Properties of Selected Thermal Spray Coatings for Valve Applications

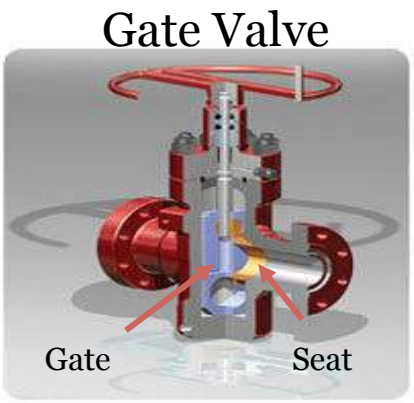
Alain Gardette
Praxair Surface Technologies, Inc
Indianapolis, USA

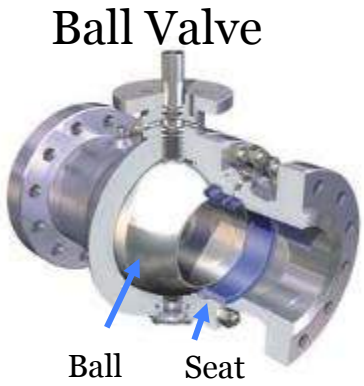
Outline

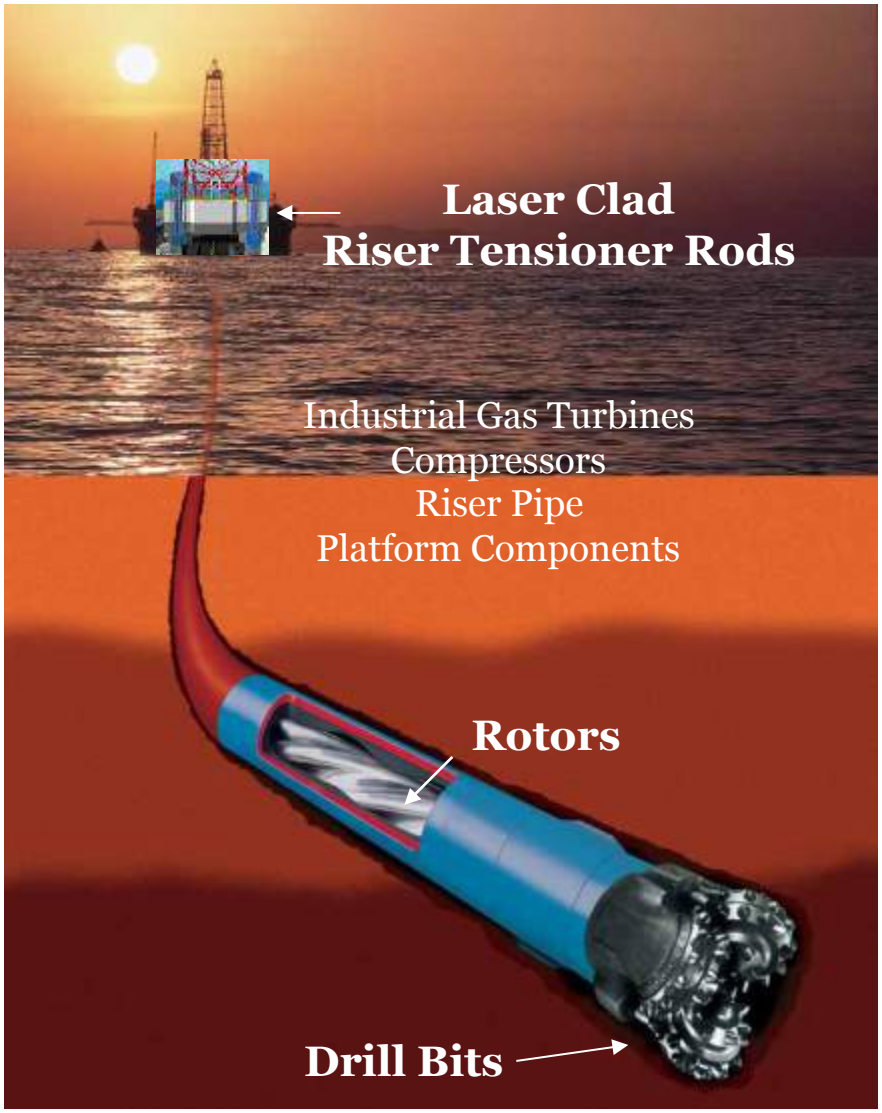
- Coating Processes and Materials
- Selected Mechanical Properties
- Wear & Corrosion Properties
- Sealing Integrity of the Coatings
- Coating Market Trends

Oil & Gas Coatings

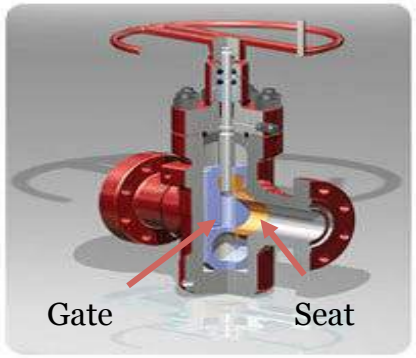
- Protective coatings for gate and ball valves, rotors, mandrels, tensioner rods, drill bits and tools used in the exploration/production of oil and gas







Gate Valves



Manual actuation
Hydraulic actuation
Pneumatic actuation

$F > F_{\text{friction between gate and seats}}$

- metal to metal contact
- pressure of the gas or oil in the pipe in closed-valve position.

