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Replacement of Cd on Connectors Alernative and Issues

ASETSDefense 2012 – August 27-30, 2012

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Summary

1. Company Overview
2. Product Overview
3. Cadmium alternatives in Europe
4. Focus on alternatives to Cd on aluminium connector
   - ⇨ *Product requirements*
   - ⇨ *Research on alternative solution*
   - ⇨ *Development of alternative solution*
   - ⇨ *Process qualification*
5. General Conclusion

1. Company overview

- Founded in 1952
- Revenue 2011: 203 M€ ($245 M)
- Listed on NYSE-Euronext
- Ownership: 87% Gattaz family, 13% public
- R&D: +/- 8% of revenue each year

Ambition: ***To be the world preferred partner for high reliability connecting devices***

1. Compagny overview

ISO 14001 Certified
AS/EN/JISQ9100-ISOTS 16949-ISO-9001

REGISTERED AS 9100

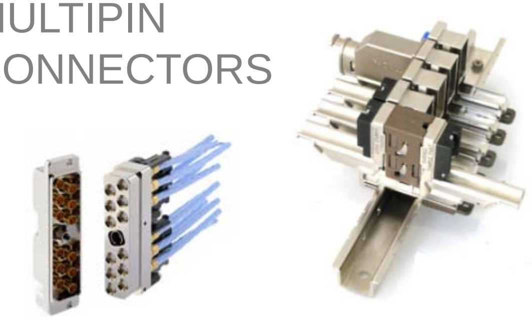
Global presence

- 9 plants worldwide: 30,000 m^2 (320,000 ft^2)
- International sales network: 13 sales subs, 50 agents
- Employees > 2000
- In US : New Haven, CT; Chandler, AZ

2. Product overview

2.1 Product lines

MULTIPIN CONNECTORS



RF & MICROWAVE SWITCHES

ANTENNAS

MICROWAVE CABLE ASSEMBLIES

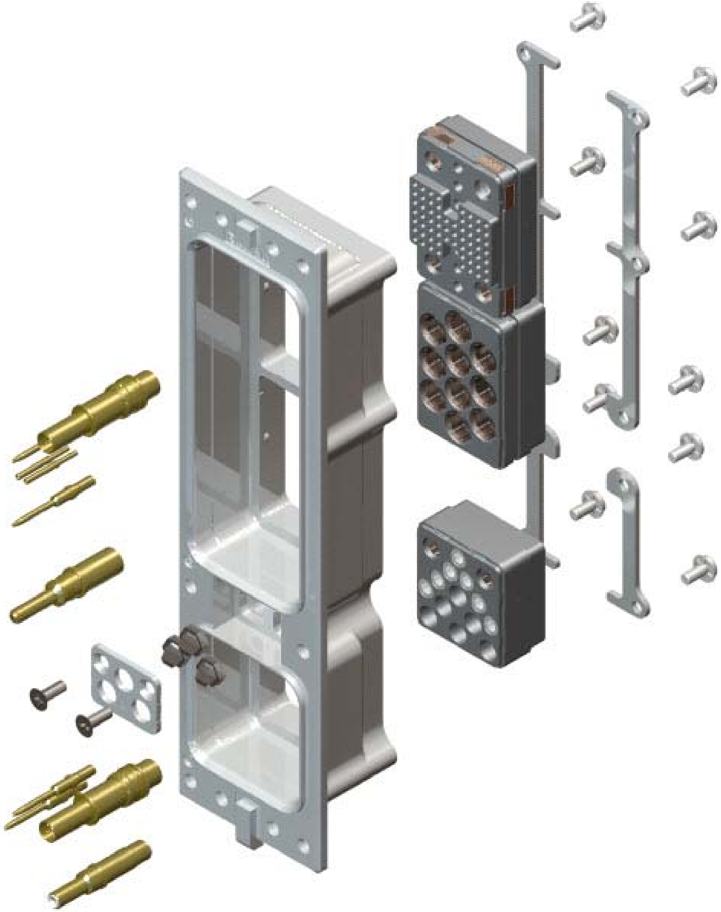
FIBER-OPTICS

RF & MICROWAVE CONNECTORS

2. Product overview
2.2 Interconnect applications

General shell requirements:

- Electrical performance
- Environmental performance
- Mechanical performance



➔ Use of Cadmium and Chromate was largely intend for these properties

3. Cadmium alternatives in Europe

Cd free European requirements:

