

REFERENCE COMPILATION OF PARENT MATERIAL STRESS RUPTURE PROPERTIES FOR CONFORMITY ASSESSMENT OF WELDING CONSUMABLES

*Edited by: S R Holdsworth, European Creep Collaborative Committee (ECCC)*¹

Dr Stuart Holdsworth has worked with the European Creep Collaborative Committee since its foundation in 1991. He is Convenor of the WG1 working group (Data Generation and Assessment Procedures) and is a member of the Management Board. Dr Holdsworth has worked for ALSTOM Power (and its UK predecessor companies) since 1974 with a focus on R&D to establish and exploit the fracture properties of low and high temperature turbine materials and their interaction with microstructure and damage mechanism.

Abstract

Short duration creep-rupture strength values are reviewed for a wide range of carbon, carbon-manganese, low and high alloy ferritic, and low and high alloy austenitic steels. Tabulations provide a reference compilation of parent material stress rupture properties for conformity assessment of welding consumables and other purposes.

Background

Long duration creep-rupture strength values for a wide range of engineering steels, i.e. for $t_u \geq 10\text{kh}$, are given in a number of published documents, e.g. [1,2].² The purpose of this review is to provide a reference source of short duration creep rupture strength values, i.e. for $t_u \leq 10\text{kh}$. The collated strength values mainly originate from the $t_u^*(T, S)$ dataset assessment equations given in the ECCC Data Sheet compilation [1], but with additional and complementary information from BS-PD6525 [2].

The $R_{u/1\text{kh}/T}$ and $R_{u/10\text{kh}/T}$ rupture strength tabulations are primarily prepared for use in conjunction with the European Standard:

EN 14532-2 Welding consumables: Testing methods and quality requirements – Supplementary methods and conformity assessment of consumables for steel, nickel and nickel alloys.

The strength values provide a suitable source of reference data on parent materials for comparison with the stress rupture data to be obtained on the weld metals deposited using welding consumables for which conformity assessment is required for application in the creep range [3].

¹ Background information concerning the European Creep Collaborative Committee (ECCC) is given in Appendix A

² A list of symbols and their units is given in the Nomenclature

The steels for which rupture strength values have been tabulated are listed in Tables 1a to 1d with details of their chemical composition and room temperature tensile properties.

The 1kh and 10kh mean parent material creep rupture strength values are listed as a function of temperature for:

- i) carbon, carbon-manganese and low alloy ferritic steels (Tables 2a-c),
- ii) 5-12%Cr steels (Table 3),
- iii) Cr-Ni austenitic steels (Tables 4a-d), and
- iv) Ni-Cr austenitic steels (Table 5).

The tabulated $R_{u/1kh/T}$ and $R_{u/10kh/T}$ strength values may be used for purposes other than the conformity assessment of welding consumables.

References

- 1 ECCC Data Sheets, 1999, 'Rupture strength, creep strength and relaxation strength values for carbon-manganese, low alloy ferritic, high alloy ferritic and austenitic steels, and high temperature bolting steels/alloys', European Creep Collaborative Committee.
- 2 BS-PD6525, 1990, 'Elevated temperature properties for steels for pressure purposes, Part 1. Stress rupture properties', British Standards Institution, Issue 2, February 1994.
- 3 Allen, D.J., 2003, 'Guidance notes for the new European Standard EN 14532-2 on conformity assessment of high temperature welding consumables', OMMI www.ommi.co.uk (Vol. 2, Issue 3, December 2003)
- 4 EN 10027-1, 1992, 'Designation systems for steel - Part 1: Steel names, principal symbols', European Standard

Nomenclature

<i>TERM</i>	<i>UNITS</i>	<i>DETAILS</i>
R_M	MPa	tensile strength (room temperature)
$R_{P,0.2}$	MPa	0.2% proof strength (room temperature)
$R_{u/tT}$	MPa	rupture strength for a given time and temperature,
T	°C	temperature
t, t_u, t_u^*	h	time, observed time to rupture, predicted time to rupture
s	MPa	stress

Table 1a List of steels for which $R_{u/1kh/T}$ and $R_{u/10kh/T}$ are tabulated: Carbon, carbon-manganese and low alloy ferritic steels (see Table 2)

