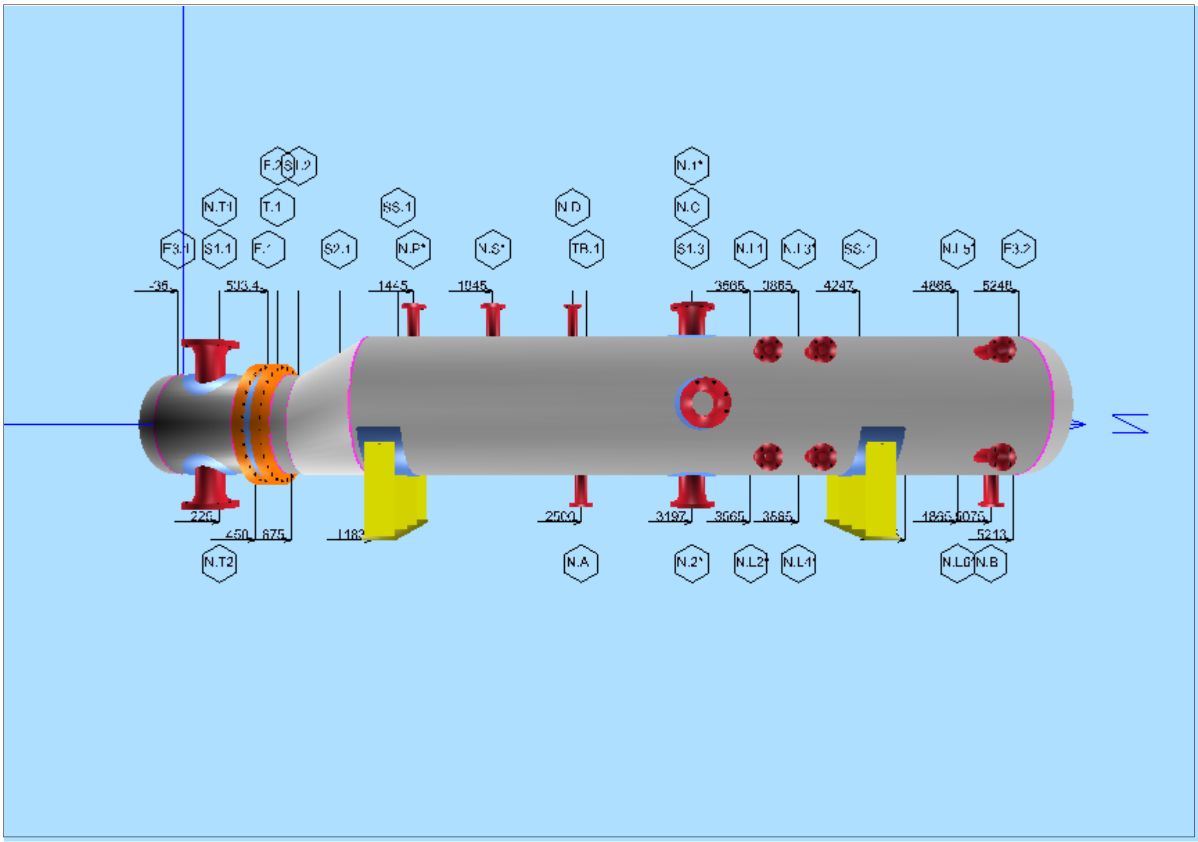
Drawing

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

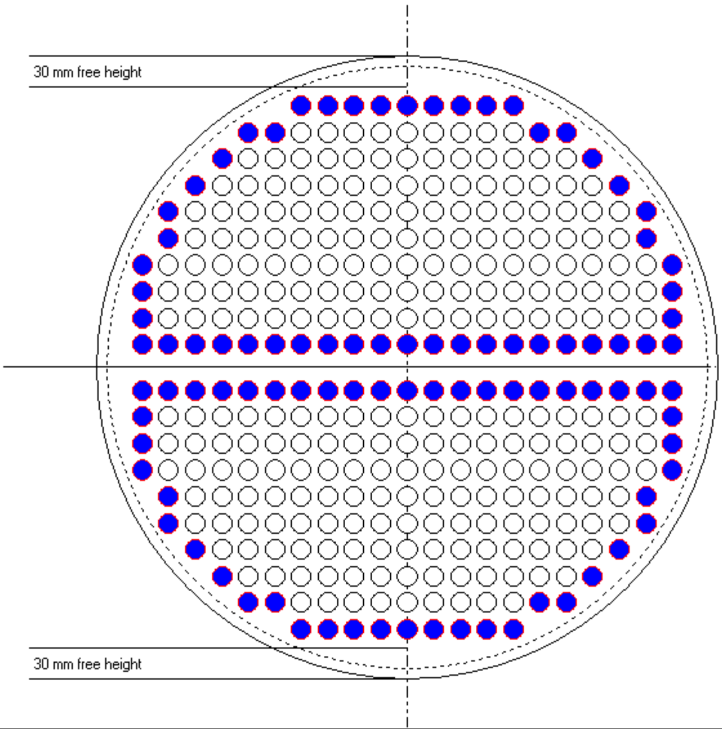


Design Data & Process Information

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			

Tube Layout

Tube Layout



VVD - Tube Layout

Total Number of Tubes:. 352
UnTubed Area:..........265,8cm²
Cylinder Inside Di:.... 610mm
OTL Diameter:.......... 590mm
Tube Outside Diameter:. 19.05mm
Tube Pitch:............ 26mm
Vertical Tube Clerance: 10mm
Free Height:...........30mm
Pass Partion Thickness:8mm
Number of Tube Passes: 2
Tube Pattern:90° Square

Pass #	Tube Count	Mean Tube Count	%Deviation From Mean
1	176	176	0%
2	176	176	0%

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

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

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.

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)
```

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 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.

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,PAD 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,PAD 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,PAD 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,PAD 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,PAD 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

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

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 ls = 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 ls = 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= 10.1mm
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

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

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

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

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

Average utilization of all components Umean= 68.8%
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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	

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Notation:
Thickness in mm, stress in N/mm2, temperature in deg.C
TG   : Test Group 1 to 4
Max.T: Maximum thickness for this stress set, 0 or 999 = No limit specified
S/C  : CS = Carbon Steel, SS = Stainless Steel
SG   : SG = Specific Gravity (Water = 1.0)
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
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PMA Requirement

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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

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.Plate	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	

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.Plate	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).
```

NDT - Requirements for Test Group:3b

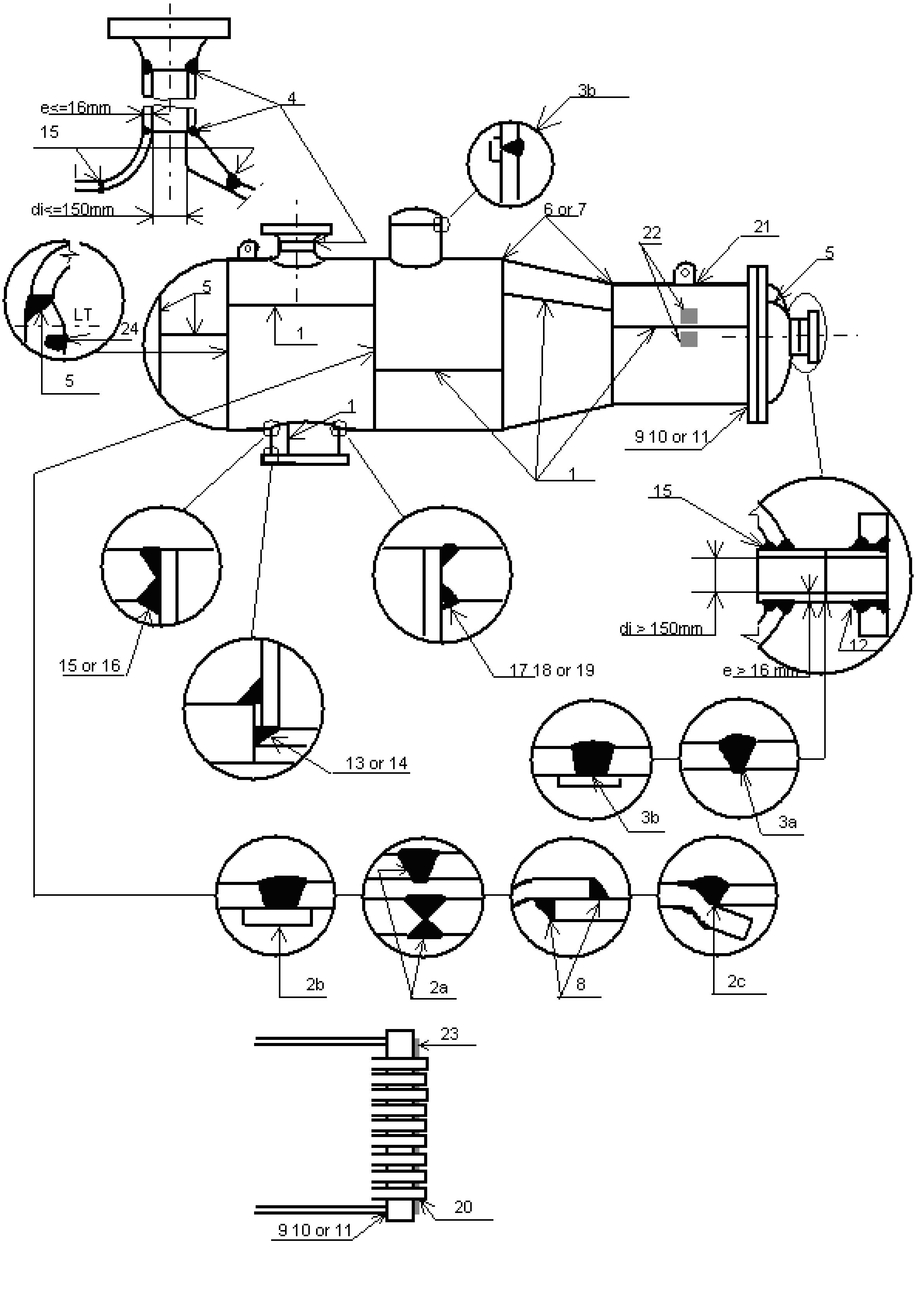
Table EN13445-5, 6.6.2-1:

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 a > 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).

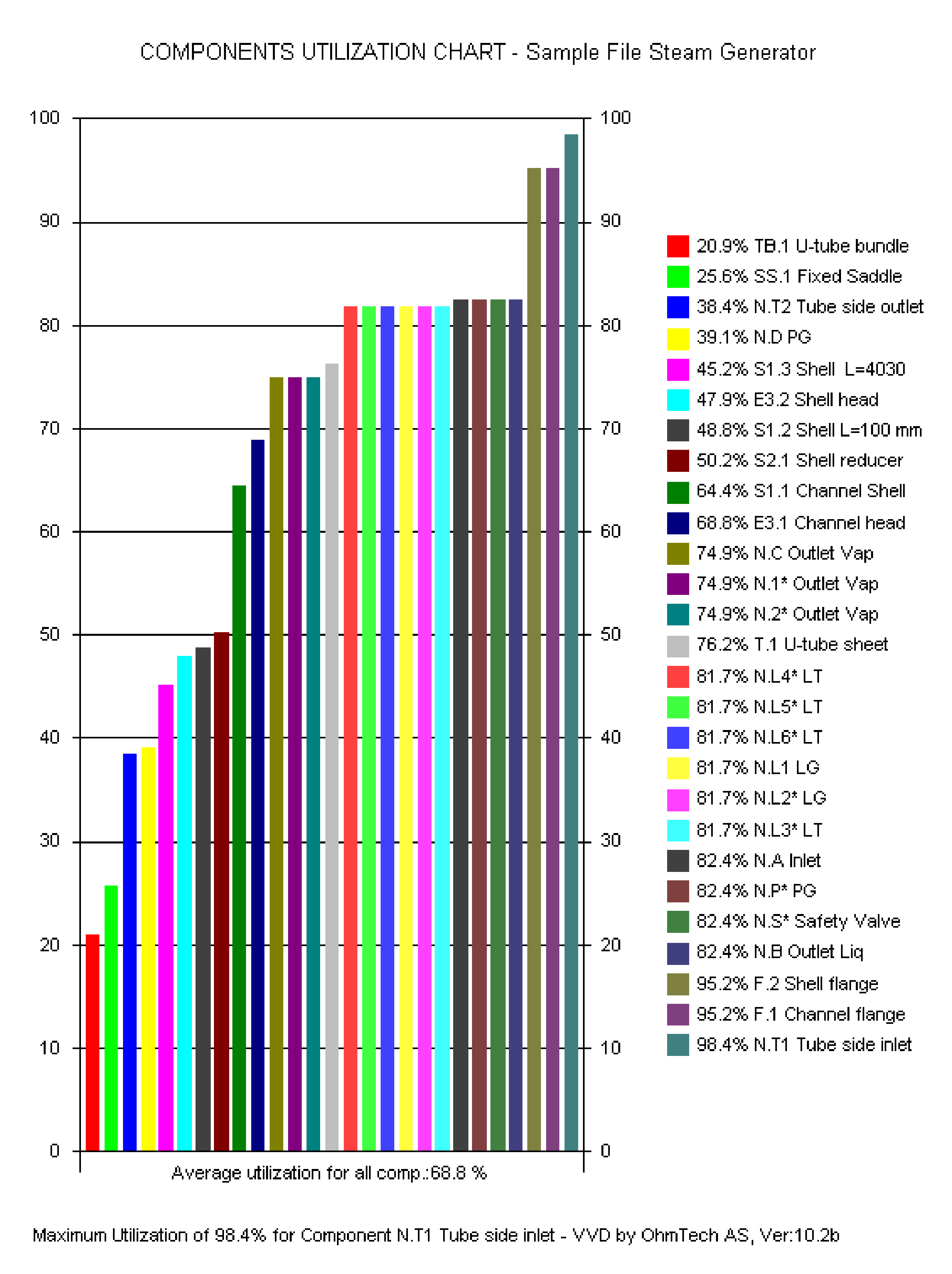
See table 6.6.3-1 for other circumstances for use of both techniques.
(k): For limitations of application see EN 134445-3:2002, 5.7.3.2.l
(l): The percentage of surface examination refers to the percentage of length of the welds both on the inside and the outsidem.
(m): RT and UT are volumetric while 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.

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



Utilization Chart

Utilization Chart



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
```

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:
  Fx(kN) - Force in vertical direction (positive upward)
  Fy(kN) - Force in transverse direction
  Fz(kN) - Force in axial direction
  My(kNm)- Longitudinal bending moment at saddle base
  Mz(kNm)- Transverse bending moment at saddle base
  Mx(kNm)- Not Applicable
```

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 Applicabilty emin/De=0.0047 <= 0.16« » OK«
»Internal Pressure emina=6.45 <= 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
```

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 * f20 / f =1.25*0.85*170.83/104=          1.75 MPa
Ptmin = 1.43 * Pd =1.43*0.85=                                1.22 MPa
```

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

MAXIMUM DIAMETER OF UNREINFORCED OPENING IN SHELL

```
Inside Radius of Shell
ris = Di / 2 (9.5-3) =610/2=                              305.00 mm
Length of Shell Contributing to Reinforcement
Is = Sqr(( 2 * ris + ea) * ea) (9.5-2) =Sqr((2*305+6.5)*6.5)=    63.30 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)
=(6.5*63.3*(104-0.5*0.85)/0.85-305*63.3)/(0.5*305+0.5*6.5)=  197.95 mm
Maximum diameter of Opening Not Requiring Reinforcement Check
dmax2 = 0.15 * Sqr(( 2 * ris + ea) * ea)                     (9.5-18)
=0.15*Sqr((2*305+6.5)*6.5)=                                9.50 mm
Maximum Diameter of Unreinforced Opening
dmax = MAX( dmax1, dmax2) =MAX(197.95,9.5)=                197.95 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) =156=                                 156.00 N/mm2
```

Preliminary Calculations

```
R = Dm / 2 =617/2=                                         308.50 mm
Z = PI * R / L (8.5.2-7) =3.14*308.5/600=                   1.62
Delta = 1.28 / Sqr( R * ea) (8.5.3-20) =1.28/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 (from fig. 8.5-3) = 0.00149
```

MEMBRANE YIELD py

```
py = Sige * ea / (R * (1 - gamma * G ))                      (8.5.3-15)
=156*6.5/(308.5*(1-0*0))=                                  3.29 MPa
```

ELASTIC INSTABILITY pe

```
pm = E * ea * eps / R (8.5.2-5) =1.851E05*6.5*0.0015/308.5=     5.81 MPa
```

MAX. ALLOWABLE EXTERNAL PRESSURE Pmax

```
Value pr/py From Figure 8.5-5 Curve   1
Value1 =  ==                                              0.7226
pr = Value1 * py =0.7226*3.29=                              2.37 MPa
Max. Allowable External Pressure
Pmax = pr / S (8.5.2-8) =2.37/1.5=                          1.58 MPa
```

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

CALCULATION SUMMARY

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
```

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

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
```

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 * f20 / f =1.25*0.85*170.83/104=               1.75 MPa

Ptmin = 1.43 * Pd =1.43*0.85=                                    1.22 MPa
```

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

MAXIMUM DIAMETER OF UNREINFORCED OPENING IN SHELL

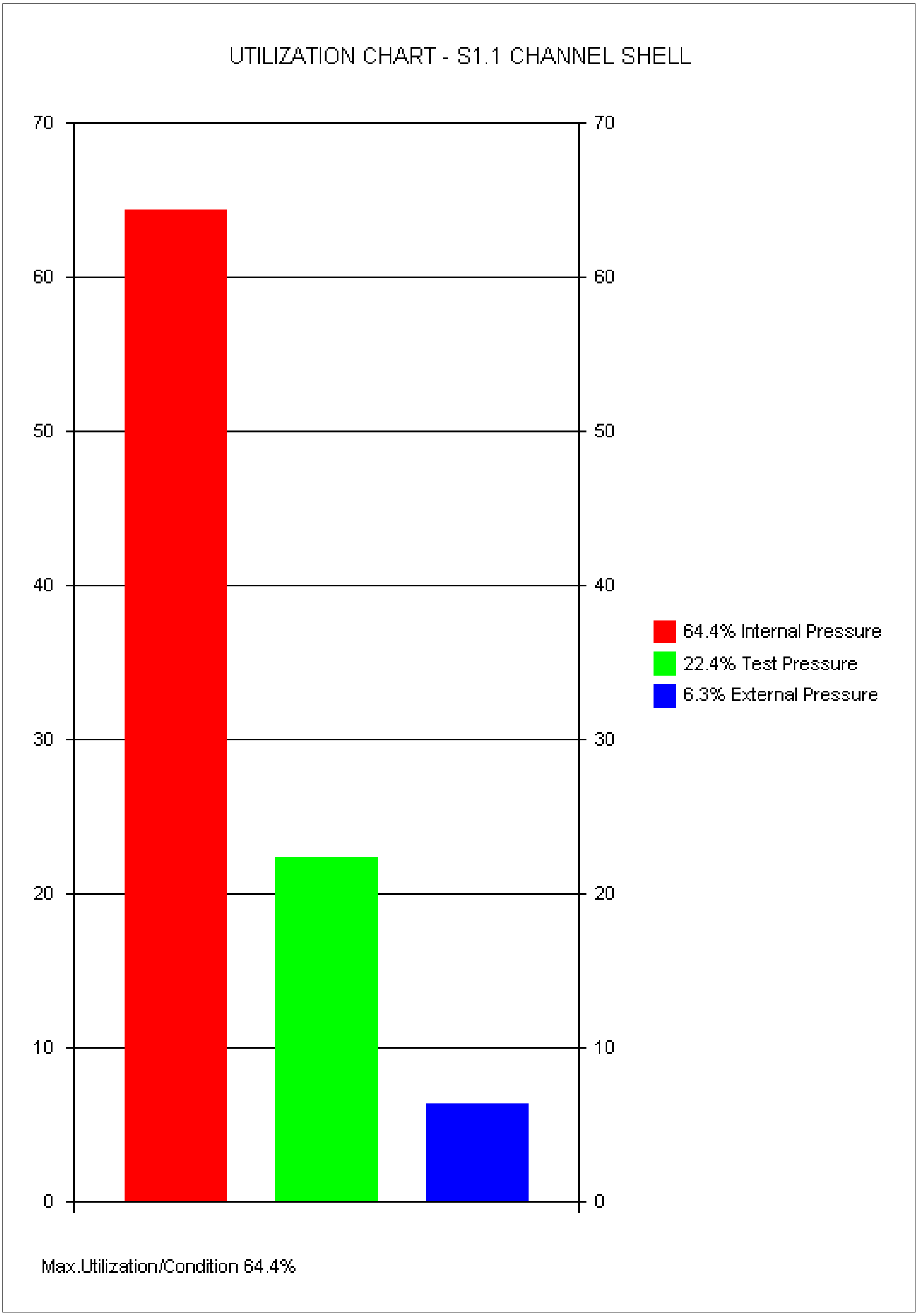
```
Maximum Diameter of Unreinforced Opening
dmax = MAX( dmax1, dmax2) =MAX(197.95,9.5)=                    197.95 mm
```

8.5 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

```
Max. Allowable External Pressure
Pmax = pr / S (8.5.2-8) =2.37/1.5=                               1.58 MPa
```

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

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


UTILIZATION CHART - S1.1 CHANNEL SHELL
70
60
50
40
30
20
10
0
64.4% Internal Pressure
22.4% Test Pressure
6.3% External Pressure
Max.Utilization/Condition 64.4%

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 :
emin = Di * P / (2 * f * z - P)                                    (7.4-1)
=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 Applicabilty 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
```

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 * f20 / f =1.25*0.5*170.83/129.41=        0.8250 MPa
Ptmin = 1.43 * Pd =1.43*0.5=                                0.7150 MPa
```

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

MAXIMUM DIAMETER OF UNREINFORCED OPENING IN SHELL

```
Inside Radius of Shell
ris = Di / 2 (9.5-3) =610/2=                                 305.00 mm
Length of Shell Contributing to Reinforcement
Is = Sqr(( 2 * ris + ea) * ea) (9.5-2) =Sqr((2*305+6.5)*6.5)=    63.30 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)
=(6.5*63.3*(129.41-0.5*0.5)/0.5-305*63.3)/(0.5*305+0.5*6.5)=   305.00 mm
Maximum diameter of Opening Not Requiring Reinforcement Check
dmax2 = 0.15 * Sqr(( 2 * ris + ea) * ea)                     (9.5-18)
=0.15*Sqr((2*305+6.5)*6.5)=                                  9.50 mm
Maximum Diameter of Unreinforced Opening
dmax = MAX( dmax1, dmax2) =MAX(305,9.5)=                     305.00 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 N/mm2
```

Preliminary Calculations

```
R = Dm / 2 =617/2=                                           308.50 mm
Z = PI * R / L (8.5.2-7) =3.14*308.5/100=                      9.69
Delta = 1.28 / Sqr( R * ea) (8.5.3-20) =1.28/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 (from fig. 8.5-3) = 0.011957
```

MEMBRANE YIELD py

```
py = Sige * ea / (R * (1 - gamma * G ))                      (8.5.3-15)
=194.12*6.5/(308.5*(1-0*0))=                                 4.09 MPa
```

ELASTIC INSTABILITY pe

```
pm = E * ea * eps / R (8.5.2-5) =196147*6.5*0.012/308.5=      49.42 MPa
```

MAX. ALLOWABLE EXTERNAL PRESSURE Pmax

```
Value pr/py From Figure 8.5-5 Curve   1
Value1 =  ==                                                 0.9585
pr = Value1 * py =0.9585*4.09=                                 3.92 MPa
Max. Allowable External Pressure
Pmax = pr / S (8.5.2-8) =3.92/1.5=                             2.61 MPa
```

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

CALCULATION SUMMARY

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*0.5/(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
```

»Internal Pressure emina=4.89 <= en=10[mm] « » (U= 48.8%) OK«

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
```

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 * f20 / f =1.25*0.5*170.83/129.41=           0.8250 MPa

Ptmin = 1.43 * Pd =1.43*0.5=                                   0.7150 MPa
```

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

MAXIMUM DIAMETER OF UNREINFORCED OPENING IN SHELL

```
Maximum Diameter of Unreinforced Opening
dmax = MAX( dmax1, dmax2) =MAX(305,9.5)=                        305.00 mm
```

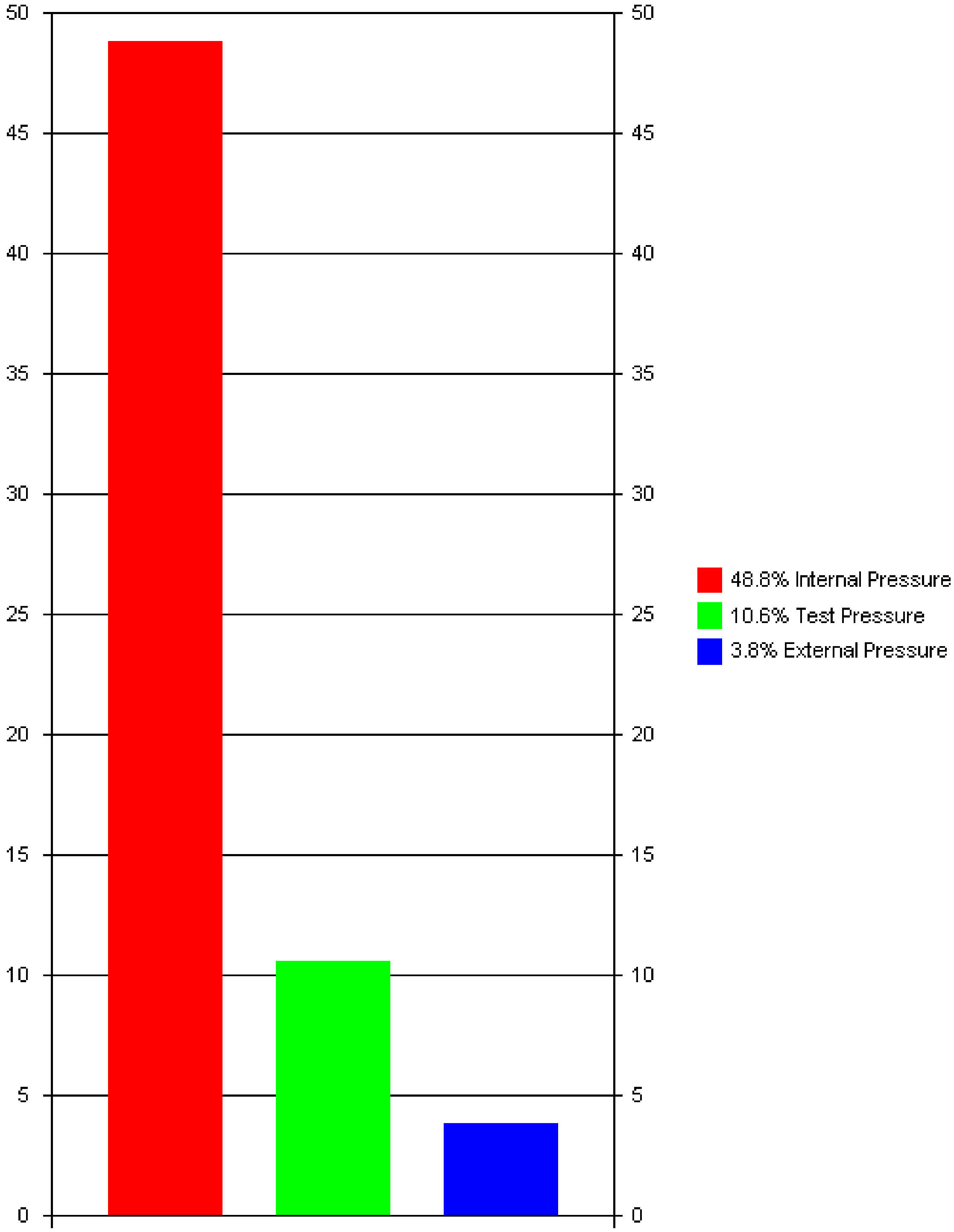
8.5 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

```
Max. Allowable External Pressure
Pmax = pr / S (8.5.2-8) =3.92/1.5=                                2.61 MPa
```

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

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

UTILIZATION CHART - S1.2 SHELL L=100 MM



Max.Utilization/Condition 48.8%

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 :
emin = Di * P / (2 * f * z - P)                                    (7.4-1)
=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
```

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 * f20 / f =1.25*0.5*170.83/129.41=        0.8250 MPa
Ptmin = 1.43 * Pd =1.43*0.5=                                0.7150 MPa
```

»Test Pressure Ptmin=0.825 <= Ptmax=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 mm
Length of Shell Contributing to Reinforcement
Is = Sqr(( 2 * ris + ea) * ea) (9.5-2) =Sqr((2*423+8.5)*8.5)=    85.22 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)=   423.00 mm
Maximum diameter of Opening Not Requiring Reinforcement Check
dmax2 = 0.15 * Sqr(( 2 * ris + ea) * ea)                           (9.5-18)
=0.15*Sqr((2*423+8.5)*8.5)=                                 12.78 mm
Maximum Diameter of Unreinforced Opening
dmax = MAX( dmax1, dmax2) =MAX(423,12.78)=                    423.00 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 N/mm2
```

Preliminary Calculations

```
R = Dm / 2 =855/2=                                            427.50 mm
Z = PI * R / L (8.5.2-7) =3.14*427.5/4151=                  0.3235
Delta = 1.28 / Sqr( R * ea) (8.5.3-20) =1.28/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 (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))=                                  3.86 MPa
```

ELASTIC INSTABILITY pe

```
pm = E * ea * eps / R (8.5.2-5) =196147*8.5*3.1174E-04/427.5=      1.22 MPa
```

MAX. ALLOWABLE EXTERNAL PRESSURE Pmax

```
Value pr/py From Figure 8.5-5 Curve   1
Value1 =  ==                                                0.1570
pr = Value1 * py =0.157*3.86=                               0.6061 MPa
Max. Allowable External Pressure
Pmax = pr / S (8.5.2-8) =0.6061/1.5=                        0.4041 MPa
```

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

CALCULATION SUMMARY

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)
=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
```

»Internal Pressure emina=5.43 <= en=12[mm] « » (U= 45.2%) OK«

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
```

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 * f20 / f =1.25*0.5*170.83/129.41=          0.8250 MPa

Ptmin = 1.43 * Pd =1.43*0.5=                                  0.7150 MPa
```

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

MAXIMUM DIAMETER OF UNREINFORCED OPENING IN SHELL

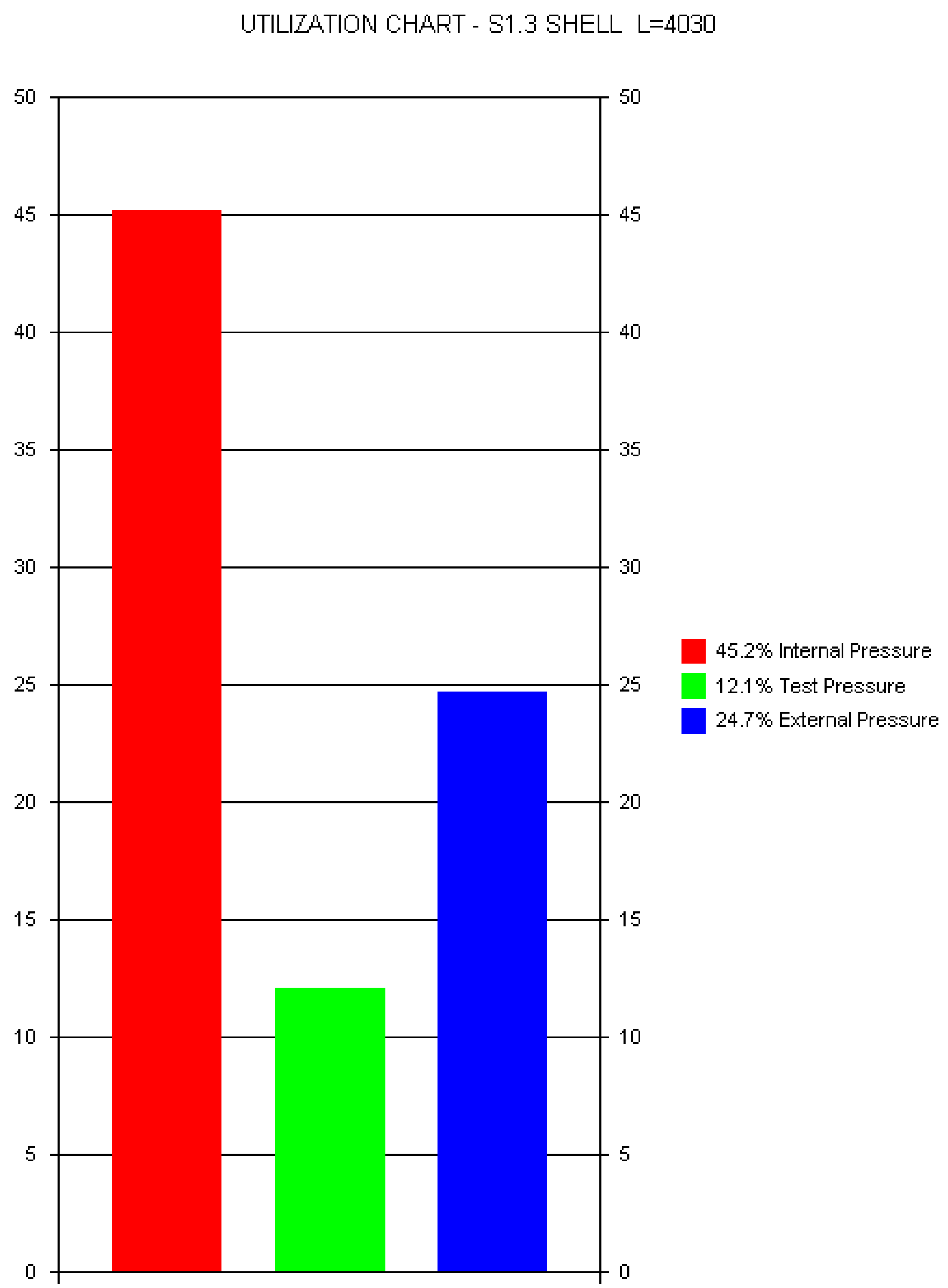
```
Maximum Diameter of Unreinforced Opening
dmax = MAX( dmax1, dmax2) =MAX(423,12.78)=                     423.00 mm
```

8.5 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

```
Max. Allowable External Pressure
Pmax = pr / S (8.5.2-8) =0.6061/1.5=                          0.4041 MPa
```

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

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



Max.Utilization/Condition 45.2%

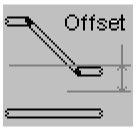
INPUT DATA

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
```

```
Required Cone Thickness at Large Base Excl.Allow. emin :
emin = P * Dk / (2 * f * z - P) / Cos( alfa)                (6.4.4-1)
=0.5*823.09/(2*129.41*0.85-0.5)/Cos(30.05)=          2.17 mm
Required Cone Thickness at Large Base Incl.Allow. emina :
emina = emin + c + th =2.17+3+0.5=                     5.67 mm
```

»Cone Thk. emina=5.67 <= en=12[mm] « » (U= 47.2%) OK«

```
Required Cone Thickness at Small Base Incl.Allow. eminS :
eminS = P * DiS / (2 * f * z - P) / Cos( alfa) + 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

Analysis Thickness
ea = en - c - th =12-3-0.5=                            8.50 mm
Dm = DiL + ea / Cos( alfa) =846+8.5/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
InvCos = 1 / (Sqr( Cos( alfa))) =1/(Sqr(Cos(30.05)))=  1.07
beta = Sqr(DcL/ejL)/3*Tan(alfa)/(1+InvCos)-0.15
=Sqr(847.93/2.53)/3*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 e1L :

```
e1(min)(corroded) largest of ecylL, ej = ==            2.53 mm
Required Minimum Shell Thickness Incl.Allow. :
e1minL = e1L + c =2.53+3=                              5.53 mm
```

