NSRP | National Shipbuilding Research Program

Improving Preconstruction Primer Removal at Newport News Shipbuilding through Laser Ablation

2/25-27/2025

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NATIONAL SHIPBUILDING RESEARCH PROGRAM™
Taking Shipbuilding and Repair to the Next Level

Today's Presentation

- Issue, Goal, & Objectives
- Project Approach
- Insertion Areas
- Socializing Project Ideas
- Qualification Test Plan
- Laboratory and Equipment
- Processing
- Preliminary and Qualification Testing
- Implementation Planning
- Next Steps
- Acknowledgements
- Questions

Issue, Goal, and Objectives

- Issue
  - Preconstruction primer (PCP) must be removed prior to welding.
  - Removal is conducted using needle guns, handheld or walk-behind grinders, and/or abrasive blast equipment.
  - Methods are laborious, dangerous, often cause material erosion, and may produce excessive amounts of waste material. A better solution is desired.
- Goal:
  - Transition automated LA technology to remove PCP from HSLA steels within the Steel Fabrication and Assembly (SFA) facilities at NNS.
- Objectives:
  - Reduce labor costs associated with PCP removal during construction of the CVN.
  - Reduce substrate erosion associated with current methods of PCP removal during CVN construction.
  - Reduce consumables associated with PCP removal during CVN construction.

Manual grinding removal of PCP

Laser ablation trials during NSRP project – courtesy of NNS

Project Approach

- *Phase 1: Equipment Procurement and Qualification Testing Planning*
  - Evaluate shop Flow vs. LA equipment capabilities Q2FY19
  - Socialize project ideas Q4FY20
  - Develop qualification test plan Q2FY21
  - Outline and initiate procurement plan Q2FY20
  - Install and debug LA system at Penn State ARL Q1FY21
  - Conduct process optimization / preliminary coupon testing Q1FY23
- *Qualification Testing and Transition Planning*
  - Prepare qualification test specimens Q3FY24
  - Conduct qualification testing Q4FY24
  - Report to technical warrant holders (TWHs) & draft approval letter Q3FY25 est.
  - Update business case Q4FY24
  - Conduct implementation planning Q4FY24

Draft Letter Supporting Approval is outside the POP and conducted by the TWHs; all information was provided to the TWHs as of Q1FY25

Identifying Insertion Areas

- Preferred LA insertion points in 2019 vs. 2024.

2019

- Edge Preparation (and milling)
  - Edge Milling: Location targeted for laser ablation
  - Walk behind grinders: 10” strip weld prep removal where preheat is required
  - Hand-held 7” grinders: Near edge and touch up (area where welding will occur and something was not removed properly or oxidation had occurred before welding)
    - Unique mechanized system would need to be developed
  - Walk behind blast machine: Not permitted near edges because grit spews everywhere; 7” to 17” from edge permissible, depending on location, for 8” - 10” wide
- Marking and burning
  - Stiffener prep (fillet welding): T bars welded on, double-sided fillet weld for large T-bars for the plates that have been butt-welded together

2024

- Edge Preparation (and milling)
  - Edge Milling: No change
  - Walk behind grinders: Address edge areas on butt welds.
    - Possibly address 10” strip weld prep removal per side, where preheat is required
  - Hand-held 7” grinders: No Change
  - Walk behind blast machine (#5): No Change, but mechanization possible
- Marking and burning
  - Stiffener prep (fillet welding): No Change
  - Edge Preparation: Automated LA removes some 7” grinder or walk-behind grinder labor.
- Toe Blast area
  - T-bar Toe: Significantly increase automated %PCP removal with 4th laser to strip 4” on both sides of T-bar (to weld to plate)

Targeted Insertion Areas

Socializing Project Ideas

- Leveraged other Navy work – NUWC - Keyport
  - Reviewed preliminary test plan initially.
  - Leveraged each others work throughout; eliminated unnecessary testing

Process Steps:	Primer	Pre-weld	Weld	Pre-paint	Paint	Test Atm.
Variables:	New IOZ	Blast	Weld	Blast	Paint	Air
	Aged/Marked	Ablate	No Weld	No Blast	No Paint	Seawater

Requested by TWH

Not varied

  - Testing:
    - Metallography (macroetch)
    - Weld Testing (TP-248): Tensile, Guided Bend, NDI
      - Visual
      - Radiographic inspection
      - Magnetic Particle inspection
    - Stress Corrosion (ASTM G39)
    - Fatigue

Qualification Test Plan

- Visual Inspection for Specimen Preparation
- Weld Testing: NAVSEA Technical Publication S9074-AQ-GIB-010/248, *Requirements for Welding and Brazing Procedure and Performance Qualification (referred to as TP 248)*
  - Inspection: MIL-STD-2035, *Department of Defense Test Method: Non-Destructive Testing Acceptance Criteria, Class 1*
    - ❖ Visual Inspection associated with welding
    - ❖ Magnetic Particle Inspection
    - ❖ Radiographic Inspection
  - Guided Bend Testing: AWS B4.0: *Standard Methods for Mechanical Testing of Welds*
  - Tensile Testing: AWS B4.0: *Standard Methods for Mechanical Testing of Welds*
    - ❖ ASTM E 8, *Standard Test Methods for Tension Testing of Metallic Materials*
    - ❖ ASTM E 4, Standard Practices for Force Verification of Testing Machines
- Fatigue Testing: ASTM E466: *Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials*
  - R = -1.0, cruciform/butt-welds
- Optional Testing: OM, SEM, Hardness, XRD

Pre-weld Process	Post-Weld Process	Test Effect	Weld Inspection	Guided Bend Test	Tensile Test	Fatigue	Microscopy
Grind	Blast	Baseline Process	All weldments receive visual inspection; only 1 weldment overall receives radiographic and magnetic particle inspection	2 root 2 face	3 req'd 4 done	4 per stress level per process Stress levels include 12, 15, 30, and 45 ksi	≤2 per process scenario to evaluate for surface erosion and paint removal.
Grind	No Blast	Discriminator for Baseline Process		2 root 2 face	3 req'd 4 done		
Ablate	Blast	Alternative Process		2 root 2 face	3 req'd 4 done		
Ablate	No Blast	Discriminator for Alternative Process		2 root 2 face	3 req'd 4 done		

Total Samples of Each Geometry	Historical Cycles to Failure	Load (ksi)	Frequency Limitation Acc to NAVSEA (Hz)	Typical Frequency (Hz)	Anticipated Frequency Range (Hz)
16	10,000	45	≤10	1	1
16	200,000	30	≤10	2	2 - 5
16	1,000,000	15	≤10	4	5 - 7
12	2,000,000	12	≤15	4	10 - 15
4	10,000,000	12	≤15	4	10 - 15

Established Laser Ablation Laboratory

- System allows:
  - Ordered and non-ordered layouts, ID marking, etc.
  - Varying patch parameters and multi-parameter settings to reduce substrate damage
  - Multiple, subsequent scan paths without having to do multiple sweeps over substrate

- Other Equipment Not Shown
  - IPG pulsed laser remote controller
  - IPG Chiller
  - ScanLab scanner controller
  - Airflow Systems dust collector
  - The Imaging Source focus camera
  - PTZ Optics camera
  - Aerotech linear stages
  - Black Box equipment rack
  - National Instruments DAQ

