INTRO TO THERMAL SPRAY
Thermal Spray is a process where a material is heated and propelled in a gas stream onto a substrate forming splats. The splats build up to create a coating.

Almost any material on almost any substrate.
WHAT IS THERMAL SPRAY?
PROPERTIES OF THERMAL SPRAY

- Bond Strength
- Surface Finish
- Inclusions
- Porosity
WHERE IS THERMAL SPRAY USED

- Aerospace
- Petrochemical
- Oil and Gas
- Medical
- Agriculture
- Automotive
PROPERTIES OF THERMAL SPRAY
1909

the early 1900s, Max Ulrich Schoop, of Zurich, Switzerland experiments with the spraying of lead and zinc metals for protective coatings. In 1909, Schoop obtained a patent covering the use of a combustion process (oxygen fuel) to melt wire and direct it to a substrate. Schoop’s second patent, in 1911, incorporated an electric arc as a production heat source. Thus, the technology of thermal spraying was begun. During its early application, the metallizing process was used mainly for corrosion protective coatings.
1933

In the midst of the worst economic depression ever in the United States, Rea Axline, a recent California Institute of Technology graduate, founds a small shop in Jersey City, New Jersey to sell wire spray equipment for corrosion control and repair of simple machine elements. The company started with 5 employees and included two of Rea’s talented associates from Cal Tech.
HISTORY

- 1948
- Detonation gun (D-Gun) coating concept originated; patented in 1955; continues to be the leading thermal spray process when extraordinary wear and mechanical properties are needed
HISTORY

- 1951

- First coating plant is established on Main Street in Speedway, Indiana (located within greater Indianapolis) to support the aviation industry and the new jet engine
1958

Flame spray and high-velocity oxy fuel (HVOF) patents issued
1962
Plasma spray process patent issued
1964

Metco introduced Metco 404 self-fluxing, exothermic, nickel aluminide powder – first in a family of composite spray materials excellent for use as bond coats and for surface build-up.
1973

Electro-Plasma Inc. (EPI) was founded in California, U.S.A. By isolating the spray gun and part of the handling equipment in a low pressure chamber, Eric Muehlberger invented a highly practical method of producing high-quality plasma coatings with properties near "as-cast" conditions. Known as LPPS® systems, these chambers produce coatings with optimal adhesion, reduced stress and added durability, ideal for the aerospace and medical implant industries.
TYPES OF THERMAL SPRAY BY FEED STOCK

Wire
- Flame Spray
- Two Wire Arc
- Single Wire Plasma

Ceramic Rod

Powder
- Flame Spray
- HVOF
- Plasma
- Slurry Plasma
  - D-gun
  - HVAF
  - LPPS
Pure Metals and Metal Alloy

- Nickel Aluminum Molybdenum
- Iron Chrome Aluminum
- Aluminum 12% Silicon
- Aluminum 6% Silicon
- Aluminum 1100
- Zinc Aluminum
- Zinc Tin
- Pure Tin
- Zinc
- Babbitt
Pure Metals and Metal Alloy (con’t)

- Copper
- Nickel Chrome
- Nickel
- Aluminum Bronze
- Aluminum Bronze Nickel
- Brass
- Molybdenum
- Titanium
- Silicon Bronze
- Silver Copper Zinc
Pure Metals and Metal Alloy (con’t)

- Low Carbon Steel
- High Carbon Steel (0.8C)
- High Carbon Steel (1.0C)
- Nickel Chrome Titanium
- 18/5 Stainless
- Copper Nickel Indium
- Nickel
- 430 Stainless Steel
- Nickel Copper
- Nickel Chrome Molybdenum
Pure Metals and Metal Alloy (con’t)

- Nickel 5% Aluminum
- Alloy C-276 Nickel Chrome Molybdenum
- Alloy 718 Nickel Chrome Molybdenum
- Nickel 20% Aluminum
- 18/8 Stainless Steel
- 316 Stainless Steel
- 300 Series Stainless Steel
- Kirksite type (94 Zinc 6 Aluminum)
Cored Wire

- Iron-based High Carbon Alloy
- Iron Chrome Carbon
- Nickel Chrome Aluminum
- Nickel Aluminum Molybdenenum
- Nickel Chrome Aluminum
- Iron Chrome Boron
- Iron Nickel Chrome
- Nickel Chrome Tungsten Carbide Iron
- Iron Chrome Nickel
- Cobalt Nickel Chrome Tungsten
- Nano Composite
- Nickel Chrome Aluminum Molybdenenum
WIRE FLAME SPRAY

- Oldest of Thermal Spray Technologies
- Uses single wire
- Typically uses oxy-acetylene
- Most common wire size 1/16
WIRE FLAME SPRAY
WIRE FLAME SPRAY
Similar to Single Wire Flame spray but uses ceramic rods

Limited selection of materials

- Aluminum Oxide
- Chrome Oxide
- Titanium Oxide
- Aluminum Oxide-Titanium Oxide
- Zirconium Oxide
Hundreds of Selections

