Cincinnati Thermal Spray, Inc.

An Overview of Thermal Spray Processes

American Galvanizer's Association

TECHFORUM, New Orleans

10-4-16

Robert K. Betts, P.E. The VERY IDEA !, LLC

THE THERMAL SPRAY PROCESS

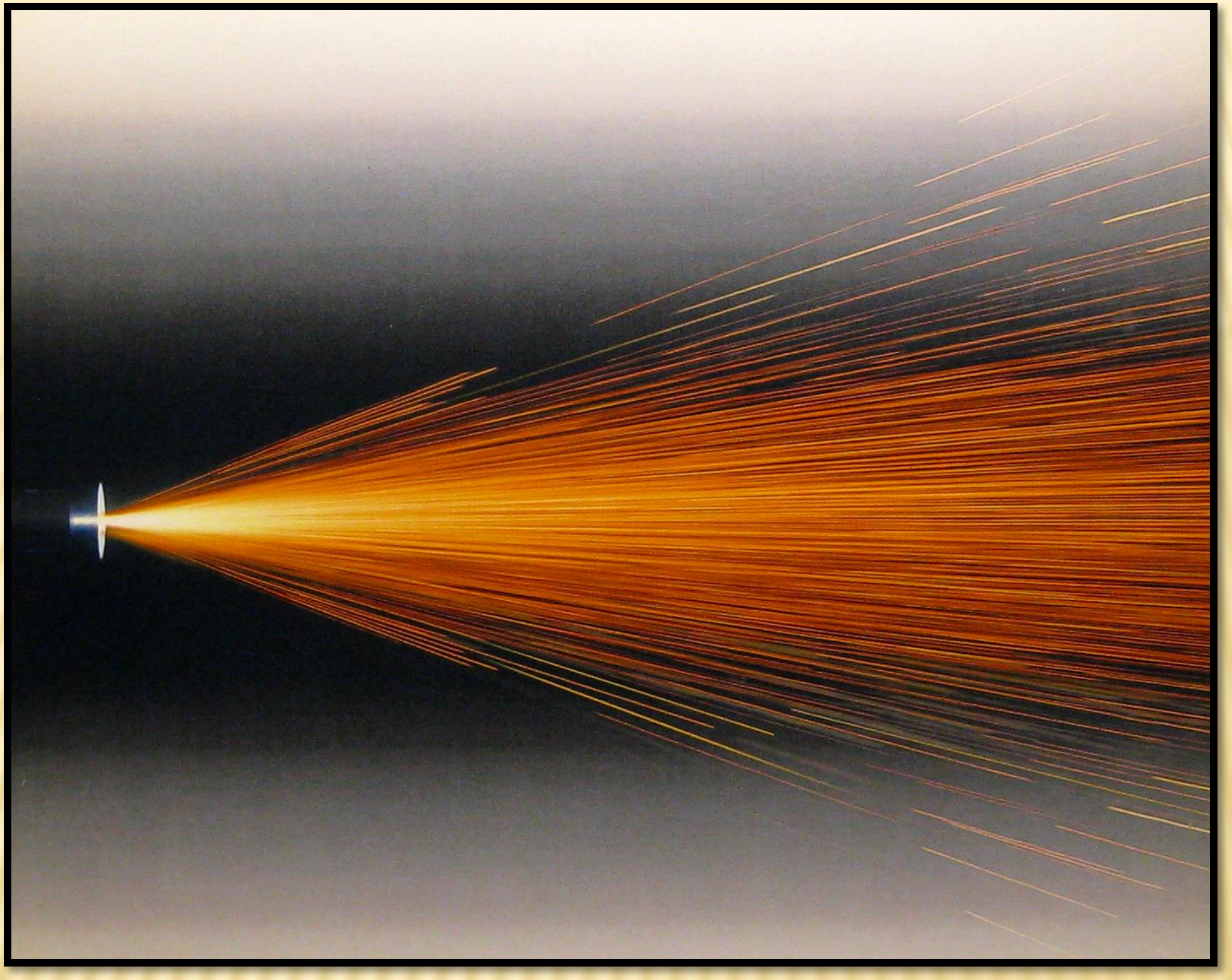
It is unlike any other coating method !!

Essentially the functional principles are:

A. Melt particles of metallic and/or ceramic materials

B. Project particles onto a surface where they adhere and solidify to form a coating

C. Utilize spray devices which generate a very high velocity gas jet and temperature adaptable to coating component surfaces



Visual Dynamics of Thermal Spray

Heat coloration and kinetic trajectories of molten particles

THE THERMAL SPRAY PROCESS

Interesting functional principles adapt

[1] **Spray System features** and

[2] **Material Characteristics** to

Produce coatings which

PROTECT

IMPROVE

RESTORE

Functional Requirements of parts to be coated.

THE THERMAL SPRAY PROCESS

This presentation will discuss:

1. **Brief background of Thermal Spraying**
2. **Fundamentals of the Thermal Spray process**
3. **Coating characteristics and properties**
4. **Materials and thermal spray devices**

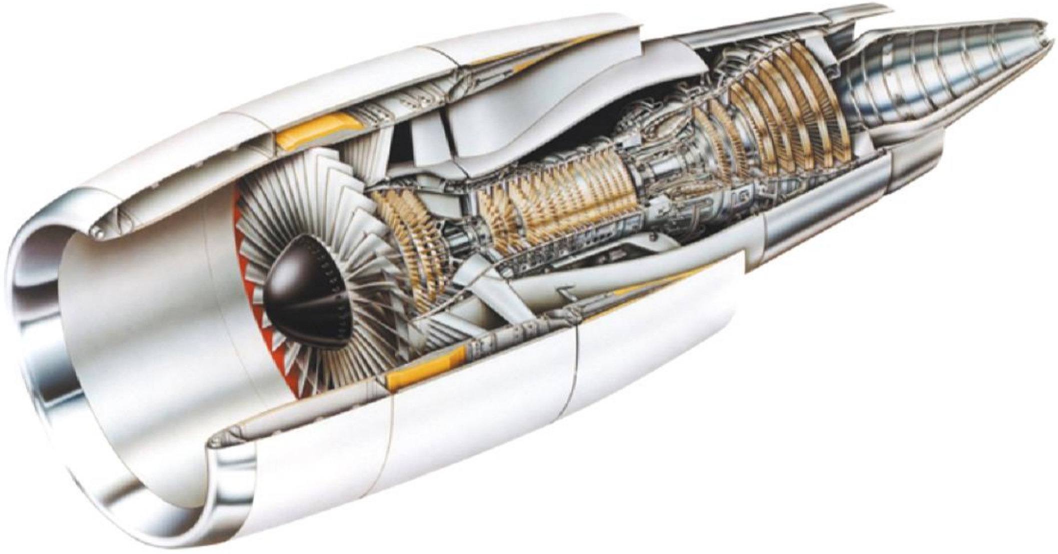
as it is adapted to Galvanizing Operations.

THE THERMAL SPRAY PROCESS

PART 1

Brief background of Thermal Spraying

Cincinnati Thermal Spray



General Electric CF6 Commercial Turbofan Engines

--- FOUNDATION of CTS' expertise & diverse business ---

Classified by Aerospace and other industries as a **Special Process**

Requires **ISO 9001 quality system compliance** for Equipment, Materials, Procedures, as well as

Certification of personnel and product.

INDUSTRY RECOGNITION

THE THERMAL SPRAY PROCESS

PART 2

Thermal Spray Fundamentals

OVERVIEW

Principles of Thermal Spraying

I. Any ADAPTABLE MATERIAL may be Thermal Sprayed

Includes: *Metallic*, *Ceramic* or *Polymeric* materials having *useful physical & chemical properties* – and will :

- *Melt* to form sprayable particulates in a hot gas jet
- *Adhere* by impact onto a surface, forming a coating
- *Re-solidify* with desired engineering properties

II. Any SURFACE MATERIAL may be Thermal Spray Coated

Metallic, *Ceramic*, *Polymer*, *Glass*, *Paper* – that :

- Has *line-of-sight access* to the spray stream
- Can be *cleaned and textured* for adherence
- Will *not be degraded* by the heat and stress

OVERVIEW

What are some Applications?

- Aircraft jet engines - blades, vanes, combustors
- Steel Mill - galvanize, aluminize, furnace , bridle rolls
- Steel Caster - copper narrows and broadfaces
- Power Generation Turbines – Steam Turbine Systems
- Automotive– shifter forks , valves, rings, cylinders
- Aircraft Structures - flap actuators, landing gear
- Ships - container conditioner compressors
- Medical Prostheses - surgical devices - implants
- Paper Mills - chippers - tanks - driers - rolls –
- Petro-Chemical Plants - pumps, compressors, valves

OVERVIEW

What are some Specialized Functions ?

- Wear Resistance
- Corrosion Protection
- Erosion Resistance
- Restoration/Repair
- Molten Metal resistance

THE THERMAL SPRAY PROCESS

PART 3

Coating Characteristics & Properties

What are some Specialized Materials?

METALS

Pure

Aluminum
Copper
Zinc

Alloys

Cu-Ni-In
Ni-Cr   Co-Mo
Plain C-steel
Stainless Steel

CERAMS

Oxides

Alumina
Chromia
Zirconia-Yttria

CERMETS

Carbides

WC-Co
CrC-NiCr
TiC-Ni

POLYMERS

Plastics

Ekonol
Teflon
Polyethylene

BLENDS/COMPOSITES

Ni-Graphite
Al-Polyester

LUBES

MoS_2
Graphite
Oxides

SEALERS

Na-K Silicates
Boron nitride
Epoxy

STEEL STRIP GALVANIZING / ALUMINIZING

Potential benefit of Thermal Spray Coating for Galvanize Line Maintenance

> Molten galvanizing of steel alloy strip involves fundamental metallurgical diffusion reactions which form Fe-Zn and Fe-Al metalides

> Vital reaction bonds the functional ZnAlSi alloy layer, initiates the robust galvanize coating.

> At pot liquid temperature ~850^{0}F, diffusion is fast and thin, during the 9-sec strip passage.

STEEL STRIP GALVANIZING / ALUMINIZING

Diffusion: a two-edged sword for productivity

> Submerged fixtures, baskets, rolls, etc., are *continuously reacted*, forming thick, brittle Fe-Zn-Al metalide surface layers.

> Structural metals dissolve, loading-unloading wear away this re-forming metalide layer.

> Equipment must be replaced, affecting productivity.

STEEL STRIP GALVANIZING / ALUMINIZING

Equipment life can be effectively extended by Thermal Spray coatings

> Coatings are essentially inert to molten metal, retaining structural integrity for longer production campaigns.

> Coatings are beneficial to structures for batch dipping and electrolytic galvanizing.

Cincinnati Thermal Spray

THERMAL SPRAY PROCESS

Part 2

Coating Principles

THERMAL SPRAY PROCESS

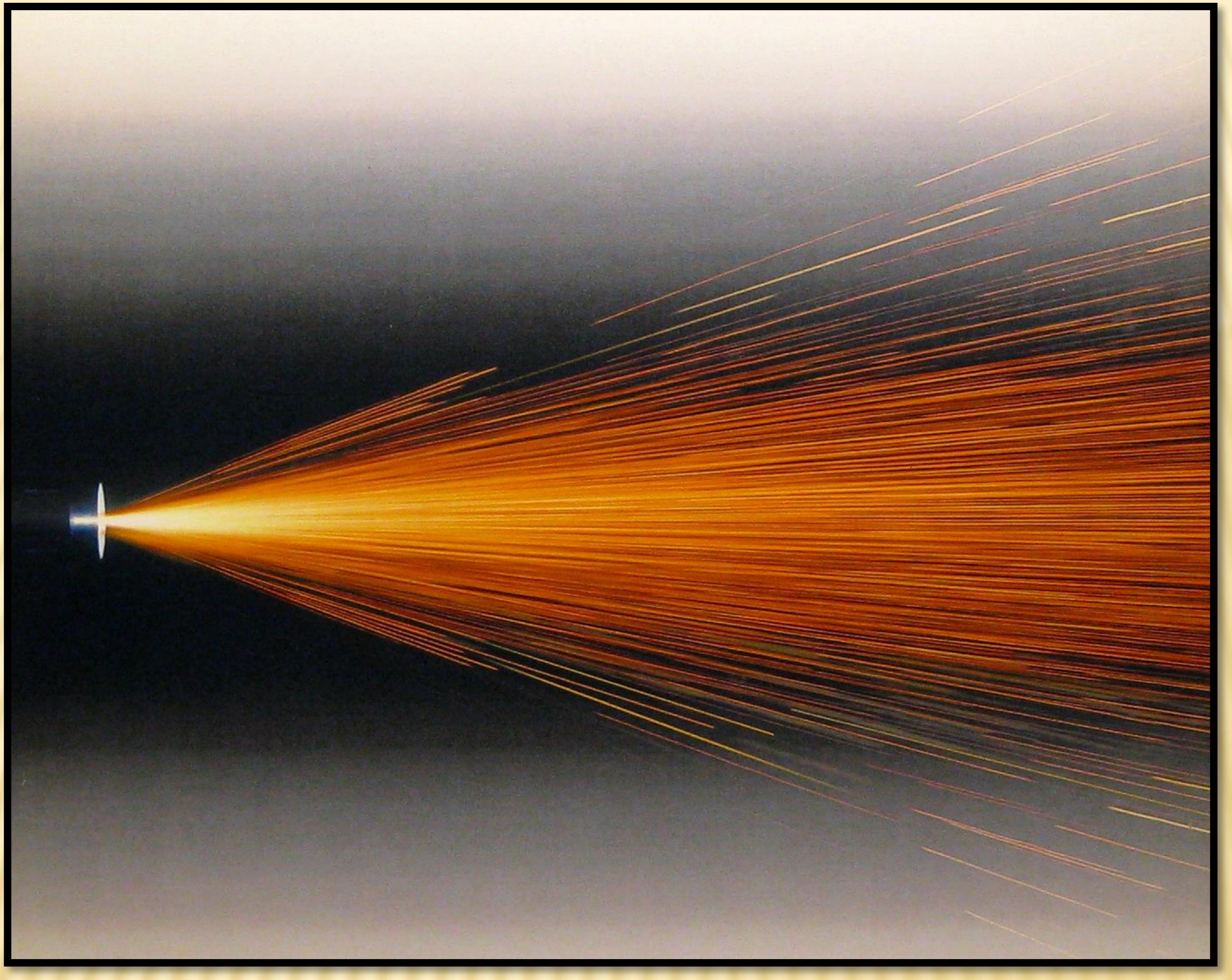
THE FUNCTIONAL FORCE: HEAT *ENERGY*

Process uses **Heat Energy** to melt coating material

Burning Fuel
Electric Arc

Converts to **Kinetic Energy** to spray melted particles onto a surface

High Velocity Gas Expansion Jet
Spray Devices



Visual Dynamics of Thermal Spray

Heat coloration and kinetic trajectories of molten particles

THERMAL SPRAY PROCESS

What are the Heat (Thermal) Sources?

