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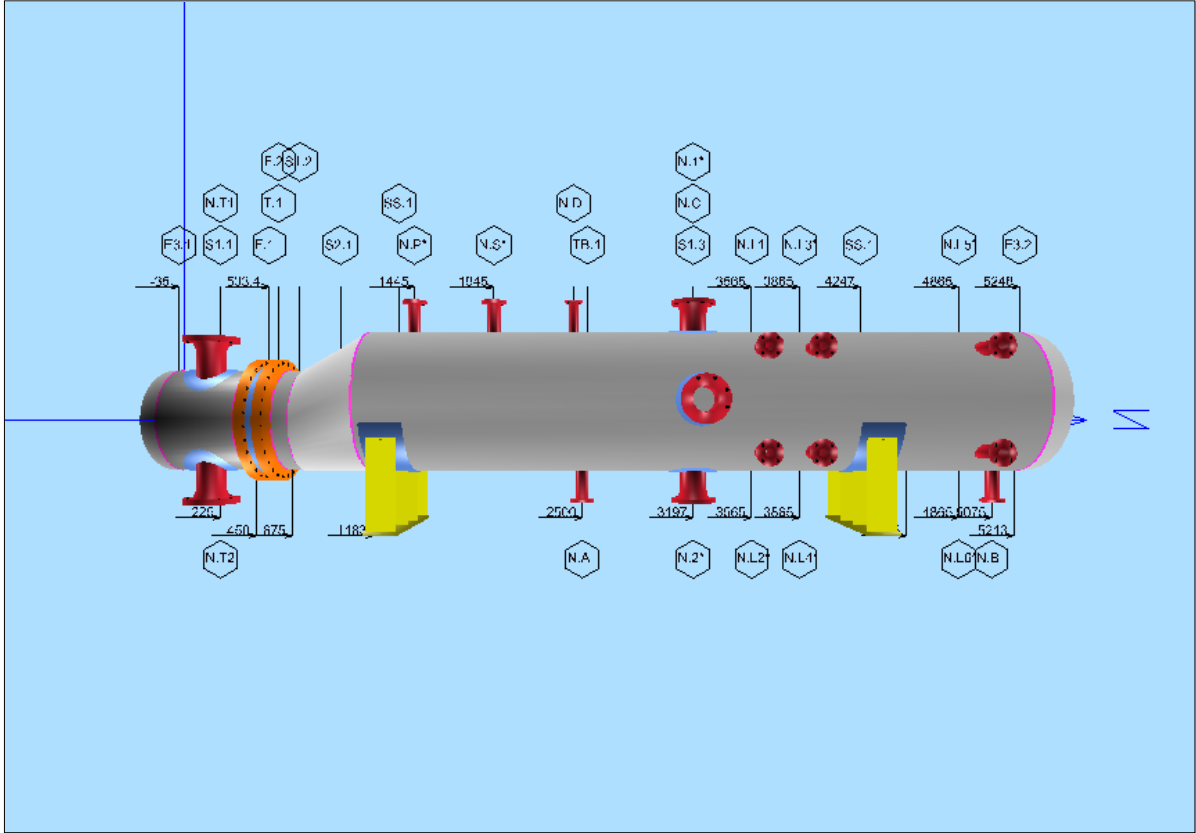
Sample File

Steam Generator

Visual Vessel Design by OhmTech Ver:10.2b Operator : Rev.:A

Drawing

3D View of Vessel (alter by using the Save User Specified View command)



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Design Data & Process Information

Description	Units	Design Data	Design Data
Process Card		Shell Side	Tube Side
Design Code & Specifications		EN13445:Issue32 TG = 3b	EN13445:Issue32 TG = 3b
Internal Design Pressure (MPa)	MPa	0.5	0.85
External Design Pressure (MPa)	MPa	0.1	0.1
Hydrotest Pressure (MPa)	MPa		
Maximum Design Temperature (°C)	°C	232	370
Minimum Design Temperature (°C)	°C	0	0
Operating Temperature (°C)	°C		
Corrosion Allowance (mm)	mm	3	3
Content of Vessel			
Specific Density of Oper.Liq			

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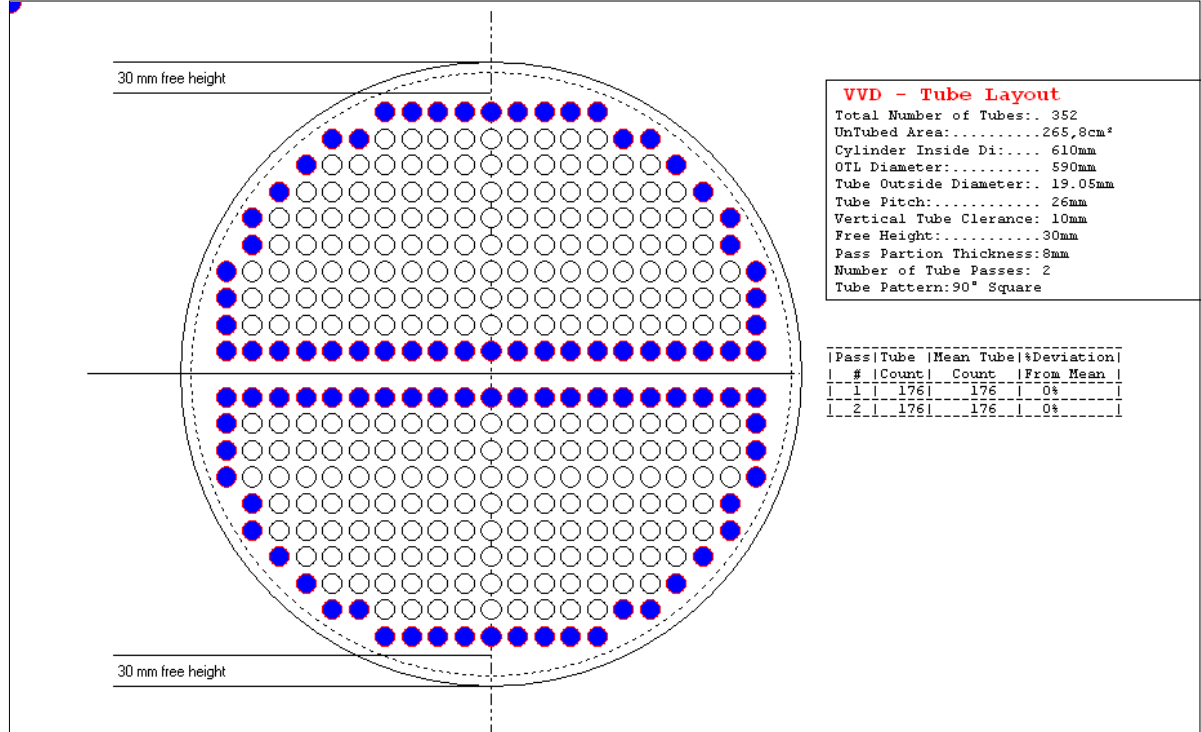
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Tube Layout

Tube Layout



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Weight & Volume of Vessel

PROCESS CARD NO.: 1 SHELL SIDE

ID	No.	Wt-UnFinish.	Wt-Finished	Tot. Volume	Test.Liq.Wt	Oper.Liq.Wt
TB.1	1	0.0 kg	0.0 kg	-0.355 m3	-355.0 kg	0.0 kg
F.2	1	59.0 kg	59.0 kg	0.025 m3	25.0 kg	0.0 kg
S1.2	1	16.0 kg	16.0 kg	0.029 m3	29.0 kg	0.0 kg
S2.1	1	90.0 kg	90.0 kg	0.171 m3	171.0 kg	0.0 kg
S1.3	1	1017.0 kg	1004.9 kg	2.265 m3	2265.0 kg	0.0 kg
E3.2	1	74.0 kg	74.0 kg	0.099 m3	99.0 kg	0.0 kg
N.A	1	7.0 kg	7.0 kg	0.000 m3	0.0 kg	0.0 kg
N.C	1	19.0 kg	19.0 kg	0.004 m3	4.0 kg	0.0 kg
N.B	1	7.0 kg	7.0 kg	0.000 m3	0.0 kg	0.0 kg
N.D	1	4.0 kg	4.0 kg	0.000 m3	0.0 kg	0.0 kg
N.P*	1	7.0 kg	7.0 kg	0.000 m3	0.0 kg	0.0 kg
N.S*	1	7.0 kg	7.0 kg	0.000 m3	0.0 kg	0.0 kg
N.L1	1	9.0 kg	9.0 kg	0.001 m3	1.0 kg	0.0 kg
N.L2*	1	9.0 kg	9.0 kg	0.001 m3	1.0 kg	0.0 kg
N.L3*	1	9.0 kg	9.0 kg	0.001 m3	1.0 kg	0.0 kg
N.L4*	1	9.0 kg	9.0 kg	0.001 m3	1.0 kg	0.0 kg
N.L5*	1	9.0 kg	9.0 kg	0.001 m3	1.0 kg	0.0 kg
N.L6*	1	9.0 kg	9.0 kg	0.001 m3	1.0 kg	0.0 kg
SS.1	2	260.0 kg	260.0 kg	0.000 m3	0.0 kg	0.0 kg
N.1*	1	19.0 kg	19.0 kg	0.004 m3	4.0 kg	0.0 kg
N.2*	1	19.0 kg	19.0 kg	0.004 m3	4.0 kg	0.0 kg
Total	22	1659.0 kg	1646.9 kg	2.252 m3	2252.0 kg	0.0 kg

PROCESS CARD NO.: 2 TUBE SIDE

ID	No.	Wt-UnFinish.	Wt-Finished	Tot. Volume	Test.Liq.Wt	Oper.Liq.Wt
S1.1	1	69.0 kg	65.2 kg	0.132 m3	132.0 kg	0.0 kg
E3.1	1	33.0 kg	33.0 kg	0.040 m3	40.0 kg	0.0 kg
N.T1	1	30.0 kg	30.0 kg	0.004 m3	4.0 kg	0.0 kg
N.T2	1	30.0 kg	30.0 kg	0.004 m3	4.0 kg	0.0 kg
F.1	1	59.0 kg	59.0 kg	0.025 m3	25.0 kg	0.0 kg
T.1	1	152.0 kg	110.0 kg	0.000 m3	0.0 kg	0.0 kg
TB.1	1	1215.0 kg	1215.0 kg	0.238 m3	238.0 kg	0.0 kg
Total	7	1588.0 kg	1542.2 kg	0.443 m3	443.0 kg	0.0 kg

SUMMATION OF DATA FOR ALL COMPONENTS :

Total : 29 3247 kg 3189 kg 2.695 m3 2695 kg 0 kg

Weight Summary/Condition	Shell Side	Tube Side	Total
Empty Weight of Vessel incl. 5% Contingency	1729 kg	1619 kg	3348 kg
Total Test Weight of Vessel (Testing with Water)	3981 kg	2062 kg	6043 kg
Total Operating Weight of Vessel	1729 kg	1619 kg	3348 kg

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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
F.2	0	0	633	0	0	633	0	0	633
S1.2	0	0	725	0	0	725	-128	0	725
S2.1	0	0	990	0	0	990	-185	0	1001
S1.3	118	-2	3194	118	0	3198	118	0	3198
E3.2	118	0	5371	118	0	5309	-49	0	5432
N.A	-433	0	2500	-404	0	2500	-404	0	2500
N.C	683	0	3197	637	0	3197	637	0	3197
N.B	-433	0	5075	-404	0	5075	-404	0	5075
N.D	663	0	2445	641	0	2445	641	0	2445
N.P*	669	0	1445	640	0	1445	640	0	1445
N.S*	669	0	1945	640	0	1945	640	0	1945
N.L1	418	389	3565	418	357	3565	418	357	3565
N.L2*	-182	389	3565	-182	357	3565	-182	357	3565
N.L3*	418	389	3865	418	357	3865	418	357	3865
N.L4*	-182	389	3865	-182	357	3865	-182	357	3865
N.L5*	418	389	4865	418	357	4865	418	357	4865
N.L6*	-182	389	4865	-182	357	4865	-182	357	4865
SS.1	-313	0	2797	-313	0	2797	-313	0	2797
N.1*	118	565	3197	118	519	3197	118	519	3197
N.2*	-447	0	3197	-401	0	3197	-401	0	3197

SHELL SIDE CENTER OF GRAVITY AT CONDITIONS BELOW	X	Y	Z
Empty Vessel	39	18	3013
Test Condition of Vessel (Testing with Water)	81	8	3056
Operating Condition of Vessel	39	18	3013

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
S1.1	0	-6	222	0	0	225	-128	0	225
E3.1	0	0	-120	0	0	-73	-121	0	-155
N.T1	421	110	225	349	110	225	349	110	225
N.T2	-421	110	225	-349	110	225	-349	110	225
F.1	0	0	493	0	0	493	0	0	493
T.1	0	0	563	0	0	563	0	0	563
TB.1	0	0	3153	0	0	3153	0	0	3153

TUBE SIDE CENTER OF GRAVITY AT CONDITIONS BELOW	X	Y	Z
Empty Vessel	0	4	2558
Test Condition of Vessel (Testing with Water)	0	4	2386
Operating Condition of Vessel	0	4	2558

CENTER OF GRAVITY AT CONDITIONS BELOW	X	Y	Z
Empty Vessel	20	11	2793
Test Condition of Vessel (Testing with Water)	55	7	2843
Operating Condition of Vessel	20	11	2793

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Max. Allowable Pressure MAWP

PROCESS CARD NO.: 1 SHELL SIDE

ID	Comp. Type	Liq.Head	MAWP New & Cold	MAWP Hot & Corr.
T.1	Tubesheet	0.000 MPa	2.972 MPa	1.148 MPa
TB.1	Tube Bundle	0.000 MPa	39.450 MPa	13.162 MPa
F.2	WN - Flange	0.000 MPa	1.612 MPa	1.612 MPa
S1.2	Cylindrical Shell	0.000 MPa	4.471 MPa	2.318 MPa
S2.1	Reducers	0.000 MPa	3.378 MPa	1.643 MPa
S1.3	Cylindrical Shell	0.000 MPa	3.906 MPa	2.187 MPa
E3.2	Torispherical End	0.000 MPa	4.345 MPa	2.251 MPa
N.A	Nozzle, Forging (LWN)	0.000 MPa	4.537 MPa	2.536 MPa
N.C	Nozzle, Seamless Pipe	0.000 MPa	4.300 MPa	2.606 MPa
N.B	Nozzle, Forging (LWN)	0.000 MPa	4.537 MPa	2.536 MPa
N.D	Nozzle, Forging (LWN)	0.000 MPa	4.746 MPa	2.643 MPa
N.P*	Nozzle, Forging (LWN)	0.000 MPa	4.537 MPa	2.536 MPa
N.S*	Nozzle, Forging (LWN)	0.000 MPa	4.537 MPa	2.536 MPa
N.L1	Nozzle, Forging (LWN)	0.000 MPa	4.537 MPa	2.536 MPa
N.L2*	Nozzle, Forging (LWN)	0.000 MPa	4.537 MPa	2.536 MPa
N.L3*	Nozzle, Forging (LWN)	0.000 MPa	4.537 MPa	2.536 MPa
N.L4*	Nozzle, Forging (LWN)	0.000 MPa	4.537 MPa	2.536 MPa
N.L5*	Nozzle, Forging (LWN)	0.000 MPa	4.537 MPa	2.536 MPa
N.L6*	Nozzle, Forging (LWN)	0.000 MPa	4.537 MPa	2.536 MPa
N.1*	Nozzle, Seamless Pipe	0.000 MPa	4.300 MPa	2.606 MPa
N.2*	Nozzle, Seamless Pipe	0.000 MPa	4.300 MPa	2.606 MPa
	MAWP		1.612 MPa	1.148 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	Liq.Head	MAWP New & Cold	MAWP Hot & Corr.
S1.1	Cylindrical Shell	0.000 MPa	4.471 MPa	1.863 MPa
E3.1	Torispherical End	0.000 MPa	4.933 MPa	1.842 MPa
N.T1	Nozzle, Seamless Pipe	0.000 MPa	4.782 MPa	2.194 MPa
N.T2	Nozzle, Seamless Pipe	0.000 MPa	4.782 MPa	2.194 MPa
F.1	WN - Flange	0.000 MPa	1.098 MPa	1.098 MPa
T.1	Tubesheet	0.000 MPa	2.972 MPa	1.146 MPa
TB.1	Tube Bundle	0.000 MPa	26.452 MPa	13.732 MPa
	MAWP		1.098 MPa	1.098 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.

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Test Pressure

PROCESS CARD NO.: 1 SHELL SIDE

TEST PRESSURE OF VESSEL - NEW & COLD - HORIZONTAL

Design Pressure.....: 0.500 MPa

Design Temperature.....: 232.0 C

ID	Description	Pdesign	PtMax	PtMin	Wat.Head	PtTop	PtTopMax
T.1	Tubesheet-U-tube sheet	0.500	4.420	1.256	0.011	1.256	4.409
TB.1	Tube Bundle-U-tube bundle	0.600	35.864	1.445	0.008	1.445	35.856
F.2	WN - Flange-Shell flange	0.500	3.248	0.882	0.011	0.882	3.237
S1.2	Cylindrical Shell-Shell L=100 mm	0.500	7.772	0.825	0.011	0.825	7.761
S2.1	Reducers-Shell reducer	0.500	5.765	0.825	0.011	0.814	5.754
S1.3	Cylindrical Shell-Shell L=4030	0.500	6.789	0.825	0.010	0.825	6.779
E3.2	Torispherical End-Shell head	0.500	6.419	0.825	0.011	0.825	6.407
N.A	2" ANSI B16.5 150 lbs LWN -RF Raised Face	0.500	3.102	NA	0.014	NA	3.089
N.A	Nozzle,Forging (LWN)-Inlet	0.500	6.632	NA	0.014	NA	6.618
N.C	6" ANSI B16.5 150 lbs WN -RF Raised Face	0.500	3.102	NA	0.004	NA	3.099
N.C	Nozzle,Seamless Pipe- Outlet Vap	0.500	6.312	NA	0.004	NA	6.308
N.B	2" ANSI B16.5 150 lbs LWN -RF Raised Face	0.500	3.102	NA	0.014	NA	3.089
N.B	Nozzle,Forging (LWN)- Outlet Liq	0.500	6.632	NA	0.014	NA	6.618
N.D	1" ANSI B16.5 150 lbs LWN -RF Raised Face	0.500	3.102	NA	0.003	NA	3.099
N.D	Nozzle,Forging (LWN)-PG	0.500	6.950	NA	0.003	NA	6.947
N.P*	2" ANSI B16.5 150 lbs LWN -RF Raised Face	0.500	3.102	NA	0.003	NA	3.099
N.P*	Nozzle,Forging (LWN)-PG	0.500	6.632	NA	0.003	NA	6.628
N.S*	2" ANSI B16.5 150 lbs LWN -RF Raised Face	0.500	3.102	NA	0.003	NA	3.099
N.S*	Nozzle,Forging (LWN)- Safety Valve	0.500	6.632	NA	0.003	NA	6.628
N.L1	2" ANSI B16.5 150 lbs LWN -RF Raised Face	0.500	3.102	NA	0.007	NA	3.095
N.L1	Nozzle,Forging (LWN)-LG	0.500	6.632	NA	0.007	NA	6.625
N.L2*	2" ANSI B16.5 150 lbs LWN -RF Raised Face	0.500	3.102	NA	0.013	NA	3.089
N.L2*	Nozzle,Forging (LWN)-LG	0.500	6.632	NA	0.013	NA	6.619
N.L3*	2" ANSI B16.5 150 lbs LWN -RF Raised Face	0.500	3.102	NA	0.007	NA	3.095
N.L3*	Nozzle,Forging (LWN)-LT	0.500	6.632	NA	0.007	NA	6.625
N.L4*	2" ANSI B16.5 150 lbs LWN -RF Raised Face	0.500	3.102	NA	0.013	NA	3.089
N.L4*	Nozzle,Forging (LWN)-LT	0.500	6.632	NA	0.013	NA	6.619
N.L5*	2" ANSI B16.5 150 lbs LWN -RF Raised Face	0.500	3.102	NA	0.007	NA	3.095
N.L5*	Nozzle,Forging (LWN)-LT	0.500	6.632	NA	0.007	NA	6.625
N.L6*	2" ANSI B16.5 150 lbs LWN -RF Raised Face	0.500	3.102	NA	0.013	NA	3.089
N.L6*	Nozzle,Forging (LWN)-LT	0.500	6.632	NA	0.013	NA	6.619
N.1*	6" ANSI B16.5 150 lbs WN -RF Raised Face	0.500	3.102	NA	0.011	NA	3.091
N.1*	Nozzle,Seamless Pipe- Outlet Vap	0.500	6.312	NA	0.011	NA	6.300
N.2*	6" ANSI B16.5 150 lbs WN -RF Raised Face	0.500	3.102	NA	0.014	NA	3.088
N.2*	Nozzle,Seamless Pipe- Outlet Vap	0.500	6.312	NA	0.014	NA	6.297

PtReq = MAX(MIN(PtTop), 1.43*p)= 0.8139 MPa (EN13445-5, 10.2.3.3.1-1 & 2)

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HYDRO-TEST

REQUIRED TEST PRESSURE AT TOP OF VESSEL PtReq(Hydro Test): 0.814 MPa
 MAXIMUM TEST PRESSURE AT TOP OF VESSEL PtLim(Hydro Test): 3.088 MPa

PNEUMATIC TEST

REQUIRED TEST PRESSURE AT TOP OF VESSEL PtReq(Pneumatic Test) ...: 0.814 MPa
 MAXIMUM TEST PRESSURE AT TOP OF VESSEL PtLim(Pneumatic Test) ...: 3.102 MPa

Note : Other components may limit Ptlim than the ones checked above.

PROCESS CARD NO.: 2 TUBE SIDE

TEST PRESSURE OF VESSEL - NEW & COLD - HORIZONTAL

Design Pressure.....: 0.850 MPa
 Design Temperature.....: 370.0 C

ID	Description	Pdesign	PtMax	PtMin	Wat.Head	PtTop	PtTopMax
N.T1	6" ANSI B16.5 300 lbs WN -RF Raised Face	0.850	7.756	NA	0.004	NA	7.001
N.T2	6" ANSI B16.5 300 lbs WN -RF Raised Face	0.850	7.756	NA	0.011	NA	6.993
S1.1	Cylindrical Shell-Channel Shell	0.850	7.772	1.745	0.009	1.745	7.763
E3.1	Torispherical End-Channel head	0.850	7.287	1.745	0.006	1.745	7.282
N.T1	6" ANSI B16.5 300 lbs WN -RF Raised Face	0.850	7.756	NA	0.004	NA	7.001
N.T1	Nozzle,Seamless Pipe- Tube side inlet	0.850	7.005	NA	0.004	NA	7.001
N.T2	6" ANSI B16.5 300 lbs WN -RF Raised Face	0.850	7.756	NA	0.011	NA	6.993
N.T2	Nozzle,Seamless Pipe- Tube side outlet	0.850	7.005	NA	0.011	NA	6.993
F.1	WN - Flange-Channel flange	0.850	3.154	2.135	0.009	2.135	3.145
T.1	Tubesheet-U-tube sheet	0.850	4.434	2.135	0.009	2.135	4.425
TB.1	Tube Bundle-U-tube bundle	0.950	39.468	2.287	0.006	2.287	39.462

PtReq = MAX(MIN(PtTop), 1.43*p)= 1.7453 MPa (EN13445-5, 10.2.3.3.1-1 & 2)

HYDRO-TEST

REQUIRED TEST PRESSURE AT TOP OF VESSEL PtReq(Hydro Test): 1.745 MPa
 MAXIMUM TEST PRESSURE AT TOP OF VESSEL PtLim(Hydro Test): 3.145 MPa

PNEUMATIC TEST

REQUIRED TEST PRESSURE AT TOP OF VESSEL PtReq(Pneumatic Test) ...: 1.745 MPa
 MAXIMUM TEST PRESSURE AT TOP OF VESSEL PtLim(Pneumatic Test) ...: 3.154 MPa

Note : Other components may limit Ptlim than the ones checked above.

NOMENCLATURE:

- Pdesign- is the design pressure including liquid head at the part under consideration.
- PtMax - is the maximum allowed test pressure determined at the part under consideration.
- PtMin - is the required test pressure determined at the part under consideration.
- Wat.Head - is the water head during hydrotesting at the part under consideration.
- PtBot - is the required test pressure at bottom of the vessel, for the part under consideration.
- PtTop - is the required test pressure at top of the vessel, for the part under consideration.
- PtTopMax - is the maximum test pressure allowed at top of the vessel, for the part under consideration.
- PtReq - is the required minimum test pressure (largest value of PtTop) at top of vessel for the listed components.
- PtLim - is the maximum allowed test pressure (minimum value for PtTopMax) at top of vessel for the listed components.

EN13445-5 10.2.3.3.8 Pressure of vessels under test shall be gradually increased to a value of approximately 50 % of the specified test pressure, thereafter the pressure shall be increased in stages of approximately 10 % of the specified test pressure until this is reached. The required test pressure shall be maintained for not less than 30 min. At no stage shall the vessel be approached for close examination until the pressure has been positively reduced by at least 10 % to a

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level lower than that previously attained. The pressure shall be maintained at the specified close examination level for a sufficient length of time to permit a visual inspection to be made of all surfaces and joints.

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Bill of Materials

ID	No	Description	Component Dimensions	Material Standard
E3.1	1	Torispherical End-Channel head	De= 624, wt= 8.5, h= 162.61, R= 499.2, r= 96.096, KORBBOGEN DIN 28013-28014/SMS	ID 1, EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N
E3.2	1	Torispherical End-Shell head	De= 864, wt= 10.5, h= 225.08, R= 691.2, r= 133.056, KORBBOGEN DIN 28013-28014/SM	ID 6, EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N
F.1	1	WN - Flange-Channel flange	OD= 760, ID= 604, thk= 45, h= 40, g1= 17	ID 3, ASME SA-105, PMA, ,
F.1	28	Bolts	7/8"(0.875), Area= 270.32	ID 4, ASME SA-193 Gr.B7, PMA, ,
F.2	1	WN - Flange-Shell flange	OD= 760, ID= 604, thk= 45, h= 40, g1= 17	ID 7, ASME SA-105, PMA, ,
F.2	28	Bolts	7/8"(0.875), Area= 270.32	ID 4, ASME SA-193 Gr.B7, PMA, ,
N.1*	1	Flange:ANSI B16.5:Class 150 lbs	WN Welding Neck, 1a RF Raised Face	1.1 - Carbon Steel - A105, A515 70, A516 70, A350 LF2 (BS 1503 164 490, BS 1504 161 480)
N.1*	1	Nozzle,Seamless Pipe-Outlet Vap	6" do=168.3,wt=10.97,L=220.5,ho=200,P AD OD=300	ID 8, ASME SA-106 Gr.B, PMA, ,
N.1*	1	Reinforcement Pad	PAD OD=300, wt= 9.5, width= 65.85	ID 6, EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N
N.2*	1	Flange:ANSI B16.5:Class 150 lbs	WN Welding Neck, 1a RF Raised Face	1.1 - Carbon Steel - A105, A515 70, A516 70, A350 LF2 (BS 1503 164 490, BS 1504 161 480)
N.2*	1	Nozzle,Seamless Pipe-Outlet Vap	6" do=168.3,wt=10.97,L=220.5,ho=200,P AD OD=300	ID 8, ASME SA-106 Gr.B, PMA, ,
N.2*	1	Reinforcement Pad	PAD OD=300, wt= 9.5, width= 65.85	ID 6, EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N
N.A	1	Nozzle,Forging (LWN)-Inlet	2" do=77.8,wt=13.49,L=213.8,ho=200	ID 7, ASME SA-105, PMA, ,
N.B	1	Nozzle,Forging (LWN)-Outlet Liq	2" do=77.8,wt=13.49,L=213.8,ho=200	ID 7, ASME SA-105, PMA, ,
N.C	1	Flange:ANSI B16.5:Class 150 lbs	WN Welding Neck, 1a RF Raised Face	1.1 - Carbon Steel - A105, A515 70, A516 70, A350 LF2 (BS 1503 164 490, BS 1504 161 480)
N.C	1	Nozzle,Seamless Pipe-Outlet Vap	6" do=168.3,wt=10.97,L=220.5,ho=200,P AD OD=300	ID 8, ASME SA-106 Gr.B, PMA, ,
N.C	1	Reinforcement Pad	PAD OD=300, wt= 9.5, width= 65.85	ID 6, EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N
N.D	1	Nozzle,Forging (LWN)-PG	1" do=50.8,wt=12.69,L=212.8,ho=200	ID 7, ASME SA-105, PMA, ,
N.L1	1	Nozzle,Forging (LWN)-LG	2" do=77.8,wt=13.49,L=296,ho=200	ID 7, ASME SA-105, PMA, ,
N.L2*	1	Nozzle,Forging (LWN)-LG	2" do=77.8,wt=13.49,L=296,ho=200	ID 7, ASME SA-105, PMA, ,
N.L3*	1	Nozzle,Forging (LWN)-LT	2" do=77.8,wt=13.49,L=296,ho=200	ID 7, ASME SA-105, PMA, ,
N.L4*	1	Nozzle,Forging (LWN)-LT	2" do=77.8,wt=13.49,L=296,ho=200	ID 7, ASME SA-105, PMA, ,
N.L5*	1	Nozzle,Forging (LWN)-LT	2" do=77.8,wt=13.49,L=296,ho=200	ID 7, ASME SA-105, PMA, ,
N.L6*	1	Nozzle,Forging (LWN)-LT	2" do=77.8,wt=13.49,L=296,ho=200	ID 7, ASME SA-105, PMA, ,
N.P*	1	Nozzle,Forging (LWN)-PG	2" do=77.8,wt=13.49,L=213.8,ho=200	ID 7, ASME SA-105, PMA, ,
N.S*	1	Nozzle,Forging (LWN)-Safety Valve	2" do=77.8,wt=13.49,L=213.8,ho=200	ID 7, ASME SA-105, PMA, ,
N.T1	1	Flange:ANSI B16.5:Class 300 lbs	WN Welding Neck, 1a RF Raised Face	1.1 - Carbon Steel - A105, A515 70, A516 70, A350 LF2 (BS 1503 164 490, BS 1504 161 480)
N.T1	1	Nozzle,Seamless Pipe-Tube side inlet	6" do=168.3,wt=10.97,L=279.6,ho=200,P AD OD=300	ID 2, ASME SA-106 Gr.B, PMA, ,
N.T1	1	Reinforcement Pad	PAD OD=300, wt= 7.5, width= 65.85	ID 1, EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N
N.T2	1	Flange:ANSI B16.5:Class 300 lbs	WN Welding Neck, 1a RF Raised Face	1.1 - Carbon Steel - A105, A515 70, A516 70, A350 LF2 (BS 1503 164 490, BS 1504 161 480)
N.T2	1	Nozzle,Seamless Pipe-Tube side outlet	6" do=168.3,wt=10.97,L=279.6,ho=200,P AD OD=300	ID 2, ASME SA-106 Gr.B, PMA, ,
N.T2	1	Reinforcement Pad	PAD OD=300, wt= 9.5, width= 65.85	ID 1, EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N
S1.1	1	Cylindrical Shell-Channel Shell	De= 624, en= 10, L= 450	ID 1, EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N
S1.2	1	Cylindrical Shell-Shell L=100 mm	De= 624, en= 10, L= 100	ID 6, EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N
S1.3	1	Cylindrical Shell-Shell L=4030	De= 864, en= 12, L= 4030	ID 6, EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N
S2.1	1	Reducers-Shell reducer	DiL= 846, DiS= 610, Lc= 408, en= 12, rL= 0	ID 6, EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N

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Steam Generator

Visual Vessel Design by OhmTech Ver:10.2b Operator : Rev.:A

ID	No	Description	Component Dimensions	Material Standard
SS.1	2	Baseplate	PL. 20, W= 210, L= 808.2	ID 6, EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N
SS.1	2	Center/Webplate	PL. 15, W= 770, H= 517	ID 6, EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N
SS.1	2	Wrapperplate	PL. 12, W= 250, L= 1085.7	ID 6, EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N
SS.1	4	Stiff.Plates	PL. 15,W= 180,H= 517	ID 6, EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N
SS.1	8	Stiff.Plates	PL. 15,W= 82.5,H= 335	ID 6, EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N
T.1	1	Tubesheet-U-tube sheet	OD= 670, thk= 55, N= 340 tubes	ID 3, ASME SA-105, PMA, ,
TB.1	1	Tube Bundle-U-tube bundle	N= 340, De= 19.05, et= 2.108, L= 4055	ID 5, EN 10216-2:2002/A2:07, 1.0345 P235GH seamless tube, HT:N

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Steam Generator

Visual Vessel Design by OhmTech Ver:10.2b Operator : Rev.:A

Notes, Warning & Error Messages

ID & Comp. Description	Notes/Warnings/Error Messages
N.T1 Nozzle,Seamless Pipe Tube side inlet	
-	NOTE : Formula 9.5-20 $eap > eas$, the value of ep used in the calculations is limited to eas
-	NOTE : The width of the pad used in the calculations is limited to $Is = 63.4$ mm
-	NOTE : In case of high mean wall temperature for the shell(more than 250C) or severe temp. gradients the use of reinforcing plates shall be avoided(ref.9.4.5.2).
N.T2 Nozzle,Seamless Pipe Tube side outlet	
-	NOTE : Formula 9.5-20 $eap > eas$, the value of ep used in the calculations is limited to eas
-	NOTE : The width of the pad used in the calculations is limited to $Is = 63.4$ mm
-	NOTE : In case of high mean wall temperature for the shell(more than 250C) or severe temp. gradients the use of reinforcing plates shall be avoided(ref.9.4.5.2).
F.1 WN - Flange Channel flange	
-	NOTE : Unable to verify that the selected bolting material is a bolting material:ASME SA-193 Gr.B7, PMA, , THK<=64mm 370'C
-	NOTE : The design may benefit by reducing the bolting area, or reducing the allowable stress for the bolts.
TB.1 Tube Bundle U-tube bundle	
-	NOTE: U-bends formed from tube materials having low ductility, or materials which are susceptible to work-hardening, may require special consideration.
F.2 WN - Flange Shell flange	
-	WARNING : TEMPERATURE MISMATCH FOR MATERIAL:ASME SA-193 Gr.B7, PMA, , THK<=64mm 370'C
-	NOTE : Unable to verify that the selected bolting material is a bolting material:ASME SA-193 Gr.B7, PMA, , THK<=64mm 370'C
-	NOTE : The design may benefit by reducing the bolting area, or reducing the allowable stress for the bolts.
S2.1 Reducers Shell reducer	
-	NOTE: The largest thickness calculated for the junctions(large&small base) shall apply for the whole cone.
N.C Nozzle,Seamless Pipe Outlet Vap	
-	NOTE : Formula 9.5-20 $eap > eas$, the value of ep used in the calculations is limited to eas
SS.1 Saddle/Ring Support Fixed Saddle	
-	NOTE: The thermal expansion at sliding saddle is approximately: $dL=L*expc*dT= 2900*0.000015* 232= 10.1$ mm
N.1* Nozzle,Seamless Pipe Outlet Vap	
-	NOTE : Formula 9.5-20 $eap > eas$, the value of ep used in the calculations is limited to eas
N.2* Nozzle,Seamless Pipe Outlet Vap	
-	NOTE : Formula 9.5-20 $eap > eas$, the value of ep used in the calculations is limited to eas

TOTAL No. OF ERRORS/WARNINGS : 1

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Steam Generator

Visual Vessel Design by OhmTech Ver:10.2b Operator : Rev.:A

Nozzle List

ID	Service	SIZE	STANDARD/CLASS	ID	Standout	X	Y	Z	Rot.	Orient.
N.A	Inlet	2"	ANSI B16.5 150 lbs LWN -RF Raised Face CLASS :150 LWN Long Welding Neck	56.79	200	-426	0	2500	180	Radial
N.B	Outlet Liq	2"	ANSI B16.5 150 lbs LWN -RF Raised Face CLASS :150 LWN Long Welding Neck	56.79	200	-426	0	5075	180	Radial
N.C	Outlet Vap	6"	ANSI B16.5 150 lbs WN -RF Raised Face Ex.Str.	155.07	200	426	0	3197	0	Radial
N.D	PG	1"	ANSI B16.5 150 lbs LWN -RF Raised Face CLASS :150 LWN Long Welding Neck	31.39	200	426	0	2445	0	Radial
N.L1	LG	2"	ANSI B16.5 150 lbs LWN -RF Raised Face CLASS :150 LWN Long Welding Neck	56.79	200	300	302.4	3565	45.2	Non Rad.
N.L2*	LG	2"	ANSI B16.5 150 lbs LWN -RF Raised Face CLASS :150 LWN Long Welding Neck	56.79	200	-300	302.4	3565	134.8	Non Rad.
N.L3*	LT	2"	ANSI B16.5 150 lbs LWN -RF Raised Face CLASS :150 LWN Long Welding Neck	56.79	200	300	302.4	3865	45.2	Non Rad.
N.L4*	LT	2"	ANSI B16.5 150 lbs LWN -RF Raised Face CLASS :150 LWN Long Welding Neck	56.79	200	-300	302.4	3865	134.8	Non Rad.
N.L5*	LT	2"	ANSI B16.5 150 lbs LWN -RF Raised Face CLASS :150 LWN Long Welding Neck	56.79	200	300	302.4	4865	45.2	Non Rad.
N.L6*	LT	2"	ANSI B16.5 150 lbs LWN -RF Raised Face CLASS :150 LWN Long Welding Neck	56.79	200	-300	302.4	4865	134.8	Non Rad.
N.P*	PG	2"	ANSI B16.5 150 lbs LWN -RF Raised Face CLASS :150 LWN Long Welding Neck	56.79	200	426	0	1445	0	Radial
N.S*	Safety Valve	2"	ANSI B16.5 150 lbs LWN -RF Raised Face CLASS :150 LWN Long Welding Neck	56.79	200	426	0	1945	0	Radial
N.T1	Tube side inlet	6"	ANSI B16.5 300 lbs WN -RF Raised Face Ex.Str.	155.07	200	286.6	110	225	21	Non Rad.
N.T2	Tube side outlet	6"	ANSI B16.5 300 lbs WN -RF Raised Face Ex.Str.	155.07	200	-286.6	110	225	159	Non Rad.
N.1*	Outlet Vap	6"	ANSI B16.5 150 lbs WN -RF Raised Face Ex.Str.	155.07	200	0	426	3197	90	Radial
N.2*	Outlet Vap	6"	ANSI B16.5 150 lbs WN -RF Raised Face Ex.Str.	155.07	200	-426	0	3197	180	Radial

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Steam Generator

Visual Vessel Design by OhmTech Ver:10.2b Operator : Rev.:A

Nozzle Loads

ID	Load Desc.	Nozzle Loads
N.1*	Outlet Vap	Fz=-7.5/7.5kN,My=-3/3,Mx=-2.5/2.5,Mt=-3/3kNm,Fl=-7.5/7.5,Fc=
N.2*	Outlet Vap	Fz=-7.5/7.5kN,My=-3/3,Mx=-2.5/2.5,Mt=-3/3kNm,Fl=-7.5/7.5,Fc=
N.A	Inlet	Fz=-2.5/2.5kN,My=-.29/.29,Mx=-.29/.29,Mt=-3/3kNm,Fl=-2.5/2.5
N.B	Outlet Liq	Fz=-2.5/2.5kN,My=-.29/.29,Mx=-.29/.29,Mt=-3/3kNm,Fl=-2.5/2.5
N.C	Outlet Vap	Fz=-7.5/7.5kN,My=-3/3,Mx=-2.5/2.5,Mt=-3/3kNm,Fl=-7.5/7.5,Fc=
N.L1	LG	Fz=-2.5/2.5kN,My=-.29/.29,Mx=-.29/.29,Mt=-3/3kNm,Fl=-2.5/2.5
N.L2*	LG	Fz=-2.5/2.5kN,My=-.29/.29,Mx=-.29/.29,Mt=-3/3kNm,Fl=-2.5/2.5
N.L3*	LT	Fz=-2.5/2.5kN,My=-.29/.29,Mx=-.29/.29,Mt=-3/3kNm,Fl=-2.5/2.5
N.L4*	LT	Fz=-2.5/2.5kN,My=-.29/.29,Mx=-.29/.29,Mt=-3/3kNm,Fl=-2.5/2.5
N.L5*	LT	Fz=-2.5/2.5kN,My=-.29/.29,Mx=-.29/.29,Mt=-3/3kNm,Fl=-2.5/2.5
N.L6*	LT	Fz=-2.5/2.5kN,My=-.29/.29,Mx=-.29/.29,Mt=-3/3kNm,Fl=-2.5/2.5
N.P*	PG	Fz=-2.5/2.5kN,My=-.29/.29,Mx=-.29/.29,Mt=-3/3kNm,Fl=-2.5/2.5
N.S*	Safety Valve	Fz=-2.5/2.5kN,My=-.29/.29,Mx=-.29/.29,Mt=-3/3kNm,Fl=-2.5/2.5
N.T1	Tube side inlet	Fz=-5/5kN,My=-2/2,Mx=-1.6/1.6,Mt=-2/2kNm,Fl=-5/5,Fc=-5/5kN

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Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2b Operator : Rev.:A

Maximum Component Utilization - Umax

ID	Comp.Type	Umax(%)	Limited by
S1.1	Cylindrical Shell	64.4%	Internal Pressure
E3.1	Torispherical End	68.8%	Internal Pressure
N.T1	Nozzle,Seamless Pipe	98.4%	PhiAll AT EDGE OF PAD
N.T2	Nozzle,Seamless Pipe	38.4%	Nozzle Reinforcement
F.1	WN - Flange	95.2%	Bolt Stress
T.1	Tubesheet	76.2%	Bending Stress
TB.1	Tube Bundle	20.9%	Internal Pressure
F.2	WN - Flange	95.2%	Bolt Stress
S1.2	Cylindrical Shell	48.8%	Internal Pressure
S2.1	Reducers	50.2%	Cone Thk.Near Junction
S1.3	Cylindrical Shell	45.2%	Internal Pressure
E3.2	Torispherical End	47.9%	Internal Pressure
N.A	Nozzle,Forging (LWN)	82.4%	PhiAll AT NOZZLE OD
N.C	Nozzle,Seamless Pipe	74.9%	PhiAll AT EDGE OF PAD
N.B	Nozzle,Forging (LWN)	82.4%	PhiAll AT NOZZLE OD
N.D	Nozzle,Forging (LWN)	39.1%	ANSI 150lb-Flange Rating(at 23
N.P*	Nozzle,Forging (LWN)	82.4%	PhiAll AT NOZZLE OD
N.S*	Nozzle,Forging (LWN)	82.4%	PhiAll AT NOZZLE OD
N.L1	Nozzle,Forging (LWN)	81.7%	PhiAll AT NOZZLE OD
N.L2*	Nozzle,Forging (LWN)	81.7%	PhiAll AT NOZZLE OD
N.L3*	Nozzle,Forging (LWN)	81.7%	PhiAll AT NOZZLE OD
N.L4*	Nozzle,Forging (LWN)	81.7%	PhiAll AT NOZZLE OD
N.L5*	Nozzle,Forging (LWN)	81.7%	PhiAll AT NOZZLE OD
N.L6*	Nozzle,Forging (LWN)	81.7%	PhiAll AT NOZZLE OD
SS.1	Saddle/Ring Support	25.6%	Instability Check
N.1*	Nozzle,Seamless Pipe	74.9%	PhiAll AT EDGE OF PAD
N.2*	Nozzle,Seamless Pipe	74.9%	PhiAll AT EDGE OF PAD

Component with highest utilization Umax = 98.4% N.T1 Tube side inlet

Average utilization of all components Umean= 68.8%

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Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2b Operator : Rev.:A

Material Data/Mechanical Properties

ID	Material Name	Temp	Rm	Rp	Rpt	f_d	f20	ftest	E-mod	Note
1	EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N TG3, CS, Mat.Group:1.1, Max.T= 16mm, SG=7.85	370	410	265	156	104	170.8	252.4	185095	a)
2	ASME SA-106 Gr.B, PMA, , TG3, CS, , Max.T= 999mm, SG=7.85	370	415	240	122.2	81.5	160	228.6	185095	a)
3	ASME SA-105, PMA, , TG3, CS, , Max.T= 250mm, SG=7.85	370	485	250	124.4	82.9	166.7	238.1	185095	a)
4	ASME SA-193 Gr.B7, PMA, , TG3 , , Max.T= 64mm, SG=7.85	370	860	507	388	129.3	169	253.5	185095	a)
5	EN 10216-2:2002/A2:07, 1.0345 P235GH seamless tube, HT:N TG3, CS, Mat.Group:1.1, Max.T= 16mm, SG=7.85	370	360	235	116.8	77.9	150	223.8	185095	a)
6	EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N TG3, CS, Mat.Group:1.1, Max.T= 16mm, SG=7.85	232	410	265	194.1	129.4	170.8	252.4	196147	a)
7	ASME SA-105, PMA, , TG3, CS, , Max.T= 250mm, SG=7.85	232	485	250	177.2	118.1	166.7	238.1	196147	a)
8	ASME SA-106 Gr.B, PMA, , TG3, CS, , Max.T= 999mm, SG=7.85	232	415	240	171.6	114.4	160	228.6	196147	

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)

Rm : MIN.TENSILE STRENGTH at ambient temp.

Rp : MIN. PROOF STRENGTH at ambient temp.

Rpt : MIN. PROOF STRENGTH at calc.temp.

f_d : DESIGN STRESS at calc.temp.

f20 : DESIGN STRESS at ambient temp.

GRP : 1.1 = Steels with a specified minimum specified yield strength ReH <= 275 N/mm²

GRP : 1.0 = Steels with a specified minimum yield strength ReH <= 460 N/mm² a and with analysis in %:C <= 0,25, Si <= 0,60, Mn <= 1,70, Mo <= 0,70b, S <= 0,045, P <= 0,045, Cu <= 0,40b, Ni <= 0,5b, Cr <= 0,3 (0,4 for castings)b, Nb <= 0,05, V <= 0,12b, Ti <= 0,05

Note : a = Because of the carbon content special precautions are necessary when the material is welded.

HT : N = normalised

HT : N = normalised

HT : N = normalised

PMA Requirement

A Particular Material Appraisal(PMA) is required for the following materials:

- 2 ASME SA-106 Gr.B, PMA, ,
- 3 ASME SA-105, PMA, ,
- 4 ASME SA-193 Gr.B7, PMA, ,
- 7 ASME SA-105, PMA, ,
- 8 ASME SA-106 Gr.B, PMA, ,

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Comp.Location in Global Coord.System

ID	Comp. Type	X	Y	Z	Teta	Phi	ConnID
E3.1	Torispherical End	0	0	0	0.0	0.0	S1.1
E3.2	Torispherical End	0	0	5213	0.0	0.0	S1.3
F.1	WN - Flange	0	0	450	0.0	0.0	S1.1
F.2	WN - Flange	0	0	590	0.0	0.0	T.1
N.1*	Nozzle,Seamless Pipe	0	426	3197	90.0	90.0	S1.3
N.2*	Nozzle,Seamless Pipe	-426	0	3197	90.0	180.0	S1.3
N.A	Nozzle,Forging (LWN)	-426	0	2500	90.0	180.0	S1.3
N.B	Nozzle,Forging (LWN)	-426	0	5075	90.0	180.0	S1.3
N.C	Nozzle,Seamless Pipe	426	0	3197	90.0	0.0	S1.3
N.D	Nozzle,Forging (LWN)	426	0	2445	90.0	0.0	S1.3
N.L1	Nozzle,Forging (LWN)	300	302	3565	90.0	90.0	S1.3
N.L2*	Nozzle,Forging (LWN)	-300	302	3565	90.0	90.0	S1.3
N.L3*	Nozzle,Forging (LWN)	300	302	3865	90.0	90.0	S1.3
N.L4*	Nozzle,Forging (LWN)	-300	302	3865	90.0	90.0	S1.3
N.L5*	Nozzle,Forging (LWN)	300	302	4865	90.0	90.0	S1.3
N.L6*	Nozzle,Forging (LWN)	-300	302	4865	90.0	90.0	S1.3
N.P*	Nozzle,Forging (LWN)	426	0	1445	90.0	0.0	S1.3
N.S*	Nozzle,Forging (LWN)	426	0	1945	90.0	0.0	S1.3
N.T1	Nozzle,Seamless Pipe	287	110	225	90.0	0.0	S1.1
N.T2	Nozzle,Seamless Pipe	-287	110	225	90.0	180.0	S1.1
S1.1	Cylindrical Shell	0	0	0	0.0	0.0	
S1.2	Cylindrical Shell	0	0	675	0.0	0.0	F.2
S1.3	Cylindrical Shell	118	0	1183	0.0	0.0	S2.1
S2.1	Reducers	0	0	775	0.0	0.0	S1.2
SS.1	Saddle/Ring Support	118	0	1347	0.0	0.0	S1.3
T.1	Tubesheet	0	0	535	0.0	0.0	F.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

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Visual Vessel Design by OhmTech Ver:10.2b Operator : Rev.:A

Impact Test Requirements

Table :

ID-Description	Material Name	en(mm)	eB(mm)	Re(N/mm2)
E3.1 Channel head - End	EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N	8.5	8.5	265.0
E3.2 Shell head - End	EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N	10.5	10.5	265.0
F.1 Channel flange - Bolts	ASME SA-193 Gr.B7, PMA, ,	21.0	21.0	507.0
F.1 Channel flange - Flange	ASME SA-105, PMA, ,	45.0	11.3	250.0
F.1 Channel flange - Hub	ASME SA-105, PMA, ,	7.0	7.0	250.0
F.2 Shell flange - Bolts	ASME SA-193 Gr.B7, PMA, ,	21.0	21.0	507.0
F.2 Shell flange - Flange	ASME SA-105, PMA, ,	45.0	11.3	250.0
F.2 Shell flange - Hub	ASME SA-105, PMA, ,	7.0	7.0	250.0
N.1* Outlet Vap - Nozzle	ASME SA-106 Gr.B, PMA, ,	11.0	11.0	240.0
N.1* Outlet Vap - Pad	EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N	9.5	12.0	265.0
N.2* Outlet Vap - Nozzle	ASME SA-106 Gr.B, PMA, ,	11.0	11.0	240.0
N.2* Outlet Vap - Pad	EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N	9.5	12.0	265.0
N.A Inlet - Nozzle	ASME SA-105, PMA, ,	13.5	13.5	250.0
N.B Outlet Liq - Nozzle	ASME SA-105, PMA, ,	13.5	13.5	250.0
N.C Outlet Vap - Nozzle	ASME SA-106 Gr.B, PMA, ,	11.0	11.0	240.0
N.C Outlet Vap - Pad	EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N	9.5	12.0	265.0
N.D PG - Nozzle	ASME SA-105, PMA, ,	12.7	12.7	250.0
N.L1 LG - Nozzle	ASME SA-105, PMA, ,	13.5	13.5	250.0
N.L2* LG - Nozzle	ASME SA-105, PMA, ,	13.5	13.5	250.0
N.L3* LT - Nozzle	ASME SA-105, PMA, ,	13.5	13.5	250.0
N.L4* LT - Nozzle	ASME SA-105, PMA, ,	13.5	13.5	250.0
N.L5* LT - Nozzle	ASME SA-105, PMA, ,	13.5	13.5	250.0
N.L6* LT - Nozzle	ASME SA-105, PMA, ,	13.5	13.5	250.0
N.P* PG - Nozzle	ASME SA-105, PMA, ,	13.5	13.5	250.0
N.S* Safety Valve - Nozzle	ASME SA-105, PMA, ,	13.5	13.5	250.0
N.T1 Tube side inlet - Nozzle	ASME SA-106 Gr.B, PMA, ,	11.0	11.0	240.0
N.T1 Tube side inlet - Pad	EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N	7.5	10.0	265.0
N.T2 Tube side outlet - Nozzle	ASME SA-106 Gr.B, PMA, ,	11.0	11.0	240.0
N.T2 Tube side outlet - Pad	EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N	9.5	10.0	265.0
S1.1 Channel Shell - Shell	EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N	10.0	10.0	265.0
S1.2 Shell L=100 mm - Shell	EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N	10.0	10.0	265.0
S1.3 Shell L=4030 - Shell	EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N	12.0	12.0	265.0
S2.1 Shell reducer - Shell	EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N	12.0	12.0	265.0
SS.1 Fixed Saddle - Reinf.Pl.ate	EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N	12.0	12.0	265.0
T.1 U-tube sheet - T-Sheet	ASME SA-105, PMA, ,	55.0	13.8	250.0
TB.1 U-tube bundle - Tube	EN 10216-2:2002/A2:07, 1.0345 P235GH seamless tube, HT:N	2.1	2.1	235.0

Table Continued

ID-Description	TR(C)	TKVPWHT(C)	TKVAW(C)	Comments
E3.1 Channel head - End	0.0	20	20	
E3.2 Shell head - End	0.0	20	20	
F.1 Channel flange - Bolts	0.0	Re>500	Re>500	NOTE: Re>500 Unable to determine TKV, the use of B.2.4 Method 3 is required.
F.1 Channel flange - Flange	0.0	20	20	
F.1 Channel flange - Hub	0.0	20	20	
F.2 Shell flange - Bolts	0.0	Re>500	Re>500	NOTE: Re>500 Unable to determine TKV, the use of B.2.4 Method 3 is required.
F.2 Shell flange - Flange	0.0	20	20	
F.2 Shell flange - Hub	0.0	20	20	
N.1* Outlet Vap - Nozzle	0.0	20	20	NOTE: Steel designation unknown, this method is only applicable for ferritic steels(C, CMn and fine grain) and 1.5% to 5% Ni-alloy steels.
N.1* Outlet Vap - Pad	0.0	20	20	
N.2* Outlet Vap - Nozzle	0.0	20	20	NOTE: Steel designation unknown, this method is only applicable for ferritic steels(C, CMn and fine grain) and 1.5% to 5% Ni-alloy steels.
N.2* Outlet Vap - Pad	0.0	20	20	
N.A Inlet - Nozzle	0.0	20	20	
N.B Outlet Liq - Nozzle	0.0	20	20	
N.C Outlet Vap - Nozzle	0.0	20	20	NOTE: Steel designation unknown, this method is only applicable for ferritic steels(C, CMn and fine grain) and 1.5% to 5% Ni-alloy steels.
N.C Outlet Vap - Pad	0.0	20	20	
N.D PG - Nozzle	0.0	20	20	
N.L1 LG - Nozzle	0.0	20	20	
N.L2* LG - Nozzle	0.0	20	20	
N.L3* LT - Nozzle	0.0	20	20	
N.L4* LT - Nozzle	0.0	20	20	

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ID-Description	TR(C)	TKVPWHT(C)	TKVAW(C)	Comments
N.L5* LT - Nozzle	0.0	20	20	
N.L6* LT - Nozzle	0.0	20	20	
N.P* PG - Nozzle	0.0	20	20	
N.S* Safety Valve - Nozzle	0.0	20	20	
N.T1 Tube side inlet - Nozzle	0.0	20	20	
N.T1 Tube side inlet - Pad	0.0	20	20	
N.T2 Tube side outlet - Nozzle	0.0	20	20	
N.T2 Tube side outlet - Pad	0.0	20	20	
S1.1 Channel Shell - Shell	0.0	20	20	
S1.2 Shell L=100 mm - Shell	0.0	20	20	
S1.3 Shell L=4030 - Shell	0.0	20	20	
S2.1 Shell reducer - Shell	0.0	20	20	
SS.1 Fixed Saddle - Reinf.Plates	0.0	20	20	
T.1 U-tube sheet - T-Sheet	0.0	20	20	
TB.1 U-tube bundle - Tube	0.0	20	20	

EN13445-2 Annex B, Requirements for Prevention of Brittle Fracture
B.2.3 Method 2 - Code of practice developed from fracture mechanics

NOMENCLATURE :

- en - Nominal thickness of component under consideration (including corr. allow.).
- eB - Reference thickness of component under consideration from Table B.4-1.
- Re - Minimum specified yield strength at room temperature.
- AW - As Welded condition.
- PWHT - Post Weld Heat Treatment.
- TR - Design Reference Temperature.
- TKVPWHT - Material impact test temperature for PWHT condition from Figure B.2-1, 3, 5 or 7, and required impact energy 27J.
- TKVAW - Material impact test temperature for AW condition from Figure B.2-2, 4, 6, 8, 9, 10 or 11, and required impact energy 27J (40J for austenitic-ferritic steels).

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NDT - Requirements for Test Group:3b

Table EN13445-5, 6.6.2-1:

Weld ID	Weld Category	Weld Type	RT or UT	MT or PT
1	Full Penetration butt weld	Longitudinal joints	10%	10%(d)
2a	Full Penetration butt weld	Circumferential joints on a shell	10%(c)	10%(d)
2b	Full Penetration butt weld	Circumferential joints on a shell with backing strip (k)	25%	10%
2c	Full Penetration butt weld	Circumferential joggle joint (k)	25%	10%
3a	Full Penetration butt weld	Circumferential joints on a nozzle di > 150 mm or e > 16 mm	10%(c)	10%(d)
3b	Full Penetration butt weld	Circumferential joints on a nozzle di > 150 mm or e > 16 mm with backing strip (k)	25%	10%
4	Full Penetration butt weld	Circumferential joints on a nozzle with di <= 150 mm and e <= 16mm	0	10%
5	Full Penetration butt weld	All welds in spheres, heads and hemispherical heads to shells	10%	10%(d)
6	Full Penetration butt weld	Assembly of a conical shell with a cylindrical shell without a knuckle(large end of cone)	10%	100%
7	Full Penetration butt weld	Assembly of a conical shell with a cylindrical shell without a knuckle(small end of cone)	10%	10%(d)
8a	Circumferential lapped joints (k)	General application shell to head	NA	NA
8b	Circumferential lapped joints (k)	Bellows to shell e <= 8 mm	0 %	10%
9	Assembly of a flat head or a tubesheet, with a cylindrical shell Assembly of a flange or a collar with a shell	With full penetration	10%	10%(d)
10	Assembly of a flat head or a tubesheet, with a cylindrical shell Assembly of a flange or a collar with a shell	With partial penetration if a > 16 mm (a as defined in figure 6.6.2-1)(j)	10%	10%
11	Assembly of a flat head or a tubesheet, with a cylindrical shell Assembly of a flange or a collar with a shell	With partial penetration if a <= 16 mm (a as defined in figure 6.6.2-1) (j)	0	10%
12	Assembly of a flange or a collar with a nozzle	With full penetration	10%	10%(d)
13	Assembly of a flange or a collar with a nozzle	With partial penetration (j)	0	10%
14	Assembly of a flange or a collar with a nozzle	With full or partial penetration di <= 150 mm and e <= 16 mm j	0	10%
15	Nozzle or branch (e)	With full penetration di > 150 mm or e > 16 mm	10%	10%(d)
16	Nozzle or branch (e)	With full penetration di <= 150 mm and e <= 16 mm	0	10%
17	Nozzle or branch (e)	With partial penetration for any di > 16 mm (see figure 6.6.2-2)	10%	10%(d)
18	Nozzle or branch (e)	With partial penetration di > 150 mm a <= 16 mm (see figure 6.6.2-2)	0	10%
19	Nozzle or branch (e)	With partial penetration di <= 150 mm a <= 16 mm (see figure 6.6.2-2)	0	10%
20	Tube ends into tubesheet	-	-	10%
21	Permanent attachments (f)	With full penetration or partial penetration	10%(d)	10%(d)
22	Pressure retaining areas after removal of temporary attachments	-	-	100%
23	Cladding by welding	-	-	100%
24	Repairs	-	100 %	100%

The above requirements are for test group TG:3b

Notes:

(a): See figure 6.6.2-3 for an explanation on Weld ID.

(b): RT=Radiographic Testing, UT=Ultrasonic Testing, MT=Magnetic Particle Testing, PT=Penetrant Testing.

(c): 2 % if e <= 30mm and same WPS as longitudinal, for steel groups 1.1 and 8.1

(d): 10 % if e > 30 mm, 0 % if e <= 30 mm

(e): Percentage in the table refers to the aggregate weld length of all the nozzles see 6.6.1.2 b).

(f): No RT or UT for weld throat thickness <= 16 mm

(g): 10 % for steel groups 8.2, 9.1, 9.2, 9.3 and 10

(h): Volumetric testing if risks of cracks due to parent material or heat treatment

(i): For explanation of the reduction in NDT in testing group 2, see 6.6.1.2

(j): In exceptional cases or where the design or load bearing on the joint is critical, it may be necessary to employ both techniques (i.e. RT & UT, MT & PT).

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See table 6.6.3-1 for other circumstances for use of both techniques.
(k): For limitations of application see EN 134445-3:2002, 5.7.3.2.1
(l): The percentage of surface examination refers to the percentage of length of the welds both on the inside and the outside.
(m): RT and UT are volumetric while MT and PT are surface testing. When referenced in this table both volumetric and surface are necessary to the extent shown.
(n): NA means 'Not Applicable'.
(o): In case of cyclic loading refer to Annex G.2.
(p): Annex A of EN 13445-3 gives design limitations on welds.

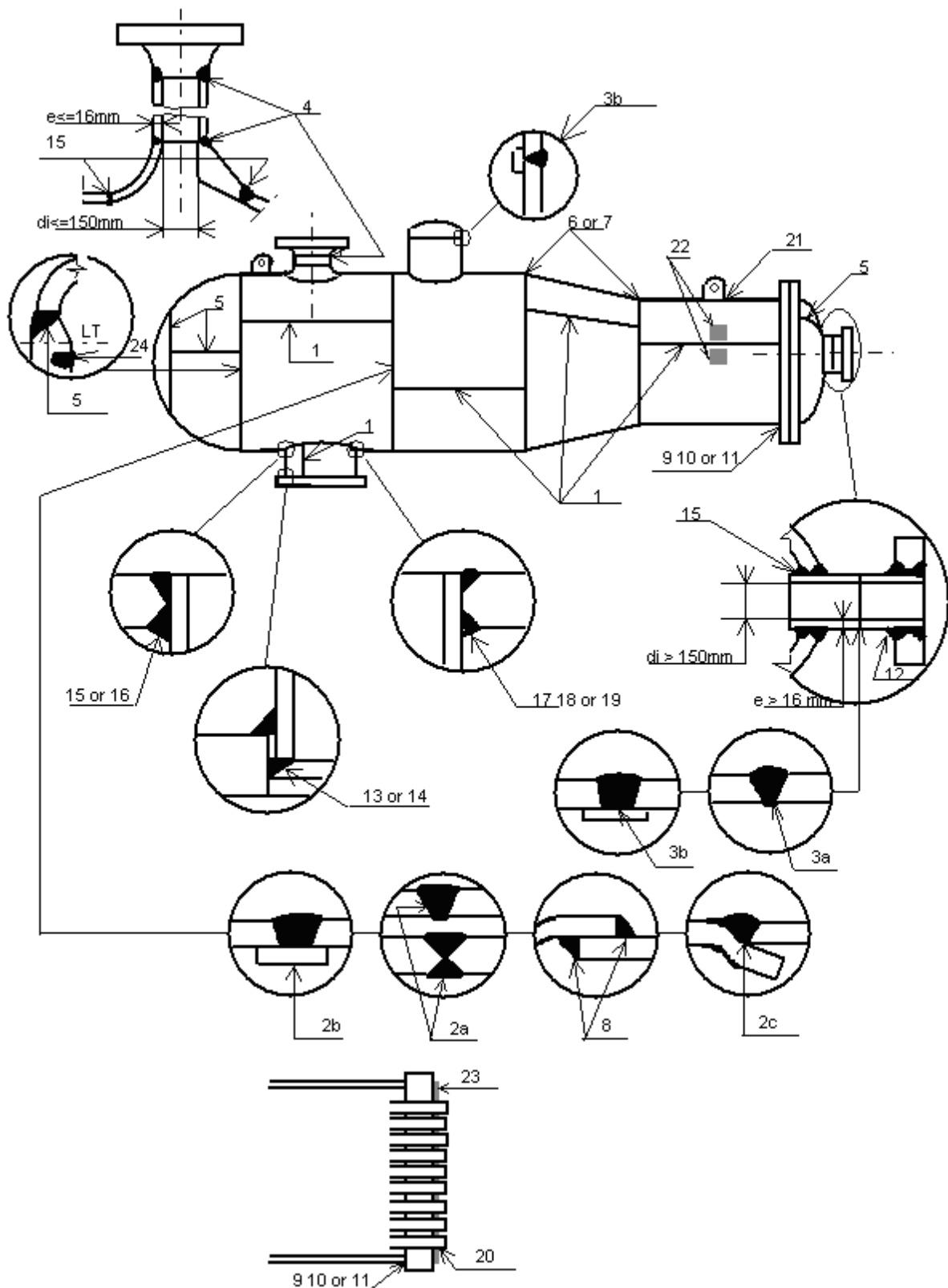
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EN13445-5, Table 6.6.2-3, Map of Weld Types/Weld ID.



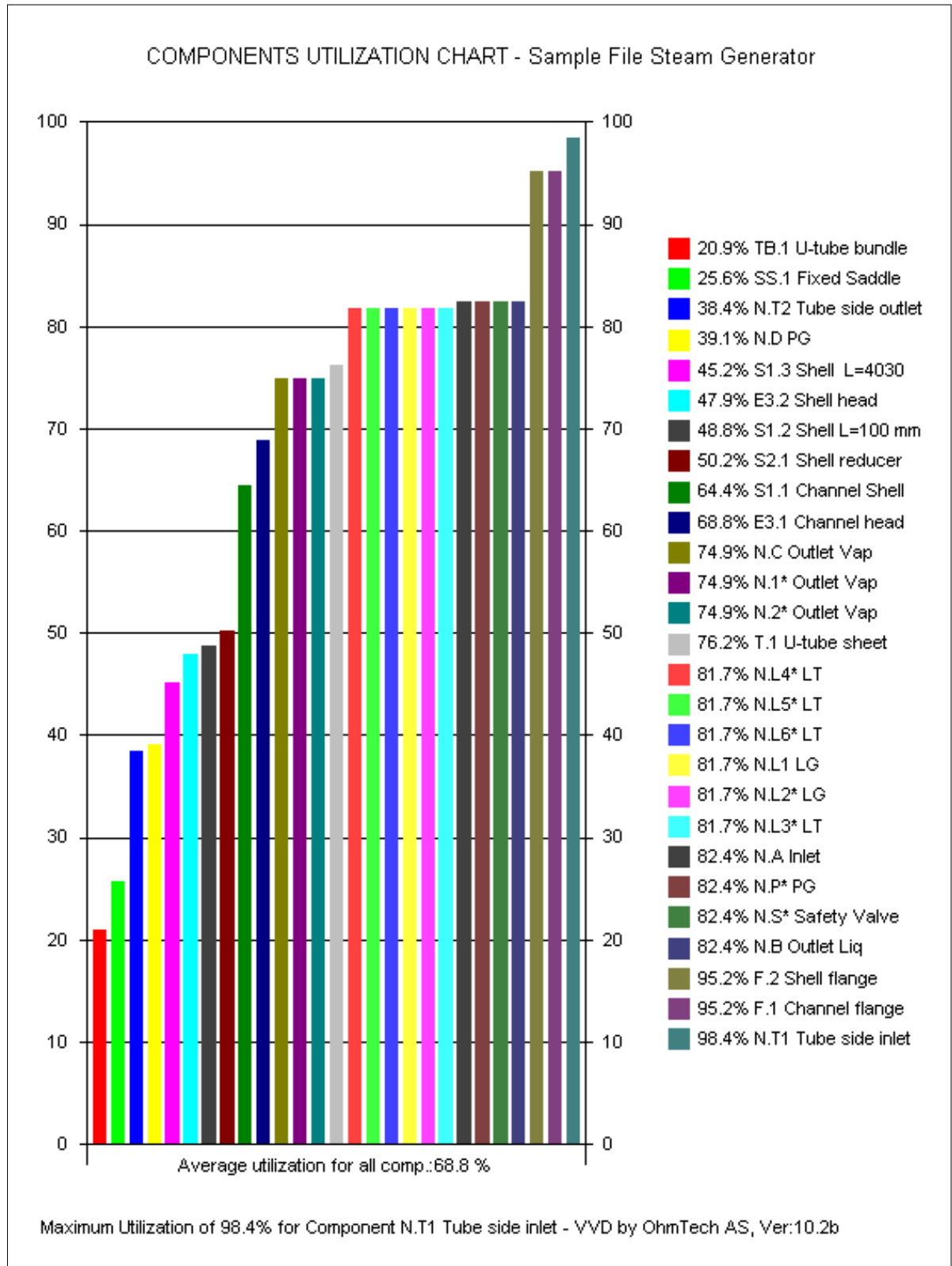
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Utilization Chart

Utilization Chart



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Surface Area

PROCESS CARD NO.: 1 SHELL SIDE

Table Surface Area:

ID	No.	Description	Area Outside(m2)	Area Inside(m2)
F.2	1	WN - Flange, Shell flange	0.334	0.161
S1.2	1	Cylindrical Shell, Shell L=100 mm	0.196	0.192
S2.1	1	Reducers, Shell reducer	1.003	0.971
S1.3	1	Cylindrical Shell, Shell L=4030	10.939	10.711
E3.2	1	Torispherical End, Shell head	0.905	0.884
N.A	1	Nozzle, Forging (LWN), Inlet	0.049	0.032
N.C	1	Nozzle, Seamless Pipe, Outlet Vap	0.106	0.092
N.B	1	Nozzle, Forging (LWN), Outlet Liq	0.049	0.032
N.D	1	Nozzle, Forging (LWN), PG	0.032	0.016
N.P*	1	Nozzle, Forging (LWN), PG	0.049	0.032
N.S*	1	Nozzle, Forging (LWN), Safety Valve	0.049	0.032
N.L1	1	Nozzle, Forging (LWN), LG	0.049	0.032
N.L2*	1	Nozzle, Forging (LWN), LG	0.049	0.032
N.L3*	1	Nozzle, Forging (LWN), LT	0.049	0.032
N.L4*	1	Nozzle, Forging (LWN), LT	0.049	0.032
N.L5*	1	Nozzle, Forging (LWN), LT	0.049	0.032
N.L6*	1	Nozzle, Forging (LWN), LT	0.049	0.032
SS.1	2	Saddle/Ring Support, Fixed Saddle	3.082	0.000
N.1*	1	Nozzle, Seamless Pipe, Outlet Vap	0.106	0.092
N.2*	1	Nozzle, Seamless Pipe, Outlet Vap	0.106	0.092
Total	21		17.299	13.531

PROCESS CARD NO.: 2 TUBE SIDE

Table Surface Area:

ID	No.	Description	Area Outside(m2)	Area Inside(m2)
S1.1	1	Cylindrical Shell, Channel Shell	0.882	0.862
E3.1	1	Torispherical End, Channel head	0.491	0.477
N.T1	1	Nozzle, Seamless Pipe, Tube side inlet	0.106	0.092
N.T2	1	Nozzle, Seamless Pipe, Tube side outlet	0.106	0.092
F.1	1	WN - Flange, Channel flange	0.334	0.161
T.1	1	Tubesheet, U-tube sheet	0.000	0.000
TB.1	1	Tube Bundle, U-tube bundle	82.512	64.251
Total	7		84.431	65.935

SUMMATION OF DATA FOR ALL COMPONENTS :

Total :Ao= 17.299 m2, Ai= 13.531 m2

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Foundation Loading

Table Foundation Loading:

No	Load Case	Fx(kN)	Fy(kN)	Fz(kN)	Mx(kNm)	My(kNm)	Mz(kNm)
1	SS.1-LOAD CASE NO: 1 - HYDROTEST (z = 1347)	-32.77	0.56	0.18	0.08	0.44	0.00
2	SS.1-LOAD CASE NO: 2 - OPER.WIND (z = 1347)	-21.76	1.11	8.54	3.65	0.87	0.00
3	SS.1-LOAD CASE NO: 1 - HYDROTEST (z = 4247)	-27.79	0.53	0.00	0.00	0.42	0.00
4	SS.1-LOAD CASE NO: 2 - OPER.WIND (z = 4247)	-15.09	1.07	5.29	2.25	0.83	0.00

NOMENCLATURE :

F_x(kN) - Force in vertical direction (positive upward)

F_y(kN) - Force in transverse direction

F_z(kN) - Force in axial direction

M_y(kNm) - Longitudinal bending moment at saddle base

M_z(kNm) - Transverse bending moment at saddle base

M_x(kNm) - Not Applicable

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EN13445:2009 Issue 1 - 7.4.2 CYLINDRICAL SHELL

S1.1 Channel Shell 05 Feb. 2010 12:10 PC# 2

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

GENERAL DESIGN DATA

PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Tube Side : Temp= 370°C, P= .85MPa, c= 3mm, Pext= .1MPa

SHELL DATA

CYLINDER FABRICATION: Plate Material
WELD JOINT COEFFICIENT: Testing Group 3 (z=0.85)
DIAMETER INPUT: Base Design on Shell Inside Diameter
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 370'C
Rm=410 Rp=265 Rpt=156 f=104 f20=170.83 ftest=252.38 E=185095(N/mm2) ro=7.85
INSIDE SHELL DIAMETER (corroded).....:Di 610.00 mm
LENGTH OF CYLINDRICAL PART OF SHELL.....:Lcyl 450.00 mm
SAFETY FACTOR (1.0 carbon and 1.25 austenitic steels):s 1.00
AS BUILT WALL THICKNESS (uncorroded).....:en 10.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....:th 0.5000 mm
Split shell into several shell courses and include welding information: NO

DATA FOR STIFFENER RINGS

SHELL STIFFENER RINGS: Shell without stiffening rings
UNSUPPORTED LENGTH OF SHELL (Fig. 8.5-2).....:L 600.00 mm

CALCULATION DATA

7.4.2 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

Required Minimum Shell Thickness Excl.Allow. emin :
 $emin = Di * P / (2 * f * z - P)$ (7.4-1)
 $=610*0.85/(2*104*0.85-0.85)=$ 2.95 mm

Required Minimum Shell Thickness Incl.Allow. :
 $emina = emin + c + th =2.95+3+0.5=$ 6.45 mm

Analysis Thickness
 $ea = en - c - th =10-3-0.5=$ 6.50 mm

»7.4.1 Cond.of Applicability $emin/De=0.0047 \leq 0.16$ « » OK«

»Internal Pressure $emina=6.45 \leq en=10$ [mm] « » (U= 64.4%) OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :

Outside Diameter of Shell
 $De = Di + 2 * (ea + th) =610+2*(6.5+0.5)=$ 624.00 mm

Mean Diameter of Shell
 $Dm = (De + Di) / 2 =(624+610)/2=$ 617.00 mm

MAWP HOT & CORR. (Corroded condition at design temp.)
 $MAWPHC = 2 * f * z * ea / Dm =2*104*0.85*6.5/617=$ 1.86 MPa

MAWP NEW & COLD (Uncorroded condition at ambient temp.)
 $MAWPNC = 2 * f20 * z * (ea + c) / Dm$
 $=2*170.83*0.85*(6.5+3)/617=$ 4.47 MPa

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

$Ptmax = 2 * ftest * ztest * (ea + c) / Dm$
 $=2*252.38*1*(6.5+3)/617=$ 7.77 MPa

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EN13445:2009 Issue 1 - 7.4.2 CYLINDRICAL SHELL

S1.1 Channel Shell 05 Feb. 2010 12:10 PC# 2

EN13445-5;10.2.3.3 REQUIRED MIN.HYDROSTATIC TEST PRESSURE:Ptmin

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3

$$Ptmin = 1.25 * Pd * f_{20} / f = 1.25 * 0.85 * 170.83 / 104 = \underline{1.75 \text{ MPa}}$$

$$Ptmin = 1.43 * Pd = 1.43 * 0.85 = \underline{1.22 \text{ MPa}}$$

»Test Pressure Ptmin=1.75 <= Pmax=7.77[MPa] « » (U= 22.4%) OK«

MAXIMUM DIAMETER OF UNREINFORCED OPENING IN SHELL

Inside Radius of Shell

$$ris = Di / 2 \text{ (9.5-3)} = 610 / 2 = 305.00 \text{ mm}$$

Length of Shell Contributing to Reinforcement

$$Is = \text{Sqr}((2 * ris + ea) * ea) \text{ (9.5-2)} = \text{Sqr}((2 * 305 + 6.5) * 6.5) = 63.30 \text{ mm}$$

Maximum Diameter of Unreinforced Opening in Shell Checked to Rules in Section 9

$$dmax1 = (ea * Is * (f - 0.5 * P) / (P - ris * Is)) / (0.5 * ris + 0.5 * ea) \text{ (9.5-7, 22, 23)} \\ = (6.5 * 63.3 * (104 - 0.5 * 0.85)) / (0.85 - 305 * 63.3) / (0.5 * 305 + 0.5 * 6.5) = \underline{197.95 \text{ mm}}$$

Maximum diameter of Opening Not Requiring Reinforcement Check

$$dmax2 = 0.15 * \text{Sqr}((2 * ris + ea) * ea) \text{ (9.5-18)}$$

$$= 0.15 * \text{Sqr}((2 * 305 + 6.5) * 6.5) = \underline{9.50 \text{ mm}}$$

Maximum Diameter of Unreinforced Opening

$$dmax = \text{MAX}(dmax1, dmax2) = \text{MAX}(197.95, 9.5) = \underline{\underline{197.95 \text{ mm}}}$$

8.5 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

8.5.1.1 Circularity Limits

»The requirements of 8.5.2 and 8.5.3 apply to cylinders that are circular to within 0.5% on radius (i.e. 0.005R) measured from the true centre. The tolerance shall appear on the vessel drawing.

8.4.2 Nominal Elastic Limit Sig_e:

$$Sig_e = R_{pt} \text{ (8.4.2-1)} = 156 = 156.00 \text{ N/mm}^2$$

Preliminary Calculations

$$R = Dm / 2 = 617 / 2 = 308.50 \text{ mm}$$

$$Z = PI * R / L \text{ (8.5.2-7)} = 3.14 * 308.5 / 600 = 1.62$$

$$\Delta = 1.28 / \text{Sqr}(R * ea) \text{ (8.5.3-20)} = 1.28 / \text{Sqr}(308.5 * 6.5) = 0.0286$$

gamma = 0 for No Stiffeners

DETERMINATION OF eps FROM FIGURE 8.5-3 :

eps is a minimum when n= 5

$$eps \text{ (from fig. 8.5-3)} = 0.00149$$

MEMBRANE YIELD py

$$py = Sig_e * ea / (R * (1 - gamma * G)) \text{ (8.5.3-15)}$$

$$= 156 * 6.5 / (308.5 * (1 - 0 * 0)) = \underline{3.29 \text{ MPa}}$$

ELASTIC INSTABILITY pe

$$pm = E * ea * eps / R \text{ (8.5.2-5)} = 1.851E05 * 6.5 * 0.0015 / 308.5 = \underline{5.81 \text{ MPa}}$$

MAX. ALLOWABLE EXTERNAL PRESSURE Pmax

Value pr/py From Figure 8.5-5 Curve 1

$$\text{Value1} = \underline{0.7226}$$

$$pr = \text{Value1} * py = 0.7226 * 3.29 = 2.37 \text{ MPa}$$

Max. Allowable External Pressure

$$Pmax = pr / S \text{ (8.5.2-8)} = 2.37 / 1.5 = \underline{\underline{1.58 \text{ MPa}}}$$

»External Pressure Pmax=1.58 >= Pext=0.1[MPa] « » (U= 6.3%) OK«

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EN13445:2009 Issue 1 - 7.4.2 CYLINDRICAL SHELL

S1.1 Channel Shell 05 Feb. 2010 12:10 PC# 2

CALCULATION SUMMARY

7.4.2 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

Required Minimum Shell Thickness Excl.Allow. e_{min} :

$$e_{min} = D_i * P / (2 * f * z - P) \quad (7.4-1)$$
$$= 610 * 0.85 / (2 * 104 * 0.85 - 0.85) = \underline{\underline{2.95 \text{ mm}}}$$

Required Minimum Shell Thickness Incl.Allow. :

$$e_{min_a} = e_{min} + c + t_h = 2.95 + 3 + 0.5 = \underline{\underline{6.45 \text{ mm}}}$$

»Internal Pressure $e_{min_a}=6.45 \leq e_n=10[\text{mm}]$ « » (U= 64.4%) OK«

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

$P_{tmax} = 2 * f_{test} * z_{test} * (e_a + c) / D_m$

$$= 2 * 252.38 * 1 * (6.5 + 3) / 617 = \underline{\underline{7.77 \text{ MPa}}}$$

EN13445-5;10.2.3.3 REQUIRED MIN.HYDROSTATIC TEST PRESSURE: P_{tmin}

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3

$$P_{tmin} = 1.25 * P_d * f_{20} / f = 1.25 * 0.85 * 170.83 / 104 = \underline{\underline{1.75 \text{ MPa}}}$$

$$P_{tmin} = 1.43 * P_d = 1.43 * 0.85 = \underline{\underline{1.22 \text{ MPa}}}$$

»Test Pressure $P_{tmin}=1.75 \leq P_{tmax}=7.77[\text{MPa}]$ « » (U= 22.4%) OK«

MAXIMUM DIAMETER OF UNREINFORCED OPENING IN SHELL

Maximum Diameter of Unreinforced Opening

$$d_{max} = \text{MAX}(d_{max1}, d_{max2}) = \text{MAX}(197.95, 9.5) = \underline{\underline{197.95 \text{ mm}}}$$

8.5 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

Max. Allowable External Pressure

$$P_{max} = p_r / S \quad (8.5.2-8) = 2.37 / 1.5 = \underline{\underline{1.58 \text{ MPa}}}$$

»External Pressure $P_{max}=1.58 \geq P_{ext}=0.1[\text{MPa}]$ « » (U= 6.3%) OK«

Volume:0.13 m³ Weight:68.1 kg (SG= 7.85)

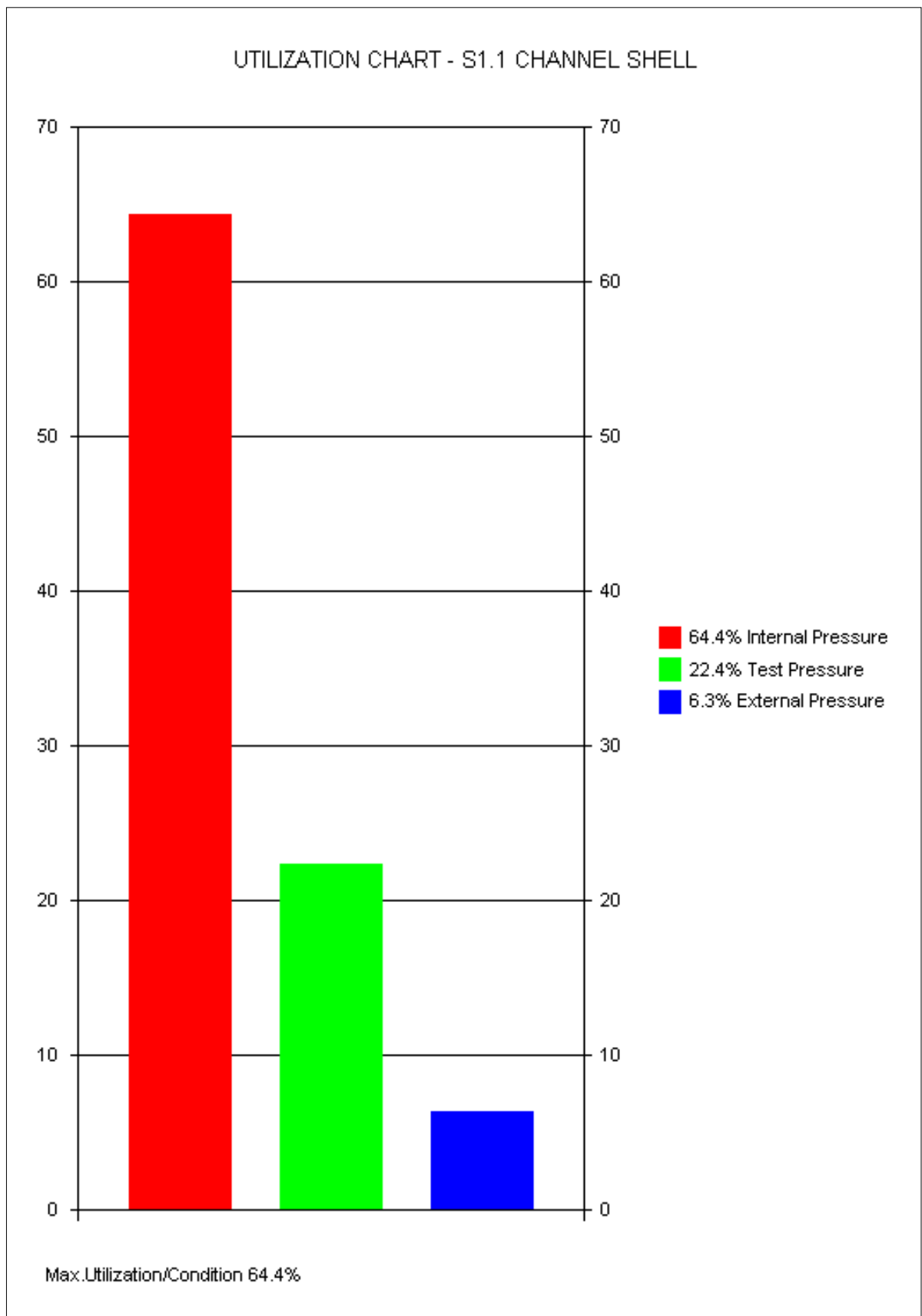
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EN13445:2009 Issue 1 - 7.4.2 CYLINDRICAL SHELL

S1.1 Channel Shell 05 Feb. 2010 12:10 PC# 2



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Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.4.2 CYLINDRICAL SHELL

S1.2 Shell L=100 mm 05 Feb. 2010 12:10 ConnID:F.2 PC# 1

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

Attachment: F.2 WN - Flange Shell flange T.1
Location: Along z-axis z1= 675

GENERAL DESIGN DATA

PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm, Pext= .1MPa

SHELL DATA

CYLINDER FABRICATION: Plate Material
WELD JOINT COEFFICIENT: Testing Group 3 (z=0.85)
DIAMETER INPUT: Base Design on Shell Inside Diameter
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
Rm=410 Rp=265 Rpt=194.12 f=129.41 f20=170.83 ftest=252.38 E=196147(N/mm²) ro=7.85
INSIDE SHELL DIAMETER (corroded).....:Di 610.00 mm
LENGTH OF CYLINDRICAL PART OF SHELL.....:Lcyl 100.00 mm
SAFETY FACTOR (1.0 carbon and 1.25 austenitic steels):s 1.00
AS BUILT WALL THICKNESS (uncorroded).....:en 10.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....:th 0.5000 mm
Split shell into several shell courses and include welding information: NO

DATA FOR STIFFENER RINGS

SHELL STIFFENER RINGS: Shell without stiffening rings
UNSUPPORTED LENGTH OF SHELL (Fig. 8.5-2).....:L 100.00 mm

CALCULATION DATA

7.4.2 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

Required Minimum Shell Thickness Excl.Allow. emin : (7.4-1)
emin = Di * P / (2 * f * z - P)
=610*0.5/(2*129.41*0.85-0.5)= 1.39 mm

Required Minimum Shell Thickness Incl.Allow. :
emina = emin + c + th =1.39+3+0.5= 4.89 mm

Analysis Thickness
ea = en - c - th =10-3-0.5= 6.50 mm

»7.4.1 Cond.of Applicability emin/De=0.0022 <= 0.16« » OK«
»Internal Pressure emina=4.89 <= en=10[mm] « » (U= 48.8%) OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :

Outside Diameter of Shell
De = Di + 2 * (ea + th) =610+2*(6.5+0.5)= 624.00 mm

Mean Diameter of Shell
Dm = (De + Di) / 2 =(624+610)/2= 617.00 mm

MAWP HOT & CORR. (Corroded condition at design temp.)
MAWPHC = 2 * f * z * ea / Dm =2*129.41*0.85*6.5/617= 2.32 MPa

MAWP NEW & COLD (Uncorroded condition at ambient temp.)
MAWPNC = 2 * f20 * z * (ea + c) / Dm
=2*170.83*0.85*(6.5+3)/617= 4.47 MPa

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

Ptmax = 2 * ftest * ztest * (ea + c) / Dm
=2*252.38*1*(6.5+3)/617= 7.77 MPa

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Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.4.2 CYLINDRICAL SHELL

S1.2 Shell L=100 mm 05 Feb. 2010 12:10 ConnID:F.2 PC# 1

EN13445-5;10.2.3.3 REQUIRED MIN.HYDROSTATIC TEST PRESSURE:Ptmin

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3

$$Ptmin = 1.25 * Pd * f_{20} / f = 1.25 * 0.5 * 170.83 / 129.41 = \underline{0.8250 \text{ MPa}}$$

$$Ptmin = 1.43 * Pd = 1.43 * 0.5 = \underline{0.7150 \text{ MPa}}$$

»Test Pressure Ptmin=0.825 <= Pmax=7.77[MPa] « » (U= 10.6%) OK«

MAXIMUM DIAMETER OF UNREINFORCED OPENING IN SHELL

Inside Radius of Shell

$$ris = Di / 2 \text{ (9.5-3)} = 610 / 2 = 305.00 \text{ mm}$$

Length of Shell Contributing to Reinforcement

$$Is = \text{Sqr}((2 * ris + ea) * ea) \text{ (9.5-2)} = \text{Sqr}((2 * 305 + 6.5) * 6.5) = 63.30 \text{ mm}$$

Maximum Diameter of Unreinforced Opening in Shell Checked to Rules in Section 9

$$dmax1 = (ea * Is * (f - 0.5 * P) / (P - ris * Is)) / (0.5 * ris + 0.5 * ea) \text{ (9.5-7, 22, 23)} \\ = (6.5 * 63.3 * (129.41 - 0.5 * 0.5) / (0.5 - 305 * 63.3)) / (0.5 * 305 + 0.5 * 6.5) = \underline{305.00 \text{ mm}}$$

Maximum diameter of Opening Not Requiring Reinforcement Check

$$dmax2 = 0.15 * \text{Sqr}((2 * ris + ea) * ea) \text{ (9.5-18)} \\ = 0.15 * \text{Sqr}((2 * 305 + 6.5) * 6.5) = \underline{9.50 \text{ mm}}$$

Maximum Diameter of Unreinforced Opening

$$dmax = \text{MAX}(dmax1, dmax2) = \text{MAX}(305, 9.5) = \underline{\underline{305.00 \text{ mm}}}$$

8.5 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

8.5.1.1 Circularity Limits

»The requirements of 8.5.2 and 8.5.3 apply to cylinders that are circular to within 0.5% on radius (i.e. 0.005R) measured from the true centre. The tolerance shall appear on the vessel drawing.

