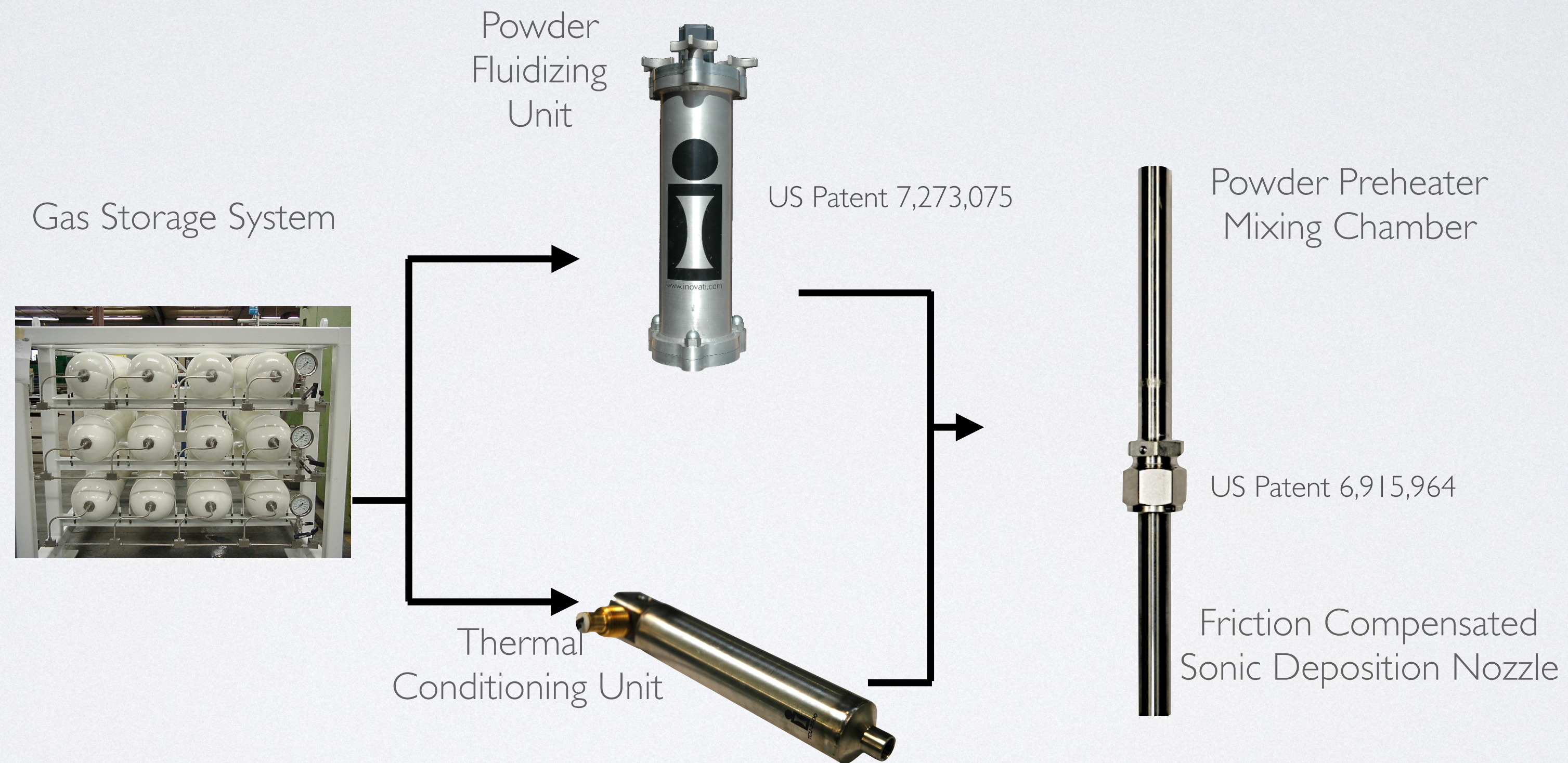


KINETIC METALLIZATION

An Industry Perspective

MegaRust 2018 - West Coast

Kinetic Metallization™ Process



PRESSURE
GAS
POWDER

PRESSURE

High	Low
Higher gas flow	Lower gas flow
Higher process variation	Lower process variation
Larger footprint	Smaller footprint
Louder	Quieter

GAS

	Type	Gas Speed
CS	He, N ₂ , Air?	Supersonic
	Vendors advertise N ₂ due to high flow rate, but quality coatings only available with He	Mach 3 Gas Mach 1 Particles
KM	He, N ₂ , <u>He/N₂</u>	Sonic
	Use gas type which produces Highest quality at lowest price coating	Mach 1 Gas Mach 1 Particles

POWDER

	Injection	Pressurized	Types	Flow Stable	Powder/Gas Independent	Powder Temp	Powder Speed
CS	Outlet	No	Fluidized Bed	No suction operation	No!	Low	Low
CS	Inlet	Yes	Gear Type	Subject to puffing	No	Higher	Higher
KM	Inlet	Yes	Brush - Sieve PFU	Yes	Yes	Highest	Highest



Kinetic Metallization System Overview

Low Operating Cost | Easy to Operate | Meets ES&H Requirements | Production Ready

Benefits

- Meets ES&H Requirements
- ISO 9001 Conformant
- Low Operating Cost
- Low Temperature
- Low Pressure
- High Particle Velocity
- Quiet
- Inert Gas
- Preserves Heat Treatments

Industries Served

- Aerospace
- Marine
- Oil and Gas
- Electronics

Application

- Hard Chrome Replacement
- Wear Resistance
- Fatigue Resistance
- Dimensional Restoration
- Corrosion Protection
- Temperature Sensitive Materials
- Metal Coatings on Ceramics



Kinetic Metallization™ (KM) is a powder based additive manufacturing process invented by Inovati. KM systems operate at low temperatures and pressures, making them suitable for depositing onto heat treated substrates. They require minimal equipment, and can deposit a wide variety of metals, plastics, and composites. Kinetic Metallization is also an environmentally friendly alternative to hard chrome.

Hardware

Powder Feeders: Inovati's patented brush-sieve powder feeders allow users to consistently and reliably feed powders from 1-100 microns.

Control Cabinet: Contains Electronic Control Box and Gas Control Panel

Spray Enclosure: Contains the robot, KM Gun, part fixtures, and an integrated safety circuit.

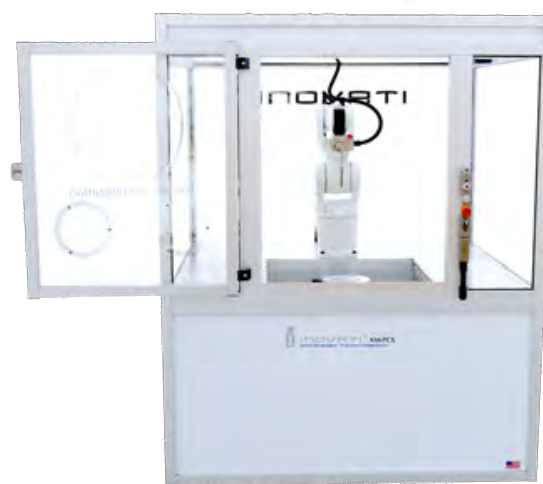
Dust Collector: Removes excess powder and prevents asphyxiants from building up in the spray enclosure.

Robot and Rotation Stage: Control gun and part motion for accurate, repeatable results.

KM Gun: Heated gas and powder carrying gas mix in the gun before being accelerated out the nozzle.

Friction Compensated Nozzle: Inovati's patented nozzle design accelerates gas to the sonic speed of He, propelling powder up to 1000 m/s.

Touchscreen User Interface: Allows operators to easily set and monitor process parameters.



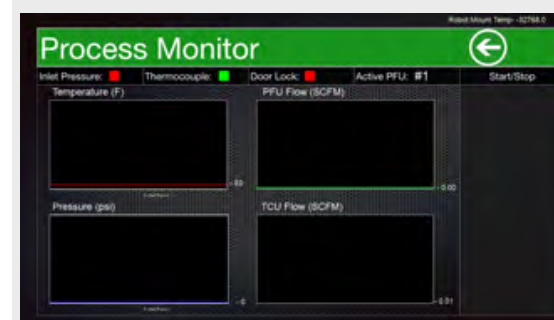
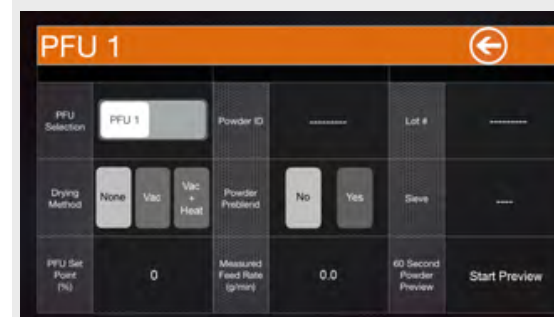
KM-PCS

- Production Coating System
- Coat and Repair Parts
- Custom Robotic Integration
- Custom Enclosure if Necessary

KM-CDS

- Coating Development System
- Simple Flat Coatings
- Outer Diameter of Rods

Screenshots



Software Packages

Inovati offers software packages suited for your specific needs. All software runs on a user friendly touchscreen interface. Users can easily select parameters, track them during deposition, and results are automatically recorded. The main difference between software packages comes in the motion control and intended use.

System Package	KM-PCS	KM-CDS
Purpose	Production	Research
Hardware	Identical	
Software & Automation	Part Centric	<ul style="list-style-type: none"> • Raster • Rotation • Multi-Coupon • Spline • Raster/Rotation

KM-PCS: Production Coating System

A KM-PCS unit is designed for a specific application. For example, NAVAIR's Production System allows them to load one of five components into the spray enclosure, and run software specifically designed for that part. Although generally this system is sold with the standard hardware, Inovati will work with customers to repair large or oddly shaped components. For tasks that vary regularly, such as components which corrode unevenly, a KM-PCS unit may be sold with a handheld gun and gloves which allow an operator to work inside the cabinet with no exposure to gas or dust.

KM-CDS: Coating Development System

The KM-CDS is our turn-key unit, which comes with built in motion programs for development level spraying including Raster, Outer Diameter, and Multi-Coupon programs. In addition to the built in programs, users have the ability to add their own custom, part specific motion programs. The KM-CDS comes with fixtures for spraying coupons, and a chuck for components requiring rotation. Since the hardware is identical, transitioning from research to production is one software update away.

