Advances in Testing and Validation for EV Fluids

Steven Tang

Business Manager, Industrial Lubricants, Oil & Gas, CASE & EP

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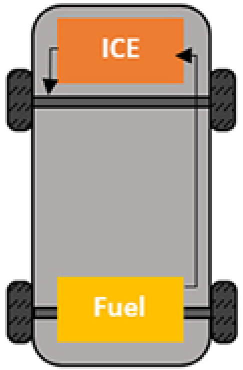
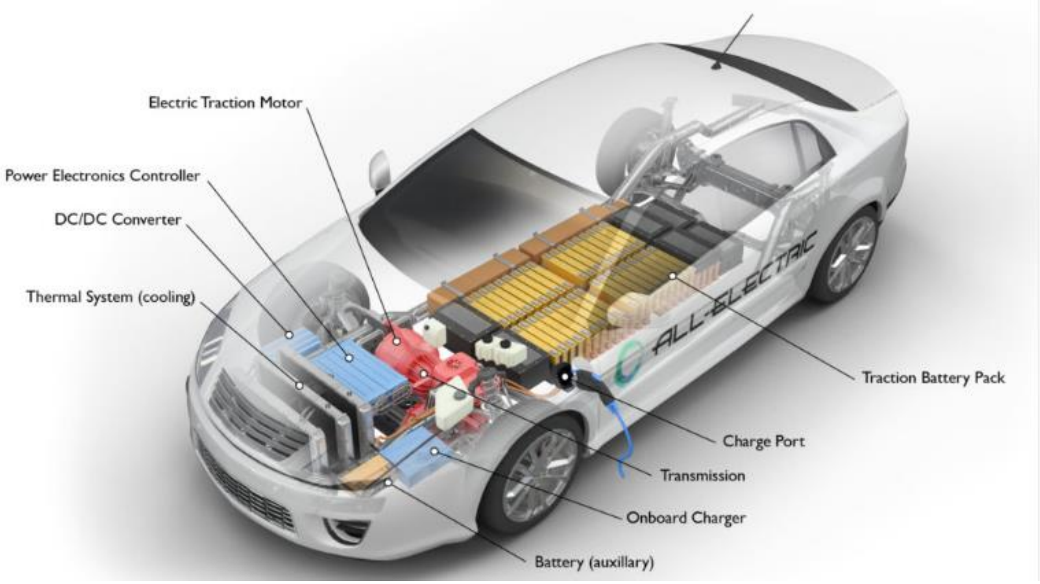
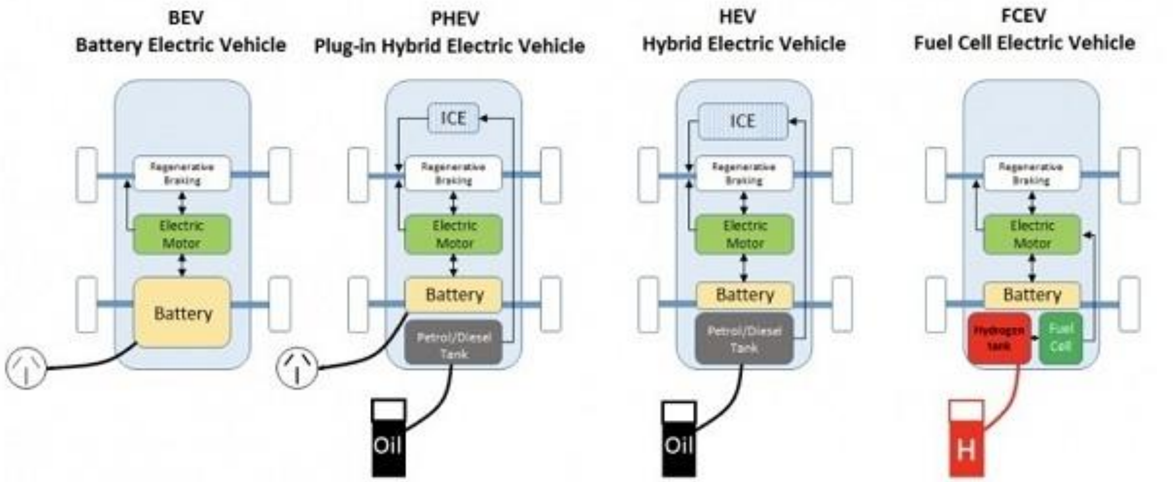
Electrical Vehicles

