RCC-MRx

DESIGN AND CONSTRUCTION RULES FOR MECHANICAL COMPONENTS OF NUCLEAR INSTALLATIONS

2012 EDITION

1st Erratum – March 2016

afcen

French Association for Design, Construction, and In Service Inspection Rules for Nuclear Island Components

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NOTE TO THE USERS

This document proposes modifications which correspond to errors in the RCC-MRx 2012 English edition.

These errors have been detected through the preparation of the RCC-MRx 2015 Edition.

The corrections impact the irradiation border lines of 6061-T6 alloy and the associated S_{em} and S_{et} values.

The following pages (7 pages) have to be replaced:

- Section III - Tome 1 - Volume Z – Pages A3.2A 4/24, A3.2A 19/24, A3.2A 20/24, A3.2A 21/24, A3.2A 22/24, A3.2A 23/24 and A3.2A 24/24.

A3.2A.3 BORDER LINES

A3.2A.31 *NEGLIGIBLE CREEP AND THERMAL AGEING CURVES*

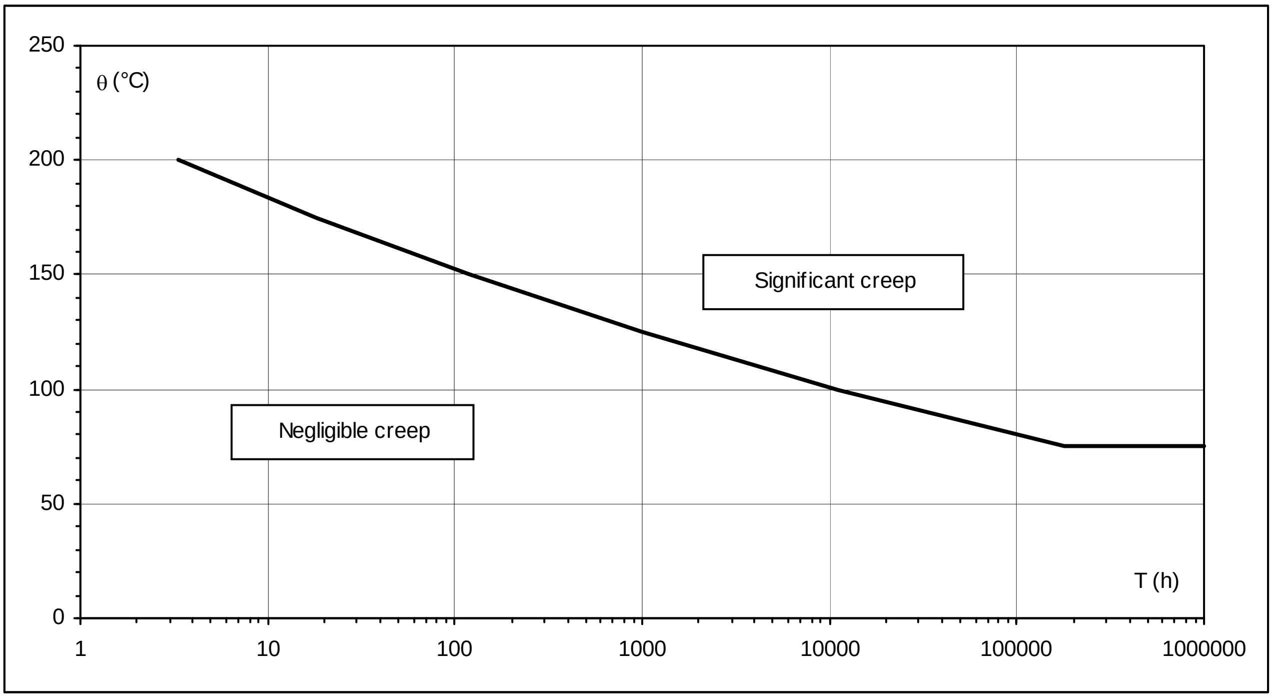
A3.2A.311 NEGLIGIBLE CREEP CURVE

For temperatures less than 75°C, creep is negligible whatever the holding time.
The maximum time T (h) which the structure may remain at temperature θ without creep becoming significant is given as a function of θ by the **table A3.2A.311** and the **figure A3.2A.311**.

Table A3.2A.311: negligible creep curve

θ (°C)	**75**	**100**	**125**	**150**	**175**	**200**
T (h)	$1.8.10^5$	11200	1000	119	18	3.3

Figure A3.2A.311: negligible creep curve



A3.2A.312 NEGLIGIBLE THERMAL AGEING CURVE

For temperatures less than 75°C, thermal ageing is negligible whatever the holding time.
The maximum time T (h) during which the structure can remain at temperature θ without significant thermal ageing is given, as a function of θ, using **Table A3.2A.51**.

A3.2A.32 *NEGLIGIBLE IRRADIATION CURVE*

Negligible irradiation fluences $\Phi_{ir.neg}$ are given as a function of temperature θ in the **table A3.2A.32** and the **figure A3.2A.32**. Irradiation fluence $\Phi_{ir.neg}$ is expressed using conventional thermal neutrons designated n_{th} (E = 0.0254 eV) per cm^2.

