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SPACE

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ECI Presentation Days

29th-30th September, 2016
Italian Space Agency, Roma

ESA EMITS AO_1-6839_11_EM EEE10

Development of new high temperature standard wires for space applications

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Arnaud Bertrand – Project Manager
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esa

Project objectives review

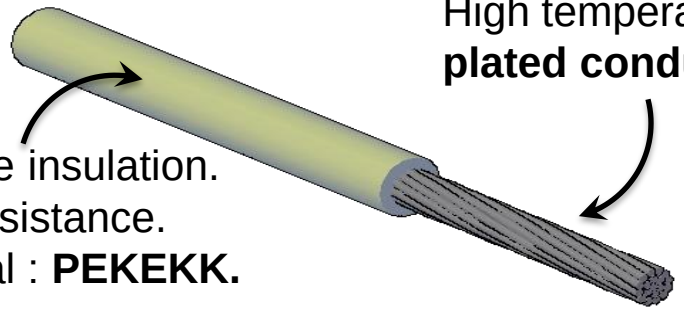
Objectives

Development of a new range of wires with **higher maximum operating temperature** to fill two kinds of purposes :

- **Operation in environments involving higher temperature.**
- **Increasing the amperage capacity.**

For the second one, **adapted derating rules** shall be studied.

Wires design



Main features

- **Maximum** operating **temperature** expected : **250° C**
- **Maximum radiation** resistance : **250 MRad**

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Project milestones

Delivery : **Evaluation** Test Plan

Testing phase : **Evaluation** tests campaign

Deliveries
- Evaluation test Report
- Detailed specification Draft
- PID Draft

Mid Term Review

Testing Phase : **Qualification** Test campaign

Deliveries
- Qualification test Report
- Executive Summary
- Summary Report

Phase 1

Phase 2

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ESA EMITS AO_1-6839_11_EM EEE10
PHASE 1 – WIRES' EVALUATION

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I. Test series

Preliminary tests	**CHART III Preliminary test series**		
Stripping ability of the HT wires Nickel plated conductor crimping			
- Step Stress Accelerated Aging - Long term ageing (T°:250°C)	**CHART V Long term ageing / 250°C**	**CHART VI Long term ageing / 250°C**	**CHART II Test series**
250 MRad Radiation testing	**CHART IV**		
High intensity tests on single wires in vacuum			
High intensity tests on a harness configuration in vacuum			

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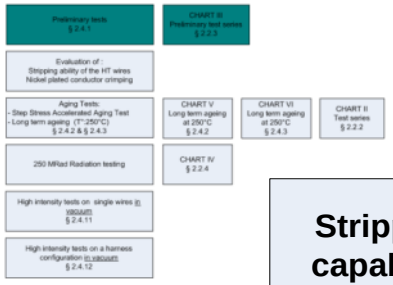
Preliminary Test Sequence



Stripping capability

Blocking

Cut-through Resistance

Notch resistance

Shrinkage

Abrasion Resistance

Crimping tests

Cold Bend Test → **Voltage Test**

Resistance to fluids → **Wrap test at ambient temperature** → **Voltage Test**

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I. Test series

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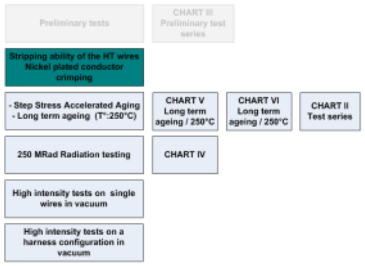
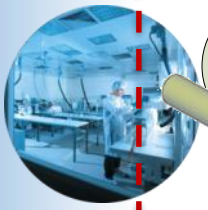
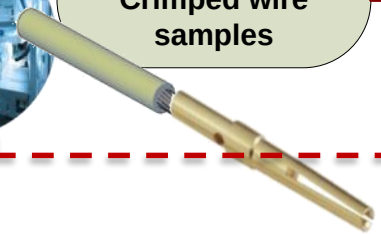
Crimping test sequence (ageing)



AWG 3007,2419,2219 & 1237 Wire samples

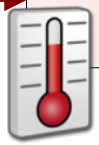
Test series CHART II





AWG 2419 & 2219 Crimped wire samples

Pull-test & micrographic section



2000 hours thermal aging @ 250°C

Pull-test & micrographic section

Wrap-test/voltage every 500 hours

Test series CHART II

Samples description

Characterization tests

Aging test

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I. Test series

Preliminary tests	CHART III Preliminary test series		
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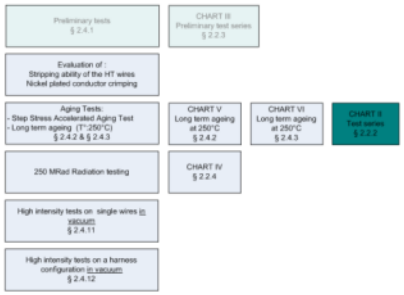
Characterization test series



This complete test series was carried out on initial samples and aged samples.

Test series
Insulation resistance and voltage test according to ESCC 3901
Dielectric breakdown at **different temperature between ambient T° and 250°C** § 2.4.4
Insulation resistance **at high temperature up to 250°C** § 2.4.5
Visual Inspection and conductor inspection
Tensile strength Elongation test § 2.4.7

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I. Test series

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High intensity tests on single wires in vacuum			
High intensity tests on a harness configuration in vacuum			

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Long term ageing and radiation test sequence

Test series CHART II

250°C Long term ageing Test

AWG 2419,2219 Non-aged Wire samples

AWG 3007,2419,2219 & 1237 Wire samples

Test series CHART II

2000 hours thermal aging @ 250°C

Wrap-test/voltage every 500 hours

Test series CHART II

Test series CHART II

Wrap Test at Ambient Temperature.

Voltage test

250 MRAd Radiation test

Test series CHART II

Wrap Test at ambient temperature

Voltage test

Samples description

Characterization tests

Aging test

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II. Single wire variants selected

ESA ESCC 3901 Generic Specification defines the general requirements for qualification testing of eletrical low frequency 600V wires and cables for space application.

Then, **each** qualified family of wires is specified as an ESCC **3901/0XX** called a *Detail Specification* and may contain single wires and assemblies.

Generally, the wires gauge range goes from **AWG 30 to AWG 12**.

AWG 30 to AWG 24 wires are with silver coated **copper alloy** conductor.
AWG22 to AWG 12 wires are with Silver coated **copper** conductor.

