Effects of Thermal Exposure on Properties of Al-Li Alloys

by

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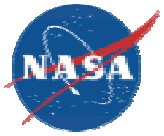

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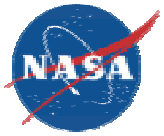
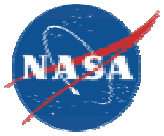


Objective

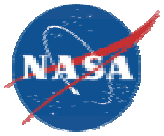
The objective of this investigation is to evaluate the effects of thermal exposure on the mechanical properties of both production mature and developmental Al-Li alloys



Al-Li Alloy Background

Aluminum-Lithium Alloys Composition and Features

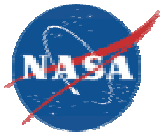
Alloy	Heats to date	Rolled Gage Thickness	Density Lb/in^3	Cu	Li	Mg	Ag	Zr	Mn	Zn
2195	Many	2" max	0.098	4.00	1.00	0.40	0.40	0.12	-----	-----
2297	300 to 400	2" to 6"	0.096	2.90	1.25	-----	-----	0.11	0.35	-----
L277	~14	0.5" to 6"	0.098	3.50	0.90	0.40	0.40	0.10	0.35	-----
C458	~14	0.25" to 6"	0.095	2.60	1.80	0.30	-----	0.09	0.25	0.60



Key Characteristics of Al-Li Alloys

Alloy	Key Characteristics
2195	?? In production for Shuttle External Tank ?? Rolled and tested to thickness of 1.8 inch
2097 2297	?? In production for F-16 ?? Two AMS specs evolving for same application ?? Not designed for FSW or cryogenic use
L277	?? Developmental alloy with high toughness ?? Deriv ative of 2195 with 0.2% less Li
C458	?? Development alloy with high toughness ?? Developed under AF sponsorship

LT15



Research Approach

Approach

- Select 2195, C458, L277 and 2219 alloys and plate stock
- Select exposure temperature (200F to 350F) and time (0 to 1000 hrs)
- Thermally expose thin plate, thick plate and friction stir welds
- Test thin plate @ t/2, thick plate @ t/6 or 5t/6 and friction stir welds @ t/2 —through thickness
- Conduct room temperature tensile tests for all temperature/time exposure conditions
- Select temperature/time conditions for additional tests
- Additional tests include cryogenic tensile test, room and cryo fracture toughness (Kjic) test and microstructure evaluation

Available & Tested Material

Alloys	Thin Plate	Thick Plate	Friction Stir Welds
Baseline 2219	None	None	0.375 T8
2195	None	1.50 T8	0.75 T8
L277	0.85 T8	2.50 T8	0.85 T8
C458	0.50 T8	1.80 T8	0.75 T8

Thermal Exposure Matrix

	Hours of Exposure				
Temp.	0 hrs	50 hrs	100 hrs	500 hrs	1000 hrs
200 °F			RT	RT	RT, CT, F FSW-RT
250 °F			RT	RT	RT, CT, F FSW-RT
300 °F			RT	RT, CT FSW-RT, F	RT, CT, F FSW-RT
350 °F		RT	RT	RT	RT
unexposed	RT, CT, F, FSW-RT, F				