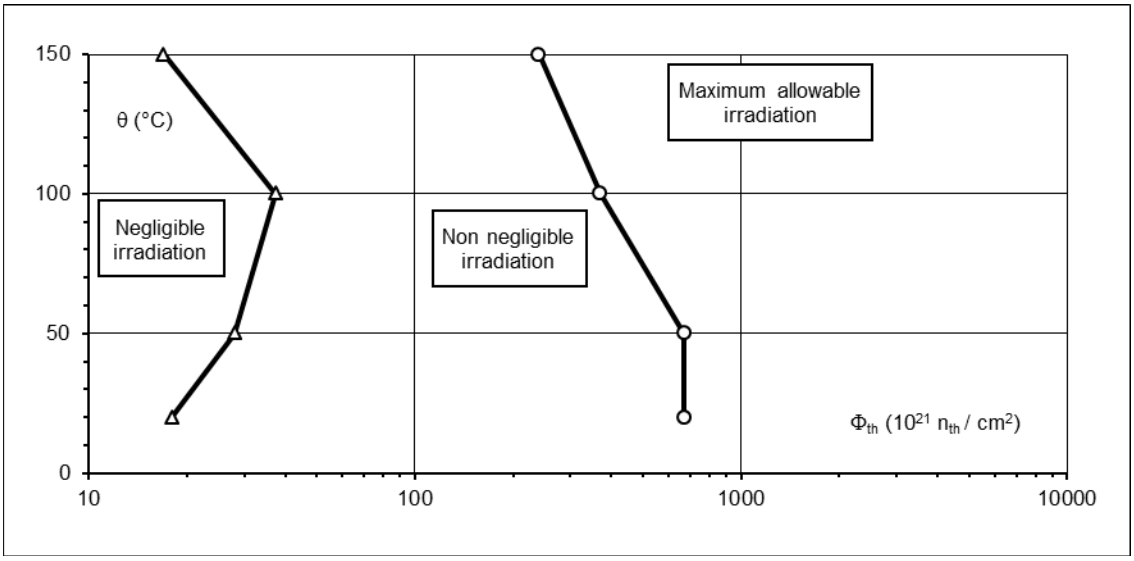
A3.2A.33 *MAXIMUM ALLOWABLE IRRADIATION*

Maximum allowable irradiation $\Phi_{ir.max}$ are given as a function of temperature θ in the **table A3.2A.32** and the **figure A3.2A.32**. Irradiation fluence $\Phi_{ir.max}$ is expressed using conventional thermal neutrons designated n_{th} (E = 0.0254 eV) per cm^2.

Table A3.2A.32: negligible and maximum allowable irradiation

θ (°C)	**20°C**	**50°C**	**100°C**	**150°C**
$\Phi_{ir.neg}$ (10^{21} n_{th}/cm^2)	18	28	37.5	17
$\Phi_{ir.max}$ (10^{21} n_{th}/cm^2)	670	670	370	240

Figure A3.2A.32: negligible and maximum allowable irradiation curves



A3.2A.63 *VALUES OF S_{em} AND S_{et} (after irradiation)*

For level A, C and D criteria, the allowable elastic membrane stresses S_{em}^A, S_{em}^C, S_{em}^D and the allowable elastic total stresses S_{et}^A, S_{et}^C, S_{et}^D, piping and branches excluded, are given by the **table A3.2A.63** and the **figure A3.2A.63** as a function of the temperature θ (°C) and the damage D in dpa NRT
For this material: S_e^A= (2 / 2,5) S_e^C=(1,35 / 2,5) .S_e^D
For piping and branches, formulae are proposed in **A3.GEN.42.**

