AFTER COOLER MECHANICAL STRENGHT CALCULATION FOR NITROGEN GAS BOOSTER

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Design Data & Process Information

Description	Units	Design Data	Design Data
Process Card		Shell Side	Tube Side
Design Code & Specifications		ASME VIII Div.1 2019	ASME VIII Div.1 2019
Internal Design Pressure (MPa)	MPa	2.5	1
External Design Pressure (MPa)	MPa	0.1	0.1
Hydrotest Pressure (MPa)	MPa	3.75	1.5
Maximum Design Temperature ('C)	'C	210	95
Minimum Design Temperature ('C)	'C	-10	-10
Operating Temperature ('C)	'C		
Corrosion Allowance (mm)	mm	1	1
Content of Vessel			
Specific Density of Oper.Liq		1	1
Normal Liquid Level NLL (mm)	mm	200	200

Weight & Volume of Vessel

PROCESS CARD NO.: 1 SHELL SIDE

ID	No.	Wt-UnFinish.	Wt-Finished	Tot.Volume	Test.Liq.Wt	Oper.Liq.Wt
S1.1	1	13.0 kg	12.8 kg	0.016 m3	16.0 kg	14.9 kg
TB.1	1	0.0 kg	0.0 kg	-0.001 m3	-1.3 kg	-1.9 kg
Total	**2**	**13.0 kg**	**12.8 kg**	**0.015 m3**	**14.7 kg**	**13.1 kg**

PROCESS CARD NO.: 2 TUBE SIDE

ID	No.	Wt-UnFinish.	Wt-Finished	Tot.Volume	Test.Liq.Wt	Oper.Liq.Wt
E4.1	1	7.0 kg	6.5 kg	0.000 m3	0.0 kg	0.0 kg
E4.2*	1	7.0 kg	7.0 kg	0.000 m3	0.0 kg	0.0 kg
F.1	1	6.0 kg	6.0 kg	0.001 m3	1.0 kg	0.5 kg
F.2*	1	6.0 kg	6.0 kg	0.001 m3	1.0 kg	0.8 kg
F.3	1	6.0 kg	6.0 kg	0.001 m3	1.0 kg	0.8 kg
F.4*	1	6.0 kg	6.0 kg	0.001 m3	1.0 kg	0.8 kg
N.1	1	4.0 kg	4.0 kg	0.000 m3	0.0 kg	0.2 kg
N.2*	1	4.0 kg	4.0 kg	0.000 m3	0.0 kg	0.2 kg
N.3	1	0.0 kg	0.0 kg	0.000 m3	0.0 kg	0.0 kg
N.4*	1	0.0 kg	0.0 kg	0.000 m3	0.0 kg	0.0 kg
S1.2	1	2.0 kg	2.0 kg	0.001 m3	1.0 kg	0.8 kg
S1.3*	1	2.0 kg	2.0 kg	0.001 m3	1.0 kg	0.8 kg
T.1	1	3.0 kg	3.0 kg	0.000 m3	0.0 kg	0.0 kg
T.2	1	3.0 kg	3.0 kg	0.000 m3	0.0 kg	0.0 kg
TB.1	1	4.0 kg	4.0 kg	0.001 m3	1.0 kg	1.4 kg
Total	**15**	**60.0 kg**	**59.5 kg**	**0.007 m3**	**7.0 kg**	**6.4 kg**

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SUMMATION OF DATA FOR ALL COMPONENTS :
Total : 17         73 kg        72 kg     0.022 m3        22 kg        19 kg
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Weight Summary/Condition	Shell Side	Tube Side	Total
Empty Weight of Vessel incl. 5% Contingency	13 kg / 0.0 Tons	62 kg / 0.1 Tons	75 kg
Total Test Weight of Vessel (Testing with Water)	28 kg / 0.0 Tons	69 kg / 0.1 Tons	97 kg
Total Operating Weight of Vessel	27 kg / 0.0 Tons	69 kg / 0.1 Tons	96 kg

Center of Gravity

PROCESS CARD NO.: 1 SHELL SIDE

ID	X-Empty	Y-Empty	Z-Empty	X-Test	Y-Test	Z-Test	X-Oper	Y-Oper	Z-Oper
S1.1	0	0	490	0	0	525	0	0	525

SHELL SIDE CENTER OF GRAVITY AT CONDITIONS BELOW	X	Y	Z
Empty Vessel	0	0	490
Test Condition of Vessel (Testing with Water)	0	0	509
Operating Condition of Vessel	0	0	509

PROCESS CARD NO.: 2 TUBE SIDE

ID	X-Empty	Y-Empty	Z-Empty	X-Test	Y-Test	Z-Test	X-Oper	Y-Oper	Z-Oper
E4.1	0	0	-138	0	0	-134	0	0	-134
E4.2*	0	0	1184	0	0	1184	0	0	1184
F.1	0	0	-72	0	0	-72	0	0	-72
F.2*	0	0	1113	0	0	1113	0	0	1113
F.3	0	0	-27	0	0	-27	0	0	-27
F.4*	0	0	1077	0	0	1077	0	0	1077
N.1	151	0	80	115	0	80	115	0	80
N.2*	-151	0	980	-115	0	980	-115	0	980
N.3	41	0	-153	41	0	-160	41	0	-160
N.4*	-40	0	-152	-40	0	-159	-40	0	-159
S1.2	0	0	-105	0	0	-105	0	0	-105
S1.3*	0	0	1155	0	0	1155	0	0	1155
T.1	0	0	-68	0	0	-68	0	0	-68
T.2	0	0	510	0	0	510	0	0	510
TB.1	0	0	221	0	0	221	0	0	221

TUBE SIDE CENTER OF GRAVITY AT CONDITIONS BELOW	X	Y	Z
Empty Vessel	0	0	479
Test Condition of Vessel (Testing with Water)	0	0	479
Operating Condition of Vessel	0	0	479

CENTER OF GRAVITY AT CONDITIONS BELOW	X	Y	Z
Empty Vessel	0	0	481
Test Condition of Vessel (Testing with Water)	0	0	488
Operating Condition of Vessel	0	0	488

Max. Allowable Pressure MAWP

PROCESS CARD NO.: 1 SHELL SIDE

ID	Comp. Type	Description	Liq.Head	MAWP New & Cold	MAWP Hot & Corr.
S1.1	Cylindrical Shell	Main Shell	0.003 MPa	5.021 MPa	3.314 MPa
T.1	Tubesheet	Tubesheet	0.000 MPa	12.115 MPa	10.684 MPa
T.2	Tubesheet	Tubesheet floating	0.000 MPa	17.231 MPa	15.183 MPa
TB.1	Tube Bundle	Tube bundle	0.000 MPa	2.764 MPa	2.709 MPa
	MAWP			**2.764 MPa**	**2.709 MPa**

Note : Other components may limit the MAWP than the ones checked above.
Note : The value for MAWP is at top of vessel, with static liquid head subtracted.

PROCESS CARD NO.: 2 TUBE SIDE

ID	Comp. Type	Description	Liq.Head	MAWP New & Cold	MAWP Hot & Corr.
E4.1	Welded Flat End	Head left	0.003 MPa	9.836 MPa	9.120 MPa
E4.2*	Welded Flat End	Head right	0.003 MPa	9.836 MPa	9.120 MPa
F.1	RT - Flange	Flangering Head left	0.003 MPa	3.310 MPa	3.310 MPa
F.2*	RT - Flange	Flangering Head right	0.003 MPa	3.310 MPa	3.310 MPa
F.3	RT - Flange	Flangering Shell left	0.003 MPa	3.310 MPa	3.310 MPa
F.4*	RT - Flange	Flangering Shell right	0.003 MPa	3.310 MPa	3.310 MPa
N.3	Open.Without Nozzle	N4	0.002 MPa	5.244 MPa	4.756 MPa
N.4*	Open.Without Nozzle	N3	0.002 MPa	5.244 MPa	4.756 MPa
S1.2	Cylindrical Shell	Channel Head left	0.003 MPa	11.102 MPa	10.112 MPa
S1.3*	Cylindrical Shell	Channel Head right	0.003 MPa	11.102 MPa	10.112 MPa
T.1	Tubesheet	Tubesheet	0.000 MPa	12.104 MPa	10.680 MPa
T.2	Tubesheet	Tubesheet floating	0.000 MPa	17.216 MPa	15.184 MPa

ID	Comp. Type	Description	Liq.Head	MAWP New & Cold	MAWP Hot & Corr.
TB.1	Tube Bundle	Tube bundle	0.000 MPa	8.432 MPa	8.432 MPa
	MAWP			**3.310 MPa**	**3.310 MPa**

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Note : Other components may limit the MAWP than the ones checked above.
Note : The value for MAWP is at top of vessel, with static liquid head subtracted.
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Bill of Materials

ID	No	Description	Component Dimensions	Material Standard
E4.1	1	Welded Flat End-Head left	Do= 215, t= 27, Lcyl= 1, es= .85, r= 20	ID 3, SA-182(M) Gr.F316L, S31603 Forgings, PNo=8
E4.2*	1	Welded Flat End-Head right	Do= 215, t= 27, Lcyl= 1, es= .85, r= 20	ID 3, SA-182(M) Gr.F316L, S31603 Forgings, PNo=8
F.1	1	RT - Flange-Flangering Head left	OD= 215, ID= 133.3, thk= 36, h= 0, g1= 15.8	ID 3, SA-182(M) Gr.F316L, S31603 Forgings, PNo=8
F.1	4	Bolts	M12x1.75 ;, Area= 76.25	ID 4, SA-193(M) Gr.B7, G41400 Bolting
F.2*	1	RT - Flange-Flangering Head right	OD= 215, ID= 134.5, thk= 36, h= 18, g1= 17.5	ID 3, SA-182(M) Gr.F316L, S31603 Forgings, PNo=8
F.2*	4	Bolts	M12x1.75 ;, Area= 76.25	ID 4, SA-193(M) Gr.B7, G41400 Bolting
F.3	1	RT - Flange-Flangering Shell left	OD= 215, ID= 134.5, thk= 36, h= 18, g1= 17.5	ID 3, SA-182(M) Gr.F316L, S31603 Forgings, PNo=8
F.3	4	Bolts	M12x1.75 ;, Area= 76.25	ID 4, SA-193(M) Gr.B7, G41400 Bolting
F.4*	1	RT - Flange-Flangering Shell right	OD= 215, ID= 134.5, thk= 36, h= 18, g1= 17.5	ID 3, SA-182(M) Gr.F316L, S31603 Forgings, PNo=8
F.4*	4	Bolts	M12x1.75 ;, Area= 76.25	ID 4, SA-193(M) Gr.B7, G41400 Bolting
N.1	1	Flange:ASME B16.5:Class 300 lbs	WN Welding Neck, 1a RF Raised Face	2.3 16Cr-12Ni-2Mo :A 182 Gr. F316L - A 240 Gr. 316L
N.1	1	Nozzle,Plate Body-N1	2" do=60.3,t=3.91,L=110.5,ho=100	ID 9, SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8
N.2*	1	Flange:ASME B16.5:Class 300 lbs	WN Welding Neck, 1a RF Raised Face	2.3 16Cr-12Ni-2Mo :A 182 Gr. F316L - A 240 Gr. 316L
N.2*	1	Nozzle,Plate Body-N1	2" do=60.3,t=3.91,L=110.5,ho=100	ID 9, SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8
N.3	1	Open.Without Nozzle-N4	di=40	ID 5, SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8
N.4*	1	Open.Without Nozzle-N3	di=40	ID 5, SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8
S1.1	1	Cylindrical Shell-Main Shell	Do= 141.3, t= 3.4, L= 1050	ID 5, SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8
S1.2	1	Cylindrical Shell-Channel Head left	Do= 215, t= 13.35, L= 30	ID 3, SA-182(M) Gr.F316L, S31603 Forgings, PNo=8
S1.3*	1	Cylindrical Shell-Channel Head right	Do= 215, t= 13.35, L= 30	ID 3, SA-182(M) Gr.F316L, S31603 Forgings, PNo=8
T.1	1	Tubesheet-Tubesheet	OD= 132.2, thk= 28, N= 72 tubes	ID 11, SB-148(M), M01, C95820 Castings
T.2	1	Tubesheet-Tubesheet floating	OD= 132.2, thk= 28, N= 72 tubes	ID 11, SB-148(M), M01, C95820 Castings
TB.1	1	Tube Bundle-Tube bundle	N= 72, dt= 7.5, tt= .5, L= 606	ID 7, SB-111(M), O61, C70600 Smls. cond. tube

Nozzle List

ID	Service	SIZE	STANDARD/CLASS	ID	Standout	X	Y	Z	Rot.	Orient.
N.1	N1	2"	ASME B16.5 300 lbs WN -RF Raised Face SCH 40S	55.5	100	69	0	80	0	Radial
N.2*	N1	2"	ASME B16.5 300 lbs WN -RF Raised Face SCH 40S	55.5	100	-69	0	980	180	Radial
N.3	N4	2"		0	100	40.5	0	-153.5	0	Radial
N.4*	N3	2"		0	100	-40.5	0	-152.5	180	Radial

Maximum Component Utilization - Umax

ID	Comp.Type	Umax(%)	Limited by
E4.1	Welded Flat End	35.6%	Flat Head Thickness
E4.2*	Welded Flat End	35.6%	Flat Head Thickness

ID	Comp.Type	Umax(%)	Limited by
F.1	RT - Flange	30.2%	Bolting Area Check
F.2*	RT - Flange	30.2%	Bolting Area Check
F.3	RT - Flange	30.2%	Bolting Area Check
F.4*	RT - Flange	30.2%	Bolting Area Check
N.1	Nozzle,Plate Body	73.3%	UG-45 Min.Nozzle Neck Thk.
N.2*	Nozzle,Plate Body	73.3%	UG-45 Min.Nozzle Neck Thk.
N.3	Open.Without Nozzle	19.0%	UG-37 Nozzle Reinforcement
N.4*	Open.Without Nozzle	19.0%	UG-37 Nozzle Reinforcement
S1.1	Cylindrical Shell	85.8%	Internal Pressure
S1.2	Cylindrical Shell	28.2%	Internal Pressure
S1.3*	Cylindrical Shell	28.2%	Internal Pressure
T.1	Tubesheet	26.4%	Tubesheet Bending Stress
T.2	Tubesheet	18.5%	Tubesheet Bending Stress
TB.1	Tube Bundle	95.9%	External Pressure

Component with highest utilization Umax = 95.9% TB.1 Tube bundle

Average utilization of all components Umean= 41.2%

Material Data/Mechanical Properties

ID	Material Name	Temp	ST	SY	SYd	S_d	Sr	ftest	E-mod	Note
1	SA-213(M) Gr.TP316L, S31603 Smls. tube, PNo=8 , SG=7.85	120	485	170	138.6	115	115	153	185000	G5
2	SA-479(M) Gr.304L, S30403 Bar, PNo=8 , SG=7.85	100	485	170	146	115	115	153	187909	G5, G21, G22, T4
3	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 , SG=7.85	120	450	170	138.6	115	115	153	185000	G5
4	SA-193(M) Gr.B7, G41400 Bolting , Max.T= 100mm, SG=7.85	95	795	655	609.6	159	159	589.5	0	T5
5	SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 , SG=7.85	120	515	205	169.6	138	138	184.5	186212	G5, G12, T8, W12, W13, W14
6	SA-240(M) Gr.316Ti, S31635 Plate, PNo=8 , SG=7.85	100	515	205	180	138	138	184.5	187909	G5, G12, T8
7	SB-111(M), O61, C70600 Smls. cond. tube , SG=7.85	95	275	100	97.9	68.9	68.9	90	122285	G5, T5
8	SA-479(M) Gr.304L, S30403 Bar, PNo=8 , SG=7.85	120	485	170	139.6	115	115	153	186212	G5, G21, G22, T4
9	SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8 , SG=7.85	100	485	170	145	115	115	153	187000	G5, G21, W12, W14
10	SB-111(M), O61, C68700 Smls. cond. tube , SG=7.85	210	345	125	0	20.8	82.7	112.5	124000	T3
11	SB-148(M), M01, C95820 Castings , SG=7.85	204	650	270	259.8	167.5	179	243	141976	G15

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Notation:
Thickness in mm, stress in N/mm2, temperature in deg.C
TG    : Test Group 1 to 4
Max.T: Maximum thickness for this stress set, 0 or 999 = No limit specified
S/C   : CS = Carbon Steel, SS = Stainless Steel
SG    : SG = Specific Gravity (Water = 1.0)
ST    : MIN.TENSILE STRENGTH at room temp.
SY    : MIN. YIELD STRENGTH at room temp.
SYd   : MIN. YIELD STRENGTH at calc.temp.
S_d   : DESIGN STRESS at calc.temp.
Sr    : DESIGN STRESS at room temp.
Note : G5 = Due to the relatively low yield strength of these materials, these
higher stress values were established at temperatures where the shorttime  tensile
properties govern to permit the use of these alloys where slightly greater
deformation is acceptable. The stress values in this range exce
ed 662/3% but do not exceed 90% of the yield strength at temperature. Use of these
stresses may result in dimensional changes due to permanent strain. These stress
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values are not recommended for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction. For Section III applications, Table Y-2 lists multiplying factors that, when applied to the yield strength values shown in Table Y-1, will give allowable stress values that will result in lower levels of permanent strain.
Note : G21 = For Section I, use is limited to PEB–5.3. See PG–5.5 for cautionary note.
Note : G22 = For Section I applications, use of external pressure charts for material in the form of barstock is permitted for stiffening rings only.
Note : T4 = Allowable stresses for temperatures of 480°C and above are values obtained from time-dependent properties.
Note : T5 = Allowable stresses for temperatures of 450°C and above are values obtained from time–dependent properties.
Note : G12 = At temperatures above 550°C, these stress values apply only when the carbon is 0.04% or higher on heat analysis.
Note : T8 = Allowable stresses for temperatures of 595°C and above are values obtained from time-dependent properties.
Note : W12 = These S values do not include a longitudinal weld efficiency factor. For Section III applications, for materials welded without filler metal, ultrasonic examination, radiographic examination, or eddy current examination, in accordance with NC-2550, shall provide a longitudinal weld eff iciency factor of 1.00. Materials welded with filler metal meeting the requirements of NC-2560 shall receive a longitudinal weld efficiency factor of 1.00. Other longitudinal weld efficiency factors shall be in accordance with the following: (a) for single butt weld, with filler metal, 0.80; (b) for single or double butt weld, without filler metal, 0.85; (c) for double butt weld, with filler metal, 0.90; (d) for single or double butt weld, with radiography, 1.00.
Note : W13 = For Section I applications, electric resistance and autogenous welded tubing may be used with these stresses, provided the following additional restrictions and requirements are met: (a) The tubing shall be used for boiler, waterwall, superheater, and economizer tubes that are enclosed within the setting. (b) The maximum outside diameter shall be 89 mm. (c) The weld seam of each tube shall be subjected to an angle beam ultrasonic inspection per SA-450. (d) A complete volumetric inspection of the entire length of each tube shall be performed in accordance with SA-450. (e) Material test reports shall be supplied.
Note : W14 = These S values do not include a weld factor. For Section VIII, Division 1, and Section XII applications using welds made without filler metal, the tabulated tensile stress values shall be multiplied by 0.85. For welds made with filler metal, consult UW-12 for Section VIII, Division 1, or TW-130.4 for Section XII, as applicable.
Note : T3 = Allowable stresses for temperatures of 175°C and above are values obtained from time-dependent properties.
Note : G15 = To these stress values a quality factor as specified in ND-3115 of Section III; UG-24 of Section VIII, Division 1; or TM-190 of Section XII shall be applied for castings. This is not intended to apply to valves and fittings made to recognized standards.

Comp.Location in Global Coord.System

ID	Comp. Type	X	Y	Z	Teta	Phi	ConnID
E4.1	Welded Flat End	0	0	-120	0.0	0.0	S1.2
E4.2*	Welded Flat End	0	0	1170	0.0	0.0	S1.3*
F.1	RT - Flange	0	0	-54	0.0	0.0	F.3
F.2*	RT - Flange	0	0	1086	0.0	0.0	F.4*
F.3	RT - Flange	0	0	0	0.0	0.0	S1.1
F.4*	RT - Flange	0	0	1050	0.0	0.0	S1.1
N.1	Nozzle,Plate Body	69	0	80	90.0	0.0	S1.1
N.2*	Nozzle,Plate Body	-69	0	980	90.0	180.0	S1.1
N.3	Open.Without Nozzle	41	0	-153	0.0	0.0	E4.1
N.4*	Open.Without Nozzle	-40	0	-152	0.0	180.0	E4.1
S1.1	Cylindrical Shell	0	0	0	0.0	0.0	
S1.2	Cylindrical Shell	0	0	-90	0.0	0.0	F.1

ID	Comp. Type	X	Y	Z	Teta	Phi	ConnID
S1.3*	Cylindrical Shell	0	0	1140	0.0	0.0	F.2*
T.1	Tubesheet	0	0	-54	0.0	0.0	F.3
T.2	Tubesheet	0	0	496	0.0	0.0	TB.1
TB.1	Tube Bundle	0	0	0	0.0	0.0	T.1

The report above shows the location of the connecting point (x, y and z) for each component referenced to the coordinate system of the connecting component (ConnID). The connecting point (x, y and z) is always on the center axis of rotational symmetry for the component under consideration, i.e. the connecting point for a nozzle connected to a cylindrical shell will be at the intersection of the nozzle center axis and the mid thickness of the shell referenced to the shell s coordinate system. In addition the orientation of the the center axis of the component is given by the two angles Teta and Phi, where Teta is the angle between the center axis of the two components and Phi is the orientation in the x-y plane
The basis for the coordinate system used by the software is a right handed coordinate system with the z-axis as the center axis of rotational geometry for the components, and Teta as the Polar Angle and Phi as the Azimuthal Angle

MDMT Minimum Design Metal Temperature

Table :

ID-Description	Material Name	tn(mm)	tg(mm)	Ratio	E(*)	Curve
E4.1 Head left - End	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	27.0	6.8	0.10	1.00	
E4.2* Head right - End	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	27.0	6.8	0.10	1.00	
F.1 Flangering Head left - Bolts	SA-193(M) Gr.B7, G41400 Bolting	11.0	11.0	0.30	1.00	
F.1 Flangering Head left - Flange	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	36.0	9.0	0.30	1.00	
F.2* Flangering Head right - Bolts	SA-193(M) Gr.B7, G41400 Bolting	11.0	11.0	0.30	1.00	
F.2* Flangering Head right - Flange	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	36.0	9.0	0.30	1.00	
F.2* Flangering Head right - Hub	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	3.2	3.2	0.19	1.00	
F.3 Flangering Shell left - Bolts	SA-193(M) Gr.B7, G41400 Bolting	11.0	11.0	0.30	1.00	
F.3 Flangering Shell left - Flange	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	36.0	9.0	0.30	1.00	
F.3 Flangering Shell left - Hub	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	3.2	3.2	0.19	1.00	
F.4* Flangering Shell right - Bolts	SA-193(M) Gr.B7, G41400 Bolting	11.0	11.0	0.30	1.00	
F.4* Flangering Shell right - Flange	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	36.0	9.0	0.30	1.00	
F.4* Flangering Shell right - Hub	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	3.2	3.2	0.19	1.00	
N.1 N1 - Flange	2.3 16Cr-12Ni-2Mo :A 182 Gr. F316L - A 240 Gr. 316L	0.0	0.0	0.28	1.00	NA
N.1 N1 - Nozzle	SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8	3.9	3.9	0.12	0.85	
N.2* N1 - Flange	2.3 16Cr-12Ni-2Mo :A 182 Gr. F316L - A 240 Gr. 316L	0.0	0.0	0.28	1.00	NA
N.2* N1 - Nozzle	SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8	3.9	3.9	0.12	0.85	
N.3 N4 - Nozzle	SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8	3.9	3.9	0.19	1.00	
N.4* N3 - Nozzle	SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8	3.9	3.9	0.19	1.00	
S1.1 Main Shell - Shell	SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8	3.4	3.4	0.75	0.85	
S1.2 Channel Head left - Shell	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	13.4	13.4	0.10	0.85	
S1.3* Channel Head right - Shell	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	13.4	13.4	0.10	0.85	
T.1 Tubesheet - T-Sheet	SB-148(M), M01, C95820 Castings	28.0	7.0	0.26	1.00	
T.2 Tubesheet floating - T-Sheet	SB-148(M), M01, C95820 Castings	28.0	7.0	0.19	1.00	
TB.1 Tube bundle - Tube	SB-111(M), O61, C70600 Smls. cond. tube	0.5	0.5	0.96	1.00	

Table Continued

ID-Description	T1(C)	T2(C)	MDMT(C)	Comments
E4.1 Head left - End			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
E4.2* Head right - End			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
F.1 Flangering Head left - Bolts	-48.0	-80.0	-105	

ID-Description	T1(C)	T2(C)	MDMT(C)	Comments
F.1 Flangering Head left - Flange			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
F.2* Flangering Head right - Bolts	-48.0	-80.0	-105	
F.2* Flangering Head right - Flange			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
F.2* Flangering Head right - Hub			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
F.3 Flangering Shell left - Bolts	-48.0	-80.0	-105	
F.3 Flangering Shell left - Flange			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
F.3 Flangering Shell left - Hub			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
F.4* Flangering Shell right - Bolts	-48.0	-80.0	-105	
F.4* Flangering Shell right - Flange			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
F.4* Flangering Shell right - Hub			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
N.1 N1 - Flange	-196	-80.0	-276	ASME B16.5 Flange
N.1 N1 - Nozzle			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
N.2* N1 - Flange	-196	-80.0	-276	ASME B16.5 Flange
N.2* N1 - Nozzle			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
N.3 N4 - Nozzle			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
N.4* N3 - Nozzle			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
S1.1 Main Shell - Shell			-196	For thermally treated materials, ref. is made to UHA-51(c)
S1.2 Channel Head left - Shell			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
S1.3* Channel Head right - Shell			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
T.1 Tubesheet - T-Sheet			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
T.2 Tubesheet floating - T-Sheet			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
TB.1 Tube bundle - Tube			-196	NOTE: If the carbon content is above 0.1% impact testing of base material and HAZ is required if MDMT required is lower than -48C.

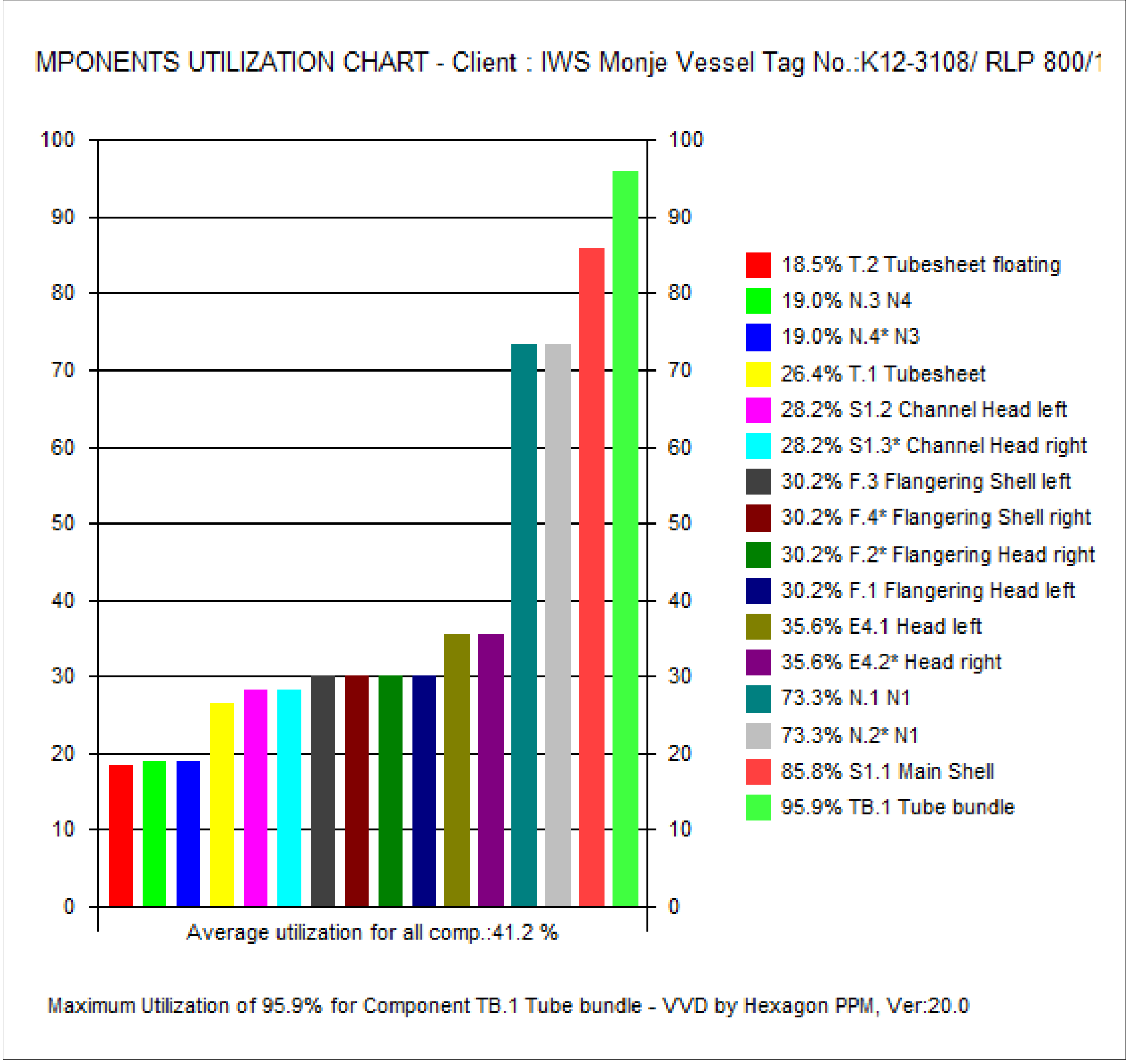
```
MDMT CALCULATIONS PER UCS-66, UG-20(f), UHA-51 and Appendix JJ
MDMT Required        : -10.0 C
MDMT Lowest Allowable: -105 C

NOMENCLATURE:
  tn   - Nominal thickness of component under consideration(including corr.
allow.).
  tg   - Governing thickness of component under consideration.
  Ratio- tr*E(*)/(tn-c), utiliztion of component for given process conditions.
  tr   - Required minimum thickness of component at calculation temperature of
MDMT.
  E(*) - Joint efficiency factor, not lower than 0.8.
  Curve- Applicable curve A, B, C or D in Figure UCS-66.
  T1   - Unadjusted MDMT/Lowest allowable temperature for given part, value taken
from Figure UCS-66 based on curve A, B, C or D.
  T2   - Reduction in MDMT without impact testing per Figure UCS-66.1.

NOTES:
  UCS-68(c) If postweld heat treatment is performed when it is not otherwise a
requirement, a 17C reduction in impact test exemption temp. may be given to the
```

min. permissible temp. for P.no.1 materials.
The maximum general primary stress in the pads are conservatively assumed to be the same as that in the corroded shell.
Note: For austenitic stainless steels, reference is made to UHA-51(c) for thermally treated materials.

NOTE: LOWEST MDMT = -105 C (Warmest Value)

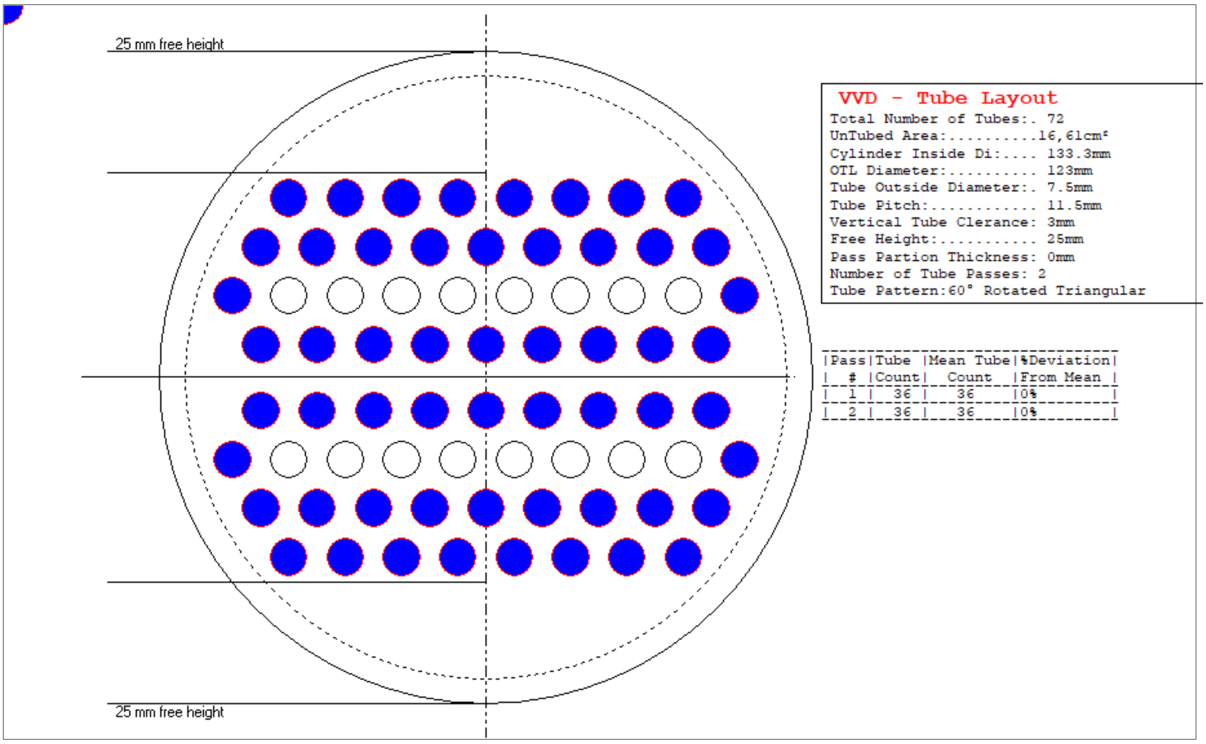
Utilization Chart

Utilization Chart



Tube Layout

Tube Layout



Surface Area

PROCESS CARD NO.: 1 SHELL SIDE

ID	No.	Description	Area Outside(m2)	Area Inside(m2)
S1.1	1	Cylindrical Shell, Main Shell	0.466	0.453
Total	**1**		**0.466**	**0.453**

PROCESS CARD NO.: 2 TUBE SIDE

ID	No.	Description	Area Outside(m2)	Area Inside(m2)
E4.1	1	Welded Flat End, Head left	0.036	0.036
E4.2*	1	Welded Flat End, Head right	0.036	0.036
F.1	1	RT - Flange, Flangering Head left	0.024	0.015
F.2*	1	RT - Flange, Flangering Head right	0.053	0.023
F.3	1	RT - Flange, Flangering Shell left	0.053	0.023
F.4*	1	RT - Flange, Flangering Shell right	0.053	0.023
N.1	1	Nozzle,Plate Body, N1	0.019	0.016
N.2*	1	Nozzle,Plate Body, N1	0.019	0.016
N.3	1	Open.Without Nozzle, N4	0.000	0.000
N.4*	1	Open.Without Nozzle, N3	0.000	0.000
S1.2	1	Cylindrical Shell, Channel Head left	0.020	0.018
S1.3*	1	Cylindrical Shell, Channel Head right	0.020	0.018
T.1	1	Tubesheet, Tubesheet	0.000	0.000
T.2	1	Tubesheet, Tubesheet floating	0.000	0.000
TB.1	1	Tube Bundle, Tube bundle	1.028	0.891
Total	**15**		**1.361**	**1.115**

```
SUMMATION OF DATA FOR ALL COMPONENTS :
Total :Ao=       0.466 m2, Ai=       0.453 m2
```

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

GENERAL DESIGN DATA

```
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Shell Side : Temp= 210°C, P=2.5000 MPa, c=1.0 mm, Pext=0.1000 MPa
SPECIFIC DENSITY OF OPERATING LIQUID................:SG        1.0000
LIQUID HEAD.........................................:LH        268.67 mm
```

SHELL DATA

```
CYLINDER FABRICATION: Welded Pipe
NEGATIVE TOLERANCE: Negative tolerance specified in % of nominal thickness
SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 120'C
ST=515 SY=205 SYd=169.6 S=138 Sr=138 Stest=184.5  (N/mm2)
WELD JOINT EFFICIENCY FACTOR: Spot RT UW-11(b) Type 1 (E=0.85)
Minimum thickness check to UG-16 does NOT apply.: NO
OUTSIDE DIAMETER OF SHELL...........................:Do        141.30 mm
LENGTH OF CYLINDRICAL PART OF SHELL.................:Lcyl     1050.00 mm
NOMINAL WALL THICKNESS (uncorroded).................:tn        3.4000 mm
NEGATIVE DEVIATION/TOLERANCE........................:           12.50 %
Split shell into several shell courses and include welding information: NO
```

EXTERNAL PRESSURE

```
UNSUPPORTED LENGTH OF SHELL (Fig.UG-28.1)...........:L           0.00 mm
```

CALCULATION DATA

UG-27 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

```
Outside Radius of Shell
Ro = Do / 2 =141.3/2=                                           70.65 mm
```

»Thin Cylinder Check P=2.5026 <= 0.385 * S * E=45.16[MPa] «» OK«

```
Required Minimum Shell Thickness Excl.Allow. tmin :
tmin = P * Ro / (S * E + 0.4 * P)                                   (APP.1-1 (1))
=2.5026*70.65/(138*0.85+0.4*2.5026)=                          1.4946 mm
```

»Thin Cylinder Check tmin=1.49 < 0.5 * R=35.33[mm] « » OK«

```
Required Minimum Shell Thickness Incl.Allow. :
tmina = tmin + c + NegDev =1.49+1+0.425=                        2.9196 mm

Analysis Thickness
ta = tn - c - NegDev =3.4-1-0.425=                              1.9750 mm
```

Internal Pressure tmina=2.92 <= tn=3.4[mm]	85.8%	OK

»Shell - Min.thickness to UG-16 Thk=1.975 >= UG-16(b) (1.5mm)=1.5[mm] «» OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :

```
Inside Diameter of Shell
Di = Do - 2 * ta =141.3-2*1.975=                               137.35 mm
Inside Radius of Shell
R = Di / 2 =137.35/2=                                           68.68 mm
MAWP HOT & CORR. (Corroded condition at design temp.)
MAWPHC = S * E * ta / (R + 0.6 * ta)
=138*0.85*1.975/(68.675+0.6*1.975)=                           3.3162 MPa

MAWP NEW & COLD (Uncorroded condition at ambient temp.)
MAWPNC = Sr * E * (ta + c) / (R - c + 0.6 * (ta + c))
=138*0.85*(1.975+1)/(68.675-1+0.6*(1.975+1))=                 5.0240 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)
Ptmax = SYtest * Etest * (ta + c) / (R + 0.6 * (ta + c))
=184.5*1*(1.975+1)/(68.675+0.6*(1.975+1))=              7.7901 MPa
```

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Ptmin = 1.1 * Pd * Sr / S =1.1*2.5*138/138=               2.7500 MPa
```

Test Pressure Ptmin=2.75 <= Ptmax=7.79[MPa]	35.3%	OK

SECT. UG28 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

Preliminary Calculations

```
Ratio1 = Do / t =141.3/1.975=                                71.54
Ratio2 = L / Do =0/141.3=                                     0.00
Value of A from Fig.G (Part D), A =0.097478
Value of B from External Pressure Chart HA-2(based on Temp=210)  B =97.29
Pmax = (4 / 3) * B / (Do / t)
=(4/3)*97.29/(141.3/1.975)=                                1.8131 MPa
```

External Pressure Pmax=1.81 >= Pext=0.1[MPa]	5.5%	OK

Required Minimum Thickness Due to External Pressure Incl.Allow.:1.6 mm

CALCULATION SUMMARY

UG-27 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

```
Required Minimum Shell Thickness Excl.Allow. tmin :
tmin = P * Ro / (S * E + 0.4 * P)                              (APP.1-1 (1))
=2.5026*70.65/(138*0.85+0.4*2.5026)=                  1.4946 mm

Required Minimum Shell Thickness Incl.Allow. :
tmina = tmin + c + NegDev =1.49+1+0.425=                 2.9196 mm
```

Internal Pressure tmina=2.92 <= tn=3.4[mm]	85.8%	OK

```
MAWP HOT & CORR. (Corroded condition at design temp.)
MAWPHC = S * E * ta / (R + 0.6 * ta)
=138*0.85*1.975/(68.675+0.6*1.975)=                   3.3162 MPa

MAWP NEW & COLD (Uncorroded condition at ambient temp.)
MAWPNC = Sr * E * (ta + c) / (R - c + 0.6 * (ta + c))
=138*0.85*(1.975+1)/(68.675-1+0.6*(1.975+1))=         5.0240 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)
Ptmax = SYtest * Etest * (ta + c) / (R + 0.6 * (ta + c))
=184.5*1*(1.975+1)/(68.675+0.6*(1.975+1))=              7.7901 MPa
```

Test Pressure Ptmin=2.75 <= Ptmax=7.79[MPa]	35.3%	OK

SECT. UG28 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

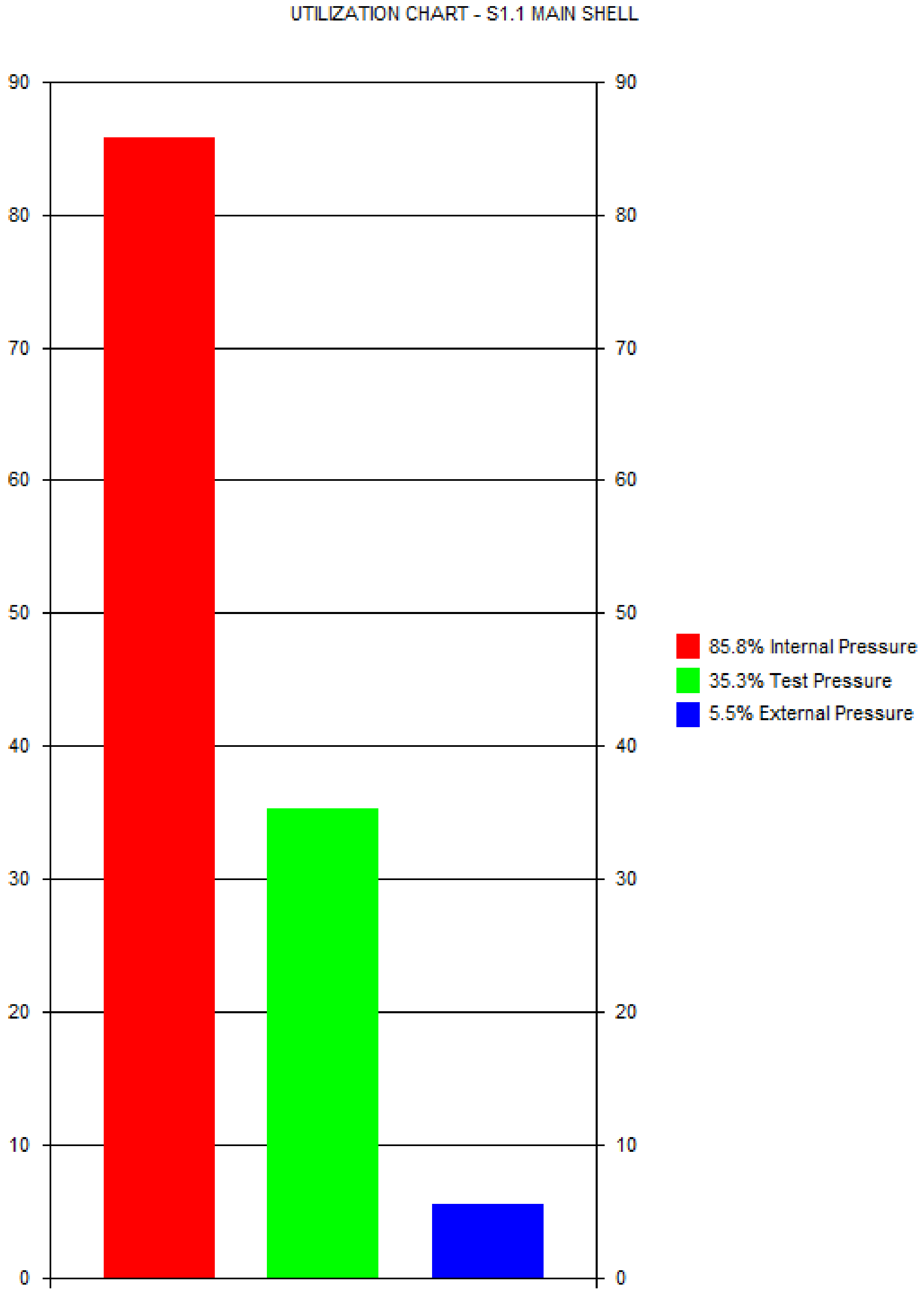
```
Pmax = (4 / 3) * B / (Do / t)
=(4/3)*97.29/(141.3/1.975)=                                1.8131 MPa
```

External Pressure Pmax=1.81 >= Pext=0.1[MPa]	5.5%	OK

Required Minimum Thickness Due to External Pressure Incl.Allow.:1.6 mm

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 210 FOR: 5 SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.
WARNING: A non zero value needs to be specified for the unsupported length.

Volume:0.0156 m3 Weight:12.1 kg (SG= 7.85)



Max.Utilization/Condition 85.8%

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

```
Attachment: F.1     RT - Flange          Flangering Head left          F.3
Location: Along z-axis z1= -90
```

GENERAL DESIGN DATA

```
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Tube Side : Temp= 95°C, P=1.0000 MPa, c=1.0 mm, Pext=0.1000 MPa
SPECIFIC DENSITY OF OPERATING LIQUID................:SG        1.0000
LIQUID HEAD.........................................:LH        267.65 mm
```

SHELL DATA

```
CYLINDER FABRICATION: Seamless Pipe
NEGATIVE TOLERANCE: Negative tolerance specified in % of nominal thickness
SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 120'C
ST=450 SY=170 SYd=138.6 S=115 Sr=115 Stest=153  (N/mm2)
WELD JOINT EFFICIENCY FACTOR: Spot RT UW-11(b) Type 1 (E=0.85)
Minimum thickness check to UG-16 does NOT apply.: NO
OUTSIDE DIAMETER OF SHELL...........................:Do        215.00 mm
LENGTH OF CYLINDRICAL PART OF SHELL.................:Lcyl       30.00 mm
NOMINAL WALL THICKNESS (uncorroded).................:tn         13.35 mm
NEGATIVE DEVIATION/TOLERANCE........................:          12.50 %
Split shell into several shell courses and include welding information: NO
```

EXTERNAL PRESSURE

```
UNSUPPORTED LENGTH OF SHELL (Fig.UG-28.1)...........:L           0.00 mm
```

CALCULATION DATA

UG-27 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

```
Outside Radius of Shell
Ro = Do / 2 =215/2=                                         107.50 mm
```

»Thin Cylinder Check P=1.0026 <= 0.385 * S * E=37.63[MPa] «» OK«

```
Required Minimum Shell Thickness Excl.Allow. tmin :
tmin = P * Ro / (S * E + 0.4 * P)                              (APP.1-1 (1))
=1.0026*107.5/(115*0.85+0.4*1.0026)=                       1.0981 mm
```

»Thin Cylinder Check tmin=1.1 < 0.5 * R=53.75[mm] « » OK«

```
Required Minimum Shell Thickness Incl.Allow. :
tmina = tmin + c + NegDev =1.1+1+1.67=                       3.7668 mm

Analysis Thickness
ta = tn - c - NegDev =13.35-1-1.67=                           10.68 mm
```

Internal Pressure tmina=3.77 <= tn=13.35[mm]	28.2%	OK

»Shell - Min.thickness to UG-16 Thk=10.68 >= UG-16(b) (1.5mm)=1.5[mm] «» OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :

```
Inside Diameter of Shell
Di = Do - 2 * ta =215-2*10.68=                               193.64 mm
Inside Radius of Shell
R = Di / 2 =193.64/2=                                         96.82 mm
MAWP HOT & CORR. (Corroded condition at design temp.)
MAWPHC = S * E * ta / (R + 0.6 * ta)
=115*0.85*10.68/(96.82+0.6*10.68)=                          10.11 MPa

MAWP NEW & COLD (Uncorroded condition at ambient temp.)
MAWPNC = Sr * E * (ta + c) / (R - c + 0.6 * (ta + c))
=115*0.85*(10.68+1)/(96.82-1+0.6*(10.68+1))=                11.10 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)
Ptmax = SYtest * Etest * (ta + c) / (R + 0.6 * (ta + c))
=153*1*(10.68+1)/(96.82+0.6*(10.68+1))=                     17.21 MPa
```

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Ptmin = 1.1 * Pd * Sr / S =1.1*1*115/115=                   1.1000 MPa
```

Test Pressure Ptmin=1.1 <= Ptmax=17.21[MPa]	6.3%	OK

SECT. UG28 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

Preliminary Calculations

```
Ratio1 = Do / t =215/10.68=                                    20.13
Ratio2 = L / Do =0/215=                                         0.00
Value of A from Fig.G (Part D), A =0.09793
Value of B from External Pressure Chart HA-4(based on Temp=95)  B =97.92
Pmax = (4 / 3) * B / (Do / t)
=(4/3)*97.92/(215/10.68)=                                  6.4864 MPa
```

External Pressure Pmax=6.49 >= Pext=0.1[MPa]	1.5%	OK

Required Minimum Thickness Due to External Pressure Incl.Allow.:3 mm

CALCULATION SUMMARY

UG-27 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

```
Required Minimum Shell Thickness Excl.Allow. tmin :
tmin = P * Ro / (S * E + 0.4 * P)                              (APP.1-1 (1))
=1.0026*107.5/(115*0.85+0.4*1.0026)=                       1.0981 mm

Required Minimum Shell Thickness Incl.Allow. :
tmina = tmin + c + NegDev =1.1+1+1.67=                       3.7668 mm
```

Internal Pressure tmina=3.77 <= tn=13.35[mm]	28.2%	OK

```
MAWP HOT & CORR. (Corroded condition at design temp.)
MAWPHC = S * E * ta / (R + 0.6 * ta)
=115*0.85*10.68/(96.82+0.6*10.68)=                          10.11 MPa

MAWP NEW & COLD (Uncorroded condition at ambient temp.)
MAWPNC = Sr * E * (ta + c) / (R - c + 0.6 * (ta + c))
=115*0.85*(10.68+1)/(96.82-1+0.6*(10.68+1))=                11.10 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)
Ptmax = SYtest * Etest * (ta + c) / (R + 0.6 * (ta + c))
=153*1*(10.68+1)/(96.82+0.6*(10.68+1))=                     17.21 MPa
```

Test Pressure Ptmin=1.1 <= Ptmax=17.21[MPa]	6.3%	OK

SECT. UG28 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

```
Pmax = (4 / 3) * B / (Do / t)
=(4/3)*97.92/(215/10.68)=                                  6.4864 MPa
```

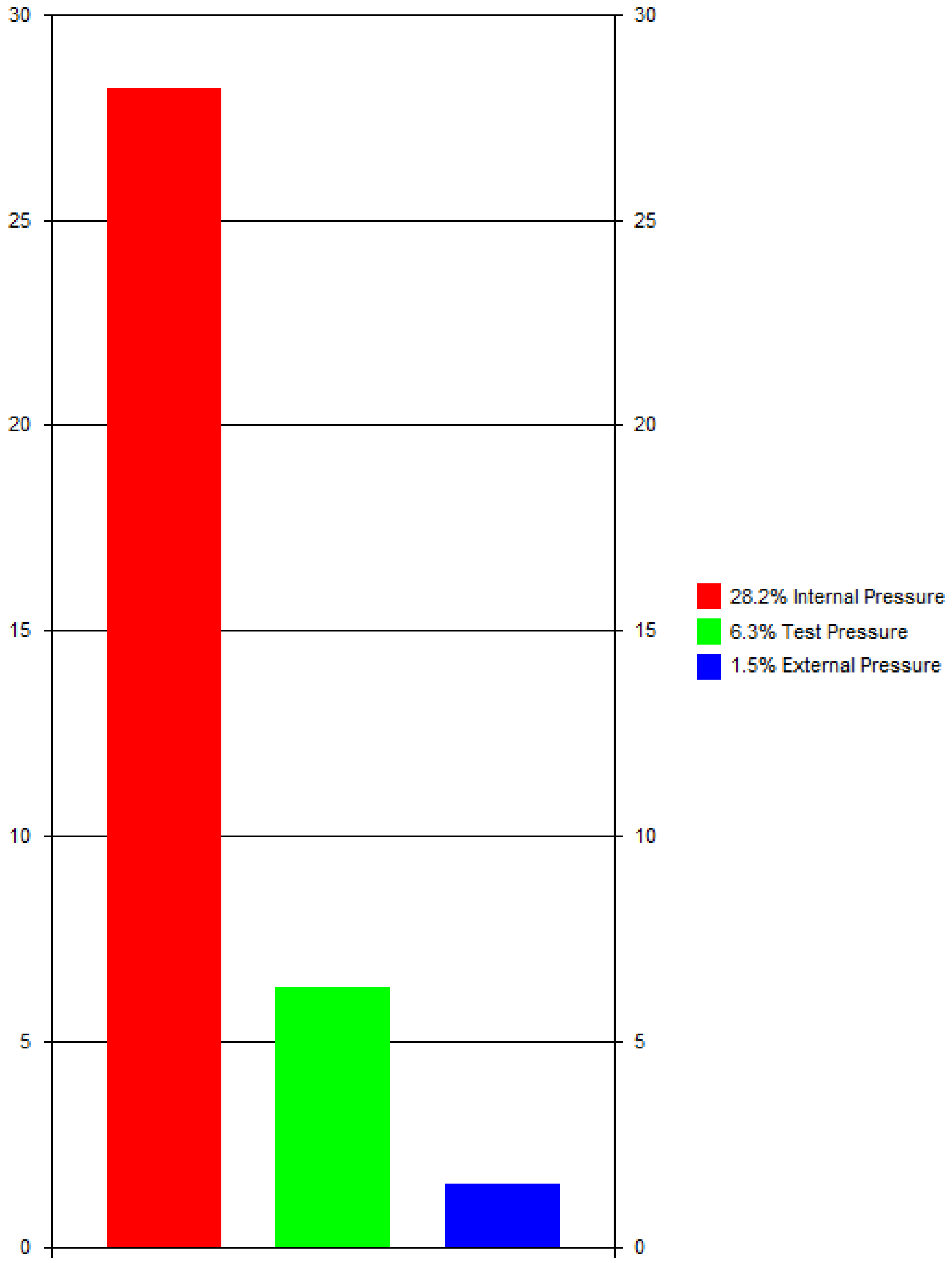
External Pressure Pmax=6.49 >= Pext=0.1[MPa]	1.5%	OK

Required Minimum Thickness Due to External Pressure Incl.Allow.:3 mm

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 3 SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 , the material must be re-selected from the material database.
WARNING: A non zero value needs to be specified for the unsupported length.

