



Cold Spray Technology for Military Applications

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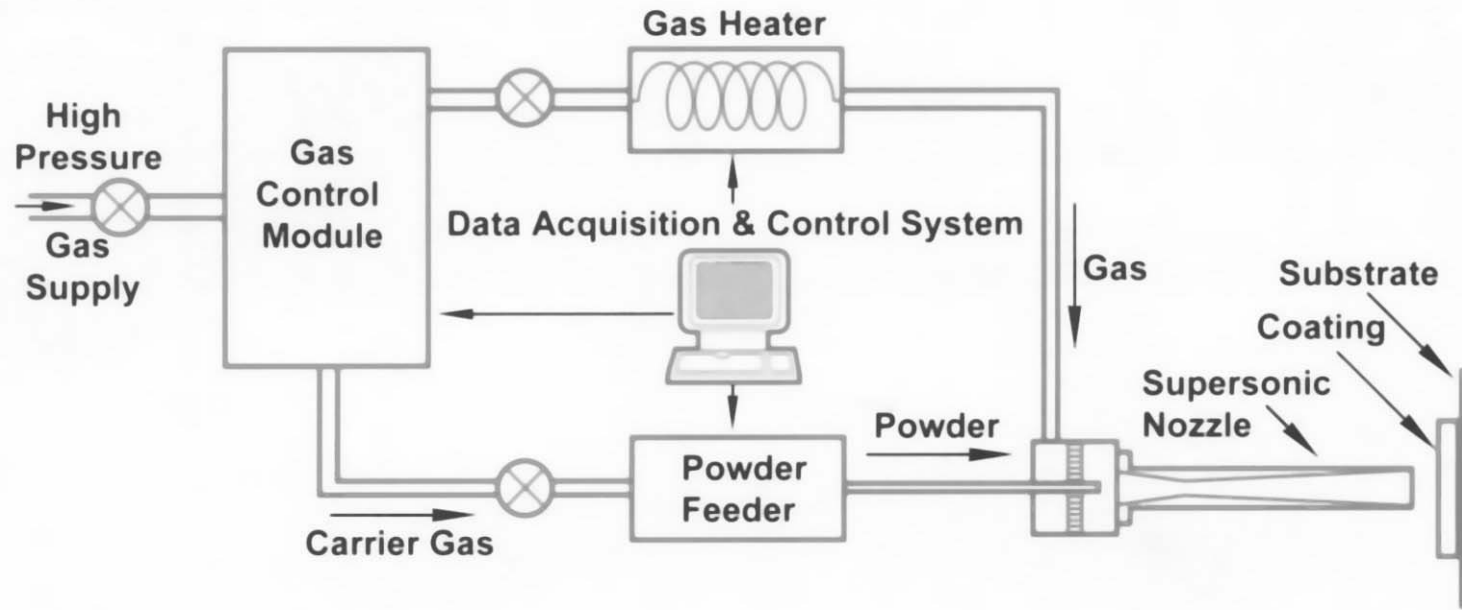


What is Cold Spray?

Cold spray is a material deposition process whereby metal powder particles are utilized to form a coating or a free-standing structure by means of ballistic impingement upon a suitable substrate.



