U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

SOLAR ENERGY TECHNOLOGIES OFFICE

SETO CSP Program Summit 2019

Creep-Fatigue Behavior and Damage Accumulation of a Candidate Structural Material for CSP Thermal Receivers

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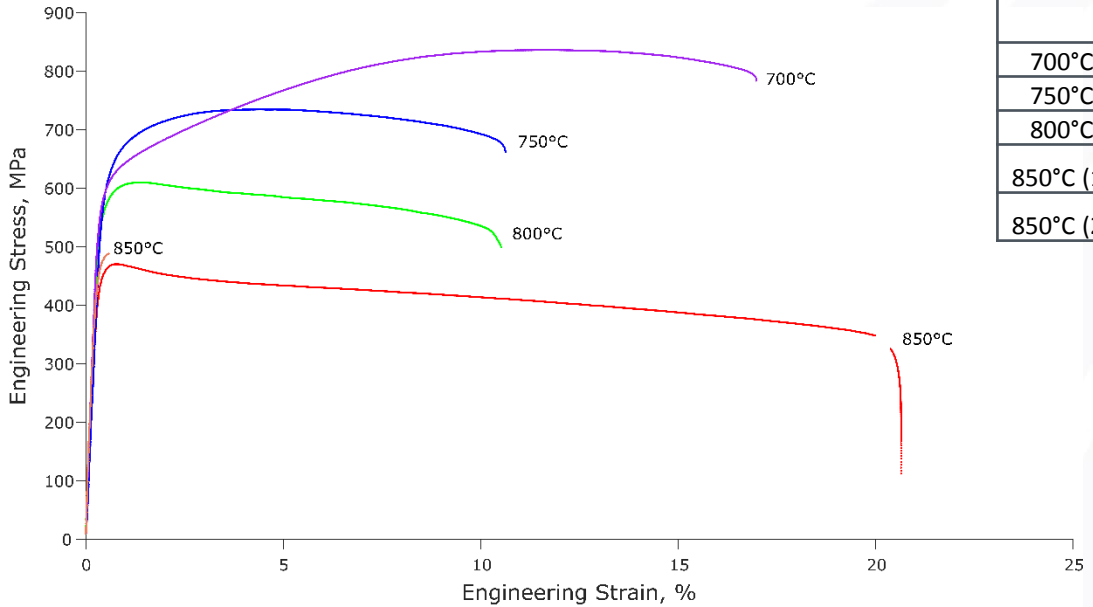
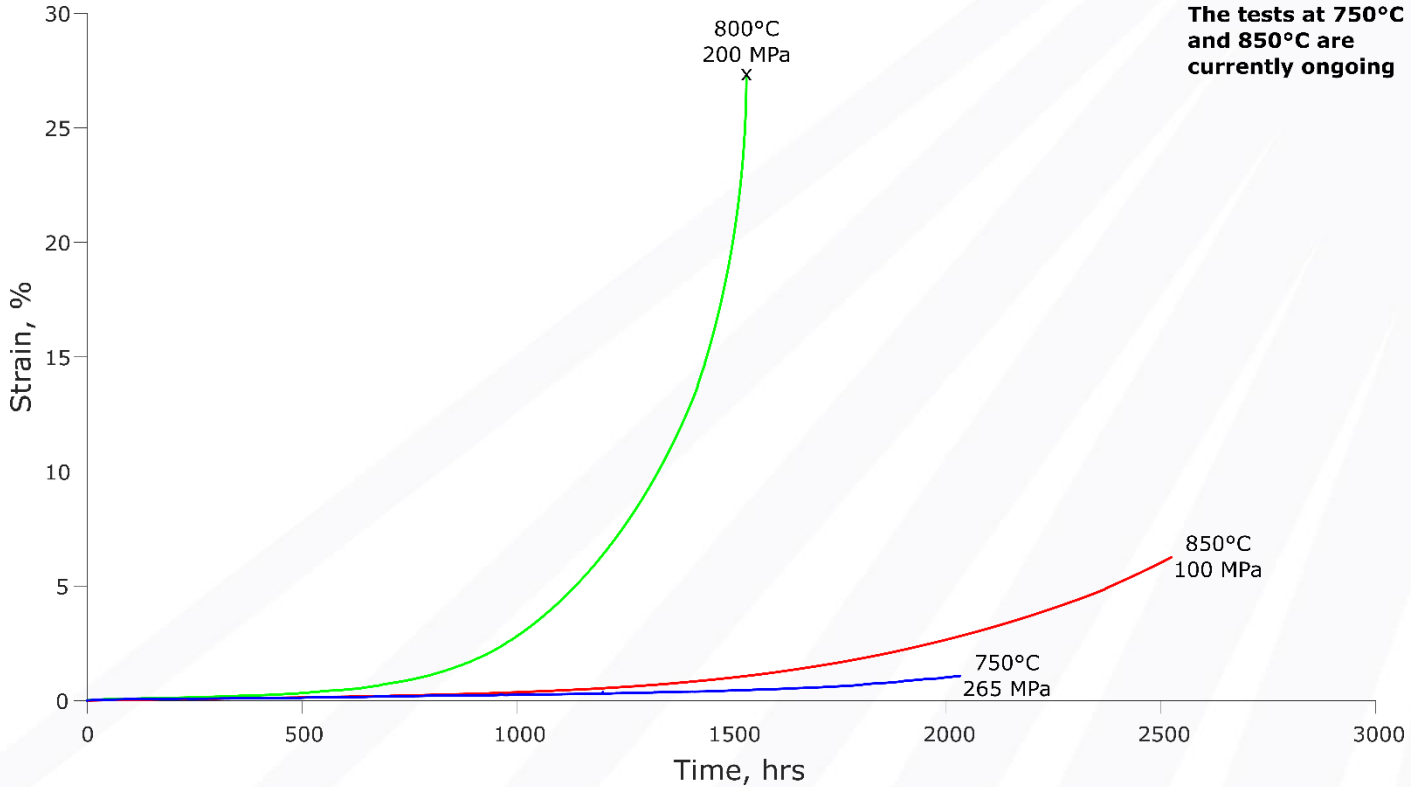
Tensile testing