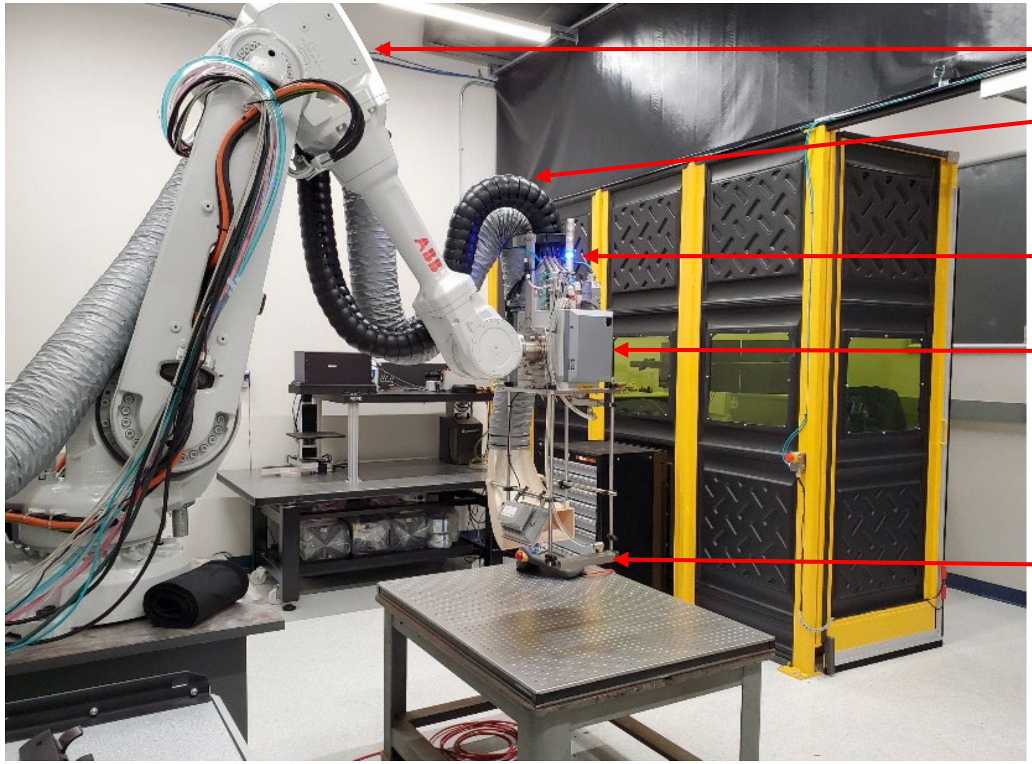


ABB Robot

Effluent Removal Suction Hose

IPG pulsed ns fiber laser

ScanLab Intelliweld scanner

Exair Air Knives

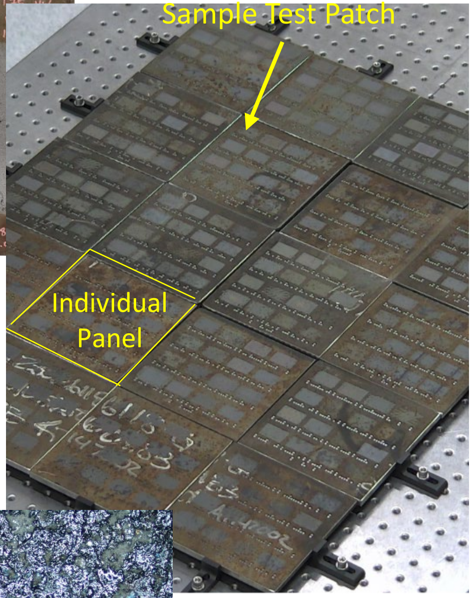
Develop Processing Recipes

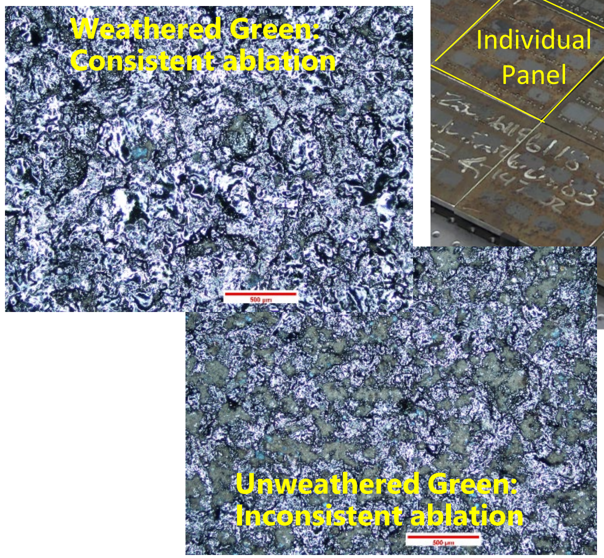
- Conducted 1000+ stripping trials to remove red and green primer on HSLA steels in 5 DOEs
  - Reduced variables evaluating fluence vs. appearance
    - Conducted surface and cross-sectional microscopy, XRF, and hardness testing
      - Ensured Zn removal and HSLA integrity remained
  - Developed two-parameter set application
    - 1st removed paint, then oxidation to optimize properties
  - Examined stripping parameters on unweathered and weathered primers and new colors
    - Required new optic to meet energy density needs
  - Finalized processing parameters and proceeded to produce weldments.

One-Parameter Two-Parameter

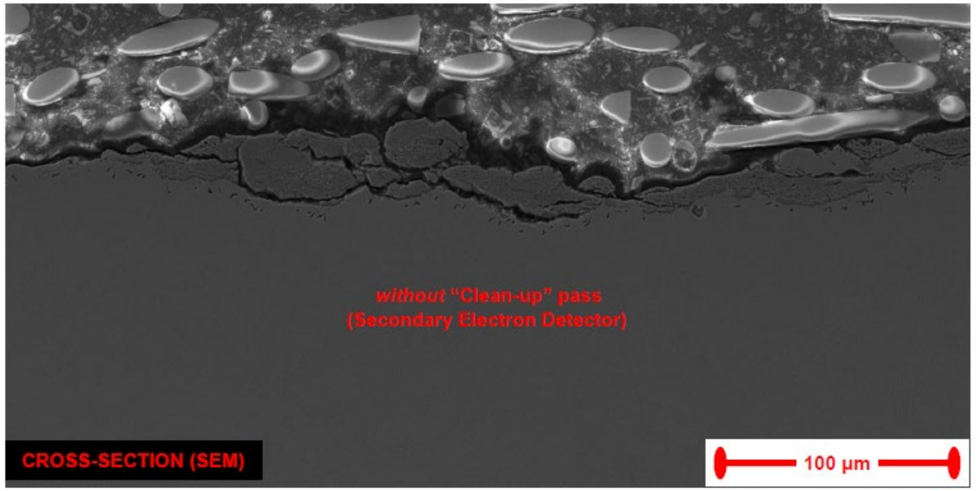
Normal Lighting
(easier to see bluing)