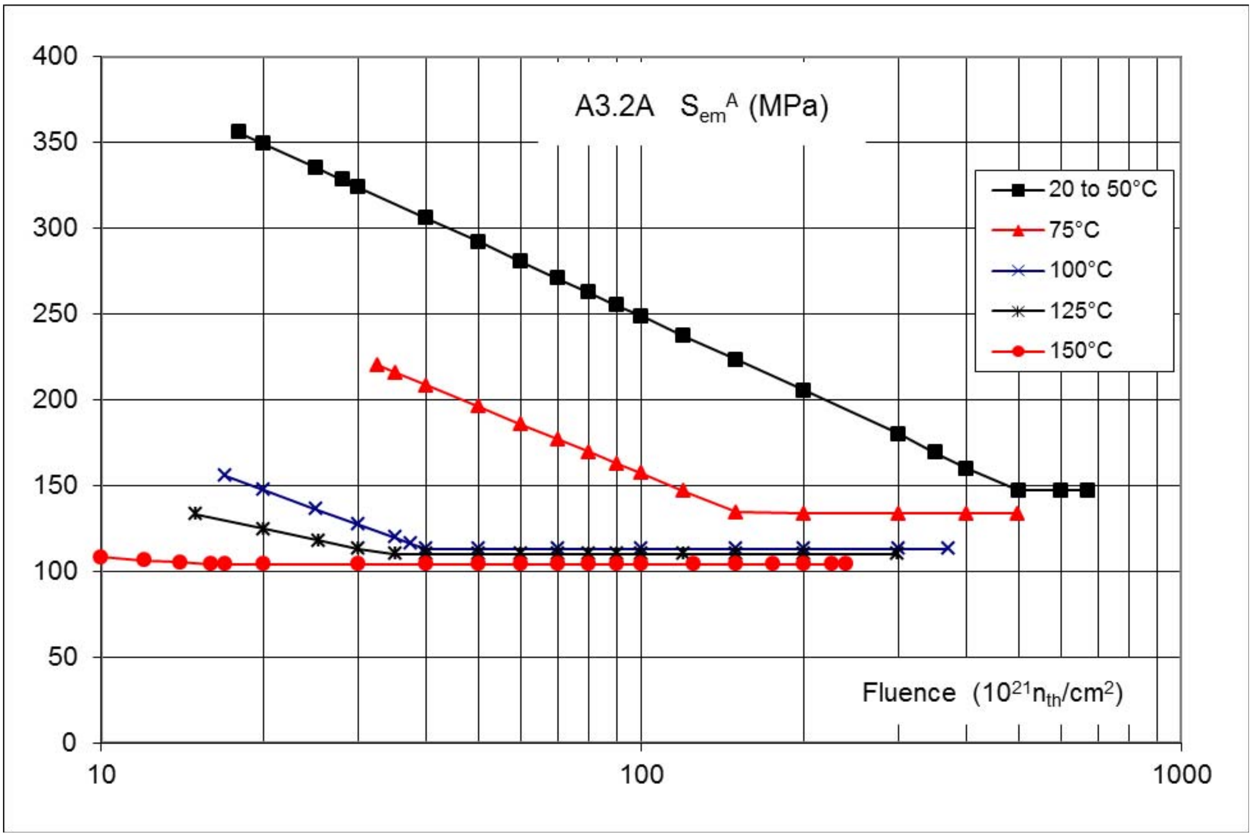
Table A3.2A.63: values of S_{em}^A , S_{em}^C , S_{em}^D and S_{et}^A , S_{et}^C, S_{et}^D (MPa) function of temperature θ (°C) and fluence Φ_{th} (10^{21} n_{th} / cm^2)

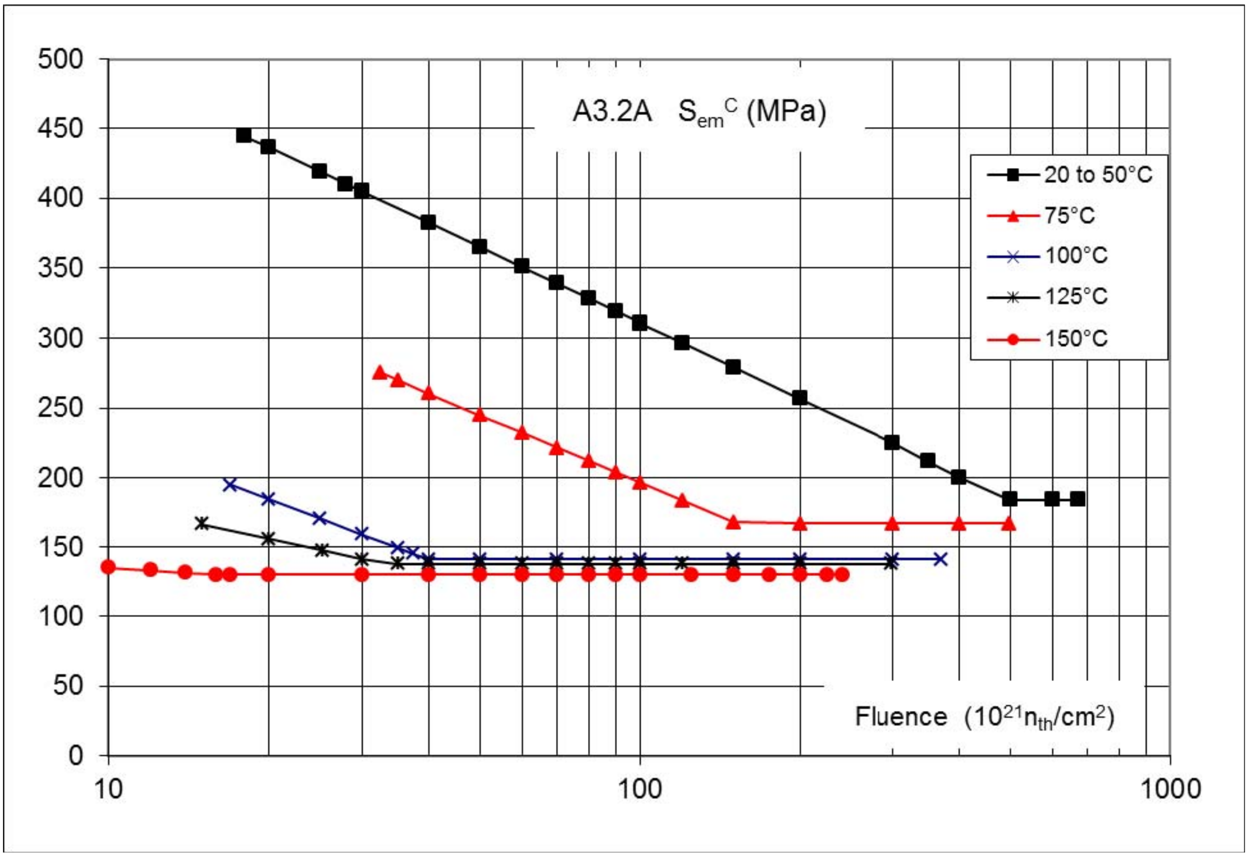
20 à 50°C							75°C						
Φ_{th}	S_{em}^A	S_{em}^C	S_{em}^D	S_{et}^A	S_{et}^C	S_{et}^D	Φ_{th}	S_{em}^A	S_{em}^C	S_{em}^D	S_{et}^A	S_{et}^C	S_{et}^D
18	356	445	659	720	901	1334	**32**	220	275	408	565	706	1046
20	349	437	647	716	895	1326	**35**	216	270	400	556	696	1030
25	335	419	621	706	883	1307	**40**	209	261	386	537	672	995
28	328	410	608	701	876	1298	**50**	196	245	363	497	621	921
30	324	405	600	690	862	1277	**60**	186	232	344	464	579	858
35	314	393	582	664	830	1230	**70**	177	221	328	434	543	804
40	306	382	566	642	802	1188	**80**	170	212	314	408	510	755
50	292	365	541	604	755	1119	**90**	163	204	302	383	479	709
60	281	351	520	574	717	1062	**100**	157	196	291	360	450	666
70	271	339	502	548	685	1014	**120**	147	184	272	314	392	581
80	263	328	486	525	656	972	**150**	134	168	249	236	295	438
90	255	319	473	505	631	935	**200**	134	167	248	194	243	360
100	249	311	460	487	609	902	**300**	134	167	248	162	203	301
120	237	297	439	456	570	844	**400**	134	167	248	137	172	254
150	223	279	414	417	521	772	**498**	134	167	248	137	171	254
200	205	257	380	365	456	676							
300	180	225	333	286	358	530							
350	169	212	313	251	314	465							
400	160	200	296	217	271	401							
500	147	184	273	152	190	282							
600	147	184	273	147	184	273							
670	147	184	273	147	184	273							

