Savannah River National Laboratory®

ASME Criteria for Powder Bed Fusion Additive Manufacturing

ASME Special Committee on Additive Man

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ASME Criteria for Powder Bed Fusion Additive Manufacturing

- **What is Additive Manufacturing**
- **Additive Manufacturing (AM)** - a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies.
- **Subtractive Manufacturing** - making objects by removing material (for example, milling, drilling, grinding, etc.) from a bulk solid to leave a desired shape.

Subtractive

Additive

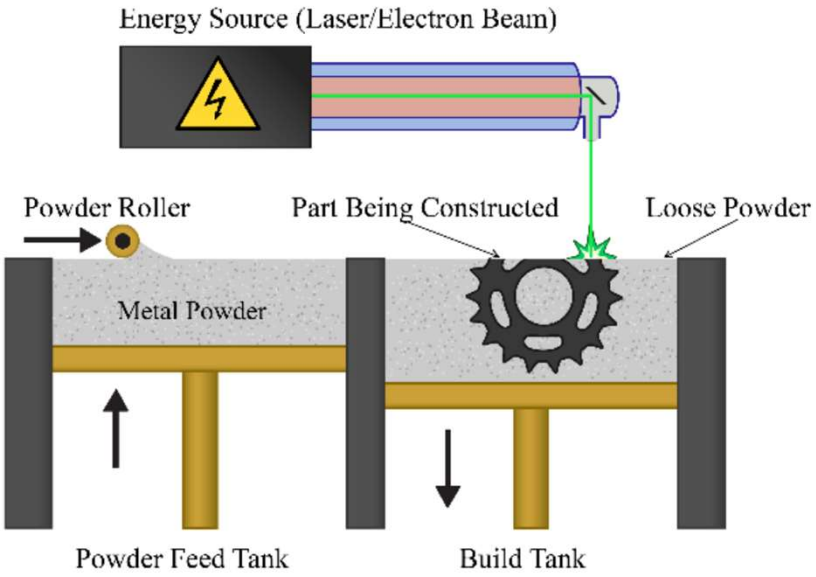
Additive + Subtractive

Application will require additive joined to non-additive

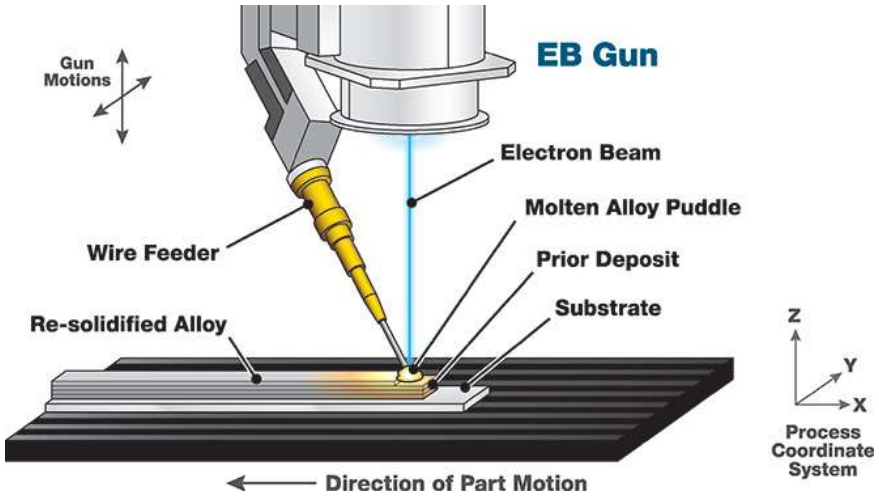
ASME Criteria for Powder Bed Fusion Additive Manufacturing

- **Additive Manufacturing Technologies**

Powder Bed Fusion



Direct Energy Deposition



ASME Criteria for Powder Bed Fusion Additive Manufacturing

- **The ASME Special Committee has produced a final draft document providing Criteria for Pressure Retaining Metallic Components Using Additive Manufacturing.**

- **The document is intended to provide criteria on the materials, design, fabrication, examination, inspection, testing and quality control essential to be addressed in any proposed standard for the construction of metallic pressure retaining equipment using powder bed fusion additive manufacturing.**
- **The additive manufacturing criteria document addresses the follow areas.**

