|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **طرح نگهداشت و افزایش تولید 27 مخزن** | | | | | | | |
| **Thermal/Mechnical Calculation Book**  **نگهداشت و افزایش تولید میدان نفتی بینک** | | | | | | | |
| V05 | Jan.2025 | AFC | AAC | M.FAKHARIAN | S.FRAMARZPOUR |  |
| V04 | Nov.2024 | AFC | AAC | M.FAKHARIAN | M.SADEGHIAN |  |
| V03 | Oct.2024 | AFC | AAC | M.FAKHARIAN | M.SADEGHIAN |  |
| V02 | Jul.2024 | IFA | AAC | M.FAKHARIAN | M.SADEGHIAN |  |
| V01 | Mar.2024 | IFA | AAC | M.FAKHARIAN | S.FRAMARZPOUR |  |
| V00 | Nov.2023 | IFA | AAC | M.FAKHARIAN | S.FRAMARZPOUR |  |
| **Rev.** | **Date** | **Purpose of Issue/Status** | **Prepared by:** | **Checked by:** | **Approved by:** | **CLIENT Approval** |
|  | | | | | | |
| **Status:** | **IFA: Issued For Approval**  **IFI: Issued For Information**  **AFC: Approved For Construction** | | | | | |

**REVISION RECORD SHEET**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **PAGE** | **V00** | **V01** | **V02** | **V03** | **V04** | **V05** |  | **PAGE** | **V00** | **V01** | **V02** | **V03** | **V04** | **V05** |
| **1** | X | X | X | X | X | X |  | **66** |  |  | X | X | X |  |
| **2** | X | X | X | X | X | X | **67** |  |  | X | X | X |  |
| **3** | X |  | X | X | X | X | **68** |  |  | X | X | X |  |
| **4** | X |  | X | X | X |  | **69** |  |  | X | X | X |  |
| **5** | X | X | X |  | X |  | **70** |  |  | X | X | X |  |
| **6** | X | X | X | X | X |  | **71** |  |  | X | X | X |  |
| **7** | X | X | X | X | X |  | **72** |  |  | X | X | X |  |
| **8** | X | X | X | X | X |  | **73** |  |  | X | X | X |  |
| **9** |  |  | X | X | X | X | **74** |  |  | X | X | X |  |
| **10** |  |  | X | X | X | X | **75** |  |  | X |  | X |  |
| **11** |  |  | X | X | X |  | **76** |  |  | X |  | X |  |
| **12** |  |  | X | X | X |  | **77** |  |  | X |  | X |  |
| **13** |  |  | X | X | X |  | **78** |  |  | X |  | X |  |
| **14** |  |  | X | X | X |  | **79** |  |  | X |  | X |  |
| **15** |  |  | X | X | X |  | **80** |  |  | X |  | X |  |
| **16** |  |  | X | X | X |  | **81** |  |  | X |  | X |  |
| **17** |  |  | X | X | X |  | **82** |  |  | X |  | X |  |
| **18** |  |  | X | X | X |  | **83** |  |  | X |  | X |  |
| **19** |  |  | X | X | X |  | **84** |  |  | X |  | X |  |
| **20** |  |  | X | X | X |  | **85** |  |  | X |  | X |  |
| **21** |  |  | X | X | X |  | **86** |  |  | X |  | X |  |
| **22** |  |  | X | X | X |  | **87** |  |  | X |  | X |  |
| **23** |  |  | X | X | X |  | **88** |  |  | X |  | X |  |
| **24** |  |  | X | X | X |  | **89** |  |  | X |  | X |  |
| **25** |  |  | X | X | X |  | **90** |  |  | X |  | X |  |
| **26** |  |  | X | X | X |  | **91** |  |  | X |  | X |  |
| **27** |  |  | X | X | X |  | **92** |  |  | X |  | X |  |
| **28** |  |  | X | X | X |  | **93** |  |  |  |  | X |  |
| **29** |  |  | X | X | X |  | **94** |  |  |  | X | X |  |
| **30** |  |  | X | X | X |  | **95** |  |  |  | X | X |  |
| **31** |  |  | X | X | X |  | **96** |  |  |  | X | X |  |
| **32** |  |  | X | X | X |  | **97** |  |  |  | X | X |  |
| **33** |  |  | X | X | X |  | **98** |  |  |  | X | X |  |
| **34** |  |  | X |  | X |  | **99** |  |  |  | X | X |  |
| **35** |  |  | X |  | X |  | **100** |  |  |  | X | X |  |
| **36** |  |  | X |  | X |  | **101** |  |  |  | X | X |  |
| **37** |  |  | X |  | X |  | **102** |  |  |  | X | X |  |
