Challenges and Outlook for Transmission Fluids in EVs

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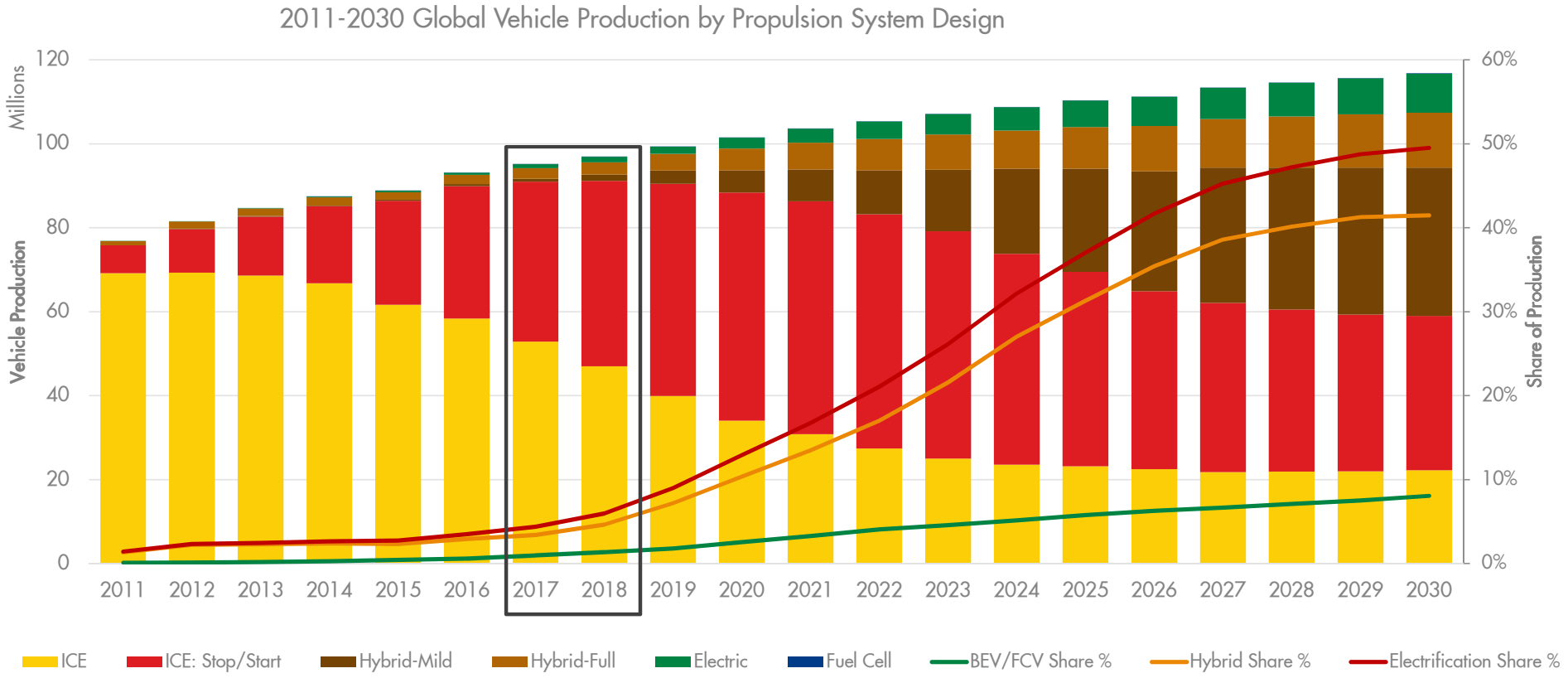
Torsten Murr
Global Technology Manager, Shell Lubricants Technology

