INL/MIS-23-72776-Revision-0

GCR: Development of Improved Alloy 800H Weldment

June 2023

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U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

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Joint ART Materials/AMMT Program Review

DOE Headquarters, Germantown, MD

June 5-8, 2023

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Fiscal Year 2023 Work Package

- AT-22IN060405, Long-term VHTR Material Qualification – INL

Team

- Tate Patterson (INL)
- Ryann Bass (now at US NRC)
- Michael McMurtrey (INL)
- Richard Wright (Structural Alloys, LLC)
- Sam Sham (INL)

Background

- America Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) Section III, Division 5 is the construction code for high temperature reactors
- Section III, Division 5 requires weldments to be designed using a stress rupture factor (R)
- The stress rupture factor is a ratio of the stress-to-rupture of the filler metal and the stress-to-rupture of the base metal

$$R = \frac{average\ rupture\ strength\ of\ the\ filler\ metal}{average\ rupture\ strength\ of\ the\ base\ metal}$$

Background/Motivation

- **Stress rupture factors for Alloy 800H from ASME BPVC Section III Division 5**

SFA-5.11 ERNiCr-Fe2 (INCO A)

Temp. [°C]	30 000 h	100 000 h	300 000 h
600	0.84	0.79	0.74
625	0.83	0.77	0.72
650	0.81	0.75	0.70
675	0.80	0.73	0.68
700	0.77	0.71	0.65
725	0.76	**0.69**	**0.63**
750	0.74	**0.66**	**0.60**

Shielded Metal Arc Welding (SMAW)

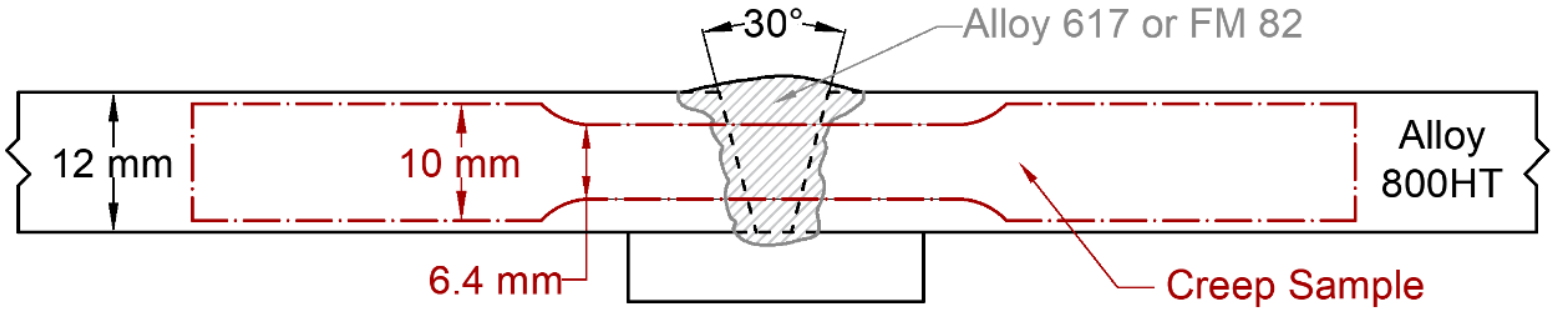
SFA-5.14 ERNiCr-3 (Alloy 82)

Temp. [°C]	30 000 h	100 000 h	300 000 h
600	0.85	0.83	0.81
625	0.85	0.83	0.81
650	0.86	0.83	0.81
675	0.85	0.82	0.80
700	0.85	0.82	0.78
725	0.84	**0.78**	**0.71**
750	0.76	**0.67**	**0.59**

Gas Tungsten Arc Welding (GTAW)