- For 12 years with ELV directive for automotive application
- For 6 years with ROHS directive for electrical application
- For 10 years for aerospace application development of new aircraft program (A380, A400 M, A350, Dassault F7X)

Cd advantages:

- Sacrificial deposit
- Environemental, electrical, properties
- Dissolution potential equivalent to aluminium material

3. Cadmium alternatives in Europe

Cd free european solution overview in 2012

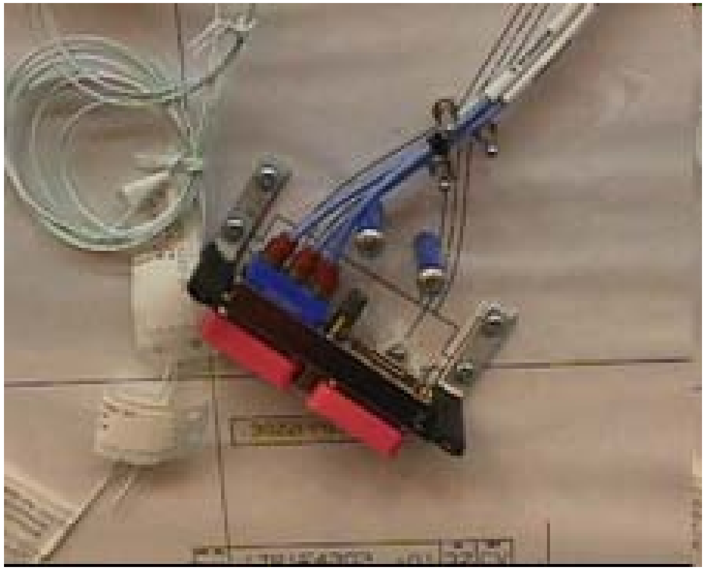
Deposit	Basis metal	Market	Examples of users
ZnNi(12-15%)	Steel alloys	Automotive	PSA, RENAULT
		Aerospace	SAFRAN, EUROCOPTER, DASSAULT
	Aluminium	Connectors	SOURIAU
Lamelar ZnAlu	Steel alloys	Automotive	LISI
ZnCo	Aluminium	Aerospace	AIRBUS, BAE, SOURIAU, AMPHENOL
ENPTFE	Aluminium	Connectors	AMPHENOL, RADIALL

Cd free candidate for connector application

- ZnNi
- ZnCo
- ZnFeCo
- NiSn
- SnZn
- Black EN
- NiPTFE

4. Alternative to Cd on EPX® connectors

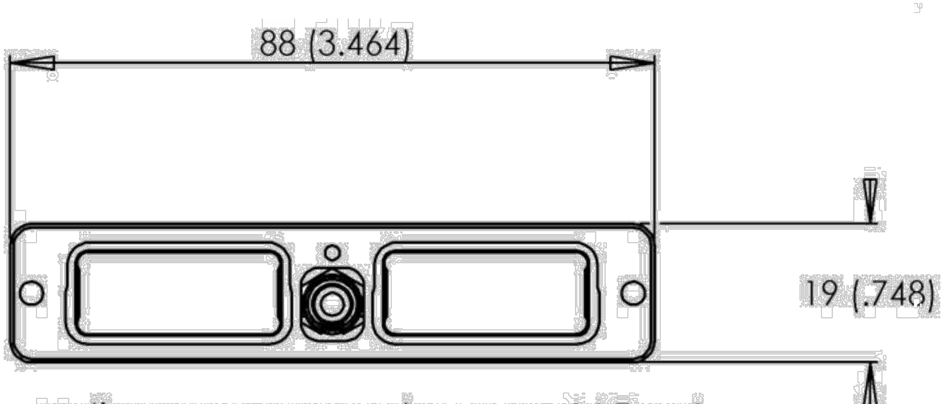
1. EPX® presentation
2. EPX® Requirements
3. Alternative solution research
4. Alternative solution development