»Cylinder Thk.Large Base e1minL=5.53 <= enL=12[mm] « » (U= 46.1%) OK«

Min. extend of the increased cylinder thickness Lcyl :

```
From the junction
LcylL = 1.4 * Sqr( DcL * e1L) =1.4*Sqr(847.93*2.53)=  64.87 mm
```

Required cone thickness near junction e2L :

```
e2(min)(corroded) largest of emin, ej = ==             2.53 mm
Required Minimum Cone Thickness Incl.Allow. :
e2minL = e2L + c + th =2.53+3+0.5=                     6.03 mm
```

»Cone Thk.Near Junction e2minL=6.03 <= en=12[mm] « » (U= 50.2%) OK«

Min. extend of the increased cone thickness Lcone :

```
From the junction
LconeL = 1.4 * Sqr( DcL * e2L / cos( alfa))
=1.4*Sqr(847.93*2.53/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
e2S = en - c - th =12-3-0.5=                           8.50 mm
DcS = DiS + ecylS =610+1.39=                         611.39 mm
s = e2S / e1S =8.5/1.16=                               7.38
tau = 1 + Sqr( (1 + s ^ 2) * s / ( 2 * cos( alfa)))         (6.4.8-3)
=1+Sqr((1+7.38^2)*7.38/(2*cos(30.05)))=             16.07
beta = 0.4 * Sqr( DcS / e1S) * Tan( alfa) / Tau + 0.5       (6.4.8-4)
=0.4*Sqr(611.39/1.16)*Tan(30.05)/16.07+0.5=        0.8315
e1S = P * DcS * beta / (2 * f * z)
=0.5*611.39*0.8315/(2*129.41*0.85)=                  1.16 mm
```

Required cylinder thickness near junction e1S :

```
e1(min)(corroded) largest of ecylS, e1S = ==                1.39 mm
Required Minimum Shell Thickness Incl.Allow. :
e1minS = e1S + c =1.16+3=                                   4.39 mm
```

»Cylinder Thk.Small Base e1minS=4.39 <= enS=10[mm] « » (U= 43.8%) OK«

Min. extend of the increased cylinder thickness Lcyl :

```
LcylS = SQR( DcS * e1S) =SQR(611.39*1.16)=                 29.15 mm
```

Required cone thickness near junction e2S :

```
e2(min)(corroded) largest of emin, e2S = ==                 8.50 mm
Required Minimum Cone Thickness Incl.Allow. :
e2minS = e2S + c + th =8.5+3+0.5=                          12.00 mm
```

Min. extend of the increased cone thickness Lcone :

```
LconeS = SQR( DcS * e2S / cos( alfa))
=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 alfa=30.05 <= 75[degr] «» OK«
»b) Geometry Check ea*cos(alfa)/DcL=0.0087 > 0.001« » 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 1,4ej, in which case the normal rules forthe 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 Lo=118 <= (DiL-DiS)/2=118«» OK«

MAWP New & Cold (Ambient Temp. & Uncorroded)

```
Analysis Thickness
ea = en - ca - th =12-0-0.5=                               11.50 mm
Conical Shell
Pmaxc = 2 * fa * z * ea * Cos( alfa) / Dm
=2*170.83*0.85*11.5*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
PcylL = 2 * fL * z * (enL - ca - th) / Dm                       (6.4.4-3)
=2*170.83*0.85*(12-0-0.5)/855.82=                          3.90 MPa
Pmax1L = 2 * fa * ej / (DcL * beta1)                            (6.4.6-4)
=2*170.83*2.54/(847.93*0.6479)=                            7.15 MPa
PmaxL is the smallest of (Pmax1L and PcylL) = PmaxL
=3.9=                                                      3.90 MPa
```

6.4.8.3 Rating - Junction at Small Base of Cone

```
Max.Allowable Pressure of Cylinder at Small Base of Cone
PcylS = 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
Tau (from equation 6.4.8-2/3) =2.312952
betaH (from equation 6.4.8-4) =1.302478
Pmax1S = 2 * fa * z * e1a / (DcS * betaH)                     (6.4.7-5)
=2*170.83*0.85*9.5/(611.39*1.3)=                         3.46 MPa
PmaxS is the smallest of (Pmax1S and PcylS) = PmaxS
=3.46=                                                   3.46 MPa

Pmax is the smallest of (Pmaxc, PmaxL and PmaxS) = Pmax
=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
Pmaxc = 2 * fa * z * ea * Cos( alfa) / 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
PcylL = 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
Pmax1L = 2 * fa * ej / (DcL * beta1)                          (6.4.6-4)
=2*129.41*2.54/(847.93*0.7781)=                          3.33 MPa
PmaxL is the smallest of (Pmax1L and PcylL) = PmaxL
=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
PcylS = 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
Tau (from equation 6.4.8-2/3) =2.430746
betaH (from equation 6.4.8-4) =1.423136
Pmax1S = 2 * fa * z * e1a / (DcS * betaH)                     (6.4.7-5)
=2*129.41*0.85*6.5/(611.39*1.42)=                        1.64 MPa
PmaxS is the smallest of (Pmax1S and PcylS) = PmaxS
=1.64=                                                   1.64 MPa

Pmax is the smallest of (Pmaxc, PmaxL and PmaxS) = Pmax
=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
Pmaxc = 2 * fa * z * ea * Cos( alfa) / 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
PcylL = 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
Pmax1L = 2 * fa * ej / (DcL * beta1)                          (6.4.6-4)
=2*252.38*2.54/(847.93*0.6479)=                         10.57 MPa
PmaxL is the smallest of (Pmax1L and PcylL) = PmaxL
=5.77=                                                   5.77 MPa
```

6.4.8.3 Rating - Junction at Small Base of Cone

```
Max.Allowable Pressure of Cylinder at Small Base of Cone
PcylS = 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
Tau (from equation 6.4.8-2/3) =2.312952
betaH (from equation 6.4.8-4) =1.302478
Pmax1S = 2 * fa * z * e1a / (DcS * betaH)                       (6.4.7-5)
=2*252.38*1*9.5/(611.39*1.3)=                            6.02 MPa
PmaxS is the smallest of (Pmax1S and PcylS) = PmaxS
=6.02=                                                   6.02 MPa

Pmax is the smallest of (Pmaxc, PmaxL and PmaxS) = Pmax
=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
Ptmin = 1.25 * Pd * f20 / f =1.25*0.5*170.83/129.41=    0.8250 MPa

Ptmin = 1.43 * Pd =1.43*0.5=                            0.7150 MPa
```

»Test Pressure Ptmin=0.825 <= Ptmax=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
Rmean = (DiL + DiS) / 4 + 0.5 * ea / Cos( alfa)
=(846+610)/4+0.5*8.5/Cos(30.05)=                       368.91 mm
Maximum Radius of Conical Shell
Rmax = DiL / 2 + ea / Cos( alfa)
=846/2+8.5/Cos(30.05)=                                 432.82 mm
```

8.4.2 Nominal Elastic Limit Sige:

```
Sige = Rpt (8.4.2-1) =194.12=                            194.12 N/mm2
```

9.3.2 Interstiffener Collapse

```
py = ea * Sige * Cos( alfa) / Rmax                              (9.3.2-1)
=8.5*194.12*Cos(30.05)/432.82=                           3.30 MPa

Z = PI * Rmean * Cos( alfa) / L
=3.14*368.91*Cos(30.05)/408=                             2.46
eps is a minimum when n=6
eps (from fig. 8.5-3) =0.003419
pm = E * ea * eps * (Cos( alfa)) ^ 3 / Rmean                    (9.3.2-2)
=196147*8.5*0.0034*(Cos(30.05))^3/368.91=               10.02 MPa
```

MAX. ALLOWABLE EXTERNAL PRESSURE Pmax

```
Value pr/py From Figure 8.5-5 Curve   1
Value1 =  ==                                            0.8376
pr = Value1 * py =0.8376*3.3=                              2.76 MPa
Max. Allowable External Pressure
Pmax = pr / S =2.76/1.5=                                   1.84 MPa
```

»External Pressure Pmax=1.84 >= Pext=0.1[MPa] « » (U= 5.4%) OK«

CALCULATION SUMMARY

SECT. 6.4 - REDUCERS UNDER INTERNAL PRESSURE

6.4.4 CONICAL SHELLS

```
Required Cone Thickness at Large Base Incl.Allow. emina :
emina = emin + c + th =2.17+3+0.5=                              5.67 mm
```

»Cone Thk. emina=5.67 <= en=12[mm] « » (U= 47.2%) OK«

```
Required Cone Thickness at Small Base Incl.Allow. eminS :
eminS = P * DiS / (2 * f * z - P) / Cos( alfa) + 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 e1minL=5.53 <= enL=12[mm] « » (U= 46.1%) OK«

»Cone Thk.Near Junction e2minL=6.03 <= en=12[mm] « » (U= 50.2%) OK«

6.4.8 JUNCTION AT THE SMALL BASE OF CONE

»Cylinder Thk.Small Base e1minS=4.39 <= enS=10[mm] « » (U= 43.8%) OK«

MAWP New & Cold (Ambient Temp. & Uncorroded)

```
Pmax is the smallest of (Pmaxc, PmaxL and PmaxS) = Pmax
=3.38=                                                         3.38 MPa
```

MAWP Hot & Corroded (Design Temp.)

```
Pmax is the smallest of (Pmaxc, PmaxL and PmaxS) = Pmax
=1.64=                                                         1.64 MPa
```

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

```
Pmax is the smallest of (Pmaxc, PmaxL and PmaxS) = Pmax
=5.77=                                                         5.77 MPa
```

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

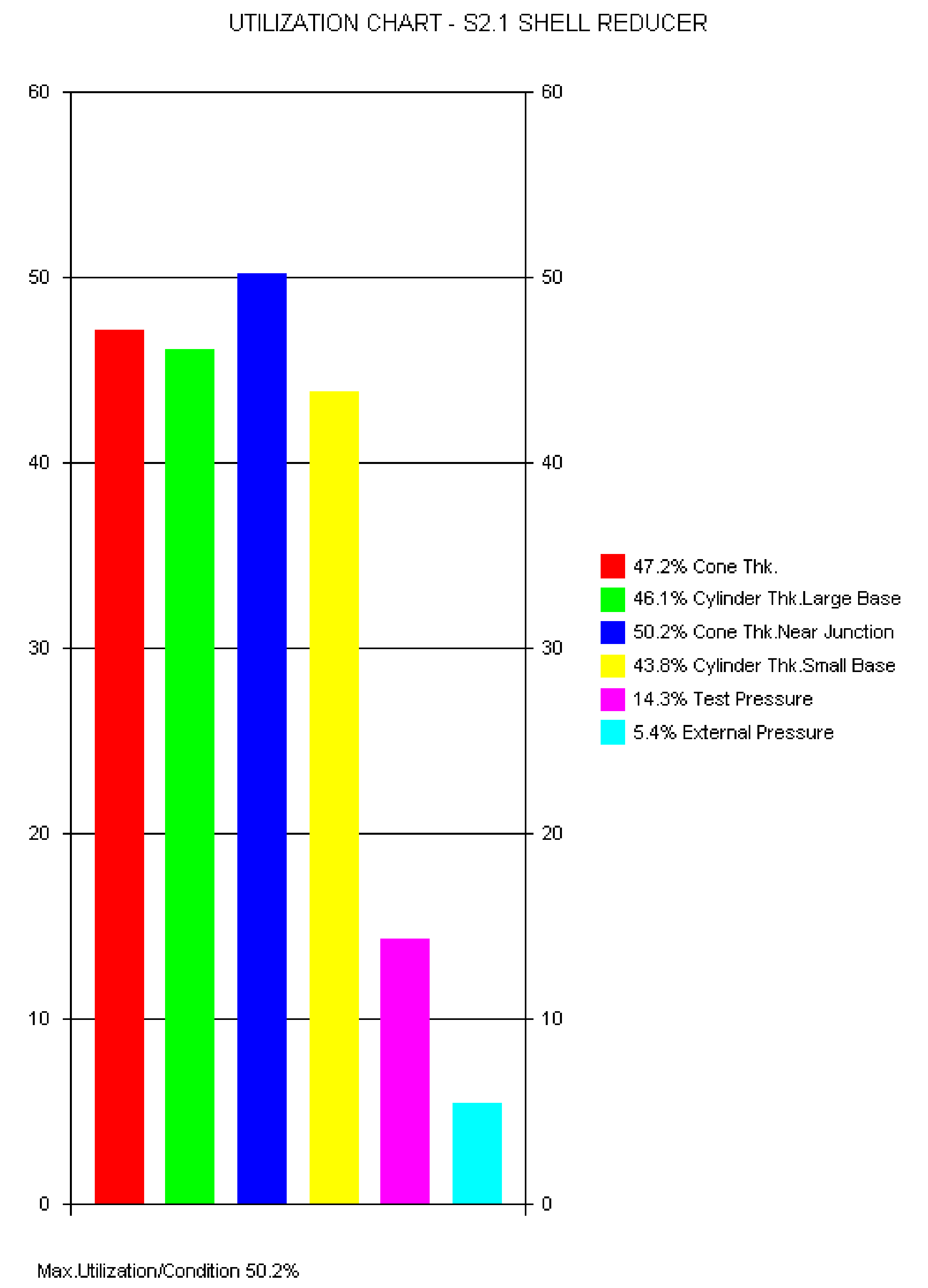
```
NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3
Ptmin = 1.25 * Pd * f20 / f =1.25*0.5*170.83/129.41=          0.8250 MPa
Ptmin = 1.43 * Pd =1.43*0.5=                                  0.7150 MPa
```

»Test Pressure Ptmin=0.825 <= Ptmax=5.77[MPa] « » (U= 14.3%) OK«

SECT. 9.4 - REDUCER/CONICAL SHELL UNDER EXTERNAL PRESSURE

»External Pressure Pmax=1.84 >= Pext=0.1[MPa] « » (U= 5.4%) OK«

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


UTILIZATION CHART - S2.1 SHELL REDUCER
60
50
40
30
20
10
0
47.2% Cone Thk.
46.1% Cylinder Thk.Large Base
50.2% Cone Thk.Near Junction
43.8% Cylinder Thk.Small Base
14.3% Test Pressure
5.4% External Pressure
Max.Utilization/Condition 50.2%

INPUT DATA

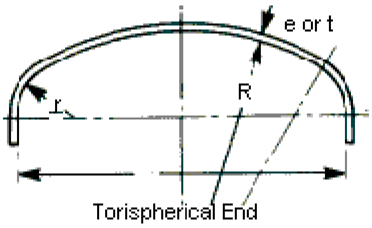
COMPONENT ATTACHMENT/LOCATION

```
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
es = P * R / (2 * f * z - 0.5 * P)                                 (7.5-1)
=0.85*499.2/(2*104*1-0.5*0.85)=                                 2.04 mm
fb = Rpt / 1.5 (7.5-4) =156/1.5=                                104.00 N/mm2
Required Thickness of Knuckle to Avoid Plastic Buckling
eb = (0.75*R+0.2*Di)*((P/(111*fb)*(Di/r)^0.825)^(0.667)            (7.5-3)
=(0.75*499.2+0.2*613)*((0.85/(111*104)*(613/96.096)^0.825)^(0.667)=     2.41 mm
7.5.3.5 Formulas for Calculation of Factor Beta
Y = MIN( emin / R, 0.04) (7.5-9) =MIN(2.84/499.2,0.04)=     0.0057
Z = LOG( 1 / Y) (7.5-10) =LOG(1/0.0057)=                       2.25
X = r / Di (7.5-11) =96.096/618.32=                         0.1554
N = 1.006 - 1 / (6.2 + (90 * Y) ^ 4)                               (7.5-12)
=1.006-1/(6.2+(90*0.0057)^4)=                             0.8465
Beta01 = N*(-0.1833*Z^3+1.0383*Z^2-1.2943*Z+0.837)                 (7.5-15)
=0.8465*(-0.1833*2.25^3+1.0383*2.25^2-1.2943*2.25+0.837)=  0.9230
Beta02 = MAX( 0.5, 0.95 * (0.56 - 1.94 * Y - 82.5 * Y ^ 2))        (7.5-17)
=MAX(0.5,0.95*(0.56-1.94*0.0057-82.5*0.0057^2))=          0.5190
beta = 10 * ((0.2 - X) * Beta01 + (X - 0.1) * Beta02)              (7.5-16)
=10*((0.2-0.1554)*0.923+(0.1554-0.1)*0.519)=              0.6991
```

```
Required Thickness of Knuckle to Avoid Axisymmetric Yielding
ey = beta * P * (0.75 * R + 0.2 * Di) / f                       (7.5-2)
=0.6991*0.85*(0.75*499.2+0.2*613)/104=                       2.85 mm

Required Minimum End Thickness Excl.Allow. emin :
emin = emin =2.85=                                             2.85 mm

Required Minimum End Thickness Incl.Allow. :
emina = emin + c + th =2.85+3+0=                               5.85 mm
```

»Internal Pressure emina=5.85 <= en=8.5[mm] « » (U= 68.8%) OK«

```
Analysis Thickness
ea = en - c - th =8.5-3-0=                                     5.50 mm
Inside Diameter of Shell
Di = De - 2 * (en - c) =624-2*(8.5-3)=                       613.00 mm
Mean Diameter of Shell
Dm = (De + Di) / 2 =(624+613)/2=                             618.50 mm
```

7.5.3.4 - Required Minimum Thickness of Straight Cylindrical Flange

```
Llim = 0.2 * SQR( Di * emin) =0.2*SQR(613*2.85)=               8.35 mm
Since Lcyl > Llim, Required Thickness of Straight Cylindrical Flange to 7.4.2
Minimum Thickness of Straight Flange Excl. Allow.
ecyl = P * Di / (2 * f * z - P)                                 (7.4-1)
=0.85*613/(2*104*1-0.85)=                                    2.52 mm
```

7.5.3.1 Conditions of Applicability - Torispherical Ends

»Geometry Check r=96.096 <= 0.2 * Di=122.6[mm] « » OK«
»Geometry Check r=96.096 >= 0.06 * Di=36.78[mm] « » OK«
»Geometry Check r=96.096 >= 2*e[mm] « » OK«
»Geometry Check e=2.85 <= 0.08*De=49.92[mm] « » OK«
»Geometry Check ea=5.5 >= 0.001*De=0.624[mm] « » OK«
»Geometry Check R=499.2 <= De=624[mm] « » OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD

```
Ps = 2 * f * z * ea / (R + 0.5 * ea)                            (7.5-6)
=2*170.83*1*8.5/(496.2+0.5*8.5)=                             5.80 MPa
Py = f * ea / ( beta * ( 0.75 * R + 0.2 * Di))                  (7.5-7)
=170.83*8.5/(0.595*(0.75*496.2+0.2*613))=                    4.93 MPa
PB = 111*fb*(ea/(0.75*R+0.2*Di))^1.5*(r/Di)^0.825               (7.5-8)
=111*176.67*(8.5/(0.75*496.2+0.2*613))^1.5*(96.096/613)^0.825=      9.57 MPa
Pmax (is the least of Ps, Py and Pb) = Pmax =4.93=             4.93 MPa
```

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR

```
Ps = 2 * f * z * ea / (R + 0.5 * ea)                            (7.5-6)
=2*104*1*5.5/(499.2+0.5*5.5)=                                2.28 MPa
Py = f * ea / ( beta * ( 0.75 * R + 0.2 * Di))                  (7.5-7)
=104*5.5/(0.625*(0.75*499.2+0.2*613))=                       1.84 MPa
PB = 111*fb*(ea/(0.75*R+0.2*Di))^1.5*(r/Di)^0.825               (7.5-8)
=111*104*(5.5/(0.75*499.2+0.2*613))^1.5*(96.096/613)^0.825=      2.91 MPa
Pmax (is the least of Ps, Py and Pb) = Pmax =1.84=             1.84 MPa
```

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

```
Ps = 2 * f * z * ea / (R + 0.5 * ea)                            (7.5-6)
=2*252.38*1*8.5/(496.2+0.5*8.5)=                             8.57 MPa
Py = f * ea / ( beta * ( 0.75 * R + 0.2 * Di))                  (7.5-7)
=252.38*8.5/(0.595*(0.75*496.2+0.2*613))=                    7.29 MPa
PB = 111*fb*(ea/(0.75*R+0.2*Di))^1.5*(r/Di)^0.825               (7.5-8)
=111*252.38*(8.5/(0.75*496.2+0.2*613))^1.5*(96.096/613)^0.825=     13.68 MPa
Pmax (is the least of Ps, Py and Pb) = Pmax =7.29=             7.29 MPa
```

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 * f20 / f =1.25*0.85*170.83/104=              1.75 MPa
Ptmin = 1.43 * Pd =1.43*0.85=                                   1.22 MPa
```

»Test Pressure Ptmin=1.75 <= Ptmax=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 mm
Length of Shell Contributing to Reinforcement
Is = Sqr(( 2 * ris + ea) * ea)                                       (9.5-2)
=Sqr((2*499.2+5.5)*5.5)=                                      74.31 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)
=(5.5*74.31*(104-0.5*0.85)/0.85-499.2*74.31)/(0.5*499.2+0.5*5.5)=    50.35 mm

Maximum diameter of Opening Not Requiring Reinforcement Check
dmax2 = 0.15 * Sqr(( 2 * ris + ea) * ea)                             (9.5-18)
=0.15*Sqr((2*499.2+5.5)*5.5)=                                 11.15 mm

Maximum Diameter of Unreinforced Opening
dmax = MAX( dmax1, dmax2) =MAX(50.35,11.15)=                    50.35 mm
```

8.7 - SPHERICAL SHELL UNDER EXTERNAL PRESSURE

8.4.2 Nominal Elastic Limit Sige:

```
Sige = Rpt (8.4.2-1) =156=                                     156.00 N/mm2
Mean Radius R:
Rmean = R + ea / 2 =499.2+5.5/2=                               501.95 mm
MEMBRANE YIELD py
py = 2 * Sige * ea / Rmean (8.7.1-1) =2*156*5.5/501.95=          3.42 MPa

ELASTIC INSTABILITY pm
pm = 1.21 * E * ea ^ 2 / Rmean ^ 2                                   (8.7.1-2)
=1.21*1.851E05*5.5^2/501.95^2=                                26.89 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 MPa
Pmax = pr / S =1.95/1.5=                                        1.30 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*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=                                              2.85 mm

Required Minimum End Thickness Incl.Allow. :
emina = emin + c + th =2.85+3+0=                                5.85 mm
```

»Internal Pressure emina=5.85 <= en=8.5[mm] « » (U= 68.8%) OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD

```
Pmax (is the least of Ps, Py and Pb) = Pmax =4.93=          4.93 MPa
```

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR

```
Pmax (is the least of Ps, Py and Pb) = Pmax =1.84=          1.84 MPa
```

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

```
Pmax (is the least of Ps, Py and Pb) = Pmax =7.29=          7.29 MPa
```

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 * f20 / f =1.25*0.85*170.83/104=          1.75 MPa
Ptmin = 1.43 * Pd =1.43*0.85=                               1.22 MPa
```

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

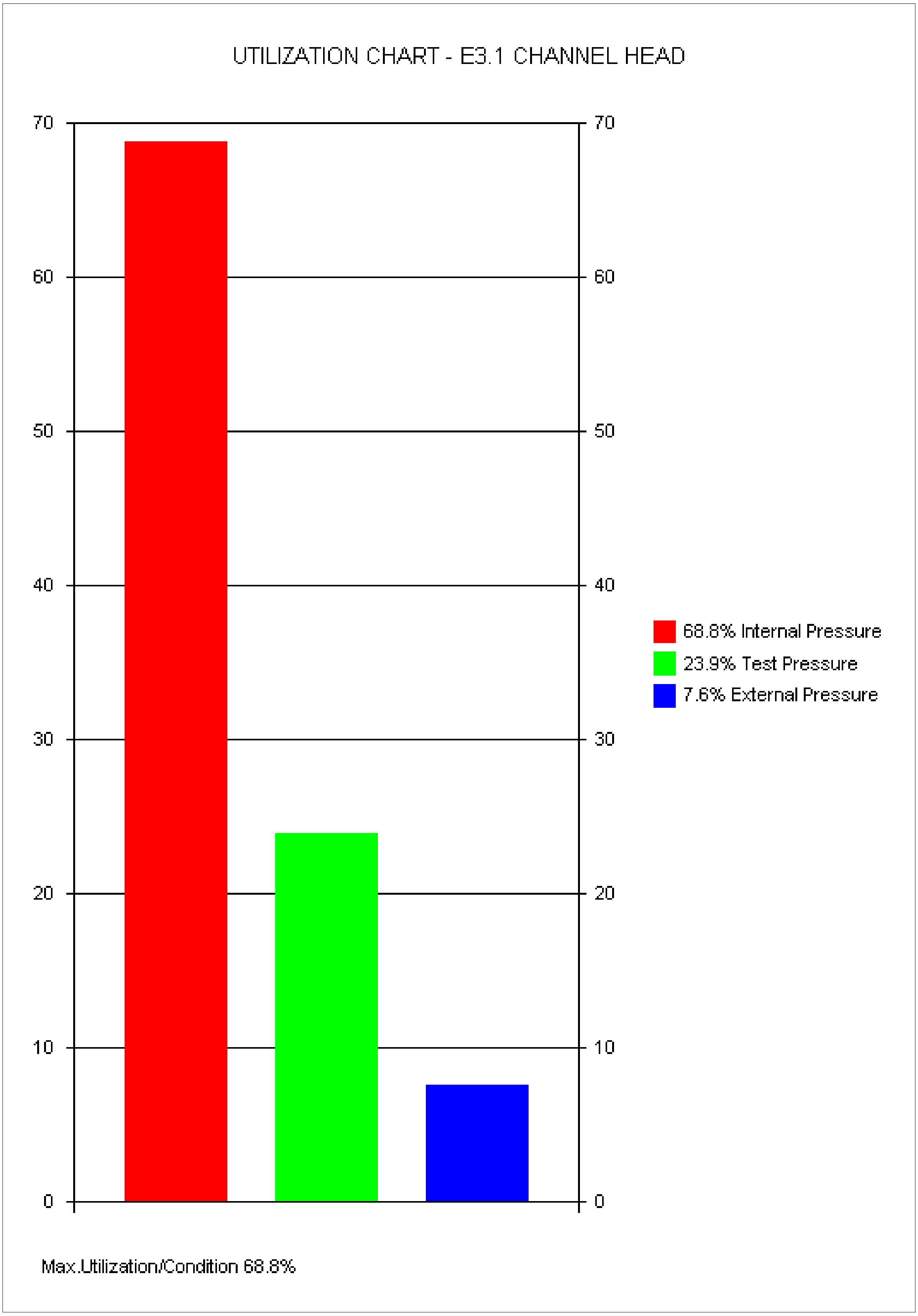
Maximum diameter of Opening Not Requiring Reinforcement Check , dmax

```
Maximum Diameter of Unreinforced Opening
dmax = MAX( dmax1, dmax2) =MAX(50.35,11.15)=               50.35 mm
```

8.7 - SPHERICAL SHELL UNDER EXTERNAL PRESSURE

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

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


UTILIZATION CHART - E3.1 CHANNEL HEAD
70
60
50
40
30
20
10
0
68.8% Internal Pressure
23.9% Test Pressure
7.6% External Pressure
Max.Utilization/Condition 68.8%

INPUT DATA

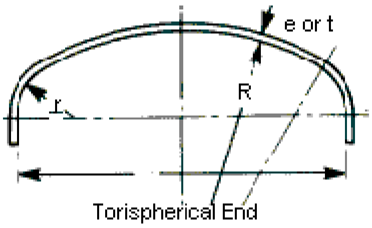
COMPONENT ATTACHMENT/LOCATION

```
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
es = P * R / (2 * f * z - 0.5 * P)                                  (7.5-1)
=0.5*691.2/(2*129.41*1-0.5*0.5)=                                1.34 mm

fb = Rpt / 1.5 (7.5-4) =194.12/1.5=                             129.41 N/mm2
Required Thickness of Knuckle to Avoid Plastic Buckling
eb = (0.75*R+0.2*Di)*((P/(111*fb)*(Di/r)^0.825)^(0.667)             (7.5-3)
=(0.75*691.2+0.2*849)*((0.5/(111*129.41)*(849/133.06)^0.825)^(0.667)
=      2.03 mm

7.5.3.5 Formulas for Calculation of Factor Beta
Y = MIN( emin / R, 0.04) (7.5-9) =MIN(2.03/691.2,0.04)=      0.0029
Z = LOG( 1 / Y) (7.5-10) =LOG(1/0.0029)=                        2.53
X = r / Di (7.5-11) =133.06/859.94=                          0.1547
N = 1.006 - 1 / (6.2 + (90 * Y) ^ 4)                                (7.5-12)
=1.006-1/(6.2+(90*0.0029)^4)=                              0.8448
Beta01 = N*(-0.1833*Z^3+1.0383*Z^2-1.2943*Z+0.837)                  (7.5-15)
=0.8448*(-0.1833*2.53^3+1.0383*2.53^2-1.2943*2.53+0.837)=      1.05
Beta02 = MAX( 0.5, 0.95 * (0.56 - 1.94 * Y - 82.5 * Y ^ 2))         (7.5-17)
=MAX(0.5,0.95*(0.56-1.94*0.0029-82.5*0.0029^2))=           0.5259
beta = 10 * ((0.2 - X) * Beta01 + (X - 0.1) * Beta02)               (7.5-16)
```

```
=10*((0.2-0.1547)*1.05+(0.1547-0.1)*0.5259)=              0.7624
Required Thickness of Knuckle to Avoid Axisymmetric Yielding
ey = beta * P * (0.75 * R + 0.2 * Di) / f                              (7.5-2)
=0.7624*0.5*(0.75*691.2+0.2*849)/129.41=                         2.03 mm

Required Minimum End Thickness Excl.Allow. emin :
emin = emin =2.03=                                                 2.03 mm

Required Minimum End Thickness Incl.Allow. :
emina = emin + c + th =2.03+3+0=                                   5.03 mm
```

»Internal Pressure emina=5.03 <= en=10.5[mm] « » (U= 47.9%) OK«

```
Analysis Thickness
ea = en - c - th =10.5-3-0=                                        7.50 mm
Inside Diameter of Shell
Di = De - 2 * (en - c) =864-2*(10.5-3)=                          849.00 mm
Mean Diameter of Shell
Dm = (De + Di) / 2 =(864+849)/2=                                 856.50 mm
```

7.5.3.4 - Required Minimum Thickness of Straight Cylindrical Flange

```
Llim = 0.2 * SQR( Di * emin) =0.2*SQR(849*2.03)=                   8.31 mm
Since Lcyl > Llim, Required Thickness of Straight Cylindrical Flange to 7.4.2
Minimum Thickness of Straight Flange Excl. Allow.
ecyl = P * Di / (2 * f * z - P)                                        (7.4-1)
=0.5*849/(2*129.41*1-0.5)=                                       1.64 mm
```

7.5.3.1 Conditions of Applicability - Torispherical Ends

»Geometry Check r=133.06 <= 0.2 * Di=169.8[mm] « » OK«

»Geometry Check r=133.06 >= 0.06 * Di=50.94[mm] « » OK«

»Geometry Check r=133.06 >= 2*e[mm] « » OK«

»Geometry Check e=2.03 <= 0.08*De=69.12[mm] « » OK«

»Geometry Check ea=7.5 >= 0.001*De=0.864[mm] « » OK«

»Geometry Check R=691.2 <= De=864[mm] « » OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD

```
Ps = 2 * f * z * ea / (R + 0.5 * ea)                                   (7.5-6)
=2*170.83*1*10.5/(688.2+0.5*10.5)=                               5.17 MPa
Py = f * ea / ( beta * ( 0.75 * R + 0.2 * Di))                         (7.5-7)
=170.83*10.5/(0.6019*(0.75*688.2+0.2*849))=                      4.34 MPa
PB = 111*fb*(ea/(0.75*R+0.2*Di))^1.5*(r/Di)^0.825                      (7.5-8)
=111*176.67*(10.5/(0.75*688.2+0.2*849))^1.5*(133.06/849)^0.825=     8.05 MPa
Pmax (is the least of Ps, Py and Pb) = Pmax =4.34=                 4.34 MPa
```

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR

```
Ps = 2 * f * z * ea / (R + 0.5 * ea)                                   (7.5-6)
=2*129.41*1*7.5/(691.2+0.5*7.5)=                                 2.79 MPa
Py = f * ea / ( beta * ( 0.75 * R + 0.2 * Di))                         (7.5-7)
=129.41*7.5/(0.6266*(0.75*691.2+0.2*849))=                       2.25 MPa
PB = 111*fb*(ea/(0.75*R+0.2*Di))^1.5*(r/Di)^0.825                      (7.5-8)
=111*129.41*(7.5/(0.75*691.2+0.2*849))^1.5*(133.06/849)^0.825=     3.54 MPa
Pmax (is the least of Ps, Py and Pb) = Pmax =2.25=                 2.25 MPa
```

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

```
Ps = 2 * f * z * ea / (R + 0.5 * ea)                                   (7.5-6)
=2*252.38*1*10.5/(688.2+0.5*10.5)=                               7.64 MPa
Py = f * ea / ( beta * ( 0.75 * R + 0.2 * Di))                         (7.5-7)
=252.38*10.5/(0.6019*(0.75*688.2+0.2*849))=                      6.42 MPa
PB = 111*fb*(ea/(0.75*R+0.2*Di))^1.5*(r/Di)^0.825                      (7.5-8)
=111*252.38*(10.5/(0.75*688.2+0.2*849))^1.5*(133.06/849)^0.825=    11.50 MPa
Pmax (is the least of Ps, Py and Pb) = Pmax =6.42=                 6.42 MPa
```

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 * f20 / f =1.25*0.5*170.83/129.41=          0.8250 MPa

Ptmin = 1.43 * Pd =1.43*0.5=                                  0.7150 MPa
```

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

Maximum diameter of Opening Not Requiring Reinforcement Check , dmax

```
ris = R (9.5-4) =691.2=                                         691.20 mm
Length of Shell Contributing to Reinforcement
Is = Sqr(( 2 * ris + ea) * ea)                                        (9.5-2)
=Sqr((2*691.2+7.5)*7.5)=                                      102.10 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)
=(7.5*102.1*(129.41-0.5*0.5)/0.5-691.2*102.1)/(0.5*691.2+0.5*7.5)=   364.21 mm

Maximum diameter of Opening Not Requiring Reinforcement Check
dmax2 = 0.15 * Sqr(( 2 * ris + ea) * ea)                              (9.5-18)
=0.15*Sqr((2*691.2+7.5)*7.5)=                                 15.31 mm

Maximum Diameter of Unreinforced Opening
dmax = MAX( dmax1, dmax2) =MAX(364.21,15.31)=                   364.21 mm
```

8.7 - SPHERICAL SHELL UNDER EXTERNAL PRESSURE

8.4.2 Nominal Elastic Limit Sige:

```
Sige = Rpt (8.4.2-1) =194.12=                                   194.12 N/mm2
Mean Radius R:
Rmean = R + ea / 2 =691.2+7.5/2=                                694.95 mm
MEMBRANE YIELD py
py = 2 * Sige * ea / Rmean (8.7.1-1) =2*194.12*7.5/694.95=        4.19 MPa

ELASTIC INSTABILITY pm
pm = 1.21 * E * ea ^ 2 / Rmean ^ 2                                    (8.7.1-2)
=1.21*196147*7.5^2/694.95^2=                                  27.64 MPa

Value pr/py From Figure 8.5-5 Curve   2
Value1 =  ==                                                  0.5700
```

MAX. ALLOWABLE EXTERNAL PRESSURE Pmax

