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| --- | --- | --- | --- | --- | --- | --- | --- |
| **طرح نگهداشت و افزایش تولید 27 مخزن** | | | | | | | |
| **Thermal/Mechanical Calculation Book**  **نگهداشت و افزایش تولید میدان نفتی بینک** | | | | | | | |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| V02 | Aug.2024 | IFA | AAC | M.FAKHARIAN | M.SADEGHIAN |  |
| V01 | Mar.2024 | IFA | AAC | M.FAKHARIAN | S.FRAMARZPOUR |  |
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| **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** |  | **PAGE** | **V00** | **V01** | **V02** | **V03** | **V04** |
| **1** | X | X | X |  |  | **66** |  |  | X |  |  |
| **2** | X | X | X |  |  | **67** |  |  | X |  |  |
| **3** | X |  | X |  |  | **68** |  |  | X |  |  |
| **4** | X |  | X |  |  | **69** |  |  | X |  |  |
| **5** | X | X | X |  |  | **70** |  |  | X |  |  |
| **6** | X | X | X |  |  | **71** |  |  | X |  |  |
| **7** | X | X | X |  |  | **72** |  |  | X |  |  |
| **8** | X | X | X |  |  | **73** |  |  | X |  |  |
| **9** |  |  | X |  |  | **74** |  |  | X |  |  |
| **10** |  |  | X |  |  | **75** |  |  | X |  |  |
| **11** |  |  | X |  |  | **76** |  |  | X |  |  |
| **12** |  |  | X |  |  | **77** |  |  | X |  |  |
| **13** |  |  | X |  |  | **78** |  |  | X |  |  |
| **14** |  |  | X |  |  | **79** |  |  | X |  |  |
| **15** |  |  | X |  |  | **80** |  |  | X |  |  |
| **16** |  |  | X |  |  | **81** |  |  | X |  |  |
| **17** |  |  | X |  |  | **82** |  |  | X |  |  |
| **18** |  |  | X |  |  | **83** |  |  | X |  |  |
| **19** |  |  | X |  |  | **84** |  |  | X |  |  |
| **20** |  |  | X |  |  | **85** |  |  | X |  |  |
| **21** |  |  | X |  |  | **86** |  |  | X |  |  |
| **22** |  |  | X |  |  | **87** |  |  | X |  |  |
| **23** |  |  | X |  |  | **88** |  |  | X |  |  |
| **24** |  |  | X |  |  | **89** |  |  | X |  |  |
| **25** |  |  | X |  |  | **90** |  |  | X |  |  |
| **26** |  |  | X |  |  | **91** |  |  | X |  |  |
| **27** |  |  | X |  |  | **92** |  |  | X |  |  |
| **28** |  |  | X |  |  | **93** |  |  | X |  |  |
| **29** |  |  | X |  |  | **94** |  |  |  |  |  |
| **30** |  |  | X |  |  | **95** |  |  |  |  |  |
| **31** |  |  | X |  |  | **96** |  |  |  |  |  |
| **32** |  |  | X |  |  | **97** |  |  |  |  |  |
| **33** |  |  | X |  |  | **98** |  |  |  |  |  |
| **34** |  |  | X |  |  | **99** |  |  |  |  |  |
| **35** |  |  | X |  |  | **100** |  |  |  |  |  |
| **36** |  |  | X |  |  | **101** |  |  |  |  |  |
| **37** |  |  | X |  |  | **102** |  |  |  |  |  |
| **38** |  |  | X |  |  | **103** |  |  |  |  |  |
| **39** |  |  | X |  |  | **104** |  |  |  |  |  |
| **40** |  |  | X |  |  | **105** |  |  |  |  |  |
| **41** |  |  | X |  |  | **106** |  |  |  |  |  |
| **42** |  |  | X |  |  | **107** |  |  |  |  |  |
| **43** |  |  | X |  |  | **108** |  |  |  |  |  |
| **44** |  |  | X |  |  | **109** |  |  |  |  |  |
| **45** |  |  | X |  |  | **110** |  |  |  |  |  |
| **46** |  |  | X |  |  | **111** |  |  |  |  |  |
| **47** |  |  | X |  |  | **112** |  |  |  |  |  |
| **48** |  |  | X |  |  | **113** |  |  |  |  |  |
| **49** |  |  | X |  |  | **114** |  |  |  |  |  |
| **50** |  |  | X |  |  | **115** |  |  |  |  |  |
| **51** |  |  | X |  |  | **116** |  |  |  |  |  |
| **52** |  |  | X |  |  | **117** |  |  |  |  |  |
| **53** |  |  | X |  |  | **118** |  |  |  |  |  |
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| **55** |  |  | X |  |  | **120** |  |  |  |  |  |
| **56** |  |  | X |  |  | **121** |  |  |  |  |  |
| **57** |  |  | X |  |  | **122** |  |  |  |  |  |
| **58** |  |  | X |  |  | **123** |  |  |  |  |  |
| **59** |  |  | X |  |  | **124** |  |  |  |  |  |
| **60** |  |  | X |  |  | **125** |  |  |  |  |  |
| **61** |  |  | X |  |  | **126** |  |  |  |  |  |
| **62** |  |  | X |  |  | **127** |  |  |  |  |  |
| **63** |  |  | X |  |  | **128** |  |  |  |  |  |
| **64** |  |  | X |  |  | **129** |  |  |  |  |  |
| **65** |  |  | X |  |  | **130** |  |  |  |  |  |

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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. **ThermalCalculation Book**

















**Mechanical Calculation**

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 15.0000 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 61.0000 mm.

Uniform Hole Diameter d0 25.6500 mm.

Depth of Holes T0 20.0000 mm.

Long-side Plate # 2,

Pitch Distance p 61.0000 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, 2019 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

= 15.000 - 0.000 / 2

= 7.500 mm.

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

= -( t1 - CA ) / 2

= -( 15.000 - 0.000 ) / 2

= -7.500 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

= 15.000 - 0.000 / 2

= 7.500 mm.

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

= -( t1 - CA ) / 2

= -( 15.000 - 0.000 ) / 2

= -7.500 mm.

***Long-side 1 Calculations***

Effective Diameter [De]: 25.700 mm.

Membrane Ligament Efficiency [Em]:

= Pitch - De / Pitch

= 61.000 - 25.700 / 61.000

= 0.579

Bending Ligament Efficiency [Eb]:

*As diameter holes are uniform Eb = Em*

= 0.579

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

= 61.000 - 29.618 / 61.000

= 0.514

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 )

= (( 0.97 \* 2.70 \* ( 2.70 /2 + 17.30 + 0.00 )) + ( 1.28\* 17.30 \*

( 17.30 /2 + 0.00 )) + ( 2.40 \* 0.00 \* ( 0.00 /2 ))) /

( 0.97 \* 2.70 + 1.28 \* 17.30 + 2.40 \* 0.00 )

= 9.713 mm.

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

*Ci = Xbar*

= 9.713 mm.

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

= -( t - CA - Xbar )

= -( 20.000 - 0.000 - 9.713 )

= -10.287 mm.

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

= 0.079 cm\*\*4

Effective Diameter [De]:

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

= 61.00 - (( 6 \* 0.08 ) / ((20.00 - 0.00 )^2 \* (10.29 )))

= 31.851 mm.

Bending Ligament Efficiency [Eb]:

= Pitch - De / Pitch

= 61.000 - 31.851 / 61.000

= 0.478

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

Em Eb Ci Co

Short-side 1 0.850 0.850 7.500 -7.500

2 0.850 0.850 7.500 -7.500

Long-side 1 0.579 0.579 10.000 -10.000

2 0.514 0.478 9.713 -10.287

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

Thickness t1, I1 = 0.0281 cm\*\*4

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

**Rectangular Vessel Parameters:**

Alpha = H / h = 1.3115

K = (I2/I1)\*Alpha = 3.1087

**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 \* 15.00 ) \* { 3- [( 6 + 3.11 \*

( 11 - 1.312) / ( 3 + 5 \* 3.11 )]}

= 10.03 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 \* 15.00 ) \* { 3- [( 6 + 3.11 \*

( 11 - 1.312) / ( 3 + 5 \* 3.11 )]}

= 10.03 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( 0.579 ) < E( 0.850 ) and Eb( 0.579 ) < E( 0.850 ) then*

Sml = Sml / Em

= 8.80 / 0.58

= 15.21 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( 0.514 ) < E( 0.850 ) and Eb( 0.478 ) < E( 0.850 ) then*

Sml = Sml / Em

= 8.80 / 0.51

= 17.11 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 )]

= 22.00 \* 122.00 / ( 2 \* 10.00 ) \* [( 6 + 3.11 \* ( 11 -

1.312) / ( 3 + 5 \* 3.11 )]

= 25.22 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 + 3.11 \* ( 11 -

1.312) / ( 3 + 5 \* 3.11 )]

