



ECCC RECOMMENDATIONS - VOLUME 9 Part III [Issue 1]

**HIGH TEMPERATURE COMPONENT ANALYSIS
DATABASE OF COMPONENT TESTS AND
ASSESSMENTS**

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HIGH TEMPERATURE COMPONENT ASSESSMENT DATABASE OF COMPONENT TESTS AND ASSESSMENTS

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ABSTRACT

Volume 9 Part III provides an overview of the component testing experience of members of the ECCC-WG4 (Components) working group.

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BACKGROUND AND INTRODUCTION

High temperature component tests provide a valuable means of:

- i) characterising a materials resistance to damage and crack development under representative service conditions, and more importantly
- ii) validating high temperature defect-free and defect assessment procedures.

However, such tests are invariably costly to prepare and run, even with the availability of appropriate testing facilities. At least 2 recent surveys have shown that the number of facilities capable of performing component tests has been in rapid decline in recent years [1,2]. The purpose of the WG4 review of existing component testing experience was to ascertain the availability of existing case study material which could be first evaluated before embarking on a costly test programme

The accompanying tables provide a catalogue of summary details for 36 high temperature components tests, involving ferritic and austenitic steels, with an indication of the assessment route(s) performed where appropriate.

REFERENCES

- 1 ECCC Recommendations Volume 3, 2005, 'Part V: Testing practices for multi-axial features and components', eds. Brown, T.B. & Holdsworth, S.R.
- 2 Holdsworth, S.R., 2002, 'Overview of activities of the Structural Mechanics Cluster of the Plant Life Assessment Network', Materials at High Temperature, 19(2), 69-74.

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No	TYPE	TEST DESCRIPTION	MATERIAL	STARTER CRACK(S)	TEMP	LOADING	DURATION	MONITORING INFORMATION	REFERENCES	ANALYSIS ROUTE
1	Ferritic	MEL Vessel FM1 Ri = 115mm t = 60mm	0.5CrMoV parent	Various circ. Notches	565°C	P = 62.5 MPa	1.6kh (total failure at site of deepest fully circ.notch)	Creep strain Strain gauges Notch CMOD Crack size DCPD Ultrasonics Post test exam.	(a) Coleman, Price and Williams, ICF4, 649-662, 1977. (b) Ainsworth & Coleman, Fat. Fract. Eng. Mater. Struct., 10, 129-140, 1987.	R5
2	Ferritic	MEL Vessel FM2 Ri = 115mm t = 60mm	0.5CrMoV parent 2.25Cr1Mo welds (AW & SR)	Various defects spark machined in circ. welds (HAZ & Type IV zones).	565°C	P = 35 MPa	46kh (steam leak)	Creep strain Creep pips Strain gauges Crack size Ultrasonics Post test exam.	Jones & Coleman, (a) RD/B/6242/R89 (b) CFEMS4, 605-619, 1990. Budden TIGM/REP/0088/93	R5
3	Ferritic	MEL Vessel FM2A Ri = 115mm t = 60mm	0.5CrMoV parent 2.25Cr1Mo welds (AW & SR)	Various defects spark machined in circ. welds (HAZ & Type IV zones).	565°C	P = 35 MPa	54kh (steam leak)	Creep strain Creep pips Strain gauges Crack size Ultrasonics Post test exam.	Budden (a) TIGM/REP/0089/93 (b) Int. J. Pres. Vess. & Piping, 75, 509-519 1998.	R5

No	TYPE	TEST DESCRIPTION	MATERIAL	STARTER CRACK(S)	TEMP	LOADING	DURATION	MONITORING INFORMATION	REFERENCES	ANALYSIS ROUTE
4	Ferritic	MEL Vessel TWMC1A Ri = 212mm t = 28mm	0.5CrMoV parent 2.25Cr1Mo welds (AW & SR)	None	575°C	P = 7 MPa	47kh (steam leak due to Type IV crack in end cap weld)	Creep strain Creep pips Strain gauges Crack size Ultrasonics Post test exam.	Budden (a) EPD/GEN/REP/0297/98 (b) Int. J. Pres. Vess. & Piping, 75, 509-519 1998.	R5
5	Ferritic	MEL Vessel TWMC2 Ri = 230mm t = 28mm	0.5CrMoV parent 2.25Cr1Mo welds (AW & SR)	None	575°C	P = 7 MPa	59kh (steam leak due to Type IV crack in end cap weld)	Creep strain Creep pips Strain gauges Crack size Ultrasonics Post test exam.	Budden (a) EPD/GEN/REP/0297/98 (b) Int. J. Pres. Vess. & Piping, 75, 509-519 1998.	R5
6	Ferritic	Large Bore Branch Ri = 229mm T = 32mm ri = 146mm t = 16mm	0.5CrMoV parent 2.25Cr1Mo weld (SR)	None	585°C (535°C in service)	P = 3.6 MPa Out-of-plane moment = 30kNm	11.7kh (stopped – NDT indication of deep Type IV crack at tensile flank)	Creep strain Creep pips Strain gauges Crack size Ultrasonics Post test exam.	Al Laham EPD/GEN/REP/0371/98 P J Budden, Creep Crack Growth Assessment of the Large Bore Branch Vessel Test, E/EAN/GEN/0023/00, 2000. R D Patel, S Al Laham and P J Budden, R5 Creep Assessment of Welded Trunnion & Large Bore Branch Components, CFEMS Ap	R5

