 = 0.850

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Long-side 1 Calculations***

Effective Diameter [De]: 25.650 mm.

Membrane Ligament Efficiency [Em]:

 = Pitch - De / Pitch

 = 70.500 - 25.650 / 70.500

 = 0.636

Bending Ligament Efficiency [Eb]:

*As diameter holes are uniform Eb = Em*

 = 0.636

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 = t1 - CA / 2

 = 20.000 - 0.000 / 2

 = 10.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t1 - CA ) / 2

 = -( 20.000 - 0.000 ) / 2

 = -10.000 mm.

***Long-side 2 Calculations***

Effective Diameter [De]:

 = ( d0 \* T0 + d1 \* T1 + d2 \* T2 ) / ( t1 - CA )

 = ( 36.30 \* 2.70 + 28.57 \* 17.30 + 0.00 \* 0.00 ) /

 ( 20.00 - 0.00 )

 = 29.618 mm.

Membrane Ligament Efficiency [Em]:

 = Pitch - De / Pitch

 = 70.500 - 29.618 / 70.500

 = 0.580

Dist from Neutral axis of c/s to extreme fibers [Ci & Co]:

*Calculation of Xbar:*

 = (( b0 \* T0 \* ( T0/2 + T1 + T2 )) + ( b1 \* T1 \*

 ( T1/2 + T2 )) + ( b2 \* T2 \* ( T2/2 ))) /

 ( b0 \* T0 + b1 \* T1 + b2 \* T2 )

 = (( 1.35 \* 2.70 \* ( 2.70 /2 + 17.30 + 0.00 )) + ( 1.65\* 17.30 \*

 ( 17.30 /2 + 0.00 )) + ( 2.78 \* 0.00 \* ( 0.00 /2 ))) /

 ( 1.35 \* 2.70 + 1.65 \* 17.30 + 2.78 \* 0.00 )

 = 9.779 mm.

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:

 *Ci = Xbar*

 = 9.779 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:

 = -( t - CA - Xbar )

 = -( 20.000 - 0.000 - 9.779 )

 = -10.221 mm.

Moment of Inertia (Section 13-6, Equation (5)) [I]:

 = 0.104 cm\*\*4

Effective Diameter [De]:

 = Pitch - (( 6 \* I ) / (( t - CA)^2 \* (-Co)))

 = 70.50 - (( 6 \* 0.10 ) / ((20.00 - 0.00 )^2 \* (10.22 )))

 = 31.848 mm.

Bending Ligament Efficiency [Eb]:

 = Pitch - De / Pitch

 = 70.500 - 31.848 / 70.500

 = 0.548

**Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):**

 Em Eb Ci Co

 Short-side 1 0.850 0.850 10.000 -10.000

 2 0.850 0.850 10.000 -10.000

 Long-side 1 0.636 0.636 10.000 -10.000

 2 0.580 0.548 9.779 -10.221

**Moment of Inertia of a Strip of the Vessel Wall:**

 Thickness t1, I1 = 0.0667 cm\*\*4

 Thickness t2, I2 = 0.0667 cm\*\*4

**Rectangular Vessel Parameters:**

 Alpha = H / h = 1.6667

 K = (I2/I1)\*Alpha = 1.6667

**Membrane Stress Calculations per Section 13-9**

***Membrane Stresses at Short-side 1***

Membrane Stress at Short-side 1 [Sms]:

 = P \* h / ( 2 \* t1 ) \* { 3 - [( 6 + K \*

 ( 11 - alpha2) / ( 3 + 5 \* K )]}

 = 80.60 \* 60.00 / ( 2 \* 20.00 ) \* { 3- [( 6 + 1.67 \*

 ( 11 - 1.672) / ( 3 + 5 \* 1.67 )]}

 = 15.25 N./mm^2

***Membrane Stresses at Short-side 2***

Membrane Stress at Short-side 2 [Sms]:

 = P \* h / ( 2 \* t1 ) \* { 3 - [( 6 + K \*

 ( 11 - alpha2) / ( 3 + 5 \* K )]}

 = 80.60 \* 60.00 / ( 2 \* 20.00 ) \* { 3- [( 6 + 1.67 \*

 ( 11 - 1.672) / ( 3 + 5 \* 1.67 )]}

 = 15.25 N./mm^2

***Membrane Stresses at Long-side 1***

Membrane Stress at Long-side 1 at A [Sml]:

 = P \* H / 2 \* t2

 = 80.60 \* 100.00 / 2 \* 20.00

 = 20.15 N./mm^2

 *If Em( 0.636 ) < E( 0.850 ) and Eb( 0.636 ) < E( 0.850 ) then*

 Sml = Sml / Em

 = 20.15 / 0.64

 = 31.68 N./mm^2

***Membrane Stresses at Long-side 2***

Membrane Stress at Long-side 2 at A [Sml]:

 = P \* H / 2 \* t2

 = 80.60 \* 100.00 / 2 \* 20.00

 = 20.15 N./mm^2

 *If Em( 0.580 ) < E( 0.850 ) and Eb( 0.548 ) < E( 0.850 ) then*

 Sml = Sml / Em

 = 20.15 / 0.58

 = 34.75 N./mm^2

***Membrane Stresses at Stay Plate***

Membrane Stress at Stay Plate [t3]:

 = P \* h / ( 2 \* t3 ) \* [( 6 + K \* ( 11 -

 alpha2) / ( 3 + 5 \* K )]

 = 80.60 \* 60.00 / ( 2 \* 10.00 ) \* [( 6 + 1.67 \* ( 11 -

 1.672) / ( 3 + 5 \* 1.67 )]

 = 42.04 N./mm^2

Membrane Stress at Stay Plate [t4]:

 = P \* h / ( 2 \* t4 ) \* [( 6 + K \* ( 11 -

 alpha2) / ( 3 + 5 \* K )]

 = 80.60 \* 60.00 / ( 2 \* 10.00 ) \* [( 6 + 1.67 \* ( 11 -

 1.672) / ( 3 + 5 \* 1.67 )]

 = 42.04 N./mm^2

**MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-9,**

 **Equations (13-15). (N./mm^2) :**

 STRESS LOCATIONS Actual Allowable

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

 Short-side 1 15.25 131.75

 Short-side 2 15.25 131.75

 Short-side Corner 15.25 131.75

 Long-side 1 at A 31.68 155.00

 Long-side 2 at A 34.75 155.00

 Long-side Corner 20.15 131.75

 Stay Plate (t3) 42.04 114.39

 Stay Plate (t4) 42.04 114.39

**Bending Stress Calculations per Section 13-9**

***Bending Stresses at Short-side 1***

Bending Stress at Short-side 1 at N Inner[SbsNi]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 80.60 \* 10.00 / ( 24 \* 0.07 ) \* [ -3 \* 100.002 + 2 \* 60.002 \*

 (( 3 + 5 \* 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 ))]

 = -67.45 N./mm^2

Bending Stress at Short-side 1 at N Outer[SbsNo]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 80.60 \* -10.00 /( 24 \* 0.07 ) \* [ -3 \* 100.002 + 2 \* 60.002 \*

 (( 3 + 5 \* 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 ))]

 = 67.45 N./mm^2

Bending Stress at Short-side 1 at Q Inner[SbsQi]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 80.60 \* 60.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 ))

 = 83.69 N./mm^2

Bending Stress at Short-side 1 at Q Outer[SbsQo]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 80.60 \* 60.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 ))

 = -83.69 N./mm^2

***Bending Stresses at Short-side 2***

Bending Stress at Short-side 2 at N Inner[SbsNi]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 80.60 \* 10.00 / ( 24 \* 0.07 ) \* [ -3 \* 100.002 + 2 \* 60.002 \*

 (( 3 + 5 \* 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 ))]

 = -67.45 N./mm^2

Bending Stress at Short-side 2 at N Outer[SbsNo]:

 = P \* c / ( 24 \* I1 ) \* [ -3 \* H2 + 2 \* h2 \*

 (( 3 + 5 \* Alpha2 \* K ) / ( 3 + 5 \* K ))]

 = 80.60 \* -10.00 /( 24 \* 0.07 ) \* [ -3 \* 100.002 + 2 \* 60.002 \*

 (( 3 + 5 \* 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 ))]

 = 67.45 N./mm^2

Bending Stress at Short-side 2 at Q Inner[SbsQi]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 80.60 \* 60.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 ))

 = 83.69 N./mm^2

Bending Stress at Short-side 2 at Q Outer[SbsQo]:

 = P \* h2 \* c / ( 12 \* I1 ) \* (( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K ))

 = 80.60 \* 60.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 ))

 = -83.69 N./mm^2

***Bending Stresses at Long-side 1***

Bending Stress at Long-side 1 at M Inner[SblMi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 80.60 \* 60.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 3 + 1.67 \*

 ( 6 - 1.672)) / ( 3 + 5 \* 1.67 )]

 = 26.79 N./mm^2

 *If Em( 0.636 ) < E( 0.850 ) and Eb( 0.636 ) < E( 0.850 ) then*

 SblMi = SblMi / Eb

 = 26.79 / 0.64

 = 42.11 N./mm^2

Bending Stress at Long-side 1 at M Outer[SblMo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 80.60 \* 60.002 \* -10.00 / ( 12 \* 0.07 ) \* [( 3 + 1.67 \*

 ( 6 - 1.672)) / ( 3 + 5 \* 1.67 )]

 = -26.79 N./mm^2

 *If Em( 0.636 ) < E( 0.850 ) and Eb( 0.636 ) < E( 0.850 ) then*

 SblMo = SblMo / Eb

 = -26.79 / 0.64

 = -42.11 N./mm^2

Bending Stress at Long-side 1 at Q Inner[SblQi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 80.60 \* 60.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 )]

 = 83.69 N./mm^2

Bending Stress at Long-side 1 at Q Outer[SblQo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 80.60 \* 60.002 \* -10.00 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 )]

 = -83.69 N./mm^2

***Bending Stresses at Long-side 2***

Bending Stress at Long-side 2 at M Inner[SblMi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 80.60 \* 60.002 \* 9.78 / ( 12 \* 0.07 ) \* [( 3 + 1.67 \*

 ( 6 - 1.672)) / ( 3 + 5 \* 1.67 )]

 = 26.20 N./mm^2

 *If Em( 0.580 ) < E( 0.850 ) and Eb( 0.548 ) < E( 0.850 ) then*

 SblMi = SblMi / Eb

 = 26.20 / 0.55

 = 47.78 N./mm^2

Bending Stress at Long-side 2 at M Outer[SblMo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + K \*

 ( 6 - Alpha2)) / ( 3 + 5 \* K )]

 = 80.60 \* 60.002 \* -10.22 / ( 12 \* 0.07 ) \* [( 3 + 1.67 \*

 ( 6 - 1.672)) / ( 3 + 5 \* 1.67 )]