= 25.22 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 10.03 97.23

Short-side 2 10.03 97.23

Short-side Corner 10.03 97.23

Long-side 1 at A 15.21 114.39

Long-side 2 at A 17.11 114.39

Long-side Corner 8.80 97.23

Stay Plate (t3) 25.22 114.39

Stay Plate (t4) 25.22 114.39

**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 \* 7.50 / ( 24 \* 0.03 ) \* [ -3 \* 160.002 + 2 \* 122.002 \*

(( 3 + 5 \* 1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 ))]

= -71.06 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 \* -7.50 /( 24 \* 0.03 ) \* [ -3 \* 160.002 + 2 \* 122.002 \*

(( 3 + 5 \* 1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 ))]

= 71.06 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 \* 7.50 / ( 12 \* 0.03 ) \* (( 3 + 5 \*

1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 ))

= 116.69 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 ))

= 22.00 \* 122.002 \* -7.50 / ( 12 \* 0.03 ) \* (( 3 + 5 \*

1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 ))

= -116.69 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 ))]

= 22.00 \* 7.50 / ( 24 \* 0.03 ) \* [ -3 \* 160.002 + 2 \* 122.002 \*

(( 3 + 5 \* 1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 ))]

= -71.06 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 \* -7.50 /( 24 \* 0.03 ) \* [ -3 \* 160.002 + 2 \* 122.002 \*

(( 3 + 5 \* 1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 ))]

= 71.06 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 \* 7.50 / ( 12 \* 0.03 ) \* (( 3 + 5 \*

1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 ))

= 116.69 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 ))

= 22.00 \* 122.002 \* -7.50 / ( 12 \* 0.03 ) \* (( 3 + 5 \*

1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 ))

= -116.69 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 )]

= 22.00 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 3 + 3.11 \*

( 6 - 1.312)) / ( 3 + 5 \* 3.11 )]

= 35.99 N./mm^2

*If Em( 0.579 ) < E( 0.850 ) and Eb( 0.579 ) < E( 0.850 ) then*

SblMi = SblMi / Eb

= 35.99 / 0.58

= 62.20 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 + 3.11 \*

( 6 - 1.312)) / ( 3 + 5 \* 3.11 )]

= -35.99 N./mm^2

*If Em( 0.579 ) < E( 0.850 ) and Eb( 0.579 ) < E( 0.850 ) then*

SblMo = SblMo / Eb

= -35.99 / 0.58

= -62.20 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 \* 3.11 ) / ( 3 + 5 \* 3.11 )]

= 65.64 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 \* 3.11 ) / ( 3 + 5 \* 3.11 )]

= -65.64 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 \* 9.71 / ( 12 \* 0.07 ) \* [( 3 + 3.11 \*

( 6 - 1.312)) / ( 3 + 5 \* 3.11 )]

= 34.96 N./mm^2

*If Em( 0.514 ) < E( 0.850 ) and Eb( 0.478 ) < E( 0.850 ) then*

SblMi = SblMi / Eb

= 34.96 / 0.48

= 73.16 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 \* -10.29 / ( 12 \* 0.07 ) \* [( 3 + 3.11 \*

( 6 - 1.312)) / ( 3 + 5 \* 3.11 )]

= -37.03 N./mm^2

*If Em( 0.514 ) < E( 0.850 ) and Eb( 0.478 ) < E( 0.850 ) then*

SblMo = SblMo / Eb

= -37.03 / 0.48

= -77.49 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 \* 9.71 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 )]

= 63.75 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 \* -10.29 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 )]

= -67.52 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 -71.06 71.06 145.85

at Q 116.69 -116.69 145.85

Short-side 2 at N -71.06 71.06 145.85

at Q 116.69 -116.69 145.85

Long-side 1 at M 62.20 -62.20 171.58

at Q 65.64 -65.64 145.85

Long-side 2 at M 73.16 -77.49 171.58

at Q 63.75 -67.52 145.85

**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

= 10.03 + -71.06

= -61.03 N./mm^2

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

= Sms + SbsNo

= 10.03 + 71.06

= 81.08 N./mm^2

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

= Sms + SbsQi

= 10.03 + 116.69

= 126.71 N./mm^2

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

= Sms + SbsQo

= 10.03 + -116.69

= -106.66 N./mm^2

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

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

= Sms + SbsNi

= 10.03 + -71.06

= -61.03 N./mm^2

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

= Sms + SbsNo

= 10.03 + 71.06

= 81.08 N./mm^2

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

= Sms + SbsQi

= 10.03 + 116.69

= 126.71 N./mm^2

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

= Sms + SbsQo

= 10.03 + -116.69

= -106.66 N./mm^2

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

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

= Sml + SblMi

= 15.21 + 62.20

= 77.40 N./mm^2

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

= Sml + SblMo

= 15.21 + -62.20

= -46.99 N./mm^2

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

= Sml + SblQi

= 8.80 + 65.64

= 74.44 N./mm^2

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

= SmlB + SblQo

= 8.80 + -65.64

= -56.84 N./mm^2

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

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

= Sml + SblMi

= 17.11 + 73.16

= 90.26 N./mm^2

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

= Sml + SblMo

= 17.11 + -77.49

= -60.38 N./mm^2

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

= Sml + SblQi

= 8.80 + 63.75

= 72.55 N./mm^2

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

= SmlB + SblQo

= 8.80 + -67.52

= -58.72 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 -61.03 81.08 145.85

at Q 126.71 -106.66 145.85

Short-side 2 at N -61.03 81.08 145.85

at Q 126.71 -106.66 145.85

Long-side 1 at M 77.40 -46.99 171.58

at Q 74.44 -56.84 145.85

Long-side 2 at M 90.26 -60.38 171.58

at Q 72.55 -58.72 145.85

**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) 25.22 N./mm^2

High Stress Percentage 22.05 %

M.A.W.P. for Membrane Stresses 99.78 bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable) -116.69 N./mm^2

High Stress Percentage 80.01 %

M.A.W.P. for Bending Stresses 27.50 bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable) 126.71 N./mm^2

High Stress Percentage 86.88 %

M.A.W.P. for Total Stresses 25.32 bars

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

**SUMMARY OF RESULTS:**

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable) 25.22 N./mm^2

High Stress Percentage 22.05 %

M.A.W.P. for Membrane Stresses 99.78 bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable) -116.69 N./mm^2

High Stress Percentage 80.01 %

M.A.W.P. for Bending Stresses 27.50 bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable) 126.71 N./mm^2

High Stress Percentage 86.88 %

M.A.W.P. for Total Stresses 25.32 bars

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

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

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 15.0000 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 61.0000 mm.

Uniform Hole Diameter d0 25.6500 mm.

Depth of Holes T0 20.0000 mm.

Long-side Plate # 2,

Pitch Distance p 61.0000 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, 2019 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

= 15.000 - 0.000 / 2

= 7.500 mm.

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

= -( t1 - CA ) / 2

= -( 15.000 - 0.000 ) / 2

= -7.500 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

= 15.000 - 0.000 / 2

= 7.500 mm.

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

= -( t1 - CA ) / 2

= -( 15.000 - 0.000 ) / 2

= -7.500 mm.

***Long-side 1 Calculations***

Effective Diameter [De]: 25.650 mm.

Membrane Ligament Efficiency [Em]:

= Pitch - De / Pitch

= 61.000 - 25.650 / 61.000

= 0.580

Bending Ligament Efficiency [Eb]:

*As diameter holes are uniform Eb = Em*

= 0.580

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

= 61.000 - 29.618 / 61.000

= 0.514

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 )

= (( 0.97 \* 2.70 \* ( 2.70 /2 + 17.30 + 0.00 )) + ( 1.28\* 17.30 \*

( 17.30 /2 + 0.00 )) + ( 2.40 \* 0.00 \* ( 0.00 /2 ))) /

( 0.97 \* 2.70 + 1.28 \* 17.30 + 2.40 \* 0.00 )

= 9.713 mm.

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

*Ci = Xbar*

= 9.713 mm.

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

= -( t - CA - Xbar )

= -( 20.000 - 0.000 - 9.713 )

= -10.287 mm.

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

= 0.079 cm\*\*4

Effective Diameter [De]:

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

= 61.00 - (( 6 \* 0.08 ) / ((20.00 - 0.00 )^2 \* (10.29 )))

= 31.851 mm.