Type of failures

Adhesive Wear: Material transferred from one surface to another

Scuffing/Galling: Severe adhesive wear (micro welding & smearing)

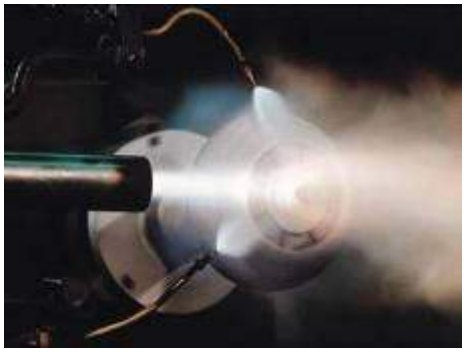
Abrasive Wear: Wear by a harder material moving along the surface under load

Corrosion

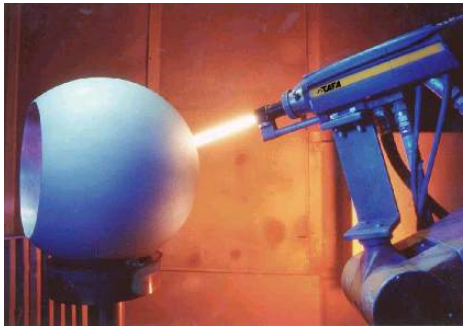
Coating processes

Thermal Spray	Detonation
	HVOF
Plating	Electroless nickel
	Hard chrome
Diffusion	Nitriding
Others	Conversion
	Plasma Transferred Arc (PTA)
	Laser cladding
	Weld overlays
	CVD (DLC)

