

# High Pressure Cold Spray for Structural Applications

VRC Metal Systems

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# VRC Metal Systems

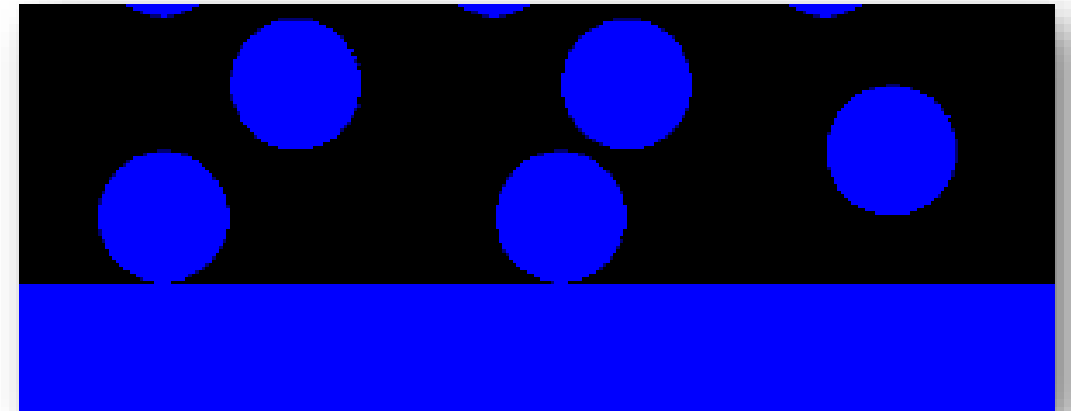
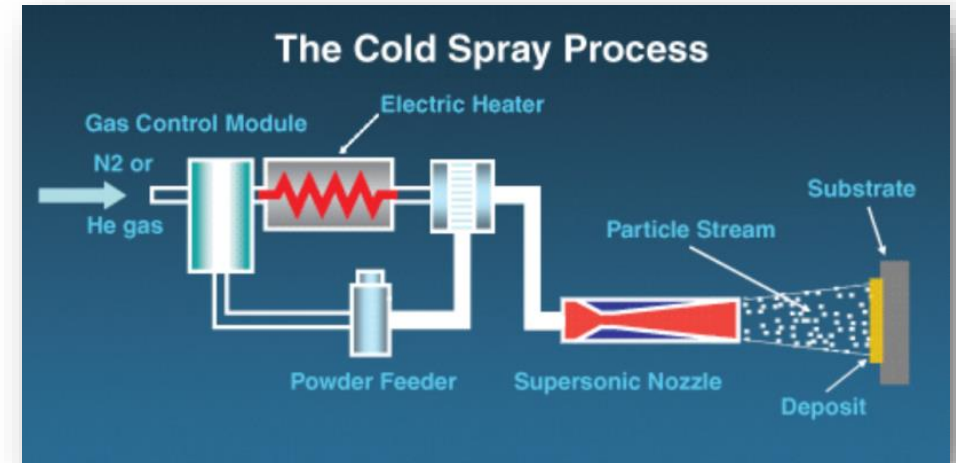


- Cold Spray Equipment Manufacturer and Commercialization Partner, specializing in process development for Repair, Additive Manufacturing, Coating, and Joining applications.
- Veteran Owned Small Business Established in 2012 focused primarily on DoD applications.
- Headquartered in Box Elder, South Dakota. 3 US locations.
- 67 Employees, 25% Workforce are Veterans, 34% Engineers