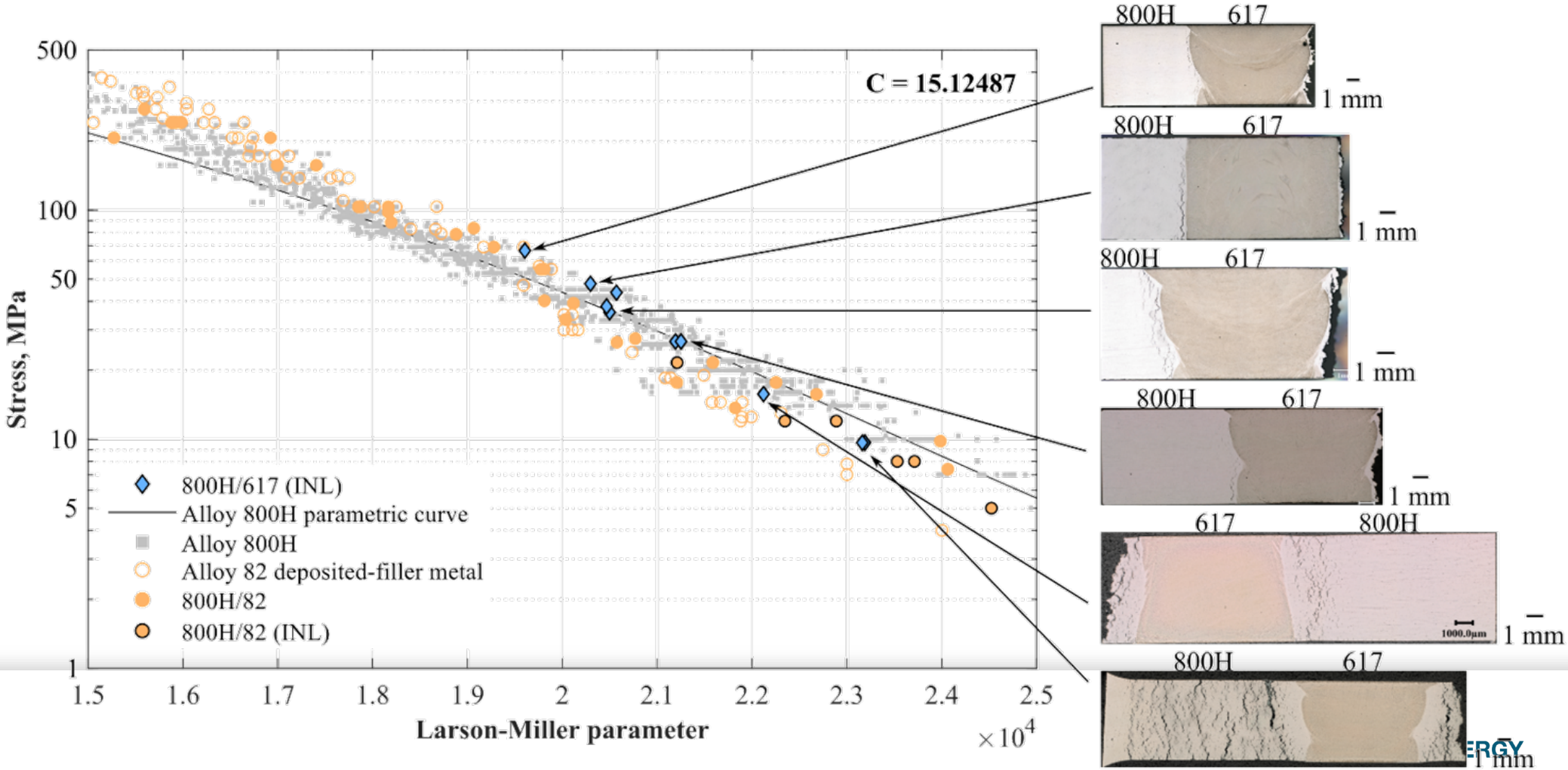
Materials and Procedures

Chemical Compositions (wt%)														
	Fe	Ni	Cr	Mo	Nb	Ti	Al	Co	Cu	Si	Mn	C	S	P
800HT	47.05	30.45	19.30	0.21	-	0.45	0.43	0.11	0.21	0.37	1.31	0.063	0.001	-
Alloy 617	1.37	53.91	22.41	8.98	-	0.34	1.10	11.49	0.04	0.04	0.11	0.089	0.001	0.005
Alloy 82	0.96	73.50	19.50	<0.01	2.33	0.38	0.06	0.02	0.01	0.21	2.86	0.049	0.002	0.003
UTP A 2133 Mn	Bal.	32.1	21.6	<0.1	1.23	-	-	-	<0.1	0.2	4.8	0.16	0.001	0.008