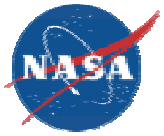
RT = Room Temp. tensile test

CT = Cryogenic (-320F) tensile test

F = Fracture Toughness (Kjic) tests conducted at room and cryogenic temperature

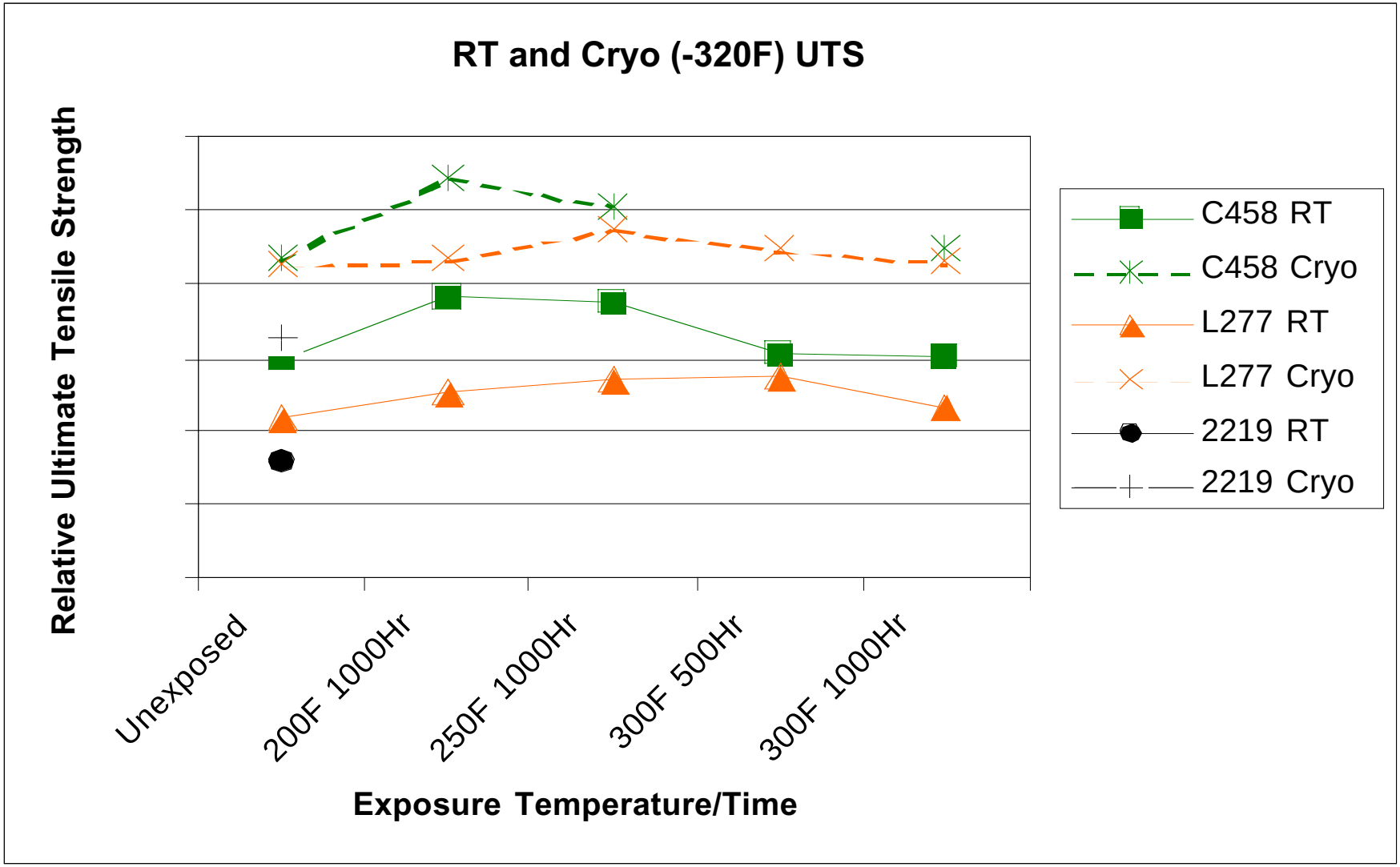
FSW = Friction Stir Welds, Plate to Plate.