8.4.2 Nominal Elastic Limit Sige:

$$Sige = Rpt \text{ (8.4.2-1)} = 194.12 = 194.12 \text{ N/mm}^2$$

Preliminary Calculations

$$R = Dm / 2 = 617 / 2 = 308.50 \text{ mm}$$

$$Z = PI * R / L \text{ (8.5.2-7)} = 3.14 * 308.5 / 100 = 9.69$$

$$\Delta = 1.28 / \text{Sqr}(R * ea) \text{ (8.5.3-20)} = 1.28 / \text{Sqr}(308.5 * 6.5) = 0.0286$$

gamma = 0 for No Stiffeners

DETERMINATION OF eps FROM FIGURE 8.5-3 :

eps is a minimum when n= 9

$$eps \text{ (from fig. 8.5-3)} = 0.011957$$

MEMBRANE YIELD py

$$py = Sige * ea / (R * (1 - gamma * G)) \text{ (8.5.3-15)} \\ = 194.12 * 6.5 / (308.5 * (1 - 0 * 0)) = \underline{4.09 \text{ MPa}}$$

ELASTIC INSTABILITY pe

$$pm = E * ea * eps / R \text{ (8.5.2-5)} = 196147 * 6.5 * 0.012 / 308.5 = \underline{49.42 \text{ MPa}}$$

MAX. ALLOWABLE EXTERNAL PRESSURE Pmax

Value pr/py From Figure 8.5-5 Curve 1

$$\text{Value1} = = 0.9585$$

$$pr = \text{Value1} * py = 0.9585 * 4.09 = 3.92 \text{ MPa}$$

Max. Allowable External Pressure

$$Pmax = pr / S \text{ (8.5.2-8)} = 3.92 / 1.5 = \underline{\underline{2.61 \text{ MPa}}}$$

»External Pressure Pmax=2.61 >= Pext=0.1[MPa] « » (U= 3.8%) OK«

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.4.2 CYLINDRICAL SHELL

S1.2 Shell L=100 mm 05 Feb. 2010 12:10 ConnID:F.2 PC# 1

CALCULATION SUMMARY

7.4.2 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

Required Minimum Shell Thickness Excl.Allow. e_{min} :

$$e_{min} = D_i * P / (2 * f * z - P) \quad (7.4-1)$$
$$= 610 * 0.5 / (2 * 129.41 * 0.85 - 0.5) = \underline{\underline{1.39 \text{ mm}}}$$

Required Minimum Shell Thickness Incl.Allow. :

$$e_{min_a} = e_{min} + c + t_h = 1.39 + 3 + 0.5 = \underline{\underline{4.89 \text{ mm}}}$$

»Internal Pressure $e_{min_a}=4.89 \leq e_n=10[\text{mm}]$ « » (U= 48.8%) OK«

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

$P_{tmax} = 2 * f_{test} * z_{test} * (e_a + c) / D_m$

$$= 2 * 252.38 * 1 * (6.5 + 3) / 617 = \underline{\underline{7.77 \text{ MPa}}}$$

EN13445-5;10.2.3.3 REQUIRED MIN.HYDROSTATIC TEST PRESSURE: P_{tmin}

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3

$$P_{tmin} = 1.25 * P_d * f_{20} / f = 1.25 * 0.5 * 170.83 / 129.41 = \underline{\underline{0.8250 \text{ MPa}}}$$

$$P_{tmin} = 1.43 * P_d = 1.43 * 0.5 = \underline{\underline{0.7150 \text{ MPa}}}$$

»Test Pressure $P_{tmin}=0.825 \leq P_{tmax}=7.77[\text{MPa}]$ « » (U= 10.6%) OK«

MAXIMUM DIAMETER OF UNREINFORCED OPENING IN SHELL

Maximum Diameter of Unreinforced Opening

$$d_{max} = \text{MAX}(d_{max1}, d_{max2}) = \text{MAX}(305, 9.5) = \underline{\underline{305.00 \text{ mm}}}$$

8.5 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

Max. Allowable External Pressure

$$P_{max} = p_r / S \quad (8.5.2-8) = 3.92 / 1.5 = \underline{\underline{2.61 \text{ MPa}}}$$

»External Pressure $P_{max}=2.61 \geq P_{ext}=0.1[\text{MPa}]$ « » (U= 3.8%) OK«

Volume:0.03 m³ Weight:15.1 kg (SG= 7.85)

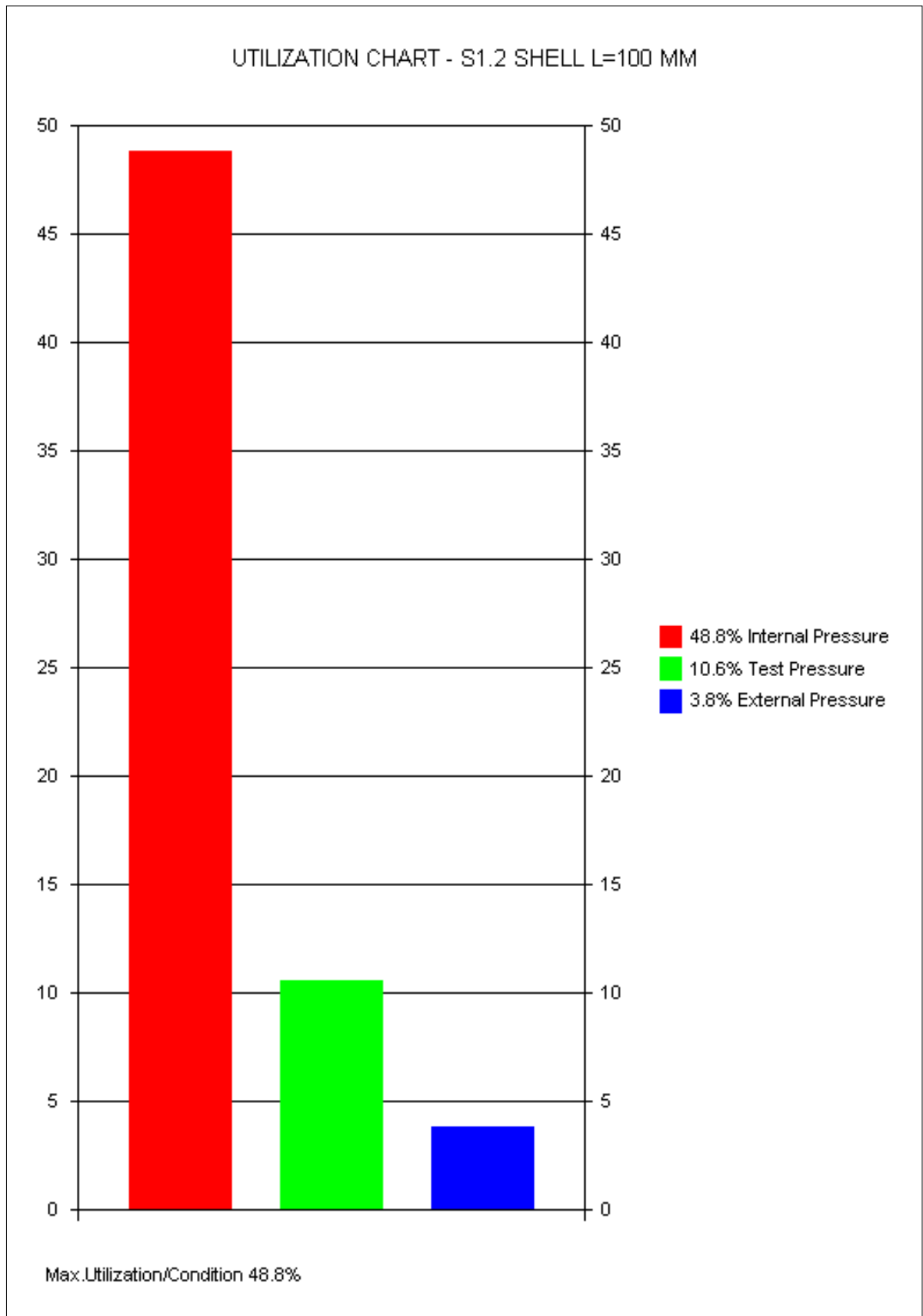
Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.4.2 CYLINDRICAL SHELL

S1.2 Shell L=100 mm 05 Feb. 2010 12:10 ConnID:F.2 PC# 1



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Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.4.2 CYLINDRICAL SHELL

S1.3 Shell L=4030 05 Feb. 2010 12:10 ConnID:S2.1 PC# 1

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

Attachment: S2.1 Reducers Shell reducer S1.2
Location: Along z-axis z1= 1183

GENERAL DESIGN DATA

PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm, Pext= .1MPa

SHELL DATA

CYLINDER FABRICATION: Plate Material
WELD JOINT COEFFICIENT: Testing Group 3 (z=0.85)
DIAMETER INPUT: Base Design on Shell Inside Diameter
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
Rm=410 Rp=265 Rpt=194.12 f=129.41 f20=170.83 ftest=252.38 E=196147(N/mm²) ro=7.85
INSIDE SHELL DIAMETER (corroded).....:Di 846.00 mm
LENGTH OF CYLINDRICAL PART OF SHELL.....:Lcyl 4030.00 mm
SAFETY FACTOR (1.0 carbon and 1.25 austenitic steels):s 1.00
AS BUILT WALL THICKNESS (uncorroded).....:en 12.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....:th 0.5000 mm
Split shell into several shell courses and include welding information: NO

DATA FOR STIFFENER RINGS

SHELL STIFFENER RINGS: Shell without stiffening rings
UNSUPPORTED LENGTH OF SHELL (Fig. 8.5-2).....:L 4151.00 mm

CALCULATION DATA

7.4.2 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

Required Minimum Shell Thickness Excl.Allow. emin : (7.4-1)
 $emin = Di * P / (2 * f * z - P)$
 $=846*0.5/(2*129.41*0.85-0.5)=$ 1.93 mm

Required Minimum Shell Thickness Incl.Allow. :
 $emina = emin + c + th =1.93+3+0.5=$ 5.43 mm

Analysis Thickness
 $ea = en - c - th =12-3-0.5=$ 8.50 mm

»7.4.1 Cond.of Applicabilty $emin/De=0.0022 <= 0.16$ « » OK«
»Internal Pressure $emina=5.43 <= en=12[mm]$ « » (U= 45.2%) OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :

Outside Diameter of Shell
 $De = Di + 2 * (ea + th) =846+2*(8.5+0.5)=$ 864.00 mm

Mean Diameter of Shell
 $Dm = (De + Di) / 2 =(864+846)/2=$ 855.00 mm

MAWP HOT & CORR. (Corroded condition at design temp.)
 $MAWPHC = 2 * f * z * ea / Dm =2*129.41*0.85*8.5/855=$ 2.19 MPa

MAWP NEW & COLD (Uncorroded condition at ambient temp.)
 $MAWPNC = 2 * f20 * z * (ea + c) / Dm$
 $=2*170.83*0.85*(8.5+3)/855=$ 3.91 MPa

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

$Ptmax = 2 * ftest * ztest * (ea + c) / Dm$
 $=2*252.38*1*(8.5+3)/855=$ 6.79 MPa

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.4.2 CYLINDRICAL SHELL

S1.3 Shell L=4030 05 Feb. 2010 12:10 ConnID:S2.1 PC# 1

EN13445-5;10.2.3.3 REQUIRED MIN.HYDROSTATIC TEST PRESSURE:Ptmin

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3

$$Ptmin = 1.25 * Pd * f_{20} / f = 1.25 * 0.5 * 170.83 / 129.41 = \underline{0.8250 \text{ MPa}}$$

$$Ptmin = 1.43 * Pd = 1.43 * 0.5 = \underline{0.7150 \text{ MPa}}$$

»Test Pressure Ptmin=0.825 <= Pmax=6.79[MPa] « » (U= 12.1%) OK«

MAXIMUM DIAMETER OF UNREINFORCED OPENING IN SHELL

Inside Radius of Shell

$$ris = Di / 2 (9.5-3) = 846 / 2 = 423.00 \text{ mm}$$

Length of Shell Contributing to Reinforcement

$$Is = \text{Sqr}((2 * ris + ea) * ea) (9.5-2) = \text{Sqr}((2 * 423 + 8.5) * 8.5) = 85.22 \text{ mm}$$

Maximum Diameter of Unreinforced Opening in Shell Checked to Rules in Section 9

$$dmax1 = (ea * Is * (f - 0.5 * P) / (P - ris * Is)) / (0.5 * ris + 0.5 * ea) (9.5-7, 22, 23) \\ = (8.5 * 85.22 * (129.41 - 0.5 * 0.5) / (0.5 * 423 * 85.22)) / (0.5 * 423 + 0.5 * 8.5) = \underline{423.00 \text{ mm}}$$

Maximum diameter of Opening Not Requiring Reinforcement Check

$$dmax2 = 0.15 * \text{Sqr}((2 * ris + ea) * ea) (9.5-18)$$

$$= 0.15 * \text{Sqr}((2 * 423 + 8.5) * 8.5) = \underline{12.78 \text{ mm}}$$

Maximum Diameter of Unreinforced Opening

$$dmax = \text{MAX}(dmax1, dmax2) = \text{MAX}(423, 12.78) = \underline{\underline{423.00 \text{ mm}}}$$

8.5 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

8.5.1.1 Circularity Limits

»The requirements of 8.5.2 and 8.5.3 apply to cylinders that are circular to within 0.5% on radius (i.e. 0.005R) measured from the true centre. The tolerance shall appear on the vessel drawing.

8.4.2 Nominal Elastic Limit Sige:

$$Sige = Rpt (8.4.2-1) = 194.12 = 194.12 \text{ N/mm}^2$$

Preliminary Calculations

$$R = Dm / 2 = 855 / 2 = 427.50 \text{ mm}$$

$$Z = PI * R / L (8.5.2-7) = 3.14 * 427.5 / 4151 = 0.3235$$

$$\Delta = 1.28 / \text{Sqr}(R * ea) (8.5.3-20) = 1.28 / \text{Sqr}(427.5 * 8.5) = 0.0212$$

gamma = 0 for No Stiffeners

DETERMINATION OF eps FROM FIGURE 8.5-3 :

eps is a minimum when n= 3

$$eps (\text{from fig. 8.5-3}) = 0.000312$$

MEMBRANE YIELD py

$$py = Sige * ea / (R * (1 - gamma * G)) (8.5.3-15)$$

$$= 194.12 * 8.5 / (427.5 * (1 - 0 * 0)) = \underline{3.86 \text{ MPa}}$$

ELASTIC INSTABILITY pe

$$pm = E * ea * eps / R (8.5.2-5) = 196147 * 8.5 * 3.1174E-04 / 427.5 = \underline{1.22 \text{ MPa}}$$

MAX. ALLOWABLE EXTERNAL PRESSURE Pmax

Value pr/py From Figure 8.5-5 Curve 1

$$\text{Value1} = = 0.1570$$

$$pr = \text{Value1} * py = 0.157 * 3.86 = 0.6061 \text{ MPa}$$

Max. Allowable External Pressure

$$Pmax = pr / S (8.5.2-8) = 0.6061 / 1.5 = \underline{\underline{0.4041 \text{ MPa}}}$$

»External Pressure Pmax=0.4041 >= Pext=0.1[MPa] « » (U= 24.7%) OK«

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.4.2 CYLINDRICAL SHELL

S1.3 Shell L=4030 05 Feb. 2010 12:10 ConnID:S2.1 PC# 1

CALCULATION SUMMARY

7.4.2 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

Required Minimum Shell Thickness Excl.Allow. e_{min} :

$$e_{min} = D_i * P / (2 * f * z - P) \quad (7.4-1)$$
$$= 846 * 0.5 / (2 * 129.41 * 0.85 - 0.5) = \underline{\underline{1.93 \text{ mm}}}$$

Required Minimum Shell Thickness Incl.Allow. :

$$e_{min_a} = e_{min} + c + t_h = 1.93 + 3 + 0.5 = \underline{\underline{5.43 \text{ mm}}}$$

»Internal Pressure $e_{min_a}=5.43 \leq e_n=12[\text{mm}]$ « » (U= 45.2%) OK«

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

$P_{tmax} = 2 * f_{test} * z_{test} * (e_a + c) / D_m$

$$= 2 * 252.38 * 1 * (8.5 + 3) / 855 = \underline{\underline{6.79 \text{ MPa}}}$$

EN13445-5;10.2.3.3 REQUIRED MIN.HYDROSTATIC TEST PRESSURE: P_{tmin}

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3

$$P_{tmin} = 1.25 * P_d * f_{20} / f = 1.25 * 0.5 * 170.83 / 129.41 = \underline{\underline{0.8250 \text{ MPa}}}$$

$$P_{tmin} = 1.43 * P_d = 1.43 * 0.5 = \underline{\underline{0.7150 \text{ MPa}}}$$

»Test Pressure $P_{tmin}=0.825 \leq P_{tmax}=6.79[\text{MPa}]$ « » (U= 12.1%) OK«

MAXIMUM DIAMETER OF UNREINFORCED OPENING IN SHELL

Maximum Diameter of Unreinforced Opening

$$d_{max} = \text{MAX}(d_{max1}, d_{max2}) = \text{MAX}(423, 12.78) = \underline{\underline{423.00 \text{ mm}}}$$

8.5 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

Max. Allowable External Pressure

$$P_{max} = p_r / S \quad (8.5.2-8) = 0.6061 / 1.5 = \underline{\underline{0.4041 \text{ MPa}}}$$

»External Pressure $P_{max}=0.4041 \geq P_{ext}=0.1[\text{MPa}]$ « » (U= 24.7%) OK«

Volume:2.27 m³ Weight:1016.1 kg (SG= 7.85)

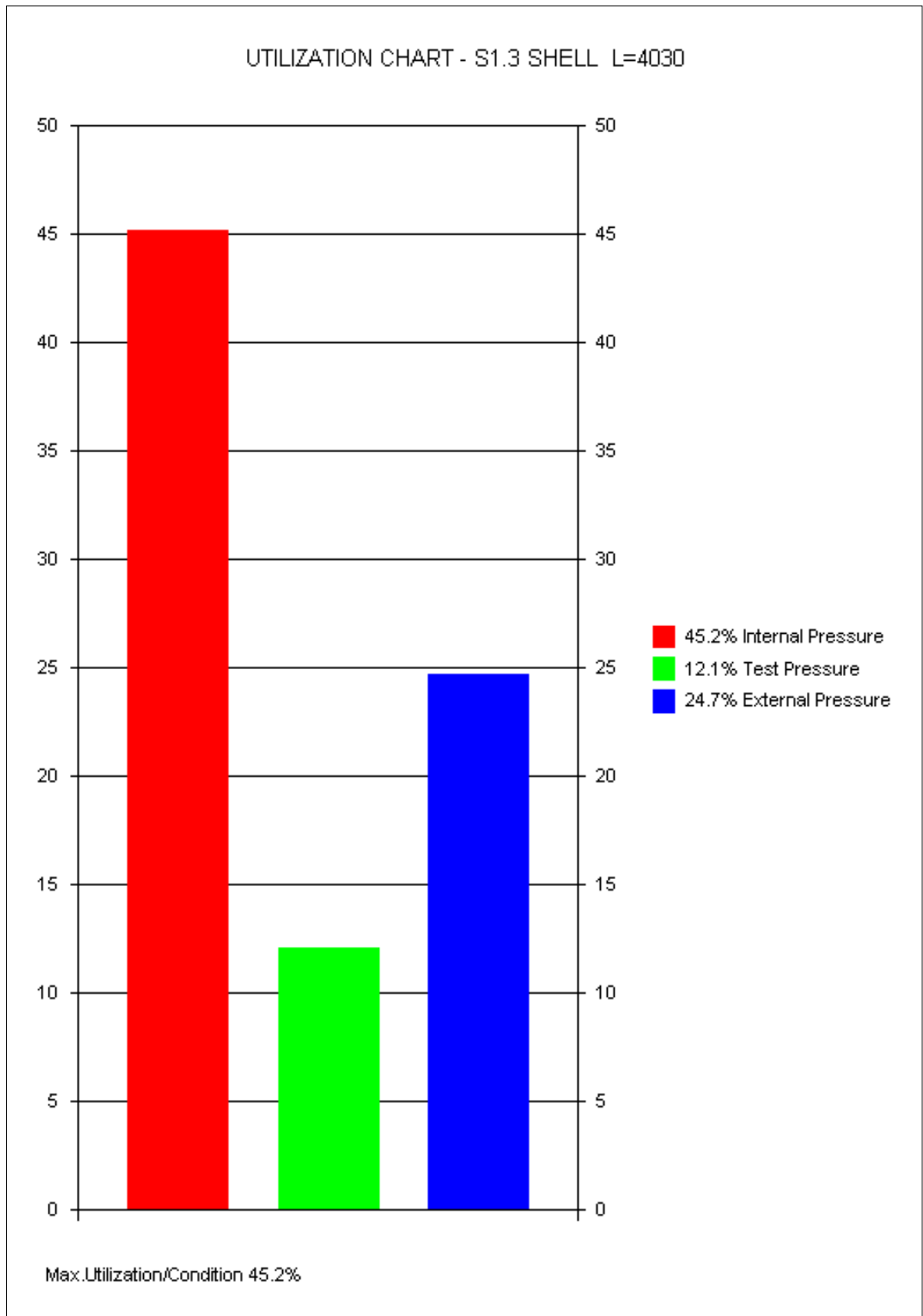
Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.4.2 CYLINDRICAL SHELL

S1.3 Shell L=4030 05 Feb. 2010 12:10 ConnID:S2.1 PC# 1



Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-01 Operator : Rev.:A

EN13480-3:2002/A3:2009 - 6.4 REDUCERS

S2.1 Shell reducer 05 Feb. 2010 12:10 ConnID:S1.2 PC# 1

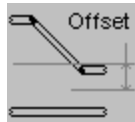
INPUT DATA

COMPONENT ATTACHMENT/LOCATION

Attachment: S1.2 Cylindrical Shell Shell L=100 mm F.2
Location: Along z-axis z1= 775

GENERAL DESIGN DATA

PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm, Pext= .1MPa
Base of Cone Connecting Component: Connected Comp.S1.2 is at SMALL base of cone



Type of Transitions: Offset Conical Shells

DATA FOR CONE

Specify the Total Length of the Conical Section
WELD JOINT COEFFICIENT: Testing Group 3 (z=0.85)
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
Rm=410 Rp=265 Rpt=194.12 f=129.41 f20=170.83 ftest=252.38 E=196147(N/mm2) ro=7.85
TOTAL LENGTH OF THE CONE IN THE CENTERLINE DIRECTION:Lc 408.00 mm
INSIDE RADIUS OF CURVATURE(large base of cone).....:rL 0.00 mm
OFFSET BETWEEN THE CENTERLINES OF ADJOINING CYL.SHELLS:Lo 118.00 mm
SAFETY FACTOR (1.0 carbon and 1.25 austenitic steels):s 1.00
UNSUPPORTED LENGTH OF PIPE (Fig. 9.3.1-1).....:L 408.00 mm
AS BUILT THICKNESS OF THE CONE.....:en 12.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....:th 0.5000 mm

DATA FOR CYL.SHELL AT LARGE BASE OF CONE

EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
Rm=410 Rp=265 Rpt=194.12 fl=129.41 fl20=170.83 fltest=252.38 E
=196147(N/mm2) ro= =7.85
INSIDE DIAMETER AT LARGE BASE OF CONE(corroded).....:DiL 846.00 mm
AS BUILT THK.OF CYLINDER AT LARGE JUNCTION(uncorr.)..:enL 12.00 mm
WELD JOINT COEFFICIENT: Testing Group 3 (z=0.85)

DATA FOR CYL.SHELL AT SMALL BASE OF CONE

EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
Rm=410 Rp=265 Rpt=194.12 fs=129.41 fs20=170.83 fstest=252.38 E
=196147(N/mm2) ro= =7.85
INSIDE DIAMETER AT SMALL BASE OF CONE(corroded).....:DiS 610.00 mm
AS BUILT THK.OF CYLINDER AT SMALL JUNCTION(uncorr.)..:enS 10.00 mm
WELD JOINT COEFFICIENT: Testing Group 3 (z=0.85)

DATA FOR STIFFENER RINGS

Shell without stiffening rings

CALCULATION DATA

SECT. 6.4 - REDUCERS UNDER INTERNAL PRESSURE

Calculated angle of conical shell, alfa :
alfa = ATN((0.5 * (DiL - DiS) + Lo) / Lc)
=ATN((0.5*(846-610)+118)/408)= 30.05 degr.

6.4.4 CONICAL SHELLS

l2 = Sqr((DiL + emin) * emin / Cos(alfa))
=Sqr((846+2.17)*2.17/Cos(30.05))= 45.76 mm
Dk = DiL - 2 * rL * (1 - Cos(alfa)) - l2 * Sin(alfa) (6.4.4-7)
=846-2*0*(1-Cos(30.05))-45.76*Sin(30.05)= 823.09 mm

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-01 Operator : Rev.:A

EN13480-3:2002/A3:2009 - 6.4 REDUCERS

S2.1 Shell reducer 05 Feb. 2010 12:10 ConnID:S1.2 PC# 1

Required Cone Thickness at Large Base Excl.Allow. e_{min} :
 $e_{min} = P * Dk / (2 * f * z - P) / \text{Cos}(\alpha)$ (6.4.4-1)
 $= 0.5 * 823.09 / (2 * 129.41 * 0.85 - 0.5) / \text{Cos}(30.05) =$ 2.17 mm

Required Cone Thickness at Large Base Incl.Allow. e_{minA} :
 $e_{minA} = e_{min} + c + th = 2.17 + 3 + 0.5 =$ 5.67 mm

»Cone Thk. $e_{minA}=5.67 \leq e_n=12$ [mm] « » (U= 47.2%) OK«

Required Cone Thickness at Small Base Incl.Allow. e_{minS} :
 $e_{minS} = P * DiS / (2 * f * z - P) / \text{Cos}(\alpha) + c + th$ (6.4.4-1)
 $= 0.5 * 610 / (2 * 129.41 * 0.85 - 0.5) / \text{Cos}(30.05) + 3 + 0.5 =$ 5.11 mm

Analysis Thickness
 $ea = e_n - c - th = 12 - 3 - 0.5 =$ 8.50 mm
 $Dm = DiL + ea / \text{Cos}(\alpha) = 846 + 8.5 / \text{Cos}(30.05) =$ 855.82 mm

6.4.6 JUNCTION BETWEEN THE LARGE END OF CONE AND CYL.WITHOUT KNUCKLE

Required Thickness of Cylinder at Large Base of Cone
 $ecylL = P * DiL / (2 * fl * z - P)$ (6.4.4-1)
 $= 0.5 * 846 / (2 * 129.41 * 0.85 - 0.5) =$ 1.93 mm

$DcL = DiL + ecylL = 846 + 1.927 =$ 847.93 mm
 $\text{InvCos} = 1 / (\text{Sqr}(\text{Cos}(\alpha))) = 1 / (\text{Sqr}(\text{Cos}(30.05))) =$ 1.07

$\beta = \text{Sqr}(DcL / ejL) / 3 * \text{Tan}(\alpha) / (1 + \text{InvCos}) - 0.15$
 $= \text{Sqr}(847.93 / 2.53) / 3 * \text{Tan}(30.05) / (1 + 1.07) - 0.15 =$ 1.55
 $ej = P * DcL * \beta / (2 * f)$ (6.4.6-2)
 $= 0.5 * 847.93 * 1.55 / (2 * 129.41) =$ 2.54 mm

Required cylinder thickness near junction e_{1L} :

$e_{1L}(\text{min})(\text{corroded})$ largest of $ecylL, ej =$ 2.53 mm

Required Minimum Shell Thickness Incl.Allow. :
 $e_{1minL} = e_{1L} + c = 2.53 + 3 =$ 5.53 mm

»Cylinder Thk.Large Base $e_{1minL}=5.53 \leq e_n=12$ [mm] « » (U= 46.1%) OK«

Min. extend of the increased cylinder thickness L_{cyl} :

From the junction
 $L_{cylL} = 1.4 * \text{Sqr}(DcL * e_{1L}) = 1.4 * \text{Sqr}(847.93 * 2.53) =$ 64.87 mm

Required cone thickness near junction e_{2L} :

$e_{2L}(\text{min})(\text{corroded})$ largest of $e_{min}, ej =$ 2.53 mm

Required Minimum Cone Thickness Incl.Allow. :
 $e_{2minL} = e_{2L} + c + th = 2.53 + 3 + 0.5 =$ 6.03 mm

»Cone Thk.Near Junction $e_{2minL}=6.03 \leq e_n=12$ [mm] « » (U= 50.2%) OK«

Min. extend of the increased cone thickness L_{cone} :

From the junction
 $L_{coneL} = 1.4 * \text{Sqr}(DcL * e_{2L} / \text{cos}(\alpha))$
 $= 1.4 * \text{Sqr}(847.93 * 2.53 / \text{cos}(30.05)) =$ 69.73 mm

6.4.8 JUNCTION AT THE SMALL BASE OF CONE

Required Cylinder Thk.at Small Base of Cone Based on Cone Analysis Thk.

$ecylS = P * DiS / (2 * fs * z - P)$
 $= 0.5 * 610 / (2 * 129.41 * 0.85 - 0.5) =$ 1.39 mm

$e_{2S} = e_n - c - th = 12 - 3 - 0.5 =$ 8.50 mm

$DcS = DiS + ecylS = 610 + 1.39 =$ 611.39 mm

$s = e_{2S} / e_{1S} = 8.5 / 1.16 =$ 7.38

$\tau = 1 + \text{Sqr}((1 + s^2) * s / (2 * \text{cos}(\alpha)))$ (6.4.8-3)

$= 1 + \text{Sqr}((1 + 7.38^2) * 7.38 / (2 * \text{cos}(30.05))) =$ 16.07

$\beta = 0.4 * \text{Sqr}(DcS / e_{1S}) * \text{Tan}(\alpha) / \tau + 0.5$ (6.4.8-4)

$= 0.4 * \text{Sqr}(611.39 / 1.16) * \text{Tan}(30.05) / 16.07 + 0.5 =$ 0.8315

$e_{1S} = P * DcS * \beta / (2 * f * z)$
 $= 0.5 * 611.39 * 0.8315 / (2 * 129.41 * 0.85) =$ 1.16 mm

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Visual Vessel Design by OhmTech Ver:10.2-01 Operator : Rev.:A

EN13480-3:2002/A3:2009 - 6.4 REDUCERS

S2.1 Shell reducer 05 Feb. 2010 12:10 ConnID:S1.2 PC# 1

Required cylinder thickness near junction e1S :

$e1(\min)(\text{corroded})$ largest of e_{cylS} , $e1S = ==$ 1.39 mm
Required Minimum Shell Thickness Incl.Allow. :
 $e1\min S = e1S + c = 1.16 + 3 =$ 4.39 mm

»Cylinder Thk.Small Base $e1\min S = 4.39 \leq e_n S = 10[\text{mm}] \llcorner \llcorner$ (U= 43.8%) OK«

Min. extend of the increased cylinder thickness Lcyl :

$L_{cylS} = \text{SQR}(DcS * e1S) = \text{SQR}(611.39 * 1.16) =$ 29.15 mm

Required cone thickness near junction e2S :

$e2(\min)(\text{corroded})$ largest of e_{\min} , $e2S = ==$ 8.50 mm
Required Minimum Cone Thickness Incl.Allow. :
 $e2\min S = e2S + c + th = 8.5 + 3 + 0.5 =$ 12.00 mm

Min. extend of the increased cone thickness Lcone :

$L_{\text{cone}S} = \text{SQR}(DcS * e2S / \cos(\text{alfa}))$
 $= \text{SQR}(611.39 * 8.5 / \cos(30.05)) =$ 77.48 mm

6.4.1 Conditions of Applicability - Conical Shells

»a) Half angle at the apex of the cone $\text{alfa} = 30.05 \leq 75[\text{degr}] \llcorner \llcorner$ OK«

»b) Geometry Check $e_a * \cos(\text{alfa}) / DcL = 0.0087 > 0.001 \llcorner \llcorner$ OK«

»c) The requirements do NOT apply for short cones joining a jacket to a shell

6.4.6.1 Conditions of Applicability - Junction Without Knuckle (large base)

»a) The joint is a butt weld where the inside and outside surfaces merge smoothly with the adjacent cone and cylinder without local reduction in thickness.

»b) the weld at the junction shall be subject to 100 % non-destructive examination, either by radiography or ultrasonic techniques, unless the design is such that the thickness at the weld exceeds $1.4e_j$, in which case the normal rules for the relevant construction category shall be applied.

6.4.8.1 Conditions of Applicability - Junction at Small Base

»a) The required thickness of the cylinder $e1$ is maintained for a distance $l1$ and that of the cone $e2$ is maintained for a distance $l2$ from the junction

6.4.9 Conditions of Applicability - Offset Cones

» The cylinders shall have parallel centre lines.

» Offset less than difference of radii $L_o = 118 \leq (D_iL - D_iS) / 2 = 118 \llcorner \llcorner$ OK«

MAWP New & Cold (Ambient Temp. & Uncorroded)

Analysis Thickness

$e_a = e_n - c_a - th = 12 - 0 - 0.5 =$ 11.50 mm

Conical Shell

$P_{\text{max}c} = 2 * f_a * z * e_a * \text{Cos}(\text{alfa}) / D_m$
 $= 2 * 170.83 * 0.85 * 11.5 * \text{Cos}(30.05) / 855.82 =$ 3.38 MPa

6.4.6.3 Rating - Junction at Large Base of Cone Without Knuckle

Max.Allowable Pressure of Cylinder at Large Base of Cone

$P_{\text{cyl}L} = 2 * f_L * z * (e_nL - c_a - th) / D_m$ (6.4.4-3)

$= 2 * 170.83 * 0.85 * (12 - 0 - 0.5) / 855.82 =$ 3.90 MPa

$P_{\text{max}1L} = 2 * f_a * e_j / (DcL * \text{beta}1)$ (6.4.6-4)

$= 2 * 170.83 * 2.54 / (847.93 * 0.6479) =$ 7.15 MPa

$P_{\text{max}L}$ is the smallest of ($P_{\text{max}1L}$ and $P_{\text{cyl}L}$) = $P_{\text{max}L}$

$= 3.9 =$ 3.90 MPa

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6.4.8.3 Rating - Junction at Small Base of Cone

Max.Allowable Pressure of Cylinder at Small Base of Cone
 $P_{cylS} = 2 * fS * z * (enS - ca - th) / (DiS + enS)$ (6.4.6-3)
 $= 2 * 170.83 * 0.85 * (10 - 0 - 0.5) / (610 + 10) =$ 4.45 MPa
 τ (from equation 6.4.8-2/3) = 2.312952
 β_{eH} (from equation 6.4.8-4) = 1.302478
 $P_{max1S} = 2 * fa * z * ea / (DcS * \beta_{eH})$ (6.4.7-5)
 $= 2 * 170.83 * 0.85 * 9.5 / (611.39 * 1.3) =$ 3.46 MPa
 P_{maxS} is the smallest of (P_{max1S} and P_{cylS}) = P_{maxS}
 $= 3.46 =$ 3.46 MPa
 P_{max} is the smallest of (P_{maxc} , P_{maxL} and P_{maxS}) = P_{max}
 $= 3.38 =$ 3.38 MPa

MAWP Hot & Corroded (Design Temp.)

Analysis Thickness
 $ea = en - ca - th = 12 - 3 - 0.5 =$ 8.50 mm
Conical Shell
 $P_{maxc} = 2 * fa * z * ea * \cos(\alpha) / Dm$
 $= 2 * 129.41 * 0.85 * 8.5 * \cos(30.05) / 855.82 =$ 1.89 MPa

6.4.6.3 Rating - Junction at Large Base of Cone Without Knuckle

Max.Allowable Pressure of Cylinder at Large Base of Cone
 $P_{cylL} = 2 * fL * z * (enL - ca - th) / Dm$ (6.4.4-3)
 $= 2 * 129.41 * 0.85 * (12 - 3 - 0.5) / 855.82 =$ 2.19 MPa
 $P_{max1L} = 2 * fa * ej / (DcL * \beta_{eL})$ (6.4.6-4)
 $= 2 * 129.41 * 2.54 / (847.93 * 0.7781) =$ 3.33 MPa
 P_{maxL} is the smallest of (P_{max1L} and P_{cylL}) = P_{maxL}
 $= 2.19 =$ 2.19 MPa

6.4.8.3 Rating - Junction at Small Base of Cone

Max.Allowable Pressure of Cylinder at Small Base of Cone
 $P_{cylS} = 2 * fS * z * (enS - ca - th) / (DiS + enS)$ (6.4.6-3)
 $= 2 * 129.41 * 0.85 * (10 - 3 - 0.5) / (610 + 10) =$ 2.31 MPa
 τ (from equation 6.4.8-2/3) = 2.430746
 β_{eH} (from equation 6.4.8-4) = 1.423136
 $P_{max1S} = 2 * fa * z * ea / (DcS * \beta_{eH})$ (6.4.7-5)
 $= 2 * 129.41 * 0.85 * 6.5 / (611.39 * 1.42) =$ 1.64 MPa
 P_{maxS} is the smallest of (P_{max1S} and P_{cylS}) = P_{maxS}
 $= 1.64 =$ 1.64 MPa
 P_{max} is the smallest of (P_{maxc} , P_{maxL} and P_{maxS}) = P_{max}
 $= 1.64 =$ 1.64 MPa

Max Hydro Test Pressure - New (Ambient Temp. & Uncorroded)

Analysis Thickness
 $ea = en - ca - th = 12 - 0 - 0.5 =$ 11.50 mm
Conical Shell
 $P_{maxc} = 2 * fa * z * ea * \cos(\alpha) / Dm$
 $= 2 * 252.38 * 1 * 11.5 * \cos(30.05) / 855.82 =$ 5.87 MPa

6.4.6.3 Rating - Junction at Large Base of Cone Without Knuckle

Max.Allowable Pressure of Cylinder at Large Base of Cone
 $P_{cylL} = 2 * fL * z * (enL - ca - th) / Dm$ (6.4.4-3)
 $= 2 * 252.38 * 0.85 * (12 - 0 - 0.5) / 855.82 =$ 5.77 MPa
 $P_{max1L} = 2 * fa * ej / (DcL * \beta_{eL})$ (6.4.6-4)
 $= 2 * 252.38 * 2.54 / (847.93 * 0.6479) =$ 10.57 MPa
 P_{maxL} is the smallest of (P_{max1L} and P_{cylL}) = P_{maxL}
 $= 5.77 =$ 5.77 MPa

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Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-01 Operator : Rev.:A

EN13480-3:2002/A3:2009 - 6.4 REDUCERS

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6.4.8.3 Rating - Junction at Small Base of Cone

Max.Allowable Pressure of Cylinder at Small Base of Cone
 $P_{cylS} = 2 * fS * z * (enS - ca - th) / (DiS + enS)$ (6.4.6-3)
 $= 2 * 252.38 * 0.85 * (10 - 0 - 0.5) / (610 + 10) =$ 6.57 MPa
 τ (from equation 6.4.8-2/3) = 2.312952
 β_{tH} (from equation 6.4.8-4) = 1.302478
 $P_{max1S} = 2 * fa * z * e_{1a} / (DcS * \beta_{tH})$ (6.4.7-5)
 $= 2 * 252.38 * 1 * 9.5 / (611.39 * 1.3) =$ 6.02 MPa
 P_{maxS} is the smallest of (P_{max1S} and P_{cylS}) = P_{maxS}
 $= 6.02 =$ 6.02 MPa
 P_{max} is the smallest of (P_{maxc} , P_{maxL} and P_{maxS}) = P_{max}
 $= 5.77 =$ 5.77 MPa

EN13445-5;10.2.3.3 REQUIRED MIN.HYDROSTATIC TEST PRESSURE:Ptmin

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3
 $P_{tmin} = 1.25 * Pd * f_{20} / f = 1.25 * 0.5 * 170.83 / 129.41 =$ 0.8250 MPa
 $P_{tmin} = 1.43 * Pd = 1.43 * 0.5 =$ 0.7150 MPa

»Test Pressure $P_{tmin}=0.825 \leq P_{tmax}=5.77$ [MPa] « » (U= 14.3%) OK«

SECT. 9.4 - REDUCER/CONICAL SHELL UNDER EXTERNAL PRESSURE

8.5.1.1 Circularity Limits

Preliminary Calculations

Mean Radius of Conical Shell
 $R_{mean} = (DiL + DiS) / 4 + 0.5 * e_a / \cos(\alpha)$
 $= (846 + 610) / 4 + 0.5 * 8.5 / \cos(30.05) =$ 368.91 mm
Maximum Radius of Conical Shell
 $R_{max} = DiL / 2 + e_a / \cos(\alpha)$
 $= 846 / 2 + 8.5 / \cos(30.05) =$ 432.82 mm

8.4.2 Nominal Elastic Limit Sig_e:

$Sig_e = R_{pt} (8.4.2-1) = 194.12 =$ 194.12 N/mm²

9.3.2 Interstiffener Collapse

$p_y = e_a * Sig_e * \cos(\alpha) / R_{max}$ (9.3.2-1)
 $= 8.5 * 194.12 * \cos(30.05) / 432.82 =$ 3.30 MPa
 $Z = \pi * R_{mean} * \cos(\alpha) / L$
 $= 3.14 * 368.91 * \cos(30.05) / 408 =$ 2.46
 ϵ is a minimum when $n=6$
 ϵ (from fig. 8.5-3) = 0.003419
 $p_m = E * e_a * \epsilon * (\cos(\alpha))^3 / R_{mean}$ (9.3.2-2)
 $= 196147 * 8.5 * 0.0034 * (\cos(30.05))^3 / 368.91 =$ 10.02 MPa

MAX. ALLOWABLE EXTERNAL PRESSURE P_{max}

Value p_r/p_y From Figure 8.5-5 Curve 1
 $Value1 = =$ 0.8376
 $p_r = Value1 * p_y = 0.8376 * 3.3 =$ 2.76 MPa
Max. Allowable External Pressure
 $P_{max} = p_r / S = 2.76 / 1.5 =$ 1.84 MPa

»External Pressure $P_{max}=1.84 \geq P_{ext}=0.1$ [MPa] « » (U= 5.4%) OK«

CALCULATION SUMMARY

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-01 Operator : Rev.:A

EN13480-3:2002/A3:2009 - 6.4 REDUCERS

S2.1 Shell reducer 05 Feb. 2010 12:10 ConnID:S1.2 PC# 1

SECT. 6.4 - REDUCERS UNDER INTERNAL PRESSURE

6.4.4 CONICAL SHELLS

Required Cone Thickness at Large Base Incl.Allow. e_{minA} :

$$e_{minA} = e_{min} + c + th = 2.17 + 3 + 0.5 =$$

5.67 mm

»Cone Thk. $e_{minA}=5.67 \leq e_n=12$ [mm] « » (U= 47.2%) OK«

Required Cone Thickness at Small Base Incl.Allow. e_{minS} :

$$e_{minS} = P * DiS / (2 * f * z - P) / \cos(\alpha) + c + th$$

(6.4.4-1)

$$= 0.5 * 610 / (2 * 129.41 * 0.85 - 0.5) / \cos(30.05) + 3 + 0.5 =$$

5.11 mm

6.4.6 JUNCTION BETWEEN THE LARGE END OF CONE AND CYL.WITHOUT KNUCKLE

»Cylinder Thk.Large Base $e_{1minL}=5.53 \leq e_nL=12$ [mm] « » (U= 46.1%) OK«

»Cone Thk.Near Junction $e_{2minL}=6.03 \leq e_n=12$ [mm] « » (U= 50.2%) OK«

6.4.8 JUNCTION AT THE SMALL BASE OF CONE

»Cylinder Thk.Small Base $e_{1minS}=4.39 \leq e_nS=10$ [mm] « » (U= 43.8%) OK«

MAWP New & Cold (Ambient Temp. & Uncorroded)

P_{max} is the smallest of (P_{maxC} , P_{maxL} and P_{maxS}) = P_{max}

$$= 3.38 =$$

3.38 MPa

MAWP Hot & Corroded (Design Temp.)

P_{max} is the smallest of (P_{maxC} , P_{maxL} and P_{maxS}) = P_{max}

$$= 1.64 =$$

1.64 MPa

Max Hydro Test Pressure - New (Ambient Temp. & Uncorroded)

P_{max} is the smallest of (P_{maxC} , P_{maxL} and P_{maxS}) = P_{max}

$$= 5.77 =$$

5.77 MPa

EN13445-5;10.2.3.3 REQUIRED MIN.HYDROSTATIC TEST PRESSURE: P_{tmin}

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3

$$P_{tmin} = 1.25 * P_d * f_{20} / f = 1.25 * 0.5 * 170.83 / 129.41 =$$

0.8250 MPa

$$P_{tmin} = 1.43 * P_d = 1.43 * 0.5 =$$

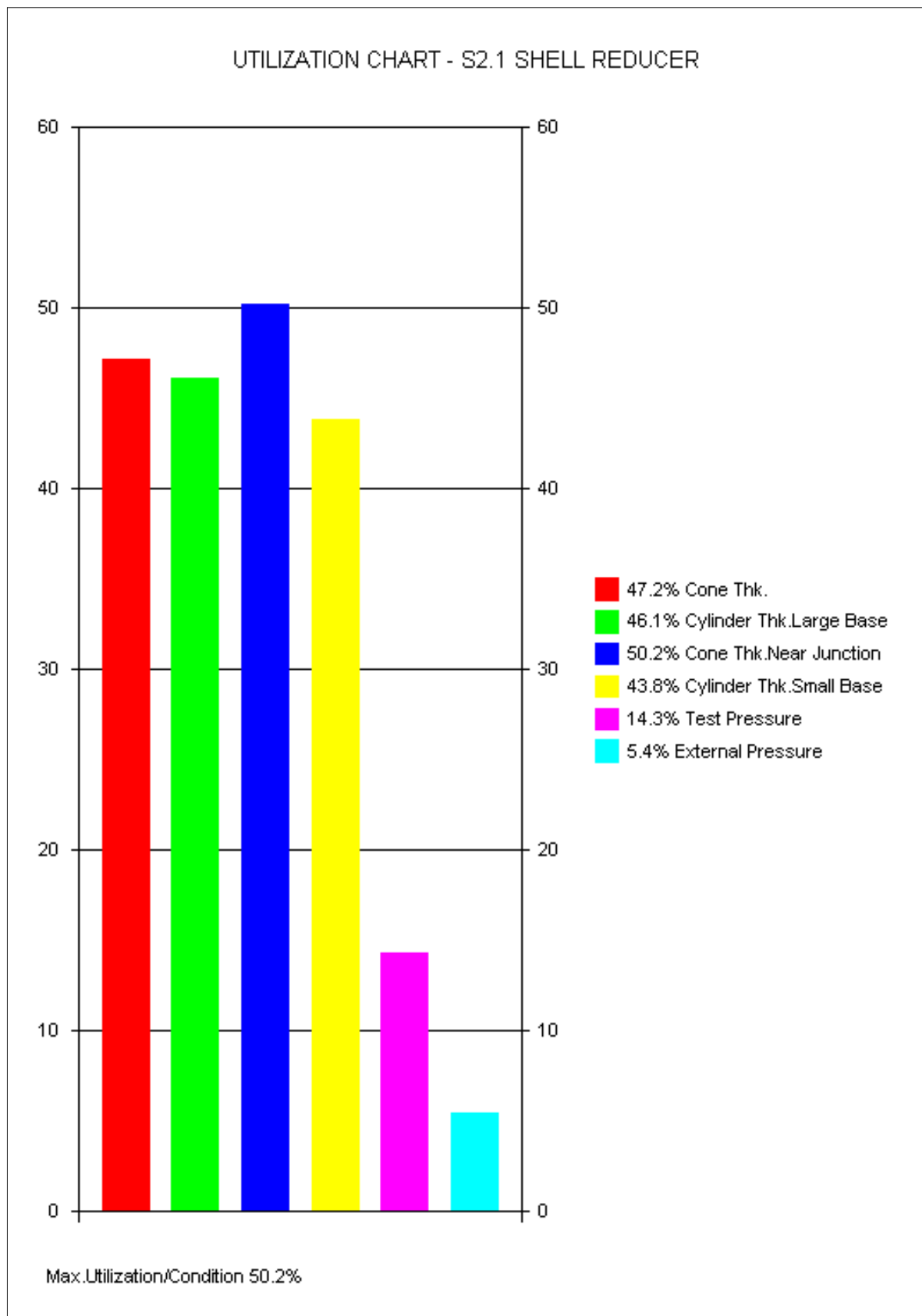
0.7150 MPa

»Test Pressure $P_{tmin}=0.825 \leq P_{tmax}=5.77$ [MPa] « » (U= 14.3%) OK«

SECT. 9.4 - REDUCER/CONICAL SHELL UNDER EXTERNAL PRESSURE

»External Pressure $P_{max}=1.84 \geq P_{ext}=0.1$ [MPa] « » (U= 5.4%) OK«

Volume:0.17 m3 Weight:89.9 kg (SG= 7.85)



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Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.5 DOMED ENDS

E3.1 Channel head 05 Feb. 2010 12:10 ConnID:S1.1 PC# 2

INPUT DATA

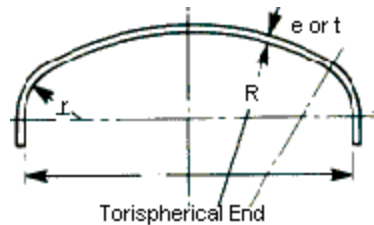
COMPONENT ATTACHMENT/LOCATION

Attachment: S1.1 Cylindrical Shell Channel Shell
Location: Along z-axis zo= 0

GENERAL DESIGN DATA

PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Tube Side : Temp= 370°C, P= .85MPa, c= 3mm, Pext= .1MPa

DIMENSIONS OF END



Type of Torispherical End: Dished End KORBBOGEN DIN 28013-28014/SMS 482

WELD JOINT COEFFICIENT: Unwelded Component (z=1.0)

OUTSIDE DIAMETER OF CYLINDRICAL FLANGE OF END.....:De	624.00 mm
LENGTH OF CYLINDRICAL FLANGE OF END.....:Lcyl	35.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....:th	0.00 mm
AS BUILT THICKNESS OF HEAD/END (uncorroded).....:en	8.50 mm

MATERIAL DATA FOR END

EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 370'C
Rm=410 Rp=265 Rpt=156 f=104 f20=170.83 ftest=252.38 E=185095(N/mm2) ro=7.85
SAFETY FACTOR (1.0 carbon and 1.25 austenitic steels):s 1.00
Material & Delivery Form: NOT Cold Spun Seamless Austenitic Stainless Steel

NOZZLES IN KNUCKLE REGION TO SECTION 7.7

Nozzles In Knuckle Region: NO

CALCULATION DATA

7.5.3 - TORISPHERICAL ENDS UNDER INTERNAL PRESSURE

7.5.3.2 Required Minimum End Thickness

Required Thickness of End to Limit Membrane Stress in Central Part

$$e_s = P * R / (2 * f * z - 0.5 * P) \quad (7.5-1)$$

$$= 0.85 * 499.2 / (2 * 104 * 1 - 0.5 * 0.85) = \underline{2.04 \text{ mm}}$$

$$f_b = R_{pt} / 1.5 \quad (7.5-4) = 156 / 1.5 = 104.00 \text{ N/mm}^2$$

Required Thickness of Knuckle to Avoid Plastic Buckling

$$e_b = (0.75 * R + 0.2 * D_i) * ((P / (111 * f_b)) * (D_i / r)^{0.825})^{(0.667)} \quad (7.5-3)$$

$$= (0.75 * 499.2 + 0.2 * 613) * ((0.85 / (111 * 104)) * (613 / 96.096)^{0.825})^{(0.667)} = \underline{2.41 \text{ mm}}$$

7.5.3.5 Formulas for Calculation of Factor Beta

$$Y = \text{MIN}(e_{min} / R, 0.04) \quad (7.5-9) = \text{MIN}(2.84 / 499.2, 0.04) = 0.0057$$

$$Z = \text{LOG}(1 / Y) \quad (7.5-10) = \text{LOG}(1 / 0.0057) = 2.25$$

$$X = r / D_i \quad (7.5-11) = 96.096 / 618.32 = 0.1554$$

$$N = 1.006 - 1 / (6.2 + (90 * Y)^4) \quad (7.5-12)$$

$$= 1.006 - 1 / (6.2 + (90 * 0.0057)^4) = 0.8465$$

$$\text{Beta}01 = N * (-0.1833 * Z^3 + 1.0383 * Z^2 - 1.2943 * Z + 0.837) \quad (7.5-15)$$

$$= 0.8465 * (-0.1833 * 2.25^3 + 1.0383 * 2.25^2 - 1.2943 * 2.25 + 0.837) = 0.9230$$

$$\text{Beta}02 = \text{MAX}(0.5, 0.95 * (0.56 - 1.94 * Y - 82.5 * Y^2)) \quad (7.5-17)$$

$$= \text{MAX}(0.5, 0.95 * (0.56 - 1.94 * 0.0057 - 82.5 * 0.0057^2)) = 0.5190$$

$$\text{beta} = 10 * ((0.2 - X) * \text{Beta}01 + (X - 0.1) * \text{Beta}02) \quad (7.5-16)$$

$$= 10 * ((0.2 - 0.1554) * 0.923 + (0.1554 - 0.1) * 0.519) = 0.6991$$

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.5 DOMED ENDS

E3.1 Channel head 05 Feb. 2010 12:10 ConnID:S1.1 PC# 2

Required Thickness of Knuckle to Avoid Axisymmetric Yielding

$$e_y = \beta * P * (0.75 * R + 0.2 * D_i) / f \quad (7.5-2)$$
$$= 0.6991 * 0.85 * (0.75 * 499.2 + 0.2 * 613) / 104 = 2.85 \text{ mm}$$

Required Minimum End Thickness Excl.Allow. e_{min} :

$$e_{min} = e_{min} = 2.85 = 2.85 \text{ mm}$$

Required Minimum End Thickness Incl.Allow. :

$$e_{minA} = e_{min} + c + t_h = 2.85 + 3 + 0 = 5.85 \text{ mm}$$

»Internal Pressure $e_{minA}=5.85 \leq e_n=8.5$ [mm] « » (U= 68.8%) OK«

Analysis Thickness

$$e_a = e_n - c - t_h = 8.5 - 3 - 0 = 5.50 \text{ mm}$$

Inside Diameter of Shell

$$D_i = D_e - 2 * (e_n - c) = 624 - 2 * (8.5 - 3) = 613.00 \text{ mm}$$

Mean Diameter of Shell

$$D_m = (D_e + D_i) / 2 = (624 + 613) / 2 = 618.50 \text{ mm}$$

7.5.3.4 - Required Minimum Thickness of Straight Cylindrical Flange

$$L_{lim} = 0.2 * \sqrt{D_i * e_{min}} = 0.2 * \sqrt{613 * 2.85} = 8.35 \text{ mm}$$

Since $L_{cyl} > L_{lim}$, Required Thickness of Straight Cylindrical Flange to 7.4.2

Minimum Thickness of Straight Flange Excl. Allow.

$$e_{cyl} = P * D_i / (2 * f * z - P) \quad (7.4-1)$$
$$= 0.85 * 613 / (2 * 104 * 1 - 0.85) = 2.52 \text{ mm}$$

7.5.3.1 Conditions of Applicability - Torispherical Ends

»Geometry Check $r=96.096 \leq 0.2 * D_i=122.6$ [mm] « » OK«

»Geometry Check $r=96.096 \geq 0.06 * D_i=36.78$ [mm] « » OK«

»Geometry Check $r=96.096 \geq 2 * e=2.85$ [mm] « » OK«

»Geometry Check $e=2.85 \leq 0.08 * D_e=49.92$ [mm] « » OK«

»Geometry Check $e_a=5.5 \geq 0.001 * D_e=0.624$ [mm] « » OK«

»Geometry Check $R=499.2 \leq D_e=624$ [mm] « » OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD

$$P_s = 2 * f * z * e_a / (R + 0.5 * e_a) \quad (7.5-6)$$

$$= 2 * 170.83 * 1 * 8.5 / (496.2 + 0.5 * 8.5) = 5.80 \text{ MPa}$$

$$P_y = f * e_a / (\beta * (0.75 * R + 0.2 * D_i)) \quad (7.5-7)$$

$$= 170.83 * 8.5 / (0.595 * (0.75 * 496.2 + 0.2 * 613)) = 4.93 \text{ MPa}$$

$$P_B = 111 * f_b * (e_a / (0.75 * R + 0.2 * D_i))^{1.5} * (r / D_i)^{0.825} \quad (7.5-8)$$

$$= 111 * 176.67 * (8.5 / (0.75 * 496.2 + 0.2 * 613))^{1.5} * (96.096 / 613)^{0.825} = 9.57 \text{ MPa}$$

$$P_{max} \text{ (is the least of } P_s, P_y \text{ and } P_b) = P_{max} = 4.93 = 4.93 \text{ MPa}$$

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR

$$P_s = 2 * f * z * e_a / (R + 0.5 * e_a) \quad (7.5-6)$$

$$= 2 * 104 * 1 * 5.5 / (499.2 + 0.5 * 5.5) = 2.28 \text{ MPa}$$

$$P_y = f * e_a / (\beta * (0.75 * R + 0.2 * D_i)) \quad (7.5-7)$$

$$= 104 * 5.5 / (0.625 * (0.75 * 499.2 + 0.2 * 613)) = 1.84 \text{ MPa}$$

$$P_B = 111 * f_b * (e_a / (0.75 * R + 0.2 * D_i))^{1.5} * (r / D_i)^{0.825} \quad (7.5-8)$$

$$= 111 * 104 * (5.5 / (0.75 * 499.2 + 0.2 * 613))^{1.5} * (96.096 / 613)^{0.825} = 2.91 \text{ MPa}$$

$$P_{max} \text{ (is the least of } P_s, P_y \text{ and } P_b) = P_{max} = 1.84 = 1.84 \text{ MPa}$$

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

$$P_s = 2 * f * z * e_a / (R + 0.5 * e_a) \quad (7.5-6)$$

$$= 2 * 252.38 * 1 * 8.5 / (496.2 + 0.5 * 8.5) = 8.57 \text{ MPa}$$

$$P_y = f * e_a / (\beta * (0.75 * R + 0.2 * D_i)) \quad (7.5-7)$$

$$= 252.38 * 8.5 / (0.595 * (0.75 * 496.2 + 0.2 * 613)) = 7.29 \text{ MPa}$$

$$P_B = 111 * f_b * (e_a / (0.75 * R + 0.2 * D_i))^{1.5} * (r / D_i)^{0.825} \quad (7.5-8)$$

$$= 111 * 252.38 * (8.5 / (0.75 * 496.2 + 0.2 * 613))^{1.5} * (96.096 / 613)^{0.825} = 13.68 \text{ MPa}$$

$$P_{max} \text{ (is the least of } P_s, P_y \text{ and } P_b) = P_{max} = 7.29 = 7.29 \text{ MPa}$$

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.5 DOMED ENDS

E3.1 Channel head 05 Feb. 2010 12:10 ConnID:S1.1 PC# 2

EN13445-5;10.2.3.3 REQUIRED MIN.HYDROSTATIC TEST PRESSURE:Ptmin

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3

$$Ptmin = 1.25 * Pd * f_{20} / f = 1.25 * 0.85 * 170.83 / 104 = \underline{\underline{1.75 \text{ MPa}}}$$

$$Ptmin = 1.43 * Pd = 1.43 * 0.85 = \underline{\underline{1.22 \text{ MPa}}}$$

»Test Pressure Ptmin=1.75 <= Pmax=7.29[MPa] « » (U= 23.9%) OK«

Maximum diameter of Opening Not Requiring Reinforcement Check , dmax

$$ris = R (9.5-4) = 499.2 = 499.20 \text{ mm}$$

Length of Shell Contributing to Reinforcement

$$Is = \text{Sqr}((2 * ris + ea) * ea) \quad (9.5-2)$$

$$= \text{Sqr}((2 * 499.2 + 5.5) * 5.5) = 74.31 \text{ mm}$$

Maximum Diameter of Unreinforced Opening in Shell Checked to Rules in Section 9

$$dmax1 = (ea * Is * (f - 0.5 * P) / P - ris * Is) / (0.5 * ris + 0.5 * ea) \quad (9.5-7, 22, 23)$$

$$= (5.5 * 74.31 * (104 - 0.5 * 0.85) / 0.85 - 499.2 * 74.31) / (0.5 * 499.2 + 0.5 * 5.5) = \underline{\underline{50.35 \text{ mm}}}$$

Maximum diameter of Opening Not Requiring Reinforcement Check

$$dmax2 = 0.15 * \text{Sqr}((2 * ris + ea) * ea) \quad (9.5-18)$$

$$= 0.15 * \text{Sqr}((2 * 499.2 + 5.5) * 5.5) = \underline{\underline{11.15 \text{ mm}}}$$

Maximum Diameter of Unreinforced Opening

$$dmax = \text{MAX}(dmax1, dmax2) = \text{MAX}(50.35, 11.15) = \underline{\underline{50.35 \text{ mm}}}$$

8.7 - SPHERICAL SHELL UNDER EXTERNAL PRESSURE

8.4.2 Nominal Elastic Limit Sige:

$$Sige = Rpt (8.4.2-1) = 156 = 156.00 \text{ N/mm}^2$$

Mean Radius R:

$$Rmean = R + ea / 2 = 499.2 + 5.5 / 2 = 501.95 \text{ mm}$$

MEMBRANE YIELD py

$$py = 2 * Sige * ea / Rmean (8.7.1-1) = 2 * 156 * 5.5 / 501.95 = \underline{\underline{3.42 \text{ MPa}}}$$

ELASTIC INSTABILITY pm

$$pm = 1.21 * E * ea^2 / Rmean^2 \quad (8.7.1-2)$$

$$= 1.21 * 1.851 \text{E}05 * 5.5^2 / 501.95^2 = \underline{\underline{26.89 \text{ MPa}}}$$

Value pr/py From Figure 8.5-5 Curve 2

$$Value1 = == 0.5700$$

MAX. ALLOWABLE EXTERNAL PRESSURE Pmax

$$pr = Value1 * py = 0.57 * 3.42 = 1.95 \text{ MPa}$$

$$Pmax = pr / S = 1.95 / 1.5 = \underline{\underline{1.30 \text{ MPa}}}$$

»External Pressure Pmax=1.3 >= Pext=0.1[MPa] « » (U= 7.6%) OK«

8.7.2 - Permissible Shape Deviations

»The method of 8.7.1 applies to dished ends that are spherical to within 1% on radius and in which the radius of curvature based on an arc length of $2.4 * \text{Sqr}(ea * Rmax)$ does not exceed the nominal value by more than 30%.

CALCULATION SUMMARY

7.5.3 - TORISPHERICAL ENDS UNDER INTERNAL PRESSURE

7.5.3.2 Required Minimum End Thickness

Required Minimum End Thickness Excl.Allow. emin :

$$emin = emin = 2.85 = \underline{\underline{2.85 \text{ mm}}}$$

Required Minimum End Thickness Incl.Allow. :

$$emina = emin + c + th = 2.85 + 3 + 0 = \underline{\underline{5.85 \text{ mm}}}$$

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.5 DOMED ENDS

E3.1 Channel head 05 Feb. 2010 12:10 ConnID:S1.1 PC# 2

»Internal Pressure $e_{min}=5.85 \leq e_n=8.5[\text{mm}]$ « » (U= 68.8%) OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD

P_{max} (is the least of P_s , P_y and P_b) = $P_{max} = 4.93 =$ 4.93 MPa

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR

P_{max} (is the least of P_s , P_y and P_b) = $P_{max} = 1.84 =$ 1.84 MPa

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

P_{max} (is the least of P_s , P_y and P_b) = $P_{max} = 7.29 =$ 7.29 MPa

EN13445-5;10.2.3.3 REQUIRED MIN.HYDROSTATIC TEST PRESSURE: P_{tmin}

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3

$P_{tmin} = 1.25 * P_d * f_{20} / f = 1.25 * 0.85 * 170.83 / 104 =$ 1.75 MPa

$P_{tmin} = 1.43 * P_d = 1.43 * 0.85 =$ 1.22 MPa

»Test Pressure $P_{tmin}=1.75 \leq P_{tmax}=7.29[\text{MPa}]$ « » (U= 23.9%) OK«

Maximum diameter of Opening Not Requiring Reinforcement Check , d_{max}

Maximum Diameter of Unreinforced Opening

$d_{max} = \text{MAX}(d_{max1}, d_{max2}) = \text{MAX}(50.35, 11.15) =$ 50.35 mm

8.7 - SPHERICAL SHELL UNDER EXTERNAL PRESSURE

»External Pressure $P_{max}=1.3 \geq P_{ext}=0.1[\text{MPa}]$ « » (U= 7.6%) OK«

Volume:0.04 m³ Weight:32.3 kg (SG= 7.85)

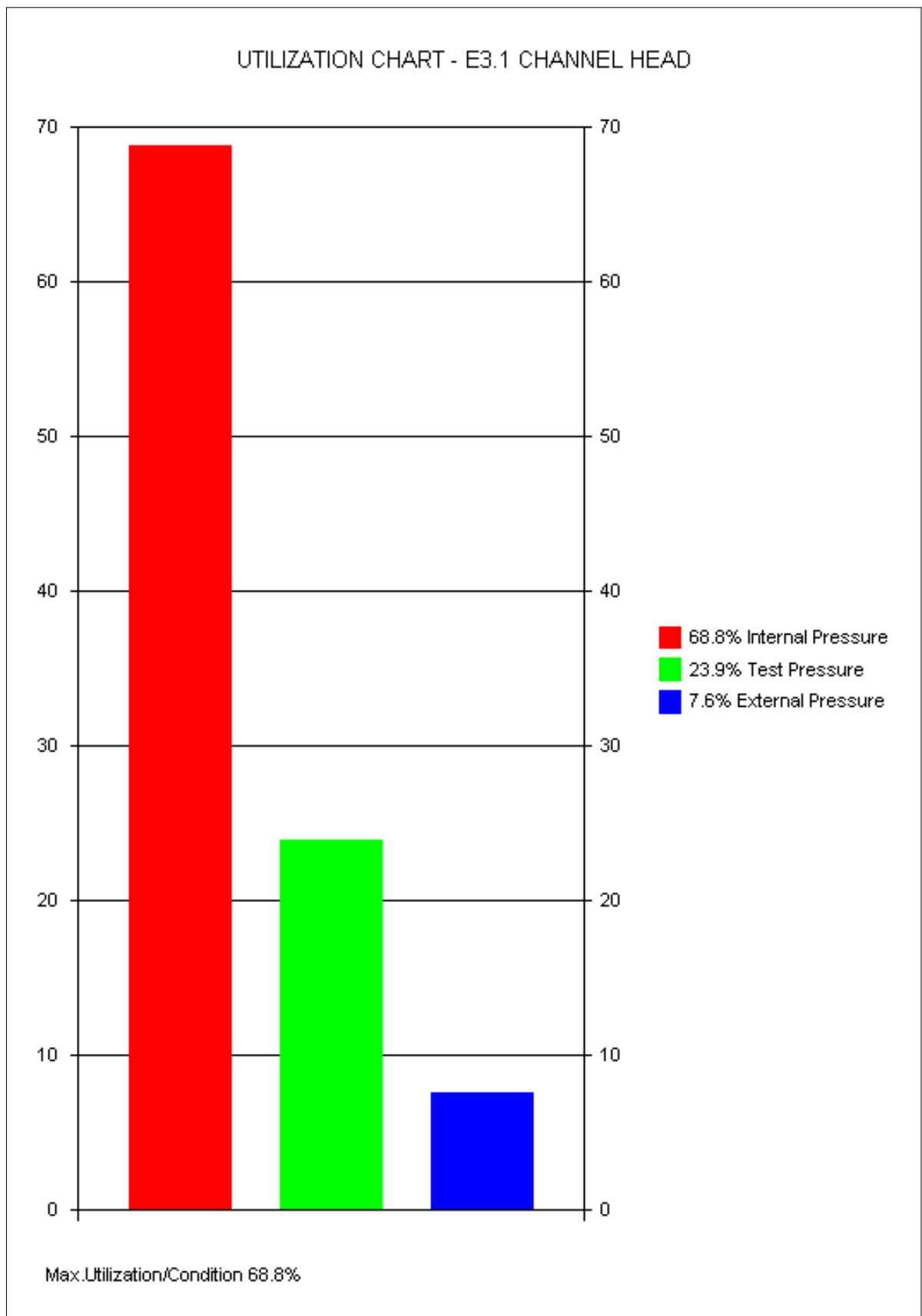
Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.5 DOMED ENDS

E3.1 Channel head 05 Feb. 2010 12:10 ConnID:S1.1 PC# 2



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Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.5 DOMED ENDS

E3.2 Shell head 05 Feb. 2010 12:10 ConnID:S1.3 PC# 1

INPUT DATA

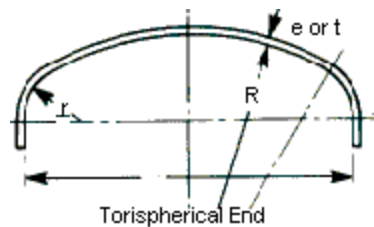
COMPONENT ATTACHMENT/LOCATION

Attachment: S1.3 Cylindrical Shell Shell L=4030 S2.1
Location: Along z-axis z1= 5213

GENERAL DESIGN DATA

PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm, Pext= .1MPa

DIMENSIONS OF END



Type of Torispherical End: Dished End KORBBOGEN DIN 28013-28014/SMS 482
WELD JOINT COEFFICIENT: Unwelded Component (z=1.0)
OUTSIDE DIAMETER OF CYLINDRICAL FLANGE OF END.....:De 864.00 mm
LENGTH OF CYLINDRICAL FLANGE OF END.....:Lcyl 35.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....:th 0.00 mm
AS BUILT THICKNESS OF HEAD/END (uncorroded).....:en 10.50 mm

MATERIAL DATA FOR END

EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
Rm=410 Rp=265 Rpt=194.12 f=129.41 f20=170.83 ftest=252.38 E=196147(N/mm2) ro=7.85
SAFETY FACTOR (1.0 carbon and 1.25 austenitic steels):s 1.00
Material & Delivery Form: NOT Cold Spun Seamless Austenitic Stainless Steel

NOZZLES IN KNUCKLE REGION TO SECTION 7.7

Nozzles In Knuckle Region: NO

CALCULATION DATA

7.5.3 - TORISPHERICAL ENDS UNDER INTERNAL PRESSURE

7.5.3.2 Required Minimum End Thickness

Required Thickness of End to Limit Membrane Stress in Central Part

$$e_s = P * R / (2 * f * z - 0.5 * P) \quad (7.5-1)$$

$$= 0.5 * 691.2 / (2 * 129.41 * 1 - 0.5 * 0.5) = \underline{1.34 \text{ mm}}$$

$$f_b = R_{pt} / 1.5 \quad (7.5-4) = 194.12 / 1.5 = \underline{129.41 \text{ N/mm}^2}$$
 Required Thickness of Knuckle to Avoid Plastic Buckling

$$e_b = (0.75 * R + 0.2 * D_i) * ((P / (111 * f_b)) * (D_i / r)^{0.825})^{(0.667)} \quad (7.5-3)$$

$$= (0.75 * 691.2 + 0.2 * 849) * ((0.5 / (111 * 129.41)) * (849 / 133.06)^{0.825})^{(0.667)}$$

$$= \underline{2.03 \text{ mm}}$$

7.5.3.5 Formulas for Calculation of Factor Beta

$$Y = \text{MIN}(e_{min} / R, 0.04) \quad (7.5-9) = \text{MIN}(2.03 / 691.2, 0.04) = 0.0029$$

$$Z = \text{LOG}(1 / Y) \quad (7.5-10) = \text{LOG}(1 / 0.0029) = 2.53$$

$$X = r / D_i \quad (7.5-11) = 133.06 / 859.94 = 0.1547$$

$$N = 1.006 - 1 / (6.2 + (90 * Y)^4) \quad (7.5-12)$$

$$= 1.006 - 1 / (6.2 + (90 * 0.0029)^4) = 0.8448$$

$$\text{Beta01} = N * (-0.1833 * Z^3 + 1.0383 * Z^2 - 1.2943 * Z + 0.837) \quad (7.5-15)$$

$$= 0.8448 * (-0.1833 * 2.53^3 + 1.0383 * 2.53^2 - 1.2943 * 2.53 + 0.837) = 1.05$$

$$\text{Beta02} = \text{MAX}(0.5, 0.95 * (0.56 - 1.94 * Y - 82.5 * Y^2)) \quad (7.5-17)$$

$$= \text{MAX}(0.5, 0.95 * (0.56 - 1.94 * 0.0029 - 82.5 * 0.0029^2)) = 0.5259$$

$$\text{beta} = 10 * ((0.2 - X) * \text{Beta01} + (X - 0.1) * \text{Beta02}) \quad (7.5-16)$$

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.5 DOMED ENDS

E3.2 Shell head 05 Feb. 2010 12:10 ConnID:S1.3 PC# 1

$$=10*((0.2-0.1547)*1.05+(0.1547-0.1)*0.5259)= 0.7624$$

Required Thickness of Knuckle to Avoid Axisymmetric Yielding

$$e_y = \beta * P * (0.75 * R + 0.2 * D_i) / f \quad (7.5-2)$$

$$=0.7624*0.5*(0.75*691.2+0.2*849)/129.41= 2.03 \text{ mm}$$

Required Minimum End Thickness Excl.Allow. e_{min} :

$$e_{min} = e_{min} = 2.03 = 2.03 \text{ mm}$$

Required Minimum End Thickness Incl.Allow. :

$$e_{minA} = e_{min} + c + t_h = 2.03 + 3 + 0 = 5.03 \text{ mm}$$

»Internal Pressure $e_{minA}=5.03 \leq e_n=10.5$ [mm] « » (U= 47.9%) OK«

Analysis Thickness

$$e_a = e_n - c - t_h = 10.5 - 3 - 0 = 7.50 \text{ mm}$$

Inside Diameter of Shell

$$D_i = D_e - 2 * (e_n - c) = 864 - 2*(10.5 - 3) = 849.00 \text{ mm}$$

Mean Diameter of Shell

$$D_m = (D_e + D_i) / 2 = (864 + 849) / 2 = 856.50 \text{ mm}$$

7.5.3.4 - Required Minimum Thickness of Straight Cylindrical Flange

$$L_{lim} = 0.2 * \text{SQR}(D_i * e_{min}) = 0.2 * \text{SQR}(849 * 2.03) = 8.31 \text{ mm}$$

Since $L_{cyl} > L_{lim}$, Required Thickness of Straight Cylindrical Flange to 7.4.2

Minimum Thickness of Straight Flange Excl. Allow.

$$e_{cyl} = P * D_i / (2 * f * z - P) \quad (7.4-1)$$

$$= 0.5 * 849 / (2 * 129.41 * 1 - 0.5) = 1.64 \text{ mm}$$

7.5.3.1 Conditions of Applicability - Torispherical Ends

- »Geometry Check $r=133.06 \leq 0.2 * D_i=169.8$ [mm] « » OK«
- »Geometry Check $r=133.06 \geq 0.06 * D_i=50.94$ [mm] « » OK«
- »Geometry Check $r=133.06 \geq 2 * e=2.03$ [mm] « » OK«
- »Geometry Check $e=2.03 \leq 0.08 * D_e=69.12$ [mm] « » OK«
- »Geometry Check $e_a=7.5 \geq 0.001 * D_e=0.864$ [mm] « » OK«
- »Geometry Check $R=691.2 \leq D_e=864$ [mm] « » OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD

$$P_s = 2 * f * z * e_a / (R + 0.5 * e_a) \quad (7.5-6)$$

$$= 2 * 170.83 * 1 * 10.5 / (688.2 + 0.5 * 10.5) = 5.17 \text{ MPa}$$

$$P_y = f * e_a / (\beta * (0.75 * R + 0.2 * D_i)) \quad (7.5-7)$$

$$= 170.83 * 10.5 / (0.6019 * (0.75 * 688.2 + 0.2 * 849)) = 4.34 \text{ MPa}$$

$$P_B = 111 * f_b * (e_a / (0.75 * R + 0.2 * D_i))^{1.5} * (r / D_i)^{0.825} \quad (7.5-8)$$

$$= 111 * 176.67 * (10.5 / (0.75 * 688.2 + 0.2 * 849))^{1.5} * (133.06 / 849)^{0.825} = 8.05 \text{ MPa}$$

P_{max} (is the least of P_s , P_y and P_b) = $P_{max} = 4.34 = 4.34 \text{ MPa}$

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR

$$P_s = 2 * f * z * e_a / (R + 0.5 * e_a) \quad (7.5-6)$$

$$= 2 * 129.41 * 1 * 7.5 / (691.2 + 0.5 * 7.5) = 2.79 \text{ MPa}$$

$$P_y = f * e_a / (\beta * (0.75 * R + 0.2 * D_i)) \quad (7.5-7)$$

$$= 129.41 * 7.5 / (0.6266 * (0.75 * 691.2 + 0.2 * 849)) = 2.25 \text{ MPa}$$

$$P_B = 111 * f_b * (e_a / (0.75 * R + 0.2 * D_i))^{1.5} * (r / D_i)^{0.825} \quad (7.5-8)$$

$$= 111 * 129.41 * (7.5 / (0.75 * 691.2 + 0.2 * 849))^{1.5} * (133.06 / 849)^{0.825} = 3.54 \text{ MPa}$$

P_{max} (is the least of P_s , P_y and P_b) = $P_{max} = 2.25 = 2.25 \text{ MPa}$

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

$$P_s = 2 * f * z * e_a / (R + 0.5 * e_a) \quad (7.5-6)$$

$$= 2 * 252.38 * 1 * 10.5 / (688.2 + 0.5 * 10.5) = 7.64 \text{ MPa}$$

$$P_y = f * e_a / (\beta * (0.75 * R + 0.2 * D_i)) \quad (7.5-7)$$

$$= 252.38 * 10.5 / (0.6019 * (0.75 * 688.2 + 0.2 * 849)) = 6.42 \text{ MPa}$$

$$P_B = 111 * f_b * (e_a / (0.75 * R + 0.2 * D_i))^{1.5} * (r / D_i)^{0.825} \quad (7.5-8)$$

$$= 111 * 252.38 * (10.5 / (0.75 * 688.2 + 0.2 * 849))^{1.5} * (133.06 / 849)^{0.825} = 11.50 \text{ MPa}$$

P_{max} (is the least of P_s , P_y and P_b) = $P_{max} = 6.42 = 6.42 \text{ MPa}$

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.5 DOMED ENDS

E3.2 Shell head 05 Feb. 2010 12:10 ConnID:S1.3 PC# 1

EN13445-5;10.2.3.3 REQUIRED MIN.HYDROSTATIC TEST PRESSURE:Ptmin

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3

$$Ptmin = 1.25 * Pd * f_{20} / f = 1.25 * 0.5 * 170.83 / 129.41 = \underline{0.8250 \text{ MPa}}$$

$$Ptmin = 1.43 * Pd = 1.43 * 0.5 = \underline{0.7150 \text{ MPa}}$$

»Test Pressure Ptmin=0.825 <= Pmax=6.42[MPa] « » (U= 12.8%) OK«

Maximum diameter of Opening Not Requiring Reinforcement Check , dmax

$$ris = R (9.5-4) = 691.2 = \underline{691.20 \text{ mm}}$$

Length of Shell Contributing to Reinforcement

$$Is = \text{Sqr}((2 * ris + ea) * ea) \quad (9.5-2)$$

$$= \text{Sqr}((2 * 691.2 + 7.5) * 7.5) = \underline{102.10 \text{ mm}}$$

Maximum Diameter of Unreinforced Opening in Shell Checked to Rules in Section 9

$$dmax1 = (ea * Is * (f - 0.5 * P) / P - ris * Is) / (0.5 * ris + 0.5 * ea) \quad (9.5-7, 22, 23)$$

$$= (7.5 * 102.1 * (129.41 - 0.5 * 0.5) / 0.5 - 691.2 * 102.1) / (0.5 * 691.2 + 0.5 * 7.5) = \underline{364.21 \text{ mm}}$$

Maximum diameter of Opening Not Requiring Reinforcement Check

$$dmax2 = 0.15 * \text{Sqr}((2 * ris + ea) * ea) \quad (9.5-18)$$

$$= 0.15 * \text{Sqr}((2 * 691.2 + 7.5) * 7.5) = \underline{15.31 \text{ mm}}$$

Maximum Diameter of Unreinforced Opening

$$dmax = \text{MAX}(dmax1, dmax2) = \text{MAX}(364.21, 15.31) = \underline{364.21 \text{ mm}}$$

8.7 - SPHERICAL SHELL UNDER EXTERNAL PRESSURE

8.4.2 Nominal Elastic Limit Sige:

$$Sige = Rpt (8.4.2-1) = 194.12 = \underline{194.12 \text{ N/mm}^2}$$

Mean Radius R:

$$Rmean = R + ea / 2 = 691.2 + 7.5 / 2 = \underline{694.95 \text{ mm}}$$

MEMBRANE YIELD py

$$py = 2 * Sige * ea / Rmean (8.7.1-1) = 2 * 194.12 * 7.5 / 694.95 = \underline{4.19 \text{ MPa}}$$

ELASTIC INSTABILITY pm

$$pm = 1.21 * E * ea^2 / Rmean^2 \quad (8.7.1-2)$$

$$= 1.21 * 196147 * 7.5^2 / 694.95^2 = \underline{27.64 \text{ MPa}}$$

Value pr/py From Figure 8.5-5 Curve 2

$$Value1 = \underline{0.5700}$$

MAX. ALLOWABLE EXTERNAL PRESSURE Pmax

$$pr = Value1 * py = 0.57 * 4.19 = \underline{2.39 \text{ MPa}}$$

$$Pmax = pr / S = 2.39 / 1.5 = \underline{1.59 \text{ MPa}}$$

»External Pressure Pmax=1.59 >= Pext=0.1[MPa] « » (U= 6.2%) OK«

8.7.2 - Permissible Shape Deviations

»The method of 8.7.1 applies to dished ends that are spherical to within 1% on radius and in which the radius of curvature based on an arc length of $2.4 * \text{Sqr}(ea * Rmax)$ does not exceed the nominal value by more than 30%.