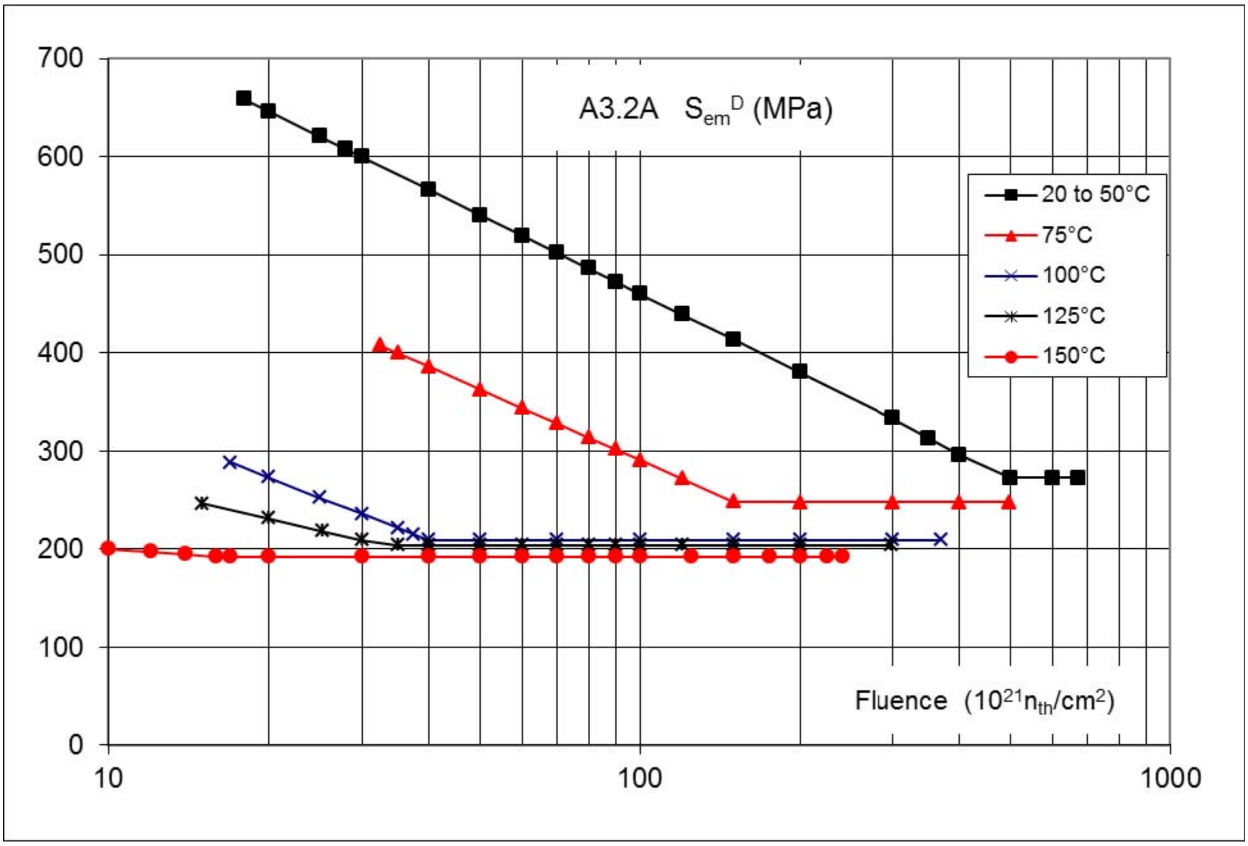
100°C							125°C						
Φ_{th}	S_{em}^A	S_{em}^C	S_{em}^D	S_{et}^A	S_{et}^C	S_{et}^D	Φ_{th}	S_{em}^A	S_{em}^C	S_{em}^D	S_{et}^A	S_{et}^C	S_{et}^D
17	156	195	288	471	589	872	**15**	133	167	247	476	595	882
20	148	184	273	459	574	851	**20**	125	156	231	440	549	814
25	136	171	253	438	548	812	**25**	118	148	219	391	489	725
30	127	159	236	411	514	762	**30**	113	141	209	342	427	633
35	120	150	222	373	466	691	**35**	110	138	204	298	372	551
37.5	116	145	215	346	433	641	**40**	110	138	204	289	361	535
40	113	141	209	307	383	568	**50**	110	138	204	269	336	498
50	113	141	209	283	354	524	**60**	110	138	204	252	315	467
70	113	141	209	255	318	471	**70**	110	138	204	239	298	442
100	113	141	209	224	280	415	**80**	110	138	204	227	283	420
150	113	141	209	190	237	352	**90**	110	138	204	216	270	400
200	113	141	209	165	207	306	**100**	110	138	204	207	258	383
300	113	141	209	131	164	243	**120**	110	138	204	190	238	352
370	113	141	209	127	158	235	**150**	110	138	204	170	213	316
							200	110	138	204	145	181	268
							298	110	138	204	125	156	231