Bending Ligament Efficiency [Eb]:

= Pitch - De / Pitch

= 61.000 - 31.851 / 61.000

= 0.478

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

Em Eb Ci Co

Short-side 1 0.850 0.850 7.500 -7.500

2 0.850 0.850 7.500 -7.500

Long-side 1 0.580 0.580 10.000 -10.000

2 0.514 0.478 9.713 -10.287

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

Thickness t1, I1 = 0.0281 cm\*\*4

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

**Rectangular Vessel Parameters:**

Alpha = H / h = 1.3115

K = (I2/I1)\*Alpha = 3.1087

**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 \* 15.00 ) \* { 3- [( 6 + 3.11 \*

( 11 - 1.312) / ( 3 + 5 \* 3.11 )]}

= 13.04 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 \* 15.00 ) \* { 3- [( 6 + 3.11 \*

( 11 - 1.312) / ( 3 + 5 \* 3.11 )]}

= 13.04 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( 0.580 ) < E( 0.850 ) and Eb( 0.580 ) < E( 0.850 ) then*

Sml = Sml / Em

= 11.44 / 0.58

= 19.74 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( 0.514 ) < E( 0.850 ) and Eb( 0.478 ) < E( 0.850 ) then*

Sml = Sml / Em

= 11.44 / 0.51

= 22.24 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 + 3.11 \* ( 11 -

1.312) / ( 3 + 5 \* 3.11 )]

= 32.79 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 + 3.11 \* ( 11 -

1.312) / ( 3 + 5 \* 3.11 )]

= 32.79 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 13.04 131.75

Short-side 2 13.04 131.75

Short-side Corner 13.04 131.75

Long-side 1 at A 19.74 155.00

Long-side 2 at A 22.24 155.00

Long-side Corner 11.44 131.75

Stay Plate (t3) 32.79 114.39

Stay Plate (t4) 32.79 114.39

**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 \* 7.50 / ( 24 \* 0.03 ) \* [ -3 \* 160.002 + 2 \* 122.002 \*

(( 3 + 5 \* 1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 ))]

= -92.37 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 \* -7.50 /( 24 \* 0.03 ) \* [ -3 \* 160.002 + 2 \* 122.002 \*

(( 3 + 5 \* 1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 ))]

= 92.37 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 \* 7.50 / ( 12 \* 0.03 ) \* (( 3 + 5 \*

1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 ))

= 151.69 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 ))

= 28.60 \* 122.002 \* -7.50 / ( 12 \* 0.03 ) \* (( 3 + 5 \*

1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 ))

= -151.69 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 ))]

= 28.60 \* 7.50 / ( 24 \* 0.03 ) \* [ -3 \* 160.002 + 2 \* 122.002 \*

(( 3 + 5 \* 1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 ))]

= -92.37 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 \* -7.50 /( 24 \* 0.03 ) \* [ -3 \* 160.002 + 2 \* 122.002 \*

(( 3 + 5 \* 1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 ))]

= 92.37 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 \* 7.50 / ( 12 \* 0.03 ) \* (( 3 + 5 \*

1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 ))

= 151.69 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 ))

= 28.60 \* 122.002 \* -7.50 / ( 12 \* 0.03 ) \* (( 3 + 5 \*

1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 ))

= -151.69 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 )]

= 28.60 \* 122.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 3 + 3.11 \*

( 6 - 1.312)) / ( 3 + 5 \* 3.11 )]

= 46.79 N./mm^2

*If Em( 0.580 ) < E( 0.850 ) and Eb( 0.580 ) < E( 0.850 ) then*

SblMi = SblMi / Eb

= 46.79 / 0.58

= 80.74 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 + 3.11 \*

( 6 - 1.312)) / ( 3 + 5 \* 3.11 )]

= -46.79 N./mm^2

*If Em( 0.580 ) < E( 0.850 ) and Eb( 0.580 ) < E( 0.850 ) then*

SblMo = SblMo / Eb

= -46.79 / 0.58

= -80.74 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 \* 3.11 ) / ( 3 + 5 \* 3.11 )]

= 85.33 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 \* 3.11 ) / ( 3 + 5 \* 3.11 )]

= -85.33 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 \* 9.71 / ( 12 \* 0.07 ) \* [( 3 + 3.11 \*

( 6 - 1.312)) / ( 3 + 5 \* 3.11 )]

= 45.45 N./mm^2

*If Em( 0.514 ) < E( 0.850 ) and Eb( 0.478 ) < E( 0.850 ) then*

SblMi = SblMi / Eb

= 45.45 / 0.48

= 95.10 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 \* -10.29 / ( 12 \* 0.07 ) \* [( 3 + 3.11 \*

( 6 - 1.312)) / ( 3 + 5 \* 3.11 )]

= -48.14 N./mm^2

*If Em( 0.514 ) < E( 0.850 ) and Eb( 0.478 ) < E( 0.850 ) then*

SblMo = SblMo / Eb

= -48.14 / 0.48

= -100.73 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 \* 9.71 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 )]

= 82.87 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 \* -10.29 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

1.312 \* 3.11 ) / ( 3 + 5 \* 3.11 )]

= -87.78 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 -92.37 92.37 197.62

at Q 151.69 -151.69 197.62

Short-side 2 at N -92.37 92.37 197.62

at Q 151.69 -151.69 197.62

Long-side 1 at M 80.74 -80.74 232.50

at Q 85.33 -85.33 197.62

Long-side 2 at M 95.10 -100.73 232.50

at Q 82.87 -87.78 197.62

**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

= 13.04 + -92.37

= -79.34 N./mm^2

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

= Sms + SbsNo

= 13.04 + 92.37

= 105.41 N./mm^2

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

= Sms + SbsQi

= 13.04 + 151.69

= 164.73 N./mm^2

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

= Sms + SbsQo

= 13.04 + -151.69

= -138.66 N./mm^2

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

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

= Sms + SbsNi

= 13.04 + -92.37

= -79.34 N./mm^2

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

= Sms + SbsNo

= 13.04 + 92.37

= 105.41 N./mm^2

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

= Sms + SbsQi

= 13.04 + 151.69

= 164.73 N./mm^2

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

= Sms + SbsQo

= 13.04 + -151.69

= -138.66 N./mm^2

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

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

= Sml + SblMi

= 19.74 + 80.74

= 100.48 N./mm^2

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

= Sml + SblMo

= 19.74 + -80.74

= -61.00 N./mm^2

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

= Sml + SblQi

= 11.44 + 85.33

= 96.77 N./mm^2

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

= SmlB + SblQo

= 11.44 + -85.33

= -73.89 N./mm^2

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

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

= Sml + SblMi

= 22.24 + 95.10

= 117.34 N./mm^2

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

= Sml + SblMo

= 22.24 + -100.73

= -78.49 N./mm^2

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

= Sml + SblQi

= 11.44 + 82.87

= 94.32 N./mm^2

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

= SmlB + SblQo

= 11.44 + -87.78

= -76.34 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 -79.34 105.41 197.62

at Q 164.73 -138.66 197.62

Short-side 2 at N -79.34 105.41 197.62

at Q 164.73 -138.66 197.62

Long-side 1 at M 100.48 -61.00 232.50

at Q 96.77 -73.89 197.62

Long-side 2 at M 117.34 -78.49 232.50

at Q 94.32 -76.34 197.62

**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) 32.79 N./mm^2

High Stress Percentage 28.66 %

M.A.W.P. for Membrane Stresses 99.78 bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable) -151.69 N./mm^2

High Stress Percentage 76.76 %

M.A.W.P. for Bending Stresses 37.26 bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable) 164.73 N./mm^2

High Stress Percentage 83.35 %

M.A.W.P. for Total Stresses 34.31 bars

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

**SUMMARY OF RESULTS:**

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable) 32.79 N./mm^2

High Stress Percentage 28.66 %

M.A.W.P. for Membrane Stresses 99.78 bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable) -151.69 N./mm^2

High Stress Percentage 76.76 %

M.A.W.P. for Bending Stresses 37.26 bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable) 164.73 N./mm^2

High Stress Percentage 83.35 %

M.A.W.P. for Total Stresses 34.31 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 15.0000 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 61.0000 mm.

Uniform Hole Diameter d0 25.6500 mm.

Depth of Holes T0 20.0000 mm.

Long-side Plate # 2,

Pitch Distance p 61.0000 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, 2019 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

= 15.000 - 0.000 / 2

= 7.500 mm.

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

= -( t1 - CA ) / 2

= -( 15.000 - 0.000 ) / 2

= -7.500 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

= 15.000 - 0.000 / 2

= 7.500 mm.

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

= -( t1 - CA ) / 2

= -( 15.000 - 0.000 ) / 2

= -7.500 mm.

***Long-side 1 Calculations***

Effective Diameter [De]: 25.700 mm.

Membrane Ligament Efficiency [Em]:

= Pitch - De / Pitch

= 61.000 - 25.700 / 61.000

= 0.579

Bending Ligament Efficiency [Eb]:

*As diameter holes are uniform Eb = Em*

= 0.579

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

= 61.000 - 29.618 / 61.000

= 0.514

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 )

= (( 0.97 \* 2.70 \* ( 2.70 /2 + 17.30 + 0.00 )) + ( 1.28\* 17.30 \*

( 17.30 /2 + 0.00 )) + ( 2.40 \* 0.00 \* ( 0.00 /2 ))) /

( 0.97 \* 2.70 + 1.28 \* 17.30 + 2.40 \* 0.00 )

= 9.713 mm.

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

*Ci = Xbar*

= 9.713 mm.

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

= -( t - CA - Xbar )

= -( 20.000 - 0.000 - 9.713 )

= -10.287 mm.

