



Plasma spray coatings for IDs

HCAT Program Review
Greensboro, NC
March 2005

Progress

- ❑ Work completed and final report submitted
- ❑ Designed to provide as much information as possible



CLEAN DRY-COATING TECHNOLOGY FOR ID CHROME REPLACEMENT

SERDP Project #1151

Final Report
October 2004

Bruce D. Sartwell
Naval Research Laboratory
Surface Chemistry Branch
Code 6170, 4555 Overlook Ave SW
Washington, DC 20375-5342
Phone: 202.767.0722
e-mail: sartwell@nrl.navy.mil

Keith O. Legg
Rowan Technology Group
Phone: 847.680.9420
e-mail: klegg@rowantechnology.com

Appendices

Appendix 1. METALLOGRAPHIC PREPARATION AND POROSITY – NRC

In order to developed a The following

- Sample Coating compres Use Load Speed Clear

- Sample Preheat be used) Put sam Mix epox Impregn Maintain Fill up m for Cald

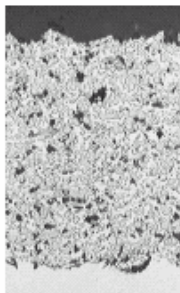
- Sample First, ens SiC, 220 flat. (Us Wash (b DP Alleg keep sur Wash (b DP Dec,

Wash (brush-soap-water) + Ultrasc OP-Chem, OP-A(50% water), 150 Wash (brush-soap-water) + Ultrasc (Note: you may use MD products in

Appendix 2. Characterization of Plasma Sprayed Coatings

CHARACTERIZATION OF PLASMA SPRAYED COATINGS

There are a large num which the Sulzer Metco optimizing ID WC pla Sulzer Metco report on Figure 1 shows an ini Diamalloy 2005 powder



1.1. Diama

Appendix 3. Implementation Assessment of ID Plasma Spray at NADEP JAX



Implemente
Replaceme
Chrome with Pla
NADEP Jackson

Appendix 4. Three Team Meeting Report – ID Coating Technology

A meetin conjuncti view the

Appendix 5. ESOH Issues for Plasma Spray

An analysis was containing materi

Appendix 6. Thermal Spray of Nanomaterials

A survey assembled

Appendix 7. New Developments

Under ONR funding Smuel Eidelman of SAIC has developed a pulse (detonation) thermal spray method built on a space thruster design. The system is computerized and uses high speed valves to inject the fuel, oxygen, and powder in the correct sequence so that the powder is driven out at high speed with the hot gas plume from the fuel/oxygen explosion. This makes it a form of miniaturized detonation gun, which is an HVOF deposition method. The system has been quite extensively modeled and appears capable of achieving high particle velocities, especially for nanoparticles.

The gun itself is very small (typically 1/4"-3/8" diameter), and when using nanoparticle feedstock it can deposit onto interior walls using a bent tube as a "barrel", with a very small standoff distance. This allows the gun to coat inside an ID of $\phi 1''$. We have visited Dr. Eidelman's

