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Dacro Job No. :	**12-864**
Customer :	**WorleyParsons**
End User:	**MEG Energy Corp.**
Project Title:	**Christina Lake Regional Project, Phase II B**
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2/27/2012	0	Original Issue	JW
5/10/2012	1	Revised As Noted	JW
7/16/2012	2	Revised Per Customer Comments	JW
7/16/2012	3	Updated Pressure & Test Summaries	JW

JW

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Deficiencies Summary

Deficiencies for Platform #2

Packed bed diameter (2,133 mm) is greater than inner diameter of Top of vessel (609.6 mm)

Pressure Summary

Pressure Summary for Chamber bounded by Right Head and Left Head

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Identifier	P Design (kPa)	T Design (°C)	MAWP (kPa)	MAP (kPa)	MAEP (kPa)	T_e external (°C)	MDMT (°C)	MDMT Exemption		Impact Tested
Left Head	862	150	866.16	1,305.66	160.2	150	-48	Note 1		No
Straight Flange on Left Head	862	150	1,192.12	1,631.66	180.89	150	-48	Note 2		No
Shell #1/#2	862	150	1,192.12	1,631.66	126.22	150	-48	Note 2		No
Shell #2	862	150	1,192.12	1,631.66	126.22	150	-48	Note 2		No
Straight Flange on Right Head	862	150	1,192.12	1,631.66	126.22	150	-48	Note 2		No
Right Head	862	150	866.16	1,305.66	160.2	150	-48	Note 3		No
Stiffening Ring	N/A	N/A	N/A	N/A	103	150	N/A	N/A		No
Platform Support (J53, LC5)	862	150	866.16	N/A	N/A	N/A	N/A	N/A		N/A
Platform Support (J55, LC5)	862	150	866.16	N/A	N/A	N/A	N/A	N/A		N/A
Saddle	862	150	866.16	N/A	N/A	N/A	N/A	N/A		N/A
M1 24" CL150 RFWN (M1)	862	150	866.16	1,305.66	126.22	150	-48	Nozzle	Note 4	No
								Pad	Note 5	No
N1 16" CL150 RFWN (N1)	862	150	866.16	1,305.66	160.19	150	-29	Nozzle	Note 6	No
								Pad	Note 7	No
N10A 2" CL150 RFLWN (N10A/B)	862	150	866.16	1,305.66	160.19	150	-48	Note 8		No
N10B 2" CL150 RFLWN (N10B)	862	150	866.16	1,305.66	126.22	150	-48	Note 8		No
N11 3" CL150 RFWN (N11/N12)	862	150	866.16	1,305.66	126.22	150	-48	Note 9		No
N12 3" CL150 RFWN (N12)	862	150	866.16	1,305.66	126.22	150	-48	Note 9		No
N13 2" CL150 RFWN (N13/N16B)	862	150	866.16	1,305.66	126.21	150	-48	Nozzle	Note 10	No
								Pad	Note 11	No
N14 3" CL150 RFLWN (N14)	862	150	866.16	1,305.66	126.22	150	-48	Note 12		No
N15 2" CL150 RFWN (N15)	862	150	866.16	1,305.66	126.21	150	-48	Note 9		No
N16A 2" CL150 RFWN (N16A)	862	150	866.16	1,305.66	126.21	150	-48	Note 9		No
N16B 2" CL150 RFWN (N16B)	862	150	866.16	1,305.66	126.21	150	-48	Nozzle	Note 10	No
								Pad	Note 11	No
N2 12" CL150 RFWN (N2)	862	150	866.16	1,305.66	126.21	150	-48	Nozzle	Note 13	No
								Pad	Note 14	No
N3 4" CL150 RFLWN (N3)	862	150	866.16	1,305.66	126.21	150	-48	Note 15		No
N4 2" CL150 RFWN (N4)	862	150	866.16	1,305.66	126.22	150	-48	Note 9		No
N5A 3" CL150 RFWN (N5A/N6A)	862	150	866.16	1,305.66	126.21	150	-48	Note 9		No
N5B 3" CL150 RFWN (N5B/N6B)	862	150	866.16	1,305.66	126.21	150	-48	Nozzle	Note 16	No
								Pad	Note 11	No
N6A 3" CL150 RFWN (N6A)	862	150	866.16	1,305.66	126.21	150	-48	Note 9		No
N6B 3" CL150 RFWN (N6B)	862	150	866.16	1,305.66	126.21	150	-48	Nozzle	Note 16	No
								Pad	Note 11	No
N7 10" CL150 RFWN (N7/N8)	862	150	866.16	1,305.66	126.21	150	-48	Nozzle	Note 17	No
								Pad	Note 14	No
N8 10" CL150 RFWN (N8)	862	150	866.16	1,305.66	126.21	150	-48	Nozzle	Note 17	No
								Pad	Note 14	No
N9 3" CL600 RFWN (N9)	862	150	866.16	1,305.66	126.22	150	-48	Note 18		No

Chamber design MDMT is -29 °C
Chamber rated MDMT is -29 °C @ 866.16 kPa

Chamber MAWP hot & corroded is 866.16 kPa @ 150 °C

Chamber MAP cold & new is 1,305.66 kPa @ 5 °C

Chamber MAEP is 103 kPa @ 150 °C
External pressure rating was governed by the vacuum ring Stiffening Ring.

