

# Tungsten Carbide coatings for Valves' market: State of the Art and on-going developments

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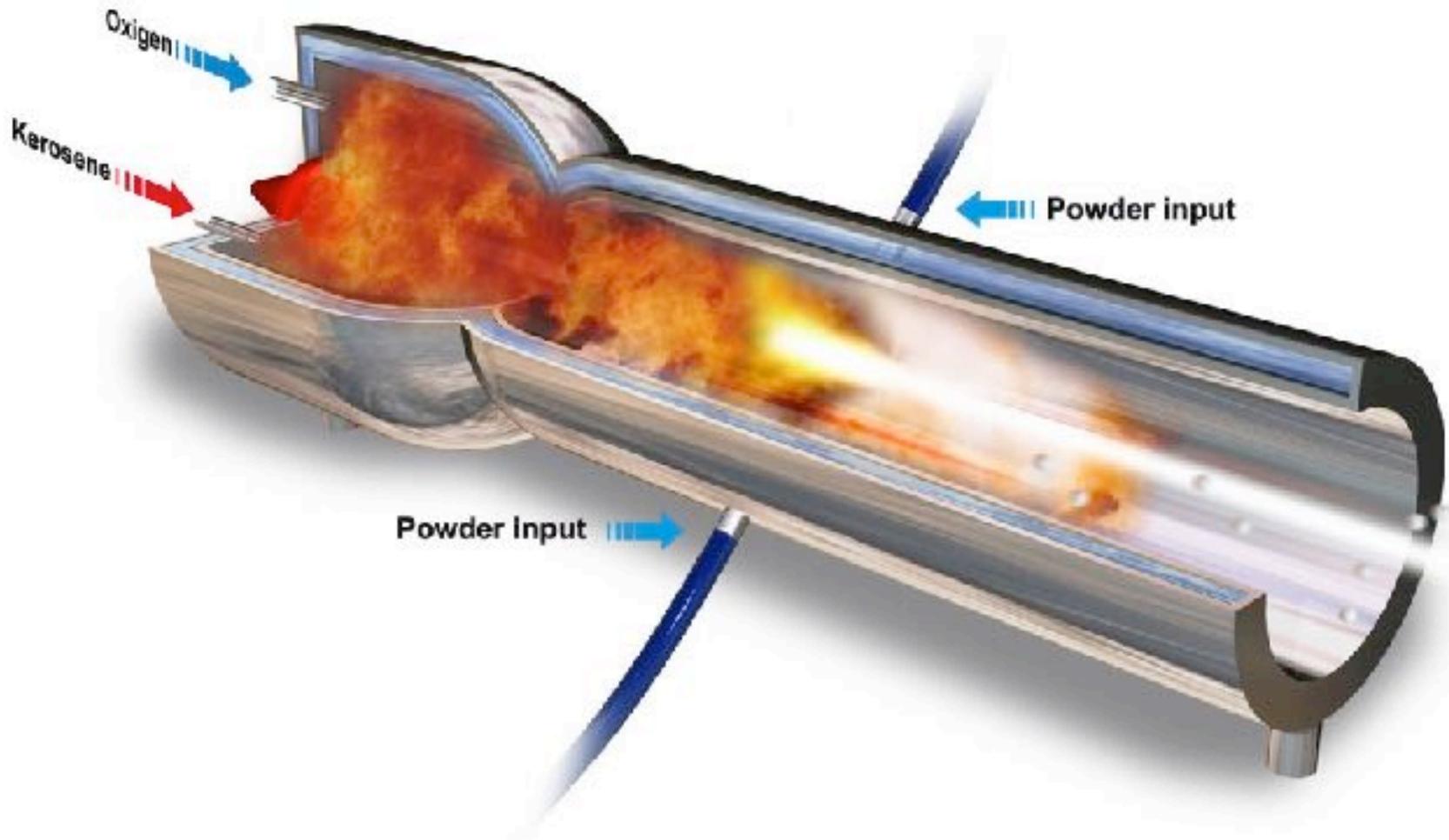
# Introduction

Valves in petrochemical applications have to face very severe operating conditions in which corrosion and wear are very critical factors for the service life cycle. Metal to Metal (MtM) valves can guarantee superior protection against such problems