STEEL TYPE	EUROPEAN DESIGNATIONS [4]			C %	Si %	Mn %	P %	S %	Cr %	Mo %	Ni %	V %	Nb %	Al %	Cu %	Ti %	B %	Sn %	R _{P,0.2} MPa	R _M MPa	
C semi and Si killed	C7 - C24		max	0.25	0.35	1.40	0.045	0.045													
			min	-	-	0.40	-	-													
C Si and Al killed	P195		max	0.13	0.35	0.70	0.030	0.025	0.30	0.08	0.30	0.02	0.010	-	0.30	0.030				-	440
			min	-	-	-	-	-	-	-	-	-	-	0.020	-	-				195	320
C Si and Al killed	P235		max	0.16	0.35	1.20	0.030	0.025	0.30	0.08	0.30	0.02	0.010	-	0.30	0.030				-	500
			min	-	-	-	-	-	-	-	-	-	-	0.020	-	-				235	360
C Si and Al killed	P265		max	0.20	0.40	1.40	0.030	0.025	0.30	0.08	0.30	0.02	0.010	-	0.30	0.030				-	570
			min	-	-	-	-	-	-	-	-	-	-	0.020	-	-				265	410
C-Mn	P355		max	0.22	0.35	1.50	0.030	0.025						0.10	0.060					-	650
			min	-	0.15	1.00	-	-						0.015	-					355	500
0.3%Mo	16Mo3		max	0.20	0.35	0.80	0.030	0.025		0.35					0.040					-	600
			min	0.12	0.15	0.40	-	-		0.25										280	450
MoB	8MoB5-4		max	0.10	0.35	0.80	0.020	0.025	0.20	0.50					0.060		0.060	0.006		-	690
			min	0.06	0.10	0.60	-	-	-	0.40							-	0.002		400	540
0.5% Mo	17Mo5		max	0.25	0.40	0.90	0.040	0.040		0.65					0.012					-	
			min	-	0.15	-	-	-	-	0.45											
NiCrMoV	13NiMoV4-2		max	0.14	0.40	1.40	0.025	0.015	0.70	0.30	1.00	0.12									
			min	-	-	1.00	-	-	0.40	0.24	0.6	0.04									
MnCrMoV	15MnCrMoV5-3		max	0.17	0.40	1.50	0.040	0.040	1.00	0.35	0.80	0.12			0.020	0.30					
			min	-	-	1.00	-	-	0.40	0.20	-	0.04				-	-				
1NiMoCuNb	9NiMoCuNb5-6-4		max	0.17	0.50	1.20	0.030	0.025	0.30	0.50	1.30			0.045	0.050	0.80				-	780
			min	-	0.25	0.80	-	-	-	0.25	1.00			0.015	-	0.50				440	610
½Cr½Mo½V	12MoCrV6-2-2		max	0.15	0.35	0.70	0.030	0.025	0.60	0.70		0.28			0.040					-	610
			min	0.10	0.15	0.40	-	-	0.30	0.50		0.22								320	470
1CrMo	25CrMo4		max	0.29	0.40	0.90	0.035	0.030	1.20	0.30					0.040					-	690
			min	0.22	-	0.60	-	-	0.90	0.15										345	540
1%CrMo (Norm)	13CrMo4-5+N		max	0.18	0.40	0.70	0.040	0.040	1.20	0.65	0.30				0.020	0.30			0.03		
			min	-	0.10	0.40	-	-	0.70	0.45	-						-			-	
1%CrMo / 1¼%CrMo (Norm, +T)	13CrMo4-5/5-5+NT		max	0.17	0.35	0.70	0.030	0.025	1.10	0.65					0.040					-	590
			min	0.10	0.15	0.40	-	-	0.07	0.45										290	440
0.4%C1¼%CrMoV	40CrMo5-6+NT		max	0.45	0.35	0.70	0.035	0.040	1.50	0.70	0.40										
			min	0.35	0.10	0.40	-	-	-	0.50	-										
Durehete 900	42CrMo5-6	1.7233	max	0.45	0.40	0.75	0.035	0.035	1.50	0.70	0.29				0.026					-	1000
			min	0.39	-	0.40	-	-	1.20	0.50	0.09					0.004				640	850
1CrMoV	21CrMoV5-7	1.7709	max	0.27	0.43	0.84	0.035	0.035	1.55	0.85	0.63	0.38								-	850
			min	0.16	-	0.36	-	-	1.15	0.52	-	0.15								550	700
Durehete 1055	20CrMoVTiB4-10	1.7729	max	0.23	0.40	0.75	0.020	0.020	1.20	1.10	0.20	0.80			0.080	0.20	0.15	0.010	0.020	-	1000
			min	0.17	-	0.35	-	-	0.90	0.90	-	0.60			0.015	-	0.07	0.001	-	660	820

Table 1a continued

STEEL TYPE	EUROPEAN DESIGNATIONS [4]		C %	Si %	Mn %	P %	S %	Cr %	Mo %	Ni %	V %	Nb %	Al %	Cu %	Ti %	B %	Sn %	R _{P,0.2} MPa	R _M MPa
2¼%CrMo (Annealed)	11CrMo9-10	max	0.18	0.50	0.80	0.040	0.040	2.50	1.20				0.020						
		min	-	-	0.30	-	-	2.00	0.90				-						
2¼%CrMo (Norm. +T<720°C)	11CrMo9-10+NT1	max	0.18	0.50	0.80	0.040	0.040	2.50	1.20	0.30			0.020	0.30			0.030		
		min	-	-	0.30	-	-	2.00	0.90	-			-	-			-		
2¼%CrMo (Norm. +T<750°C)	11CrMo9-10+NT2	max	0.15	0.40	0.70	0.030	0.025	2.50	1.20				0.040					-	630
		min	0.08	0.15	0.30	-	-	2.00	0.90				-					280	480
2¼Cr1Mo (quenched + tempered)	11CrMo9-10+QT	max	0.15	0.40	0.70	0.030	0.025	2.50	1.20				0.040					-	620
		min	0.08	0.15	0.30	-	-	2.00	0.90				-					355	540
3CrMoV	20CrMoV13-5	max	0.23	0.35	0.50	0.020	0.020	3.30	0.60		0.55		0.040					-	880
		min	0.17	0.15	0.30	-	-	3.00	0.50		0.45		-					590	740

Table 1b List of steels for which $R_{u/1kh/T}$ and $R_{u/10kh/T}$ are tabulated: 5-12%Cr steels (see Table 3)