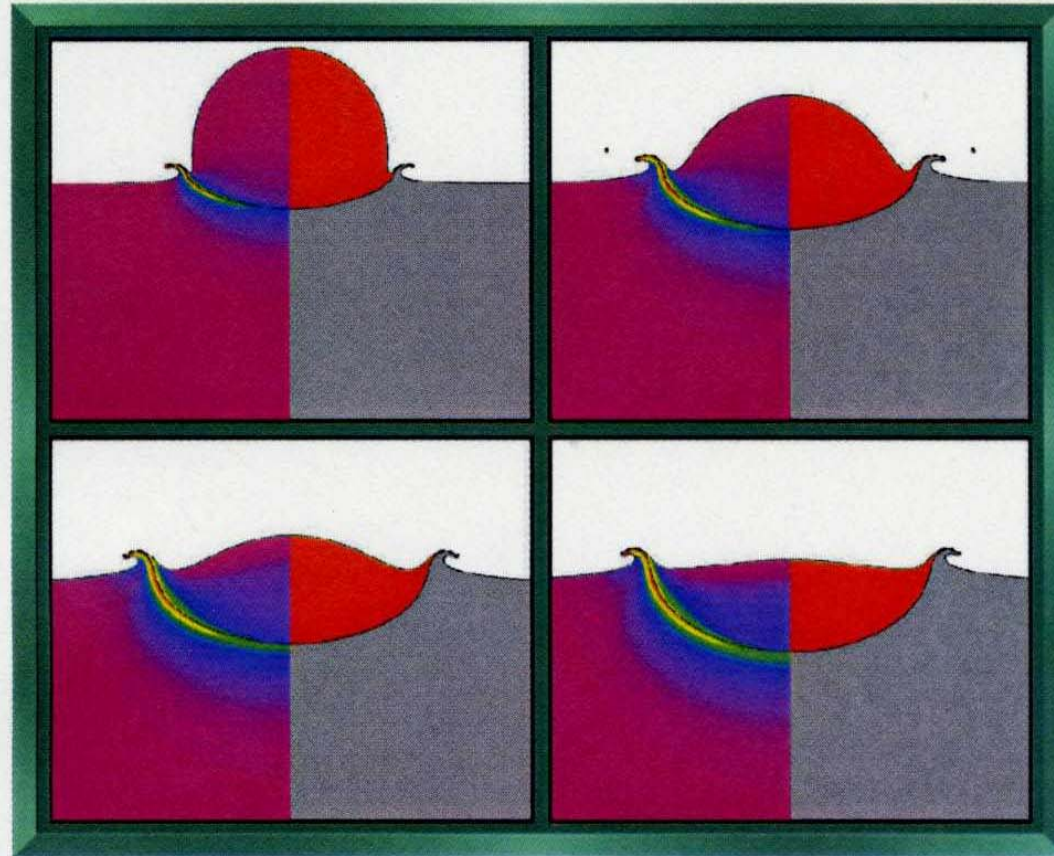
Cold Spray Schematic



Uses high pressure N_2 or He gas
Particle Velocity: 500 – 3000 ft/s



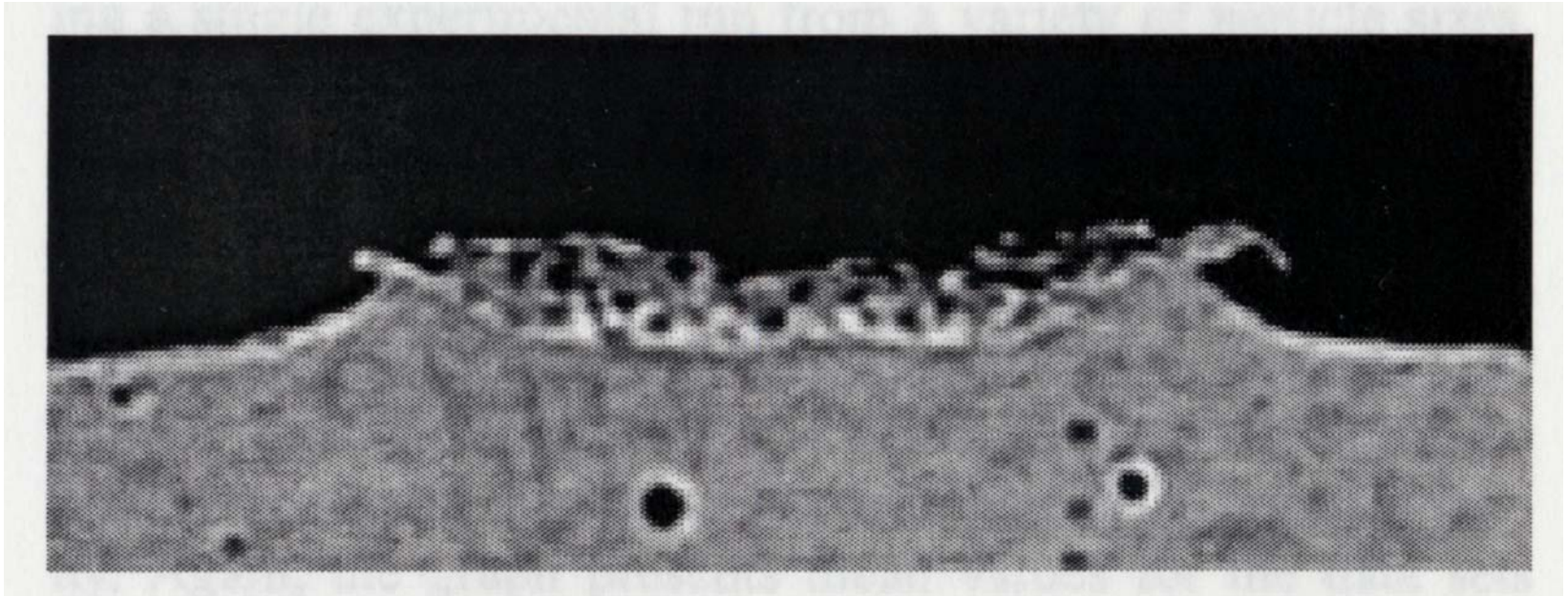
Impact Simulation



