316L Stainless Steel Manufactured via Laser Powder Bed Fusion Additive Manufacturing

Data Package & Code Case

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U.S. NRC Workshop on Advanced Manufacturing Technologies for Nuclear Applications
December 9, 2020

DOE Project:
DE-NE0008521

ELECTRIC POWER RESEARCH INSTITUTE

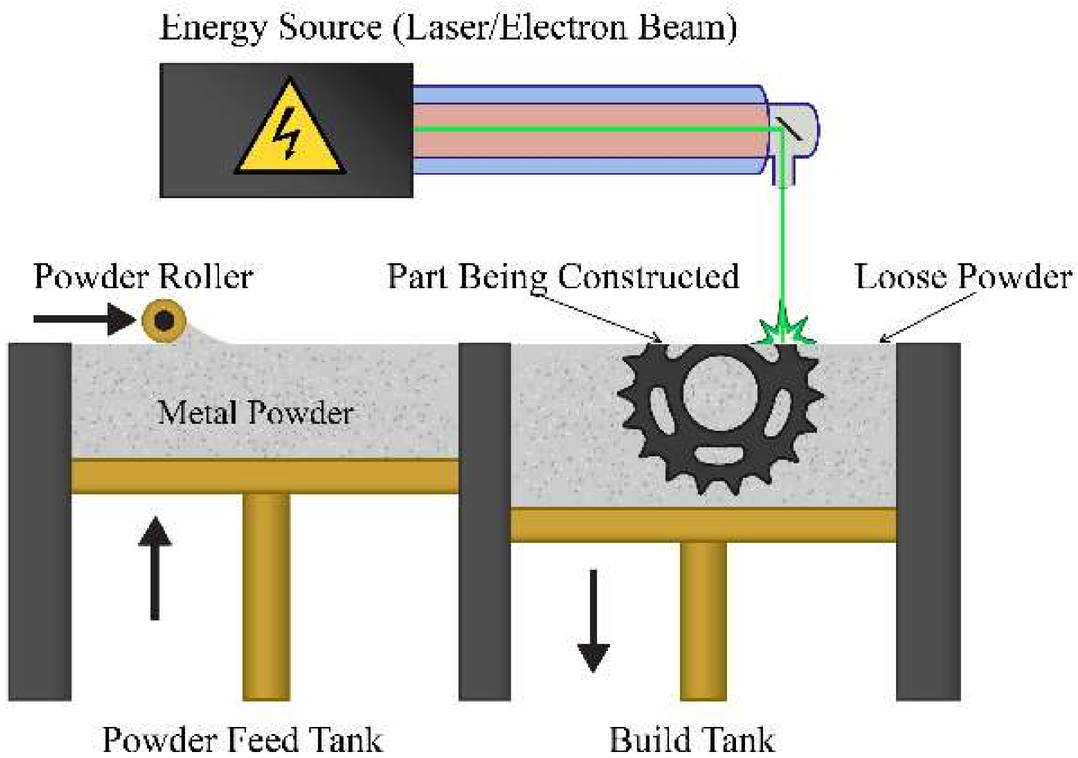
Westinghouse

A Few Attributes of LPBF-AM

- Attractive for pressure retaining applications across the power-, chemical-, process-, and pulp & paper industries, etc. including:
  1. Speed to produce a final part/component
  2. Capability to produce multiple parts using identical parameters with little or no variance between the parts
  3. Ability to monitor/capture build conditions throughout the build process
  4. Ability to produce structural parts with optimized support / features, enabling lighter and/or stronger components
  5. The ability to produce obsolete components in a relatively short timeframe

AM Qualification for Nuclear Applications
--ASME Data Package Development

- DOE Project: **DE-NE0008521**
- EPRI lead
- Five organizations involved
  - Rolls-Royce
  - Westinghouse
  - ORNL MDF
  - Auburn University
  - Oerlikon
- Laser Powder Bed-AM
- 316L SS



Laser Powder Bed-AM (*courtesy of 3DEO*)

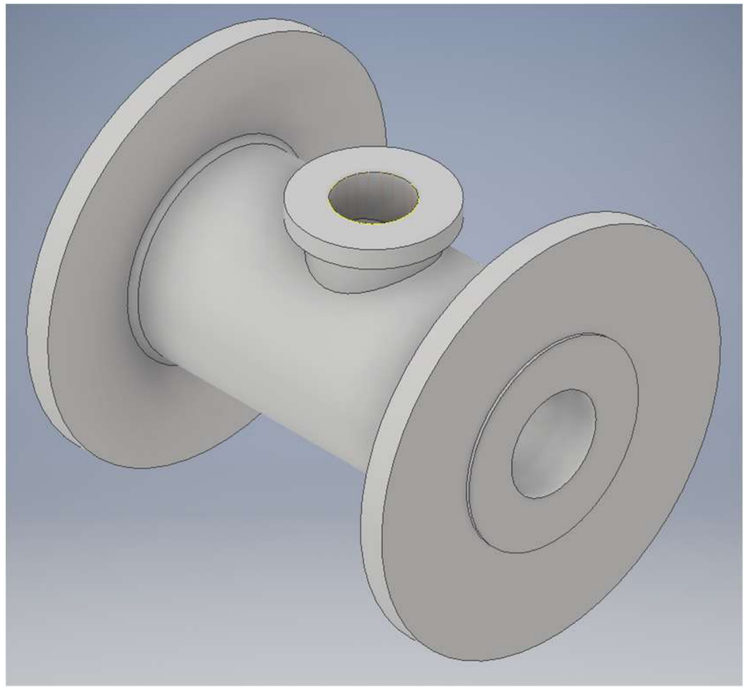
AM Qualification for Nuclear Applications
--ASME Data Package Development

- 2 Types of machines
  - EOS, Renishaw
- 4 sets of processing parameters
- 4 different 316L powder heats
- 3 different components (next slide)
- Components are >8-inches in diameter and ~0.5-inch thick
- Different build environments --argon and nitrogen
- Two conditions: HIP and SA; SA only
- Vertical control/witness samples included
- Parameter data sheet recorded for each build

EOS M290 System

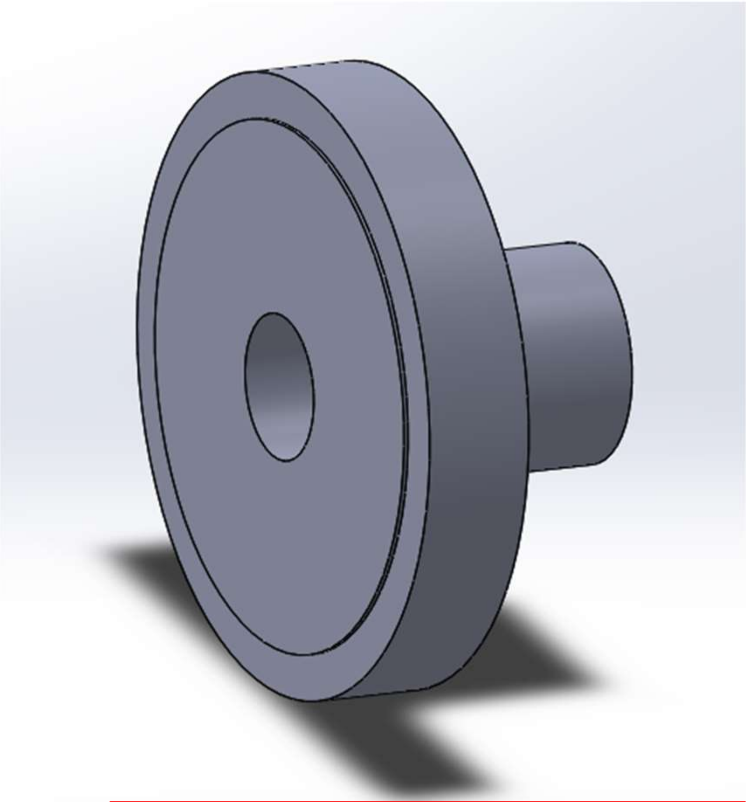
Courtesy: Westinghouse / Penn United Technologies