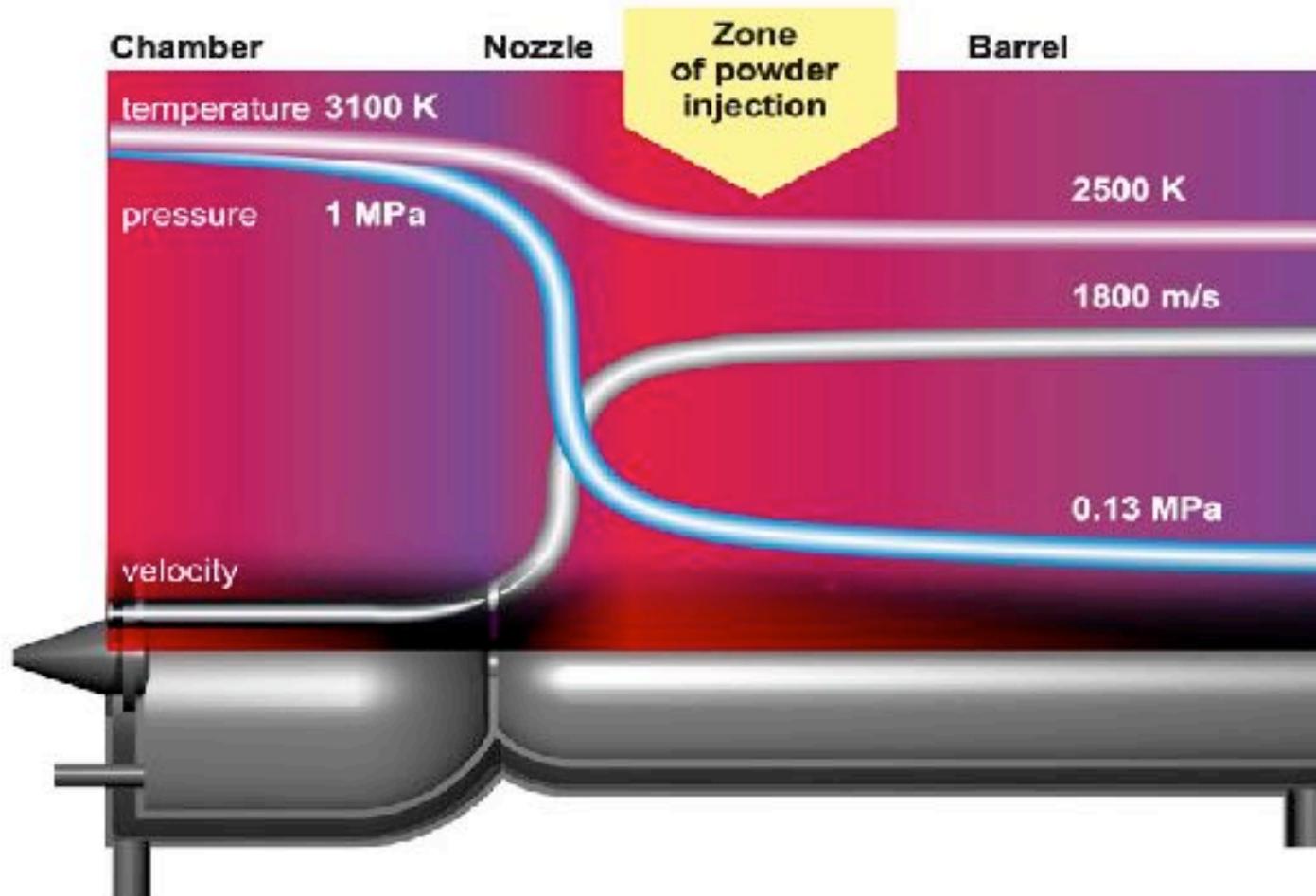
# Introduction

- Tungsten Carbides in a metallic matrix (WC/Co/Cr 86%/10%/4%), applied by HVOF (High Velocity Oxy Fuel), nowadays, represent the state of the art of the coatings for MtM valves.
- Higher operating pressures, like in subsea applications, could lead to a deformations of the coated components and than the cracking of the TCC layer, due to its low ductility.

# HP/HVOF



# HP/HVOF



# Introduction

Since 2014 Flame Spray launched a development project aimed to improve tungsten carbide coating with cobalt-chrome binder (Flame Spray process H653SC) .

The project was driven by requirements in aerospace market (Hard Chrome Replacement applications).