KM SYSTEM NAVAIR FRC-SW

75 dBA

Gas Usage: 7 SCFM

No Robot Programming

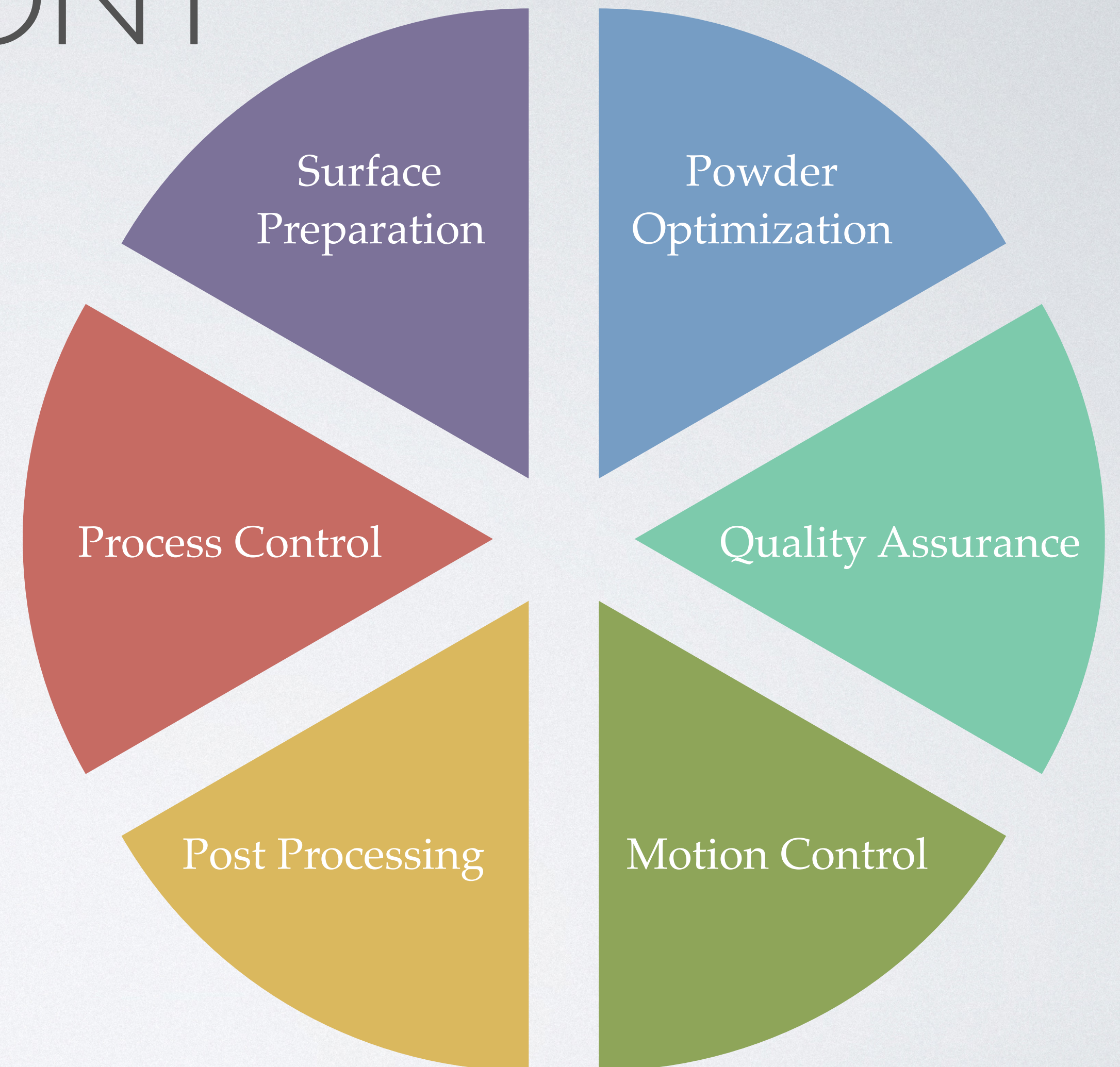
Custom HMI

7-Axis Coordinated Motion



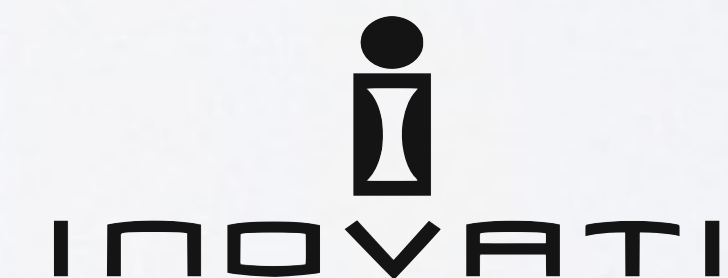
HARMONY

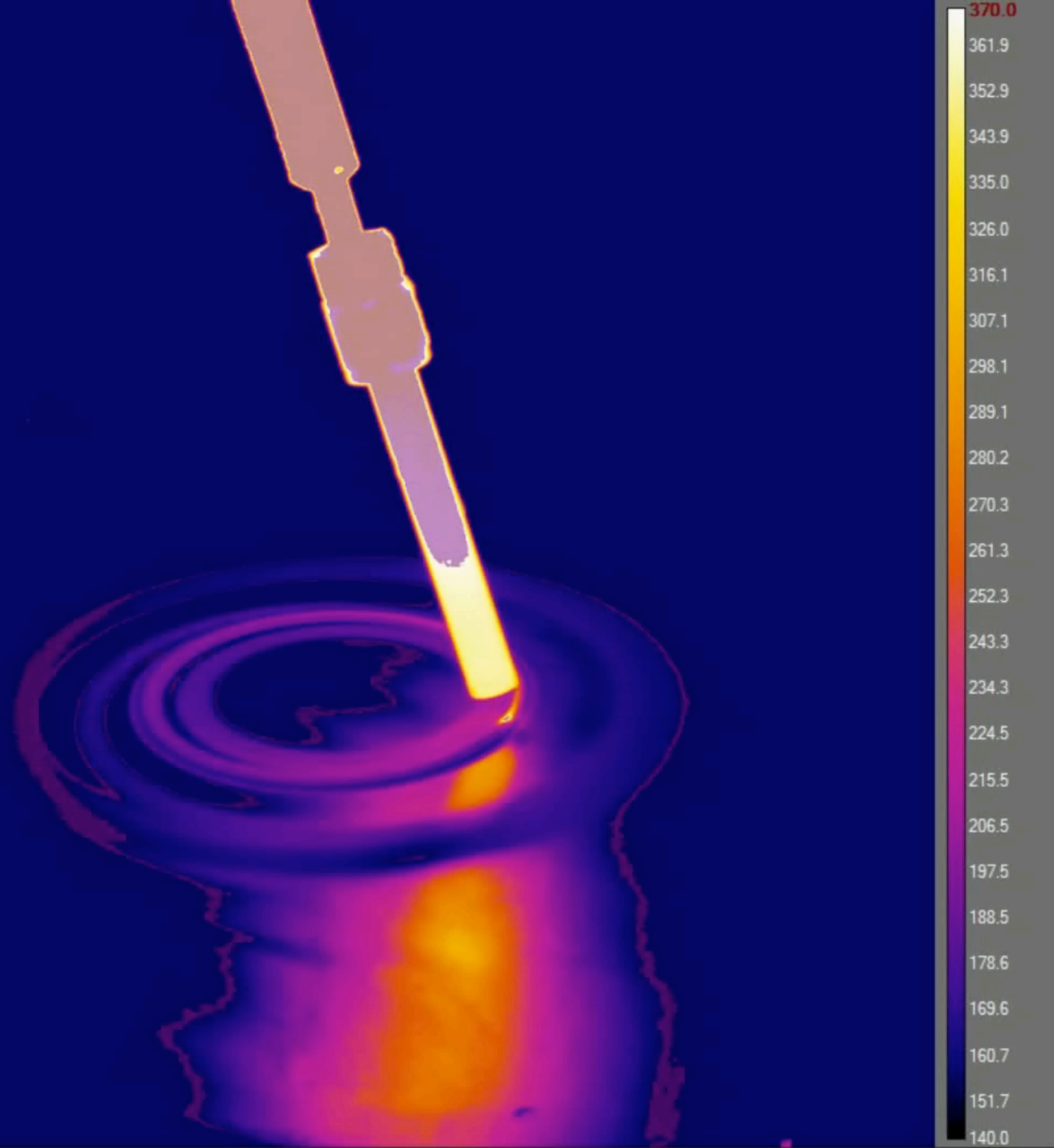
- Kinetic Metallization
- Equipment / Feedstock / Procedure
- All parts are harmonized
- Results are reproducible and verifiable



KM HARMONY

Powder Optimization	Surface Preparation	Process Control	Motion Control	Post Processing	Quality Assurance
Chemical Purity	Grit Blast Media	PAC Process Control	6-Axis Robot	Heat Treatment	Objective Quality Evidence
Particle Size Distribution	Pressure	Electronic Pressure Control	7th-Axis Rotation 8th-Axis Choice	Cleaning	Real Time Process Log
Microstructure	Preheating	Electronic Flow Control	Integrated Motion Control	Machining	Quality Report
Powder Blend Hard-Soft	Cleaning	Brush Sieve Powder Feeder	Part Specific Motion Programs	Finishing	Traceability





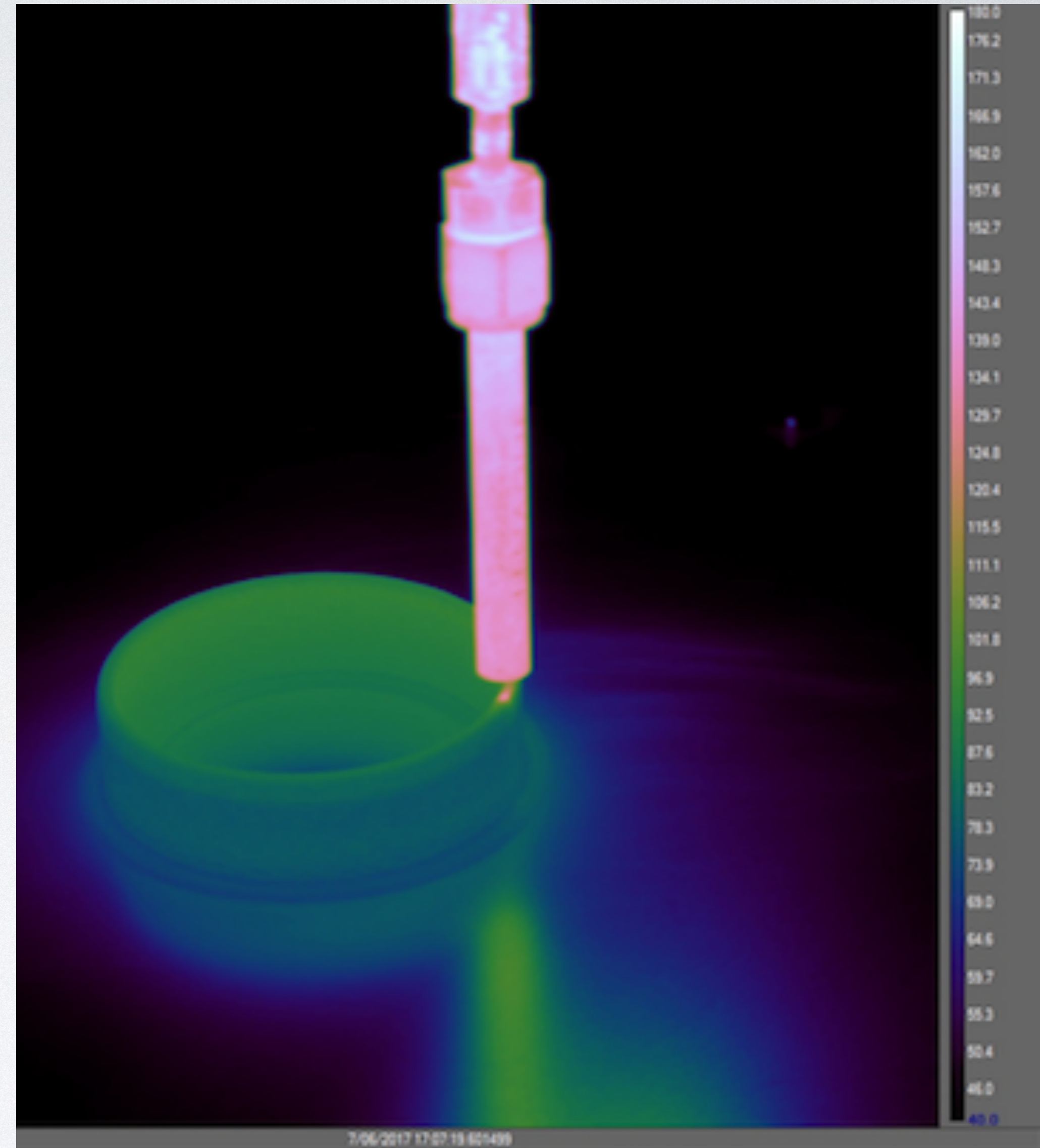
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*Not corrected for emissivity