CALCULATION SUMMARY

7.5.3 - TORISPHERICAL ENDS UNDER INTERNAL PRESSURE

7.5.3.2 Required Minimum End Thickness

Required Minimum End Thickness Excl.Allow. emin :

$$emin = emin = 2.03 = \underline{2.03 \text{ mm}}$$

Required Minimum End Thickness Incl.Allow. :

$$emina = emin + c + th = 2.03 + 3 + 0 = \underline{5.03 \text{ mm}}$$

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.5 DOMED ENDS

E3.2 Shell head 05 Feb. 2010 12:10 ConnID:S1.3 PC# 1

»Internal Pressure $e_{min}=5.03 \leq e_n=10.5[\text{mm}]$ « » (U= 47.9%) OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD

P_{max} (is the least of P_s , P_y and P_b) = $P_{max} = 4.34 =$ 4.34 MPa

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR

P_{max} (is the least of P_s , P_y and P_b) = $P_{max} = 2.25 =$ 2.25 MPa

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

P_{max} (is the least of P_s , P_y and P_b) = $P_{max} = 6.42 =$ 6.42 MPa

EN13445-5;10.2.3.3 REQUIRED MIN.HYDROSTATIC TEST PRESSURE: P_{tmin}

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3

$P_{tmin} = 1.25 * P_d * f_{20} / f = 1.25 * 0.5 * 170.83 / 129.41 =$ 0.8250 MPa

$P_{tmin} = 1.43 * P_d = 1.43 * 0.5 =$ 0.7150 MPa

»Test Pressure $P_{tmin}=0.825 \leq P_{tmax}=6.42[\text{MPa}]$ « » (U= 12.8%) OK«

Maximum diameter of Opening Not Requiring Reinforcement Check , d_{max}

Maximum Diameter of Unreinforced Opening

$d_{max} = \text{MAX}(d_{max1}, d_{max2}) = \text{MAX}(364.21, 15.31) =$ 364.21 mm

8.7 - SPHERICAL SHELL UNDER EXTERNAL PRESSURE

»External Pressure $P_{max}=1.59 \geq P_{ext}=0.1[\text{MPa}]$ « » (U= 6.2%) OK«

Volume:0.1 m³ Weight:73.7 kg (SG= 7.85)

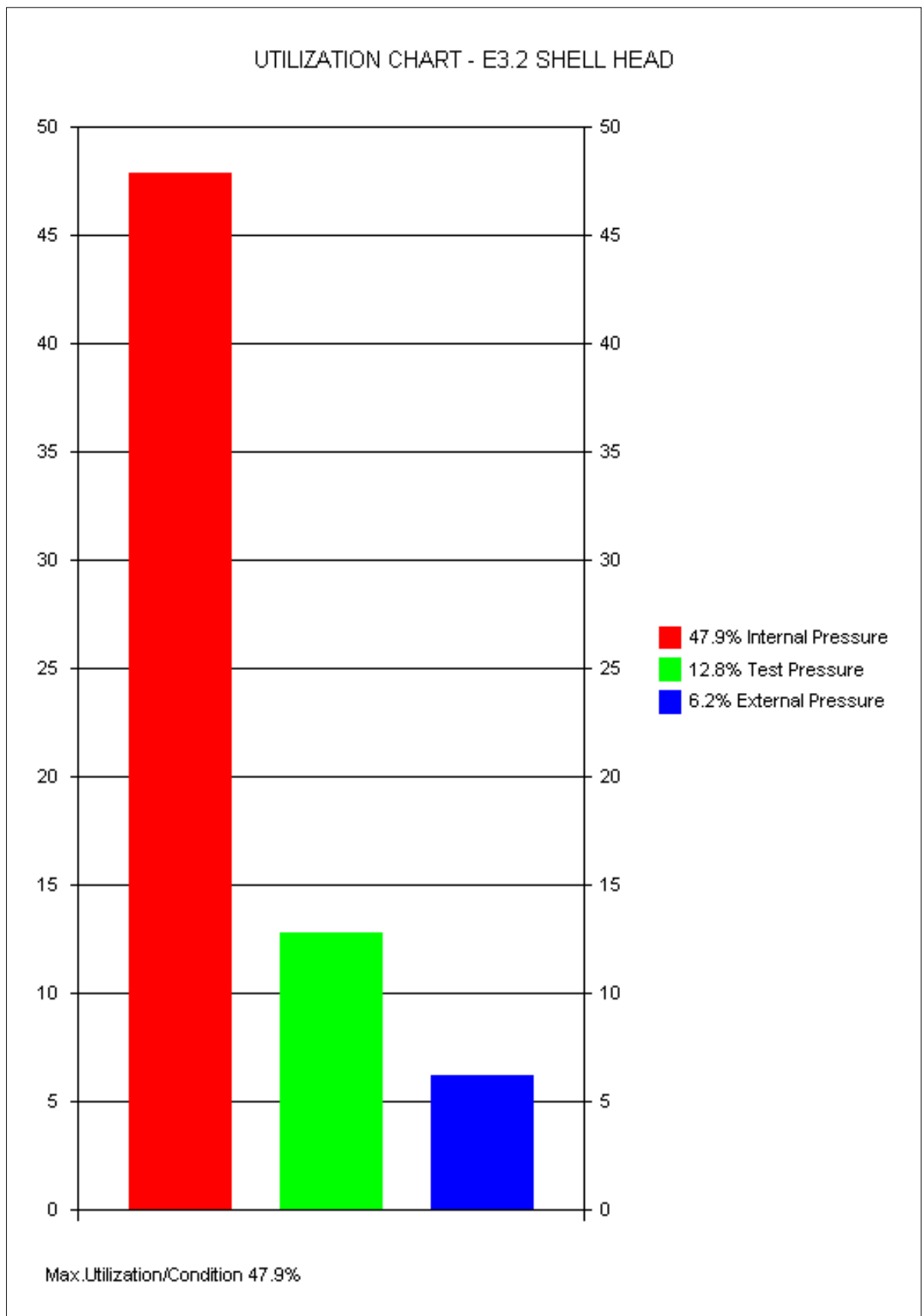
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E3.2 Shell head 05 Feb. 2010 12:10 ConnID:S1.3 PC# 1



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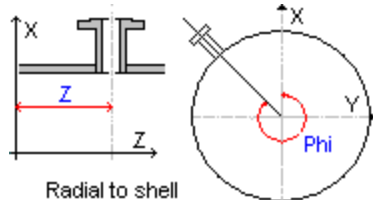
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INPUT DATA

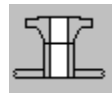
COMPONENT ATTACHMENT/LOCATION

Attachment: S1.3 Cylindrical Shell Shell L=4030 S2.1



Orientation & Location of Nozzle: Radial to Shell
z-location of nozzle along axis of attachment.....:z 2500.00 mm
Angle of Rotation of nozzle axis projected in the x-y plane:Phi 180.00 Degr.

GENERAL DESIGN DATA



Type of Opening: Nozzle With Standard ANSI or DIN/EN Flange Attachment
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm, Pext= .1MPa
Include Nozzle Load Calculation: YES

SHELL DATA (S1.3)

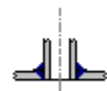
Shell Type: Cylindrical Shell
OUTSIDE DIAMETER OF SHELL.....:De 864.00 mm
AS BUILT WALL THICKNESS (uncorroded).....:en 12.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....:th 0.5000 mm
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
Rm=410 Rp=265 Rpt=194.12 fs=129.41 f20=170.83 ftest=252.38 E=196147(N/mm²) ro=7.85

NOZZLE MATERIAL DATA



Delivery Form: Forging (LWN)
ASME SA-105, PMA, , THK<=250mm 232'C
Rm=485 Rp=250 Rpt=177.2 fb=118.13 f20=166.67 ftest=238.1 (N/mm²)
NOTE: A PARTICULAR MATERIAL APPRAISAL(PMA) MAY BE REQUIRED FOR THIS MATERIAL.

NOZZLE DIMENSIONAL DATA



Attachment: Set In Flush Nozzle
Base calculations on Forging OD: NO
Shape of Nozzle/Opening: Circular
Application:
9.4.6.3 NOT a critical fatigue area, and calc.temp.is outside creep range.
INSIDE DIAMETER OF NOZZLE (corroded).....:dib 56.79 mm
AS BUILT NOZZLE THICKNESS (uncorroded).....:enb 13.49 mm
Size of Flange and Nozzle: 2"
Comment (Optional): CLASS :150# LWN Long Welding Neck
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....: 0.00 mm
NOZZLE STANDOUT MEASURED FROM VESSEL OD.....:ho 200.00 mm

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FLANGE DATA

A: Flange Standard: ANSI B16.5 Flanges
 E: Pressure Class: ANSI B16.5:Class 150 lbs
 C: Flange Type: LWN Long Welding Neck
 D: Facing Sketch/ANSI facing (Table 3.8.3(2)): 1a RF Raised Face
 Flange Material Category:
 1.1 - Carbon Steel - A105, A515 70, A516 70, A350 LF2 (BS 1503 164 490, BS 1504 161 480)

WELDING DATA

Nozzle/Pad to Shell Welding Area: Exclude Area of Nozzle to Shell Weld
 Nozzle Weld Intersect: Nozzle Does NOT Intersect with a Welded Shell Seam
 ANGLE PhiC(OBLIQUE IN TRANSVERSE.CROSS SECT.)Fig.9.5-2:PhiC 0.00 Degr.
 ANGLE PhiL(OBLIQUE IN LONG.CROSS SECT.)Fig.9.5-1:PhiL 0.00 Degr.

DATA FOR REINFORCEMENT PAD



Type of Pad: No Pad

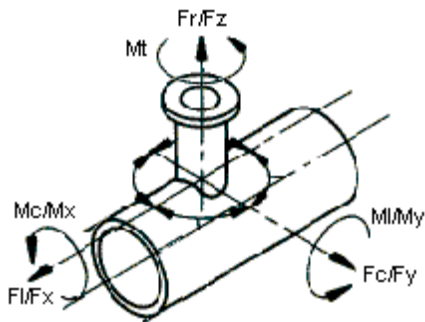
LIMITS OF REINFORCEMENT

Reduction of Limits of Reinforcement: No Reduction Required

EXTERNAL LOADS ON NOZZLE

FACTOR C4:

C4 = 1.1 Nozzle is Attached to a Piping System with due Allowance for Expansion and Thrust



TYPE OF LOAD INPUT: Load Cases

External Nozzle Loads: User Specified Loads

LOADING DATA

Table NOZZLE LOADS:

Load Description	ID	Units	Load Case 1	Load Case 2
Pressure	P	MPa	-0.1	0.42
Radial Load	Fz	kN	-2.5	2.5
Longitudinal Moment	My	kNm	-0.29	0.29
Circumferential Moment:	Mx	kNm	-0.29	0.29
Longitudinal Shear Force	Fl	kN	-2.5	2.5
Circumferential Shear Force	Fc	kN	-1.92	1.92
Torsional Moment	Mt	kNm	-3	3

CALCULATION DATA

FLANGE RATING

ANSI 150lb-Flange Rating(at 232C)= 1.276 MPa, Max.Test Pressure = 3.102 MPa

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PRELIMINARY CALCULATIONS

Shell Analysis Thickness eas
 $eas = en - c - th = 12 - 3 - 0.5 = 8.50 \text{ mm}$
Nozzle Analysis Thickness eab
 $eab = enb - c - NegDev = 13.49 - 3 - 0 = 10.49 \text{ mm}$
Inside Radius of Curvature
 $ris = De / 2 - eas = 864 / 2 - 8.5 = 423.50 \text{ mm}$
 $deb = dib + 2 * eab = 56.79 + 2 * 10.49 = 77.77 \text{ mm}$
Min.Nozzle Thk.Based on Internal Pressure ebp
 $ebp = P * dib / (2 * fb * z - P) = 0.5 * 56.79 / (2 * 118.13 * 1 - 0.5) = 0.1200 \text{ mm}$
Allowable Stresses
 $fob = \text{Min}(fs, fb) = \text{Min}(16.5 - 8, 118.13) = 118.13 \text{ N/mm}^2$

GEOMETRIC LIMITATIONS

»Check Max.Diameter of Nozzle $dib / (2 * ris) = 0.067 \leq 1 [\text{mm}] \llcorner \llcorner \text{ OK} \llcorner \llcorner$
»Min.Nozzle Thk. $ebp = 0.12 \leq eab = 10.49 [\text{mm}] \llcorner \llcorner (U = 1.1\%) \text{ OK} \llcorner \llcorner$

9.5.2.4.4 Nozzles normal to the shell, with or without reinforcement pads.

Calculation of Stress Loaded Areas Effective as Reinforcement

Area of Shell Afs

Limit of Reinforcement Along Shell
 $Iso = \text{Sqr}((2 * ris + eas) * eas) = \text{Sqr}((2 * 423.5 + 8.5) * 8.5) = 85.27 \text{ mm}$
Set In Nozzle
 $Afs = eas * Iso = 8.5 * 85.27 = 724.83 \text{ mm}^2$

Area of Nozzle Afb

Limit of Reinforcement Along Nozzle (outside shell)
 $Ibo = \text{MIN}(\text{Sqr}((deb - eb) * eb), ho) = \text{MIN}(\text{Sqr}((77.77 - 10.49) * 10.49), 200) = 26.57 \text{ mm}$
Set In Nozzle
 $Afb = eb * (Ibo + Ibi + eas) = 10.49 * (26.57 + 0 + 8.5) = 367.85 \text{ mm}^2$

Calculation of Pressure Loaded Areas

In the Nozzle Apb
 $Apb = 0.5 * dib * (Ibo + eas) = 0.5 * 56.79 * (26.57 + 8.5) = 995.71 \text{ mm}^2$
Cyl.Shell in the Longitudinal Section Aps
 $ApsL = ris * (Iso + a) = 423.5 * (85.27 + 38.89) = 52581.57 \text{ mm}^2$
Cyl.Shell in the Transverse Cross Section Aps
 $ApsT = 0.5 * ris^2 * (Iso + a) / (0.5 * eas + ris) = 0.5 * 423.5^2 * (85.27 + 38.89) / (0.5 * 8.5 + 423.5) = 26040.84 \text{ mm}^2$
 $Aps = \text{MAX}(ApsL, ApsT) = \text{MAX}(52581.57, 26040.84) = 52581.57 \text{ mm}^2$

9.5.2 Reinforcement Rules

Pressure Area Required pA(req.)

$pAReqL = P * (ApsL + Apb) = 0.5 * (52581.57 + 995.71) = 26.79 \text{ kN}$
 $pAReqT = P * (ApsT + Apb + 0.5 * Apphi) = 0.5 * (26040.84 + 995.71 + 0.5 * 0) = 13.52 \text{ kN}$
 $pAReq = \text{MAX}(pAReqL, pAReqT) = \text{MAX}(26.79, 13.52) = 26.79 \text{ kN}$

Pressure Area Available pA(aval.)

$pAAval = (Afs + Afb) * (fs - 0.5 * P) + Afp * (fop - 0.5 * P) + Afb * (fob - 0.5 * P) = (724.83 + 0) * (118.13 - 0.5 * 0.5) + 0 * (0 - 0.5 * 0.5) + 367.85 * (118.13 - 0.5 * 0.5) = 136.98 \text{ kN}$

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»Nozzle Reinforcement pAAval=136.98 >= pAReq=26.79[kN] « » (U= 19.5%) OK«

Maximum Allowable Pressure Pmax

$$P_{max} = (A_{fs} + A_{fw}) * f_s + A_{fb} * f_{ob} / ((A_{ps} + A_{pb} + 0.5 * A_{pphi}) + 0.5 * (A_{fs} + A_{fw} + A_{fb} + A_{fp})) \quad (10)$$
$$= +0) * 129.41 + 367.85 * 118.13 / ((52581.57 + 995.71 + 0.5 * 0) + 0.5 * (724.83 + 0 + 367.85 + 0))$$
$$= 2.54 \text{ MPa}$$

Max.Allowable Test Pressure P_{tmax}

$$P_{tmax} = 6.63 \text{ MPa}$$

»ANSI 150lb-Flange Rating(at 232C) P=0.5 <= P_{Max}(flange)=1.28[MPa] «» (U= 39.1%) OK«

16.5 LOCAL LOADS ON NOZZLES IN CYLINDRICAL SHELLS

PRELIMINARY CALCULATIONS

Shell Analysis Thickness e _{as}	
e _{as} = e _n - c - t _h = 12 - 3 - 0.5 =	8.50 mm
Nozzle Analysis Thickness e _b	
e _b = e _{nb} - c - NegDev = 13.49 - 3 - 0 =	10.49 mm
Mean diameter of shell	
D = D _e - e _a = 864 - 8.5 =	855.50 mm
Mean radius of shell	
R = D / 2 = 855.5 / 2 =	427.75 mm

16.5.3 CONDITIONS OF APPLICABILITY

»a) e_a/D = 0.0099 >= 0.001 « » OK«

»a) e_a/D = 0.0099 <= 0.1 « » OK«

»b) λ_C = 0.789 <= 10 « » OK«

»c) Dist. to any other local load shall not be less than SQR(D * e_c) = 85.3 mm

»d) Nozzle thickness shall be maintained over a distance of SQR(d * e_b) = 26.6 mm

LOAD CASE NO: 1 - Load Case 1

Total Moment

$$M_B = \sqrt{M_x^2 + M_y^2} = \sqrt{(-0.29)^2 + (-0.29)^2} = 0.4101 \text{ kNm}$$

STRESSES AT OUTER DIAMETER OF NOZZLE

Mean Diameter of Nozzle	
d = d _{eb} - e _b = 77.77 - 10.49 =	67.28 mm
Combined Analysis Thickness	
e _c = e _a = 8.5 =	8.50 mm
λ _C = d / SQR(D * e _c) = 67.28 / SQR(855.5 * 8.5) =	0.7890
Ratio1 = e _b / e _c = 10.49 / 8.5 =	1.23
Ratio2 = D / e _c = 855.5 / 8.5 =	100.65
VALUES FOR C ₁ , C ₂ AND C ₃ FROM FIGURES 16.5-2 to 16.5-4	
C ₁ = 1.810 C ₂ = 4.900 C ₃ = 7.338	

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

Permissible Pressure P _{max} :	
P _{max} (from nozzle calculation) = P _{max} (16.5-2) = 2.54 =	2.54 MPa
Allowable Axial Load F _{zmax} :	
F _{zmax} = f * e _c ² * C ₁ (16.5-3) = 129.41 * 8.5 ² * 1.81 =	16.92 kN
Allowable Circumferential Moment M _{xmax} :	
M _{xmax} = f * e _c ² * d / 4 * C ₂ (16.5-5)	
= 129.41 * 8.5 ² * 67.28 / 4 * 4.9 =	0.7706 kNm
Allowable Longitudinal Moment M _{xmax} :	
M _{ymax} = f * e _c ² * d / 4 * C ₃ (16.5-7)	
= 129.41 * 8.5 ² * 67.28 / 4 * 7.34 =	1.15 kNm

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SHEAR STRESS FORMULAE (PD5500 Section G.2.3.6.3)

Shear Stresses due to Longitudinal Shear Force, TauFl:

$$\text{TauFl} = 2 * F_l / (\text{PI} * \text{deb} * \text{ec}) \\ = 2 * -2.5 / (3.14 * 77.77 * 8.5) = -2.41 \text{ N/mm}^2$$

Shear Stresses due to Circumferential Force, TauFc:

$$\text{TauFc} = 2 * F_c / (\text{PI} * \text{deb} * \text{ec}) \\ = 2 * -1.92 / (3.14 * 77.77 * 8.5) = -1.85 \text{ N/mm}^2$$

Shear Stresses due to Torsional Moment, TauMt:

$$\text{TauMt} = 2 * M_t / (\text{PI} * \text{deb}^2 * \text{ec}) \\ = 2 * -3 / (3.14 * 77.77^2 * 8.5) = -37.15 \text{ N/mm}^2$$

Total Shear Stresses, Tau:

$$\text{Tau} = \text{Sqr}(\text{TauFc}^2 + \text{TauFl}^2) + \text{TauMt} \\ = \text{Sqr}(-1.85^2 + -2.41^2) + -37.15 = -34.11 \text{ N/mm}^2$$

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

$$\text{PhiP} = P / P_{\text{max}} \text{ (16.5-9)} = -0.1 / 2.54 = -0.0394$$

$$\text{PhiZ} = F_z / F_{z\text{max}} \text{ (16.5-10)} = -2.5 / 16.92 = -0.1477$$

$$\text{PhiTau} = \text{Tau} / (0.5 * f) = -34.11 / (0.5 * 129.41) = 0.5272$$

$$\text{PhiB} = \text{Sqr}((M_x / M_{x\text{max}})^2 + (M_y / M_{y\text{max}})^2) \text{ (16.5-11)} \\ = \text{Sqr}((-0.29 / 0.7706)^2 + (-0.29 / 1.15)^2) = 0.4525$$

$$\text{MaxAll} = \text{MAX}(\text{Abs}(\text{PhiP}/C4 + \text{PhiZ}), \text{Abs}(\text{PhiZ}), \text{Abs}(\text{PhiP}/C4 - 0.2 * \text{PhiZ}) \text{ (16.5-15)} \\ = \text{MAX}(\text{Abs}(-0.0394 / 1.1 + -0.1477), \text{Abs}(-0.1477), \text{Abs}(-0.0394 / 1.1 - 0.2 * -0.1477)) \\ = 0.1836$$

$$\text{PhiAll} = \text{Sqr}(\text{MaxAll}^2 + \text{PhiB}^2 + \text{PhiTau}^2) \text{ (16.5-15)} \\ = \text{Sqr}(0.1836^2 + 0.4525^2 + 0.5272^2) = 0.7186$$

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT NOZZLE OD PhiP=0.0394 <= 1.0=1(16.5-12)« » (U= 3.9%) OK«

»PhiZ AT NOZZLE OD PhiZ=0.1477 <= 1.0=1(16.5-13)« » (U= 14.7%) OK«

»PhiB AT NOZZLE OD PhiB=0.4525 <= 1.0=1(16.5-14)« » (U= 45.2%) OK«

»PhiTau AT NOZZLE OD PhiTau=0.5272 <= 1.0=1« » (U= 52.7%) OK«

»PhiAll AT NOZZLE OD PhiAll=0.7186 <= 1.0=1(16.5-15)« » (U= 71.8%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

16.5.7.1 LOAD RANGES

$$\text{DeltaP} = \text{Max}(P_{\text{max}}, 0) - \text{Min}(P_{\text{min}}, 0) \text{ (16.5-16)} \\ = \text{Max}(0.1, 0) - \text{Min}(0, 0) = 0.1000 \text{ MPa}$$

$$\text{DeltaFz} = \text{Max}(F_{z\text{max}}, 0) - \text{Min}(F_{z\text{min}}, 0) \text{ (16.5-17)} \\ = \text{Max}(2.5, 0) - \text{Min}(0, 0) = 2.50 \text{ kN}$$

$$\text{DeltaMx} = \text{Max}(M_{x\text{max}}, 0) - \text{Min}(M_{x\text{min}}, 0) \text{ (16.5-18)} \\ = \text{Max}(0.29, 0) - \text{Min}(0, 0) = 0.2900 \text{ kNm}$$

$$\text{DeltaMy} = \text{Max}(M_{y\text{max}}, 0) - \text{Min}(M_{y\text{min}}, 0) \text{ (16.5-19)} \\ = \text{Max}(0.29, 0) - \text{Min}(0, 0) = 0.2900 \text{ kNm}$$

$$\text{DeltaFl} = \text{Max}(F_{l\text{max}}, 0) - \text{Min}(F_{l\text{min}}, 0) \\ = \text{Max}(2.5, 0) - \text{Min}(0, 0) = 0.00 \text{ kN}$$

$$\text{DeltaFc} = \text{Max}(F_{c\text{max}}, 0) - \text{Min}(F_{c\text{min}}, 0) \\ = \text{Max}(1.92, 0) - \text{Min}(0, 0) = 0.00 \text{ kN}$$

$$\text{DeltaFshear} = \text{Sqr}(\text{DeltaFl}^2 + \text{DeltaFc}^2) \\ = \text{Sqr}(0^2 + 0^2) = 0.00 \text{ kN}$$

$$\text{DeltaMt} = \text{Max}(M_{t\text{max}}, 0) - \text{Min}(M_{t\text{min}}, 0) \\ = \text{Max}(3, 0) - \text{Min}(0, 0) = 0.00 \text{ kNm}$$

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16.5.7.2 EQUIVALENT SHELL THICKNESS

$eeq = ec = 8.5 = 8.50 \text{ mm}$

16.5.7.3 STRESSES

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

$C1 = 1.810 \quad C2 = 4.900 \quad C3 = 7.338$

$Tmp1 = \text{Sqr}(d * eb / (D * eeq)) = \text{Sqr}(67.28 * 10.49 / (855.5 * 8.5)) = 0.3115$

$Tmp2 = (2 + 2 * d / D * Tmp1 + 1.25 * d / D * \text{Sqr}(D / eeq)) / (1 + eb / eeq * Tmp1) = (2 + 2 * 67.28 / 855.5 * 0.3115 + 1.25 * 67.28 / 855.5 * \text{Sqr}(855.5 / 8.5)) / (1 + 10.49 / 8.5 * 0.3115) = 2.19$

Stresses due to Pressure Range

$SigP = \Delta P * D / (2 * eeq) * Tmp2 = 0.1 * 855.5 / (2 * 8.5) * 2.19 = 11.03 \text{ N/mm}^2$ (16.5-21)

Stresses due to Axial Load Range

$SigFz = 2.25 / C1 * (\Delta Fz / eeq^2) = 2.25 / 1.81 * (2.5 / 8.5^2) = 43.01 \text{ N/mm}^2$ (16.5-22)

Stresses due to Circumferential Moment Range

$SigMx = 2.25 / C2 * (4 * \Delta Mx / (eeq^2 * d)) = 2.25 / 4.9 * (4 * 0.29 / (8.5^2 * 67.28)) = 109.58 \text{ N/mm}^2$ (16.5-23)

Stresses due to Longitudinal Moment Range

$SigMy = 2.25 / C3 * (4 * \Delta My / (eeq^2 * d)) = 2.25 / 7.34 * (4 * 0.29 / (8.5^2 * 67.28)) = 73.17 \text{ N/mm}^2$ (16.5-24)

Shear Stresses due to Longitudinal Shear Force, ΔF_l :

$TauFl = 2 * \Delta F_l / (\text{PI} * deb * eeq) = 2 * 0 / (3.14 * 77.77 * 8.5) = 0.00 \text{ N/mm}^2$

Shear Stresses due to Circumferential Force, ΔF_c :

$TauFc = 2 * \Delta F_c / (\text{PI} * deb * eeq) = 2 * 0 / (3.14 * 77.77 * 8.5) = 0.00 \text{ N/mm}^2$

Shear Stresses due to Torsional Moment, ΔM_t :

$TauMt = 2 * \Delta M_t / (\text{PI} * deb^2 * eeq) = 2 * 0 / (3.14 * 77.77^2 * 8.5) = 0.00 \text{ N/mm}^2$

Total Shear Stresses, τ :

$\tau = \text{Sqr}(TauFc^2 + TauFl^2) + TauMt = \text{Sqr}(0^2 + 0^2) + 0 = 0.00 \text{ N/mm}^2$

Total Stress Intensity due to Load Range

$SigTot = \text{Abs}(SigP + \text{Sqr}((SigFz + SigMx^2 + SigMy^2 + 4 * Tau^2))) = \text{Abs}(11.03 + \text{Sqr}(43.01^2 + 109.58^2 + 73.17^2 + 4 * 0^2)) = 142.41 \text{ N/mm}^2$ (16.5-25)

»Total Stress in Shell $SigTot=142.41 \leq 3 * f=388.23 \text{ [N/mm}^2]$ «» (U= 36.6%) OK«

16.5.8 NOZZLE LONGITUDINAL STRESSES

Maximum Longitudinal Stresses in Nozzle

$SigLong = P * d / (4 * eb) + 4 * MB / (\text{PI} * d^2 * eb) + Fz / (\text{PI} * d * eb) = -0.1 * 67.28 / (4 * 10.49) + 4 * 0.4101 / (3.14 * 67.28^2 * 10.49) + 0 / (3.14 * 67.28 * 10.49) = 10.84 \text{ N/mm}^2$ (16.5-26)

»Nozzle Long.Stress $SigLong=10.84 \leq fb=118.13 \text{ [N/mm}^2]$ « » (U= 9.1%) OK«

16.14.6 COMPRESSIVE STRESS LIMITS

$K = 1.21 * E * ea / (Sige * D) = 1.21 * 196147 * 10.49 / (177.2 * 67.28) = 208.83$ (16.14-15)

$\alpha = 0.83 / \text{Sqr}(1 + 0.005 * D / ea) = 0.83 / \text{Sqr}(1 + 0.005 * 67.28 / 10.49) = 0.8170$ (16.14-16)

$\delta = (1 - 0.4123 / (\alpha * K)^{0.6}) / S = (1 - 0.4123 / (0.817 * 208.83)^{0.6}) / 1.5 = 0.6541$ (16.14-19)

Maximum Allowable Compressive Stress

$Sigcall = Sige * \delta = 177.2 * 0.6541 = 115.90 \text{ N/mm}^2$

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16.14.4 PERMISSIBLE INDIVIDUAL LOADS

Maximum Tensile Force Ftmax

$$F_{tmax} = \pi * D * e_a * f \quad (16.14-1) = 3.14 * 67.28 * 10.49 * 118.13 = \underline{261.92 \text{ kN}}$$

Maximum Compressive Force Fcmax

$$F_{cmax} = \pi * D * e_a * \text{Sigcall} \quad (16.14-2) = 3.14 * 67.28 * 10.49 * 115.9 = \underline{256.98 \text{ kN}}$$

Maximum Bending Moment Mmax

$$M_{max} = \pi / 4 * D^2 * e_a * \text{Sigcall} \quad (16.14-3) \\ = 3.14 / 4 * 67.28^2 * 10.49 * 115.9 = \underline{4.32 \text{ kNm}}$$

Longitudinal Stability Check (P=0)

$$\text{LongStab} = MB / M_{max} + \text{Abs}(F_{zmin}) / F_{cmax} \quad (16.5-27) \\ = 0.4101 / 4.32 + \text{Abs}(0) / 256.98 = \underline{0.0949}$$

»Nozzle Long.Stability LongStab=0.0949 <= 1.0=1« » (U= 9.4%) OK«

LOAD CASE NO: 2 - Load Case 2

Total Moment

$$MB = \text{Sqr}(M_x^2 + M_y^2) = \text{Sqr}(0.29^2 + 0.29^2) = \underline{0.4101 \text{ kNm}}$$

STRESSES AT OUTER DIAMETER OF NOZZLE

Mean Diameter of Nozzle

$$d = d_{eb} - e_b = 77.77 - 10.49 = \underline{67.28 \text{ mm}}$$

Combined Analysis Thickness

$$e_c = e_a = 8.5 = \underline{8.50 \text{ mm}}$$

$$\text{LamdaC} = d / \text{Sqr}(D * e_c) = 67.28 / \text{Sqr}(855.5 * 8.5) = \underline{0.7890}$$

$$\text{Ratio1} = e_b / e_c = 10.49 / 8.5 = \underline{1.23}$$

$$\text{Ratio2} = D / e_c = 855.5 / 8.5 = \underline{100.65}$$

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

$$C1 = 1.810 \quad C2 = 4.900 \quad C3 = 7.338$$

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

Permissible Pressure Pmax:

$$P_{max} \text{ (from nozzle calculation)} = P_{max} \quad (16.5-2) = 2.54 = \underline{2.54 \text{ MPa}}$$

Allowable Axial Load Fzmax:

$$F_{zmax} = f * e_c^2 * C1 \quad (16.5-3) = 129.41 * 8.5^2 * 1.81 = \underline{16.92 \text{ kN}}$$

Allowable Circumferential Moment Mxmax:

$$M_{xmax} = f * e_c^2 * d / 4 * C2 \quad (16.5-5) \\ = 129.41 * 8.5^2 * 67.28 / 4 * 4.9 = \underline{0.7706 \text{ kNm}}$$

Allowable Longitudinal Moment Mxmax:

$$M_{ymax} = f * e_c^2 * d / 4 * C3 \quad (16.5-7) \\ = 129.41 * 8.5^2 * 67.28 / 4 * 7.34 = \underline{1.15 \text{ kNm}}$$

SHEAR STRESS FORMULAE (PD5500 Section G.2.3.6.3)

Shear Stresses due to Longitudinal Shear Force, TauFl:

$$\text{TauFl} = 2 * F_l / (\pi * d_{eb} * e_c) \\ = 2 * 2.5 / (3.14 * 77.77 * 8.5) = \underline{2.41 \text{ N/mm}^2}$$

Shear Stresses due to Circumferential Force, TauFc:

$$\text{TauFc} = 2 * F_c / (\pi * d_{eb} * e_c) \\ = 2 * 1.92 / (3.14 * 77.77 * 8.5) = \underline{1.85 \text{ N/mm}^2}$$

Shear Stresses due to Torsional Moment, TauMt:

$$\text{TauMt} = 2 * M_t / (\pi * d_{eb}^2 * e_c) \\ = 2 * 3 / (3.14 * 77.77^2 * 8.5) = \underline{37.15 \text{ N/mm}^2}$$

Total Shear Stresses, Tau:

$$\text{Tau} = \text{Sqr}(\text{TauFc}^2 + \text{TauFl}^2) + \text{TauMt} \\ = \text{Sqr}(1.85^2 + 2.41^2) + 37.15 = \underline{40.19 \text{ N/mm}^2}$$

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

$$\text{PhiP} = P / P_{max} \quad (16.5-9) = 0.5 / 2.54 = \underline{0.1656}$$

$$\text{PhiZ} = F_z / F_{zmax} \quad (16.5-10) = 2.5 / 16.92 = \underline{0.1477}$$

$$\text{PhiTau} = \text{Tau} / (0.5 * f) = 40.19 / (0.5 * 129.41) = \underline{0.6211}$$

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$$\begin{aligned} \text{PhiB} &= \text{Sqr}((\text{Mx} / \text{Mxmax})^2 + (\text{My} / \text{Mymax})^2) && (16.5-11) \\ &= \text{Sqr}((0.29/0.7706)^2 + (0.29/1.15)^2) = && 0.4525 \end{aligned}$$

$$\begin{aligned} \text{MaxAll} &= \text{MAX}(\text{Abs}(\text{PhiP}/\text{C4} + \text{PhiZ}), \text{Abs}(\text{PhiZ}), \text{Abs}(\text{PhiP}/\text{C4} - 0.2 * \text{PhiZ}) && (16.5-15) \\ &= \text{MAX}(\text{Abs}(0.1656/1.1 + 0.1477), \text{Abs}(0.1477), \text{Abs}(0.1656/1.1 - 0.2 * 0.1477)) = && 0.2983 \end{aligned}$$

$$\begin{aligned} \text{PhiAll} &= \text{Sqr}(\text{MaxAll}^2 + \text{PhiB}^2 + \text{PhiTau}^2) && (16.5-15) \\ &= \text{Sqr}(0.2983^2 + 0.4525^2 + 0.6211^2) = && 0.8243 \end{aligned}$$

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT NOZZLE OD PhiP=0.1656 <= 1.0=1(16.5-12)« » (U= 16.5%) OK«

»PhiZ AT NOZZLE OD PhiZ=0.1477 <= 1.0=1(16.5-13)« » (U= 14.7%) OK«

»PhiB AT NOZZLE OD PhiB=0.4525 <= 1.0=1(16.5-14)« » (U= 45.2%) OK«

»PhiTau AT NOZZLE OD PhiTau=0.6211 <= 1.0=1« » (U= 62.1%) OK«

»PhiAll AT NOZZLE OD PhiAll=0.8243 <= 1.0=1(16.5-15)« » (U= 82.4%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

16.5.7.1 LOAD RANGES

$$\begin{aligned} \text{DeltaP} &= \text{Max}(\text{Pmax}, 0) - \text{Min}(\text{Pmin}, 0) && (16.5-16) \\ &= \text{Max}(0.42, 0) - \text{Min}(0, 0) = && 0.4200 \text{ MPa} \end{aligned}$$

$$\begin{aligned} \text{DeltaFz} &= \text{Max}(\text{Fzmax}, 0) - \text{Min}(\text{Fzmin}, 0) && (16.5-17) \\ &= \text{Max}(2.5, 0) - \text{Min}(0, 0) = && 2.50 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{DeltaMx} &= \text{Max}(\text{Mxmax}, 0) - \text{Min}(\text{Mxmin}, 0) && (16.5-18) \\ &= \text{Max}(0.29, 0) - \text{Min}(0, 0) = && 0.2900 \text{ kNm} \end{aligned}$$

$$\begin{aligned} \text{DeltaMy} &= \text{Max}(\text{Mymax}, 0) - \text{Min}(\text{Mymin}, 0) && (16.5-19) \\ &= \text{Max}(0.29, 0) - \text{Min}(0, 0) = && 0.2900 \text{ kNm} \end{aligned}$$

$$\begin{aligned} \text{DeltaFl} &= \text{Max}(\text{Flmax}, 0) - \text{Min}(\text{Flmin}, 0) \\ &= \text{Max}(2.5, 0) - \text{Min}(0, 0) = && 2.50 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{DeltaFc} &= \text{Max}(\text{Fcmax}, 0) - \text{Min}(\text{Fcmin}, 0) \\ &= \text{Max}(1.92, 0) - \text{Min}(0, 0) = && 1.92 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{DeltaFshear} &= \text{Sqr}(\text{DeltaFl}^2 + \text{DeltaFc}^2) \\ &= \text{Sqr}(2.5^2 + 1.92^2) = && 3.15 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{DeltaMt} &= \text{Max}(\text{Mtmax}, 0) - \text{Min}(\text{Mtmin}, 0) \\ &= \text{Max}(3, 0) - \text{Min}(0, 0) = && 3.00 \text{ kNm} \end{aligned}$$

16.5.7.2 EQUIVALENT SHELL THICKNESS

$$\text{eeq} = \text{ec} = 8.5 = 8.50 \text{ mm}$$

16.5.7.3 STRESSES

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

$$\text{C1} = 1.810 \quad \text{C2} = 4.900 \quad \text{C3} = 7.338$$

$$\begin{aligned} \text{Tmp1} &= \text{Sqr}(d * \text{eb} / (D * \text{eeq})) \\ &= \text{Sqr}(67.28 * 10.49 / (855.5 * 8.5)) = && 0.3115 \end{aligned}$$

$$\begin{aligned} \text{Tmp2} &= (2 + 2 * d / D * \text{Tmp1} + 1.25 * d / D * \text{Sqr}(D / \text{eeq})) / (1 + \text{eb} / \text{eeq} * \text{Tmp1}) \\ &= (2 + 2 * 67.28 / 855.5 * 0.3115 + 1.25 * 67.28 / 855.5 * \text{Sqr}(855.5 / 8.5)) / (1 + 10.49 / 8.5 * 0.3115) = && 2.19 \end{aligned}$$

Stresses due to Pressure Range

$$\begin{aligned} \text{SigP} &= \text{DeltaP} * D / (2 * \text{eeq}) * \text{Tmp2} && (16.5-21) \\ &= 0.42 * 855.5 / (2 * 8.5) * 2.19 = && 46.34 \text{ N/mm}^2 \end{aligned}$$

Stresses due to Axial Load Range

$$\begin{aligned} \text{SigFz} &= 2.25 / \text{C1} * (\text{DeltaFz} / \text{eeq}^2) && (16.5-22) \\ &= 2.25 / 1.81 * (2.5 / 8.5^2) = && 43.01 \text{ N/mm}^2 \end{aligned}$$

Stresses due to Circumferential Moment Range

$$\begin{aligned} \text{SigMx} &= 2.25 / \text{C2} * (4 * \text{DeltaMx} / (\text{eeq}^2 * d)) && (16.5-23) \\ &= 2.25 / 4.9 * (4 * 0.29 / (8.5^2 * 67.28)) = && 109.58 \text{ N/mm}^2 \end{aligned}$$

Stresses due to Longitudinal Moment Range

$$\text{SigMy} = 2.25 / \text{C3} * (4 * \text{DeltaMy} / (\text{eeq}^2 * d)) \quad (16.5-24)$$

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$= 2.25 / 7.34 * (4 * 0.29 / (8.5^2 * 67.28)) =$ 73.17 N/mm2

Shear Stresses due to Longitudinal Shear Force, DeltaF1:
TauF1 = 2 * DeltaF1 / (PI * deb * eeq)
 $= 2 * 2.5 / (3.14 * 77.77 * 8.5) =$ 2.41 N/mm2

Shear Stresses due to Circumferential Force, TauFc:
TauFc = 2 * DeltaFc / (PI * deb * eeq)
 $= 2 * 1.92 / (3.14 * 77.77 * 8.5) =$ 1.85 N/mm2

Shear Stresses due to Torsional Moment, TauMt:
TauMt = 2 * DeltaMt / (PI * deb ^ 2 * eeq)
 $= 2 * 3 / (3.14 * 77.77^2 * 8.5) =$ 37.15 N/mm2

Total Shear Stresses, Tau:
Tau = Sqr(TauFc ^ 2 + TauF1 ^ 2) + TauMt
 $= \text{Sqr}(1.85^2 + 2.41^2) + 37.15 =$ 40.19 N/mm2

Total Stress Intensity due to Load Range
SigTot = Abs(SigT+Sqr((SigP+SigFz)^2+SigMx^2+SigMy^2+4*Tau^2)) (16.5-25)
 $= \text{Abs}(0 + \text{Sqr}((46.34 + 43.01)^2 + 109.58^2 + 73.17^2 + 4 * 40.19^2)) =$ 178.34 N/mm2

»Total Stress in Shell SigTot=178.34 <= 3*f=388.23[N/mm2] <> (U= 45.9%) OK<<

16.5.8 NOZZLE LONGITUDINAL STRESSES

Maximum Longitudinal Stresses in Nozzle
SigLong = P*d/(4*eb)+4*MB/(PI*d^2*eb)+Fz/(PI*d*eb) (16.5-26)
 $= 0.5 * 67.28 / (4 * 10.49) + 4 * 0.4101 / (3.14 * 67.28^2 * 10.49) + 2500 / (3.14 * 67.28 * 10.49)$
 $= 12.80 \text{ N/mm2}$

»Nozzle Long.Stress SigLong=12.8 <= fb=118.13[N/mm2] << » (U= 10.8%) OK<<

16.14.6 COMPRESSIVE STRESS LIMITS

$K = 1.21 * E * ea / (\text{Sige} * D)$ (16.14-15)
 $= 1.21 * 196147 * 10.49 / (177.2 * 67.28) =$ 208.83

$\text{alfa} = 0.83 / \text{Sqr}(1 + 0.005 * D / ea)$ (16.14-16)
 $= 0.83 / \text{Sqr}(1 + 0.005 * 67.28 / 10.49) =$ 0.8170

$\text{delta} = (1 - 0.4123 / (\text{alfa} * K) ^ 0.6) / S$ (16.14-19)
 $= (1 - 0.4123 / (0.817 * 208.83) ^ 0.6) / 1.5 =$ 0.6541

Maximum Allowable Compressive Stress
Sigcall = Sige * delta (16.14-20) = $177.2 * 0.6541 =$ 115.90 N/mm2

16.14.4 PERMISSIBLE INDIVIDUAL LOADS

Maximum Tensile Force Ftmax
Ftmax = PI * D * ea * f (16.14-1) = $3.14 * 67.28 * 10.49 * 118.13 =$ 261.92 kN

Maximum Compressive Force Fcmax
Fcmax = PI * D * ea * Sigcall (16.14-2) = $3.14 * 67.28 * 10.49 * 115.9 =$ 256.98 kN

Maximum Bending Moment Mmax
Mmax = PI / 4 * D ^ 2 * ea * Sigcall (16.14-3)
 $= 3.14 / 4 * 67.28^2 * 10.49 * 115.9 =$ 4.32 kNm

Longitudinal Stability Check (P=0)
LongStab = MB / Mmax + Abs(Fzmin) / Fcmax (16.5-27)
 $= 0.4101 / 4.32 + \text{Abs}(0) / 256.98 =$ 0.0949

»Nozzle Long.Stability LongStab=0.0949 <= 1.0=1<< » (U= 9.4%) OK<<

CALCULATION SUMMARY

9.5.2.4.4 Nozzles normal to the shell, with or without reinforcement pads.

Limit of Reinforcement Along Shell
Iso = Sqr((2 * ris + eas) * eas)
 $= \text{Sqr}((2 * 423.5 + 8.5) * 8.5) =$ 85.27 mm

Limit of Reinforcement Along Nozzle (outside shell)
Ibo = MIN(Sqr((deb - eb) * eb), ho) (16.5-75)
 $= \text{MIN}(\text{Sqr}((77.77 - 10.49) * 10.49), 200) =$ 26.57 mm

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Pressure Area Required pA(req.)

$$pAReqL = P * (ApsL + Apb) (16.5-7) = 0.5 * (52581.57 + 995.71) = \underline{26.79 \text{ kN}}$$

$$pAReqT = P * (ApsT + Apb + 0.5 * Apphi) (16.5-7) \\ = 0.5 * (26040.84 + 995.71 + 0.5 * 0) = \underline{13.52 \text{ kN}}$$

$$pAReq = \text{MAX}(pAReqL, pAReqT) = \text{MAX}(26.79, 13.52) = \underline{\underline{26.79 \text{ kN}}}$$

Pressure Area Available pA(aval.)

$$pAAval = (Afs + Afw) * (fs - 0.5 * P) + Afp * (fop - 0.5 * P) + Afb * (fob - 0.5 * P) (16.5-7) \\ = (724.83 + 0) * (129.41 - 0.5 * 0.5) + 0 * (0 - 0.5 * 0.5) + 367.85 * (118.13 - 0.5 * 0.5) = \underline{\underline{136.98 \text{ kN}}}$$

»Nozzle Reinforcement pAAval=136.98 >= pAReq=26.79[kN] « » (U= 19.5%) OK«

Maximum Allowable Pressure Pmax

$$Pmax = (Afs + Afw) * fs + Afb * fob / ((Aps + Apb + 0.5 * Apphi) + 0.5 * (Afs + Afw + Afb + Afp)) (10) \\ = (724.83 + 0) * 129.41 + 367.85 * 118.13 / ((52581.57 + 995.71 + 0.5 * 0) + 0.5 * (724.83 + 0 + 367.85 + 0)) \\ = \underline{\underline{2.54 \text{ MPa}}}$$

»ANSI 150lb-Flange Rating(at 232C) P=0.5 <= PMax(flange)=1.28[MPa] «» (U= 39.1%) OK«

LOAD CASE NO: 1 - Load Case 1

STRESSES AT OUTER DIAMETER OF NOZZLE

16.5.6.4 Check of Individual Load Ratio Limits

- »PhiP AT NOZZLE OD PhiP=0.0394 <= 1.0=1(16.5-12)« » (U= 3.9%) OK«
»PhiZ AT NOZZLE OD PhiZ=0.1477 <= 1.0=1(16.5-13)« » (U= 14.7%) OK«
»PhiB AT NOZZLE OD PhiB=0.4525 <= 1.0=1(16.5-14)« » (U= 45.2%) OK«
»PhiTau AT NOZZLE OD PhiTau=0.5272 <= 1.0=1« » (U= 52.7%) OK«
»PhiAll AT NOZZLE OD PhiAll=0.7186 <= 1.0=1(16.5-15)« » (U= 71.8%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

»Total Stress in Shell SigTot=142.41 <= 3*f=388.23[N/mm2] «» (U= 36.6%) OK«

16.5.8 NOZZLE LONGITUDINAL STRESSES

»Nozzle Long.Stress SigLong=10.84 <= fb=118.13[N/mm2] « » (U= 9.1%) OK«
»Nozzle Long.Stability LongStab=0.0949 <= 1.0=1« » (U= 9.4%) OK«

LOAD CASE NO: 2 - Load Case 2

STRESSES AT OUTER DIAMETER OF NOZZLE

16.5.6.4 Check of Individual Load Ratio Limits

- »PhiP AT NOZZLE OD PhiP=0.1656 <= 1.0=1(16.5-12)« » (U= 16.5%) OK«
»PhiZ AT NOZZLE OD PhiZ=0.1477 <= 1.0=1(16.5-13)« » (U= 14.7%) OK«
»PhiB AT NOZZLE OD PhiB=0.4525 <= 1.0=1(16.5-14)« » (U= 45.2%) OK«
»PhiTau AT NOZZLE OD PhiTau=0.6211 <= 1.0=1« » (U= 62.1%) OK«
»PhiAll AT NOZZLE OD PhiAll=0.8243 <= 1.0=1(16.5-15)« » (U= 82.4%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

»Total Stress in Shell SigTot=178.34 <= 3*f=388.23[N/mm2] «» (U= 45.9%) OK«

16.5.8 NOZZLE LONGITUDINAL STRESSES

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»Nozzle Long.Stress SigLong=12.8 <= fb=118.13[N/mm²] « » (U= 10.8%) OK«

»Nozzle Long.Stability LongStab=0.0949 <= 1.0=1« » (U= 9.4%) OK«

Volume:0 m³ Weight:6.4 kg (SG= 7.85)

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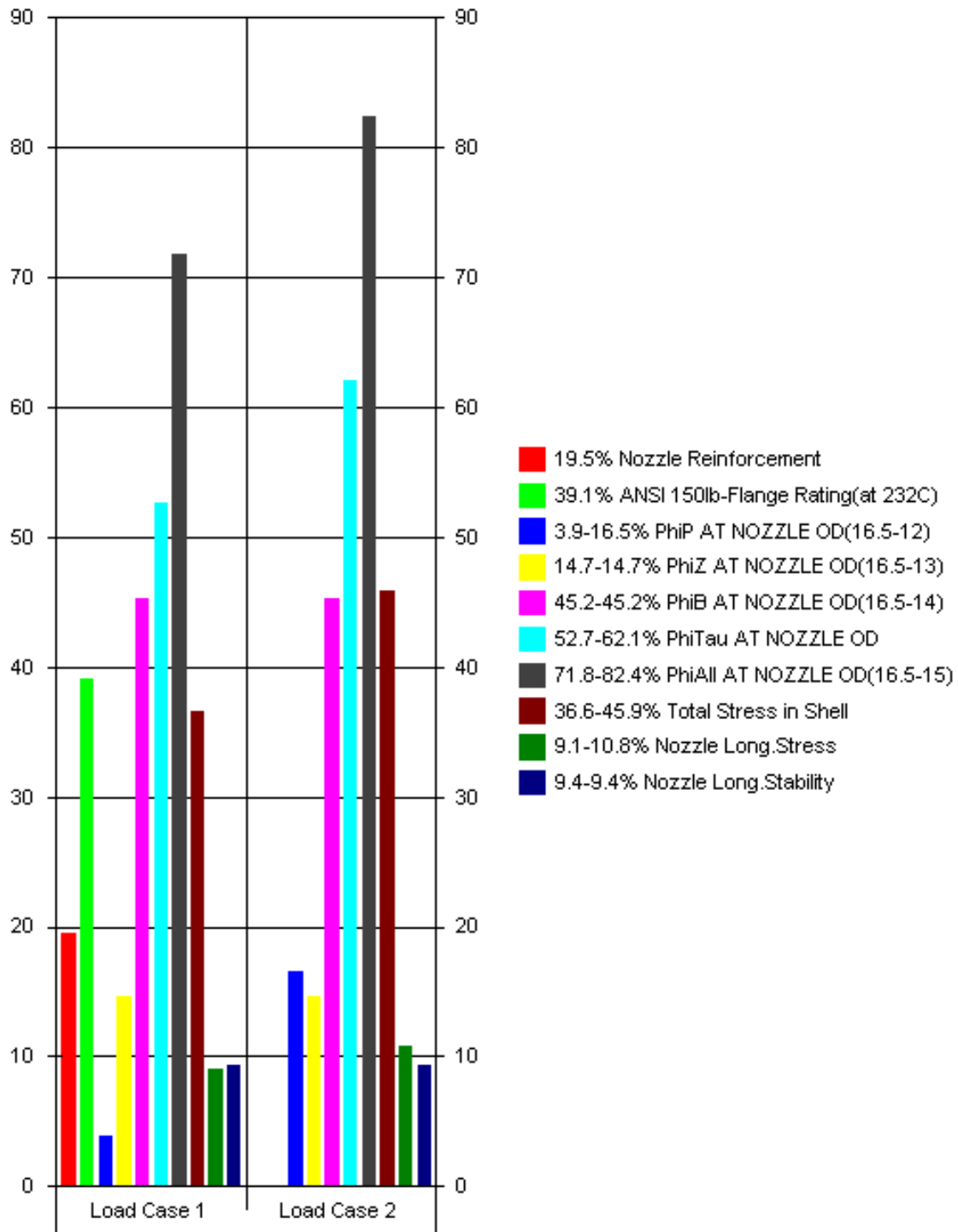
Sample File Steam Generator

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UTILIZATION CHART - N.A INLET



Max.Utilization/Condition 82.4% CASE:Load Case 2

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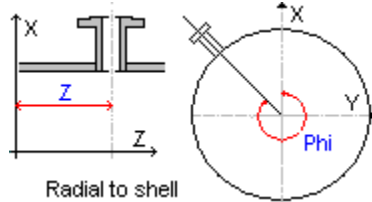
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INPUT DATA

COMPONENT ATTACHMENT/LOCATION

Attachment: S1.3 Cylindrical Shell Shell L=4030 S2.1



Orientation & Location of Nozzle: Radial to Shell
z-location of nozzle along axis of attachment.....:z 5075.00 mm
Angle of Rotation of nozzle axis projected in the x-y plane:Phi 180.00 Degr.

GENERAL DESIGN DATA



Type of Opening: Nozzle With Standard ANSI or DIN/EN Flange Attachment
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm, Pext= .1MPa
Include Nozzle Load Calculation: YES

SHELL DATA (S1.3)

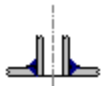
Shell Type: Cylindrical Shell
OUTSIDE DIAMETER OF SHELL.....:De 864.00 mm
AS BUILT WALL THICKNESS (uncorroded).....:en 12.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....:th 0.5000 mm
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
Rm=410 Rp=265 Rpt=194.12 fs=129.41 f20=170.83 ftest=252.38 E=196147(N/mm2) ro=7.85

NOZZLE MATERIAL DATA



Delivery Form: Forging (LWN)
ASME SA-105, PMA, , THK<=250mm 232'C
Rm=485 Rp=250 Rpt=177.2 fb=118.13 f20=166.67 ftest=238.1 (N/mm2)
NOTE: A PARTICULAR MATERIAL APPRAISAL(PMA) MAY BE REQUIRED FOR THIS MATERIAL.

NOZZLE DIMENSIONAL DATA



Attachment: Set In Flush Nozzle
Base calculations on Forging OD: NO
Shape of Nozzle/Opening: Circular
Application:
9.4.6.3 NOT a critical fatigue area, and calc.temp.is outside creep range.
INSIDE DIAMETER OF NOZZLE (corroded).....:dib 56.79 mm
AS BUILT NOZZLE THICKNESS (uncorroded).....:enb 13.49 mm
Size of Flange and Nozzle: 2"
Comment (Optional): CLASS :150# LWN Long Welding Neck
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....: 0.00 mm
NOZZLE STANDOUT MEASURED FROM VESSEL OD.....:ho 200.00 mm

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FLANGE DATA

A: Flange Standard: ANSI B16.5 Flanges
 E: Pressure Class: ANSI B16.5:Class 150 lbs
 C: Flange Type: LWN Long Welding Neck
 D: Facing Sketch/ANSI facing (Table 3.8.3(2)): 1a RF Raised Face
 Flange Material Category:
 1.1 - Carbon Steel - A105, A515 70, A516 70, A350 LF2 (BS 1503 164 490, BS 1504 161 480)

WELDING DATA

Nozzle/Pad to Shell Welding Area: Exclude Area of Nozzle to Shell Weld
 Nozzle Weld Intersect: Nozzle Does NOT Intersect with a Welded Shell Seam
 ANGLE PhiC(OBLIQUE IN TRANSVERSE.CROSS SECT.)Fig.9.5-2:PhiC 0.00 Degr.
 ANGLE PhiL(OBLIQUE IN LONG.CROSS SECT.)Fig.9.5-1....:PhiL 0.00 Degr.

DATA FOR REINFORCEMENT PAD



Type of Pad: No Pad

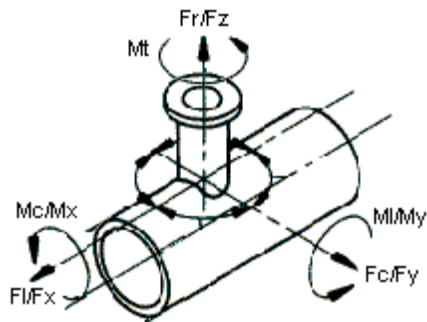
LIMITS OF REINFORCEMENT

Reduction of Limits of Reinforcement: No Reduction Required

EXTERNAL LOADS ON NOZZLE

FACTOR C4:

C4 = 1.1 Nozzle is Attached to a Piping System with due Allowance for Expansion and Thrust



TYPE OF LOAD INPUT: Load Cases

External Nozzle Loads: User Specified Loads

LOADING DATA

Table NOZZLE LOADS:

Load Description	ID	Units	Load Case 1	Load Case 2
Pressure	P	MPa	-0.1	0.42
Radial Load	Fz	kN	-2.5	2.5
Longitudinal Moment	My	kNm	-0.29	0.29
Circumferential Moment:	Mx	kNm	-0.29	0.29
Longitudinal Shear Force	Fl	kN	-2.5	2.5
Circumferential Shear Force	Fc	kN	-1.92	1.92
Torsional Moment	Mt	kNm	-3	3

CALCULATION DATA

FLANGE RATING

ANSI 150lb-Flange Rating(at 232C)= 1.276 MPa, Max.Test Pressure = 3.102 MPa

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PRELIMINARY CALCULATIONS

Shell Analysis Thickness eas
 $eas = en - c - th = 12 - 3 - 0.5 = 8.50 \text{ mm}$
Nozzle Analysis Thickness eab
 $eab = enb - c - NegDev = 13.49 - 3 - 0 = 10.49 \text{ mm}$
Inside Radius of Curvature
 $ris = De / 2 - eas = 864 / 2 - 8.5 = 423.50 \text{ mm}$
 $deb = dib + 2 * eab = 56.79 + 2 * 10.49 = 77.77 \text{ mm}$
Min.Nozzle Thk.Based on Internal Pressure ebp
 $ebp = P * dib / (2 * fb * z - P)$
 $= 0.5 * 56.79 / (2 * 118.13 * 1 - 0.5) = 0.1200 \text{ mm}$
Allowable Stresses
 $fob = \text{Min}(fs, fb) = \text{Min}(16.5 - 8) = \text{Min}(129.41, 118.13) = 118.13 \text{ N/mm}^2$

GEOMETRIC LIMITATIONS

»Check Max.Diameter of Nozzle $dib / (2 * ris) = 0.067 \leq 1 [\text{mm}] \llcorner \text{OK} \llcorner$
»Min.Nozzle Thk. $ebp = 0.12 \leq eab = 10.49 [\text{mm}] \llcorner (U = 1.1\%) \text{OK} \llcorner$

9.5.2.4.4 Nozzles normal to the shell, with or without reinforcement pads.

Calculation of Stress Loaded Areas Effective as Reinforcement

Area of Shell Afs

Limit of Reinforcement Along Shell
 $Iso = \text{Sqr}((2 * ris + eas) * eas) = \text{Sqr}((2 * 423.5 + 8.5) * 8.5) = 85.27 \text{ mm}$
Set In Nozzle
 $Afs = eas * Iso = 8.5 * 85.27 = 724.83 \text{ mm}^2$

Area of Nozzle Afb

Limit of Reinforcement Along Nozzle (outside shell)
 $Ibo = \text{MIN}(\text{Sqr}((deb - eb) * eb), ho) = \text{MIN}(\text{Sqr}((77.77 - 10.49) * 10.49), 200) = 26.57 \text{ mm}$
Set In Nozzle
 $Afb = eb * (Ibo + Ibi + eas) = 10.49 * (26.57 + 0 + 8.5) = 367.85 \text{ mm}^2$

Calculation of Pressure Loaded Areas

In the Nozzle Apb
 $Apb = 0.5 * dib * (Ibo + eas) = 0.5 * 56.79 * (26.57 + 8.5) = 995.71 \text{ mm}^2$
Cyl.Shell in the Longitudinal Section Aps
 $ApsL = ris * (Iso + a) = 423.5 * (85.27 + 38.89) = 52581.57 \text{ mm}^2$
Cyl.Shell in the Transverse Cross Section Aps
 $ApsT = 0.5 * ris^2 * (Iso + a) / (0.5 * eas + ris) = 0.5 * 423.5^2 * (85.27 + 38.94) / (0.5 * 8.5 + 423.5) = 26040.84 \text{ mm}^2$
 $Aps = \text{MAX}(ApsL, ApsT) = \text{MAX}(52581.57, 26040.84) = 52581.57 \text{ mm}^2$

9.5.2 Reinforcement Rules

Pressure Area Required pA(req.)

$pAReqL = P * (ApsL + Apb) = 0.5 * (52581.57 + 995.71) = 26.79 \text{ kN}$
 $pAReqT = P * (ApsT + Apb + 0.5 * Apphi) = 0.5 * (26040.84 + 995.71 + 0.5 * 0) = 13.52 \text{ kN}$
 $pAReq = \text{MAX}(pAReqL, pAReqT) = \text{MAX}(26.79, 13.52) = 26.79 \text{ kN}$

Pressure Area Available pA(aval.)

$pAAval = (Afs + Afb) * (fs - 0.5 * P) + Afp * (fop - 0.5 * P) + Afb * (fob - 0.5 * P) = (724.83 + 0) * (129.41 - 0.5 * 0.5) + 0 * (0 - 0.5 * 0.5) + 367.85 * (118.13 - 0.5 * 0.5) = 136.98 \text{ kN}$

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»Nozzle Reinforcement pAAval=136.98 >= pAReq=26.79[kN] « » (U= 19.5%) OK«

Maximum Allowable Pressure Pmax

$$P_{max} = (A_{fs} + A_{fw}) * f_s + A_{fb} * f_{ob} / ((A_{ps} + A_{pb} + 0.5 * A_{pphi}) + 0.5 * (A_{fs} + A_{fw} + A_{fb} + A_{fp})) \quad (10)$$
$$= +0) * 129.41 + 367.85 * 118.13 / ((52581.57 + 995.71 + 0.5 * 0) + 0.5 * (724.83 + 0 + 367.85 + 0))$$
$$= 2.54 \text{ MPa}$$

Max.Allowable Test Pressure P_{tmax}

$$P_{tmax} = 6.63 \text{ MPa}$$

»ANSI 150lb-Flange Rating(at 232C) P=0.5 <= P_{Max}(flange)=1.28[MPa] «» (U= 39.1%) OK«

16.5 LOCAL LOADS ON NOZZLES IN CYLINDRICAL SHELLS

PRELIMINARY CALCULATIONS

Shell Analysis Thickness e _{as}	
e _{as} = e _n - c - t _h = 12 - 3 - 0.5 =	8.50 mm
Nozzle Analysis Thickness e _b	
e _b = e _{nb} - c - NegDev = 13.49 - 3 - 0 =	10.49 mm
Mean diameter of shell	
D = D _e - e _a = 864 - 8.5 =	855.50 mm
Mean radius of shell	
R = D / 2 = 855.5 / 2 =	427.75 mm

16.5.3 CONDITIONS OF APPLICABILITY

»a) e_a/D = 0.0099 >= 0.001 « » OK «

»a) e_a/D = 0.0099 <= 0.1 « » OK «

»b) λ_C = 0.789 <= 10 « » OK «

»c) Dist. to any other local load shall not be less than $\sqrt{D * e_c} = 85.3 \text{ mm}$

»d) Nozzle thickness shall be maintained over a distance of $\sqrt{d * e_b} = 26.6 \text{ mm}$

LOAD CASE NO: 1 - Load Case 1

Total Moment

$$M_B = \sqrt{M_x^2 + M_y^2} = \sqrt{(-0.29)^2 + (-0.29)^2} = 0.4101 \text{ kNm}$$

STRESSES AT OUTER DIAMETER OF NOZZLE

Mean Diameter of Nozzle	
d = d _{eb} - e _b = 77.77 - 10.49 =	67.28 mm
Combined Analysis Thickness	
e _c = e _a = 8.5 =	8.50 mm
λ _C = d / $\sqrt{D * e_c}$ = 67.28 / $\sqrt{855.5 * 8.5}$ =	0.7890
Ratio1 = e _b / e _c = 10.49 / 8.5 =	1.23
Ratio2 = D / e _c = 855.5 / 8.5 =	100.65
VALUES FOR C ₁ , C ₂ AND C ₃ FROM FIGURES 16.5-2 to 16.5-4	
C ₁ = 1.810 C ₂ = 4.900 C ₃ = 7.338	

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

Permissible Pressure P _{max} :	
P _{max} (from nozzle calculation) = P _{max} (16.5-2) = 2.54 =	2.54 MPa
Allowable Axial Load F _{zmax} :	
F _{zmax} = f * e _c ² * C ₁ (16.5-3) = 129.41 * 8.5 ² * 1.81 =	16.92 kN
Allowable Circumferential Moment M _{xmax} :	
M _{xmax} = f * e _c ² * d / 4 * C ₂ (16.5-5)	
= 129.41 * 8.5 ² * 67.28 / 4 * 4.9 =	0.7706 kNm
Allowable Longitudinal Moment M _{xmax} :	
M _{ymax} = f * e _c ² * d / 4 * C ₃ (16.5-7)	
= 129.41 * 8.5 ² * 67.28 / 4 * 7.34 =	1.15 kNm

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SHEAR STRESS FORMULAE (PD5500 Section G.2.3.6.3)

Shear Stresses due to Longitudinal Shear Force, TauFl:

$$\text{TauFl} = 2 * F_l / (\text{PI} * \text{deb} * \text{ec}) \\ = 2 * -2.5 / (3.14 * 77.77 * 8.5) = \underline{\underline{-2.41 \text{ N/mm}^2}}$$

Shear Stresses due to Circumferential Force, TauFc:

$$\text{TauFc} = 2 * F_c / (\text{PI} * \text{deb} * \text{ec}) \\ = 2 * -1.92 / (3.14 * 77.77 * 8.5) = \underline{\underline{-1.85 \text{ N/mm}^2}}$$

Shear Stresses due to Torsional Moment, TauMt:

$$\text{TauMt} = 2 * M_t / (\text{PI} * \text{deb}^2 * \text{ec}) \\ = 2 * -3 / (3.14 * 77.77^2 * 8.5) = \underline{\underline{-37.15 \text{ N/mm}^2}}$$

Total Shear Stresses, Tau:

$$\text{Tau} = \text{Sqr}(\text{TauFc}^2 + \text{TauFl}^2) + \text{TauMt} \\ = \text{Sqr}(-1.85^2 + -2.41^2) + -37.15 = \underline{\underline{-34.11 \text{ N/mm}^2}}$$

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

$$\text{PhiP} = P / P_{\text{max}} \text{ (16.5-9)} = -0.1 / 2.54 = \underline{\underline{-0.0394}}$$

$$\text{PhiZ} = F_z / F_{z\text{max}} \text{ (16.5-10)} = -2.5 / 16.92 = \underline{\underline{-0.1477}}$$

$$\text{PhiTau} = \text{Tau} / (0.5 * f) = -34.11 / (0.5 * 129.41) = \underline{\underline{0.5272}}$$

$$\text{PhiB} = \text{Sqr}((M_x / M_{x\text{max}})^2 + (M_y / M_{y\text{max}})^2) \text{ (16.5-11)} \\ = \text{Sqr}((-0.29 / 0.7706)^2 + (-0.29 / 1.15)^2) = \underline{\underline{0.4525}}$$

$$\text{MaxAll} = \text{MAX}(\text{Abs}(\text{PhiP}/C4 + \text{PhiZ}), \text{Abs}(\text{PhiZ}), \text{Abs}(\text{PhiP}/C4 - 0.2 * \text{PhiZ}) \text{ (16.5-15)} \\ = \text{MAX}(\text{Abs}(-0.0394/1.1 + -0.1477), \text{Abs}(-0.1477), \text{Abs}(-0.0394/1.1 - 0.2 * -0.1477)) \\ = 0.1836$$

$$\text{PhiAll} = \text{Sqr}(\text{MaxAll}^2 + \text{PhiB}^2 + \text{PhiTau}^2) \text{ (16.5-15)} \\ = \text{Sqr}(0.1836^2 + 0.4525^2 + 0.5272^2) = \underline{\underline{0.7186}}$$

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT NOZZLE OD PhiP=0.0394 <= 1.0=1(16.5-12)« » (U= 3.9%) OK«

»PhiZ AT NOZZLE OD PhiZ=0.1477 <= 1.0=1(16.5-13)« » (U= 14.7%) OK«

»PhiB AT NOZZLE OD PhiB=0.4525 <= 1.0=1(16.5-14)« » (U= 45.2%) OK«

»PhiTau AT NOZZLE OD PhiTau=0.5272 <= 1.0=1« » (U= 52.7%) OK«

»PhiAll AT NOZZLE OD PhiAll=0.7186 <= 1.0=1(16.5-15)« » (U= 71.8%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

16.5.7.1 LOAD RANGES

$$\text{DeltaP} = \text{Max}(P_{\text{max}}, 0) - \text{Min}(P_{\text{min}}, 0) \text{ (16.5-16)} \\ = \text{Max}(0.1, 0) - \text{Min}(0, 0) = \underline{\underline{0.1000 \text{ MPa}}}$$

$$\text{DeltaFz} = \text{Max}(F_{z\text{max}}, 0) - \text{Min}(F_{z\text{min}}, 0) \text{ (16.5-17)} \\ = \text{Max}(2.5, 0) - \text{Min}(0, 0) = \underline{\underline{2.50 \text{ kN}}}$$

$$\text{DeltaMx} = \text{Max}(M_{x\text{max}}, 0) - \text{Min}(M_{x\text{min}}, 0) \text{ (16.5-18)} \\ = \text{Max}(0.29, 0) - \text{Min}(0, 0) = \underline{\underline{0.2900 \text{ kNm}}}$$

$$\text{DeltaMy} = \text{Max}(M_{y\text{max}}, 0) - \text{Min}(M_{y\text{min}}, 0) \text{ (16.5-19)} \\ = \text{Max}(0.29, 0) - \text{Min}(0, 0) = \underline{\underline{0.2900 \text{ kNm}}}$$

$$\text{DeltaFl} = \text{Max}(F_{l\text{max}}, 0) - \text{Min}(F_{l\text{min}}, 0) \\ = \text{Max}(2.5, 0) - \text{Min}(0, 0) = \underline{\underline{0.00 \text{ kN}}}$$

$$\text{DeltaFc} = \text{Max}(F_{c\text{max}}, 0) - \text{Min}(F_{c\text{min}}, 0) \\ = \text{Max}(1.92, 0) - \text{Min}(0, 0) = \underline{\underline{0.00 \text{ kN}}}$$

$$\text{DeltaFshear} = \text{Sqr}(\text{DeltaFl}^2 + \text{DeltaFc}^2) \\ = \text{Sqr}(0^2 + 0^2) = \underline{\underline{0.00 \text{ kN}}}$$

$$\text{DeltaMt} = \text{Max}(M_{t\text{max}}, 0) - \text{Min}(M_{t\text{min}}, 0) \\ = \text{Max}(3, 0) - \text{Min}(0, 0) = \underline{\underline{0.00 \text{ kNm}}}$$

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16.5.7.2 EQUIVALENT SHELL THICKNESS

$eeq = ec = 8.5 = 8.50 \text{ mm}$

16.5.7.3 STRESSES

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

$C1 = 1.810 \quad C2 = 4.900 \quad C3 = 7.338$

$Tmp1 = \text{Sqr}(d * eb / (D * eeq)) = \text{Sqr}(67.28 * 10.49 / (855.5 * 8.5)) = 0.3115$

$Tmp2 = (2 + 2 * d / D * Tmp1 + 1.25 * d / D * \text{Sqr}(D / eeq)) / (1 + eb / eeq * Tmp1) = (2 + 2 * 67.28 / 855.5 * 0.3115 + 1.25 * 67.28 / 855.5 * \text{Sqr}(855.5 / 8.5)) / (1 + 10.49 / 8.5 * 0.3115) = 2.19$

Stresses due to Pressure Range

$SigP = \text{DeltaP} * D / (2 * eeq) * Tmp2 = 0.1 * 855.5 / (2 * 8.5) * 2.19 = 11.03 \text{ N/mm}^2$ (16.5-21)

Stresses due to Axial Load Range

$SigFz = 2.25 / C1 * (\text{DeltaFz} / eeq^2) = 2.25 / 1.81 * (2.5 / 8.5^2) = 43.01 \text{ N/mm}^2$ (16.5-22)

Stresses due to Circumferential Moment Range

$SigMx = 2.25 / C2 * (4 * \text{DeltaMx} / (eeq^2 * d)) = 2.25 / 4.9 * (4 * 0.29 / (8.5^2 * 67.28)) = 109.58 \text{ N/mm}^2$ (16.5-23)

Stresses due to Longitudinal Moment Range

$SigMy = 2.25 / C3 * (4 * \text{DeltaMy} / (eeq^2 * d)) = 2.25 / 7.34 * (4 * 0.29 / (8.5^2 * 67.28)) = 73.17 \text{ N/mm}^2$ (16.5-24)

Shear Stresses due to Longitudinal Shear Force, DeltaFl:

$TauFl = 2 * \text{DeltaFl} / (\text{PI} * deb * eeq) = 2 * 0 / (3.14 * 77.77 * 8.5) = 0.00 \text{ N/mm}^2$

Shear Stresses due to Circumferential Force, TauFc:

$TauFc = 2 * \text{DeltaFc} / (\text{PI} * deb * eeq) = 2 * 0 / (3.14 * 77.77 * 8.5) = 0.00 \text{ N/mm}^2$

Shear Stresses due to Torsional Moment, TauMt:

$TauMt = 2 * \text{DeltaMt} / (\text{PI} * deb^2 * eeq) = 2 * 0 / (3.14 * 77.77^2 * 8.5) = 0.00 \text{ N/mm}^2$

Total Shear Stresses, Tau:

$Tau = \text{Sqr}(TauFc^2 + TauFl^2) + TauMt = \text{Sqr}(0^2 + 0^2) + 0 = 0.00 \text{ N/mm}^2$

Total Stress Intensity due to Load Range

$SigTot = \text{Abs}(SigT + \text{Sqr}((SigP + SigFz)^2 + SigMx^2 + SigMy^2 + 4 * Tau^2)) = \text{Abs}(0 + \text{Sqr}((11.03 + 43.01)^2 + 109.58^2 + 73.17^2 + 4 * 0^2)) = 142.41 \text{ N/mm}^2$ (16.5-25)

»Total Stress in Shell SigTot=142.41 <= 3*f=388.23[N/mm2] <>> (U= 36.6%) OK<<

16.5.8 NOZZLE LONGITUDINAL STRESSES

Maximum Longitudinal Stresses in Nozzle

$SigLong = P * d / (4 * eb) + 4 * MB / (\text{PI} * d^2 * eb) + Fz / (\text{PI} * d * eb) = -0.1 * 67.28 / (4 * 10.49) + 4 * 0.4101 / (3.14 * 67.28^2 * 10.49) + 0 / (3.14 * 67.28 * 10.49) = 10.84 \text{ N/mm}^2$ (16.5-26)

»Nozzle Long.Stress SigLong=10.84 <= fb=118.13[N/mm2] << >> (U= 9.1%) OK<<

16.14.6 COMPRESSIVE STRESS LIMITS

$K = 1.21 * E * ea / (Sige * D) = 1.21 * 196147 * 10.49 / (177.2 * 67.28) = 208.83$ (16.14-15)

$alfa = 0.83 / \text{Sqr}(1 + 0.005 * D / ea) = 0.83 / \text{Sqr}(1 + 0.005 * 67.28 / 10.49) = 0.8170$ (16.14-16)

$delta = (1 - 0.4123 / (alfa * K))^0.6 / S = (1 - 0.4123 / (0.817 * 208.83))^0.6 / 1.5 = 0.6541$ (16.14-19)

Maximum Allowable Compressive Stress

$Sigcall = Sige * delta = 177.2 * 0.6541 = 115.90 \text{ N/mm}^2$

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16.14.4 PERMISSIBLE INDIVIDUAL LOADS

Maximum Tensile Force Ftmax

$$Ftmax = PI * D * ea * f (16.14-1) = 3.14 * 67.28 * 10.49 * 118.13 = \underline{261.92 \text{ kN}}$$

Maximum Compressive Force Fcmax

$$Fcmax = PI * D * ea * Sigcall (16.14-2) = 3.14 * 67.28 * 10.49 * 115.9 = \underline{256.98 \text{ kN}}$$

Maximum Bending Moment Mmax

$$Mmax = PI / 4 * D^2 * ea * Sigcall (16.14-3) \\ = 3.14 / 4 * 67.28^2 * 10.49 * 115.9 = \underline{4.32 \text{ kNm}}$$

Longitudinal Stability Check (P=0)

$$LongStab = MB / Mmax + Abs(Fzmin) / Fcmax (16.5-27) \\ = 0.4101 / 4.32 + Abs(0) / 256.98 = \underline{0.0949}$$

»Nozzle Long.Stability LongStab=0.0949 <= 1.0=1« » (U= 9.4%) OK«

LOAD CASE NO: 2 - Load Case 2

Total Moment

$$MB = Sqr(Mx^2 + My^2) = Sqr(0.29^2 + 0.29^2) = 0.4101 \text{ kNm}$$

STRESSES AT OUTER DIAMETER OF NOZZLE

Mean Diameter of Nozzle

$$d = deb - eb = 77.77 - 10.49 = 67.28 \text{ mm}$$

Combined Analysis Thickness

$$ec = ea = 8.5 = 8.50 \text{ mm}$$

$$\lambda dC = d / Sqr(D * ec) = 67.28 / Sqr(855.5 * 8.5) = 0.7890$$

$$Ratio1 = eb / ec = 10.49 / 8.5 = 1.23$$

$$Ratio2 = D / ec = 855.5 / 8.5 = 100.65$$

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

$$C1 = 1.810 \quad C2 = 4.900 \quad C3 = 7.338$$

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

Permissible Pressure Pmax:

$$Pmax (\text{from nozzle calculation}) = Pmax (16.5-2) = 2.54 = \underline{2.54 \text{ MPa}}$$

Allowable Axial Load Fzmax:

$$Fzmax = f * ec^2 * C1 (16.5-3) = 129.41 * 8.5^2 * 1.81 = \underline{16.92 \text{ kN}}$$

Allowable Circumferential Moment Mxmax:

$$Mxmax = f * ec^2 * d / 4 * C2 (16.5-5) \\ = 129.41 * 8.5^2 * 67.28 / 4 * 4.9 = \underline{0.7706 \text{ kNm}}$$

Allowable Longitudinal Moment Mxmax:

$$Mymax = f * ec^2 * d / 4 * C3 (16.5-7) \\ = 129.41 * 8.5^2 * 67.28 / 4 * 7.34 = \underline{1.15 \text{ kNm}}$$

SHEAR STRESS FORMULAE (PD5500 Section G.2.3.6.3)

Shear Stresses due to Longitudinal Shear Force, TauFl:

$$TauFl = 2 * F1 / (PI * deb * ec) \\ = 2 * 2.5 / (3.14 * 77.77 * 8.5) = \underline{2.41 \text{ N/mm}^2}$$

Shear Stresses due to Circumferential Force, TauFc:

$$TauFc = 2 * Fc / (PI * deb * ec) \\ = 2 * 1.92 / (3.14 * 77.77 * 8.5) = \underline{1.85 \text{ N/mm}^2}$$

Shear Stresses due to Torsional Moment, TauMt:

$$TauMt = 2 * Mt / (PI * deb^2 * ec) \\ = 2 * 3 / (3.14 * 77.77^2 * 8.5) = \underline{37.15 \text{ N/mm}^2}$$

Total Shear Stresses, Tau:

$$Tau = Sqr(TauFc^2 + TauFl^2) + TauMt \\ = Sqr(1.85^2 + 2.41^2) + 37.15 = \underline{40.19 \text{ N/mm}^2}$$

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

$$PhiP = P / Pmax (16.5-9) = 0.5 / 2.54 = \underline{0.1656}$$

$$PhiZ = Fz / Fzmax (16.5-10) = 2.5 / 16.92 = \underline{0.1477}$$

$$PhiTau = Tau / (0.5 * f) = 40.19 / (0.5 * 129.41) = \underline{0.6211}$$

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$$\begin{aligned} \text{PhiB} &= \text{Sqr}((\text{Mx} / \text{Mxmax})^2 + (\text{My} / \text{Mymax})^2) && (16.5-11) \\ &= \text{Sqr}((0.29/0.7706)^2 + (0.29/1.15)^2) = && 0.4525 \end{aligned}$$

$$\begin{aligned} \text{MaxAll} &= \text{MAX}(\text{Abs}(\text{PhiP}/\text{C4} + \text{PhiZ}), \text{Abs}(\text{PhiZ}), \text{Abs}(\text{PhiP}/\text{C4} - 0.2 * \text{PhiZ}) && (16.5-15) \\ &= \text{MAX}(\text{Abs}(0.1656/1.1 + 0.1477), \text{Abs}(0.1477), \text{Abs}(0.1656/1.1 - 0.2 * 0.1477)) = && 0.2983 \end{aligned}$$

$$\begin{aligned} \text{PhiAll} &= \text{Sqr}(\text{MaxAll}^2 + \text{PhiB}^2 + \text{PhiTau}^2) && (16.5-15) \\ &= \text{Sqr}(0.2983^2 + 0.4525^2 + 0.6211^2) = && 0.8243 \end{aligned}$$