Notes for MDMT Rating:

Note #	Exemption	Details
1.	Straight Flange governs MDMT	
2.	Material impact test exemption temperature from Fig UCS-66M Curve D = -48 °C 17 °C MDMT reduction per UCS-68(c) applies. Fig UCS-66.1M MDMT reduction = 15 °C, (coincident ratio = 0.7316) Rated MDMT of -80°C is limited to -48°C by UCS-66(b)(2)	UCS-66 governing thickness = 12.7 mm
3.	Straight Flange governs MDMT	
4.	Nozzle impact test exemption temperature from Fig UCS-66M Curve D = -48 °C 17 °C MDMT reduction per UCS-68(c) applies. Fig UCS-66.1M MDMT reduction = 15.5 °C, (coincident ratio = 0.7229) Rated MDMT of -80.5°C is limited to -48°C by UCS-66(b)(2)	UCS-66 governing thickness = 12.7 mm.
5.	Pad impact test exemption temperature from Fig UCS-66M Curve D = -48 °C 17 °C MDMT reduction per UCS-68(c) applies. Fig UCS-66.1M MDMT reduction = 15.5 °C, (coincident ratio = 0.7229) Rated MDMT of -80.5°C is limited to -48°C by UCS-66(b)(2)	UCS-66 governing thickness = 12.7 mm.
6.	Nozzle is impact test exempt per UG-20(f)	UCS-66 governing thickness = 12.7 mm.
7.	Pad impact test exemption temperature from Fig UCS-66M Curve D = -48 °C 17 °C MDMT reduction per UCS-68(c) applies. Fig UCS-66.1M MDMT reduction = 6.5 °C, (coincident ratio = 0.8844) Rated MDMT of -71.5°C is limited to -48°C by UCS-66(b)(2)	UCS-66 governing thickness = 12.7 mm.
8.	Nozzle impact test exemption temperature from Fig UCS-66M Curve C = -45 °C 17 °C MDMT reduction per UCS-68(c) applies. Fig UCS-66.1M MDMT reduction = 0.2 °C, (coincident ratio = 0.997) Rated MDMT of -62.2°C is limited to -48°C by UCS-66(b)(2)	UCS-66 governing thickness = 10.1 mm.
9.	Flange rating governs: Flange rated MDMT = -65 °C (UCS-68(c) applies.) Bolts rated MDMT per Fig UCS-66 note (c) = -48 °C	UCS-66(b)(1)(b)
10.	Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.0421).	
11.	Pad impact test exemption temperature from Fig UCS-66M Curve D = -48 °C 17 °C MDMT reduction per UCS-68(c) applies. Fig UCS-66.1M MDMT reduction = 15.1 °C, (coincident ratio = 0.7304) Rated MDMT of -80.1°C is limited to -48°C by UCS-66(b)(2)	UCS-66 governing thickness = 12.7 mm.
12.	Nozzle impact test exemption temperature from Fig UCS-66M Curve C = -37 °C 17 °C MDMT reduction per UCS-68(c) applies. Fig UCS-66.1M MDMT reduction = 15 °C, (coincident ratio = 0.7317) Rated MDMT of -69°C is limited to -48°C by UCS-66(b)(2)	UCS-66 governing thickness = 12.7 mm.
13.	Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.2523).	
14.	Pad impact test exemption temperature from Fig UCS-66M Curve D = -48 °C 17 °C MDMT reduction per UCS-68(c) applies. Fig UCS-66.1M MDMT reduction = 16 °C, (coincident ratio = 0.7143) Rated MDMT of -81°C is limited to -48°C by UCS-66(b)(2)	UCS-66 governing thickness = 12.7 mm.
15.	Nozzle impact test exemption temperature from Fig UCS-66M Curve B = -22 °C 17 °C MDMT reduction per UCS-68(c) applies. Fig UCS-66.1M MDMT reduction = 15 °C, (coincident ratio = 0.7317) Rated MDMT of -54°C is limited to -48°C by UCS-66(b)(2)	UCS-66 governing thickness = 12.7 mm.
16.	Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.0424).	
17.	Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.244).	
18.	Flange rating governs: Flange rated MDMT = -105 °C (UCS-68(c) applies.) Bolts rated MDMT per Fig UCS-66 note (c) = -48 °C	UCS-66(b)(3): Coincident ratio = 0.0848

Design notes are available on the Settings Summary page.

