طرح نگهداشت و افزایش تولید 27 مخزن

Thermal/Mechnical Calculation Book

نگهداشت و افزایش تولید میدان نفتی بینک

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IFI: Issued For Information
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REVISION RECORD SHEET

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03

Contents

1.0 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.

2.0 THERMAL/MECHANICAL CALCULATION BOOK

03

HTRI

API 661 Air-Cooled Heat Exchanger - Specification Sheet

Job No.		Item No.	2101 (summer)
Page	Page 1	By	
Date		V03	V03
Proposal No.		Contract No.	
Inquiry No.		Order No.	

Manufacturer			Heat exchanged	(MegaWatts)	0.3818
Model no.			Surface/Item-Finned tube	(m2)	658.66
Customer		PEDCO/NISOC	Bare tube	(m2)	31.536
Plant location		BINAK Oilfeild	MTD, Eff.	(Deg. C)	29.1
Service		1st stage Gas Compression Coo	Transfer rate-Finned	(W/m2-K)	20.607
Type draft		INDUCED	Bare tube, service	(W/m2-K)	430.41
Bay size (WxL)	(m)	1.9x 3.8	Bare tube, clean	(W/m2-K)	483.18
No. of bays/Items		1			

Basic design data

Pressure design code		Structural code	
Tube bundle code stamped		Flammable service	
Heating coil code stamped		Lethal/toxic service	

Performance Data - Tube Side

					In	Out
Fluid name		Hydrocarbon				
Total fluid entering	(kg/hr)	9530.4	Total flow rate (Liq/Vap)	(kg/hr)	9530.4	9530.4
Dew /bubble point	(Deg. C)	/	Water/Steam	(kg/hr)		0
	(Deg. C)		Noncondensables	(kg/hr)		0
Latent heat	(kJ/kg)		Molecular Wt. (Vap/Non-cond)			
Inlet pressure	(barG)	17.9	Density (Liq/Vap)	(kg/m3)	14.197	17.141
Pressure drop (All/Calc)	(bar)	0.7 / 0.473	Specific heat (Liq/Vap)	(kJ/kg-C)	2.2057	1.9724
Velocity (Allow /Calc)	(m/s)	/ 17.09	Thermal cond. (Liq/Vap)	(W/m-K)	0.0438	0.0336
Inside fouling resistance	(m2-K/W)	0.0002	Viscosity (Liq/Vap)	(mN-s/m2)	0.0137	0.0117
		In / Out				
Temperature	(Deg. C)	129 / 60				

Performance Data - Air Side

Air inlet temperature	(Deg. C)	50.26	Face velocity	(m/s)	2.99
Air flow rate/item	(m3/s)	24.4	Minimum design ambient temp.	(Deg. C)	5
Mass velocity	(kg/s-m2)		Altitude	(m)	12.5
Air outlet temperature	(Deg. C)	65.2	Static pressure	(Pa)	145.05
Air flow rate/fan	(m3/s)	12.2			

Design, Material, and Construction

Design pressure	(barG)	22	**Heating Coil**		NO
Test pressure	(barG)	28.6	No. of tubes		
Design temperature	(Deg. C)	155	Tube outside diameter	(mm)	
Min. design metal temp.	(Deg. C)		Tube material		
Tube bundle			Fin material and type		
Size (WxL)	(m)	1.86X 3.8	Fin thickness	(mm)	
No./Bay		1	ASME Code, Sec. VIII, Div. 1		
Number of tube rows		4	Heating fluid		
Bundles in parallel		1	Heating fluid flow rate	(kg/hr)	
Bundles in series			Temperature (In/Out)	(Deg. C)	/
Structure mounting			Inlet pressure	(barG)	
Pipe rack beams			Pressure drop (All/Calc)	(kPa)	/
Ladders, walkways, platforms			Design temperature	(Deg. C)	
Structure surface prep.			Design pressure	(barG)	
Header surface prep.			Inlet/Outlet nozzle		/
Louver		YES	**Header**		
Material			Type		Plug
Action control		Manual	Material		SA-240 TP316L
Action type			Corrosion Allowance	(mm)	0
			No. of passes		4

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API 661 Air-Cooled Heat Exchanger - Specification Sheet

Job No.		Item No.	2101 (summer)
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Design, Material, and Construction (continued)

Header (continued)

Slope		1% ON LAST PASS	
Plug material		SA 182 F316L	
Gasket material		Solid metal	

Nozzle	No.	Size, (In)	Rating/Facing
Inlet	1	6	300 RF
Outlet	1	6	300 RF
Vent	1	2	300 RF
Drain	1	2	300 RF
Chemical Cleaning			
Min. Wall Thk.			

Tube

Material		SA-213 TP316L Tube (S) S31603
Tube outside diameter	(mm)	25.4
wall thickness	(mm)	1.651

No./Bundle		104
Length	(m)	3.8
Pitch	(mm)	61
Layout		Triangular

Fin

Type		Extruded
Material		Aluminum Alloy 1060 - O
Thickness	(mm)	0.48
Selection temp.	(C)	
Outside diameter	(mm)	57.15
Fin density	(fin/in)	10
ASME Code, Sec. VIII, Div. 1		
Customer Specifications		

Mechanical Equipment

Fan

Manufacturer		
No./Bay		2
RPM	(Revs/min.)	696
Diameter	(mm)	1372
No. of blades		5
Angle	(degrees)	
Pitch adjustment		50% Auto
Blade material		AL
Hub material		ALU/Steel
@design temp		3.4
@min. ambient temp		4.5
Tip speed		

Driver

Type		
Manufacturer		
No./Bay		2
Driver	(kW)	5.5

RPM		1500
Service factor		1
Enclosure		EExd,IIB T3 (IP55)
Voltage		400
Phase		3
Cycle		50
Fan noise level	(dB)	≤85

Speed Reducer

Type		V-BELT
Manufacturer		
No./Bay		2
Service factor		
Speed ratio		
Support		
Vib. Switch		YES,EExd,IIB T3 (IP65)
Enclosure		

Controls - Air Side

Air recirculation		NO	
Degree control of outlet process temp.			
(Max. Cooling),+/-		/	
Action on control signal failure			
Fan pitch			
Louvers			
Actuator air supply			
Fan			

Louvers			
Positioner			
Signal air pressure (barG)			
From		To	
From		To	
Supply air pressure (barG)			
From		To	
From		To	

Shipping

Plot area (WxL)	(m)	1.9 x 3.8	Total	(kg)	8986.5
Bundle weight	(kg)	2205.9	Shipping	(kg)	
Bay	(kg)				

Note: 1) Reported duty and flow rates include a user-specifiedmultiplier of 1.10
2-Max allowable nozzle load = 3xAPI
3-Material will be meet requirements of NACE MR0175/ISO1516 and specification for material requirments in sour service (BK-GNRAL-PEDCO-000-PI-SP-0008)
4-HTRI Weight is reported

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API 661 Air-Cooled Heat Exchanger - Specification Sheet

Job No.		Item No.	2101 (winter)
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Manufacturer			Heat exchanged	(MegaWatts)	0.268
Model no.			Surface/Item-Finned tube	(m2)	658.66
Customer		PEDCO/NISOC	Bare tube	(m2)	31.536
Plant location		Binak oilfield	MTD, Eff.	(Deg. C)	26.4
Service	1st stage Gas	Compression Coole	Transfer rate-Finned	(W/m2-K)	19.508
Type draft		INDUCED	Bare tube, service	(W/m2-K)	407.45
Bay size (WxL)	(m)	1.9 x 3.8	Bare tube, clean	(W/m2-K)	454.43
No. of bays/Items		1			

Basic design data

Pressure design code		Structural code	
Tube bundle code stamped		Flammable service	
Heating coil code stamped		Lethal/toxic service	

Performance Data - Tube Side

					In	Out
Fluid name		HYDROCARBON				
Total fluid entering	(kg/hr)	8343.5	Total flow rate (Liq/Vap)	(kg/hr)	8343.5	8343.5
Dew /bubble point	(Deg. C)	/	Water/Steam	(kg/hr)	/	/
	(Deg. C)		Noncondensables	(kg/hr)		
Latent heat	(kJ/kg)		Molecular Wt. (Vap/Non-cond)		/	/
Inlet pressure	(barG)	17.9	Density (Liq/Vap)	(kg/m3)	14.72	17.251
Pressure drop (All/Calc)	(bar)	0.7 / 0.36	Specific heat (Liq/Vap)	(kJ/kg-C)	2.1616	1.9724
Velocity (Allow /Calc)	(m/s)	/ 14.63	Thermal cond. (Liq/Vap)	(W/m-K)	0.0418	0.0336
Inside fouling resistance	(m2-K/W)	0.0002	Viscosity (Liq/Vap)	(mN-s/m2)	0.0133	0.0117
		In / Out				
Temperature	(Deg. C)	116 / 60				

Performance Data - Air Side

Air inlet temperature	(Deg. C)	50.26	Face velocity	(m/s)	2.99
Air flow rate/item	(m3/s)	24.072	Minimum design ambient temp.	(Deg. C)	5
Mass velocity	(kg/s-m2)		Altitude	(m)	12.5
Air outlet temperature	(Deg. C)	60.76	Static pressure	(Pa)	143.54
Air flow rate/fan	(m3/s)	12.036			

Design, Material, and Construction

Design pressure	(barG)	22	**Heating Coil**		NO
Test pressure	(barG)	28.6	No. of tubes		
Design temperature	(Deg. C)	155	Tube outside diameter	(mm)	
Min. design metal temp.	(Deg. C)		Tube material		
Tube bundle			Fin material and type		
Size (WxL)	(m)	1.86X 3.80	Fin thickness	(mm)	
No./Bay		1	ASME Code, Sec. VIII, Div. 1		
Number of tube rows		4	Heating fluid		
Bundles in parallel		1	Heating fluid flow rate	(kg/hr)	
Bundles in series			Temperature (In/Out)	(Deg. C)	/
Structure mounting			Inlet pressure	(barG)	
Pipe rack beams			Pressure drop (All/Calc)	(kPa)	/
Ladders, walkways, platforms			Design temperature	(Deg. C)	
Structure surface prep.			Design pressure	(barG)	
Header surface prep.			Inlet/Outlet nozzle		/
Louver		YES	**Header**		
Material			Type		plug
Action control		Manual	Material		SA-240 TP316L
Action type			Corrosion Allowance	(mm)	0
			No. of passes		4

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API 661 Air-Cooled Heat Exchanger - Specification Sheet

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Design, Material, and Construction (continued)

Header (continued)				No./Bundle		104
Slope		1% ON LAST PASS		Length	(m)	3.8
Plug material		SA 182 F316L		Pitch	(mm)	61
Gasket material		Solid Metal		Layout		Triangular
Nozzle	No.	Size, (In)	Rating/Facing	**Fin**		
Inlet	1	6	300 RF	Type		EXTRUDED
Outlet	1	6	300RF	Material		Aluminum Alloy 1060 - O
Vent	1	2	300RF	Thickness	(mm)	0.48
Drain	1	2	300RF	Selection temp.	(C)	
Chemical Cleaning				Outside diameter	(mm)	57.15
Min. Wall Thk.				Fin density	(fin/in)	10
Tube				ASME Code, Sec. VIII, Div. 1		
Material		SA-213 TP316L Tube (S) S31603		Customer Specifications		
Tube outside diameter	(mm)	25.4				
w all thickness	(mm)	1.651				

Mechanical Equipment

Fan				RPM		1500
Manufacturer				Service factor		1
No./Bay		2		Enclosure		EExd, IIB T3 (IP55)
RPM	(Revs/min.)	696		Voltage		400
Diameter	(MM)	1372		Phase		3
No. of blades		4		Cycle		50
Angle	(degrees)			Fan noise level	(dB)	<85
Pitch adjustment		50% Auto		**Speed Reducer**		
Blade material		AL		Type		V-Belt
Hub material		Alu/Steel		Manufacturer		
@design temp		3.4		No./Bay		2
@min. ambient temp		4.5		Service factor		1.8
Tip speed				Speed ratio		
Driver				Support		
Type				Vib. sw itch		YES EExd, IIB T3 (IP55)
Manufacturer				Enclosure		
No./Bay		2				
Driver	(kW)	5.5				

Controls - Air Side

Air recirculation	NO	Louvers	
Degree control of outlet process temp.		Positioner	
(Max. Cooling),+/-	/	Signal air pressure (barG)	
Action on control signal failure		From	To
Fan pitch		From	To
Louvers		Supply air pressure (barG)	
Actuator air supply		From	To
Fan		From	To

Shipping

Plot area (WxL)	(m)	1.86 x 3.8	Total (Note 4)	(kg)	8986.5
Bundle w eight (Note 4)	(kg)	2205.9	Shipping	(kg)	
Bay	(kg)				

Note:1- Reported duty and flow rates include a user-specifiedmultiplier of 1.10
2-Maximum allow able nozzle load = 3 x API.
3-Material w ill be meet requirements of NACE MR0175/ISO1516 and specification for material requirments in sour service (BK-GNRAL-PEDCO-000-PI-SP-0008)
4-HTRI Weight is reported

API 661 Air-Cooled Heat Exchanger - Specification Sheet

Job No.		Item No.	2102 (Summer)
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Manufacturer			Heat exchanged	(MegaWatts)	0.4992
Model no.			Surface/Item-Finned tube	(m2)	1010.5
Customer		PEDCO/NISOC	Bare tube	(m2)	48.548
Plant location		BINAK oil.feild	MTD, Eff.	(Deg. C)	33.7
Service		2st Stage Gas Compression Cool	Transfer rate-Finned	(W/m2-K)	17.389
Type draft		INDUCED	Bare tube, service	(W/m2-K)	361.95
Bay size (WxL)	(m)	2.12 x 3.900	Bare tube, clean	(W/m2-K)	398.69
No. of bays/Items		1			

Basic design data

Pressure design code		Structural code	
Tube bundle code stamped		Flammable service	
Heating coil code stamped		Lethal/toxic service	

Performance Data - Tube Side

						In	Out
Fluid name		HYDROCARBON					
Total fluid entering	(kg/hr)	9530.4	Total flow rate (Liq/Vap)	(kg/hr)		9530.4	9530.4
Dew /bubble point	(Deg. C)	/	Water/Steam	(kg/hr)			
	(Deg. C)		Noncondensables	(kg/hr)			
Latent heat	(kJ/kg)		Molecular Wt. (Vap/Non-cond)				
Inlet pressure	(barG)	54.8	Density (Liq/Vap)	(kg/m3)		41.398	57.58
Pressure drop (All/Calc)	(bar)	0.7 / 0.091	Specific heat (Liq/Vap)	(kJ/kg-C)		2.2852	2.0007
Velocity (Allow /Calc)	(m/s)	/ 3.67	Thermal cond. (Liq/Vap)	(W/m-K)		0.0483	0.036
Inside fouling resistance	(m2-K/W)	0.0002	Viscosity (Liq/Vap)	(mN-s/m2)		0.0144	0.0121
		In / Out					
Temperature	(Deg. C)	148 / 60					

Performance Data - Air Side

Air inlet temperature	(Deg. C)	50.26	Face velocity	(m/s)	2.9
Air flow rate/item	(m3/s)	27.1	Minimum design ambient temp.	(Deg. C)	5
Mass velocity	(kg/s-m2)		Altitude	(m)	12.5
Air outlet temperature	(Deg. C)	67.97	Static pressure	(Pa)	142.13
Air flow rate/fan	(m3/s)	13.55			

Design, Material, and Construction

Design pressure	(barG)	62	**Heating Coil**		NO
Test pressure	(barG)	80.6	No. of tubes		
Design temperature	(Deg. C)	175	Tube outside diameter	(mm)	
Min. design metal temp.	(Deg. C)	5	Tube material		
Tube bundle			Fin material and type		
Size (WxL)	(m)	2.06 X 3.900	Fin thickness	(mm)	
No./Bay		1	ASME Code, Sec. VIII, Div. 1		
Number of tube rows		6	Heating fluid		
Bundles in parallel		1	Heating fluid flow rate	(kg/hr)	
Bundles in series			Temperature (In/Out)	(Deg. C)	/
Structure mounting			Inlet pressure	(barG)	
Pipe rack beams			Pressure drop (All/Calc)	(kPa)	/
Ladders, walkways, platforms			Design temperature	(Deg. C)	
Structure surface prep.			Design pressure	(barG)	
Header surface prep.			Inlet/Outlet nozzle		/
Louver			**Header**		
Material		YES	Type		PLUG
Action control		Manual	Material		SA-240 TP316L
Action type			Corrosion Allowance	(mm)	0
			No. of passes		4

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API 661 Air-Cooled Heat Exchanger - Specification Sheet

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Design, Material, and Construction (continued)

Header (continued)		**Bundle**	
Slope	1% ON LAST PASS	No./Bundle	156
Plug material	SA-182 F316 L	Length (m)	3.9
Gasket material	Solid METAL	Pitch (mm)	69
Nozzle	No. / Size, (in) / Rating/Facing	Layout	Triangular
Inlet	1 / 4 / 600 RF	**Fin**	
Outlet	1 / 4 / 600 RF	Type	Extruded
Vent	1 / 2 / 600 RF	Material	Aluminum Alloy 1060 - O
Drain	1 / 2 / 600 RF	Thickness (mm)	0.48
Chemical Cleaning		Selection temp. (C)	
Min. Wall Thk.		Outside diameter (mm)	57.15
Tube		Fin density (fin/in)	10
Material	SA-213 TP316L Tube (S) S31603	ASME Code, Sec. VIII, Div. 1	
Tube outside diameter (mm)	25.4	Customer Specifications	
wall thickness (mm)	1.651		

Mechanical Equipment

Fan		RPM	1500
Manufacturer		Service factor	1
No./Bay	2	Enclosure	EExd, IIB T3 (IP 55)
RPM (Revs/min.)	658.6	Voltage	400
Diameter (mm)	1450	Phase	3
No. of blades	5	Cycle	50
Angle (degrees)		Fan noise level (dB)	<85
Pitch adjustment	50% Auto	**Speed Reducer**	
Blade material	Al	Type	V-Belt
Hub material	steel/Alu	Manufacturer	
@design temp	3.5	No./Bay	2
@min. ambient temp	5.2	Service factor	1.8
Tip speed		Speed ratio	2.28
Driver		Support	
Type		Vib. switch	
Manufacturer		Enclosure	
No./Bay	2		
Driver (kW)	7.5		

Controls - Air Side

Air recirculation	NO	Louvers	
Degree control of outlet process temp.		Positioner	
(Max. Cooling),+/-	/	Signal air pressure (barG)	
Action on control signal failure		From / To	
Fan pitch		From / To	
Louvers		Supply air pressure (barG)	
Actuator air supply		From / To	
Fan		From / To	

Shipping

Plot area (WxL)	(m)	2.12 x 3.900	Total (kg)	10429
Bundle weight (Note 4)	(kg)	3265.9	Shipping (kg)	
Bay	(kg)			

Note: 1-Reported duty and flow rates include a user-specifiedmultiplier of 1.10
2-Maximum allow able nozzle load = 3 x API.
3-Material will be meet requirements of NACE MR0175/ISO1516 and specification for material requirments in sour service (BK-GNRAL-PEDCO-000-PI-SP-0008)
4- HTRI Weights are reported

HTRI

API 661 Air-Cooled Heat Exchanger - Specification Sheet

Job No.		Item No.	2102 (winter)
Page		By	
Date	9/30/2024	Revision	V03
Proposal No.		Contract No.	
Inquiry No.		Order No.	

Manufacturer			Heat exchanged	(MegaWatts)	0.4519
Model no.			Surface/Item-Finned tube	(m2)	1010.5
Customer		PEDCO/NISOC	Bare tube	(m2)	48.548
Plant location		BINAK oilfeild	MTD, Eff.	(Deg. C)	34.6
Service		2st Stage Gas Compression Cools	Transfer rate-Finned	(W/m2-K)	16.708
Type draft		INDUCED	Bare tube, service	(W/m2-K)	347.77
Bay size (WxL)	(m)	2.12 x 3.900	Bare tube, clean	(W/m2-K)	381.55
No. of bays/Items		1			

Basic design data

Pressure design code		Structural code	
Tube bundle code stamped		Flammable service	
Heating coil code stamped		Lethal/toxic service	

Performance Data - Tube Side

					In	Out
Fluid name		HYDROCARBON	Total flow rate (Liq/Vap)	(kg/hr)	8343.5 / 8343.5	
Total fluid entering	(kg/hr)	8343.5	Water/Steam	(kg/hr)	/	/
Dew /bubble point	(Deg. C)	/	Noncondensables	(kg/hr)		
	(Deg. C)		Molecular Wt. (Vap/Non-cond)		/	/
Latent heat	(kJ/kg)		Density (Liq/Vap)	(kg/m3)	/ 35.721	/ 48.434
Inlet pressure	(barG)	54.8	Specific heat (Liq/Vap)	(kJ/kg-C)	/ 2.3379	/ 2.0425
Pressure drop (All/Calc)	(bar)	0.7 / 0.083	Thermal cond. (Liq/Vap)	(W/m-K)	/ 0.0511	/ 0.0382
Velocity (Allow /Calc)	(m/s)	/ 3.77	Viscosity (Liq/Vap)	(mN-s/m2)	/ 0.0149	/ 0.0125
Inside fouling resistance	(m2-K/W)	0.0002				
		In / Out				
Temperature	(Deg. C)	149 / 60				

Performance Data - Air Side

Air inlet temperature	(Deg. C)	50.26	Face velocity	(m/s)	2.9
Air flow rate/item	(m3/s)	26.97	Minimum design ambient temp.	(Deg. C)	5
Mass velocity	(kg/s-m2)		Altitude	(m)	12.5
Air outlet temperature	(Deg. C)	66.3	Static pressure	(Pa)	141.64
Air flow rate/fan	(m3/s)	13.484			

Design, Material, and Construction

Design pressure	(barG)	62	**Heating Coil**		NO
Test pressure	(barG)	80.6	No. of tubes		
Design temperature	(Deg. C)	175	Tube outside diameter	(mm)	
Min. design metal temp.	(Deg. C)		Tube material		
Tube bundle			Fin material and type		
Size (WxL)	(m)	2.058 X 3.900	Fin thickness	(mm)	
No./Bay		1	ASME Code, Sec. VIII, Div. 1		
Number of tube rows		6	Heating fluid		
Bundles in parallel		1	Heating fluid flow rate	(kg/hr)	
Bundles in series			Temperature (In/Out)	(Deg. C)	/
Structure mounting			Inlet pressure	(barG)	
Pipe rack beams			Pressure drop (All/Calc)	(kPa)	/
Ladders, walkways, platforms			Design temperature	(Deg. C)	
Structure surface prep.			Design pressure	(barG)	
Header surface prep.			Inlet/Outlet nozzle		/
Louver			**Header**		
Material		YES	Type		PLUG
Action control		Manual	Material		SA-240 TP316L
Action type			Corrosion Allowance	(mm)	0
			No. of passes		4

HTRI

API 661 Air-Cooled Heat Exchanger - Specification Sheet

Job No.		Item No.	2102 (winter)
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Date		Revision	V03
Proposal No.		Contract No.	
Inquiry No.		Order No.	

Design, Material, and Construction (continued)

Header (continued)				No./Bundle			156
Slope		1% ON LAST PASS		Length	(m)		3.9
Plug material		SA-182 F316 L		Pitch	(mm)		69
Gasket material		Solid METAL		Layout			Triangular
Nozzle	No.	Size, (in)	Rating/Facing	**Fin**			
Inlet	1	4	600 RF	Type			Extruded
Outlet	1	4	600 RF	Material			Aluminum Alloy 1060 - O
Vent	1	2	600 RF	Thickness	(mm)		0.48
Drain	1	2	600 RF	Selection temp.	(C)		
Chemical Cleaning				Outside diameter	(mm)		57.15
Min. Wall Thk.				Fin density	(fin/in)		10
Tube				ASME Code, Sec. VIII, Div. 1			
Material		SA-213 TP316L Tube (S) S31603		Customer Specifications			
Tube outside diameter	(mm)	25.4					
wall thickness	(mm)	1.651					

Mechanical Equipment

Fan				RPM			1500
Manufacturer				Service factor			1
No./Bay		2		Enclosure			
RPM	(Revs/min.)	658.6		Voltage			400
Diameter	(mm)	1450		Phase			3
No. of blades		4		Cycle			50
Angle	(degrees)			Fan noise level	(dB)		<85
Pitch adjustment		50% Auto		**Speed Reducer**			
Blade material		Al		Type			V-Belt
Hub material		steel/Alu		Manufacturer			
@design temp		3.5		No./Bay			2
@min. ambient temp		5.2		Service factor			1.8
Tip speed				Speed ratio			2.28
Driver				Support			
Type				Vib. switch			YES,EExd, IIB T3 (IP 65)
Manufacturer				Enclosure			
No./Bay		2					
Driver	(kW)	7.5					

Controls - Air Side

Air recirculation	NO	Louvers	
Degree control of outlet process temp.		Positioner	
(Max. Cooling),+/-	/	Signal air pressure (barG)	
Action on control signal failure		From	To
Fan pitch		From	To
Louvers		Supply air pressure (barG)	
Actuator air supply		From	To
Fan		From	To

Shipping

Plot area (WxL)	(m)	2.12 x 3.900	Total	(kg)	10429
Bundle weight (Note 4)	(kg)	3265.9	Shipping	(kg)	
Bay	(kg)				

Note: 1-Reported duty and flow rates include a user-specifiedmultiplier of 1.10
2-Maximum allowable nozzle load = 3 x API.
3-Material will be meet requirements of NACE MR0175/ISO1516 and specification for material requirments in sour service (BK-GNRAL-PEDCO-000-PI-SP-0008)
4- HTRI Weights are reported

3.0 MECHANICAL CALCULATION BOOK

3.1 STATIONARY HEADER CALCULATION @ DESIGN PRESSURE FOR AE-2101.

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

03

```
Figure Number Analyzed                                    A8

Design Internal Pressure                    P         22.0000  bars
Design Temperature                        Temp       155.0000  C

VESSEL MATERIAL DATA:
Material Specification                            SA-240 316L
Shell Allowable Stress at Design Temp       S       114.3898  N./mm^2
Shell Allowable Stress at Ambient          SA       115.1465  N./mm^2
Shell Yield Stress at Design Temperature   Sy       129.8699  N./mm^2

SHORT-SIDE VESSEL DATA:
Short-side Length Dimension                 H       160.0000  mm.
Minimum Thickness of Short-side Plates     t1        20.0000  mm.
Mid-side Joint Efficiency on Short-side     E         0.8500
Corner Joint Efficiency on Short-side      EC         0.8500

LONG-SIDE VESSEL DATA:
Long-side Length Dimension                  h       122.0000  mm.
Minimum Thickness of Long-side Plates      t2        20.0000  mm.
Mid-side Joint Efficiency on Long-side      E         0.8500

ADDITIONAL VESSEL DATA:
Minimum Thickness of End Plate             t5        20.0000  mm.
C-Factor for End Plate                  Cf_Epl         0.2000

Long-side Plate # 1,
   Pitch Distance                           p        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

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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
= 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.
```

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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	10.000	-10.000
	2	0.850	0.850	10.000	-10.000
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  = 0.0667 cm**4
    Thickness  t2, I2  = 0.0667 cm**4
```

Rectangular Vessel Parameters:

```
Alpha =      H / h    = 1.3115
K     = (I2/I1)*Alpha = 1.3115
```

Membrane Stress Calculations per Section 13-9

03

Membrane Stresses at Short-side 1

Membrane Stress at Short-side 1 [Sms]:

```
  = P * h / ( 2 * t1 ) * { 3 - [( 6 + K *
    ( 11 - alpha²) / ( 3 + 5 * K )]}
  = 22.00 * 122.00 / ( 2 * 20.00 ) * { 3- [( 6 + 1.31 *
    ( 11 - 1.31²) / ( 3 + 5 * 1.31 )]}
  = 7.37 N./mm^2
```

Membrane Stresses at Short-side 2

Membrane Stress at Short-side 2 [Sms]:

```
  = P * h / ( 2 * t1 ) * { 3 - [( 6 + K *
    ( 11 - alpha²) / ( 3 + 5 * K )]}
  = 22.00 * 122.00 / ( 2 * 20.00 ) * { 3- [( 6 + 1.31 *
    ( 11 - 1.31²) / ( 3 + 5 * 1.31 )]}
  = 7.37 N./mm^2
```

Membrane Stresses at Long-side 1

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

```
  = P * H / 2 * t2
  = 22.00 * 160.00 / 2 * 20.00
  = 8.80 N./mm^2
```

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

```
  Sml =  Sml / Em
  = 8.80 / 0.58
  = 15.19 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 + 1.31 * ( 11 -
    1.31²) / ( 3 + 5 * 1.31 )]
  = 25.52 N./mm^2
```

Membrane Stress at Stay Plate [t4]:

```
  = P * h / ( 2 * t4 ) * [( 6 + K * ( 11 -
    alpha²) / ( 3 + 5 * K )]
```

```
  = 22.00 * 122.00 / ( 2 * 10.00 ) * [( 6 + 1.31 * ( 11 -
    1.31²) / ( 3 + 5 * 1.31 )]
  = 25.52 N./mm^2
```

MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-9, Equations (13-15). (N./mm^2) :

03

STRESS LOCATIONS	Actual	Allowable
Short-side 1	7.37	97.23
Short-side 2	7.37	97.23
Short-side Corner	7.37	97.23
Long-side 1 at A	15.19	114.39
Long-side 2 at A	17.11	114.39
Long-side Corner	8.80	97.23
Stay Plate (t3)	25.52	114.39
Stay Plate (t4)	25.52	114.39

Bending Stress Calculations per Section 13-9

Bending Stresses at Short-side 1

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

```
  = P * c / ( 24 * I1 ) * [ -3 * H² + 2 * h² *
    (( 3 + 5 * Alpha² * K ) / ( 3 + 5 * K ))]
  = 22.00 * 10.00 / ( 24 * 0.07 ) * [ -3 * 160.00² + 2 * 122.00² *
    (( 3 + 5 * 1.31² * 1.31 ) / ( 3 + 5 * 1.31 ))]
  = -44.45 N./mm^2
```

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