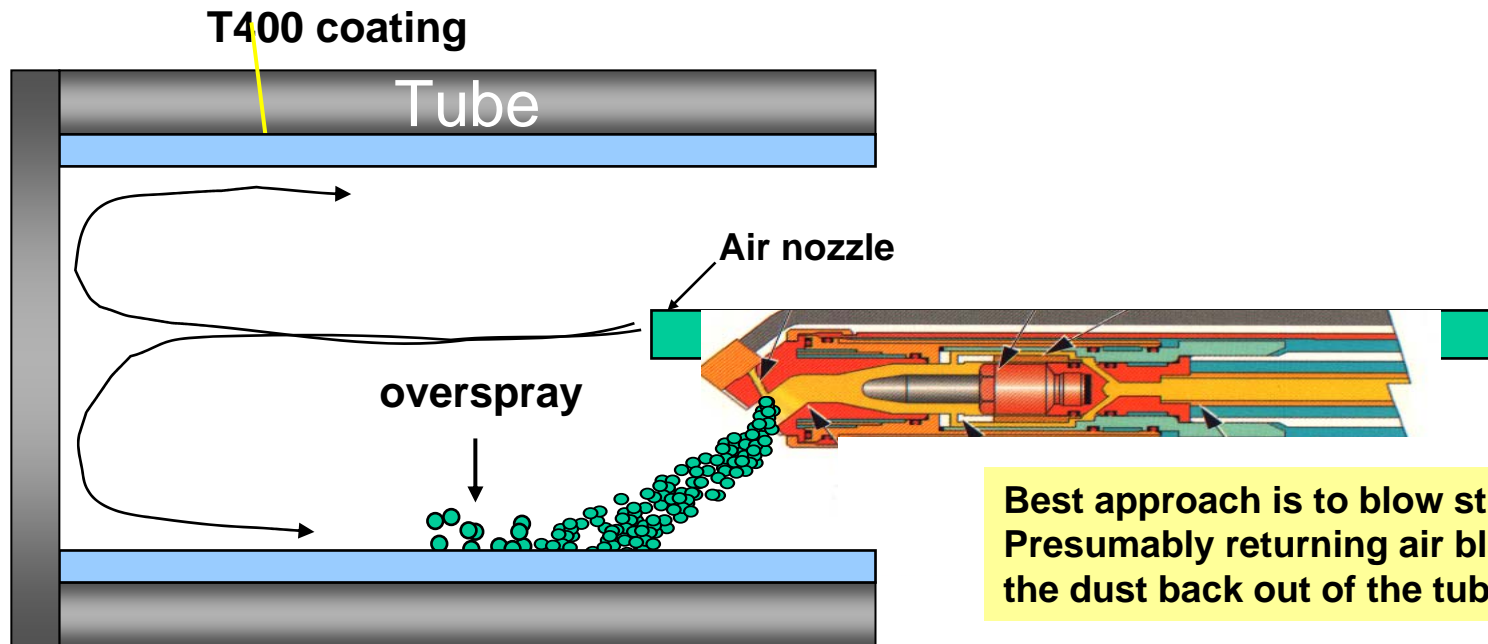


Plasma spray coatings optimized

Powder	Chemistry	Comments
Diamalloy 2003 (Sulzer Metco)	WC-12Co	Fused and crushed. Contains WC and W ₂ C.
Diamalloy 2002 (Sulzer Metco)	55%(WC 12Co) 45%(66Ni 18Cr 7Fe 4Si 4B 1C)	~55/45 mixture of WC-Co in self fluxing binder
Ni-988 (Praxair)	50%(WC 12Co) 50%(66Ni 18Cr 7Fe 4Si 4B 1C)	50/50 mixture of WC-Co in self fluxing binder
Co-109-3, Tribaloy 400 (Praxair)	Co-28 Mo-8 Cr-2 Si	Fine cut powder
W-121 (Praxair)	WC-Cr ₃ C ₂ -NiCr	Precipitated

Additional coatings tested by Sulzer Metco, but no advantage over existing coatings –
Hastelloy, NiCr, Cr₃C₂-NiCr, fine WC-Co

Overspray dust control



**Best approach is to blow straight in
Presumably returning air blast sweeps
the dust back out of the tube**



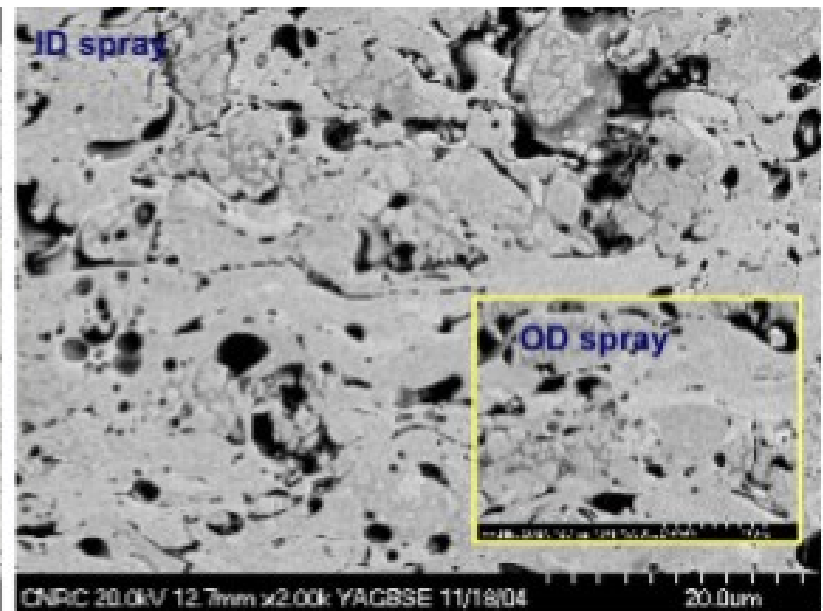
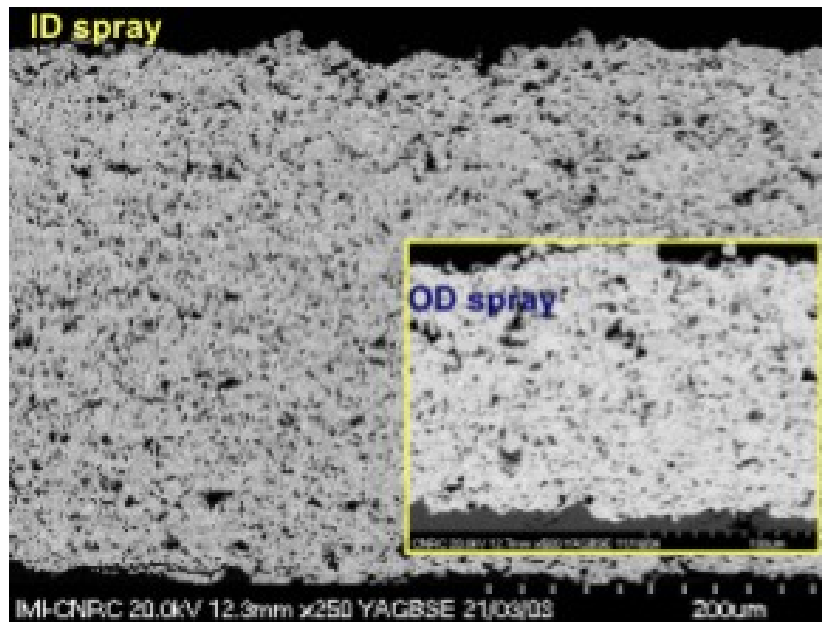
Performance