- **Scope**
- **Additive Manufacturing Specification**
- **Materials**
- **Thermal Treatment**
- **Powder Requirements**
- **Additive Manufacturing Design Requirements**
- **Additive Manufacturing Procedure**
- **Additive Manufacturing Procedure Qualification**
- **Qualification Testing of Additive Manufactured Components**
- **Production Builds**
- **Chemistry Testing**
- **Mechanical Property Testing**
- **Metallographic Evaluation**
- **Referenced Standards**
- **Definitions**
- **Records**
- **Quality Program**

ASME Criteria for Powder Bed Fusion Additive Manufacturing

- **Scope**
  - These criteria address the construction of pressure retaining equipment using the Additive Manufacturing (AM) Powder Bed Fusion process using both Laser and Electron Beam energy sources.
  - Hybrid construction incorporating AM components joined (Welded or Brazed) to non-AM components is acceptable. Additive manufactured components joined to other AM components or non-AM components shall follow the requirements for the applicable ASME Construction Code or Standard.
  - The pressure design for components shall follow the requirements of the applicable ASME Construction Code or Standard.
  - The maximum design temperature shall be at least 50°F (25° C) colder than the temperature where time-dependent material properties begin to govern for the equivalent wrought ASME material specification, as indicated in ASME Section II, Part D [15.1].
  - The minimum design temperature shall follow the requirements for the applicable ASME Construction Code or Standard.

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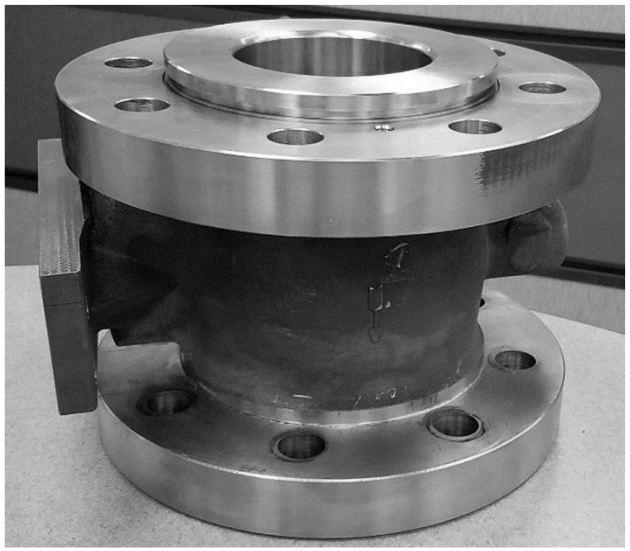
- **Materials**
  - Material for the purpose of this specification is defined as the additively manufactured component in its final heat-treated condition.
  - The Additive Manufacturer shall select a listed wrought ASME material specification from ASME Section II for the component material.
  - The requirements for chemical composition, grain size, hardness, final heat treatment and mechanical properties shall be identical to the requirement of the ASME material specification.

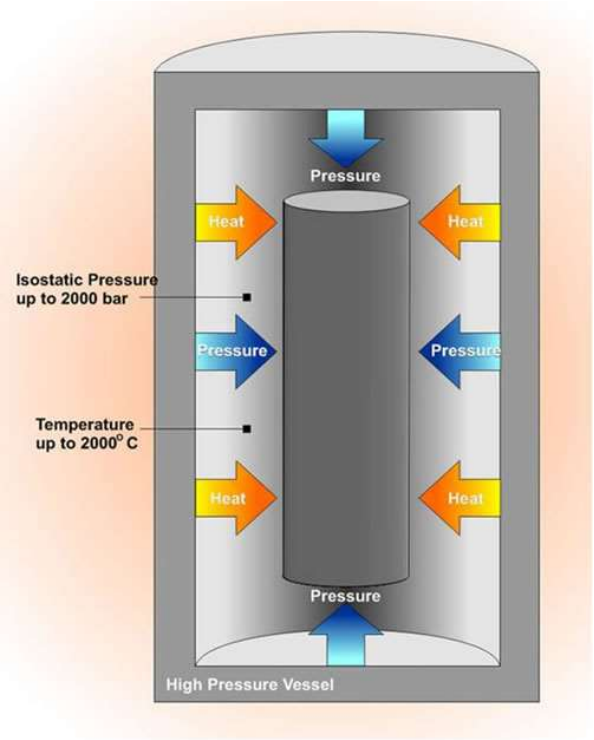


Valve Body Fabricated Using Powder Bed Fusion AM
Courtesy of Emerson

- The AM Committee basically followed the same criteria for materials that was used in the codification of component fabricated using the powder metallurgy

ASME Criteria for Powder Bed Fusion Additive Manufacturing

- **Thermal Treatment**
  - The final heat treatment requirements applied to the AM material shall be identical to those applied to the ASME material specification.
  - Additional intermediate thermal treatment is acceptable. Intermediate thermal treatment may include stress relief, hot isostatic pressing or other thermal processing.
  - When intermediate thermal treatment is performed ASTM F3301 [15.2] may be used as guidance.
  - When hot isostatic pressing is performed ASTM A988 [15.3] or ASTM A1080 [15.4] may be used as guidance.
  - All material testing shall be performed on material specimens in the final heat-treated condition ASME material specification.