<b>Specification</b>	<b>H654 State of the Art (SOA)</b>	<b>Target</b>
<b>Hardness</b>	<b>&gt; 1100 HV</b>	<b>&gt; 1100 HV</b>
<b>Salt spray fog test</b>	<b>&gt; 500 h</b>	<b>&gt; 1000 h</b>
<b>Elongation to crack</b>	<b>max. 0.3 %</b>	<b>Up to 0.5 %</b>

# Project Phases

- **Coating development by HVOF system with different powders and parameters**
- **On line control by Spraywatch of the spraying effective conditions (temperature and speed of particles at the impact)**
- **Metallographic inspection of coated samples**
- **Mechanical tests (tensile tests)**
- **Corrosion tests (salt spray fog tests)**

## **Spraying Parameters Developments**

**Based on the customer and Flame Spray experiences, the development of “hot” and “fast” parameters could lead to a more ductile coating, thanks to a more uniform distribution of the WC phase inside the metallic matrix.**

**The SprayWatch camera has been used to identify these parameters.**

**A preliminary selection of Thermal Spray Powders has been performed, with the target to find a powder easy to “heat up”**

**Once defined the correct combination of spray parameters and powder, a full set of samples has been sprayed and tested**

## SprayWatch

### Product Family

SprayWatch systems consist of a camera and a control unit. There are two different camera designs both with two different models. The systems can be delivered with either portable controller configuration or a fixed controller for factory floor use.

### SprayWatch camera units:



### Key Features:

Continuous real-time measurement of all critical parameters, such as particle temperature, velocity and flow, spray vertical position, width, angle and divergence, particle size (X Scientific mode)

Simultaneous measurement of a large area and volume for excellent repeatability and significant data. No mechanical scanning required for measuring the full width of the particle plume.

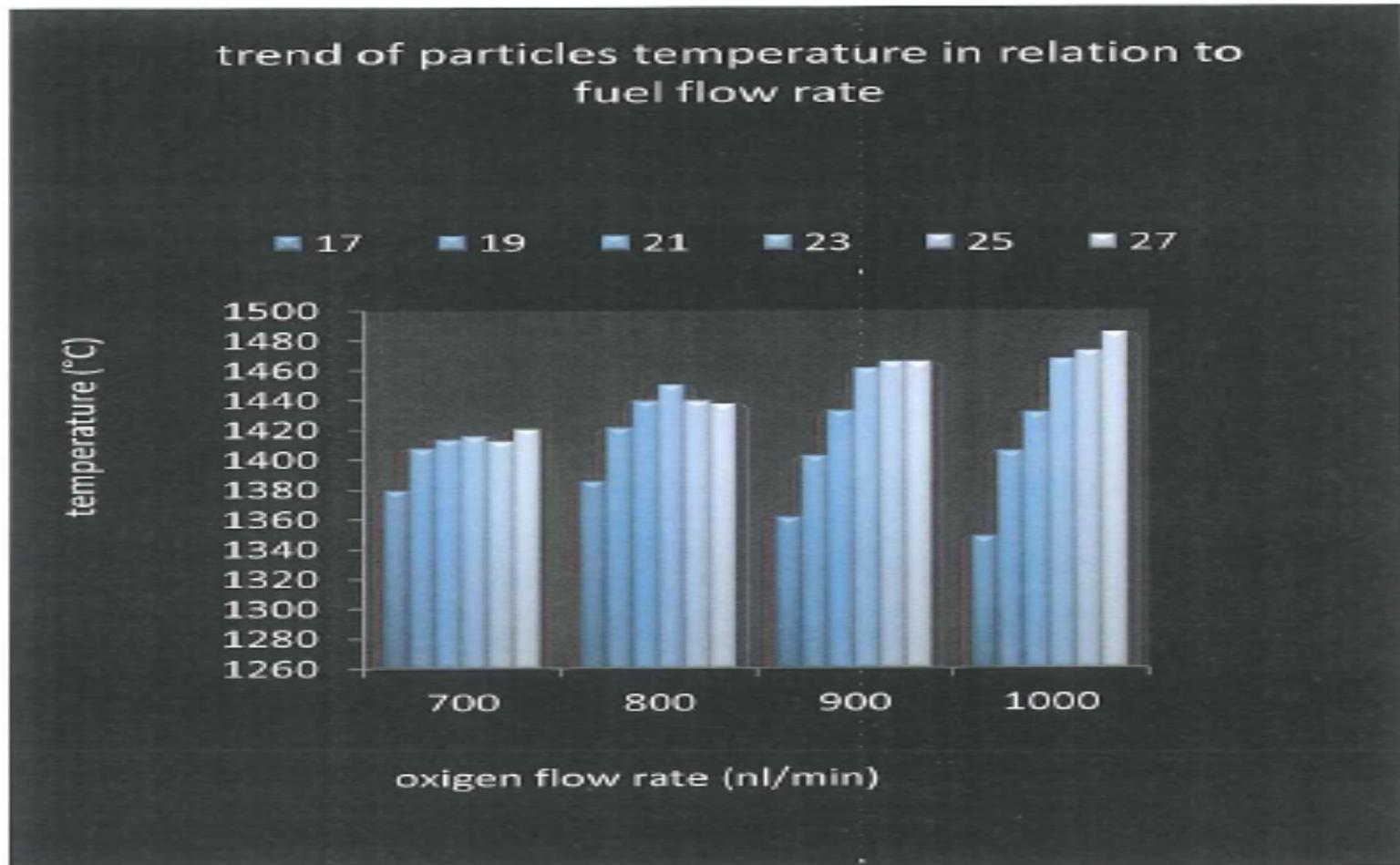
Easy in set up and use. User-friendly graphical interface. No calibration needed between measurements