Rusted samples
with test patches

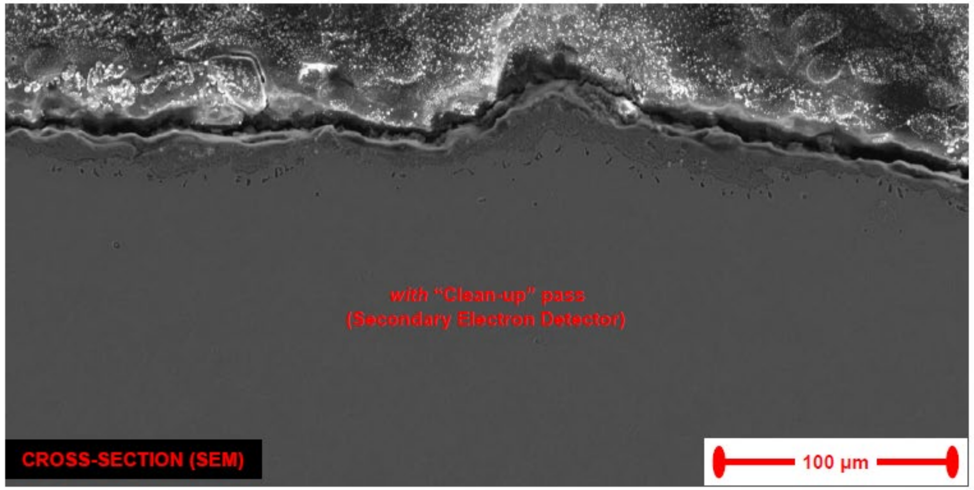


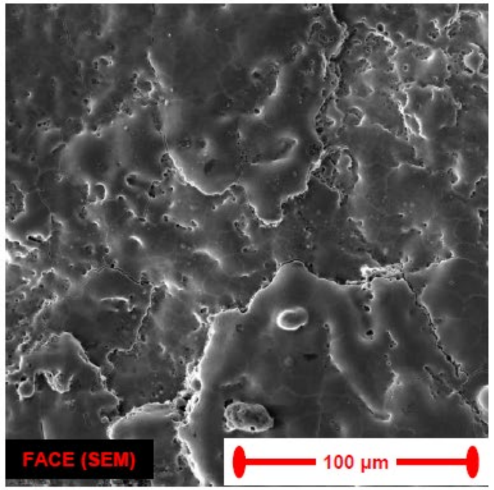


Preliminary Testing: Microscopy



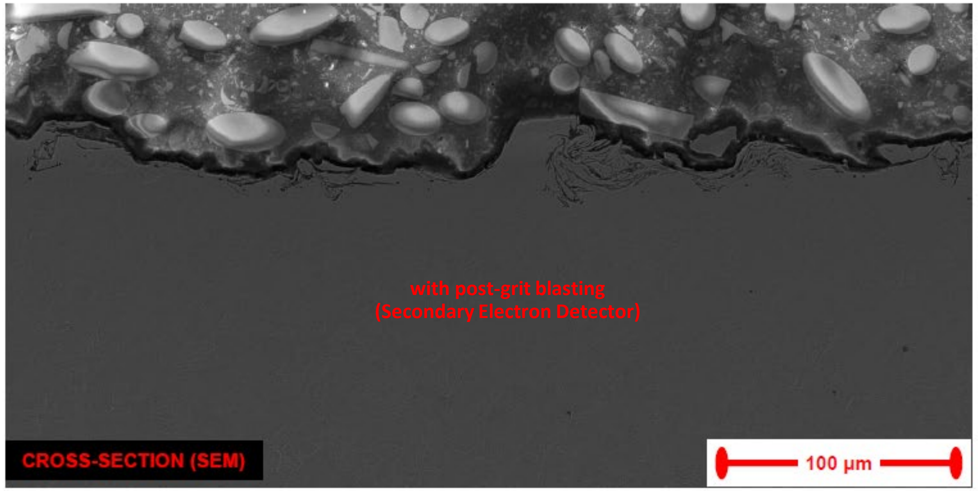
* Resolution, as-displayed (where 100 µm ~2 in)

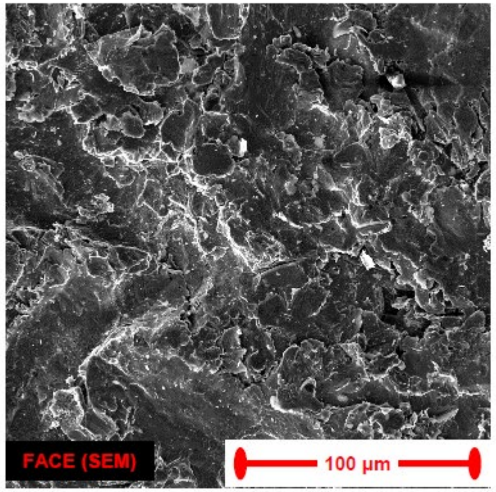




* Resolution, as-displayed (where 100 µm ~2 in)

- 200x OM showed macroscopic effects of melting; etched cross-sections show unclear HAZ (~ <50 µm?)
- 500x SEM cross sections and surface shots of LA (above) reveal melting/cracking for most conditions, but limited to loosely bound oxide (< 50 µm)
- Melting increased with increased E_{avg}
- Surface-connected micro-porosity (< 5 µm) decreased with decreased LA Parameters
- Subsurface micro-porosity within ~5 µm from oxide-steel interface is persistent
- Subsurface folding/voids in "LA + Grit Blasted" extend to ~25 µm





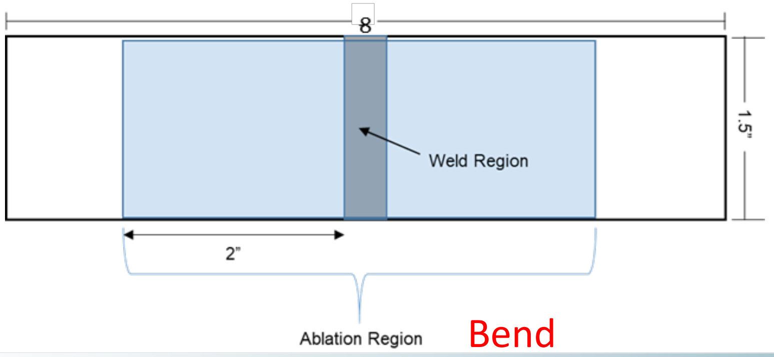
* Resolution, as-displayed (where 100 µm ~2 in)

Preliminary Testing: Hardness and Fatigue

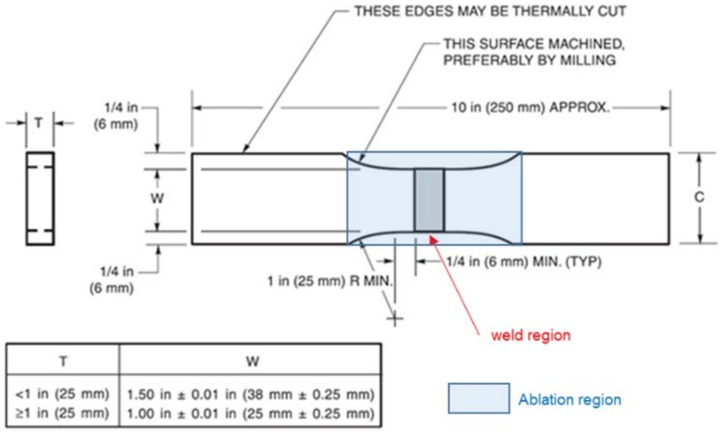
- Conducted Rockwell B hardness testing (e.g., Rockwell B)
  - “Composite” measurements show possible trends correlating with LA parameters
  - Minimum LA tolerances result in slightly (~1%) reduced HRB
  - Hardness remains steady from 1 – 2 LA passes (with overlapping LA swaths)
  - Possible hardness reduction (~3%) from 2 – 3 LA passes
  - Reduced (~5%) hardness for LA-only surfaces (no “clean-up” pass; thicker oxide).
  - Reduced (~4%) hardness for “LA + Grit Blast” surfaces (including LA “clean-up”)
- Conducted Vickers microhardness testing
  - Indentation was immeasurable on unpolished LA faces
    - No noticeable trends observed at ASTM minimum depth (~175 μm)
    - No noticeable trends observed at nearest-to-surface depth (~35 μm)
    - Near-surface hardness increased (~5%) for LA-only surfaces (i.e., no tandem “clean-up” pass)
  - Team determined only Rockwell B “composite” hardness would be considered in future comparisons of LA conditions, if chosen for examination
- Preliminary fatigue testing was inconclusive; TWHs suggested move to weldments
- Note: No hardness testing was required in qualification testing.

Qualification Testing

- Stripped PCP from HSLA steel plate using 1 kW IPG Photonics pulsed fiber laser on ½ the plates
- Bagged stripped plates with dessicant before shipping to NNS to avoid oxidation before welding.
- NNS ground baseline specimens using 7” alumina abrasive disk
- NNS conducted fillet and butt welding on all specimens
  - GMAW-M and MIL 100S 1 filler per NNS CVN welding procedures.
  - Butt Joint: Joint design was B2V.3 and welding position was 1G.
  - Fillet Weld: Joint design was T2V.2 and welding position was 2F.
- NNS grit blasted (steel) half of the previously LA panels and half of the previously grit blasted panels after welding.
- Penn State ARL had plates sectioned into bend, tensile and fatigue test specimens.
  - Bend = 0.375” h x 1.5” w x 8” l
  - Tensile = 0.375” h x 2” w x 10” l
  - Fatigue = 0.375” h x 3.75” w x 14” l