Thus, the wire variants selected for the projects were:

- **AWG 30**
- **AWG 24**

→ **Nickel plated copper ALLOY**

- **AWG 22**
- **AWG 12**

→ **Nickel plated copper**

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II. Preliminary tests results

Stripping capability	**Compliant**
Blocking Test @ 250°C	**Compliant**
Surface resistance	**Compliant**
Cut through resistance	**Compliant**
Notch resistance	**Compliant**
Shrinkage	**Compliant**
Abrasion resistance	**Compliant**
Cold bend test	**Compliant**
Anthony and Brown test on conductors	**Compliant**
Resistance to fluids • Solvents	**Compliant**

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Resistance to fluids

In the solvents (internal tests)

Solvent nature	AWG 30	AWG 24	AWG 22	AWG 12
Ethyl alcohol	OK	OK	OK	OK
Isopropyl alcohol	OK	OK	OK	OK
Acetone	OK	OK	OK	OK
Xylene	OK	OK	OK	OK

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Stripping capability

A critical concern from processing point of view. Stripping is sometimes achieved on-site with manual tools. Thus, the stripping ability is an important aspect of the product.

Tests have been realized by **Thales Alenia Space.**
Trials have been made using No-Nik® and Stripmaster® strippers.

Main conclusion :

No more problem of effort to apply.
The blade seems much stronger.
The use of "STRIP MASTER" strippers is the most appropriate.

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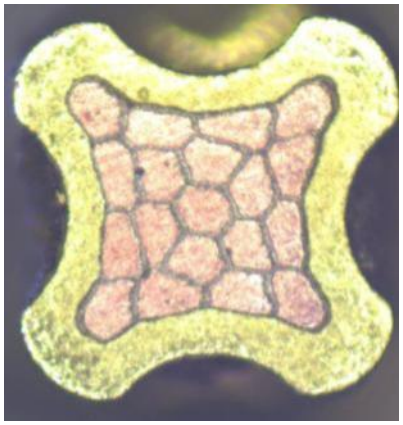
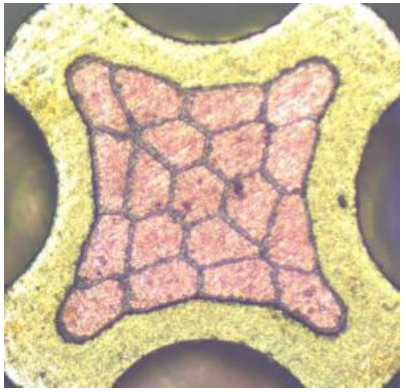
2000 hours ageing @ 250℃

Results on AWG 2219 & AWG 2419 crimped parts

Female Contact



Male contact pin



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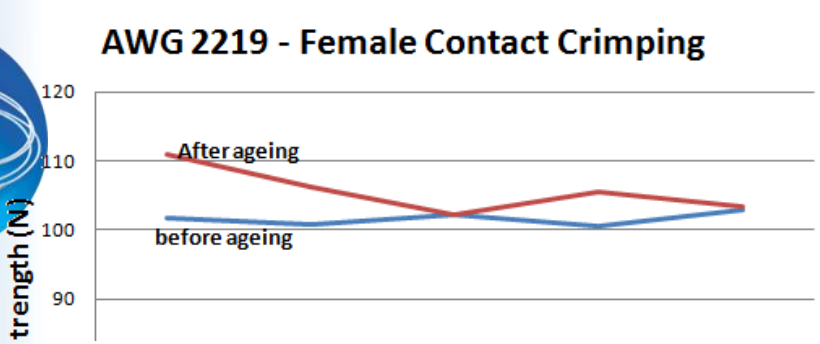
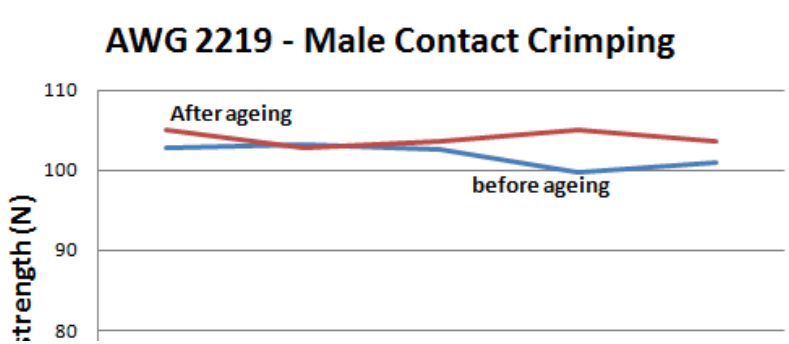
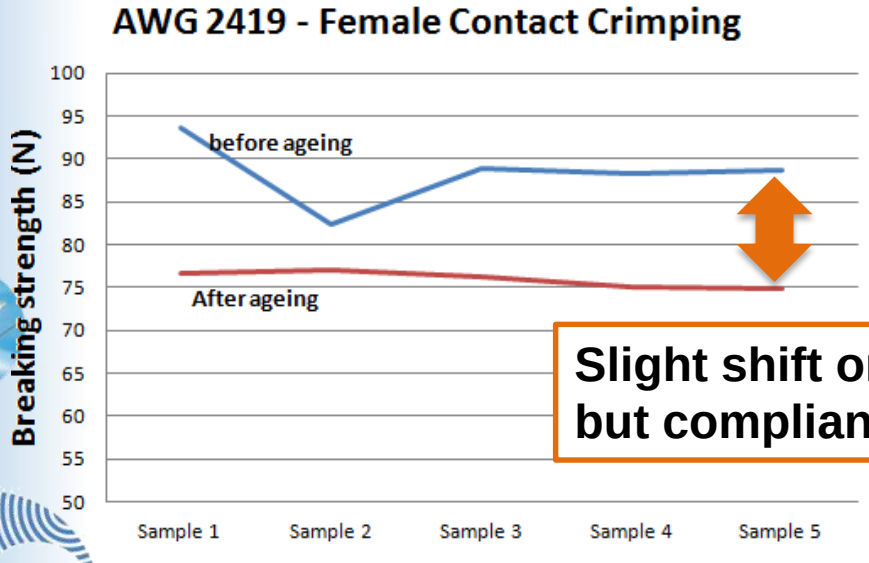
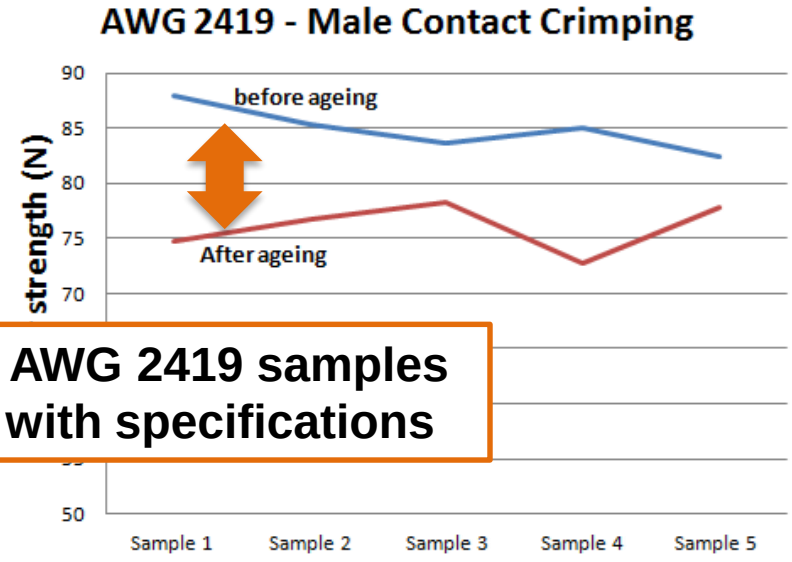
2000 hours ageing @ 250°C