```
  = P * c / ( 24 * I1 ) * [ -3 * H² + 2 * h² *
    (( 3 + 5 * Alpha² * K ) / ( 3 + 5 * K ))]
  = 22.00 * -10.00 /( 24 * 0.07 ) * [ -3 * 160.00² + 2 * 122.00² *
    (( 3 + 5 * 1.31² * 1.31 ) / ( 3 + 5 * 1.31 ))]
  = 44.45 N./mm^2
```

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

```
  = P * h² * c / ( 12 * I1 ) * (( 3 + 5 *
    Alpha² * K ) / ( 3 + 5 * K ))
  = 22.00 * 122.00² * 10.00 / ( 12 * 0.07 ) * (( 3 + 5 *
    1.31² * 1.31 ) / ( 3 + 5 * 1.31 ))
  = 61.15 N./mm^2
```

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

```
  = P * h² * c / ( 12 * I1 ) * (( 3 + 5 *
    Alpha² * K ) / ( 3 + 5 * K ))
  = 22.00 * 122.00² * -10.00 / ( 12 * 0.07 ) * (( 3 + 5 *
    1.31² * 1.31 ) / ( 3 + 5 * 1.31 ))
  = -61.15 N./mm^2
```

Bending Stresses at Short-side 2

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

```
  = P * c / ( 24 * I1 ) * [ -3 * H² + 2 * h² *
    (( 3 + 5 * Alpha² * K ) / ( 3 + 5 * K ))]
  = 22.00 * 10.00 / ( 24 * 0.07 ) * [ -3 * 160.00² + 2 * 122.00² *
    (( 3 + 5 * 1.31² * 1.31 ) / ( 3 + 5 * 1.31 ))]
  = -44.45 N./mm^2
```

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

```
  = P * c / ( 24 * I1 ) * [ -3 * H² + 2 * h² *
    (( 3 + 5 * Alpha² * K ) / ( 3 + 5 * K ))]
  = 22.00 * -10.00 /( 24 * 0.07 ) * [ -3 * 160.00² + 2 * 122.00² *
    (( 3 + 5 * 1.31² * 1.31 ) / ( 3 + 5 * 1.31 ))]
  = 44.45 N./mm^2
```

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

```
  = P * h² * c / ( 12 * I1 ) * (( 3 + 5 *
    Alpha² * K ) / ( 3 + 5 * K ))
  = 22.00 * 122.00² * 10.00 / ( 12 * 0.07 ) * (( 3 + 5 *
    1.31² * 1.31 ) / ( 3 + 5 * 1.31 ))
  = 61.15 N./mm^2
```

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

```
  = P * h² * c / ( 12 * I1 ) * (( 3 + 5 *
    Alpha² * K ) / ( 3 + 5 * K ))
  = 22.00 * 122.00² * -10.00 / ( 12 * 0.07 ) * (( 3 + 5 *
    1.31² * 1.31 ) / ( 3 + 5 * 1.31 ))
  = -61.15 N./mm^2
```

Bending Stresses at Long-side 1

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

```
  = P * h² * c / ( 12 * I2 ) * [( 3 + K *
    ( 6 - Alpha²)) / ( 3 + 5 * K )]
  = 22.00 * 122.00² * 10.00 / ( 12 * 0.07 ) * [( 3 + 1.31 *
    ( 6 - 1.31²)) / ( 3 + 5 * 1.31 )]
  = 36.89 N./mm^2
```

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

```
  SblMi =  SblMi / Eb
  = 36.89 / 0.58
  = 63.66 N./mm^2
```

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

```
  = P * h² * c / ( 12 * I2 ) * [( 3 + K *
    ( 6 - Alpha²)) / ( 3 + 5 * K )]
  = 22.00 * 122.00² * -10.00 / ( 12 * 0.07 ) * [( 3 + 1.31 *
    ( 6 - 1.31²)) / ( 3 + 5 * 1.31 )]
  = -36.89 N./mm^2
```

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

```
  SblMo =  SblMo / Eb
  = -36.89 / 0.58
  = -63.66 N./mm^2
```

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

```
  = P * h² * c / ( 12 * I2 ) * [( 3 + 5 *
    Alpha² * K ) / ( 3 + 5 * K )]
  = 22.00 * 122.00² * 10.00 / ( 12 * 0.07 ) * [( 3 + 5 *
    1.31² * 1.31 ) / ( 3 + 5 * 1.31 )]
  = 61.15 N./mm^2
```

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

```
  = P * h² * c / ( 12 * I2 ) * [( 3 + 5 *
    Alpha² * K ) / ( 3 + 5 * K )]
  = 22.00 * 122.00² * -10.00 / ( 12 * 0.07 ) * [( 3 + 5 *
    1.31² * 1.31 ) / ( 3 + 5 * 1.31 )]
  = -61.15 N./mm^2
```

Bending Stresses at Long-side 2

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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 + 1.31 *
(6 - 1.31²)) / (3 + 5 * 1.31)]
= 35.83 N./mm^2

If Em(0.514) < E(0.850) and Eb(0.478) < E(0.850) then
SblMi = SblMi / Eb
= 35.83 / 0.48
= 74.98 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 + 1.31 *
(6 - 1.31²)) / (3 + 5 * 1.31)]
= -37.95 N./mm^2

If Em(0.514) < E(0.850) and Eb(0.478) < E(0.850) then
SblMo = SblMo / Eb
= -37.95 / 0.48
= -79.42 N./mm^2

Bending Stress at Long-side 2 at Q Inner[SblQi]:
= P * h² * c / (12 * I2) * [(3 + 5 *
Alpha² * K) / (3 + 5 * K)]
= 22.00 * 122.00² * 9.71 / (12 * 0.07) * [(3 + 5 *
1.31² * 1.31) / (3 + 5 * 1.31)]
= 59.40 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 * 1.31) / (3 + 5 * 1.31)]
= -62.91 N./mm^2

BENDING STRESSES: Bending Stress Calculations per Section 13-9, Equations (16-19). (N./mm^2) :

STRESS LOCATIONS	Inner	Outer	Allowable
Short-side 1 at N	-44.45	44.45	145.85
at Q	61.15	-61.15	145.85
Short-side 2 at N	-44.45	44.45	145.85
at Q	61.15	-61.15	145.85
Long-side 1 at M	63.66	-63.66	171.58
at Q	61.15	-61.15	145.85
Long-side 2 at M	74.98	-79.42	171.58
at Q	59.40	-62.91	145.85

Total Stress Calculations per Section 13-9

Total Stresses at Short-side 1

Total Stress at short side 1 at N inner [STS_Ni]:

```
  = Sms + SbsNi
  = 7.37 + -44.45
  = -37.08 N./mm^2
```

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Total Stress at short side 1 at N outer [STS_No]:
```
  = Sms + SbsNo
  = 7.37 + 44.45
  = 51.83 N./mm^2
```

Total Stress at short side 1 at Q inner [STS_Qi]:
```
  = Sms + SbsQi
  = 7.37 + 61.15
  = 68.53 N./mm^2
```

Total Stress at short side 1 at Q outer [STS_Qo]:
```
  = Sms + SbsQo
  = 7.37 + -61.15
  = -53.78 N./mm^2
```

Total Stresses at Short-side 2

Total Stress at short side 2 at N inner [STS_Ni]:
```
  = Sms + SbsNi
  = 7.37 + -44.45
  = -37.08 N./mm^2
```

Total Stress at short side 2 at N outer [STS_No]:
```
  = Sms + SbsNo
  = 7.37 + 44.45
  = 51.83 N./mm^2
```

Total Stress at short side 2 at Q inner [STS_Qi]:
```
  = Sms + SbsQi
  = 7.37 + 61.15
  = 68.53 N./mm^2
```

Total Stress at short side 2 at Q outer [STS_Qo]:
```
  = Sms + SbsQo
  = 7.37 + -61.15
  = -53.78 N./mm^2
```

Total Stresses at Long-side 1

Total Stress at long side 1 at M inner [STL_Mi]:
```
  = Sml + SblMi
  = 15.19 + 63.66
  = 78.84 N./mm^2
```

Total Stress at long side 1 at M outer [STL_Mo]:
```
  = Sml + SblMo
  = 15.19 + -63.66
  = -48.47 N./mm^2
```

Total Stress at long side 1 at Q inner [STL_Qi]:
```
  = Sml + SblQi
  = 8.80 + 61.15
  = 69.95 N./mm^2
```

Total Stress at long side 1 at Q outer [STL_Qo]:
```
  = SmlB + SblQo
```

```
  = 8.80 + -61.15
  = -52.35 N./mm^2
```

Total Stresses at Long-side 2

03

Total Stress at long side 2 at M inner [STL_Mi]:
```
  = Sml + SblMi
  = 17.11 + 74.98
  = 92.08 N./mm^2
```

Total Stress at long side 2 at M outer [STL_Mo]:
```
  = Sml + SblMo
  = 17.11 + -79.42
  = -62.31 N./mm^2
```

Total Stress at long side 2 at Q inner [STL_Qi]:
```
  = Sml + SblQi
  = 8.80 + 59.40
  = 68.20 N./mm^2
```

Total Stress at long side 2 at Q outer [STL_Qo]:
```
  = SmlB + SblQo
  = 8.80 + -62.91
  = -54.11 N./mm^2
```

TOTAL STRESSES: Total Stress Calculations per Section 13-9, Equations (20-24). (N./mm^2) :

STRESS LOCATIONS	Inner	Outer	Allowable
Short-side 1 at N	-37.08	51.83	145.85
at Q	68.53	-53.78	145.85
Short-side 2 at N	-37.08	51.83	145.85
at Q	68.53	-53.78	145.85
Long-side 1 at M	78.84	-48.47	171.58
at Q	69.95	-52.35	145.85
Long-side 2 at M	92.08	-62.31	171.58
at Q	68.20	-54.11	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:

03

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	25.52	N./mm^2
High Stress Percentage	22.31	%
M.A.W.P. for Membrane Stresses	98.63	bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	-79.42	N./mm^2
High Stress Percentage	46.28	%
M.A.W.P. for Bending Stresses	47.53	bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	92.08	N./mm^2
High Stress Percentage	53.67	%
M.A.W.P. for Total Stresses	40.99	bars

Rectangular Vessel Results For Item 1 : A8

SUMMARY OF RESULTS:

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	25.52	N./mm^2
High Stress Percentage	22.31	%
M.A.W.P. for Membrane Stresses	98.63	bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	-79.42	N./mm^2
High Stress Percentage	46.28	%
M.A.W.P. for Bending Stresses	47.53	bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	92.08	N./mm^2
High Stress Percentage	53.67	%
M.A.W.P. for Total Stresses	40.99	bars

3.2 STATIONARY HEADER CALCULATION @ TEST PRESSURE FOR AE-2101.

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

03

```
Figure Number Analyzed                                    A8

Design Internal Pressure                    P          28.6000  bars
Design Temperature                        Temp         25.0000  C

VESSEL MATERIAL DATA:
Material Specification                                SA-240 316L
Shell Allowable Stress at Design Temp       S          155.0000  N./mm^2
Shell Allowable Stress at Ambient          SA          155.0000  N./mm^2
Shell Yield Stress at Design Temperature   Sy          172.3750  N./mm^2

SHORT-SIDE VESSEL DATA:
Short-side Length Dimension                 H          160.0000  mm.
Minimum Thickness of Short-side Plates     t1           20.0000  mm.
Mid-side Joint Efficiency on Short-side     E            0.8500
Corner Joint Efficiency on Short-side      EC            0.8500

LONG-SIDE VESSEL DATA:
Long-side Length Dimension                  h          122.0000  mm.
Minimum Thickness of Long-side Plates      t2           20.0000  mm.
Mid-side Joint Efficiency on Long-side      E            0.8500

ADDITIONAL VESSEL DATA:
Minimum Thickness of End Plate             t5           20.0000  mm.
C-Factor for End Plate                  Cf_Epl           0.2000

Long-side Plate # 1,
   Pitch Distance                           p           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

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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
= 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.
```

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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	10.000	-10.000
	2	0.850	0.850	10.000	-10.000
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  = 0.0667 cm**4
Thickness  t2, I2  = 0.0667 cm**4
```

Rectangular Vessel Parameters:

```
Alpha =      H / h    = 1.3115
K     = (I2/I1)*Alpha = 1.3115
```

Membrane Stress Calculations per Section 13-9

03

Membrane Stresses at Short-side 1

Membrane Stress at Short-side 1 [Sms]:

$= P * h / (2 * t1) * \{ 3 - [(6 + K * (11 - alpha^2) / (3 + 5 * K)]\}$

$= 28.60 * 122.00 / (2 * 20.00) * \{ 3- [(6 + 1.31 * (11 - 1.31^2) / (3 + 5 * 1.31)]\}$

$= 9.59$ N./mm^2

Membrane Stresses at Short-side 2

Membrane Stress at Short-side 2 [Sms]:

$= P * h / (2 * t1) * \{ 3 - [(6 + K * (11 - alpha^2) / (3 + 5 * K)]\}$

$= 28.60 * 122.00 / (2 * 20.00) * \{ 3- [(6 + 1.31 * (11 - 1.31^2) / (3 + 5 * 1.31)]\}$

$= 9.59$ N./mm^2

Membrane Stresses at Long-side 1

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

$= P * H / 2 * t2$

$= 28.60 * 160.00 / 2 * 20.00$

$= 11.44$ N./mm^2

If Em(0.580) < 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]:

$= P * h / (2 * t3) * [(6 + K * (11 - alpha^2) / (3 + 5 * K)]$

$= 28.60 * 122.00 / (2 * 10.00) * [(6 + 1.31 * (11 - 1.31^2) / (3 + 5 * 1.31)]$

$= 33.17$ N./mm^2

Membrane Stress at Stay Plate [t4]:

$= P * h / (2 * t4) * [(6 + K * (11 - alpha^2) / (3 + 5 * K)]$

$= 28.60 * 122.00 / (2 * 10.00) * [(6 + 1.31 * (11 - 1.31^2) / (3 + 5 * 1.31)]$

$= 33.17$ N./mm^2

MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-9, Equations (13-15). (N./mm^2) :

03

STRESS LOCATIONS	Actual	Allowable
Short-side 1	9.59	131.75
Short-side 2	9.59	131.75
Short-side Corner	9.59	131.75
Long-side 1 at A	19.74	155.00
Long-side 2 at A	22.24	155.00
Long-side Corner	11.44	131.75
Stay Plate (t3)	33.17	114.39
Stay Plate (t4)	33.17	114.39

Bending Stress Calculations per Section 13-9

Bending Stresses at Short-side 1

Bending Stress at Short-side 1 at N Inner[SbsNi]:
$= P * c / (24 * I1) * [-3 * H^2 + 2 * h^2 * ((3 + 5 * Alpha^2 * K) / (3 + 5 * K))]$
$= 28.60 * 10.00 / (24 * 0.07) * [-3 * 160.00^2 + 2 * 122.00^2 * ((3 + 5 * 1.31^2 * 1.31) / (3 + 5 * 1.31))]$
$= -57.79$ N./mm^2

Bending Stress at Short-side 1 at N Outer[SbsNo]:
$= P * c / (24 * I1) * [-3 * H^2 + 2 * h^2 * ((3 + 5 * Alpha^2 * K) / (3 + 5 * K))]$
$= 28.60 * -10.00 /(24 * 0.07) * [-3 * 160.00^2 + 2 * 122.00^2 * ((3 + 5 * 1.31^2 * 1.31) / (3 + 5 * 1.31))]$
$= 57.79$ N./mm^2

Bending Stress at Short-side 1 at Q Inner[SbsQi]:
$= P * h^2 * c / (12 * I1) * ((3 + 5 * Alpha^2 * K) / (3 + 5 * K))$
$= 28.60 * 122.00^2 * 10.00 / (12 * 0.07) * ((3 + 5 * 1.31^2 * 1.31) / (3 + 5 * 1.31))$
$= 79.50$ N./mm^2

Bending Stress at Short-side 1 at Q Outer[SbsQo]:
$= P * h^2 * c / (12 * I1) * ((3 + 5 * Alpha^2 * K) / (3 + 5 * K))$
$= 28.60 * 122.00^2 * -10.00 / (12 * 0.07) * ((3 + 5 * 1.31^2 * 1.31) / (3 + 5 * 1.31))$
$= -79.50$ N./mm^2

Bending Stresses at Short-side 2

Bending Stress at Short-side 2 at N Inner[SbsNi]:
$= P * c / (24 * I1) * [-3 * H^2 + 2 * h^2 * ((3 + 5 * Alpha^2 * K) / (3 + 5 * K))]$
$= 28.60 * 10.00 / (24 * 0.07) * [-3 * 160.00^2 + 2 * 122.00^2 * ((3 + 5 * 1.31^2 * 1.31) / (3 + 5 * 1.31))]$
$= -57.79$ N./mm^2

Bending Stress at Short-side 2 at N Outer[SbsNo]:
$= P * c / (24 * I1) * [-3 * H^2 + 2 * h^2 * ((3 + 5 * Alpha^2 * K) / (3 + 5 * K))]$
$= 28.60 * -10.00 /(24 * 0.07) * [-3 * 160.00^2 + 2 * 122.00^2 * ((3 + 5 * 1.31^2 * 1.31) / (3 + 5 * 1.31))]$

= 57.79 N./mm^2

03

Bending Stress at Short-side 2 at Q Inner[SbsQi]:
= P * h² * c / (12 * I1) * ((3 + 5 * Alpha² * K) / (3 + 5 * K))
= 28.60 * 122.00² * 10.00 / (12 * 0.07) * ((3 + 5 * 1.31² * 1.31) / (3 + 5 * 1.31))
= 79.50 N./mm^2

Bending Stress at Short-side 2 at Q Outer[SbsQo]:
= P * h² * c / (12 * I1) * ((3 + 5 * Alpha² * K) / (3 + 5 * K))
= 28.60 * 122.00² * -10.00 / (12 * 0.07) * ((3 + 5 * 1.31² * 1.31) / (3 + 5 * 1.31))
= -79.50 N./mm^2

Bending Stresses at Long-side 1

Bending Stress at Long-side 1 at M Inner[SblMi]:
= P * h² * c / (12 * I2) * [(3 + K * (6 - Alpha²)) / (3 + 5 * K)]
= 28.60 * 122.00² * 10.00 / (12 * 0.07) * [(3 + 1.31 * (6 - 1.31²)) / (3 + 5 * 1.31)]
= 47.96 N./mm^2

If Em(0.580) < E(0.850) and Eb(0.580) < E(0.850) then
SblMi = SblMi / Eb
= 47.96 / 0.58
= 82.75 N./mm^2

Bending Stress at Long-side 1 at M Outer[SblMo]:
= P * h² * c / (12 * I2) * [(3 + K * (6 - Alpha²)) / (3 + 5 * K)]
= 28.60 * 122.00² * -10.00 / (12 * 0.07) * [(3 + 1.31 * (6 - 1.31²)) / (3 + 5 * 1.31)]
= -47.96 N./mm^2

If Em(0.580) < E(0.850) and Eb(0.580) < E(0.850) then
SblMo = SblMo / Eb
= -47.96 / 0.58
= -82.75 N./mm^2

Bending Stress at Long-side 1 at Q Inner[SblQi]:
= P * h² * c / (12 * I2) * [(3 + 5 * Alpha² * K) / (3 + 5 * K)]
= 28.60 * 122.00² * 10.00 / (12 * 0.07) * [(3 + 5 * 1.31² * 1.31) / (3 + 5 * 1.31)]
= 79.50 N./mm^2

Bending Stress at Long-side 1 at Q Outer[SblQo]:
= P * h² * c / (12 * I2) * [(3 + 5 * Alpha² * K) / (3 + 5 * K)]
= 28.60 * 122.00² * -10.00 / (12 * 0.07) * [(3 + 5 * 1.31² * 1.31) / (3 + 5 * 1.31)]
= -79.50 N./mm^2

Bending Stresses at Long-side 2

Bending Stress at Long-side 2 at M Inner[SblMi]:
= P * h² * c / (12 * I2) * [(3 + K *

03

```
    ( 6 - Alpha²)) / ( 3 + 5 * K )]
  = 28.60 * 122.00² * 9.71 / ( 12 * 0.07 ) * [( 3 + 1.31 *
    ( 6 - 1.31²)) / ( 3 + 5 * 1.31 )]
  = 46.58 N./mm^2
```

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

```
  SblMi =  SblMi / Eb
  = 46.58 / 0.48
  = 97.47 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 + 1.31 *
    ( 6 - 1.31²)) / ( 3 + 5 * 1.31 )]
  = -49.33 N./mm^2
```

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

```
  SblMo =  SblMo / Eb
  = -49.33 / 0.48
  = -103.24 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 * 1.31 ) / ( 3 + 5 * 1.31 )]
  = 77.21 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 * 1.31 ) / ( 3 + 5 * 1.31 )]
  = -81.78 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	-57.79	57.79	197.62
at Q	79.50	-79.50	197.62
Short-side 2 at N	-57.79	57.79	197.62
at Q	79.50	-79.50	197.62
Long-side 1 at M	82.75	-82.75	232.50
at Q	79.50	-79.50	197.62
Long-side 2 at M	97.47	-103.24	232.50
at Q	77.21	-81.78	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
  = 9.59 + -57.79
  = -48.20 N./mm^2
```

03

Total Stress at short side 1 at N outer [STS_No]:
= Sms + SbsNo
= 9.59 + 57.79
= 67.37 N./mm^2

Total Stress at short side 1 at Q inner [STS_Qi]:
= Sms + SbsQi
= 9.59 + 79.50
= 89.08 N./mm^2

Total Stress at short side 1 at Q outer [STS_Qo]:
= Sms + SbsQo
= 9.59 + -79.50
= -69.91 N./mm^2

Total Stresses at Short-side 2

Total Stress at short side 2 at N inner [STS_Ni]:
= Sms + SbsNi
= 9.59 + -57.79
= -48.20 N./mm^2

Total Stress at short side 2 at N outer [STS_No]:
= Sms + SbsNo
= 9.59 + 57.79
= 67.37 N./mm^2

Total Stress at short side 2 at Q inner [STS_Qi]:
= Sms + SbsQi
= 9.59 + 79.50
= 89.08 N./mm^2

Total Stress at short side 2 at Q outer [STS_Qo]:
= Sms + SbsQo
= 9.59 + -79.50
= -69.91 N./mm^2

Total Stresses at Long-side 1

Total Stress at long side 1 at M inner [STL_Mi]:
= Sml + SblMi
= 19.74 + 82.75
= 102.50 N./mm^2

Total Stress at long side 1 at M outer [STL_Mo]:
= Sml + SblMo
= 19.74 + -82.75
= -63.01 N./mm^2

Total Stress at long side 1 at Q inner [STL_Qi]:
= Sml + SblQi
= 11.44 + 79.50
= 90.94 N./mm^2

Total Stress at long side 1 at Q outer [STL_Qo]:
= SmlB + SblQo
= 11.44 + -79.50
= -68.06 N./mm^2

Total Stresses at Long-side 2

03

Total Stress at long side 2 at M inner [STL_Mi]:
= Sml + SblMi
= 22.24 + 97.47
= 119.71 N./mm^2

Total Stress at long side 2 at M outer [STL_Mo]:
= Sml + SblMo
= 22.24 + -103.24
= -81.00 N./mm^2

Total Stress at long side 2 at Q inner [STL_Qi]:
= Sml + SblQi
= 11.44 + 77.21
= 88.65 N./mm^2

Total Stress at long side 2 at Q outer [STL_Qo]:
= SmlB + SblQo
= 11.44 + -81.78
= -70.34 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	-48.20	67.37	197.62
	at Q	89.08	-69.91	197.62
Short-side 2	at N	-48.20	67.37	197.62
	at Q	89.08	-69.91	197.62
Long-side 1	at M	102.50	-63.01	232.50
	at Q	90.94	-68.06	197.62
Long-side 2	at M	119.71	-81.00	232.50
	at Q	88.65	-70.34	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)	33.17	N./mm^2
High Stress Percentage	29.00	%

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

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	-103.24	N./mm^2
High Stress Percentage	44.40	%
M.A.W.P. for Bending Stresses	64.41	bars

03

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	119.71	N./mm^2
High Stress Percentage	51.49	%
M.A.W.P. for Total Stresses	55.55	bars

Rectangular Vessel Results For Item 1 : A8

SUMMARY OF RESULTS:

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	33.17	N./mm^2
High Stress Percentage	29.00	%
M.A.W.P. for Membrane Stresses	98.63	bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	-103.24	N./mm^2
High Stress Percentage	44.40	%
M.A.W.P. for Bending Stresses	64.41	bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	119.71	N./mm^2
High Stress Percentage	51.49	%
M.A.W.P. for Total Stresses	55.55	bars

3.3 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]:

$= p * h / (4 * t1) * \{ 4 - [(2 + K * (5 - alpha^2)) / (1 + 2 * K)]\}$

$= 22.00 * 122.00 / (4 * 15.00) * \{ 4 - [(2 + 1.94 * (5 - 0.82^2)) / (1 + 2 * 1.94)]\}$

$= 8.36$ N./mm^2

Membrane Stresses at Short-side 2

Membrane Stress at Short-side 2 [Sms]:

$= p * h / (4 * t1) * \{ 4 - [(2 + K * (5 - alpha^2)) / (1 + 2 * K)]\}$

$= 22.00 * 122.00 / (4 * 15.00) * \{ 4 - [(2 + 1.94 * (5 - 0.82^2)) / (1 + 2 * 1.94)]\}$

$= 8.36$ 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]:

$= P * h / (2 * t3) * [(2 + K * (5 - alpha^2)) / (1 + 2 * K)]$

$= 22.00 * 122.00 / (2 * 10.00) * [(2 + 1.94 * (5 -$

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]:

$$= P * h^2 * c / (12 * I2) * [(1 + K * (3 - Alpha^2)) / (1 + 2 * K)]$$
$$= 22.00 * 122.00^2 * 9.71 / (12 * 0.07) * [(1 + 1.94 * (3 - 0.82^2)) / (1 + 2 * 1.94)]$$
$$= 44.94 \text{ N./mm}^2$$

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

$$SblMi = SblMi / Eb$$
$$= 44.94 / 0.48$$
$$= 94.05 \text{ N./mm}^2$$

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

$$= P * h^2 * c / (12 * I2) * [(1 + K * (3 - Alpha^2)) / (1 + 2 * K)]$$
$$= 22.00 * 122.00^2 * -10.29 / (12 * 0.07) * [(1 + 1.94 * (3 - 0.82^2)) / (1 + 2 * 1.94)]$$
$$= -47.60 \text{ N./mm}^2$$

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

$$SblMo = SblMo / Eb$$
$$= -47.60 / 0.48$$
$$= -99.62 \text{ N./mm}^2$$

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

$$= P * h^2 * c / (12 * I2) * [(1 + 2 * Alpha^2 * K) / (1 + 2 * K)]$$
$$= 22.00 * 122.00^2 * 9.71 / (12 * 0.07) * [(1 + 2 * 0.82^2 * 1.94) / (1 + 2 * 1.94)]$$
$$= 29.38 \text{ N./mm}^2$$

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

$$= P * h^2 * c / (12 * I2) * [(1 + 2 * Alpha^2 * K) / (1 + 2 * K)]$$
$$= 22.00 * 122.00^2 * -10.29 / (12 * 0.07) * [(1 + 2 * 0.82^2 * 1.94) / (1 + 2 * 1.94)]$$
$$= -31.12 \text{ N./mm}^2$$