No	TYPE	TEST DESCRIPTION	MATERIAL	STARTER CRACK(S)	TEMP	LOADING	DURATION	MONITORING INFORMATION	REFERENCES	ANALYSIS ROUTE
7	Ferritic	Medium Bore Branch Ri = 210mm T = 18mm ri = 56mm t = 8mm	0.5CrMoV parent 2.25Cr1Mo weld (SR)	None	590°C	P = 4.0 MPa	20.038kh (completed, transverse through-wall crotch crack)	Creep strain Creep pips Strain gauges Crack size Ultrasonics Post test exam.	R D Patel, R5 Medium Bore Branch Life Assessment, BEGL Report E/REP/ATEC/0005/GEN/01 Post test examination results: E/EAN/MATS/0024/AGR/01	R5
8	Ferritic	Pipework Trunnion Ri = 232mm T = 26mm ri = 149mm t = 16mm	0.5CrMoV parent 2.25Cr1Mo weld (SR) Ex-service (91.7kh)	None	585°C (527°C in service)	P = 3.5 MPa In-plane moment = 11kNm	15.4kh (stopped)	Creep strain Creep pips Strain gauges Crack size Ultrasonics Post test exam.	R D Patel, R5 Trunnion Life Assessment, BEGL Report E/REP/GEN/0036/00, October 2000. R D Patel, S Al Laham and P J Budden, R5 Creep Assessment of Welded Trunnion & Large Bore Branch Components, CFEMS April 2001	R5
9	Austenitic	BRITE 2147 Vessel 1 Ri = 75mm t = 40mm	316L(N) parent and welds (AW & SR)	None	510°C-620°C	P = 63 MPa	14.7 kh (stopped)	Creep strain Creep pips Strain gauges Crack size Ultrasonics	Budden TIGM/REP/0069/93 O'Donnell EPD/GEN/REP/0287/98	R5

No	TYPE	TEST DESCRIPTION	MATERIAL	STARTER CRACK(S)	TEMP	LOADING	DURATION	MONITORING INFORMATION	REFERENCES	ANALYSIS ROUTE
10	Austenitic	BRITE 2147 Vessel 2 Ri = 75mm t = 40mm	316L(N) parent and welds (AW & SR)	Various defects spark machined in centre line of circ. welds	510°C- 620°C	P = 63 MPa	11.5 kh (stopped – increase in hoop strain at SR weld but NDT did not reveal any cracking)	Creep strain Creep pips Strain gauges Crack size Ultrasonics	Budden TIGM/REP/0069/93 O'Donnell (a) EPD/GEN/REP/0287/98 (b) EPD/GEN/REP/0319/98	R5
11	Austenitic	HYA Superheater Header (1C1/4) Lead Joint Ri = 152.4mm T = 63.5mm ri = 51.6mm t = 62.7mm (tapered)	316H parent and weld (AW) Ex-service	Reheat crack Max depth ~ 20mm	550°C	P = 18.8 MPa Nozzle end load = 15.4 kN Thermal Shocks (510°C- 330°C in 1h) every 500 h	8.8 kh + 17 thermal shocks (stopped)	Creep strain Strain gauges Crack size Ultrasonics Post test exam.		-
12	Austenitic	HYA Superheater Header (2A1/1) Pressure Only Ri = 152.4mm T = 63.5mm ri = 51.6mm t = 62.7mm (tapered)	316H parent and weld (AW) Ex-service	Reheat crack	550°C	P = 18.8 MPa	20 kh (planned)	Creep strain Strain gauges Crack size Ultrasonics Post test exam.		-