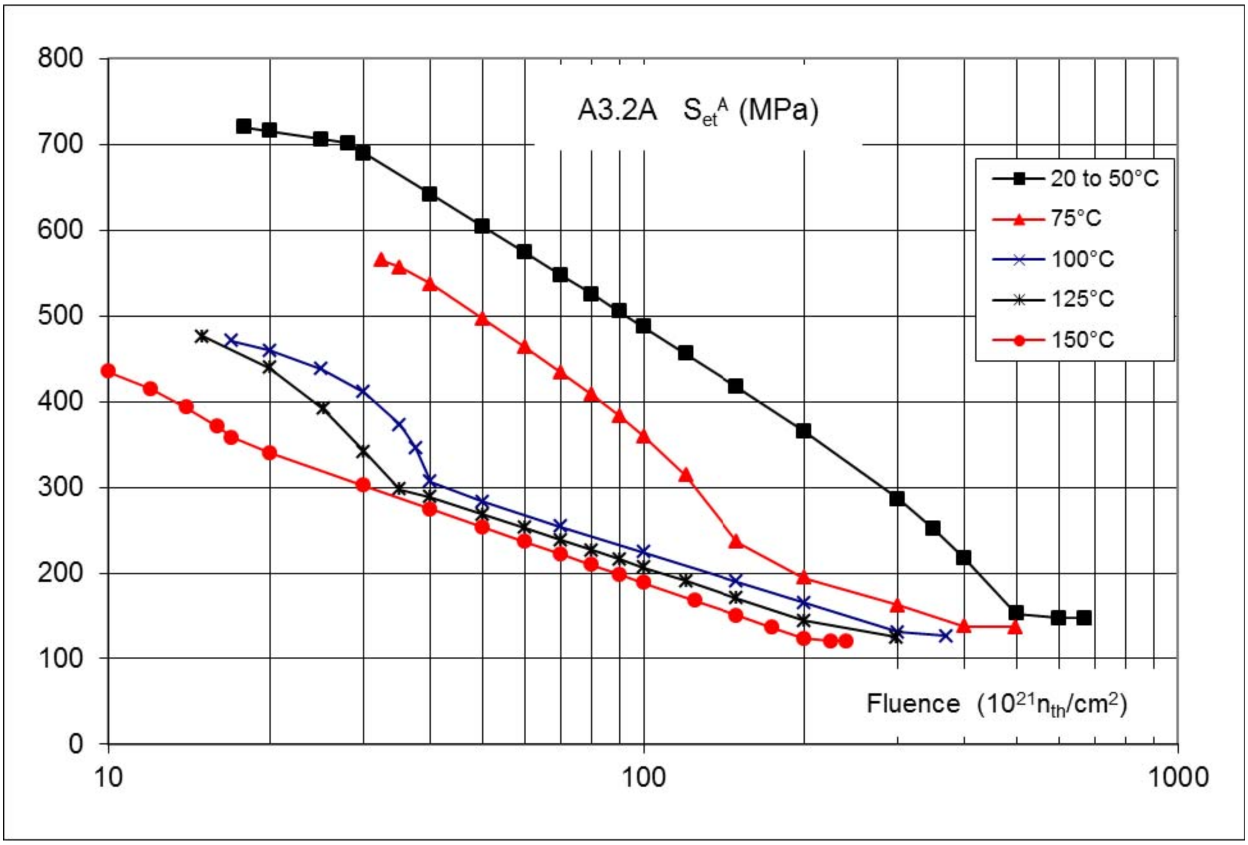
150°C						
Φ_{th}	**S_{em}^A**	**S_{em}^C**	**S_{em}^D**	**S_{et}^A**	**S_{et}^C**	**S_{et}^D**
10	108	135	200	435	544	806
12	107	133	197	415	519	768
14	105	132	195	393	492	728
16	104	130	193	370	463	686
17	104	130	193	358	448	663
20	104	130	193	340	425	629
30	104	130	193	302	377	559
40	104	130	193	275	343	508
50	104	130	193	254	317	470
60	104	130	193	236	296	438
70	104	130	193	222	277	411
80	104	130	193	209	262	388
90	104	130	193	198	248	367
100	104	130	193	188	236	349
125	104	130	193	167	209	310
150	104	130	193	150	188	278
175	104	130	193	136	170	252
200	104	130	193	123	154	228
240	104	130	193	120	150	223
240	104	130	193	120	150	223