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
```

3.4 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]:

$= p * h / (4 * t1) * \{ 4 - [(2 + K * (5 - alpha^2)) / (1 + 2 * K)]\}$

$= 28.60 * 122.00 / (4 * 15.00) * \{ 4 - [(2 + 1.94 * (5 - 0.82^2)) / (1 + 2 * 1.94)]\}$

$= 10.87$ N./mm^2

Membrane Stresses at Short-side 2

Membrane Stress at Short-side 2 [Sms]:

$= p * h / (4 * t1) * \{ 4 - [(2 + K * (5 - alpha^2)) / (1 + 2 * K)]\}$

$= 28.60 * 122.00 / (4 * 15.00) * \{ 4 - [(2 + 1.94 * (5 - 0.82^2)) / (1 + 2 * 1.94)]\}$

$= 10.87$ 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]:

$= P * h / (2 * t3) * [(2 + K * (5 - alpha^2)) / (1 + 2 * K)]$

$= 28.60 * 122.00 / (2 * 10.00) * [(2 + 1.94 * (5 -$

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]:

$= P * h^2 * c / (12 * I2) * [(1 + K * (3 - Alpha^2)) / (1 + 2 * K)]$

$= 28.60 * 122.00^2 * 9.71 / (12 * 0.07) * [(1 + 1.94 * (3 - 0.82^2)) / (1 + 2 * 1.94)]$

$= 58.43$ 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]:

$= P * h^2 * c / (12 * I2) * [(1 + K * (3 - Alpha^2)) / (1 + 2 * K)]$

$= 28.60 * 122.00^2 * -10.29 / (12 * 0.07) * [(1 + 1.94 * (3 - 0.82^2)) / (1 + 2 * 1.94)]$

$= -61.89$ 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]:

$= P * h^2 * c / (12 * I2) * [(1 + 2 * Alpha^2 * K) / (1 + 2 * K)]$

$= 28.60 * 122.00^2 * 9.71 / (12 * 0.07) * [(1 + 2 * 0.82^2 * 1.94) / (1 + 2 * 1.94)]$

$= 38.20$ N./mm^2

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

$= P * h^2 * c / (12 * I2) * [(1 + 2 * Alpha^2 * K) / (1 + 2 * K)]$

$= 28.60 * 122.00^2 * -10.29 / (12 * 0.07) * [(1 + 2 * 0.82^2 * 1.94) / (1 + 2 * 1.94)]$

$= -40.46$ 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

3.5 STATIONARY HEADER CALCULATION @ DESIGN PRESSURE FOR AE-2102.

Input Echo, COMPONENT 1, Description: St.AE-2102

03

Figure Number Analyzed		A8	
Design Internal Pressure	P	62.0000	bars
Design Temperature	Temp	175.0000	C
VESSEL MATERIAL DATA:			
Material Specification		SA-240 316L	
Shell Allowable Stress at Design Temp	S	111.9078	N./mm^2
Shell Allowable Stress at Ambient	SA	115.1465	N./mm^2
Shell Yield Stress at Design Temperature	Sy	126.1469	N./mm^2
SHORT-SIDE VESSEL DATA:			
Short-side Length Dimension	H	110.0000	mm.
Minimum Thickness of Short-side Plates	t1	20.0000	mm.
Mid-side Joint Efficiency on Short-side	E	0.8500	
Corner Joint Efficiency on Short-side	EC	0.8500	
LONG-SIDE VESSEL DATA:			
Long-side Length Dimension	h	130.0000	mm.
Minimum Thickness of Long-side Plates	t2	28.0000	mm.
Mid-side Joint Efficiency on Long-side	E	0.8500	
ADDITIONAL VESSEL DATA:			
Minimum Thickness of End Plate	t5	20.0000	mm.
C-Factor for End Plate	Cf_Epl	0.2000	
Long-side Plate # 1,			
Pitch Distance	p	69.0000	mm.
Uniform Hole Diameter	d0	25.6500	mm.
Depth of Holes	T0	28.0000	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	25.3000	mm.
STAY PLATE MATERIAL DATA:			
Stay Material Specification		SA-240 316L	
Stay Allowable Stress at Design Temp	Sr	114.3898	N./mm^2
Stay Allowable Stress at Ambient	SA	115.1465	N./mm^2
Stay Yield Stress at Design Temp	Sy	129.8699	N./mm^2
STAY PLATE DATA:			
Minimum Thickness of Stay	t3	10.0000	mm.
Minimum Thickness of Stay	t4	10.0000	mm.
The Stay(s) Are Not Welded to the End Plate			

Rectangular Vessel Results, Item number 1, Desc: St.AE-2102
ASME Code, Section VIII, Division 1, 2019 App. 13

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

Short-side 1 Calculations

03

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
= 28.000 - 0.000 / 2
= 14.000 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
= -(t1 - CA) / 2
= -(28.000 - 0.000) / 2
= -14.000 mm.

Long-side 2 Calculations

03

Effective Diameter [De]:
```
  = ( d0 * T0 + d1 * T1 + d2 * T2 ) / ( t1 - CA )
  = ( 36.30 * 2.70 + 28.57 * 25.30 + 0.00 * 0.00 ) /
    ( 28.00 - 0.00 )
  = 29.320 mm.
```

Membrane Ligament Efficiency [Em]:
```
  = Pitch - De / Pitch
  = 69.000 - 29.320 / 69.000
  = 0.575
```

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 + 25.30 + 0.00 )) + ( 1.59* 25.30 *
    ( 25.30 /2 + 0.00 )) + ( 2.72 * 0.00 * ( 0.00 /2 ))) /
    ( 1.29 * 2.70 + 1.59 * 25.30 + 2.72 * 0.00 )
  = 13.763 mm.
```

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
Ci = Xbar
```
  = 13.763 mm.
```

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
```
  = -( t - CA - Xbar )
  = -( 28.000 - 0.000 - 13.763 )
  = -14.237 mm.
```

Moment of Inertia (Section 13-6, Equation (5)) [I]:
```
  = 0.278 cm**4
```

Effective Diameter [De]:
```
  = Pitch - (( 6 * I ) / (( t - CA)^2 * (-Co)))
  = 69.00 - (( 6 * 0.28 ) / ((28.00 - 0.00 )^2 * (14.24 )))
  = 31.084 mm.
```

Bending Ligament Efficiency [Eb]:
```
  = Pitch - De / Pitch
  = 69.000 - 31.084 / 69.000
  = 0.550
```

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	14.000	-14.000
	2	0.575	0.550	13.763	-14.237

Moment of Inertia of a Strip of the Vessel Wall:

```
    Thickness  t1, I1  = 0.0667 cm**4
    Thickness  t2, I2  = 0.1829 cm**4
```

03

Rectangular Vessel Parameters:

```
Alpha =      H / h    = 0.8462
K     = (I2/I1)*Alpha = 2.3218
```

Membrane Stress Calculations per Section 13-9

Membrane Stresses at Short-side 1

Membrane Stress at Short-side 1 [Sms]:

```
= P * h / ( 2 * t1 ) * { 3 - [( 6 + K *
  ( 11 - alpha²) / ( 3 + 5 * K )]}
= 62.00 * 130.00 / ( 2 * 20.00 ) * { 3- [( 6 + 2.32 *
  ( 11 - 0.85²) / ( 3 + 5 * 2.32 )]}
= 19.24 N./mm^2
```

Membrane Stresses at Short-side 2

Membrane Stress at Short-side 2 [Sms]:

```
= P * h / ( 2 * t1 ) * { 3 - [( 6 + K *
  ( 11 - alpha²) / ( 3 + 5 * K )]}
= 62.00 * 130.00 / ( 2 * 20.00 ) * { 3- [( 6 + 2.32 *
  ( 11 - 0.85²) / ( 3 + 5 * 2.32 )]}
= 19.24 N./mm^2
```

Membrane Stresses at Long-side 1

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

```
= P * H / 2 * t2
= 62.00 * 110.00 / 2 * 28.00
= 12.18 N./mm^2
```

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

```
Sml =  Sml / Em
= 12.18 / 0.63
= 19.39 N./mm^2
```

Membrane Stresses at Long-side 2

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

```
= P * H / 2 * t2
= 62.00 * 110.00 / 2 * 28.00
= 12.18 N./mm^2
```

If Em(0.575) < E(0.850) and Eb(0.550) < E(0.850) then

```
Sml =  Sml / Em
= 12.18 / 0.58
= 21.18 N./mm^2
```

Membrane Stresses at Stay Plate

Membrane Stress at Stay Plate [t3]:

```
= P * h / ( 2 * t3 ) * [( 6 + K * ( 11 -
  alpha²) / ( 3 + 5 * K )]
= 62.00 * 130.00 / ( 2 * 10.00 ) * [( 6 + 2.32 * ( 11 -
 0.85²) / ( 3 + 5 * 2.32 )]
= 82.42 N./mm^2
```

Membrane Stress at Stay Plate [t4]:

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

```
   alpha²) / ( 3 + 5 * K )]
 = 62.00 * 130.00 / ( 2 * 10.00 ) * [( 6 + 2.32 * ( 11 -
  0.85²) / ( 3 + 5 * 2.32 )]
 = 82.42 N./mm^2
```

03

MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-9, Equations (13-15). (N./mm^2) :

STRESS LOCATIONS	Actual	Allowable
Short-side 1	19.24	95.12
Short-side 2	19.24	95.12
Short-side Corner	19.24	95.12
Long-side 1 at A	19.39	111.91
Long-side 2 at A	21.18	111.91
Long-side Corner	12.18	95.12
Stay Plate (t3)	82.42	114.39
Stay Plate (t4)	82.42	114.39

Bending Stress Calculations per Section 13-9

Bending Stresses at Short-side 1

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

```
  = P * c / ( 24 * I1 ) * [ -3 * H² + 2 * h² *
    (( 3 + 5 * Alpha² * K ) / ( 3 + 5 * K ))]
  = 62.00 * 10.00 / ( 24 * 0.07 ) * [ -3 * 110.00² + 2 * 130.00² *
    (( 3 + 5 * 0.85² * 2.32 ) / ( 3 + 5 * 2.32 ))]
  = -39.25 N./mm^2
```

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

```
  = P * c / ( 24 * I1 ) * [ -3 * H² + 2 * h² *
    (( 3 + 5 * Alpha² * K ) / ( 3 + 5 * K ))]
  = 62.00 * -10.00 /( 24 * 0.07 ) * [ -3 * 110.00² + 2 * 130.00² *
    (( 3 + 5 * 0.85² * 2.32 ) / ( 3 + 5 * 2.32 ))]
  = 39.25 N./mm^2
```

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

```
  = P * h² * c / ( 12 * I1 ) * (( 3 + 5 *
    Alpha² * K ) / ( 3 + 5 * K ))
  = 62.00 * 130.00² * 10.00 / ( 12 * 0.07 ) * (( 3 + 5 *
   0.85² * 2.32 ) / ( 3 + 5 * 2.32 ))
  = 101.42 N./mm^2
```

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

```
  = P * h² * c / ( 12 * I1 ) * (( 3 + 5 *
    Alpha² * K ) / ( 3 + 5 * K ))
  = 62.00 * 130.00² * -10.00 / ( 12 * 0.07 ) * (( 3 + 5 *
   0.85² * 2.32 ) / ( 3 + 5 * 2.32 ))
  = -101.42 N./mm^2
```

Bending Stresses at Short-side 2

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

```
  = P * c / ( 24 * I1 ) * [ -3 * H² + 2 * h² *
    (( 3 + 5 * Alpha² * K ) / ( 3 + 5 * K ))]
  = 62.00 * 10.00 / ( 24 * 0.07 ) * [ -3 * 110.00² + 2 * 130.00² *
    (( 3 + 5 * 0.85² * 2.32 ) / ( 3 + 5 * 2.32 ))]
  = -39.25 N./mm^2
```

03

Bending Stress at Short-side 2 at N Outer[SbsNo]:
= P * c / (24 * I1) * [-3 * H² + 2 * h² *
((3 + 5 * Alpha² * K) / (3 + 5 * K))]
= 62.00 * -10.00 /(24 * 0.07) * [-3 * 110.00² + 2 * 130.00² *
((3 + 5 * 0.85² * 2.32) / (3 + 5 * 2.32))]
= 39.25 N./mm^2

Bending Stress at Short-side 2 at Q Inner[SbsQi]:
= P * h² * c / (12 * I1) * ((3 + 5 *
Alpha² * K) / (3 + 5 * K))
= 62.00 * 130.00² * 10.00 / (12 * 0.07) * ((3 + 5 *
0.85² * 2.32) / (3 + 5 * 2.32))
= 101.42 N./mm^2

Bending Stress at Short-side 2 at Q Outer[SbsQo]:
= P * h² * c / (12 * I1) * ((3 + 5 *
Alpha² * K) / (3 + 5 * K))
= 62.00 * 130.00² * -10.00 / (12 * 0.07) * ((3 + 5 *
0.85² * 2.32) / (3 + 5 * 2.32))
= -101.42 N./mm^2

Bending Stresses at Long-side 1

Bending Stress at Long-side 1 at M Inner[SblMi]:
= P * h² * c / (12 * I2) * [(3 + K *
(6 - Alpha²)) / (3 + 5 * K)]
= 62.00 * 130.00² * 14.00 / (12 * 0.18) * [(3 + 2.32 *
(6 - 0.85²)) / (3 + 5 * 2.32)]
= 69.84 N./mm^2

If Em(0.628) < E(0.850) and Eb(0.628) < E(0.850) then
SblMi = SblMi / Eb
= 69.84 / 0.63
= 111.17 N./mm^2

Bending Stress at Long-side 1 at M Outer[SblMo]:
= P * h² * c / (12 * I2) * [(3 + K *
(6 - Alpha²)) / (3 + 5 * K)]
= 62.00 * 130.00² * -14.00 / (12 * 0.18) * [(3 + 2.32 *
(6 - 0.85²)) / (3 + 5 * 2.32)]
= -69.84 N./mm^2

If Em(0.628) < E(0.850) and Eb(0.628) < E(0.850) then
SblMo = SblMo / Eb
= -69.84 / 0.63
= -111.17 N./mm^2

Bending Stress at Long-side 1 at Q Inner[SblQi]:
= P * h² * c / (12 * I2) * [(3 + 5 *
Alpha² * K) / (3 + 5 * K)]
= 62.00 * 130.00² * 14.00 / (12 * 0.18) * [(3 + 5 *
0.85² * 2.32) / (3 + 5 * 2.32)]
= 51.74 N./mm^2

Bending Stress at Long-side 1 at Q Outer[SblQo]:
= P * h² * c / (12 * I2) * [(3 + 5 *
Alpha² * K) / (3 + 5 * K)]
= 62.00 * 130.00² * -14.00 / (12 * 0.18) * [(3 + 5 *
0.85² * 2.32) / (3 + 5 * 2.32)]
= -51.74 N./mm^2

03

Bending Stresses at Long-side 2

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

```
  = P * h² * c / ( 12 * I2 ) * [( 3 + K *
    ( 6 - Alpha²)) / ( 3 + 5 * K )]
  = 62.00 * 130.00² * 13.76 / ( 12 * 0.18 ) * [( 3 + 2.32 *
    ( 6 - 0.85²)) / ( 3 + 5 * 2.32 )]
  = 68.66 N./mm^2
```

If Em(0.575) < E(0.850) and Eb(0.550) < E(0.850) then

```
  SblMi =  SblMi / Eb
  = 68.66 / 0.55
  = 124.95 N./mm^2
```

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

```
  = P * h² * c / ( 12 * I2 ) * [( 3 + K *
    ( 6 - Alpha²)) / ( 3 + 5 * K )]
  = 62.00 * 130.00² * -14.24 / ( 12 * 0.18 ) * [( 3 + 2.32 *
    ( 6 - 0.85²)) / ( 3 + 5 * 2.32 )]
  = -71.03 N./mm^2
```

If Em(0.575) < E(0.850) and Eb(0.550) < E(0.850) then

```
  SblMo =  SblMo / Eb
  = -71.03 / 0.55
  = -129.26 N./mm^2
```

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

```
  = P * h² * c / ( 12 * I2 ) * [( 3 + 5 *
    Alpha² * K ) / ( 3 + 5 * K )]
  = 62.00 * 130.00² * 13.76 / ( 12 * 0.18 ) * [( 3 + 5 *
   0.85² * 2.32 ) / ( 3 + 5 * 2.32 )]
  = 50.87 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 )]
  = 62.00 * 130.00² * -14.24 / ( 12 * 0.18 ) * [( 3 + 5 *
   0.85² * 2.32 ) / ( 3 + 5 * 2.32 )]
  = -52.62 N./mm^2
```

BENDING STRESSES: Bending Stress Calculations per Section 13-9, Equations (16-19). (N./mm^2) :

STRESS LOCATIONS	Inner	Outer	Allowable
Short-side 1 at N	-39.25	39.25	142.68
at Q	101.42	-101.42	142.68
Short-side 2 at N	-39.25	39.25	142.68
at Q	101.42	-101.42	142.68
Long-side 1 at M	111.17	-111.17	167.86
at Q	51.74	-51.74	142.68
Long-side 2 at M	124.95	-129.26	167.86
at Q	50.87	-52.62	142.68

Total Stress Calculations per Section 13-9

Total Stresses at Short-side 1

03

Total Stress at short side 1 at N inner [STS_Ni]:
= Sms + SbsNi
= 19.24 + -39.25
= -20.01 N./mm^2

Total Stress at short side 1 at N outer [STS_No]:
= Sms + SbsNo
= 19.24 + 39.25
= 58.49 N./mm^2

Total Stress at short side 1 at Q inner [STS_Qi]:
= Sms + SbsQi
= 19.24 + 101.42
= 120.66 N./mm^2

Total Stress at short side 1 at Q outer [STS_Qo]:
= Sms + SbsQo
= 19.24 + -101.42
= -82.18 N./mm^2

Total Stresses at Short-side 2

Total Stress at short side 2 at N inner [STS_Ni]:
= Sms + SbsNi
= 19.24 + -39.25
= -20.01 N./mm^2

Total Stress at short side 2 at N outer [STS_No]:
= Sms + SbsNo
= 19.24 + 39.25
= 58.49 N./mm^2

Total Stress at short side 2 at Q inner [STS_Qi]:
= Sms + SbsQi
= 19.24 + 101.42
= 120.66 N./mm^2

Total Stress at short side 2 at Q outer [STS_Qo]:
= Sms + SbsQo
= 19.24 + -101.42
= -82.18 N./mm^2

Total Stresses at Long-side 1

Total Stress at long side 1 at M inner [STL_Mi]:
= Sml + SblMi
= 19.39 + 111.17
= 130.56 N./mm^2

Total Stress at long side 1 at M outer [STL_Mo]:
= Sml + SblMo
= 19.39 + -111.17
= -91.79 N./mm^2

Total Stress at long side 1 at Q inner [STL_Qi]:
= Sml + SblQi
= 12.18 + 51.74
= 63.92 N./mm^2

Total Stress at long side 1 at Q outer [STL_Qo]:

```
  = SmlB + SblQo
  = 12.18 + -51.74
  = -39.57 N./mm^2
```

03

Total Stresses at Long-side 2

Total Stress at long side 2 at M inner [STL_Mi]:
```
  = Sml + SblMi
  = 21.18 + 124.95
  = 146.13 N./mm^2
```

Total Stress at long side 2 at M outer [STL_Mo]:
```
  = Sml + SblMo
  = 21.18 + -129.26
  = -108.08 N./mm^2
```

Total Stress at long side 2 at Q inner [STL_Qi]:
```
  = Sml + SblQi
  = 12.18 + 50.87
  = 63.05 N./mm^2
```

Total Stress at long side 2 at Q outer [STL_Qo]:
```
  = SmlB + SblQo
  = 12.18 + -52.62
  = -40.44 N./mm^2
```

TOTAL STRESSES: Total Stress Calculations per Section 13-9, Equations (20-24). (N./mm^2) :

STRESS LOCATIONS	Inner	Outer	Allowable
Short-side 1 at N	-20.01	58.49	142.68
at Q	120.66	-82.18	142.68
Short-side 2 at N	-20.01	58.49	142.68
at Q	120.66	-82.18	142.68
Long-side 1 at M	130.56	-91.79	167.86
at Q	63.92	-39.57	142.68
Long-side 2 at M	146.13	-108.08	167.86
at Q	63.05	-40.44	142.68

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

	Actual	Allowable
End Plate	93.78	111.91

Required End Plate thickness due to Internal Pressure [trEP]:
```
  = d * sqrt( Z * C * P / ( SE ) ) + ca
  = 110.000 * sqrt( 2.500 * 0.200 * 62.000 / ( 111.908 ) ) + 0.000
  = 18.309 mm.
```

End Plate MAWP at given Thickness [MAWPEP]:
```
  = ((T-ca)/d)^2 * ((SE)/(C*Z)) per UG-34 (c)(3)
  = ((20.0000-0.0000)/110.0000)^2*((111)/(.20*2.50))
  = 73.984 bars
```

where Z is:
```
   = min( 3.4 - 2.4( d/D ), 2.5 )
   = min( 3.4 - 2.4( 110.000 / 410.000 ), 2.5 )
   = 2.500
```

03

SUMMARY OF RESULTS:

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	82.42	N./mm^2
High Stress Percentage	72.06	%
M.A.W.P. for Membrane Stresses	86.04	bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	-129.26	N./mm^2
High Stress Percentage	77.00	%
M.A.W.P. for Bending Stresses	80.52	bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	146.13	N./mm^2
High Stress Percentage	87.05	%
M.A.W.P. for Total Stresses	71.22	bars

Rectangular Vessel Results For Item 1 : A8

SUMMARY OF RESULTS:

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	82.42	N./mm^2
High Stress Percentage	72.06	%
M.A.W.P. for Membrane Stresses	86.04	bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	-129.26	N./mm^2
High Stress Percentage	77.00	%
M.A.W.P. for Bending Stresses	80.52	bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	146.13	N./mm^2
High Stress Percentage	87.05	%
M.A.W.P. for Total Stresses	71.22	bars

3.6 STATIONARY HEADER CALCULATION @ TEST PRESSURE FOR AE-2102.

Input Echo, COMPONENT 1, Description: St.AE-2102-Test

03

```
Figure Number Analyzed                                   A8

Design Internal Pressure                    P         80.6000  bars
Design Temperature                        Temp        25.0000  C

VESSEL MATERIAL DATA:
Material Specification                             SA-240 316L
Shell Allowable Stress at Design Temp       S       155.1000  N./mm^2
Shell Allowable Stress at Ambient          SA       155.1000  N./mm^2
Shell Yield Stress at Design Temperature   Sy       172.3750  N./mm^2

SHORT-SIDE VESSEL DATA:
Short-side Length Dimension                 H       110.0000  mm.
Minimum Thickness of Short-side Plates     t1        20.0000  mm.
Mid-side Joint Efficiency on Short-side     E         0.8500
Corner Joint Efficiency on Short-side      EC         0.8500

LONG-SIDE VESSEL DATA:
Long-side Length Dimension                  h       130.0000  mm.
Minimum Thickness of Long-side Plates      t2        28.0000  mm.
Mid-side Joint Efficiency on Long-side      E         0.8500

ADDITIONAL VESSEL DATA:
Minimum Thickness of End Plate             t5        20.0000  mm.
C-Factor for End Plate                  Cf_Epl         0.2000

Long-side Plate # 1,
   Pitch Distance                           p        69.0000  mm.
   Uniform Hole Diameter                   d0        25.6500  mm.
   Depth of Holes                          T0        28.0000  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        25.3000  mm.
STAY PLATE MATERIAL DATA:
Stay Material Specification                        SA-240 316L
Stay Allowable Stress at Design Temp        Sr       116.9000  N./mm^2
Stay Allowable Stress at Ambient           SA       116.9000  N./mm^2
Stay Yield Stress at Design Temp           Sy       129.8699  N./mm^2

STAY PLATE DATA:
Minimum Thickness of Stay                  t3        10.0000  mm.
Minimum Thickness of Stay                  t4        10.0000  mm.
The Stay(s) Are Not Welded to the End  Plate
```

03

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
= 28.000 - 0.000 / 2
= 14.000 mm.

03

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
= -(t1 - CA) / 2
= -(28.000 - 0.000) / 2
= -14.000 mm.

Long-side 2 Calculations

Effective Diameter [De]:
= (d0 * T0 + d1 * T1 + d2 * T2) / (t1 - CA)
= (36.30 * 2.70 + 28.57 * 25.30 + 0.00 * 0.00) /
(28.00 - 0.00)
= 29.320 mm.

Membrane Ligament Efficiency [Em]:
= Pitch - De / Pitch
= 69.000 - 29.320 / 69.000
= 0.575

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 + 25.30 + 0.00)) + (1.59* 25.30 *
(25.30 /2 + 0.00)) + (2.72 * 0.00 * (0.00 /2))) /
(1.29 * 2.70 + 1.59 * 25.30 + 2.72 * 0.00)
= 13.763 mm.

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
Ci = Xbar
= 13.763 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
= -(t - CA - Xbar)
= -(28.000 - 0.000 - 13.763)
= -14.237 mm.

Moment of Inertia (Section 13-6, Equation (5)) [I]:
= 0.278 cm**4

Effective Diameter [De]:
= Pitch - ((6 * I) / ((t - CA)^2 * (-Co)))
= 69.00 - ((6 * 0.28) / ((28.00 - 0.00)^2 * (14.24)))
= 31.084 mm.

Bending Ligament Efficiency [Eb]:
= Pitch - De / Pitch
= 69.000 - 31.084 / 69.000
= 0.550

03

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	14.000	-14.000
	2	0.575	0.550	13.763	-14.237

Moment of Inertia of a Strip of the Vessel Wall:

```
Thickness  t1, I1  = 0.0667 cm**4
Thickness  t2, I2  = 0.1829 cm**4
```

Rectangular Vessel Parameters:

```
Alpha =      H / h    = 0.8462
K     = (I2/I1)*Alpha = 2.3218
```

Membrane Stress Calculations per Section 13-9

Membrane Stresses at Short-side 1

Membrane Stress at Short-side 1 [Sms]:

$= P * h / (2 * t1) * \{ 3 - [(6 + K * (11 - alpha^2) / (3 + 5 * K)]\}$

$= 80.60 * 130.00 / (2 * 20.00) * \{ 3- [(6 + 2.32 * (11 - 0.85^2) / (3 + 5 * 2.32)]\}$

$= 25.01$ N./mm^2

Membrane Stresses at Short-side 2

Membrane Stress at Short-side 2 [Sms]:

$= P * h / (2 * t1) * \{ 3 - [(6 + K * (11 - alpha^2) / (3 + 5 * K)]\}$

$= 80.60 * 130.00 / (2 * 20.00) * \{ 3- [(6 + 2.32 * (11 - 0.85^2) / (3 + 5 * 2.32)]\}$

$= 25.01$ N./mm^2

Membrane Stresses at Long-side 1

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

$= P * H / 2 * t2$

$= 80.60 * 110.00 / 2 * 28.00$

$= 15.83$ N./mm^2

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

$Sml = Sml / Em$

$= 15.83 / 0.63$

$= 25.20$ N./mm^2

Membrane Stresses at Long-side 2

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

$= P * H / 2 * t2$

$= 80.60 * 110.00 / 2 * 28.00$

$= 15.83$ N./mm^2

03

If Em(0.575) < E(0.850) and Eb(0.550) < E(0.850) then

```
  Sml =  Sml / Em
  = 15.83 / 0.58
  = 27.53 N./mm^2
```

Membrane Stresses at Stay Plate

Membrane Stress at Stay Plate [t3]:

```
  = P * h / ( 2 * t3 ) * [( 6 + K * ( 11 -
    alpha²) / ( 3 + 5 * K )]
  = 80.60 * 130.00 / ( 2 * 10.00 ) * [( 6 + 2.32 * ( 11 -
   0.85²) / ( 3 + 5 * 2.32 )]
  = 107.15 N./mm^2
```

Membrane Stress at Stay Plate [t4]:

```
  = P * h / ( 2 * t4 ) * [( 6 + K * ( 11 -
    alpha²) / ( 3 + 5 * K )]
  = 80.60 * 130.00 / ( 2 * 10.00 ) * [( 6 + 2.32 * ( 11 -
   0.85²) / ( 3 + 5 * 2.32 )]
  = 107.15 N./mm^2
```

MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-9, Equations (13-15). (N./mm^2) :

STRESS LOCATIONS	Actual	Allowable
Short-side 1	25.01	131.84
Short-side 2	25.01	131.84
Short-side Corner	25.01	131.84
Long-side 1 at A	25.20	155.10
Long-side 2 at A	27.53	155.10
Long-side Corner	15.83	131.84
Stay Plate (t3)	107.15	116.90
Stay Plate (t4)	107.15	116.90

Bending Stress Calculations per Section 13-9

Bending Stresses at Short-side 1

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

```
  = P * c / ( 24 * I1 ) * [ -3 * H² + 2 * h² *
    (( 3 + 5 * Alpha² * K ) / ( 3 + 5 * K ))]
  = 80.60 * 10.00 / ( 24 * 0.07 ) * [ -3 * 110.00² + 2 * 130.00² *
    (( 3 + 5 * 0.85² * 2.32 ) / ( 3 + 5 * 2.32 ))]
  = -51.03 N./mm^2
```

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

```
  = P * c / ( 24 * I1 ) * [ -3 * H² + 2 * h² *
    (( 3 + 5 * Alpha² * K ) / ( 3 + 5 * K ))]
  = 80.60 * -10.00 /( 24 * 0.07 ) * [ -3 * 110.00² + 2 * 130.00² *
    (( 3 + 5 * 0.85² * 2.32 ) / ( 3 + 5 * 2.32 ))]
  = 51.03 N./mm^2
```

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

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

03

```
    Alpha² * K ) / ( 3 + 5 * K ))
  = 80.60 * 130.00² * 10.00 / ( 12 * 0.07 ) * (( 3 + 5 *
   0.85² * 2.32 ) / ( 3 + 5 * 2.32 ))
  = 131.85 N./mm^2
```

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

```
  = P * h² * c / ( 12 * I1 ) * (( 3 + 5 *
    Alpha² * K ) / ( 3 + 5 * K ))
  = 80.60 * 130.00² * -10.00 / ( 12 * 0.07 ) * (( 3 + 5 *
   0.85² * 2.32 ) / ( 3 + 5 * 2.32 ))
  = -131.85 N./mm^2
```

Bending Stresses at Short-side 2

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

```
  = P * c / ( 24 * I1 ) * [ -3 * H² + 2 * h² *
    (( 3 + 5 * Alpha² * K ) / ( 3 + 5 * K ))]
  = 80.60 * 10.00 / ( 24 * 0.07 ) * [ -3 * 110.00² + 2 * 130.00² *
    (( 3 + 5 * 0.85² * 2.32 ) / ( 3 + 5 * 2.32 ))]
  = -51.03 N./mm^2
```

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

```
  = P * c / ( 24 * I1 ) * [ -3 * H² + 2 * h² *
    (( 3 + 5 * Alpha² * K ) / ( 3 + 5 * K ))]
  = 80.60 * -10.00 /( 24 * 0.07 ) * [ -3 * 110.00² + 2 * 130.00² *
    (( 3 + 5 * 0.85² * 2.32 ) / ( 3 + 5 * 2.32 ))]
  = 51.03 N./mm^2
```

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

```
  = P * h² * c / ( 12 * I1 ) * (( 3 + 5 *
    Alpha² * K ) / ( 3 + 5 * K ))
  = 80.60 * 130.00² * 10.00 / ( 12 * 0.07 ) * (( 3 + 5 *
   0.85² * 2.32 ) / ( 3 + 5 * 2.32 ))
  = 131.85 N./mm^2
```

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

```
  = P * h² * c / ( 12 * I1 ) * (( 3 + 5 *
    Alpha² * K ) / ( 3 + 5 * K ))
  = 80.60 * 130.00² * -10.00 / ( 12 * 0.07 ) * (( 3 + 5 *
   0.85² * 2.32 ) / ( 3 + 5 * 2.32 ))
  = -131.85 N./mm^2
```

Bending Stresses at Long-side 1

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

```
  = P * h² * c / ( 12 * I2 ) * [( 3 + K *
    ( 6 - Alpha²)) / ( 3 + 5 * K )]
  = 80.60 * 130.00² * 14.00 / ( 12 * 0.18 ) * [( 3 + 2.32 *
    ( 6 - 0.85²)) / ( 3 + 5 * 2.32 )]
  = 90.80 N./mm^2
```