No	TYPE	TEST DESCRIPTION	MATERIAL	STARTER CRACK(S)	TEMP	LOADING	DURATION	MONITORING INFORMATION	REFERENCES	ANALYSIS ROUTE
13	Austenitic	Full scale gimbals feature test.	347 Casting 347 Weld 321 Tube	Yes EDM in centre of weld	$T_{min}=20^{\circ}\text{C}$ $T_{max}=650^{\circ}\text{C}$	50 refuelling cycles:- charge/discharge transient 120 hr creep dwell 10 ECD elastic cycles	6 khrs approx. (50 x 120 hrs)	Crack size acpc destructive examination	IJS (draft)	R5 (inelastic route)
14	Transition	EE Mk III Vessel $R_i = 152.5\text{mm}$ $t = 27.5\text{mm}$	Transition joint (2.25Cr/316/316) Ex-service 94 khrs	None	550°C (540°C , 3.9 MPa pressure in service)	$P = 11.5\text{ MPa}$ Axial load = 1565 kN	11.5 kh (initiation and growth of a single semi-elliptical crack in HAZ on the ferritic interface. Failure was non-catastrophic)	Crack size Ultrasonics	O'Donnell EPD/GEN/REP/0192/97	R5
15	Transition	Inconel DMW	Transition joint (2.25Cr/Inconel/316)	None	540°C	$P = 32\text{ MPa}$ End load = 1058kN	21,887 hrs (Failure by initiation and growth of a crack at the Weld E interface.	Crack size Dye pen. Ultrasonics	Patel EPD/GEN/REP/0282/98	R5, Vol. 6
16	Austenitic	Welded 18Cr11Ni wide plate test	Parent and weld are 304 stainless steel	None	570°C	Constant axial load = 10MPa & bending cycles of +0.2% and -0.2% with creep dwell of 40hrs.	Test stopped after 117 cycles (4680 hrs). Evidence of micro-cracking and mirco-crack coalescence within the transverse weld metal.	?	P Booth, TEM/MEM/0016/95. BRITE-3 EURAM C-FAT, PROJECT NO: BE 5245, Task 5.	R5, Vols. 2 and 3

No	TYPE	TEST DESCRIPTION	MATERIAL	STARTER CRACK(S)	TEMP	LOADING	DURATION	MONITORING INFORMATION	REFERENCES	ANALYSIS ROUTE
17	Austenitic	Welded 18Cr11Ni wide plate test	German designation X6 Cr Ni 18 11, DIN no. 1.4948.	None	570°C	Constant axial load = 10MPa & bending cycles of +0.2% and -0.2% with creep dwell of 40hrs.	Test stopped after 117 cycles (4680 hrs). Evidence of micro-cracking and mirco-crack coalescence within the transverse weld metal.	?	U. Lohse, S-KWU NLS3/93/0079. BRITE-EURAM C-FAT, PROJECT NO: BE 5245, Task 5.	Siemens/ INTERATOM procedure.
18	Austenitic	Welded 18Cr11Ni wide plate test								
19	Ferritic	BRITE 2341 Circumferentially welded vessel diXt = 126X65 (Question - what does this mean? I.e is it internal diameter?)	P91	?	600°C	49MPa	8000 hrs	Strain measurements	OBTAINED FROM list_tommy_13_03_02.doc, (WG4/meeting3 folder in my_f_disk)	?
20	Ferritic	BE-1702 HIDA bendings diXt = 190X23 (same question as above) - units? four vessels two P91 and two P22	P91/P22	?	565°C/ 625°C	Up to 25MPa	Up to 8400 hrs	Creep crack growth and strain	OBTAINED FROM list_tommy_13_03_02.doc, (WG4/meeting3 folder in my_f_disk)	?

No	TYPE	TEST DESCRIPTION	MATERIAL	STARTER CRACK(S)	TEMP	LOADING	DURATION	MONITORING INFORMATION	REFERENCES	ANALYSIS ROUTE
21	Ferritic	Belgian vessel Circumferentially welded vessel diXt = 240X30 (same question as above) - units? 3 vessels	P91/P22	?	Up to 610°C	Up to 20MPa	Up to 10000 hrs	Strain measurements	OBTAINED FROM list_tommy_13_03_02.doc, (WG4/meeting3 folder in my_f_disk)	?
22	Ferritic	BW48 Mitsui babcock T-junction and circumferentially w. Di=210 units? 3 vessels, data not complete	1Cr½Mo	?	?	?	?	?	OBTAINED FROM list_tommy_13_03_02.doc, (WG4/meeting3 folder in my_f_disk)	?
23		MPA bending bendings diXt = 175X30 (what does this mean and what are the units?) 2 vessels, only paper available	14MoV 6 3 and X20	?	550°C	?	Up to 25000 hrs	Strain measurements	OBTAINED FROM list_tommy_13_03_02.doc, (WG4/meeting3 folder in my_f_disk)	?