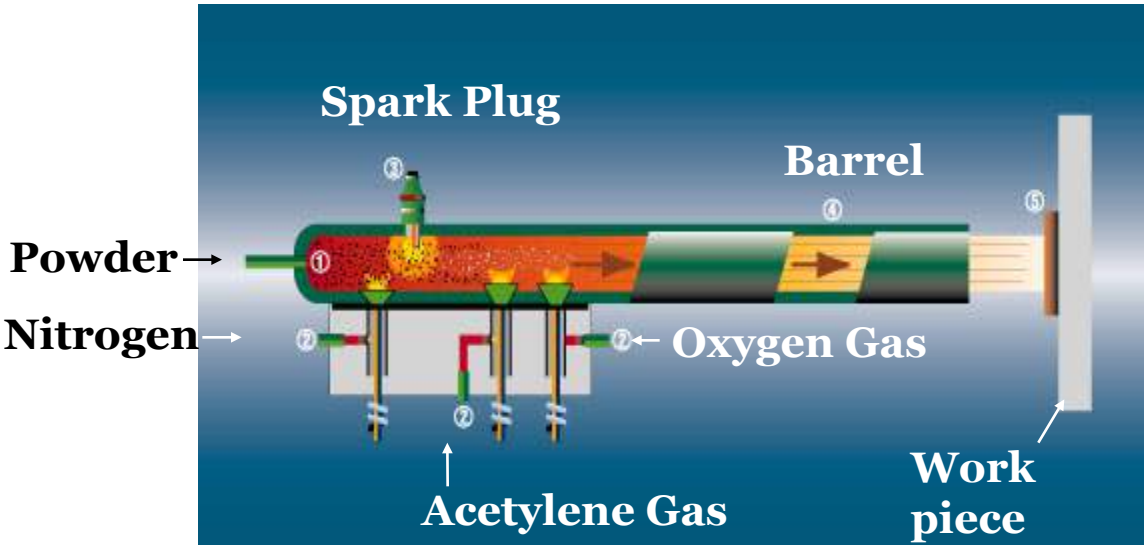
Detonation Gun

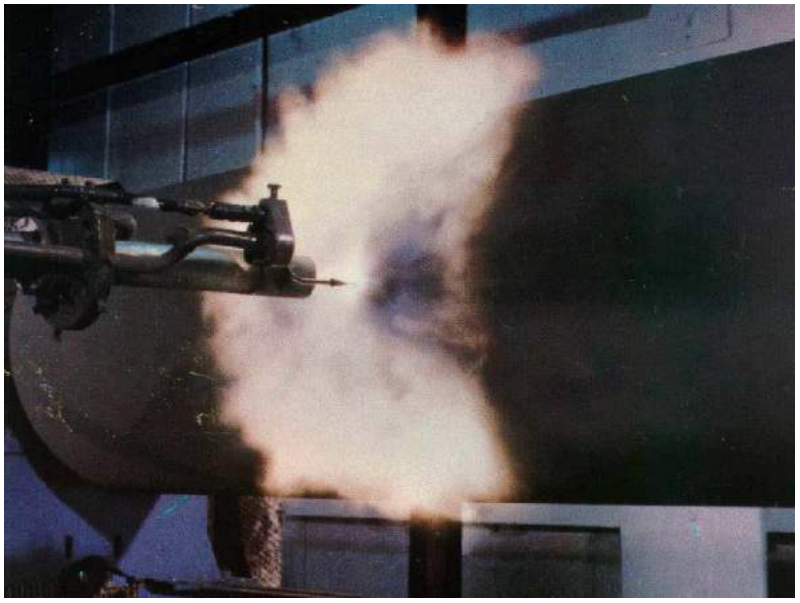


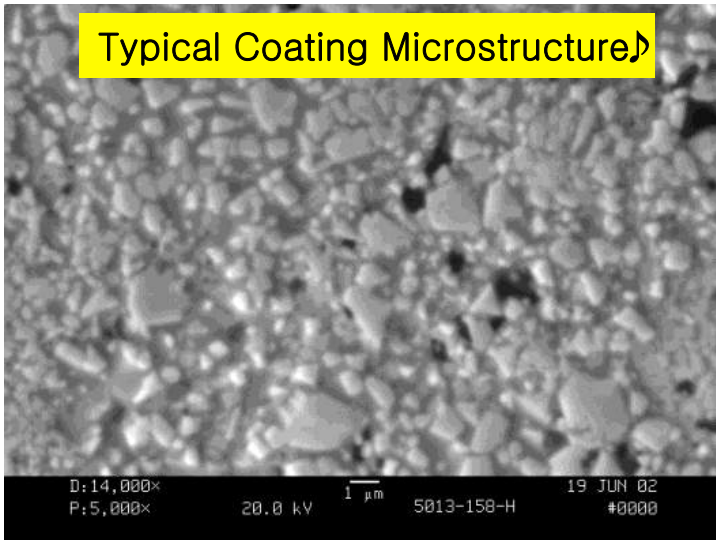
High Velocity Oxy Fuel



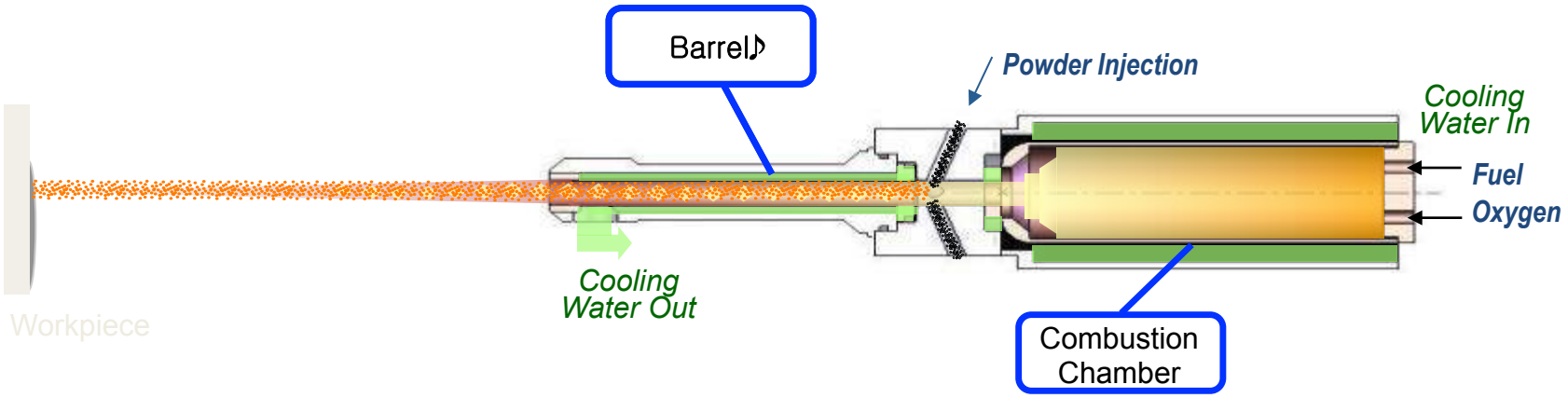
D-Gun and Super D-Gun™







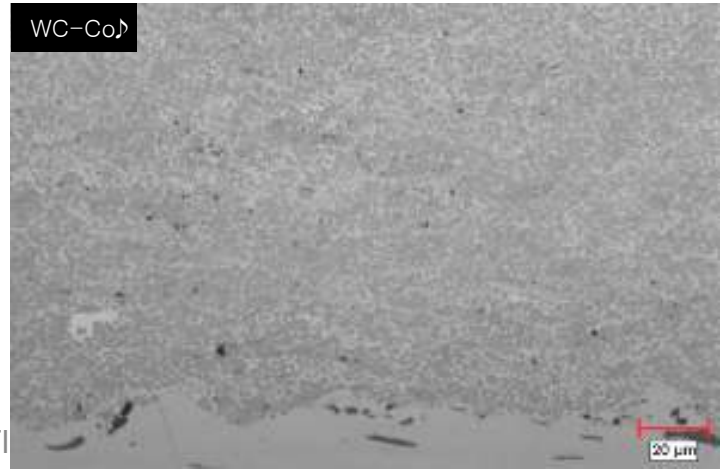
HVOF



High Velocity Oxy-Fuel (HVOF)

- combustion ⟶ heating gas & particles
- de Laval nozzle ⟶ supersonic jet velocity
- produces dense tungsten carbide coating

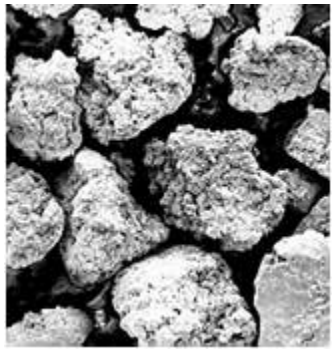
Typical Coating Microstructure♪



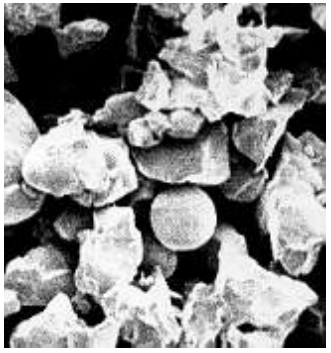
Coating Materials

Ceramic/metallic composites (cermets)

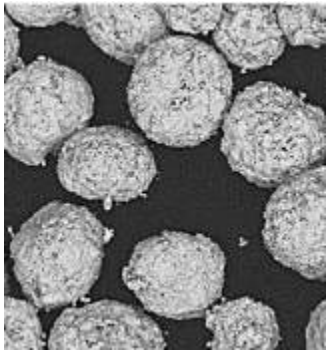
- Chromium carbide – nickel – chromium
- Tungsten carbide – nickel – chromium
- Tungsten carbide – cobalt – chromium



