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Novel Methods for Corrosivity Assessment of Automotive and Industrial Lubricants

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Prova Interlaboratorio Prodotti Lubrificanti
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Contents

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New testing methodologies are available at PLI to design, together with OEMs, tailor made E-fluids for E-application.

New Generation of Electric Drive Units (EDUs)

The Electric Drive Unit (EDU) is made by 3 key elements:

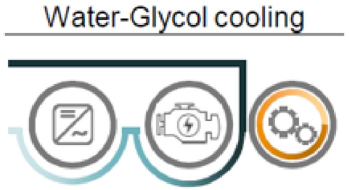
- Power electronics/Inverter
- Reduction Gear
- E-Motor

Direct cooling can increase the output up to 50%
Possible to downsize the E-Motor

Electric motor

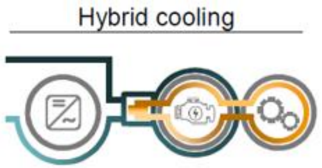
\+

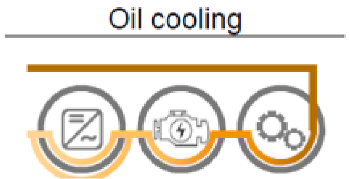
Reduction gear



1st Generation

Electric Drive Unit





2nd Generation

2° Generation requirements

- Dielectric properties

- Anti-wear
- Anti-corrosion
- Anti-oxidation
- Aeration
- Foaming
- Friction reduction

- Copper compatibility
- Coating material compatibility
- Non-ferrous metal compatibility

2^{nd} Generation

Integrated EDU

- Dielectric properties
- Flashpoint
- Heat transfer capability
- Thermal properties for effective cooling

- Cleanliness
- Thermal stability
- Lifetime filling

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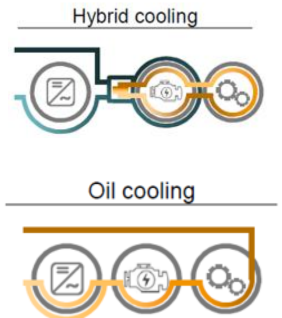
Iona – Fluids for 2nd Generation of EDUs

Electric Drive Unit



2nd Generation

E-Axle

- Usually, higher scuffing protection needed
- Usually no clutches involved (multi-stage e-Axle only on high power applications)
- E-motor can be integrated

DHT (e-DCT / e-ATF)

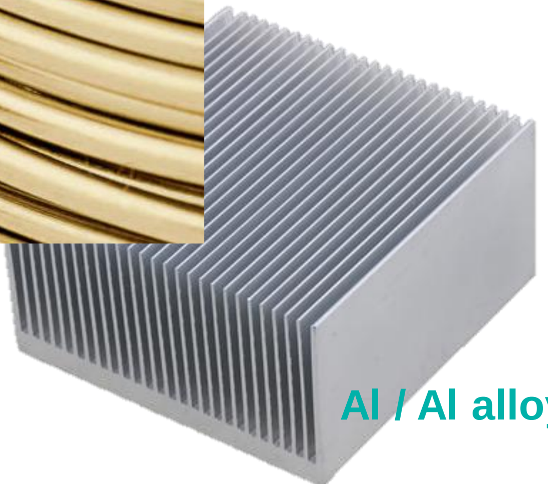
- Usually, lower scuffing protection needed
- Clutches involved
- E-motor is integrated