Porosity

Coating	Powder	Measurement	Porosity	Stdev	vol% carbide	Stdev
WC-Co self flux	D-2002	%pores	6.3	0.6		
WC-Co self flux	D-2002 thick	% pores	10.0		19.9	2.5
WC-Co self flux	Ni-988	% pores	7.5		17.9	1.6
WC-12Co	D-2003	% pores	6.0	0.7		0.7
T400	T-400	%pores+oxide	7.2	1.3		1.3
Ni5Al	D-4008	%pores	4.5	0.5		0.5
Ni5Al	D-4008	%oxide	3.4	0.2		0.2

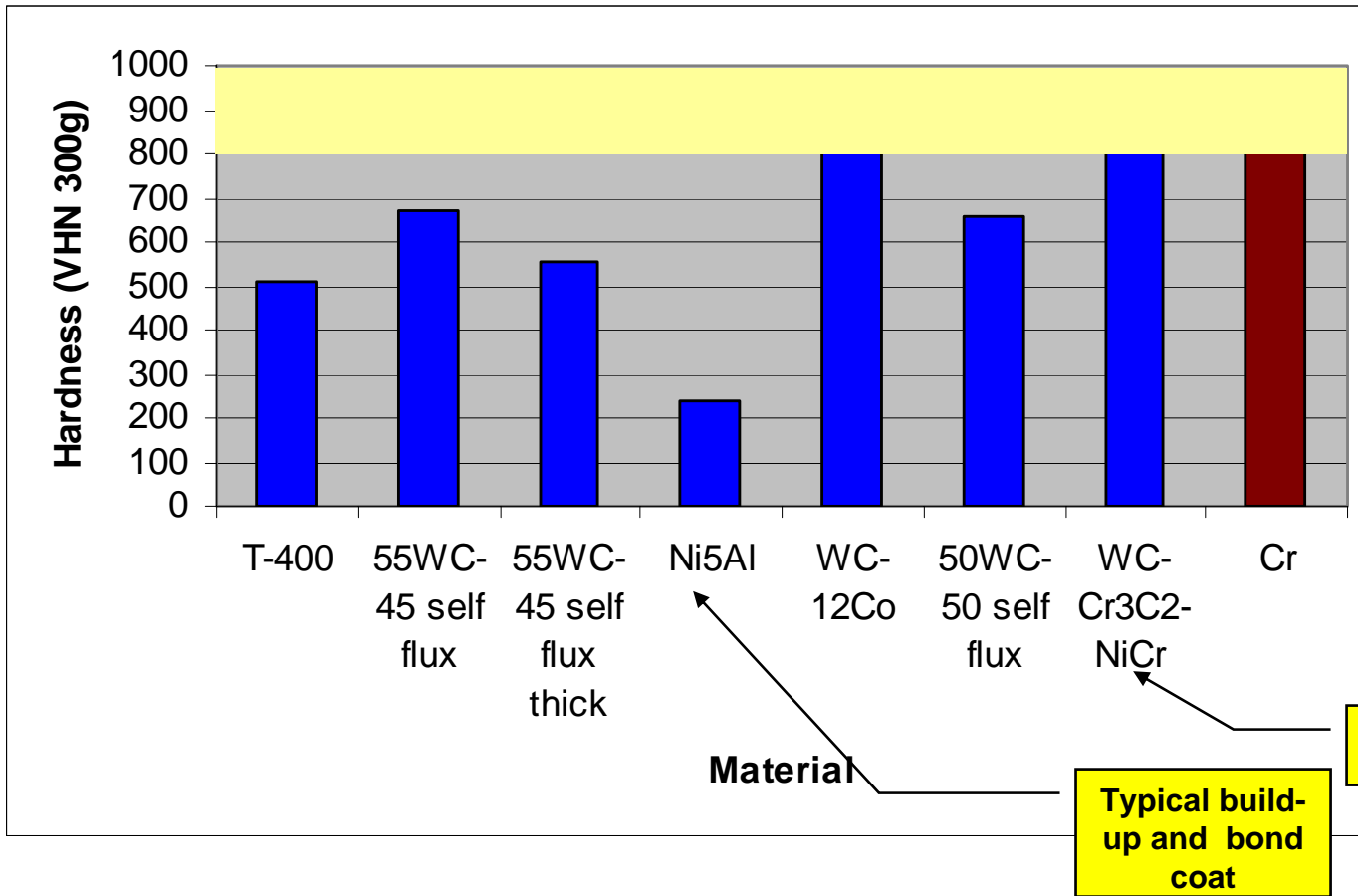
A lot more porous than HVOF

OD and ID structure



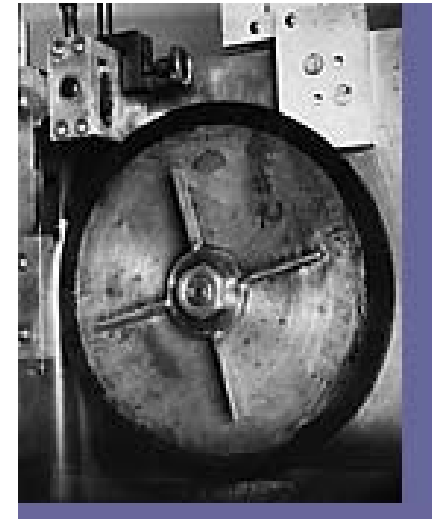
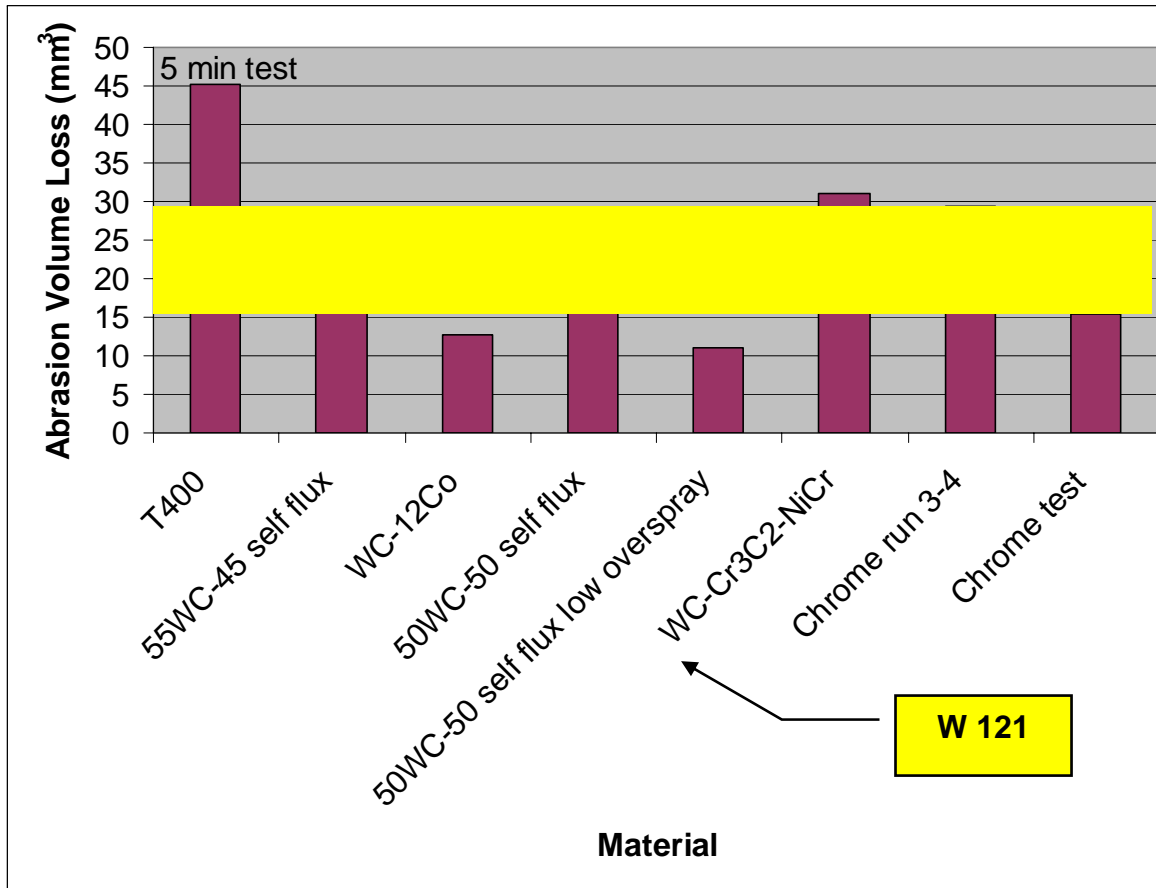
Structure is pretty much the same for OD and ID spray with same spray parameters