 = -27.38 N./mm^2

 *If Em( 0.580 ) < E( 0.850 ) and Eb( 0.548 ) < E( 0.850 ) then*

 SblMo = SblMo / Eb

 = -27.38 / 0.55

 = -49.94 N./mm^2

Bending Stress at Long-side 2 at Q Inner[SblQi]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 80.60 \* 60.002 \* 9.78 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 )]

 = 81.84 N./mm^2

Bending Stress at Long-side 2 at Q Outer[SblQo]:

 = P \* h2 \* c / ( 12 \* I2 ) \* [( 3 + 5 \*

 Alpha2 \* K ) / ( 3 + 5 \* K )]

 = 80.60 \* 60.002 \* -10.22 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

 1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 )]

 = -85.53 N./mm^2

**BENDING STRESSES: Bending Stress Calculations per Section 13-9,**

 **Equations (16-19). (N./mm^2) :**

 STRESS LOCATIONS Inner Outer Allowable

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

 Short-side 1 at N -67.45 67.45 197.62

 at Q 83.69 -83.69 197.62

 Short-side 2 at N -67.45 67.45 197.62

 at Q 83.69 -83.69 197.62

 Long-side 1 at M 42.11 -42.11 232.50

 at Q 83.69 -83.69 197.62

 Long-side 2 at M 47.78 -49.94 232.50

 at Q 81.84 -85.53 197.62

**Total Stress Calculations per Section 13-9**

***Total Stresses at Short-side 1***

Total Stress at short side 1 at N inner [STS\_Ni]:

 = Sms + SbsNi

 = 15.25 + -67.45

 = -52.20 N./mm^2

Total Stress at short side 1 at N outer [STS\_No]:

 = Sms + SbsNo

 = 15.25 + 67.45

 = 82.70 N./mm^2

Total Stress at short side 1 at Q inner [STS\_Qi]:

 = Sms + SbsQi

 = 15.25 + 83.69

 = 98.94 N./mm^2

Total Stress at short side 1 at Q outer [STS\_Qo]:

 = Sms + SbsQo

 = 15.25 + -83.69

 = -68.43 N./mm^2

***Total Stresses at Short-side 2***

Total Stress at short side 2 at N inner [STS\_Ni]:

 = Sms + SbsNi

 = 15.25 + -67.45

 = -52.20 N./mm^2

Total Stress at short side 2 at N outer [STS\_No]:

 = Sms + SbsNo

 = 15.25 + 67.45

 = 82.70 N./mm^2

Total Stress at short side 2 at Q inner [STS\_Qi]:

 = Sms + SbsQi

 = 15.25 + 83.69

 = 98.94 N./mm^2

Total Stress at short side 2 at Q outer [STS\_Qo]:

 = Sms + SbsQo

 = 15.25 + -83.69

 = -68.43 N./mm^2

***Total Stresses at Long-side 1***

Total Stress at long side 1 at M inner [STL\_Mi]:

 = Sml + SblMi

 = 31.68 + 42.11

 = 73.79 N./mm^2

Total Stress at long side 1 at M outer [STL\_Mo]:

 = Sml + SblMo

 = 31.68 + -42.11

 = -10.43 N./mm^2

Total Stress at long side 1 at Q inner [STL\_Qi]:

 = Sml + SblQi

 = 20.15 + 83.69

 = 103.84 N./mm^2

Total Stress at long side 1 at Q outer [STL\_Qo]:

 = SmlB + SblQo

 = 20.15 + -83.69

 = -63.54 N./mm^2

***Total Stresses at Long-side 2***

Total Stress at long side 2 at M inner [STL\_Mi]:

 = Sml + SblMi

 = 34.75 + 47.78

 = 82.53 N./mm^2

Total Stress at long side 2 at M outer [STL\_Mo]:

 = Sml + SblMo

 = 34.75 + -49.94

 = -15.19 N./mm^2

Total Stress at long side 2 at Q inner [STL\_Qi]:

 = Sml + SblQi

 = 20.15 + 81.84

 = 101.99 N./mm^2

Total Stress at long side 2 at Q outer [STL\_Qo]:

 = SmlB + SblQo

 = 20.15 + -85.53

 = -65.38 N./mm^2

**TOTAL STRESSES: Total Stress Calculations per Section 13-9,**

 **Equations (20-24). (N./mm^2) :**

 STRESS LOCATIONS Inner Outer Allowable

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

 Short-side 1 at N -52.20 82.70 197.62

 at Q 98.94 -68.43 197.62

 Short-side 2 at N -52.20 82.70 197.62

 at Q 98.94 -68.43 197.62

 Long-side 1 at M 73.79 -10.43 232.50

 at Q 103.84 -63.54 197.62

 Long-side 2 at M 82.53 -15.19 232.50

 at Q 101.99 -65.38 197.62

**End Plate Stresses (N./mm^2):**

 Actual Allowable

 End Plate 88.67 155.00

**Required End Plate thickness due to Internal Pressure [trEP]:**

 = d \* sqrt( Z \* C \* P / ( SE ) ) + ca

 = 100.000 \* sqrt( 2.200 \* 0.200 \* 80.600 / ( 155.000 ) ) + 0.000

 = 15.127 mm.

**End Plate MAWP at given Thickness [MAWPEP]:**

 = ((T-ca)/d)^2 \* ((SE)/(C\*Z)) per UG-34 (c)(3)

 = ((20.0000-0.0000)/100.0000)^2\*((155)/(.20\*2.20))

 = 140.901 bars

 *where Z is:*

 = min( 3.4 - 2.4( d/D ), 2.5 )

 = min( 3.4 - 2.4( 100.000 / 200.000 ), 2.5 )

 = 2.200

**SUMMARY OF RESULTS:**

 MEMBRANE STRESS SUMMARY,

 High Stress (Highest % of Allowable) 42.04 N./mm^2

 High Stress Percentage 36.75 %

 M.A.W.P. for Membrane Stresses 219.31 bars

 BENDING STRESS SUMMARY,

 High Stress (Highest % of Allowable) -85.53 N./mm^2

 High Stress Percentage 43.28 %

 M.A.W.P. for Bending Stresses 186.23 bars

 TOTAL STRESS SUMMARY,

 High Stress (Highest % of Allowable) 103.84 N./mm^2

 High Stress Percentage 52.54 %

 M.A.W.P. for Total Stresses 153.40 bars

**Rectangular Vessel Results For Item 1 : A8**

**SUMMARY OF RESULTS:**

 MEMBRANE STRESS SUMMARY,

 High Stress (Highest % of Allowable) 42.04 N./mm^2

 High Stress Percentage 36.75 %

 M.A.W.P. for Membrane Stresses 219.31 bars

 BENDING STRESS SUMMARY,

 High Stress (Highest % of Allowable) -85.53 N./mm^2

 High Stress Percentage 43.28 %

 M.A.W.P. for Bending Stresses 186.23 bars

 TOTAL STRESS SUMMARY,

 High Stress (Highest % of Allowable) 103.84 N./mm^2

 High Stress Percentage 52.54 %

 M.A.W.P. for Total Stresses 153.40 bars

## FINITE ELEMENT FOR AE-2101

**Tabular Results**

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Mon Nov 25 13:33:28 2024.

* [Model Notes, Tube Results and API Check](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2101%5C17208-AE-2101%5COUTPUT_661PRO%5Csetup2.htm#1)
* [Load Case Report](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2101%5C17208-AE-2101%5COUTPUT_661PRO%5Csetup2.htm#2)
* [Solution Data](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2101%5C17208-AE-2101%5COUTPUT_661PRO%5Csetup2.htm#3)
* [ASME Code Stress Output Plots](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2101%5C17208-AE-2101%5COUTPUT_661PRO%5Csetup2.htm#4)
* [Stress Results - Notes](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2101%5C17208-AE-2101%5COUTPUT_661PRO%5Csetup2.htm#5)
* [ASME Overstressed Areas](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2101%5C17208-AE-2101%5COUTPUT_661PRO%5Csetup2.htm#6)
* [Highest Primary Stress Ratios](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2101%5C17208-AE-2101%5COUTPUT_661PRO%5Csetup2.htm#7)
* [Highest Secondary Stress Ratios](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2101%5C17208-AE-2101%5COUTPUT_661PRO%5Csetup2.htm#8)
* [Highest Fatigue Stress Ratios](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2101%5C17208-AE-2101%5COUTPUT_661PRO%5Csetup2.htm#9)
* [Highest Stress Ratios Per Region](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2101%5C17208-AE-2101%5COUTPUT_661PRO%5Csetup2.htm#10)
* [Compressive Stress Summary](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2101%5C17208-AE-2101%5COUTPUT_661PRO%5Csetup2.htm#11)
* [Graphical Results](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2101%5C17208-AE-2101%5COUTPUT_661PRO%5Csetup2-ppics.htm)

 Model Notes, Tube Results and API Check

 Model Notes, Tube Results and API Check

 661PRO 3.0 - API 661 - Air-Cooled Heat Exchanger Nozzle Model

 Input Echo:

 Notes:

 - The centerline of the header box is along the -Z axis.

 - Only 1 Nozzle will be modeled at a time. The Nozzle Number

 Modeled can be seen below.

 - User Defined Loads API 661 Check is shown below.

 - Sum of ALL Nozzle Loads must not exceed 3\*API Allowable

 Loads shown in paragraph 7.1.10.2 according to API 661

 2013 paragraph 7.1.10.3.

 - Results are given as: Actual Load, Allowable Load,

 percentage of allowable for API Check in lbs. and ft-lbs. for

 English Units and N. and N-m for SI Units.

 Nozzle Number Modelled : 1

 Top or Bottom Nozzle : Top

 Analysis Type : User Defined Loads

 Nozzle Type : Straight

 Flange Type : Weldneck

 Header Box Dimensions:

 Centerline on :Centerline on LEFT Side

 Height : 333.000 mm.

 Width : 200.000 mm.

 Length : 1939.000 mm.

 Outboard Thickness : 20.000 mm.

 Tubesheet Side Thickness : 20.000 mm.

 Top Plate Thickness : 20.000 mm.

 Free End Plate Thickness : 20.000 mm.

 Header Box Pressure : 2.200 MPa

 Symmetric Boundary Condition at Centerline

 Parition Plates:

 Number of Partition Plates : 2

 Partition Plate #1

 Plate Elevation from Bottom : 91.000 mm.

 Plate Thickness : 10.000 mm.

 Partition Plate #2

 Plate Elevation from Bottom : 223.000 mm.

 Plate Thickness : 10.000 mm.

 Nozzle Dimensions:

 Distance to CenterLine : 969.500 mm.

 Nozzle Outside Diameter : 168.300 mm.

 Nozzle Thickness : 9.600 mm.

 Projection to Face of Flange : 315.000 mm.

 Flange Thickness Used : 31.800 mm.

 Flange ID : 202.480 mm.

 Flange Hub Length Used : 47.700 mm.

 Weld Size and SCF : 0.000, 1.350

 Engineering Details:

 Operating Cycles : 7000

 Occasional Cycles : 0

 Ambient Temperature : 21.100 deg.