| **38** |  |  | X |  | X |  | **103** |  |  |  | X | X |  |
| **39** |  |  | X |  | X |  | **104** |  |  |  | X | X |  |
| **40** |  |  | X |  | X |  | **105** |  |  |  | X | X |  |
| **41** |  |  | X |  | X |  | **106** |  |  |  | X | X |  |
| **42** |  |  | X |  | X |  | **107** |  |  |  | X | X |  |
| **43** |  |  | X |  | X |  | **108** |  |  |  | X | X |  |
| **44** |  |  | X |  | X |  | **109** |  |  |  | X | X |  |
| **45** |  |  | X |  | X |  | **110** |  |  |  | X | X |  |
| **46** |  |  | X |  | X |  | **111** |  |  |  | X | X |  |
| **47** |  |  | X |  | X |  | **112** |  |  |  | X | X |  |
| **48** |  |  | X |  | X |  | **113** |  |  |  | X | X |  |
| **49** |  |  | X |  | X |  | **114** |  |  |  | X | X |  |
| **50** |  |  | X |  | X |  | **115** |  |  |  | X | X |  |
| **51** |  |  | X |  | X |  | **116** |  |  |  | X | X |  |
| **52** |  |  | X |  | X |  | **117** |  |  |  | X | X |  |
| **53** |  |  | X |  | X |  | **118** |  |  |  | X | X |  |
| **54** |  |  | X | X | X |  | **119** |  |  |  | X | X |  |
| **55** |  |  | X | X | X |  | **120** |  |  |  | X | X |  |
| **56** |  |  | X | X | X |  | **121** |  |  |  | X | X |  |
| **57** |  |  | X | X | X |  | **122** |  |  |  | X | X |  |
| **58** |  |  | X | X | X |  | **123** |  |  |  | X | X |  |
| **59** |  |  | X | X | X |  | **124** |  |  |  | X | X |  |
| **60** |  |  | X | X | X |  | **125** |  |  |  | X | X |  |
| **61** |  |  | X | X | X |  | **126** |  |  |  | X | X |  |
| **62** |  |  | X | X | X |  | **127** |  |  |  | X | X |  |
| **63** |  |  | X | X | X |  | **128** |  |  |  | X | X |  |
| **64** |  |  | X | X | X |  | **129** |  |  |  | X | X |  |
| **65** |  |  | X | X | X |  | **130** |  |  |  | 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:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2101\17208-AE-2101\OUTPUT_661PRO\setup2.htm#1)
* [Load Case Report](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2101\17208-AE-2101\OUTPUT_661PRO\setup2.htm#2)
* [Solution Data](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2101\17208-AE-2101\OUTPUT_661PRO\setup2.htm#3)
* [ASME Code Stress Output Plots](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2101\17208-AE-2101\OUTPUT_661PRO\setup2.htm#4)
* [Stress Results - Notes](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2101\17208-AE-2101\OUTPUT_661PRO\setup2.htm#5)
* [ASME Overstressed Areas](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2101\17208-AE-2101\OUTPUT_661PRO\setup2.htm#6)
* [Highest Primary Stress Ratios](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2101\17208-AE-2101\OUTPUT_661PRO\setup2.htm#7)
* [Highest Secondary Stress Ratios](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2101\17208-AE-2101\OUTPUT_661PRO\setup2.htm#8)
* [Highest Fatigue Stress Ratios](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2101\17208-AE-2101\OUTPUT_661PRO\setup2.htm#9)
* [Highest Stress Ratios Per Region](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2101\17208-AE-2101\OUTPUT_661PRO\setup2.htm#10)
* [Compressive Stress Summary](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2101\17208-AE-2101\OUTPUT_661PRO\setup2.htm#11)
* [Graphical Results](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2101\17208-AE-2101\OUTPUT_661PRO\setup2-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