```
pr = Value1 * py =0.57*4.19=                                      2.39 MPa
Pmax = pr / S =2.39/1.5=                                          1.59 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*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=                                                2.03 mm

Required Minimum End Thickness Incl.Allow. :
emina = emin + c + th =2.03+3+0=                                  5.03 mm
```

»Internal Pressure emina=5.03 <= en=10.5[mm] « » (U= 47.9%) OK«

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :NEW & COLD
```
Pmax (is the least of Ps, Py and Pb) = Pmax =4.34=          4.34 MPa
```

MAXIMUM ALLOWABLE WORKING PRESSURE MAWP :HOT & CORR
```
Pmax (is the least of Ps, Py and Pb) = Pmax =2.25=          2.25 MPa
```

MAX TEST PRESSURE (Uncorroded cond.at ambient temp.)
```
Pmax (is the least of Ps, Py and Pb) = Pmax =6.42=          6.42 MPa
```

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 * f20 / f =1.25*0.5*170.83/129.41=       0.8250 MPa
Ptmin = 1.43 * Pd =1.43*0.5=                               0.7150 MPa
```

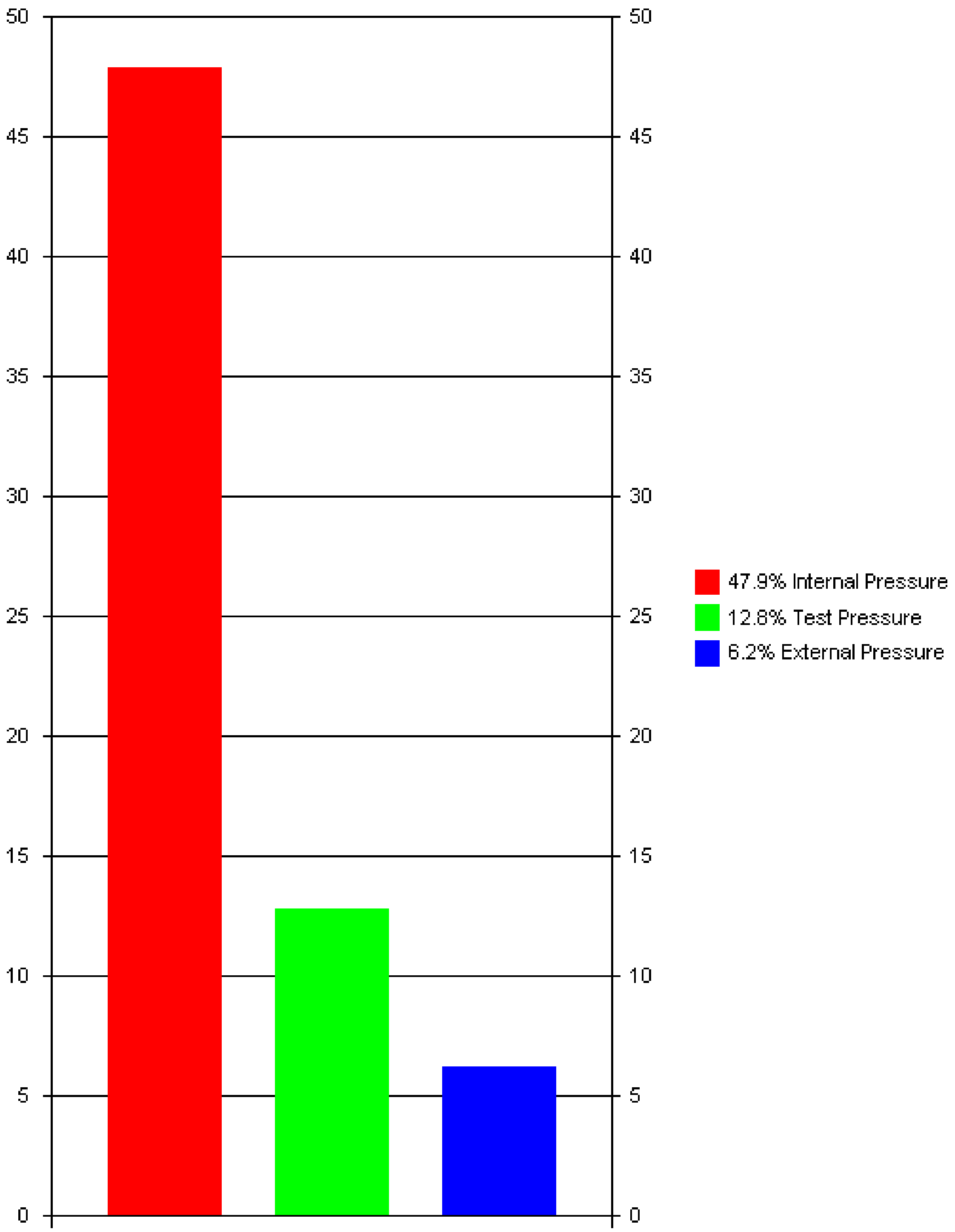
»Test Pressure Ptmin=0.825 <= Ptmax=6.42[MPa] « » (U= 12.8%) OK«

Maximum diameter of Opening Not Requiring Reinforcement Check , dmax
```
Maximum Diameter of Unreinforced Opening
dmax = MAX( dmax1, dmax2) =MAX(364.21,15.31)=               364.21 mm
```

8.7 - SPHERICAL SHELL UNDER EXTERNAL PRESSURE
»External Pressure Pmax=1.59 >= Pext=0.1[MPa] « » (U= 6.2%) OK«

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

UTILIZATION CHART - E3.2 SHELL HEAD

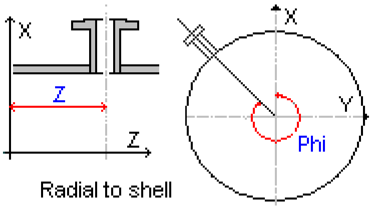


Max.Utilization/Condition 47.9%

INPUT DATA

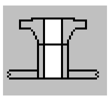
COMPONENT ATTACHMENT/LOCATION

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



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

GENERAL DESIGN DATA

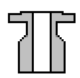


Type of Opening: Nozzle With Standard ANSI or DIN/EN Flange Attachment
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm, Pext= .1MPa
Include Nozzle Load Calculation: YES

SHELL DATA (S1.3)

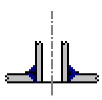
Shell Type: Cylindrical Shell
OUTSIDE DIAMETER OF SHELL...........................:De 864.00 mm
AS BUILT WALL THICKNESS (uncorroded)................:en 12.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE...............:th 0.5000 mm
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
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

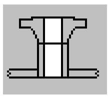
FLANGE DATA

```
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



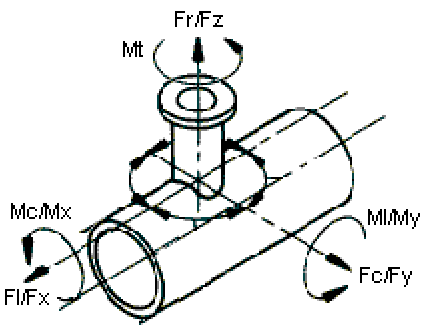
Type of Pad: No Pad

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

PRELIMINARY CALCULATIONS

```
Shell Analysis Thickness eas
eas = en - c - th =12-3-0.5=                                8.50 mm
Nozzle Analysis Thickness eab
eab = enb - c - NegDev =13.49-3-0=                         10.49 mm
Inside Radius of Curvature
ris = De / 2 - eas (9.5-3) =864/2-8.5=                    423.50 mm
deb = dib + 2 * eab =56.79+2*10.49=                        77.77 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 mm
Allowable Stresses
fob = Min( fs, fb) (16.5-8) =Min(129.41,118.13)=          118.13 N/mm2
```

GEOMETRIC LIMITATIONS

»Check Max.Diameter of Nozzle dib/(2*ris)=0.067 <= 1[mm] «» OK«

»Min.Nozzle Thk. ebp=0.12 <= eab=10.49[mm] « » (U= 1.1%) OK«

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

Calculation of Stress Loaded Areas Effective as Reinforcement

Area of Shell Afs

```
Limit of Reinforcement Along Shell
Iso = Sqr(( 2 * ris + eas) * eas)
=Sqr((2*423.5+8.5)*8.5)=                                 85.27 mm
Set In Nozzle
Afs = eas * Is (16.5-78) =8.5*85.27=                      724.83 mm2
```

Area of Nozzle Afb

```
Limit of Reinforcement Along Nozzle (outside shell)
Ibo = MIN( Sqr(( deb - eb) * eb), ho)                           (16.5-75)
=MIN(Sqr((77.77-10.49)*10.49,)200)=                      26.57 mm
Set In Nozzle
Afb = eb * (Ibo + Ibi + eas) (16.5-77) =10.49*(26.57+0+8.5)=   367.85 mm2
```

Calculation of Pressure Loaded Areas

```
In the Nozzle Apb
Apb = 0.5 * dib * (Ibo + eas) (16.5-83) =0.5*56.79*(26.57+8.5)=   995.71 mm2

Cyl.Shell in the Longitudinal Section Aps
ApsL = ris * (Is + a) (16.5-93) =423.5*(85.27+38.89)=      52581.57 mm2

Cyl.Shell in the Transverse Cross Section Aps
ApsT = 0.5 * ris ^ 2 * (Is + a ) / (0.5 * eas + ris)            (16.5-104)
=0.5*423.5^2*(85.27+38.94)/(0.5*8.5+423.5)=              26040.84 mm2

Aps = MAX( ApsL ApsT) =MAX(52581.57,26040.84)=             52581.57 mm2
```

9.5.2 Reinforcement Rules

Pressure Area Required pA(req.)

```
pAReqL = P * (ApsL + Apb) (16.5-7) =0.5*(52581.57+995.71)=   26.79 kN

pAReqT = P * (ApsT + Apb + 0.5 * Apphi)                        (16.5-7)
=0.5*(26040.84+995.71+0.5*0)=                             13.52 kN

pAReq = MAX( pAReqL, pAReqT) =MAX(26.79,13.52)=              26.79 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)=   136.98 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)
=+0)*129.41+367.85*118.13/((52581.57+995.71+0.5*0)+0.5*(724.83+0+367.85+0))
=      2.54 MPa
```

Max.Allowable Test Pressure Ptmax

```
Ptmax =  ==                                                      6.63 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=                               10.49 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=0.789 <= 10« » OK«

```
»c) Dist.to any other local load shall not be less than SQR(D*ec)=  85.3 mm
»d) Nozzle thickness shall be maintained over a distance of SQR(d*eb)=  26.6 mm
```

LOAD CASE NO: 1 - Load Case 1

```
Total Moment
MB = Sqr( Mx ^ 2 + My ^ 2) =Sqr(-0.29^2+-0.29^2)=             0.4101 kNm
```

STRESSES AT OUTER DIAMETER OF NOZZLE

```
Mean Diameter of Nozzle
d = deb - eb =77.77-10.49=                                      67.28 mm
Combined Analysis Thickness
ec = ea =8.5=                                                    8.50 mm
LamdaC = 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 FIGURES16.5-2 to 16.5-4
C1 =     1.810  C2 =     4.900  C3 =     7.338
```

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

```
Permissible Pressure Pmax:
Pmax (from nozzle calculation) = Pmax (16.5-2) =2.54=            2.54 MPa

Allowable Axial Load Fzmax:
Fzmax = f * ec ^ 2 * C1 (16.5-3) =129.41*8.5^2*1.81=            16.92 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=                                   0.7706 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=                                    1.15 kNm
```

SHEAR STRESS FORMULAES (PD5500 Section G.2.3.6.3)

```
Shear Stresses due to Longitudinal Shear Force, TauFl:
TauFl = 2 * Fl / (PI * deb * ec)
=2*-2.5/(3.14*77.77*8.5)=                                -2.41 N/mm2

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

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

Total Shear Stresses, Tau:
Tau = Sqr( TauFc ^ 2 + TauFl ^ 2) + TauMt
=Sqr(-1.85^2+-2.41^2)+-37.15=                           -34.11 N/mm2
```

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

```
PhiP = P / Pmax (16.5-9) =-0.1/2.54=                      -0.0394

PhiZ = Fz / Fzmax (16.5-10) =-2.5/16.92=                  -0.1477

PhiTau = Tau / (0.5 * f) =-34.11/(0.5*129.41)=            0.5272

PhiB = Sqr(( Mx / Mxmax) ^ 2 + (My / Mymax) ^ 2)                (16.5-11)
=Sqr((-0.29/0.7706)^2+(-0.29/1.15)^2)=                  0.4525

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

PhiAll = Sqr( MaxAll ^ 2 + PhiB ^ 2 + PhiTau ^ 2)               (16.5-15)
=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

```
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)
=Max(2.5,0)-Min(0,0)=                                     2.50 kN

DeltaMx = Max( Mxmax , 0) - Min( Mxmin , 0)                     (16.5-18)
=Max(0.29,0)-Min(0,0)=                                  0.2900 kNm

DeltaMy = Max( Mymax , 0) - Min( Mymin , 0)                     (16.5-19)
=Max(0.29,0)-Min(0,0)=                                  0.2900 kNm

DeltaFl = Max( Flmax , 0) - Min( Flmin , 0)
=Max(2.5,0)-Min(0,0)=                                     0.00 kN

DeltaFc = Max( Fcmax , 0) - Min( Fcmin , 0)
=Max(1.92,0)-Min(0,0)=                                    0.00 kN

DeltaFshear = Sqr( DeltaFl ^ 2 + DeltaFc ^ 2)
=Sqr(0^2+0^2)=                                            0.00 kN

DeltaMt = Max( Mtmax , 0) - Min( Mtmin , 0)
=Max(3,0)-Min(0,0)=                                       0.00 kNm
```

16.5.7.2 EQVIVALENT SHELL THICKNESS

```
eeq = ec =8.5=                                                    8.50 mm
```

16.5.7.3 STRESSES

```
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 to 16.5-4
C1 =    1.810  C2 =    4.900  C3 =    7.338
Tmp1 = Sqr( d * eb / (D * eeq))
=Sqr(67.28*10.49/(855.5*8.5))=                               0.3115
Tmp2 = (2+2*d/D*Tmp1+1.25*d/D*Sqr(D/eeq))/(1+eb/eeq*Tmp1)
=(2+2*67.28/855.5*0.3115+1.25*67.28/855.5*Sqr(855.5/8.5))/(1+10.49/8.5*0.31
15)=                                                            =     2.19
Stresses due to Pressure Range
SigP = DeltaP * D / (2 * eeq) * Tmp2                                 (16.5-21)
=0.1*855.5/(2*8.5)*2.19=                                      11.03 N/mm2

Stresses due to Axial Load Range
SigFz = 2.25 / C1 * (DeltaFz / eeq ^ 2)                              (16.5-22)
=2.25/1.81*(2.5/8.5^2)=                                       43.01 N/mm2

Stresses due to Circumferential Moment Range
SigMx = 2.25 / C2 * (4 * DeltaMx / (eeq ^ 2 * d))                    (16.5-23)
=2.25/4.9*(4*0.29/(8.5^2*67.28))=                            109.58 N/mm2

Stresses due to Longitudinal Moment Range
SigMy = 2.25 / C3 * (4 * DeltaMy / (eeq ^ 2 * d))                    (16.5-24)
=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 * DeltaFl / (PI * deb * eeq)
=2*0/(3.14*77.77*8.5)=                                         0.00 N/mm2

Shear Stresses due to Circumferential Force, TauFc:
TauFc = 2 * DeltaFc / (PI * deb * eeq)
=2*0/(3.14*77.77*8.5)=                                         0.00 N/mm2

Shear Stresses due to Torsional Moment, TauMt:
TauMt = 2 * DeltaMt / (PI * deb ^ 2 * eeq)
=2*0/(3.14*77.77^2*8.5)=                                       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((11.03+43.01)^2+109.58^2+73.17^2+4*0^2))=         142.41 N/mm2
```

»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/(PI*d^2*eb)+Fz/(PI*d*eb)                   (16.5-26)
=-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 N/mm2
```

»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)                                      (16.14-15)
=1.21*196147*10.49/(177.2*67.28)=                            208.83
alfa = 0.83 / Sqr( 1 + 0.005 * D / ea)                              (16.14-16)
=0.83/Sqr(1+0.005*67.28/10.49)=                             0.8170
delta = (1 - 0.4123 / (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+Abs(0)/256.98=                               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 kNm
```

STRESSES AT OUTER DIAMETER OF NOZZLE

```
Mean Diameter of Nozzle
d = deb - eb =77.77-10.49=                                     67.28 mm
Combined Analysis Thickness
ec = ea =8.5=                                                   8.50 mm
LamdaC = 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 FIGURES16.5-2 to 16.5-4
C1 =    1.810  C2 =    4.900  C3 =    7.338
```

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

```
Permissible Pressure Pmax:
Pmax (from nozzle calculation) = Pmax (16.5-2) =2.54=           2.54 MPa

Allowable Axial Load Fzmax:
Fzmax = f * ec ^ 2 * C1 (16.5-3) =129.41*8.5^2*1.81=           16.92 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=                                0.7706 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=                                 1.15 kNm
```

SHEAR STRESS FORMULAES (PD5500 Section G.2.3.6.3)

```
Shear Stresses due to Longitudinal Shear Force, TauFl:
TauFl = 2 * Fl / (PI * deb * ec)
=2*2.5/(3.14*77.77*8.5)=                                    2.41 N/mm2

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

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

Total Shear Stresses, Tau:
Tau = Sqr( TauFc ^ 2 + TauFl ^ 2) + TauMt
=Sqr(1.85^2+2.41^2)+37.15=                                 40.19 N/mm2
```

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

```
PhiP = P / Pmax (16.5-9) =0.5/2.54=                          0.1656

PhiZ = Fz / Fzmax (16.5-10) =2.5/16.92=                      0.1477

PhiTau = Tau / (0.5 * f) =40.19/(0.5*129.41)=                0.6211
```

```
PhiB = Sqr(( Mx / Mxmax) ^ 2 + (My / Mymax) ^ 2)                        (16.5-11)
=Sqr((0.29/0.7706)^2+(0.29/1.15)^2)=                           0.4525

MaxAll = MAX(Abs(PhiP/C4+PhiZ),Abs(PhiZ),Abs(PhiP/C4-0.2*PhiZ)          (16.5-15)
=MAX(Abs(0.1656/1.1+0.1477,)Abs(0.1477,)Abs(0.1656/1.1-0.2*0.1477)=   0.2983

PhiAll = Sqr( MaxAll ^ 2 + PhiB ^ 2 + PhiTau ^ 2)                       (16.5-15)
=Sqr(0.2983^2+0.4525^2+0.6211^2)=                              0.8243
```

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

```
DeltaP = Max( Pmax , 0) - Min( Pmin , 0)                                (16.5-16)
=Max(0.42,0)-Min(0,0)=                                         0.4200 MPa

DeltaFz = Max( Fzmax , 0) - Min( Fzmin , 0)                             (16.5-17)
=Max(2.5,0)-Min(0,0)=                                             2.50 kN

DeltaMx = Max( Mxmax , 0) - Min( Mxmin , 0)                             (16.5-18)
=Max(0.29,0)-Min(0,0)=                                         0.2900 kNm

DeltaMy = Max( Mymax , 0) - Min( Mymin , 0)                             (16.5-19)
=Max(0.29,0)-Min(0,0)=                                         0.2900 kNm

DeltaFl = Max( Flmax , 0) - Min( Flmin , 0)
=Max(2.5,0)-Min(0,0)=                                             2.50 kN

DeltaFc = Max( Fcmax , 0) - Min( Fcmin , 0)
=Max(1.92,0)-Min(0,0)=                                            1.92 kN

DeltaFshear = Sqr( DeltaFl ^ 2 + DeltaFc ^ 2)
=Sqr(2.5^2+1.92^2)=                                               3.15 kN

DeltaMt = Max( Mtmax , 0) - Min( Mtmin , 0)
=Max(3,0)-Min(0,0)=                                               3.00 kNm
```

16.5.7.2 EQVIVALENT SHELL THICKNESS

```
eeq = ec =8.5=                                                      8.50 mm
```

16.5.7.3 STRESSES

```
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 to 16.5-4
C1 =     1.810  C2 =     4.900  C3 =     7.338
Tmp1 = Sqr( d * eb / (D * eeq))
=Sqr(67.28*10.49/(855.5*8.5))=                                 0.3115
Tmp2 = (2+2*d/D*Tmp1+1.25*d/D*Sqr(D/eeq))/(1+eb/eeq*Tmp1)
=(2+2*67.28/855.5*0.3115+1.25*67.28/855.5*Sqr(855.5/8.5))/(1+10.49/8.5*0.31
15)=                                                              =     2.19
Stresses due to Pressure Range
SigP = DeltaP * D / (2 * eeq) * Tmp2                                    (16.5-21)
=0.42*855.5/(2*8.5)*2.19=                                       46.34 N/mm2

Stresses due to Axial Load Range
SigFz = 2.25 / C1 * (DeltaFz / eeq ^ 2)                                 (16.5-22)
=2.25/1.81*(2.5/8.5^2)=                                         43.01 N/mm2

Stresses due to Circumferential Moment Range
SigMx = 2.25 / C2 * (4 * DeltaMx / (eeq ^ 2 * d))                       (16.5-23)
=2.25/4.9*(4*0.29/(8.5^2*67.28))=                              109.58 N/mm2

Stresses due to Longitudinal Moment Range
SigMy = 2.25 / C3 * (4 * DeltaMy / (eeq ^ 2 * d))                       (16.5-24)
```

```
=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 * DeltaFl / (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 + TauFl ^ 2) + TauMt
=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)
=Abs(0+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 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 / (Sige * D)                                      (16.14-15)
=1.21*196147*10.49/(177.2*67.28)=                        208.83
alfa = 0.83 / Sqr( 1 + 0.005 * D / ea)                              (16.14-16)
=0.83/Sqr(1+0.005*67.28/10.49)=                         0.8170
delta = (1 - 0.4123 / (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+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)
=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)
=MIN(Sqr((77.77-10.49)*10.49,)200)=                       26.57 mm
```

Pressure Area Required pA(req.)

```
pAReqL = P * (ApsL + Apb) (16.5-7) =0.5*(52581.57+995.71)=     26.79 kN
pAReqT = P * (ApsT + Apb + 0.5 * Apphi)                          (16.5-7)
=0.5*(26040.84+995.71+0.5*0)=                                  13.52 kN
pAReq = MAX( pAReqL, pAReqT) =MAX(26.79,13.52)=                 26.79 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)=   136.98 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)
=+0)*129.41+367.85*118.13/((52581.57+995.71+0.5*0)+0.5*(724.83+0+367.85+0))
=     2.54 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

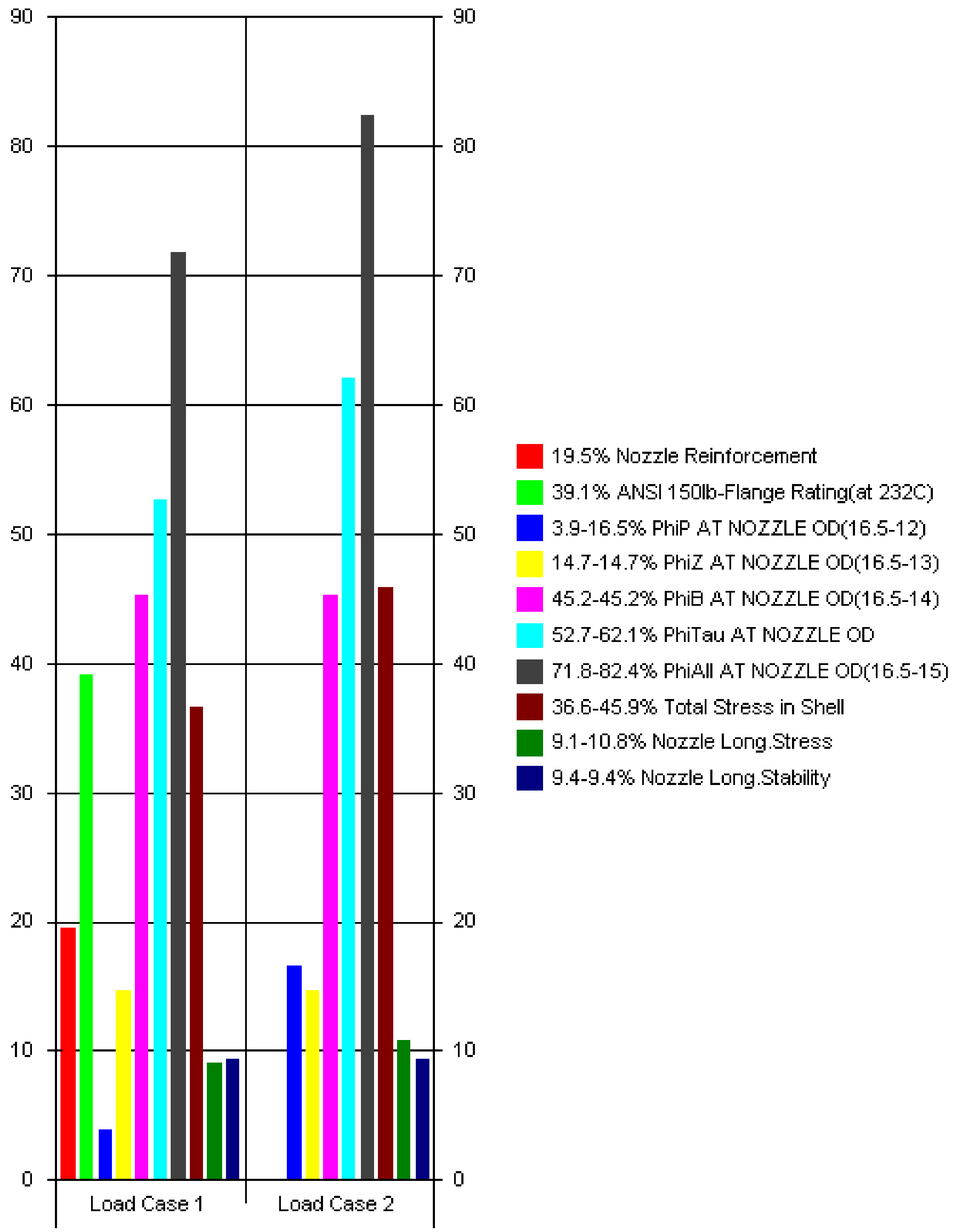
»Total Stress in Shell SigTot=178.34 <= 3*f=388.23[N/mm2] «» (U= 45.9%) OK«

16.5.8 NOZZLE LONGITUDINAL STRESSES

»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)

UTILIZATION CHART - N.A INLET

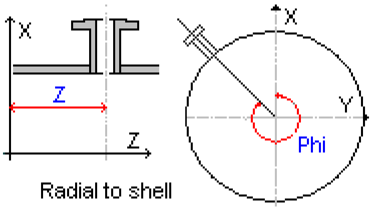


Max.Utilization/Condition 82.4% CASE:Load Case 2

INPUT DATA

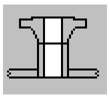
COMPONENT ATTACHMENT/LOCATION

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




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

GENERAL DESIGN DATA

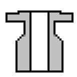


```
Type of Opening: Nozzle With Standard ANSI or DIN/EN Flange Attachment
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm, Pext= .1MPa
Include Nozzle Load Calculation: YES
```

SHELL DATA (S1.3)

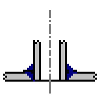
```
Shell Type: Cylindrical Shell
OUTSIDE DIAMETER OF SHELL...........................:De        864.00 mm
AS BUILT WALL THICKNESS (uncorroded)................:en         12.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE...............:th       0.5000 mm
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, 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
```

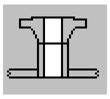
FLANGE DATA

```
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



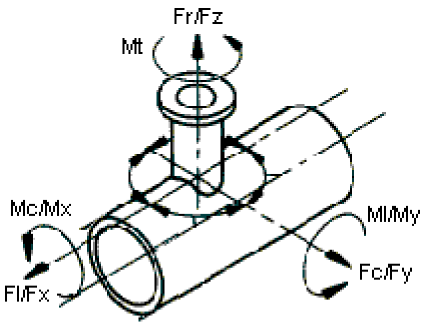
Type of Pad: No Pad

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

PRELIMINARY CALCULATIONS

```
Shell Analysis Thickness eas
eas = en - c - th =12-3-0.5=                              8.50 mm
Nozzle Analysis Thickness eab
eab = enb - c - NegDev =13.49-3-0=                       10.49 mm
Inside Radius of Curvature
ris = De / 2 - eas (9.5-3) =864/2-8.5=                  423.50 mm
deb = dib + 2 * eab =56.79+2*10.49=                      77.77 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 mm
Allowable Stresses
fob = Min( fs, fb) (16.5-8) =Min(129.41,118.13)=        118.13 N/mm2
```

GEOMETRIC LIMITATIONS

»Check Max.Diameter of Nozzle dib/(2*ris)=0.067 <= 1[mm] «» OK«

»Min.Nozzle Thk. ebp=0.12 <= eab=10.49[mm] « » (U= 1.1%) 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
Iso = Sqr(( 2 * ris + eas) * eas)
=Sqr((2*423.5+8.5)*8.5)=                               85.27 mm
Set In Nozzle
Afs = eas * Is (16.5-78) =8.5*85.27=                    724.83 mm2
```

Area of Nozzle Afb

```
Limit of Reinforcement Along Nozzle (outside shell)
Ibo = MIN( Sqr(( deb - eb) * eb), ho)                          (16.5-75)
=MIN(Sqr((77.77-10.49)*10.49,)200)=                    26.57 mm
Set In Nozzle
Afb = eb * (Ibo + Ibi + eas) (16.5-77) =10.49*(26.57+0+8.5)=    367.85 mm2
```

Calculation of Pressure Loaded Areas

```
In the Nozzle Apb
Apb = 0.5 * dib * (Ibo + eas) (16.5-83) =0.5*56.79*(26.57+8.5)=    995.71 mm2

Cyl.Shell in the Longitudinal Section Aps
ApsL = ris * (Is + a) (16.5-93) =423.5*(85.27+38.89)=      52581.57 mm2

Cyl.Shell in the Transverse Cross Section Aps
ApsT = 0.5 * ris ^ 2 * (Is + a ) / (0.5 * eas + ris)          (16.5-104)
=0.5*423.5^2*(85.27+38.94)/(0.5*8.5+423.5)=          26040.84 mm2

Aps = MAX( ApsL ApsT) =MAX(52581.57,26040.84)=           52581.57 mm2
```

9.5.2 Reinforcement Rules

Pressure Area Required pA(req.)

```
pAReqL = P * (ApsL + Apb) (16.5-7) =0.5*(52581.57+995.71)=    26.79 kN

pAReqT = P * (ApsT + Apb + 0.5 * Apphi)                        (16.5-7)
=0.5*(26040.84+995.71+0.5*0)=                          13.52 kN

pAReq = MAX( pAReqL, pAReqT) =MAX(26.79,13.52)=            26.79 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)=   136.98 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)
=+0)*129.41+367.85*118.13/((52581.57+995.71+0.5*0)+0.5*(724.83+0+367.85+0))
=      2.54 MPa
```

Max.Allowable Test Pressure Ptmax

```
Ptmax =  ==                                                    6.63 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=                             10.49 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=0.789 <= 10« » OK«

```
»c) Dist.to any other local load shall not be less than SQR(D*ec)=  85.3 mm
»d) Nozzle thickness shall be maintained over a distance of SQR(d*eb)=  26.6 mm
```

LOAD CASE NO: 1 - Load Case 1

```
Total Moment
MB = Sqr( Mx ^ 2 + My ^ 2) =Sqr(-0.29^2+-0.29^2)=          0.4101 kNm
```

STRESSES AT OUTER DIAMETER OF NOZZLE

```
Mean Diameter of Nozzle
d = deb - eb =77.77-10.49=                                    67.28 mm
Combined Analysis Thickness
ec = ea =8.5=                                                  8.50 mm
LamdaC = 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 FIGURES16.5-2 to 16.5-4
C1 =     1.810  C2 =     4.900  C3 =     7.338
```

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

```
Permissible Pressure Pmax:
Pmax (from nozzle calculation) = Pmax (16.5-2) =2.54=          2.54 MPa

Allowable Axial Load Fzmax:
Fzmax = f * ec ^ 2 * C1 (16.5-3) =129.41*8.5^2*1.81=         16.92 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=                                 0.7706 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=                                  1.15 kNm
```

SHEAR STRESS FORMULAES (PD5500 Section G.2.3.6.3)

```
Shear Stresses due to Longitudinal Shear Force, TauFl:
TauFl = 2 * Fl / (PI * deb * ec)
=2*-2.5/(3.14*77.77*8.5)=                                      -2.41 N/mm2

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

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

Total Shear Stresses, Tau:
Tau = Sqr( TauFc ^ 2 + TauFl ^ 2) + TauMt
=Sqr(-1.85^2+-2.41^2)+-37.15=                                 -34.11 N/mm2
```

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

```
PhiP = P / Pmax (16.5-9) =-0.1/2.54=                            -0.0394

PhiZ = Fz / Fzmax (16.5-10) =-2.5/16.92=                        -0.1477

PhiTau = Tau / (0.5 * f) =-34.11/(0.5*129.41)=                 0.5272

PhiB = Sqr(( Mx / Mxmax) ^ 2 + (My / Mymax) ^ 2)                (16.5-11)
=Sqr((-0.29/0.7706)^2+(-0.29/1.15)^2)=                       0.4525

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

PhiAll = Sqr( MaxAll ^ 2 + PhiB ^ 2 + PhiTau ^ 2)               (16.5-15)
=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

```
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)
=Max(2.5,0)-Min(0,0)=                                          2.50 kN

DeltaMx = Max( Mxmax , 0) - Min( Mxmin , 0)                     (16.5-18)
=Max(0.29,0)-Min(0,0)=                                       0.2900 kNm

DeltaMy = Max( Mymax , 0) - Min( Mymin , 0)                     (16.5-19)
=Max(0.29,0)-Min(0,0)=                                       0.2900 kNm

DeltaFl = Max( Flmax , 0) - Min( Flmin , 0)
=Max(2.5,0)-Min(0,0)=                                          0.00 kN

DeltaFc = Max( Fcmax , 0) - Min( Fcmin , 0)
=Max(1.92,0)-Min(0,0)=                                         0.00 kN

DeltaFshear = Sqr( DeltaFl ^ 2 + DeltaFc ^ 2)
=Sqr(0^2+0^2)=                                                 0.00 kN

DeltaMt = Max( Mtmax , 0) - Min( Mtmin , 0)
=Max(3,0)-Min(0,0)=                                            0.00 kNm
```

16.5.7.2 EQVIVALENT SHELL THICKNESS

```
eeq = ec =8.5=                                              8.50 mm
```

16.5.7.3 STRESSES

```
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 to 16.5-4
C1 =    1.810  C2 =    4.900  C3 =    7.338
Tmp1 = Sqr( d * eb / (D * eeq))
=Sqr(67.28*10.49/(855.5*8.5))=                         0.3115
Tmp2 = (2+2*d/D*Tmp1+1.25*d/D*Sqr(D/eeq))/(1+eb/eeq*Tmp1)
=(2+2*67.28/855.5*0.3115+1.25*67.28/855.5*Sqr(855.5/8.5))/(1+10.49/8.5*0.31
15)=                                                   =     2.19
Stresses due to Pressure Range
SigP = DeltaP * D / (2 * eeq) * Tmp2                            (16.5-21)
=0.1*855.5/(2*8.5)*2.19=                               11.03 N/mm2

Stresses due to Axial Load Range
SigFz = 2.25 / C1 * (DeltaFz / eeq ^ 2)                         (16.5-22)
=2.25/1.81*(2.5/8.5^2)=                                43.01 N/mm2

Stresses due to Circumferential Moment Range
SigMx = 2.25 / C2 * (4 * DeltaMx / (eeq ^ 2 * d))               (16.5-23)
=2.25/4.9*(4*0.29/(8.5^2*67.28))=                     109.58 N/mm2

Stresses due to Longitudinal Moment Range
SigMy = 2.25 / C3 * (4 * DeltaMy / (eeq ^ 2 * d))               (16.5-24)
=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 * DeltaFl / (PI * deb * eeq)
=2*0/(3.14*77.77*8.5)=                                  0.00 N/mm2

Shear Stresses due to Circumferential Force, TauFc:
TauFc = 2 * DeltaFc / (PI * deb * eeq)
=2*0/(3.14*77.77*8.5)=                                  0.00 N/mm2

Shear Stresses due to Torsional Moment, TauMt:
TauMt = 2 * DeltaMt / (PI * deb ^ 2 * eeq)
=2*0/(3.14*77.77^2*8.5)=                                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((11.03+43.01)^2+109.58^2+73.17^2+4*0^2))=  142.41 N/mm2
```

