



Kinetic Metallization

November, 2003

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Report Documentation Page

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Kinetic Metallization

- Impact Consolidation Process
- Feed-stock: fine powder
- Accelerant: inert light gas
- Solid-state Consolidation
- No Bulk Melting
- No Liquid Chemicals
- Environmentally Innocuous
- No Particle or Hazardous Gas Emission



KM-CDS

First KM-CDS Shipped!!

Buyer: US Naval Academy

Located: NAVSEA-Carderock



- Coating Development System
- Desk sized
- Production unit
- Same footprint
- Remove spray enclosure



Critical Components

- Powder Fluidizing Unit
- Closed-loop mass-loss control
- Thermal Conditioning Unit
- Low power
- Deposition Nozzle
- Friction compensated



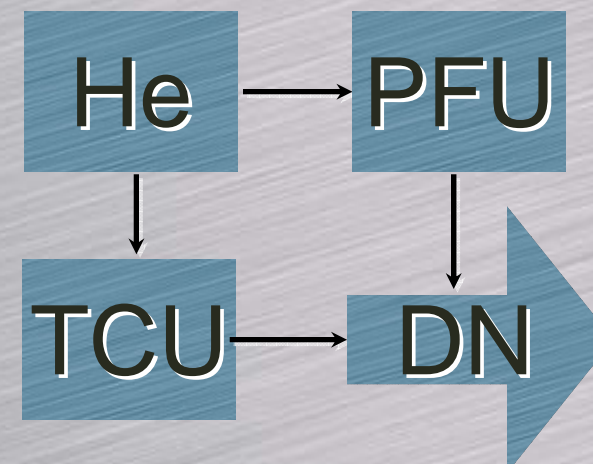
PFU



TCU



DN



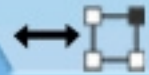
PFU Set Point

lb/hr

TCU Set Point

deg F

Width



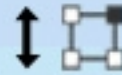
in

Step Size



in

Length



in

Sweep Velocity

in/s

Strokes/Step

Layers



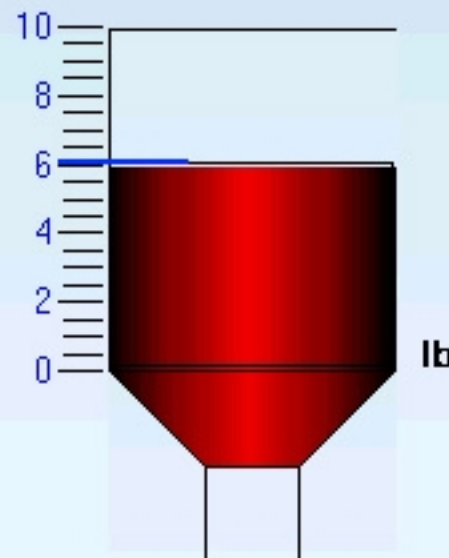
PFU Actual



TCU Actual



Powder Weight



Initial
 lb

Final
 lb

PFU Active



PFU ECV



TCU Active



TCU ECV



Operator Name

Test Name

Description

START

Preview

- Powder Flow
- Motion

PFU Heat



Units

English SI

Robotic Control

- Compatible with any robot
- 5-pin connector provides
- All KM power/control interface



**So, how does it
work?**



Particle Velocity!

- $KE = 1/2 \cdot \text{mass} \cdot \text{Particle Velocity}^2$
- $KE \propto$
- Deposition Efficiency (Cost)
- Deposition Density (Quality)
- **Gas velocity is a means not an end**
- Particle velocity
- $f(\text{gas } \textit{velocity} \times \text{gas } \textit{density})$

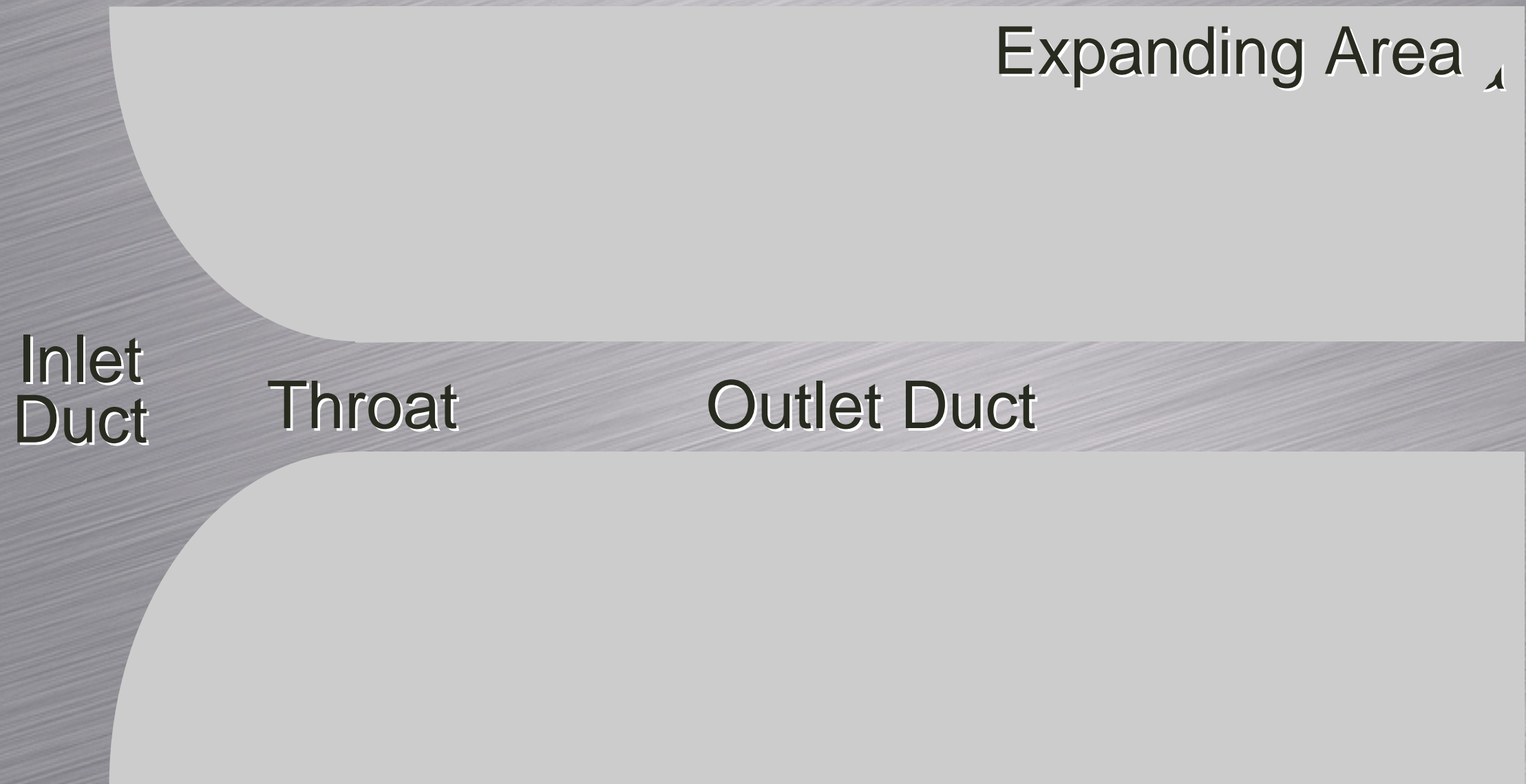


Nozzle Design

- Nozzle Anatomy
- Exit duct design
- Increasing Area
- Supersonic
- Constant Area
- Friction Compensated
- Sonic