Results on AWG 2219 & AWG 2419 crimped parts









Slight shift on AWG 2419 samples but compliant with specifications

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2000 hours Long Term ageing @ 250°C

Wires

NCA 2419 - 0,23 mm PEKEKK insulation	2000 hours		
NCA 3007 - 0,23 mm PEKEKK insulation	2000 hours		
NPC 2219 A1 CONC - 0,23 mm PEKEKK insulation	2000 hours		
NPC 1237 A1 C - 0,23 mm PEKEKK insulation	1000 hours		

A few cracks were observed on some samples, always after wrap test.
In consequence, the mandrels diameters were adapted.

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2000 hours ageing @ 250°C

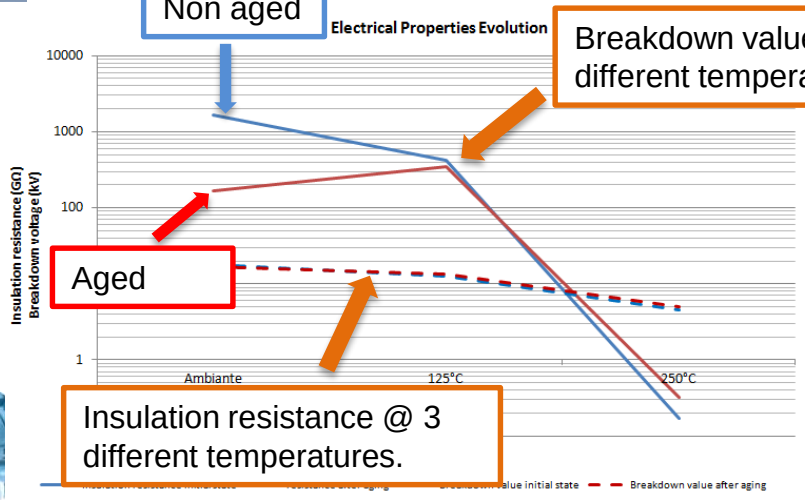
Results on AWG 3007, 2419, 2219 and 1237 wires

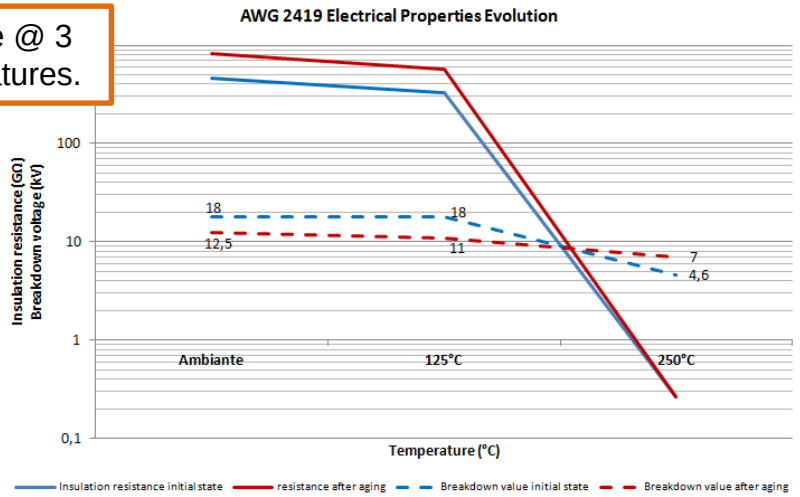
Non aged

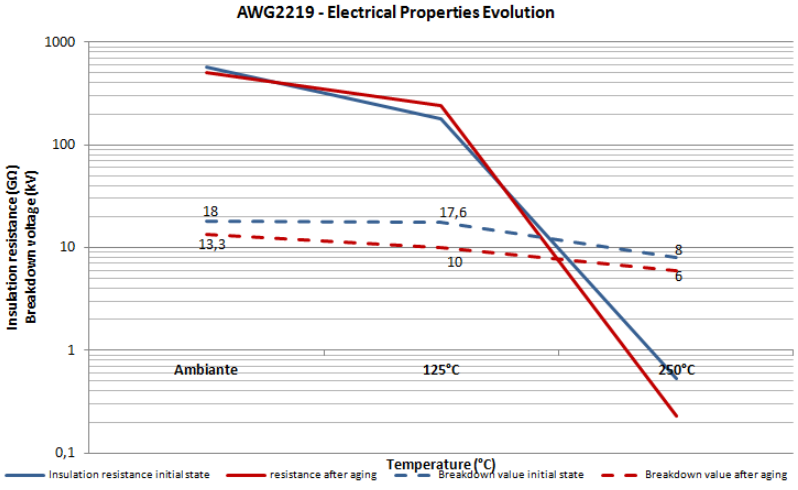
Aged

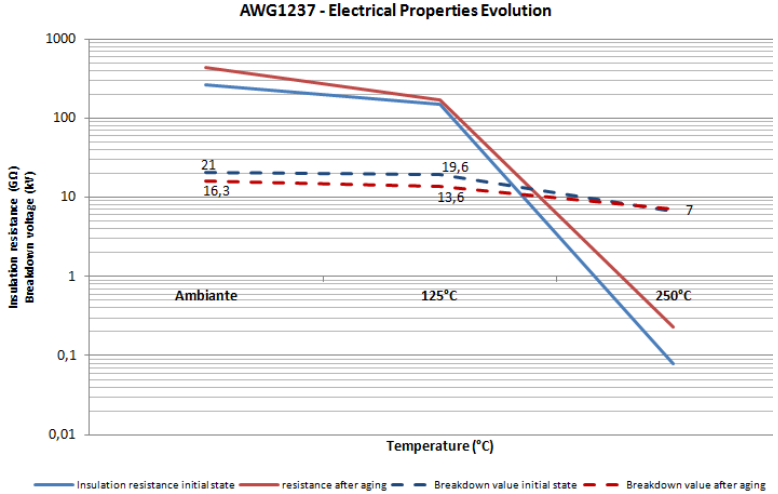
Breakdown value @ 3 different temperatures.