Prior Results – Weldment Creep Rupture

- **Alloy 800H Weldment with Various Weld Consumables**



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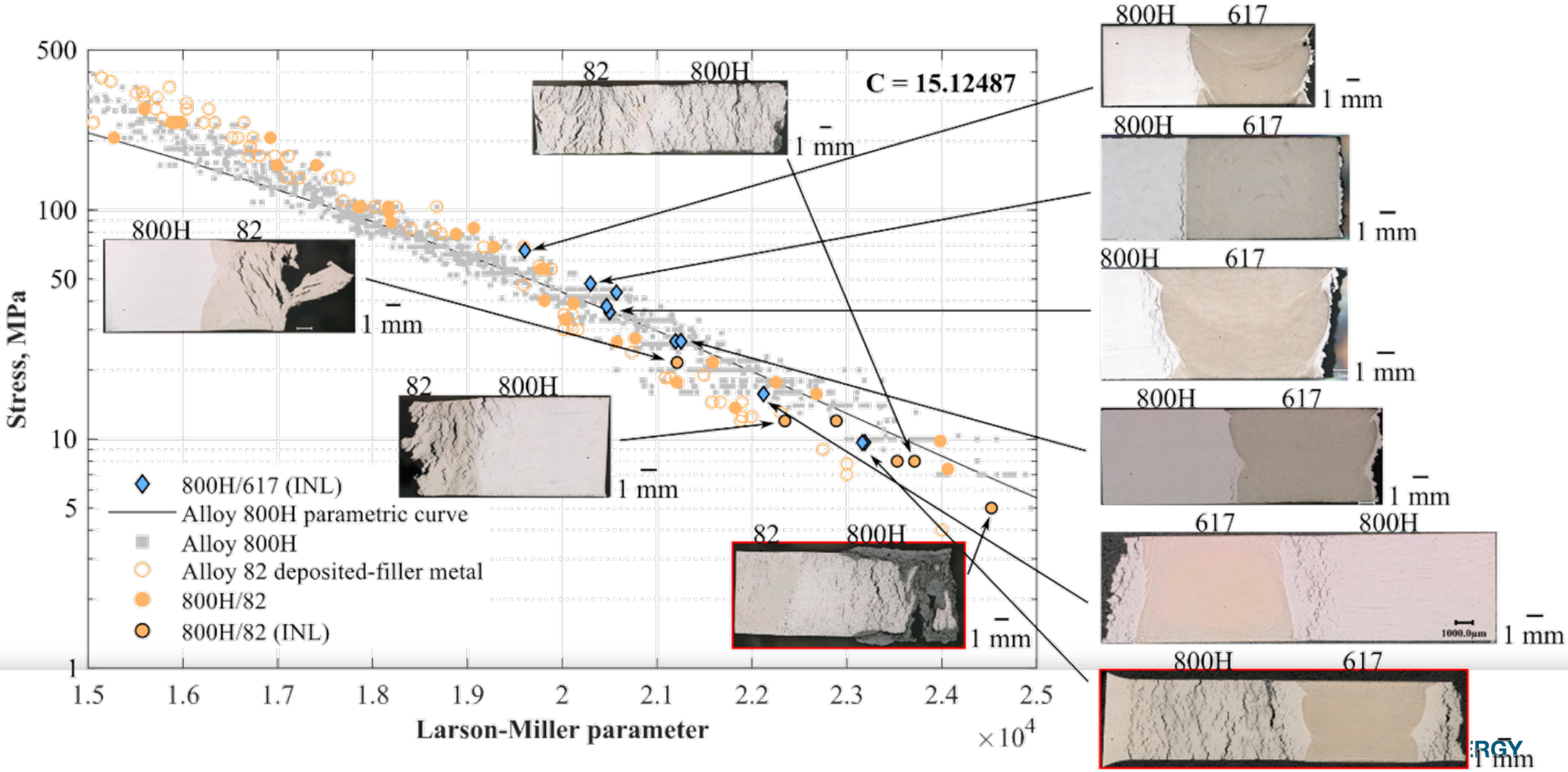
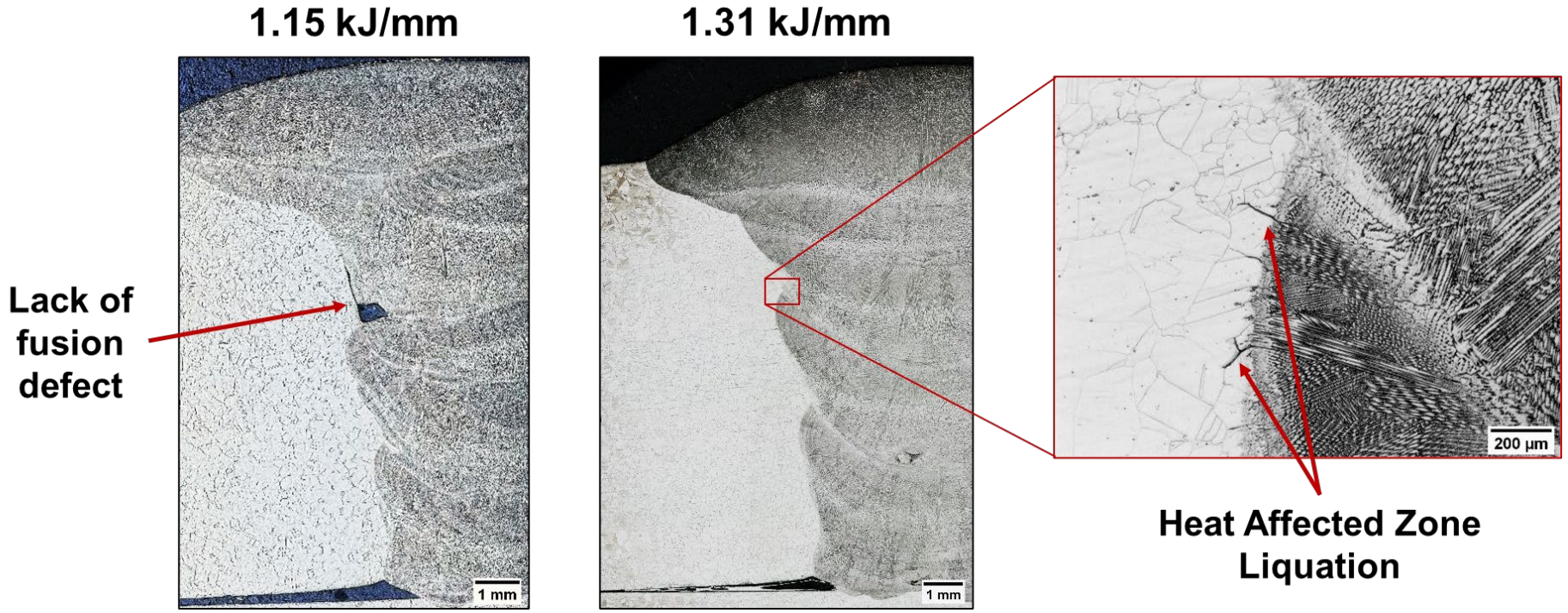