Thickness Summary

Component Identifier	Material	Diameter (mm)	Length (mm)	Nominal t (mm)	Design t (mm)	Total Corrosion (mm)	Joint E	Load
Left Head	SA-516 70	2,133 ID	543.35	10.1*	10.07	3.2	1.00	Internal
Straight Flange on Left Head	SA-516 70	2,133 ID	50	12.7	10.82	3.2	1.00	External
Shell #1/#2	SA-516 70	2,133 ID	3,048	12.7	12.01	3.2	1.00	External
Shell #2	SA-516 70	2,133 ID	3,048	12.7	12.01	3.2	1.00	External
Straight Flange on Right Head	SA-516 70	2,133 ID	50	12.7	12.01	3.2	1.00	External
Right Head	SA-516 70	2,133 ID	543.35	10.1*	10.07	3.2	1.00	Internal

Nominal t: Vessel wall nominal thickness

Design t: Required vessel thickness due to governing loading + corrosion

Joint E: Longitudinal seam joint efficiency

* Head minimum thickness after forming

Load

internal: Circumferential stress due to internal pressure governs

external: External pressure governs

Wind: Combined longitudinal stress of pressure + weight + wind governs

Seismic: Combined longitudinal stress of pressure + weight + seismic governs

Hydrostatic Test

Shop test pressure determination for Chamber bounded by Right Head and Left Head based on MAWP per UG-99(b)

Shop hydrostatic test gauge pressure is 1,126.01 kPa at 5 °C (the chamber MAWP = 866.16 kPa)

The shop test is performed with the vessel in the horizontal position.

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Identifier	Local test pressure kPa	Test liquid static head kPa	UG-99(b) stress ratio	UG-99(b) pressure factor	Stress during test MPa	Allowable test stress MPa	Stress excessive?
Left Head (1)	1,152.89	26.88	1	1.30	109.565	235.8	No
Straight Flange on Left Head	1,152.89	26.88	1	1.30	97.391	235.8	No
Shell #1/#2	1,152.89	26.88	1	1.30	97.391	235.8	No
Shell #2	1,152.89	26.88	1	1.30	97.391	235.8	No
Straight Flange on Right Head	1,152.89	26.88	1	1.30	97.391	235.8	No
Right Head	1,152.89	26.88	1	1.30	109.565	235.8	No
M1 24" CL150 RFWN (M1)	1,145.31	19.3	1	1.30	163.311	351	No
N1 16" CL150 RFWN (N1)	1,138.16	12.15	1	1.30	91.583	351	No
N10A 2" CL150 RFLWN (N10A/B)	1,150.53	24.52	1	1.30	118.762	351	No
N10B 2" CL150 RFLWN (N10B)	1,150.53	24.52	1	1.30	118.762	351	No
N11 3" CL150 RFWN (N11/N12)	1,131.91	5.9	1	1.30	112.729	351	No
N12 3" CL150 RFWN (N12)	1,131.91	5.9	1	1.30	112.729	351	No
N13 2" CL150 RFWN (N13/N16B)	1,151.67	25.66	1	1.30	48.356	351	No
N14 3" CL150 RFLWN (N14)	1,155.5	29.49	1	1.30	107.271	351	No
N15 2" CL150 RFWN (N15)	1,131.87	5.86	1	1.30	110.586	351	No
N16A 2" CL150 RFWN (N16A)	1,134.03	8.02	1	1.30	105.924	351	No
N16B 2" CL150 RFWN (N16B)	1,151.67	25.66	1	1.30	48.356	351	No
N2 12" CL150 RFWN (N2)	1,131.87	5.86	1	1.30	108.75	351	No
N3 4" CL150 RFLWN (N3)	1,155.5	29.49	1	1.30	105.743	351	No
N4 2" CL150 RFWN (N4)	1,131.91	5.9	1	1.30	105.726	351	No
N5A 3" CL150 RFWN (N5A/N6A)	1,132.28	6.27	1	1.30	112.766	351	No
N5B 3" CL150 RFWN (N5B/N6B)	1,151.78	25.77	1	1.30	53.154	351	No
N6A 3" CL150 RFWN (N6A)	1,132.28	6.27	1	1.30	112.766	351	No
N6B 3" CL150 RFWN (N6B)	1,151.78	25.77	1	1.30	53.154	351	No
N7 10" CL150 RFWN (N7/N8)	1,131.87	5.86	1	1.30	85.861	351	No
N8 10" CL150 RFWN (N8)	1,131.87	5.86	1	1.30	85.861	351	No
N9 3" CL600 RFWN (N9)	1,131.91	5.9	1	1.30	112.729	351	No

Notes:
(1) Left Head limits the UG-99(b) stress ratio.
(2) P_L stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.
(3) $1.5*0.9*S_y$ used as the basis for the maximum local primary membrane stress at the nozzle intersection P_L.
(4) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.