Insulation resistance @ 3 different temperatures.









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2000 hours ageing @ 250℃

Conclusion

- No significant degradation observed on crimped parts. Pull test values are compliant before and after ageing.
- Voltage resistance, reflected by dielectric breakdown tests, is impacted by long term ageing. We observe a reduction of 25 to 40% of the values. However, the values are still quite high – more than 10 kV AC.
- Some wires suffered from cracks after being wrapped on a mandrel. Cracks only appear when the wires are wrapped on mandrel, in consequence some of the mandrels diameters were adapted to suppress this issue.
- Insulation resistance is also impacted by the thermal ageing but, as for voltage resistance, the values are still high.

From electrical perspective, the wires show good performance after long term ageing @ 250° C.

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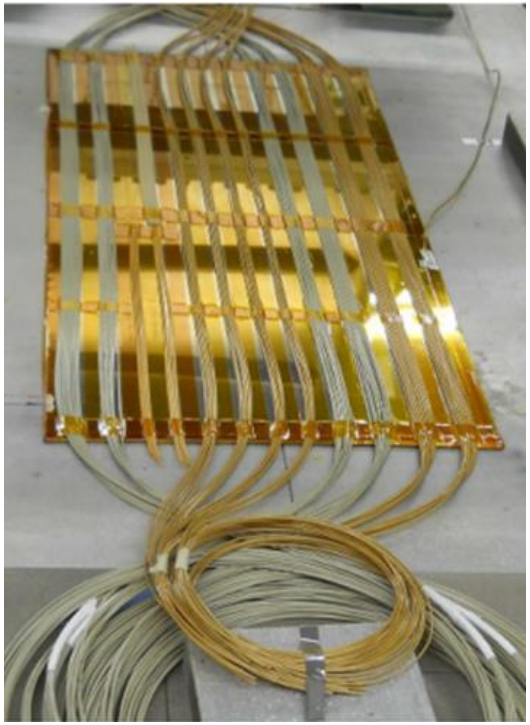
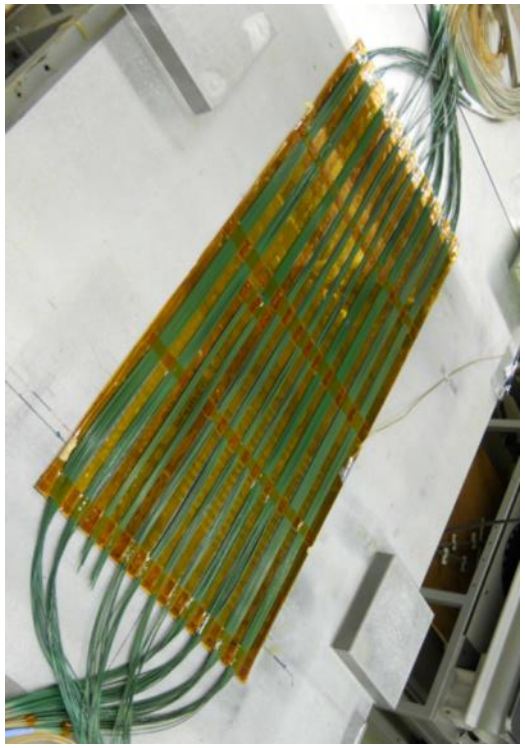
V. 250 Mrad Radiation Test

Test setup



TID
250 MRad

ß irradiation



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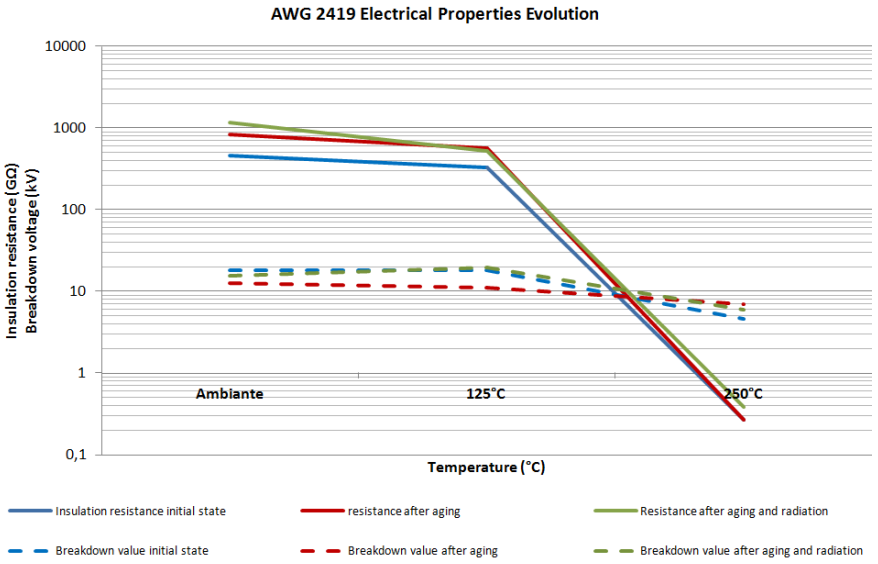
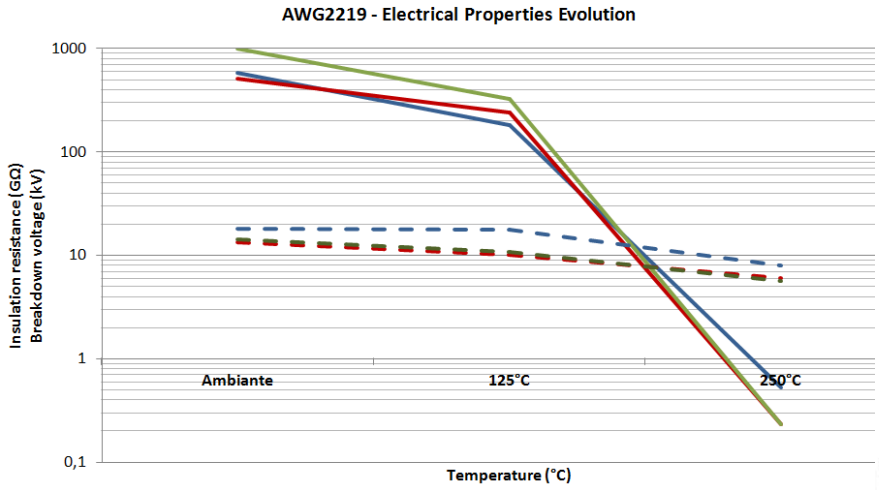
250 Mrad Radiation Test