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

```
  SblMi =  SblMi / Eb
  = 90.80 / 0.63
  = 144.52 N./mm^2
```

03

Bending Stress at Long-side 1 at M Outer[SblMo]:
= P * h² * c / (12 * I2) * [(3 + K *
(6 - Alpha²)) / (3 + 5 * K)]
= 80.60 * 130.00² * -14.00 / (12 * 0.18) * [(3 + 2.32 *
(6 - 0.85²)) / (3 + 5 * 2.32)]
= -90.80 N./mm^2

If Em(0.628) < E(0.850) and Eb(0.628) < E(0.850) then
SblMo = SblMo / Eb
= -90.80 / 0.63
= -144.52 N./mm^2

Bending Stress at Long-side 1 at Q Inner[SblQi]:
= P * h² * c / (12 * I2) * [(3 + 5 *
Alpha² * K) / (3 + 5 * K)]
= 80.60 * 130.00² * 14.00 / (12 * 0.18) * [(3 + 5 *
0.85² * 2.32) / (3 + 5 * 2.32)]
= 67.27 N./mm^2

Bending Stress at Long-side 1 at Q Outer[SblQo]:
= P * h² * c / (12 * I2) * [(3 + 5 *
Alpha² * K) / (3 + 5 * K)]
= 80.60 * 130.00² * -14.00 / (12 * 0.18) * [(3 + 5 *
0.85² * 2.32) / (3 + 5 * 2.32)]
= -67.27 N./mm^2

Bending Stresses at Long-side 2

Bending Stress at Long-side 2 at M Inner[SblMi]:
= P * h² * c / (12 * I2) * [(3 + K *
(6 - Alpha²)) / (3 + 5 * K)]
= 80.60 * 130.00² * 13.76 / (12 * 0.18) * [(3 + 2.32 *
(6 - 0.85²)) / (3 + 5 * 2.32)]
= 89.26 N./mm^2

If Em(0.575) < E(0.850) and Eb(0.550) < E(0.850) then
SblMi = SblMi / Eb
= 89.26 / 0.55
= 162.43 N./mm^2

Bending Stress at Long-side 2 at M Outer[SblMo]:
= P * h² * c / (12 * I2) * [(3 + K *
(6 - Alpha²)) / (3 + 5 * K)]
= 80.60 * 130.00² * -14.24 / (12 * 0.18) * [(3 + 2.32 *
(6 - 0.85²)) / (3 + 5 * 2.32)]
= -92.34 N./mm^2

If Em(0.575) < E(0.850) and Eb(0.550) < E(0.850) then
SblMo = SblMo / Eb
= -92.34 / 0.55
= -168.04 N./mm^2

Bending Stress at Long-side 2 at Q Inner[SblQi]:
= P * h² * c / (12 * I2) * [(3 + 5 *
Alpha² * K) / (3 + 5 * K)]
= 80.60 * 130.00² * 13.76 / (12 * 0.18) * [(3 + 5 *
0.85² * 2.32) / (3 + 5 * 2.32)]

= 66.13 N./mm^2

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Bending Stress at Long-side 2 at Q Outer[SblQo]:
= P * h² * c / (12 * I2) * [(3 + 5 *
Alpha² * K) / (3 + 5 * K)]
= 80.60 * 130.00² * -14.24 / (12 * 0.18) * [(3 + 5 *
0.85² * 2.32) / (3 + 5 * 2.32)]
= -68.41 N./mm^2

BENDING STRESSES: Bending Stress Calculations per Section 13-9, Equations (16-19). (N./mm^2) :

STRESS LOCATIONS	Inner	Outer	Allowable
Short-side 1 at N	-51.03	51.03	197.75
at Q	131.85	-131.85	197.75
Short-side 2 at N	-51.03	51.03	197.75
at Q	131.85	-131.85	197.75
Long-side 1 at M	144.52	-144.52	232.65
at Q	67.27	-67.27	197.75
Long-side 2 at M	162.43	-168.04	232.65
at Q	66.13	-68.41	197.75

Total Stress Calculations per Section 13-9

Total Stresses at Short-side 1

Total Stress at short side 1 at N inner [STS_Ni]:
= Sms + SbsNi
= 25.01 + -51.03
= -26.01 N./mm^2

Total Stress at short side 1 at N outer [STS_No]:
= Sms + SbsNo
= 25.01 + 51.03
= 76.04 N./mm^2

Total Stress at short side 1 at Q inner [STS_Qi]:
= Sms + SbsQi
= 25.01 + 131.85
= 156.86 N./mm^2

Total Stress at short side 1 at Q outer [STS_Qo]:
= Sms + SbsQo
= 25.01 + -131.85
= -106.83 N./mm^2

Total Stresses at Short-side 2

Total Stress at short side 2 at N inner [STS_Ni]:
= Sms + SbsNi
= 25.01 + -51.03
= -26.01 N./mm^2

03

Total Stress at short side 2 at N outer [STS_No]:
= Sms + SbsNo
= 25.01 + 51.03
= 76.04 N./mm^2

Total Stress at short side 2 at Q inner [STS_Qi]:
= Sms + SbsQi
= 25.01 + 131.85
= 156.86 N./mm^2

Total Stress at short side 2 at Q outer [STS_Qo]:
= Sms + SbsQo
= 25.01 + -131.85
= -106.83 N./mm^2

Total Stresses at Long-side 1

Total Stress at long side 1 at M inner [STL_Mi]:
= Sml + SblMi
= 25.20 + 144.52
= 169.72 N./mm^2

Total Stress at long side 1 at M outer [STL_Mo]:
= Sml + SblMo
= 25.20 + -144.52
= -119.32 N./mm^2

Total Stress at long side 1 at Q inner [STL_Qi]:
= Sml + SblQi
= 15.83 + 67.27
= 83.10 N./mm^2

Total Stress at long side 1 at Q outer [STL_Qo]:
= SmlB + SblQo
= 15.83 + -67.27
= -51.44 N./mm^2

Total Stresses at Long-side 2

Total Stress at long side 2 at M inner [STL_Mi]:
= Sml + SblMi
= 27.53 + 162.43
= 189.96 N./mm^2

Total Stress at long side 2 at M outer [STL_Mo]:
= Sml + SblMo
= 27.53 + -168.04
= -140.50 N./mm^2

Total Stress at long side 2 at Q inner [STL_Qi]:
= Sml + SblQi
= 15.83 + 66.13
= 81.96 N./mm^2

Total Stress at long side 2 at Q outer [STL_Qo]:
= SmlB + SblQo

```
= 15.83 + -68.41
= -52.58 N./mm^2
```

03

TOTAL STRESSES: Total Stress Calculations per Section 13-9, Equations (20-24). (N./mm^2) :

STRESS LOCATIONS	Inner	Outer	Allowable
Short-side 1 at N	-26.01	76.04	197.75
at Q	156.86	-106.83	197.75
Short-side 2 at N	-26.01	76.04	197.75
at Q	156.86	-106.83	197.75
Long-side 1 at M	169.72	-119.32	232.65
at Q	83.10	-51.44	197.75
Long-side 2 at M	189.96	-140.50	232.65
at Q	81.96	-52.58	197.75

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

	Actual	Allowable
End Plate	121.91	155.10

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

```
= d * sqrt( Z * C * P / ( SE ) ) + ca
= 110.000 * sqrt( 2.500 * 0.200 * 80.600 / ( 155.100 ) ) + 0.000
= 17.732 mm.
```

End Plate MAWP at given Thickness [MAWPEP]:

```
= ((T-ca)/d)^2 * ((SE)/(C*Z)) per UG-34 (c)(3)
= ((20.0000-0.0000)/110.0000)^2*((155)/(.20*2.50))
= 102.540 bars
```

where Z is:

```
= min( 3.4 - 2.4( d/D ), 2.5 )
= min( 3.4 - 2.4( 110.000 / 410.000 ), 2.5 )
= 2.500
```

SUMMARY OF RESULTS:

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	107.15	N./mm^2
High Stress Percentage	91.66	%
M.A.W.P. for Membrane Stresses	87.93	bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	-168.04	N./mm^2
High Stress Percentage	72.23	%
M.A.W.P. for Bending Stresses	111.59	bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	189.96	N./mm^2
High Stress Percentage	81.65	%
M.A.W.P. for Total Stresses	98.71	bars

03

Rectangular Vessel Results For Item 1 : A8

SUMMARY OF RESULTS:

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	107.15	N./mm^2
High Stress Percentage	91.66	%
M.A.W.P. for Membrane Stresses	87.93	bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	-168.04	N./mm^2
High Stress Percentage	72.23	%
M.A.W.P. for Bending Stresses	111.59	bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	189.96	N./mm^2
High Stress Percentage	81.65	%
M.A.W.P. for Total Stresses	98.71	bars

3.7 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]:

$$= P * c / (24 * I1) * [-3 * H^2 + 2 * h^2 * ((3 + 5 * Alpha^2 * K) / (3 + 5 * K))]$$
$$= 62.00 * 10.00 / (24 * 0.07) * [-3 * 100.00^2 + 2 * 60.00^2 * ((3 + 5 * 1.67^2 * 1.67) / (3 + 5 * 1.67))]$$
$$= -51.88 \text{ N./mm^2}$$

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

$$= P * c / (24 * I1) * [-3 * H^2 + 2 * h^2 * ((3 + 5 * Alpha^2 * K) / (3 + 5 * K))]$$
$$= 62.00 * -10.00 /(24 * 0.07) * [-3 * 100.00^2 + 2 * 60.00^2 * ((3 + 5 * 1.67^2 * 1.67) / (3 + 5 * 1.67))]$$
$$= 51.88 \text{ N./mm^2}$$

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

$$= P * h^2 * c / (12 * I1) * ((3 + 5 * Alpha^2 * K) / (3 + 5 * K))$$
$$= 62.00 * 60.00^2 * 10.00 / (12 * 0.07) * ((3 + 5 * 1.67^2 * 1.67) / (3 + 5 * 1.67))$$
$$= 64.37 \text{ N./mm^2}$$

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

$$= P * h^2 * c / (12 * I1) * ((3 + 5 * Alpha^2 * K) / (3 + 5 * K))$$
$$= 62.00 * 60.00^2 * -10.00 / (12 * 0.07) * ((3 + 5 * 1.67^2 * 1.67) / (3 + 5 * 1.67))$$
$$= -64.37 \text{ N./mm^2}$$

Bending Stresses at Long-side 1

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

$$= P * h^2 * c / (12 * I2) * [(3 + K * (6 - Alpha^2)) / (3 + 5 * K)]$$
$$= 62.00 * 60.00^2 * 10.00 / (12 * 0.07) * [(3 + 1.67 * (6 - 1.67^2)) / (3 + 5 * 1.67)]$$
$$= 20.61 \text{ N./mm^2}$$

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

$$SblMi = SblMi / Eb$$
$$= 20.61 / 0.63$$
$$= 32.80 \text{ N./mm^2}$$

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

$$= P * h^2 * c / (12 * I2) * [(3 + K * (6 - Alpha^2)) / (3 + 5 * K)]$$
$$= 62.00 * 60.00^2 * -10.00 / (12 * 0.07) * [(3 + 1.67 * (6 - 1.67^2)) / (3 + 5 * 1.67)]$$
$$= -20.61 \text{ N./mm^2}$$

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

$$SblMo = SblMo / Eb$$
$$= -20.61 / 0.63$$
$$= -32.80 \text{ N./mm^2}$$

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

$$= P * h^2 * c / (12 * I2) * [(3 + 5 * Alpha^2 * K) / (3 + 5 * K)]$$
$$= 62.00 * 60.00^2 * 10.00 / (12 * 0.07) * [(3 + 5 *$$

```
    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

3.8 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

3.9 FINITE ELEMENT FOR AE-2101

Tabular Results

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Tue Oct 01 08:56:40 2024.

03

```
Model Notes, Tube Results and API Check
Model Notes, Tube Results and API Check

  661PRO 3.0 - API 661 - Air-Cooled Heat Exchanger Nozzle Model

  Input Echo:


  Notes:

   -  The centerline of the header box is along the -Z axis.
   -  Only 1 Nozzle will be modeled at a time. The Nozzle Number
      Modeled can be seen below.
   -  User Defined Loads API 661 Check is shown below.
   -  Sum of ALL Nozzle Loads must not exceed 3*API Allowable
      Loads shown in paragraph 7.1.10.2 according to API 661
      2013 paragraph 7.1.10.3.
   -  Results are given as: Actual Load, Allowable Load,
      percentage of allowable for API Check in lbs. and ft-lbs. for
      English Units and N. and N-m for SI Units.


  Nozzle Number Modelled        : 1
  Top or Bottom Nozzle          : Top

  Analysis Type                 : User Defined Loads

  Nozzle Type                   : Straight
  Flange Type                   : Weldneck


  Header Box Dimensions:
  Centerline on                 :Centerline on LEFT  Side
  Height                        :     323.000 mm.
  Width                         :     200.000 mm.
  Length                        :    1842.000 mm.
```

03

```
Outboard Thickness            :      20.000 mm.
Tubesheet Side Thickness      :      20.000 mm.
Top Plate Thickness           :      20.000 mm.
Free End Plate Thickness      :      20.000 mm.

Header Box Pressure           :       2.200 MPa

Symmetric Boundary Condition at Centerline


Parition Plates:
Number of Partition Plates    :    2

Partition Plate #1
Plate Elevation from Bottom   :      91.000 mm.
Plate Thickness               :      10.000 mm.

Partition Plate #2
Plate Elevation from Bottom   :     223.000 mm.
Plate Thickness               :      10.000 mm.


Nozzle Dimensions:
Distance to CenterLine        :     921.000 mm.
Nozzle Outside Diameter       :     168.300 mm.
Nozzle Thickness              :       9.600 mm.
Projection to Face of Flange  :     260.000 mm.
Flange Thickness Used         :      31.800 mm.
Flange ID                     :     202.480 mm.
Flange Hub Length Used        :      47.700 mm.


Weld Size and SCF            : 0.000, 1.350


Engineering Details:
Operating  Cycles            :        7000
Occasional Cycles            :           0
Ambient Temperature          :      21.100 deg.
Computation Type             : Gauss Average


Material Properties

Nozzle:
       Cold Allowable Stress :     115.100 MPa
       Hot  Allowable Stress :      86.600 MPa
       Elastic Modulus       :   0.186E+06 MPa
       Poissons Ratio        :       0.300
       Material ID           :4-Austenitic Steels
       Density               :   0.000E+00  N /cu. mm.
       Cold Yield Stress     :     172.400 MPa
       Hot  Yield Stress     :     129.900 MPa
       Cold Tensile Stress   :     482.600 MPa
       Density               :   0.000E+00  N /cu. mm.

Header Box:
       Cold Allowable Stress :     115.100 MPa
       Hot  Allowable Stress :      86.600 MPa
       Elastic Modulus       :   0.186E+06 MPa
       Poissons Ratio        :       0.300
       Material ID           :4-Austenitic Steels
       Density               :   0.000E+00  N /cu. mm.
       Cold Yield Stress     :     172.400 MPa
       Hot  Yield Stress     :     129.900 MPa
       Cold Tensile Stress   :     482.600 MPa
       Density               :   0.000E+00  N /cu. mm.


Tubesheet was not modeled
```

03

User Defined Loads:

Forces [N] Moments [mm.- N]

	FX	FY	FZ	MX	MY	MZ
Weight	12000	15090	15090	6420000	9150000	4890000
Operating	12000	15090	15090	6420000	9150000	4890000
Occasional	0	0	0	0	0	0

No Tube Results

API Check for User Defined Loads and API Evaluation
API 661 2013 paragraph 7.1.10.2 and 7.1.10.3.

Results below are shown as:
Actual Load, Allowable Load, % of Allowable
Allowable Load: 3x API Allowable from para. 7.1.10.2

Total Nozzle Loads per DOF in [N and N.m]

Global FX	:	12000, 15015,	79 %
Global FY	:	15090, 30030,	50 %
Global FZ	:	15090, 25020,	60 %
Global MX	:	6420, 9150,	70 %
Global MY	:	9150, 12195,	75 %
Global MZ	:	4890, 6105,	80 %

API 661 para. 7.1.10.3 check PASSED. The summation of all nozzle loads did NOT exceed the 1.5x API value from para. 7.1.10.2.

Symmetric boundary condition applied at the center of the headerbox, the API multiplier from paragraph 7.1.10.3 will be 1.5 since total loads will be 2x larger due to symmetry.

Table of Contents

Load Case Report
FEPipe Version 15.0 Jobname: setup2 $P
Released Jan. 2021 8:55am OCT 1,2024

Load Case Report $X

Inner and outer element temperatures are the same throughout the model. No thermal ratcheting calculations will be performed.

THE 4 LOAD CASES ANALYZED ARE:

1 WEIGHT ONLY (Wgt Only)

Weight ONLY case run to get the stress range between the installed and the operating states.

/-------- Loads in Case 1
Loads due to Weight

2 SUSTAINED (Wgt+Pr)

Sustained case run to satisfy local primary membrane and bending stress limits.

/-------- Loads in Case 2
Loads due to Weight

03

```
      Pressure Case    1

3   OPERATING

    Case run to compute the operating stresses used in
    secondary, peak and range calculations as needed.

    /-------- Loads in Case   3
      Pressure Case    1
      Loads from (Operating)

4   RANGE          (Fatigue Calc Performed)

    Case run to get the RANGE of stresses.
    as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

    /-------- Combinations in Range Case   4
      Plus  Stress Results from CASE   3
      Minus Stress Results from CASE   1
```

Table of Contents

```
Solution Data
FEPipe Version 15.0          Jobname: setup2                $P
Released Jan. 2021            8:55am   OCT  1,2024



Solution Data


Maximum Solution Row Size =    1758
Number of Nodes           =    8591
Number of Elements        =    2923
Number of Solution Cases  =       3

Summation of Loads per Case

Case #               FX                  FY                  FZ

   1             12000.              53502.              15090.
   2             12000.             -44684.            -104898.
   3             12000.             -44684.            -104898.
```

Table of Contents

```
ASME Code Stress Output Plots
FEPipe Version 15.0          Jobname: setup2                $P
Released Jan. 2021            8:56am   OCT  1,2024



ASME Code Stress Output Plots                          $X

    1) Pl < SPL (SUS,Membrane) Case 2

    2) Qb < SPS (SUS,Bending) Case 2

    3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

    4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
```

03

5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

8) Membrane < User (OPE,Membrane) Case 3

9) Bending < User (OPE,Bending) Case 3

10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

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Stress Results - Notes
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Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.
- Using 2019 ASME Section VIII Division 2
- Use Polished Bar fatigue curve.
- Ratio between Operating and Design Pressure = 1.000000
  Range cases use operating pressure. Primary cases use design pressure.
- Assume free end displacements of attached pipe (e.g. thermal loads) are secondary loads.
- Primary bending stresses at discontinuities are treated like secondary stresses. (Pb=0)
- Use Equivalent Stress (Von Mises).
- TRIAXIAL Stress Guidelines:
  S1+S2+S3 evaluation omitted from operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Bending stress NOT included for all S1+S2+S3 calculations.
- Use local tensor values for averaged and not averaged stresses.

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ASME Overstressed Areas
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ASME Overstressed Areas $X

*** NO OVERSTRESSED NODES IN THIS MODEL ***

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Highest Primary Stress Ratios
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Highest Primary Stress Ratios $X

Circ Plate for Plate # 1

Pl	SPL	Primary Membrane Load Case 2
43	130	Min Prin. Stress = -65. (51% Neg, 8% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2

33%

Long Plate for Plate # 1

Pl	SPL	Primary Membrane Load Case 2
103	130	Min Prin. Stress = -107. (97% Neg, 19% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2

79%

Circ Plate for Plate # 2

Pl	SPL	Primary Membrane Load Case 2
50	130	Min Prin. Stress = -27. (58% Neg, 9% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2

38%

Circ Plate for Plate # 3

Pl	SPL	Primary Membrane Load Case 2
122	130	Min Prin. Stress = -175. (89% Neg, 49% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2

93%

Circ Plate for Plate # 4

Pl	SPL	Primary Membrane Load Case 2
93	130	Min Prin. Stress = -113. (76% Neg, 20% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2

71%

Long Plate for Plate # 4

Pl	SPL	Primary Membrane Load Case 2

22	130	Min Prin. Stress = -15. (79% Neg, 12% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
16%		

03

Circ Plate for Plate # 5

Pl	SPL	Primary Membrane Load Case 2
35	130	Min Prin. Stress = -10. (42% Neg, 11% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
26%		

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Highest Secondary Stress Ratios
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Highest Secondary Stress Ratios $X

In combination case 4 the max range stress divided
by the max component stress is 1.99. The case tensor components
are in some directions additive and so the combination
case will have HIGHER stresses than the largest of any
of the individual cases by more than 50%.

Load Case	Combined/Max (Inside)	Combined/Max (Outside)
4	1.993	1.970

Circ Plate for Plate # 1

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
88	303	Min Prin. Stress = -65. (51% Neg, 8% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
29%		

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 3
88	303	Min Prin. Stress = -65. (51% Neg, 8% NegHi)
MPa	MPa	Plot Reference:
		6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
29%		

Long Plate for Plate # 1

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
190	303	Min Prin. Stress = -107. (97% Neg, 19% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
62%		

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 3
190	303	Min Prin. Stress = -107. (97% Neg, 19% NegHi)
MPa	MPa	Plot Reference:
		7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
62%		

Circ Plate for Plate # 2

03

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
75	303	Min Prin. Stress = -27. (58% Neg, 9% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
24%		

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 3
75	303	Min Prin. Stress = -27. (58% Neg, 9% NegHi)
MPa	MPa	Plot Reference:
		7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
24%		

Circ Plate for Plate # 3

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
245	303	Min Prin. Stress = -175. (89% Neg, 49% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
80%		

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 3
245	303	Min Prin. Stress = -175. (89% Neg, 49% NegHi)
MPa	MPa	Plot Reference:
		6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
80%		

Circ Plate for Plate # 4

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
157	303	Min Prin. Stress = -113. (76% Neg, 20% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
52%		

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 3
157	303	Min Prin. Stress = -113. (76% Neg, 20% NegHi)
MPa	MPa	Plot Reference:
		6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
52%		

Long Plate for Plate # 4

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
39	303	Min Prin. Stress = -15. (79% Neg, 12% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
12%		

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 3
39	303	Min Prin. Stress = -15. (79% Neg, 12% NegHi)
MPa	MPa	Plot Reference:
		7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
12%		

Circ Plate for Plate # 5

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
56	302	Min Prin. Stress = -10. (42% Neg, 11% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
18%		

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 3
56	302	Min Prin. Stress = -10. (42% Neg, 11% NegHi)
MPa	MPa	Plot Reference:
		7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
18%		

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Highest Fatigue Stress Ratios
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Highest Fatigue Stress Ratios $X

Circ Plate for Plate # 1

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 4
40	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.052 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.0000E11
Allowable		"B31" Fatigue Stress Allowable = 504.2
777.2		Markl Fatigue Stress Allowable = 659.5
MPa		WRC 474 Mean Cycles to Failure = 53,800,080.
		WRC 474 99% Probability Cycles = 12,498,247.
5%		WRC 474 95% Probability Cycles = 17,352,244.
		BS5500 Allowed Cycles(Curve F) = 17,406,096.
		Membrane-to-Bending Ratio = 0.287
		Bending-to-PL+PB+Q Ratio = 0.777
		Plot Reference:
		12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Long Plate for Plate # 1

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 4
67	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.087 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.0000E11
Allowable		"B31" Fatigue Stress Allowable = 504.2
777.2		Markl Fatigue Stress Allowable = 659.5
MPa		WRC 474 Mean Cycles to Failure = 12,005,280.
		WRC 474 99% Probability Cycles = 2,788,933.
8%		WRC 474 95% Probability Cycles = 3,872,082.
		BS5500 Allowed Cycles(Curve F) = 2,956,780.
		Membrane-to-Bending Ratio = 0.249
		Bending-to-PL+PB+Q Ratio = 0.800
		Plot Reference:
		13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Circ Plate for Plate # 2

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 4
40	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.052 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.0000E11
Allowable		"B31" Fatigue Stress Allowable = 504.2
777.2		Markl Fatigue Stress Allowable = 659.5
MPa		WRC 474 Mean Cycles to Failure = 53,800,080.
		WRC 474 99% Probability Cycles = 12,498,247.
5%		WRC 474 95% Probability Cycles = 17,352,244.
		BS5500 Allowed Cycles(Curve F) = 17,406,096.
		Membrane-to-Bending Ratio = 0.287
		Bending-to-PL+PB+Q Ratio = 0.777
		Plot Reference:
		12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Circ Plate for Plate # 3

03

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Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
       62     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.079 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 504.2
    777.2                    Markl Fatigue Stress Allowable = 659.5
      MPa                    WRC 474 Mean Cycles to Failure = 22,928,718.
                             WRC 474 99% Probability Cycles = 5,326,544.
       7%                    WRC 474 95% Probability Cycles = 7,395,236.
                             BS5500 Allowed Cycles(Curve F) = 3,877,636.
                             Membrane-to-Bending Ratio = 0.577
                             Bending-to-PL+PB+Q Ratio = 0.634
                             Plot Reference:
                             12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4


Circ Plate for Plate # 4

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
       29     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.038 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 504.2
    777.2                    Markl Fatigue Stress Allowable = 659.5
      MPa                    WRC 474 Mean Cycles to Failure = 2.2774E8
                             WRC 474 99% Probability Cycles = 52,906,380.
       3%                    WRC 474 95% Probability Cycles = 73,453,848.
                             BS5500 Allowed Cycles(Curve F) = 86,924,216.
                             Membrane-to-Bending Ratio = 0.912
                             Bending-to-PL+PB+Q Ratio = 0.523
                             Plot Reference:
                             12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4


Long Plate for Plate # 4

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
       10     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.013 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 504.2
    777.2                    Markl Fatigue Stress Allowable = 659.5
      MPa                    WRC 474 Mean Cycles to Failure = 2.2647E9
                             WRC 474 99% Probability Cycles = 5.2612E8
       1%                    WRC 474 95% Probability Cycles = 7.3045E8
                             BS5500 Allowed Cycles(Curve F) = 7.5188E9
                             Membrane-to-Bending Ratio = 0.919
                             Bending-to-PL+PB+Q Ratio = 0.521
                             Plot Reference:
                             12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4


Circ Plate for Plate # 5

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
       29     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.054 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 0.0
    530.5                    Markl Fatigue Stress Allowable = 575.0
      MPa                    WRC 474 Mean Cycles to Failure = 2.1487E8
                             WRC 474 99% Probability Cycles = 49,916,348.
       5%                    WRC 474 95% Probability Cycles = 69,302,576.
                             BS5500 Allowed Cycles(Curve F) = 91,314,408.
                             Membrane-to-Bending Ratio = 9.370
                             Bending-to-PL+PB+Q Ratio = 0.096
                             Plot Reference:
                             12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
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Highest Stress Ratios Per Region
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Highest Stress Ratios Per Region $X

Circ Plate for Plate # 1

Pl	SPL	Primary Membrane Load Case 2
43	130	Min Prin. Stress = -65. (51% Neg, 8% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
33%		
Qb	SPS	Primary Bending Load Case 2
59	303	Min Prin. Stress = -65. (51% Neg, 8% NegHi)
MPa	MPa	Plot Reference:
		2) Qb < SPS (SUS,Bending) Case 2
19%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
88	303	Min Prin. Stress = -65. (51% Neg, 8% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
29%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
72	303	Min Prin. Stress = -65. (51% Neg, 8% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
23%		
S1+S2+S3	4S	Part 5 (5.3.2) Load Case 2
46	346	Min Prin. Stress = -65. (51% Neg, 8% NegHi)
MPa	MPa	Plot Reference:
		5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
13%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 3
88	303	Min Prin. Stress = -65. (51% Neg, 8% NegHi)
MPa	MPa	Plot Reference:
		6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
29%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 3
72	303	Min Prin. Stress = -65. (51% Neg, 8% NegHi)
MPa	MPa	Plot Reference:
		7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
23%		
Membrane	User	Component Evaluation Load Case 3
43	303	Min Prin. Stress = -65. (51% Neg, 8% NegHi)
MPa	MPa	Plot Reference:
		8) Membrane < User (OPE,Membrane) Case 3
14%		
Bending	User	Component Evaluation Load Case 3
59	303	Min Prin. Stress = -65. (51% Neg, 8% NegHi)
MPa	MPa	Plot Reference:
		9) Bending < User (OPE,Bending) Case 3
19%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 4
40	303	Min Prin. Stress = -16. (49% Neg, 7% NegHi)

03

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      MPa              MPa      Plot Reference:
                                10) Pl+Pb+Q < SPS (EXP,Inside) Case 4
              13%

   Pl+Pb+Q             SPS      Primary+Secondary (Outer) Load Case 4
       35              303      Min Prin. Stress = -16. (49% Neg, 7% NegHi)
      MPa              MPa      Plot Reference:
                                11) Pl+Pb+Q < SPS (EXP,Outside) Case 4
              11%

Pl+Pb+Q+F    Damage Ratio      Primary+Secondary+Peak (Inner) Load Case 4
       40     0.000 Life       Stress Concentration Factor = 1.000
      MPa     0.052 Stress     Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1.0000E11
Allowable                      "B31" Fatigue Stress Allowable = 504.2
    777.2                      Markl Fatigue Stress Allowable = 659.5
      MPa                      WRC 474 Mean Cycles to Failure = 53,800,080.
                               WRC 474 99% Probability Cycles = 12,498,247.
       5%                      WRC 474 95% Probability Cycles = 17,352,244.
                               BS5500 Allowed Cycles(Curve F) = 17,406,096.
                               Membrane-to-Bending Ratio = 0.287
                               Bending-to-PL+PB+Q Ratio = 0.777
                               Plot Reference:
                               12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio      Primary+Secondary+Peak (Outer) Load Case 4
       35     0.000 Life       Stress Concentration Factor = 1.000
      MPa     0.045 Stress     Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1.0000E11
Allowable                      "B31" Fatigue Stress Allowable = 504.2
    777.2                      Markl Fatigue Stress Allowable = 659.5
      MPa                      WRC 474 Mean Cycles to Failure = 80,855,728.
                               WRC 474 99% Probability Cycles = 18,783,518.
       4%                      WRC 474 95% Probability Cycles = 26,078,552.
                               BS5500 Allowed Cycles(Curve F) = 34,168,636.
                               Membrane-to-Bending Ratio = 0.359
                               Bending-to-PL+PB+Q Ratio = 0.736
                               Plot Reference:
                               13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Long Plate for Plate # 1

       Pl              SPL      Primary Membrane Load Case 2
      103              130      Min Prin. Stress = -107. (97% Neg, 19% NegHi)
      MPa              MPa      Plot Reference:
                                1) Pl < SPL (SUS,Membrane) Case 2
              79%

       Qb              SPS      Primary Bending Load Case 2
      139              303      Min Prin. Stress = -107. (97% Neg, 19% NegHi)
      MPa              MPa      Plot Reference:
                                2) Qb < SPS (SUS,Bending) Case 2
              45%

   Pl+Pb+Q             SPS      Primary+Secondary (Inner) Load Case 2
      138              303      Min Prin. Stress = -107. (97% Neg, 19% NegHi)
      MPa              MPa      Plot Reference:
                                3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
              45%

   Pl+Pb+Q             SPS      Primary+Secondary (Outer) Load Case 2
      190              303      Min Prin. Stress = -107. (97% Neg, 19% NegHi)
      MPa              MPa      Plot Reference:
                                4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
              62%

  S1+S2+S3              4S      Part 5 (5.3.2) Load Case 2
      122              346      Min Prin. Stress = -107. (97% Neg, 19% NegHi)
      MPa              MPa      Plot Reference:
                                5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
              35%
```