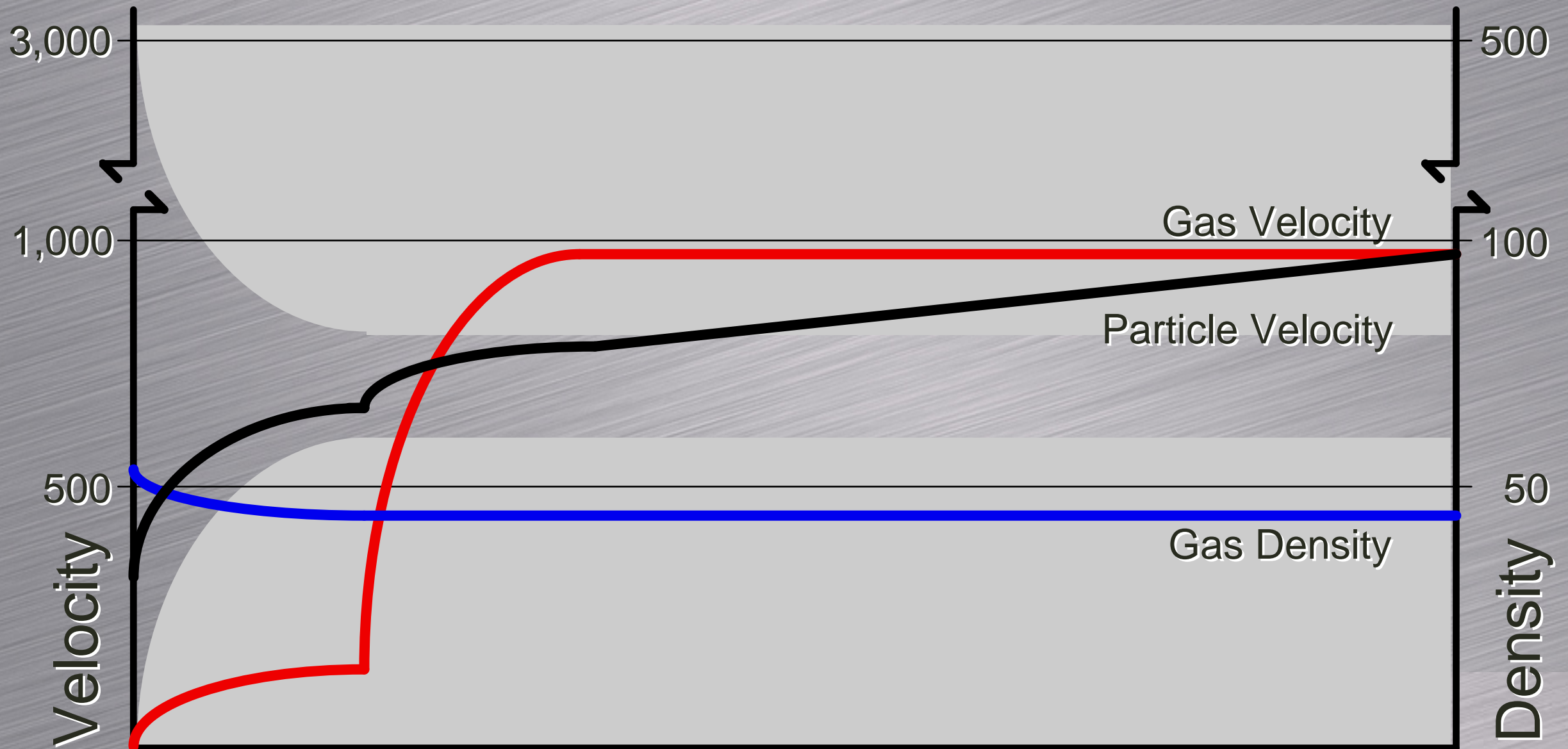


Nozzle Anatomy



KM Sonic Nozzle

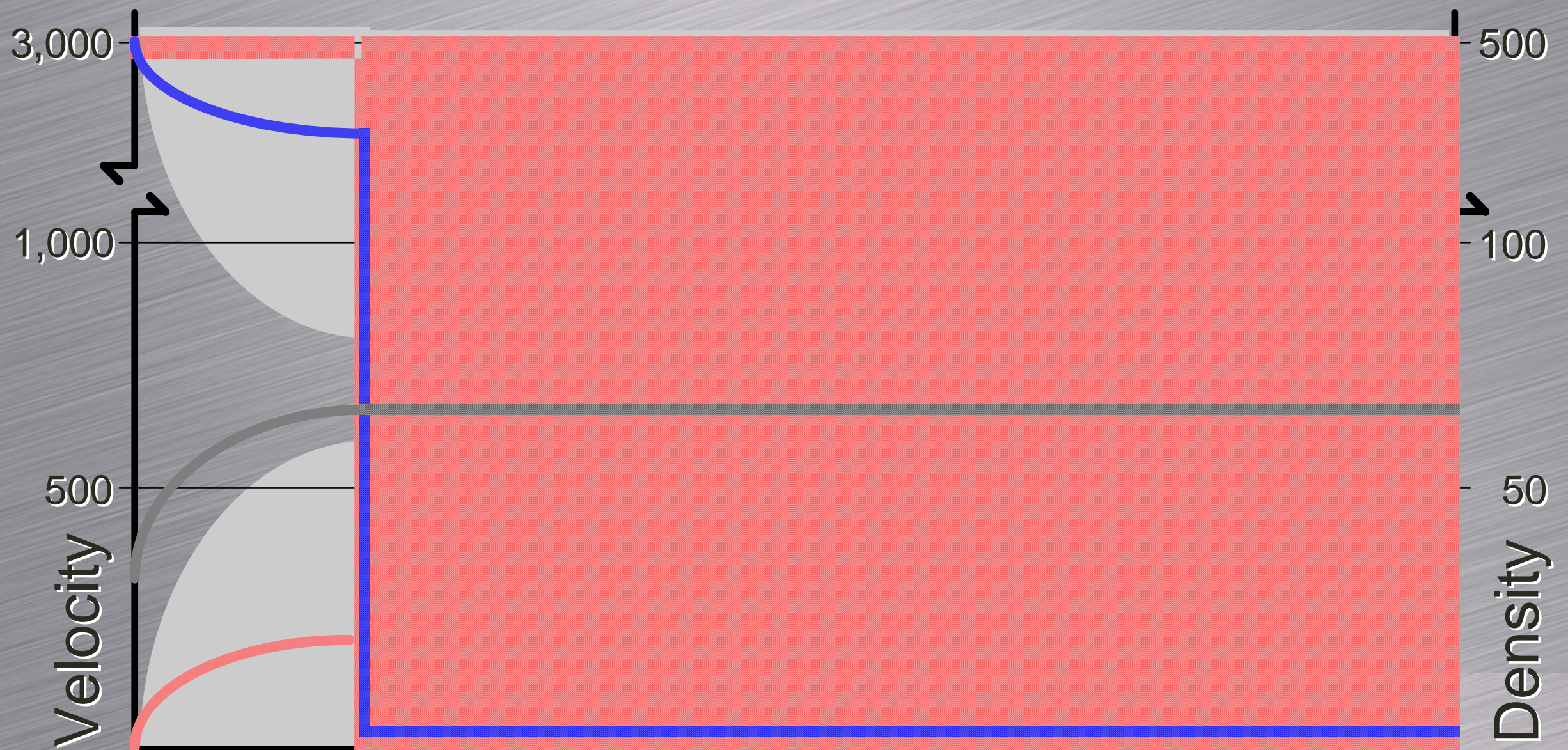
Constant Area Nozzle modified to compensate for flow friction