Results on AWG 2419 wires





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250 Mrad Radiation Test

Conclusion

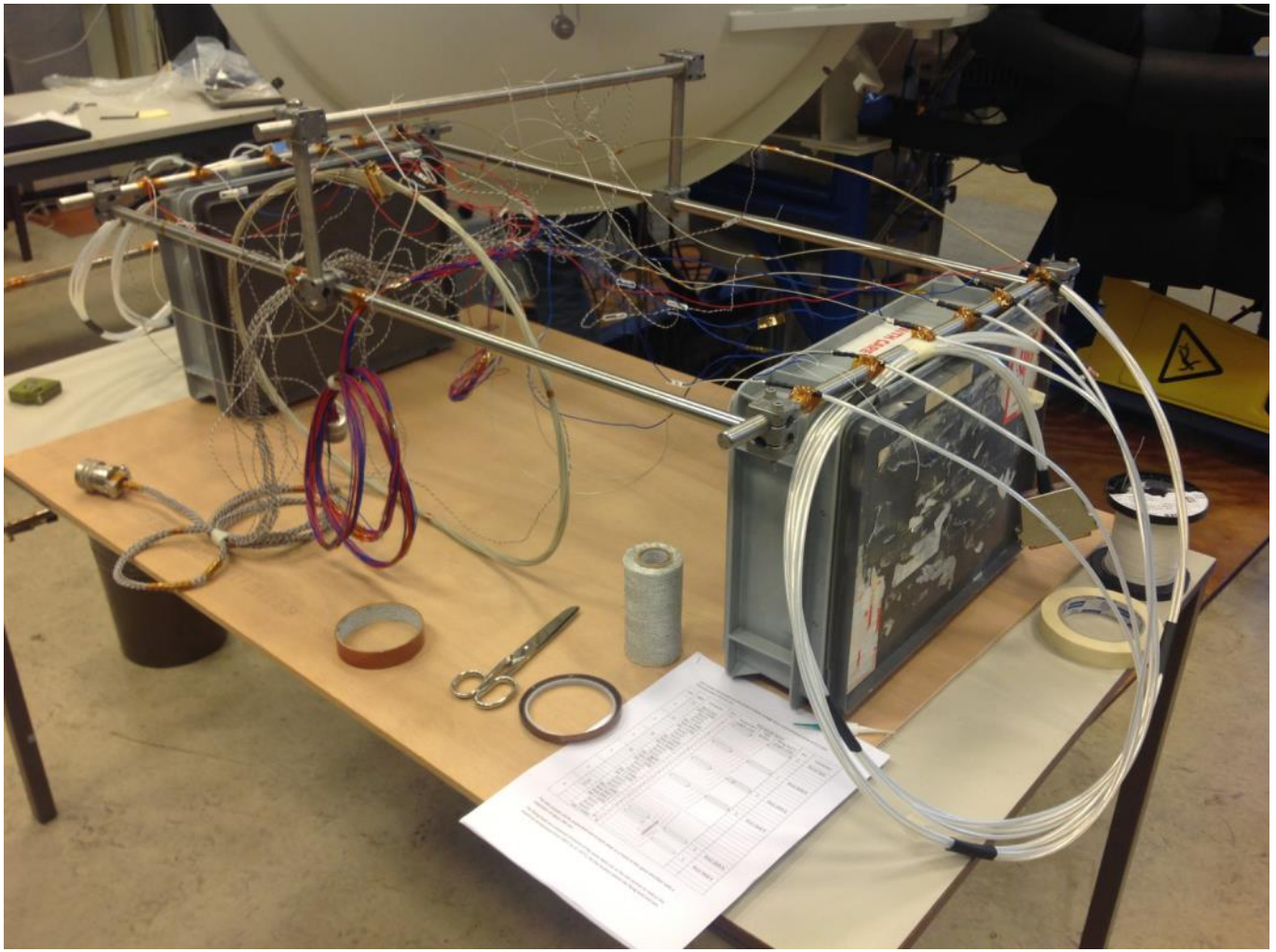
Test values obtained on aged and [aged + irradiated] samples show that the 250 MRad irradiation has minor effect on the wires characteristics.

Neither insulation resistance, nor voltage resistance are significantly impacted.

Such results confirm the outstanding radiation resistance of PEEK materials.