 Computation Type : Gauss Average

 Material Properties

 Nozzle:

 Cold Allowable Stress : 115.100 MPa

 Hot Allowable Stress : 86.600 MPa

 Elastic Modulus : 0.186E+06 MPa

 Poissons Ratio : 0.300

 Material ID :4-Austenitic Steels

 Density : 0.000E+00 N /cu. mm.

 Cold Yield Stress : 172.400 MPa

 Hot Yield Stress : 129.900 MPa

 Cold Tensile Stress : 482.600 MPa

 Density : 0.000E+00 N /cu. mm.

 Header Box:

 Cold Allowable Stress : 115.100 MPa

 Hot Allowable Stress : 86.600 MPa

 Elastic Modulus : 0.186E+06 MPa

 Poissons Ratio : 0.300

 Material ID :4-Austenitic Steels

 Density : 0.000E+00 N /cu. mm.

 Cold Yield Stress : 172.400 MPa

 Hot Yield Stress : 129.900 MPa

 Cold Tensile Stress : 482.600 MPa

 Density : 0.000E+00 N /cu. mm.

 Tubesheet was not modeled

 User Defined Loads:

 Forces [ N ] Moments [ mm.- N ]

 FX FY FZ MX MY MZ

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

 Weight 12000 15090 15090 6420000 9150000 4890000

 Operating 12000 15090 15090 6420000 9150000 4890000

 Occasional 0 0 0 0 0 0

 No Tube Results

 API Check for User Defined Loads and API Evaluation

 API 661 2013 paragraph 7.1.10.2 and 7.1.10.3.

 Results below are shown as:

 Actual Load, Allowable Load, % of Allowable

 Allowable Load: 3x API Allowable from para. 7.1.10.2

 Total Nozzle Loads per DOF in [N and N.m]

 Global FX : 12000, 15015, 79 %

 Global FY : 15090, 30030, 50 %

 Global FZ : 15090, 25020, 60 %

 Global MX : 6420, 9150, 70 %

 Global MY : 9150, 12195, 75 %

 Global MZ : 4890, 6105, 80 %

 API 661 para. 7.1.10.3 check PASSED. The summation of

 all nozzle loads did NOT exceed the 1.5x API value from

 para. 7.1.10.2.

 Symmetric boundary condition applied at the center of the

 headerbox, the API multiplier from paragraph 7.1.10.3 will

 be 1.5 since total loads will be 2x larger due to symmetry.

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 Load Case Report

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 12:34am NOV 25,2024

 Load Case Report $X

 Inner and outer element temperatures are the same

 throughout the model. No thermal ratcheting

 calculations will be performed.

 THE 4 LOAD CASES ANALYZED ARE:

 1 WEIGHT ONLY (Wgt Only)

 Weight ONLY case run to get the stress range

 between the installed and the operating states.

 /-------- Loads in Case 1

 Loads due to Weight

 2 SUSTAINED (Wgt+Pr)

 Sustained case run to satisfy local primary

 membrane and bending stress limits.

 /-------- Loads in Case 2

 Loads due to Weight

 Pressure Case 1

 3 OPERATING

 Case run to compute the operating stresses used in

 secondary, peak and range calculations as needed.

 /-------- Loads in Case 3

 Pressure Case 1

 Loads from (Operating)

 4 RANGE (Fatigue Calc Performed)

 Case run to get the RANGE of stresses.

 as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

 /-------- Combinations in Range Case 4

 Plus Stress Results from CASE 3

 Minus Stress Results from CASE 1

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 Solution Data

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 1:32pm NOV 25,2024

 Solution Data

 Maximum Solution Row Size = 1758

 Number of Nodes = 8895

 Number of Elements = 3027

 Number of Solution Cases = 3

 Summation of Loads per Case

 Case # FX FY FZ

 1 12000. 53502. 15090.

 2 12000. -44684. -108858.

 3 12000. -44684. -108858.

[Table of Contents](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2101%5C17208-AE-2101%5COUTPUT_661PRO%5Csetup2.htm#TOC)

 ASME Code Stress Output Plots

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 1:33pm NOV 25,2024

 ASME Code Stress Output Plots $X

 1) Pl < SPL (SUS,Membrane) Case 2

 2) Qb < SPS (SUS,Bending) Case 2

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 8) Membrane < User (OPE,Membrane) Case 3

 9) Bending < User (OPE,Bending) Case 3

 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

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 Stress Results - Notes

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 1:33pm NOV 25,2024

 Stress Results - Notes

 - Results in this analysis were generated using the finite

 element solution method.

 - Using 2019 ASME Section VIII Division 2

 - Use Polished Bar fatigue curve.

 - Ratio between Operating and Design Pressure = 1.000000

 Range cases use operating pressure. Primary cases

 use design pressure.

 - Assume free end displacements of attached pipe

 (e.g. thermal loads) are secondary loads.

 - Primary bending stresses at discontinuities

 are treated like secondary stresses. (Pb=0)

 - Use Equivalent Stress (Von Mises).

 - TRIAXIAL Stress Guidelines:

 S1+S2+S3 evaluation omitted from operating stress.

 Include S1+S2+S3 evaluation in primary case evaluation.

 Bending stress NOT included for all S1+S2+S3 calculations.

 - Use local tensor values for averaged and not averaged stresses.

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 ASME Overstressed Areas

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 1:33pm NOV 25,2024

 ASME Overstressed Areas $X

 \*\*\* NO OVERSTRESSED NODES IN THIS MODEL \*\*\*

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 Highest Primary Stress Ratios

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 1:33pm NOV 25,2024

 Highest Primary Stress Ratios $X

 Circ Plate for Plate # 1

 Pl SPL Primary Membrane Load Case 2

 43 130 Min Prin. Stress = -66. (49% Neg, 6% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 33%

 Long Plate for Plate # 1

 Pl SPL Primary Membrane Load Case 2

 108 130 Min Prin. Stress = -114. (97% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 83%

 Circ Plate for Plate # 2

 Pl SPL Primary Membrane Load Case 2

 53 130 Min Prin. Stress = -30. (56% Neg, 8% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 40%

 Circ Plate for Plate # 3

 Pl SPL Primary Membrane Load Case 2

 121 130 Min Prin. Stress = -169. (87% Neg, 46% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 93%

 Circ Plate for Plate # 4

 Pl SPL Primary Membrane Load Case 2

 92 130 Min Prin. Stress = -114. (76% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 70%

 Long Plate for Plate # 4

 Pl SPL Primary Membrane Load Case 2

 23 130 Min Prin. Stress = -16. (77% Neg, 10% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 17%

 Circ Plate for Plate # 5

 Pl SPL Primary Membrane Load Case 2

 35 130 Min Prin. Stress = -9. (37% Neg, 9% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 26%

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 Highest Secondary Stress Ratios

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 1:33pm NOV 25,2024

 Highest Secondary Stress Ratios $X

 In combination case 4 the max range stress divided

 by the max component stress is 1.99. The case tensor components

 are in some directions additive and so the combination

 case will have HIGHER stresses than the largest of any

 of the individual cases by more than 50%.

 Load Combined/Max Combined/Max

 Case (Inside) (Outside)

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

 4 1.989 1.976

 Circ Plate for Plate # 1

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 90 303 Min Prin. Stress = -66. (49% Neg, 6% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 29%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 90 303 Min Prin. Stress = -66. (49% Neg, 6% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 29%

 Long Plate for Plate # 1

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 201 303 Min Prin. Stress = -114. (97% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 66%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 201 303 Min Prin. Stress = -114. (97% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 66%

 Circ Plate for Plate # 2

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 75 303 Min Prin. Stress = -30. (56% Neg, 8% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 24%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 75 303 Min Prin. Stress = -30. (56% Neg, 8% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 24%

 Circ Plate for Plate # 3

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 227 303 Min Prin. Stress = -169. (87% Neg, 46% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 75%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 227 303 Min Prin. Stress = -169. (87% Neg, 46% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 75%

 Circ Plate for Plate # 4

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 154 303 Min Prin. Stress = -114. (76% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 50%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 154 303 Min Prin. Stress = -114. (76% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 50%

 Long Plate for Plate # 4

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 38 303 Min Prin. Stress = -16. (77% Neg, 10% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 12%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 38 303 Min Prin. Stress = -16. (77% Neg, 10% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 12%

 Circ Plate for Plate # 5

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 57 302 Min Prin. Stress = -9. (37% Neg, 9% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 18%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 57 302 Min Prin. Stress = -9. (37% Neg, 9% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 18%

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 Highest Fatigue Stress Ratios

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 1:33pm NOV 25,2024

 Highest Fatigue Stress Ratios $X

 Circ Plate for Plate # 1

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 40 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.051 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 56,350,536.

 WRC 474 99% Probability Cycles = 13,090,740.

 5% WRC 474 95% Probability Cycles = 18,174,846.

 BS5500 Allowed Cycles(Curve F) = 18,787,840.

 Membrane-to-Bending Ratio = 0.293

 Bending-to-PL+PB+Q Ratio = 0.774

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Long Plate for Plate # 1

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 67 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.087 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 12,010,429.

 WRC 474 99% Probability Cycles = 2,790,129.

 8% WRC 474 95% Probability Cycles = 3,873,743.

 BS5500 Allowed Cycles(Curve F) = 2,958,582.

 Membrane-to-Bending Ratio = 0.250

 Bending-to-PL+PB+Q Ratio = 0.800

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

 Circ Plate for Plate # 2

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 40 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.051 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 56,350,524.

 WRC 474 99% Probability Cycles = 13,090,738.

 5% WRC 474 95% Probability Cycles = 18,174,842.

 BS5500 Allowed Cycles(Curve F) = 18,787,830.

 Membrane-to-Bending Ratio = 0.293

 Bending-to-PL+PB+Q Ratio = 0.774

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Circ Plate for Plate # 3

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 55 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.071 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 32,177,282.

 WRC 474 99% Probability Cycles = 7,475,067.

 7% WRC 474 95% Probability Cycles = 10,378,200.

 BS5500 Allowed Cycles(Curve F) = 5,431,522.

 Membrane-to-Bending Ratio = 0.699

 Bending-to-PL+PB+Q Ratio = 0.589

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Circ Plate for Plate # 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 28 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.036 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 2.4830E8

 WRC 474 99% Probability Cycles = 57,681,924.

 3% WRC 474 95% Probability Cycles = 80,084,096.

 BS5500 Allowed Cycles(Curve F) = 1.0043E8

 Membrane-to-Bending Ratio = 0.992

 Bending-to-PL+PB+Q Ratio = 0.502

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Long Plate for Plate # 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 10 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.013 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 2.1819E9

 WRC 474 99% Probability Cycles = 5.0689E8

 1% WRC 474 95% Probability Cycles = 7.0375E8

 BS5500 Allowed Cycles(Curve F) = 7.0539E9

 Membrane-to-Bending Ratio = 0.884

 Bending-to-PL+PB+Q Ratio = 0.531

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Circ Plate for Plate # 5

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 29 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.055 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 0.0

 530.5 Markl Fatigue Stress Allowable = 575.0

 MPa WRC 474 Mean Cycles to Failure = 2.0803E8

 WRC 474 99% Probability Cycles = 48,327,864.

