ASME Additive Manufacturing Codification
Workshop on Advanced Manufacturing Technologies for Nuclear Applications

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Rockville, Maryland

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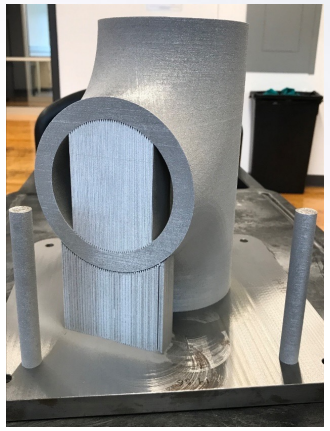
- The ASME goal is to have AM requirements in ASME Construction Codes and Product Standards with the 2025 Editions with Code Cases preceding the 2025 Edition.
- The ASME Special Committee on AM has drafted criteria for two Code Cases for Additive Manufacturing.
  - AM Construction of Pressure Equipment using the Direct Energy Deposition Process with Wire Feedstock.
    - Includes Gas Metal Arc Process.
  - AM Construction of Pressure Equipment using the Powder Bed Fusion AM Process.
    - Includes Laser and Electron Beam Energy Sources.
    - The material property verification testing in the PBF Code Case is being update to be parallel to the DED Criteria.
- The maximum design temperature shall be at least 50°F (25° C) colder than the temperature where time-dependent material properties govern.



Tee Built using PBF
4” Diameter x 8” Tall ≅ 50 lbs.
(Rolls-Royce)

Valve Built Using Gas Metal Arc DED
8” Valve ≅ 1000 lbs.
(EPRI/ Lincoln Electric)

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- **PBF and DED Criteria**
- Both the PBF and DED criteria provide the needed requirements for the materials, design, fabrication, examination, inspection, testing and quality control.

- **Powder Bed Fusion**
- Scope
- Additive Manufacturing Specification
- Materials
- Thermal Treatment
- Powder Requirements
- Design Requirements
- PBF Procedure
- Procedure Qualification Builds
- Production Builds
- Chemical Composition Testing
- Mechanical Property Testing
- Metallographic Evaluation
- Referenced Standards
- Definitions
- Records
- Quality Program

- **Direct Energy Deposition**
- Scope
- Additive Manufacturing Specification
- Materials
- Thermal Treatment
- Design Requirements
- Welding Qualification (Section IX, Article VI)
- Procedure Qualification Builds
- Production Builds
- Chemical Composition Testing
- Mechanical Property Testing
- Metallographic Evaluation
- Referenced Standards
- Definitions
- Records
- Quality Program

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- **Allowable Stress Values for DED AM Weld Metal**
- The ASME AM Committee and BPVC Section II have developed criteria for verification testing AM Material to ensure mechanical properties.
  - What criteria and verification testing is needed to enter the allowable stress tables in ASME BPVC Section II Part D and use base metal property data for the allowable stress values for AM deposited weld metal?
    - Tensile data for deposited weld metal needs to show the same trends with temperature for properties between the deposited metal and base metal.
    - Verification testing to address heat input and cooling rates for the AM deposited weld metal.
    - ASME BPVC has an extensive successful experience with welding in a wide verity of materials and services.
- Heat input and cooling rate, which are Additive Manufacturer process dependent, and PWHT control the final tensile properties.
  - Different criteria are needed for acceptance of AM material because of the variability in tensile properties for a given filler material with heat input and cooling rate.
  - The current Section II Appendix 5 process for new materials is impractical for AM because of the variability in heat input and cooling rate.