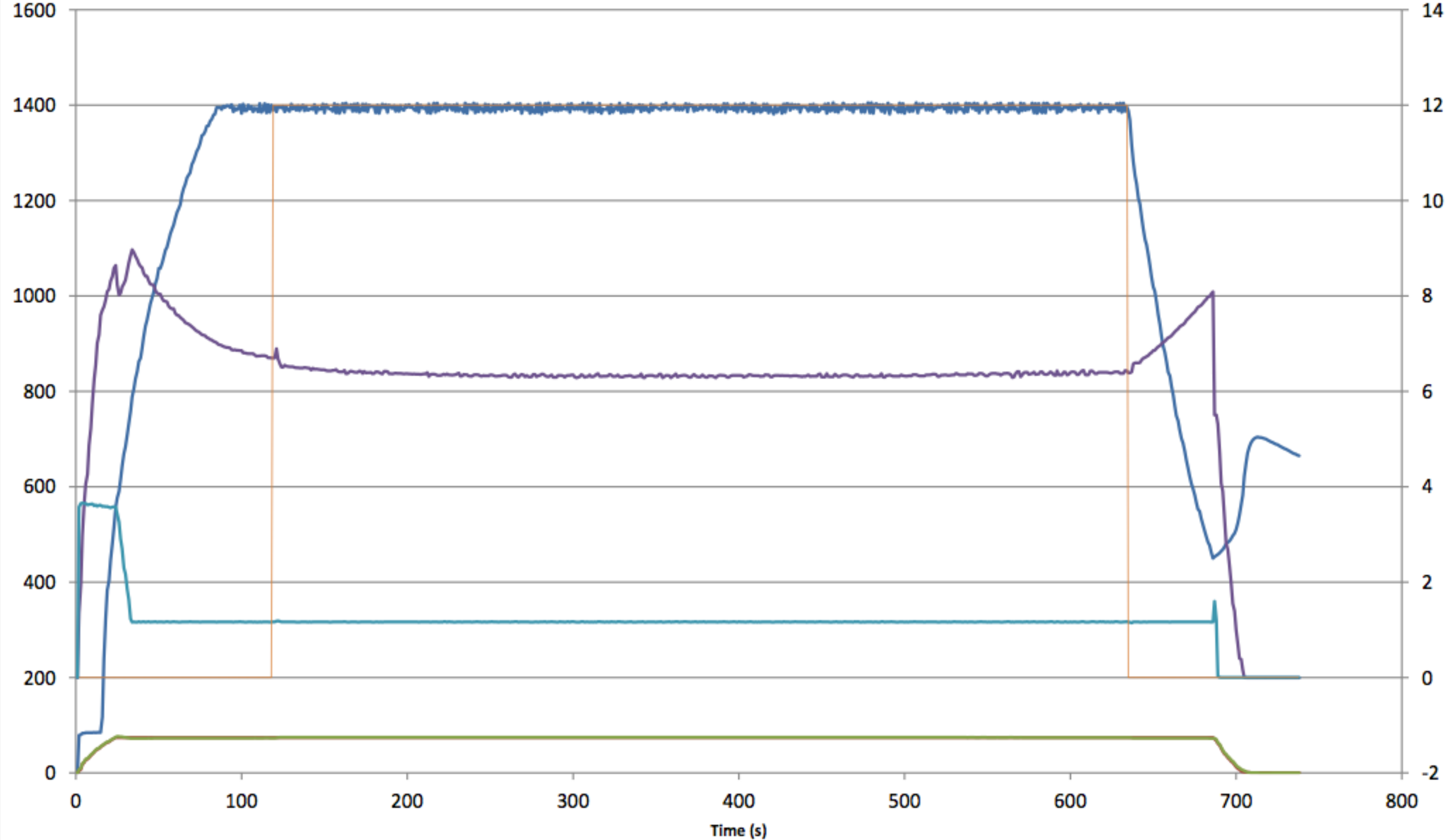
THERMAL IMAGING POINT OF CONTACT QA

Real-Time Temperature of Al-Trans[®]
3D Printing Application

Temp Scale — 40 to 180 °C
Impingement Zone ~ 125 °C



Spray Parameters



— TCU Temperature(F) — TCU Pressure(psi) — PFU Pressure(psi)
— TCU Flow(scfm) — PFU Flow(scfm) — Powder Feed

QUALITY REPORT

Auto generated for each run
High-Low-Average-Std. Dev
All operational parameters
SetPoints and Actuals

Kinetic Metallization Objective Quality Evidence

System S/N : 30203

KM Process Performance			Date: 10/29/2015	Time 12:12:29		
	Units	Set Point	Min	Max	Average	Std. dev
Temperature	F	400	392.00	477.00	414.45	15.49
Pressure	psig	75	73.92	74.15	73.99	0.05
TCU Flow	SCFM	He	9.02	9.50	9.14	0.08
PFU Flow	SCFM	He	1.16	1.19	1.17	0.00
PFU Motor 1	%	75	0.10	74.50	73.41	7.51
PFU Motor 2	%	0	0.00	0.00	0.00	0.00

Component

Component Name	Serial Number	4130
----------------	---------------	------

Powder 1

Powder ID	AllTrans 10-10-50	Lot Number	none
Sieve	70	Drying Method	None
Set Point (%)	75	Feed Rate (g/min)	10

Powder 2

Powder ID	-----	Lot Number	-----
Sieve	----	Drying Method	None
Set Point (%)	0	Feed Rate (g/min)	0

Nozzle

Throat Diameter (in)	0.06	Serial Number	0415-059-20115
----------------------	------	---------------	----------------

Motion Variables

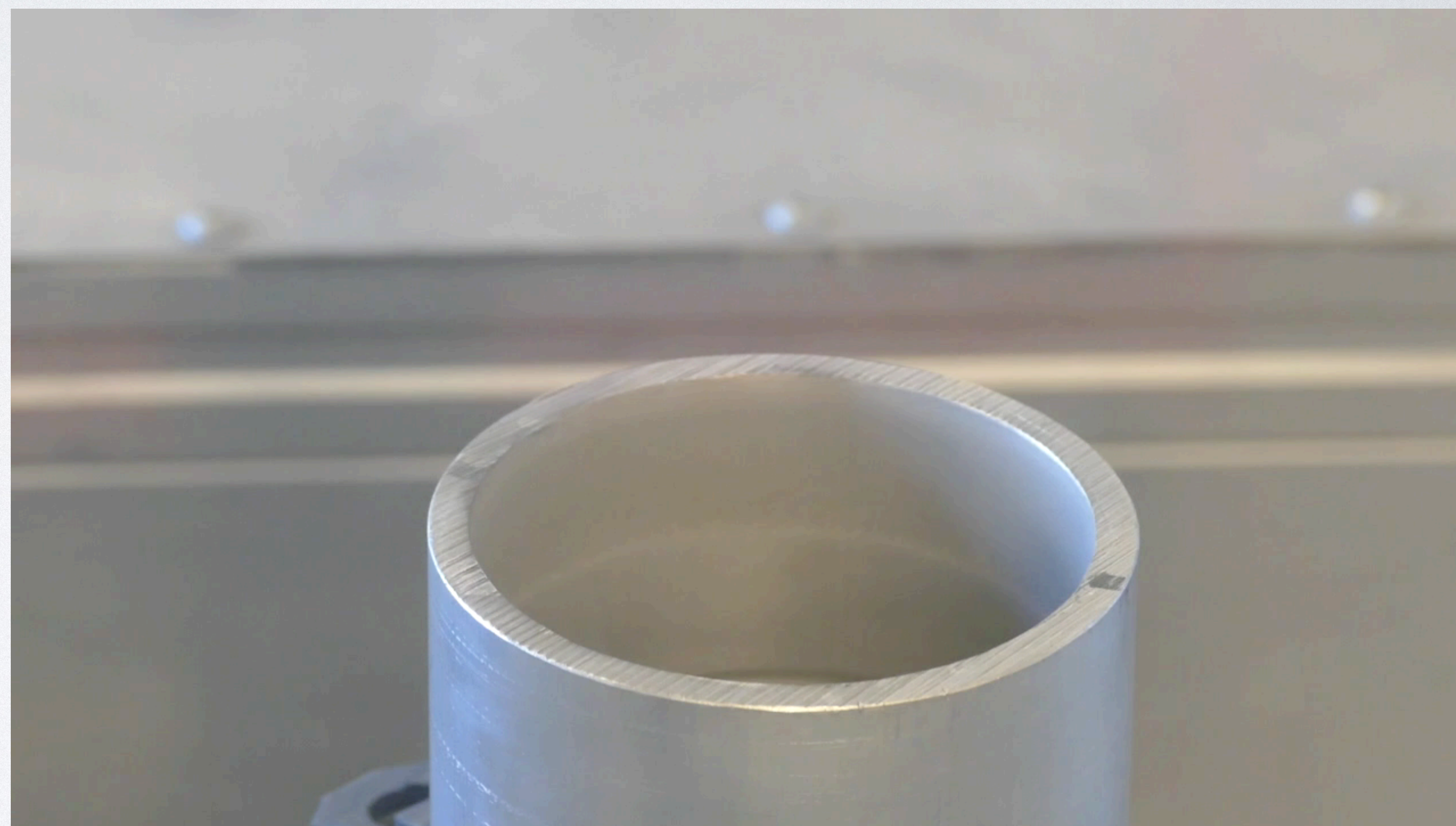
Description	Units	Set Point
Length	in	12
Width	in	10
Surface Speed	in/sec	40
Step Size	in	20
Layers	---	1
Height	in	0.65
Strokes	---	1
---	---	-
---	---	-
---	---	-

KM COMPARED TO CS

	Kinetic Metallization	Cold Spray
Nozzle Type	Sonic	Supersonic
Particle Acceleration	Inlet and Outlet Duct	Inlet Duct
Maximum Particle Speed	Mach 1	Mach 1
Consolidation	Solid-State	Solid-State

ORBITAL KM GUN — BORE COATINGS

- Orbital KM ID Gun for Stationary Bores
 - Robotic coordinated orbital+rotary motion
 - 2 — 20 inch ID bores
 - Bearing hubs
 - Actuator bores





