



GCR: Development of Improved Alloy 800H Weldment

June 2023

Changing the World's Energy Future

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Joint ART Materials/AMMT Program Review

DOE Headquarters, Germantown, MD

June 5-8, 2023

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Idaho National Laboratory

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

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

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)

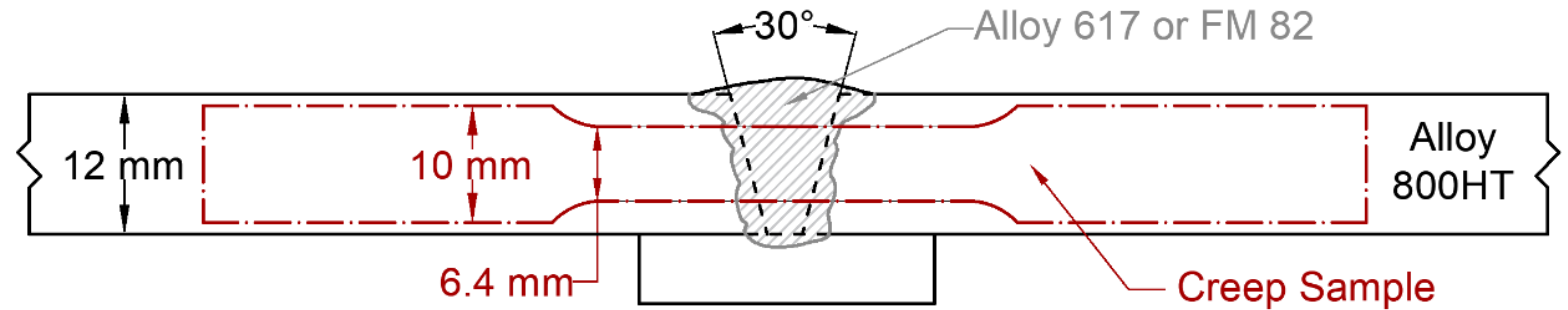
Temp. [°C]	30 000 h	100 000 h	300 000 h
600	0.85	0.83	0.81
625	0.85	0.83	0.81
650	0.86	0.83	0.81
675	0.85	0.82	0.80
700	0.85	0.82	0.78
725	0.84	0.78	0.71
750	0.76	0.67	0.59

Gas Tungsten Arc Welding (GTAW)