Sintered & crushed



Blend



Spray dried & agglomerated

Carbide grains

- 2-5 µm
- 1-2 µm
- < 1 µm

Powder size and chemistry may not be enough to specify the proper powder

WC → **W_2C** → **W**

In-flight particle temperature, gas chemistry, velocity

Coating Development for Gate Valves

Deposition parameters

Powder
- morphology
- particle size
- WC grain size

Wear performance

Process optimization

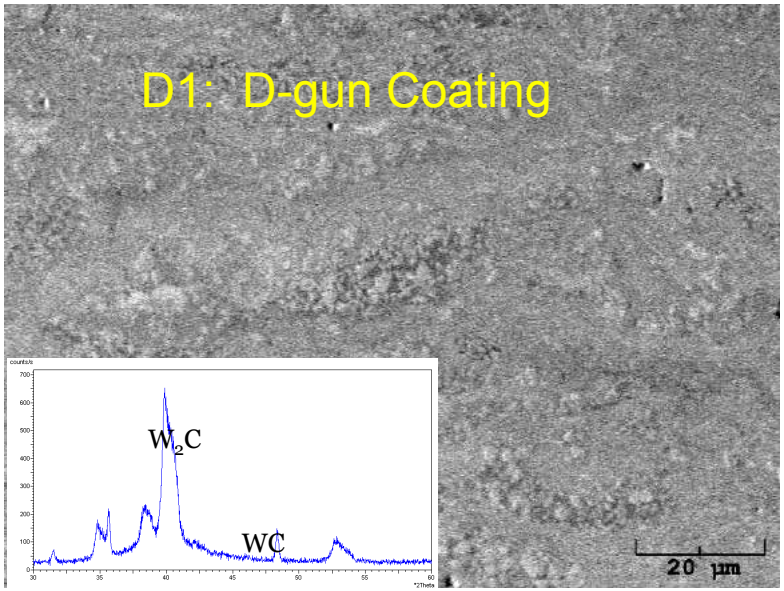
- microstructure / phase composition
- porosity, oxides
- microhardness
- adhesion (tensile bond and bend)
- strain to fracture (4 point bend test)
- residual stress
- sealer depth of penetration
- salt spray corrosion resistance
- high pressure leak test (sealer integrity)
- sand abrasion resistance
- sliding wear
- coating cost