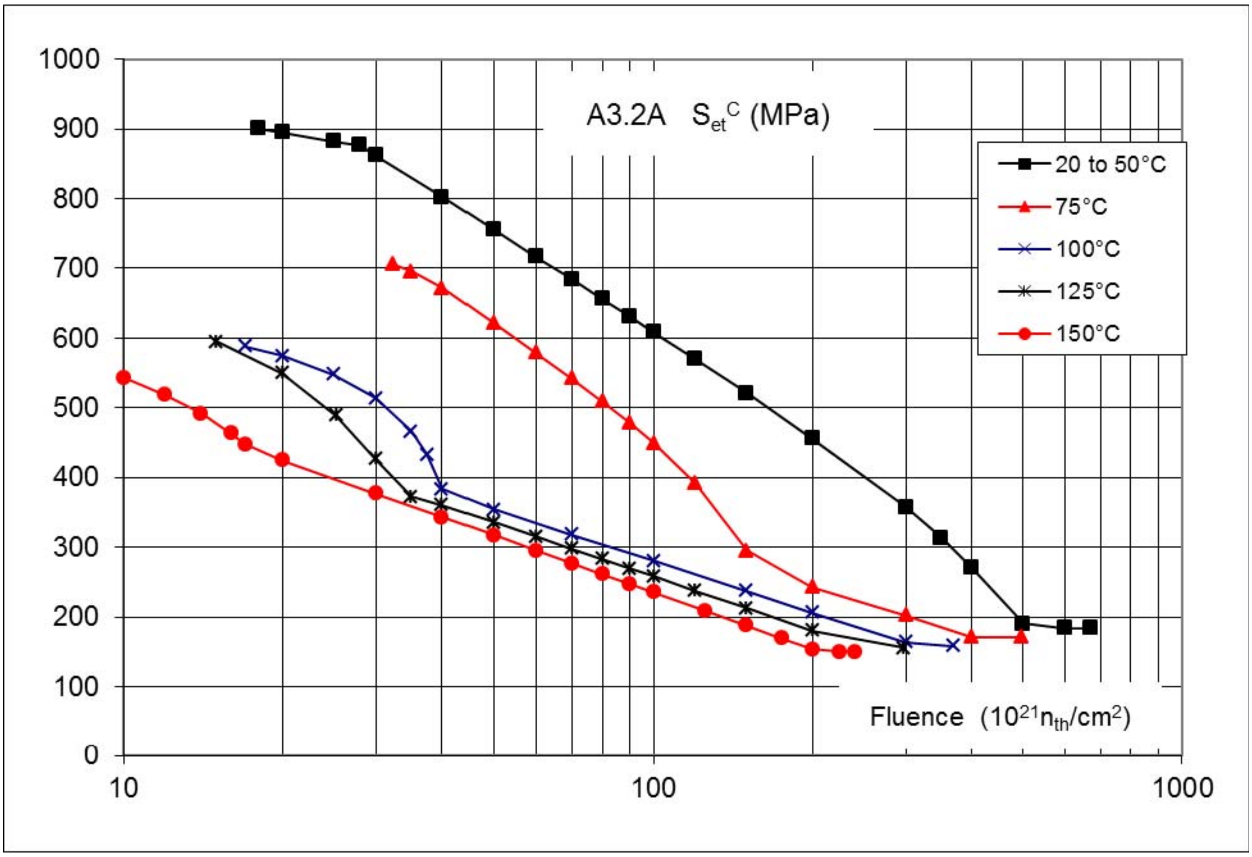
Figure A3.2A.63: values of S_{em}^A , S_{em}^C , S_{em}^D and S_{et}^A , S_{et}^C, S_{et}^D (MPa) function of temperature θ (°C) and fluence Φ_{th} (10^{21} n_{th} / cm^2)