# Cold Spray Process

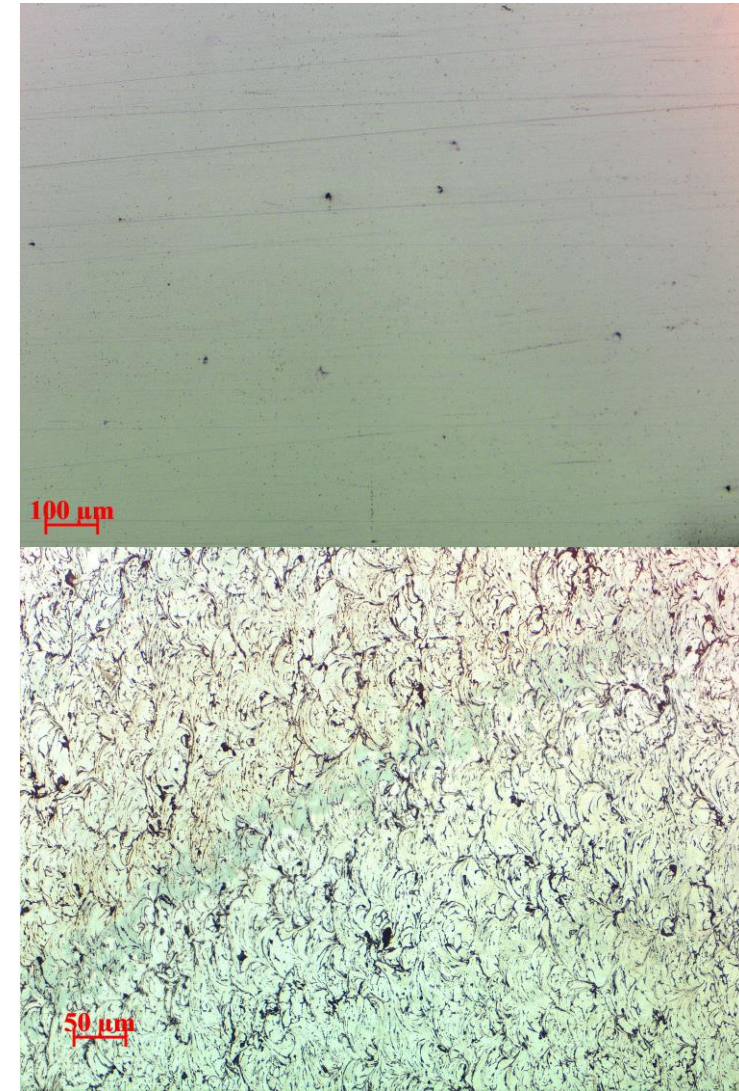
- Applied at Low Temperatures
  - Coatings can be applied as low as 400 °C
  - No heat affected zone formation
- Dense and Highly Adherent
  - Less than 1% porosity and greater than 10ksi adhesion typical
- Can be applied with Nitrogen for cost sensitive applications
  - Pure Metals (e.g. CP-Ni), Alloys (e.g. 316L) and Metal Matrix Composites (e.g. Ni / CrC) can be sprayed with high Deposition Efficiency.
- Cold Spray contains crack retarding compressive residual stresses
  - Resists stress corrosion cracking
- Coating quality and mechanical properties sufficient for some structural applications.