03

```
  Pl+Pb+Q              SPS      Primary+Secondary (Inner) Load Case 3
      138              303      Min Prin. Stress = -107. (97% Neg, 19% NegHi)
      MPa              MPa      Plot Reference:
                                6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
              45%

  Pl+Pb+Q              SPS      Primary+Secondary (Outer) Load Case 3
      190              303      Min Prin. Stress = -107. (97% Neg, 19% NegHi)
      MPa              MPa      Plot Reference:
                                7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
              62%

 Membrane             User      Component Evaluation Load Case 3
      103              303      Min Prin. Stress = -107. (97% Neg, 19% NegHi)
      MPa              MPa      Plot Reference:
                                8) Membrane < User (OPE,Membrane) Case 3
              33%

  Bending              User      Component Evaluation Load Case 3
      139              303      Min Prin. Stress = -107. (97% Neg, 19% NegHi)
      MPa              MPa      Plot Reference:
                                9) Bending < User (OPE,Bending) Case 3
              45%

  Pl+Pb+Q              SPS      Primary+Secondary (Inner) Load Case 4
       67              303      Min Prin. Stress = -32. (91% Neg, 15% NegHi)
      MPa              MPa      Plot Reference:
                                10) Pl+Pb+Q < SPS (EXP,Inside) Case 4
              22%

  Pl+Pb+Q              SPS      Primary+Secondary (Outer) Load Case 4
       67              303      Min Prin. Stress = -32. (91% Neg, 15% NegHi)
      MPa              MPa      Plot Reference:
                                11) Pl+Pb+Q < SPS (EXP,Outside) Case 4
              22%

Pl+Pb+Q+F     Damage Ratio      Primary+Secondary+Peak (Inner) Load Case 4
       67      0.000 Life       Stress Concentration Factor = 1.000
      MPa      0.086 Stress     Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 1.0000E11
Allowable                       "B31" Fatigue Stress Allowable = 504.2
    777.2                       Markl Fatigue Stress Allowable = 659.5
      MPa                       WRC 474 Mean Cycles to Failure = 12,298,224.
                                WRC 474 99% Probability Cycles = 2,856,986.
        8%                      WRC 474 95% Probability Cycles = 3,966,566.
                                BS5500 Allowed Cycles(Curve F) = 3,014,588.
                                Membrane-to-Bending Ratio = 0.248
                                Bending-to-PL+PB+Q Ratio = 0.802
                                Plot Reference:
                                12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F     Damage Ratio      Primary+Secondary+Peak (Outer) Load Case 4
       67      0.000 Life       Stress Concentration Factor = 1.000
      MPa      0.087 Stress     Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 1.0000E11
Allowable                       "B31" Fatigue Stress Allowable = 504.2
    777.2                       Markl Fatigue Stress Allowable = 659.5
      MPa                       WRC 474 Mean Cycles to Failure = 12,005,280.
                                WRC 474 99% Probability Cycles = 2,788,933.
        8%                      WRC 474 95% Probability Cycles = 3,872,082.
                                BS5500 Allowed Cycles(Curve F) = 2,956,780.
                                Membrane-to-Bending Ratio = 0.249
                                Bending-to-PL+PB+Q Ratio = 0.800
                                Plot Reference:
                                13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Circ Plate for Plate # 2

       Pl             SPL      Primary Membrane Load Case 2
       50             130      Min Prin. Stress = -27. (58% Neg, 9% NegHi)
```

03

MPa		MPa	Plot Reference:
			1) Pl < SPL (SUS,Membrane) Case 2
	38%		
Qb		SPS	Primary Bending Load Case 2
54		303	Min Prin. Stress = -27. (58% Neg, 9% NegHi)
MPa		MPa	Plot Reference:
			2) Qb < SPS (SUS,Bending) Case 2
	17%		
Pl+Pb+Q		SPS	Primary+Secondary (Inner) Load Case 2
57		303	Min Prin. Stress = -27. (58% Neg, 9% NegHi)
MPa		MPa	Plot Reference:
			3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
	18%		
Pl+Pb+Q		SPS	Primary+Secondary (Outer) Load Case 2
75		303	Min Prin. Stress = -27. (58% Neg, 9% NegHi)
MPa		MPa	Plot Reference:
			4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
	24%		
S1+S2+S3		4S	Part 5 (5.3.2) Load Case 2
28		346	Min Prin. Stress = -27. (58% Neg, 9% NegHi)
MPa		MPa	Plot Reference:
			5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
	8%		
Pl+Pb+Q		SPS	Primary+Secondary (Inner) Load Case 3
57		303	Min Prin. Stress = -27. (58% Neg, 9% NegHi)
MPa		MPa	Plot Reference:
			6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
	18%		
Pl+Pb+Q		SPS	Primary+Secondary (Outer) Load Case 3
75		303	Min Prin. Stress = -27. (58% Neg, 9% NegHi)
MPa		MPa	Plot Reference:
			7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
	24%		
Membrane		User	Component Evaluation Load Case 3
50		303	Min Prin. Stress = -27. (58% Neg, 9% NegHi)
MPa		MPa	Plot Reference:
			8) Membrane < User (OPE,Membrane) Case 3
	16%		
Bending		User	Component Evaluation Load Case 3
54		303	Min Prin. Stress = -27. (58% Neg, 9% NegHi)
MPa		MPa	Plot Reference:
			9) Bending < User (OPE,Bending) Case 3
	17%		
Pl+Pb+Q		SPS	Primary+Secondary (Inner) Load Case 4
40		303	Min Prin. Stress = -16. (52% Neg, 9% NegHi)
MPa		MPa	Plot Reference:
			10) Pl+Pb+Q < SPS (EXP,Inside) Case 4
	13%		
Pl+Pb+Q		SPS	Primary+Secondary (Outer) Load Case 4
35		303	Min Prin. Stress = -16. (52% Neg, 9% NegHi)
MPa		MPa	Plot Reference:
			11) Pl+Pb+Q < SPS (EXP,Outside) Case 4
	11%		
Pl+Pb+Q+F	Damage Ratio		Primary+Secondary+Peak (Inner) Load Case 4
40	0.000 Life		Stress Concentration Factor = 1.000
MPa	0.052 Stress		Strain Concentration Factor = 1.000
			Cycles Allowed for this Stress = 1.0000E11
Allowable			"B31" Fatigue Stress Allowable = 504.2
777.2			Markl Fatigue Stress Allowable = 659.5
MPa			WRC 474 Mean Cycles to Failure = 53,800,080.
			WRC 474 99% Probability Cycles = 12,498,247.

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       5%                    WRC 474 95% Probability Cycles = 17,352,244.
                             BS5500 Allowed Cycles(Curve F) = 17,406,096.
                             Membrane-to-Bending Ratio = 0.287
                             Bending-to-PL+PB+Q Ratio = 0.777
                             Plot Reference:
                             12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
      35     0.000 Life      Stress Concentration Factor = 1.000
     MPa     0.045 Stress    Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 504.2
   777.2                     Markl Fatigue Stress Allowable = 659.5
     MPa                     WRC 474 Mean Cycles to Failure = 80,855,760.
                             WRC 474 99% Probability Cycles = 18,783,526.
       4%                    WRC 474 95% Probability Cycles = 26,078,564.
                             BS5500 Allowed Cycles(Curve F) = 34,168,652.
                             Membrane-to-Bending Ratio = 0.359
                             Bending-to-PL+PB+Q Ratio = 0.736
                             Plot Reference:
                             13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Circ Plate for Plate # 3

       Pl            SPL     Primary Membrane Load Case 2
      122            130     Min Prin. Stress = -175. (89% Neg, 49% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
             93%

       Qb            SPS     Primary Bending Load Case 2
      203            303     Min Prin. Stress = -175. (89% Neg, 49% NegHi)
      MPa            MPa     Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
             67%

    Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 2
      245            303     Min Prin. Stress = -175. (89% Neg, 49% NegHi)
      MPa            MPa     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             80%

    Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 2
      185            303     Min Prin. Stress = -175. (89% Neg, 49% NegHi)
      MPa            MPa     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             61%

   S1+S2+S3            4S     Part 5 (5.3.2) Load Case 2
      170            346     Min Prin. Stress = -175. (89% Neg, 49% NegHi)
      MPa            MPa     Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
             49%

    Pl+Pb+Q           SPS     Primary+Secondary (Inner) Load Case 3
      245            303     Min Prin. Stress = -175. (89% Neg, 49% NegHi)
      MPa            MPa     Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
             80%

    Pl+Pb+Q           SPS     Primary+Secondary (Outer) Load Case 3
      185            303     Min Prin. Stress = -175. (89% Neg, 49% NegHi)
      MPa            MPa     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
             61%

   Membrane          User     Component Evaluation Load Case 3
      122            303     Min Prin. Stress = -175. (89% Neg, 49% NegHi)
      MPa            MPa     Plot Reference:
                             8) Membrane < User (OPE,Membrane) Case 3
             40%
```

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  Bending            User      Component Evaluation Load Case 3
      203             303      Min Prin. Stress = -175. (89% Neg, 49% NegHi)
      MPa             MPa      Plot Reference:
                               9) Bending < User (OPE,Bending) Case 3
             67%

  Pl+Pb+Q              SPS      Primary+Secondary (Inner) Load Case 4
       62              303      Min Prin. Stress = -40. (99% Neg, 28% NegHi)
      MPa              MPa      Plot Reference:
                               10) Pl+Pb+Q < SPS (EXP,Inside) Case 4
             20%

  Pl+Pb+Q              SPS      Primary+Secondary (Outer) Load Case 4
       34              303      Min Prin. Stress = -40. (99% Neg, 28% NegHi)
      MPa              MPa      Plot Reference:
                               11) Pl+Pb+Q < SPS (EXP,Outside) Case 4
             11%

Pl+Pb+Q+F     Damage Ratio      Primary+Secondary+Peak (Inner) Load Case 4
       62      0.000 Life       Stress Concentration Factor = 1.000
      MPa      0.079 Stress     Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 1.0000E11
Allowable                       "B31" Fatigue Stress Allowable = 504.2
    777.2                       Markl Fatigue Stress Allowable = 659.5
      MPa                       WRC 474 Mean Cycles to Failure = 22,928,718.
                                WRC 474 99% Probability Cycles = 5,326,544.
        7%                      WRC 474 95% Probability Cycles = 7,395,236.
                                BS5500 Allowed Cycles(Curve F) = 3,877,636.
                                Membrane-to-Bending Ratio = 0.577
                                Bending-to-PL+PB+Q Ratio = 0.634
                                Plot Reference:
                                12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F     Damage Ratio      Primary+Secondary+Peak (Outer) Load Case 4
       34      0.000 Life       Stress Concentration Factor = 1.000
      MPa      0.044 Stress     Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 1.0000E11
Allowable                       "B31" Fatigue Stress Allowable = 504.2
    777.2                       Markl Fatigue Stress Allowable = 659.5
      MPa                       WRC 474 Mean Cycles to Failure = 1.3199E8
                                WRC 474 99% Probability Cycles = 30,662,112.
        4%                      WRC 474 95% Probability Cycles = 42,570,488.
                                BS5500 Allowed Cycles(Curve F) = 39,697,960.
                                Membrane-to-Bending Ratio = 4.769
                                Bending-to-PL+PB+Q Ratio = 0.173
                                Plot Reference:
                                13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Circ Plate for Plate # 4

       Pl              SPL      Primary Membrane Load Case 2
       93              130      Min Prin. Stress = -113. (76% Neg, 20% NegHi)
      MPa              MPa      Plot Reference:
                               1) Pl < SPL (SUS,Membrane) Case 2
             71%

       Qb              SPS      Primary Bending Load Case 2
      100              303      Min Prin. Stress = -113. (76% Neg, 20% NegHi)
      MPa              MPa      Plot Reference:
                               2) Qb < SPS (SUS,Bending) Case 2
             32%

  Pl+Pb+Q              SPS      Primary+Secondary (Inner) Load Case 2
      157              303      Min Prin. Stress = -113. (76% Neg, 20% NegHi)
      MPa              MPa      Plot Reference:
                               3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             52%

  Pl+Pb+Q              SPS      Primary+Secondary (Outer) Load Case 2
      113              303      Min Prin. Stress = -113. (76% Neg, 20% NegHi)
```

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MPa		MPa	Plot Reference: 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
	37%		
S1+S2+S3		4S	Part 5 (5.3.2) Load Case 2
148		346	Min Prin. Stress = -113. (76% Neg, 20% NegHi)
MPa		MPa	Plot Reference: 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
	42%		
Pl+Pb+Q		SPS	Primary+Secondary (Inner) Load Case 3
157		303	Min Prin. Stress = -113. (76% Neg, 20% NegHi)
MPa		MPa	Plot Reference: 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
	52%		
Pl+Pb+Q		SPS	Primary+Secondary (Outer) Load Case 3
113		303	Min Prin. Stress = -113. (76% Neg, 20% NegHi)
MPa		MPa	Plot Reference: 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
	37%		
Membrane		User	Component Evaluation Load Case 3
93		303	Min Prin. Stress = -113. (76% Neg, 20% NegHi)
MPa		MPa	Plot Reference: 8) Membrane < User (OPE,Membrane) Case 3
	30%		
Bending		User	Component Evaluation Load Case 3
100		303	Min Prin. Stress = -113. (76% Neg, 20% NegHi)
MPa		MPa	Plot Reference: 9) Bending < User (OPE,Bending) Case 3
	32%		
Pl+Pb+Q		SPS	Primary+Secondary (Inner) Load Case 4
29		303	Min Prin. Stress = -19. (60% Neg, 11% NegHi)
MPa		MPa	Plot Reference: 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4
	9%		
Pl+Pb+Q		SPS	Primary+Secondary (Outer) Load Case 4
28		303	Min Prin. Stress = -19. (60% Neg, 11% NegHi)
MPa		MPa	Plot Reference: 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4
	9%		
Pl+Pb+Q+F	Damage Ratio		Primary+Secondary+Peak (Inner) Load Case 4
29	0.000 Life		Stress Concentration Factor = 1.000
MPa	0.038 Stress		Strain Concentration Factor = 1.000 Cycles Allowed for this Stress = 1.0000E11
Allowable			"B31" Fatigue Stress Allowable = 504.2
777.2			Markl Fatigue Stress Allowable = 659.5
MPa			WRC 474 Mean Cycles to Failure = 2.2774E8
			WRC 474 99% Probability Cycles = 52,906,380.
3%			WRC 474 95% Probability Cycles = 73,453,848.
			BS5500 Allowed Cycles(Curve F) = 86,924,216.
			Membrane-to-Bending Ratio = 0.912
			Bending-to-PL+PB+Q Ratio = 0.523
			Plot Reference: 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
Pl+Pb+Q+F	Damage Ratio		Primary+Secondary+Peak (Outer) Load Case 4
28	0.000 Life		Stress Concentration Factor = 1.000
MPa	0.036 Stress		Strain Concentration Factor = 1.000 Cycles Allowed for this Stress = 1.0000E11
Allowable			"B31" Fatigue Stress Allowable = 504.2
777.2			Markl Fatigue Stress Allowable = 659.5
MPa			WRC 474 Mean Cycles to Failure = 2.5213E8
			WRC 474 99% Probability Cycles = 58,572,912.
3%			WRC 474 95% Probability Cycles = 81,321,112.
			BS5500 Allowed Cycles(Curve F) = 1.0450E8
			Membrane-to-Bending Ratio = 1.230

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                                Bending-to-PL+PB+Q Ratio = 0.448
                                Plot Reference:
                                13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Long Plate for Plate # 4

       Pl              SPL      Primary Membrane Load Case 2
       22              130      Min Prin. Stress = -15. (79% Neg, 12% NegHi)
      MPa              MPa      Plot Reference:
                                1) Pl < SPL (SUS,Membrane) Case 2
              16%

       Qb              SPS      Primary Bending Load Case 2
       26              303      Min Prin. Stress = -15. (79% Neg, 12% NegHi)
      MPa              MPa      Plot Reference:
                                2) Qb < SPS (SUS,Bending) Case 2
               8%

    Pl+Pb+Q             SPS      Primary+Secondary (Inner) Load Case 2
       24               303      Min Prin. Stress = -15. (79% Neg, 12% NegHi)
      MPa               MPa      Plot Reference:
                                 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
               7%

    Pl+Pb+Q             SPS      Primary+Secondary (Outer) Load Case 2
       39               303      Min Prin. Stress = -15. (79% Neg, 12% NegHi)
      MPa               MPa      Plot Reference:
                                 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
              12%

   S1+S2+S3              4S      Part 5 (5.3.2) Load Case 2
       17               346      Min Prin. Stress = -15. (79% Neg, 12% NegHi)
      MPa               MPa      Plot Reference:
                                 5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
               5%

    Pl+Pb+Q             SPS      Primary+Secondary (Inner) Load Case 3
       24               303      Min Prin. Stress = -15. (79% Neg, 12% NegHi)
      MPa               MPa      Plot Reference:
                                 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
               7%

    Pl+Pb+Q             SPS      Primary+Secondary (Outer) Load Case 3
       39               303      Min Prin. Stress = -15. (79% Neg, 12% NegHi)
      MPa               MPa      Plot Reference:
                                 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
              12%

   Membrane            User      Component Evaluation Load Case 3
       22               303      Min Prin. Stress = -15. (79% Neg, 12% NegHi)
      MPa               MPa      Plot Reference:
                                 8) Membrane < User (OPE,Membrane) Case 3
               7%

    Bending             User      Component Evaluation Load Case 3
       26               303      Min Prin. Stress = -15. (79% Neg, 12% NegHi)
      MPa               MPa      Plot Reference:
                                 9) Bending < User (OPE,Bending) Case 3
               8%

    Pl+Pb+Q             SPS      Primary+Secondary (Inner) Load Case 4
       10               303      Min Prin. Stress = -4. (51% Neg, 8% NegHi)
      MPa               MPa      Plot Reference:
                                 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4
               3%

    Pl+Pb+Q             SPS      Primary+Secondary (Outer) Load Case 4
        7               303      Min Prin. Stress = -4. (51% Neg, 8% NegHi)
      MPa               MPa      Plot Reference:
                                 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4
               2%
```

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Pl+Pb+Q+F 10 MPa	Damage Ratio 0.000 Life 0.013 Stress	Primary+Secondary+Peak (Inner) Load Case 4 Stress Concentration Factor = 1.000 Strain Concentration Factor = 1.000 Cycles Allowed for this Stress = 1.0000E11
Allowable 777.2 MPa 1%		"B31" Fatigue Stress Allowable = 504.2 Markl Fatigue Stress Allowable = 659.5 WRC 474 Mean Cycles to Failure = 2.2647E9 WRC 474 99% Probability Cycles = 5.2612E8 WRC 474 95% Probability Cycles = 7.3045E8 BS5500 Allowed Cycles(Curve F) = 7.5188E9 Membrane-to-Bending Ratio = 0.919 Bending-to-PL+PB+Q Ratio = 0.521 Plot Reference: 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
Pl+Pb+Q+F 7 MPa	Damage Ratio 0.000 Life 0.008 Stress	Primary+Secondary+Peak (Outer) Load Case 4 Stress Concentration Factor = 1.000 Strain Concentration Factor = 1.000 Cycles Allowed for this Stress = 1.0000E11
Allowable 777.2 MPa 0%		"B31" Fatigue Stress Allowable = 504.2 Markl Fatigue Stress Allowable = 659.5 WRC 474 Mean Cycles to Failure = 9.5210E9 WRC 474 99% Probability Cycles = 2.2118E9 WRC 474 95% Probability Cycles = 3.0708E9 BS5500 Allowed Cycles(Curve F) = 5.9365E10 Membrane-to-Bending Ratio = 0.913 Bending-to-PL+PB+Q Ratio = 0.523 Plot Reference: 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Circ Plate for Plate # 5

Pl 35 MPa 26%	SPL 130 MPa	Primary Membrane Load Case 2 Min Prin. Stress = -10. (42% Neg, 11% NegHi) Plot Reference: 1) Pl < SPL (SUS,Membrane) Case 2
Qb 23 MPa 7%	SPS 302 MPa	Primary Bending Load Case 2 Min Prin. Stress = -10. (42% Neg, 11% NegHi) Plot Reference: 2) Qb < SPS (SUS,Bending) Case 2
Pl+Pb+Q 47 MPa 15%	SPS 302 MPa	Primary+Secondary (Inner) Load Case 2 Min Prin. Stress = -10. (42% Neg, 11% NegHi) Plot Reference: 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
Pl+Pb+Q 56 MPa 18%	SPS 302 MPa	Primary+Secondary (Outer) Load Case 2 Min Prin. Stress = -10. (42% Neg, 11% NegHi) Plot Reference: 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
Pl+Pb+Q 47 MPa 15%	SPS 302 MPa	Primary+Secondary (Inner) Load Case 3 Min Prin. Stress = -10. (42% Neg, 11% NegHi) Plot Reference: 6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
Pl+Pb+Q 56 MPa 18%	SPS 302 MPa	Primary+Secondary (Outer) Load Case 3 Min Prin. Stress = -10. (42% Neg, 11% NegHi) Plot Reference: 7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
Membrane 35	User 302	Component Evaluation Load Case 3 Min Prin. Stress = -10. (42% Neg, 11% NegHi)

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      MPa              MPa      Plot Reference:
                                8) Membrane < User (OPE,Membrane) Case 3
            11%

    Bending            User     Component Evaluation Load Case 3
         23             302     Min Prin. Stress = -10. (42% Neg, 11% NegHi)
        MPa             MPa     Plot Reference:
                                9) Bending < User (OPE,Bending) Case 3
             7%

    Pl+Pb+Q             SPS     Primary+Secondary (Inner) Load Case 4
         29             302     Min Prin. Stress = -3. (17% Neg, 5% NegHi)
        MPa             MPa     Plot Reference:
                                10) Pl+Pb+Q < SPS (EXP,Inside) Case 4
             9%

    Pl+Pb+Q             SPS     Primary+Secondary (Outer) Load Case 4
         29             302     Min Prin. Stress = -3. (17% Neg, 5% NegHi)
        MPa             MPa     Plot Reference:
                                11) Pl+Pb+Q < SPS (EXP,Outside) Case 4
             9%

  Pl+Pb+Q+F  Damage Ratio       Primary+Secondary+Peak (Inner) Load Case 4
         29   0.000 Life        Stress Concentration Factor = 1.000
        MPa   0.054 Stress      Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 1.0000E11
  Allowable                     "B31" Fatigue Stress Allowable = 0.0
      530.5                     Markl Fatigue Stress Allowable = 575.0
        MPa                     WRC 474 Mean Cycles to Failure = 2.1487E8
                                WRC 474 99% Probability Cycles = 49,916,348.
         5%                     WRC 474 95% Probability Cycles = 69,302,576.
                                BS5500 Allowed Cycles(Curve F) = 91,314,408.
                                Membrane-to-Bending Ratio = 9.370
                                Bending-to-PL+PB+Q Ratio = 0.096
                                Plot Reference:
                                12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

  Pl+Pb+Q+F  Damage Ratio       Primary+Secondary+Peak (Outer) Load Case 4
         29   0.000 Life        Stress Concentration Factor = 1.000
        MPa   0.054 Stress      Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 1.0000E11
  Allowable                     "B31" Fatigue Stress Allowable = 0.0
      530.5                     Markl Fatigue Stress Allowable = 575.0
        MPa                     WRC 474 Mean Cycles to Failure = 2.2377E8
                                WRC 474 99% Probability Cycles = 51,982,772.
         5%                     WRC 474 95% Probability Cycles = 72,171,536.
                                BS5500 Allowed Cycles(Curve F) = 97,284,968.
                                Membrane-to-Bending Ratio = 7.767
                                Bending-to-PL+PB+Q Ratio = 0.114
                                Plot Reference:
                                13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
```

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```
Compressive Stress Summary
FEPipe Version 15.0          Jobname: setup2                $P
Released Jan. 2021            8:56am   OCT  1,2024