AM Qualification for Nuclear Applications
--ASME Data Package Development



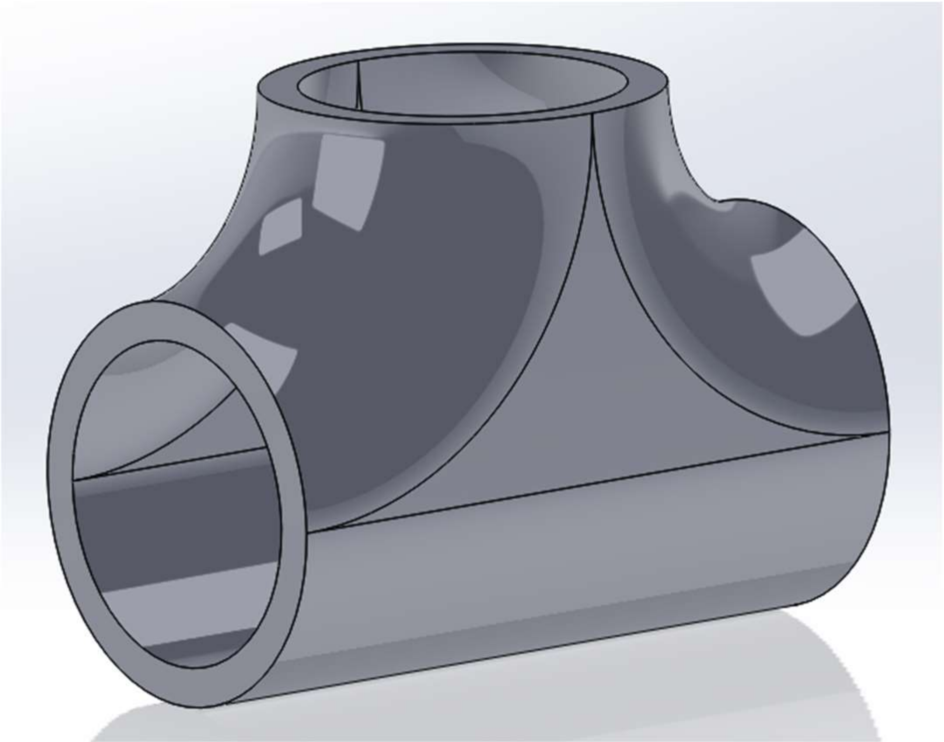
Class 300 Forged Gate Valve Body

8"Ø x 2"bore x 4"OD x ½"T



Ring Flange End Connection

8.5"Ø x 1.5"T x 2" bore



Straight Pipe Tee

8-1/4"W x 4-1/8"T

2.0 Chemical Composition Requirements

Table 2-1. Chemical Composition of S31603 (316L) Manufactured Components

Element	C*	Mn*	P*	S*	Si*	Cr	Ni	Mo	Fe
	0.030	2.00	0.045	0.030	1.0	16.0-18.0	10.0-14.0	2.0-3.0	Bal

**maximum*

2.1 Tensile Requirements

The minimum tensile requirements per ASTM F3184-16 are shown below:

Table 2-2. Minimum Tensile Requirements

TABLE 3 Minimum Tensile Requirements[A]

Room Temperature Condition	Tensile Strength, MPa (ksi], X and Y Directions	Tensile Strength, MPa (ksi], Z Direction	Yield Strength at 0.2% Offset, MPa (ksi), X and Y Directions	Yield Strength at 0.2% Offset, MPa (ksi), Z Direction	Elongation in 50 mm (2 in.) or 4D, (%), X and Y Directions	Elongation in 50 mm (2 in.) or 4D, (%), Z Direction	Reduction of Area, %, X and Y Directions	Reduction of Area, %, Z Direction
A - Stress Relieved[B]	515 (75)	515 (75)	205 (30)	205 (30)	30	30	40	40
A - Solution Annealed	515 (75)	515 (75)	205 (30)	205 (30)	30	30	30	30
B	515 (75)	515 (75)	205 (30)	205 (30)	30	30	30	30
C	515 (75)	515 (75)	205 (30)	205 (30)	30	30	30	30
E	no requirement	no requirement	no requirement	no requirement	no requirement	no requirement	no requirement	no requirement

[A] A gauge length corresponding to ISO 6892 may be used when agreed upon by the component supplier and purchaser.
[B] Mechanical properties conform to Specification A479/A479M.

2.2 Heat Treatment Requirements

The minimum heat treatment requirements per ASTM F3184-16 are shown below:

Process components under inert atmosphere at not less than 100MPa (14.5ksi) within the range of 1120 to 1163°C (2050 to 2125°F); hold at the selected temperature within ± 14°C (± 25°F) for 240 ± 60 min and cool under inert atmosphere to below 427°C (800°F), or to parameters agreed upon by the component supplier and purchaser.

NOTE 10—Proper heat treatment of Condition C components may be necessary to enhance corrosion and environmental cracking resistance. When specified by the purchaser, the component supplier shall test the material in its final condition in accordance with Supplementary Requirement S16.

Components shall be solution annealed in accordance with AMS 2759 or Specification A484/A484M.

2.3 Hardness Requirement

Not applicable under ASTM F3184-16.

3.0 COMPONENT BUILD AM PARAMETERS

Table 3-1. Component Build Parameters Used by Each Manufacturer

Parameter	Westinghouse Build	Auburn University Build	Rolls-Royce Build	Oerlikon Build
Laser Power:	214W	200W	195W	265
Layer Thickness:	40 microns	50 microns	20microns	40
Melting Method:	Stripe, (12mm)	Stripe, (8mm)	Stripe, (5mm)	Stripe (7mm)
Rotation:	47 degrees	67 degrees	67 degrees	67 degrees
Exposure Time:	N/A	80 us	N/A	N/A
Point Distance:	N/A	60 microns	N/A	N/A
Effective Velocity:	0.928 m/s	0.75 m/s	1.083 m/s	1.15 m/s
Hatch Spacing:	100 microns	100 microns	90 microns	100 microns
Energy Density (J/mm3)	57.65	53.33	100.03	57.61
Recoater Blade Type	Hard (Steel)	Silicon Rubber	High speed steel	Silicone Rubber
Atomized Powder Gas Type	Argon	Argon	Nitrogen	Argon
Build Chamber Gas Type	Argon	Argon	Nitrogen	Argon
Equipment Type	**EOS M290**	**Renishaw AM250**	**EOS M280**	**EOS M290**

The actual components are shown in Section 5.5 of this Data Package.

4.0 HEAT TREATMENT OF COMPONENT BUILDS

4.1 Hot Isostatic Pressing and Solution Anneal Parameters

Two of the component builds (Westinghouse and Auburn U.) were hot isostatically pressed (HIP'ed) at 2050°F (1120°C) for 2 hours in an argon environment, then cooled to room temperature. Following HIP, the component builds were solution heat treated for 2 hours at 2050°F and quenched in water.

4.2 Solution Anneal Parameters

Two additional component builds (Oerlikon and the second Westinghouse build) were solution annealed only (no HIP applied) at 2050°F (1120°C) for 2 hours in an argon environment and quenched in water.

Chemical Composition of 316L SS Powder

Element	S31603 (316L) Spec	Auburn	Westinghouse	Oerlikon	Rolls Royce
C	0.030 max	0.023	0.012	0.02	0.02
Mn	2.00 max	0.88	1.24	0.41	0.01
P	0.045 max	0.008	<0.005	0.014	<0.01
S	0.030 max	0.004	0.004	<0.010	0.014
Si	1.00 max	0.70	0.47	0.38	0.56
Ni	10.0-14.0	12.7	12.02	12.43	12.78
Cr	16.0-18.0	17.7	17.02	17.28	17.23
Mo	2.0-3.0	2.29	2.50	2.33	2.51
N	0.10 max	0.10	0.01	0.08	0.07
Cu	NS	0.04	0.01	0.08	NA
Fe	NS	Bal	Bal	Bal	Bal
O	NS	NR	0.04	0.04	0.034
Powder Manufacturer	---	LPW	Praxair	Oerlikon Metco	LSN Diffusion
Powder Lot/Batch No.	---	UK83448	22	471705	55999
Powder Product Name	---	LPW-316-AAAV	TruForm 316-3	MetcoAdd 316L-A	F-316LNRR-ALMD
AM Equipment	---	**Renishaw 250**	**EOS M290**	**EOS M290**	**EOS M280**