Electrifications is expected to be 50% (BEV 8%, full hybrid 11%) in year 2030



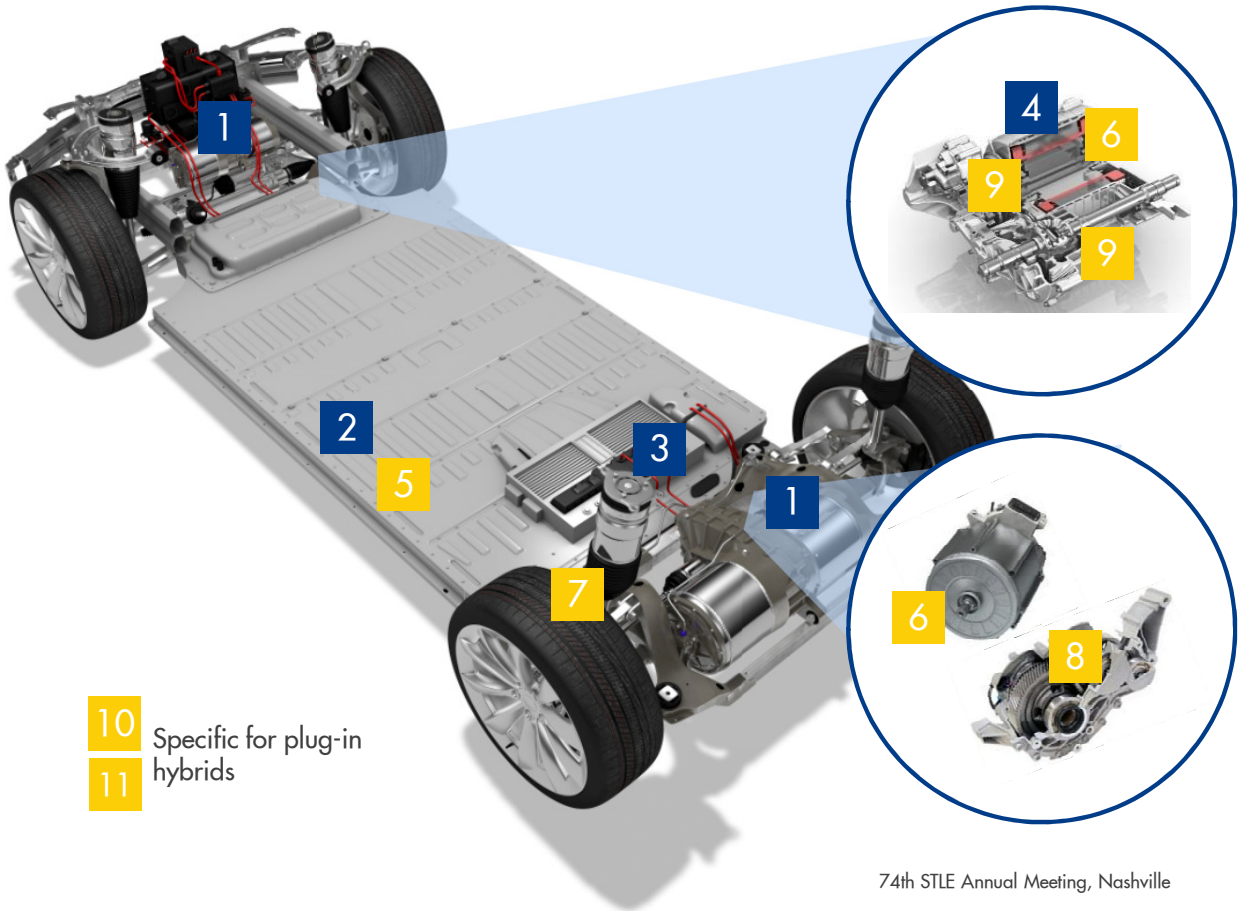
Electrification: Mild-/Full-Hybrid, BEV, FCV

Source: IHS, 2018

Agenda

- Market & Hardware Trends
- Baseoil selection for Efficency
- Electric Properties & Corrosion Protection
- Shell EV-Fluid Technology
- Summary