Combustion Flame	Electric Arc
Heat from Burning a *Fuel Gas* with *Oxygen*	Heat Energy Transfer by *Electrical Resistance*

Flame | HVOF -- SPRAY SYSTEMS -- Wire Arc | Plasma

HEAT does Two Things:

1. Expands Gas, producing High Velocity Jet Stream.
2. Softens & Melts the Material to be Sprayed.

THERMAL SPRAY PROCESS

Unique Coating Structure !!

- Starting material usually powder. Particles 10 - 200µm.
  - Softened, melted, and projected by the hot gas jet.
  - Similar to paint spraying, but far more dynamic and complex.
  - Involves Micro and Macro phenomena
- Visualize particles as *CLAY BALLS* thrown at brick wall.
  - Rough brick is like grit blasted surface preparation of parts.
  - Clay balls flatten, stick to brick, and to each other.
  - Physical interlocking forms a Mechanical bond.

> No chemical / metallurgical fusion reaction <

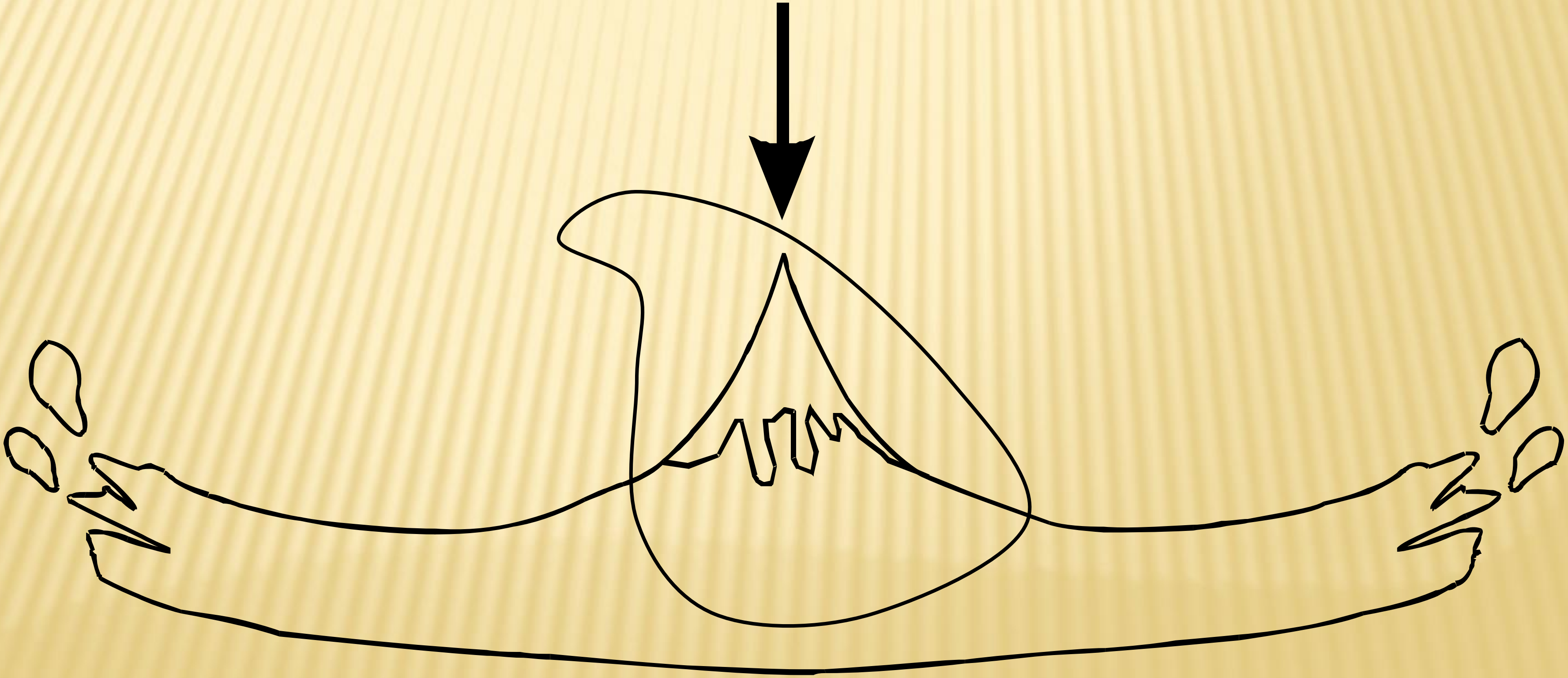
Physical and van der Waals atomic force adhesion

Profound technical word describes this particle impact:

THERMAL SPRAY PROCESS

Profound Mechanism

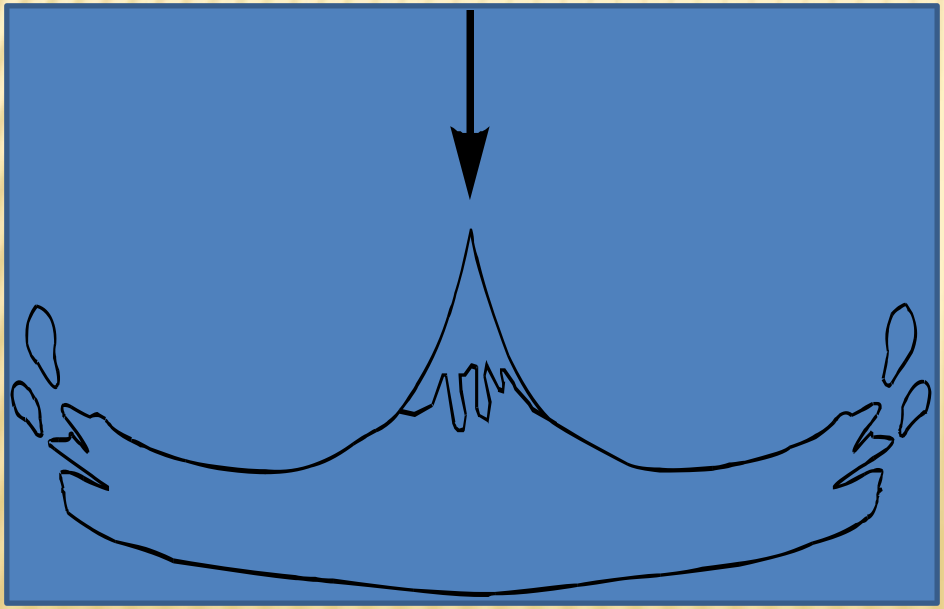
SPLAT !!



THERMAL SPRAY PROCESS

SPLAT

!!



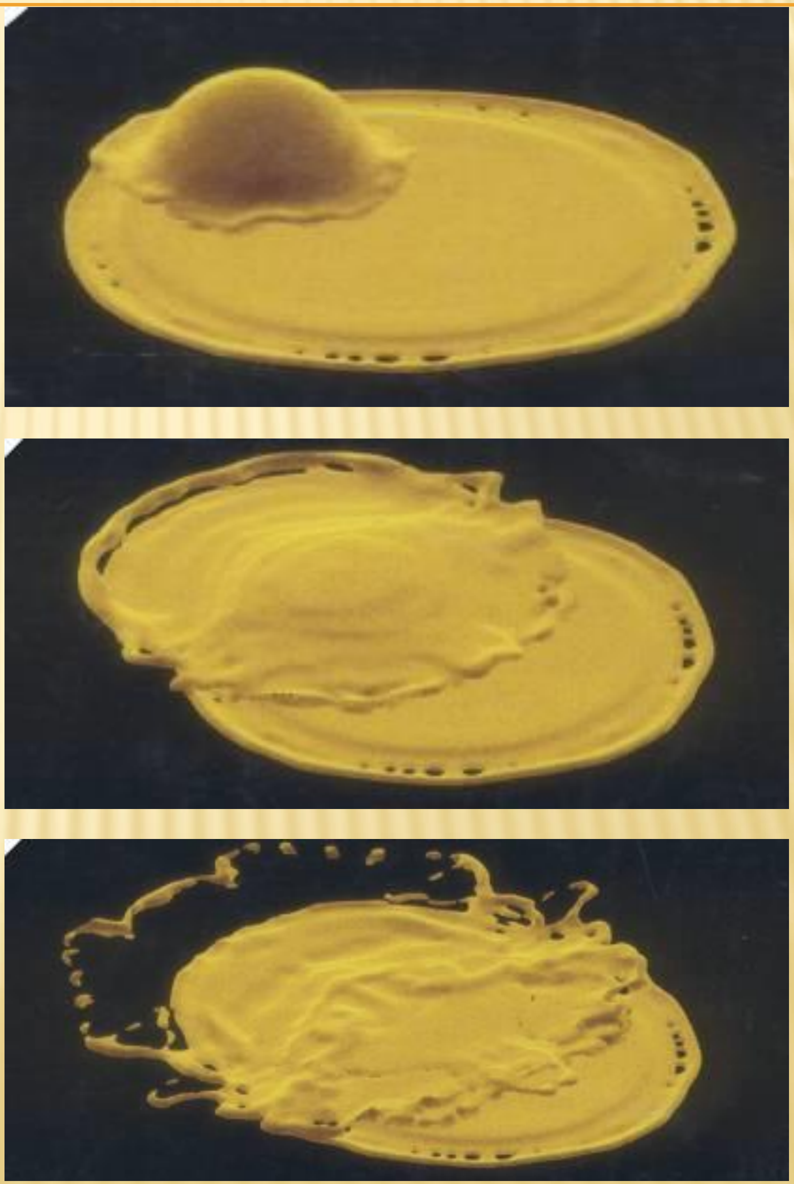
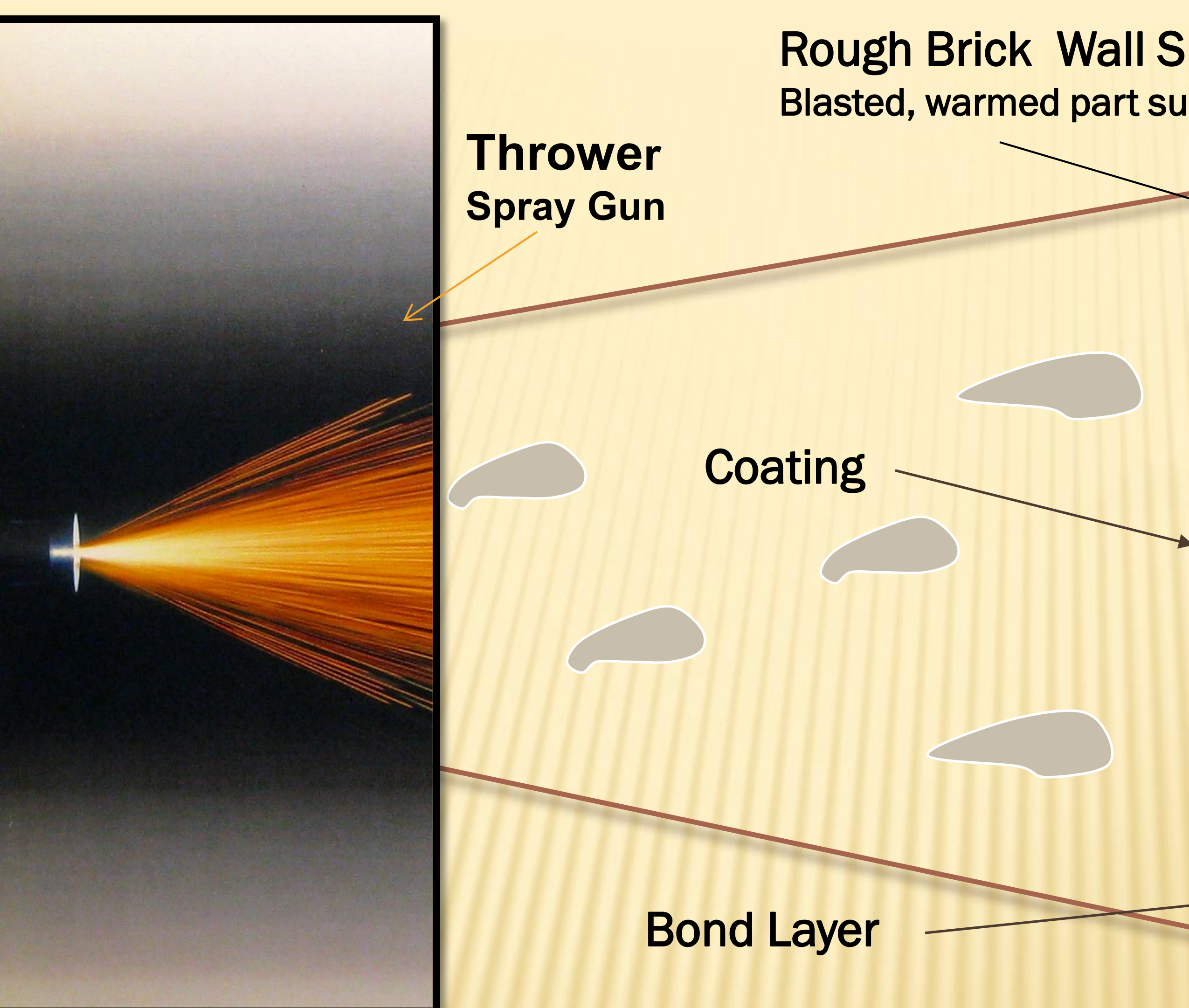
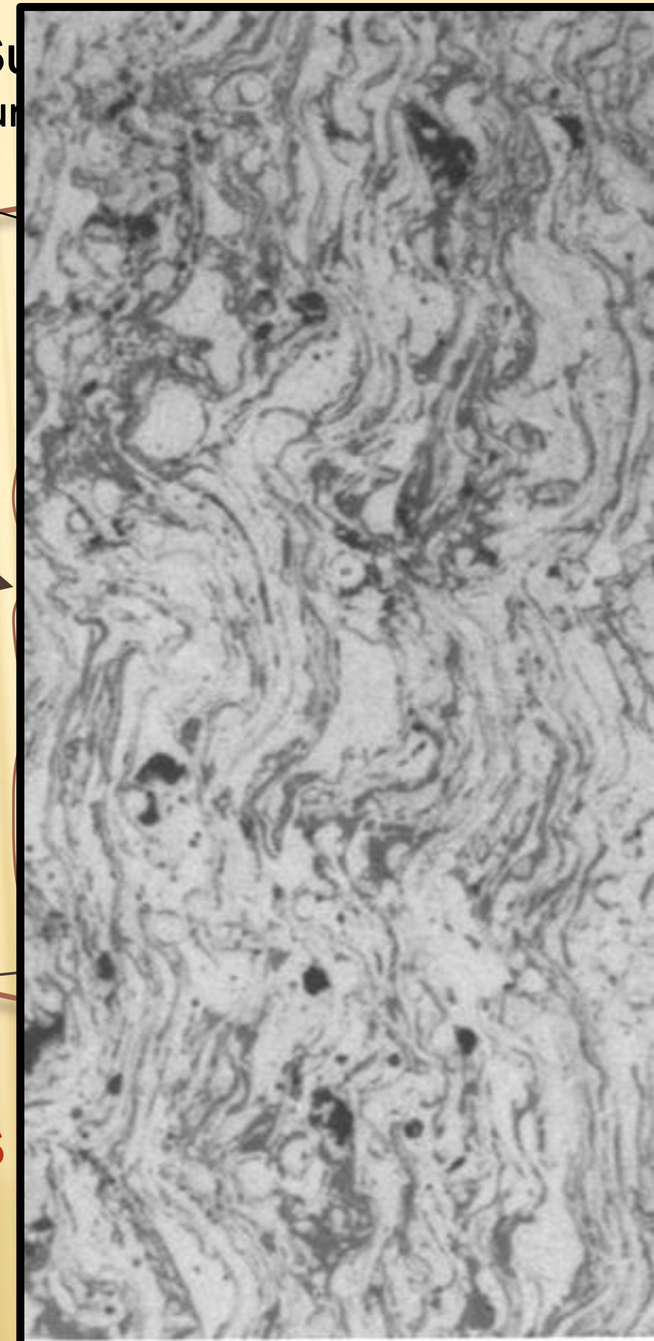
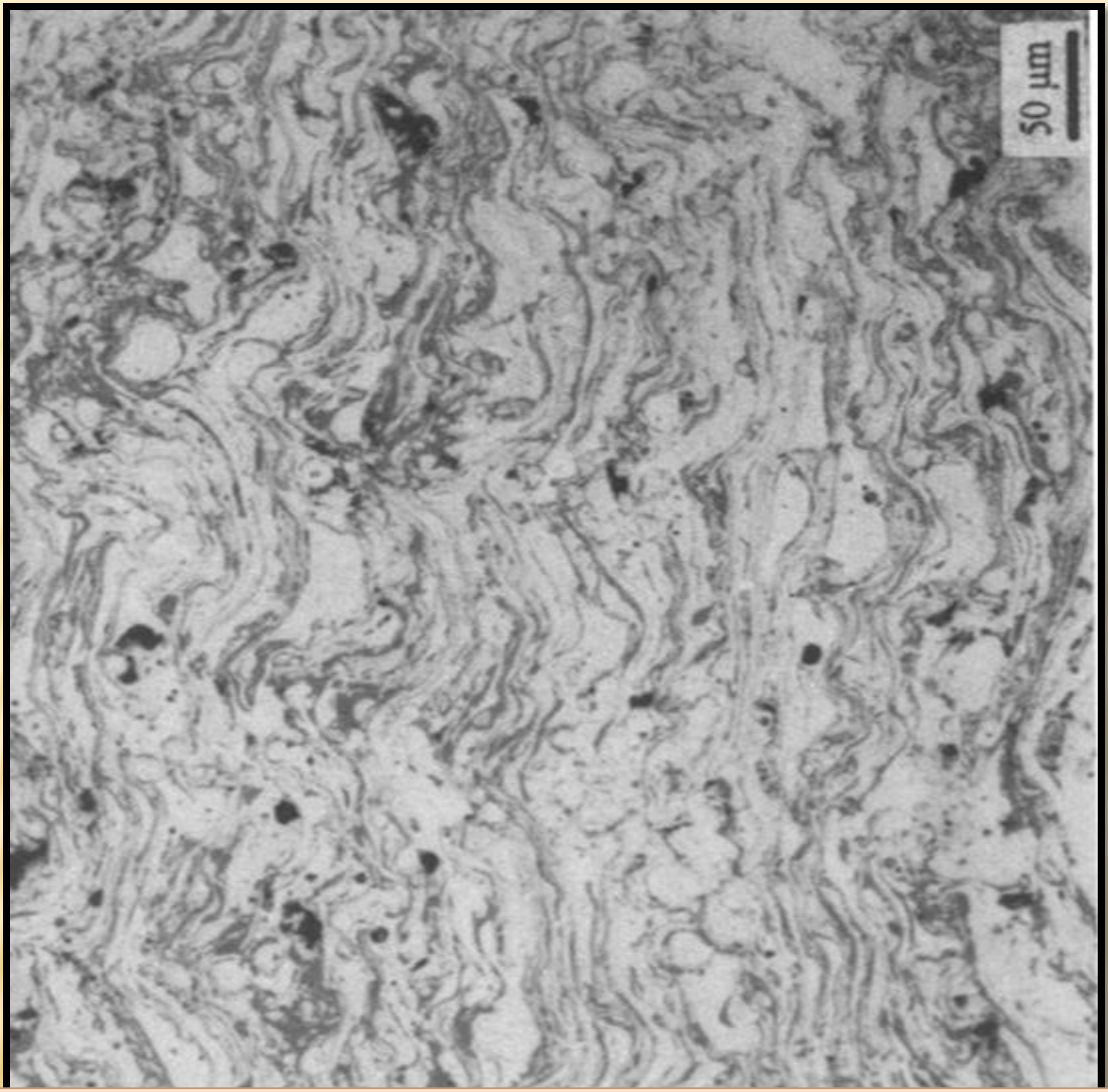