»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/(PI*d^2*eb)+Fz/(PI*d*eb)              (16.5-26)
=-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 N/mm2
```

»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)                                  (16.14-15)
=1.21*196147*10.49/(177.2*67.28)=                     208.83
alfa = 0.83 / Sqr( 1 + 0.005 * D / ea)                          (16.14-16)
=0.83/Sqr(1+0.005*67.28/10.49)=                      0.8170
delta = (1 - 0.4123 / (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+Abs(0)/256.98=                                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 kNm
```

STRESSES AT OUTER DIAMETER OF NOZZLE

```
Mean Diameter of Nozzle
d = deb - eb =77.77-10.49=                                     67.28 mm
Combined Analysis Thickness
ec = ea =8.5=                                                   8.50 mm
LamdaC = 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 FIGURES16.5-2 to 16.5-4
C1 =    1.810  C2 =    4.900  C3 =    7.338
```

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

```
Permissible Pressure Pmax:
Pmax (from nozzle calculation) = Pmax (16.5-2) =2.54=           2.54 MPa

Allowable Axial Load Fzmax:
Fzmax = f * ec ^ 2 * C1 (16.5-3) =129.41*8.5^2*1.81=           16.92 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=                                 0.7706 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=                                   1.15 kNm
```

SHEAR STRESS FORMULAES (PD5500 Section G.2.3.6.3)

```
Shear Stresses due to Longitudinal Shear Force, TauFl:
TauFl = 2 * Fl / (PI * deb * ec)
=2*2.5/(3.14*77.77*8.5)=                                      2.41 N/mm2

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

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

Total Shear Stresses, Tau:
Tau = Sqr( TauFc ^ 2 + TauFl ^ 2) + TauMt
=Sqr(1.85^2+2.41^2)+37.15=                                   40.19 N/mm2
```

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

```
PhiP = P / Pmax (16.5-9) =0.5/2.54=                          0.1656

PhiZ = Fz / Fzmax (16.5-10) =2.5/16.92=                      0.1477

PhiTau = Tau / (0.5 * f) =40.19/(0.5*129.41)=                0.6211
```

```
PhiB = Sqr(( Mx / Mxmax) ^ 2 + (My / Mymax) ^ 2)                    (16.5-11)
=Sqr((0.29/0.7706)^2+(0.29/1.15)^2)=                         0.4525

MaxAll = MAX(Abs(PhiP/C4+PhiZ),Abs(PhiZ),Abs(PhiP/C4-0.2*PhiZ)      (16.5-15)
=MAX(Abs(0.1656/1.1+0.1477,)Abs(0.1477,)Abs(0.1656/1.1-0.2*0.1477)=  0.2983

PhiAll = Sqr( MaxAll ^ 2 + PhiB ^ 2 + PhiTau ^ 2)                   (16.5-15)
=Sqr(0.2983^2+0.4525^2+0.6211^2)=                            0.8243
```

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

```
DeltaP = Max( Pmax , 0) - Min( Pmin , 0)                            (16.5-16)
=Max(0.42,0)-Min(0,0)=                                       0.4200 MPa

DeltaFz = Max( Fzmax , 0) - Min( Fzmin , 0)                         (16.5-17)
=Max(2.5,0)-Min(0,0)=                                          2.50 kN

DeltaMx = Max( Mxmax , 0) - Min( Mxmin , 0)                         (16.5-18)
=Max(0.29,0)-Min(0,0)=                                       0.2900 kNm

DeltaMy = Max( Mymax , 0) - Min( Mymin , 0)                         (16.5-19)
=Max(0.29,0)-Min(0,0)=                                       0.2900 kNm

DeltaFl = Max( Flmax , 0) - Min( Flmin , 0)
=Max(2.5,0)-Min(0,0)=                                          2.50 kN

DeltaFc = Max( Fcmax , 0) - Min( Fcmin , 0)
=Max(1.92,0)-Min(0,0)=                                         1.92 kN

DeltaFshear = Sqr( DeltaFl ^ 2 + DeltaFc ^ 2)
=Sqr(2.5^2+1.92^2)=                                            3.15 kN

DeltaMt = Max( Mtmax , 0) - Min( Mtmin , 0)
=Max(3,0)-Min(0,0)=                                            3.00 kNm
```

16.5.7.2 EQVIVALENT SHELL THICKNESS

```
eeq = ec =8.5=                                                   8.50 mm
```

16.5.7.3 STRESSES

```
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 to 16.5-4
C1 =     1.810  C2 =     4.900  C3 =     7.338
Tmp1 = Sqr( d * eb / (D * eeq))
=Sqr(67.28*10.49/(855.5*8.5))=                               0.3115
Tmp2 = (2+2*d/D*Tmp1+1.25*d/D*Sqr(D/eeq))/(1+eb/eeq*Tmp1)
=(2+2*67.28/855.5*0.3115+1.25*67.28/855.5*Sqr(855.5/8.5))/(1+10.49/8.5*0.31
15)=                                                           =     2.19
Stresses due to Pressure Range
SigP = DeltaP * D / (2 * eeq) * Tmp2                                (16.5-21)
=0.42*855.5/(2*8.5)*2.19=                                      46.34 N/mm2

Stresses due to Axial Load Range
SigFz = 2.25 / C1 * (DeltaFz / eeq ^ 2)                             (16.5-22)
=2.25/1.81*(2.5/8.5^2)=                                        43.01 N/mm2

Stresses due to Circumferential Moment Range
SigMx = 2.25 / C2 * (4 * DeltaMx / (eeq ^ 2 * d))                   (16.5-23)
=2.25/4.9*(4*0.29/(8.5^2*67.28))=                             109.58 N/mm2

Stresses due to Longitudinal Moment Range
SigMy = 2.25 / C3 * (4 * DeltaMy / (eeq ^ 2 * d))                   (16.5-24)
```

```
=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 * DeltaFl / (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 + TauFl ^ 2) + TauMt
=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)
=Abs(0+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 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 / (Sige * D)                                       (16.14-15)
=1.21*196147*10.49/(177.2*67.28)=                          208.83
alfa = 0.83 / Sqr( 1 + 0.005 * D / ea)                               (16.14-16)
=0.83/Sqr(1+0.005*67.28/10.49)=                          0.8170
delta = (1 - 0.4123 / (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+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)
=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)
=MIN(Sqr((77.77-10.49)*10.49,)200)=                               26.57 mm
```

Pressure Area Required pA(req.)

```
pAReqL = P * (ApsL + Apb) (16.5-7) =0.5*(52581.57+995.71)=     26.79 kN
pAReqT = P * (ApsT + Apb + 0.5 * Apphi)                             (16.5-7)
=0.5*(26040.84+995.71+0.5*0)=                                  13.52 kN
pAReq = MAX( pAReqL, pAReqT) =MAX(26.79,13.52)=                26.79 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)=   136.98 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)
=+0)*129.41+367.85*118.13/((52581.57+995.71+0.5*0)+0.5*(724.83+0+367.85+0))
=     2.54 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

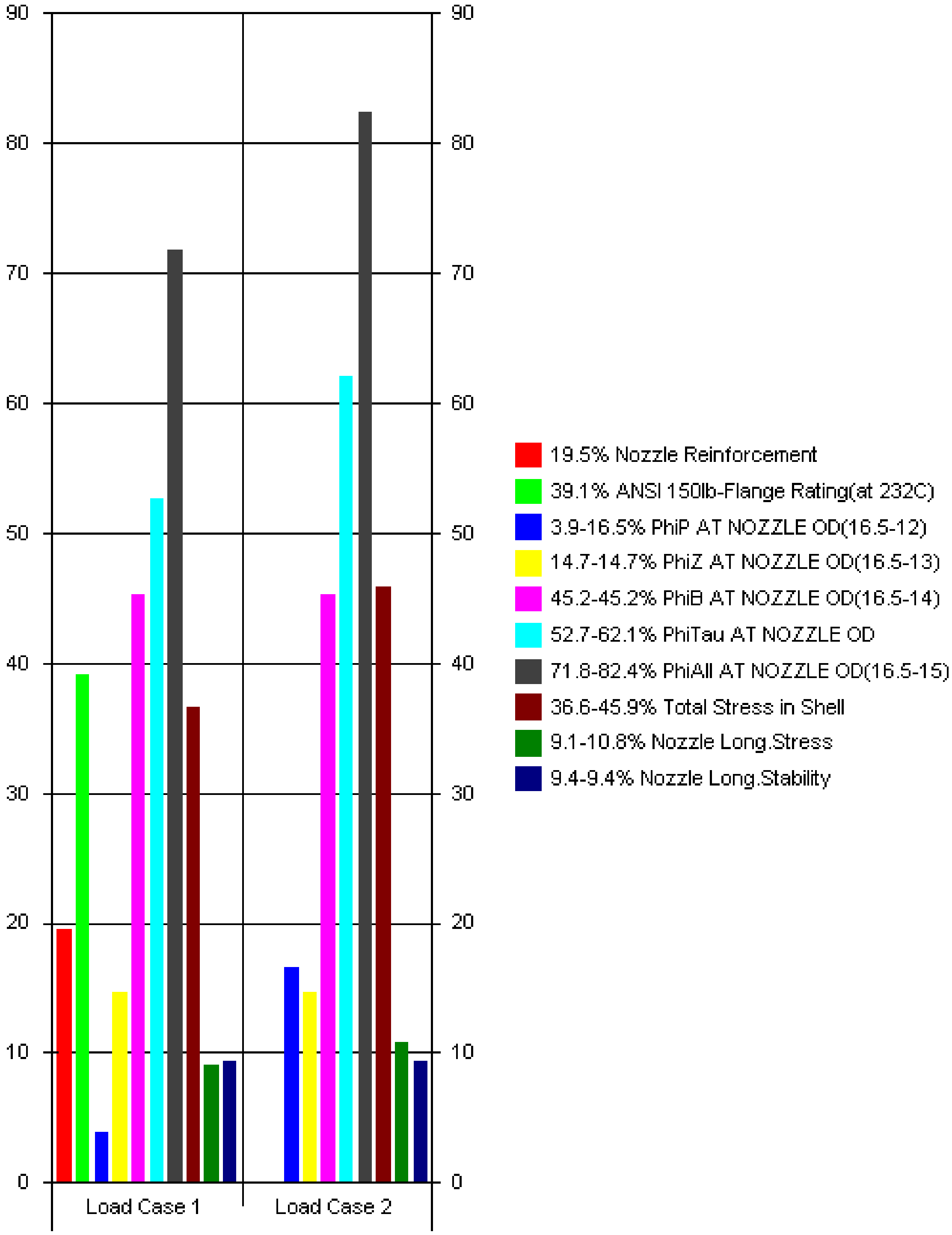
»Total Stress in Shell SigTot=178.34 <= 3*f=388.23[N/mm2] «» (U= 45.9%) OK«

16.5.8 NOZZLE LONGITUDINAL STRESSES

»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)

UTILIZATION CHART - N.B OUTLET LIQ

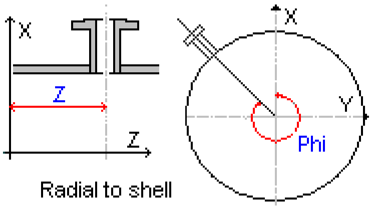


Max.Utilization/Condition 82.4% CASE:Load Case 2

INPUT DATA

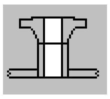
COMPONENT ATTACHMENT/LOCATION

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




```
Orientation & Location of Nozzle: Radial to Shell
z-location of nozzle along axis of attacment........:z        3197.00 mm
Angle of Rotation of nozzle axis projected in the x-y plane:Phi     0.00 Degr.
```

GENERAL DESIGN DATA

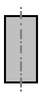


```
Type of Opening: Nozzle With Standard ANSI or DIN/EN Flange Attachment
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm, Pext= .1MPa
Include Nozzle Load Calculation: YES
```

SHELL DATA (S1.3)

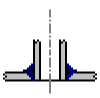
```
Shell Type: Cylindrical Shell
OUTSIDE DIAMETER OF SHELL...........................:De        864.00 mm
AS BUILT WALL THICKNESS (uncorroded)................:en         12.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE...............:th       0.5000 mm
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, 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
```

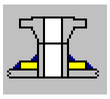
FLANGE DATA

```
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



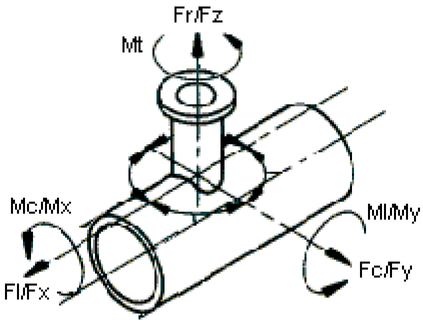
```
Type of Pad: Single Pad
THICKNESS OF THE REINFORCEMENT PAD..................:eap          9.50 mm
WIDTH OF THE REINFORCEMENT PAD......................:lp          65.85 mm
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
Rm=410 Rp=265 Rpt=194.12 fp=129.41 f20=170.83 ftest=252.38 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*

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 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) (16.5-20) =MIN(9.5,8.5)=              8.50 mm
Inside Radius of Curvature
ris = De / 2 - eas (9.5-3) =864/2-8.5=                  423.50 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)
=0.5*168.27/(2*114.37*1+0.5)=                         0.3700 mm
Allowable Stresses
fob = Min( fs, fb) (16.5-8) =Min(129.41,114.37)=        114.37 N/mm2
fop = Min( fs, fp) (16.5-9) =Min(129.41,129.41)=        129.41 N/mm2
```

GEOMETRIC LIMITATIONS

»Check Max.Thk.of Pad eap=9.5 <= 1.5*eas=12.75[mm] « » OK«
»Check Max.Diameter of Nozzle dib/(2*ris)=0.1831 <= .5[mm] «» OK«
»Min.Nozzle Thk. ebp=0.37 <= eab=6.6[mm] « » (U= 5.6%) 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
Iso = Sqr(( 2 * ris + eas) * eas)
=Sqr((2*423.5+8.5)*8.5)=                                85.27 mm
Set In Nozzle
Afs = eas * Is (16.5-78) =8.5*85.27=                    724.83 mm2
```

Area of Reinforcement Pad Afp

```
Limit of Reinforcement Along Pad
Ip = Min( Ip, Is ) (16.5-86) =Min(65.85,85.27)=          65.85 mm
ep = Min( ep, eas) (16.5-87) =Min(8.5,8.5)=               8.50 mm
Afp = ep * Ip (16.5-85) =8.5*65.85=                     559.73 mm2
```

Area of Nozzle Afb

```
Limit of Reinforcement Along Nozzle (outside shell)
Ibo = MIN( Sqr(( deb - eb) * eb), ho)                        (16.5-75)
=MIN(Sqr((168.27-6.6)*6.6,)200)=                        32.66 mm
Set In Nozzle
Afb = eb * (Ibo + Ibi + eas) (16.5-77) =6.6*(32.66+0+8.5)=   271.62 mm2
```

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 mm2

Cyl.Shell in the Longitudinal Section Aps
ApsL = ris * (Is + a) (16.5-93) =423.5*(85.27+84.14)=     71744.95 mm2

Cyl.Shell in the Transverse Cross Section Aps
ApsT = 0.5 * ris ^ 2 * (Is + a ) / (0.5 * eas + ris)         (16.5-104)
=0.5*423.5^2*(85.27+84.69)/(0.5*8.5+423.5)=            35631.82 mm2

Aps = MAX( ApsL ApsT) =MAX(71744.95,35631.82)=           71744.95 mm2
```

9.5.2 Reinforcement Rules

Pressure Area Required pA(req.)

```
pAReqL = P * (ApsL + Apb) (16.5-7) =0.5*(71744.95+3191.57)=      37.47 kN

pAReqT = P * (ApsT + Apb + 0.5 * Apphi)                          (16.5-7)
=0.5*(35631.82+3191.57+0.5*0)=                                  19.41 kN

pAReq = MAX( pAReqL, pAReqT) =MAX(37.47,19.41)=                    37.47 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)+559.73*(129.41-0.5*0.5)+271.62*(114.37-0.5*0.5
)=                                                               =    196.91 kN
```

»Nozzle Reinforcement pAAval=196.91 >= pAReq=37.47[kN] « » (U= 19%) OK«

Maximum Allowable Pressure Pmax

```
Pmax =(Afs+Afw)*fs+Afp*fop+Afb*fob/((Aps+Apb+0.5*Apphi)+0.5*(Afs+Afw+Afb+Afp))(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))=                                            =      2.61 MPa
```

Max.Allowable Test Pressure Ptmax

```
Ptmax =  ==                                                         6.31 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 =10.97-3-1.37=                                6.60 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=1.3 <= 10« » OK«

```
»c) Dist.to any other local load shall not be less than SQR(D*ec)=  124.1 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(-2.5^2+-3^2)=                       3.91 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 / f 1)
=8.5+9.5*Min(129.41/129.41,1)=                                  18.00 mm
LamdaC = d / Sqr( D * ec) =161.67/Sqr(855.5*18)=                    1.30
Ratio1 = eb / ec =6.6/18=                                       0.3666
Ratio2 = D / ec =855.5/18=                                        47.53
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 to 16.5-4
C1 =    1.847  C2 =    4.900  C3 =    8.005
```

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

```
Permissible Pressure Pmax:
Pmax (from nozzle calculation) = Pmax (16.5-2) =2.61=          2.61 MPa

Allowable Axial Load Fzmax:
Fzmax = f * ec ^ 2 * C1 (16.5-3) =129.41*18^2*1.85=           77.43 kN

Allowable Circumferential Moment Mxmax:
Mxmax = f * ec ^ 2 * d / 4 * C2                                 (16.5-5)
=129.41*18^2*161.67/4*4.9=                                   8.30 kNm

Allowable Longitudinal Moment Mxmax:
Mymax = f * ec ^ 2 * d / 4 * C3                                 (16.5-7)
=129.41*18^2*161.67/4*8.=                                   13.57 kNm
```

SHEAR STRESS FORMULAES (PD5500 Section G.2.3.6.3)

```
Shear Stresses due to Longitudinal Shear Force, TauFl:
TauFl = 2 * Fl / (PI * deb * ec)
=2*-7.5/(3.14*168.27*18)=                                   -1.58 N/mm2

Shear Stresses due to Circumferential Force, TauFc:
TauFc = 2 * Fc / (PI * deb * ec)
=2*-5.5/(3.14*168.27*18)=                                   -1.16 N/mm2

Shear Stresses due to Torsional Moment, TauMt:
TauMt = 2 * Mt / (PI * deb ^ 2 * ec)
=2*-3/(3.14*168.27^2*18)=                                   -3.75 N/mm2

Total Shear Stresses, Tau:
Tau = Sqr( TauFc ^ 2 + TauFl ^ 2) + TauMt
=Sqr(-1.16^2+-1.58^2)+-3.75=                                -1.79 N/mm2
```

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

```
PhiP = P / Pmax (16.5-9) =-0.1/2.61=                          -0.0384

PhiZ = Fz / Fzmax (16.5-10) =-7.5/77.43=                      -0.0969

PhiTau = Tau / (0.5 * f) =-1.79/(0.5*129.41)=                0.0277

PhiB = Sqr(( Mx / Mxmax) ^ 2 + (My / Mymax) ^ 2)                (16.5-11)
=Sqr((-2.5/8.3)^2+(-3/13.57)^2)=                            0.3736

MaxAll = MAX(Abs(PhiP/C4+PhiZ),Abs(PhiZ),Abs(PhiP/C4-0.2*PhiZ)) (16.5-15)
=MAX(Abs(-0.0384/1.1+-0.0969,)Abs(-0.0969,)Abs(-0.0384/1.1-0.2*-0.0969)
=  0.1317

PhiAll = Sqr( MaxAll ^ 2 + PhiB ^ 2 + PhiTau ^ 2)               (16.5-15)
=Sqr(0.1317^2+0.3736^2+0.0277^2)=                           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 = deb + 2 * lp =168.27+2*65.85=                            299.97 mm
Combined Analysis Thickness
ec = ea =8.5=                                                  8.50 mm
LamdaC = d / Sqr( D * ec) =299.97/Sqr(855.5*8.5)=             3.52
Ratio1 = MAX( eb / ec , 0.5) =MAX(6.6/8.5,0.5)=              0.7763
Ratio2 = D / ec =855.5/8.5=                                  100.65
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 to 16.5-4
C1 =    3.953  C2 =    5.944  C3 =   20.029
```

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

```
Permissible Pressure Pmax:
Pmax (from nozzle calculation) = Pmax (16.5-2) =2.61=          2.61 MPa

Allowable Axial Load Fzmax:
Fzmax = f * ec ^ 2 * C1 (16.5-3) =129.41*8.5^2*3.95=          36.96 kN

Allowable Circumferential Moment Mxmax:
Mxmax = f * ec ^ 2 * d / 4 * C2                                (16.5-5)
=129.41*8.5^2*299.97/4*5.94=                                4.17 kNm

Allowable Longitudinal Moment Mxmax:
Mymax = f * ec ^ 2 * d / 4 * C3                                (16.5-7)
=129.41*8.5^2*299.97/4*20.03=                              14.04 kNm
```

SHEAR STRESS FORMULAES (PD5500 Section G.2.3.6.3)

```
Shear Stresses due to Longitudinal Shear Force, TauFl:
TauFl = 2 * Fl / (PI * deb * ec)
=2*-7.5/(3.14*168.27*8.5)=                                 -3.34 N/mm2

Shear Stresses due to Circumferential Force, TauFc:
TauFc = 2 * Fc / (PI * deb * ec)
=2*-5.5/(3.14*168.27*8.5)=                                 -2.45 N/mm2

Shear Stresses due to Torsional Moment, TauMt:
TauMt = 2 * Mt / (PI * deb ^ 2 * ec)
=2*-3/(3.14*168.27^2*8.5)=                                 -7.94 N/mm2

Total Shear Stresses, Tau:
Tau = Sqr( TauFc ^ 2 + TauFl ^ 2) + TauMt
=Sqr(-2.45^2+-3.34^2)+-7.94=                               -3.80 N/mm2
```

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

```
PhiP = P / Pmax (16.5-9) =-0.1/2.61=                         -0.0384

PhiZ = Fz / Fzmax (16.5-10) =-7.5/36.96=                     -0.2029

PhiTau = Tau / (0.5 * f) =-3.8/(0.5*129.41)=                 0.0587

PhiB = Sqr(( Mx / Mxmax) ^ 2 + (My / Mymax) ^ 2)             (16.5-11)
=Sqr((-2.5/4.17)^2+(-3/14.04)^2)=                       0.6368

MaxAll = MAX(Abs(PhiP/C4+PhiZ),Abs(PhiZ),Abs(PhiP/C4-0.2*PhiZ)     (16.5-15)
=MAX(Abs(-0.0384/1.1+-0.2029,)Abs(-0.2029,)Abs(-0.0384/1.1-0.2*-0.2029)
=  0.2378

PhiAll = Sqr( MaxAll ^ 2 + PhiB ^ 2 + PhiTau ^ 2)            (16.5-15)
=Sqr(0.2378^2+0.6368^2+0.0587^2)=                       0.6823
```

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«

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)
=Max(7.5,0)-Min(0,0)=                                     7.50 kN

DeltaMx = Max( Mxmax , 0) - Min( Mxmin , 0)                  (16.5-18)
=Max(2.5,0)-Min(0,0)=                                     2.50 kNm

DeltaMy = Max( Mymax , 0) - Min( Mymin , 0)                  (16.5-19)
```

```
=Max(3,0)-Min(0,0)=                                            3.00 kNm

DeltaFl = Max( Flmax , 0) - Min( Flmin , 0)
=Max(7.5,0)-Min(0,0)=                                          0.00 kN

DeltaFc = Max( Fcmax , 0) - Min( Fcmin , 0)
=Max(5.5,0)-Min(0,0)=                                          0.00 kN

DeltaFshear = Sqr( DeltaFl ^ 2 + DeltaFc ^ 2)
=Sqr(0^2+0^2)=                                                 0.00 kN

DeltaMt = Max( Mtmax , 0) - Min( Mtmin , 0)
=Max(3,0)-Min(0,0)=                                            0.00 kNm
```

16.5.7.2 EQVIVALENT SHELL THICKNESS

```
eeq = ea+Min(eap*Ip/Sqr(D*(ea+eap)),eap)*Min(fp/f1)                (16.5-20)
=8.5+Min(9.5*65.85/Sqr(855.5*(8.5+9.5,))9.5)*Min(129.41/129.41,1)=    13.54 mm
```

16.5.7.3 STRESSES

```
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 to 16.5-4
C1 =    2.038  C2 =    4.914  C3 =   10.270
Tmp1 = Sqr( d * eb / (D * eeq))
=Sqr(161.67*6.6/(855.5*13.54))=                              0.3035
Tmp2 = (2+2*d/D*Tmp1+1.25*d/D*Sqr(D/eeq))/(1+eb/eeq*Tmp1)
=(2+2*161.67/855.5*0.3035+1.25*161.67/855.5*Sqr(855.5/13.54))/(1+6.6/13.54*
0.3035)=                                                        =     3.48
Stresses due to Pressure Range
SigP = DeltaP * D / (2 * eeq) * Tmp2                               (16.5-21)
=0.1*855.5/(2*13.54)*3.48=                                    10.99 N/mm2

Stresses due to Axial Load Range
SigFz = 2.25 / C1 * (DeltaFz / eeq ^ 2)                            (16.5-22)
=2.25/2.04*(7.5/13.54^2)=                                     45.17 N/mm2

Stresses due to Circumferential Moment Range
SigMx = 2.25 / C2 * (4 * DeltaMx / (eeq ^ 2 * d))                  (16.5-23)
=2.25/4.91*(4*2.5/(13.54^2*161.67))=                         154.47 N/mm2

Stresses due to Longitudinal Moment Range
SigMy = 2.25 / C3 * (4 * DeltaMy / (eeq ^ 2 * d))                  (16.5-24)
=2.25/10.27*(4*3/(13.54^2*161.67))=                           88.68 N/mm2

Shear Stresses due to Longitudinal Shear Force, DeltaFl:
TauFl = 2 * DeltaFl / (PI * deb * eeq)
=2*0/(3.14*168.27*13.54)=                                      0.00 N/mm2

Shear Stresses due to Circumferential Force, TauFc:
TauFc = 2 * DeltaFc / (PI * deb * eeq)
=2*0/(3.14*168.27*13.54)=                                      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*13.54)=                                    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((10.99+45.17)^2+154.47^2+88.68^2+4*0^2))=         186.76 N/mm2
```

»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
SigLong = P*d/(4*eb)+4*MB/(PI*d^2*eb)+Fz/(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 N/mm2
```

»Nozzle Long.Stress SigLong=28.22 <= fb=114.37[N/mm2] « » (U= 24.6%) OK«

16.14.6 COMPRESSIVE STRESS LIMITS

```
K = 1.21 * E * ea / (Sige * D)                                  (16.14-15)
=1.21*196147*6.6/(171.56*161.67)=                        56.47
alfa = 0.83 / Sqr( 1 + 0.005 * D / ea)                          (16.14-16)
=0.83/Sqr(1+0.005*161.67/6.6)=                         0.7834
delta = (1 - 0.4123 / (alfa * K) ^ 0.6) / S                     (16.14-19)
=(1-0.4123/(0.7834*56.47)^0.6)/1.5=                    0.6384
Maximum Allowable Compressive Stress
Sigcall = Sige * delta (16.14-20) =171.56*0.6384=         109.52 N/mm2
```

16.14.4 PERMISSIBLE INDIVIDUAL LOADS

```
Maximum Tensile Force Ftmax
Ftmax = PI * D * ea * f (16.14-1) =3.14*161.67*6.6*114.37=   383.32 kN

Maximum Compressive Force Fcmax
Fcmax = PI * D * ea * Sigcall (16.14-2) =3.14*161.67*6.6*109.52=   367.06 kN

Maximum Bending Moment Mmax
Mmax = PI / 4 * D ^ 2 * ea * Sigcall                            (16.14-3)
=3.14/4*161.67^2*6.6*109.52=                             14.84 kNm

Longitudinal Stability Check (P=0)
LongStab = MB / Mmax + Abs( Fzmin) / Fcmax                      (16.5-27)
=3.91/14.84+Abs(0)/367.06=                             0.2632
```

»Nozzle Long.Stability LongStab=0.2632 <= 1.0=1« » (U= 26.3%) OK«

LOAD CASE NO: 2 - Load Case 2

```
Total Moment
MB = Sqr( Mx ^ 2 + My ^ 2) =Sqr(2.5^2+3^2)=                     3.91 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 / f 1)
=8.5+9.5*Min(129.41/129.41,1)=                           18.00 mm
LamdaC = d / Sqr( D * ec) =161.67/Sqr(855.5*18)=            1.30
Ratio1 = eb / ec =6.6/18=                                0.3666
Ratio2 = D / ec =855.5/18=                                 47.53
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 to 16.5-4
C1 =    1.847  C2 =    4.900  C3 =    8.005
```

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

```
Permissible Pressure Pmax:
Pmax (from nozzle calculation) = Pmax (16.5-2) =2.61=       2.61 MPa

Allowable Axial Load Fzmax:
Fzmax = f * ec ^ 2 * C1 (16.5-3) =129.41*18^2*1.85=        77.43 kN

Allowable Circumferential Moment Mxmax:
Mxmax = f * ec ^ 2 * d / 4 * C2                                 (16.5-5)
=129.41*18^2*161.67/4*4.9=                                8.30 kNm

Allowable Longitudinal Moment Mxmax:
Mymax = f * ec ^ 2 * d / 4 * C3                                 (16.5-7)
=129.41*18^2*161.67/4*8.=                                13.57 kNm
```

SHEAR STRESS FORMULAES (PD5500 Section G.2.3.6.3)

```
Shear Stresses due to Longitudinal Shear Force, TauFl:
TauFl = 2 * Fl / (PI * deb * ec)
=2*7.5/(3.14*168.27*18)=                                  1.58 N/mm2

Shear Stresses due to Circumferential Force, TauFc:
TauFc = 2 * Fc / (PI * deb * ec)
=2*5.5/(3.14*168.27*18)=                                  1.16 N/mm2
```

```
Shear Stresses due to Torsional Moment, TauMt:
TauMt = 2 * Mt / (PI * deb ^ 2 * ec)
=2*3/(3.14*168.27^2*18)=                                  3.75 N/mm2

Total Shear Stresses, Tau:
Tau = Sqr( TauFc ^ 2 + TauFl ^ 2) + TauMt
=Sqr(1.16^2+1.58^2)+3.75=                                 5.70 N/mm2
```

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

```
PhiP = P / Pmax (16.5-9) =0.42/2.61=                     0.1612

PhiZ = Fz / Fzmax (16.5-10) =7.5/77.43=                  0.0969

PhiTau = Tau / (0.5 * f) =5.7/(0.5*129.41)=              0.0881

PhiB = Sqr(( Mx / Mxmax) ^ 2 + (My / Mymax) ^ 2)               (16.5-11)
=Sqr((2.5/8.3)^2+(3/13.57)^2)=                         0.3736

MaxAll = MAX(Abs(PhiP/C4+PhiZ),Abs(PhiZ),Abs(PhiP/C4-0.2*PhiZ)     (16.5-15)
=MAX(Abs(0.1612/1.1+0.0969,)Abs(0.0969,)Abs(0.1612/1.1-0.2*0.0969)=  0.2434

PhiAll = Sqr( MaxAll ^ 2 + PhiB ^ 2 + PhiTau ^ 2)              (16.5-15)
=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
d = deb + 2 * Ip =168.27+2*65.85=                          299.97 mm
Combined Analysis Thickness
ec = ea =8.5=                                                8.50 mm
LamdaC = d / Sqr( D * ec) =299.97/Sqr(855.5*8.5)=            3.52
Ratio1 = MAX( eb / ec , 0.5) =MAX(6.6/8.5,0.5)=            0.7763
Ratio2 = D / ec =855.5/8.5=                                100.65
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 to 16.5-4
C1 =     3.953   C2 =     5.944   C3 =    20.029
```

16.5.5 MAXIMUM ALLOWABLE INDIVIDUAL LOADS

```
Permissible Pressure Pmax:
Pmax (from nozzle calculation) = Pmax (16.5-2) =2.61=        2.61 MPa

Allowable Axial Load Fzmax:
Fzmax = f * ec ^ 2 * C1 (16.5-3) =129.41*8.5^2*3.95=        36.96 kN

Allowable Circumferential Moment Mxmax:
Mxmax = f * ec ^ 2 * d / 4 * C2                                (16.5-5)
=129.41*8.5^2*299.97/4*5.94=                               4.17 kNm

Allowable Longitudinal Moment Mxmax:
Mymax = f * ec ^ 2 * d / 4 * C3                                (16.5-7)
=129.41*8.5^2*299.97/4*20.03=                            14.04 kNm
```

SHEAR STRESS FORMULAES (PD5500 Section G.2.3.6.3)

```
Shear Stresses due to Longitudinal Shear Force, TauFl:
TauFl = 2 * Fl / (PI * deb * ec)
=2*7.5/(3.14*168.27*8.5)=                                  3.34 N/mm2

Shear Stresses due to Circumferential Force, TauFc:
TauFc = 2 * Fc / (PI * deb * ec)
=2*5.5/(3.14*168.27*8.5)=                                  2.45 N/mm2

Shear Stresses due to Torsional Moment, TauMt:
```

```
TauMt = 2 * Mt / (PI * deb ^ 2 * ec)
=2*3/(3.14*168.27^2*8.5)=                                   7.94 N/mm2

Total Shear Stresses, Tau:
Tau = Sqr( TauFc ^ 2 + TauFl ^ 2) + TauMt
=Sqr(2.45^2+3.34^2)+7.94=                                  12.08 N/mm2
```

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

```
PhiP = P / Pmax (16.5-9) =0.5/2.61=                        0.1612

PhiZ = Fz / Fzmax (16.5-10) =7.5/36.96=                    0.2029

PhiTau = Tau / (0.5 * f) =12.08/(0.5*129.41)=              0.1866

PhiB = Sqr(( Mx / Mxmax) ^ 2 + (My / Mymax) ^ 2)                 (16.5-11)
=Sqr((2.5/4.17)^2+(3/14.04)^2)=                          0.6368

MaxAll = MAX(Abs(PhiP/C4+PhiZ),Abs(PhiZ),Abs(PhiP/C4-0.2*PhiZ)   (16.5-15)
=MAX(Abs(0.1612/1.1+0.2029,)Abs(0.2029,)Abs(0.1612/1.1-0.2*0.2029)=  0.3495

PhiAll = Sqr( MaxAll ^ 2 + PhiB ^ 2 + PhiTau ^ 2)                (16.5-15)
=Sqr(0.3495^2+0.6368^2+0.1866^2)=                        0.7500
```

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