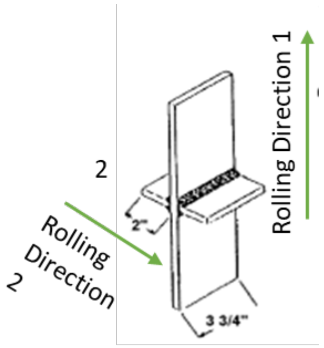


Bend

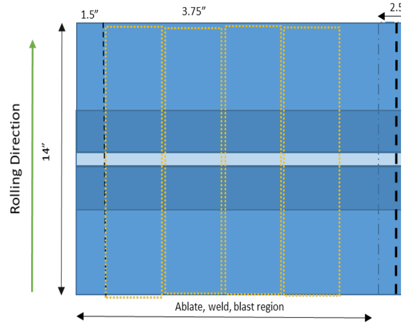


Tensile

Cruciform



Butt-weld

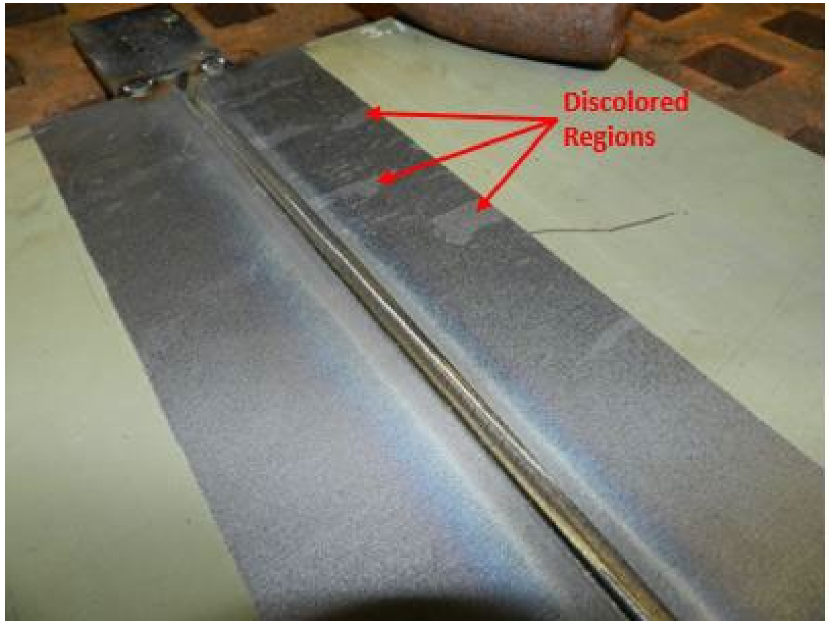


Fatigue

Weld Analysis

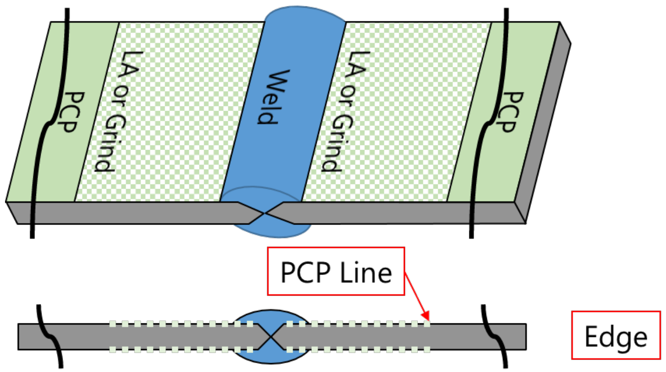
- All "UNSAT" results failed VT due (only) to excessive weld reinforcement, which would be ground off
- LA regions identified as "discolored" were assessed via XRF; no PCP remained but only differences in roughness
- 21% of the weld (by bead count) on Weldment L exceeded the maximum heat input by ~5%
- 8% of the weld (by bead count) on Weldment M exceeded the maximum heat input by ~40%

Weldment	Joint Design	Pre-weld	Post-weld	NDT	Result
A	B2V.1	LA/Grind/LA		VT	UNSAT
	B2V.1	LA/Grind/LA		MT	SAT
	B2V.1	LA/Grind/LA		RT	SAT
B	B2V.1	LA/Grind/LA	Blast	VT	UNSAT
C	B2V.1	LA/Grind	Blast	VT	UNSAT
D	B2V.1	LA		VT	UNSAT
E	B2V.1	LA		VT	UNSAT
F	B2V.1	LA	Blast	VT	UNSAT
G	B2V.1	LA	Blast	VT	UNSAT
H	B2V.1	Grind		VT	UNSAT
I	B2V.1	Grind		VT	UNSAT
J	B2V.1	Grind	Blast	VT	UNSAT
K	B2V.1	Grind	Blast	VT	UNSAT
L	T2V.2	LA/Grind		VT	SAT
M	T2V.2	Grind	Blast	VT	SAT
N	T2V.2	LA		VT	SAT
O	T2V.2	LA	Blast	VT	SAT
P	T2V.2	LA	Blast	VT	SAT
Q	T2V.2	LA/Grind	Blast	VT	SAT
R	T2V.2	Grind		VT	UNSAT
S	T2V.2	Grind		VT	UNSAT
T	T2V.2	Grind	Blast	VT	UNSAT
U	T2V.2	LA		VT	SAT



Example of "discolored" LA regions

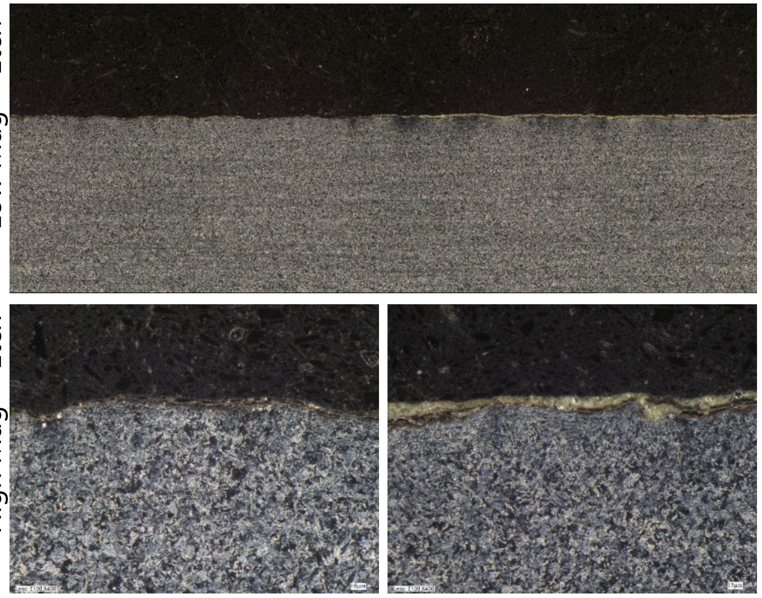
Weld Analysis: Microscopy - Erosion



			Sample Sites				
			Faces			Cross-sections	
Plate	**Pre-weld**	**Post-weld**	Toe	Midway	PCP Line	Toe	PCP Line
A	**Ablate**	**No Blast**	✓ (AS1)	(AS1)	✓ (AS1)	✓ (AS1)	✓ (AS1)
A	**Grind**	**No Blast**	✓ (AS3)	(AS3)	✓ (AS3)	✓ (AS3)	✓ (AS3)
B	**Ablate**	**Blast**	✓ (BS1)	(BS1)	✗	✓ (BS1)	✗
B	**Grind**	**Blast**	✓ (BS3)	(BS3)	✗	✓ (BS3)	✗

Low Mag + Etch

High Mag + Etch

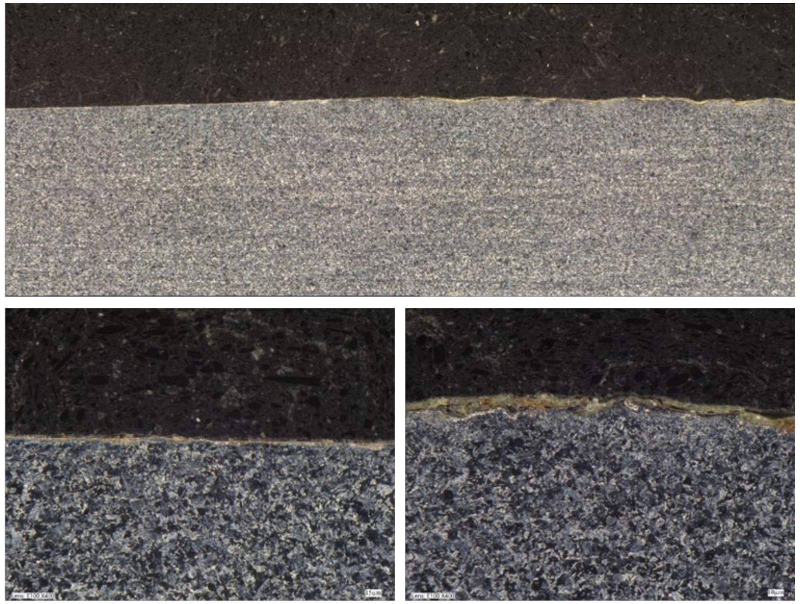


No PCP PCP

LA only: Resulted in no discernable substrate erosion.