# Cold Sprayed Nickel

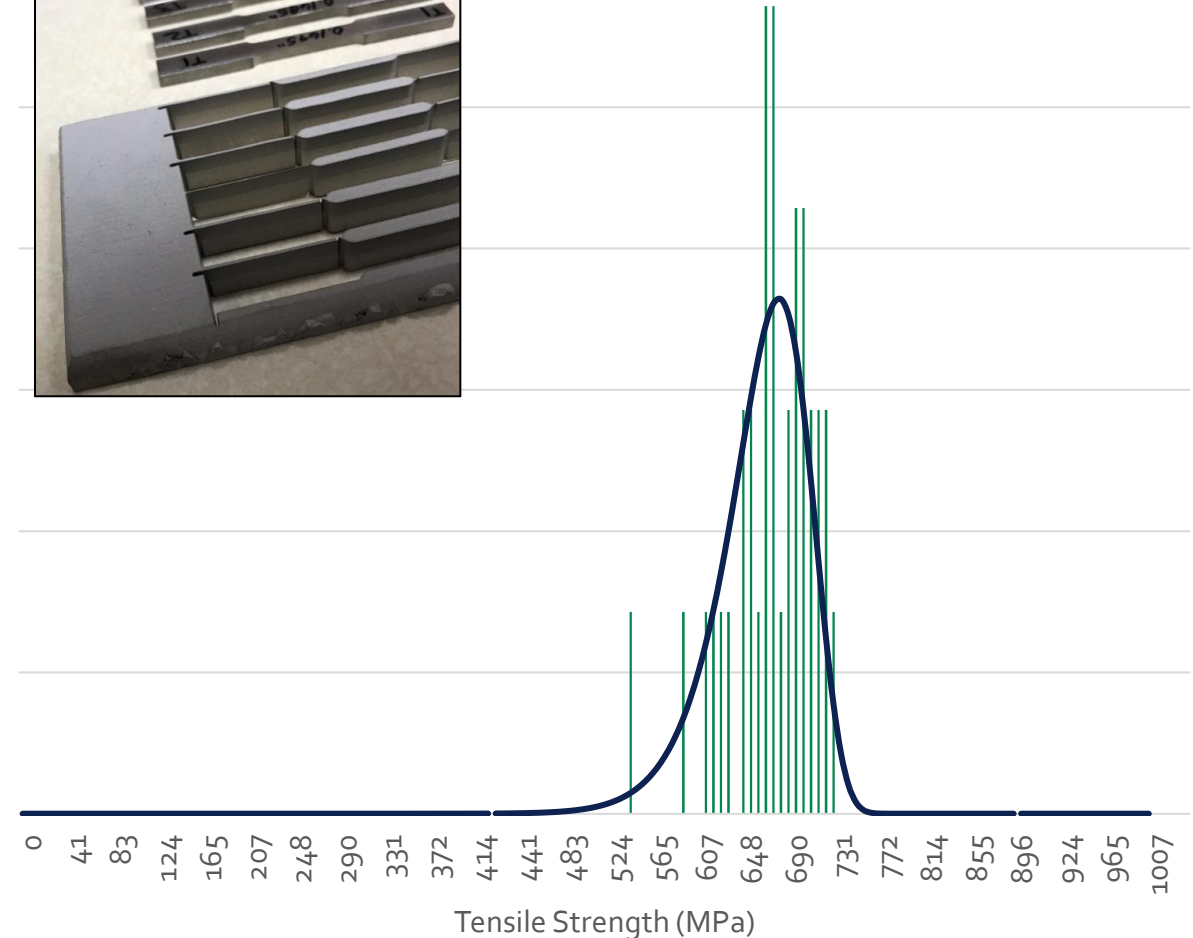
- Typical Cold Spray coatings exhibit porosity less than 1%.
- Dependent on material and processing parameters
- Polished cross section – No particles can be seen
- Etched cross section shows particle boundaries
- Significant flattening observed
- High degree of plastic deformation and strain hardening present



# Cold Sprayed Nickel – Structural Properties

- Testing Free-Standing Cold Spray Coatings - ASTM E-8 Subsize
- Cold Sprayed Nickel
- Statistical Material Property Data