```
DeltaP = Max( Pmax , 0) - Min( Pmin , 0)                         (16.5-16)
=Max(0.42,0)-Min(0,0)=                                   0.4200 MPa

DeltaFz = Max( Fzmax , 0) - Min( Fzmin , 0)                      (16.5-17)
=Max(7.5,0)-Min(0,0)=                                       7.50 kN

DeltaMx = Max( Mxmax , 0) - Min( Mxmin , 0)                      (16.5-18)
=Max(2.5,0)-Min(0,0)=                                       2.50 kNm

DeltaMy = Max( Mymax , 0) - Min( Mymin , 0)                      (16.5-19)
=Max(3,0)-Min(0,0)=                                         3.00 kNm

DeltaFl = Max( Flmax , 0) - Min( Flmin , 0)
=Max(7.5,0)-Min(0,0)=                                       7.50 kN

DeltaFc = Max( Fcmax , 0) - Min( Fcmin , 0)
=Max(5.5,0)-Min(0,0)=                                       5.50 kN

DeltaFshear = Sqr( DeltaFl ^ 2 + DeltaFc ^ 2)
=Sqr(7.5^2+5.5^2)=                                          9.30 kN

DeltaMt = Max( Mtmax , 0) - Min( Mtmin , 0)
=Max(3,0)-Min(0,0)=                                         3.00 kNm
```

16.5.7.2 EQVIVALENT SHELL THICKNESS

```
eeq = ea+Min(eap*Ip/Sqr(D*(ea+eap)),eap)*Min(fp/f1)              (16.5-20)
=8.5+Min(9.5*65.85/Sqr(855.5*(8.5+9.5,))9.5)*Min(129.41/129.41,1)=   13.54 mm
```

16.5.7.3 STRESSES

```
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 to 16.5-4
C1 =    2.038   C2 =    4.914   C3 =    10.270
Tmp1 = Sqr( d * eb / (D * eeq))
=Sqr(161.67*6.6/(855.5*13.54))=                          0.3035
Tmp2 = (2+2*d/D*Tmp1+1.25*d/D*Sqr(D/eeq))/(1+eb/eeq*Tmp1)
```

```
=(2+2*161.67/855.5*0.3035+1.25*161.67/855.5*Sqr(855.5/13.54))/(1+6.6/13.54*
0.3035)=                                                            =     3.48
Stresses due to Pressure Range
SigP = DeltaP * D / (2 * eeq) * Tmp2                                  (16.5-21)
=0.42*855.5/(2*13.54)*3.48=                                 46.14 N/mm2

Stresses due to Axial Load Range
SigFz = 2.25 / C1 * (DeltaFz / eeq ^ 2)                               (16.5-22)
=2.25/2.04*(7.5/13.54^2)=                                   45.17 N/mm2

Stresses due to Circumferential Moment Range
SigMx = 2.25 / C2 * (4 * DeltaMx / (eeq ^ 2 * d))                     (16.5-23)
=2.25/4.91*(4*2.5/(13.54^2*161.67))=                       154.47 N/mm2

Stresses due to Longitudinal Moment Range
SigMy = 2.25 / C3 * (4 * DeltaMy / (eeq ^ 2 * d))                     (16.5-24)
=2.25/10.27*(4*3/(13.54^2*161.67))=                         88.68 N/mm2

Shear Stresses due to Longitudinal Shear Force, DeltaFl:
TauFl = 2 * DeltaFl / (PI * deb * eeq)
=2*7.5/(3.14*168.27*13.54)=                                  2.10 N/mm2

Shear Stresses due to Circumferential Force, TauFc:
TauFc = 2 * DeltaFc / (PI * deb * eeq)
=2*5.5/(3.14*168.27*13.54)=                                  1.54 N/mm2

Shear Stresses due to Torsional Moment, TauMt:
TauMt = 2 * DeltaMt / (PI * deb ^ 2 * eeq)
=2*3/(3.14*168.27^2*13.54)=                                  4.98 N/mm2

Total Shear Stresses, Tau:
Tau = Sqr( TauFc ^ 2 + TauFl ^ 2) + TauMt
=Sqr(1.54^2+2.1^2)+4.98=                                     7.58 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((46.14+45.17)^2+154.47^2+88.68^2+4*7.58^2))=    200.73 N/mm2
```

»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
SigLong = P*d/(4*eb)+4*MB/(PI*d^2*eb)+Fz/(PI*d*eb)                    (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 N/mm2
```

»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 / (Sige * D)                                         (16.14-15)
=1.21*196147*6.6/(171.56*161.67)=                           56.47
alfa = 0.83 / Sqr( 1 + 0.005 * D / ea)                                 (16.14-16)
=0.83/Sqr(1+0.005*161.67/6.6)=                            0.7834
delta = (1 - 0.4123 / (alfa * K) ^ 0.6) / S                            (16.14-19)
=(1-0.4123/(0.7834*56.47)^0.6)/1.5=                       0.6384
Maximum Allowable Compressive Stress
Sigcall = Sige * delta (16.14-20) =171.56*0.6384=            109.52 N/mm2
```

16.14.4 PERMISSIBLE INDIVIDUAL LOADS

```
Maximum Tensile Force Ftmax
Ftmax = PI * D * ea * f (16.14-1) =3.14*161.67*6.6*114.37=   383.32 kN

Maximum Compressive Force Fcmax
Fcmax = PI * D * ea * Sigcall (16.14-2) =3.14*161.67*6.6*109.52=   367.06 kN

Maximum Bending Moment Mmax
Mmax = PI / 4 * D ^ 2 * ea * Sigcall                                  (16.14-3)
=3.14/4*161.67^2*6.6*109.52=                                14.84 kNm

Longitudinal Stability Check (P=0)
LongStab = MB / Mmax + Abs( Fzmin) / Fcmax                            (16.5-27)
=3.91/14.84+Abs(0)/367.06=                                0.2632
```

»Nozzle Long.Stability LongStab=0.2632 <= 1.0=1« » (U= 26.3%) 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)
=Sqr((2*423.5+8.5)*8.5)=                                  85.27 mm
Limit of Reinforcement Along Pad
Ip = Min( Ip, Is ) (16.5-86) =Min(65.85,85.27)=             65.85 mm
Limit of Reinforcement Along Nozzle (outside shell)
Ibo = MIN( Sqr(( deb - eb) * eb), ho)                             (16.5-75)
=MIN(Sqr((168.27-6.6)*6.6,)200)=                          32.66 mm
```

Pressure Area Required pA(req.)

```
pAReqL = P * (ApsL + Apb) (16.5-7) =0.5*(71744.95+3191.57)=   37.47 kN

pAReqT = P * (ApsT + Apb + 0.5 * Apphi)                           (16.5-7)
=0.5*(35631.82+3191.57+0.5*0)=                            19.41 kN

pAReq = MAX( pAReqL, pAReqT) =MAX(37.47,19.41)=             37.47 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)+559.73*(129.41-0.5*0.5)+271.62*(114.37-0.5*0.5
)=                                                        =    196.91 kN
```

»Nozzle Reinforcement pAAval=196.91 >= pAReq=37.47[kN] « » (U= 19%) OK«

Maximum Allowable Pressure Pmax

```
Pmax =(Afs+Afw)*fs+Afp*fop+Afb*fob/((Aps+Apb+0.5*Apphi)+0.5*(Afs+Afw+Afb+Afp))(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))=                                     =      2.61 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«

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«

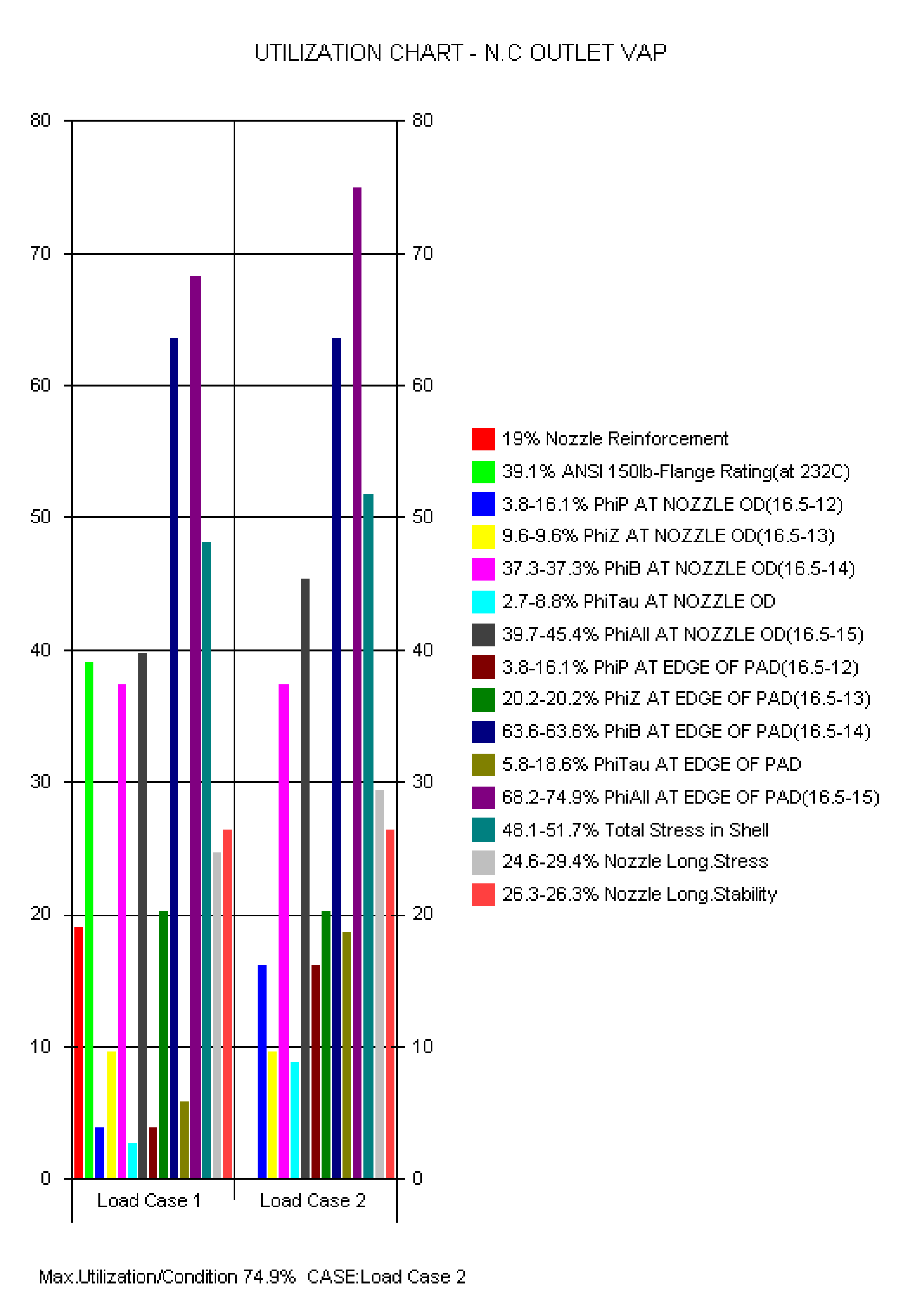
STRESSES AT OUTER EDGE OF PAD

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«

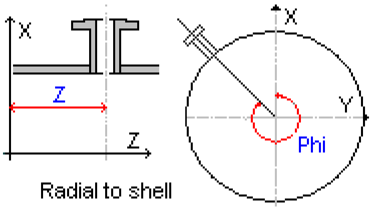
Volume:0 m3 Weight:18.2 kg (SG= 7.85)


UTILIZATION CHART - N.C OUTLET VAP
80
70
60
50
40
30
20
10
0
Load Case 1
Load Case 2
19% Nozzle Reinforcement
39.1% ANSI 150lb-Flange Rating(at 232C)
3.8-16.1% PhiP AT NOZZLE OD(16.5-12)
9.6-9.6% PhiZ AT NOZZLE OD(16.5-13)
37.3-37.3% PhiB AT NOZZLE OD(16.5-14)
2.7-8.8% PhiTau AT NOZZLE OD
39.7-45.4% PhiAll AT NOZZLE OD(16.5-15)
3.8-16.1% PhiP AT EDGE OF PAD(16.5-12)
20.2-20.2% PhiZ AT EDGE OF PAD(16.5-13)
63.6-63.6% PhiB AT EDGE OF PAD(16.5-14)
5.8-18.6% PhiTau AT EDGE OF PAD
68.2-74.9% PhiAll AT EDGE OF PAD(16.5-15)
48.1-51.7% Total Stress in Shell
24.6-29.4% Nozzle Long.Stress
26.3-26.3% Nozzle Long.Stability
Max.Utilization/Condition 74.9% CASE:Load Case 2

INPUT DATA

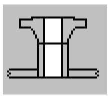
COMPONENT ATTACHMENT/LOCATION

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




```
Orientation & Location of Nozzle: Radial to Shell
z-location of nozzle along axis of attacment........:z        2445.00 mm
Angle of Rotation of nozzle axis projected in the x-y plane:Phi     0.00 Degr.
```

GENERAL DESIGN DATA

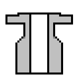


```
Type of Opening: Nozzle With Standard ANSI or DIN/EN Flange Attachment
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm, Pext= .1MPa
Include Nozzle Load Calculation: NO
```

SHELL DATA (S1.3)

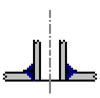
```
Shell Type: Cylindrical Shell
OUTSIDE DIAMETER OF SHELL...........................:De        864.00 mm
AS BUILT WALL THICKNESS (uncorroded)................:en         12.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE...............:th        0.5000 mm
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, 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
```

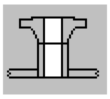
FLANGE DATA

```
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
eas = en - c - th =12-3-0.5=                                    8.50 mm
Nozzle Analysis Thickness eab
eab = enb - c - NegDev =12.69-3-0=                              9.69 mm
Inside Radius of Curvature
ris = De / 2 - eas (9.5-3) =864/2-8.5=                        423.50 mm
deb = dib + 2 * eab =31.39+2*9.69=                             50.77 mm
Min.Nozzle Thk.Based on Internal Pressure ebp
ebp = P * dib / (2 * fb * z - P)
=0.5*31.39/(2*118.13*1-0.5)=                                0.0700 mm
Allowable Stresses
fob = Min( fs, fb) (9.5-8) =Min(129.41,118.13)=               118.13 N/mm2
```

GEOMETRIC LIMITATIONS

»Check Max.Diameter of Nozzle dib/(2*ris)=0.0371 <= 1=1[mm] «» OK«
»Min.Nozzle Thk. ebp=0.07 <= eab=9.69[mm] « » (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
Iso = Sqr(( 2 * ris + eas) * eas)
=Sqr((2*423.5+8.5)*8.5)=                                      85.27 mm
Set In Nozzle
Afs = eas * Is (9.5-78) =8.5*85.27=                           724.83 mm2
```

Area of Nozzle Afb

```
Limit of Reinforcement Along Nozzle (outside shell)
Ibo = MIN( Sqr(( deb - eb) * eb), ho)                           (9.5-75)
=MIN(Sqr((50.77-9.69)*9.69,)200)=                        19.95 mm
Set In Nozzle
Afb = eb * (Ibo + Ibi + eas) (9.5-77) =9.69*(19.95+0+8.5)=  275.70 mm2
```

Calculation of Pressure Loaded Areas

```
In the Nozzle Apb
Apb = 0.5 * dib * (Ibo + eas) (9.5-83) =0.5*31.39*(19.95+8.5)=   446.55 mm2

Cyl.Shell in the Longitudinal Section Aps
ApsL = ris * (Is + a) (9.5-93) =423.5*(85.27+25.38)=      46864.32 mm2

Cyl.Shell in the Transverse Cross Section Aps
ApsT = 0.5 * ris ^ 2 * (Is + a ) / (0.5 * eas + ris)            (9.5-104)
=0.5*423.5^2*(85.27+25.4)/(0.5*8.5+423.5)=             23202.47 mm2

Aps = MAX( ApsL ApsT) =MAX(46864.32,23202.47)=            46864.32 mm2
```

9.5.2 Reinforcement Rules

Pressure Area Required pA(req.)

```
pAReqL = P * (ApsL + Apb) (9.5-7) =0.5*(46864.32+446.55)=    23.66 kN

pAReqT = P * (ApsT + Apb + 0.5 * Apphi)                         (9.5-7)
=0.5*(23202.47+446.55+0.5*0)=                            11.82 kN

pAReq = MAX( pAReqL, pAReqT) =MAX(23.66,11.82)=              23.66 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)
=(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 kN
```

»Nozzle Reinforcement pAAval=126.12 >= pAReq=23.66[kN] « » (U= 18.7%) OK«

Maximum Allowable Pressure Pmax

```
Pmax =(Afs+Afw)*fs+Afb*fob/((Aps+Apb+0.5*Apphi)+0.5*(Afs+Afw+Afb+Afp)) (10)
=+0)*129.41+275.7*118.13/((46864.32+446.55+0.5*0)+0.5*(724.83+0+275.7+0))
=     2.64 MPa
```

Max.Allowable Test Pressure Ptmax

```
Ptmax =  ==                                                  6.95 MPa
```

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

CALCULATION SUMMARY

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

```
Limit of Reinforcement Along Shell
Iso = Sqr(( 2 * ris + eas) * eas)
=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)                           (9.5-75)
=MIN(Sqr((50.77-9.69)*9.69,)200)=                        19.95 mm
```

Pressure Area Required pA(req.)

```
pAReqL = P * (ApsL + Apb) (9.5-7) =0.5*(46864.32+446.55)=    23.66 kN

pAReqT = P * (ApsT + Apb + 0.5 * Apphi)                         (9.5-7)
=0.5*(23202.47+446.55+0.5*0)=                            11.82 kN

pAReq = MAX( pAReqL, pAReqT) =MAX(23.66,11.82)=              23.66 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)
=(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 kN
```

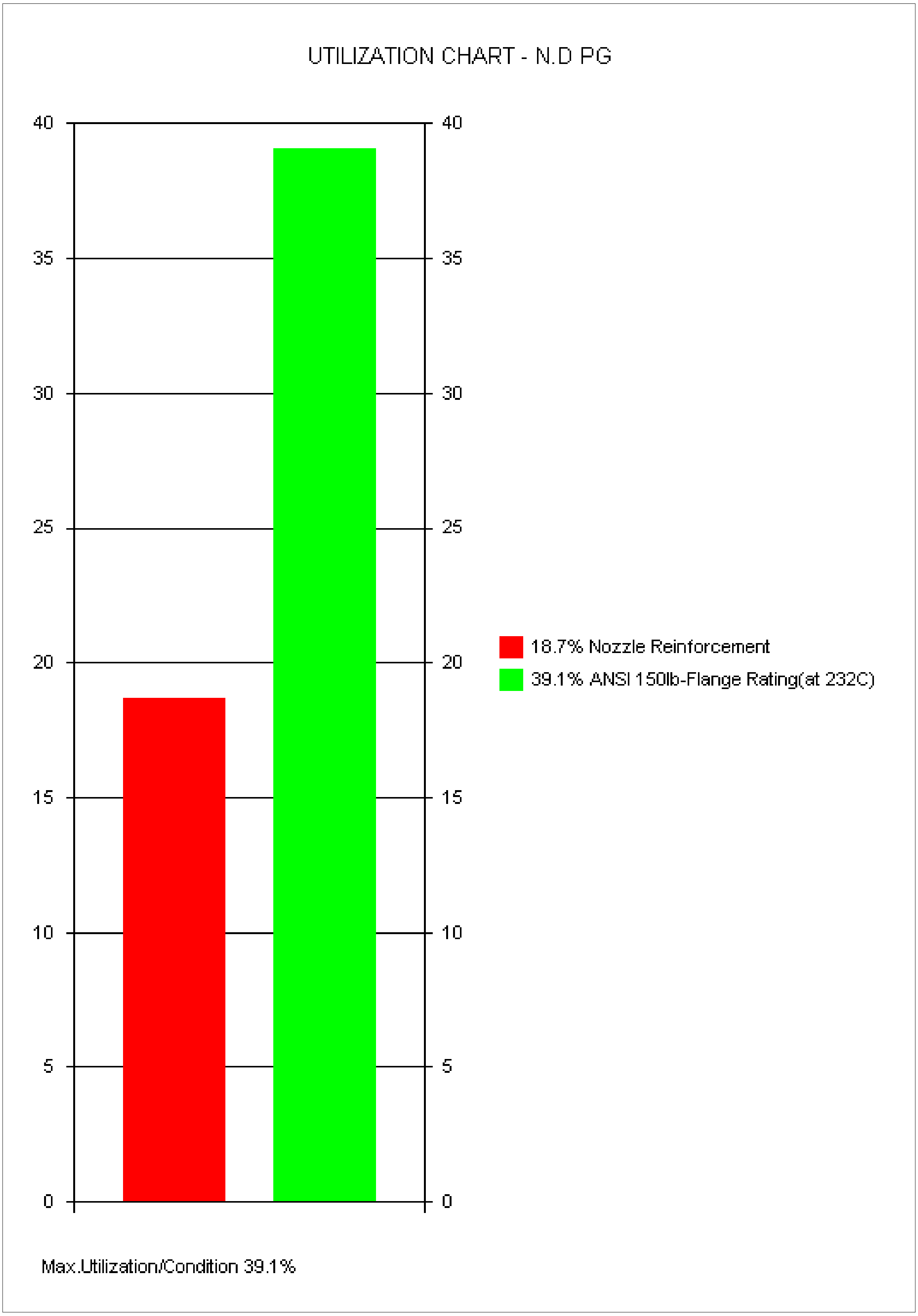
»Nozzle Reinforcement pAAval=126.12 >= pAReq=23.66[kN] « » (U= 18.7%) OK«

Maximum Allowable Pressure Pmax

```
Pmax =(Afs+Afw)*fs+Afb*fob/((Aps+Apb+0.5*Apphi)+0.5*(Afs+Afw+Afb+Afp)) (10)
=+0)*129.41+275.7*118.13/((46864.32+446.55+0.5*0)+0.5*(724.83+0+275.7+0))
=     2.64 MPa
```

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

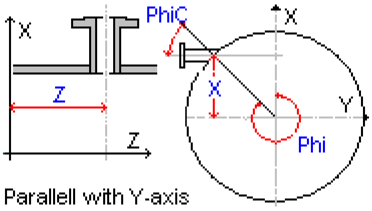
Volume:0 m3 Weight:3.3 kg (SG= 7.85)


UTILIZATION CHART - N.D PG
40
35
30
25
20
15
10
5
0
18.7% Nozzle Reinforcement
39.1% ANSI 150lb-Flange Rating(at 232C)
Max.Utilization/Condition 39.1%

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

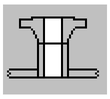
```
Attachment: S1.3    Cylindrical Shell    Shell  L=4030                S2.1
```



Parallell 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 attacment........:z         3565.00 mm
Nozzle located in section 0-180degr.==> k=1 ELSE k=-1:k           0.00 mm
```

GENERAL DESIGN DATA

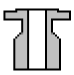


```
Type of Opening: Nozzle With Standard ANSI or DIN/EN Flange Attachment
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm, Pext= .1MPa
Include Nozzle Load Calculation: YES
```

SHELL DATA (S1.3)

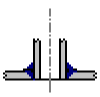
```
Shell Type: Cylindrical Shell
OUTSIDE DIAMETER OF SHELL...........................:De         864.00 mm
AS BUILT WALL THICKNESS (uncorroded)................:en          12.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE...............:th         0.5000 mm
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and 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
```

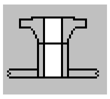
FLANGE DATA

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



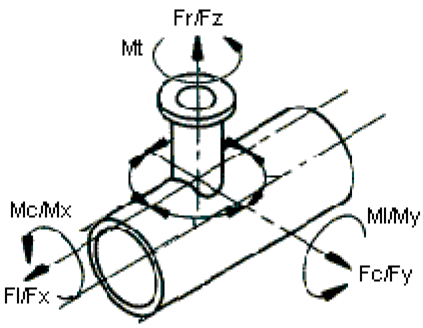
Type of Pad: No Pad

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

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 mm
Nozzle Analysis Thickness eab
eab = enb - c - NegDev =13.49-3-0=                           10.49 mm
Inside Radius of Curvature
ris = De / 2 - eas (9.5-3) =864/2-8.5=                      423.50 mm
deb = dib + 2 * eab =56.79+2*10.49=                          77.77 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 mm
Allowable Stresses
fob = Min( fs, fb) (16.5-8) =Min(129.41,118.13)=            118.13 N/mm2
```

GEOMETRIC LIMITATIONS

»Check Max.Diameter of Nozzle dib/(2*ris)=0.067 <= 1[mm] «» OK«
»Min.Nozzle Thk. ebp=0.12 <= eab=10.49[mm] « » (U= 1.1%) OK«

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 = Sqr(( 2 * ris + eas) * eas)
=Sqr((2*423.5+8.5)*8.5)=                                 85.27 mm
Set In Nozzle
Afs = eas * Is (16.5-78) =8.5*85.27=                       724.83 mm2
```

Area of Nozzle Afb

```
Limit of Reinforcement Along Nozzle (outside shell)
Ibo = MIN( Sqr(( deb - eb) * eb), ho)                              (16.5-75)
=MIN(Sqr((77.77-10.49)*10.49,)200)=                      26.57 mm
Set In Nozzle
Afb = eb * (Ibo + Ibi + eas) (16.5-77) =10.49*(26.57+0+8.5)=   367.85 mm2
```

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 mm2

Additional Area due to Obliquity of Nozzle Ap(phi)
Apphi = 0.5 * dib ^ 2 * Tan( phi)                                  (16.5-111)
=0.5*56.79^2*Tan(0.7813)=                              1599.49 mm2

Cyl.Shell in the Longitudinal Section Aps
ApsL = ris * (Is + a) (16.5-112) =423.5*(85.27+38.89)=     52581.57 mm2

Cyl.Shell in the Transverse Cross Section Aps
ApsT = 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 mm2

Aps = MAX( ApsL ApsT) =MAX(52581.57,29489.08)=             52581.57 mm2
```

9.5.2 Reinforcement Rules

Pressure Area Required pA(req.)

```
pAReqL = P * (ApsL + Apb) (16.5-7) =0.5*(52581.57+995.71)=    26.79 kN

pAReqT = P * (ApsT + Apb + 0.5 * Apphi)                            (16.5-7)
=0.5*(29489.08+995.71+0.5*1599.49)=                     15.64 kN

pAReq = MAX( pAReqL, pAReqT) =MAX(26.79,15.64)=               26.79 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)=   136.98 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)
=+0)*129.41+367.85*118.13/((52581.57+995.71+0.5*0)+0.5*(724.83+0+367.85+0))
=     2.54 MPa
```

Max.Allowable Test Pressure Ptmax

```
Ptmax =   ==                                                        6.63 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 SQR(D*ec)=  85.3 mm
»d) Nozzle thickness shall be maintained over a distance of SQR(d*eb)=  24.6 mm
```

LOAD CASE NO: 1 - Load Case 1

```
Total Moment
MB = Sqr( Mx ^ 2 + My ^ 2) =Sqr(-0.29^2+-0.29^2)=            0.4101 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 / Sqr( D * ec) =68.97/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 (from nozzle calculation) = Pmax (16.5-2) =2.54=           2.54 MPa

Allowable Axial Load Fzmax:
Fzmax = f * ec ^ 2 * C1 (16.5-3) =129.41*8.5^2*1.81=           16.92 kN

Allowable Circumferential Moment Mxmax:
Mxmax = f * ec ^ 2 * d / 4 * C2                                     (16.5-5)
=129.41*8.5^2*68.97/4*4.9=                                  0.7899 kNm

Allowable Longitudinal Moment Mxmax:
Mymax = f * ec ^ 2 * d / 4 * C3                                     (16.5-7)
=129.41*8.5^2*68.97/4*7.42=                                   1.20 kNm
```

SHEAR STRESS FORMULAES (PD5500 Section G.2.3.6.3)

```
Shear Stresses due to Longitudinal Shear Force, TauFl:
TauFl = 2 * Fl / (PI * deb * ec)
=2*-2.5/(3.14*77.77*8.5)=                                   -2.41 N/mm2

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

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

Total Shear Stresses, Tau:
Tau = Sqr( TauFc ^ 2 + TauFl ^ 2) + TauMt
=Sqr(-1.85^2+-2.41^2)+-37.15=                              -34.11 N/mm2
```

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

```
PhiP = P / Pmax (16.5-9) =-0.1/2.54=                         -0.0394

PhiZ = Fz / Fzmax (16.5-10) =-2.5/16.92=                     -0.1477

PhiTau = Tau / (0.5 * f) =-34.11/(0.5*129.41)=               0.5272

PhiB = Sqr(( Mx / Mxmax) ^ 2 + (My / Mymax) ^ 2)                  (16.5-11)
=Sqr((-0.29/0.7899)^2+(-0.29/1.2)^2)=                      0.4400

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

PhiAll = Sqr( MaxAll ^ 2 + PhiB ^ 2 + PhiTau ^ 2)                 (16.5-15)
=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

```
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)
=Max(2.5,0)-Min(0,0)=                                        2.50 kN

DeltaMx = Max( Mxmax , 0) - Min( Mxmin , 0)                       (16.5-18)
=Max(0.29,0)-Min(0,0)=                                     0.2900 kNm

DeltaMy = Max( Mymax , 0) - Min( Mymin , 0)                       (16.5-19)
=Max(0.29,0)-Min(0,0)=                                     0.2900 kNm

DeltaFl = Max( Flmax , 0) - Min( Flmin , 0)
=Max(2.5,0)-Min(0,0)=                                        0.00 kN

DeltaFc = Max( Fcmax , 0) - Min( Fcmin , 0)
=Max(1.92,0)-Min(0,0)=                                       0.00 kN

DeltaFshear = Sqr( DeltaFl ^ 2 + DeltaFc ^ 2)
=Sqr(0^2+0^2)=                                               0.00 kN

DeltaMt = Max( Mtmax , 0) - Min( Mtmin , 0)
=Max(3,0)-Min(0,0)=                                          0.00 kNm
```

16.5.7.2 EQVIVALENT SHELL THICKNESS

```
eeq = ec =8.5=                                                    8.50 mm
```

16.5.7.3 STRESSES

```
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 to 16.5-4
C1 =    1.810  C2 =    4.900  C3 =    7.416
Tmp1 = Sqr( d * eb / (D * eeq))
=Sqr(68.97*10.49/(855.5*8.5))=                               0.2890
Tmp2 = (2+2*d/D*Tmp1+1.25*d/D*Sqr(D/eeq))/(1+eb/eeq*Tmp1)
=(2+2*68.97/855.5*0.289+1.25*68.97/855.5*Sqr(855.5/8.5))/(1+10.49/8.5*0.289
)=                                                              =     2.35
Stresses due to Pressure Range
SigP = DeltaP * D / (2 * eeq) * Tmp2                                (16.5-21)
=0.1*855.5/(2*8.5)*2.35=                                      11.84 N/mm2

Stresses due to Axial Load Range
SigFz = 2.25 / C1 * (DeltaFz / eeq ^ 2)                             (16.5-22)
=2.25/1.81*(2.5/8.5^2)=                                       43.01 N/mm2

Stresses due to Circumferential Moment Range
SigMx = 2.25 / C2 * (4 * DeltaMx / (eeq ^ 2 * d))                   (16.5-23)
=2.25/4.9*(4*0.29/(8.5^2*68.97))=                            106.90 N/mm2

Stresses due to Longitudinal Moment Range
SigMy = 2.25 / C3 * (4 * DeltaMy / (eeq ^ 2 * d))                   (16.5-24)
=2.25/7.42*(4*0.29/(8.5^2*68.97))=                            70.63 N/mm2

Shear Stresses due to Longitudinal Shear Force, DeltaFl:
TauFl = 2 * DeltaFl / (PI * deb * eeq)
=2*0/(3.14*77.77*8.5)=                                         0.00 N/mm2

Shear Stresses due to Circumferential Force, TauFc:
TauFc = 2 * DeltaFc / (PI * deb * eeq)
=2*0/(3.14*77.77*8.5)=                                         0.00 N/mm2

Shear Stresses due to Torsional Moment, TauMt:
TauMt = 2 * DeltaMt / (PI * deb ^ 2 * eeq)
=2*0/(3.14*77.77^2*8.5)=                                       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((11.84+43.01)^2+106.9^2+70.63^2+4*0^2))=          139.37 N/mm2
```

»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/(PI*d^2*eb)+Fz/(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 N/mm2
```

»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 / (Sige * D)                                      (16.14-15)
=1.21*196147*8.8/(177.2*68.97)=                               170.98
alfa = 0.83 / Sqr( 1 + 0.005 * D / ea)                              (16.14-16)
=0.83/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 = Sige * delta (16.14-20) =177.2*0.6524=               115.61 N/mm2
```

16.14.4 PERMISSIBLE INDIVIDUAL LOADS

```
Maximum Tensile Force Ftmax
Ftmax = PI * D * ea * f (16.14-1) =3.14*68.97*8.8*118.13=    225.33 kN

Maximum Compressive Force Fcmax
Fcmax = PI * D * ea * Sigcall (16.14-2) =3.14*68.97*8.8*115.61=    220.53 kN

Maximum Bending Moment Mmax
Mmax = PI / 4 * D ^ 2 * ea * 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+Abs(0)/220.53=                              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)=           0.4101 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 / Sqr( D * ec) =68.97/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 (from nozzle calculation) = Pmax (16.5-2) =2.54=        2.54 MPa

Allowable Axial Load Fzmax:
Fzmax = f * ec ^ 2 * C1 (16.5-3) =129.41*8.5^2*1.81=        16.92 kN

Allowable Circumferential Moment Mxmax:
Mxmax = f * ec ^ 2 * d / 4 * C2                             (16.5-5)
=129.41*8.5^2*68.97/4*4.9=                             0.7899 kNm

Allowable Longitudinal Moment Mxmax:
Mymax = f * ec ^ 2 * d / 4 * C3                             (16.5-7)
=129.41*8.5^2*68.97/4*7.42=                              1.20 kNm
```

SHEAR STRESS FORMULAES (PD5500 Section G.2.3.6.3)

```
Shear Stresses due to Longitudinal Shear Force, TauFl:
TauFl = 2 * Fl / (PI * deb * ec)
=2*2.5/(3.14*77.77*8.5)=                                 2.41 N/mm2

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

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

Total Shear Stresses, Tau:
Tau = Sqr( TauFc ^ 2 + TauFl ^ 2) + TauMt
=Sqr(1.85^2+2.41^2)+37.15=                              40.19 N/mm2
```

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

```
PhiP = P / Pmax (16.5-9) =0.5/2.54=                        0.1656

PhiZ = Fz / Fzmax (16.5-10) =2.5/16.92=                    0.1477

PhiTau = Tau / (0.5 * f) =40.19/(0.5*129.41)=              0.6211
```

```
PhiB = Sqr(( Mx / Mxmax) ^ 2 + (My / Mymax) ^ 2)                        (16.5-11)
=Sqr((0.29/0.7899)^2+(0.29/1.2)^2)=                           0.4400

MaxAll = MAX(Abs(PhiP/C4+PhiZ),Abs(PhiZ),Abs(PhiP/C4-0.2*PhiZ)     (16.5-15)
=MAX(Abs(0.1656/1.1+0.1477,)Abs(0.1477,)Abs(0.1656/1.1-0.2*0.1477)=  0.2983

PhiAll = Sqr( MaxAll ^ 2 + PhiB ^ 2 + PhiTau ^ 2)                       (16.5-15)
=Sqr(0.2983^2+0.44^2+0.6211^2)=                               0.8175
```

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

```
DeltaP = Max( Pmax , 0) - Min( Pmin , 0)                                (16.5-16)
=Max(0.42,0)-Min(0,0)=                                        0.4200 MPa

DeltaFz = Max( Fzmax , 0) - Min( Fzmin , 0)                             (16.5-17)
=Max(2.5,0)-Min(0,0)=                                            2.50 kN

DeltaMx = Max( Mxmax , 0) - Min( Mxmin , 0)                             (16.5-18)
=Max(0.29,0)-Min(0,0)=                                        0.2900 kNm

DeltaMy = Max( Mymax , 0) - Min( Mymin , 0)                             (16.5-19)
=Max(0.29,0)-Min(0,0)=                                        0.2900 kNm

DeltaFl = Max( Flmax , 0) - Min( Flmin , 0)
=Max(2.5,0)-Min(0,0)=                                            2.50 kN

DeltaFc = Max( Fcmax , 0) - Min( Fcmin , 0)
=Max(1.92,0)-Min(0,0)=                                           1.92 kN

DeltaFshear = Sqr( DeltaFl ^ 2 + DeltaFc ^ 2)
=Sqr(2.5^2+1.92^2)=                                              3.15 kN

DeltaMt = Max( Mtmax , 0) - Min( Mtmin , 0)
=Max(3,0)-Min(0,0)=                                              3.00 kNm
```

16.5.7.2 EQVIVALENT SHELL THICKNESS

```
eeq = ec =8.5=                                                     8.50 mm
```

16.5.7.3 STRESSES

```
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 to 16.5-4
C1 =    1.810  C2 =     4.900  C3 =     7.416
Tmp1 = Sqr( d * eb / (D * eeq))
=Sqr(68.97*10.49/(855.5*8.5))=                                0.2890
Tmp2 = (2+2*d/D*Tmp1+1.25*d/D*Sqr(D/eeq))/(1+eb/eeq*Tmp1)
=(2+2*68.97/855.5*0.289+1.25*68.97/855.5*Sqr(855.5/8.5))/(1+10.49/8.5*0.289
)=                                                              =     2.35
Stresses due to Pressure Range
SigP = DeltaP * D / (2 * eeq) * Tmp2                                    (16.5-21)
=0.42*855.5/(2*8.5)*2.35=                                      49.74 N/mm2

Stresses due to Axial Load Range
SigFz = 2.25 / C1 * (DeltaFz / eeq ^ 2)                                 (16.5-22)
=2.25/1.81*(2.5/8.5^2)=                                        43.01 N/mm2

Stresses due to Circumferential Moment Range
SigMx = 2.25 / C2 * (4 * DeltaMx / (eeq ^ 2 * d))                       (16.5-23)
=2.25/4.9*(4*0.29/(8.5^2*68.97))=                             106.90 N/mm2

Stresses due to Longitudinal Moment Range
SigMy = 2.25 / C3 * (4 * DeltaMy / (eeq ^ 2 * d))                       (16.5-24)
```

```
=2.25/7.42*(4*0.29/(8.5^2*68.97))=                                      70.63 N/mm2

Shear Stresses due to Longitudinal Shear Force, DeltaFl:
TauFl = 2 * DeltaFl / (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 + TauFl ^ 2) + TauMt
=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)
=Abs(0+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
alfa = 0.83 / Sqr( 1 + 0.005 * D / ea)                             (16.14-16)
=0.83/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 = Sige * delta (16.14-20) =177.2*0.6524=                 115.61 N/mm2
```

16.14.4 PERMISSIBLE INDIVIDUAL LOADS

```
Maximum Tensile Force Ftmax
Ftmax = PI * D * ea * f (16.14-1) =3.14*68.97*8.8*118.13=        225.33 kN

Maximum Compressive Force Fcmax
Fcmax = PI * D * ea * Sigcall (16.14-2) =3.14*68.97*8.8*115.61=   220.53 kN

Maximum Bending Moment Mmax
Mmax = PI / 4 * D ^ 2 * ea * 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+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)
=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)
=MIN(Sqr((77.77-10.49)*10.49,)200)=                           26.57 mm
```

Pressure Area Required pA(req.)