Critical components

Cu / Cu alloys

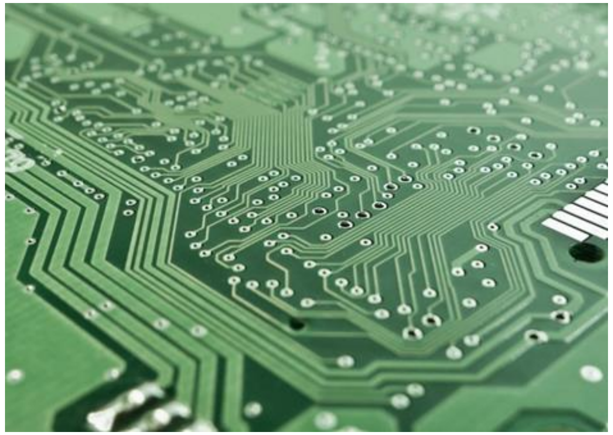
Sn

Brass

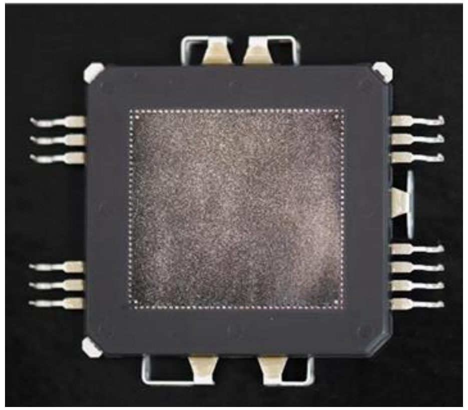


Al / Al alloys

Printed Circuit Boards



Microelectronics packaging



Transistors and
electronic components

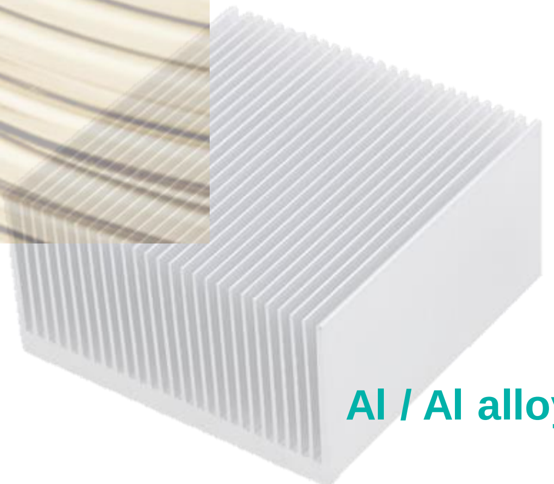
Hairpins Insulating Lacquers

Critical components

Cu / Cu alloys

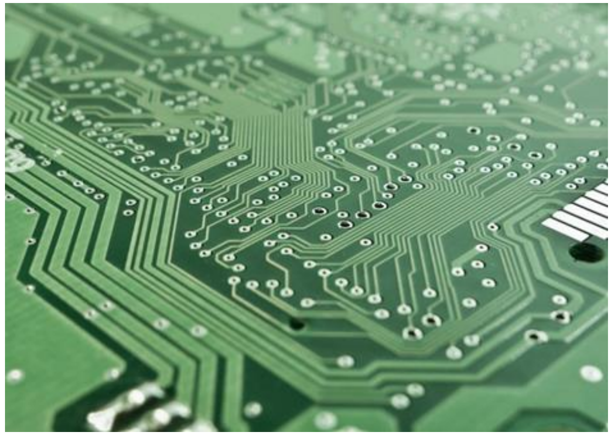
Sn

Brass

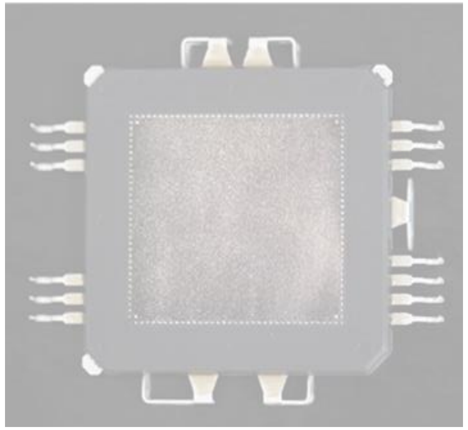


Al / Al alloys

Printed Circuit Boards



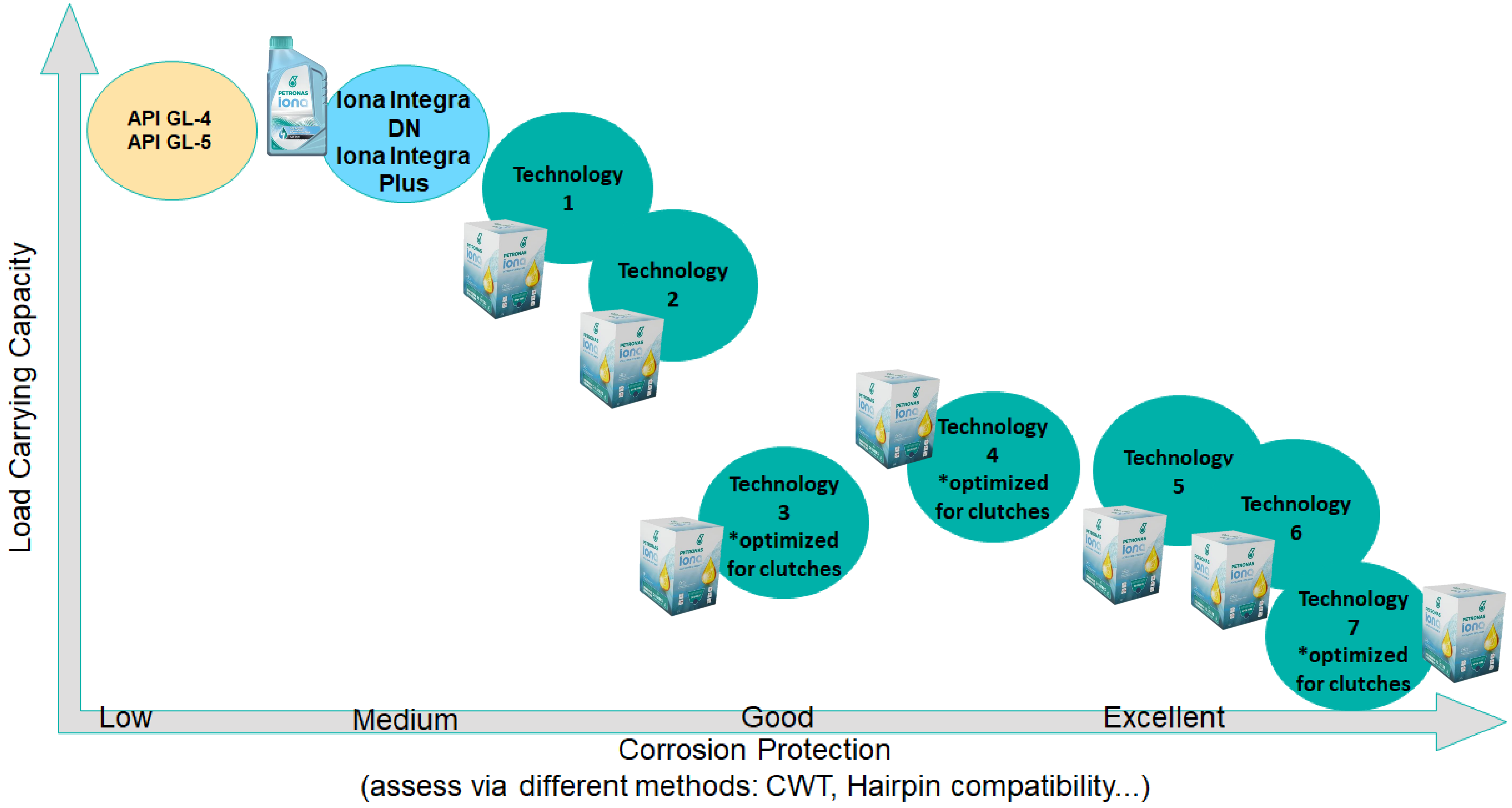