Results – UTP A 2133 Mn Weld Metal

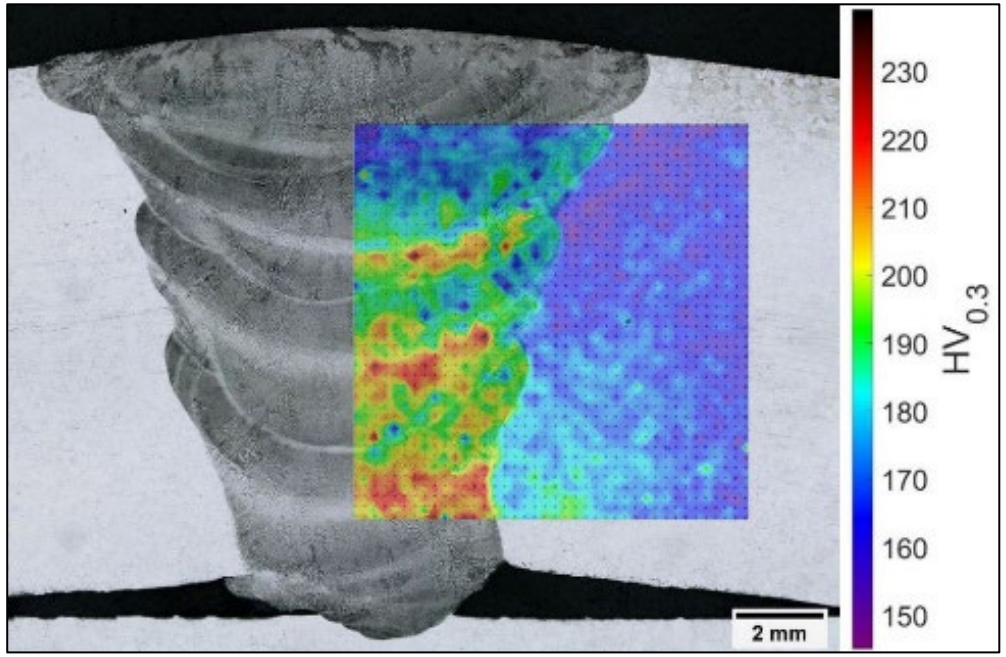
- UTP 2133 Mn Weld Parameter Optimization