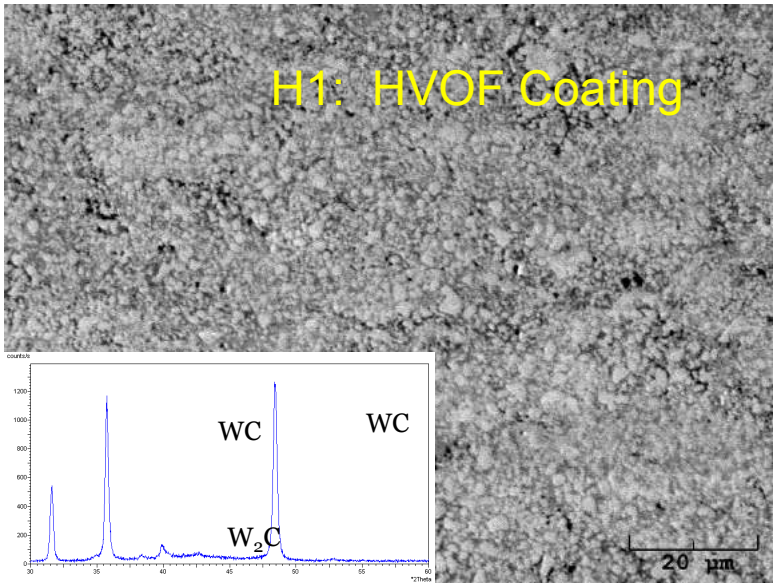
Low Friction

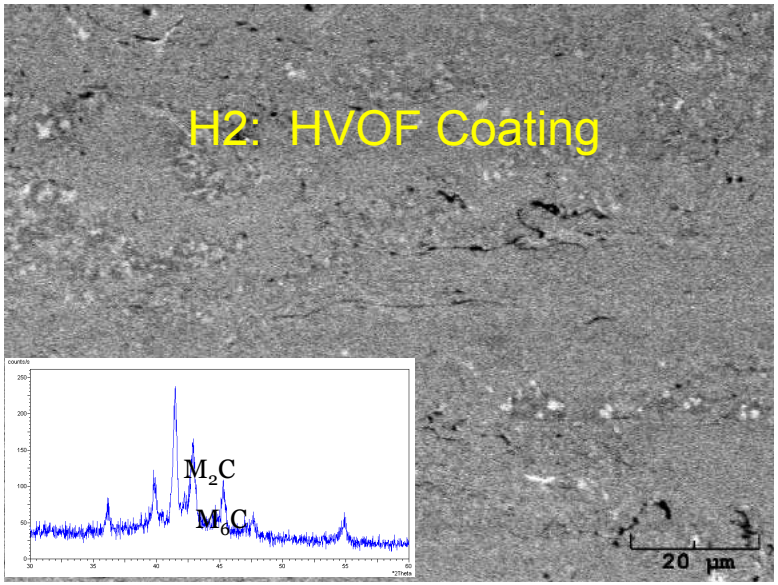
Galling resistant

Gas tight

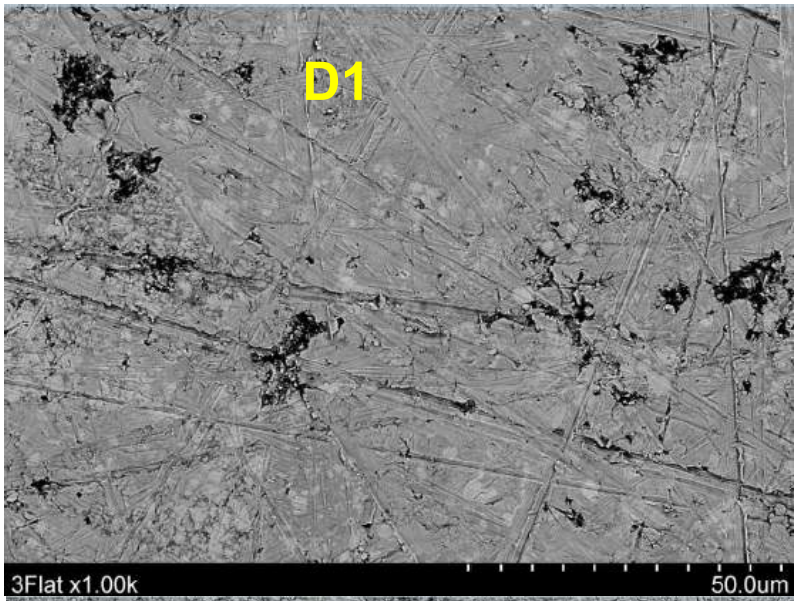
Structure of Selected WC-Co-Cr Coatings

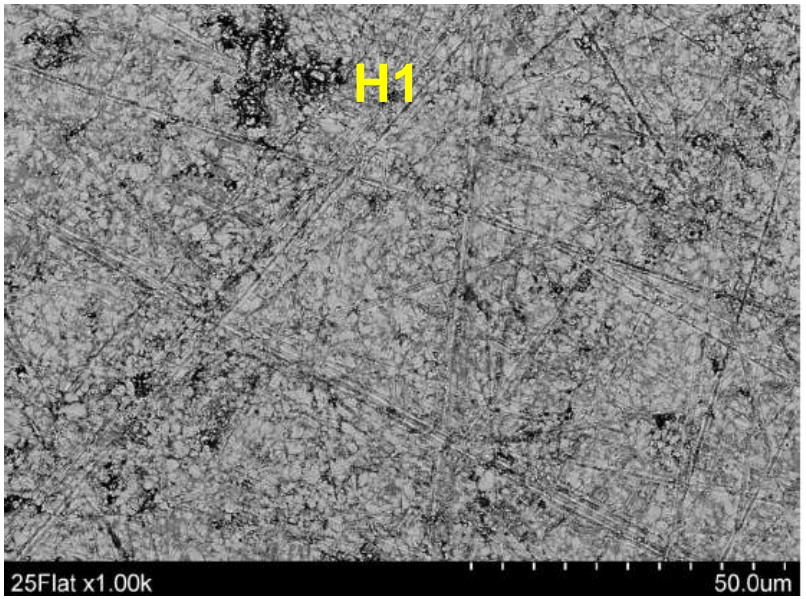


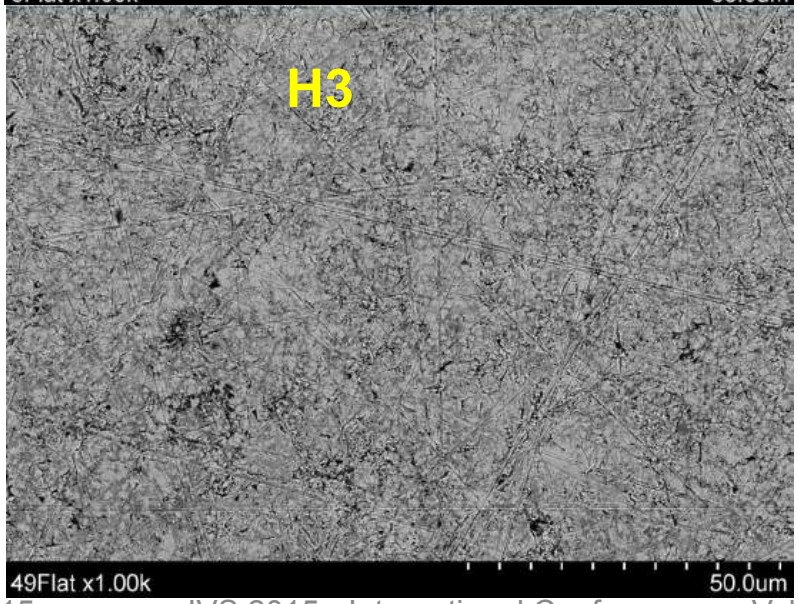


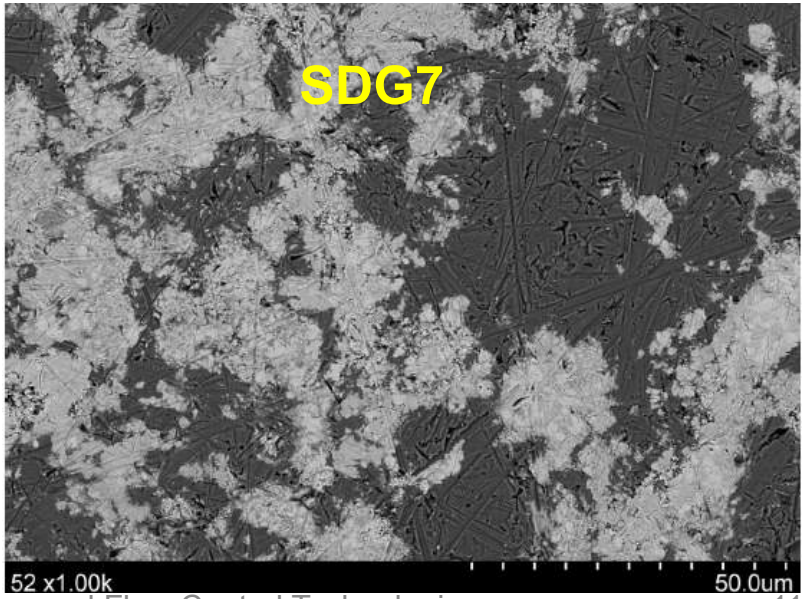


Wear surfaces of selected coatings



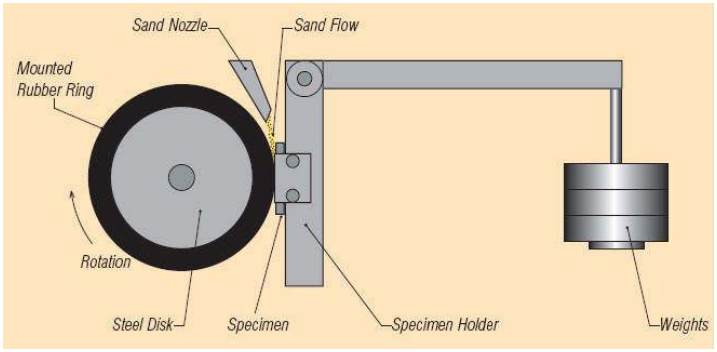


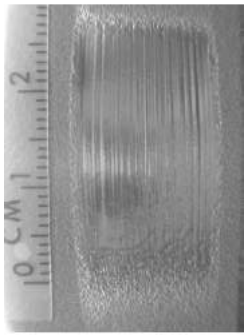




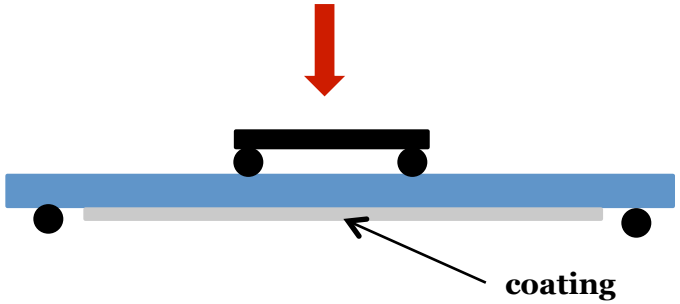
Mechanical properties

Sand Abrasion (ASTM G-65)





4 point bend



