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Kermetico High Velocity Air-Fuel Thermal Spray

HVAF Application Development

1. Superior hard & tough coatings for new markets

- Gas-tight
- WC-based 1,500-1,700 HV_{300}
- Cr_3C_2-based 1,100 HV_{300}, service up to 900^oC
- MoB-based 1,200 HV_{300}, service up to 1,100^oC
- Thin coatings (40-70 micron) for:

  High and alternating stress, impact, etc.

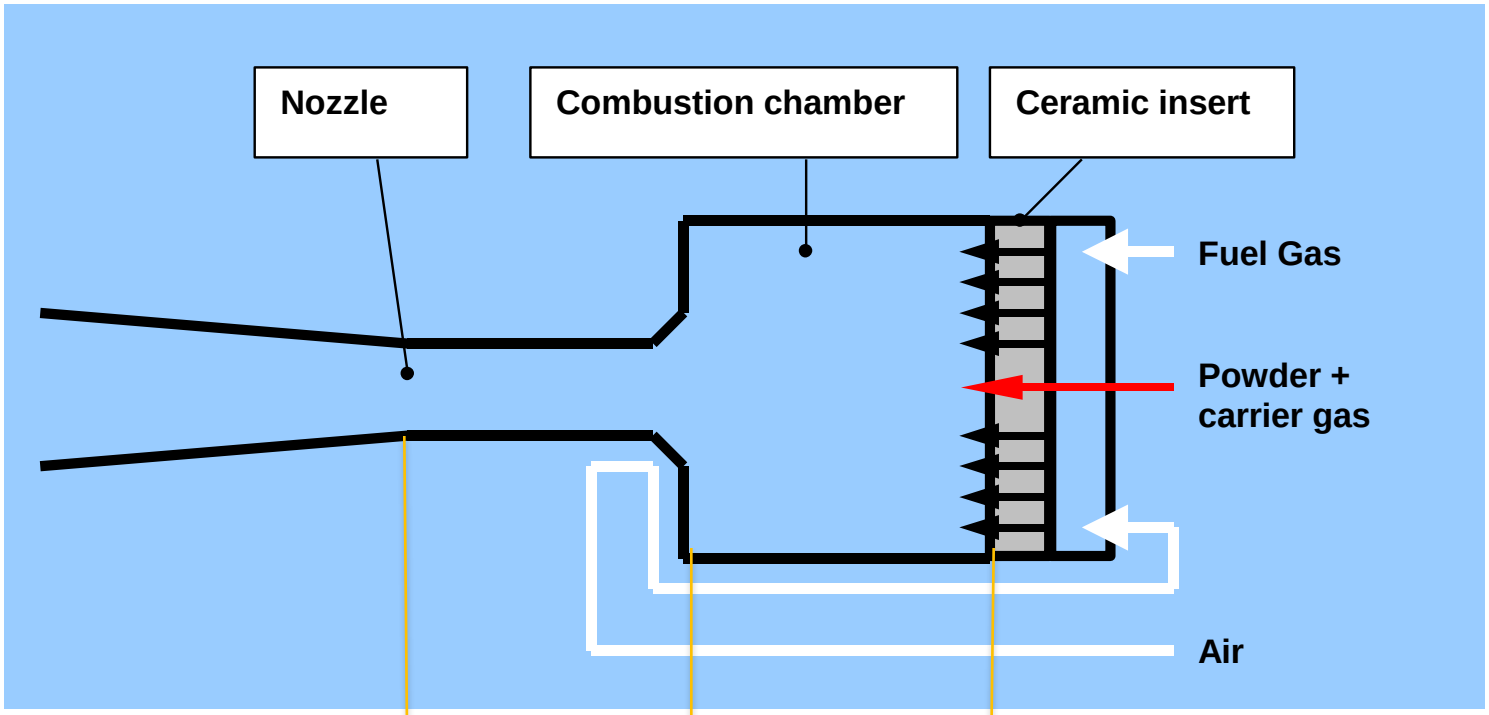
  Economy grades for “flash chrome” replacement

HVAF Application Development

2. Economical “currently specified quality” coatings for existing and new markets

1,200 HV_{300} /<0.8% porosity WC-coatings, sprayed at 65-70% DE with spray rates 33+ kg/hour

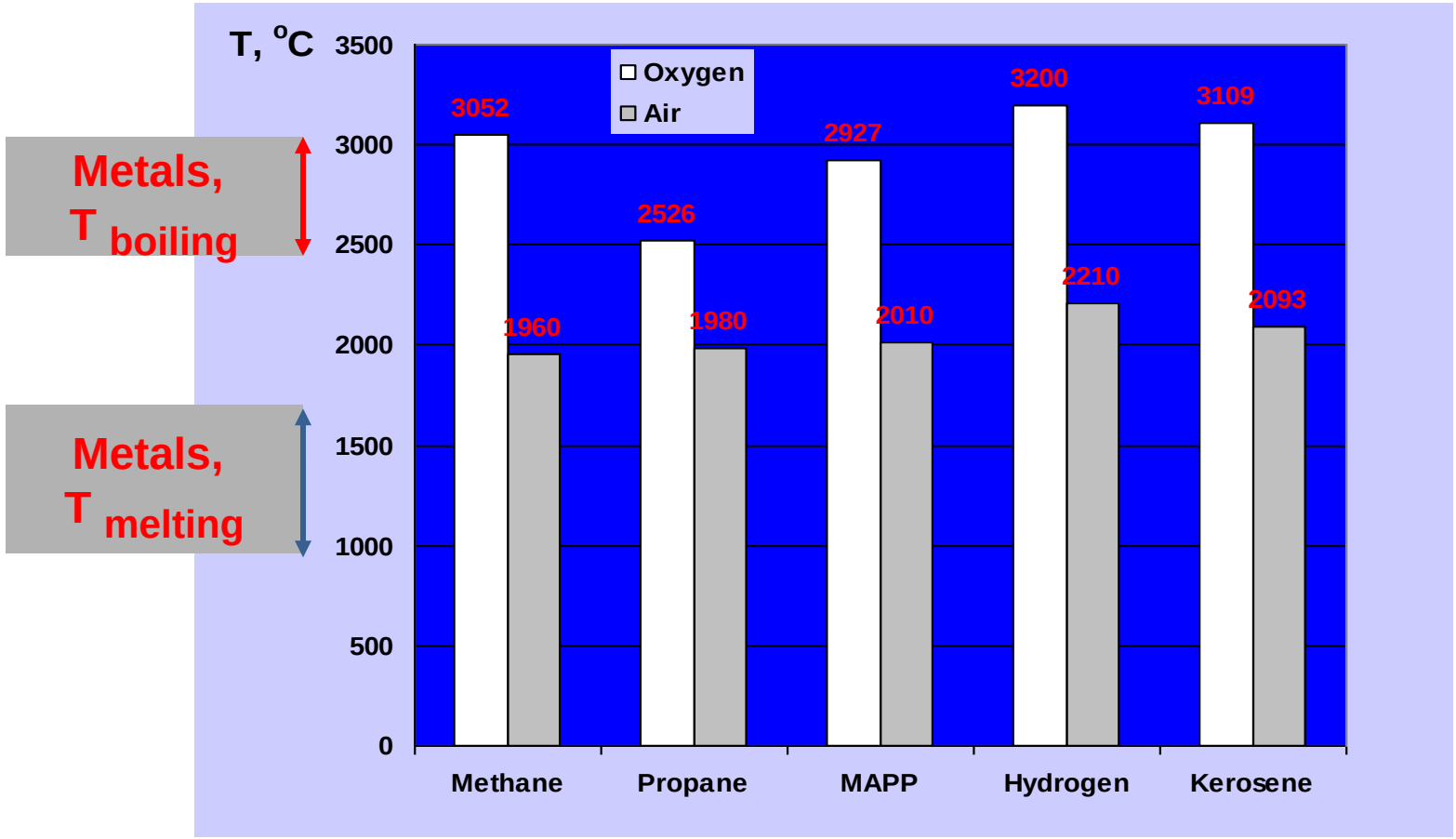
Kermetico HVAF Gun Design



1100-1500 m/s	850 m/s	40-50 m/s	Gas velocity
<1500°C	~1600°C	1900°C	Gas temperature
Acceleration		Heating	Spray particle

Combustion Temperature: HVAF vs. HVOF

Adiabatic combustion temperature of fuels in oxygen and air (α=1, 20°C, 1 Bar)



Lower Gas Temperature in HVAF:

HVOF:

Combustion temperature is higher by more than 1000°C than melting temperature of metals;

Combustion temperature may exceed metal boiling temperature.

HVAF:

Combustion temperature only slightly higher than metal melting temperature.

Lower Gas Temperature in HVAF:

- **Affects coating properties**

Prevention of oxidation of metals and oxidation/ thermal deterioration of carbides

Note: oxygen activity is 5-times lower in HVAF

- **Influences gun design**

HVAF ability to use heating in long/ slow-gas combustion chambers = long time for "soft" heating

High pressure in the chamber = better heat transfer

Combustion Temperature: AF vs OF Design

Ability to use heating in long/ slow-gas combustion chambers =

long time for “soft” heating

High pressure in the chamber =

better heat transfer

Result:

High energy efficiency of HVAF

(same or lower power while higher spray rates than HVOF)

Energy Efficiency = COST

State-of-the-art HVOF:

JP 5000	**270 kW**	**spray rate 5 kg/hour**
DJ 2600	**115 kW**	**spray rate 4 kg/hour**

Kermetico HVAF:

AK6	**130 kW**	**spray rate 28 kg/ hour**
AK5	**80 kW**	**spray rate 15 kg/hour**
AK-ID	**30 kW**	**spray rate 5 kg/hour**

Acceleration of spray particles in the nozzle:

- **Gas velocity & density**
- **Time (nozzle length)**
- **Particle size**

Smaller particles are accelerated to higher velocities.

HVAF uses smaller particle size without material oxidation/ thermal deterioration

Note on nozzle wall influence on particle velocity:

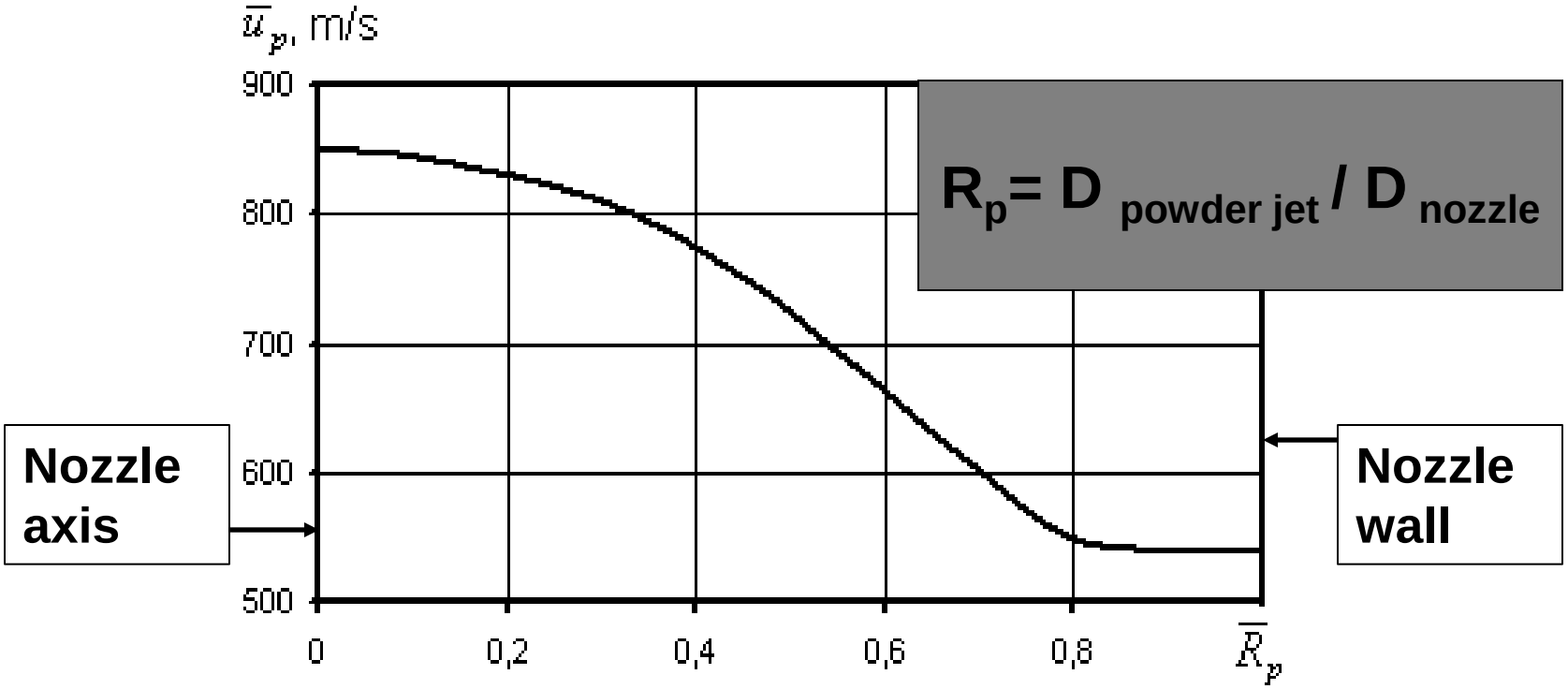
HVOF – dramatic

(more so – in radial injection)

HVAF – no influence

Particles Acceleration: Influence of the Nozzle Walls

HVOF (kerosene) per A. Voronetsky et. all, ITSC2004



Influence of R_p on the mean particles velocity at L_S=250 mm. (p_{cc} =0.9 MPa, d_p=30 μm, L_b=100 mm)

Particles Acceleration in the Nozzle

Kermetico HVAF:

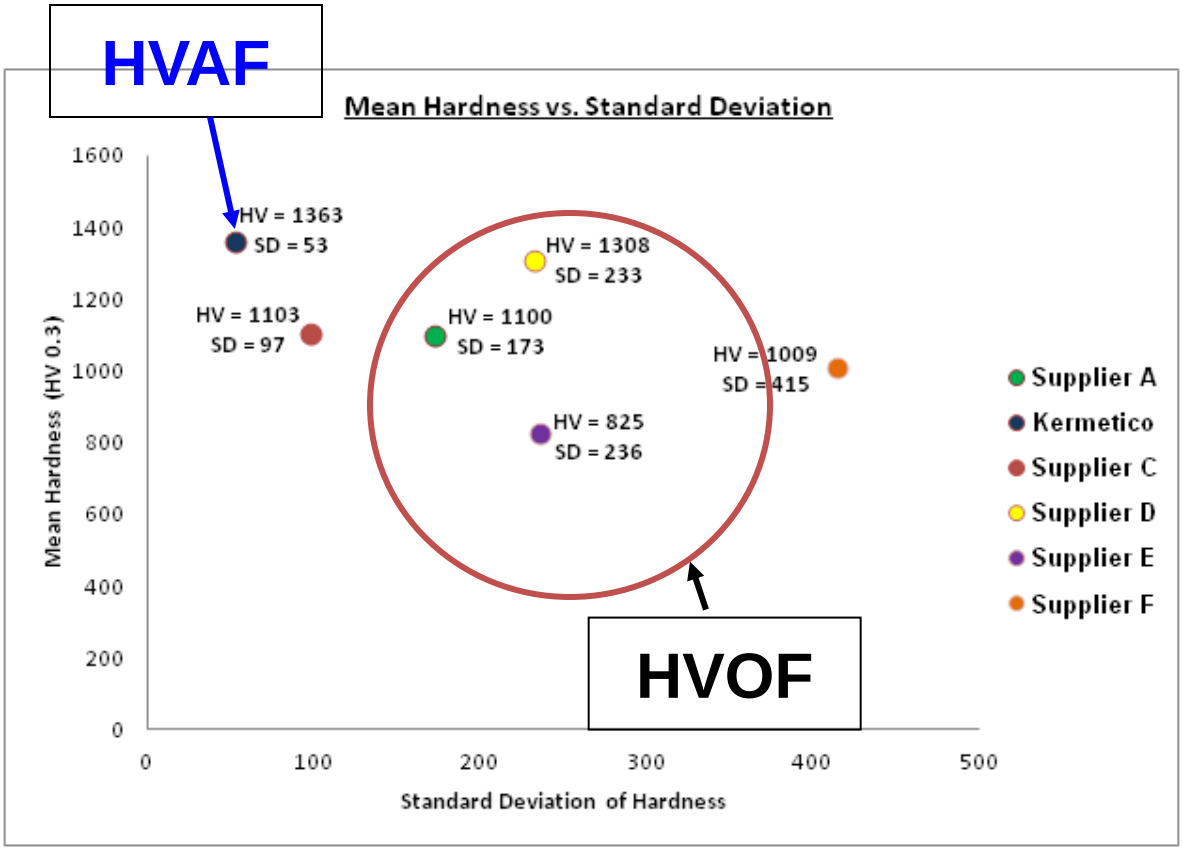
$$D_{powder\ jet} / D_{nozzle} = 0.1\text{-}0.2$$

