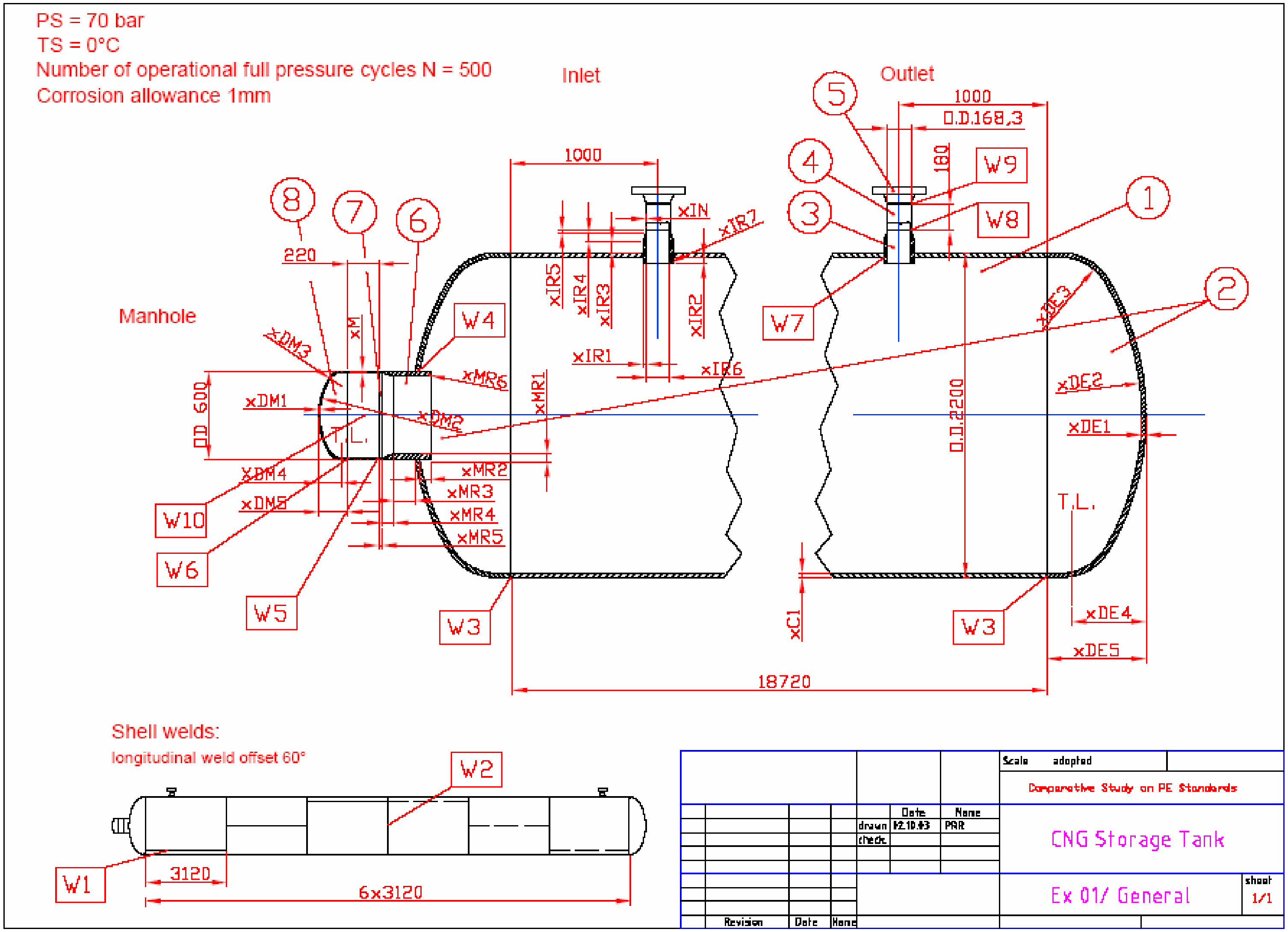
COMPARATIVE STUDY

EN 13445 / ASME Section VIII Div. 1 & 2

Reinhard Preiss and Josef L. Zeman


PS = 70 bar
TS = 0°C
Number of operational full pressure cycles N = 500
Corrosion allowance 1mm
Inlet
Outlet
Manhole
1000
O.D.168,3
180
220
OD 600
O.D.2200
18720
T.L.
W1
W2
W3
W4
W5
W6
W7
W8
W9
W10
Shell welds:
longitudinal weld offset 60°
3120
6x3120
Scale adopted
Comparative Study on PE Standards
CNG Storage Tank
Ex 01/ General
sheet 1/1
Revision
Date
Name
drawn
check

EX 01

Material	Fine-grained carbon steel; the particular grade is to be selected within the code used in order to arrive at the most economic solution (according to EN 13445 or the ASME B&PV code).
Actions	PS = 70 bar Ambient temperature
Operational cycles	500
Geometry	Diameter 2200 mm (length 20000 mm) Volume = 73000 l Inlet and outlet nozzles DN 150 on the shell 1 manhole DN 600 in the dished end Positioned underground; calculation for external pressure not required Corrosion allowance 1 mm
Details to be investigated	None
Design approaches	DBF according to EN13445, ASME Section VIII Division 1 and ASME Section VIII Division 2; DBA according to EN13445 Annex B and ASME Section VIII Division 2

EX 01

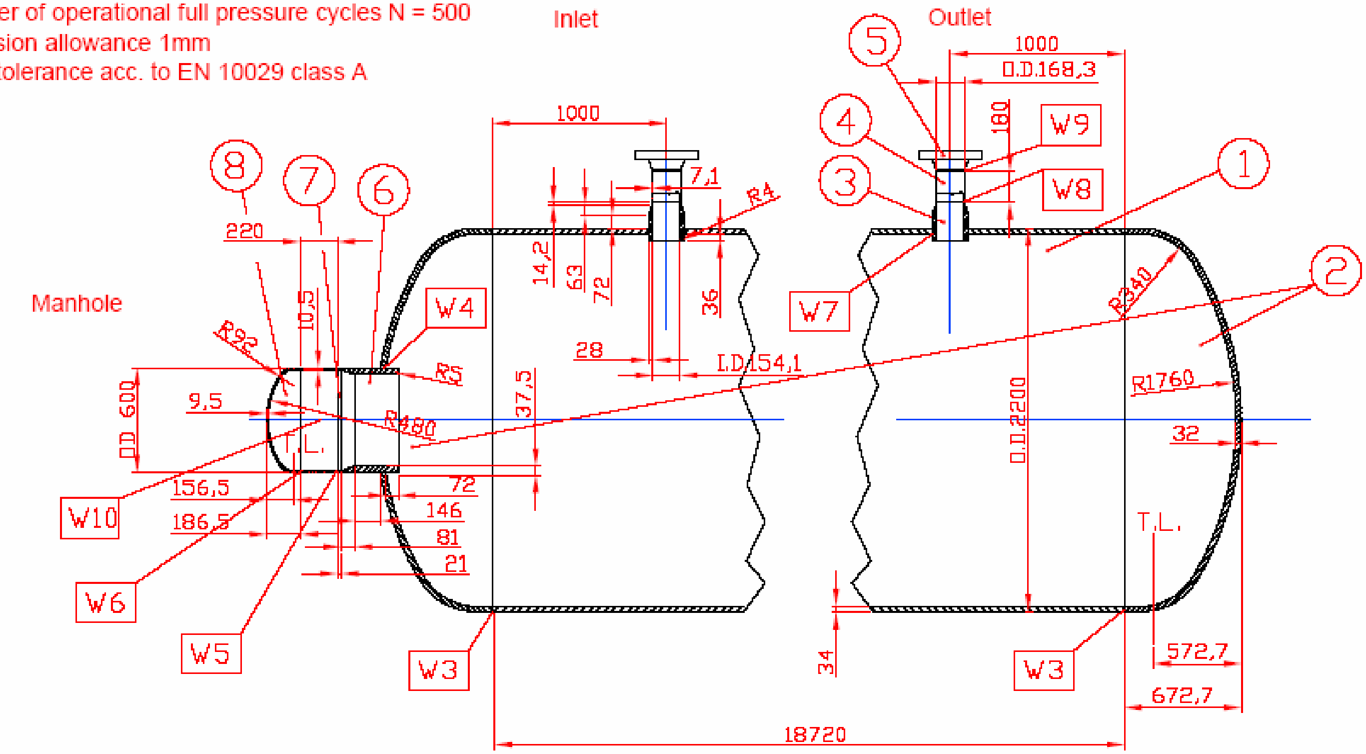
Dimension Table: Comp. Study EX1 (CNG Storage Tank)

Dimension	Design Route (Code)						Note
	EN 13345 DBF	EN 13445 DBA	ASME VIII/1	ASME VIII/1 + PED[9]	ASME VIII/2 DBF	ASME VIII/2 App.4	
xC1	34mm	28,5mm	47,5mm	51mm	40mm	40mm	manufact. tol. acc. to EN 10029 class A
xDE1	32mm	30mm	46mm	49mm	43mm	40mm	minimum wall thickness
xDE2	1760mm	1760mm	1899mm	1899mm	1903mm	1903mm	EN: Korbbogen-form acc. to DIN 28013; ASME: ellipsodial form (2:1)
xDE3	340mm	340mm	359mm	359mm	360mm	360mm	
xDE4	572,7mm	512mm	571mm	571mm	571mm	571mm	
xDE5	672,7mm[1]	602mm[2]	571mm[4]	571mm[4]	591mm[7]	571mm[8]	
xMR1	37,5mm	43mm	52mm	52mm	60mm	40mm	
xMR2	72mm	80mm	112,5mm	112,5mm	110mm	100mm	
xMR3	146mm	150mm	112,5mm	120mm	110mm	80mm	
xMR4	81mm	97,5mm	65mm	65mm	144mm	84mm	
xMR5	21mm	21mm	29mm[6]	29mm[6]	24mm[6]	24mm[6]	
xMR6	radius 5mm[6]	radius 5mm[6]	radius 5mm[6]	radius 5mm[6]	radius 6mm	radius 6mm	
xM	10,5mm	10,5mm	14,5mm	14,5mm	12,5mm	12,5mm	manufact. tol. acc. to EN 10029 class A
xDM1	9,5mm	9,5mm	13,5mm	13,5mm	12,5mm	12,5mm	minimum wall thickness
xDM2	480mm	480mm	515,5mm	515,5mm	515,5mm	515,5mm	EN: Korbbogen-form acc. to DIN 28013; ASME: ellipsodial form (2:1)
xDM3	92mm	92mm	98mm	98mm	98mm	98mm	
xDM4	156,5mm	156,5mm	156,5mm	156,5mm	156,5mm	156,5mm	
xDM5	186,5mm[3]	186,5mm[3]	156,5mm[5]	156,5mm[5]	156,5mm[8]	156,5mm[8]	
xIR1	28mm	28mm	31mm	31mm	28mm	28mm	
xIR2	36mm	36mm	72,5mm	77,5mm	70mm	70mm	
xIR3	72mm	72mm	75mm	77,5mm	70mm	70mm	
xIR4	63mm	63mm	72mm	72mm	51mm	51mm	
xIR5	14,2mm	14,2mm	14,2mm[6]	14,2mm[6]	22mm[6]	22mm[6]	
xIR6	I.D. 154,1mm	I.D. 154,1mm	I.D. 154,1mm	I.D. 154,1mm	I.D. 148,3mm	I.D. 148,3mm	
xIR7	radius 4mm[6]	radius 4mm[6]	radius 4mm[6]	radius 4mm[6]	radius 6mm	radius 6mm	
xIN	7,1mm	7,1mm	7,1mm	7,1mm	10,97mm (XS)	10,97mm (XS)	

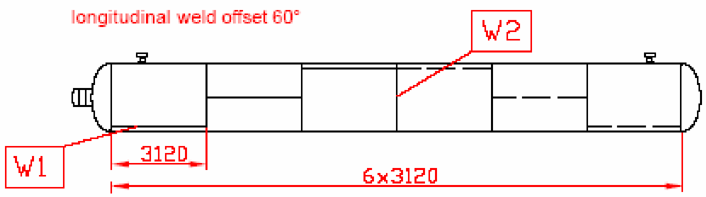
1) flange length 100mm acc. to DIN 28013
2) flange length 90mm acc. to DIN 28013
3) flange length 30mm acc. to DIN 28013
4) flange length 0mm - see UW-13(e)(3)
5) flange length 0mm - see UW-13(e)(3)
6) no code requirement
7) flange length 20mm, skirt machined to cyl. wall thickness - see AD-420.2
8) flange length 0mm (no wall thickness difference)
9) wall thickness based on pressure test acc. to the PED

EX 01

PS = 70 bar
TS = 0°C
Number of operational full pressure cycles N = 500
Corrosion allowance 1mm
Plate tolerance acc. to EN 10029 class A