Schematic of the Hot Isostatic Pressing Process

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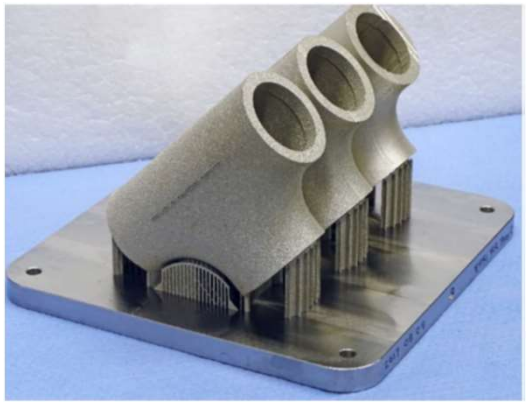
- **Design**
  - In addition to the design requirements of the ASME Construction Code or Standard the following design requirements apply for components produced using the powder bed fusion AM process.
  - Any material produced during the AM build that is specified as cosmetic material shall not be credited as load bearing material in the stress analysis.
  - Fatigue critical surfaces shall be designed to be accessible for liquid penetrant examination.
  - Surfaces interfacing with sacrificial supports shall be fully accessible for removal of supports and for liquid penetrant examination.
  - The effect of any support that will not be removed following the AM build shall be included in the stress analysis.

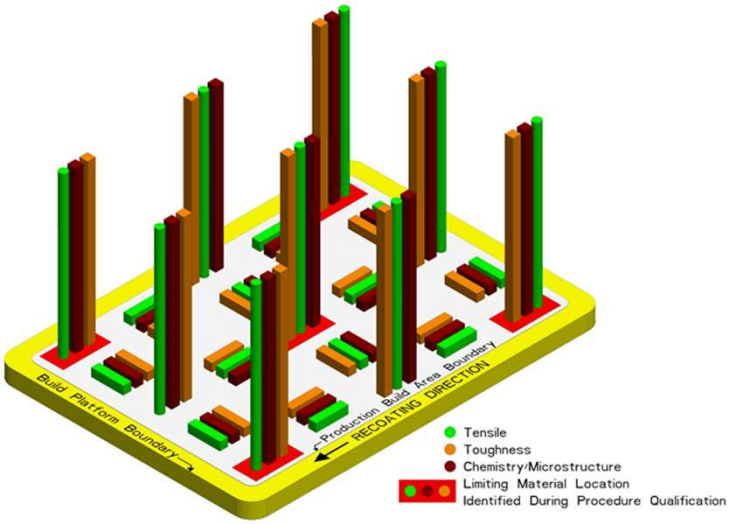


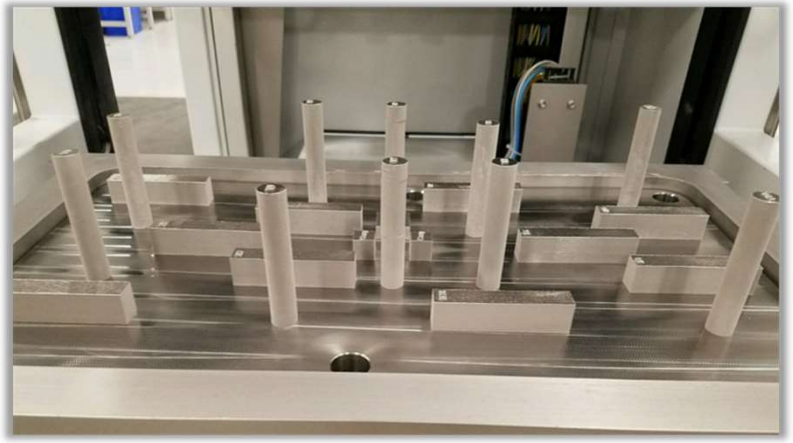
Sacrificial Supports
Courtesy of Rolls- Royce