Volume:0.0008835 m3 Weight:2 kg (SG= 7.85)

UTILIZATION CHART - S1.2 CHANNEL HEAD LEFT



Max.Utilization/Condition 28.2%

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

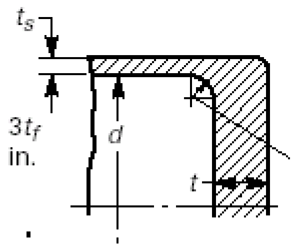
```
Attachment: S1.2    Cylindrical Shell    Channel Head left             F.1
Location: Along z-axis z1= -120
```

GENERAL DESIGN DATA

```
PROCESS CARD: Tube Side : Temp= 95°C, P=1.0000 MPa, c=1.0 mm
SPECIFIC DENSITY OF OPERATING LIQUID................:SG        1.0000
LIQUID HEAD.........................................:LH        295.15 mm
```

DATA FOR FLAT END

```
Include Straight Bar Stiffeners to Reduce Cover Deflection.: NO
Shape of Cover: Circular
WELD JOINT EFFICIENCY FACTOR: Spot RT UW-11(b) Type 1 (E=0.85)
```




```
TYPE OF FLAT WELDED END:
b_2) C=0.33m Integral head with rmin=10mm when ts<=38mm and rmin=0.25ts
INSIDE HUB/CORNER RADIUS............................:r          20.00 mm
LENGTH OF CYLINDRICAL PART OF END...................:Lc        1.0000 mm
NOMINAL THICKNESS OF HEAD/END (uncorroded)..........:tn         27.00 mm
SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 120'C
ST=450 SY=170 SYd=138.6 S=115 Sr=115 Stest=153  (N/mm2)
```

DATA FOR CYLINDRICAL SHELL SECTION

```
CYLINDER DIAMETER: Base Design on Cylinder Outside Diameter
OUTSIDE DIAMETER OF SHELL...........................:Do        215.00 mm
NOMINAL WALL THICKNESS (uncorroded).................:tsn        13.35 mm
WELD JOINT EFFICIENCY FACTOR: Spot RT UW-11(b) Type 1 (E=0.85)
SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 120'C
ST=450 SY=170 SYd=138.6 Ss=115 Ssr=115 Sstest=153  (N/mm2)
```

CALCULATION DATA

```
Analysis thickness of cylindrical shell
ts = tsn - c =13.35-1=                                        12.35 mm

Inside diameter of cylindrical shell
Di = Do - 2 * ts =215-2*12.35=                               190.30 mm

m = tr / tsn =1.1/13.35=                                     0.0823
C = MAX( C * m 0.2) =MAX(0.33*0.0823,0.2)=                   0.2000
```

UG-34(c) MIN.THICKNESS OF FLAT HEAD t

```
Minimum thickness excluding corrosion tmin
tmin = d * Sqr( C * P / (S * E))
=190.3*Sqr(0.2*1.0029/(115*0.85))=                         8.6203 mm

Minimum thickness including corrosion t
t = tmin + c =8.62+1=                                        9.6203 mm
```

Flat Head Thickness th=27 >= t=9.62[mm]	35.6%	OK

```
Minimum hub/corner radius rmin:
rmin (Min(19 and 10 or 0.25*tsn) = rmin =10=                  10.00 mm
```

»Corner Radius Check r=20 >= rmin=10[mm] « » OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD

```
Pmax = S * E * (t / (d)) ^ 2 / (C)
=115*0.85*(27/(190.3))^2/(0.2)=                    9.8387 MPa
```

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR

```
Pmax = S * E * (t / (d)) ^ 2 / (C)
=115*0.85*(26/(190.3))^2/(0.2)=                    9.1234 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
Pmax = S * E * (t / (d)) ^ 2 / (C)
=153*0.85*(27/(190.3))^2/(0.2)=                     13.09 MPa
```

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Ptmin = 1.1 * Pd * Sr / S =1.1*1*115/115=           1.1000 MPa
```

Test Pressure Ptmin=1.1 <= Ptmax=13.09[MPa]	8.4%	OK

CALCULATION SUMMARY

UG-34(c) MIN.THICKNESS OF FLAT HEAD t

```
Minimum thickness including corrosion t
t = tmin + c =8.62+1=                               9.6203 mm
```

Flat Head Thickness th=27 >= t=9.62[mm]	35.6%	OK

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD

```
Pmax = S * E * (t / (d)) ^ 2 / (C)
=115*0.85*(27/(190.3))^2/(0.2)=                    9.8387 MPa
```

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR

```
Pmax = S * E * (t / (d)) ^ 2 / (C)
=115*0.85*(26/(190.3))^2/(0.2)=                    9.1234 MPa
```

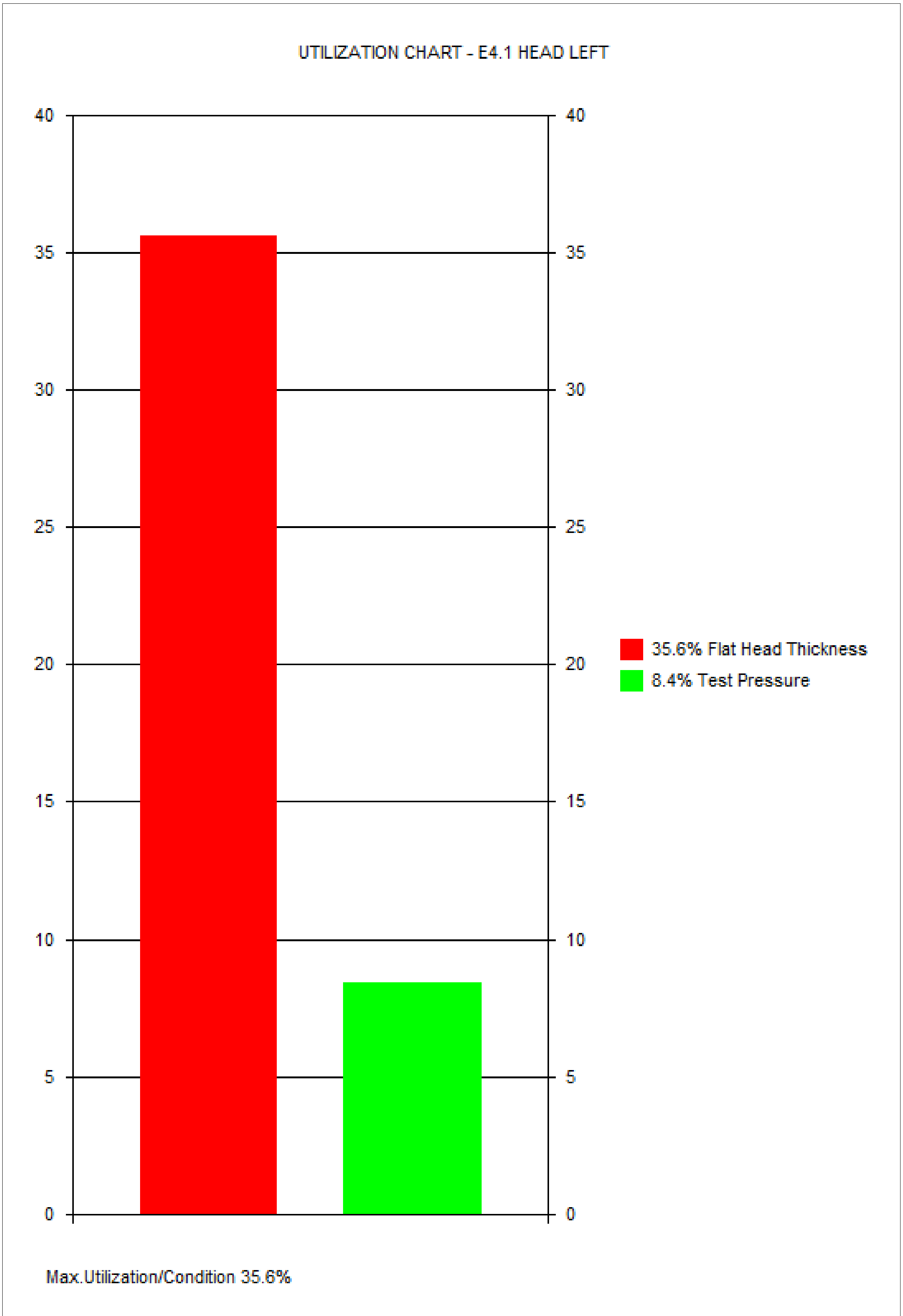
MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
Pmax = S * E * (t / (d)) ^ 2 / (C)
=153*0.85*(27/(190.3))^2/(0.2)=                     13.09 MPa
```

Test Pressure Ptmin=1.1 <= Ptmax=13.09[MPa]	8.4%	OK

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 3 SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 , the material must be re-selected from the material database.

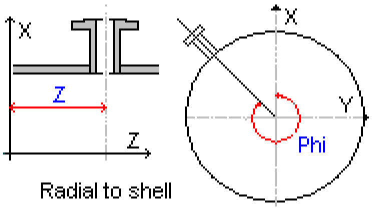
Volume:0.00 m3 Weight:7 kg (SG= 7.85)


UTILIZATION CHART - E4.1 HEAD LEFT
40
35
30
25
20
15
10
5
0
35.6% Flat Head Thickness
8.4% Test Pressure
Max.Utilization/Condition 35.6%

INPUT DATA

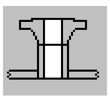
COMPONENT ATTACHMENT/LOCATION

```
Attachment: S1.1    Cylindrical Shell    Main Shell
Connect this nozzle to the nozzle neck of another nozzle: NO
```

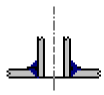



```
Orientation & Location of Nozzle: Radial to Shell
z-location of nozzle along axis of attacment........:z          80.00 mm
Angle of Rotation of nozzle axis projected in the x-y plane:Phi     0.00 Degr.
```

GENERAL DESIGN DATA



```
Type of Opening: Standard ASME or DIN/EN Flange Attachment
```



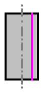
```
Nozzle Type: Set In Flush Nozzle
Nozzle Weld Intersect: Nozzle Does NOT Intersect with a Welded Shell Seam
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Tube Side : Temp= 95°C, P=1.0000 MPa, c=1.0 mm, Pext=0.1000 MPa
Apply a different corrosion allowance to nozzle neck than the shell thickness.: NO
SPECIFIC DENSITY OF OPERATING LIQUID................:SG        1.0000
LIQUID HEAD.........................................:LH        131.05 mm
Include Nozzle Load Calculation: NO
```

SHELL DATA (S1.1)

```
Shell Type: Cylindrical Shell
OUTSIDE DIAMETER OF SHELL...........................:Do        141.30 mm
NOMINAL WALL THICKNESS (uncorroded).................:tn        3.4000 mm
WELD JOINT EFFICIENCY FACTOR........................:E1        1.0000
NEGATIVE TOLERANCE/THINNING ALLOWANCE...............:th        0.4250 mm
REQUIRED THICKNESS FOR EXTERNAL PRESSURE(excl.allow.):text     0.1898 mm
SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 120'C
ST=515 SY=205 SYd=169.6 Sv=138 Sr=138 Stest=184.5  (N/mm2)
```

NOZZLE DATA

```
SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8 100'C
ST=485 SY=170 SYd=145 Sn=115 Sr=115 Stest=153  (N/mm2)
Nozzle without pipe connections(access/inspection openings): NO
```



```
Delivery Form: Plate Body
Nozzle Diameter: Base Design on Nozzle OD
WELD JOINT EFFICIENCY FACTOR: Spot RT UW-11(b) Type 1 (E=0.85)
OUTSIDE NOZZLE DIAMETER..............................:deb        60.32 mm
NOMINAL NOZZLE THICKNESS (uncorroded)................:tnb       3.9100 mm
Size of Flange and Nozzle: 2"
Comment (Optional): SCH 40S
NEGATIVE TOLERANCE/THINNING ALLOWANCE................:          0.5000 mm
NOZZLE STANDOUT MEASURED FROM VESSEL OD..............:ho        100.00 mm
```

FLANGE DATA

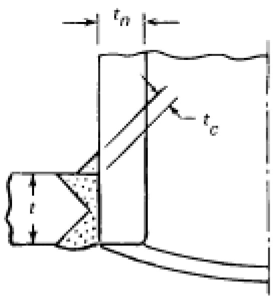
```
A: Flange Standard: ASME B16.5/B16.47 Flanges
E:  Pressure Class: ASME B16.5:Class 300 lbs
C: Flange Type: WN  Welding Neck
D: Facing Sketch/ANSI facing (Table 3.8.3(2)): 1a  RF  Raised Face
Flange Material Category: 2.3 16Cr-12Ni-2Mo :A 182 Gr. F316L - A 240 Gr. 316L
ASME 300lb-Flange Rating(at 95C)= 3.532 MPa, Max.Test Pressure = 6.3 MPa
```

DATA FOR REINFORCEMENT PAD

```
Type of Pad: No Pad
```

WELDING DATA

```
Nozzle to Shell Welding Area: Include Area of Nozzle to Shell Weld as Min.Required
```




```
Weld Connection:
Full Penetration Weld(from both sides) + Outward Fillet Weld (to=tc)
```

LIMITS OF REINFORCEMENT

```
Reduction of Limits of Reinforcement: No Reduction Required
```

CALCULATION DATA

GEOMETRIC LIMITATIONS

Material Strength Reduction Factor fr1-4

```
Strength Reduction Factor for Nozzle Inserted Through Vessel Wall fr1
fr1 = MIN( Sn / Sv, 1) =MIN(115/138,1)=                     0.8333
Strength Reduction Factor for Nozzle fr2
fr2 = MIN( Sn / Sv, 1) =MIN(115/138,1)=                     0.8333
```

PRELIMINARY CALCULATIONS

```
Shell Analysis Thickness t
t = tn - c - th =3.4-1-0.425=                               1.9750 mm
Nozzle Analysis Thickness tn
tn = tnb - cn - NegDev =3.91-1-0.5=                         2.4100 mm
Inside Radius of Shell R
```

```
R = Do / 2 - t =141.3/2-1.975=                               68.68 mm
Required Thickness of a Seamless Shell tr
tr = P * R / (Sv * E1 - 0.6 * P)
=1.0013*68.675/(138*1-0.6*1.0013)=                         0.5005 mm
d = deb - 2 * tn =60.32-2*2.41=                              55.50 mm
Inside Radius of Nozzle Rn
Rn = (deb - 2 * tn) / 2 =(60.32-2*2.41)/2=                   27.75 mm
Minimum nozzle thickness due to pressure
trn = P * Rn / (Sn * E - 0.6 * P)
=1.0013*27.75/(115*0.85-0.6*1.0013)=                       0.2860 mm
```

UG-40 LIMITS OF REINFORCEMENT

```
Parallel to Vessel Wall (half diameter limit)
Lv = MAX( d , d / 2 + t + tn)
=MAX(55.5,55.5/2+1.975+2.41)=                                55.50 mm
Normal to Vessel Wall Outside
Lno = MIN( 2.5 * t , 2.5 * tn + te)
=MIN(2.5*1.975,2.5*2.41+0)=                                4.9375 mm
Effective Material Diameter Limit
deff = 2 * Lv =2*55.5=                                      111.00 mm
```

UG-37 Calculation of Stress Loaded Areas Effective as Reinforcement

Area Available in Shell A1

```
A1 = (deff-d)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)
=(111-55.5)*(1*1.975-1*0.5005)-2*2.41*(1*1.975-1*0.5005)*(1-0.8333)
=    80.65 mm2
```

Area Available in Nozzle Projecting Outward A2

```
A2 = 2 * (tn - trn) * fr2 * MIN( Lno, ho)
=2*(2.41-0.286)*0.8333*MIN(4.94,100)=                        17.48 mm2
```

Area Available in Welds A4

```
Area Available in Nozzle Outward Weld A41
A41 = Leg41 ^ 2 * fr2 =3.4^2*0.8333=                        9.6333 mm2
A4 = A41 + A42 + A43 =9.63+0+0=                             9.6333 mm2
```

Total Area Available Aavail

```
Aavail = A1 + A2 + A3 + A4 + A5 =80.65+17.48+0+9.63+0=      107.76 mm2
```

UG-37(c) Total Area Required

```
Total Area Required Areq
Areq = d * tr * F + 2 * tn * tr * F * (1 - fr1)
=55.5*0.5005*1+2*2.41*0.5005*1*(1-0.8333)=                   28.18 mm2
```

UG-37 Nozzle Reinforcement Aavail=107.76 >= Areq=28.18[mm2]	26.1%	OK

NOTE : UG-36(c)(3a) THIS NOZZLE IS EXEMPT FROM AREA CALCULATIONS WHEN CONSIDERED ISOLATED AND WITHOUT RAPID PRESSURE FLUCTUATIONS.

UG-41.1 WELD STRENGTH AND WELD LOADS (Sketch a or b)

NOTE: UW-15(b) Strength calculations for attachment welds are NOT required for this detail.

MAXIMUM ALLOWABLE PRESSURES

FLANGE RATING

ASME 300lb-Flange Rating(at 95C)= 3.532 MPa, Max.Test Pressure = 6.3 MPa

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR

Pmax (t,tn,Sv,Sn)(2,2.4,138,115) = == 2.3656 MPa

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD

Pmax (t,tn,Sv,Sn)(3,3.4,138,115) = == 3.5922 MPa

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

Pmax (t,tn,Sv,Sn)(3,3.4,184.5,153) = == 4.7937 MPa

UG-37(d) Nozzle Reinforcement - External Pressure

Available Reinforcement Area
Aavail = A1 + A2 + A3 + A4 + A5 =97.64+17.89+0+9.63+0= 125.17 mm2

UG-37(d) Nozzle Reinforcement Ext.Press. Aavail=125.17 >= Areq=5.34[mm2]	4.2%	OK

UW-16(d) DIMENSIONS OF FILLET WELDS:

Throat dimension of fillet welds on nozzle:
- at outward nozzle weld at nozzle OD, tmin = lesser of 19.0, tn or t/te)= 3.4 mm

to(min)=MIN(6, 0.7*tmin)= 2.38 mm
Minimum length of legs:
- at outward nozzle weld at nozzle OD, Leg41(min) = 3.4 mm

»UW-16(d) Outward Nozzle Fillet Weld, Leg Size Leg41=3.4 >= Leg41(min)=3.4[mm] «» OK«

UG-45 NOZZLE NECK THICKNESS

UG-45 Minimum Nozzle Neck Thickness Required for Internal and External Pressure
ta = MAX(trn , textn) + cn =MAX(0.286,0.2355)+1= 1.2860 mm
tb1 = MAX(tr , tmin16) + cn =MAX(0.5005,1.5)+1= 2.5000 mm
tb2 = MAX(trPext , tmin16) + cn =MAX(0.0372,1.5)+1= 2.5000 mm
tb3(Value from Table UG-45 + cn)= == 4.4200 mm
tb = MIN(tb3 , MAX(tb1 , tb2))
=MIN(4.42,MAX(2.5,2.5))= 2.5000 mm
Minimum Thickness of Nozzle Neck to UG-45
tUG45 = MAX(ta , tb) =MAX(1.29,2.5)= 2.5000 mm

UG-45 Min.Nozzle Neck Thk. tUG45=2.5 <= tnb-tolerance=3.41[mm]	73.3%	OK

Weight of Nozzle:0.2779kg Flange: 4kg

CALCULATION SUMMARY

Aavail = A1 + A2 + A3 + A4 + A5 =80.65+17.48+0+9.63+0= 107.76 mm2

Total Area Required Areq
Areq = d * tr * F + 2 * tn * tr * F * (1 - fr1)
=55.5*0.5005*1+2*2.41*0.5005*1*(1-0.8333)= 28.18 mm2

UG-37 Nozzle Reinforcement Aavail=107.76 >= Areq=28.18[mm2]	26.1%	OK

MAXIMUM ALLOWABLE PRESSURES

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR

Pmax (t,tn,Sv,Sn)(2,2.4,138,115) = == 2.3656 MPa

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD

```
Pmax (t,tn,Sv,Sn)(3,3.4,138,115) = ==                    3.5922 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
Pmax (t,tn,Sv,Sn)(3,3.4,184.5,153) = ==                  4.7937 MPa
```

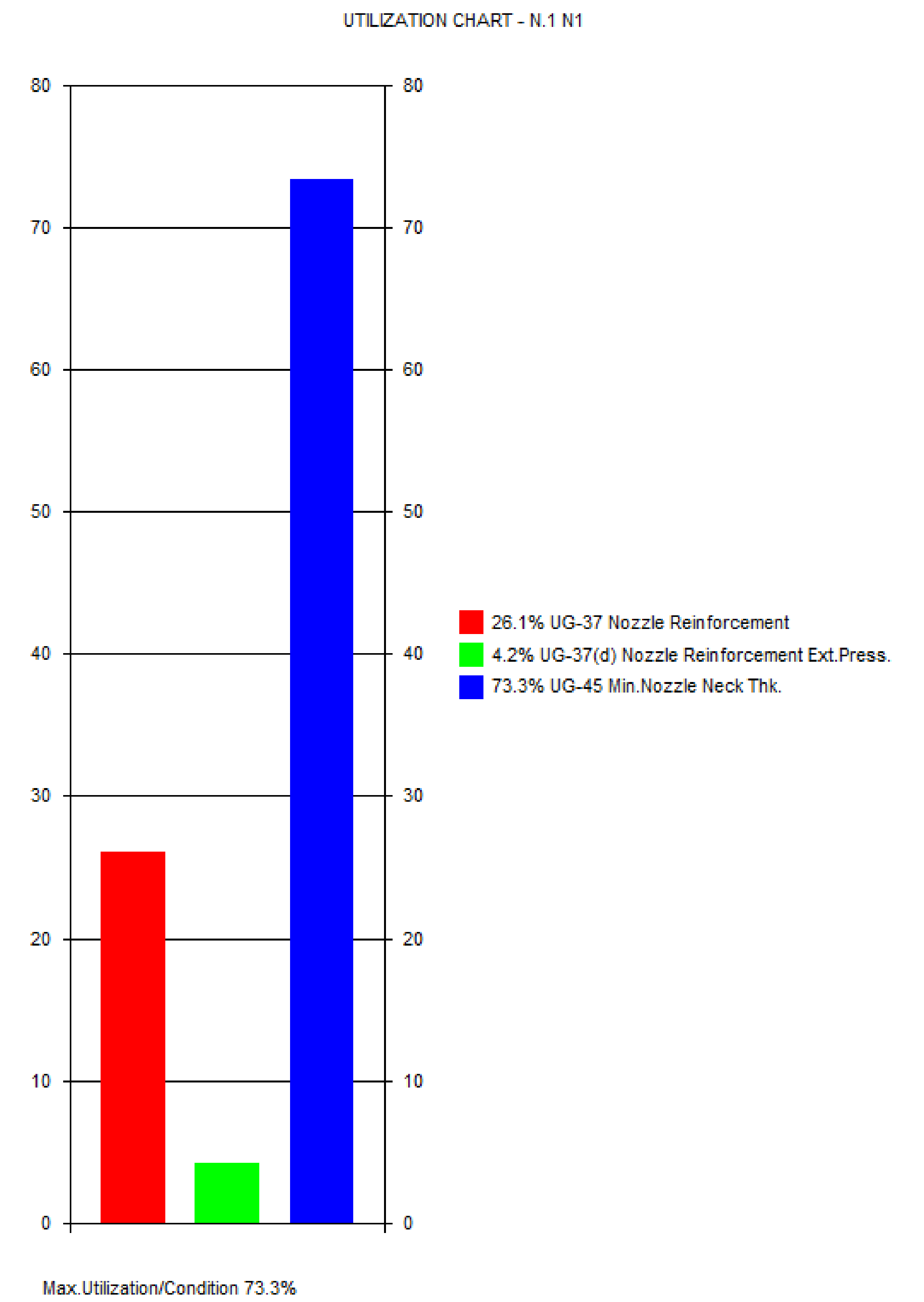
UG-37(d) Nozzle Reinforcement - External Pressure

```
Available Reinforcement Area
Aavail = A1 + A2 + A3 + A4 + A5 =97.64+17.89+0+9.63+0=     125.17 mm2
```

UG-37(d) Nozzle Reinforcement Ext.Press. Aavail=125.17 >= Areq=5.34[mm2]	4.2%	OK
UG-45 Min.Nozzle Neck Thk. tUG45=2.5 <= tnb-tolerance=3.41[mm]	73.3%	OK

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 5 SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.
WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 9 SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.
WARNING : U-1(c)(2) APPLICABILITY, ID OF VESSEL IS LESS THAN 152 mm.

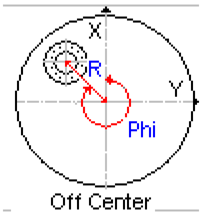
Volume:0.0002000 m3 Weight:4 kg (SG= 7.85)


UTILIZATION CHART - N.1 N1
80
70
60
50
40
30
20
10
0
26.1% UG-37 Nozzle Reinforcement
4.2% UG-37(d) Nozzle Reinforcement Ext.Press.
73.3% UG-45 Min.Nozzle Neck Thk.
Max.Utilization/Condition 73.3%

INPUT DATA

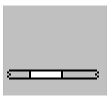
COMPONENT ATTACHMENT/LOCATION

```
Attachment: E4.1    Welded Flat End      Head left                    S1.2
Connect this nozzle to the nozzle neck of another nozzle: NO
```




```
Orientation & Location of Nozzle: Radial to End (Off Center)
Angle of Rotation of nozzle axis projected in the x-y plane:Phi     0.00 Degr.
Distance between Center of End and Center of Nozzle.:R         40.50 mm
```

GENERAL DESIGN DATA



```
Type of Opening: Opening Without Nozzle/Ring
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Tube Side : Temp= 95°C, P=1.0000 MPa, c=1.0 mm, Pext=0.1000 MPa
Apply a different corrosion allowance to nozzle neck than the shell thickness.: NO
SPECIFIC DENSITY OF OPERATING LIQUID................:SG        1.0000
LIQUID HEAD.........................................:LH        159.50 mm
```

SHELL DATA (E4.1)

```
Shell Type: Welded Flat End
OUTSIDE DIAMETER OF SHELL...........................:Do        215.00 mm
NOMINAL WALL THICKNESS (uncorroded).................:tn         27.00 mm
WELD JOINT EFFICIENCY FACTOR........................:E1        1.0000
REQUIRED THICKNESS FOR EXTERNAL PRESSURE(excl.allow.):text     0.1898 mm
REQUIRED THICKNESS OF UNPIERCED COVER(corroded).....:t         8.6203 mm
SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 120'C
ST=450 SY=170 SYd=138.6 Sv=115 Sr=115 Stest=153  (N/mm2)
```

OPENING DATA

```
DIAMETER OF OPENING IN SHELL(corroded).............:dib        40.00 mm
```

LIMITS OF REINFORCEMENT

```
Reduction of Limits of Reinforcement: No Reduction Required
```

CALCULATION DATA

GEOMETRIC LIMITATIONS

PRELIMINARY CALCULATIONS

```
Shell Analysis Thickness t
t = tn - c - th =27-1-0=                                      26.00 mm
Inside Radius of Shell R
R = Do / 2 - t =215/2-26=                                     81.50 mm
deb = d + 2 * tn =40+2*0=                                     40.00 mm
deb = d + 2 * tn =40+2*0=                                     40.00 mm
Inside Radius of Nozzle Rn
Rn = d / 2 =40/2=                                             20.00 mm
Minimum nozzle thickness due to pressure
```

```
trn = P * Rn / (Sn * E - 0.6 * P)
=1.0016*20/(115*1-0.6*1.0016)=                          0.1751 mm
```

UG-40 LIMITS OF REINFORCEMENT

```
Parallel to Vessel Wall (half diameter limit)
Lv = MAX( d , d / 2 + t + tn) =MAX(40,40/2+26+0)=         46.00 mm
Normal to Vessel Wall Outside
Lno = MIN( 2.5 * t , 2.5 * tn + te)
=MIN(2.5*26,2.5*0+0)=                                    0.00 mm
Effective Material Diameter Limit
deff = 2 * Lv =2*46=                                      92.00 mm
```

UG-37 Calculation of Stress Loaded Areas Effective as Reinforcement

Area Available in Shell A1

```
A1 = (deff-d)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)
=(92-40)*(1*26-1*8.62)-2*0*(1*26-1*8.62)*(1-1)=          903.74 mm2
```

Area Available in Nozzle Projecting Outward A2

```
A2 = 2 * (tn - trn) * fr2 * MIN( Lno, ho)
=2*(0-0.1751)*1*MIN(0,0)=                                 0.00 mm2
```

Area Available in Welds A4

```
A4 = A41 + A42 + A43 =0+0+0=                                0.00 mm2
```

Total Area Available Aavail

```
Aavail = A1 + A2 + A3 + A4 + A5 =903.74+0+0+0+0=          903.74 mm2
```

UG-39(b)(1) Total Area Required

```
Total Area Required Areq
Areq = 0.5 * d * tr + tn * tr * (1 - fr1)
=0.5*40*8.62+0*8.62*(1-1)=                               172.41 mm2
```

UG-39(d)(1) Alternative to (b)(1), Minimum Head/Cover Thickness trmin

```
Cnew = MIN( 2 * C , 0.75) =MIN(2*0.2,0.75)=                0.4000
trmin = tr * SQR( Cnew / C) =8.62*SQR(0.4/0.2)=             12.19 mm
```

UG-37 Nozzle Reinforcement Aavail=903.74 >= Areq=172.41[mm2]	19.0%	OK

MAXIMUM ALLOWABLE PRESSURES

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR

```
Pmax (t,tn,Sv,Sn)(26,0,115,115) = ==                    4.7576 MPa
```

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD

```
Pmax (t,tn,Sv,Sn)(27,0,115,115) = ==                    5.2459 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
Pmax (t,tn,Sv,Sn)(27,0,153,153) = ==                    6.9611 MPa
```

UG-37(d) Nozzle Reinforcement - External Pressure

```
Available Reinforcement Area
Aavail = A1 + A2 + A3 + A4 + A5 =1342.13+0+0+0+0=        1342.13 mm2
```

UG-37(d) Nozzle Reinforcement Ext.Press. Aavail=1342.13 >= Areq=1.9[mm2]	0.1%	OK

```
Weight of Nozzle:0.00kg
```

CALCULATION SUMMARY

Aavail = A1 + A2 + A3 + A4 + A5 =903.74+0+0+0+0= 903.74 mm2

Total Area Required Areq
Areq = 0.5 * d * tr + tn * tr * (1 - fr1)
=0.5*40*8.62+0*8.62*(1-1)= 172.41 mm2

UG-37 Nozzle Reinforcement Aavail=903.74 >= Areq=172.41[mm2]	19.0%	OK

MAXIMUM ALLOWABLE PRESSURES

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR
Pmax (t,tn,Sv,Sn)(26,0,115,115) = == 4.7576 MPa

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD
Pmax (t,tn,Sv,Sn)(27,0,115,115) = == 5.2459 MPa

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)
Pmax (t,tn,Sv,Sn)(27,0,153,153) = == 6.9611 MPa

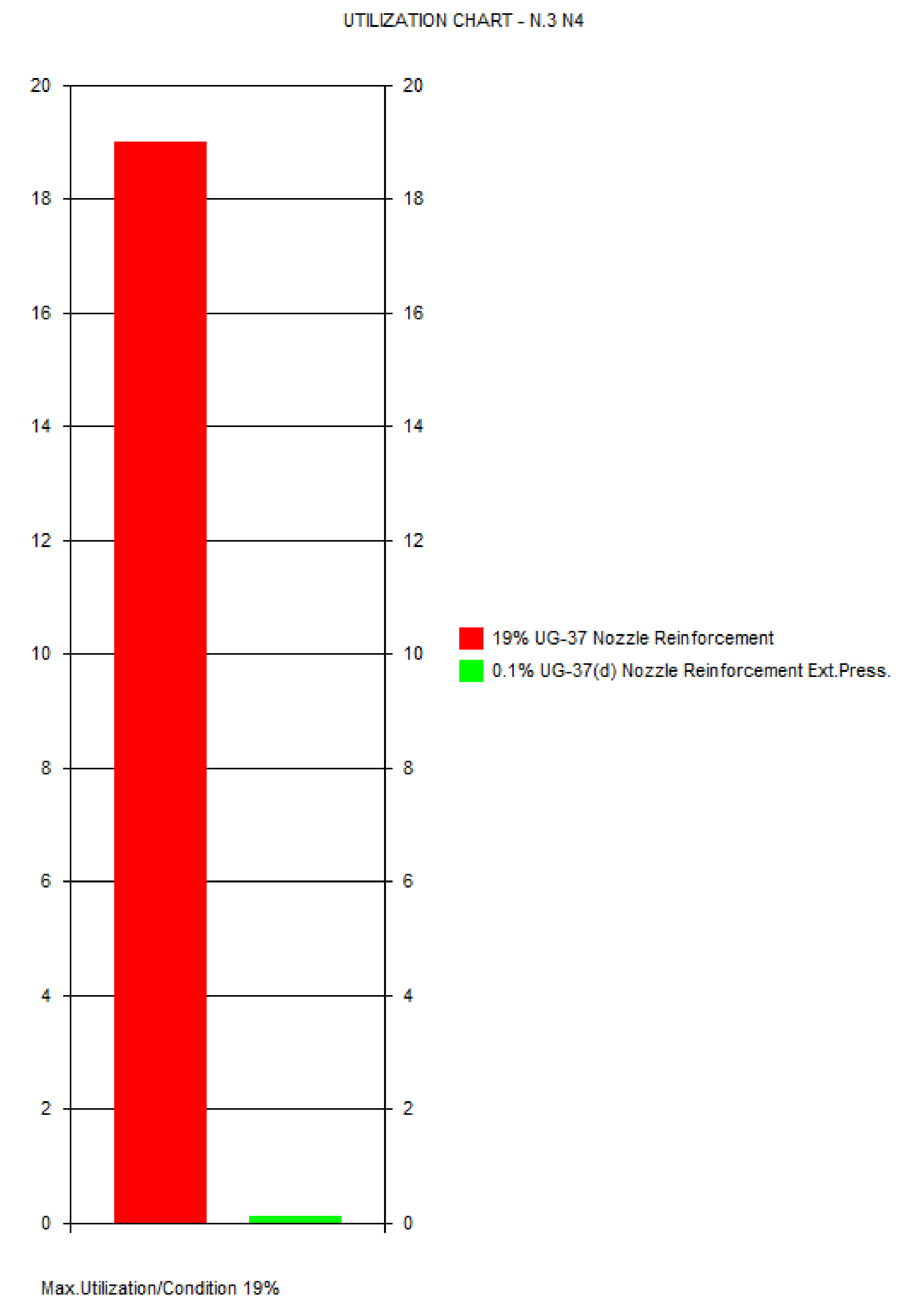
UG-37(d) Nozzle Reinforcement - External Pressure

Available Reinforcement Area
Aavail = A1 + A2 + A3 + A4 + A5 =1342.13+0+0+0+0= 1342.13 mm2

UG-37(d) Nozzle Reinforcement Ext.Press. Aavail=1342.13 >= Areq=1.9[mm2]	0.1%	OK

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 3 SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 , the material must be re-selected from the material database.

Volume:0.00 m3 Weight:0 kg (SG= 7.85)


UTILIZATION CHART - N.3 N4
20
18
16
14
12
10
8
6
4
2
0
19% UG-37 Nozzle Reinforcement
0.1% UG-37(d) Nozzle Reinforcement Ext.Press.
Max.Utilization/Condition 19%

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

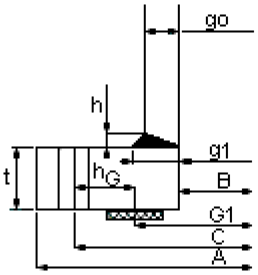
```
Attachment: F.3     RT - Flange         Flangering Shell left         S1.1
Location: Along z-axis z1= -54
Include a standard ANSI, DIN or EN flange without performing detailed
calculations.: NO
```

GENERAL DESIGN DATA

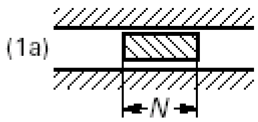
```
PROCESS CARD: Tube Side : Temp= 95°C, P=1.0000 MPa, c=1.0 mm
SPECIFIC DENSITY OF OPERATING LIQUID................:SG        1.0000
LIQUID HEAD.........................................:LH        307.50 mm
B: Pressure loading: Flange under internal pressure
LETHAL SERVICE - APPLY BOLT SPACING CORR.FACTOR TO 2-6 AND RIGIDITY INDEX TO 2-
14.: NO
EXTERNAL LOADS ON FLANGE  (PD5500 ENQ 5500/123): NO
SPECIFY BOLT LOADS FROM 2nd./MATING FLANGE: NO
```

TYPE OF FLANGE AND GASKET FACING

```
A: Flange Standard: User Specified Flanges
```




```
C: Flange Type: RT  Ring Type(Smooth or Stepped bore)
```




```
D: Flange Facing (Sketch/Description): 1a  Flat Face
```

SHELL/NOZZLE DATA

```
SHELL/NOZZLE SIZE & COMMENT: S1.1
SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 120'C
ST=450 SY=170 SYd=138.6 fs=115 fs20=115 Stest=153  (N/mm2)
OUTSIDE DIAMETER OF SHELL/NOZZLE ...................:Do        215.00 mm
WALL THICKNESS OF NOZZLE/SHELL(uncorroded)..........:s1         40.85 mm
```

FLANGE DATA

```
FLANGE HUB: Flange Without Hub
REVERSE FLANGE: No (The bolts are located on the outside)
DESIGN METHOD: B) LOOSE FLANGE METHOD(If requirements are met)
FLANGE BORE: Smooth           .
OUTSIDE DIAMETER OF FLANGE..........................:A         215.00 mm
THICKNESS OF FLANGE(uncorroded).....................:e          36.00 mm
CORROSION ALLOWANCE FOR FLANGE FACE.................:cf          0.00 mm
SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 120'C
ST=450 SY=170 SYd=138.6 SFO=115 SFA=115 Stest=153  (N/mm2)
INCLUDE APPENDIX 2-14, FLANGE RIGIDITY CALCULATION: YES
MODULUS OF ELASTICITY at design temp................:E       2,0E05 N/mm2
MODULUS OF ELASTICITY at ambient temp...............:E20     2,0E05 N/mm2
```

BOLTING DATA

```
REDUCE SAFETY AGAINST ABUSE BY CAREFULLY CONTROLLING THE BOLTING-UP TORQUE: NO
BOLTING TORQUE CALCULATION: NO
NOMINAL BOLTING SIZE & COMMENT: M12x1.75 ;
EFFECTIVE BOLT AREA per bolt........................:Ae         76.25 mm2
RECOMMENDED MINIMUM BOLT CENTER TO EDGE CLEARANCE...:Bce        16.00 mm
RECOMMENDED MINIMUM BOLT CENTER/RADIAL CLEARANCE....:Bcr        20.00 mm
DIAMETER OF BOLT HOLES IN FLANGE....................:d          12.00 mm
NUMBER OF BOLTS.....................................:n         4.0000
BOLT-CIRCLE DIAMETER................................:C         180.00 mm
SA-193(M) Gr.B7, G41400 Bolting THK<=100mm 95'C
ST=795 SY=655 SYd=609.57 Sb=159 Sa=159 Stest=589.5  (N/mm2)
```

GASKET DATA

```
Table 2-5.1 Gasket factors m & y   Facing:
Mineral Fiber 1.6 mm thick       m=2.75  Y=25.5  2 1a,1b,1c,1d,4,5
CONTACT WIDTH OF GASKET.............................:N         1.0000 mm
OUTSIDE DIAMETER OF GASKET..........................:Go        132.20 mm
TEMA RGP-RCB-11.7 Include Additional Loads from Pass Partition Plate Gasket: NO
```

CALCULATION DATA

GASKET DETAILS

```
b = MIN VALUE(2.52 * Sqr(bo), bo ) = ==                      0.5000 mm
```

FLANGE LOADS

```
HD = 0.785 * B ^ 2 * p =0.785*135.3^2*1.003=                  14.41 kN
H = 0.785 * G ^ 2 * p =0.785*131.2^2*1.003=                   13.55 kN
Hp = (2 * PI * b * G * m) * p
=(2*3.14*0.5*131.2*2.75)*1.003=                             1.1369 kN
HT = H - HD =13553.09-14413.39=                              -0.8603 kN
```

MOMENT ARMS

```
hG = (C - G) / 2 =(180-131.2)/2=                              24.40 mm
hD = (C - B - g1) / 2 =(180-135.3-39.85)/2=                  2.4250 mm
hT = (2 * C - B - G) / 4 =(2*180-135.3-131.2)/4=              23.38 mm
```

BOLT LOADS

```
Operating condition
Wop = H + Hp =13553.09+1136.89=                               14.69 kN

Bolting up condition
Wamb = PI * b * G * y =3.14*0.5*131.2*25.5=                  5.2553 kN
```

BOLTING AREA

```
Am1 = Wop / Sb =14689.97/159=                                 92.39 mm2

Am2 = Wamb / Sa =5255.26/159=                                 33.05 mm2

Required Bolting Area Am
Am = MAX( Am1 , Am2) =MAX(92.39,33.05)=                       92.39 mm2

Available Bolting Area Ab
Ab (num.bolts*root area) = n * Ae =4*76.25=                  305.00 mm2
```

Bolting Area Check Ab=305 >= Am=92.39[mm2]	30.2%	OK

```
Bolt Spacing
Bs = C * PI / n =180*3.14/4=                                 141.37 mm

2-5 Recommended Maximum Bolt Spacing
Bmax = 2 * db + 6 * e / (m + 0.5)
=2*12+6*36/(2.75+0.5)=                                       90.46 mm

W = 0.5 * (Ab + Am) * Sa =0.5*(305+92.39)*159=                31.59 kN
```

FLANGE MOMENTS

```
Mop = HD * hD + HT * hT + HG * hG
=14413.39*2.42+-860.3*23.375+1136.89*24.4=                 42.58 Nm

Mamb = W * hG =31592.49*24.4=                               770.86 Nm

Mo = Mop =42.58=                                             42.58 Nm
Ma = Mamb =770.86=                                          770.86 Nm
```

SHAPE CONSTANTS

```
K = A / B =215/135.3=                                       1.5891
ho=SQR(B*go)= 73.428  h/ho=  0.000  K=A/B=  1.589  g1/go=  1.000
VALUES FOR T,U,Y AND Z FROM FIGURE 2-7.1
T =     1.672  Z =     2.311  Y =     4.367  U =     4.799
F =     0.909  V =     0.550  f =     1.000
d = U / V * ho * go ^ 2 =4.799/0.5501*73.43*39.85^2=     1,0172E06 mm3
e = F / ho =0.9089/73.43=                                   0.0124 mm-1
L = (t * e + 1) / T + t ^ 3 / d
=(36*0.0124+1)/1.672+36^3/1.0172E06=                      0.9105
```

OPERATING CONDITION

```
M = Mo =42.58=                                               42.58 Nm
```

Flange Stresses with Flange Thickness e= 36 mm

```
Longitudinal Hub Stress
SH = f * M / (L * g1 ^ 2 * B)
=1*42.58/(0.9105*39.85^2*135.3)=                          0.2177 N/mm2

Radial Flange Stress
SR = (1.333 * t * e + 1) * M / (L * t ^ 2 * B)
=(1.333*36*0.0124+1)*42.58/(0.9105*36^2*135.3)=           0.4252 N/mm2

Tangential Flange Stress
ST = Y * M / (t ^ 2 * B) - (Z * SR)
=4.367*42.58/(36^2*135.3)-(2.311*0.4252)=                 0.0780 N/mm2
```

Stress Limits

Hub Stress SH=0.2177 <= 1.5 * MIN(Sf;SfH)=172.5[N/mm2]	0.1%	OK
Radial Stress SR=0.4252 <= Sf=115[N/mm2]	0.3%	OK
Tangential Stress ST=0.078 <= Sf=115[N/mm2]	0.0%	OK
Radial+Hub Stress 0.5*(SH+SR)=0.3214 <= Sf=115[N/mm2]	0.2%	OK
Tangential+Hub Stress 0.5*(SH+ST)=0.1478 <= Sf=115[N/mm2]	0.1%	OK

APPENDIX 2-14, FLANGE RIGIDITY

```
Rigidity Index
J = 52.14 * V * M / (L * E * go ^ 2 * 0.3 * ho)
=52.14*0.5501*42582.89/(0.9105*200000*39.85^2*0.3*73.43)=1,9174E-04
```

BOLTING UP CONDITION

```
M = Ma =770.86=                                             770.86 Nm
```

Flange Stresses with Flange Thickness e= 36 mm

```
Longitudinal Hub Stress
SH = f * M / (L * g1 ^ 2 * B)
=1*770.86/(0.9105*39.85^2*135.3)=                         3.9405 N/mm2

Radial Flange Stress
SR = (1.333 * t * e + 1) * M / (L * t ^ 2 * B)
=(1.333*36*0.0124+1)*770.86/(0.9105*36^2*135.3)=          7.6966 N/mm2

Tangential Flange Stress
ST = Y * M / (t ^ 2 * B) - (Z * SR)
=4.367*770.86/(36^2*135.3)-(2.311*7.7)=                   1.4112 N/mm2
```

Stress Limits

Hub Stress SH=3.94 <= 1.5 * MIN(Sf;SfH)=172.5[N/mm2]	2.2%	OK
Radial Stress SR=7.7 <= Sf=115[N/mm2]	6.6%	OK
Tangential Stress ST=1.41 <= Sf=115[N/mm2]	1.2%	OK
Radial+Hub Stress 0.5*(SH+SR)=5.82 <= Sf=115[N/mm2]	5.0%	OK
Tangential+Hub Stress 0.5*(SH+ST)=2.68 <= Sf=115[N/mm2]	2.3%	OK

APPENDIX 2-14, FLANGE RIGIDITY

```
Rigidity Index
J = 52.14 * V * M / (L * E * go ^ 2 * 0.3 * ho)
=52.14*0.5501*7.7086E05/(0.9105*200000*39.85^2*0.3*73.43)=   0.0035
```

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Ptmin = 1.1 * Pd * Sr / S =1.1*1*115/115=                     1.1000 MPa
```

Test Pressure Ptmin=1.1 <= Ptmax=11.371[MPa]	9.6%	OK

PRESSURE AND TORQUE SUMMARY

Table PRESSURE AND TORQUE SUMMARY FOR F.1 :

Description	Temp(C)	P(MPa)	Limited By	Min.Req.Total Bolt Force(kN)
Design Pressure(corroded)	95	1.00	Bolting Area Check	14.69
Max.Allow.Pressure(corroded)	95	3.31	Bolting Area Check	48.53
Max.Allow.Pressure(corroded)	Ambient	3.31	Bolting Area Check	48.53
Max.Allow.Test Pressure(corroded)	Ambient	11.37	Bolting Area Check	166.54
Required Test Pressure	Ambient	1.10	Bolting Area Check	16.15

```
The nominal Force and Torque values are based on the following bolting up method:
```

CALCULATION SUMMARY

BOLTING AREA

Bolting Area Check Ab=305 >= Am=92.39[mm2]	30.2%	OK

OPERATING CONDITION

Flange Stresses with Flange Thickness e= 36 mm

```
Longitudinal Hub Stress
SH = f * M / (L * g1 ^ 2 * B)
=1*42.58/(0.9105*39.85^2*135.3)=                        0.2177 N/mm2

Radial Flange Stress
SR = (1.333 * t * e + 1) * M / (L * t ^ 2 * B)
=(1.333*36*0.0124+1)*42.58/(0.9105*36^2*135.3)=         0.4252 N/mm2

Tangential Flange Stress
ST = Y * M / (t ^ 2 * B) - (Z * SR)
=4.367*42.58/(36^2*135.3)-(2.311*0.4252)=               0.0780 N/mm2
```

Stress Limits

Hub Stress SH=0.2177 <= 1.5 * MIN(Sf;SfH)=172.5[N/mm2]	0.1%	OK
Radial Stress SR=0.4252 <= Sf=115[N/mm2]	0.3%	OK
Tangential Stress ST=0.078 <= Sf=115[N/mm2]	0.0%	OK
Radial+Hub Stress 0.5*(SH+SR)=0.3214 <= Sf=115[N/mm2]	0.2%	OK
Tangential+Hub Stress 0.5*(SH+ST)=0.1478 <= Sf=115[N/mm2]	0.1%	OK

APPENDIX 2-14, FLANGE RIGIDITY

```
Rigidity Index
J = 52.14 * V * M / (L * E * go ^ 2 * 0.3 * ho)
=52.14*0.5501*42582.89/(0.9105*200000*39.85^2*0.3*73.43)=1,9174E-04
```

BOLTING UP CONDITION

Flange Stresses with Flange Thickness e= 36 mm

```
Longitudinal Hub Stress
SH = f * M / (L * g1 ^ 2 * B)
=1*770.86/(0.9105*39.85^2*135.3)=                        3.9405 N/mm2

Radial Flange Stress
SR = (1.333 * t * e + 1) * M / (L * t ^ 2 * B)
=(1.333*36*0.0124+1)*770.86/(0.9105*36^2*135.3)=         7.6966 N/mm2

Tangential Flange Stress
ST = Y * M / (t ^ 2 * B) - (Z * SR)
=4.367*770.86/(36^2*135.3)-(2.311*7.7)=                  1.4112 N/mm2
```

Stress Limits

Hub Stress SH=3.94 <= 1.5 * MIN(Sf;SfH)=172.5[N/mm2]	2.2%	OK
Radial Stress SR=7.7 <= Sf=115[N/mm2]	6.6%	OK
Tangential Stress ST=1.41 <= Sf=115[N/mm2]	1.2%	OK
Radial+Hub Stress 0.5*(SH+SR)=5.82 <= Sf=115[N/mm2]	5.0%	OK
Tangential+Hub Stress 0.5*(SH+ST)=2.68 <= Sf=115[N/mm2]	2.3%	OK

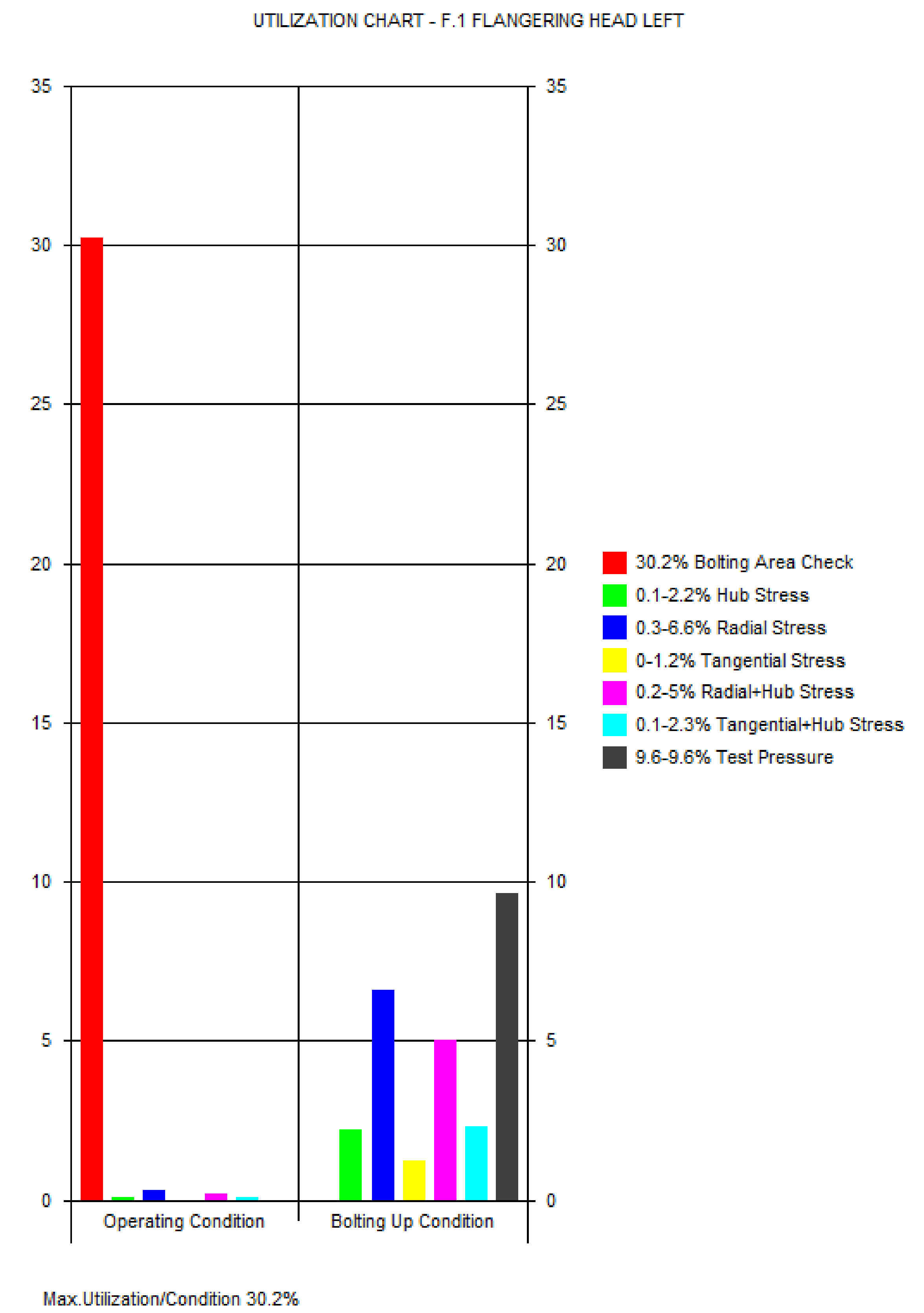
APPENDIX 2-14, FLANGE RIGIDITY

```
Rigidity Index
J = 52.14 * V * M / (L * E * go ^ 2 * 0.3 * ho)
=52.14*0.5501*7.7086E05/(0.9105*200000*39.85^2*0.3*73.43)=  0.0035
```

Test Pressure Ptmin=1.1 <= Ptmax=11.371[MPa]	9.6%	OK

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 3 SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 , the material must be re-selected from the material database.
Warning: Invalid gasket location/dimension.

Volume:0.0005176 m3 Weight:6 kg (SG= 7.85)


UTILIZATION CHART - F.1 FLANGERING HEAD LEFT
35
30
25
20
15
10
5
0
Operating Condition
Bolting Up Condition
30.2% Bolting Area Check
0.1-2.2% Hub Stress
0.3-6.6% Radial Stress
0-1.2% Tangential Stress
0.2-5% Radial+Hub Stress
0.1-2.3% Tangential+Hub Stress
9.6-9.6% Test Pressure
Max.Utilization/Condition 30.2%

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

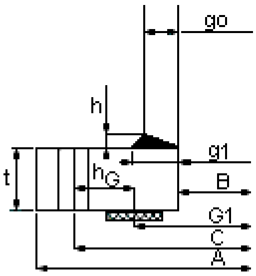
```
Attachment: S1.1    Cylindrical Shell    Main Shell
Location: Along z-axis zo=  0
Include a standard ANSI, DIN or EN flange without performing detailed
calculations.: NO
```

GENERAL DESIGN DATA

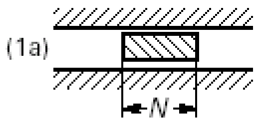
```
PROCESS CARD: Tube Side : Temp= 95°C, P=1.0000 MPa, c=1.0 mm
SPECIFIC DENSITY OF OPERATING LIQUID................:SG        1.0000
LIQUID HEAD.........................................:LH        270.65 mm
B: Pressure loading: Flange under internal pressure
LETHAL SERVICE - APPLY BOLT SPACING CORR.FACTOR TO 2-6 AND RIGIDITY INDEX TO 2-
14.: NO
EXTERNAL LOADS ON FLANGE  (PD5500 ENQ 5500/123): NO
SPECIFY BOLT LOADS FROM 2nd./MATING FLANGE: NO
```

TYPE OF FLANGE AND GASKET FACING

A: Flange Standard: User Specified Flanges



C: Flange Type: RT Ring Type(Smooth or Stepped bore)



D: Flange Facing (Sketch/Description): 1a Flat Face

SHELL/NOZZLE DATA