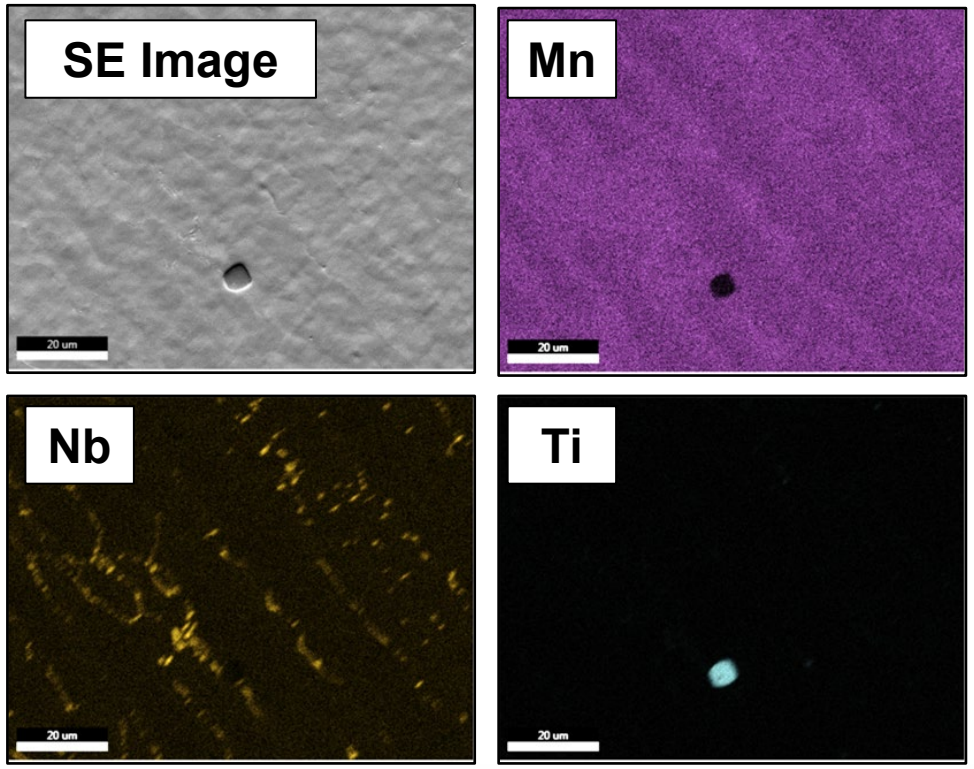


Results – UTP A 2133 Mn Weld Metal

- **UTP 2133 Mn ASME BPVC Section IX Qualification Weld with Defect-Free Parameters**

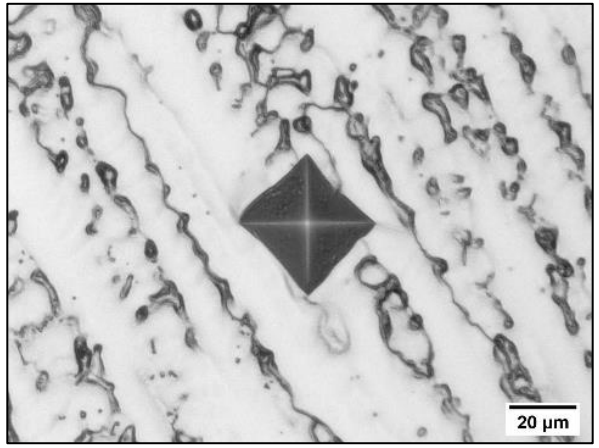
Vickers Hardness (300 g)