PROTOTYPE ORBITAL GUN

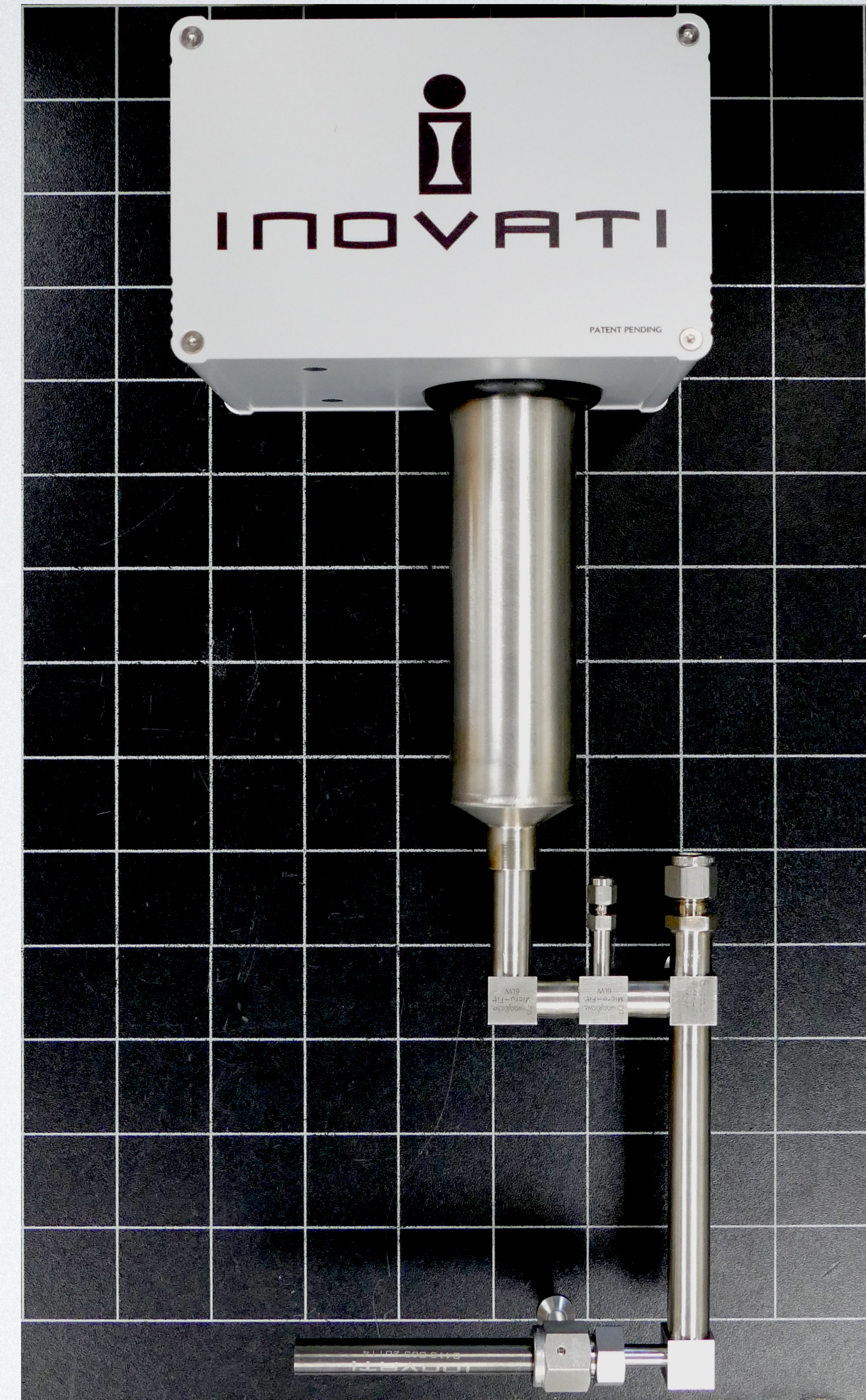
E2 RADAR DOME GEARBOX

2" ID Above
14" ID Right



KM ORBITAL ID GUN

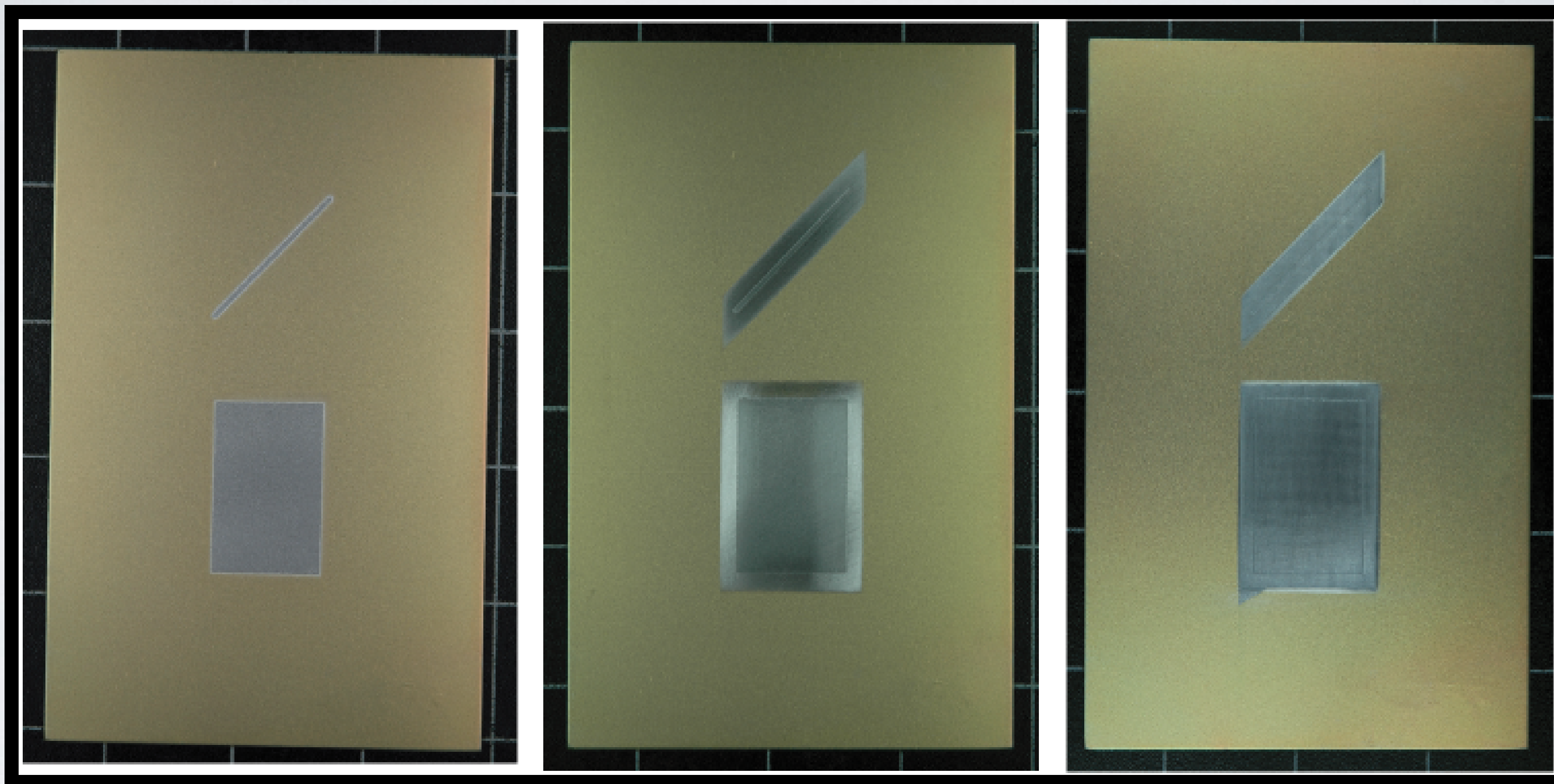
Patent Pending - 2018



PROBLEM - REPAIR OF DAMAGED IVD ALUMINUM



- HSS Landing Gear & Components
- Problem: Brush plating Cd
- Need: Environmentally sustainable repair

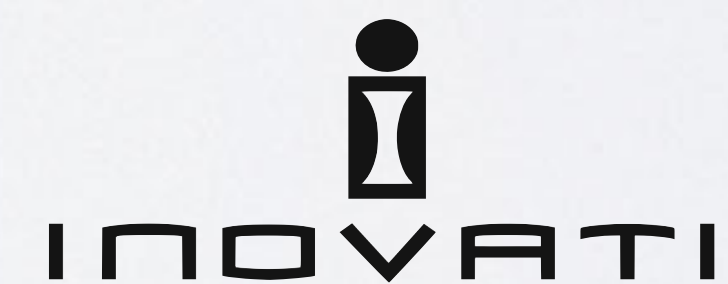


IVD-AI
Removed

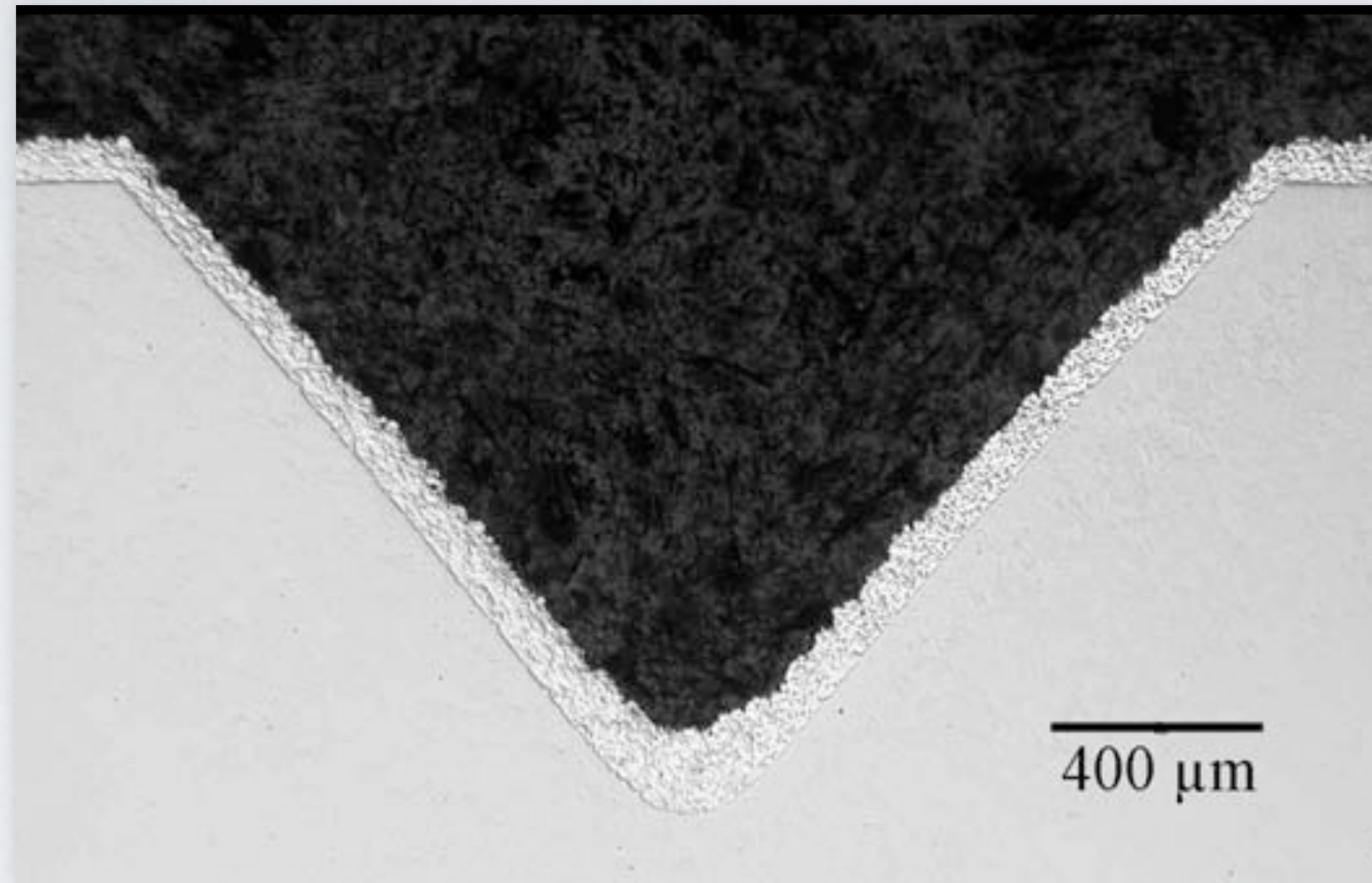
Feather
Edges

KM AI-Trans®
Repair

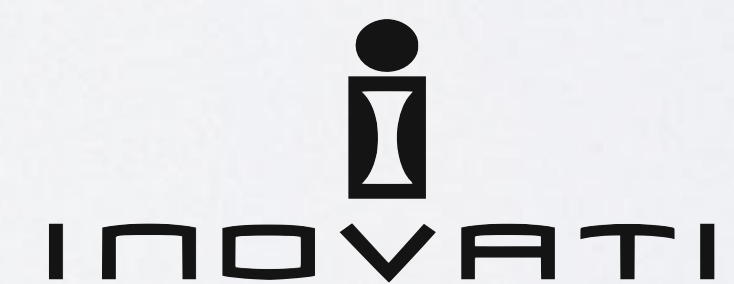
KM REPAIR SEQUENCE FOR IVD-AI

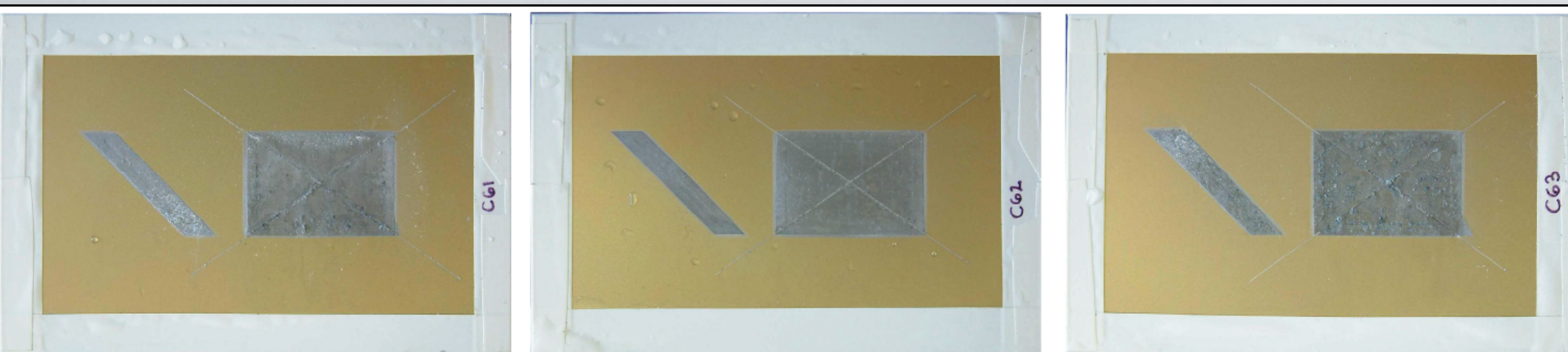


AL-TRANS® CORROSION PROTECTION IVD-AL REPAIRS

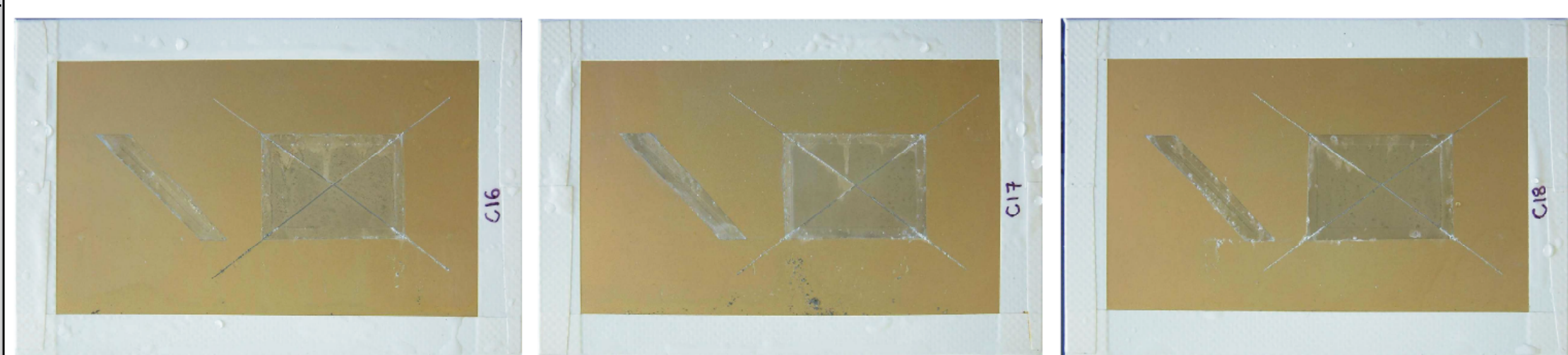


- NAVAIR Phase II SBIR 2005
- Qualified Testing
 - JTP-2003 -Repairs
 - Brush Cd Control
- Completed 2007