```
SHELL/NOZZLE SIZE & COMMENT: S1.1
SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 120'C
ST=515 SY=205 SYd=169.6 fs=138 fs20=138 Stest=184.5  (N/mm2)
OUTSIDE DIAMETER OF SHELL/NOZZLE ...................:Do        141.30 mm
WALL THICKNESS OF NOZZLE/SHELL(uncorroded)..........:s1        3.4000 mm
```

FLANGE DATA

```
FLANGE HUB: Flange With Hub
REVERSE FLANGE: No (The bolts are located on the outside)
DESIGN METHOD: A) INTEGRAL FLANGE METHOD
FLANGE BORE: Smooth          .
OUTSIDE DIAMETER OF FLANGE..........................:A         215.00 mm
THICKNESS OF FLANGE(uncorroded).....................:e          36.00 mm
CORROSION ALLOWANCE FOR FLANGE FACE.................:cf          0.00 mm
SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 120'C
ST=450 SY=170 SYd=138.6 SFO=115 SFA=115 Stest=153  (N/mm2)
INCLUDE APPENDIX 2-14, FLANGE RIGIDITY CALCULATION: YES
MODULUS OF ELASTICITY at design temp................:E      2,0E05 N/mm2
MODULUS OF ELASTICITY at ambient temp...............:E20    2,0E05 N/mm2
```

DATA FOR FLANGE HUB

```
LENGTH OF HUB......................................:h          18.00 mm
THICKNESS OF HUB AT BACK OF FLANGE corroded.........:g1         17.50 mm
THICKNESS OF HUB AT SMALL END      corroded.........:go         3.2000 mm
SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 120'C
ST=450 SY=170 SYd=138.6 SHO=115 SHA=115 Stest=153  (N/mm2)
```

BOLTING DATA

```
REDUCE SAFETY AGAINST ABUSE BY CAREFULLY CONTROLLING THE BOLTING-UP TORQUE: NO
BOLTING TORQUE CALCULATION: NO
NOMINAL BOLTING SIZE & COMMENT: M12x1.75 ;
EFFECTIVE BOLT AREA per bolt........................:Ae         76.25 mm2
RECOMMENDED MINIMUM BOLT CENTER TO EDGE CLEARANCE...:Bce        16.00 mm
RECOMMENDED MINIMUM BOLT CENTER/RADIAL CLEARANCE....:Bcr        20.00 mm
DIAMETER OF BOLT HOLES IN FLANGE....................:d          12.00 mm
NUMBER OF BOLTS.....................................:n         4.0000
BOLT-CIRCLE DIAMETER................................:C         180.00 mm
SA-193(M) Gr.B7, G41400 Bolting THK<=100mm 95'C
ST=795 SY=655 SYd=609.57 Sb=159 Sa=159 Stest=589.5  (N/mm2)
```

GASKET DATA

```
Table 2-5.1 Gasket factors m & y   Facing:
Mineral Fiber 1.6 mm thick       m=2.75  Y=25.5  2 1a,1b,1c,1d,4,5
CONTACT WIDTH OF GASKET.............................:N         1.0000 mm
OUTSIDE DIAMETER OF GASKET..........................:Go        132.20 mm
TEMA RGP-RCB-11.7 Include Additional Loads from Pass Partition Plate Gasket: NO
```

CALCULATION DATA

GASKET DETAILS

```
b = MIN VALUE(2.52 * Sqr(bo), bo ) = ==                      0.5000 mm
```

FLANGE LOADS

```
HD = 0.785 * B ^ 2 * p =0.785*136.5^2*1.0027=                  14.67 kN
H = 0.785 * G ^ 2 * p =0.785*131.2^2*1.0027=                   13.55 kN
Hp = (2 * PI * b * G * m) * p
=(2*3.14*0.5*131.2*2.75)*1.0027=                            1.1365 kN
HT = H - HD =13549.03-14665.81=                               -1.12 kN
```

MOMENT ARMS

```
hG = (C - G) / 2 =(180-131.2)/2=                               24.40 mm
hD = (C - B - g1) / 2 =(180-136.5-17.5)/2=                     13.00 mm
hT = (2 * C - B - G) / 4 =(2*180-136.5-131.2)/4=               23.08 mm
```

BOLT LOADS

```
Operating condition
Wop = H + Hp =13549.03+1136.55=                                14.69 kN
Bolting up condition
Wamb = PI * b * G * y =3.14*0.5*131.2*25.5=                   5.2553 kN
```

BOLTING AREA

```
Am1 = Wop / Sb =14685.58/159=                                  92.36 mm2
Am2 = Wamb / Sa =5255.26/159=                                  33.05 mm2
Required Bolting Area Am
Am = MAX( Am1 , Am2) =MAX(92.36,33.05)=                        92.36 mm2
Available Bolting Area Ab
Ab (num.bolts*root area) = n * Ae =4*76.25=                   305.00 mm2
```

Bolting Area Check Ab=305 >= Am=92.36[mm2]	30.2%	OK

```
Bolt Spacing
Bs = C * PI / n =180*3.14/4=                                  141.37 mm
```

```
2-5 Recommended Maximum Bolt Spacing
Bmax = 2 * db + 6 * e / (m + 0.5)
=2*12+6*36/(2.75+0.5)=                                   90.46 mm

W = 0.5 * (Ab + Am) * Sa =0.5*(305+92.36)*159=            31.59 kN
```

FLANGE MOMENTS

```
Mop = HD * hD + HT * hT + HG * hG
=14665.81*13+-1120*23.075+1136.55*24.4=                  192.62 Nm

Mamb = W * hG =31590.29*24.4=                              770.80 Nm

Mo = Mop =192.62=                                          192.62 Nm
Ma = Mamb =770.8=                                          770.80 Nm
```

SHAPE CONSTANTS

```
K = A / B =215/136.5=                                      1.5751
ho=SQR(B*go)= 20.900  h/ho=  0.861  K=A/B=  1.575  g1/go=  5.469
VALUES FOR T,U,Y AND Z FROM FIGURE 2-7.1
T =     1.678  Z =     2.351  Y =     4.448  U =     4.888
F =     0.685  V =     0.047  f =     4.676
d = U / V * ho * go ^ 2 =4.888/0.0467*20.9*3.2^2=          22384.03 mm3
e = F / ho =0.6845/20.9=                                   0.0328 mm-1
L = (t * e + 1) / T + t ^ 3 / d
=(36*0.0328+1)/1.678+36^3/22384.03=                        3.3830
```

OPERATING CONDITION

```
M = Mo =192.62=                                            192.62 Nm
```

Flange Stresses with Flange Thickness e= 36 mm

```
Longitudinal Hub Stress
SH = f * M / (L * g1 ^ 2 * B)
=4.68*192.62/(3.38*17.5^2*136.5)=                          6.3694 N/mm2

Radial Flange Stress
SR = (1.333 * t * e + 1) * M / (L * t ^ 2 * B)
=(1.333*36*0.0328+1)*192.62/(3.38*36^2*136.5)=             0.8277 N/mm2

Tangential Flange Stress
ST = Y * M / (t ^ 2 * B) - (Z * SR)
=4.448*192.62/(36^2*136.5)-(2.351*0.8277)=                 2.8971 N/mm2
```

Stress Limits

Hub Stress SH=6.37 <= 1.5 * MIN(Sf;SfH)=172.5[N/mm2]	3.6%	OK
Radial Stress SR=0.8277 <= Sf=115[N/mm2]	0.7%	OK
Tangential Stress ST=2.9 <= Sf=115[N/mm2]	2.5%	OK
Radial+Hub Stress 0.5*(SH+SR)=3.6 <= Sf=115[N/mm2]	3.1%	OK
Tangential+Hub Stress 0.5*(SH+ST)=4.63 <= Sf=115[N/mm2]	4.0%	OK

APPENDIX 2-14, FLANGE RIGIDITY

```
Rigidity Index
J = 52.14 * V * M / (L * E * go ^ 2 * 0.3 * ho)
=52.14*0.0467*1.9262E05/(3.38*200000*3.2^2*0.3*20.9)=      0.0108
```

BOLTING UP CONDITION

```
M = Ma =770.8=                                             770.80 Nm
```

Flange Stresses with Flange Thickness e= 36 mm

```
Longitudinal Hub Stress
SH = f * M / (L * g1 ^ 2 * B)
=4.68*770.8/(3.38*17.5^2*136.5)=                           25.49 N/mm2

Radial Flange Stress
SR = (1.333 * t * e + 1) * M / (L * t ^ 2 * B)
```

```
=(1.333*36*0.0328+1)*770.8/(3.38*36^2*136.5)=            3.3124 N/mm2

Tangential Flange Stress
ST = Y * M / (t ^ 2 * B) - (Z * SR)
=4.448*770.8/(36^2*136.5)-(2.351*3.31)=                   11.59 N/mm2
```

Stress Limits

Hub Stress SH=25.49 <= 1.5 * MIN(Sf;SfH)=172.5[N/mm2]	14.7%	OK
Radial Stress SR=3.31 <= Sf=115[N/mm2]	2.8%	OK
Tangential Stress ST=11.59 <= Sf=115[N/mm2]	10.0%	OK
Radial+Hub Stress 0.5*(SH+SR)=14.4 <= Sf=115[N/mm2]	12.5%	OK
Tangential+Hub Stress 0.5*(SH+ST)=18.54 <= Sf=115[N/mm2]	16.1%	OK

APPENDIX 2-14, FLANGE RIGIDITY

```
Rigidity Index
J = 52.14 * V * M / (L * E * go ^ 2 * 0.3 * ho)
=52.14*0.0467*7.708E05/(3.38*200000*3.2^2*0.3*20.9)=     0.0432
```

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Ptmin = 1.1 * Pd * Sr / S =1.1*1*115/115=                  1.1000 MPa
```

Test Pressure Ptmin=1.1 <= Ptmax=11.371[MPa]	9.6%	OK

PRESSURE AND TORQUE SUMMARY

Table PRESSURE AND TORQUE SUMMARY FOR F.3 :

Description	Temp(C)	P(MPa)	Limited By	Min.Req.Total Bolt Force(kN)
Design Pressure(corroded)	95	1.00	Bolting Area Check	14.69
Max.Allow.Pressure(corroded)	95	3.31	Bolting Area Check	48.52
Max.Allow.Pressure(corroded)	Ambient	3.31	Bolting Area Check	48.52
Max.Allow.Test Pressure(corroded)	Ambient	11.37	Bolting Area Check	166.54
Required Test Pressure	Ambient	1.10	Bolting Area Check	16.15

The nominal Force and Torque values are based on the following bolting up method:

CALCULATION SUMMARY

BOLTING AREA

Bolting Area Check Ab=305 >= Am=92.36[mm2]	30.2%	OK

OPERATING CONDITION

Flange Stresses with Flange Thickness e= 36 mm

```
Longitudinal Hub Stress
SH = f * M / (L * g1 ^ 2 * B)
=4.68*192.62/(3.38*17.5^2*136.5)=                         6.3694 N/mm2

Radial Flange Stress
SR = (1.333 * t * e + 1) * M / (L * t ^ 2 * B)
=(1.333*36*0.0328+1)*192.62/(3.38*36^2*136.5)=            0.8277 N/mm2

Tangential Flange Stress
ST = Y * M / (t ^ 2 * B) - (Z * SR)
=4.448*192.62/(36^2*136.5)-(2.351*0.8277)=                2.8971 N/mm2
```

Stress Limits

Hub Stress SH=6.37 <= 1.5 * MIN(Sf;SfH)=172.5[N/mm2]	3.6%	OK
Radial Stress SR=0.8277 <= Sf=115[N/mm2]	0.7%	OK
Tangential Stress ST=2.9 <= Sf=115[N/mm2]	2.5%	OK
Radial+Hub Stress 0.5*(SH+SR)=3.6 <= Sf=115[N/mm2]	3.1%	OK
Tangential+Hub Stress 0.5*(SH+ST)=4.63 <= Sf=115[N/mm2]	4.0%	OK

APPENDIX 2-14, FLANGE RIGIDITY

```
Rigidity Index
J = 52.14 * V * M / (L * E * go ^ 2 * 0.3 * ho)
=52.14*0.0467*1.9262E05/(3.38*200000*3.2^2*0.3*20.9)=       0.0108
```

BOLTING UP CONDITION

Flange Stresses with Flange Thickness e= 36 mm

```
Longitudinal Hub Stress
SH = f * M / (L * g1 ^ 2 * B)
=4.68*770.8/(3.38*17.5^2*136.5)=                             25.49 N/mm2

Radial Flange Stress
SR = (1.333 * t * e + 1) * M / (L * t ^ 2 * B)
=(1.333*36*0.0328+1)*770.8/(3.38*36^2*136.5)=               3.3124 N/mm2

Tangential Flange Stress
ST = Y * M / (t ^ 2 * B) - (Z * SR)
=4.448*770.8/(36^2*136.5)-(2.351*3.31)=                      11.59 N/mm2
```

Stress Limits

Hub Stress SH=25.49 <= 1.5 * MIN(Sf;SfH)=172.5[N/mm2]	14.7%	OK
Radial Stress SR=3.31 <= Sf=115[N/mm2]	2.8%	OK
Tangential Stress ST=11.59 <= Sf=115[N/mm2]	10.0%	OK
Radial+Hub Stress 0.5*(SH+SR)=14.4 <= Sf=115[N/mm2]	12.5%	OK
Tangential+Hub Stress 0.5*(SH+ST)=18.54 <= Sf=115[N/mm2]	16.1%	OK

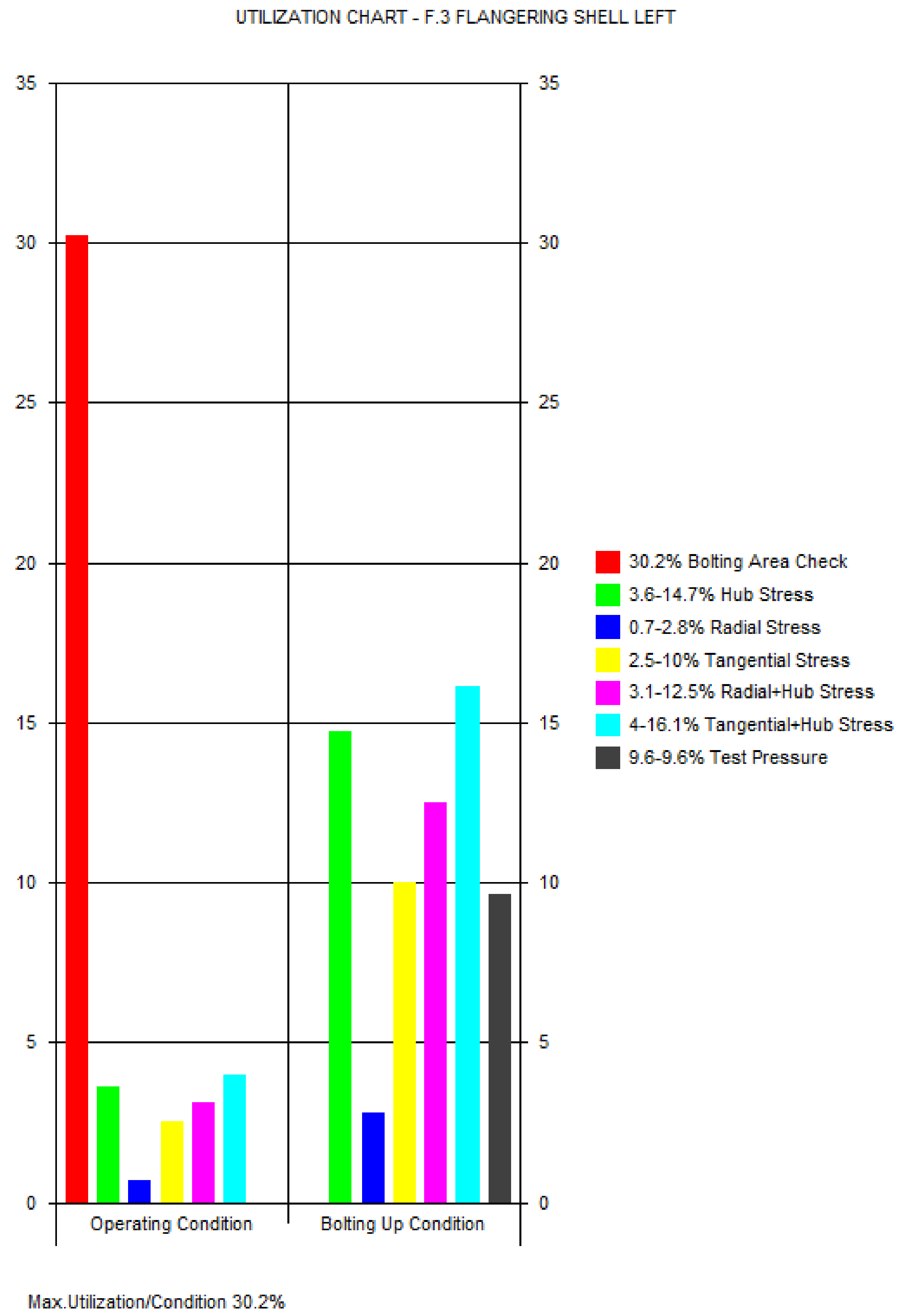
APPENDIX 2-14, FLANGE RIGIDITY

```
Rigidity Index
J = 52.14 * V * M / (L * E * go ^ 2 * 0.3 * ho)
=52.14*0.0467*7.708E05/(3.38*200000*3.2^2*0.3*20.9)=        0.0432
```

Test Pressure Ptmin=1.1 <= Ptmax=11.371[MPa]	9.6%	OK

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 5 SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.
WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 3 SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 , the material must be re-selected from the material database.
Warning: Invalid gasket location/dimension.

Volume:0.0007902 m3 Weight:6 kg (SG= 7.85)

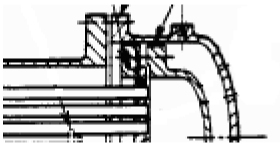

UTILIZATION CHART - F.3 FLANGERING SHELL LEFT
35
30
25
20
15
10
5
0
Operating Condition
Bolting Up Condition
30.2% Bolting Area Check
3.6-14.7% Hub Stress
0.7-2.8% Radial Stress
2.5-10% Tangential Stress
3.1-12.5% Radial+Hub Stress
4-16.1% Tangential+Hub Stress
9.6-9.6% Test Pressure
Max.Utilization/Condition 30.2%

INPUT DATA

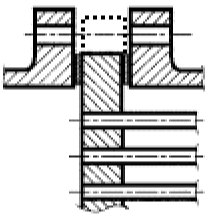
COMPONENT ATTACHMENT/LOCATION

Attachment: F.3 RT - Flange Flangering Shell left S1.1
Location: Along z-axis z1= -54

GENERAL DESIGN DATA



Type of Heat Exchanger: UHX-14 Floating Tubesheet Heat Exchangers
Type of Tubesheet: Stationary Tubesheet
Type of Floating Tubesheet Exchanger: With Immersed Floating Head



Configuration Type: d1 Tubesheet gasketed with shell and channel
UHX-14.6 Calc.Procedure for Effect of Radial Differential Thermal Exp. Adj.to Tubesheet: NO

LOAD CASES (LC)

Table LOAD CASES:

Description	ID	=LC1=	=LC2=	=LC3=
Shell-Side Pressure (MPa)	Ps	0	2.82	2.82
Tube-Side Pressure (MPa)	Pt	1	0	1
Shell-Side Corr.Allow. (mm)	cs	1	1	1
Tube-Side Corr.Allow. (mm)	ct	1	1	1
Thermal Stress Factor	MdT	0	0	0
Mean Shell Temperature ('C)	Tsm	NA	NA	NA
Mean Tube Temperature ('C)	Ttm	NA	NA	NA

=LC1=: =LC1=
=LC2=: =LC2=
=LC3=: =LC3=

ALLOWBALE STRESS FOR EACH LOAD CASE

Material Design Temperatures:
Select material design temperatures from the process card.
Ttubesheet= 210, Tshell= 210, Ttube= 210, Tchannel= 95(all values in °C)

Table LOAD CASES:

Description	ID	=LC1=	=LC2=	=LC3=
Allowable Stress M Factor	Mf	1.0	1.0	1.0

DATA FOR TUBESHEET

```
SB-148(M), M01, C95820 Castings 204'C
ST=650 SY=270 Sy=259.84 S=167.52 Sr=179 Stest=243  (N/mm2)
OUTSIDE DIAMETER OF TUBESHEET(Ref. UHX-10(b)).......:A         132.20 mm
NOMINAL THICKNESS OF TUBESHEET (uncorroded).........:hn         28.00 mm
ELASTIC MODULUS OF TUBESHEET at tubesheet design temp.:E    1,894E05 N/mm2
POISSON'S RATIO FOR TUBESHEET MATERIAL..............:v         0.3000
```

DATA FOR TUBES AND TUBES LAYOUT

```
Tube Layout: Triangular Pattern
SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8 100'C
ST=485 SY=170 Syt=145 St=115 Sr=115 Stest=153  (N/mm2)
ELASTIC MODULUS OF TUBES at tube design temp........:Et     1,8621E05 N/mm2
NOMINAL OUTSIDE DIAMETER OF TUBES...................:dt        7.5000 mm
TUBE SIZE & COMMENT: S1.2
NOMINAL THICKNESS OF TUBES..........................:tt        0.5000 mm
TUBE PITCH (Spacing between centers)................:p          11.50 mm
DIAMETER OF TUBEHOLE IN TUBESHEET...................:dh        8.0000 mm
DIAMETER OF OUTER TUBE LIMIT CIRCLE.................:Do        123.00 mm
NUMBER OF TUBEHOLES IN TUBESHEET....................:Nt         72.00 piec
TOTAL AREA OF UNTUBED LANES(UL1*Ll1+UL2*Ll2+..).....:AL      1600.00 mm2
TUBE EXPANSION DEPTH RATIO (0<=ro<=1.0).............:ro       1.0000
TUBE-SIDE PASS PARTITION GROOVE DEPTH(Fig.UHX-11.1).:hg       1.0000 mm
THERMAL EXPANSION COEF.OF TUBES at mean metal temp..:atm    1,614E-05 mm/mmC
TUBE BUCKLING LENGTH lt=l*k (Ref. UHX-13.5.9(b)(1)).:lt       1.0000 mm
TUBE LENGTH BETWEEN INNER FACES OF TUBESHEETS.......:L        800.00 mm
POISSON'S RATIO FOR TUBE MATERIAL...................:vt       0.3000
PERIMETER OF THE TUBE LAYOUT MEASURED CENTER ON OUTER MOST TUBES:Cp     0.00 mm
TOTAL AREA ENCLOSED BY Cp...........................:Ap         0.00 mm2
```

DATA FOR TUBE TO TUBESHEET JOINT

```
Tube to Tubesheet Weld: Full Strength Weld to UW-20.4
Qualification of Tube-to-Tubesheet Joint: The Joint IS Qualified by Tests
FIG. UW-20.1 Weld Types: Sketch a) Fillet Weld
TUBE TO TUBESHEET FILLET WELD LEG...................:af       1.0000 mm
```

SHELL DATA

```
SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 120'C
ST=515 SY=205 Sys=169.6 Ss=138 Sr=138 Stest=184.5  (N/mm2)
INSIDE DIAMETER OF SHELL(corroded)..................:Ds       133.30 mm
THICKNESS OF SHELL (uncorroded).....................:ts       3.2000 mm
ELASTIC MODULUS OF SHELL MATERIAL at shell design temp:Es   1,8621E05 N/mm2
POISSON'S RATIO FOR SHELL MATERIAL..................:vs       0.3000
```

CHANNEL DATA

```
SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 120'C
ST=515 SY=205 Syc=169.6 Sc=138 Sr=138 Stest=184.5  (N/mm2)
INSIDE DIAMETER OF CHANNEL(corroded)................:Dc       133.30 mm
THICKNESS OF CHANNEL (uncorroded)...................:tc       3.2000 mm
ELASTIC MODULUS OF CHANNEL at channel design temp...:Ec     1,8833E05 N/mm2
POISSON'S RATIO FOR CHANNEL MATERIAL................:vc       0.3000
```

FLANGE DATA

```
DIAMETER OF SHELL GASKET LOAD REACTION..............:Gs       152.00 mm
SHELL FLANGE DESIGN BOLT LOAD FOR ASSEMBLY COND.....:Ws        53.00 kN
SHELL FLANGE DESIGN BOLT LOAD FOR OPERATING COND....:Wm1s      53.00 kN
DIAMETER OF CHANNEL GASKET LOAD REACTION............:Gc       152.00 mm
CHANNEL FLANGE DESIGN BOLT LOAD FOR ASSEMBLY COND...:Wc        53.00 kN
CHANNEL FLANGE DESIGN BOLT LOAD FOR OPERATING COND..:Wm1c      53.00 kN
BOLT-CIRCLE DIAMETER................................:C        152.00 mm
```

CALCULATION DATA

LOAD CASE:=LC1==LC1=

PRELIMINARY CALCULATIONS

UW-20 TUBE-TO-TUBESHEET WELDS

```
Allowable Stress in Weld
Sw = MIN( S , St) =MIN(167.52,115)=                        115.00 N/mm2
Weld Strength Factor
fw = St / Sw =115/115=                                     1.0000
Axial Tube Strength
Ft = PI * tt * (dt - tt) * St =3.14*0.5*(7.5-0.5)*115=     1264.49 N

Minimum Required Length of the Weld Leg
ar = Sqr((0.75*dt)^2+2.73*tt*(dt-tt)*fw*fd)-0.75*dt
=Sqr((0.75*7.5)^2+2.73*0.5*(7.5-0.5)*1*1)-0.75*7.5=       0.7934 mm
Minimum Required Size of Fillet Weld Leg
afmin = MAX( ar, tt) =MAX(0.7934,0.5)=                     0.7934 mm

Fillet Weld Strength
Ff = MIN( 0.55 * PI * af * (dt + 0.67 * af) * Sw , Ft)
=MIN(0.55*3.14*1*(7.5+0.67*1)*115,1264.49)=              1264.49 N
```

TABLE UHX-8.1 TUBESHEET EFFECTIVE BOLT LOAD W*=Wm1c= 53.00kN

```
Tubesheet Analysis Thickness h
h = hn - ct - cs =28-1-1=                                   26.00 mm
```

UHX-11.5.1 Determination of Effective Dimensions and Ligament Efficiency

```
Basic efficiency for shear
my = (p - dt) / p =(11.5-7.5)/11.5=                        0.3478
Effective Tube Hole Diameter (dstar)
dstar = MAX(dt-2*tt*(Et/E)*(St/S)*ro,dt-2*tt)
=MAX(7.5-2*0.5*(186212/189400)*(115/167.52)*1,7.5-2*0.5)=   6.8251 mm
Effective Pitch(pstar)
pstar = p/Sqr(1-4*MIN(AL,4*Do*p)/(PI*Do^2))
=11.5/Sqr(1-4*MIN(1600,4*123*11.5)/(3.14*123^2))=          12.36 mm
Mystar = (pstar - dstar) / pstar =(12.36-6.83)/12.36=      0.4479
```

UHX-11.5.2 Determination of Effective Elastic Properties Estar and vstar

```
EstarOverE(Estar/E) from figure UHX-11.3a) =  0.4763(h/p=2.26)
Estar = EstarOverE * E =0.4763*189400=                    90213.95 N/mm2
vstar from figure UHX-11.3b) =  0.3032(h/p=2.26)
```

UHX-14.5.1 Step 1

```
Radial Channel Dimension ac
ac = Gc / 2 =152/2=                                         76.00 mm
Radial Shell Dimension as
as = Gs / 2 =152/2=                                         76.00 mm
Parameters
ao = Do / 2 =123/2=                                         61.50 mm
Diameter Ratio ros for Shell
ros = as / ao =76/61.5=                                    1.2358
Diameter Ratio roc for Channel
roc = ac / ao =76/61.5=                                    1.2358
Tubesheet Drilling Coefficients
xs = 1 - Nt * (dt / (2 * ao)) ^ 2
=1-72*(7.5/(2*61.5))^2=                                   0.7323
xt = 1 - Nt * ((dt - 2 * tt) / (2 * ao)) ^ 2
=1-72*((7.5-2*0.5)/(2*61.5))^2=                           0.7989
```

UHX-14.5.2 Step 2, Shell and Tube Axial Stiffness

UHX-14.5.3 Step 3, Tube Bundle to Tubesheet Rigidity Ratio

```
Xa = (24*(1-vstar^2)*Nt*Et*tt*(dt-tt)*ao^2/(Estar*L*h^3))^0.25
=(24*(1-0.3032^2)*72*186212*0.5*(7.5-0.5)*61.5^2/(90213.95*800*26^3))^0.25
=   1.3214
Zd (from figure UHX-13.2) =  0.7123
Zv (from figure UHX-13.2) =  0.1859
Zw (from figure UHX-13.2) =  0.1859
Zm (from figure UHX-13.2) =  0.7493
```

UHX-14.5.4 Step 4, Ratio K and Parameters F, Phi, Q and U

```
Diameter Ratio K
K = A / Do =132.2/123=                                        1.0748
F = (1 - vstar) / Estar * (LamdaS + LamdaC + E * Log( K))
=(1-0.3032)/90213.95*(0+0+189400*Log(1.07))=                0.1055
phi = (1 + vstar) * F =(1+0.3032)*0.1055=                     0.1375
Q1 = (ros - 1 - phi * Zv) / (1 + phi * Zm)
=(1.24-1-0.1375*0.1859)/(1+0.1375*0.7493)=                  0.1906
```

UHX-14.5.5 Step 5

```
Omegas = ros * ks * Betas * Deltas * (1 + h * Betas)
=1.24*0*0*0*(1+26*0)=                                         0.00 mm2
Omegasstar = ao ^ 2 * (ros ^ 2 - 1) * (ros - 1) / 4 - Omegas
=61.5^2*(1.24^2-1)*(1.24-1)/4-0=                            117.52 mm2
Omegac = roc * kc * Betac * Deltac * (1 + h * Betac)
=1.24*0*0*0*(1+26*0)=                                         0.00 mm2
Omegacstar = ao^2*((roc^2+1)*(roc-1)/4-(ros-1)/2)-Omegac
=61.5^2*((1.24^2+1)*(1.24-1)/4-(1.24-1)/2)-0=               117.52 mm2
yb = (Gc - Gs) / Do =(152-152)/123=                             0.00 mm
Psstar = 0 =0=                                                  0.00 MPa
Pcstar = 0 =0=                                                  0.00 MPa
```

UHX-14.5.6 Step 6

```
Effective Pressure Pe
Pe = Ps - Pt =0-1=                                            -1 MPa
```

UHX-14.5.7 Step 7

```
Q2 = (Omegasstar*Ps-Omegacstar*Pt+yb/(2*PI)*Wstar)/(1+phi*Zm)
=(117.52*0-117.52*1+0/(2*3.14)*53000)/(1+0.1375*0.7493)=  -106.54 N
Q3 = Q1 + 2 * Q2 / (Pe * ao ^ 2)
=0.1906+2*-106.54/(-1*61.5^2)=                              0.2469
Fm = MAX(Fm(x)) (from Table UHX-13.1) =  0.3141
```

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.3141/0.4479*(2*61.5/(26-0))^2*-1=                   -23.54 N/mm2
```

Tubesheet Bending Stress Sigma=23.54 <= 1.5 * S=251.28[N/mm2]	9.3%	OK

UHX-14.5.8 Step 8, Shear Stress in Tubesheet (Tau)

```
UHX-14.5.8(a) Tau is not required to be calculated since ABS(Pe) < 1.6 * s_0 * my
* H_1 / ao ;     1.000 <     39.414 (MPa)
```

Tubesheet Shear Stress Tau=0 <= MIN(0.8*S, 0.533*Sy)=134.02[N/mm2]	0.0%	OK

UHX-14.5.9 Step 9, Tube Design

```
Ftmin = MIN(Ft(x)) (from Table UHX-13.2) =  0.8300
Ftmax = MAX(Ft(x)) (from Table UHX-13.2) =  1.1559
```

Axial Tube Stress (Pe <> 0)

```
Sigt1 = (Ps * xs - Pt * xt - Pe * Ftmin) / (xt - xs)
=(0*0.7323-1*0.7989--1*0.83)/(0.7989-0.7323)=            0.4658 N/mm2

Sigt2 = (Ps * xs - Pt * xt - Pe * Ftmax) / (xt - xs)
=(0*0.7323-1*0.7989--1*1.16)/(0.7989-0.7323)=            5.3583 N/mm2

SigtMax = MAX( Sigt1 , Sigt2) =MAX(0.4658,5.36)=           5.3583 N/mm2
```

Tube Axial Stress SigtMax=5.36 <= St=115[N/mm2]	4.6%	OK

```
Largest Tube-to-Tubesheet Joint Load, Wt
Wt = PI * (dt - tt) * tt * SigtMax
=3.14*(7.5-0.5)*0.5*5.36=                                   58.92 N
```

Tube Weld Max.Axial Load Wt=58.92 <= Lmax=1264.49[N] (UW-20)	4.6%	OK

UHX-14.5.10 Step 10, Stresses in Shell

```
Axial Membrane Stress Sigsm
Sigsm = (ao^2*(Pe+(ros^2-1)*(Ps-Pt))+as^2*Pt)/(Gs*ts)
=(61.5^2*(-1+(1.24^2-1)*(0-1))+76^2*1)/(152*2.2)=      -3,793E-07 N/mm2

Temp1 = Betas * Deltas * Ps =0*0*0=                          0.00
Temp2 = 6*(1-vstar^2)/Estar*(ao^3/h^3)*(1+h*Betas/2)
=6*(1-0.3032^2)/90213.95*(61.5^3/26^3)*(1+26*0/2)=     7,9927E-04
Temp3 = Pe * (Zv + Zm * Q1) + 2 / ao ^ 2 * Zm * Q2
=-1*(0.1859+0.7493*0.1906)+2/61.5^2*0.7493*-106.54=       -0.3709
Axial Bending Stress Sigsb
Sigsb = 6 * ks / ts ^ 2 * (Temp1 + Temp2 * Temp3)
=6*0/2.2^2*(0+7.9927E-04*-0.3709)=                          0.00 N/mm2

Total Axial Stress Sigs
Sigs = ABS( Sigsm) + ABS( Sigsb)
=ABS(-3.793E-07)+ABS(0)=                               3,793E-07 N/mm2
```

Total Axial Shell Stress Sigs=3.793E-07 <= 1.5 * Ss=207[N/mm2]	0.0%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

LOAD CASE:=LC2==LC2=

PRELIMINARY CALCULATIONS

UW-20 TUBE-TO-TUBESHEET WELDS

```
Allowable Stress in Weld
Sw = MIN( S , St) =MIN(167.52,115)=                         115.00 N/mm2
Weld Strength Factor
fw = St / Sw =115/115=                                      1.0000
Axial Tube Strength
Ft = PI * tt * (dt - tt) * St =3.14*0.5*(7.5-0.5)*115=     1264.49 N

Minimum Required Length of the Weld Leg
ar = Sqr((0.75*dt)^2+2.73*tt*(dt-tt)*fw*fd)-0.75*dt
=Sqr((0.75*7.5)^2+2.73*0.5*(7.5-0.5)*1*1)-0.75*7.5=        0.7934 mm
Minimum Required Size of Fillet Weld Leg
afmin = MAX( ar, tt) =MAX(0.7934,0.5)=                      0.7934 mm

Fillet Weld Strength
Ff = MIN( 0.55 * PI * af * (dt + 0.67 * af) * Sw , Ft)
=MIN(0.55*3.14*1*(7.5+0.67*1)*115,1264.49)=              1264.49 N
```

TABLE UHX-8.1 TUBESHEET EFFECTIVE BOLT LOAD W*=Wm1s= 53.00kN

```
Tubesheet Analysis Thickness h
h = hn - ct - cs =28-1-1=                                      26.00 mm
```

UHX-11.5.1 Determination of Effective Dimensions and Ligament Efficiency

```
Basic efficiency for shear
my = (p - dt) / p =(11.5-7.5)/11.5=                           0.3478
Effective Tube Hole Diameter (dstar)
dstar = MAX(dt-2*tt*(Et/E)*(St/S)*ro,dt-2*tt)
=MAX(7.5-2*0.5*(186212/189400)*(115/167.52)*1,7.5-2*0.5)=   6.8251 mm
Effective Pitch(pstar)
pstar = p/Sqr(1-4*MIN(AL,4*Do*p)/(PI*Do^2))
=11.5/Sqr(1-4*MIN(1600,4*123*11.5)/(3.14*123^2))=           12.36 mm
Mystar = (pstar - dstar) / pstar =(12.36-6.83)/12.36=         0.4479
```

UHX-11.5.2 Determination of Effective Elastic Properties Estar and vstar

```
EstarOverE(Estar/E) from figure UHX-11.3a) =  0.4763(h/p=2.26)
Estar = EstarOverE * E =0.4763*189400=                      90213.95 N/mm2
vstar from figure UHX-11.3b) =  0.3032(h/p=2.26)
```

UHX-14.5.1 Step 1

```
Radial Channel Dimension ac
ac = Gc / 2 =152/2=                                            76.00 mm
Radial Shell Dimension as
as = Gs / 2 =152/2=                                            76.00 mm
Parameters
ao = Do / 2 =123/2=                                            61.50 mm
Diameter Ratio ros for Shell
ros = as / ao =76/61.5=                                       1.2358
Diameter Ratio roc for Channel
roc = ac / ao =76/61.5=                                       1.2358
Tubesheet Drilling Coefficients
xs = 1 - Nt * (dt / (2 * ao)) ^ 2
=1-72*(7.5/(2*61.5))^2=                                     0.7323
xt = 1 - Nt * ((dt - 2 * tt) / (2 * ao)) ^ 2
=1-72*((7.5-2*0.5)/(2*61.5))^2=                             0.7989
```

UHX-14.5.2 Step 2, Shell and Tube Axial Stiffness

UHX-14.5.3 Step 3, Tube Bundle to Tubesheet Rigidity Ratio

```
Xa = (24*(1-vstar^2)*Nt*Et*tt*(dt-tt)*ao^2/(Estar*L*h^3))^0.25
=(24*(1-0.3032^2)*72*186212*0.5*(7.5-0.5)*61.5^2/(90213.95*800*26^3))^0.25
=   1.3214
Zd (from figure UHX-13.2) =  0.7123
Zv (from figure UHX-13.2) =  0.1859
Zw (from figure UHX-13.2) =  0.1859
Zm (from figure UHX-13.2) =  0.7493
```

UHX-14.5.4 Step 4, Ratio K and Parameters F, Phi, Q and U

```
Diameter Ratio K
K = A / Do =132.2/123=                                        1.0748
F = (1 - vstar) / Estar * (LamdaS + LamdaC + E * Log( K))
=(1-0.3032)/90213.95*(0+0+189400*Log(1.07))=                0.1055
phi = (1 + vstar) * F =(1+0.3032)*0.1055=                     0.1375
Q1 = (ros - 1 - phi * Zv) / (1 + phi * Zm)
=(1.24-1-0.1375*0.1859)/(1+0.1375*0.7493)=                  0.1906
```

UHX-14.5.5 Step 5

```
Omegas = ros * ks * Betas * Deltas * (1 + h * Betas)
=1.24*0*0*0*(1+26*0)=                                         0.00 mm2
Omegasstar = ao ^ 2 * (ros ^ 2 - 1) * (ros - 1) / 4 - Omegas
=61.5^2*(1.24^2-1)*(1.24-1)/4-0=                            117.52 mm2
Omegac = roc * kc * Betac * Deltac * (1 + h * Betac)
=1.24*0*0*0*(1+26*0)=                                         0.00 mm2
```

```
Omegacstar = ao^2*((roc^2+1)*(roc-1)/4-(ros-1)/2)-Omegac
=61.5^2*((1.24^2+1)*(1.24-1)/4-(1.24-1)/2)-0=           117.52 mm2
yb = (Gc - Gs) / Do =(152-152)/123=                         0.00 mm
Psstar = 0 =0=                                              0.00 MPa
Pcstar = 0 =0=                                              0.00 MPa
```

UHX-14.5.6 Step 6

```
Effective Pressure Pe
Pe = Ps - Pt =2.82-0=                                     2.8200 MPa
```

UHX-14.5.7 Step 7

```
Q2 = (Omegasstar*Ps-Omegacstar*Pt+yb/(2*PI)*Wstar)/(1+phi*Zm)
=(117.52*2.82-117.52*0+0/(2*3.14)*53000)/(1+0.1375*0.7493)=   300.44 N
Q3 = Q1 + 2 * Q2 / (Pe * ao ^ 2)
=0.1906+2*300.44/(2.82*61.5^2)=                         0.2469
Fm = MAX(Fm(x)) (from Table UHX-13.1) =  0.3141
```

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.3141/0.4479*(2*61.5/(26-0))^2*2.82=               66.38 N/mm2
```

Tubesheet Bending Stress Sigma=66.38 <= 1.5 * S=251.28[N/mm2]	26.4%	OK

UHX-14.5.8 Step 8, Shear Stress in Tubesheet (Tau)

```
UHX-14.5.8(a) Tau is not required to be calculated since ABS(Pe) < 1.6 * s_0 * my
* H_1 / ao ;     2.820 <     39.414 (MPa)
```

Tubesheet Shear Stress Tau=0 <= MIN(0.8*S, 0.533*Sy)=134.02[N/mm2]	0.0%	OK

UHX-14.5.9 Step 9, Tube Design

```
Ftmin = MIN(Ft(x)) (from Table UHX-13.2) =  0.8300
Ftmax = MAX(Ft(x)) (from Table UHX-13.2) =  1.1559
```

Axial Tube Stress (Pe <> 0)

```
Sigt1 = (Ps * xs - Pt * xt - Pe * Ftmin) / (xt - xs)
=(2.82*0.7323-0*0.7989-2.82*0.83)/(0.7989-0.7323)=       -4.13 N/mm2
Sigt2 = (Ps * xs - Pt * xt - Pe * Ftmax) / (xt - xs)
=(2.82*0.7323-0*0.7989-2.82*1.16)/(0.7989-0.7323)=       -17.93 N/mm2
SigtMax = MAX( Sigt1 , Sigt2) =MAX(-4.13,-17.93)=           17.93 N/mm2
```

Tube Axial Stress SigtMax=17.93 <= St=115[N/mm2]	15.5%	OK

```
Largest Tube-to-Tubesheet Joint Load, Wt
Wt = PI * (dt - tt) * tt * SigtMax
=3.14*(7.5-0.5)*0.5*17.93=                              197.15 N
```

Tube Weld Max.Axial Load Wt=197.15 <= Lmax=1264.49[N] (UW-20)	15.5%	OK

UHX-14.5.9(b) Tube Buckling Check

```
rt = Sqr( dt ^ 2 + (dt - 2 * tt) ^ 2) / 4
=Sqr(7.5^2+(7.5-2*0.5)^2)/4=                            2.4812 mm
Ft = lt / rt =1/2.48=                                     0.4030
Ct = Sqr( 2 * PI ^ 2 * Et / Syt)
=Sqr(2*3.14^2*186212/145)=                              159.22
Fs = MIN(2.0,MAX(3.25-0.25*(Zd+Q3*Zw)*Xa^4,1.25))
=MIN(2.0,MAX(3.25-0.25*(0.7123+0.2469*0.1859)*1.32^4,1.25))=   2.0000

UHX-14.5.9(b)(3)(b) Maximum Permissable Buckling Stress Stb
Stb = MIN( Syt / Fs * (1 - Ft / (2 * Ct)), St)
=MIN(145/2*(1-0.403/(2*159.22,))115)=                    72.41 N/mm2
```

Tube Buckling Stress SigtMin=17.93 <= Stb=72.41[N/mm2]	24.7%	OK

UHX-14.5.10 Step 10, Stresses in Shell

```
Axial Membrane Stress Sigsm
Sigsm = (ao^2*(Pe+(ros^2-1)*(Ps-Pt))+as^2*Pt)/(Gs*ts)
=(61.5^2*(2.82+(1.24^2-1)*(2.82-0))+76^2*0)/(152*2.2)=      48.71 N/mm2
Temp1 = Betas * Deltas * Ps =0*0*2.82=                           0.00
Temp2 = 6*(1-vstar^2)/Estar*(ao^3/h^3)*(1+h*Betas/2)
=6*(1-0.3032^2)/90213.95*(61.5^3/26^3)*(1+26*0/2)=      7,9927E-04
Temp3 = Pe * (Zv + Zm * Q1) + 2 / ao ^ 2 * Zm * Q2
=2.82*(0.1859+0.7493*0.1906)+2/61.5^2*0.7493*300.44=       1.0458
Axial Bending Stress Sigsb
Sigsb = 6 * ks / ts ^ 2 * (Temp1 + Temp2 * Temp3)
=6*0/2.2^2*(0+7.9927E-04*1.05)=                             0.00 N/mm2
Total Axial Stress Sigs
Sigs = ABS( Sigsm) + ABS( Sigsb) =ABS(48.71)+ABS(0)=          48.71 N/mm2
```

Total Axial Shell Stress Sigs=48.71 <= 1.5 * Ss=207[N/mm2]	23.5%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

LOAD CASE:=LC3==LC3=

PRELIMINARY CALCULATIONS

UW-20 TUBE-TO-TUBESHEET WELDS

```
Allowable Stress in Weld
Sw = MIN( S , St) =MIN(167.52,115)=                            115.00 N/mm2
Weld Strength Factor
fw = St / Sw =115/115=                                         1.0000
Axial Tube Strength
Ft = PI * tt * (dt - tt) * St =3.14*0.5*(7.5-0.5)*115=      1264.49 N
Minimum Required Length of the Weld Leg
ar = Sqr((0.75*dt)^2+2.73*tt*(dt-tt)*fw*fd)-0.75*dt
=Sqr((0.75*7.5)^2+2.73*0.5*(7.5-0.5)*1*1)-0.75*7.5=        0.7934 mm
Minimum Required Size of Fillet Weld Leg
afmin = MAX( ar, tt) =MAX(0.7934,0.5)=                        0.7934 mm
Fillet Weld Strength
Ff = MIN( 0.55 * PI * af * (dt + 0.67 * af) * Sw , Ft)
=MIN(0.55*3.14*1*(7.5+0.67*1)*115,1264.49)=               1264.49 N
```

TABLE UHX-8.1 TUBESHEET EFFECTIVE BOLT LOAD W*=Wm1max= 53.00kN

```
Tubesheet Analysis Thickness h
h = hn - ct - cs =28-1-1=                                       26.00 mm
```

UHX-11.5.1 Determination of Effective Dimensions and Ligament Efficiency

```
Basic efficiency for shear
my = (p - dt) / p =(11.5-7.5)/11.5=                            0.3478
Effective Tube Hole Diameter (dstar)
dstar = MAX(dt-2*tt*(Et/E)*(St/S)*ro,dt-2*tt)
=MAX(7.5-2*0.5*(186212/189400)*(115/167.52)*1,7.5-2*0.5)=   6.8251 mm
Effective Pitch(pstar)
pstar = p/Sqr(1-4*MIN(AL,4*Do*p)/(PI*Do^2))
=11.5/Sqr(1-4*MIN(1600,4*123*11.5)/(3.14*123^2))=          12.36 mm
Mystar = (pstar - dstar) / pstar =(12.36-6.83)/12.36=         0.4479
```

UHX-11.5.2 Determination of Effective Elastic Properties Estar and vstar

```
EstarOverE(Estar/E) from figure UHX-11.3a) =  0.4763(h/p=2.26)
Estar = EstarOverE * E =0.4763*189400=                    90213.95 N/mm2
vstar from figure UHX-11.3b) =  0.3032(h/p=2.26)
```

UHX-14.5.1 Step 1

```
Radial Channel Dimension ac
ac = Gc / 2 =152/2=                                          76.00 mm
Radial Shell Dimension as
as = Gs / 2 =152/2=                                          76.00 mm
Parameters
ao = Do / 2 =123/2=                                          61.50 mm
Diameter Ratio ros for Shell
ros = as / ao =76/61.5=                                     1.2358
Diameter Ratio roc for Channel
roc = ac / ao =76/61.5=                                     1.2358
Tubesheet Drilling Coefficients
xs = 1 - Nt * (dt / (2 * ao)) ^ 2
=1-72*(7.5/(2*61.5))^2=                                   0.7323
xt = 1 - Nt * ((dt - 2 * tt) / (2 * ao)) ^ 2
=1-72*((7.5-2*0.5)/(2*61.5))^2=                           0.7989
```

UHX-14.5.2 Step 2, Shell and Tube Axial Stiffness

UHX-14.5.3 Step 3, Tube Bundle to Tubesheet Rigidity Ratio

```
Xa = (24*(1-vstar^2)*Nt*Et*tt*(dt-tt)*ao^2/(Estar*L*h^3))^0.25
=(24*(1-0.3032^2)*72*186212*0.5*(7.5-0.5)*61.5^2/(90213.95*800*26^3))^0.25
=   1.3214
Zd (from figure UHX-13.2) =  0.7123
Zv (from figure UHX-13.2) =  0.1859
Zw (from figure UHX-13.2) =  0.1859
Zm (from figure UHX-13.2) =  0.7493
```

UHX-14.5.4 Step 4, Ratio K and Parameters F, Phi, Q and U

```
Diameter Ratio K
K = A / Do =132.2/123=                                      1.0748
F = (1 - vstar) / Estar * (LamdaS + LamdaC + E * Log( K))
=(1-0.3032)/90213.95*(0+0+189400*Log(1.07))=              0.1055
phi = (1 + vstar) * F =(1+0.3032)*0.1055=                   0.1375
Q1 = (ros - 1 - phi * Zv) / (1 + phi * Zm)
=(1.24-1-0.1375*0.1859)/(1+0.1375*0.7493)=                0.1906
```

UHX-14.5.5 Step 5

```
Omegas = ros * ks * Betas * Deltas * (1 + h * Betas)
=1.24*0*0*0*(1+26*0)=                                       0.00 mm2
Omegasstar = ao ^ 2 * (ros ^ 2 - 1) * (ros - 1) / 4 - Omegas
=61.5^2*(1.24^2-1)*(1.24-1)/4-0=                          117.52 mm2
Omegac = roc * kc * Betac * Deltac * (1 + h * Betac)
=1.24*0*0*0*(1+26*0)=                                       0.00 mm2
Omegacstar = ao^2*((roc^2+1)*(roc-1)/4-(ros-1)/2)-Omegac
=61.5^2*((1.24^2+1)*(1.24-1)/4-(1.24-1)/2)-0=             117.52 mm2
yb = (Gc - Gs) / Do =(152-152)/123=                           0.00 mm
Psstar = 0 =0=                                                0.00 MPa
Pcstar = 0 =0=                                                0.00 MPa
```

UHX-14.5.6 Step 6

```
Effective Pressure Pe
Pe = Ps - Pt =2.82-1=                                       1.8200 MPa
```

UHX-14.5.7 Step 7

```
Q2 = (Omegasstar*Ps-Omegacstar*Pt+yb/(2*PI)*Wstar)/(1+phi*Zm)
=(117.52*2.82-117.52*1+0/(2*3.14)*53000)/(1+0.1375*0.7493)=   193.90 N
Q3 = Q1 + 2 * Q2 / (Pe * ao ^ 2)
=0.1906+2*193.9/(1.82*61.5^2)=                            0.2469
```

```
Fm = MAX(Fm(x)) (from Table UHX-13.1) =  0.3141
```

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.3141/0.4479*(2*61.5/(26-0))^2*1.82=                 42.84 N/mm2
```

Tubesheet Bending Stress Sigma=42.84 <= 1.5 * S=251.28[N/mm2]	17.0%	OK

UHX-14.5.8 Step 8, Shear Stress in Tubesheet (Tau)

```
UHX-14.5.8(a) Tau is not required to be calculated since ABS(Pe) < 1.6 * s_0 * my
* H_1 / ao ;     1.820 <     39.414 (MPa)
```

Tubesheet Shear Stress Tau=0 <= MIN(0.8*S, 0.533*Sy)=134.02[N/mm2]	0.0%	OK

UHX-14.5.9 Step 9, Tube Design

```
Ftmin = MIN(Ft(x)) (from Table UHX-13.2) =  0.8300
Ftmax = MAX(Ft(x)) (from Table UHX-13.2) =  1.1559
```

Axial Tube Stress (Pe <> 0)

```
Sigt1 = (Ps * xs - Pt * xt - Pe * Ftmin) / (xt - xs)
=(2.82*0.7323-1*0.7989-1.82*0.83)/(0.7989-0.7323)=         -3.67 N/mm2

Sigt2 = (Ps * xs - Pt * xt - Pe * Ftmax) / (xt - xs)
=(2.82*0.7323-1*0.7989-1.82*1.16)/(0.7989-0.7323)=        -12.57 N/mm2

SigtMax = MAX( Sigt1 , Sigt2) =MAX(-3.67,-12.57)=            12.57 N/mm2
```

Tube Axial Stress SigtMax=12.57 <= St=115[N/mm2]	10.9%	OK

```
Largest Tube-to-Tubesheet Joint Load, Wt
Wt = PI * (dt - tt) * tt * SigtMax
=3.14*(7.5-0.5)*0.5*12.57=                                 138.24 N
```

Tube Weld Max.Axial Load Wt=138.24 <= Lmax=1264.49[N] (UW-20)	10.9%	OK

UHX-14.5.9(b) Tube Buckling Check

```
rt = Sqr( dt ^ 2 + (dt - 2 * tt) ^ 2) / 4
=Sqr(7.5^2+(7.5-2*0.5)^2)/4=                               2.4812 mm
Ft = lt / rt =1/2.48=                                        0.4030
Ct = Sqr( 2 * PI ^ 2 * Et / Syt)
=Sqr(2*3.14^2*186212/145)=                                 159.22
Fs = MIN(2.0,MAX(3.25-0.25*(Zd+Q3*Zw)*Xa^4,1.25))
=MIN(2.0,MAX(3.25-0.25*(0.7123+0.2469*0.1859)*1.32^4,1.25))=   2.0000