I. **There is practically no restriction on the nozzle length to reach necessary acceleration of spray particles**

II. **Uniform acceleration = uniform coating structure and properties**

Uniformity of HVAF Coatings Properties:

Hardness of HVOF and Kermetico HVAF WC-10Co-4Cr coatings (Schlumberger, UK)



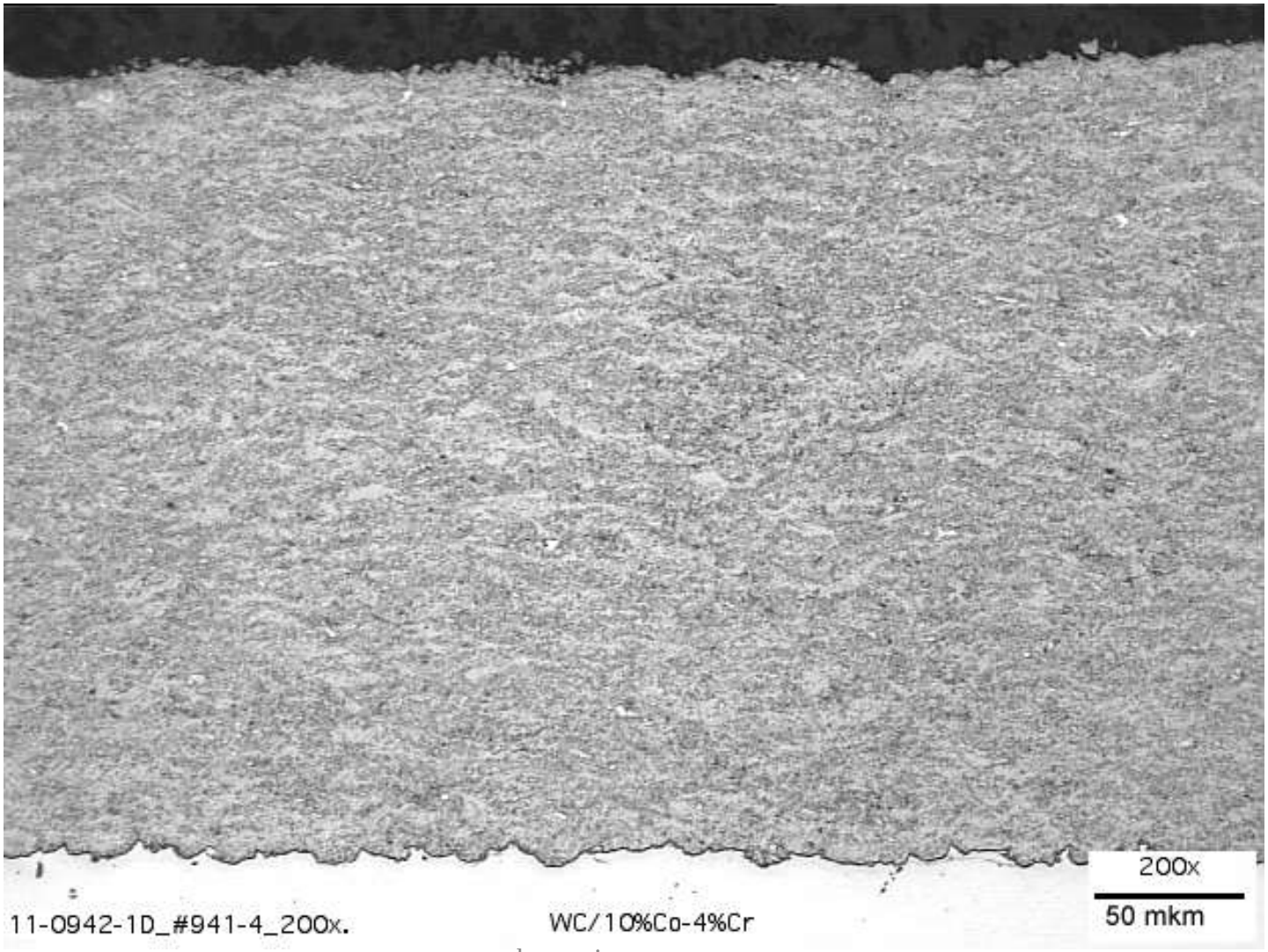
Relative standard deviation, %

HVAF: 3.9 %

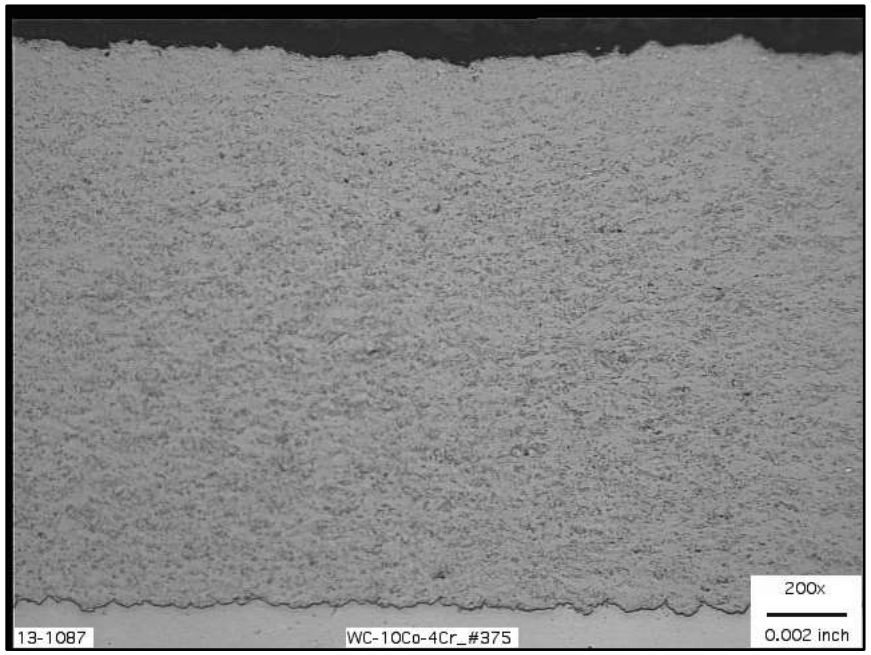
HVOF: 15.7-17.8%

WC-10Co-4Cr Coating Characterization

Propane
1470 HV300



WC-10Co-4Cr Coating Characterization

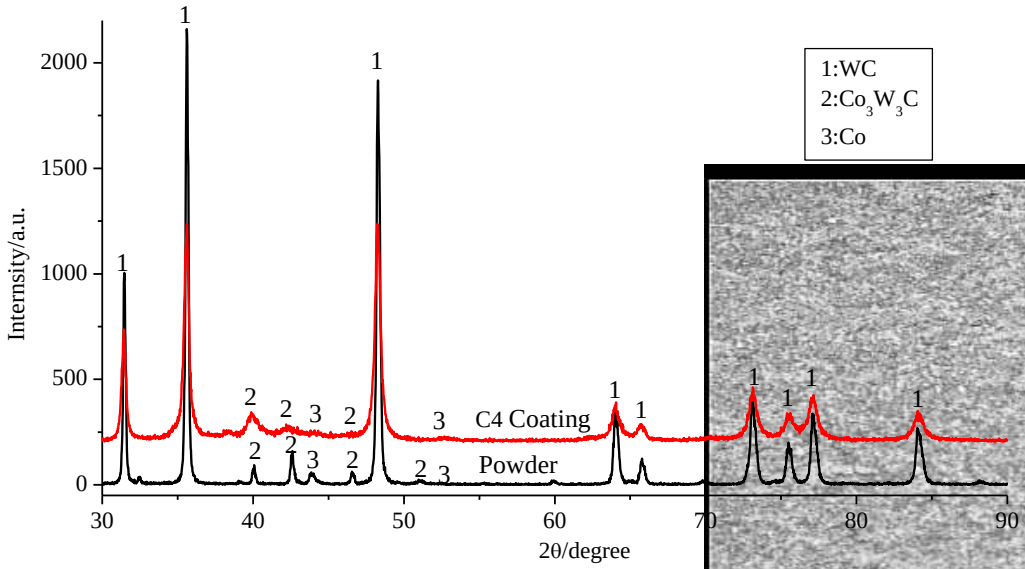


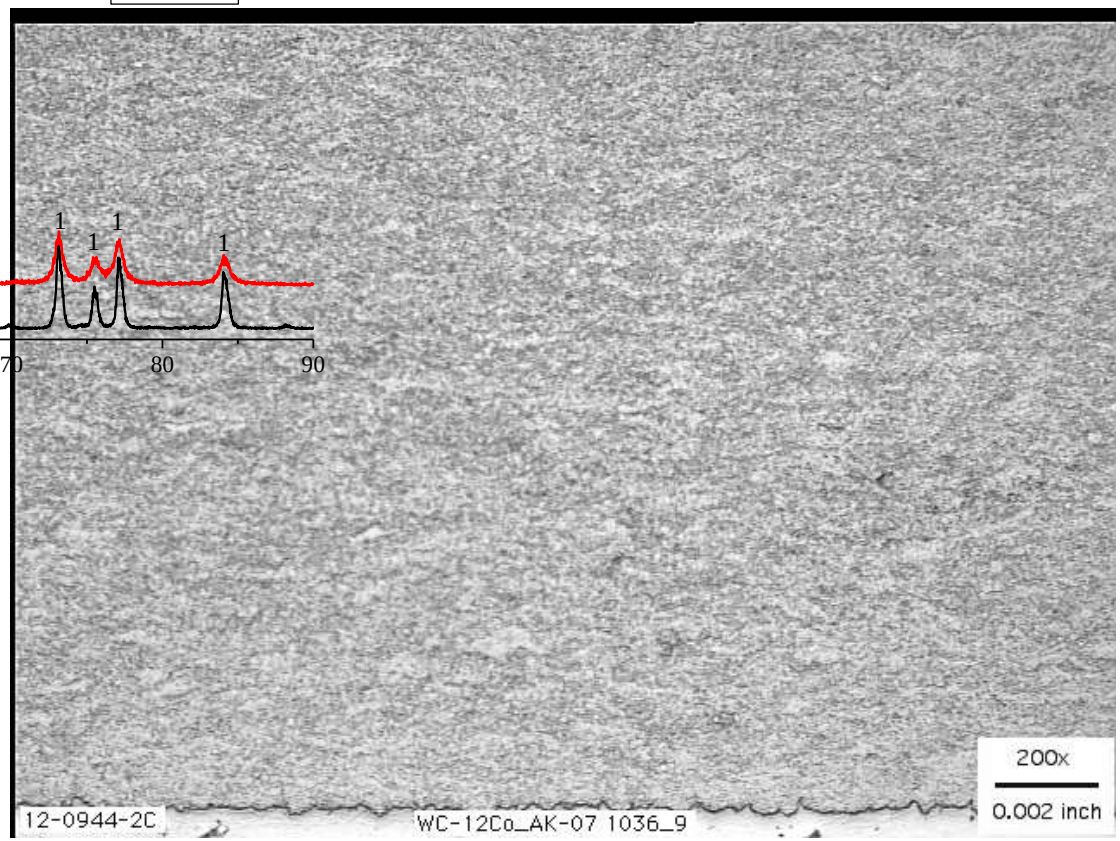
Propane- 60% Butane
1500 HV300

Propylene
1650 HV300

Kermetico HVAF:

Carbides are hard, but… ductile





WC-12Co
Propane
1540 HV300

Data of Central Power Research Institute Bangalore, India

Comparison of WC-10Co-4Cr coatings, deposited with HVOF (JP5000) and Kermetico HVAF (AK06)

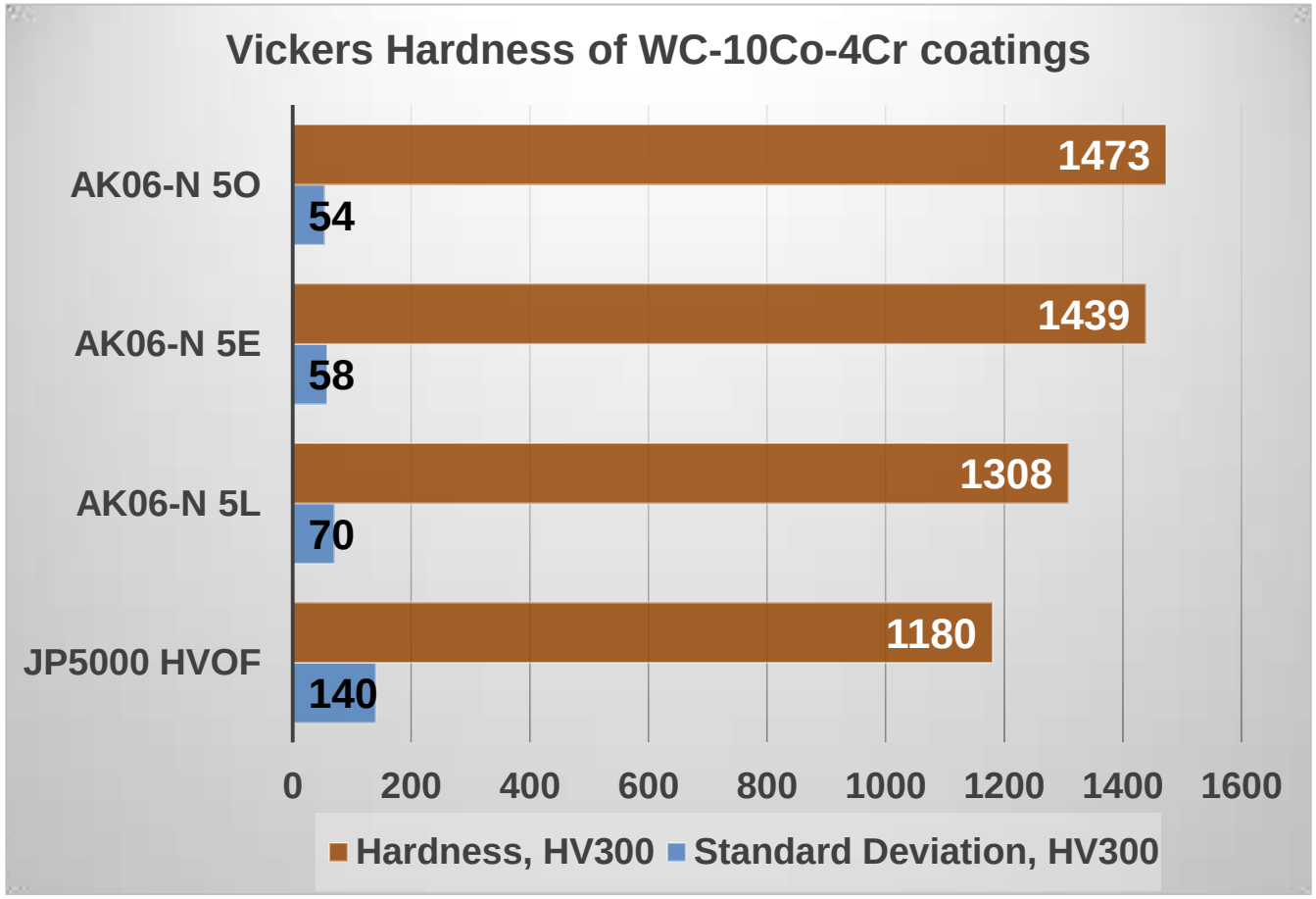
Notes:
HVOF optimized for the best cavitation resistance