No	TYPE	TEST DESCRIPTION	MATERIAL	STARTER CRACK(S)	TEMP	LOADING	DURATION	MONITORING INFORMATION	REFERENCES	ANALYSIS ROUTE
24		Pipe bend tests Ri = 225 mm t = 20 mm 90° bend	P91 (P91/B1) static end-constraint	In longitudinal direction: 3 at bend extrados X, Y, Z 3 in neutral axis Q, R	625°C	15 MPa 20 MPa	1300 hrs (no cracks) 1460hrs (stopped without failure)	Thermocouples Load deflection measurements AC-PD (CCG) HT strain gauges post test exam.: Metallography a.o.	BE-1702 HIDA	Two-Criteria (CC initiation) C*, sigamref, K acc. BS7910 (CCG)
25		Pipe bend tests Ri = 225 mm t = 20 mm 90° bend	P91 (P91/B2) static without constraint	In longitudinal direction: 3 at bend extrados X, Y, Z 3 in neutral axis Q, R	625°C	16 MPa	2840 hrs	Thermocouples Load deflection measurements AC-PD (CCG) HT strain gauges post test exam.: Metallography a.o.	BE-1702 HIDA	Two-Criteria (CC initiation) C*, sigmaref, K acc. BS7910 (CCG)
26		Pipe bend tests Ri = 156 mm t = 20 mm 90° bend	P22 (P22/B1) static end-constraint	In longitudinal direction: 3 at bend extrados X, Y, Z 3 in neutral axis Q, R	565°C	15 MPa 20 MPa	1300 hrs (no cracks) 8440 hrs	Thermocouples Load deflection measurements AC-PD (CCG) HT strain gauges post test exam.: Metallography a.o.	BE-1702 HIDA	Two-Criteria (CC initiation) C*, sigmaref, K acc. BS7910 (CCG)

No	TYPE	TEST DESCRIPTION	MATERIAL	STARTER CRACK(S)	TEMP	LOADING	DURATION	MONITORING INFORMATION	REFERENCES	ANALYSIS ROUTE
27		Pipe bend tests Ri = 156 mm t = 20 mm 90° bend	P22 (P22/B2) static without constraint	In longitudinal direction: 3 at bend extrados X, Y, Z 3 in neutral axis Q, R	565°C	25 MPa	3600 hrs	Thermocouples Load deflection measurements AC-PD (CCG) HT strain gauges post test exam.: Metallography a.o.	BE-1702 HIDA	Two-Criteria (CC initiation) C*, sigmaref, K acc. BS7910 (CCG)
28		4-Point bending Ri = 156 mm t = 20 mm	P91 (P91/P1) Creep Crack Growth CCG	In circumfer. direction: 2 at parent metal (A, C) 1 in HAZ (B)	625°C	Pi = 20 MPa Fext.= 96 kN Pi = 20 MPa Fext.= 120 kN	3648 hrs (no crack growth) 1440 hrs (leakage in weld)	Thermocouples Load deflection measurements AC-PD (CCG) HT strain gauges (notch opening) post test exam.: Metallography a.o.	BE-1702 HIDA	Two-Criteria (CC initiation) C*, sigmaref, K acc. BS7910 (CCG)
29		4-Point bending Ri = 156 mm t = 20 mm	P91 (P91/P2) creep/fatigue crack growth CFG	In circumfer. direction: 2 at parent metal (A, C) 1 in HAZ (B)	625°C	Pi = 20 MPa deltaFext.= 96 kN Pi = 20 MPa deltaFext.= 120 kN f= 0,001 Hz	3648 h/ 12740 cycl. (no crack growth) 1440 h/ 4634 cycl.	Thermocouples Load deflection measurements AC-PD (CCG) HT strain gauges post test exam.: Metallography a.o.	BE-1702 HIDA	Two-Criteria (CC initiation) C*, sigmaref, K acc. BS7910 (CCG)