Lubricants and Greases in Electric Vehicles



10 Specific for plug-in hybrids
11

1 E-motor cooling*
2 Battery thermal management
3 Inverter cooling
4 Direct cooling of e-motor windings

5 Battery membrane production

6 E-motor bearing lubrication
7 Wheel and steering bearing lubrication

8 Reduction gear lubrication
9 Differential lubrication

10 Plug-in hybrid transmission
11 Plug-in hybrid engine oil

*alternatively with transmission lubes

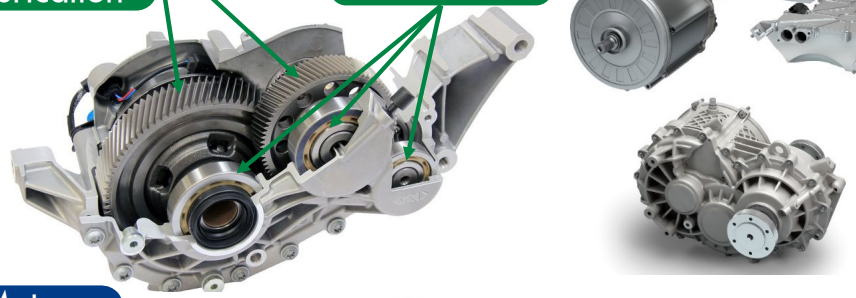
Electric Drive Unit Design for BEV

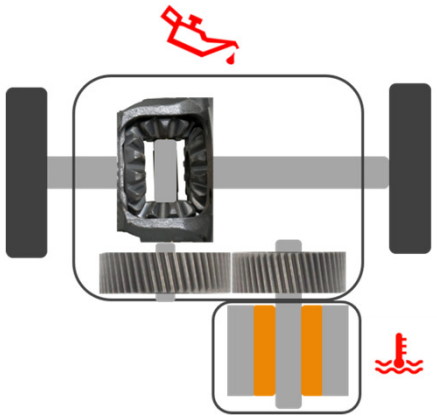
Dry E-Motor Design

Gear / Differential lubrication

Bearing lubrication

Attached E-Motor

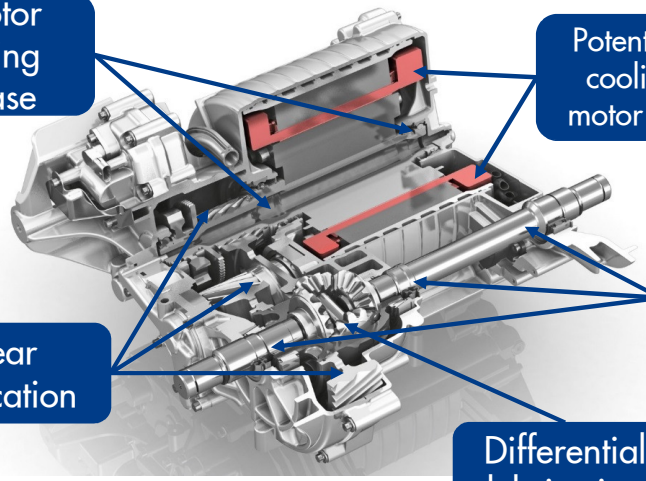




Wet E-Motor Design

E-Motor Bearing Grease

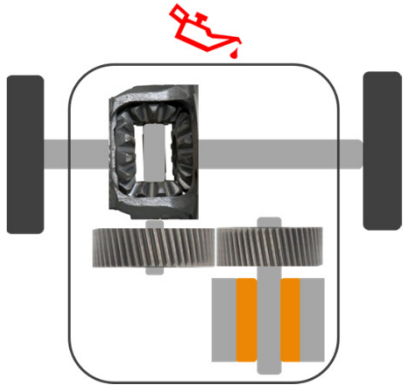
Potential direct cooling of e-motor windings