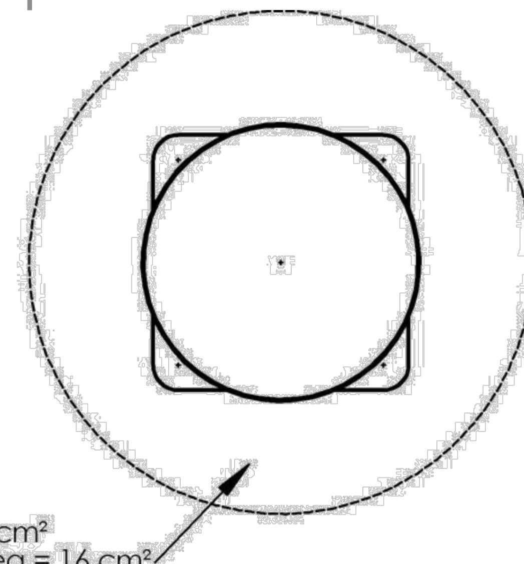
4. Alternative to Cd on EPX® connectors

4.1 EPX® Presentation

- A modular and expandable concept
- Designed for rack, cable to cable and front panel applications
- Standard and custom shells sizes
- A cost saving and user friendly solution
- EN 4644 European Standard



Mating area = connector area = 16,7 cm²



4. Alternative to Cd on EPX® connectors

4.2 EPX® Requirements

Application	Civil and Military shell
Basis metal	2024, 2017 alloy
	7075 alloy
	6061 alloy
Deposit	**Deposit according to MIL DTL 38999L**
	Conductive
	Color: non reflective
	RoHS and REACH compliant

	File test	Requirement
Evaluation of performances	Examination of product	Non reflective color
	SRT	**-65/+175ºC: 5 cycles**
	Vibrations	Test 53 gr
	Durability	**500 cycles**
	Temperature life	**1000h at 175° C**
	Dynamic Salt spray (*)	**500h**
	Lightning strike current and voltage pulse	1600A / 1600V (J54291)
	Electrical continuity	**Shell to shell < 2,5 mΩ**

(*) : dynamic salt spray : 50 mating cycle + 452h NSS + 48h NSS + 450 mating cycle

4. Alternative to Cd on EPX® connectors

4.3 Alternative solution research

Abstracts and comments on MIL DTL 38999 plating requirements

P - Pure dense electrodeposited aluminum in accordance with MIL-DTL-83488, Type II, to withstand 500 hours of dynamic salt spray testing. Color shall be nonreflective.

Color is bright

T - Nickel fluorocarbon polymer. Nickel with fluorocarbon polymer additives over a suitable underplate to withstand 500 hours of dynamic salt spray testing. Color shall be nonreflective.

NiPTFE specification existes now (AMS 2454) but is not applied

Z - Zinc nickel in accordance with ASTM B841, type D (black), over a suitable underplate to withstand 500 hours of dynamic salt spray testing. Color shall be nonreflective.

6.2.1 The coating shall consist of a zinc nickel alloy that has a minimum of 5 and maximum 12 mass percent nickel, the balance being zinc.

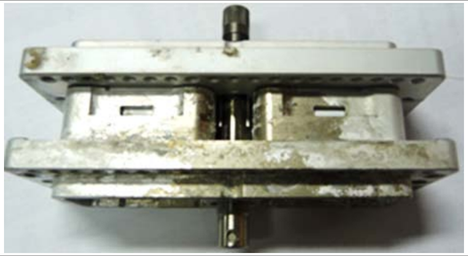
All Zn/Ni formulation are now at 12-15% of Nickel

4. Alternative to Cd on EPX® connectors

4.3 Alternative solution research

Deposit	Specification
Aluminium	MIL-DTL-83488, Class 2
Chemical conversion	MIL-DTL-5541F, Class 3 Conductive

➔ Pure Aluminium

Designation	Characteristic	Initial	Speed Rate Temperature	NSS 500 hours
Pure aluminium deposit	Contact Resistance	5 mΩ	5 mΩ	115 mΩ
	Aspect			
	Bright and uniform color			Pit on several areas

Conclusion: Pure aluminium deposit didn’t answer the environmental and electrical requirements of the MIL 38999 on EPX connectors

4. Alternative to Cd on EPX® connectors
4.3 Alternative solution research

➔ **Zn/Ni**

Main Configurations	Initial Contact Resistance	After SRT	After Salt Spray
Zinc nickel	0,87	0,96	NC
Zinc nickel Black with fixator	486,333	321,000	4000
Zinc nickel black top coat Cr+III	650	481	NC
Zinc nickel black top coat Cr VI	292,333	NC	6000

Initial

After 500H NSS

Conclusion:

- Same results from different suppliers process
- Contact resistance is good without topcoat
- With topcoat all contact resistance are superior to 38999 requirement
- High dispersion of thickness in/out parts compare to cad
- Reproducibility of color is difficult
- Salt Spray test failed for most of samples

4. Alternative to Cd on EPX® connectors

4.3 Alternative solution research

➔ EN-PTFE

Substrate: Aluminium 6061
Parts: Panel
Test: According MIL-DTL-81706 (load=200 Psi)

Check contact resistance on load (890N)	Initial Contact Resistance (mΩ)	NSS 500 Hours	Final Contact Resistance (mΩ)
Supplier 1	0,35	Several pits	41,21
Supplier 2	0,25	Several pits	216,00
Supplier 3	0,43	Several pits	41,76
Supplier 4	0,15	Several pits	21,58
Supplier 5	0,47	No corrosion	1,11

Conclusion:

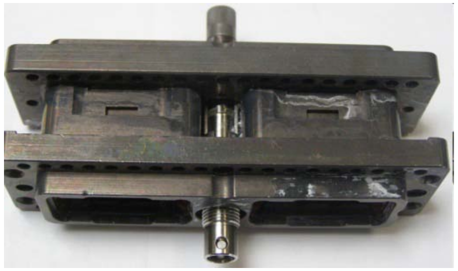
- Different behavior between all process supplier formulations (Corrosion and degradation of contact resistance after NSS)
- Ni PTFE provided by Supplier 5 meets electrical requirements after all tests.

➔ **Dimension of PTFE particles of supplier 5 is lower**

4. Alternative to Cd on EPX® connectors
4.4 Alternative solution development

➔ EN-PTFE: *Definition of underplate*

Configuration	Contact Resistance (mΩ)			Visual aspect after NSS
	Initial	After SRT -65ºC/+180ºC 5 cycles	After NSS	
SnEN + ENPTFE	0,23	0,09	0,12	Pits on screw
SnEN + LP EN + ENPTFE	0,09	0,07	0,08	No corrosion
HP EN + ENPTFE	0,08	0,06	0,06	No corrosion
HP EN + LP EN + ENPTFE	0,34	0,08	0,17	Pits on screw


Aspect after 500 Hours NSS

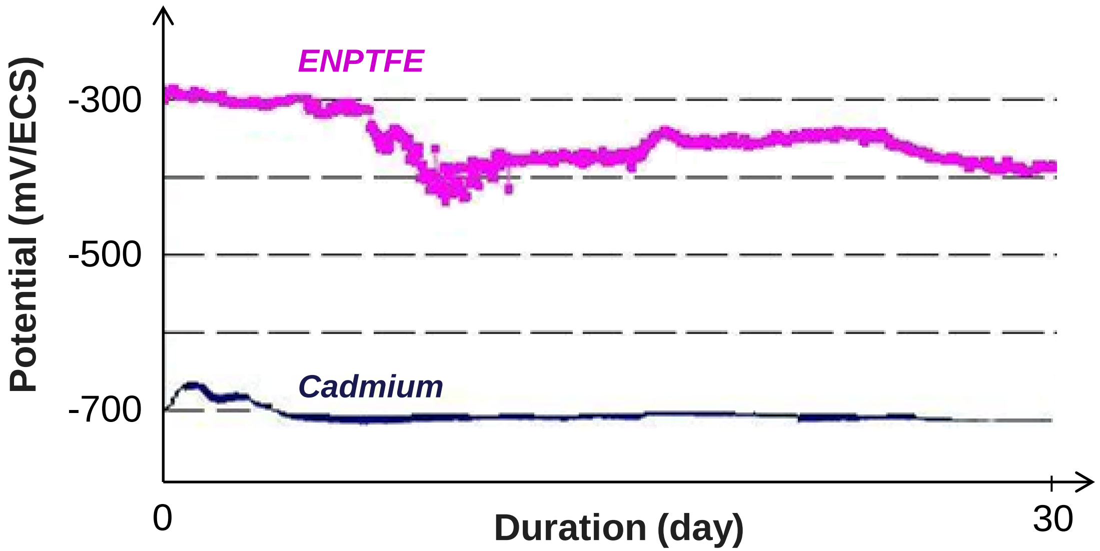
Conclusion:

All trial tests are in accordance with RADIALL and MIL-DTL-38999L requirements in terms of contact resistance

