

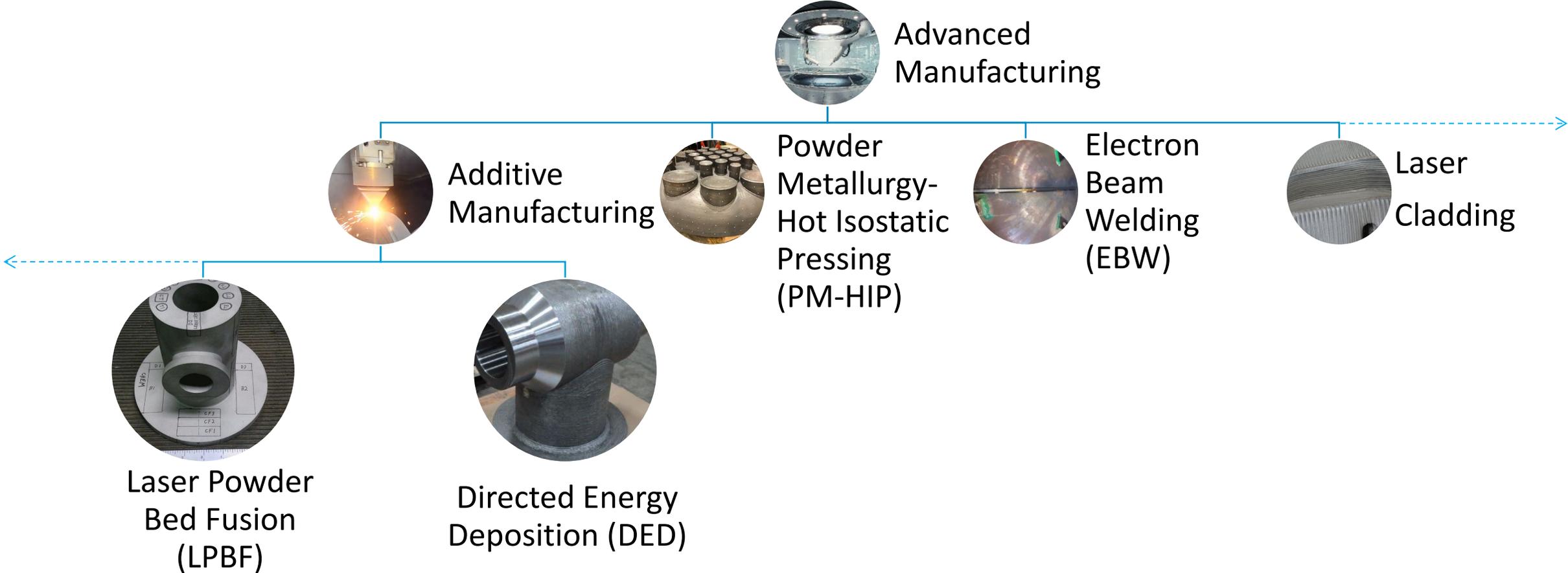
Advanced Manufacturing Update



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NRC Industry NDE Technical Information Exchange
January 21, 2026

Introduction

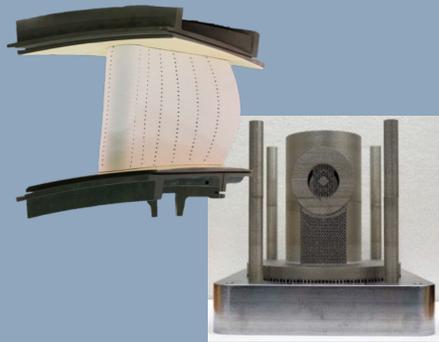


Today: focusing on EBW and DED

Advanced Manufacturing Research at EPRI

Higher Quality | Reduced Lead Times | Alternative Supply Chains | Cost Competitive

Additive Manufacturing



Powder-Bed Based Methods (New Components, Code Acceptance)

Directed Energy Deposition (DED) for Large Components



Near Net Shape & Surface Modification



Powder Metallurgy Hot Isostatic Pressing (PM-HIP)

Diode Laser Cladding (DLC)

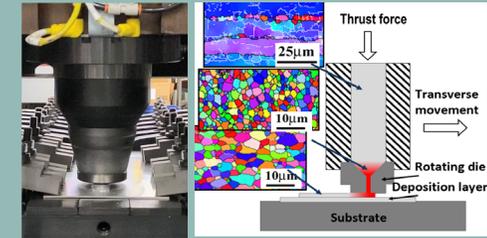


Advanced Welding & Fabrication



Advanced welding: Adaptive feedback, electron beam, etc.