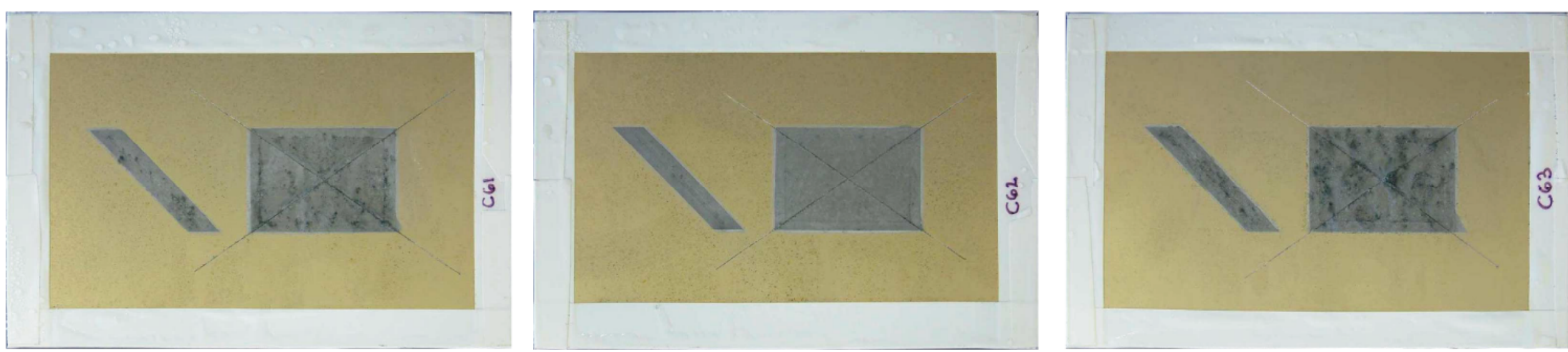




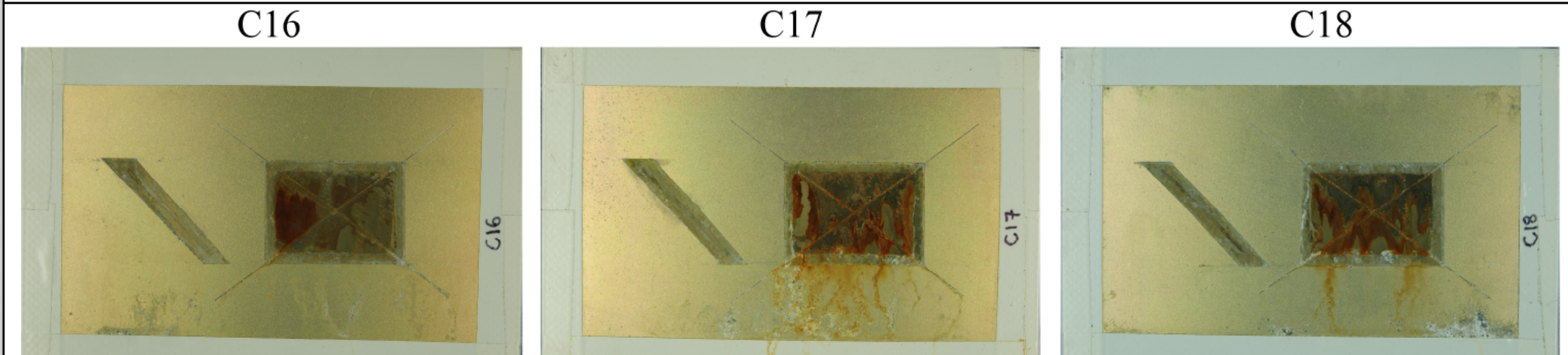
24 Hours



24 Hours



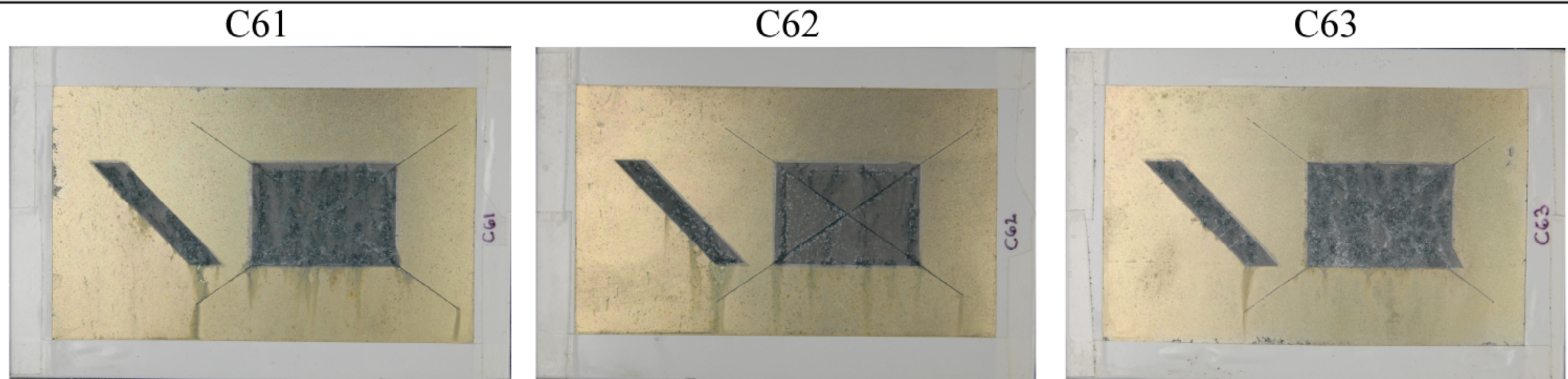
168 Hours



Removed after 120 Hours

168 Hours

168 Hours



504 Hours

KM Al-Trans® - 504 hrs

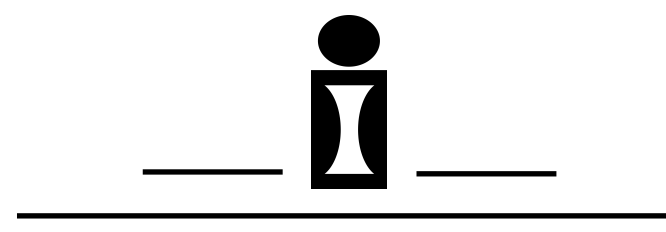
Passed

Brush Cd - 168 Hrs
Failed

Scribed Cyclic SO₂ Salt Fog
ASTM G85 annex 4, B117/SO₂

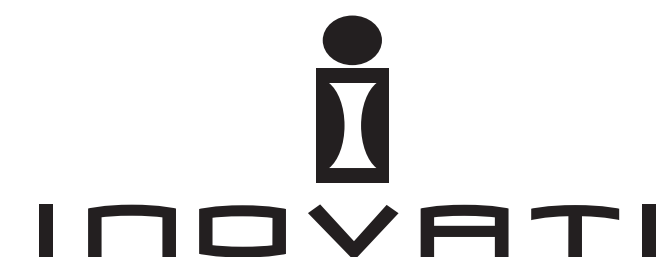


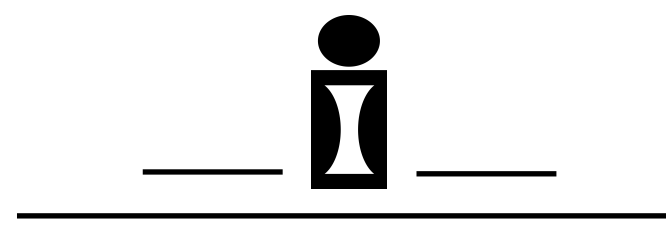
Scribed SO ₂ Salt Spray										
JTP	4.1.2									
Repair Material	Sample ID	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs	168 hrs	336 hrs	504 hrs	Pass/Fail
Control Specimens										
Brush LHE-Cd	C16	White rust, small dark spots in test areas	Dark stains at bottom, few dark spots in test areas, white and dark rust in lower scribe areas, few small blisters on diagonal test area	No change from 48	Red rust in one area of the square test area, few more dark spots in scribes	Red rust increased noticeably, removed on 1/13/07	Removed 1/13/07	----	----	Control
	C17	White rust, large corroded area below test areas	Same as C16	No change from 48	More white rust, few more dark spots in scribes	Dark at rectangle corners and in center	Heavier red rust & bleeding, white rust heavier in diagonal	----	----	Control
	C18	White rust, small dark spots	Some dark staining at bottom, dark and white rust in lower scribe area	No change from 48	Dark area at bottom has increased, few more dark spots in scribes	Dark spots increased, rectangle has darkened somewhat	Red rust on left side of rectangle, darker everywhere in test areas	----	----	Control
Candidate Specimens										
Nano Al-Trans	C61	Medium white rust, darkening of test areas	Darkened test areas, white rust in test areas heavier than at 24-hr insp.	No change from 48	More white rust, few more dark spots in scribes	More white rust, some dark spots in test areas	More dark spots in both test areas, original spots are larger	Much darker in both areas	Increase in dark corrosion, small blisters in both areas, no red rust.	Pass
	C62	Darkened test area, but otherwise clear, few dark spots in scribe	Slight darkening of test areas, otherwise no change from 24-hr insp.	No change from 48	Still clean, slightly darker	Little or no change	Little or no change	Some dark corrosion has developed at scribe lines and about 3/16" from outside of rectangle and along centerline of rectangle	Small amount of dark corrosion at edges and in a band about 1/4" from perimeter of rectangle and at center of diagonal. No red rust.	Pass
	C63	White rust and darkening like C61. C61 and C63 are very different from C62	Same as C61	No change from 48	More white rust, scribe marks clean	Dark spots in rectangle	Dark in both test areas, heavier in rectangle	Much darker corrosion in both areas	Dark corrosion increased, small blisters over test area.	Pass