Photo J. of Thermal Spray Technology, Sep. 1999
Mostaghimi, Psasandideh-Fard, Chandra, and University of Toronto.





Analogy of Clay Balls, Brick Walls
Basis for Characterizing Coating



Thermal Spray Coating MICROSTRUCTURE

Quality System Certification

ISO

International

Standards

Organization

TÜV USA

Member of TÜV NORD Group

CERTIFICATE

TUV USA Inc.

Accredited under the Aerospace Registration Management Program

hereby certifies that

Cincinnati Thermal Spray, Inc.

5901 Creek Road

Cincinnati, OH 45242

has established and applies
a quality system for the

Coatings, Technology, Solutions for Aircraft Engine, Land Based Turbine, Automotive, Industrial Equipment, Medical, Steel and other Commercial Markets.

(Exclusion 7.3 Design and 7.5.1.4 Post Delivery Support)

Proof has been furnished that the requirements according to

ISO 9001:2008/AS9100C

are fulfilled.

COATING QUALITY

WHAT ARE COATING CHARACTERISTICS AND PROPERTIES?

Physical
- Thickness
- Porosity
- Layering
- Cracking
- Texture
- Uniformity

Mechanical
- Adhesion
- Cohesion
- Hardness
- Erosivity
- Ductility
- Cyclic

Engineering
- Expansion
- Conductivity
  - Thermal
  - Electrical
- Modulous
- Wear
- Chemical

COATING CHARACTERISTICS

Top Coat

Intermediate Blend Layers

Bond Coat

Each having functional Structures

Physical & Mechanical Properties

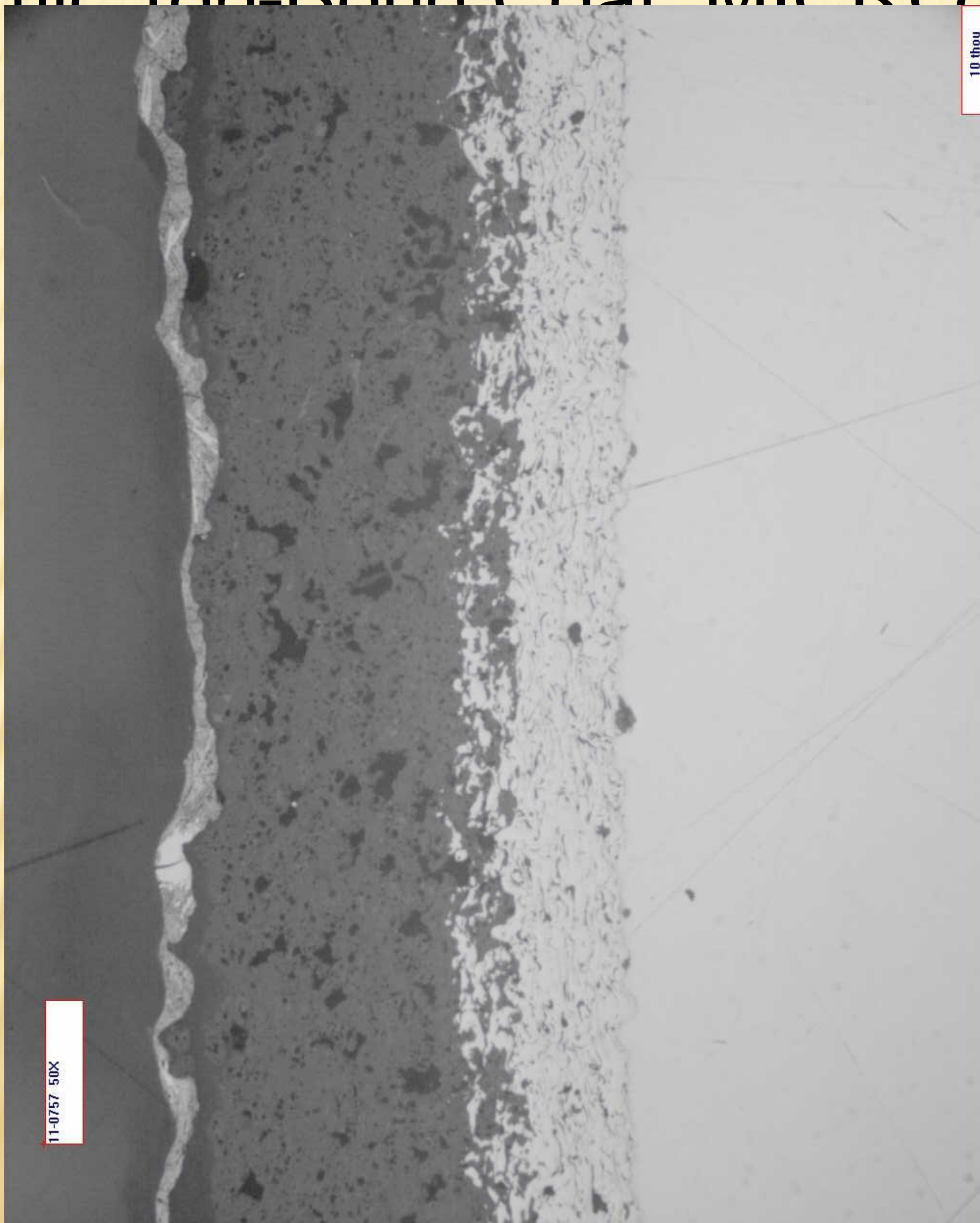
THERMAL SPRAY COATING QUALITY METALLOGRAPHY

Microstruc ure

50 – 500x magnification

Microstruc urte

Ceramic Top-Bond Coat MICROSTRUCTURE



Mount

Top Coat

Blend Layer

Bond Coat

Grit Blast

Base Metal

ation

MICROMETER THICKNESS

RELEVANT THICKNESS COMPARISONS

	Inch	Mils	mm
Hair	0.001 - 0.002	1 – 2	0.025 - 0.050
Paper	0.003 - 0.004	3 – 4	0.077 - 0.100
Playing Card	0.010 - 0.012	10 – 12	0.254 - 0.310
Credit Card	0.030 - 0.040	30 – 40	0.770 - 1.000
Book Cover	0.100	100	2.54

Conversion reference : 1 = 1000 = 25.4

Hardness - Softness

TENSILE BOND STRENGTH

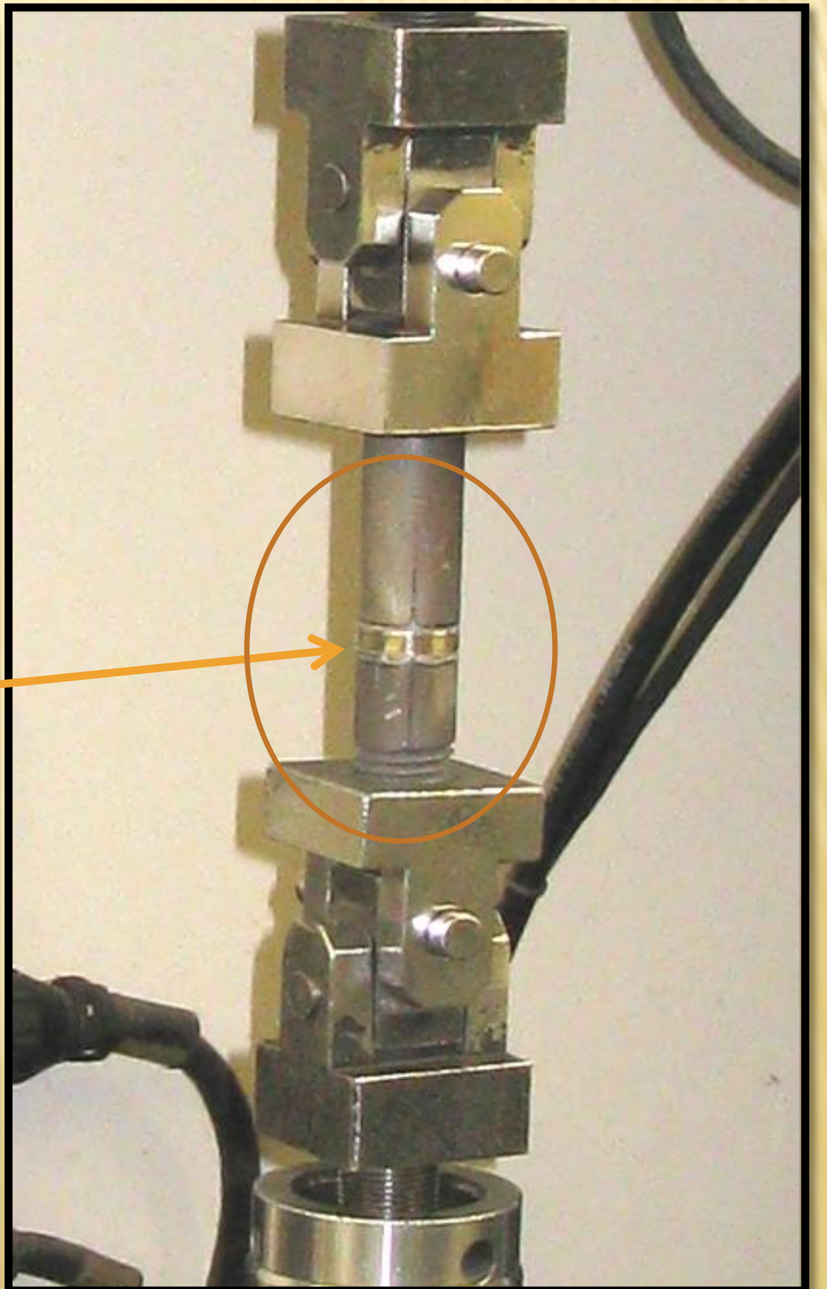
Adhesion – Bonding of Coating to Surface

First layer of individual particles that actually splat onto, and stick to the part surface.