[Table of Contents](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2101\17208-AE-2101\OUTPUT_661PRO\setup2.htm#TOC)

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:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2101\17208-AE-2101\OUTPUT_661PRO\setup2.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

[Table of Contents](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2101\17208-AE-2101\OUTPUT_661PRO\setup2.htm#TOC)

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

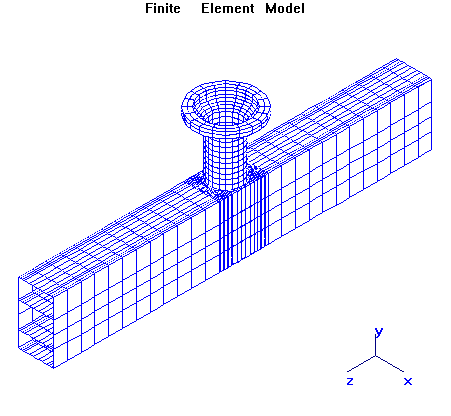
18 EXPANSION 4 -4. 640 46% 8% Long Plate for Plate # 4

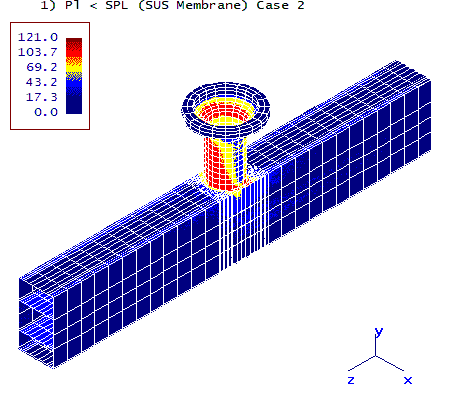
19 SUSTAINED 2 -9. 8624 37% 9% Circ Plate for Plate # 5

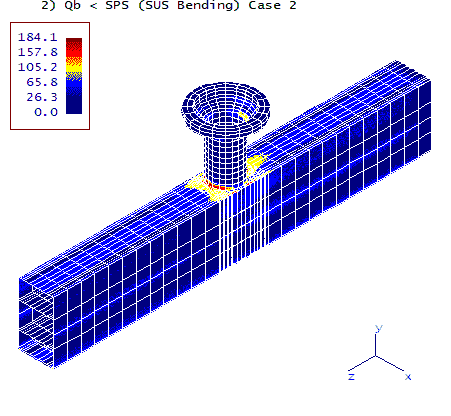
20 OPERATING 3 -9. 8624 37% 9% Circ Plate for Plate # 5

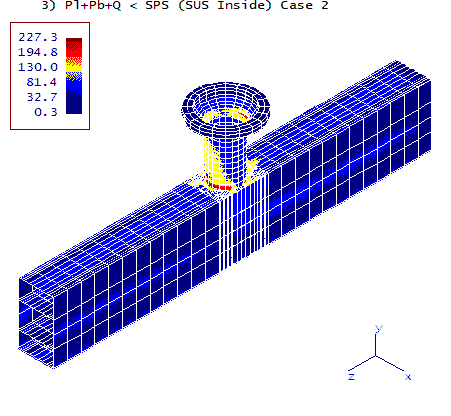
21 EXPANSION 4 -3. 8624 13% 4% Circ Plate for Plate # 5