Microelectronics packaging



Transistors and
electronic components

Hairpins Insulating Lacquers

Iona 2nd Generation: Copper compatibility vs. Load Carrying Capacity



Standard ASTM methods for corrosivity assessment & their limitations

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Compatibility with Copper: Standard ASTM methods and their limitations

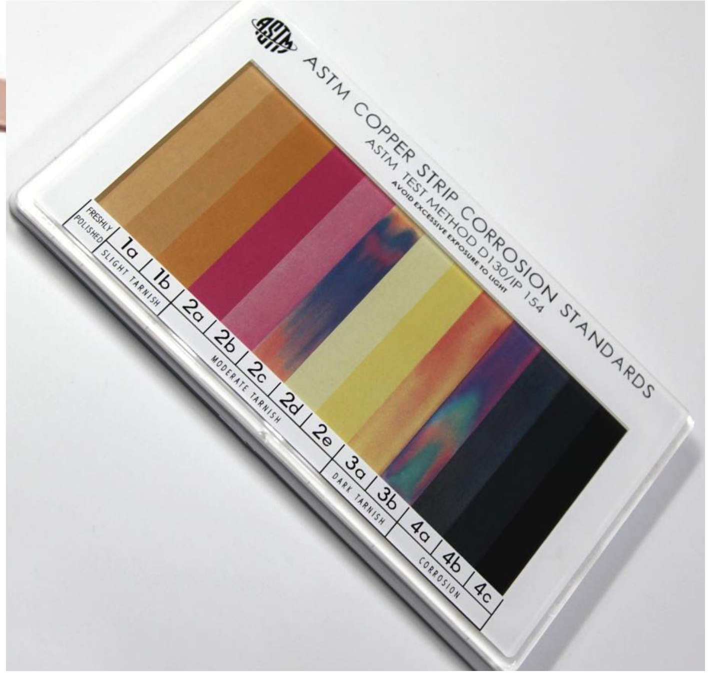
Designation: D130 – 18

Federation of Societies for
Paint Technology Standard No. Dt-28-65
British Standard 4351