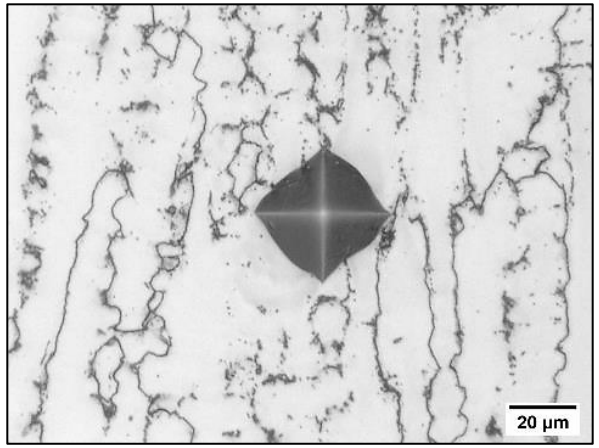


Results – UTP A 2133 Mn Weld Metal

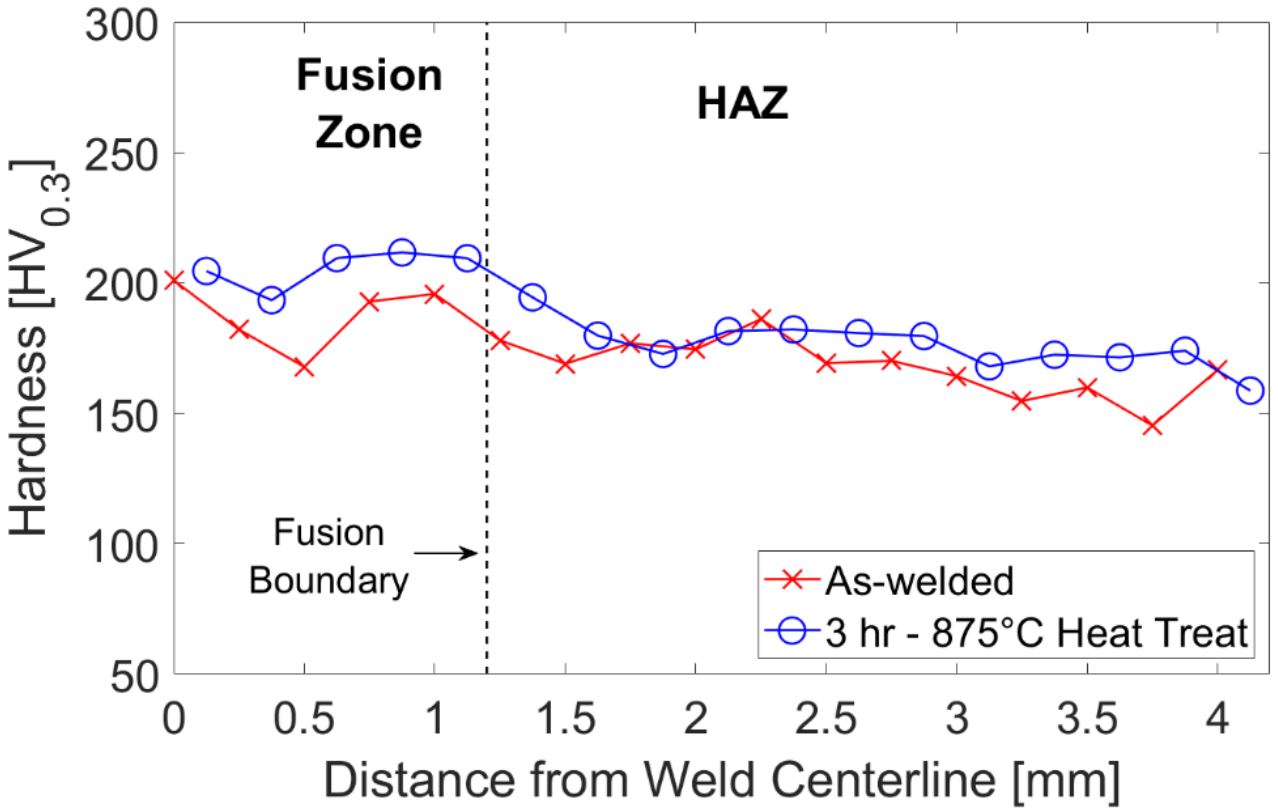
As Welded Fusion Zone



Heat Treated Fusion Zone (875°C for 3 hours)