Hardness



Note: Only WC-12Co and WC-Cr₃C₂-NiCr are as hard as EHC

Abrasion resistance – ASTM G-65



Rubber wheel + dray sand

WC-Cr3C2-NiCr not very good

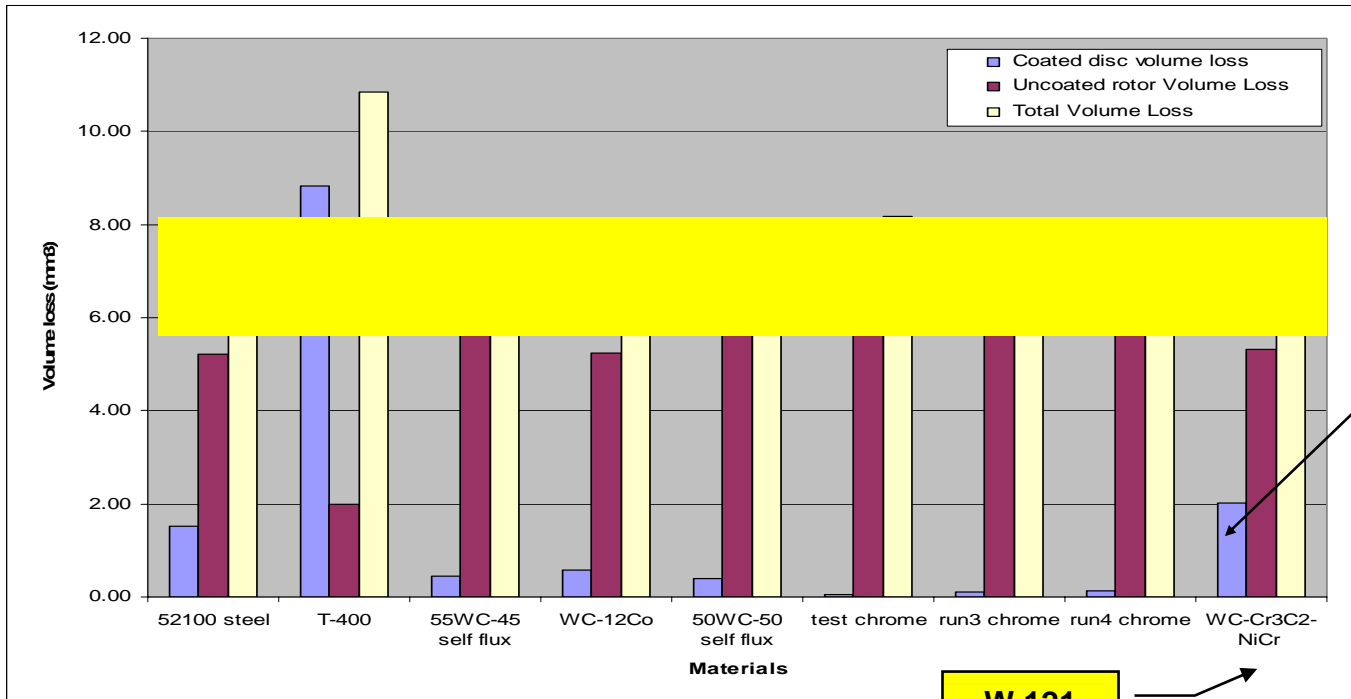
With best overspray removal, self-fluxing material is as good as WC-12Co

Test: Rubber wheel, dry sand abrasion

Test relevance: Debris in hydraulic fluid

Note: Abrasion resistance increases with hardness, but depends also on material.

Sliding Wear



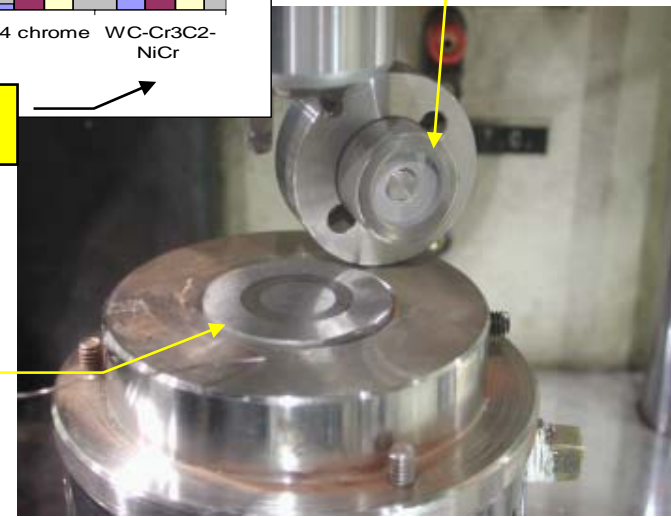
WC-Cr3C2-NiCr not very good for coating wear