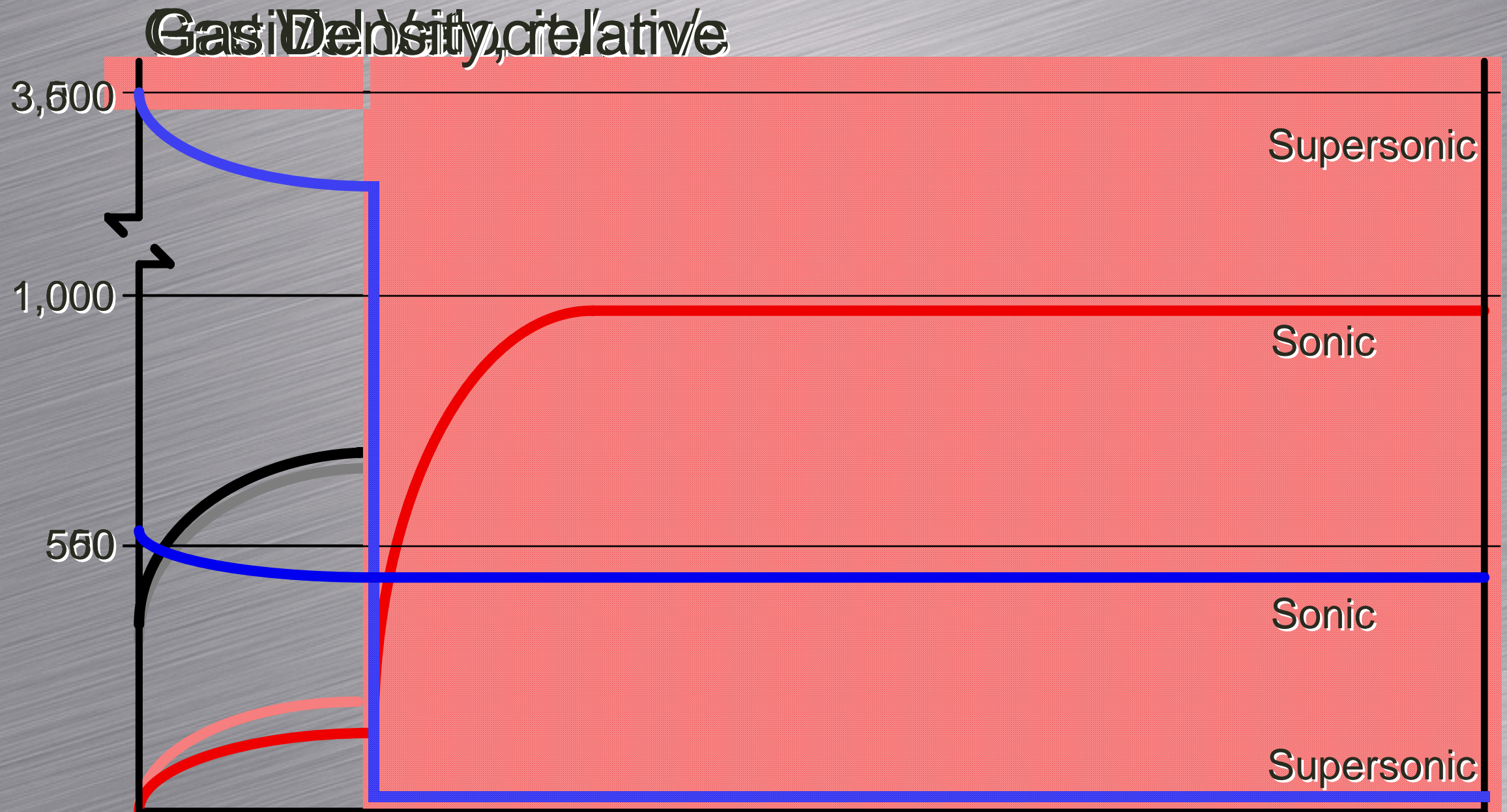
Friction Compensated

INOVATI

Supersonic Nozzle



Sonic vs. Supersonic



Why Not Air?

Nozzle	Supersonic	Supersonic	Supersonic	Sonic
Accelerant	Air	N ₂	He	He
Max Particle Velocity, m/s		330	960	960
Heat Input, W	8,000	8,000	25,000	2,500
Explosion/Fire Hazard	Safe only for Cu, Ni	Ti, Nb, Hf, Zr, U, Th	—	—

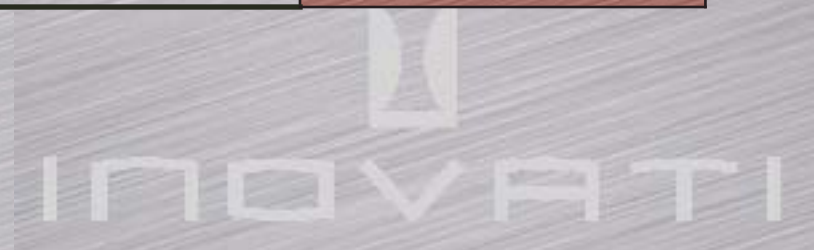
$X \sqrt{T}$



Nozzle /Accelerant

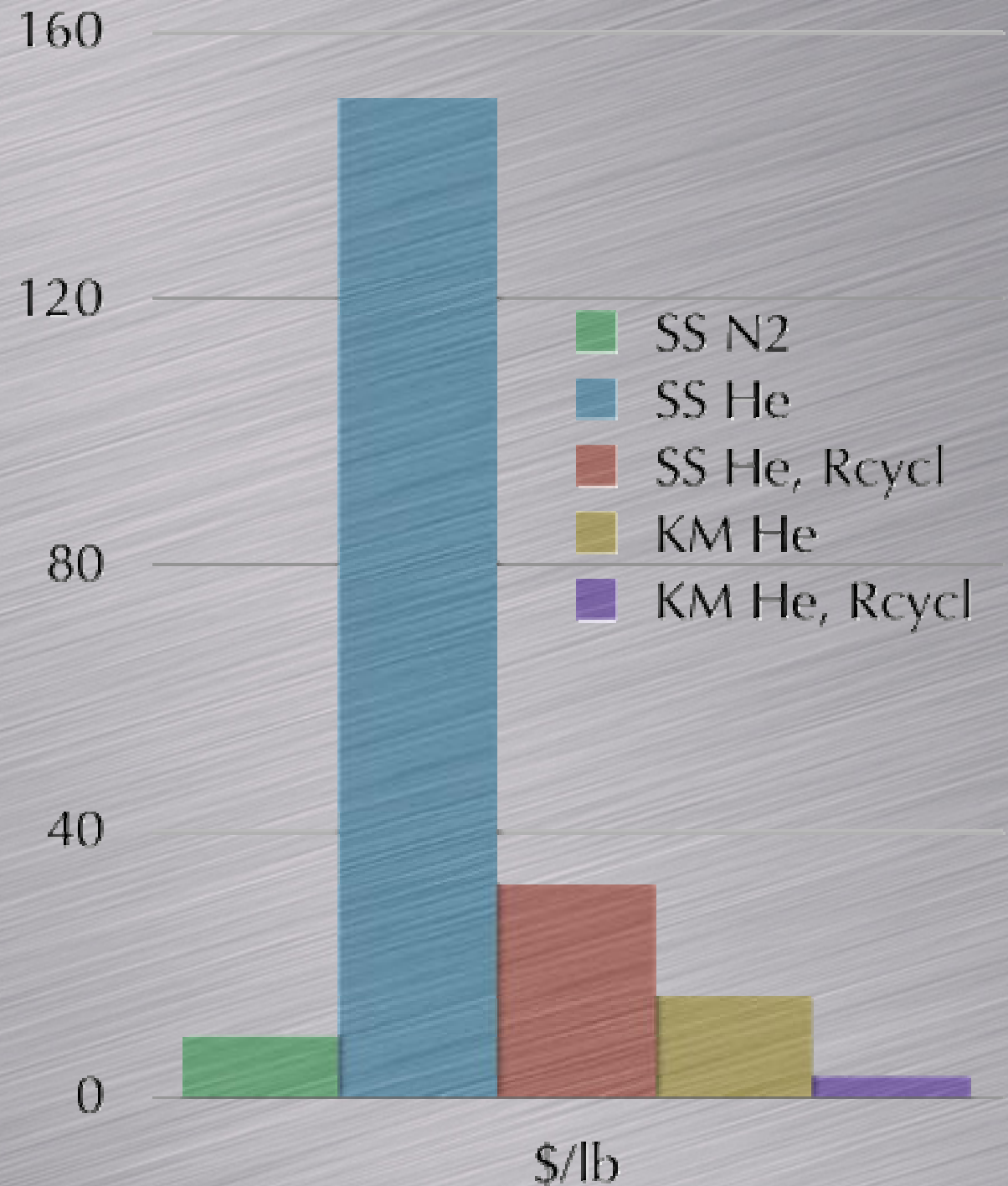
Nozzle	Supersonic	Supersonic	Supersonic Recycle	Sonic	Sonic Recycle
<i>Accelerant</i>	N2	He	He	He	He
<i>Pressure, psi</i>	500	500	500	50	50
<i>Flow, SCFM</i>	26.5	75	75	7.5	7.5
<i>Cost, \$/SCF</i>	0.04	0.10	0.03	0.10	0.02
<i>Cost, \$/min</i>	1.06	7.50	2.25	0.75	0.16
<i>Cost, \$/lb</i>	9	150	32	15	3
<i>Capital, \$</i>	—	—	1,000,000	—	50,000
<i>Recycle, %</i>	—	—	98	—	90