Compressive Stress Summary (MPa)                      $X

Nomenclature:
-------------
Min Stress       - Compressive Membrane and Bending Stress
Pts in Region    - No. of nodes in the model region
>5% Compression  - 5% or more of Compressive Stress Limit
```

>50% Compression - 50% or more of Compressive Stress Limit

Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section slenderness ratio (elastic buckling) not considered.

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#	Load Type	Case	Min Stress	Pts in Region	>5% Compression and Bending	>50% Compression and Bending	Region
1	SUSTAINED	2	-65.	1856	51%	8%	Circ Plate for Plate # 1
2	OPERATING	3	-65.	1856	51%	8%	Circ Plate for Plate # 1
3	EXPANSION	4	-16.	1856	49%	7%	Circ Plate for Plate # 1
4	SUSTAINED	2	-107.	8072	97%	19%	Long Plate for Plate # 1
5	OPERATING	3	-107.	8072	97%	19%	Long Plate for Plate # 1
6	EXPANSION	4	-32.	8072	91%	15%	Long Plate for Plate # 1
7	SUSTAINED	2	-27.	1504	58%	9%	Circ Plate for Plate # 2
8	OPERATING	3	-27.	1504	58%	9%	Circ Plate for Plate # 2
9	EXPANSION	4	-16.	1504	52%	9%	Circ Plate for Plate # 2
10	SUSTAINED	2	-175.	1600	89%	49%	Circ Plate for Plate # 3
11	OPERATING	3	-175.	1600	89%	49%	Circ Plate for Plate # 3
12	EXPANSION	4	-40.	1600	99%	28%	Circ Plate for Plate # 3
13	SUSTAINED	2	-113.	1440	76%	20%	Circ Plate for Plate # 4
14	OPERATING	3	-113.	1440	76%	20%	Circ Plate for Plate # 4
15	EXPANSION	4	-19.	1440	60%	11%	Circ Plate for Plate # 4
16	SUSTAINED	2	-15.	640	79%	12%	Long Plate for Plate # 4
17	OPERATING	3	-15.	640	79%	12%	Long Plate for Plate # 4
18	EXPANSION	4	-4.	640	51%	8%	Long Plate for Plate # 4
19	SUSTAINED	2	-10.	8272	42%	11%	Circ Plate for Plate # 5
20	OPERATING	3	-10.	8272	42%	11%	Circ Plate for Plate # 5
21	EXPANSION	4	-3.	8272	17%	5%	Circ Plate for Plate # 5

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Finite Element Model

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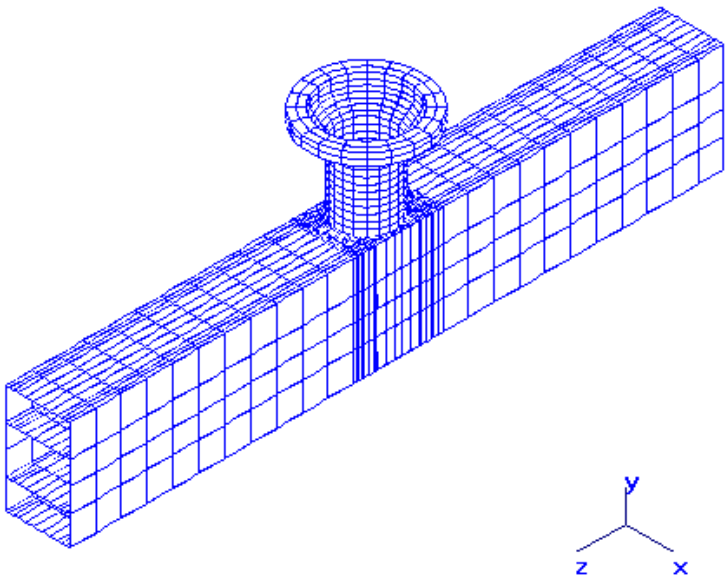
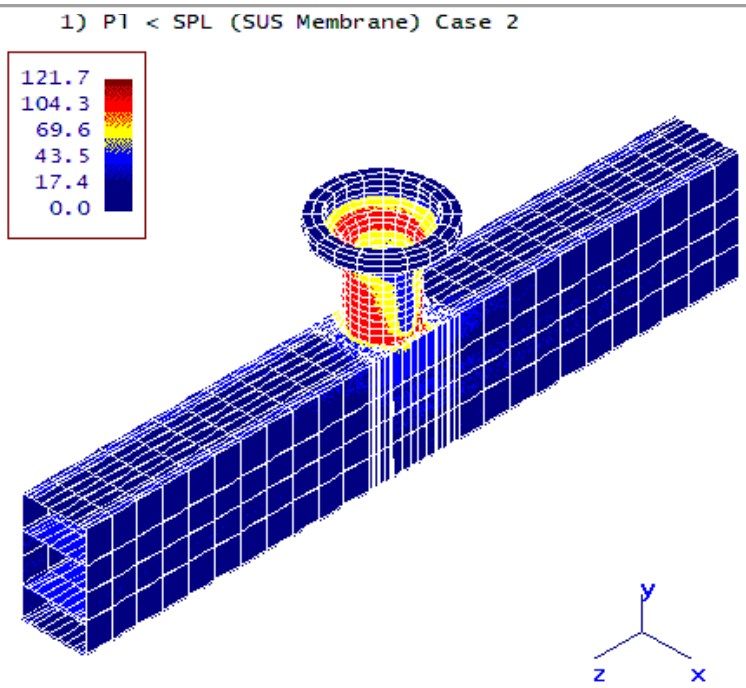


3d



3d(Deformed) 3d

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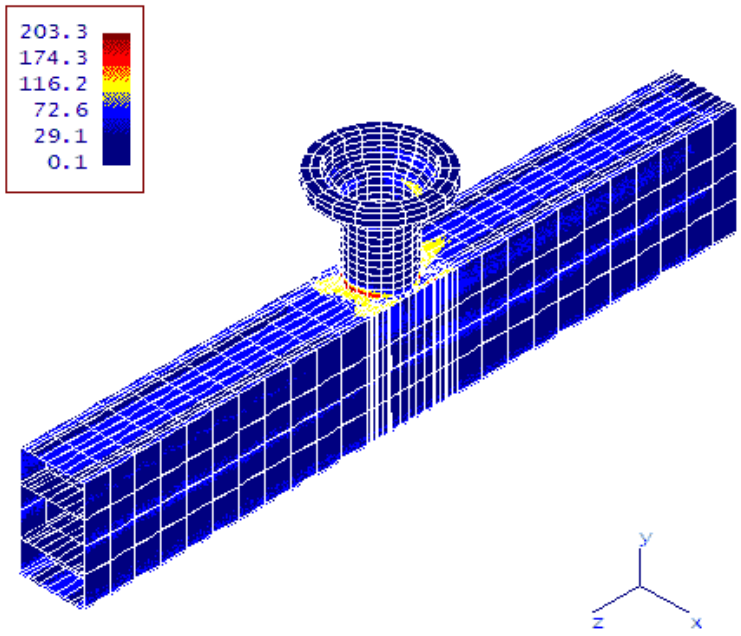
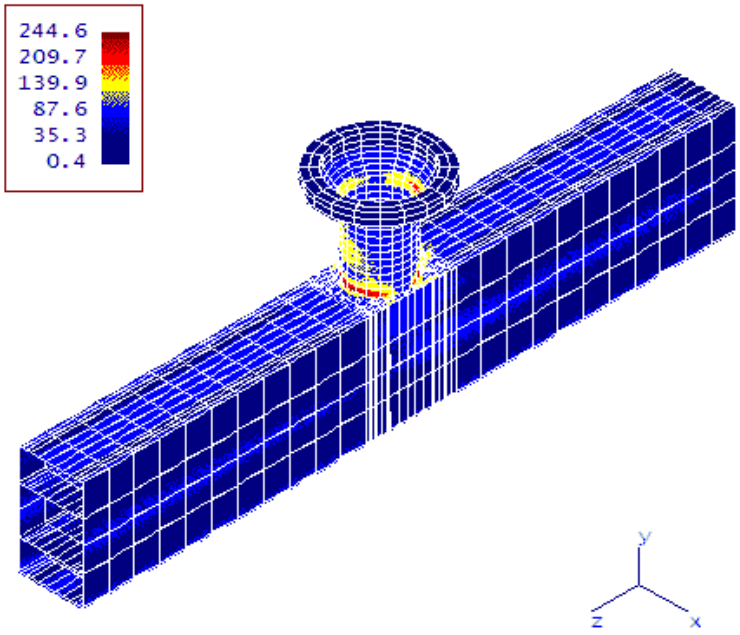
2) Qb < SPS (SUS Bending) Case 2



3d(Deformed) 3d

3) Pl+Pb+Q < SPS (SUS Inside) Case 2



3d(Deformed) 3d

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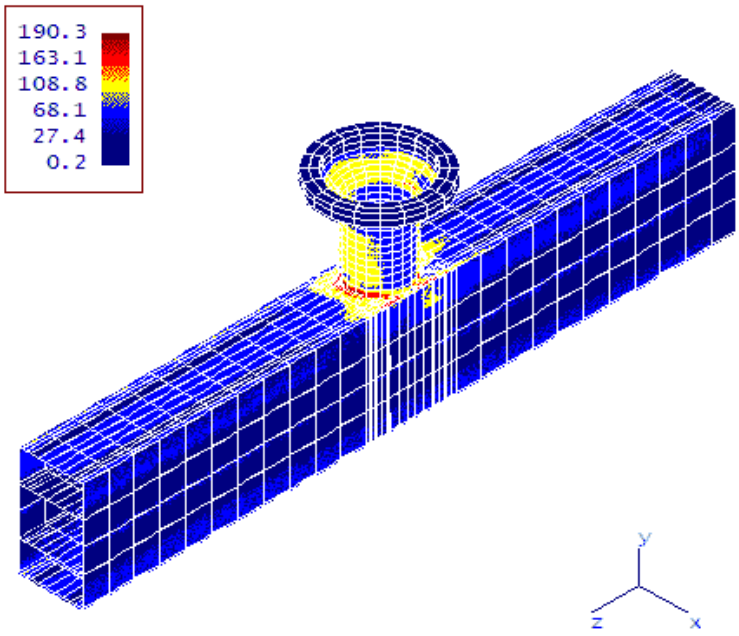
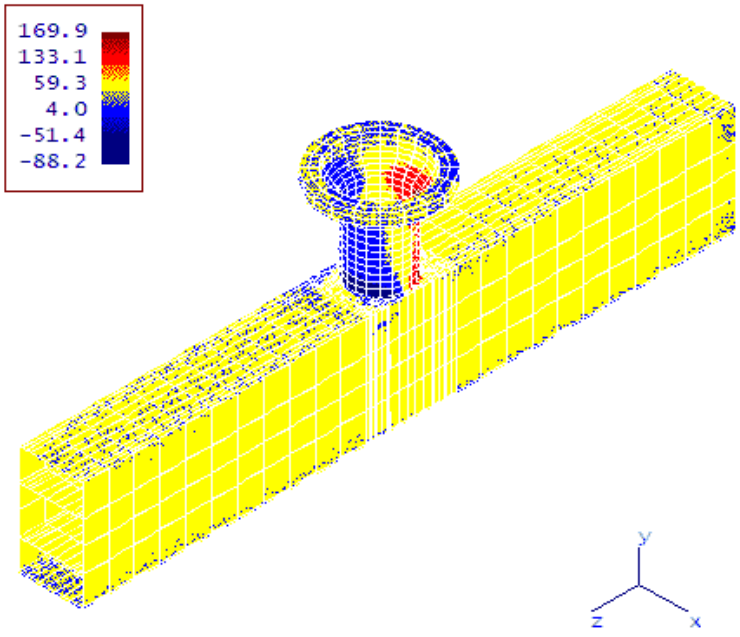
4) Pl+Pb+Q < SPS (SUS Outside) Case 2



3d(Deformed) 3d

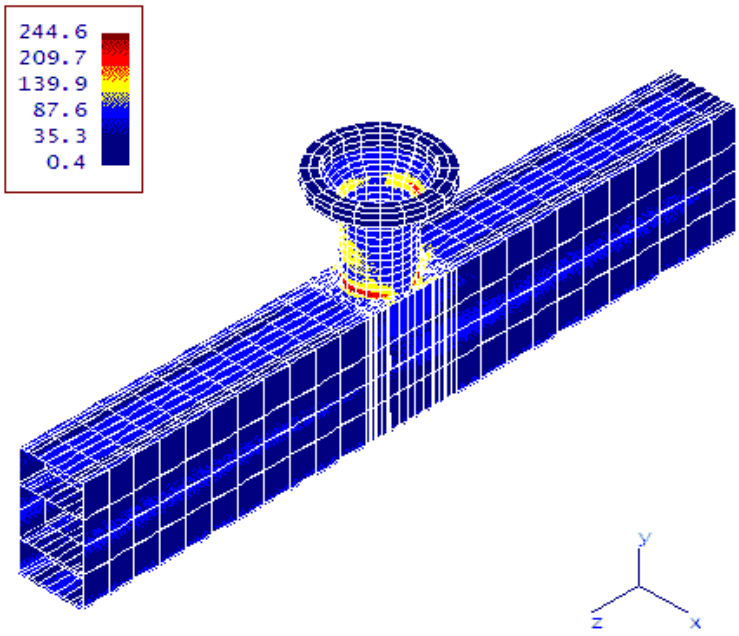
5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 2



3d(Deformed) 3d

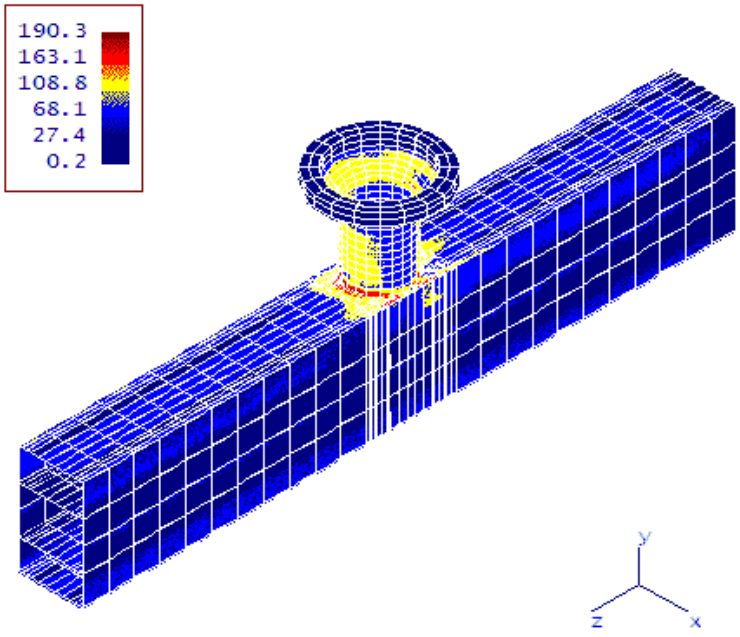
03

6) Pl+Pb+Q < SPS (OPE Inside) Case 3



3d(Deformed) 3d

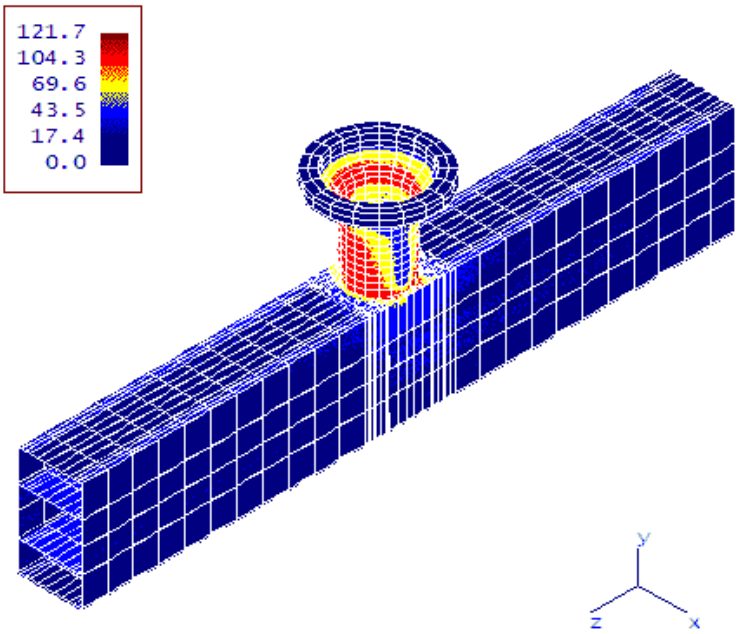
7) Pl+Pb+Q < SPS (OPE Outside) Case 3



3d(Deformed) 3d

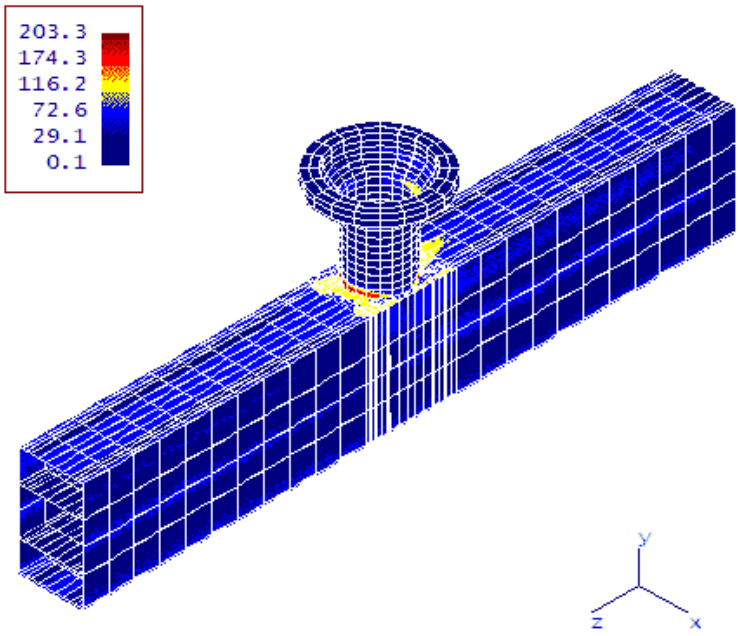
03

8) Membrane < User (OPE Membrane) Case 3



3d(Deformed) 3d

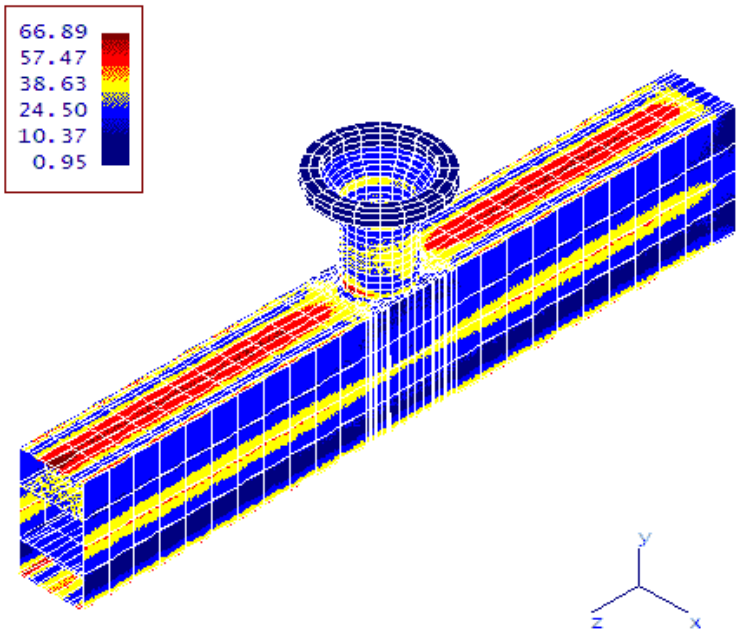
9) Bending < User (OPE Bending) Case 3



3d(Deformed) 3d

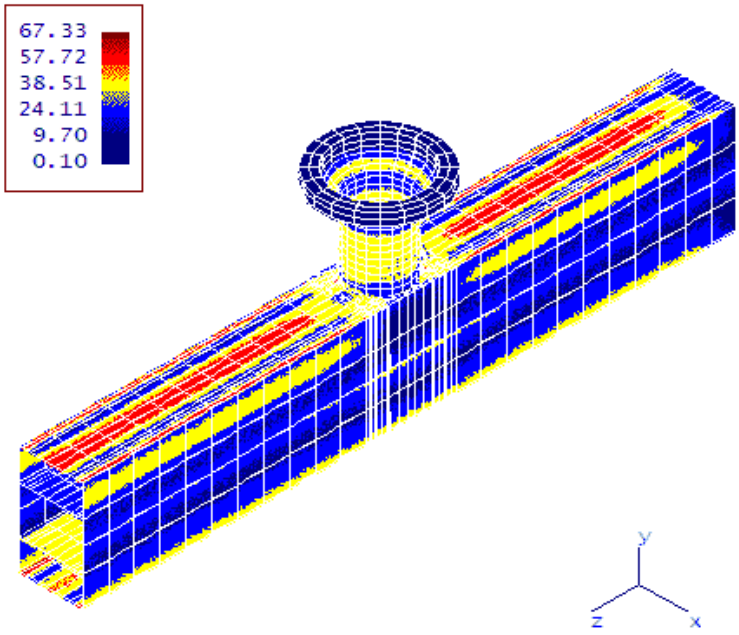
03

10) Pl+Pb+Q < SPS (EXP Inside) Case 4



3d

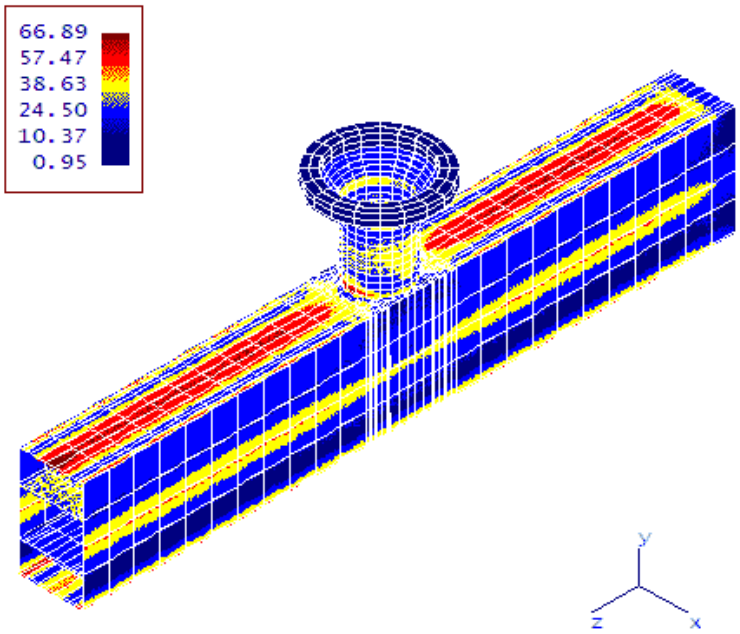
11) Pl+Pb+Q < SPS (EXP Outside) Case 4



3d

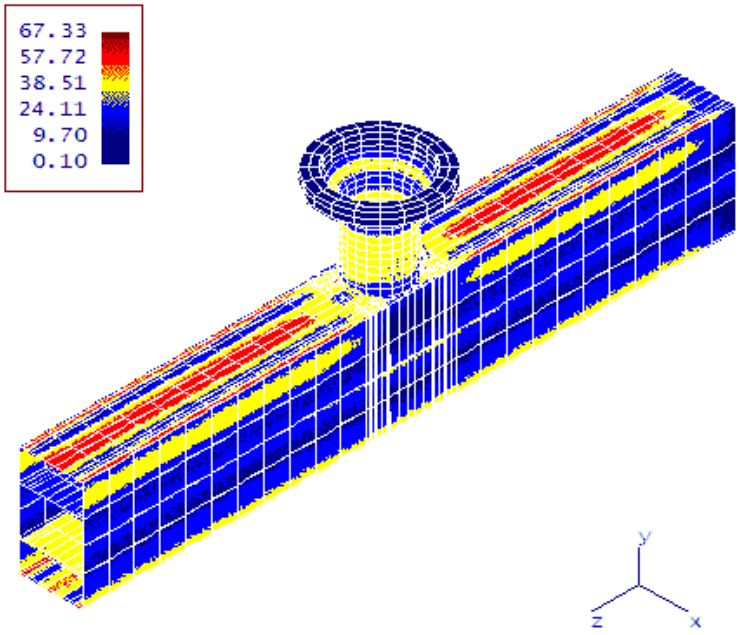
12) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 4

03



3d

13) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 4



3d

3.10 FINITE ELEMENT FOR AE-2102

Tabular Results

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Wed Oct 02 11:48:52 2024.

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```
Model Notes, Tube Results and API Check
Model Notes, Tube Results and API Check

  661PRO 3.0 - API 661 - Air-Cooled Heat Exchanger Nozzle Model

  Input Echo:


  Notes:

   -  The centerline of the header box is along the -Z axis.
   -  Only 1 Nozzle will be modeled at a time. The Nozzle Number
      Modeled can be seen below.
   -  User Defined Loads API 661 Check is shown below.
   -  Sum of ALL Nozzle Loads must not exceed 3*API Allowable
      Loads shown in paragraph 7.1.10.2 according to API 661
      2013 paragraph 7.1.10.3.
   -  Results are given as: Actual Load, Allowable Load,
      percentage of allowable for API Check in lbs. and ft-lbs. for
      English Units and N. and N-m for SI Units.


  Nozzle Number Modelled        : 1
  Top or Bottom Nozzle          : Top

  Analysis Type                 : User Defined Loads

  Nozzle Type                   : Straight
  Flange Type                   : Weldneck


  Header Box Dimensions:
  Centerline on                 :Centerline on LEFT  Side
  Height                        :     485.000 mm.
  Width                         :     166.000 mm.
  Length                        :    2065.000 mm.
```

03

```
Outboard Thickness            :      28.000 mm.
Tubesheet Side Thickness      :      28.000 mm.
Top Plate Thickness           :      20.000 mm.
Free End Plate Thickness      :      20.000 mm.

Header Box Pressure           :       6.200 MPa

Symmetric Boundary Condition at Centerline


Parition Plates:
Number of Partition Plates    :    2

Partition Plate #1
Plate Elevation from Bottom   :     165.000 mm.
Plate Thickness               :      10.000 mm.

Partition Plate #2
Plate Elevation from Bottom   :     305.000 mm.
Plate Thickness               :      10.000 mm.


Nozzle Dimensions:
Distance to CenterLine        :    1032.500 mm.
Nozzle Outside Diameter       :     114.300 mm.
Nozzle Thickness              :       7.500 mm.
Projection to Face of Flange  :     270.000 mm.
Flange Thickness Used         :      27.300 mm.
Flange ID                     :     154.059 mm.
Flange Hub Length Used        :      40.950 mm.


Weld Size and SCF            : 0.000, 1.350


Engineering Details:
Operating  Cycles            :        7000
Occasional Cycles            :           0
Ambient Temperature          :      21.100 deg.
Computation Type             : Gauss Average


Material Properties

Nozzle:
       Cold Allowable Stress :     115.100 MPa
       Hot  Allowable Stress :     111.900 MPa
       Elastic Modulus       :   0.184E+06 MPa
       Poissons Ratio        :       0.300
       Material ID           :4-Austenitic Steels
       Density               :   0.000E+00  N /cu. mm.
       Cold Yield Stress     :     172.400 MPa
       Hot  Yield Stress     :     126.100 MPa
       Cold Tensile Stress   :     482.700 MPa
       Density               :   0.000E+00  N /cu. mm.

Header Box:
       Cold Allowable Stress :     115.100 MPa
       Hot  Allowable Stress :     111.900 MPa
       Elastic Modulus       :   0.184E+06 MPa
       Poissons Ratio        :       0.300
       Material ID           :4-Austenitic Steels
       Density               :   0.000E+00  N /cu. mm.
       Cold Yield Stress     :     172.400 MPa
       Hot  Yield Stress     :     126.100 MPa
       Cold Tensile Stress   :     482.700 MPa
       Density               :   0.000E+00  N /cu. mm.


Tubesheet was not modeled
```

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User Defined Loads:

Forces [N] Moments [mm.- N]

	FX	FY	FZ	MX	MY	MZ
Weight	10020	8010	10020	2430000	3660000	2430000
Operating	10020	8010	10020	2430000	3660000	2430000
Occasional	0	0	0	0	0	0

No Tube Results

API Check for User Defined Loads and API Evaluation
API 661 2013 paragraph 7.1.10.2 and 7.1.10.3.

Results below are shown as:
Actual Load, Allowable Load, % of Allowable
Allowable Load: 3x API Allowable from para. 7.1.10.2

Total Nozzle Loads per DOF in [N and N.m]
Global FX : 10020, 15015, 66 %
Global FY : 8010, 30030, 26 %
Global FZ : 10020, 25020, 40 %
Global MX : 2430, 9150, 26 %
Global MY : 3660, 12195, 30 %
Global MZ : 2430, 6105, 39 %

API 661 para. 7.1.10.3 check PASSED. The summation of all nozzle loads did NOT exceed the 1.5x API value from para. 7.1.10.2.

Symmetric boundary condition applied at the center of the headerbox, the API multiplier from paragraph 7.1.10.3 will be 1.5 since total loads will be 2x larger due to symmetry.

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Load Case Report
FEPipe Version 15.0 Jobname: setup2 $P
Released Jan. 2021 11:46am OCT 2,2024

Load Case Report $X

Inner and outer element temperatures are the same throughout the model. No thermal ratcheting calculations will be performed.

THE 4 LOAD CASES ANALYZED ARE:

1 WEIGHT ONLY (Wgt Only)

Weight ONLY case run to get the stress range between the installed and the operating states.

/-------- Loads in Case 1
Loads due to Weight

2 SUSTAINED (Wgt+Pr)

Sustained case run to satisfy local primary membrane and bending stress limits.

/-------- Loads in Case 2
Loads due to Weight

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```
      Pressure Case    1

 3    OPERATING

      Case run to compute the operating stresses used in
      secondary, peak and range calculations as needed.