STEEL TYPE	EUROPEAN DESIGNATIONS [4]		C %	Si %	Mn %	P %	S %	Cr %	Mo %	W %	Ni %	V %	Nb %	Al %	N %	Cu %	B %	R _{P,0.2} MPa	R _M MPa
5CrMo (annealed)	X11CrMo5+I	max	0.15	0.50	0.60	0.030	0.025	6.00	0.65					0.040				-	580
		min	0.08	0.15	0.30	-	-	4.00	0.45					-				175	430
5CrMo (normalised + tempered)	X11CrMo5+NT1	max	0.15	0.50	0.60	0.030	0.025	6.00	0.65					0.040				-	640
		min	0.08	0.15	0.30	-	-	4.00	0.45					-				280	480
5CrMo (normalised + tempered)	X11CrMo5+NT2	max	0.15	0.50	0.60	0.030	0.025	6.00	0.65					0.040				-	740
		min	0.08	0.15	0.30	-	-	4.00	0.45					-				390	570
9Cr1Mo (annealed 890-950°C)	X11CrMo9-1+1	max	0.15	1.00	0.60	0.030	0.025	10.00	1.10					0.040				-	620
		min	0.08	0.25	0.30	-	-	8.00	0.90					-				185	410
9Cr1Mo (annealed 950-980°C)	X11CrMo9-1+2	max	0.15	1.00	0.60	0.030	0.025	10.00	1.10					0.040				-	640
		min	0.08	0.25	0.30	-	-	8.00	0.90					-				210	460
9Cr1Mo (normalised + tempered)	X11CrMo9-1+NT	max	0.15	1.00	0.60	0.030	0.025	10.00	1.10					0.040				-	740
		min	0.08	0.25	0.30	-	-	8.00	0.90					-				390	590
Steel 91 (P91/T91)	X10CrMoVNb9-1	max	0.12	0.50	0.60	0.020	0.010	9.50	1.05		0.40	0.25	0.10	0.040	0.070			-	830
		min	0.08	0.20	0.30	-	-	8.00	0.85		-	0.18	0.06	-	0.030			450	630
E911	X10CrMoWVNb9-1-1	max	0.13	0.50	0.60	0.020	0.010	9.50	1.10	1.10	0.4	0.25	0.10	0.040	0.090		0.0050	-	850
		min	0.09	0.10	0.30	-	-	8.50	0.90	0.90	0.1	0.18	0.06	-	0.050		0.0005	450	620
ASTM Grade 92 (P92/T92)	X10CrMoWVNb9-2-2	max	0.13	0.50	0.60	0.020	0.010	9.50	0.60	2.00	0.40	0.25	0.09	0.040	0.070		0.006	-	-
		min	0.07	-	0.30	-	-	8.50	0.30	1.50	-	0.15	0.04	-	0.030		0.001	440	620
12CrMoV	X20CrMoNiV11-1	max	0.23	0.50	1.00	0.030	0.025	12.50	1.20		0.80	0.55		0.040				-	840
		min	0.17	0.15	-	-	-	10.00	0.80		0.30	0.45		-				490	690

Table 1c List of steels for which $R_{u/1kh/T}$ and $R_{u/10kh/T}$ are tabulated: Cr-Ni austenitic steels (see Table 4)