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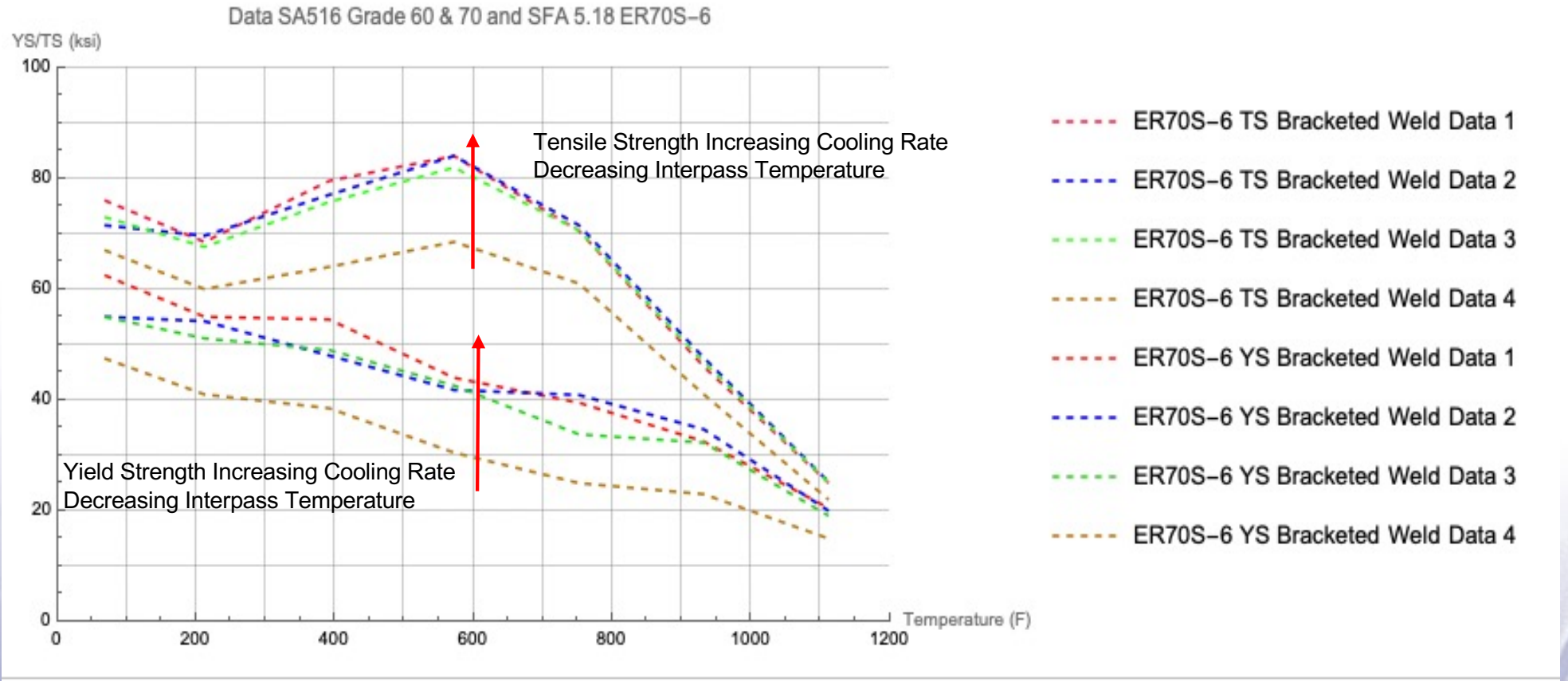
- **Tensile Properties for Weld Metal and DED Sample Builds**
  - Data for ER70S-6 Filler - Variability in material properties for a given filler material with heat input and cooling rate.
  - Lincoln Electric Design of Experiments Project



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- **Tension Test Requirements in ASME BPVC Section IX Article VI Bracket Weld Qualification is required in the DED Criteria.**
- Additive Material Manufacturing Procedure Qualification Requirements.
  - Required for each filler material.
  - Minimum of 4 Tension Tests – 2 High Cooling Rate – 2 Low Cooling Rate.
  - Minimum of 4 Bend Tests – 2 High Cooling Rate – 2 Low Cooling Rate.
- Additional Testing Required by the AM DED Criteria.
  - One (1) additional high temperature tension test from low cooling rate temperature QW-600 weldment.
  - Analyze tensile test data to calculate the minimum required room temperature tensile properties for the AM Qualification Builds and Production Builds.