Automated monitoring of particle characteristics and process limits with alarms if the limits are exceeded.

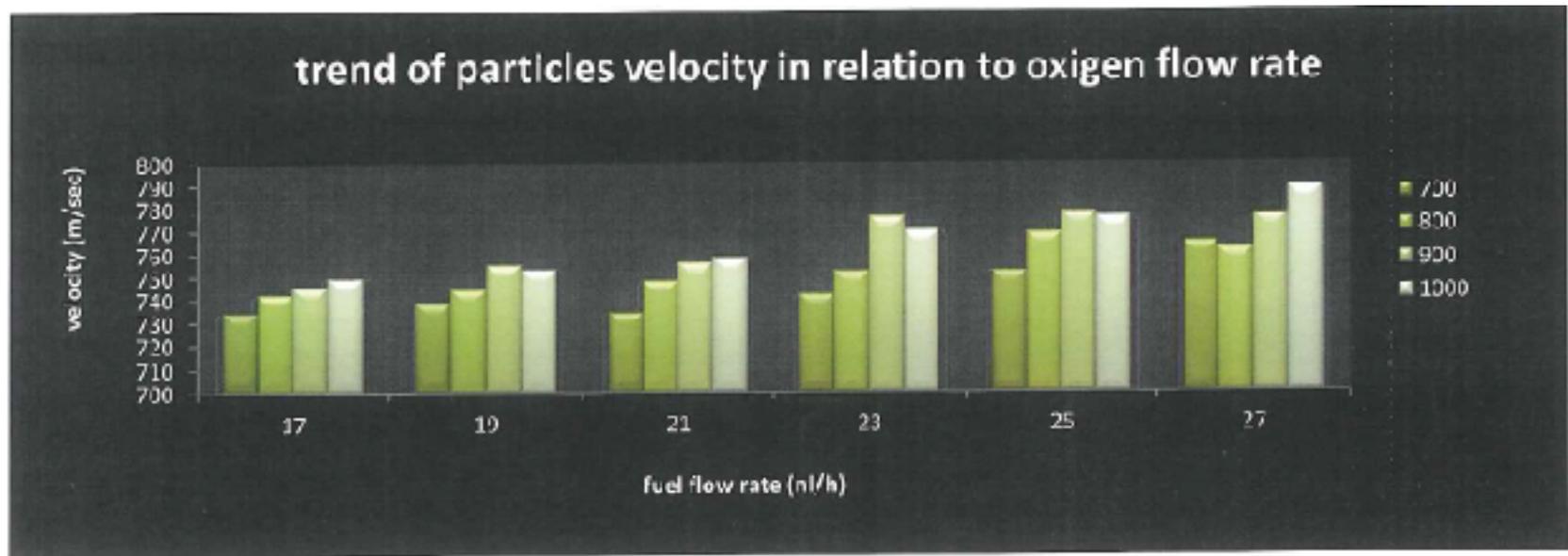
Measurement data can be automatically saved into csv files

Robust design and no maintenance requirements suitable for industrial use.