The field test condition has not been investigated for the Chamber bounded by Right Head and Left Head.

The test temperature of 5 °C is warmer than the minimum recommended temperature of -12 °C so the brittle fracture

provision of UG-99(h) has been met.

Corroded Hydrostatic Test

The shop test condition has not been investigated for the Chamber bounded by Right Head and Left Head.

Field test pressure determination for Chamber bounded by Right Head and Left Head based on MAWP per UG-99(b)

Field hydrostatic test gauge pressure is 1,126.01 kPa at 5 °C (the chamber MAWP = 866.16 kPa)

The field test is performed with the vessel in the horizontal position.

3

Identifier	Local test pressure kPa	Test liquid static head kPa	UG-99(b) stress ratio	UG-99(b) pressure factor	Stress during test MPa	Allowable test stress MPa	Stress excessive?
Left Head (1)	1,152.92	26.91	1	1.30	160.872	235.8	No
Straight Flange on Left Head	1,152.92	26.91	1	1.30	130.4	235.8	No
Shell #1/#2	1,152.92	26.91	1	1.30	130.4	235.8	No
Shell #2	1,152.92	26.91	1	1.30	130.4	235.8	No
Straight Flange on Right Head	1,152.92	26.91	1	1.30	130.4	235.8	No
Right Head	1,152.92	26.91	1	1.30	160.872	235.8	No
M1 24" CL150 RFWN (M1)	1,145.34	19.33	1	1.30	234.063	351	No
N1 16" CL150 RFWN (N1)	1,138.19	12.18	1	1.30	107.124	351	No
N10A 2" CL150 RFLWN (N10A/B)	1,150.56	24.55	1	1.30	183.468	351	No
N10B 2" CL150 RFLWN (N10B)	1,150.56	24.55	1	1.30	183.468	351	No
N11 3" CL150 RFWN (N11/N12)	1,131.91	5.9	1	1.30	168.085	351	No
N12 3" CL150 RFWN (N12)	1,131.91	5.9	1	1.30	168.085	351	No
N13 2" CL150 RFWN (N13/N16B)	1,151.7	25.69	1	1.30	55.495	351	No
N14 3" CL150 RFLWN (N14)	1,155.5	29.49	1	1.30	143.576	351	No
N15 2" CL150 RFWN (N15)	1,131.87	5.86	1	1.30	158.202	351	No
N16A 2" CL150 RFWN (N16A)	1,134.06	8.05	1	1.30	158.509	351	No
N16B 2" CL150 RFWN (N16B)	1,151.7	25.69	1	1.30	55.495	351	No
N2 12" CL150 RFWN (N2)	1,131.87	5.86	1	1.30	122.073	351	No
N3 4" CL150 RFLWN (N3)	1,155.5	29.49	1	1.30	136.868	351	No
N4 2" CL150 RFWN (N4)	1,131.91	5.9	1	1.30	158.208	351	No
N5A 3" CL150 RFWN (N5A/N6A)	1,132.28	6.27	1	1.30	168.14	351	No
N5B 3" CL150 RFWN (N5B/N6B)	1,151.81	25.8	1	1.30	55.501	351	No
N6A 3" CL150 RFWN (N6A)	1,132.28	6.27	1	1.30	168.14	351	No
N6B 3" CL150 RFWN (N6B)	1,151.81	25.8	1	1.30	55.501	351	No
N7 10" CL150 RFWN (N7/N8)	1,131.87	5.86	1	1.30	88.053	351	No
N8 10" CL150 RFWN (N8)	1,131.87	5.86	1	1.30	88.053	351	No
N9 3" CL600 RFWN (N9)	1,131.91	5.9	1	1.30	168.085	351	No

Notes:
(1) Left Head limits the UG-99(b) stress ratio.
(2) P_L stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.
(3) $1.5*0.9*S_y$ used as the basis for the maximum local primary membrane stress at the nozzle intersection P_L.
(4) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.

The test temperature of 5 °C is warmer than the minimum recommended temperature of -12 °C so the brittle fracture provision of UG-99(h) has been met.