ICE Vehicles





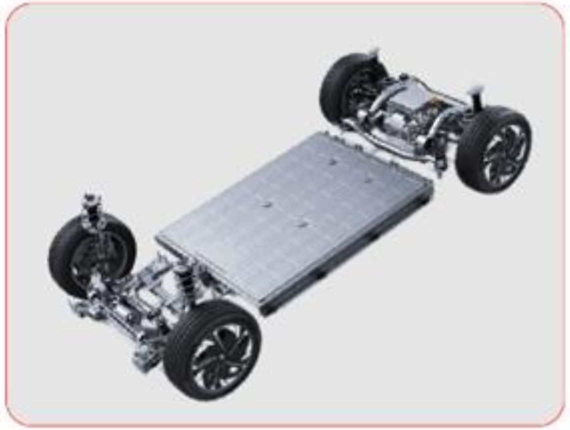


https://www.omazaki.co.id/en/types-of-electric-cars-and-working-principles/

EV *vs.* ICE Vehicles: Mechanical Perspectives

ICE Powertrain

EV Powertrain



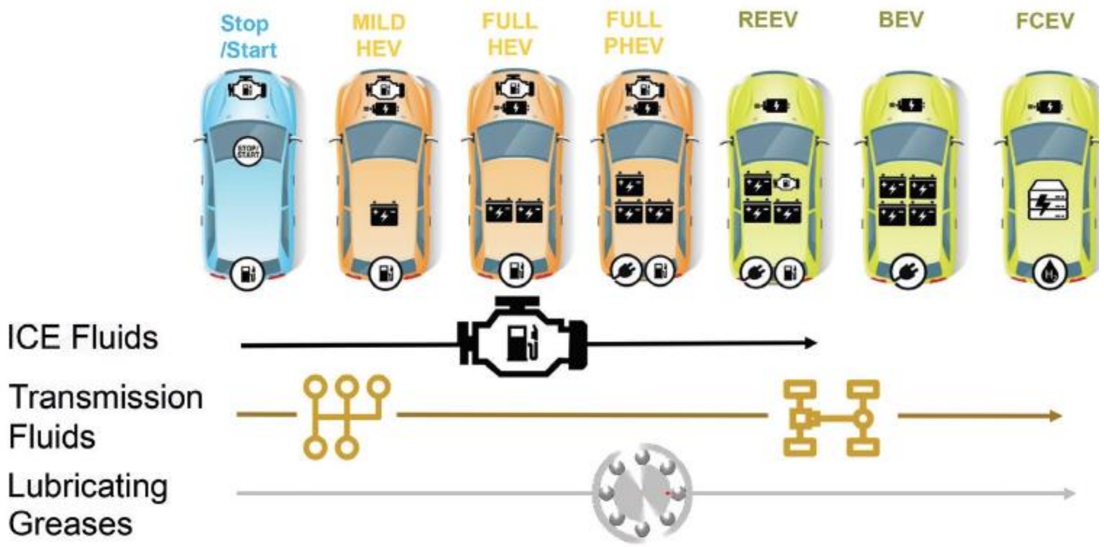
Function	ICE	EV
Energy Storage	Fuel Tank	Battery Pack
Energy Conversion	ICE	Motor
Drivetrain	Engine & Transmission	Electric motor
Gear Box	Multi-speed gearbox & differential	Single-speed gearbox & differential
Control Unit	Electronic Control Unit (ECU)	ECU & Battery Management System (BMS)
Control System	Fuel Control System	Traction control unit

Conventional ICE Vehicles vs. EV: Non-Mechanical Perspectives

Parameter	ICE Vehicle	EV
Energy Source	Fuel	Battery/Fuel Cell
Cost	Cheaper	Currently expensive
Energy Efficiency	20 – 40%	• Up to 90% from E-motor to wheels • 59-77% mechanical efficiency
Emission	GHG and toxic emissions	No
Maintenance	High	Low
Moving Parts	Numerous	Less
Reliability	High – low start-up time, availability, high range, & high energy density	Low – high battery charging time, less battery charging station, availability, lower range, & lower battery energy density
Sustainability	High Carbon footprint	Low Carbon footprint
Weight	Bulky & heavy	Lighter with ICE removed; But Battery weight can make it heavier than ICE
Servicing	Standardized tests available for servicing of vehicles	Standard tests, i.e. for noise, are lacking for servicing of vehicles
Fuel Energy Density	High – Fossil fuel	Low - battery