## Spraying Parameters Parameters Developments



## Spraying Parameters Parameters Developments



# Tests Performed

- Metallographic exam
  - Micrography (porosity check)
  - Microhardness
- Adhesion Test (ASTM C633)
- Salt Fog Testing (ASTM B117)
- Elongation Tests

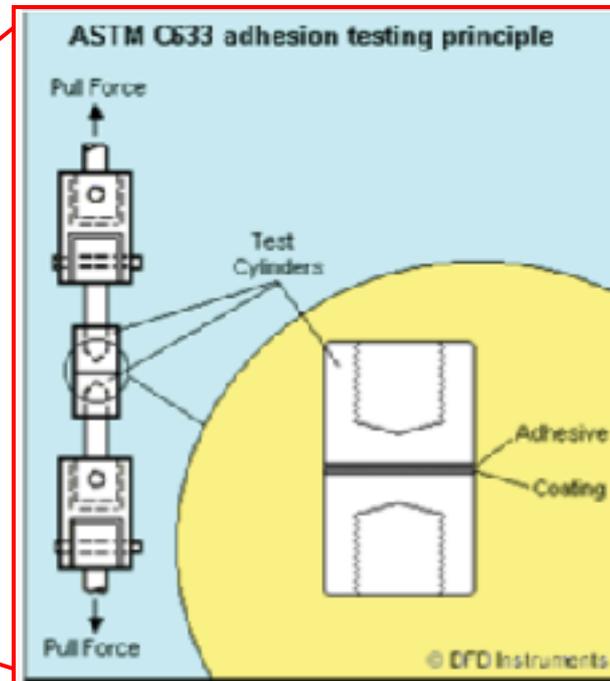
# Metallographic Test

- Microhardness according to ASTM E384, 300 g load for 15 sec.
- Porosity checked with optical microscope and image analysis software



# Adhesion Test

- According to ASTM C633
- Standard test to adhesion and cohesion of the coatings



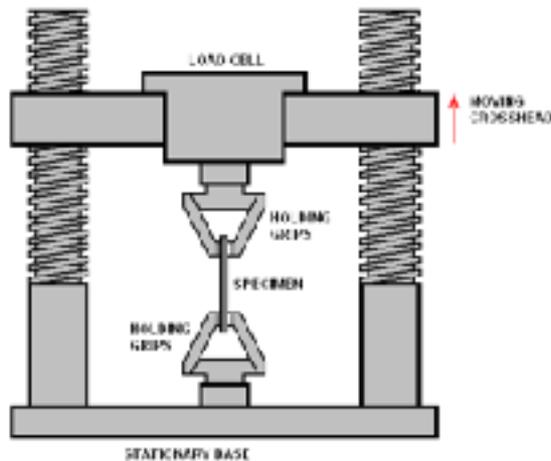
# Salt Fog Test

- According to ASTM B117
- Standard test to check the corrosion resistance

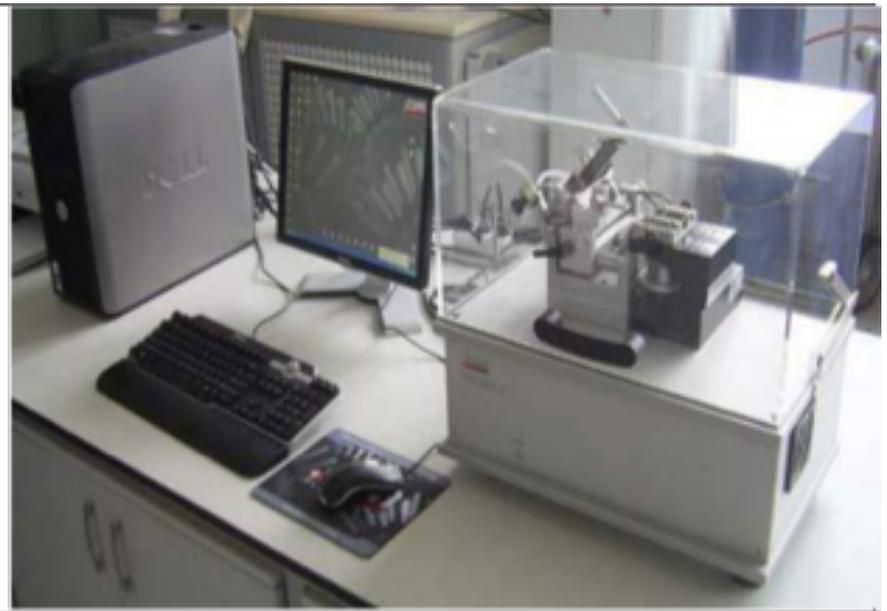
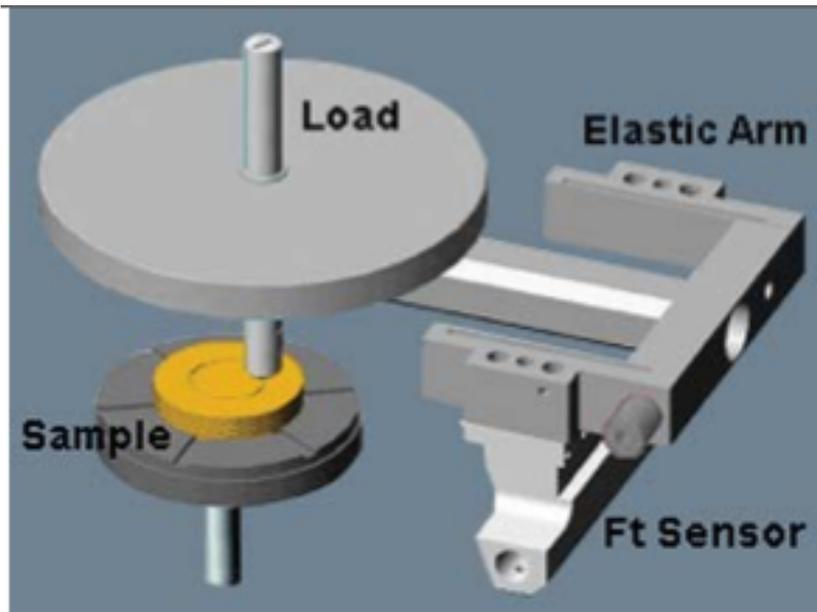