Left Head

ASME Section VIII, Division 1, 2010 Edition Metric

Component: Ellipsoidal Head
Material Specification: SA-516 70 (II-D Metric p.18, ln. 19)
Straight Flange governs MDMT

Internal design pressure: P = 862 kPa @ 150 °C
External design pressure: P_e = 103 kPa @ 150 °C

Static liquid head:

P_s= 26.91 kPa (SG=1, H_s=2746.7 mm Operating head)
P_{th}= 26.88 kPa (SG=1, H_s=2743.5 mm Horizontal test head)

Corrosion allowance: Inner C = 3.2 mm Outer C = 0 mm

Design MDMT = -29°C
Rated MDMT = -48°C

No impact test performed
Material is normalized
Material is produced to fine grain practice
PWHT is performed
Do not Optimize MDMT / Find MAWP

Radiography: Category A joints - Seamless No RT
Head to shell seam - Full UW-11(a) Type 1

Estimated weight*: new = 442.4 kg corr = 305.5 kg
Capacity*: new = 1,449 liters corr = 1,465.4 liters
* includes straight flange

Inner diameter	= 2133 mm
Minimum head thickness	= 10.1 mm
Head ratio D/2h	= 2 (new)
Head ratio D/2h	= 1.994 (corroded)
Straight flange length L_{sf}	= 50 mm
Nominal straight flange thickness t_{sf}	= 12.7 mm

Insulation thk*: 50 mm density: 240.277 kg/m^{3}weight: 66.2151 kg
Insulation support ring spacing: 0 mm individual weight: 0 kg total weight: 0 kg
* includes straight flange if applicable

Results Summary

The governing condition is internal pressure.

Minimum thickness per UG-16	= 1.5 mm + 3.2 mm = 4.7 mm
Design thickness due to internal pressure (t)	= 10.07 mm
Design thickness due to external pressure (t_e)	= 8.74 mm
Maximum allowable working pressure (MAWP)	= 866.16 kPa
Maximum allowable pressure (MAP)	= 1,305.66 kPa
Maximum allowable external pressure (MAEP)	= 160.2 kPa

K (Corroded)

$K=(1/6)*[2 + (D / (2*h))^2]=(1/6)*[2 + (2,139.4 / (2*536.45))^2]=0.996029$

K (New)

$K=(1/6)*[2 + (D / (2*h))^2]=(1/6)*[2 + (2,133 / (2*533.25))^2]=1$

Design thickness for internal pressure, (Corroded at 150 °C) Appendix 1-4(c)

t = P*D*K / (2*S*E - 0.2*P) + Corrosion
= 888.91*2,139.4*0.996029 / (2*138,000.002*1 - 0.2*888.91) + 3.2
= 10.07 mm

The head internal pressure design thickness is 10.07 mm.

Maximum allowable working pressure, (Corroded at 150 °C) Appendix 1-4(c)

$P = 2*S*E*t / (K*D + 0.2*t) - P_s$
= 2*138,000.002*1*6.9 / (0.996029*2,139.4 +0.2*6.9) - 26.91
= 866.16 kPa

The maximum allowable working pressure (MAWP) is 866.16 kPa.

Maximum allowable pressure, (New at 5 °C) Appendix 1-4(c)

$P = 2*S*E*t / (K*D + 0.2*t) - P_s$
= 2*138,000.002*1*10.1 / (1*2,133 +0.2*10.1) - 0
= 1,305.66 kPa

The maximum allowable pressure (MAP) is 1,305.66 kPa.

Design thickness for external pressure, (Corroded at 150 °C) UG-33(d)

Equivalent outside spherical radius (R_o)
$R_o = K_o*D_o$
= 0.8916*2,153.2
= 1,919.87 mm

$A = 0.125 / (R_o / t)$
= 0.125 / (1,919.87 / 5.54)
= 0.00036

From Table CS-2 Metric: B = 35.7247 MPa

$P_a = B / (R_o / t)$
= 35,724.67 / (1,919.87 / 5.54)
= 103 kPa

t = 5.54 mm + Corrosion = 5.54 mm + 3.2 mm = 8.74 mm
Check the external pressure per UG-33(a)(1) Appendix 1-4(c)

$t = 1.67*P_e*D*K / (2*S*E - 0.2*1.67*P_e) + Corrosion$
= 1.67*103*2,139.4*0.996029 / (2*138,000.002*1 - 0.2*1.67*103) + 3.2
= 4.53 mm

The head external pressure design thickness (t_e) is 8.74 mm.

Maximum Allowable External Pressure, (Corroded at 150 °C) UG-33(d)

Equivalent outside spherical radius (R_o)
$R_o = K_o*D_o$

= 0.8916*2,153.2
= 1,919.87 mm

A = 0.125 / (R_o / t)
= 0.125 / (1,919.87 / 6.9)
= 0.000449

From Table CS-2 Metric: B = 44.5761 MPa

P_a = B / (R_o / t)
= 44,576.09 / (1,919.87 / 6.9)
= 160.197 kPa

Check the Maximum External Pressure, UG-33(a)(1) Appendix 1-4(c)

P = 2*S*E*t / ((K*D + 0.2*t)*1.67) - P_{s2}
= 2*138,000.002*1*6.9 / ((0.996029*2,139.4 +0.2*6.9)*1.67) - 0
= 534.78 kPa

The maximum allowable external pressure (MAEP) is 160.2 kPa.