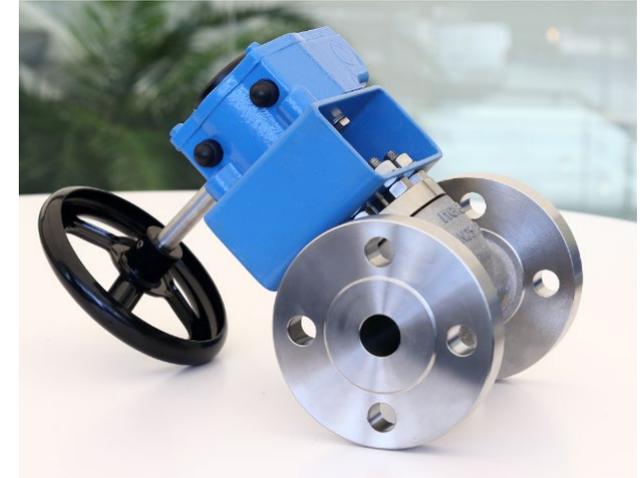
Solid state processing



Opportunities for repair, replacement, and new technology deployment

Current Nuclear Power Additive Applications

- Secondary systems
 - Fire service pump impeller at Krsko
 - Valve at TVO
- Fuel/Internals
 - Channel fastener at Browns Ferry
 - Thimble plugging device at Byron
 - Fuel assembly parts at KKG
 - Tie plate at Forsmark
- Piping supports
- All are laser powder bed fusion process



<https://www.tvo.fi/en/index/news/pressrelease-sstockexchangereleases/2021/valveproducedusing3dprintingtechnologytestedinolkiluoto.html>



<https://world-nuclear-news.org/Articles/Westinghouse-3D-printed-component-installed-in-ind>

Directed Energy Deposition (DED)



*316LSi valve body, 1600 pounds (700 kg), 11 days build time
Collaborative effort between EPRI and Lincoln Electric Additive Solutions*



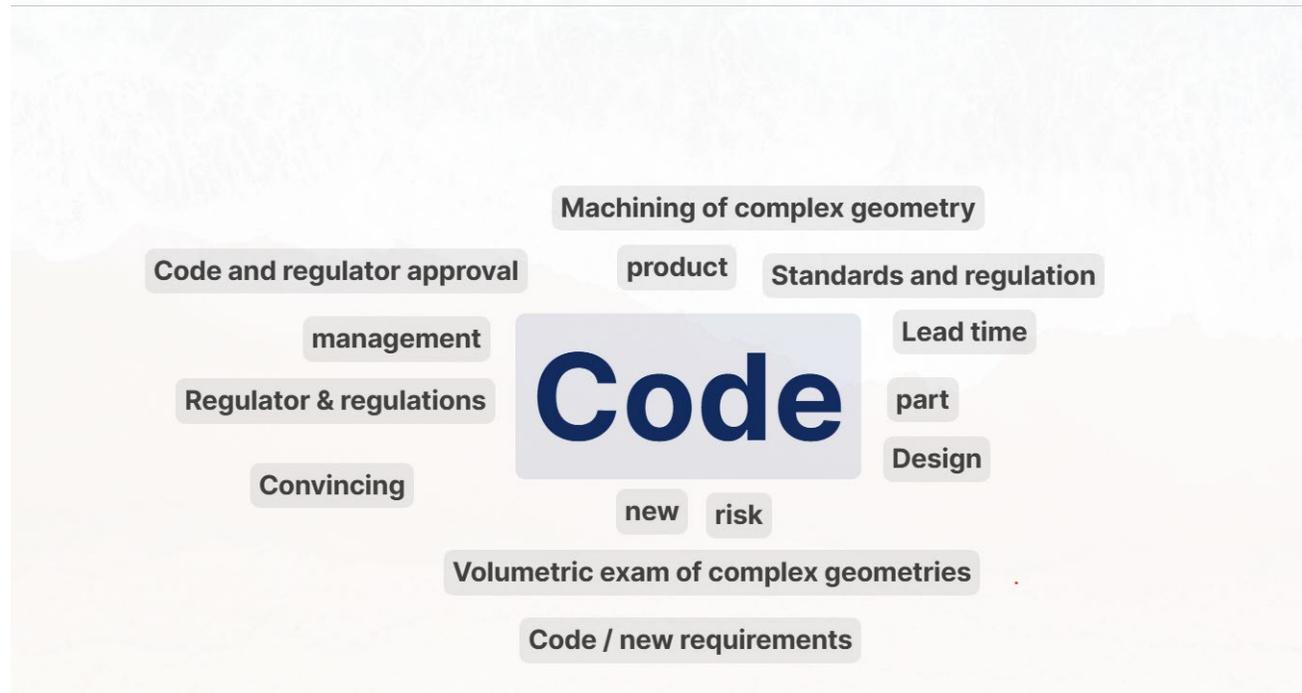
*316L valve body, 200 pounds (90 kg)
Courtesy Connecticut Center for Advanced Manufacturing*