```
pAReqL = P * (ApsL + Apb) (16.5-7) =0.5*(52581.57+995.71)=     26.79 kN

pAReqT = P * (ApsT + Apb + 0.5 * Apphi)                               (16.5-7)
=0.5*(29489.08+995.71+0.5*1599.49)=                              15.64 kN

pAReq = MAX( pAReqL, pAReqT) =MAX(26.79,15.64)=                    26.79 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)=   136.98 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)
=+0)*129.41+367.85*118.13/((52581.57+995.71+0.5*0)+0.5*(724.83+0+367.85+0))
=     2.54 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«

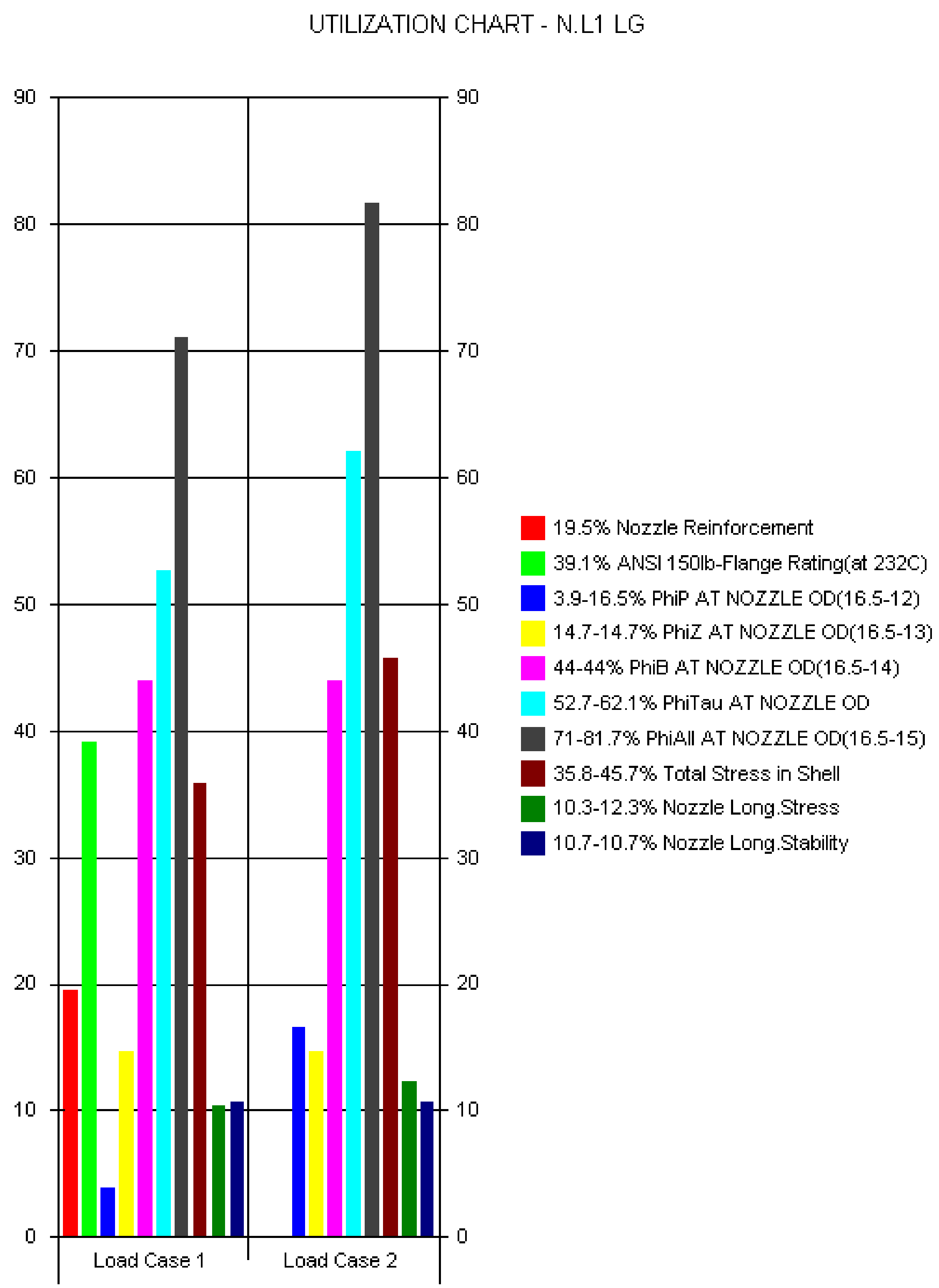
16.5.7 STRESS RANGES AND THEIR COMBINATIONS

»Total Stress in Shell SigTot=177.42 <= 3*f=388.23[N/mm2] «» (U= 45.7%) OK«

16.5.8 NOZZLE LONGITUDINAL STRESSES

»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)

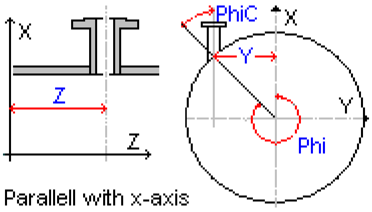


Max.Utilization/Condition 81.7% CASE:Load Case 2

INPUT DATA

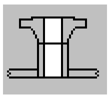
COMPONENT ATTACHMENT/LOCATION

```
Attachment: S1.1    Cylindrical Shell    Channel Shell
```




```
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 attacment........:z         225.00 mm
Nozzle located in section -90 and 90degr.==> k=1 ELSE k=-1:k     1.00
```

GENERAL DESIGN DATA

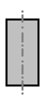


```
Type of Opening: Nozzle With Standard ANSI or DIN/EN Flange Attachment
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Tube Side : Temp= 370°C, P= .85MPa, c= 3mm, Pext= .1MPa
Include Nozzle Load Calculation: YES
```

SHELL DATA (S1.1)

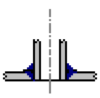
```
Shell Type: Cylindrical Shell
OUTSIDE DIAMETER OF SHELL...........................:De        624.00 mm
AS BUILT WALL THICKNESS (uncorroded)................:en         10.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE...............:th        0.5000 mm
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, 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
```

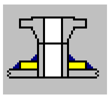
FLANGE DATA

```
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



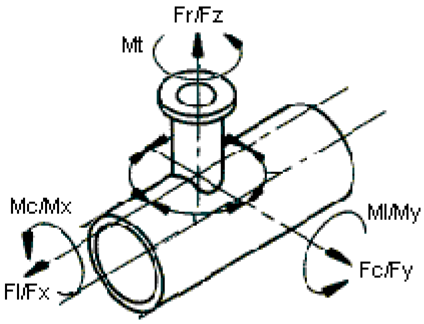
```
Type of Pad: Single Pad
THICKNESS OF THE REINFORCEMENT PAD..................:eap         7.50 mm
WIDTH OF THE REINFORCEMENT PAD......................:Ip         65.85 mm
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 370'C
Rm=410 Rp=265 Rpt=156 fp=104 f20=170.83 ftest=252.38 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

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) (16.5-20) =MIN(7.5,6.5)=                  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) (16.5-8) =Min(104,81.47)=                 81.47 N/mm2
fop = Min( fs, fp) (16.5-9) =Min(104,104)=                  104.00 N/mm2
```

GEOMETRIC LIMITATIONS

»Check Max.Thk.of Pad eap=7.5 <= 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.

Calculation of Stress Loaded Areas Effective as Reinforcement

Area of Shell Afs

```
Limit of Reinforcement Along Shell
Iso = Sqr(( 2 * ris + eas) * eas)
=Sqr((2*305.5+6.5)*6.5)=                                  63.35 mm
Set In Nozzle
Afs = eas * Is (16.5-78) =6.5*63.35=                        411.80 mm2
```

Area of Reinforcement Pad Afp

```
Limit of Reinforcement Along Pad
Ip = Min( Ip, Is ) (16.5-86) =Min(65.85,63.35)=              63.35 mm
ep = Min( ep, eas) (16.5-87) =Min(6.5,6.5)=                   6.50 mm
Afp = ep * Ip (16.5-85) =6.5*63.35=                         411.80 mm2
```

Area of Nozzle Afb

```
Limit of Reinforcement Along Nozzle (outside shell)
Ibo = MIN( Sqr(( deb - eb) * eb), ho)                              (16.5-75)
=MIN(Sqr((168.27-6.6)*6.6,)200)=                          32.66 mm
Set In Nozzle
Afb = eb * (Ibo + Ibi + eas) (16.5-77) =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) (16.5-77) =0.5*155.07*(32.66+6.5)=  3036.50 mm2

Additional Area due to Obliquity of Nozzle Ap(phi)
Apphi = 0.5 * dib ^ 2 * Tan( phi)                                  (16.5-111)
=0.5*155.07^2*Tan(0.3665)=                             4614.57 mm2

Cyl.Shell in the Longitudinal Section Aps
ApsL = ris * (Is + a) (16.5-112) =305.5*(63.35+84.14)=     45057.94 mm2

Cyl.Shell in the Transverse Cross Section Aps
```

```
ApsT = 0.5 * ris ^ 2 * (Is + a ) / (0.5 * eas + ris)            (16.5-114)
=0.5*305.5^2*(63.35+92.11)/(0.5*6.5+305.5)=          23497.66 mm2

Aps = MAX( ApsL ApsT) =MAX(45057.94,23497.66)=         45057.94 mm2
```

9.5.2 Reinforcement Rules

Pressure Area Required pA(req.)

```
pAReqL = P * (ApsL + Apb) (16.5-7) =0.85*(45057.94+3036.5)=   40.88 kN

pAReqT = P * (ApsT + Apb + 0.5 * Apphi)                      (16.5-7)
=0.85*(23497.66+3036.5+0.5*4614.57)=                  24.52 kN

pAReq = MAX( pAReqL, pAReqT) =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)      (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 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*Apphi)+0.5*(Afs+Afw+Afb+Afp))(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))=                                            =      2.19 MPa
```

Max.Allowable Test Pressure Ptmax

```
Ptmax =   ==                                               7.00 MPa
```

»ANSI 300lb-Flange Rating(at 370C) P=0.85 <= PMax(flange)=3.69[MPa] «» (U= 23%) OK«

16.5 LOCAL LOADS ON NOZZLES IN CYLINDRICAL SHELLS

PRELIMINARY CALCULATIONS

```
Shell Analysis Thickness eas
eas = en - c - th =10-3-0.5=                               6.50 mm
Nozzle Analysis Thickness eb
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 / f 1)
=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
```

```
Ratio2 = D / ec =617.5/14=                                  44.11
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 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 FORMULAES (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
```

```
Ratio2 = D / ec =617.5/6.5=                                  95.00
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 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 Mxmax:
Mymax = f * ec ^ 2 * d / 4 * C3                                   (16.5-7)
=104*6.5^2*299.97/4*25.43=                                   8.38 kNm
```

SHEAR STRESS FORMULAES (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)
```

```
=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( Mtmax , 0) - Min( Mtmin , 0)
=Max(2,0)-Min(0,0)=                                            0.00 kNm
```

16.5.7.2 EQVIVALENT SHELL THICKNESS

```
eeq = ea+Min(eap*Ip/Sqr(D*(ea+eap)),eap)*Min(fp/f1)                 (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 FIGURES16.5-2 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«

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)
=-0.1*161.67/(4*6.6)+4*2.56/(3.14*161.67^2*6.6)+0/(3.14*161.67*6.6)
=    18.30 N/mm2
```

»Nozzle Long.Stress SigLong=18.3 <= fb=81.47[N/mm2] « » (U= 22.4%) OK«

16.14.6 COMPRESSIVE STRESS LIMITS

```
K = 1.21 * E * ea / (Sige * D)                                     (16.14-15)
=1.21*1.851E05*6.6/(122.2*161.67)=                          74.81
alfa = 0.83 / Sqr( 1 + 0.005 * D / ea)                             (16.14-16)
=0.83/Sqr(1+0.005*161.67/6.6)=                            0.7834
delta = (1 - 0.4123 / (alfa * K) ^ 0.6) / S                        (16.14-19)
=(1-0.4123/(0.7834*74.81)^0.6)/1.5=                       0.6428
Maximum Allowable Compressive Stress
Sigcall = Sige * delta (16.14-20) =122.2*0.6428=              78.55 N/mm2
```

16.14.4 PERMISSIBLE INDIVIDUAL LOADS

```
Maximum Tensile Force Ftmax
Ftmax = PI * D * ea * f (16.14-1) =3.14*161.67*6.6*81.47=    273.05 kN

Maximum Compressive Force Fcmax
Fcmax = PI * D * ea * Sigcall (16.14-2) =3.14*161.67*6.6*78.546=   263.25 kN

Maximum Bending Moment Mmax
Mmax = PI / 4 * D ^ 2 * ea * Sigcall                               (16.14-3)
=3.14/4*161.67^2*6.6*78.546=                                10.64 kNm

Longitudinal Stability Check (P=0)
LongStab = MB / Mmax + Abs( Fzmin) / Fcmax                         (16.5-27)
=2.56/10.64+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
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 / f 1)
=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
Ratio2 = D / ec =617.5/14=                                    44.11
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 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 FORMULAES (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=                                5.12 N/mm2
```

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

```
PhiP = P / Pmax (16.5-9) =0.85/2.19=                    0.3874

PhiZ = Fz / Fzmax (16.5-10) =5/46.16=                   0.1083

PhiTau = Tau / (0.5 * f) =5.12/(0.5*104)=               0.0985

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(0.3874/1.1+0.1083,)Abs(0.1083,)Abs(0.3874/1.1-0.2*0.1083)=  0.4605

PhiAll = Sqr( MaxAll ^ 2 + PhiB ^ 2 + PhiTau ^ 2)              (16.5-15)
=Sqr(0.4605^2+0.4445^2+0.0985^2)=                     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 = 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
Ratio2 = D / ec =617.5/6.5=                               95.00
VALUES FOR C1, C2 AND C3 FROM FIGURES16.5-2 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 Mxmax:
Mymax = f * ec ^ 2 * d / 4 * C3                               (16.5-7)
=104*6.5^2*299.97/4*25.43=                               8.38 kNm
```

SHEAR STRESS FORMULAES (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=                                11.03 N/mm2
```

16.5.6 COMBINATIONS OF EXTERNAL LOADS AND INTERNAL PRESSURE

```
PhiP = P / Pmax (16.5-9) =0.85/2.19=                     0.3874

PhiZ = Fz / Fzmax (16.5-10) =5/22.3=                     0.2242

PhiTau = Tau / (0.5 * f) =11.03/(0.5*104)=               0.2122

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(0.3874/1.1+0.2242,)Abs(0.2242,)Abs(0.3874/1.1-0.2*0.2242)=  0.5764

PhiAll = Sqr( MaxAll ^ 2 + PhiB ^ 2 + PhiTau ^ 2)             (16.5-15)
=Sqr(0.5764^2+0.7695^2+0.2122^2)=                      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

```
DeltaP = Max( Pmax , 0) - Min( Pmin , 0)                      (16.5-16)
=Max(0.85,0)-Min(0,0)=                                 0.8500 MPa

DeltaFz = Max( Fzmax , 0) - Min( Fzmin , 0)                   (16.5-17)
=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)=                                       5.00 kN

DeltaFc = Max( Fcmax , 0) - Min( Fcmin , 0)
=Max(5,0)-Min(0,0)=                                       5.00 kN

DeltaFshear = Sqr( DeltaFl ^ 2 + DeltaFc ^ 2)
=Sqr(5^2+5^2)=                                            7.07 kN

DeltaMt = Max( Mtmax , 0) - Min( Mtmin , 0)
=Max(2,0)-Min(0,0)=                                       2.00 kNm
```

16.5.7.2 EQVIVALENT SHELL THICKNESS

```
eeq = ea+Min(eap*Ip/Sqr(D*(ea+eap)),eap)*Min(fp/f1)                (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 FIGURES16.5-2 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)
=0.85*617.5/(2*11.81)*3.76=                                83.60 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*5/(3.14*168.27*11.81)=                                   1.60 N/mm2

Shear Stresses due to Circumferential Force, TauFc:
TauFc = 2 * DeltaFc / (PI * deb * eeq)
=2*5/(3.14*168.27*11.81)=                                   1.60 N/mm2

Shear Stresses due to Torsional Moment, TauMt:
TauMt = 2 * DeltaMt / (PI * deb ^ 2 * eeq)
=2*2/(3.14*168.27^2*11.81)=                                 3.81 N/mm2

Total Shear Stresses, Tau:
Tau = Sqr( TauFc ^ 2 + TauFl ^ 2) + TauMt
=Sqr(1.6^2+1.6^2)+3.81=                                     6.07 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((83.6+15.89)^2+96.18^2+31.39^2+4*6.07^2))=     142.41 N/mm2
```

»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
SigLong = P*d/(4*eb)+4*MB/(PI*d^2*eb)+Fz/(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)
=    25.61 N/mm2
```

»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 / (Sige * D)                                     (16.14-15)
=1.21*1.851E05*6.6/(122.2*161.67)=                         74.81
alfa = 0.83 / Sqr( 1 + 0.005 * D / ea)                             (16.14-16)
=0.83/Sqr(1+0.005*161.67/6.6)=                           0.7834
delta = (1 - 0.4123 / (alfa * K) ^ 0.6) / S                        (16.14-19)
=(1-0.4123/(0.7834*74.81)^0.6)/1.5=                      0.6428
Maximum Allowable Compressive Stress
Sigcall = Sige * delta (16.14-20) =122.2*0.6428=             78.55 N/mm2
```

16.14.4 PERMISSIBLE INDIVIDUAL LOADS

```
Maximum Tensile Force Ftmax
Ftmax = PI * D * ea * f (16.14-1) =3.14*161.67*6.6*81.47=    273.05 kN

Maximum Compressive Force Fcmax
Fcmax = PI * D * ea * Sigcall (16.14-2) =3.14*161.67*6.6*78.546=   263.25 kN

Maximum Bending Moment Mmax
Mmax = PI / 4 * D ^ 2 * ea * Sigcall                            (16.14-3)
=3.14/4*161.67^2*6.6*78.546=                          10.64 kNm

Longitudinal Stability Check (P=0)
LongStab = MB / Mmax + Abs( Fzmin) / Fcmax                      (16.5-27)
=2.56/10.64+Abs(0)/263.25=                          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
Iso = Sqr(( 2 * ris + eas) * eas)
=Sqr((2*305.5+6.5)*6.5)=                              63.35 mm
Limit of Reinforcement Along Pad
Ip = Min( Ip, Is ) (16.5-86) =Min(65.85,63.35)=        63.35 mm
Limit of Reinforcement Along Nozzle (outside shell)
Ibo = MIN( Sqr(( deb - eb) * eb), ho)                           (16.5-75)
=MIN(Sqr((168.27-6.6)*6.6,)200)=                      32.66 mm
```

Pressure Area Required pA(req.)

```
pAReqL = P * (ApsL + Apb) (16.5-7) =0.85*(45057.94+3036.5)=   40.88 kN

pAReqT = P * (ApsT + Apb + 0.5 * Apphi)                         (16.5-7)
=0.85*(23497.66+3036.5+0.5*4614.57)=                  24.52 kN

pAReq = MAX( pAReqL, pAReqT) =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)      (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 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*Apphi)+0.5*(Afs+Afw+Afb+Afp))(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))=                                            =     2.19 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«

»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

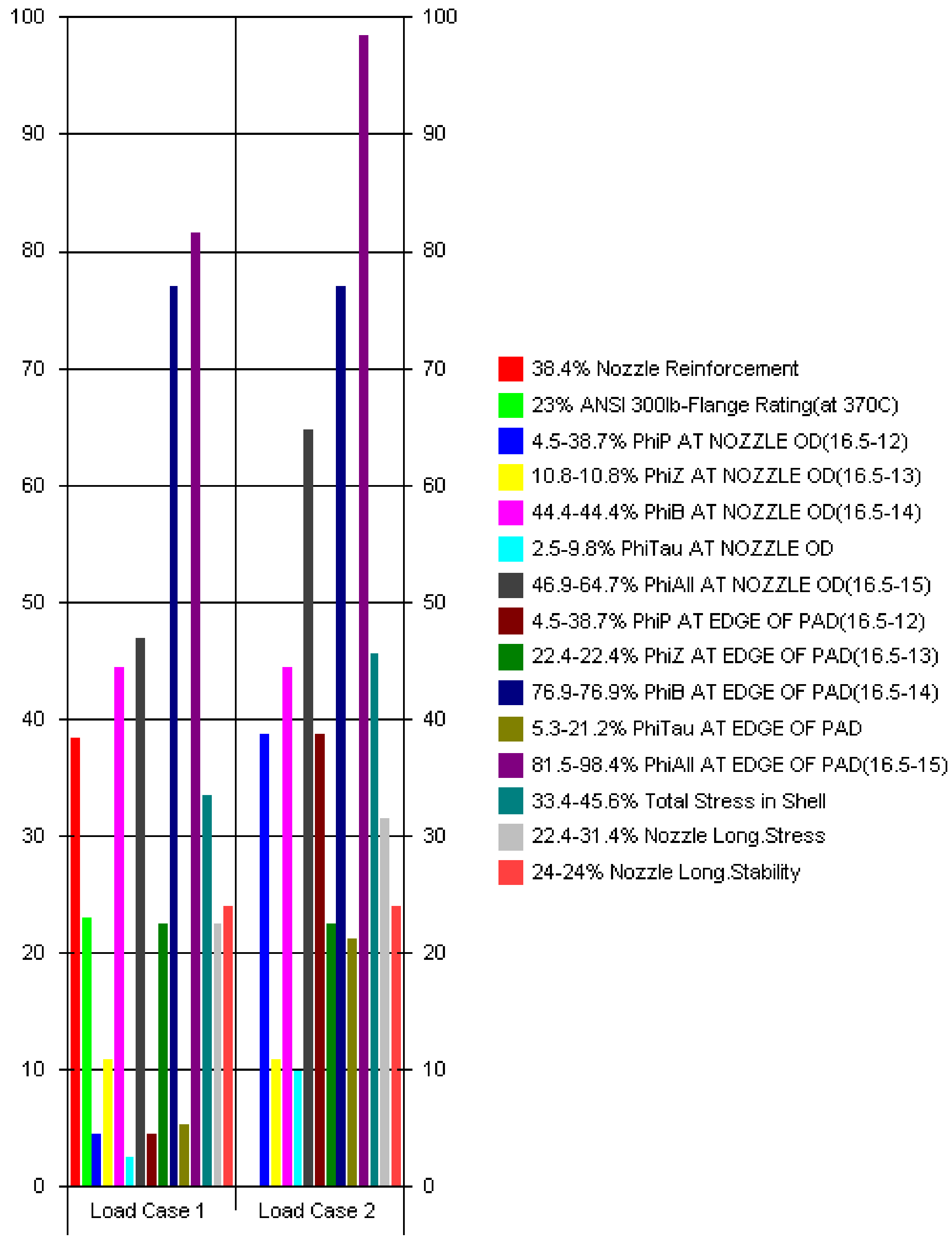
»Total Stress in Shell SigTot=142.41 <= 3*f=312[N/mm2] « » (U= 45.6%) OK«

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

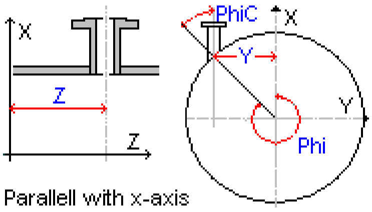


Max.Utilization/Condition 98.4% CASE:Load Case 2

INPUT DATA

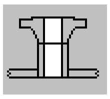
COMPONENT ATTACHMENT/LOCATION

```
Attachment: S1.1    Cylindrical Shell    Channel Shell
```




```
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 attacment........:z        225.00 mm
Nozzle located in section -90 and 90degr.==> k=1 ELSE k=-1:k    -1.00
```

GENERAL DESIGN DATA

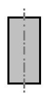


```
Type of Opening: Nozzle With Standard ANSI or DIN/EN Flange Attachment
PRESSURE LOADING: Design Component for Internal and External Pressure
PROCESS CARD: Tube Side : Temp= 370°C, P= .85MPa, c= 3mm, Pext= .1MPa
Include Nozzle Load Calculation: NO
```

SHELL DATA (S1.1)

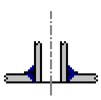
```
Shell Type: Cylindrical Shell
OUTSIDE DIAMETER OF SHELL...........................:De       624.00 mm
AS BUILT WALL THICKNESS (uncorroded)................:en        10.00 mm
NEGATIVE TOLERANCE/THINNING ALLOWANCE...............:th       0.5000 mm
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, 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
```

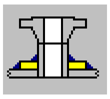
FLANGE DATA

```
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......................:lp         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 reiforcement pads.

Calculation of Stress Loaded Areas Effective as Reinforcement

Area of Shell Afs

```
Limit of Reinforcement Along Shell
Iso = Sqr(( 2 * ris + eas) * eas)
=Sqr((2*305.5+6.5)*6.5)=                                   63.35 mm
Set In Nozzle
Afs = eas * Is (9.5-78) =6.5*63.35=                         411.80 mm2
```

Area of Reinforcement Pad Afp

```
Limit of Reinforcement Along Pad
Ip = Min( Ip, Is ) (9.5-86) =Min(65.85,63.35)=               63.35 mm
ep = Min( ep, eas) (9.5-87) =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 = MIN( Sqr(( deb - eb) * eb), ho)                              (9.5-75)
=MIN(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 Ap(phi)
Apphi = 0.5 * dib ^ 2 * Tan( phi)                                  (9.5-111)
=0.5*155.07^2*Tan(0.3665)=                               4614.57 mm2

Cyl.Shell in the Longitudinal Section Aps
ApsL = ris * (Is + 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 * (Is + 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 = MAX( ApsL ApsT) =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 * Apphi)                            (9.5-7)
=0.85*(23497.66+3036.5+0.5*4614.57)=                        24.52 kN

pAReq = MAX( pAReqL, pAReqT) =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 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*Apphi)+0.5*(Afs+Afw+Afb+Afp))(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))=                                                  =     2.19 MPa
```

Max.Allowable Test Pressure Ptmax

```
Ptmax =  ==                                                       7.00 MPa
```

»ANSI 300lb-Flange Rating(at 370C) P=0.85 <= PMax(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
Iso = Sqr(( 2 * ris + eas) * eas)
=Sqr((2*305.5+6.5)*6.5)=                                    63.35 mm
Limit of Reinforcement Along Pad
Ip = Min( Ip, Is ) (9.5-86) =Min(65.85,63.35)=                63.35 mm
Limit of Reinforcement Along Nozzle (outside shell)
Ibo = MIN( Sqr(( deb - eb) * eb), ho)                                (9.5-75)
=MIN(Sqr((168.27-6.6)*6.6,)200)=                            32.66 mm
```

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 * Apphi)                              (9.5-7)
=0.85*(23497.66+3036.5+0.5*4614.57)=                        24.52 kN
pAReq = MAX( pAReqL, pAReqT) =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 kN
```

»Nozzle Reinforcement pAAval=106.25 >= pAReq=40.88[kN] « » (U= 38.4%) OK«

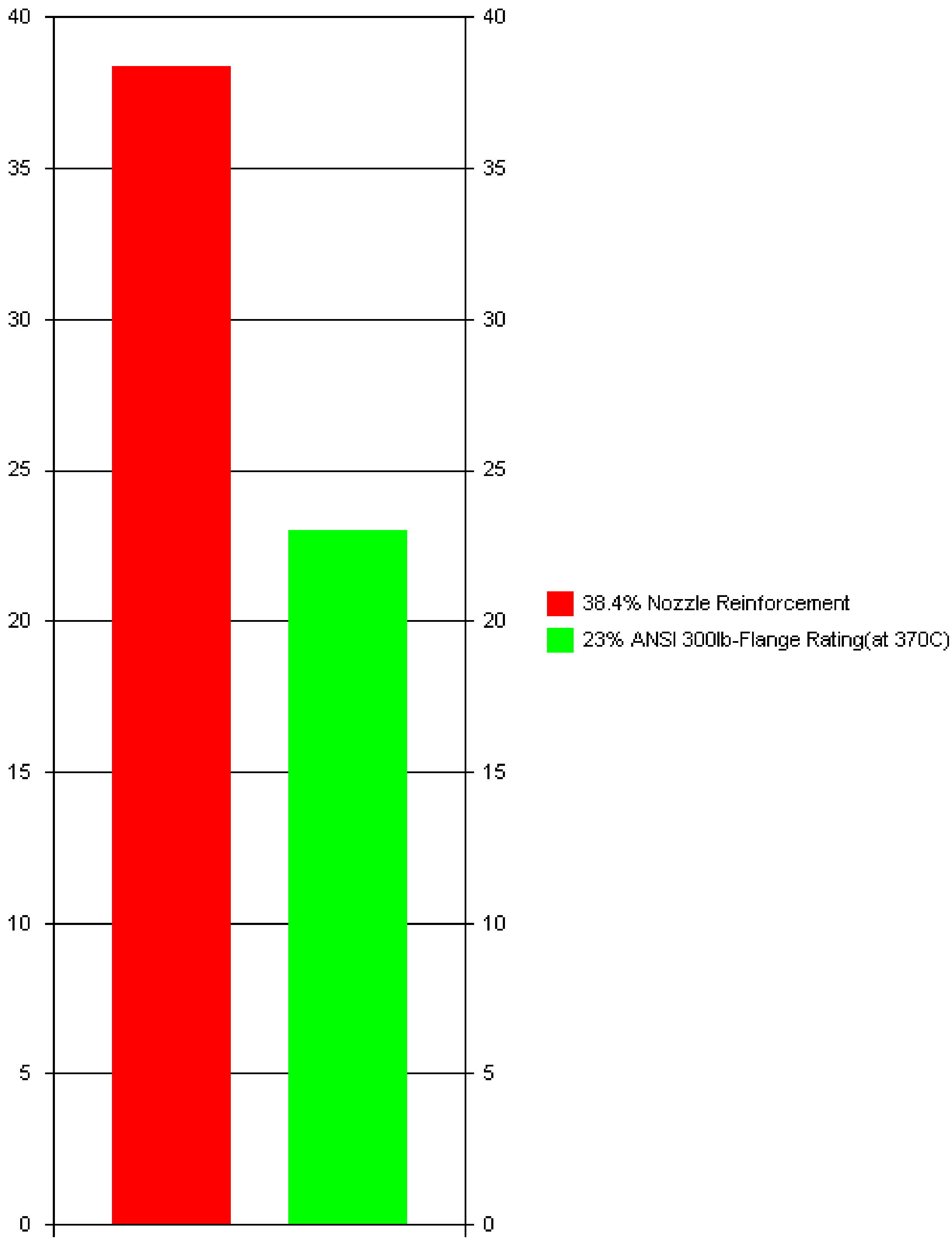
Maximum Allowable Pressure Pmax

```
Pmax =(Afs+Afw)*fs+Afp*fop+Afb*fob/((Aps+Apb+0.5*Apphi)+0.5*(Afs+Afw+Afb+Afp))(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))=                                                  =      2.19 MPa
```

»ANSI 300lb-Flange Rating(at 370C) P=0.85 <= PMax(flange)=3.69[MPa] «» (U= 23%) OK«

Volume:0 m3 Weight:29.9 kg (SG= 7.85)

UTILIZATION CHART - N.T2 TUBE SIDE OUTLET



Max.Utilization/Condition 38.4%

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

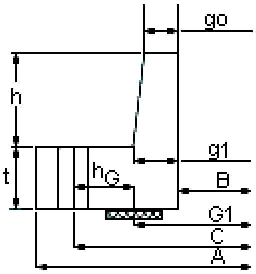
```
Attachment: S1.1    Cylindrical Shell    Channel Shell
Location: Along z-axis z1=  450
Flange Design Method: Section 11 - Taylor Forge
```

GENERAL DESIGN DATA

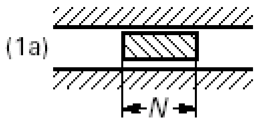
```
PROCESS CARD: Tube Side : Temp= 370°C, P= .85MPa, c= 3mm
B: Pressure loading: Flange under internal pressure
BOLT LOAD FROM 2nd. FLANGE - (Oper.Cond.)...........:Wm1'        0.00 kN
BOLT LOAD FROM 2nd. FLANGE - (Bolting Up.Cond.).....:Wm2'        0.00 kN
EXTERNAL LOADS ON FLANGE  (PD5500 ENQ 5500/123): 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.
```