Shell welds:
longitudinal weld offset 60°



Scale adopted
Comparative Study on PE Standards

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drawn	02.12.03	PAR
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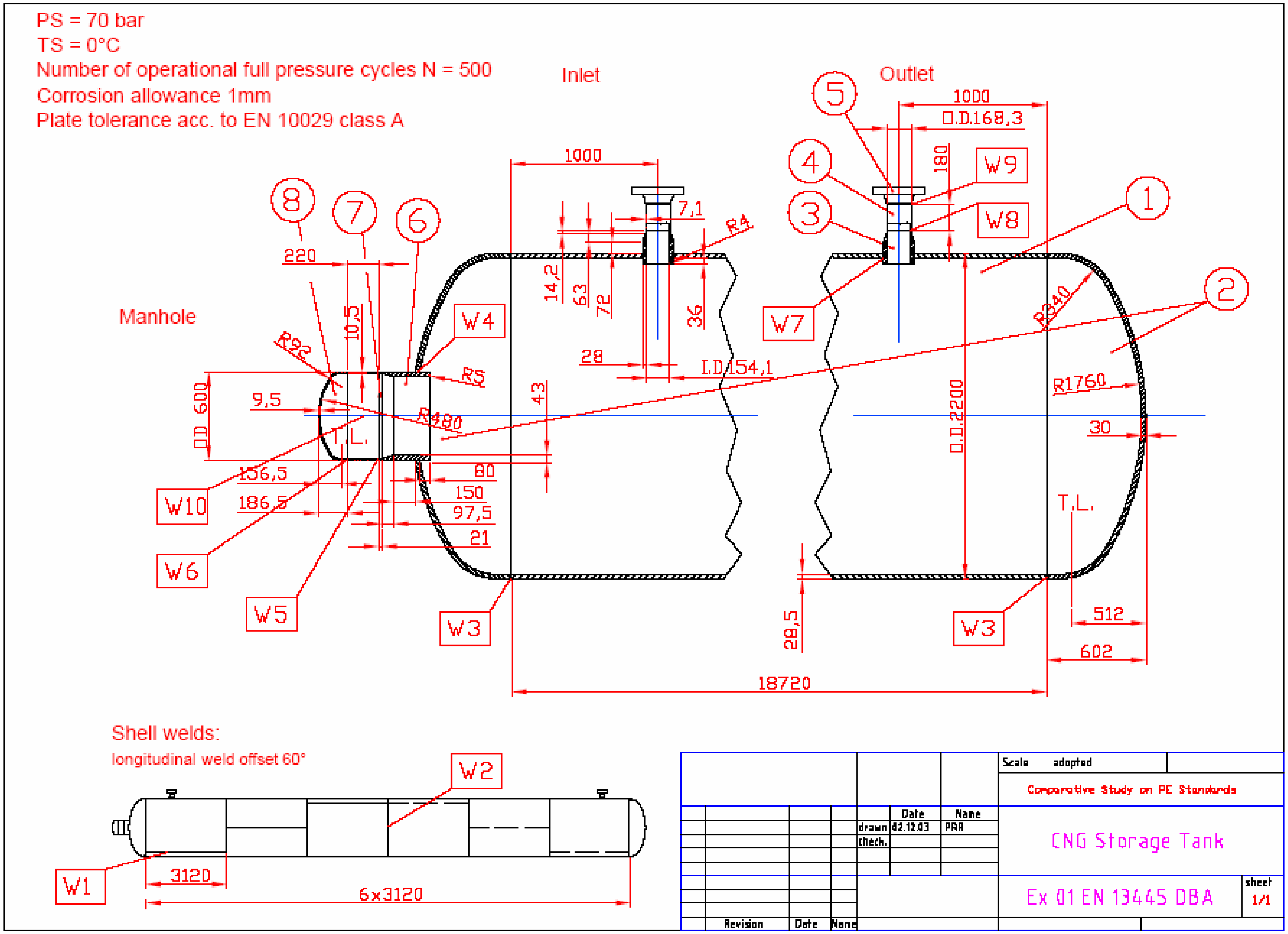
CNG Storage Tank

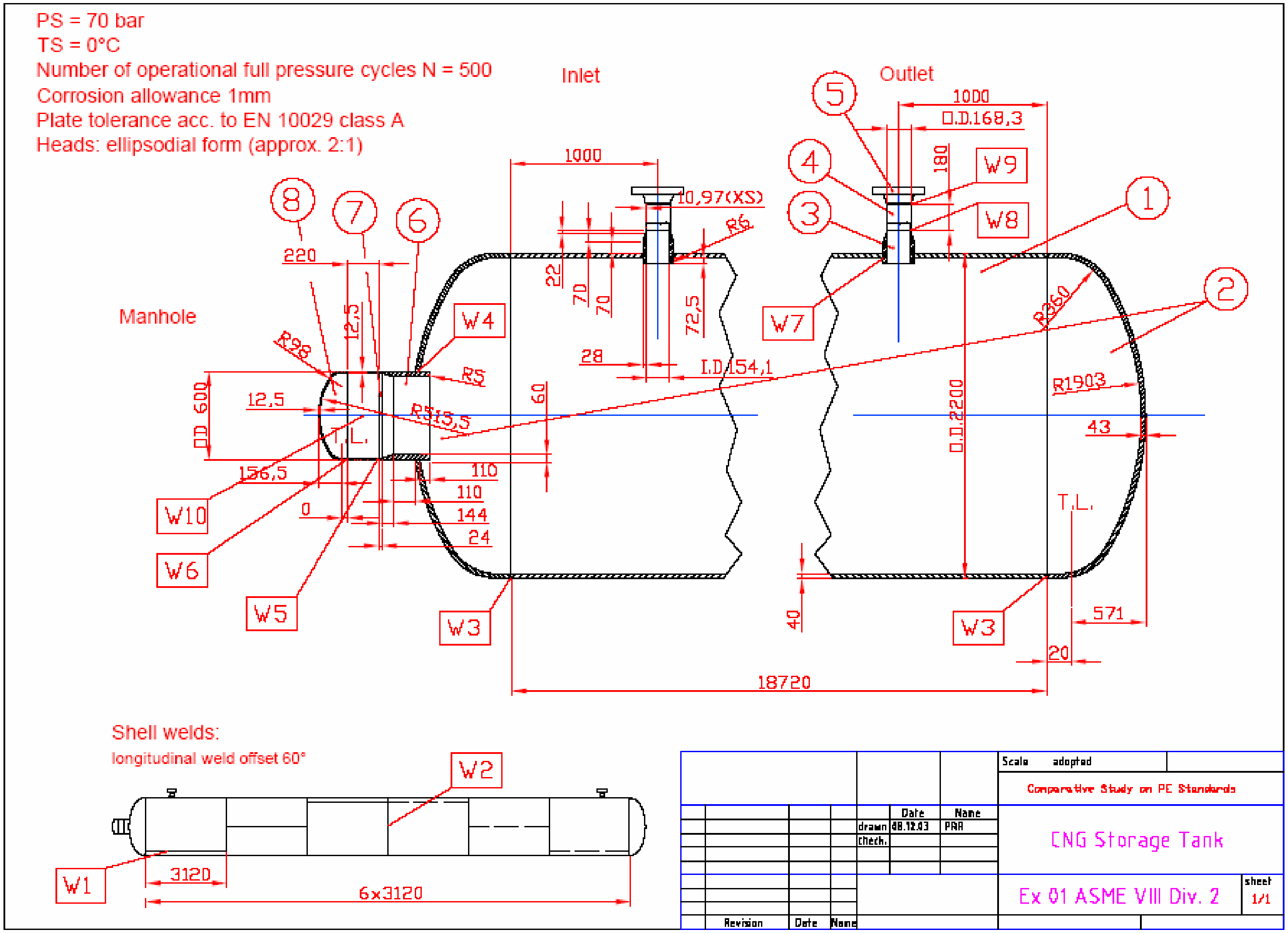
Ex 01 EN 13445 DBF — sheet 1/1

Revision | Date | Name

EX 01

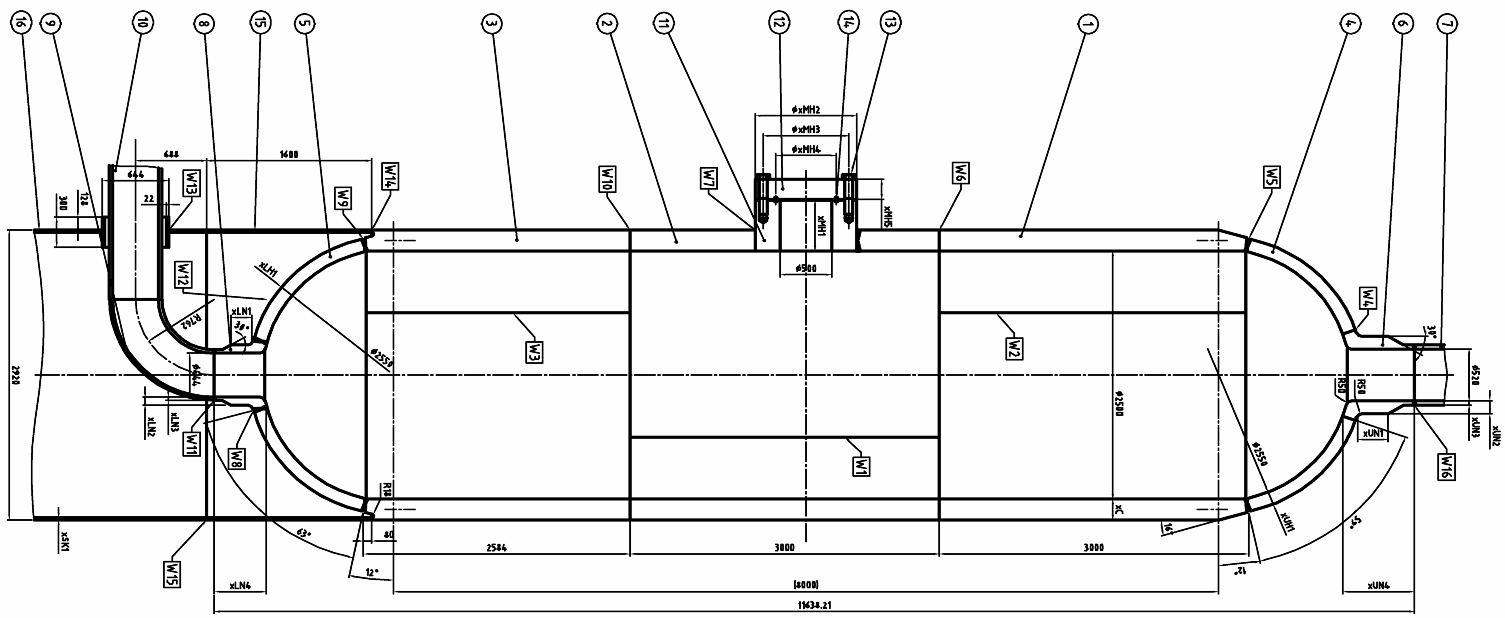

PS = 70 bar
TS = 0°C
Number of operational full pressure cycles N = 500
Corrosion allowance 1mm
Plate tolerance acc. to EN 10029 class A
Inlet
Outlet
Manhole
Shell welds:
longitudinal weld offset 60°
Comparative Study on PE Standards
CNG Storage Tank
Ex 01 EN 13445 DBA
drawn 02.12.03 PRR
sheet 1/1

EX 01


PS = 70 bar
TS = 0°C
Number of operational full pressure cycles N = 500
Corrosion allowance 1mm
Plate tolerance acc. to EN 10029 class A
Heads: ellipsodial form (approx. 2:1)
Inlet
Outlet
Manhole
1000
O.D.168,3
180
10,97(XS)
R6
22
70
70
72,5
28
I.D.154,1
60
220
12,5
R98
R5
R515,5
OD 600
12,5
156,5
T.L.
110
110
144
24
0
D.I.2200
R360
R1903
43
T.L.
571
20
40
18720
W1
W2
W3
W3
W4
W5
W6
W7
W8
W9
W10
Shell welds:
longitudinal weld offset 60°
3120
6x3120
Scale adopted
Comparative Study on PE Standards
Date
Name
drawn 08.12.03 PAR
check.
CNG Storage Tank
Ex 01 ASME VIII Div. 2
sheet 1/1
Revision
Date
Name