Chemical Composition of 316L SS Manufactured Components

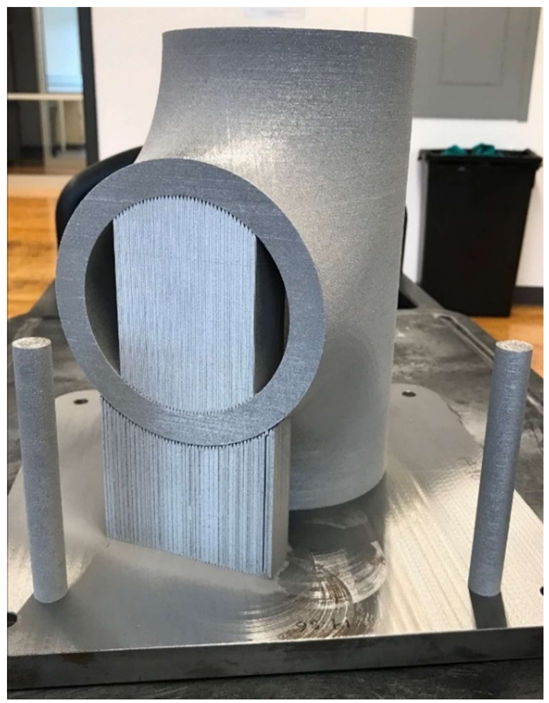
Element	S31603 (316L) Spec	Auburn	Westinghouse	Oerlikon	Rolls Royce
C	0.030 max	0.023	0.012	0.017	0.017
Mn	2.00 max	0.89	1.14	0.34	0.02
P	0.045 max	0.012	0.004	0.01	0.002
S	0.030 max	0.005	0.003	0.004	0.012
Si	1.00 max	0.77	0.44	0.38	0.64
Ni	10.0-14.0	12.8	11.83	12.82	12.57
Cr	16.0-18.0	17.82	16.96	17.66	17.04
Mo	2.0-3.0	2.26	2.64	2.38	2.52
N	0.10 max	0.0885	0.0099	0.0568	0.089
Cu	NS	0.03	0.01	0.04	<0.01
Fe	NS	Bal	Bal	Bal	Bal
O	NS	0.0214	0.0334	0.0568	0.030

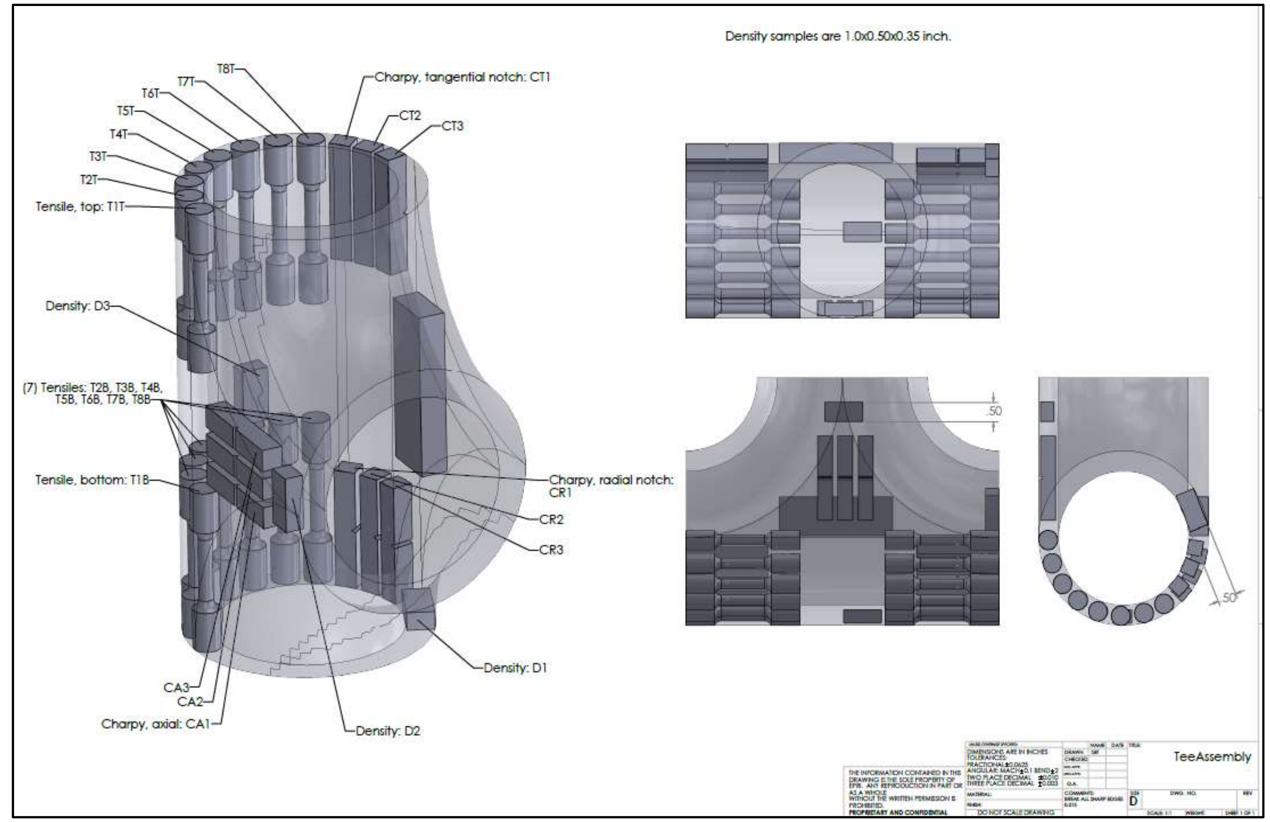
Hardness (Vickers)

Part	Orientation	Average Hardness (HV 0.5)	Standard Deviation (HV 0.5)	Maximum (HV 0.5)	Minimum (HV 0.5)
WEC	Build Direction	166	3.3	175	150
	Transverse 1	170	3.3	180	161
	Transverse 2	163	3.1	172	151
Auburn	Build Direction	155	4.1	166	146
	Transverse 1	157	3.8	168	149
	Transverse 2	160	12.2	210	145
Oerlikon	Build Direction	194	5.1	212	180
	Transverse 1	185	7.0	198	118
	Transverse 2	188	4.5	198	177
WEC SA only	Build Direction	161	3.9	172	149
	Transverse 1	164	3.9	178	154
	Transverse 2	168	6.4	186	152

Note: Average Hardness Data provided in Table 5-4 is an average of 180 indents per ASTM E384 over a 5mm x 6mm area from each component Hardness maps for one component, the Westinghouse Flange, is shown in Figures 5-1 through 5-3 as an example.

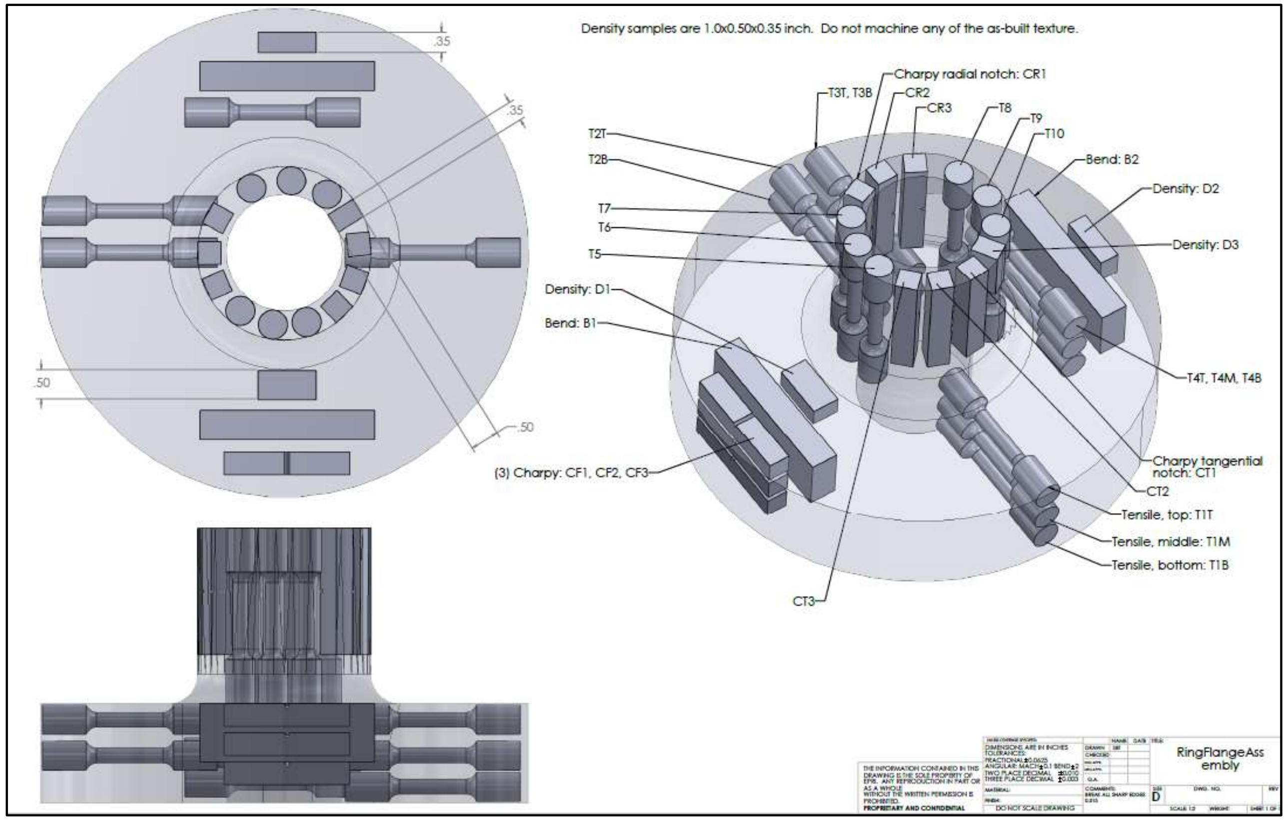
Pipe Tee Section - Auburn U.