Permanent Supports

ASME Criteria for Powder Bed Fusion Additive Manufacturing

- **Additive Manufacturing Procedure**
  - Additive Manufacturing Procedure
    - The Additive Manufacturer shall prepare an Additive Manufacturing Procedure.
    - The AM Procedure shall address applicable process variables.
    - The Additive Manufacturer shall complete sufficient qualification builds and produce sufficient material qualification specimens to support a 95% confidence that 99% of the produced material is in accordance the ASME material specification.
    - <u>The Additive Manufacturer shall identify the locations of limiting material conditions for each energy source.</u>

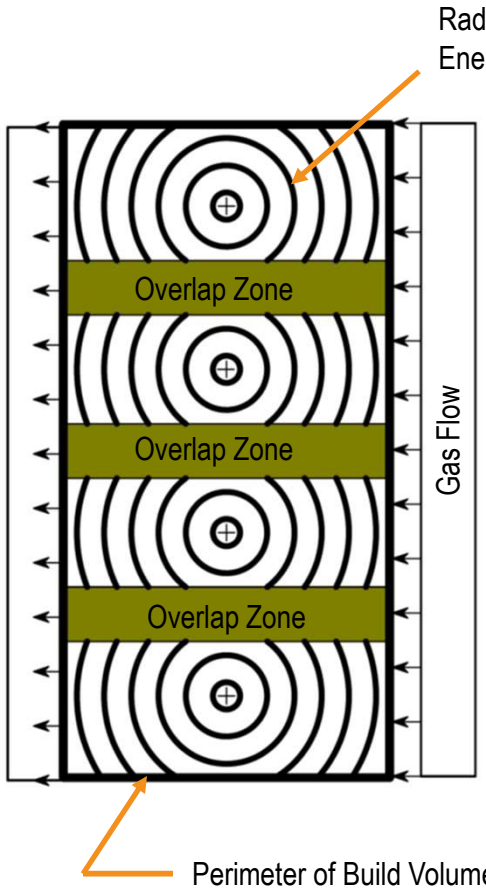


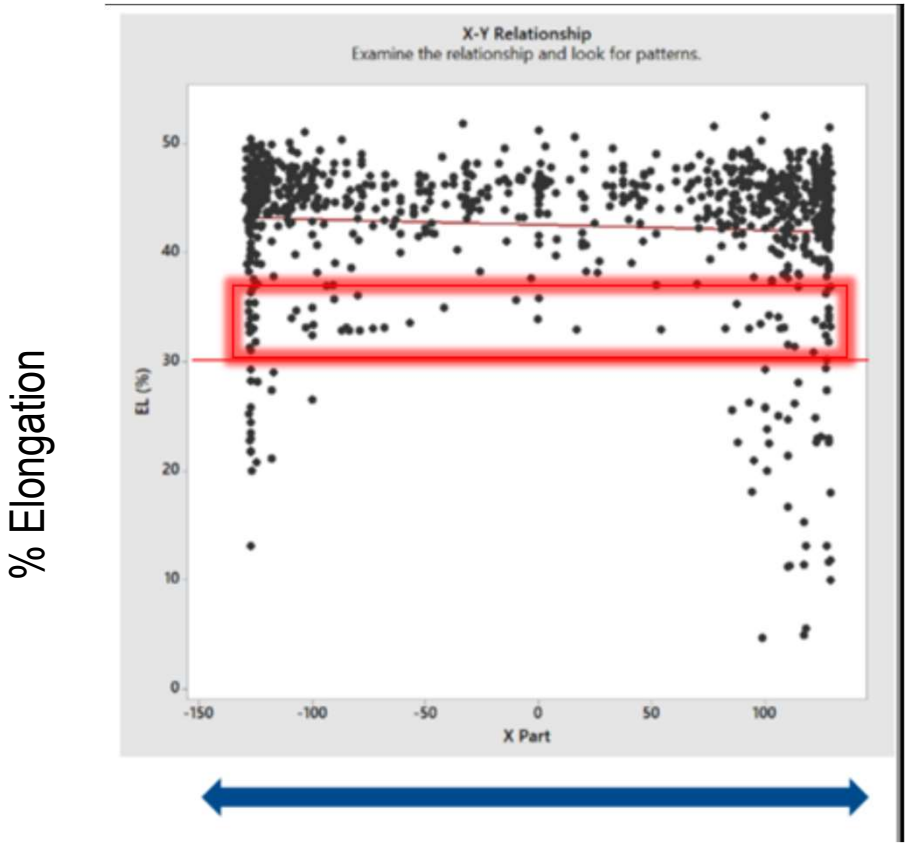


Material Qualification Specimens for Additive Manufacturing Procedure Qualification
Courtesy of Emerson

ASME Criteria for Powder Bed Fusion Additive Manufacturing

- **Additive Manufacturing Procedure Qualification**
  - Limiting material conditions for each energy source.