Data presented from these blocks

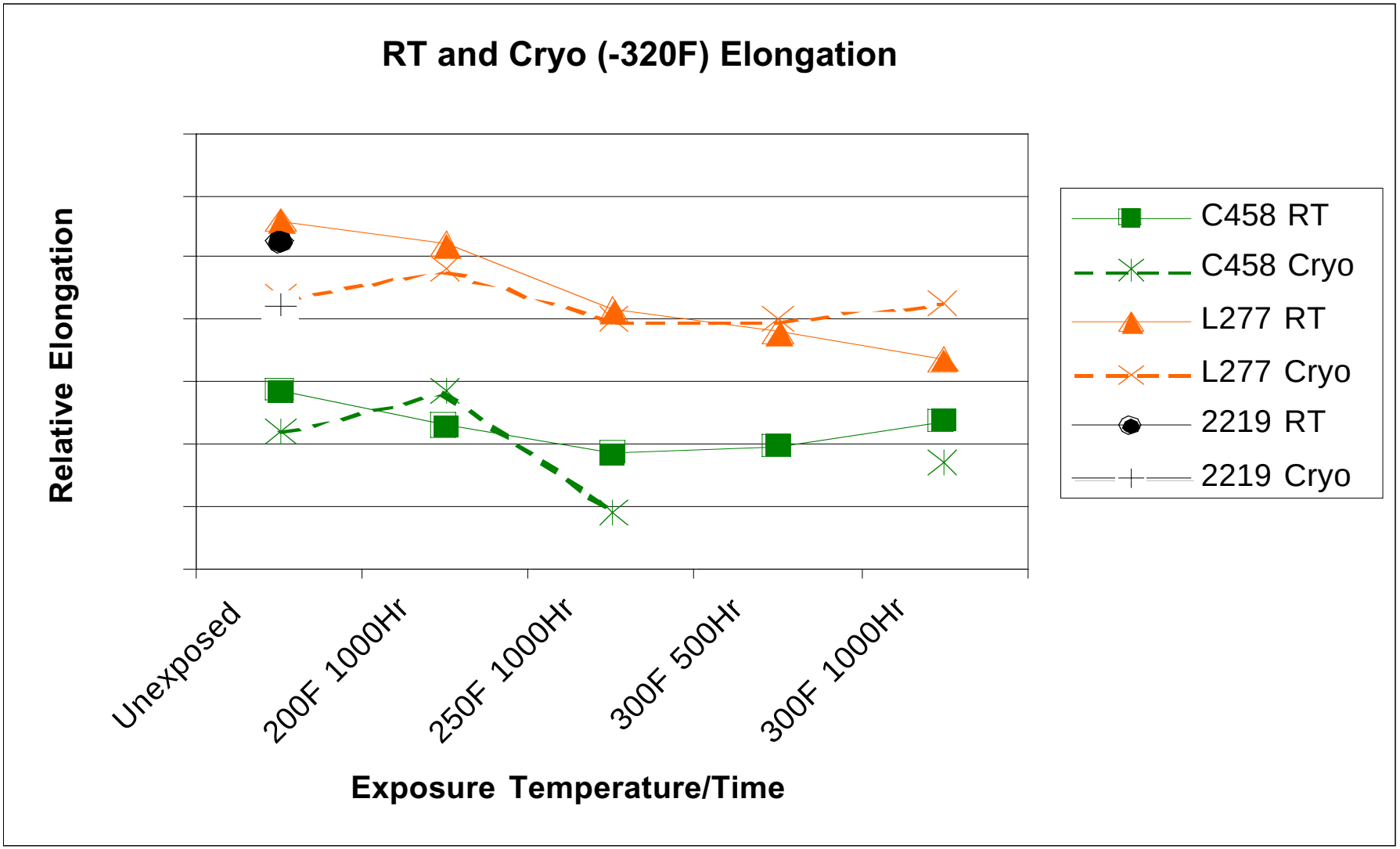


Results and Observations

Thin Plate Tensile Results – t/2, LT



Thin Plate Tensile Results - t/2, LT



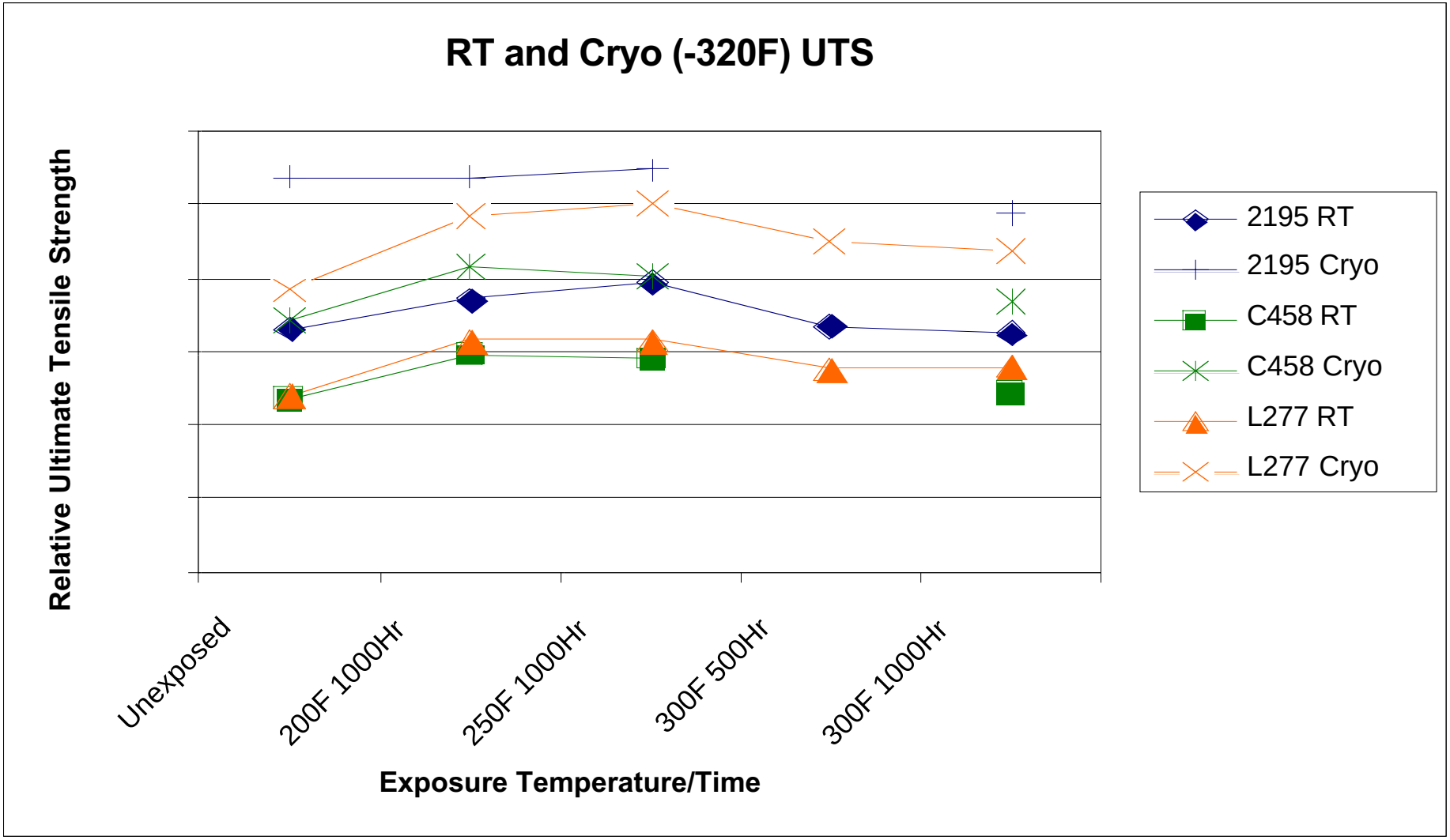
Thin Plate Tensile Observations

- For C458 and L277 Thin Plate RT and CT tests indicate that thermally exposed strengths