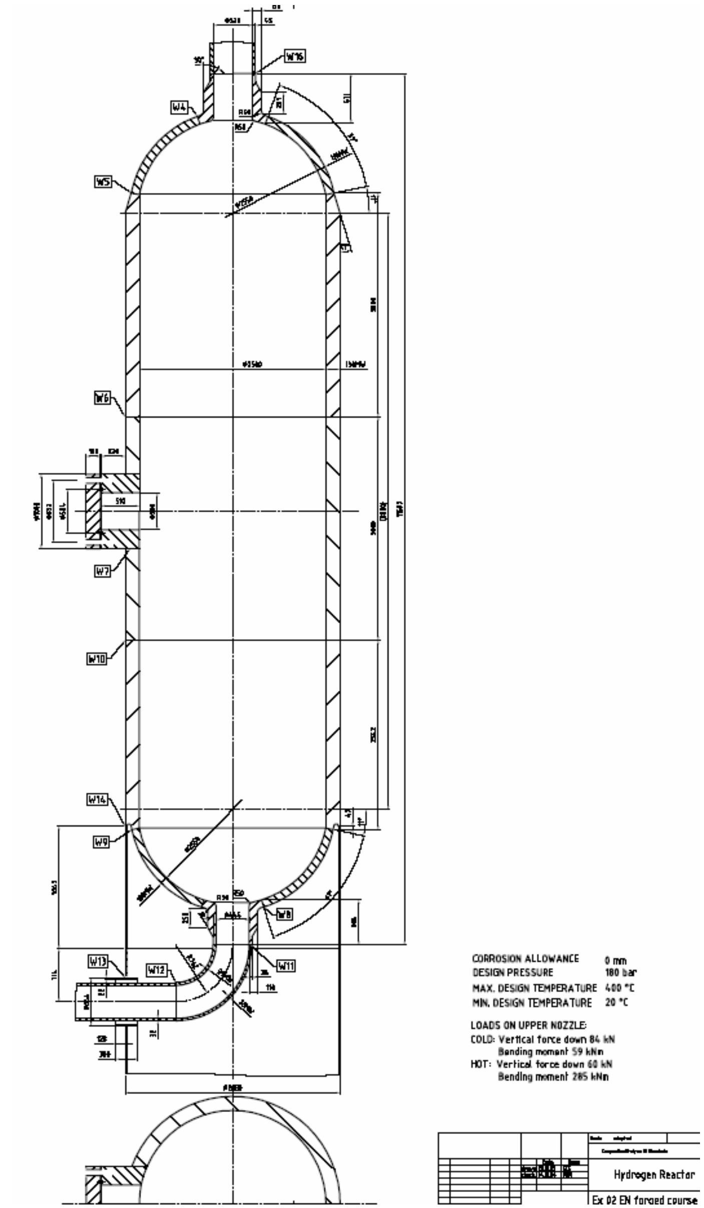
EX 01

Example 2: Hydrogen Reactor / General



Part	EN 13345-3 DBF (forged course)[B]	
	nom thickness / reference	material
main cylindrical shell	190 mm (MW)	11CrMo9-10 EN10222-2
manhole cover	190 mm	11CrMo9-10 EN10222-2
upper end	110 mm (MW)	11CrMo9-10 EN10222-2
lower end	100 mm (MW)	11CrMo9-10 EN10222-2

[B)] DBA does not render reduced wall thicknesses for the upper end



EX 02

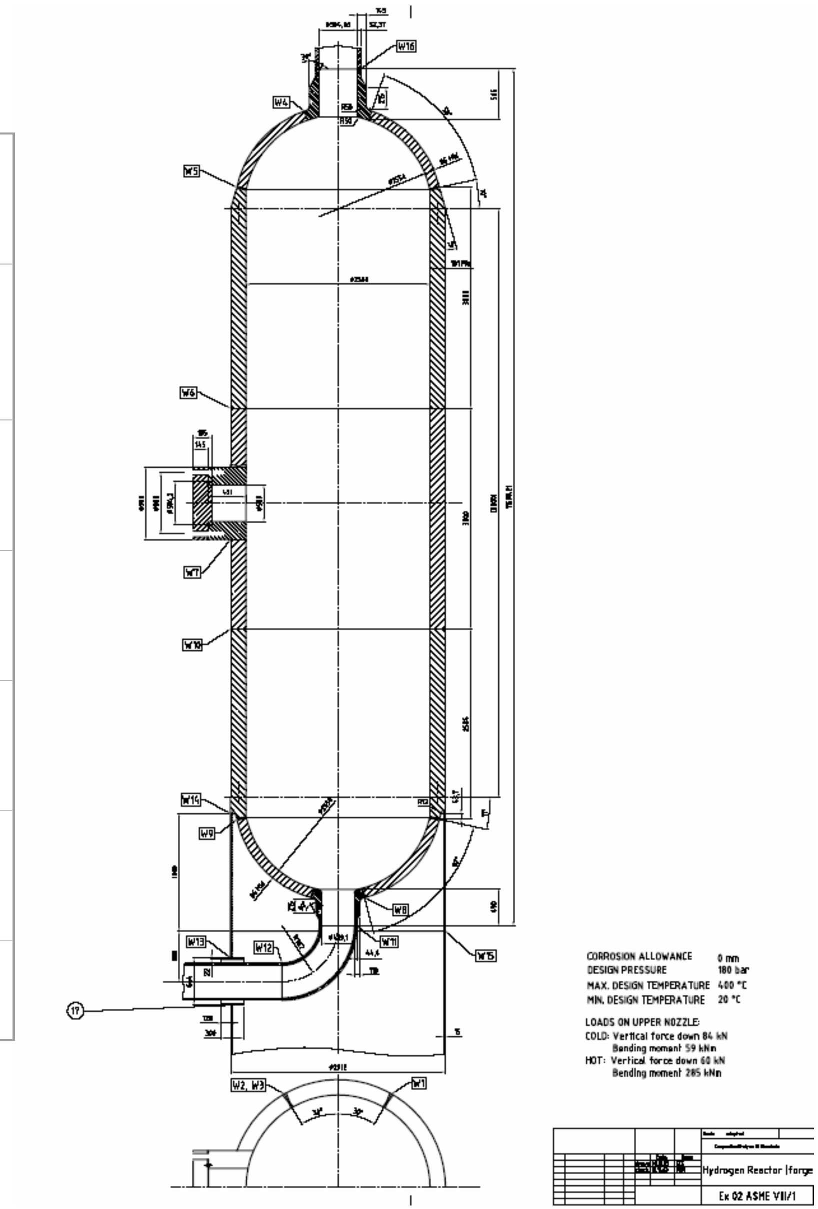
Technical Specification:

Material	10CrMo9 10 (or similar)
Actions	PS= 180 bar Temperature in service TC = 400°C
Operational cycles	100 cycles
Geometry	Diameter: 2500 mm; Cylindrical length: 8000 mm. Hemispherical heads. Nozzles: DN 600 in the upper end, DN 500 in the lower end Manhole, internal diameter 500 in the cylindrical shell
Other requirements	External load from piping Forces and moments at the upper nozzle: Load case 1: Cold: Vertical force down: 84 kN Bending moment: 59 kNm Load case 2: Hot: Vertical force down: 60 kN Bending moment: 285 kNm (same axis as in load case 1)
Design approaches	DBF according to EN13445, ASME Section VIII Division 1 and ASME Section VIII Division 2; DBA according to EN13445 Annex B and ASME Section VIII Division 2 for upper nozzle.

EX 02

Part	ASME VIII/1 (forged [C] course)	
	nom thickness / reference	material
main cylindrical shell	181 mm (MW) (190)[f] (124)[w]	SA 387 Gr. 22 Cl.2; SA 336 *F22 Cl. 3*
manhole cover	185 mm (center) 145 mm (periphery) (190)[f] (155)[w]	SA 387 Gr. 22 Cl. 2
upper end	86 mm (MW) (110)[f] (100)[w]	SA 387 Gr. 22 Cl. 2: SA 336 *F22 Cl. 3*
lower end	86 mm (MW) (100)[f] (75)[w]	SA 387 Gr. 22 Cl. 2: SA 336 *F22 Cl. 3*

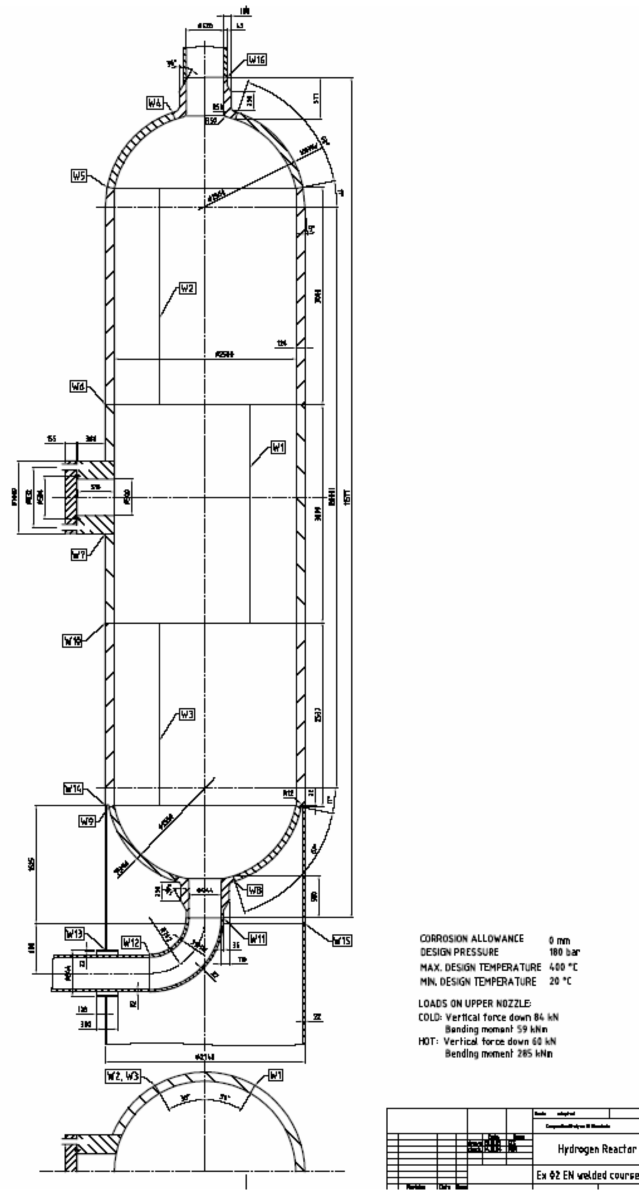
[B] DBA does not render reduced wall thicknesses for the upper end



EX 02

Part	EN 13345-3 DBF (welded course)[B) 2)]	
	nom thickness / reference	material
main cylindrical shell	124 mm (MW) (190)[f)]	12CrMo9-10 EN10028-2
manhole cover	155 mm (190)[f)]	12CrMo9-10 EN10028-2
upper end	100 mm (MW) (110)[f)]	12CrMo9-10 EN10028-2
lower end	75 mm (MW) (100)[f)]	12CrMo9-10 EN10028-2

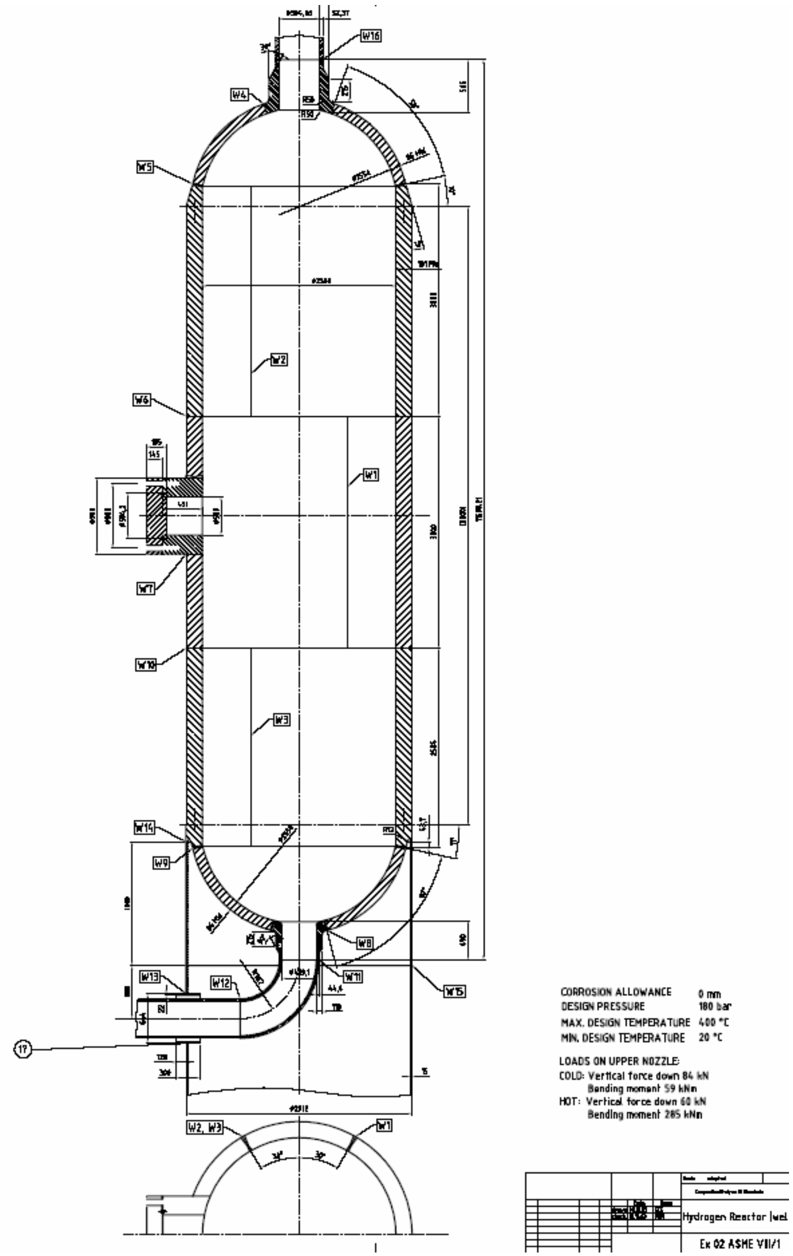
[B)] DBA does not render reduced wall thicknesses for the upper end