Simulated impact of a copper particle on a stainless steel substrate



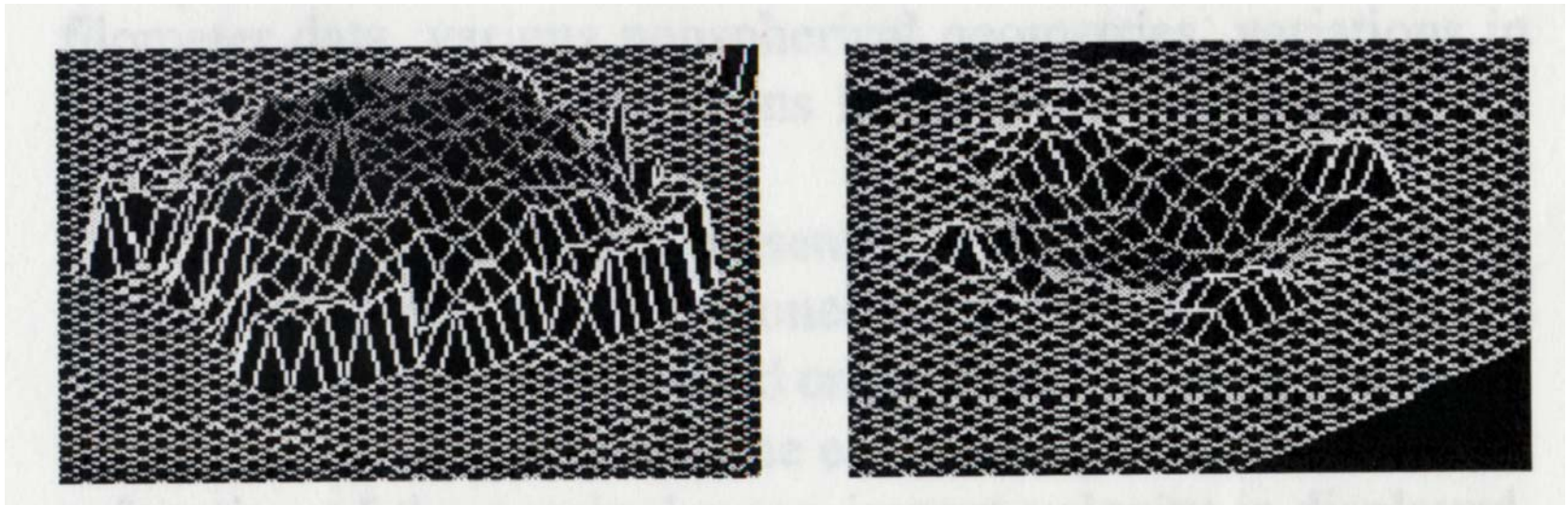
Copper Particle Impact Site



Cross section of the impact site between a copper particle and a stainless steel substrate.