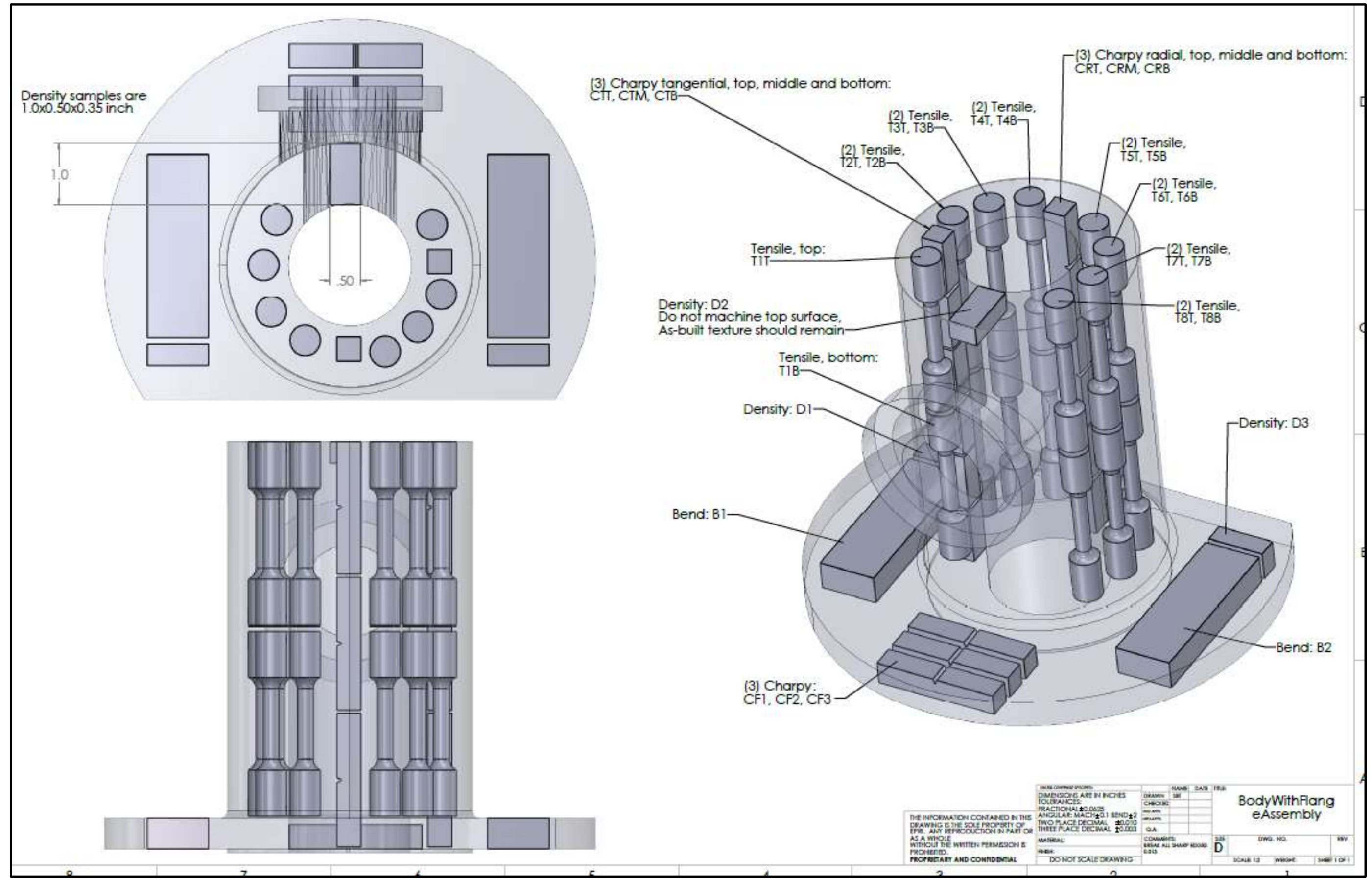
8-1/4”W x 4-1/8”T

Ring Flange End Connection - Westinghouse



8.5"Ø x 1.5"T x 2" bore

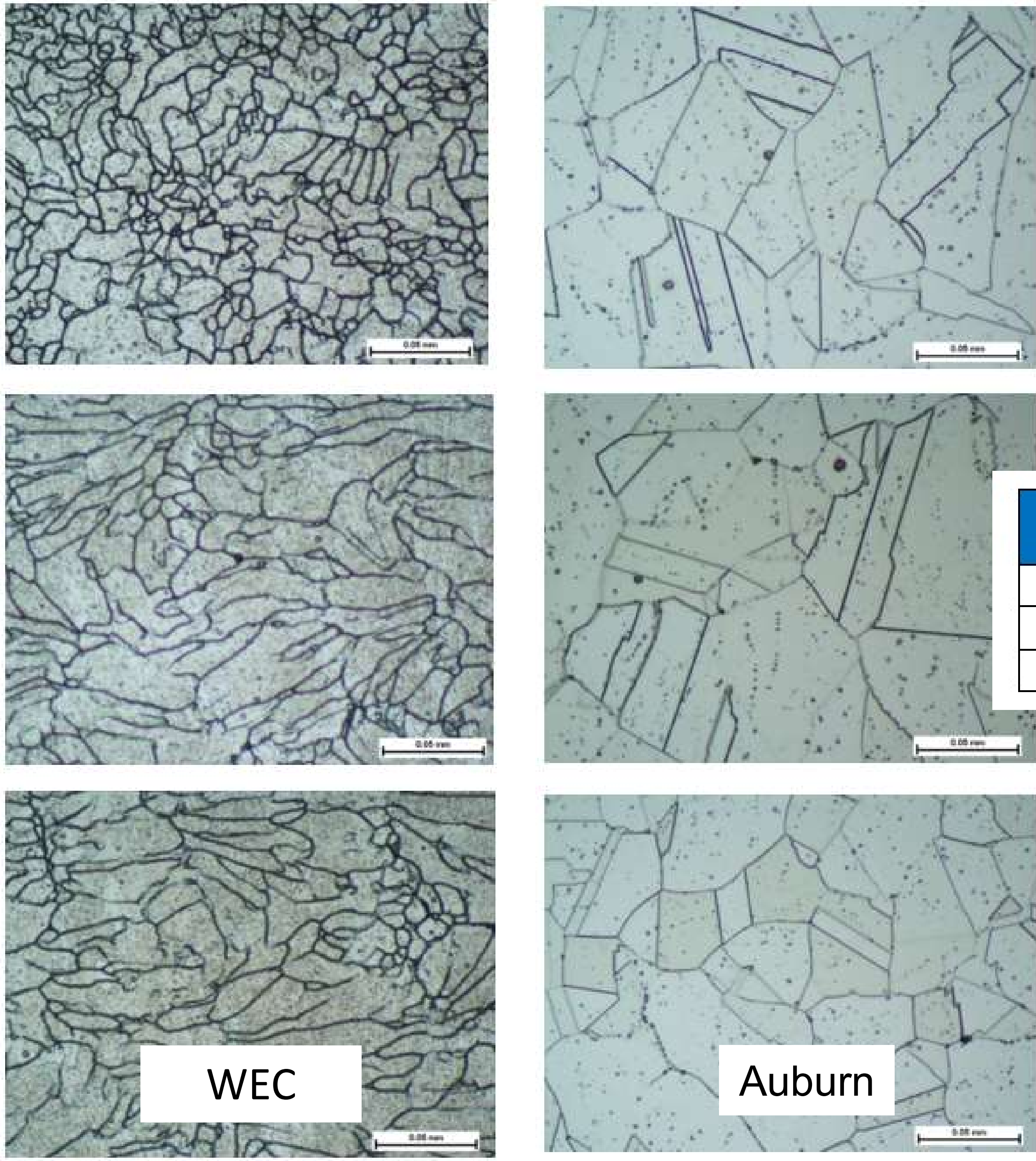
Gate Valve Body - Oerlikon



8"Ø x 2"bore x 4"OD x ½"T

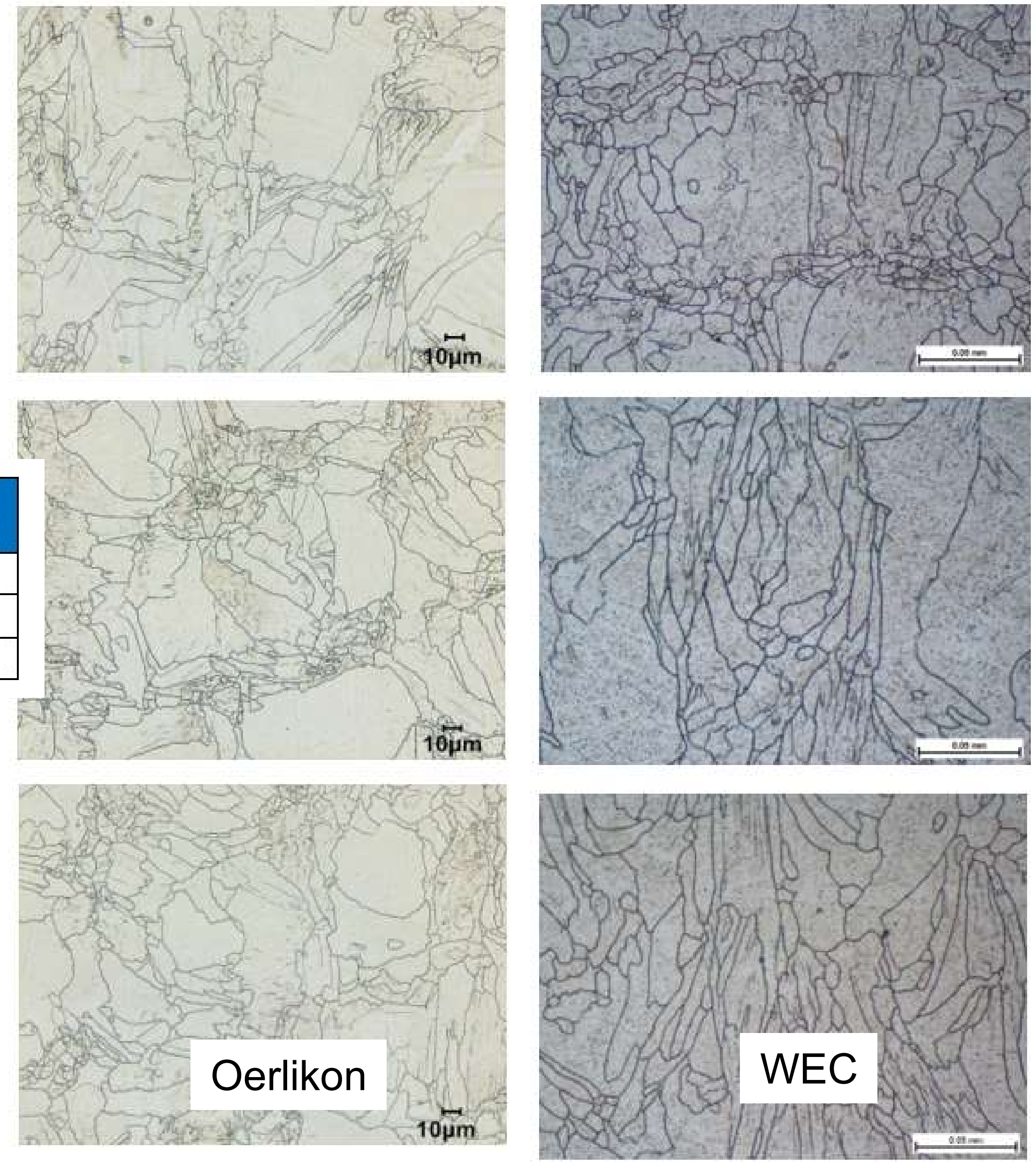
HIP & Solution Annealed

Solution Annealed only



Part	Grain Size
WEC	8
Auburn	4
Oerlikon	6.5

500X



Charpy Impact Results – HIP & Solution Anneal

Table 5.7a. Westinghouse – Ring Flange Charpy Toughness Results					
Sample ID	**Test Log Number**	**Test Temp. (F)**	**Energy ft-lbs**	**Mils Lat Exp**	**% Shear**
CF1	294KXH	73	107	81	100
CF2	295KXH	73	111	83	100
CF3	296KXH	73	110	79	100
	Average		**109**	**81**	**100**
CT1	297KXH	73	168	66	100
CT2	298KXH	73	158	73	100
CT3	299KXH	73	172	74	100
	Average		**166**	**71**	**100**
CR1	300KXH	73	183	75	100
CR2	301KXH	73	177	70	100
CR3	302KXH	73	167	77	100
	Average		**176**	**74**	**100**

Table 5.7b. Auburn – Pipe Tee Charpy Toughness Results					
Sample ID	**Test Log Number**	**Test Temp. (F)**	**Energy ft-lbs**	**Mils Lat Exp**	**% Shear**
CT1	046LNH	73	113.9	75	100
CT2	047LNH	73	122.8	75	100
CT3	048LNH	73	125.6	78	100
	Average		**120.8**	**76**	**100**
CR1	049LNH	73	136.9	78	100
CR2	050LNH	73	136.5	77	100