EX 02

Part	ASME VIII/1 (welded [C] course)	
	nom thickness / reference	material
main cylindrical shell	181 mm (MW) (190)[f] (124)[w]	SA 387 Gr. 22 Cl.2; SA 336 *F22 Cl. 3*
manhole cover	185 mm (center) 145 mm (periphery) (190)[f] (155)[w]	SA 387 Gr. 22 Cl. 2
upper end	86 mm (MW) (110)[f] (100)[w]	SA 387 Gr. 22 Cl. 2: SA 336 *F22 Cl. 3*
lower end	86 mm (MW) (100)[f] (75)[w]	SA 387 Gr. 22 Cl. 2: SA 336 *F22 Cl. 3*

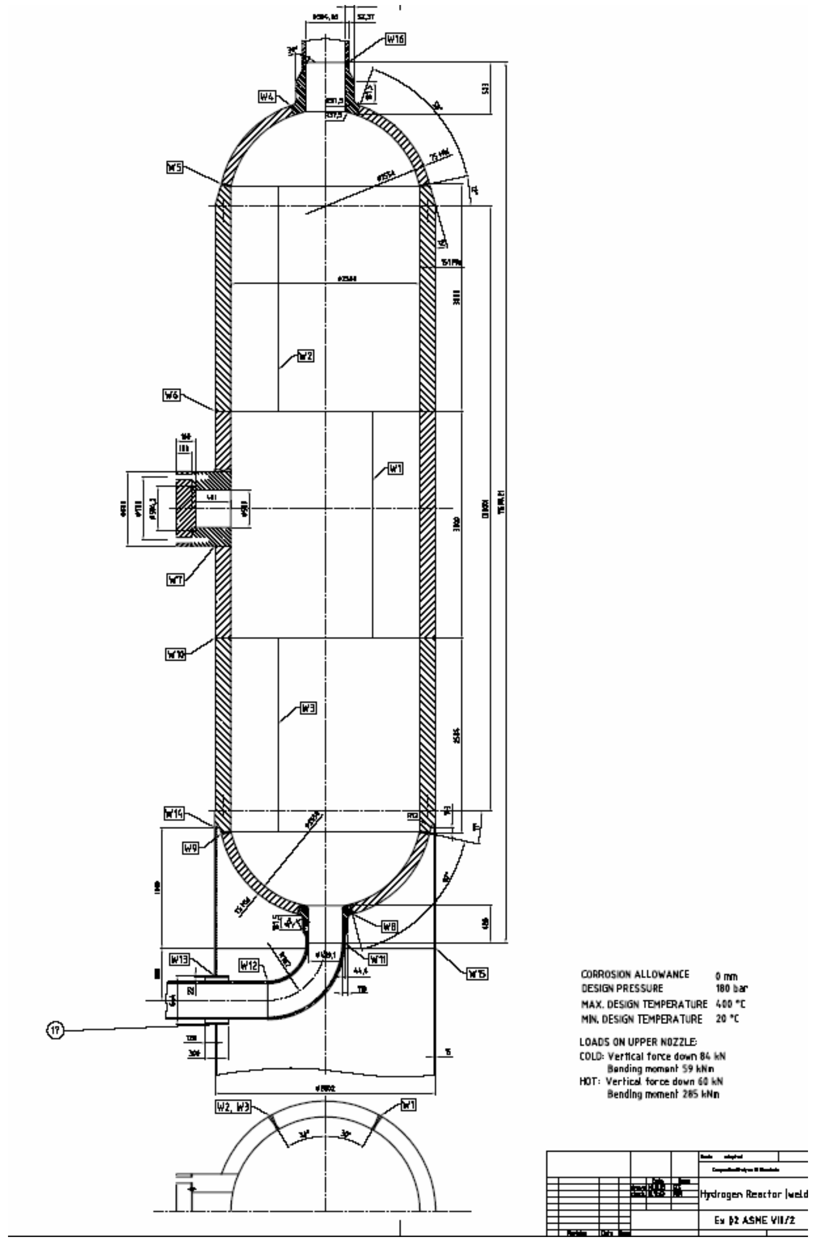
[B] DBA does not render reduced wall thicknesses for the upper end



EX 02

Part	ASME VIII/2 A) (welded B) / forged C) course)	
	nom thickness / reference	material
main cylindrical shell	151 mm (MW) (190)f) (124)w)	SA 387 Gr. 22 Cl.2; SA 336 *F22 Cl. 3*
manhole cover	160 mm (center) 108 mm (periphery) (190)f) (155)w)	SA 387 Gr. 22 Cl. 2
upper end	75 mm (MW) (110)f) (100)w)	SA 387 Gr. 22 Cl. 2: SA 336 *F22 Cl. 3*
lower end	75 mm (MW) (100)f) (75)w)	SA 387 Gr. 22 Cl. 2: SA 336 *F22 Cl. 3*

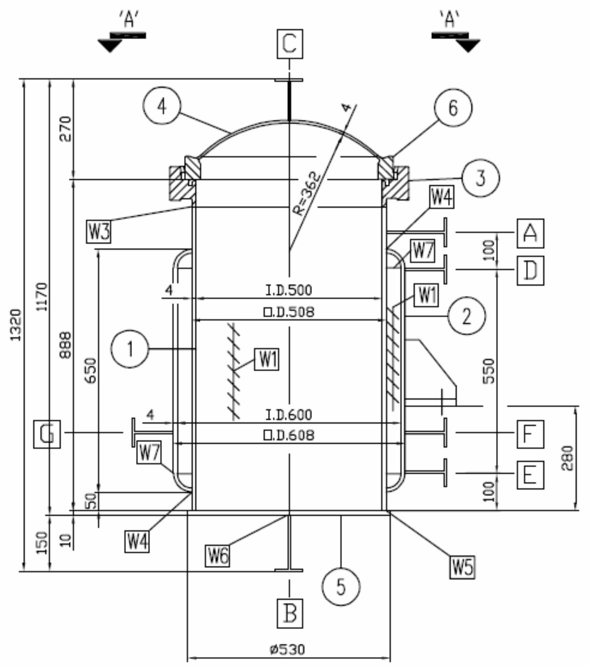
B) DBA does not render reduced wall thicknesses for the upper end

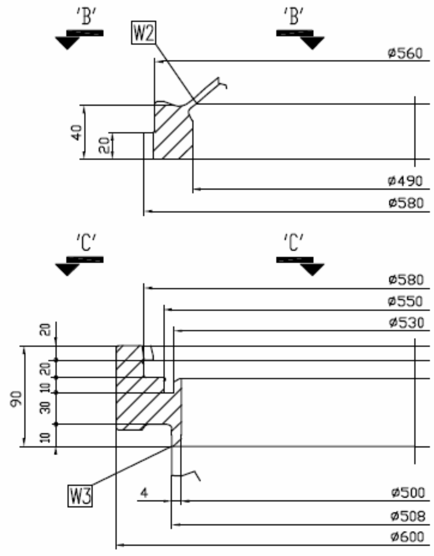


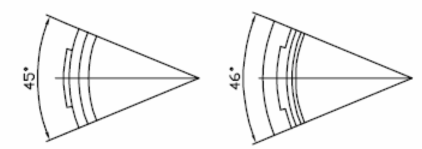
EX 02

A comparison of the materials used for the main parts and the corresponding allowable stresses f at 400°C is given in the following table:

Material / Standard	Tensile strength R_m at 20°C [MPa]	Yield strength $R_{0,2}$ at 400°C [MPa]	f acc. to EN 13445 DBF at 400°C [MPa]	f used for ASME VIII Div. 1 at 400°C [MPa]	f used for ASME VIII Div. 2 at 400°C [MPa]
11CrMo9-10 / EN 10222-2 (forged c.)	520	195	$R_{0,2}$/1.5 = 130 MPa	-	-
12CrMo9-10 / EN 10028-2 (welded c.)	540	287	$R_{0,2}$/1.5 = 191.3 MPa	-	-
SA 387 Gr.22 Cl.2 (welded c.)	517,1	241,3	-	acc. to ASME II PART D Table 1A 135.8 MPa	acc. to ASME II PART D Table 2A 158.4 MPa
SA 336 Gr.22 Cl. 3 (forged c.)	517,1	241,3	-	acc. to ASME II PART D Table 1A 135.8 MPa	acc. to ASME II PART D Table 2A 158.4 MPa



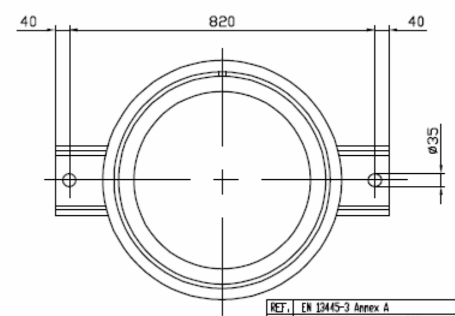




VIEW 'B-B'

VIEW 'C-C'

EXCHANGER WEIGHTS	
EMPTY (Kg.)	172
——— (Kg.)	--
——— (Kg.)	--
MATERIALS	
PLATES - shell, jacket, heads	X5CrNi18-10 EN 10028-7
FORGINGS	X5CrNi18-10 EN 10222-5
PIPES	X5CrNi18-10 EN 10216-5
-	--
-	--
BOLTINGS	X5CrNi18-10 EN 10269



VIEW 'A-A'

DESIGN DATA		SHELL	JACKET
DESIGN PRESS.	bar	2.7/-1	4
DESIGN TEMPERAT.	°C	150	20
TEST PRESS.	bar	4.51	7.15
CORROSION ALLOW.	mm	0	0
INSULATION THK.	mm	0	0
JOINT EFFICIENCY		0.85	0.85
X-RAY		SPOT	SPOT

NOTES:

1)- EN 13445
2)- Flanges according to EN 1092-1
3)- tolerances : for plates acc. to EN 10029 class C- for heads MW
4)- total number is 10
5)- 33500 cycles

NOZZLE SCHEDULE

	REF.	No.	DN	THk.	PN	PAD	SERVICE
shell	A	1	50	4	PN 6	0 x 0	inlet
shell	B	1	50	4	PN 6	0 x 0	outlet
	C	1	25	3,2	PN 6	0 x 0	vent
jacket	D	1	50	4	PN 6	0 x 0	inlet
jacket	E	1	25	3.2	PN 6	0 x 0	outlet
jacket	F	1	50	4	PN 6	0 x 0	sighthole
	G	1	100	4	PN 6	0 x 0	manhole

REF.	EN 13445-3 Annex A	EN 13445-5 tab. 6.6.2.1
W1	tab A1 case M1	1
W2	tab A2 case C1	5
W3	tab A7 case F1	3a
W4	-	-
W5	tab A3 case E6	9
W6	tab A2 case C1	16
W7	tab A2 case C10	2a

REV.	DESCRIPTION	DRAWN	CHECKED	APPROV.
△				
△				
△				
A	ISSUED FOR QUOTATION	S.A		

CLIENT & LOCATION:

PLANT:

UNIT:

REQUISITION N°:

SERVICE:

Comparative Study on PE Standards	jacketed autoclave	
EX3 / EN 13445	DATE: 22/01/2004	REV.: A
N° REQ.D: 10	DWG. N°:	

EX 03

Material	X5Cr Ni18-10 (or similar)
Actions	PS = 2.5 bar Temperature in service TC = Steam saturation temperature (~ 140°C) Temperature/Pressure cycle: Sequence of pressure/temperature combinations to be considered in the fatigue check: Step 1: TO1 = TO2 = 20°C, PO1 = PO2 = 0 bar Step 2: TO1 = 20°C, PO1 = 0 bar TO2 = 140°C, PO2 acc. to steam saturation pressure Step 3: TO1 = TO2 = 140°C, PO1 = PO2 acc. to steam saturation pressure Step 4: TO1 = 140°C, PO1 acc. to steam saturation pressure TO2 = 20°C, PO2 = 4 bar (air) Step 5 = Step 1. TO1, PO1 refer to operating temperature and pressure in the inner chamber, TO2, PO2 refer to temperature and pressure in the outer chamber (jacket) Outer chamber and lower end ideally insulated.
Operational cycles	Allowable number to be determined.
Geometry	Cylindrical Diameter: 500 mm; Cylindrical length: 800 mm Bayonet – type closure with domed end Flat Lower end Nozzles : Jacket: In DN50; Out DN10 Body: In DN50; Out DN50
Design approaches	DBF according to EN13445 and ASME Section VIII Div. 1.
Other requirements	Fatigue analysis mandatory, NDT as required for serial production. In view of the economic evaluation, a batch of 10 pieces shall be considered