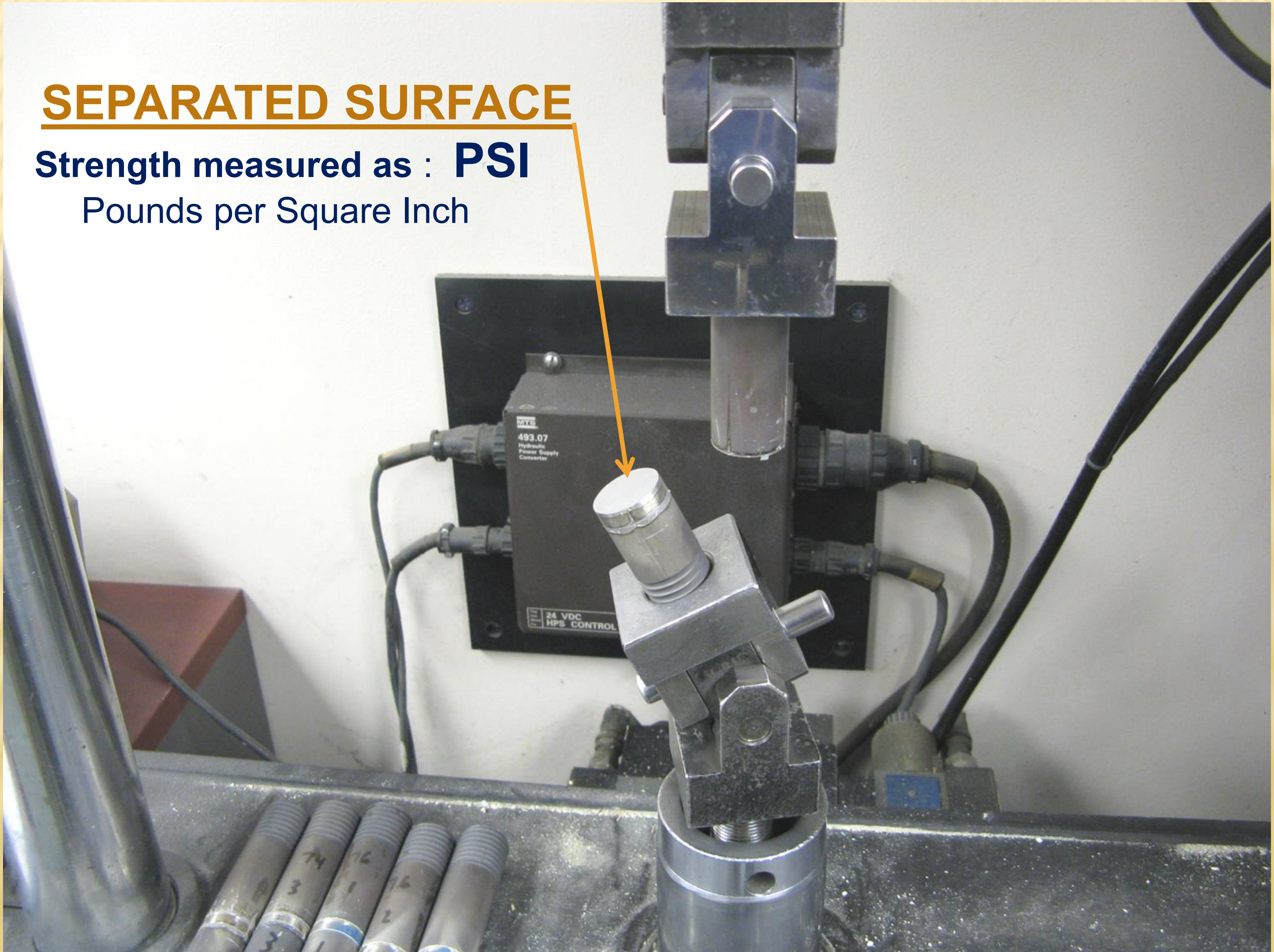
Cohesion – Inter-particle Bonding of Coating

All other particles splat and attach to previous layers of the coating itself, as thickness builds.

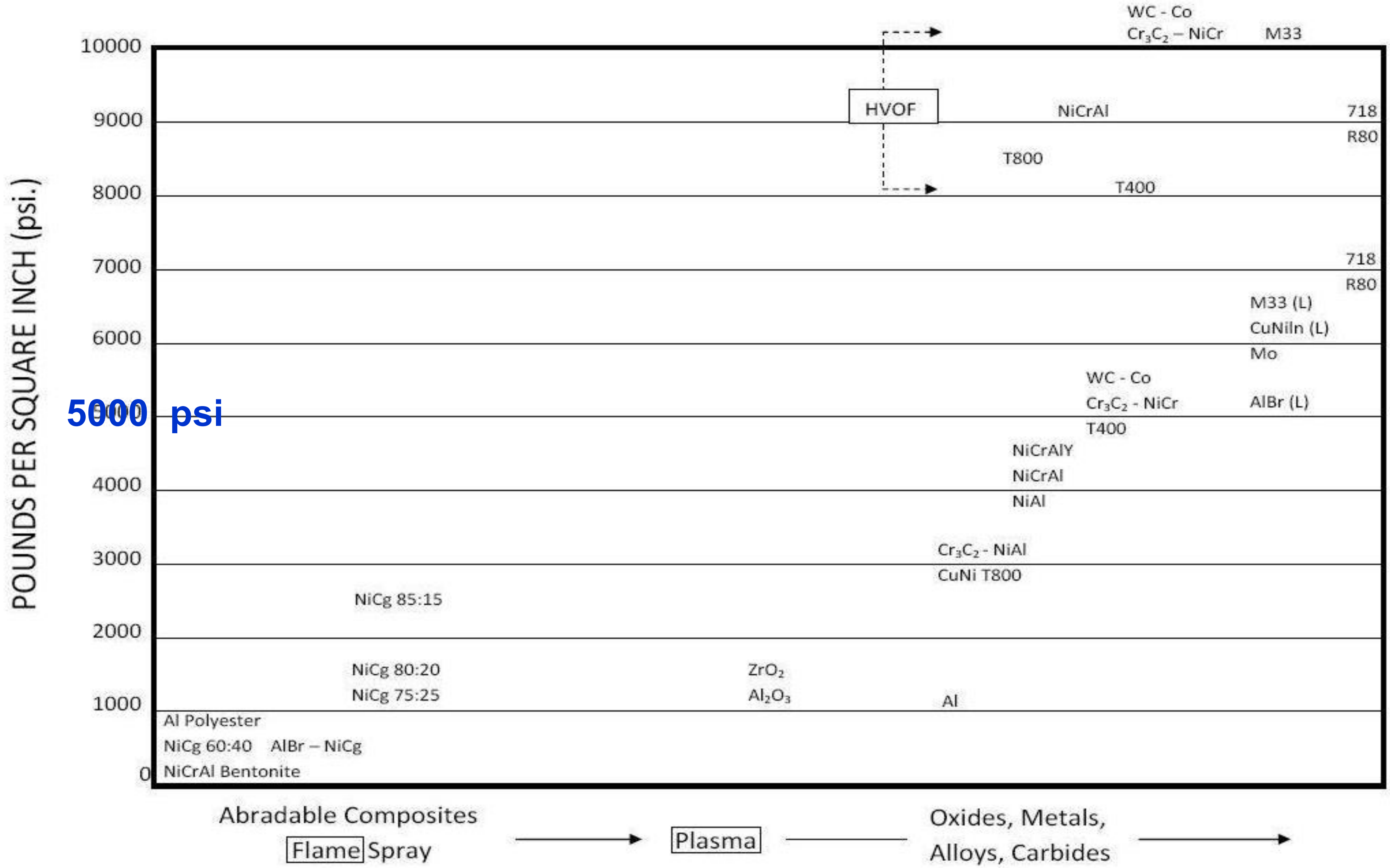
Tensile Test Machine



Pulled Tensile Specimen

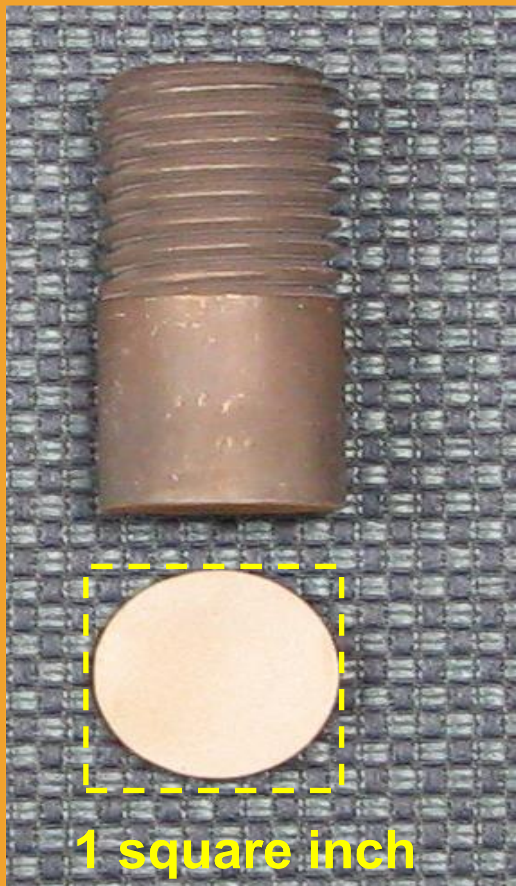


COATING BOND STRENGTHS



WHAT IS A RELEVANT BOND STRENGTH COMPARISON?

5000 PSI, *POUNDS PER SQUARE INCH*



(approx.)

5000 lbs., 2.5 Tons

5000 pounds pull

2 ½ ton pick-up

THE THERMAL SPRAY PROCESS

Part 4

Thermal Spray Materials and Spray Application Devices

THERMAL SPRAY PROCESS

What are the HEAT Sources for Thermal Spraying ?

Combustible Gas

Heat from Burning a

Fuel Gas *with Oxygen*

CHEMICAL

Electrical Energy

Heat generation/transfer

by I^2R Arc Resistance

PHYSICAL

Flame

HVOF

SPRAY SYSTEMS

Wire Arc

Plasma

STOICHIOMETRY

Ideal max temperature & mass efficiency of combustion flame

ENTHALPY

BTU 'Heat Content' of a Reaction

THERMAL SPRAY PROCESS

What are the Basic Thermal Spray Systems?

FLAME | HVOF | WIRE ARC | PLASMA

Systems Have in Common:

- Internal Heat Energy Generation Device (‘gun’)
- Nozzle to Form & Direct the Kinetic Gas Jet
- Controls & Monitors for Power and Gas Flow
- Powder or Wire Feed systems
- Cooling Water & Compressed Air systems
- Mechanized and Robotic Manipulation

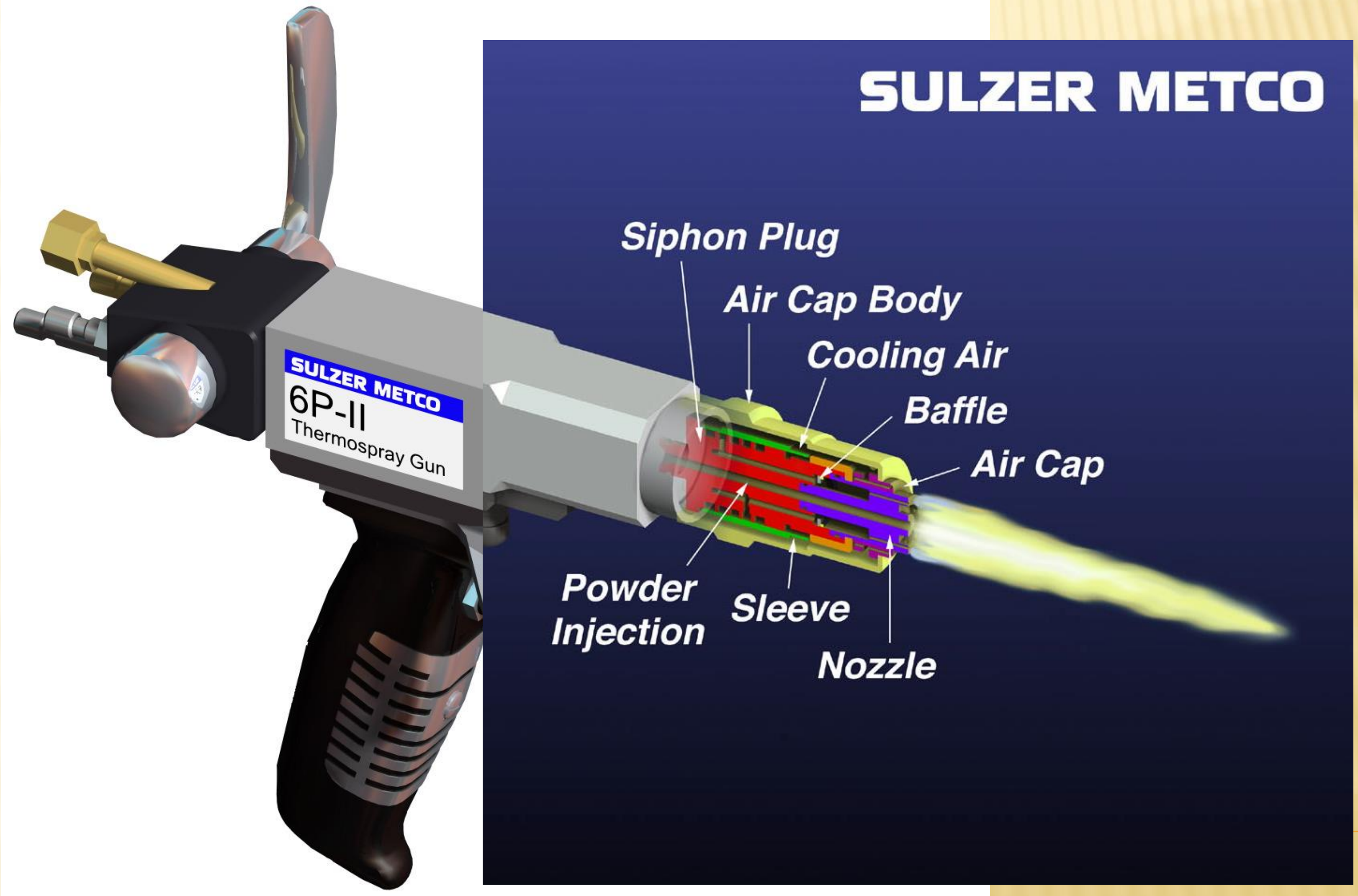
THERMAL SPRAY PROCESS

Thermal Spray Systems

Combustion Flame Spray

- System is a modified oxy-acetylene torch.
- Burns highest temperature fuel gas, 5800 ° F.
- Nozzle design adds aerodynamic velocity to source pressure of gas and heat expansion.
- Material powder, wire, or rod, feeds thru the gun into the nozzle, is melted and sprayed.

COMBUSTION FLAME SPRAY GUN



Combustion Flame Spray Gun

Why Acetylene?