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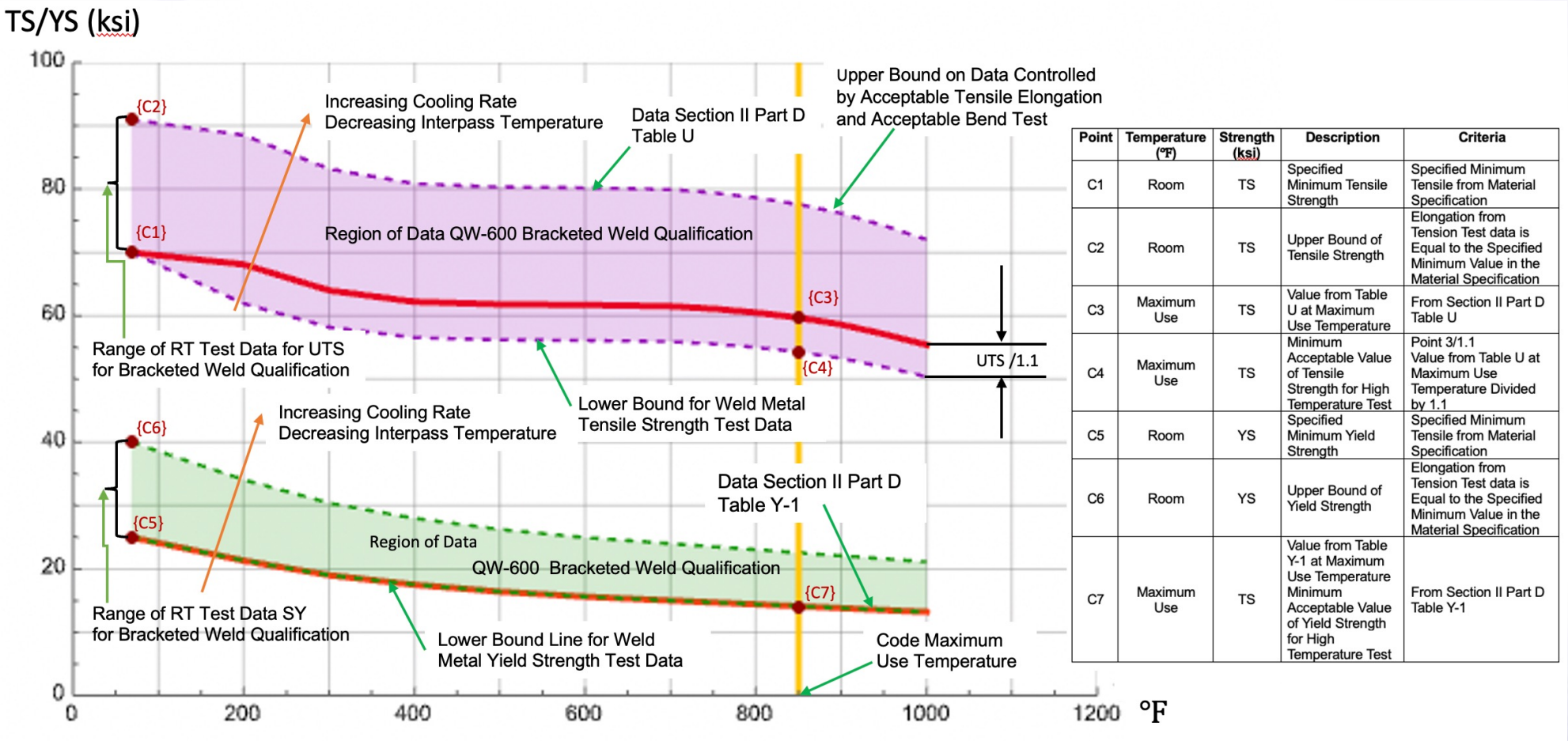
- **Bounding Criteria for DED Bracketed Weld Qualification**