Primary driver is lead time

Member Feedback on Additive Manufacturing

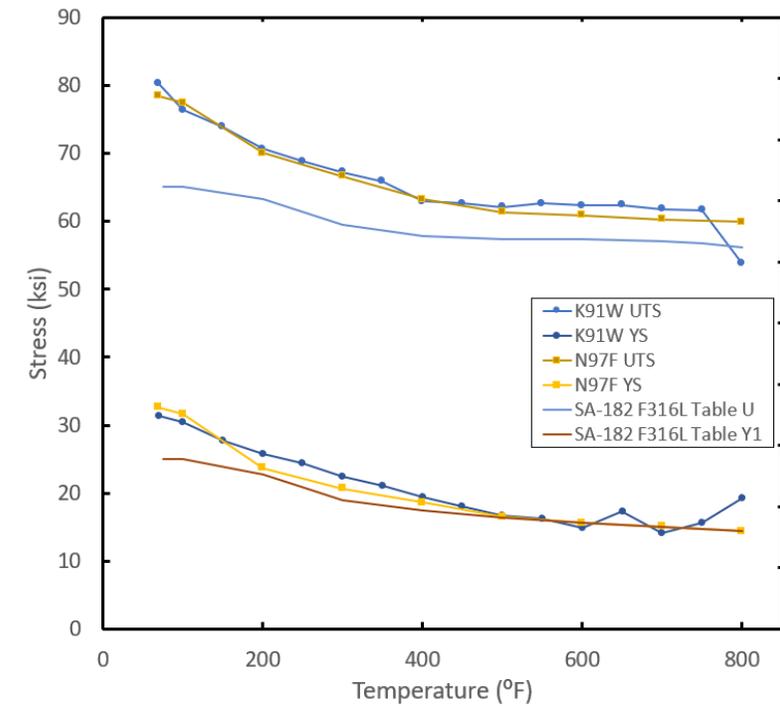
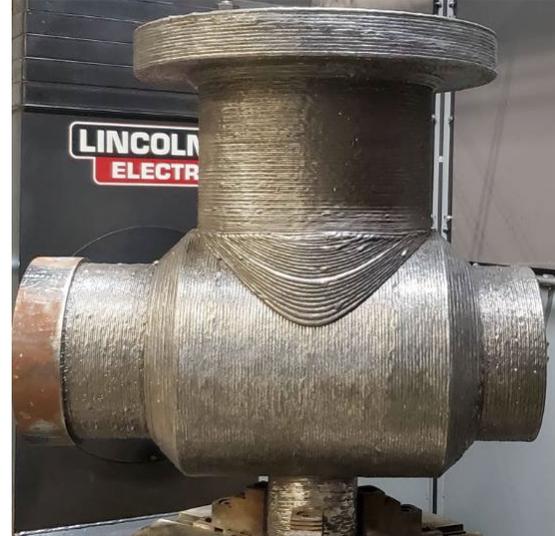
- Where are things in Codes and Standards?
- Can you share any operating experience?