% Extreme fiber elongation - UCS-79(d)

EFE = (75*t / R_f)*(1 - R_f / R_o)
= (75*12.7 / 368.96)*(1 - 368.96 / ∞)
= 2.5816%

The extreme fiber elongation does not exceed 5%.

Straight Flange on Left Head

ASME Section VIII Division 1, 2010 Edition Metric

Component: Straight Flange
Material specification: SA-516 70 (II-D Metric p. 18, ln. 19)
Material impact test exemption temperature from Fig UCS-66M Curve D = -48 °C
17 °C MDMT reduction per UCS-68(c) applies.
Fig UCS-66.1M MDMT reduction = 15 °C, (coincident ratio = 0.7316)
Rated MDMT of -80°C is limited to -48°C by UCS-66(b)(2)
UCS-66 governing thickness = 12.7 mm

Internal design pressure: P = 862 kPa @ 150 °C
External design pressure: P_e = 103 kPa @ 150 °C

Static liquid head:

P_s = 26.91 kPa (SG = 1, H_s = 2,746.7 mm,Operating head)
P_{th} = 26.88 kPa (SG = 1, H_s = 2,743.5 mm, Horizontal test head)

Corrosion allowance Inner C = 3.2 mm Outer C = 0 mm

Design MDMT = -29 °C
Rated MDMT = -48 °C

No impact test performed
Material is normalized
Material is produced to Fine Grain Practice
PWHT is performed

Radiography: Longitudinal joint - Seamless No RT
Circumferential joint - Full UW-11(a) Type 1

Estimated weight New = 33.5 kg corr = 25.1 kg
Capacity New = 178.67 liters corr = 179.74 liters

ID = 2,133 mm
Length L_c = 50 mm
t = 12.7 mm
Insulation thk: 50 mm density: 240.28 kg/m^3 Weight: 0 kg

Design thickness, (at 150 °C) UG-27(c)(1)

t = P*R / (S*E - 0.60*P) + Corrosion
= 888.91*1,069.7 / (138,000*1.00 - 0.60*888.91) + 3.2
= 10.12 mm

Maximum allowable working pressure, (at 150 °C) UG-27(c)(1)

P = S*E*t / (R + 0.60*t) - P_s
= 138,000*1.00*9.5 / (1,069.7 + 0.60*9.5) - 26.91
= 1,192.12 kPa

Maximum allowable pressure, (at 5 °C) UG-27(c)(1)

P = S*E*t / (R + 0.60*t)
= 138,000*1.00*12.7 / (1,066.5 + 0.60*12.7)
= 1,631.66 kPa

External Pressure, (Corroded & at 150 °C) UG-28(c)

L / D_o = 2,719.82 / 2,158.4 = 1.2601
D_o / t = 2,158.4 / 7.62 = 283.2441
From table G: A = 0.000221
From table CS-2 Metric: B = 21.8805 MPa

P_a = 4*B / (3*(D_o / t))
= 4*21,880.55 / (3*(2,158.4 / 7.62))
= 103 kPa

Design thickness for external pressure P_a = 103 kPa

t_a = t + Corrosion = 7.62 + 3.2 = 10.82 mm

Maximum Allowable External Pressure, (Corroded & at 150 °C) UG-28(c)

L / D_o = 2,719.82 / 2,158.4 = 1.2601
D_o / t = 2,158.4 / 9.5 = 227.2096
From table G: A = 0.000311
From table CS-2 Metric: B = 30.8252 MPa

P_a = 4*B / (3*(D_o / t))
= 4*30,825.17 / (3*(2,158.4 / 9.5))
= 180.89 kPa

% Extreme fiber elongation - UCS-79(d)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*12.7 / 1,072.85)*(1 - 1,072.85 / ∞)
= 0.5919%

The extreme fiber elongation does not exceed 5%.