CR3	051LNH	73	153	78	100
	Average		**142.1**	**77.7**	**100**
CA1	043LNH	73	123.8	79	100
CA2	044LNH	73	119.7	73	100
CA3	045LNH	73	112.8	76	100
	Average		**118.8**	**76.0**	**100**

Charpy Impact Results – Solution Anneal only

Table 5.7c. Oerlikon – Valve Body (Solution Annealed only - No HIP) Charpy Toughness Results					
Sample ID	**Test Log Number**	**Test Temp. (F)**	**Energy ft-lbs**	**Mils Lat Exp**	**% Shear**
CF1	046LNH	73	114	86	62
CF2	047LNH	73	113	85	62
CF3	048LNH	73	119	80	60
	Average		**115**	**84**	**61**
CTT	049LNH	73	207	83	89
CTM	050LNH	73	197	82	89
CTB	051LNH	73	143	81	92
	Average		**182**	**82**	**90**
CRT	043LNH	73	200	76	100
CRM	044LNH	73	159	81	90
CRB	045LNH	73	128	80	84
	Average		**162**	**79**	**91**

Table 5.7d. Westinghouse – 2nd Ring Flange (Solution Annealed only - No HIP) Charpy Toughness Results					
Sample ID	**Test Log Number**	**Test Temp. (F)**	**Energy ft-lbs**	**Mils Lat Exp**	**% Shear**
CF1	474QNH	73	87	76	100
CF2	475QNH	73	88	87	100
CF3	476QNH	73	86	70	100
	Average		**87**	**78**	**100**
CT1	477QNH	73	123	79	100
CT2	478QNH	73	119	84	100
CT3	479QNH	73	113	58	100
	Average		**118**	**74**	**100**
CR1	480QNH	73	119	79	100
CR2	481QNH	73	115	90	100
CR3	482QNH	73	109	83	100
	Average		**114**	**84**	**100**