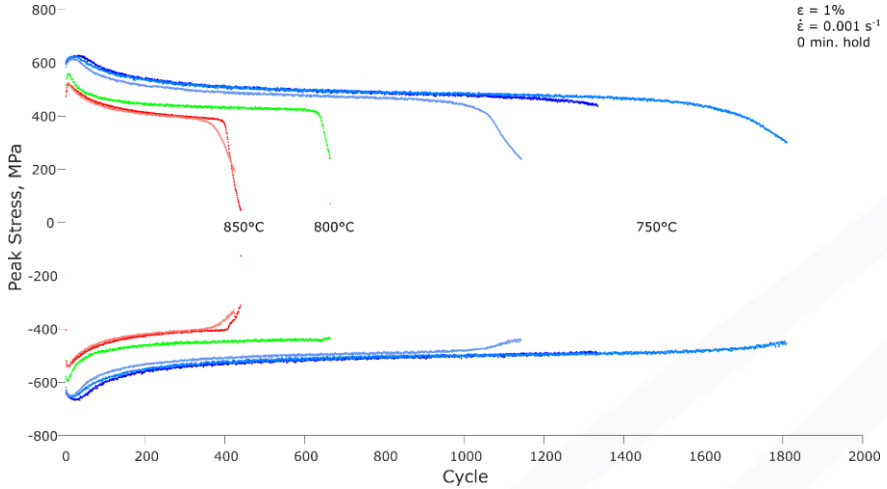


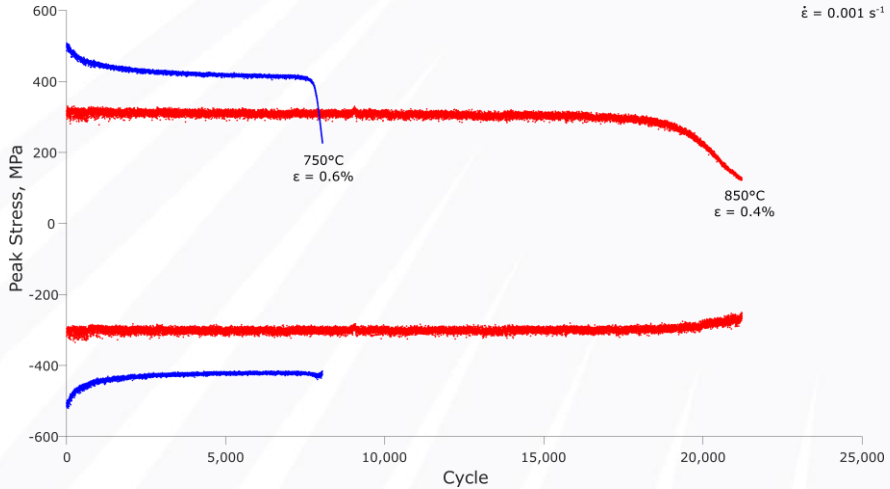
	Young's modulus	0.2% Yield Strength	UTS	Elongation	RA
	GPa	MPa	MPa	%	%
700°C	171	601.1	835.9	16.6	19.3
750°C	147	627.9	734.2	11.9	9.6
800°C	154	576.5	609.6	12.7	10.5
850°C (1)	159	481.7	-	-	-
850°C (2)	144	460.5	469.9	23.6	21