Coating	Aver. Hardness (HV300 kg/mm^2)	Strain to fracture (%)	Sand Abrasion* (mm^3/1000revs)
H1	1120	0.23	0.7
H2	1000	0.24	5.3
H3	1100	0.20	0.9
D1	1150	0.17	1.5
SDG7	830	0.28	5.1

Wear Characterization

PV (pressure-velocity test)

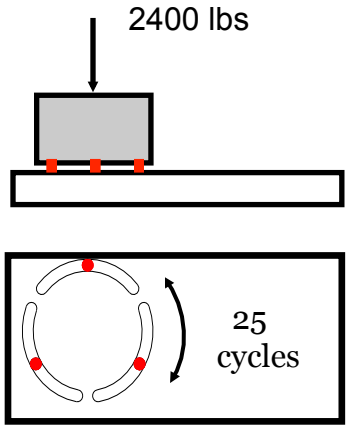


Plate to Pin pressure
112 MPa (16,300 psi)

Evaluation of:

- Coefficient of friction
- Pin velocity
- Wear Scar

Galling Threshold Test

Contact pressure up to
241 MPa (35,000 psi)

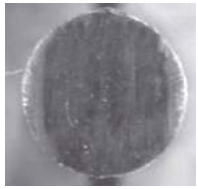
Evaluation of:

- Coefficient of friction (static)
- Coefficient of friction (at breakdown)
- Time to breakdown
- Wear scar