Materials and Procedures

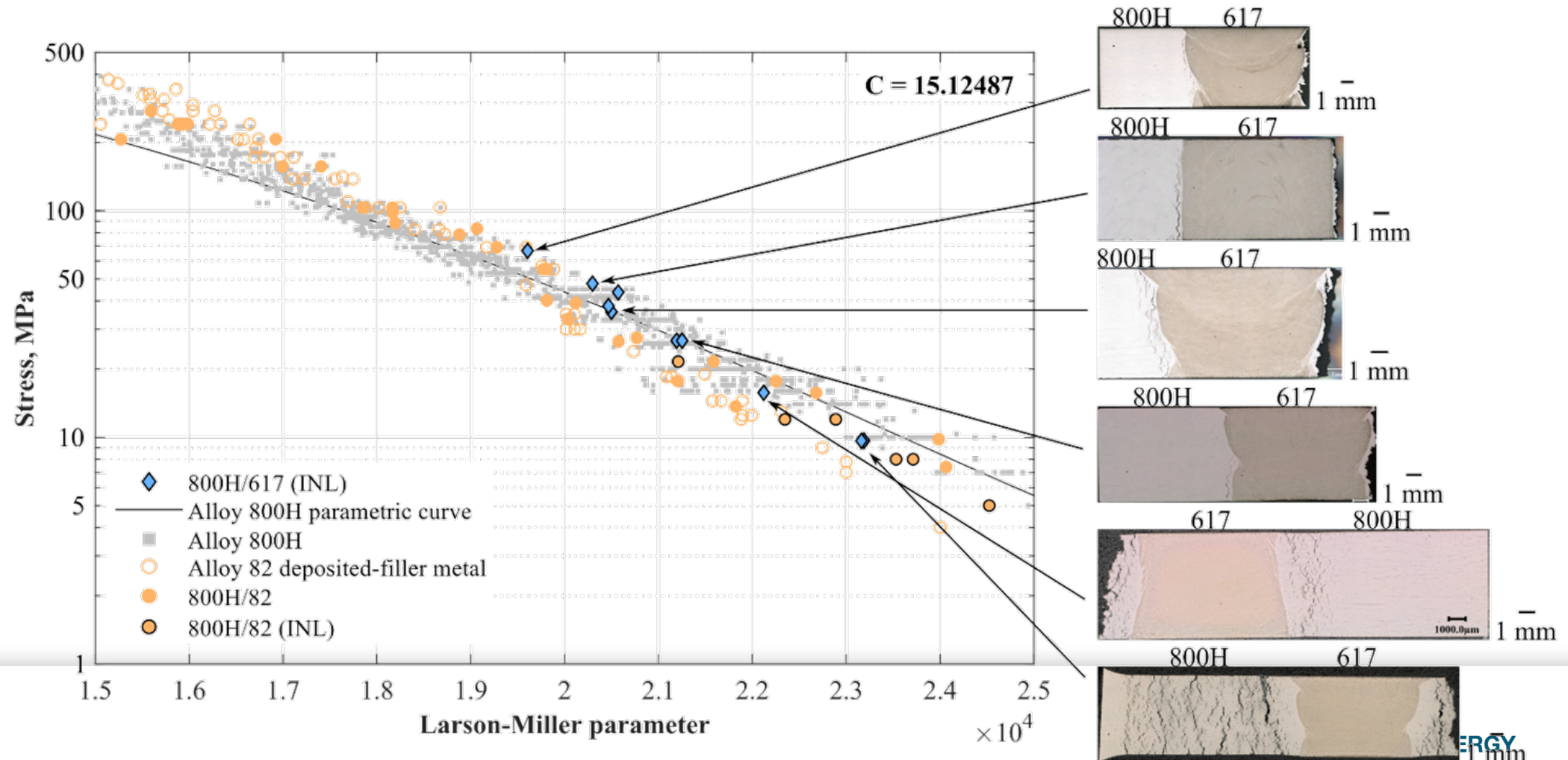
Chemical Compositions (wt%)