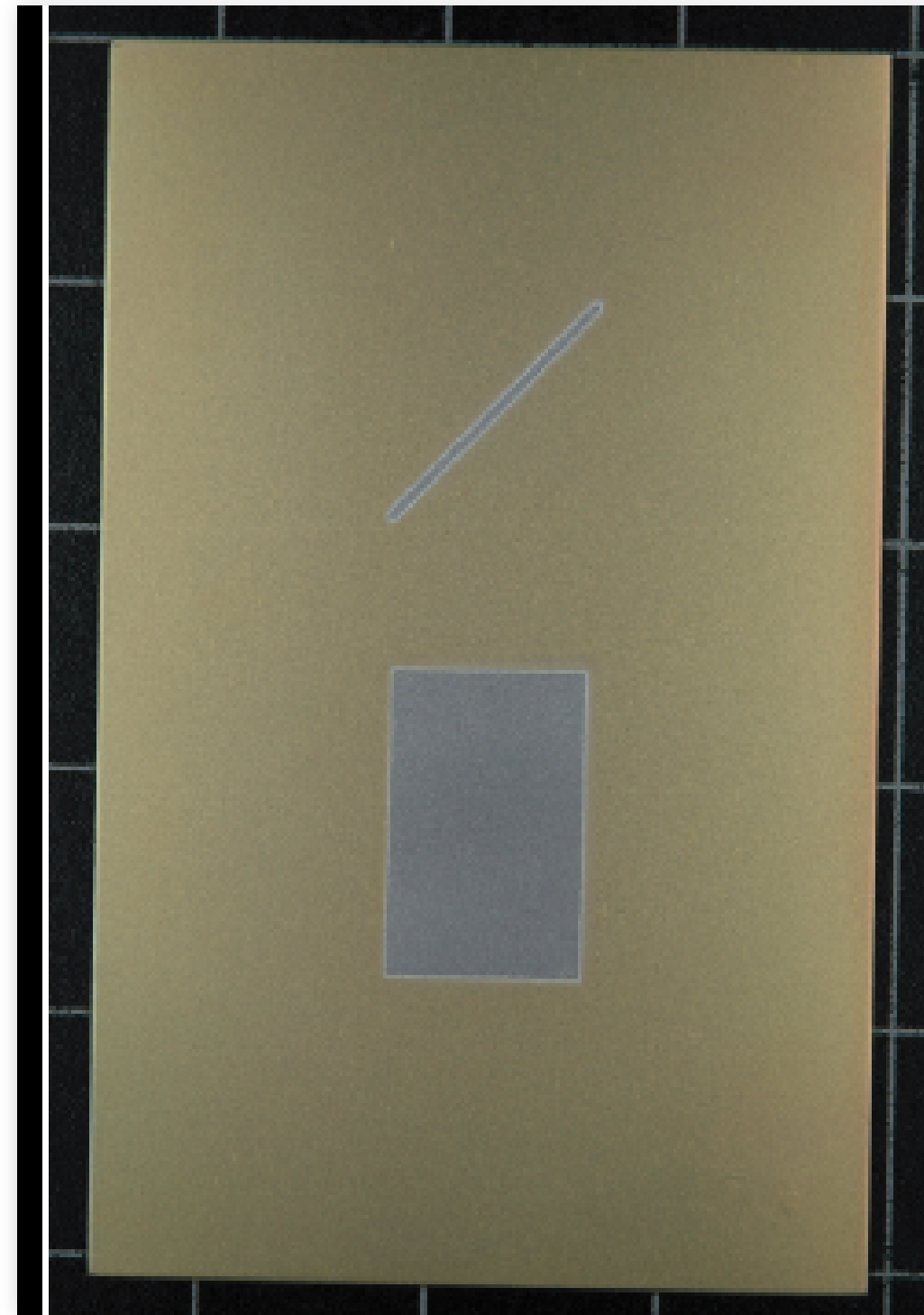
Al-Trans[®] IVD Aluminum Repairs

- ❖ Surface Preparation
- ❖ Removable of topcoat, primer, & IVD Al with bristle disk abrasion
- ❖ Masking of repair area with aluminum tape to protect border areas
- ❖ Al-Trans[®] Coating Properties on High Strength Steels
- ❖ Adhesion of > 10 ksi without de-lamination
- ❖ Coating protection >3000 hrs in salt fog per ASTM B117
- ❖ Superior corrosion protection in SO₂ salt fog per ASTM-G85
- ❖ Passed Joint Test Protocol-2003 specifications