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

= 0.079 cm\*\*4

Effective Diameter [De]:

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

= 61.00 - (( 6 \* 0.08 ) / ((20.00 - 0.00 )^2 \* (10.29 )))

= 31.851 mm.

Bending Ligament Efficiency [Eb]:

= Pitch - De / Pitch

= 61.000 - 31.851 / 61.000

= 0.478

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

Em Eb Ci Co

Short-side 1 0.850 0.850 7.500 -7.500

2 0.850 0.850 7.500 -7.500

Long-side 1 0.579 0.579 10.000 -10.000

2 0.514 0.478 9.713 -10.287

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

Thickness t1, I1 = 0.0281 cm\*\*4

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

**Rectangular Vessel Parameters:**

Alpha = H / h = 0.8197

K = (I2/I1)\*Alpha = 1.9429

**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 \* 15.00 ) \* { 4 - [( 2 + 1.94 \*

( 5 - 0.822)) / ( 1 + 2 \* 1.94 )]}

= 8.36 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 \* 15.00 ) \* { 4 - [( 2 + 1.94 \*

( 5 - 0.822)) / ( 1 + 2 \* 1.94 )]}

= 8.36 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( 0.579 ) < E( 0.850 ) and Eb( 0.579 ) < E( 0.850 ) then*

Sml = Sml / Em

= 5.50 / 0.58

= 9.50 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( 0.514 ) < E( 0.850 ) and Eb( 0.478 ) < E( 0.850 ) then*

Sml = Sml / Em

= 5.50 / 0.51

= 10.69 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 + 1.94 \* ( 5 -

0.822)) / ( 1 + 2 \* 1.94 )]

= 28.59 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 8.36 97.23

Short-side 2 8.36 97.23

Short-side Corner 8.36 97.23

Long-side 1 at A 9.50 114.39

Long-side 2 at A 10.69 114.39

Long-side Corner 5.50 97.23

Stay Plate (t3) 28.59 114.39

**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 \* 7.50 / ( 24 \* 0.03 ) \* [ -3 \* 100.002 + 2 \* 122.002 \*

(( 1 + 2 \* 0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 ))]

= -19.56 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 \* -7.50 / ( 24 \* 0.03 ) \* [ -3 \* 100.002 + 2 \* 122.002 \*

(( 1 + 2 \* 0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 ))]

= 19.56 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 \* 7.50 / ( 12 \* 0.03 ) \* (( 1 + 2 \*

0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 ))

= 53.78 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 \* -7.50 / ( 12 \* 0.03 ) \* (( 1 + 2 \*

0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 ))

= -53.78 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 \* 7.50 / ( 24 \* 0.03 ) \* [ -3 \* 100.002 + 2 \* 122.002 \*

(( 1 + 2 \* 0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 ))]

= -19.56 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 \* -7.50 / ( 24 \* 0.03 ) \* [ -3 \* 100.002 + 2 \* 122.002 \*

(( 1 + 2 \* 0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 ))]

= 19.56 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 \* 7.50 / ( 12 \* 0.03 ) \* (( 1 + 2 \*

0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 ))

= 53.78 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 \* -7.50 / ( 12 \* 0.03 ) \* (( 1 + 2 \*

0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 ))

= -53.78 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 + 1.94 \*

( 3 - 0.822)) / ( 1 + 2 \* 1.94 )]

= 46.27 N./mm^2

*If Em( 0.579 ) < E( 0.850 ) and Eb( 0.579 ) < E( 0.850 ) then*

SblMi = SblMi / Eb

= 46.27 / 0.58

= 79.96 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 + 1.94 \*

( 3 - 0.822)) / ( 1 + 2 \* 1.94 )]

= -46.27 N./mm^2

*If Em( 0.579 ) < E( 0.850 ) and Eb( 0.579 ) < E( 0.850 ) then*

SblMo = SblMo / Eb

= -46.27 / 0.58

= -79.96 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 \* 1.94 ) / ( 1 + 2 \* 1.94 )]

= 30.25 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 \* 1.94 ) / ( 1 + 2 \* 1.94 )]

= -30.25 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 \* 9.71 / ( 12 \* 0.07 ) \* [( 1 + 1.94 \*

( 3 - 0.822)) / ( 1 + 2 \* 1.94 )]

= 44.94 N./mm^2

*If Em( 0.514 ) < E( 0.850 ) and Eb( 0.478 ) < E( 0.850 ) then*

SblMi = SblMi / Eb

= 44.94 / 0.48

= 94.05 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 \* -10.29 / ( 12 \* 0.07 ) \* [( 1 + 1.94 \*

( 3 - 0.822)) / ( 1 + 2 \* 1.94 )]

= -47.60 N./mm^2

*If Em( 0.514 ) < E( 0.850 ) and Eb( 0.478 ) < E( 0.850 ) then*

SblMo = SblMo / Eb

= -47.60 / 0.48

= -99.62 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 \* 9.71 / ( 12 \* 0.07 ) \* [( 1 + 2 \*

0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 )]

= 29.38 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 \* -10.29 / ( 12 \* 0.07 ) \* [( 1 + 2 \*

0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 )]

= -31.12 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 -19.56 19.56 145.85

at Q 53.78 -53.78 145.85

Short-side 2 at N -19.56 19.56 145.85

at Q 53.78 -53.78 145.85

Long-side 1 at M 79.96 -79.96 171.58

at Q 30.25 -30.25 145.85

Long-side 2 at M 94.05 -99.62 171.58

at Q 29.38 -31.12 145.85

**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

= 8.36 + -19.56

= -11.20 N./mm^2

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

= Sms + SbsNo

= 8.36 + 19.56

= 27.92 N./mm^2

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

= Sms + SbsQi

= 8.36 + 53.78

= 62.14 N./mm^2

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

= Sms + SbsQo

= 8.36 + -53.78

= -45.42 N./mm^2

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

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

= Sms + SbsNi

= 8.36 + -19.56

= -11.20 N./mm^2

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

= Sms + SbsNo

= 8.36 + 19.56

= 27.92 N./mm^2

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

= Sms + SbsQi

= 8.36 + 53.78

= 62.14 N./mm^2

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

= Sms + SbsQo

= 8.36 + -53.78

= -45.42 N./mm^2

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

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

= Sml + SblMi

= 9.50 + 79.96

= 89.47 N./mm^2

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

= Sml + SblMo

= 9.50 + -79.96

= -70.46 N./mm^2

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

= Sml + SblQi

= 5.50 + 30.25

= 35.75 N./mm^2

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

= Sml + SblQo

= 5.50 + -30.25

= -24.75 N./mm^2

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

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

= Sml + SblMi

= 10.69 + 94.05

= 104.75 N./mm^2

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

= Sml + SblMo

= 10.69 + -99.62

= -88.93 N./mm^2

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

= Sml + SblQi

= 5.50 + 29.38

= 34.88 N./mm^2

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

= Sml + SblQo

= 5.50 + -31.12

= -25.62 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 -11.20 27.92 145.85

at Q 62.14 -45.42 145.85

Short-side 2 at N -11.20 27.92 145.85

at Q 62.14 -45.42 145.85

Long-side 1 at M 89.47 -70.46 171.58

at Q 35.75 -24.75 145.85

Long-side 2 at M 104.75 -88.93 171.58

at Q 34.88 -25.62 145.85

**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) 28.59 N./mm^2

High Stress Percentage 25.00 %

M.A.W.P. for Membrane Stresses 88.01 bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable) -99.62 N./mm^2

High Stress Percentage 58.06 %

M.A.W.P. for Bending Stresses 37.89 bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable) 104.75 N./mm^2

High Stress Percentage 61.05 %

M.A.W.P. for Total Stresses 36.04 bars

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

**SUMMARY OF RESULTS:**

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable) 28.59 N./mm^2

High Stress Percentage 25.00 %

M.A.W.P. for Membrane Stresses 88.01 bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable) -99.62 N./mm^2

High Stress Percentage 58.06 %

M.A.W.P. for Bending Stresses 37.89 bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable) 104.75 N./mm^2

High Stress Percentage 61.05 %

M.A.W.P. for Total Stresses 36.04 bars

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

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

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 15.0000 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 61.0000 mm.

Uniform Hole Diameter d0 25.6500 mm.

Depth of Holes T0 20.0000 mm.

Long-side Plate # 2,

Pitch Distance p 61.0000 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, 2019 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

= 15.000 - 0.000 / 2

= 7.500 mm.

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

= -( t1 - CA ) / 2

= -( 15.000 - 0.000 ) / 2

= -7.500 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

= 15.000 - 0.000 / 2

= 7.500 mm.

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

= -( t1 - CA ) / 2

= -( 15.000 - 0.000 ) / 2

= -7.500 mm.

***Long-side 1 Calculations***

Effective Diameter [De]: 25.650 mm.