	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



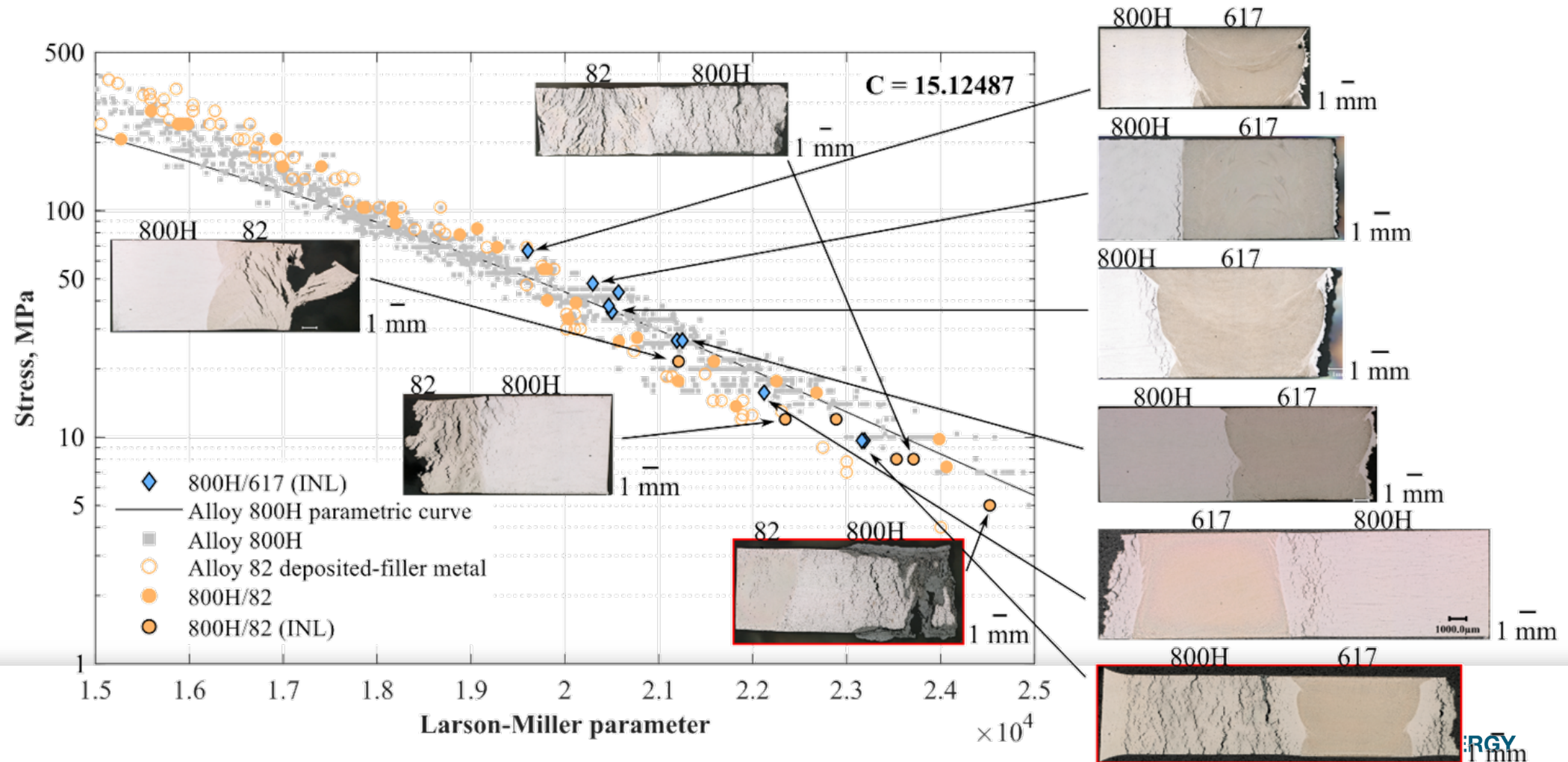
Prior Results – Weldment Creep Rupture

- Alloy 800H Weldment with Various Weld Consumables



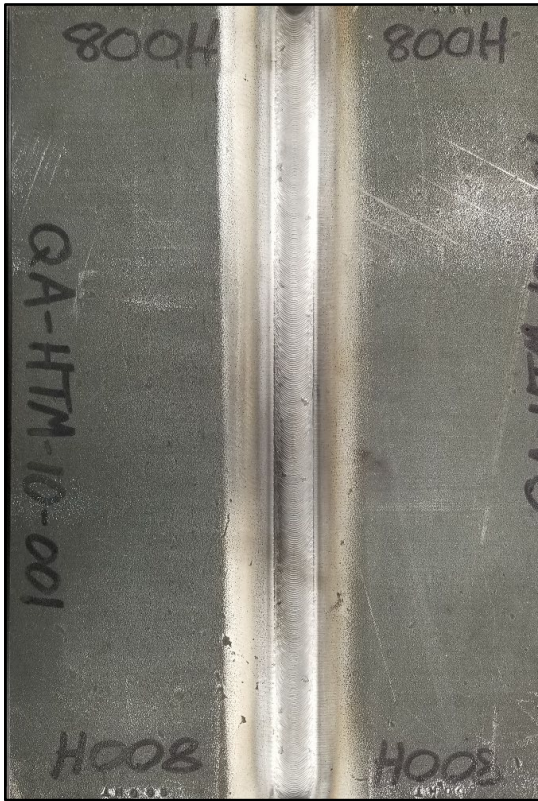
Prior Results – Weldment Creep Rupture