1/6" Throat



Cost Summary

- Recycled KM is the lowest cost
- Once through KM is lower cost than recycled SS He



KM Examples

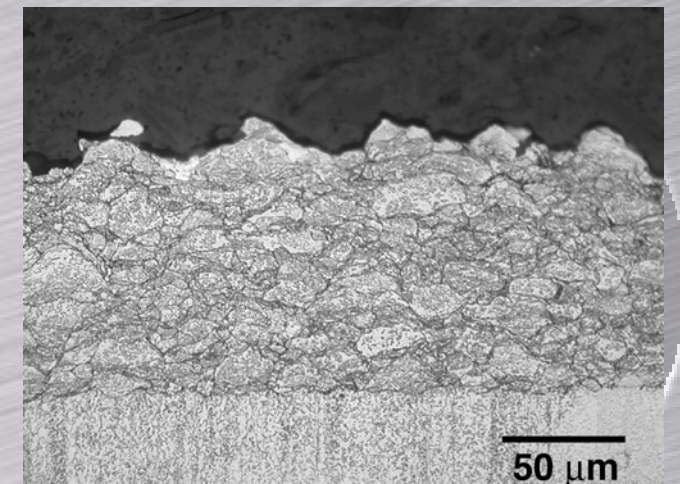
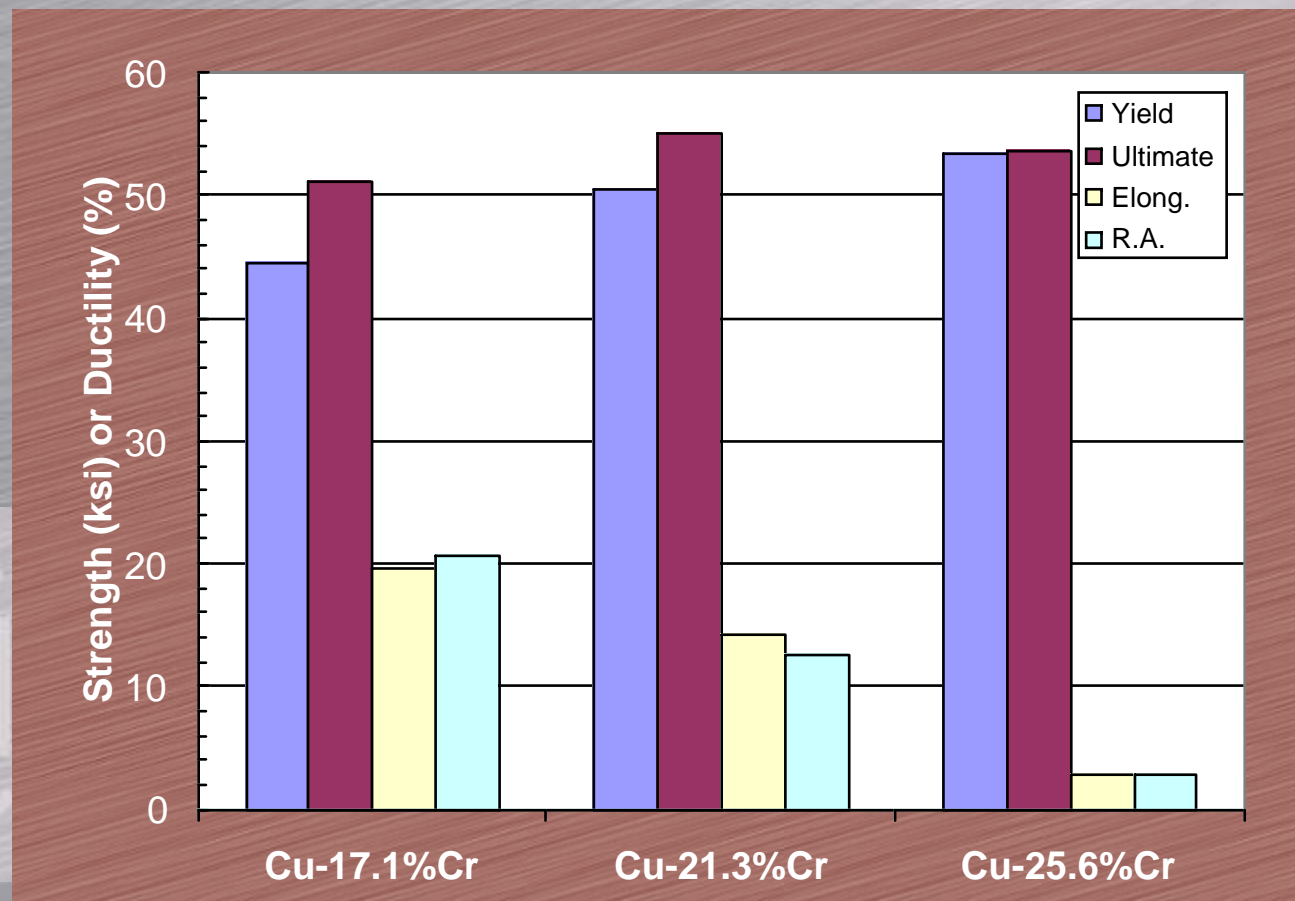
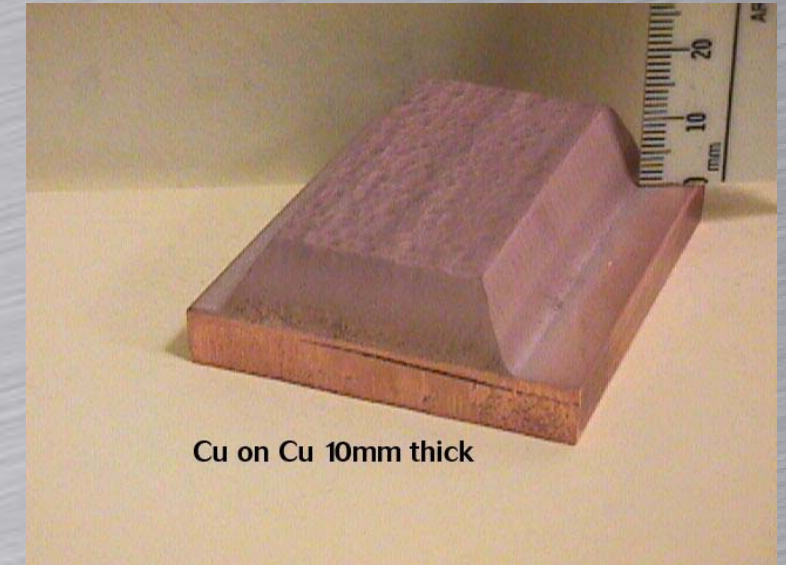
- Cu-Cr on Cu alloy (Narloy Z)
- Nb on Cu alloy (GRCOP 84)
- Al-SiC MMC on metal foam
- NiCrAlY on Waspalloy
- Ti on Ti
- AlTrans on Steel
- WC-Co on 4340