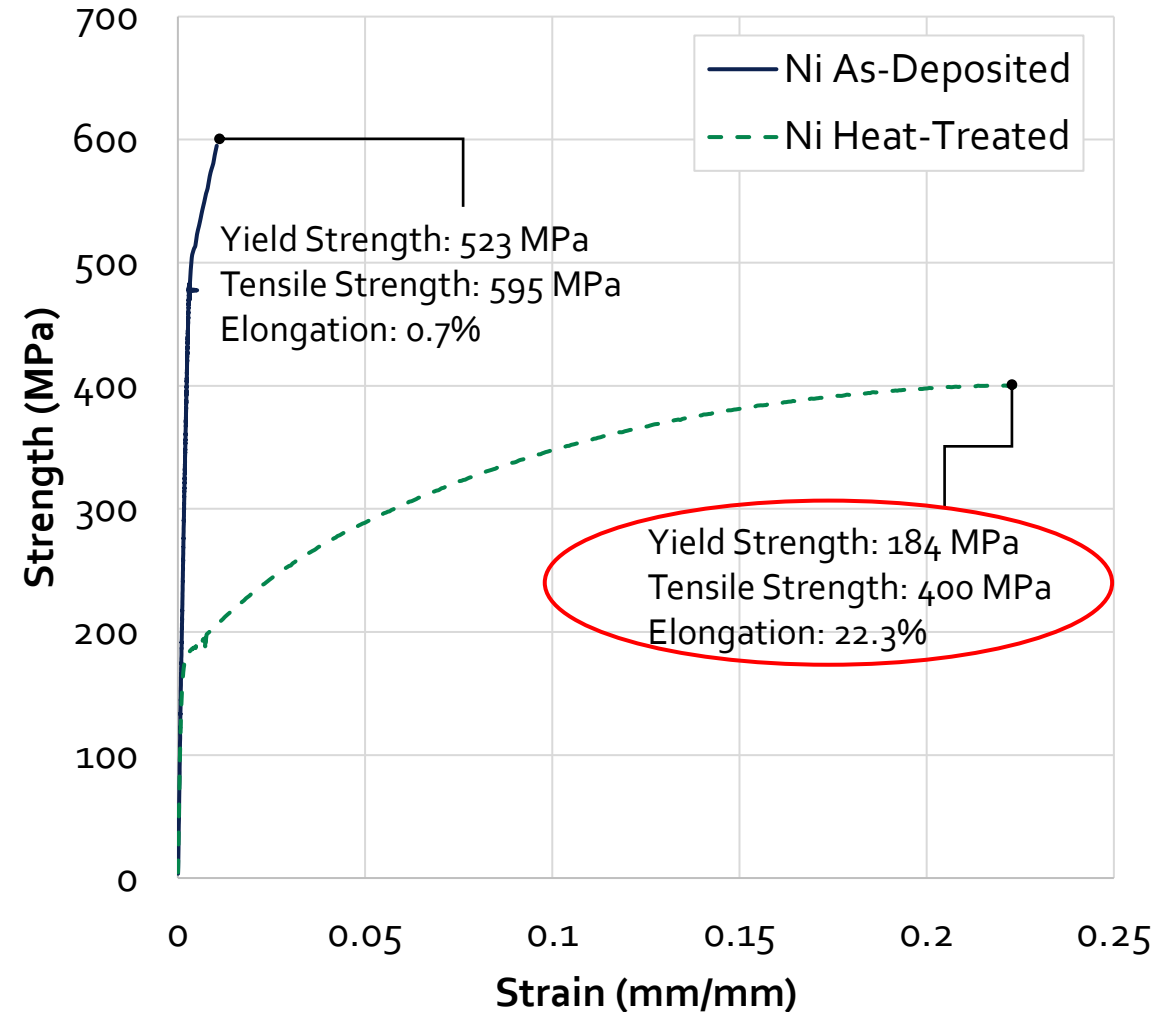
	Tensile Strength	Elongation
Mean:	634 MPa	0.567 %
Std. Err Mean:	6.8 MPa	0.156 %
S-Basis (Spec Min):	534 MPa	0.0 %
Estimated A-Basis:	538 MPa	0.0 %



# Cold Sprayed Nickel – Structural Properties

- As-Deposited coating
  - *High Strength*
  - *Low Ductility*
- Post-Deposition Heat Treatment can be employed to enhance Structural Properties
- Results

	Tensile Strength	Elongation
As-Deposited:	595 MPa	0.7 %
Post Heat Treatment:	400 MPa	<b>22.3 %</b>