VI. High Current/Temperature Tests

Test setup



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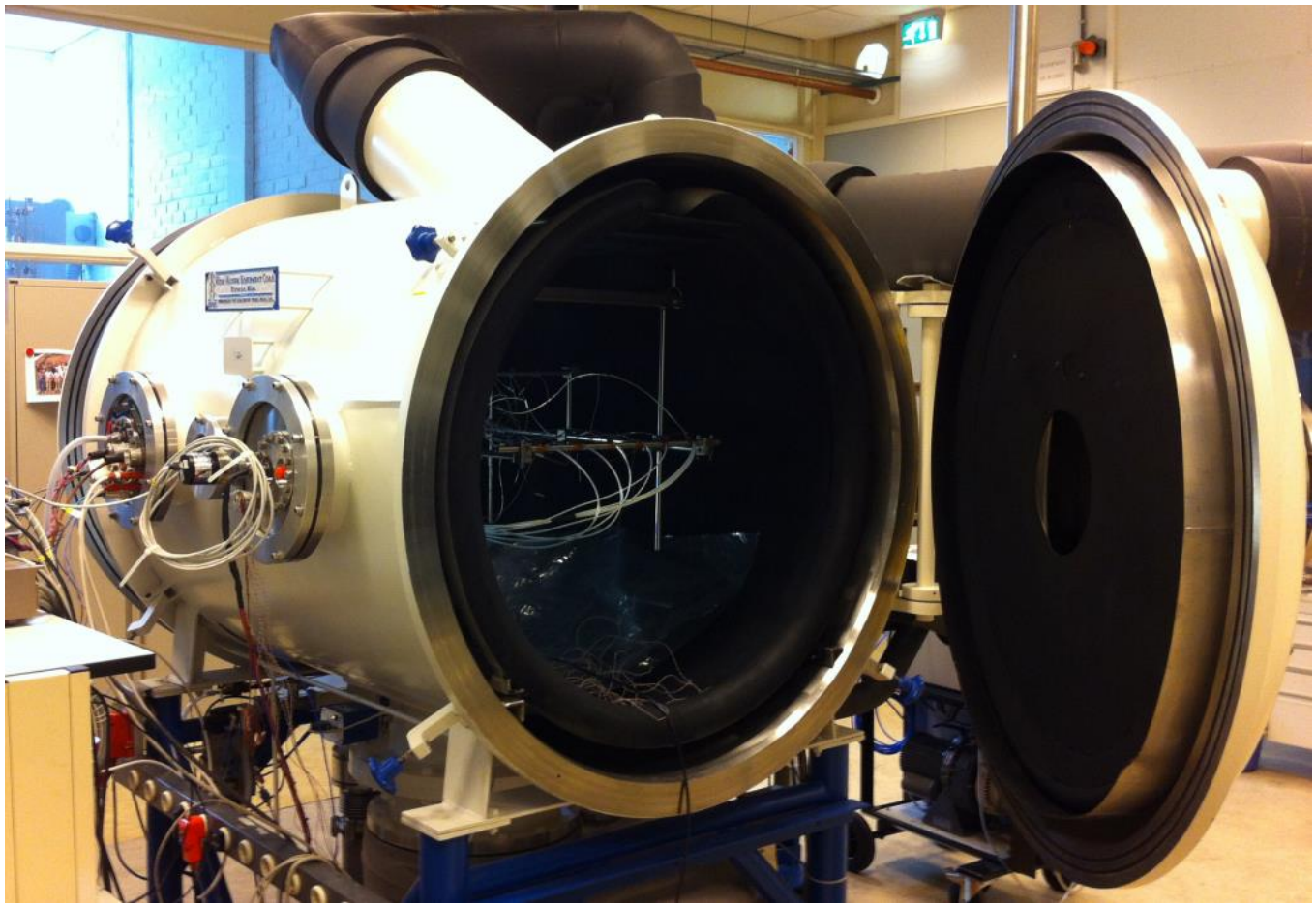
High Current/Temperature Tests

Test setup



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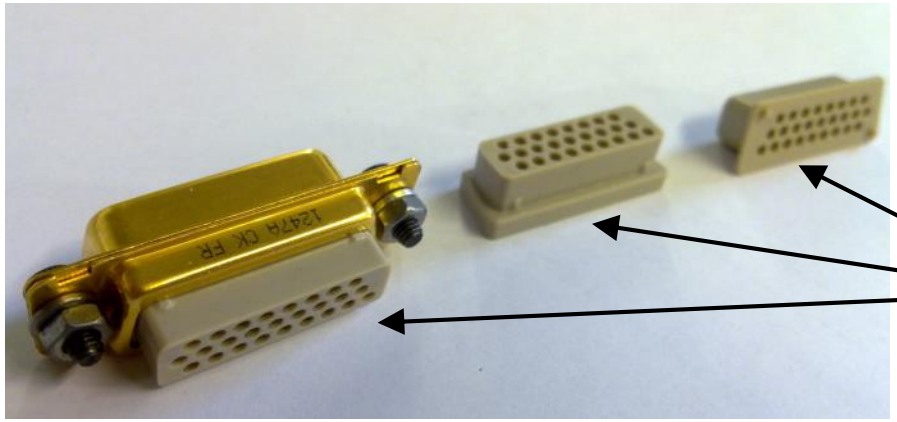
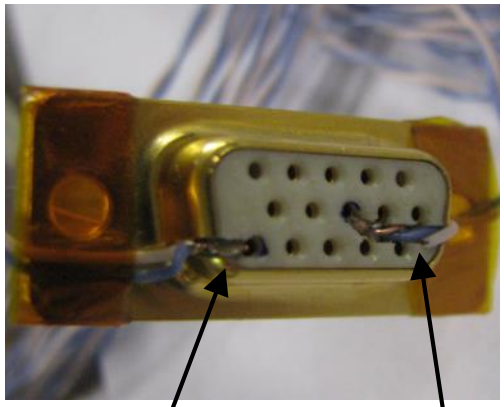
High Current/Temperature Tests

High temperature D-Sub connector



AWG 22 wires.

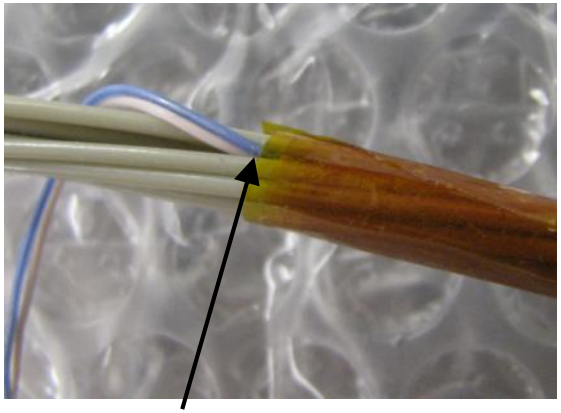
PEEK Machined D-Sub connector inserts



Thermocouple close to the edge of D-Sub connector

Thermocouple in the center of the connector.

Plugged connectors



Thermocouple placed at the center of the bundle

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High Current/Temperature Tests

Results on single lines

40°C – in vacuum			
Line	**T_{target} = 125**	**T_{target} = 200**	**T_{target} = 250**
AWG 1237	29.8	44.6	**53.0**
AWG 2219	8.23	12.1	**15.1**
AWG 2419	5.49	8.63	**10.2**
AWG 3007	2.65	3.95	**4.77**

125°C – in vacuum		
Line	**T_{target} = 200**	**T_{target} = 250**
AWG 1237	35.4	**46.4**
AWG 2219	9.70	**13.7**
AWG 2419	6.56	**8.69**
AWG 3007	3.24	**4.30**

40°C – in air			
Line	**T_{target} = 125**	**T_{target} = 200**	**T_{target} = 250**
AWG 1237	52.2	60.0*	-
AWG 2219	15.8	20.0*	-
AWG 2419	11.3	15.5	**17.6**
AWG 3007	5.22	7.03	**7.97**

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High Current/Temperature Tests

Results

I_{max} = Amperage causing a temperature elevation of 50° C.
From ESCC specifications, I_{max} can be used up to 150° C environment.
Beyond this temperature I_{max} shall be drastically reduced in order to not overpass 200° C.