are better than or equal to unexposed strength. Unexposed plate temper is below peak age condition. Elongation does not exhibit a consistent trend.

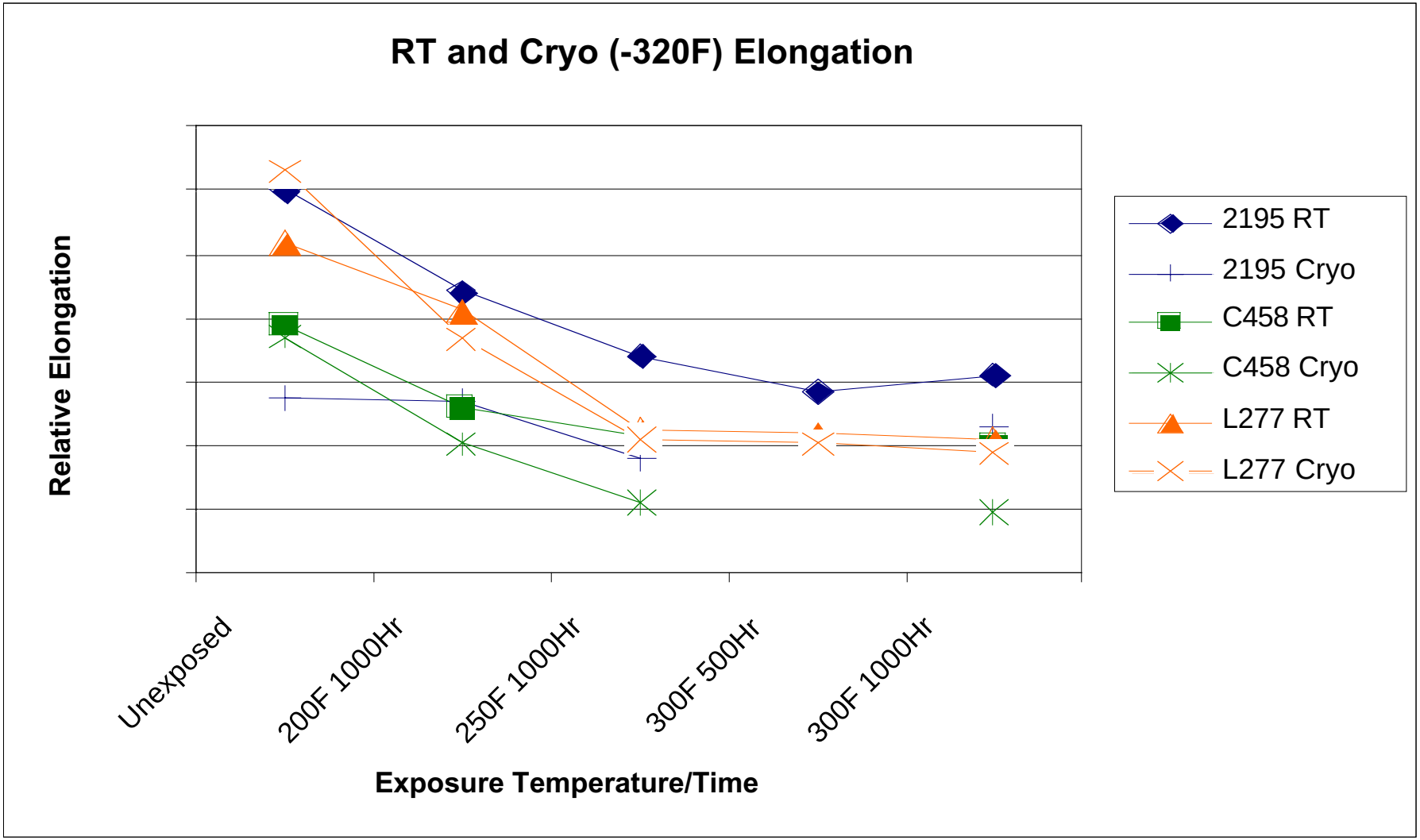
- All Thin Plate alloy exhibited and increase in cryo strengths over RT strengths for all exposure conditions. Elongation does not exhibit a consistent trend.