UHX-14.5.9(b)(3)(b) Maximum Permissable Buckling Stress Stb
Stb = MIN( Syt / Fs * (1 - Ft / (2 * Ct)), St)
=MIN(145/2*(1-0.403/(2*159.22,))115)=                        72.41 N/mm2
```

Tube Buckling Stress SigtMin=12.57 <= Stb=72.41[N/mm2]	17.3%	OK

UHX-14.5.10 Step 10, Stresses in Shell

```
Axial Membrane Stress Sigsm
Sigsm = (ao^2*(Pe+(ros^2-1)*(Ps-Pt))+as^2*Pt)/(Gs*ts)
=(61.5^2*(1.82+(1.24^2-1)*(2.82-1))+76^2*1)/(152*2.2)=      48.71 N/mm2

Temp1 = Betas * Deltas * Ps =0*0*2.82=                          0.00
Temp2 = 6*(1-vstar^2)/Estar*(ao^3/h^3)*(1+h*Betas/2)
=6*(1-0.3032^2)/90213.95*(61.5^3/26^3)*(1+26*0/2)=      7,9927E-04
Temp3 = Pe * (Zv + Zm * Q1) + 2 / ao ^ 2 * Zm * Q2
=1.82*(0.1859+0.7493*0.1906)+2/61.5^2*0.7493*193.9=        0.6750
Axial Bending Stress Sigsb
Sigsb = 6 * ks / ts ^ 2 * (Temp1 + Temp2 * Temp3)
=6*0/2.2^2*(0+7.9927E-04*0.675)=                              0.00 N/mm2

Total Axial Stress Sigs
```

```
Sigs = ABS( Sigsm) + ABS( Sigsb) =ABS(48.71)+ABS(0)=          48.71 N/mm2
```

Total Axial Shell Stress Sigs=48.71 <= 1.5 * Ss=207[N/mm2]	23.5%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

MAXIMUM ALLOWABLE PRESSURE SUMMARY

Table MAWP SUMMARY FOR T.1 :

Description	P(MPa)	LimitedBy
Max.Allow.Test Pressure (tubeside)	17.66	Tubesheet Bending Stress
Max.Allow.Test Pressure(shellside)	14.35	Tube Buckling Stress
Max.Allow.Pressure Hot&Corroded(tubeside)	10.68	Tubesheet Bending Stress
Max.Allow.Pressure Hot&Corroded(shellside)	10.68	Tubesheet Bending Stress
Max.Allow.Pressure New&Cold(tubeside)	12.10	Tubesheet Bending Stress
Max.Allow.Pressure New&Cold(shellside)	12.11	Tubesheet Bending Stress

TEST PRESSURES

TEST PRESSURE ON TUBESIDE

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Pttmin = 1.1 * Ptd * Sr / S =1.1*1*179/167.52=          1.1754 MPa
```

TEST PRESSURE ON SHELLSIDE

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Ptsmin = 1.1 * Psd * Sr / S =1.1*2.82*179/167.52=          3.3146 MPa
```

CALCULATION SUMMARY

LOAD CASE:=LC1==LC1=

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.3141/0.4479*(2*61.5/(26-0))^2*-1=          -23.54 N/mm2
```

Tubesheet Bending Stress Sigma=23.54 <= 1.5 * S=251.28[N/mm2]	9.3%	OK

UHX-14.5.8 Step 8, Shear Stress in Tubesheet (Tau)

Tubesheet Shear Stress Tau=0 <= MIN(0.8*S, 0.533*Sy)=134.02[N/mm2]	0.0%	OK

UHX-14.5.9 Step 9, Tube Design

Axial Tube Stress (Pe <> 0)

```
SigtMax = MAX( Sigt1 , Sigt2) =MAX(0.4658,5.36)=          5.3583 N/mm2
```

Tube Axial Stress SigtMax=5.36 <= St=115[N/mm2]	4.6%	OK
Tube Weld Max.Axial Load Wt=58.92 <= Lmax=1264.49[N] (UW-20)	4.6%	OK
Tube Buckling Stress SigtMin=0 <= Stb=100000[N/mm2]	0.0%	OK

```
Total Axial Stress Sigs
Sigs = ABS( Sigsm) + ABS( Sigsb)
=ABS(-3.793E-07)+ABS(0)=          3,793E-07 N/mm2
```

Total Axial Shell Stress Sigs=3.793E-07 <= 1.5 * Ss=207[N/mm2]	0.0%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

LOAD CASE:=LC2==LC2=

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.3141/0.4479*(2*61.5/(26-0))^2*2.82=                 66.38 N/mm2
```

Tubesheet Bending Stress Sigma=66.38 <= 1.5 * S=251.28[N/mm2]	26.4%	OK

UHX-14.5.8 Step 8, Shear Stress in Tubesheet (Tau)

Tubesheet Shear Stress Tau=0 <= MIN(0.8*S, 0.533*Sy)=134.02[N/mm2]	0.0%	OK

UHX-14.5.9 Step 9, Tube Design

Axial Tube Stress (Pe <> 0)

```
SigtMax = MAX( Sigt1 , Sigt2) =MAX(-4.13,-17.93)=          17.93 N/mm2
```

Tube Axial Stress SigtMax=17.93 <= St=115[N/mm2]	15.5%	OK
Tube Weld Max.Axial Load Wt=197.15 <= Lmax=1264.49[N] (UW-20)	15.5%	OK
Tube Buckling Stress SigtMin=17.93 <= Stb=72.41[N/mm2]	24.7%	OK

```
Total Axial Stress Sigs
Sigs = ABS( Sigsm) + ABS( Sigsb) =ABS(48.71)+ABS(0)=       48.71 N/mm2
```

Total Axial Shell Stress Sigs=48.71 <= 1.5 * Ss=207[N/mm2]	23.5%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

LOAD CASE:=LC3==LC3=

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.3141/0.4479*(2*61.5/(26-0))^2*1.82=                 42.84 N/mm2
```

Tubesheet Bending Stress Sigma=42.84 <= 1.5 * S=251.28[N/mm2]	17.0%	OK

UHX-14.5.8 Step 8, Shear Stress in Tubesheet (Tau)

Tubesheet Shear Stress Tau=0 <= MIN(0.8*S, 0.533*Sy)=134.02[N/mm2]	0.0%	OK

UHX-14.5.9 Step 9, Tube Design

Axial Tube Stress (Pe <> 0)

```
SigtMax = MAX( Sigt1 , Sigt2) =MAX(-3.67,-12.57)=          12.57 N/mm2
```

Tube Axial Stress SigtMax=12.57 <= St=115[N/mm2]	10.9%	OK
Tube Weld Max.Axial Load Wt=138.24 <= Lmax=1264.49[N] (UW-20)	10.9%	OK

Tube Buckling Stress SigtMin=12.57 <= Stb=72.41[N/mm2]	17.3%	OK

```
Total Axial Stress Sigs
Sigs = ABS( Sigsm) + ABS( Sigsb) =ABS(48.71)+ABS(0)=          48.71 N/mm2
```

Total Axial Shell Stress Sigs=48.71 <= 1.5 * Ss=207[N/mm2]	23.5%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

MAXIMUM ALLOWABLE PRESSURE SUMMARY

Table MAWP SUMMARY FOR T.1 :

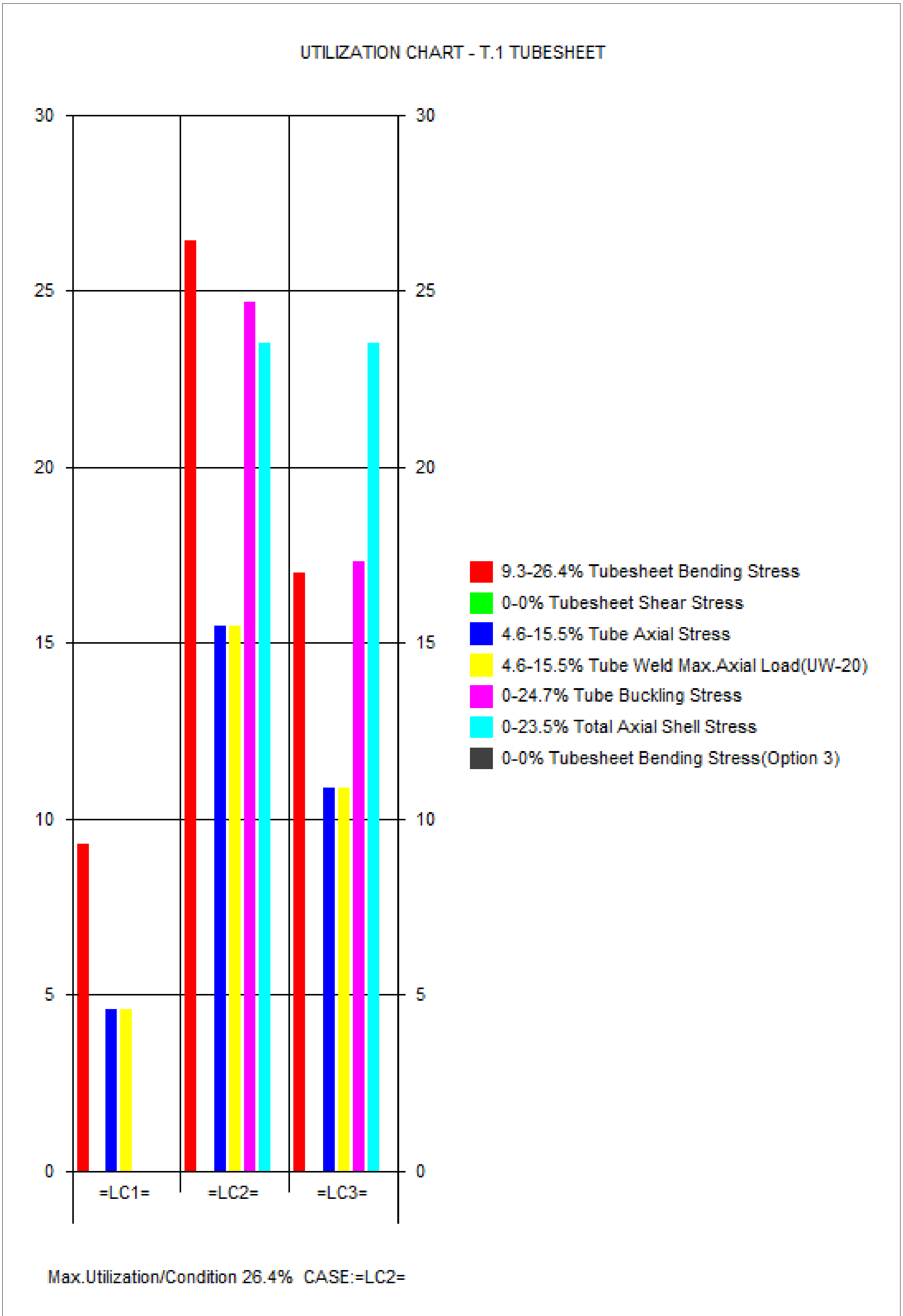
Description	P(MPa)	LimitedBy
Max.Allow.Test Pressure (tubeside)	17.66	Tubesheet Bending Stress
Max.Allow.Test Pressure(shellside)	14.35	Tube Buckling Stress
Max.Allow.Pressure Hot&Corroded(tubeside)	10.68	Tubesheet Bending Stress
Max.Allow.Pressure Hot&Corroded(shellside)	10.68	Tubesheet Bending Stress
Max.Allow.Pressure New&Cold(tubeside)	12.10	Tubesheet Bending Stress
Max.Allow.Pressure New&Cold(shellside)	12.11	Tubesheet Bending Stress

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 210 FOR: 9 SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 210 FOR: 5 SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 5 SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.

Volume:0.00 m3 Weight:3 kg (SG= 7.85)

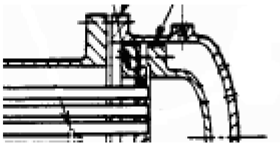

UTILIZATION CHART - T.1 TUBESHEET
30
25
20
15
10
5
0
=LC1=
=LC2=
=LC3=
9.3-26.4% Tubesheet Bending Stress
0-0% Tubesheet Shear Stress
4.6-15.5% Tube Axial Stress
4.6-15.5% Tube Weld Max.Axial Load(UW-20)
0-24.7% Tube Buckling Stress
0-23.5% Total Axial Shell Stress
0-0% Tubesheet Bending Stress(Option 3)
Max.Utilization/Condition 26.4% CASE:=LC2=

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

```
Attachment: TB.1    Tube Bundle         Tube bundle                    T.1
Location: Along z-axis z1=  496
```

GENERAL DESIGN DATA



```
Type of Heat Exchanger: UHX-14 Floating Tubesheet Heat Exchangers
Type of Tubesheet: Floating Tubesheet
Type of Floating Tubesheet Exchanger: With Immersed Floating Head
Configuration Type: D Tubesheet Internally Sealed
```

LOAD CASES (LC)

Table LOAD CASES:

Description	ID	=LC1=	=LC2=	=LC3=
Shell-Side Pressure (MPa)	Ps	0	2.82	2.82
Tube-Side Pressure (MPa)	Pt	1	0	1
Shell-Side Corr.Allow. (mm)	cs	1	1	1
Tube-Side Corr.Allow. (mm)	ct	1	1	1

```
=LC1=: =LC1=
=LC2=: =LC2=
=LC3=: =LC3=
```

ALLOWBALE STRESS FOR EACH LOAD CASE

```
Material Design Temperatures:
Select material design temperatures from the process card.
Ttubesheet= 210, Tshell= 210, Ttube= 210, Tchannel= 95(all values in °C)
```

Table LOAD CASES:

Description	ID	=LC1=	=LC2=	=LC3=
Allowable Stress M Factor	Mf	1.0	1.0	1.0

DATA FOR TUBESHEET

```
SB-148(M), M01, C95820 Castings 204'C
ST=650 SY=270 Sy=259.84 S=167.52 Sr=179 Stest=243  (N/mm2)
OUTSIDE DIAMETER OF TUBESHEET(Ref. UHX-10(b))........:A         132.20 mm
NOMINAL THICKNESS OF TUBESHEET (uncorroded).........:hn          28.00 mm
ELASTIC MODULUS OF TUBESHEET at tubesheet design temp.:E     1,894E05 N/mm2
POISSON'S RATIO FOR TUBESHEET MATERIAL..............:v          0.3000
```

DATA FOR TUBES AND TUBES LAYOUT

```
Tube Layout: Triangular Pattern
SA-213(M) Gr.TP316L, S31603 Smls. tube, PNo=8 120'C
ST=485 SY=170 Syt=138.6 St=115 Sr=115 Stest=153  (N/mm2)
ELASTIC MODULUS OF TUBES at tube design temp........:Et     1,8621E05 N/mm2
NOMINAL OUTSIDE DIAMETER OF TUBES...................:dt         7.5000 mm
TUBE SIZE & COMMENT: S1.2
NOMINAL THICKNESS OF TUBES..........................:tt         0.5000 mm
TUBE PITCH (Spacing between centers)................:p           11.50 mm
DIAMETER OF TUBEHOLE IN TUBESHEET...................:dh         8.0000 mm
DIAMETER OF OUTER TUBE LIMIT CIRCLE.................:Do         123.00 mm
```

```
NUMBER OF TUBEHOLES IN TUBESHEET....................:Nt        72.00 piec
TOTAL AREA OF UNTUBED LANES(UL1*Ll1+UL2*Ll2+..).....:AL      1600.00 mm2
TUBE EXPANSION DEPTH RATIO (0<=ro<=1.0).............:ro       1.0000
TUBE-SIDE PASS PARTITION GROOVE DEPTH(Fig.UHX-11.1).:hg       1.0000 mm
THERMAL EXPANSION COEF.OF TUBES at mean metal temp..:atm   1,614E-05 mm/mmC
TUBE BUCKLING LENGTH lt=l*k (Ref. UHX-13.5.9(b)(1)).:lt       1.0000 mm
TUBE LENGTH BETWEEN INNER FACES OF TUBESHEETS.......:L        800.00 mm
POISSON'S RATIO FOR TUBE MATERIAL...................:vt       0.3000
PERIMETER OF THE TUBE LAYOUT MEASURED CENTER ON OUTER MOST TUBES:Cp     0.00 mm
TOTAL AREA ENCLOSED BY Cp...........................:Ap         0.00 mm2
```

DATA FOR TUBE TO TUBESHEET JOINT

```
Tube to Tubesheet Weld: Full Strength Weld to UW-20.4
Qualification of Tube-to-Tubesheet Joint: The Joint IS Qualified by Tests
FIG. UW-20.1 Weld Types: Sketch a) Fillet Weld
TUBE TO TUBESHEET FILLET WELD LEG...................:af       1.0000 mm
```

SHELL DATA

```
SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 120'C
ST=515 SY=205 Sys=169.6 Ss=138 Sr=138 Stest=184.5  (N/mm2)
INSIDE DIAMETER OF SHELL(corroded)..................:Ds       133.30 mm
THICKNESS OF SHELL (uncorroded).....................:ts       3.2000 mm
ELASTIC MODULUS OF SHELL MATERIAL at shell design temp:Es   1,8621E05 N/mm2
POISSON'S RATIO FOR SHELL MATERIAL..................:vs       0.3000
```

CHANNEL DATA

```
SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8 100'C
ST=485 SY=170 Syc=145 Sc=115 Sr=115 Stest=153  (N/mm2)
INSIDE DIAMETER OF CHANNEL(corroded)................:Dc       133.30 mm
THICKNESS OF CHANNEL (uncorroded)...................:tc       3.2000 mm
ELASTIC MODULUS OF CHANNEL at channel design temp...:Ec     1,8833E05 N/mm2
POISSON'S RATIO FOR CHANNEL MATERIAL................:vc       0.3000
```

FLANGE DATA

```
DIAMETER OF SHELL GASKET LOAD REACTION..............:Gs       152.00 mm
SHELL FLANGE DESIGN BOLT LOAD FOR ASSEMBLY COND.....:Ws        53.00 kN
SHELL FLANGE DESIGN BOLT LOAD FOR OPERATING COND....:Wm1s      53.00 kN
DIAMETER OF CHANNEL GASKET LOAD REACTION............:Gc       152.00 mm
CHANNEL FLANGE DESIGN BOLT LOAD FOR ASSEMBLY COND...:Wc        53.00 kN
CHANNEL FLANGE DESIGN BOLT LOAD FOR OPERATING COND..:Wm1c      53.00 kN
BOLT-CIRCLE DIAMETER................................:C        152.00 mm
```

CALCULATION DATA

LOAD CASE:=LC1==LC1=

PRELIMINARY CALCULATIONS

UW-20 TUBE-TO-TUBESHEET WELDS

```
Allowable Stress in Weld
Sw = MIN( S , St) =MIN(167.52,115)=                      115.00 N/mm2
Weld Strength Factor
fw = St / Sw =115/115=                                   1.0000
Axial Tube Strength
Ft = PI * tt * (dt - tt) * St =3.14*0.5*(7.5-0.5)*115=  1264.49 N

Minimum Required Length of the Weld Leg
ar = Sqr((0.75*dt)^2+2.73*tt*(dt-tt)*fw*fd)-0.75*dt
=Sqr((0.75*7.5)^2+2.73*0.5*(7.5-0.5)*1*1)-0.75*7.5=    0.7934 mm
Minimum Required Size of Fillet Weld Leg
afmin = MAX( ar, tt) =MAX(0.7934,0.5)=                   0.7934 mm

Fillet Weld Strength
Ff = MIN( 0.55 * PI * af * (dt + 0.67 * af) * Sw , Ft)
=MIN(0.55*3.14*1*(7.5+0.67*1)*115,1264.49)=            1264.49 N
```

TABLE UHX-8.1 TUBESHEET EFFECTIVE BOLT LOAD W*=0= 0.00kN

```
Tubesheet Analysis Thickness h
h = hn - ct - cs =28-1-1=                                 26.00 mm
```

UHX-11.5.1 Determination of Effective Dimensions and Ligament Efficiency

```
Basic efficiency for shear
my = (p - dt) / p =(11.5-7.5)/11.5=                      0.3478
Effective Tube Hole Diameter (dstar)
dstar = MAX(dt-2*tt*(Et/E)*(St/S)*ro,dt-2*tt)
=MAX(7.5-2*0.5*(186212/189400)*(115/167.52)*1,7.5-2*0.5)=   6.8251 mm
Effective Pitch(pstar)
pstar = p/Sqr(1-4*MIN(AL,4*Do*p)/(PI*Do^2))
=11.5/Sqr(1-4*MIN(1600,4*123*11.5)/(3.14*123^2))=          12.36 mm
Mystar = (pstar - dstar) / pstar =(12.36-6.83)/12.36=      0.4479
```

UHX-11.5.2 Determination of Effective Elastic Properties Estar and vstar

```
EstarOverE(Estar/E) from figure UHX-11.3a) =  0.4763(h/p=2.26)
Estar = EstarOverE * E =0.4763*189400=                  90213.95 N/mm2
vstar from figure UHX-11.3b) =  0.3032(h/p=2.26)
```

UHX-14.5.1 Step 1

```
Radial Channel Dimension ac
ac = A / 2 =132.2/2=                                      66.10 mm
Radial Shell Dimension as
as = ac =66.1=                                            66.10 mm
Parameters
ao = Do / 2 =123/2=                                       61.50 mm
Diameter Ratio ros for Shell
ros = as / ao =66.1/61.5=                                1.0748
Diameter Ratio roc for Channel
roc = ac / ao =66.1/61.5=                                1.0748
Tubesheet Drilling Coefficients
xs = 1 - Nt * (dt / (2 * ao)) ^ 2
=1-72*(7.5/(2*61.5))^2=                                 0.7323
xt = 1 - Nt * ((dt - 2 * tt) / (2 * ao)) ^ 2
=1-72*((7.5-2*0.5)/(2*61.5))^2=                         0.7989
```

UHX-14.5.2 Step 2, Shell and Tube Axial Stiffness

UHX-14.5.3 Step 3, Tube Bundle to Tubesheet Rigidity Ratio

```
Xa = (24*(1-vstar^2)*Nt*Et*tt*(dt-tt)*ao^2/(Estar*L*h^3))^0.25
=(24*(1-0.3032^2)*72*186212*0.5*(7.5-0.5)*61.5^2/(90213.95*800*26^3))^0.25
=   1.3214
Zd (from figure UHX-13.2) =  0.7123
Zv (from figure UHX-13.2) =  0.1859
Zw (from figure UHX-13.2) =  0.1859
Zm (from figure UHX-13.2) =  0.7493
```

UHX-14.5.4 Step 4, Ratio K and Parameters F, Phi, Q and U

```
Diameter Ratio K
K = A / Do =132.2/123=                                   1.0748
F = (1 - vstar) / Estar * (LamdaS + LamdaC + E * Log( K))
=(1-0.3032)/90213.95*(0+0+189400*Log(1.07))=            0.1055
phi = (1 + vstar) * F =(1+0.3032)*0.1055=                0.1375
Q1 = (ros - 1 - phi * Zv) / (1 + phi * Zm)
=(1.07-1-0.1375*0.1859)/(1+0.1375*0.7493)=              0.0446
```

UHX-14.5.5 Step 5

```
Omegas = ros * ks * Betas * Deltas * (1 + h * Betas)
=1.07*0*0*0*(1+26*0)=                                    0.00 mm2
Omegasstar = ao ^ 2 * (ros ^ 2 - 1) * (ros - 1) / 4 - Omegas
=61.5^2*(1.07^2-1)*(1.07-1)/4-0=                        10.98 mm2
Omegac = roc * kc * Betac * Deltac * (1 + h * Betac)
=1.07*0*0*0*(1+26*0)=                                    0.00 mm2
```

```
Omegacstar = ao^2*((roc^2+1)*(roc-1)/4-(ros-1)/2)-Omegac
=61.5^2*((1.07^2+1)*(1.07-1)/4-(1.07-1)/2)-0=            10.98 mm2
Zm (from figure UHX-13.2) =  0.7493 =0.7493=              0.00 mm
Psstar = 0 =0=                                               0.00 MPa
Pcstar = 0 =0=                                               0.00 MPa
```

UHX-14.5.6 Step 6

```
Effective Pressure Pe
Pe = Ps - Pt =0-1=                                        -1 MPa
```

UHX-14.5.7 Step 7

```
Q2 = (Omegasstar*Ps-Omegacstar*Pt+yb/(2*PI)*Wstar)/(1+phi*Zm)
=(10.98*0-10.98*1+0/(2*3.14)*0)/(1+0.1375*0.7493)=        -9.95 N
Q3 = Q1 + 2 * Q2 / (Pe * ao ^ 2)
=0.0446+2*-9.95/(-1*61.5^2)=                              0.0499
Fm = MAX(Fm(x)) (from Table UHX-13.1) =  0.2209
```

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.2209/0.4479*(2*61.5/(26-0))^2*-1=                 -16.55 N/mm2
```

Tubesheet Bending Stress Sigma=16.55 <= 1.5 * S=251.28[N/mm2]	6.5%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

LOAD CASE:=LC2==LC2=

PRELIMINARY CALCULATIONS

UW-20 TUBE-TO-TUBESHEET WELDS

```
Allowable Stress in Weld
Sw = MIN( S , St) =MIN(167.52,115)=                        115.00 N/mm2
Weld Strength Factor
fw = St / Sw =115/115=                                     1.0000
Axial Tube Strength
Ft = PI * tt * (dt - tt) * St =3.14*0.5*(7.5-0.5)*115=    1264.49 N
Minimum Required Length of the Weld Leg
ar = Sqr((0.75*dt)^2+2.73*tt*(dt-tt)*fw*fd)-0.75*dt
=Sqr((0.75*7.5)^2+2.73*0.5*(7.5-0.5)*1*1)-0.75*7.5=      0.7934 mm
Minimum Required Size of Fillet Weld Leg
afmin = MAX( ar, tt) =MAX(0.7934,0.5)=                     0.7934 mm
Fillet Weld Strength
Ff = MIN( 0.55 * PI * af * (dt + 0.67 * af) * Sw , Ft)
=MIN(0.55*3.14*1*(7.5+0.67*1)*115,1264.49)=             1264.49 N
```

TABLE UHX-8.1 TUBESHEET EFFECTIVE BOLT LOAD W*=0= 0.00kN

```
Tubesheet Analysis Thickness h
h = hn - ct - cs =28-1-1=                                   26.00 mm
```

UHX-11.5.1 Determination of Effective Dimensions and Ligament Efficiency

```
Basic efficiency for shear
my = (p - dt) / p =(11.5-7.5)/11.5=                        0.3478
Effective Tube Hole Diameter (dstar)
dstar = MAX(dt-2*tt*(Et/E)*(St/S)*ro,dt-2*tt)
=MAX(7.5-2*0.5*(186212/189400)*(115/167.52)*1,7.5-2*0.5)=   6.8251 mm
Effective Pitch(pstar)
pstar = p/Sqr(1-4*MIN(AL,4*Do*p)/(PI*Do^2))
```

```
=11.5/Sqr(1-4*MIN(1600,4*123*11.5)/(3.14*123^2))=          12.36 mm
Mystar = (pstar - dstar) / pstar =(12.36-6.83)/12.36=       0.4479
```

UHX-11.5.2 Determination of Effective Elastic Properties Estar and vstar

```
EstarOverE(Estar/E) from figure UHX-11.3a) =  0.4763(h/p=2.26)
Estar = EstarOverE * E =0.4763*189400=                    90213.95 N/mm2
vstar from figure UHX-11.3b) =  0.3032(h/p=2.26)
```

UHX-14.5.1 Step 1

```
Radial Channel Dimension ac
ac = A / 2 =132.2/2=                                         66.10 mm
Radial Shell Dimension as
as = ac =66.1=                                               66.10 mm
Parameters
ao = Do / 2 =123/2=                                          61.50 mm
Diameter Ratio ros for Shell
ros = as / ao =66.1/61.5=                                   1.0748
Diameter Ratio roc for Channel
roc = ac / ao =66.1/61.5=                                   1.0748
Tubesheet Drilling Coefficients
xs = 1 - Nt * (dt / (2 * ao)) ^ 2
=1-72*(7.5/(2*61.5))^2=                                   0.7323
xt = 1 - Nt * ((dt - 2 * tt) / (2 * ao)) ^ 2
=1-72*((7.5-2*0.5)/(2*61.5))^2=                           0.7989
```

UHX-14.5.2 Step 2, Shell and Tube Axial Stiffness

UHX-14.5.3 Step 3, Tube Bundle to Tubesheet Rigidity Ratio

```
Xa = (24*(1-vstar^2)*Nt*Et*tt*(dt-tt)*ao^2/(Estar*L*h^3))^0.25
=(24*(1-0.3032^2)*72*186212*0.5*(7.5-0.5)*61.5^2/(90213.95*800*26^3))^0.25
=   1.3214
Zd (from figure UHX-13.2) =  0.7123
Zv (from figure UHX-13.2) =  0.1859
Zw (from figure UHX-13.2) =  0.1859
Zm (from figure UHX-13.2) =  0.7493
```

UHX-14.5.4 Step 4, Ratio K and Parameters F, Phi, Q and U

```
Diameter Ratio K
K = A / Do =132.2/123=                                      1.0748
F = (1 - vstar) / Estar * (LamdaS + LamdaC + E * Log( K))
=(1-0.3032)/90213.95*(0+0+189400*Log(1.07))=              0.1055
phi = (1 + vstar) * F =(1+0.3032)*0.1055=                   0.1375
Q1 = (ros - 1 - phi * Zv) / (1 + phi * Zm)
=(1.07-1-0.1375*0.1859)/(1+0.1375*0.7493)=                0.0446
```

UHX-14.5.5 Step 5

```
Omegas = ros * ks * Betas * Deltas * (1 + h * Betas)
=1.07*0*0*0*(1+26*0)=                                       0.00 mm2
Omegasstar = ao ^ 2 * (ros ^ 2 - 1) * (ros - 1) / 4 - Omegas
=61.5^2*(1.07^2-1)*(1.07-1)/4-0=                           10.98 mm2
Omegac = roc * kc * Betac * Deltac * (1 + h * Betac)
=1.07*0*0*0*(1+26*0)=                                       0.00 mm2
Omegacstar = ao^2*((roc^2+1)*(roc-1)/4-(ros-1)/2)-Omegac
=61.5^2*((1.07^2+1)*(1.07-1)/4-(1.07-1)/2)-0=              10.98 mm2
Zm (from figure UHX-13.2) =  0.7493 =0.7493=                0.00 mm
Psstar = 0 =0=                                                0.00 MPa
Pcstar = 0 =0=                                                0.00 MPa
```

UHX-14.5.6 Step 6

```
Effective Pressure Pe
Pe = Ps - Pt =2.82-0=                                       2.8200 MPa
```

UHX-14.5.7 Step 7

```
Q2 = (Omegasstar*Ps-Omegacstar*Pt+yb/(2*PI)*Wstar)/(1+phi*Zm)
=(10.98*2.82-10.98*0+0/(2*3.14)*0)/(1+0.1375*0.7493)=       28.06 N
Q3 = Q1 + 2 * Q2 / (Pe * ao ^ 2)
=0.0446+2*28.06/(2.82*61.5^2)=                             0.0499
Fm = MAX(Fm(x)) (from Table UHX-13.1) =  0.2209
```

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.2209/0.4479*(2*61.5/(26-0))^2*2.82=                  46.68 N/mm2
```

Tubesheet Bending Stress Sigma=46.68 <= 1.5 * S=251.28[N/mm2]	18.5%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

LOAD CASE:=LC3==LC3=

PRELIMINARY CALCULATIONS

UW-20 TUBE-TO-TUBESHEET WELDS

```
Allowable Stress in Weld
Sw = MIN( S , St) =MIN(167.52,115)=                          115.00 N/mm2
Weld Strength Factor
fw = St / Sw =115/115=                                       1.0000
Axial Tube Strength
Ft = PI * tt * (dt - tt) * St =3.14*0.5*(7.5-0.5)*115=      1264.49 N

Minimum Required Length of the Weld Leg
ar = Sqr((0.75*dt)^2+2.73*tt*(dt-tt)*fw*fd)-0.75*dt
=Sqr((0.75*7.5)^2+2.73*0.5*(7.5-0.5)*1*1)-0.75*7.5=        0.7934 mm
Minimum Required Size of Fillet Weld Leg
afmin = MAX( ar, tt) =MAX(0.7934,0.5)=                       0.7934 mm

Fillet Weld Strength
Ff = MIN( 0.55 * PI * af * (dt + 0.67 * af) * Sw , Ft)
=MIN(0.55*3.14*1*(7.5+0.67*1)*115,1264.49)=               1264.49 N
```

TABLE UHX-8.1 TUBESHEET EFFECTIVE BOLT LOAD W*=0= 0.00kN

```
Tubesheet Analysis Thickness h
h = hn - ct - cs =28-1-1=                                     26.00 mm
```

UHX-11.5.1 Determination of Effective Dimensions and Ligament Efficiency

```
Basic efficiency for shear
my = (p - dt) / p =(11.5-7.5)/11.5=                          0.3478
Effective Tube Hole Diameter (dstar)
dstar = MAX(dt-2*tt*(Et/E)*(St/S)*ro,dt-2*tt)
=MAX(7.5-2*0.5*(186212/189400)*(115/167.52)*1,7.5-2*0.5)=   6.8251 mm
Effective Pitch(pstar)
pstar = p/Sqr(1-4*MIN(AL,4*Do*p)/(PI*Do^2))
=11.5/Sqr(1-4*MIN(1600,4*123*11.5)/(3.14*123^2))=          12.36 mm
Mystar = (pstar - dstar) / pstar =(12.36-6.83)/12.36=       0.4479
```

UHX-11.5.2 Determination of Effective Elastic Properties Estar and vstar

```
EstarOverE(Estar/E) from figure UHX-11.3a) =  0.4763(h/p=2.26)
Estar = EstarOverE * E =0.4763*189400=                     90213.95 N/mm2
vstar from figure UHX-11.3b) =  0.3032(h/p=2.26)
```

UHX-14.5.1 Step 1

```
Radial Channel Dimension ac
ac = A / 2 =132.2/2=                                            66.10 mm
Radial Shell Dimension as
as = ac =66.1=                                                  66.10 mm
Parameters
ao = Do / 2 =123/2=                                             61.50 mm
Diameter Ratio ros for Shell
ros = as / ao =66.1/61.5=                                      1.0748
Diameter Ratio roc for Channel
roc = ac / ao =66.1/61.5=                                      1.0748
Tubesheet Drilling Coefficients
xs = 1 - Nt * (dt / (2 * ao)) ^ 2
=1-72*(7.5/(2*61.5))^2=                                      0.7323
xt = 1 - Nt * ((dt - 2 * tt) / (2 * ao)) ^ 2
=1-72*((7.5-2*0.5)/(2*61.5))^2=                              0.7989
```

UHX-14.5.2 Step 2, Shell and Tube Axial Stiffness

UHX-14.5.3 Step 3, Tube Bundle to Tubesheet Rigidity Ratio

```
Xa = (24*(1-vstar^2)*Nt*Et*tt*(dt-tt)*ao^2/(Estar*L*h^3))^0.25
=(24*(1-0.3032^2)*72*186212*0.5*(7.5-0.5)*61.5^2/(90213.95*800*26^3))^0.25
=   1.3214
Zd (from figure UHX-13.2) =  0.7123
Zv (from figure UHX-13.2) =  0.1859
Zw (from figure UHX-13.2) =  0.1859
Zm (from figure UHX-13.2) =  0.7493
```

UHX-14.5.4 Step 4, Ratio K and Parameters F, Phi, Q and U

```
Diameter Ratio K
K = A / Do =132.2/123=                                         1.0748
F = (1 - vstar) / Estar * (LamdaS + LamdaC + E * Log( K))
=(1-0.3032)/90213.95*(0+0+189400*Log(1.07))=                 0.1055
phi = (1 + vstar) * F =(1+0.3032)*0.1055=                      0.1375
Q1 = (ros - 1 - phi * Zv) / (1 + phi * Zm)
=(1.07-1-0.1375*0.1859)/(1+0.1375*0.7493)=                   0.0446
```

UHX-14.5.5 Step 5

```
Omegas = ros * ks * Betas * Deltas * (1 + h * Betas)
=1.07*0*0*0*(1+26*0)=                                          0.00 mm2
Omegasstar = ao ^ 2 * (ros ^ 2 - 1) * (ros - 1) / 4 - Omegas
=61.5^2*(1.07^2-1)*(1.07-1)/4-0=                              10.98 mm2
Omegac = roc * kc * Betac * Deltac * (1 + h * Betac)
=1.07*0*0*0*(1+26*0)=                                          0.00 mm2
Omegacstar = ao^2*((roc^2+1)*(roc-1)/4-(ros-1)/2)-Omegac
=61.5^2*((1.07^2+1)*(1.07-1)/4-(1.07-1)/2)-0=                 10.98 mm2
Zm (from figure UHX-13.2) =  0.7493 =0.7493=                   0.00 mm
Psstar = 0 =0=                                                   0.00 MPa
Pcstar = 0 =0=                                                   0.00 MPa
```

UHX-14.5.6 Step 6

```
Effective Pressure Pe
Pe = Ps - Pt =2.82-1=                                          1.8200 MPa
```

UHX-14.5.7 Step 7

```
Q2 = (Omegasstar*Ps-Omegacstar*Pt+yb/(2*PI)*Wstar)/(1+phi*Zm)
=(10.98*2.82-10.98*1+0/(2*3.14)*0)/(1+0.1375*0.7493)=       18.11 N
Q3 = Q1 + 2 * Q2 / (Pe * ao ^ 2)
=0.0446+2*18.11/(1.82*61.5^2)=                               0.0499
Fm = MAX(Fm(x)) (from Table UHX-13.1) =  0.2209
```

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.2209/0.4479*(2*61.5/(26-0))^2*1.82=                30.13 N/mm2
```

Tubesheet Bending Stress Sigma=30.13 <= 1.5 * S=251.28[N/mm2]	11.9%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

MAXIMUM ALLOWABLE PRESSURE SUMMARY

Table MAWP SUMMARY FOR T.2 :

Description	P(MPa)	LimitedBy
Max.Allow.Test Pressure (tubeside)	25.13	Tubesheet Bending Stress
Max.Allow.Test Pressure(shellside)	25.13	Tubesheet Bending Stress
Max.Allow.Pressure Hot&Corroded(tubeside)	15.18	Tubesheet Bending Stress
Max.Allow.Pressure Hot&Corroded(shellside)	15.18	Tubesheet Bending Stress
Max.Allow.Pressure New&Cold(tubeside)	17.22	Tubesheet Bending Stress
Max.Allow.Pressure New&Cold(shellside)	17.23	Tubesheet Bending Stress

TEST PRESSURES

TEST PRESSURE ON TUBESIDE

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Pttmin = 1.1 * Ptd * Sr / S =1.1*1*179/167.52=            1.1754 MPa
```

TEST PRESSURE ON SHELLSIDE

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Ptsmin = 1.1 * Psd * Sr / S =1.1*2.82*179/167.52=         3.3146 MPa
```

CALCULATION SUMMARY

LOAD CASE:=LC1==LC1=

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.2209/0.4479*(2*61.5/(26-0))^2*-1=                 -16.55 N/mm2
```

Tubesheet Bending Stress Sigma=16.55 <= 1.5 * S=251.28[N/mm2]	6.5%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

LOAD CASE:=LC2==LC2=

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.2209/0.4479*(2*61.5/(26-0))^2*2.82=                46.68 N/mm2
```

Tubesheet Bending Stress Sigma=46.68 <= 1.5 * S=251.28[N/mm2]	18.5%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

LOAD CASE:=LC3==LC3=

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.2209/0.4479*(2*61.5/(26-0))^2*1.82=                30.13 N/mm2
```

Tubesheet Bending Stress Sigma=30.13 <= 1.5 * S=251.28[N/mm2]	11.9%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

MAXIMUM ALLOWABLE PRESSURE SUMMARY

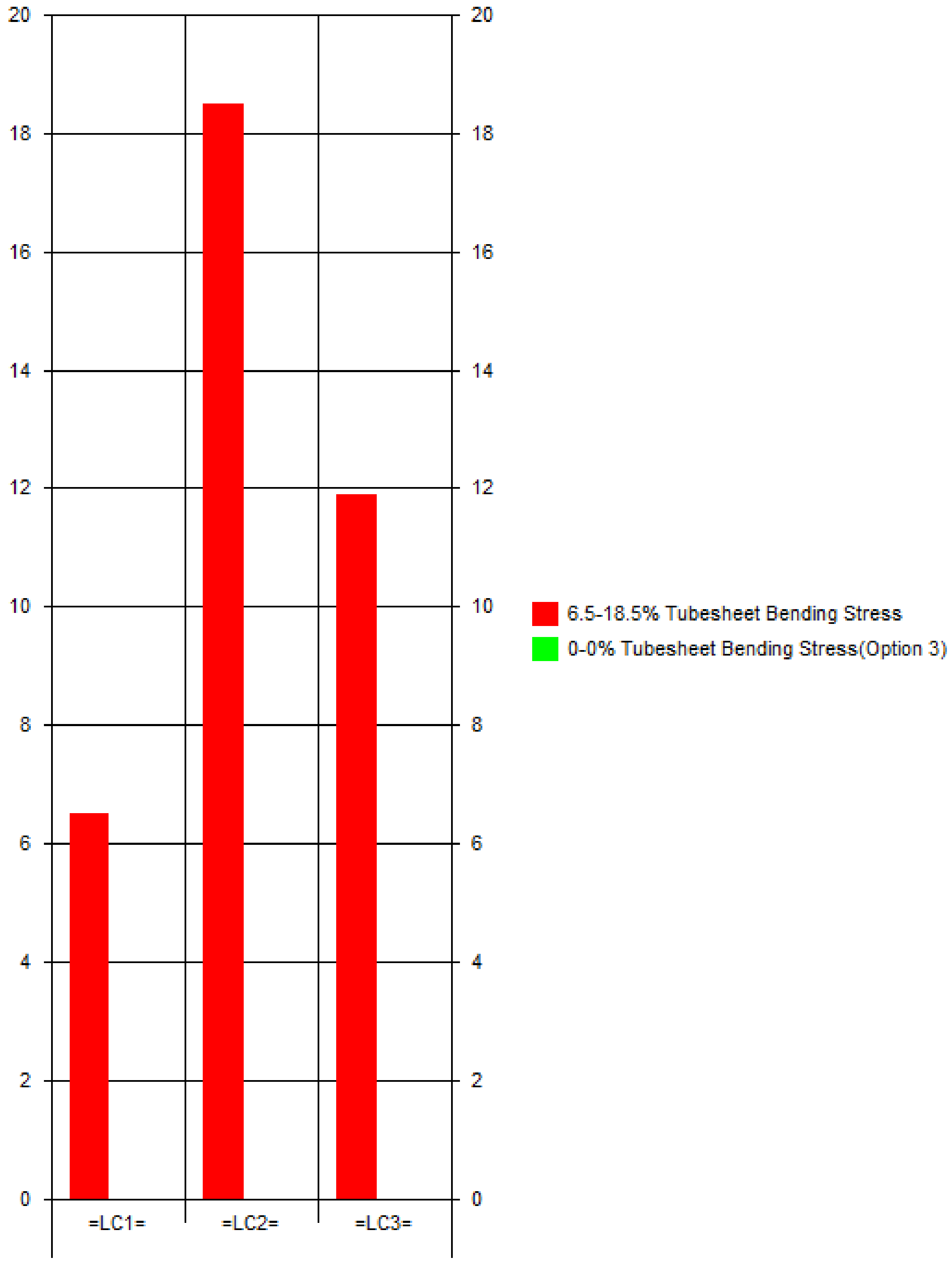
Table MAWP SUMMARY FOR T.2 :

Description	P(MPa)	LimitedBy
Max.Allow.Test Pressure (tubeside)	25.13	Tubesheet Bending Stress
Max.Allow.Test Pressure(shellside)	25.13	Tubesheet Bending Stress
Max.Allow.Pressure Hot&Corroded(tubeside)	15.18	Tubesheet Bending Stress
Max.Allow.Pressure Hot&Corroded(shellside)	15.18	Tubesheet Bending Stress
Max.Allow.Pressure New&Cold(tubeside)	17.22	Tubesheet Bending Stress
Max.Allow.Pressure New&Cold(shellside)	17.23	Tubesheet Bending Stress

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 210 FOR: 1 SA-213(M) Gr.TP316L, S31603 Smls. tube, PNo=8 , the material must be re-selected from the material database.
WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 210 FOR: 5 SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.
WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 9 SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.

Volume:0.00 m3 Weight:3 kg (SG= 7.85)

UTILIZATION CHART - T.2 TUBESHEET FLOATING



Max.Utilization/Condition 18.5% CASE:=LC2=

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

```
Attachment: T.1      Tubesheet          Tubesheet                       F.3
Location: Along z-axis zo= -54
```

GENERAL DESIGN DATA

```
DESIGN PRESSURE.....................................:P          1.1000 MPa
EXTERNAL DESIGN PRESSURE............................:Pext       2.6000 MPa
CORROSION ALLOWANCE FOR TUBES.......................:c            0.00 mm
```

TUBE BUNDLE DATA

```
U-TUBES - CHECK THINNING OF TUBES DUE TO BENDING: NO
SB-111(M), O61, C70600 Smls. cond. tube 95'C
ST=275 SY=100 SYd=97.91 S=68.9 Sr=68.9 Stest=90  (N/mm2)
NOMINAL THICKNESS OF TUBES..........................:tt         0.5000 mm
TUBE PITCH (Spacing between centers)................:p           11.50 mm
NOMINAL OUTSIDE DIAMETER OF TUBES...................:dt         7.5000 mm
DIAMETER OF OUTER TUBE LIMIT CIRCLE.................:Do         123.00 mm
NUMBER OF TUBEHOLES IN TUBESHEET....................:Nt          72.00 piec
TUBE LENGTH BETWEEN INNER FACES OF TUBESHEETS.......:L          550.00 mm
NOMINAL THICKNESS OF TUBESHEET (uncorroded).........:hn          28.00 mm
NEGATIVE DEVIATION/TOLERANCE........................:            12.50 %
```

DATA FOR BAFFLE PLATES

```
BAFFLE PLATES: Excluded
```

CALCULATION DATA

UG-27 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

```
Outside Radius of Tube
Ro = dt / 2 =7.5/2=                                       3.7500 mm
```

»Thin Cylinder Check P=1.1 <= 0.385 * S * E=26.53[MPa] « » OK«

```
Required Minimum Shell Thickness Excl.Allow. tmin :
tmin = P * Ro / (S * E + 0.4 * P)
=1.1*3.75/(68.9*1+0.4*1.1)=                             0.0595 mm
```

»Thin Cylinder Check tmin=0.0595 < 0.5 * R=1.875[mm] « » OK«

```
Required Minimum Tube Thickness Incl.Allow. :
tmina = (tmin + c + th) * (1 + thbend / 100)
=(0.0595+0+0.0625)*(1+0/100)=                           0.1220 mm

Analysis Thickness
ta = tn / (1 + thbend / 100) - c - th
=0.5/(1+0/100)-0-0.0625=                                0.4375 mm
```

Internal Pressure tmina=0.122 <= tn=0.5[mm]	24.3%	OK

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :

```
Inside Diameter of Shell
Di = dt - 2 * ta =7.5-2*0.4375=                           6.6250 mm
Inside Radius of Shell
R = Di / 2 =6.625/2=                                      3.3125 mm
MAWP HOT & CORR. (Corroded condition at design temp.)
MAWPHC = S * E * ta / (R + 0.6 * ta)
=68.9*1*0.4375/(3.3125+0.6*0.4375)=                     8.4318 MPa

MAWP NEW & COLD (Uncorroded condition at ambient temp.)
MAWPNC = Sr * E * (ta + c) / (R + 0.6 * (ta + c))
=68.9*1*(0.4375+0)/(3.3125+0.6*(0.4375+0))=             8.4318 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)
Ptmax = SYtest * Etest * (ta + c) / (R + 0.6 * (ta + c))
=90*1*(0.4375+0)/(3.3125+0.6*(0.4375+0))=                  11.01 MPa
```

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Ptmin = 1.1 * Pd * Sr / S =1.1*1.1*68.9/68.9=               1.2100 MPa
```

Test Pressure Ptmin=1.21 <= Ptmax=11.01[MPa]	10.9%	OK

SECT. UG28 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

Preliminary Calculations

```
Ratio1 = dt / t =7.5/0.4375=                                  17.14
Ratio2 = L / dt =550/7.5=                                     73.33
Value of A from Fig.G (Part D), A =0.003979
Value of B from External Pressure Chart NFC-3(based on Temp=95)  B =34.83
Pmax = (4 / 3) * B / (dt / t)
=(4/3)*34.83/(7.5/0.4375)=                                  2.7087 MPa
```

External Pressure Pmax=2.71 >= Pext=2.6[MPa]	95.9%	OK

Max. External Test Pressure

```
Max. External Test Pressure (Uncorroded cond.at ambient temp.)
Ptemax(20) = ==                                               3.3165 MPa
```

CALCULATION SUMMARY

UG-27 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

```
Required Minimum Shell Thickness Excl.Allow. tmin :
tmin = P * Ro / (S * E + 0.4 * P)
=1.1*3.75/(68.9*1+0.4*1.1)=                                 0.0595 mm

Required Minimum Tube Thickness Incl.Allow. :
tmina = (tmin + c + th) * (1 + thbend / 100)
=(0.0595+0+0.0625)*(1+0/100)=                               0.1220 mm
```

Internal Pressure tmina=0.122 <= tn=0.5[mm]	24.3%	OK

```
MAWP HOT & CORR. (Corroded condition at design temp.)
MAWPHC = S * E * ta / (R + 0.6 * ta)
=68.9*1*0.4375/(3.3125+0.6*0.4375)=                         8.4318 MPa

MAWP NEW & COLD (Uncorroded condition at ambient temp.)
MAWPNC = Sr * E * (ta + c) / (R + 0.6 * (ta + c))
=68.9*1*(0.4375+0)/(3.3125+0.6*(0.4375+0))=                 8.4318 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)
Ptmax = SYtest * Etest * (ta + c) / (R + 0.6 * (ta + c))
=90*1*(0.4375+0)/(3.3125+0.6*(0.4375+0))=                  11.01 MPa
```

Test Pressure Ptmin=1.21 <= Ptmax=11.01[MPa]	10.9%	OK

SECT. UG28 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

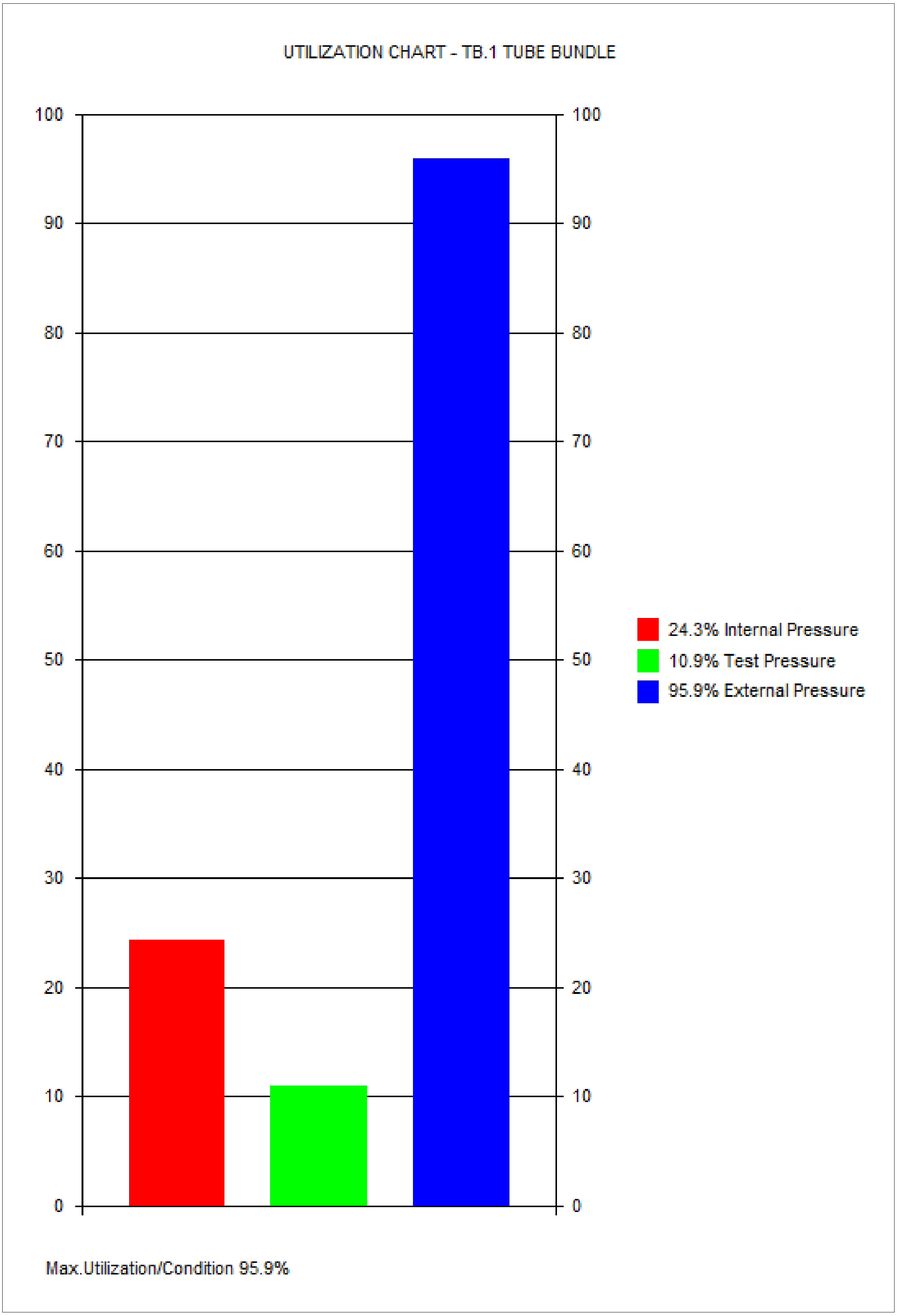
```
Pmax = (4 / 3) * B / (dt / t)
=(4/3)*34.83/(7.5/0.4375)=                                  2.7087 MPa
```

External Pressure Pmax=2.71 >= Pext=2.6[MPa]	95.9%	OK

Max. External Test Pressure