Fluids Needed: ICE *vs.* EV

Fluids/Lubricants	ICE	EV	
Engine Oil	Yes	No	--
Chassis & Wheel Bearing Greases	Yes	Yes	Different
Transmission Fluid	Yes	Yes	Different
Gear Oil	Yes	Yes	Different
Brake fluid	Yes	Yes	Same
Battery Cooling Fluids	No	Yes	Different from EOs for ICE
Windshield Washing Fluids	Yes	Yes	Same



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SAE J3200 2022-10-13: Fluid for Automotive Electrified Drivetrains

- Details the important new performance properties for e-fluids
- Recommend test methods for lubricants used in e-Mobility drivetrain components, i.e., electrified drivetrains, mainly electric-transmissions and axles (e-transmissions and e-axles).
- Limited to those geared systems in which an electric motor (e-motor) is immersed in the powertrain lubricant or comes in contact with the powertrain lubricant.
- Focuses on new lubricant attributes, while some information on conventional lubricant attributes is included. The information presented here will be helpful in understanding the similarities and differences between conventional (i.e., internal combustion engine (ICE)) and e-Mobility powertrain systems.

Key Properties of Concerns in EV Fluids & Available Test Methods

Property	Parameters of Interest	Method
Electrical Properties	• Conductivity • Relative permittivity • Dissipation factor	• **ASTM D1169**: Standard Test Method for Specific Resistance (Resistivity) of electrical insulating liquids. • **DIN 51 111**: Electrical properties of fresh and used oils from electric drives in vehicles • **ASTM D924**: Standard Methods for Dissipation Factor(or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids • **ASTM D1816**: Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using VDE Electrodes
Heat Transfer	• Thermal conductivity • Diffusivity • Specific heat capacity	• **ASTM D7896**: Standard Test Method for Thermal Conductivity, Thermal Diffusivity, and Volumetric Heat Capacity of Engine Coolants and Related Fluids by Transient Hot Wire Liquid Thermal Conductivity Method

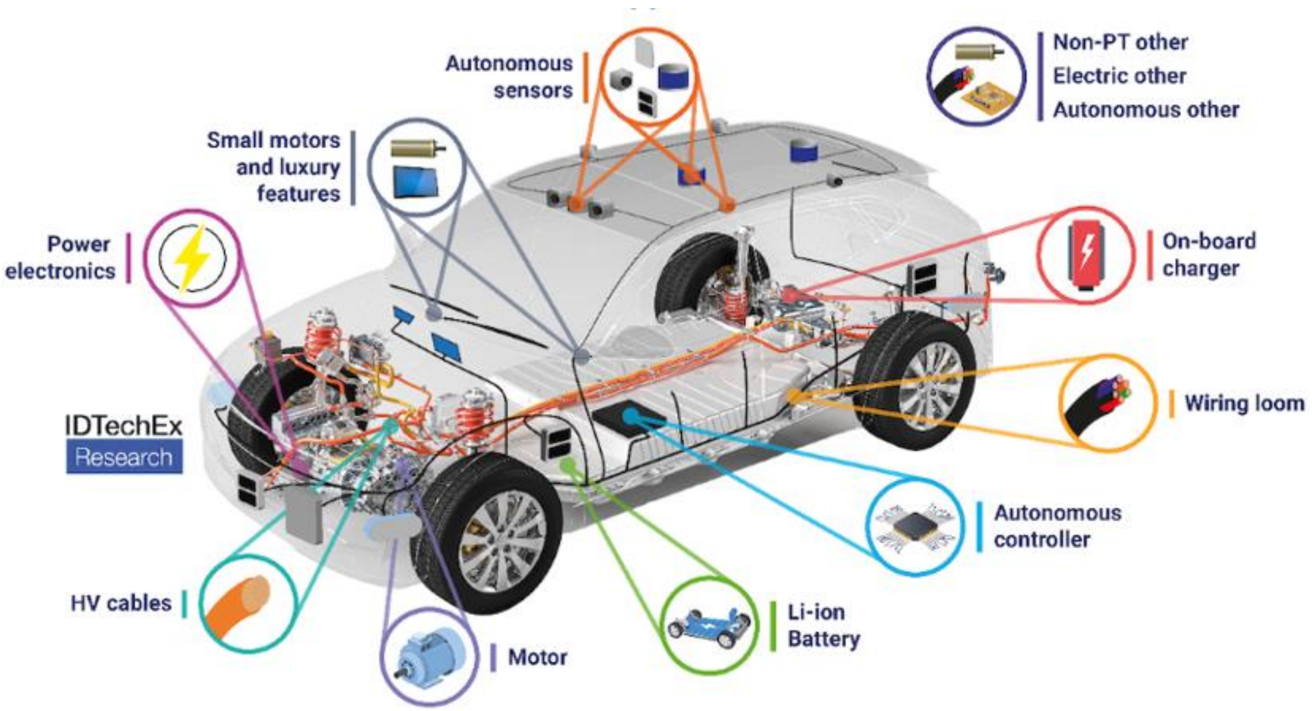
Material compatibility	• Copper corrosion (immersed & vapor)
	• Polymers/plastics compatibility
		• **Copper corrosion**
		  • **ASTM D130**: Standard Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
		  • **ASTM WK87553**: Proposed Wire Corrosion Test (WCT)
		  • **ASTM D8544**: Conductive Deposit Test (CDT)
		• **ASTM D638**: Standard Test Method for Tensile Properties of Plastics