 5% WRC 474 95% Probability Cycles = 67,097,160.

 BS5500 Allowed Cycles(Curve F) = 86,841,704.

 Membrane-to-Bending Ratio = 11.897

 Bending-to-PL+PB+Q Ratio = 0.078

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

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 Highest Stress Ratios Per Region

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 1:33pm NOV 25,2024

 Highest Stress Ratios Per Region $X

 Circ Plate for Plate # 1

 Pl SPL Primary Membrane Load Case 2

 43 130 Min Prin. Stress = -66. (49% Neg, 6% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 33%

 Qb SPS Primary Bending Load Case 2

 63 303 Min Prin. Stress = -66. (49% Neg, 6% NegHi)

 MPa MPa Plot Reference:

 2) Qb < SPS (SUS,Bending) Case 2

 20%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 90 303 Min Prin. Stress = -66. (49% Neg, 6% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 29%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 71 303 Min Prin. Stress = -66. (49% Neg, 6% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 23%

 S1+S2+S3 4S Part 5 (5.3.2) Load Case 2

 48 346 Min Prin. Stress = -66. (49% Neg, 6% NegHi)

 MPa MPa Plot Reference:

 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

 13%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 90 303 Min Prin. Stress = -66. (49% Neg, 6% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 29%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 71 303 Min Prin. Stress = -66. (49% Neg, 6% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 23%

 Membrane User Component Evaluation Load Case 3

 43 303 Min Prin. Stress = -66. (49% Neg, 6% NegHi)

 MPa MPa Plot Reference:

 8) Membrane < User (OPE,Membrane) Case 3

 14%

 Bending User Component Evaluation Load Case 3

 63 303 Min Prin. Stress = -66. (49% Neg, 6% NegHi)

 MPa MPa Plot Reference:

 9) Bending < User (OPE,Bending) Case 3

 20%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 4

 40 303 Min Prin. Stress = -16. (48% Neg, 6% NegHi)

 MPa MPa Plot Reference:

 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

 13%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 4

 34 303 Min Prin. Stress = -16. (48% Neg, 6% NegHi)

 MPa MPa Plot Reference:

 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

 11%

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 40 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.051 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 56,350,536.

 WRC 474 99% Probability Cycles = 13,090,740.

 5% WRC 474 95% Probability Cycles = 18,174,846.

 BS5500 Allowed Cycles(Curve F) = 18,787,840.

 Membrane-to-Bending Ratio = 0.293

 Bending-to-PL+PB+Q Ratio = 0.774

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 34 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.043 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 94,135,936.

 WRC 474 99% Probability Cycles = 21,868,632.

 4% WRC 474 95% Probability Cycles = 30,361,844.

 BS5500 Allowed Cycles(Curve F) = 41,888,972.

 Membrane-to-Bending Ratio = 0.452

 Bending-to-PL+PB+Q Ratio = 0.689

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

 Long Plate for Plate # 1

 Pl SPL Primary Membrane Load Case 2

 108 130 Min Prin. Stress = -114. (97% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 83%

 Qb SPS Primary Bending Load Case 2

 147 303 Min Prin. Stress = -114. (97% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 2) Qb < SPS (SUS,Bending) Case 2

 48%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 149 303 Min Prin. Stress = -114. (97% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 49%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 201 303 Min Prin. Stress = -114. (97% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 66%

 S1+S2+S3 4S Part 5 (5.3.2) Load Case 2

 128 346 Min Prin. Stress = -114. (97% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

 36%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 149 303 Min Prin. Stress = -114. (97% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 49%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 201 303 Min Prin. Stress = -114. (97% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 66%

 Membrane User Component Evaluation Load Case 3

 108 303 Min Prin. Stress = -114. (97% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 8) Membrane < User (OPE,Membrane) Case 3

 35%

 Bending User Component Evaluation Load Case 3

 147 303 Min Prin. Stress = -114. (97% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 9) Bending < User (OPE,Bending) Case 3

 48%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 4

 67 303 Min Prin. Stress = -32. (91% Neg, 15% NegHi)

 MPa MPa Plot Reference:

 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

 22%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 4

 67 303 Min Prin. Stress = -32. (91% Neg, 15% NegHi)

 MPa MPa Plot Reference:

 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

 22%

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 67 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.086 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 12,292,206.

 WRC 474 99% Probability Cycles = 2,855,588.

 8% WRC 474 95% Probability Cycles = 3,964,625.

 BS5500 Allowed Cycles(Curve F) = 3,012,915.

 Membrane-to-Bending Ratio = 0.248

 Bending-to-PL+PB+Q Ratio = 0.802

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 67 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.087 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 12,010,429.

 WRC 474 99% Probability Cycles = 2,790,129.

 8% WRC 474 95% Probability Cycles = 3,873,743.

 BS5500 Allowed Cycles(Curve F) = 2,958,582.

 Membrane-to-Bending Ratio = 0.250

 Bending-to-PL+PB+Q Ratio = 0.800

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

 Circ Plate for Plate # 2

 Pl SPL Primary Membrane Load Case 2

 53 130 Min Prin. Stress = -30. (56% Neg, 8% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 40%

 Qb SPS Primary Bending Load Case 2

 51 303 Min Prin. Stress = -30. (56% Neg, 8% NegHi)

 MPa MPa Plot Reference:

 2) Qb < SPS (SUS,Bending) Case 2

 16%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 57 303 Min Prin. Stress = -30. (56% Neg, 8% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 18%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 75 303 Min Prin. Stress = -30. (56% Neg, 8% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 24%

 S1+S2+S3 4S Part 5 (5.3.2) Load Case 2

 28 346 Min Prin. Stress = -30. (56% Neg, 8% NegHi)

 MPa MPa Plot Reference:

 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

 8%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 57 303 Min Prin. Stress = -30. (56% Neg, 8% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 18%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 75 303 Min Prin. Stress = -30. (56% Neg, 8% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 24%

 Membrane User Component Evaluation Load Case 3

 53 303 Min Prin. Stress = -30. (56% Neg, 8% NegHi)

 MPa MPa Plot Reference:

 8) Membrane < User (OPE,Membrane) Case 3

 17%

 Bending User Component Evaluation Load Case 3

 51 303 Min Prin. Stress = -30. (56% Neg, 8% NegHi)

 MPa MPa Plot Reference:

 9) Bending < User (OPE,Bending) Case 3

 16%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 4

 40 303 Min Prin. Stress = -16. (51% Neg, 7% NegHi)

 MPa MPa Plot Reference:

 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

 13%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 4

 34 303 Min Prin. Stress = -16. (51% Neg, 7% NegHi)

 MPa MPa Plot Reference:

 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

 11%

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 40 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.051 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 56,350,524.

 WRC 474 99% Probability Cycles = 13,090,738.

 5% WRC 474 95% Probability Cycles = 18,174,842.

 BS5500 Allowed Cycles(Curve F) = 18,787,830.

 Membrane-to-Bending Ratio = 0.293

 Bending-to-PL+PB+Q Ratio = 0.774

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 34 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.043 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 1.0976E8

 WRC 474 99% Probability Cycles = 25,499,066.

 4% WRC 474 95% Probability Cycles = 35,402,244.

 BS5500 Allowed Cycles(Curve F) = 42,899,516.

 Membrane-to-Bending Ratio = 0.254

 Bending-to-PL+PB+Q Ratio = 0.797

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

 Circ Plate for Plate # 3

 Pl SPL Primary Membrane Load Case 2

 121 130 Min Prin. Stress = -169. (87% Neg, 46% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 93%

 Qb SPS Primary Bending Load Case 2

 184 303 Min Prin. Stress = -169. (87% Neg, 46% NegHi)

 MPa MPa Plot Reference:

 2) Qb < SPS (SUS,Bending) Case 2

 60%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 227 303 Min Prin. Stress = -169. (87% Neg, 46% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 75%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 170 303 Min Prin. Stress = -169. (87% Neg, 46% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 56%

 S1+S2+S3 4S Part 5 (5.3.2) Load Case 2

 171 346 Min Prin. Stress = -169. (87% Neg, 46% NegHi)

 MPa MPa Plot Reference:

 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

 49%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 227 303 Min Prin. Stress = -169. (87% Neg, 46% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 75%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 170 303 Min Prin. Stress = -169. (87% Neg, 46% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 56%

 Membrane User Component Evaluation Load Case 3

 121 303 Min Prin. Stress = -169. (87% Neg, 46% NegHi)

 MPa MPa Plot Reference:

 8) Membrane < User (OPE,Membrane) Case 3

 39%

 Bending User Component Evaluation Load Case 3

 184 303 Min Prin. Stress = -169. (87% Neg, 46% NegHi)

 MPa MPa Plot Reference:

 9) Bending < User (OPE,Bending) Case 3

 60%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 4

 55 303 Min Prin. Stress = -36. (99% Neg, 29% NegHi)

 MPa MPa Plot Reference:

 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

 18%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 4

 34 303 Min Prin. Stress = -36. (99% Neg, 29% NegHi)

 MPa MPa Plot Reference:

 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

 11%

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 55 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.071 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 32,177,282.

 WRC 474 99% Probability Cycles = 7,475,067.

 7% WRC 474 95% Probability Cycles = 10,378,200.

 BS5500 Allowed Cycles(Curve F) = 5,431,522.

 Membrane-to-Bending Ratio = 0.699

 Bending-to-PL+PB+Q Ratio = 0.589

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 34 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.044 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 1.3386E8

 WRC 474 99% Probability Cycles = 31,096,466.

 4% WRC 474 95% Probability Cycles = 43,173,532.

 BS5500 Allowed Cycles(Curve F) = 40,585,156.

 Membrane-to-Bending Ratio = 4.699

 Bending-to-PL+PB+Q Ratio = 0.175

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

 Circ Plate for Plate # 4

 Pl SPL Primary Membrane Load Case 2

 92 130 Min Prin. Stress = -114. (76% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 70%

 Qb SPS Primary Bending Load Case 2

 97 303 Min Prin. Stress = -114. (76% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 2) Qb < SPS (SUS,Bending) Case 2

 32%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 154 303 Min Prin. Stress = -114. (76% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 50%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 107 303 Min Prin. Stress = -114. (76% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 35%

 S1+S2+S3 4S Part 5 (5.3.2) Load Case 2

 143 346 Min Prin. Stress = -114. (76% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

 41%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 154 303 Min Prin. Stress = -114. (76% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 50%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 107 303 Min Prin. Stress = -114. (76% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 35%

 Membrane User Component Evaluation Load Case 3

 92 303 Min Prin. Stress = -114. (76% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 8) Membrane < User (OPE,Membrane) Case 3

 30%

 Bending User Component Evaluation Load Case 3

 97 303 Min Prin. Stress = -114. (76% Neg, 19% NegHi)

 MPa MPa Plot Reference:

 9) Bending < User (OPE,Bending) Case 3

 32%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 4

 28 303 Min Prin. Stress = -19. (60% Neg, 11% NegHi)

 MPa MPa Plot Reference:

 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

 9%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 4

 28 303 Min Prin. Stress = -19. (60% Neg, 11% NegHi)

 MPa MPa Plot Reference:

 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

 9%

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 28 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.036 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 2.4830E8

 WRC 474 99% Probability Cycles = 57,681,924.