STEEL TYPE	EUROPEAN DESIGNATIONS [4]			C %	Si %	Mn %	P %	S %	Cr %	Mo %	Ni %	V %	Nb %	N %	Cu %	Ti %	Co (Ce) %	B %	R _{P,0.2} MPa	R _m MPa	
Essshete 1250	X10CrNiMoMnNbVB15-10-1	1.4982	max	0.15	1.00	7.00	0.040	0.030	16.0	1.20	11.0	0.40	1.25					0.009	-	740	
			min	0.06	0.20	5.50	-	-	14.0	0.80	9.0	0.15	0.75						0.003	220	540
18%Cr8%Ni (Type 304H)	X6CrNi18-10	1.4948	max	0.08	1.00	2.00	0.045	0.015	19.0		11.0			0.11					-	710	
			min	0.04	-	-	-	-	17.0		8.0			-						190	510
18%Cr8%NiN	X4CrNiN18-10		max	0.10	1.00	2.00	0.045	0.030	19.0		12.0		0.05								
			min	0.06	-	-	-	-	17.0		8.0		-								
Type 304 LN	X2CrNiN18-10	1.4311	max	0.030	1.00	2.00	0.045	0.015	19.5		11.5			0.22					-	750	
			min	-	-	-	-	-	17.0		8.5			0.11						270	550
Type 304L	X2CrNi18-9	1.4307	max	0.030	1.00	2.00	0.045	0.015	19.5		10.0			0.11					-	680	
			min	-	-	-	-	-	17.5		8.0			-						175	450
18%Cr12%NiMo (Type 316)	X5CrNiMo17-12-2	1.4401	max	0.07	1.00	2.00	0.045	0.015	18.5	2.50	13.0			0.11					-	700	
			min	-	-	-	-	-	16.5	2.00	10.0			-						200	500
18%Cr12%NiMoB	X5CrNiMoB17-13-3		max	0.10	1.00	2.00	0.045	0.030	18.5	3.00	15.0							0.006			
			min	-	-	-	-	-	16.0	2.00	10.0								0.002		
Type 316L	X2CrNiMo17-12-2	1.4404	max	0.03	1.00	2.00	0.045	0.015	18.5	2.50	13.0			0.11					-	700	
			min	-	-	-	-	-	16.5	2.00	10.0			-						200	500
Type 316 LNB	X3CrNiMoBN17-13-3	1.4910	max	0.04	0.75	2.00	0.035	0.025	18.0	3.00	14.0			0.18				0.0050	-	750	
			min	-	-	-	-	-	16.0	2.00	12.0			0.10					0.0015	260	550
18%Cr12%NiMoN	X3CrNiMoN17-12-3		max	.07	1.00	2.00	0.045	0.030	19.0	3.00	14.5			0.22							
			min	-	-	-	-	-	16.5	2.00	10.0			0.12							
Type 316 LN	X2CrNiMoN17-13-3	1.4429	max	0.030	1.00	2.00	0.045	0.015	18.5	3.0	14.0			0.22					-	800	
			min	-	-	-	-	-	16.5	2.5	11.0			0.12						280	580
Type 316 L(N)	X2CrNiMo17-12-2	1.4909	max	0.030	0.50	2.00	0.035	0.025	18.0	2.7	12.5			0.080	1.00		0.25	0.0020	-	-	
			min	-	-	1.60	-	-	17.0	2.3	12.0			0.060	-		-	-	220	525	
Type 316 Ti	X6CrNiMoTi17-12-2	1.4571	max	0.08	1.00	2.00	0.045	0.015	18.5	2.5	13.5					0.70			-	700	
			min	-	-	-	-	-	16.5	2.0	10.5					5x %C				200	500
Type 321H, SA 950-1070°C	X7CrNiTi18-10	1.4941	max	0.08	1.00	2.00	0.035	0.015	19.0	0.60	12.0							0.0050			
			min	0.04	-	-	-	-	17.0	-	9.0					5x %C			0.0015		
Type 321H, SA 1070-1150°C	X7CrNiTi18-10	1.4941	max	0.08	1.00	2.00	0.035	0.015	19.0	0.60	12.0					0.80		0.0050	-	700	
			min	0.04	-	-	-	-	17.0	-	9.0					5x %C			0.0015	200	500
Type 347, SA 950-1070°C	X6CrNiNb18-10	1.4550	max	0.08	1.00	2.00	0.045	0.015	19.0		12.0		1.00						-	700	
			min	-	-	-	-	-	17.0		9.0		10x %C							200	500
Type 347, SA 1070-1125°C	X6CrNiNb18-10	1.4550	max	0.08	1.00	2.00	0.045	0.015	19.0		12.0		1.00						-	700	
			min	-	-	-	-	-	17.0		9.0		10x %C							200	500
18%Cr10%NiNbN	X5CrNiNbN18-10		max	0.08	1.00	2.00	0.045	0.030	19.0		12.0		1.00	0.25							
			min	-	0.20	0.50	-	-	17.0		9.0		10x %C	0.15							
15%Cr10%Ni6%MnNbV	X10CrNiMnNbV15-10-6-1		max	0.15	1.00	7.00	0.040	0.030	16.0	1.20	11.0	0.40	1.25						0.009		
			min	0.06	0.20	5.50	-	-	14.0	0.80	9.0	0.15	0.75							0.003	
16%Cr16%NiMoNb	X7CrNiMnNbV16-16-2-1		max	0.09	1.00	2.00	0.030	0.030	17.5	2.50	18.0		1.25								
			min	0.03	-	-	-	-	15.5	1.50	15.0		0.50								
253MA	X7CrNiSiNCe21-11		max	0.10	2.0	0.80	0.040	0.030	22.0		12.0				0.20			(0.08)		-	850
			min	0.05	1.4	-	-	-	20.0		10.0				0.14			(0.03)		295	640
BS1503 310S31 (Type 310)	X15CrNi25-21		max	0.15	1.50	2.00	0.045	0.030	26.0		22.0									-	710
			min	-	-	-	-	-	23.0		19.0										240

Table 1d List of steels for which $R_{w/1kh/T}$ and $R_{w/10kh/T}$ are tabulated: Ni-Cr austenitic steels (see Table 5)

STEEL TYPE	EUROPEAN DESIGNATIONS [4]			C %	Si %	Mn %	P %	S %	Cr %	Mo %	Ni %	Nb %	Al %	N %	Cu %	Ti %	Co %	Ce %	R _{P,0.2} MPa	R _M MPa
Alloy 800, solution annealed	X5NiCrAlTi31-20	1.4958	max	0.08	0.70	1.50	0.015	0.010	22.0		32.5	0.10	0.50	0.030	0.50	0.50	0.50		-	750
			min	0.03	-	-	-	-	19.0		30.0	-	0.20	-	-	0.20	-		170	500
Alloy 800, recrystallised	X5NiCrAlTi31-20 RK		max	0.08	0.70	1.50	0.015	0.010	22.0		32.5	0.10	0.50	0.030	0.50	0.50	0.50		-	750
			min	0.03	-	-	-	-	19.0		30.0	-	0.20	-	-	0.20	-		210	500
Alloy 800H solution annealed	X8NiCrAlTi32-21	1.4959	max	0.10	0.70	1.50	0.015	0.010	22.0		34.0		0.65	0.030	0.50	0.65	0.50		-	750
			min	0.05	-	-	-	-	19.0		30.0		0.25	-	-	0.25	-		170	500
Alloy 800HT, restricted Al + Ti	X8NiCrAlTi32-21		max	0.10	0.70	1.50	0.015	0.010	22.0		34.0		0.65	0.030	0.50	0.65	0.50		-	750
			min	0.05	-	-	-	-	19.0		30.0		0.25	-	-	0.25	-		170	500
AC 66	X6NiCrNbCe32-27	1.4877	max	0.08	0.30	1.00	0.020	0.010	28.0		33.0	1.00	0.025	0.110			(0.10)	0.10	-	750
			min	0.04	-	-	-	-	26.0		31.0	0.60	-	-			(0.05)	0.05	180	500