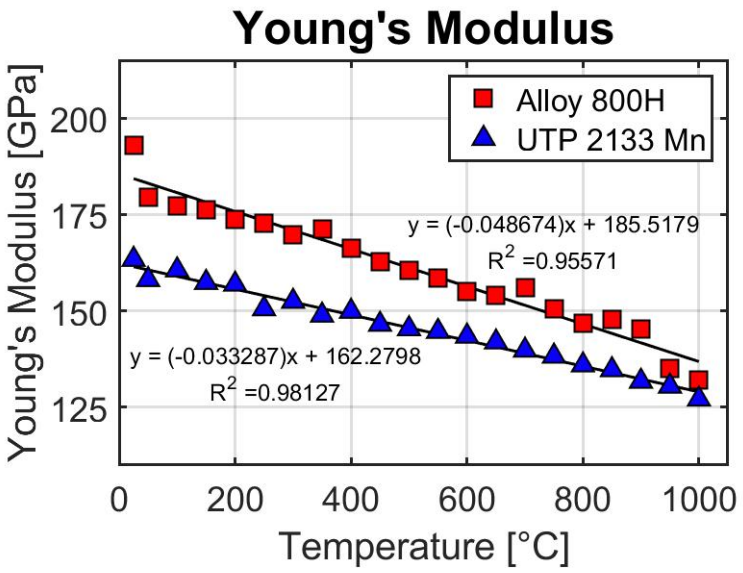
1.31 kJ/mm (33.2 kJ/in)