PV Test Data

FLAT

“Good” Result

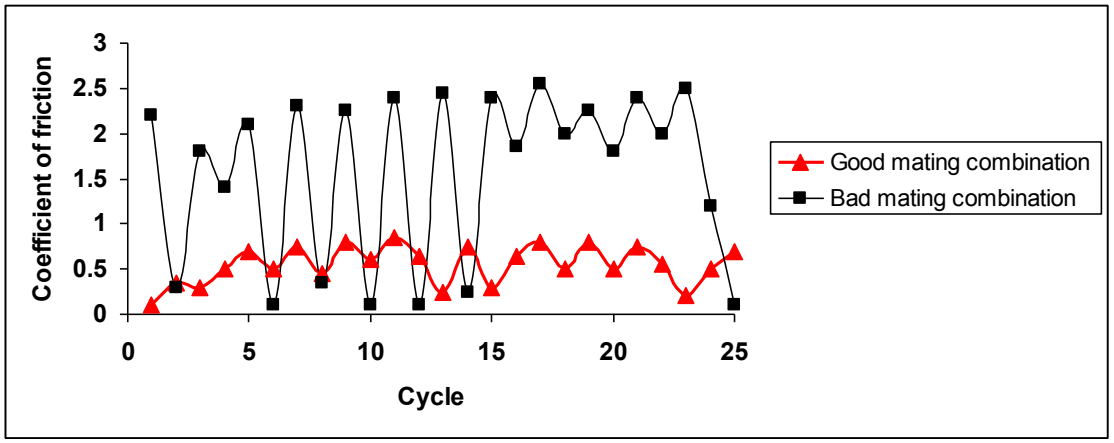


PIN

FLAT

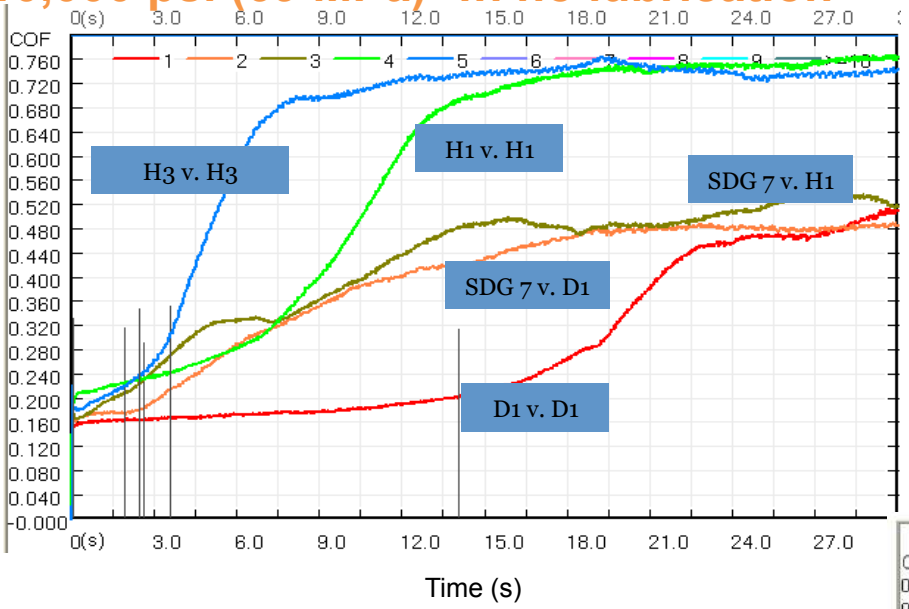
“Bad” Result

PIN

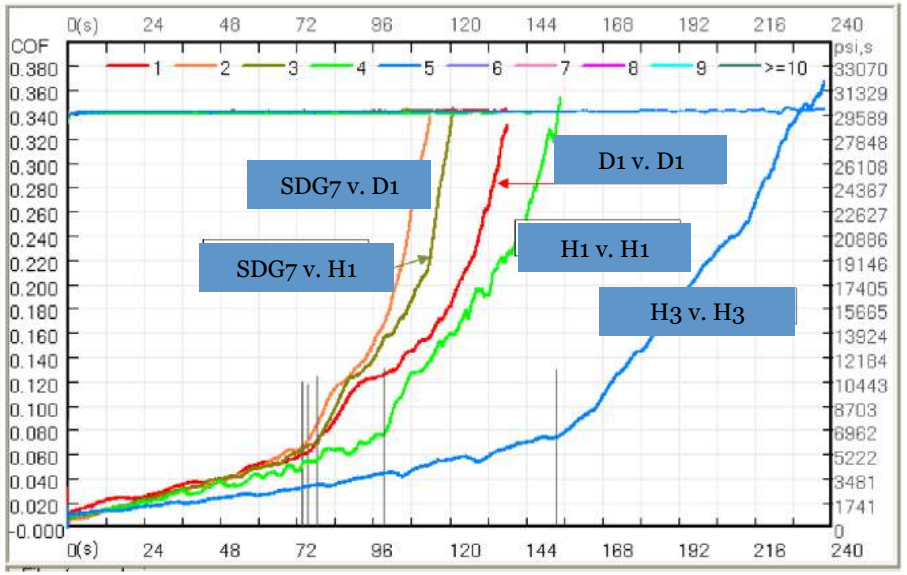


Galling Threshold Test

10,000 psi (69 MPa) w. no lubrication

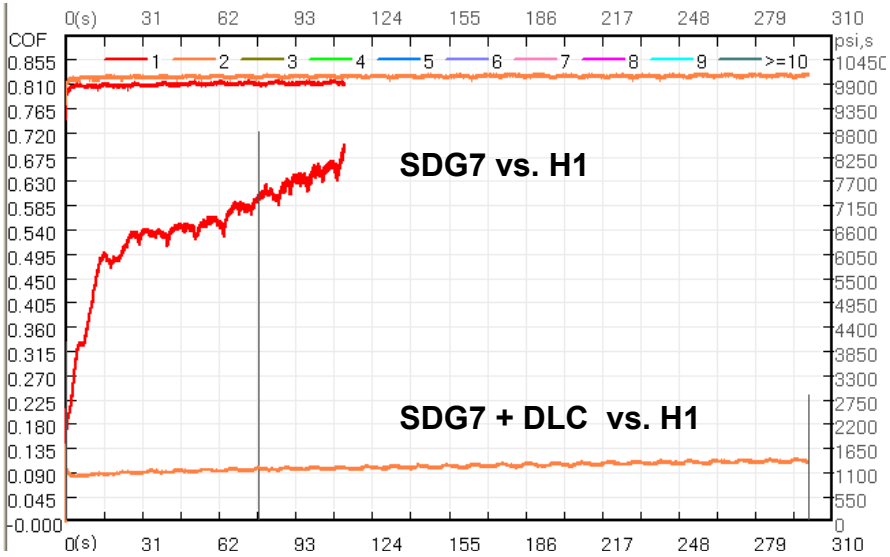


30,000 psi (207 MPa) w. HT Grease

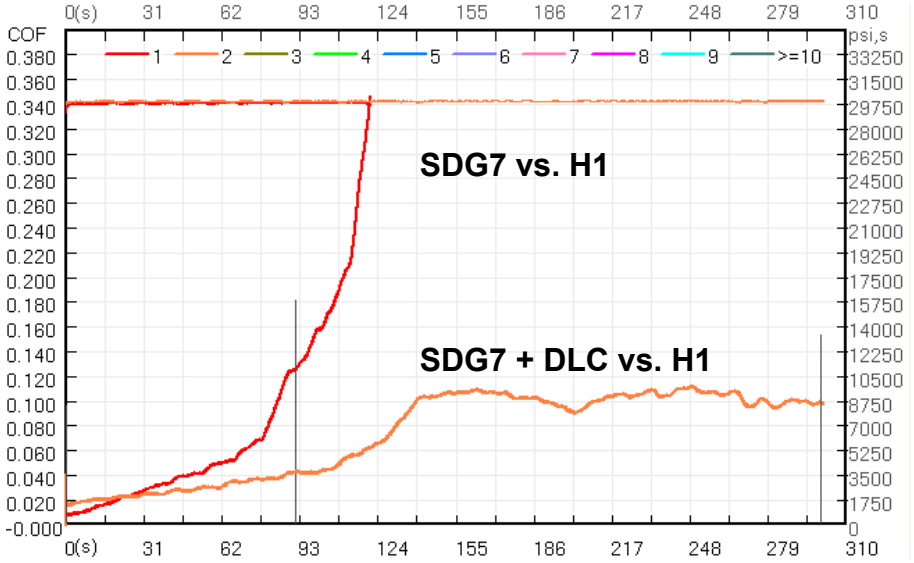


DLC (diamond like carbon)

- low temperature vacuum deposition process
- DLC applied on top of dense thermal spray coating
- no sealer
- possible post treatment after DLC