- Alloy 800H Weldment with Various Weld Consumables



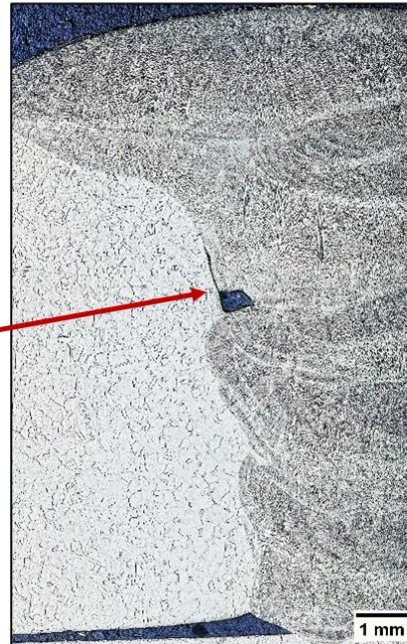
Results – UTP A 2133 Mn Weld Metal

- UTP 2133 Mn Weld Parameter Optimization

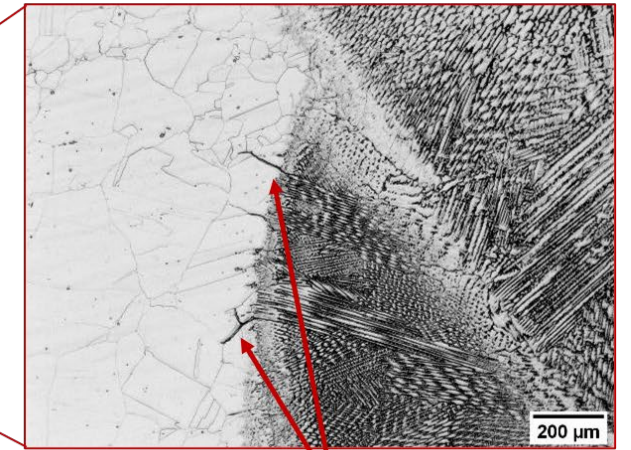


Lack of fusion defect

1.15 kJ/mm



1.31 kJ/mm