Membrane Ligament Efficiency [Em]:

= Pitch - De / Pitch

= 61.000 - 25.650 / 61.000

= 0.580

Bending Ligament Efficiency [Eb]:

*As diameter holes are uniform Eb = Em*

= 0.580

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

= 61.000 - 29.618 / 61.000

= 0.514

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 )

= (( 0.97 \* 2.70 \* ( 2.70 /2 + 17.30 + 0.00 )) + ( 1.28\* 17.30 \*

( 17.30 /2 + 0.00 )) + ( 2.40 \* 0.00 \* ( 0.00 /2 ))) /

( 0.97 \* 2.70 + 1.28 \* 17.30 + 2.40 \* 0.00 )

= 9.713 mm.

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

*Ci = Xbar*

= 9.713 mm.

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

= -( t - CA - Xbar )

= -( 20.000 - 0.000 - 9.713 )

= -10.287 mm.

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

= 0.079 cm\*\*4

Effective Diameter [De]:

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

= 61.00 - (( 6 \* 0.08 ) / ((20.00 - 0.00 )^2 \* (10.29 )))

= 31.851 mm.

Bending Ligament Efficiency [Eb]:

= Pitch - De / Pitch

= 61.000 - 31.851 / 61.000

= 0.478

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

Em Eb Ci Co

Short-side 1 0.850 0.850 7.500 -7.500

2 0.850 0.850 7.500 -7.500

Long-side 1 0.580 0.580 10.000 -10.000

2 0.514 0.478 9.713 -10.287

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

Thickness t1, I1 = 0.0281 cm\*\*4

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

**Rectangular Vessel Parameters:**

Alpha = H / h = 0.8197

K = (I2/I1)\*Alpha = 1.9429

**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 \* 15.00 ) \* { 4 - [( 2 + 1.94 \*

( 5 - 0.822)) / ( 1 + 2 \* 1.94 )]}

= 10.87 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 \* 15.00 ) \* { 4 - [( 2 + 1.94 \*

( 5 - 0.822)) / ( 1 + 2 \* 1.94 )]}

= 10.87 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( 0.580 ) < E( 0.850 ) and Eb( 0.580 ) < E( 0.850 ) then*

Sml = Sml / Em

= 7.15 / 0.58

= 12.34 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( 0.514 ) < E( 0.850 ) and Eb( 0.478 ) < E( 0.850 ) then*

Sml = Sml / Em

= 7.15 / 0.51

= 13.90 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 + 1.94 \* ( 5 -

0.822)) / ( 1 + 2 \* 1.94 )]

= 37.17 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 10.87 131.75

Short-side 2 10.87 131.75

Short-side Corner 10.87 131.75

Long-side 1 at A 12.34 155.00

Long-side 2 at A 13.90 155.00

Long-side Corner 7.15 131.75

Stay Plate (t3) 37.17 114.39

**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 \*

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

= 28.60 \* 7.50 / ( 24 \* 0.03 ) \* [ -3 \* 100.002 + 2 \* 122.002 \*

(( 1 + 2 \* 0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 ))]

= -25.43 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 \* -7.50 / ( 24 \* 0.03 ) \* [ -3 \* 100.002 + 2 \* 122.002 \*

(( 1 + 2 \* 0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 ))]

= 25.43 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 \* 7.50 / ( 12 \* 0.03 ) \* (( 1 + 2 \*

0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 ))

= 69.91 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 \* -7.50 / ( 12 \* 0.03 ) \* (( 1 + 2 \*

0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 ))

= -69.91 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 \* 7.50 / ( 24 \* 0.03 ) \* [ -3 \* 100.002 + 2 \* 122.002 \*

(( 1 + 2 \* 0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 ))]

= -25.43 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 \* -7.50 / ( 24 \* 0.03 ) \* [ -3 \* 100.002 + 2 \* 122.002 \*

(( 1 + 2 \* 0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 ))]

= 25.43 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 \* 7.50 / ( 12 \* 0.03 ) \* (( 1 + 2 \*

0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 ))

= 69.91 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 \* -7.50 / ( 12 \* 0.03 ) \* (( 1 + 2 \*

0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 ))

= -69.91 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 + 1.94 \*

( 3 - 0.822)) / ( 1 + 2 \* 1.94 )]

= 60.16 N./mm^2

*If Em( 0.580 ) < E( 0.850 ) and Eb( 0.580 ) < E( 0.850 ) then*

SblMi = SblMi / Eb

= 60.16 / 0.58

= 103.81 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 + 1.94 \*

( 3 - 0.822)) / ( 1 + 2 \* 1.94 )]

= -60.16 N./mm^2

*If Em( 0.580 ) < E( 0.850 ) and Eb( 0.580 ) < E( 0.850 ) then*

SblMo = SblMo / Eb

= -60.16 / 0.58

= -103.81 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 \* 1.94 ) / ( 1 + 2 \* 1.94 )]

= 39.33 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 \* 1.94 ) / ( 1 + 2 \* 1.94 )]

= -39.33 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 \* 9.71 / ( 12 \* 0.07 ) \* [( 1 + 1.94 \*

( 3 - 0.822)) / ( 1 + 2 \* 1.94 )]

= 58.43 N./mm^2

*If Em( 0.514 ) < E( 0.850 ) and Eb( 0.478 ) < E( 0.850 ) then*

SblMi = SblMi / Eb

= 58.43 / 0.48

= 122.27 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 \* -10.29 / ( 12 \* 0.07 ) \* [( 1 + 1.94 \*

( 3 - 0.822)) / ( 1 + 2 \* 1.94 )]

= -61.89 N./mm^2

*If Em( 0.514 ) < E( 0.850 ) and Eb( 0.478 ) < E( 0.850 ) then*

SblMo = SblMo / Eb

= -61.89 / 0.48

= -129.51 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 \* 9.71 / ( 12 \* 0.07 ) \* [( 1 + 2 \*

0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 )]

= 38.20 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 \* -10.29 / ( 12 \* 0.07 ) \* [( 1 + 2 \*

0.822 \* 1.94 ) / ( 1 + 2 \* 1.94 )]

= -40.46 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 -25.43 25.43 197.62

at Q 69.91 -69.91 197.62

Short-side 2 at N -25.43 25.43 197.62

at Q 69.91 -69.91 197.62

Long-side 1 at M 103.81 -103.81 232.50

at Q 39.33 -39.33 197.62

Long-side 2 at M 122.27 -129.51 232.50

at Q 38.20 -40.46 197.62

**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

= 10.87 + -25.43

= -14.55 N./mm^2

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

= Sms + SbsNo

= 10.87 + 25.43

= 36.30 N./mm^2

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

= Sms + SbsQi

= 10.87 + 69.91

= 80.79 N./mm^2

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

= Sms + SbsQo

= 10.87 + -69.91

= -59.04 N./mm^2

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

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

= Sms + SbsNi

= 10.87 + -25.43

= -14.55 N./mm^2

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

= Sms + SbsNo

= 10.87 + 25.43

= 36.30 N./mm^2

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

= Sms + SbsQi

= 10.87 + 69.91

= 80.79 N./mm^2

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

= Sms + SbsQo

= 10.87 + -69.91

= -59.04 N./mm^2

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

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

= Sml + SblMi

= 12.34 + 103.81

= 116.15 N./mm^2

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

= Sml + SblMo

= 12.34 + -103.81

= -91.47 N./mm^2

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

= Sml + SblQi

= 7.15 + 39.33

= 46.48 N./mm^2

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

= Sml + SblQo

= 7.15 + -39.33

= -32.18 N./mm^2

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

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

= Sml + SblMi

= 13.90 + 122.27

= 136.17 N./mm^2

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

= Sml + SblMo

= 13.90 + -129.51

= -115.61 N./mm^2

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

= Sml + SblQi

= 7.15 + 38.20

= 45.35 N./mm^2

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

= Sml + SblQo

= 7.15 + -40.46

= -33.31 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 -14.55 36.30 197.62

at Q 80.79 -59.04 197.62

Short-side 2 at N -14.55 36.30 197.62

at Q 80.79 -59.04 197.62

Long-side 1 at M 116.15 -91.47 232.50

at Q 46.48 -32.18 197.62

Long-side 2 at M 136.17 -115.61 232.50

at Q 45.35 -33.31 197.62

**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) 37.17 N./mm^2

High Stress Percentage 32.49 %

M.A.W.P. for Membrane Stresses 88.01 bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable) -129.51 N./mm^2

High Stress Percentage 55.70 %

M.A.W.P. for Bending Stresses 51.34 bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable) 136.17 N./mm^2

High Stress Percentage 58.57 %

M.A.W.P. for Total Stresses 48.83 bars

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

**SUMMARY OF RESULTS:**

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable) 37.17 N./mm^2

High Stress Percentage 32.49 %

M.A.W.P. for Membrane Stresses 88.01 bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable) -129.51 N./mm^2

High Stress Percentage 55.70 %

M.A.W.P. for Bending Stresses 51.34 bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable) 136.17 N./mm^2

High Stress Percentage 58.57 %

M.A.W.P. for Total Stresses 48.83 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 95.0000 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 69.0000 mm.

Uniform Hole Diameter d0 25.6500 mm.

Depth of Holes T0 20.0000 mm.