Highest Flame Temperature Hydrocarbon Fuel Gas

Oxy-Fuel Combustion:	°F	Formula
Acetylene	5800	C_2H_2
Propylene	5200	C_3H_6
Hydrogen	3990	H_2
Methane	3810	CH_4
Kerosene	3000	$C_{12}H_{26}$

WHY FLAME SPRAY?

Simple, modified oxy-acetylene torch methodology.

Adaptable oxy-acetylene 5800ºF flame melts all practical materials in powder, wire or rod form.

Easily portable for on-site work, needs only bottle gas, air and basic electricity.

Economical, low cost gases and electric use.

Low velocity spray and deposition rates.

THERMAL SPRAY PROCESS

Plasma Spray Physics

What in the World is…?

PLASMA

4TH Physical State of Matter

colder | hotter

SOLID → LIQUID → GAS → PLASMA

diAtom MOLECULES are SEPARATED **ATOMS are DISSOCIATED**

GAS is *IONIZED* with FREE ELECTRONS and UNSTABLE NUCLEUS

THERMAL SPRAY PROCESS

Plasma Spray

- HEAT is generated by ~ELECTRIC ARC~ inside gun.

NO COMBUSTION--It's PHYSICAL TRANSFER OF HEAT

- INERT GAS flows around **ELECTRODE,** exits thru **NOZZLE**.
- 70 VOLTs DC *energizes an arc* across the electrode-nozzle gap.
- *400 AMPs flow through the gas. Creates **Resistance Heat.***

  I^2R Arc Current heats gas stream to **>10,000°F**

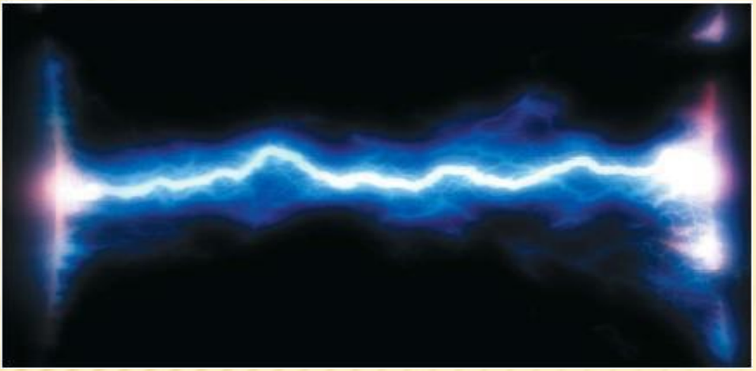
  Thermal Power @ 400 A & 200 Ω = 32 MW

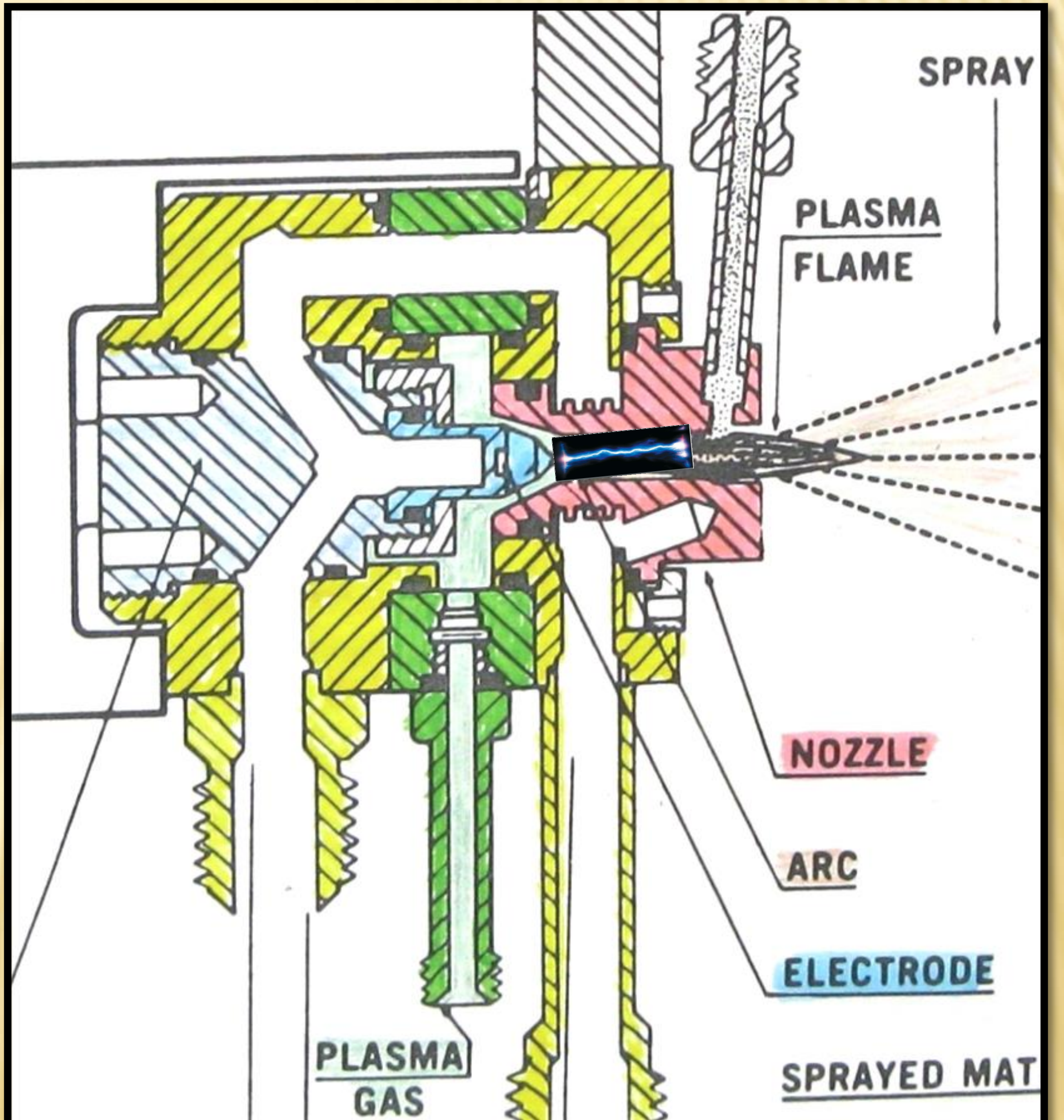
  Gas in the arc path IONIZES, forms the PLASMA state

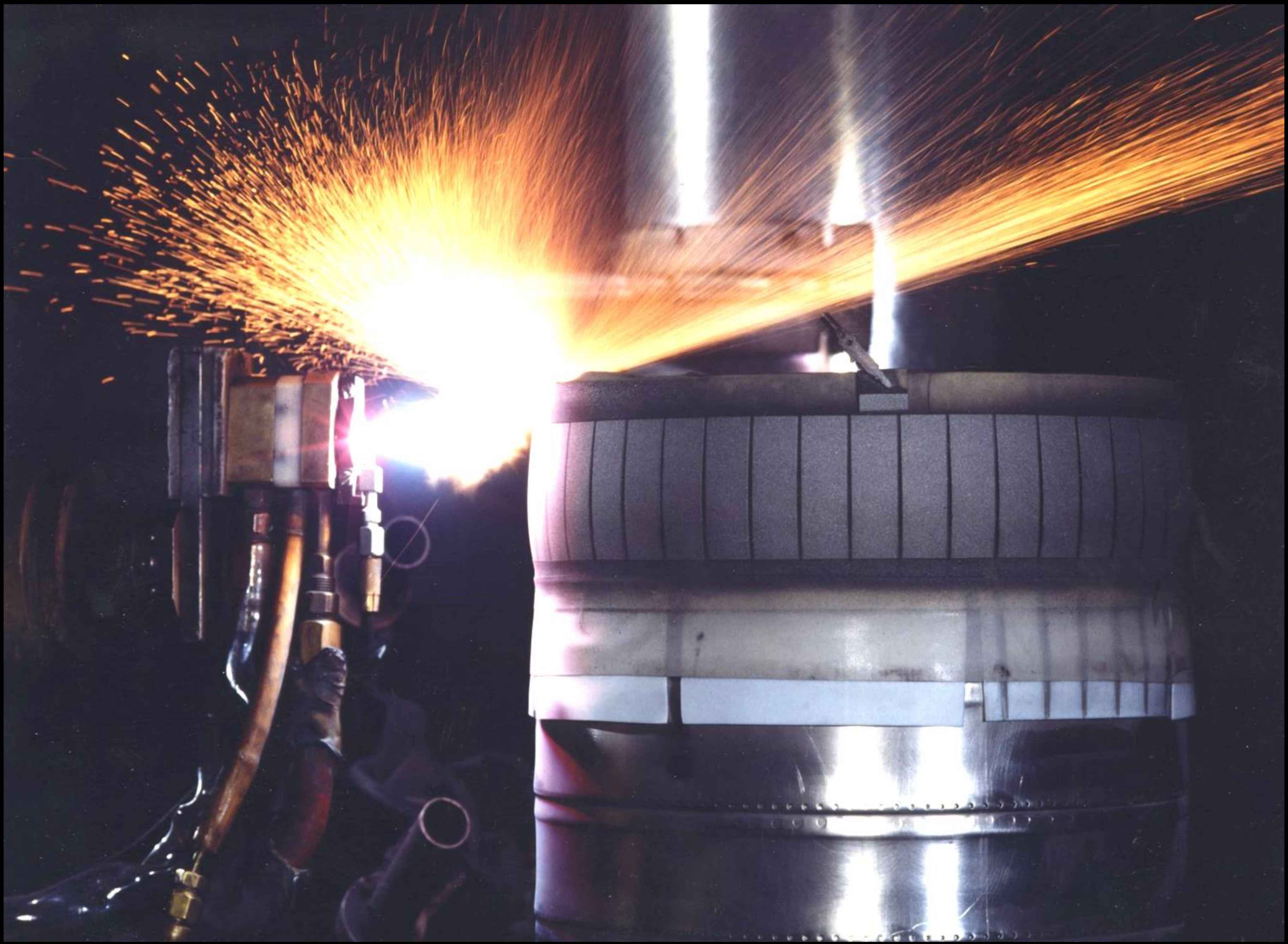
- *SUPER-HOT gas expands violently out the nozzle*. PV=nRT
- *HIGH VELOCITY* gas jet transfers heat and kinetic *energies* to melt and spray the powder injected into exiting *gas jet.*


METCO
Type 3MB-II PLASMA SPRAY GUN
METCO
Type 3MB-II
PLASMA GUN
Metco Division
The Perkin-Elmer Corporation
Westbury, NY 11590
EMERG OFF
POWDER FEED
ON/OFF
METCO
PERKIN ELMER

PLASMA GUN CROSS SECTION







WHY PLASMA SPRAY?

- Plasma produces highest temperature/enthalpy gas jet.

  T H

- T capability to melt any useful engineering material.
- Quantitative Heat input and High velocity enable wide variation of desired coating properties.
- Process capable of high economical deposition rate.
- ARC HEAT results from electrical I^2R amps-ohms.

THERMAL SPRAY PROCESS

Wire Arc Spray

- Electric arc shorting, melting twin wires.
- Spray atomized by compressed gas.
- Nozzle adds aerodynamic gas velocity.
- Sprays metals readily available as wire.
- Sprays cermet composite cored wires.

Electric Arc Short Circuit

Twin Wire Arc Spray Gun

C. WHY WIRE ARC ?

- **Wire *Less Expensive* than sized powder.**
- ***High Capacity* melting energy, feed rate.**
- **Portable for *Off-Site* use.**
- **Overall *Economy* for Limited Materials.**