Tensile Properties - HIP & Solution Anneal - Westinghouse

Sample ID	Temp. (°F)	Temp. (°C)	UTS (ksi)	UTS (MPa)	YS (ksi)	YS (MPa)	Elong. in 4D (%)	ROA (%)
T1T	70	21.1	87.8	605.4	45.8	315.8	72.7	78
T1M	100	37.8	83.8	577.8	46.5	320.6	69.9	76.5
T1B	150	65.6	78.7	542.6	44.1	304.1	61.7	78.5
T2T	200	93.3	73.1	504.0	41.7	287.5	48.7	77
T2M	250	121.1	71.7	494.4	42.3	291.6	47.0	74.5
T2B	300	148.9	69.5	479.2	40.0	275.8	44.7	76.5
T3T	350	176.7	68.1	469.5	37.9	261.3	43.2	76.5
T3B	400	204.4	66.6	459.2	38.9	268.2	40.6	73
T4T	450	232.2	65.5	451.6	37.2	256.5	39.1	73
T4B	500	260.0	65.1	448.8	37.3	257.2	37.2	73.5
T5	550	287.8	61.0	420.6	34.1	235.1	44.1	76
T6	600	315.6	61.1	421.3	33.7	232.4	44.9	73
T7	650	343.3	61.4	423.3	32.9	226.8	47.9	72
T8	700	371.1	60.7	418.5	32.6	224.8	44.6	72.5
T9	750	398.9	61.0	420.6	31.7	218.6	47.2	74.5
T10	800	426.7	61.3	422.6	31.4	216.5	48.5	69.5
Witness Samples								
T11 (HIP)	70	21.1	84.2	580.5	43.7	301.3	86.1	73
T12 (HIP)	70	21.1	84.1	579.8	44.7	308.2	87.3	79
T13 (AB)	70	21.1	87.3	601.9	63.0	434.4	76.0	78
T14 (AB)	70	21.1	87.3	601.9	62.9	433.7	76.5	78

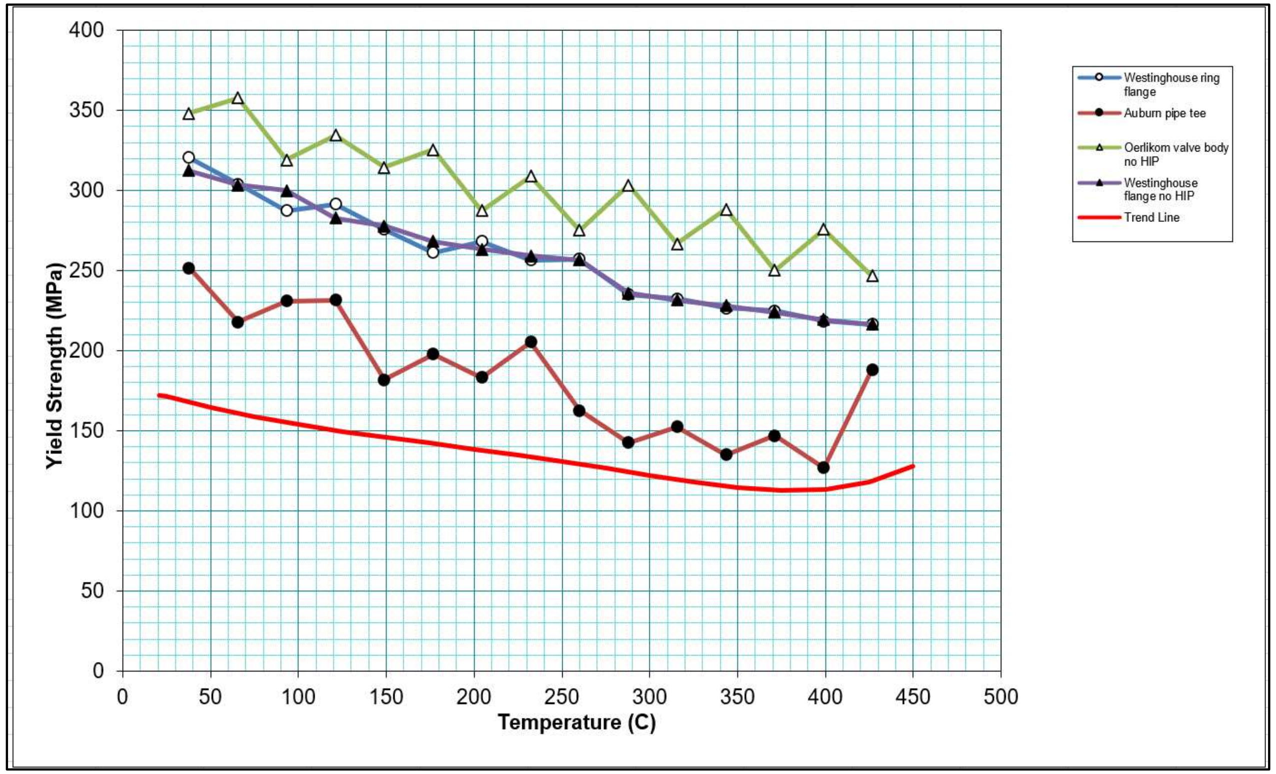
Note: 0.252 diameter coupons per ASTM E21-17

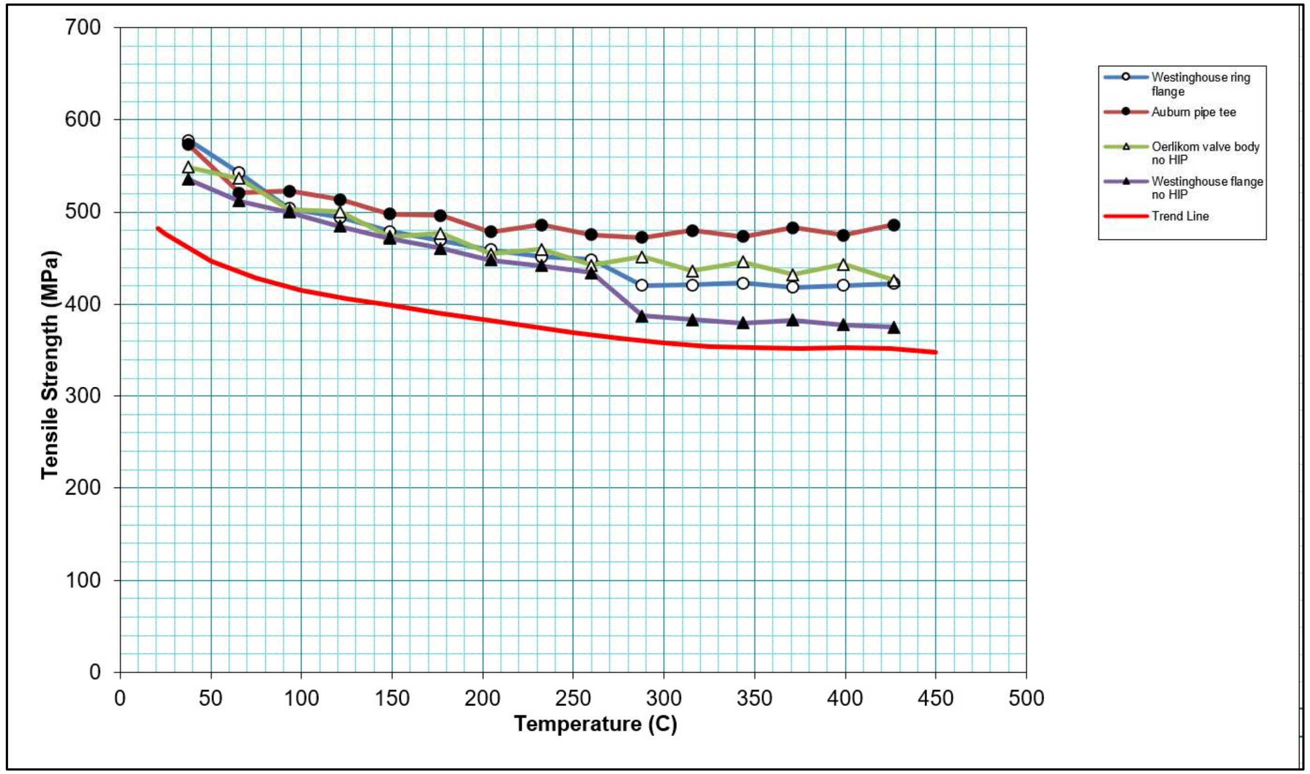
Tensile Properties – Solution Anneal <u>only</u> - Westinghouse

Sample ID	Temp. (°F)	Temp. (°C)	UTS (ksi)	UTS (MPa)	YS (ksi)	YS (MPa)	Elong. in 4D (%)	ROA (%)
T1T	70	21.1	81.6	562.6	46.7	322.0	58	67
T1M	100	37.8	77.7	535.7	45.3	312.3	53	67.5
T1B	150	65.6	74.3	512.3	44	303.4	46	70.5
T2T	200	93.3	72.5	499.9	43.5	299.9	43	68
T2M	250	121.1	70.3	484.7	41	282.7	40	72
T2B	300	148.9	68.4	471.6	40.3	277.9	40	71
T3T	350	176.7	66.8	460.6	38.9	268.2	38	71.5
T3B	400	204.4	65	448.2	38.2	263.4	36	73
T4T	450	232.2	64.1	442.0	37.6	259.2	35	68
T4B	500	260.0	63	434.4	37.2	256.5	35	70.5
T5	550	287.8	56.2	387.5	34.2	235.8	41	71
T6	600	315.6	55.6	383.3	33.6	231.7	41	72.5
T7	650	343.3	55.1	379.9	33.1	228.2	41	70.5
T8	700	371.1	55.5	382.7	32.5	224.1	45	68.5
T9	750	398.9	54.8	377.8	31.8	219.3	43	65
T10	800	426.7	54.4	375.1	31.4	216.5	43	69
Witness Samples								
T11 (HIP)	70	21.1	74.7	515.0	44.5	306.8	45	37
T12 (HIP)	70	21.1	75.5	520.6	44.3	305.4	72	69