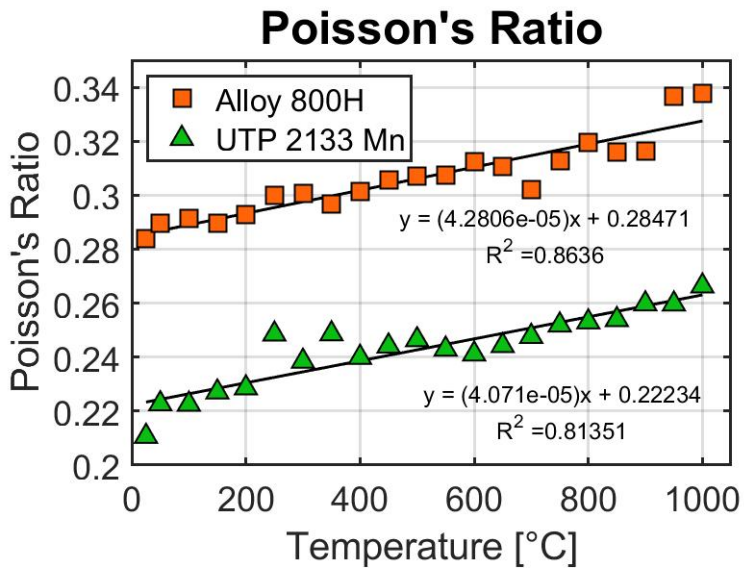


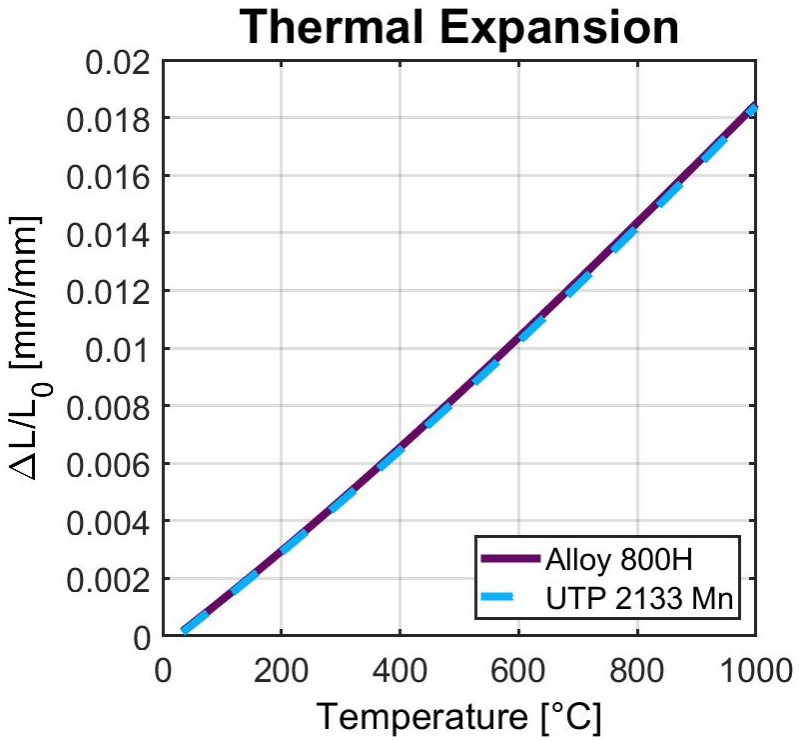
Results – UTP A 2133 Mn Weld Metal

- **Measured weld metal property data for comparison to Alloy 617 and Alloy 82 filler metals**

Laser Ultrasound Measurements Based on Sound Speed





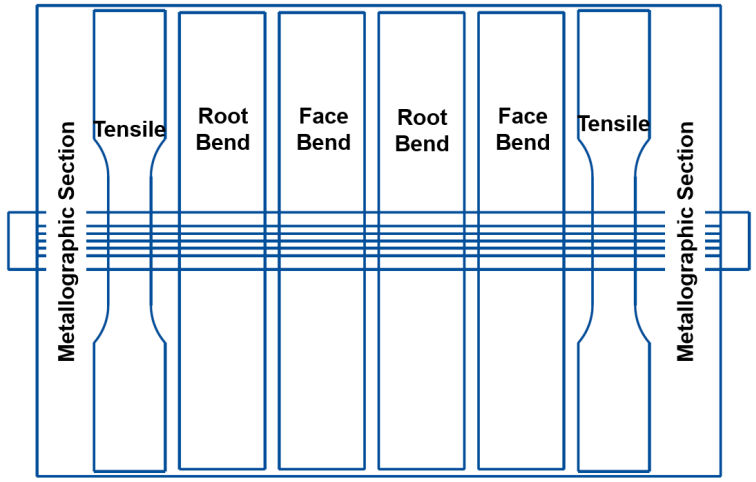


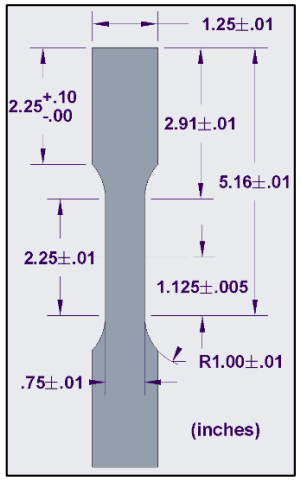
Conclusions – UTP A 2133 Mn Filler

- Higher heat input at or above ~1.3 kJ/mm showed sound weld cross-sections with no rejectable defects according to BPVC Section IX
- Weld metal showed higher hardness, lower Young's modulus, and nearly the same coefficient of thermal expansion compared to Alloy 800HT
- Niobium segregated to interdendritic regions, but heat treatments appear to reduce the segregation
- Heat affected zone showed a higher hardness than the as-processed base material

Future Work

- **Complete tensile and bend tests of the Alloy 800H welds**
  - The cross-weld UTS must equal to the UTS of the base metal (65 ksi, 800 MPa) or fail outside weld metal and be within 5% of the UTS
- **If successful, complete Alloy 800H welds with same parameters and initiate cross-weld creep testing**





Milestone

M3AT-23IN0604051, 09/22/2023

- Continue the effort to fabricate ASME Section IX qualified Alloy 800H weldment with a matching filler metal and initiate cross-weld creep rupture tests and issue a report to document FY23 progress

Thank you

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