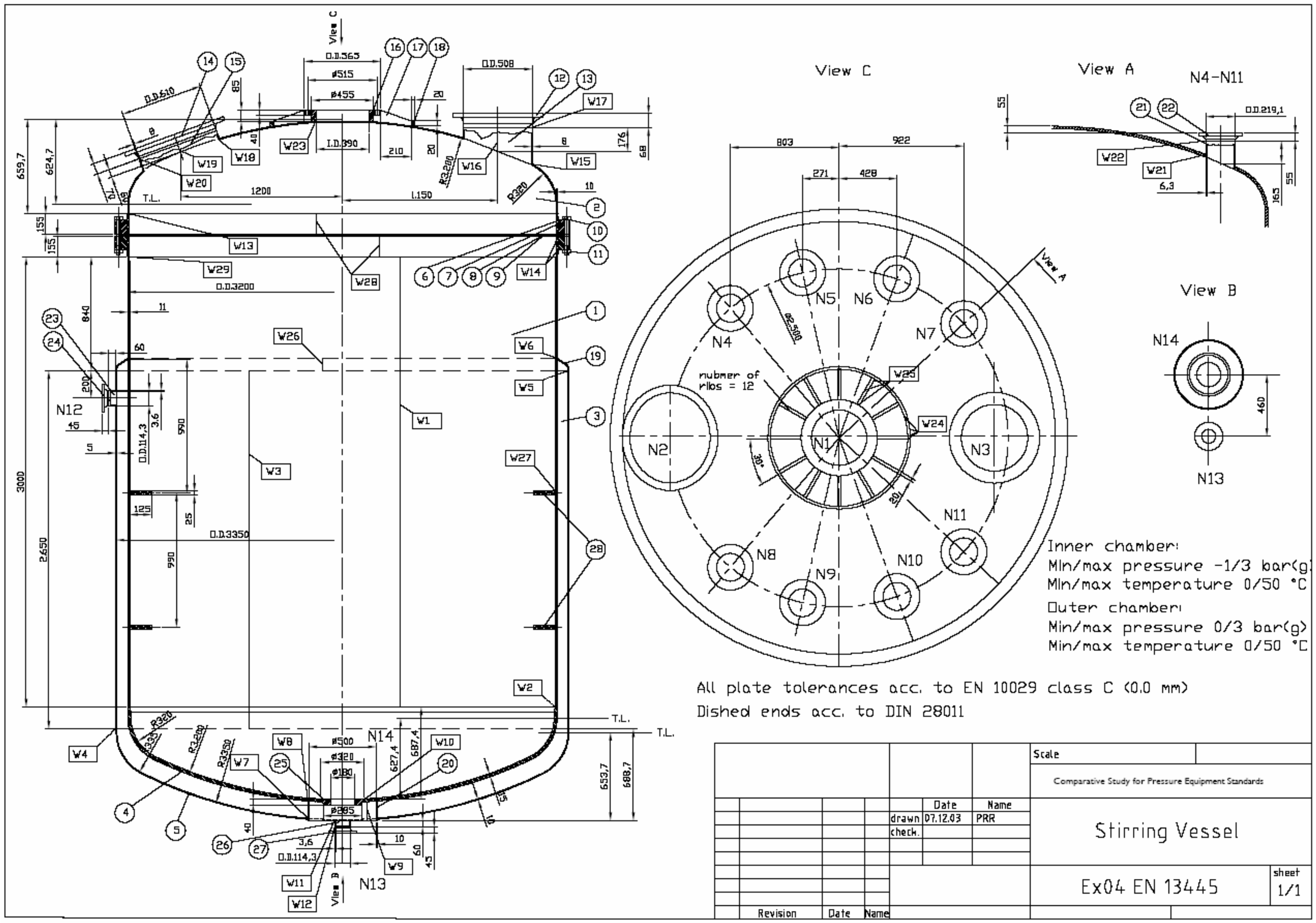
EX 03

Comparision of Results: Comp. Study EX3 (Jacketed Autoclave)

Part No.	Part	EN 13345-3 DBF			ASME VIII/1			+ PED
		nom. thickness / reference	material	note	nom. thickness / reference	material	note	nom. thickness / reference[1)]
1	Shell	4 mm	X5CrNi18-10 EN 10028-7		5 mm	SA-240 TP304		5 mm
2	Jacket	4 mm	X5CrNi18-10 EN 10028-7		4 mm	SA-240 TP304		4 mm
3	Flange (bayonet closure)[3)]	42.88 mm[2)]	X5CrNi18-10 EN 10222-5		42.88 mm[2)]	SA-182 F304 L.S		42.88 mm[2)]
4	Cover	4 mm	X5CrNi18-10 EN 10028-7		4 mm	SA-240 TP304		4 mm
5	Flat end	10 mm	X5CrNi18-10 EN 10028-7		14 mm	SA-240 TP304		15 mm
6	Floating flange	40 mm	X5CrNi18-10 EN 10222-5		40 mm	SA-182 F304 L.S		40 mm

[1)] based upon the test pressure required by the PED
[2)] Equivalent thickness
[3)] In a formal ASME approach the design is not allowed - no specific formulae are given

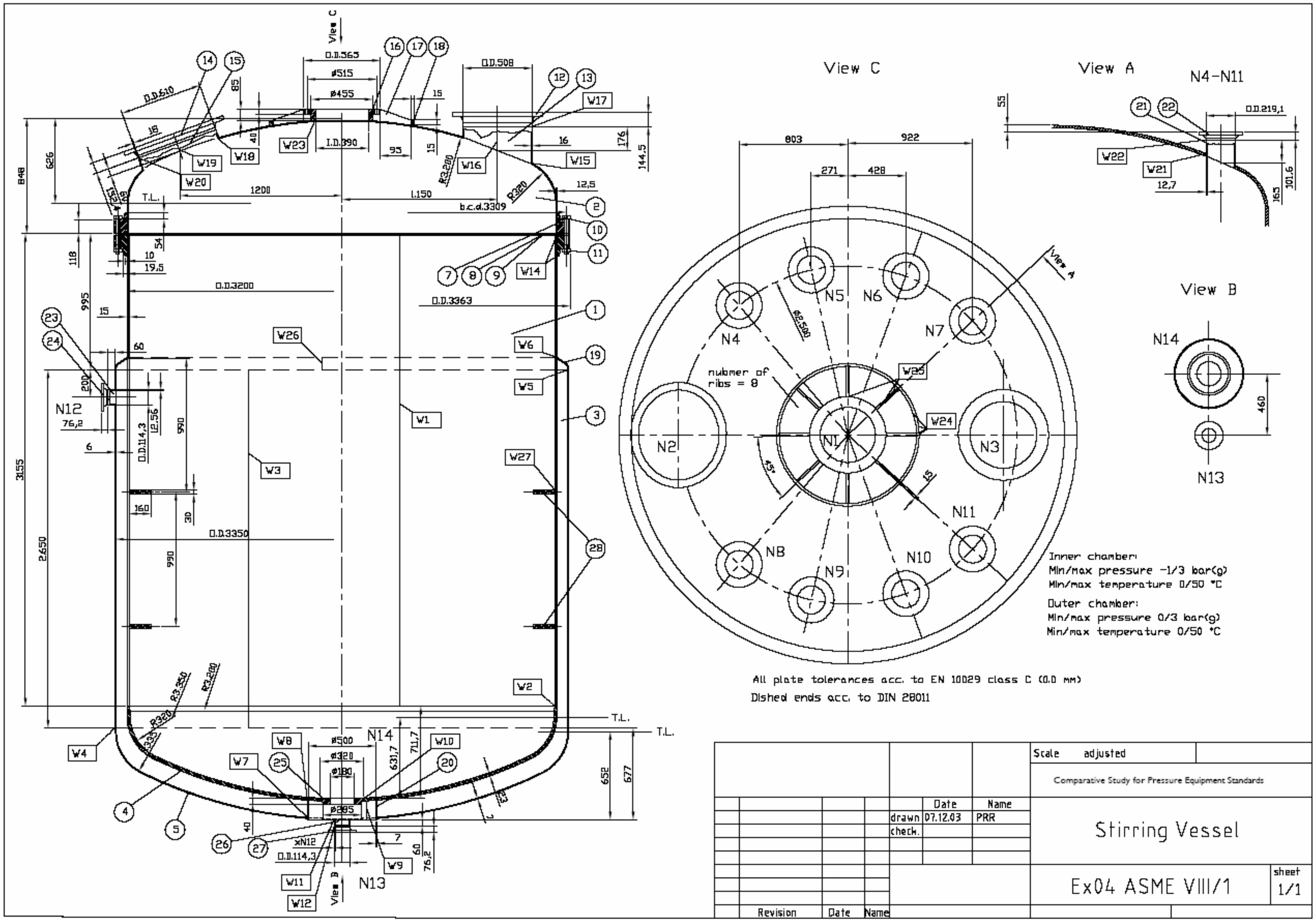
Notes:
Tolerances : for plates acc. to EN 10029 class C- for heads MW
Fatigue analysis according to EN 13445-3 clause 18 : 33576 cycles allowed
Fatigue analysis according to ASME VIII Div.2 App. 5 : >10^6 cycles allowed


View C
View A
N4-N11
View B
N14
N13
N12
Inner chamber:
Min/max pressure -1/3 bar(g)
Min/max temperature 0/50 °C
Outer chamber:
Min/max pressure 0/3 bar(g)
Min/max temperature 0/50 °C
All plate tolerances acc. to EN 10029 class C (0.0 mm)
Dished ends acc. to DIN 28011
Scale
Comparative Study for Pressure Equipment Standards
Date
Name
drawn 07.12.03 PRR
check.
Stirring Vessel
Ex04 EN 13445
sheet
1/1
Revision
Date
Name

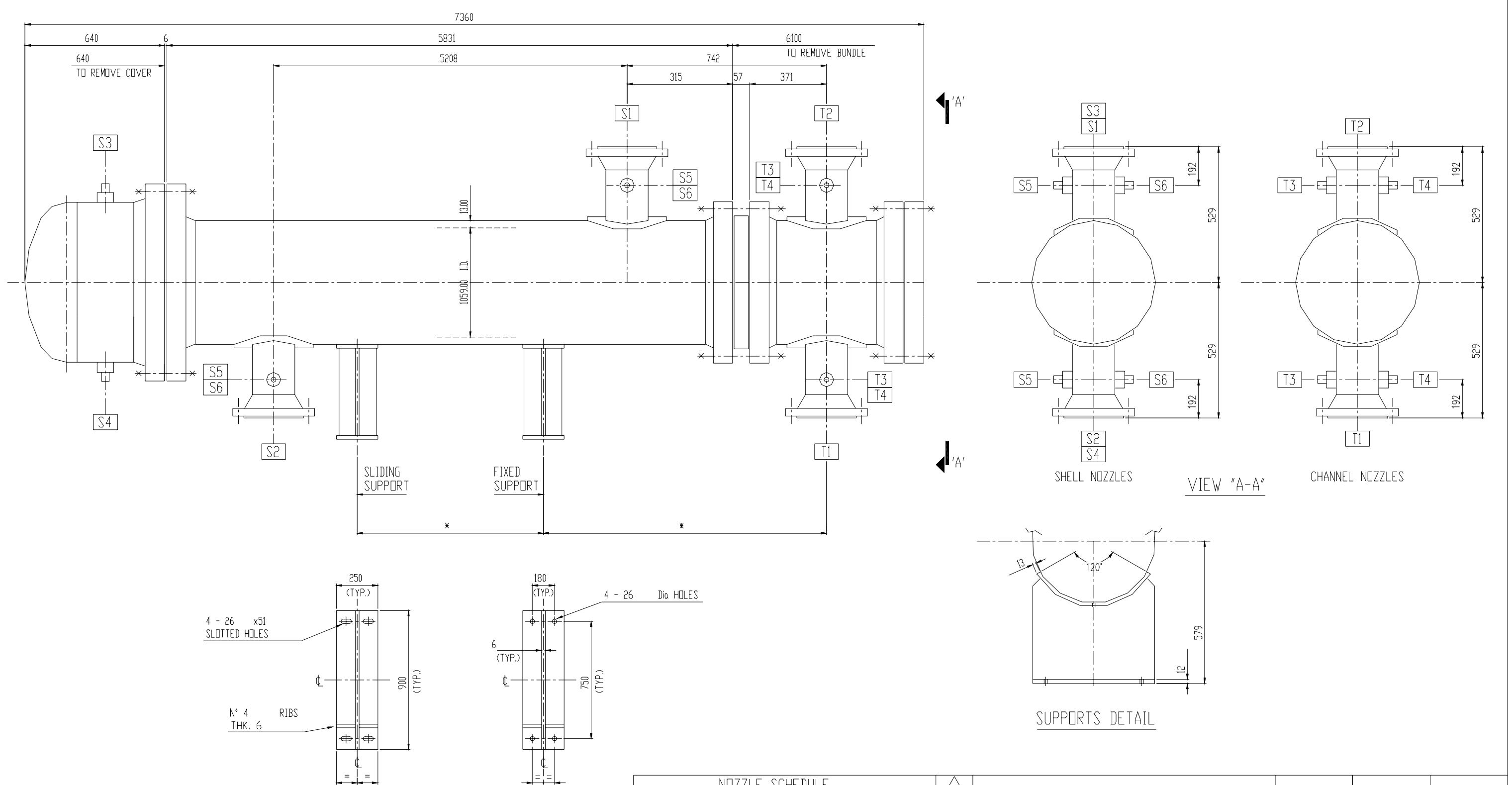
EX 04

Vessel type	DIN 28136 – A 32000–3200 AM
Material	X6CrNiMoTi 17-12-2
Actions	Pressure PS = -1 / +3,0 bar for the inner chamber Pressure PS = 0 /+3,0 bar for the jacket Temperature TC= 50°C Rotating (n = 1/s) longitudinal bending moment Stirrer forces: Vertical down: Mean: 8.5 kN, Fluctuating: +/- 2.5 kN Shear: Mean: 0 Fluctuating: +/- 1.9 kN Stirrer moments: Bending: Mean: 1.1 MNmm Fluctuating: +/- 4.8 MNmm Torsion: Mean: 2.7 MNmm Fluctuating: +/- 0.8 MNmm
Operational cycles	T = const = TC, Normally the stirrer force and moment loads occur synchronously at p = 1.8 bar . However it is foreseen that these can also occur for an internal pressure of –0,95 bar but on average, for only 1% of the batch time.
Geometry	Nozzle Arrangement : M Mounting flange for stirrer unit: Flange DIN 28137-AN 400 – 1.4571
Details to be investigated	Stirring forces/moments Note: The fluctuating load components rotate about the stirrer axes, and shall be assumed to act in the most unfavourable way. Design for an infinite number of cycles is required.
Design approaches	DBF according to EN13445, ASME Section VIII Division 1 and ASME Section VIII Division 2; For the upper head: DBA according to EN13445 Annex B and ASME Section VIII Division 2
Other requirements	Fatigue analysis mandatory (upper head)