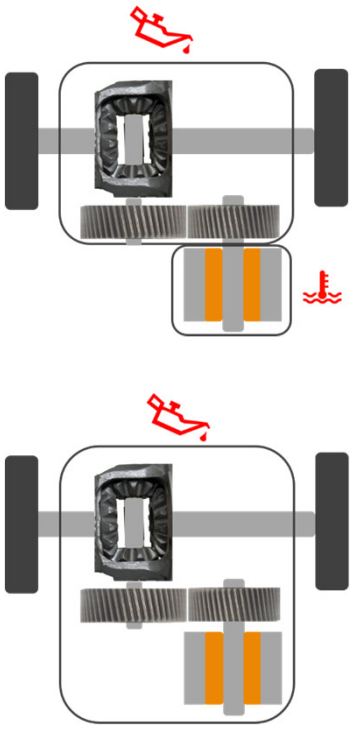
Gear lubrication

Bearing lubrication

Differential lubrication



EV transmission fluid application

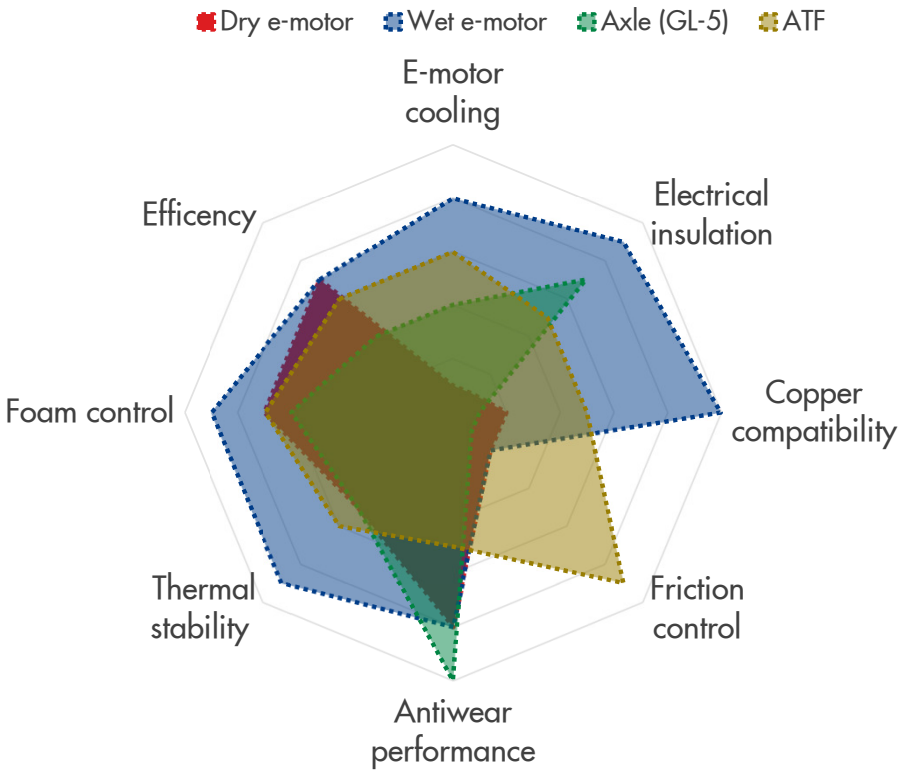


Gear lubrication
Differential lubrication
Bearing lubrication

Gear lubrication
Differential lubrication
Bearing lubrication
E-motor cooling

Operating conditions

- High torque
- High speed
- Recuperation



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- **Baseoil selection for efficency and cooling**