HVAF applied in different modes, targeting different particle velocity (coating hardness)

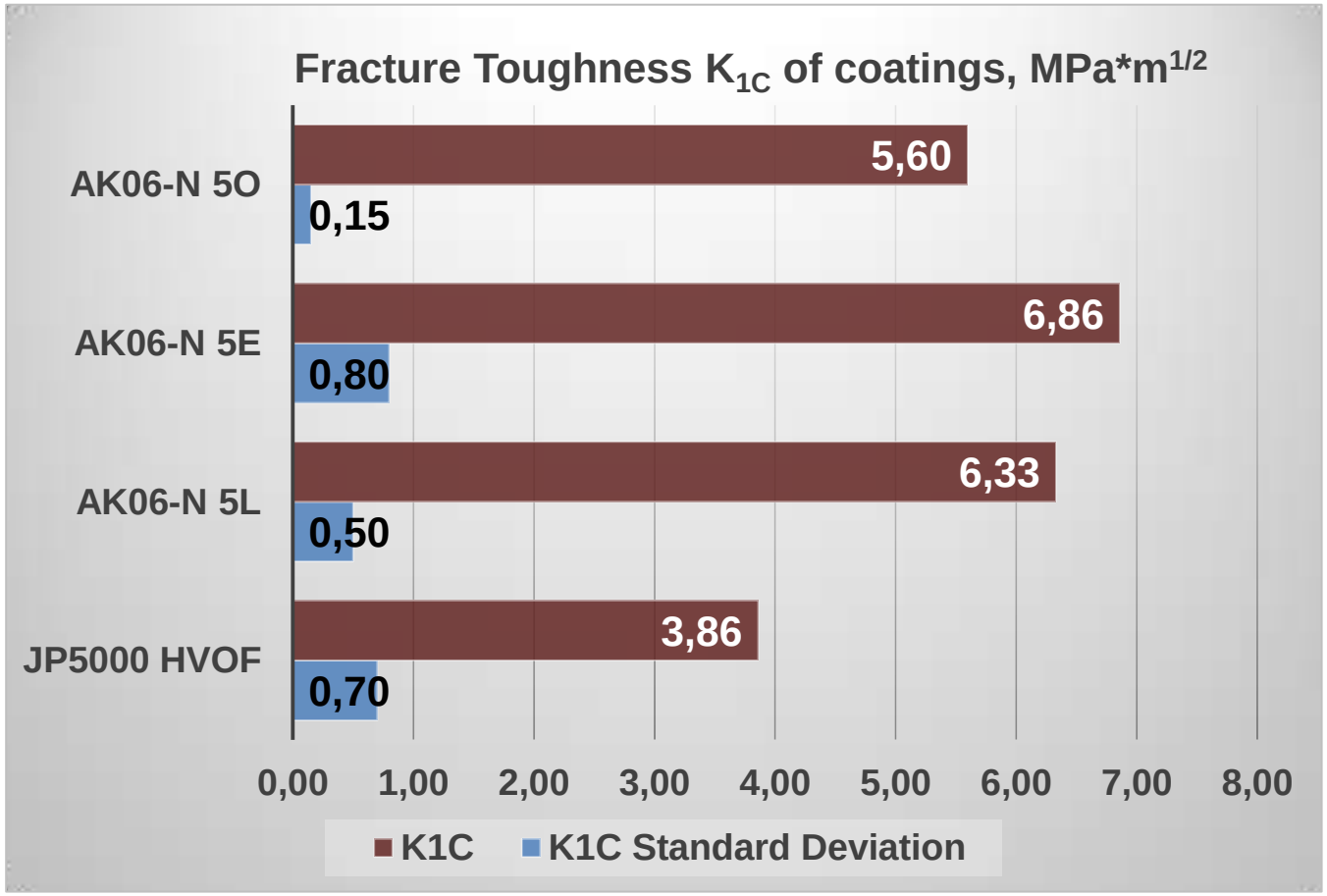
Spray Parameters: Normalized

	JP5000 HVOF	Kermetico AK6 HVAF		
		Nozzle 5L	Nozzle 5E	Nozzle 5O
Oxidizer flow, SLPM	O2: 873.1	Air: 2,104 (O2: 421.0)		
Fuel, g/sec	5.01	2.65		
O_2/Fuel Ratio vs. Stoichiometric	1.16 (Oxidizing)	1.03 (~Neutral)		
Carrier Nitrogen, SLPM	10.85	21		
Combustion pressure, Bar	7.56	5.25		
Powder feed rate, g/sec	1.50	2.22		
Particle average size, micron	27	18		
Particle velocity, m/s	740	895 +/-2	960 +/-3	1010+/-4
Particle temperature, ^{o}C	1790-1840	1470 +/-10	1460 +/-10	1470 +/-10
Particle kinetic energy, μJ	29.4	12.7	14.7	16.2
Energy density, GJ/m^3 = = Contact pressure, GPa	**3.8**	**5.6**	**6.4**	**7.1**

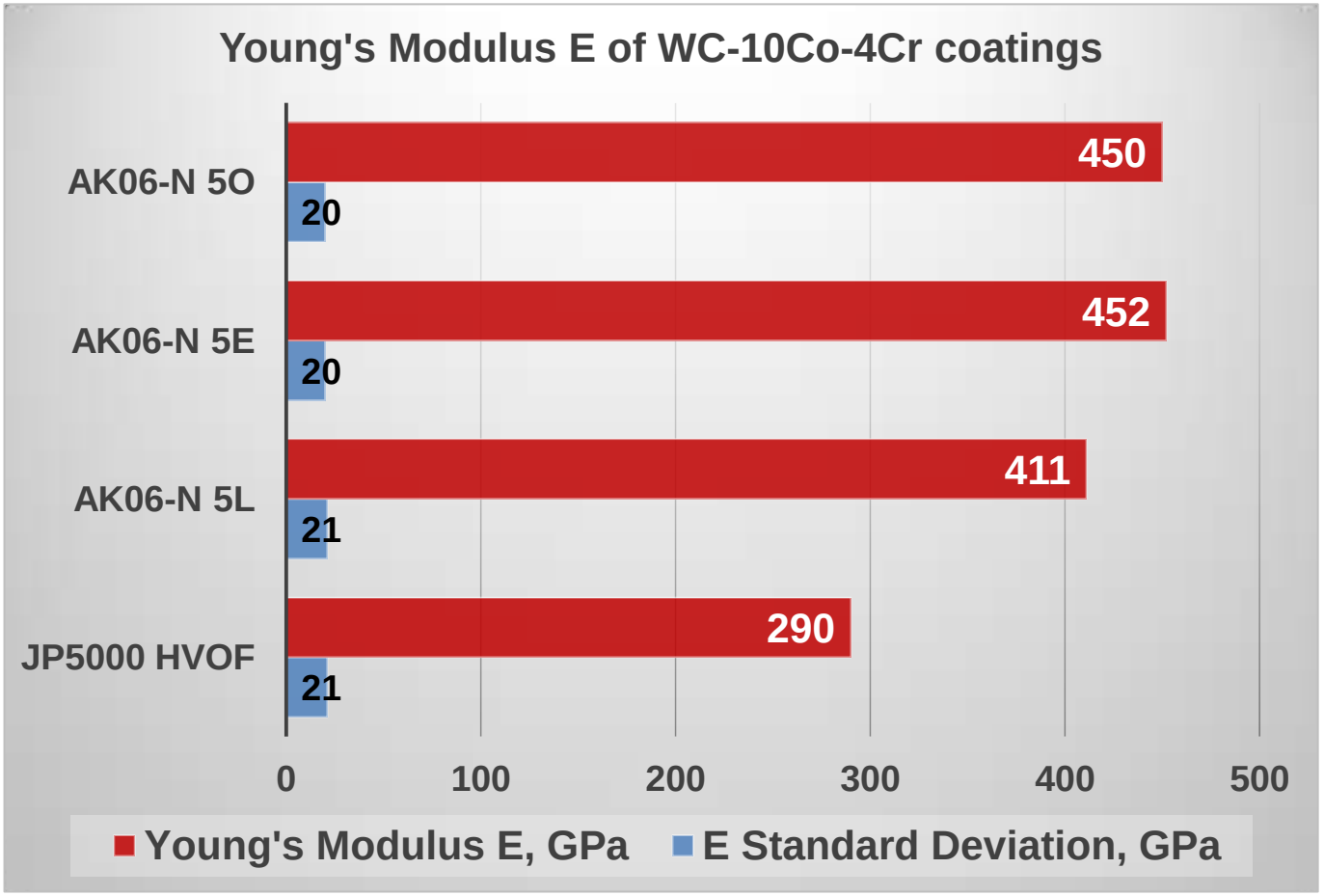
Mechanical Properties: WC-10Co-4Cr



Mechanical Properties: WC-10Co-4Cr



Mechanical Properties: WC-10Co-4Cr

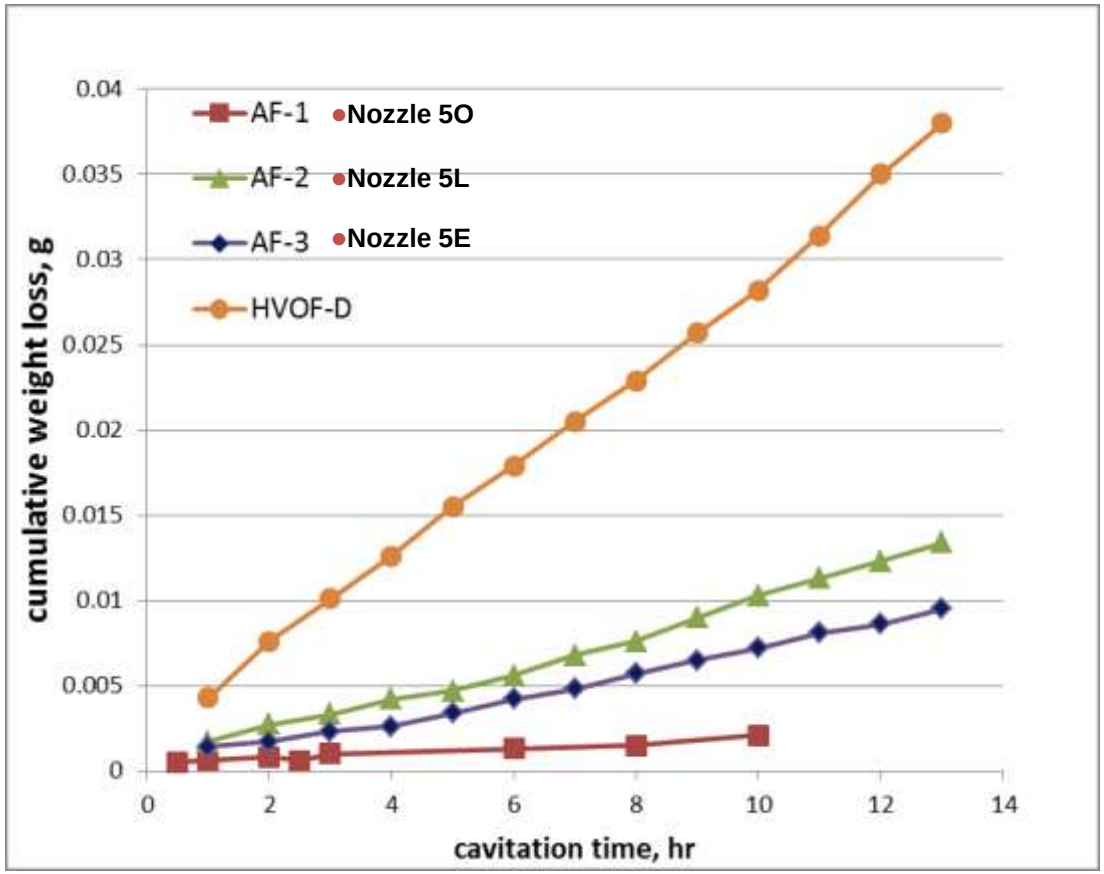


Cavitation Resistance
of WC-10Co-4Cr HVOF and HVAF coatings

(dw/dt) AF1 (5O) = 0.23 mg/h
(dw/dt) AF3 (5E) = 0.71 mg/h
(dw/dt) AF2 (5L) = 0.96 mg/h

(dw/dt) HVOF = > 3.26 mg/h

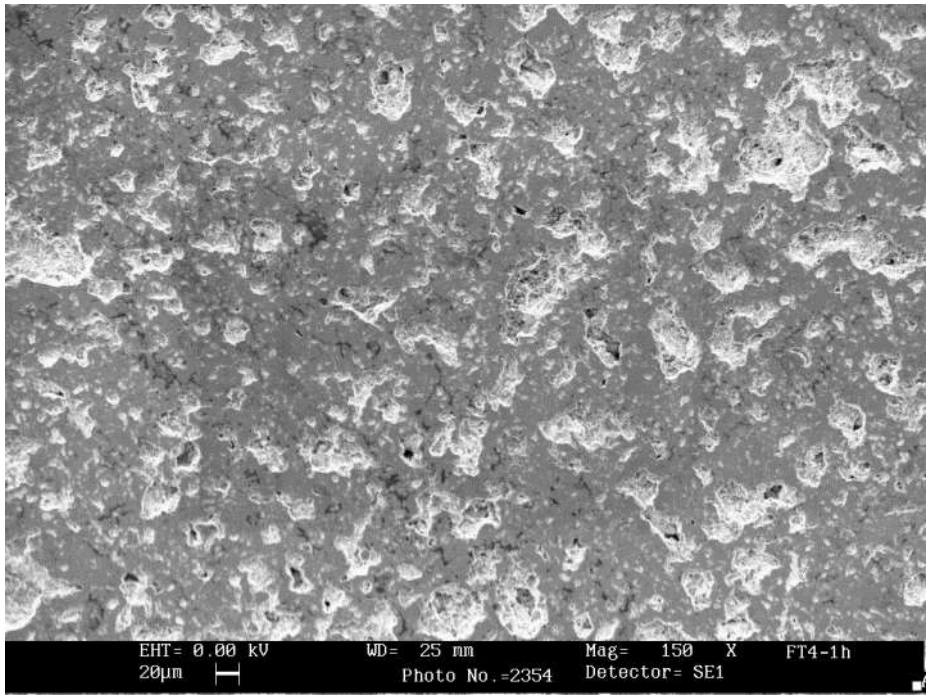
(dw/dt) 16Cr-5Ni steel = 2.0 - 2.5 mg/h



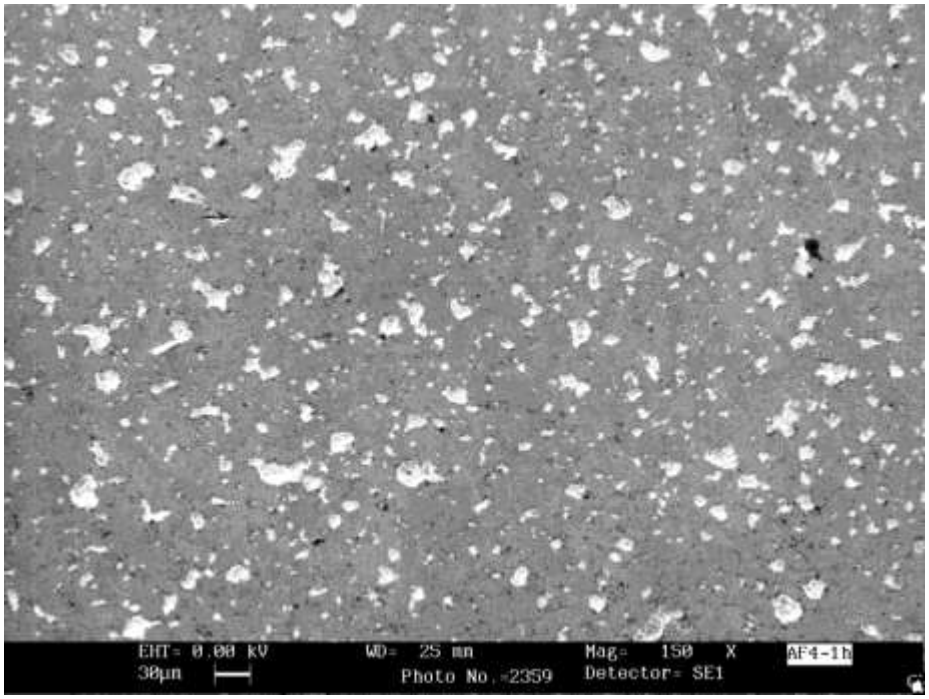
Surface SEM Micrographs of WC-10Co-4Cr Coatings after Cavitation Testing