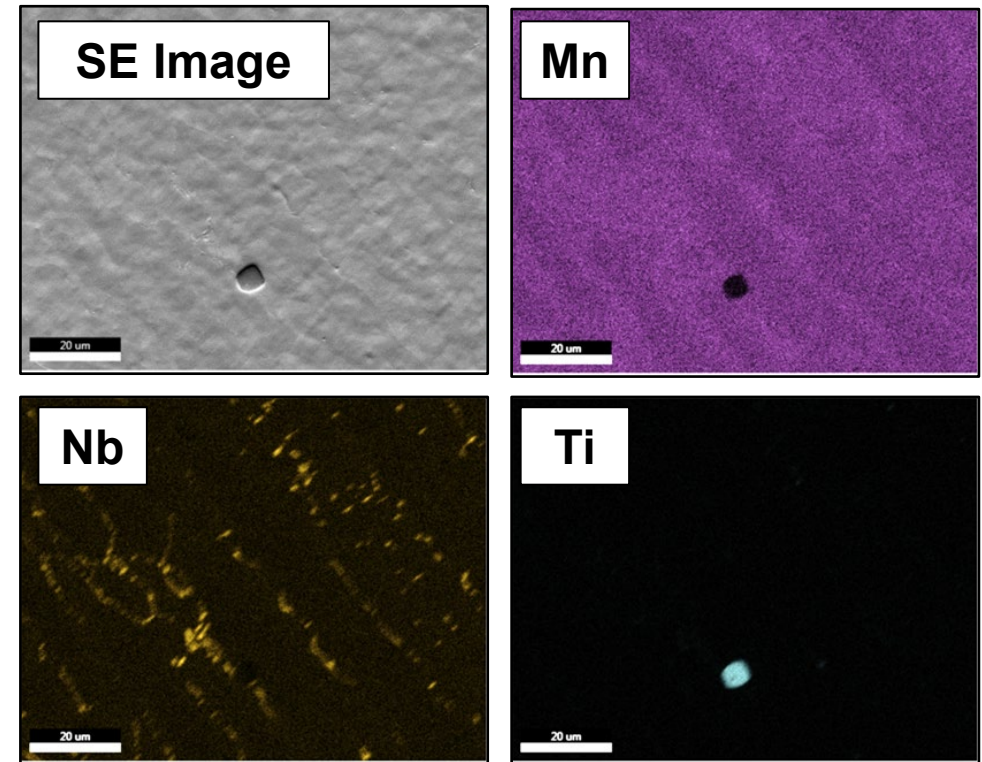
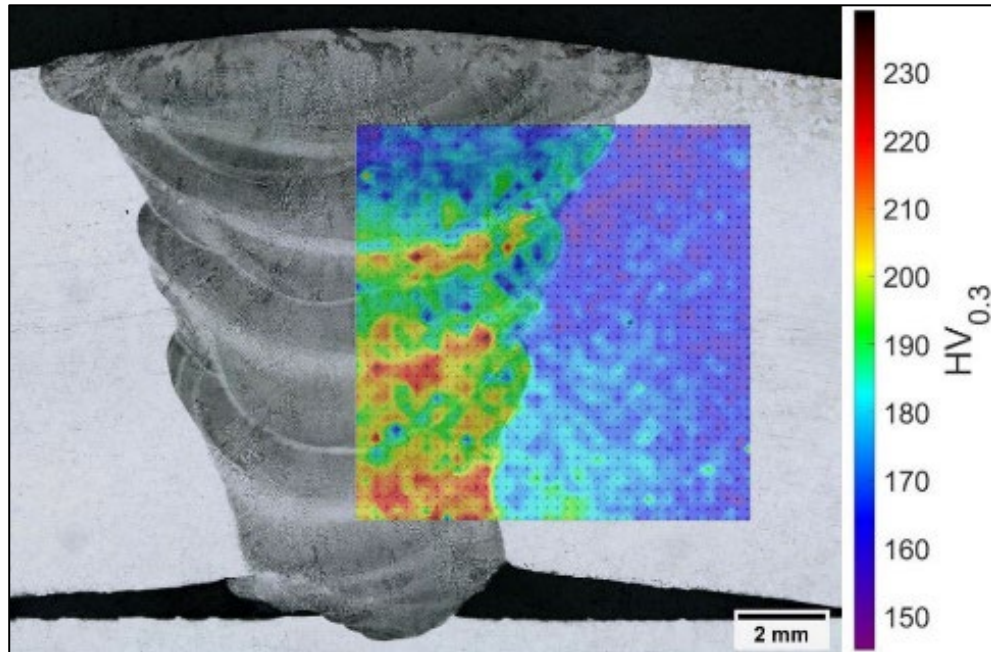


Heat Affected Zone
Liquation

Results – UTP A 2133 Mn Weld Metal

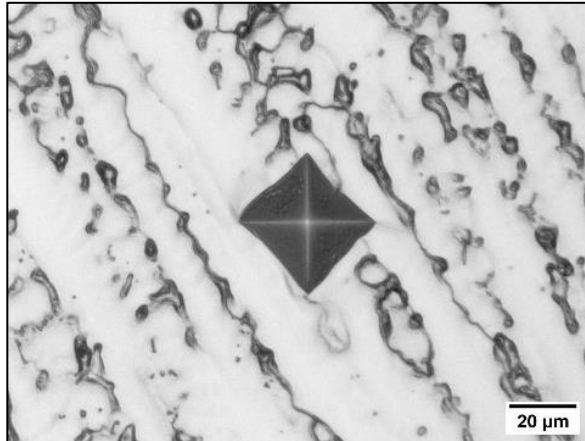
- UTP 2133 Mn ASME BPVC Section IX Qualification Weld with Defect-Free Parameters