Rocket Nozzle

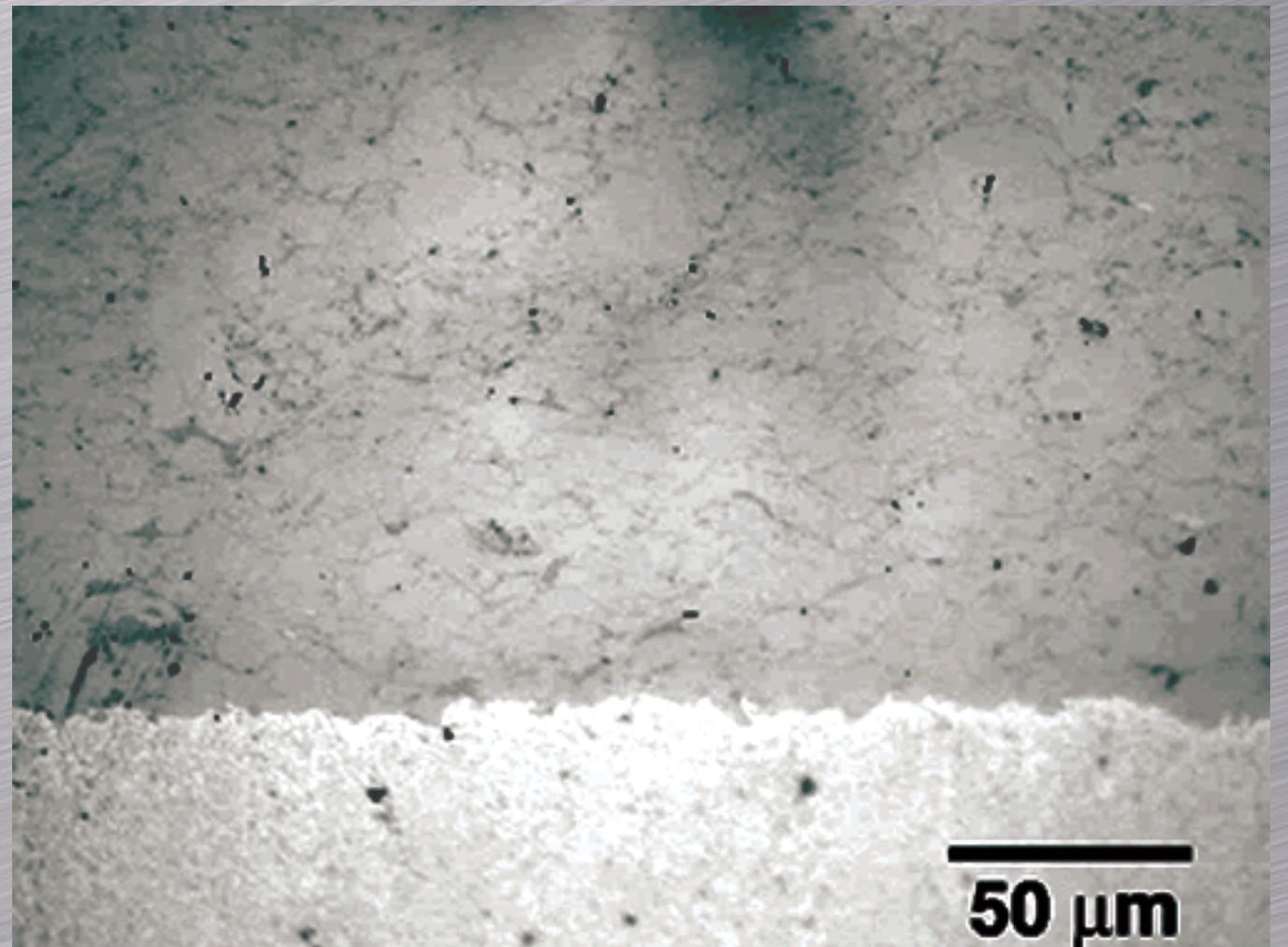
Coating

- Cu 21% Cr best compromise
- Oxidation resistant
- High thermal conductivity
- High strength/ductility



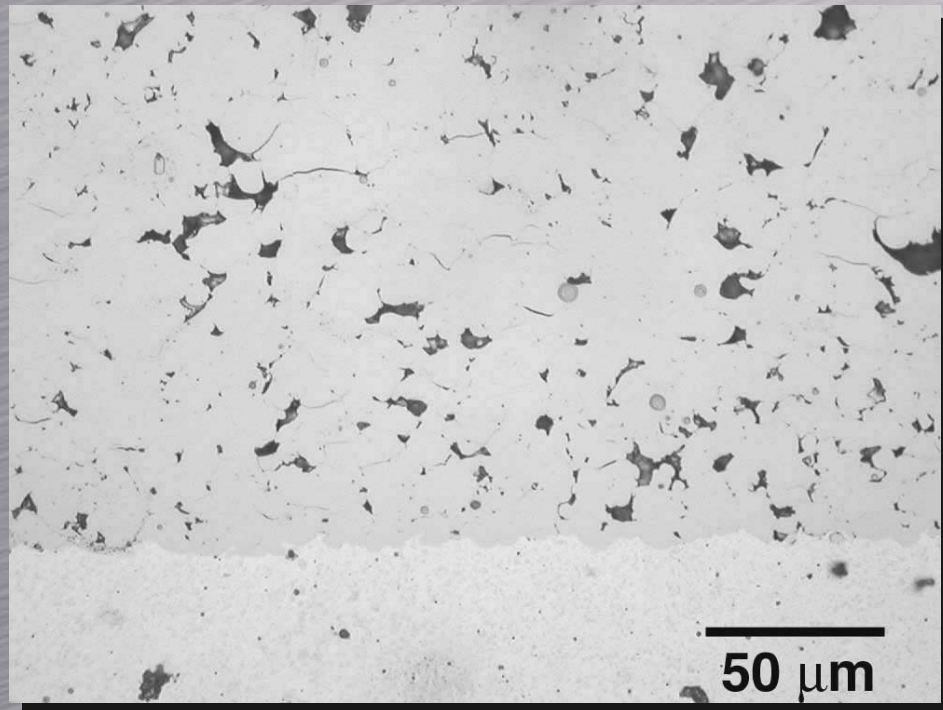
Nb on Cu Alloy

- Allows bonding
- Cu to Al
- Diffusion barrier
- Cu / Al
- Prevents formation
- of intermetallics
- Provides
- Hermetic seal