No	TYPE	TEST DESCRIPTION	MATERIAL	STARTER CRACK(S)	TEMP	LOADING	DURATION	MONITORING INFORMATION	REFERENCES	ANALYSIS ROUTE
30		4-Point bending Ri = 156 mm t = 20 mm	P22 (P22/P1) Creep Crack Growth CCG	In circumfer. direction: 2 at parent metal (A, C) 1 in HAZ (B)	565°C	Pi = 20 MPa Fext.= 47 kN Pi = 20 MPa Fext.= 90 kN	5020 h(no crack growth) 2800 h(test stop)	Thermocouples Load deflection measurements AC-PD (CCG) post test exam.: Metallography a.o.	BE-1702 HIDA	Two-Criteria (CC initiation) C*, sigmaref, K acc. BS7910 (CCG)
31		4-Point bending Ri = 156 mm t = 20 mm	P22 (P22/P2) Creep/Fatigue Crack Growth CFG	In circumfer. direction: 2 at parent metal (A, C) 1 in HAZ (B)	565°C	Pi = 20 MPa deltaFext.= 47 kN Pi = 20 MPa deltaFext.= 90 kN f= 0,001 Hz	5020 h/ 16420 cycl. (no crack growth) 2800 h/ 9655 cycl. (test stop)	Thermocouples Load deflection measurements AC-PD (CCG) post test exam.: Metallography a.o.	BE-1702 HIDA	Two-Criteria (CC initiation) C*, sigmaref, K acc. BS7910 (CCG)
32	Ferritic	SENB specimen Length=450mm Width=100mm t=75mm	Cast 1CrMoV	6mm radius, single edged, semi-circular section notch on the 100mm face	550°C	3 loadings: 1) pure fatigue 2) creep-fatigue with a dwell of either 30mins or 16hrs at max displacement. 3) a single case of a creep- fatigue cycle with a superimposed constant end stress to simulate primary loading.	10 tests performed - ranged from 153 to 4000 cycles	Direct current potential drop technique (DCPD)	BRITE-EURAM C-FAT, Task 5 Milestone report. Development & validation of creep-fatigue assessment methodologies (AEAT - 0483)	Volume 3 of R5

No	TYPE	TEST DESCRIPTION	MATERIAL	STARTER CRACK(S)	TEMP	LOADING	DURATION	MONITORING INFORMATION	REFERENCES	ANALYSIS ROUTE
33	Ferritic	SENB specimen Length=450mm Width = 100mm t=75mm	Cast 1CrMoV	6mm radius, single edged, semi-circular section notch on the 100mm face	550°C	3 loadings: 1) pure fatigue 2) creep-fatigue with a dwell of either 30mins or 16hrs at max displacement. 3) a single case of a creep-fatigue cycle with a superimposed constant end stress to simulate primary loading.	6 tests analysed: ranged from 177 to 4000 cycles	Direct current potential drop technique (DCPD)	BRITE-EURAM C-FAT, Task 5 Milestone report. Development & validation of creep-fatigue assessment methodologies (Nuclear Electric EPD/GEN/REP/0095/96)	R5 Volumes 2 & 3
34	Ferritic	LICON 1:1 Tee junction, Ri = 142.5mm, t = 21.925mm	E011, Thyssen MTS011 weld metal	None	625°C	P1 = 10.21MPa P2 = 5.88MPa P3 = 8.5MPa	P1: 1078hr (90° flank 7.5mm deep defect) P2: 620hr P3: 4482hr (90° flank indication), 7218hr (90° flank 150mm, 0.5mm defect)	Creep Strain: Strain gauges, creep pips Crack size: ACPD, ultrasonics, post test examination	Russell, G, Hack, R, Fleming, A and McMillan, G LICON: Task 5 Final Report Mitsui Babcock Report E/00/115	?
35	Ferritic	HIDA seam-welded straight pipe	2.25Cr1Mo Parent & welds	3 EDM semi-elliptical defects machined one in the HAZ and 2 in the base material	565°C	Static pressure p=15MPa p=17.5MPa	5.88kH 4.32kH	Thermocouples, DC-PD gauges Capacitance gauges	Le Mat Hamata & Shibli (a) Int. J. Pres. Vess. & Piping, 78, 819-826 2001. (b) Int. J. Pres. Vess. & Piping, 778, 827-836 2001.	R5, BS7910
						Cyclic pressure p= 0 - 17.5MPa p= 0 - 20MPa freq=10 ⁻⁴	4.62kH-1540cycl 1.60kH -533cycl			
36	Bainitic	HIDA seam-welded straight pipe	P91 Parent & welds	3 spark machined defects, one in the HAZ and two in the base material	625°C	Static pressure p=15MPa	1.43kH	Thermocouples, DC-PD gauges Capacitance gauges	Le Mat Hamata & Shibli (a) Int. J. Pres. Vess. & Piping, 78, 819-826 2001. (b) Int. J. Pres. Vess. & Piping, 778, 827-836 2001.	R5, BS7911
						Cyclic pressure p= 0 - 11MPa freq=10 ⁻⁴	5.55kH -1850cycl			