# Elongation Test

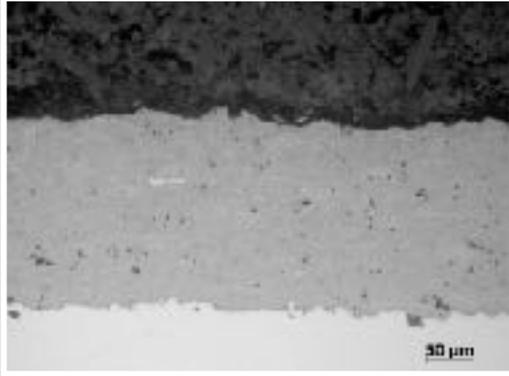
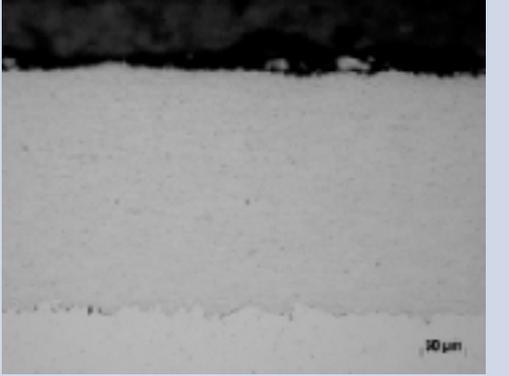
- Tensile test with fixed elongation ratio (0,20%, 0,35% and 0,50%)
- Presence of cracks checked by Fluorescent Penetrant Inspection (FPI)



# Wear Test and COF measurement (on-going tests)



# Tests Results – Metallography and Adhesion

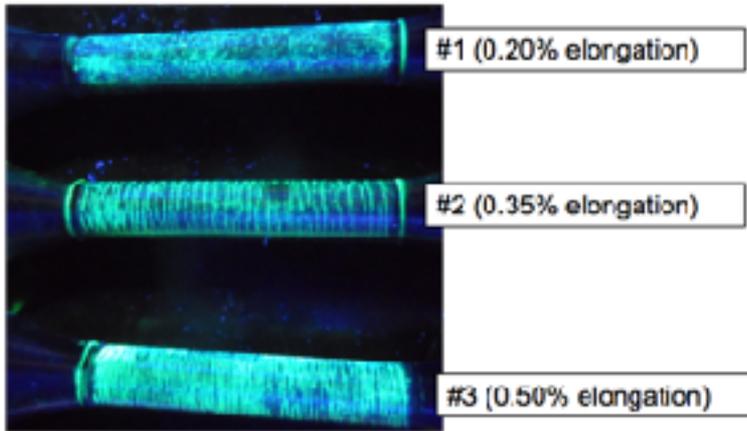
	H654 - SoA	H653SC
<b>Microstructure</b>		
<b>Porosity (%)</b>	< 1	< 0,5
<b>Microhardness HV300-average</b>	> 1100	> 1300
<b>Adhesion (Mpa)</b>	> 70	> 70