Gauge	Current ESCC 3901 Maximum Amperage (A)	Proposal of Maximum amperage rating (A)	Amperage capacity gain
AWG 1237	23	**35**	**+ 52%**
AWG 1419	17	**25**	**+ 47%**
AWG 1619	13	**19**	**+ 46%**
AWG 1819	10	**15**	**+ 50%**
AWG 2019	7.5	**11**	**+ 47%**
AWG 2219	5	**9**	**+ 80%**
AWG 2419	3.5	**6**	**+ 71%**
AWG 2619	2.5	**4**	**+ 60%**
AWG 2819	2	**3.5**	**+ 75%**
AWG 3007	1.5	**3**	**+ 100%**

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Evaluation phase main conclusions

Radiation Resistance

Excellent resistance. No significant effect observed.

Chemical Resistance

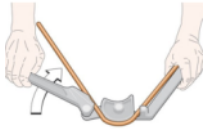
Good resistance to solvents. Less to Ergols.

Heat Resistance

Excellent accelerated ageing results.
Some issues during long term ageing.

Stripping ability

Stripping is obviously more difficult.



Stiffness

These wires are obviously stiffer.

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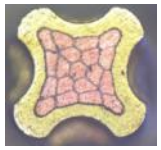
Evaluation phase main conclusions



Crimping ability

Results are compliant.

Amperage capacity

Maximum ampacity increased from 47% to 100% depending of the gauge.

Qualification phase

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PHASE 2 – WIRES' QUALIFICATION

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Control tests

External Visual Inspection
ESCC 3901 § 9.1

Weight
§ 9.2 **With deviation**

Dimensions
ESCC 3901 § 9.3

Coating Tests
ESCC 3901 § 9.4

Conductor Resistance
ESCC 3901 § 9.5

Spark Test
ESCC 3901 § 9.6

Voltage Test
ESCC 3901 § 9.7

Insulation Resistance
ESCC 3901 § 9.8

Stripping Capability
§ 9.9 **With deviation**

To Chart II

These ESCC 3901 testing procedures have been adapted, i.e. more weight on sample, improved stripping procedure…

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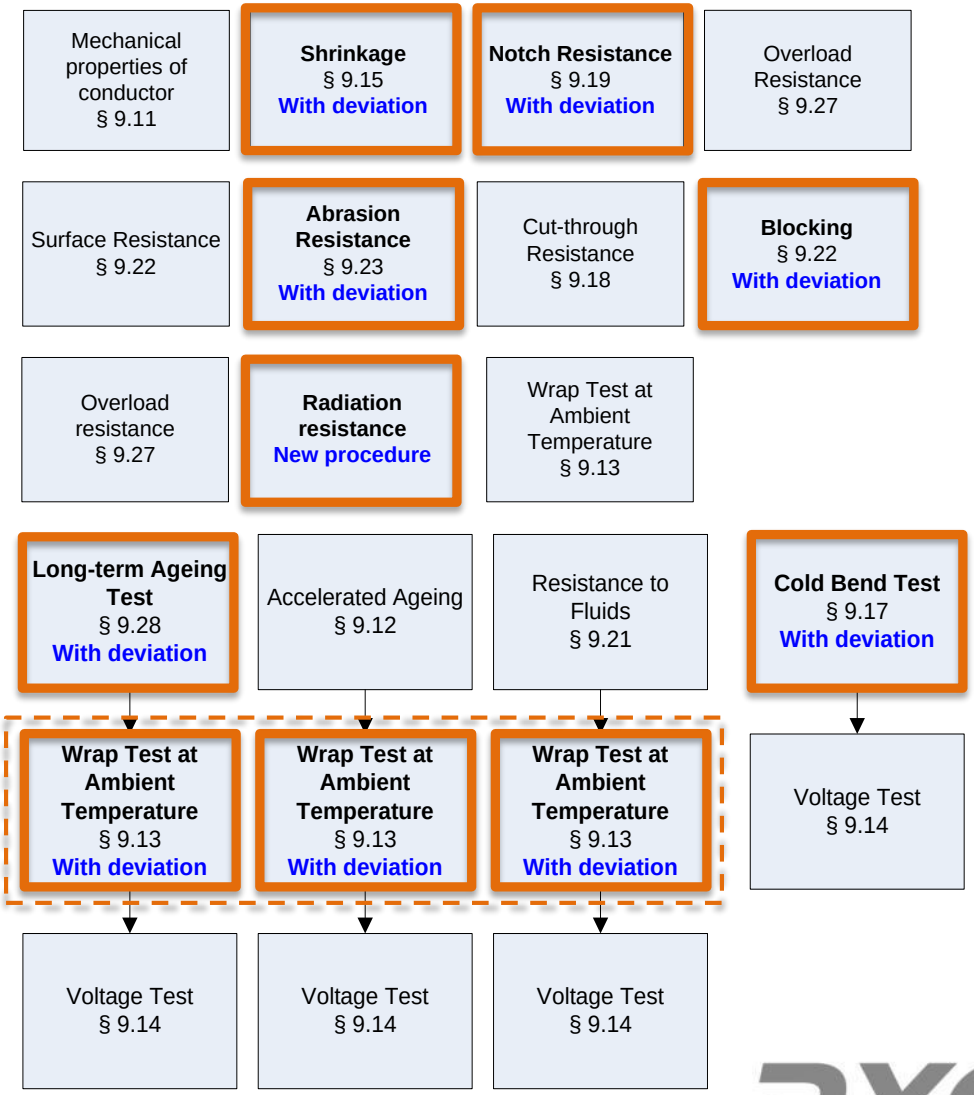
Qualification test sequence



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Accelerated ageing mandrels adaptation

During ageing :

Wire reference	Mandrel diameter from ESCC 3901/012 (mm)	Adapted Mandrel diameter in (mm)	Standard weights defined in ESCC 3901/012 (kg)	Adapted weight (kg)
NPC1237 PEEK STG45	*38*	38	*0.68*	**1**
NPC2219 PEEK STG45	*10*	**16**	*0.17*	**0.5**
NCA2419 PEEK STG45	*13*	**16**	*0.115*	**0.2**
NCA3007 PEEK STG45	*6.5*	6.5	*0.06*	**0.2**

For wrap-test:

Wire reference	Mandrel diameter from ESCC 3901/012 (mm)	Adapted Mandrel diameter in (mm)	Standard weights defined in ESCC 3901/012 (kg)	Adapted weight (kg)
NPC1237 PEEK STG45	*38*	38	*0.68*	**2**
NPC2219 PEEK STG45	*13*	**16**	*0.17*	**0.8**
NCA2419 PEEK STG45	*10*	**16**	*0.115*	**0.8**
NCA3007 PEEK STG45	*6.5*	6.5	*0.06*	**0.4**

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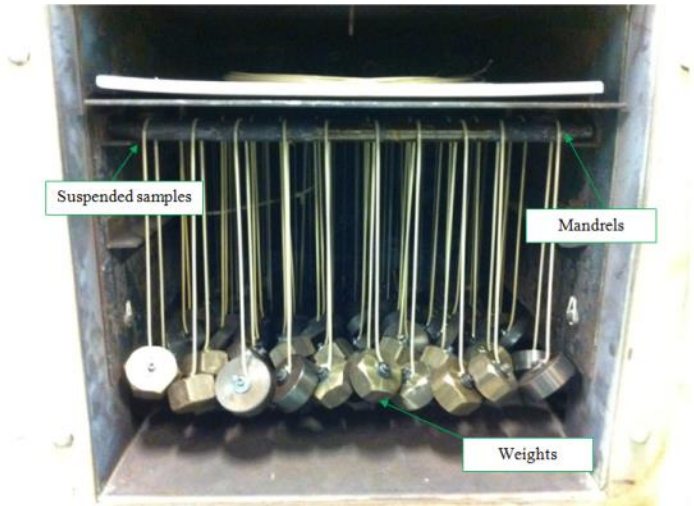
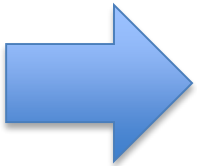
Long term ageing procedure adaptation



From individually hanged samples



To a rolled wire configuration.

This configuration limits the shape memory effect and the deformations caused by heavier weights.

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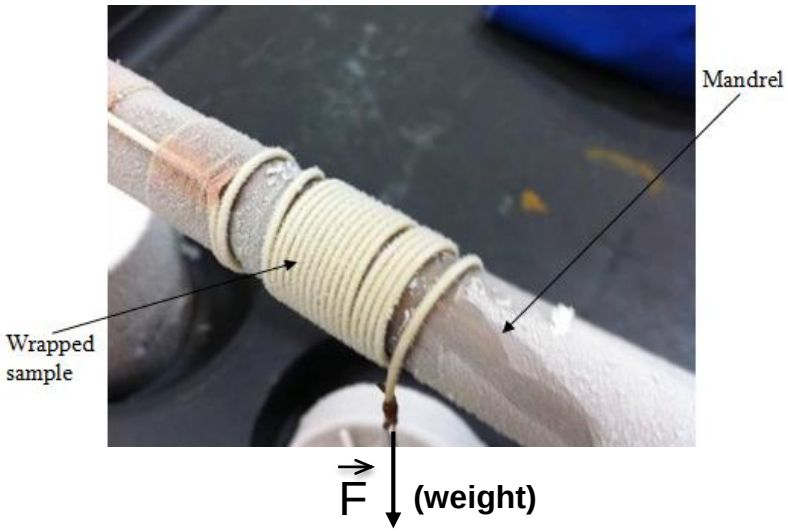
Cold bend test mandrels adaptation



Wire reference	Standard weight from ESCC 3901/012 (kg)	Weight (kg)	Standard mandrel from ESCC 3901/012 (mm)	Mandrel diameter (mm)
NPC1237 PEEK STG45	*1.36*	**2**	50.8	50.8
NPC2219 PEEK STG45	*0.45*	**0.8**	20	20
NCA2419 PEEK STG45	*0.45*	**0.8**	12.5	**16**
NCA3007 PEEK STG45	*0.23*	**0.4**	10	**10**

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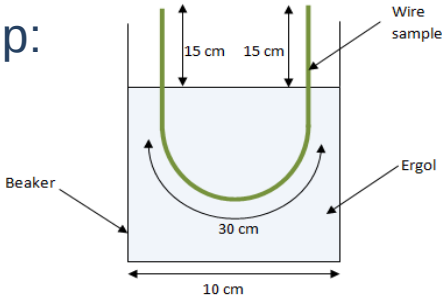
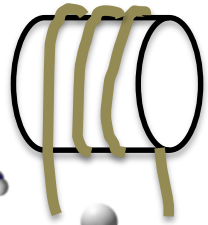
Ergols resistance results

Test setup:



UDMH : Dimethylhydrazine
N2H4 : Hydrazine
N2O4 : Nitrogen Tetroxide

After immersion, the samples were submitted to **wrap-test**



Results:

Samples were properly cristallized.

	UDMH	N_2H_4	N_2O_4
NPC1237	Failed	Failed	Failed
NPC2219	Failed	Compliant	Failed
NPC2419	Failed	Compliant	Failed
NPC3007	Compliant	Compliant	Failed

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Ergols resistance results

However, the tested samples did not show any visual particular signs of degradation **before** wrap-test :

AWG 1237 wire example

UDMH

N_2H_4

N_2O_4

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Specific tests

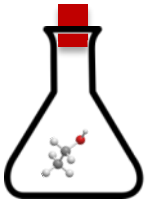
Required when qualification involves new material

Flammability tests

ECSS-Q-ST-70-21C

Outgassing test at 125 °C

ECSS-Q-ST-70-02C



Offgassing test

ESCC-Q-ST-70-29C

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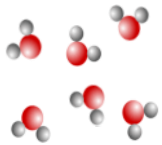
Conclusions

Fire retardancy

The material is intrinsically flame retardant (rated UL 94 V0 for thickness down to 1.5 mm).



Outgasing / Offgassing

Fully compliant.

Abrasion

Outstanding resistance to abrasion.

Deviations

Deviations regarding ESCC 3901 to fulfill the higher requirements but also to limit mechanical strain on aged samples.

Finalization of the detail specification draft.

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ESCC detail specification draft

- **The detailed specification has been reviewed in end of January.**
- **New ESCC Code Application implemented : No. 203.**

ESCC
European Space Components Coordination

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EXTRUDED POLYARYLETHERKETONE INSULATED WIRES ON NICKEL-PLATED COPPER CONDUCTOR, LOW FREQUENCY, 600V, -100 TO +250°C

ESCC Detail Specification No. 203 (3901/xxx)

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Development of new high temperature wires and cables for space applications

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Thank You!

Any question…?

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