Table 2b Short duration creep rupture strength values for carbon, carbon-manganese and low alloy ferritic steels

STEEL TYPE	EUROPEAN DESIGNATIONS [4]	Ref	TEMP	380°C	390°C	400°C	410°C	420°C	430°C	440°C	450°C	460°C	470°C	480°C	490°C	500°C	510°C	520°C	530°C	540°C	
½Cr½Mo¼V	12MoCrV6-2-2		1	1kh							441	417	393	370	346	323	300	278	256	234	
			1	10kh							377	349	324	298	274	249	225	203	181	162	
1CrMo	25CrMo4		1	1kh				-	-	-	-	-	-	-	-	-	-	-	-	-	-
			1	10kh					387	364	338	311	283	255	226	200	176	153	133	114	95
1%CrMo (Norm)	13CrMo4-5+N		2	1kh							481	446	413	380	349	319	289	261	234	209	
			2	10kh							406	368	332	297	264	232	202	174	149	126	
1%CrMo / 1¼%CrMo (Norm, +T)	13CrMo4-5/5-5+NT		2	1kh							455	423	393	365	337	310	285	260	236	212	
			2	10kh							373	343	315	287	261	235	210	185	160	136	
0.4%C1¼%CrMoV	40CrMo5-6+NT		2	1kh							590	548	508	476	440	405	373	340	303	270	
			2	10kh							534	489	447	406	366	324	283	245	213	186	
Durehete 900	42CrMo5-6	1.7233	2	1kh							565	528	489	448	405	360	315	272	234	201	
			1	10kh							495	450	399	342	281	229	190	160	137	118	
1CrMoV	21CrMoV5-7	1.7709	1	1kh				532	511	489	467	445	423	400	377	355	332	309	286	262	
			1	10kh				466	443	420	396	373	349	325	301	277	253	228	204	180	
Durehete 1055	20CrMoVTiB4-10	1.7729	1	1kh							578	549	521	495	471	448	426	405	384	363	
			1	10kh							520	491	463	437	412	388	364	340	315	289	

STEEL TYPE	EUROPEAN DESIGNATIONS [4]	Ref	TEMP	550°C	560°C	570°C	580°C	590°C	600°C	610°C	620°C	630°C	
½Cr½Mo¼V	12MoCrV6-2-2		1	1kh	213	193	175	157	140	125			
			1	10kh	143	126	112	97	85	74			
1CrMo	25CrMo4		1	1kh	-								
			1	10kh	79								
1%CrMo (Norm)	13CrMo4-5+N		2	1kh	185	162	141	122	105	90	77	66	
			2	10kh	105	88	73	61	52	44	38	33	
1%CrMo / 1¼%CrMo (Norm, +T)	13CrMo4-5/5-5+NT		2	1kh	189	165	142	119	97	77	61	50	43
			2	10kh	112	88	69	55	46	39	35	31	20
0.4%C1¼%CrMoV	40CrMo5-6+NT		2	1kh	241								
			2	10kh	151								
Durehete 900	42CrMo5-6	1.7233	2	1kh	175								
			1	10kh	99								
1CrMoV	21CrMoV5-7	1.7709	1	1kh	239								
			1	10kh	157								
Durehete 1055	20CrMoVTiB4-10	1.7729	1	1kh	342	321	299	275	251	224			
			1	10kh	261	231	200	170	146	127			

Table 2c Short duration creep rupture strength values for carbon, carbon-manganese and low alloy ferritic steels

STEEL TYPE	EUROPEAN DESIGNATIONS [4]	Ref	TEMP	380°C	390°C	400°C	410°C	420°C	430°C	440°C	450°C	460°C	470°C	480°C	490°C	500°C	510°C	520°C	530°C	540°C	
2¼%CrMo (Annealed)	11CrM09-10		2	1kh											250	232	216	201	187	174	161
			2	10kh								251*	236*	221	206	191	177	162	147	133	121
2¼%CrMo (Norm. +T<720°C)	11CrM09-10+NT1		2	1kh										325	300	277	255	236	217	199	182
			2	10kh										275	251	228	207	188	169	151	134
2¼%CrMo (Norm. +T<750°C)	11CrM09-10+NT2		2	1kh										330	300	273	250	228	209	191	175
			1	10kh								308	284	261	238	216	195	176	158	142	126
2¼Cr1Mo (quenched + tempered)	11CrMo9-10+QT		1	1kh			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			1	10kh			382	355	333	312	294	276	259	242	225	208	191	174	157	-	-
3CrMoV	20CrMoV13-5		1	1kh				-	-	-	-	-	-	-	-	-	-	-	-	-	-
			1	10kh					470	440	410	360	310	270	240	210	186	169	152	134	117