Low Mag + Etch

High Mag + Etch



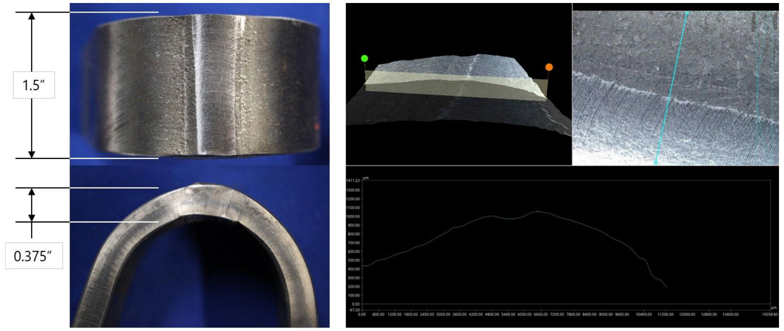
No PCP PCP

Grinding Only: Results in > 160 µm of substrate erosion.

- Slope continues off-screen indicating deeper erosion.

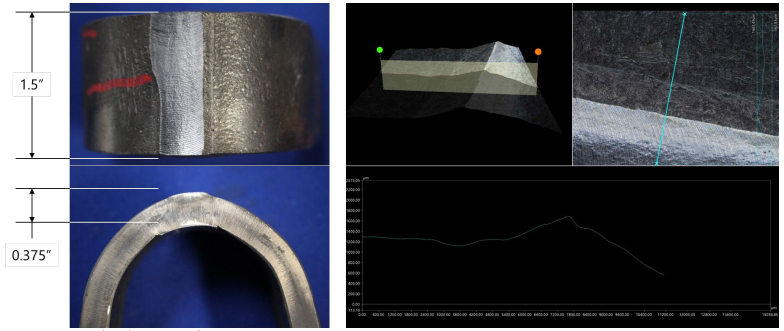
Bend Test

- Guided bend specimen will have no cracks or other open defects greater than 1/8” after bending.
- All “root” bends passed and all “face” bends failed, for all processes.



Scale and orientation of images is approximate.

Sample A9 – Grind, No Blast (Root)



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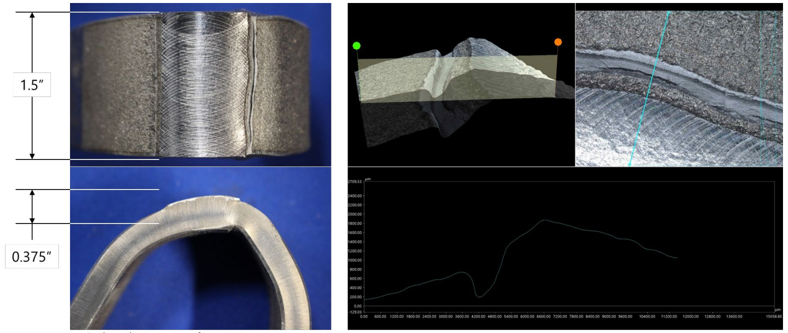
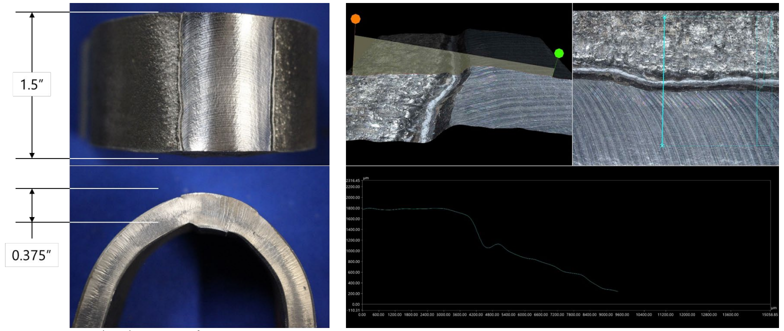
Sample A13 – LA, No Blast (Root)



Scale and orientation of images is approximate.

Sample B12 – Grind, Blast (Face)



Scale and orientation of images is approximate.

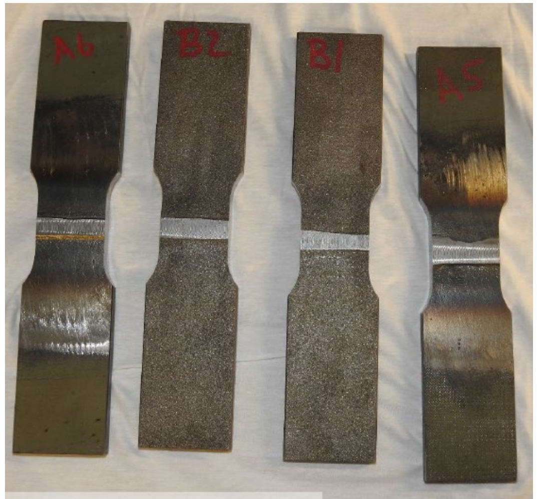
Sample A16 – LA, No Blast (Face)

Note: Cracks occurring on the corners of the specimen are not considered failing unless evidence of slag inclusions or other internal defects in the weld is definite. Openings in the base metal outside the weld deposit and HAZ shall not be cause for rejection of the weld, but will be noted, including location to determine whether HAZ from ablation could be responsible.

Tensile Test

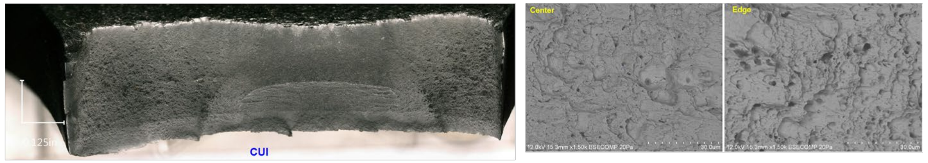
- All samples exceeded the minimum ultimate tensile strength requirement.
- Test conducted per ASTM E 8.

	Sample	TS (ksi)	TS Avg.
Laser Ablated before Welding Not Blasted After Welding	A1	120.5	122.2 ksi (σ_S = 1.6 ksi)
	A2	124.1	
	A3	122.8	
	A4	121.6	
Grinder Cleaned before Welding Not Blasted After Welding	A5	117.1	117.4 ksi (σ_S = 0.6 ksi)
	A6	118.0	
	A7	117.8	
	A8	116.7	
Laser Ablated before Welding SSPC-SP 10 Blasted After Welding	B1	118.6	120.6 ksi (σ_S = 1.5 ksi)
	B2	120.6	
	B3	120.9	
	B4	122.2	
Grinder Cleaned before Welding SSPC-SP 10 Blasted After Welding	B5	113.2	116.9 ksi (σ_S = 2.5 ksi)
	B6	117.5	
	B7	118.2	
	B8	118.8	

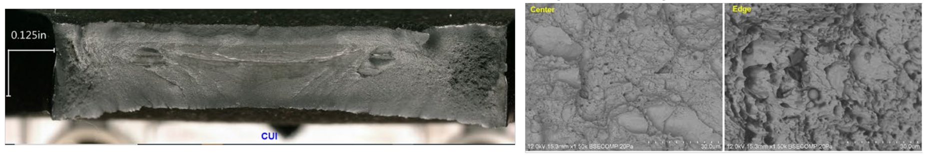


Samples A6, B2, B1, A5 (L-R)

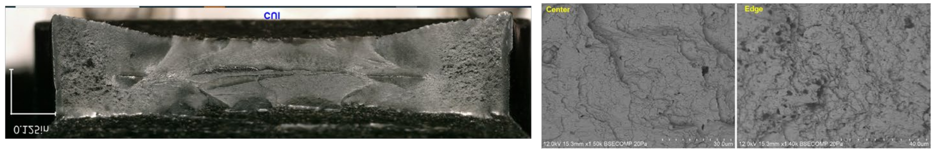
Sample B4 – Laser Ablation, Blast: Failure in Base Metal (122.2 ksi)