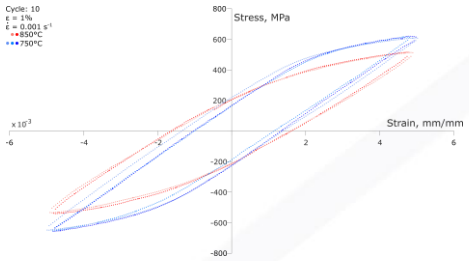
Creep testing

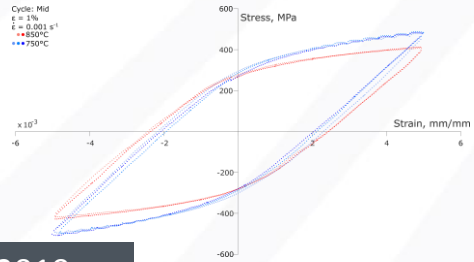


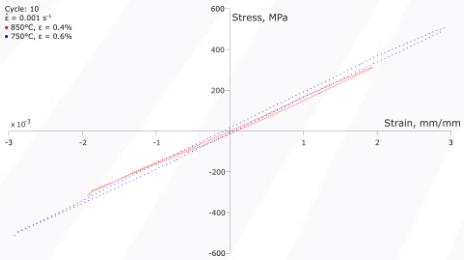
Fatigue testing

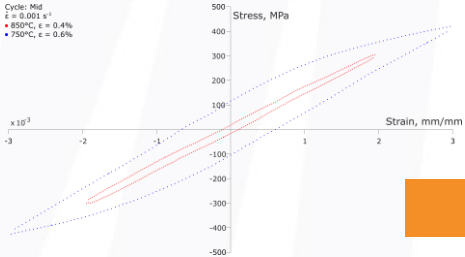




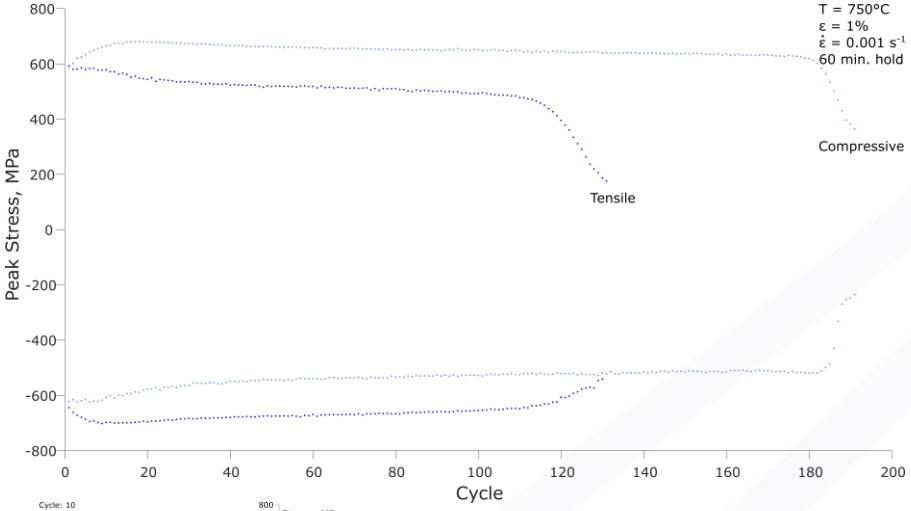


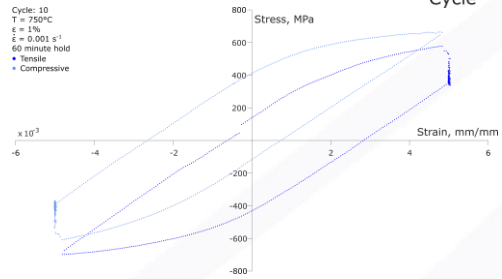