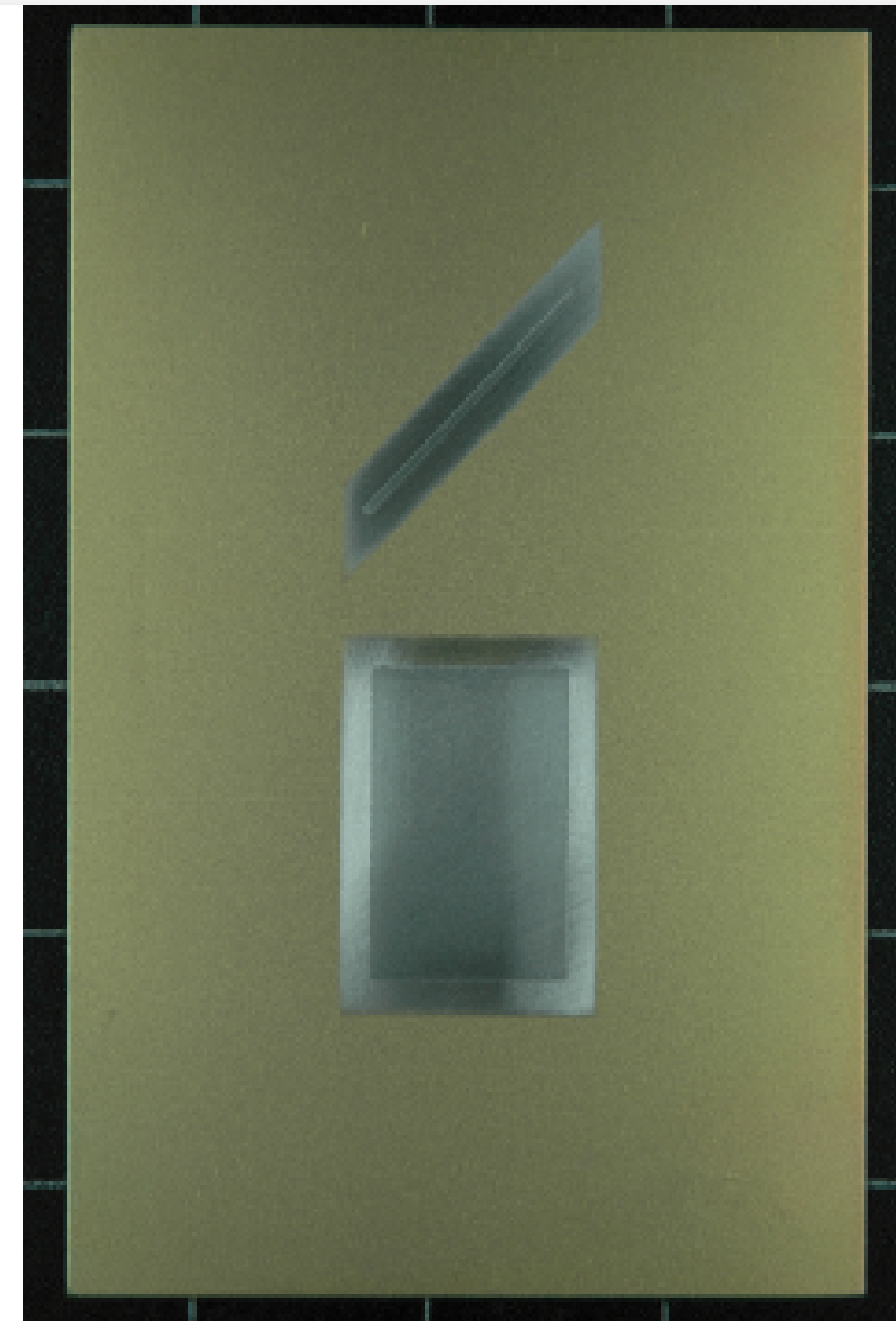




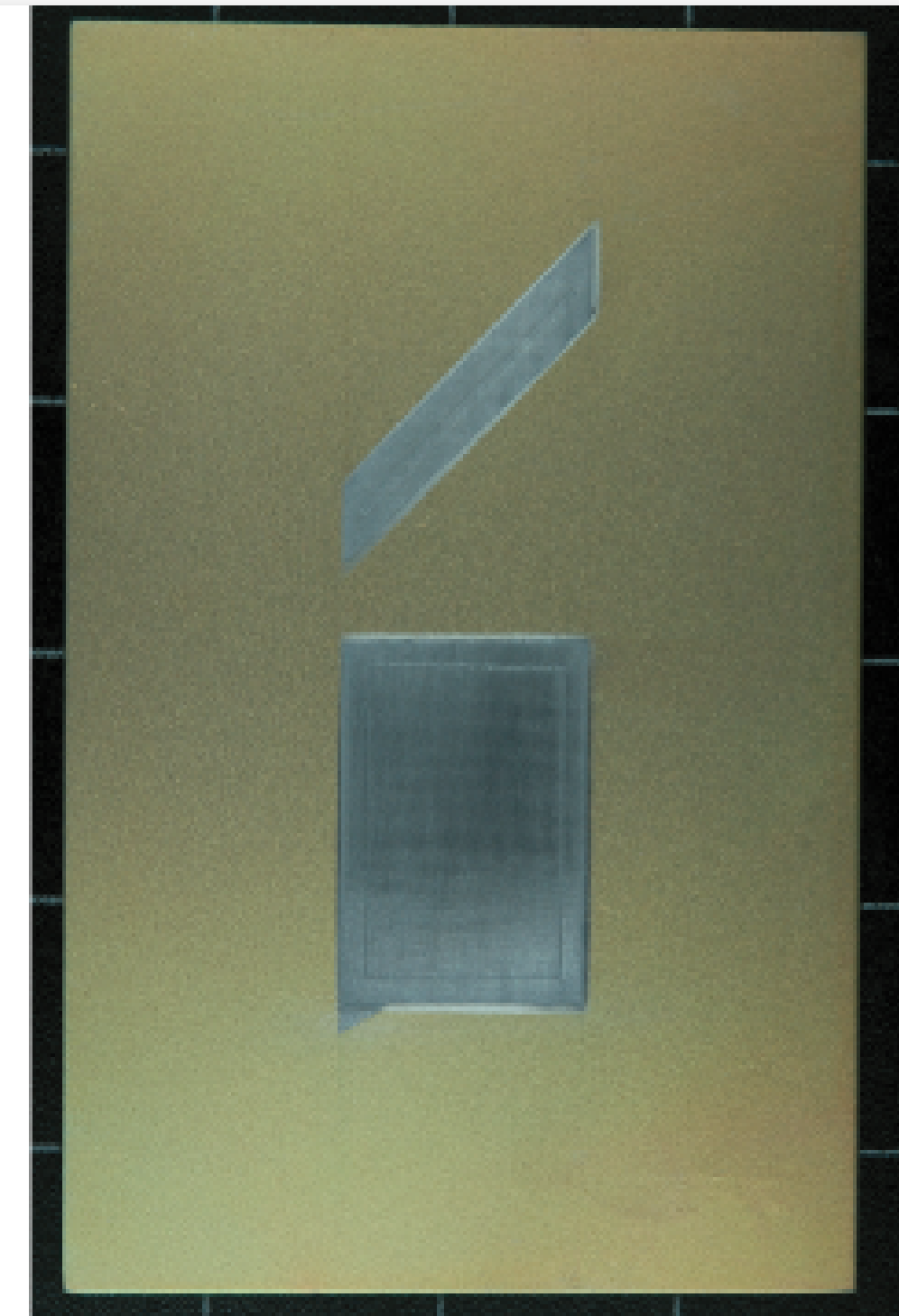
KM Repair Sequence for IVD-AI



IVD-AI Removed



Feather Edges

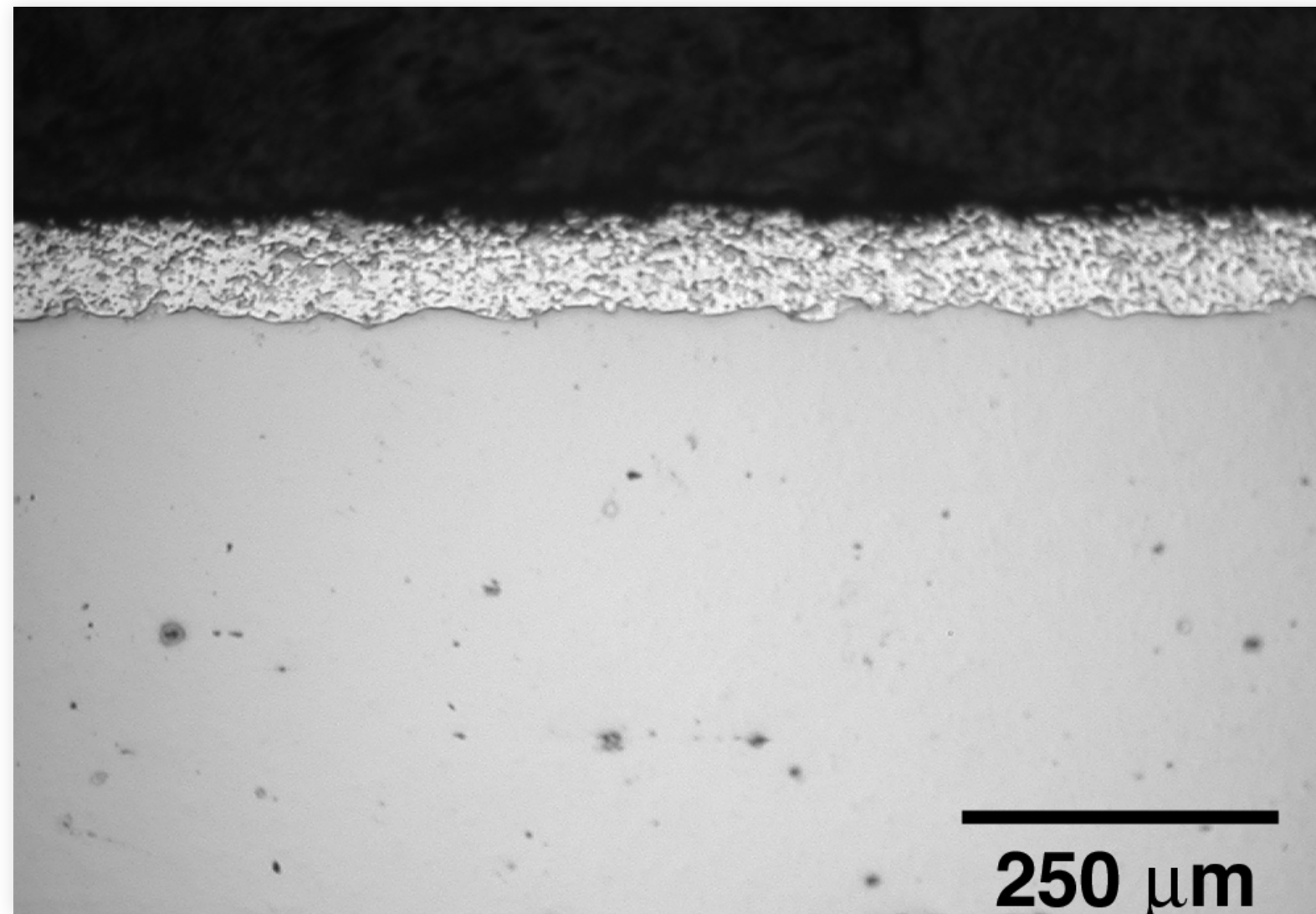


KM AI-Trans® Repair





Al-Trans® Corrosion Protection IVD-AI Repairs



Composite Al-Trans® Coating

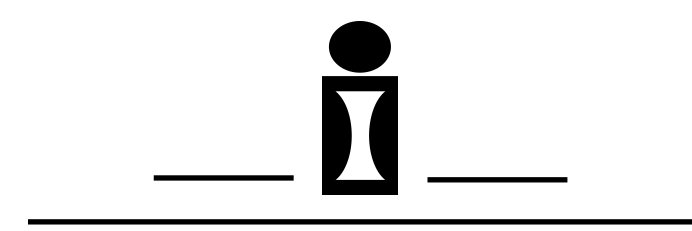
- ❖ Composite Al-Trans®/Cr Coating
- ❖ Properties
 - ❖ Hardness HRB = 62
 - ❖ Porosity < 0.5%
 - ❖ Corrosion - Salt Fog B117
 - ❖ 3000 Hrs
 - ❖ Substrate 4130 steel



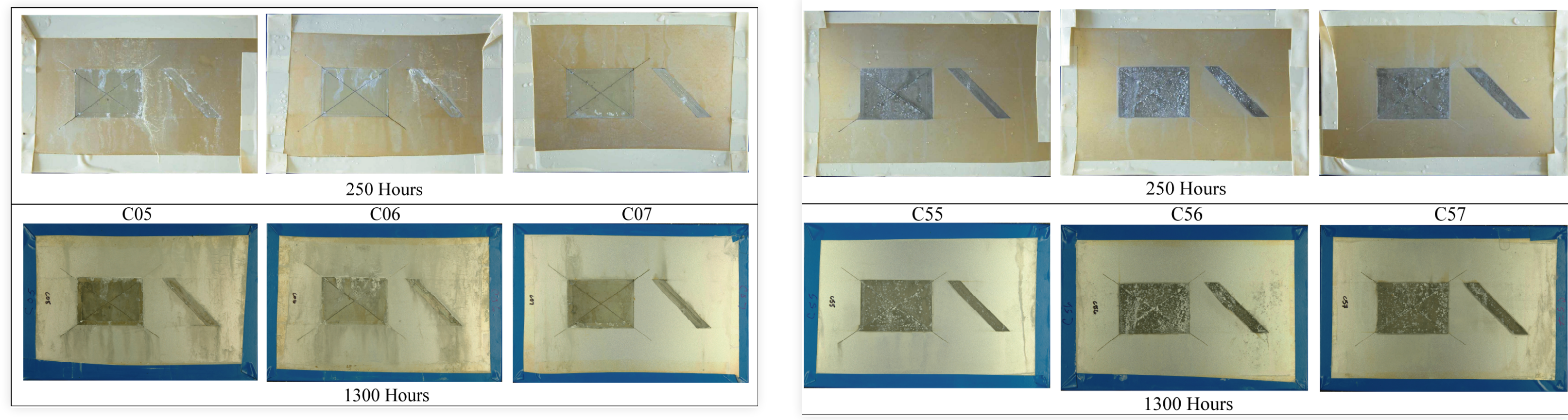
Al-Trans® Kinetic Metallization JTP-2003 Qualification Tests

Reparability Test	JTP	Acceptance Criteria	Pass/Fail
Unscribed Salt Fog	3.3.1 3.7.1	3000 Hrs ASTM B117-94	Pass
Scribed Salt Fog	3.3.2 3.7.1	1000 Hrs ASTM B117 94	Pass
Unscribed SO2 Salt Fog	4.1.1	500 Hrs ASTM G85	Pass
Scribed SO2 Salt Fog	4.1.2	500 Hrs ASTM G85	Pass
Unscribed Salt Fog	3.1.4	3000 Hr ASTM B117-94	Pass





Scribed Salt Fog Testing ASTM B-117

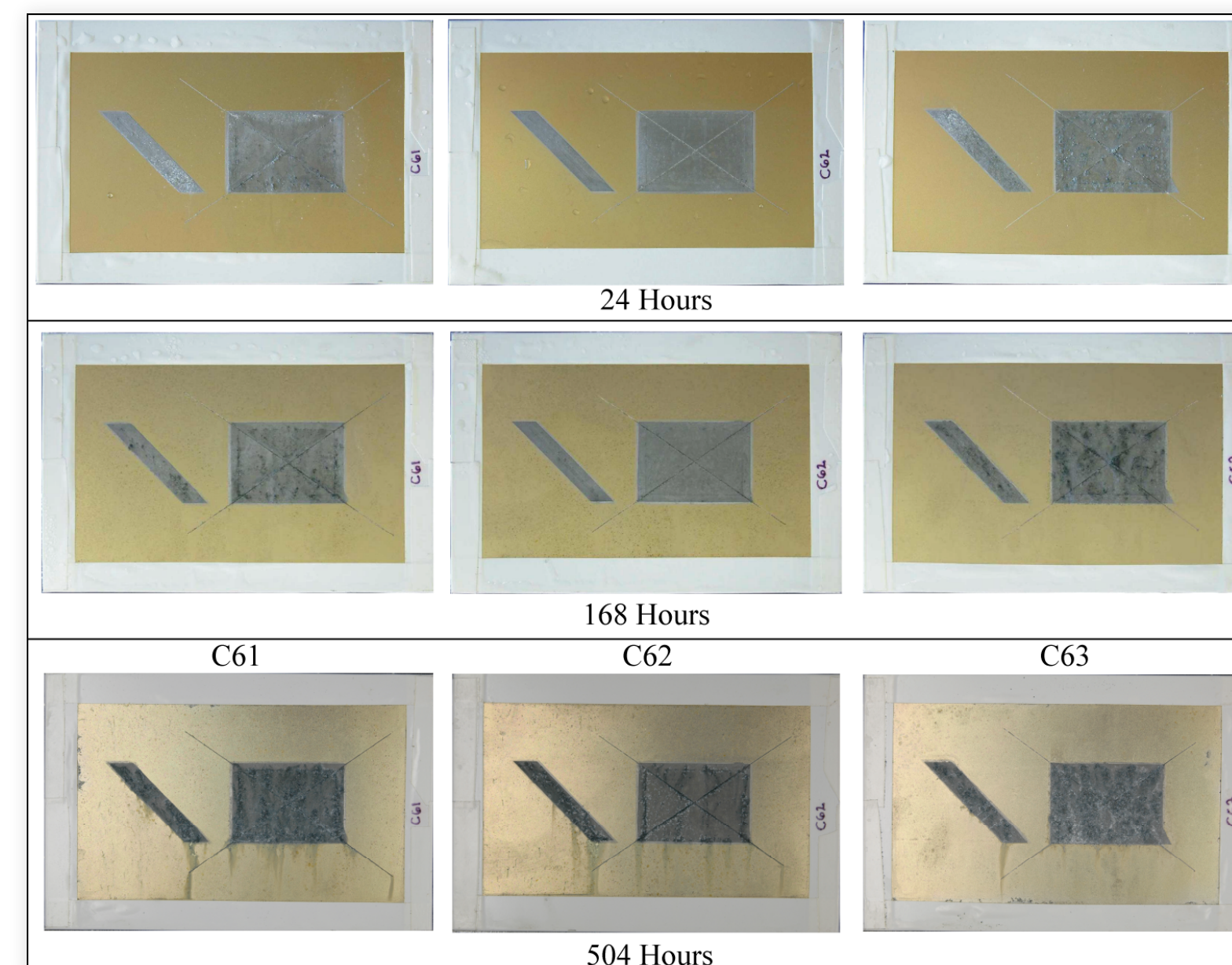
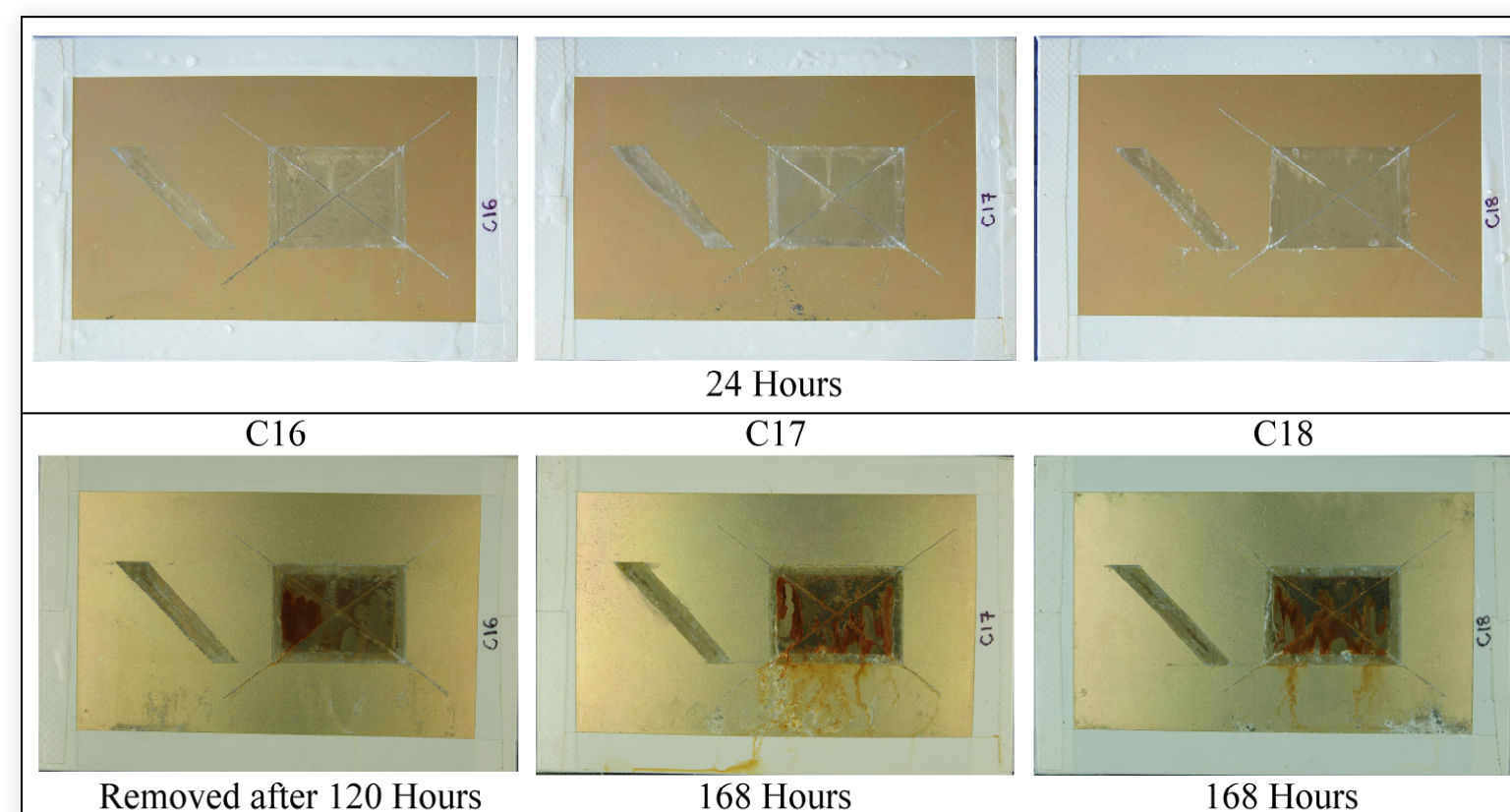


❖ Brush Cd specimens

❖ KM Al-Trans® repair



Scribed Cyclic SO₂ Salt Fog (ASTM G85 annex 4, B117/SO₂)