Test duration: 1 hour

JP5000 HVOF



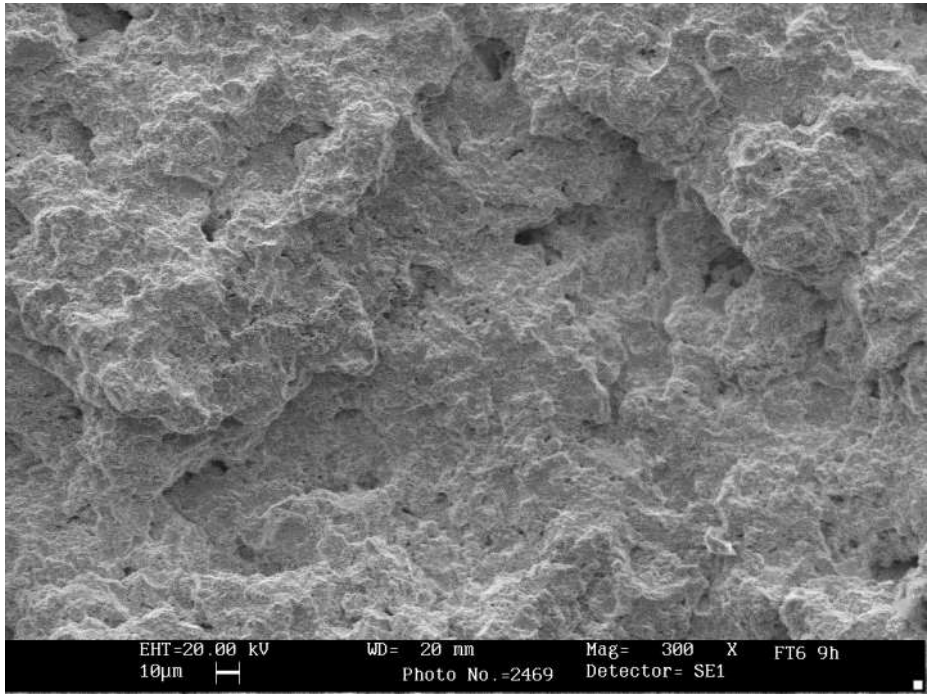
AK6 HVAF



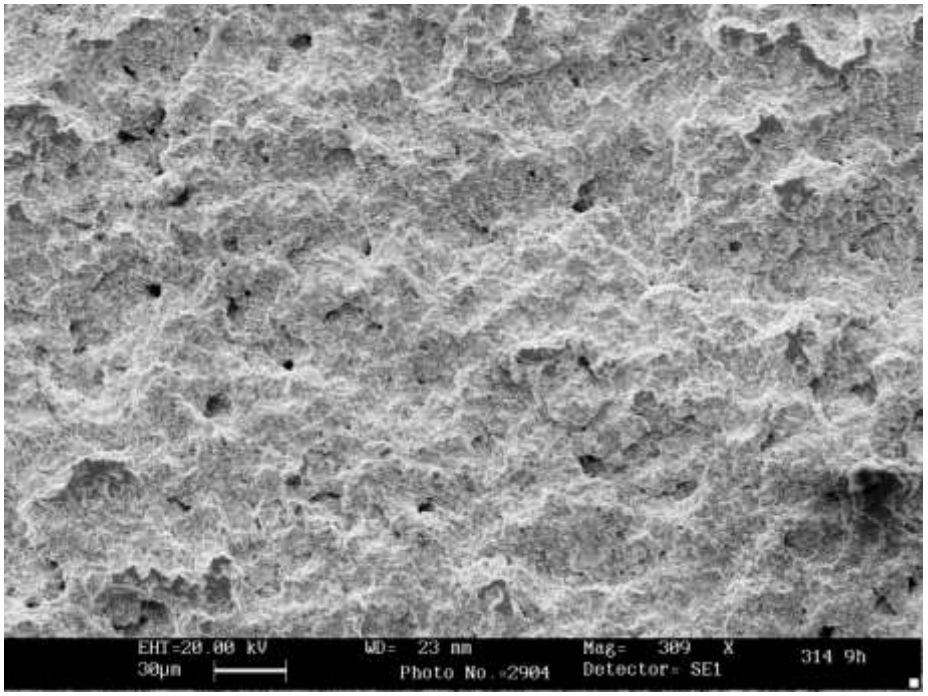
Surface SEM Micrographs of WC-10Co-4Cr Coatings after Cavitation Testing

Test duration: 9 hours

JP5000 HVOF

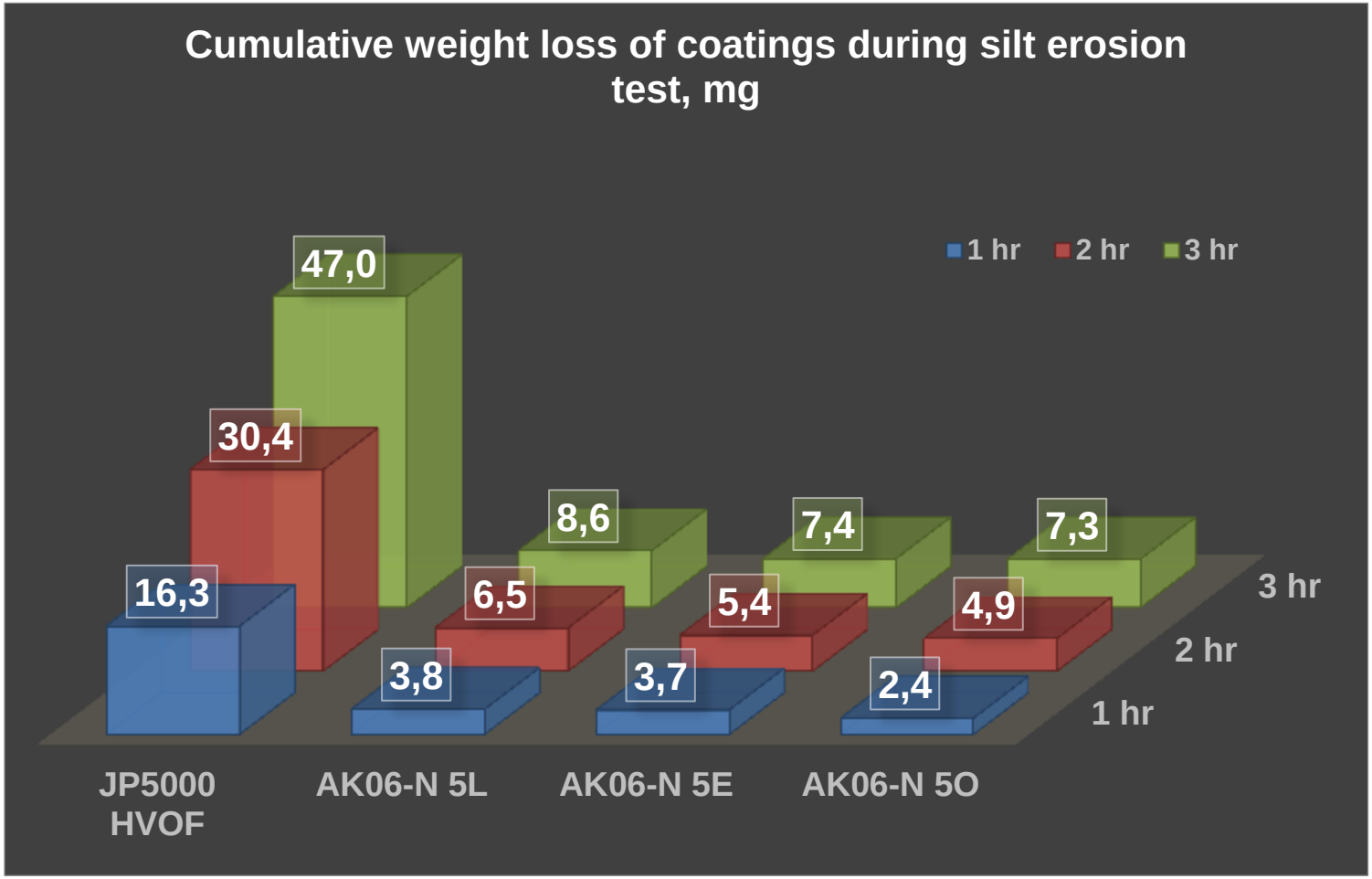


AK6 HVAF



Resistance to Silt Erosion

WC-10Co-4Cr HVOF and HVAF coatings



Other Third-party Data, Comparing Kermetico HVAF WC-10Co-4Cr Coatings to the Best HVOF and Detonation Systems

Test Results

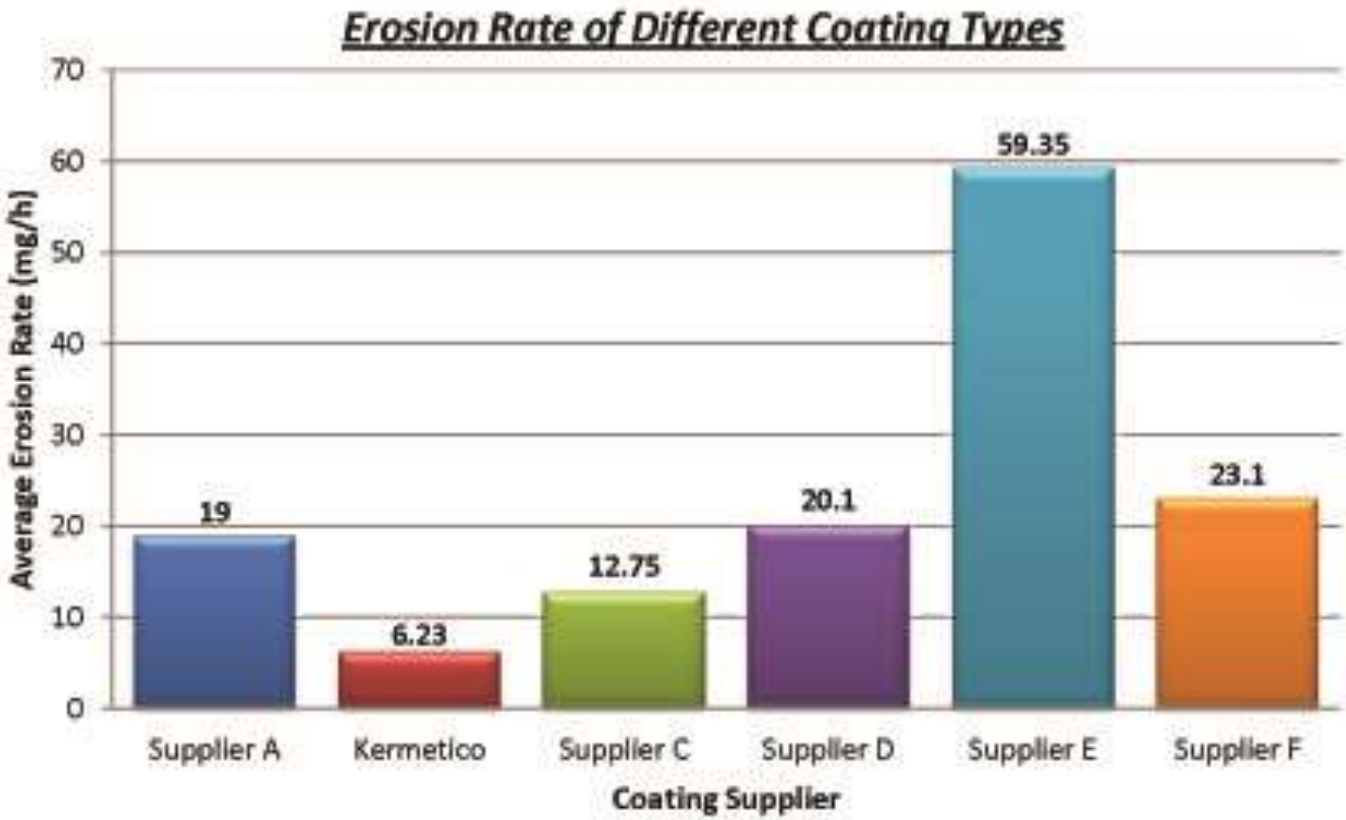
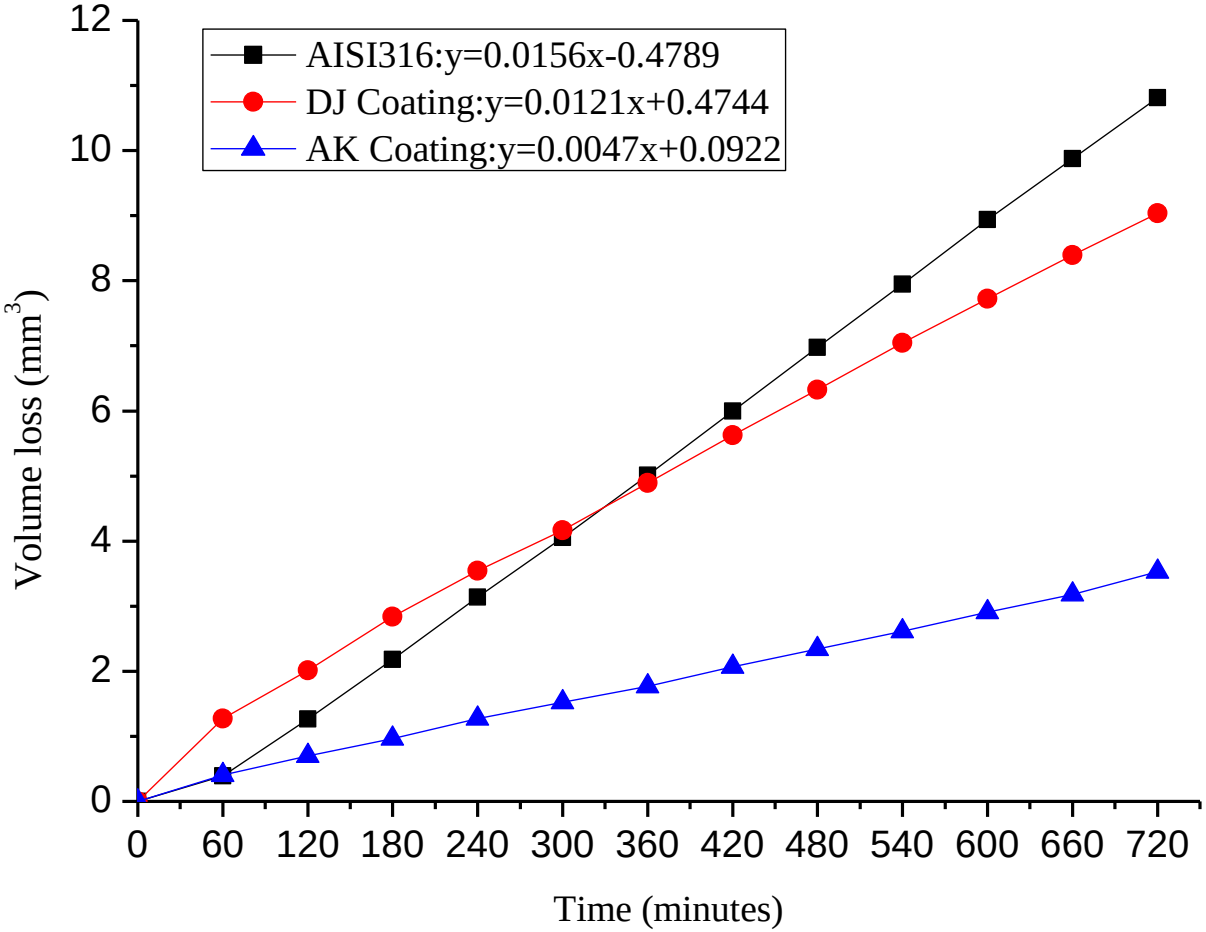