 3% WRC 474 95% Probability Cycles = 80,084,096.

 BS5500 Allowed Cycles(Curve F) = 1.0043E8

 Membrane-to-Bending Ratio = 0.992

 Bending-to-PL+PB+Q Ratio = 0.502

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 28 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.036 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 2.5702E8

 WRC 474 99% Probability Cycles = 59,708,216.

 3% WRC 474 95% Probability Cycles = 82,897,344.

 BS5500 Allowed Cycles(Curve F) = 1.0771E8

 Membrane-to-Bending Ratio = 1.230

 Bending-to-PL+PB+Q Ratio = 0.448

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

 Long Plate for Plate # 4

 Pl SPL Primary Membrane Load Case 2

 23 130 Min Prin. Stress = -16. (77% Neg, 10% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 17%

 Qb SPS Primary Bending Load Case 2

 26 303 Min Prin. Stress = -16. (77% Neg, 10% NegHi)

 MPa MPa Plot Reference:

 2) Qb < SPS (SUS,Bending) Case 2

 8%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 24 303 Min Prin. Stress = -16. (77% Neg, 10% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 7%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 38 303 Min Prin. Stress = -16. (77% Neg, 10% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 12%

 S1+S2+S3 4S Part 5 (5.3.2) Load Case 2

 17 346 Min Prin. Stress = -16. (77% Neg, 10% NegHi)

 MPa MPa Plot Reference:

 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

 4%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 24 303 Min Prin. Stress = -16. (77% Neg, 10% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 7%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 38 303 Min Prin. Stress = -16. (77% Neg, 10% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 12%

 Membrane User Component Evaluation Load Case 3

 23 303 Min Prin. Stress = -16. (77% Neg, 10% NegHi)

 MPa MPa Plot Reference:

 8) Membrane < User (OPE,Membrane) Case 3

 7%

 Bending User Component Evaluation Load Case 3

 26 303 Min Prin. Stress = -16. (77% Neg, 10% NegHi)

 MPa MPa Plot Reference:

 9) Bending < User (OPE,Bending) Case 3

 8%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 4

 10 303 Min Prin. Stress = -4. (46% Neg, 8% NegHi)

 MPa MPa Plot Reference:

 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

 3%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 4

 7 303 Min Prin. Stress = -4. (46% Neg, 8% NegHi)

 MPa MPa Plot Reference:

 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

 2%

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 10 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.013 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 2.1819E9

 WRC 474 99% Probability Cycles = 5.0689E8

 1% WRC 474 95% Probability Cycles = 7.0375E8

 BS5500 Allowed Cycles(Curve F) = 7.0539E9

 Membrane-to-Bending Ratio = 0.884

 Bending-to-PL+PB+Q Ratio = 0.531

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 7 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.008 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 504.2

 777.2 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 9.6172E9

 WRC 474 99% Probability Cycles = 2.2342E9

 0% WRC 474 95% Probability Cycles = 3.1018E9

 BS5500 Allowed Cycles(Curve F) = 5.8682E10

 Membrane-to-Bending Ratio = 0.877

 Bending-to-PL+PB+Q Ratio = 0.533

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

 Circ Plate for Plate # 5

 Pl SPL Primary Membrane Load Case 2

 35 130 Min Prin. Stress = -9. (37% Neg, 9% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 26%

 Qb SPS Primary Bending Load Case 2

 23 302 Min Prin. Stress = -9. (37% Neg, 9% NegHi)

 MPa MPa Plot Reference:

 2) Qb < SPS (SUS,Bending) Case 2

 7%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 46 302 Min Prin. Stress = -9. (37% Neg, 9% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 15%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 57 302 Min Prin. Stress = -9. (37% Neg, 9% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 18%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 46 302 Min Prin. Stress = -9. (37% Neg, 9% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 15%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 57 302 Min Prin. Stress = -9. (37% Neg, 9% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 18%

 Membrane User Component Evaluation Load Case 3

 35 302 Min Prin. Stress = -9. (37% Neg, 9% NegHi)

 MPa MPa Plot Reference:

 8) Membrane < User (OPE,Membrane) Case 3

 11%

 Bending User Component Evaluation Load Case 3

 23 302 Min Prin. Stress = -9. (37% Neg, 9% NegHi)

 MPa MPa Plot Reference:

 9) Bending < User (OPE,Bending) Case 3

 7%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 4

 29 302 Min Prin. Stress = -3. (13% Neg, 4% NegHi)

 MPa MPa Plot Reference:

 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

 9%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 4

 28 302 Min Prin. Stress = -3. (13% Neg, 4% NegHi)

 MPa MPa Plot Reference:

 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

 9%

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 29 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.055 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 0.0

 530.5 Markl Fatigue Stress Allowable = 575.0

 MPa WRC 474 Mean Cycles to Failure = 2.0803E8

 WRC 474 99% Probability Cycles = 48,327,864.

 5% WRC 474 95% Probability Cycles = 67,097,160.

 BS5500 Allowed Cycles(Curve F) = 86,841,704.

 Membrane-to-Bending Ratio = 11.897

 Bending-to-PL+PB+Q Ratio = 0.078

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 28 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.054 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 0.0

 530.5 Markl Fatigue Stress Allowable = 575.0

 MPa WRC 474 Mean Cycles to Failure = 2.2691E8

 WRC 474 99% Probability Cycles = 52,713,152.

 5% WRC 474 95% Probability Cycles = 73,185,576.

 BS5500 Allowed Cycles(Curve F) = 99,494,024.

 Membrane-to-Bending Ratio = 7.877

 Bending-to-PL+PB+Q Ratio = 0.113

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

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 Compressive Stress Summary

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 1:33pm NOV 25,2024

 Compressive Stress Summary (MPa) $X

 Nomenclature:

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

 Min Stress - Compressive Membrane and Bending Stress

 Pts in Region - No. of nodes in the model region

 >5% Compression - 5% or more of Compressive Stress Limit

 >50% Compression - 50% or more of Compressive Stress Limit

 Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section

 slenderness ratio (elastic buckling) not considered.

 >5% >50%

 Min Pts Compression

 # Load Type Case Stress in Region and Bending Region

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

 1 SUSTAINED 2 -66. 1920 49% 6% Circ Plate for Plate # 1

 2 OPERATING 3 -66. 1920 49% 6% Circ Plate for Plate # 1

 3 EXPANSION 4 -16. 1920 48% 6% Circ Plate for Plate # 1

 4 SUSTAINED 2 -114. 8424 97% 19% Long Plate for Plate # 1

 5 OPERATING 3 -114. 8424 97% 19% Long Plate for Plate # 1

 6 EXPANSION 4 -32. 8424 91% 15% Long Plate for Plate # 1

 7 SUSTAINED 2 -30. 1568 56% 8% Circ Plate for Plate # 2

 8 OPERATING 3 -30. 1568 56% 8% Circ Plate for Plate # 2

 9 EXPANSION 4 -16. 1568 51% 7% Circ Plate for Plate # 2

 10 SUSTAINED 2 -169. 1600 87% 46% Circ Plate for Plate # 3

 11 OPERATING 3 -169. 1600 87% 46% Circ Plate for Plate # 3

 12 EXPANSION 4 -36. 1600 99% 29% Circ Plate for Plate # 3

 13 SUSTAINED 2 -114. 1440 76% 19% Circ Plate for Plate # 4

 14 OPERATING 3 -114. 1440 76% 19% Circ Plate for Plate # 4

 15 EXPANSION 4 -19. 1440 60% 11% Circ Plate for Plate # 4

 16 SUSTAINED 2 -16. 640 77% 10% Long Plate for Plate # 4

 17 OPERATING 3 -16. 640 77% 10% Long Plate for Plate # 4

 18 EXPANSION 4 -4. 640 46% 8% Long Plate for Plate # 4

 19 SUSTAINED 2 -9. 8624 37% 9% Circ Plate for Plate # 5

 20 OPERATING 3 -9. 8624 37% 9% Circ Plate for Plate # 5

 21 EXPANSION 4 -3. 8624 13% 4% Circ Plate for Plate # 5

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## FINITE ELEMENT FOR AE-2102

**Tabular Results**

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Mon Nov 25 14:42:44 2024.

* [Model Notes, Tube Results and API Check](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2102%5C17208-AE-2102%5COUTPUT_661PRO%5Csetup2.htm#1)
* [Load Case Report](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2102%5C17208-AE-2102%5COUTPUT_661PRO%5Csetup2.htm#2)
* [Solution Data](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2102%5C17208-AE-2102%5COUTPUT_661PRO%5Csetup2.htm#3)
* [ASME Code Stress Output Plots](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2102%5C17208-AE-2102%5COUTPUT_661PRO%5Csetup2.htm#4)
* [Stress Results - Notes](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2102%5C17208-AE-2102%5COUTPUT_661PRO%5Csetup2.htm#5)
* [ASME Overstressed Areas](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2102%5C17208-AE-2102%5COUTPUT_661PRO%5Csetup2.htm#6)
* [Highest Primary Stress Ratios](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2102%5C17208-AE-2102%5COUTPUT_661PRO%5Csetup2.htm#7)
* [Highest Secondary Stress Ratios](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2102%5C17208-AE-2102%5COUTPUT_661PRO%5Csetup2.htm#8)
* [Highest Fatigue Stress Ratios](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2102%5C17208-AE-2102%5COUTPUT_661PRO%5Csetup2.htm#9)
* [Highest Stress Ratios Per Region](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2102%5C17208-AE-2102%5COUTPUT_661PRO%5Csetup2.htm#10)
* [Compressive Stress Summary](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2102%5C17208-AE-2102%5COUTPUT_661PRO%5Csetup2.htm#11)
* [Graphical Results](file:///F%3A%5CSH.A%5CAir%20Cooler%5C17208%5CCalculation%5CRev.02%5CMechanical%20Cal%5CNozzle%20PRO%5CAE-2102%5C17208-AE-2102%5COUTPUT_661PRO%5Csetup2-ppics.htm)

 Model Notes, Tube Results and API Check

 Model Notes, Tube Results and API Check

 661PRO 3.0 - API 661 - Air-Cooled Heat Exchanger Nozzle Model

 Input Echo:

 Notes:

 - The centerline of the header box is along the -Z axis.

 - Only 1 Nozzle will be modeled at a time. The Nozzle Number

 Modeled can be seen below.

 - User Defined Loads API 661 Check is shown below.

 - Sum of ALL Nozzle Loads must not exceed 3\*API Allowable

 Loads shown in paragraph 7.1.10.2 according to API 661

 2013 paragraph 7.1.10.3.