4. Alternative to Cd on EPX® connectors

4.4 Alternative solution development

➔ **EN-PTFE:** *Dissolution potential Cadmium/ENPTFE*



Conclusion:

- Potential difference from 300 to 400 Mv/ECS between Cad and NiPTFE
- Each assembly condition needs to be studied in order to validate galvanic corrosion behavior (surface, environmental stress,…)

4. Alternative to Cd on EPX® connectors

4.4 Alternative solution development

➔ **EN-PTFE:** *Cd/ENPTFE assembly - Electrical performance*

NiPFE shell fixed on
Cd plated panel

Trial	Initial (mΩ)	After SRT (mΩ)	After NSS (mΩ)
Cadmium/ Standard EN	0,13	0,09	0,15
Cadmium/ ENPTFE	0,11	0,12	0,14

Conclusion:

All trial tests are in accordance with RADIALL's requirement in terms of contact resistance (less than 2.5 milliOhm)

4. Alternative to Cd on EPX® connectors

4.4 Alternative solution development

➔ **EN-PTFE:** *Cd/ENPTFE assembly*

Trial	Visual aspect after 500h NSS
Cadmium / Standard EN	Basis metal corrosion on shell
Cadmium / ENPTFE	Cadmium corrosion

Spectre	Cl	Cr	Cd
Moyenne	1.0	12.1	86.9

Spectre	Cl	Ni	Cd
Moyenne	24.1	1.4	74.6

Spectre	Na	P	Cl	Ni	Cd
Moyenne	0.6	0.9	0.9	25.8	71.9

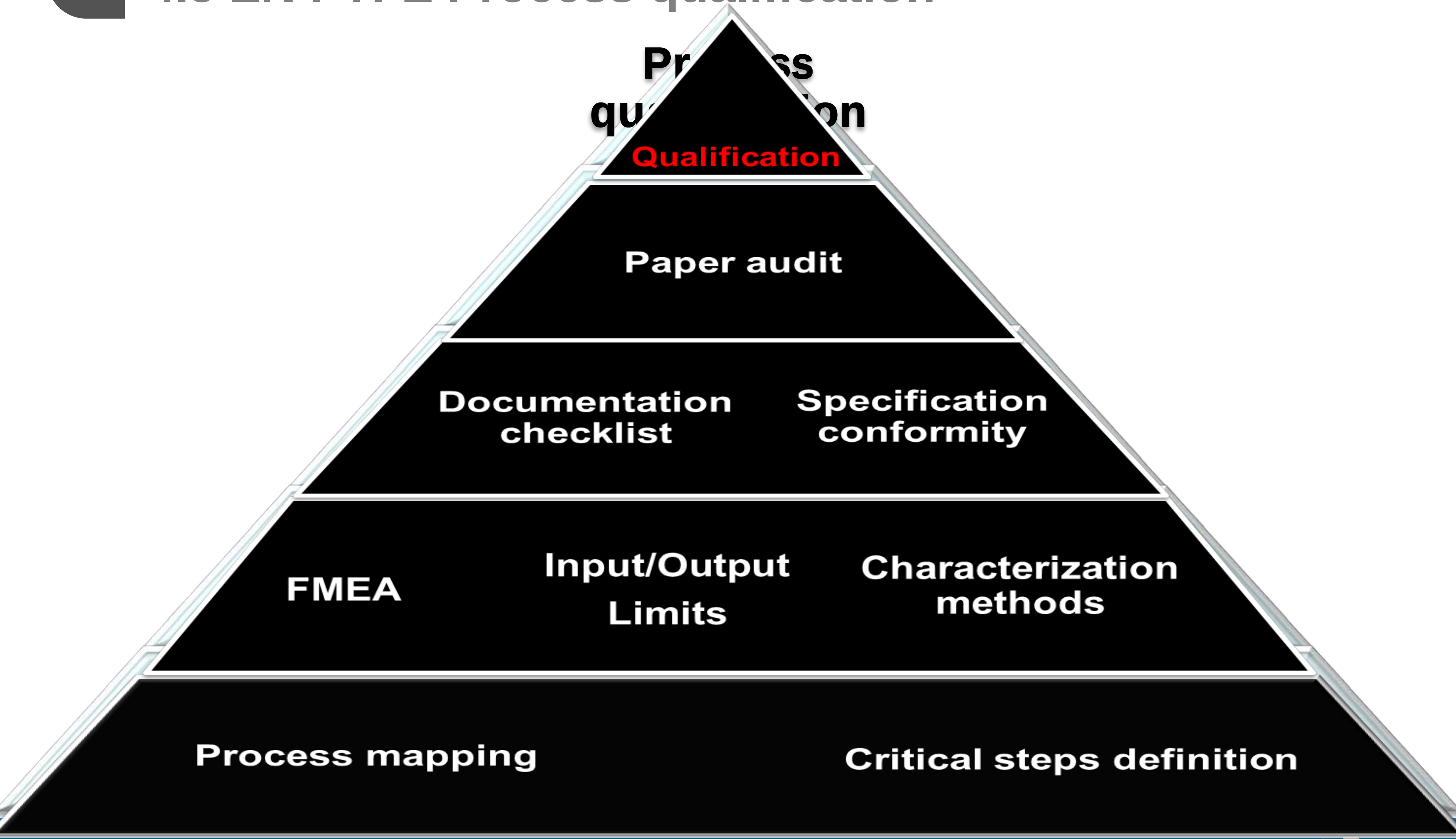
SEM+EDS results

Conclusion:

- Trial with ENPTFE produced better results in terms of corrosion resistance
- Discoloration is due to the degradation of Olive drab topcoat, no apparition of the base metal with ENPTFE sample

4. Alternative to Cd on EPX® connectors

4.5 EN PTFE Process qualification



4. Alternative to Cd on EPX® connectors

4.5 EN PTFE Process qualification

➔ EN-PTFE: *Reliability of characterization methods*

	Parameters	Methods	Production/Expertise	Acceptance criteria	Accuracy of the method
Characterization of the deposit	Thickness	X-Ray	Prod	…	…
		Eddy current	Prod		
		SEM	Exp		
		Microscope	Exp		
	PTFE into the deposit	…	…		
	Phosphorus				
	Particle size				
	…				
Bath Following	Surface tension				
	Temperature				
	pH				
	[Ni]				
	…				

➔ R&R approach to define capability of each device

4. Alternative to Cd on EPX® connectors

4.5 EN PTFE Process qualification

➔ **EN-PTFE:** *Input / Output Matrix (impact on process)*