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 ftest=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*657.15^2*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*610^2*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

```
Am1 = 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 Am1 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
```

»Bolting Area Check Ab=7568.96 >= Am=6644.45[mm2] « » (U= 87.7%) OK«

```
W = 0.5 * (Ab + Am) * Sa (11.5-16) =0.5*(7568.96+6644.45)*169=  1201.03 kN
```

FLANGE MOMENTS

```
Mop = HD * hD + HT * hT + HG * hG                                   (11.5-18)
=248.28*41.5+39.87*38.21+83.*26.42=                        14020.35 Nm

Mamb = W * hG (11.5-17) =1201.03*26.42=                      31737.03 Nm

Bolt Spacing
Bspc = C * PI / n =710*3.14/28=                                79.66 mm

Bolt Pitch Correction Factor
CF = MAX( Sqr( Bspc / (2 * db + 6 * e / (m + 0.5))) , 1)           (11.5-20)
=MAX(Sqr(79.66/(2*22.225+6*40/(3+0.5))),1)=                   1.00
Mo = Mop * CF / B (11.5-27) =14020.35*1/610=                   22.98 Nm
Ma = Mamb * CF / B (11.5-26) =31737.03*1/610=                  52.03 Nm
```

SHAPE CONSTANTS

```
K = A / B (11.5-21) =760/610=                                   1.25
lo = SQR( B * go) (11.5-22) =SQR(610*7)=                       65.35
h/lo=  0.612  K=A/B=  1.246  g1/go=  2.429
VALUES FROM FIGURES 11.5-4 to 8
BetaT =     1.820  BetaZ =     4.621  BetaY =     8.958  BetaU =     9.844
BetaF=      0.789  BetaV =     0.162  phi =     1.369
lamda = (e*BetaF+lo)/(BetaT*lo)+e^3*BetaV/(BetaU*lo*go^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 = Mo =22.98=                                                 22.98 Nm
```

11.5.4.1 Flange Stresses with Flange Thickness e= 40 mm

```
Longitudinal Hub Stress
SigH = phi * M / (lamda * g1 ^ 2)                                  (11.5-29)
=1.37*22.98/(1.14*17^2)=                                      95.21 N/mm2

Radial Flange Stress
Sigr = (1.333 * e * BetaF + lo) * M / (lamda * e ^ 2 * lo)        (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
SigTeta = BetaY*M/e^2-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*SigH=95.21 <= 1.5 * MIN(f;fH)=124.4[N/mm2] (11.5-39)«» (U= 76.5%) OK«
»Radial Stress k*SigR=20.65 <= f=82.93[N/mm2] (11.5-40)« » (U= 24.8%) OK«
»Tangential Stress k*SigTeta=33.25 <= f=82.93[N/mm2] (11.5-41)«» (U= 40%) OK«
»Radial+Hub Stress 0.5*k*(SigH+SigR)=57.93 <= f=82.93[N/mm2] (11.5-42)«» (U= 69.8%) OK«
»Tangential+Hub Stress 0.5*k*(SigH+SigTeta)=64.23 <= f=82.93[N/mm2] (11.5-43)«» (U= 77.4%) OK«

BOLTING UP CONDITION

```
M = Ma =52.03=                                                 52.03 Nm
```

11.5.4.1 Flange Stresses with Flange Thickness e= 40 mm

```
Longitudinal Hub Stress
SigH = phi * M / (lamda * g1 ^ 2)                                  (11.5-29)
=1.37*52.03/(1.14*17^2)=                                     215.53 N/mm2

Radial Flange Stress
Sigr = (1.333 * e * BetaF + lo) * M / (lamda * e ^ 2 * lo)        (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
```

```
SigTeta = BetaY*M/e^2-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*SigH=215.53 <= 1.5 * MIN(f;fH)=250[N/mm2] (11.5-39)«» (U= 86.2%) OK«

»Radial Stress k*SigR=46.74 <= f=166.67[N/mm2] (11.5-40)« » (U= 28%) OK«

»Tangential Stress k*SigTeta=75.27 <= f=166.67[N/mm2] (11.5-41)«» (U= 45.1%) OK«

»Radial+Hub Stress 0.5*k*(SigH+SigR)=131.13 <= f=166.67[N/mm2] (11.5-42)«» (U= 78.6%) OK«

»Tangential+Hub Stress 0.5*k*(SigH+SigTeta)=145.4 <= f=166.67[N/mm2] (11.5-43)«» (U= 87.2%) OK«

BOLTING-UP TORQUE - EN13445 ANNEX G.8

```
kB = 1.2 * µ * dB0 (G.8-5) =1.2*0.2*22.225=                 5.33 mm
epsn = eps * (1 + 3 / SQR( n)) / 4                               (G.6-16)
=0.2*(1+3/SQR(28))/4=                                  0.0783
Required Minimum Total Pre-Load(Max. of operating and bolting up cond.)
Fb0nom (Max. of Wop and Wamb) = Fb0req  =1122.91=         1122.91 kN
Nominal Total Pre-Load
Fb0nom = Fb0req / (1 - epsn) (G.6-21) =1122.91/(1-0.0783)=  1218.37 kN
Nominal Total Pre-Load per Bolt
Fbnom = Fb0nom / n =1218.37/28=                             43.51 kN

Bolt Stress(Assembly Cond.)
SigBoltamb = Wamb / ((1 - epsn) * n * Ae)
=1.1229E06/((1-0.0783)*28*270.32)=                        160.97 N/mm2

Bolt Stress(Operating Cond.)
SigBoltamb = Wop / ((1 - epsn) * n * Ae)
=3.7115E05/((1-0.0783)*28*270.32)=                         53.20 N/mm2
```

»Bolt Stress SigBolt=160.97 <= Sa=169[N/mm2] « » (U= 95.2%) OK«

```
Nominal Torque Per Bolt
Mtnom = kB * Fb0nom / n =5.334*1218.37/28=                 232.10 Nm
```

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 * f20 / f =1.25*0.85*166.67/82.93=          2.14 MPa

Ptmin = 1.43 * Pd =1.43*0.85=                                  1.22 MPa
```

»Test Pressure Ptmin=2.14 <= Ptmax=3.154[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.Torqueper 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) eps= 0.1+0.5* µ
```

CALCULATION SUMMARY

BOLTING AREA

»Bolting Area Check Ab=7568.96 >= Am=6644.45[mm2] « » (U= 87.7%) OK«

OPERATING CONDITION

11.5.4.1 Flange Stresses with Flange Thickness e= 40 mm

```
Longitudinal Hub Stress
SigH = phi * M / (lamda * g1 ^ 2)                              (11.5-29)
=1.37*22.98/(1.14*17^2)=                                   95.21 N/mm2

Radial Flange Stress
Sigr = (1.333 * e * BetaF + lo) * M / (lamda * e ^ 2 * lo)     (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
SigTeta = BetaY*M/e^2-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*SigH=95.21 <= 1.5 * MIN(f;fH)=124.4[N/mm2] (11.5-39)«» (U= 76.5%) OK«
»Radial Stress k*SigR=20.65 <= f=82.93[N/mm2] (11.5-40)« » (U= 24.8%) OK«
»Tangential Stress k*SigTeta=33.25 <= f=82.93[N/mm2] (11.5-41)«» (U= 40%) OK«
»Radial+Hub Stress 0.5*k*(SigH+SigR)=57.93 <= f=82.93[N/mm2] (11.5-42)«» (U= 69.8%) OK«
»Tangential+Hub Stress 0.5*k*(SigH+SigTeta)=64.23 <= f=82.93[N/mm2] (11.5-43)«» (U= 77.4%) OK«

BOLTING UP CONDITION

11.5.4.1 Flange Stresses with Flange Thickness e= 40 mm

```
Longitudinal Hub Stress
SigH = phi * M / (lamda * g1 ^ 2)                              (11.5-29)
=1.37*52.03/(1.14*17^2)=                                  215.53 N/mm2

Radial Flange Stress
Sigr = (1.333 * e * BetaF + lo) * M / (lamda * e ^ 2 * lo)     (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
SigTeta = BetaY*M/e^2-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*SigH=215.53 <= 1.5 * MIN(f;fH)=250[N/mm2] (11.5-39)«» (U= 86.2%) OK«
»Radial Stress k*SigR=46.74 <= f=166.67[N/mm2] (11.5-40)« » (U= 28%) OK«
»Tangential Stress k*SigTeta=75.27 <= f=166.67[N/mm2] (11.5-41)«» (U= 45.1%) OK«
»Radial+Hub Stress 0.5*k*(SigH+SigR)=131.13 <= f=166.67[N/mm2] (11.5-42)«» (U= 78.6%) OK«
»Tangential+Hub Stress 0.5*k*(SigH+SigTeta)=145.4 <= f=166.67[N/mm2] (11.5-43)«» (U= 87.2%) OK«
»Bolt Stress SigBolt=160.97 <= Sa=169[N/mm2] « » (U= 95.2%) OK«

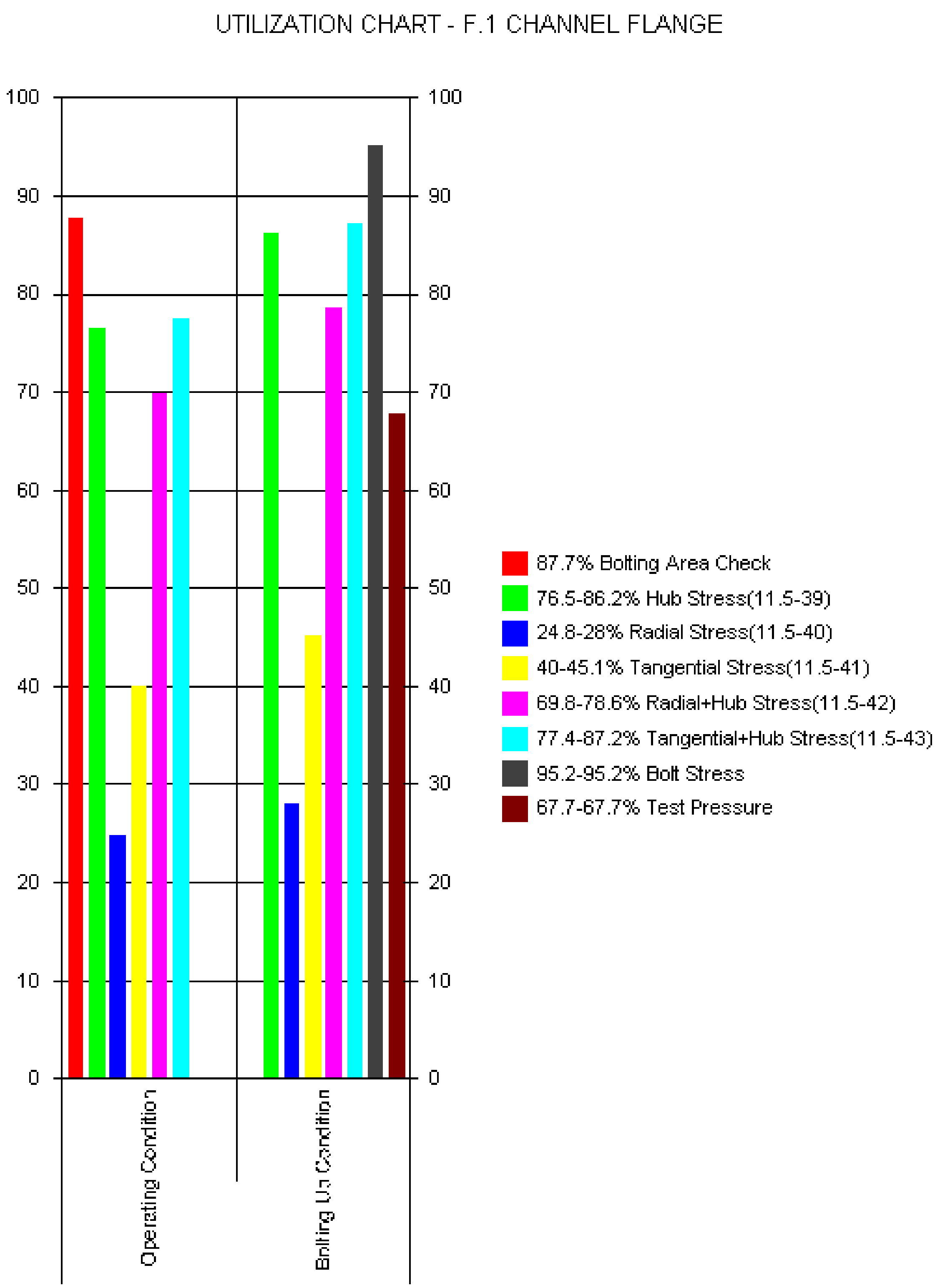
EN13445-5;10.2.3.3 REQUIRED MIN.HYDROSTATIC TEST PRESSURE:Ptmin

```
NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3
Ptmin = 1.25 * Pd * f20 / f =1.25*0.85*166.67/82.93=          2.14 MPa

Ptmin = 1.43 * Pd =1.43*0.85=                                 1.22 MPa
```

»Test Pressure Ptmin=2.14 <= Ptmax=3.154[MPa] « » (U= 67.7%) OK«

Volume:0.02 m3 Weight:59 kg (SG= 7.85)

EN13445:2009 Issue 1 - 11.5 NARROW FACE GASKETED FLANGES
F.1 Channel flange 05 Feb. 2010 12:10 ConnID:S1.1 PC# 2



Max.Utilization/Condition 95.2% CASE:Bolting Up Condition

INPUT DATA

COMPONENT ATTACHMENT/LOCATION

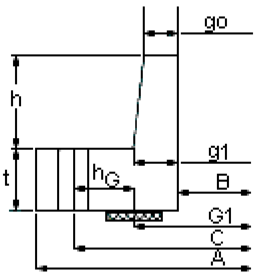
```
Attachment: T.1      Tubesheet          U-tube sheet                     F.1
Location: Along z-axis z1=  590
Flange Design Method: Section 11 - Taylor Forge
```

GENERAL DESIGN DATA

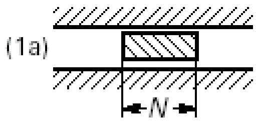
```
PROCESS CARD: Shell Side : Temp= 232°C, P= .5MPa, c= 3mm
B: Pressure loading: Flange under internal pressure
BOLT LOAD FROM 2nd. FLANGE - (Oper.Cond.)...........:Wm1'      371.15 kN
BOLT LOAD FROM 2nd. FLANGE - (Bolting Up.Cond.).....:Wm2'     1122.91 kN
EXTERNAL LOADS ON FLANGE  (PD5500 ENQ 5500/123): 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.
```

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 ftest=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=             6644.44 mm2

Available Bolting Area Ab
Ab (num.bolts*root area) = n * Ae =28*270.32=               7568.96 mm2
```

»Bolting Area Check Ab=7568.96 >= Am=6644.44[mm2] « » (U= 87.7%) OK«

```
W = 0.5 * (Ab + Am) * Sa (11.5-16) =0.5*(7568.96+6644.44)*169=  1201.03 kN

HG increased due to user specified load Wop
HG = HG + Abs( Wop - Wop2nd)                                     (11.5-19)
=39.76+Abs(209.26-371150)=                                 201.65 kN
```

FLANGE MOMENTS

```
Mop = HD * hD + HT * hT + HG * hG                                (11.5-18)
=146.05*41.5+23.45*38.21+201.65*26.42=                   12285.71 Nm

Mamb = W * hG (11.5-17) =1201.03*26.42=                     31737.00 Nm

Bolt Spacing
Bspc = C * PI / n =710*3.14/28=                                79.66 mm

Bolt Pitch Correction Factor
CF = MAX( Sqr( Bspc / (2 * db + 6 * e / (m + 0.5))) , 1)        (11.5-20)
=MAX(Sqr(79.66/(2*22.225+6*40/(3+0.5))),1)=                  1.00
Mo = Mop * CF / B (11.5-27) =12285.71*1/610=                   20.14 Nm
Ma = Mamb * CF / B (11.5-26) =31737.*1/610=                    52.03 Nm
```

SHAPE CONSTANTS

```
K = A / B (11.5-21) =760/610=                                   1.25
lo = SQR( B * go) (11.5-22) =SQR(610*7)=                       65.35
h/lo=  0.612  K=A/B=  1.246  g1/go=  2.429
VALUES FROM FIGURES 11.5-4 to 8
BetaT =    1.820  BetaZ =    4.621  BetaY =    8.958  BetaU =    9.844
BetaF=     0.789  BetaV =    0.162  phi =    1.369
lamda = (e*BetaF+lo)/(BetaT*lo)+e^3*BetaV/(BetaU*lo*go^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 = Mo =20.14=                                                 20.14 Nm
```

11.5.4.1 Flange Stresses with Flange Thickness e= 40 mm

```
Longitudinal Hub Stress
SigH = phi * M / (lamda * g1 ^ 2)                                (11.5-29)
=1.37*20.14/(1.14*17^2)=                                    83.43 N/mm2

Radial Flange Stress
Sigr = (1.333 * e * BetaF + lo) * M / (lamda * e ^ 2 * lo)      (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
SigTeta = BetaY*M/e^2-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*SigH=83.43 <= 1.5 * MIN(f;fH)=177.19[N/mm2] (11.5-39)«» (U= 47%) OK«
»Radial Stress k*SigR=18.09 <= f=118.13[N/mm2] (11.5-40)« » (U= 15.3%) OK«
»Tangential Stress k*SigTeta=29.14 <= f=118.13[N/mm2] (11.5-41)«» (U= 24.6%) OK«
»Radial+Hub Stress 0.5*k*(SigH+SigR)=50.76 <= f=118.13[N/mm2] (11.5-42)«» (U= 42.9%) OK«
»Tangential+Hub Stress 0.5*k*(SigH+SigTeta)=56.29 <= f=118.13[N/mm2] (11.5-43)«» (U= 47.6%) OK«

BOLTING UP CONDITION

```
M = Ma =52.03=                                                 52.03 Nm
```

11.5.4.1 Flange Stresses with Flange Thickness e= 40 mm

```
Longitudinal Hub Stress
SigH = phi * M / (lamda * g1 ^ 2)                                (11.5-29)
=1.37*52.03/(1.14*17^2)=                                   215.53 N/mm2

Radial Flange Stress
```

```
Sigr = (1.333 * e * BetaF + lo) * M / (lamda * e ^ 2 * lo)          (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
SigTeta = BetaY*M/e^2-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*SigH=215.53 <= 1.5 * MIN(f;fH)=250[N/mm2] (11.5-39)«» (U= 86.2%) OK«
»Radial Stress k*SigR=46.74 <= f=166.67[N/mm2] (11.5-40)« » (U= 28%) OK«
»Tangential Stress k*SigTeta=75.27 <= f=166.67[N/mm2] (11.5-41)«» (U= 45.1%) OK«
»Radial+Hub Stress 0.5*k*(SigH+SigR)=131.13 <= f=166.67[N/mm2] (11.5-42)«» (U= 78.6%) OK«
»Tangential+Hub Stress 0.5*k*(SigH+SigTeta)=145.4 <= f=166.67[N/mm2] (11.5-43)«» (U= 87.2%) OK«

BOLTING-UP TORQUE - EN13445 ANNEX G.8

```
kB = 1.2 * µ * dB0 (G.8-5) =1.2*0.2*22.225=                          5.33 mm
epsn = eps * (1 + 3 / SQR( n)) / 4                                       (G.6-16)
=0.2*(1+3/SQR(28))/4=                                       0.0783
Required Minimum Total Pre-Load(Max. of operating and bolting up cond.)
Fb0nom (Max. of Wop and Wamb) = Fb0req  =1122.91=         1122.91 kN
Nominal Total Pre-Load
Fb0nom = Fb0req / (1 - epsn) (G.6-21) =1122.91/(1-0.0783)=  1218.37 kN
Nominal Total Pre-Load per Bolt
Fbnom = Fb0nom / n =1218.37/28=                               43.51 kN

Bolt Stress(Assembly Cond.)
SigBoltamb = Wamb / ((1 - epsn) * n * Ae)
=1.1229E06/((1-0.0783)*28*270.32)=                          160.97 N/mm2

Bolt Stress(Operating Cond.)
SigBoltamb = Wop / ((1 - epsn) * n * Ae)
=371150/((1-0.0783)*28*270.32)=                               53.20 N/mm2
```

»Bolt Stress SigBolt=160.97 <= Sa=169[N/mm2] « » (U= 95.2%) OK«

```
Nominal Torque Per Bolt
Mtnom = kB * Fb0nom / n =5.334*1218.37/28=                     232.10 Nm
```

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 * f20 / f =1.25*0.5*166.67/118.13=       0.8818 MPa

Ptmin = 1.43 * Pd =1.43*0.5=                                0.7150 MPa
```

»Test Pressure Ptmin=0.8818 <= Ptmax=3.248[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.Torqueper 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) eps= 0.1+0.5* µ
```

CALCULATION SUMMARY

BOLTING AREA

»Bolting Area Check Ab=7568.96 >= Am=6644.44[mm2] « » (U= 87.7%) OK«

OPERATING CONDITION

11.5.4.1 Flange Stresses with Flange Thickness e= 40 mm

```
Longitudinal Hub Stress
SigH = phi * M / (lamda * g1 ^ 2)                               (11.5-29)
=1.37*20.14/(1.14*17^2)=                                   83.43 N/mm2

Radial Flange Stress
Sigr = (1.333 * e * BetaF + lo) * M / (lamda * e ^ 2 * lo)      (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
SigTeta = BetaY*M/e^2-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*SigH=83.43 <= 1.5 * MIN(f;fH)=177.19[N/mm2] (11.5-39)«» (U= 47%) OK«
»Radial Stress k*SigR=18.09 <= f=118.13[N/mm2] (11.5-40)« » (U= 15.3%) OK«
»Tangential Stress k*SigTeta=29.14 <= f=118.13[N/mm2] (11.5-41)«» (U= 24.6%) OK«
»Radial+Hub Stress 0.5*k*(SigH+SigR)=50.76 <= f=118.13[N/mm2] (11.5-42)«» (U= 42.9%) OK«
»Tangential+Hub Stress 0.5*k*(SigH+SigTeta)=56.29 <= f=118.13[N/mm2] (11.5-43)«» (U= 47.6%) OK«

BOLTING UP CONDITION

11.5.4.1 Flange Stresses with Flange Thickness e= 40 mm

```
Longitudinal Hub Stress
SigH = phi * M / (lamda * g1 ^ 2)                               (11.5-29)
=1.37*52.03/(1.14*17^2)=                                  215.53 N/mm2

Radial Flange Stress
Sigr = (1.333 * e * BetaF + lo) * M / (lamda * e ^ 2 * lo)      (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
SigTeta = BetaY*M/e^2-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*SigH=215.53 <= 1.5 * MIN(f;fH)=250[N/mm2] (11.5-39)«» (U= 86.2%) OK«
»Radial Stress k*SigR=46.74 <= f=166.67[N/mm2] (11.5-40)« » (U= 28%) OK«
»Tangential Stress k*SigTeta=75.27 <= f=166.67[N/mm2] (11.5-41)«» (U= 45.1%) OK«
»Radial+Hub Stress 0.5*k*(SigH+SigR)=131.13 <= f=166.67[N/mm2] (11.5-42)«» (U= 78.6%) OK«
»Tangential+Hub Stress 0.5*k*(SigH+SigTeta)=145.4 <= f=166.67[N/mm2] (11.5-43)«» (U= 87.2%) OK«
»Bolt Stress SigBolt=160.97 <= Sa=169[N/mm2] « » (U= 95.2%) OK«

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

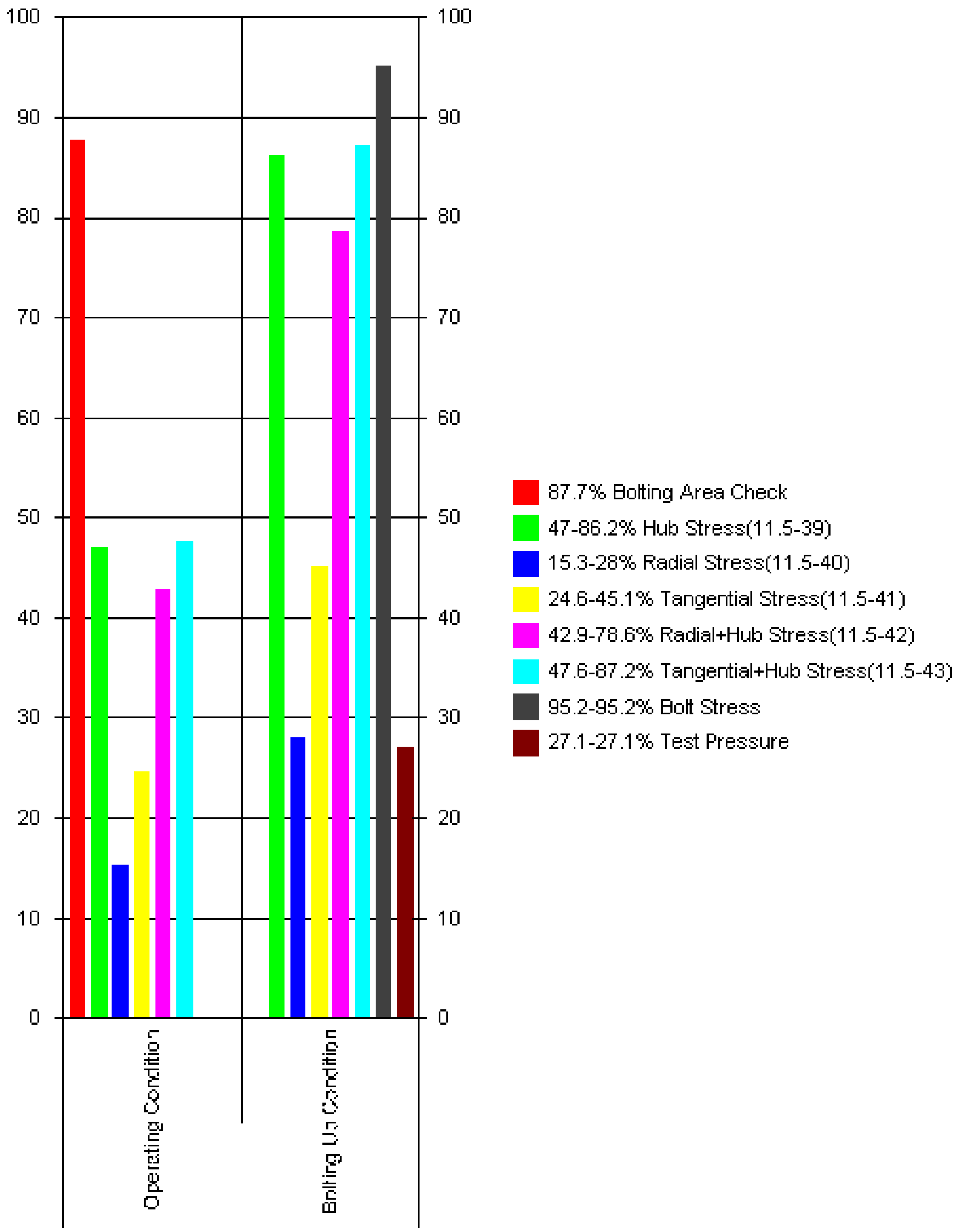
```
NEW AT AMBIENT TEMP. FOR TEST GROUPS 1, 2 and 3
Ptmin = 1.25 * Pd * f20 / f =1.25*0.5*166.67/118.13=       0.8818 MPa

Ptmin = 1.43 * Pd =1.43*0.5=                               0.7150 MPa
```

»Test Pressure Ptmin=0.8818 <= Ptmax=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

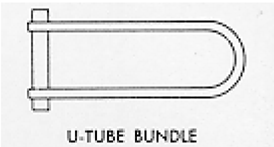
INPUT DATA

COMPONENT ATTACHMENT/LOCATION

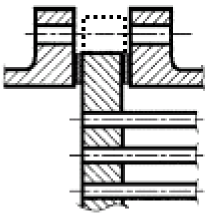
```
Attachment: F.1     WN - Flange         Channel flange                S1.1
Location: Along z-axis z1=  535
```

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
```

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
```

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)*-0.1-(1.11-1)*(1.11^2+1)*0.85)= -5270.63 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)
=-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
Mp = (Mstar - Do ^ 2 / 32 * F * (Ps - Pt)) / (1 + F)                (13.4.5-8)
=(-5270.63-590^2/32*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
Mo = Mp + Do ^ 2 / 64 * (3 + vstar) * (Ps - Pt)                     (13.4.5-9)
=-2944.83+590^2/64*(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( Abs( Mp), Abs( Mo))                                        (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 / (Mystar * (ea - hg) ^ 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 * Do / (my * ea) * (Ps - Pt)                             (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
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
```

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
```

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
```

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)*0.85)= -1941.81 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)
=-1941.81+1201.03*(657.15-657.15)/(2*3.14*590)=             -1941.81 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)
=(-1941.81-590^2/32*0.1751*(0.5-0.85))/(1+0.1751)=          -1084.94 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)
=-1084.94+590^2/64*(3+0.3112)*(0.5-0.85)=                   -7388.39 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(-1084.94,)Abs(-7388.39))=                           7388.39 Nmm/mm
```

13.4.5.2 Bending Stress in Tubesheet (Sigma)

```
Sigma = 6 * M / (Mystar * (ea - hg) ^ 2)                               (13.4.5-11)
=6*7388.39/(0.4307*(49-2)^2)=                                   46.60 N/mm2
```

»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)

```
Tau = 0.25 * Do / (my * ea) * (Ps - Pt)                    (13.4.5-13)
=0.25*590/(0.2673*49)*(0.5-0.85)=                    -3.94 N/mm2
```

»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

```
Pttmin = MAX( 1.43 * Ptd , 1.25 * Ptd * f20 / f)
=MAX(1.43*0.85,1.25*0.85*166.67/82.93)=                2.14 MPa
```

»Tubeside Test Pressure(limited by:Bending Stress) Pttmin=2.14 <= Pttmax=4.4336[MPa] «» OK«

TEST PRESSURE ON SHELLSIDE

```
Ptsmin = MAX( 1.43 * Psd , 1.25 * Psd * f20 / f)
=MAX(1.43*0.5,1.25*0.5*166.67/82.93)=                  1.26 MPa
```

»Shellside Test Pressure(limited by:Bending Stress) Pttmin=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)

```
Sigma = 6 * M / (Mystar * (ea - hg) ^ 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 * Do / (my * ea) * (Ps - Pt)                    (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)

13.4.5 Tubesheet Design

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.