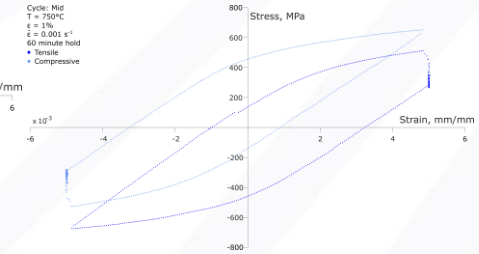


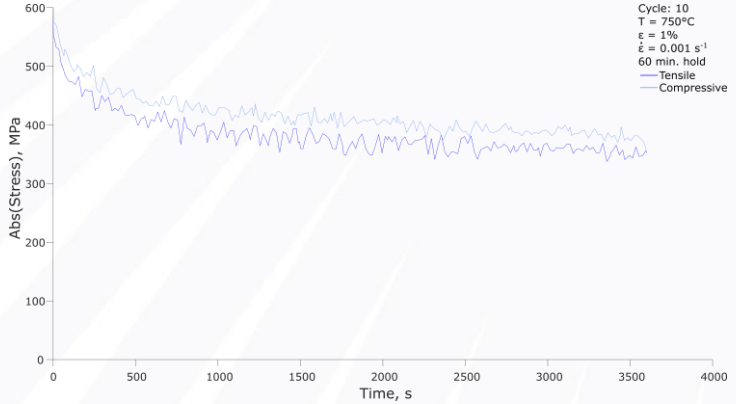


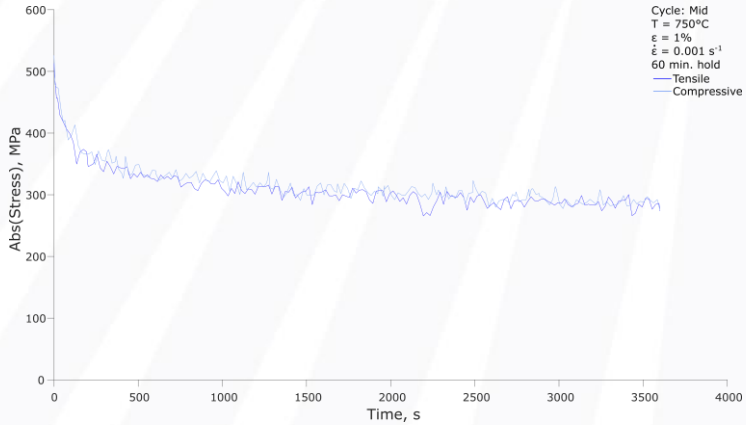
Creep-fatigue testing





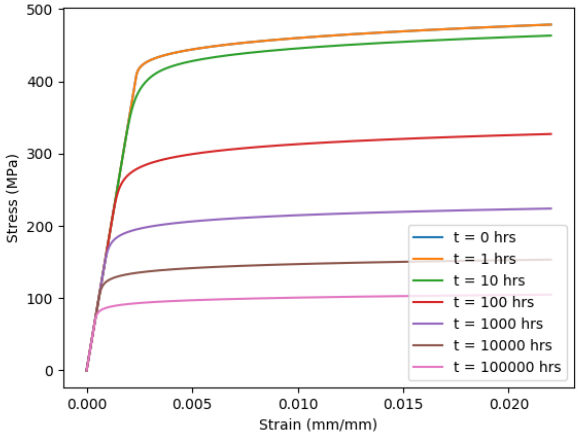




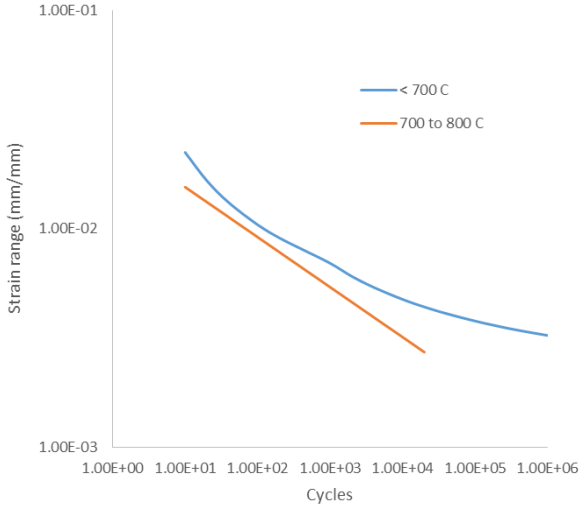


Design curves

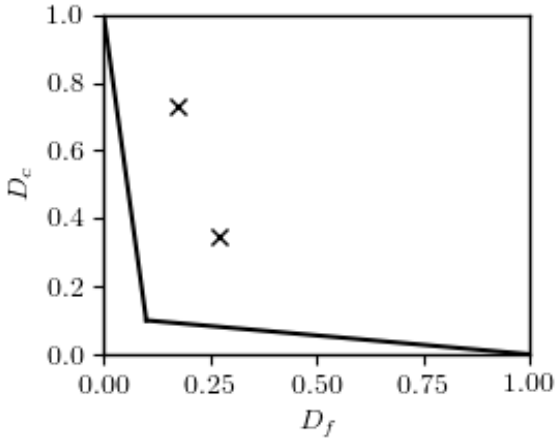
Isochronous (750°C)