16.5.6.4 Check of Individual Load Ratio Limits

- »PhiP AT NOZZLE OD PhiP=0.1656 <= 1.0=1(16.5-12)« » (U= 16.5%) OK«
- »PhiZ AT NOZZLE OD PhiZ=0.1477 <= 1.0=1(16.5-13)« » (U= 14.7%) OK«
- »PhiB AT NOZZLE OD PhiB=0.4525 <= 1.0=1(16.5-14)« » (U= 45.2%) OK«
- »PhiTau AT NOZZLE OD PhiTau=0.6211 <= 1.0=1« » (U= 62.1%) OK«
- »PhiAll AT NOZZLE OD PhiAll=0.8243 <= 1.0=1(16.5-15)« » (U= 82.4%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

16.5.7.1 LOAD RANGES

$$\begin{aligned} \text{DeltaP} &= \text{Max}(\text{Pmax}, 0) - \text{Min}(\text{Pmin}, 0) && (16.5-16) \\ &= \text{Max}(0.42, 0) - \text{Min}(0, 0) = && 0.4200 \text{ MPa} \end{aligned}$$

$$\begin{aligned} \text{DeltaFz} &= \text{Max}(\text{Fzmax}, 0) - \text{Min}(\text{Fzmin}, 0) && (16.5-17) \\ &= \text{Max}(2.5, 0) - \text{Min}(0, 0) = && 2.50 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{DeltaMx} &= \text{Max}(\text{Mxmax}, 0) - \text{Min}(\text{Mxmin}, 0) && (16.5-18) \\ &= \text{Max}(0.29, 0) - \text{Min}(0, 0) = && 0.2900 \text{ kNm} \end{aligned}$$

$$\begin{aligned} \text{DeltaMy} &= \text{Max}(\text{Mymax}, 0) - \text{Min}(\text{Mymin}, 0) && (16.5-19) \\ &= \text{Max}(0.29, 0) - \text{Min}(0, 0) = && 0.2900 \text{ kNm} \end{aligned}$$

$$\begin{aligned} \text{DeltaFl} &= \text{Max}(\text{Flmax}, 0) - \text{Min}(\text{Flmin}, 0) \\ &= \text{Max}(2.5, 0) - \text{Min}(0, 0) = && 2.50 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{DeltaFc} &= \text{Max}(\text{Fcmax}, 0) - \text{Min}(\text{Fcmin}, 0) \\ &= \text{Max}(1.92, 0) - \text{Min}(0, 0) = && 1.92 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{DeltaFshear} &= \text{Sqr}(\text{DeltaFl}^2 + \text{DeltaFc}^2) \\ &= \text{Sqr}(2.5^2 + 1.92^2) = && 3.15 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{DeltaMt} &= \text{Max}(\text{Mtmax}, 0) - \text{Min}(\text{Mtmin}, 0) \\ &= \text{Max}(3, 0) - \text{Min}(0, 0) = && 3.00 \text{ kNm} \end{aligned}$$

16.5.7.2 EQUIVALENT SHELL THICKNESS

$$\text{eeq} = \text{ec} = 8.5 = 8.50 \text{ mm}$$

16.5.7.3 STRESSES

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

$$\text{C1} = 1.810 \quad \text{C2} = 4.900 \quad \text{C3} = 7.338$$

$$\begin{aligned} \text{Tmp1} &= \text{Sqr}(d * \text{eb} / (D * \text{eeq})) \\ &= \text{Sqr}(67.28 * 10.49 / (855.5 * 8.5)) = && 0.3115 \end{aligned}$$

$$\begin{aligned} \text{Tmp2} &= (2 + 2 * d / D * \text{Tmp1} + 1.25 * d / D * \text{Sqr}(D / \text{eeq})) / (1 + \text{eb} / \text{eeq} * \text{Tmp1}) \\ &= (2 + 2 * 67.28 / 855.5 * 0.3115 + 1.25 * 67.28 / 855.5 * \text{Sqr}(855.5 / 8.5)) / (1 + 10.49 / 8.5 * 0.3115) = && 2.19 \end{aligned}$$

$$\begin{aligned} \text{Stresses due to Pressure Range} \\ \text{SigP} &= \text{DeltaP} * D / (2 * \text{eeq}) * \text{Tmp2} && (16.5-21) \\ &= 0.42 * 855.5 / (2 * 8.5) * 2.19 = && 46.34 \text{ N/mm}^2 \end{aligned}$$

$$\begin{aligned} \text{Stresses due to Axial Load Range} \\ \text{SigFz} &= 2.25 / \text{C1} * (\text{DeltaFz} / \text{eeq}^2) && (16.5-22) \\ &= 2.25 / 1.81 * (2.5 / 8.5^2) = && 43.01 \text{ N/mm}^2 \end{aligned}$$

$$\begin{aligned} \text{Stresses due to Circumferential Moment Range} \\ \text{SigMx} &= 2.25 / \text{C2} * (4 * \text{DeltaMx} / (\text{eeq}^2 * d)) && (16.5-23) \\ &= 2.25 / 4.9 * (4 * 0.29 / (8.5^2 * 67.28)) = && 109.58 \text{ N/mm}^2 \end{aligned}$$

$$\begin{aligned} \text{Stresses due to Longitudinal Moment Range} \\ \text{SigMy} &= 2.25 / \text{C3} * (4 * \text{DeltaMy} / (\text{eeq}^2 * d)) && (16.5-24) \end{aligned}$$

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$= 2.25 / 7.34 * (4 * 0.29 / (8.5^2 * 67.28)) =$ 73.17 N/mm2

Shear Stresses due to Longitudinal Shear Force, DeltaFl:
TauFl = $2 * \text{DeltaFl} / (\text{PI} * \text{deb} * \text{eeq})$
 $= 2 * 2.5 / (3.14 * 77.77 * 8.5) =$ 2.41 N/mm2

Shear Stresses due to Circumferential Force, TauFc:
TauFc = $2 * \text{DeltaFc} / (\text{PI} * \text{deb} * \text{eeq})$
 $= 2 * 1.92 / (3.14 * 77.77 * 8.5) =$ 1.85 N/mm2

Shear Stresses due to Torsional Moment, TauMt:
TauMt = $2 * \text{DeltaMt} / (\text{PI} * \text{deb}^2 * \text{eeq})$
 $= 2 * 3 / (3.14 * 77.77^2 * 8.5) =$ 37.15 N/mm2

Total Shear Stresses, Tau:
Tau = $\text{Sqr}(\text{TauFc}^2 + \text{TauFl}^2) + \text{TauMt}$
 $= \text{Sqr}(1.85^2 + 2.41^2) + 37.15 =$ 40.19 N/mm2

Total Stress Intensity due to Load Range
SigTot = $\text{Abs}(\text{SigT} + \text{Sqr}((\text{SigP} + \text{SigFz})^2 + \text{SigMx}^2 + \text{SigMy}^2 + 4 * \text{Tau}^2))$ (16.5-25)
 $= \text{Abs}(0 + \text{Sqr}((46.34 + 43.01)^2 + 109.58^2 + 73.17^2 + 4 * 40.19^2)) =$ 178.34 N/mm2

»Total Stress in Shell SigTot=178.34 <= 3*f=388.23[N/mm2] <> (U= 45.9%) OK<<

16.5.8 NOZZLE LONGITUDINAL STRESSES

Maximum Longitudinal Stresses in Nozzle
SigLong = $\text{P} * \text{d} / (4 * \text{eb}) + 4 * \text{MB} / (\text{PI} * \text{d}^2 * \text{eb}) + \text{Fz} / (\text{PI} * \text{d} * \text{eb})$ (16.5-26)
 $= 0.5 * 67.28 / (4 * 10.49) + 4 * 0.4101 / (3.14 * 67.28^2 * 10.49) + 2500 / (3.14 * 67.28 * 10.49)$
 $= 12.80 \text{ N/mm2}$

»Nozzle Long.Stress SigLong=12.8 <= fb=118.13[N/mm2] << » (U= 10.8%) OK<<

16.14.6 COMPRESSIVE STRESS LIMITS

$K = 1.21 * E * \text{ea} / (\text{Sige} * D)$ (16.14-15)
 $= 1.21 * 196147 * 10.49 / (177.2 * 67.28) =$ 208.83

$\text{alfa} = 0.83 / \text{Sqr}(1 + 0.005 * D / \text{ea})$ (16.14-16)
 $= 0.83 / \text{Sqr}(1 + 0.005 * 67.28 / 10.49) =$ 0.8170

$\text{delta} = (1 - 0.4123 / (\text{alfa} * K)^{0.6}) / S$ (16.14-19)
 $= (1 - 0.4123 / (0.817 * 208.83)^{0.6}) / 1.5 =$ 0.6541

Maximum Allowable Compressive Stress
Sigcall = $\text{Sige} * \text{delta}$ (16.14-20) = $177.2 * 0.6541 =$ 115.90 N/mm2

16.14.4 PERMISSIBLE INDIVIDUAL LOADS

Maximum Tensile Force Ftmax
Ftmax = $\text{PI} * D * \text{ea} * f$ (16.14-1) = $3.14 * 67.28 * 10.49 * 118.13 =$ 261.92 kN

Maximum Compressive Force Fcmax
Fcmax = $\text{PI} * D * \text{ea} * \text{Sigcall}$ (16.14-2) = $3.14 * 67.28 * 10.49 * 115.9 =$ 256.98 kN

Maximum Bending Moment Mmax
Mmax = $\text{PI} / 4 * D^2 * \text{ea} * \text{Sigcall}$ (16.14-3)
 $= 3.14 / 4 * 67.28^2 * 10.49 * 115.9 =$ 4.32 kNm

Longitudinal Stability Check (P=0)
LongStab = $\text{MB} / \text{Mmax} + \text{Abs}(\text{Fzmin}) / \text{Fcmax}$ (16.5-27)
 $= 0.4101 / 4.32 + \text{Abs}(0) / 256.98 =$ 0.0949

»Nozzle Long.Stability LongStab=0.0949 <= 1.0=1<< » (U= 9.4%) OK<<

CALCULATION SUMMARY

9.5.2.4.4 Nozzles normal to the shell, with or without reinforcement pads.

Limit of Reinforcement Along Shell
Iso = $\text{Sqr}((2 * \text{ris} + \text{eas}) * \text{eas})$
 $= \text{Sqr}((2 * 423.5 + 8.5) * 8.5) =$ 85.27 mm

Limit of Reinforcement Along Nozzle (outside shell)
Ibo = $\text{MIN}(\text{Sqr}((\text{deb} - \text{eb}) * \text{eb}), \text{ho})$ (16.5-75)
 $= \text{MIN}(\text{Sqr}((77.77 - 10.49) * 10.49), 200) =$ 26.57 mm

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Pressure Area Required pA(req.)

$$pAReqL = P * (ApsL + Apb) (16.5-7) = 0.5 * (52581.57 + 995.71) = \underline{26.79 \text{ kN}}$$

$$pAReqT = P * (ApsT + Apb + 0.5 * Apphi) (16.5-7) \\ = 0.5 * (26040.84 + 995.71 + 0.5 * 0) = \underline{13.52 \text{ kN}}$$

$$pAReq = \text{MAX}(pAReqL, pAReqT) = \text{MAX}(26.79, 13.52) = \underline{\underline{26.79 \text{ kN}}}$$

Pressure Area Available pA(aval.)

$$pAAval = (Afs + Afw) * (fs - 0.5 * P) + Afp * (fop - 0.5 * P) + Afb * (fob - 0.5 * P) (16.5-7) \\ = (724.83 + 0) * (129.41 - 0.5 * 0.5) + 0 * (0 - 0.5 * 0.5) + 367.85 * (118.13 - 0.5 * 0.5) = \underline{\underline{136.98 \text{ kN}}}$$

»Nozzle Reinforcement pAAval=136.98 >= pAReq=26.79[kN] « » (U= 19.5%) OK«

Maximum Allowable Pressure Pmax

$$Pmax = (Afs + Afw) * fs + Afb * fob / ((Aps + Apb + 0.5 * Apphi) + 0.5 * (Afs + Afw + Afb + Afp)) (10) \\ = (724.83 + 0) * 129.41 + 367.85 * 118.13 / ((52581.57 + 995.71 + 0.5 * 0) + 0.5 * (724.83 + 0 + 367.85 + 0)) \\ = \underline{\underline{2.54 \text{ MPa}}}$$

»ANSI 150lb-Flange Rating(at 232C) P=0.5 <= PMax(flange)=1.28[MPa] «» (U= 39.1%) OK«

LOAD CASE NO: 1 - Load Case 1

STRESSES AT OUTER DIAMETER OF NOZZLE

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT NOZZLE OD PhiP=0.0394 <= 1.0=1(16.5-12)« » (U= 3.9%) OK«
»PhiZ AT NOZZLE OD PhiZ=0.1477 <= 1.0=1(16.5-13)« » (U= 14.7%) OK«
»PhiB AT NOZZLE OD PhiB=0.4525 <= 1.0=1(16.5-14)« » (U= 45.2%) OK«
»PhiTau AT NOZZLE OD PhiTau=0.5272 <= 1.0=1« » (U= 52.7%) OK«
»PhiAll AT NOZZLE OD PhiAll=0.7186 <= 1.0=1(16.5-15)« » (U= 71.8%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

»Total Stress in Shell SigTot=142.41 <= 3*f=388.23[N/mm2] «» (U= 36.6%) OK«

16.5.8 NOZZLE LONGITUDINAL STRESSES

»Nozzle Long.Stress SigLong=10.84 <= fb=118.13[N/mm2] « » (U= 9.1%) OK«
»Nozzle Long.Stability LongStab=0.0949 <= 1.0=1« » (U= 9.4%) OK«

LOAD CASE NO: 2 - Load Case 2

STRESSES AT OUTER DIAMETER OF NOZZLE

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT NOZZLE OD PhiP=0.1656 <= 1.0=1(16.5-12)« » (U= 16.5%) OK«
»PhiZ AT NOZZLE OD PhiZ=0.1477 <= 1.0=1(16.5-13)« » (U= 14.7%) OK«
»PhiB AT NOZZLE OD PhiB=0.4525 <= 1.0=1(16.5-14)« » (U= 45.2%) OK«
»PhiTau AT NOZZLE OD PhiTau=0.6211 <= 1.0=1« » (U= 62.1%) OK«
»PhiAll AT NOZZLE OD PhiAll=0.8243 <= 1.0=1(16.5-15)« » (U= 82.4%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

»Total Stress in Shell SigTot=178.34 <= 3*f=388.23[N/mm2] «» (U= 45.9%) OK«

16.5.8 NOZZLE LONGITUDINAL STRESSES

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»Nozzle Long.Stress SigLong=12.8 <= fb=118.13[N/mm²] « » (U= 10.8%) OK«

»Nozzle Long.Stability LongStab=0.0949 <= 1.0=1« » (U= 9.4%) OK«

Volume:0 m³ Weight:6.4 kg (SG= 7.85)

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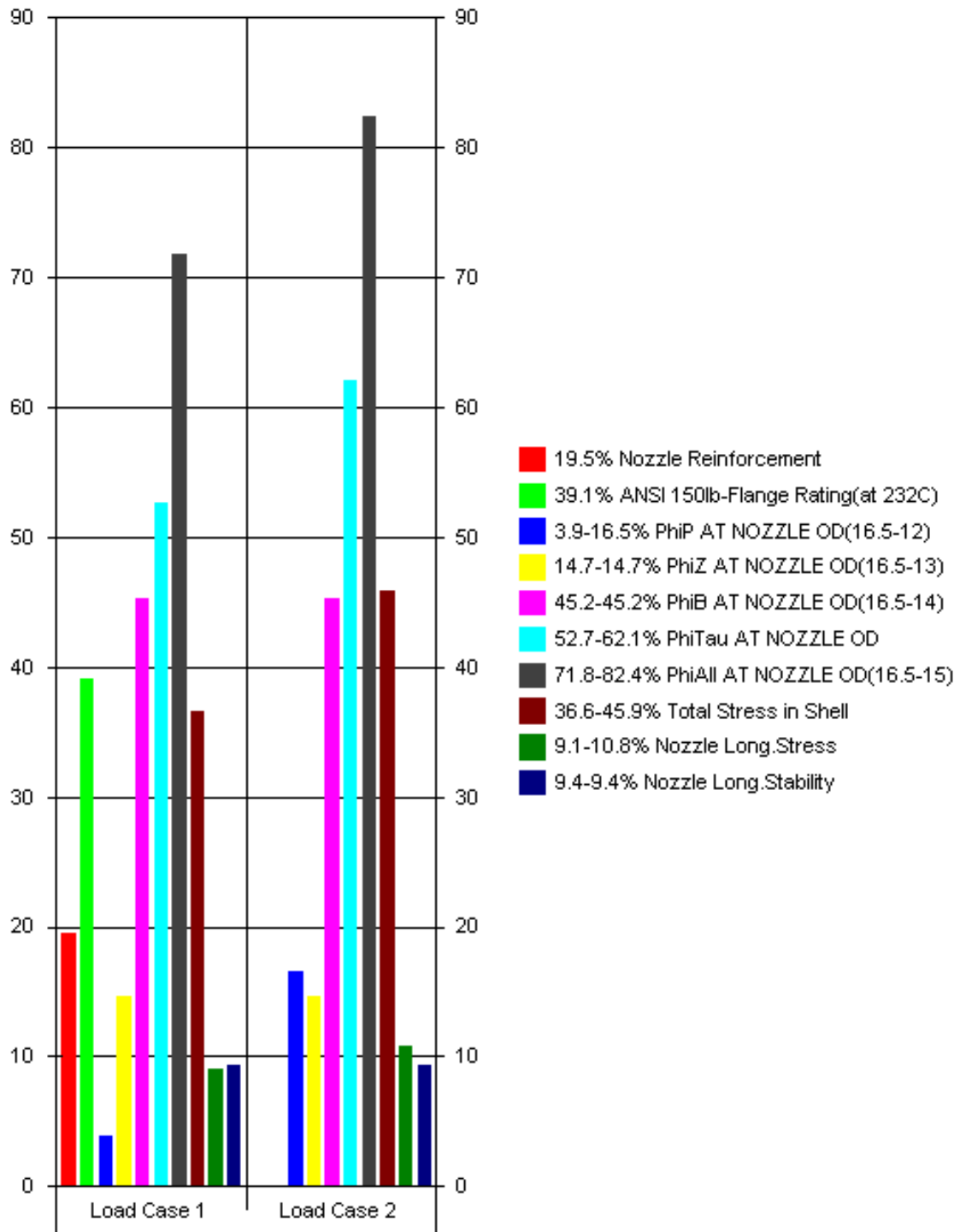
Sample File Steam Generator

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UTILIZATION CHART - N.B OUTLET LIQ



Max.Utilization/Condition 82.4% CASE:Load Case 2

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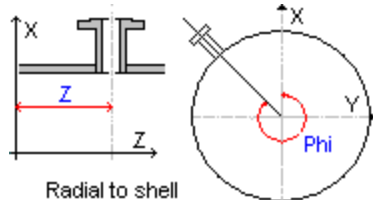
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INPUT DATA

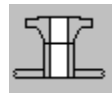
COMPONENT ATTACHMENT/LOCATION

Attachment: S1.3 Cylindrical Shell Shell L=4030 S2.1



Orientation & Location of Nozzle: Radial to Shell
z-location of nozzle along axis of attachment.....:z 3197.00 mm
Angle of Rotation of nozzle axis projected in the x-y plane:Phi 0.00 Degr.

GENERAL DESIGN DATA



Type of Opening: Nozzle With Standard ANSI or DIN/EN Flange Attachment
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm, Pext= .1MPa
Include Nozzle Load Calculation: YES

SHELL DATA (S1.3)

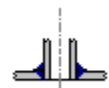
Shell Type: Cylindrical Shell
OUTSIDE DIAMETER OF SHELL.....:De 864.00 mm
AS BUILT WALL THICKNESS (uncorroded).....:en 12.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....:th 0.5000 mm
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
Rm=410 Rp=265 Rpt=194.12 fs=129.41 f20=170.83 ftest=252.38 E=196147(N/mm²) ro=7.85

NOZZLE MATERIAL DATA



Delivery Form: Seamless Pipe
ASME SA-106 Gr.B, PMA, , THK<=999mm 232'C
Rm=415 Rp=240 Rpt=171.56 fb=114.37 f20=160 ftest=228.57 (N/mm²)
NOTE: A PARTICULAR MATERIAL APPRAISAL(PMA) MAY BE REQUIRED FOR THIS MATERIAL.

NOZZLE DIMENSIONAL DATA



Attachment: Set In Flush Nozzle
Shape of Nozzle/Opening: Circular
Application:
9.4.6.3 NOT a critical fatigue area, and calc.temp.is outside creep range.
OUTSIDE NOZZLE DIAMETER.....:deb 168.27 mm
AS BUILT NOZZLE THICKNESS (uncorroded).....:enb 10.97 mm
Size of Flange and Nozzle: 6"
Comment (Optional): Ex.Str.
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....: 12.50 %
NOZZLE STANDOUT MEASURED FROM VESSEL OD.....:ho 200.00 mm

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FLANGE DATA

A: Flange Standard: ANSI B16.5 Flanges
 E: Pressure Class: ANSI B16.5:Class 150 lbs
 C: Flange Type: WN Welding Neck
 D: Facing Sketch/ANSI facing (Table 3.8.3(2)): 1a RF Raised Face
 Flange Material Category:
 1.1 - Carbon Steel - A105, A515 70, A516 70, A350 LF2 (BS 1503 164 490, BS 1504 161 480)

WELDING DATA

Nozzle/Pad to Shell Welding Area: Exclude Area of Nozzle to Shell Weld
 Nozzle Weld Intersect: Nozzle Does NOT Intersect with a Welded Shell Seam
 ANGLE PhiC(OBLIQUE IN TRANSVERSE.CROSS SECT.)Fig.9.5-2:PhiC 0.00 Degr.
 ANGLE PhiL(OBLIQUE IN LONG.CROSS SECT.)Fig.9.5-1.....:PhiL 0.00 Degr.

DATA FOR REINFORCEMENT PAD



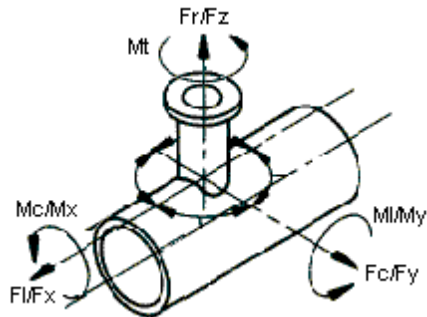
Type of Pad: Single Pad
 THICKNESS OF THE REINFORCEMENT PAD.....:eap 9.50 mm
 WIDTH OF THE REINFORCEMENT PAD.....:Ip 65.85 mm
 EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
 Rm=410 Rp=265 Rpt=194.12 fp=129.41 f20=170.83 fttest=252.38 E=196147(N/mm2) ro=7.85

LIMITS OF REINFORCEMENT

Reduction of Limits of Reinforcement: No Reduction Required

EXTERNAL LOADS ON NOZZLE

FACTOR C4:
 C4 = 1.1 Nozzle is Attached to a Piping System with due Allowance for Expansion and Thrust



TYPE OF LOAD INPUT: Load Cases
 External Nozzle Loads: User Specified Loads

LOADING DATA

Table NOZZLE LOADS:

Load Description	ID	Units	Load Case 1	Load Case 2
Pressure	P	MPa	-0.1	0.42
Radial Load	Fz	kN	-7.5	7.5
Longitudinal Moment	My	kNm	-3	3
Circumferential Moment:	Mx	kNm	-2.5	2.5
Longitudinal Shear Force	Fl	kN	-7.5	7.5
Circumferential Shear Force	Fc	kN	-5.5	5.5
Torsional Moment	Mt	kNm	-3	3

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CALCULATION DATA

FLANGE RATING

ANSI 150lb-Flange Rating(at 232C)= 1.276 MPa, Max.Test Pressure = 3.102 MPa

PRELIMINARY CALCULATIONS

Shell Analysis Thickness eas
 $eas = en - c - th = 12 - 3 - 0.5 = 8.50 \text{ mm}$
Nozzle Analysis Thickness eab
 $eab = enb - c - NegDev = 10.97 - 3 - 1.37 = 6.60 \text{ mm}$
Reinf.Pad Analysis Thickness ep
 $ep = \text{MIN}(eap, eas) (16.5-20) = \text{MIN}(9.5, 8.5) = 8.50 \text{ mm}$
Inside Radius of Curvature
 $ris = De / 2 - eas (9.5-3) = 864 / 2 - 8.5 = 423.50 \text{ mm}$
 $dib = deb - 2 * eab = 168.27 - 2 * 6.6 = 155.07 \text{ mm}$
Min.Nozzle Thk.Based on Internal Pressure ebp
 $ebp = P * deb / (2 * fb * z + P) = 0.5 * 168.27 / (2 * 114.37 * 1 + 0.5) = 0.3700 \text{ mm}$
Allowable Stresses
 $fob = \text{Min}(fs, fb) (16.5-8) = \text{Min}(129.41, 114.37) = 114.37 \text{ N/mm}^2$
 $fop = \text{Min}(fs, fp) (16.5-9) = \text{Min}(129.41, 129.41) = 129.41 \text{ N/mm}^2$

GEOMETRIC LIMITATIONS

»Check Max.Thk.of Pad $eap=9.5 \leq 1.5 * eas=12.75[\text{mm}] \ll \gg \text{OK} \ll$
»Check Max.Diameter of Nozzle $dib/(2 * ris)=0.1831 \leq .5[\text{mm}] \ll \gg \text{OK} \ll$
»Min.Nozzle Thk. $ebp=0.37 \leq eab=6.6[\text{mm}] \ll \gg (U= 5.6\%) \text{OK} \ll$

9.5.2.4.4 Nozzles normal to the shell, with or without reinforcement pads.

Calculation of Stress Loaded Areas Effective as Reinforcement

Area of Shell Afs

Limit of Reinforcement Along Shell
 $Iso = \text{Sqr}((2 * ris + eas) * eas) = \text{Sqr}((2 * 423.5 + 8.5) * 8.5) = 85.27 \text{ mm}$
Set In Nozzle
 $Afs = eas * Iso (16.5-78) = 8.5 * 85.27 = 724.83 \text{ mm}^2$

Area of Reinforcement Pad Afp

Limit of Reinforcement Along Pad
 $Ip = \text{Min}(Ip, Iso) (16.5-86) = \text{Min}(65.85, 85.27) = 65.85 \text{ mm}$
 $ep = \text{Min}(ep, eas) (16.5-87) = \text{Min}(8.5, 8.5) = 8.50 \text{ mm}$
 $Afp = ep * Ip (16.5-85) = 8.5 * 65.85 = 559.73 \text{ mm}^2$

Area of Nozzle Afb

Limit of Reinforcement Along Nozzle (outside shell)
 $Ibo = \text{MIN}(\text{Sqr}((deb - eb) * eb), ho) (16.5-75) = 32.66 \text{ mm}$
 $= \text{MIN}(\text{Sqr}((168.27 - 6.6) * 6.6), 200) = 32.66 \text{ mm}$
Set In Nozzle
 $Afb = eb * (Ibo + Ibi + eas) (16.5-77) = 6.6 * (32.66 + 0 + 8.5) = 271.62 \text{ mm}^2$

Calculation of Pressure Loaded Areas

In the Nozzle Apb
 $Apb = 0.5 * dib * (Ibo + eas) (16.5-83) = 0.5 * 155.07 * (32.66 + 8.5) = 3191.57 \text{ mm}^2$
Cyl.Shell in the Longitudinal Section Aps
 $ApsL = ris * (Is + a) (16.5-93) = 423.5 * (85.27 + 84.14) = 71744.95 \text{ mm}^2$
Cyl.Shell in the Transverse Cross Section Aps
 $ApsT = 0.5 * ris ^ 2 * (Is + a) / (0.5 * eas + ris) (16.5-104) = 35631.82 \text{ mm}^2$
 $= 0.5 * 423.5 ^ 2 * (85.27 + 84.69) / (0.5 * 8.5 + 423.5) = 35631.82 \text{ mm}^2$
 $Aps = \text{MAX}(ApsL, ApsT) = \text{MAX}(71744.95, 35631.82) = 71744.95 \text{ mm}^2$

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9.5.2 Reinforcement Rules

Pressure Area Required pA(req.)

$$\begin{aligned} pA_{ReqL} &= P * (A_{psL} + A_{pb}) \quad (16.5-7) = 0.5 * (71744.95 + 3191.57) = \underline{37.47 \text{ kN}} \\ pA_{ReqT} &= P * (A_{psT} + A_{pb} + 0.5 * A_{pphi}) \quad (16.5-7) \\ &= 0.5 * (35631.82 + 3191.57 + 0.5 * 0) = \underline{19.41 \text{ kN}} \\ pA_{Req} &= \text{MAX}(pA_{ReqL}, pA_{ReqT}) = \text{MAX}(37.47, 19.41) = \underline{\underline{37.47 \text{ kN}}} \end{aligned}$$

Pressure Area Available pA(aval.)

$$\begin{aligned} pA_{Aval} &= (A_{fs} + A_{fw}) * (f_s - 0.5 * P) + A_{fp} * (f_{op} - 0.5 * P) + A_{fb} * (f_{ob} - 0.5 * P) \quad (16.5-7) \\ &= (724.83 + 0) * (129.41 - 0.5 * 0.5) + 559.73 * (129.41 - 0.5 * 0.5) + 271.62 * (114.37 - 0.5 * 0.5) \\ &= \underline{\underline{196.91 \text{ kN}}} \end{aligned}$$

»Nozzle Reinforcement pAAval=196.91 >= pAReq=37.47[kN] « » (U= 19%) OK«

Maximum Allowable Pressure Pmax

$$\begin{aligned} P_{max} &= (A_{fs} + A_{fw}) * f_s + A_{fp} * f_{op} + A_{fb} * f_{ob} / ((A_{ps} + A_{pb} + 0.5 * A_{pphi}) + 0.5 * (A_{fs} + A_{fw} + A_{fb} + A_{fp})) \quad (10) \\ &= (0) * 129.41 + 559.73 * 129.41 + 271.62 * 114.37 / ((71744.95 + 3191.57 + 0.5 * 0) + 0.5 * (724.83 + 0 + 271.62 + 559.73)) = \underline{\underline{2.61 \text{ MPa}}} \end{aligned}$$

Max.Allowable Test Pressure P_{tmax}

$$P_{tmax} = \underline{\underline{6.31 \text{ MPa}}}$$

»ANSI 150lb-Flange Rating(at 232C) P=0.5 <= P_{Max}(flange)=1.28[MPa] «» (U= 39.1%) OK«

16.5 LOCAL LOADS ON NOZZLES IN CYLINDRICAL SHELLS

PRELIMINARY CALCULATIONS

$$\begin{aligned} \text{Shell Analysis Thickness } e_{as} &= e_n - c - t_h = 12 - 3 - 0.5 = 8.50 \text{ mm} \\ \text{Nozzle Analysis Thickness } e_b &= e_{nb} - c - \text{NegDev} = 10.97 - 3 - 1.37 = 6.60 \text{ mm} \\ \text{Mean diameter of shell } D &= D_e - e_a = 864 - 8.5 = 855.50 \text{ mm} \\ \text{Mean radius of shell } R &= D / 2 = 855.5 / 2 = 427.75 \text{ mm} \end{aligned}$$

16.5.3 CONDITIONS OF APPLICABILITY

»a) $e_a/D = 0.0099 \geq 0.001$ « » OK«

»a) $e_a/D = 0.0099 \leq 0.1$ « » OK«

»b) $\lambda C = 1.3 \leq 10$ « » OK«

»c) Dist.to any other local load shall not be less than $\text{SQR}(D * e_c) = 124.1 \text{ mm}$

»d) Nozzle thickness shall be maintained over a distance of $\text{SQR}(d * e_b) = 32.7 \text{ mm}$

LOAD CASE NO: 1 - Load Case 1

$$\begin{aligned} \text{Total Moment } MB &= \text{Sqr}(M_x^2 + M_y^2) = \text{Sqr}(-2.5^2 + -3^2) = 3.91 \text{ kNm} \end{aligned}$$

STRESSES AT OUTER DIAMETER OF NOZZLE

$$\begin{aligned} \text{Mean Diameter of Nozzle } d &= d_{eb} - e_b = 168.27 - 6.6 = 161.67 \text{ mm} \\ \text{Combined Analysis Thickness } e_c &= e_a + e_{ap} * \text{Min}(f_p / f_1) \\ &= 8.5 + 9.5 * \text{Min}(129.41 / 129.41, 1) = 18.00 \text{ mm} \\ \lambda C &= d / \text{Sqr}(D * e_c) = 161.67 / \text{Sqr}(855.5 * 18) = 1.30 \\ \text{Ratio1} &= e_b / e_c = 6.6 / 18 = 0.3666 \\ \text{Ratio2} &= D / e_c = 855.5 / 18 = 47.53 \\ \text{VALUES FOR } C_1, C_2 \text{ AND } C_3 \text{ FROM FIGURES 16.5-2 to 16.5-4} \\ C_1 &= 1.847 \quad C_2 = 4.900 \quad C_3 = 8.005 \end{aligned}$$

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16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

Permissible Pressure Pmax:

$$P_{max} \text{ (from nozzle calculation)} = P_{max} (16.5-2) = 2.61 = \underline{\underline{2.61 \text{ MPa}}}$$

Allowable Axial Load Fzmax:

$$F_{zmax} = f * e_c^2 * C1 (16.5-3) = 129.41 * 18^2 * 1.85 = \underline{\underline{77.43 \text{ kN}}}$$

Allowable Circumferential Moment Mxmax:

$$M_{xmax} = f * e_c^2 * d / 4 * C2 (16.5-5) \\ = 129.41 * 18^2 * 161.67 / 4 * 4.9 = \underline{\underline{8.30 \text{ kNm}}}$$

Allowable Longitudinal Moment Mymax:

$$M_{ymax} = f * e_c^2 * d / 4 * C3 (16.5-7) \\ = 129.41 * 18^2 * 161.67 / 4 * 8 = \underline{\underline{13.57 \text{ kNm}}}$$

SHEAR STRESS FORMULAE (PD5500 Section G.2.3.6.3)

Shear Stresses due to Longitudinal Shear Force, TauFl:

$$\tau_{Fl} = 2 * F_l / (\pi * d * e_c) \\ = 2 * -7.5 / (3.14 * 168.27 * 18) = \underline{\underline{-1.58 \text{ N/mm}^2}}$$

Shear Stresses due to Circumferential Force, TauFc:

$$\tau_{Fc} = 2 * F_c / (\pi * d * e_c) \\ = 2 * -5.5 / (3.14 * 168.27 * 18) = \underline{\underline{-1.16 \text{ N/mm}^2}}$$

Shear Stresses due to Torsional Moment, TauMt:

$$\tau_{Mt} = 2 * M_t / (\pi * d^2 * e_c) \\ = 2 * -3 / (3.14 * 168.27^2 * 18) = \underline{\underline{-3.75 \text{ N/mm}^2}}$$

Total Shear Stresses, Tau:

$$\tau = \sqrt{(\tau_{Fc}^2 + \tau_{Fl}^2) + \tau_{Mt}} \\ = \sqrt{(-1.16^2 + -1.58^2) + -3.75} = \underline{\underline{-1.79 \text{ N/mm}^2}}$$

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

$$\Phi_P = P / P_{max} (16.5-9) = -0.1 / 2.61 = \underline{\underline{-0.0384}}$$

$$\Phi_Z = F_z / F_{zmax} (16.5-10) = -7.5 / 77.43 = \underline{\underline{-0.0969}}$$

$$\Phi_{\tau} = \tau / (0.5 * f) = -1.79 / (0.5 * 129.41) = \underline{\underline{0.0277}}$$

$$\Phi_B = \sqrt{((M_x / M_{xmax})^2 + (M_y / M_{ymax})^2)} (16.5-11) \\ = \sqrt{((-2.5 / 8.3)^2 + (-3 / 13.57)^2)} = \underline{\underline{0.3736}}$$

$$Max_{All} = \text{MAX}(\text{Abs}(\Phi_P / C4 + \Phi_Z), \text{Abs}(\Phi_Z), \text{Abs}(\Phi_P / C4 - 0.2 * \Phi_Z)) (16.5-15) \\ = \text{MAX}(\text{Abs}(-0.0384 / 1.1 + -0.0969), \text{Abs}(-0.0969), \text{Abs}(-0.0384 / 1.1 - 0.2 * -0.0969)) \\ = 0.1317$$

$$\Phi_{All} = \sqrt{Max_{All}^2 + \Phi_B^2 + \Phi_{\tau}^2} (16.5-15) \\ = \sqrt{0.1317^2 + 0.3736^2 + 0.0277^2} = \underline{\underline{0.3971}}$$

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT NOZZLE OD PhiP=0.0384 <= 1.0=1(16.5-12)« » (U= 3.8%) OK«

»PhiZ AT NOZZLE OD PhiZ=0.0969 <= 1.0=1(16.5-13)« » (U= 9.6%) OK«

»PhiB AT NOZZLE OD PhiB=0.3736 <= 1.0=1(16.5-14)« » (U= 37.3%) OK«

»PhiTau AT NOZZLE OD PhiTau=0.0277 <= 1.0=1« » (U= 2.7%) OK«

»PhiAll AT NOZZLE OD PhiAll=0.3971 <= 1.0=1(16.5-15)« » (U= 39.7%) OK«

STRESSES AT OUTER EDGE OF PAD

Diameter at Edge of Reinforcement Pad

$$d = d_b + 2 * t_p = 168.27 + 2 * 65.85 = 299.97 \text{ mm}$$

Combined Analysis Thickness

$$e_c = e_a = 8.5 = 8.50 \text{ mm}$$

$$\lambda_{dC} = d / \sqrt{D * e_c} = 299.97 / \sqrt{855.5 * 8.5} = 3.52$$

$$Ratio1 = \text{MAX}(e_b / e_c, 0.5) = \text{MAX}(6.6 / 8.5, 0.5) = 0.7763$$

$$Ratio2 = D / e_c = 855.5 / 8.5 = 100.65$$

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

$$C1 = 3.953 \quad C2 = 5.944 \quad C3 = 20.029$$

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16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

Permissible Pressure Pmax:

$$P_{max} \text{ (from nozzle calculation)} = P_{max} \text{ (16.5-2)} = 2.61 = \underline{\underline{2.61 \text{ MPa}}}$$

Allowable Axial Load Fzmax:

$$F_{zmax} = f * e_c^2 * C1 \text{ (16.5-3)} = 129.41 * 8.5^2 * 3.95 = \underline{\underline{36.96 \text{ kN}}}$$

Allowable Circumferential Moment Mxmax:

$$M_{xmax} = f * e_c^2 * d / 4 * C2 \text{ (16.5-5)} \\ = 129.41 * 8.5^2 * 299.97 / 4 * 5.94 = \underline{\underline{4.17 \text{ kNm}}}$$

Allowable Longitudinal Moment Mymax:

$$M_{ymax} = f * e_c^2 * d / 4 * C3 \text{ (16.5-7)} \\ = 129.41 * 8.5^2 * 299.97 / 4 * 20.03 = \underline{\underline{14.04 \text{ kNm}}}$$

SHEAR STRESS FORMULAE (PD5500 Section G.2.3.6.3)

Shear Stresses due to Longitudinal Shear Force, TauFl:

$$\tau_{Fl} = 2 * F_l / (\pi * d * e_c) \\ = 2 * -7.5 / (3.14 * 168.27 * 8.5) = \underline{\underline{-3.34 \text{ N/mm}^2}}$$

Shear Stresses due to Circumferential Force, TauFc:

$$\tau_{Fc} = 2 * F_c / (\pi * d * e_c) \\ = 2 * -5.5 / (3.14 * 168.27 * 8.5) = \underline{\underline{-2.45 \text{ N/mm}^2}}$$

Shear Stresses due to Torsional Moment, TauMt:

$$\tau_{Mt} = 2 * M_t / (\pi * d^2 * e_c) \\ = 2 * -3 / (3.14 * 168.27^2 * 8.5) = \underline{\underline{-7.94 \text{ N/mm}^2}}$$

Total Shear Stresses, Tau:

$$\tau = \sqrt{\tau_{Fc}^2 + \tau_{Fl}^2} + \tau_{Mt} \\ = \sqrt{(-2.45^2 + -3.34^2)} + -7.94 = \underline{\underline{-3.80 \text{ N/mm}^2}}$$

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

$$\phi_P = P / P_{max} \text{ (16.5-9)} = -0.1 / 2.61 = \underline{\underline{-0.0384}}$$

$$\phi_Z = F_z / F_{zmax} \text{ (16.5-10)} = -7.5 / 36.96 = \underline{\underline{-0.2029}}$$

$$\phi_{\tau} = \tau / (0.5 * f) = -3.8 / (0.5 * 129.41) = \underline{\underline{0.0587}}$$

$$\phi_B = \sqrt{(\phi_Mx / M_{xmax})^2 + (\phi_My / M_{ymax})^2} \text{ (16.5-11)} \\ = \sqrt{(-2.5 / 4.17)^2 + (-3 / 14.04)^2} = \underline{\underline{0.6368}}$$

$$\phi_{All} = \text{MAX}(\text{Abs}(\phi_P / C4 + \phi_Z), \text{Abs}(\phi_Z), \text{Abs}(\phi_P / C4 - 0.2 * \phi_Z)) \text{ (16.5-15)} \\ = \text{MAX}(\text{Abs}(-0.0384 / 1.1 + -0.2029), \text{Abs}(-0.2029), \text{Abs}(-0.0384 / 1.1 - 0.2 * -0.2029)) \\ = 0.2378$$

$$\phi_{All} = \sqrt{\phi_{All}^2 + \phi_B^2 + \phi_{\tau}^2} \text{ (16.5-15)} \\ = \sqrt{0.2378^2 + 0.6368^2 + 0.0587^2} = \underline{\underline{0.6823}}$$

16.5.6.4 Check of Individual Load Ratio Limits

$$\gg \phi_P \text{ AT EDGE OF PAD } \phi_P = 0.0384 \leq 1.0 = 1 \text{ (16.5-12)} \ll \gg (U = 3.8\%) \text{ OK} \ll$$

$$\gg \phi_Z \text{ AT EDGE OF PAD } \phi_Z = 0.2029 \leq 1.0 = 1 \text{ (16.5-13)} \ll \gg (U = 20.2\%) \text{ OK} \ll$$

$$\gg \phi_B \text{ AT EDGE OF PAD } \phi_B = 0.6368 \leq 1.0 = 1 \text{ (16.5-14)} \ll \gg (U = 63.6\%) \text{ OK} \ll$$

$$\gg \phi_{\tau} \text{ AT EDGE OF PAD } \phi_{\tau} = 0.0587 \leq 1.0 = 1 \ll \gg (U = 5.8\%) \text{ OK} \ll$$

$$\gg \phi_{All} \text{ AT EDGE OF PAD } \phi_{All} = 0.6823 \leq 1.0 = 1 \text{ (16.5-15)} \ll \gg (U = 68.2\%) \text{ OK} \ll$$

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

16.5.7.1 LOAD RANGES

$$\Delta P = \text{Max}(P_{max}, 0) - \text{Min}(P_{min}, 0) \text{ (16.5-16)} \\ = \text{Max}(0.1, 0) - \text{Min}(0, 0) = \underline{\underline{0.1000 \text{ MPa}}}$$

$$\Delta F_z = \text{Max}(F_{zmax}, 0) - \text{Min}(F_{zmin}, 0) \text{ (16.5-17)} \\ = \text{Max}(7.5, 0) - \text{Min}(0, 0) = \underline{\underline{7.50 \text{ kN}}}$$

$$\Delta M_x = \text{Max}(M_{xmax}, 0) - \text{Min}(M_{xmin}, 0) \text{ (16.5-18)} \\ = \text{Max}(2.5, 0) - \text{Min}(0, 0) = \underline{\underline{2.50 \text{ kNm}}}$$

$$\Delta M_y = \text{Max}(M_{ymax}, 0) - \text{Min}(M_{ymin}, 0) \text{ (16.5-19)}$$

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$=\text{Max}(3,0)-\text{Min}(0,0)=$	3.00 kNm
DeltaFl = Max(Flmax , 0) - Min(Flmin , 0) $=\text{Max}(7.5,0)-\text{Min}(0,0)=$	0.00 kN
DeltaFc = Max(Fcmax , 0) - Min(Fcmin , 0) $=\text{Max}(5.5,0)-\text{Min}(0,0)=$	0.00 kN
DeltaFshear = Sqr(DeltaFl ^ 2 + DeltaFc ^ 2) $=\text{Sqr}(0^2+0^2)=$	0.00 kN
DeltaMt = Max(Mtmax , 0) - Min(Mtmin , 0) $=\text{Max}(3,0)-\text{Min}(0,0)=$	0.00 kNm

16.5.7.2 EQUIVALENT SHELL THICKNESS

$$\begin{aligned} eeq &= ea + \text{Min}(eap * Ip / \text{Sqr}(D * (ea + eap)), eap) * \text{Min}(fp / fl) && (16.5-20) \\ &= 8.5 + \text{Min}(9.5 * 65.85 / \text{Sqr}(855.5 * (8.5 + 9.5)), 9.5) * \text{Min}(129.41 / 129.41, 1) = && 13.54 \text{ mm} \end{aligned}$$

16.5.7.3 STRESSES

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

$$C1 = 2.038 \quad C2 = 4.914 \quad C3 = 10.270$$

$$\begin{aligned} \text{Tmp1} &= \text{Sqr}(d * eb / (D * eeq)) \\ &= \text{Sqr}(161.67 * 6.6 / (855.5 * 13.54)) = && 0.3035 \end{aligned}$$

$$\begin{aligned} \text{Tmp2} &= (2 + 2 * d / D * \text{Tmp1} + 1.25 * d / D * \text{Sqr}(D / eeq)) / (1 + eb / eeq * \text{Tmp1}) \\ &= (2 + 2 * 161.67 / 855.5 * 0.3035 + 1.25 * 161.67 / 855.5 * \text{Sqr}(855.5 / 13.54)) / (1 + 6.6 / 13.54 * 0.3035) = && 3.48 \end{aligned}$$

Stresses due to Pressure Range

$$\begin{aligned} \text{SigP} &= \text{DeltaP} * D / (2 * eeq) * \text{Tmp2} && (16.5-21) \\ &= 0.1 * 855.5 / (2 * 13.54) * 3.48 = && 10.99 \text{ N/mm}^2 \end{aligned}$$

Stresses due to Axial Load Range

$$\begin{aligned} \text{SigFz} &= 2.25 / C1 * (\text{DeltaFz} / eeq ^ 2) && (16.5-22) \\ &= 2.25 / 2.04 * (7.5 / 13.54 ^ 2) = && 45.17 \text{ N/mm}^2 \end{aligned}$$

Stresses due to Circumferential Moment Range

$$\begin{aligned} \text{SigMx} &= 2.25 / C2 * (4 * \text{DeltaMx} / (eeq ^ 2 * d)) && (16.5-23) \\ &= 2.25 / 4.91 * (4 * 2.5 / (13.54 ^ 2 * 161.67)) = && 154.47 \text{ N/mm}^2 \end{aligned}$$

Stresses due to Longitudinal Moment Range

$$\begin{aligned} \text{SigMy} &= 2.25 / C3 * (4 * \text{DeltaMy} / (eeq ^ 2 * d)) && (16.5-24) \\ &= 2.25 / 10.27 * (4 * 3 / (13.54 ^ 2 * 161.67)) = && 88.68 \text{ N/mm}^2 \end{aligned}$$

Shear Stresses due to Longitudinal Shear Force, DeltaFl:

$$\begin{aligned} \text{TauFl} &= 2 * \text{DeltaFl} / (\text{PI} * deb * eeq) \\ &= 2 * 0 / (3.14 * 168.27 * 13.54) = && 0.00 \text{ N/mm}^2 \end{aligned}$$

Shear Stresses due to Circumferential Force, TauFc:

$$\begin{aligned} \text{TauFc} &= 2 * \text{DeltaFc} / (\text{PI} * deb * eeq) \\ &= 2 * 0 / (3.14 * 168.27 * 13.54) = && 0.00 \text{ N/mm}^2 \end{aligned}$$

Shear Stresses due to Torsional Moment, TauMt:

$$\begin{aligned} \text{TauMt} &= 2 * \text{DeltaMt} / (\text{PI} * deb ^ 2 * eeq) \\ &= 2 * 0 / (3.14 * 168.27 ^ 2 * 13.54) = && 0.00 \text{ N/mm}^2 \end{aligned}$$

Total Shear Stresses, Tau:

$$\begin{aligned} \text{Tau} &= \text{Sqr}(\text{TauFc} ^ 2 + \text{TauFl} ^ 2) + \text{TauMt} \\ &= \text{Sqr}(0^2 + 0^2) + 0 = && 0.00 \text{ N/mm}^2 \end{aligned}$$

Total Stress Intensity due to Load Range

$$\begin{aligned} \text{SigTot} &= \text{Abs}(\text{SigT} + \text{Sqr}((\text{SigP} + \text{SigFz})^2 + \text{SigMx}^2 + \text{SigMy}^2 + 4 * \text{Tau}^2)) && (16.5-25) \\ &= \text{Abs}(0 + \text{Sqr}((10.99 + 45.17)^2 + 154.47^2 + 88.68^2 + 4 * 0^2)) = && 186.76 \text{ N/mm}^2 \end{aligned}$$

»Total Stress in Shell SigTot=186.76 <= 3*f=388.23[N/mm2] «» (U= 48.1%) OK«

16.5.8 NOZZLE LONGITUDINAL STRESSES

Maximum Longitudinal Stresses in Nozzle

$$\begin{aligned} \text{SigLong} &= P * d / (4 * eb) + 4 * MB / (\text{PI} * d^2 * eb) + Fz / (\text{PI} * d * eb) && (16.5-26) \\ &= -0.1 * 161.67 / (4 * 6.6) + 4 * 3.91 / (3.14 * 161.67^2 * 6.6) + 0 / (3.14 * 161.67 * 6.6) \\ &= 28.22 \text{ N/mm}^2 \end{aligned}$$

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»Nozzle Long.Stress SigLong=28.22 <= fb=114.37[N/mm2] « » (U= 24.6%) OK«

16.14.6 COMPRESSIVE STRESS LIMITS

$$\begin{aligned} K &= 1.21 * E * ea / (Sige * D) && (16.14-15) \\ &= 1.21 * 196147 * 6.6 / (171.56 * 161.67) = && 56.47 \\ \text{alfa} &= 0.83 / \text{Sqr}(1 + 0.005 * D / ea) && (16.14-16) \\ &= 0.83 / \text{Sqr}(1 + 0.005 * 161.67 / 6.6) = && 0.7834 \\ \text{delta} &= (1 - 0.4123 / (\text{alfa} * K) ^ 0.6) / S && (16.14-19) \\ &= (1 - 0.4123 / (0.7834 * 56.47) ^ 0.6) / 1.5 = && 0.6384 \\ \text{Maximum Allowable Compressive Stress} &&& \\ \text{Sigcall} &= Sige * \text{delta} \quad (16.14-20) = 171.56 * 0.6384 = && \underline{109.52 \text{ N/mm}^2} \end{aligned}$$

16.14.4 PERMISSIBLE INDIVIDUAL LOADS

$$\begin{aligned} \text{Maximum Tensile Force Ftmax} &&& \\ \text{Ftmax} &= \text{PI} * D * ea * f \quad (16.14-1) = 3.14 * 161.67 * 6.6 * 114.37 = && \underline{383.32 \text{ kN}} \\ \text{Maximum Compressive Force Fcmax} &&& \\ \text{Fcmax} &= \text{PI} * D * ea * \text{Sigcall} \quad (16.14-2) = 3.14 * 161.67 * 6.6 * 109.52 = && \underline{367.06 \text{ kN}} \\ \text{Maximum Bending Moment Mmax} &&& \\ \text{Mmax} &= \text{PI} / 4 * D ^ 2 * ea * \text{Sigcall} && (16.14-3) \\ &= 3.14 / 4 * 161.67 ^ 2 * 6.6 * 109.52 = && \underline{14.84 \text{ kNm}} \\ \text{Longitudinal Stability Check (P=0)} &&& \\ \text{LongStab} &= \text{MB} / \text{Mmax} + \text{Abs}(Fzmin) / \text{Fcmax} && (16.5-27) \\ &= 3.91 / 14.84 + \text{Abs}(0) / 367.06 = && \underline{\underline{0.2632}} \end{aligned}$$

»Nozzle Long.Stability LongStab=0.2632 <= 1.0=1« » (U= 26.3%) OK«

LOAD CASE NO: 2 - Load Case 2

$$\begin{aligned} \text{Total Moment} &&& \\ \text{MB} &= \text{Sqr}(Mx ^ 2 + My ^ 2) = \text{Sqr}(2.5^2 + 3^2) = && \underline{3.91 \text{ kNm}} \end{aligned}$$

STRESSES AT OUTER DIAMETER OF NOZZLE

$$\begin{aligned} \text{Mean Diameter of Nozzle} &&& \\ d &= deb - eb = 168.27 - 6.6 = && \underline{161.67 \text{ mm}} \\ \text{Combined Analysis Thickness} &&& \\ ec &= ea + eap * \text{Min}(fp / f1) && \\ &= 8.5 + 9.5 * \text{Min}(129.41 / 129.41, 1) = && \underline{18.00 \text{ mm}} \\ \text{LamdaC} &= d / \text{Sqr}(D * ec) = 161.67 / \text{Sqr}(855.5 * 18) = && \underline{1.30} \\ \text{Ratio1} &= eb / ec = 6.6 / 18 = && \underline{0.3666} \\ \text{Ratio2} &= D / ec = 855.5 / 18 = && \underline{47.53} \\ \text{VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4} &&& \\ C1 &= 1.847 \quad C2 = 4.900 \quad C3 = 8.005 && \end{aligned}$$

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

$$\begin{aligned} \text{Permissible Pressure Pmax:} &&& \\ \text{Pmax (from nozzle calculation)} &= \text{Pmax} \quad (16.5-2) = 2.61 = && \underline{2.61 \text{ MPa}} \\ \text{Allowable Axial Load Fzmax:} &&& \\ \text{Fzmax} &= f * ec ^ 2 * C1 \quad (16.5-3) = 129.41 * 18^2 * 1.85 = && \underline{77.43 \text{ kN}} \\ \text{Allowable Circumferential Moment Mxmax:} &&& \\ \text{Mxmax} &= f * ec ^ 2 * d / 4 * C2 && (16.5-5) \\ &= 129.41 * 18^2 * 161.67 / 4 * 4.9 = && \underline{8.30 \text{ kNm}} \\ \text{Allowable Longitudinal Moment Mxmax:} &&& \\ \text{Mymax} &= f * ec ^ 2 * d / 4 * C3 && (16.5-7) \\ &= 129.41 * 18^2 * 161.67 / 4 * 8. = && \underline{13.57 \text{ kNm}} \end{aligned}$$

SHEAR STRESS FORMULAE (PD5500 Section G.2.3.6.3)

$$\begin{aligned} \text{Shear Stresses due to Longitudinal Shear Force, TauFl:} &&& \\ \text{TauFl} &= 2 * F1 / (\text{PI} * deb * ec) && \\ &= 2 * 7.5 / (3.14 * 168.27 * 18) = && \underline{1.58 \text{ N/mm}^2} \\ \text{Shear Stresses due to Circumferential Force, TauFc:} &&& \\ \text{TauFc} &= 2 * Fc / (\text{PI} * deb * ec) && \\ &= 2 * 5.5 / (3.14 * 168.27 * 18) = && \underline{1.16 \text{ N/mm}^2} \end{aligned}$$

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Shear Stresses due to Torsional Moment, TauMt:

$$\text{TauMt} = 2 * \text{Mt} / (\text{PI} * \text{deb}^2 * \text{ec})$$

$$= 2 * 3 / (3.14 * 168.27^2 * 18) =$$

3.75 N/mm2

Total Shear Stresses, Tau:

$$\text{Tau} = \text{Sqr}(\text{TauFc}^2 + \text{TauFl}^2) + \text{TauMt}$$

$$= \text{Sqr}(1.16^2 + 1.58^2) + 3.75 =$$

5.70 N/mm2

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

$$\text{PhiP} = \text{P} / \text{Pmax} \text{ (16.5-9)} = 0.42 / 2.61 =$$

0.1612

$$\text{PhiZ} = \text{Fz} / \text{Fzmax} \text{ (16.5-10)} = 7.5 / 77.43 =$$

0.0969

$$\text{PhiTau} = \text{Tau} / (0.5 * \text{f}) = 5.7 / (0.5 * 129.41) =$$

0.0881

$$\text{PhiB} = \text{Sqr}((\text{Mx} / \text{Mxmax})^2 + (\text{My} / \text{Mymax})^2) \text{ (16.5-11)}$$

$$= \text{Sqr}((2.5 / 8.3)^2 + (3 / 13.57)^2) =$$

0.3736

$$\text{MaxAll} = \text{MAX}(\text{Abs}(\text{PhiP} / \text{C4} + \text{PhiZ}), \text{Abs}(\text{PhiZ}), \text{Abs}(\text{PhiP} / \text{C4} - 0.2 * \text{PhiZ}) \text{ (16.5-15)}$$

$$= \text{MAX}(\text{Abs}(0.1612 / 1.1 + 0.0969), \text{Abs}(0.0969), \text{Abs}(0.1612 / 1.1 - 0.2 * 0.0969)) =$$

0.2434

$$\text{PhiAll} = \text{Sqr}(\text{MaxAll}^2 + \text{PhiB}^2 + \text{PhiTau}^2) \text{ (16.5-15)}$$

$$= \text{Sqr}(0.2434^2 + 0.3736^2 + 0.0881^2) =$$

0.4545

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT NOZZLE OD PhiP=0.1612 <= 1.0=1(16.5-12)« » (U= 16.1%) OK«

»PhiZ AT NOZZLE OD PhiZ=0.0969 <= 1.0=1(16.5-13)« » (U= 9.6%) OK«

»PhiB AT NOZZLE OD PhiB=0.3736 <= 1.0=1(16.5-14)« » (U= 37.3%) OK«

»PhiTau AT NOZZLE OD PhiTau=0.0881 <= 1.0=1« » (U= 8.8%) OK«

»PhiAll AT NOZZLE OD PhiAll=0.4545 <= 1.0=1(16.5-15)« » (U= 45.4%) OK«

STRESSES AT OUTER EDGE OF PAD

Diameter at Edge of Reinforcement Pad

$$\text{d} = \text{deb} + 2 * \text{Ip} = 168.27 + 2 * 65.85 =$$

299.97 mm

Combined Analysis Thickness

$$\text{ec} = \text{ea} = 8.5 =$$

8.50 mm

$$\text{LamdaC} = \text{d} / \text{Sqr}(\text{D} * \text{ec}) = 299.97 / \text{Sqr}(855.5 * 8.5) =$$

3.52

$$\text{Ratio1} = \text{MAX}(\text{eb} / \text{ec}, 0.5) = \text{MAX}(6.6 / 8.5, 0.5) =$$

0.7763

$$\text{Ratio2} = \text{D} / \text{ec} = 855.5 / 8.5 =$$

100.65

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

$$\text{C1} = 3.953 \quad \text{C2} = 5.944 \quad \text{C3} = 20.029$$

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

Permissible Pressure Pmax:

$$\text{Pmax} \text{ (from nozzle calculation)} = \text{Pmax} \text{ (16.5-2)} = 2.61 =$$

2.61 MPa

Allowable Axial Load Fzmax:

$$\text{Fzmax} = \text{f} * \text{ec}^2 * \text{C1} \text{ (16.5-3)} = 129.41 * 8.5^2 * 3.95 =$$

36.96 kN

Allowable Circumferential Moment Mxmax:

$$\text{Mxmax} = \text{f} * \text{ec}^2 * \text{d} / 4 * \text{C2} \text{ (16.5-5)}$$

$$= 129.41 * 8.5^2 * 299.97 / 4 * 5.94 =$$

4.17 kNm

Allowable Longitudinal Moment Mxmax:

$$\text{Mymax} = \text{f} * \text{ec}^2 * \text{d} / 4 * \text{C3} \text{ (16.5-7)}$$

$$= 129.41 * 8.5^2 * 299.97 / 4 * 20.03 =$$

14.04 kNm

SHEAR STRESS FORMULAE (PD500 Section G.2.3.6.3)

Shear Stresses due to Longitudinal Shear Force, TauFl:

$$\text{TauFl} = 2 * \text{Fl} / (\text{PI} * \text{deb} * \text{ec})$$

$$= 2 * 7.5 / (3.14 * 168.27 * 8.5) =$$

3.34 N/mm2

Shear Stresses due to Circumferential Force, TauFc:

$$\text{TauFc} = 2 * \text{Fc} / (\text{PI} * \text{deb} * \text{ec})$$

$$= 2 * 5.5 / (3.14 * 168.27 * 8.5) =$$

2.45 N/mm2

Shear Stresses due to Torsional Moment, TauMt:

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$$\begin{aligned} \text{TauMt} &= 2 * \text{Mt} / (\text{PI} * \text{deb} ^ 2 * \text{ec}) \\ &= 2 * 3 / (3.14 * 168.27 ^ 2 * 8.5) = \end{aligned} \quad \underline{\underline{7.94 \text{ N/mm}^2}}$$

Total Shear Stresses, Tau:
 $\text{Tau} = \text{Sqr}(\text{TauFc} ^ 2 + \text{TauFl} ^ 2) + \text{TauMt}$
 $= \text{Sqr}(2.45 ^ 2 + 3.34 ^ 2) + 7.94 = \underline{\underline{12.08 \text{ N/mm}^2}}$

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

$$\text{PhiP} = \text{P} / \text{Pmax} \text{ (16.5-9)} = 0.5 / 2.61 = \underline{\underline{0.1612}}$$

$$\text{PhiZ} = \text{Fz} / \text{Fzmax} \text{ (16.5-10)} = 7.5 / 36.96 = \underline{\underline{0.2029}}$$

$$\text{PhiTau} = \text{Tau} / (0.5 * \text{f}) = 12.08 / (0.5 * 129.41) = \underline{\underline{0.1866}}$$

$$\begin{aligned} \text{PhiB} &= \text{Sqr}((\text{Mx} / \text{Mxmax}) ^ 2 + (\text{My} / \text{Mymax}) ^ 2) \text{ (16.5-11)} \\ &= \text{Sqr}((2.5 / 4.17) ^ 2 + (3 / 14.04) ^ 2) = \underline{\underline{0.6368}} \end{aligned}$$

$$\begin{aligned} \text{MaxAll} &= \text{MAX}(\text{Abs}(\text{PhiP}/\text{C4} + \text{PhiZ}), \text{Abs}(\text{PhiZ}), \text{Abs}(\text{PhiP}/\text{C4} - 0.2 * \text{PhiZ}) \text{ (16.5-15)} \\ &= \text{MAX}(\text{Abs}(0.1612/1.1 + 0.2029), \text{Abs}(0.2029), \text{Abs}(0.1612/1.1 - 0.2 * 0.2029)) = \underline{\underline{0.3495}} \end{aligned}$$

$$\begin{aligned} \text{PhiAll} &= \text{Sqr}(\text{MaxAll} ^ 2 + \text{PhiB} ^ 2 + \text{PhiTau} ^ 2) \text{ (16.5-15)} \\ &= \text{Sqr}(0.3495 ^ 2 + 0.6368 ^ 2 + 0.1866 ^ 2) = \underline{\underline{0.7500}} \end{aligned}$$

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT EDGE OF PAD PhiP=0.1612 <= 1.0=1(16.5-12)« » (U= 16.1%) OK«

»PhiZ AT EDGE OF PAD PhiZ=0.2029 <= 1.0=1(16.5-13)« » (U= 20.2%) OK«

»PhiB AT EDGE OF PAD PhiB=0.6368 <= 1.0=1(16.5-14)« » (U= 63.6%) OK«

»PhiTau AT EDGE OF PAD PhiTau=0.1866 <= 1.0=1« » (U= 18.6%) OK«

»PhiAll AT EDGE OF PAD PhiAll=0.75 <= 1.0=1(16.5-15)« » (U= 74.9%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

16.5.7.1 LOAD RANGES

$$\begin{aligned} \text{DeltaP} &= \text{Max}(\text{Pmax}, 0) - \text{Min}(\text{Pmin}, 0) \text{ (16.5-16)} \\ &= \text{Max}(0.42, 0) - \text{Min}(0, 0) = \underline{\underline{0.4200 \text{ MPa}}} \end{aligned}$$

$$\begin{aligned} \text{DeltaFz} &= \text{Max}(\text{Fzmax}, 0) - \text{Min}(\text{Fzmin}, 0) \text{ (16.5-17)} \\ &= \text{Max}(7.5, 0) - \text{Min}(0, 0) = \underline{\underline{7.50 \text{ kN}}} \end{aligned}$$

$$\begin{aligned} \text{DeltaMx} &= \text{Max}(\text{Mxmax}, 0) - \text{Min}(\text{Mxmin}, 0) \text{ (16.5-18)} \\ &= \text{Max}(2.5, 0) - \text{Min}(0, 0) = \underline{\underline{2.50 \text{ kNm}}} \end{aligned}$$

$$\begin{aligned} \text{DeltaMy} &= \text{Max}(\text{Mymax}, 0) - \text{Min}(\text{Mymmin}, 0) \text{ (16.5-19)} \\ &= \text{Max}(3, 0) - \text{Min}(0, 0) = \underline{\underline{3.00 \text{ kNm}}} \end{aligned}$$

$$\begin{aligned} \text{DeltaFl} &= \text{Max}(\text{Flmax}, 0) - \text{Min}(\text{Flmin}, 0) \\ &= \text{Max}(7.5, 0) - \text{Min}(0, 0) = \underline{\underline{7.50 \text{ kN}}} \end{aligned}$$

$$\begin{aligned} \text{DeltaFc} &= \text{Max}(\text{Fcmax}, 0) - \text{Min}(\text{Fcmin}, 0) \\ &= \text{Max}(5.5, 0) - \text{Min}(0, 0) = \underline{\underline{5.50 \text{ kN}}} \end{aligned}$$

$$\begin{aligned} \text{DeltaFshear} &= \text{Sqr}(\text{DeltaFl} ^ 2 + \text{DeltaFc} ^ 2) \\ &= \text{Sqr}(7.5 ^ 2 + 5.5 ^ 2) = \underline{\underline{9.30 \text{ kN}}} \end{aligned}$$

$$\begin{aligned} \text{DeltaMt} &= \text{Max}(\text{Mtmax}, 0) - \text{Min}(\text{Mtmin}, 0) \\ &= \text{Max}(3, 0) - \text{Min}(0, 0) = \underline{\underline{3.00 \text{ kNm}}} \end{aligned}$$

16.5.7.2 EQUIVALENT SHELL THICKNESS

$$\begin{aligned} \text{eeq} &= \text{ea} + \text{Min}(\text{eap} * \text{Ip} / \text{Sqr}(\text{D} * (\text{ea} + \text{eap})), \text{eap}) * \text{Min}(\text{fp} / \text{fl}) \text{ (16.5-20)} \\ &= 8.5 + \text{Min}(9.5 * 65.85 / \text{Sqr}(855.5 * (8.5 + 9.5)), 9.5) * \text{Min}(129.41 / 129.41, 1) = \underline{\underline{13.54 \text{ mm}}} \end{aligned}$$

16.5.7.3 STRESSES

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

$$\text{C1} = 2.038 \quad \text{C2} = 4.914 \quad \text{C3} = 10.270$$

$$\begin{aligned} \text{Tmp1} &= \text{Sqr}(\text{d} * \text{eb} / (\text{D} * \text{eeq})) \\ &= \text{Sqr}(161.67 * 6.6 / (855.5 * 13.54)) = 0.3035 \end{aligned}$$

$$\text{Tmp2} = (2 + 2 * \text{d} / \text{D} * \text{Tmp1} + 1.25 * \text{d} / \text{D} * \text{Sqr}(\text{D} / \text{eeq})) / (1 + \text{eb} / \text{eeq} * \text{Tmp1})$$

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$$=(2+2*161.67/855.5*0.3035+1.25*161.67/855.5*\text{Sqr}(855.5/13.54))/(1+6.6/13.54*0.3035)= 3.48$$

Stresses due to Pressure Range
$$\text{SigP} = \text{DeltaP} * D / (2 * \text{eeq}) * \text{Tmp2} \quad (16.5-21)$$
$$=0.42*855.5/(2*13.54)*3.48= 46.14 \text{ N/mm}^2$$

Stresses due to Axial Load Range
$$\text{SigFz} = 2.25 / C1 * (\text{DeltaFz} / \text{eeq}^2) \quad (16.5-22)$$
$$=2.25/2.04*(7.5/13.54^2)= 45.17 \text{ N/mm}^2$$

Stresses due to Circumferential Moment Range
$$\text{SigMx} = 2.25 / C2 * (4 * \text{DeltaMx} / (\text{eeq}^2 * d)) \quad (16.5-23)$$
$$=2.25/4.91*(4*2.5/(13.54^2*161.67))= 154.47 \text{ N/mm}^2$$

Stresses due to Longitudinal Moment Range
$$\text{SigMy} = 2.25 / C3 * (4 * \text{DeltaMy} / (\text{eeq}^2 * d)) \quad (16.5-24)$$
$$=2.25/10.27*(4*3/(13.54^2*161.67))= 88.68 \text{ N/mm}^2$$

Shear Stresses due to Longitudinal Shear Force, DeltaFl:
$$\text{TauFl} = 2 * \text{DeltaFl} / (\text{PI} * \text{deb} * \text{eeq})$$
$$=2*7.5/(3.14*168.27*13.54)= 2.10 \text{ N/mm}^2$$

Shear Stresses due to Circumferential Force, TauFc:
$$\text{TauFc} = 2 * \text{DeltaFc} / (\text{PI} * \text{deb} * \text{eeq})$$
$$=2*5.5/(3.14*168.27*13.54)= 1.54 \text{ N/mm}^2$$

Shear Stresses due to Torsional Moment, TauMt:
$$\text{TauMt} = 2 * \text{DeltaMt} / (\text{PI} * \text{deb}^2 * \text{eeq})$$
$$=2*3/(3.14*168.27^2*13.54)= 4.98 \text{ N/mm}^2$$

Total Shear Stresses, Tau:
$$\text{Tau} = \text{Sqr}(\text{TauFc}^2 + \text{TauFl}^2) + \text{TauMt}$$
$$=\text{Sqr}(1.54^2+2.1^2)+4.98= 7.58 \text{ N/mm}^2$$

Total Stress Intensity due to Load Range
$$\text{SigTot} = \text{Abs}(\text{SigT}+\text{Sqr}((\text{SigP}+\text{SigFz})^2+\text{SigMx}^2+\text{SigMy}^2+4*\text{Tau}^2)) \quad (16.5-25)$$
$$=\text{Abs}(0+\text{Sqr}((46.14+45.17)^2+154.47^2+88.68^2+4*7.58^2))= 200.73 \text{ N/mm}^2$$

»Total Stress in Shell SigTot=200.73 <= 3*f=388.23[N/mm2] <<> (U= 51.7%) OK<<

16.5.8 NOZZLE LONGITUDINAL STRESSES

Maximum Longitudinal Stresses in Nozzle
$$\text{SigLong} = P*d/(4*eb)+4*MB/(\text{PI}*d^2*eb)+Fz/(\text{PI}*d*eb) \quad (16.5-26)$$
$$=0.5*161.67/(4*6.6)+4*3.91/(3.14*161.67^2*6.6)+7500/(3.14*161.67*6.6)$$
$$= 33.64 \text{ N/mm}^2$$

»Nozzle Long.Stress SigLong=33.64 <= fb=114.37[N/mm2] << » (U= 29.4%) OK<<

16.14.6 COMPRESSIVE STRESS LIMITS

$$K = 1.21 * E * ea / (\text{Sige} * D) \quad (16.14-15)$$
$$=1.21*196147*6.6/(171.56*161.67)= 56.47$$
$$\text{alfa} = 0.83 / \text{Sqr}(1 + 0.005 * D / ea) \quad (16.14-16)$$
$$=0.83/\text{Sqr}(1+0.005*161.67/6.6)= 0.7834$$
$$\text{delta} = (1 - 0.4123 / (\text{alfa} * K) ^ 0.6) / S \quad (16.14-19)$$
$$=(1-0.4123/(0.7834*56.47)^0.6)/1.5= 0.6384$$

Maximum Allowable Compressive Stress
$$\text{Sigcall} = \text{Sige} * \text{delta} \quad (16.14-20) = 171.56*0.6384= 109.52 \text{ N/mm}^2$$

16.14.4 PERMISSIBLE INDIVIDUAL LOADS

Maximum Tensile Force Ftmax
$$\text{Ftmax} = \text{PI} * D * ea * f \quad (16.14-1) = 3.14*161.67*6.6*114.37= 383.32 \text{ kN}$$

Maximum Compressive Force Fcmax
$$\text{Fcmax} = \text{PI} * D * ea * \text{Sigcall} \quad (16.14-2) = 3.14*161.67*6.6*109.52= 367.06 \text{ kN}$$

Maximum Bending Moment Mmax
$$\text{Mmax} = \text{PI} / 4 * D^2 * ea * \text{Sigcall} \quad (16.14-3)$$
$$=3.14/4*161.67^2*6.6*109.52= 14.84 \text{ kNm}$$

Longitudinal Stability Check (P=0)
$$\text{LongStab} = MB / \text{Mmax} + \text{Abs}(Fzmin) / \text{Fcmax} \quad (16.5-27)$$
$$=3.91/14.84+\text{Abs}(0)/367.06= 0.2632$$

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»Nozzle Long.Stability LongStab=0.2632 <= 1.0=1« » (U= 26.3%) OK«

CALCULATION SUMMARY

9.5.2.4 Nozzles normal to the shell, with or without reinforcement pads.

Limit of Reinforcement Along Shell

$$\text{Iso} = \text{Sqr}((2 * \text{ris} + \text{eas}) * \text{eas}) \\ = \text{Sqr}((2 * 423.5 + 8.5) * 8.5) = 85.27 \text{ mm}$$

Limit of Reinforcement Along Pad

$$\text{Ip} = \text{Min}(\text{Ip}, \text{Is}) (16.5-86) = \text{Min}(65.85, 85.27) = 65.85 \text{ mm}$$

Limit of Reinforcement Along Nozzle (outside shell)

$$\text{Ibo} = \text{MIN}(\text{Sqr}((\text{deb} - \text{eb}) * \text{eb}), \text{ho}) (16.5-75)$$

$$= \text{MIN}(\text{Sqr}((168.27 - 6.6) * 6.6), 200) = 32.66 \text{ mm}$$

Pressure Area Required pA(req.)

$$\text{pAReqL} = P * (\text{ApsL} + \text{Apb}) (16.5-7) = 0.5 * (71744.95 + 3191.57) = 37.47 \text{ kN}$$

$$\text{pAReqT} = P * (\text{ApsT} + \text{Apb} + 0.5 * \text{Apphi}) (16.5-7) \\ = 0.5 * (35631.82 + 3191.57 + 0.5 * 0) = 19.41 \text{ kN}$$

$$\text{pAReq} = \text{MAX}(\text{pAReqL}, \text{pAReqT}) = \text{MAX}(37.47, 19.41) = 37.47 \text{ kN}$$

Pressure Area Available pA(aval.)

$$\text{pAAval} = (\text{Afs} + \text{Afw}) * (\text{fs} - 0.5 * P) + \text{Afp} * (\text{fop} - 0.5 * P) + \text{Afb} * (\text{fob} - 0.5 * P) (16.5-7) \\ = (724.83 + 0) * (129.41 - 0.5 * 0.5) + 559.73 * (129.41 - 0.5 * 0.5) + 271.62 * (114.37 - 0.5 * 0.5) \\ = 196.91 \text{ kN}$$

»Nozzle Reinforcement pAAval=196.91 >= pAReq=37.47[kN] « » (U= 19%) OK«

Maximum Allowable Pressure Pmax

$$\text{Pmax} = (\text{Afs} + \text{Afw}) * \text{fs} + \text{Afp} * \text{fop} + \text{Afb} * \text{fob} / ((\text{Aps} + \text{Apb} + 0.5 * \text{Apphi}) + 0.5 * (\text{Afs} + \text{Afw} + \text{Afb} + \text{Afp})) (10) \\ = (724.83 + 0 + 271.62 + 559.73) * 129.41 / ((71744.95 + 3191.57 + 0.5 * 0) + 0.5 * (724.83 + 0 + 271.62 + 559.73)) = 2.61 \text{ MPa}$$

»ANSI 150lb-Flange Rating(at 232C) P=0.5 <= PMax(flange)=1.28[MPa] «» (U= 39.1%) OK«

LOAD CASE NO: 1 - Load Case 1

STRESSES AT OUTER DIAMETER OF NOZZLE

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT NOZZLE OD PhiP=0.0384 <= 1.0 =1(16.5-12)« » (U= 3.8%) OK«

»PhiZ AT NOZZLE OD PhiZ=0.0969 <= 1.0 =1(16.5-13)« » (U= 9.6%) OK«

»PhiB AT NOZZLE OD PhiB=0.3736 <= 1.0 =1(16.5-14)« » (U= 37.3%) OK«

»PhiTau AT NOZZLE OD PhiTau=0.0277 <= 1.0 =1« » (U= 2.7%) OK«

»PhiAll AT NOZZLE OD PhiAll=0.3971 <= 1.0 =1(16.5-15)« » (U= 39.7%) OK«

STRESSES AT OUTER EDGE OF PAD

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT EDGE OF PAD PhiP=0.0384 <= 1.0 =1(16.5-12)« » (U= 3.8%) OK«

»PhiZ AT EDGE OF PAD PhiZ=0.2029 <= 1.0 =1(16.5-13)« » (U= 20.2%) OK«

»PhiB AT EDGE OF PAD PhiB=0.6368 <= 1.0 =1(16.5-14)« » (U= 63.6%) OK«

»PhiTau AT EDGE OF PAD PhiTau=0.0587 <= 1.0 =1« » (U= 5.8%) OK«

»PhiAll AT EDGE OF PAD PhiAll=0.6823 <= 1.0 =1(16.5-15)« » (U= 68.2%) OK«

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Visual Vessel Design by OhmTech Ver:10.2-01 Operator : Rev.:A

EN13445:2009 Issue 1 - 9.5 ISOLATED OPENINGS IN SHELLS

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16.5.7 STRESS RANGES AND THEIR COMBINATIONS

»Total Stress in Shell SigTot=186.76 <= 3*f=388.23[N/mm2] <>> (U= 48.1%) OK«

16.5.8 NOZZLE LONGITUDINAL STRESSES

»Nozzle Long.Stress SigLong=28.22 <= fb=114.37[N/mm2] < > (U= 24.6%) OK«

»Nozzle Long.Stability LongStab=0.2632 <= 1.0=1« > (U= 26.3%) OK«

LOAD CASE NO: 2 - Load Case 2

STRESSES AT OUTER DIAMETER OF NOZZLE

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT NOZZLE OD PhiP=0.1612 <= 1.0 =1(16.5-12)« > (U= 16.1%) OK«

»PhiZ AT NOZZLE OD PhiZ=0.0969 <= 1.0=1(16.5-13)« > (U= 9.6%) OK«

»PhiB AT NOZZLE OD PhiB=0.3736 <= 1.0=1(16.5-14)« > (U= 37.3%) OK«

»PhiTau AT NOZZLE OD PhiTau=0.0881 <= 1.0=1« > (U= 8.8%) OK«

»PhiAll AT NOZZLE OD PhiAll=0.4545 <= 1.0=1(16.5-15)« > (U= 45.4%) OK«

STRESSES AT OUTER EDGE OF PAD

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT EDGE OF PAD PhiP=0.1612 <= 1.0 =1(16.5-12)« > (U= 16.1%) OK«

»PhiZ AT EDGE OF PAD PhiZ=0.2029 <= 1.0=1(16.5-13)« > (U= 20.2%) OK«

»PhiB AT EDGE OF PAD PhiB=0.6368 <= 1.0=1(16.5-14)« > (U= 63.6%) OK«

»PhiTau AT EDGE OF PAD PhiTau=0.1866 <= 1.0=1« > (U= 18.6%) OK«

»PhiAll AT EDGE OF PAD PhiAll=0.75 <= 1.0=1(16.5-15)« > (U= 74.9%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

»Total Stress in Shell SigTot=200.73 <= 3*f=388.23[N/mm2] <>> (U= 51.7%) OK«

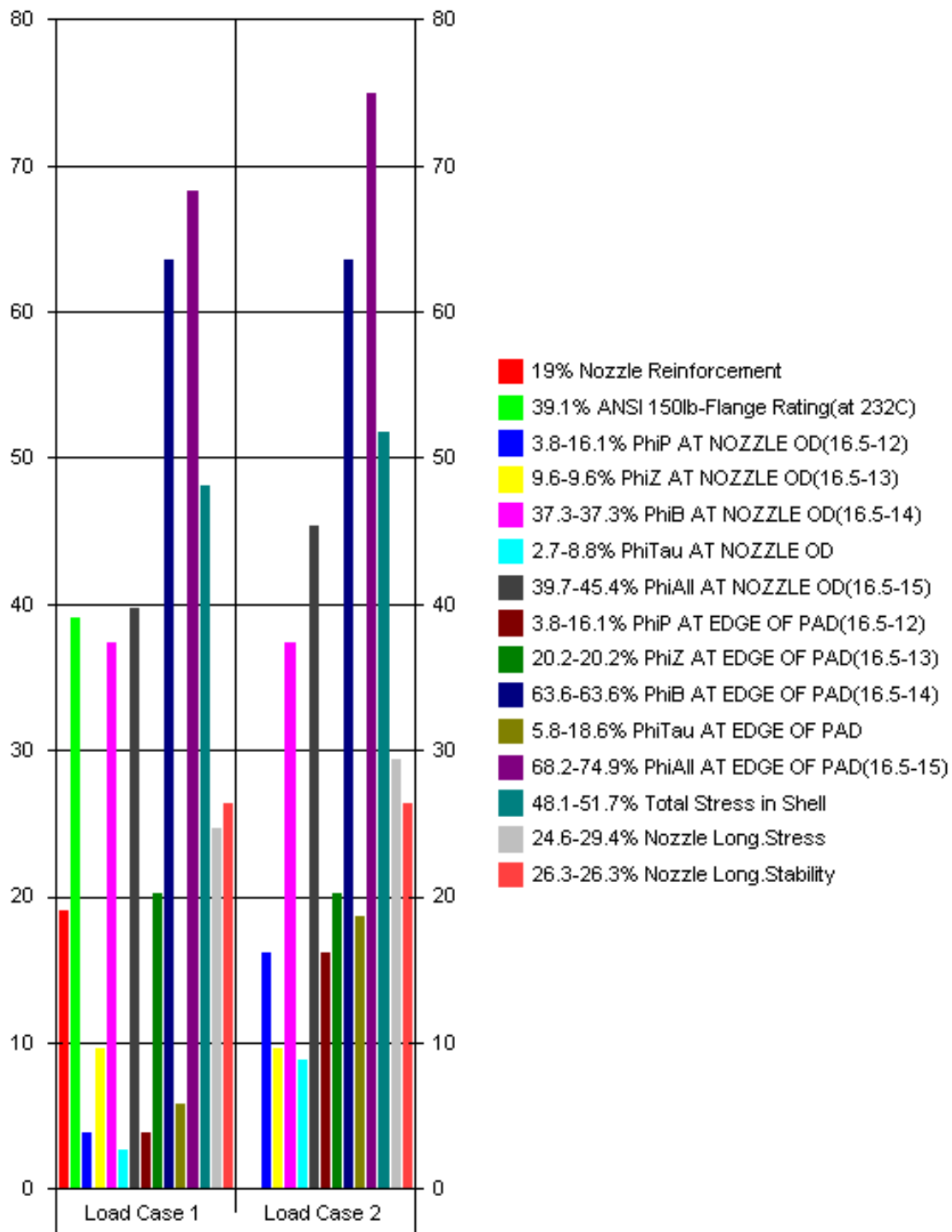
16.5.8 NOZZLE LONGITUDINAL STRESSES

»Nozzle Long.Stress SigLong=33.64 <= fb=114.37[N/mm2] < > (U= 29.4%) OK«

»Nozzle Long.Stability LongStab=0.2632 <= 1.0=1« > (U= 26.3%) OK«

Volume:0 m3 Weight:18.2 kg (SG= 7.85)

UTILIZATION CHART - N.C OUTLET VAP



Max.Utilization/Condition 74.9% CASE:Load Case 2

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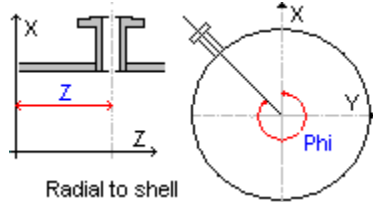
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INPUT DATA

COMPONENT ATTACHMENT/LOCATION

Attachment: S1.3 Cylindrical Shell Shell L=4030 S2.1



Orientation & Location of Nozzle: Radial to Shell
z-location of nozzle along axis of attachment.....:z 2445.00 mm
Angle of Rotation of nozzle axis projected in the x-y plane:Phi 0.00 Degr.