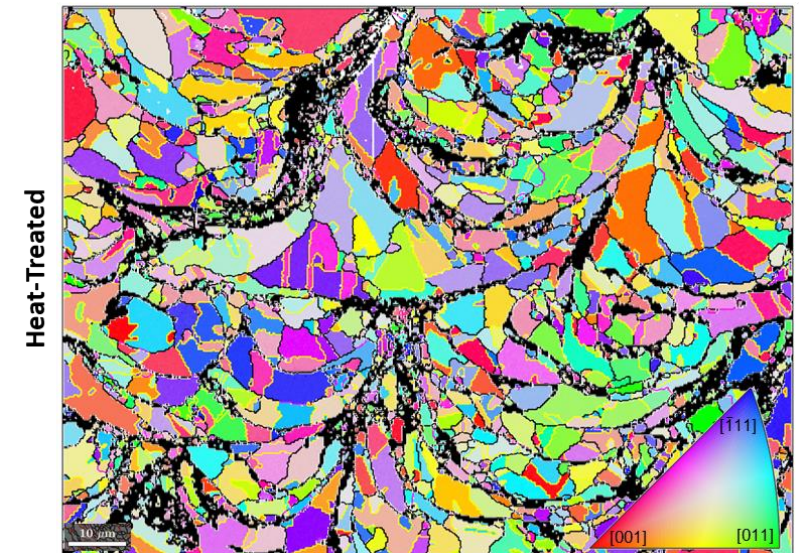
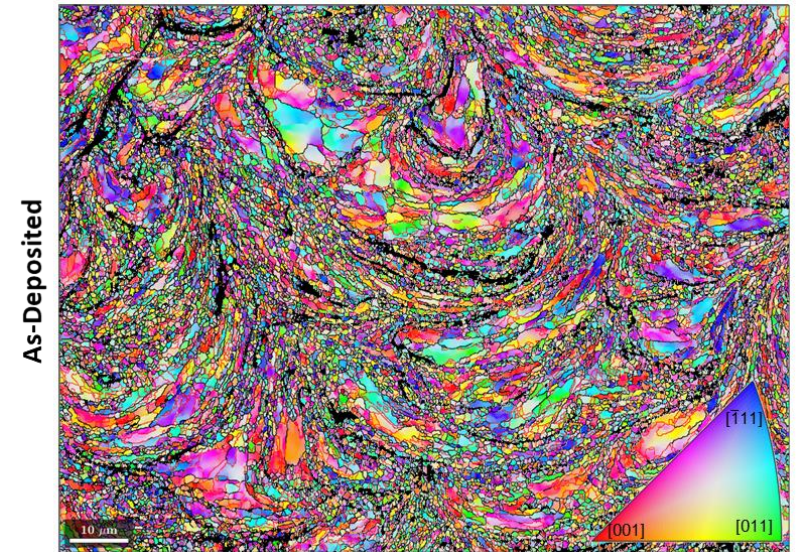


Ductility is improved with Heat Treatment.



# Cold Sprayed Nickel – Structural Insights

- EBSD Inverse Pole Maps
- As-Deposited State
  - Highly deformed, blended and interlocked microstructure
  - Larger grains within particles show misorientation within the grain – High degree of residual stress
  - Particle boundaries are composed of submicron grains with high misorientation resulting from dynamic recrystallization
  - High density of low angle grain boundaries (LAGBs)
    - Solid State Fracturing of the crystal structure from the high velocity impact, severe plastic deformation, and dynamic recrystallization
- Heat Treated State
  - Coalescence and Grain Growth results in larger grains, uniform in orientation indicating residual strain has been relieved.
  - The residual stresses relax and the defects coalesce, forming a network of high angle grain boundaries (HAGBs) and Twins.
- These processes reduce the material strength (Hall Petch) and improve the ductility (Strain Relief).
- These processes can occur at low temperatures because of the high strain energy in the coating, which reduces the activation energy requirement.