EX 04


View C
View A
N4-N11
View B
N14
N13
N12
N1
N2
N3
N4
N5
N6
N7
N8
N9
N10
N11
nubmer of ribs = 8
Inner chamber:
Min/max pressure -1/3 bar(g)
Min/max temperature 0/50 °C
Outer chamber:
Min/max pressure 0/3 bar(g)
Min/max temperature 0/50 °C
All plate tolerances acc. to EN 10029 class C (0.0 mm)
Dished ends acc. to DIN 28011
T.L.
Scale adjusted
Comparative Study for Pressure Equipment Standards
Date
Name
drawn 07.12.03 PRR
check.
Stirring Vessel
Ex04 ASME VIII/1
sheet 1/1
Revision
Date
Name

EX 04



NOZZLE SCHEDULE

	REF.	No.	SIZE	Thk.	RATING	PAD	SERVICE
SHELL SIDE	S1	1	DN 250	9.27	PN 25	0 x0	INLET
	S2	1	DN 250	9.27	PN 25	0 x0	OUTLET
	S3	1	DN 25	--			VENT
	S4	1	DN 25	--			DRAIN
	S5	2	DN 25	--			THERMOWELL
	S6	2	DN 20	--			PRESSURE
TUBE SIDE	T1	1	DN 250	9.27	PN 40	380 x13	INLET
	T2	1	DN 250	9.27	PN 40	380 x13	OUTLET
	T3	2	DN 25	--			THERMOWELL
	T4	2	DN 20	--			PRESSURE

	SHELL	TUBE
CORROSION ALLOW. mm	3	3

NOTES:

TUBE TO TUBESHEET JOINT: EXPANDED WITH GROOVES

REV.	DESCRIPTION	DRAWN	CHECKED	APPROV.
A	ISSUED FOR QUOTATION	S.A		

CLIENT & LOCATION: Commission

PLANT:

UNIT:

REQUISITION N°:

SERVICE: Floating Head H.E.

ITEM: E001

JOB N°: 0001

DATE: 08/05/2002

REV.: A

N° REQ.D: 1

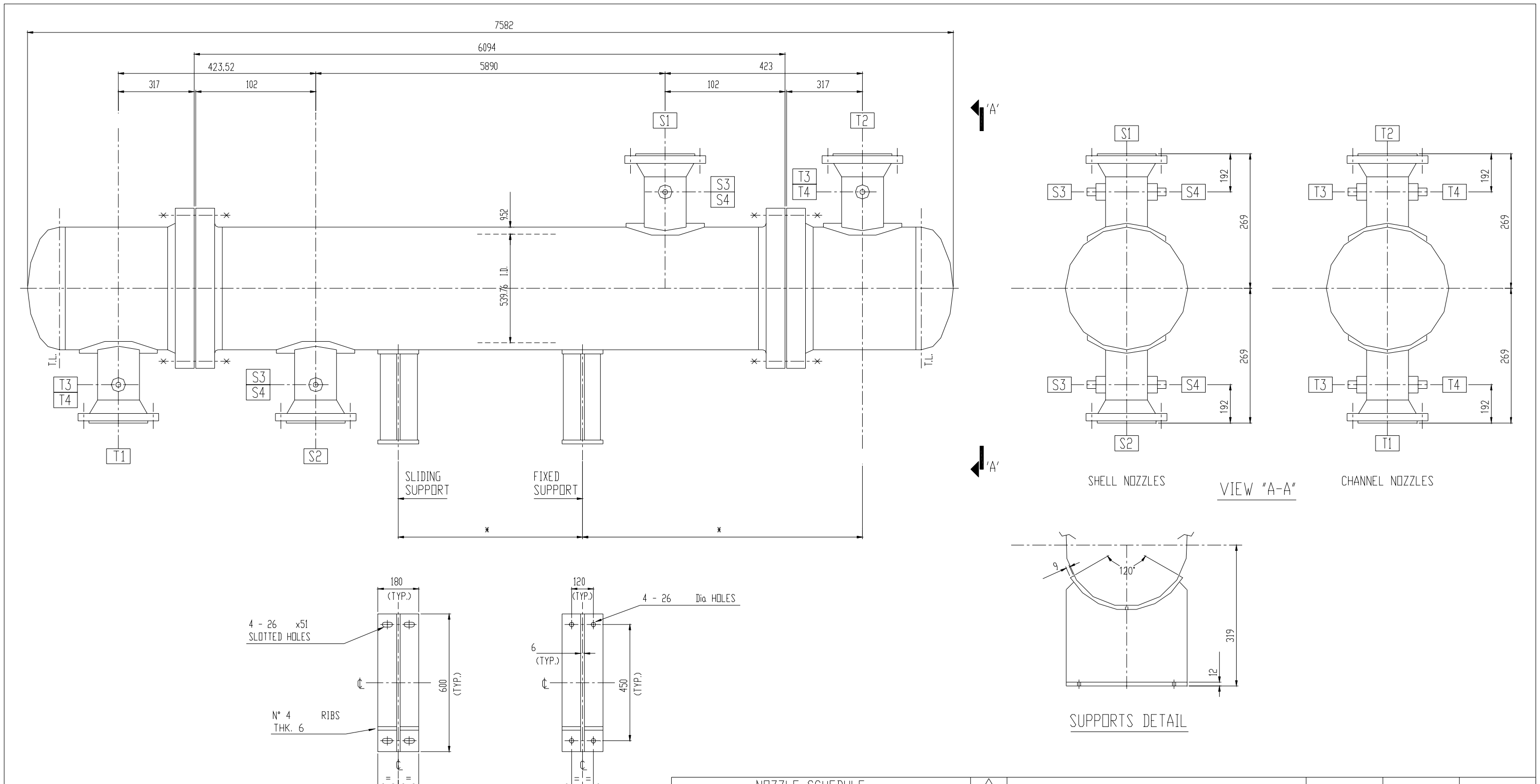
TEMA TYPE: AES

DWG. N°: 0001A

EX 05

Technical Specification:

Material	Carbon steel (standard refinery heat exchanger)
Actions	PS = 10 bar shell side, PS = 20 bar tube side Calculation temperature TC = 200°C on both sides Corrosion allowance: Shell side: 3 mm Tube side: 3 mm
Operational cycles	500
Geometry	According to indicative drawings. The following prescriptions in the drawings must be followed: Inner diameter No and size of heat exchangers tubes Nozzle size, thickness and rating, where given (Pad indicative) Number of baffles
Design approaches	DBF according to EN13445 and ASME Section VIII Division 1.



NOZZLE SCHEDULE							
	REF.	No.	SIZE	Thk.	RATING	PAD	SERVICE
SHELL SIDE	S1	1	DN 150	7.11	PN 25	0 x0	INLET
	S2	1	DN 150	7.11	PN 25	0 x0	OUTLET
	S3	2	DN 25	--			THERMOWELL
	S4	2	DN 20	--			PRESSURE
TUBE SIDE	T1	1	DN 250	9.27	PN 40	353 x9	INLET
	T2	1	DN 250	9.27	PN 40	353 x9	OUTLET
	T3	2	DN 25	--			THERMOWELL
	T4	2	DN 20	--			PRESSURE

		SHELL	TUBE
CORROSION ALLOW.	mm	3	3

NOTES:

TUBE TO TUBESHEET JOINT: EXPANDED WITH GROOVES

REV.	DESCRIPTION	DRAWN	CHECKED	APPROV.
A	ISSUED FOR QUOTATION	S.A		

CLIENT & LOCATION: Commission

PLANT:

UNIT:

REQUISITION N°:

SERVICE: Fixed Tubesheet H.E.

ITEM: E002	JOB N°: 0002	
	DATE: 08/05/2002	REV.: A
N° REQ.D: TEMA TYPE: BEM	DWG. N°: 0002A	

EX 06

Technical Specification:

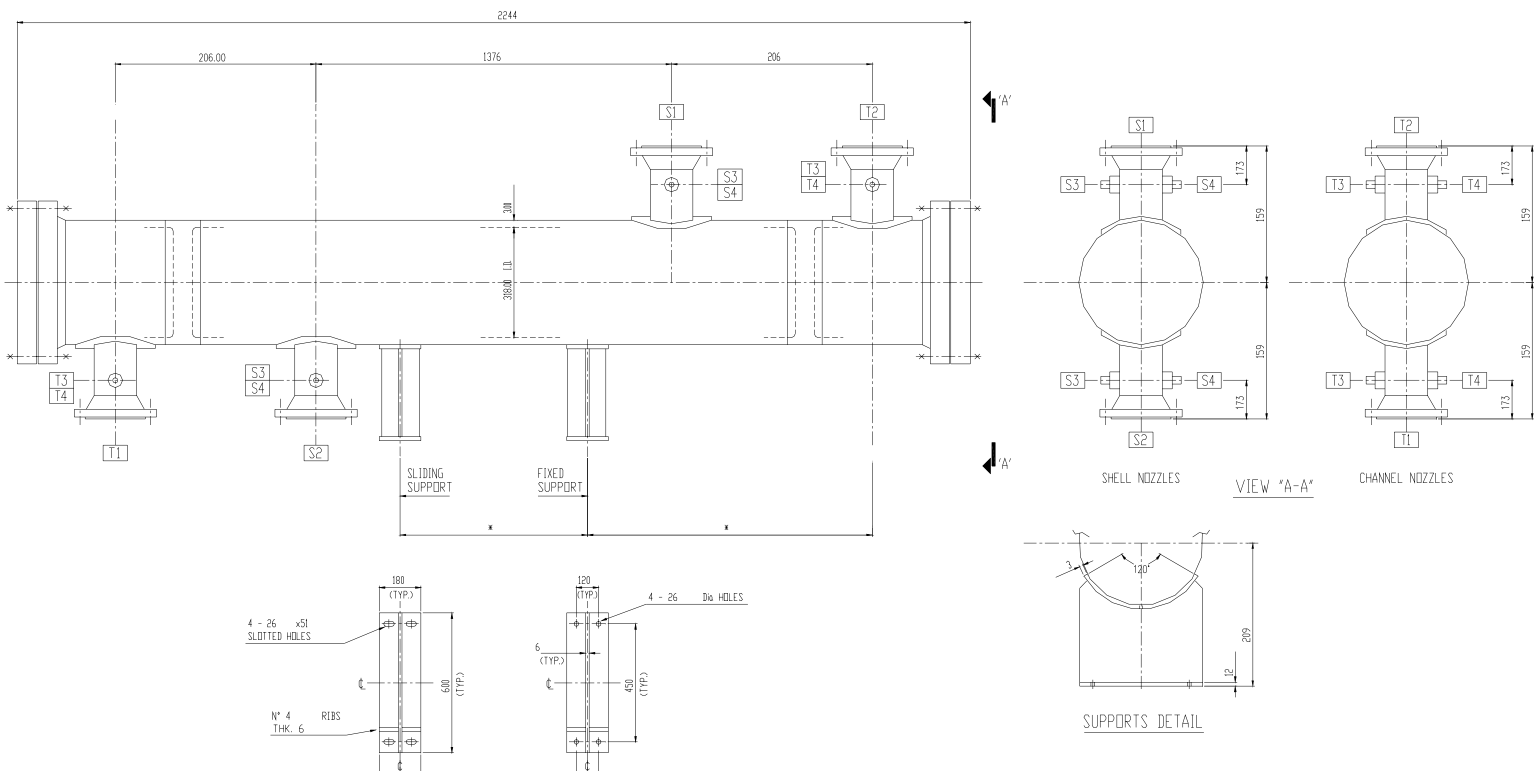
Material	Carbon steel (standard refinery heat exchanger)
Actions	PS = 10 bar shell side, PS = 20 bar tube side Calculation temperature TC = 200°C on both sides Mean metal temperatures: Shell 100°C, Tube 125°C Corrosion allowance: Shell side: 3 mm Tube side: 3 mm
Operational cycles	500
Geometry	According to indicative drawings. The following prescriptions in the drawings must be followed: Inner diameter No and size of heat exchangers tubes Nozzle size, thickness and rating, where given (Pad indicative) Number of baffles
Design approaches	DBF according to EN13445 and ASME Section VIII Division 1.