- In general alloy C458 has better strength than L277, and L277 has better ductility than C458.

Thick Plate Tensile Results - t/6, LT



Thick Plate Tensile Results - t/6, LT



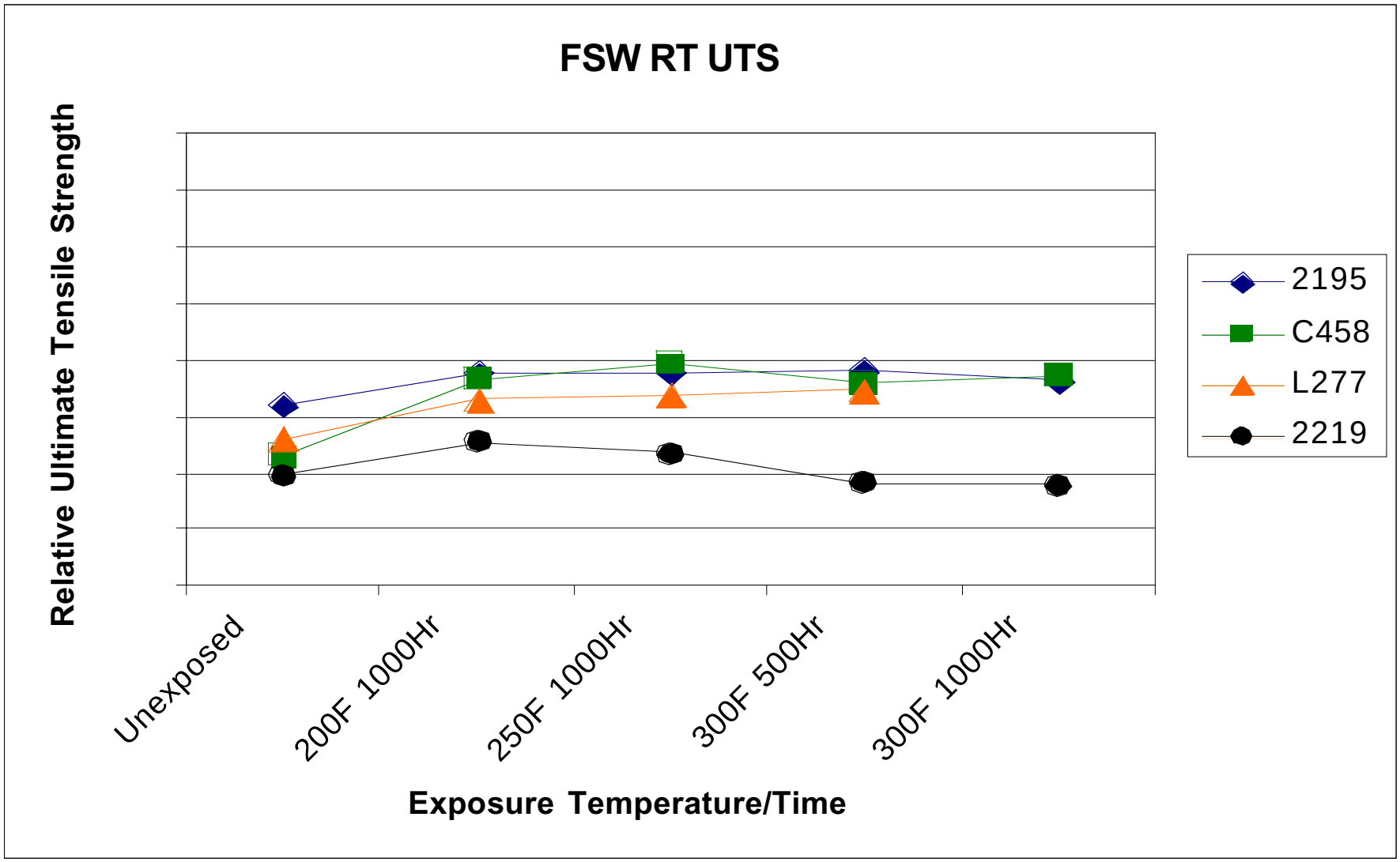
Thick Plate Tensile Observations

- In general, all Thick Plate alloy RT and CT tests indicate that thermally exposed strengths are better than or equal to unexposed strength (except 2195 at very high temperatures). Unexposed plate temper is below peak age condition.