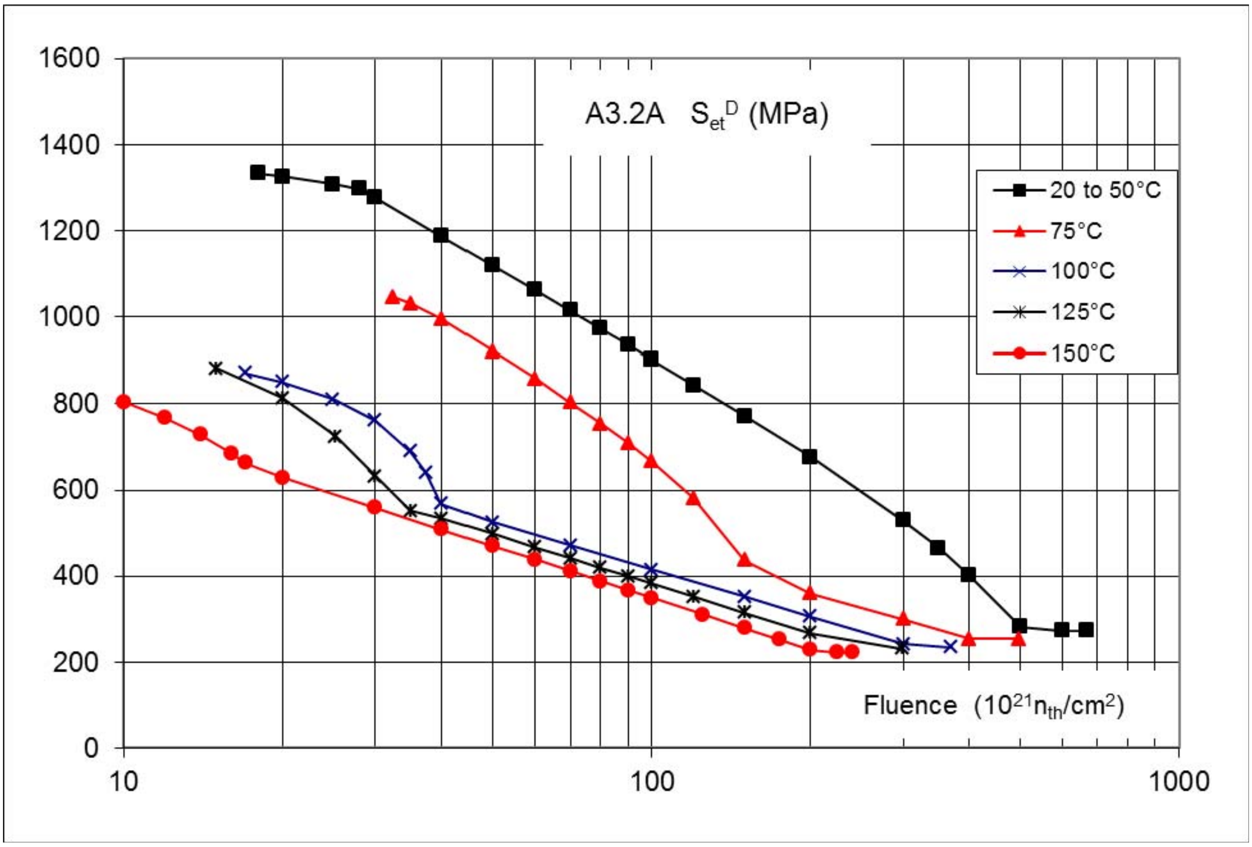



A3.2A S_{em}^{C} (MPa)
20 to 50°C
75°C
100°C
125°C
150°C
Fluence ($10^{21}n_{th}/cm^2$)
0
50
100
150
200
250
300
350
400
450
500
10
100
1000


A3.2A S_{em}^{D} (MPa)
20 to 50°C
75°C
100°C
125°C
150°C
Fluence ($10^{21}n_{th}/cm^2$)
0
100
200
300
400
500
600
700
10
100
1000


A3.2A S_{et}^{A} (MPa)
800
700
600
500
400
300
200
100
0
10
100
1000
Fluence ($10^{21}n_{th}/cm^2$)
20 to 50°C
75°C
100°C
125°C
150°C


A3.2A S_{et}^{C} (MPa)
1000
900
800
700
600
500
400
300
200
100
0
10
100
1000
Fluence ($10^{21}n_{th}/cm^2$)
20 to 50°C
75°C
100°C
125°C
150°C



A3.2A.64 *DUCTILITY CHARACTERISTICS (before and after irradiation)*

The ductility characteristics are percentage total elongation at fracture (A_t) and percentage total elongation at maximum force (A_{gt}).

- Before irradiation, the minimum values of A_t and A_{gt} are given as a function of temperature θ by the **table A3.2A.64a**.
- After irradiation, the values of A_t and A_{gt} are given by the **table A3.2A.64b** and the **figure A3.2A.64** as a function of the fluence Φ_{th} expressed using conventional thermal neutrons per cm^2,.

For intermediate values of the temperature, the values of A_{gt} and A_t may be obtained by linear interpolation.