Long-side Plate # 2,

Pitch Distance p 69.0000 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-2102**

**ASME Code, Section VIII, Division 1, 2019 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

= 69.000 - 25.650 / 69.000

= 0.628

Bending Ligament Efficiency [Eb]:

*As diameter holes are uniform Eb = Em*

= 0.628

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

= 69.000 - 29.618 / 69.000

= 0.571

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 )

= (( 1.29 \* 2.70 \* ( 2.70 /2 + 17.30 + 0.00 )) + ( 1.59\* 17.30 \*

( 17.30 /2 + 0.00 )) + ( 2.72 \* 0.00 \* ( 0.00 /2 ))) /

( 1.29 \* 2.70 + 1.59 \* 17.30 + 2.72 \* 0.00 )

= 9.771 mm.

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

*Ci = Xbar*

= 9.771 mm.

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

= -( t - CA - Xbar )

= -( 20.000 - 0.000 - 9.771 )

= -10.229 mm.

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

= 0.100 cm\*\*4

Effective Diameter [De]:

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

= 69.00 - (( 6 \* 0.10 ) / ((20.00 - 0.00 )^2 \* (10.23 )))

= 31.848 mm.

Bending Ligament Efficiency [Eb]:

= Pitch - De / Pitch

= 69.000 - 31.848 / 69.000

= 0.538

**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 0.628 0.628 10.000 -10.000

2 0.571 0.538 9.771 -10.229

**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 = 1.1579

K = (I2/I1)\*Alpha = 1.1579

**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 \* 95.00 / ( 2 \* 20.00 ) \* { 3- [( 6 + 1.16 \*

( 11 - 1.162) / ( 3 + 5 \* 1.16 )]}

= 15.39 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 \* 95.00 / ( 2 \* 20.00 ) \* { 3- [( 6 + 1.16 \*

( 11 - 1.162) / ( 3 + 5 \* 1.16 )]}

= 15.39 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 \* 20.00

= 17.05 N./mm^2

*If Em( 0.628 ) < E( 0.850 ) and Eb( 0.628 ) < E( 0.850 ) then*

Sml = Sml / Em

= 17.05 / 0.63

= 27.14 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 \* 20.00

= 17.05 N./mm^2

*If Em( 0.571 ) < E( 0.850 ) and Eb( 0.538 ) < E( 0.850 ) then*

Sml = Sml / Em

= 17.05 / 0.57

= 29.87 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 \* 95.00 / ( 2 \* 10.00 ) \* [( 6 + 1.16 \* ( 11 -

1.162) / ( 3 + 5 \* 1.16 )]

= 57.58 N./mm^2

Membrane Stress at Stay Plate [t4]:

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

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

= 62.00 \* 95.00 / ( 2 \* 10.00 ) \* [( 6 + 1.16 \* ( 11 -

1.162) / ( 3 + 5 \* 1.16 )]

= 57.58 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 15.39 95.12

Short-side 2 15.39 95.12

Short-side Corner 15.39 95.12

Long-side 1 at A 27.14 111.91

Long-side 2 at A 29.87 111.91

Long-side Corner 17.05 95.12

Stay Plate (t3) 57.58 114.39

Stay Plate (t4) 57.58 114.39

**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 \* 95.002 \*

(( 3 + 5 \* 1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 ))]

= -55.02 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 \* 95.002 \*

(( 3 + 5 \* 1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 ))]

= 55.02 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 \* 95.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 ))

= 85.65 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 \* 95.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 ))

= -85.65 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 \* 95.002 \*

(( 3 + 5 \* 1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 ))]

= -55.02 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 \* 95.002 \*

(( 3 + 5 \* 1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 ))]

= 55.02 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 \* 95.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 ))

= 85.65 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 \* 95.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 ))

= -85.65 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 \* 95.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 3 + 1.16 \*

( 6 - 1.162)) / ( 3 + 5 \* 1.16 )]

= 66.81 N./mm^2

*If Em( 0.628 ) < E( 0.850 ) and Eb( 0.628 ) < E( 0.850 ) then*

SblMi = SblMi / Eb

= 66.81 / 0.63

= 106.34 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 \* 95.002 \* -10.00 / ( 12 \* 0.07 ) \* [( 3 + 1.16 \*

( 6 - 1.162)) / ( 3 + 5 \* 1.16 )]

= -66.81 N./mm^2

*If Em( 0.628 ) < E( 0.850 ) and Eb( 0.628 ) < E( 0.850 ) then*

SblMo = SblMo / Eb

= -66.81 / 0.63

= -106.34 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 \* 95.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 )]

= 85.65 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 \* 95.002 \* -10.00 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 )]

= -85.65 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 \* 95.002 \* 9.77 / ( 12 \* 0.07 ) \* [( 3 + 1.16 \*

( 6 - 1.162)) / ( 3 + 5 \* 1.16 )]

= 65.28 N./mm^2

*If Em( 0.571 ) < E( 0.850 ) and Eb( 0.538 ) < E( 0.850 ) then*

SblMi = SblMi / Eb

= 65.28 / 0.54

= 121.24 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 \* 95.002 \* -10.23 / ( 12 \* 0.07 ) \* [( 3 + 1.16 \*

( 6 - 1.162)) / ( 3 + 5 \* 1.16 )]

= -68.34 N./mm^2

*If Em( 0.571 ) < E( 0.850 ) and Eb( 0.538 ) < E( 0.850 ) then*

SblMo = SblMo / Eb

= -68.34 / 0.54

= -126.92 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 \* 95.002 \* 9.77 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 )]

= 83.68 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 \* 95.002 \* -10.23 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 )]

= -87.61 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 -55.02 55.02 142.68

at Q 85.65 -85.65 142.68

Short-side 2 at N -55.02 55.02 142.68

at Q 85.65 -85.65 142.68

Long-side 1 at M 106.34 -106.34 167.86

at Q 85.65 -85.65 142.68

Long-side 2 at M 121.24 -126.92 167.86

at Q 83.68 -87.61 142.68

**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

= 15.39 + -55.02

= -39.64 N./mm^2

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

= Sms + SbsNo

= 15.39 + 55.02

= 70.41 N./mm^2

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

= Sms + SbsQi

= 15.39 + 85.65

= 101.03 N./mm^2

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

= Sms + SbsQo

= 15.39 + -85.65

= -70.26 N./mm^2

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

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

= Sms + SbsNi

= 15.39 + -55.02

= -39.64 N./mm^2

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

= Sms + SbsNo

= 15.39 + 55.02

= 70.41 N./mm^2

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

= Sms + SbsQi

= 15.39 + 85.65

= 101.03 N./mm^2

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

= Sms + SbsQo

= 15.39 + -85.65

= -70.26 N./mm^2

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

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

= Sml + SblMi

= 27.14 + 106.34

= 133.48 N./mm^2

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

= Sml + SblMo

= 27.14 + -106.34

= -79.20 N./mm^2

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

= Sml + SblQi

= 17.05 + 85.65

= 102.70 N./mm^2

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

= SmlB + SblQo

= 17.05 + -85.65

= -68.59 N./mm^2

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

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

= Sml + SblMi

= 29.87 + 121.24

= 151.11 N./mm^2

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

= Sml + SblMo

= 29.87 + -126.92

= -97.05 N./mm^2

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

= Sml + SblQi

= 17.05 + 83.68

= 100.74 N./mm^2

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

= SmlB + SblQo

= 17.05 + -87.61

= -70.56 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 -39.64 70.41 142.68

at Q 101.03 -70.26 142.68

Short-side 2 at N -39.64 70.41 142.68

at Q 101.03 -70.26 142.68

Long-side 1 at M 133.48 -79.20 167.86

at Q 102.70 -68.59 142.68

Long-side 2 at M 151.11 -97.05 167.86

at Q 100.74 -70.56 142.68

**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 / 305.000 ), 2.5 )

= 2.500

**SUMMARY OF RESULTS:**

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable) 57.58 N./mm^2

High Stress Percentage 50.34 %

M.A.W.P. for Membrane Stresses 123.17 bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable) -126.92 N./mm^2

High Stress Percentage 75.61 %

M.A.W.P. for Bending Stresses 82.00 bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable) 151.11 N./mm^2

High Stress Percentage 90.02 %

M.A.W.P. for Total Stresses 68.87 bars

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

**SUMMARY OF RESULTS:**

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable) 57.58 N./mm^2

High Stress Percentage 50.34 %

M.A.W.P. for Membrane Stresses 123.17 bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable) -126.92 N./mm^2

High Stress Percentage 75.61 %

M.A.W.P. for Bending Stresses 82.00 bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable) 151.11 N./mm^2

High Stress Percentage 90.02 %

M.A.W.P. for Total Stresses 68.87 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 155.0000 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 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 95.0000 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 69.0000 mm.

Uniform Hole Diameter d0 25.6500 mm.

Depth of Holes T0 20.0000 mm.