- In general, all Thick Plate alloy elongation decrease with thermal exposure and seems to reach a plateau above 250 F.

- All Thick Plate alloys exhibit an increase in cryo strengths over RT strengths for all exposure conditions. Elongation, in general, is lower at cryo temperatures.

FSW Tensile Results - t/2



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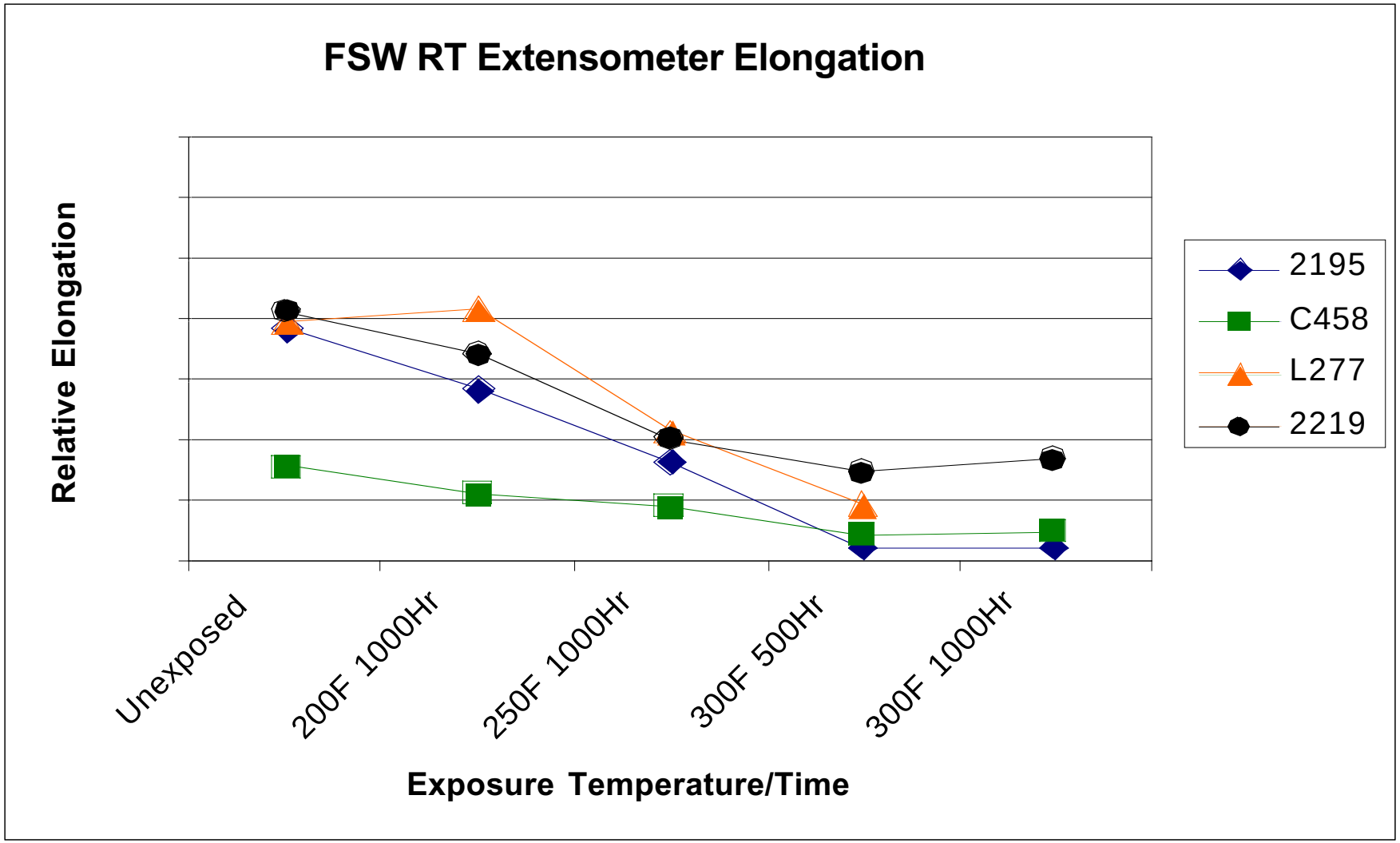
FSW Tensile Results – t/2