- Pure Metals and Alloys
- Carbides
- Ceramics
- Plastics
- Blends
- Aluminum 99+
- Aluminum 12 Silicon
- Cobalt Chrome Tungsten (Stellite)
- Cobalt Moly Chrome Silicon (Tribaloy, T-400, T-800)
- Copper 99+
- Aluminum Bronze
- Copper Nickel
- Copper Nickel Indium
- 400 Stainless (420, 430)
- 316L Stainless
- Iron Nickel Aluminum
- Iron Nickel Aluminum Moly
- Molydbenum 99.5+
- Nickel 99.5+
- Nickel 5 Aluminum

**Powders**
- Nickel 20 Aluminum
- Nickel 20 Chrome
- Nickel Chrome Aluminum
- Nickel Chrome Aluminum Moly
- Inconel Type (718, 625)
- Hastelloy Type C276
- Nickel Moly Aluminum
- Silicon 99+
- Titanium
- Titanium 6Al 4V
- Self fluxing
  - Nickel Boron Silicon
  - Nickel Chrome Boron
  - Nickel Chrome Boron With carbide
- Chromium Carbide
- Chromium Carbide Nickel Chrome Blends
- Chrome Carbide Nickel Chrome Fused
- Tungsten Carbide 12 Cobalt (W2C/WC)
- Tungsten Carbide 12 Cobalt (WC)
- Tungsten Carbide 17 Cobalt
- Tungsten Carbide 20 Cobalt
- Tungsten Carbide 10 Nickel
- Tungsten Carbide 12 Nickel
- Tungsten Carbide 17 Nickel
- Tungsten Carbide 10 Cobalt 4 Chrome
- Tungsten Carbide 15 Nickel Chrome (80/20)
- Tungsten Carbide Chrome Carbide Nickel

**Powders cont’d**

- Cermets
  - Aluminum Oxide Nickel Aluminum
  - Zirconium Oxide Nickel Chrome Aluminum
- Aluminum Oxide
- Mullite (Aluminum Silicate)
- Aluminum Oxide 3 Titanium Oxide
- Aluminum Oxide 13 Titanium Oxide
- Aluminum Oxide 40 Titanium Oxide
- Chrome Oxide
- Chrome Oxide 4 Silicon Oxide 3 Titanium Oxide
- Chrome Oxide 25 Titanium Oxide
- Chrome Oxide 40 Titanium Oxide
- Titanium Oxide
- Titanium Oxide 45 Chrome Oxide
- Yttrium Oxide
- Zirconium Oxide 5 Calcia
- Zirconium Oxide 24 Ceria 2.5 Yttria
- Zirconium Oxide 25 Magnesia
- Zirconium Oxide 18 Titania 10 Yttria
- Zirconium Oxide 8 Yttria
- Zirconium Oxide 20 Yttria
- Polyester
- Nylon

- Abradables
- Aluminum Silicon Boron Nitride
- Aluminum Silicon Graphite
- Aluminum Silicon Polyester
- Aluminum Silicon Polyester
- Aluminum Bronze Polyester
- Nickel Graphite
- Nickel Chrome Aluminum Bentonite
- Nickel Chrome Iron Aluminum Boron Nitride
The Physical Properties Affect the Coating

- Particle Size is very important
- Powders of the same material are affected by method of manufacture
Powder size measurement uses mixed system

- Sieve or screen size
  - Numbers are assigned by number of holes per square inch
  - Screen wire sieves are used to measure size by the powder that will not or passes through the screen
  - + remains on top of screen – passes through

- Microns
  - Powder smaller than 325 mesh are measured in size by microns
  - 325 mesh is 45 microns
Measuring Particle Size

- Most common method uses **screens of different mesh sizes**
- **Mesh count** - refers to the number of openings per linear inch of screen
  - A mesh count of 200 means there are 200 openings per linear inch
  - Higher mesh count = smaller particle size

Figure 16.2 Screen mesh for sorting particle sizes.
MICROTRAC
FLAME SPRAY

- Generally use Oxy Acetylene
- Powder size generally -120 +325
- Size for each manufactures’ gun varies within size range
FLAME SPRAY
FLAME SPRAY
FLAME SPRAY
FLAME SPRAY
HVOF

- Uses high pressure Oxygen (200 psi)
- High pressure gas or liquid fuel
- Powder size generally -270 +15 micron
- Produces very dense coatings

High Velocity Oxy Fuel
HVOF
HVOF
HVOF
HVOF
Similar to HVOF
Air produces dirtier coatings
Higher deposition efficiency than HVOF
- Most versatile of thermal spray processes
- Uses powder generally -100 +270 and -20 + 5 microns
- Temperatures of 15,000 – 20,000 deg.
SLURRY PLASMA

- Used to spray powders that will not flow
- Nano materials
Fig. 3. Solution Plasma Spray Process
LPPS

Low Pressure Plasma System

- Uses low pressure chamber
- Can produce near rought conditions
LPPS
D-GUN
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<tr>
<th>POWDER SHAPE</th>
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<tbody>
<tr>
<td>Agglomerated and Sintered</td>
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<td>Water Atomized</td>
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**POWDER SHAPE**