FIGURE 5 - EROSION RATE OF DIFFERENT SUPPLIER COATINGS

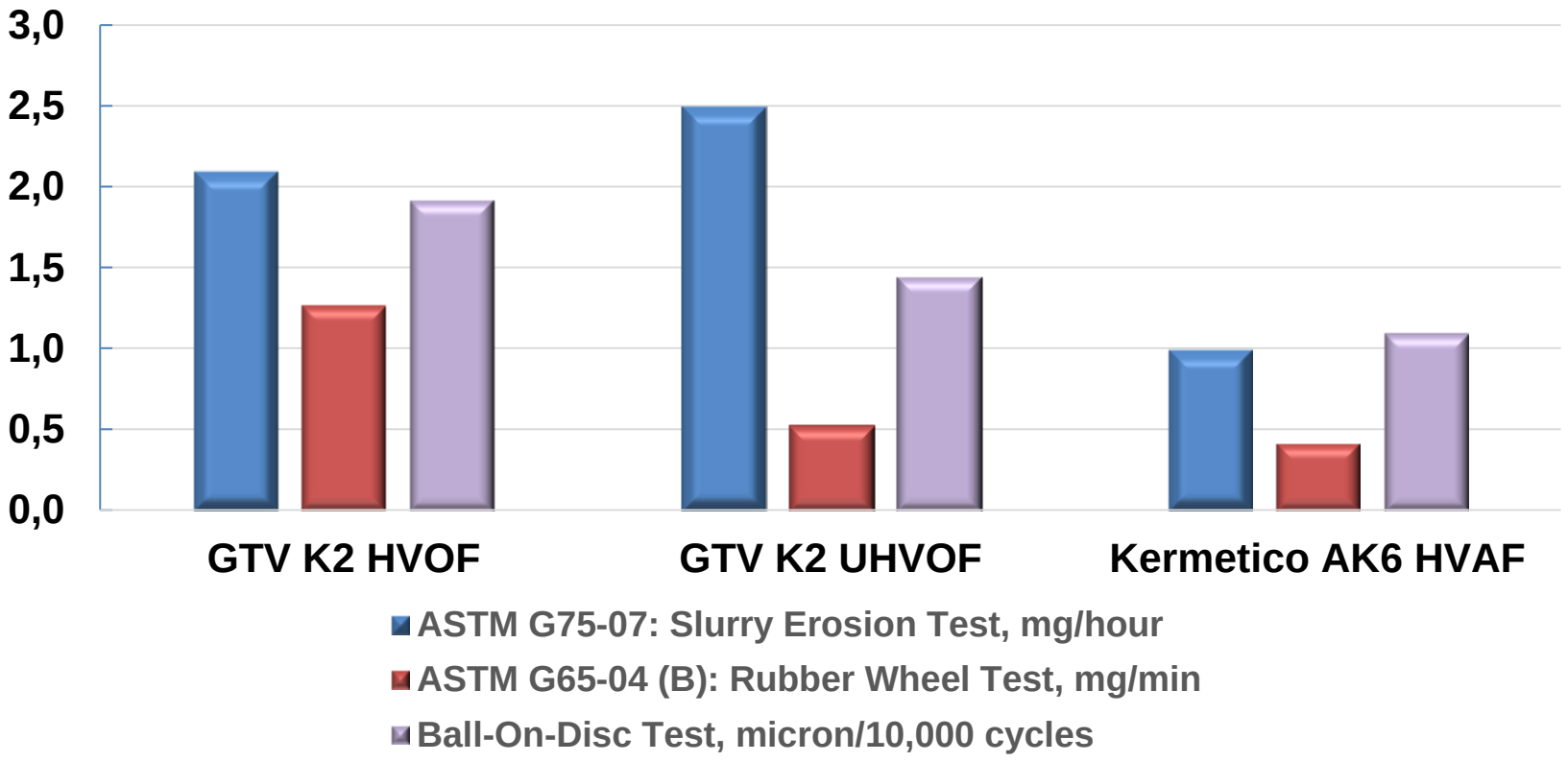
Hunan University
Changsha, Hunan, China:
WC-10Co-4Cr HVOF & HVAF coatings. Cavitation test



Gesellschaft für innovative Materialtechnik
InnoMat GmbH
Annaberger Str. 240, 09125 Chemnitz

Stellba AG
Wohlerstrasse 51
CH - 5605 Dottikon

InnoMat GmbH Report on WCCoCr coatings for Stellba AG (2016)

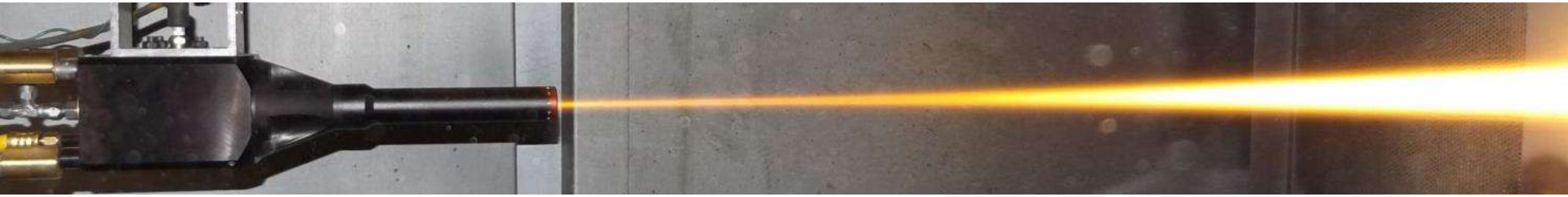


Slat Spray: All WCCoCr Samples Passed 312-Hour Test

	K2 HVOF	K2 UHVOF	AK6 HVAF
Before testing			
After 312-hours testing			

Note: HVAF samples were tested after Pin-On-Disc Wear Test

Economic Aspects of Kermetico HVAF Spraying:
Your Choice of Cost and Quality



HVAF-E (Economy) – meets HVOF specs

HVAF-B (Balanced) – exceeds HVOF specs

HVAF-U (Ultra) – substantially exceeds HVOF specs

Economic Aspects of Kermetico HVAF

Gun Setup	Coating Hardness , HV_{300}	Coating Porosity, %	Deposition Efficiency, %
Economy (E)	1050-1250	<0.8	65+
Balanced (B)	1250-1350	<0.5	48 - 58
Ultra (U)	1450-1700	<0.1	36 - 42

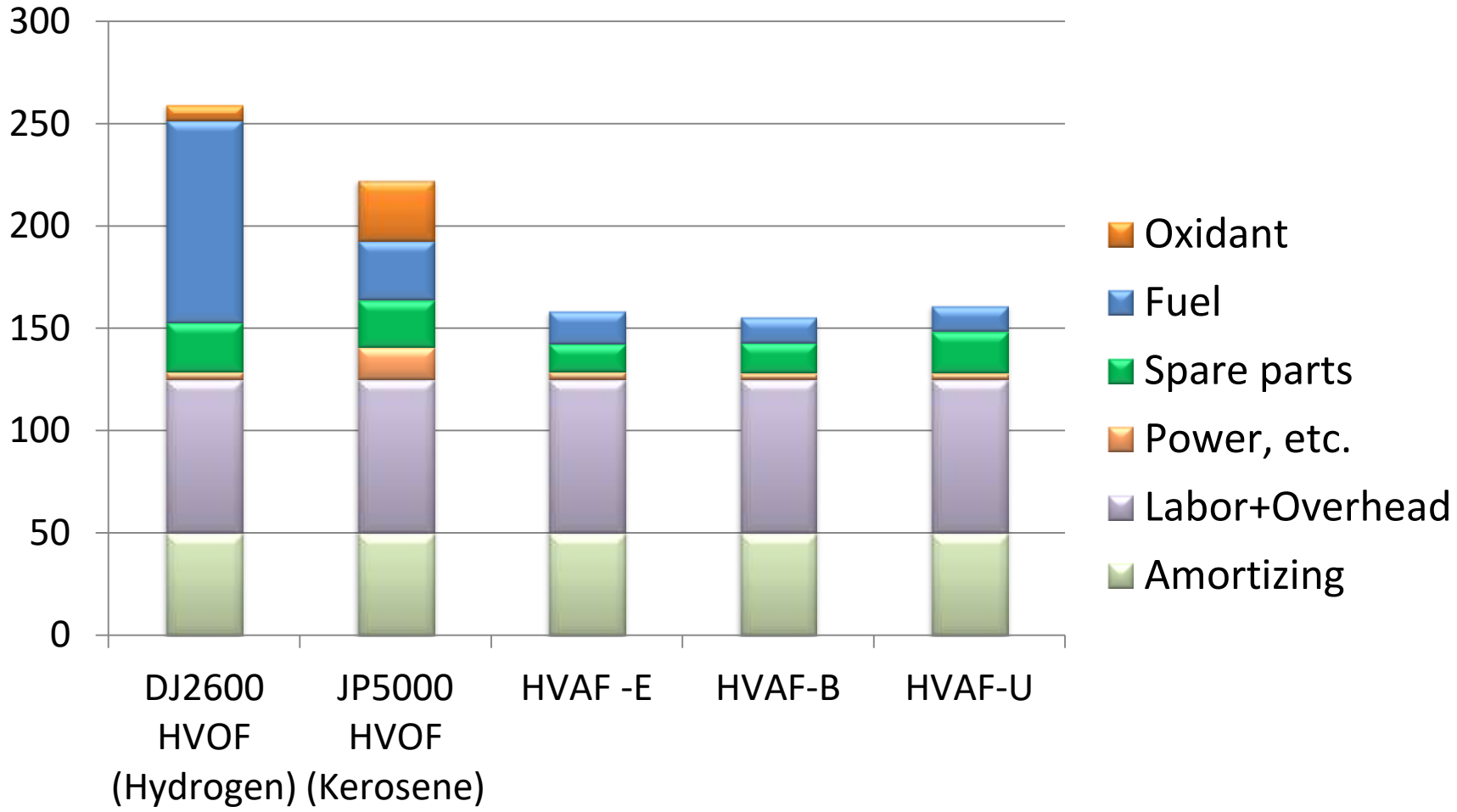
High spray rates are applicable for large and small parts

O.D. 38 mm: Rate 25 kg/hour

O.D. 330 mm: Rate 32 kg/hour

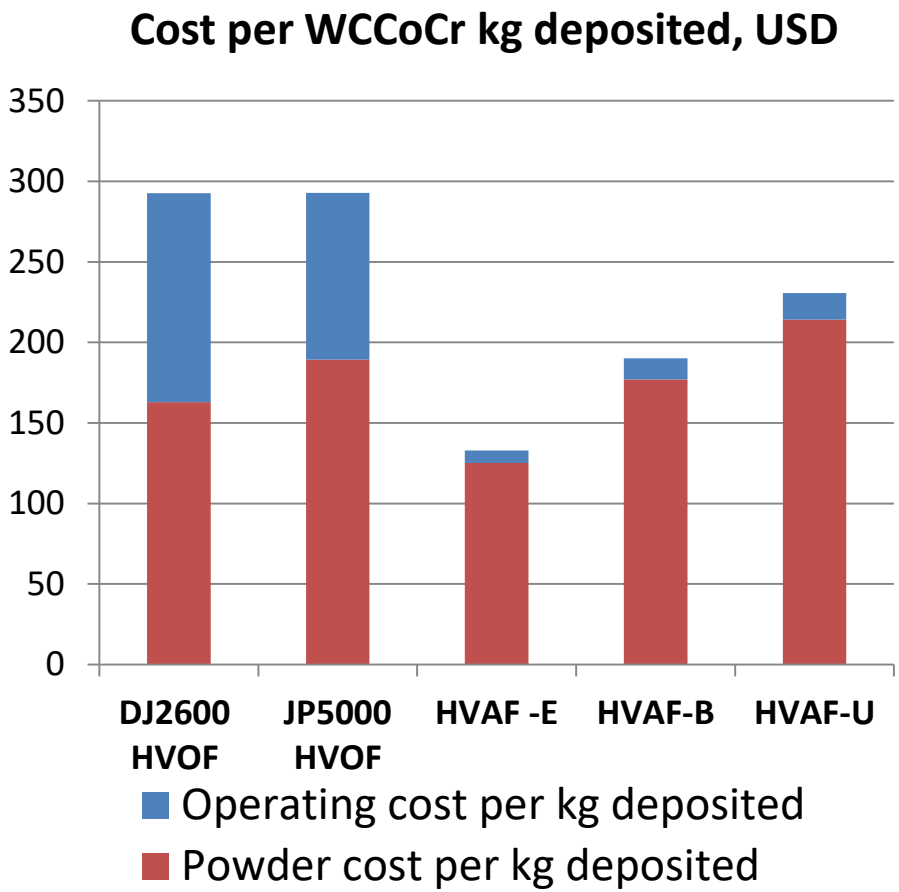
Data for WC-10Co-4Cr, agglomerated & sintered powder

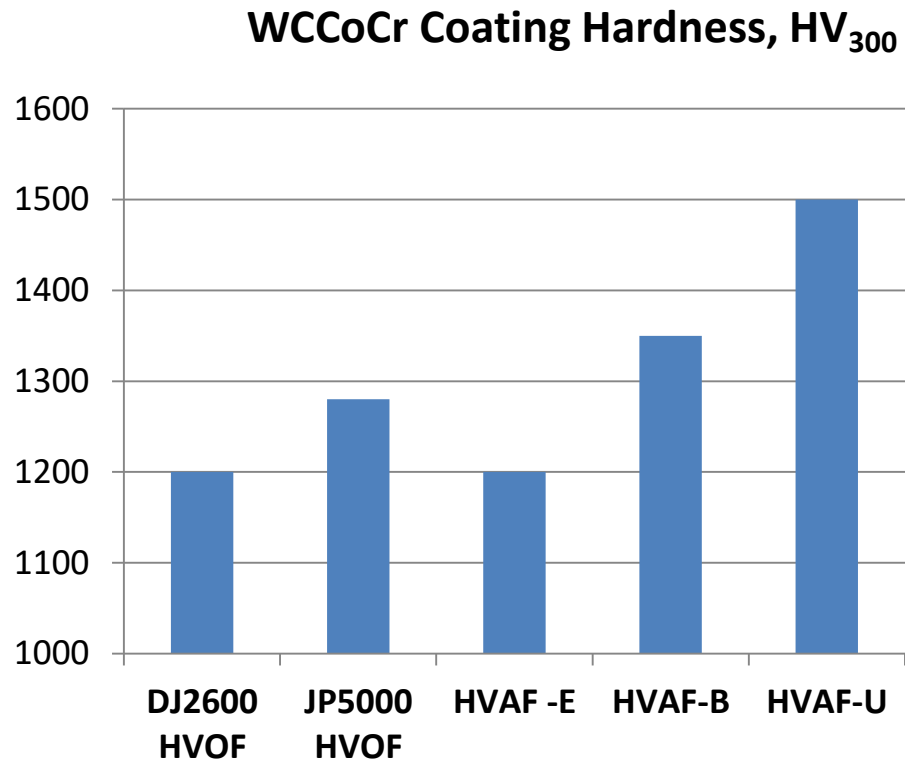
HVOF vs HVAF WC-10Co-4Cr Costs



Comparison of HVAF and HVOF operating costs, USD per hour (prices in Texas, USA)