Straight Flange on Right Head

ASME Section VIII Division 1, 2010 Edition Metric

Component: Straight Flange
Material specification: SA-516 70 (II-D Metric p. 18, ln. 19)
Material impact test exemption temperature from Fig UCS-66M Curve D = -48 °C
17 °C MDMT reduction per UCS-68(c) applies.
Fig UCS-66.1M MDMT reduction = 15 °C, (coincident ratio = 0.7316)
Rated MDMT of -80°C is limited to -48°C by UCS-66(b)(2)
UCS-66 governing thickness = 12.7 mm

Internal design pressure: P = 862 kPa @ 150 °C
External design pressure: P_e = 103 kPa @ 150 °C

Static liquid head:

P_s = 26.91 kPa (SG = 1, H_s = 2,746.7 mm,Operating head)
P_{th} = 26.88 kPa (SG = 1, H_s = 2,743.5 mm, Horizontal test head)

Corrosion allowance Inner C = 3.2 mm Outer C = 0 mm

Design MDMT = -29 °C
Rated MDMT = -48 °C

No impact test performed
Material is normalized
Material is produced to Fine Grain Practice
PWHT is performed

Radiography: Longitudinal joint - Seamless No RT
Circumferential joint - Full UW-11(a) Type 1

Estimated weight New = 33.5 kg corr = 25.1 kg
Capacity New = 178.67 liters corr = 179.74 liters

ID = 2,133 mm
Length L_c = 50 mm
t = 12.7 mm

Design thickness, (at 150 °C) UG-27(c)(1)

t = P*R / (S*E - 0.60*P) + Corrosion
= 888.91*1,069.7 / (138,000*1.00 - 0.60*888.91) + 3.2
= 10.12 mm

Maximum allowable working pressure, (at 150 °C) UG-27(c)(1)

P = S*E*t / (R + 0.60*t) - P_s
= 138,000*1.00*9.5 / (1,069.7 + 0.60*9.5) - 26.91
= 1,192.12 kPa

Maximum allowable pressure, (at 5 °C) UG-27(c)(1)

P = S*E*t / (R + 0.60*t)
= 138,000*1.00*12.7 / (1,066.5 + 0.60*12.7)
= 1,631.66 kPa

External Pressure, (Corroded & at 150 °C) UG-28(c)

L / D_o = 3,833.82 / 2,158.4 = 1.7762
D_o / t = 2,158.4 / 8.81 = 245.0701
From table G: A = 0.000192
From table CS-2 Metric: B = 18.9316 MPa

P_a = 4*B / (3*(D_o / t))
= 4*18,931.61 / (3*(2,158.4 / 8.81))
= 103 kPa

Design thickness for external pressure P_a = 103 kPa

t_a = t + Corrosion = 8.81 + 3.2 = 12.01 mm

Maximum Allowable External Pressure, (Corroded & at 150 °C) UG-28(c)

L / D_o = 3,833.82 / 2,158.4 = 1.7762
D_o / t = 2,158.4 / 9.5 = 227.2096
From table G: A = 0.000217
From table CS-2 Metric: B = 21.5086 MPa

P_a = 4*B / (3*(D_o / t))
= 4*21,508.62 / (3*(2,158.4 / 9.5))
= 126.22 kPa

% Extreme fiber elongation - UCS-79(d)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*12.7 / 1,072.85)*(1 - 1,072.85 / ∞)
= 0.5919%

The extreme fiber elongation does not exceed 5%.

Shell #1/#2

ASME Section VIII Division 1, 2010 Edition Metric

Component: Cylinder
Material specification: SA-516 70 (II-D Metric p. 18, ln. 19)
Material impact test exemption temperature from Fig UCS-66M Curve D = -48 °C
17 °C MDMT reduction per UCS-68(c) applies.
Fig UCS-66.1M MDMT reduction = 15 °C, (coincident ratio = 0.7316)
Rated MDMT of -80°C is limited to -48°C by UCS-66(b)(2)
UCS-66 governing thickness = 12.7 mm

Internal design pressure: P = 862 kPa @ 150 °C
External design pressure: P_e = 103 kPa @ 150 °C

Static liquid head:

P_s = 26.91 kPa (SG = 1, H_s = 2,746.7 mm,Operating head)
P_{th} = 26.88 kPa (SG = 1, H_s = 2,743.5 mm, Horizontal test head)

Corrosion allowance Inner C = 3.2 mm Outer C = 0 mm

Design MDMT = -29 °C
Rated MDMT = -48 °C

No impact test performed
Material is normalized
Material is produced to Fine Grain Practice
PWHT is performed

Radiography: Longitudinal joint - Full UW-11(a) Type 1
Left circumferential joint - Full UW-11(a) Type 1
Right circumferential joint - Full UW-11(a) Type 1

Estimated weight New = 2,011.8 kg corr = 1,507.1 kg
Capacity New = 10,891.47 liters corr = 10,956.94 liters

ID = 2,133 mm
Length L_c = 3,048 mm
t = 12.7 mm
Insulation thk: 50 mm density: 240.28 kg/m^3 Weight: 254.1 kg

Design thickness, (at 150 °C) UG-27(c)(1)

t = P*R / (S*E - 0.60*P) + Corrosion
= 888.91*1,069.7 / (138,000*1.00 - 0.60*888.91) + 3.2
= 10.12 mm