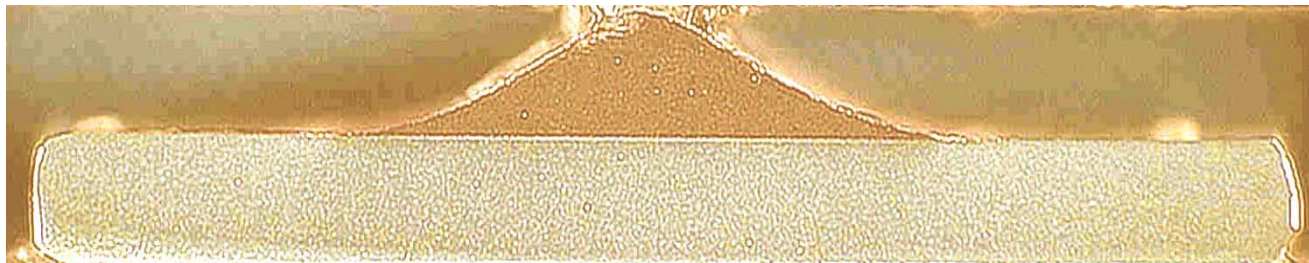
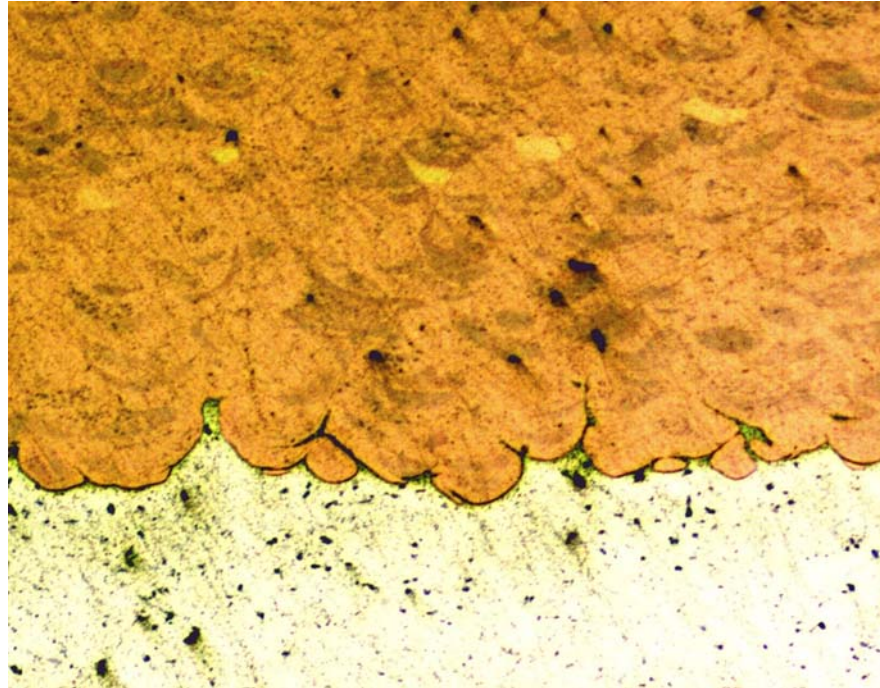
Particle Impact & Crater Site



Profilometry results before and after removal of a copper splat from a 600 m/s impact.