Comparison of HVAF and HVOF Cost
(prices in Texas, USA)





Note: Cost of WC-Co-Cr powder: $81.4 per kg

	DJ2600 HVOF	JP5000 HVOF	HVAF-E	HVAF-B	HVAF-U
Spray Rate, kg/hour	4	5	32	26	26
Deposition Efficiency	50%	43%	65%	46%	38%

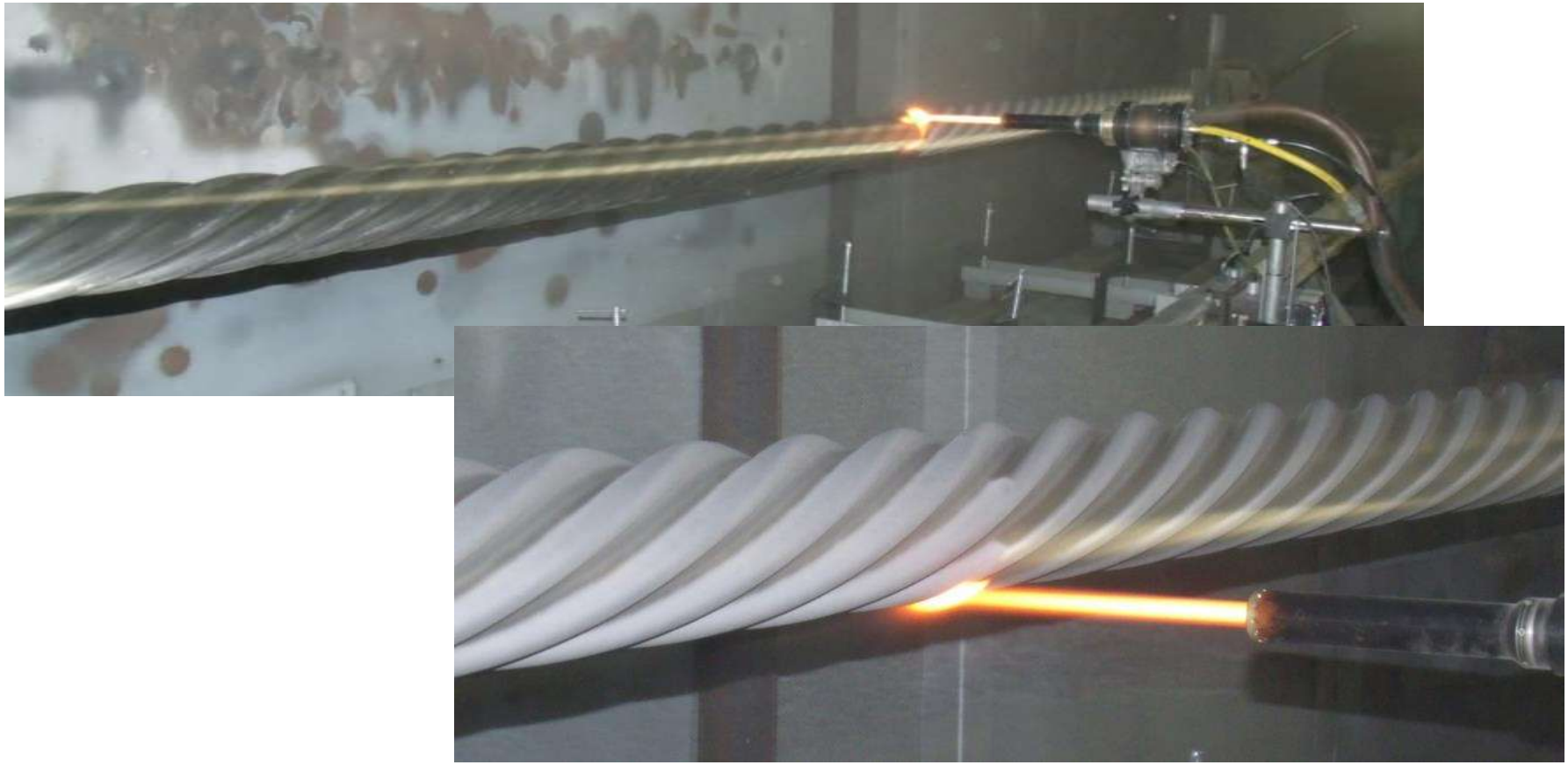
HVOF vs HVAF WC-10Co-4Cr Costs

WC-Co-Cr powder cost: 81.4 USD/kg	DJ2600 HVOF	JP5000 HVOF	AK7 HVAF (E)
Total operating cost, USD/hour	$260	$223	$160
Spray rate, kg/hour	4	5	32
Deposition efficiency, %	50	43	65
Deposition rate, kg/hour	2.2	2.2	20.8
Cost per KG of sprayed coating, USD	$293	$293	$133
AK7 savings per KG of deposited coating, USD	$160	$160	

Changing a HVOF system to Kermetico HVAF saves $160,000 USD per each metric ton of deposited tungsten carbide coating

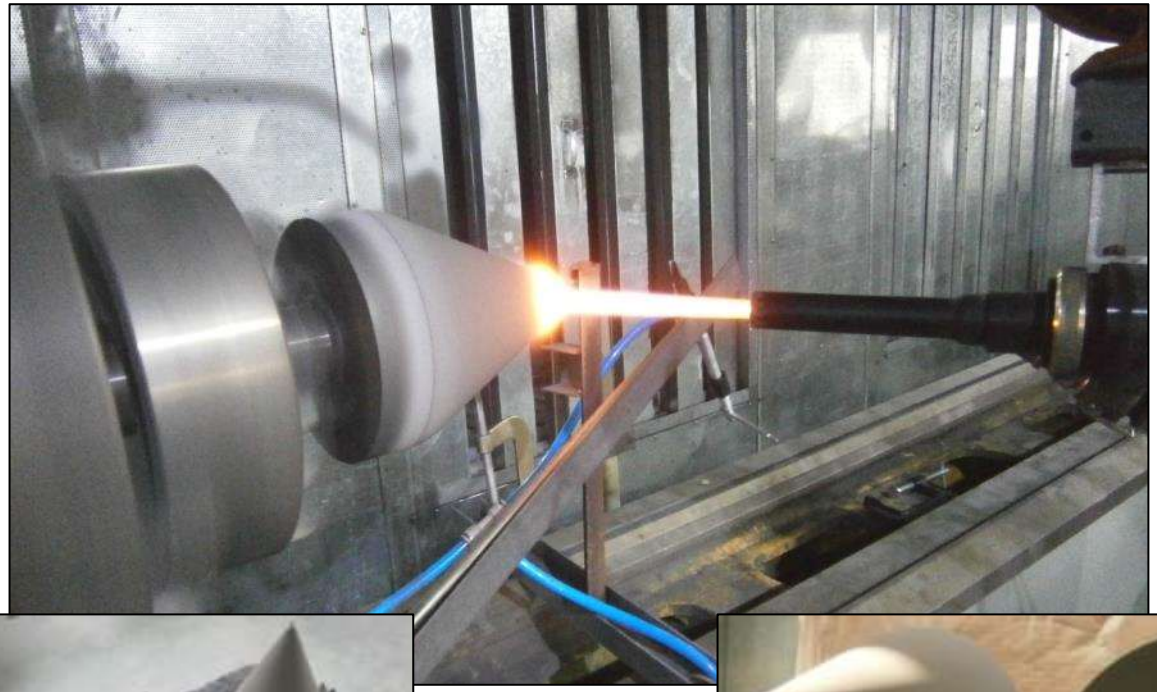
Examples of Kermetico HVAF Applications

Mud Rotors, Oil Drilling: WC-20Cr7Ni, WC-10Co-4Cr



Hydro-Power:
Francis Turbine Runner and Head Cover
WCCoCr Application by Plackart Ltd., Russia

Hydro-Power:
a Metering Needle Valve and a Seat
Application by RenCoat Ltd., China



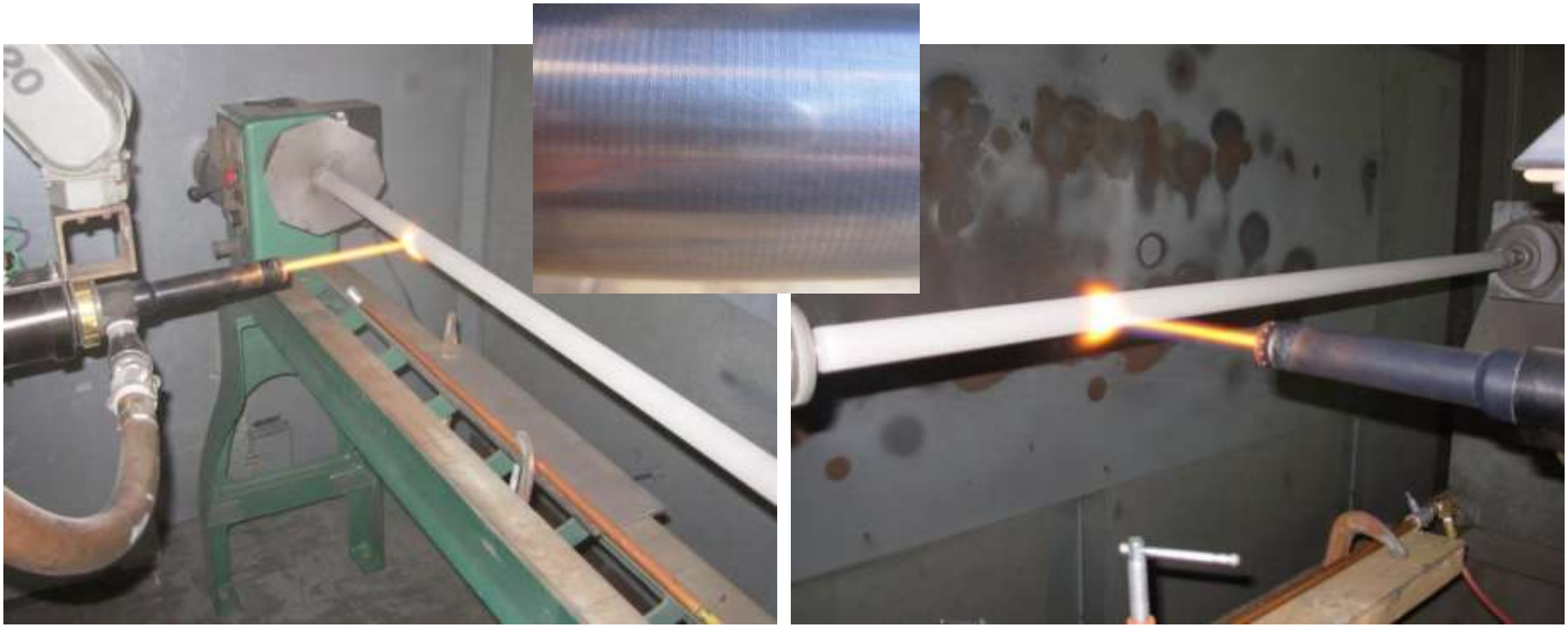
A Sliding Gate of a Catalyst Tower

Spraying: Upper slide gate

Hydraulic Rods of Dock Cranes

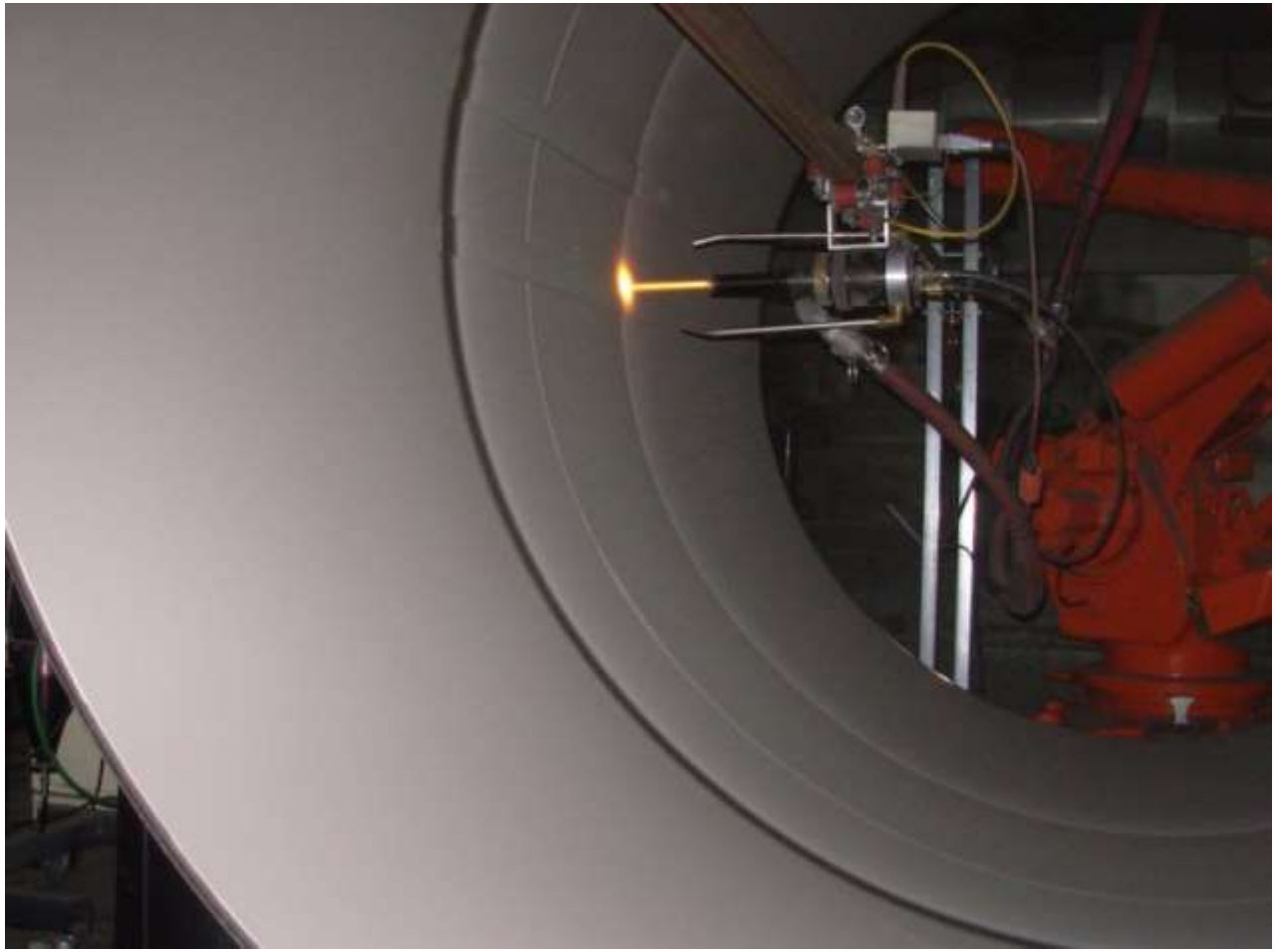
Hard chrome performance: 0.5 year max (pitting)