13.4.5 Tubesheet Design

13.4.5.2 Bending Stress in Tubesheet (Sigma)

```
Sigma = 6 * M / (Mystar * (ea - hg) ^ 2)                   (13.4.5-11)
=6*7388.39/(0.4307*(49-2)^2)=                       46.60 N/mm2
```

»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)

```
Tau = 0.25 * Do / (my * ea) * (Ps - Pt)                    (13.4.5-13)
=0.25*590/(0.2673*49)*(0.5-0.85)=                  -3.94 N/mm2
```

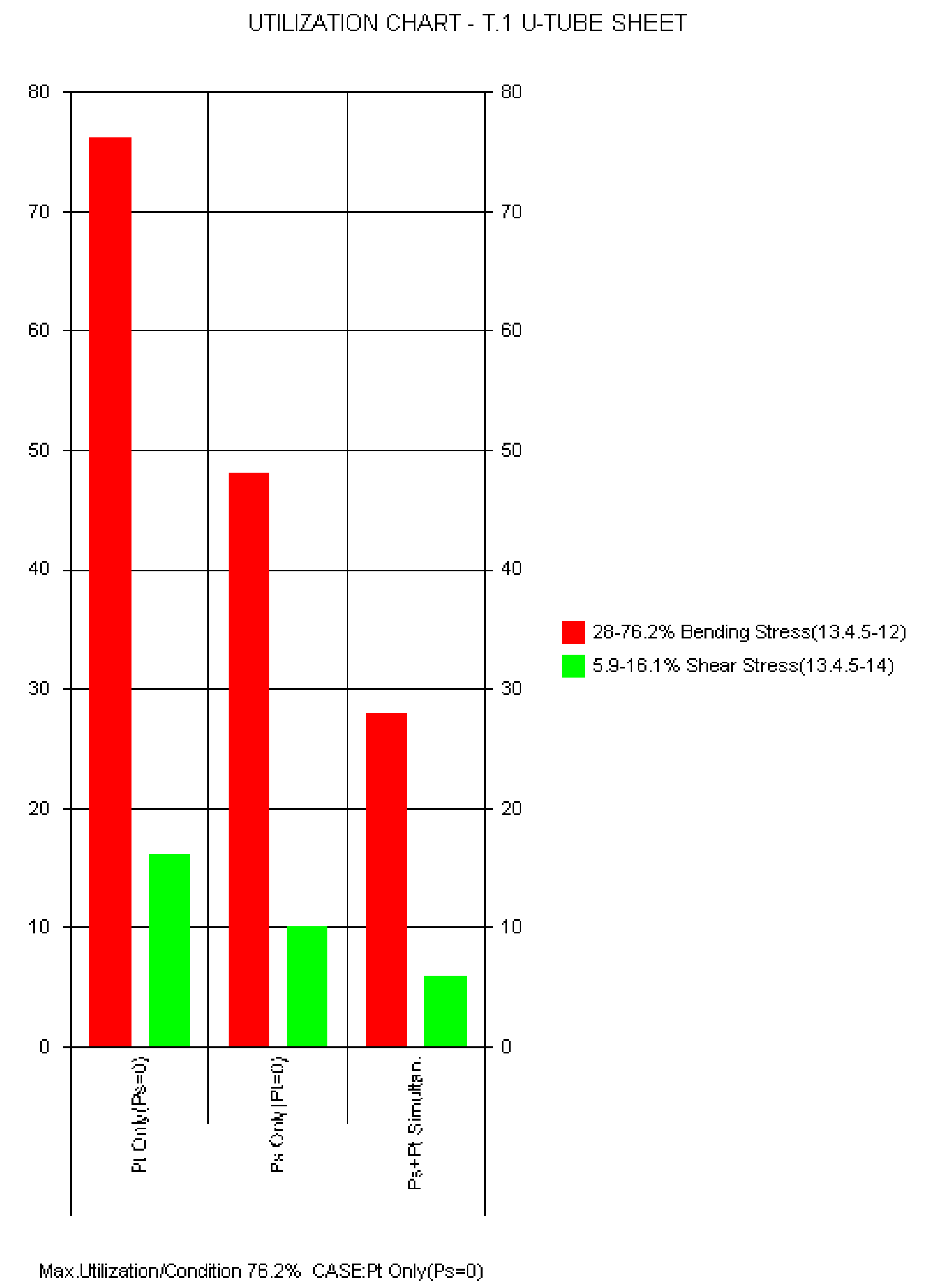
»Shear Stress Tau=3.94 <= 0.8 * f=66.34[N/mm2] (13.4.5-14)«» (U= 5.9%) OK«

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
80
70
60
50
40
30
20
10
0
Pt Only(Ps=0)
Ps Only(Pt=0)
Ps+Pt Simultan.
28-76.2% Bending Stress(13.4.5-12)
5.9-16.1% Shear Stress(13.4.5-14)
Max.Utilization/Condition 76.2% CASE:Pt Only(Ps=0)

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 Applicabilty 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
```

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

```
Ptmax = 2 * ftest * (ea + c) / Dm
=2*223.81*(1.54+0)/17.51=                                  39.47 MPa
```

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 * f20 / f =1.25*0.95*150/77.87=             2.29 MPa
Ptmin = 1.43 * Pd =1.43*0.95=                                 1.36 MPa
```

»Test Pressure Ptmin=2.29 <= Ptmax=39.47[MPa] « » (U= 5.7%) OK«

SECT. 8.5 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

8.4.2 Nominal Elastic Limit Sige:

```
Sige = Rpt (8.4.2-1) =116.8=                                 116.80 N/mm2
```

Preliminary Calculations

```
R = Dm / 2 =17.51/2=                                            8.75 mm
Z = PI * R / L (8.5.2-7) =3.14*8.75/3945=                    0.0070
Delta = 1.28 / Sqr( R * ea) (8.5.3-20) =1.28/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 py

```
py = Sige * ea / (R * (1 - gamma * G ))                          (8.5.3-15)
=116.8*1.54/(8.75*(1-0*0))=                                  20.60 MPa
```

ELASTIC INSTABILITY pe

```
pm = E * ea * eps / R (8.5.2-5) =1.851E05*1.54*0.0085/8.75=   278.87 MPa
```

MAX. ALLOWABLE EXTERNAL PRESSURE Pmax

```
Value pr/py From Figure 8.5-5 Curve   1
Value1 =  ==                                                 0.9585
pr = Value1 * py =0.9585*20.6=                                 19.74 MPa
Max. Allowable External Pressure
Pmax = pr / k =19.74/1.5=                                      13.16 MPa
```

»External Pressure Pmax=13.16 >= Pext=0.6[MPa] « » (U= 4.5%) OK«

Max. External Test Pressure

```
Max. External Test Pressure (Uncorroded cond.at ambient temp.)
Ptemax = Pr1 / 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. emin :
emin = De * P / (2 * f * z + P)                                 (7.4-2)
=19.05*0.95/(2*77.87*1+0.95)=                              0.1155 mm
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
```

»Internal Pressure emina=0.4421 <= en=2.108[mm] « » (U= 20.9%) OK«

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

```
Ptmax = 2 * ftest * (ea + c) / Dm
=2*223.81*(1.54+0)/17.51=                              39.47 MPa
```

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 * f20 / f =1.25*0.95*150/77.87=       2.29 MPa
Ptmin = 1.43 * Pd =1.43*0.95=                           1.36 MPa
```

»Test Pressure Ptmin=2.29 <= Ptmax=39.47[MPa] « » (U= 5.7%) OK«

SECT. 8.5 - CYLINDRICAL SHELL UNDER EXTERNAL PRESSURE

```
Max. Allowable External Pressure
Pmax = pr / k =19.74/1.5=                              13.16 MPa
```

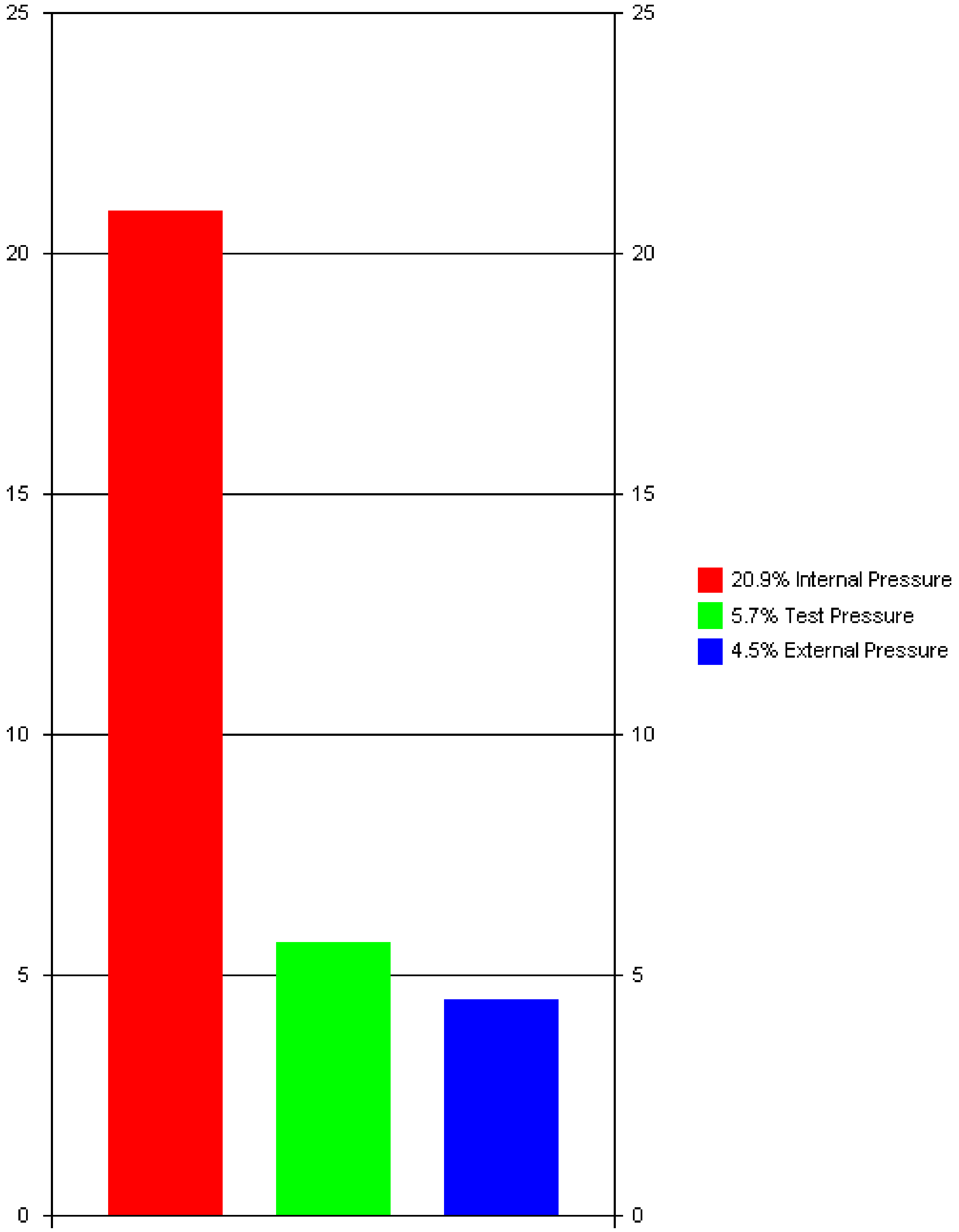
»External Pressure Pmax=13.16 >= Pext=0.6[MPa] « » (U= 4.5%) OK«

Max. External Test Pressure

```
Max. External Test Pressure (Uncorroded cond.at ambient temp.)
Ptemax = Pr1 / 1.1 =39.45/1.1=                         35.86 MPa
```

Volume:0.24 m3 Weight:1214.3 kg (SG= 7.85)

UTILIZATION CHART - TB.1 U-TUBE BUNDLE



Max.Utilization/Condition 20.9%

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

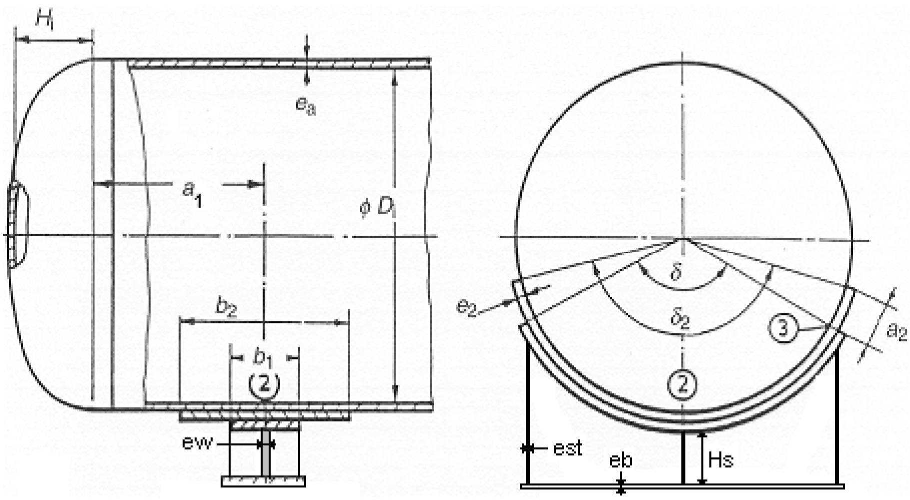
EN 10028-2:2003/AC:06, 1.0425 P265GH plate and strip, HT:N THK<=16mm 232'C
Rm=410 Rp=265 Rpt=194.12 fs=129.41 f20=170.83 ftest=252.38 E=196147(N/mm2) ro=7.85
OUTSIDE DIAMETER OF SHELL...........................:De 864.00 mm
AS BUILT WALL THICKNESS (uncorroded)................:en 12.00 mm
NEGATIVE TOLERANCE/THINNING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



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)

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 >= 0.001« » OK«
»a) en/Di=0.0142 <= 0.05« » OK«
»a) Delta=120 >= 60[Degr] « » OK«
»a) Delta=120 <= 180[Degr] « » OK«
»b) e2=12 >= en=12[mm] « » OK«
»b) a2=90.48 >= 0.1*Di=84.7[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
thefoundation 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 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 kNmm
Mij (Moment between Saddels)= ==                              7843.57 kNmm
```

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 kNm

Additional Vertical Force due to Horizontal Moment Mt
```

```
FvMt = 3 * Mt / Lsw =3*0.4359/748.25=                             1.75 kN

Additional Vertical Force due to Axial Load Fva
Fva = Fha * (De / 2 + Hs) / LengthBetweenSaddles
=0.1832*(864/2+350)/2900=                                       0.0494 kN

Total Vertical Force Fv
Fvtot = Fvi + FvMt + Fva =30.97+1.75+0.0494=                     32.77 kN

NOTE: No thermal expansion is considered at ambient temperature, hence the
friction coefficent 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)=  0.0778 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
=(32.77*0.204+0.5574)/5160=                                        1.40 N/mm2
```

»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)=                                         0.2402 N/mm2
```

»Saddle Stresses due to Axial Loads Sigt=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=                                   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*252.38/(196147*8.5)*(566./(10*15))^2)^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 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)=              0.2433 N/mm2
```

»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)=                               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*0.2433/252.38)=                                   4.57 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))=                               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
```

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 Diamater 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 <= 8.7*SQR(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*Sqr(R/L*(1+42*(R/L)^3*(ea/R)^1.5))                 (16.8-30)
=8357.89*Sqr(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
alfa = 0.83 / Sqr( 1 + 0.005 * D / ea)                         (16.14-16)
=0.83/Sqr(1+0.005*855.5/8.5)=                            0.6770
delta = (1 - 0.4123 / (alfa * 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 <= 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 <= 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

```
gamma = 2.83 * (a1 / Di) * Sqr( ea / Di)                       (16.8-15)
=2.83*(164/847)*Sqr(8.5/847)=                            0.0549
beta = 0.91 * b1 / Sqr( Di * ea)                               (16.8-16)
=0.91*250/Sqr(847*8.5)=                                      2.68
```

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 * Sqr( Di * ea) * ea / (K3 * K5)
=0.7*393.92*Sqr(847*8.5)*8.5/(0.25*0.8307)=                 957.66 kN
```

Maximum Allowable Saddle Load at Location 3, F3max

```
F3max = 0.9*Sigball3*Sqr(Di*ea)*ea/(K7*K9*K10)
=0.9*84.03*Sqr(847*8.5)*8.5/(0.3883*0.6215*0.3264)=         692.45 kN
```

»Max.Saddle Forces Fvtot=32766.31 <= Min(F2max, F3max)=6.9245E05«» (U= 4.7%) OK«

Eqvivalent Global Axial Force Feq

```
Feq = Fvtot * PI / 4 * Sqr( Di / ea) * K6 * K8
=32.77*3.14/4*Sqr(847/8.5)*0.021*0.2056=                    1108.18 N
```

Instability Check

```
Inst = Pext/Pmax+Mi/Mmax+Feq/Fmax+(Qi/Qmax)^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 = Sqr((en-c-th)^2+e2^2*MIN(1,(f2/fs)^2))
=Sqr((12-3-0.5)^2+12^2*MIN(1,(129.41/129.41)^2))=            14.71 mm
Shell Inside Diamater Di
Di = De - 2 * (en - c - th) =864-2*(12-3-0.5)=                 847.00 mm
Mean Diameter D
D = Di + ea =847+14.71=                                        861.71 mm
Mean Shell Radius R
R = D / 2 =861.71/2=                                           430.85 mm
```

Parameters gamma and beta

```
gamma = 2.83 * (a1 / Di) * Sqr( ea / Di)                          (16.8-15)
=2.83*(164/847)*Sqr(14.71/847)=                         0.0722
beta = 0.91 * b1 / Sqr( Di * ea)                                  (16.8-16)
=0.91*180/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 * Sin( 0.5 * Delta))
=-0.53*0.6652/(0.6344*0.613*0.4923*Sin(0.5*120))=          -2.13
Ratio v2 at location 2 when P=0
v212 = -4 * Mi / (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/(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
Sigball2= K1 * K2 * fs =1.44*1.05*252.38=                  382.27

K1 at location 3 (from figure 16.6-1)=    0.402
Sigball3= K1 * K2 * fs =0.4023*1.05*252.38=                106.61
```

Maximum Allowable Saddle Load at Location 2, F2max

```
F2max = 0.7 * Sigball2 * Sqr( Di * ea) * ea / (K3 * K5)
=0.7*382.27*Sqr(847*14.71)*14.71/(0.25*0.9815)=        1789.79 kN
```

Maximum Allowable Saddle Load at Location 3, F3max

```
F3max = 0.9*Sigball3*Sqr(Di*ea)*ea/(K7*K9*K10)
=0.9*106.61*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 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) =1.11*(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
```

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 Diamater 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 <= 8.7*SQR(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*Sqr(R/L*(1+42*(R/L)^3*(ea/R)^1.5)) (16.8-30)
=8357.89*Sqr(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/(194.12*855.5)= 12.15
alfa = 0.83 / Sqr(1 + 0.005 * D / ea) (16.14-16)
=0.83/Sqr(1+0.005*855.5/8.5)= 0.6770
delta = (1 - 0.4123 / (alfa * 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 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*129.41= 2956.36 kN

Maximum Compressive Force Fcmax
Fcmax = PI * D * ea * Sigcall (16.14-2) =3.14*855.5*8.5*114.34= 2612.13 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 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 N/mm2

»Vessel Stress Btwn.Saddles fact=13.71 <= 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 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)
Inst = Abs(Pext) / Pmax + Abs(Mij) / (1000 * Mmax)
=Abs(0.1)/0.4041+Abs(4786.64)/(1000*558.67)= 0.2560

»Instability Check Inst=0.256 <= 1.0=1(16.8-14)« » (U= 25.6%) OK«

Parameters gamma and beta

```
gamma = 2.83 * (a1 / Di) * Sqr( ea / Di)                              (16.8-15)
=2.83*(164/847)*Sqr(8.5/847)=                                0.0549
beta = 0.91 * b1 / Sqr( Di * ea)                                      (16.8-16)
=0.91*250/Sqr(847*8.5)=                                        2.68
```

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*4786.64/(3.14*847^2*8.5*1.25*129.41)=                     -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)
=(0.5*847/(4*8.5)-4*4786.64/(3.14*847^2*8.5))*1/(1.25*129.41)=  0.0708
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
```

16.6.5 Bending Stress Limit

```
K1 at location 2 (from figure 16.6-1)=    1.491
Sigball2= K1 * K2 * fs =1.49*1.25*129.41=                       241.17

K1 at location 3 (from figure 16.6-1)=    0.317
Sigball3= K1 * K2 * fs =0.3171*1.25*129.41=                       51.29
```

Maximum Allowable Saddle Load at Location 2, F2max

```
F2max = 0.7 * Sigball2 * Sqr( Di * ea) * ea / (K3 * K5)
=0.7*241.17*Sqr(847*8.5)*8.5/(0.25*0.8307)=                   586.31 kN
```

Maximum Allowable Saddle Load at Location 3, F3max

```
F3max = 0.9*Sigball3*Sqr(Di*ea)*ea/(K7*K9*K10)
=0.9*51.29*Sqr(847*8.5)*8.5/(0.3883*0.6215*0.3264)=           422.69 kN
```

»Max.Saddle Forces Fvtot=21756.57 <= Min(F2max, F3max)=4.2269E05«» (U= 5.1%) OK«

Eqvivalent Global Axial Force Feq

```
Feq = Fvtot * PI / 4 * Sqr( Di / ea) * K6 * K8
=21.76*3.14/4*Sqr(847/8.5)*0.021*0.2056=                      735.82 N
```

Instability Check

```
Inst = Pext/Pmax+Mi/Mmax+Feq/Fmax+(Qi/Qmax)^2
=0.1/0.4041+4786.64/558.67+735.82/2.6121E06+(10.72/2711.39)^2=  0.2563
```

»Instability Check Inst_0=0.2563 <= 1.0=1(16.8-28)« » (U= 25.6%) OK«

CALCULATION 2, ea = ec, b=b1, Delta=Delta

PRELIMINARY CALCULATIONS

```
Combined Analysis Thickness ec, ea
ea = Sqr((en-c-th)^2+e2^2*MIN(1,(f2/fs)^2))
=Sqr((12-3-0.5)^2+12^2*MIN(1,(129.41/129.41)^2))=               14.71 mm
Shell Inside Diamater Di
Di = De - 2 * (en - c - th) =864-2*(12-3-0.5)=                  847.00 mm
```

```
Mean Diameter D
D = Di + ea =847+14.71=                                        861.71 mm
Mean Shell Radius R
R = D / 2 =861.71/2=                                           430.85 mm
```

Parameters gamma and beta

```
gamma = 2.83 * (a1 / Di) * Sqr( ea / Di)                              (16.8-15)
=2.83*(164/847)*Sqr(14.71/847)=                             0.0722
beta = 0.91 * b1 / Sqr( Di * ea)                                      (16.8-16)
=0.91*180/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 * Sin( 0.5 * Delta))
=-0.53*0.6652/(0.6344*0.613*0.4923*Sin(0.5*120))=             -2.13
Ratio v2 at location 2 when P=0
v212 = -4 * Mi / (PI * Di ^ 2 * ea * K2 * fs)
=-4*4786.64/(3.14*847^2*14.71*1.25*129.41)=                  -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/(PI*Di^2*ea))*1/(K2*fs)
=(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
v223 = (P * Di / (2 * ea)) * 1 / (K2 * 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)=    1.448
Sigball2= K1 * K2 * fs =1.45*1.25*129.41=                      234.21

K1 at location 3 (from figure 16.6-1)=    0.402
Sigball3= K1 * K2 * fs =0.4023*1.25*129.41=                     65.08
```

Maximum Allowable Saddle Load at Location 2, F2max

```
F2max = 0.7 * Sigball2 * Sqr( Di * ea) * ea / (K3 * K5)
=0.7*234.21*Sqr(847*14.71)*14.71/(0.25*0.9815)=           1096.57 kN
```

Maximum Allowable Saddle Load at Location 3, F3max

```
F3max = 0.9*Sigball3*Sqr(Di*ea)*ea/(K7*K9*K10)
=0.9*65.08*Sqr(847*14.71)*14.71/(0.6344*0.613*0.4923)=      502.10 kN
```

»Max.Saddle Forces(ea=ec) Fvtot=21756.57 <= Min(F2max, F3max)=5.021E05«» (U= 4.3%) OK«

LOAD CASE NO: 1 - HYDROTEST (z = 4247)

Summation of Total Loads for Load Case :HYDROTEST

```
Fi  (Force in Vertical Direction)= ==                            26.12 kN
Fht (Force in Transverse Direction)= ==                        0.5325 kN
Fha (Force in Axial Direction, Sliding Saddle Fha=0)=
==                                                               0.00 kN
Qi  (Shear Force)= ==                                            15.84 kN
Mi  (Moment at Saddle)= ==                                     5378.67 kNmm
Mij (Moment between Saddels)= ==                               7843.57 kNmm
```

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) =0.5325*(864/2+350)=              0.4164 kNm

Additional Vertical Force due to Horizontal Moment Mt
FvMt = 3 * Mt / Lsw =3*0.4164/748.25=                         1.67 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 =26.12+1.67+0=                      27.79 kN

NOTE: No thermal expansion is considered at ambient temperature, hence the
friction coefficent 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 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
=(27.79*0.204+0.5325)/5160=                                  1.20 N/mm2
```

»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 N/mm2
```

»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 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*252.38/(196147*8.5)*(566./(10*15))^2)^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 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 N/mm2
```

»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 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*0.2064/252.38)=                            4.21 mm
```

»Baseplate Thickness eb=20 >= ebmin=4.21« » (U= 21%) 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
```

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 Diamater 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 <= 8.7*SQR(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*Sqr(R/L*(1+42*(R/L)^3*(ea/R)^1.5))                      (16.8-30)
=8357.89*Sqr(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
alfa = 0.83 / Sqr( 1 + 0.005 * D / ea)                              (16.14-16)
=0.83/Sqr(1+0.005*855.5/8.5)=                              0.6770
delta = (1 - 0.4123 / (alfa * 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 <= 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 <= 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

```
gamma = 2.83 * (a1 / Di) * Sqr( ea / Di)                          (16.8-15)
=2.83*(164/847)*Sqr(8.5/847)=                            0.0549
beta = 0.91 * b1 / Sqr( Di * ea)                                  (16.8-16)
=0.91*250/Sqr(847*8.5)=                                     2.68
```

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*5378.67/(3.14*847^2*8.5*1.05*252.38)=                 -0.0042
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*5378.67/(3.14*847^2*8.5))*1/(1.05*252.38)=  0.0898
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=                    393.77

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 * Sqr( Di * ea) * ea / (K3 * K5)
=0.7*393.77*Sqr(847*8.5)*8.5/(0.25*0.8307)=               957.30 kN
```

Maximum Allowable Saddle Load at Location 3, F3max

```
F3max = 0.9*Sigball3*Sqr(Di*ea)*ea/(K7*K9*K10)
=0.9*84.03*Sqr(847*8.5)*8.5/(0.3883*0.6215*0.3264)=       692.45 kN
```

»Max.Saddle Forces Fvtot=27794.35 <= Min(F2max, F3max)=6.9245E05«» (U= 4%)OK«

Eqvivalent Global Axial Force Feq

```
Feq = Fvtot * PI / 4 * Sqr( Di / ea) * K6 * K8
=27.79*3.14/4*Sqr(847/8.5)*0.021*0.2056=                  940.03 N
```

Instability Check

```
Inst = Pext/Pmax+Mi/Mmax+Feq/Fmax+(Qi/Qmax)^2
=0/0.4041+5378.67/1060.03+940.03/4.9563E06+(15.84/2711.39)^2=  0.0053
```

»Instability Check Inst_0=0.0053 <= 1.0=1(16.8-28)« » (U= .5%) OK«

CALCULATION 2, ea = ec, b=b1, Delta=Delta

PRELIMINARY CALCULATIONS

```
Combined Analysis Thickness ec, ea
ea = Sqr((en-c-th)^2+e2^2*MIN(1,(f2/fs)^2))
=Sqr((12-3-0.5)^2+12^2*MIN(1,(129.41/129.41)^2))=           14.71 mm
Shell Inside Diamater Di
Di = De - 2 * (en - c - th) =864-2*(12-3-0.5)=               847.00 mm
Mean Diameter D
D = Di + ea =847+14.71=                                      861.71 mm
Mean Shell Radius R
R = D / 2 =861.71/2=                                         430.85 mm
```

Parameters gamma and beta

```
gamma = 2.83 * (a1 / Di) * Sqr( ea / Di)                           (16.8-15)
=2.83*(164/847)*Sqr(14.71/847)=                            0.0722
beta = 0.91 * b1 / Sqr( Di * ea)                                   (16.8-16)
=0.91*180/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 * Sin( 0.5 * Delta))
=-0.53*0.6652/(0.6344*0.613*0.4923*Sin(0.5*120))=            -2.13
Ratio v2 at location 2 when P=0
v212 = -4 * Mi / (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/(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 at location 2 (from figure 16.6-1)=    1.442
Sigball2= K1 * K2 * fs =1.44*1.05*252.38=                    382.11

K1 at location 3 (from figure 16.6-1)=    0.402
Sigball3= K1 * K2 * fs =0.4023*1.05*252.38=                  106.61
```

Maximum Allowable Saddle Load at Location 2, F2max

```
F2max = 0.7 * Sigball2 * Sqr( Di * ea) * ea / (K3 * K5)
=0.7*382.11*Sqr(847*14.71)*14.71/(0.25*0.9815)=           1789.02 kN
```

Maximum Allowable Saddle Load at Location 3, F3max

```
F3max = 0.9*Sigball3*Sqr(Di*ea)*ea/(K7*K9*K10)
=0.9*106.61*Sqr(847*14.71)*14.71/(0.6344*0.613*0.4923)=     822.54 kN
```

»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)

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
```

»Webplate Buckling Fw=5031.59 <= Fwmax=6.2434E05« » (U= .8%) OK«

```
Foundation Bearing Pressure  Pb
Pbearing = Fvtot / (b1 * Lsw) =15.09/(180*748.25)=            0.1121 N/mm2
```

»Foundation Bearing Pressure Pbearing=0.1121 <= Fba=3« » (U= 3.7%) 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*0.1121/170.83)=                              3.77 mm
```

»Baseplate Thickness eb=20 >= ebmin=3.77« » (U= 18.8%) 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
```

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 Diamater 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 <= 8.7*SQR(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*Sqr(R/L*(1+42*(R/L)^3*(ea/R)^1.5))                         (16.8-30)
=8357.89*Sqr(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/(194.12*855.5)=                              12.15
alfa = 0.83 / Sqr( 1 + 0.005 * D / ea)                                 (16.14-16)
=0.83/Sqr(1+0.005*855.5/8.5)=                               0.6770
delta = (1 - 0.4123 / (alfa * 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 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*129.41=    2956.36 kN

Maximum Compressive Force Fcmax
Fcmax = PI * D * ea * Sigcall (16.14-2) =3.14*855.5*8.5*114.34=  2612.13 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 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 N/mm2
```

»Vessel Stress Btwn.Saddles fact=13.71 <= 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 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)
Inst = Abs( Pext) / Pmax + Abs( Mij) / (1000 * Mmax)
=Abs(0.1)/0.4041+Abs(4786.64)/(1000*558.67)=                0.2560
```

»Instability Check Inst=0.256 <= 1.0=1(16.8-14)« » (U= 25.6%) OK«

Parameters gamma and beta

```
gamma = 2.83 * (a1 / Di) * Sqr( ea / Di)                            (16.8-15)
=2.83*(164/847)*Sqr(8.5/847)=                               0.0549
beta = 0.91 * b1 / Sqr( Di * ea)                                    (16.8-16)
=0.91*250/Sqr(847*8.5)=                                        2.68
```

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*1965.55/(3.14*847^2*8.5*1.25*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*Di/(4*ea)-4*Mi/(PI*Di^2*ea))*1/(K2*fs)
=(0.5*847/(4*8.5)-4*1965.55/(3.14*847^2*8.5))*1/(1.25*129.41)=  0.0745
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
```

16.6.5 Bending Stress Limit

```
K1 at location 2 (from figure 16.6-1)=    1.490
Sigball2= K1 * K2 * fs =1.49*1.25*129.41=                      241.03

K1 at location 3 (from figure 16.6-1)=    0.317
Sigball3= K1 * K2 * fs =0.3171*1.25*129.41=                     51.29
```

Maximum Allowable Saddle Load at Location 2, F2max

```
F2max = 0.7 * Sigball2 * Sqr( Di * ea) * ea / (K3 * K5)
=0.7*241.03*Sqr(847*8.5)*8.5/(0.25*0.8307)=                  585.97 kN
```

Maximum Allowable Saddle Load at Location 3, F3max

```
F3max = 0.9*Sigball3*Sqr(Di*ea)*ea/(K7*K9*K10)
=0.9*51.29*Sqr(847*8.5)*8.5/(0.3883*0.6215*0.3264)=          422.69 kN
```

»Max.Saddle Forces Fvtot=15094.76 <= Min(F2max, F3max)=4.2269E05«» (U= 3.5%) OK«

Eqvivalent Global Axial Force Feq

```
Feq = Fvtot * PI / 4 * Sqr( Di / ea) * K6 * K8
=15.09*3.14/4*Sqr(847/8.5)*0.021*0.2056=                  510.52 N
```

Instability Check

```
Inst = Pext/Pmax+Mi/Mmax+Feq/Fmax+(Qi/Qmax)^2
=0.1/0.4041+1965.55/558.67+510.52/2.6121E06+(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
ea = Sqr((en-c-th)^2+e2^2*MIN(1,(f2/fs)^2))
=Sqr((12-3-0.5)^2+12^2*MIN(1,(129.41/129.41)^2))=          14.71 mm
Shell Inside Diamater Di
Di = De - 2 * (en - c - th) =864-2*(12-3-0.5)=              847.00 mm
Mean Diameter D
D = Di + ea =847+14.71=                                     861.71 mm
Mean Shell Radius R
R = D / 2 =861.71/2=                                        430.85 mm
```

Parameters gamma and beta

```
gamma = 2.83 * (a1 / Di) * Sqr( ea / Di)                         (16.8-15)
=2.83*(164/847)*Sqr(14.71/847)=                          0.0722
beta = 0.91 * b1 / Sqr( Di * ea)                                 (16.8-16)
=0.91*180/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 * Sin( 0.5 * Delta))
=-0.53*0.6652/(0.6344*0.613*0.4923*Sin(0.5*120))=           -2.13
Ratio v2 at location 2 when P=0
v212 = -4 * Mi / (PI * Di ^ 2 * ea * K2 * fs)
=-4*1965.55/(3.14*847^2*14.71*1.25*129.41)=                -0.0015
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)
=(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
v223 = (P * Di / (2 * ea)) * 1 / (K2 * 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
Sigball2= K1 * K2 * fs =1.45*1.25*129.41=                   234.03

K1 at location 3 (from figure 16.6-1)=    0.402
Sigball3= K1 * K2 * fs =0.4023*1.25*129.41=                  65.08
```

Maximum Allowable Saddle Load at Location 2, F2max

```
F2max = 0.7 * Sigball2 * Sqr( Di * ea) * ea / (K3 * K5)
=0.7*234.03*Sqr(847*14.71)*14.71/(0.25*0.9815)=          1095.72 kN
```

Maximum Allowable Saddle Load at Location 3, F3max

```
F3max = 0.9*Sigball3*Sqr(Di*ea)*ea/(K7*K9*K10)
=0.9*65.08*Sqr(847*14.71)*14.71/(0.6344*0.613*0.4923)=     502.10 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) Sigt=1.4 <= fsw*2/3=168.25«» (U= .8%) OK«
»Saddle Stresses due to Axial Loads Sigt=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 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=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) Sigt=1.08 <= fsw*2/3=113.89«» (U= .9%)OK«
»Saddle Stresses due to Axial Loads Sigt=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 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«

»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«

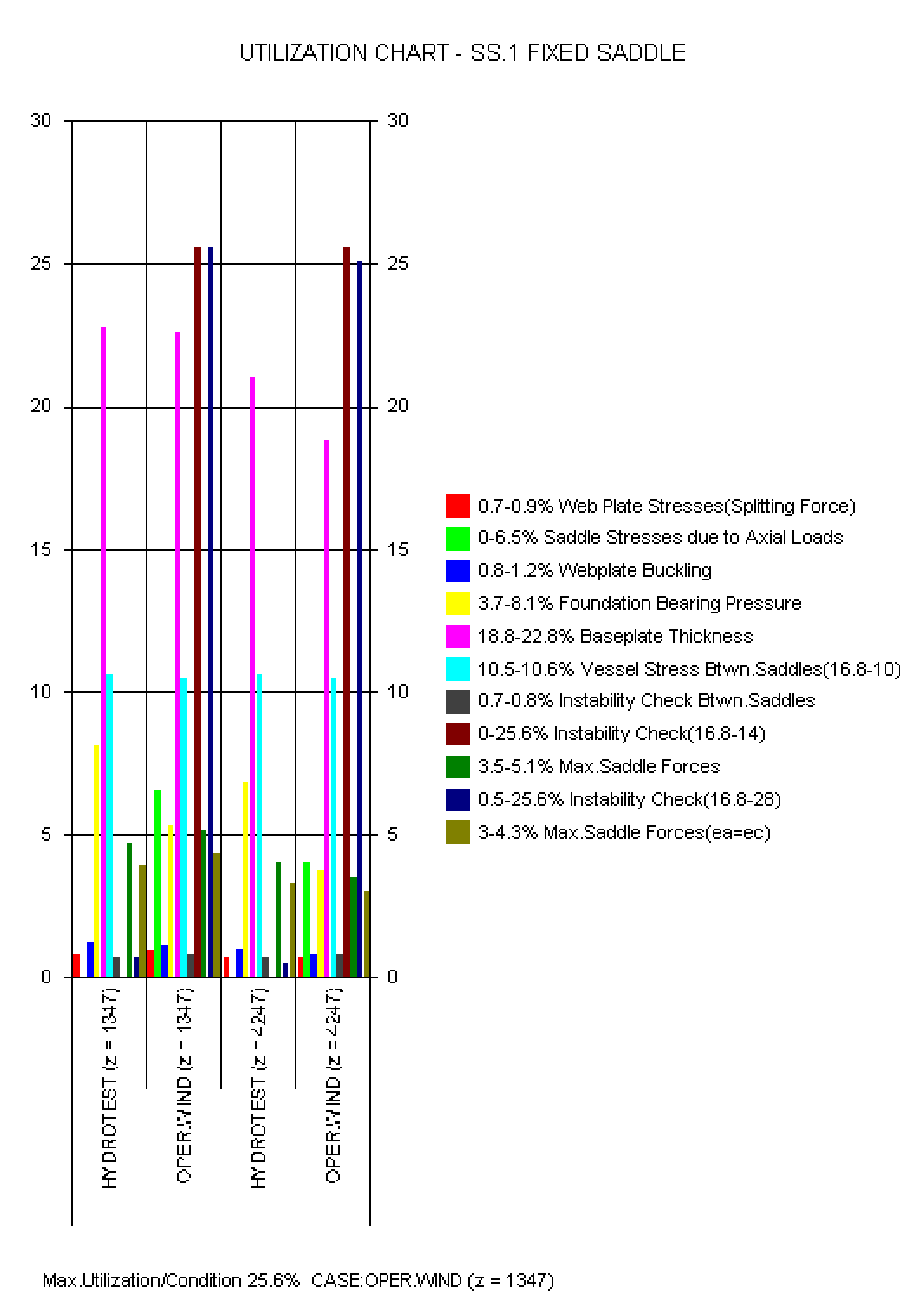
»Max.Saddle Forces Fvtot=15094.76 <= Min(F2max, F3max)=4.2269E05«» (U= 3.5%) OK«

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)


UTILIZATION CHART - SS.1 FIXED SADDLE
30
25
20
15
10
5
0
HYDROTEST (z = 1347)
OPER.WIND (z = 1347)
HYDROTEST (z = 4247)
OPER.WIND (z = 4247)
0.7-0.9% Web Plate Stresses(Splitting Force)
0-6.5% Saddle Stresses due to Axial Loads
0.8-1.2% Webplate Buckling
3.7-8.1% Foundation Bearing Pressure
18.8-22.8% Baseplate Thickness
10.5-10.6% Vessel Stress Btwn.Saddles(16.8-10)
0.7-0.8% Instability Check Btwn.Saddles
0-25.6% Instability Check(16.8-14)
3.5-5.1% Max.Saddle Forces
0.5-25.6% Instability Check(16.8-28)
3-4.3% Max.Saddle Forces(ea=ec)
Max.Utilization/Condition 25.6% CASE:OPER.WIND (z = 1347)