Vickers Hardness (300 g)

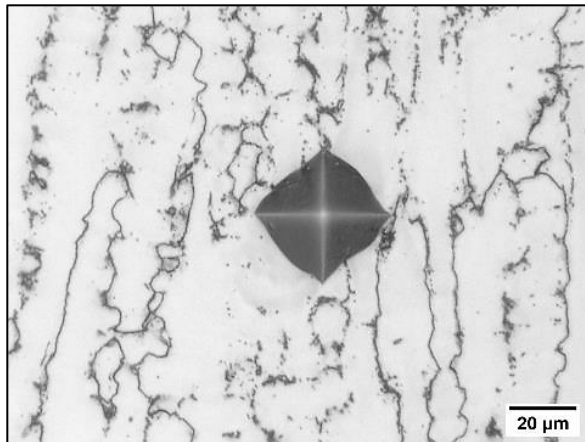


Results – UTP A 2133 Mn Weld Metal

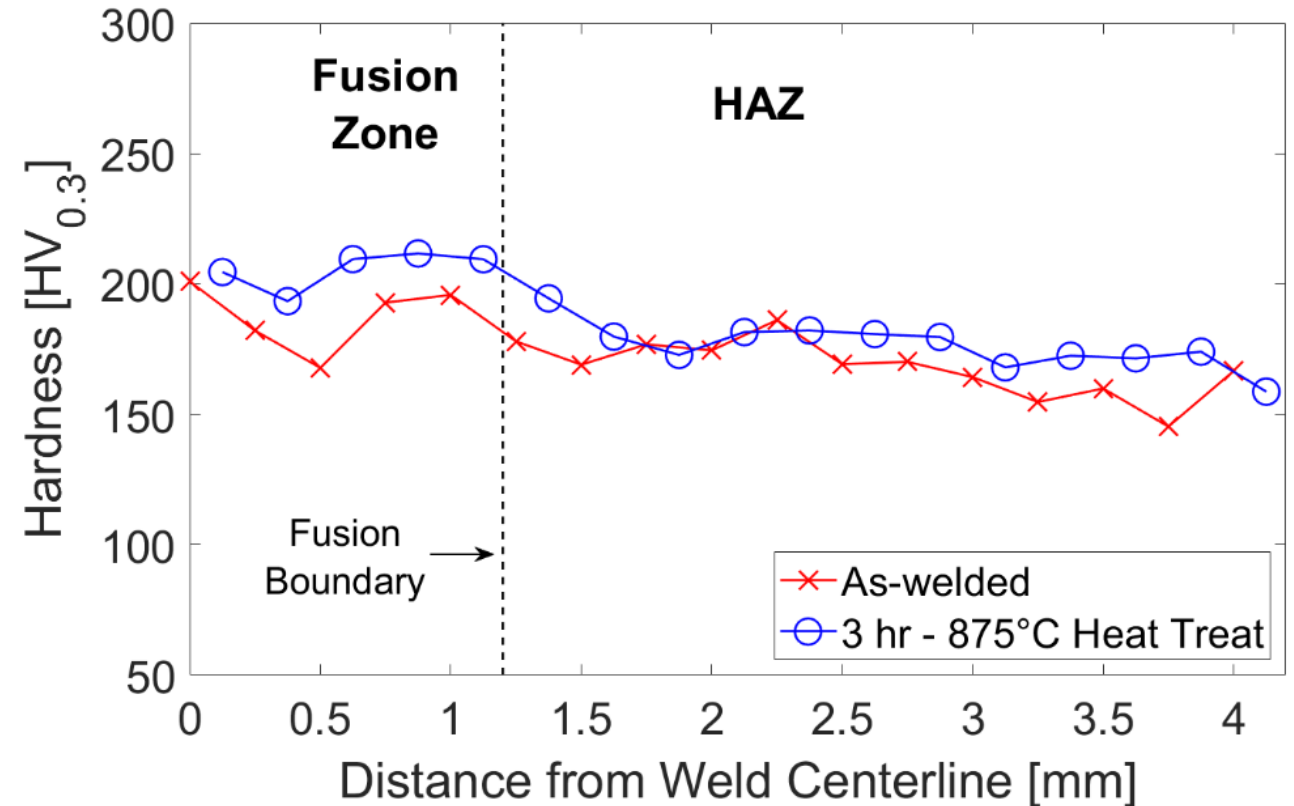
As Welded
Fusion Zone