Washer

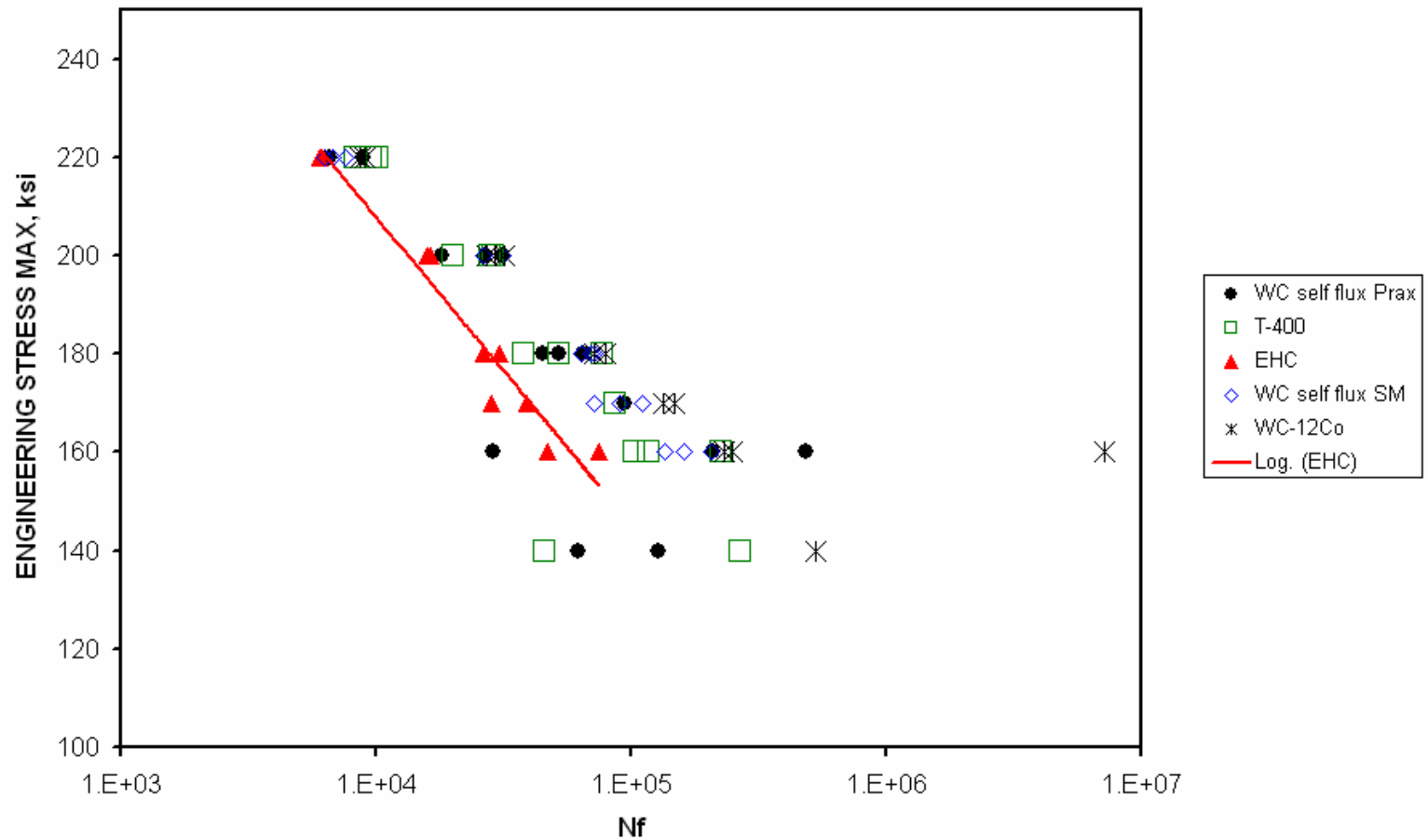
W 121

- Dry sliding, 5200 steel rotor
- What is most important is total wear
- All coatings show more coating wear than EHC, although WC coatings are similar
- Only Tribaloy shows significantly more total wear than EHC, primarily from coating wear