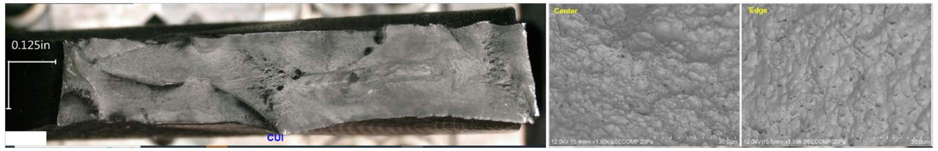
Sample B8 – Grind, Blast: Failure in Base Metal (118.8 ksi)



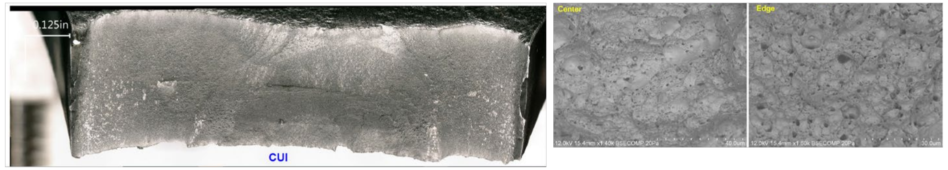
Sample B5 – Grind, Blast: Failure in Base Metal (113.2 ksi)



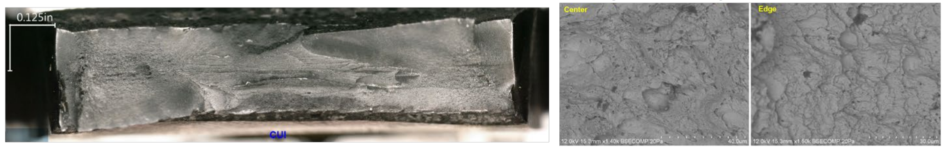
Sample A1 – Laser Ablation, No Blast: Failure at Fusion Line (120.5 ksi)



Sample A3 – Laser Ablation, No Blast: Failure in Base Metal (122.8 ksi)

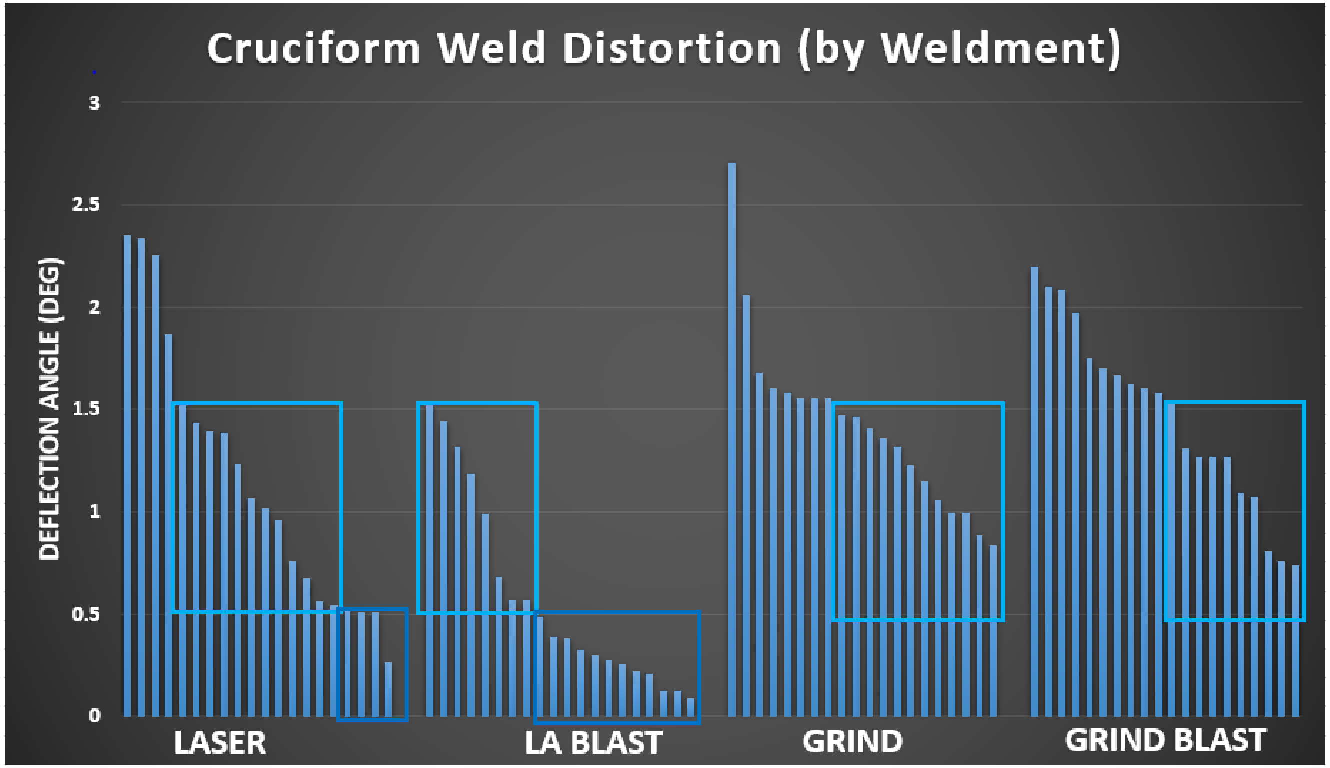


Sample A8 – Grind, No Blast: Failure in Base Metal (116.7 ksi)



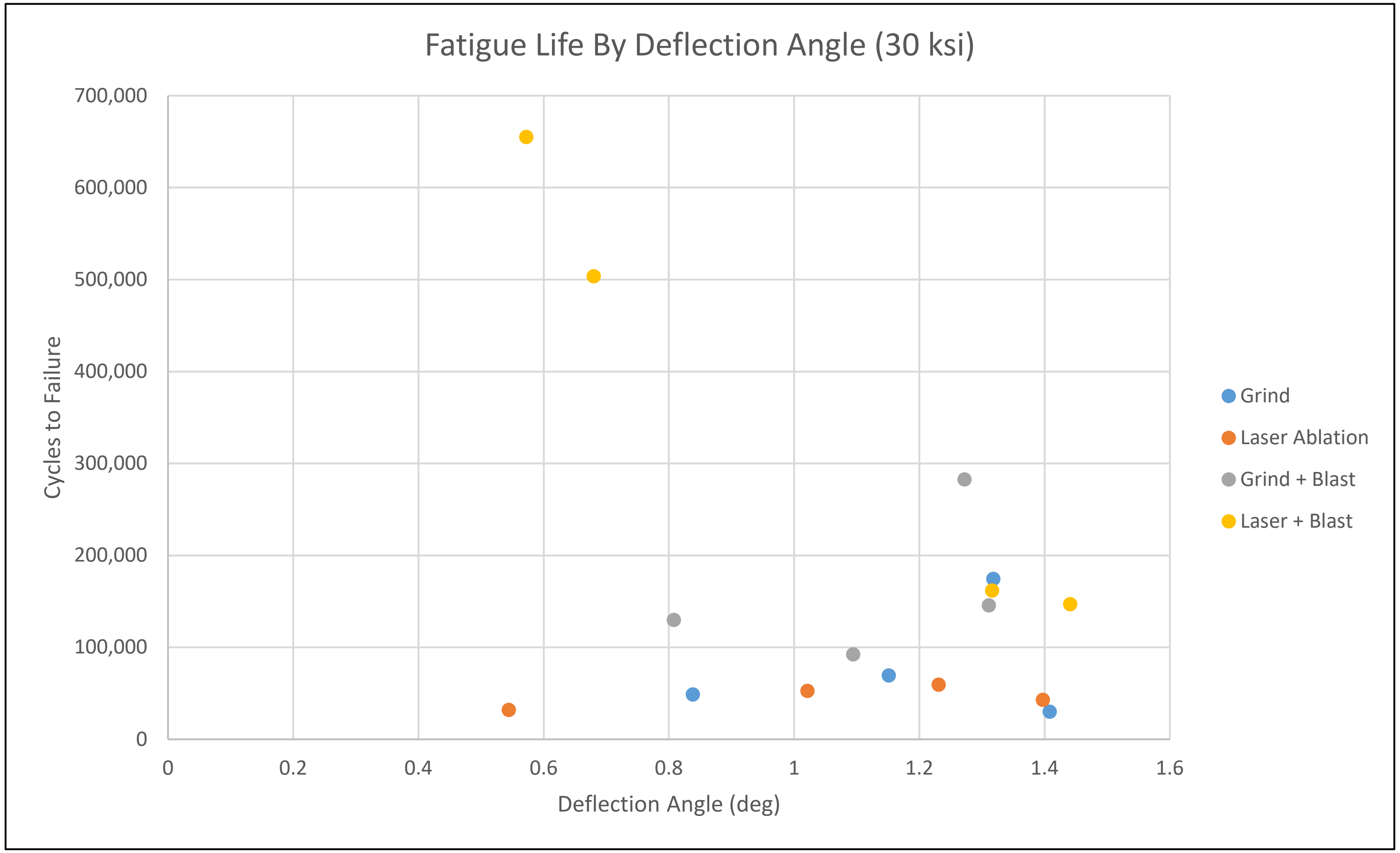
Fatigue Test Concerns

- Butt-welded specimens were completed first and displayed significant distortion using rough ruler measurements of flatness.
  - TWHs suggested awaiting testing until cruciforms were received.
- Cruciform specimens displayed distortion using Faro-arm.
- Tested most consistent cruciform specimens: 0.5<DA<1.5
  - Tested only 30, 15, and 12 ksi loads
  - Reduced specimens for 15 ksi load
- Eliminated butt-welds for project testing due to time/$ constraints