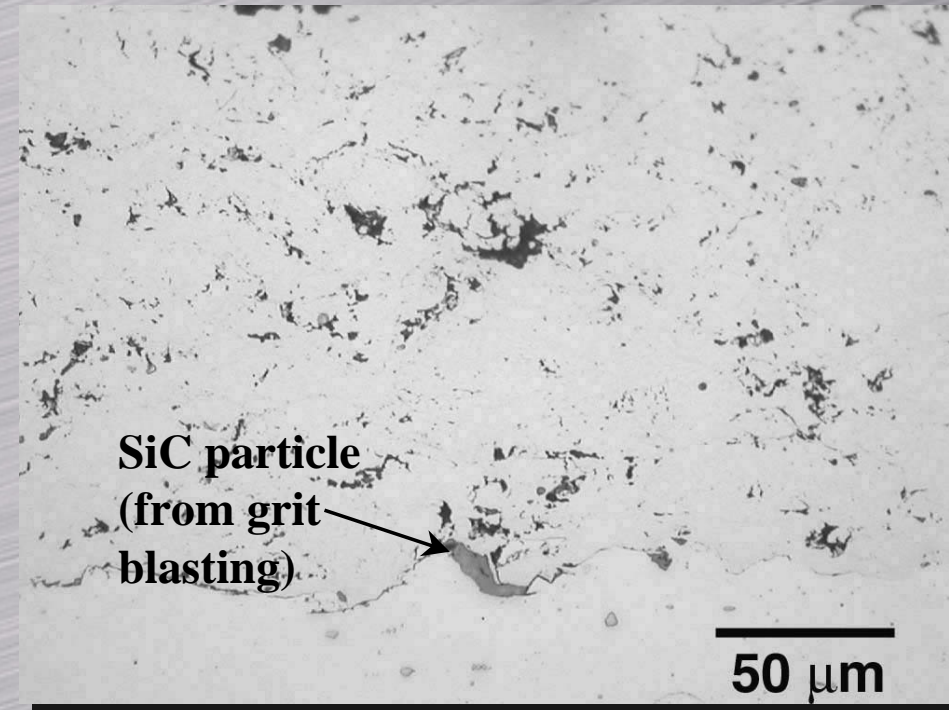


The KM Alternative

KM NiCrAlY



HVOF CoNiCrAlY



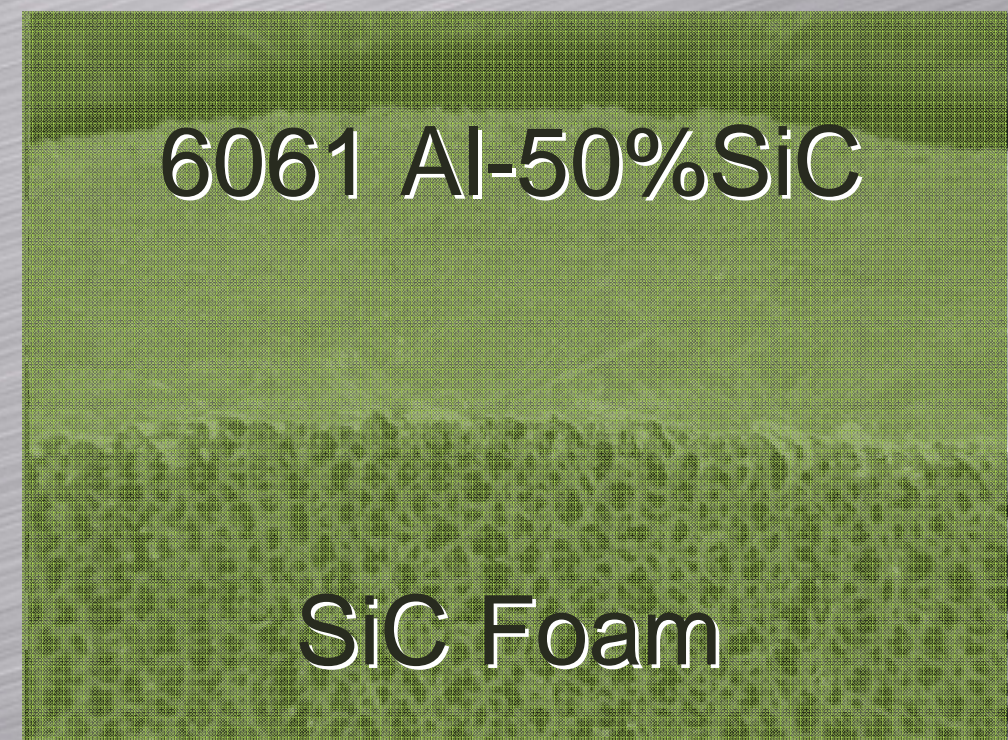
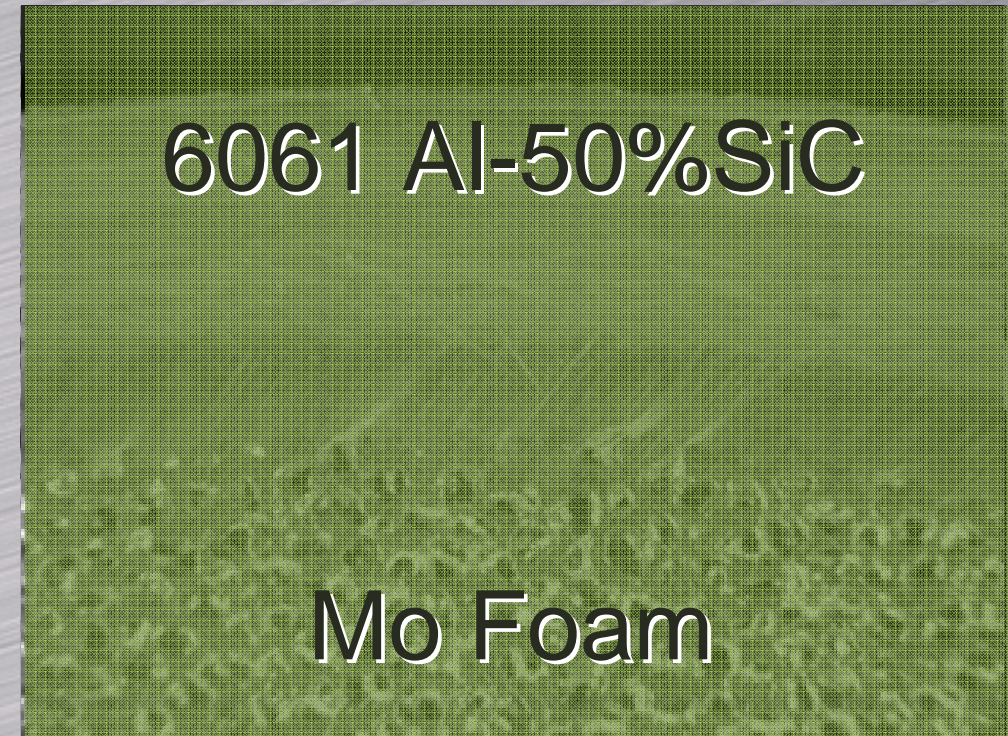
Process	Coating Composition	Substrate Material	Porosity	Adhesion Strength
KM	Ni-16Cr-6Al-0.5Y	Cu-8Cr-4Nb	5.3%	>10.5 ksi (1)
HVOF	Co-Ni-Cr-Al-Y	Waspaloy	5.4%	~10ksi (2)

(1) Failure in epoxy (Sebastian stud-pull test per ASTM C 633)