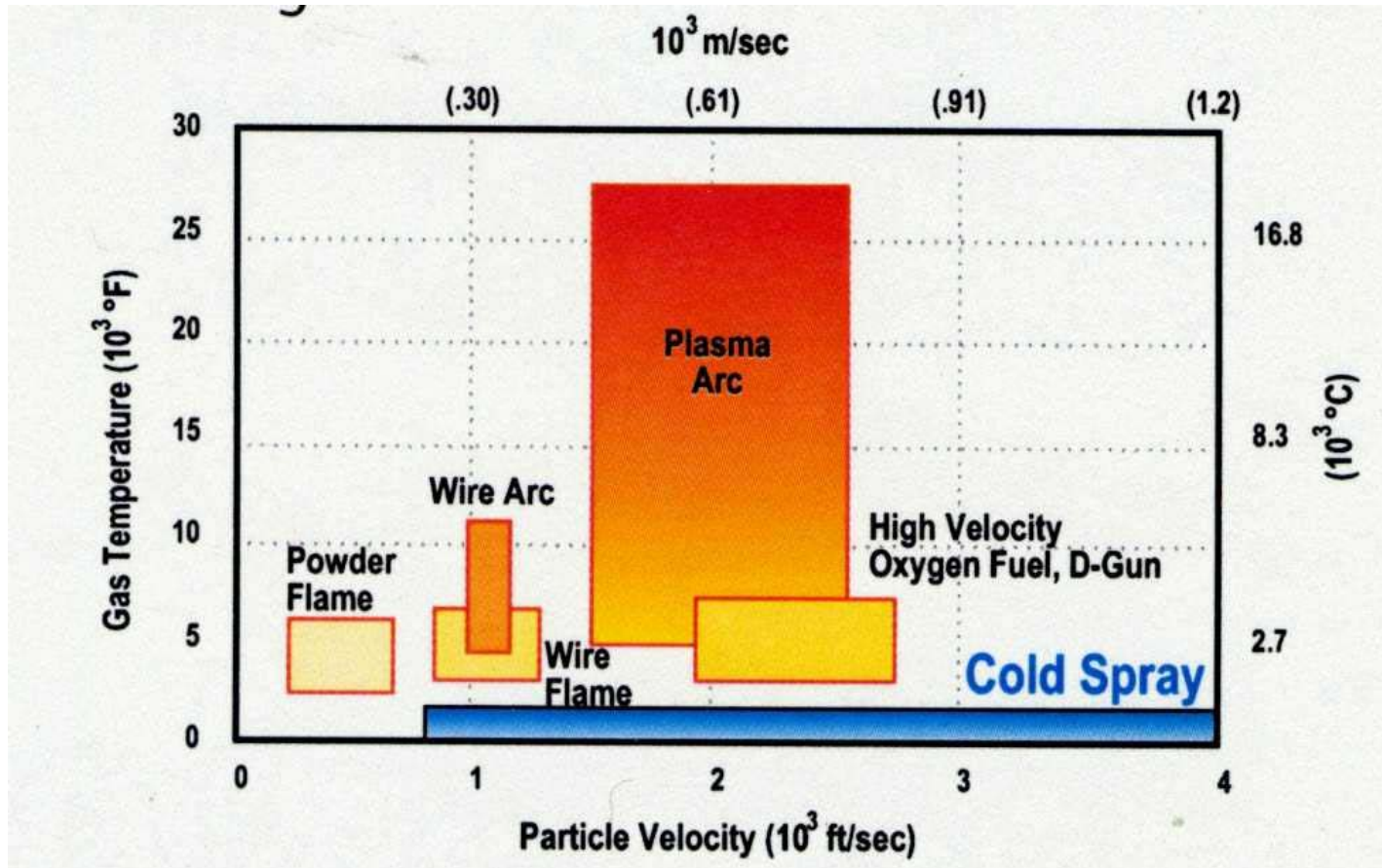


Copper Sprayed on Aluminum





Cold Spray vs. Thermal Spray

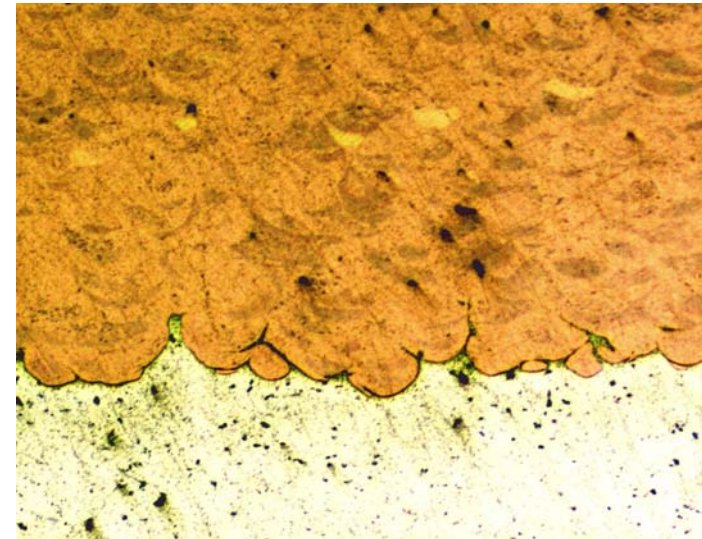


Comparison of thermal spray and cold spray particle velocity and gas temperature.



Cold Spray Advantages

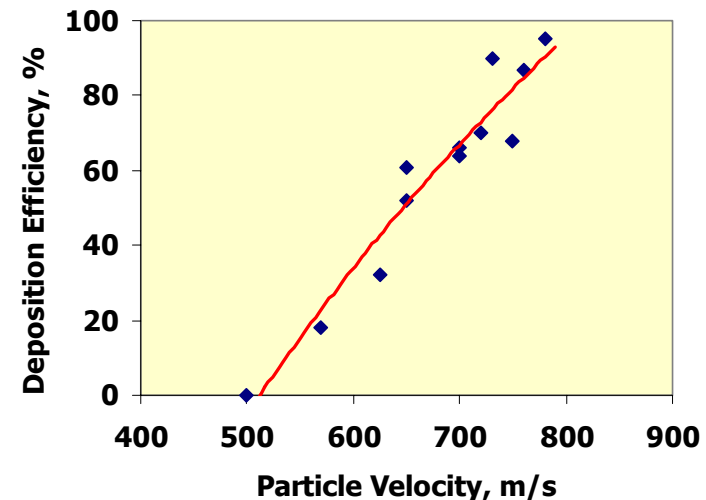
- **Metallurgical bond**
 - Plastic deformation may disrupt thin surface films to permit bonding
 - Similar to explosive welding
- **Compressive residual stresses**
 - Particles “peen” surface
 - Plasma and wire-arc thermal spray tend to be tensile
 - HVOF and gun detonation thermal spray are compressive
- **High density**
 - Porosity: < 1% - 10%
- **Thick coatings**
 - Consider free-form fabrication





Cold Spray Advantages

- **Low temperature**
 - Thermally sensitive substrates
 - Minimal grain growth
 - No stresses due to CTE mismatch
- **Little oxidation**
 - Good electrical/thermal conductivity
 - Electrical conductivity: 80% of OFHC Copper
- **High deposition rates & efficiencies**
 - Rates – (mm/min), up to 20 kg/hr
 - Efficiencies – up to 98%, generally 50-80%
- **Wide variety of coating materials & substrates**