# Tests Results – Salt Fog Test

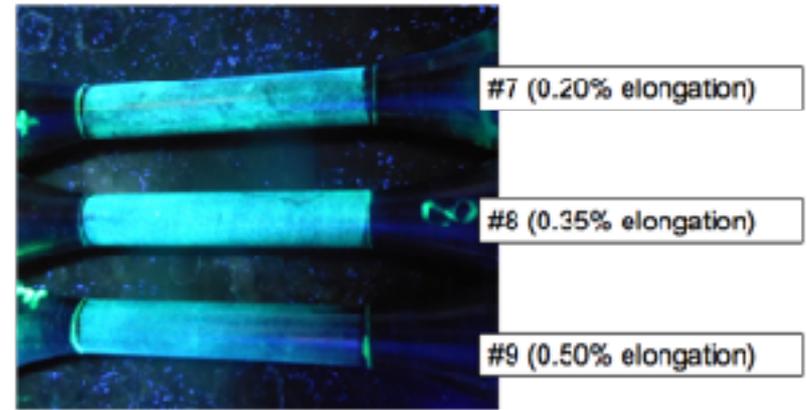
	H654 - SoA	H653SC
<b>Salt Fog Test - 1000 hours – coating without sealing</b>	 <p>A circular metal component, likely a valve cover, showing significant surface corrosion and discoloration after 1000 hours of salt fog testing. The surface is dark and uneven. The number '26' is handwritten below the component.</p>	 <p>A circular metal component, similar to the one on the left, showing much less surface corrosion and maintaining a more uniform, metallic appearance after 1000 hours of salt fog testing. The number '16' is handwritten below the component.</p>

# Tests Results - Elongation

SoA process H654



H653SC PROCESS



	H654 - SoA	H653SC
Elongation (%)	Up to 0,30%	Up to 0,50%

# Summary

**Chemical composition : WC 86% - Co 10% - Cr 4%**

**The composition is not modified with respect to assessed Flame Spray processes H654, thus allowing to maintain the qualifications already achieved in several environments / chemical operative conditions.**

**Microhardness : > 1300 HV (100 HV higher than the average microhardness achieved by H654 coating); therefore a higher wear resistance is expected in service.**

**Porosity : < 0,5% (to be compared with < 1% achieved by H654 coating); therefore a better corrosion resistance is expected in service and salt spray fog tests already confirmed this expectation (no corrosion pits were observed in salt spray fog tests on H653SC samples after 1000 h of test)**

**Ductility : the results in terms of maximum elongation before the start of a first crack are very positive : the max. elongation without cracks is around 0.5% for H653SC coating, a value double with respect to H654 standard coating.**

# **State of the art of industrial applications – July 2016**

- **Coating of seats for ball valves in high pressure classes applications in production with excellent feedback (cracks eliminated)**
- **Coating of gate valves in high pressure classes, for subsea application in production**
- **Coating of components for landing gears : under qualification**
- **Coating of Pelton runner : first runner coated for comparative tests in Q1 - 2016.**

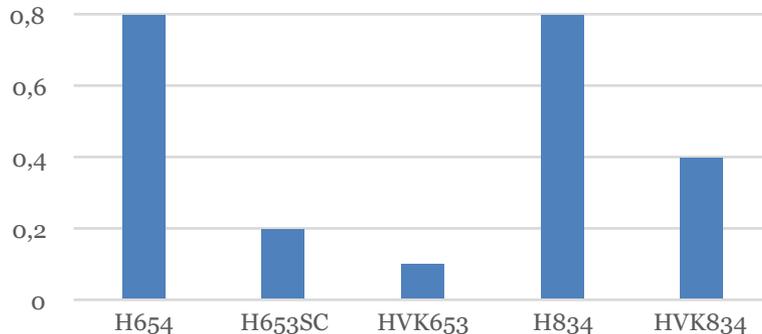
# On going tests

Flame Spray, in cooperation with our subsidiary in the US, is developing an advanced combustion supersonic process for the application of carbides.