Comparision of Results: Comp. Study EX6 (BEM Heat Exchanger)

Part No.	Part	EN 13345-3 DBF			ASME VIII/1			+ PED
		nom. thickness / reference	material	note	nom. thickness / reference	material	note	nom. thickness / reference[1)]
1	Flange	49 mm	P305GH EN 10222-2		51 mm	SA-266 Gr. 2		51 mm
2	Shell	10 mm	P295GH EN 10028-2	TEMA req.[2)]	10 mm	SA-516 Gr. 70	TEMA req.[2)]	10 mm
3	Tubesheet	57 mm	P305GH EN 10222-2		103 mm	SA-266 Gr. 2		103 mm
4	Ellipsoidal head	10 mm	P295GH EN 10028-2	TEMA req.[2)]	10 mm	SA-516 Gr. 70	TEMA req.[2)]	10 mm
5	Channel	10 mm	P295GH EN 10028-2	TEMA req.[2)]	10 mm	SA-516 Gr. 70	TEMA req.[2)]	10 mm

[1)] based upon the test pressure required by the PED
[2)] TEMA class R

tolerances : for plates acc. to EN 10029 class C- for heads MW



	SHELL	TUBE
CORROSION ALLOW. mm	0	0

NOTES:

TUBE TO TUBESHEET JOINT: WELDED

NOZZLE SCHEDULE

	REF.	No.	SIZE	Thk.	RATING	PAD		SERVICE
SHELL SIDE	S1	1	DN 150	7.11	PN 16	0	x0	INLET
	S2	1	DN 50	3.91	PN 16	0	x0	OUTLET
	S3	2	DN 25	--				THERMOWELL
	S4	2	DN 20	--				PRESSURE
TUBE SIDE	T1	1	DN 150	7.11	PN 10	0	x0	INLET
	T2	1	DN 150	7.11	PN 10	0	x0	OUTLET
	T3	2	DN 25	--				THERMOWELL
	T4	2	DN 20	--				PRESSURE

REV.	DESCRIPTION	DRAWN	CHECKED	APPROV.
A	ISSUED FOR QUOTATION	S.A		

CLIENT & LOCATION: Commission

PLANT:

UNIT:

REQUISITION N°:

SERVICE: Small SS Heat Exchanger (NEN)

ITEM: E003

JOB N°: 0003

DATE: 08/05/2002 REV.: A

N° REQ.D:

TEMA TYPE: NEN

DWG. N°: 0003B

EX 07

Technical Specification:

Material	X5CrNi18-10 (or similar)
Actions	PS = 6 bar shell side, PS = 3 bar tube side Calculation temperature TC = 180°C shell side, 150°C tube side Mean metal temperatures: Shell 140°C, Tube 115°C Corrosion allowance: Shell side: 0 mm Tube side: 0 mm
Operational cycles	10000
Geometry	According to indicative drawings. The following prescriptions in the drawings must be followed: Inner diameter No and size of heat exchangers tubes Nozzle size, thickness and rating, where given (Pad indicative) Number of baffles
Design approaches	DBF according to EN13445 and ASME Section VIII Division 1.
Other requirements	Fatigue analysis mandatory; in view of the economic evaluation, a batch of 10 pieces shall be considered

EX 07

Comparision of Results: Comp. Study EX7 (Fixed Tube Heat Exchanger)

Part No.	Part	EN 13345-3 DBF			ASME VIII/1			+ PED
		nom. thickness / reference	material	note	nom. thickness / reference	material	note	nom. thickness / reference[1)]
1	Shell	3 mm	X5CrNi18-10 EN 10028-7		3 mm	SA-240 TP304		3 mm
2	Channel	3 mm	X5CrNi18-10 EN 10028-7		3 mm	SA-240 TP304		3 mm
3	Flange	26 mm	X5CrNi18-10 EN 10222-5		28 mm	SA-336 F304 L.S		28 mm
4	Tubesheet	11 mm	X5CrNi18-10 EN 10028-7		10 mm	SA-240 TP304		10 mm
5	Cover	26 mm	X5CrNi18-10 EN 10028-7		28 mm	SA-240 TP304		28 mm

Fatigue analysis not required by EN 13445-3 Annex J.10 and per ASME VIII div. 2 AD-160.2, respectively.

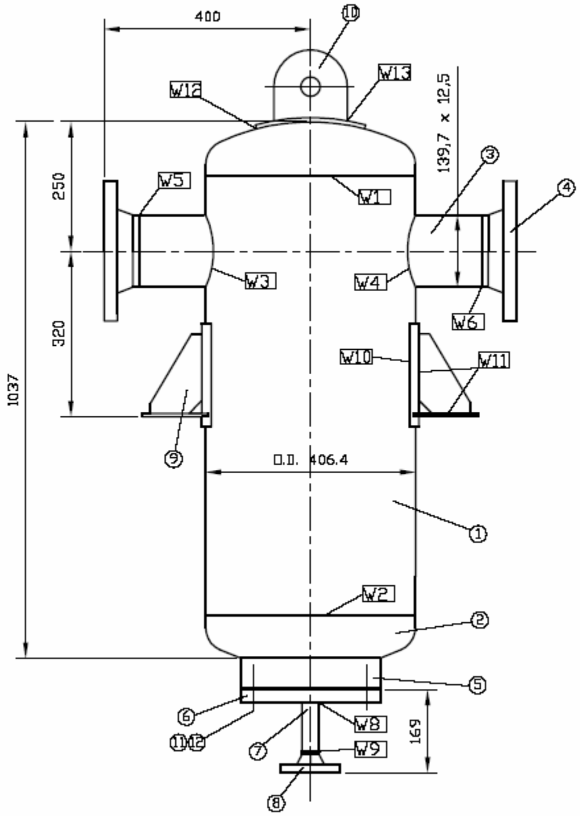
1) based upon the test pressure required by the PED

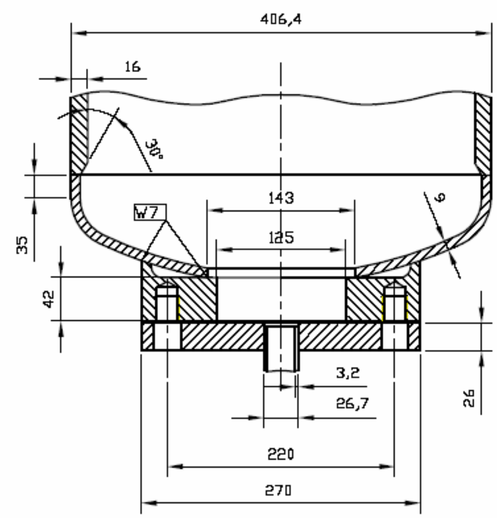
PS = 34 bar TS = 240°C
corrosion allowance 1mm; Number of operational cycles N = 500

Nozzle loadings:
F_A = +/- 7.00 kN (axial force)
F_L = +/- 7.00 kN (axial force in plane of flange)
F_C = +/- 5.25 kN (tangential force in plane of flange)
M_L = +/- 2.27 kNm (longitudinal bending moment)
M_C = +/- 1.75 kNm (circumferential bending moment)
M_T = +/- 2.62 kNm (torsional moment)

Note: the internal non-pressurized parts are not considered

liftung lug: DIN 28086
bracket support: DIN 28083





					Scale 1:8, 1:4	
					Comparative Study on PE Standards	
				Date	Name	Water Separator
			drawn	29.07.03	PRR	
			check.			
						Ex 08 EN 13445 — sheet 1/1
	Revision	Date	Name			

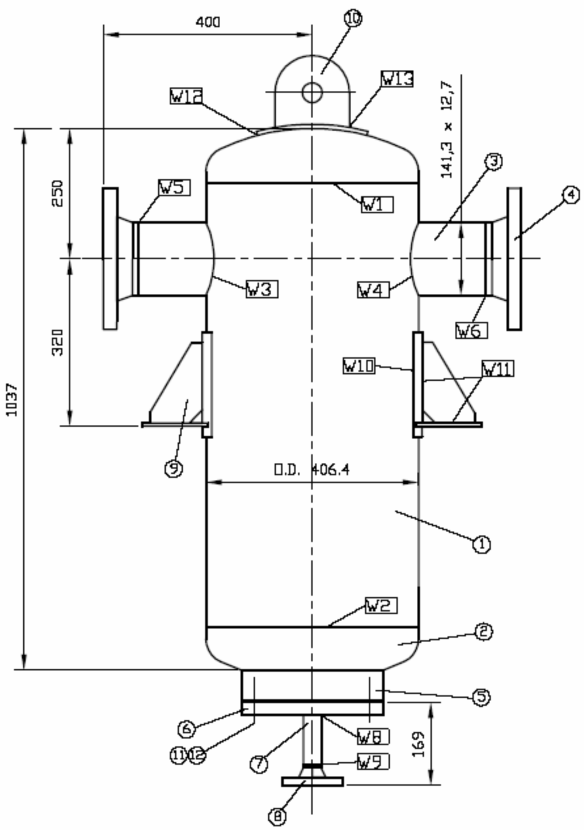
EX 08

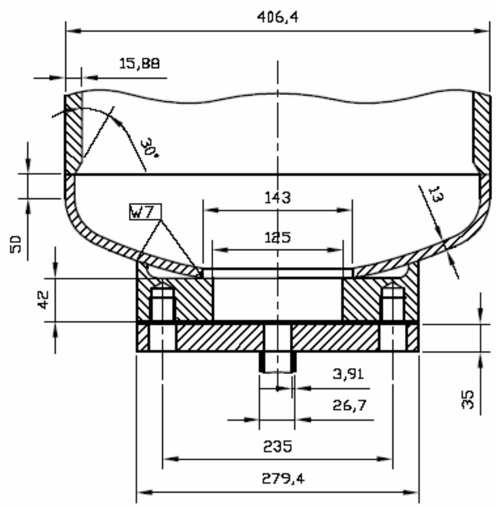
PS = 34 bar TS = 240°C
corrosion allowance 1mm; Number of operational cycles N = 500

Nozzle loadings:
F_A = +/- 7.00 kN (axial force)
F_L = +/- 7.00 kN (axial force in plane of flange)
F_C = +/- 5.25 kN (tangential force in plane of flange)
M_L = +/- 2.27 kNm (longitudinal bending moment)
M_C = +/- 1.75 kNm (circumferential bending moment)
M_T = +/- 2.62 kNm (torsional moment)

Note: the internal non-pressurized parts are not considered

liftung lug: DIN 28086
bracket support: DIN 28083





Scale 1:8, 1:4

Comparative Study on PE Standards

	Date	Name
drawn	09.12.03	PRR
check.		

Water Separator

Ex 08 ASME VIII Div. 1

sheet 1/1

Revision Date Name

EX 08

Technical specification:

Material	Carbon steel
Actions	Pressure PS = 34 bar Temperature TC = 240°C Nozzle loads: F_A = +/- 7.00 kN F_L = +/- 7.00 kN F_C = +/- 5.25 kN M_L = +/- 2.27 kNm M_C = +/- 1.76 kNm M_T = +/- 2.62 kNm
Operational cycles	500
Geometry	Main shell DN 400 Inlet, outlet nozzles DN 125 Dished ends Studded bolt flange DN 125 in the upper dished end Volume approximately 140 l Bracket support according to DIN 28083 Lifting lug according to DIN 28086
Design approaches	DBF according to EN13445 and ASME Section VIII Division 1, including the nozzle loads and the support.
Other requirements	In view of the economic evaluation, a batch of 30 pieces shall be considered