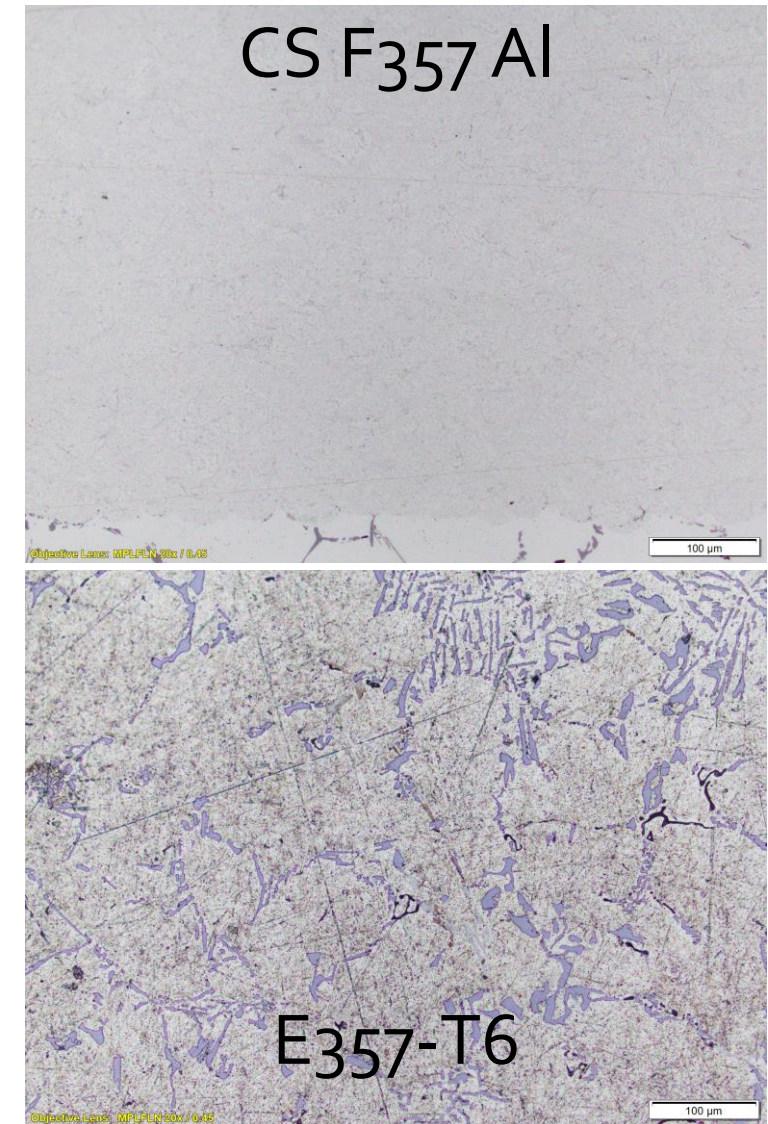


# Cold Sprayed F357 Aluminum Alloy

- F357 chosen for Aluminum Casting Repair
- Structural Properties of As-Deposited Material shown below compared to a cast equivalent.

	Cold Sprayed F357 As-Deposited	Cast E357-T6
Porosity:	0.01 %	0.86 %
Hardness:	106.2 HV	98.0 HV
Adhesion (to E357-T6):	> 82 MPa	-
Yield Strength:	210 MPa	232 MPa
Tensile Strength:	274 MPa	256 MPa
Elongation:	4.9 %	6.0 %