What is the biggest barrier to considering additive manufacturing for replacement parts?



GMA-DED 316LSi Project Summary

- Three 316LSi valve bodies built by Lincoln Electric and solution heat treated
- Demonstrated portions of the Section III Draft Code Case process
- Corresponding Material: SA-182 F316L
- Mechanical Testing: CVN, tensile, hardness
- NDE: PT, UT, RT
- Takeaways:
 - Mechanical properties met minimums for acceptance
 - No rejectable indications for NDE requirements set by corresponding material, note grinding / surface prep



S.Tate, et.al.; "[Evaluation of Directed Energy Deposition 316LSi Stainless Steel Pressure Boundary Parts.](#)" ASM-EPRI. Advances in Materials, Manufacturing, and Repair for Power Plants 2024.

Section III GMA-DED NDE Requirements

- **Section III Draft Code Case:**
 - “Materials in Section II, Part D, Subpart 1, Tables 1A, 1B, 2A and 2B may be selected as a corresponding material, as applicable to the Section III class of the item being constructed. The material produced by wire-DED shall be subject to examination based on that of the corresponding material.”
- Section III Div 1. NB-2500 requires volumetric and surface exam
 - Forging gets UT
 - Casting gets RT, except ferritic materials can opt for UT
 - MT or PT for surface exam
 - Acceptance criteria scale with part thickness
- Requirements for Class 2/3 (NCD-2500) less stringent, but more varied



Section III NB-2500 NDE Methods and Acceptance Criteria

- PT
 - Section III Div. 1 NB-2546 references Section V, Article 6 for method
 - 3/16-inch (5 mm) limit for linear or rounded indications
- UT
 - Section III Div. 1 NB-2542 references Section V, Article 5 which references SA-745
 - 1/4 inch (6 mm) flat bottom hole calibration block produced, based on Quality level 2

(b) Imperfections producing the following relevant indications are unacceptable:

(1) any linear indications greater than $\frac{1}{16}$ in. (1.5 mm) long for material less than $\frac{5}{8}$ in. (16 mm) thick, greater than $\frac{1}{8}$ in. (3 mm) long for material from $\frac{5}{8}$ in. (16 mm) thick to under 2 in. (50 mm) thick, and $\frac{3}{16}$ in. (5 mm) long for material 2 in. (50 mm) thick and greater;

(2) rounded indications with dimensions greater than $\frac{1}{8}$ in. (3 mm) for thicknesses less than $\frac{5}{8}$ in. (16 mm) and greater than $\frac{3}{16}$ in. (5 mm) for thicknesses $\frac{5}{8}$ in. (16 mm) and greater;

(3) four or more relevant indications in a line separated by $\frac{1}{16}$ in. (1.5 mm) or less edge to edge;

(4) ten or more relevant indications in any 6 in.² (4 000 mm²) of area whose major dimension is no more than 6 in. (150 mm) with the dimensions taken in the most unfavorable location relative to the indications being evaluated.



12.1.1 Straight Beam:

12.1.1.1 Material producing an indication response whose maximized amplitude equals or exceeds 100 % of the primary reference or distance-amplitude correction curve at the estimated discontinuity depth shall be considered unacceptable.

(a) QL-1—A distance-amplitude curve shall be based upon the amplitude response from No. 8 flat-bottom hole ($\frac{8}{64}$ in. [3 mm]).

>3 inch

(b) QL-2—A distance-amplitude curve shall be based upon the amplitude response from No. 16 flat-bottom hole ($\frac{16}{64}$ in. [6 mm]).