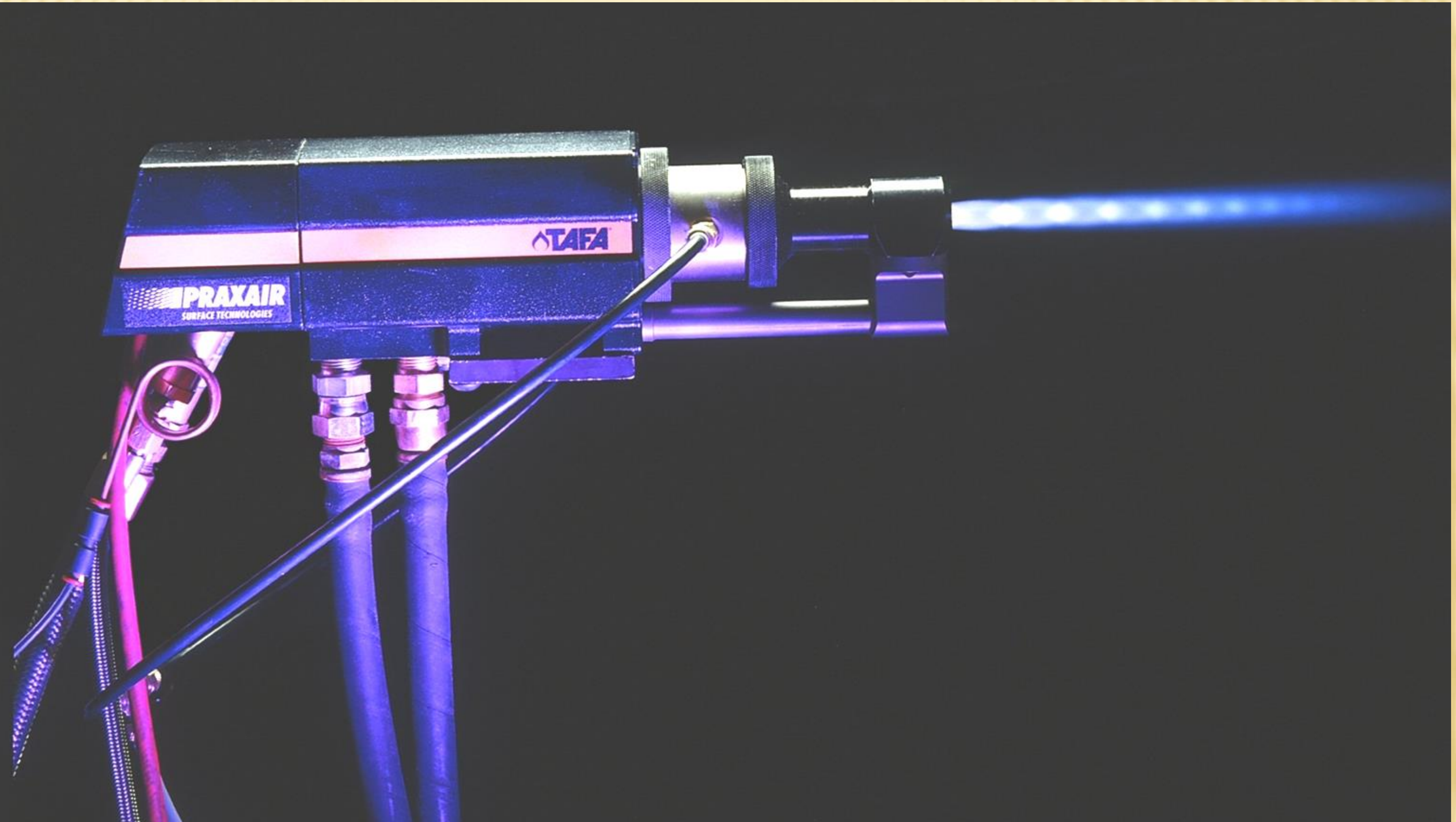
HVOF **Big League Velocity**

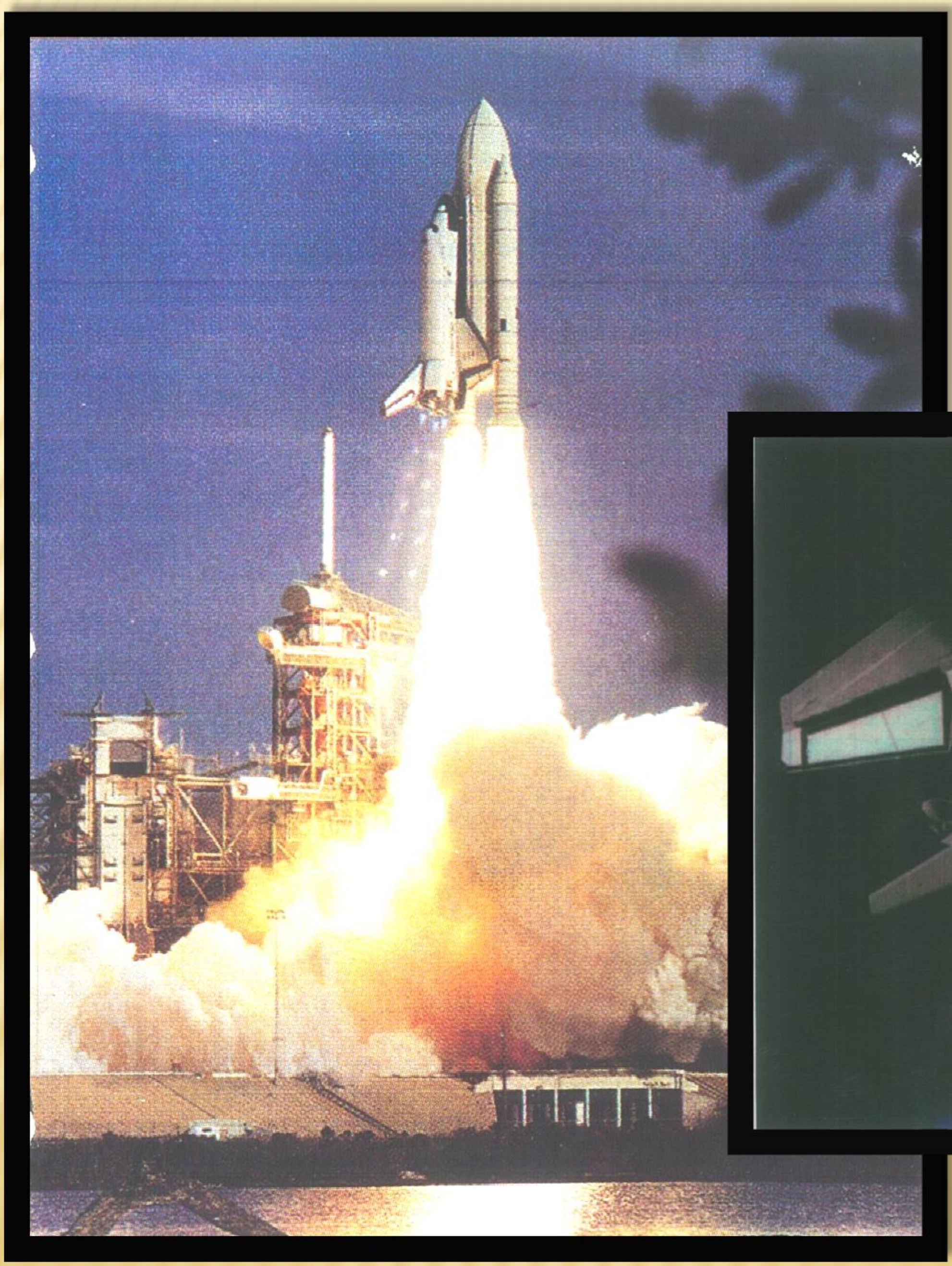
HVOF High Velocity Oxygen-Fuel

- Rocket science for supersonic velocity.
- Combustion of H_2 or kerosene fuel.
- Oxygen for max flame temperature
- Chamber-nozzle design pressure for max kinetic gas jet propulsion of particles.
- Excellent coating adhesion and density.

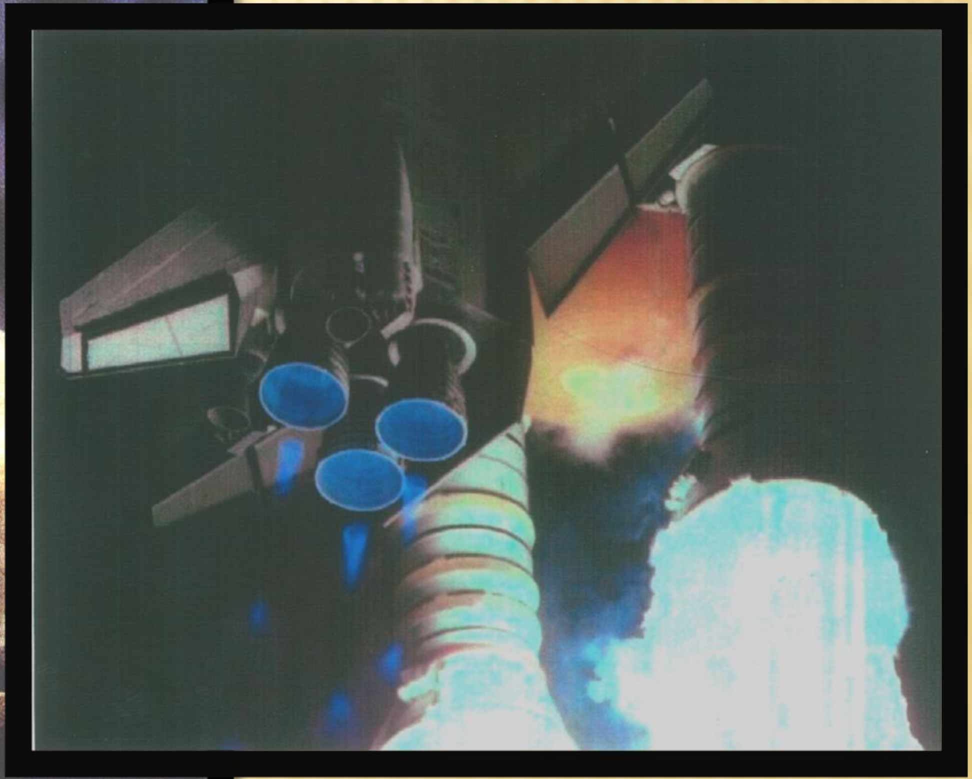
THERMAL SPRAY PROCESS

Supersonic Shock Diamonds **HVOF JP-5000**





Shock diamonds from the Space Shuttle Main Engines



Steam Power!

Why HVOF ?

- Excellent coating characteristics.
- Supersonic particle splatting velocity.
- Strong adhesion.
- High density, low porosity.
- Responds to stoichiometry.

THERMAL SPRAY PROCESS

Adjunct Processes for Coatings

Post-application processes can further enhance primary Thermal Spray coatings

1. **Heat treatment for stress relief and diffusion.**
2. **Sealers as final top coats fill natural inter-splat porosity, adding further corrosion resistance.**
3. **Lubricants of the dry-film type are applied to improve wear resistance.**
4. **Spray & Fuse is a flame type Thermal Spray process used to apply coatings composited for melting point suppression, to promote post-spray diffusion solidification.**
5. **Plasma Transferred Arc adapts plasma arc spraying, wherein the anodic arc is struck to a work surface, melting the flowing powder and surface for a weld-like coating.**

THERMAL SPRAY PROCESS

Thank you for the opportunity

Robert Betts, P.E. ***The VERY IDEA !, LLC***
- rkbetts231@gmail.com

Our Service is Your Solution

Coatings,
Technology,
Solutions

Cincinnati Thermal Spray, Inc.

INTRODUCTION

Cincinnati Thermal Spray, Inc. (**CTS**) is the preeminent provider of coatings, technology and solutions to protect and enhance products for a wide range of industrial uses.

We can help you improve the performance of your components by selectively applying top-quality metal, ceramic and lubricating coatings, and offering component manufacturing.

- Established in 1978
- Offshoot of GE Aircraft Engine thermal spray operation
- Started with aerospace applications only
- Developed additional applications in a wide range of industries
- Among the nation’s most respected and largest thermal spray companies

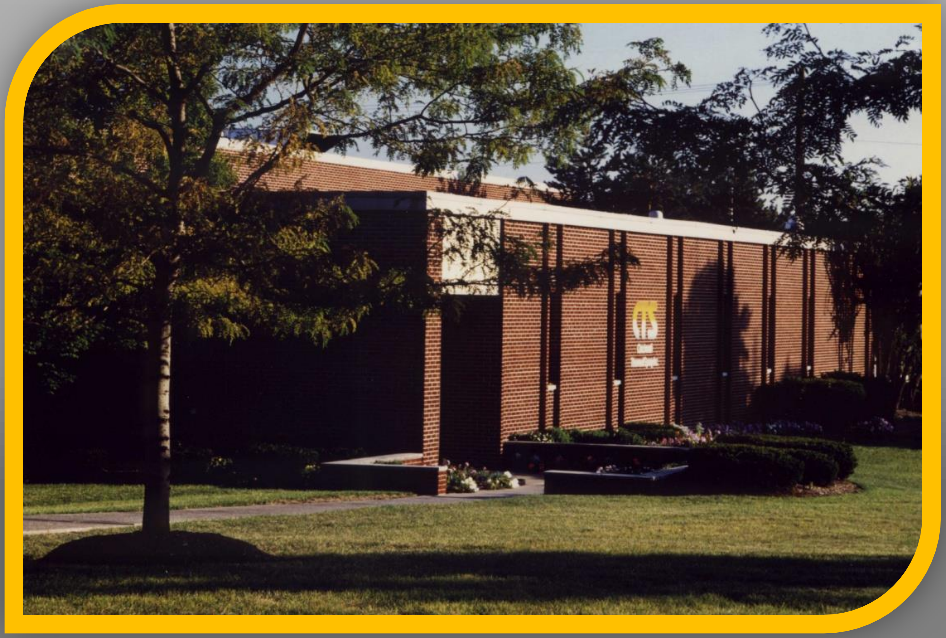
GEOGRAPHICAL LOCATIONS

Our facilities serve customers worldwide

- Cincinnati, OH
- Wilmington, NC
- Springfield, NJ
- Houston, TX

FACILITIES - MIDWEST

- Thermal Spray Equipment
  - Plasma
    - Metco 3M, 9M, 7M
  - Wire Arc
  - Combustion Flame (Wire and Flame)
  - HVOF
    - JP 5000, JetKote
  - Production Painting
  - Dry Film Lubrication
  - Metallographic Laboratory
  - 19 Spray Booths
  - 42, 000 Sq. Ft. Facility
- Quality Certifications
  - AS9100
  - Nadcap (Coatings)
  - ISO 9001
  - FAA CKNR597K



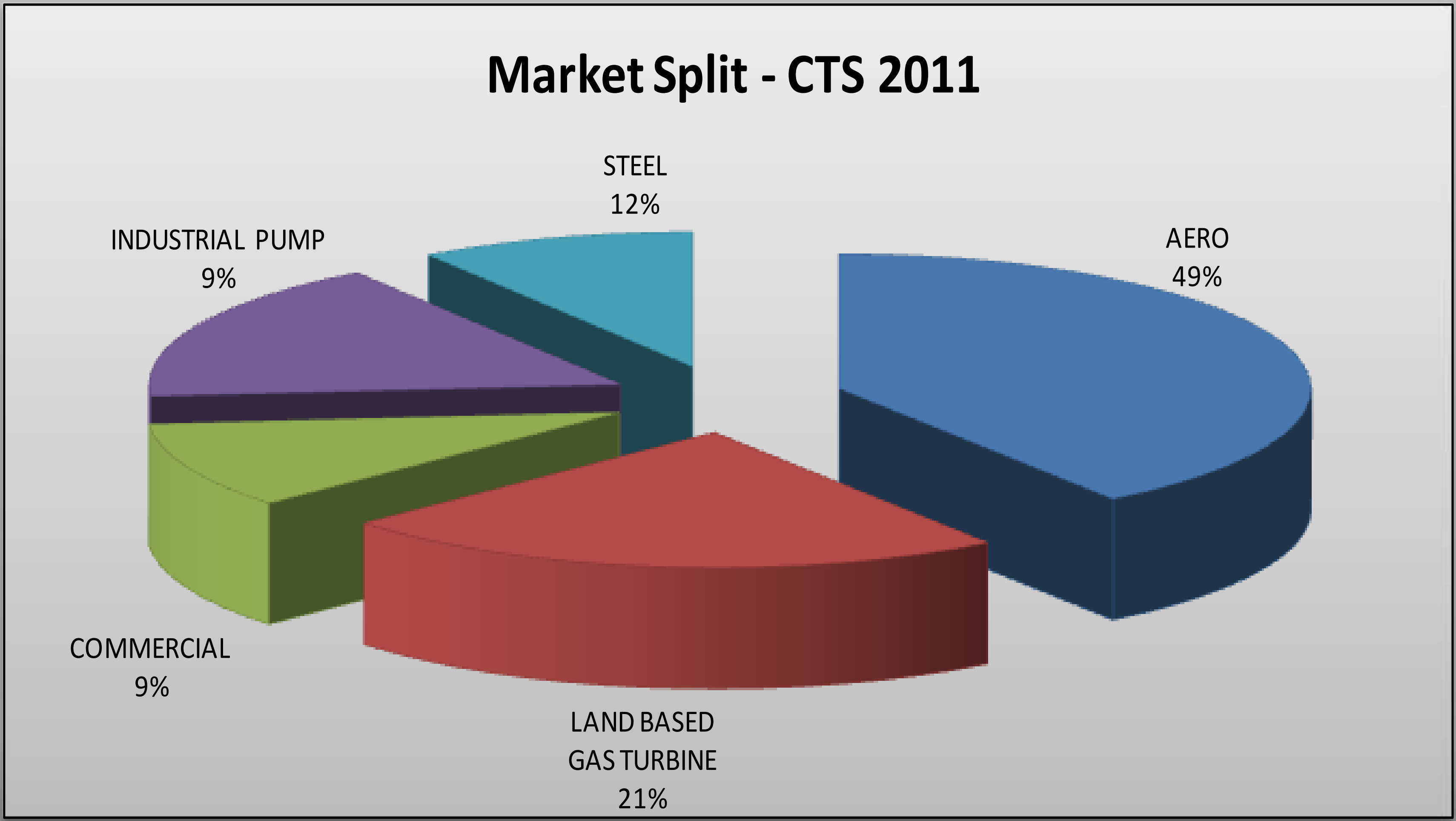
PRIMARY INDUSTRIES

We specialize in component performance enhancement solutions in many industries, including