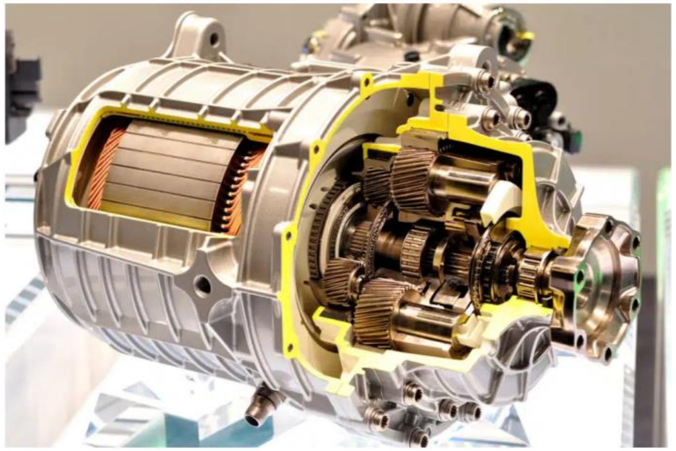
Oxidation & Aeration	• Oil oxidation	• Oxidation
		  • No ASTM standard method for EV-specific fluids;
		  • Useful methods: ABOT (BJ 110-04); DKA (CEC L-48); L-60-1 (ASTM D5704); ISOT (JIS K2514)
		• Aeration
		  • **ISO 12152**: Lubricants, industrial oils and related products — Determination of the foaming and air release properties of industrial gear oils using a spur gear test rig — Flender foam test procedure
		  • **ASTM D3427**: Standard Test Method for Air Release Properties of Hydrocarbon Based Oils
		  • **ASTM D892**: Standard Test Method for Foaming Characteristics of Lubricating Oils

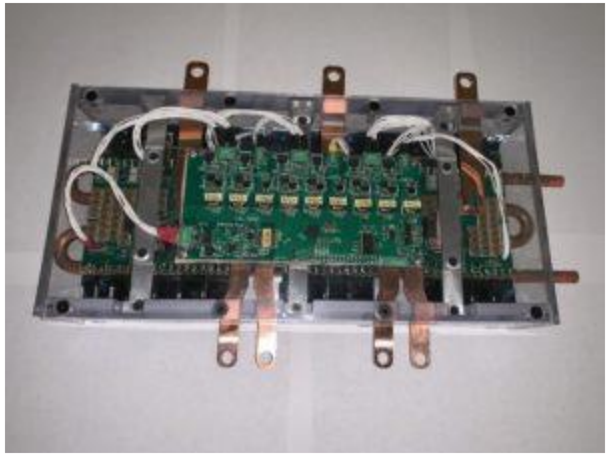
Viscosity & friction	• Wear	• **DIN-ISO-14635-2 Part 2**: FZG step load test A10/16, 6R/120 for relative scuffing load-carrying capacity of high EP oils • **DIN 51819-3**: Testing of Lubricants: Mechanical-dynamic Testing in the roller Bearing Test Apparatus
Load-carrying ability	• Gear performance under high torque stress	• Conventional methods FZG L-37-1 & L-42 could be applied to reduction gears. • Methods to evaluate the high-speed lubricant performance is under development.