Standard Test Method for
Corrosiveness to Copper from Petroleum Products by Copper Strip Test[1]

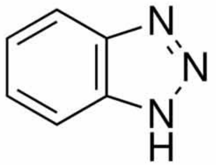
This standard is issued under the fixed designation D130; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

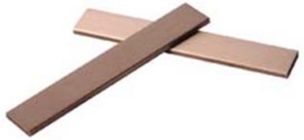
This standard has been approved for use by agencies of the U.S. Department of Defense.



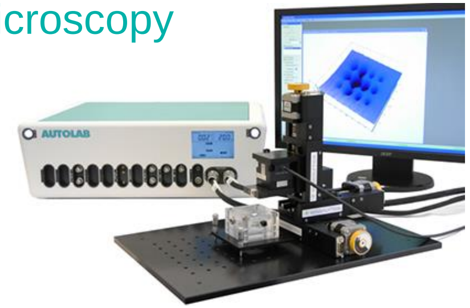
[1]Scanning electrochemical microscopy (SCEM) Principle and Application. *Dr. Michaela Nabel. Metrohm Users Meeting 2019, Zofinghen.*

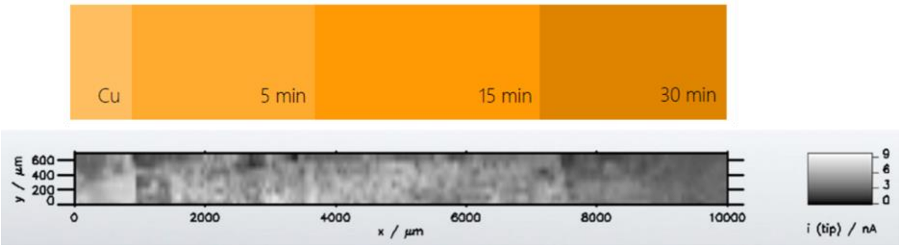
Benzotriazole,
Cu Corrosion inhibitor





Scanning Electrochemical Microscopy





Tarnishing degree

Corrosion Current

In presence of surface-active molecules ASTM D130 results can be misleading

Compatibility with Copper: Standard ASTM methods and their limitations

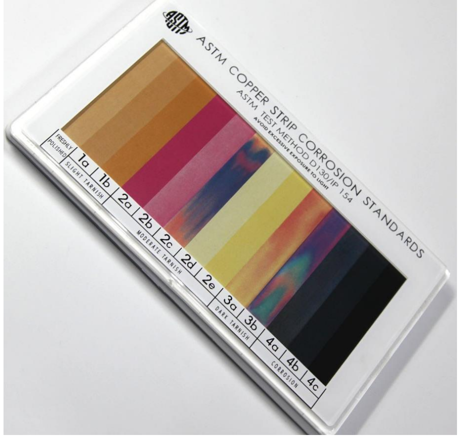
Designation: D 6594 – 04

An American National Standard

Standard Test Method for Evaluation of Corrosiveness of Diesel Engine Oil at 135°C[1]

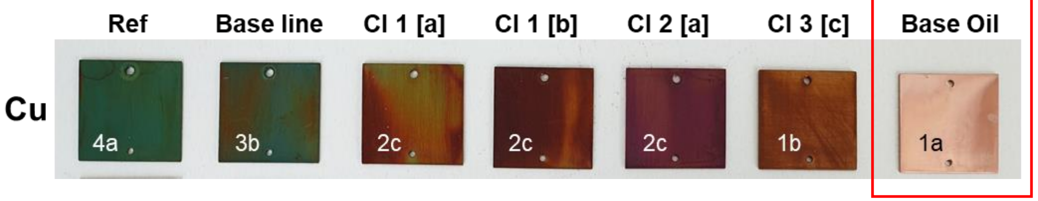
This standard is issued under the fixed designation D 6594; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ASTM D5185 ICP
+
ASTM D130 Rating