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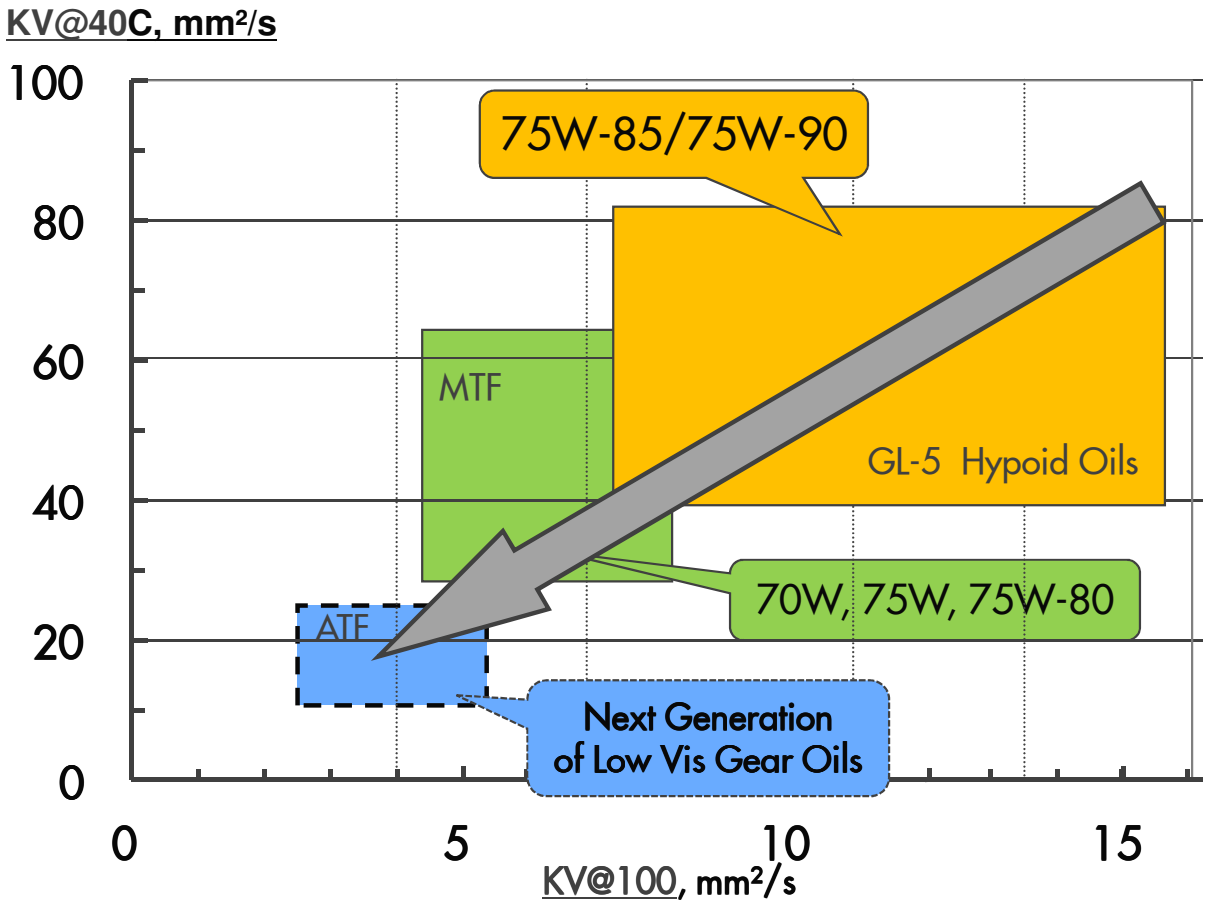
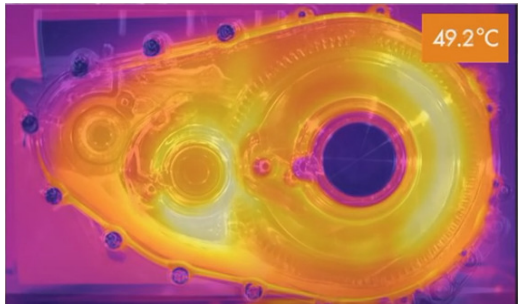
Low viscosity for high efficency in the electric drive unit



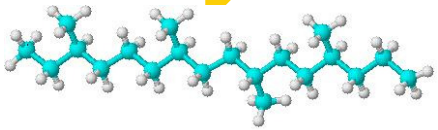
Choosing low viscosity synthetic base stocks for high efficency

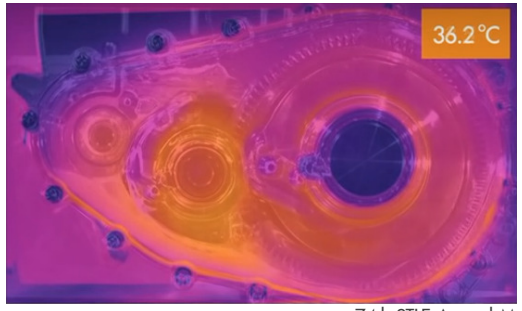
- Lower Viscosity Oils will reduce friction losses
- Lower Operating temperatures of gearboxes possible
- Higher efficency of the system
- Improvement of up to 0,4% efficency (WHTC Driveline Test)