      /-------- Loads in Case   3
        Pressure Case    1
        Loads from (Operating)

 4    RANGE          (Fatigue Calc Performed)

      Case run to get the RANGE of stresses.
      as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

      /-------- Combinations in Range Case   4
        Plus  Stress Results from CASE   3
        Minus Stress Results from CASE   1
```

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```
Solution Data
FEPipe Version 15.0           Jobname: setup2                $P
Released Jan. 2021             11:46am  OCT  2,2024
```

```
Solution Data

Maximum Solution Row Size =    2466
Number of Nodes           =   13117
Number of Elements        =    4421
Number of Solution Cases  =       3

Summation of Loads per Case

Case #               FX                  FY                  FZ

   1             10020.              56025.              10020.
   2             10020.            -119625.            -387834.
   3             10020.            -119625.            -387834.
```

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```
ASME Code Stress Output Plots
FEPipe Version 15.0           Jobname: setup2                $P
Released Jan. 2021             11:48am  OCT  2,2024
```

```
ASME Code Stress Output Plots                          $X

    1) Pl < SPL (SUS,Membrane) Case 2

    2) Qb < SPS (SUS,Bending) Case 2

    3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

    4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
```

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5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

8) Membrane < User (OPE,Membrane) Case 3

9) Bending < User (OPE,Bending) Case 3

10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

11) Pl+Pb+Q < SPS (EXP,Outside) Case 4

12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

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Stress Results - Notes
FEPipe Version 15.0 Jobname: setup2 $P
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Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.
- Using 2019 ASME Section VIII Division 2
- Use Polished Bar fatigue curve.
- Ratio between Operating and Design Pressure = 1.000000
  Range cases use operating pressure. Primary cases use design pressure.
- Assume free end displacements of attached pipe (e.g. thermal loads) are secondary loads.
- Primary bending stresses at discontinuities are treated like secondary stresses. (Pb=0)
- Use Equivalent Stress (Von Mises).
- TRIAXIAL Stress Guidelines:
  S1+S2+S3 evaluation omitted from operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Bending stress NOT included for all S1+S2+S3 calculations.
- Use local tensor values for averaged and not averaged stresses.

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ASME Overstressed Areas
FEPipe Version 15.0 Jobname: setup2 $P
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ASME Overstressed Areas $X

*** NO OVERSTRESSED NODES IN THIS MODEL ***

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Highest Primary Stress Ratios
FEPipe Version 15.0 Jobname: setup2 $P
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Highest Primary Stress Ratios $X

Circ Plate for Plate # 1

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
120	340	Min Prin. Stress = -49. (59% Neg, 5% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
35%		

Long Plate for Plate # 1

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
237	340	Min Prin. Stress = -121. (91% Neg, 29% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
69%		

Circ Plate for Plate # 2

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
102	340	Min Prin. Stress = -28. (59% Neg, 4% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
30%		

Circ Plate for Plate # 3

Pl	SPL	Primary Membrane Load Case 2
143	168	Min Prin. Stress = -192. (77% Neg, 47% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
84%		

Circ Plate for Plate # 4

Pl	SPL	Primary Membrane Load Case 2
121	168	Min Prin. Stress = -175. (68% Neg, 22% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
72%		

Long Plate for Plate # 4

Pl	SPL	Primary Membrane Load Case 2

03

```
       27            168     Min Prin. Stress = -17. (75% Neg, 4% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            15%

Circ Plate for Plate # 5

       Pl            SPL     Primary Membrane Load Case 2
      104            126     Min Prin. Stress = -7. (10% Neg, 3% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
            82%
```

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```
Highest Secondary Stress Ratios
FEPipe Version 15.0          Jobname: setup2                $P
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Highest Secondary Stress Ratios                          $X

In combination case  4 the max range stress divided
by the max component stress is 1.84. The case tensor components
are in some directions additive and so the combination
case will have HIGHER stresses than the largest of any
of the individual cases by more than 50%.

Load      Combined/Max       Combined/Max
Case        (Inside)           (Outside)
------    -------------      -------------
   4         1.838              1.691


Circ Plate for Plate # 1

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
      120            340     Min Prin. Stress = -49. (59% Neg, 5% NegHi)
      MPa            MPa     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            35%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 3
      120            340     Min Prin. Stress = -49. (59% Neg, 5% NegHi)
      MPa            MPa     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
            35%


Long Plate for Plate # 1

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
      237            340     Min Prin. Stress = -121. (91% Neg, 29% NegHi)
      MPa            MPa     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
            69%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 3
      237            340     Min Prin. Stress = -121. (91% Neg, 29% NegHi)
      MPa            MPa     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
```

03

69%

Circ Plate for Plate # 2

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
102	340	Min Prin. Stress = -28. (59% Neg, 4% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
30%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 3
102	340	Min Prin. Stress = -28. (59% Neg, 4% NegHi)
MPa	MPa	Plot Reference:
		7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
30%		

Circ Plate for Plate # 3

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
271	340	Min Prin. Stress = -192. (77% Neg, 47% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
79%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 3
271	340	Min Prin. Stress = -192. (77% Neg, 47% NegHi)
MPa	MPa	Plot Reference:
		6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
79%		

Circ Plate for Plate # 4

Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
210	340	Min Prin. Stress = -175. (68% Neg, 22% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
61%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 3
210	340	Min Prin. Stress = -175. (68% Neg, 22% NegHi)
MPa	MPa	Plot Reference:
		6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
61%		

Long Plate for Plate # 4

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
47	340	Min Prin. Stress = -17. (75% Neg, 4% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
13%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 3
47	340	Min Prin. Stress = -17. (75% Neg, 4% NegHi)
MPa	MPa	Plot Reference:
		7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
13%		

Circ Plate for Plate # 5

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
115	298	Min Prin. Stress = -7. (10% Neg, 3% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
38%		

```
  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 3
      115            298     Min Prin. Stress = -7. (10% Neg, 3% NegHi)
      MPa            MPa     Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
            38%
```

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```
Highest Fatigue Stress Ratios
FEPipe Version 15.0          Jobname: setup2                $P
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Highest Fatigue Stress Ratios                          $X


Circ Plate for Plate # 1

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
      120     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.155 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 567.5
    771.0                    Markl Fatigue Stress Allowable = 659.5
      MPa                    WRC 474 Mean Cycles to Failure = 1,771,558.
                             WRC 474 99% Probability Cycles = 411,549.
      15%                    WRC 474 95% Probability Cycles = 571,384.
                             BS5500 Allowed Cycles(Curve F) = 537,311.
                             Membrane-to-Bending Ratio = 0.385
                             Bending-to-PL+PB+Q Ratio = 0.722
                             Plot Reference:
                             13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Long Plate for Plate # 1

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
      169     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.220 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 567.5
    771.0                    Markl Fatigue Stress Allowable = 659.5
      MPa                    WRC 474 Mean Cycles to Failure = 607,122.
                             WRC 474 99% Probability Cycles = 141,040.
      21%                    WRC 474 95% Probability Cycles = 195,816.
                             BS5500 Allowed Cycles(Curve F) = 190,383.
                             Membrane-to-Bending Ratio = 0.303
                             Bending-to-PL+PB+Q Ratio = 0.768
                             Plot Reference:
                             13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Circ Plate for Plate # 2

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
       84     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.109 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 567.5
    770.9                    Markl Fatigue Stress Allowable = 659.5
      MPa                    WRC 474 Mean Cycles to Failure = 4,542,684.
                             WRC 474 99% Probability Cycles = 1,055,307.
      10%                    WRC 474 95% Probability Cycles = 1,465,161.
                             BS5500 Allowed Cycles(Curve F) = 1,316,472.
                             Membrane-to-Bending Ratio = 0.150
                             Bending-to-PL+PB+Q Ratio = 0.869
```

03

Plot Reference:
12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Circ Plate for Plate # 3

Pl+Pb+Q+F Damage Ratio
153 0.000 Life
MPa 0.198 Stress

Allowable
770.9
MPa

19%

Primary+Secondary+Peak (Inner) Load Case 4
Stress Concentration Factor = 1.000
Strain Concentration Factor = 1.000
Cycles Allowed for this Stress = 1.0000E11
"B31" Fatigue Stress Allowable = 567.5
Markl Fatigue Stress Allowable = 659.5
WRC 474 Mean Cycles to Failure = 1,478,924.
WRC 474 99% Probability Cycles = 343,567.
WRC 474 95% Probability Cycles = 477,000.
BS5500 Allowed Cycles(Curve F) = 258,260.
Membrane-to-Bending Ratio = 0.914
Bending-to-PL+PB+Q Ratio = 0.523
Plot Reference:
12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Circ Plate for Plate # 4

Pl+Pb+Q+F Damage Ratio
108 0.000 Life
MPa 0.140 Stress

Allowable
770.9
MPa

13%

Primary+Secondary+Peak (Inner) Load Case 4
Stress Concentration Factor = 1.000
Strain Concentration Factor = 1.000
Cycles Allowed for this Stress = 1.0000E11
"B31" Fatigue Stress Allowable = 567.5
Markl Fatigue Stress Allowable = 659.5
WRC 474 Mean Cycles to Failure = 4,459,746.
WRC 474 99% Probability Cycles = 1,036,040.
WRC 474 95% Probability Cycles = 1,438,410.
BS5500 Allowed Cycles(Curve F) = 735,938.
Membrane-to-Bending Ratio = 0.790
Bending-to-PL+PB+Q Ratio = 0.559
Plot Reference:
12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Long Plate for Plate # 4

Pl+Pb+Q+F Damage Ratio
33 0.000 Life
MPa 0.042 Stress

Allowable
770.9
MPa

4%

Primary+Secondary+Peak (Inner) Load Case 4
Stress Concentration Factor = 1.000
Strain Concentration Factor = 1.000
Cycles Allowed for this Stress = 1.0000E11
"B31" Fatigue Stress Allowable = 567.5
Markl Fatigue Stress Allowable = 659.5
WRC 474 Mean Cycles to Failure = 61,483,976.
WRC 474 99% Probability Cycles = 14,283,285.
WRC 474 95% Probability Cycles = 19,830,544.
BS5500 Allowed Cycles(Curve F) = 26,126,478.
Membrane-to-Bending Ratio = 0.826
Bending-to-PL+PB+Q Ratio = 0.548
Plot Reference:
12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Circ Plate for Plate # 5

Pl+Pb+Q+F Damage Ratio
108 0.000 Life
MPa 0.205 Stress

Allowable
526.2
MPa

20%

Primary+Secondary+Peak (Outer) Load Case 4
Stress Concentration Factor = 1.000
Strain Concentration Factor = 1.000
Cycles Allowed for this Stress = 1.0145E9
"B31" Fatigue Stress Allowable = 0.0
Markl Fatigue Stress Allowable = 575.0
WRC 474 Mean Cycles to Failure = 3,397,071.
WRC 474 99% Probability Cycles = 789,170.
WRC 474 95% Probability Cycles = 1,095,664.
BS5500 Allowed Cycles(Curve F) = 734,195.
Membrane-to-Bending Ratio = 25.637
Bending-to-PL+PB+Q Ratio = 0.038

Plot Reference:
13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

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Highest Stress Ratios Per Region
FEPipe Version 15.0 Jobname: setup2 $P
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Highest Stress Ratios Per Region $X

Circ Plate for Plate # 1

Pl	SPL	Primary Membrane Load Case 2
40	168	Min Prin. Stress = -49. (59% Neg, 5% NegHi)
MPa	MPa	Plot Reference:
		1) Pl < SPL (SUS,Membrane) Case 2
23%		
Qb	SPS	Primary Bending Load Case 2
99	340	Min Prin. Stress = -49. (59% Neg, 5% NegHi)
MPa	MPa	Plot Reference:
		2) Qb < SPS (SUS,Bending) Case 2
28%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 2
92	340	Min Prin. Stress = -49. (59% Neg, 5% NegHi)
MPa	MPa	Plot Reference:
		3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
27%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
120	340	Min Prin. Stress = -49. (59% Neg, 5% NegHi)
MPa	MPa	Plot Reference:
		4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
35%		
S1+S2+S3	4S	Part 5 (5.3.2) Load Case 2
65	448	Min Prin. Stress = -49. (59% Neg, 5% NegHi)
MPa	MPa	Plot Reference:
		5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
14%		
Pl+Pb+Q	SPS	Primary+Secondary (Inner) Load Case 3
92	340	Min Prin. Stress = -49. (59% Neg, 5% NegHi)
MPa	MPa	Plot Reference:
		6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
27%		
Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 3
120	340	Min Prin. Stress = -49. (59% Neg, 5% NegHi)
MPa	MPa	Plot Reference:
		7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
35%		
Membrane	User	Component Evaluation Load Case 3
40	340	Min Prin. Stress = -49. (59% Neg, 5% NegHi)
MPa	MPa	Plot Reference:
		8) Membrane < User (OPE,Membrane) Case 3
11%		
Bending	User	Component Evaluation Load Case 3
99	340	Min Prin. Stress = -49. (59% Neg, 5% NegHi)
MPa	MPa	Plot Reference:

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                                9) Bending < User (OPE,Bending) Case 3
          28%

  Pl+Pb+Q                SPS     Primary+Secondary (Inner) Load Case 4
       89                340     Min Prin. Stress = -33. (61% Neg, 5% NegHi)
      MPa                MPa     Plot Reference:
                                 10) Pl+Pb+Q < SPS (EXP,Inside) Case 4
          26%

  Pl+Pb+Q                SPS     Primary+Secondary (Outer) Load Case 4
      120                340     Min Prin. Stress = -33. (61% Neg, 5% NegHi)
      MPa                MPa     Plot Reference:
                                 11) Pl+Pb+Q < SPS (EXP,Outside) Case 4
          35%

Pl+Pb+Q+F     Damage Ratio       Primary+Secondary+Peak (Inner) Load Case 4
       89      0.000 Life        Stress Concentration Factor = 1.000
      MPa      0.115 Stress      Strain Concentration Factor = 1.000
                                 Cycles Allowed for this Stress = 1.0000E11
Allowable                        "B31" Fatigue Stress Allowable = 567.5
    771.0                        Markl Fatigue Stress Allowable = 659.5
      MPa                        WRC 474 Mean Cycles to Failure = 5,583,941.
                                 WRC 474 99% Probability Cycles = 1,297,200.
      11%                        WRC 474 95% Probability Cycles = 1,800,999.
                                 BS5500 Allowed Cycles(Curve F) = 1,320,867.
                                 Membrane-to-Bending Ratio = 0.385
                                 Bending-to-PL+PB+Q Ratio = 0.722
                                 Plot Reference:
                                 12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F     Damage Ratio       Primary+Secondary+Peak (Outer) Load Case 4
      120      0.000 Life        Stress Concentration Factor = 1.000
      MPa      0.155 Stress      Strain Concentration Factor = 1.000
                                 Cycles Allowed for this Stress = 1.0000E11
Allowable                        "B31" Fatigue Stress Allowable = 567.5
    771.0                        Markl Fatigue Stress Allowable = 659.5
      MPa                        WRC 474 Mean Cycles to Failure = 1,771,558.
                                 WRC 474 99% Probability Cycles = 411,549.
      15%                        WRC 474 95% Probability Cycles = 571,384.
                                 BS5500 Allowed Cycles(Curve F) = 537,311.
                                 Membrane-to-Bending Ratio = 0.385
                                 Bending-to-PL+PB+Q Ratio = 0.722
                                 Plot Reference:
                                 13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Long Plate for Plate # 1

       Pl                SPL     Primary Membrane Load Case 2
      107                168     Min Prin. Stress = -121. (91% Neg, 29% NegHi)
      MPa                MPa     Plot Reference:
                                 1) Pl < SPL (SUS,Membrane) Case 2
          63%

       Qb                SPS     Primary Bending Load Case 2
      190                340     Min Prin. Stress = -121. (91% Neg, 29% NegHi)
      MPa                MPa     Plot Reference:
                                 2) Qb < SPS (SUS,Bending) Case 2
          55%

  Pl+Pb+Q                SPS     Primary+Secondary (Inner) Load Case 2
      165                340     Min Prin. Stress = -121. (91% Neg, 29% NegHi)
      MPa                MPa     Plot Reference:
                                 3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
          48%

  Pl+Pb+Q                SPS     Primary+Secondary (Outer) Load Case 2
      237                340     Min Prin. Stress = -121. (91% Neg, 29% NegHi)
      MPa                MPa     Plot Reference:
                                 4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
          69%
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S1+S2+S3		4S	Part 5 (5.3.2) Load Case 2
124		448	Min Prin. Stress = -121. (91% Neg, 29% NegHi)
MPa		MPa	Plot Reference:
			5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
	27%		
Pl+Pb+Q		SPS	Primary+Secondary (Inner) Load Case 3
165		340	Min Prin. Stress = -121. (91% Neg, 29% NegHi)
MPa		MPa	Plot Reference:
			6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
	48%		
Pl+Pb+Q		SPS	Primary+Secondary (Outer) Load Case 3
237		340	Min Prin. Stress = -121. (91% Neg, 29% NegHi)
MPa		MPa	Plot Reference:
			7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
	69%		
Membrane		User	Component Evaluation Load Case 3
107		340	Min Prin. Stress = -121. (91% Neg, 29% NegHi)
MPa		MPa	Plot Reference:
			8) Membrane < User (OPE,Membrane) Case 3
	31%		
Bending		User	Component Evaluation Load Case 3
190		340	Min Prin. Stress = -121. (91% Neg, 29% NegHi)
MPa		MPa	Plot Reference:
			9) Bending < User (OPE,Bending) Case 3
	55%		
Pl+Pb+Q		SPS	Primary+Secondary (Inner) Load Case 4
125		340	Min Prin. Stress = -71. (89% Neg, 24% NegHi)
MPa		MPa	Plot Reference:
			10) Pl+Pb+Q < SPS (EXP,Inside) Case 4
	36%		
Pl+Pb+Q		SPS	Primary+Secondary (Outer) Load Case 4
169		340	Min Prin. Stress = -71. (89% Neg, 24% NegHi)
MPa		MPa	Plot Reference:
			11) Pl+Pb+Q < SPS (EXP,Outside) Case 4
	49%		

Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Inner) Load Case 4
125	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.162 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.0000E11
Allowable		"B31" Fatigue Stress Allowable = 567.5
771.0		Markl Fatigue Stress Allowable = 659.5
MPa		WRC 474 Mean Cycles to Failure = 1,988,003.
		WRC 474 99% Probability Cycles = 461,831.
16%		WRC 474 95% Probability Cycles = 641,194.
		BS5500 Allowed Cycles(Curve F) = 474,054.
		Membrane-to-Bending Ratio = 0.303
		Bending-to-PL+PB+Q Ratio = 0.768
		Plot Reference:
		12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4
Pl+Pb+Q+F	Damage Ratio	Primary+Secondary+Peak (Outer) Load Case 4
169	0.000 Life	Stress Concentration Factor = 1.000
MPa	0.220 Stress	Strain Concentration Factor = 1.000
		Cycles Allowed for this Stress = 1.0000E11
Allowable		"B31" Fatigue Stress Allowable = 567.5
771.0		Markl Fatigue Stress Allowable = 659.5
MPa		WRC 474 Mean Cycles to Failure = 607,122.
		WRC 474 99% Probability Cycles = 141,040.
21%		WRC 474 95% Probability Cycles = 195,816.
		BS5500 Allowed Cycles(Curve F) = 190,383.
		Membrane-to-Bending Ratio = 0.303
		Bending-to-PL+PB+Q Ratio = 0.768
		Plot Reference:
		13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

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Circ Plate for Plate # 2

Pl		SPL	Primary Membrane Load Case 2
38		168	Min Prin. Stress = -28. (59% Neg, 4% NegHi)
MPa		MPa	Plot Reference:
			1) Pl < SPL (SUS,Membrane) Case 2
	22%		
Qb		SPS	Primary Bending Load Case 2
87		340	Min Prin. Stress = -28. (59% Neg, 4% NegHi)
MPa		MPa	Plot Reference:
			2) Qb < SPS (SUS,Bending) Case 2
	25%		
Pl+Pb+Q		SPS	Primary+Secondary (Inner) Load Case 2
86		340	Min Prin. Stress = -28. (59% Neg, 4% NegHi)
MPa		MPa	Plot Reference:
			3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
	25%		
Pl+Pb+Q		SPS	Primary+Secondary (Outer) Load Case 2
102		340	Min Prin. Stress = -28. (59% Neg, 4% NegHi)
MPa		MPa	Plot Reference:
			4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
	30%		
S1+S2+S3		4S	Part 5 (5.3.2) Load Case 2
63		448	Min Prin. Stress = -28. (59% Neg, 4% NegHi)
MPa		MPa	Plot Reference:
			5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
	14%		
Pl+Pb+Q		SPS	Primary+Secondary (Inner) Load Case 3
86		340	Min Prin. Stress = -28. (59% Neg, 4% NegHi)
MPa		MPa	Plot Reference:
			6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
	25%		
Pl+Pb+Q		SPS	Primary+Secondary (Outer) Load Case 3
102		340	Min Prin. Stress = -28. (59% Neg, 4% NegHi)
MPa		MPa	Plot Reference:
			7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
	30%		
Membrane		User	Component Evaluation Load Case 3
38		340	Min Prin. Stress = -28. (59% Neg, 4% NegHi)
MPa		MPa	Plot Reference:
			8) Membrane < User (OPE,Membrane) Case 3
	11%		
Bending		User	Component Evaluation Load Case 3
87		340	Min Prin. Stress = -28. (59% Neg, 4% NegHi)
MPa		MPa	Plot Reference:
			9) Bending < User (OPE,Bending) Case 3
	25%		
Pl+Pb+Q		SPS	Primary+Secondary (Inner) Load Case 4
84		340	Min Prin. Stress = -31. (57% Neg, 4% NegHi)
MPa		MPa	Plot Reference:
			10) Pl+Pb+Q < SPS (EXP,Inside) Case 4
	24%		
Pl+Pb+Q		SPS	Primary+Secondary (Outer) Load Case 4
79		340	Min Prin. Stress = -31. (57% Neg, 4% NegHi)
MPa		MPa	Plot Reference:
			11) Pl+Pb+Q < SPS (EXP,Outside) Case 4
	23%		
Pl+Pb+Q+F	Damage Ratio		Primary+Secondary+Peak (Inner) Load Case 4
84	0.000 Life		Stress Concentration Factor = 1.000
MPa	0.109 Stress		Strain Concentration Factor = 1.000

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                                Cycles Allowed for this Stress = 1.0000E11
Allowable                       "B31" Fatigue Stress Allowable = 567.5
    770.9                       Markl Fatigue Stress Allowable = 659.5
      MPa                       WRC 474 Mean Cycles to Failure = 4,542,684.
                                WRC 474 99% Probability Cycles = 1,055,307.
      10%                       WRC 474 95% Probability Cycles = 1,465,161.
                                BS5500 Allowed Cycles(Curve F) = 1,316,472.
                                Membrane-to-Bending Ratio = 0.150
                                Bending-to-PL+PB+Q Ratio = 0.869
                                Plot Reference:
                                12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio       Primary+Secondary+Peak (Outer) Load Case 4
       79     0.000 Life        Stress Concentration Factor = 1.000
      MPa     0.102 Stress      Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 1.0000E11
Allowable                       "B31" Fatigue Stress Allowable = 567.5
    770.9                       Markl Fatigue Stress Allowable = 659.5
      MPa                       WRC 474 Mean Cycles to Failure = 5,778,046.
                                WRC 474 99% Probability Cycles = 1,342,292.
      10%                       WRC 474 95% Probability Cycles = 1,863,604.
                                BS5500 Allowed Cycles(Curve F) = 1,577,694.
                                Membrane-to-Bending Ratio = 0.108
                                Bending-to-PL+PB+Q Ratio = 0.903
                                Plot Reference:
                                13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Circ Plate for Plate # 3

       Pl           SPL      Primary Membrane Load Case 2
      143           168      Min Prin. Stress = -192. (77% Neg, 47% NegHi)
      MPa           MPa      Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
             84%

       Qb           SPS      Primary Bending Load Case 2
      184           340      Min Prin. Stress = -192. (77% Neg, 47% NegHi)
      MPa           MPa      Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
             54%

  Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 2
      271           340      Min Prin. Stress = -192. (77% Neg, 47% NegHi)
      MPa           MPa      Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             79%

  Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 2
      159           340      Min Prin. Stress = -192. (77% Neg, 47% NegHi)
      MPa           MPa      Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             46%

 S1+S2+S3            4S      Part 5 (5.3.2) Load Case 2
      148           448      Min Prin. Stress = -192. (77% Neg, 47% NegHi)
      MPa           MPa      Plot Reference:
                             5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
             33%

  Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 3
      271           340      Min Prin. Stress = -192. (77% Neg, 47% NegHi)
      MPa           MPa      Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
             79%

  Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 3
      159           340      Min Prin. Stress = -192. (77% Neg, 47% NegHi)
      MPa           MPa      Plot Reference:
                             7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
             46%
```

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Membrane          User      Component Evaluation Load Case 3
     143           340      Min Prin. Stress = -192. (77% Neg, 47% NegHi)
     MPa           MPa      Plot Reference:
                            8) Membrane < User (OPE,Membrane) Case 3
          41%

 Bending          User      Component Evaluation Load Case 3
     184           340      Min Prin. Stress = -192. (77% Neg, 47% NegHi)
     MPa           MPa      Plot Reference:
                            9) Bending < User (OPE,Bending) Case 3
          54%

 Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 4
     153           340      Min Prin. Stress = -119. (99% Neg, 68% NegHi)
     MPa           MPa      Plot Reference:
                            10) Pl+Pb+Q < SPS (EXP,Inside) Case 4
          44%

 Pl+Pb+Q           SPS      Primary+Secondary (Outer) Load Case 4
     103           340      Min Prin. Stress = -119. (99% Neg, 68% NegHi)
     MPa           MPa      Plot Reference:
                            11) Pl+Pb+Q < SPS (EXP,Outside) Case 4
          30%

Pl+Pb+Q+F   Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
     153     0.000 Life     Stress Concentration Factor = 1.000
     MPa     0.198 Stress   Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 567.5
   770.9                    Markl Fatigue Stress Allowable = 659.5
     MPa                    WRC 474 Mean Cycles to Failure = 1,478,924.
                            WRC 474 99% Probability Cycles = 343,567.
     19%                    WRC 474 95% Probability Cycles = 477,000.
                            BS5500 Allowed Cycles(Curve F) = 258,260.
                            Membrane-to-Bending Ratio = 0.914
                            Bending-to-PL+PB+Q Ratio = 0.523
                            Plot Reference:
                            12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F   Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
     103     0.000 Life     Stress Concentration Factor = 1.000
     MPa     0.134 Stress   Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 1.0000E11
Allowable                   "B31" Fatigue Stress Allowable = 567.5
   770.9                    Markl Fatigue Stress Allowable = 659.5
     MPa                    WRC 474 Mean Cycles to Failure = 4,763,216.
                            WRC 474 99% Probability Cycles = 1,106,538.
     13%                    WRC 474 95% Probability Cycles = 1,536,289.
                            BS5500 Allowed Cycles(Curve F) = 837,188.
                            Membrane-to-Bending Ratio = 13.210
                            Bending-to-PL+PB+Q Ratio = 0.070
                            Plot Reference:
                            13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Circ Plate for Plate # 4

      Pl            SPL     Primary Membrane Load Case 2
     121           168      Min Prin. Stress = -175. (68% Neg, 22% NegHi)
     MPa           MPa      Plot Reference:
                            1) Pl < SPL (SUS,Membrane) Case 2
          72%

      Qb            SPS     Primary Bending Load Case 2
     128           340      Min Prin. Stress = -175. (68% Neg, 22% NegHi)
     MPa           MPa      Plot Reference:
                            2) Qb < SPS (SUS,Bending) Case 2
          37%

 Pl+Pb+Q           SPS      Primary+Secondary (Inner) Load Case 2
     210           340      Min Prin. Stress = -175. (68% Neg, 22% NegHi)
     MPa           MPa      Plot Reference:
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                                3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
          61%

  Pl+Pb+Q              SPS      Primary+Secondary (Outer) Load Case 2
      149              340      Min Prin. Stress = -175. (68% Neg, 22% NegHi)
      MPa              MPa      Plot Reference:
                                4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
          43%

 S1+S2+S3               4S      Part 5 (5.3.2) Load Case 2
      151              448      Min Prin. Stress = -175. (68% Neg, 22% NegHi)
      MPa              MPa      Plot Reference:
                                5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
          33%

  Pl+Pb+Q              SPS      Primary+Secondary (Inner) Load Case 3
      210              340      Min Prin. Stress = -175. (68% Neg, 22% NegHi)
      MPa              MPa      Plot Reference:
                                6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
          61%

  Pl+Pb+Q              SPS      Primary+Secondary (Outer) Load Case 3
      149              340      Min Prin. Stress = -175. (68% Neg, 22% NegHi)
      MPa              MPa      Plot Reference:
                                7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
          43%

 Membrane             User      Component Evaluation Load Case 3
      121              340      Min Prin. Stress = -175. (68% Neg, 22% NegHi)
      MPa              MPa      Plot Reference:
                                8) Membrane < User (OPE,Membrane) Case 3
          35%

  Bending              User      Component Evaluation Load Case 3
      128              340      Min Prin. Stress = -175. (68% Neg, 22% NegHi)
      MPa              MPa      Plot Reference:
                                9) Bending < User (OPE,Bending) Case 3
          37%

  Pl+Pb+Q              SPS      Primary+Secondary (Inner) Load Case 4
      108              340      Min Prin. Stress = -73. (78% Neg, 22% NegHi)
      MPa              MPa      Plot Reference:
                                10) Pl+Pb+Q < SPS (EXP,Inside) Case 4
          31%

  Pl+Pb+Q              SPS      Primary+Secondary (Outer) Load Case 4
      106              340      Min Prin. Stress = -73. (78% Neg, 22% NegHi)
      MPa              MPa      Plot Reference:
                                11) Pl+Pb+Q < SPS (EXP,Outside) Case 4
          31%

Pl+Pb+Q+F    Damage Ratio      Primary+Secondary+Peak (Inner) Load Case 4
      108     0.000 Life       Stress Concentration Factor = 1.000
      MPa     0.140 Stress     Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1.0000E11
Allowable                      "B31" Fatigue Stress Allowable = 567.5
    770.9                      Markl Fatigue Stress Allowable = 659.5
      MPa                      WRC 474 Mean Cycles to Failure = 4,459,746.
                               WRC 474 99% Probability Cycles = 1,036,040.
      13%                      WRC 474 95% Probability Cycles = 1,438,410.
                               BS5500 Allowed Cycles(Curve F) = 735,938.
                               Membrane-to-Bending Ratio = 0.790
                               Bending-to-PL+PB+Q Ratio = 0.559
                               Plot Reference:
                               12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio      Primary+Secondary+Peak (Outer) Load Case 4
      106     0.000 Life       Stress Concentration Factor = 1.000
      MPa     0.138 Stress     Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1.0000E11
Allowable                      "B31" Fatigue Stress Allowable = 567.5
    770.9                      Markl Fatigue Stress Allowable = 659.5
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MPa
13%

WRC 474 Mean Cycles to Failure = 4,608,486.
WRC 474 99% Probability Cycles = 1,070,593.
WRC 474 95% Probability Cycles = 1,486,384.
BS5500 Allowed Cycles(Curve F) = 770,017.
Membrane-to-Bending Ratio = 1.090
Bending-to-PL+PB+Q Ratio = 0.478
Plot Reference:
13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4

Long Plate for Plate # 4

Pl	SPL		Primary Membrane Load Case 2
27	168		Min Prin. Stress = -17. (75% Neg, 4% NegHi)
MPa	MPa		Plot Reference:
		15%	1) Pl < SPL (SUS,Membrane) Case 2
Qb	SPS		Primary Bending Load Case 2
37	340		Min Prin. Stress = -17. (75% Neg, 4% NegHi)
MPa	MPa		Plot Reference:
		10%	2) Qb < SPS (SUS,Bending) Case 2
Pl+Pb+Q	SPS		Primary+Secondary (Inner) Load Case 2
38	340		Min Prin. Stress = -17. (75% Neg, 4% NegHi)
MPa	MPa		Plot Reference:
		11%	3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
Pl+Pb+Q	SPS		Primary+Secondary (Outer) Load Case 2
47	340		Min Prin. Stress = -17. (75% Neg, 4% NegHi)
MPa	MPa		Plot Reference:
		13%	4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
S1+S2+S3	4S		Part 5 (5.3.2) Load Case 2
21	448		Min Prin. Stress = -17. (75% Neg, 4% NegHi)
MPa	MPa		Plot Reference:
		4%	5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2
Pl+Pb+Q	SPS		Primary+Secondary (Inner) Load Case 3
38	340		Min Prin. Stress = -17. (75% Neg, 4% NegHi)
MPa	MPa		Plot Reference:
		11%	6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
Pl+Pb+Q	SPS		Primary+Secondary (Outer) Load Case 3
47	340		Min Prin. Stress = -17. (75% Neg, 4% NegHi)
MPa	MPa		Plot Reference:
		13%	7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
Membrane	User		Component Evaluation Load Case 3
27	340		Min Prin. Stress = -17. (75% Neg, 4% NegHi)
MPa	MPa		Plot Reference:
		7%	8) Membrane < User (OPE,Membrane) Case 3
Bending	User		Component Evaluation Load Case 3
37	340		Min Prin. Stress = -17. (75% Neg, 4% NegHi)
MPa	MPa		Plot Reference:
		10%	9) Bending < User (OPE,Bending) Case 3
Pl+Pb+Q	SPS		Primary+Secondary (Inner) Load Case 4
33	340		Min Prin. Stress = -14. (88% Neg, 5% NegHi)
MPa	MPa		Plot Reference:
		9%	10) Pl+Pb+Q < SPS (EXP,Inside) Case 4

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  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
       20            340     Min Prin. Stress = -14. (88% Neg, 5% NegHi)
      MPa            MPa     Plot Reference:
                             11) Pl+Pb+Q < SPS (EXP,Outside) Case 4
              5%