HVAF WC-Co-Cr coating performance: 4+ years



A Refinery Sulfur Condenser Vessel

Application of Hastelloy C HVAF coating
DIA 1.8 m x L 2.4 m



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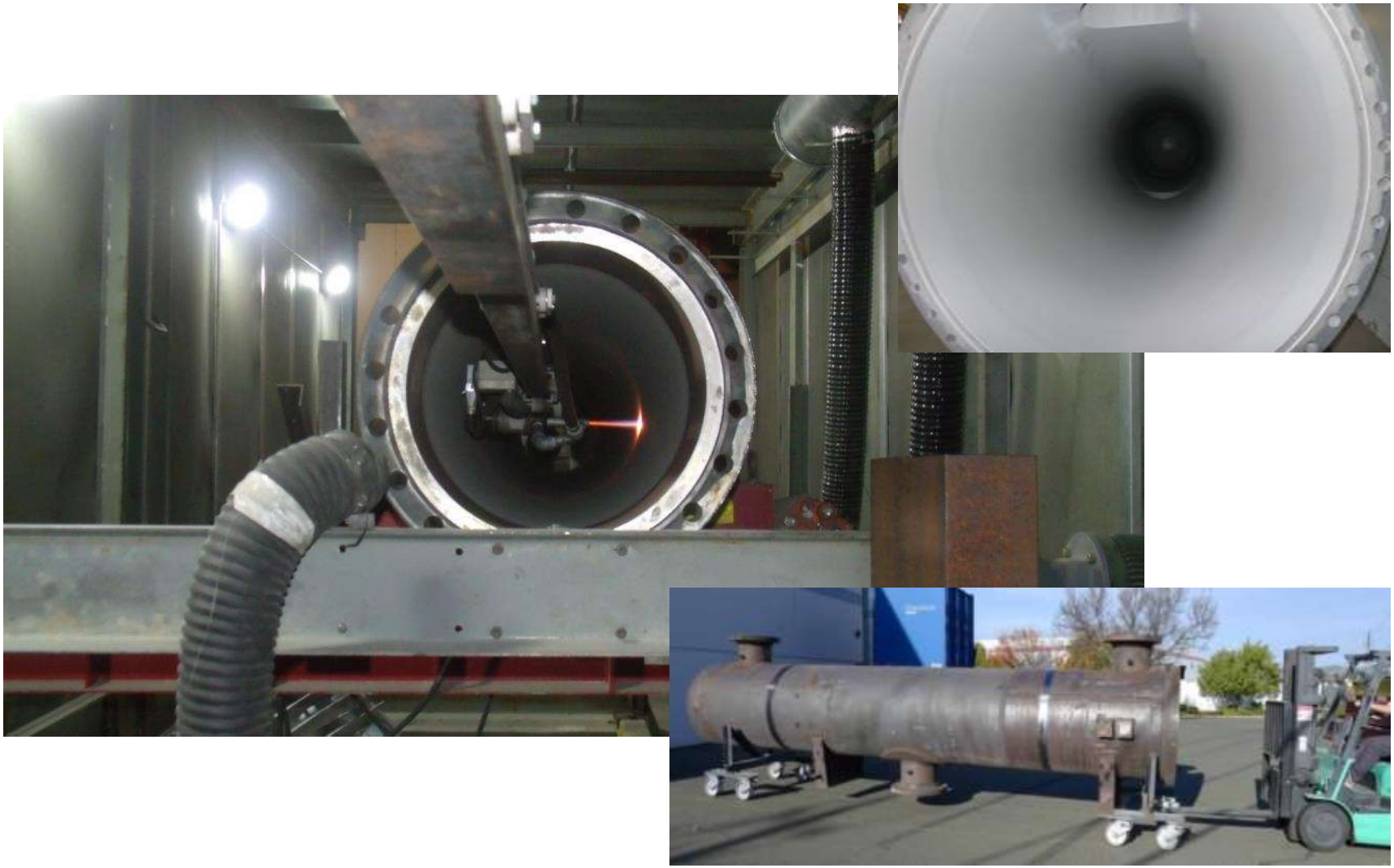
Refinery: Automated Coating Application with the Rotating AK5 Gun Inside a Processing Vessel

Diameter: 1.8 m

Length: 11.8 m

Refinery: Heat exchanger vessels



Double-Elbow, Coke Transport Line

12-inch ID,

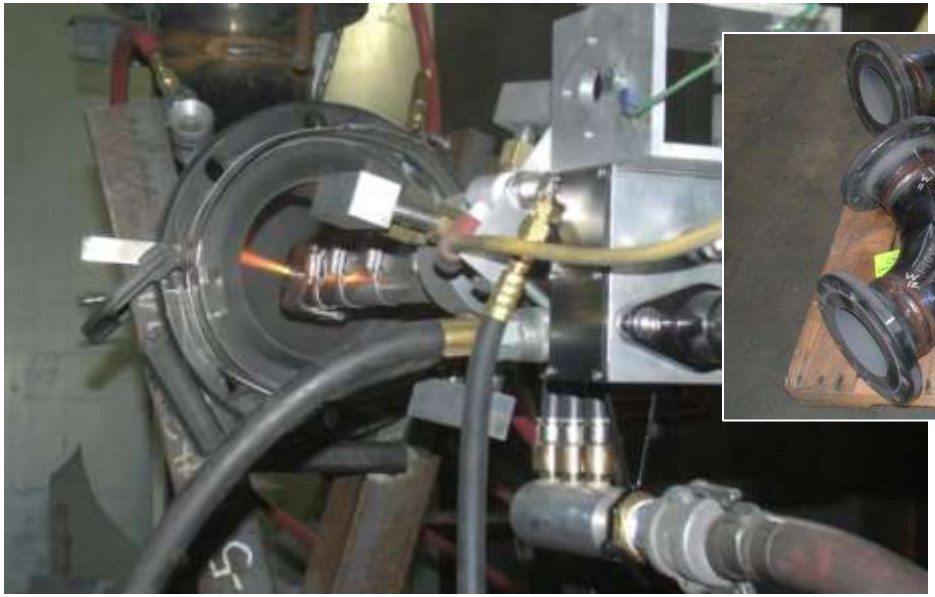
6-feet long

Double-Elbow, Spraying with rotating AK5 gun

Coke Line Cyclone: Application of WC-10Co-4Cr Coating with the Rotating AK5 Gun

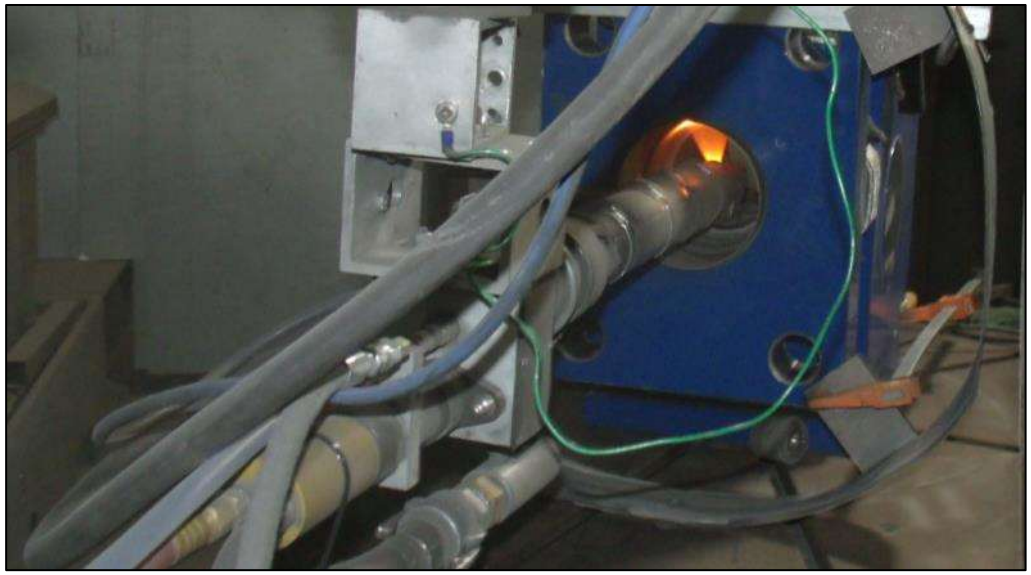
Coke Line Cyclone: Application of WC-10Co-4Cr Coating with the Rotating AK5 Gun

Small ID Transport Pipe Line Components: Application of WC-10Co-4Cr Coating with the Rotating AK-IDR Gun



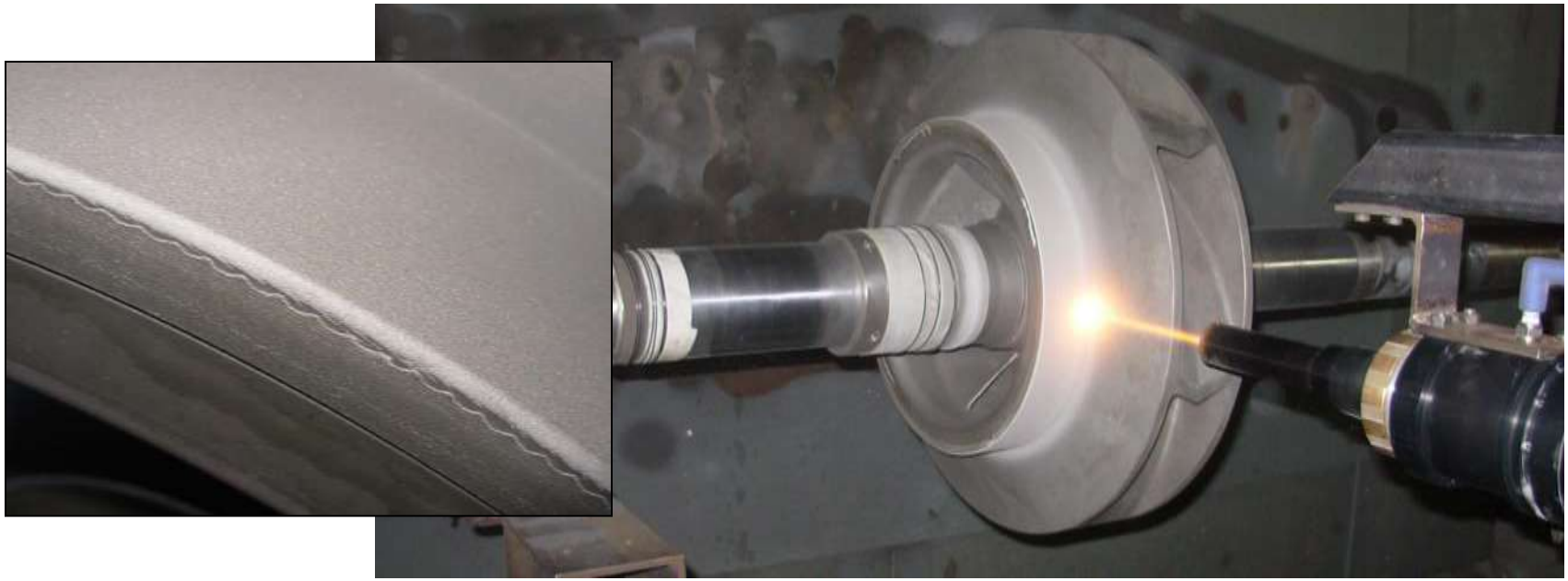
Oil Refinery:
Pump Casing ID Spraying

Oil Drilling:
Fluid-End Pump Casing, 5-inch (125 mm) ID
Application of coating with AK-IDR rotating gun



Wear Rings on HT Pump Housings and Impeller Hubs

AK7 Stellite 6 coating over Stellite weld overlay



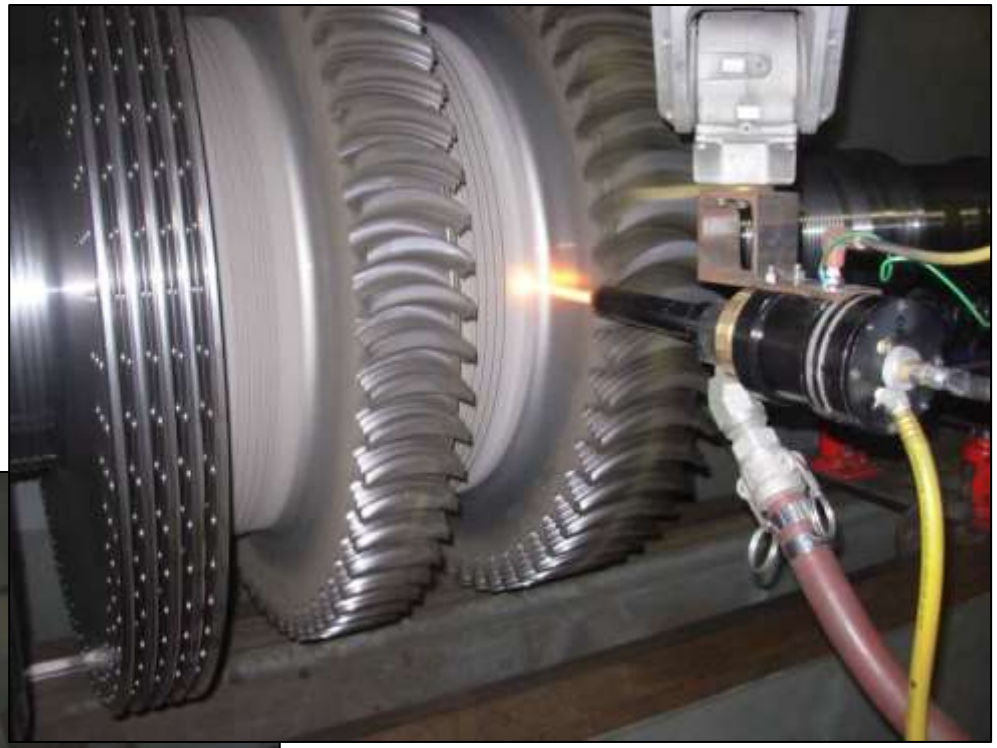
HT (400°C) Pump coating solutions:

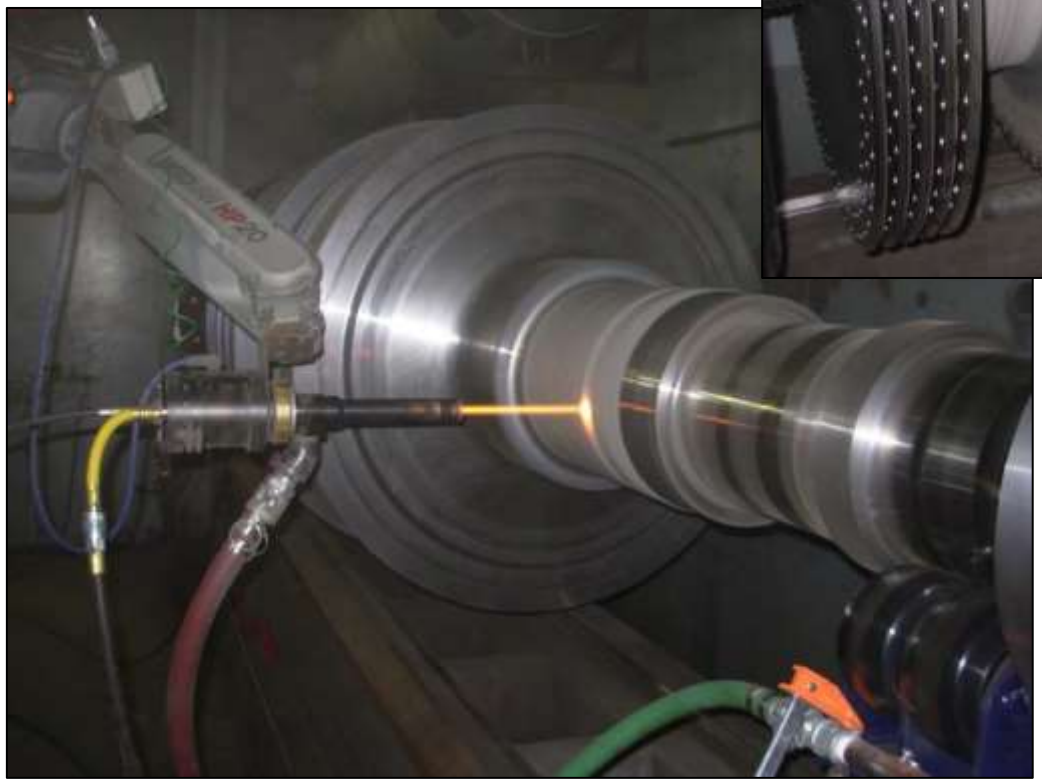
Housing ring: Stellite 6
Impeller ring: Stellite 1