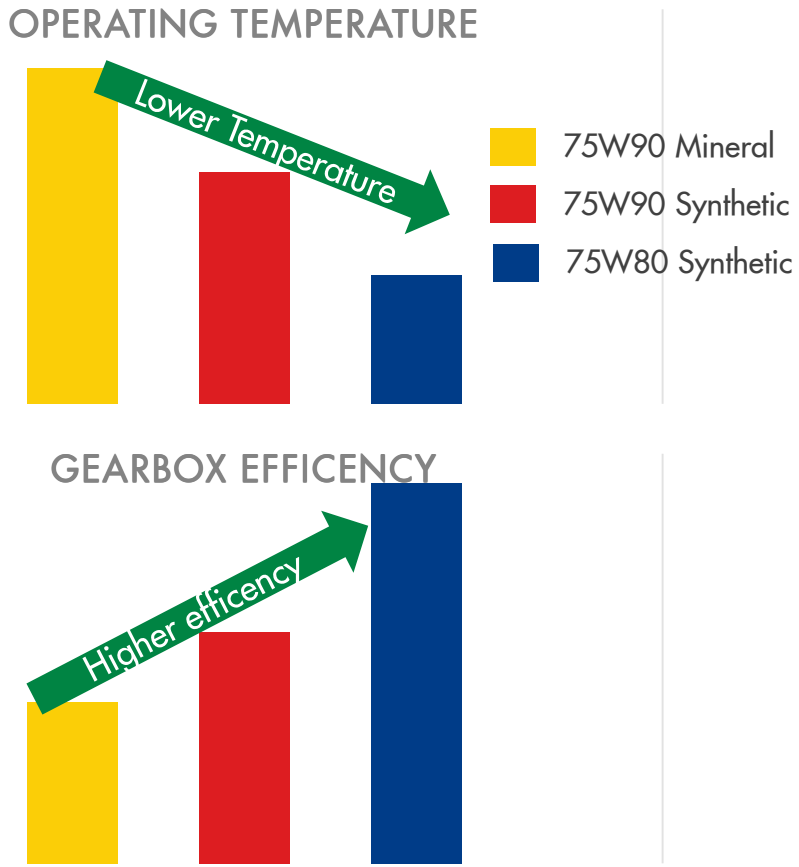


Lubricant using mineral base oil

Lubricant using synthetic base oil

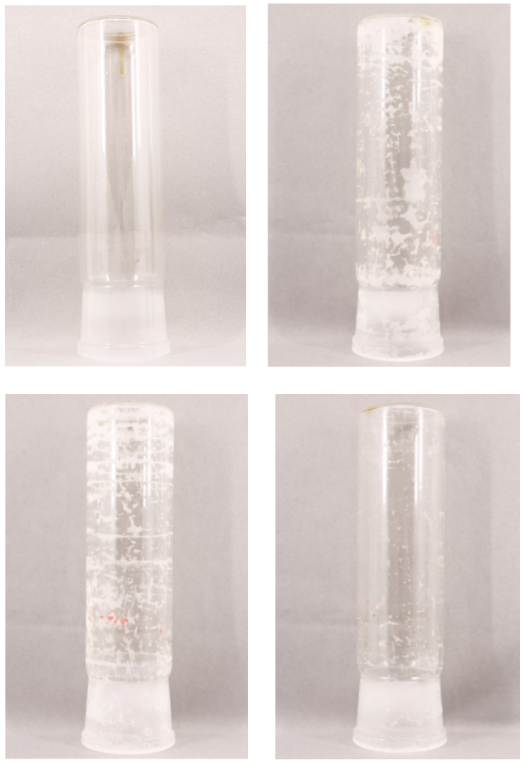




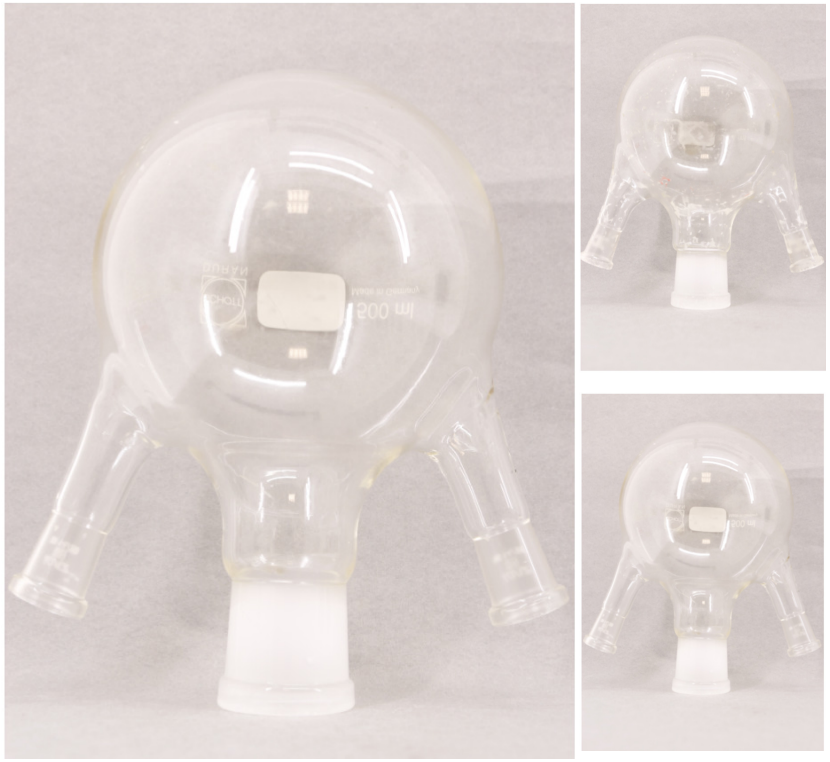


Superior oxidation stability, tested multiple times
Example of Shell E-Fluids i Range