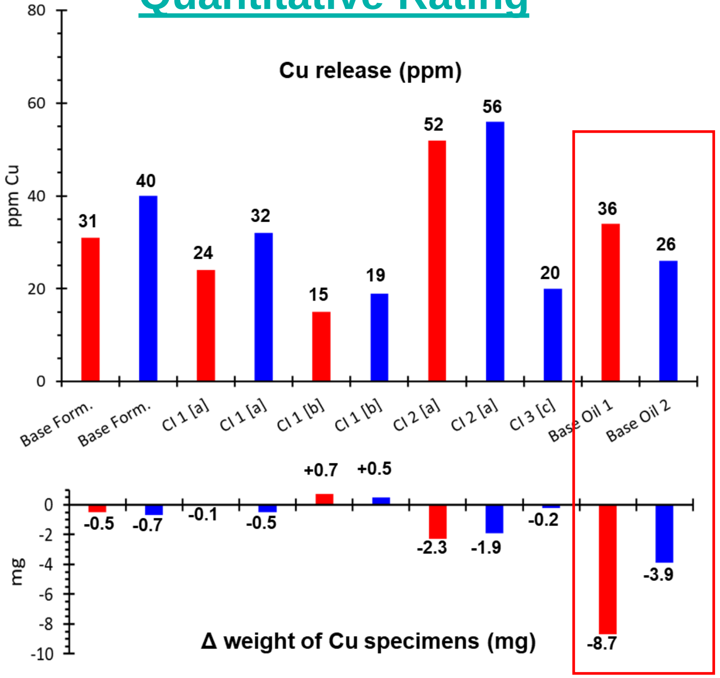


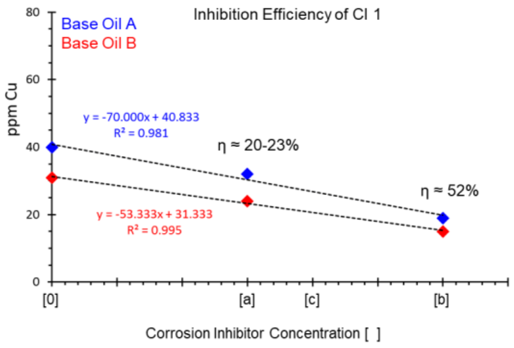
Use of ASTM D6594 for Automatic Transmission Fluid (ATF) Development

Visual Rating



Quantitative Rating





ASTM D6594 results can be misleading

Novel Method for Corrosivity Assessment:

Copper wire resistance method

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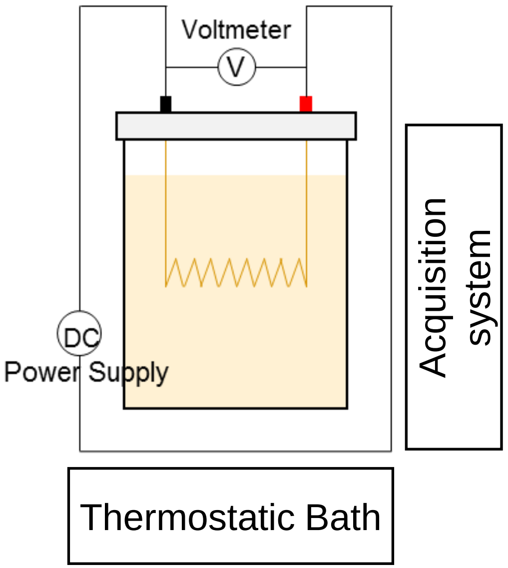
Copper wire resistance method[1,2,3]: Principles

Despite the method is not an ASTM standard, PLI recognized its potentialities and decided to invest resources to implement it in house as key method for e-fluids development and technology selection.