- Aerospace
- Land Based Gas Turbine
- Steel
- Industrial Pump
- Commercial
- Oil & Gas
- Military/Defense
- Medical Device







Market Split - CTS 2011
STEEL
12%
INDUSTRIAL PUMP
9%
AERO
49%
COMMERCIAL
9%
LAND BASED
GAS TURBINE
21%

AEROSPACE-APPROVED COATINGS LIST

GE Transportation
DSQR inspection approved
CCL evaluation lab approved
F5OTF11
F5OTF13
F5OTF14
F5OTF15
F5OTF18
F5OTF22
F5OTF23
F5OTF24
F5OTF25
F5OTF32
F5OTF45
F5OTF50
F5OTF69
F5OTF71
F5OTF75
F5OTF77
F5OTF83
F5OTF87
F5OTF92
F5OTF94
F5OTF95
F5OTF102
F5OTF107
P16TF5
Resistance welding (tack only)

Honeywell
91547-P6405
EMS52432
EMS52510
EMS52521
EMS52533
FP5045
LHP5111
LHP5113
PNCP52519
PNCP52551

Pratt & Whitney
LCS approved
Grinding of ID, OD, and Flats
CPW 33-13 (SS)
CPW 33-16 (SS)
CPW 33-18 (SS)
CPW 33-37 (SS)
CPW 33-48 (SS)
CPW 33-80 (SS)
PWA 53-1 (SS)
PWA 53-2 (SS)
PWA 53-5 (SS)
PWA 53-15 (SS)
PWA 53-16 (SS & TI)
PWA 53-18 (SS)
PWA 53-33 (SS)
PWA 53-37 (SS)
PWA 74-1 (SS)
PWA 257-1 (SS)
PWA 261 (SS)
PWA 265 (SS)

Rolls-Royce
Molydag Dry Film Lube
EPS 10411
EPS 10414
EPS 10420
EPS 10425
EPS 10436
EPS 10479
EPS 10482
EPS 10483
EPS 10486
EPS 10540
EPS 10550
RPS 386
RPS 392
RPS 427
RPS 576
RPS 592/8
RPS 643
RPS 661

Teledyne Ryan
Thermal barrier coatings
Build-up repairs

Paint and Dry Film Lubricants (GEAE)
A50TF9
A50TF15A
A50TF147 per F50TF33
A50TF171
A50TF201
A50TF279
A50TF305 per F50TF96
A50TF306 per F50TF98
A8B35 sealer
F50TF118
Lube-Lok 2006 to F65A-GP12

FAA Repair Station CKNR597K (Midwest)
Airframe:
Boeing
Lockheed/Martin
Airbus
Powerplant:
General Electric
Pratt & Whitney
Rolls-Royce
Honeywell

FAA Repair Station CKND597K (East)
Thermal spray and machining

Wear Coatings

Chrome plating alternative coating applied to bearing journal.

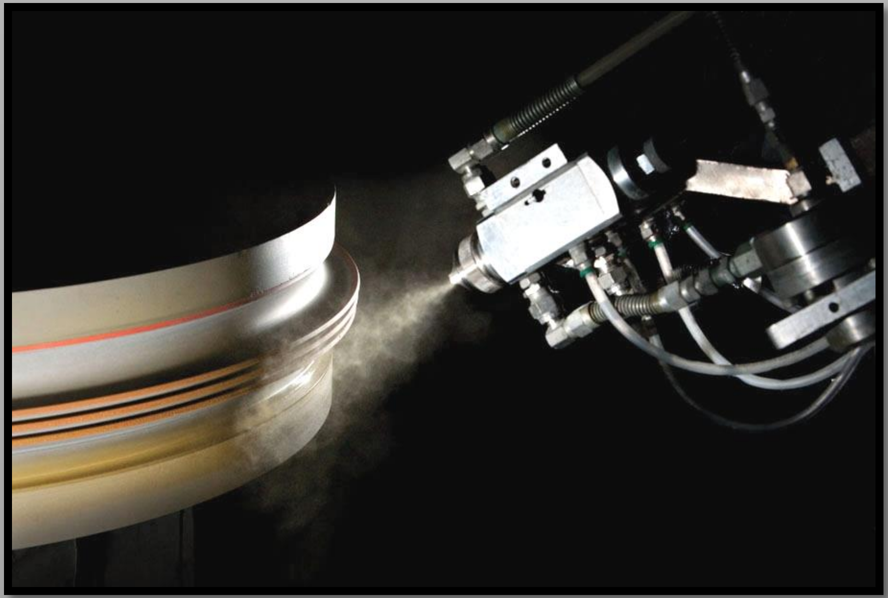
Thermal Protection

Yttria Stabilized Zirconia thermal barrier coating applied to inner combustor ring.

Fan Disk

Copper Nickel Indium plasma spray coating applied to pressure faces on CF6 Fan Disk.

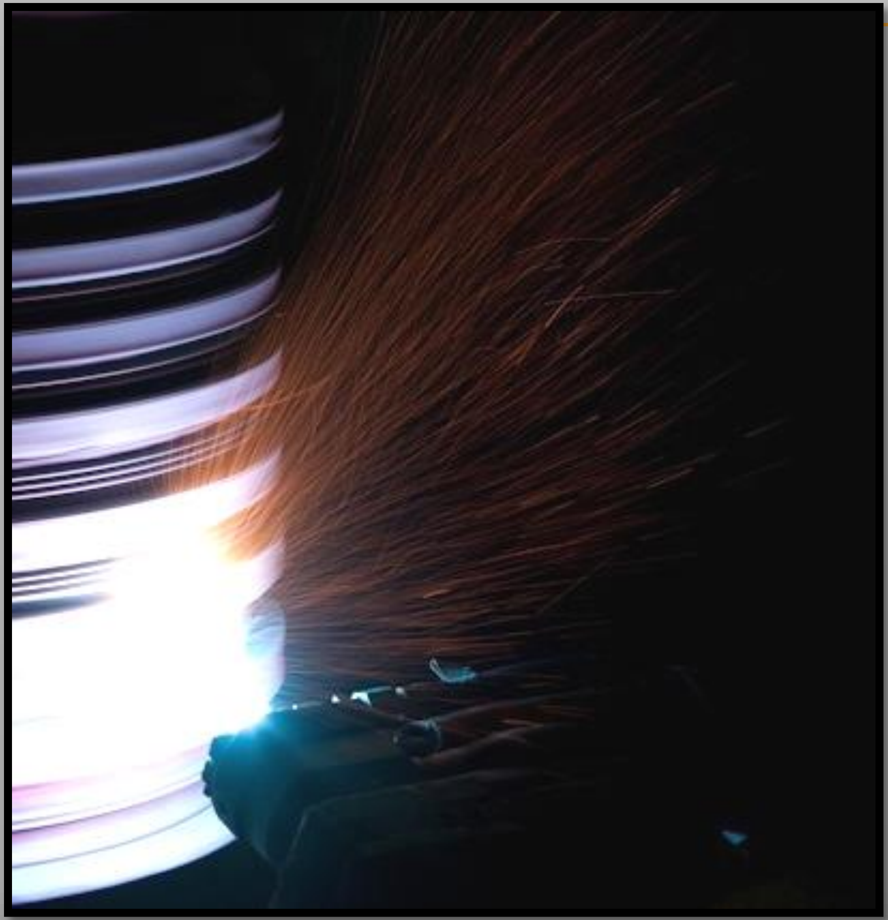
AlSeal™



Compressor Midseal, AlSeal™ coating applied to prevent sulfidation within aircraft engine.

Gas turbine compressor blade, power generation
Compressor blades in tooling rack

Dome Assembly
Thermal barrier coating applied to Combustor Dome Assembly.

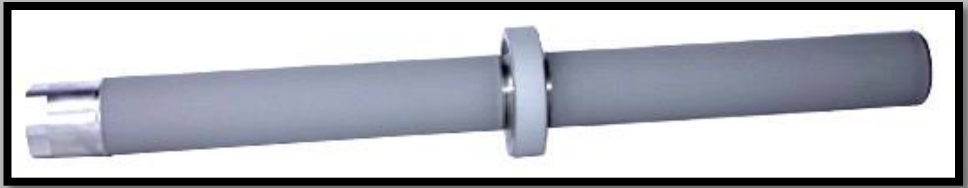


CFM 56, stage 4-9 spool

Aluminum Oxide wear coating applied to seals.

CFM 56, stage 1-2 spool

Aluminum Oxide wear coating applied to seals. Dry film lubricant applied within dovetail slots for fret wear protection.



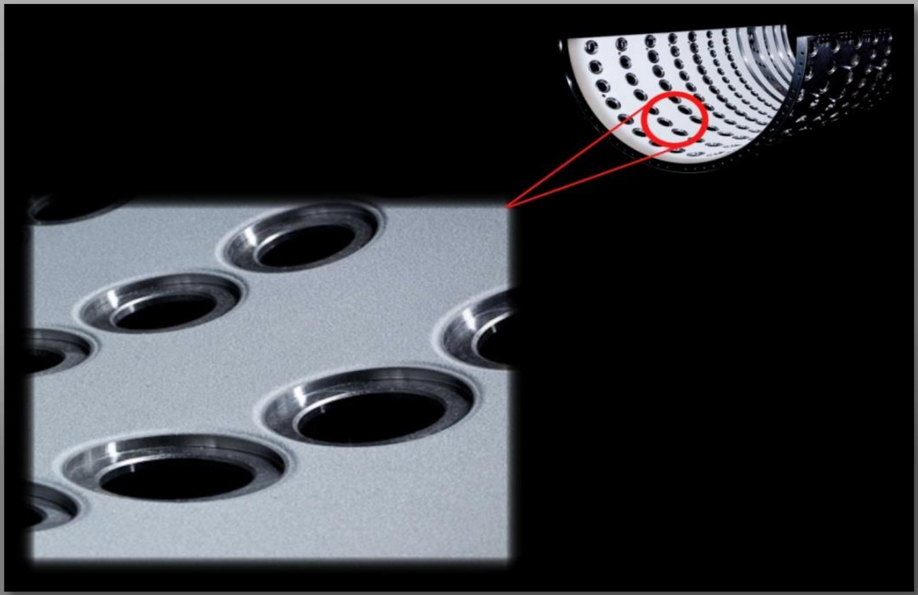
Aircraft and commercial actuators for control systems

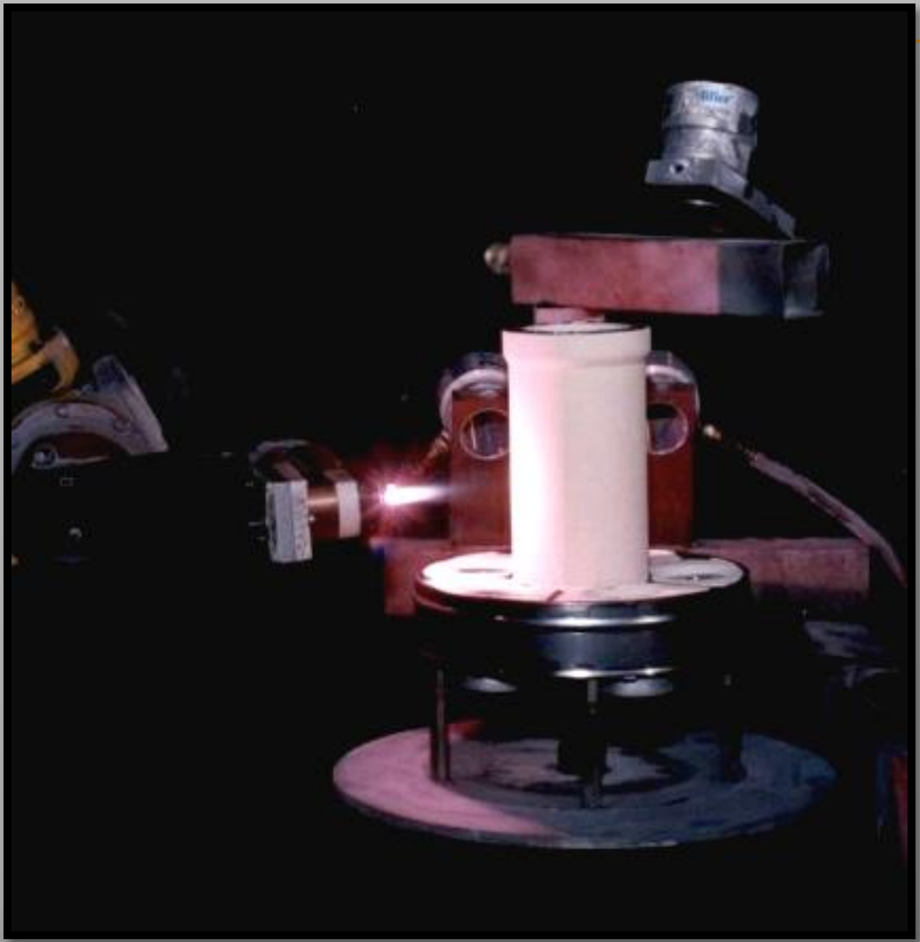
Apply thermal sprayed coatings as a Chrome plating alternative for impact wear protection in service on airframes and other actuation systems.

Quality

Depending on your components and the coating solution, we employ the latest technologies in inspection equipment, including:

- Gauging and measuring equipment
- Hardness testers
- Laboratories for conventional testing
    - Tensile bond strength
    - Microhardness
    - Macrohardness
    - Metallographic evaluation to standards
    - Erosion Testing
    - Furnace Cycle Testing



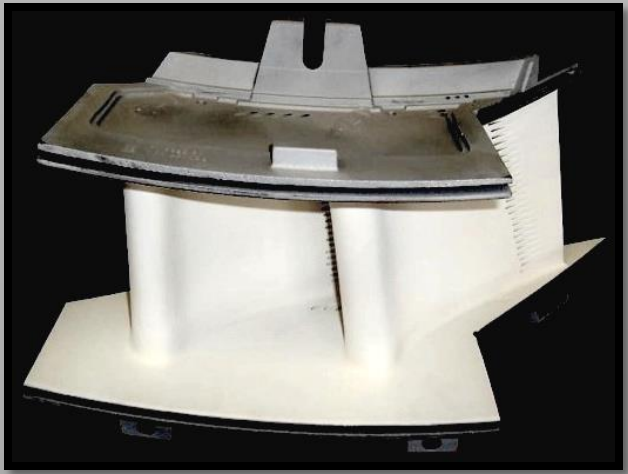


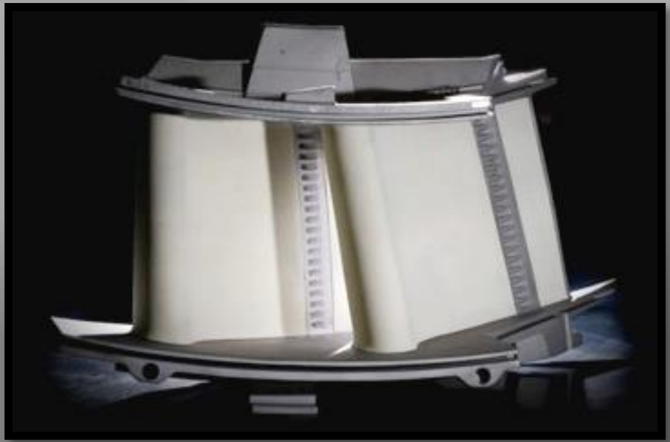
Fixed processes

Thermal barrier coating applied utilizing fixed air stands as part of controlled plasma spray process. CTS easily transfers engineered processes across facilities.