❖ Brush CD - 168 Hrs

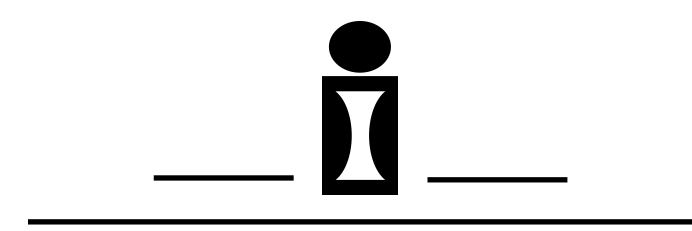
❖ KM Al-Trans® - 504 hrs



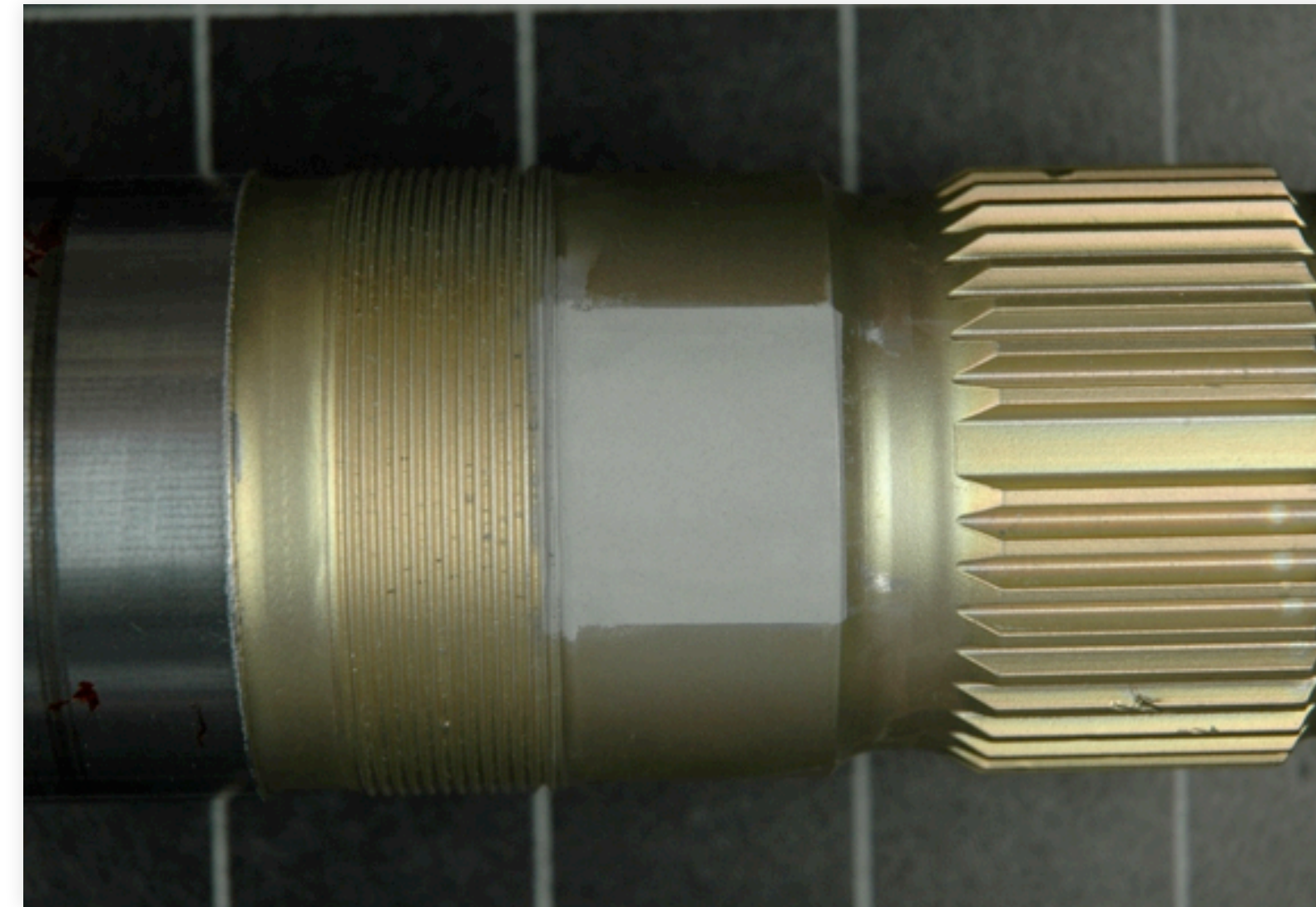
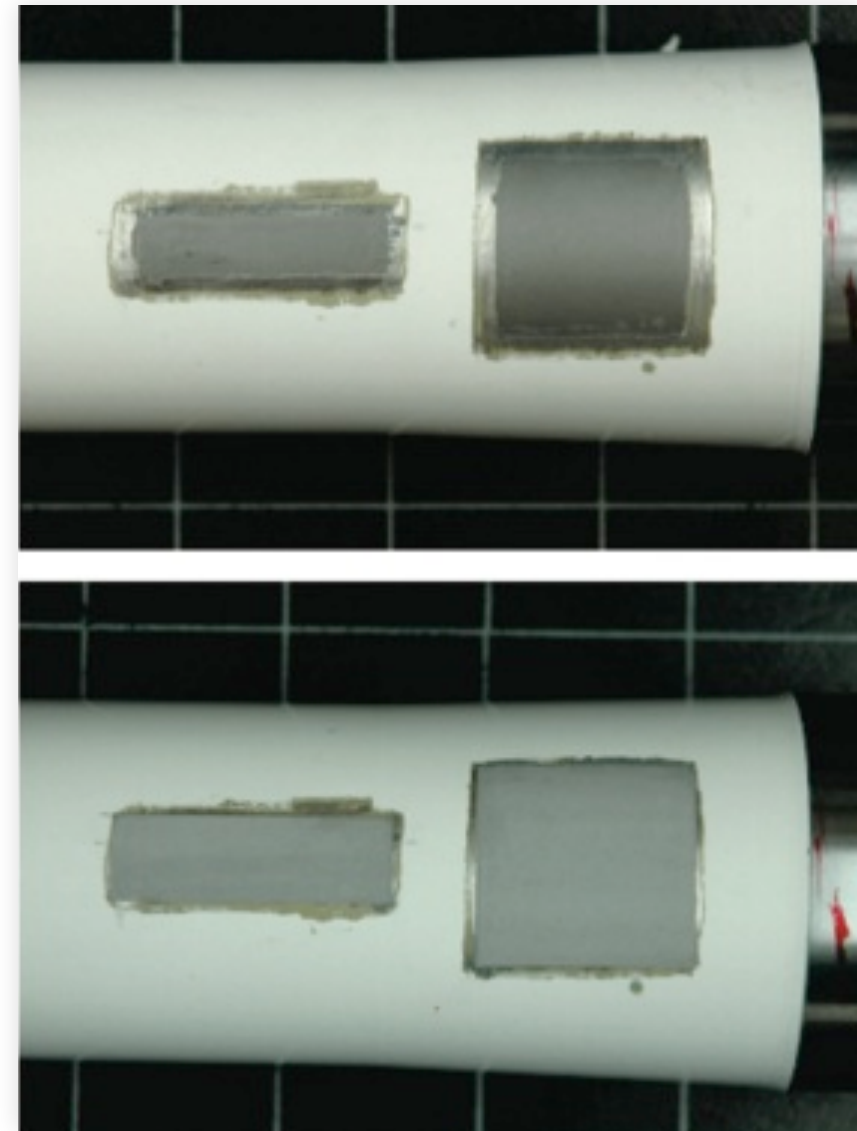
Al-Trans® Kinetic Metallization JTP-2003 Qualification Tests

Reparability Test	JTP	Acceptance Criteria	Pass/Fail
Hydrogen Embrittlement	3.6.1 3.7.1	200 Hr/75% ASTM F519	Pass
Hydrogen Re-Embrittlement	3.6.1 3.7.1	200 Hr/75% ASTM F519	Pass
Corrosion Resistance 14 Fluids	3.3.4	No Coat Degradation Compared to Brush Cd	Pass
Stress Corrosion Cracking	4.3	SEM Fractography	Pass
Scribed Painted Coating	3.3.5	3000 Hrs ASTM B117 - 94	Pass





F-18 Axle

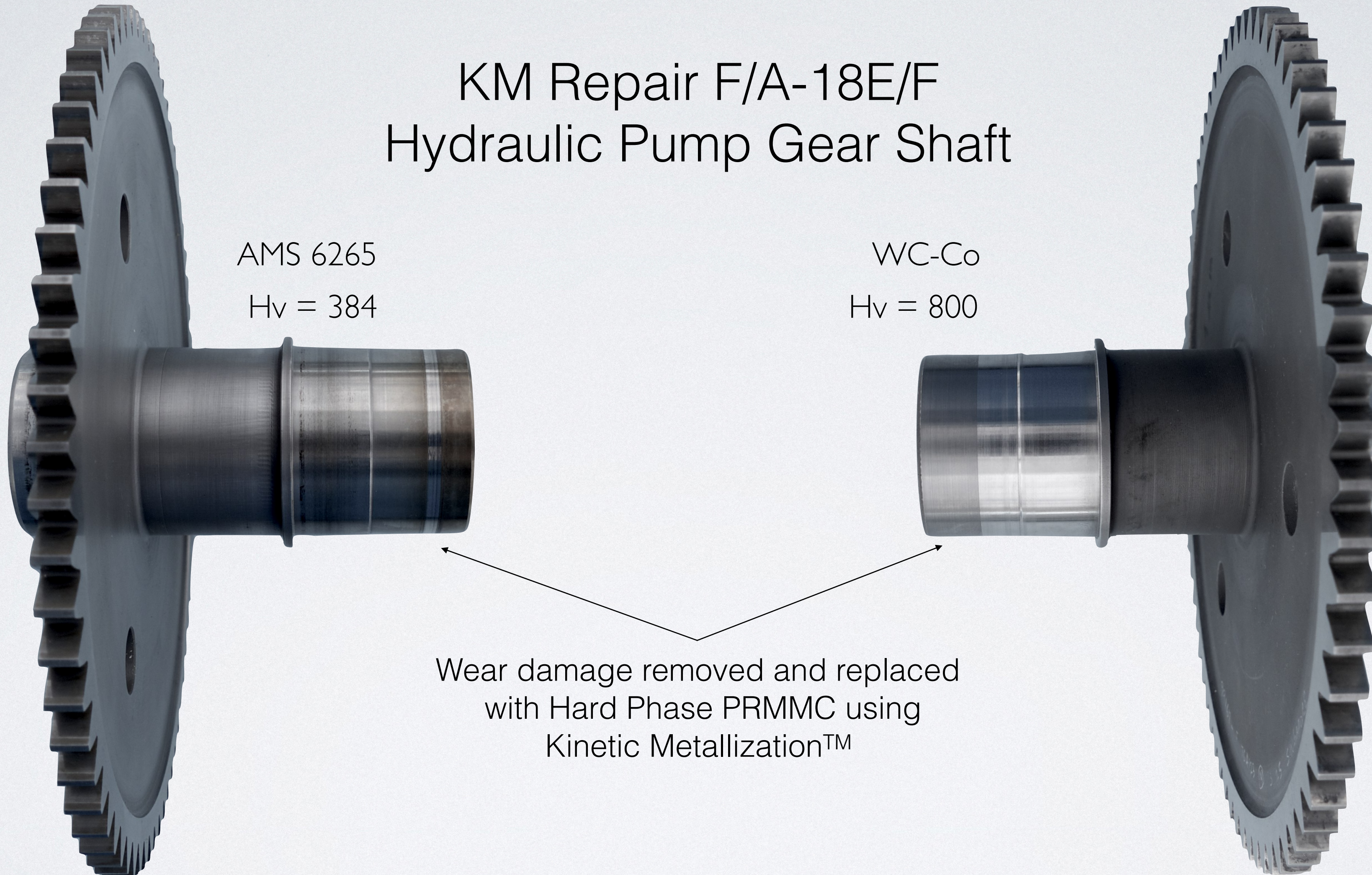


❖ KM AI-Trans® IVD Repairs

KM Repair F/A-18E/F Hydraulic Pump Gear Shaft

AMS 6265
Hv = 384

WC-Co
Hv = 800



Wear damage removed and replaced
with Hard Phase PRMMC using
Kinetic Metallization™

ACCELERATED WEAR TESTING

	Hours of Accelerated Wear	Surface Roughness (Ra) (μ -in) Before	Surface Roughness (Ra) (μ -in) After
OEM Gear AMS 6265	22	18-20	>200
Chrome Plate	21	4-5	>200
KM WC-Co	61	2-3	16-17