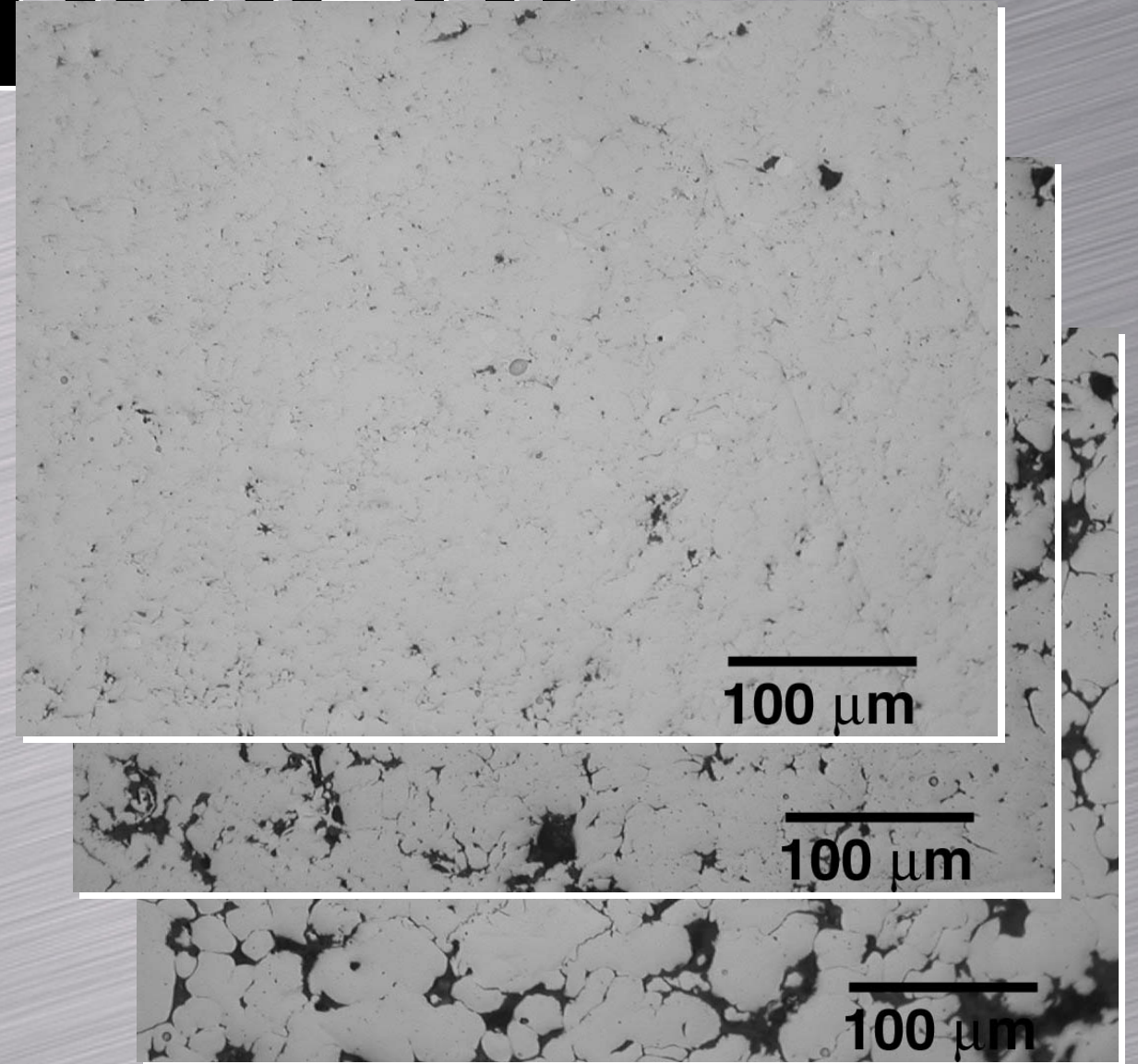
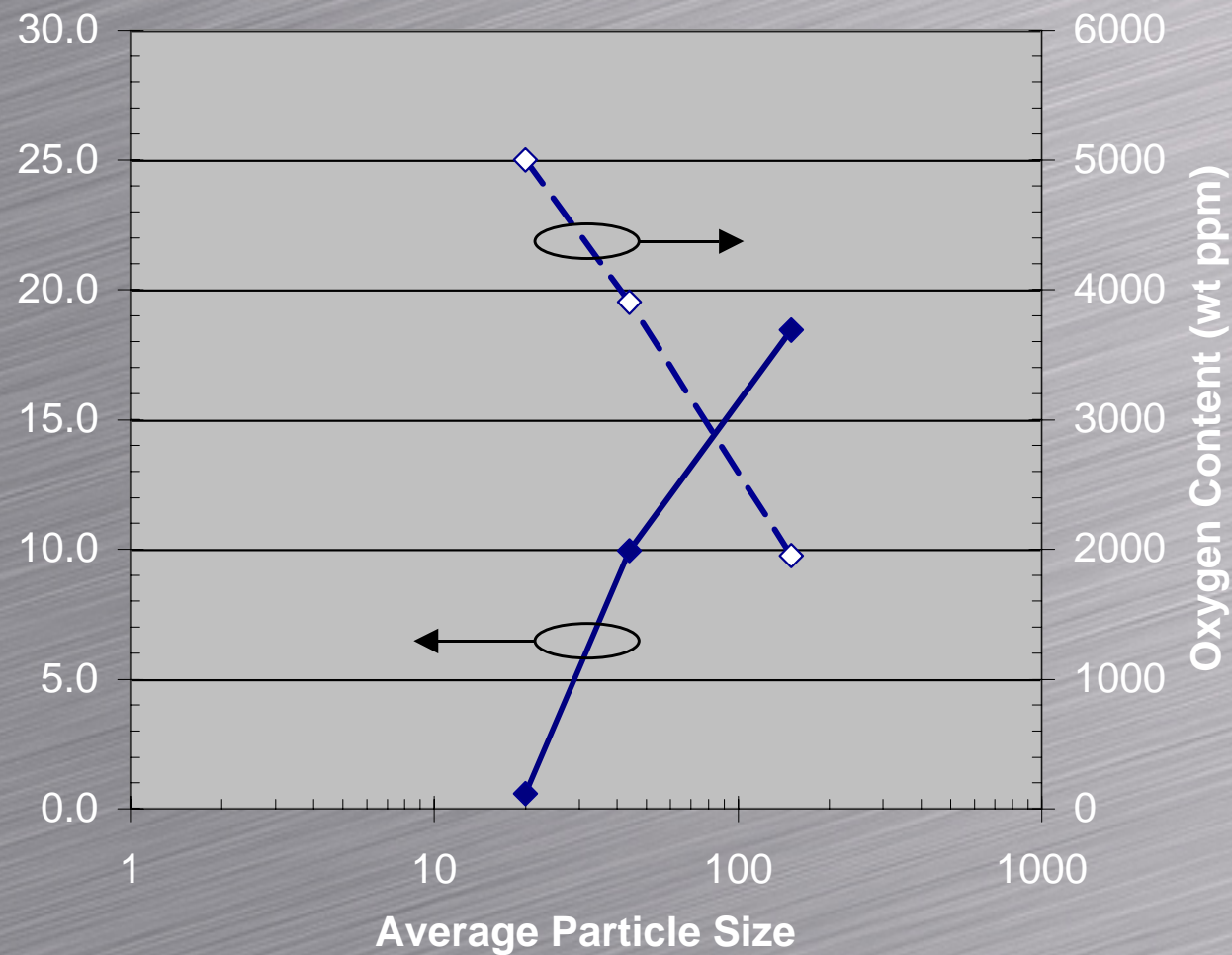
(2) Failure in coating (1.0" dia. epoxied loading fixture per ASTM C 633)

Rocket Nozzle Jacket

- KM Al-SiC MMC
- Applied to porous metal foams
- Mo top
- SiC bottom
- Seals
- Provides Strength
- Matches CTE