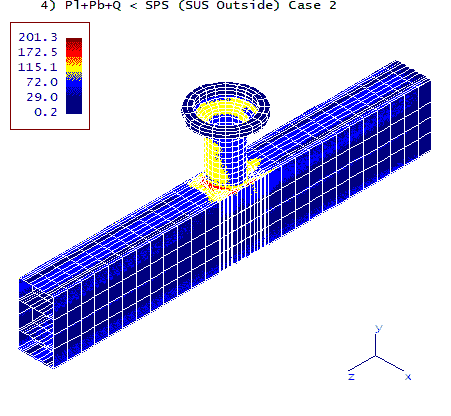
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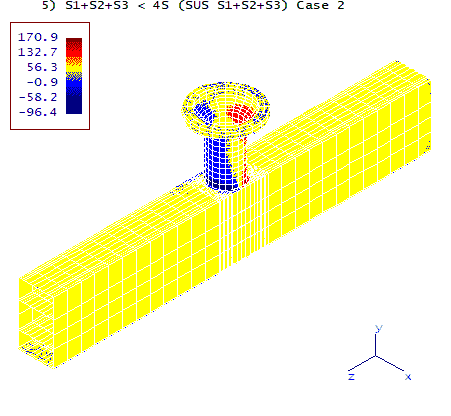