Long-side Plate # 2,

Pitch Distance p 69.0000 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-2102-Test**

**ASME Code, Section VIII, Division 1, 2019 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

= 69.000 - 25.650 / 69.000

= 0.628

Bending Ligament Efficiency [Eb]:

*As diameter holes are uniform Eb = Em*

= 0.628

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

= 69.000 - 29.618 / 69.000

= 0.571

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 )

= (( 1.29 \* 2.70 \* ( 2.70 /2 + 17.30 + 0.00 )) + ( 1.59\* 17.30 \*

( 17.30 /2 + 0.00 )) + ( 2.72 \* 0.00 \* ( 0.00 /2 ))) /

( 1.29 \* 2.70 + 1.59 \* 17.30 + 2.72 \* 0.00 )

= 9.771 mm.

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

*Ci = Xbar*

= 9.771 mm.

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

= -( t - CA - Xbar )

= -( 20.000 - 0.000 - 9.771 )

= -10.229 mm.

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

= 0.100 cm\*\*4

Effective Diameter [De]:

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

= 69.00 - (( 6 \* 0.10 ) / ((20.00 - 0.00 )^2 \* (10.23 )))

= 31.848 mm.

Bending Ligament Efficiency [Eb]:

= Pitch - De / Pitch

= 69.000 - 31.848 / 69.000

= 0.538

**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 0.628 0.628 10.000 -10.000

2 0.571 0.538 9.771 -10.229

**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 = 1.1579

K = (I2/I1)\*Alpha = 1.1579

**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 \* 95.00 / ( 2 \* 20.00 ) \* { 3- [( 6 + 1.16 \*

( 11 - 1.162) / ( 3 + 5 \* 1.16 )]}

= 20.00 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 \* 95.00 / ( 2 \* 20.00 ) \* { 3- [( 6 + 1.16 \*

( 11 - 1.162) / ( 3 + 5 \* 1.16 )]}

= 20.00 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 \* 20.00

= 22.17 N./mm^2

*If Em( 0.628 ) < E( 0.850 ) and Eb( 0.628 ) < E( 0.850 ) then*

Sml = Sml / Em

= 22.17 / 0.63

= 35.28 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 \* 20.00

= 22.17 N./mm^2

*If Em( 0.571 ) < E( 0.850 ) and Eb( 0.538 ) < E( 0.850 ) then*

Sml = Sml / Em

= 22.17 / 0.57

= 38.84 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 \* 95.00 / ( 2 \* 10.00 ) \* [( 6 + 1.16 \* ( 11 -

1.162) / ( 3 + 5 \* 1.16 )]

= 74.86 N./mm^2

Membrane Stress at Stay Plate [t4]:

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

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

= 80.60 \* 95.00 / ( 2 \* 10.00 ) \* [( 6 + 1.16 \* ( 11 -

1.162) / ( 3 + 5 \* 1.16 )]

= 74.86 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 20.00 131.75

Short-side 2 20.00 131.75

Short-side Corner 20.00 131.75

Long-side 1 at A 35.28 155.00

Long-side 2 at A 38.84 155.00

Long-side Corner 22.17 131.75

Stay Plate (t3) 74.86 114.39

Stay Plate (t4) 74.86 114.39

**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 \* 110.002 + 2 \* 95.002 \*

(( 3 + 5 \* 1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 ))]

= -71.53 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 \* 95.002 \*

(( 3 + 5 \* 1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 ))]

= 71.53 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 \* 95.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 ))

= 111.34 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 \* 95.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 ))

= -111.34 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 \* 95.002 \*

(( 3 + 5 \* 1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 ))]

= -71.53 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 \* 95.002 \*

(( 3 + 5 \* 1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 ))]

= 71.53 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 \* 95.002 \* 10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 ))

= 111.34 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 \* 95.002 \* -10.00 / ( 12 \* 0.07 ) \* (( 3 + 5 \*

1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 ))

= -111.34 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 \* 95.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 3 + 1.16 \*

( 6 - 1.162)) / ( 3 + 5 \* 1.16 )]

= 86.85 N./mm^2

*If Em( 0.628 ) < E( 0.850 ) and Eb( 0.628 ) < E( 0.850 ) then*

SblMi = SblMi / Eb

= 86.85 / 0.63

= 138.24 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 \* 95.002 \* -10.00 / ( 12 \* 0.07 ) \* [( 3 + 1.16 \*

( 6 - 1.162)) / ( 3 + 5 \* 1.16 )]

= -86.85 N./mm^2

*If Em( 0.628 ) < E( 0.850 ) and Eb( 0.628 ) < E( 0.850 ) then*

SblMo = SblMo / Eb

= -86.85 / 0.63

= -138.24 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 \* 95.002 \* 10.00 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 )]

= 111.34 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 \* 95.002 \* -10.00 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 )]

= -111.34 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 \* 95.002 \* 9.77 / ( 12 \* 0.07 ) \* [( 3 + 1.16 \*

( 6 - 1.162)) / ( 3 + 5 \* 1.16 )]

= 84.86 N./mm^2

*If Em( 0.571 ) < E( 0.850 ) and Eb( 0.538 ) < E( 0.850 ) then*

SblMi = SblMi / Eb

= 84.86 / 0.54

= 157.61 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 \* 95.002 \* -10.23 / ( 12 \* 0.07 ) \* [( 3 + 1.16 \*

( 6 - 1.162)) / ( 3 + 5 \* 1.16 )]

= -88.84 N./mm^2

*If Em( 0.571 ) < E( 0.850 ) and Eb( 0.538 ) < E( 0.850 ) then*

SblMo = SblMo / Eb

= -88.84 / 0.54

= -165.00 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 \* 95.002 \* 9.77 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 )]

= 108.79 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 \* 95.002 \* -10.23 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

1.162 \* 1.16 ) / ( 3 + 5 \* 1.16 )]

= -113.89 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 -71.53 71.53 197.62

at Q 111.34 -111.34 197.62

Short-side 2 at N -71.53 71.53 197.62

at Q 111.34 -111.34 197.62

Long-side 1 at M 138.24 -138.24 232.50

at Q 111.34 -111.34 197.62

Long-side 2 at M 157.61 -165.00 232.50

at Q 108.79 -113.89 197.62

**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

= 20.00 + -71.53

= -51.53 N./mm^2

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

= Sms + SbsNo

= 20.00 + 71.53

= 91.53 N./mm^2

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

= Sms + SbsQi

= 20.00 + 111.34

= 131.34 N./mm^2

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

= Sms + SbsQo

= 20.00 + -111.34

= -91.34 N./mm^2

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

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

= Sms + SbsNi

= 20.00 + -71.53

= -51.53 N./mm^2

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

= Sms + SbsNo

= 20.00 + 71.53

= 91.53 N./mm^2

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

= Sms + SbsQi

= 20.00 + 111.34

= 131.34 N./mm^2

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

= Sms + SbsQo

= 20.00 + -111.34

= -91.34 N./mm^2

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

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

= Sml + SblMi

= 35.28 + 138.24

= 173.52 N./mm^2

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

= Sml + SblMo

= 35.28 + -138.24

= -102.96 N./mm^2

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

= Sml + SblQi

= 22.17 + 111.34

= 133.51 N./mm^2

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

= SmlB + SblQo

= 22.17 + -111.34

= -89.17 N./mm^2

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

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

= Sml + SblMi

= 38.84 + 157.61

= 196.44 N./mm^2

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

= Sml + SblMo

= 38.84 + -165.00

= -126.16 N./mm^2

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

= Sml + SblQi

= 22.17 + 108.79

= 130.96 N./mm^2

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

= SmlB + SblQo

= 22.17 + -113.89

= -91.72 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 -51.53 91.53 197.62

at Q 131.34 -91.34 197.62

Short-side 2 at N -51.53 91.53 197.62

at Q 131.34 -91.34 197.62

Long-side 1 at M 173.52 -102.96 232.50

at Q 133.51 -89.17 197.62

Long-side 2 at M 196.44 -126.16 232.50

at Q 130.96 -91.72 197.62

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

Actual Allowable

End Plate 121.91 155.00

**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 / ( 155.000 ) ) + 0.000

= 17.737 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))

= 102.473 bars

*where Z is:*

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

= min( 3.4 - 2.4( 110.000 / 305.000 ), 2.5 )

= 2.500

**SUMMARY OF RESULTS:**

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable) 74.86 N./mm^2

High Stress Percentage 65.44 %

M.A.W.P. for Membrane Stresses 123.17 bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable) -165.00 N./mm^2

High Stress Percentage 70.97 %

M.A.W.P. for Bending Stresses 113.58 bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable) 196.44 N./mm^2

High Stress Percentage 84.49 %

M.A.W.P. for Total Stresses 95.39 bars

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

**SUMMARY OF RESULTS:**

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable) 74.86 N./mm^2

High Stress Percentage 65.44 %

M.A.W.P. for Membrane Stresses 123.17 bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable) -165.00 N./mm^2

High Stress Percentage 70.97 %

M.A.W.P. for Bending Stresses 113.58 bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable) 196.44 N./mm^2

High Stress Percentage 84.49 %

M.A.W.P. for Total Stresses 95.39 bars

## floating Header Calculation @ Design Pressure for ae-2102.

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

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 69.0000 mm.