Experimental Set-up



Outputs information

$$Resistance = \frac{\rho Cu_T l}{\pi r^2}$$

ρCu_T *Resistivity of Copper at Testing Temperature T (Ωm)*

T *Testing temperature (°C) → Constant (Imposed/Measured)*

$\rho Cu_{20°C}$ *Resistivity of Copper at 20°C (Ωm) → Constant*

α *Coefficient of thermal expansion of Cu → Constant*

$$\rho Cu_T = \rho Cu_{20°C} + \alpha(T - 20)\rho Cu_{20°C}$$

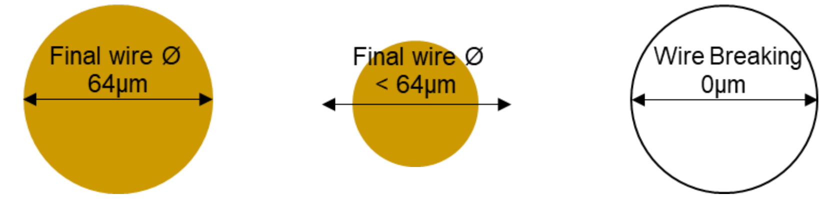
l *Copper wire length (m) → Constant*

r *Copper wire radius (m)*

Practical meaning of the outputs

Realtime Resistance evolution:

Ω Constant	Ω Constant Increase	Ω Exponential Increase
Ø Constant	Ø Reduction	Wire braking



Corrosivity: **No/Low**	Corrosivity: **Low/Medium**	Corrosivity: **High**
Cu compatibility: **High**	Cu compatibility: **Medium/TBD**	Cu compatibility: **No**

[1] **New Insight on the Impact of Automatic Transmission Fluid (ATF) Additives on Corrosion of Copper**. *Michel P. Gahagan et al. International Journal of Automotive Engineering 7 (2016) 115-120*

[2] **Wire resistance method for measuring the carrion of copper by lubricating fluids**. *Gregory J. Hunt et al. Lubrication Science 29 (2017) 279-280*

[3] **Automatic transmission fluid corrosion inhibitor interaction with copper**. *Michel P. Gahagan et al. Lubrication Science 30 (2018) 301-315*

Copper wire resistance method[1,2,3] : PLI Measurement set-up

Instrument: Metrohm Autolab Multi 204.

Temperature Measure: pX1000 Module

Software: NOVA 2.1.5

Acquisition mode: Galvanostatic

Applied Current: 1 mA

Sampling interval: 10 s

Temperature: TBD typical 50 – 160°C

Time: TBD, typical 168 – 336 hours

Raw Data Analysis: Excel

Method improvement

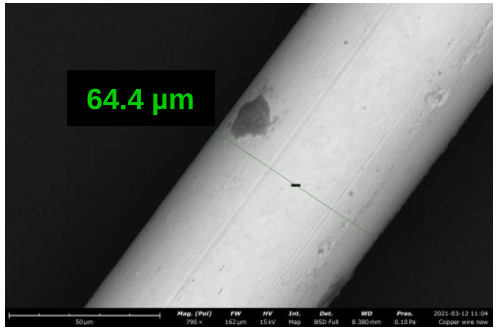
Scanning Electron Microscopy (SEM)+

Energy Dispersive X-Ray Analysis (EDX)

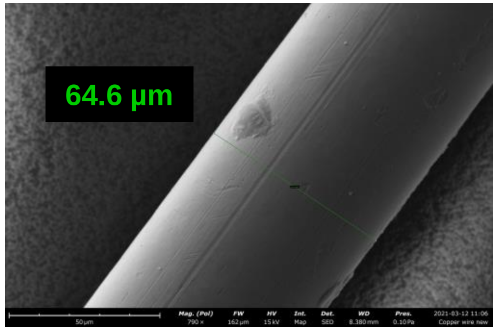
PLI decided to invest in a Benchtop SEM + EDX to maximise the information and to achieve a deep understanding of the corrosion phenomena taking place on the copper wire surface.

SEM images of Cu wire in pristine state

Backscattered Electron Detector (**BSD**)



Secondary Electron Detector (**SED**)