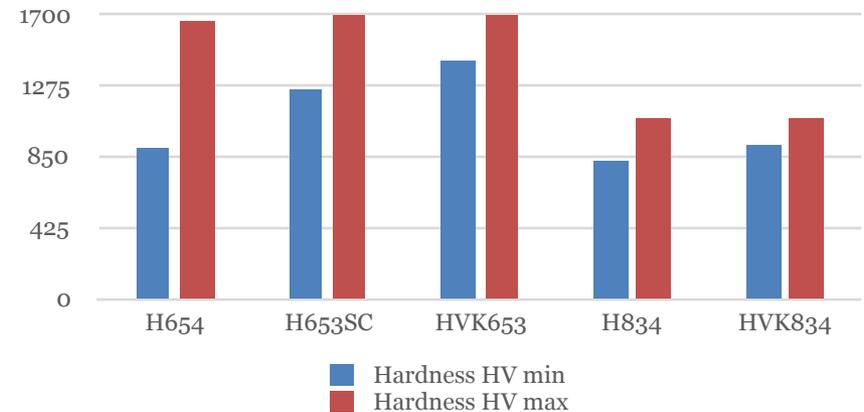
With this technique, FS has developed the new HVK653 process, that promises to be a step forward even compared with the H653SC.

Comparative values of porosity and hardness are shown below:

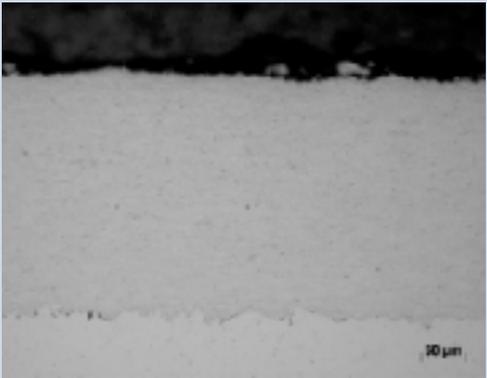
**Porosity %**



**Hardness HV (300g - 15 sec)**



# Tests Results – Metallography and Adhesion

	HVK653	H653SC
<b>Microstructure</b>		
<b>Porosity (%)</b>	< 0,2	< 0,5
<b>Microhardness HV300-average</b>	> 1500	> 1300
<b>Adhesion (Mpa)</b>	> 70	> 70

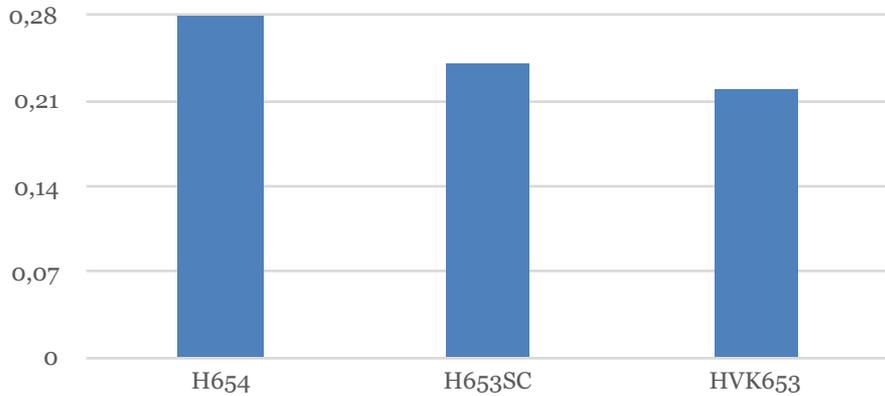
# On going tests

Wear test (pin on disk) has been performed on the Tungsten Carbides samples

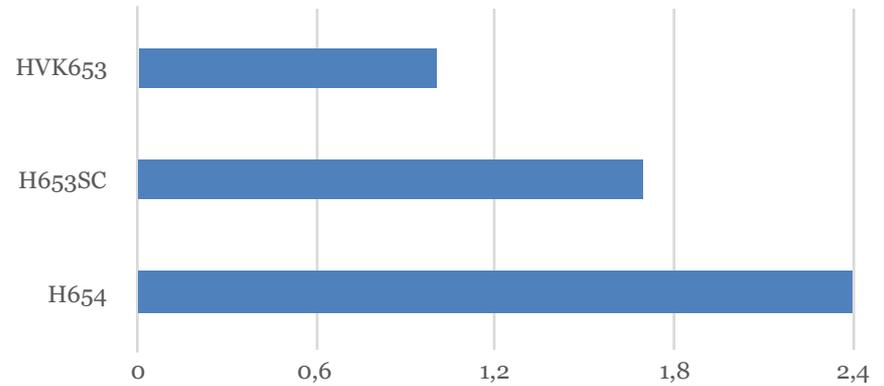
The Coefficient of Friction (COF) has been measured

The wear loss has been measured at 5N of Load. The values have been normalized

### COF



### Wear Test





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