STEEL TYPE	EUROPEAN DESIGNATIONS [4]	Ref	TEMP	550°C	560°C	570°C	580°C	590°C	600°C	610°C	620°C	630°C
2¼%CrMo (Annealed)	11CrM09-10		2	1kh	149	136	124	112	101	92		
			2	10kh	108	96	85	76	68	61		
2¼%CrMo (Norm. +T<720°C)	11CrM09-10+NT1		2	1kh	166	151	137	123	110	99	89	
			2	10kh	119	105	92	82	72	63	54	
2¼%CrMo (Norm. +T<750°C)	11CrM09-10+NT2		2	1kh	160	146	134	122	110	100	90	
			1	10kh	111	99	88	78	69	60		
2¼Cr1Mo (quenched + tempered)	11CrMo9-10+QT		1	1kh								
			1	10kh								
3CrMoV	20CrMoV13-5		1	1kh	-							
			1	10kh	98							

Table 3 Short duration creep rupture strength values for 5-12%Cr steels

STEEL TYPE	EUROPEAN DESIGNATIONS [4]	Ref	TEMP	450°C	460°C	470°C	480°C	490°C	500°C	510°C	520°C	530°C	540°C	550°C	560°C	570°C	580°C	590°C	600°C	610°C	
5CrMo (annealed)	X11CrMo5+I		2	1kh	-	230	212	199	181	169	152	143	132	121	112	103	94	86	78	70	64
			1	10kh	196	180	166	152	140	128	116	105	95	85	77	69	63	56	50	45	41
5CrMo (normalised + tempered)	X11CrMo5+NT1, +NT2		2	1kh	-	-	-	261	221	196	172	156	140	128	113	102	92	82	74	66	
			1	10kh			242	215	188	164	145	128	113	100	88	78	69	60	53	46	40
9Cr1Mo (annealed 890-950°C)	X11CrMo9-1+I1		2	1kh	323	294	268	244	223	203	184	167	151	136	122	110	98	88	80	72	65
			1	10kh	278	250	226	203	182	163	145	129	114	101	89	79	71	63	57	52	47
9Cr1Mo (annealed 950-980°C)	X11CrMo9-1+I2		1	1kh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			1	10kh		275	240	210	190	170	152	134	118	104	90	78	68	60	53	48	
9Cr1Mo (normalised + tempered)	X11CrMo9-1+NT		2	1kh	425	386	351	320	293	268	245	225	206	188	172	156	142	128	115	102	90
			1	10kh	335	308	284	261	239	219	200	182	164	148	132	117	102	89	77	65	55
Steel 91 (P91/T91)	X10CrMoVNb9-1		2	1kh					335	317	299	281	264	247	231	215	200	184	170	155	142
			1	10kh						289	271	252	234	216	199	182	166	151	136	123	110
E911	X10CrMoWVNb9-1-1		1	1kh									271	257	243	229	216	202	189	176	163
			1	10kh										236	222	207	193	179	166	152	139
ASTM Grade 92 (P92/T92)	X10CrMoWVNb9-2-2		1	1kh											262	247	232	218	203	189	175
			1	10kh												229	214	199	184	170	156
12CrMoV	X20CrMoNiV11-1		2	1kh				403	370	339	312	287	264	242	221	202	184	167	150	134	120
			1	10kh					348	319	292	269	247	225	205	184	165	147	130	113	97

STEEL TYPE	EUROPEAN DESIGNATIONS [4]	Ref	TEMP	620°C	630°C	640°C	650°C	660°C	670°C	680°C	
5CrMo (annealed)	X11CrMo5+I		2	1kh	57	52					
			1	10kh	37	33					
5CrMo (normalised + tempered)	X11CrMo5+NT1, +NT2		2	1kh	59						
			1	10kh	36						
9Cr1Mo (annealed 890-950°C)	X11CrMo9-1+I1		2	1kh	60	54	50				
			1	10kh	43	39	35				
9Cr1Mo (annealed 950-980°C)	X11CrMo9-1+I2		1	1kh							
			1	10kh							
9Cr1Mo (normalised + tempered)	X11CrMo9-1+NT		2	1kh	78	67	57	48			
			1	10kh	47	40	34	30			
Steel 91 (P91/T91)	X10CrMoVNb9-1		2	1kh	128	116	105	94	84	76	
			1	10kh	99	89	79	70	62	55	
E911	X10CrMoWVNb9-1-1		1	1kh	150	138	125	113	101	90	
			1	10kh	113	100	88	76	65	54	
ASTM Grade 92 (P92/T92)	X10CrMoWVNb9-2-2		1	1kh	162	149	136	124	112	101	90
			1	10kh	129	116	104	92	81	71	62
12CrMoV	X20CrMoNiV11-1		2	1kh	106	94	82	73			
			1	10kh	72	61	52	44			

Table 4b Short duration creep rupture strength values for Cr-Ni austenitic steels