```
Max. External Test Pressure (Uncorroded cond.at ambient temp.)
Ptemax(20) = ==                                              3.3165 MPa
```

Volume:0.0014 m3 Weight:3.8 kg (SG= 7.85)


UTILIZATION CHART - TB.1 TUBE BUNDLE
100
90
80
70
60
50
40
30
20
10
0
24.3% Internal Pressure
10.9% Test Pressure
95.9% External Pressure
Max.Utilization/Condition 95.9%

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Design Data & Process Information

Description	Units	Design Data	Design Data
Process Card		Shell Side	Tube Side
Design Code & Specifications		ASME VIII Div.1 2019	ASME VIII Div.1 2019
Internal Design Pressure (MPa)	MPa	2.5	1
External Design Pressure (MPa)	MPa	0.1	0.1
Hydrotest Pressure (MPa)	MPa	3.75	1.5
Maximum Design Temperature ('C)	'C	210	95
Minimum Design Temperature ('C)	'C	-10	-10
Operating Temperature ('C)	'C		
Corrosion Allowance (mm)	mm	1	1
Content of Vessel			
Specific Density of Oper.Liq		1	1
Normal Liquid Level NLL (mm)	mm	200	200

Weight & Volume of Vessel

PROCESS CARD NO.: 1 SHELL SIDE

ID	No.	Wt-UnFinish.	Wt-Finished	Tot.Volume	Test.Liq.Wt	Oper.Liq.Wt
S1.1	1	13.0 kg	12.8 kg	0.016 m3	16.0 kg	14.9 kg
TB.1	1	0.0 kg	0.0 kg	-0.001 m3	-1.3 kg	-1.9 kg
Total	**2**	**13.0 kg**	**12.8 kg**	**0.015 m3**	**14.7 kg**	**13.1 kg**

PROCESS CARD NO.: 2 TUBE SIDE

ID	No.	Wt-UnFinish.	Wt-Finished	Tot.Volume	Test.Liq.Wt	Oper.Liq.Wt
E4.1	1	7.0 kg	6.5 kg	0.000 m3	0.0 kg	0.0 kg
E4.2*	1	7.0 kg	7.0 kg	0.000 m3	0.0 kg	0.0 kg
F.1	1	6.0 kg	6.0 kg	0.001 m3	1.0 kg	0.5 kg
F.2*	1	6.0 kg	6.0 kg	0.001 m3	1.0 kg	0.8 kg
F.3	1	6.0 kg	6.0 kg	0.001 m3	1.0 kg	0.8 kg
F.4*	1	6.0 kg	6.0 kg	0.001 m3	1.0 kg	0.8 kg
N.1	1	4.0 kg	4.0 kg	0.000 m3	0.0 kg	0.2 kg
N.2*	1	4.0 kg	4.0 kg	0.000 m3	0.0 kg	0.2 kg
N.3	1	0.0 kg	0.0 kg	0.000 m3	0.0 kg	0.0 kg
N.4*	1	0.0 kg	0.0 kg	0.000 m3	0.0 kg	0.0 kg
S1.2	1	2.0 kg	2.0 kg	0.001 m3	1.0 kg	0.8 kg
S1.3*	1	2.0 kg	2.0 kg	0.001 m3	1.0 kg	0.8 kg
T.1	1	3.0 kg	3.0 kg	0.000 m3	0.0 kg	0.0 kg
T.2	1	3.0 kg	3.0 kg	0.000 m3	0.0 kg	0.0 kg
TB.1	1	4.0 kg	4.0 kg	0.001 m3	1.0 kg	1.4 kg
Total	**15**	**60.0 kg**	**59.5 kg**	**0.007 m3**	**7.0 kg**	**6.4 kg**

```
SUMMATION OF DATA FOR ALL COMPONENTS :
Total : 17         73 kg        72 kg     0.022 m3        22 kg         19 kg
```

Weight Summary/Condition	Shell Side	Tube Side	Total
Empty Weight of Vessel incl. 5% Contingency	13 kg / 0.0 Tons	62 kg / 0.1 Tons	75 kg
Total Test Weight of Vessel (Testing with Water)	28 kg / 0.0 Tons	69 kg / 0.1 Tons	97 kg
Total Operating Weight of Vessel	27 kg / 0.0 Tons	69 kg / 0.1 Tons	96 kg

Center of Gravity

PROCESS CARD NO.: 1 SHELL SIDE

ID	X-Empty	Y-Empty	Z-Empty	X-Test	Y-Test	Z-Test	X-Oper	Y-Oper	Z-Oper
S1.1	0	0	490	0	0	525	0	0	525

SHELL SIDE CENTER OF GRAVITY AT CONDITIONS BELOW	X	Y	Z
Empty Vessel	0	0	490
Test Condition of Vessel (Testing with Water)	0	0	509
Operating Condition of Vessel	0	0	509

PROCESS CARD NO.: 2 TUBE SIDE

ID	X-Empty	Y-Empty	Z-Empty	X-Test	Y-Test	Z-Test	X-Oper	Y-Oper	Z-Oper
E4.1	0	0	-138	0	0	-134	0	0	-134
E4.2*	0	0	1184	0	0	1184	0	0	1184
F.1	0	0	-72	0	0	-72	0	0	-72
F.2*	0	0	1113	0	0	1113	0	0	1113
F.3	0	0	-27	0	0	-27	0	0	-27
F.4*	0	0	1077	0	0	1077	0	0	1077
N.1	150	0	80	115	0	80	115	0	80
N.2*	-150	0	980	-115	0	980	-115	0	980
N.3	41	0	-153	41	0	-160	41	0	-160
N.4*	-40	0	-152	-40	0	-159	-40	0	-159
S1.2	0	0	-105	0	0	-105	0	0	-105
S1.3*	0	0	1155	0	0	1155	0	0	1155
T.1	0	0	-68	0	0	-68	0	0	-68
T.2	0	0	510	0	0	510	0	0	510
TB.1	0	0	221	0	0	221	0	0	221

TUBE SIDE CENTER OF GRAVITY AT CONDITIONS BELOW	X	Y	Z
Empty Vessel	0	0	479
Test Condition of Vessel (Testing with Water)	0	0	479
Operating Condition of Vessel	0	0	479

CENTER OF GRAVITY AT CONDITIONS BELOW	X	Y	Z
Empty Vessel	0	0	481
Test Condition of Vessel (Testing with Water)	0	0	488
Operating Condition of Vessel	0	0	488

Max. Allowable Pressure MAWP

PROCESS CARD NO.: 1 SHELL SIDE

ID	Comp. Type	Description	Liq.Head	MAWP New & Cold	MAWP Hot & Corr.
S1.1	Cylindrical Shell	Main Shell	0.003 MPa	5.021 MPa	3.314 MPa
T.1	Tubesheet	Tubesheet	0.000 MPa	12.115 MPa	10.684 MPa
T.2	Tubesheet	Tubesheet floating	0.000 MPa	17.231 MPa	15.183 MPa
TB.1	Tube Bundle	Tube bundle	0.000 MPa	2.764 MPa	2.492 MPa
	MAWP			**2.764 MPa**	**2.492 MPa**

Note : Other components may limit the MAWP than the ones checked above.
Note : The value for MAWP is at top of vessel, with static liquid head subtracted.

PROCESS CARD NO.: 2 TUBE SIDE

ID	Comp. Type	Description	Liq.Head	MAWP New & Cold	MAWP Hot & Corr.
E4.1	Welded Flat End	Head left	0.003 MPa	9.836 MPa	9.120 MPa
E4.2*	Welded Flat End	Head right	0.003 MPa	9.836 MPa	9.120 MPa
F.1	RT - Flange	Flangering Head left	0.003 MPa	3.310 MPa	3.310 MPa
F.2*	RT - Flange	Flangering Head right	0.003 MPa	3.310 MPa	3.310 MPa
F.3	RT - Flange	Flangering Shell left	0.003 MPa	3.310 MPa	3.310 MPa
F.4*	RT - Flange	Flangering Shell right	0.003 MPa	3.310 MPa	3.310 MPa
N.3	Open.Without Nozzle	N4	0.002 MPa	5.244 MPa	4.756 MPa
N.4*	Open.Without Nozzle	N3	0.002 MPa	5.244 MPa	4.756 MPa
S1.2	Cylindrical Shell	Channel Head left	0.003 MPa	11.102 MPa	10.112 MPa
S1.3*	Cylindrical Shell	Channel Head right	0.003 MPa	11.102 MPa	10.112 MPa
T.1	Tubesheet	Tubesheet	0.000 MPa	12.104 MPa	10.680 MPa
T.2	Tubesheet	Tubesheet floating	0.000 MPa	17.216 MPa	15.184 MPa

ID	Comp. Type	Description	Liq.Head	MAWP New & Cold	MAWP Hot & Corr.
TB.1	Tube Bundle	Tube bundle	0.000 MPa	8.432 MPa	8.432 MPa
	MAWP			**3.310 MPa**	**3.310 MPa**

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Note : Other components may limit the MAWP than the ones checked above.
Note : The value for MAWP is at top of vessel, with static liquid head subtracted.
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Bill of Materials

ID	No	Description	Component Dimensions	Material Standard
E4.1	1	Welded Flat End-Head left	Do= 215, t= 27, Lcyl= 1, es= .85, r= 20	ID 3, SA-182(M) Gr.F316L, S31603 Forgings, PNo=8
E4.2*	1	Welded Flat End-Head right	Do= 215, t= 27, Lcyl= 1, es= .85, r= 20	ID 3, SA-182(M) Gr.F316L, S31603 Forgings, PNo=8
F.1	1	RT - Flange-Flangering Head left	OD= 215, ID= 133.3, thk= 36, h= 0, g1= 15.8	ID 3, SA-182(M) Gr.F316L, S31603 Forgings, PNo=8
F.1	4	Bolts	M12x1.75 ;, Area= 76.25	ID 4, SA-193(M) Gr.B7, G41400 Bolting
F.2*	1	RT - Flange-Flangering Head right	OD= 215, ID= 134.5, thk= 36, h= 18, g1= 17.5	ID 3, SA-182(M) Gr.F316L, S31603 Forgings, PNo=8
F.2*	4	Bolts	M12x1.75 ;, Area= 76.25	ID 4, SA-193(M) Gr.B7, G41400 Bolting
F.3	1	RT - Flange-Flangering Shell left	OD= 215, ID= 134.5, thk= 36, h= 18, g1= 17.5	ID 3, SA-182(M) Gr.F316L, S31603 Forgings, PNo=8
F.3	4	Bolts	M12x1.75 ;, Area= 76.25	ID 4, SA-193(M) Gr.B7, G41400 Bolting
F.4*	1	RT - Flange-Flangering Shell right	OD= 215, ID= 134.5, thk= 36, h= 18, g1= 17.5	ID 3, SA-182(M) Gr.F316L, S31603 Forgings, PNo=8
F.4*	4	Bolts	M12x1.75 ;, Area= 76.25	ID 4, SA-193(M) Gr.B7, G41400 Bolting
N.1	1	Flange:ASME B16.5:Class 300 lbs	WN Welding Neck, 1a RF Raised Face	2.3 16Cr-12Ni-2Mo :A 182 Gr. F316L - A 240 Gr. 316L
N.1	1	Nozzle,Plate Body-N1	2" do=60.3,t=3.91,L=110.5,ho=100	ID 9, SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8
N.2*	1	Flange:ASME B16.5:Class 300 lbs	WN Welding Neck, 1a RF Raised Face	2.3 16Cr-12Ni-2Mo :A 182 Gr. F316L - A 240 Gr. 316L
N.2*	1	Nozzle,Plate Body-N1	2" do=60.3,t=3.91,L=110.5,ho=100	ID 9, SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8
N.3	1	Open.Without Nozzle-N4	di=40	ID 5, SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8
N.4*	1	Open.Without Nozzle-N3	di=40	ID 5, SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8
S1.1	1	Cylindrical Shell-Main Shell	Do= 141.3, t= 3.4, L= 1050	ID 5, SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8
S1.2	1	Cylindrical Shell-Channel Head left	Do= 215, t= 13.35, L= 30	ID 3, SA-182(M) Gr.F316L, S31603 Forgings, PNo=8
S1.3*	1	Cylindrical Shell-Channel Head right	Do= 215, t= 13.35, L= 30	ID 3, SA-182(M) Gr.F316L, S31603 Forgings, PNo=8
T.1	1	Tubesheet-Tubesheet	OD= 132.2, thk= 28, N= 72 tubes	ID 11, SB-148(M), M01, C95820 Castings
T.2	1	Tubesheet-Tubesheet floating	OD= 132.2, thk= 28, N= 72 tubes	ID 11, SB-148(M), M01, C95820 Castings
TB.1	1	Tube Bundle-Tube bundle	N= 72, dt= 7.5, tt= .5, L= 606	ID 7, SB-111(M), O61, C70600 Smls. cond. tube

Nozzle List

ID	Service	SIZE	STANDARD/CLASS	ID	Standout	X	Y	Z	Rot.	Orient.
N.1	N1	2"	ASME B16.5 300 lbs WN -RF Raised Face SCH 40S	55.5	100	69	0	80	0	Radial
N.2*	N1	2"	ASME B16.5 300 lbs WN -RF Raised Face SCH 40S	55.5	100	-69	0	980	180	Radial
N.3	N4	2"		0	100	40.5	0	-153.5	0	Radial
N.4*	N3	2"		0	100	-40.5	0	-152.5	180	Radial

Maximum Component Utilization - Umax

ID	Comp.Type	Umax(%)	Limited by
E4.1	Welded Flat End	35.6%	Flat Head Thickness
E4.2*	Welded Flat End	35.6%	Flat Head Thickness

ID	Comp.Type	Umax(%)	Limited by
F.1	RT - Flange	30.2%	Bolting Area Check
F.2*	RT - Flange	30.2%	Bolting Area Check
F.3	RT - Flange	30.2%	Bolting Area Check
F.4*	RT - Flange	30.2%	Bolting Area Check
N.1	Nozzle,Plate Body	73.3%	UG-45 Min.Nozzle Neck Thk.
N.2*	Nozzle,Plate Body	73.3%	UG-45 Min.Nozzle Neck Thk.
N.3	Open.Without Nozzle	19.0%	UG-37 Nozzle Reinforcement
N.4*	Open.Without Nozzle	19.0%	UG-37 Nozzle Reinforcement
S1.1	Cylindrical Shell	85.8%	Internal Pressure
S1.2	Cylindrical Shell	28.2%	Internal Pressure
S1.3*	Cylindrical Shell	28.2%	Internal Pressure
T.1	Tubesheet	26.4%	Tubesheet Bending Stress
T.2	Tubesheet	18.5%	Tubesheet Bending Stress
TB.1	Tube Bundle	23.3%	Internal Pressure

Component with highest utilization Umax = 85.8% S1.1 Main Shell

Average utilization of all components Umean= 36.7%

Material Data/Mechanical Properties

ID	Material Name	Temp	ST	SY	SYd	S_d	Sr	ftest	E-mod	Note
1	SA-213(M) Gr.TP316L, S31603 Smls. tube, PNo=8 , SG=7.85	120	485	170	138.6	115	115	153	185000	G5
2	SA-479(M) Gr.304L, S30403 Bar, PNo=8 , SG=7.85	100	485	170	146	115	115	153	187909	G5, G21, G22, T4
3	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 , SG=7.85	120	450	170	138.6	115	115	153	185000	G5
4	SA-193(M) Gr.B7, G41400 Bolting , Max.T= 100mm, SG=7.85	95	795	655	609.6	159	159	589.5	0	T5
5	SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 , SG=7.85	120	515	205	169.6	138	138	184.5	186212	G5, G12, T8, W12, W13, W14
6	SA-240(M) Gr.316Ti, S31635 Plate, PNo=8 , SG=7.85	100	515	205	180	138	138	184.5	187909	G5, G12, T8
7	SB-111(M), O61, C70600 Smls. cond. tube , SG=7.85	95	275	100	97.9	68.9	68.9	90	122285	G5, T5
8	SA-479(M) Gr.304L, S30403 Bar, PNo=8 , SG=7.85	120	485	170	139.6	115	115	153	186212	G5, G21, G22, T4
9	SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8 , SG=7.85	100	485	170	145	115	115	153	187000	G5, G21, W12, W14
10	SB-111(M), O61, C68700 Smls. cond. tube , SG=7.85	210	345	125	0	20.8	82.7	112.5	124000	T3
11	SB-148(M), M01, C95820 Castings , SG=7.85	95	650	270	263.3	176.1	179	243	148181	G15

Notation:
Thickness in mm, stress in N/mm2, temperature in deg.C
TG : Test Group 1 to 4
Max.T: Maximum thickness for this stress set, 0 or 999 = No limit specified
S/C : CS = Carbon Steel, SS = Stainless Steel
SG : SG = Specific Gravity (Water = 1.0)
ST : MIN.TENSILE STRENGTH at room temp.
SY : MIN. YIELD STRENGTH at room temp.
SYd : MIN. YIELD STRENGTH at calc.temp.
S_d : DESIGN STRESS at calc.temp.
Sr : DESIGN STRESS at room temp.
Note : G5 = Due to the relatively low yield strength of these materials, these higher stress values were established at temperatures where the shorttime tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. The stress values in this range exce
ed 662/3% but do not exceed 90% of the yield strength at temperature. Use of these stresses may result in dimensional changes due to permanent strain. These stress

values are not recommended for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction. For Section III applications, Table Y-2 lists multiplying factors that, when applied to the yield strength values shown in Table Y-1, will give allowable stress values that will result in lower levels of permanent strain.
Note : G21 = For Section I, use is limited to PEB–5.3. See PG–5.5 for cautionary note.
Note : G22 = For Section I applications, use of external pressure charts for material in the form of barstock is permitted for stiffening rings only.
Note : T4 = Allowable stresses for temperatures of 480°C and above are values obtained from time-dependent properties.
Note : T5 = Allowable stresses for temperatures of 450°C and above are values obtained from time–dependent properties.
Note : G12 = At temperatures above 550°C, these stress values apply only when the carbon is 0.04% or higher on heat analysis.
Note : T8 = Allowable stresses for temperatures of 595°C and above are values obtained from time-dependent properties.
Note : W12 = These S values do not include a longitudinal weld efficiency factor. For Section III applications, for materials welded without filler metal, ultrasonic examination, radiographic examination, or eddy current examination, in accordance with NC-2550, shall provide a longitudinal weld eff
iciency factor of 1.00. Materials welded with filler metal meeting the requirements of NC-2560 shall receive a longitudinal weld efficiency factor of 1.00. Other longitudinal weld efficiency factors shall be in accordance with the following: (a) for single butt weld, with filler metal, 0.80; (b) for single or double butt weld, without filler metal, 0.85; (c) for double butt weld, with filler metal, 0.90; (d) for single or double butt weld, with radiography, 1.00.
Note : W13 = For Section I applications, electric resistance and autogenous welded tubing may be used with these stresses, provided the following additional restrictions and requirements are met: (a) The tubing shall be used for boiler, waterwall, superheater, and economizer tubes that are enclosed within the setting. (b) The maximum outside diameter shall be 89 mm. (c) The weld seam of each tube shall be subjected to an angle beam ultrasonic inspection per SA-450. (d) A complete volumetric inspection of the entire length of each tube shall be performed in accordance with SA-450. (e) Material test reports shall be supplied.
Note : W14 = These S values do not include a weld factor. For Section VIII, Division 1, and Section XII applications using welds made without filler metal, the tabulated tensile stress values shall be multiplied by 0.85. For welds made with filler metal, consult UW-12 for Section VIII, Division 1, or TW-130.4 for Section XII, as applicable.
Note : T3 = Allowable stresses for temperatures of 175°C and above are values obtained from time-dependent properties.
Note : G15 = To these stress values a quality factor as specified in ND-3115 of Section III; UG-24 of Section VIII, Division 1; or TM-190 of Section XII shall be applied for castings. This is not intended to apply to valves and fittings made to recognized standards.

Comp.Location in Global Coord.System

ID	Comp. Type	X	Y	Z	Teta	Phi	ConnID
E4.1	Welded Flat End	0	0	-120	0.0	0.0	S1.2
E4.2*	Welded Flat End	0	0	1170	0.0	0.0	S1.3*
F.1	RT - Flange	0	0	-54	0.0	0.0	F.3
F.2*	RT - Flange	0	0	1086	0.0	0.0	F.4*
F.3	RT - Flange	0	0	0	0.0	0.0	S1.1
F.4*	RT - Flange	0	0	1050	0.0	0.0	S1.1
N.1	Nozzle,Plate Body	69	0	80	90.0	0.0	S1.1
N.2*	Nozzle,Plate Body	-69	0	980	90.0	180.0	S1.1
N.3	Open.Without Nozzle	41	0	-153	0.0	0.0	E4.1
N.4*	Open.Without Nozzle	-40	0	-152	0.0	180.0	E4.1
S1.1	Cylindrical Shell	0	0	0	0.0	0.0	
S1.2	Cylindrical Shell	0	0	-90	0.0	0.0	F.1

ID	Comp. Type	X	Y	Z	Teta	Phi	ConnID
S1.3*	Cylindrical Shell	0	0	1140	0.0	0.0	F.2*
T.1	Tubesheet	0	0	-54	0.0	0.0	F.3
T.2	Tubesheet	0	0	496	0.0	0.0	TB.1
TB.1	Tube Bundle	0	0	0	0.0	0.0	T.1

The report above shows the location of the connecting point (x, y and z) for each component referenced to the coordinate system of the connecting component (ConnID). The connecting point (x, y and z) is always on the center axis of rotational symmetry for the component under consideration, i.e. the connecting point for a nozzle connected to a cylindrical shell will be at the intersection of the nozzle center axis and the mid thickness of the shell referenced to the shell s coordinate system. In addition the orientation of the the center axis of the component is given by the two angles Teta and Phi, where Teta is the angle between the center axis of the two components and Phi is the orientation in the x-y plane
The basis for the coordinate system used by the software is a right handed coordinate system with the z-axis as the center axis of rotational geometry for the components, and Teta as the Polar Angle and Phi as the Azimuthal Angle

MDMT Minimum Design Metal Temperature

Table :

ID-Description	Material Name	tn(mm)	tg(mm)	Ratio	E(*)	Curve
E4.1 Head left - End	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	27.0	6.8	0.10	1.00	
E4.2* Head right - End	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	27.0	6.8	0.10	1.00	
F.1 Flangering Head left - Bolts	SA-193(M) Gr.B7, G41400 Bolting	11.0	11.0	0.30	1.00	
F.1 Flangering Head left - Flange	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	36.0	9.0	0.30	1.00	
F.2* Flangering Head right - Bolts	SA-193(M) Gr.B7, G41400 Bolting	11.0	11.0	0.30	1.00	
F.2* Flangering Head right - Flange	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	36.0	9.0	0.30	1.00	
F.2* Flangering Head right - Hub	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	3.2	3.2	0.19	1.00	
F.3 Flangering Shell left - Bolts	SA-193(M) Gr.B7, G41400 Bolting	11.0	11.0	0.30	1.00	
F.3 Flangering Shell left - Flange	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	36.0	9.0	0.30	1.00	
F.3 Flangering Shell left - Hub	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	3.2	3.2	0.19	1.00	
F.4* Flangering Shell right - Bolts	SA-193(M) Gr.B7, G41400 Bolting	11.0	11.0	0.30	1.00	
F.4* Flangering Shell right - Flange	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	36.0	9.0	0.30	1.00	
F.4* Flangering Shell right - Hub	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	3.2	3.2	0.19	1.00	
N.1 N1 - Flange	2.3 16Cr-12Ni-2Mo :A 182 Gr. F316L - A 240 Gr. 316L	0.0	0.0	0.28	1.00	NA
N.1 N1 - Nozzle	SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8	3.9	3.9	0.12	0.85	
N.2* N1 - Flange	2.3 16Cr-12Ni-2Mo :A 182 Gr. F316L - A 240 Gr. 316L	0.0	0.0	0.28	1.00	NA
N.2* N1 - Nozzle	SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8	3.9	3.9	0.12	0.85	
N.3 N4 - Nozzle	SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8	3.9	3.9	0.19	1.00	
N.4* N3 - Nozzle	SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8	3.9	3.9	0.19	1.00	
S1.1 Main Shell - Shell	SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8	3.4	3.4	0.75	0.85	
S1.2 Channel Head left - Shell	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	13.4	13.4	0.10	0.85	
S1.3* Channel Head right - Shell	SA-182(M) Gr.F316L, S31603 Forgings, PNo=8	13.4	13.4	0.10	0.85	
T.1 Tubesheet - T-Sheet	SB-148(M), M01, C95820 Castings	28.0	7.0	0.26	1.00	
T.2 Tubesheet floating - T-Sheet	SB-148(M), M01, C95820 Castings	28.0	7.0	0.19	1.00	
TB.1 Tube bundle - Tube	SB-111(M), O61, C70600 Smls. cond. tube	0.5	0.5	0.23	1.00	

Table Continued

ID-Description	T1(C)	T2(C)	MDMT(C)	Comments
E4.1 Head left - End			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
E4.2* Head right - End			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
F.1 Flangering Head left - Bolts	-48.0	-80.0	-105	

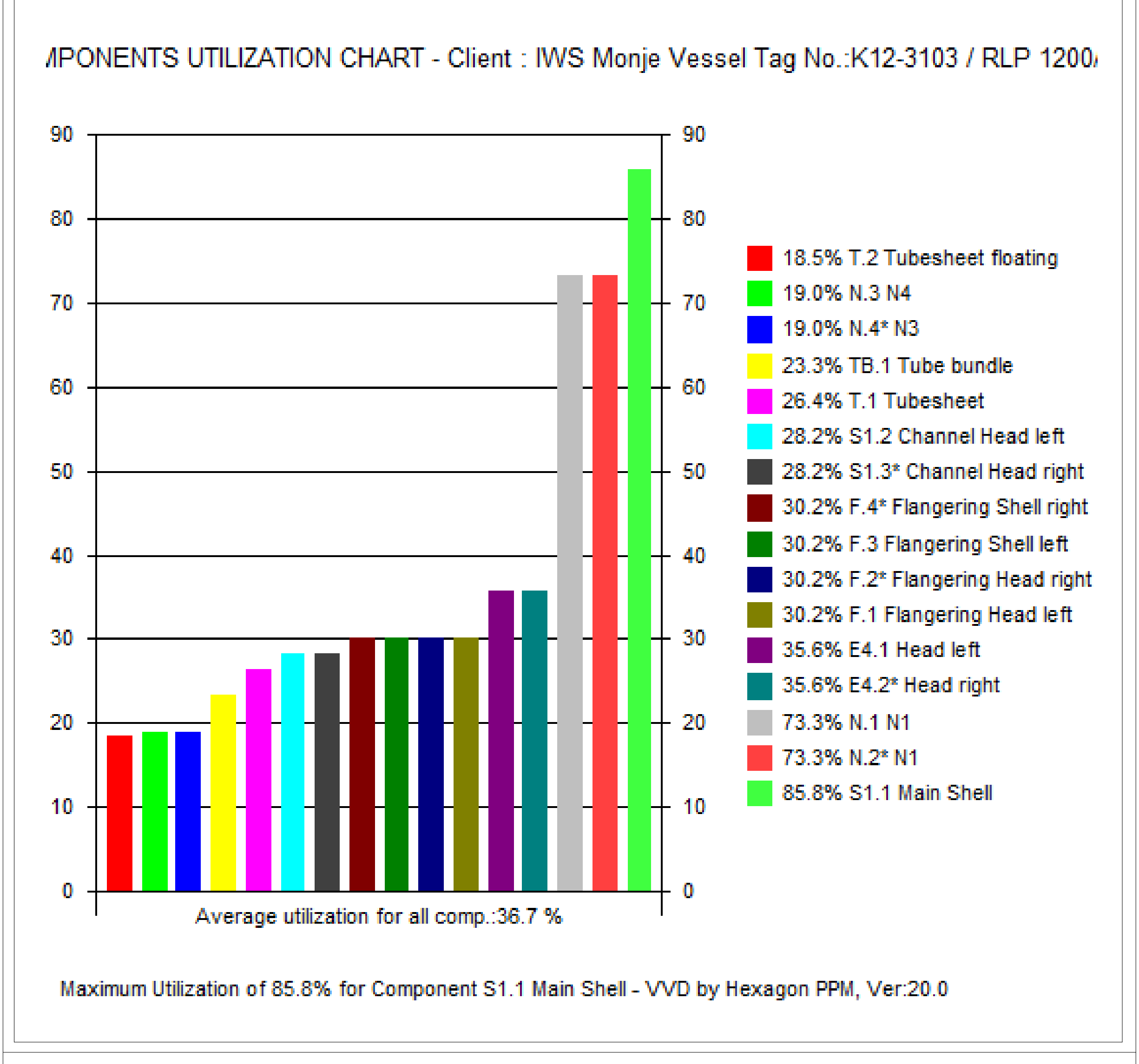
ID-Description	T1(C)	T2(C)	MDMT(C)	Comments
F.1 Flangering Head left - Flange			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
F.2* Flangering Head right - Bolts	-48.0	-80.0	-105	
F.2* Flangering Head right - Flange			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
F.2* Flangering Head right - Hub			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
F.3 Flangering Shell left - Bolts	-48.0	-80.0	-105	
F.3 Flangering Shell left - Flange			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
F.3 Flangering Shell left - Hub			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
F.4* Flangering Shell right - Bolts	-48.0	-80.0	-105	
F.4* Flangering Shell right - Flange			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
F.4* Flangering Shell right - Hub			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
N.1 N1 - Flange	-196	-80.0	-276	ASME B16.5 Flange
N.1 N1 - Nozzle			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
N.2* N1 - Flange	-196	-80.0	-276	ASME B16.5 Flange
N.2* N1 - Nozzle			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
N.3 N4 - Nozzle			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
N.4* N3 - Nozzle			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
S1.1 Main Shell - Shell			-196	For thermally treated materials, ref. is made to UHA-51(c)
S1.2 Channel Head left - Shell			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
S1.3* Channel Head right - Shell			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
T.1 Tubesheet - T-Sheet			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
T.2 Tubesheet floating - T-Sheet			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.
TB.1 Tube bundle - Tube			-	NOTE: UHA-51(g) Material is exempted from impact testing due to low stress. Ratio of design stress to allowable tensile stress is less than 0.35.

```
MDMT CALCULATIONS PER UCS-66, UG-20(f), UHA-51 and Appendix JJ
MDMT Required        : -10.0 C
MDMT Lowest Allowable: -105 C

NOMENCLATURE:
  tn   - Nominal thickness of component under consideration(including corr.
allow.).
  tg   - Governing thickness of component under consideration.
  Ratio- tr*E(*)/(tn-c), utiliztion of component for given process conditions.
  tr   - Required minimum thickness of component at calculation temperature of
MDMT.
  E(*) - Joint efficiency factor, not lower than 0.8.
  Curve- Applicable curve A, B, C or D in Figure UCS-66.
  T1   - Unadjusted MDMT/Lowest allowable temperature for given part, value taken
from Figure UCS-66 based on curve A, B, C or D.
  T2   - Reduction in MDMT without impact testing per Figure UCS-66.1.

NOTES:
  UCS-68(c) If postweld heat treatment is performed when it is not otherwise a
```

requirement, a 17C reduction in impact test exemption temp. may be given to the min. permissible temp. for P.no.1 materials.
The maximum general primary stress in the pads are conservatively assumed to be the same as that in the corroded shell.
Note: For austenitic stainless steels, reference is made to UHA-51(c) for thermally treated materials.
NOTE: LOWEST MDMT = -105 C (Warmest Value)

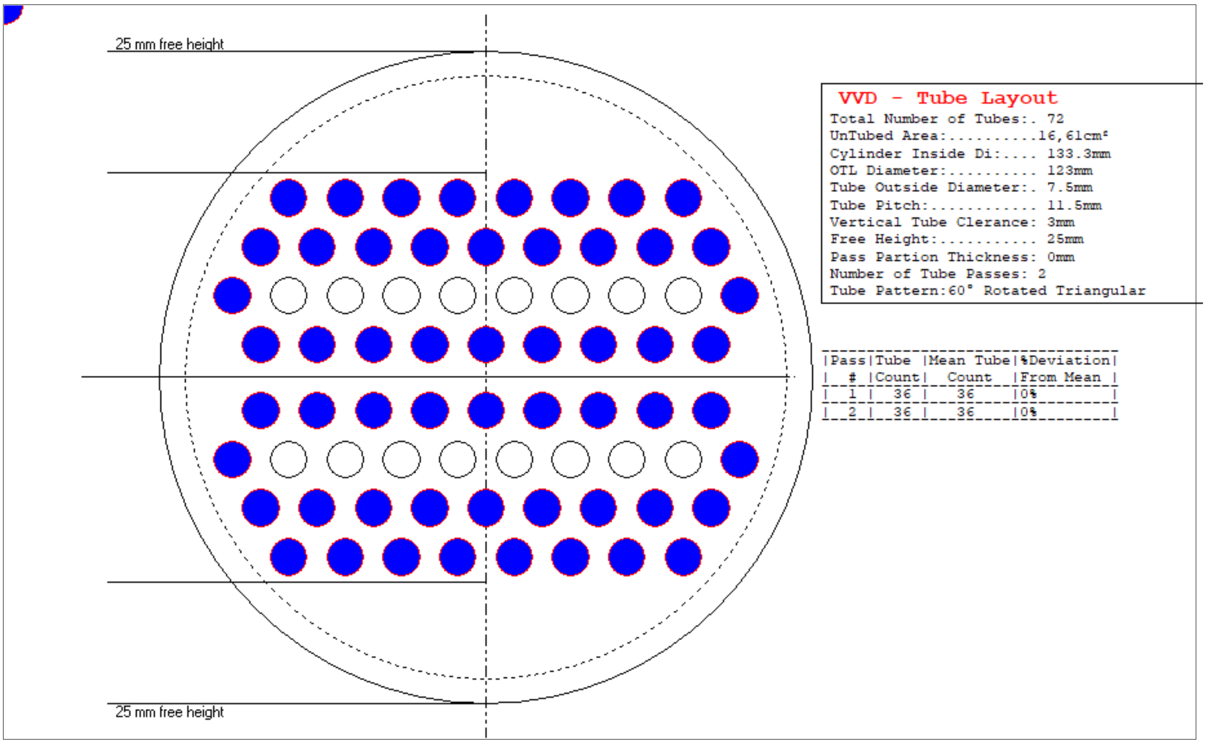
Utilization Chart

Utilization Chart



Tube Layout

Tube Layout



Surface Area

PROCESS CARD NO.: 1 SHELL SIDE

ID	No.	Description	Area Outside(m2)	Area Inside(m2)
S1.1	1	Cylindrical Shell, Main Shell	0.466	0.453
Total	**1**		**0.466**	**0.453**

PROCESS CARD NO.: 2 TUBE SIDE

ID	No.	Description	Area Outside(m2)	Area Inside(m2)
E4.1	1	Welded Flat End, Head left	0.036	0.036
E4.2*	1	Welded Flat End, Head right	0.036	0.036
F.1	1	RT - Flange, Flangering Head left	0.024	0.015
F.2*	1	RT - Flange, Flangering Head right	0.053	0.023
F.3	1	RT - Flange, Flangering Shell left	0.053	0.023
F.4*	1	RT - Flange, Flangering Shell right	0.053	0.023
N.1	1	Nozzle,Plate Body, N1	0.019	0.016
N.2*	1	Nozzle,Plate Body, N1	0.019	0.016
N.3	1	Open.Without Nozzle, N4	0.000	0.000
N.4*	1	Open.Without Nozzle, N3	0.000	0.000
S1.2	1	Cylindrical Shell, Channel Head left	0.020	0.018
S1.3*	1	Cylindrical Shell, Channel Head right	0.020	0.018
T.1	1	Tubesheet, Tubesheet	0.000	0.000
T.2	1	Tubesheet, Tubesheet floating	0.000	0.000
TB.1	1	Tube Bundle, Tube bundle	1.028	0.891
Total	**15**		**1.361**	**1.115**

```
SUMMATION OF DATA FOR ALL COMPONENTS :
Total :Ao=       0.466 m2, Ai=       0.453 m2
```

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

GENERAL DESIGN DATA

```
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Shell Side : Temp= 210°C, P=2.5000 MPa, c=1.0 mm, Pext=0.1000 MPa
SPECIFIC DENSITY OF OPERATING LIQUID................:SG        1.0000
LIQUID HEAD.........................................:LH        268.67 mm
```

SHELL DATA

```
CYLINDER FABRICATION: Welded Pipe
NEGATIVE TOLERANCE: Negative tolerance specified in % of nominal thickness
SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 120'C
ST=515 SY=205 SYd=169.6 S=138 Sr=138 Stest=184.5  (N/mm2)
WELD JOINT EFFICIENCY FACTOR: Spot RT UW-11(b) Type 1 (E=0.85)
Minimum thickness check to UG-16 does NOT apply.: NO
OUTSIDE DIAMETER OF SHELL...........................:Do        141.30 mm
LENGTH OF CYLINDRICAL PART OF SHELL.................:Lcyl     1050.00 mm
NOMINAL WALL THICKNESS (uncorroded).................:tn        3.4000 mm
NEGATIVE DEVIATION/TOLERANCE........................:           12.50 %
Split shell into several shell courses and include welding information: NO
```

EXTERNAL PRESSURE

```
UNSUPPORTED LENGTH OF SHELL (Fig.UG-28.1)...........:L            0.00 mm
```

CALCULATION DATA

UG-27 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

```
Outside Radius of Shell
Ro = Do / 2 =141.3/2=                                          70.65 mm
```

»Thin Cylinder Check P=2.5026 <= 0.385 * S * E=45.16[MPa] «» OK«

```
Required Minimum Shell Thickness Excl.Allow. tmin :
tmin = P * Ro / (S * E + 0.4 * P)                                 (APP.1-1 (1))
=2.5026*70.65/(138*0.85+0.4*2.5026)=                        1.4946 mm
```

»Thin Cylinder Check tmin=1.49 < 0.5 * R=35.33[mm] « » OK«

```
Required Minimum Shell Thickness Incl.Allow. :
tmina = tmin + c + NegDev =1.49+1+0.425=                      2.9196 mm

Analysis Thickness
ta = tn - c - NegDev =3.4-1-0.425=                            1.9750 mm
```

Internal Pressure tmina=2.92 <= tn=3.4[mm]	85.8%	OK

»Shell - Min.thickness to UG-16 Thk=1.975 >= UG-16(b) (1.5mm)=1.5[mm] «» OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :

```
Inside Diameter of Shell
Di = Do - 2 * ta =141.3-2*1.975=                              137.35 mm
Inside Radius of Shell
R = Di / 2 =137.35/2=                                          68.68 mm
MAWP HOT & CORR. (Corroded condition at design temp.)
MAWPHC = S * E * ta / (R + 0.6 * ta)
=138*0.85*1.975/(68.675+0.6*1.975)=                         3.3162 MPa

MAWP NEW & COLD (Uncorroded condition at ambient temp.)
MAWPNC = Sr * E * (ta + c) / (R - c + 0.6 * (ta + c))
=138*0.85*(1.975+1)/(68.675-1+0.6*(1.975+1))=               5.0240 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)
Ptmax = SYtest * Etest * (ta + c) / (R + 0.6 * (ta + c))
=184.5*1*(1.975+1)/(68.675+0.6*(1.975+1))=                7.7901 MPa
```

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Ptmin = 1.1 * Pd * Sr / S =1.1*2.5*138/138=                  2.7500 MPa
```

Test Pressure Ptmin=2.75 <= Ptmax=7.79[MPa]	35.3%	OK

SECT. UG28 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

Preliminary Calculations

```
Ratio1 = Do / t =141.3/1.975=                                  71.54
Ratio2 = L / Do =0/141.3=                                       0.00
Value of A from Fig.G (Part D), A =0.097478
Value of B from External Pressure Chart HA-2(based on Temp=210)  B =97.29
Pmax = (4 / 3) * B / (Do / t)
=(4/3)*97.29/(141.3/1.975)=                               1.8131 MPa
```

External Pressure Pmax=1.81 >= Pext=0.1[MPa]	5.5%	OK

Required Minimum Thickness Due to External Pressure Incl.Allow.:1.6 mm

CALCULATION SUMMARY

UG-27 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

```
Required Minimum Shell Thickness Excl.Allow. tmin :
tmin = P * Ro / (S * E + 0.4 * P)                               (APP.1-1 (1))
=2.5026*70.65/(138*0.85+0.4*2.5026)=                      1.4946 mm

Required Minimum Shell Thickness Incl.Allow. :
tmina = tmin + c + NegDev =1.49+1+0.425=                     2.9196 mm
```

Internal Pressure tmina=2.92 <= tn=3.4[mm]	85.8%	OK

```
MAWP HOT & CORR. (Corroded condition at design temp.)
MAWPHC = S * E * ta / (R + 0.6 * ta)
=138*0.85*1.975/(68.675+0.6*1.975)=                       3.3162 MPa

MAWP NEW & COLD (Uncorroded condition at ambient temp.)
MAWPNC = Sr * E * (ta + c) / (R - c + 0.6 * (ta + c))
=138*0.85*(1.975+1)/(68.675-1+0.6*(1.975+1))=             5.0240 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)
Ptmax = SYtest * Etest * (ta + c) / (R + 0.6 * (ta + c))
=184.5*1*(1.975+1)/(68.675+0.6*(1.975+1))=                7.7901 MPa
```

Test Pressure Ptmin=2.75 <= Ptmax=7.79[MPa]	35.3%	OK

SECT. UG28 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

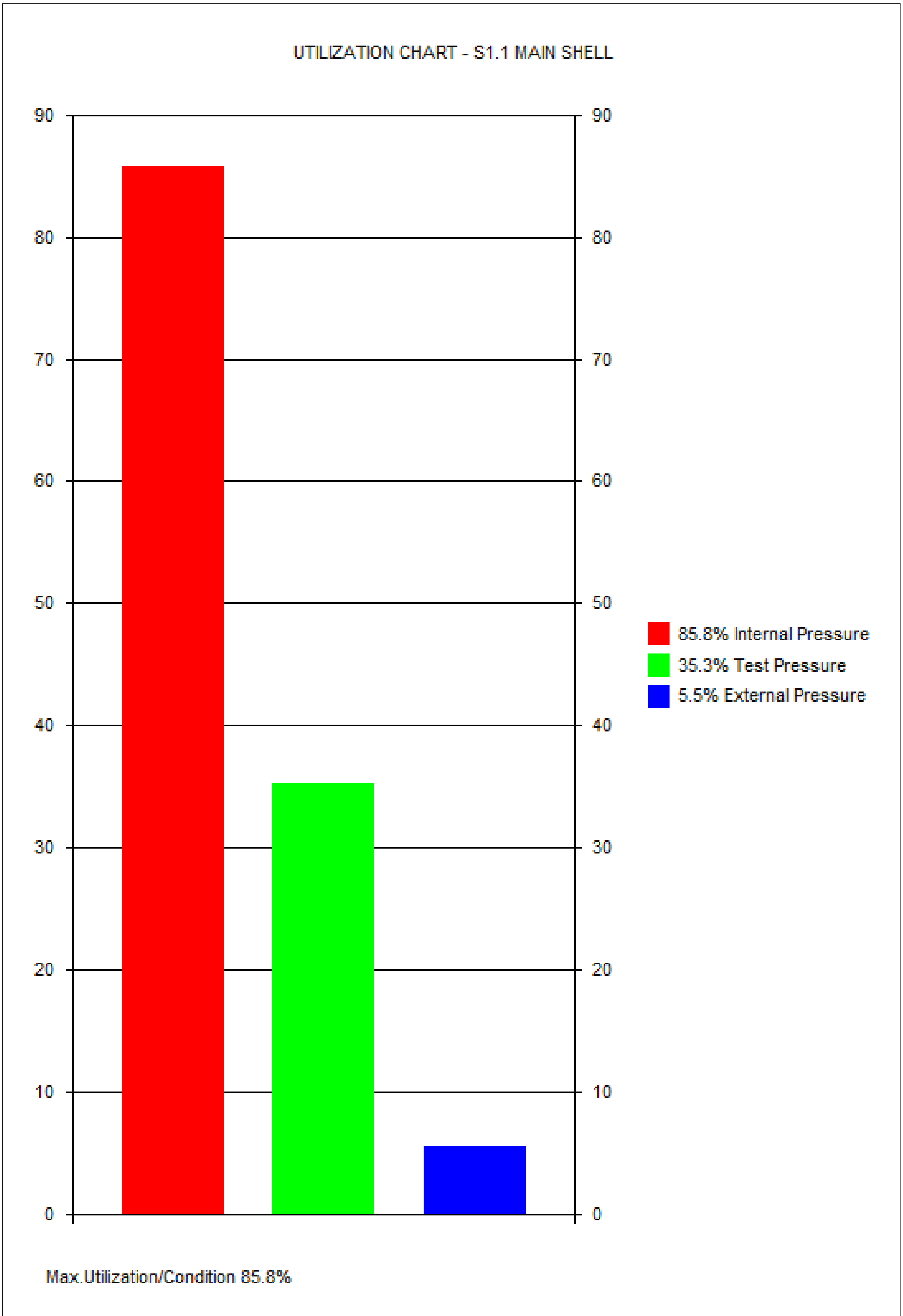
```
Pmax = (4 / 3) * B / (Do / t)
=(4/3)*97.29/(141.3/1.975)=                               1.8131 MPa
```

External Pressure Pmax=1.81 >= Pext=0.1[MPa]	5.5%	OK

Required Minimum Thickness Due to External Pressure Incl.Allow.:1.6 mm

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 210 FOR: 5 SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.
WARNING: A non zero value needs to be specified for the unsupported length.

Volume:0.0156 m3 Weight:12.1 kg (SG= 7.85)


UTILIZATION CHART - S1.1 MAIN SHELL
90
80
70
60
50
40
30
20
10
0
85.8% Internal Pressure
35.3% Test Pressure
5.5% External Pressure
Max.Utilization/Condition 85.8%

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

```
Attachment: F.1     RT - Flange         Flangering Head left          F.3
Location: Along z-axis z1= -90
```

GENERAL DESIGN DATA

```
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Tube Side : Temp= 95°C, P=1.0000 MPa, c=1.0 mm, Pext=0.1000 MPa
SPECIFIC DENSITY OF OPERATING LIQUID................:SG        1.0000
LIQUID HEAD.........................................:LH        267.65 mm
```

SHELL DATA

```
CYLINDER FABRICATION: Seamless Pipe
NEGATIVE TOLERANCE: Negative tolerance specified in % of nominal thickness
SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 120'C
ST=450 SY=170 SYd=138.6 S=115 Sr=115 Stest=153  (N/mm2)
WELD JOINT EFFICIENCY FACTOR: Spot RT UW-11(b) Type 1 (E=0.85)
Minimum thickness check to UG-16 does NOT apply.: NO
OUTSIDE DIAMETER OF SHELL...........................:Do        215.00 mm
LENGTH OF CYLINDRICAL PART OF SHELL.................:Lcyl       30.00 mm
NOMINAL WALL THICKNESS (uncorroded).................:tn         13.35 mm
NEGATIVE DEVIATION/TOLERANCE........................:          12.50 %
Split shell into several shell courses and include welding information: NO
```

EXTERNAL PRESSURE

```
UNSUPPORTED LENGTH OF SHELL (Fig.UG-28.1)...........:L           0.00 mm
```

CALCULATION DATA

UG-27 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

```
Outside Radius of Shell
Ro = Do / 2 =215/2=                                        107.50 mm
```

»Thin Cylinder Check P=1.0026 <= 0.385 * S * E=37.63[MPa] «» OK«

```
Required Minimum Shell Thickness Excl.Allow. tmin :
tmin = P * Ro / (S * E + 0.4 * P)                              (APP.1-1 (1))
=1.0026*107.5/(115*0.85+0.4*1.0026)=                     1.0981 mm
```

»Thin Cylinder Check tmin=1.1 < 0.5 * R=53.75[mm] « » OK«

```
Required Minimum Shell Thickness Incl.Allow. :
tmina = tmin + c + NegDev =1.1+1+1.67=                     3.7668 mm

Analysis Thickness
ta = tn - c - NegDev =13.35-1-1.67=                         10.68 mm
```

Internal Pressure tmina=3.77 <= tn=13.35[mm]	28.2%	OK

»Shell - Min.thickness to UG-16 Thk=10.68 >= UG-16(b) (1.5mm)=1.5[mm] «» OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :

```
Inside Diameter of Shell
Di = Do - 2 * ta =215-2*10.68=                             193.64 mm
Inside Radius of Shell
R = Di / 2 =193.64/2=                                       96.82 mm
MAWP HOT & CORR. (Corroded condition at design temp.)
MAWPHC = S * E * ta / (R + 0.6 * ta)
=115*0.85*10.68/(96.82+0.6*10.68)=                        10.11 MPa

MAWP NEW & COLD (Uncorroded condition at ambient temp.)
MAWPNC = Sr * E * (ta + c) / (R - c + 0.6 * (ta + c))
=115*0.85*(10.68+1)/(96.82-1+0.6*(10.68+1))=              11.10 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)
Ptmax = SYtest * Etest * (ta + c) / (R + 0.6 * (ta + c))
=153*1*(10.68+1)/(96.82+0.6*(10.68+1))=                     17.21 MPa
```

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Ptmin = 1.1 * Pd * Sr / S =1.1*1*115/115=                    1.1000 MPa
```

Test Pressure Ptmin=1.1 <= Ptmax=17.21[MPa]	6.3%	OK

SECT. UG28 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

Preliminary Calculations

```
Ratio1 = Do / t =215/10.68=                                  20.13
Ratio2 = L / Do =0/215=                                       0.00
Value of A from Fig.G (Part D), A =0.09793
Value of B from External Pressure Chart HA-4(based on Temp=95)  B =97.92
Pmax = (4 / 3) * B / (Do / t)
=(4/3)*97.92/(215/10.68)=                                   6.4864 MPa
```

External Pressure Pmax=6.49 >= Pext=0.1[MPa]	1.5%	OK

Required Minimum Thickness Due to External Pressure Incl.Allow.:3 mm

CALCULATION SUMMARY

UG-27 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

```
Required Minimum Shell Thickness Excl.Allow. tmin :
tmin = P * Ro / (S * E + 0.4 * P)                            (APP.1-1 (1))
=1.0026*107.5/(115*0.85+0.4*1.0026)=                        1.0981 mm

Required Minimum Shell Thickness Incl.Allow. :
tmina = tmin + c + NegDev =1.1+1+1.67=                        3.7668 mm
```

Internal Pressure tmina=3.77 <= tn=13.35[mm]	28.2%	OK

```
MAWP HOT & CORR. (Corroded condition at design temp.)
MAWPHC = S * E * ta / (R + 0.6 * ta)
=115*0.85*10.68/(96.82+0.6*10.68)=                           10.11 MPa

MAWP NEW & COLD (Uncorroded condition at ambient temp.)
MAWPNC = Sr * E * (ta + c) / (R - c + 0.6 * (ta + c))
=115*0.85*(10.68+1)/(96.82-1+0.6*(10.68+1))=                 11.10 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)
Ptmax = SYtest * Etest * (ta + c) / (R + 0.6 * (ta + c))
=153*1*(10.68+1)/(96.82+0.6*(10.68+1))=                     17.21 MPa
```

Test Pressure Ptmin=1.1 <= Ptmax=17.21[MPa]	6.3%	OK

SECT. UG28 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

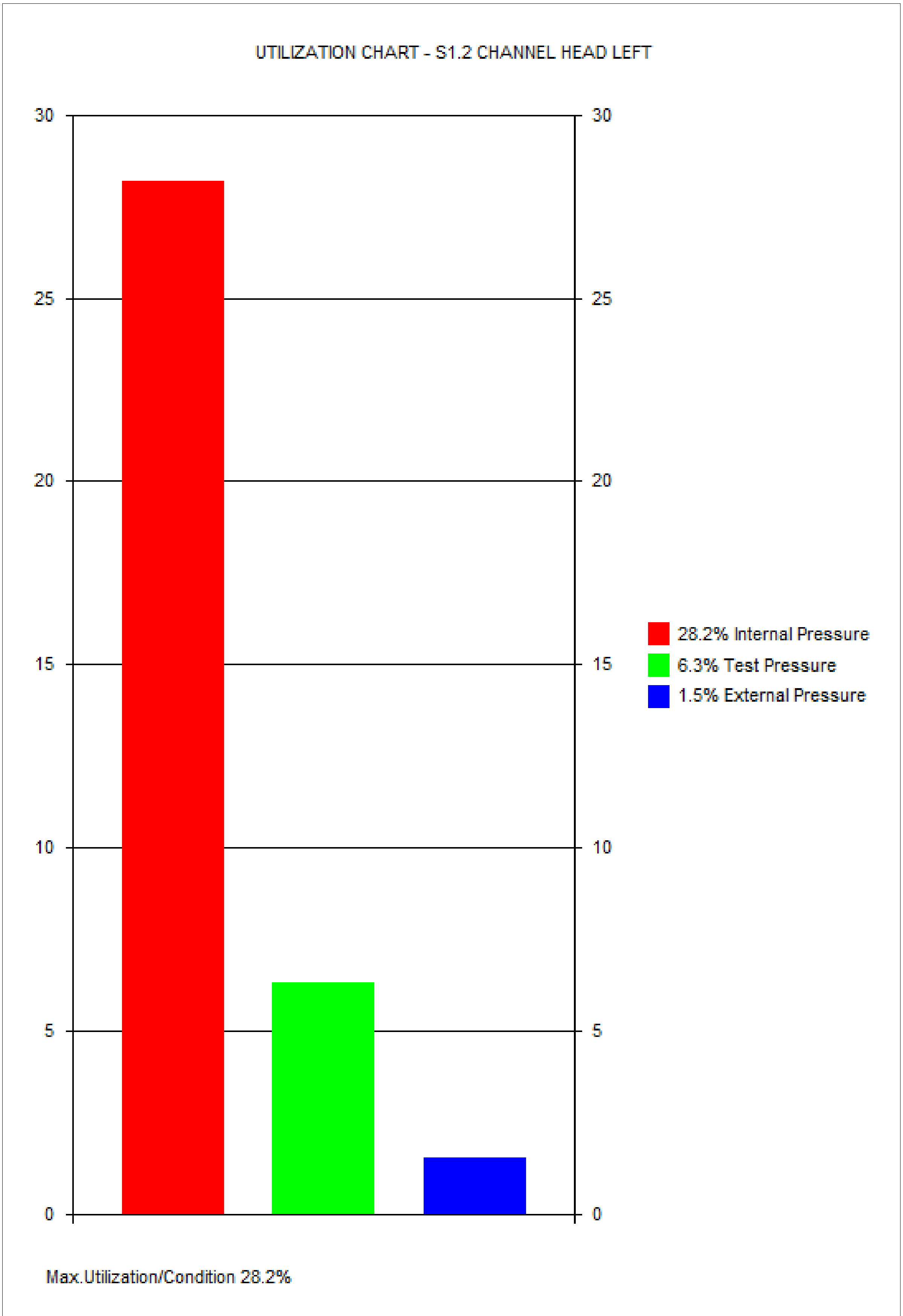
```
Pmax = (4 / 3) * B / (Do / t)
=(4/3)*97.92/(215/10.68)=                                   6.4864 MPa
```

External Pressure Pmax=6.49 >= Pext=0.1[MPa]	1.5%	OK

Required Minimum Thickness Due to External Pressure Incl.Allow.:3 mm

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 3 SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 , the material must be re-selected from the material database.
WARNING: A non zero value needs to be specified for the unsupported length.

Volume:0.0008835 m3 Weight:2 kg (SG= 7.85)


UTILIZATION CHART - S1.2 CHANNEL HEAD LEFT
30
25
20
15
10
5
0
28.2% Internal Pressure
6.3% Test Pressure
1.5% External Pressure
Max.Utilization/Condition 28.2%

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

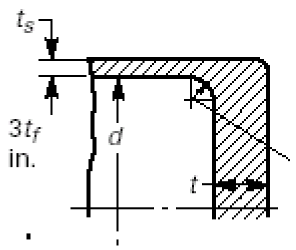
```
Attachment: S1.2    Cylindrical Shell    Channel Head left              F.1
Location: Along z-axis z1= -120
```

GENERAL DESIGN DATA