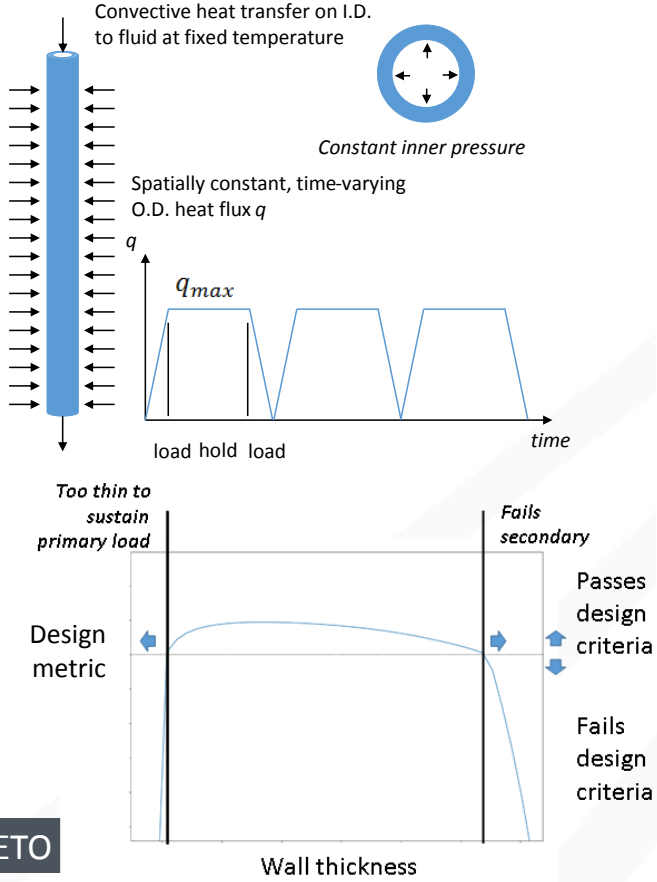
Fatigue



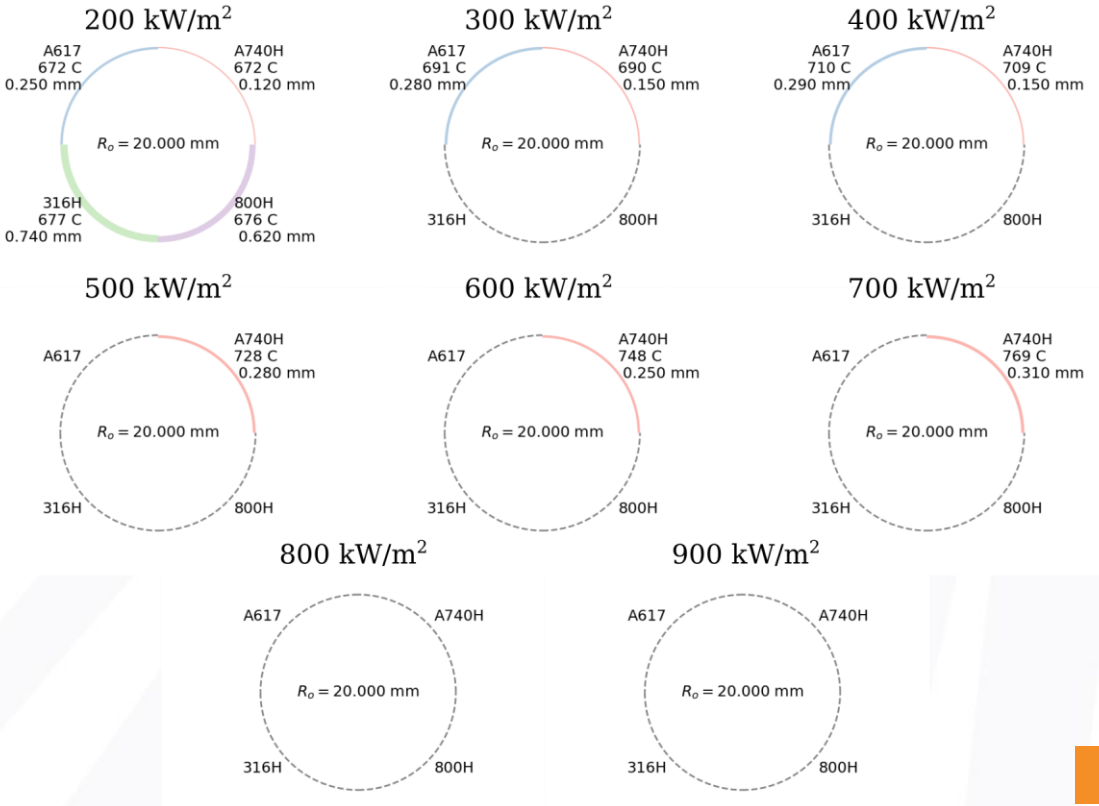
Creep-Fatigue



Simplified design case



15 year design life



Summary

- Mechanical testing is still underway, so design models do not have sufficient data
  - Limited creep testing will provide basic understanding of creep above 750°C
  - Creep-fatigue testing to determine if 0.3, 0.3 is an appropriate interesting in the D diagram
  - Additional fatigue testing at to fill out fatigue design curves above 700°C
- Current design curves show improvement over other materials currently allowed by the ASME BPVC for high temperature application
- While not a high temperature ASME Code Case, these results will provide information for receiver design engineers critical for ensuring safety and proper function of components at elevated temperatures.

Summary of fatigue and Creep-fatigue testing

Temp.	Strain Rate	Hold time[1]	$\Delta\varepsilon_t$	At Cycle 10				Midlife						
				σ_{max}	σ_{min}	$\sigma_{h\text{-}start}$	$\sigma_{h\text{-}end}$	cycle used	σ_{max}	σ_{min}	$\sigma_{h\text{-}start}$	$\sigma_{h\text{-}end}$	Cycles to Initiation	Cycles to Failure