Ti Powder Development



Application: Air Frame Repair



Cd Replacement

- Al-Trans™ mixture

- Aluminum

- Transition metal

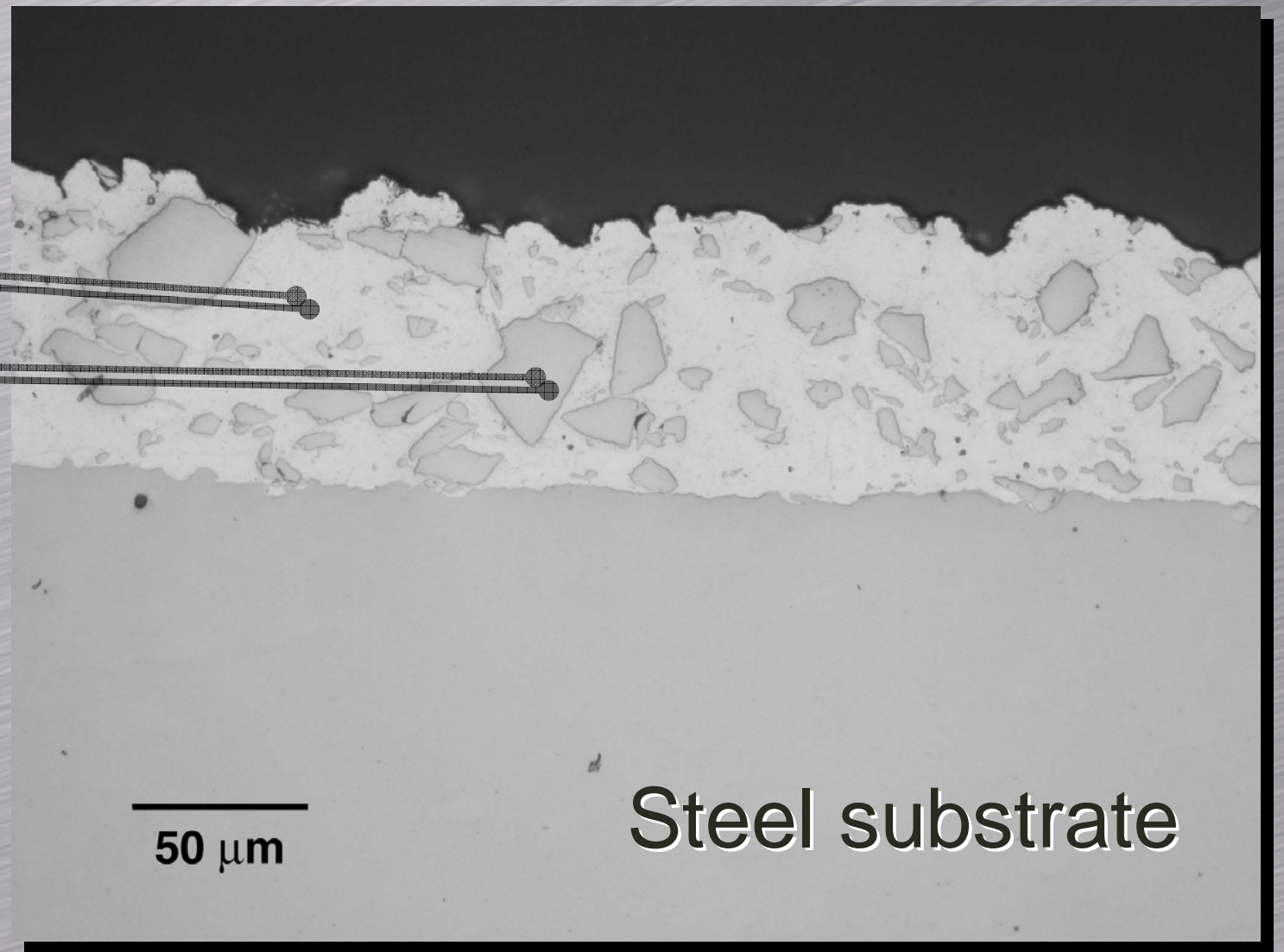
- Adhesion to

- Substrate: ASTM B571

- Paint: ASTM D2794, 120 ft-lb

- Corrosion

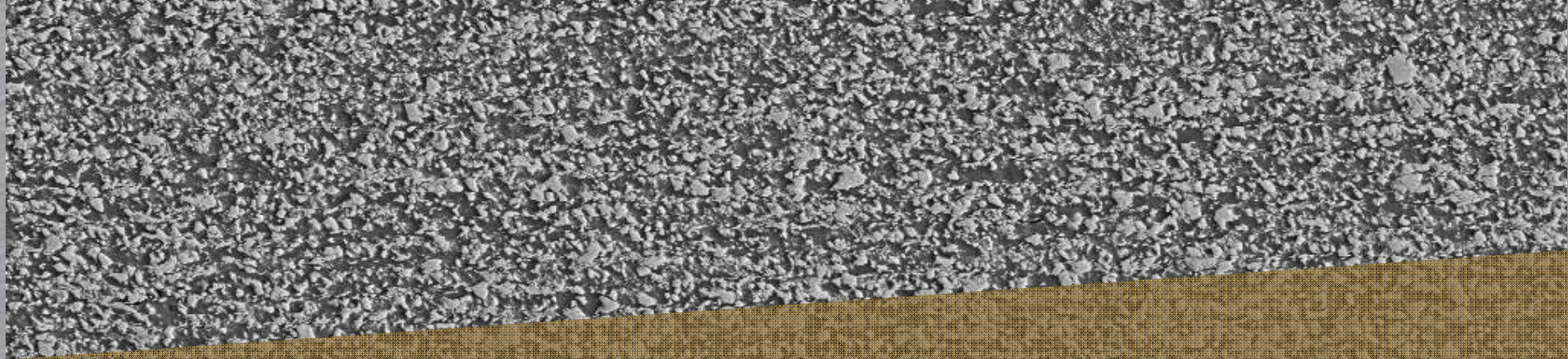
- ASTM B117, 500 hrs



KM Al-Trans™ vs ED Cd

<i>Shared Attributes</i>	<i>KM Al-Trans Superior</i>	<i>ED Cd Superior</i>
Corrosion resistance	No H2 bake cycle	Threaded fasteners
Paint adhesion	No hazardous waste stream	Lubricity
Sacrificial	May be applied thicker	Oxide volume = metal volume





WC-17Co

4340


WC-Co x800 10µm

KM Alternative

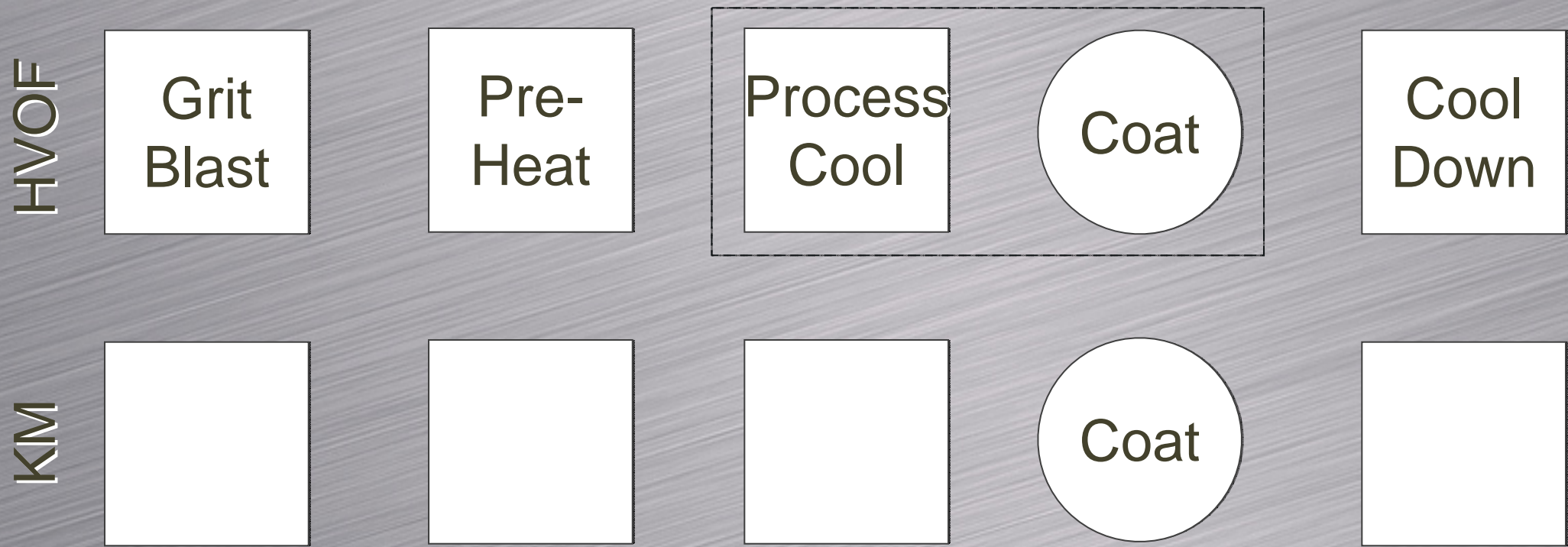


Quality

- Highly Uniform
- WC 3 μ average
- Smooth interface

WC-Co x800 10 μ m 

Process Simplification





KM WC-Co

<i>Eliminates</i>	<i>Enhanced</i>
Grit Blast	Fatigue resistance
Preheat	Throughput
Process cooling	Simplicity
Cool-down	Throughput
Heat distortion	Usability
Masking	Throughput
Sharp transitions	Fatigue resistance
Porosity	Ductility
Oxide inclusions	Ductility, corrosion resistance
Explosive Gases	Safety



KM Particle

		
Hight	H	0.2 H
Volume	V	V
Area	A	3.34 A
Strain perpendicular	—	-80%
Strain parallel	—	334%
Impact Velocity		1 km/s
Shear Velocity		4.2 km/s

PEWG Review

- Endorsed by OC-ALOC and DoD JPCC
- Assess and verify KM for
- Repair and manufacturing GTE components
- Request AF Materiel Command, FY05 environmental funding