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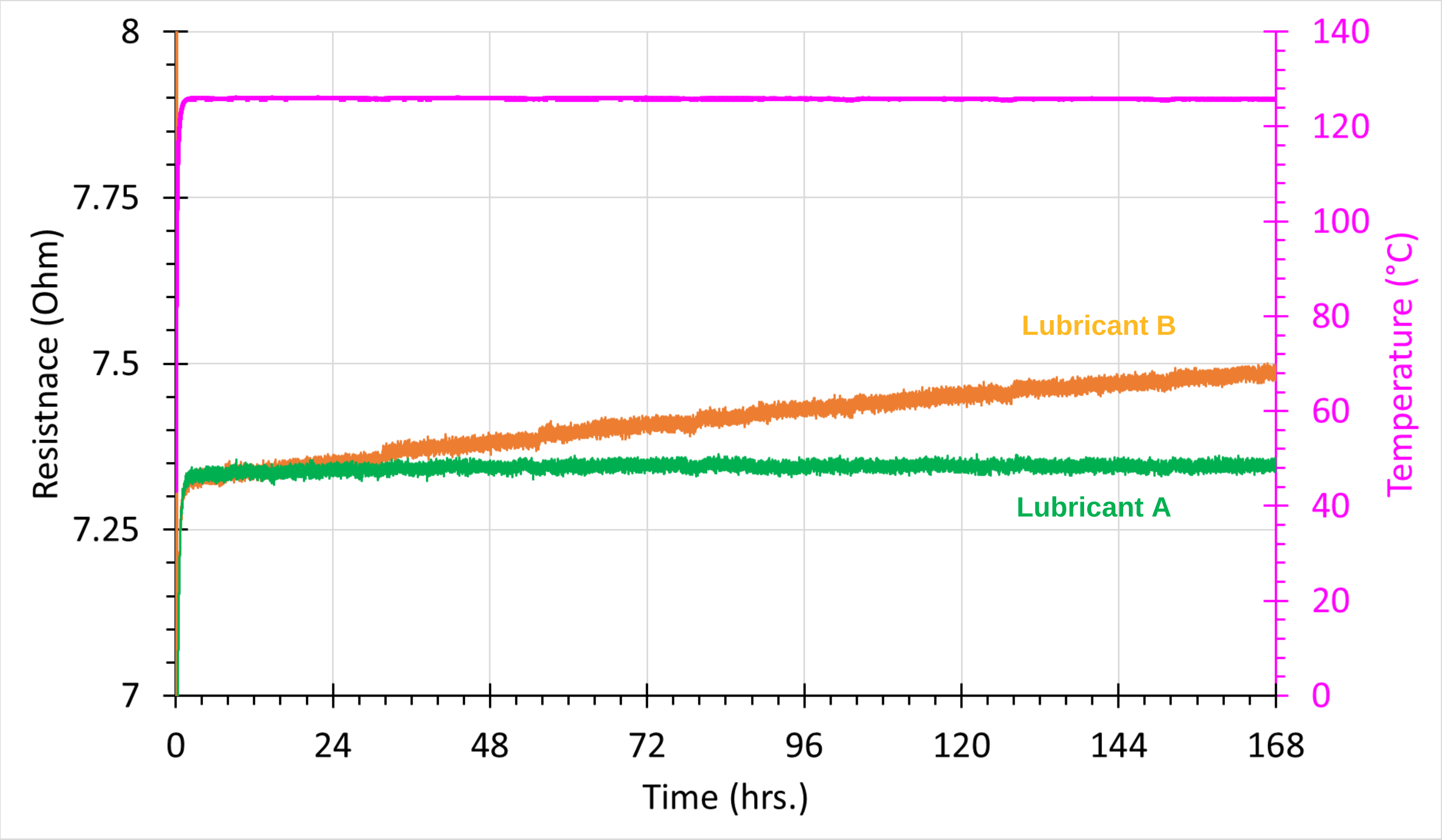
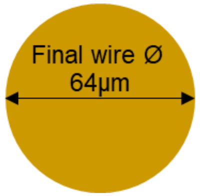
Copper wire resistance method: Typical output plot



Lubricant A

Ω Constant

Ø Constant



Corrosivity:

No

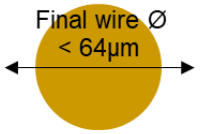
Cu compatibility:

High

Lubricant B

Ω Constant Increase

Ø Reduction



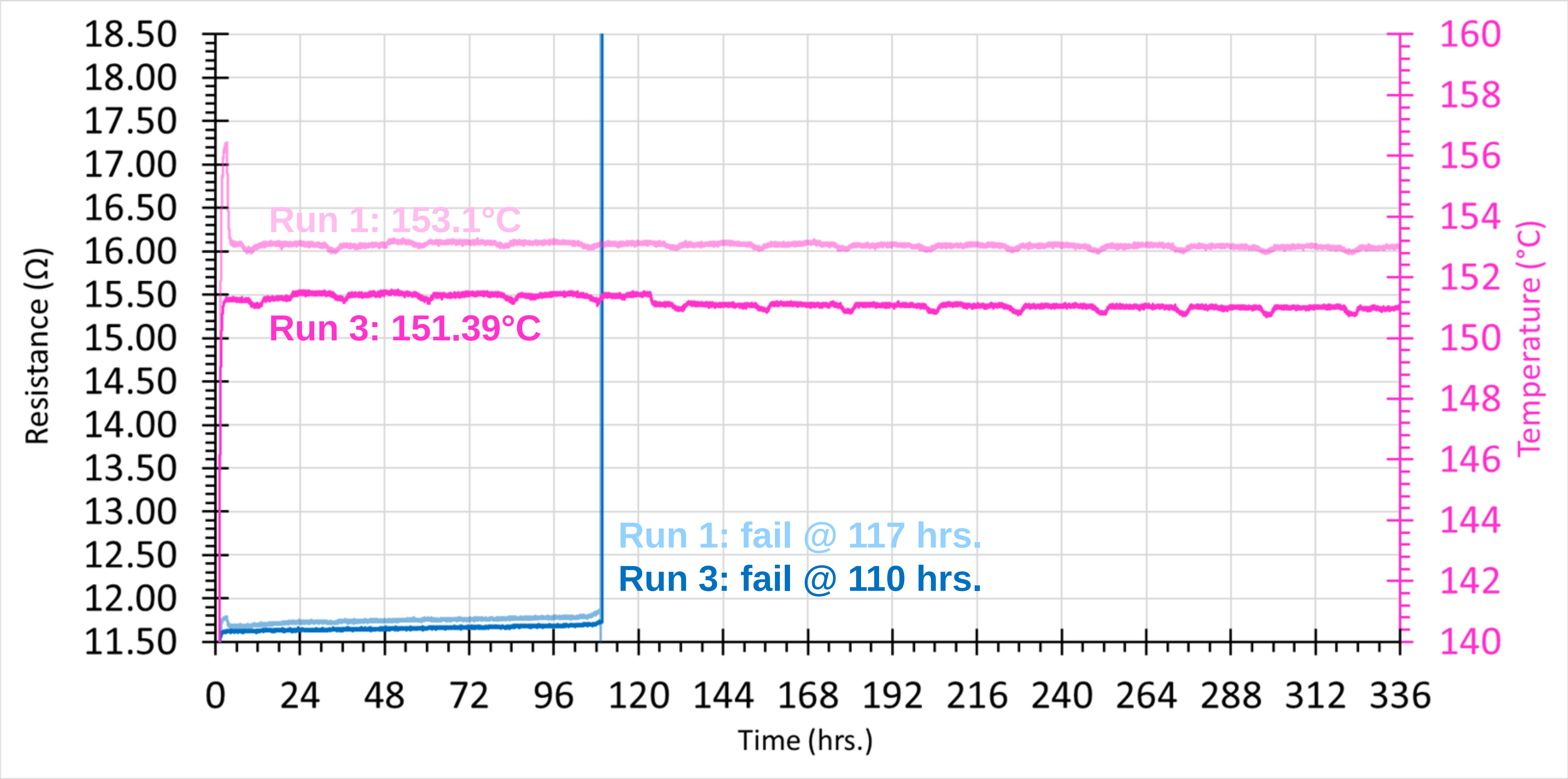
Corrosivity:

Low

Cu compatibility:

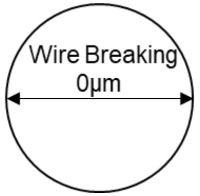
Good

Copper wire resistance method: Repeatability Assessment



Ω Exponential Increase

Wire braking



Corrosivity:

High

Cu compatibility:

No

Copper wire resistance method.

Case Study:

Performance additive selection

(Technology)

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Copper wire resistance method.

Case Study:

Formulation components optimization

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Copper wire resistance method.

Case Study:

Formulation performances optimization

Outcomes

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Outcomes

- ASTM D130 and ASTM D6594 results can be misleading in particular if surface-active molecules are present in the formulation.
- The Copper Wire Resistance Method combined with SEM + EDX allows a well understanding of the corrosion mechanism of copper in contact with lubricants.
- The Copper Wire Resistance Method demonstrated to be very important for lubricants development in particular for technology selection and performances – component optimization.
- The application field of the Copper Wire Resistance Method is going to be extended to other metallic materials and other fluid e.g. Coolant and Battery fluids.

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Thank you for your passion!

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