Point	Temperature (°F)	Strength (ksi)	Description	Criteria
C1	Room	TS	Specified Minimum Tensile Strength	Specified Minimum Tensile from Material Specification
C2	Room	TS	Upper Bound of Tensile Strength	Elongation from Tension Test data is Equal to the Specified Minimum Value in the Material Specification
C3	Maximum Use	TS	Value from Table U at Maximum Use Temperature	From Section II Part D Table U
C4	Maximum Use	TS	Minimum Acceptable Value of Tensile Strength for High Temperature Test	Point 3/1.1 Value from Table U at Maximum Use Temperature Divided by 1.1
C5	Room	YS	Specified Minimum Yield Strength	Specified Minimum Tensile from Material Specification
C6	Room	YS	Upper Bound of Yield Strength	Elongation from Tension Test data is Equal to the Specified Minimum Value in the Material Specification
C7	Maximum Use	TS	Value from Table Y-1 at Maximum Use Temperature Minimum Acceptable Value of Yield Strength for High Temperature Test	From Section II Part D Table Y-1

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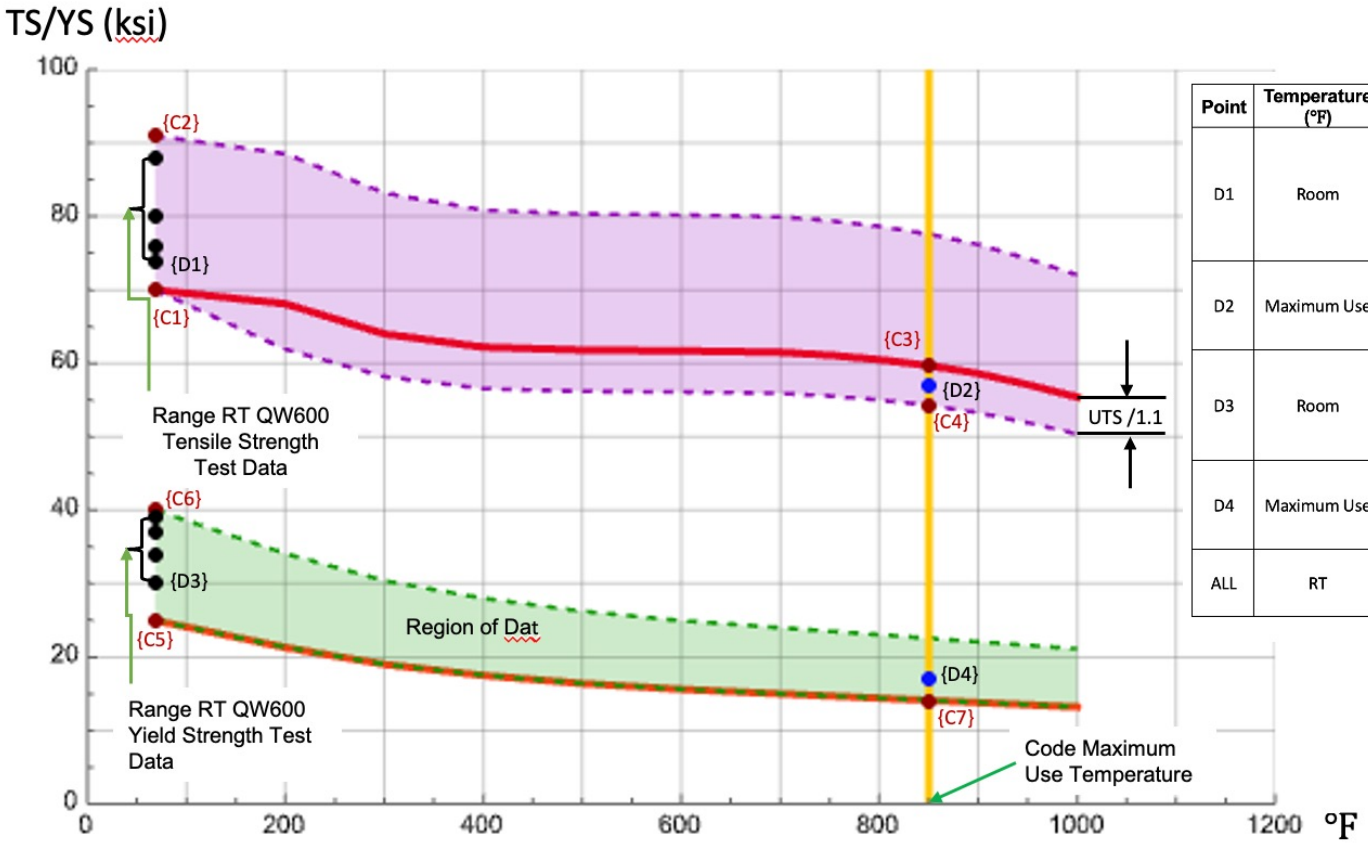
- **Bounding Criteria for DED Bracketed Weld Qualification**
  - Showing Example Test Data