	Deposition rate (Thickness)	%PTFE (deposit)	%P (deposit)	Distribution of PTFE	…
Temperature	✓	✓			
pH	✓	✓			
[Ni]	✓				
[NaPO2H2]			✓		
PTFE dispersion quality		✓		✓	
…					

Decrease of the impact of each critical parameter
by definition of tight process ranges

4. Alternative to Cd on EPX® connectors

4.5 EN PTFE Process qualification

➔ **EN-PTFE:** *Input / Output Matrix (impact on properties)*

	Corrosion resistance	Wear resistance	Hydrophobicity	Coloration	…
Thickness	✓	✓			
PTFE content	✓	✓	✓	✓	
Phosphorus content	✓				
PTFE distribution	✓	✓			
Particle size	✓	✓	✓		
…					

Decrease of the impact of each critical parameter
by definition of tight process ranges

4. Alternative to Cd on EPX® connectors

4.5 EN PTFE Process qualification

➔ **EN-PTFE:** Process industrialization

Challenging process requirements:

- Dedicated tooling
- Dedicated stripping line

} To Avoid contamination of other baths

- Agitation method adapted to maintain PTFE particles into solution without degrading them
- Periodic decontamination to avoid total plate out of the bath
- Improvement of method to control PTFE content into the deposit

5. Conclusion

- Cadmium deposit was used for different markets and applications
- European market switched for ZnNi for main applications
- RADIALL launched Cd free project since 2006 and different solutions were tested internally (ZnNi, Pure aluminium deposit, Black EN, NiSn,…)
- According RADIALL evaluation, the best candidate to meet 38999 requirements is the NiPTFE deposit

5. Conclusion

- RADIALL launched industrialization step in order to add NiPTFE on production
- The whole system needs to be considered in order to match product requirements :
  - Surface preparation (etching and zincate step)
  - Underlayer (nature and thickness)
  - NiPTFE parameters (thickness, PTFE%)
- NiPTFE process is more complex than standard EN and industrial experience is limited for such application, a specific process following need to be defined
- RADIALL will be able to propose MPCoating in 2013 for ROHS connectors application

THANK YOU

Questions or Comments ?

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