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



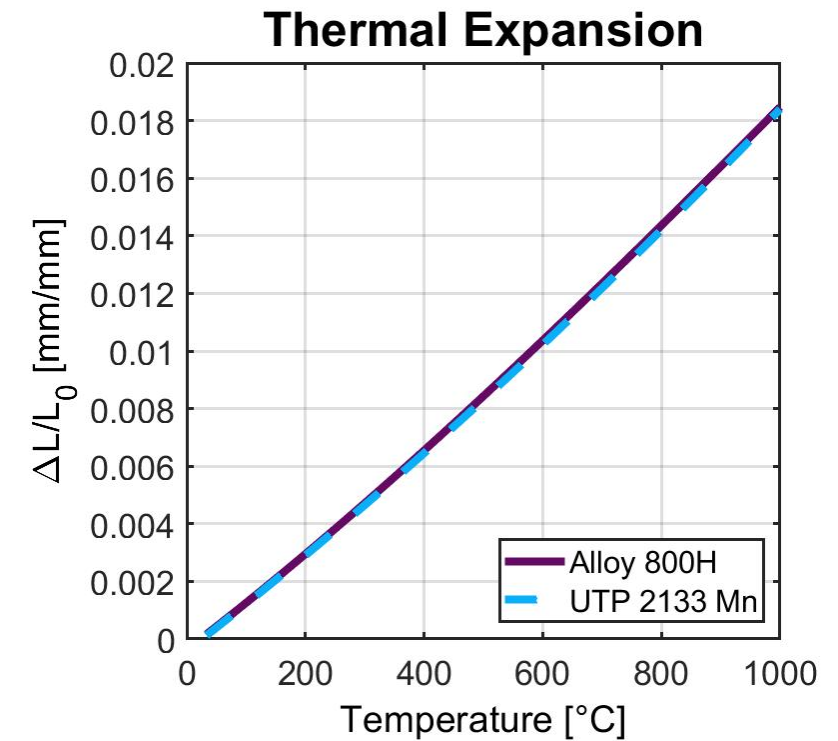
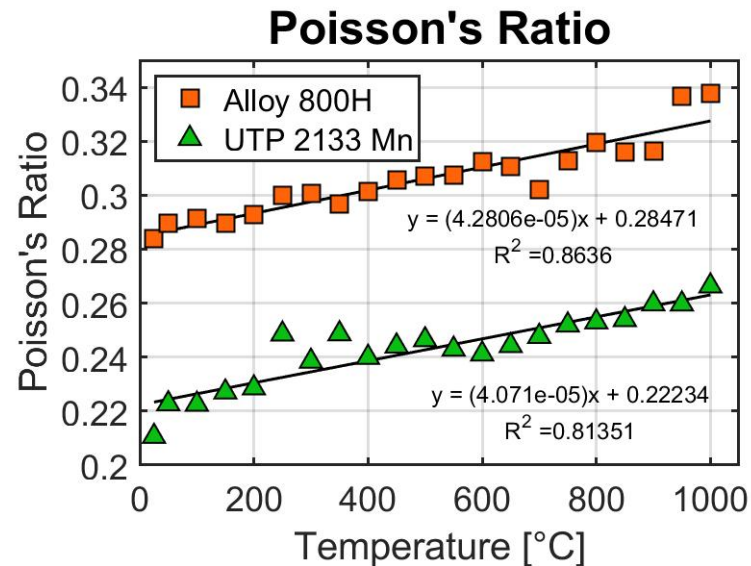
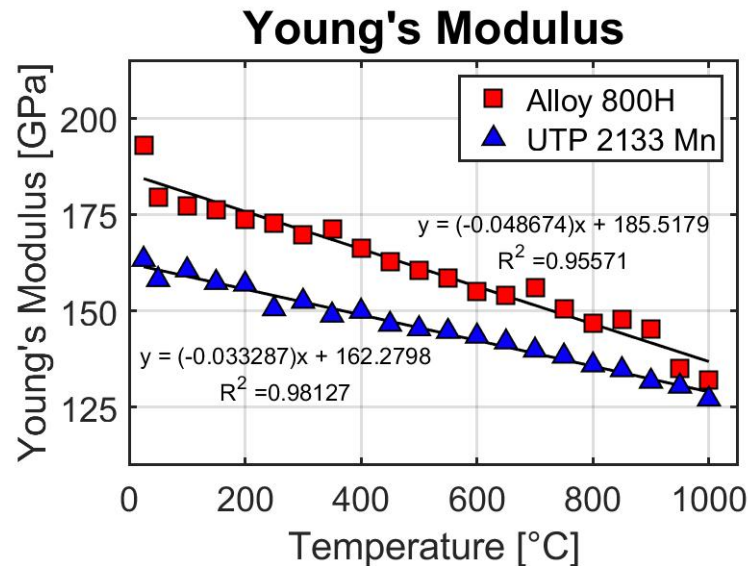
1.31 kJ/mm (33.2 kJ/in)