STEEL TYPE	EUROPEAN DESIGNATIONS [4]	Ref	TEMP	500°C	510°C	520°C	530°C	540°C	550°C	560°C	570°C	580°C	590°C	600°C	610°C	620°C	630°C	640°C	650°C	660°C		
18%Cr12%NiMo (Type 316)	X5CrNiMo17-12-2	1.4401	1 1kh	412	390	370	350	330	312	293	276	259	243	227	212	197	184	171	158	147		
			1 10kh	344	323	303	284	265	247	230	213	198	183	168	155	142	130	119	109	99		
18%Cr12%NiMoB	X5CrNiMoB17-13-3		2 1kh					345	320	301	282	265	250	234	221	209	195	182	171	160		
			2 10kh					268	251	236	222	208	195	183	171	159	147	135	124	112		
Type 316L	X2CrNiMo17-12-2	1.4404	1 1kh	380	359	339	320	301	283	266	250	234	219	205	191	178	166	155	144	133		
			1 10kh	321	300	281	262	245	228	211	196	181	168	155	142	131	120	110	101	92		
Type 316 LNB	X3CrNiMoBN17-13-3	1.4910	1 1kh						-	-	-	-	-	-	-	-	-	-	-	-		
			1 10kh						290	272	254	237	220	205	190	174	162	148	135	122		
18%Cr12%NiMoN	X3CrNiMoN17-12-3		2 1kh				412	386	365	345	328	311	296	281	267	254	240	227	214	202		
			2 10kh				349	329	311	294	278	262	247	233	218	204	189	175	159	142		
Type 316 LN	X2CrNiMoN17-13-3	1.4429	1 1kh						-	-	-	-	-	-	-	-	-	-	-	-		
			1 10kh						300	284	267	250	236	221	205	189	173	157	143	128		
Type 316 L(N)	X2CrNiMo17-12-2	1.4909	1 1kh	468	441	415	390	366	343	322	301	281	263	245	228	212	197	182	169	156		
			1 10kh	386	361	338	316	295	275	255	237	220	204	189	174	160	147	135	124	113		
Type 316 Ti	X6CrNiMoTi17-12-2	1.4571	1 1kh											259	243	227	212	197	184	171	158	147
			1 10kh												198	183	168	155	142	130	119	109

STEEL TYPE	EUROPEAN DESIGNATIONS [4]	Ref	TEMP	670°C	680°C	690°C	700°C	710°C	720°C	730°C	740°C	750°C	760°C	770°C	780°C	790°C	800°C	810°C	820°C	830°C
18%Cr12%NiMo (Type 316)	X5CrNiMo17-12-2	1.4401	1 1kh	136	125	115	106	98	90	83	76	70	64	59	54	49	45	41	38	
			1 10kh	90	82	75	68	61	56	50	46	41	37	34	31	28	25	23	21	
18%Cr12%NiMoB	X5CrNiMoB17-13-3		2 1kh	149	137	126	115	103	93	83										
			2 10kh	101	90	80	71	65	60	56										
Type 316L	X2CrNiMo17-12-2	1.4404	1 1kh	124	115	106	98													
			1 10kh	84	77	70	64													
Type 316 LNB	X3CrNiMoBN17-13-3	1.4910	1 1kh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			1 10kh	112	102	93	84	78	71	65	58	52	48	44	41	37	33			
18%Cr12%NiMoN	X3CrNiMoN17-12-3		2 1kh	188																
			2 10kh	122																
Type 316 LN	X2CrNiMoN17-13-3	1.4429	1 1kh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			1 10kh	115	102	90	78	69	62	54	48	42								
Type 316 L(N)	X2CrNiMo17-12-2	1.4909	1 1kh	144	132	121	111	101	92	83	75	67								
			1 10kh	102	93	84	75	67	60	53	48	40								
Type 316 Ti	X6CrNiMoTi17-12-2	1.4571	1 1kh	136	125	115	106	98	90	83	76	70	64	59	54	49	45	41	38	
			1 10kh	90	82	75	68	61	56	50	46	41	37	34	31	28	25	23	21	

Table 4c Short duration creep rupture strength values for Cr-Ni austenitic steels

STEEL TYPE	EUROPEAN DESIGNATIONS [4]	Ref	TEMP	500°C	510°C	520°C	530°C	540°C	550°C	560°C	570°C	580°C	590°C	600°C	610°C	620°C	630°C	640°C	650°C	660°C	
Type 321H, SA 950-1070°C	X7CrNiTi18-10	1.4941	1	1kh					297	279	262	246	230	215	201	188	175	163	151	139	129
			1	10kh					222	206	192	178	165	152	140	129	118	108	98	88	79
Type 321H, SA 1070-1150°C	X7CrNiTi18-10	1.4941	2	1kh					288	276	264	253	241	229	217	205	193	182	170	158	147
			1	10kh					230	220	210	190	170	160	140	130	120	110	100	90	
Type 347, SA 950-1070°C	X6CrNiNb18-10	1.4550	1	1kh					411	360	323	294	269	248	230	214	199	186	174	163	153
			1	10kh					258	236	218	202	187	174	162	151	140	131	121	113	104
Type 347, SA 1070-1125°C	X6CrNiNb18-10	1.4550	1	1kh					328	311	295	279	263	248	233	218	204	191	178	166	154
			1	10kh					253	237	221	206	192	178	166	154	142	132	122	112	104
18%Cr10%NiNbN	X5CrNiNbN18-10		2	1kh				387	370	353	336	318	301	283	266	248	231	215	199	185	171
			2	10kh				324	305	285	266	247	229	211	194	179	165	152	140	130	120
15%Cr10%Ni6%MnNbV	X10CrNiMnNbV15-10-6-1		2	1kh											273	266	258	250	242	232	223
			2	10kh												241	231	221	210	198	184
16%Cr16%NiMoNb	X7CrNiMnNbV16-16-2-1		2	1kh											270	255	237	222	210	198	184
			2	10kh												220	203	186	171	157	143