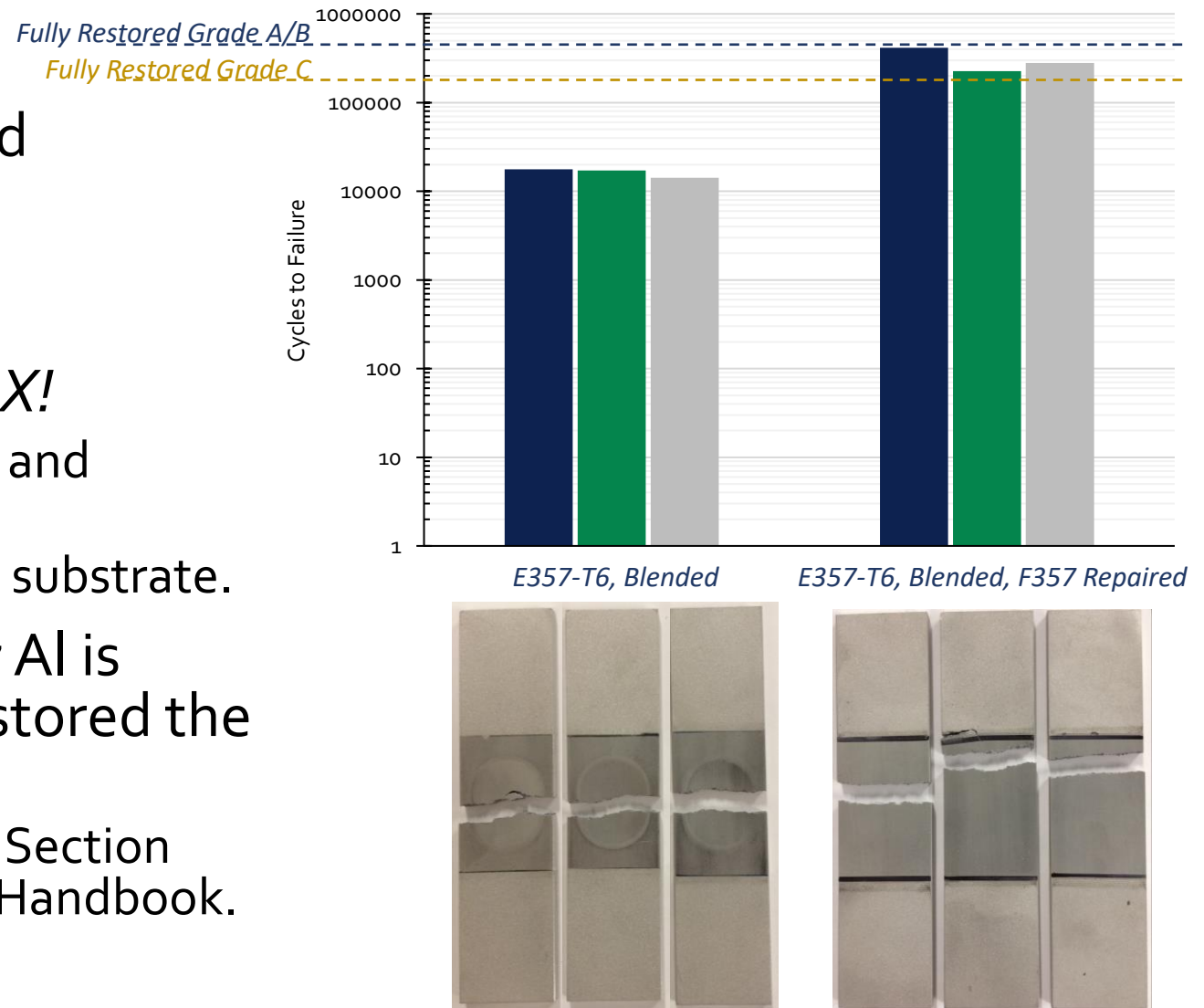
- As-Deposited F357 Al properties are suitable for structural casting repair; *but can the coating Carry Load?*





# F357 Fatigue Strength

- Fatigue Resistance – ASTM E466
- E357-T6 Cast coupons with 20:1 blend
- Samples cold sprayed with F357 Al
- R=0.1, 145 MPa Net Section Stress
- *Cold Spray increased fatigue life by 15X!*
  - Failures initiating from substrate edges and substrate defects.
  - Damage accumulation occurring within substrate.
- Results indicate that Cold Spray F357 Al is indeed carrying load and has fully restored the material.
  - Compared to D375-T6 Grade C Casting, Section 3.5.1.9, Aerospace Structural Materials Handbook.