Coated disc

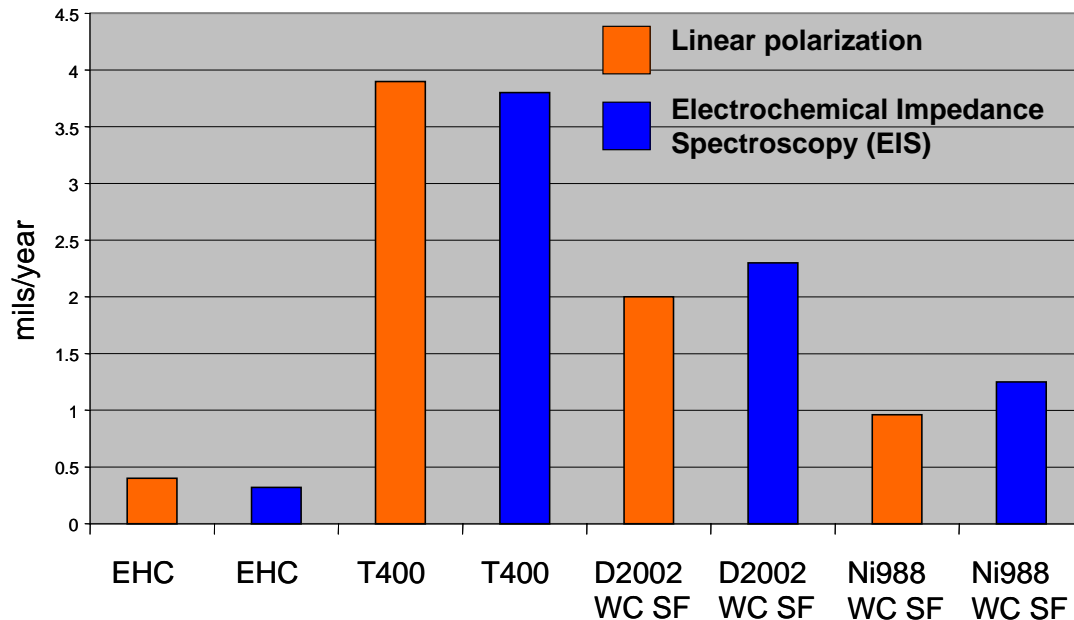


Fatigue



Corrosion – electrochemical testing

Corrosion Rates



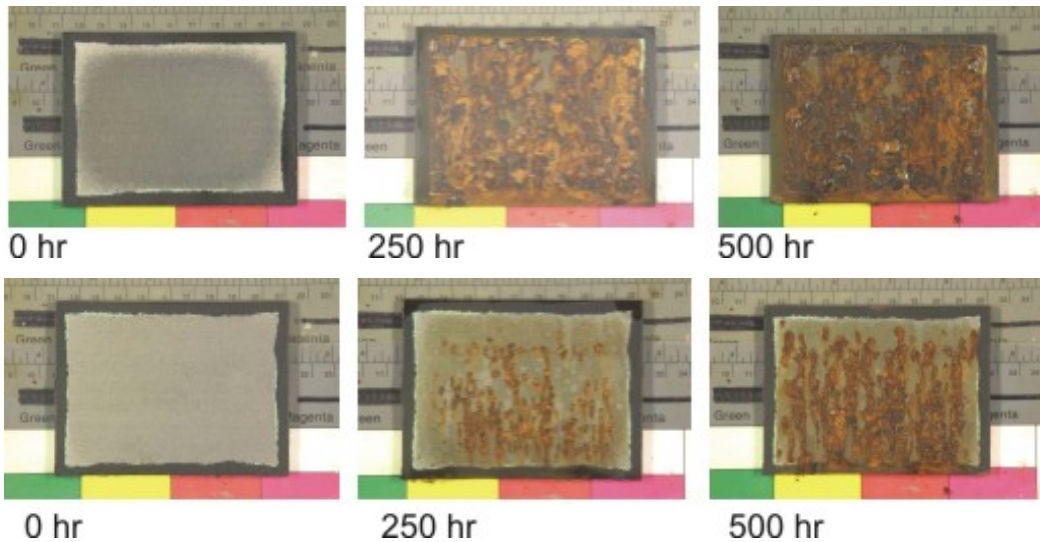
- As usual, electrochemical testing shows thermal spray worse than EHC because the matrix corrodes

Corrosion – B117

NRLKW Sample Designation	Manu-facturer	Powder	Coating Material	Thick-ness	Finish	Sealed?	Protect-ion Rating (as received)	Protect-ion Rating (after scrub)
HCAT #1D2	Praxair	NI988	WC self flux	0.008"	As-sprayed	N	0	0
HCAT #1D3	Praxair	Co-109-3	Tribaloy 400	0.003"	Ground	N	0	0
HCAT #1D4	Praxair	NI988	WC self flux	0.003"	Ground	N	0	0
HCAT #1D5	Praxair	Co-109-3	Tribaloy 400	0.008"	As-sprayed	N	0	0
HCAT #1D6	Praxair	NI988	WC self flux	0.003"	Ground	Y	6	4
HCAT #1D7	Praxair	Co-109-3	Tribaloy 400	0.003"	Ground	Y	2	0
HCAT #1D10	Sulzer-Metco	Diamalloy 2002	WC self flux	0.003"	Ground	Y*	5	1
HCAT #1D11	Sulzer-Metco	Diamalloy 2002	WC self flux	0.009"	As-sprayed	N	1	0
HCAT #1D12	Sulzer-Metco	Diamalloy 2002	WC self flux	0.003"	Ground	N	1	0
HCAT #1D13	Sulzer-Metco	Diamalloy 2003	WC-12Co	0.003"	Ground	N	0	0
HCAT #1D14	Sulzer-Metco	Diamalloy 2003	WC-12Co	0.009"	As-sprayed	N	0	0
HCAT #1D16	Sulzer-Metco	Diamalloy 2003	WC-12Co	0.003"	Ground	Y*	0	0

Nothing does all that well (not unexpected)

B117corrosion



Unsealed T400 0.003"

Sealed T400 0.003"

Sealing does helps corrosion a little



Implementation Assessment and Cost Benefit Analysis

Report

- We have done an Implementation Assessment rather than a simple CBA because it tells us much more
- C-MAT cost model developed under SERDP Stainless Steel Landing Gear program



Implementation Assessment

Replacement of Internal Diameter Hard Chrome with Plasma Spray Coatings at NADEP Jacksonville

Authored by:

Keith Legg

Rowan Technology Group

Organization: HCAT

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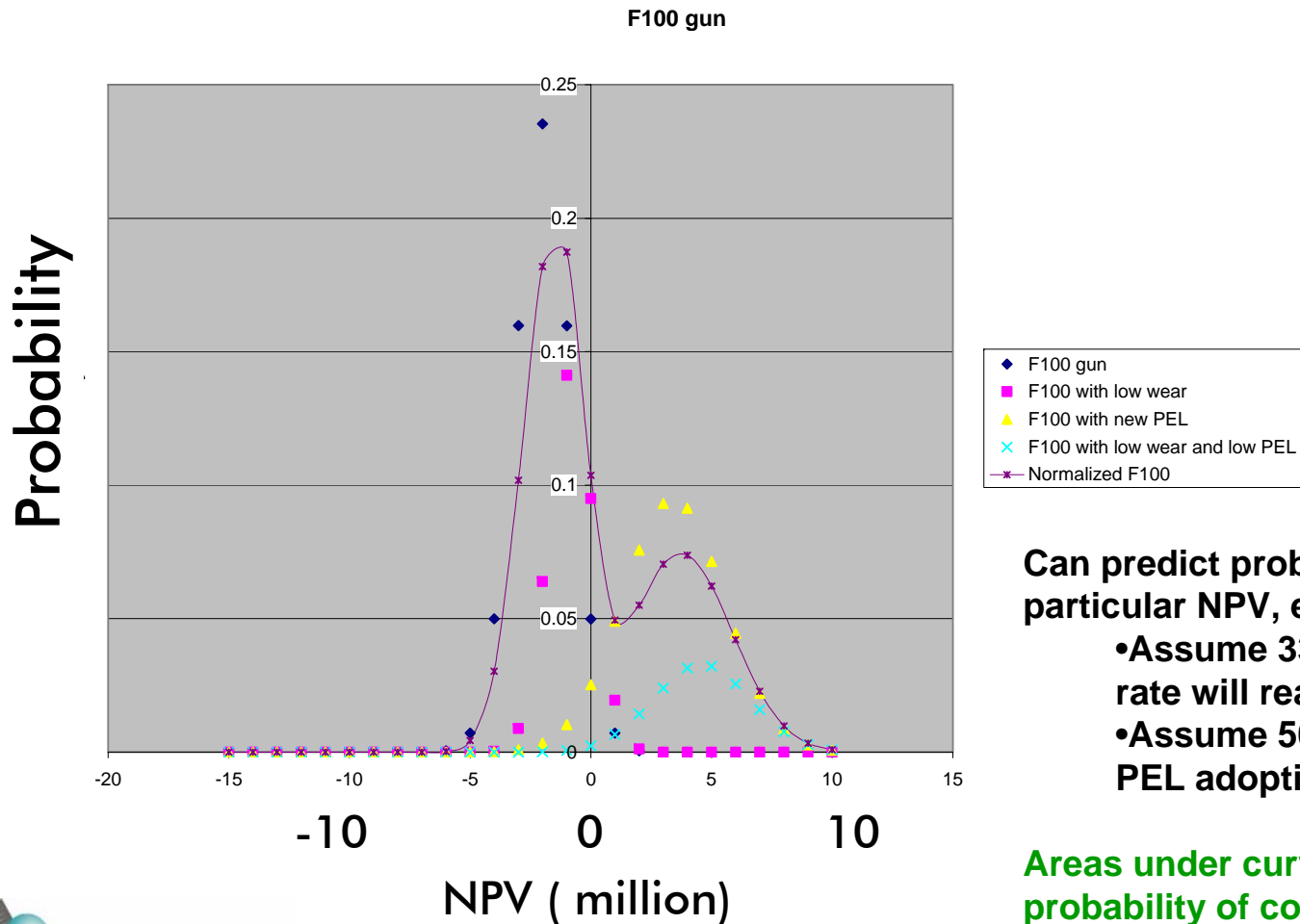
ROWAN TECHNOLOGY GROUP

1590 S. Milwaukee Ave., Suite 205, Libertyville, IL 60048, USA • 847-680-9420 • Fax: 847-680-9682
Email: rowan@rowantechnology.com • www.rowantechnology.com

Cost

- ❑ If use SM F100 gun or equivalent, cost is about the same as EHC
- ❑ Smaller and lower-rate guns are not as cost-effective
- ❑ Use the biggest gun you can lay your hands on!

So, what is the likelihood it will really be cost-effective?



Can predict probability of a particular NPV, e.g.

- Assume 33% chance wear rate will really be $\frac{1}{2}$
- Assume 50% chance of PEL adoption and cost

Areas under curves – 50% probability of coming out ahead

Is it worthwhile?

- ❑ Yes, because it permits faster turnaround
 - Faster turnaround is critical to readiness and reduces fleet costs, even though it makes no direct financial impact on that specific component or process being assessed
- ❑ Cost impact should be considered on a broader basis since readiness impact is critically important in a wartime environment

Conclusions

- ❑ Porosity higher and adhesion lower than HVOF
- ❑ Abrasive wear better than EHC
 - Longer repair cycle (lower LCC, less pollution)
- ❑ Pin on disc wear not as good
 - Not a good measure of actual service performance
- ❑ Corrosion worse than EHC
 - Different mechanism, in common with other thermal spray
 - Probably need sealer for corrosion and high pressure leak-by
 - B117 testing to be done
- ❑ Fatigue good
- ❑ In general plasma spray works well for ID >2.75" most guns (1.6"ID for Sulzer F300 gun)
 - High deposition rate
 - Quality similar to OD coatings when properly optimized and flushed with gas to remove overspray
- ❑ Producibility
 - Good, especially for shops already using HVOF for OD chrome replacement
- ❑ Makes sense as an ID chrome alternative, especially
 - If faster turnaround is important
 - If already using HVOF on ODs