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
       33     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.042 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 567.5
    770.9                    Markl Fatigue Stress Allowable = 659.5
      MPa                    WRC 474 Mean Cycles to Failure = 61,483,976.
                             WRC 474 99% Probability Cycles = 14,283,285.
       4%                    WRC 474 95% Probability Cycles = 19,830,544.
                             BS5500 Allowed Cycles(Curve F) = 26,126,478.
                             Membrane-to-Bending Ratio = 0.826
                             Bending-to-PL+PB+Q Ratio = 0.548
                             Plot Reference:
                             12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
       20     0.000 Life     Stress Concentration Factor = 1.000
      MPa     0.026 Stress   Strain Concentration Factor = 1.000
                             Cycles Allowed for this Stress = 1.0000E11
Allowable                    "B31" Fatigue Stress Allowable = 567.5
    770.9                    Markl Fatigue Stress Allowable = 659.5
      MPa                    WRC 474 Mean Cycles to Failure = 3.3834E8
                             WRC 474 99% Probability Cycles = 78,598,464.
       2%                    WRC 474 95% Probability Cycles = 1.0912E8
                             BS5500 Allowed Cycles(Curve F) = 2.9743E8
                             Membrane-to-Bending Ratio = 0.854
                             Bending-to-PL+PB+Q Ratio = 0.539
                             Plot Reference:
                             13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4


Circ Plate for Plate # 5

       Pl            SPL     Primary Membrane Load Case 2
      104            126     Min Prin. Stress = -7. (10% Neg, 3% NegHi)
      MPa            MPa     Plot Reference:
                             1) Pl < SPL (SUS,Membrane) Case 2
             82%

       Qb            SPS     Primary Bending Load Case 2
       37            298     Min Prin. Stress = -7. (10% Neg, 3% NegHi)
      MPa            MPa     Plot Reference:
                             2) Qb < SPS (SUS,Bending) Case 2
             12%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
      107            298     Min Prin. Stress = -7. (10% Neg, 3% NegHi)
      MPa            MPa     Plot Reference:
                             3) Pl+Pb+Q < SPS (SUS,Inside) Case 2
             35%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
      115            298     Min Prin. Stress = -7. (10% Neg, 3% NegHi)
      MPa            MPa     Plot Reference:
                             4) Pl+Pb+Q < SPS (SUS,Outside) Case 2
             38%

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 3
      107            298     Min Prin. Stress = -7. (10% Neg, 3% NegHi)
      MPa            MPa     Plot Reference:
                             6) Pl+Pb+Q < SPS (OPE,Inside) Case 3
             35%

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 3
      115            298     Min Prin. Stress = -7. (10% Neg, 3% NegHi)
      MPa            MPa     Plot Reference:
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                                7) Pl+Pb+Q < SPS (OPE,Outside) Case 3
          38%

 Membrane            User       Component Evaluation Load Case 3
      104             298       Min Prin. Stress = -7. (10% Neg, 3% NegHi)
      MPa             MPa       Plot Reference:
                                8) Membrane < User (OPE,Membrane) Case 3
          34%

  Bending            User       Component Evaluation Load Case 3
       37             298       Min Prin. Stress = -7. (10% Neg, 3% NegHi)
      MPa             MPa       Plot Reference:
                                9) Bending < User (OPE,Bending) Case 3
          12%

  Pl+Pb+Q             SPS       Primary+Secondary (Inner) Load Case 4
      100             298       Min Prin. Stress = -5. ( 8% Neg, 1% NegHi)
      MPa             MPa       Plot Reference:
                                10) Pl+Pb+Q < SPS (EXP,Inside) Case 4
          33%

  Pl+Pb+Q             SPS       Primary+Secondary (Outer) Load Case 4
      108             298       Min Prin. Stress = -5. ( 8% Neg, 1% NegHi)
      MPa             MPa       Plot Reference:
                                11) Pl+Pb+Q < SPS (EXP,Outside) Case 4
          36%

Pl+Pb+Q+F    Damage Ratio       Primary+Secondary+Peak (Inner) Load Case 4
      100     0.000 Life        Stress Concentration Factor = 1.000
      MPa     0.191 Stress      Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 4.8949E9
Allowable                       "B31" Fatigue Stress Allowable = 0.0
    526.2                       Markl Fatigue Stress Allowable = 575.0
      MPa                       WRC 474 Mean Cycles to Failure = 4,277,923.
                                WRC 474 99% Probability Cycles = 993,800.
      19%                       WRC 474 95% Probability Cycles = 1,379,767.
                                BS5500 Allowed Cycles(Curve F) = 915,978.
                                Membrane-to-Bending Ratio = 25.639
                                Bending-to-PL+PB+Q Ratio = 0.038
                                Plot Reference:
                                12) Pl+Pb+Q+F < 2Sa (EXP,Inside) Case 4

Pl+Pb+Q+F    Damage Ratio       Primary+Secondary+Peak (Outer) Load Case 4
      108     0.000 Life        Stress Concentration Factor = 1.000
      MPa     0.205 Stress      Strain Concentration Factor = 1.000
                                Cycles Allowed for this Stress = 1.0145E9
Allowable                       "B31" Fatigue Stress Allowable = 0.0
    526.2                       Markl Fatigue Stress Allowable = 575.0
      MPa                       WRC 474 Mean Cycles to Failure = 3,397,071.
                                WRC 474 99% Probability Cycles = 789,170.
      20%                       WRC 474 95% Probability Cycles = 1,095,664.
                                BS5500 Allowed Cycles(Curve F) = 734,195.
                                Membrane-to-Bending Ratio = 25.637
                                Bending-to-PL+PB+Q Ratio = 0.038
                                Plot Reference:
                                13) Pl+Pb+Q+F < 2Sa (EXP,Outside) Case 4
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Compressive Stress Summary
FEPipe Version 15.0          Jobname: setup2                $P
Released Jan. 2021            11:48am  OCT  2,2024



Compressive Stress Summary (MPa)                    $X
```

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Nomenclature:

Min Stress - Compressive Membrane and Bending Stress
Pts in Region - No. of nodes in the model region
>5% Compression - 5% or more of Compressive Stress Limit
>50% Compression - 50% or more of Compressive Stress Limit

Compressive Stress Limit = -0.55 Min(Sy, kEt/R), Section slenderness ratio (elastic buckling) not considered.

#	Load Type	Case	Min Stress	Pts in Region	>5% Compression and Bending	>50% Bending	Region
1	SUSTAINED	2	-49.	3024	59%	5%	Circ Plate for Plate # 1
2	OPERATING	3	-49.	3024	59%	5%	Circ Plate for Plate # 1
3	EXPANSION	4	-33.	3024	61%	5%	Circ Plate for Plate # 1
4	SUSTAINED	2	-121.	13176	91%	29%	Long Plate for Plate # 1
5	OPERATING	3	-121.	13176	91%	29%	Long Plate for Plate # 1
6	EXPANSION	4	-71.	13176	89%	24%	Long Plate for Plate # 1
7	SUSTAINED	2	-28.	2112	59%	4%	Circ Plate for Plate # 2
8	OPERATING	3	-28.	2112	59%	4%	Circ Plate for Plate # 2
9	EXPANSION	4	-31.	2112	57%	4%	Circ Plate for Plate # 2
10	SUSTAINED	2	-192.	1600	77%	47%	Circ Plate for Plate # 3
11	OPERATING	3	-192.	1600	77%	47%	Circ Plate for Plate # 3
12	EXPANSION	4	-119.	1600	99%	68%	Circ Plate for Plate # 3
13	SUSTAINED	2	-175.	1440	68%	22%	Circ Plate for Plate # 4
14	OPERATING	3	-175.	1440	68%	22%	Circ Plate for Plate # 4
15	EXPANSION	4	-73.	1440	78%	22%	Circ Plate for Plate # 4
16	SUSTAINED	2	-17.	640	75%	4%	Long Plate for Plate # 4
17	OPERATING	3	-17.	640	75%	4%	Long Plate for Plate # 4
18	EXPANSION	4	-14.	640	88%	5%	Long Plate for Plate # 4
19	SUSTAINED	2	-7.	13376	10%	3%	Circ Plate for Plate # 5
20	OPERATING	3	-7.	13376	10%	3%	Circ Plate for Plate # 5
21	EXPANSION	4	-5.	13376	8%	1%	Circ Plate for Plate # 5

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Finite Element Model

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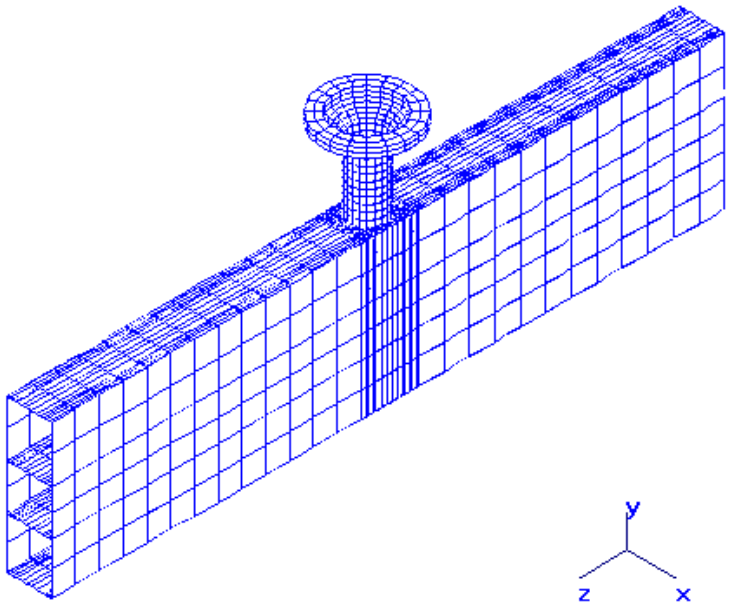

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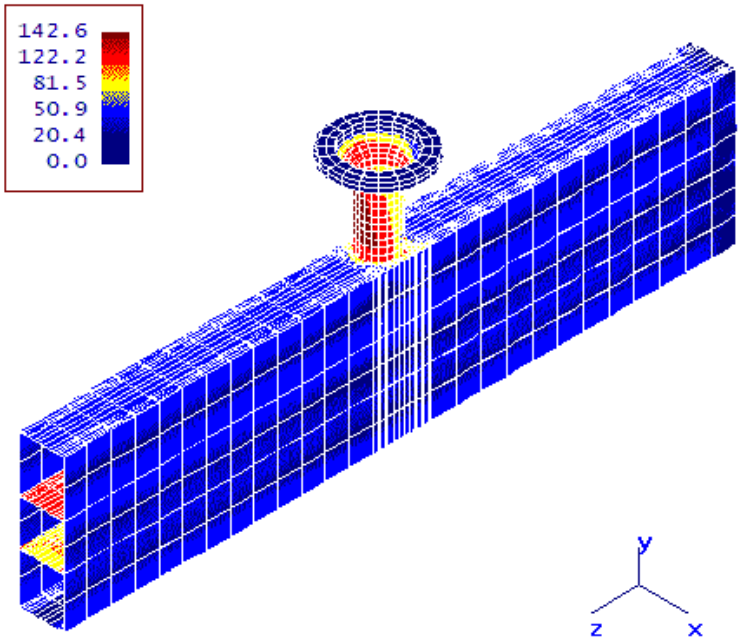
1) P1 < SPL (SUS Membrane) Case 2



3d(Deformed) 3d

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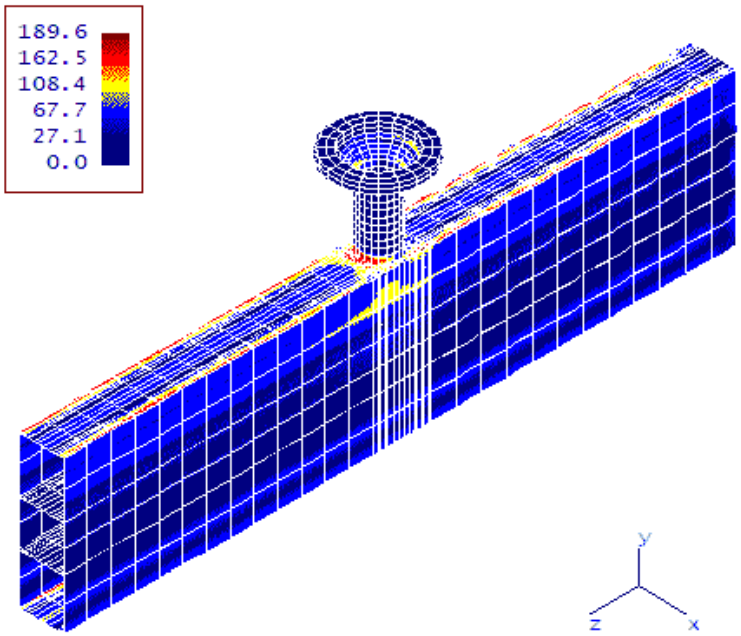
2) Qb < SPS (SUS Bending) Case 2



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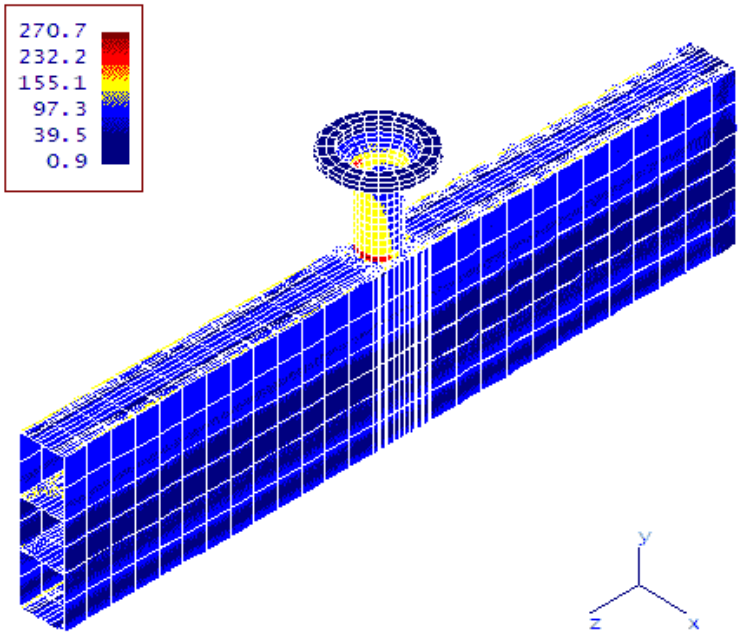
3) Pl+Pb+Q < SPS (SUS Inside) Case 2



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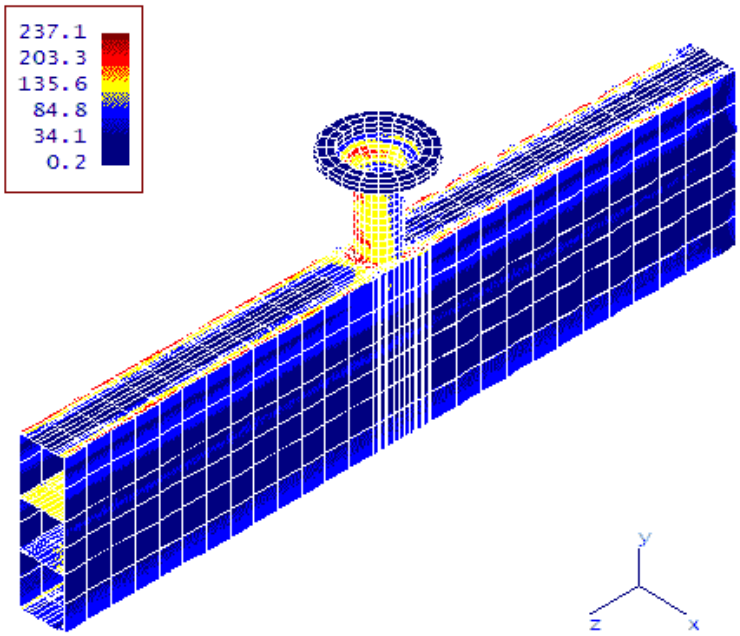
4) Pl+Pb+Q < SPS (SUS Outside) Case 2



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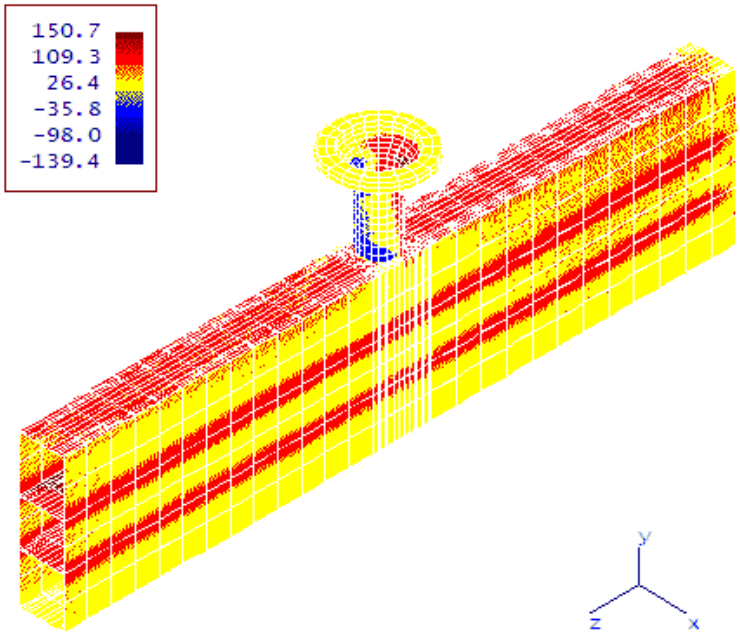
5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 2



3d(Deformed) 3d

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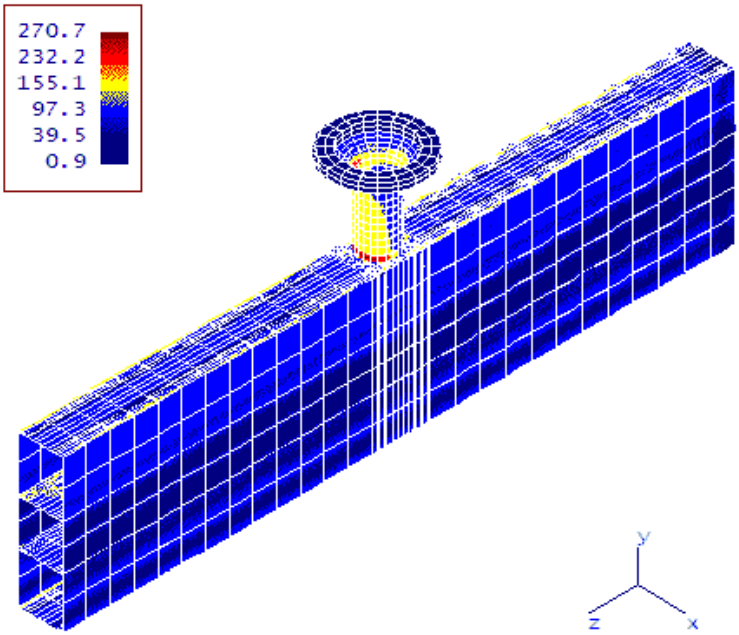
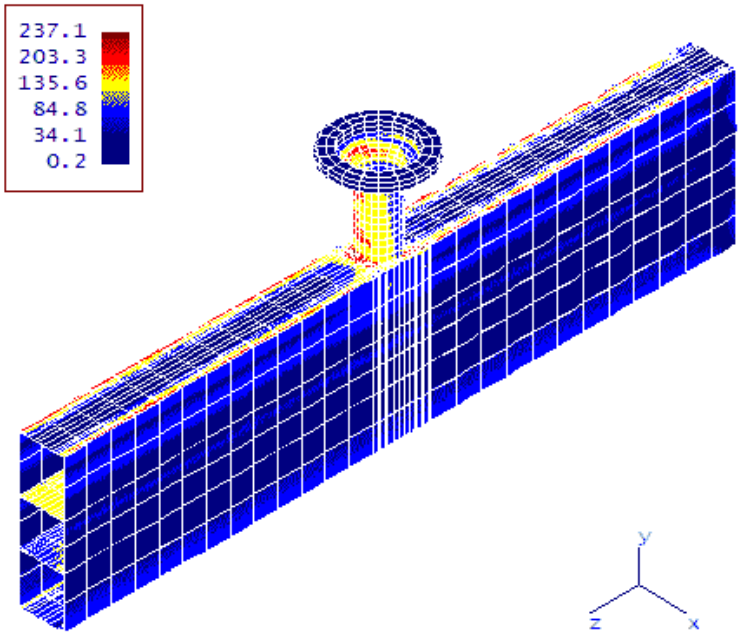
6) Pl+Pb+Q < SPS (OPE Inside) Case 3



3d(Deformed) 3d

7) Pl+Pb+Q < SPS (OPE Outside) Case 3



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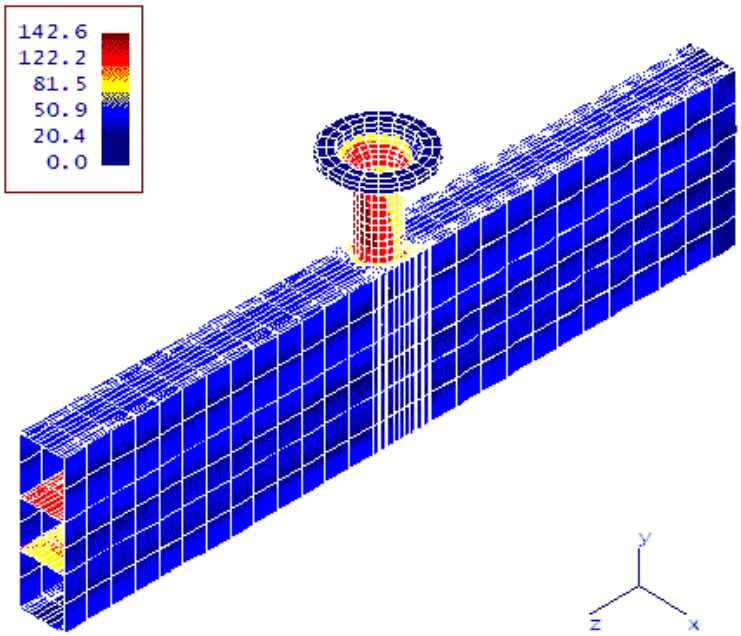
8) Membrane < User (OPE Membrane) Case 3



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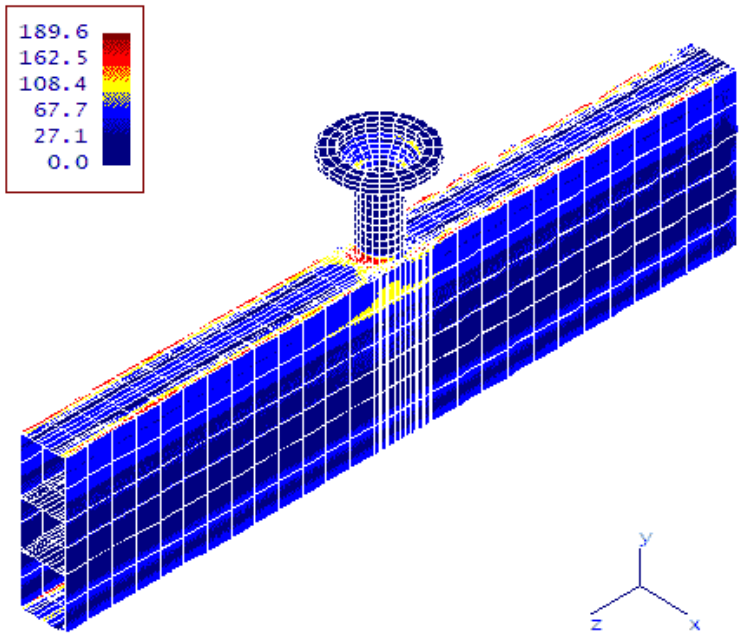
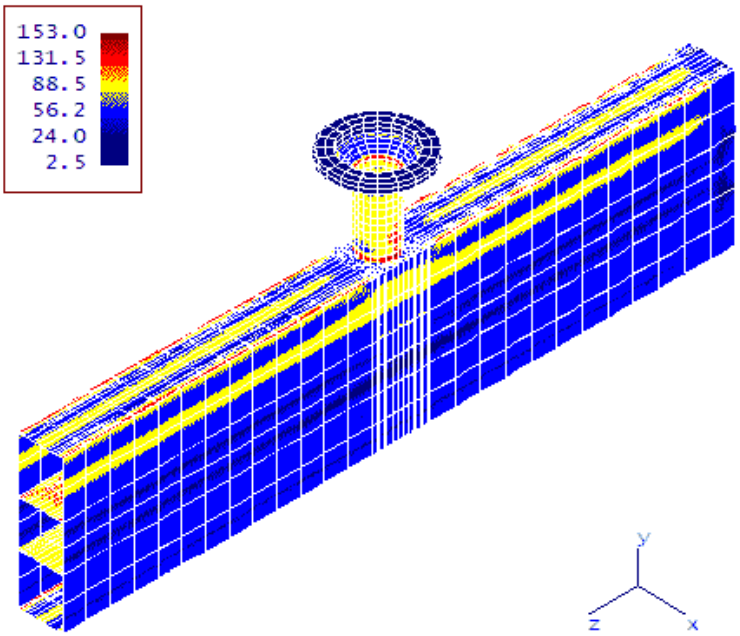
9) Bending < User (OPE Bending) Case 3



3d(Deformed) 3d

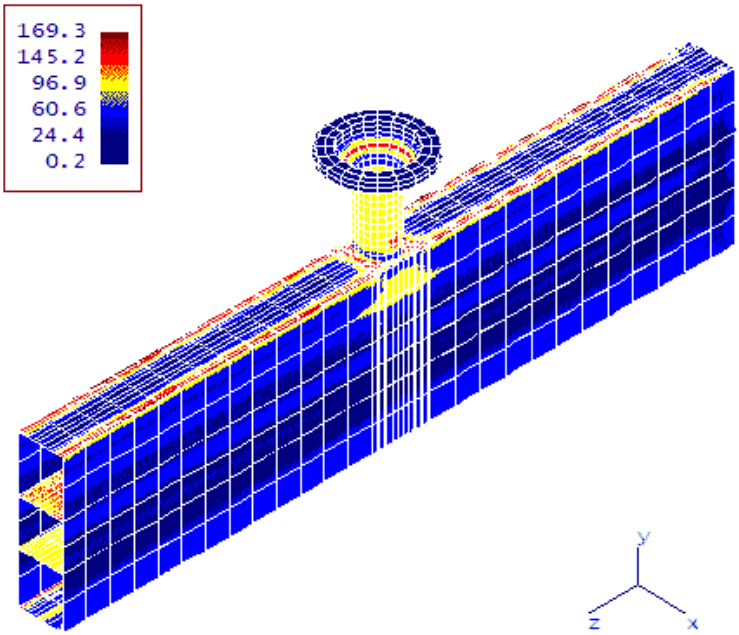
03

10) Pl+Pb+Q < SPS (EXP Inside) Case 4



3d

11) Pl+Pb+Q < SPS (EXP Outside) Case 4



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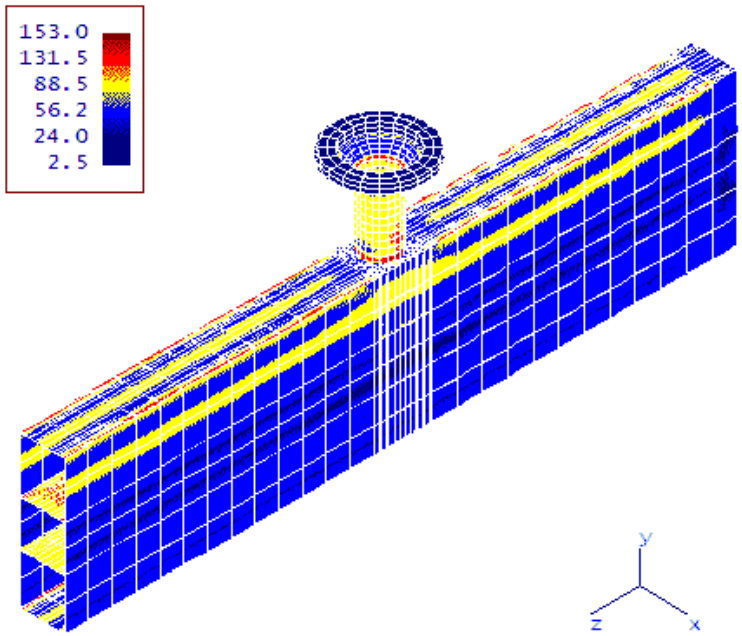
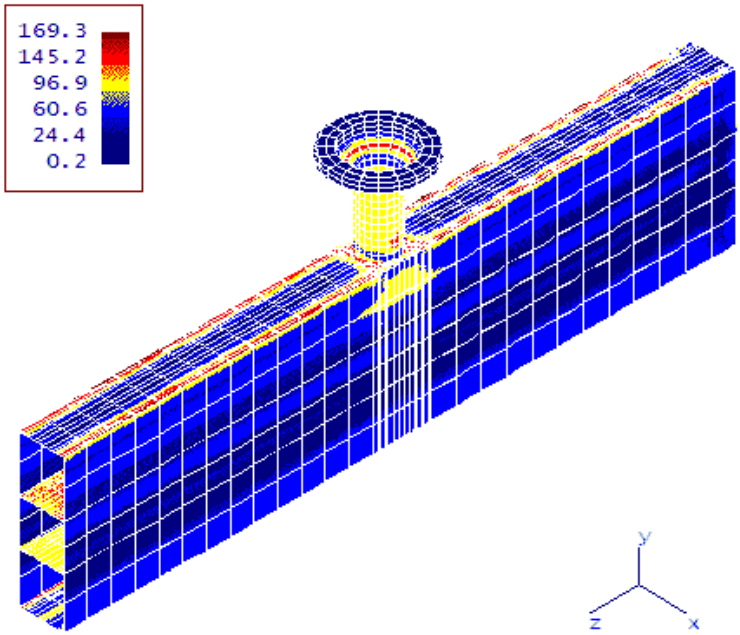
12) Pl+Pb+Q+F < 2Sa (EXP Inside) Case 4



03

3d

13) Pl+Pb+Q+F < 2Sa (EXP Outside) Case 4



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