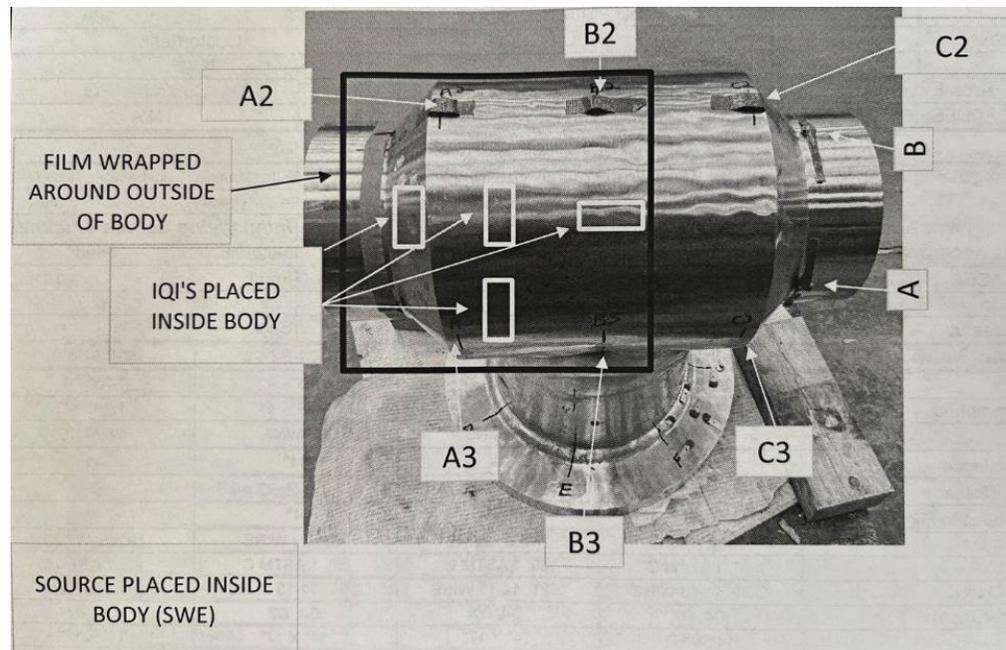
3-8 inch

(c) QL-3—A distance-amplitude curve shall be based upon the amplitude response from No. 24 flat-bottom hole ($\frac{24}{64}$ in. [10 mm]).

8-12 inch

Section III NB-2500 NDE Methods and Acceptance Criteria

- RT
 - Section III Div. 1 NB-2500 for castings sends to ASTM E446, E186 or E280
 - Severity level 2, 0.2 fraction of indication length to feature length
 - Section III Div. 1 NB-5000 weld acceptance criteria
 - Rounded indications of 0.156 inch random, 0.250 inch isolated



NB-5320 RADIOGRAPHIC ACCEPTANCE STANDARDS

Indications shown on the radiographs of welds and characterized as imperfections are unacceptable under the following conditions:

(a) any indication characterized as a crack or zone of incomplete fusion or penetration;

(b) any other elongated indication that has a length greater than:

(1) $\frac{1}{4}$ in. (6 mm) for t up to $\frac{3}{4}$ in. (19 mm), inclusive

(2) $\frac{1}{5}t$ for t from $\frac{3}{4}$ in. (19 mm) to $2\frac{1}{4}$ in. (57 mm), inclusive

(3) $\frac{3}{4}$ in. (19 mm) for t over $2\frac{1}{4}$ in. (57 mm)

where t is the thickness of the thinner portion of the weld;

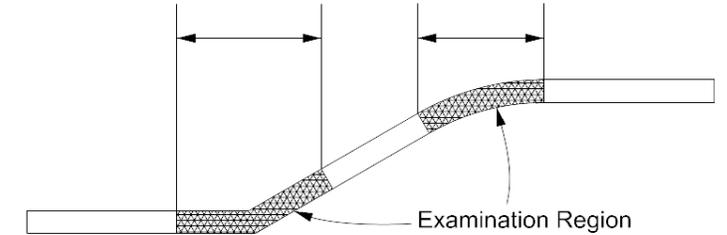
(c) internal root weld conditions are acceptable when the density change or image brightness difference as indicated in the radiograph is not abrupt; elongated indications on the radiograph at either edge of such conditions shall be unacceptable, as provided in (b) above;

(d) any group of aligned indications (excluding non-relevant indications) having an aggregate length greater than t in a length of $12t$, unless the minimum distance between successive indications exceeds $6L$, in which case the aggregate length is unlimited, L being the length of the largest indication;

(e) rounded indications in excess of that shown as acceptable in Section III Appendices, Mandatory Appendix VI.