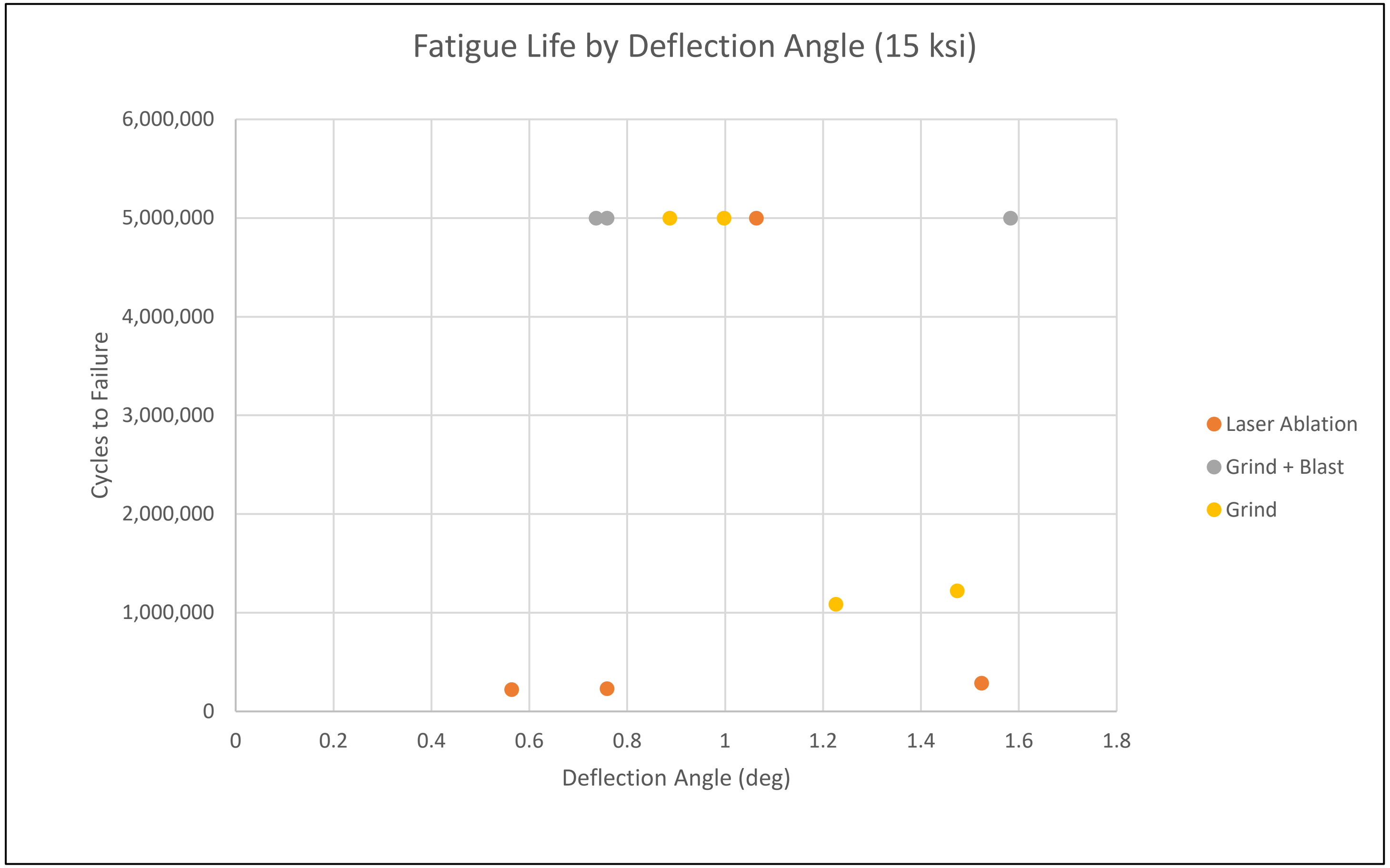
Total Samples of Each Geometry	Original Expected Cycles to Failure	Cycles to Discontinue Testing per NAVSEA	Load (ksi)	Frequency Limitation Acc to NAVSEA (Hz)	Typical Frequency (Hz)	Anticipated Frequency Range (Hz)	Actual Frequency Range (Hz)
16	10,000	N/A	45	≤10	1	1	N/A
16	200,000	500,000	30	≤10	2	2 - 5	2 - 3
16	1,000,000	5,000,000	15	≤10	4	5 - 7	4 - 10
12	2,000,000	12,000,000	12	≤15	4	10 - 15	10 - 15
4	10,000,000	12,000,000	12	≤15	4	10 - 15	10 - 15

Fatigue Test: 30 ksi Load



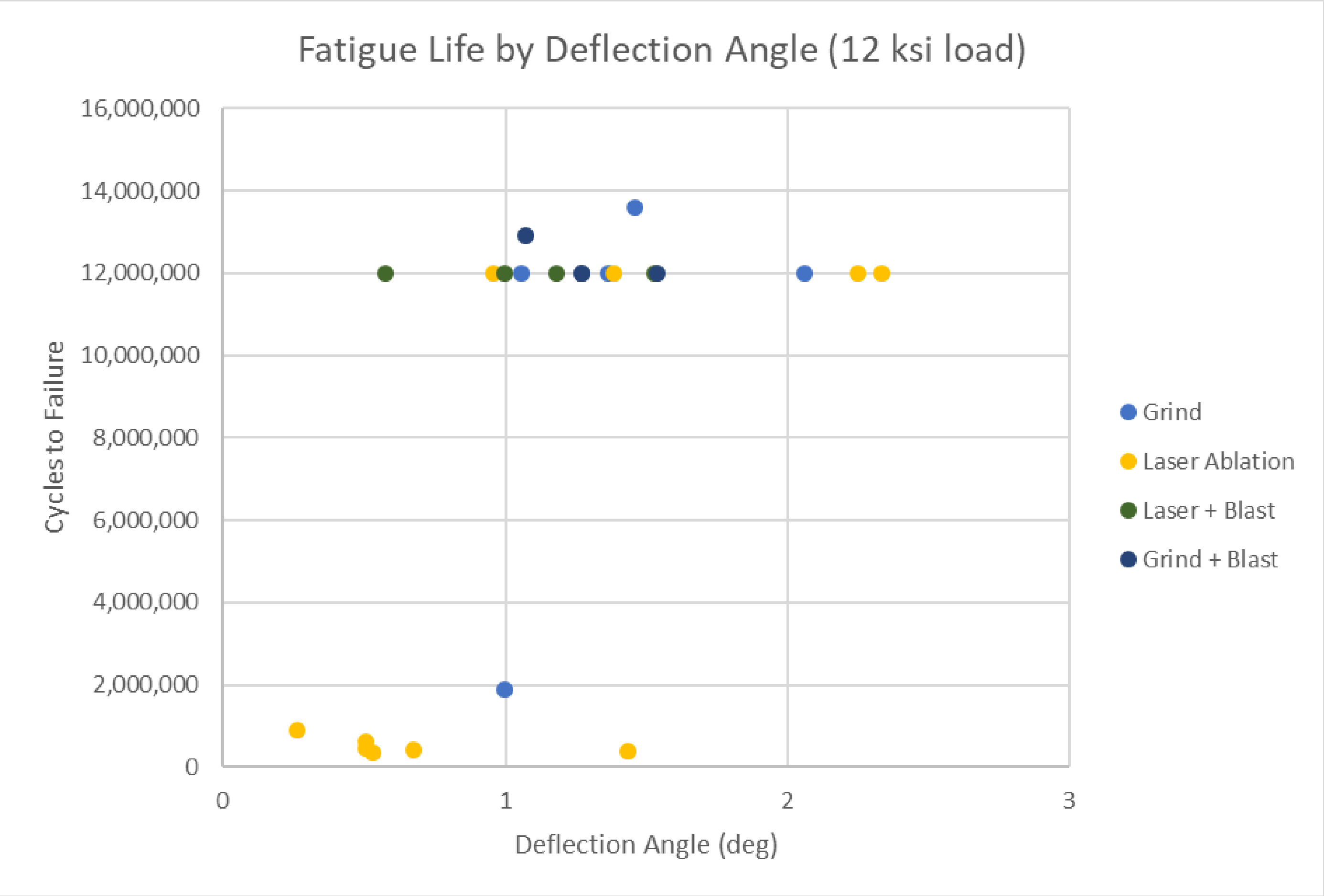
Deflection Angle	Cycles to Fail	Treat	ID
1.408	30,062	Base	S4
0.838	48,618	Base	R2
1.151	69,461	Base	R5
1.318	174,503	Base	R8
0.544	32,097	Alt	U4
1.397	42,930	Alt	N4
1.231	59,360	Alt	N5
1.021	52,720	Alt	N8
0.808	129,871	Base+	M3
1.311	145,551	Base+	M5
1.094	92,192	Base+	M6
1.272	282,515	Base+	T8
0.572	655,060	Alt+	O6
0.68	503,445	Alt+	O8
1.316	161,846	Alt+	Q2
1.441	147,001	Alt+	Q3