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

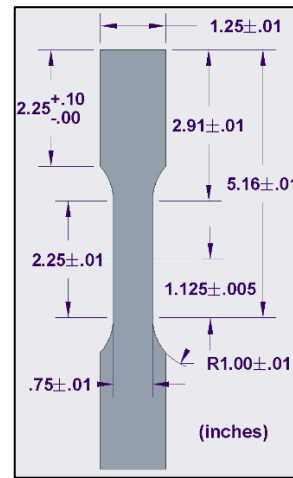
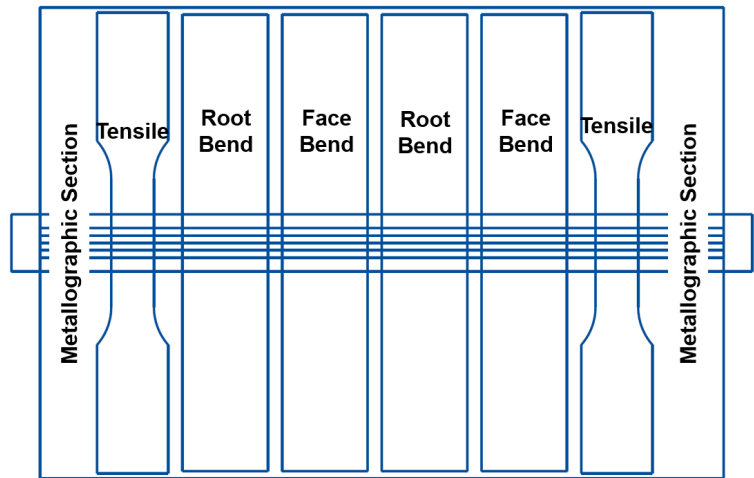


Conclusions – UTP A 2133 Mn Filler

- 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**

The background is a collage of various nuclear energy-related images, including a nuclear reactor core, a cooling tower, a worker in a hard hat, and a bundle of fuel rods. The images are overlaid with a blue and teal geometric pattern of intersecting lines.

Thank you

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