Section VIII GMA-DED NDE Requirements

- **Section VIII Code Case :**
 - “(h) The extent of full volumetric examination of an AM pressure part shall include examination of 100% of the final volume.
 - (i) The extent of spot volumetric examination for AM pressure parts shall include a minimum of 10 percent of the volume of the examination regions as show in Table 3.
 - (j) Radiographic Examination shall be performed in accordance with the requirements of UW-51.”
- AM Strength Reduction Factor (AMSRF) shall be used in place of the joint efficiency



Examination	AMSRF
Full volumetric	1.0
Spot volumetric	0.85
No volumetric	0.7

Section VIII GMA-DED NDE Requirements

- Section VIII UW-51 (RT) Acceptance Criteria

Table 4-1

Customary Units			
Thickness, t , in.	Maximum Size of Acceptable Rounded Indication, in.		Maximum Size of Nonrelevant Indication, in.
	Random	Isolated	
Less than $\frac{1}{8}$	$\frac{1}{4} t$	$\frac{1}{3} t$	$\frac{1}{10} t$
$\frac{1}{8}$	0.031	0.042	0.015
$\frac{3}{16}$	0.047	0.063	0.015
$\frac{1}{4}$	0.063	0.083	0.015
$\frac{5}{16}$	0.078	0.104	0.031
$\frac{3}{8}$	0.091	0.125	0.031
$\frac{7}{16}$	0.109	0.146	0.031
$\frac{1}{2}$	0.125	0.168	0.031
$\frac{9}{16}$	0.142	0.188	0.031
$\frac{5}{8}$	0.156	0.210	0.031
$\frac{11}{16}$	0.156	0.230	0.031
$\frac{3}{4}$ to 2, incl.	0.156	0.250	0.031
Over 2	0.156	0.375	0.063

Figure 4-6
Charts for t Over $\frac{3}{4}$ in. to 2 in. (19 mm to 50 mm), Inclusive



(a) Random Rounded Indications [See Note (1)]



(b) Isolated Indication [See Note (2)]



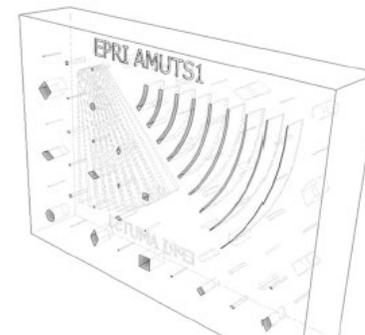
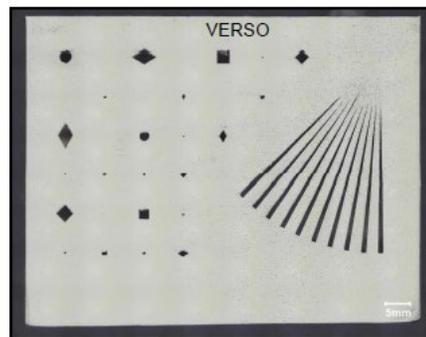
(c) Cluster

Current Code Progress

Code/Standard	Status
ASME Section III, GMA-DED	Code Case pending final Board approval
ASME Section III, LPBF	Draft Code Case needs revision, 2026?
ASME Section VIII, GMA-DED	Approved Code Case
ASME Section I and VIII, GMA-DED	In progress, timing unknown
ASME B31.1	Interpretation request to use
ASME B16	Under consideration
ISO 13445-14	Draft, publication timing unknown

Additive Manufacturing NDE Completed Work

- GMA-DED 316LSi, [3002033639](#), [EPRI-ASM Conference Proceedings](#)
- Laser Powder Bed Fusion 316L, [3002018273](#), [3002026400](#)
- Ultrasonic Testing (UT) Nondestructive Evaluation (NDE) Perspective on Additive Manufacturing, [3002021044](#)
- Ultrasonic Testing (UT) Reference Standard for Additive Manufacturing Quality Control, [3002025339](#)



Additive Manufacturing NDE Current Gaps

- Evaluate in-service inspection
- Attenuation of UT in GMA-DED
- Challenges inspecting as-built surface
- Metallurgical reflectors causing false UT indications