```
PROCESS CARD: Tube Side : Temp= 95°C, P=1.0000 MPa, c=1.0 mm
SPECIFIC DENSITY OF OPERATING LIQUID................:SG        1.0000
LIQUID HEAD.........................................:LH        295.15 mm
```

DATA FOR FLAT END

```
Include Straight Bar Stiffeners to Reduce Cover Deflection.: NO
Shape of Cover: Circular
WELD JOINT EFFICIENCY FACTOR: Spot RT UW-11(b) Type 1 (E=0.85)
```




```
TYPE OF FLAT WELDED END:
b_2) C=0.33m Integral head with rmin=10mm when ts<=38mm and rmin=0.25ts
INSIDE HUB/CORNER RADIUS............................:r          20.00 mm
LENGTH OF CYLINDRICAL PART OF END...................:Lc        1.0000 mm
NOMINAL THICKNESS OF HEAD/END (uncorroded)..........:tn         27.00 mm
SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 120'C
ST=450 SY=170 SYd=138.6 S=115 Sr=115 Stest=153  (N/mm2)
```

DATA FOR CYLINDRICAL SHELL SECTION

```
CYLINDER DIAMETER: Base Design on Cylinder Outside Diameter
OUTSIDE DIAMETER OF SHELL...........................:Do        215.00 mm
NOMINAL WALL THICKNESS (uncorroded).................:tsn        13.35 mm
WELD JOINT EFFICIENCY FACTOR: Spot RT UW-11(b) Type 1 (E=0.85)
SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 120'C
ST=450 SY=170 SYd=138.6 Ss=115 Ssr=115 Sstest=153  (N/mm2)
```

CALCULATION DATA

```
Analysis thickness of cylindrical shell
ts = tsn - c =13.35-1=                                  12.35 mm

Inside diameter of cylindrical shell
Di = Do - 2 * ts =215-2*12.35=                         190.30 mm

m = tr / tsn =1.1/13.35=                               0.0823
C = MAX( C * m 0.2) =MAX(0.33*0.0823,0.2)=             0.2000
```

UG-34(c) MIN.THICKNESS OF FLAT HEAD t

```
Minimum thickness excluding corrosion tmin
tmin = d * Sqr( C * P / (S * E))
=190.3*Sqr(0.2*1.0029/(115*0.85))=                   8.6203 mm

Minimum thickness including corrosion t
t = tmin + c =8.62+1=                                  9.6203 mm
```

Flat Head Thickness th=27 >= t=9.62[mm]	35.6%	OK

```
Minimum hub/corner radius rmin:
rmin (Min(19 and 10 or 0.25*tsn) = rmin =10=            10.00 mm
```

»Corner Radius Check r=20 >= rmin=10[mm] « » OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD
```
Pmax = S * E * (t / (d)) ^ 2 / (C)
=115*0.85*(27/(190.3))^2/(0.2)=                          9.8387 MPa
```

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR
```
Pmax = S * E * (t / (d)) ^ 2 / (C)
=115*0.85*(26/(190.3))^2/(0.2)=                          9.1234 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)
```
Pmax = S * E * (t / (d)) ^ 2 / (C)
=153*0.85*(27/(190.3))^2/(0.2)=                          13.09 MPa
```

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin
```
Ptmin = 1.1 * Pd * Sr / S =1.1*1*115/115=                1.1000 MPa
```

Test Pressure Ptmin=1.1 <= Ptmax=13.09[MPa]	8.4%	OK

CALCULATION SUMMARY

UG-34(c) MIN.THICKNESS OF FLAT HEAD t
```
Minimum thickness including corrosion t
t = tmin + c =8.62+1=                                    9.6203 mm
```

Flat Head Thickness th=27 >= t=9.62[mm]	35.6%	OK

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD
```
Pmax = S * E * (t / (d)) ^ 2 / (C)
=115*0.85*(27/(190.3))^2/(0.2)=                          9.8387 MPa
```

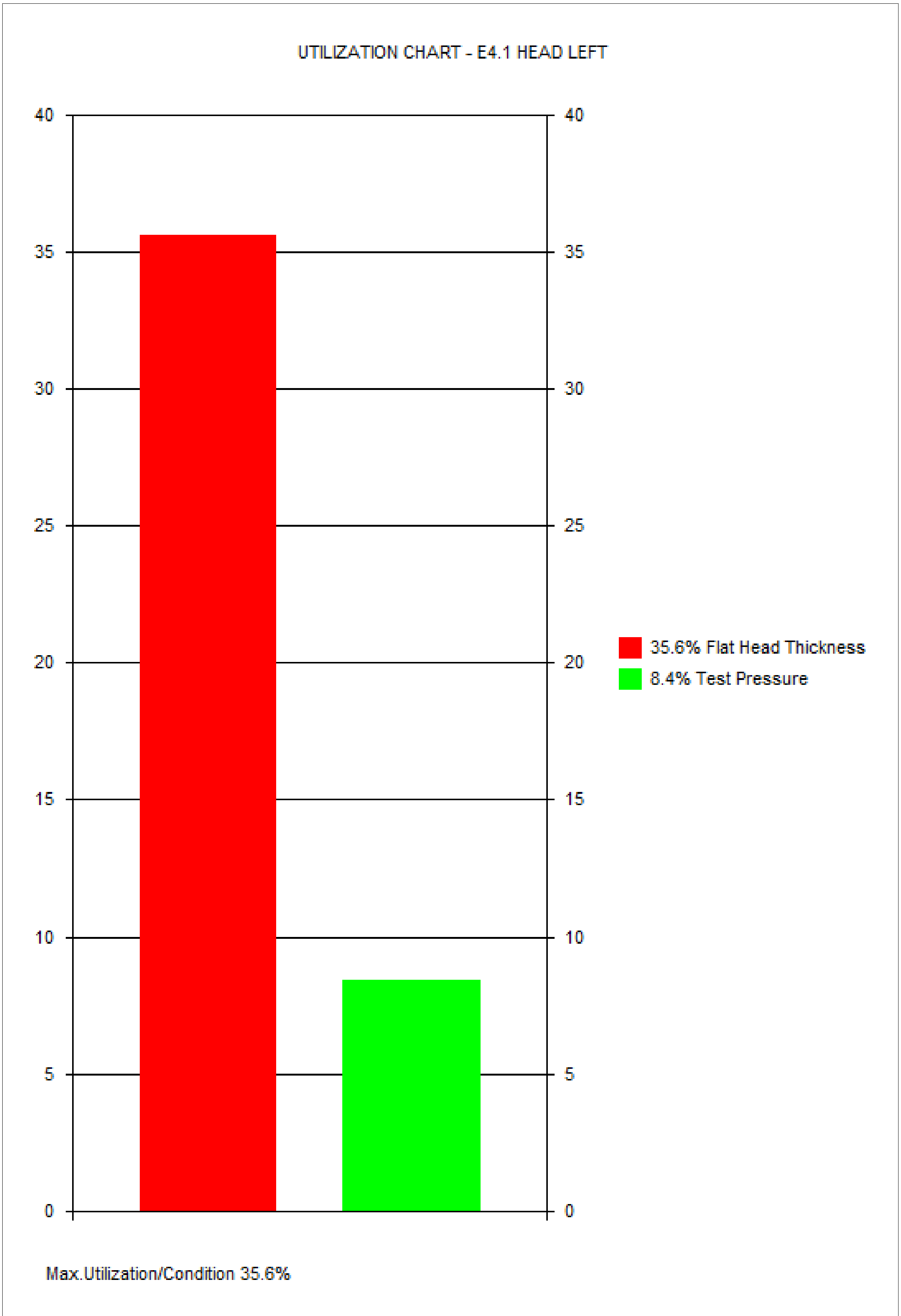
MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR
```
Pmax = S * E * (t / (d)) ^ 2 / (C)
=115*0.85*(26/(190.3))^2/(0.2)=                          9.1234 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)
```
Pmax = S * E * (t / (d)) ^ 2 / (C)
=153*0.85*(27/(190.3))^2/(0.2)=                          13.09 MPa
```

Test Pressure Ptmin=1.1 <= Ptmax=13.09[MPa]	8.4%	OK

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 3 SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 , the material must be re-selected from the material database.

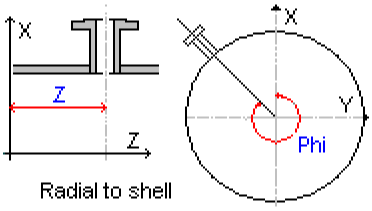
Volume:0.00 m3 Weight:7 kg (SG= 7.85)


UTILIZATION CHART - E4.1 HEAD LEFT
40
35
30
25
20
15
10
5
0
35.6% Flat Head Thickness
8.4% Test Pressure
Max.Utilization/Condition 35.6%

INPUT DATA

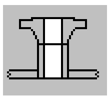
COMPONENT ATTACHMENT/LOCATION

Attachment: S1.1 Cylindrical Shell Main Shell
Connect this nozzle to the nozzle neck of another nozzle: NO

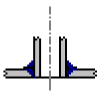


Orientation & Location of Nozzle: Radial to Shell
z-location of nozzle along axis of attacment........:z 80.00 mm
Angle of Rotation of nozzle axis projected in the x-y plane:Phi 0.00 Degr.

GENERAL DESIGN DATA



Type of Opening: Standard ASME or DIN/EN Flange Attachment



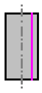
Nozzle Type: Set In Flush Nozzle
Nozzle Weld Intersect: Nozzle Does NOT Intersect with a Welded Shell Seam
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Tube Side : Temp= 95°C, P=1.0000 MPa, c=1.0 mm, Pext=0.1000 MPa
Apply a different corrosion allowance to nozzle neck than the shell thickness.: NO
SPECIFIC DENSITY OF OPERATING LIQUID................:SG 1.0000
LIQUID HEAD...:LH 131.05 mm
Include Nozzle Load Calculation: NO

SHELL DATA (S1.1)

Shell Type: Cylindrical Shell
OUTSIDE DIAMETER OF SHELL...........................:Do 141.30 mm
NOMINAL WALL THICKNESS (uncorroded).................:tn 3.4000 mm
WELD JOINT EFFICIENCY FACTOR........................:E1 1.0000
NEGATIVE TOLERANCE/THINNING ALLOWANCE...............:th 0.4250 mm
REQUIRED THICKNESS FOR EXTERNAL PRESSURE(excl.allow.):text 0.1898 mm
SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 120'C
ST=515 SY=205 SYd=169.6 Sv=138 Sr=138 Stest=184.5 (N/mm2)

NOZZLE DATA

SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8 100'C
ST=485 SY=170 SYd=145 Sn=115 Sr=115 Stest=153 (N/mm2)
Nozzle without pipe connections(access/inspection openings): NO



```
Delivery Form: Plate Body
Nozzle Diameter: Base Design on Nozzle OD
WELD JOINT EFFICIENCY FACTOR: Spot RT UW-11(b) Type 1 (E=0.85)
OUTSIDE NOZZLE DIAMETER..............................:deb        60.32 mm
NOMINAL NOZZLE THICKNESS (uncorroded)...............:tnb       3.9100 mm
Size of Flange and Nozzle: 2"
Comment (Optional): SCH 40S
NEGATIVE TOLERANCE/THINNING ALLOWANCE...............:          0.5000 mm
NOZZLE STANDOUT MEASURED FROM VESSEL OD.............:ho        100.00 mm
```

FLANGE DATA

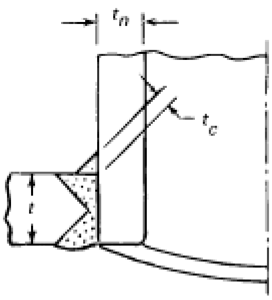
```
A: Flange Standard: ASME B16.5/B16.47 Flanges
E:  Pressure Class: ASME B16.5:Class 300 lbs
C: Flange Type: WN  Welding Neck
D: Facing Sketch/ANSI facing (Table 3.8.3(2)): 1a  RF  Raised Face
Flange Material Category: 2.3 16Cr-12Ni-2Mo :A 182 Gr. F316L - A 240 Gr. 316L
ASME 300lb-Flange Rating(at 95C)= 3.532 MPa, Max.Test Pressure = 6.3 MPa
```

DATA FOR REINFORCEMENT PAD

Type of Pad: No Pad

WELDING DATA

Nozzle to Shell Welding Area: Include Area of Nozzle to Shell Weld as Min.Required



Weld Connection:
Full Penetration Weld(from both sides) + Outward Fillet Weld (to=tc)

LIMITS OF REINFORCEMENT

Reduction of Limits of Reinforcement: No Reduction Required

CALCULATION DATA

GEOMETRIC LIMITATIONS

Material Strength Reduction Factor fr1-4

```
Strength Reduction Factor for Nozzle Inserted Through Vessel Wall fr1
fr1 = MIN( Sn / Sv, 1) =MIN(115/138,1)=                      0.8333
Strength Reduction Factor for Nozzle fr2
fr2 = MIN( Sn / Sv, 1) =MIN(115/138,1)=                      0.8333
```

PRELIMINARY CALCULATIONS

```
Shell Analysis Thickness t
t = tn - c - th =3.4-1-0.425=                                1.9750 mm
Nozzle Analysis Thickness tn
tn = tnb - cn - NegDev =3.91-1-0.5=                          2.4100 mm
Inside Radius of Shell R
```

ASME VIII Div.1:2019 - UG-37 REINFORCEMENT REQUIRED FOR OPENINGS IN SHELLS
N.1 N1 17 Feb. 2022 12:46 ConnID:S1.1 PC# 2

```
R = Do / 2 - t =141.3/2-1.975=                          68.68 mm
Required Thickness of a Seamless Shell tr
tr = P * R / (Sv * E1 - 0.6 * P)
=1.0013*68.675/(138*1-0.6*1.0013)=                    0.5005 mm
d = deb - 2 * tn =60.32-2*2.41=                         55.50 mm
Inside Radius of Nozzle Rn
Rn = (deb - 2 * tn) / 2 =(60.32-2*2.41)/2=              27.75 mm
Minimum nozzle thickness due to pressure
trn = P * Rn / (Sn * E - 0.6 * P)
=1.0013*27.75/(115*0.85-0.6*1.0013)=                  0.2860 mm
```

UG-40 LIMITS OF REINFORCEMENT

```
Parallel to Vessel Wall (half diameter limit)
Lv = MAX( d , d / 2 + t + tn)
=MAX(55.5,55.5/2+1.975+2.41)=                           55.50 mm
Normal to Vessel Wall Outside
Lno = MIN( 2.5 * t , 2.5 * tn + te)
=MIN(2.5*1.975,2.5*2.41+0)=                           4.9375 mm
Effective Material Diameter Limit
deff = 2 * Lv =2*55.5=                                  111.00 mm
```

UG-37 Calculation of Stress Loaded Areas Effective as Reinforcement

Area Available in Shell A1

```
A1 = (deff-d)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)
=(111-55.5)*(1*1.975-1*0.5005)-2*2.41*(1*1.975-1*0.5005)*(1-0.8333)
=     80.65 mm2
```

Area Available in Nozzle Projecting Outward A2

```
A2 = 2 * (tn - trn) * fr2 * MIN( Lno, ho)
=2*(2.41-0.286)*0.8333*MIN(4.94,100)=                   17.48 mm2
```

Area Available in Welds A4

```
Area Available in Nozzle Outward Weld A41
A41 = Leg41 ^ 2 * fr2 =3.4^2*0.8333=                     9.6333 mm2
A4 = A41 + A42 + A43 =9.63+0+0=                          9.6333 mm2
```

Total Area Available Aavail

```
Aavail = A1 + A2 + A3 + A4 + A5 =80.65+17.48+0+9.63+0=   107.76 mm2
```

UG-37(c) Total Area Required

```
Total Area Required Areq
Areq = d * tr * F + 2 * tn * tr * F * (1 - fr1)
=55.5*0.5005*1+2*2.41*0.5005*1*(1-0.8333)=               28.18 mm2
```

UG-37 Nozzle Reinforcement Aavail=107.76 >= Areq=28.18[mm2]	26.1%	OK

NOTE : UG-36(c)(3a) THIS NOZZLE IS EXEMPT FROM AREA CALCULATIONS WHEN CONSIDERED ISOLATED AND WITHOUT RAPID PRESSURE FLUCTUATIONS.

UG-41.1 WELD STRENGTH AND WELD LOADS (Sketch a or b)

NOTE: UW-15(b) Strength calculations for attachment welds are NOT required for this detail.

MAXIMUM ALLOWABLE PRESSURES

FLANGE RATING

ASME 300lb-Flange Rating(at 95C)= 3.532 MPa, Max.Test Pressure = 6.3 MPa

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR

Pmax (t,tn,Sv,Sn)(2,2.4,138,115) = == 2.3656 MPa

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD

Pmax (t,tn,Sv,Sn)(3,3.4,138,115) = == 3.5922 MPa

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

Pmax (t,tn,Sv,Sn)(3,3.4,184.5,153) = == 4.7937 MPa

UG-37(d) Nozzle Reinforcement - External Pressure

Available Reinforcement Area
Aavail = A1 + A2 + A3 + A4 + A5 =97.64+17.89+0+9.63+0= 125.17 mm2

UG-37(d) Nozzle Reinforcement Ext.Press. Aavail=125.17 >= Areq=5.34[mm2]	4.2%	OK

UW-16(d) DIMENSIONS OF FILLET WELDS:

Throat dimension of fillet welds on nozzle:
- at outward nozzle weld at nozzle OD, tmin = lesser of 19.0, tn or t/te)= 3.4 mm
to(min)=MIN(6, 0.7*tmin)= 2.38 mm
Minimum length of legs:
- at outward nozzle weld at nozzle OD, Leg41(min) = 3.4 mm

»UW-16(d) Outward Nozzle Fillet Weld, Leg Size Leg41=3.4 >= Leg41(min)=3.4[mm] «» OK«

UG-45 NOZZLE NECK THICKNESS

UG-45 Minimum Nozzle Neck Thickness Required for Internal and External Pressure
ta = MAX(trn , textn) + cn =MAX(0.286,0.2355)+1= 1.2860 mm
tb1 = MAX(tr , tmin16) + cn =MAX(0.5005,1.5)+1= 2.5000 mm
tb2 = MAX(trPext , tmin16) + cn =MAX(0.0372,1.5)+1= 2.5000 mm
tb3(Value from Table UG-45 + cn)= == 4.4200 mm
tb = MIN(tb3 , MAX(tb1 , tb2))
=MIN(4.42,MAX(2.5,2.5))= 2.5000 mm
Minimum Thickness of Nozzle Neck to UG-45
tUG45 = MAX(ta , tb) =MAX(1.29,2.5)= 2.5000 mm

UG-45 Min.Nozzle Neck Thk. tUG45=2.5 <= tnb-tolerance=3.41[mm]	73.3%	OK

Weight of Nozzle:0.2594kg Flange: 4kg

CALCULATION SUMMARY

Aavail = A1 + A2 + A3 + A4 + A5 =80.65+17.48+0+9.63+0= 107.76 mm2

Total Area Required Areq
Areq = d * tr * F + 2 * tn * tr * F * (1 - fr1)
=55.5*0.5005*1+2*2.41*0.5005*1*(1-0.8333)= 28.18 mm2

UG-37 Nozzle Reinforcement Aavail=107.76 >= Areq=28.18[mm2]	26.1%	OK

MAXIMUM ALLOWABLE PRESSURES

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR

Pmax (t,tn,Sv,Sn)(2,2.4,138,115) = == 2.3656 MPa

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD

Pmax (t,tn,Sv,Sn)(3,3.4,138,115) = == 3.5922 MPa

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

Pmax (t,tn,Sv,Sn)(3,3.4,184.5,153) = == 4.7937 MPa

UG-37(d) Nozzle Reinforcement - External Pressure

Available Reinforcement Area

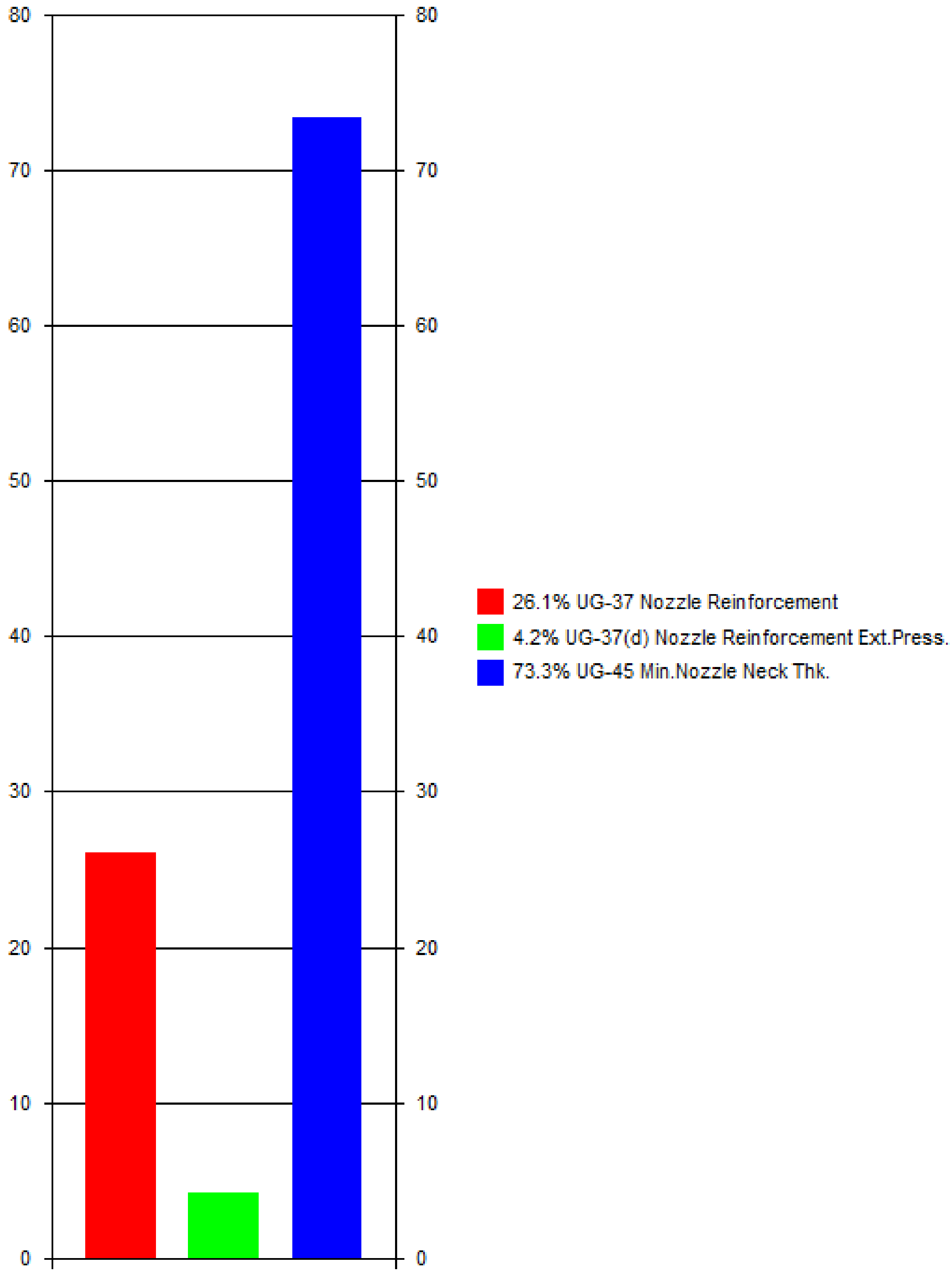
Aavail = A1 + A2 + A3 + A4 + A5 =97.64+17.89+0+9.63+0= 125.17 mm2

UG-37(d) Nozzle Reinforcement Ext.Press. Aavail=125.17 >= Areq=5.34[mm2]	4.2%	OK
UG-45 Min.Nozzle Neck Thk. tUG45=2.5 <= tnb-tolerance=3.41[mm]	73.3%	OK

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 5 SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.
WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 9 SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.
WARNING : U-1(c)(2) APPLICABILITY, ID OF VESSEL IS LESS THAN 152 mm.

Volume:0.0002000 m3 Weight:4 kg (SG= 7.85)

UTILIZATION CHART - N.1 N1

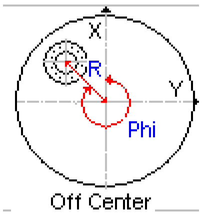


Max.Utilization/Condition 73.3%

INPUT DATA

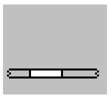
COMPONENT ATTACHMENT/LOCATION

```
Attachment: E4.1    Welded Flat End      Head left                    S1.2
Connect this nozzle to the nozzle neck of another nozzle: NO
```




```
Orientation & Location of Nozzle: Radial to End (Off Center)
Angle of Rotation of nozzle axis projected in the x-y plane:Phi     0.00 Degr.
Distance between Center of End and Center of Nozzle.:R         40.50 mm
```

GENERAL DESIGN DATA



```
Type of Opening: Opening Without Nozzle/Ring
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Tube Side : Temp= 95°C, P=1.0000 MPa, c=1.0 mm, Pext=0.1000 MPa
Apply a different corrosion allowance to nozzle neck than the shell thickness.: NO
SPECIFIC DENSITY OF OPERATING LIQUID................:SG        1.0000
LIQUID HEAD.........................................:LH        159.50 mm
```

SHELL DATA (E4.1)

```
Shell Type: Welded Flat End
OUTSIDE DIAMETER OF SHELL...........................:Do        215.00 mm
NOMINAL WALL THICKNESS (uncorroded).................:tn         27.00 mm
WELD JOINT EFFICIENCY FACTOR........................:E1        1.0000
REQUIRED THICKNESS FOR EXTERNAL PRESSURE(excl.allow.):text     0.1898 mm
REQUIRED THICKNESS OF UNPIERCED COVER(corroded).....:t         8.6203 mm
SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 120'C
ST=450 SY=170 SYd=138.6 Sv=115 Sr=115 Stest=153  (N/mm2)
```

OPENING DATA

```
DIAMETER OF OPENING IN SHELL(corroded).............:dib        40.00 mm
```

LIMITS OF REINFORCEMENT

```
Reduction of Limits of Reinforcement: No Reduction Required
```

CALCULATION DATA

GEOMETRIC LIMITATIONS

PRELIMINARY CALCULATIONS

```
Shell Analysis Thickness t
t = tn - c - th =27-1-0=                                      26.00 mm
Inside Radius of Shell R
R = Do / 2 - t =215/2-26=                                     81.50 mm
deb = d + 2 * tn =40+2*0=                                     40.00 mm
deb = d + 2 * tn =40+2*0=                                     40.00 mm
Inside Radius of Nozzle Rn
Rn = d / 2 =40/2=                                             20.00 mm
Minimum nozzle thickness due to pressure
```

trn = P * Rn / (Sn * E - 0.6 * P)
=1.0016*20/(115*1-0.6*1.0016)= 0.1751 mm

UG-40 LIMITS OF REINFORCEMENT

Parallel to Vessel Wall (half diameter limit)
Lv = MAX(d , d / 2 + t + tn) =MAX(40,40/2+26+0)= 46.00 mm
Normal to Vessel Wall Outside
Lno = MIN(2.5 * t , 2.5 * tn + te)
=MIN(2.5*26,2.5*0+0)= 0.00 mm
Effective Material Diameter Limit
deff = 2 * Lv =2*46= 92.00 mm

UG-37 Calculation of Stress Loaded Areas Effective as Reinforcement

Area Available in Shell A1

A1 = (deff-d)*(E1*t-F*tr)-2*tn*(E1*t-F*tr)*(1-fr1)
=(92-40)*(1*26-1*8.62)-2*0*(1*26-1*8.62)*(1-1)= 903.74 mm2

Area Available in Nozzle Projecting Outward A2

A2 = 2 * (tn - trn) * fr2 * MIN(Lno, ho)
=2*(0-0.1751)*1*MIN(0,0)= 0.00 mm2

Area Available in Welds A4

A4 = A41 + A42 + A43 =0+0+0= 0.00 mm2

Total Area Available Aavail

Aavail = A1 + A2 + A3 + A4 + A5 =903.74+0+0+0+0= 903.74 mm2

UG-39(b)(1) Total Area Required

Total Area Required Areq
Areq = 0.5 * d * tr + tn * tr * (1 - fr1)
=0.5*40*8.62+0*8.62*(1-1)= 172.41 mm2

UG-39(d)(1) Alternative to (b)(1), Minimum Head/Cover Thickness trmin

Cnew = MIN(2 * C , 0.75) =MIN(2*0.2,0.75)= 0.4000
trmin = tr * SQR(Cnew / C) =8.62*SQR(0.4/0.2)= 12.19 mm

UG-37 Nozzle Reinforcement Aavail=903.74 >= Areq=172.41[mm2]	19.0%	OK

MAXIMUM ALLOWABLE PRESSURES

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR

Pmax (t,tn,Sv,Sn)(26,0,115,115) = == 4.7576 MPa

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD

Pmax (t,tn,Sv,Sn)(27,0,115,115) = == 5.2459 MPa

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

Pmax (t,tn,Sv,Sn)(27,0,153,153) = == 6.9611 MPa

UG-37(d) Nozzle Reinforcement - External Pressure

Available Reinforcement Area
Aavail = A1 + A2 + A3 + A4 + A5 =1342.13+0+0+0+0= 1342.13 mm2

UG-37(d) Nozzle Reinforcement Ext.Press. Aavail=1342.13 >= Areq=1.9[mm2]	0.1%	OK

Weight of Nozzle:0.00kg

CALCULATION SUMMARY

```
Aavail = A1 + A2 + A3 + A4 + A5 =903.74+0+0+0+0=              903.74 mm2

Total Area Required Areq
Areq = 0.5 * d * tr + tn * tr * (1 - fr1)
=0.5*40*8.62+0*8.62*(1-1)=                                   172.41 mm2
```

UG-37 Nozzle Reinforcement Aavail=903.74 >= Areq=172.41[mm2]	19.0%	OK

MAXIMUM ALLOWABLE PRESSURES

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR

```
Pmax (t,tn,Sv,Sn)(26,0,115,115) = ==                         4.7576 MPa
```

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD

```
Pmax (t,tn,Sv,Sn)(27,0,115,115) = ==                         5.2459 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
Pmax (t,tn,Sv,Sn)(27,0,153,153) = ==                         6.9611 MPa
```

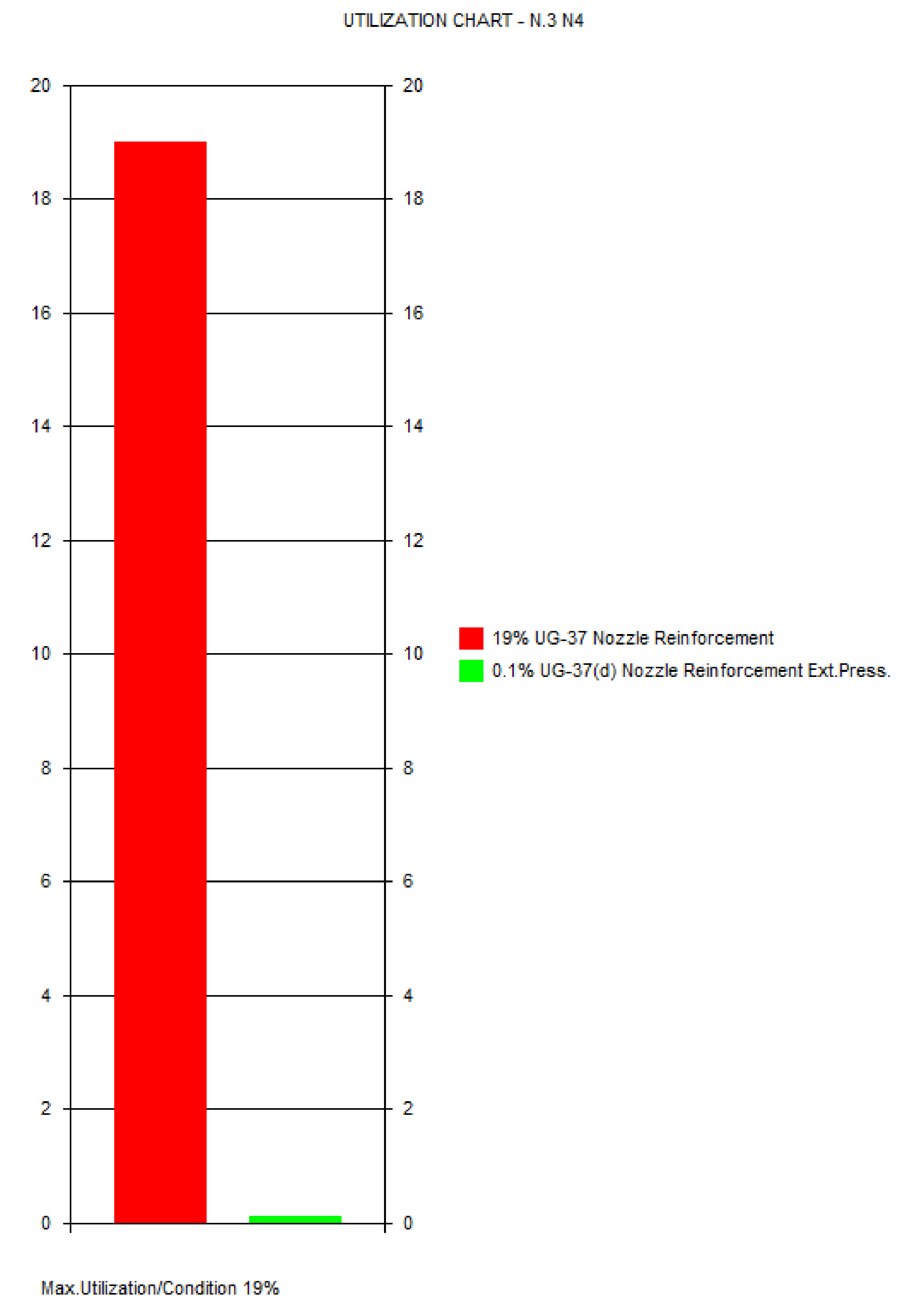
UG-37(d) Nozzle Reinforcement - External Pressure

```
Available Reinforcement Area
Aavail = A1 + A2 + A3 + A4 + A5 =1342.13+0+0+0+0=            1342.13 mm2
```

UG-37(d) Nozzle Reinforcement Ext.Press. Aavail=1342.13 >= Areq=1.9[mm2]	0.1%	OK

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 3 SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 , the material must be re-selected from the material database.

Volume:0.00 m3 Weight:0 kg (SG= 7.85)


UTILIZATION CHART - N.3 N4
20
18
16
14
12
10
8
6
4
2
0
19% UG-37 Nozzle Reinforcement
0.1% UG-37(d) Nozzle Reinforcement Ext.Press.
Max.Utilization/Condition 19%

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

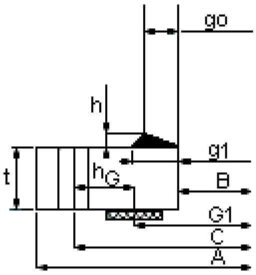
```
Attachment: F.3     RT - Flange          Flangering Shell left         S1.1
Location: Along z-axis z1= -54
Include a standard ANSI, DIN or EN flange without performing detailed
calculations.: NO
```

GENERAL DESIGN DATA

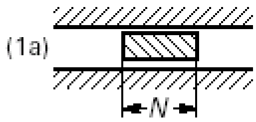
```
PROCESS CARD: Tube Side : Temp= 95°C, P=1.0000 MPa, c=1.0 mm
SPECIFIC DENSITY OF OPERATING LIQUID................:SG        1.0000
LIQUID HEAD.........................................:LH        307.50 mm
B: Pressure loading: Flange under internal pressure
LETHAL SERVICE - APPLY BOLT SPACING CORR.FACTOR TO 2-6 AND RIGIDITY INDEX TO 2-
14.: NO
EXTERNAL LOADS ON FLANGE  (PD5500 ENQ 5500/123): NO
SPECIFY BOLT LOADS FROM 2nd./MATING FLANGE: NO
```

TYPE OF FLANGE AND GASKET FACING

```
A: Flange Standard: User Specified Flanges
```




```
C: Flange Type: RT  Ring Type(Smooth or Stepped bore)
```




```
D: Flange Facing (Sketch/Description): 1a  Flat Face
```

SHELL/NOZZLE DATA

```
SHELL/NOZZLE SIZE & COMMENT: S1.1
SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 120'C
ST=450 SY=170 SYd=138.6 fs=115 fs20=115 Stest=153  (N/mm2)
OUTSIDE DIAMETER OF SHELL/NOZZLE ...................:Do        215.00 mm
WALL THICKNESS OF NOZZLE/SHELL(uncorroded)..........:s1         40.85 mm
```

FLANGE DATA

```
FLANGE HUB: Flange Without Hub
REVERSE FLANGE: No (The bolts are located on the outside)
DESIGN METHOD: B) LOOSE FLANGE METHOD(If requirements are met)
FLANGE BORE: Smooth          .
OUTSIDE DIAMETER OF FLANGE..........................:A         215.00 mm
THICKNESS OF FLANGE(uncorroded).....................:e          36.00 mm
CORROSION ALLOWANCE FOR FLANGE FACE.................:cf          0.00 mm
SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 120'C
ST=450 SY=170 SYd=138.6 SFO=115 SFA=115 Stest=153  (N/mm2)
INCLUDE APPENDIX 2-14, FLANGE RIGIDITY CALCULATION: YES
MODULUS OF ELASTICITY at design temp................:E      2,0E05 N/mm2
MODULUS OF ELASTICITY at ambient temp...............:E20    2,0E05 N/mm2
```

BOLTING DATA

```
REDUCE SAFETY AGAINST ABUSE BY CAREFULLY CONTROLLING THE BOLTING-UP TORQUE: NO
BOLTING TORQUE CALCULATION: NO
NOMINAL BOLTING SIZE & COMMENT: M12x1.75 ;
EFFECTIVE BOLT AREA per bolt........................:Ae          76.25 mm2
RECOMMENDED MINIMUM BOLT CENTER TO EDGE CLEARANCE...:Bce         16.00 mm
RECOMMENDED MINIMUM BOLT CENTER/RADIAL CLEARANCE....:Bcr         20.00 mm
DIAMETER OF BOLT HOLES IN FLANGE....................:d           12.00 mm
NUMBER OF BOLTS.....................................:n          4.0000
BOLT-CIRCLE DIAMETER................................:C          180.00 mm
SA-193(M) Gr.B7, G41400 Bolting THK<=100mm 95'C
ST=795 SY=655 SYd=609.57 Sb=159 Sa=159 Stest=589.5  (N/mm2)
```

GASKET DATA

```
Table 2-5.1 Gasket factors m & y   Facing:
Mineral Fiber 1.6 mm thick       m=2.75  Y=25.5  2 1a,1b,1c,1d,4,5
CONTACT WIDTH OF GASKET.............................:N          1.0000 mm
OUTSIDE DIAMETER OF GASKET..........................:Go         132.20 mm
TEMA RGP-RCB-11.7 Include Additional Loads from Pass Partition Plate Gasket: NO
```

CALCULATION DATA

GASKET DETAILS

```
b = MIN VALUE(2.52 * Sqr(bo), bo ) = ==                       0.5000 mm
```

FLANGE LOADS

```
HD = 0.785 * B ^ 2 * p =0.785*135.3^2*1.003=                    14.41 kN
H = 0.785 * G ^ 2 * p =0.785*131.2^2*1.003=                     13.55 kN
Hp = (2 * PI * b * G * m) * p
=(2*3.14*0.5*131.2*2.75)*1.003=                              1.1369 kN
HT = H - HD =13553.09-14413.39=                                -0.8603 kN
```

MOMENT ARMS

```
hG = (C - G) / 2 =(180-131.2)/2=                                24.40 mm
hD = (C - B - g1) / 2 =(180-135.3-39.85)/2=                    2.4250 mm
hT = (2 * C - B - G) / 4 =(2*180-135.3-131.2)/4=                23.38 mm
```

BOLT LOADS

```
Operating condition
Wop = H + Hp =13553.09+1136.89=                                 14.69 kN

Bolting up condition
Wamb = PI * b * G * y =3.14*0.5*131.2*25.5=                    5.2553 kN
```

BOLTING AREA

```
Am1 = Wop / Sb =14689.97/159=                                   92.39 mm2

Am2 = Wamb / Sa =5255.26/159=                                   33.05 mm2

Required Bolting Area Am
Am = MAX( Am1 , Am2) =MAX(92.39,33.05)=                         92.39 mm2

Available Bolting Area Ab
Ab (num.bolts*root area) = n * Ae =4*76.25=                   305.00 mm2
```

Bolting Area Check Ab=305 >= Am=92.39[mm2]	30.2%	OK

```
Bolt Spacing
Bs = C * PI / n =180*3.14/4=                                  141.37 mm

2-5 Recommended Maximum Bolt Spacing
Bmax = 2 * db + 6 * e / (m + 0.5)
=2*12+6*36/(2.75+0.5)=                                        90.46 mm

W = 0.5 * (Ab + Am) * Sa =0.5*(305+92.39)*159=                  31.59 kN
```

FLANGE MOMENTS

```
Mop = HD * hD + HT * hT + HG * hG
=14413.39*2.42+-860.3*23.375+1136.89*24.4=                    42.58 Nm
Mamb = W * hG =31592.49*24.4=                                 770.86 Nm
Mo = Mop =42.58=                                               42.58 Nm
Ma = Mamb =770.86=                                            770.86 Nm
```

SHAPE CONSTANTS

```
K = A / B =215/135.3=                                          1.5891
ho=SQR(B*go)= 73.428  h/ho=  0.000  K=A/B=  1.589  g1/go=  1.000
VALUES FOR T,U,Y AND Z FROM FIGURE 2-7.1
T =     1.672  Z =     2.311  Y =     4.367  U =     4.799
F =     0.909  V =     0.550  f =     1.000
d = U / V * ho * go ^ 2 =4.799/0.5501*73.43*39.85^2=      1,0172E06 mm3
e = F / ho =0.9089/73.43=                                   0.0124 mm-1
L = (t * e + 1) / T + t ^ 3 / d
=(36*0.0124+1)/1.672+36^3/1.0172E06=                      0.9105
```

OPERATING CONDITION

```
M = Mo =42.58=                                                 42.58 Nm
```

Flange Stresses with Flange Thickness e= 36 mm

```
Longitudinal Hub Stress
SH = f * M / (L * g1 ^ 2 * B)
=1*42.58/(0.9105*39.85^2*135.3)=                          0.2177 N/mm2

Radial Flange Stress
SR = (1.333 * t * e + 1) * M / (L * t ^ 2 * B)
=(1.333*36*0.0124+1)*42.58/(0.9105*36^2*135.3)=           0.4252 N/mm2

Tangential Flange Stress
ST = Y * M / (t ^ 2 * B) - (Z * SR)
=4.367*42.58/(36^2*135.3)-(2.311*0.4252)=                 0.0780 N/mm2
```

Stress Limits

Hub Stress SH=0.2177 <= 1.5 * MIN(Sf;SfH)=172.5[N/mm2]	0.1%	OK
Radial Stress SR=0.4252 <= Sf=115[N/mm2]	0.3%	OK
Tangential Stress ST=0.078 <= Sf=115[N/mm2]	0.0%	OK
Radial+Hub Stress 0.5*(SH+SR)=0.3214 <= Sf=115[N/mm2]	0.2%	OK
Tangential+Hub Stress 0.5*(SH+ST)=0.1478 <= Sf=115[N/mm2]	0.1%	OK

APPENDIX 2-14, FLANGE RIGIDITY

```
Rigidity Index
J = 52.14 * V * M / (L * E * go ^ 2 * 0.3 * ho)
=52.14*0.5501*42582.89/(0.9105*200000*39.85^2*0.3*73.43)=1,9174E-04
```

BOLTING UP CONDITION

```
M = Ma =770.86=                                               770.86 Nm
```

Flange Stresses with Flange Thickness e= 36 mm

```
Longitudinal Hub Stress
SH = f * M / (L * g1 ^ 2 * B)
=1*770.86/(0.9105*39.85^2*135.3)=                         3.9405 N/mm2

Radial Flange Stress
SR = (1.333 * t * e + 1) * M / (L * t ^ 2 * B)
=(1.333*36*0.0124+1)*770.86/(0.9105*36^2*135.3)=          7.6966 N/mm2

Tangential Flange Stress
ST = Y * M / (t ^ 2 * B) - (Z * SR)
=4.367*770.86/(36^2*135.3)-(2.311*7.7)=                   1.4112 N/mm2
```

Stress Limits

Hub Stress SH=3.94 <= 1.5 * MIN(Sf;SfH)=172.5[N/mm2]	2.2%	OK
Radial Stress SR=7.7 <= Sf=115[N/mm2]	6.6%	OK
Tangential Stress ST=1.41 <= Sf=115[N/mm2]	1.2%	OK
Radial+Hub Stress 0.5*(SH+SR)=5.82 <= Sf=115[N/mm2]	5.0%	OK
Tangential+Hub Stress 0.5*(SH+ST)=2.68 <= Sf=115[N/mm2]	2.3%	OK

APPENDIX 2-14, FLANGE RIGIDITY

```
Rigidity Index
J = 52.14 * V * M / (L * E * go ^ 2 * 0.3 * ho)
=52.14*0.5501*7.7086E05/(0.9105*200000*39.85^2*0.3*73.43)=    0.0035
```

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Ptmin = 1.1 * Pd * Sr / S =1.1*1*115/115=                       1.1000 MPa
```

Test Pressure Ptmin=1.1 <= Ptmax=11.371[MPa]	9.6%	OK

PRESSURE AND TORQUE SUMMARY

Table PRESSURE AND TORQUE SUMMARY FOR F.1 :

Description	Temp(C)	P(MPa)	Limited By	Min.Req.Total Bolt Force(kN)
Design Pressure(corroded)	95	1.00	Bolting Area Check	14.69
Max.Allow.Pressure(corroded)	95	3.31	Bolting Area Check	48.53
Max.Allow.Pressure(corroded)	Ambient	3.31	Bolting Area Check	48.53
Max.Allow.Test Pressure(corroded)	Ambient	11.37	Bolting Area Check	166.54
Required Test Pressure	Ambient	1.10	Bolting Area Check	16.15

The nominal Force and Torque values are based on the following bolting up method:

CALCULATION SUMMARY

BOLTING AREA

Bolting Area Check Ab=305 >= Am=92.39[mm2]	30.2%	OK

OPERATING CONDITION

Flange Stresses with Flange Thickness e= 36 mm

```
Longitudinal Hub Stress
SH = f * M / (L * g1 ^ 2 * B)
=1*42.58/(0.9105*39.85^2*135.3)=                        0.2177 N/mm2

Radial Flange Stress
SR = (1.333 * t * e + 1) * M / (L * t ^ 2 * B)
=(1.333*36*0.0124+1)*42.58/(0.9105*36^2*135.3)=         0.4252 N/mm2

Tangential Flange Stress
ST = Y * M / (t ^ 2 * B) - (Z * SR)
=4.367*42.58/(36^2*135.3)-(2.311*0.4252)=               0.0780 N/mm2
```

Stress Limits

Hub Stress SH=0.2177 <= 1.5 * MIN(Sf;SfH)=172.5[N/mm2]	0.1%	OK
Radial Stress SR=0.4252 <= Sf=115[N/mm2]	0.3%	OK
Tangential Stress ST=0.078 <= Sf=115[N/mm2]	0.0%	OK
Radial+Hub Stress 0.5*(SH+SR)=0.3214 <= Sf=115[N/mm2]	0.2%	OK
Tangential+Hub Stress 0.5*(SH+ST)=0.1478 <= Sf=115[N/mm2]	0.1%	OK

APPENDIX 2-14, FLANGE RIGIDITY

```
Rigidity Index
J = 52.14 * V * M / (L * E * go ^ 2 * 0.3 * ho)
=52.14*0.5501*42582.89/(0.9105*200000*39.85^2*0.3*73.43)=1,9174E-04
```

BOLTING UP CONDITION

Flange Stresses with Flange Thickness e= 36 mm

```
Longitudinal Hub Stress
SH = f * M / (L * g1 ^ 2 * B)
=1*770.86/(0.9105*39.85^2*135.3)=                        3.9405 N/mm2

Radial Flange Stress
SR = (1.333 * t * e + 1) * M / (L * t ^ 2 * B)
=(1.333*36*0.0124+1)*770.86/(0.9105*36^2*135.3)=         7.6966 N/mm2

Tangential Flange Stress
ST = Y * M / (t ^ 2 * B) - (Z * SR)
=4.367*770.86/(36^2*135.3)-(2.311*7.7)=                  1.4112 N/mm2
```

Stress Limits

Hub Stress SH=3.94 <= 1.5 * MIN(Sf;SfH)=172.5[N/mm2]	2.2%	OK
Radial Stress SR=7.7 <= Sf=115[N/mm2]	6.6%	OK
Tangential Stress ST=1.41 <= Sf=115[N/mm2]	1.2%	OK
Radial+Hub Stress 0.5*(SH+SR)=5.82 <= Sf=115[N/mm2]	5.0%	OK
Tangential+Hub Stress 0.5*(SH+ST)=2.68 <= Sf=115[N/mm2]	2.3%	OK

APPENDIX 2-14, FLANGE RIGIDITY

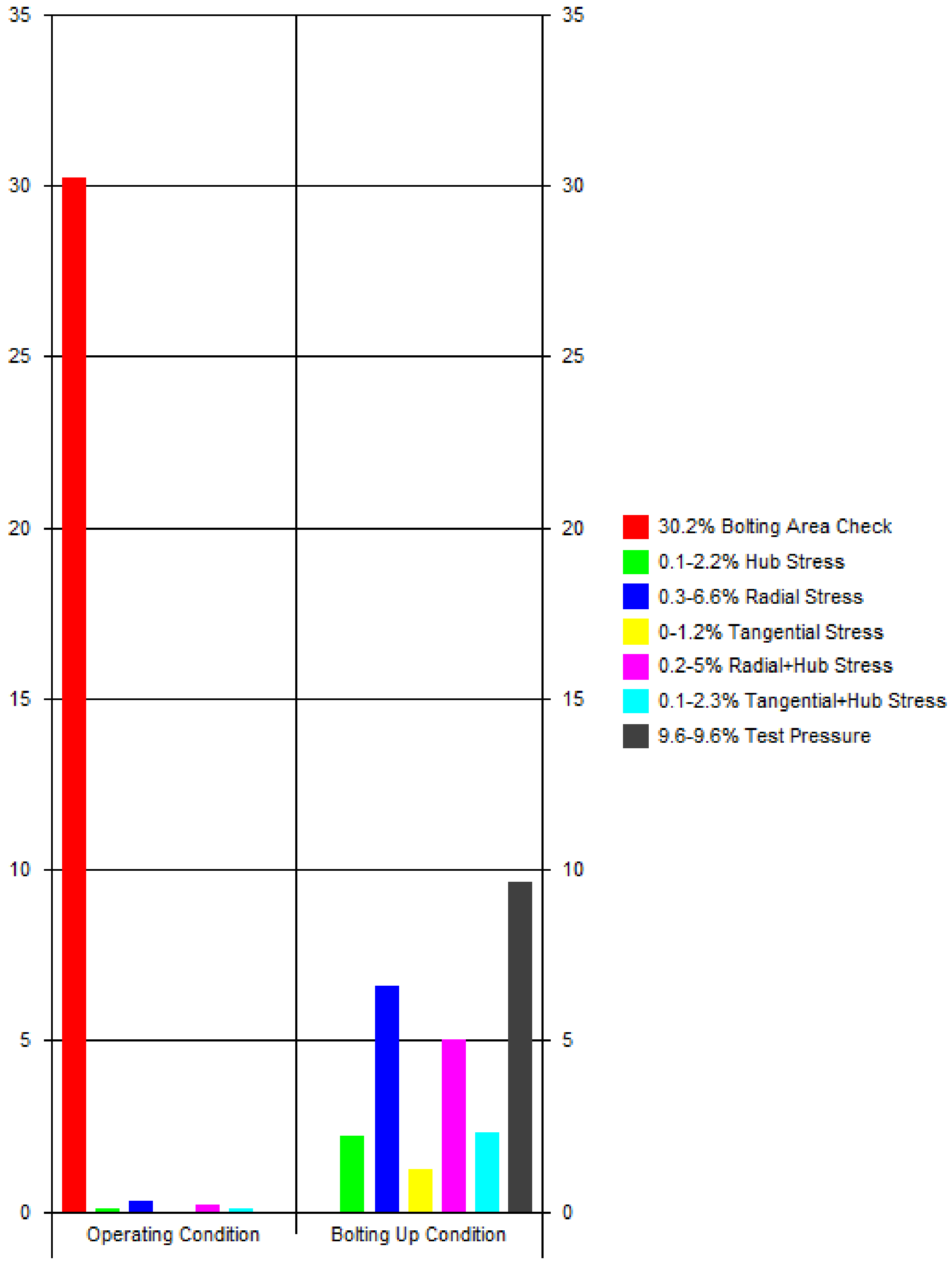
```
Rigidity Index
J = 52.14 * V * M / (L * E * go ^ 2 * 0.3 * ho)
=52.14*0.5501*7.7086E05/(0.9105*200000*39.85^2*0.3*73.43)=   0.0035
```

Test Pressure Ptmin=1.1 <= Ptmax=11.371[MPa]	9.6%	OK

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 3 SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 , the material must be re-selected from the material database.
Warning: Invalid gasket location/dimension.