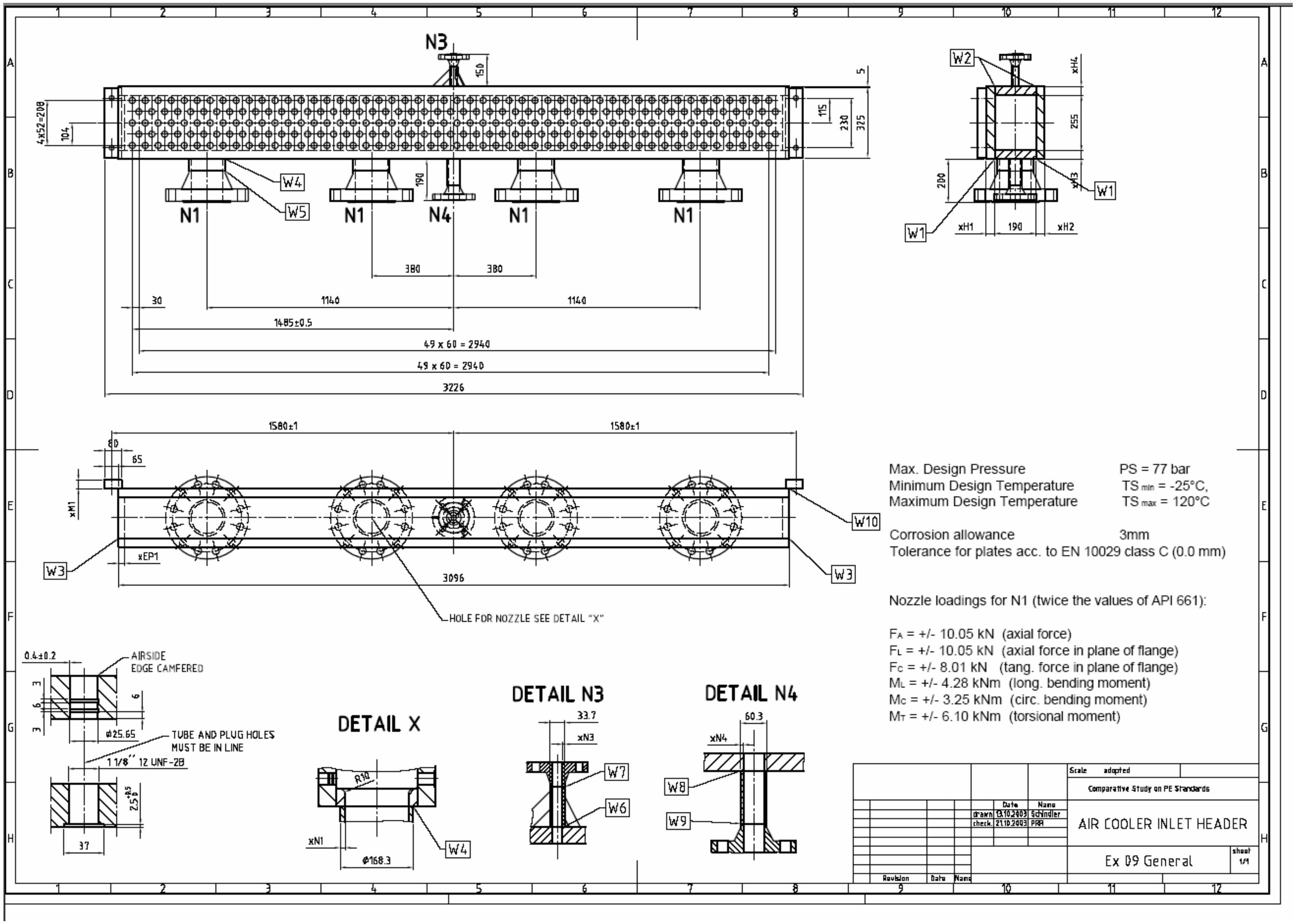
Comparision of Results: Comp. Study EX8 (Water Seperator)

Part No.	Part	EN 13345-3 DBF			ASME VIII/1			+ PED
		nom. thickness / reference	material	note	nom. thickness / reference	material	note	nom. thickness / reference
1	main shell[1)2)]	O.D. 406,4mm x 16mm	P265GH / EN 10216-2		O.D. 406,4mm x 15,88mm	SA-106 Gr. B		O.D. 406,4mm x 15,88mm
2	upper dished head (Klöpperboden-form)	9mm	P265GH / EN 10028-2	DIN 28011	13mm	SA-285 Gr. C	DIN 28011	13mm
2	lower dished head (Klöpperboden-form)	9mm	P265GH / EN 10028-2	DIN 28011	13mm	SA-285 Gr. C	DIN 28011	14mm
3	inlet / outlet nozzle[1)2)]	O.D. 139,7mm x 11mm	P235GH / EN 10216-2		O.D. 141,3mm x 12,7mm	SA-106 Gr. B		O.D. 141,3mm x 12,7mm
4	inlet / outlet nozzle flange	EN 1092-1 PN 40 DN 125	P280GH / EN 10222-2		ASME B16.5 class 300 NPS 5"	SA-105		ASME B16.5 class 300 NPS 5"
5	block flange	DIN 28117 PN 40 form A	P280GH / EN 10222-2		DIN 28117 PN 40 form A	SA-105		DIN 28117 PN 40 form A
6	blind flange	EN 1092-1 PN 40 DN 125	P280GH / EN 10222-2		ASME B16.5 class 300 NPS 5"	SA-105		ASME B16.5 class 300 NPS 5"
7	drain nozzle	O.D. 26,7mm x 3,2 mm	P235GH / EN 10216-2		O.D. 26,7mm x 3,91 mm	SA-106 Gr. B		O.D. 26,7mm x 3,91 mm
8	drain nozzle flange	EN 1092-1 PN 40 DN 25	P280GH / EN 10222-2		ASME B16.5 class 300 NPS 1"	SA-105		ASME B16.5 class 300 NPS 1"
9	bracket support	DIN 28083 size 2	P265GH / EN 10028-2		DIN 28083 size 2	SA-283 Gr. B		DIN 28083 size 2
10	lifting lug	DIN 28086 size 1	P265GH / EN 10028-2 S235JRG2 / EN 10025		DIN 28086 size 1	SA-283 Gr. B		DIN 28086 size 1

1) made from pipe

2) wall thickness required due to nozzle loads

EX 08


N3
N1
N4
W1
W2
W3
W4
W5
W6
W7
W8
W9
W10
1485±0.5
49 x 60 = 2940
3226
1580±1
3096
HOLE FOR NOZZLE SEE DETAIL "X"
AIRSIDE EDGE CAMFERED
TUBE AND PLUG HOLES MUST BE IN LINE
1 1/8" 12 UNF-2B
DETAIL X
DETAIL N3
DETAIL N4
Max. Design Pressure PS = 77 bar
Minimum Design Temperature TS min = -25°C,
Maximum Design Temperature TS max = 120°C
Corrosion allowance 3mm
Tolerance for plates acc. to EN 10029 class C (0.0 mm)
Nozzle loadings for N1 (twice the values of API 661):
FA = +/- 10.05 kN (axial force)
FL = +/- 10.05 kN (axial force in plane of flange)
FC = +/- 8.01 kN (tang. force in plane of flange)
ML = +/- 4.28 kNm (long. bending moment)
MC = +/- 3.25 kNm (circ. bending moment)
MT = +/- 6.10 kNm (torsional moment)
Comparative Study on PE Standards
AIR COOLER INLET HEADER
Ex 09 General

EX 09

Material	Fine-grained carbon steel
Medium	Natural gas
Corrosion allowance	3mm
Actions	Pressure PS = 77 bar Temperature TC_{min} = -25°C, TC_{max} = 120°C Nozzle forces and moments according to API 662 (chapter 4.1.10)
Operational cycles	500
Geometry	Rectangular cross section, according to indicative drawing. Nozzles: N1 / N2: DN 150 N3: DN 50 N4: DN 25 Tubes 25,4x2,4; pitch and pattern according to indicative drawing; tubes expanded into headers.
Design approaches	DBF according to EN13445 and ASME Section VIII Division 1; DBA according to EN13445 Annex B and ASME Section VIII Division 2 for the headers.
Detail to be investigated	Headers

EX 09

Dimension Table: Comp. Study EX9 (Air Cooler)

Dimension	Design Route (Code)				Note
	EN 13345 DBF	EN 13345 DBA	ASME VIII/1	ASME VIII/1 + PED	
xH1	40	34	46	47	
xH2	40	34	46	47	
xH3	40	34	43	43	
xH4	40	34	43	43	
xEP1	28	19	29	30	
xN1	11	11	18.26 (0.791 in)	18.26 (0.791 in)	
xN3	5	5	6.35 (0.25 in)	6.35 (0.25 in)	
xN4	6,3	6,3	7.14 (0.281 in)	7.14 (0.281 in)	
xM1	40	40	40	40	

Example 1 – CNG Storage Tank
Relative costs

Example 1 – CNG Storage Tank:

Differences in the design wall thicknesses (e.g. for the main cylindrical shell 34mm for EN 13445 DBF, 28.5 mm for EN 13445 DBA, 47.5 mm for ASME VIII Div.1, and 40 mm for ASME VIII Div. 2) are mainly caused by the different allowable stresses. This affects also the requirements for post weld heat treatment, which is necessary for the ASME designs (because of the resulting wall thicknesses) but not for the EN designs.

The following table gives an overview of the relative costs quoted by the manufacturers:

Manufacturer	EN 13445 DBF	EN 13445 DBA	ASME VIII Div 1	ASME VIII Div 1 + PED	ASME VIII Div. 2	ASME VIII Div. 2 + PED
A	100,0 %	92,5 %	156,9 %	166,3 %	138,5 %	137,6%
B	100,0 %	99,3 %	116,8 %	125,7 %	108,9 %	109,7 %
C	100,0 %	95,0 %	117,5 %	123,7 %	106,9 %	106,5 %

Example 2 – Hydrogen Reactor
Relative costs

Differences in the design wall thicknesses (e.g. for the main cylindrical shell / forged courses 190 mm for EN 13445 DBF, 181 mm for ASME VIII Div.1, and 151 mm for ASME VIII Div. 2; and for the main cylindrical shell / welded courses 124 mm for EN 13445 DBF, 181 mm for ASME VIII Div.1, and 151 mm for ASME VIII Div. 2) are mainly caused by the different allowable stresses.

The following table gives an overview of the relative costs quoted by the manufacturers:

Manufacturer / course type	EN 13445 DBF	ASME VIII Div 1	ASME VIII Div 1 + PED	ASME VIII Div. 2	ASME VIII Div. 2 + PED
A / forged	100,0 %	93,3 %	93,3 %	86,6 %	86,6%
B / forged	100,0 %	95,9 %	97,5 %	88,2 %	89,4 %
C / forged	100,0 %	93,8 %	93,8 %	79,9 %	79,9 %
A / welded	100,0 %	112,2 %	-	-	-
B / welded	100,0 %	-	-	105,5 %	106,9 %
C / welded	100,0 %	119,6 %	122,8 %	107,5 %	114,2 %

Example 3 – Jacketed Autoclave
Relative costs, Series production (10)

The following table gives an overview of the relative costs quoted by the manufacturers:

Manufacturer	EN 13445 DBF	ASME VIII Div 1	ASME VIII Div 1 + PED
A	100,0 %	109,4 %	109,4 %
B	100,0 %	92,6 %	94,7 %
C	100,0 %	91,7 %	91,7 %

Example 4 – Stirring vessel
Relative costs

The following table gives an overview of the relative costs quoted by the manufacturers:

Manufacturer	EN 13445 DBF	ASME VIII Div 1	ASME VIII Div 1 + PED
A	100,0 %	127,6 %	125,9 %
B	100,0 %	100,6 %	102,3 %
C	100,0 %	103,6 %	103,5 %

Example 5 –AES Heat Exchanger
Relative costs

Manufacturer	EN 13445 DBF	ASME VIII Div 1	ASME VIII Div 1 + PED
A	100,0 %	105,6 %	106,6 %
B	100,0 %	94,1 %	97,8 %
C	100,0 %	101,0 %	101,0 %

Example 6 –BEM Heat Exchanger
Relative costs

Manufacturer	EN 13445 DBF	ASME VIII Div 1	ASME VIII Div 1 + PED
A	100,0 %	106,0 %	107,8 %
B	100,0 %	89,0 %	95,8 %
C	100,0 %	102,0 %	102,0 %

Example 7 – NEN Heat Exchanger
Relative costs

Manufacturer	EN 13445 DBF	ASME VIII Div 1	ASME VIII Div 1 + PED
A	100,0 %	117,4 %	117,4 %
B	100,0 %	99,0 %	96,3 %

Example 8 – Water Separator Relative costs, Series production (30)

The following table gives an overview of the relative costs quoted by the manufacturers:

Manufacturer	EN 13445 DBF	ASME VIII Div 1	ASME VIII Div 1 + PED
A	100,0 %	106,6 %	115,6 %
B	100,0 %	104,6 %	104,6 %

Example 9 – Air Cooler Header Relative costs

The following table gives an overview of the relative costs quoted by the manufacturer:

Manufacturer	EN 13445 DBF	EN 13445 DBA	ASME VIII Div 1	ASME VIII Div 1 + PED
A	100,0 %	88,1	106,7 %	108,2 %

Conclusions 1

- Thickness differences in most cases due to different nominal design stresses (allowable stresses) EN DBA, EN DBF, ASME VIII/2, ASME VIII/1
- Thickness differences result in small material cost differences
- Thickness differences result sometimes in different PWHT requirements, result in possibly decisive cost differences

Conclusions 2

- Thickness differences due to different nominal design stresses mainly in the cryogenic, the “ambient“, and the medium temperature regime (up to appr. 200°C)
- Savings in material cost for EN is partly “compensated“ by increase in DT requirements
- Thickness differences for external pressure action!

Conclusions 3

- Additional cost for ASME designs plus PED conformity assessment (marginally) small
- NDT requirements EN/ASME are similar, related cost differences small
- DT requirements (test coupons) higher for EN designs, related cost differences small

Conclusions 4

- Cost differences between different manufacturers greater than differences for single manufacturer and different standards
- Overly conservative DBF formulae may result in cost disadvantages compared to DBA-DR, larger DBA costs are easily offset

Conclusions 5

- ASME fatigue results are considered unconservative for welded regions, not in conformity with PED requirements
- Problems for ASME designs with standard hydraulic test requirements in accordance with PED (to be applied as a general rule)

$$PT = 1{,}43.PS$$

$$PT = 1{,}25.PS.C(T)$$