 - Results are given as: Actual Load, Allowable Load,

 percentage of allowable for API Check in lbs. and ft-lbs. for

 English Units and N. and N-m for SI Units.

 Nozzle Number Modelled : 1

 Top or Bottom Nozzle : Top

 Analysis Type : User Defined Loads

 Nozzle Type : Straight

 Flange Type : Weldneck

 Header Box Dimensions:

 Centerline on :Centerline on LEFT Side

 Height : 485.000 mm.

 Width : 166.000 mm.

 Length : 2135.000 mm.

 Outboard Thickness : 28.000 mm.

 Tubesheet Side Thickness : 28.000 mm.

 Top Plate Thickness : 20.000 mm.

 Free End Plate Thickness : 20.000 mm.

 Header Box Pressure : 6.200 MPa

 Symmetric Boundary Condition at Centerline

 Parition Plates:

 Number of Partition Plates : 2

 Partition Plate #1

 Plate Elevation from Bottom : 130.000 mm.

 Plate Thickness : 10.000 mm.

 Partition Plate #2

 Plate Elevation from Bottom : 305.000 mm.

 Plate Thickness : 10.000 mm.

 Nozzle Dimensions:

 Distance to CenterLine : 1067.500 mm.

 Nozzle Outside Diameter : 114.300 mm.

 Nozzle Thickness : 7.500 mm.

 Projection to Face of Flange : 320.000 mm.

 Flange Thickness Used : 27.300 mm.

 Flange ID : 154.059 mm.

 Flange Hub Length Used : 40.950 mm.

 Weld Size and SCF : 0.000, 1.350

 Engineering Details:

 Operating Cycles : 7000

 Occasional Cycles : 0

 Ambient Temperature : 21.100 deg.

 Computation Type : Gauss Average

 Material Properties

 Nozzle:

 Cold Allowable Stress : 115.100 MPa

 Hot Allowable Stress : 111.900 MPa

 Elastic Modulus : 0.184E+06 MPa

 Poissons Ratio : 0.300

 Material ID :4-Austenitic Steels

 Density : 0.000E+00 N /cu. mm.

 Cold Yield Stress : 172.400 MPa

 Hot Yield Stress : 126.100 MPa

 Cold Tensile Stress : 482.700 MPa

 Density : 0.000E+00 N /cu. mm.

 Header Box:

 Cold Allowable Stress : 115.100 MPa

 Hot Allowable Stress : 111.900 MPa

 Elastic Modulus : 0.184E+06 MPa

 Poissons Ratio : 0.300

 Material ID :4-Austenitic Steels

 Density : 0.000E+00 N /cu. mm.

 Cold Yield Stress : 172.400 MPa

 Hot Yield Stress : 126.100 MPa

 Cold Tensile Stress : 482.700 MPa

 Density : 0.000E+00 N /cu. mm.

 Tubesheet was not modeled

 User Defined Loads:

 Forces [ N ] Moments [ mm.- N ]

 FX FY FZ MX MY MZ

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

 Weight 10020 8010 10020 2430000 3660000 2430000

 Operating 10020 8010 10020 2430000 3660000 2430000

 Occasional 0 0 0 0 0 0

 No Tube Results

 API Check for User Defined Loads and API Evaluation

 API 661 2013 paragraph 7.1.10.2 and 7.1.10.3.

 Results below are shown as:

 Actual Load, Allowable Load, % of Allowable

 Allowable Load: 3x API Allowable from para. 7.1.10.2

 Total Nozzle Loads per DOF in [N and N.m]

 Global FX : 10020, 15015, 66 %

 Global FY : 8010, 30030, 26 %

 Global FZ : 10020, 25020, 40 %

 Global MX : 2430, 9150, 26 %

 Global MY : 3660, 12195, 30 %

 Global MZ : 2430, 6105, 39 %

 API 661 para. 7.1.10.3 check PASSED. The summation of

 all nozzle loads did NOT exceed the 1.5x API value from

 para. 7.1.10.2.

 Symmetric boundary condition applied at the center of the

 headerbox, the API multiplier from paragraph 7.1.10.3 will

 be 1.5 since total loads will be 2x larger due to symmetry.

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 Load Case Report

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 2:39pm NOV 25,2024

 Load Case Report $X

 Inner and outer element temperatures are the same

 throughout the model. No thermal ratcheting

 calculations will be performed.

 THE 4 LOAD CASES ANALYZED ARE:

 1 WEIGHT ONLY (Wgt Only)

 Weight ONLY case run to get the stress range

 between the installed and the operating states.

 /-------- Loads in Case 1

 Loads due to Weight

 2 SUSTAINED (Wgt+Pr)

 Sustained case run to satisfy local primary

 membrane and bending stress limits.

 /-------- Loads in Case 2

 Loads due to Weight

 Pressure Case 1

 3 OPERATING

 Case run to compute the operating stresses used in

 secondary, peak and range calculations as needed.

 /-------- Loads in Case 3

 Pressure Case 1

 Loads from (Operating)

 4 RANGE (Fatigue Calc Performed)

 Case run to get the RANGE of stresses.

 as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

 /-------- Combinations in Range Case 4

 Plus Stress Results from CASE 3

 Minus Stress Results from CASE 1

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 Solution Data

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 2:40pm NOV 25,2024

 Solution Data

 Maximum Solution Row Size = 2370

 Number of Nodes = 13048

 Number of Elements = 4400

 Number of Solution Cases = 3

 Summation of Loads per Case

 Case # FX FY FZ

 1 10020. 56025. 10020.

 2 10020. -119625. -387834.

 3 10020. -119625. -387834.

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 ASME Code Stress Output Plots

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 2:42pm NOV 25,2024

 ASME Code Stress Output Plots $X

 1) Pl < SPL (SUS,Membrane) Case 2

 2) Qb < SPS (SUS,Bending) Case 2

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 8) Membrane < User (OPE,Membrane) Case 3

 9) Bending < User (OPE,Bending) Case 3

 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

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 Stress Results - Notes

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 2:42pm NOV 25,2024

 Stress Results - Notes

 - Results in this analysis were generated using the finite

 element solution method.

 - Using 2019 ASME Section VIII Division 2

 - Use Polished Bar fatigue curve.

 - Ratio between Operating and Design Pressure = 1.000000

 Range cases use operating pressure. Primary cases

 use design pressure.

 - Assume free end displacements of attached pipe

 (e.g. thermal loads) are secondary loads.

 - Primary bending stresses at discontinuities

 are treated like secondary stresses. (Pb=0)

 - Use Equivalent Stress (Von Mises).

 - TRIAXIAL Stress Guidelines:

 S1+S2+S3 evaluation omitted from operating stress.

 Include S1+S2+S3 evaluation in primary case evaluation.

 Bending stress NOT included for all S1+S2+S3 calculations.

 - Use local tensor values for averaged and not averaged stresses.

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 ASME Overstressed Areas

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 2:42pm NOV 25,2024

 ASME Overstressed Areas $X

 \*\*\* NO OVERSTRESSED NODES IN THIS MODEL \*\*\*

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 Highest Primary Stress Ratios

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 2:42pm NOV 25,2024

 Highest Primary Stress Ratios $X

 Circ Plate for Plate # 1

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 126 340 Min Prin. Stress = -51. (57% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 36%

 Long Plate for Plate # 1

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 241 340 Min Prin. Stress = -125. (92% Neg, 27% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 70%

 Circ Plate for Plate # 2

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 104 340 Min Prin. Stress = -31. (58% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 30%

 Circ Plate for Plate # 3

 Pl SPL Primary Membrane Load Case 2

 146 168 Min Prin. Stress = -189. (76% Neg, 47% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 86%

 Circ Plate for Plate # 4

 Pl SPL Primary Membrane Load Case 2

 122 168 Min Prin. Stress = -172. (69% Neg, 22% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 72%

 Long Plate for Plate # 4

 Pl SPL Primary Membrane Load Case 2

 27 168 Min Prin. Stress = -18. (75% Neg, 4% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 15%

 Circ Plate for Plate # 5

 Pl SPL Primary Membrane Load Case 2

 118 126 Min Prin. Stress = -7. (10% Neg, 2% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 93%

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 Highest Secondary Stress Ratios

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 2:42pm NOV 25,2024

 Highest Secondary Stress Ratios $X

 In combination case 4 the max range stress divided

 by the max component stress is 1.85. The case tensor components

 are in some directions additive and so the combination

 case will have HIGHER stresses than the largest of any

 of the individual cases by more than 50%.

 Load Combined/Max Combined/Max

 Case (Inside) (Outside)

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

 4 1.849 1.663

 Circ Plate for Plate # 1

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 126 340 Min Prin. Stress = -51. (57% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 36%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 126 340 Min Prin. Stress = -51. (57% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 36%

 Long Plate for Plate # 1

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 241 340 Min Prin. Stress = -125. (92% Neg, 27% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 70%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 241 340 Min Prin. Stress = -125. (92% Neg, 27% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 70%

 Circ Plate for Plate # 2

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 104 340 Min Prin. Stress = -31. (58% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 30%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 104 340 Min Prin. Stress = -31. (58% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 30%

 Circ Plate for Plate # 3

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 256 340 Min Prin. Stress = -189. (76% Neg, 47% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 75%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 256 340 Min Prin. Stress = -189. (76% Neg, 47% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 75%

 Circ Plate for Plate # 4

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 211 340 Min Prin. Stress = -172. (69% Neg, 22% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 61%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 211 340 Min Prin. Stress = -172. (69% Neg, 22% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 61%

 Long Plate for Plate # 4

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 46 340 Min Prin. Stress = -18. (75% Neg, 4% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 13%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 46 340 Min Prin. Stress = -18. (75% Neg, 4% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 13%

 Circ Plate for Plate # 5

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 126 298 Min Prin. Stress = -7. (10% Neg, 2% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 42%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 126 298 Min Prin. Stress = -7. (10% Neg, 2% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 42%

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 Highest Fatigue Stress Ratios

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 2:42pm NOV 25,2024

 Highest Fatigue Stress Ratios $X

 Circ Plate for Plate # 1

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 126 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.163 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 771.0 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 1,528,132.

 WRC 474 99% Probability Cycles = 354,999.

 16% WRC 474 95% Probability Cycles = 492,872.

 BS5500 Allowed Cycles(Curve F) = 464,450.

 Membrane-to-Bending Ratio = 0.370

 Bending-to-PL+PB+Q Ratio = 0.730

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

 Long Plate for Plate # 1

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 164 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.213 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 771.0 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 667,819.

 WRC 474 99% Probability Cycles = 155,140.

 21% WRC 474 95% Probability Cycles = 215,393.

 BS5500 Allowed Cycles(Curve F) = 208,596.

 Membrane-to-Bending Ratio = 0.308

 Bending-to-PL+PB+Q Ratio = 0.764

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

 Circ Plate for Plate # 2

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 74 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.096 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 770.9 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 6,294,933.

 WRC 474 99% Probability Cycles = 1,462,370.

 9% WRC 474 95% Probability Cycles = 2,030,317.