Copper Corrosion

- Used in the electric motors, batteries, inverters, wiring and in charging stations
- Copper corrosion in EV can cause severe consequences
  - Electrical shorts
  - Engine disablement
  - Reduced electrical conductivity
  - Others: Surface discoloration, Intermittent connectivity, Loose contacts, Skin reactions, and Device failure.

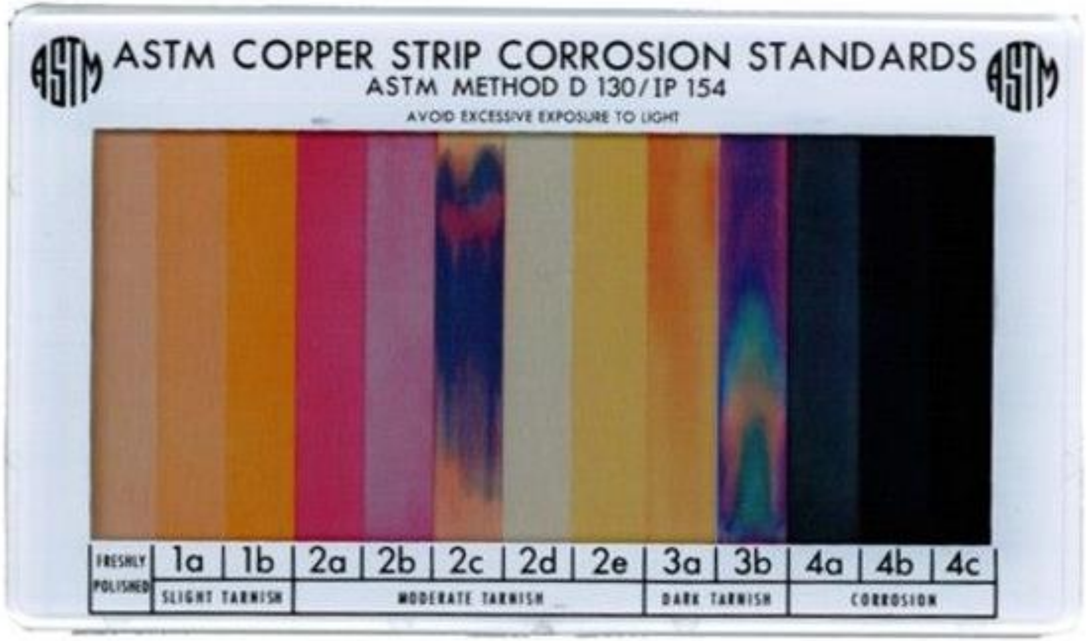






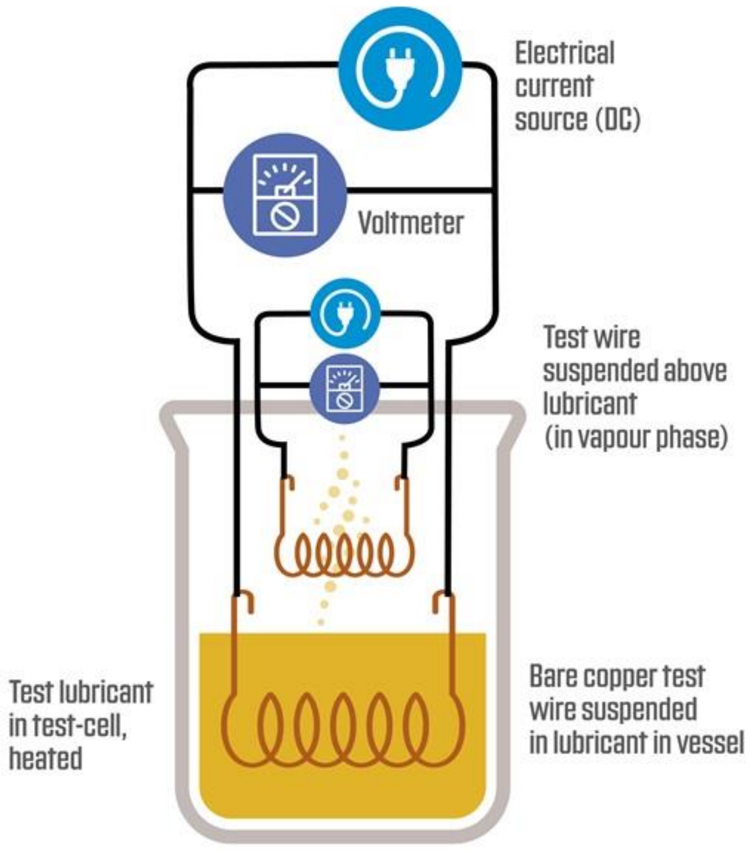
Copper Corrosion Test Method–1: ASTM D130