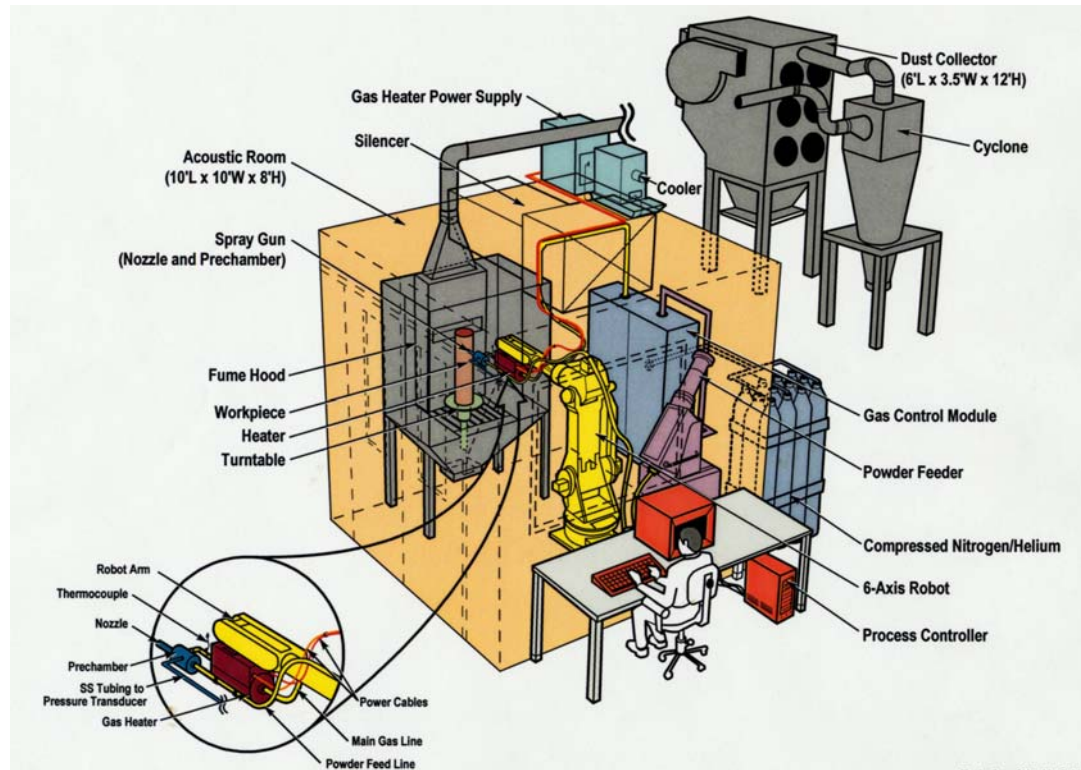


Gas & Powder Operating Parameter Ranges

Parameter	Value
Main Gas Stagnation Pressure	100 to 500 psi
Main Gas Stagnation Temperature	0 to 1300 degree F
Main Gas Flow Rate	30 to 100 CFM
Powder Feed Gas Flow	40 to 110 CFM
Powder Feed Rate	10 to 30 pounds/hour
Gas Heater Power	0 to 25 KW