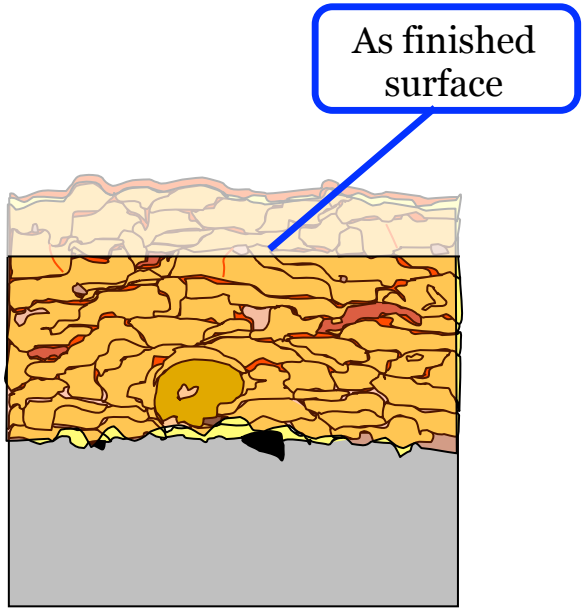
10 KSI no grease



30 KSI with grease

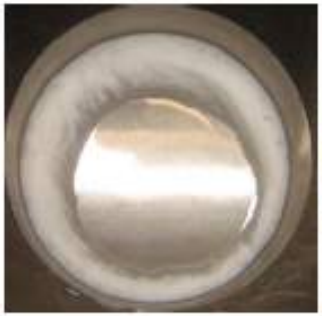
Coating sealing

- Sealer applied on as coated surface
- Penetration through coating thickness
- Protect substrate from attack by corrosive media
- Block passages for gas leakage



Sealing Integrity Testing (high pressure leak test)

- 10,000 psi N_2
- 2.5 inch diameter
- Testing at full coating thickness
- Layer removal and testing for depth of penetration
- Bubble detection/Leak test



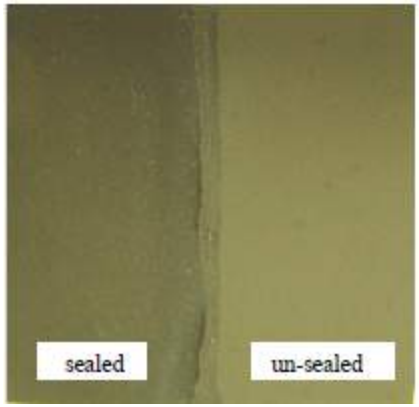
Typical leakage through unsealed coating

Typical leakage through poorly sealed coating

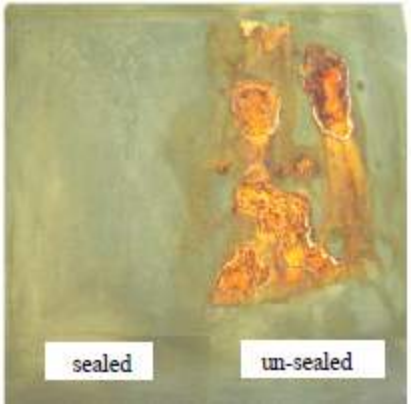
Gas tight coating

Salt Spray Corrosion per ASTM B-117

- Evaluate corrosion resistance of coating and substrate combination in wet environment such as a marine and wet atmosphere
- Controlled salt solution
  - 5% sodium chloride in deionized water
  - 6.6-7.2 pH at 35°C (95°F)
- Exposure time
  - 30 days as standard
- Evaluation
  - Appearance by visual inspection
- Acceptance
  - Per specification or agreement

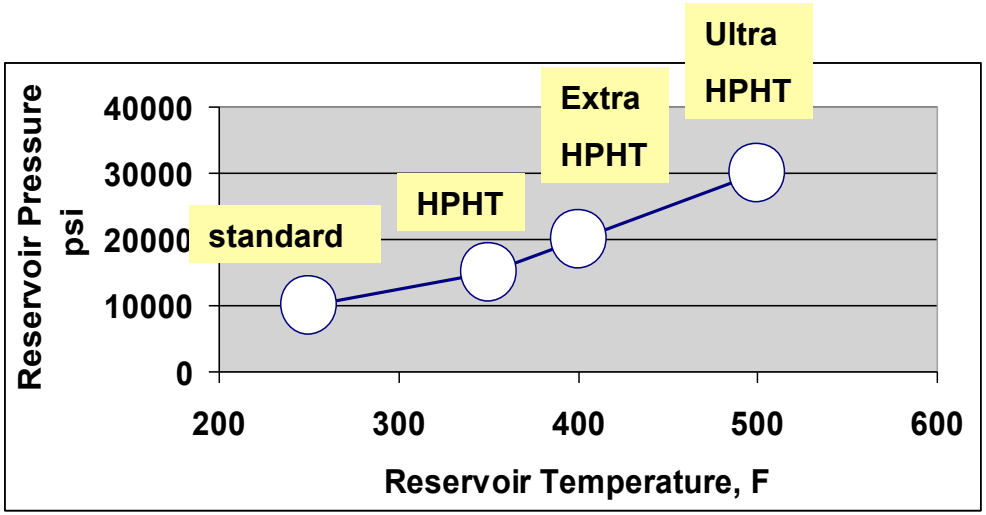


as sprayed
H1 coating



ground and tested
H1coating

Coatings Trends: Oil and Gas



- Higher Temperatures and Pressures
- More Aggressive Corrosion Exposure
- Lower Friction
- Demand for Better Sealants for Corrosion Protection
- Fully dense coating with no sealer

Praxair Surface Technologies Overview

- **Protective Coatings**
  - Engineering and technology to solve tough performance problems
  - Metallic and ceramic protective coatings that resist wear, corrosion and heat degradation
  - Extend product life, increase productivity, and reduce operating costs
- **Materials and Equipment**
  - Thermal spray and additive manufacturing powders; engineered slurries
  - Thermal spray equipment, wires, and spare parts

Applications of PST's Products & Technology

Aerospace

Automotive

Chemicals & Plastics

Metal Production

Oil & Gas Exploration

Power Generation

Company Statistics

- Leading high-performance surface technology company established in 1946
- 2014 Sales of $679 million
- Manufacturing operations in more than 35 locations in 12 countries
- 2,500 employees worldwide
- More than 600 coatings to select from
- Focused on the aviation, energy, and industrial markets