Fatigue Test: 15 ksi Load



Deflection Angle	Cycles to Fail	Treat	ID
1.474	1,221,119	Base	L8
1.226	1,086,759	Base	R4
0.998	5,000,000	Base	R6
0.887	5,000,000	Base	R7
0.759	232,039	Alt	U1
0.564	223,150	Alt	U6
1.524	285,486	Alt	N2
1.064	5,000,000	Alt	N7
0.736	5,000,000	Base+	M1
0.759	5,000,000	Base+	M2
1.583	5,000,000	Base+	M8

Fatigue Test: 12 ksi Load



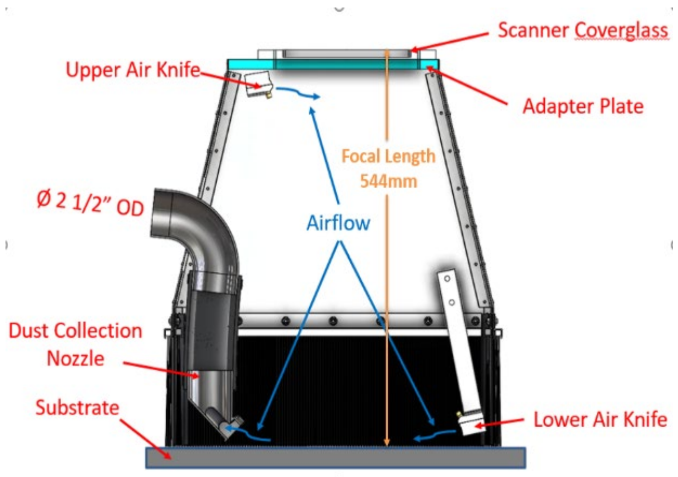
Dist Angle	Cycles to Fail	Treat	ID
1.433	377,739	LA	N3
0.959	12,000,000	LA	N6
0.675	422,841	LA	U3
1.386	12,000,000	LA	L1
0.528	350,584	LA	U5
0.506	620,636	LA	U7
0.505	459,466	LA	U2
2.251	12,000,000	LA	L2
2.333	12,000,000	LA	L4
0.262	893,634	LA	U8
1.461	13,580,625	Grind	S7
1.363	12,000,000	Grind	L7
1.057	12,000,000	Grind	R1
2.06	12,000,001	Grind	L6
0.995	1,876,563	Grind	R3
0.573	12,000,000	LA + Blast	P1
1.182	12,000,000	LA + Blast	Q1
1.528	12,000,000	LA + Blast	Q4
0.997	12,000,000	LA + Blast	O7
1.072	12,908,092	Grind + Blast	M4
1.27	12,000,000	Grind + Blast	M7
1.27	12,000,000	Grind + Blast	Q7
1.537	12,000,000	Grind + Blast	T7

Fatigue Testing: 12 ksi Load

- Additional LA Only and Grind Only specimens were tested at 12 ksi – all from weldment L. Specimen deflection angles were much greater than other treatments.
  - Note: Weldment L is a unique weldment in that both LA and Grinding were conducted on the same weldment.
  - Grind Only, L6, went to run-out (12M cycles).
    - L6 DA = 2.06 and L7 DA = 1.363 – 12M cycles
    - L8 DA = 1.474 – 1.2M cycles at 15 ksi (low for this weldment, but end of weldment)
    - L5 DA = 2.709 ; still available for testing
  - LA Only, L2 and L4, went to run-out (12M cycles).
    - L2 DA = 2.251 and L4 = 2.333 – 12M cycles
    - L1 DA = 1.386 – 12M cycles at 12 ksi in earlier testing
    - L3 DA = 2.348 ; still available for testing

Implementation Planning

- Planned installation locations:
  - Marking and Burning area has 2 installation locations:
    - Will make use existing gantries (automation) for marking/burning areas.
  - Edge Milling area has 1 installation location:
    - May get its own automation rather than make use of existing conveyor. This is TBD by Facilities and Production Engineering.
  - Toe blaster area has 1 Installation location:
    - Has existing traversing blast units (where stiffeners go in and come out free of paint); system modification would install LA where blasting had occurred.
- Laser Shroud: Integrators are evaluating options including NSRP-funded shroud design.
- Feedback control: Not necessary based on testing results and process flow requirements.
- Real time surface evaluation: Not required
- Preliminary Laser Selection Considerations:
  - IPG Photonics
    - (2) 500W air-cooled pulsed lasers each in Edge Preparation & Toe Blast for both sides
    - 1-2kW pulsed lasers in Marking and Burning area
- Laser Scanner: NNS Technology Development has suggested ScanLab Intelliweld



Laser Shroud (NSRP 2019)

Implementation Planning

- NNS is planning integrator services using CY25 equipment acquisition funding.
  - Formal RFQ is planned to be sent after process approval.
  - Assuming concepts are agreeable, each will provide bids/proposals.
- Cost Benefit:

	4-laser system	3-laser system
5-Yr Savings:	$16M*	$19M*
ROI:	2.12	2.18

Stiffener prep area – requires 4th laser (see "b" version of CBA), but significantly increases the percentage of PCP removal that can be automated

- Considers new insertion areas: Hand paint removal at plate edges and manual grinding in stud placement areas (issues with grit recovery using automated blasting)
- Eliminates cost to fully blast entire plates and improves throughput (2x faster conservative value)
- Injuries (ESOH data) and reduced consumable use (with updated rates) are included.
- Intangibles:
  - Blast machine maintenance: Difficult to quantify in terms of cost. NNS doesn't want to lose days of production.
  - Reclaim valuable real estate in SPF: LA installation at Marking/Burning enables NNS to reclaim full plate blasting area.
  - Surface erosion: Eliminates excessive steel removal using conventional means, which may lead to replacement of panels after being integrated into sections due to excessive rust.

**These savings are EROM estimates based upon fully implemented suites of laser ablation systems.*

Next Steps

- Near-Term Milestones to be Addressed
  - Receive technical bids and issue contract to build/integrate systems
  - Receive final Approval to Use Letter from NAVSEA 05 (TWH input)
- Technical Progress to be Accomplished
  - Install systems at NNS, debug, and test
- Risk Reduction Items to be Addressed
  - Continue communication with potential integrators.
  - Conduct pre-installation training for operators/users/engineers.

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Questions?