Point	Temperature (°F)	Strength (ksi)	Description	Criteria
D1	Room	TS	Minimum Value of Tensile Strength from QW 600 Data	Minimum Tensile Strength and Elongation from the QW-600 Tests Shall Equal or Exceed the Specified Minimum Tensile Strength in the Material Specification (Point C1)
D2	Maximum Use	TS	High Temperature Tensile Strength Test Data Point	Minimum Tensile Strength Value from QW-600 Test Shall Equal or Exceed Value Calculated for Point C4
D3	Room	YS	Minimum Value of Yield Strength from QW 600 Data	Minimum Yield and Elongation from the QW-600 Tests Shall Equal or Exceed the Specified Minimum Yield Strength in the Material Specification (Point C5)
D4	Maximum Use	YS	High Temperature Yield Strength Test Data Point	Minimum Yield Strength and Elongation from QW-600 High Temperature Test Equal or Exceed Value of C7
ALL	RT	TS/YS	Range of QW 600 Tensile Data	Elongation from Tension Test is Below Specified Minimum in the Material Specification

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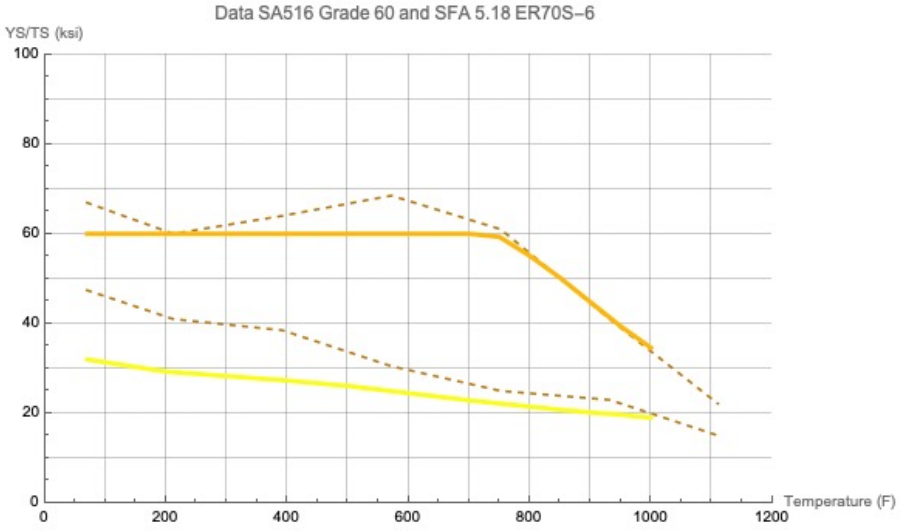
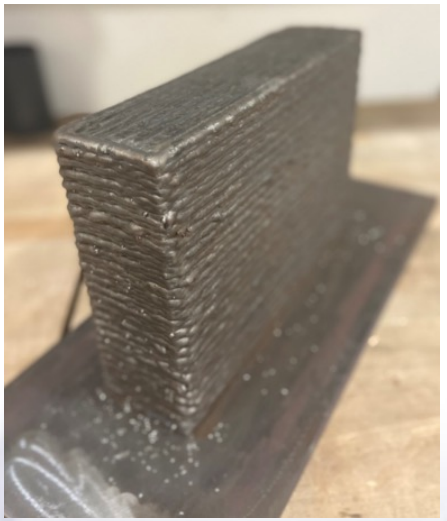
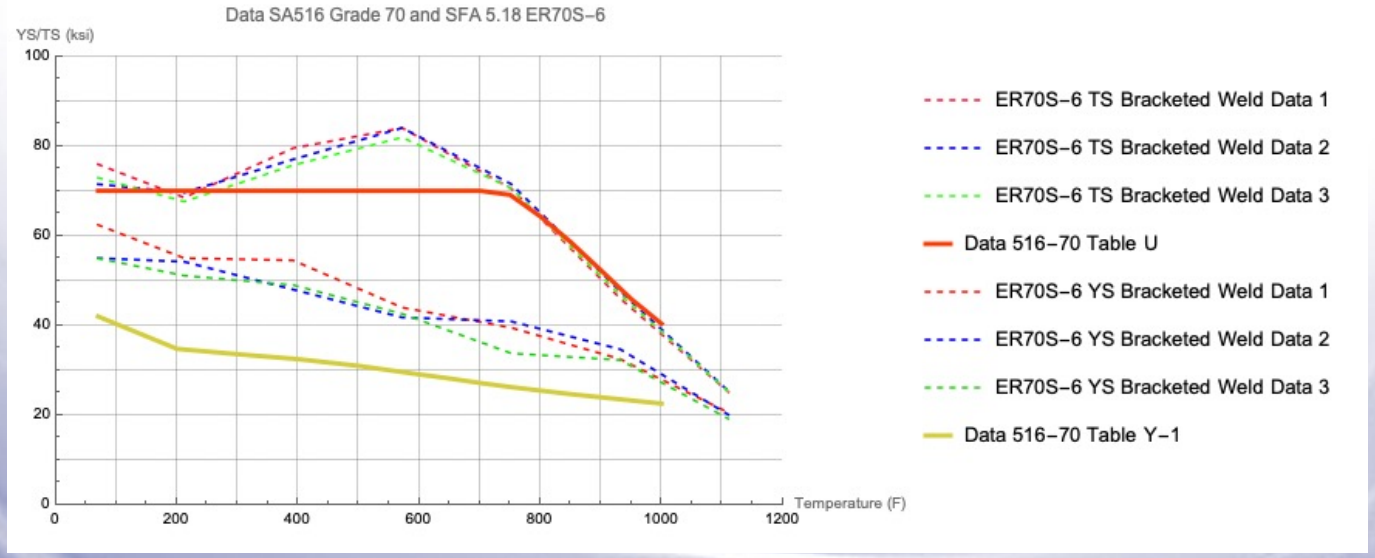
- **ER70S-6 can be qualified for either SA516-60 or SA516-70.**
- **The effect of heat input and interpass temperature must be addressed for AM**
- **Verification testing and controls are required at the AM facility.**