Note: 0.252 diameter coupons per ASTM E21-17

Yield and Tensile Strength as a Function of Temperature

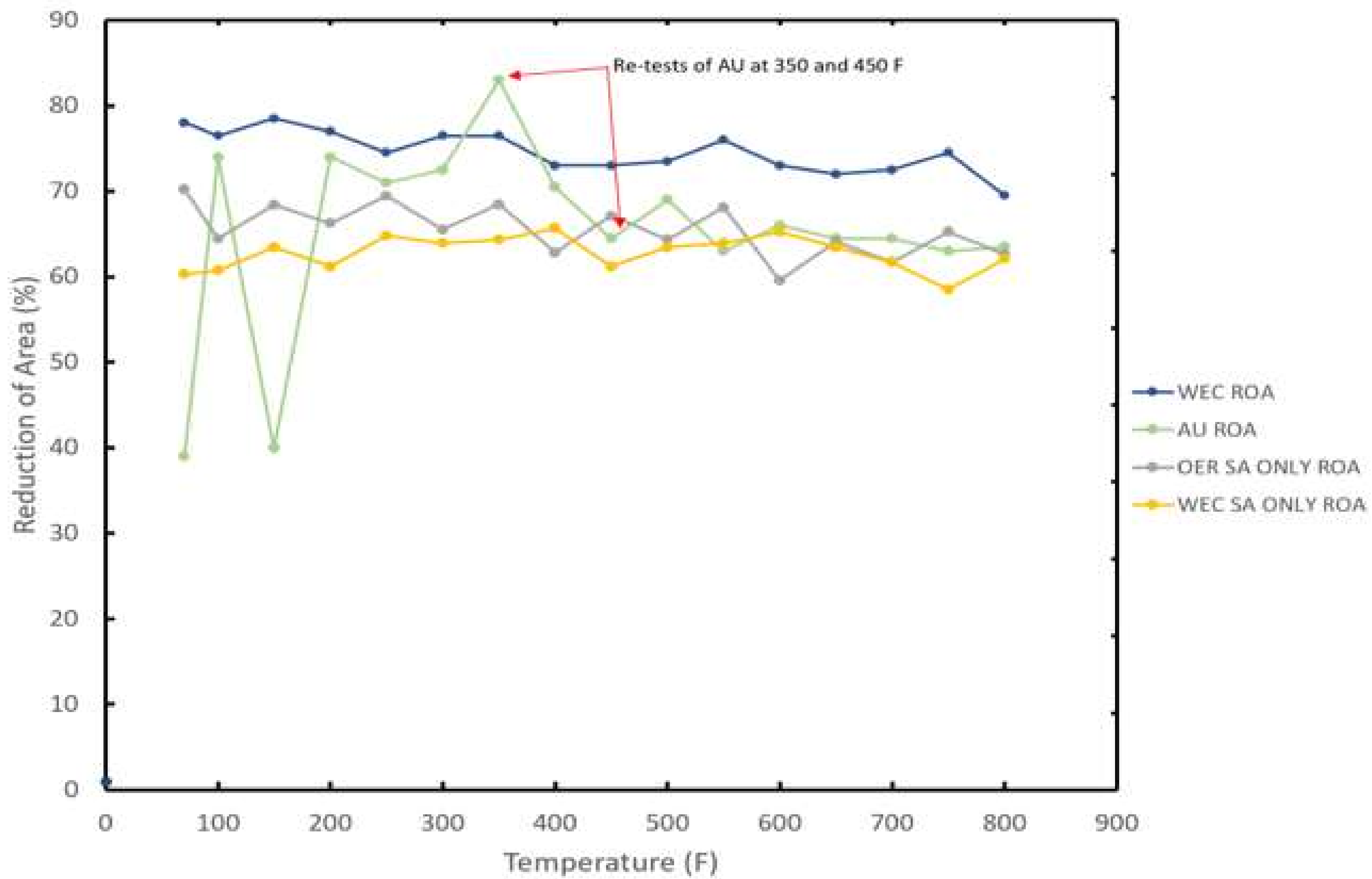




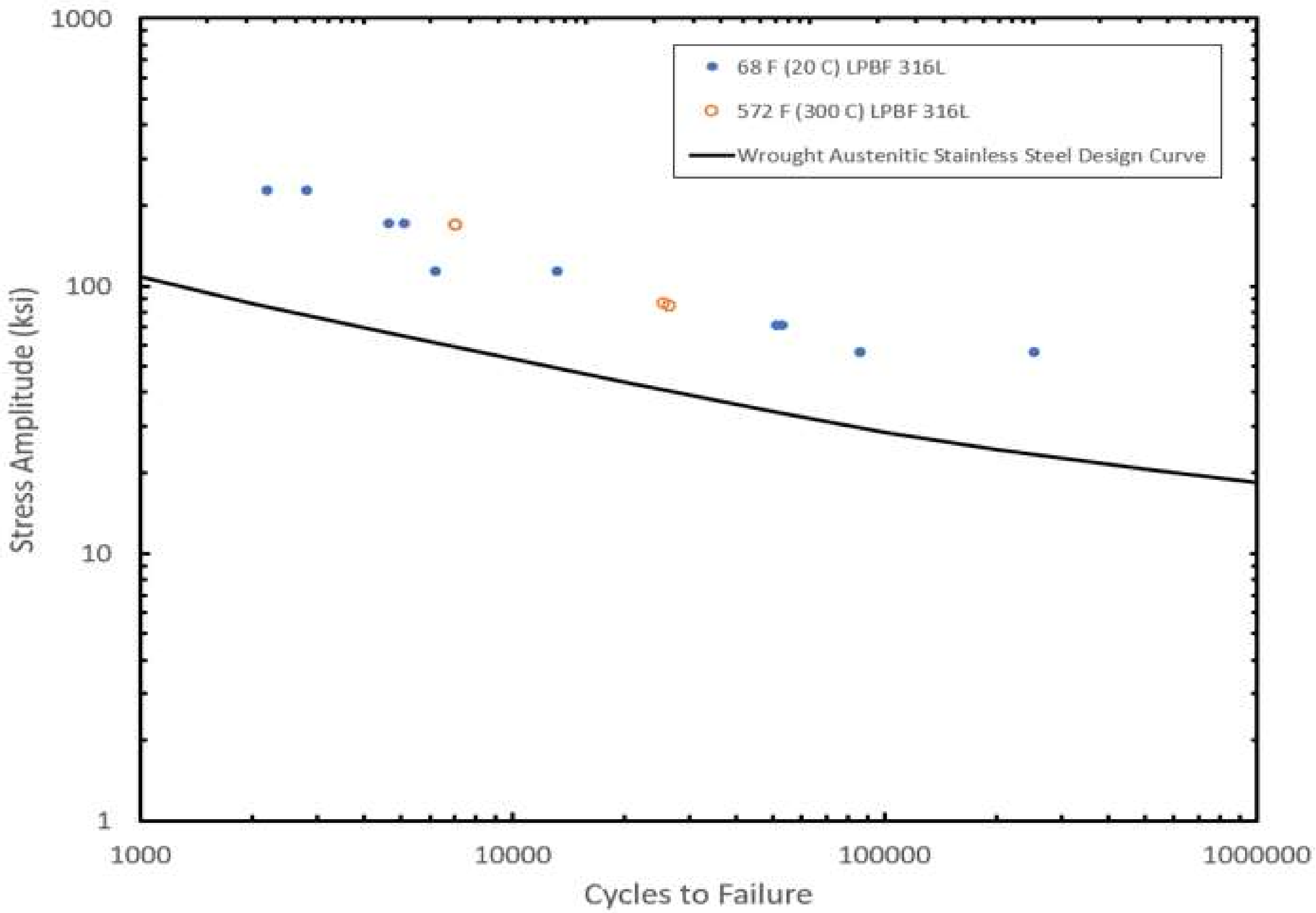
Note: Shift (lower) in Westinghouse Yield and Ultimate Strength between 260°C (500°F) and 287.8°C (550°F), is due to the transition from Z to XY direction specimens