Radial Distance From Energy Source
Courtesy of Emerson

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- **Qualification Testing of Additive Manufactured Components**
  - Fabricated components shall be subjected to qualification testing.
  - Correlation between the samples and the actual component.
- **Prototype Testing Requirements**

Prototype Test	Number of Prototypes	Test Criteria
Proof	1	Section 9.12
Fatigue	2 to 5	Section 9.13
Material Properties	1	Sections 12-14
Toughness	1	Construction Code

- **Locations for Material Qualification Specimens for Component Qualification Build**

Location	Description	Minimum Samples
CQ1	Locations of limiting material conditions identified during the procedure qualification.	2 per Energy Source
CQ2	Thinnest pressure retaining feature in the component	1
CQ3	Highest stressed location in the component	1

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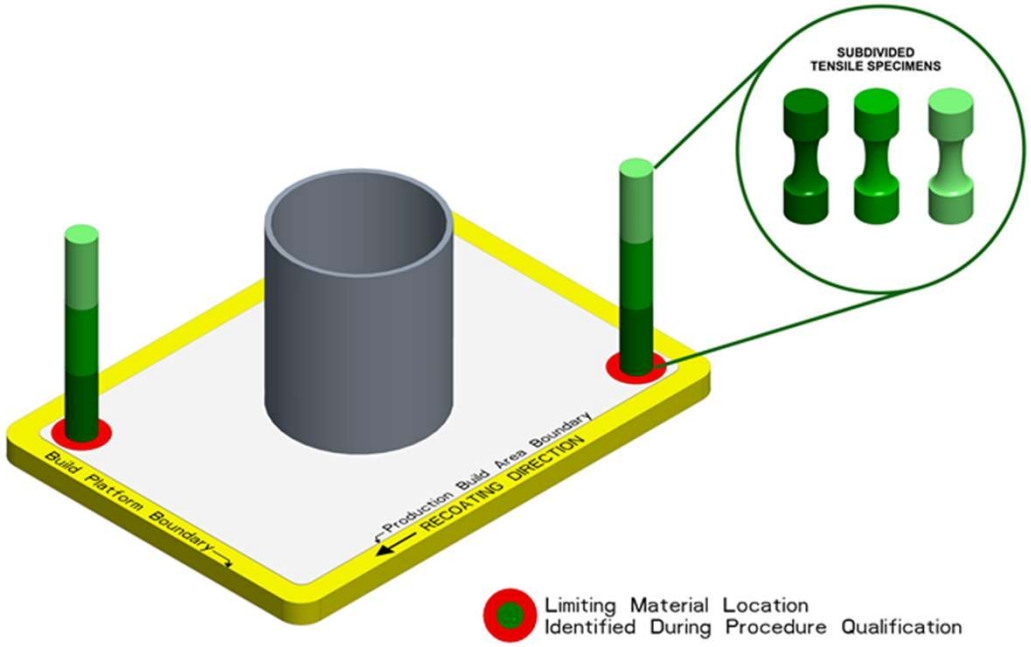
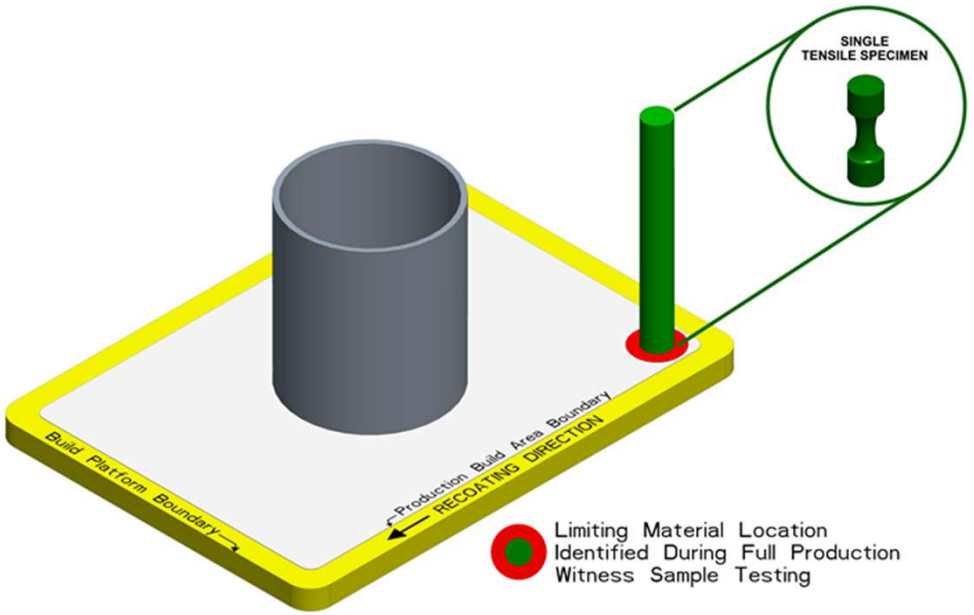
- **Production Builds**
  - First 10 Production Builds
  - A vertically oriented witness specimen shall be constructed over the total height of the build volume at a minimum of 2 locations of limiting material conditions determined during procedure qualification for each energy source.
  - Witness specimens shall be subdivided when required to meet the requirement of ASTM E8.
  - All tensile specimens from each energy source shall be tested.