STEEL TYPE	EUROPEAN DESIGNATIONS [4]	Ref	TEMP	670°C	680°C	690°C	700°C	710°C	720°C	730°C	740°C	750°C	760°C	770°C	780°C	790°C	800°C	810°C	820°C	830°C	
Type 321H, SA 950-1070°C	X7CrNiTi18-10	1.4941	1	1kh	119	108	99	90	81	73											
			1	10kh	71	63	56	49	43	38											
Type 321H, SA 1070-1150°C	X7CrNiTi18-10	1.4941	2	1kh	136	125	115	106	98	90											
			1	10kh	82	74	66	60													
Type 347, SA 950-1070°C	X6CrNiNb18-10	1.4550	1	1kh	143	134	126	118	110												
			1	10kh	96	88	80	71	61												
Type 347, SA 1070-1125°C	X6CrNiNb18-10	1.4550	1	1kh	144	133	124	115	107	99	91										
			1	10kh	96	88	81	74	68	61	55										
18%Cr10%NiNbN	X5CrNiNbN18-10		2	1kh	159	148															
			2	10kh	110	100															
15%Cr10%Ni6%MnNbV	X10CrNiMnNbV15-10-6-1		2	1kh	212	201	188	173	155	134	112	94	81	72	65	59	54				
			2	10kh	147	124	102	86	75	67	61	55	51	46	42	38	34				
16%Cr16%NiMoNb	X7CrNiMnNbV16-16-2-1		2	1kh	173	160	150	139	128	118	108	100	90	83	76	70					
			2	10kh	120	109	99	90	82	75	68	61	55	50	45	40					

APPENDIX A

EUROPEAN CREEP COLLABORATIVE COMMITTEE

The European Creep Collaborative Committee (ECCC) is an industry led group comprising 44 organisations from 16 countries. The interests of material producers, plant manufacturers and end users are represented. ECCC was formed in 1991 to co-ordinate Europe-wide creep data generation, collation and assessment activities. In particular, the aim is to pool National data resources to provide the optimum basis for creep-rupture strength values for European Product and Design Standards.

During the period 1992-1996, ECCC concentrated its efforts on the creep-rupture properties of non-welded materials through EC funding support by means of the Concerted Action *CREEP* (BE5524). Focus switched to the consideration of properties for welded materials between 1997 and 2001 when EC support was provided by the *WELD-CREEP* Thematic Network BET2-0509 contract. The work undertaken in these projects resulted in the development and publication of *i*) extensive ECCC guidelines on data generation, exchange and assessment methods [A1] and *ii*) approved Data Sheets on a scale that had previously not been possible [1]. Current activity (2001-2005) is focused on achieving the objectives of the *ADVANCED-CREEP* project relating to the assessment of creep strain, creep ductility, multiaxiality and components.

Creep test programme co-ordination, data exchange/collation, data assessment and Data Sheet preparation is the responsibility of the alloy focused WG3x groups (Fig. A1). The strength values listed in Tables 2 to 5 are the result of the work of the WG3x groups. Technical support is provided by WG1 and its sub-groups. The main role of WG1 is to provide recommendations on procedures for data generation, collation and assessment to form the basis of common practices followed within ECCC [A1]. These recommendations are published and available to other users.

Further information may be obtained on www.etd1.co.uk/eccc/advancedcreep

Reference

- A1. ECCC Recommendations, 2001, 'Creep data validation and assessment procedures', Holdsworth, S.R. et al, eds., ERA Technol. publ., (a) Vol.1: Overview, (b) Vol.2: Terms and terminology, (c) Vol.3: Data acceptability criterion, (d) Vol.4: Data generation, Data exchange and collation, (e) Vol.5: Data assessment.

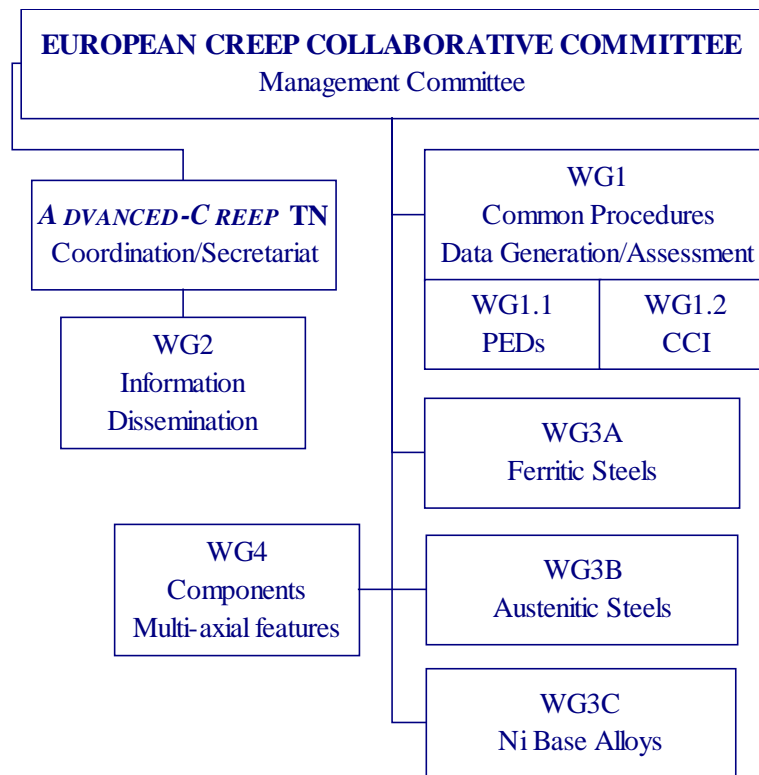


Fig. A1 Structure of European Creep Collaborative Committee (ECCC)