GENERAL DESIGN DATA



Type of Opening: Nozzle With Standard ANSI or DIN/EN Flange Attachment
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm, Pext= .1MPa
Include Nozzle Load Calculation: NO

SHELL DATA (S1.3)

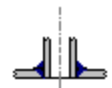
Shell Type: Cylindrical Shell
OUTSIDE DIAMETER OF SHELL.....:De 864.00 mm
AS BUILT WALL THICKNESS (uncorroded).....:en 12.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....:th 0.5000 mm
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
Rm=410 Rp=265 Rpt=194.12 fs=129.41 f20=170.83 ftest=252.38 E=196147(N/mm2) ro=7.85

NOZZLE MATERIAL DATA



Delivery Form: Forging (LWN)
ASME SA-105, PMA, , THK<=250mm 232'C
Rm=485 Rp=250 Rpt=177.2 fb=118.13 f20=166.67 ftest=238.1 (N/mm2)
NOTE: A PARTICULAR MATERIAL APPRAISAL(PMA) MAY BE REQUIRED FOR THIS MATERIAL.

NOZZLE DIMENSIONAL DATA



Attachment: Set In Flush Nozzle
Base calculations on Forging OD: NO
Shape of Nozzle/Opening: Circular
Application:
9.4.6.3 NOT a critical fatigue area, and calc.temp.is outside creep range.
INSIDE DIAMETER OF NOZZLE (corroded).....:dib 31.39 mm
AS BUILT NOZZLE THICKNESS (uncorroded).....:enb 12.69 mm
Size of Flange and Nozzle: 1"
Comment (Optional): CLASS :150# LWN Long Welding Neck
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....: 0.00 mm
NOZZLE STANDOUT MEASURED FROM VESSEL OD.....:ho 200.00 mm

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FLANGE DATA

A: Flange Standard: ANSI B16.5 Flanges
E: Pressure Class: ANSI B16.5:Class 150 lbs
C: Flange Type: LWN Long Welding Neck
D: Facing Sketch/ANSI facing (Table 3.8.3(2)): 1a RF Raised Face
Flange Material Category:
1.1 - Carbon Steel - A105, A515 70, A516 70, A350 LF2 (BS 1503 164 490, BS 1504 161 480)

WELDING DATA

Nozzle/Pad to Shell Welding Area: Exclude Area of Nozzle to Shell Weld
Nozzle Weld Intersect: Nozzle Does NOT Intersect with a Welded Shell Seam
ANGLE PhiC(OBLIQUE IN TRANSVERSE.CROSS SECT.)Fig.9.5-2:PhiC 0.00 Degr.
ANGLE PhiL(OBLIQUE IN LONG.CROSS SECT.)Fig.9.5-1.....:PhiL 0.00 Degr.

DATA FOR REINFORCEMENT PAD



Type of Pad: No Pad

LIMITS OF REINFORCEMENT

Reduction of Limits of Reinforcement: No Reduction Required

CALCULATION DATA

FLANGE RATING

ANSI 150lb-Flange Rating(at 232C)= 1.276 MPa, Max.Test Pressure = 3.102 MPa

PRELIMINARY CALCULATIONS

Shell Analysis Thickness eas 8.50 mm
 $eas = en - c - th = 12 - 3 - 0.5 =$
Nozzle Analysis Thickness eab 9.69 mm
 $eab = enb - c - NegDev = 12.69 - 3 - 0 =$
Inside Radius of Curvature 423.50 mm
 $ris = De / 2 - eas (9.5-3) = 864 / 2 - 8.5 =$
 $deb = dib + 2 * eab = 31.39 + 2 * 9.69 =$ 50.77 mm
Min.Nozzle Thk.Based on Internal Pressure ebp 0.0700 mm
 $ebp = P * dib / (2 * fb * z - P)$
 $= 0.5 * 31.39 / (2 * 118.13 * 1 - 0.5) =$
Allowable Stresses 118.13 N/mm2
 $fob = Min(fs, fb) (9.5-8) = Min(129.41, 118.13) =$

GEOMETRIC LIMITATIONS

»Check Max.Diameter of Nozzle $dib / (2 * ris) = 0.0371 \leq 1 = 1 [mm] \llcorner \llcorner$ OK«
»Min.Nozzle Thk. $ebp = 0.07 \leq eab = 9.69 [mm] \llcorner$ » (U= .7%) OK«

9.5.2.4.4 Nozzles normal to the shell, with or without reinforcement pads.

Calculation of Stress Loaded Areas Effective as Reinforcement

Area of Shell Afs

Limit of Reinforcement Along Shell 85.27 mm
 $Iso = Sqr((2 * ris + eas) * eas)$
 $= Sqr((2 * 423.5 + 8.5) * 8.5) =$
Set In Nozzle
 $Afs = eas * Iso (9.5-78) = 8.5 * 85.27 =$ 724.83 mm2

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Area of Nozzle Afb

Limit of Reinforcement Along Nozzle (outside shell)
 $Ibo = \text{MIN}(\text{Sqr}((deb - eb) * eb), ho) \quad (9.5-75)$
 $= \text{MIN}(\text{Sqr}((50.77-9.69)*9.69), 200) = 19.95 \text{ mm}$
Set In Nozzle
 $Afb = eb * (Ibo + Ibi + eas) \quad (9.5-77) = 9.69 * (19.95 + 0 + 8.5) = 275.70 \text{ mm}^2$

Calculation of Pressure Loaded Areas

In the Nozzle Apb
 $Apb = 0.5 * dib * (Ibo + eas) \quad (9.5-83) = 0.5 * 31.39 * (19.95 + 8.5) = 446.55 \text{ mm}^2$
Cyl.Shell in the Longitudinal Section Aps
 $ApsL = ris * (Is + a) \quad (9.5-93) = 423.5 * (85.27 + 25.38) = 46864.32 \text{ mm}^2$
Cyl.Shell in the Transverse Cross Section Aps
 $ApsT = 0.5 * ris^2 * (Is + a) / (0.5 * eas + ris) \quad (9.5-104)$
 $= 0.5 * 423.5^2 * (85.27 + 25.4) / (0.5 * 8.5 + 423.5) = 23202.47 \text{ mm}^2$
 $Aps = \text{MAX}(ApsL, ApsT) = \text{MAX}(46864.32, 23202.47) = 46864.32 \text{ mm}^2$

9.5.2 Reinforcement Rules

Pressure Area Required pA(req.)

$pAReqL = P * (ApsL + Apb) \quad (9.5-7) = 0.5 * (46864.32 + 446.55) = 23.66 \text{ kN}$
 $pAReqT = P * (ApsT + Apb + 0.5 * Apphi) \quad (9.5-7)$
 $= 0.5 * (23202.47 + 446.55 + 0.5 * 0) = 11.82 \text{ kN}$
 $pAReq = \text{MAX}(pAReqL, pAReqT) = \text{MAX}(23.66, 11.82) = 23.66 \text{ kN}$

Pressure Area Available pA(aval.)

$pAAval = (Afs + Afw) * fs + Afb * fob / ((Aps + Apb + 0.5 * Apphi) + 0.5 * (Afs + Afw + Afb + Afp)) \quad (9.5-7)$
 $= (724.83 + 0) * (129.41 - 0.5 * 0.5) + 0 * (0 - 0.5 * 0.5) + 275.7 * (118.13 - 0.5 * 0.5) = 126.12 \text{ kN}$

»Nozzle Reinforcement $pAAval = 126.12 > pAReq = 23.66 [\text{kN}] \ll \gg (U = 18.7\%) \text{ OK} \ll$

Maximum Allowable Pressure Pmax

$Pmax = (Afs + Afw) * fs + Afb * fob / ((Aps + Apb + 0.5 * Apphi) + 0.5 * (Afs + Afw + Afb + Afp)) \quad (10)$
 $= (724.83 + 0) * (129.41 - 0.5 * 0.5) + 0 * (0 - 0.5 * 0.5) + 275.7 * (118.13 - 0.5 * 0.5) / ((46864.32 + 446.55 + 0.5 * 0) + 0.5 * (724.83 + 0 + 275.7 + 0))$
 $= 2.64 \text{ MPa}$

Max.Allowable Test Pressure Pmax

$Ptmax = 6.95 \text{ MPa}$

»ANSI 150lb-Flange Rating(at 232C) $P = 0.5 \leq Pmax(\text{flange}) = 1.28 [\text{MPa}] \ll \gg (U = 39.1\%) \text{ OK} \ll$

CALCULATION SUMMARY

9.5.2.4 Nozzles normal to the shell, with or without reinforcement pads.

Limit of Reinforcement Along Shell
 $Iso = \text{Sqr}((2 * ris + eas) * eas)$
 $= \text{Sqr}((2 * 423.5 + 8.5) * 8.5) = 85.27 \text{ mm}$
Limit of Reinforcement Along Nozzle (outside shell)
 $Ibo = \text{MIN}(\text{Sqr}((deb - eb) * eb), ho) \quad (9.5-75)$
 $= \text{MIN}(\text{Sqr}((50.77 - 9.69) * 9.69), 200) = 19.95 \text{ mm}$

Pressure Area Required pA(req.)

$pAReqL = P * (ApsL + Apb) \quad (9.5-7) = 0.5 * (46864.32 + 446.55) = 23.66 \text{ kN}$
 $pAReqT = P * (ApsT + Apb + 0.5 * Apphi) \quad (9.5-7)$
 $= 0.5 * (23202.47 + 446.55 + 0.5 * 0) = 11.82 \text{ kN}$
 $pAReq = \text{MAX}(pAReqL, pAReqT) = \text{MAX}(23.66, 11.82) = 23.66 \text{ kN}$

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Pressure Area Available pA(aval.)

$$pAAval = (Afs+Af_w)*(fs-0.5*P)+Afp*(fop-0.5*P)+Afb*(fob-0.5*P) \quad (9.5-7)$$
$$=(724.83+0)*(129.41-0.5*0.5)+0*(0-0.5*0.5)+275.7*(118.13-0.5*0.5)= \underline{\underline{126.12}} \text{ kN}$$

»Nozzle Reinforcement pAAval=126.12 >= pAReq=23.66[kN] « » (U= 18.7%) OK«

Maximum Allowable Pressure Pmax

$$Pmax = (Afs+Af_w)*fs+Afb*fob / ((Aps+Apb+0.5*Apphi)+0.5*(Afs+Af_w+Afb+Af_p)) \quad (10)$$
$$=+0)*129.41+275.7*118.13 / ((46864.32+446.55+0.5*0)+0.5*(724.83+0+275.7+0))$$
$$= \underline{\underline{2.64}} \text{ MPa}$$

»ANSI 150lb-Flange Rating(at 232C) P=0.5 <= PMax(flange)=1.28[MPa] «» (U= 39.1%) OK«

Volume:0 m3 Weight:3.3 kg (SG= 7.85)

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Sample File

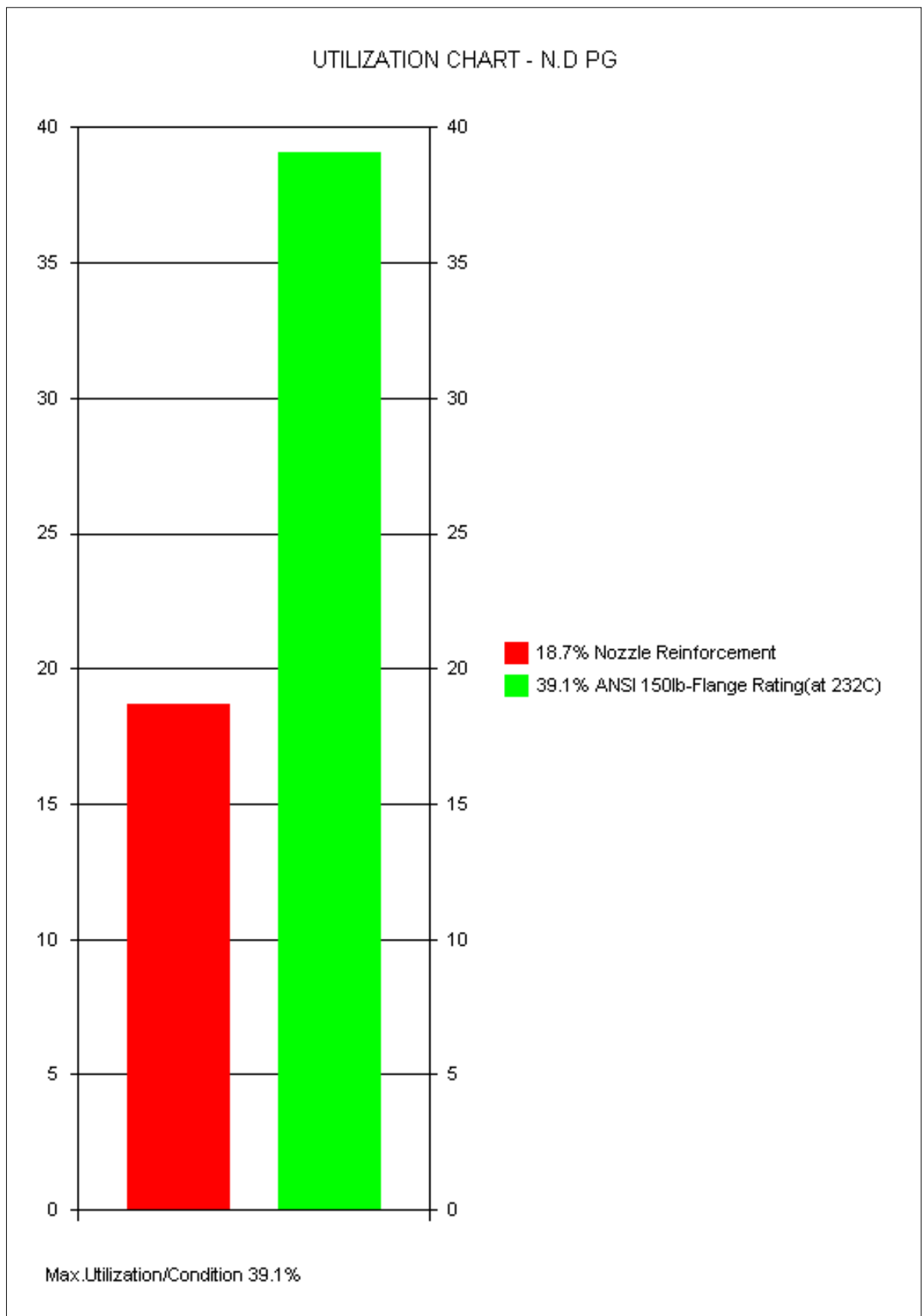
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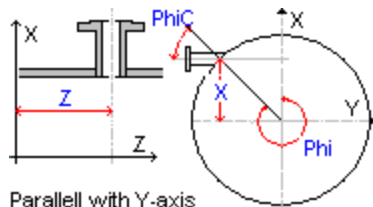
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INPUT DATA

COMPONENT ATTACHMENT/LOCATION

Attachment: S1.3 Cylindrical Shell Shell L=4030 S2.1

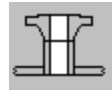


Parallel with Y-axis

Orientation & Location of Nozzle: Horizontal to Component

Off-Center location in the x-direction (+/-).....:x 300.00 mm
z-location of nozzle along axis of attachment.....:z 3565.00 mm
Nozzle located in section 0-180degr.==> k=1 ELSE k=-1:k 0.00 mm

GENERAL DESIGN DATA



Type of Opening: Nozzle With Standard ANSI or DIN/EN Flange Attachment
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm, Pext= .1MPa
Include Nozzle Load Calculation: YES

SHELL DATA (S1.3)

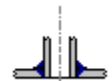
Shell Type: Cylindrical Shell
OUTSIDE DIAMETER OF SHELL.....:De 864.00 mm
AS BUILT WALL THICKNESS (uncorroded).....:en 12.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....:th 0.5000 mm
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
Rm=410 Rp=265 Rpt=194.12 fs=129.41 f20=170.83 ftest=252.38 E=196147(N/mm²) ro=7.85

NOZZLE MATERIAL DATA



Delivery Form: Forging (LWN)
ASME SA-105, PMA, , THK<=250mm 232'C
Rm=485 Rp=250 Rpt=177.2 fb=118.13 f20=166.67 ftest=238.1 (N/mm²)
NOTE: A PARTICULAR MATERIAL APPRAISAL(PMA) MAY BE REQUIRED FOR THIS MATERIAL.

NOZZLE DIMENSIONAL DATA



Attachment: Set In Flush Nozzle
Base calculations on Forging OD: NO
Shape of Nozzle/Opening: Circular
Application:
9.4.6.3 NOT a critical fatigue area, and calc.temp.is outside creep range.
INSIDE DIAMETER OF NOZZLE (corroded).....:dib 56.79 mm
AS BUILT NOZZLE THICKNESS (uncorroded).....:enb 13.49 mm
Size of Flange and Nozzle: 2"
Comment (Optional): CLASS :150# LWN Long Welding Neck
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....: 0.00 mm
NOZZLE STANDOUT MEASURED FROM VESSEL OD.....:ho 200.00 mm

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FLANGE DATA

A: Flange Standard: ANSI B16.5 Flanges
E: Pressure Class: ANSI B16.5:Class 150 lbs
C: Flange Type: LWN Long Welding Neck
D: Facing Sketch/ANSI facing (Table 3.8.3(2)): 1a RF Raised Face
Flange Material Category:
1.1 - Carbon Steel - A105, A515 70, A516 70, A350 LF2 (BS 1503 164 490, BS 1504 161 480)

WELDING DATA

Nozzle/Pad to Shell Welding Area: Exclude Area of Nozzle to Shell Weld
Nozzle Weld Intersect: Nozzle Does NOT Intersect with a Welded Shell Seam
ANGLE PhiC(OBLIQUE IN TRANSVERSE.CROSS SECT.)Fig.9.5-2:PhiC 44.77 Degr.
ANGLE PhiL(OBLIQUE IN LONG.CROSS SECT.)Fig.9.5-1....:PhiL 0.00 Degr.

DATA FOR REINFORCEMENT PAD



Type of Pad: No Pad

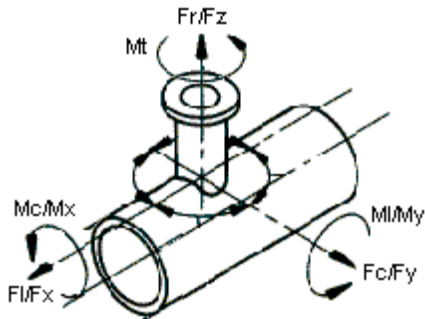
LIMITS OF REINFORCEMENT

Reduction of Limits of Reinforcement: No Reduction Required

EXTERNAL LOADS ON NOZZLE

FACTOR C4:

C4 = 1.1 Nozzle is Attached to a Piping System with due Allowance for Expansion and Thrust



TYPE OF LOAD INPUT: Load Cases

External Nozzle Loads: User Specified Loads

LOADING DATA

Table NOZZLE LOADS:

Load Description	ID	Units	Load Case 1	Load Case 2
Pressure	P	MPa	-0.1	0.42
Radial Load	Fz	kN	-2.5	2.5
Longitudinal Moment	My	kNm	-0.29	0.29
Circumferential Moment:	Mx	kNm	-0.29	0.29
Longitudinal Shear Force	Fl	kN	-2.5	2.5
Circumferential Shear Force	Fc	kN	-1.92	1.92
Torsional Moment	Mt	kNm	-3	3

CALCULATION DATA

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FLANGE RATING

ANSI 150lb-Flange Rating(at 232C)= 1.276 MPa, Max.Test Pressure = 3.102 MPa

PRELIMINARY CALCULATIONS

Shell Analysis Thickness eas
 $eas = en - c - th = 12 - 3 - 0.5 = 8.50 \text{ mm}$
Nozzle Analysis Thickness eab
 $eab = enb - c - NegDev = 13.49 - 3 - 0 = 10.49 \text{ mm}$
Inside Radius of Curvature
 $ris = De / 2 - eas (9.5 - 3) = 864 / 2 - 8.5 = 423.50 \text{ mm}$
 $deb = dib + 2 * eab = 56.79 + 2 * 10.49 = 77.77 \text{ mm}$
Min.Nozzle Thk.Based on Internal Pressure ebp
 $ebp = P * dib / (2 * fb * z - P) = 0.5 * 56.79 / (2 * 118.13 * 1 - 0.5) = 0.1200 \text{ mm}$
Allowable Stresses
 $fob = \text{Min}(fs, fb) (16.5 - 8) = \text{Min}(129.41, 118.13) = 118.13 \text{ N/mm}^2$

GEOMETRIC LIMITATIONS

»Check Max.Diameter of Nozzle $dib / (2 * ris) = 0.067 \leq 1 [\text{mm}] \llcorner \text{OK} \llcorner$
»Min.Nozzle Thk. $ebp = 0.12 \leq eab = 10.49 [\text{mm}] \llcorner \llcorner (U = 1.1\%) \text{OK} \llcorner$

9.5.2.4.5 Nozzles oblique to the shell, with or without reinforcement pads.

Calculation of Stress Loaded Areas Effective as Reinforcement

Area of Shell Afs

Limit of Reinforcement Along Shell
 $Iso = \text{Sqr}((2 * ris + eas) * eas) = \text{Sqr}((2 * 423.5 + 8.5) * 8.5) = 85.27 \text{ mm}$
Set In Nozzle
 $Afs = eas * Iso (16.5 - 78) = 8.5 * 85.27 = 724.83 \text{ mm}^2$

Area of Nozzle Afb

Limit of Reinforcement Along Nozzle (outside shell)
 $Ibo = \text{MIN}(\text{Sqr}((deb - eb) * eb), ho) (16.5 - 75) = \text{MIN}(\text{Sqr}((77.77 - 10.49) * 10.49), 200) = 26.57 \text{ mm}$
Set In Nozzle
 $Afb = eb * (Ibo + Ibi + eas) (16.5 - 77) = 10.49 * (26.57 + 0 + 8.5) = 367.85 \text{ mm}^2$

Calculation of Pressure Loaded Areas

In the Nozzle Apb
 $Apb = 0.5 * dib * (Ibo + eas) (16.5 - 77) = 0.5 * 56.79 * (26.57 + 8.5) = 995.71 \text{ mm}^2$
Additional Area due to Obliquity of Nozzle $A_p(\phi)$
 $A_{p\phi} = 0.5 * dib^2 * \text{Tan}(\phi) (16.5 - 111) = 0.5 * 56.79^2 * \text{Tan}(0.7813) = 1599.49 \text{ mm}^2$
Cyl.Shell in the Longitudinal Section A_{ps}
 $A_{psL} = ris * (Is + a) (16.5 - 112) = 423.5 * (85.27 + 38.89) = 52581.57 \text{ mm}^2$
Cyl.Shell in the Transverse Cross Section A_{ps}
 $A_{psT} = 0.5 * ris^2 * (Is + a) / (0.5 * eas + ris) (16.5 - 114) = 0.5 * 423.5^2 * (85.27 + 55.39) / (0.5 * 8.5 + 423.5) = 29489.08 \text{ mm}^2$
 $A_{ps} = \text{MAX}(A_{psL}, A_{psT}) = \text{MAX}(52581.57, 29489.08) = 52581.57 \text{ mm}^2$

9.5.2 Reinforcement Rules

Pressure Area Required $pA(\text{req.})$

$pA_{\text{reqL}} = P * (A_{psL} + A_{pb}) (16.5 - 7) = 0.5 * (52581.57 + 995.71) = 26.79 \text{ kN}$
 $pA_{\text{reqT}} = P * (A_{psT} + A_{pb} + 0.5 * A_{p\phi}) (16.5 - 7) = 0.5 * (29489.08 + 995.71 + 0.5 * 1599.49) = 15.64 \text{ kN}$
 $pA_{\text{req}} = \text{MAX}(pA_{\text{reqL}}, pA_{\text{reqT}}) = \text{MAX}(26.79, 15.64) = 26.79 \text{ kN}$

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Pressure Area Available pA(aval.)

$$pAAval = (Afs+Af_w)*(fs-0.5*P)+Afp*(fop-0.5*P)+Afb*(fob-0.5*P) \quad (16.5-7)$$
$$=(724.83+0)*(129.41-0.5*0.5)+0*(0-0.5*0.5)+367.85*(118.13-0.5*0.5)= \underline{136.98 \text{ kN}}$$

»Nozzle Reinforcement pAAval=136.98 >= pAReq=26.79[kN] « » (U= 19.5%) OK«

Maximum Allowable Pressure Pmax

$$Pmax = (Afs+Af_w)*fs+Afb*fob/((Aps+Ap_b+0.5*Apphi)+0.5*(Afs+Af_w+Afb+Af_p)) \quad (10)$$
$$=+0)*129.41+367.85*118.13/((52581.57+995.71+0.5*0)+0.5*(724.83+0+367.85+0))$$
$$= \underline{2.54 \text{ MPa}}$$

Max.Allowable Test Pressure Ptmx

$$Ptmx = == \underline{6.63 \text{ MPa}}$$

»ANSI 150lb-Flange Rating(at 232C) P=0.5 <= PMax(flange)=1.28[MPa] «» (U= 39.1%) OK«

16.5 LOCAL LOADS ON NOZZLES IN CYLINDRICAL SHELLS

PRELIMINARY CALCULATIONS

Shell Analysis Thickness eas	
eas = en - c - th =12-3-0.5=	8.50 mm
Nozzle Analysis Thickness eb	
eb = enb - c - NegDev =13.49-3-0=	8.80 mm
Mean diameter of shell	
D = De - ea =864-8.5=	855.50 mm
Mean radius of shell	
R = D / 2 =855.5/2=	427.75 mm

16.5.3 CONDITIONS OF APPLICABILITY

»a) ea/D=0.0099 >= 0.001« » OK«

»a) ea/D=0.0099 <= 0.1« » OK«

»b) LamdaC=0.8088 <= 10« » OK«

»c) Dist.to any other local load shall not be less than $\text{SQR}(D*ec)= 85.3 \text{ mm}$

»d) Nozzle thickness shall be maintained over a distance of $\text{SQR}(d*eb)= 24.6 \text{ mm}$

LOAD CASE NO: 1 - Load Case 1

Total Moment

$$MB = \text{Sqr}(M_x^2 + M_y^2) = \text{Sqr}(-0.29^2 + -0.29^2) = \underline{0.4101 \text{ kNm}}$$

STRESSES AT OUTER DIAMETER OF NOZZLE

Mean Diameter of Nozzle	
d = deb - eb =77.77-10.49=	68.97 mm
Combined Analysis Thickness	
ec = ea =8.5=	8.50 mm
LamdaC = d / $\text{Sqr}(D * ec) = 68.97/\text{Sqr}(855.5*8.5) =$	0.8088
Ratio1 = eb / ec =10.49/8.5=	1.04
Ratio2 = D / ec =855.5/8.5=	100.65
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 to 16.5-4	
C1 = 1.810 C2 = 4.900 C3 = 7.416	

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

Permissible Pressure Pmax:

$$Pmax \text{ (from nozzle calculation)} = Pmax \text{ (16.5-2)} = 2.54 = \underline{2.54 \text{ MPa}}$$

Allowable Axial Load Fzmax:

$$Fzmax = f * ec^2 * C1 \text{ (16.5-3)} = 129.41*8.5^2*1.81 = \underline{16.92 \text{ kN}}$$

Allowable Circumferential Moment Mxmax:

$$Mxmax = f * ec^2 * d / 4 * C2 \quad (16.5-5)$$
$$= 129.41*8.5^2*68.97/4*4.9 = \underline{0.7899 \text{ kNm}}$$

Allowable Longitudinal Moment Mxmax:

$$Mymax = f * ec^2 * d / 4 * C3 \quad (16.5-7)$$
$$= 129.41*8.5^2*68.97/4*7.42 = \underline{1.20 \text{ kNm}}$$

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SHEAR STRESS FORMULAE (PD5500 Section G.2.3.6.3)

Shear Stresses due to Longitudinal Shear Force, TauFl:

$$\text{TauFl} = 2 * \text{Fl} / (\text{PI} * \text{deb} * \text{ec}) \\ = 2 * -2.5 / (3.14 * 77.77 * 8.5) = -2.41 \text{ N/mm}^2$$

Shear Stresses due to Circumferential Force, TauFc:

$$\text{TauFc} = 2 * \text{Fc} / (\text{PI} * \text{deb} * \text{ec}) \\ = 2 * -1.92 / (3.14 * 77.77 * 8.5) = -1.85 \text{ N/mm}^2$$

Shear Stresses due to Torsional Moment, TauMt:

$$\text{TauMt} = 2 * \text{Mt} / (\text{PI} * \text{deb}^2 * \text{ec}) \\ = 2 * -3 / (3.14 * 77.77^2 * 8.5) = -37.15 \text{ N/mm}^2$$

Total Shear Stresses, Tau:

$$\text{Tau} = \text{Sqr}(\text{TauFc}^2 + \text{TauFl}^2) + \text{TauMt} \\ = \text{Sqr}(-1.85^2 + -2.41^2) + -37.15 = -34.11 \text{ N/mm}^2$$

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

$$\text{PhiP} = \text{P} / \text{Pmax} \text{ (16.5-9)} = -0.1 / 2.54 = -0.0394$$

$$\text{PhiZ} = \text{Fz} / \text{Fzmax} \text{ (16.5-10)} = -2.5 / 16.92 = -0.1477$$

$$\text{PhiTau} = \text{Tau} / (0.5 * f) = -34.11 / (0.5 * 129.41) = 0.5272$$

$$\text{PhiB} = \text{Sqr}((\text{Mx} / \text{Mxmax})^2 + (\text{My} / \text{Mymax})^2) \text{ (16.5-11)} \\ = \text{Sqr}((-0.29 / 0.7899)^2 + (-0.29 / 1.2)^2) = 0.4400$$

$$\text{MaxAll} = \text{MAX}(\text{Abs}(\text{PhiP}/\text{C4} + \text{PhiZ}), \text{Abs}(\text{PhiZ}), \text{Abs}(\text{PhiP}/\text{C4} - 0.2 * \text{PhiZ}) \text{ (16.5-15)} \\ = \text{MAX}(\text{Abs}(-0.0394 / 1.1 + -0.1477), \text{Abs}(-0.1477), \text{Abs}(-0.0394 / 1.1 - 0.2 * -0.1477)) \\ = 0.1836$$

$$\text{PhiAll} = \text{Sqr}(\text{MaxAll}^2 + \text{PhiB}^2 + \text{PhiTau}^2) \text{ (16.5-15)} \\ = \text{Sqr}(0.1836^2 + 0.44^2 + 0.5272^2) = 0.7108$$

16.5.6.4 Check of Individual Load Ratio Limits

- »PhiP AT NOZZLE OD PhiP=0.0394 <= 1.0=1(16.5-12)« » (U= 3.9%) OK«
- »PhiZ AT NOZZLE OD PhiZ=0.1477 <= 1.0=1(16.5-13)« » (U= 14.7%) OK«
- »PhiB AT NOZZLE OD PhiB=0.44 <= 1.0=1(16.5-14)« » (U= 44%) OK«
- »PhiTau AT NOZZLE OD PhiTau=0.5272 <= 1.0=1« » (U= 52.7%) OK«
- »PhiAll AT NOZZLE OD PhiAll=0.7108 <= 1.0=1(16.5-15)« » (U= 71%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

16.5.7.1 LOAD RANGES

$$\text{DeltaP} = \text{Max}(\text{Pmax}, 0) - \text{Min}(\text{Pmin}, 0) \text{ (16.5-16)} \\ = \text{Max}(0.1, 0) - \text{Min}(0, 0) = 0.1000 \text{ MPa}$$

$$\text{DeltaFz} = \text{Max}(\text{Fzmax}, 0) - \text{Min}(\text{Fzmin}, 0) \text{ (16.5-17)} \\ = \text{Max}(2.5, 0) - \text{Min}(0, 0) = 2.50 \text{ kN}$$

$$\text{DeltaMx} = \text{Max}(\text{Mxmax}, 0) - \text{Min}(\text{Mxmin}, 0) \text{ (16.5-18)} \\ = \text{Max}(0.29, 0) - \text{Min}(0, 0) = 0.2900 \text{ kNm}$$

$$\text{DeltaMy} = \text{Max}(\text{Mymax}, 0) - \text{Min}(\text{Mymin}, 0) \text{ (16.5-19)} \\ = \text{Max}(0.29, 0) - \text{Min}(0, 0) = 0.2900 \text{ kNm}$$

$$\text{DeltaFl} = \text{Max}(\text{Flmax}, 0) - \text{Min}(\text{Flmin}, 0) \\ = \text{Max}(2.5, 0) - \text{Min}(0, 0) = 0.00 \text{ kN}$$

$$\text{DeltaFc} = \text{Max}(\text{Fcmax}, 0) - \text{Min}(\text{Fcmin}, 0) \\ = \text{Max}(1.92, 0) - \text{Min}(0, 0) = 0.00 \text{ kN}$$

$$\text{DeltaFshear} = \text{Sqr}(\text{DeltaFl}^2 + \text{DeltaFc}^2) \\ = \text{Sqr}(0^2 + 0^2) = 0.00 \text{ kN}$$

$$\text{DeltaMt} = \text{Max}(\text{Mtmax}, 0) - \text{Min}(\text{Mtmin}, 0) \\ = \text{Max}(3, 0) - \text{Min}(0, 0) = 0.00 \text{ kNm}$$

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16.5.7.2 EQUIVALENT SHELL THICKNESS

$eeq = ec = 8.5 = 8.50 \text{ mm}$

16.5.7.3 STRESSES

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

$C1 = 1.810 \quad C2 = 4.900 \quad C3 = 7.416$

$Tmp1 = \text{Sqr}(d * eb / (D * eeq)) = \text{Sqr}(68.97 * 10.49 / (855.5 * 8.5)) = 0.2890$

$Tmp2 = (2 + 2 * d / D * Tmp1 + 1.25 * d / D * \text{Sqr}(D / eeq)) / (1 + eb / eeq * Tmp1)$
 $= (2 + 2 * 68.97 / 855.5 * 0.289 + 1.25 * 68.97 / 855.5 * \text{Sqr}(855.5 / 8.5)) / (1 + 10.49 / 8.5 * 0.289) = 2.35$

Stresses due to Pressure Range

$SigP = \text{DeltaP} * D / (2 * eeq) * Tmp2$ (16.5-21)
 $= 0.1 * 855.5 / (2 * 8.5) * 2.35 = 11.84 \text{ N/mm}^2$

Stresses due to Axial Load Range

$SigFz = 2.25 / C1 * (\text{DeltaFz} / eeq ^ 2)$ (16.5-22)
 $= 2.25 / 1.81 * (2.5 / 8.5 ^ 2) = 43.01 \text{ N/mm}^2$

Stresses due to Circumferential Moment Range

$SigMx = 2.25 / C2 * (4 * \text{DeltaMx} / (eeq ^ 2 * d))$ (16.5-23)
 $= 2.25 / 4.9 * (4 * 0.29 / (8.5 ^ 2 * 68.97)) = 106.90 \text{ N/mm}^2$

Stresses due to Longitudinal Moment Range

$SigMy = 2.25 / C3 * (4 * \text{DeltaMy} / (eeq ^ 2 * d))$ (16.5-24)
 $= 2.25 / 7.42 * (4 * 0.29 / (8.5 ^ 2 * 68.97)) = 70.63 \text{ N/mm}^2$

Shear Stresses due to Longitudinal Shear Force, DeltaFl:

$TauFl = 2 * \text{DeltaFl} / (\text{PI} * deb * eeq)$
 $= 2 * 0 / (3.14 * 77.77 * 8.5) = 0.00 \text{ N/mm}^2$

Shear Stresses due to Circumferential Force, TauFc:

$TauFc = 2 * \text{DeltaFc} / (\text{PI} * deb * eeq)$
 $= 2 * 0 / (3.14 * 77.77 * 8.5) = 0.00 \text{ N/mm}^2$

Shear Stresses due to Torsional Moment, TauMt:

$TauMt = 2 * \text{DeltaMt} / (\text{PI} * deb ^ 2 * eeq)$
 $= 2 * 0 / (3.14 * 77.77 ^ 2 * 8.5) = 0.00 \text{ N/mm}^2$

Total Shear Stresses, Tau:

$Tau = \text{Sqr}(TauFc ^ 2 + TauFl ^ 2) + TauMt$
 $= \text{Sqr}(0 ^ 2 + 0 ^ 2) + 0 = 0.00 \text{ N/mm}^2$

Total Stress Intensity due to Load Range

$SigTot = \text{Abs}(SigT + \text{Sqr}((SigP + SigFz) ^ 2 + SigMx ^ 2 + SigMy ^ 2 + 4 * Tau ^ 2))$ (16.5-25)
 $= \text{Abs}(0 + \text{Sqr}((11.84 + 43.01) ^ 2 + 106.9 ^ 2 + 70.63 ^ 2 + 4 * 0 ^ 2)) = 139.37 \text{ N/mm}^2$

»Total Stress in Shell SigTot=139.37 <= 3*f=388.23[N/mm2] <>> (U= 35.8%) OK<<

16.5.8 NOZZLE LONGITUDINAL STRESSES

Maximum Longitudinal Stresses in Nozzle

$SigLong = P * d / (4 * eb) + 4 * MB / (\text{PI} * d ^ 2 * eb) + Fz / (\text{PI} * d * eb)$ (16.5-26)
 $= -0.1 * 68.97 / (4 * 10.49) + 4 * 0.4101 / (3.14 * 68.97 ^ 2 * 10.49) + 0 / (3.14 * 68.97 * 10.49)$
 $= 12.27 \text{ N/mm}^2$

»Nozzle Long.Stress SigLong=12.27 <= fb=118.13[N/mm2] <>> (U= 10.3%) OK<<

16.14.6 COMPRESSIVE STRESS LIMITS

$K = 1.21 * E * ea / (Sigc * D)$ (16.14-15)
 $= 1.21 * 196147 * 8.8 / (177.2 * 68.97) = 170.98$

$alfa = 0.83 / \text{Sqr}(1 + 0.005 * D / ea)$ (16.14-16)

$= 0.83 / \text{Sqr}(1 + 0.005 * 68.97 / 8.8) = 0.8142$

$delta = (1 - 0.4123 / (alfa * K) ^ 0.6) / S$ (16.14-19)

$= (1 - 0.4123 / (0.8142 * 170.98) ^ 0.6) / 1.5 = 0.6524$

Maximum Allowable Compressive Stress

$Sigcall = Sigc * delta$ (16.14-20) $= 177.2 * 0.6524 = 115.61 \text{ N/mm}^2$

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16.14.4 PERMISSIBLE INDIVIDUAL LOADS

Maximum Tensile Force Ftmax

$$Ftmax = PI * D * ea * f \text{ (16.14-1)} = 3.14 * 68.97 * 8.8 * 118.13 = \underline{225.33 \text{ kN}}$$

Maximum Compressive Force Fcmax

$$Fcmax = PI * D * ea * Sigcall \text{ (16.14-2)} = 3.14 * 68.97 * 8.8 * 115.61 = \underline{220.53 \text{ kN}}$$

Maximum Bending Moment Mmax

$$Mmax = PI / 4 * D^2 * ea * Sigcall \text{ (16.14-3)} \\ = 3.14 / 4 * 68.97^2 * 8.8 * 115.61 = \underline{3.80 \text{ kNm}}$$

Longitudinal Stability Check (P=0)

$$LongStab = MB / Mmax + Abs(Fzmin) / Fcmax \text{ (16.5-27)} \\ = 0.4101 / 3.8 + Abs(0) / 220.53 = \underline{0.1079}$$

»Nozzle Long.Stability LongStab=0.1079 <= 1.0=1« » (U= 10.7%) OK«

LOAD CASE NO: 2 - Load Case 2

Total Moment

$$MB = Sqr(Mx^2 + My^2) = Sqr(0.29^2 + 0.29^2) = \underline{0.4101 \text{ kNm}}$$

STRESSES AT OUTER DIAMETER OF NOZZLE

Mean Diameter of Nozzle

$$d = deb - eb = 77.77 - 10.49 = \underline{68.97 \text{ mm}}$$

Combined Analysis Thickness

$$ec = ea = 8.5 = \underline{8.50 \text{ mm}}$$

$$\lambda dC = d / Sqr(D * ec) = 68.97 / Sqr(855.5 * 8.5) = \underline{0.8088}$$

$$Ratio1 = eb / ec = 10.49 / 8.5 = \underline{1.04}$$

$$Ratio2 = D / ec = 855.5 / 8.5 = \underline{100.65}$$

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

$$C1 = 1.810 \quad C2 = 4.900 \quad C3 = 7.416$$

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

Permissible Pressure Pmax:

$$Pmax \text{ (from nozzle calculation)} = Pmax \text{ (16.5-2)} = 2.54 = \underline{2.54 \text{ MPa}}$$

Allowable Axial Load Fzmax:

$$Fzmax = f * ec^2 * C1 \text{ (16.5-3)} = 129.41 * 8.5^2 * 1.81 = \underline{16.92 \text{ kN}}$$

Allowable Circumferential Moment Mxmax:

$$Mxmax = f * ec^2 * d / 4 * C2 \text{ (16.5-5)} \\ = 129.41 * 8.5^2 * 68.97 / 4 * 4.9 = \underline{0.7899 \text{ kNm}}$$

Allowable Longitudinal Moment Mxmax:

$$Mymax = f * ec^2 * d / 4 * C3 \text{ (16.5-7)} \\ = 129.41 * 8.5^2 * 68.97 / 4 * 7.42 = \underline{1.20 \text{ kNm}}$$

SHEAR STRESS FORMULAE (PD5500 Section G.2.3.6.3)

Shear Stresses due to Longitudinal Shear Force, TauFl:

$$TauFl = 2 * F1 / (PI * deb * ec) \\ = 2 * 2.5 / (3.14 * 77.77 * 8.5) = \underline{2.41 \text{ N/mm}^2}$$

Shear Stresses due to Circumferential Force, TauFc:

$$TauFc = 2 * Fc / (PI * deb * ec) \\ = 2 * 1.92 / (3.14 * 77.77 * 8.5) = \underline{1.85 \text{ N/mm}^2}$$

Shear Stresses due to Torsional Moment, TauMt:

$$TauMt = 2 * Mt / (PI * deb^2 * ec) \\ = 2 * 3 / (3.14 * 77.77^2 * 8.5) = \underline{37.15 \text{ N/mm}^2}$$

Total Shear Stresses, Tau:

$$Tau = Sqr(TauFc^2 + TauFl^2) + TauMt \\ = Sqr(1.85^2 + 2.41^2) + 37.15 = \underline{40.19 \text{ N/mm}^2}$$

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

$$PhiP = P / Pmax \text{ (16.5-9)} = 0.5 / 2.54 = \underline{0.1656}$$

$$PhiZ = Fz / Fzmax \text{ (16.5-10)} = 2.5 / 16.92 = \underline{0.1477}$$

$$PhiTau = Tau / (0.5 * f) = 40.19 / (0.5 * 129.41) = \underline{0.6211}$$

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$$\begin{aligned} \text{PhiB} &= \text{Sqr}((\text{Mx} / \text{Mxmax})^2 + (\text{My} / \text{Mymax})^2) && (16.5-11) \\ &= \text{Sqr}((0.29/0.7899)^2 + (0.29/1.2)^2) = && 0.4400 \end{aligned}$$

$$\begin{aligned} \text{MaxAll} &= \text{MAX}(\text{Abs}(\text{PhiP}/\text{C4}+\text{PhiZ}), \text{Abs}(\text{PhiZ}), \text{Abs}(\text{PhiP}/\text{C4}-0.2*\text{PhiZ}) && (16.5-15) \\ &= \text{MAX}(\text{Abs}(0.1656/1.1+0.1477), \text{Abs}(0.1477), \text{Abs}(0.1656/1.1-0.2*0.1477)) = && 0.2983 \end{aligned}$$

$$\begin{aligned} \text{PhiAll} &= \text{Sqr}(\text{MaxAll}^2 + \text{PhiB}^2 + \text{PhiTau}^2) && (16.5-15) \\ &= \text{Sqr}(0.2983^2 + 0.44^2 + 0.6211^2) = && 0.8175 \end{aligned}$$

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT NOZZLE OD PhiP=0.1656 <= 1.0=1(16.5-12)« » (U= 16.5%) OK«

»PhiZ AT NOZZLE OD PhiZ=0.1477 <= 1.0=1(16.5-13)« » (U= 14.7%) OK«

»PhiB AT NOZZLE OD PhiB=0.44 <= 1.0=1(16.5-14)« » (U= 44%) OK«

»PhiTau AT NOZZLE OD PhiTau=0.6211 <= 1.0=1« » (U= 62.1%) OK«

»PhiAll AT NOZZLE OD PhiAll=0.8175 <= 1.0=1(16.5-15)« » (U= 81.7%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

16.5.7.1 LOAD RANGES

$$\begin{aligned} \text{DeltaP} &= \text{Max}(\text{Pmax}, 0) - \text{Min}(\text{Pmin}, 0) && (16.5-16) \\ &= \text{Max}(0.42, 0) - \text{Min}(0, 0) = && 0.4200 \text{ MPa} \end{aligned}$$

$$\begin{aligned} \text{DeltaFz} &= \text{Max}(\text{Fzmax}, 0) - \text{Min}(\text{Fzmin}, 0) && (16.5-17) \\ &= \text{Max}(2.5, 0) - \text{Min}(0, 0) = && 2.50 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{DeltaMx} &= \text{Max}(\text{Mxmax}, 0) - \text{Min}(\text{Mxmin}, 0) && (16.5-18) \\ &= \text{Max}(0.29, 0) - \text{Min}(0, 0) = && 0.2900 \text{ kNm} \end{aligned}$$

$$\begin{aligned} \text{DeltaMy} &= \text{Max}(\text{Mymax}, 0) - \text{Min}(\text{Mymin}, 0) && (16.5-19) \\ &= \text{Max}(0.29, 0) - \text{Min}(0, 0) = && 0.2900 \text{ kNm} \end{aligned}$$

$$\begin{aligned} \text{DeltaFl} &= \text{Max}(\text{Flmax}, 0) - \text{Min}(\text{Flmin}, 0) \\ &= \text{Max}(2.5, 0) - \text{Min}(0, 0) = && 2.50 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{DeltaFc} &= \text{Max}(\text{Fcmax}, 0) - \text{Min}(\text{Fcmin}, 0) \\ &= \text{Max}(1.92, 0) - \text{Min}(0, 0) = && 1.92 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{DeltaFshear} &= \text{Sqr}(\text{DeltaFl}^2 + \text{DeltaFc}^2) \\ &= \text{Sqr}(2.5^2 + 1.92^2) = && 3.15 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{DeltaMt} &= \text{Max}(\text{Mtmax}, 0) - \text{Min}(\text{Mtmin}, 0) \\ &= \text{Max}(3, 0) - \text{Min}(0, 0) = && 3.00 \text{ kNm} \end{aligned}$$

16.5.7.2 EQUIVALENT SHELL THICKNESS

$$\text{eeq} = \text{ec} = 8.5 = 8.50 \text{ mm}$$

16.5.7.3 STRESSES

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

$$\text{C1} = 1.810 \quad \text{C2} = 4.900 \quad \text{C3} = 7.416$$

$$\begin{aligned} \text{Tmp1} &= \text{Sqr}(d * \text{eb} / (D * \text{eeq})) \\ &= \text{Sqr}(68.97 * 10.49 / (855.5 * 8.5)) = && 0.2890 \end{aligned}$$

$$\begin{aligned} \text{Tmp2} &= (2 + 2*d/D * \text{Tmp1} + 1.25*d/D * \text{Sqr}(D/\text{eeq})) / (1 + \text{eb}/\text{eeq} * \text{Tmp1}) \\ &= (2 + 2*68.97/855.5 * 0.289 + 1.25*68.97/855.5 * \text{Sqr}(855.5/8.5)) / (1 + 10.49/8.5 * 0.289) \\ &= && 2.35 \end{aligned}$$

Stresses due to Pressure Range

$$\begin{aligned} \text{SigP} &= \text{DeltaP} * D / (2 * \text{eeq}) * \text{Tmp2} && (16.5-21) \\ &= 0.42 * 855.5 / (2 * 8.5) * 2.35 = && 49.74 \text{ N/mm}^2 \end{aligned}$$

Stresses due to Axial Load Range

$$\begin{aligned} \text{SigFz} &= 2.25 / \text{C1} * (\text{DeltaFz} / \text{eeq}^2) && (16.5-22) \\ &= 2.25 / 1.81 * (2.5 / 8.5^2) = && 43.01 \text{ N/mm}^2 \end{aligned}$$

Stresses due to Circumferential Moment Range

$$\begin{aligned} \text{SigMx} &= 2.25 / \text{C2} * (4 * \text{DeltaMx} / (\text{eeq}^2 * d)) && (16.5-23) \\ &= 2.25 / 4.9 * (4 * 0.29 / (8.5^2 * 68.97)) = && 106.90 \text{ N/mm}^2 \end{aligned}$$

Stresses due to Longitudinal Moment Range

$$\text{SigMy} = 2.25 / \text{C3} * (4 * \text{DeltaMy} / (\text{eeq}^2 * d)) \quad (16.5-24)$$

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$=2.25/7.42*(4*0.29/(8.5^2*68.97))=$ 70.63 N/mm2

Shear Stresses due to Longitudinal Shear Force, DeltaF1:
TauF1 = 2 * DeltaF1 / (PI * deb * eeq)
 $=2*2.5/(3.14*77.77*8.5)=$ 2.41 N/mm2

Shear Stresses due to Circumferential Force, TauFc:
TauFc = 2 * DeltaFc / (PI * deb * eeq)
 $=2*1.92/(3.14*77.77*8.5)=$ 1.85 N/mm2

Shear Stresses due to Torsional Moment, TauMt:
TauMt = 2 * DeltaMt / (PI * deb ^ 2 * eeq)
 $=2*3/(3.14*77.77^2*8.5)=$ 37.15 N/mm2

Total Shear Stresses, Tau:
Tau = Sqr(TauFc ^ 2 + TauF1 ^ 2) + TauMt
 $=\text{Sqr}(1.85^2+2.41^2)+37.15=$ 40.19 N/mm2

Total Stress Intensity due to Load Range
SigTot = Abs(SigT+Sqr((SigP+SigFz)^2+SigMx^2+SigMy^2+4*Tau^2)) (16.5-25)
 $=\text{Abs}(0+\text{Sqr}((49.74+43.01)^2+106.9^2+70.63^2+4*40.19^2))=$ 177.42 N/mm2

»Total Stress in Shell SigTot=177.42 <= 3*f=388.23[N/mm2] <> (U= 45.7%) OK«

16.5.8 NOZZLE LONGITUDINAL STRESSES

Maximum Longitudinal Stresses in Nozzle
SigLong = P*d/(4*eb)+4*MB/(PI*d^2*eb)+Fz/(PI*d*eb) (16.5-26)
 $=0.5*68.97/(4*10.49)+4*0.4101/(3.14*68.97^2*10.49)+2500/(3.14*68.97*10.49)$
 $=$ 14.60 N/mm2

»Nozzle Long.Stress SigLong=14.6 <= fb=118.13[N/mm2] <> (U= 12.3%) OK«

16.14.6 COMPRESSIVE STRESS LIMITS

$K = 1.21 * E * ea / (Sige * D)$ (16.14-15)
 $=1.21*196147*8.8/(177.2*68.97)=$ 170.98

$\text{alfa} = 0.83 / \text{Sqr}(1 + 0.005 * D / ea)$ (16.14-16)
 $=0.83/\text{Sqr}(1+0.005*68.97/8.8)=$ 0.8142

$\text{delta} = (1 - 0.4123 / (\text{alfa} * K) ^ 0.6) / S$ (16.14-19)
 $= (1 - 0.4123 / (0.8142 * 170.98) ^ 0.6) / 1.5 =$ 0.6524

Maximum Allowable Compressive Stress
Sigcall = Sige * delta (16.14-20) = $177.2 * 0.6524 =$ 115.61 N/mm2

16.14.4 PERMISSIBLE INDIVIDUAL LOADS

Maximum Tensile Force Ftmax
 $\text{Ftmax} = \text{PI} * D * ea * f$ (16.14-1) = $3.14*68.97*8.8*118.13 =$ 225.33 kN

Maximum Compressive Force Fcmax
 $\text{Fcmax} = \text{PI} * D * ea * \text{Sigcall}$ (16.14-2) = $3.14*68.97*8.8*115.61 =$ 220.53 kN

Maximum Bending Moment Mmax
 $\text{Mmax} = \text{PI} / 4 * D ^ 2 * ea * \text{Sigcall}$ (16.14-3)
 $=3.14/4*68.97^2*8.8*115.61 =$ 3.80 kNm

Longitudinal Stability Check (P=0)
LongStab = MB / Mmax + Abs(Fzmin) / Fcmax (16.5-27)
 $=0.4101/3.8+\text{Abs}(0)/220.53 =$ 0.1079

»Nozzle Long.Stability LongStab=0.1079 <= 1.0=1« >> (U= 10.7%) OK«

CALCULATION SUMMARY

9.5.2.4.5 Nozzles oblique to the shell, with or without reinforcement pads.

Limit of Reinforcement Along Shell
Iso = Sqr((2 * ris + eas) * eas)
 $=\text{Sqr}((2*423.5+8.5)*8.5)=$ 85.27 mm

Limit of Reinforcement Along Nozzle (outside shell)
Ibo = MIN(Sqr((deb - eb) * eb), ho) (16.5-75)
 $=\text{MIN}(\text{Sqr}((77.77-10.49)*10.49), 200) =$ 26.57 mm

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Pressure Area Required pA(req.)

$$pAReqL = P * (ApsL + Apb) (16.5-7) = 0.5 * (52581.57 + 995.71) = \underline{26.79 \text{ kN}}$$

$$pAReqT = P * (ApsT + Apb + 0.5 * Apphi) (16.5-7) \\ = 0.5 * (29489.08 + 995.71 + 0.5 * 1599.49) = \underline{15.64 \text{ kN}}$$

$$pAReq = \text{MAX}(pAReqL, pAReqT) = \text{MAX}(26.79, 15.64) = \underline{\underline{26.79 \text{ kN}}}$$

Pressure Area Available pA(aval.)

$$pAAval = (Afs + Afw) * (fs - 0.5 * P) + Afp * (fop - 0.5 * P) + Afb * (fob - 0.5 * P) (16.5-7) \\ = (724.83 + 0) * (129.41 - 0.5 * 0.5) + 0 * (0 - 0.5 * 0.5) + 367.85 * (118.13 - 0.5 * 0.5) = \underline{\underline{136.98 \text{ kN}}}$$

»Nozzle Reinforcement pAAval=136.98 >= pAReq=26.79[kN] « » (U= 19.5%) OK«

Maximum Allowable Pressure Pmax

$$Pmax = (Afs + Afw) * fs + Afb * fob / ((Aps + Apb + 0.5 * Apphi) + 0.5 * (Afs + Afw + Afb + Afp)) (10) \\ = (724.83 + 0) * 129.41 + 367.85 * 118.13 / ((52581.57 + 995.71 + 0.5 * 0) + 0.5 * (724.83 + 0 + 367.85 + 0)) \\ = \underline{\underline{2.54 \text{ MPa}}}$$

»ANSI 150lb-Flange Rating(at 232C) P=0.5 <= PMax(flange)=1.28[MPa] «» (U= 39.1%) OK«

LOAD CASE NO: 1 - Load Case 1

STRESSES AT OUTER DIAMETER OF NOZZLE

16.5.6.4 Check of Individual Load Ratio Limits

- »PhiP AT NOZZLE OD PhiP=0.0394 <= 1.0=1(16.5-12)« » (U= 3.9%) OK«
- »PhiZ AT NOZZLE OD PhiZ=0.1477 <= 1.0=1(16.5-13)« » (U= 14.7%) OK«
- »PhiB AT NOZZLE OD PhiB=0.44 <= 1.0=1(16.5-14)« » (U= 44%) OK«
- »PhiTau AT NOZZLE OD PhiTau=0.5272 <= 1.0=1« » (U= 52.7%) OK«
- »PhiAll AT NOZZLE OD PhiAll=0.7108 <= 1.0=1(16.5-15)« » (U= 71%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

»Total Stress in Shell SigTot=139.37 <= 3*f=388.23[N/mm2] «» (U= 35.8%) OK«

16.5.8 NOZZLE LONGITUDINAL STRESSES

- »Nozzle Long.Stress SigLong=12.27 <= fb=118.13[N/mm2] « » (U= 10.3%) OK«
- »Nozzle Long.Stability LongStab=0.1079 <= 1.0=1« » (U= 10.7%) OK«

LOAD CASE NO: 2 - Load Case 2

STRESSES AT OUTER DIAMETER OF NOZZLE

16.5.6.4 Check of Individual Load Ratio Limits

- »PhiP AT NOZZLE OD PhiP=0.1656 <= 1.0=1(16.5-12)« » (U= 16.5%) OK«
- »PhiZ AT NOZZLE OD PhiZ=0.1477 <= 1.0=1(16.5-13)« » (U= 14.7%) OK«
- »PhiB AT NOZZLE OD PhiB=0.44 <= 1.0=1(16.5-14)« » (U= 44%) OK«
- »PhiTau AT NOZZLE OD PhiTau=0.6211 <= 1.0=1« » (U= 62.1%) OK«
- »PhiAll AT NOZZLE OD PhiAll=0.8175 <= 1.0=1(16.5-15)« » (U= 81.7%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

»Total Stress in Shell SigTot=177.42 <= 3*f=388.23[N/mm2] «» (U= 45.7%) OK«

16.5.8 NOZZLE LONGITUDINAL STRESSES

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»Nozzle Long.Stress SigLong=14.6 <= fb=118.13[N/mm2] « » (U= 12.3%) OK«

»Nozzle Long.Stability LongStab=0.1079 <= 1.0=1« » (U= 10.7%) OK«

Volume:0 m3 Weight:8.2 kg (SG= 7.85)

Ohmtech AS

Sample File

Steam Generator

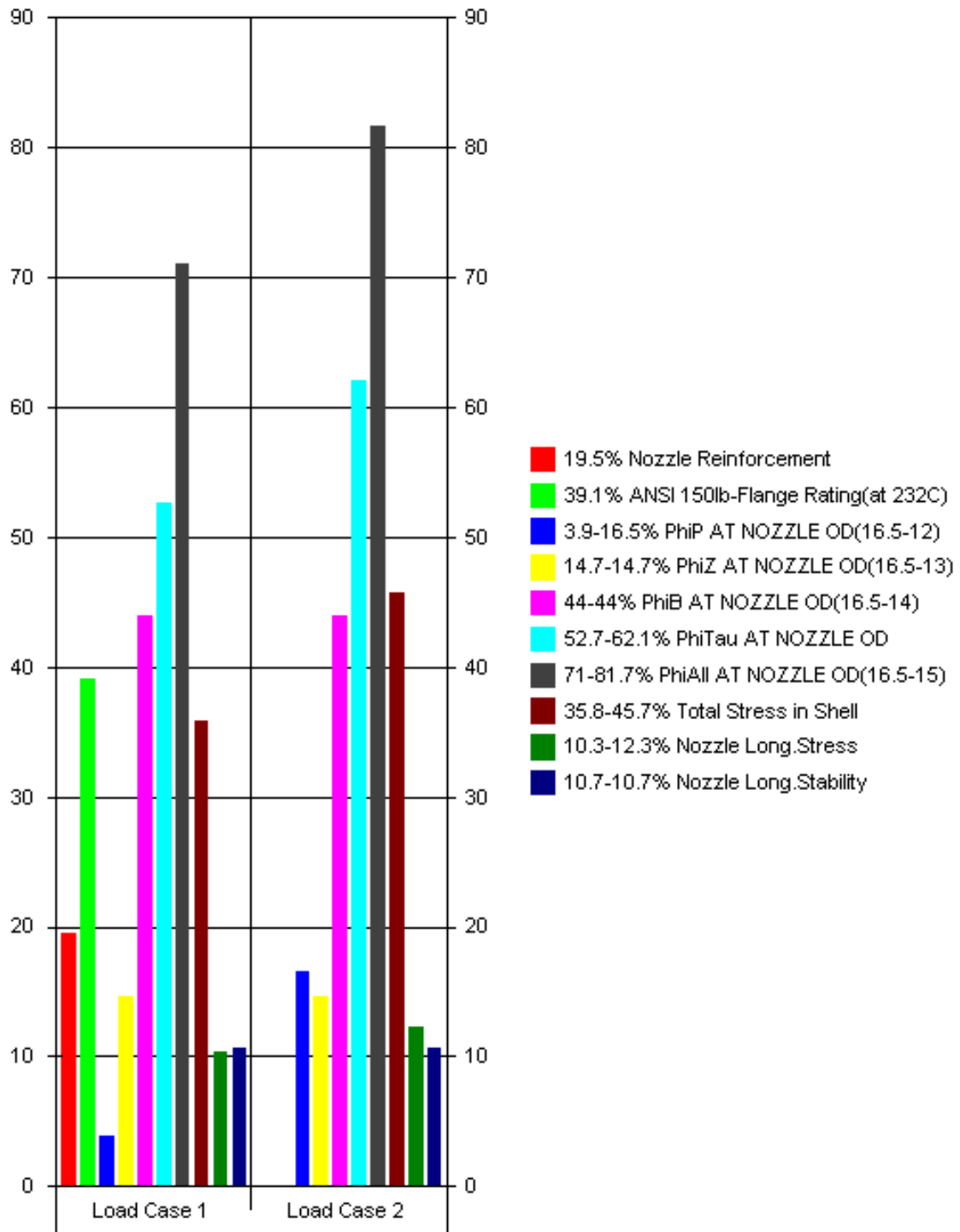
Visual Vessel Design by OhmTech Ver:10.2-01 Operator : Rev.:A

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UTILIZATION CHART - N.L1 LG



Max.Utilization/Condition 81.7% CASE:Load Case 2

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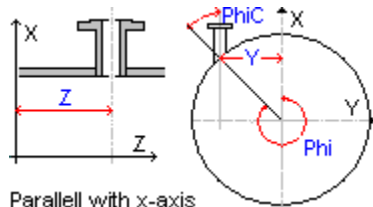
EN13445:2009 Issue 1 - 9.5 ISOLATED OPENINGS IN SHELLS

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INPUT DATA

COMPONENT ATTACHMENT/LOCATION

Attachment: S1.1 Cylindrical Shell Channel Shell



Parallel with x-axis

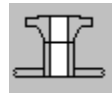
Orientation & Location of Nozzle: Vertical (Top/Bottom) to Component

Off-Center location in the y-direction (+/-).....:y 110.00 mm

z-location of nozzle along axis of attachment.....:z 225.00 mm

Nozzle located in section -90 and 90degr.==> k=1 ELSE k=-1:k 1.00

GENERAL DESIGN DATA



Type of Opening: Nozzle With Standard ANSI or DIN/EN Flange Attachment

PRESSURE LOADING: Design Component for Internal and External Pressure

PROCESS CARD: Tube Side : Temp= 370°C, P= .85MPa, c= 3mm, Pext= .1MPa

Include Nozzle Load Calculation: YES

SHELL DATA (S1.1)

Shell Type: Cylindrical Shell

OUTSIDE DIAMETER OF SHELL.....:De 624.00 mm

AS BUILT WALL THICKNESS (uncorroded).....:en 10.00 mm

NEGATIVE TOLERANCE/THINNING ALLOWANCE.....:th 0.5000 mm

EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 370'C

Rm=410 Rp=265 Rpt=156 fs=104 f20=170.83 ftest=252.38 E=185095(N/mm2) ro=7.85

NOZZLE MATERIAL DATA



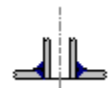
Delivery Form: Seamless Pipe

ASME SA-106 Gr.B, PMA, , THK<=999mm 370'C

Rm=415 Rp=240 Rpt=122.2 fb=81.47 f20=160 ftest=228.57 (N/mm2)

NOTE: A PARTICULAR MATERIAL APPRAISAL(PMA) MAY BE REQUIRED FOR THIS MATERIAL.

NOZZLE DIMENSIONAL DATA



Attachment: Set In Flush Nozzle

Shape of Nozzle/Opening: Circular

Application:

9.4.6.3 NOT a critical fatigue area, and calc.temp.is outside creep range.

OUTSIDE NOZZLE DIAMETER.....:deb 168.27 mm

AS BUILT NOZZLE THICKNESS (uncorroded).....:enb 10.97 mm

Size of Flange and Nozzle: 6"

Comment (Optional): Ex.Str.

NEGATIVE TOLERANCE/THINNING ALLOWANCE.....: 12.50 %

NOZZLE STANDOUT MEASURED FROM VESSEL OD.....:ho 200.00 mm

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FLANGE DATA

A: Flange Standard: ANSI B16.5 Flanges
 E: Pressure Class: ANSI 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:
 1.1 - Carbon Steel - A105, A515 70, A516 70, A350 LF2 (BS 1503 164 490, BS 1504 161 480)

WELDING DATA

Nozzle/Pad to Shell Welding Area: Exclude Area of Nozzle to Shell Weld
 Nozzle Weld Intersect: Nozzle Does NOT Intersect with a Welded Shell Seam
 ANGLE PhiC(OBLIQUE IN TRANSVERSE.CROSS SECT.)Fig.9.5-2:PhiC 21.00 Degr.
 ANGLE PhiL(OBLIQUE IN LONG.CROSS SECT.)Fig.9.5-1.....:PhiL 0.00 Degr.

DATA FOR REINFORCEMENT PAD



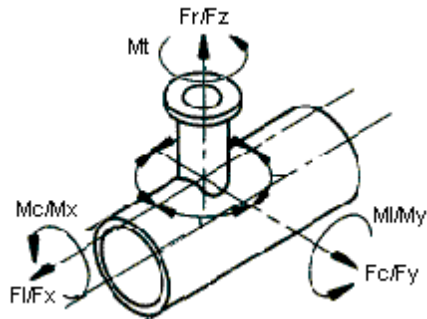
Type of Pad: Single Pad
 THICKNESS OF THE REINFORCEMENT PAD.....:eap 7.50 mm
 WIDTH OF THE REINFORCEMENT PAD.....:Ip 65.85 mm
 EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 370'C
 Rm=410 Rp=265 Rpt=156 fp=104 f20=170.83 ftest=252.38 E=185095(N/mm2) ro=7.85

LIMITS OF REINFORCEMENT

Reduction of Limits of Reinforcement: No Reduction Required

EXTERNAL LOADS ON NOZZLE

FACTOR C4:
 C4 = 1.1 Nozzle is Attached to a Piping System with due Allowance for Expansion and Thrust



TYPE OF LOAD INPUT: Load Cases
 External Nozzle Loads: User Specified Loads

LOADING DATA

Table NOZZLE LOADS:

Load Description	ID	Units	Load Case 1	Load Case 2
Pressure	P	MPa	-0.1	0.85
Radial Load	Fz	kN	-5	5
Longitudinal Moment	My	kNm	-2	2
Circumferential Moment:	Mx	kNm	-1.6	1.6
Longitudinal Shear Force	Fl	kN	-5	5
Circumferential Shear Force	Fc	kN	-5	5
Torsional Moment	Mt	kNm	-2	2

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CALCULATION DATA

FLANGE RATING

ANSI 300lb-Flange Rating(at 370C)= 3.688 MPa, Max.Test Pressure = 7.756 MPa

PRELIMINARY CALCULATIONS

Shell Analysis Thickness eas
 $eas = en - c - th = 10 - 3 - 0.5 = 6.50 \text{ mm}$
Nozzle Analysis Thickness eab
 $eab = enb - c - NegDev = 10.97 - 3 - 1.37 = 6.60 \text{ mm}$
Reinf.Pad Analysis Thickness ep
 $ep = \text{MIN}(eap, eas) (16.5-20) = \text{MIN}(7.5, 6.5) = 6.50 \text{ mm}$
Inside Radius of Curvature
 $ris = De / 2 - eas (9.5-3) = 624 / 2 - 6.5 = 305.50 \text{ mm}$
 $dib = deb - 2 * eab = 168.27 - 2 * 6.6 = 155.07 \text{ mm}$
Min.Nozzle Thk.Based on Internal Pressure ebp
 $ebp = P * deb / (2 * fb * z + P)$
 $= 0.85 * 168.27 / (2 * 81.47 * 1 + 0.85) = 0.8700 \text{ mm}$
Allowable Stresses
 $fob = \text{Min}(fs, fb) (16.5-8) = \text{Min}(104, 81.47) = 81.47 \text{ N/mm}^2$
 $fop = \text{Min}(fs, fp) (16.5-9) = \text{Min}(104, 104) = 104.00 \text{ N/mm}^2$

GEOMETRIC LIMITATIONS

»Check Max.Thk.of Pad $eap=7.5 \leq 1.5 * eas=9.75[\text{mm}] \ll \gg \text{OK} \ll$
»Check Max.Diameter of Nozzle $dib/(2 * ris)=0.2538 \leq .5[\text{mm}] \ll \gg \text{OK} \ll$
»Min.Nozzle Thk. $ebp=0.87 \leq eab=6.6[\text{mm}] \ll \gg (U= 13.1\%) \text{OK} \ll$

9.5.2.4.5 Nozzles oblique to the shell, with or without reinforcement pads.

Calculation of Stress Loaded Areas Effective as Reinforcement

Area of Shell Afs

Limit of Reinforcement Along Shell
 $Iso = \text{Sqr}((2 * ris + eas) * eas)$
 $= \text{Sqr}((2 * 305.5 + 6.5) * 6.5) = 63.35 \text{ mm}$
Set In Nozzle
 $Afs = eas * Iso (16.5-78) = 6.5 * 63.35 = 411.80 \text{ mm}^2$

Area of Reinforcement Pad Afp

Limit of Reinforcement Along Pad
 $Ip = \text{Min}(Ip, Iso) (16.5-86) = \text{Min}(65.85, 63.35) = 63.35 \text{ mm}$
 $ep = \text{Min}(ep, eas) (16.5-87) = \text{Min}(6.5, 6.5) = 6.50 \text{ mm}$
 $Afp = ep * Ip (16.5-85) = 6.5 * 63.35 = 411.80 \text{ mm}^2$

Area of Nozzle Afb

Limit of Reinforcement Along Nozzle (outside shell)
 $Ibo = \text{MIN}(\text{Sqr}((deb - eb) * eb), ho) (16.5-75)$
 $= \text{MIN}(\text{Sqr}((168.27 - 6.6) * 6.6), 200) = 32.66 \text{ mm}$
Set In Nozzle
 $Afb = eb * (Ibo + Ibi + eas) (16.5-77) = 6.6 * (32.66 + 0 + 6.5) = 258.42 \text{ mm}^2$

Calculation of Pressure Loaded Areas

In the Nozzle Apb
 $Apb = 0.5 * dib * (Ibo + eas) (16.5-77) = 0.5 * 155.07 * (32.66 + 6.5) = 3036.50 \text{ mm}^2$

Additional Area due to Obliquity of Nozzle Aphi
 $Aphi = 0.5 * dib ^ 2 * \text{Tan}(phi) (16.5-111)$
 $= 0.5 * 155.07 ^ 2 * \text{Tan}(0.3665) = 4614.57 \text{ mm}^2$

Cyl.Shell in the Longitudinal Section Aps
 $ApsL = ris * (Is + a) (16.5-112) = 305.5 * (63.35 + 84.14) = 45057.94 \text{ mm}^2$

Cyl.Shell in the Transverse Cross Section Aps

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$$A_{psT} = 0.5 * ris^2 * (Is + a) / (0.5 * eas + ris) \quad (16.5-114)$$

$$= 0.5 * 305.5^2 * (63.35 + 92.11) / (0.5 * 6.5 + 305.5) = 23497.66 \text{ mm}^2$$

$$A_{ps} = \text{MAX}(A_{psL}, A_{psT}) = \text{MAX}(45057.94, 23497.66) = 45057.94 \text{ mm}^2$$

9.5.2 Reinforcement Rules

Pressure Area Required pA(req.)

$$pA_{reqL} = P * (A_{psL} + A_{pb}) \quad (16.5-7) = 0.85 * (45057.94 + 3036.5) = 40.88 \text{ kN}$$

$$pA_{reqT} = P * (A_{psT} + A_{pb} + 0.5 * A_{pphi}) \quad (16.5-7)$$

$$= 0.85 * (23497.66 + 3036.5 + 0.5 * 4614.57) = 24.52 \text{ kN}$$

$$pA_{req} = \text{MAX}(pA_{reqL}, pA_{reqT}) = \text{MAX}(40.88, 24.52) = 40.88 \text{ kN}$$

Pressure Area Available pA(aval.)

$$pA_{aval} = (A_{fs} + A_{fw}) * (fs - 0.5 * P) + A_{fp} * (fop - 0.5 * P) + A_{fb} * (fob - 0.5 * P) \quad (16.5-7)$$

$$= (411.8 + 0) * (104 - 0.5 * 0.85) + 411.8 * (104 - 0.5 * 0.85) + 258.42 * (81.47 - 0.5 * 0.85)$$

$$= 106.25 \text{ kN}$$

»Nozzle Reinforcement pA_{aval}=106.25 >= pA_{req}=40.88[kN] « » (U= 38.4%) OK«

Maximum Allowable Pressure P_{max}

$$P_{max} = (A_{fs} + A_{fw}) * fs + A_{fp} * fop + A_{fb} * fob / ((A_{ps} + A_{pb} + 0.5 * A_{pphi}) + 0.5 * (A_{fs} + A_{fw} + A_{fb} + A_{fp})) \quad (10)$$

$$= (411.8 + 0) * 104 + 411.8 * 104 + 258.42 * 81.47 / ((45057.94 + 3036.5 + 0.5 * 0) + 0.5 * (411.8 + 0 + 258.42 + 411.8)) = 2.19 \text{ MPa}$$

Max.Allowable Test Pressure P_{tmax}

$$P_{tmax} = == 7.00 \text{ MPa}$$

»ANSI 300lb-Flange Rating(at 370C) P=0.85 <= P_{Max}(flange)=3.69[MPa] «» (U= 23%) OK«

16.5 LOCAL LOADS ON NOZZLES IN CYLINDRICAL SHELLS

PRELIMINARY CALCULATIONS

Shell Analysis Thickness eas = en - c - th = 10 - 3 - 0.5 = 6.50 mm

Nozzle Analysis Thickness eb = enb - c - NegDev = 10.97 - 3 - 1.37 = 6.60 mm

Mean diameter of shell D = De - ea = 624 - 6.5 = 617.50 mm

Mean radius of shell R = D / 2 = 617.5 / 2 = 308.75 mm

16.5.3 CONDITIONS OF APPLICABILITY

»a) ea/D=0.0105 >= 0.001« » OK«

»a) ea/D=0.0105 <= 0.1« » OK«

»b) LamdaC=1.74 <= 10« » OK«

»c) Dist.to any other local load shall not be less than SQR(D*ec)= 93 mm

»d) Nozzle thickness shall be maintained over a distance of SQR(d*eb)= 32.7 mm

LOAD CASE NO: 1 - Load Case 1

Total Moment MB = Sqr(Mx^2 + My^2) = Sqr(-1.6^2 + -2^2) = 2.56 kNm

STRESSES AT OUTER DIAMETER OF NOZZLE

Mean Diameter of Nozzle d = deb - eb = 168.27 - 6.6 = 161.67 mm

Combined Analysis Thickness ec = ea + eap * Min(fp / f1) = 6.5 + 7.5 * Min(104 / 104, 1) = 14.00 mm

LamdaC = d / Sqr(D * ec) = 161.67 / Sqr(617.5 * 14) = 1.74

Ratio1 = eb / ec = 6.6 / 14 = 0.4713

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Ratio2 = $D / ec = 617.5/14 = 44.11$
 VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4
 C1 = 2.264 C2 = 5.015 C3 = 11.125

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

Permissible Pressure Pmax:
 Pmax (from nozzle calculation) = Pmax (16.5-2) = 2.19 = 2.19 MPa

Allowable Axial Load Fzmax:
 $Fzmax = f * ec^2 * C1 (16.5-3) = 104 * 14^2 * 2.26 = 46.16$ kN

Allowable Circumferential Moment Mxmax:
 $Mxmax = f * ec^2 * d / 4 * C2 (16.5-5)$
 $= 104 * 14^2 * 161.67 / 4 * 5.01 = 4.13$ kNm

Allowable Longitudinal Moment Mxmax:
 $Mymax = f * ec^2 * d / 4 * C3 (16.5-7)$
 $= 104 * 14^2 * 161.67 / 4 * 11.13 = 9.17$ kNm

SHEAR STRESS FORMULAE (PD5500 Section G.2.3.6.3)

Shear Stresses due to Longitudinal Shear Force, TauFl:
 $TauFl = 2 * Fl / (PI * deb * ec)$
 $= 2 * -5 / (3.14 * 168.27 * 14) = -1.35$ N/mm2

Shear Stresses due to Circumferential Force, TauFc:
 $TauFc = 2 * Fc / (PI * deb * ec)$
 $= 2 * -5 / (3.14 * 168.27 * 14) = -1.35$ N/mm2

Shear Stresses due to Torsional Moment, TauMt:
 $TauMt = 2 * Mt / (PI * deb^2 * ec)$
 $= 2 * -2 / (3.14 * 168.27^2 * 14) = -3.21$ N/mm2

Total Shear Stresses, Tau:
 $Tau = Sqr(TauFc^2 + TauFl^2) + TauMt$
 $= Sqr(-1.35^2 + -1.35^2) + -3.21 = -1.30$ N/mm2

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

$PhiP = P / Pmax (16.5-9) = -0.1/2.19 = -0.0456$

$PhiZ = Fz / Fzmax (16.5-10) = -5/46.16 = -0.1083$

$PhiTau = Tau / (0.5 * f) = -1.3/(0.5*104) = 0.0250$

$PhiB = Sqr((Mx / Mxmax)^2 + (My / Mymax)^2) (16.5-11)$
 $= Sqr((-1.6/4.13)^2 + (-2/9.17)^2) = 0.4445$

$MaxAll = MAX(Abs(PhiP/C4+PhiZ), Abs(PhiZ), Abs(PhiP/C4-0.2*PhiZ)) (16.5-15)$
 $= MAX(Abs(-0.0456/1.1+-0.1083), Abs(-0.1083), Abs(-0.0456/1.1-0.2*-0.1083))$
 $= 0.1498$

$PhiAll = Sqr(MaxAll^2 + PhiB^2 + PhiTau^2) (16.5-15)$
 $= Sqr(0.1498^2 + 0.4445^2 + 0.025^2) = 0.4697$

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT NOZZLE OD PhiP=0.0456 <= 1.0=1(16.5-12)« » (U= 4.5%) OK«

»PhiZ AT NOZZLE OD PhiZ=0.1083 <= 1.0=1(16.5-13)« » (U= 10.8%) OK«

»PhiB AT NOZZLE OD PhiB=0.4445 <= 1.0=1(16.5-14)« » (U= 44.4%) OK«

»PhiTau AT NOZZLE OD PhiTau=0.025 <= 1.0=1« » (U= 2.5%) OK«

»PhiAll AT NOZZLE OD PhiAll=0.4697 <= 1.0=1(16.5-15)« » (U= 46.9%) OK«

STRESSES AT OUTER EDGE OF PAD

Diameter at Edge of Reinforcement Pad
 $d = deb + 2 * Ip = 168.27 + 2 * 65.85 = 299.97$ mm

Combined Analysis Thickness
 $ec = ea = 6.5 = 6.50$ mm

$LamdaC = d / Sqr(D * ec) = 299.97 / Sqr(617.5 * 6.5) = 4.73$

$Ratio1 = MAX(eb / ec, 0.5) = MAX(6.6/6.5, 0.5) = 1.02$

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Ratio2 = $D / ec = 617.5/6.5 = 95.00$
VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4
C1 = 5.075 C2 = 6.638 C3 = 25.427

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

Permissible Pressure Pmax:

Pmax (from nozzle calculation) = Pmax (16.5-2) = 2.19 = 2.19 MPa

Allowable Axial Load Fzmax:

Fzmax = $f * ec^2 * C1 (16.5-3) = 104 * 6.5^2 * 5.08 = 22.30$ kN

Allowable Circumferential Moment Mxmax:

Mxmax = $f * ec^2 * d / 4 * C2 (16.5-5)$
 $= 104 * 6.5^2 * 299.97 / 4 * 6.64 = 2.19$ kNm

Allowable Longitudinal Moment Mymax:

Mymax = $f * ec^2 * d / 4 * C3 (16.5-7)$
 $= 104 * 6.5^2 * 299.97 / 4 * 25.43 = 8.38$ kNm

SHEAR STRESS FORMULAE (PD5500 Section G.2.3.6.3)

Shear Stresses due to Longitudinal Shear Force, TauFl:

TauFl = $2 * Fl / (PI * deb * ec)$
 $= 2 * -5 / (3.14 * 168.27 * 6.5) = -2.91$ N/mm2

Shear Stresses due to Circumferential Force, TauFc:

TauFc = $2 * Fc / (PI * deb * ec)$
 $= 2 * -5 / (3.14 * 168.27 * 6.5) = -2.91$ N/mm2

Shear Stresses due to Torsional Moment, TauMt:

TauMt = $2 * Mt / (PI * deb^2 * ec)$
 $= 2 * -2 / (3.14 * 168.27^2 * 6.5) = -6.92$ N/mm2

Total Shear Stresses, Tau:

Tau = $Sqr(TauFc^2 + TauFl^2) + TauMt$
 $= Sqr(-2.91^2 + -2.91^2) + -6.92 = -2.80$ N/mm2

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

PhiP = $P / Pmax (16.5-9) = -0.1/2.19 = -0.0456$

PhiZ = $Fz / Fzmax (16.5-10) = -5/22.3 = -0.2242$

PhiTau = $Tau / (0.5 * f) = -2.8/(0.5*104) = 0.0539$

PhiB = $Sqr((Mx / Mxmax)^2 + (My / Mymax)^2) (16.5-11)$
 $= Sqr((-1.6/2.19)^2 + (-2/8.38)^2) = 0.7695$

MaxAll = $MAX(Abs(PhiP/C4+PhiZ), Abs(PhiZ), Abs(PhiP/C4-0.2*PhiZ)) (16.5-15)$
 $= MAX(Abs(-0.0456/1.1+-0.2242), Abs(-0.2242), Abs(-0.0456/1.1-0.2*-0.2242))$
 $= 0.2656$

PhiAll = $Sqr(MaxAll^2 + PhiB^2 + PhiTau^2) (16.5-15)$
 $= Sqr(0.2656^2 + 0.7695^2 + 0.0539^2) = 0.8158$

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT EDGE OF PAD PhiP=0.0456 <= 1.0=1(16.5-12)« » (U= 4.5%) OK«

»PhiZ AT EDGE OF PAD PhiZ=0.2242 <= 1.0=1(16.5-13)« » (U= 22.4%) OK«

»PhiB AT EDGE OF PAD PhiB=0.7695 <= 1.0=1(16.5-14)« » (U= 76.9%) OK«

»PhiTau AT EDGE OF PAD PhiTau=0.0539 <= 1.0=1« » (U= 5.3%) OK«

»PhiAll AT EDGE OF PAD PhiAll=0.8158 <= 1.0=1(16.5-15)« » (U= 81.5%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

16.5.7.1 LOAD RANGES

DeltaP = $Max(Pmax, 0) - Min(Pmin, 0) (16.5-16)$
 $= Max(0.1, 0) - Min(0, 0) = 0.1000$ MPa

DeltaFz = $Max(Fzmax, 0) - Min(Fzmin, 0) (16.5-17)$

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=Max(5,0)-Min(0,0)= 5.00 kN
DeltaMx = Max(Mxmax , 0) - Min(Mxmin , 0) (16.5-18)
=Max(1.6,0)-Min(0,0)= 1.60 kNm
DeltaMy = Max(Mymax , 0) - Min(Mymin , 0) (16.5-19)
=Max(2,0)-Min(0,0)= 2.00 kNm
DeltaFl = Max(Flmax , 0) - Min(Flmin , 0)
=Max(5,0)-Min(0,0)= 0.00 kN
DeltaFc = Max(Fcmax , 0) - Min(Fcmin , 0)
=Max(5,0)-Min(0,0)= 0.00 kN
DeltaFshear = Sqr(DeltaFl ^ 2 + DeltaFc ^ 2)
=Sqr(0^2+0^2)= 0.00 kN
DeltaMt = Max(Mtxmax , 0) - Min(Mtmin , 0)
=Max(2,0)-Min(0,0)= 0.00 kNm