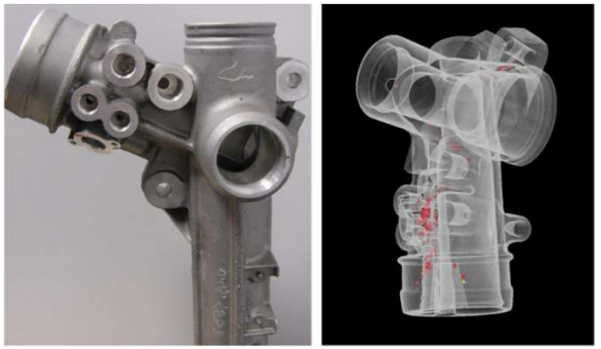
ASME Criteria for Powder Bed Fusion Additive Manufacturing

- **Production Builds**
  - Production builds greater than 10 with all tensile samples conforming.
  - One vertically oriented witness specimen for each energy source shall be constructed to the height required to capture the limiting material location determined from the data for the first 10 production build cycles for each energy source.
  - The location of the single tensile specimen shall be at the limiting location within the witness sample identified during the first 10 production build cycles.
  - The single tensile specimen from each energy source shall be tested.

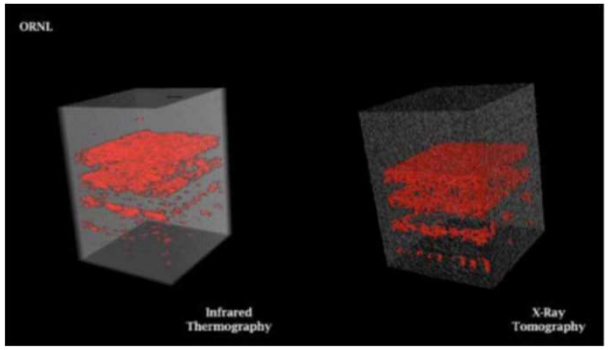


ASME Criteria for Powder Bed Fusion Additive Manufacturing

- **Examination Requirements for AM Components**
  - The current ASME Construction Codes examination.
- **Computed Tomography**
  - Computed tomography is needed to provide full volumetric examination of AM Components.
  - Section V is developing a new article for the 2021 edition for computed tomography.
- **Move to Real Time Monitoring of Flaws During an AM Build.**
- **Defect Acceptance Criteria for Load-Bearing AM Parts**
  - Fatigue Analysis of AM Parts



CT Pipe Scan EMS Corp



Comparison of Infrared Thermography and Computed Tomography Results

ASME Criteria for Powder Bed Fusion Additive Manufacturing

- **Path Forward**
  - The intent is to publish the ASME Criteria for Powder Bed Fusion Additive Manufacturing as a Pressure Technology Book (PTB) for use as a reference document for additive manufacturing Code Cases or incorporation of additive manufacturing into construction codes.
  - It will also serve as the baseline for future development of an ASME AM standard by an ASME Standards Committee.
    - *ASME has submitted a* Project Initiation Notification *with ANSI stating that they will develop a standard for additively manufactured pressure equipment.*

QUESTIONS