 BS5500 Allowed Cycles(Curve F) = 1,906,701.

 Membrane-to-Bending Ratio = 0.239

 Bending-to-PL+PB+Q Ratio = 0.807

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Circ Plate for Plate # 3

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 132 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.172 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 770.9 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 2,294,650.

 WRC 474 99% Probability Cycles = 533,068.

 17% WRC 474 95% Probability Cycles = 740,098.

 BS5500 Allowed Cycles(Curve F) = 399,227.

 Membrane-to-Bending Ratio = 1.204

 Bending-to-PL+PB+Q Ratio = 0.454

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Circ Plate for Plate # 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 108 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.140 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 770.9 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 4,468,199.

 WRC 474 99% Probability Cycles = 1,038,003.

 13% WRC 474 95% Probability Cycles = 1,441,137.

 BS5500 Allowed Cycles(Curve F) = 736,712.

 Membrane-to-Bending Ratio = 0.786

 Bending-to-PL+PB+Q Ratio = 0.560

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Long Plate for Plate # 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 32 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.042 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 770.9 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 63,477,656.

 WRC 474 99% Probability Cycles = 14,746,436.

 4% WRC 474 95% Probability Cycles = 20,473,570.

 BS5500 Allowed Cycles(Curve F) = 27,561,694.

 Membrane-to-Bending Ratio = 0.845

 Bending-to-PL+PB+Q Ratio = 0.542

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Circ Plate for Plate # 5

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 120 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.227 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.3893E8

 Allowable "B31" Fatigue Stress Allowable = 0.0

 526.2 Markl Fatigue Stress Allowable = 575.0

 MPa WRC 474 Mean Cycles to Failure = 2,470,444.

 WRC 474 99% Probability Cycles = 573,907.

 22% WRC 474 95% Probability Cycles = 796,797.

 BS5500 Allowed Cycles(Curve F) = 541,237.

 Membrane-to-Bending Ratio = 66.351

 Bending-to-PL+PB+Q Ratio = 0.015

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

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 Highest Stress Ratios Per Region

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 2:42pm NOV 25,2024

 Highest Stress Ratios Per Region $X

 Circ Plate for Plate # 1

 Pl SPL Primary Membrane Load Case 2

 41 168 Min Prin. Stress = -51. (57% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 24%

 Qb SPS Primary Bending Load Case 2

 104 340 Min Prin. Stress = -51. (57% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 2) Qb < SPS (SUS,Bending) Case 2

 30%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 97 340 Min Prin. Stress = -51. (57% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 28%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 126 340 Min Prin. Stress = -51. (57% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 36%

 S1+S2+S3 4S Part 5 (5.3.2) Load Case 2

 71 448 Min Prin. Stress = -51. (57% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

 15%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 97 340 Min Prin. Stress = -51. (57% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 28%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 126 340 Min Prin. Stress = -51. (57% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 36%

 Membrane User Component Evaluation Load Case 3

 41 340 Min Prin. Stress = -51. (57% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 8) Membrane < User (OPE,Membrane) Case 3

 11%

 Bending User Component Evaluation Load Case 3

 104 340 Min Prin. Stress = -51. (57% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 9) Bending < User (OPE,Bending) Case 3

 30%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 4

 94 340 Min Prin. Stress = -35. (57% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

 27%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 4

 126 340 Min Prin. Stress = -35. (57% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

 36%

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 94 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.123 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 771.0 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 4,582,710.

 WRC 474 99% Probability Cycles = 1,064,605.

 12% WRC 474 95% Probability Cycles = 1,478,070.

 BS5500 Allowed Cycles(Curve F) = 1,096,921.

 Membrane-to-Bending Ratio = 0.370

 Bending-to-PL+PB+Q Ratio = 0.730

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 126 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.163 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 771.0 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 1,528,132.

 WRC 474 99% Probability Cycles = 354,999.

 16% WRC 474 95% Probability Cycles = 492,872.

 BS5500 Allowed Cycles(Curve F) = 464,450.

 Membrane-to-Bending Ratio = 0.370

 Bending-to-PL+PB+Q Ratio = 0.730

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

 Long Plate for Plate # 1

 Pl SPL Primary Membrane Load Case 2

 109 168 Min Prin. Stress = -125. (92% Neg, 27% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 64%

 Qb SPS Primary Bending Load Case 2

 194 340 Min Prin. Stress = -125. (92% Neg, 27% NegHi)

 MPa MPa Plot Reference:

 2) Qb < SPS (SUS,Bending) Case 2

 57%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 175 340 Min Prin. Stress = -125. (92% Neg, 27% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 51%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 241 340 Min Prin. Stress = -125. (92% Neg, 27% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 70%

 S1+S2+S3 4S Part 5 (5.3.2) Load Case 2

 123 448 Min Prin. Stress = -125. (92% Neg, 27% NegHi)

 MPa MPa Plot Reference:

 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

 27%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 175 340 Min Prin. Stress = -125. (92% Neg, 27% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 51%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 241 340 Min Prin. Stress = -125. (92% Neg, 27% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 70%

 Membrane User Component Evaluation Load Case 3

 109 340 Min Prin. Stress = -125. (92% Neg, 27% NegHi)

 MPa MPa Plot Reference:

 8) Membrane < User (OPE,Membrane) Case 3

 32%

 Bending User Component Evaluation Load Case 3

 194 340 Min Prin. Stress = -125. (92% Neg, 27% NegHi)

 MPa MPa Plot Reference:

 9) Bending < User (OPE,Bending) Case 3

 57%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 4

 124 340 Min Prin. Stress = -64. (90% Neg, 22% NegHi)

 MPa MPa Plot Reference:

 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

 36%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 4

 164 340 Min Prin. Stress = -64. (90% Neg, 22% NegHi)

 MPa MPa Plot Reference:

 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

 48%

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 124 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.161 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 771.0 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 1,723,323.

 WRC 474 99% Probability Cycles = 400,344.

 16% WRC 474 95% Probability Cycles = 555,827.

 BS5500 Allowed Cycles(Curve F) = 484,575.

 Membrane-to-Bending Ratio = 0.302

 Bending-to-PL+PB+Q Ratio = 0.768

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 164 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.213 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 771.0 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 667,819.

 WRC 474 99% Probability Cycles = 155,140.

 21% WRC 474 95% Probability Cycles = 215,393.

 BS5500 Allowed Cycles(Curve F) = 208,596.

 Membrane-to-Bending Ratio = 0.308

 Bending-to-PL+PB+Q Ratio = 0.764

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

 Circ Plate for Plate # 2

 Pl SPL Primary Membrane Load Case 2

 42 168 Min Prin. Stress = -31. (58% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 24%

 Qb SPS Primary Bending Load Case 2

 88 340 Min Prin. Stress = -31. (58% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 2) Qb < SPS (SUS,Bending) Case 2

 25%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 79 340 Min Prin. Stress = -31. (58% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 23%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 104 340 Min Prin. Stress = -31. (58% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 30%

 S1+S2+S3 4S Part 5 (5.3.2) Load Case 2

 70 448 Min Prin. Stress = -31. (58% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

 15%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 79 340 Min Prin. Stress = -31. (58% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 23%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 104 340 Min Prin. Stress = -31. (58% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 30%

 Membrane User Component Evaluation Load Case 3

 42 340 Min Prin. Stress = -31. (58% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 8) Membrane < User (OPE,Membrane) Case 3

 12%

 Bending User Component Evaluation Load Case 3

 88 340 Min Prin. Stress = -31. (58% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 9) Bending < User (OPE,Bending) Case 3

 25%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 4

 74 340 Min Prin. Stress = -29. (55% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

 21%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 4

 73 340 Min Prin. Stress = -29. (55% Neg, 0% NegHi)

 MPa MPa Plot Reference:

 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

 21%

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 74 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.096 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 770.9 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 6,294,933.

 WRC 474 99% Probability Cycles = 1,462,370.

 9% WRC 474 95% Probability Cycles = 2,030,317.

 BS5500 Allowed Cycles(Curve F) = 1,906,701.

 Membrane-to-Bending Ratio = 0.239

 Bending-to-PL+PB+Q Ratio = 0.807

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 73 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.094 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 770.9 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 6,843,380.

 WRC 474 99% Probability Cycles = 1,589,780.

 9% WRC 474 95% Probability Cycles = 2,207,209.

 BS5500 Allowed Cycles(Curve F) = 2,014,515.

 Membrane-to-Bending Ratio = 0.379

 Bending-to-PL+PB+Q Ratio = 0.725

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

 Circ Plate for Plate # 3

 Pl SPL Primary Membrane Load Case 2

 146 168 Min Prin. Stress = -189. (76% Neg, 47% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 86%

 Qb SPS Primary Bending Load Case 2

 162 340 Min Prin. Stress = -189. (76% Neg, 47% NegHi)

 MPa MPa Plot Reference:

 2) Qb < SPS (SUS,Bending) Case 2

 47%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 256 340 Min Prin. Stress = -189. (76% Neg, 47% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 75%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 154 340 Min Prin. Stress = -189. (76% Neg, 47% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 45%

 S1+S2+S3 4S Part 5 (5.3.2) Load Case 2

 147 448 Min Prin. Stress = -189. (76% Neg, 47% NegHi)

 MPa MPa Plot Reference:

 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

 32%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 256 340 Min Prin. Stress = -189. (76% Neg, 47% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 75%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 154 340 Min Prin. Stress = -189. (76% Neg, 47% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 45%

 Membrane User Component Evaluation Load Case 3

 146 340 Min Prin. Stress = -189. (76% Neg, 47% NegHi)

 MPa MPa Plot Reference:

 8) Membrane < User (OPE,Membrane) Case 3

 42%

 Bending User Component Evaluation Load Case 3

 162 340 Min Prin. Stress = -189. (76% Neg, 47% NegHi)

 MPa MPa Plot Reference:

 9) Bending < User (OPE,Bending) Case 3

 47%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 4

 132 340 Min Prin. Stress = -105. (99% Neg, 54% NegHi)

 MPa MPa Plot Reference:

 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

 38%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 4

 100 340 Min Prin. Stress = -105. (99% Neg, 54% NegHi)

 MPa MPa Plot Reference:

 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

 29%

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 132 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.172 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 770.9 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 2,294,650.

 WRC 474 99% Probability Cycles = 533,068.

 17% WRC 474 95% Probability Cycles = 740,098.

 BS5500 Allowed Cycles(Curve F) = 399,227.

 Membrane-to-Bending Ratio = 1.204

 Bending-to-PL+PB+Q Ratio = 0.454

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 100 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.130 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 770.9 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 5,276,676.

 WRC 474 99% Probability Cycles = 1,225,820.

 12% WRC 474 95% Probability Cycles = 1,701,896.

 BS5500 Allowed Cycles(Curve F) = 925,016.