16.5.7.2 EQUIVALENT SHELL THICKNESS

eeq = ea+Min(eap*Ip/Sqr(D*(ea+eap)),eap)*Min(fp/fl) (16.5-20)
=6.5+Min(7.5*65.85/Sqr(617.5*(6.5+7.5)),7.5)*Min(104/104,1)= 11.81 mm

16.5.7.3 STRESSES

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

C1 = 5.075 C2 = 6.638 C3 = 25.427

Tmp1 = Sqr(d * eb / (D * eeq))
=Sqr(161.67*6.6/(617.5*11.81))= 0.3824

Tmp2 = (2+2*d/D*Tmp1+1.25*d/D*Sqr(D/eeq))/(1+eb/eeq*Tmp1)
=(2+2*161.67/617.5*0.3824+1.25*161.67/617.5*Sqr(617.5/11.81))/(1+6.6/11.81*0.3824)= 3.76

Stresses due to Pressure Range

SigP = DeltaP * D / (2 * eeq) * Tmp2 (16.5-21)
=0.1*617.5/(2*11.81)*3.76= 9.84 N/mm2

Stresses due to Axial Load Range

SigFz = 2.25 / C1 * (DeltaFz / eeq ^ 2) (16.5-22)
=2.25/5.08*(5/11.81^2)= 15.89 N/mm2

Stresses due to Circumferential Moment Range

SigMx = 2.25 / C2 * (4 * DeltaMx / (eeq ^ 2 * d)) (16.5-23)
=2.25/6.64*(4*1.6/(11.81^2*161.67))= 96.18 N/mm2

Stresses due to Longitudinal Moment Range

SigMy = 2.25 / C3 * (4 * DeltaMy / (eeq ^ 2 * d)) (16.5-24)
=2.25/25.43*(4*2/(11.81^2*161.67))= 31.39 N/mm2

Shear Stresses due to Longitudinal Shear Force, DeltaFl:

TauFl = 2 * DeltaFl / (PI * deb * eeq)
=2*0/(3.14*168.27*11.81)= 0.00 N/mm2

Shear Stresses due to Circumferential Force, TauFc:

TauFc = 2 * DeltaFc / (PI * deb * eeq)
=2*0/(3.14*168.27*11.81)= 0.00 N/mm2

Shear Stresses due to Torsional Moment, TauMt:

TauMt = 2 * DeltaMt / (PI * deb ^ 2 * eeq)
=2*0/(3.14*168.27^2*11.81)= 0.00 N/mm2

Total Shear Stresses, Tau:

Tau = Sqr(TauFc ^ 2 + TauFl ^ 2) + TauMt
=Sqr(0^2+0^2)+0= 0.00 N/mm2

Total Stress Intensity due to Load Range

SigTot = Abs(SigT+Sqr((SigP+SigFz)^2+SigMx^2+SigMy^2+4*Tau^2)) (16.5-25)
=Abs(0+Sqr((9.84+15.89)^2+96.18^2+31.39^2+4*0^2))= 104.39 N/mm2

»Total Stress in Shell SigTot=104.39 <= 3*f=312[N/mm2] « » (U= 33.4%) OK«

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16.5.8 NOZZLE LONGITUDINAL STRESSES

Maximum Longitudinal Stresses in Nozzle

$$\text{SigLong} = P \cdot d / (4 \cdot e_b) + 4 \cdot \text{MB} / (\text{PI} \cdot d^2 \cdot e_b) + F_z / (\text{PI} \cdot d \cdot e_b) \quad (16.5-26)$$

$$= -0.1 \cdot 161.67 / (4 \cdot 6.6) + 4 \cdot 2.56 / (3.14 \cdot 161.67^2 \cdot 6.6) + 0 / (3.14 \cdot 161.67 \cdot 6.6)$$

$$= 18.30 \text{ N/mm}^2$$

»Nozzle Long.Stress SigLong=18.3 <= fb=81.47[N/mm2] « » (U= 22.4%) OK«

16.14.6 COMPRESSIVE STRESS LIMITS

$$K = 1.21 \cdot E \cdot e_a / (\text{Sige} \cdot D) \quad (16.14-15)$$

$$= 1.21 \cdot 1.851 \text{E}05 \cdot 6.6 / (122.2 \cdot 161.67) = 74.81$$

$$\text{alfa} = 0.83 / \text{Sqr}(1 + 0.005 \cdot D / e_a) \quad (16.14-16)$$

$$= 0.83 / \text{Sqr}(1 + 0.005 \cdot 161.67 / 6.6) = 0.7834$$

$$\text{delta} = (1 - 0.4123 / (\text{alfa} \cdot K)^{0.6}) / S \quad (16.14-19)$$

$$= (1 - 0.4123 / (0.7834 \cdot 74.81)^{0.6}) / 1.5 = 0.6428$$

Maximum Allowable Compressive Stress

$$\text{Sigcall} = \text{Sige} \cdot \text{delta} \quad (16.14-20) = 122.2 \cdot 0.6428 = 78.55 \text{ N/mm}^2$$

16.14.4 PERMISSIBLE INDIVIDUAL LOADS

Maximum Tensile Force Ftmax

$$\text{Ftmax} = \text{PI} \cdot D \cdot e_a \cdot f \quad (16.14-1) = 3.14 \cdot 161.67 \cdot 6.6 \cdot 81.47 = 273.05 \text{ kN}$$

Maximum Compressive Force Fcmax

$$\text{Fcmax} = \text{PI} \cdot D \cdot e_a \cdot \text{Sigcall} \quad (16.14-2) = 3.14 \cdot 161.67 \cdot 6.6 \cdot 78.546 = 263.25 \text{ kN}$$

Maximum Bending Moment Mmax

$$\text{Mmax} = \text{PI} / 4 \cdot D^2 \cdot e_a \cdot \text{Sigcall} \quad (16.14-3)$$

$$= 3.14 / 4 \cdot 161.67^2 \cdot 6.6 \cdot 78.546 = 10.64 \text{ kNm}$$

Longitudinal Stability Check (P=0)

$$\text{LongStab} = \text{MB} / \text{Mmax} + \text{Abs}(F_z \text{min}) / \text{Fcmax} \quad (16.5-27)$$

$$= 2.56 / 10.64 + \text{Abs}(0) / 263.25 = 0.2407$$

»Nozzle Long.Stability LongStab=0.2407 <= 1.0=1« » (U= 24%) OK«

LOAD CASE NO: 2 - Load Case 2

Total Moment

$$\text{MB} = \text{Sqr}(M_x^2 + M_y^2) = \text{Sqr}(1.6^2 + 2^2) = 2.56 \text{ kNm}$$

STRESSES AT OUTER DIAMETER OF NOZZLE

Mean Diameter of Nozzle

$$d = d_{eb} - e_b = 168.27 - 6.6 = 161.67 \text{ mm}$$

Combined Analysis Thickness

$$e_c = e_a + e_{ap} \cdot \text{Min}(f_p / f_1)$$

$$= 6.5 + 7.5 \cdot \text{Min}(104 / 104, 1) = 14.00 \text{ mm}$$

$$\text{LamdaC} = d / \text{Sqr}(D \cdot e_c) = 161.67 / \text{Sqr}(617.5 \cdot 14) = 1.74$$

$$\text{Ratio1} = e_b / e_c = 6.6 / 14 = 0.4713$$

$$\text{Ratio2} = D / e_c = 617.5 / 14 = 44.11$$

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

$$C1 = 2.264 \quad C2 = 5.015 \quad C3 = 11.125$$

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

Permissible Pressure Pmax:

$$\text{Pmax (from nozzle calculation)} = \text{Pmax} \quad (16.5-2) = 2.19 = 2.19 \text{ MPa}$$

Allowable Axial Load Fzmax:

$$\text{Fzmax} = f \cdot e_c^2 \cdot C1 \quad (16.5-3) = 104 \cdot 14^2 \cdot 2.26 = 46.16 \text{ kN}$$

Allowable Circumferential Moment Mxmax:

$$\text{Mxmax} = f \cdot e_c^2 \cdot d / 4 \cdot C2 \quad (16.5-5)$$

$$= 104 \cdot 14^2 \cdot 161.67 / 4 \cdot 5.01 = 4.13 \text{ kNm}$$

Allowable Longitudinal Moment Mxmax:

$$\text{Mymax} = f \cdot e_c^2 \cdot d / 4 \cdot C3 \quad (16.5-7)$$

$$= 104 \cdot 14^2 \cdot 161.67 / 4 \cdot 11.13 = 9.17 \text{ kNm}$$

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SHEAR STRESS FORMULAE (PD5500 Section G.2.3.6.3)

Shear Stresses due to Longitudinal Shear Force, TauFl:

$$\text{TauFl} = 2 * F_l / (\text{PI} * \text{deb} * \text{ec}) = 2 * 5 / (3.14 * 168.27 * 14) = \underline{1.35 \text{ N/mm}^2}$$

Shear Stresses due to Circumferential Force, TauFc:

$$\text{TauFc} = 2 * F_c / (\text{PI} * \text{deb} * \text{ec}) = 2 * 5 / (3.14 * 168.27 * 14) = \underline{1.35 \text{ N/mm}^2}$$

Shear Stresses due to Torsional Moment, TauMt:

$$\text{TauMt} = 2 * M_t / (\text{PI} * \text{deb}^2 * \text{ec}) = 2 * 2 / (3.14 * 168.27^2 * 14) = \underline{3.21 \text{ N/mm}^2}$$

Total Shear Stresses, Tau:

$$\text{Tau} = \text{Sqr}(\text{TauFc}^2 + \text{TauFl}^2) + \text{TauMt} = \text{Sqr}(1.35^2 + 1.35^2) + 3.21 = \underline{5.12 \text{ N/mm}^2}$$

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

$$\text{PhiP} = P / P_{\text{max}} \text{ (16.5-9)} = 0.85 / 2.19 = \underline{0.3874}$$

$$\text{PhiZ} = F_z / F_{z\text{max}} \text{ (16.5-10)} = 5 / 46.16 = \underline{0.1083}$$

$$\text{PhiTau} = \text{Tau} / (0.5 * f) = 5.12 / (0.5 * 104) = \underline{0.0985}$$

$$\text{PhiB} = \text{Sqr}((M_x / M_{x\text{max}})^2 + (M_y / M_{y\text{max}})^2) \text{ (16.5-11)} = \text{Sqr}((1.6 / 4.13)^2 + (2 / 9.17)^2) = \underline{0.4445}$$

$$\text{MaxAll} = \text{MAX}(\text{Abs}(\text{PhiP} / C_4 + \text{PhiZ}), \text{Abs}(\text{PhiZ}), \text{Abs}(\text{PhiP} / C_4 - 0.2 * \text{PhiZ})) \text{ (16.5-15)} = \text{MAX}(\text{Abs}(0.3874 / 1.1 + 0.1083), \text{Abs}(0.1083), \text{Abs}(0.3874 / 1.1 - 0.2 * 0.1083)) = \underline{0.4605}$$

$$\text{PhiAll} = \text{Sqr}(\text{MaxAll}^2 + \text{PhiB}^2 + \text{PhiTau}^2) \text{ (16.5-15)} = \text{Sqr}(0.4605^2 + 0.4445^2 + 0.0985^2) = \underline{0.6476}$$

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT NOZZLE OD PhiP=0.3874 <= 1.0=1(16.5-12)« » (U= 38.7%) OK«

»PhiZ AT NOZZLE OD PhiZ=0.1083 <= 1.0=1(16.5-13)« » (U= 10.8%) OK«

»PhiB AT NOZZLE OD PhiB=0.4445 <= 1.0=1(16.5-14)« » (U= 44.4%) OK«

»PhiTau AT NOZZLE OD PhiTau=0.0985 <= 1.0=1« » (U= 9.8%) OK«

»PhiAll AT NOZZLE OD PhiAll=0.6476 <= 1.0=1(16.5-15)« » (U= 64.7%) OK«

STRESSES AT OUTER EDGE OF PAD

Diameter at Edge of Reinforcement Pad

$$d = \text{deb} + 2 * I_p = 168.27 + 2 * 65.85 = 299.97 \text{ mm}$$

Combined Analysis Thickness

$$\text{ec} = e_a = 6.5 = 6.50 \text{ mm}$$

$$\text{LamdaC} = d / \text{Sqr}(D * \text{ec}) = 299.97 / \text{Sqr}(617.5 * 6.5) = 4.73$$

$$\text{Ratio1} = \text{MAX}(e_b / \text{ec}, 0.5) = \text{MAX}(6.6 / 6.5, 0.5) = 1.02$$

$$\text{Ratio2} = D / \text{ec} = 617.5 / 6.5 = 95.00$$

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

$$C1 = 5.075 \quad C2 = 6.638 \quad C3 = 25.427$$

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

Permissible Pressure Pmax:

$$P_{\text{max}} \text{ (from nozzle calculation)} = P_{\text{max}} \text{ (16.5-2)} = 2.19 = \underline{2.19 \text{ MPa}}$$

Allowable Axial Load Fzmax:

$$F_{z\text{max}} = f * \text{ec}^2 * C1 \text{ (16.5-3)} = 104 * 6.5^2 * 5.08 = \underline{22.30 \text{ kN}}$$

Allowable Circumferential Moment Mxmax:

$$M_{x\text{max}} = f * \text{ec}^2 * d / 4 * C2 \text{ (16.5-5)} = 104 * 6.5^2 * 299.97 / 4 * 6.64 = \underline{2.19 \text{ kNm}}$$

Allowable Longitudinal Moment Mxmax:

$$M_{y\text{max}} = f * \text{ec}^2 * d / 4 * C3 \text{ (16.5-7)} = 104 * 6.5^2 * 299.97 / 4 * 25.43 = \underline{8.38 \text{ kNm}}$$

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SHEAR STRESS FORMULAE (PD5000 Section G.2.3.6.3)

Shear Stresses due to Longitudinal Shear Force, TauFl:

$$\text{TauFl} = 2 * F_l / (\text{PI} * \text{deb} * \text{ec}) \\ = 2 * 5 / (3.14 * 168.27 * 6.5) = \underline{2.91 \text{ N/mm}^2}$$

Shear Stresses due to Circumferential Force, TauFc:

$$\text{TauFc} = 2 * F_c / (\text{PI} * \text{deb} * \text{ec}) \\ = 2 * 5 / (3.14 * 168.27 * 6.5) = \underline{2.91 \text{ N/mm}^2}$$

Shear Stresses due to Torsional Moment, TauMt:

$$\text{TauMt} = 2 * M_t / (\text{PI} * \text{deb}^2 * \text{ec}) \\ = 2 * 2 / (3.14 * 168.27^2 * 6.5) = \underline{6.92 \text{ N/mm}^2}$$

Total Shear Stresses, Tau:

$$\text{Tau} = \text{Sqr}(\text{TauFc}^2 + \text{TauFl}^2) + \text{TauMt} \\ = \text{Sqr}(2.91^2 + 2.91^2) + 6.92 = \underline{\underline{11.03 \text{ N/mm}^2}}$$

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

$$\text{PhiP} = P / P_{\text{max}} \text{ (16.5-9)} = 0.85 / 2.19 = \underline{0.3874}$$

$$\text{PhiZ} = F_z / F_{z\text{max}} \text{ (16.5-10)} = 5 / 22.3 = \underline{0.2242}$$

$$\text{PhiTau} = \text{Tau} / (0.5 * f) = 11.03 / (0.5 * 104) = \underline{0.2122}$$

$$\text{PhiB} = \text{Sqr}((M_x / M_{x\text{max}})^2 + (M_y / M_{y\text{max}})^2) \text{ (16.5-11)} \\ = \text{Sqr}((1.6 / 2.19)^2 + (2 / 8.38)^2) = \underline{0.7695}$$

$$\text{MaxAll} = \text{MAX}(\text{Abs}(\text{PhiP}/C4 + \text{PhiZ}), \text{Abs}(\text{PhiZ}), \text{Abs}(\text{PhiP}/C4 - 0.2 * \text{PhiZ}) \text{ (16.5-15)} \\ = \text{MAX}(\text{Abs}(0.3874 / 1.1 + 0.2242), \text{Abs}(0.2242), \text{Abs}(0.3874 / 1.1 - 0.2 * 0.2242)) = \underline{0.5764}$$

$$\text{PhiAll} = \text{Sqr}(\text{MaxAll}^2 + \text{PhiB}^2 + \text{PhiTau}^2) \text{ (16.5-15)} \\ = \text{Sqr}(0.5764^2 + 0.7695^2 + 0.2122^2) = \underline{\underline{0.9846}}$$

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT EDGE OF PAD PhiP=0.3874 <= 1.0=1(16.5-12)« » (U= 38.7%) OK«

»PhiZ AT EDGE OF PAD PhiZ=0.2242 <= 1.0=1(16.5-13)« » (U= 22.4%) OK«

»PhiB AT EDGE OF PAD PhiB=0.7695 <= 1.0=1(16.5-14)« » (U= 76.9%) OK«

»PhiTau AT EDGE OF PAD PhiTau=0.2122 <= 1.0=1« » (U= 21.2%) OK«

»PhiAll AT EDGE OF PAD PhiAll=0.9846 <= 1.0=1(16.5-15)« » (U= 98.4%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

16.5.7.1 LOAD RANGES

$$\text{DeltaP} = \text{Max}(P_{\text{max}}, 0) - \text{Min}(P_{\text{min}}, 0) \text{ (16.5-16)} \\ = \text{Max}(0.85, 0) - \text{Min}(0, 0) = \underline{0.8500 \text{ MPa}}$$

$$\text{DeltaFz} = \text{Max}(F_{z\text{max}}, 0) - \text{Min}(F_{z\text{min}}, 0) \text{ (16.5-17)} \\ = \text{Max}(5, 0) - \text{Min}(0, 0) = \underline{5.00 \text{ kN}}$$

$$\text{DeltaMx} = \text{Max}(M_{x\text{max}}, 0) - \text{Min}(M_{x\text{min}}, 0) \text{ (16.5-18)} \\ = \text{Max}(1.6, 0) - \text{Min}(0, 0) = \underline{1.60 \text{ kNm}}$$

$$\text{DeltaMy} = \text{Max}(M_{y\text{max}}, 0) - \text{Min}(M_{y\text{min}}, 0) \text{ (16.5-19)} \\ = \text{Max}(2, 0) - \text{Min}(0, 0) = \underline{2.00 \text{ kNm}}$$

$$\text{DeltaFl} = \text{Max}(F_{l\text{max}}, 0) - \text{Min}(F_{l\text{min}}, 0) \\ = \text{Max}(5, 0) - \text{Min}(0, 0) = \underline{5.00 \text{ kN}}$$

$$\text{DeltaFc} = \text{Max}(F_{c\text{max}}, 0) - \text{Min}(F_{c\text{min}}, 0) \\ = \text{Max}(5, 0) - \text{Min}(0, 0) = \underline{5.00 \text{ kN}}$$

$$\text{DeltaFshear} = \text{Sqr}(\text{DeltaFl}^2 + \text{DeltaFc}^2) \\ = \text{Sqr}(5^2 + 5^2) = \underline{7.07 \text{ kN}}$$

$$\text{DeltaMt} = \text{Max}(M_{t\text{max}}, 0) - \text{Min}(M_{t\text{min}}, 0) \\ = \text{Max}(2, 0) - \text{Min}(0, 0) = \underline{2.00 \text{ kNm}}$$

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16.5.7.2 EQUIVALENT SHELL THICKNESS

$$\begin{aligned} eeq &= ea + \text{Min}(eap * Ip / \text{Sqr}(D * (ea + eap)), eap) * \text{Min}(fp / fl) && (16.5-20) \\ &= 6.5 + \text{Min}(7.5 * 65.85 / \text{Sqr}(617.5 * (6.5 + 7.5)), 7.5) * \text{Min}(104 / 104, 1) = && \underline{11.81 \text{ mm}} \end{aligned}$$

16.5.7.3 STRESSES

VALUES FOR C1, C2 AND C3 FROM FIGURES 16.5-2 to 16.5-4

$$C1 = 5.075 \quad C2 = 6.638 \quad C3 = 25.427$$

$$\begin{aligned} \text{Tmp1} &= \text{Sqr}(d * eb / (D * eeq)) && \\ &= \text{Sqr}(161.67 * 6.6 / (617.5 * 11.81)) = && 0.3824 \end{aligned}$$

$$\begin{aligned} \text{Tmp2} &= (2 + 2 * d / D * \text{Tmp1} + 1.25 * d / D * \text{Sqr}(D / eeq)) / (1 + eb / eeq * \text{Tmp1}) \\ &= (2 + 2 * 161.67 / 617.5 * 0.3824 + 1.25 * 161.67 / 617.5 * \text{Sqr}(617.5 / 11.81)) / (1 + 6.6 / 11.81 * 0.3824) = && 3.76 \end{aligned}$$

Stresses due to Pressure Range

$$\begin{aligned} \text{SigP} &= \text{DeltaP} * D / (2 * eeq) * \text{Tmp2} && (16.5-21) \\ &= 0.85 * 617.5 / (2 * 11.81) * 3.76 = && \underline{83.60 \text{ N/mm}^2} \end{aligned}$$

Stresses due to Axial Load Range

$$\begin{aligned} \text{SigFz} &= 2.25 / C1 * (\text{DeltaFz} / eeq^2) && (16.5-22) \\ &= 2.25 / 5.08 * (5 / 11.81^2) = && \underline{15.89 \text{ N/mm}^2} \end{aligned}$$

Stresses due to Circumferential Moment Range

$$\begin{aligned} \text{SigMx} &= 2.25 / C2 * (4 * \text{DeltaMx} / (eeq^2 * d)) && (16.5-23) \\ &= 2.25 / 6.64 * (4 * 1.6 / (11.81^2 * 161.67)) = && \underline{96.18 \text{ N/mm}^2} \end{aligned}$$

Stresses due to Longitudinal Moment Range

$$\begin{aligned} \text{SigMy} &= 2.25 / C3 * (4 * \text{DeltaMy} / (eeq^2 * d)) && (16.5-24) \\ &= 2.25 / 25.43 * (4 * 2 / (11.81^2 * 161.67)) = && \underline{31.39 \text{ N/mm}^2} \end{aligned}$$

Shear Stresses due to Longitudinal Shear Force, DeltaFl:

$$\begin{aligned} \text{TauFl} &= 2 * \text{DeltaFl} / (\text{PI} * deb * eeq) \\ &= 2 * 5 / (3.14 * 168.27 * 11.81) = && \underline{1.60 \text{ N/mm}^2} \end{aligned}$$

Shear Stresses due to Circumferential Force, TauFc:

$$\begin{aligned} \text{TauFc} &= 2 * \text{DeltaFc} / (\text{PI} * deb * eeq) \\ &= 2 * 5 / (3.14 * 168.27 * 11.81) = && \underline{1.60 \text{ N/mm}^2} \end{aligned}$$

Shear Stresses due to Torsional Moment, TauMt:

$$\begin{aligned} \text{TauMt} &= 2 * \text{DeltaMt} / (\text{PI} * deb^2 * eeq) \\ &= 2 * 2 / (3.14 * 168.27^2 * 11.81) = && \underline{3.81 \text{ N/mm}^2} \end{aligned}$$

Total Shear Stresses, Tau:

$$\begin{aligned} \text{Tau} &= \text{Sqr}(\text{TauFc}^2 + \text{TauFl}^2) + \text{TauMt} \\ &= \text{Sqr}(1.6^2 + 1.6^2) + 3.81 = && \underline{\underline{6.07 \text{ N/mm}^2}} \end{aligned}$$

Total Stress Intensity due to Load Range

$$\begin{aligned} \text{SigTot} &= \text{Abs}(\text{SigT} + \text{Sqr}((\text{SigP} + \text{SigFz})^2 + \text{SigMx}^2 + \text{SigMy}^2 + 4 * \text{Tau}^2)) && (16.5-25) \\ &= \text{Abs}(0 + \text{Sqr}((83.6 + 15.89)^2 + 96.18^2 + 31.39^2 + 4 * 6.07^2)) = && \underline{\underline{142.41 \text{ N/mm}^2}} \end{aligned}$$

»Total Stress in Shell SigTot=142.41 <= 3*f=312[N/mm2] << » (U= 45.6%) OK«

16.5.8 NOZZLE LONGITUDINAL STRESSES

Maximum Longitudinal Stresses in Nozzle

$$\begin{aligned} \text{SigLong} &= P * d / (4 * eb) + 4 * MB / (\text{PI} * d^2 * eb) + Fz / (\text{PI} * d * eb) && (16.5-26) \\ &= 0.85 * 161.67 / (4 * 6.6) + 4 * 2.56 / (3.14 * 161.67^2 * 6.6) + 5000 / (3.14 * 161.67 * 6.6) \\ &= && \underline{\underline{25.61 \text{ N/mm}^2}} \end{aligned}$$

»Nozzle Long.Stress SigLong=25.61 <= fb=81.47[N/mm2] << » (U= 31.4%) OK«

16.14.6 COMPRESSIVE STRESS LIMITS

$$K = 1.21 * E * ea / (\text{Sige} * D) \quad (16.14-15)$$

$$= 1.21 * 1.851 \text{E}05 * 6.6 / (122.2 * 161.67) = 74.81 \quad (16.14-16)$$

$$\text{alfa} = 0.83 / \text{Sqr}(1 + 0.005 * D / ea) = 0.7834 \quad (16.14-19)$$

$$\text{delta} = (1 - 0.4123 / (\text{alfa} * K)^{0.6}) / S = 0.6428$$

$$= (1 - 0.4123 / (0.7834 * 74.81)^{0.6}) / 1.5 = 0.6428$$

Maximum Allowable Compressive Stress

$$\text{Sigcall} = \text{Sige} * \text{delta} \quad (16.14-20) = 122.2 * 0.6428 = \underline{78.55 \text{ N/mm}^2}$$

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16.14.4 PERMISSIBLE INDIVIDUAL LOADS

Maximum Tensile Force Ftmax

$$F_{tmax} = \pi * D * e_a * f \quad (16.14-1) = 3.14 * 161.67 * 6.6 * 81.47 = \underline{273.05 \text{ kN}}$$

Maximum Compressive Force Fcmax

$$F_{cmax} = \pi * D * e_a * \sigma_{call} \quad (16.14-2) = 3.14 * 161.67 * 6.6 * 78.546 = \underline{263.25 \text{ kN}}$$

Maximum Bending Moment Mmax

$$M_{max} = \pi / 4 * D^2 * e_a * \sigma_{call} \quad (16.14-3) \\ = 3.14 / 4 * 161.67^2 * 6.6 * 78.546 = \underline{10.64 \text{ kNm}}$$

Longitudinal Stability Check (P=0)

$$LongStab = MB / M_{max} + Abs(F_{zmin}) / F_{cmax} \quad (16.5-27) \\ = 2.56 / 10.64 + Abs(0) / 263.25 = \underline{0.2407}$$

»Nozzle Long.Stability LongStab=0.2407 <= 1.0=1« » (U= 24%) OK«

CALCULATION SUMMARY

9.5.2.4.5 Nozzles oblique to the shell, with or without reinforcement pads.

Limit of Reinforcement Along Shell

$$I_{so} = \sqrt{(2 * r_{is} + e_{as}) * e_{as}} \\ = \sqrt{(2 * 305.5 + 6.5) * 6.5} = \underline{63.35 \text{ mm}}$$

Limit of Reinforcement Along Pad

$$I_p = \min(I_p, I_s) \quad (16.5-86) = \min(65.85, 63.35) = \underline{63.35 \text{ mm}}$$

Limit of Reinforcement Along Nozzle (outside shell)

$$I_{bo} = \min(\sqrt{(d_{eb} - e_b) * e_b}, h_o) \quad (16.5-75) \\ = \min(\sqrt{(168.27 - 6.6) * 6.6}, 200) = \underline{32.66 \text{ mm}}$$

Pressure Area Required pA(req.)

$$pA_{reqL} = P * (A_{psL} + A_{pb}) \quad (16.5-7) = 0.85 * (45057.94 + 3036.5) = \underline{40.88 \text{ kN}}$$

$$pA_{reqT} = P * (A_{psT} + A_{pb} + 0.5 * A_{pphi}) \quad (16.5-7) \\ = 0.85 * (23497.66 + 3036.5 + 0.5 * 4614.57) = \underline{24.52 \text{ kN}}$$

$$pA_{req} = \max(pA_{reqL}, pA_{reqT}) = \max(40.88, 24.52) = \underline{40.88 \text{ kN}}$$

Pressure Area Available pA(aval.)

$$pA_{aval} = (A_{fs} + A_{fw}) * (f_s - 0.5 * P) + A_{fp} * (f_{op} - 0.5 * P) + A_{fb} * (f_{ob} - 0.5 * P) \quad (16.5-7) \\ = (411.8 + 0) * (104 - 0.5 * 0.85) + 411.8 * (104 - 0.5 * 0.85) + 258.42 * (81.47 - 0.5 * 0.85) \\ = \underline{106.25 \text{ kN}}$$

»Nozzle Reinforcement pAAval=106.25 >= pAReq=40.88[kN] « » (U= 38.4%) OK«

Maximum Allowable Pressure Pmax

$$P_{max} = (A_{fs} + A_{fw}) * f_s + A_{fp} * f_{op} + A_{fb} * f_{ob} / ((A_{ps} + A_{pb} + 0.5 * A_{pphi}) + 0.5 * (A_{fs} + A_{fw} + A_{fb} + A_{fp})) * (10 \\ + 0) * 104 + 411.8 * 104 + 258.42 * 81.47 / ((45057.94 + 3036.5 + 0.5 * 0) + 0.5 * (411.8 + 0 + 258.4 \\ 2 + 411.8)) = \underline{2.19 \text{ MPa}}$$

»ANSI 300lb-Flange Rating(at 370C) P=0.85 <= PMax(flange)=3.69[MPa] «» (U= 23%) OK«

LOAD CASE NO: 1 - Load Case 1

STRESSES AT OUTER DIAMETER OF NOZZLE

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT NOZZLE OD PhiP=0.0456 <= 1.0 =1(16.5-12)« » (U= 4.5%) OK«

»PhiZ AT NOZZLE OD PhiZ=0.1083 <= 1.0 =1(16.5-13)« » (U= 10.8%) OK«

»PhiB AT NOZZLE OD PhiB=0.4445 <= 1.0 =1(16.5-14)« » (U= 44.4%) OK«

»PhiTau AT NOZZLE OD PhiTau=0.025 <= 1.0 =1« » (U= 2.5%) OK«

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»PhiAll AT NOZZLE OD PhiAll=0.4697 <= 1.0=1(16.5-15)« » (U= 46.9%) OK«

STRESSES AT OUTER EDGE OF PAD

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT EDGE OF PAD PhiP=0.0456 <= 1.0 =1(16.5-12)« » (U= 4.5%) OK«

»PhiZ AT EDGE OF PAD PhiZ=0.2242 <= 1.0=1(16.5-13)« » (U= 22.4%) OK«

»PhiB AT EDGE OF PAD PhiB=0.7695 <= 1.0=1(16.5-14)« » (U= 76.9%) OK«

»PhiTau AT EDGE OF PAD PhiTau=0.0539 <= 1.0=1« » (U= 5.3%) OK«

»PhiAll AT EDGE OF PAD PhiAll=0.8158 <= 1.0=1(16.5-15)« » (U= 81.5%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

»Total Stress in Shell SigTot=104.39 <= 3*f=312[N/mm2] « » (U= 33.4%) OK«

16.5.8 NOZZLE LONGITUDINAL STRESSES

»Nozzle Long.Stress SigLong=18.3 <= fb=81.47[N/mm2] « » (U= 22.4%) OK«

»Nozzle Long.Stability LongStab=0.2407 <= 1.0=1« » (U= 24%) OK«

LOAD CASE NO: 2 - Load Case 2

STRESSES AT OUTER DIAMETER OF NOZZLE

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT NOZZLE OD PhiP=0.3874 <= 1.0 =1(16.5-12)« » (U= 38.7%) OK«

»PhiZ AT NOZZLE OD PhiZ=0.1083 <= 1.0=1(16.5-13)« » (U= 10.8%) OK«

»PhiB AT NOZZLE OD PhiB=0.4445 <= 1.0=1(16.5-14)« » (U= 44.4%) OK«

»PhiTau AT NOZZLE OD PhiTau=0.0985 <= 1.0=1« » (U= 9.8%) OK«

»PhiAll AT NOZZLE OD PhiAll=0.6476 <= 1.0=1(16.5-15)« » (U= 64.7%) OK«

STRESSES AT OUTER EDGE OF PAD

16.5.6.4 Check of Individual Load Ratio Limits

»PhiP AT EDGE OF PAD PhiP=0.3874 <= 1.0 =1(16.5-12)« » (U= 38.7%) OK«

»PhiZ AT EDGE OF PAD PhiZ=0.2242 <= 1.0=1(16.5-13)« » (U= 22.4%) OK«

»PhiB AT EDGE OF PAD PhiB=0.7695 <= 1.0=1(16.5-14)« » (U= 76.9%) OK«

»PhiTau AT EDGE OF PAD PhiTau=0.2122 <= 1.0=1« » (U= 21.2%) OK«

»PhiAll AT EDGE OF PAD PhiAll=0.9846 <= 1.0=1(16.5-15)« » (U= 98.4%) OK«

16.5.7 STRESS RANGES AND THEIR COMBINATIONS

»Total Stress in Shell SigTot=142.41 <= 3*f=312[N/mm2] « » (U= 45.6%) OK«

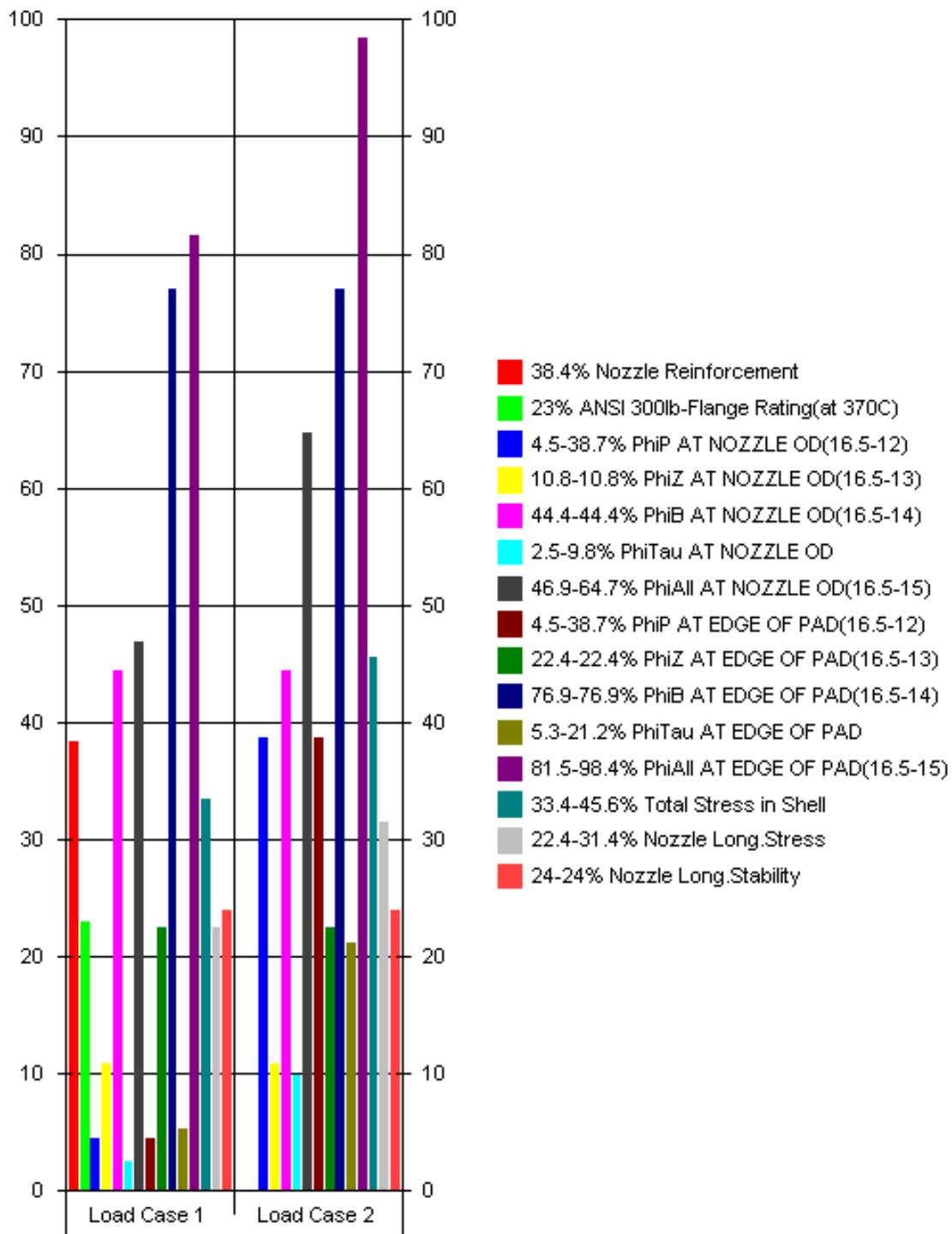
16.5.8 NOZZLE LONGITUDINAL STRESSES

»Nozzle Long.Stress SigLong=25.61 <= fb=81.47[N/mm2] « » (U= 31.4%) OK«

»Nozzle Long.Stability LongStab=0.2407 <= 1.0=1« » (U= 24%) OK«

Volume:0 m3 Weight:29.9 kg (SG= 7.85)

UTILIZATION CHART - N.T1 TUBE SIDE INLET



Max.Utilization/Condition 98.4% CASE:Load Case 2

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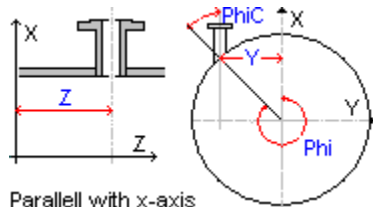
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INPUT DATA

COMPONENT ATTACHMENT/LOCATION

Attachment: S1.1 Cylindrical Shell Channel Shell



Parallel with x-axis

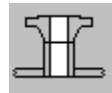
Orientation & Location of Nozzle: Vertical (Top/Bottom) to Component

Off-Center location in the y-direction (+/-).....:y 110.00 mm

z-location of nozzle along axis of attachment.....:z 225.00 mm

Nozzle located in section -90 and 90degr.==> k=1 ELSE k=-1:k -1.00

GENERAL DESIGN DATA



Type of Opening: Nozzle With Standard ANSI or DIN/EN Flange Attachment

PRESSURE LOADING: Design Component for Internal and External Pressure

PROCESS CARD: Tube Side : Temp= 370°C, P= .85MPa, c= 3mm, Pext= .1MPa

Include Nozzle Load Calculation: NO

SHELL DATA (S1.1)

Shell Type: Cylindrical Shell

OUTSIDE DIAMETER OF SHELL.....:De 624.00 mm

AS BUILT WALL THICKNESS (uncorroded).....:en 10.00 mm

NEGATIVE TOLERANCE/THINNING ALLOWANCE.....:th 0.5000 mm

EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 370'C

Rm=410 Rp=265 Rpt=156 fs=104 f20=170.83 ftest=252.38 E=185095(N/mm2) ro=7.85

NOZZLE MATERIAL DATA



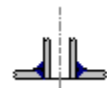
Delivery Form: Seamless Pipe

ASME SA-106 Gr.B, PMA, , THK<=999mm 370'C

Rm=415 Rp=240 Rpt=122.2 fb=81.47 f20=160 ftest=228.57 (N/mm2)

NOTE: A PARTICULAR MATERIAL APPRAISAL(PMA) MAY BE REQUIRED FOR THIS MATERIAL.

NOZZLE DIMENSIONAL DATA



Attachment: Set In Flush Nozzle

Shape of Nozzle/Opening: Circular

Application:

9.4.6.3 NOT a critical fatigue area, and calc.temp.is outside creep range.

OUTSIDE NOZZLE DIAMETER.....:deb 168.27 mm

AS BUILT NOZZLE THICKNESS (uncorroded).....:enb 10.97 mm

Size of Flange and Nozzle: 6"

Comment (Optional): Ex.Str.

NEGATIVE TOLERANCE/THINNING ALLOWANCE.....: 12.50 %

NOZZLE STANDOUT MEASURED FROM VESSEL OD.....:ho 200.00 mm

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FLANGE DATA

A: Flange Standard: ANSI B16.5 Flanges
E: Pressure Class: ANSI 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:
1.1 - Carbon Steel - A105, A515 70, A516 70, A350 LF2 (BS 1503 164 490, BS 1504 161 480)

WELDING DATA

Nozzle/Pad to Shell Welding Area: Exclude Area of Nozzle to Shell Weld
Nozzle Weld Intersect: Nozzle Does NOT Intersect with a Welded Shell Seam
ANGLE PhiC(OBLIQUE IN TRANSVERSE.CROSS SECT.)Fig.9.5-2:PhiC 21.00 Degr.
ANGLE PhiL(OBLIQUE IN LONG.CROSS SECT.)Fig.9.5-1.....:PhiL 0.00 Degr.

DATA FOR REINFORCEMENT PAD



Type of Pad: Single Pad
THICKNESS OF THE REINFORCEMENT PAD.....:eap 9.50 mm
WIDTH OF THE REINFORCEMENT PAD.....:Ip 65.85 mm
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 370'C
Rm=410 Rp=265 Rpt=156 fp=104 f20=170.83 ftest=252.38 E=185095(N/mm2) ro=7.85

LIMITS OF REINFORCEMENT

Reduction of Limits of Reinforcement: No Reduction Required

CALCULATION DATA

FLANGE RATING

ANSI 300lb-Flange Rating(at 370C)= 3.688 MPa, Max.Test Pressure = 7.756 MPa

PRELIMINARY CALCULATIONS

Shell Analysis Thickness eas
eas = en - c - th =10-3-0.5= 6.50 mm
Nozzle Analysis Thickness eab
eab = enb - c - NegDev =10.97-3-1.37= 6.60 mm
Reinf.Pad Analysis Thickness ep
ep = MIN(eap, eas) (9.5-20) =MIN(9.5,6.5)= 6.50 mm
Inside Radius of Curvature
ris = De / 2 - eas (9.5-3) =624/2-6.5= 305.50 mm
dib = deb - 2 * eab =168.27-2*6.6= 155.07 mm
Min.Nozzle Thk.Based on Internal Pressure ebp
ebp = P * deb / (2 * fb * z + P)
=0.85*168.27/(2*81.47*1+0.85)= 0.8700 mm
Allowable Stresses
fob = Min(fs, fb) (9.5-8) =Min(104,81.47)= 81.47 N/mm2
fop = Min(fs, fp) (9.5-9) =Min(104,104)= 104.00 N/mm2

GEOMETRIC LIMITATIONS

»Check Max.Thk.of Pad eap=9.5 <= 1.5*eas=9.75[mm] « » OK«
»Check Max.Diameter of Nozzle dib/(2*ris)=0.2538 <= .5[mm] «» OK«
»Min.Nozzle Thk. ebp=0.87 <= eab=6.6[mm] « » (U= 13.1%) OK«

9.5.2.4.5 Nozzles oblique to the shell, with or without reinforcement pads.

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Calculation of Stress Loaded Areas Effective as Reinforcement

Area of Shell Afs

Limit of Reinforcement Along Shell

$$Iso = \text{Sqr}((2 * ris + eas) * eas)$$

$$= \text{Sqr}((2 * 305.5 + 6.5) * 6.5) =$$

63.35 mm

Set In Nozzle

$$Afs = eas * Iso (9.5-78) = 6.5 * 63.35 =$$

411.80 mm²

Area of Reinforcement Pad Afp

Limit of Reinforcement Along Pad

$$Ip = \text{Min}(Ip, Iso) (9.5-86) = \text{Min}(65.85, 63.35) =$$

63.35 mm

$$ep = \text{Min}(ep, eas) (9.5-87) = \text{Min}(6.5, 6.5) =$$

6.50 mm

$$Afp = ep * Ip (9.5-85) = 6.5 * 63.35 =$$

411.80 mm²

Area of Nozzle Afb

Limit of Reinforcement Along Nozzle (outside shell)

$$Ibo = \text{MIN}(\text{Sqr}((deb - eb) * eb), ho)$$

(9.5-75)

$$= \text{MIN}(\text{Sqr}((168.27 - 6.6) * 6.6), 200) =$$

32.66 mm

Set In Nozzle

$$Afb = eb * (Ibo + Ibi + eas) (9.5-77) = 6.6 * (32.66 + 0 + 6.5) =$$

258.42 mm²

Calculation of Pressure Loaded Areas

In the Nozzle Apb

$$Apb = 0.5 * dib * (Ibo + eas) (9.5-77) = 0.5 * 155.07 * (32.66 + 6.5) =$$

3036.50 mm²

Additional Area due to Obliquity of Nozzle Aphi

$$Aphi = 0.5 * dib^2 * \text{Tan}(\phi)$$

(9.5-111)

$$= 0.5 * 155.07^2 * \text{Tan}(0.3665) =$$

4614.57 mm²

Cyl. Shell in the Longitudinal Section Aps

$$ApsL = ris * (Iso + a) (9.5-112) = 305.5 * (63.35 + 84.14) =$$

45057.94 mm²

Cyl. Shell in the Transverse Cross Section Aps

$$ApsT = 0.5 * ris^2 * (Iso + a) / (0.5 * eas + ris)$$

(9.5-114)

$$= 0.5 * 305.5^2 * (63.35 + 92.11) / (0.5 * 6.5 + 305.5) =$$

23497.66 mm²

$$Aps = \text{MAX}(ApsL, ApsT) = \text{MAX}(45057.94, 23497.66) =$$

45057.94 mm²

9.5.2 Reinforcement Rules

Pressure Area Required pA(req.)

$$pAReqL = P * (ApsL + Apb) (9.5-7) = 0.85 * (45057.94 + 3036.5) =$$

40.88 kN

$$pAReqT = P * (ApsT + Apb + 0.5 * Aphi)$$

(9.5-7)

$$= 0.85 * (23497.66 + 3036.5 + 0.5 * 4614.57) =$$

24.52 kN

$$pAReq = \text{MAX}(pAReqL, pAReqT) = \text{MAX}(40.88, 24.52) =$$

40.88 kN

Pressure Area Available pA(aval.)

$$pAAval = (Afs + Afw) * (fs - 0.5 * P) + Afp * (fop - 0.5 * P) + Afb * (fob - 0.5 * P)$$

(9.5-7)

$$= (411.8 + 0) * (104 - 0.5 * 0.85) + 411.8 * (104 - 0.5 * 0.85) + 258.42 * (81.47 - 0.5 * 0.85)$$

$$= 106.25 \text{ kN}$$

»Nozzle Reinforcement pAAval=106.25 >= pAReq=40.88[kN] « » (U= 38.4%) OK«

Maximum Allowable Pressure Pmax

$$Pmax = (Afs + Afw) * fs + Afp * fop + Afb * fob / ((Aps + Apb + 0.5 * Aphi) + 0.5 * (Afs + Afw + Afb + Afp)) (10)$$

$$= (0 + 0) * 104 + 411.8 * 104 + 258.42 * 81.47 / ((45057.94 + 3036.5 + 0.5 * 0) + 0.5 * (411.8 + 0 + 258.4$$

$$2 + 411.8)) =$$

2.19 MPa

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N.T2 Tube side outlet 05 Feb. 2010 12:10 ConnID:S1.1 PC# 2

Max.Allowable Test Pressure P_{tmax}

$$P_{tmax} = \underline{\underline{7.00 \text{ MPa}}}$$

»ANSI 300lb-Flange Rating(at 370C) P=0.85 <= P_{Max}(flange)=3.69[MPa] «» (U= 23%) OK«

CALCULATION SUMMARY

9.5.2.4.5 Nozzles oblique to the shell, with or without reinforcement pads.

Limit of Reinforcement Along Shell

$$I_{so} = \text{Sqr}((2 * r_{is} + e_{as}) * e_{as})$$

$$= \text{Sqr}((2 * 305.5 + 6.5) * 6.5) =$$

63.35 mm

Limit of Reinforcement Along Pad

$$I_p = \text{Min}(I_p, I_s) \text{ (9.5-86)} = \text{Min}(65.85, 63.35) =$$

63.35 mm

Limit of Reinforcement Along Nozzle (outside shell)

$$I_{bo} = \text{MIN}(\text{Sqr}((d_{eb} - e_b) * e_b), h_o) \text{ (9.5-75)}$$

$$= \text{MIN}(\text{Sqr}((168.27 - 6.6) * 6.6), 200) =$$

32.66 mm

Pressure Area Required p_A(req.)

$$p_{AReqL} = P * (A_{psL} + A_{pb}) \text{ (9.5-7)} = 0.85 * (45057.94 + 3036.5) = \underline{\underline{40.88 \text{ kN}}}$$

$$p_{AReqT} = P * (A_{psT} + A_{pb} + 0.5 * A_{pphi}) \text{ (9.5-7)}$$

$$= 0.85 * (23497.66 + 3036.5 + 0.5 * 4614.57) = \underline{\underline{24.52 \text{ kN}}}$$

$$p_{AReq} = \text{MAX}(p_{AReqL}, p_{AReqT}) = \text{MAX}(40.88, 24.52) = \underline{\underline{40.88 \text{ kN}}}$$

Pressure Area Available p_A(aval.)

$$p_{AAval} = (A_{fs} + A_{fw}) * (f_s - 0.5 * P) + A_{fp} * (f_{op} - 0.5 * P) + A_{fb} * (f_{ob} - 0.5 * P) \text{ (9.5-7)}$$

$$= (411.8 + 0) * (104 - 0.5 * 0.85) + 411.8 * (104 - 0.5 * 0.85) + 258.42 * (81.47 - 0.5 * 0.85)$$

$$= \underline{\underline{106.25 \text{ kN}}}$$

»Nozzle Reinforcement p_{AAval}=106.25 >= p_{AReq}=40.88[kN] « » (U= 38.4%) OK«

Maximum Allowable Pressure P_{max}

$$P_{max} = (A_{fs} + A_{fw}) * f_s + A_{fp} * f_{op} + A_{fb} * f_{ob} / ((A_{ps} + A_{pb} + 0.5 * A_{pphi}) + 0.5 * (A_{fs} + A_{fw} + A_{fb} + A_{fp})) \text{ (10)}$$

$$= (0 + 0) * 104 + 411.8 * 104 + 258.42 * 81.47 / ((45057.94 + 3036.5 + 0.5 * 0) + 0.5 * (411.8 + 0 + 258.42 + 411.8)) =$$

2.19 MPa

»ANSI 300lb-Flange Rating(at 370C) P=0.85 <= P_{Max}(flange)=3.69[MPa] «» (U= 23%) OK«

Volume:0 m³ Weight:29.9 kg (SG= 7.85)

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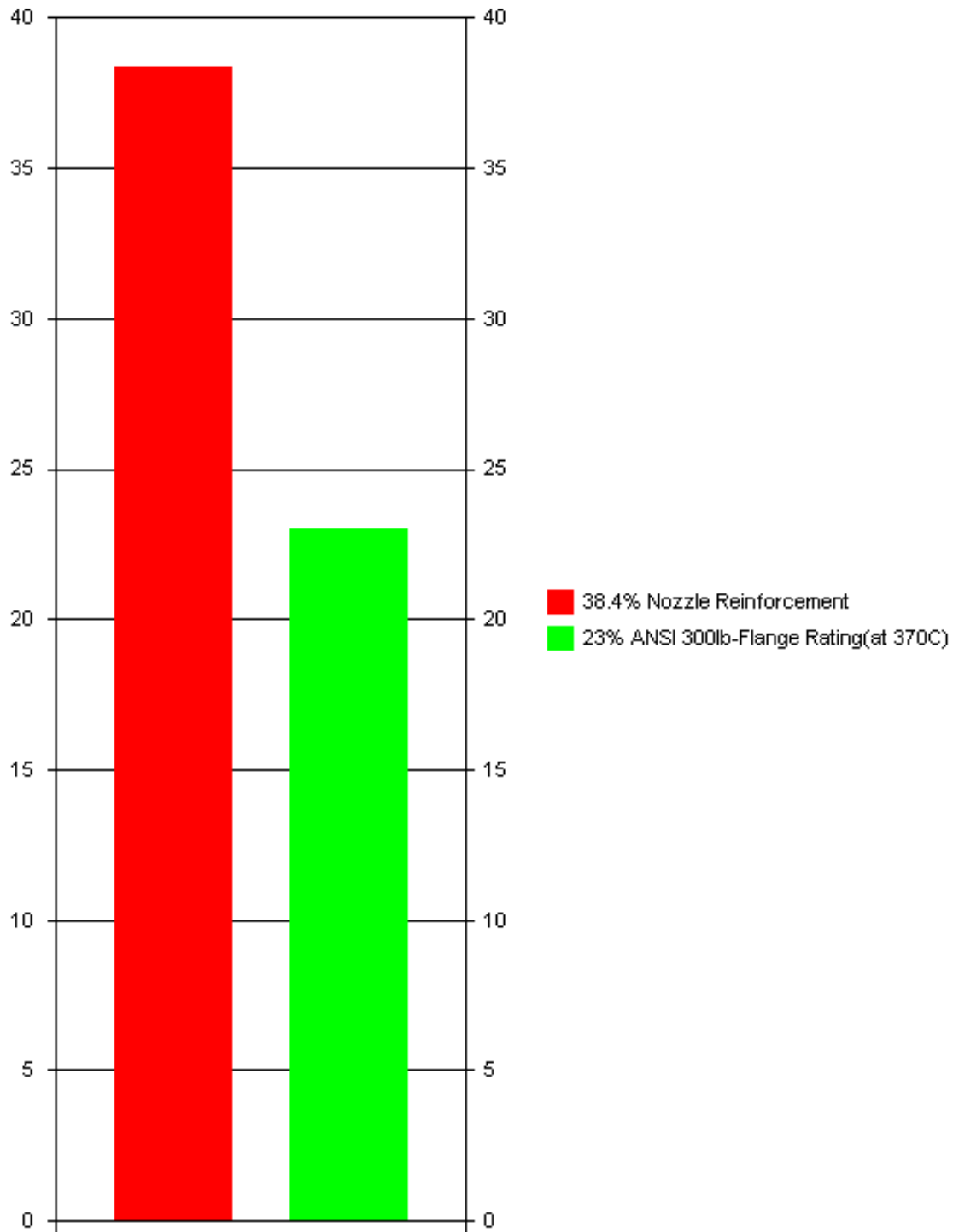
Sample File Steam Generator

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UTILIZATION CHART - N.T2 TUBE SIDE OUTLET



Max.Utilization/Condition 38.4%

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EN13445:2009 Issue 1 - 11.5 NARROW FACE GASKETED FLANGES

F.1 Channel flange 05 Feb. 2010 12:10 ConnID:S1.1 PC# 2

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

Attachment: S1.1 Cylindrical Shell Channel Shell

Location: Along z-axis z1= 450

Flange Design Method: Section 11 - Taylor Forge

GENERAL DESIGN DATA

PROCESS CARD: Tube Side : Temp= 370°C, P= .85MPa, c= 3mm

B: Pressure loading: Flange under internal pressure

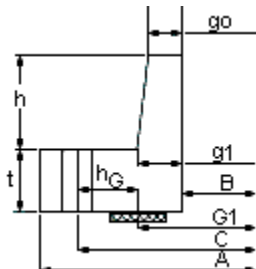
BOLT LOAD FROM 2nd. FLANGE - (Oper.Cond.).....:Wm1' 0.00 kN

BOLT LOAD FROM 2nd. FLANGE - (Bolting Up.Cond.).....:Wm2' 0.00 kN

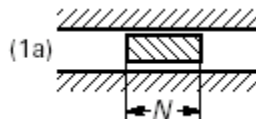
EXTERNAL LOADS ON FLANGE (PD5500 ENQ 5500/123): NO

TYPE OF FLANGE AND GASKET FACING

A: Flange Standard: User Specified Flanges



C: Flange Type: WN Welding Neck(Smooth bore)



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

SHELL/NOZZLE DATA

SHELL/NOZZLE SIZE & COMMENT: S1.1

EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 370'C

Rm=410 Rp=265 Rpt=156 fs=104 fs20=170.83 ftest=252.38 E=185095(N/mm²) ro=7.85

OUTSIDE DIAMETER OF SHELL/NOZZLE:Do 624.00 mm

WALL THICKNESS OF NOZZLE/SHELL(uncorroded).....:s1 10.00 mm

FLANGE DATA

REVERSE FLANGE: No (The bolts are located on the outside)

DESIGN METHOD: A) INTEGRAL FLANGE METHOD

OUTSIDE DIAMETER OF FLANGE.....:A 760.00 mm

THICKNESS OF FLANGE(uncorroded).....:e 45.00 mm

CORROSION ALLOWANCE FOR FLANGE FACE.....:cf 5.00 mm

ASME SA-105, PMA, , THK<=250mm 370'C

Rm=485 Rp=250 Rpt=124.4 SFO=82.93 SFA=166.67 ftest=238.1 (N/mm²)

NOTE: A PARTICULAR MATERIAL APPRAISAL(PMA) MAY BE REQUIRED FOR THIS MATERIAL.

DATA FOR FLANGE HUB

LENGTH OF HUB.....:h 40.00 mm

THICKNESS OF HUB AT BACK OF FLANGE corroded.....:g1 17.00 mm

THICKNESS OF HUB AT SMALL END corroded.....:go 7.00 mm

ASME SA-105, PMA, , THK<=250mm 370'C

Rm=485 Rp=250 Rpt=124.4 SHO=82.93 SHA=166.67 ftest=238.1 (N/mm²)

NOTE: A PARTICULAR MATERIAL APPRAISAL(PMA) MAY BE REQUIRED FOR THIS MATERIAL.

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EN13445:2009 Issue 1 - 11.5 NARROW FACE GASKETED FLANGES

F.1 Channel flange 05 Feb. 2010 12:10 ConnID:S1.1 PC# 2

BOLTING DATA

BOLTING TORQUE CALCULATION: YES
 NOMINAL BOLTING SIZE & COMMENT: 7/8"(0.875)
 EFFECTIVE BOLT AREA per bolt.....:Ae 270.32 mm²
 RECOMMENDED MINIMUM BOLT CENTER TO EDGE CLEARANCE...:Bce 24.00 mm
 RECOMMENDED MINIMUM BOLT CENTER/RADIAL CLEARANCE....:Bcr 31.75 mm
 DIAMETER OF BOLT HOLES IN FLANGE.....:d 25.00 mm
 NUMBER OF BOLTS.....:n 28.00
 BOLT-CIRCLE DIAMETER.....:C 710.00 mm
 ASME SA-193 Gr.B7, PMA, , THK<=64mm 370'C
 Rm=860 Rp=507 Rpt=388 Sb=129.33 Sa=169 fttest=253.5 (N/mm²)
 NOTE: A PARTICULAR MATERIAL APPRAISAL(PMA) MAY BE REQUIRED FOR THIS MATERIAL.
 BOLTING-UP METHOD: Torque Wrench(Torque measurements) eps= 0.1+0.5* μ
 FRICTION COEFFICIENT: Normal/Average Conditions μ=0.20

GASKET DATA

Table H-1 Gasket factors m & y Facing: User Specified Gasket Factors
 GASKET FACTOR.....:m 3.00
 GASKET OR JOINT-CONTACT-SURFACE UNIT SEATING LOAD...:y 69.00 N/mm²
 GASKET TYPE (remark) (Optional): CAMPROFILE
 OUTSIDE DIAMETER OF GASKET/RAISED FACE.....:Go 670.00 mm
 GREATER VALUE OF INSIDE DIAMETER OF GASKET/FLANGE FACE:A1 644.00 mm
 TEMA RGP-RCB-11.7 Include Additional Loads from Pass Partition Plate Gasket: YES
 PASS PARTION GASKET FACTOR.....:mp 3.00
 PASS PARTION GASKET SEATING STRESS.....:yp 69.00 N/mm²
 LENGTH OF PASS PARTION GASKET.....:lp 604.00 mm
 EFFECTIVE PASS PARTION GASKET WIDTH.....:bp 5.00 mm

CALCULATION DATA

Large Diameter Stress Correction Factor K
 k (D < 1000 mm) = 1 =1= 1.00

GASKET DETAILS

b = MIN VALUE(2.52 * Sqr(bo), bo) = == 6.42 mm

FLANGE LOADS

H = 0.785 * G ^ 2 * p (11.5-5) =0.785*657.15²*0.85= 288.15 kN
 HG = (2 * PI * b * G * m + 2 * lp * bp * mp) * p (11.5-6)
 =(2*3.14*6.42*657.15*3+2*604*5*3)*0.85= 83.00 kN
 HD = 0.785 * B ^ 2 * p =0.785*610²*0.85= 248.28 kN
 HT = H - HD (11.5-11) =288.15-248.28= 39.87 kN

MOMENT ARMS

hG = (C - G) / 2 (11.5-14) =(710-657.15)/2= 26.42 mm
 hD = (C - B - g1) / 2 (11.5-12) =(710-610-17)/2= 41.50 mm
 hT = (2 * C - B - G) / 4 (11.5-15) =(2*710-610-657.15)/4= 38.21 mm

BOLT LOADS

Operating condition
 Wop = H + HG (11.5-8) =288.15+83.= 371.15 kN
 Bolting up condition
 Wamb = PI * b * G * y + lp * bp * yp (11.5-7)
 =3.14*6.42*657.15*69+604*5*69= 1122.91 kN

BOLTING AREA

Aml = Wop / Sb =3.7115E05/129.33= 2869.77 mm²
 Am2 = Wamb / Sa =1.1229E06/169= 6644.45 mm²
 Required Bolting Area Am
 Am (Largest value of Aml and Am2)= Am =6644.45= 6644.45 mm²
 Available Bolting Area Ab
 Ab (num.bolts*root area) = n * Ae =28*270.32= 7568.96 mm²

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F.1 Channel flange 05 Feb. 2010 12:10 ConnID:S1.1 PC# 2

»Bolting Area Check $Ab=7568.96 \geq Am=6644.45[\text{mm}^2]$ « » (U= 87.7%) OK«

$$W = 0.5 * (Ab + Am) * Sa \text{ (11.5-16)} = 0.5 * (7568.96 + 6644.45) * 169 = 1201.03 \text{ kN}$$

FLANGE MOMENTS

$$\begin{aligned} Mop &= HD * hD + HT * hT + HG * hG && (11.5-18) \\ &= 248.28 * 41.5 + 39.87 * 38.21 + 83. * 26.42 = && 14020.35 \text{ Nm} \end{aligned}$$

$$Mamb = W * hG \text{ (11.5-17)} = 1201.03 * 26.42 = 31737.03 \text{ Nm}$$

$$\begin{aligned} \text{Bolt Spacing} \\ Bspc &= C * PI / n = 710 * 3.14 / 28 = && 79.66 \text{ mm} \end{aligned}$$

$$\begin{aligned} \text{Bolt Pitch Correction Factor} \\ CF &= \text{MAX}(\text{Sqr}(Bspc / (2 * db + 6 * e / (m + 0.5))) , 1) && (11.5-20) \\ &= \text{MAX}(\text{Sqr}(79.66 / (2 * 22.225 + 6 * 40 / (3 + 0.5))) , 1) = && 1.00 \end{aligned}$$

$$Mo = Mop * CF / B \text{ (11.5-27)} = 14020.35 * 1 / 610 = 22.98 \text{ Nm}$$

$$Ma = Mamb * CF / B \text{ (11.5-26)} = 31737.03 * 1 / 610 = 52.03 \text{ Nm}$$

SHAPE CONSTANTS

$$K = A / B \text{ (11.5-21)} = 760 / 610 = 1.25$$

$$lo = \text{SQR}(B * go) \text{ (11.5-22)} = \text{SQR}(610 * 7) = 65.35$$

$$h/lo = 0.612 \quad K=A/B = 1.246 \quad g1/go = 2.429$$

VALUES FROM FIGURES 11.5-4 to 8

$$\text{BetaT} = 1.820 \quad \text{BetaZ} = 4.621 \quad \text{BetaY} = 8.958 \quad \text{BetaU} = 9.844$$

$$\text{BetaF} = 0.789 \quad \text{BetaV} = 0.162 \quad \text{phi} = 1.369$$

$$\begin{aligned} \text{lamda} &= (e * \text{BetaF} + lo) / (\text{BetaT} * lo) + e^3 * \text{BetaV} / (\text{BetaU} * lo * go^2) \\ &= (40 * 0.789 + 65.35) / (1.82 * 65.35) + 40^3 * 0.1619 / (9.844 * 65.35 * 7^2) = && 1.14 \end{aligned}$$

OPERATING CONDITION

$$M = Mo = 22.98 = 22.98 \text{ Nm}$$

11.5.4.1 Flange Stresses with Flange Thickness $e = 40 \text{ mm}$

$$\begin{aligned} \text{Longitudinal Hub Stress} \\ \text{SigH} &= \text{phi} * M / (\text{lamda} * g1^2) && (11.5-29) \\ &= 1.37 * 22.98 / (1.14 * 17^2) = && 95.21 \text{ N/mm}^2 \end{aligned}$$

$$\begin{aligned} \text{Radial Flange Stress} \\ \text{SigR} &= (1.333 * e * \text{BetaF} + lo) * M / (\text{lamda} * e^2 * lo) && (11.5-30) \\ &= (1.333 * 40 * 0.789 + 65.35) * 22.98 / (1.14 * 40^2 * 65.35) = && 20.65 \text{ N/mm}^2 \end{aligned}$$

$$\begin{aligned} \text{Tangential Flange Stress} \\ \text{SigTeta} &= \text{BetaY} * M / e^2 - \text{SigR} * (K^2 + 1) / (K^2 - 1) && (11.5-31) \\ &= 8.958 * 22.98 / 40^2 - 20.65 * (1.25^2 + 1) / (1.25^2 - 1) = && 33.25 \text{ N/mm}^2 \end{aligned}$$

11.5.4.2 Stress Limits

»Hub Stress $k * \text{SigH} = 95.21 \leq 1.5 * \text{MIN}(f; fH) = 124.4[\text{N/mm}^2]$ (11.5-39)«» (U= 76.5%) OK«

»Radial Stress $k * \text{SigR} = 20.65 \leq f = 82.93[\text{N/mm}^2]$ (11.5-40)« » (U= 24.8%) OK«

»Tangential Stress $k * \text{SigTeta} = 33.25 \leq f = 82.93[\text{N/mm}^2]$ (11.5-41)«» (U= 40%) OK«

»Radial+Hub Stress $0.5 * k * (\text{SigH} + \text{SigR}) = 57.93 \leq f = 82.93[\text{N/mm}^2]$ (11.5-42)«» (U= 69.8%) OK«

»Tangential+Hub Stress $0.5 * k * (\text{SigH} + \text{SigTeta}) = 64.23 \leq f = 82.93[\text{N/mm}^2]$ (11.5-43)«» (U= 77.4%) OK«

BOLTING UP CONDITION

$$M = Ma = 52.03 = 52.03 \text{ Nm}$$

11.5.4.1 Flange Stresses with Flange Thickness $e = 40 \text{ mm}$

$$\begin{aligned} \text{Longitudinal Hub Stress} \\ \text{SigH} &= \text{phi} * M / (\text{lamda} * g1^2) && (11.5-29) \\ &= 1.37 * 52.03 / (1.14 * 17^2) = && 215.53 \text{ N/mm}^2 \end{aligned}$$

$$\begin{aligned} \text{Radial Flange Stress} \\ \text{SigR} &= (1.333 * e * \text{BetaF} + lo) * M / (\text{lamda} * e^2 * lo) && (11.5-30) \\ &= (1.333 * 40 * 0.789 + 65.35) * 52.03 / (1.14 * 40^2 * 65.35) = && 46.74 \text{ N/mm}^2 \end{aligned}$$

Tangential Flange Stress

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F.1 Channel flange 05 Feb. 2010 12:10 ConnID:S1.1 PC# 2

$$\text{SigTeta} = \text{BetaY} * \text{M} / \text{e}^2 - \text{SigR} * (\text{K}^2 + 1) / (\text{K}^2 - 1) \quad (11.5-31)$$

$$= 8.958 * 52.03 / 40^2 - 46.74 * (1.25^2 + 1) / (1.25^2 - 1) = 75.27 \text{ N/mm}^2$$

11.5.4.2 Stress Limits

»Hub Stress $k * \text{SigH} = 215.53 \leq 1.5 * \text{MIN}(f; f_H) = 250 [\text{N/mm}^2]$ (11.5-39) « (U= 86.2%) OK«
 »Radial Stress $k * \text{SigR} = 46.74 \leq f = 166.67 [\text{N/mm}^2]$ (11.5-40) « » (U= 28%) OK«
 »Tangential Stress $k * \text{SigTeta} = 75.27 \leq f = 166.67 [\text{N/mm}^2]$ (11.5-41) « (U= 45.1%) OK«
 »Radial+Hub Stress $0.5 * k * (\text{SigH} + \text{SigR}) = 131.13 \leq f = 166.67 [\text{N/mm}^2]$ (11.5-42) « (U= 78.6%) OK«
 »Tangential+Hub Stress $0.5 * k * (\text{SigH} + \text{SigTeta}) = 145.4 \leq f = 166.67 [\text{N/mm}^2]$ (11.5-43) « (U= 87.2%) OK«

BOLTING-UP TORQUE - EN13445 ANNEX G.8

$k_B = 1.2 * \mu * d_{B0}$ (G.8-5) = $1.2 * 0.2 * 22.225 = 5.33 \text{ mm}$
 $\text{epsn} = \text{eps} * (1 + 3 / \text{SQR}(n)) / 4$ (G.6-16) = $0.2 * (1 + 3 / \text{SQR}(28)) / 4 = 0.0783$
 Required Minimum Total Pre-Load (Max. of operating and bolting up cond.)
 Fb0nom (Max. of Wop and Wamb) = $\text{Fb0req} = 1122.91 = 1122.91 \text{ kN}$
 Nominal Total Pre-Load
 $\text{Fb0nom} = \text{Fb0req} / (1 - \text{epsn})$ (G.6-21) = $1122.91 / (1 - 0.0783) = 1218.37 \text{ kN}$
 Nominal Total Pre-Load per Bolt
 $\text{Fbnom} = \text{Fb0nom} / n = 1218.37 / 28 = 43.51 \text{ kN}$
 Bolt Stress (Assembly Cond.)
 $\text{SigBoltamb} = \text{Wamb} / ((1 - \text{epsn}) * n * \text{Ae})$
 $= 1.1229 \text{E}06 / ((1 - 0.0783) * 28 * 270.32) = 160.97 \text{ N/mm}^2$
 Bolt Stress (Operating Cond.)
 $\text{SigBoltamb} = \text{Wop} / ((1 - \text{epsn}) * n * \text{Ae})$
 $= 3.7115 \text{E}05 / ((1 - 0.0783) * 28 * 270.32) = 53.20 \text{ N/mm}^2$
 »Bolt Stress $\text{SigBolt} = 160.97 \leq \text{Sa} = 169 [\text{N/mm}^2]$ « (U= 95.2%) OK«
 Nominal Torque Per Bolt
 $\text{Mtnom} = k_B * \text{Fb0nom} / n = 5.334 * 1218.37 / 28 = 232.10 \text{ Nm}$

EN13445-5;10.2.3.3 REQUIRED MIN. HYDROSTATIC TEST PRESSURE: P_{tmin}

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3
 $\text{Ptmin} = 1.25 * \text{Pd} * f_{20} / f = 1.25 * 0.85 * 166.67 / 82.93 = 2.14 \text{ MPa}$
 $\text{Ptmin} = 1.43 * \text{Pd} = 1.43 * 0.85 = 1.22 \text{ MPa}$
 »Test Pressure $\text{Ptmin} = 2.14 \leq \text{Ptmax} = 3.154 [\text{MPa}]$ « (U= 67.7%) 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)	370	0.85	Bolt Stress	1122.91
Max.Allow.Pressure(corroded)	370	1.10	Tangential+Hub Stress	1122.91
Max.Allow.Pressure(corroded)	Ambient	2.21	Tangential+Hub Stress	1122.91
Max.Allow.Test Pressure(corroded)	Ambient	3.15	Tangential+Hub Stress	1377.09
Required Test Pressure	Ambient	2.13	Tangential+Hub Stress	1122.91

Table PRESSURE AND TORQUE SUMMARY FOR F.1 Continued

Description	Nom. Force per Bolt(kN)	Nom. Torque per Bolt(Nm)
Design Pressure(corroded)	43.51	232.1
Max.Allow.Pressure(corroded)	43.51	232.1
Max.Allow.Pressure(corroded)	43.51	232.1
Max.Allow.Test Pressure(corroded)	53.36	284.64
Required Test Pressure	43.51	232.1

The nominal Force and Torque values are based on the following bolting up method:
 Torque Wrench (Torque measurements) $\text{eps} = 0.1 + 0.5 * \mu$

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F.1 Channel flange 05 Feb. 2010 12:10 ConnID:S1.1 PC# 2

CALCULATION SUMMARY

BOLTING AREA

»Bolting Area Check $A_b=7568.96 \geq A_m=6644.45[\text{mm}^2]$ « » (U= 87.7%) OK«

OPERATING CONDITION

11.5.4.1 Flange Stresses with Flange Thickness $e= 40 \text{ mm}$

Longitudinal Hub Stress
 $\text{SigH} = \phi * M / (\text{lamda} * g_1^2)$ (11.5-29)
 $= 1.37 * 22.98 / (1.14 * 17^2) =$ 95.21 N/mm²

Radial Flange Stress
 $\text{SigR} = (1.333 * e * \text{BetaF} + l_0) * M / (\text{lamda} * e^2 * l_0)$ (11.5-30)
 $= (1.333 * 40 * 0.7894 + 65.35) * 22.98 / (1.14 * 40^2 * 65.35) =$ 20.65 N/mm²

Tangential Flange Stress
 $\text{SigTeta} = \text{BetaY} * M / e^2 - \text{SigR} * (K^2 + 1) / (K^2 - 1)$ (11.5-31)
 $= 8.958 * 22.98 / 40^2 - 20.65 * (1.25^2 + 1) / (1.25^2 - 1) =$ 33.25 N/mm²

11.5.4.2 Stress Limits

»Hub Stress $k * \text{SigH} = 95.21 \leq 1.5 * \text{MIN}(f; f_H) = 124.4 [\text{N/mm}^2]$ (11.5-39)«» (U= 76.5%) OK«
»Radial Stress $k * \text{SigR} = 20.65 \leq f = 82.93 [\text{N/mm}^2]$ (11.5-40)« » (U= 24.8%) OK«
»Tangential Stress $k * \text{SigTeta} = 33.25 \leq f = 82.93 [\text{N/mm}^2]$ (11.5-41)«» (U= 40%) OK«
»Radial+Hub Stress $0.5 * k * (\text{SigH} + \text{SigR}) = 57.93 \leq f = 82.93 [\text{N/mm}^2]$ (11.5-42)«» (U= 69.8%) OK«
»Tangential+Hub Stress $0.5 * k * (\text{SigH} + \text{SigTeta}) = 64.23 \leq f = 82.93 [\text{N/mm}^2]$ (11.5-43)«» (U= 77.4%) OK«

BOLTING UP CONDITION

11.5.4.1 Flange Stresses with Flange Thickness $e= 40 \text{ mm}$

Longitudinal Hub Stress
 $\text{SigH} = \phi * M / (\text{lamda} * g_1^2)$ (11.5-29)
 $= 1.37 * 52.03 / (1.14 * 17^2) =$ 215.53 N/mm²

Radial Flange Stress
 $\text{SigR} = (1.333 * e * \text{BetaF} + l_0) * M / (\text{lamda} * e^2 * l_0)$ (11.5-30)
 $= (1.333 * 40 * 0.7894 + 65.35) * 52.03 / (1.14 * 40^2 * 65.35) =$ 46.74 N/mm²

Tangential Flange Stress
 $\text{SigTeta} = \text{BetaY} * M / e^2 - \text{SigR} * (K^2 + 1) / (K^2 - 1)$ (11.5-31)
 $= 8.958 * 52.03 / 40^2 - 46.74 * (1.25^2 + 1) / (1.25^2 - 1) =$ 75.27 N/mm²

11.5.4.2 Stress Limits

»Hub Stress $k * \text{SigH} = 215.53 \leq 1.5 * \text{MIN}(f; f_H) = 250 [\text{N/mm}^2]$ (11.5-39)«» (U= 86.2%) OK«
»Radial Stress $k * \text{SigR} = 46.74 \leq f = 166.67 [\text{N/mm}^2]$ (11.5-40)« » (U= 28%) OK«
»Tangential Stress $k * \text{SigTeta} = 75.27 \leq f = 166.67 [\text{N/mm}^2]$ (11.5-41)«» (U= 45.1%) OK«
»Radial+Hub Stress $0.5 * k * (\text{SigH} + \text{SigR}) = 131.13 \leq f = 166.67 [\text{N/mm}^2]$ (11.5-42)«» (U= 78.6%) OK«
»Tangential+Hub Stress $0.5 * k * (\text{SigH} + \text{SigTeta}) = 145.4 \leq f = 166.67 [\text{N/mm}^2]$ (11.5-43)«» (U= 87.2%) OK«
»Bolt Stress $\text{SigBolt} = 160.97 \leq S_a = 169 [\text{N/mm}^2]$ « » (U= 95.2%) OK«

EN13445-5;10.2.3.3 REQUIRED MIN. HYDROSTATIC TEST PRESSURE: P_{tmin}

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3
 $P_{tmin} = 1.25 * P_d * f_{20} / f = 1.25 * 0.85 * 166.67 / 82.93 =$ 2.14 MPa

$P_{tmin} = 1.43 * P_d = 1.43 * 0.85 =$ 1.22 MPa

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Sample File Steam Generator

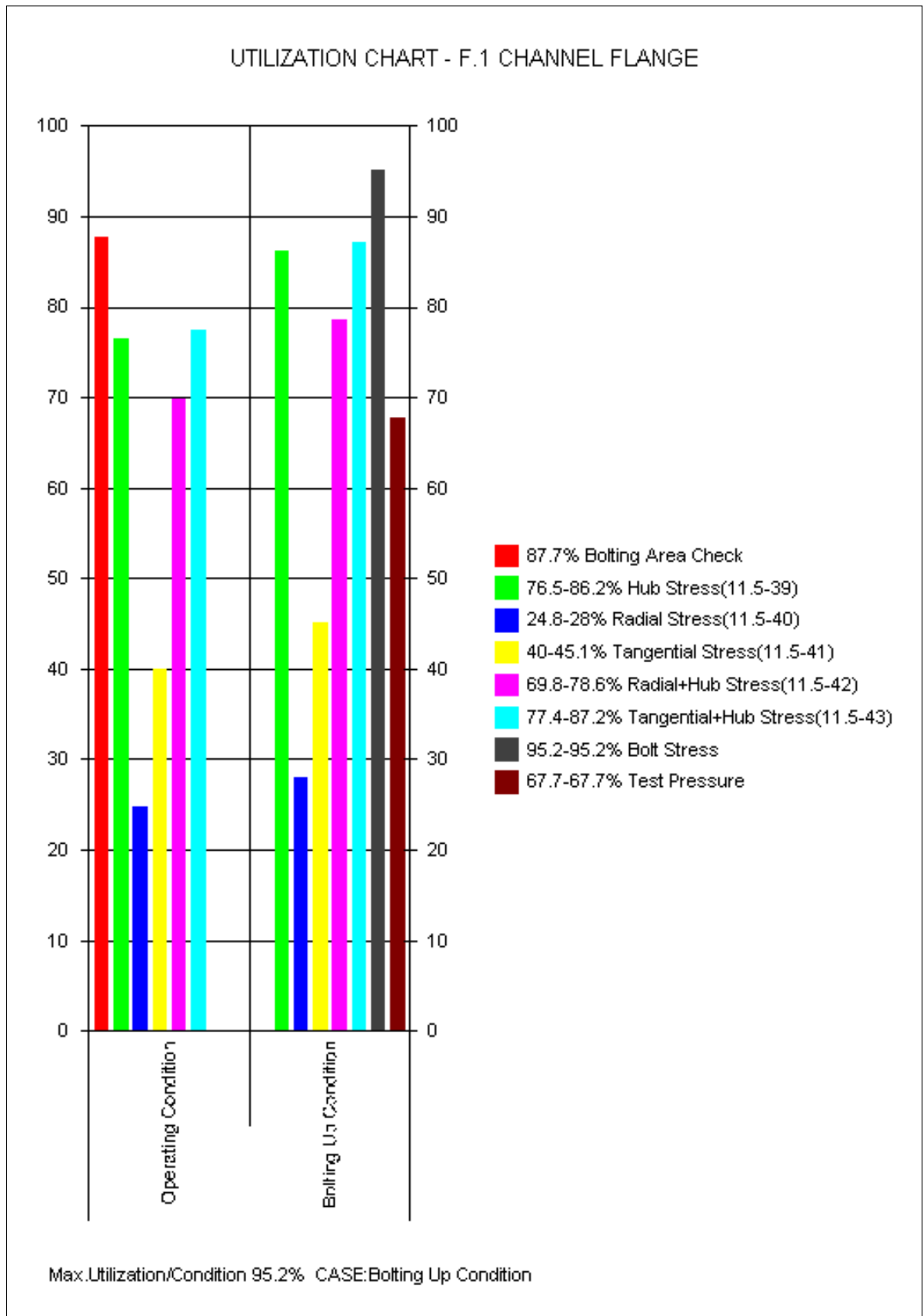
Visual Vessel Design by OhmTech Ver:10.2-02 Operator : Rev.:A

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F.1 Channel flange 05 Feb. 2010 12:10 ConnID:S1.1 PC# 2

»Test Pressure $P_{tmin}=2.14 \leq P_{tmax}=3.154$ [MPa] « » (U= 67.7%) OK«

Volume:0.02 m3 Weight:59 kg (SG= 7.85)



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Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-02 Operator : Rev.:A

EN13445:2009 Issue 1 - 11.5 NARROW FACE GASKETED FLANGES

F.2 Shell flange 05 Feb. 2010 12:10 ConnID:T.1 PC# 1

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

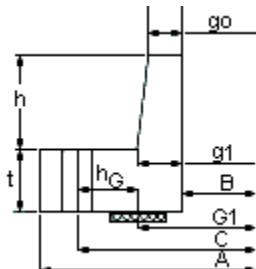
Attachment: T.1 Tubesheet U-tube sheet F.1
Location: Along z-axis z1= 590
Flange Design Method: Section 11 - Taylor Forge

GENERAL DESIGN DATA

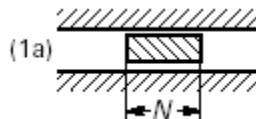
PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm
B: Pressure loading: Flange under internal pressure
BOLT LOAD FROM 2nd. FLANGE - (Oper.Cond.).....:Wm1' 371.15 kN
BOLT LOAD FROM 2nd. FLANGE - (Bolting Up.Cond.).....:Wm2' 1122.91 kN
EXTERNAL LOADS ON FLANGE (PD5500 ENQ 5500/123): NO

TYPE OF FLANGE AND GASKET FACING

A: Flange Standard: User Specified Flanges



C: Flange Type: WN Welding Neck(Smooth bore)



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

SHELL/NOZZLE DATA

SHELL/NOZZLE SIZE & COMMENT: S1.1
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
Rm=410 Rp=265 Rpt=194.12 fs=129.41 fs20=170.83 ftest=252.38 E=196147(N/mm2) ro=7.85
OUTSIDE DIAMETER OF SHELL/NOZZLE:Do 624.00 mm
WALL THICKNESS OF NOZZLE/SHELL(uncorroded).....:s1 10.00 mm

FLANGE DATA

REVERSE FLANGE: No (The bolts are located on the outside)
DESIGN METHOD: A) INTEGRAL FLANGE METHOD
OUTSIDE DIAMETER OF FLANGE.....:A 760.00 mm
THICKNESS OF FLANGE(uncorroded).....:e 45.00 mm
CORROSION ALLOWANCE FOR FLANGE FACE.....:cf 5.00 mm
ASME SA-105, PMA, , THK<=250mm 232'C
Rm=485 Rp=250 Rpt=177.2 SFO=118.13 SFA=166.67 ftest=238.1 (N/mm2)
NOTE: A PARTICULAR MATERIAL APPRAISAL(PMA) MAY BE REQUIRED FOR THIS MATERIAL.

DATA FOR FLANGE HUB

LENGTH OF HUB.....:h 40.00 mm
THICKNESS OF HUB AT BACK OF FLANGE corroded.....:g1 17.00 mm
THICKNESS OF HUB AT SMALL END corroded.....:go 7.00 mm
ASME SA-105, PMA, , THK<=250mm 232'C
Rm=485 Rp=250 Rpt=177.2 SHO=118.13 SHA=166.67 ftest=238.1 (N/mm2)
NOTE: A PARTICULAR MATERIAL APPRAISAL(PMA) MAY BE REQUIRED FOR THIS MATERIAL.