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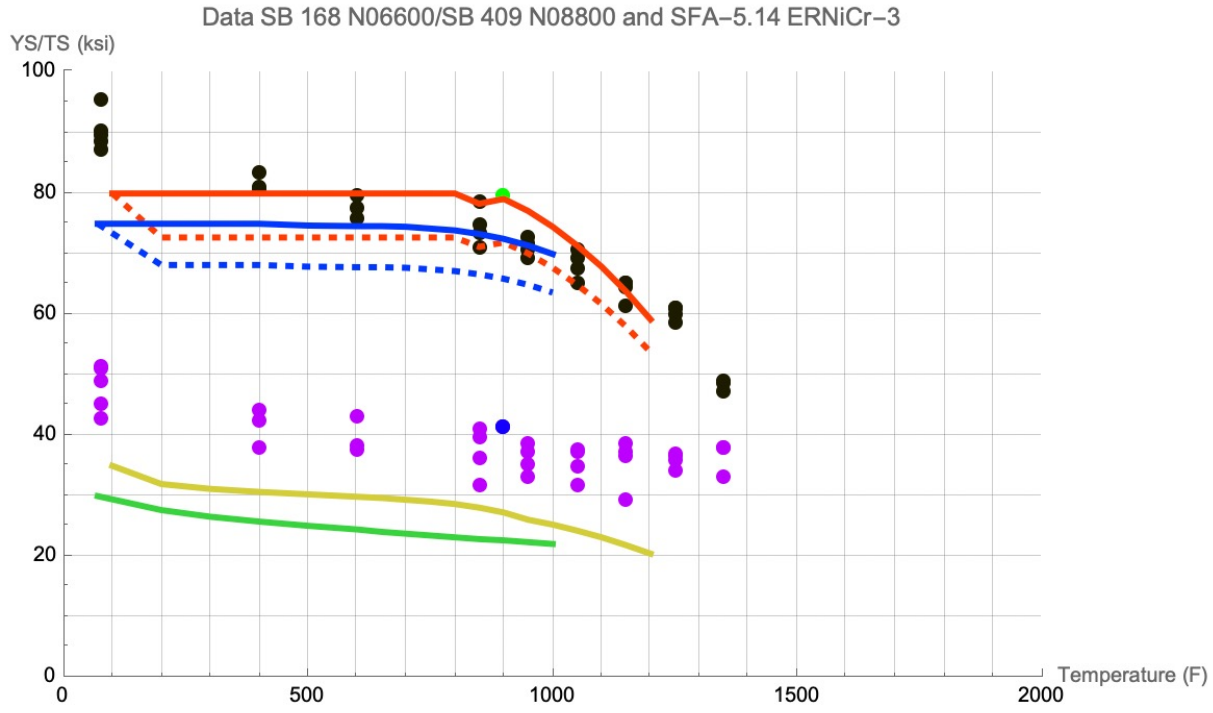
- **ERNiCr-3 compared to SB 168 N06600 and SB 409 N08800**
- **The ERNiCr-3 Data is from manual welding not DED AM**