Maximum allowable working pressure, (at 150 °C) UG-27(c)(1)

P = S*E*t / (R + 0.60*t) - P_s
= 138,000*1.00*9.5 / (1,069.7 + 0.60*9.5) - 26.91
= 1,192.12 kPa

Maximum allowable pressure, (at 5 °C) UG-27(c)(1)

P = S*E*t / (R + 0.60*t)
= 138,000*1.00*12.7 / (1,066.5 + 0.60*12.7)
= 1,631.66 kPa

External Pressure, (Corroded & at 150 °C) UG-28(c)

L / D_o = 3,833.82 / 2,158.4 = 1.7762
D_o / t = 2,158.4 / 8.81 = 245.0701
From table G: A = 0.000192
From table CS-2 Metric: B = 18.9316 MPa

P_a = 4*B / (3*(D_o / t))
= 4*18,931.61 / (3*(2,158.4 / 8.81))
= 103 kPa

Design thickness for external pressure P_a = 103 kPa

t_a = t + Corrosion = 8.81 + 3.2 = 12.01 mm

Maximum Allowable External Pressure, (Corroded & at 150 °C) UG-28(c)

L / D_o = 3,833.82 / 2,158.4 = 1.7762
D_o / t = 2,158.4 / 9.5 = 227.2096
From table G: A = 0.000217
From table CS-2 Metric: B = 21.5086 MPa

P_a = 4*B / (3*(D_o / t))
= 4*21,508.62 / (3*(2,158.4 / 9.5))
= 126.22 kPa

% Extreme fiber elongation - UCS-79(d)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*12.7 / 1,072.85)*(1 - 1,072.85 / ∞)
= 0.5919%

The extreme fiber elongation does not exceed 5%.

Stiffening Ring

Stiffener ring calculations per UG-29(a)

Ring type:	Flat bar	
Ring description:	3/8x4 Flat Bar	
Ring material:	SA-516 70 (II-D Metric p. 18, ln. 19)	
External pressure:	103	kPa
Ring is located:	outside the vessel	
Distance from ring neutral axis to datum:	3,605	mm
Ring corrosion allowance:	0	mm
Distance to previous support:	2,719.82	mm
Distance to next support:	3,833.82	mm

L / D_o = 3,833.82 / 2,158.4 = 1.7762
D_o / t = 2,158.4 / 8.81 = 245.0695
From Table G: A = 0.000192
From Table CS-2 Metric: B = 18.932 MPa

P_a = 4*B / (3*(D_o / t))
= 4*18.932 / (3*(2,158.4 / 8.81))
= 0.103 MPa

B = 0.75*P*D_o / (t + A_s / L_s)
= 0.75*103*2,158.4 / (8.81 + 967.74 / 3,276.82) / 1000
= 18.32 MPa

From Table CS-2 Metric: A = 0.00018539 (ring, 150°C)

I_s' = [D_o^2*L_s*(t + A_s / L_s)*A] / 10.9
= [2,158.4^2*3,276.82*(8.81 + 967.74 / 3,276.82)*0.00018539] / 10.9 / 10000
= 236.31 cm^4

I' for the composite corroded shell-ring cross section is 265.71 cm^4

As I' >= I_s' a 3/8x4 Flat Bar stiffener is adequate for an external pressure of 103 kPa.

Check the stiffener ring attachment welds per UG-30

Fillet weld is:	Continuous both sides
Fillet weld leg size:	6 mm
Vessel thickness at weld location, new:	12.7 mm
Vessel corrosion allowance at weld location:	3.2 mm
Stiffener thickness at weld location:	9.53 mm

Per UG-30(f)(1) the minimum attachment weld size is 6 mm

The fillet weld size of 6 mm is adequate per UG-30(f)(1).

Radial pressure load, P*L_s = 103*3,276.82 / 100 = 3,375.12 N/cm
Radial shear load, V = 0.01*P*L_s*D_o = 0.01*103 / 1000*3,276.82*2,158.4 = 7,284.86 N
First moment of area, Q = 14.96*2.18 = 32.6446 cm^3

Weld shear flow, $q = V^*Q / I' = 894.9979$ N/cm
Combined weld load, $f_w = Sqr(3{,}375.1208^2 + 894.9979^2) = 3{,}491.77$ N/cm

Allowable weld stress per UW-18(d) $S_w = 0.55^*S = 0.55^*138 = 75.9$ MPa

Fillet weld size required to resist radial pressure and shear

$= f_w^*(d_{weld\ segment} + d_{toe}) / (S_w^*d_{weld\ total}) + corrosion$
$= 3{,}491.77^*(25.4 + 0) / (10^*75.9^*50.8) + 0$
$= 2.3$ mm

The fillet weld size of 6 mm is adequate to resist radial pressure and shear.