Volume:0.0005176 m3 Weight:6 kg (SG= 7.85)

UTILIZATION CHART - F.1 FLANGERING HEAD LEFT



Max.Utilization/Condition 30.2%

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

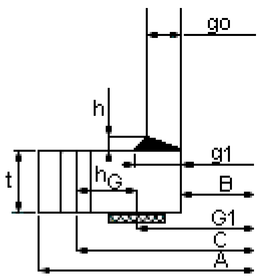
```
Attachment: S1.1    Cylindrical Shell    Main Shell
Location: Along z-axis zo=  0
Include a standard ANSI, DIN or EN flange without performing detailed
calculations.: NO
```

GENERAL DESIGN DATA

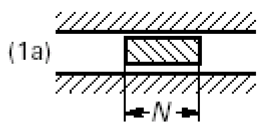
```
PROCESS CARD: Tube Side : Temp= 95°C, P=1.0000 MPa, c=1.0 mm
SPECIFIC DENSITY OF OPERATING LIQUID................:SG        1.0000
LIQUID HEAD.........................................:LH        270.65 mm
B: Pressure loading: Flange under internal pressure
LETHAL SERVICE - APPLY BOLT SPACING CORR.FACTOR TO 2-6 AND RIGIDITY INDEX TO 2-
14.: NO
EXTERNAL LOADS ON FLANGE  (PD5500 ENQ 5500/123): NO
SPECIFY BOLT LOADS FROM 2nd./MATING FLANGE: NO
```

TYPE OF FLANGE AND GASKET FACING

```
A: Flange Standard: User Specified Flanges
```




```
C: Flange Type: RT  Ring Type(Smooth or Stepped bore)
```




```
D: Flange Facing (Sketch/Description): 1a  Flat Face
```

SHELL/NOZZLE DATA

```
SHELL/NOZZLE SIZE & COMMENT: S1.1
SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 120'C
ST=515 SY=205 SYd=169.6 fs=138 fs20=138 Stest=184.5  (N/mm2)
OUTSIDE DIAMETER OF SHELL/NOZZLE ...................:Do        141.30 mm
WALL THICKNESS OF NOZZLE/SHELL(uncorroded)..........:s1        3.4000 mm
```

FLANGE DATA

```
FLANGE HUB: Flange With Hub
REVERSE FLANGE: No (The bolts are located on the outside)
DESIGN METHOD: A) INTEGRAL FLANGE METHOD
FLANGE BORE: Smooth          .
OUTSIDE DIAMETER OF FLANGE..........................:A         215.00 mm
THICKNESS OF FLANGE(uncorroded).....................:e          36.00 mm
CORROSION ALLOWANCE FOR FLANGE FACE.................:cf          0.00 mm
SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 120'C
ST=450 SY=170 SYd=138.6 SFO=115 SFA=115 Stest=153  (N/mm2)
INCLUDE APPENDIX 2-14, FLANGE RIGIDITY CALCULATION: YES
MODULUS OF ELASTICITY at design temp................:E      2,0E05 N/mm2
MODULUS OF ELASTICITY at ambient temp...............:E20    2,0E05 N/mm2
```

DATA FOR FLANGE HUB

```
LENGTH OF HUB.......................................:h           18.00 mm
THICKNESS OF HUB AT BACK OF FLANGE corroded.........:g1          17.50 mm
THICKNESS OF HUB AT SMALL END      corroded.........:go         3.2000 mm
SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 120'C
ST=450 SY=170 SYd=138.6 SHO=115 SHA=115 Stest=153  (N/mm2)
```

BOLTING DATA

```
REDUCE SAFETY AGAINST ABUSE BY CAREFULLY CONTROLLING THE BOLTING-UP TORQUE: NO
BOLTING TORQUE CALCULATION: NO
NOMINAL BOLTING SIZE & COMMENT: M12x1.75 ;
EFFECTIVE BOLT AREA per bolt........................:Ae          76.25 mm2
RECOMMENDED MINIMUM BOLT CENTER TO EDGE CLEARANCE...:Bce         16.00 mm
RECOMMENDED MINIMUM BOLT CENTER/RADIAL CLEARANCE....:Bcr         20.00 mm
DIAMETER OF BOLT HOLES IN FLANGE....................:d           12.00 mm
NUMBER OF BOLTS.....................................:n          4.0000
BOLT-CIRCLE DIAMETER................................:C          180.00 mm
SA-193(M) Gr.B7, G41400 Bolting THK<=100mm 95'C
ST=795 SY=655 SYd=609.57 Sb=159 Sa=159 Stest=589.5  (N/mm2)
```

GASKET DATA

```
Table 2-5.1 Gasket factors m & y   Facing:
Mineral Fiber 1.6 mm thick       m=2.75  Y=25.5  2 1a,1b,1c,1d,4,5
CONTACT WIDTH OF GASKET.............................:N          1.0000 mm
OUTSIDE DIAMETER OF GASKET..........................:Go         132.20 mm
TEMA RGP-RCB-11.7 Include Additional Loads from Pass Partition Plate Gasket: NO
```

CALCULATION DATA

GASKET DETAILS

```
b = MIN VALUE(2.52 * Sqr(bo), bo ) = ==                    0.5000 mm
```

FLANGE LOADS

```
HD = 0.785 * B ^ 2 * p =0.785*136.5^2*1.0027=                14.67 kN
H = 0.785 * G ^ 2 * p =0.785*131.2^2*1.0027=                 13.55 kN
Hp = (2 * PI * b * G * m) * p
=(2*3.14*0.5*131.2*2.75)*1.0027=                          1.1365 kN
HT = H - HD =13549.03-14665.81=                             -1.12 kN
```

MOMENT ARMS

```
hG = (C - G) / 2 =(180-131.2)/2=                             24.40 mm
hD = (C - B - g1) / 2 =(180-136.5-17.5)/2=                   13.00 mm
hT = (2 * C - B - G) / 4 =(2*180-136.5-131.2)/4=             23.08 mm
```

BOLT LOADS

```
Operating condition
Wop = H + Hp =13549.03+1136.55=                              14.69 kN

Bolting up condition
Wamb = PI * b * G * y =3.14*0.5*131.2*25.5=                 5.2553 kN
```

BOLTING AREA

```
Am1 = Wop / Sb =14685.58/159=                                92.36 mm2

Am2 = Wamb / Sa =5255.26/159=                                33.05 mm2

Required Bolting Area Am
Am = MAX( Am1 , Am2) =MAX(92.36,33.05)=                      92.36 mm2

Available Bolting Area Ab
Ab (num.bolts*root area) = n * Ae =4*76.25=                 305.00 mm2
```

Bolting Area Check Ab=305 >= Am=92.36[mm2]	30.2%	OK

```
Bolt Spacing
Bs = C * PI / n =180*3.14/4=                                141.37 mm
```

```
2-5 Recommended Maximum Bolt Spacing
Bmax = 2 * db + 6 * e / (m + 0.5)
=2*12+6*36/(2.75+0.5)=                                  90.46 mm
W = 0.5 * (Ab + Am) * Sa =0.5*(305+92.36)*159=           31.59 kN
```

FLANGE MOMENTS

```
Mop = HD * hD + HT * hT + HG * hG
=14665.81*13+-1120*23.075+1136.55*24.4=                 192.62 Nm
Mamb = W * hG =31590.29*24.4=                            770.80 Nm
Mo = Mop =192.62=                                        192.62 Nm
Ma = Mamb =770.8=                                        770.80 Nm
```

SHAPE CONSTANTS

```
K = A / B =215/136.5=                                    1.5751
ho=SQR(B*go)= 20.900  h/ho=  0.861  K=A/B=  1.575  g1/go=  5.469
VALUES FOR T,U,Y AND Z FROM FIGURE 2-7.1
T =    1.678  Z =    2.351  Y =    4.448  U =    4.888
F =    0.685  V =    0.047  f =    4.676
d = U / V * ho * go ^ 2 =4.888/0.0467*20.9*3.2^2=       22384.03 mm3
e = F / ho =0.6845/20.9=                                 0.0328 mm-1
L = (t * e + 1) / T + t ^ 3 / d
=(36*0.0328+1)/1.678+36^3/22384.03=                     3.3830
```

OPERATING CONDITION

```
M = Mo =192.62=                                          192.62 Nm
```

Flange Stresses with Flange Thickness e= 36 mm

```
Longitudinal Hub Stress
SH = f * M / (L * g1 ^ 2 * B)
=4.68*192.62/(3.38*17.5^2*136.5)=                       6.3694 N/mm2
Radial Flange Stress
SR = (1.333 * t * e + 1) * M / (L * t ^ 2 * B)
=(1.333*36*0.0328+1)*192.62/(3.38*36^2*136.5)=          0.8277 N/mm2
Tangential Flange Stress
ST = Y * M / (t ^ 2 * B) - (Z * SR)
=4.448*192.62/(36^2*136.5)-(2.351*0.8277)=              2.8971 N/mm2
```

Stress Limits

Hub Stress SH=6.37 <= 1.5 * MIN(Sf;SfH)=172.5[N/mm2]	3.6%	OK
Radial Stress SR=0.8277 <= Sf=115[N/mm2]	0.7%	OK
Tangential Stress ST=2.9 <= Sf=115[N/mm2]	2.5%	OK
Radial+Hub Stress 0.5*(SH+SR)=3.6 <= Sf=115[N/mm2]	3.1%	OK
Tangential+Hub Stress 0.5*(SH+ST)=4.63 <= Sf=115[N/mm2]	4.0%	OK

APPENDIX 2-14, FLANGE RIGIDITY

```
Rigidity Index
J = 52.14 * V * M / (L * E * go ^ 2 * 0.3 * ho)
=52.14*0.0467*1.9262E05/(3.38*200000*3.2^2*0.3*20.9)=   0.0108
```

BOLTING UP CONDITION

```
M = Ma =770.8=                                           770.80 Nm
```

Flange Stresses with Flange Thickness e= 36 mm

```
Longitudinal Hub Stress
SH = f * M / (L * g1 ^ 2 * B)
=4.68*770.8/(3.38*17.5^2*136.5)=                        25.49 N/mm2
Radial Flange Stress
SR = (1.333 * t * e + 1) * M / (L * t ^ 2 * B)
```

```
=(1.333*36*0.0328+1)*770.8/(3.38*36^2*136.5)=              3.3124 N/mm2

Tangential Flange Stress
ST = Y * M / (t ^ 2 * B) - (Z * SR)
=4.448*770.8/(36^2*136.5)-(2.351*3.31)=                     11.59 N/mm2
```

Stress Limits

Hub Stress SH=25.49 <= 1.5 * MIN(Sf;SfH)=172.5[N/mm2]	14.7%	OK
Radial Stress SR=3.31 <= Sf=115[N/mm2]	2.8%	OK
Tangential Stress ST=11.59 <= Sf=115[N/mm2]	10.0%	OK
Radial+Hub Stress 0.5*(SH+SR)=14.4 <= Sf=115[N/mm2]	12.5%	OK
Tangential+Hub Stress 0.5*(SH+ST)=18.54 <= Sf=115[N/mm2]	16.1%	OK

APPENDIX 2-14, FLANGE RIGIDITY

```
Rigidity Index
J = 52.14 * V * M / (L * E * go ^ 2 * 0.3 * ho)
=52.14*0.0467*7.708E05/(3.38*200000*3.2^2*0.3*20.9)=       0.0432
```

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Ptmin = 1.1 * Pd * Sr / S =1.1*1*115/115=                   1.1000 MPa
```

Test Pressure Ptmin=1.1 <= Ptmax=11.371[MPa]	9.6%	OK

PRESSURE AND TORQUE SUMMARY

Table PRESSURE AND TORQUE SUMMARY FOR F.3 :

Description	Temp(C)	P(MPa)	Limited By	Min.Req.Total Bolt Force(kN)
Design Pressure(corroded)	95	1.00	Bolting Area Check	14.69
Max.Allow.Pressure(corroded)	95	3.31	Bolting Area Check	48.52
Max.Allow.Pressure(corroded)	Ambient	3.31	Bolting Area Check	48.52
Max.Allow.Test Pressure(corroded)	Ambient	11.37	Bolting Area Check	166.54
Required Test Pressure	Ambient	1.10	Bolting Area Check	16.15

The nominal Force and Torque values are based on the following bolting up method:

CALCULATION SUMMARY

BOLTING AREA

Bolting Area Check Ab=305 >= Am=92.36[mm2]	30.2%	OK

OPERATING CONDITION

Flange Stresses with Flange Thickness e= 36 mm

```
Longitudinal Hub Stress
SH = f * M / (L * g1 ^ 2 * B)
=4.68*192.62/(3.38*17.5^2*136.5)=                          6.3694 N/mm2

Radial Flange Stress
SR = (1.333 * t * e + 1) * M / (L * t ^ 2 * B)
=(1.333*36*0.0328+1)*192.62/(3.38*36^2*136.5)=             0.8277 N/mm2

Tangential Flange Stress
ST = Y * M / (t ^ 2 * B) - (Z * SR)
=4.448*192.62/(36^2*136.5)-(2.351*0.8277)=                 2.8971 N/mm2
```

Stress Limits

Hub Stress SH=6.37 <= 1.5 * MIN(Sf;SfH)=172.5[N/mm2]	3.6%	OK
Radial Stress SR=0.8277 <= Sf=115[N/mm2]	0.7%	OK
Tangential Stress ST=2.9 <= Sf=115[N/mm2]	2.5%	OK
Radial+Hub Stress 0.5*(SH+SR)=3.6 <= Sf=115[N/mm2]	3.1%	OK
Tangential+Hub Stress 0.5*(SH+ST)=4.63 <= Sf=115[N/mm2]	4.0%	OK

APPENDIX 2-14, FLANGE RIGIDITY

```
Rigidity Index
J = 52.14 * V * M / (L * E * go ^ 2 * 0.3 * ho)
=52.14*0.0467*1.9262E05/(3.38*200000*3.2^2*0.3*20.9)=        0.0108
```

BOLTING UP CONDITION

Flange Stresses with Flange Thickness e= 36 mm

```
Longitudinal Hub Stress
SH = f * M / (L * g1 ^ 2 * B)
=4.68*770.8/(3.38*17.5^2*136.5)=                              25.49 N/mm2

Radial Flange Stress
SR = (1.333 * t * e + 1) * M / (L * t ^ 2 * B)
=(1.333*36*0.0328+1)*770.8/(3.38*36^2*136.5)=                3.3124 N/mm2

Tangential Flange Stress
ST = Y * M / (t ^ 2 * B) - (Z * SR)
=4.448*770.8/(36^2*136.5)-(2.351*3.31)=                       11.59 N/mm2
```

Stress Limits

Hub Stress SH=25.49 <= 1.5 * MIN(Sf;SfH)=172.5[N/mm2]	14.7%	OK
Radial Stress SR=3.31 <= Sf=115[N/mm2]	2.8%	OK
Tangential Stress ST=11.59 <= Sf=115[N/mm2]	10.0%	OK
Radial+Hub Stress 0.5*(SH+SR)=14.4 <= Sf=115[N/mm2]	12.5%	OK
Tangential+Hub Stress 0.5*(SH+ST)=18.54 <= Sf=115[N/mm2]	16.1%	OK

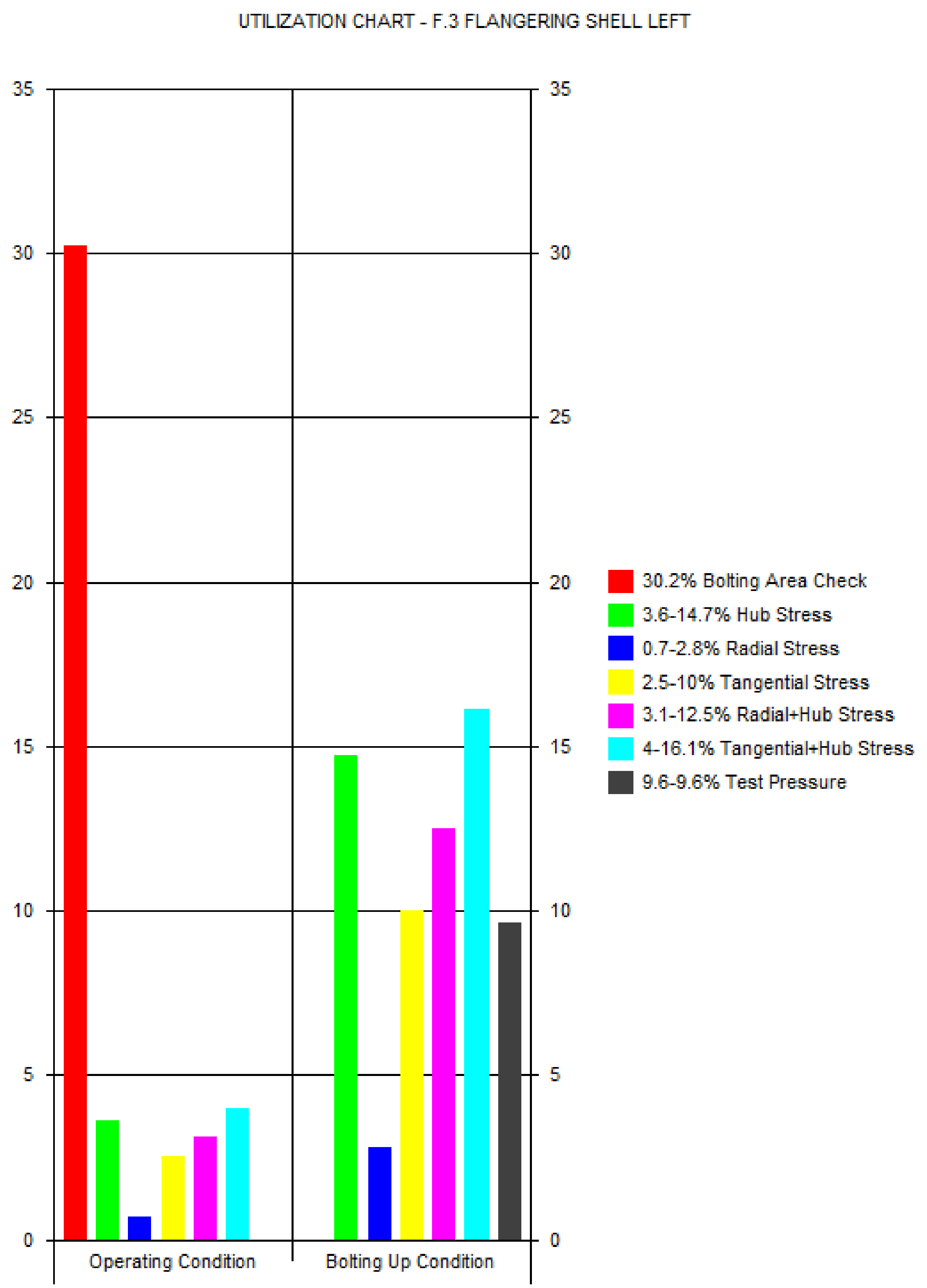
APPENDIX 2-14, FLANGE RIGIDITY

```
Rigidity Index
J = 52.14 * V * M / (L * E * go ^ 2 * 0.3 * ho)
=52.14*0.0467*7.708E05/(3.38*200000*3.2^2*0.3*20.9)=         0.0432
```

Test Pressure Ptmin=1.1 <= Ptmax=11.371[MPa]	9.6%	OK

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 5 SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.
WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 3 SA-182(M) Gr.F316L, S31603 Forgings, PNo=8 , the material must be re-selected from the material database.
Warning: Invalid gasket location/dimension.

Volume:0.0007902 m3 Weight:6 kg (SG= 7.85)



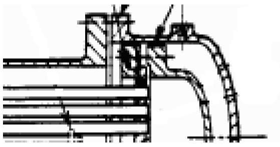
Max.Utilization/Condition 30.2%

INPUT DATA

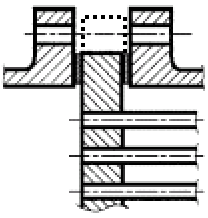
COMPONENT ATTACHMENT/LOCATION

```
Attachment: F.3     RT - Flange         Flangering Shell left         S1.1
Location: Along z-axis z1= -54
```

GENERAL DESIGN DATA



```
Type of Heat Exchanger: UHX-14 Floating Tubesheet Heat Exchangers
Type of Tubesheet: Stationary Tubesheet
Type of Floating Tubesheet Exchanger: With Immersed Floating Head
```



```
Configuration Type: d1 Tubesheet gasketed with shell and channel
UHX-14.6 Calc.Procedure for Effect of Radial Differential Thermal Exp. Adj.to
Tubesheet: NO
```

LOAD CASES (LC)

Table LOAD CASES:

Description	ID	=LC1=	=LC2=	=LC3=
Shell-Side Pressure (MPa)	Ps	0	2.82	2.82
Tube-Side Pressure (MPa)	Pt	1	0	1
Shell-Side Corr.Allow. (mm)	cs	1	1	1
Tube-Side Corr.Allow. (mm)	ct	1	1	1
Thermal Stress Factor	MdT	0	0	0
Mean Shell Temperature ('C)	Tsm	NA	NA	NA
Mean Tube Temperature ('C)	Ttm	NA	NA	NA

```
=LC1=: =LC1=
=LC2=: =LC2=
=LC3=: =LC3=
```

ALLOWBALE STRESS FOR EACH LOAD CASE

```
Material Design Temperatures:
Select material design temperatures from the process card.
Ttubesheet= 210, Tshell= 210, Ttube= 210, Tchannel= 95(all values in °C)
```

Table LOAD CASES:

Description	ID	=LC1=	=LC2=	=LC3=
Allowable Stress M Factor	Mf	1.0	1.0	1.0

DATA FOR TUBESHEET

```
SB-148(M), M01, C95820 Castings 204'C
ST=650 SY=270 Sy=259.84 S=167.52 Sr=179 Stest=243  (N/mm2)
OUTSIDE DIAMETER OF TUBESHEET(Ref. UHX-10(b)).......:A         132.20 mm
NOMINAL THICKNESS OF TUBESHEET (uncorroded).........:hn         28.00 mm
ELASTIC MODULUS OF TUBESHEET at tubesheet design temp.:E    1,894E05 N/mm2
POISSON'S RATIO FOR TUBESHEET MATERIAL..............:v         0.3000
```

DATA FOR TUBES AND TUBES LAYOUT

```
Tube Layout: Triangular Pattern
SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8 100'C
ST=485 SY=170 Syt=145 St=115 Sr=115 Stest=153  (N/mm2)
ELASTIC MODULUS OF TUBES at tube design temp........:Et     1,8621E05 N/mm2
NOMINAL OUTSIDE DIAMETER OF TUBES...................:dt        7.5000 mm
TUBE SIZE & COMMENT: S1.2
NOMINAL THICKNESS OF TUBES..........................:tt        0.5000 mm
TUBE PITCH (Spacing between centers)................:p          11.50 mm
DIAMETER OF TUBEHOLE IN TUBESHEET...................:dh        8.0000 mm
DIAMETER OF OUTER TUBE LIMIT CIRCLE.................:Do        123.00 mm
NUMBER OF TUBEHOLES IN TUBESHEET....................:Nt         72.00 piec
TOTAL AREA OF UNTUBED LANES(UL1*Ll1+UL2*Ll2+..).....:AL      1600.00 mm2
TUBE EXPANSION DEPTH RATIO (0<=ro<=1.0).............:ro        1.0000
TUBE-SIDE PASS PARTITION GROOVE DEPTH(Fig.UHX-11.1).:hg        1.0000 mm
THERMAL EXPANSION COEF.OF TUBES at mean metal temp..:atm    1,614E-05 mm/mmC
TUBE BUCKLING LENGTH lt=l*k (Ref. UHX-13.5.9(b)(1)).:lt        1.0000 mm
TUBE LENGTH BETWEEN INNER FACES OF TUBESHEETS.......:L         800.00 mm
POISSON'S RATIO FOR TUBE MATERIAL...................:vt        0.3000
PERIMETER OF THE TUBE LAYOUT MEASURED CENTER ON OUTER MOST TUBES:Cp     0.00 mm
TOTAL AREA ENCLOSED BY Cp...........................:Ap          0.00 mm2
```

DATA FOR TUBE TO TUBESHEET JOINT

```
Tube to Tubesheet Weld: Full Strength Weld to UW-20.4
Qualification of Tube-to-Tubesheet Joint: The Joint IS Qualified by Tests
FIG. UW-20.1 Weld Types: Sketch a) Fillet Weld
TUBE TO TUBESHEET FILLET WELD LEG...................:af        1.0000 mm
```

SHELL DATA

```
SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 120'C
ST=515 SY=205 Sys=169.6 Ss=138 Sr=138 Stest=184.5  (N/mm2)
INSIDE DIAMETER OF SHELL(corroded)..................:Ds        133.30 mm
THICKNESS OF SHELL (uncorroded).....................:ts        3.2000 mm
ELASTIC MODULUS OF SHELL MATERIAL at shell design temp:Es   1,8621E05 N/mm2
POISSON'S RATIO FOR SHELL MATERIAL..................:vs        0.3000
```

CHANNEL DATA

```
SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 120'C
ST=515 SY=205 Syc=169.6 Sc=138 Sr=138 Stest=184.5  (N/mm2)
INSIDE DIAMETER OF CHANNEL(corroded)................:Dc        133.30 mm
THICKNESS OF CHANNEL (uncorroded)...................:tc        3.2000 mm
ELASTIC MODULUS OF CHANNEL at channel design temp...:Ec     1,8833E05 N/mm2
POISSON'S RATIO FOR CHANNEL MATERIAL................:vc        0.3000
```

FLANGE DATA

```
DIAMETER OF SHELL GASKET LOAD REACTION..............:Gs        152.00 mm
SHELL FLANGE DESIGN BOLT LOAD FOR ASSEMBLY COND.....:Ws         53.00 kN
SHELL FLANGE DESIGN BOLT LOAD FOR OPERATING COND....:Wm1s       53.00 kN
DIAMETER OF CHANNEL GASKET LOAD REACTION............:Gc        152.00 mm
CHANNEL FLANGE DESIGN BOLT LOAD FOR ASSEMBLY COND...:Wc         53.00 kN
CHANNEL FLANGE DESIGN BOLT LOAD FOR OPERATING COND..:Wm1c       53.00 kN
BOLT-CIRCLE DIAMETER................................:C         152.00 mm
```

CALCULATION DATA

LOAD CASE:=LC1==LC1=

PRELIMINARY CALCULATIONS

UW-20 TUBE-TO-TUBESHEET WELDS

```
Allowable Stress in Weld
Sw = MIN( S , St) =MIN(167.52,115)=                         115.00 N/mm2
Weld Strength Factor
fw = St / Sw =115/115=                                      1.0000
Axial Tube Strength
Ft = PI * tt * (dt - tt) * St =3.14*0.5*(7.5-0.5)*115=      1264.49 N
Minimum Required Length of the Weld Leg
ar = Sqr((0.75*dt)^2+2.73*tt*(dt-tt)*fw*fd)-0.75*dt
=Sqr((0.75*7.5)^2+2.73*0.5*(7.5-0.5)*1*1)-0.75*7.5=       0.7934 mm
Minimum Required Size of Fillet Weld Leg
afmin = MAX( ar, tt) =MAX(0.7934,0.5)=                      0.7934 mm
Fillet Weld Strength
Ff = MIN( 0.55 * PI * af * (dt + 0.67 * af) * Sw , Ft)
=MIN(0.55*3.14*1*(7.5+0.67*1)*115,1264.49)=               1264.49 N
```

TABLE UHX-8.1 TUBESHEET EFFECTIVE BOLT LOAD W*=Wm1c= 53.00kN

```
Tubesheet Analysis Thickness h
h = hn - ct - cs =28-1-1=                                    26.00 mm
```

UHX-11.5.1 Determination of Effective Dimensions and Ligament Efficiency

```
Basic efficiency for shear
my = (p - dt) / p =(11.5-7.5)/11.5=                         0.3478
Effective Tube Hole Diameter (dstar)
dstar = MAX(dt-2*tt*(Et/E)*(St/S)*ro,dt-2*tt)
=MAX(7.5-2*0.5*(186212/189400)*(115/167.52)*1,7.5-2*0.5)=   6.8251 mm
Effective Pitch(pstar)
pstar = p/Sqr(1-4*MIN(AL,4*Do*p)/(PI*Do^2))
=11.5/Sqr(1-4*MIN(1600,4*123*11.5)/(3.14*123^2))=          12.36 mm
Mystar = (pstar - dstar) / pstar =(12.36-6.83)/12.36=       0.4479
```

UHX-11.5.2 Determination of Effective Elastic Properties Estar and vstar

```
EstarOverE(Estar/E) from figure UHX-11.3a) =  0.4763(h/p=2.26)
Estar = EstarOverE * E =0.4763*189400=                    90213.95 N/mm2
vstar from figure UHX-11.3b) =  0.3032(h/p=2.26)
```

UHX-14.5.1 Step 1

```
Radial Channel Dimension ac
ac = Gc / 2 =152/2=                                          76.00 mm
Radial Shell Dimension as
as = Gs / 2 =152/2=                                          76.00 mm
Parameters
ao = Do / 2 =123/2=                                          61.50 mm
Diameter Ratio ros for Shell
ros = as / ao =76/61.5=                                     1.2358
Diameter Ratio roc for Channel
roc = ac / ao =76/61.5=                                     1.2358
Tubesheet Drilling Coefficients
xs = 1 - Nt * (dt / (2 * ao)) ^ 2
=1-72*(7.5/(2*61.5))^2=                                   0.7323
xt = 1 - Nt * ((dt - 2 * tt) / (2 * ao)) ^ 2
=1-72*((7.5-2*0.5)/(2*61.5))^2=                           0.7989
```

UHX-14.5.2 Step 2, Shell and Tube Axial Stiffness

UHX-14.5.3 Step 3, Tube Bundle to Tubesheet Rigidity Ratio

```
Xa = (24*(1-vstar^2)*Nt*Et*tt*(dt-tt)*ao^2/(Estar*L*h^3))^0.25
=(24*(1-0.3032^2)*72*186212*0.5*(7.5-0.5)*61.5^2/(90213.95*800*26^3))^0.25
=   1.3214
Zd (from figure UHX-13.2) =  0.7123
Zv (from figure UHX-13.2) =  0.1859
Zw (from figure UHX-13.2) =  0.1859
Zm (from figure UHX-13.2) =  0.7493
```

UHX-14.5.4 Step 4, Ratio K and Parameters F, Phi, Q and U

```
Diameter Ratio K
K = A / Do =132.2/123=                                      1.0748
F = (1 - vstar) / Estar * (LamdaS + LamdaC + E * Log( K))
=(1-0.3032)/90213.95*(0+0+189400*Log(1.07))=              0.1055
phi = (1 + vstar) * F =(1+0.3032)*0.1055=                   0.1375
Q1 = (ros - 1 - phi * Zv) / (1 + phi * Zm)
=(1.24-1-0.1375*0.1859)/(1+0.1375*0.7493)=                0.1906
```

UHX-14.5.5 Step 5

```
Omegas = ros * ks * Betas * Deltas * (1 + h * Betas)
=1.24*0*0*0*(1+26*0)=                                       0.00 mm2
Omegasstar = ao ^ 2 * (ros ^ 2 - 1) * (ros - 1) / 4 - Omegas
=61.5^2*(1.24^2-1)*(1.24-1)/4-0=                          117.52 mm2
Omegac = roc * kc * Betac * Deltac * (1 + h * Betac)
=1.24*0*0*0*(1+26*0)=                                       0.00 mm2
Omegacstar = ao^2*((roc^2+1)*(roc-1)/4-(ros-1)/2)-Omegac
=61.5^2*((1.24^2+1)*(1.24-1)/4-(1.24-1)/2)-0=             117.52 mm2
yb = (Gc - Gs) / Do =(152-152)/123=                           0.00 mm
Psstar = 0 =0=                                                0.00 MPa
Pcstar = 0 =0=                                                0.00 MPa
```

UHX-14.5.6 Step 6

```
Effective Pressure Pe
Pe = Ps - Pt =0-1=                                          -1 MPa
```

UHX-14.5.7 Step 7

```
Q2 = (Omegasstar*Ps-Omegacstar*Pt+yb/(2*PI)*Wstar)/(1+phi*Zm)
=(117.52*0-117.52*1+0/(2*3.14)*53000)/(1+0.1375*0.7493)=  -106.54 N
Q3 = Q1 + 2 * Q2 / (Pe * ao ^ 2)
=0.1906+2*-106.54/(-1*61.5^2)=                            0.2469
Fm = MAX(Fm(x)) (from Table UHX-13.1) =  0.3141
```

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.3141/0.4479*(2*61.5/(26-0))^2*-1=                  -23.54 N/mm2
```

Tubesheet Bending Stress Sigma=23.54 <= 1.5 * S=251.28[N/mm2]	9.3%	OK

UHX-14.5.8 Step 8, Shear Stress in Tubesheet (Tau)

```
UHX-14.5.8(a) Tau is not required to be calculated since ABS(Pe) < 1.6 * s_0 * my
* H_1 / ao ;     1.000 <     39.414 (MPa)
```

Tubesheet Shear Stress Tau=0 <= MIN(0.8*S, 0.533*Sy)=134.02[N/mm2]	0.0%	OK

UHX-14.5.9 Step 9, Tube Design

```
Ftmin = MIN(Ft(x)) (from Table UHX-13.2) =  0.8300
Ftmax = MAX(Ft(x)) (from Table UHX-13.2) =  1.1559
```

Axial Tube Stress (Pe <> 0)

```
Sigt1 = (Ps * xs - Pt * xt - Pe * Ftmin) / (xt - xs)
=(0*0.7323-1*0.7989--1*0.83)/(0.7989-0.7323)=          0.4658 N/mm2
Sigt2 = (Ps * xs - Pt * xt - Pe * Ftmax) / (xt - xs)
=(0*0.7323-1*0.7989--1*1.16)/(0.7989-0.7323)=          5.3583 N/mm2
SigtMax = MAX( Sigt1 , Sigt2) =MAX(0.4658,5.36)=         5.3583 N/mm2
```

Tube Axial Stress SigtMax=5.36 <= St=115[N/mm2]	4.6%	OK

```
Largest Tube-to-Tubesheet Joint Load, Wt
Wt = PI * (dt - tt) * tt * SigtMax
=3.14*(7.5-0.5)*0.5*5.36=                                58.92 N
```

Tube Weld Max.Axial Load Wt=58.92 <= Lmax=1264.49[N] (UW-20)	4.6%	OK

UHX-14.5.10 Step 10, Stresses in Shell

```
Axial Membrane Stress Sigsm
Sigsm = (ao^2*(Pe+(ros^2-1)*(Ps-Pt))+as^2*Pt)/(Gs*ts)
=(61.5^2*(-1+(1.24^2-1)*(0-1))+76^2*1)/(152*2.2)=     -3,793E-07 N/mm2
Temp1 = Betas * Deltas * Ps =0*0*0=                         0.00
Temp2 = 6*(1-vstar^2)/Estar*(ao^3/h^3)*(1+h*Betas/2)
=6*(1-0.3032^2)/90213.95*(61.5^3/26^3)*(1+26*0/2)=     7,9927E-04
Temp3 = Pe * (Zv + Zm * Q1) + 2 / ao ^ 2 * Zm * Q2
=-1*(0.1859+0.7493*0.1906)+2/61.5^2*0.7493*-106.54=      -0.3709
Axial Bending Stress Sigsb
Sigsb = 6 * ks / ts ^ 2 * (Temp1 + Temp2 * Temp3)
=6*0/2.2^2*(0+7.9927E-04*-0.3709)=                       0.00 N/mm2
Total Axial Stress Sigs
Sigs = ABS( Sigsm) + ABS( Sigsb)
=ABS(-3.793E-07)+ABS(0)=                               3,793E-07 N/mm2
```

Total Axial Shell Stress Sigs=3.793E-07 <= 1.5 * Ss=207[N/mm2]	0.0%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

LOAD CASE:=LC2==LC2=

PRELIMINARY CALCULATIONS

UW-20 TUBE-TO-TUBESHEET WELDS

```
Allowable Stress in Weld
Sw = MIN( S , St) =MIN(167.52,115)=                       115.00 N/mm2
Weld Strength Factor
fw = St / Sw =115/115=                                    1.0000
Axial Tube Strength
Ft = PI * tt * (dt - tt) * St =3.14*0.5*(7.5-0.5)*115=   1264.49 N
Minimum Required Length of the Weld Leg
ar = Sqr((0.75*dt)^2+2.73*tt*(dt-tt)*fw*fd)-0.75*dt
=Sqr((0.75*7.5)^2+2.73*0.5*(7.5-0.5)*1*1)-0.75*7.5=      0.7934 mm
Minimum Required Size of Fillet Weld Leg
afmin = MAX( ar, tt) =MAX(0.7934,0.5)=                    0.7934 mm
Fillet Weld Strength
Ff = MIN( 0.55 * PI * af * (dt + 0.67 * af) * Sw , Ft)
=MIN(0.55*3.14*1*(7.5+0.67*1)*115,1264.49)=             1264.49 N
```

TABLE UHX-8.1 TUBESHEET EFFECTIVE BOLT LOAD W*=Wm1s= 53.00kN

```
Tubesheet Analysis Thickness h
h = hn - ct - cs =28-1-1=                                   26.00 mm
```

UHX-11.5.1 Determination of Effective Dimensions and Ligament Efficiency

```
Basic efficiency for shear
my = (p - dt) / p =(11.5-7.5)/11.5=                        0.3478
Effective Tube Hole Diameter (dstar)
dstar = MAX(dt-2*tt*(Et/E)*(St/S)*ro,dt-2*tt)
=MAX(7.5-2*0.5*(186212/189400)*(115/167.52)*1,7.5-2*0.5)=   6.8251 mm
Effective Pitch(pstar)
pstar = p/Sqr(1-4*MIN(AL,4*Do*p)/(PI*Do^2))
=11.5/Sqr(1-4*MIN(1600,4*123*11.5)/(3.14*123^2))=          12.36 mm
Mystar = (pstar - dstar) / pstar =(12.36-6.83)/12.36=       0.4479
```

UHX-11.5.2 Determination of Effective Elastic Properties Estar and vstar

```
EstarOverE(Estar/E) from figure UHX-11.3a) =  0.4763(h/p=2.26)
Estar = EstarOverE * E =0.4763*189400=                    90213.95 N/mm2
vstar from figure UHX-11.3b) =  0.3032(h/p=2.26)
```

UHX-14.5.1 Step 1

```
Radial Channel Dimension ac
ac = Gc / 2 =152/2=                                         76.00 mm
Radial Shell Dimension as
as = Gs / 2 =152/2=                                         76.00 mm
Parameters
ao = Do / 2 =123/2=                                         61.50 mm
Diameter Ratio ros for Shell
ros = as / ao =76/61.5=                                    1.2358
Diameter Ratio roc for Channel
roc = ac / ao =76/61.5=                                    1.2358
Tubesheet Drilling Coefficients
xs = 1 - Nt * (dt / (2 * ao)) ^ 2
=1-72*(7.5/(2*61.5))^2=                                   0.7323
xt = 1 - Nt * ((dt - 2 * tt) / (2 * ao)) ^ 2
=1-72*((7.5-2*0.5)/(2*61.5))^2=                           0.7989
```

UHX-14.5.2 Step 2, Shell and Tube Axial Stiffness

UHX-14.5.3 Step 3, Tube Bundle to Tubesheet Rigidity Ratio

```
Xa = (24*(1-vstar^2)*Nt*Et*tt*(dt-tt)*ao^2/(Estar*L*h^3))^0.25
=(24*(1-0.3032^2)*72*186212*0.5*(7.5-0.5)*61.5^2/(90213.95*800*26^3))^0.25
=   1.3214
Zd (from figure UHX-13.2) =  0.7123
Zv (from figure UHX-13.2) =  0.1859
Zw (from figure UHX-13.2) =  0.1859
Zm (from figure UHX-13.2) =  0.7493
```

UHX-14.5.4 Step 4, Ratio K and Parameters F, Phi, Q and U

```
Diameter Ratio K
K = A / Do =132.2/123=                                     1.0748
F = (1 - vstar) / Estar * (LamdaS + LamdaC + E * Log( K))
=(1-0.3032)/90213.95*(0+0+189400*Log(1.07))=              0.1055
phi = (1 + vstar) * F =(1+0.3032)*0.1055=                  0.1375
Q1 = (ros - 1 - phi * Zv) / (1 + phi * Zm)
=(1.24-1-0.1375*0.1859)/(1+0.1375*0.7493)=                0.1906
```

UHX-14.5.5 Step 5

```
Omegas = ros * ks * Betas * Deltas * (1 + h * Betas)
=1.24*0*0*0*(1+26*0)=                                      0.00 mm2
Omegasstar = ao ^ 2 * (ros ^ 2 - 1) * (ros - 1) / 4 - Omegas
=61.5^2*(1.24^2-1)*(1.24-1)/4-0=                          117.52 mm2
Omegac = roc * kc * Betac * Deltac * (1 + h * Betac)
=1.24*0*0*0*(1+26*0)=                                      0.00 mm2
```

```
Omegacstar = ao^2*((roc^2+1)*(roc-1)/4-(ros-1)/2)-Omegac
=61.5^2*((1.24^2+1)*(1.24-1)/4-(1.24-1)/2)-0=          117.52 mm2
yb = (Gc - Gs) / Do =(152-152)/123=                        0.00 mm
Psstar = 0 =0=                                             0.00 MPa
Pcstar = 0 =0=                                             0.00 MPa
```

UHX-14.5.6 Step 6

```
Effective Pressure Pe
Pe = Ps - Pt =2.82-0=                                        2.8200 MPa
```

UHX-14.5.7 Step 7

```
Q2 = (Omegasstar*Ps-Omegacstar*Pt+yb/(2*PI)*Wstar)/(1+phi*Zm)
=(117.52*2.82-117.52*0+0/(2*3.14)*53000)/(1+0.1375*0.7493)=   300.44 N
Q3 = Q1 + 2 * Q2 / (Pe * ao ^ 2)
=0.1906+2*300.44/(2.82*61.5^2)=                        0.2469
Fm = MAX(Fm(x)) (from Table UHX-13.1) =  0.3141
```

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.3141/0.4479*(2*61.5/(26-0))^2*2.82=              66.38 N/mm2
```

Tubesheet Bending Stress Sigma=66.38 <= 1.5 * S=251.28[N/mm2]	26.4%	OK

UHX-14.5.8 Step 8, Shear Stress in Tubesheet (Tau)

```
UHX-14.5.8(a) Tau is not required to be calculated since ABS(Pe) < 1.6 * s_0 * my
* H_1 / ao ;     2.820 <     39.414 (MPa)
```

Tubesheet Shear Stress Tau=0 <= MIN(0.8*S, 0.533*Sy)=134.02[N/mm2]	0.0%	OK

UHX-14.5.9 Step 9, Tube Design

```
Ftmin = MIN(Ft(x)) (from Table UHX-13.2) =  0.8300
Ftmax = MAX(Ft(x)) (from Table UHX-13.2) =  1.1559
```

Axial Tube Stress (Pe <> 0)

```
Sigt1 = (Ps * xs - Pt * xt - Pe * Ftmin) / (xt - xs)
=(2.82*0.7323-0*0.7989-2.82*0.83)/(0.7989-0.7323)=     -4.13 N/mm2

Sigt2 = (Ps * xs - Pt * xt - Pe * Ftmax) / (xt - xs)
=(2.82*0.7323-0*0.7989-2.82*1.16)/(0.7989-0.7323)=     -17.93 N/mm2

SigtMax = MAX( Sigt1 , Sigt2) =MAX(-4.13,-17.93)=         17.93 N/mm2
```

Tube Axial Stress SigtMax=17.93 <= St=115[N/mm2]	15.5%	OK

```
Largest Tube-to-Tubesheet Joint Load, Wt
Wt = PI * (dt - tt) * tt * SigtMax
=3.14*(7.5-0.5)*0.5*17.93=                             197.15 N
```

Tube Weld Max.Axial Load Wt=197.15 <= Lmax=1264.49[N] (UW-20)	15.5%	OK

UHX-14.5.9(b) Tube Buckling Check

```
rt = Sqr( dt ^ 2 + (dt - 2 * tt) ^ 2) / 4
=Sqr(7.5^2+(7.5-2*0.5)^2)/4=                           2.4812 mm
Ft = lt / rt =1/2.48=                                    0.4030
Ct = Sqr( 2 * PI ^ 2 * Et / Syt)
=Sqr(2*3.14^2*186212/145)=                             159.22
Fs = MIN(2.0,MAX(3.25-0.25*(Zd+Q3*Zw)*Xa^4,1.25))
=MIN(2.0,MAX(3.25-0.25*(0.7123+0.2469*0.1859)*1.32^4,1.25))=   2.0000

UHX-14.5.9(b)(3)(b) Maximum Permissable Buckling Stress Stb
Stb = MIN( Syt / Fs * (1 - Ft / (2 * Ct)), St)
=MIN(145/2*(1-0.403/(2*159.22,))115)=                   72.41 N/mm2
```

Tube Buckling Stress SigtMin=17.93 <= Stb=72.41[N/mm2]	24.7%	OK

UHX-14.5.10 Step 10, Stresses in Shell

```
Axial Membrane Stress Sigsm
Sigsm = (ao^2*(Pe+(ros^2-1)*(Ps-Pt))+as^2*Pt)/(Gs*ts)
=(61.5^2*(2.82+(1.24^2-1)*(2.82-0))+76^2*0)/(152*2.2)=      48.71 N/mm2
Temp1 = Betas * Deltas * Ps =0*0*2.82=                          0.00
Temp2 = 6*(1-vstar^2)/Estar*(ao^3/h^3)*(1+h*Betas/2)
=6*(1-0.3032^2)/90213.95*(61.5^3/26^3)*(1+26*0/2)=      7,9927E-04
Temp3 = Pe * (Zv + Zm * Q1) + 2 / ao ^ 2 * Zm * Q2
=2.82*(0.1859+0.7493*0.1906)+2/61.5^2*0.7493*300.44=       1.0458
Axial Bending Stress Sigsb
Sigsb = 6 * ks / ts ^ 2 * (Temp1 + Temp2 * Temp3)
=6*0/2.2^2*(0+7.9927E-04*1.05)=                              0.00 N/mm2
Total Axial Stress Sigs
Sigs = ABS( Sigsm) + ABS( Sigsb) =ABS(48.71)+ABS(0)=          48.71 N/mm2
```

Total Axial Shell Stress Sigs=48.71 <= 1.5 * Ss=207[N/mm2]	23.5%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

LOAD CASE:=LC3==LC3=

PRELIMINARY CALCULATIONS

UW-20 TUBE-TO-TUBESHEET WELDS

```
Allowable Stress in Weld
Sw = MIN( S , St) =MIN(167.52,115)=                          115.00 N/mm2
Weld Strength Factor
fw = St / Sw =115/115=                                       1.0000
Axial Tube Strength
Ft = PI * tt * (dt - tt) * St =3.14*0.5*(7.5-0.5)*115=      1264.49 N
Minimum Required Length of the Weld Leg
ar = Sqr((0.75*dt)^2+2.73*tt*(dt-tt)*fw*fd)-0.75*dt
=Sqr((0.75*7.5)^2+2.73*0.5*(7.5-0.5)*1*1)-0.75*7.5=        0.7934 mm
Minimum Required Size of Fillet Weld Leg
afmin = MAX( ar, tt) =MAX(0.7934,0.5)=                       0.7934 mm
Fillet Weld Strength
Ff = MIN( 0.55 * PI * af * (dt + 0.67 * af) * Sw , Ft)
=MIN(0.55*3.14*1*(7.5+0.67*1)*115,1264.49)=              1264.49 N
```

TABLE UHX-8.1 TUBESHEET EFFECTIVE BOLT LOAD W*=Wm1max= 53.00kN

```
Tubesheet Analysis Thickness h
h = hn - ct - cs =28-1-1=                                     26.00 mm
```

UHX-11.5.1 Determination of Effective Dimensions and Ligament Efficiency

```
Basic efficiency for shear
my = (p - dt) / p =(11.5-7.5)/11.5=                          0.3478
Effective Tube Hole Diameter (dstar)
dstar = MAX(dt-2*tt*(Et/E)*(St/S)*ro,dt-2*tt)
=MAX(7.5-2*0.5*(186212/189400)*(115/167.52)*1,7.5-2*0.5)=   6.8251 mm
Effective Pitch(pstar)
pstar = p/Sqr(1-4*MIN(AL,4*Do*p)/(PI*Do^2))
=11.5/Sqr(1-4*MIN(1600,4*123*11.5)/(3.14*123^2))=          12.36 mm
Mystar = (pstar - dstar) / pstar =(12.36-6.83)/12.36=        0.4479
```

UHX-11.5.2 Determination of Effective Elastic Properties Estar and vstar

```
EstarOverE(Estar/E) from figure UHX-11.3a) =  0.4763(h/p=2.26)
Estar = EstarOverE * E =0.4763*189400=                    90213.95 N/mm2
vstar from figure UHX-11.3b) =  0.3032(h/p=2.26)
```

UHX-14.5.1 Step 1

```
Radial Channel Dimension ac
ac = Gc / 2 =152/2=                                          76.00 mm
Radial Shell Dimension as
as = Gs / 2 =152/2=                                          76.00 mm
Parameters
ao = Do / 2 =123/2=                                          61.50 mm
Diameter Ratio ros for Shell
ros = as / ao =76/61.5=                                    1.2358
Diameter Ratio roc for Channel
roc = ac / ao =76/61.5=                                    1.2358
Tubesheet Drilling Coefficients
xs = 1 - Nt * (dt / (2 * ao)) ^ 2
=1-72*(7.5/(2*61.5))^2=                                  0.7323
xt = 1 - Nt * ((dt - 2 * tt) / (2 * ao)) ^ 2
=1-72*((7.5-2*0.5)/(2*61.5))^2=                          0.7989
```

UHX-14.5.2 Step 2, Shell and Tube Axial Stiffness

UHX-14.5.3 Step 3, Tube Bundle to Tubesheet Rigidity Ratio

```
Xa = (24*(1-vstar^2)*Nt*Et*tt*(dt-tt)*ao^2/(Estar*L*h^3))^0.25
=(24*(1-0.3032^2)*72*186212*0.5*(7.5-0.5)*61.5^2/(90213.95*800*26^3))^0.25
=   1.3214
Zd (from figure UHX-13.2) =  0.7123
Zv (from figure UHX-13.2) =  0.1859
Zw (from figure UHX-13.2) =  0.1859
Zm (from figure UHX-13.2) =  0.7493
```

UHX-14.5.4 Step 4, Ratio K and Parameters F, Phi, Q and U

```
Diameter Ratio K
K = A / Do =132.2/123=                                     1.0748
F = (1 - vstar) / Estar * (LamdaS + LamdaC + E * Log( K))
=(1-0.3032)/90213.95*(0+0+189400*Log(1.07))=             0.1055
phi = (1 + vstar) * F =(1+0.3032)*0.1055=                  0.1375
Q1 = (ros - 1 - phi * Zv) / (1 + phi * Zm)
=(1.24-1-0.1375*0.1859)/(1+0.1375*0.7493)=               0.1906
```

UHX-14.5.5 Step 5

```
Omegas = ros * ks * Betas * Deltas * (1 + h * Betas)
=1.24*0*0*0*(1+26*0)=                                      0.00 mm2
Omegasstar = ao ^ 2 * (ros ^ 2 - 1) * (ros - 1) / 4 - Omegas
=61.5^2*(1.24^2-1)*(1.24-1)/4-0=                         117.52 mm2
Omegac = roc * kc * Betac * Deltac * (1 + h * Betac)
=1.24*0*0*0*(1+26*0)=                                      0.00 mm2
Omegacstar = ao^2*((roc^2+1)*(roc-1)/4-(ros-1)/2)-Omegac
=61.5^2*((1.24^2+1)*(1.24-1)/4-(1.24-1)/2)-0=            117.52 mm2
yb = (Gc - Gs) / Do =(152-152)/123=                          0.00 mm
Psstar = 0 =0=                                               0.00 MPa
Pcstar = 0 =0=                                               0.00 MPa
```

UHX-14.5.6 Step 6

```
Effective Pressure Pe
Pe = Ps - Pt =2.82-1=                                      1.8200 MPa
```

UHX-14.5.7 Step 7

```
Q2 = (Omegasstar*Ps-Omegacstar*Pt+yb/(2*PI)*Wstar)/(1+phi*Zm)
=(117.52*2.82-117.52*1+0/(2*3.14)*53000)/(1+0.1375*0.7493)=   193.90 N
Q3 = Q1 + 2 * Q2 / (Pe * ao ^ 2)
=0.1906+2*193.9/(1.82*61.5^2)=                           0.2469
```

```
Fm = MAX(Fm(x)) (from Table UHX-13.1) =  0.3141
```

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.3141/0.4479*(2*61.5/(26-0))^2*1.82=              42.84 N/mm2
```

Tubesheet Bending Stress Sigma=42.84 <= 1.5 * S=251.28[N/mm2]	17.0%	OK

UHX-14.5.8 Step 8, Shear Stress in Tubesheet (Tau)

```
UHX-14.5.8(a) Tau is not required to be calculated since ABS(Pe) < 1.6 * s_0 * my
* H_1 / ao ;     1.820 <     39.414 (MPa)
```

Tubesheet Shear Stress Tau=0 <= MIN(0.8*S, 0.533*Sy)=134.02[N/mm2]	0.0%	OK

UHX-14.5.9 Step 9, Tube Design

```
Ftmin = MIN(Ft(x)) (from Table UHX-13.2) =  0.8300
Ftmax = MAX(Ft(x)) (from Table UHX-13.2) =  1.1559
```

Axial Tube Stress (Pe <> 0)

```
Sigt1 = (Ps * xs - Pt * xt - Pe * Ftmin) / (xt - xs)
=(2.82*0.7323-1*0.7989-1.82*0.83)/(0.7989-0.7323)=        -3.67 N/mm2

Sigt2 = (Ps * xs - Pt * xt - Pe * Ftmax) / (xt - xs)
=(2.82*0.7323-1*0.7989-1.82*1.16)/(0.7989-0.7323)=        -12.57 N/mm2

SigtMax = MAX( Sigt1 , Sigt2) =MAX(-3.67,-12.57)=           12.57 N/mm2
```

Tube Axial Stress SigtMax=12.57 <= St=115[N/mm2]	10.9%	OK

```
Largest Tube-to-Tubesheet Joint Load, Wt
Wt = PI * (dt - tt) * tt * SigtMax
=3.14*(7.5-0.5)*0.5*12.57=                                138.24 N
```

Tube Weld Max.Axial Load Wt=138.24 <= Lmax=1264.49[N] (UW-20)	10.9%	OK

UHX-14.5.9(b) Tube Buckling Check

```
rt = Sqr( dt ^ 2 + (dt - 2 * tt) ^ 2) / 4
=Sqr(7.5^2+(7.5-2*0.5)^2)/4=                              2.4812 mm
Ft = lt / rt =1/2.48=                                       0.4030
Ct = Sqr( 2 * PI ^ 2 * Et / Syt)
=Sqr(2*3.14^2*186212/145)=                                159.22
Fs = MIN(2.0,MAX(3.25-0.25*(Zd+Q3*Zw)*Xa^4,1.25))
=MIN(2.0,MAX(3.25-0.25*(0.7123+0.2469*0.1859)*1.32^4,1.25))=   2.0000

UHX-14.5.9(b)(3)(b) Maximum Permissable Buckling Stress Stb
Stb = MIN( Syt / Fs * (1 - Ft / (2 * Ct)), St)
=MIN(145/2*(1-0.403/(2*159.22,))115)=                       72.41 N/mm2
```