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F.2 Shell flange 05 Feb. 2010 12:10 ConnID:T.1 PC# 1

BOLTING DATA

BOLTING TORQUE CALCULATION: YES
 NOMINAL BOLTING SIZE & COMMENT: 7/8"(0.875)
 EFFECTIVE BOLT AREA per bolt.....:Ae 270.32 mm²
 RECOMMENDED MINIMUM BOLT CENTER TO EDGE CLEARANCE...:Bce 24.00 mm
 RECOMMENDED MINIMUM BOLT CENTER/RADIAL CLEARANCE....:Bcr 31.75 mm
 DIAMETER OF BOLT HOLES IN FLANGE.....:d 25.00 mm
 NUMBER OF BOLTS.....:n 28.00
 BOLT-CIRCLE DIAMETER.....:C 710.00 mm
 ASME SA-193 Gr.B7, PMA, , THK<=64mm 370'C
 Rm=860 Rp=507 Rpt=388 Sb=129.33 Sa=169 fttest=253.5 (N/mm²)
 NOTE: A PARTICULAR MATERIAL APPRAISAL(PMA) MAY BE REQUIRED FOR THIS MATERIAL.
 BOLTING-UP METHOD: Torque Wrench(Torque measurements) eps= 0.1+0.5* μ
 FRICTION COEFFICIENT: Normal/Average Conditions μ=0.20

GASKET DATA

Table H-1 Gasket factors m & y Facing: User Specified Gasket Factors
 GASKET FACTOR.....:m 3.00
 GASKET OR JOINT-CONTACT-SURFACE UNIT SEATING LOAD...:y 69.00 N/mm²
 GASKET TYPE (remark) (Optional): CAMPROFILE
 OUTSIDE DIAMETER OF GASKET/RAISED FACE.....:Go 670.00 mm
 GREATER VALUE OF INSIDE DIAMETER OF GASKET/FLANGE FACE:A1 644.00 mm
 TEMA RGP-RCB-11.7 Include Additional Loads from Pass Partition Plate Gasket: NO

CALCULATION DATA

Large Diameter Stress Correction Factor K
 k (D < 1000 mm) = 1 =1= 1.00

GASKET DETAILS

b = MIN VALUE(2.52 * Sqr(bo), bo) = == 6.42 mm

FLANGE LOADS

H = 0.785 * G ^ 2 * p (11.5-5) =0.785*657.15^2*0.5= 169.50 kN
 HG = (2 * PI * b * G * m) * p (11.5-6)
 =(2*3.14*6.42*657.15*3)*0.5= 39.76 kN
 HD = 0.785 * B ^ 2 * p =0.785*610^2*0.5= 146.05 kN
 HT = H - HD (11.5-11) =169.5-146.05= 23.45 kN

MOMENT ARMS

hG = (C - G) / 2 (11.5-14) =(710-657.15)/2= 26.42 mm
 hD = (C - B - g1) / 2 (11.5-12) =(710-610-17)/2= 41.50 mm
 hT = (2 * C - B - G) / 4 (11.5-15) =(2*710-610-657.15)/4= 38.21 mm

BOLT LOADS

Operating condition
 Wop = H + HG (11.5-8) =169.5+39.76= 209.26 kN
 Bolting up condition
 Wamb = PI * b * G * y (11.5-7) =3.14*6.42*657.15*69= 914.53 kN
 User specified bolt load is used for Wop
 User specified bolt load is used for Wamb

BOLTING AREA

Am1 = Wop / Sb =371150/129.33= 2869.79 mm²
 Am2 = Wamb / Sa =1.1229E06/169= 6644.44 mm²
 Required Bolting Area Am
 Am (Largest value of Am1 and Am2)= Am =6644.44 mm²
 Available Bolting Area Ab
 Ab (num.bolts*root area) = n * Ae =28*270.32= 7568.96 mm²

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F.2 Shell flange 05 Feb. 2010 12:10 ConnID:T.1 PC# 1

»Bolting Area Check $Ab=7568.96 \geq Am=6644.44[\text{mm}^2]$ « » (U= 87.7%) OK«

$$W = 0.5 * (Ab + Am) * Sa \text{ (11.5-16)} = 0.5 * (7568.96 + 6644.44) * 169 = 1201.03 \text{ kN}$$

HG increased due to user specified load Wop

$$\text{HG} = \text{HG} + \text{Abs}(\text{Wop} - \text{Wop2nd}) \text{ (11.5-19)}$$

$$= 39.76 + \text{Abs}(209.26 - 371150) = 201.65 \text{ kN}$$

FLANGE MOMENTS

$$\text{Mop} = \text{HD} * \text{hD} + \text{HT} * \text{hT} + \text{HG} * \text{hG} \text{ (11.5-18)}$$

$$= 146.05 * 41.5 + 23.45 * 38.21 + 201.65 * 26.42 = 12285.71 \text{ Nm}$$

$$\text{Mamb} = W * \text{hG} \text{ (11.5-17)} = 1201.03 * 26.42 = 31737.00 \text{ Nm}$$

Bolt Spacing

$$\text{Bspc} = C * \text{PI} / n = 710 * 3.14 / 28 = 79.66 \text{ mm}$$

Bolt Pitch Correction Factor

$$\text{CF} = \text{MAX}(\text{Sqr}(\text{Bspc} / (2 * \text{db} + 6 * e / (m + 0.5))), 1) \text{ (11.5-20)}$$

$$= \text{MAX}(\text{Sqr}(79.66 / (2 * 22.225 + 6 * 40 / (3 + 0.5))), 1) = 1.00$$

$$\text{Mo} = \text{Mop} * \text{CF} / B \text{ (11.5-27)} = 12285.71 * 1 / 610 = 20.14 \text{ Nm}$$

$$\text{Ma} = \text{Mamb} * \text{CF} / B \text{ (11.5-26)} = 31737.0 * 1 / 610 = 52.03 \text{ Nm}$$

SHAPE CONSTANTS

$$K = A / B \text{ (11.5-21)} = 760 / 610 = 1.25$$

$$l_0 = \text{SQR}(B * g_0) \text{ (11.5-22)} = \text{SQR}(610 * 7) = 65.35$$

$$h/l_0 = 0.612 \quad K=A/B= 1.246 \quad g_1/g_0= 2.429$$

VALUES FROM FIGURES 11.5-4 to 8

$$\text{BetaT} = 1.820 \quad \text{BetaZ} = 4.621 \quad \text{BetaY} = 8.958 \quad \text{BetaU} = 9.844$$

$$\text{BetaF} = 0.789 \quad \text{BetaV} = 0.162 \quad \text{phi} = 1.369$$

$$\text{lamda} = (e * \text{BetaF} + l_0) / (\text{BetaT} * l_0) + e^3 * \text{BetaV} / (\text{BetaU} * l_0 * g_0^2)$$

$$= (40 * 0.7894 + 65.35) / (1.82 * 65.35) + 40^3 * 0.1619 / (9.844 * 65.35 * 7^2) = 1.14$$

OPERATING CONDITION

$$M = \text{Mo} = 20.14 = 20.14 \text{ Nm}$$

11.5.4.1 Flange Stresses with Flange Thickness $e= 40 \text{ mm}$

Longitudinal Hub Stress

$$\text{SigH} = \text{phi} * M / (\text{lamda} * g_1^2) \text{ (11.5-29)}$$

$$= 1.37 * 20.14 / (1.14 * 17^2) = 83.43 \text{ N/mm}^2$$

Radial Flange Stress

$$\text{SigR} = (1.333 * e * \text{BetaF} + l_0) * M / (\text{lamda} * e^2 * l_0) \text{ (11.5-30)}$$

$$= (1.333 * 40 * 0.7894 + 65.35) * 20.14 / (1.14 * 40^2 * 65.35) = 18.09 \text{ N/mm}^2$$

Tangential Flange Stress

$$\text{SigTeta} = \text{BetaY} * M / e^2 - \text{SigR} * (K^2 + 1) / (K^2 - 1) \text{ (11.5-31)}$$

$$= 8.958 * 20.14 / 40^2 - 18.09 * (1.25^2 + 1) / (1.25^2 - 1) = 29.14 \text{ N/mm}^2$$

11.5.4.2 Stress Limits

»Hub Stress $k * \text{SigH} = 83.43 \leq 1.5 * \text{MIN}(f; f_H) = 177.19 [\text{N/mm}^2]$ (11.5-39)«» (U= 47%) OK«

»Radial Stress $k * \text{SigR} = 18.09 \leq f = 118.13 [\text{N/mm}^2]$ (11.5-40)« » (U= 15.3%) OK«

»Tangential Stress $k * \text{SigTeta} = 29.14 \leq f = 118.13 [\text{N/mm}^2]$ (11.5-41)«» (U= 24.6%) OK«

»Radial+Hub Stress $0.5 * k * (\text{SigH} + \text{SigR}) = 50.76 \leq f = 118.13 [\text{N/mm}^2]$ (11.5-42)«» (U= 42.9%) OK«

»Tangential+Hub Stress $0.5 * k * (\text{SigH} + \text{SigTeta}) = 56.29 \leq f = 118.13 [\text{N/mm}^2]$ (11.5-43)«» (U= 47.6%)

OK«

BOLTING UP CONDITION

$$M = \text{Ma} = 52.03 = 52.03 \text{ Nm}$$

11.5.4.1 Flange Stresses with Flange Thickness $e= 40 \text{ mm}$

Longitudinal Hub Stress

$$\text{SigH} = \text{phi} * M / (\text{lamda} * g_1^2) \text{ (11.5-29)}$$

$$= 1.37 * 52.03 / (1.14 * 17^2) = 215.53 \text{ N/mm}^2$$

Radial Flange Stress

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$$\text{Sigr} = (1.333 * e * \text{BetaF} + l_0) * M / (\text{lamda} * e^2 * l_0) \quad (11.5-30)$$

$$= (1.333 * 40 * 0.7894 + 65.35) * 52.03 / (1.14 * 40^2 * 65.35) = 46.74 \text{ N/mm}^2$$

Tangential Flange Stress

$$\text{SigTeta} = \text{BetaY} * M / e^2 - \text{Sigr} * (K^2 + 1) / (K^2 - 1) \quad (11.5-31)$$

$$= 8.958 * 52.03 / 40^2 - 46.74 * (1.25^2 + 1) / (1.25^2 - 1) = 75.27 \text{ N/mm}^2$$

11.5.4.2 Stress Limits

- »Hub Stress $k * \text{SigH} = 215.53 \leq 1.5 * \text{MIN}(f; f_H) = 250 [\text{N/mm}^2]$ (11.5-39) « (U= 86.2%) OK«
- »Radial Stress $k * \text{SigR} = 46.74 \leq f = 166.67 [\text{N/mm}^2]$ (11.5-40) « » (U= 28%) OK«
- »Tangential Stress $k * \text{SigTeta} = 75.27 \leq f = 166.67 [\text{N/mm}^2]$ (11.5-41) « (U= 45.1%) OK«
- »Radial+Hub Stress $0.5 * k * (\text{SigH} + \text{SigR}) = 131.13 \leq f = 166.67 [\text{N/mm}^2]$ (11.5-42) « (U= 78.6%) OK«
- »Tangential+Hub Stress $0.5 * k * (\text{SigH} + \text{SigTeta}) = 145.4 \leq f = 166.67 [\text{N/mm}^2]$ (11.5-43) « (U= 87.2%) OK«

BOLTING-UP TORQUE - EN13445 ANNEX G.8

$$k_B = 1.2 * \mu * d_{B0} \text{ (G.8-5)} = 1.2 * 0.2 * 22.225 = 5.33 \text{ mm}$$

$$\text{epsn} = \text{eps} * (1 + 3 / \text{SQR}(n)) / 4 \quad (G.6-16)$$

$$= 0.2 * (1 + 3 / \text{SQR}(28)) / 4 = 0.0783$$

Required Minimum Total Pre-Load (Max. of operating and bolting up cond.)

$$F_{b0nom} \text{ (Max. of Wop and Wamb)} = F_{b0req} = 1122.91 = 1122.91 \text{ kN}$$

Nominal Total Pre-Load

$$F_{b0nom} = F_{b0req} / (1 - \text{epsn}) \text{ (G.6-21)} = 1122.91 / (1 - 0.0783) = 1218.37 \text{ kN}$$

Nominal Total Pre-Load per Bolt

$$F_{bnom} = F_{b0nom} / n = 1218.37 / 28 = 43.51 \text{ kN}$$

Bolt Stress (Assembly Cond.)

$$\text{SigBoltamb} = W_{amb} / ((1 - \text{epsn}) * n * A_e) \quad (11.5-39)$$

$$= 1.1229E06 / ((1 - 0.0783) * 28 * 270.32) = 160.97 \text{ N/mm}^2$$

Bolt Stress (Operating Cond.)

$$\text{SigBoltamb} = W_{op} / ((1 - \text{epsn}) * n * A_e) \quad (11.5-39)$$

$$= 371150 / ((1 - 0.0783) * 28 * 270.32) = 53.20 \text{ N/mm}^2$$

»Bolt Stress $\text{SigBolt} = 160.97 \leq S_a = 169 [\text{N/mm}^2]$ « » (U= 95.2%) OK«

Nominal Torque Per Bolt

$$M_{tnom} = k_B * F_{b0nom} / n = 5.334 * 1218.37 / 28 = 232.10 \text{ Nm}$$

EN13445-5; 10.2.3.3 REQUIRED MIN. HYDROSTATIC TEST PRESSURE: P_{tmin}

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3

$$P_{tmin} = 1.25 * P_d * f_{20} / f = 1.25 * 0.5 * 166.67 / 118.13 = 0.8818 \text{ MPa}$$

$$P_{tmin} = 1.43 * P_d = 1.43 * 0.5 = 0.7150 \text{ MPa}$$

»Test Pressure $P_{tmin} = 0.8818 \leq P_{tmax} = 3.248 [\text{MPa}]$ « » (U= 27.1%) OK«

PRESSURE AND TORQUE SUMMARY

Table PRESSURE AND TORQUE SUMMARY FOR F.2 :

Description	Temp(C)	P(MPa)	Limited By	Min. Req. Total Bolt Force(kN)
Design Pressure(corroded)	370	0.50	Bolt Stress	1122.91
Max.Allow.Pressure(corroded)	370	1.61	Tangential+Hub Stress	1122.91
Max.Allow.Pressure(corroded)	Ambient	2.27	Tangential+Hub Stress	1122.91
Max.Allow.Test Pressure(corroded)	Ambient	3.25	Tangential+Hub Stress	1359.37
Required Test Pressure	Ambient	0.88	Tangential+Hub Stress	1122.91

Table PRESSURE AND TORQUE SUMMARY FOR F.2 Continued

Description	Nom. Force per Bolt(kN)	Nom. Torque per Bolt(Nm)
Design Pressure(corroded)	43.51	232.1
Max.Allow.Pressure(corroded)	43.51	232.1
Max.Allow.Pressure(corroded)	43.51	232.1
Max.Allow.Test Pressure(corroded)	52.68	280.97
Required Test Pressure	43.51	232.1

The nominal Force and Torque values are based on the following bolting up method:
Torque Wrench (Torque measurements) $\text{eps} = 0.1 + 0.5 * \mu$

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EN13445:2009 Issue 1 - 11.5 NARROW FACE GASKETED FLANGES

F.2 Shell flange 05 Feb. 2010 12:10 ConnID:T.1 PC# 1

CALCULATION SUMMARY

BOLTING AREA

»Bolting Area Check $A_b=7568.96 \geq A_m=6644.44[\text{mm}^2]$ « » (U= 87.7%) OK«

OPERATING CONDITION

11.5.4.1 Flange Stresses with Flange Thickness $e= 40 \text{ mm}$

Longitudinal Hub Stress
 $\text{SigH} = \phi * M / (\text{lamda} * g_1^2)$ (11.5-29)
 $= 1.37 * 20.14 / (1.14 * 17^2) =$ 83.43 N/mm²

Radial Flange Stress
 $\text{SigR} = (1.333 * e * \text{BetaF} + l_0) * M / (\text{lamda} * e^2 * l_0)$ (11.5-30)
 $= (1.333 * 40 * 0.7894 + 65.35) * 20.14 / (1.14 * 40^2 * 65.35) =$ 18.09 N/mm²

Tangential Flange Stress
 $\text{SigTeta} = \text{BetaY} * M / e^2 - \text{SigR} * (K^2 + 1) / (K^2 - 1)$ (11.5-31)
 $= 8.958 * 20.14 / 40^2 - 18.09 * (1.25^2 + 1) / (1.25^2 - 1) =$ 29.14 N/mm²

11.5.4.2 Stress Limits

»Hub Stress $k * \text{SigH} = 83.43 \leq 1.5 * \text{MIN}(f; f_H) = 177.19[\text{N/mm}^2]$ (11.5-39)«» (U= 47%) OK«
»Radial Stress $k * \text{SigR} = 18.09 \leq f = 118.13[\text{N/mm}^2]$ (11.5-40)« » (U= 15.3%) OK«
»Tangential Stress $k * \text{SigTeta} = 29.14 \leq f = 118.13[\text{N/mm}^2]$ (11.5-41)«» (U= 24.6%) OK«
»Radial+Hub Stress $0.5 * k * (\text{SigH} + \text{SigR}) = 50.76 \leq f = 118.13[\text{N/mm}^2]$ (11.5-42)«» (U= 42.9%) OK«
»Tangential+Hub Stress $0.5 * k * (\text{SigH} + \text{SigTeta}) = 56.29 \leq f = 118.13[\text{N/mm}^2]$ (11.5-43)«» (U= 47.6%) OK«

BOLTING UP CONDITION

11.5.4.1 Flange Stresses with Flange Thickness $e= 40 \text{ mm}$

Longitudinal Hub Stress
 $\text{SigH} = \phi * M / (\text{lamda} * g_1^2)$ (11.5-29)
 $= 1.37 * 52.03 / (1.14 * 17^2) =$ 215.53 N/mm²

Radial Flange Stress
 $\text{SigR} = (1.333 * e * \text{BetaF} + l_0) * M / (\text{lamda} * e^2 * l_0)$ (11.5-30)
 $= (1.333 * 40 * 0.7894 + 65.35) * 52.03 / (1.14 * 40^2 * 65.35) =$ 46.74 N/mm²

Tangential Flange Stress
 $\text{SigTeta} = \text{BetaY} * M / e^2 - \text{SigR} * (K^2 + 1) / (K^2 - 1)$ (11.5-31)
 $= 8.958 * 52.03 / 40^2 - 46.74 * (1.25^2 + 1) / (1.25^2 - 1) =$ 75.27 N/mm²

11.5.4.2 Stress Limits

»Hub Stress $k * \text{SigH} = 215.53 \leq 1.5 * \text{MIN}(f; f_H) = 250[\text{N/mm}^2]$ (11.5-39)«» (U= 86.2%) OK«
»Radial Stress $k * \text{SigR} = 46.74 \leq f = 166.67[\text{N/mm}^2]$ (11.5-40)« » (U= 28%) OK«
»Tangential Stress $k * \text{SigTeta} = 75.27 \leq f = 166.67[\text{N/mm}^2]$ (11.5-41)«» (U= 45.1%) OK«
»Radial+Hub Stress $0.5 * k * (\text{SigH} + \text{SigR}) = 131.13 \leq f = 166.67[\text{N/mm}^2]$ (11.5-42)«» (U= 78.6%) OK«
»Tangential+Hub Stress $0.5 * k * (\text{SigH} + \text{SigTeta}) = 145.4 \leq f = 166.67[\text{N/mm}^2]$ (11.5-43)«» (U= 87.2%) OK«
»Bolt Stress $\text{SigBolt} = 160.97 \leq S_a = 169[\text{N/mm}^2]$ « » (U= 95.2%) OK«

EN13445-5;10.2.3.3 REQUIRED MIN. HYDROSTATIC TEST PRESSURE: P_{tmin}

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3
 $P_{tmin} = 1.25 * P_d * f_{20} / f = 1.25 * 0.5 * 166.67 / 118.13 =$ 0.8818 MPa

$P_{tmin} = 1.43 * P_d = 1.43 * 0.5 =$ 0.7150 MPa

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Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-02 Operator : Rev.:A

EN13445:2009 Issue 1 - 11.5 NARROW FACE GASKETED FLANGES

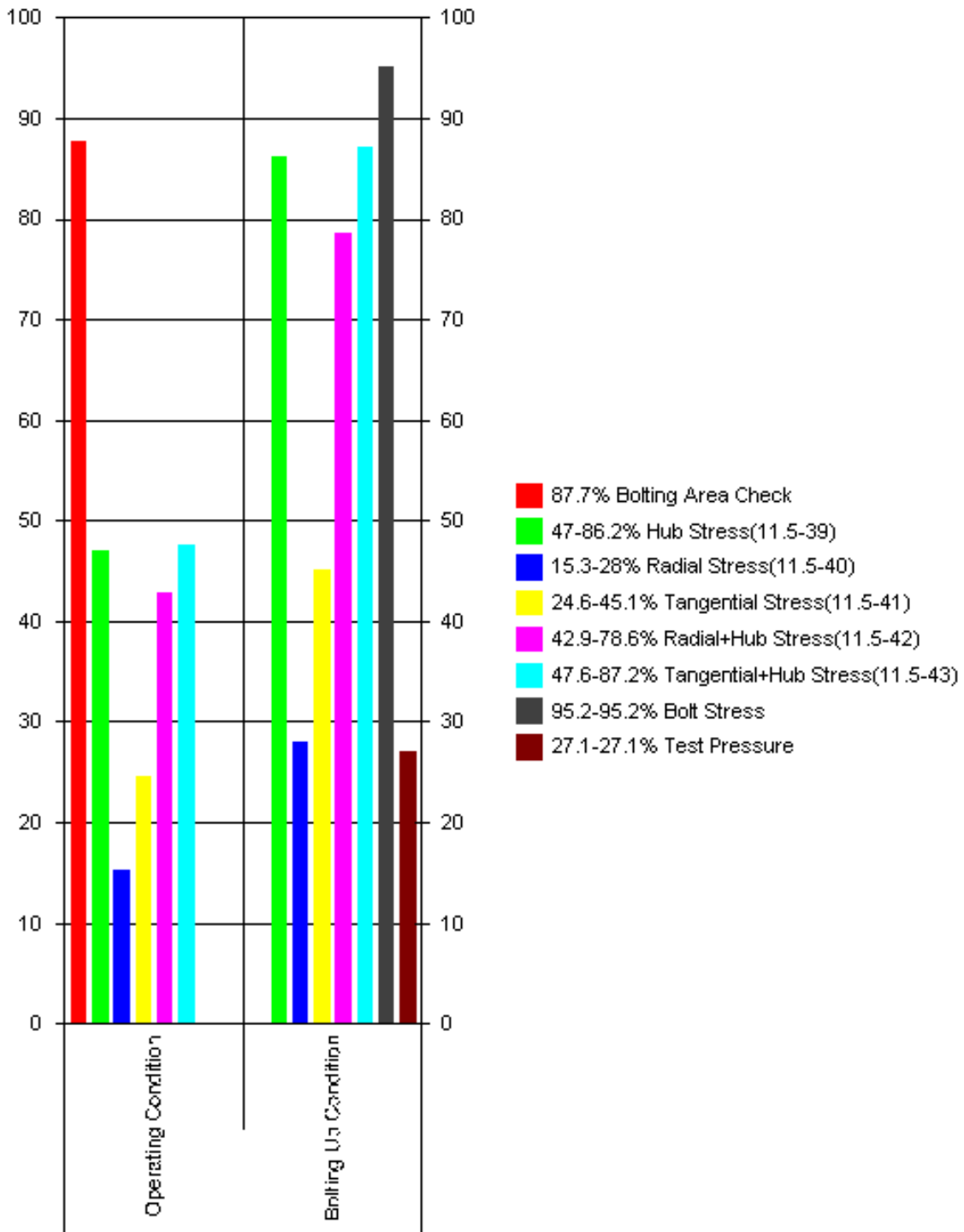
F.2 Shell flange 05 Feb. 2010 12:10 ConnID:T.1 PC# 1

»Test Pressure $P_{tmin}=0.8818 \leq P_{tmax}=3.248$ [MPa] « » (U= 27.1%) OK«

WARNING : TEMPERATURE MISMATCH FOR MATERIAL:ASME SA-193 Gr.B7, PMA, ,
THK<=64mm 370°C

Volume:0.02 m3 Weight:59 kg (SG= 7.85)

UTILIZATION CHART - F.2 SHELL FLANGE



Max.Utilization/Condition 95.2% CASE: Bolting Up Condition

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Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-02 Operator : Rev.:A

EN13445:2009 Issue 1 - 13.4 U-Tube Tubesheet Heat Exchangers

T.1 U-tube sheet 05 Feb. 2010 12:10 ConnID:F.1 PC# 2

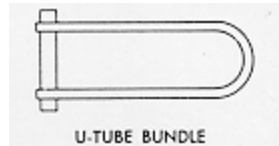
INPUT DATA

COMPONENT ATTACHMENT/LOCATION

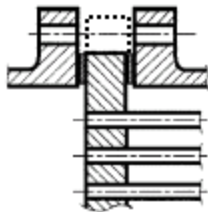
Attachment: F.1 WN - Flange Channel flange S1.1
 Location: Along z-axis z1= 535

GENERAL DESIGN DATA

Alternative Method for Design of Heat Exchanger Tubesheets to Annex J: NO



Type of Heat Exchanger: 13.4 U-Tube Tubesheet Heat Exchangers



Configuration Type:
 d1 Tubesheet gasketed with shell and channel(NOT extended flange)

LOAD CASES

Table LOAD CASES:

Description	ID	Pt Only(Ps=0)	PsOnly(Pt=0)	Ps+Pt Simultan.
Shell-Side Pressure (MPa)	Ps	-0.1	0.5	0.5
Tube-Side Pressure (MPa)	Pt	0.85	-0.1	0.85
Shell-Side Corr.Allow.(mm)	cs	3	3	3
Tube-Side Corr.Allow. (mm)	ct	3	3	3
Allowable Stress M Factor	Mf	1	1	1

DATA FOR TUBESHEET

ASME SA-105, PMA, , THK<=250mm 370'C
 Rm=485 Rp=250 Rpt=124.4 f=82.93 f20=166.67 ftest=238.1 (N/mm2)
 NOTE: A PARTICULAR MATERIAL APPRAISAL(PMA) MAY BE REQUIRED FOR THIS MATERIAL.
 OUTSIDE DIAMETER OF TUBESHEET.....:A 670.00 mm
 AS BUILT THICKNESS OF TUBESHEET (uncorroded).....:en 55.00 mm
 ELASTIC MODULUS OF TUBESHEET at design temp.....:E 1,8506E05 N/mm2
 POISSON'S RATIO FOR TUBESHEET MATERIAL.....:v 0.3000

DATA FOR TUBES AND TUBES LAYOUT

Tube Layout: Square Pattern
 EN 10216-2:2002/A2:07, 1.0345 P235GH seamless tube, HT:N THK<=16mm 370'C
 Rm=360 Rp=235 Rpt=116.8 ft=77.87 f20=150 ftest=223.81 E=185095(N/mm2) ro=7.85
 ELASTIC MODULUS OF TUBES at mean metal temp.....:Et 1,8506E05 N/mm2
 NOMINAL OUTSIDE DIAMETER OF TUBES.....:dt 19.05 mm
 TUBE SIZE & COMMENT: BWG14;
 NOMINAL THICKNESS OF TUBES.....:et 2.11 mm
 TUBE PITCH (Spacing between centers).....:p 26.00 mm
 DIAMETER OF TUBEHOLE IN TUBESHEET.....:dh 19.30 mm
 DIAMETER OF OUTER TUBE LIMIT CIRCLE.....:Do 590.00 mm
 NUMBER OF TUBEHOLES IN TUBESHEET.....:Nt 340.00 piec
 TOTAL UNPERFORATED AREA OF TUBESHEET(Fig.13.7.3-5)..:S 34000.00 mm2
 EFFECTIVE DEPTH OF TUBE-SIDE PASS PARTITION GROOVE...:hg 2.00 mm

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EN13445:2009 Issue 1 - 13.4 U-Tube Tubesheet Heat Exchangers

T.1 U-tube sheet 05 Feb. 2010 12:10 ConnID:F.1 PC# 2

DATA FOR TUBE TO TUBESHEET JOINT

Tube to Tubesheet Joint: Expanded with Two or More Grooves
EXPANDED LENGTH OF TUBES IN TUBESHEET(0<=Itx<=en)...:Itx 40.00 mm

SHELL DATA

EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
Rm=410 Rp=265 Rpt=194.12 fs=129.41 f20=170.83 ftest=252.38 E=196147(N/mm2) ro=7.85
INSIDE DIAMETER OF SHELL(corroded)...:Ds 610.00 mm
THICKNESS OF SHELL (uncorroded)...:es 10.00 mm
ELASTIC MODULUS OF SHELL MATERIAL at mean metal temp:Es 1,9611E05 N/mm2
POISSON'S RATIO FOR SHELL MATERIAL...:vs 0.3000

CHANNEL DATA

EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 370'C
Rm=410 Rp=265 Rpt=156 fc=104 f20=170.83 ftest=252.38 E=185095(N/mm2) ro=7.85
INSIDE DIAMETER OF CHANNEL(corroded)...:Dc 610.00 mm
THICKNESS OF CHANNEL (uncorroded)...:ec 10.00 mm
ELASTIC MODULUS OF CHANNEL at design temp...:Ec 1,8506E05 N/mm2
POISSON'S RATIO FOR CHANNEL MATERIAL...:vc 0.3000

FLANGE DATA

SHELL FLANGE DESIGN BOLT LOAD FOR ASSEMBLY COND...:Ws 1201.03 kN
DIAMETER OF SHELL GASKET LOAD REACTION...:Gs 657.15 mm
CHANNEL FLANGE DESIGN BOLT LOAD FOR ASSEMBLY COND...:Wc 1201.03 kN
DIAMETER OF CHANNEL GASKET LOAD REACTION...:Gc 657.15 mm
BOLT-CIRCLE DIAMETER...:C 710.00 mm

CALCULATION DATA

LOAD CASE : Pt Only(Ps=0)

PRELIMINARY CALCULATIONS

Tubesheet Analysis Thickness ea
ea = en - ct - cs =55-3-3= 49.00 mm

13.7.6 Determination of the Basic Ligament Efficiency (my) for Shear

my = (p - dt) / p (13.7.6-1) =(26-19.05)/26= 0.2673

13.7.7 Determination of the Effective Ligament Efficiency (Mystar) for Bending

Tube Expansion Depth Ratio
ro = Itx / ea (13.7.7-3) =40/49= 0.8163
Effective Tube Hole Diameter (dstar)
dstar = MAX(dt-2*et*(Et/E)*(ft/f)*ro,dt-2*et) (13.7.7-2)
=MAX(19.05-2*2.108*(185057/185057)*(77.87/82.93)*0.8163,19.05-2*2.108)
= 15.82 mm
Effective Pitch Diameter (pstar)
pstar = p/Sqr(1-4*MIN(S,4*Do*p)/(PI*Do^2)) (13.7.7-4)
=26/Sqr(1-4*MIN(34000,4*590*26)/(3.14*590^2))= 27.79 mm
Mystar = (pstar - dstar) / pstar (13.7.7-1) =(27.79-15.82)/27.79= 0.4307

13.7.8 Determination of the Effective Elastic Constants Estar and vstar

Estar/E from figure 13.7.8-2a) = 0.5001(e/p=1.88)
Estar = Estar * E =0.5001*185057= 92537.95 N/mm2
vstar from figure 13.7.8-2b) = 0.3112(e/p=1.88)

13.7.9 Determination of the Effective Bending Rigidity of the Tubesheet Dstar

Dstar = (Estar * ea ^ 3) / (12 * (1 - vstar ^ 2)) (13.7.9-1)
=(92537.95*49^3)/(12*(1-0.3112^2))= 1,0045E09 Nmm

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EN13445:2009 Issue 1 - 13.4 U-Tube Tubesheet Heat Exchangers

T.1 U-tube sheet 05 Feb. 2010 12:10 ConnID:F.1 PC# 2

Diameter Ratios and Moment MTS

Diameter Ratio ros for Shell
 $ros = G_s / D_o$ (13.4.4-2) = 657.15/590 = 1.11
Diameter Ratio roc for Channel
 $roc = G_c / D_o$ (13.4.4-4) = 657.15/590 = 1.11
Moment MTS due to Pressures Ps and Pt Acting on the Unperforated Tubesheet Rim
 $MTS = D_o^2 / 16 * ((ros-1) * (ros^2+1) * P_s - (roc-1) * (roc^2+1) * P_t)$ (13.4.4-5)
= 590²/16 * ((1.11-1) * (1.11²+1) * -0.1 - (1.11-1) * (1.11²+1) * 0.85) = -5270.63 Nmm/mm
Diameter Ratio K
 $K = A / D_o$ (13.4.4-6) = 670/590 = 1.14
Coefficient F:
 $F = (1 - v_{star}) / E_{star} * E * \log(K)$ (13.4.4-9)
= (1-0.3112)/92537.95*185057*Log(1.14) = 0.1751
Flange Design Bolt Load
 $W_{max} = \max(W_s, W_c)$ (13.4.4-11) = MAX(1201.03,1201.03) = 1201.03 kN

13.4.5 Tubesheet Design

13.4.5.1.1 Moment Mstar Acting on the Unperforated Tubesheet Rim
 $M_{star} = MTS + W_{max} * (G_c - G_s) / (2 * \pi * D_o)$ (13.4.5-4)
= -5270.63+1201.03*(657.15-657.15)/(2*3.14*590) = -5270.63 Nmm/mm
13.4.5.1.2 Moment Mp Acting at Periphery of Tubesheet
 $M_p = (M_{star} - D_o^2 / 32 * F * (P_s - P_t)) / (1 + F)$ (13.4.5-8)
= (-5270.63-590²/32*0.1751*(-0.1-0.85))/(1+0.1751) = -2944.83 Nmm/mm
13.4.5.1.3 Moment Mo Acting at Centre of Tubesheet
 $M_o = M_p + D_o^2 / 64 * (3 + v_{star}) * (P_s - P_t)$ (13.4.5-9)
= -2944.83+590²/64*(3+0.3112)*(-0.1-0.85) = -20054.21 Nmm/mm
13.4.5.1.4 Maximum Bending Moment M Acting on the Tubesheet
 $M = \max(\text{Abs}(M_p), \text{Abs}(M_o))$ (13.4.5-10)
= MAX(Abs(-2944.83), Abs(-20054.21)) = 20054.21 Nmm/mm

13.4.5.2 Bending Stress in Tubesheet (Sigma)

$\sigma = 6 * M / (M_{y_{star}} * (e_a - h_g)^2)$ (13.4.5-11)
= 6*20054.21/(0.4307*(49-2)²) = 126.47 N/mm²

»Bending Stress Sigma=126.47 <= 2 * f=165.86[N/mm²] (13.4.5-12)«» (U= 76.2%) OK«

13.4.5.3 Shear Stress in Tubesheet (Tau)

$\tau = 0.25 * D_o / (m_y * e_a) * (P_s - P_t)$ (13.4.5-13)
= 0.25*590/(0.2673*49)*(-0.1-0.85) = -10.70 N/mm²

»Shear Stress Tau=10.7 <= 0.8 * f=66.34[N/mm²] (13.4.5-14)«» (U= 16.1%) OK«

LOAD CASE : Ps Only(Pt=0)

PRELIMINARY CALCULATIONS

Tubesheet Analysis Thickness ea
 $e_a = e_n - c_t - c_s = 55-3-3 = 49.00$ mm

13.7.6 Determination of the Basic Ligament Efficiency (my) for Shear

$m_y = (p - d_t) / p$ (13.7.6-1) = (26-19.05)/26 = 0.2673

13.7.7 Determination of the Effective Ligament Efficiency (Mystar) for Bending

Tube Expansion Depth Ratio
 $r_o = I_{tx} / e_a$ (13.7.7-3) = 40/49 = 0.8163
Effective Tube Hole Diameter (dstar)
 $d_{star} = \max(d_t - 2 * e_t * (E_t / E) * (f_t / f) * r_o, d_t - 2 * e_t)$ (13.7.7-2)
= MAX(19.05-2*2.108*(185057/185057)*(77.87/82.93)*0.8163, 19.05-2*2.108)
= 15.82 mm
Effective Pitch Diameter (pstar)
 $p_{star} = p / \sqrt{1 - 4 * \min(S, 4 * D_o * p) / (\pi * D_o^2)}$ (13.7.7-4)
= 26 / sqrt(1-4*MIN(34000, 4*590*26)/(3.14*590²)) = 27.79 mm
 $M_{y_{star}} = (p_{star} - d_{star}) / p_{star}$ (13.7.7-1) = (27.79-15.82)/27.79 = 0.4307

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EN13445:2009 Issue 1 - 13.4 U-Tube Tubesheet Heat Exchangers

T.1 U-tube sheet 05 Feb. 2010 12:10 ConnID:F.1 PC# 2

13.7.8 Determination of the Effective Elastic Constants Estar and vstar

Estar/E from figure 13.7.8-2a) = 0.5001(e/p=1.88)
Estar = Estar * E = 0.5001*185057 = 92537.95 N/mm²
vstar from figure 13.7.8-2b) = 0.3112(e/p=1.88)

13.7.9 Determination of the Effective Bending Rigidity of the Tubesheet Dstar

Dstar = (Estar * ea ^ 3) / (12 * (1 - vstar ^ 2)) (13.7.9-1)
=(92537.95*49^3)/(12*(1-0.3112^2))= 1,0045E09 Nmm

Diameter Ratios and Moment MTS

Diameter Ratio ros for Shell
ros = Gs / Do (13.4.4-2) = 657.15/590 = 1.11
Diameter Ratio roc for Channel
roc = Gc / Do (13.4.4-4) = 657.15/590 = 1.11
Moment MTS due to Pressures Ps and Pt Acting on the Unperforated Tubesheet Rim
MTS = Do^2/16*((ros-1)*(ros^2+1)*Ps-(roc-1)*(roc^2+1)*Pt) (13.4.4-5)
=590^2/16*((1.11-1)*(1.11^2+1)*0.5-(1.11-1)*(1.11^2+1)*-0.1)= 3328.82 Nmm/mm
Diameter Ratio K
K = A / Do (13.4.4-6) = 670/590 = 1.14
Coefficient F:
F = (1 - vstar) / Estar * E * Log(K) (13.4.4-9)
=(1-0.3112)/92537.95*185057*Log(1.14)= 0.1751
Flange Design Bolt Load
Wmax = MAX(Ws, Wc) (13.4.4-11) = MAX(1201.03,1201.03)= 1201.03 kN

13.4.5 Tubesheet Design

13.4.5.1.1 Moment Mstar Acting on the Unperforated Tubesheet Rim
Mstar = MTS + Wmax * (Gc - Gs) / (2 * PI * Do) (13.4.5-4)
=3328.82+1201.03*(657.15-657.15)/(2*3.14*590)= 3328.82 Nmm/mm
13.4.5.1.2 Moment Mp Acting at Periphery of Tubesheet
Mp = (Mstar - Do ^ 2 / 32 * F * (Ps - Pt)) / (1 + F) (13.4.5-8)
=(3328.82-590^2/32*0.1751*(0.5--0.1))/(1+0.1751)= 1859.89 Nmm/mm
13.4.5.1.3 Moment Mo Acting at Centre of Tubesheet
Mo = Mp + Do ^ 2 / 64 * (3 + vstar) * (Ps - Pt) (13.4.5-9)
=1859.89+590^2/64*(3+0.3112)*(0.5--0.1)= 12665.82 Nmm/mm
13.4.5.1.4 Maximum Bending Moment M Acting on the Tubesheet
M = MAX(Abs(Mp), Abs(Mo)) (13.4.5-10)
=MAX(Abs(1859.89),Abs(12665.82))= 12665.82 Nmm/mm

13.4.5.2 Bending Stress in Tubesheet (Sigma)

Sigma = 6 * M / (Mystar * (ea - hg) ^ 2) (13.4.5-11)
=6*12665.82/(0.4307*(49-2)^2)= 79.88 N/mm²

»Bending Stress Sigma=79.88 <= 2 * f=165.86[N/mm²] (13.4.5-12)«» (U= 48.1%)OK«

13.4.5.3 Shear Stress in Tubesheet (Tau)

Tau = 0.25 * Do / (my * ea) * (Ps - Pt) (13.4.5-13)
=0.25*590/(0.2673*49)*(0.5--0.1)= 6.76 N/mm²

»Shear Stress Tau=6.76 <= 0.8 * f=66.34[N/mm²] (13.4.5-14)«» (U= 10.1%) OK«

LOAD CASE : Ps+Pt Simultan.

PRELIMINARY CALCULATIONS

Tubesheet Analysis Thickness ea
ea = en - ct - cs = 55-3-3 = 49.00 mm

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T.1 U-tube sheet 05 Feb. 2010 12:10 ConnID:F.1 PC# 2

13.7.6 Determination of the Basic Ligament Efficiency (my) for Shear

$$m_y = (p - dt) / p \quad (13.7.6-1) = (26 - 19.05) / 26 = 0.2673$$

13.7.7 Determination of the Effective Ligament Efficiency (Mystar) for Bending

Tube Expansion Depth Ratio

$$r_o = I_{tx} / e_a \quad (13.7.7-3) = 40 / 49 = 0.8163$$

Effective Tube Hole Diameter (dstar)

$$d_{star} = \text{MAX}(dt - 2 \cdot et \cdot (Et/E) \cdot (ft/f) \cdot r_o, dt - 2 \cdot et) \quad (13.7.7-2)$$

$$= \text{MAX}(19.05 - 2 \cdot 2.108 \cdot (185057/185057) \cdot (77.87/82.93) \cdot 0.8163, 19.05 - 2 \cdot 2.108)$$

$$= 15.82 \text{ mm}$$

Effective Pitch Diameter (pstar)

$$p_{star} = p / \text{Sqr}(1 - 4 \cdot \text{MIN}(S, 4 \cdot Do \cdot p) / (\text{PI} \cdot Do^2)) \quad (13.7.7-4)$$

$$= 26 / \text{Sqr}(1 - 4 \cdot \text{MIN}(34000, 4 \cdot 590 \cdot 26) / (3.14 \cdot 590^2)) = 27.79 \text{ mm}$$

$$M_{ystar} = (p_{star} - d_{star}) / p_{star} \quad (13.7.7-1) = (27.79 - 15.82) / 27.79 = 0.4307$$

13.7.8 Determination of the Effective Elastic Constants Estar and vstar

$$E_{star}/E \text{ from figure 13.7.8-2a) } = 0.5001 (e/p = 1.88)$$

$$E_{star} = E_{star} \cdot E = 0.5001 \cdot 185057 = 92537.95 \text{ N/mm}^2$$

$$v_{star} \text{ from figure 13.7.8-2b) } = 0.3112 (e/p = 1.88)$$

13.7.9 Determination of the Effective Bending Rigidity of the Tubesheet Dstar

$$D_{star} = (E_{star} \cdot e_a^3) / (12 \cdot (1 - v_{star}^2)) \quad (13.7.9-1)$$

$$= (92537.95 \cdot 49^3) / (12 \cdot (1 - 0.3112^2)) = 1,0045E09 \text{ Nmm}$$

Diameter Ratios and Moment MTS

Diameter Ratio ros for Shell

$$r_{os} = G_s / Do \quad (13.4.4-2) = 657.15 / 590 = 1.11$$

Diameter Ratio roc for Channel

$$r_{oc} = G_c / Do \quad (13.4.4-4) = 657.15 / 590 = 1.11$$

Moment MTS due to Pressures Ps and Pt Acting on the Unperforated Tubesheet Rim

$$M_{TS} = Do^2 / 16 \cdot ((r_{os} - 1) \cdot (r_{os}^2 + 1) \cdot P_s - (r_{oc} - 1) \cdot (r_{oc}^2 + 1) \cdot P_t) \quad (13.4.4-5)$$

$$= 590^2 / 16 \cdot ((1.11 - 1) \cdot (1.11^2 + 1) \cdot 0.5 - (1.11 - 1) \cdot (1.11^2 + 1) \cdot 0.85) = -1941.81 \text{ Nmm/mm}$$

Diameter Ratio K

$$K = A / Do \quad (13.4.4-6) = 670 / 590 = 1.14$$

Coefficient F:

$$F = (1 - v_{star}) / E_{star} \cdot E \cdot \text{Log}(K) \quad (13.4.4-9)$$

$$= (1 - 0.3112) / 92537.95 \cdot 185057 \cdot \text{Log}(1.14) = 0.1751$$

Flange Design Bolt Load

$$W_{max} = \text{MAX}(W_s, W_c) \quad (13.4.4-11) = \text{MAX}(1201.03, 1201.03) = 1201.03 \text{ kN}$$

13.4.5 Tubesheet Design

13.4.5.1.1 Moment Mstar Acting on the Unperforated Tubesheet Rim

$$M_{star} = M_{TS} + W_{max} \cdot (G_c - G_s) / (2 \cdot \text{PI} \cdot Do) \quad (13.4.5-4)$$

$$= -1941.81 + 1201.03 \cdot (657.15 - 657.15) / (2 \cdot 3.14 \cdot 590) = -1941.81 \text{ Nmm/mm}$$

13.4.5.1.2 Moment Mp Acting at Periphery of Tubesheet

$$M_p = (M_{star} - Do^2 / 32 \cdot F \cdot (P_s - P_t)) / (1 + F) \quad (13.4.5-8)$$

$$= (-1941.81 - 590^2 / 32 \cdot 0.1751 \cdot (0.5 - 0.85)) / (1 + 0.1751) = -1084.94 \text{ Nmm/mm}$$

13.4.5.1.3 Moment Mo Acting at Centre of Tubesheet

$$M_o = M_p + Do^2 / 64 \cdot (3 + v_{star}) \cdot (P_s - P_t) \quad (13.4.5-9)$$

$$= -1084.94 + 590^2 / 64 \cdot (3 + 0.3112) \cdot (0.5 - 0.85) = -7388.39 \text{ Nmm/mm}$$

13.4.5.1.4 Maximum Bending Moment M Acting on the Tubesheet

$$M = \text{MAX}(\text{Abs}(M_p), \text{Abs}(M_o)) \quad (13.4.5-10)$$

$$= \text{MAX}(\text{Abs}(-1084.94), \text{Abs}(-7388.39)) = 7388.39 \text{ Nmm/mm}$$

13.4.5.2 Bending Stress in Tubesheet (Sigma)

$$\sigma = 6 \cdot M / (M_{ystar} \cdot (e_a - h_g)^2) \quad (13.4.5-11)$$

$$= 6 \cdot 7388.39 / (0.4307 \cdot (49 - 2)^2) = 46.60 \text{ N/mm}^2$$

»Bending Stress $\sigma = 46.6 \leq 2 \cdot f = 165.86 [\text{N/mm}^2]$ (13.4.5-12)«» (U= 28%) OK«

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-02 Operator : Rev.:A

EN13445:2009 Issue 1 - 13.4 U-Tube Tubesheet Heat Exchangers

T.1 U-tube sheet 05 Feb. 2010 12:10 ConnID:F.1 PC# 2

13.4.5.3 Shear Stress in Tubesheet (Tau)

$$\begin{aligned} \text{Tau} &= 0.25 * \text{Do} / (\text{my} * \text{ea}) * (\text{Ps} - \text{Pt}) && (13.4.5-13) \\ &= 0.25 * 590 / (0.2673 * 49) * (0.5 - 0.85) = && \underline{\underline{-3.94 \text{ N/mm}^2}} \end{aligned}$$

»Shear Stress Tau=3.94 <= 0.8 * f=66.34[N/mm2] (13.4.5-14)«» (U= 5.9%) OK«

MAXIMUM ALLOWABLE PRESSURE SUMMARY

Table MAWP SUMMARY FOR T.1 :

Description	P(MPa)	LimitedBy
Max.Allow.Test Pressure (tubeside)	4.43	Bending Stress
Max.Allow.Test Pressure(shellside)	4.42	Bending Stress
Max.Allow.Pressure Hot&Corroded(tubeside)	1.15	Bending Stress
Max.Allow.Pressure Hot&Corroded(shellside)	1.15	Bending Stress
Max.Allow.Pressure New&Cold(tubeside)	2.97	Bending Stress
Max.Allow.Pressure New&Cold(shellside)	2.97	Bending Stress

TEST PRESSURES

TEST PRESSURE ON TUBESIDE

$$\begin{aligned} \text{Pttmin} &= \text{MAX}(1.43 * \text{Ptd}, 1.25 * \text{Ptd} * \text{f20} / \text{f}) \\ &= \text{MAX}(1.43 * 0.85, 1.25 * 0.85 * 166.67 / 82.93) = && \underline{\underline{2.14 \text{ MPa}}} \end{aligned}$$

»Tubeside Test Pressure(limited by:Bending Stress) Pttmin=2.14 <= Pttmax=4.4336[MPa] «» OK«

TEST PRESSURE ON SHELLSIDE

$$\begin{aligned} \text{Ptsmin} &= \text{MAX}(1.43 * \text{Psd}, 1.25 * \text{Psd} * \text{f20} / \text{f}) \\ &= \text{MAX}(1.43 * 0.5, 1.25 * 0.5 * 166.67 / 82.93) = && \underline{\underline{1.26 \text{ MPa}}} \end{aligned}$$

»Shellside Test Pressure(limited by:Bending Stress) Ptsmin=1.26 <= Pttmax=4.42[MPa] «» OK«

CALCULATION SUMMARY

LOAD CASE : Pt Only(Ps=0)

13.4.5 Tubesheet Design

13.4.5.2 Bending Stress in Tubesheet (Sigma)

$$\begin{aligned} \text{Sigma} &= 6 * \text{M} / (\text{Mystar} * (\text{ea} - \text{hg}) ^ 2) && (13.4.5-11) \\ &= 6 * 20054.21 / (0.4307 * (49-2)^2) = && \underline{\underline{126.47 \text{ N/mm}^2}} \end{aligned}$$

»Bending Stress Sigma=126.47 <= 2 * f=165.86[N/mm2] (13.4.5-12)«» (U= 76.2%) OK«

13.4.5.3 Shear Stress in Tubesheet (Tau)

$$\begin{aligned} \text{Tau} &= 0.25 * \text{Do} / (\text{my} * \text{ea}) * (\text{Ps} - \text{Pt}) && (13.4.5-13) \\ &= 0.25 * 590 / (0.2673 * 49) * (-0.1 - 0.85) = && \underline{\underline{-10.70 \text{ N/mm}^2}} \end{aligned}$$

»Shear Stress Tau=10.7 <= 0.8 * f=66.34[N/mm2] (13.4.5-14)«» (U= 16.1%) OK«

LOAD CASE : Ps Only(Pt=0)

13.4.5 Tubesheet Design

13.4.5.2 Bending Stress in Tubesheet (Sigma)

$$\begin{aligned} \text{Sigma} &= 6 * \text{M} / (\text{Mystar} * (\text{ea} - \text{hg}) ^ 2) && (13.4.5-11) \\ &= 6 * 12665.82 / (0.4307 * (49-2)^2) = && \underline{\underline{79.88 \text{ N/mm}^2}} \end{aligned}$$

»Bending Stress Sigma=79.88 <= 2 * f=165.86[N/mm2] (13.4.5-12)«» (U= 48.1%)OK«

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-02 Operator : Rev.:A

EN13445:2009 Issue 1 - 13.4 U-Tube Tubesheet Heat Exchangers

T.1 U-tube sheet 05 Feb. 2010 12:10 ConnID:F.1 PC# 2

13.4.5.3 Shear Stress in Tubesheet (Tau)

$$\begin{aligned} \text{Tau} &= 0.25 * \text{Do} / (\text{my} * \text{ea}) * (\text{Ps} - \text{Pt}) && (13.4.5-13) \\ &= 0.25 * 590 / (0.2673 * 49) * (0.5 - 0.1) = && \underline{\underline{6.76 \text{ N/mm}^2}} \end{aligned}$$

»Shear Stress Tau=6.76 <= 0.8 * f=66.34[N/mm2] (13.4.5-14)«» (U= 10.1%) OK«

LOAD CASE : Ps+Pt Simultan.

13.4.5 Tubesheet Design

13.4.5.2 Bending Stress in Tubesheet (Sigma)

$$\begin{aligned} \text{Sigma} &= 6 * \text{M} / (\text{Mystar} * (\text{ea} - \text{hg}) ^ 2) && (13.4.5-11) \\ &= 6 * 7388.39 / (0.4307 * (49 - 2) ^ 2) = && \underline{\underline{46.60 \text{ N/mm}^2}} \end{aligned}$$

»Bending Stress Sigma=46.6 <= 2 * f=165.86[N/mm2] (13.4.5-12)«» (U= 28%) OK«

13.4.5.3 Shear Stress in Tubesheet (Tau)

$$\begin{aligned} \text{Tau} &= 0.25 * \text{Do} / (\text{my} * \text{ea}) * (\text{Ps} - \text{Pt}) && (13.4.5-13) \\ &= 0.25 * 590 / (0.2673 * 49) * (0.5 - 0.85) = && \underline{\underline{-3.94 \text{ N/mm}^2}} \end{aligned}$$

»Shear Stress Tau=3.94 <= 0.8 * f=66.34[N/mm2] (13.4.5-14)«» (U= 5.9%) OK«

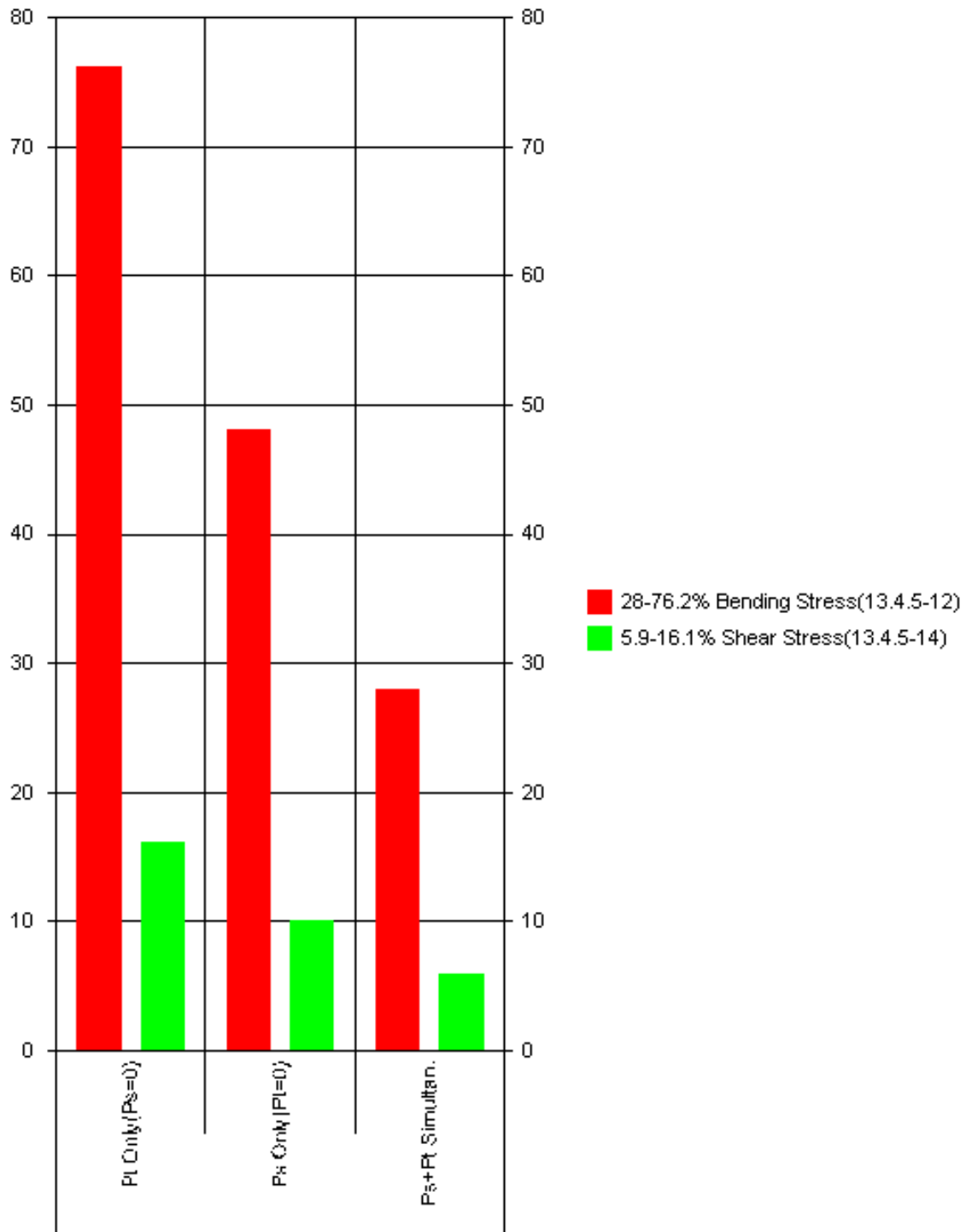
MAXIMUM ALLOWABLE PRESSURE SUMMARY

Table MAWP SUMMARY FOR T.1 :

Description	P(MPa)	LimitedBy
Max.Allow.Test Pressure (tubeside)	4.43	Bending Stress
Max.Allow.Test Pressure(shellside)	4.42	Bending Stress
Max.Allow.Pressure Hot&Corroded(tubeside)	1.15	Bending Stress
Max.Allow.Pressure Hot&Corroded(shellside)	1.15	Bending Stress
Max.Allow.Pressure New&Cold(tubeside)	2.97	Bending Stress
Max.Allow.Pressure New&Cold(shellside)	2.97	Bending Stress

Volume:0 m3 Weight:152 kg (SG= 7.85)

UTILIZATION CHART - T.1 U-TUBE SHEET



Max.Utilization/Condition 76.2% CASE:Pt Only(Ps=0)

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-01 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.4.2 CYLINDRICAL SHELL

TB.1 U-tube bundle 05 Feb. 2010 12:10 ConnID:T.1 PC# 2

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

Attachment: T.1 Tubesheet U-tube sheet F.1
Location: Along z-axis z1= 590

GENERAL DESIGN DATA

DESIGN PRESSURE.....:P 0.9500 MPa
EXTERNAL DESIGN PRESSURE.....:Pext 0.6000 MPa
CORROSION ALLOWANCE FOR TUBES.....:c 0.00 mm

TUBE BUNDLE DATA

U-Tube Tubesheet Heat Exchangers: YES
EN 10216-2:2002/A2:07, 1.0345 P235GH seamless tube, HT:N THK<=16mm 370'C
Rm=360 Rp=235 Rpt=116.8 f=77.87 f20=150 ftest=223.81 E=185095(N/mm2) ro=7.85
NOMINAL THICKNESS OF TUBES.....:et 2.11 mm
TUBE PITCH (Spacing between centers).....:p 26.00 mm
NOMINAL OUTSIDE DIAMETER OF TUBES.....:dt 19.05 mm
DIAMETER OF OUTER TUBE LIMIT CIRCLE.....:Do 590.00 mm
NUMBER OF TUBEHOLES IN TUBESHEET.....:Nt 340.00 piec
TUBE LENGTH BETWEEN INNER FACES OF TUBESHEETS.....:L 3945.00 mm
AS BUILT THICKNESS OF TUBESHEET (uncorroded).....:en 55.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE.....: 12.50 %
SAFETY FACTOR (1.0 carbon and 1.25 austenitic steels):s 1.00
MEAN RADIUS OF SMALLEST TUBE BEND.....:Rb 28.60 mm

DATA FOR BAFFLE PLATES

BAFFLE PLATES: Excluded

CALCULATION DATA

SECT. 7.4 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

Required Minimum Tube Thickness Excl.Allow. emin :
emin = De * P / (2 * f * z + P) (7.4-2)
=19.05*0.95/(2*77.87*1+0.95)= 0.1155 mm

TEMA C-2.31 Tube wall thickness thinning(%) due to bending of tube
thbend = (dt / (4 * Rb)) * 100 =(19.05/(4*28.6))*100= 16.65 %

Required Minimum Tube Thickness Incl.Allow. :
emina = (emin + c + th) * (1 + thbend / 100)
=(0.1155+0+0.2635)*(1+16.65/100)= 0.4421 mm

Analysis Thickness
ea = en / (1 + thbend / 100) - c - th
=2.108/(1+16.65/100)-0-0.2635= 1.54 mm

»Internal Pressure emina=0.4421 <= en=2.108[mm] « » (U= 20.9%) OK«

»7.4.1 Cond.of Applicability emin/De=0.0232 <= 0.16« » OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :

Inside Diameter of Tube
Di = De - 2 * ea =19.05-2*1.54= 15.96 mm

Mean Diameter of Tube
Dm = (De + Di) / 2 =(19.05+15.96)/2= 17.51 mm

MAWP HOT & CORR. (Corroded condition at design temp.)
MAWPHC = 2 * f * z * ea / Dm =2*77.87*1*1.54/17.51= 13.73 MPa

MAWP NEW & COLD (Uncorroded condition at ambient temp.)
MAWPNC = 2 * f20 * z * (ea + c) / Dm
=2*150*1*(1.54+0)/17.51= 26.45 MPa

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-01 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.4.2 CYLINDRICAL SHELL

TB.1 U-tube bundle 05 Feb. 2010 12:10 ConnID:T.1 PC# 2

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

$$P_{tmax} = 2 * f_{test} * (ea + c) / D_m$$
$$= 2 * 223.81 * (1.54 + 0) / 17.51 =$$

39.47 MPa

EN13445-5;10.2.3.3 REQUIRED MIN.HYDROSTATIC TEST PRESSURE:P_{tmin}

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3

$$P_{tmin} = 1.25 * P_d * f_{20} / f = 1.25 * 0.95 * 150 / 77.87 =$$
$$P_{tmin} = 1.43 * P_d = 1.43 * 0.95 =$$

2.29 MPa

1.36 MPa

»Test Pressure P_{tmin}=2.29 <= P_{tmax}=39.47[MPa] « » (U= 5.7%) OK«

SECT. 8.5 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

8.4.2 Nominal Elastic Limit Sige:

$$S_{ige} = R_{pt} (8.4.2-1) = 116.8 =$$

116.80 N/mm²

Preliminary Calculations

$$R = D_m / 2 = 17.51 / 2 = 8.75 \text{ mm}$$
$$Z = \pi * R / L (8.5.2-7) = 3.14 * 8.75 / 3945 = 0.0070$$
$$\Delta = 1.28 / \text{Sqr}(R * ea) (8.5.3-20) = 1.28 / \text{Sqr}(8.75 * 1.54) = 0.3482$$

gamma = 0 for No Stiffeners

DETERMINATION OF eps FROM FIGURE 8.5-3 :

eps is a minimum when n=2
eps (from fig. 8.5-3) = 0.008543

MEMBRANE YIELD p_y

$$p_y = S_{ige} * ea / (R * (1 - \gamma * G))$$
$$= 116.8 * 1.54 / (8.75 * (1 - 0 * 0)) =$$

(8.5.3-15)

20.60 MPa

ELASTIC INSTABILITY p_e

$$p_m = E * ea * \epsilon_s / R (8.5.2-5) = 1.851E05 * 1.54 * 0.0085 / 8.75 =$$

278.87 MPa

MAX. ALLOWABLE EXTERNAL PRESSURE P_{max}

Value p_r/p_y From Figure 8.5-5 Curve 1

$$\text{Value1} = 0.9585$$
$$p_r = \text{Value1} * p_y = 0.9585 * 20.6 = 19.74 \text{ MPa}$$

Max. Allowable External Pressure

$$P_{max} = p_r / k = 19.74 / 1.5 =$$

0.9585

19.74 MPa

13.16 MPa

»External Pressure P_{max}=13.16 >= P_{ext}=0.6[MPa] « » (U= 4.5%) OK«

Max. External Test Pressure

Max. External Test Pressure (Uncorroded cond.at ambient temp.)

$$P_{temax} = P_{r1} / 1.1 = 39.45 / 1.1 =$$

35.86 MPa

CALCULATION SUMMARY

SECT. 7.4 - CYLINDRICAL SHELLS UNDER INTERNAL PRESSURE

Required Minimum Tube Thickness Excl.Allow. e_{min} :

$$e_{min} = D_e * P / (2 * f * z + P)$$
$$= 19.05 * 0.95 / (2 * 77.87 * 1 + 0.95) =$$

(7.4-2)

0.1155 mm

Required Minimum Tube Thickness Incl.Allow. :

$$e_{mina} = (e_{min} + c + th) * (1 + th_{bend} / 100)$$
$$= (0.1155 + 0 + 0.2635) * (1 + 16.65 / 100) =$$

0.4421 mm

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-01 Operator : Rev.:A

EN13445:2009 Issue 1 - 7.4.2 CYLINDRICAL SHELL

TB.1 U-tube bundle 05 Feb. 2010 12:10 ConnID:T.1 PC# 2

»Internal Pressure $e_{min}=0.4421 \leq e_n=2.108[\text{mm}]$ « » (U= 20.9%) OK«

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

$P_{tmax} = 2 * f_{test} * (e_a + c) / D_m$

$= 2 * 223.81 * (1.54 + 0) / 17.51 =$

39.47 MPa

EN13445-5;10.2.3.3 REQUIRED MIN.HYDROSTATIC TEST PRESSURE: P_{tmin}

NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3

$P_{tmin} = 1.25 * P_d * f_{20} / f = 1.25 * 0.95 * 150 / 77.87 =$

2.29 MPa

$P_{tmin} = 1.43 * P_d = 1.43 * 0.95 =$

1.36 MPa

»Test Pressure $P_{tmin}=2.29 \leq P_{tmax}=39.47[\text{MPa}]$ « » (U= 5.7%) OK«

SECT. 8.5 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

Max. Allowable External Pressure

$P_{max} = p_r / k = 19.74 / 1.5 =$

13.16 MPa

»External Pressure $P_{max}=13.16 \geq P_{ext}=0.6[\text{MPa}]$ « » (U= 4.5%) OK«

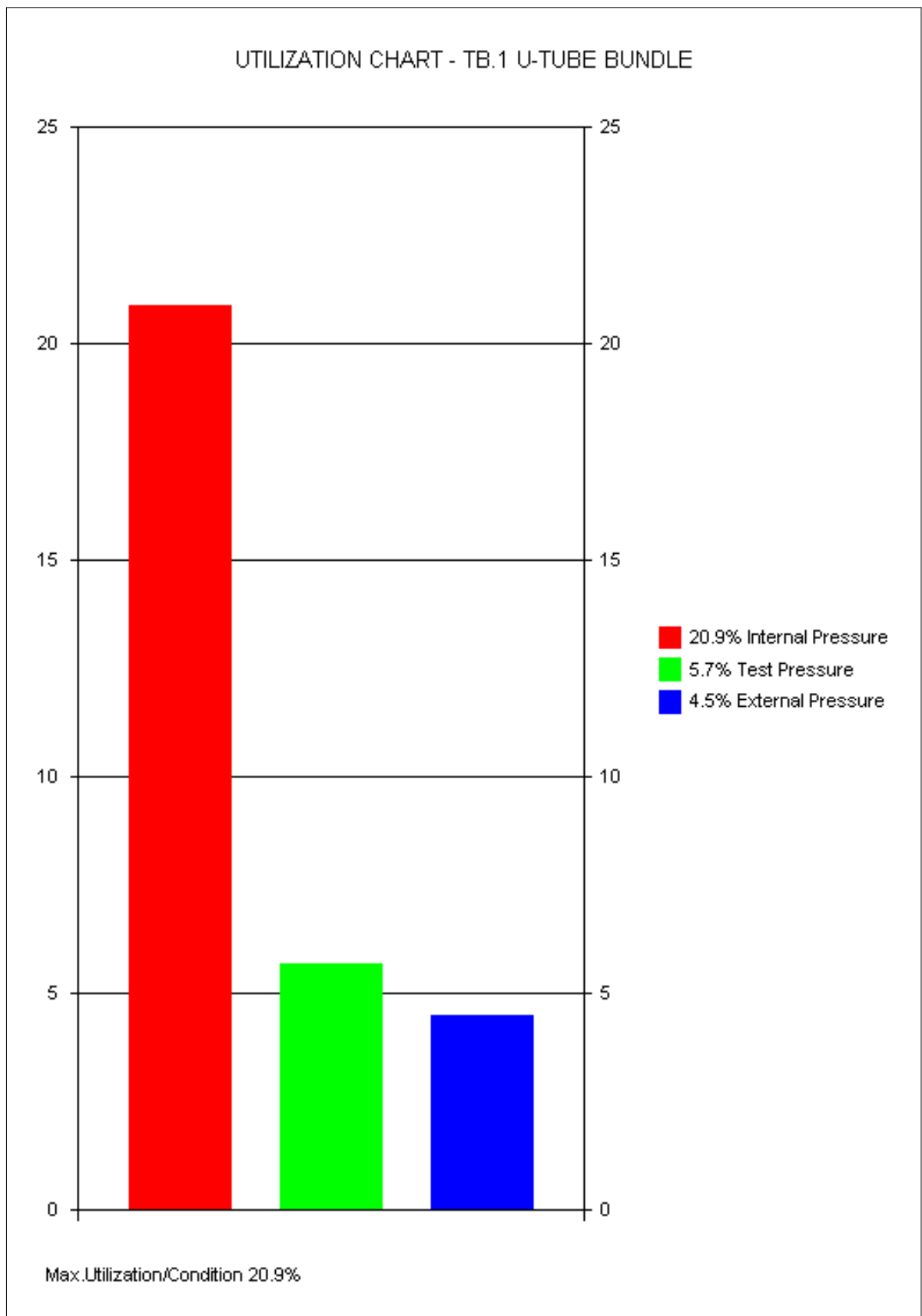
Max. External Test Pressure

Max. External Test Pressure (Uncorroded cond.at ambient temp.)

$P_{tmax} = P_{r1} / 1.1 = 39.45 / 1.1 =$

35.86 MPa

Volume:0.24 m³ Weight:1214.3 kg (SG= 7.85)



Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 16.8 HORIZONTAL VESSELS ON SADDLE SUPPORTS

SS.1 Fixed Saddle 05 Feb. 2010 12:10 ConnID:S1.3 PC# 1

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

Attachment: S1.3 Cylindrical Shell Shell L=4030 S2.1
 z-location of Centroid of Saddle/Ring Support.....:z 1347.00 mm

GENERAL DESIGN DATA

Load Analysis: Detailed Load Analysis Included(wind, seismic, blast etc.)
 Type of Support: Saddle with Shell NOT Stiffened by Rings
 PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm

SHELL DATA

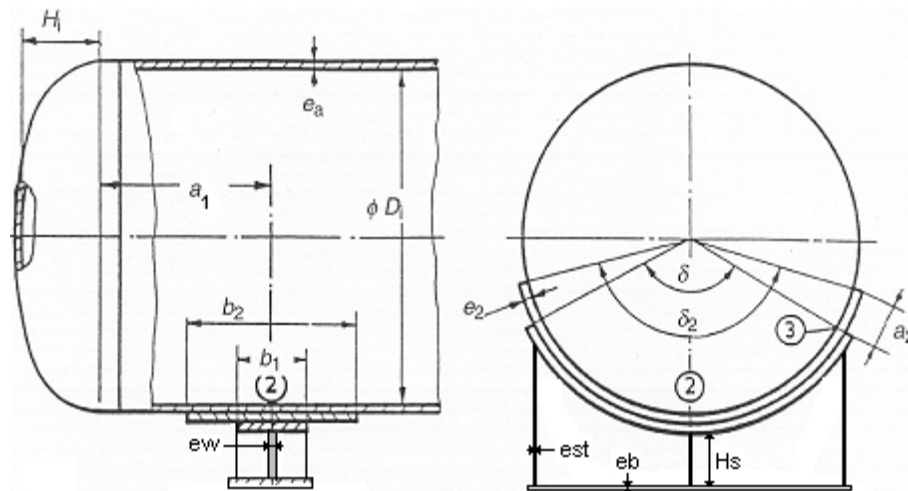
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
 Rm=410 Rp=265 Rpt=194.12 fs=129.41 f20=170.83 ftest=252.38 E=196147(N/mm²) ro=7.85
 OUTSIDE DIAMETER OF SHELL.....:De 864.00 mm
 AS BUILT WALL THICKNESS (uncorroded).....:en 12.00 mm
 NEGATIVE TOLERANCE/THINNING ALLOWANCE.....:th 0.5000 mm
 MAXIMUM ALLOWABLE EXTERNAL PRESSURE.....:Pmax 0.4041 MPa
 WELD JOINT COEFFICIENT.....:z 0.8500
 SAFETY FACTOR (1.0 carbon and 1.25 austenitic steels):s 1.00

SADDLE LOCATION/END DATA

DIST.FROM SADDLE SUPPORT TO ADJACENT END OF CYL.PART:a1 164.00 mm
 LENGTH OF CYLINDRICAL PART OF SHELL (TAN/TAN).....:L 4065.00 mm
 Z-location for the 2nd. saddle.....:z2 4247.00 mm
 Design This Saddle Type: For use at both z-locations

SADDLE GEOMETRY

INCLUDED ANGLE OF SADDLE SUPPORT (degrees).....:Delta 120.00 degr.
 AXIAL WIDTH OF SADDLE OF SADDLE SUPPORT.....:b1 180.00 mm
 HEIGHT FROM SHELL OD TO BOTTOM OF SADDLE BASE PLATE.:Hs 350.00 mm
 THICKNESS OF SADDLE WEB/CENTER PLATE.....:ew 15.00 mm
 THICKNESS OF BASE PLATE.....:eb 20.00 mm
 THICKNESS OF STIFFENER PLATES.....:est 15.00 mm
 NUMBER OF EQVISPACED STIFFENER PLATES.....:no 4.00
 EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
 Rm=410 Rp=265 Rpt=194.12 f=129.41 f20=170.83 ftest=252.38 E=196147(N/mm²) ro=7.85



Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 16.8 HORIZONTAL VESSELS ON SADDLE SUPPORTS

SS.1 Fixed Saddle 05 Feb. 2010 12:10 ConnID:S1.3 PC# 1

DATA FOR REINFORCEMENT PLATE/WRAPPER PLATE

Saddle Reinforcement Wrapper Plate: Included
 INCLUDED ANGLE OF SADDLE REINFORCEMENT PLATE(degr.):Delta2 144.00 degr.
 AXIAL WIDTH OF SADDLE REINFORCEMENT/WRAPPER PLATE...:b2 250.00 mm
 THICKNESS OF SADDLE REINFORCEMENT/WRAPPER PLATE...:e2 12.00 mm
 EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
 Rm=410 Rp=265 Rpt=194.12 f2=129.41 f20=170.83 ftest=252.38 E=196147(N/mm2) ro=7.85

ANCHOR BOLT DATA

This Saddle: Fixed
 COEFFICIENT OF FRICTION BETW.BASE PLATE AND FOUNDATION:my 0.4500
 Perform Calculation of Anchor Bolts: NO
 ALLOWABLE FOUNDATION BEARING PRESSURE.....:Fba 3.00 N/mm2

GENERAL LOAD DATA

Wind Load: YES
 Type of Wind Load: User Defined - Wind Velocity
 WIND FORCE/VESSEL SHAPE/DRAG COEFFICIENT.....:Cf 0.8000
 WIND SPEED IN TRANSVERSE DIRECTION.....:Lw 25.00 m/s
 WIND SPEED IN THE AXIAL DIRECTION.....:Lwz 25.00 m/s
 Seismic Load: NO
 Acceleration Loads: NO
 Blast Pressure Load: NO

VESSEL COMPONENTS

Table COMPONENTS:

Description	ID	Do1(mm)	Do2(mm)	L(mm)	Thk(mm)	z1(mm)	z2(mm)	Kd_	A(m2)
Channel head	E3.1	624	-1	35	8.5	-197.6	0	1.5	0.01
Channel Shell	S1.1	624	624	450	10	0	450	1.5	0.28
Channel flange	F.1	624	760	85	10	450	535	1.5	0.06
U-tube sheet	T.1	670	670	55	55	535	590	1.5	0.04
Shell flange	F.2	624	760	85	10	590	675	1.5	0.06
Shell L=100 mm	S1.2	624	624	100	10	675	775	1.5	0.06
Shell reducer	S2.1	610	846	408	12	775	1183	1.5	0.3
Shell L=4030	S1.3	864	864	4030	12	1183	5213	1.5	3.48
Shell head	E3.2	864	1	35	10.5	5213	5473.1	1.5	0.02

Table COMPONENTS Continued

Description	Sp.Dens.	Weight(kg)	Vol(m3)	Material Name	fd	fa	fcd	fca
Channel head	7.85	32.3	0.04	EN 10028-2:2003	104	170.8	95.2	156
Channel Shell	7.85	68.1	0.132	EN 10028-2:2003	104	170.8	96.1	158.2
Channel flange	7.85	59	0.025	ASME SA-105, PM	82.9	166.7	77.4	149.8
U-tube sheet	7.85	110	0	ASME SA-105, PM	82.9	166.7	81	160.7
Shell flange	7.85	59	0.025	ASME SA-105, PM	118.1	166.7	108.7	150.4
Shell L=100 mm	7.85	15.1	0.029	EN 10028-2:2003	129.4	170.8	118.6	158.8
Shell reducer	7.85	89.9	0.171	EN 10028-2:2003	129.4	170.8	119.9	161.1
Shell L=4030	7.85	1016.1	2.265	EN 10028-2:2003	129.4	170.8	117.5	157
Shell head	7.85	73.7	0.099	EN 10028-2:2003	129.4	170.8	116.3	155.1

Table COMPONENTS Continued

Description	E-Module	S
Channel head	185095.9	1
Channel Shell	185095.9	1
Channel flange	185095.9	1
U-tube sheet	185095.9	1
Shell flange	196147	1
Shell L=100 mm	196147	1
Shell reducer	196147	1
Shell L=4030	196147	1
Shell head	196147	1

DESIGN LOADS

Table DESIGN LOADS:

Load Description	ID	Fx-kN	Fy-kN	Fz-kN	Mx-kNm	My-kNm	Mz-kNm	x(mm)	y(mm)	z(mm)

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 16.8 HORIZONTAL VESSELS ON SADDLE SUPPORTS

SS.1 Fixed Saddle 05 Feb. 2010 12:10 ConnID:S1.3 PC# 1

LOAD CASES/COMBINATION

Table LOAD CASES:

Description	ID	Hydrotest	Oper.Wind
Wind Load	W	0.5	1.0
Seismic	S	0	0
Blast Load	B	0	0
Acceleration	A	0	0

LOAD CASE FACTORS

Table LOAD CASE FACTORS:

Description	ID	Hydrotest	Oper.Wind
Int.Pressure(MPa)	P	1	0.5
Ext.Pressure(MPa)	Pe	0	0.1
Temperature D/A	T	A	D
Corrosion (mm)	c	3	3
Stress M-Factor :	mf	1.425	1
Liquid Level (mm)	LL	FULL	200
Sp.Gravity (Liq.)	SG	1	0
Max.Deflection d/200	d	1	1

CALCULATION DATA

Total Length of Unit

LengthOverall = Abs(zmax - zmin) = Abs(5473--198) = 5671.00 mm

16.8.3 CONDITIONS OF APPLICABILITY

- »a) $en/Di=0.0142 \geq 0.001$ » OK«
- »a) $en/Di=0.0142 \leq 0.05$ » OK«
- »a) $\Delta=120 \geq 60[\text{Degr}]$ « » OK«
- »a) $\Delta=120 \leq 180[\text{Degr}]$ « » OK«
- »b) $e2=12 \geq en=12[\text{mm}]$ « » OK«
- »b) $a2=90.48 \geq 0.1*Di=84.7[\text{mm}]$ « » OK«

»c) The saddles are loaded vertically downwards

»d) If welding is not possible, care should be taken to ensure that the vessel is uniformly supported.

»e) If axial displacements are to be expected, one saddle shall be fixed to the foundation while the other saddle shall be free to move in the axial direction.»f) Required minimum distance from saddle to any other local load Lmin

100.8 mm

Saddle Width based on Included Angle of Support

$Lsw = De * \sin(\Delta / 2) = 864 * \sin(120/2) = 748.25 \text{ mm}$

Factor K9 from Table G.3.3-5 in PD5500, K9 = .204

LOAD CASE NO: 1 - HYDROTEST (z = 1347)

Summation of Total Loads for Load Case :HYDROTEST

Fi (Force in Vertical Direction)= ==	30.97 kN
Fht (Force in Transverse Direction)= ==	0.5574 kN
Fha (Force in Axial Direction)= ==	0.1832 kN
Qi (Shear Force)= ==	18.54 kN
Mi (Moment at Saddle)= ==	7843.57 kNm
Mij (Moment between Saddels)= ==	7843.57 kNm

LOAD DATA

Int.Pressure(MPa):P =1	Ext.Pressure(MPa):Pe=0
Temperature D/A:T =A	Corrosion (mm):c =3
Stress M-Factor :mf=1.425	Liquid Level (mm):LL=FULL
Sp.Gravity (Liq.):SG=1	Max.Deflection d/200:d=1

Transverse Bending Moment at Saddle Base Mt

$Mt = Fht * (De / 2 + Hs) = 0.5574 * (864/2 + 350) = 0.4359 \text{ kNm}$

Additional Vertical Force due to Horizontal Moment Mt

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$$FvMt = 3 * Mt / Lsw = 3 * 0.4359 / 748.25 = \underline{1.75 \text{ kN}}$$

Additional Vertical Force due to Axial Load Fva
 $Fva = Fha * (De / 2 + Hs) / \text{LengthBetweenSaddles}$
 $= 0.1832 * (864 / 2 + 350) / 2900 = \underline{0.0494 \text{ kN}}$

Total Vertical Force Fv
 $Fvtot = Fvi + FvMt + Fva = 30.97 + 1.75 + 0.0494 = \underline{32.77 \text{ kN}}$

NOTE: No thermal expansion is considered at ambient temperature, hence the friction coefficient is set to zero.

Longitudinal Bending Moment at Saddle Base Ml
 $Ml = ((Fvi + Fva) * my + Fha) * (De / 2 * (1 - \sin(\Delta)) * 3 / \pi) + Hs$
 $= ((30.97 + 0.0494) * 0 + 0.1832) * (864 / 2 * (1 - \sin(120)) * 3 / 3.14) + 350 = \underline{0.0778 \text{ kNm}}$

Stresses in Web Plate Due to Vertical Splitting Force

The saddle at lowest section must resist the horizontal forces.
The effective cross section of the saddle to resist this load is one third of the vessel radius.