Masking techniques

CTS utilizes various masking techniques to protect cooling holes during coating applications. U/V liquid masking and hard tooling masking can be engineered to maintain airflow on a a case by case basis.





LAND BASED TURBINES - APPROVED COATINGS LIST

GE Energy

P16A-AG6
P16B-AG3
P16B-AG8
P16B-AG9
P16B-AG11
P16B-AG20
P16B-AG33
P6A-AG1 Paint
P6A-AG6 Paint
P11C-AG11 Shot Peen
P16-AL-0200

Siemens

83269A4
83336AA
83336AB

Alstom Power

HZLM 601 501
HZLM 603 610

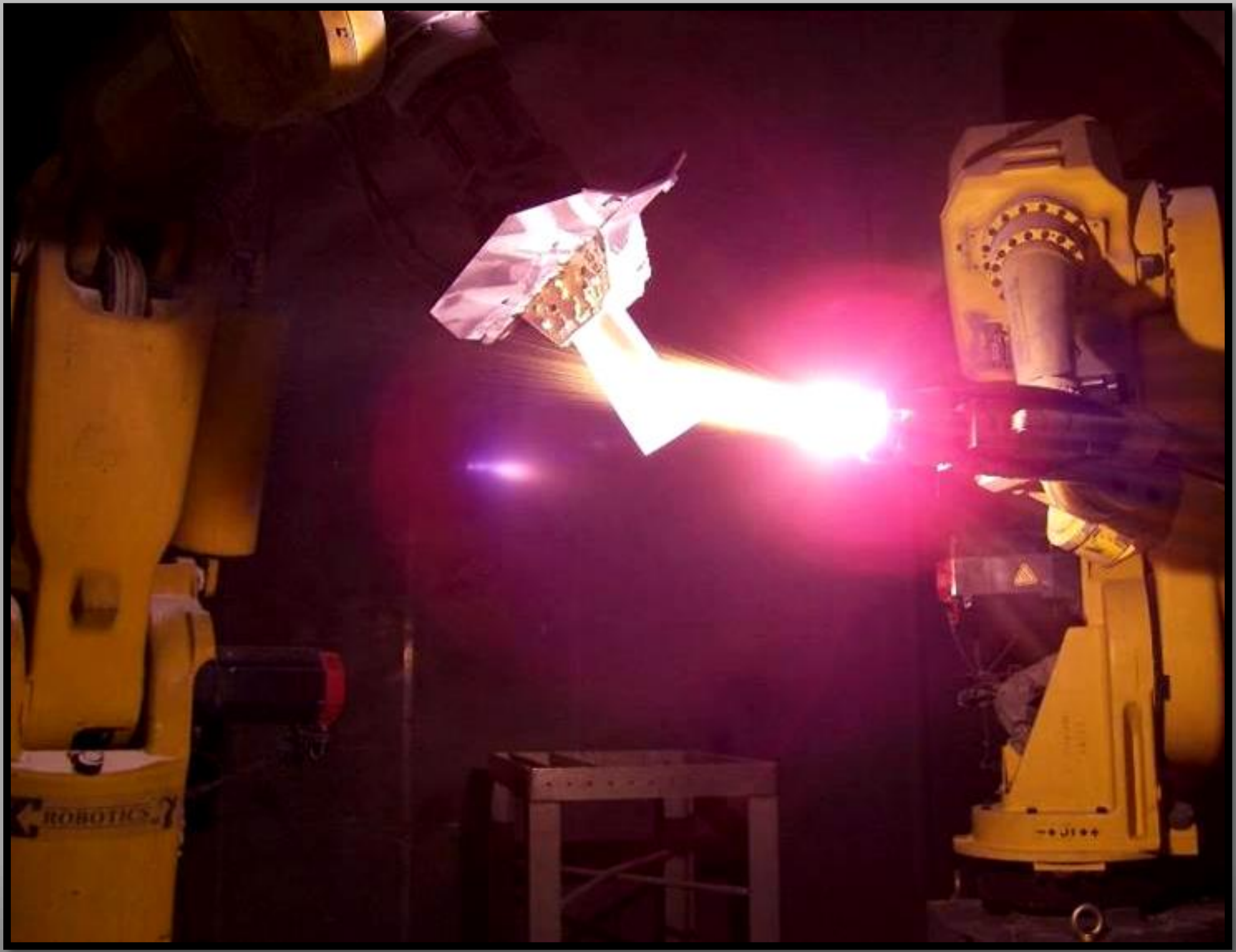
Solar Turbines

ES 9-107
ES 9-353

Combustion assembly

Ceramic coating for thermal barrier protection in power generation applications. Assembly of combustion hardware details after coating.

Transition Spray Process



Frame 7 Bucket Plasma TBC

HVOF Coat and Grind Fuel Nozzle

Aluminum and Zinc coatings

Sacrificial coatings to protect against oxidation from atmospheric corrosion. Extends mild steel service life, exceeding 10 years in service.

Our Service is Your Solution

Coatings used in Corrosion Applications

- Sealed coatings for environmental corrosion protection
  -all exposed exterior components
- Aluminum, Zinc, Zinc/Aluminum, Stainless Steel
- Coatings provide long term corrosion protection in severe applications such as exposure to marine environments or in chemical plants

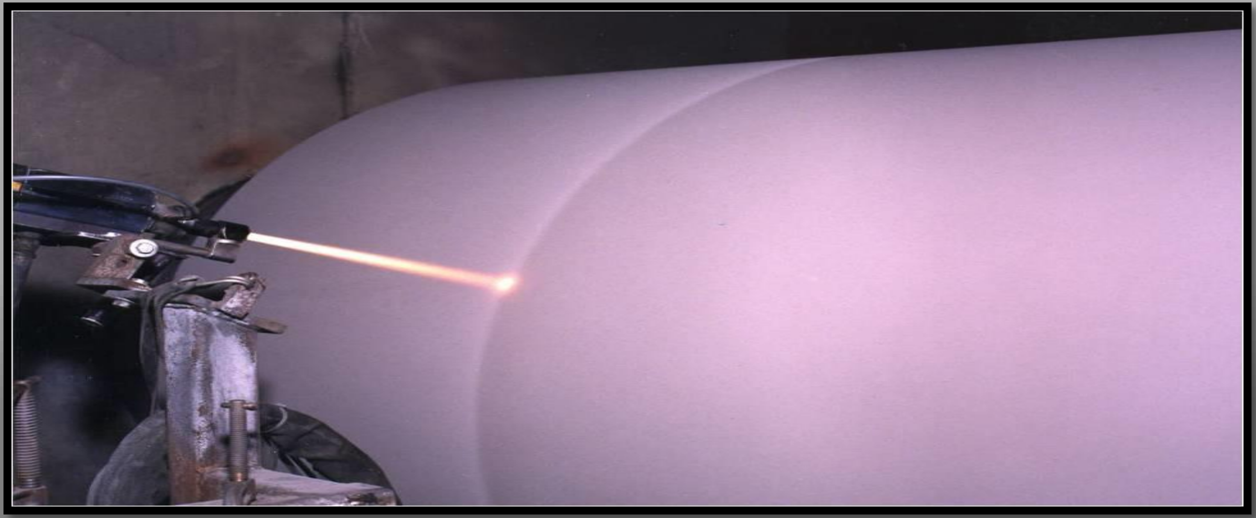
Steel Industry

Applications

- Hot dip coating lines
  - Galvanize
  - Galvanneal
  - Aluminize
- Temper mills
- Pickling lines
- Steel making
  - Continuous caster
  - BOF
  - LMF
- Annealing lines
- Slitting lines
- Tin mills
- Tandem mills

Steel

- 5-7 days turn around time (TAT) for coat and polish
- 24-hour outage support
- Customer-consigned rolls in finished goods for immediate shipment
- 2-3 weeks full service restoration
- Surface finish at 5-10 minimum Ra increments
- Custom roll profiling (crowning)



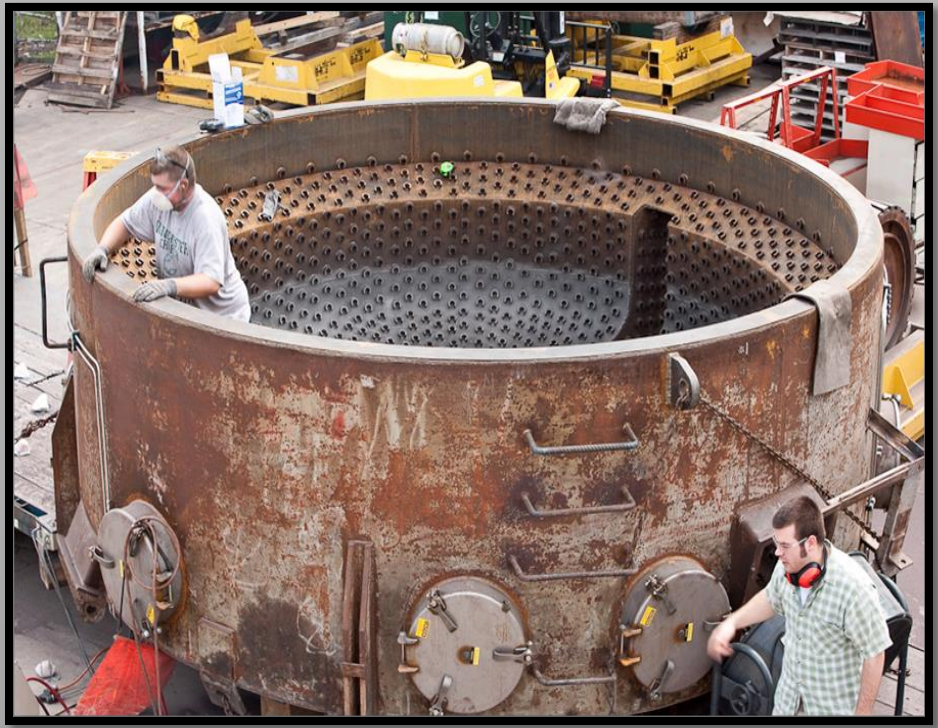
Tungsten Carbide Wear Coating-Bridle Roll
(prevents pickup, replaces rubber)

Continuous Caster Mold Broadface

Paper roller tubes

Wear coating applied and polished, providing extended service life within harsh wear environments.

On-Site Services



On-Site Coating Services

CTS can take any of our thermal spray processes onsite to apply coatings to components that are too big to move or where scheduling will not permit delay.

On-Site Coating Services

We mobilize very quickly and arrive at your site prepared to apply any of our thermal spray coatings to your components.

Pump Industry

Manufactures Pump Components

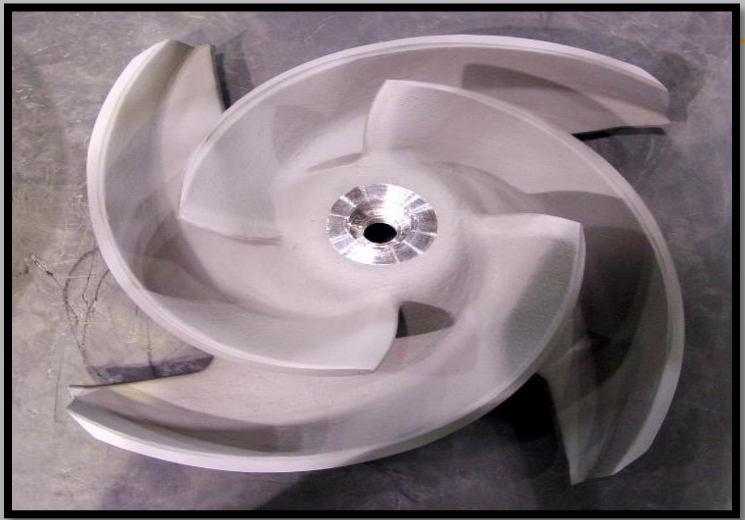
- CNC & Manual Machining and Grinding

Sleeves	Wear rings
Shafts	Bushings

- Integrated Thermal Spray

HVOF	Plasma

- Spray and Fuse — Wire Spray



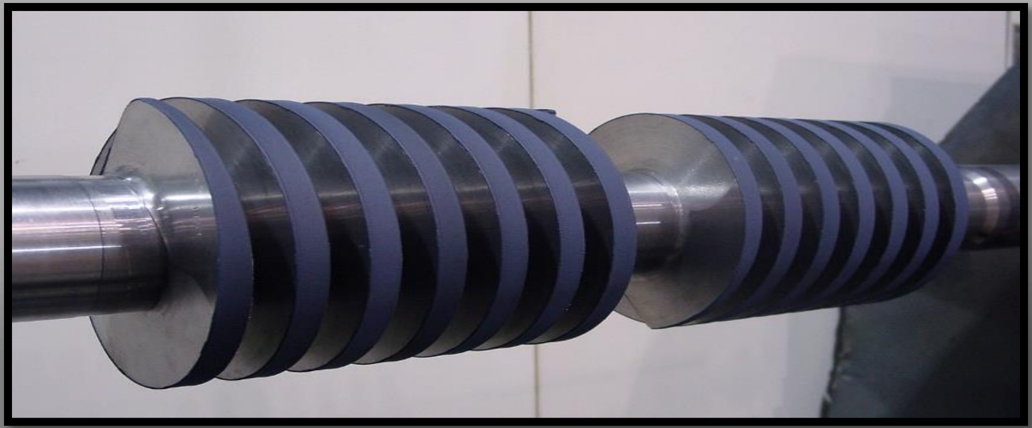
Tungsten carbide coated pump impeller

NCrB coated sleeves

Tungsten Carbide, Chrome Oxide, and HVOF Stellite coated sleeves

Throttle bearing sleeves

Chrome Oxide coated Plungers and Shaft



Screw Pump Rotor – Alumina Titania

THANK YOU!

At CTS, our specialty is developing and applying innovative solutions for your unique situations – on task, on time and on budget.

Put our superior customer service, uncomp quality solutions

and innovative technology to the

test.

We've got you covered every step

of the way.