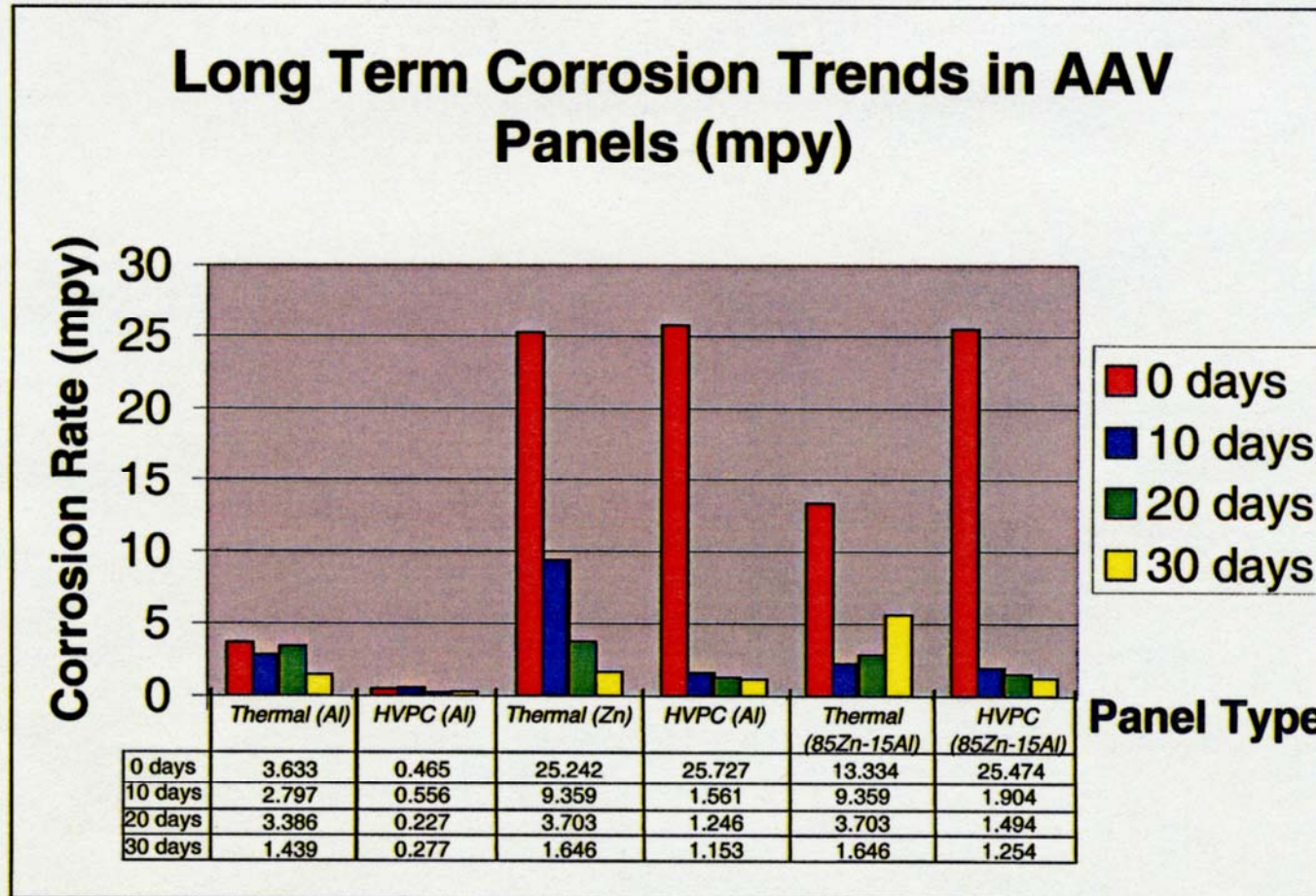
ARL Cold Spray System



- Nitrogen and/or helium gas
- Metals sprayed on metals, ceramics, or plastics
- Accommodates pieces up to 90 kg and 3m
- Only DoD cold spray laboratory



Long Term Corrosion Testing



Comparison of corrosion rates for aluminum, zinc, and 85zinc-15aluminum sacrificial coatings sprayed onto steel.



DoD Applications

- **Repair & build-up of worn parts**
- **Alternative to Ni & Cr electroplating (SERDP Ni replacement proposal)**
- **Coating ceramic substrates w/ titanium**
- **Stainless steel or Ni coatings for tungsten penetrators**
- **Munitions applications**
 - Gun tube hardening
 - Jacketed “Green Penetrator”
- **Free-standing structures**





Conclusions

- **Particle velocity controls deposition efficiency and coating quality**
- **Work is required to understand processing parameters and prediction of processing parameters**
- **Work is required to understand the materials properties of the cold spray coatings**
- **For certain applications cold spray coatings are superior to thermal spray coatings**
- **ARL will focus on DoD applications related to severe environments and unique materials**



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