 Membrane-to-Bending Ratio = 26.654

 Bending-to-PL+PB+Q Ratio = 0.036

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

 Circ Plate for Plate # 4

 Pl SPL Primary Membrane Load Case 2

 122 168 Min Prin. Stress = -172. (69% Neg, 22% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 72%

 Qb SPS Primary Bending Load Case 2

 129 340 Min Prin. Stress = -172. (69% Neg, 22% NegHi)

 MPa MPa Plot Reference:

 2) Qb < SPS (SUS,Bending) Case 2

 37%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 211 340 Min Prin. Stress = -172. (69% Neg, 22% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 61%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 149 340 Min Prin. Stress = -172. (69% Neg, 22% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 43%

 S1+S2+S3 4S Part 5 (5.3.2) Load Case 2

 151 448 Min Prin. Stress = -172. (69% Neg, 22% NegHi)

 MPa MPa Plot Reference:

 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

 33%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 211 340 Min Prin. Stress = -172. (69% Neg, 22% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 61%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 149 340 Min Prin. Stress = -172. (69% Neg, 22% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 43%

 Membrane User Component Evaluation Load Case 3

 122 340 Min Prin. Stress = -172. (69% Neg, 22% NegHi)

 MPa MPa Plot Reference:

 8) Membrane < User (OPE,Membrane) Case 3

 35%

 Bending User Component Evaluation Load Case 3

 129 340 Min Prin. Stress = -172. (69% Neg, 22% NegHi)

 MPa MPa Plot Reference:

 9) Bending < User (OPE,Bending) Case 3

 37%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 4

 108 340 Min Prin. Stress = -73. (77% Neg, 22% NegHi)

 MPa MPa Plot Reference:

 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

 31%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 4

 106 340 Min Prin. Stress = -73. (77% Neg, 22% NegHi)

 MPa MPa Plot Reference:

 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

 31%

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 108 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.140 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 770.9 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 4,468,199.

 WRC 474 99% Probability Cycles = 1,038,003.

 13% WRC 474 95% Probability Cycles = 1,441,137.

 BS5500 Allowed Cycles(Curve F) = 736,712.

 Membrane-to-Bending Ratio = 0.786

 Bending-to-PL+PB+Q Ratio = 0.560

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 106 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.137 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 770.9 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 4,657,004.

 WRC 474 99% Probability Cycles = 1,081,864.

 13% WRC 474 95% Probability Cycles = 1,502,033.

 BS5500 Allowed Cycles(Curve F) = 777,781.

 Membrane-to-Bending Ratio = 1.095

 Bending-to-PL+PB+Q Ratio = 0.477

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

 Long Plate for Plate # 4

 Pl SPL Primary Membrane Load Case 2

 27 168 Min Prin. Stress = -18. (75% Neg, 4% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 15%

 Qb SPS Primary Bending Load Case 2

 37 340 Min Prin. Stress = -18. (75% Neg, 4% NegHi)

 MPa MPa Plot Reference:

 2) Qb < SPS (SUS,Bending) Case 2

 10%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 38 340 Min Prin. Stress = -18. (75% Neg, 4% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 11%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 46 340 Min Prin. Stress = -18. (75% Neg, 4% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 13%

 S1+S2+S3 4S Part 5 (5.3.2) Load Case 2

 21 448 Min Prin. Stress = -18. (75% Neg, 4% NegHi)

 MPa MPa Plot Reference:

 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

 4%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 38 340 Min Prin. Stress = -18. (75% Neg, 4% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 11%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 46 340 Min Prin. Stress = -18. (75% Neg, 4% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 13%

 Membrane User Component Evaluation Load Case 3

 27 340 Min Prin. Stress = -18. (75% Neg, 4% NegHi)

 MPa MPa Plot Reference:

 8) Membrane < User (OPE,Membrane) Case 3

 7%

 Bending User Component Evaluation Load Case 3

 37 340 Min Prin. Stress = -18. (75% Neg, 4% NegHi)

 MPa MPa Plot Reference:

 9) Bending < User (OPE,Bending) Case 3

 10%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 4

 32 340 Min Prin. Stress = -14. (87% Neg, 5% NegHi)

 MPa MPa Plot Reference:

 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

 9%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 4

 20 340 Min Prin. Stress = -14. (87% Neg, 5% NegHi)

 MPa MPa Plot Reference:

 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

 5%

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 32 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.042 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 770.9 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 63,477,656.

 WRC 474 99% Probability Cycles = 14,746,436.

 4% WRC 474 95% Probability Cycles = 20,473,570.

 BS5500 Allowed Cycles(Curve F) = 27,561,694.

 Membrane-to-Bending Ratio = 0.845

 Bending-to-PL+PB+Q Ratio = 0.542

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 20 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.026 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.0000E11

 Allowable "B31" Fatigue Stress Allowable = 567.5

 770.9 Markl Fatigue Stress Allowable = 659.5

 MPa WRC 474 Mean Cycles to Failure = 3.3666E8

 WRC 474 99% Probability Cycles = 78,208,688.

 2% WRC 474 95% Probability Cycles = 1.0858E8

 BS5500 Allowed Cycles(Curve F) = 2.8954E8

 Membrane-to-Bending Ratio = 0.834

 Bending-to-PL+PB+Q Ratio = 0.545

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

 Circ Plate for Plate # 5

 Pl SPL Primary Membrane Load Case 2

 118 126 Min Prin. Stress = -7. (10% Neg, 2% NegHi)

 MPa MPa Plot Reference:

 1) Pl < SPL (SUS,Membrane) Case 2

 93%

 Qb SPS Primary Bending Load Case 2

 41 298 Min Prin. Stress = -7. (10% Neg, 2% NegHi)

 MPa MPa Plot Reference:

 2) Qb < SPS (SUS,Bending) Case 2

 13%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 2

 126 298 Min Prin. Stress = -7. (10% Neg, 2% NegHi)

 MPa MPa Plot Reference:

 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

 42%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 2

 123 298 Min Prin. Stress = -7. (10% Neg, 2% NegHi)

 MPa MPa Plot Reference:

 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

 41%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 3

 126 298 Min Prin. Stress = -7. (10% Neg, 2% NegHi)

 MPa MPa Plot Reference:

 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

 42%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 3

 123 298 Min Prin. Stress = -7. (10% Neg, 2% NegHi)

 MPa MPa Plot Reference:

 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

 41%

 Membrane User Component Evaluation Load Case 3

 118 298 Min Prin. Stress = -7. (10% Neg, 2% NegHi)

 MPa MPa Plot Reference:

 8) Membrane < User (OPE,Membrane) Case 3

 39%

 Bending User Component Evaluation Load Case 3

 41 298 Min Prin. Stress = -7. (10% Neg, 2% NegHi)

 MPa MPa Plot Reference:

 9) Bending < User (OPE,Bending) Case 3

 13%

 Pl+Pb+Q SPS Primary+Secondary (Inner) Load Case 4

 120 298 Min Prin. Stress = -5. ( 7% Neg, 2% NegHi)

 MPa MPa Plot Reference:

 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

 40%

 Pl+Pb+Q SPS Primary+Secondary (Outer) Load Case 4

 116 298 Min Prin. Stress = -5. ( 7% Neg, 2% NegHi)

 MPa MPa Plot Reference:

 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

 38%

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Inner) Load Case 4

 120 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.227 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 1.3893E8

 Allowable "B31" Fatigue Stress Allowable = 0.0

 526.2 Markl Fatigue Stress Allowable = 575.0

 MPa WRC 474 Mean Cycles to Failure = 2,470,444.

 WRC 474 99% Probability Cycles = 573,907.

 22% WRC 474 95% Probability Cycles = 796,797.

 BS5500 Allowed Cycles(Curve F) = 541,237.

 Membrane-to-Bending Ratio = 66.351

 Bending-to-PL+PB+Q Ratio = 0.015

 Plot Reference:

 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

 Pl+Pb+Q+F Damage Ratio Primary+Secondary+Peak (Outer) Load Case 4

 116 0.000 Life Stress Concentration Factor = 1.000

 MPa 0.221 Stress Strain Concentration Factor = 1.000

 Cycles Allowed for this Stress = 2.4288E8

 Allowable "B31" Fatigue Stress Allowable = 0.0

 526.2 Markl Fatigue Stress Allowable = 575.0

 MPa WRC 474 Mean Cycles to Failure = 2,701,216.

 WRC 474 99% Probability Cycles = 627,517.

 22% WRC 474 95% Probability Cycles = 871,228.

 BS5500 Allowed Cycles(Curve F) = 589,676.

 Membrane-to-Bending Ratio = 66.363

 Bending-to-PL+PB+Q Ratio = 0.015

 Plot Reference:

 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

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 Compressive Stress Summary

 FEPipe Version 15.0 Jobname: setup2 $P

 Released Jan. 2021 2:42pm NOV 25,2024

 Compressive Stress Summary (MPa) $X

 Nomenclature:

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 Min Stress - Compressive Membrane and Bending Stress

 Pts in Region - No. of nodes in the model region

 >5% Compression - 5% or more of Compressive Stress Limit

 >50% Compression - 50% or more of Compressive Stress Limit

 Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section

 slenderness ratio (elastic buckling) not considered.

 >5% >50%

 Min Pts Compression

 # Load Type Case Stress in Region and Bending Region

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

 1 SUSTAINED 2 -51. 2560 57% 0% Circ Plate for Plate # 1

 2 OPERATING 3 -51. 2560 57% 0% Circ Plate for Plate # 1

 3 EXPANSION 4 -35. 2560 57% 0% Circ Plate for Plate # 1

 4 SUSTAINED 2 -125. 13480 92% 27% Long Plate for Plate # 1

 5 OPERATING 3 -125. 13480 92% 27% Long Plate for Plate # 1

 6 EXPANSION 4 -64. 13480 90% 22% Long Plate for Plate # 1

 7 SUSTAINED 2 -31. 1800 58% 0% Circ Plate for Plate # 2

 8 OPERATING 3 -31. 1800 58% 0% Circ Plate for Plate # 2

 9 EXPANSION 4 -29. 1800 55% 0% Circ Plate for Plate # 2

 10 SUSTAINED 2 -189. 1600 76% 47% Circ Plate for Plate # 3

 11 OPERATING 3 -189. 1600 76% 47% Circ Plate for Plate # 3

 12 EXPANSION 4 -105. 1600 99% 54% Circ Plate for Plate # 3

 13 SUSTAINED 2 -172. 1440 69% 22% Circ Plate for Plate # 4

 14 OPERATING 3 -172. 1440 69% 22% Circ Plate for Plate # 4

 15 EXPANSION 4 -73. 1440 77% 22% Circ Plate for Plate # 4

 16 SUSTAINED 2 -18. 640 75% 4% Long Plate for Plate # 4

 17 OPERATING 3 -18. 640 75% 4% Long Plate for Plate # 4

 18 EXPANSION 4 -14. 640 87% 5% Long Plate for Plate # 4

 19 SUSTAINED 2 -7. 13680 10% 2% Circ Plate for Plate # 5

 20 OPERATING 3 -7. 13680 10% 2% Circ Plate for Plate # 5

 21 EXPANSION 4 -5. 13680 7% 2% Circ Plate for Plate # 5

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