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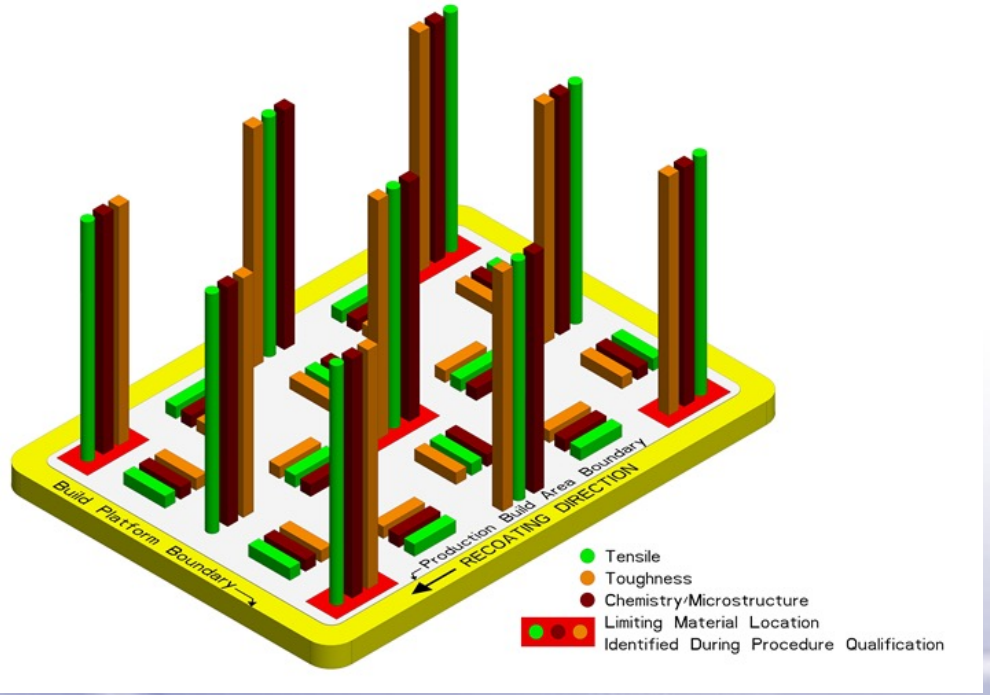
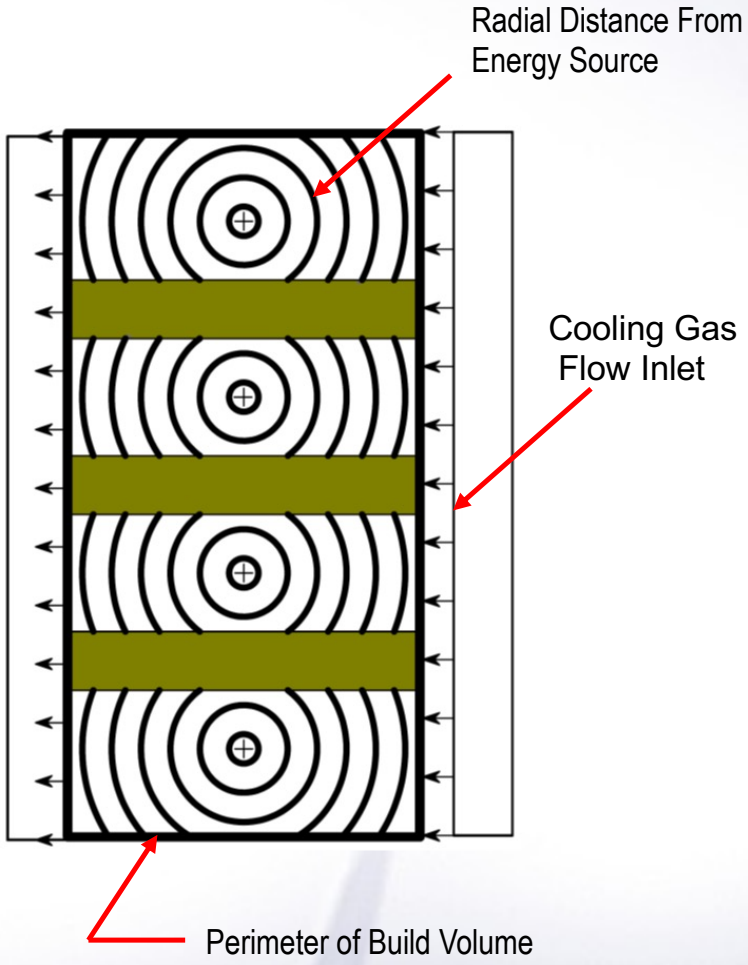
- **Additive Manufacturing Procedure**

- The Additive Manufacturer shall identify the locations of limiting material conditions for each energy source
- The qualification builds shall include a minimum of 3 powder lots.
- Understanding material cooling rates





Specimens for PBF Additive Manufacturing Procedure Qualification

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- The ASME Special Committee AM document “Criteria for Pressure Retaining Metallic Components Using Additive Manufacturing” was published in Pressure Technology Book-13 in May 2021.
- The criteria in PTB-13 has been applied to develop an ASME BPVC Section I Code Case for pressure relief valve bodies using PBF AM

Revisions needed to PTB-13

- The same material property verification testing will be used for PBF that has been developed for DED.
- PTB-13 will be revised to address the PBF process for one-off components vs multiple duplicate components.
- PTB-13 will be used to document the work done to develop the technical baseline for both the PBF and DED AM Processes

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- **Integration of AM into ASME Codes and Standards**
- **ASME Nuclear and Pressure Technology Code Committee Activities**
- **Section I (Power Boilers)**
  - AM Task Group meeting to incorporate DED AM
  - Issued a PBF Code Case for relief valve parts
- **Section III (Nuclear Facility Components)**
  - AM Task Group has begun incorporation of PBF and DED AM
  - Balloted Code Cases for DED and LPBF for Grade 316L material
- **Section VIII (Pressure Vessels)**
  - AM Task Group has begun incorporation of DED AM
- **B31 (Code for Pressure Piping)**
  - AM Task Group to begin incorporation of AM
  - B31 has issued a review and comment ballet for using DED AM
- **B16 (Standards for Pipes and Fittings)**
  - Formed a Task Group to begin incorporation of AM

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Questions ???

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