Uniform Hole Diameter d0 25.6500 mm.

Depth of Holes T0 20.0000 mm.

Long-side Plate # 2,

Pitch Distance p 69.0000 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-2101**

**ASME Code, Section VIII, Division 1, 2019 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

= 69.000 - 25.650 / 69.000

= 0.628

Bending Ligament Efficiency [Eb]:

*As diameter holes are uniform Eb = Em*

= 0.628

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

= 69.000 - 29.618 / 69.000

= 0.571

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 )

= (( 1.29 \* 2.70 \* ( 2.70 /2 + 17.30 + 0.00 )) + ( 1.59\* 17.30 \*

( 17.30 /2 + 0.00 )) + ( 2.72 \* 0.00 \* ( 0.00 /2 ))) /

( 1.29 \* 2.70 + 1.59 \* 17.30 + 2.72 \* 0.00 )

= 9.771 mm.

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

*Ci = Xbar*

= 9.771 mm.

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

= -( t - CA - Xbar )

= -( 20.000 - 0.000 - 9.771 )

= -10.229 mm.

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

= 0.100 cm\*\*4

Effective Diameter [De]:

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

= 69.00 - (( 6 \* 0.10 ) / ((20.00 - 0.00 )^2 \* (10.23 )))

= 31.848 mm.

Bending Ligament Efficiency [Eb]:

= Pitch - De / Pitch

= 69.000 - 31.848 / 69.000

= 0.538

**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 0.628 0.628 10.000 -10.000

2 0.571 0.538 9.771 -10.229

**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( 0.628 ) < E( 0.850 ) and Eb( 0.628 ) < E( 0.850 ) then*

Sml = Sml / Em

= 15.50 / 0.63

= 24.67 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( 0.571 ) < E( 0.850 ) and Eb( 0.538 ) < E( 0.850 ) then*

Sml = Sml / Em

= 15.50 / 0.57

= 27.16 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 24.67 111.91

Long-side 2 at A 27.16 111.91

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( 0.628 ) < E( 0.850 ) and Eb( 0.628 ) < E( 0.850 ) then*

SblMi = SblMi / Eb

= 20.61 / 0.63

= 32.80 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( 0.628 ) < E( 0.850 ) and Eb( 0.628 ) < E( 0.850 ) then*

SblMo = SblMo / Eb

= -20.61 / 0.63

= -32.80 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 \* 9.77 / ( 12 \* 0.07 ) \* [( 3 + 1.67 \*

( 6 - 1.672)) / ( 3 + 5 \* 1.67 )]

= 20.14 N./mm^2

*If Em( 0.571 ) < E( 0.850 ) and Eb( 0.538 ) < E( 0.850 ) then*

SblMi = SblMi / Eb

= 20.14 / 0.54

= 37.40 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 \* -10.23 / ( 12 \* 0.07 ) \* [( 3 + 1.67 \*

( 6 - 1.672)) / ( 3 + 5 \* 1.67 )]

= -21.08 N./mm^2

*If Em( 0.571 ) < E( 0.850 ) and Eb( 0.538 ) < E( 0.850 ) then*

SblMo = SblMo / Eb

= -21.08 / 0.54

= -39.15 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 \* 9.77 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 )]

= 62.90 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 \* 60.002 \* -10.23 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 )]

= -65.85 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 32.80 -32.80 167.86

at Q 64.37 -64.37 142.68

Long-side 2 at M 37.40 -39.15 167.86

at Q 62.90 -65.85 142.68

**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

= 24.67 + 32.80

= 57.47 N./mm^2

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

= Sml + SblMo

= 24.67 + -32.80

= -8.13 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

= 27.16 + 37.40

= 64.55 N./mm^2

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

= Sml + SblMo

= 27.16 + -39.15

= -11.99 N./mm^2

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

= Sml + SblQi

= 15.50 + 62.90

= 78.40 N./mm^2

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

= SmlB + SblQo

= 15.50 + -65.85

= -50.35 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 57.47 -8.13 167.86

at Q 79.88 -48.87 142.68

Long-side 2 at M 64.55 -11.99 167.86

at Q 78.40 -50.35 142.68

**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) -65.85 N./mm^2

High Stress Percentage 46.15 %

M.A.W.P. for Bending Stresses 134.34 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) -65.85 N./mm^2

High Stress Percentage 46.15 %

M.A.W.P. for Bending Stresses 134.34 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-2101-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 69.0000 mm.

Uniform Hole Diameter d0 25.6500 mm.

Depth of Holes T0 20.0000 mm.

Long-side Plate # 2,

Pitch Distance p 69.0000 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-2101-Test**

**ASME Code, Section VIII, Division 1, 2019 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

= 69.000 - 25.650 / 69.000

= 0.628

Bending Ligament Efficiency [Eb]:

*As diameter holes are uniform Eb = Em*

= 0.628

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

= 69.000 - 29.618 / 69.000

= 0.571

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 )

= (( 1.29 \* 2.70 \* ( 2.70 /2 + 17.30 + 0.00 )) + ( 1.59\* 17.30 \*

( 17.30 /2 + 0.00 )) + ( 2.72 \* 0.00 \* ( 0.00 /2 ))) /

( 1.29 \* 2.70 + 1.59 \* 17.30 + 2.72 \* 0.00 )

= 9.771 mm.

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

*Ci = Xbar*

= 9.771 mm.

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

= -( t - CA - Xbar )

= -( 20.000 - 0.000 - 9.771 )

= -10.229 mm.

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

= 0.100 cm\*\*4

Effective Diameter [De]:

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

= 69.00 - (( 6 \* 0.10 ) / ((20.00 - 0.00 )^2 \* (10.23 )))

= 31.848 mm.

Bending Ligament Efficiency [Eb]:

= Pitch - De / Pitch

= 69.000 - 31.848 / 69.000

= 0.538

**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 0.628 0.628 10.000 -10.000

2 0.571 0.538 9.771 -10.229

**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( 0.628 ) < E( 0.850 ) and Eb( 0.628 ) < E( 0.850 ) then*

Sml = Sml / Em

= 20.15 / 0.63

= 32.07 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( 0.571 ) < E( 0.850 ) and Eb( 0.538 ) < E( 0.850 ) then*

Sml = Sml / Em

= 20.15 / 0.57

= 35.31 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 32.07 155.00

Long-side 2 at A 35.31 155.00

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( 0.628 ) < E( 0.850 ) and Eb( 0.628 ) < E( 0.850 ) then*

SblMi = SblMi / Eb

= 26.79 / 0.63

= 42.64 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( 0.628 ) < E( 0.850 ) and Eb( 0.628 ) < E( 0.850 ) then*

SblMo = SblMo / Eb

= -26.79 / 0.63

= -42.64 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 \* 9.77 / ( 12 \* 0.07 ) \* [( 3 + 1.67 \*

( 6 - 1.672)) / ( 3 + 5 \* 1.67 )]

= 26.18 N./mm^2

*If Em( 0.571 ) < E( 0.850 ) and Eb( 0.538 ) < E( 0.850 ) then*

SblMi = SblMi / Eb

= 26.18 / 0.54

= 48.61 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 \* -10.23 / ( 12 \* 0.07 ) \* [( 3 + 1.67 \*

( 6 - 1.672)) / ( 3 + 5 \* 1.67 )]

= -27.40 N./mm^2

*If Em( 0.571 ) < E( 0.850 ) and Eb( 0.538 ) < E( 0.850 ) then*

SblMo = SblMo / Eb

= -27.40 / 0.54

= -50.89 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 \* 9.77 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 )]

= 81.77 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 \* -10.23 / ( 12 \* 0.07 ) \* [( 3 + 5 \*

1.672 \* 1.67 ) / ( 3 + 5 \* 1.67 )]

= -85.60 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 42.64 -42.64 232.50

at Q 83.69 -83.69 197.62

Long-side 2 at M 48.61 -50.89 232.50

at Q 81.77 -85.60 197.62

**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

= 32.07 + 42.64

= 74.71 N./mm^2

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

= Sml + SblMo

= 32.07 + -42.64

= -10.57 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

= 35.31 + 48.61

= 83.92 N./mm^2

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

= Sml + SblMo

= 35.31 + -50.89

= -15.59 N./mm^2

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

= Sml + SblQi

= 20.15 + 81.77

= 101.92 N./mm^2

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

= SmlB + SblQo

= 20.15 + -85.60

= -65.45 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 74.71 -10.57 232.50

at Q 103.84 -63.54 197.62

Long-side 2 at M 83.92 -15.59 232.50

at Q 101.92 -65.45 197.62

**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) -85.60 N./mm^2

High Stress Percentage 43.32 %

M.A.W.P. for Bending Stresses 186.07 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) -85.60 N./mm^2

High Stress Percentage 43.32 %

M.A.W.P. for Bending Stresses 186.07 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