- The most widely available test for assessing copper corrosion
- A qualitative image-based assessment.
- Does not adequately predict fluid performance in electrified drivetrains
- Limited to evaluation of copper metal strips.



Copper Corrosion Test Method–2: Wire Corrosion Test (WCT)

- ASTM WK87553: Proposed Wire Corrosion Test (WCT)
- Monitors the change of resistance for 72 hours at a specific temperature under an electrified conditions.
- Offers real-time, quantitative corrosion rate information in both the solution and vapor phase.
- Extremely useful to assess corrosion performance and to making predictions relating to motor burnouts.



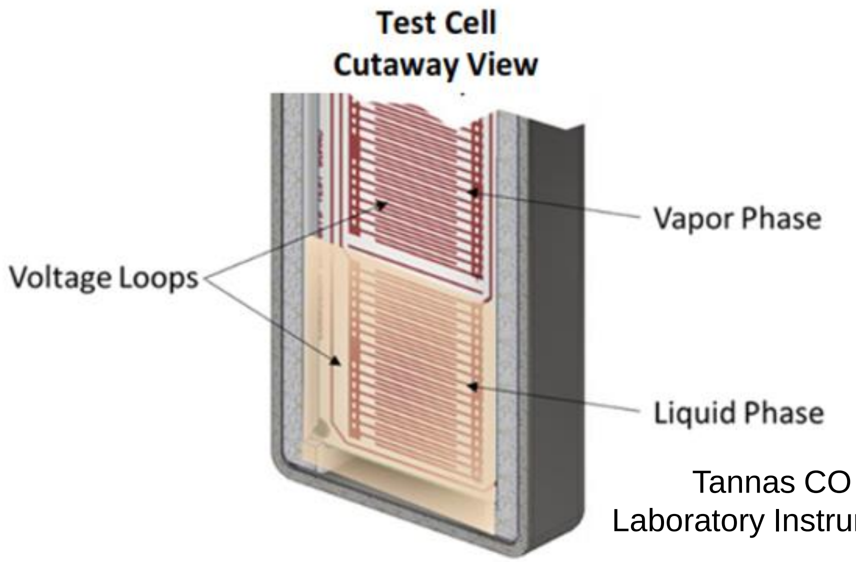
https://360.lubrizol.com/2021/Protecting-the-Electrics-in-EV-Transmissions

Copper Corrosion Test Method–3: Conductive Deposit Test (CDT)

- ASTM D8544: Conductive Deposit Test (CDT)

- Determine the tendency of lubricating fluids to form conductive layer deposits on exposed copper motor windings, connectors, and electrical components Assess risk to electronics (PCB) and motors.

- Exposed to lubricant or vapor with voltage applied.