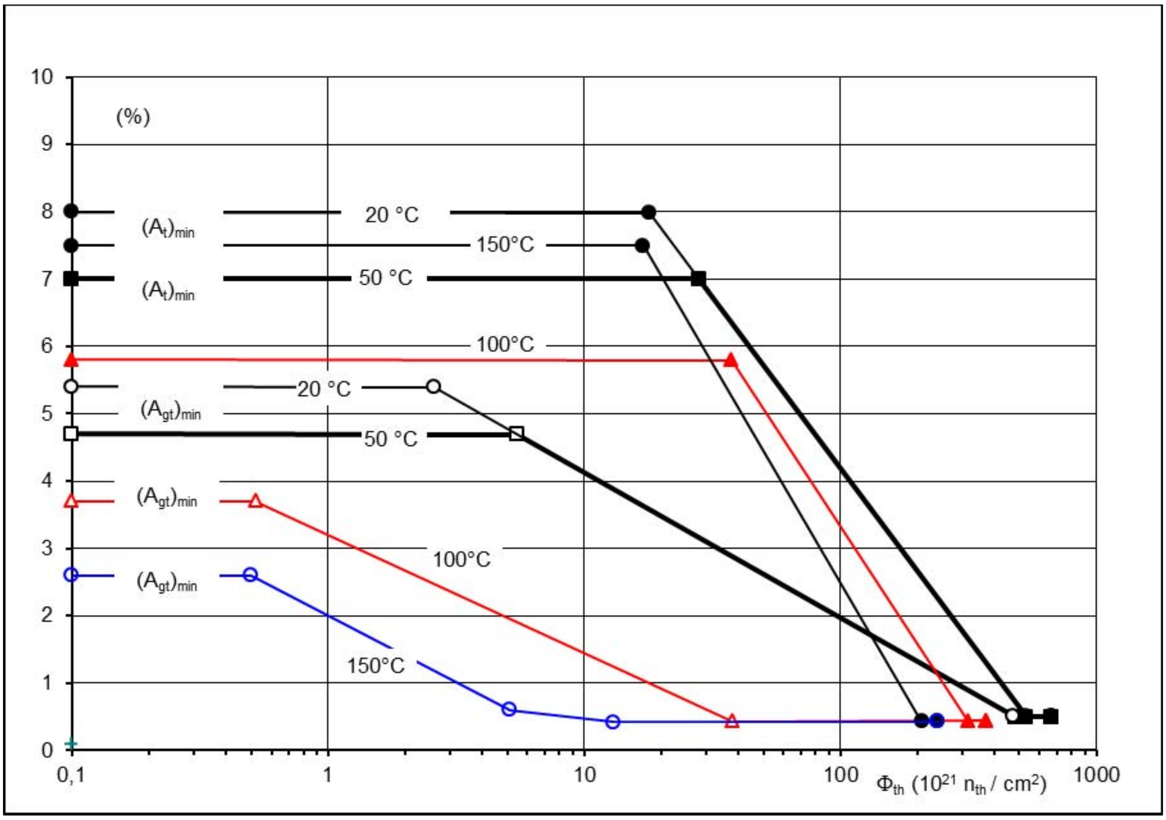
Table A3.2A.64a: A_{gt} and A_t before irradiation

θ (°C)	**20**	**50**	**100**	**150**
$(A_{gt})_{min}$ (%)	5.4	4.7	3.7	2.6
$(A_t)_{min}$ (%)	8	7	5.8	7.5

Table A3.2A.64b: A_{gt} and A_t after irradiation

	Φ_{th} (10^{21} n_{th}/cm^2)	**$(A_{gt})_{min}$ (%)**	**Φ_{th} (10^{21} n_{th}/cm^2)**	**$(A_t)_{min}$ (%)**
20°C	**2.6 < Φ_{th}** ≤ 472	51.7 - 0.939 Ln(Φ_{th})	**18 < Φ_{th}** ≤ 528	121.23 - 2.210 Ln(Φ_{th})
	Φ_{th} > 472	0.51	**Φ_{th} >** 528	0.51
50°C	**5.5 < Φ_{th}** ≤ 481	51.7 - 0.939 Ln(Φ_{th})	**28 < Φ_{th}** ≤ 532	121.23 - 2.210 Ln(Φ_{th})
	Φ_{th} > 481	0.50	**Φ_{th} >** 532	0.50
100°C	**0.52 < Φ_{th}** ≤ 38	40 - 0.761 Ln(Φ_{th})	**37.5 < Φ_{th} <** 314	136.62 - 2.517 Ln(Φ_{th})
	Φ_{th} > 38	0.44	**Φ_{th} >** 314	0.44
150°C	**0.5 < Φ_{th} ≤ 5.13**	43.402 - 0.8562 Ln(Φ_{th})	**17 < Φ_{th}** <208	152 - 2.823 Ln(Φ_{th})
	5.13 < Φ_{th} ≤ 13	10.417 - 0.1963 Ln(Φ_{th})	**Φ_{th}** >208	0.43
	Φ_{th} > 13	0.43		

Figure A3.2A.64: A_{gt} and A_t after irradiation



A3.2A.65 *TENSILE STRESS-STRAIN CURVES (after irradiation)- not supplied*

A3.2A.66 *CYCLIC CURVES, VALUES OF K_ε , K_ν AND K_s (after irradiation) - not supplied*

A3.2A.67 *FATIGUE CURVES (after irradiation)*

The fatigue curves before irradiation given in **A3.2A.47** are applicable.

A3.2A.68 *Number not used*

A3.2A.69 *SWELLING (after irradiation)*

For temperatures less or equal than 55°C and a fluence $\Phi_{th} \leq 300.10^{21}$ n_{th} / cm^2, the swelling is smaller than 1.5 %.

A3.2A.7 Number not used

A3.2A.8 PROPERTIES FOR ANALYSIS - FRACTURE MECHANICS

A3.2A.81 *FRACTURE MECHANICS - BASIC*

A3.2A.811 VALUES OF J_{IC}

For temperatures θ as $20 \leq \theta$ (°C) ≤ 150, the minimum value of K_{IC} = 25.3 MPa$\sqrt{}$m; the corresponding value of J_{Ic} is given by the formula $J_{IC} = K_{IC}^2/E$.