(°C)	(/s)	(min)	(%)	(MPa)	(MPa)	(MPa)	(MPa)	(N_{25}/2)	(MPa)	(MPa)	(MPa)	(MPa)	(N_0)	(N_{25})
Fatigue testing														
850	0.001	0	0.4	313	-301	-	-	10000	305	-305	-	-	18619	19969
850	0.001	0	1.0	516	-540	-	-	200	413	-428	-	-	398	409
850	0.001	0	1.0	514	-535	-	-	200	409	-417	-	-	370	402
800	0.001	0	1.0	554	-583			350	436	-450			637	653
750	0.001	0	0.6	508	-500	-	-	4000	420	-425	-	-	7827	7950
750	0.001	0	1.0	610	-650	-	-	550	479	-496	-	-	1038	1095
750	0.001	0	1.0	620	-656	-	-	900	484	-508	-	-	-	-
750	0.001	0	1.0	616	-654	-	-	900	487	-498	-	-	1541	1767
Creep-Fatigue testing														
750	0.001	60 T	1.0	578	-698	578	352	61	513	-676	513	274	111	122
750	0.001	60 C	1.0	665	-607	-607	-355	94	652	-527	-526	-275	181	187
850	0.001	600 T	1	311	-390	310	82	Test Ongoing						

Notes

1) In the case of hold times, T refers to a hold at peak tension stress and C refers to a hold at peak compressive stress
2) Testing using alternative methods of heating were found to vary the results and the data was not used in developing the design models
3) These cycles to failure are the total number of cycles performed by the test frame rather than the calculated 25% load drop from N_0)