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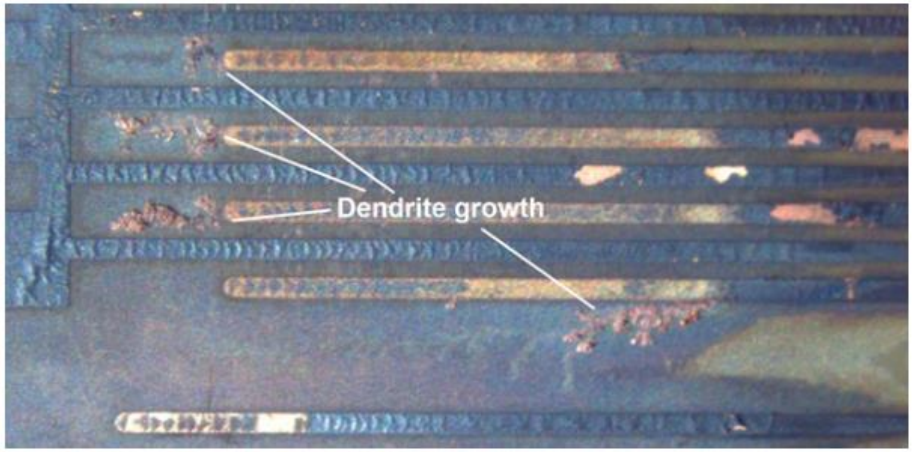
Laboratory Instruments

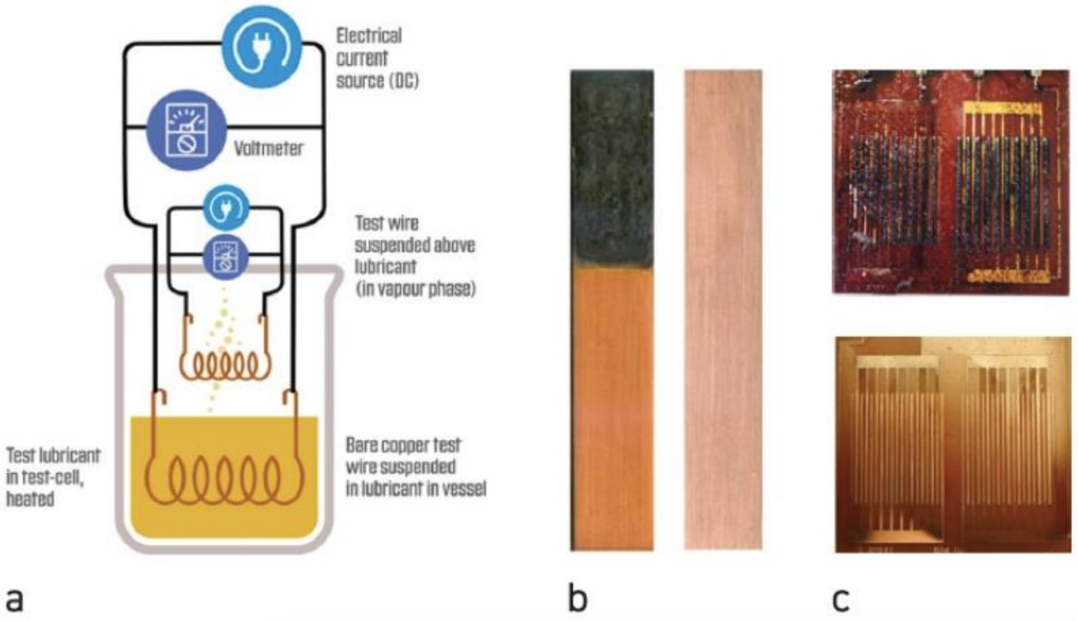


Other Methods for Cu Corrosion Testing

- Cupper Digital Detection Imaging (CuDDI)
  - Uses a stable and controlled LED light source
  - Create an artificial but consistent ambient environment
  - Automatically detect the copper stripe size
  - Eliminate the inherent bias with the manual rating
  - Yet to be established as an ASTM method.

Testing Methods & Chemical Solutions

Testing Methods



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Copper Corrosion Inhibitors

- Triazoles & thiadiazoles

- Phosphate esters

Status: Methods for Testing and Validation for EV Fluids

- Standard methods: i.e. ASTM
- Customized standard methods
- In-house Methods
- New Methods under Development

Forward Look: Testing and Validation for EV Fluids

- EV design has been progressing well but it's at its infancy stage.
- The test methods for EV fluids will continue to evolve with EV drive unit design
- More standardized tests are still under development
- The development of hardware and lubricants may need to occur concurrently!

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- The author appreciate the contributions of the original authors without citing their names one by one.

Thank you!

steven.tang@colonialchem.com