Total Area Resisting Splitting Force
 $Atot = ew * \text{MIN}(De / 6, Hs) + e2 * b2$
 $= 15 * \text{MIN}(864 / 6, 350) + 12 * 250 = \underline{5160.00 \text{ mm}^2}$

Tensile Stress Sigt
 $Sigt = (Fvtot * K9 + Fht) / Atot$
 $= (32.77 * 0.204 + 0.5574) / 5160 = \underline{1.40 \text{ N/mm}^2}$

»Web Plate Stresses(Splitting Force) Sigt=1.4 <= fsw*2/3=168.25«» (U= .8%) OK«

Stresses in Saddle due to Axial Loads - RKF Part 3 BR-B2, 6.2(9&10)

Stresses at Saddle Base due to Longitudinal Moment Ml
 $SigBase = Ml / (Nos * est * b1 ^ 2 / 6)$
 $= 0.0778 / (4 * 15 * 180 ^ 2 / 6) = \underline{0.2402 \text{ N/mm}^2}$

»Saddle Stresses due to Axial Loads Sig=0.2402 <= fsw=252.38«» (U= 0%) OK«

Webplate Compression Check Against Buckling- AD2000 S3/2, 6.1.1/RKF Part 3 BR-B2, 6.1(5&6)

$be = 0.5 * De * (1 - \cos(0.5 * \Delta)) + Hs$
 $= 0.5 * 864 * (1 - \cos(0.5 * 120)) + 350 = \underline{566.00 \text{ mm}}$

Factor K13 from Table 7 / 15, K13 = 8.5
Stability Factor for Plate Buckling, Phi
 $\phi = 1 / \sqrt{1 + (150 * fsw / (Esw * K13) * (be / (10 * ew)) ^ 2) ^ 2}$
 $= 1 / \sqrt{1 + (150 * 252.38 / (196147 * 8.5) * (566. / (10 * 15)) ^ 2) ^ 2} = \underline{0.9515}$

Maximum Vertical Force on Webplate, Fwmax
 $Fwmax = Lsw / (Nos - 1) * ew * fsw * \phi$
 $= 748.25 / (4 - 1) * 15 * 252.38 * 0.9515 = \underline{898.43 \text{ kN}}$

»Webplate Buckling Fw=10922.1 <= Fwmax=8.9843E05« » (U= 1.2%) OK«

Foundation Bearing Pressure Pb
 $Pbearing = Fvtot / (b1 * Lsw) = 32.77 / (180 * 748.25) = \underline{0.2433 \text{ N/mm}^2}$

»Foundation Bearing Pressure Pbearing=0.2433 <= Fba=3« » (U= 8.1%) OK«

Distance Between Vertical Stiffeners Lw
 $Lw = Lsw / (Nos - 1) = 748.25 / (4 - 1) = \underline{249.42 \text{ mm}}$
 $K = 1.145 * 2 * Lw / b1 - 0.5 = 1.145 * 2 * 249.42 / 180 - 0.5 = \underline{2.67}$

Minimum Thickness of Baseplate ebmin (AD2000 S3/1)
 $ebmin = 0.5 * b1 * \text{SQR}(K * Pbearing / fsw)$
 $= 0.5 * 180 * \text{SQR}(2.67 * 0.2433 / 252.38) = \underline{4.57 \text{ mm}}$

»Baseplate Thickness eb=20 >= ebmin=4.57« » (U= 22.8%) OK«

$K11 = 5 / (0.10472 * \Delta * (Di / ea) ^ (1 / 3))$ (16.8-33)
 $= 5 / (0.10472 * 120 * (847 / 8.5) ^ (1 / 3)) = \underline{0.0858}$

Limit on axial width of reinforcement pad - blim
 $blim = K11 * Di + 1.5 * b1$ (16.8-32) $= 0.0858 * 847 + 1.5 * 180 = \underline{342.69 \text{ mm}}$

b2 = 250 mm is smaller than blim

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CALCULATION 1, ea = ea, b=b2, Delta=Delta2

PRELIMINARY CALCULATIONS

Shell Analysis Thickness eas
 $ea = en - c - th = 12 - 3 - 0.5 = 8.50$ mm
Shell Inside Diameter Di
 $Di = De - 2 * ea = 864 - 2 * 8.5 = 847.00$ mm
Mean Shell Diameter D
 $D = De - ea = 864 - 8.5 = 855.50$ mm
Mean Shell Radius R
 $R = D / 2 = 855.5 / 2 = 427.75$ mm
Allowable Global Shear Force Qmax when $L/R \leq 8.7 * \sqrt{Di/ea}$
 $Qtmp = 0.75 * \pi * R * ea * E * (ea / R)^{1.25 / 1.5}$
 $= 0.75 * 3.14 * 427.75 * 8.5 * 196147 * (8.5 / 427.75)^{1.25 / 1.5} = 8357.89$ kN
 $Qmax = Qtmp * \sqrt{R/L * (1 + 42 * (R/L)^3 * (ea/R)^{1.5})}$ (16.8-30)
 $= 8357.89 * \sqrt{427.75 / 4065 * (1 + 42 * (427.75 / 4065)^3 * (8.5 / 427.75)^{1.5})} = 2711.39$ kN

16.14.6 COMPRESSIVE STRESS LIMITS

$K = 1.21 * E * ea / (Sige * D)$ (16.14-15)
 $= 1.21 * 196147 * 8.5 / (265 * 855.5) = 8.90$
 $\alpha = 0.83 / \sqrt{1 + 0.005 * D / ea}$ (16.14-16)
 $= 0.83 / \sqrt{1 + 0.005 * 855.5 / 8.5} = 0.6770$
 $\delta = (1 - 0.4123 / (\alpha * K)^{0.6}) / S$ (16.14-19)
 $= (1 - 0.4123 / (0.677 * 8.9)^{0.6}) / 1.05 = 0.8187$
Maximum Allowable Compressive Stress
 $Sigcall = Sige * \delta$ (16.14-20) $= 265 * 0.8187 = 216.95$ N/mm2

16.14.4 PERMISSIBLE INDIVIDUAL LOADS

Maximum Tensile Force Ftmax
 $Ftmax = \pi * D * ea * f$ (16.14-1) $= 3.14 * 855.5 * 8.5 * 252.38 = 5765.59$ kN
Maximum Compressive Force Fcmax
 $Fcmax = \pi * D * ea * Sigcall$ (16.14-2) $= 3.14 * 855.5 * 8.5 * 216.95 = 4956.29$ kN
Maximum Bending Moment Mmax
 $Mmax = \pi / 4 * D^2 * ea * Sigcall$ (16.14-3)
 $= 3.14 / 4 * 855.5^2 * 8.5 * 216.95 = 1060.03$ kNm

16.8.6 LOAD LIMIT FOR THE SHELL BETWEEN SADDLES

16.8.6.1 Vessels under internal pressure or no pressure

$x = L / Di = 4065 / 847 = 4.80$
 $y = Di / ea = 847 / 8.5 = 99.65$
K12 from figure 16.8-12 = 1.258
a) Strength Calculation
 $fact = P * Di / (4 * ea) + 4 * Abs(Mij) * K12 / (\pi * Di^2 * ea)$
 $= 1 * 847 / (4 * 8.5) + 4 * Abs(7843.57) * 1.26 / (3.14 * 847^2 * 8.5) = 26.97$ N/mm2

»Vessel Stress Btwn.Saddles $fact=26.97 \leq fs=252.38$ (16.8-10)« (U= 10.6%) OK«

b) Instability Check

$Inst = Abs(Mij) / (1000 * Mmax)$
 $= Abs(7843.57) / (1000 * 1060.03) = 0.0074$

»Instability Check Btwn.Saddles $Inst=0.0074 \leq 1.0=1$ « (U= .7%) OK«

16.8.6.2 Vessels under external pressure

»Instability Check $P=0$ (Not Applicable) $Inst=0 \leq 1.0=1$ (16.8-14)« (U= 0%) OK«

Parameters gamma and beta

$\gamma = 2.83 * (a1 / Di) * \sqrt{ea / Di}$ (16.8-15)
 $= 2.83 * (164 / 847) * \sqrt{8.5 / 847} = 0.0549$
 $\beta = 0.91 * b1 / \sqrt{Di * ea}$ (16.8-16)
 $= 0.91 * 250 / \sqrt{847 * 8.5} = 2.68$

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Values for factors K3 to K11 from fig.16.8-7 to 16.8-12

K3 = 0.250 K4 = 0.396 K5 = 0.831 K6 = 0.021
K7 = 0.388 K8 = 0.206 K9 = 0.621 K10 = 0.326
Ratio v1 at location 2
v12 = $-0.23 * K6 * K8 / (K5 * K3)$
= $-0.23 * 0.021 * 0.2056 / (0.8307 * 0.25) = -0.0048$
Ratio v1 at location 3
v13 = $-0.53 * K4 / (K7 * K9 * K10 * \sin(0.5 * \Delta))$
= $-0.53 * 0.3958 / (0.3883 * 0.6215 * 0.3264 * \sin(0.5 * 144)) = -2.80$
Ratio v2 at location 2 when P=0
v212 = $-4 * Mi / (\pi * Di^2 * ea * K2 * fs)$
= $-4 * 7843.57 / (3.14 * 847^2 * 8.5 * 1.05 * 252.38) = -0.0062$
Ratio v2 at location 3 when P=0
v213 = 0 = 0 = 0.00
Ratio v2 at location 2 when P > 0
v222 = $(P * Di / (4 * ea) - 4 * Mi / (\pi * Di^2 * ea)) * 1 / (K2 * fs)$
= $(1 * 847 / (4 * 8.5) - 4 * 7843.57 / (3.14 * 847^2 * 8.5)) * 1 / (1.05 * 252.38) = 0.0878$
Ratio v2 at location 3 when P > 0
v223 = $(P * Di / (2 * ea)) * 1 / (K2 * fs)$
= $(1 * 847 / (2 * 8.5)) * 1 / (1.05 * 252.38) = 0.1880$

16.6.5 Bending Stress Limit

K1 at location 2 (from figure 16.6-1) = 1.486
Sigball2 = $K1 * K2 * fs = 1.49 * 1.05 * 252.38 = 393.92$
K1 at location 3 (from figure 16.6-1) = 0.317
Sigball3 = $K1 * K2 * fs = 0.3171 * 1.05 * 252.38 = 84.03$

Maximum Allowable Saddle Load at Location 2, F2max

F2max = $0.7 * Sigball2 * \sqrt{Di * ea} * ea / (K3 * K5)$
= $0.7 * 393.92 * \sqrt{847 * 8.5} * 8.5 / (0.25 * 0.8307) = 957.66 \text{ kN}$

Maximum Allowable Saddle Load at Location 3, F3max

F3max = $0.9 * Sigball3 * \sqrt{Di * ea} * ea / (K7 * K9 * K10)$
= $0.9 * 84.03 * \sqrt{847 * 8.5} * 8.5 / (0.3883 * 0.6215 * 0.3264) = 692.45 \text{ kN}$

»Max.Saddle Forces Fvtot=32766.31 <= Min(F2max, F3max)=6.9245E05« (U= 4.7%) OK«

Equivalent Global Axial Force Feq

Feq = $Fvtot * \pi / 4 * \sqrt{Di / ea} * K6 * K8$
= $32.77 * 3.14 / 4 * \sqrt{847 / 8.5} * 0.021 * 0.2056 = 1108.18 \text{ N}$

Instability Check

Inst = $P_{ext} / P_{max} + Mi / M_{max} + Feq / F_{max} + (Qi / Q_{max})^2$
= $0 / 0.4041 + 7843.57 / 1060.03 + 1108.18 / 4.9563E06 + (18.54 / 2711.39)^2 = 0.0077$
»Instability Check Inst_0=0.0077 <= 1.0=1(16.8-28)« » (U= .7%) OK«

CALCULATION 2, ea = ec, b=b1, Delta=Delta

PRELIMINARY CALCULATIONS

Combined Analysis Thickness ec, ea
ea = $\sqrt{(en - c - th)^2 + e^2 * \min(1, (f2 / fs)^2)}$
= $\sqrt{(12 - 3 - 0.5)^2 + 12^2 * \min(1, (129.41 / 129.41)^2)} = 14.71 \text{ mm}$
Shell Inside Diameter Di
Di = $De - 2 * (en - c - th) = 864 - 2 * (12 - 3 - 0.5) = 847.00 \text{ mm}$
Mean Diameter D
D = $Di + ea = 847 + 14.71 = 861.71 \text{ mm}$
Mean Shell Radius R
R = $D / 2 = 861.71 / 2 = 430.85 \text{ mm}$

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Parameters gamma and beta

$\gamma = 2.83 * (a1 / Di) * \text{Sqr}(ea / Di)$ (16.8-15)
= $2.83 * (164/847) * \text{Sqr}(14.71/847) =$ 0.0722
 $\beta = 0.91 * b1 / \text{Sqr}(Di * ea)$ (16.8-16)
= $0.91 * 180 / \text{Sqr}(847 * 14.71) =$ 1.47

Values for factors K3 to K11 from fig.16.8-7 to 16.8-12

K3 = 0.250 K4 = 0.665 K5 = 0.981 K6 = 0.346
K7 = 0.634 K8 = 0.309 K9 = 0.613 K10 = 0.492
Ratio v1 at location 2
 $v12 = -0.23 * K6 * K8 / (K5 * K3)$
= $-0.23 * 0.3464 * 0.3095 / (0.9815 * 0.25) =$ -0.1005
Ratio v1 at location 3
 $v13 = -0.53 * K4 / (K7 * K9 * K10 * \text{Sin}(0.5 * \Delta))$
= $-0.53 * 0.6652 / (0.6344 * 0.613 * 0.4923 * \text{Sin}(0.5 * 120)) =$ -2.13
Ratio v2 at location 2 when P=0
 $v212 = -4 * Mi / (\text{PI} * Di^2 * ea * K2 * fs)$
= $-4 * 7843.57 / (3.14 * 847^2 * 14.71 * 1.05 * 252.38) =$ -0.0036
Ratio v2 at location 3 when P=0
 $v213 = 0 = 0 =$ 0.00
Ratio v2 at location 2 when P<>0
 $v222 = (P * Di / (4 * ea) - 4 * Mi / (\text{PI} * Di^2 * ea)) * 1 / (K2 * fs)$
= $(1 * 847 / (4 * 14.71) - 4 * 7843.57 / (3.14 * 847^2 * 14.71)) * 1 / (1.05 * 252.38) =$ 0.0508
Ratio v2 at location 3 when P<>0
 $v223 = (P * Di / (2 * ea)) * 1 / (K2 * fs)$
= $(1 * 847 / (2 * 14.71)) * 1 / (1.05 * 252.38) =$ 0.1087

16.6.5 Bending Stress Limit

K1 at location 2 (from figure 16.6-1) = 1.443
 $\text{Sigball2} = K1 * K2 * fs = 1.44 * 1.05 * 252.38 =$ 382.27
K1 at location 3 (from figure 16.6-1) = 0.402
 $\text{Sigball3} = K1 * K2 * fs = 0.4023 * 1.05 * 252.38 =$ 106.61

Maximum Allowable Saddle Load at Location 2, F2max

$F2max = 0.7 * \text{Sigball2} * \text{Sqr}(Di * ea) * ea / (K3 * K5)$
= $0.7 * 382.27 * \text{Sqr}(847 * 14.71) * 14.71 / (0.25 * 0.9815) =$ 1789.79 kN

Maximum Allowable Saddle Load at Location 3, F3max

$F3max = 0.9 * \text{Sigball3} * \text{Sqr}(Di * ea) * ea / (K7 * K9 * K10)$
= $0.9 * 106.61 * \text{Sqr}(847 * 14.71) * 14.71 / (0.6344 * 0.613 * 0.4923) =$ 822.54 kN

»Max.Saddle Forces(ea=ec) Fvtot=32766.31 <= Min(F2max, F3max)=8.2254E05«» (U= 3.9%) OK«

LOAD CASE NO: 2 - OPER.WIND (z = 1347)

Summation of Total Loads for Load Case :OPER.WIND

Fi (Force in Vertical Direction) = == 18.16 kN
Fht (Force in Transverse Direction) = == 1.11 kN
Fha (Force in Axial Direction) = == 0.3664 kN
Qi (Shear Force) = == 10.72 kN
Mi (Moment at Saddle) = == 4786.64 kNm
Mij (Moment between Saddels) = == 4786.64 kNm

LOAD DATA

Int.Pressure(MPa):P =0.5 Ext.Pressure(MPa):Pe=0.1
Temperature D/A:T =D Corrosion (mm):c =3
Stress M-Factor ::mf=1 Liquid Level (mm):LL=200
Sp.Gravity (Liq.):SG=0 Max.Deflection d/200:d=1

Transverse Bending Moment at Saddle Base Mt

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Mt = Fht * (De / 2 + Hs) = 1.11*(864/2+350)= 0.8717 kNm
Additional Vertical Force due to Horizontal Moment Mt
FvMt = 3 * Mt / Lsw = 3*0.8717/748.25= 3.50 kN
Additional Vertical Force due to Axial Load Fva
Fva = Fha * (De / 2 + Hs) / LengthBetweenSaddles
= 0.3664*(864/2+350)/2900= 0.0988 kN
Total Vertical Force Fv
Fvtot = Fvi + FvMt + Fva = 18.16+3.5+0.0988= 21.76 kN
Longitudinal Bending Moment at Saddle Base Ml
Ml = ((Fvi+Fva)*my+Fha)*(De/2*(1-Sin(Delta)*3/PI)+Hs)
= ((18.16+0.0988)*0.45+0.3664)*(864/2*(1-Sin(120)*3/3.14)+350)= 3.65 kNm

Stresses in Web Plate Due to Vertical Splitting Force

The saddle at lowest section must resist the horizontal forces.
The effective cross section of the saddle to resist this load is one third of the vessel radius.

Total Area Resisting Splitting Force
Atot = ew * MIN(De / 6, Hs) + e2 * b2
= 15*MIN(864/6, 350)+12*250= 5160.00 mm2
Tensile Stress Sigt
Sigt = (Fvtot * K9 + Fht) / Atot
= (21.76*0.204+1.11)/5160= 1.08 N/mm2

»Web Plate Stresses(Splitting Force) Sigt=1.08 <= fsw*2/3=113.89« (U= .9%)OK«

Stresses in Saddle due to Axial Loads - RKF Part 3 BR-B2, 6.2(9&10)

Stresses at Saddle Base due to Longitudinal Moment Ml
SigBase = Ml / (Nos * est * b1 ^ 2 / 6)
= 3.65/(4*15*180^2/6)= 11.25 N/mm2

»Saddle Stresses due to Axial Loads Sigt=11.25 <= fsw=170.83« (U= 6.5%) OK«

Webplate Compression Check Against Buckling- AD2000 S3/2, 6.1.1/RKF Part 3 BR-B2, 6.1(5&6)

be = 0.5 * De * (1 - Cos(0.5 * Delta)) + Hs
= 0.5*864*(1-Cos(0.5*120))+350= 566.00 mm
Factor K13 from Table 7 / 15, K13 = 8.5
Stability Factor for Plate Buckling, Phi
phi = 1/Sqr(1+(150*fsw/(Esw*K13)*(be/(10*ew))^2)^2)
= 1/Sqr(1+(150*170.83/(196147*8.5)*(566./(10*15))^2)^2)= 0.9769
Maximum Vertical Force on Webplate, Fwmax
Fwmax = Lsw / (Nos - 1) * ew * fsw * phi
= 748.25/(4-1)*15*170.83*0.9769= 624.34 kN

»Webplate Buckling Fw=7252.19 <= Fwmax=6.2434E05« » (U= 1.1%) OK«

Foundation Bearing Pressure Pb
Pbearing = Fvtot / (b1 * Lsw) = 21.76/(180*748.25)= 0.1615 N/mm2

»Foundation Bearing Pressure Pbearing=0.1615 <= Fba=3« » (U= 5.3%) OK«

Distance Between Vertical Stiffeners Lw
Lw = Lsw / (Nos - 1) = 748.25/(4-1)= 249.42 mm
K = 1.145 * 2 * Lw / b1 - 0.5 = 1.145*2*249.42/180-0.5= 2.67
Minimum Thickness of Baseplate ebmin (AD2000 S3/1)
ebmin = 0.5 * b1 * SQR(K * Pbearing / fsw)
= 0.5*180*SQR(2.67*0.1615/170.83)= 4.52 mm

»Baseplate Thickness eb=20 >= ebmin=4.52« » (U= 22.6%) OK«

K11 = 5 / (0.10472 * Delta * (Di / ea) ^ (1 / 3)) (16.8-33)
= 5/(0.10472*120*(847/8.5)^(1/3))= 0.0858

Limit on axial width of reinforcement pad - blim
blim = K11 * Di + 1.5 * b1 (16.8-32) = 0.0858*847+1.5*180= 342.69 mm

b2 = 250 mm is smaller than blim

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CALCULATION 1, ea = ea, b=b2, Delta=Delta2

PRELIMINARY CALCULATIONS

Shell Analysis Thickness eas
 $ea = en - c - th = 12 - 3 - 0.5 = 8.50 \text{ mm}$
Shell Inside Diameter Di
 $Di = De - 2 * ea = 864 - 2 * 8.5 = 847.00 \text{ mm}$
Mean Shell Diameter D
 $D = De - ea = 864 - 8.5 = 855.50 \text{ mm}$
Mean Shell Radius R
 $R = D / 2 = 855.5 / 2 = 427.75 \text{ mm}$
Allowable Global Shear Force Qmax when $L/R \leq 8.7 * \sqrt{Di/ea}$
 $Qtmp = 0.75 * \pi * R * ea * E * (ea / R)^{1.25 / 1.5}$
 $= 0.75 * 3.14 * 427.75 * 8.5 * 196147 * (8.5 / 427.75)^{1.25 / 1.5} = 8357.89 \text{ kN}$
 $Qmax = Qtmp * \sqrt{R/L * (1 + 42 * (R/L)^3 * (ea/R)^{1.5})}$ (16.8-30)
 $= 8357.89 * \sqrt{427.75 / 4065 * (1 + 42 * (427.75 / 4065)^3 * (8.5 / 427.75)^{1.5})} = 2711.39 \text{ kN}$

16.14.6 COMPRESSIVE STRESS LIMITS

$K = 1.21 * E * ea / (Sige * D)$ (16.14-15)
 $= 1.21 * 196147 * 8.5 / (194.12 * 855.5) = 12.15$
 $\alpha = 0.83 / \sqrt{1 + 0.005 * D / ea}$ (16.14-16)
 $= 0.83 / \sqrt{1 + 0.005 * 855.5 / 8.5} = 0.6770$
 $\delta = (1 - 0.4123 / (\alpha * K)^{0.6}) / S$ (16.14-19)
 $= (1 - 0.4123 / (0.677 * 12.15)^{0.6}) / 1.5 = 0.5890$
Maximum Allowable Compressive Stress
 $Sigcall = Sige * \delta$ (16.14-20) $= 194.12 * 0.589 = 114.34 \text{ N/mm}^2$

16.14.4 PERMISSIBLE INDIVIDUAL LOADS

Maximum Tensile Force Ftmax
 $Ftmax = \pi * D * ea * f$ (16.14-1) $= 3.14 * 855.5 * 8.5 * 129.41 = 2956.36 \text{ kN}$
Maximum Compressive Force Fcmax
 $Fcmax = \pi * D * ea * Sigcall$ (16.14-2) $= 3.14 * 855.5 * 8.5 * 114.34 = 2612.13 \text{ kN}$
Maximum Bending Moment Mmax
 $Mmax = \pi / 4 * D^2 * ea * Sigcall$ (16.14-3)
 $= 3.14 / 4 * 855.5^2 * 8.5 * 114.34 = 558.67 \text{ kNm}$

16.8.6 LOAD LIMIT FOR THE SHELL BETWEEN SADDLES

16.8.6.1 Vessels under internal pressure or no pressure

$x = L / Di = 4065 / 847 = 4.80$
 $y = Di / ea = 847 / 8.5 = 99.65$
 $K12$ from figure 16.8-12 = 1.258
a) Strength Calculation
 $fact = P * Di / (4 * ea) + 4 * Abs(Mij) * K12 / (\pi * Di^2 * ea)$
 $= 0.5 * 847 / (4 * 8.5) + 4 * Abs(4786.64) * 1.26 / (3.14 * 847^2 * 8.5) = 13.71 \text{ N/mm}^2$

»Vessel Stress Btw.Saddles $fact = 13.71 \leq fs = 129.41$ (16.8-10)« (U= 10.5%) OK«

b) Instability Check

$Inst = Abs(Mij) / (1000 * Mmax)$
 $= Abs(4786.64) / (1000 * 558.67) = 0.0086$

»Instability Check Btw.Saddles $Inst = 0.0086 \leq 1.0 = 1$ « (U= .8%) OK«

16.8.6.2 Vessels under external pressure

b) Instability Check (with P=0)

$Inst = Abs(Pext) / Pmax + Abs(Mij) / (1000 * Mmax)$
 $= Abs(0.1) / 0.4041 + Abs(4786.64) / (1000 * 558.67) = 0.2560$

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»Instability Check Inst=0.256 <= 1.0=1(16.8-14)« » (U= 25.6%) OK«

Parameters gamma and beta

$$\begin{aligned} \text{gamma} &= 2.83 * (a1 / Di) * \text{Sqr}(ea / Di) && (16.8-15) \\ &= 2.83 * (164/847) * \text{Sqr}(8.5/847) = && 0.0549 \\ \text{beta} &= 0.91 * b1 / \text{Sqr}(Di * ea) && (16.8-16) \\ &= 0.91 * 250 / \text{Sqr}(847 * 8.5) = && 2.68 \end{aligned}$$

Values for factors K3 to K11 from fig.16.8-7 to 16.8-12

$$\begin{aligned} K3 &= 0.250 & K4 &= 0.396 & K5 &= 0.831 & K6 &= 0.021 \\ K7 &= 0.388 & K8 &= 0.206 & K9 &= 0.621 & K10 &= 0.326 \\ \text{Ratio v1 at location 2} \\ v12 &= -0.23 * K6 * K8 / (K5 * K3) \\ &= -0.23 * 0.021 * 0.2056 / (0.8307 * 0.25) = && -0.0048 \\ \text{Ratio v1 at location 3} \\ v13 &= -0.53 * K4 / (K7 * K9 * K10 * \text{Sin}(0.5 * \text{Delta})) \\ &= -0.53 * 0.3958 / (0.3883 * 0.6215 * 0.3264 * \text{Sin}(0.5 * 144)) = && -2.80 \\ \text{Ratio v2 at location 2 when P=0} \\ v212 &= -4 * Mi / (\text{PI} * Di ^ 2 * ea * K2 * fs) \\ &= -4 * 4786.64 / (3.14 * 847 ^ 2 * 8.5 * 1.25 * 129.41) = && -0.0062 \\ \text{Ratio v2 at location 3 when P=0} \\ v213 &= 0 = 0 = && 0.00 \\ \text{Ratio v2 at location 2 when P<>0} \\ v222 &= (P * Di / (4 * ea) - 4 * Mi / (\text{PI} * Di ^ 2 * ea)) * 1 / (K2 * fs) \\ &= (0.5 * 847 / (4 * 8.5) - 4 * 4786.64 / (3.14 * 847 ^ 2 * 8.5)) * 1 / (1.25 * 129.41) = && 0.0708 \\ \text{Ratio v2 at location 3 when P<>0} \\ v223 &= (P * Di / (2 * ea)) * 1 / (K2 * fs) \\ &= (0.5 * 847 / (2 * 8.5)) * 1 / (1.25 * 129.41) = && 0.1540 \end{aligned}$$

16.6.5 Bending Stress Limit

$$\begin{aligned} K1 \text{ at location 2 (from figure 16.6-1)} &= 1.491 \\ \text{Sigball2} &= K1 * K2 * fs = 1.49 * 1.25 * 129.41 = && \underline{\underline{241.17}} \\ K1 \text{ at location 3 (from figure 16.6-1)} &= 0.317 \\ \text{Sigball3} &= K1 * K2 * fs = 0.3171 * 1.25 * 129.41 = && \underline{\underline{51.29}} \end{aligned}$$

Maximum Allowable Saddle Load at Location 2, F2max

$$\begin{aligned} F2_{\text{max}} &= 0.7 * \text{Sigball2} * \text{Sqr}(Di * ea) * ea / (K3 * K5) \\ &= 0.7 * 241.17 * \text{Sqr}(847 * 8.5) * 8.5 / (0.25 * 0.8307) = && \underline{\underline{586.31 \text{ kN}}} \end{aligned}$$

Maximum Allowable Saddle Load at Location 3, F3max

$$\begin{aligned} F3_{\text{max}} &= 0.9 * \text{Sigball3} * \text{Sqr}(Di * ea) * ea / (K7 * K9 * K10) \\ &= 0.9 * 51.29 * \text{Sqr}(847 * 8.5) * 8.5 / (0.3883 * 0.6215 * 0.3264) = && \underline{\underline{422.69 \text{ kN}}} \end{aligned}$$

»Max.Saddle Forces Fvtot=21756.57 <= Min(F2max, F3max)=4.2269E05«» (U= 5.1%) OK«

Equivalent Global Axial Force Feq

$$\begin{aligned} Feq &= Fvtot * \text{PI} / 4 * \text{Sqr}(Di / ea) * K6 * K8 \\ &= 21.76 * 3.14 / 4 * \text{Sqr}(847 / 8.5) * 0.021 * 0.2056 = && 735.82 \text{ N} \end{aligned}$$

Instability Check

$$\begin{aligned} \text{Inst} &= P_{\text{ext}} / P_{\text{max}} + Mi / M_{\text{max}} + Feq / F_{\text{max}} + (Qi / Q_{\text{max}})^2 \\ &= 0.1 / 0.4041 + 4786.64 / 558.67 + 735.82 / 2.6121E06 + (10.72 / 2711.39)^2 = && 0.2563 \\ \text{»Instability Check Inst}_0 &= 0.2563 <= 1.0 = 1(16.8-28) \text{«} && \text{» (U= 25.6%) OK«} \end{aligned}$$

CALCULATION 2, ea = ec, b=b1, Delta=Delta

PRELIMINARY CALCULATIONS

$$\begin{aligned} \text{Combined Analysis Thickness } ec, ea \\ ea &= \text{Sqr}((en - c - th)^2 + e2^2 * \text{MIN}(1, (f2 / fs)^2)) \\ &= \text{Sqr}((12 - 3 - 0.5)^2 + 12^2 * \text{MIN}(1, (129.41 / 129.41)^2)) = && 14.71 \text{ mm} \\ \text{Shell Inside Diameter } Di \\ Di &= De - 2 * (en - c - th) = 864 - 2 * (12 - 3 - 0.5) = && 847.00 \text{ mm} \end{aligned}$$

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Mean Diameter D
 $D = D_i + e_a = 847 + 14.71 = 861.71 \text{ mm}$
 Mean Shell Radius R
 $R = D / 2 = 861.71 / 2 = 430.85 \text{ mm}$

Parameters gamma and beta

$\gamma = 2.83 * (a_1 / D_i) * \text{Sqr}(e_a / D_i) \quad (16.8-15)$
 $= 2.83 * (164 / 847) * \text{Sqr}(14.71 / 847) = 0.0722$
 $\beta = 0.91 * b_1 / \text{Sqr}(D_i * e_a) \quad (16.8-16)$
 $= 0.91 * 180 / \text{Sqr}(847 * 14.71) = 1.47$

Values for factors K3 to K11 from fig.16.8-7 to 16.8-12

$K_3 = 0.250 \quad K_4 = 0.665 \quad K_5 = 0.981 \quad K_6 = 0.346$
 $K_7 = 0.634 \quad K_8 = 0.309 \quad K_9 = 0.613 \quad K_{10} = 0.492$
 Ratio v1 at location 2
 $v_{12} = -0.23 * K_6 * K_8 / (K_5 * K_3)$
 $= -0.23 * 0.3464 * 0.3095 / (0.9815 * 0.25) = -0.1005$
 Ratio v1 at location 3
 $v_{13} = -0.53 * K_4 / (K_7 * K_9 * K_{10} * \text{Sin}(0.5 * \Delta))$
 $= -0.53 * 0.6652 / (0.6344 * 0.613 * 0.4923 * \text{Sin}(0.5 * 120)) = -2.13$
 Ratio v2 at location 2 when P=0
 $v_{212} = -4 * M_i / (\text{PI} * D_i^2 * e_a * K_2 * f_s)$
 $= -4 * 4786.64 / (3.14 * 847^2 * 14.71 * 1.25 * 129.41) = -0.0036$
 Ratio v2 at location 3 when P=0
 $v_{213} = 0 = 0 = 0.00$
 Ratio v2 at location 2 when P<>0
 $v_{222} = (P * D_i / (4 * e_a) - 4 * M_i / (\text{PI} * D_i^2 * e_a)) * 1 / (K_2 * f_s)$
 $= (0.5 * 847 / (4 * 14.71) - 4 * 4786.64 / (3.14 * 847^2 * 14.71)) * 1 / (1.25 * 129.41) = 0.0409$
 Ratio v2 at location 3 when P<>0
 $v_{223} = (P * D_i / (2 * e_a)) * 1 / (K_2 * f_s)$
 $= (0.5 * 847 / (2 * 14.71)) * 1 / (1.25 * 129.41) = 0.0890$

16.6.5 Bending Stress Limit

K1 at location 2 (from figure 16.6-1) = 1.448
 $\text{Sigball2} = K_1 * K_2 * f_s = 1.45 * 1.25 * 129.41 = \underline{\underline{234.21}}$
 K1 at location 3 (from figure 16.6-1) = 0.402
 $\text{Sigball3} = K_1 * K_2 * f_s = 0.4023 * 1.25 * 129.41 = \underline{\underline{65.08}}$

Maximum Allowable Saddle Load at Location 2, F2max

$F_{2\text{max}} = 0.7 * \text{Sigball2} * \text{Sqr}(D_i * e_a) * e_a / (K_3 * K_5)$
 $= 0.7 * 234.21 * \text{Sqr}(847 * 14.71) * 14.71 / (0.25 * 0.9815) = \underline{\underline{1096.57 \text{ kN}}}$

Maximum Allowable Saddle Load at Location 3, F3max

$F_{3\text{max}} = 0.9 * \text{Sigball3} * \text{Sqr}(D_i * e_a) * e_a / (K_7 * K_9 * K_{10})$
 $= 0.9 * 65.08 * \text{Sqr}(847 * 14.71) * 14.71 / (0.6344 * 0.613 * 0.4923) = \underline{\underline{502.10 \text{ kN}}}$

»Max.Saddle Forces($e_a=e_c$) $F_{\text{vtot}}=21756.57 \leq \text{Min}(F_{2\text{max}}, F_{3\text{max}})=5.021\text{E}05\llcorner\llcorner$ (U= 4.3%) OK«

LOAD CASE NO: 1 - HYDROTEST (z = 4247)

Summation of Total Loads for Load Case :HYDROTEST

F_i (Force in Vertical Direction) = 26.12 kN
 F_{ht} (Force in Transverse Direction) = 0.5325 kN
 F_{ha} (Force in Axial Direction, Sliding Saddle $F_{ha}=0$) = 0.00 kN
 Q_i (Shear Force) = 15.84 kN
 M_i (Moment at Saddle) = 5378.67 kNm
 M_{ij} (Moment between Saddels) = 7843.57 kNm

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LOAD DATA

Int.Pressure(MPa):P =1
Temperature D/A:T =A
Stress M-Factor :mf=1.425
Sp.Gravity (Liq.):SG=1
Ext.Pressure(MPa):Pe=0
Corrosion (mm):c =3
Liquid Level (mm):LL=FULL
Max.Deflection d/200:d=1

Transverse Bending Moment at Saddle Base Mt
 $Mt = Fht * (De / 2 + Hs) = 0.5325 * (864/2 + 350) = 0.4164 \text{ kNm}$

Additional Vertical Force due to Horizontal Moment Mt
 $FvMt = 3 * Mt / Lsw = 3 * 0.4164 / 748.25 = 1.67 \text{ kN}$

Additional Vertical Force due to Axial Load Fva
 $Fva = Fha * (De / 2 + Hs) / \text{LengthBetweenSaddles} = 0 * (864/2 + 350) / 2900 = 0.00 \text{ kN}$

Total Vertical Force Fv
 $Fvtot = Fvi + FvMt + Fva = 26.12 + 1.67 + 0 = 27.79 \text{ kN}$

NOTE: No thermal expansion is considered at ambient temperature, hence the friction coefficient is set to zero.

Longitudinal Bending Moment at Saddle Base Ml
 $Ml = ((Fvi + Fva) * my + Fha) * (De / 2 * (1 - \sin(\Delta)) * 3 / \pi) + Hs = ((26.12 + 0) * 0 + 0) * (864 / 2 * (1 - \sin(120)) * 3 / 3.14) + 350 = 0.00 \text{ kNm}$

Stresses in Web Plate Due to Vertical Splitting Force

The saddle at lowest section must resist the horizontal forces.
The effective cross section of the saddle to resist this load is one third of the vessel radius.

Total Area Resisting Splitting Force
 $Atot = ew * \text{MIN}(De / 6, Hs) + e2 * b2 = 15 * \text{MIN}(864/6, 350) + 12 * 250 = 5160.00 \text{ mm}^2$

Tensile Stress Sigt
 $Sigt = (Fvtot * K9 + Fht) / Atot = (27.79 * 0.204 + 0.5325) / 5160 = 1.20 \text{ N/mm}^2$

»Web Plate Stresses(Splitting Force) Sigt=1.2 <= fsw*2/3=168.25«» (U= .7%) OK«

Stresses in Saddle due to Axial Loads - RKF Part 3 BR-B2, 6.2(9&10)

Stresses at Saddle Base due to Longitudinal Moment Ml
 $SigBase = Ml / (Nos * est * b1 ^ 2 / 6) = 0 / (4 * 15 * 180 ^ 2 / 6) = 0.00 \text{ N/mm}^2$

»Saddle Stresses due to Axial Loads Sigt=0 <= fsw=252.38« » (U= 0%) OK«

Webplate Compression Check Against Buckling- AD2000 S3/2, 6.1.1/RKF Part 3 BR-B2, 6.1(5&6)

$be = 0.5 * De * (1 - \cos(0.5 * \Delta)) + Hs = 0.5 * 864 * (1 - \cos(0.5 * 120)) + 350 = 566.00 \text{ mm}$

Factor K13 from Table 7 / 15, K13 = 8.5
Stability Factor for Plate Buckling, Phi
 $\phi = 1 / \sqrt{1 + (150 * fsw / (Esw * K13)) * (be / (10 * ew)) ^ 2} = 1 / \sqrt{1 + (150 * 252.38 / (196147 * 8.5)) * (566. / (10 * 15)) ^ 2} = 0.9515$

Maximum Vertical Force on Webplate, Fwmax
 $Fwmax = Lsw / (Nos - 1) * ew * fsw * \phi = 748.25 / (4 - 1) * 15 * 252.38 * 0.9515 = 898.43 \text{ kN}$

»Webplate Buckling Fw=9264.78 <= Fwmax=8.9843E05« » (U= 1%) OK«

Foundation Bearing Pressure Pb
 $Pbearing = Fvtot / (b1 * Lsw) = 27.79 / (180 * 748.25) = 0.2064 \text{ N/mm}^2$

»Foundation Bearing Pressure Pbearing=0.2064 <= Fba=3« » (U= 6.8%) OK«

Distance Between Vertical Stiffeners Lw
 $Lw = Lsw / (Nos - 1) = 748.25 / (4 - 1) = 249.42 \text{ mm}$
 $K = 1.145 * 2 * Lw / b1 - 0.5 = 1.145 * 2 * 249.42 / 180 - 0.5 = 2.67$

Minimum Thickness of Baseplate ebmin (AD2000 S3/1)
 $ebmin = 0.5 * b1 * \text{SQR}(K * Pbearing / fsw) = 0.5 * 180 * \text{SQR}(2.67 * 0.2064 / 252.38) = 4.21 \text{ mm}$

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»Baseplate Thickness $eb=20 \geq ebmin=4.21$ » (U= 21%) OK«

$$K11 = 5 / (0.10472 * \Delta * (Di / ea) ^ (1 / 3)) \quad (16.8-33)$$

$$= 5 / (0.10472 * 120 * (847 / 8.5) ^ (1 / 3)) = 0.0858$$

Limit on axial width of reinforcement pad - blim

$$blim = K11 * Di + 1.5 * b1 \quad (16.8-32) = 0.0858 * 847 + 1.5 * 180 = \underline{342.69 \text{ mm}}$$

b2 = 250 mm is smaller than blim

CALCULATION 1, ea = ea, b=b2, Delta=Delta2

PRELIMINARY CALCULATIONS

Shell Analysis Thickness eas

$$ea = en - c - th = 12 - 3 - 0.5 = 8.50 \text{ mm}$$

Shell Inside Diameter Di

$$Di = De - 2 * ea = 864 - 2 * 8.5 = 847.00 \text{ mm}$$

Mean Shell Diameter D

$$D = De - ea = 864 - 8.5 = 855.50 \text{ mm}$$

Mean Shell Radius R

$$R = D / 2 = 855.5 / 2 = 427.75 \text{ mm}$$

Allowable Global Shear Force Qmax when $L/R \leq 8.7 * \text{SQR}(Di/ea)$

$$Q_{tmp} = 0.75 * \text{PI} * R * ea * E * (ea / R) ^ {1.25 / 1.5} \\ = 0.75 * 3.14 * 427.75 * 8.5 * 196147 * (8.5 / 427.75) ^ {1.25 / 1.5} = 8357.89 \text{ kN}$$

$$Q_{max} = Q_{tmp} * \text{Sqr}(R/L * (1 + 42 * (R/L) ^ 3 * (ea/R) ^ 1.5)) \quad (16.8-30)$$

$$= 8357.89 * \text{Sqr}(427.75 / 4065 * (1 + 42 * (427.75 / 4065) ^ 3 * (8.5 / 427.75) ^ 1.5)) = \underline{2711.39 \text{ kN}}$$

16.14.6 COMPRESSIVE STRESS LIMITS

$$K = 1.21 * E * ea / (\text{Sige} * D) \quad (16.14-15)$$

$$= 1.21 * 196147 * 8.5 / (265 * 855.5) = 8.90$$

$$\text{alfa} = 0.83 / \text{Sqr}(1 + 0.005 * D / ea) \quad (16.14-16)$$

$$= 0.83 / \text{Sqr}(1 + 0.005 * 855.5 / 8.5) = 0.6770$$

$$\text{delta} = (1 - 0.4123 / (\text{alfa} * K) ^ 0.6) / S \quad (16.14-19)$$

$$= (1 - 0.4123 / (0.677 * 8.9) ^ 0.6) / 1.05 = 0.8187$$

Maximum Allowable Compressive Stress

$$\text{Sigcall} = \text{Sige} * \text{delta} \quad (16.14-20) = 265 * 0.8187 = \underline{216.95 \text{ N/mm}^2}$$

16.14.4 PERMISSIBLE INDIVIDUAL LOADS

Maximum Tensile Force Ftmax

$$F_{tmax} = \text{PI} * D * ea * f \quad (16.14-1) = 3.14 * 855.5 * 8.5 * 252.38 = \underline{5765.59 \text{ kN}}$$

Maximum Compressive Force Fcmax

$$F_{cmax} = \text{PI} * D * ea * \text{Sigcall} \quad (16.14-2) = 3.14 * 855.5 * 8.5 * 216.95 = \underline{4956.29 \text{ kN}}$$

Maximum Bending Moment Mmax

$$M_{max} = \text{PI} / 4 * D ^ 2 * ea * \text{Sigcall} \quad (16.14-3)$$

$$= 3.14 / 4 * 855.5 ^ 2 * 8.5 * 216.95 = \underline{1060.03 \text{ kNm}}$$

16.8.6 LOAD LIMIT FOR THE SHELL BETWEEN SADDLES

16.8.6.1 Vessels under internal pressure or no pressure

$$x = L / Di = 4065 / 847 = 4.80$$

$$y = Di / ea = 847 / 8.5 = 99.65$$

$$K12 \text{ from figure 16.8-12} = 1.258$$

a) Strength Calculation

$$\text{fact} = P * Di / (4 * ea) + 4 * \text{Abs}(Mij) * K12 / (\text{PI} * Di ^ 2 * ea)$$

$$= 1 * 847 / (4 * 8.5) + 4 * \text{Abs}(7843.57) * 1.26 / (3.14 * 847 ^ 2 * 8.5) = \underline{26.97 \text{ N/mm}^2}$$

»Vessel Stress Btw. Saddles $\text{fact}=26.97 \leq fs=252.38(16.8-10)$ « (U= 10.6%) OK«

b) Instability Check

$$\text{Inst} = \text{Abs}(Mij) / (1000 * Mmax)$$

$$= \text{Abs}(7843.57) / (1000 * 1060.03) = \underline{0.0074}$$

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»Instability Check Btwn.Saddles Inst=0.0074 <= 1.0=1« » (U= .7%) OK«

16.8.6.2 Vessels under external pressure

»Instability Check P=0 (Not Applicable) Inst=0 <= 1.0=1(16.8-14)«» (U= 0%) OK«

Parameters gamma and beta

$$\begin{aligned} \text{gamma} &= 2.83 * (a1 / Di) * \text{Sqr}(ea / Di) && (16.8-15) \\ &= 2.83 * (164/847) * \text{Sqr}(8.5/847) = && 0.0549 \\ \text{beta} &= 0.91 * b1 / \text{Sqr}(Di * ea) && (16.8-16) \\ &= 0.91 * 250 / \text{Sqr}(847 * 8.5) = && 2.68 \end{aligned}$$

Values for factors K3 to K11 from fig.16.8-7 to 16.8-12

$$\begin{aligned} K3 &= 0.250 & K4 &= 0.396 & K5 &= 0.831 & K6 &= 0.021 \\ K7 &= 0.388 & K8 &= 0.206 & K9 &= 0.621 & K10 &= 0.326 \\ \text{Ratio v1 at location 2} \\ v12 &= -0.23 * K6 * K8 / (K5 * K3) && -0.0048 \\ &= -0.23 * 0.021 * 0.2056 / (0.8307 * 0.25) = \\ \text{Ratio v1 at location 3} \\ v13 &= -0.53 * K4 / (K7 * K9 * K10 * \text{Sin}(0.5 * \text{Delta})) && -2.80 \\ &= -0.53 * 0.3958 / (0.3883 * 0.6215 * 0.3264 * \text{Sin}(0.5 * 144)) = \\ \text{Ratio v2 at location 2 when P=0} \\ v212 &= -4 * Mi / (\text{PI} * Di ^ 2 * ea * K2 * fs) && -0.0042 \\ &= -4 * 5378.67 / (3.14 * 847 ^ 2 * 8.5 * 1.05 * 252.38) = \\ \text{Ratio v2 at location 3 when P=0} \\ v213 &= 0 = 0 = && 0.00 \\ \text{Ratio v2 at location 2 when P<>0} \\ v222 &= (P * Di / (4 * ea) - 4 * Mi / (\text{PI} * Di ^ 2 * ea)) * 1 / (K2 * fs) && \\ &= (1 * 847 / (4 * 8.5) - 4 * 5378.67 / (3.14 * 847 ^ 2 * 8.5)) * 1 / (1.05 * 252.38) = && 0.0898 \\ \text{Ratio v2 at location 3 when P<>0} \\ v223 &= (P * Di / (2 * ea)) * 1 / (K2 * fs) && 0.1880 \\ &= (1 * 847 / (2 * 8.5)) * 1 / (1.05 * 252.38) = \end{aligned}$$

16.6.5 Bending Stress Limit

$$\begin{aligned} K1 \text{ at location 2 (from figure 16.6-1)} &= 1.486 \\ \text{Sigball2} &= K1 * K2 * fs = 1.49 * 1.05 * 252.38 = && \underline{\underline{393.77}} \\ K1 \text{ at location 3 (from figure 16.6-1)} &= 0.317 \\ \text{Sigball3} &= K1 * K2 * fs = 0.3171 * 1.05 * 252.38 = && \underline{\underline{84.03}} \end{aligned}$$

Maximum Allowable Saddle Load at Location 2, F2max

$$\begin{aligned} F2\text{max} &= 0.7 * \text{Sigball2} * \text{Sqr}(Di * ea) * ea / (K3 * K5) \\ &= 0.7 * 393.77 * \text{Sqr}(847 * 8.5) * 8.5 / (0.25 * 0.8307) = && \underline{\underline{957.30 \text{ kN}}} \end{aligned}$$

Maximum Allowable Saddle Load at Location 3, F3max

$$\begin{aligned} F3\text{max} &= 0.9 * \text{Sigball3} * \text{Sqr}(Di * ea) * ea / (K7 * K9 * K10) \\ &= 0.9 * 84.03 * \text{Sqr}(847 * 8.5) * 8.5 / (0.3883 * 0.6215 * 0.3264) = && \underline{\underline{692.45 \text{ kN}}} \end{aligned}$$

»Max.Saddle Forces Fvtot=27794.35 <= Min(F2max, F3max)=6.9245E05«» (U= 4%)OK«

Equivalent Global Axial Force Feq

$$\begin{aligned} F\text{eq} &= F\text{vtot} * \text{PI} / 4 * \text{Sqr}(Di / ea) * K6 * K8 \\ &= 27.79 * 3.14 / 4 * \text{Sqr}(847 / 8.5) * 0.021 * 0.2056 = && 940.03 \text{ N} \end{aligned}$$

Instability Check

$$\begin{aligned} \text{Inst} &= P\text{ext} / P\text{max} + Mi / M\text{max} + F\text{eq} / F\text{max} + (Qi / Q\text{max}) ^ 2 \\ &= 0 / 0.4041 + 5378.67 / 1060.03 + 940.03 / 4.9563E06 + (15.84 / 2711.39) ^ 2 = && 0.0053 \\ \text{»Instability Check Inst}_0 &= 0.0053 <= 1.0=1(16.8-28)« && \text{» (U= .5%) OK«} \end{aligned}$$

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CALCULATION 2, ea = ec, b=b1, Delta=Delta

PRELIMINARY CALCULATIONS

Combined Analysis Thickness ec, ea

$$ea = \text{Sqr}((en-c-th)^2 + e^2 * \text{MIN}(1, (f2/fs)^2)) \\ = \text{Sqr}((12-3-0.5)^2 + 12^2 * \text{MIN}(1, (129.41/129.41)^2)) = 14.71 \text{ mm}$$

Shell Inside Diameter Di

$$Di = De - 2 * (en - c - th) = 864 - 2 * (12 - 3 - 0.5) = 847.00 \text{ mm}$$

Mean Diameter D

$$D = Di + ea = 847 + 14.71 = 861.71 \text{ mm}$$

Mean Shell Radius R

$$R = D / 2 = 861.71 / 2 = 430.85 \text{ mm}$$

Parameters gamma and beta

$$\text{gamma} = 2.83 * (a1 / Di) * \text{Sqr}(ea / Di) \quad (16.8-15)$$

$$= 2.83 * (164 / 847) * \text{Sqr}(14.71 / 847) = 0.0722$$

$$\text{beta} = 0.91 * b1 / \text{Sqr}(Di * ea) \quad (16.8-16)$$

$$= 0.91 * 180 / \text{Sqr}(847 * 14.71) = 1.47$$

Values for factors K3 to K11 from fig.16.8-7 to 16.8-12

$$K3 = 0.250 \quad K4 = 0.665 \quad K5 = 0.981 \quad K6 = 0.346$$

$$K7 = 0.634 \quad K8 = 0.309 \quad K9 = 0.613 \quad K10 = 0.492$$

Ratio v1 at location 2

$$v12 = -0.23 * K6 * K8 / (K5 * K3) \\ = -0.23 * 0.3464 * 0.3095 / (0.9815 * 0.25) = -0.1005$$

Ratio v1 at location 3

$$v13 = -0.53 * K4 / (K7 * K9 * K10 * \text{Sin}(0.5 * \text{Delta})) \\ = -0.53 * 0.6652 / (0.6344 * 0.613 * 0.4923 * \text{Sin}(0.5 * 120)) = -2.13$$

Ratio v2 at location 2 when P=0

$$v212 = -4 * Mi / (\text{PI} * Di^2 * ea * K2 * fs) \\ = -4 * 5378.67 / (3.14 * 847^2 * 14.71 * 1.05 * 252.38) = -0.0024$$

Ratio v2 at location 3 when P=0

$$v213 = 0 = 0 = 0.00$$

Ratio v2 at location 2 when P<>0

$$v222 = (P * Di / (4 * ea) - 4 * Mi / (\text{PI} * Di^2 * ea)) * 1 / (K2 * fs) \\ = (1 * 847 / (4 * 14.71) - 4 * 5378.67 / (3.14 * 847^2 * 14.71)) * 1 / (1.05 * 252.38) = 0.0519$$

Ratio v2 at location 3 when P<>0

$$v223 = (P * Di / (2 * ea)) * 1 / (K2 * fs) \\ = (1 * 847 / (2 * 14.71)) * 1 / (1.05 * 252.38) = 0.1087$$

16.6.5 Bending Stress Limit

$$K1 \text{ at location 2 (from figure 16.6-1)} = 1.442$$

$$\text{Sigball2} = K1 * K2 * fs = 1.44 * 1.05 * 252.38 = \underline{\underline{382.11}}$$

$$K1 \text{ at location 3 (from figure 16.6-1)} = 0.402$$

$$\text{Sigball3} = K1 * K2 * fs = 0.4023 * 1.05 * 252.38 = \underline{\underline{106.61}}$$

Maximum Allowable Saddle Load at Location 2, F2max

$$F2\text{max} = 0.7 * \text{Sigball2} * \text{Sqr}(Di * ea) * ea / (K3 * K5) \\ = 0.7 * 382.11 * \text{Sqr}(847 * 14.71) * 14.71 / (0.25 * 0.9815) = \underline{\underline{1789.02 \text{ kN}}}$$

Maximum Allowable Saddle Load at Location 3, F3max

$$F3\text{max} = 0.9 * \text{Sigball3} * \text{Sqr}(Di * ea) * ea / (K7 * K9 * K10) \\ = 0.9 * 106.61 * \text{Sqr}(847 * 14.71) * 14.71 / (0.6344 * 0.613 * 0.4923) = \underline{\underline{822.54 \text{ kN}}}$$

»Max.Saddle Forces(ea=ec) Fvtot=27794.35 <= Min(F2max, F3max)=8.2254E05«» (U= 3.3%) OK«

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LOAD CASE NO: 2 - OPER.WIND (z = 4247)

Summation of Total Loads for Load Case :OPER.WIND

Fi (Force in Vertical Direction)= ==	11.76 kN
Fht (Force in Transverse Direction)= ==	1.07 kN
Fha (Force in Axial Direction, Sliding Saddle Fha=0)=	
==	0.00 kN
Qi (Shear Force)= ==	7.75 kN
Mi (Moment at Saddle)= ==	1965.55 kNmm
Mij (Moment between Saddels)= ==	4786.64 kNmm

LOAD DATA

Int.Pressure(MPa):P =0.5	Ext.Pressure(MPa):Pe=0.1
Temperature D/A:T =D	Corrosion (mm):c =3
Stress M-Factor :mf=1	Liquid Level (mm):LL=200
Sp.Gravity (Liq.):SG=0	Max.Deflection d/200:d=1

Transverse Bending Moment at Saddle Base Mt
 $Mt = Fht * (De / 2 + Hs) = 1.07 * (864 / 2 + 350) =$ 0.8328 kNm

Additional Vertical Force due to Horizontal Moment Mt
 $FvMt = 3 * Mt / Lsw = 3 * 0.8328 / 748.25 =$ 3.34 kN

Additional Vertical Force due to Axial Load Fva
 $Fva = Fha * (De / 2 + Hs) / LengthBetweenSaddles$
 $= 0 * (864 / 2 + 350) / 2900 =$ 0.00 kN

Total Vertical Force Fv
 $Fvtot = Fvi + FvMt + Fva = 11.76 + 3.34 + 0 =$ 15.09 kN

Longitudinal Bending Moment at Saddle Base Ml
 $Ml = ((Fvi + Fva) * my + Fha) * (De / 2 * (1 - Sin(Delta)) * 3 / PI + Hs)$
 $= ((11.76 + 0) * 0.45 + 0) * (864 / 2 * (1 - Sin(120)) * 3 / 3.14 + 350) =$ 2.25 kNm

Stresses in Web Plate Due to Vertical Splitting Force

The saddle at lowest section must resist the horizontal forces.
The effective cross section of the saddle to resist this load is one third of the vessel radius.

Total Area Resisting Splitting Force
 $Atot = ew * MIN(De / 6, Hs) + e2 * b2$
 $= 15 * MIN(864 / 6, 350) + 12 * 250 =$ 5160.00 mm²

Tensile Stress Sigt
 $Sigt = (Fvtot * K9 + Fht) / Atot$
 $= (15.09 * 0.204 + 1.07) / 5160 =$ 0.8032 N/mm²

»Web Plate Stresses(Splitting Force) Sigt=0.8032 <= fsw*2/3=113.89« (U= .7%) OK«

Stresses in Saddle due to Axial Loads - RKF Part 3 BR-B2, 6.2(9&10)

Stresses at Saddle Base due to Longitudinal Moment Ml
 $SigBase = Ml / (Nos * est * b1 ^ 2 / 6)$
 $= 2.25 / (4 * 15 * 180 ^ 2 / 6) =$ 6.93 N/mm²

»Saddle Stresses due to Axial Loads Sigt=6.93 <= fsw=170.83« (U= 4%) OK«

Webplate Compression Check Against Buckling- AD2000 S3/2, 6.1.1/RKF Part 3 BR-B2, 6.1(5&6)

$be = 0.5 * De * (1 - Cos(0.5 * Delta)) + Hs$
 $= 0.5 * 864 * (1 - Cos(0.5 * 120)) + 350 =$ 566.00 mm

Factor K13 from Table 7 / 15, K13 = 8.5
Stability Factor for Plate Buckling, Phi
 $phi = 1 / Sqr(1 + (150 * fsw / (Esw * K13) * (be / (10 * ew)) ^ 2) ^ 2)$
 $= 1 / Sqr(1 + (150 * 170.83 / (196147 * 8.5) * (566. / (10 * 15)) ^ 2) ^ 2) =$ 0.9769

Maximum Vertical Force on Webplate, Fwmax
 $Fwmax = Lsw / (Nos - 1) * ew * fsw * phi$
 $= 748.25 / (4 - 1) * 15 * 170.83 * 0.9769 =$ 624.34 kN

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»Webplate Buckling $F_w=5031.59 \leq F_{wmax}=6.2434E05$ « » (U= .8%) OK«

Foundation Bearing Pressure P_b
 $P_{bearing} = F_{vtot} / (b1 * L_{sw}) = 15.09 / (180 * 748.25) = 0.1121 \text{ N/mm}^2$

»Foundation Bearing Pressure $P_{bearing}=0.1121 \leq F_{ba}=3$ « » (U= 3.7%) OK«

Distance Between Vertical Stiffeners L_w
 $L_w = L_{sw} / (N_{os} - 1) = 748.25 / (4 - 1) = 249.42 \text{ mm}$
 $K = 1.145 * 2 * L_w / b1 - 0.5 = 1.145 * 2 * 249.42 / 180 - 0.5 = 2.67$
Minimum Thickness of Baseplate e_{bmin} (AD2000 S3/1)
 $e_{bmin} = 0.5 * b1 * \text{SQR}(K * P_{bearing} / f_{sw})$
 $= 0.5 * 180 * \text{SQR}(2.67 * 0.1121 / 170.83) = 3.77 \text{ mm}$

»Baseplate Thickness $e_b=20 \geq e_{bmin}=3.77$ « » (U= 18.8%) OK«

$K_{11} = 5 / (0.10472 * \Delta * (D_i / e_a)^{1/3}) = 16.8-33$
 $= 5 / (0.10472 * 120 * (847/8.5)^{1/3}) = 0.0858$

Limit on axial width of reinforcement pad - b_{lim}
 $b_{lim} = K_{11} * D_i + 1.5 * b1 = 0.0858 * 847 + 1.5 * 180 = 342.69 \text{ mm}$

$b_2 = 250 \text{ mm}$ is smaller than b_{lim}

CALCULATION 1, $e_a = e_a$, $b=b_2$, $\Delta=\Delta_2$

PRELIMINARY CALCULATIONS

Shell Analysis Thickness e_{as}
 $e_a = e_n - c - t_h = 12 - 3 - 0.5 = 8.50 \text{ mm}$
Shell Inside Diameter D_i
 $D_i = D_e - 2 * e_a = 864 - 2 * 8.5 = 847.00 \text{ mm}$
Mean Shell Diameter D
 $D = D_e - e_a = 864 - 8.5 = 855.50 \text{ mm}$
Mean Shell Radius R
 $R = D / 2 = 855.5 / 2 = 427.75 \text{ mm}$
Allowable Global Shear Force Q_{max} when $L/R \leq 8.7 * \text{SQR}(D_i / e_a)$
 $Q_{tmp} = 0.75 * \text{PI} * R * e_a * E * (e_a / R)^{1.25 / 1.5}$
 $= 0.75 * 3.14 * 427.75 * 8.5 * 196147 * (8.5 / 427.75)^{1.25 / 1.5} = 8357.89 \text{ kN}$
 $Q_{max} = Q_{tmp} * \text{Sqr}(R / L * (1 + 42 * (R / L)^3 * (e_a / R)^{1.5}))$ (16.8-30)
 $= 8357.89 * \text{Sqr}(427.75 / 4065 * (1 + 42 * (427.75 / 4065)^3 * (8.5 / 427.75)^{1.5})) = 2711.39 \text{ kN}$

16.14.6 COMPRESSIVE STRESS LIMITS

$K = 1.21 * E * e_a / (\text{Sige} * D)$ (16.14-15)
 $= 1.21 * 196147 * 8.5 / (194.12 * 855.5) = 12.15$
 $\alpha = 0.83 / \text{Sqr}(1 + 0.005 * D / e_a)$ (16.14-16)
 $= 0.83 / \text{Sqr}(1 + 0.005 * 855.5 / 8.5) = 0.6770$
 $\Delta = (1 - 0.4123 / (\alpha * K)^{0.6}) / S$ (16.14-19)
 $= (1 - 0.4123 / (0.677 * 12.15)^{0.6}) / 1.5 = 0.5890$
Maximum Allowable Compressive Stress
 $\text{Sigcall} = \text{Sige} * \Delta$ (16.14-20) $= 194.12 * 0.589 = 114.34 \text{ N/mm}^2$

16.14.4 PERMISSIBLE INDIVIDUAL LOADS

Maximum Tensile Force F_{tmax}
 $F_{tmax} = \text{PI} * D * e_a * f$ (16.14-1) $= 3.14 * 855.5 * 8.5 * 129.41 = 2956.36 \text{ kN}$
Maximum Compressive Force F_{cmax}
 $F_{cmax} = \text{PI} * D * e_a * \text{Sigcall}$ (16.14-2) $= 3.14 * 855.5 * 8.5 * 114.34 = 2612.13 \text{ kN}$
Maximum Bending Moment M_{max}
 $M_{max} = \text{PI} / 4 * D^2 * e_a * \text{Sigcall}$ (16.14-3)
 $= 3.14 / 4 * 855.5^2 * 8.5 * 114.34 = 558.67 \text{ kNm}$

16.8.6 LOAD LIMIT FOR THE SHELL BETWEEN SADDLES

16.8.6.1 Vessels under internal pressure or no pressure

$x = L / D_i = 4065 / 847 = 4.80$
 $y = D_i / e_a = 847 / 8.5 = 99.65$
 K_{12} from figure 16.8-12 = 1.258
a) Strength Calculation

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$$\text{fact} = P \cdot Di / (4 \cdot ea) + 4 \cdot \text{Abs}(Mij) \cdot K12 / (\pi \cdot Di^2 \cdot ea) \\ = 0.5 \cdot 847 / (4 \cdot 8.5) + 4 \cdot \text{Abs}(4786.64) \cdot 1.26 / (3.14 \cdot 847^2 \cdot 8.5) = \underline{\underline{13.71 \text{ N/mm}^2}}$$

»Vessel Stress Btwn.Saddles fact=13.71 <= fs=129.41(16.8-10)«» (U= 10.5%) OK«

b) Instability Check

$$\text{Inst} = \text{Abs}(Mij) / (1000 \cdot Mmax) \\ = \text{Abs}(4786.64) / (1000 \cdot 558.67) = \underline{\underline{0.0086}}$$

»Instability Check Btwn.Saddles Inst=0.0086 <= 1.0=1« » (U= .8%) OK«

16.8.6.2 Vessels under external pressure

b) Instability Check (with P=0)

$$\text{Inst} = \text{Abs}(Pext) / Pmax + \text{Abs}(Mij) / (1000 \cdot Mmax) \\ = \text{Abs}(0.1) / 0.4041 + \text{Abs}(4786.64) / (1000 \cdot 558.67) = \underline{\underline{0.2560}}$$

»Instability Check Inst=0.256 <= 1.0=1(16.8-14)« » (U= 25.6%) OK«

Parameters gamma and beta

$$\text{gamma} = 2.83 \cdot (a1 / Di) \cdot \text{Sqr}(ea / Di) \quad (16.8-15) \\ = 2.83 \cdot (164 / 847) \cdot \text{Sqr}(8.5 / 847) = 0.0549$$

$$\text{beta} = 0.91 \cdot b1 / \text{Sqr}(Di \cdot ea) \quad (16.8-16) \\ = 0.91 \cdot 250 / \text{Sqr}(847 \cdot 8.5) = 2.68$$

Values for factors K3 to K11 from fig.16.8-7 to 16.8-12

$$K3 = 0.250 \quad K4 = 0.396 \quad K5 = 0.831 \quad K6 = 0.021 \\ K7 = 0.388 \quad K8 = 0.206 \quad K9 = 0.621 \quad K10 = 0.326$$

Ratio v1 at location 2

$$v12 = -0.23 \cdot K6 \cdot K8 / (K5 \cdot K3) \\ = -0.23 \cdot 0.021 \cdot 0.2056 / (0.8307 \cdot 0.25) = -0.0048$$

Ratio v1 at location 3

$$v13 = -0.53 \cdot K4 / (K7 \cdot K9 \cdot K10 \cdot \text{Sin}(0.5 \cdot \text{Delta})) \\ = -0.53 \cdot 0.3958 / (0.3883 \cdot 0.6215 \cdot 0.3264 \cdot \text{Sin}(0.5 \cdot 144)) = -2.80$$

Ratio v2 at location 2 when P=0

$$v212 = -4 \cdot Mi / (\pi \cdot Di^2 \cdot ea \cdot K2 \cdot fs) \\ = -4 \cdot 1965.55 / (3.14 \cdot 847^2 \cdot 8.5 \cdot 1.25 \cdot 129.41) = -0.0025$$

Ratio v2 at location 3 when P=0

$$v213 = 0 = 0 = 0.00$$

Ratio v2 at location 2 when P<>0

$$v222 = (P \cdot Di / (4 \cdot ea) - 4 \cdot Mi / (\pi \cdot Di^2 \cdot ea)) \cdot 1 / (K2 \cdot fs) \\ = (0.5 \cdot 847 / (4 \cdot 8.5) - 4 \cdot 1965.55 / (3.14 \cdot 847^2 \cdot 8.5)) \cdot 1 / (1.25 \cdot 129.41) = 0.0745$$

Ratio v2 at location 3 when P<>0

$$v223 = (P \cdot Di / (2 \cdot ea)) \cdot 1 / (K2 \cdot fs) \\ = (0.5 \cdot 847 / (2 \cdot 8.5)) \cdot 1 / (1.25 \cdot 129.41) = 0.1540$$

16.6.5 Bending Stress Limit

K1 at location 2 (from figure 16.6-1)= 1.490

$$\text{Sigball}2 = K1 \cdot K2 \cdot fs = 1.49 \cdot 1.25 \cdot 129.41 = \underline{\underline{241.03}}$$

K1 at location 3 (from figure 16.6-1)= 0.317

$$\text{Sigball}3 = K1 \cdot K2 \cdot fs = 0.3171 \cdot 1.25 \cdot 129.41 = \underline{\underline{51.29}}$$

Maximum Allowable Saddle Load at Location 2, F2max

$$F2max = 0.7 \cdot \text{Sigball}2 \cdot \text{Sqr}(Di \cdot ea) \cdot ea / (K3 \cdot K5) \\ = 0.7 \cdot 241.03 \cdot \text{Sqr}(847 \cdot 8.5) \cdot 8.5 / (0.25 \cdot 0.8307) = \underline{\underline{585.97 \text{ kN}}}$$

Maximum Allowable Saddle Load at Location 3, F3max

$$F3max = 0.9 \cdot \text{Sigball}3 \cdot \text{Sqr}(Di \cdot ea) \cdot ea / (K7 \cdot K9 \cdot K10) \\ = 0.9 \cdot 51.29 \cdot \text{Sqr}(847 \cdot 8.5) \cdot 8.5 / (0.3883 \cdot 0.6215 \cdot 0.3264) = \underline{\underline{422.69 \text{ kN}}}$$

»Max.Saddle Forces Fvtot=15094.76 <= Min(F2max, F3max)=4.2269E05«» (U= 3.5%) OK«

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Equivalent Global Axial Force Feq

$$\text{Feq} = \text{Fvtot} * \text{PI} / 4 * \text{Sqr}(\text{Di} / \text{ea}) * \text{K6} * \text{K8}$$
$$= 15.09 * 3.14 / 4 * \text{Sqr}(847 / 8.5) * 0.021 * 0.2056 = 510.52 \text{ N}$$

Instability Check

$$\text{Inst} = \text{Pext} / \text{Pmax} + \text{Mi} / \text{Mmax} + \text{Feq} / \text{Fmax} + (\text{Qi} / \text{Qmax})^2$$
$$= 0.1 / 0.4041 + 1965.55 / 558.67 + 510.52 / 2.6121 \text{E}06 + (7.75 / 2711.39)^2 = 0.2512$$

»Instability Check Inst_0=0.2512 <= 1.0=1(16.8-28)« » (U= 25.1%) OK«

CALCULATION 2, ea = ec, b=b1, Delta=Delta

PRELIMINARY CALCULATIONS

Combined Analysis Thickness ec, ea

$$\text{ea} = \text{Sqr}((\text{en}-\text{c}-\text{th})^2 + \text{e}2^2 * \text{MIN}(1, (\text{f}2/\text{fs})^2))$$
$$= \text{Sqr}((12-3-0.5)^2 + 12^2 * \text{MIN}(1, (129.41/129.41)^2)) = 14.71 \text{ mm}$$

Shell Inside Diameter Di

$$\text{Di} = \text{De} - 2 * (\text{en} - \text{c} - \text{th}) = 864 - 2 * (12 - 3 - 0.5) = 847.00 \text{ mm}$$

Mean Diameter D

$$\text{D} = \text{Di} + \text{ea} = 847 + 14.71 = 861.71 \text{ mm}$$

Mean Shell Radius R

$$\text{R} = \text{D} / 2 = 861.71 / 2 = 430.85 \text{ mm}$$

Parameters gamma and beta

$$\text{gamma} = 2.83 * (\text{a1} / \text{Di}) * \text{Sqr}(\text{ea} / \text{Di}) \quad (16.8-15)$$
$$= 2.83 * (164 / 847) * \text{Sqr}(14.71 / 847) = 0.0722$$
$$\text{beta} = 0.91 * \text{b1} / \text{Sqr}(\text{Di} * \text{ea}) \quad (16.8-16)$$
$$= 0.91 * 180 / \text{Sqr}(847 * 14.71) = 1.47$$

Values for factors K3 to K11 from fig.16.8-7 to 16.8-12

$$\text{K3} = 0.250 \quad \text{K4} = 0.665 \quad \text{K5} = 0.981 \quad \text{K6} = 0.346$$
$$\text{K7} = 0.634 \quad \text{K8} = 0.309 \quad \text{K9} = 0.613 \quad \text{K10} = 0.492$$

Ratio v1 at location 2

$$\text{v12} = -0.23 * \text{K6} * \text{K8} / (\text{K5} * \text{K3})$$
$$= -0.23 * 0.3464 * 0.3095 / (0.9815 * 0.25) = -0.1005$$

Ratio v1 at location 3

$$\text{v13} = -0.53 * \text{K4} / (\text{K7} * \text{K9} * \text{K10} * \text{Sin}(0.5 * \text{Delta}))$$
$$= -0.53 * 0.6652 / (0.6344 * 0.613 * 0.4923 * \text{Sin}(0.5 * 120)) = -2.13$$

Ratio v2 at location 2 when P=0

$$\text{v212} = -4 * \text{Mi} / (\text{PI} * \text{Di}^2 * \text{ea} * \text{K2} * \text{fs})$$
$$= -4 * 1965.55 / (3.14 * 847^2 * 14.71 * 1.25 * 129.41) = -0.0015$$

Ratio v2 at location 3 when P=0

$$\text{v213} = 0 = 0 = 0.00$$

Ratio v2 at location 2 when P<>0

$$\text{v222} = (\text{P} * \text{Di} / (4 * \text{ea}) - 4 * \text{Mi} / (\text{PI} * \text{Di}^2 * \text{ea})) * 1 / (\text{K2} * \text{fs})$$
$$= (0.5 * 847 / (4 * 14.71) - 4 * 1965.55 / (3.14 * 847^2 * 14.71)) * 1 / (1.25 * 129.41) = 0.0430$$

Ratio v2 at location 3 when P<>0

$$\text{v223} = (\text{P} * \text{Di} / (2 * \text{ea})) * 1 / (\text{K2} * \text{fs})$$
$$= (0.5 * 847 / (2 * 14.71)) * 1 / (1.25 * 129.41) = 0.0890$$

16.6.5 Bending Stress Limit

K1 at location 2 (from figure 16.6-1) = 1.447

$$\text{Sigball2} = \text{K1} * \text{K2} * \text{fs} = 1.45 * 1.25 * 129.41 = 234.03$$

K1 at location 3 (from figure 16.6-1) = 0.402

$$\text{Sigball3} = \text{K1} * \text{K2} * \text{fs} = 0.4023 * 1.25 * 129.41 = 65.08$$

Maximum Allowable Saddle Load at Location 2, F2max

$$\text{F2max} = 0.7 * \text{Sigball2} * \text{Sqr}(\text{Di} * \text{ea}) * \text{ea} / (\text{K3} * \text{K5})$$
$$= 0.7 * 234.03 * \text{Sqr}(847 * 14.71) * 14.71 / (0.25 * 0.9815) = 1095.72 \text{ kN}$$

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Maximum Allowable Saddle Load at Location 3, F3max

$$F3max = 0.9 * Sigball13 * Sqr(Di * ea) * ea / (K7 * K9 * K10) \\ = 0.9 * 65.08 * Sqr(847 * 14.71) * 14.71 / (0.6344 * 0.613 * 0.4923) = \underline{\underline{502.10 \text{ kN}}}$$

»Max.Saddle Forces(ea=ec) Fvtot=15094.76 <= Min(F2max, F3max)=5.021E05« (U= 3%) OK«

CALCULATION SUMMARY

LOAD CASE NO: 1 - HYDROTEST (z = 1347)

Int.Pressure(MPa):P =1 Ext.Pressure(MPa):Pe=0
Temperature D/A:T =A Corrosion (mm):c =3
Stress M-Factor :mf=1.425 Liquid Level (mm):LL=FULL
Sp.Gravity (Liq.):SG=1 Max.Deflection d/200:d=1

»Web Plate Stresses(Splitting Force) Sig_t=1.4 <= fsw*2/3=168.25« (U= .8%) OK«

»Saddle Stresses due to Axial Loads Sig_t=0.2402 <= fsw=252.38« (U= 0%) OK«

»Webplate Buckling Fw=10922.1 <= Fwmax=8.9843E05« (U= 1.2%) OK«

»Foundation Bearing Pressure Pbearing=0.2433 <= Fba=3« (U= 8.1%) OK«

»Baseplate Thickness eb=20 >= ebmin=4.57« (U= 22.8%) OK«

CALCULATION 1, ea = ea, b=b2, Delta=Delta2

16.8.6 LOAD LIMIT FOR THE SHELL BETWEEN SADDLES

»Vessel Stress Btw.Saddles fact=26.97 <= fs=252.38(16.8-10)« (U= 10.6%) OK«

»Instability Check Btw.Saddles Inst=0.0074 <= 1.0=1« (U= .7%) OK«

»Instability Check P=0 (Not Applicable) Inst=0 <= 1.0=1(16.8-14)« (U= 0%) OK«

»Max.Saddle Forces Fvtot=32766.31 <= Min(F2max, F3max)=6.9245E05« (U= 4.7%) OK«

Instability Check

»Instability Check Inst_0=0.0077 <= 1.0=1(16.8-28)« (U= .7%) OK«

CALCULATION 2, ea = ec, b=b1, Delta=Delta

»Max.Saddle Forces(ea=ec) Fvtot=32766.31 <= Min(F2max, F3max)=8.2254E05« (U= 3.9%) OK«

LOAD CASE NO: 2 - OPER.WIND (z = 1347)

Int.Pressure(MPa):P =0.5 Ext.Pressure(MPa):Pe=0.1
Temperature D/A:T =D Corrosion (mm):c =3
Stress M-Factor :mf=1 Liquid Level (mm):LL=200
Sp.Gravity (Liq.):SG=0 Max.Deflection d/200:d=1

»Web Plate Stresses(Splitting Force) Sig_t=1.08 <= fsw*2/3=113.89« (U= .9%) OK«

»Saddle Stresses due to Axial Loads Sig_t=11.25 <= fsw=170.83« (U= 6.5%) OK«

»Webplate Buckling Fw=7252.19 <= Fwmax=6.2434E05« (U= 1.1%) OK«

»Foundation Bearing Pressure Pbearing=0.1615 <= Fba=3« (U= 5.3%) OK«

»Baseplate Thickness eb=20 >= ebmin=4.52« (U= 22.6%) OK«

CALCULATION 1, ea = ea, b=b2, Delta=Delta2

16.8.6 LOAD LIMIT FOR THE SHELL BETWEEN SADDLES

»Vessel Stress Btw.Saddles fact=13.71 <= fs=129.41(16.8-10)« (U= 10.5%) OK«

»Instability Check Btw.Saddles Inst=0.0086 <= 1.0=1« (U= .8%) OK«

»Instability Check Inst=0.256 <= 1.0=1(16.8-14)« (U= 25.6%) OK«

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 16.8 HORIZONTAL VESSELS ON SADDLE SUPPORTS

SS.1 Fixed Saddle 05 Feb. 2010 12:10 ConnID:S1.3 PC# 1

»Max.Saddle Forces Fvtot=21756.57 <= Min(F2max, F3max)=4.2269E05« (U= 5.1%) OK«

Instability Check

»Instability Check Inst_0=0.2563 <= 1.0=1(16.8-28)« » (U= 25.6%) OK«

CALCULATION 2, ea = ec, b=b1, Delta=Delta

»Max.Saddle Forces(ea=ec) Fvtot=21756.57 <= Min(F2max, F3max)=5.021E05« (U= 4.3%) OK«

LOAD CASE NO: 1 - HYDROTEST (z = 4247)

Int.Pressure(MPa):P =1

Ext.Pressure(MPa):Pe=0

Temperature D/A:T =A

Corrosion (mm):c =3

Stress M-Factor :mf=1.425

Liquid Level (mm):LL=FULL

Sp.Gravity (Liq.):SG=1

Max.Deflection d/200:d=1

»Web Plate Stresses(Splitting Force) Sigt=1.2 <= fsw*2/3=168.25« (U= .7%) OK«

»Saddle Stresses due to Axial Loads Sigt=0 <= fsw=252.38« » (U= 0%) OK«

»Webplate Buckling Fw=9264.78 <= Fwmax=8.9843E05« » (U= 1%) OK«

»Foundation Bearing Pressure Pbearing=0.2064 <= Fba=3« » (U= 6.8%) OK«

»Baseplate Thickness eb=20 >= ebmin=4.21« » (U= 21%) OK«

CALCULATION 1, ea = ea, b=b2, Delta=Delta2

16.8.6 LOAD LIMIT FOR THE SHELL BETWEEN SADDLES

»Vessel Stress Btwn.Saddles fact=26.97 <= fs=252.38(16.8-10)« (U= 10.6%) OK«

»Instability Check Btwn.Saddles Inst=0.0074 <= 1.0=1« » (U= .7%) OK«

»Instability Check P=0 (Not Applicable) Inst=0 <= 1.0=1(16.8-14)« (U= 0%) OK«

»Max.Saddle Forces Fvtot=27794.35 <= Min(F2max, F3max)=6.9245E05« (U= 4%) OK«

Instability Check

»Instability Check Inst_0=0.0053 <= 1.0=1(16.8-28)« » (U= .5%) OK«

CALCULATION 2, ea = ec, b=b1, Delta=Delta

»Max.Saddle Forces(ea=ec) Fvtot=27794.35 <= Min(F2max, F3max)=8.2254E05« (U= 3.3%) OK«

LOAD CASE NO: 2 - OPER.WIND (z = 4247)

Int.Pressure(MPa):P =0.5

Ext.Pressure(MPa):Pe=0.1

Temperature D/A:T =D

Corrosion (mm):c =3

Stress M-Factor :mf=1

Liquid Level (mm):LL=200

Sp.Gravity (Liq.):SG=0

Max.Deflection d/200:d=1

»Web Plate Stresses(Splitting Force) Sigt=0.8032 <= fsw*2/3=113.89« (U= .7%) OK«

»Saddle Stresses due to Axial Loads Sigt=6.93 <= fsw=170.83« (U= 4%) OK«

»Webplate Buckling Fw=5031.59 <= Fwmax=6.2434E05« » (U= .8%) OK«

»Foundation Bearing Pressure Pbearing=0.1121 <= Fba=3« » (U= 3.7%) OK«

»Baseplate Thickness eb=20 >= ebmin=3.77« » (U= 18.8%) OK«

CALCULATION 1, ea = ea, b=b2, Delta=Delta2

16.8.6 LOAD LIMIT FOR THE SHELL BETWEEN SADDLES

»Vessel Stress Btwn.Saddles fact=13.71 <= fs=129.41(16.8-10)« (U= 10.5%) OK«

»Instability Check Btwn.Saddles Inst=0.0086 <= 1.0=1« » (U= .8%) OK«

»Instability Check Inst=0.256 <= 1.0=1(16.8-14)« » (U= 25.6%) OK«

Ohmtech AS

Sample File Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 16.8 HORIZONTAL VESSELS ON SADDLE SUPPORTS

SS.1 Fixed Saddle 05 Feb. 2010 12:10 ConnID:S1.3 PC# 1

»Max.Saddle Forces Fvtot=15094.76 <= Min(F2max, F3max)=4.2269E05«» (U= 3.5%) OK«

Instability Check

»Instability Check Inst_0=0.2512 <= 1.0=1(16.8-28)« » (U= 25.1%) OK«

CALCULATION 2, ea = ec, b=b1, Delta=Delta

»Max.Saddle Forces(ea=ec) Fvtot=15094.76 <= Min(F2max, F3max)=5.021E05«» (U= 3%) OK«

Volume:0 m3 Weight:129.8 kg (SG= 7.85)

Ohmtech AS

Sample File

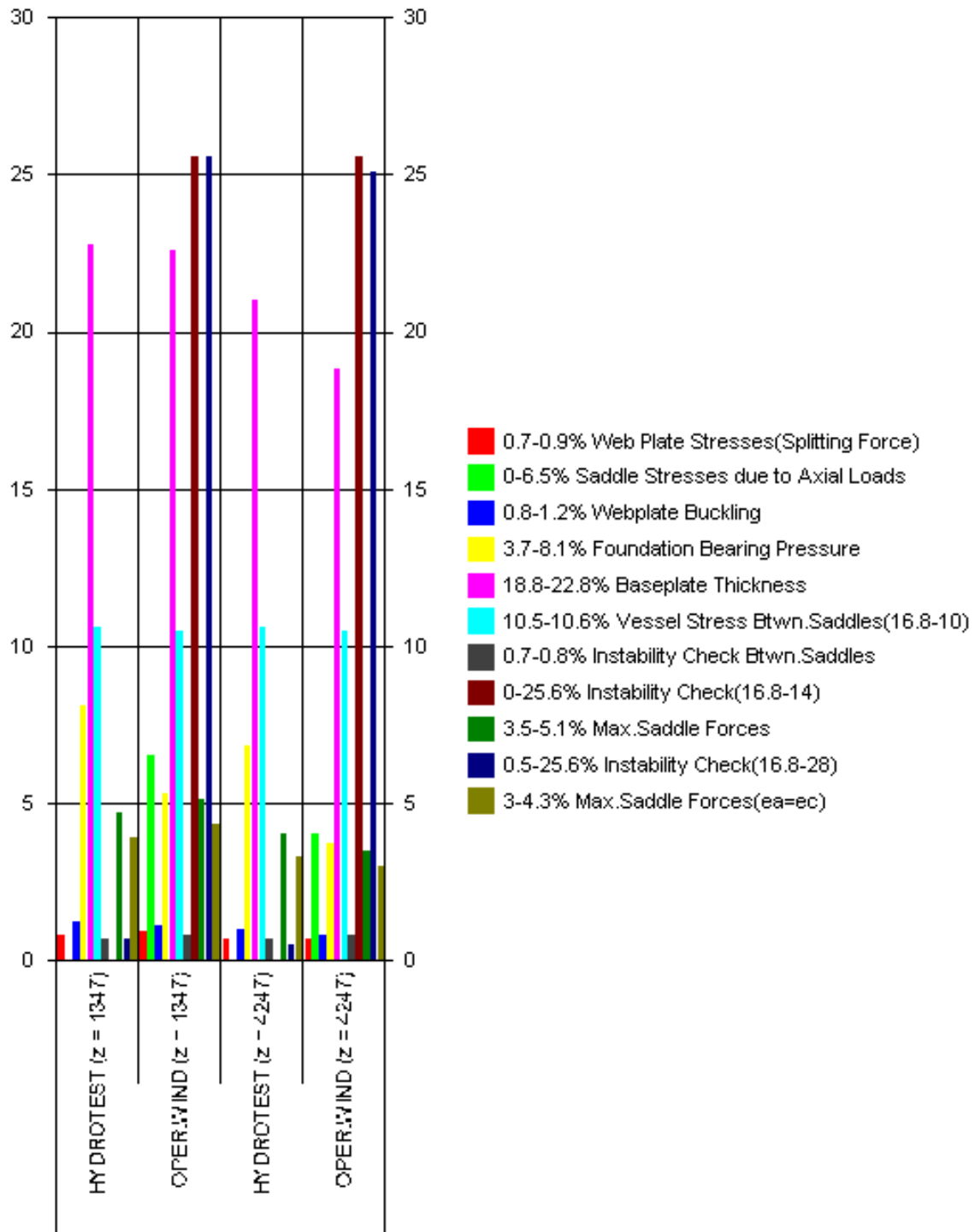
Steam Generator

Visual Vessel Design by OhmTech Ver:10.2-04 Operator : Rev.:A

EN13445:2009 Issue 1 - 16.8 HORIZONTAL VESSELS ON SADDLE SUPPORTS

SS.1 Fixed Saddle 05 Feb. 2010 12:10 ConnID:S1.3 PC# 1

UTILIZATION CHART - SS.1 FIXED SADDLE



Max.Utilization/Condition 25.6% CASE: OPER.WIND (z = 1347)