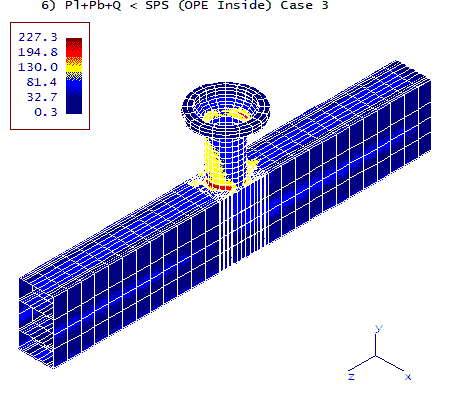


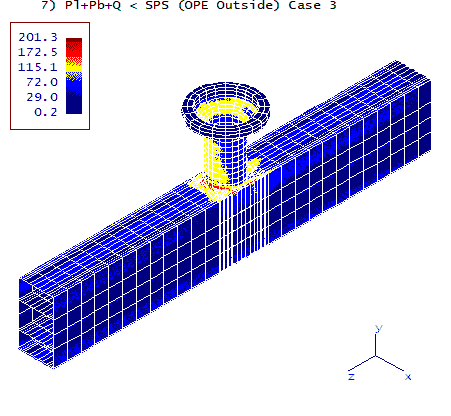


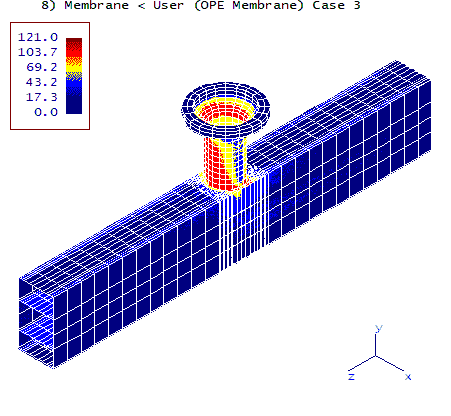


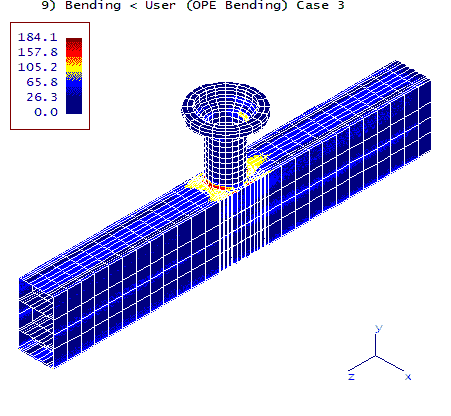


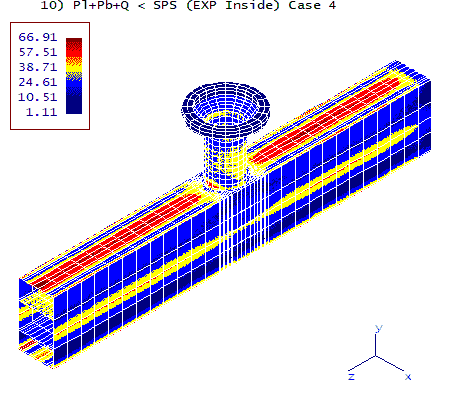


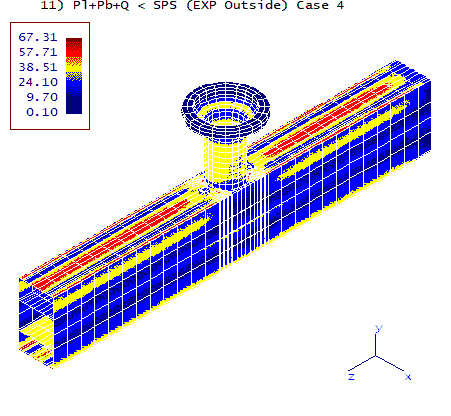


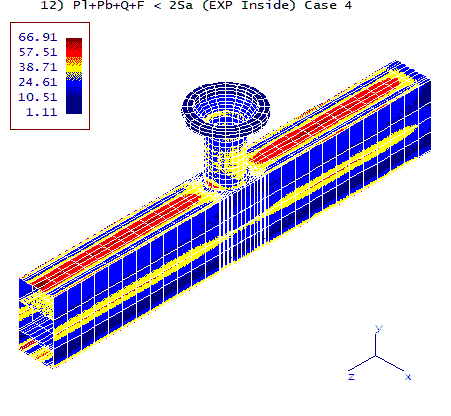


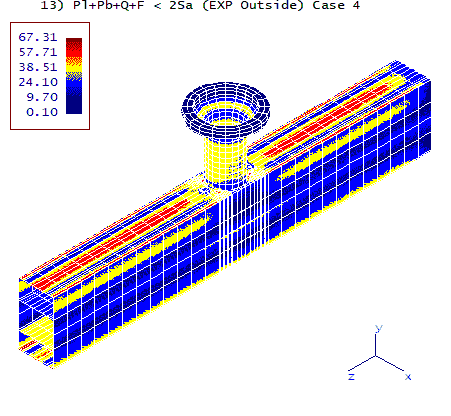












## FINITE ELEMENT FOR AE-2102

**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:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2102\17208-AE-2102\OUTPUT_661PRO\setup2.htm#1)
* [Load Case Report](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2102\17208-AE-2102\OUTPUT_661PRO\setup2.htm#2)
* [Solution Data](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2102\17208-AE-2102\OUTPUT_661PRO\setup2.htm#3)
* [ASME Code Stress Output Plots](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2102\17208-AE-2102\OUTPUT_661PRO\setup2.htm#4)
* [Stress Results - Notes](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2102\17208-AE-2102\OUTPUT_661PRO\setup2.htm#5)
* [ASME Overstressed Areas](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2102\17208-AE-2102\OUTPUT_661PRO\setup2.htm#6)
* [Highest Primary Stress Ratios](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2102\17208-AE-2102\OUTPUT_661PRO\setup2.htm#7)
* [Highest Secondary Stress Ratios](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2102\17208-AE-2102\OUTPUT_661PRO\setup2.htm#8)
* [Highest Fatigue Stress Ratios](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2102\17208-AE-2102\OUTPUT_661PRO\setup2.htm#9)
* [Highest Stress Ratios Per Region](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2102\17208-AE-2102\OUTPUT_661PRO\setup2.htm#10)
* [Compressive Stress Summary](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2102\17208-AE-2102\OUTPUT_661PRO\setup2.htm#11)
* [Graphical Results](file:///F:\SH.A\Air%20Cooler\17208\Calculation\Rev.02\Mechanical%20Cal\Nozzle%20PRO\AE-2102\17208-AE-2102\OUTPUT_661PRO\setup2-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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