- See slide 14 for specimen layout and slides 19 and 20 for associated tensile results

Reduction of Area as a Function of Temperature



Fatigue Data - HIP and Solution Anneal - Rolls Royce component build



Summary

- Three components, 5 builds performed
- >0.50-inch thick components (for testing)
- All builds provide acceptable microstructural and mechanical properties
  - HIP and Solution annealed
  - Solution annealed only
- Good fatigue properties
- Stress allowables developed
- Weldment data to be provided shortly

Draft ASME Section III Code Case for LPBF AM 316L

- Submitted to Section III MF&E sub-committee for August 2020 Code Week
  - Record # 20-254
  - Section III, Division 1 – Subsection NB/NC/ND, Class 1, 2 and 3 Components
- Standard ASME approach of calling out ASTM material / process spec and adding clarifications and additional requirements
  - ASTM F3184-16 is base spec for LPBF 316L
  - Significant clarification required due many requirements are left open to be agreed upon by the component supplier and purchaser
- Proposes use of HIP (per ASTM F3184-16 section 13, Condition C) plus Solution Anneal (per ASTM F3184-16 section 12.2, Condition B)
- For welding procedure and performance qualification, material considered P-number 8

Draft ASME Section III Code Case for LPBF AM 316L (Cond)

- Design stress intensity values and the maximum allowable stress values are included in the code case Tables 1(1M) and 2(2M)
- Feedstock powder: Re-cert after 10 uses and max powder size of 100um
- Manufacturing plan: requiring documentation of essential process parameters
- Witness specimens, in 2 limiting locations: tensile (4x), hardnes (1x), microstructure (Z & XY, 100X & 500X), chemistry (1x, 1^{st} and last build only)
- UT and RT per the sub-article of NB/NC/ND-2500 applicable to the product form being produced
- Components shall be pressure tested per NB-6000
- Neutron dose $<7x10^{20}$ n/cm^2 (E > 1 MeV) for design life

Next Steps

- AM 316L Code Case Routing
  - David Gandy has been appointed project manager for the code case
  - EPRI is completing weld testing & weldment data will be added to the data package
  - The code case will go through ASME commenting, editing and balloting
  - It will likely be routed to Section II (Materials) and potentially Section IX (welding) for review
- Additional Code Cases
  - Directed energy deposition (DED) for valve production (Korean WG)
  - Westinghouse is looking to collaborate on material testing, analysis, data package consolidation and code case submittals
    - Currently producing 718 Ni Alloy, 304 SST, 17-4 PH, MS1, Haynes 230 and select high temperature alloys with LPBF
- ASME Interactions
  - AM Special Committee and Div 5 Advanced Manufacturing Task Group

Together...Shaping the Future of Electricity

Acknowledgements

US Department of Energy

Tansel Selekler, Dirk Cairns-Gallimore, Isabella van Rooyen

ORNL & UTK-ORNL

- Suresh Babu, UTK-ORNL
- Fred List, ORNL
- Caitlin Hensley, UTK-ORNL
- Kevin Sisco, UTK-ORNL
- Amy Godfrey, UTK-ORNL
- Serena Beauchamp, UTK-ORNL
- Xiao Lou, Auburn University

Industry

- David Poole, Rolls-Royce
- Dane Buller, Rolls-Royce
- Thomas Jones, Rolls-Royce
- Thomas Pomorski, Penn United Technologies
- Brian Bishop, Oerlikon

Backup Materials:

Full Draft LPBF AM 316L Code Case Verbiage,

Fatigue Data

DRAFT Code Case – XXXX (p.1/4)

Record 20-254

DRAFT Code Case XXXX
Austenitic Stainless Steel (UNS S31603)
Section III, Division 1 – Subsection NB/NC/ND, Class 1, 2 and 3 Components

Inquiry: May UNS S31603 that meets the specification requirements of ASTM F3184-16 for additively manufactured stainless steel products produced using the laser powder bed fusion process, then hot isostatic pressed and solution annealed, be used for Section III, Division 1--Subsection NB/NC/ND, Class 1, 2 and 3 components construction?

Reply: It is the opinion of the Committee that UNS S31603 conforming to ASTM F3184-16 for additively manufactured stainless steel products produced using laser powder bed fusion, then hot isostatic pressed and solution annealed, may be used for Section III, Division 1 – Subsection NB/NC/ND, Class 1, 2 and 3 components construction provided the following additional requirements are met:

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(a) For purposes of welding procedure and performance qualification, this material shall be considered P-number 8.

(b) The design stress intensity values and the maximum allowable stress values for the material shall be those given in Tables 1(1M) and 2(2M).

(c) Feedstock powder cert(s) associated to individual lots and/or powder blends will be provided for each production build. In addition to the Feedstock requirements in ASTM F3184-16 Section 7, the following requirements apply:

  a. Complete or partially used powder lots will be re-analyzed after 10 uses maximum, to ensure it conforms to the specified chemical composition, size distribution, shape, density and flow rate.

  b. The maximum allowable powder size is 100 microns or less.

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(d) Essential laser powder bed fusion build variables, captured within the manufacturing plan, shall include, at a minimum:

a. Layer thickness
b. Laser power
c. Pulse Characteristics
d. Pulsing
e. Focus Settings
f. Beam Diameter
g. Position of Beam Diameter Relative to Feedstock Layer
h. Energy density
i. Effective velocity
j. Scan strategy
k. Stripe width
l. Offset
m. Hatch spacing
n. Shielding gas composition and flow rate
o. Recoater blade type / material

(e) All production components and witness specimens produced by the laser powder bed fusion process shall be hot isostatic pressed per the requirements of ASTM F3184-16 section 13 (Condition C), and then solution annealed per the requirements of ASTM F3184-16 Section 12.2 (Condition B).

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(f) Witness specimens shall be constructed with each production build and tested after all thermal post-processing.
   a. One witness specimen from the first and final production builds, for each production run, shall be analyzed for chemical composition per the requirements of ASTM F3184-16 Section 9.
   b. A minimum of 4 tensile specimens (2 built in the Z orientation, 2 built in the X-Y orientation) will be built in the 2 locations of limiting material conditions, and tested per the requirements of ASTM F3184-16 Section 11.
      i. Locations of limiting material conditions shall be identified during machine and/or process qualification builds (supplemental requirement to ASTM F3184-16 Section 6.1.1 and Note 3)
   c. Hardness testing shall be completed on one witness specimen per the requirements of ASTM F3184-16 Supplemental Requirement S4.
   d. Microstructure examination shall be completed on one witness specimen.
      i. 100X and 500X micrographs will be supplied for the Z and X-Y build orientations.
      ii. Per ASTM F3184-16 Section 10, Specimen preparation shall be in accordance with ASTM Guide E3 and Practice E407.

(g) The material shall be examined using either the ultrasonic method or radiographic method per the Sub-article of NB/NC/ND-2500 applicable to the product form being produced.

(h) All production components shall be pressure tested per NB-6000 requirements.

(i) The material shall not be used for components where neutron dose will exceed 7×10^{20} n/cm^2 (E > 1 Mev) within the design life of the component.

High values (Sect III)

For Metal Temperature Not Exceeding , °F	Stress Values, ksi
-20 to 100	16.7
200	16.7
300	16.7
400	16.7
500	16.7
600	15.6
650	15.1
700	14.7
750	14.7
800	14.7

Extra -- Fatigue Data

Table 7-1. Fatigue Data for Rolls Royce Tee

Sample ID	Temp. (°F)	Temp. (°C)	Stress Amplitude (ksi)	Stress Amplitude (MPa)	Total Strain Amplitude (%)	Cycles to Failure
1	68	20	226.4	1561	0.8	2202
2	68	20	226.4	1561	0.8	2821
3	68	20	169.8	1171	0.6	5160
4	68	20	169.8	1171	0.6	4693
5	68	20	113.2	780	0.4	6229
6	68	20	113.2	780	0.4	13227
7	68	20	56.6	390	0.2	254532
8	68	20	56.6	390	0.2	86286
9	68	20	70.8	488	0.25	51370
10	68	20	70.8	488	0.25	53154
11	572	300	84.9	585	0.3	26420
12	572	300	86.3	595	0.305	25536
13	572	300	169.8	1171	0.6	7000
14	572	300	169.8	1171	0.6	7000

Note: Per ASTM E606—19e1