# VRC Cold Spray Systems

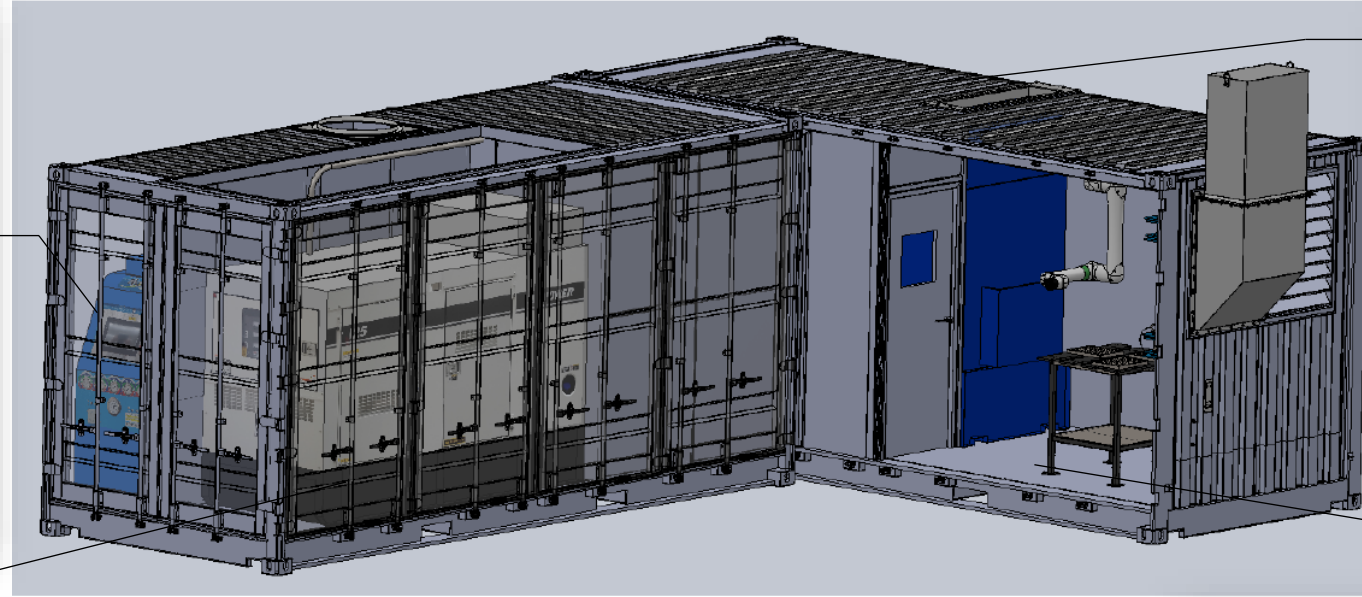
- Cold Spray is rapidly gaining momentum for structural repair applications.
- VRC Metal Systems offers Equipment for laboratory, industrial, and field environments
  - Raptor Cold Spray System – Available Now
  - Dragonfly Cold Spray System – Available Now
  - Gen IV Cold Spray System – 2022
  - Mobile C.A.M.P Site System – 2022
- VRC Partners with powder suppliers and experts in the industry to deliver the customer the best possible material systems and performance.



**PowdersOnDemand**



# Mobile C.A.M.P Site System



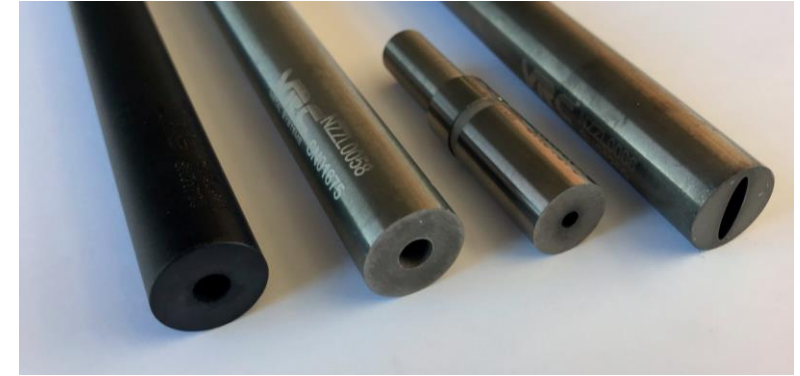
- 7.5x9' Cold Spray Booth w/ Robot and lifting provisions.
- Integrated Raptor cold spray system and dust collector.
- Prep room for testing, inspection, heat treatment/baking, and storage.
- On-board diesel generator rated at 110kW to supply power to the entire C.A.M.P. Site system if needed.
- On-board compressed air gas storage and generation for use as process gas for Aluminum, Nickel, and multi-phase powder mixture sprays.
- Gas supplied at up to 4500 psi for extended sprays up to 8 hrs.





# VRC Cold Spray Systems

- Recent R&D developments have resulted in state-of-the-art equipment and accessories offerings, including:
  - Complete suite of nozzles: PBI, WC, Internal Diameter, Wide Area, and more.
  - Portable Glove Box spray enclosures with optional Robotics
  - Portable Wet-Type dust collection for collection of hazardous dust and code compliance.
  - Complete installations including Spray Booth, Dust Collection, Robotics, and Helium Recovery.



# Thank you for your Attention!

Contact VRC Metal Systems for more information:

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