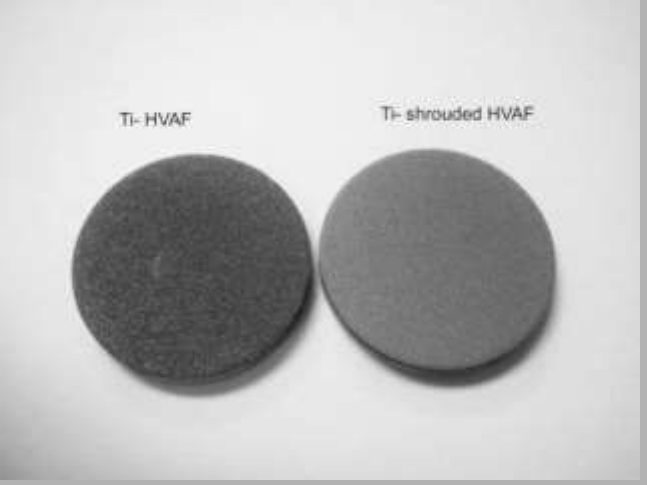
⇨

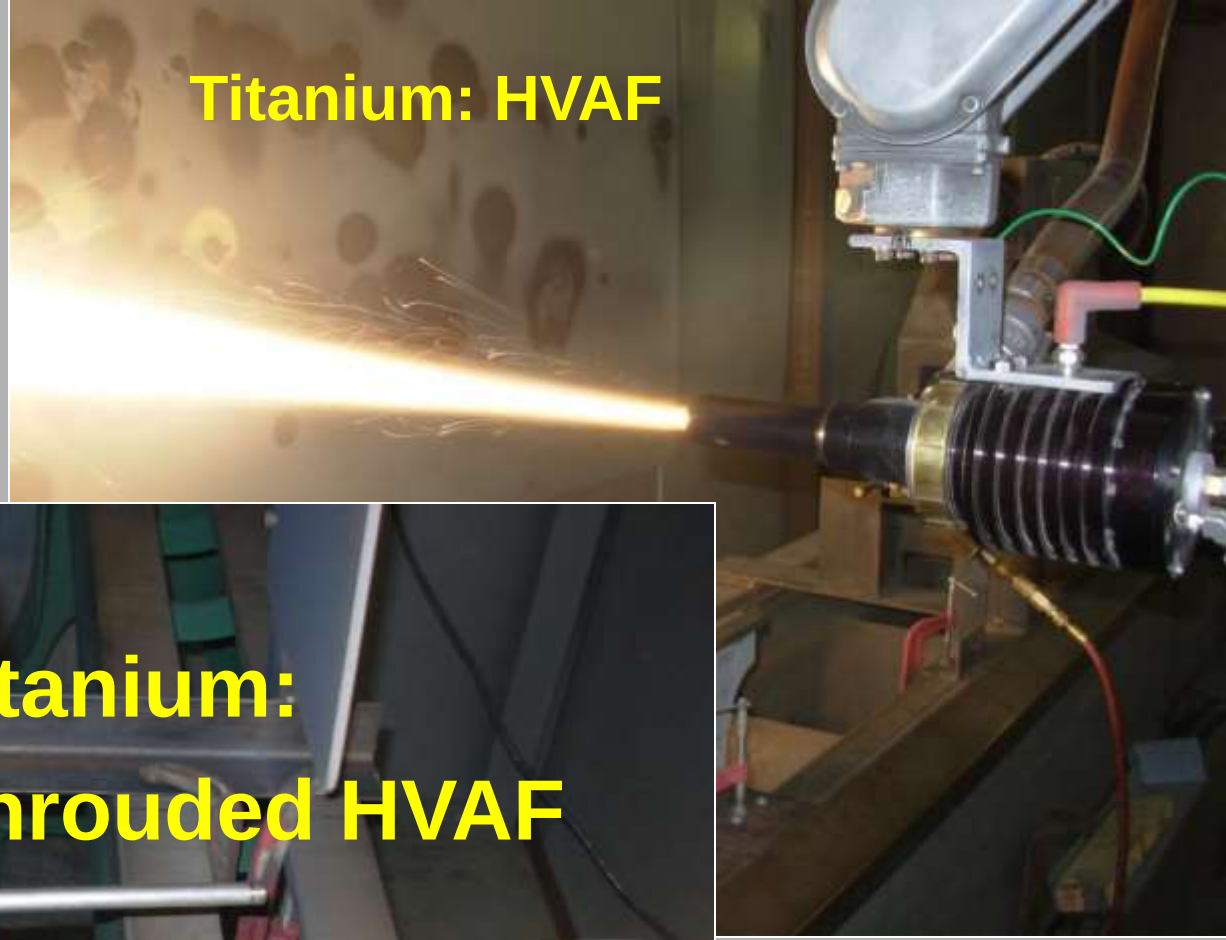
Housing ring: Stellite 6
Impeller ring: WCCoCr

Geothermal Power: Turbine Rotor WCCoCr 86/10/4



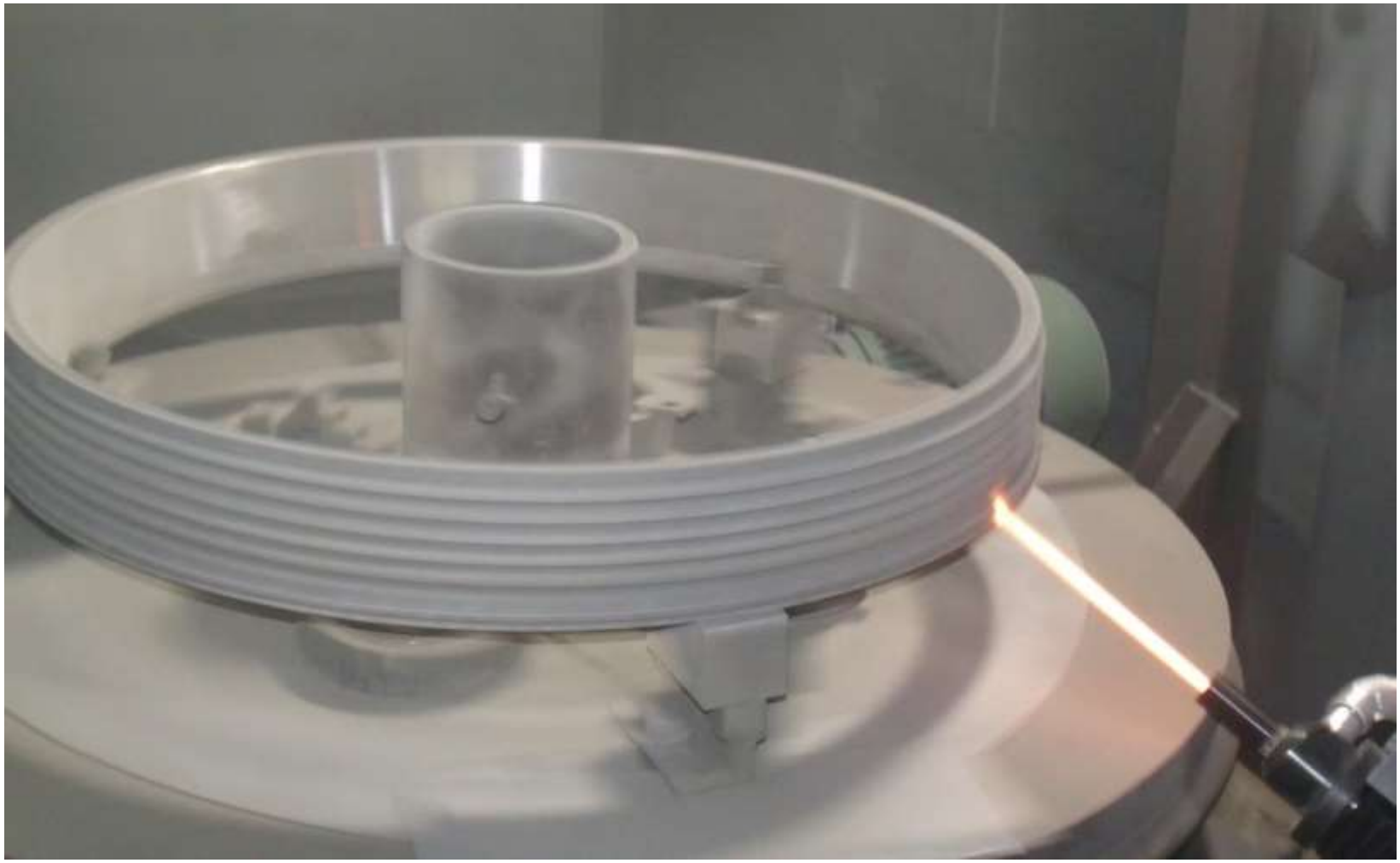



Ti- HVAF
Ti- shrouded HVAF

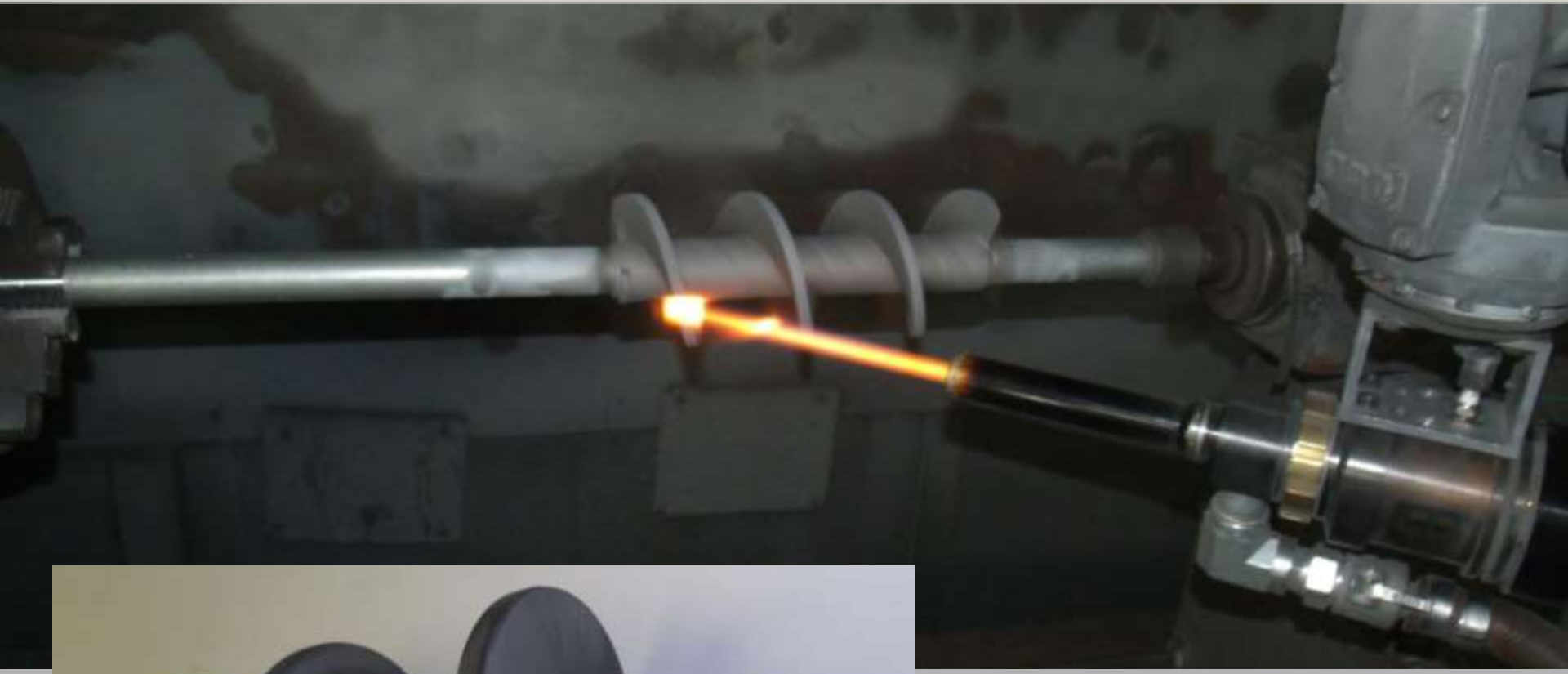

Titanium: HVAF


Titanium:
Shrouded HVAF

Tin Spraying with HVAF SL Gun for Low-melting Point Metals



Kermetico HVAF



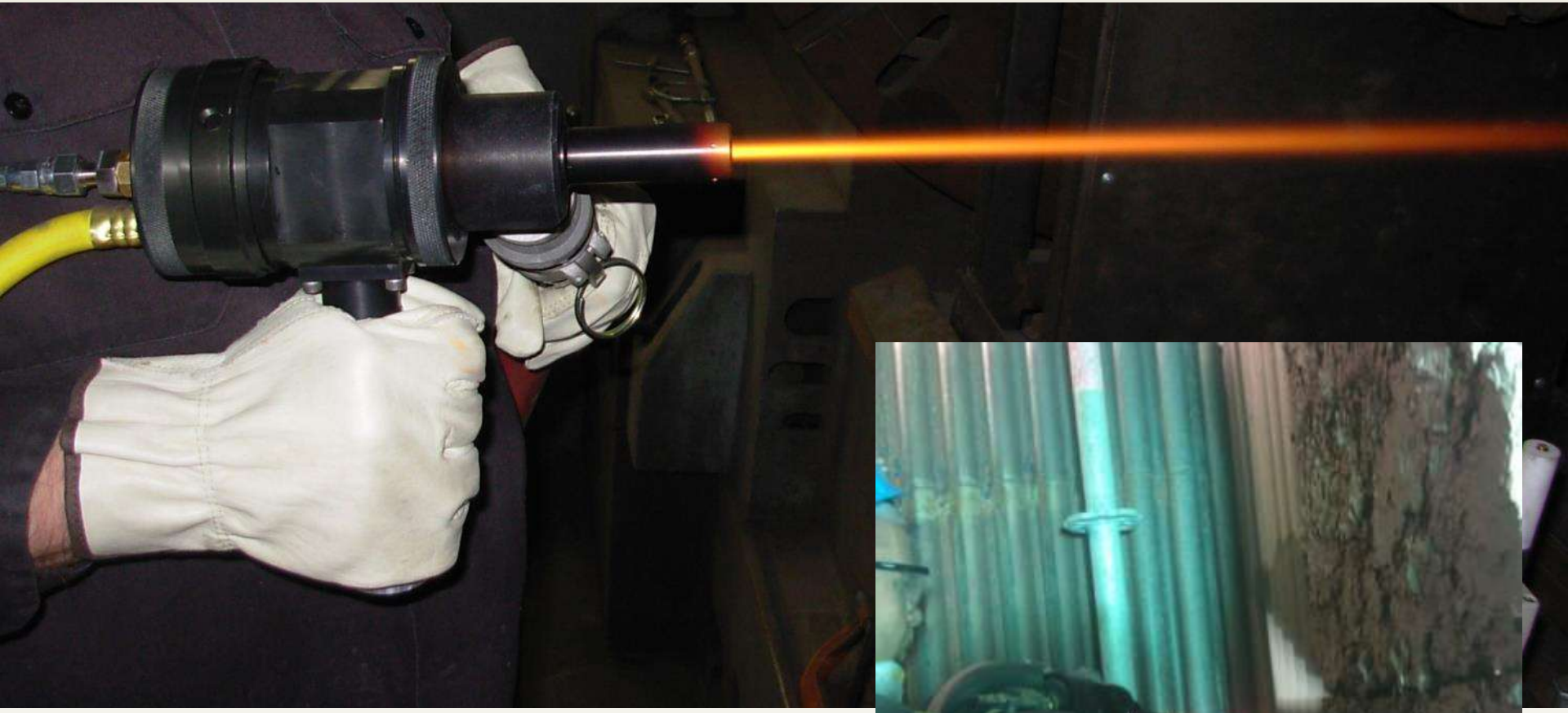
WC-Co-Cr

1 mm thick

www.kermetico.com
averstak@kermetico.com

Tensiometer Roll:

AK7 HVAF, WC-10Co-4Cr, 1.8 mm thick



AK-HH: hand-held HVAF

Press Pistons, Winemaking

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