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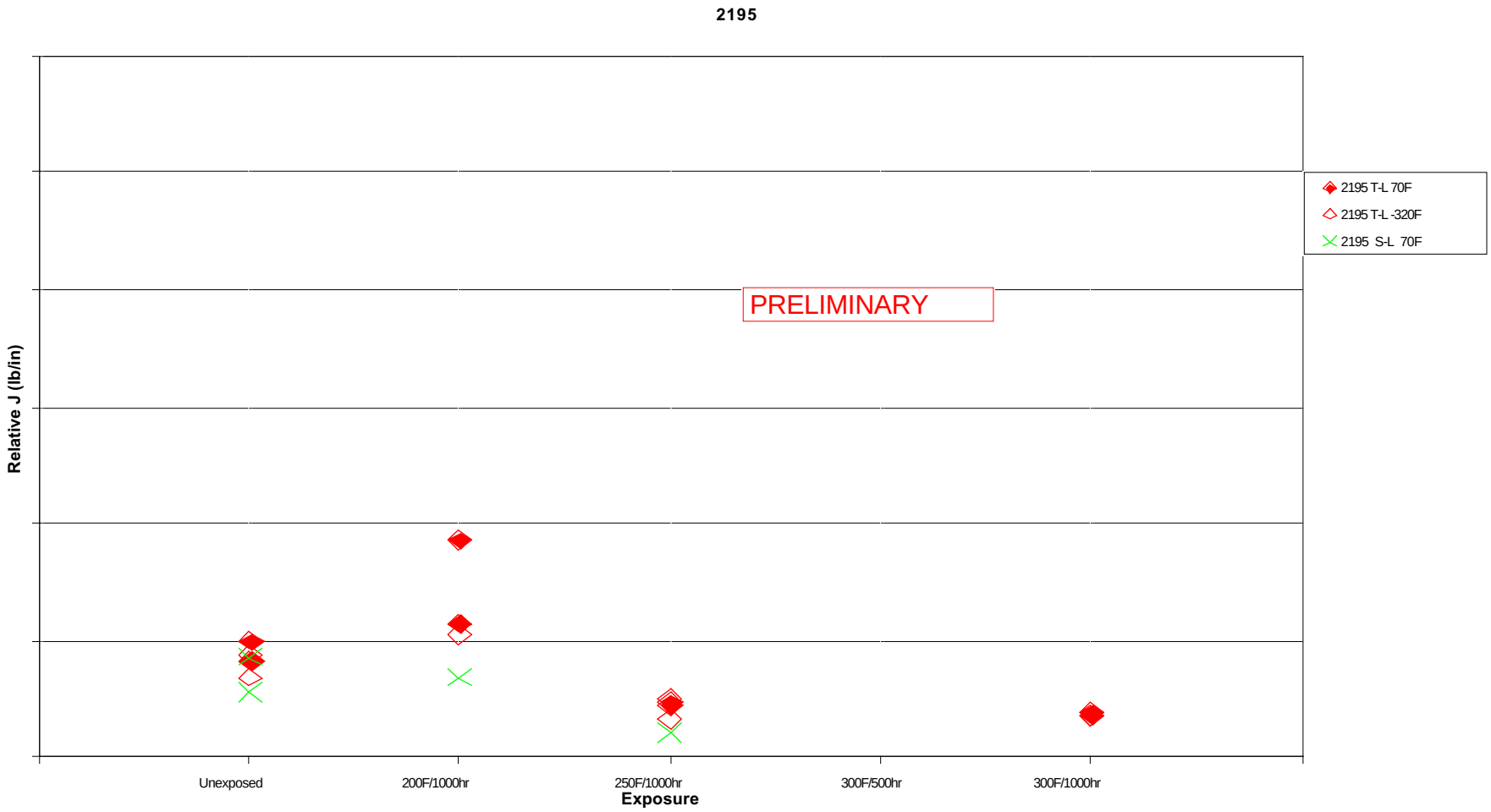
FSW Tensile Observations

- For all FSW alloys RT strengths generally increase with thermal exposure except for 2219.

- At high exposure temperatures, the elongation of the FSW welds decreases significantly, similar to the behavior of thick plates.

- Most of the tensile failures occur in heat affected zone rather than in the weld zone.