- Long term, can in-situ monitoring reduce post process NDE

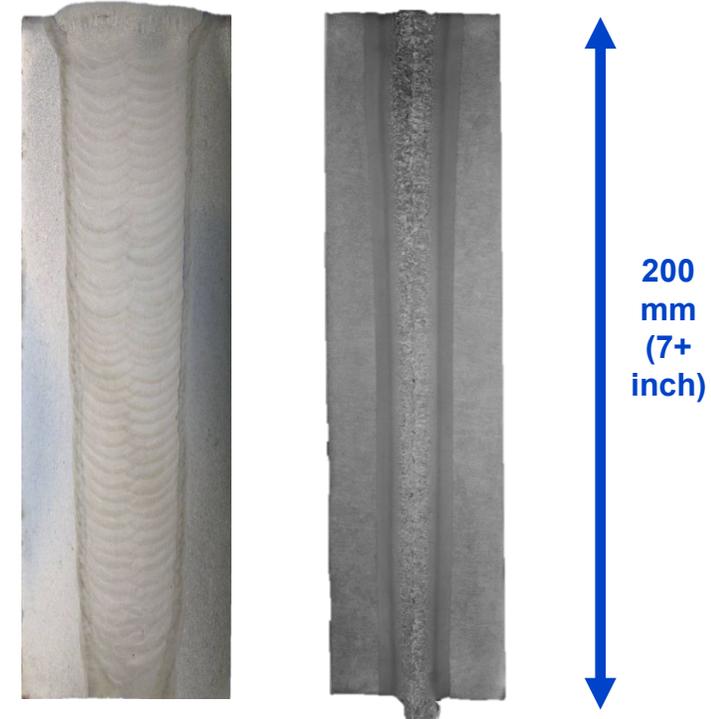
**Continue work on Code progress, industry implementation.
Plan to address gaps**

Deployment of Heavy Section EBW – EPRI Supplemental (Joint Industry Project)

- Basis for SA-508 Grade 3 EBW without Preheating
- Transferring Slope-out Welding Techniques
- Development/Demonstration of Repair Techniques
- **NDE & Destructive Testing/Validation**
- Magnetism, Cleaning and Surface Finish



Full circumferential pressure vessel weld



Narrow-gap TIG: 90 passes = months

EBW: single pass = hours

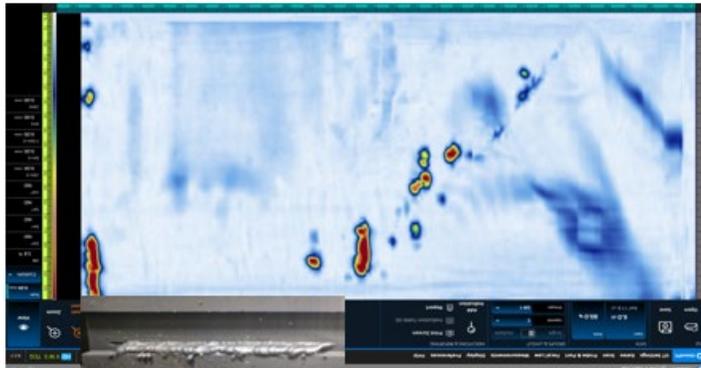


Final activities to enable full manufacturing readiness and commercial application

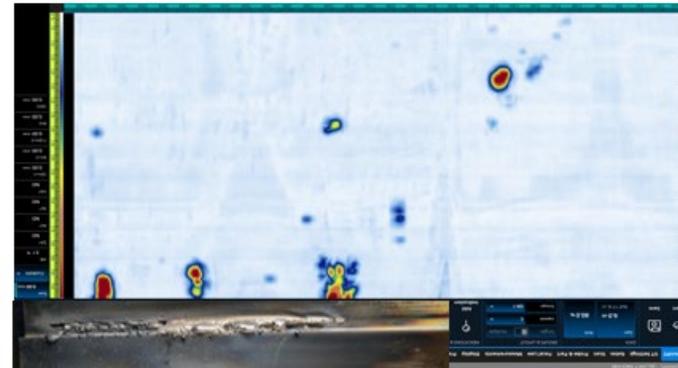
Deployment of Heavy Section EBW NDE Scope

- Matrix showing flaw types, orientation, and detection capability of different methods
 - Missed joint, spiking porosity, cracking
- Focused on UT, some radiography to assist characterization

K wide oscillation (50 x 55)



F wide oscillation (50 x 65)





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