Tube Buckling Stress SigtMin=12.57 <= Stb=72.41[N/mm2]	17.3%	OK

UHX-14.5.10 Step 10, Stresses in Shell

```
Axial Membrane Stress Sigsm
Sigsm = (ao^2*(Pe+(ros^2-1)*(Ps-Pt))+as^2*Pt)/(Gs*ts)
=(61.5^2*(1.82+(1.24^2-1)*(2.82-1))+76^2*1)/(152*2.2)=     48.71 N/mm2

Temp1 = Betas * Deltas * Ps =0*0*2.82=                       0.00
Temp2 = 6*(1-vstar^2)/Estar*(ao^3/h^3)*(1+h*Betas/2)
=6*(1-0.3032^2)/90213.95*(61.5^3/26^3)*(1+26*0/2)=      7,9927E-04
Temp3 = Pe * (Zv + Zm * Q1) + 2 / ao ^ 2 * Zm * Q2
=1.82*(0.1859+0.7493*0.1906)+2/61.5^2*0.7493*193.9=       0.6750
Axial Bending Stress Sigsb
Sigsb = 6 * ks / ts ^ 2 * (Temp1 + Temp2 * Temp3)
=6*0/2.2^2*(0+7.9927E-04*0.675)=                            0.00 N/mm2

Total Axial Stress Sigs
```

```
Sigs = ABS( Sigsm) + ABS( Sigsb) =ABS(48.71)+ABS(0)=          48.71 N/mm2
```

Total Axial Shell Stress Sigs=48.71 <= 1.5 * Ss=207[N/mm2]	23.5%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

MAXIMUM ALLOWABLE PRESSURE SUMMARY

Table MAWP SUMMARY FOR T.1 :

Description	P(MPa)	LimitedBy
Max.Allow.Test Pressure (tubeside)	17.66	Tubesheet Bending Stress
Max.Allow.Test Pressure(shellside)	14.35	Tube Buckling Stress
Max.Allow.Pressure Hot&Corroded(tubeside)	10.68	Tubesheet Bending Stress
Max.Allow.Pressure Hot&Corroded(shellside)	10.68	Tubesheet Bending Stress
Max.Allow.Pressure New&Cold(tubeside)	12.10	Tubesheet Bending Stress
Max.Allow.Pressure New&Cold(shellside)	12.11	Tubesheet Bending Stress

TEST PRESSURES

TEST PRESSURE ON TUBESIDE

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Pttmin = 1.1 * Ptd * Sr / S =1.1*1*179/167.52=          1.1754 MPa
```

TEST PRESSURE ON SHELLSIDE

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Ptsmin = 1.1 * Psd * Sr / S =1.1*2.82*179/167.52=          3.3146 MPa
```

CALCULATION SUMMARY

LOAD CASE:=LC1==LC1=

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.3141/0.4479*(2*61.5/(26-0))^2*-1=          -23.54 N/mm2
```

Tubesheet Bending Stress Sigma=23.54 <= 1.5 * S=251.28[N/mm2]	9.3%	OK

UHX-14.5.8 Step 8, Shear Stress in Tubesheet (Tau)

Tubesheet Shear Stress Tau=0 <= MIN(0.8*S, 0.533*Sy)=134.02[N/mm2]	0.0%	OK

UHX-14.5.9 Step 9, Tube Design

Axial Tube Stress (Pe <> 0)

```
SigtMax = MAX( Sigt1 , Sigt2) =MAX(0.4658,5.36)=          5.3583 N/mm2
```

Tube Axial Stress SigtMax=5.36 <= St=115[N/mm2]	4.6%	OK
Tube Weld Max.Axial Load Wt=58.92 <= Lmax=1264.49[N] (UW-20)	4.6%	OK
Tube Buckling Stress SigtMin=0 <= Stb=100000[N/mm2]	0.0%	OK

```
Total Axial Stress Sigs
Sigs = ABS( Sigsm) + ABS( Sigsb)
=ABS(-3.793E-07)+ABS(0)=          3,793E-07 N/mm2
```

Total Axial Shell Stress Sigs=3.793E-07 <= 1.5 * Ss=207[N/mm2]	0.0%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

LOAD CASE:=LC2==LC2=

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.3141/0.4479*(2*61.5/(26-0))^2*2.82=                66.38 N/mm2
```

Tubesheet Bending Stress Sigma=66.38 <= 1.5 * S=251.28[N/mm2]	26.4%	OK

UHX-14.5.8 Step 8, Shear Stress in Tubesheet (Tau)

Tubesheet Shear Stress Tau=0 <= MIN(0.8*S, 0.533*Sy)=134.02[N/mm2]	0.0%	OK

UHX-14.5.9 Step 9, Tube Design

Axial Tube Stress (Pe <> 0)

```
SigtMax = MAX( Sigt1 , Sigt2) =MAX(-4.13,-17.93)=          17.93 N/mm2
```

Tube Axial Stress SigtMax=17.93 <= St=115[N/mm2]	15.5%	OK
Tube Weld Max.Axial Load Wt=197.15 <= Lmax=1264.49[N] (UW-20)	15.5%	OK
Tube Buckling Stress SigtMin=17.93 <= Stb=72.41[N/mm2]	24.7%	OK

```
Total Axial Stress Sigs
Sigs = ABS( Sigsm) + ABS( Sigsb) =ABS(48.71)+ABS(0)=        48.71 N/mm2
```

Total Axial Shell Stress Sigs=48.71 <= 1.5 * Ss=207[N/mm2]	23.5%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

LOAD CASE:=LC3==LC3=

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.3141/0.4479*(2*61.5/(26-0))^2*1.82=                42.84 N/mm2
```

Tubesheet Bending Stress Sigma=42.84 <= 1.5 * S=251.28[N/mm2]	17.0%	OK

UHX-14.5.8 Step 8, Shear Stress in Tubesheet (Tau)

Tubesheet Shear Stress Tau=0 <= MIN(0.8*S, 0.533*Sy)=134.02[N/mm2]	0.0%	OK

UHX-14.5.9 Step 9, Tube Design

Axial Tube Stress (Pe <> 0)

```
SigtMax = MAX( Sigt1 , Sigt2) =MAX(-3.67,-12.57)=          12.57 N/mm2
```

Tube Axial Stress SigtMax=12.57 <= St=115[N/mm2]	10.9%	OK
Tube Weld Max.Axial Load Wt=138.24 <= Lmax=1264.49[N] (UW-20)	10.9%	OK

Tube Buckling Stress SigtMin=12.57 <= Stb=72.41[N/mm2]	17.3%	OK

```
Total Axial Stress Sigs
Sigs = ABS( Sigsm) + ABS( Sigsb) =ABS(48.71)+ABS(0)=          48.71 N/mm2
```

Total Axial Shell Stress Sigs=48.71 <= 1.5 * Ss=207[N/mm2]	23.5%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

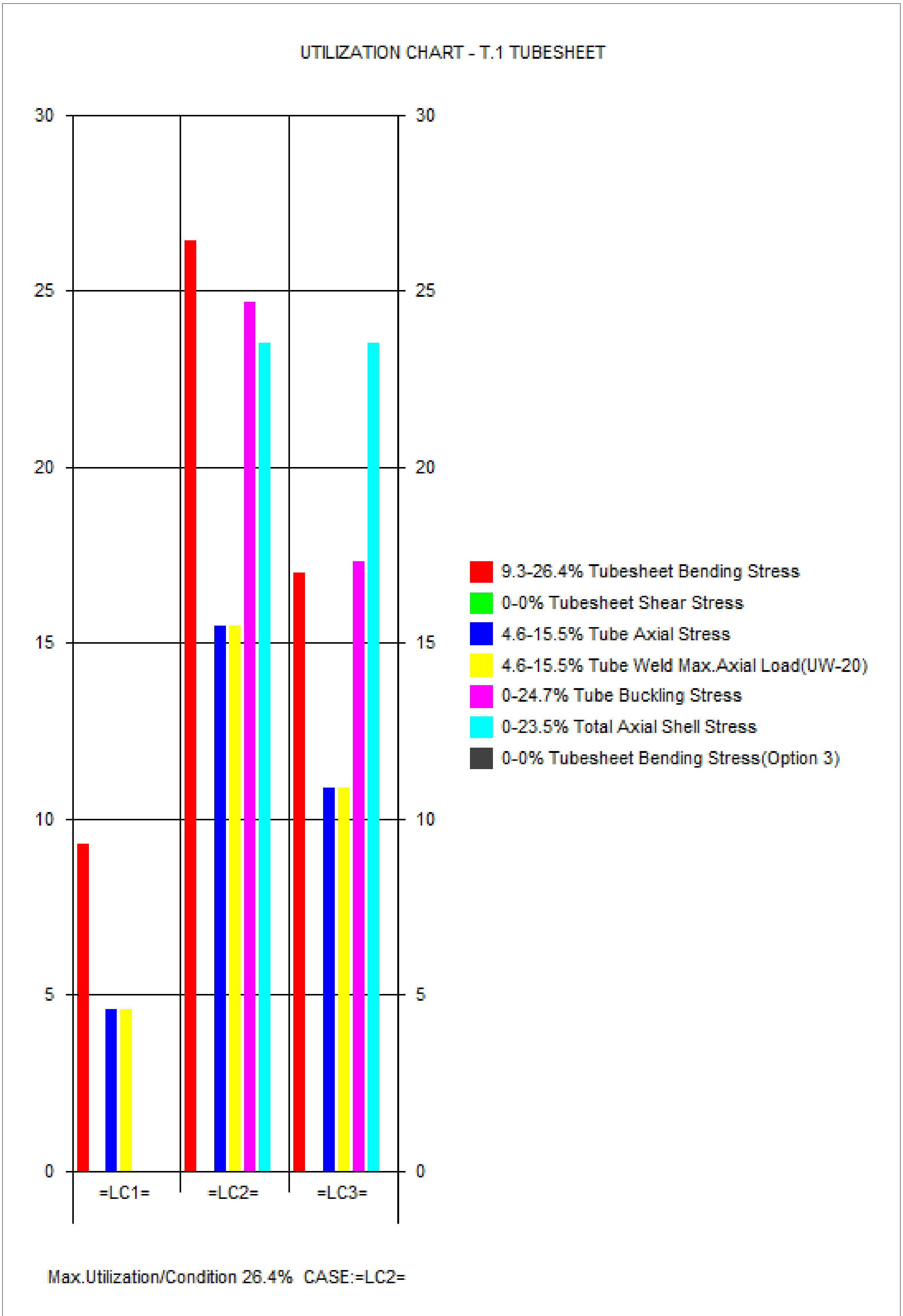
MAXIMUM ALLOWABLE PRESSURE SUMMARY

Table MAWP SUMMARY FOR T.1 :

Description	P(MPa)	LimitedBy
Max.Allow.Test Pressure (tubeside)	17.66	Tubesheet Bending Stress
Max.Allow.Test Pressure(shellside)	14.35	Tube Buckling Stress
Max.Allow.Pressure Hot&Corroded(tubeside)	10.68	Tubesheet Bending Stress
Max.Allow.Pressure Hot&Corroded(shellside)	10.68	Tubesheet Bending Stress
Max.Allow.Pressure New&Cold(tubeside)	12.10	Tubesheet Bending Stress
Max.Allow.Pressure New&Cold(shellside)	12.11	Tubesheet Bending Stress

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 210 FOR: 9 SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.
WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 210 FOR: 5 SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.
WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 5 SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.

Volume:0.00 m3 Weight:3 kg (SG= 7.85)

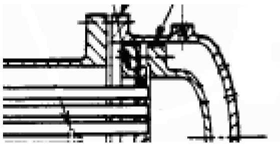

UTILIZATION CHART - T.1 TUBESHEET
30
25
20
15
10
5
0
=LC1=
=LC2=
=LC3=
9.3-26.4% Tubesheet Bending Stress
0-0% Tubesheet Shear Stress
4.6-15.5% Tube Axial Stress
4.6-15.5% Tube Weld Max.Axial Load(UW-20)
0-24.7% Tube Buckling Stress
0-23.5% Total Axial Shell Stress
0-0% Tubesheet Bending Stress(Option 3)
Max.Utilization/Condition 26.4% CASE:=LC2=

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

```
Attachment: TB.1    Tube Bundle        Tube bundle                    T.1
Location: Along z-axis z1=  496
```

GENERAL DESIGN DATA



```
Type of Heat Exchanger: UHX-14 Floating Tubesheet Heat Exchangers
Type of Tubesheet: Floating Tubesheet
Type of Floating Tubesheet Exchanger: With Immersed Floating Head
Configuration Type: D Tubesheet Internally Sealed
```

LOAD CASES (LC)

Table LOAD CASES:

Description	ID	=LC1=	=LC2=	=LC3=
Shell-Side Pressure (MPa)	Ps	0	2.82	2.82
Tube-Side Pressure (MPa)	Pt	1	0	1
Shell-Side Corr.Allow. (mm)	cs	1	1	1
Tube-Side Corr.Allow. (mm)	ct	1	1	1

```
=LC1=: =LC1=
=LC2=: =LC2=
=LC3=: =LC3=
```

ALLOWBALE STRESS FOR EACH LOAD CASE

```
Material Design Temperatures:
Select material design temperatures from the process card.
Ttubesheet= 210, Tshell= 210, Ttube= 210, Tchannel= 95(all values in °C)
```

Table LOAD CASES:

Description	ID	=LC1=	=LC2=	=LC3=
Allowable Stress M Factor	Mf	1.0	1.0	1.0

DATA FOR TUBESHEET

```
SB-148(M), M01, C95820 Castings 204'C
ST=650 SY=270 Sy=259.84 S=167.52 Sr=179 Stest=243  (N/mm2)
OUTSIDE DIAMETER OF TUBESHEET(Ref. UHX-10(b))........:A        132.20 mm
NOMINAL THICKNESS OF TUBESHEET (uncorroded).........:hn         28.00 mm
ELASTIC MODULUS OF TUBESHEET at tubesheet design temp.:E    1,894E05 N/mm2
POISSON'S RATIO FOR TUBESHEET MATERIAL..............:v         0.3000
```

DATA FOR TUBES AND TUBES LAYOUT

```
Tube Layout: Triangular Pattern
SA-213(M) Gr.TP316L, S31603 Smls. tube, PNo=8 120'C
ST=485 SY=170 Syt=138.6 St=115 Sr=115 Stest=153  (N/mm2)
ELASTIC MODULUS OF TUBES at tube design temp........:Et     1,8621E05 N/mm2
NOMINAL OUTSIDE DIAMETER OF TUBES...................:dt        7.5000 mm
TUBE SIZE & COMMENT: S1.2
NOMINAL THICKNESS OF TUBES..........................:tt        0.5000 mm
TUBE PITCH (Spacing between centers)................:p          11.50 mm
DIAMETER OF TUBEHOLE IN TUBESHEET...................:dh        8.0000 mm
DIAMETER OF OUTER TUBE LIMIT CIRCLE.................:Do        123.00 mm
```

```
NUMBER OF TUBEHOLES IN TUBESHEET....................:Nt        72.00 piec
TOTAL AREA OF UNTUBED LANES(UL1*Ll1+UL2*Ll2+..).....:AL      1600.00 mm2
TUBE EXPANSION DEPTH RATIO (0<=ro<=1.0).............:ro       1.0000
TUBE-SIDE PASS PARTITION GROOVE DEPTH(Fig.UHX-11.1).:hg       1.0000 mm
THERMAL EXPANSION COEF.OF TUBES at mean metal temp..:atm   1,614E-05 mm/mmC
TUBE BUCKLING LENGTH lt=l*k (Ref. UHX-13.5.9(b)(1)).:lt       1.0000 mm
TUBE LENGTH BETWEEN INNER FACES OF TUBESHEETS.......:L        800.00 mm
POISSON'S RATIO FOR TUBE MATERIAL...................:vt       0.3000
PERIMETER OF THE TUBE LAYOUT MEASURED CENTER ON OUTER MOST TUBES:Cp     0.00 mm
TOTAL AREA ENCLOSED BY Cp...........................:Ap         0.00 mm2
```

DATA FOR TUBE TO TUBESHEET JOINT

```
Tube to Tubesheet Weld: Full Strength Weld to UW-20.4
Qualification of Tube-to-Tubesheet Joint: The Joint IS Qualified by Tests
FIG. UW-20.1 Weld Types: Sketch a) Fillet Weld
TUBE TO TUBESHEET FILLET WELD LEG...................:af       1.0000 mm
```

SHELL DATA

```
SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 120'C
ST=515 SY=205 Sys=169.6 Ss=138 Sr=138 Stest=184.5  (N/mm2)
INSIDE DIAMETER OF SHELL(corroded)..................:Ds       133.30 mm
THICKNESS OF SHELL (uncorroded).....................:ts       3.2000 mm
ELASTIC MODULUS OF SHELL MATERIAL at shell design temp:Es   1,8621E05 N/mm2
POISSON'S RATIO FOR SHELL MATERIAL..................:vs       0.3000
```

CHANNEL DATA

```
SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8 100'C
ST=485 SY=170 Syc=145 Sc=115 Sr=115 Stest=153  (N/mm2)
INSIDE DIAMETER OF CHANNEL(corroded)................:Dc       133.30 mm
THICKNESS OF CHANNEL (uncorroded)...................:tc       3.2000 mm
ELASTIC MODULUS OF CHANNEL at channel design temp...:Ec    1,8833E05 N/mm2
POISSON'S RATIO FOR CHANNEL MATERIAL................:vc       0.3000
```

FLANGE DATA

```
DIAMETER OF SHELL GASKET LOAD REACTION..............:Gs       152.00 mm
SHELL FLANGE DESIGN BOLT LOAD FOR ASSEMBLY COND.....:Ws        53.00 kN
SHELL FLANGE DESIGN BOLT LOAD FOR OPERATING COND....:Wm1s      53.00 kN
DIAMETER OF CHANNEL GASKET LOAD REACTION............:Gc       152.00 mm
CHANNEL FLANGE DESIGN BOLT LOAD FOR ASSEMBLY COND...:Wc        53.00 kN
CHANNEL FLANGE DESIGN BOLT LOAD FOR OPERATING COND..:Wm1c      53.00 kN
BOLT-CIRCLE DIAMETER................................:C        152.00 mm
```

CALCULATION DATA

LOAD CASE:=LC1==LC1=

PRELIMINARY CALCULATIONS

UW-20 TUBE-TO-TUBESHEET WELDS

```
Allowable Stress in Weld
Sw = MIN( S , St) =MIN(167.52,115)=                      115.00 N/mm2
Weld Strength Factor
fw = St / Sw =115/115=                                   1.0000
Axial Tube Strength
Ft = PI * tt * (dt - tt) * St =3.14*0.5*(7.5-0.5)*115=  1264.49 N

Minimum Required Length of the Weld Leg
ar = Sqr((0.75*dt)^2+2.73*tt*(dt-tt)*fw*fd)-0.75*dt
=Sqr((0.75*7.5)^2+2.73*0.5*(7.5-0.5)*1*1)-0.75*7.5=    0.7934 mm
Minimum Required Size of Fillet Weld Leg
afmin = MAX( ar, tt) =MAX(0.7934,0.5)=                   0.7934 mm

Fillet Weld Strength
Ff = MIN( 0.55 * PI * af * (dt + 0.67 * af) * Sw , Ft)
=MIN(0.55*3.14*1*(7.5+0.67*1)*115,1264.49)=           1264.49 N
```

TABLE UHX-8.1 TUBESHEET EFFECTIVE BOLT LOAD W*=0=   0.00kN

```
Tubesheet Analysis Thickness h
h = hn - ct - cs =28-1-1=                                     26.00 mm
```

UHX-11.5.1 Determination of Effective Dimensions and Ligament Efficiency

```
Basic efficiency for shear
my = (p - dt) / p =(11.5-7.5)/11.5=                         0.3478
Effective Tube Hole Diameter (dstar)
dstar = MAX(dt-2*tt*(Et/E)*(St/S)*ro,dt-2*tt)
=MAX(7.5-2*0.5*(186212/189400)*(115/167.52)*1,7.5-2*0.5)=   6.8251 mm
Effective Pitch(pstar)
pstar = p/Sqr(1-4*MIN(AL,4*Do*p)/(PI*Do^2))
=11.5/Sqr(1-4*MIN(1600,4*123*11.5)/(3.14*123^2))=          12.36 mm
Mystar = (pstar - dstar) / pstar =(12.36-6.83)/12.36=       0.4479
```

UHX-11.5.2 Determination of Effective Elastic Properties Estar and vstar

```
EstarOverE(Estar/E) from figure UHX-11.3a) =  0.4763(h/p=2.26)
Estar = EstarOverE * E =0.4763*189400=                    90213.95 N/mm2
vstar from figure UHX-11.3b) =  0.3032(h/p=2.26)
```

UHX-14.5.1 Step 1

```
Radial Channel Dimension ac
ac = A / 2 =132.2/2=                                          66.10 mm
Radial Shell Dimension as
as = ac =66.1=                                                66.10 mm
Parameters
ao = Do / 2 =123/2=                                           61.50 mm
Diameter Ratio ros for Shell
ros = as / ao =66.1/61.5=                                   1.0748
Diameter Ratio roc for Channel
roc = ac / ao =66.1/61.5=                                   1.0748
Tubesheet Drilling Coefficients
xs = 1 - Nt * (dt / (2 * ao)) ^ 2
=1-72*(7.5/(2*61.5))^2=                                   0.7323
xt = 1 - Nt * ((dt - 2 * tt) / (2 * ao)) ^ 2
=1-72*((7.5-2*0.5)/(2*61.5))^2=                           0.7989
```

UHX-14.5.2 Step 2, Shell and Tube Axial Stiffness

UHX-14.5.3 Step 3, Tube Bundle to Tubesheet Rigidity Ratio

```
Xa = (24*(1-vstar^2)*Nt*Et*tt*(dt-tt)*ao^2/(Estar*L*h^3))^0.25
=(24*(1-0.3032^2)*72*186212*0.5*(7.5-0.5)*61.5^2/(90213.95*800*26^3))^0.25
=   1.3214
Zd (from figure UHX-13.2) =  0.7123
Zv (from figure UHX-13.2) =  0.1859
Zw (from figure UHX-13.2) =  0.1859
Zm (from figure UHX-13.2) =  0.7493
```

UHX-14.5.4 Step 4, Ratio K and Parameters F, Phi, Q and U

```
Diameter Ratio K
K = A / Do =132.2/123=                                      1.0748
F = (1 - vstar) / Estar * (LamdaS + LamdaC + E * Log( K))
=(1-0.3032)/90213.95*(0+0+189400*Log(1.07))=              0.1055
phi = (1 + vstar) * F =(1+0.3032)*0.1055=                   0.1375
Q1 = (ros - 1 - phi * Zv) / (1 + phi * Zm)
=(1.07-1-0.1375*0.1859)/(1+0.1375*0.7493)=                0.0446
```

UHX-14.5.5 Step 5

```
Omegas = ros * ks * Betas * Deltas * (1 + h * Betas)
=1.07*0*0*0*(1+26*0)=                                       0.00 mm2
Omegasstar = ao ^ 2 * (ros ^ 2 - 1) * (ros - 1) / 4 - Omegas
=61.5^2*(1.07^2-1)*(1.07-1)/4-0=                           10.98 mm2
Omegac = roc * kc * Betac * Deltac * (1 + h * Betac)
=1.07*0*0*0*(1+26*0)=                                       0.00 mm2
```

```
Omegacstar = ao^2*((roc^2+1)*(roc-1)/4-(ros-1)/2)-Omegac
=61.5^2*((1.07^2+1)*(1.07-1)/4-(1.07-1)/2)-0=            10.98 mm2
Zm (from figure UHX-13.2) =  0.7493 =0.7493=              0.00 mm
Psstar = 0 =0=                                              0.00 MPa
Pcstar = 0 =0=                                              0.00 MPa
```

UHX-14.5.6 Step 6

```
Effective Pressure Pe
Pe = Ps - Pt =0-1=                                        -1 MPa
```

UHX-14.5.7 Step 7

```
Q2 = (Omegasstar*Ps-Omegacstar*Pt+yb/(2*PI)*Wstar)/(1+phi*Zm)
=(10.98*0-10.98*1+0/(2*3.14)*0)/(1+0.1375*0.7493)=       -9.95 N
Q3 = Q1 + 2 * Q2 / (Pe * ao ^ 2)
=0.0446+2*-9.95/(-1*61.5^2)=                             0.0499
Fm = MAX(Fm(x)) (from Table UHX-13.1) =  0.2209
```

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.2209/0.4479*(2*61.5/(26-0))^2*-1=                 -16.55 N/mm2
```

Tubesheet Bending Stress Sigma=16.55 <= 1.5 * S=251.28[N/mm2]	6.5%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

LOAD CASE:=LC2==LC2=

PRELIMINARY CALCULATIONS

UW-20 TUBE-TO-TUBESHEET WELDS

```
Allowable Stress in Weld
Sw = MIN( S , St) =MIN(167.52,115)=                       115.00 N/mm2
Weld Strength Factor
fw = St / Sw =115/115=                                    1.0000
Axial Tube Strength
Ft = PI * tt * (dt - tt) * St =3.14*0.5*(7.5-0.5)*115=   1264.49 N

Minimum Required Length of the Weld Leg
ar = Sqr((0.75*dt)^2+2.73*tt*(dt-tt)*fw*fd)-0.75*dt
=Sqr((0.75*7.5)^2+2.73*0.5*(7.5-0.5)*1*1)-0.75*7.5=      0.7934 mm
Minimum Required Size of Fillet Weld Leg
afmin = MAX( ar, tt) =MAX(0.7934,0.5)=                    0.7934 mm

Fillet Weld Strength
Ff = MIN( 0.55 * PI * af * (dt + 0.67 * af) * Sw , Ft)
=MIN(0.55*3.14*1*(7.5+0.67*1)*115,1264.49)=             1264.49 N
```

TABLE UHX-8.1 TUBESHEET EFFECTIVE BOLT LOAD W*=0= 0.00kN

```
Tubesheet Analysis Thickness h
h = hn - ct - cs =28-1-1=                                  26.00 mm
```

UHX-11.5.1 Determination of Effective Dimensions and Ligament Efficiency

```
Basic efficiency for shear
my = (p - dt) / p =(11.5-7.5)/11.5=                       0.3478
Effective Tube Hole Diameter (dstar)
dstar = MAX(dt-2*tt*(Et/E)*(St/S)*ro,dt-2*tt)
=MAX(7.5-2*0.5*(186212/189400)*(115/167.52)*1,7.5-2*0.5)=   6.8251 mm
Effective Pitch(pstar)
pstar = p/Sqr(1-4*MIN(AL,4*Do*p)/(PI*Do^2))
```

```
=11.5/Sqr(1-4*MIN(1600,4*123*11.5)/(3.14*123^2))=          12.36 mm
Mystar = (pstar - dstar) / pstar =(12.36-6.83)/12.36=       0.4479
```

UHX-11.5.2 Determination of Effective Elastic Properties Estar and vstar

```
EstarOverE(Estar/E) from figure UHX-11.3a) =  0.4763(h/p=2.26)
Estar = EstarOverE * E =0.4763*189400=                    90213.95 N/mm2
vstar from figure UHX-11.3b) =  0.3032(h/p=2.26)
```

UHX-14.5.1 Step 1

```
Radial Channel Dimension ac
ac = A / 2 =132.2/2=                                         66.10 mm
Radial Shell Dimension as
as = ac =66.1=                                               66.10 mm
Parameters
ao = Do / 2 =123/2=                                          61.50 mm
Diameter Ratio ros for Shell
ros = as / ao =66.1/61.5=                                   1.0748
Diameter Ratio roc for Channel
roc = ac / ao =66.1/61.5=                                   1.0748
Tubesheet Drilling Coefficients
xs = 1 - Nt * (dt / (2 * ao)) ^ 2
=1-72*(7.5/(2*61.5))^2=                                   0.7323
xt = 1 - Nt * ((dt - 2 * tt) / (2 * ao)) ^ 2
=1-72*((7.5-2*0.5)/(2*61.5))^2=                           0.7989
```

UHX-14.5.2 Step 2, Shell and Tube Axial Stiffness

UHX-14.5.3 Step 3, Tube Bundle to Tubesheet Rigidity Ratio

```
Xa = (24*(1-vstar^2)*Nt*Et*tt*(dt-tt)*ao^2/(Estar*L*h^3))^0.25
=(24*(1-0.3032^2)*72*186212*0.5*(7.5-0.5)*61.5^2/(90213.95*800*26^3))^0.25
=   1.3214
Zd (from figure UHX-13.2) =  0.7123
Zv (from figure UHX-13.2) =  0.1859
Zw (from figure UHX-13.2) =  0.1859
Zm (from figure UHX-13.2) =  0.7493
```

UHX-14.5.4 Step 4, Ratio K and Parameters F, Phi, Q and U

```
Diameter Ratio K
K = A / Do =132.2/123=                                      1.0748
F = (1 - vstar) / Estar * (LamdaS + LamdaC + E * Log( K))
=(1-0.3032)/90213.95*(0+0+189400*Log(1.07))=              0.1055
phi = (1 + vstar) * F =(1+0.3032)*0.1055=                   0.1375
Q1 = (ros - 1 - phi * Zv) / (1 + phi * Zm)
=(1.07-1-0.1375*0.1859)/(1+0.1375*0.7493)=                0.0446
```

UHX-14.5.5 Step 5

```
Omegas = ros * ks * Betas * Deltas * (1 + h * Betas)
=1.07*0*0*0*(1+26*0)=                                       0.00 mm2
Omegasstar = ao ^ 2 * (ros ^ 2 - 1) * (ros - 1) / 4 - Omegas
=61.5^2*(1.07^2-1)*(1.07-1)/4-0=                           10.98 mm2
Omegac = roc * kc * Betac * Deltac * (1 + h * Betac)
=1.07*0*0*0*(1+26*0)=                                       0.00 mm2
Omegacstar = ao^2*((roc^2+1)*(roc-1)/4-(ros-1)/2)-Omegac
=61.5^2*((1.07^2+1)*(1.07-1)/4-(1.07-1)/2)-0=              10.98 mm2
Zm (from figure UHX-13.2) =  0.7493 =0.7493=                0.00 mm
Psstar = 0 =0=                                                0.00 MPa
Pcstar = 0 =0=                                                0.00 MPa
```

UHX-14.5.6 Step 6

```
Effective Pressure Pe
Pe = Ps - Pt =2.82-0=                                       2.8200 MPa
```

UHX-14.5.7 Step 7

```
Q2 = (Omegasstar*Ps-Omegacstar*Pt+yb/(2*PI)*Wstar)/(1+phi*Zm)
=(10.98*2.82-10.98*0+0/(2*3.14)*0)/(1+0.1375*0.7493)=       28.06 N
Q3 = Q1 + 2 * Q2 / (Pe * ao ^ 2)
=0.0446+2*28.06/(2.82*61.5^2)=                             0.0499
Fm = MAX(Fm(x)) (from Table UHX-13.1) =  0.2209
```

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.2209/0.4479*(2*61.5/(26-0))^2*2.82=                  46.68 N/mm2
```

Tubesheet Bending Stress Sigma=46.68 <= 1.5 * S=251.28[N/mm2]	18.5%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

LOAD CASE:=LC3==LC3=

PRELIMINARY CALCULATIONS

UW-20 TUBE-TO-TUBESHEET WELDS

```
Allowable Stress in Weld
Sw = MIN( S , St) =MIN(167.52,115)=                          115.00 N/mm2
Weld Strength Factor
fw = St / Sw =115/115=                                       1.0000
Axial Tube Strength
Ft = PI * tt * (dt - tt) * St =3.14*0.5*(7.5-0.5)*115=      1264.49 N

Minimum Required Length of the Weld Leg
ar = Sqr((0.75*dt)^2+2.73*tt*(dt-tt)*fw*fd)-0.75*dt
=Sqr((0.75*7.5)^2+2.73*0.5*(7.5-0.5)*1*1)-0.75*7.5=        0.7934 mm
Minimum Required Size of Fillet Weld Leg
afmin = MAX( ar, tt) =MAX(0.7934,0.5)=                       0.7934 mm

Fillet Weld Strength
Ff = MIN( 0.55 * PI * af * (dt + 0.67 * af) * Sw , Ft)
=MIN(0.55*3.14*1*(7.5+0.67*1)*115,1264.49)=                1264.49 N
```

TABLE UHX-8.1 TUBESHEET EFFECTIVE BOLT LOAD W*=0= 0.00kN

```
Tubesheet Analysis Thickness h
h = hn - ct - cs =28-1-1=                                     26.00 mm
```

UHX-11.5.1 Determination of Effective Dimensions and Ligament Efficiency

```
Basic efficiency for shear
my = (p - dt) / p =(11.5-7.5)/11.5=                          0.3478
Effective Tube Hole Diameter (dstar)
dstar = MAX(dt-2*tt*(Et/E)*(St/S)*ro,dt-2*tt)
=MAX(7.5-2*0.5*(186212/189400)*(115/167.52)*1,7.5-2*0.5)=   6.8251 mm
Effective Pitch(pstar)
pstar = p/Sqr(1-4*MIN(AL,4*Do*p)/(PI*Do^2))
=11.5/Sqr(1-4*MIN(1600,4*123*11.5)/(3.14*123^2))=           12.36 mm
Mystar = (pstar - dstar) / pstar =(12.36-6.83)/12.36=       0.4479
```

UHX-11.5.2 Determination of Effective Elastic Properties Estar and vstar

```
EstarOverE(Estar/E) from figure UHX-11.3a) =  0.4763(h/p=2.26)
Estar = EstarOverE * E =0.4763*189400=                     90213.95 N/mm2
vstar from figure UHX-11.3b) =  0.3032(h/p=2.26)
```

UHX-14.5.1 Step 1

```
Radial Channel Dimension ac
ac = A / 2 =132.2/2=                                          66.10 mm
Radial Shell Dimension as
as = ac =66.1=                                                66.10 mm
Parameters
ao = Do / 2 =123/2=                                           61.50 mm
Diameter Ratio ros for Shell
ros = as / ao =66.1/61.5=                                    1.0748
Diameter Ratio roc for Channel
roc = ac / ao =66.1/61.5=                                    1.0748
Tubesheet Drilling Coefficients
xs = 1 - Nt * (dt / (2 * ao)) ^ 2
=1-72*(7.5/(2*61.5))^2=                                    0.7323
xt = 1 - Nt * ((dt - 2 * tt) / (2 * ao)) ^ 2
=1-72*((7.5-2*0.5)/(2*61.5))^2=                            0.7989
```

UHX-14.5.2 Step 2, Shell and Tube Axial Stiffness

UHX-14.5.3 Step 3, Tube Bundle to Tubesheet Rigidity Ratio

```
Xa = (24*(1-vstar^2)*Nt*Et*tt*(dt-tt)*ao^2/(Estar*L*h^3))^0.25
=(24*(1-0.3032^2)*72*186212*0.5*(7.5-0.5)*61.5^2/(90213.95*800*26^3))^0.25
=   1.3214
Zd (from figure UHX-13.2) =  0.7123
Zv (from figure UHX-13.2) =  0.1859
Zw (from figure UHX-13.2) =  0.1859
Zm (from figure UHX-13.2) =  0.7493
```

UHX-14.5.4 Step 4, Ratio K and Parameters F, Phi, Q and U

```
Diameter Ratio K
K = A / Do =132.2/123=                                       1.0748
F = (1 - vstar) / Estar * (LamdaS + LamdaC + E * Log( K))
=(1-0.3032)/90213.95*(0+0+189400*Log(1.07))=               0.1055
phi = (1 + vstar) * F =(1+0.3032)*0.1055=                    0.1375
Q1 = (ros - 1 - phi * Zv) / (1 + phi * Zm)
=(1.07-1-0.1375*0.1859)/(1+0.1375*0.7493)=                 0.0446
```

UHX-14.5.5 Step 5

```
Omegas = ros * ks * Betas * Deltas * (1 + h * Betas)
=1.07*0*0*0*(1+26*0)=                                        0.00 mm2
Omegasstar = ao ^ 2 * (ros ^ 2 - 1) * (ros - 1) / 4 - Omegas
=61.5^2*(1.07^2-1)*(1.07-1)/4-0=                            10.98 mm2
Omegac = roc * kc * Betac * Deltac * (1 + h * Betac)
=1.07*0*0*0*(1+26*0)=                                        0.00 mm2
Omegacstar = ao^2*((roc^2+1)*(roc-1)/4-(ros-1)/2)-Omegac
=61.5^2*((1.07^2+1)*(1.07-1)/4-(1.07-1)/2)-0=               10.98 mm2
Zm (from figure UHX-13.2) =  0.7493 =0.7493=                 0.00 mm
Psstar = 0 =0=                                                 0.00 MPa
Pcstar = 0 =0=                                                 0.00 MPa
```

UHX-14.5.6 Step 6

```
Effective Pressure Pe
Pe = Ps - Pt =2.82-1=                                        1.8200 MPa
```

UHX-14.5.7 Step 7

```
Q2 = (Omegasstar*Ps-Omegacstar*Pt+yb/(2*PI)*Wstar)/(1+phi*Zm)
=(10.98*2.82-10.98*1+0/(2*3.14)*0)/(1+0.1375*0.7493)=       18.11 N
Q3 = Q1 + 2 * Q2 / (Pe * ao ^ 2)
=0.0446+2*18.11/(1.82*61.5^2)=                             0.0499
Fm = MAX(Fm(x)) (from Table UHX-13.1) =  0.2209
```

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.2209/0.4479*(2*61.5/(26-0))^2*1.82=                30.13 N/mm2
```

Tubesheet Bending Stress Sigma=30.13 <= 1.5 * S=251.28[N/mm2]	11.9%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

MAXIMUM ALLOWABLE PRESSURE SUMMARY

Table MAWP SUMMARY FOR T.2 :

Description	P(MPa)	LimitedBy
Max.Allow.Test Pressure (tubeside)	25.13	Tubesheet Bending Stress
Max.Allow.Test Pressure(shellside)	25.13	Tubesheet Bending Stress
Max.Allow.Pressure Hot&Corroded(tubeside)	15.18	Tubesheet Bending Stress
Max.Allow.Pressure Hot&Corroded(shellside)	15.18	Tubesheet Bending Stress
Max.Allow.Pressure New&Cold(tubeside)	17.22	Tubesheet Bending Stress
Max.Allow.Pressure New&Cold(shellside)	17.23	Tubesheet Bending Stress

TEST PRESSURES

TEST PRESSURE ON TUBESIDE

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Pttmin = 1.1 * Ptd * Sr / S =1.1*1*179/167.52=            1.1754 MPa
```

TEST PRESSURE ON SHELLSIDE

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Ptsmin = 1.1 * Psd * Sr / S =1.1*2.82*179/167.52=         3.3146 MPa
```

CALCULATION SUMMARY

LOAD CASE:=LC1==LC1=

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.2209/0.4479*(2*61.5/(26-0))^2*-1=                 -16.55 N/mm2
```

Tubesheet Bending Stress Sigma=16.55 <= 1.5 * S=251.28[N/mm2]	6.5%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

LOAD CASE:=LC2==LC2=

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.2209/0.4479*(2*61.5/(26-0))^2*2.82=                46.68 N/mm2
```

Tubesheet Bending Stress Sigma=46.68 <= 1.5 * S=251.28[N/mm2]	18.5%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

LOAD CASE:=LC3==LC3=

UHX-14.5.7 Bending Stress in Tubesheet (Sigma)

```
Sigma = 1.5 * Fm / Mystar * (2 * ao / (h - hg)) ^ 2 * Pe
=1.5*0.2209/0.4479*(2*61.5/(26-0))^2*1.82=                 30.13 N/mm2
```

Tubesheet Bending Stress Sigma=30.13 <= 1.5 * S=251.28[N/mm2]	11.9%	OK
Tubesheet Bending Stress(Option 3) Sigma_O3=0 <= 1.5*S=251.28[N/mm2]	0.0%	OK

MAXIMUM ALLOWABLE PRESSURE SUMMARY

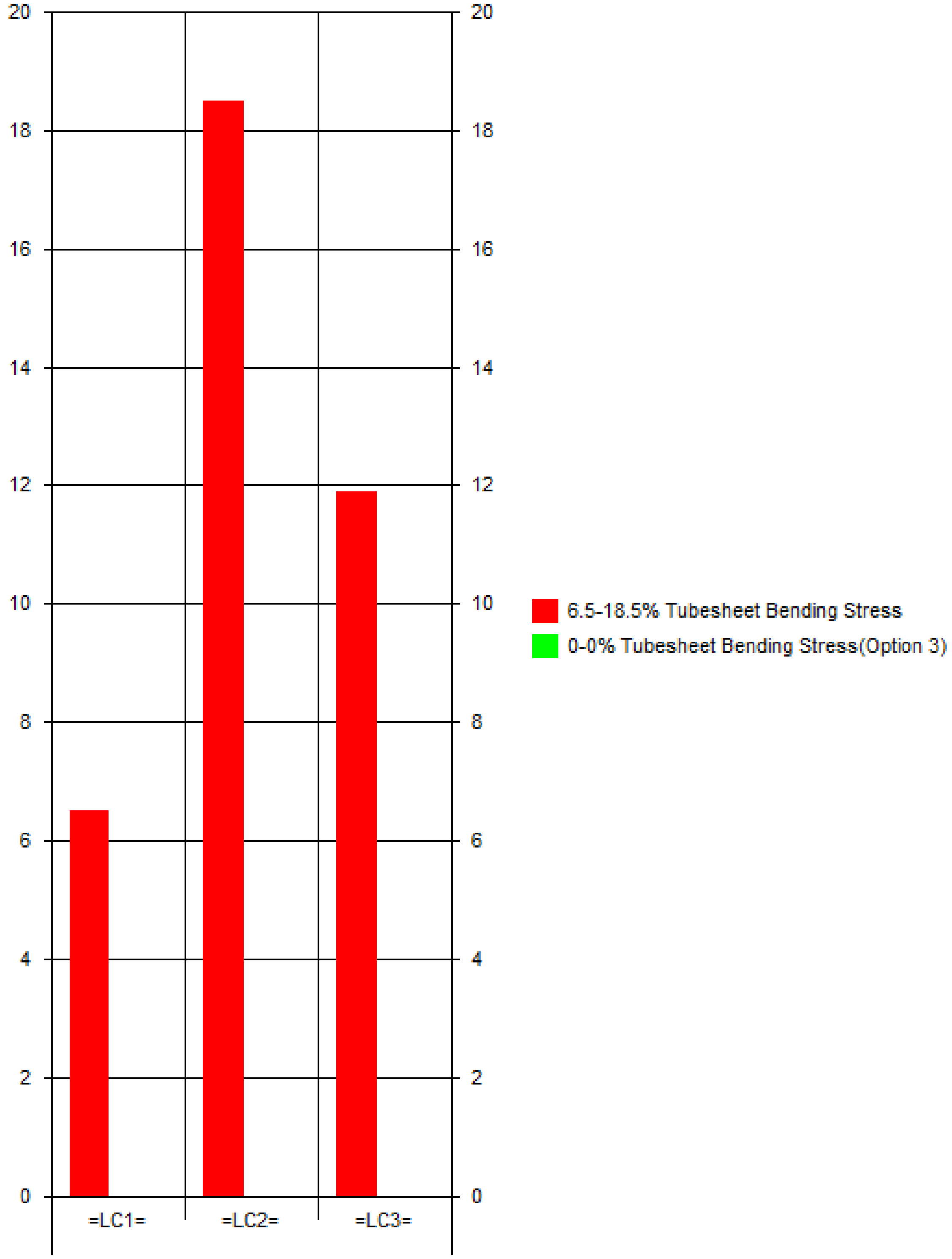
Table MAWP SUMMARY FOR T.2 :

Description	P(MPa)	LimitedBy
Max.Allow.Test Pressure (tubeside)	25.13	Tubesheet Bending Stress
Max.Allow.Test Pressure(shellside)	25.13	Tubesheet Bending Stress
Max.Allow.Pressure Hot&Corroded(tubeside)	15.18	Tubesheet Bending Stress
Max.Allow.Pressure Hot&Corroded(shellside)	15.18	Tubesheet Bending Stress
Max.Allow.Pressure New&Cold(tubeside)	17.22	Tubesheet Bending Stress
Max.Allow.Pressure New&Cold(shellside)	17.23	Tubesheet Bending Stress

WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 210 FOR: 1 SA-213(M) Gr.TP316L, S31603 Smls. tube, PNo=8 , the material must be re-selected from the material database.
WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 210 FOR: 5 SA-312(M) Gr.TP316, S31600 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.
WARNING: UNABLE TO UPDATE MATERIAL PROPERTIES AT TEMP= 95 FOR: 9 SA-312(M) Gr.TP316L, S31603 Smls. & wld. pipe, PNo=8 , the material must be re-selected from the material database.

Volume:0.00 m3 Weight:3 kg (SG= 7.85)

UTILIZATION CHART - T.2 TUBESHEET FLOATING



Max.Utilization/Condition 18.5% CASE:=LC2=

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

```
Attachment: T.1       Tubesheet        Tubesheet                   F.3
Location: Along z-axis zo= -54
```

GENERAL DESIGN DATA

```
DESIGN PRESSURE.....................................:P        1.0000 MPa
EXTERNAL DESIGN PRESSURE............................:Pext     0.1000 MPa
CORROSION ALLOWANCE FOR TUBES.......................:c          0.00 mm
```

TUBE BUNDLE DATA

```
U-TUBES - CHECK THINNING OF TUBES DUE TO BENDING: NO
SB-111(M), O61, C70600 Smls. cond. tube 210'C
ST=275 SY=100 SYd=89.38 S=68.9 Sr=68.9 Stest=90  (N/mm2)
NOMINAL THICKNESS OF TUBES..........................:tt       0.5000 mm
TUBE PITCH (Spacing between centers)................:p         11.50 mm
NOMINAL OUTSIDE DIAMETER OF TUBES...................:dt       7.5000 mm
DIAMETER OF OUTER TUBE LIMIT CIRCLE.................:Do       123.00 mm
NUMBER OF TUBEHOLES IN TUBESHEET....................:Nt        72.00 piec
TUBE LENGTH BETWEEN INNER FACES OF TUBESHEETS.......:L        550.00 mm
NOMINAL THICKNESS OF TUBESHEET (uncorroded).........:hn        28.00 mm
NEGATIVE DEVIATION/TOLERANCE........................:          12.50 %
```

DATA FOR BAFFLE PLATES

```
BAFFLE PLATES: Excluded
```

CALCULATION DATA

UG-27 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

```
Outside Radius of Tube
Ro = dt / 2 =7.5/2=                                      3.7500 mm
```

»Thin Cylinder Check P=1 <= 0.385 * S * E=26.53[MPa] « » OK«

```
Required Minimum Shell Thickness Excl.Allow. tmin :
tmin = P * Ro / (S * E + 0.4 * P)
=1*3.75/(68.9*1+0.4*1)=                                0.0541 mm
```

»Thin Cylinder Check tmin=0.0541 < 0.5 * R=1.875[mm] « » OK«

```
Required Minimum Tube Thickness Incl.Allow. :
tmina = (tmin + c + th) * (1 + thbend / 100)
=(0.0541+0+0.0625)*(1+0/100)=                          0.1166 mm

Analysis Thickness
ta = tn / (1 + thbend / 100) - c - th
=0.5/(1+0/100)-0-0.0625=                               0.4375 mm
```

Internal Pressure tmina=0.1166 <= tn=0.5[mm]	23.3%	OK

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :

```
Inside Diameter of Shell
Di = dt - 2 * ta =7.5-2*0.4375=                          6.6250 mm
Inside Radius of Shell
R = Di / 2 =6.625/2=                                     3.3125 mm
MAWP HOT & CORR. (Corroded condition at design temp.)
MAWPHC = S * E * ta / (R + 0.6 * ta)
=68.9*1*0.4375/(3.3125+0.6*0.4375)=                    8.4318 MPa

MAWP NEW & COLD (Uncorroded condition at ambient temp.)
MAWPNC = Sr * E * (ta + c) / (R + 0.6 * (ta + c))
=68.9*1*(0.4375+0)/(3.3125+0.6*(0.4375+0))=            8.4318 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)
Ptmax = SYtest * Etest * (ta + c) / (R + 0.6 * (ta + c))
=90*1*(0.4375+0)/(3.3125+0.6*(0.4375+0))=                 11.01 MPa
```

UG-100(b) REQUIRED MINIMUM PNEUMATIC TEST PRESSURE: NEW AT AMBIENT TEMP. Ptmin

```
Ptmin = 1.1 * Pd * Sr / S =1.1*1*68.9/68.9=                1.1000 MPa
```

Test Pressure Ptmin=1.1 <= Ptmax=11.01[MPa]	9.9%	OK

SECT. UG28 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

Preliminary Calculations

```
Ratio1 = dt / t =7.5/0.4375=                                 17.14
Ratio2 = L / dt =550/7.5=                                    73.33
Value of A from Fig.G (Part D), A =0.003979
Value of B from External Pressure Chart NFC-3(based on Temp=210)  B =32.05
Pmax = (4 / 3) * B / (dt / t)
=(4/3)*32.05/(7.5/0.4375)=                                 2.4925 MPa
```

External Pressure Pmax=2.49 >= Pext=0.1[MPa]	4.0%	OK

Max. External Test Pressure

```
Max. External Test Pressure (Uncorroded cond.at ambient temp.)
Ptemax(20) = ==                                             3.3165 MPa
```

CALCULATION SUMMARY

UG-27 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

```
Required Minimum Shell Thickness Excl.Allow. tmin :
tmin = P * Ro / (S * E + 0.4 * P)
=1*3.75/(68.9*1+0.4*1)=                                    0.0541 mm

Required Minimum Tube Thickness Incl.Allow. :
tmina = (tmin + c + th) * (1 + thbend / 100)
=(0.0541+0+0.0625)*(1+0/100)=                              0.1166 mm
```

Internal Pressure tmina=0.1166 <= tn=0.5[mm]	23.3%	OK

```
MAWP HOT & CORR. (Corroded condition at design temp.)
MAWPHC = S * E * ta / (R + 0.6 * ta)
=68.9*1*0.4375/(3.3125+0.6*0.4375)=                        8.4318 MPa

MAWP NEW & COLD (Uncorroded condition at ambient temp.)
MAWPNC = Sr * E * (ta + c) / (R + 0.6 * (ta + c))
=68.9*1*(0.4375+0)/(3.3125+0.6*(0.4375+0))=                8.4318 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)

```
MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)
Ptmax = SYtest * Etest * (ta + c) / (R + 0.6 * (ta + c))
=90*1*(0.4375+0)/(3.3125+0.6*(0.4375+0))=                 11.01 MPa
```

Test Pressure Ptmin=1.1 <= Ptmax=11.01[MPa]	9.9%	OK

SECT. UG28 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

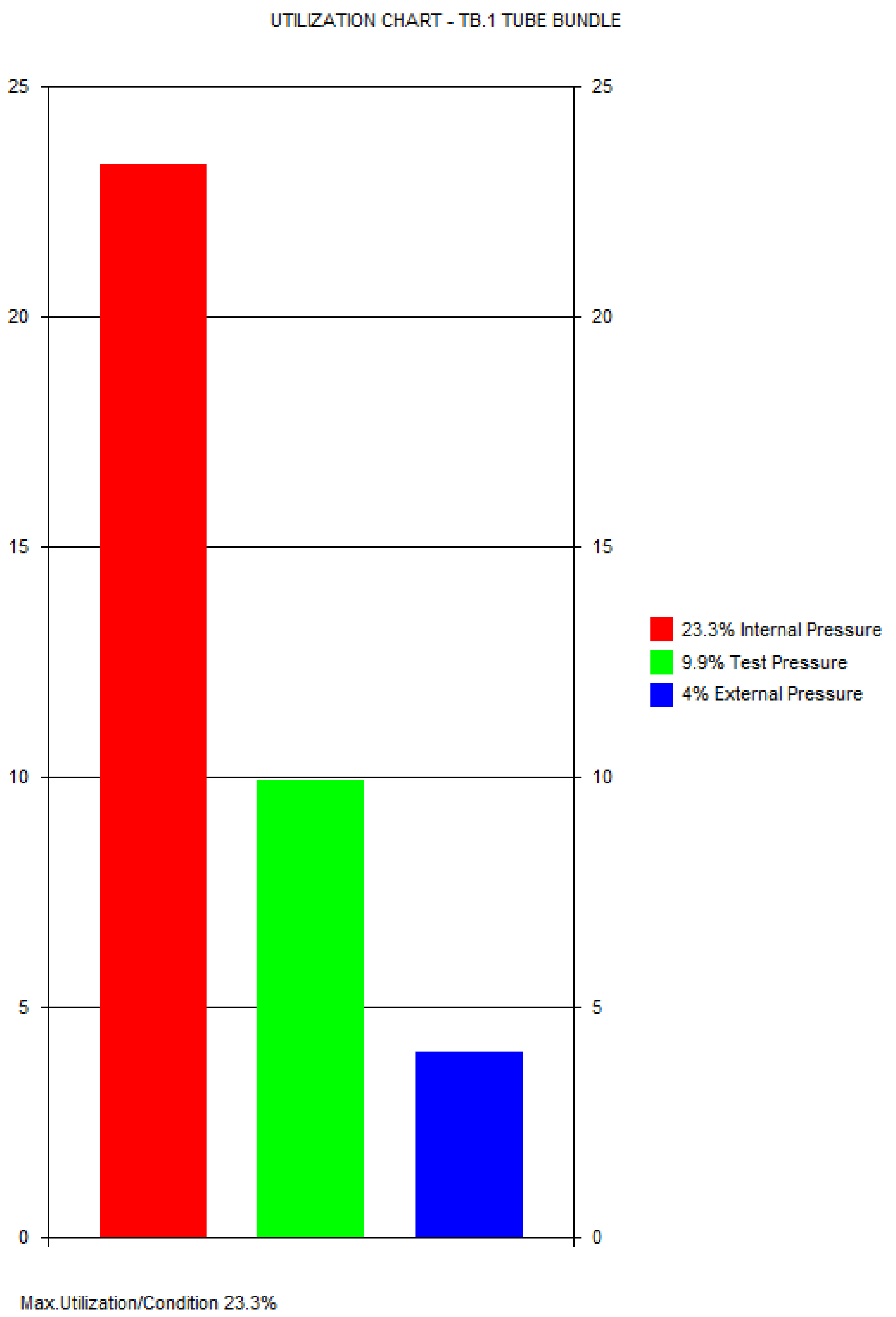
```
Pmax = (4 / 3) * B / (dt / t)
=(4/3)*32.05/(7.5/0.4375)=                                 2.4925 MPa
```

External Pressure Pmax=2.49 >= Pext=0.1[MPa]	4.0%	OK

Max. External Test Pressure

```
Max. External Test Pressure (Uncorroded cond.at ambient temp.)
Ptemax(20) = ==                                                3.3165 MPa
```

Volume:0.0014 m3 Weight:3.8 kg (SG= 7.85)


UTILIZATION CHART - TB.1 TUBE BUNDLE
25
20
15
10
5
0
23.3% Internal Pressure
9.9% Test Pressure
4% External Pressure
Max.Utilization/Condition 23.3%