2195 K_{Jlc} (E1820) Results

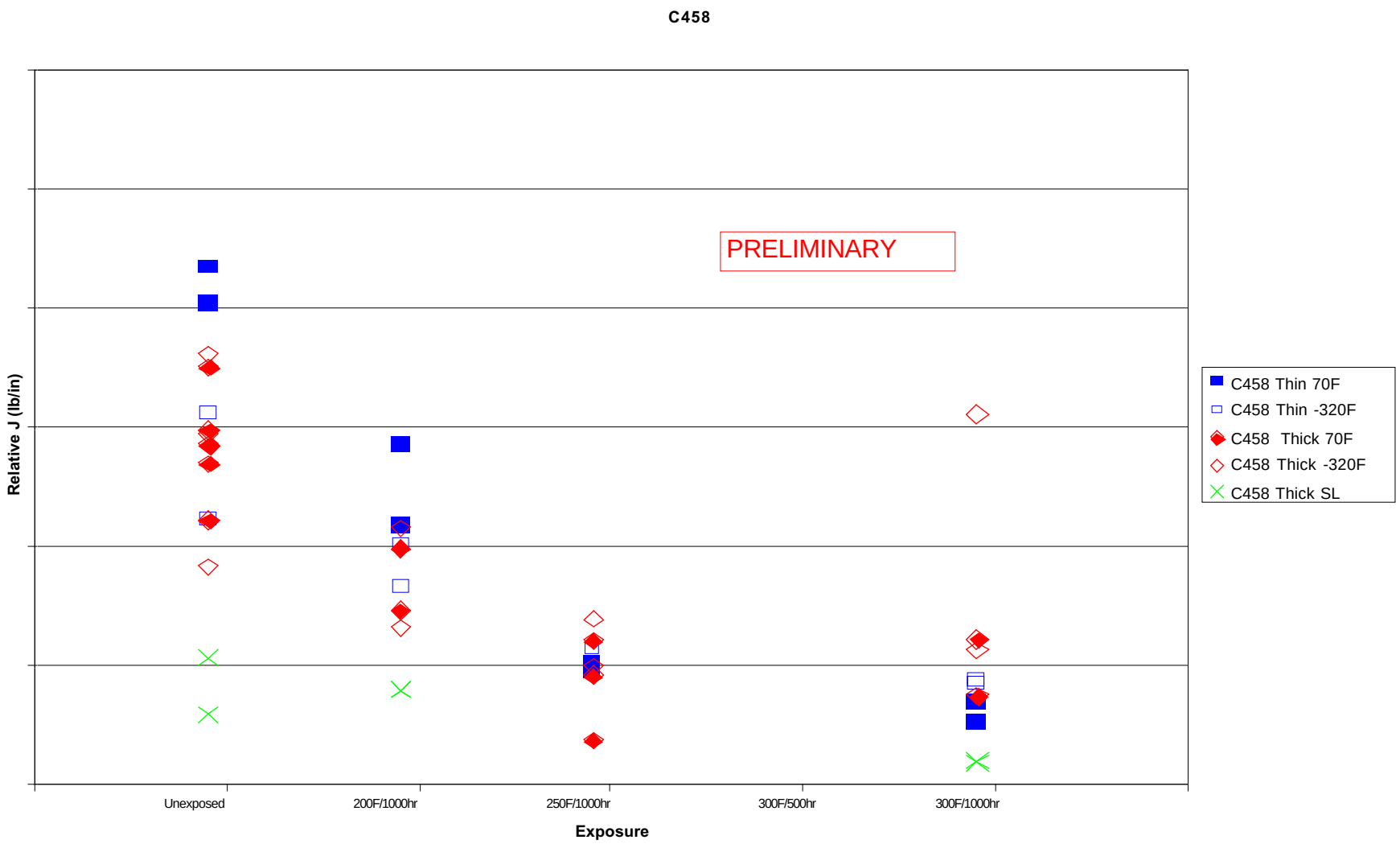


Includes results from Thick Plate, Orientation, Room & Cryo tests

L277 K_{Jlc} (E1820) Results

Includes results from Thin Plate, Thick Plate, Orientation, Room & Cryo tests

C458 K_{Jlc} (E1820) Results



Includes results from Thin Plate, Thick Plate, Orientation, Room & Cryo tests

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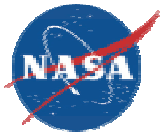
Alloy Plate Fracture Toughness Observations

- The data is preliminary and is still under investigation for validity in some tests.

- It appears that in 2195 thick plate and L277 thin plate the fracture toughness increases at lower temperature exposures but decreases at higher temperature exposures. For L277 thick plate, the toughness seems to decrease continuously with increasing exposure temperature.

- It appears that in C458 the fracture toughness, with few exceptions, decreases with higher temperature exposure.



Summary

For the alloys, their tempers, gage thickness, and product form investigated, the data clearly shows that there is no deficit in mechanical properties at lower exposure temperatures in some cases, and a significant deficit in mechanical properties at higher exposure temperatures in all cases.