Ageing under nitrogen 170°C / 192hr

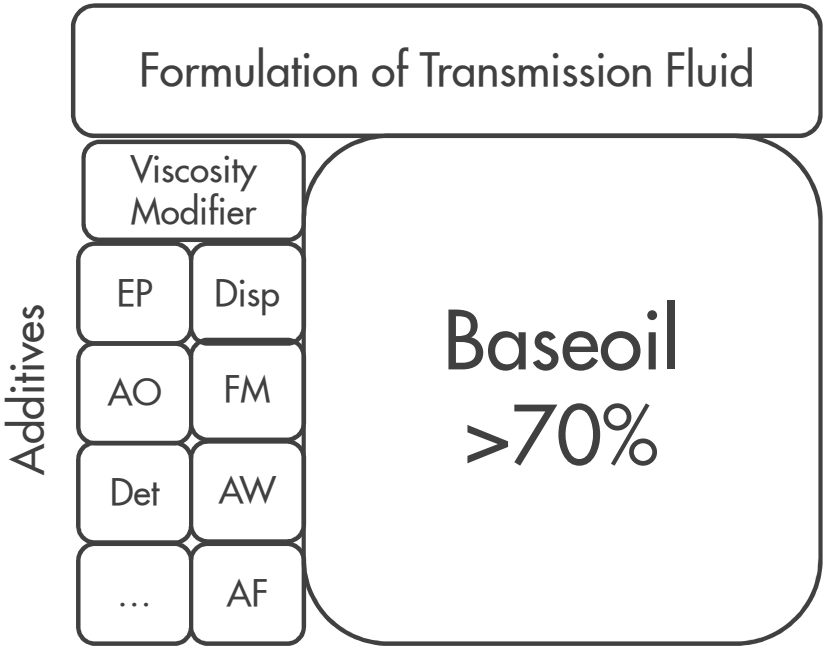


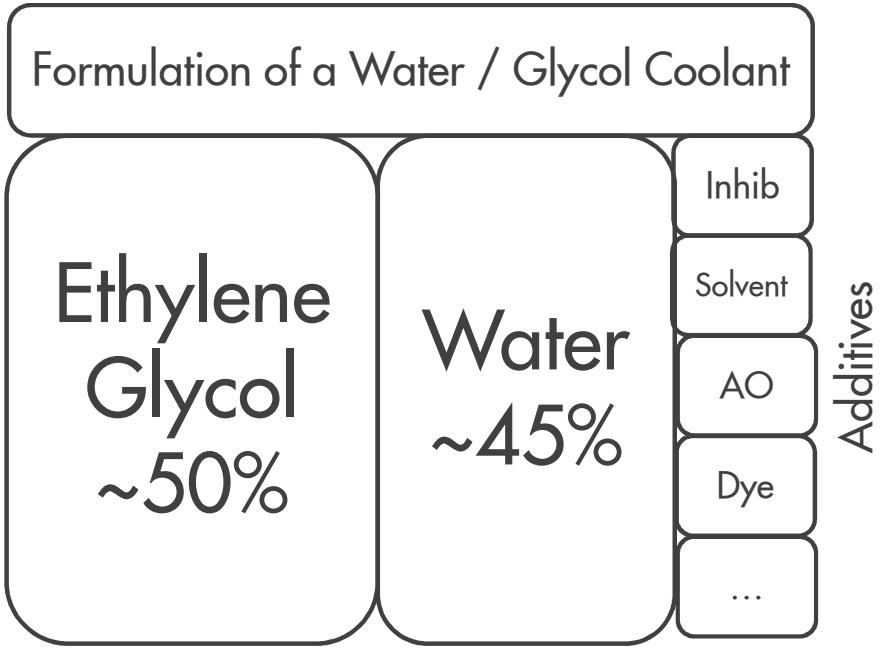
Oxidation140°C / 672hr



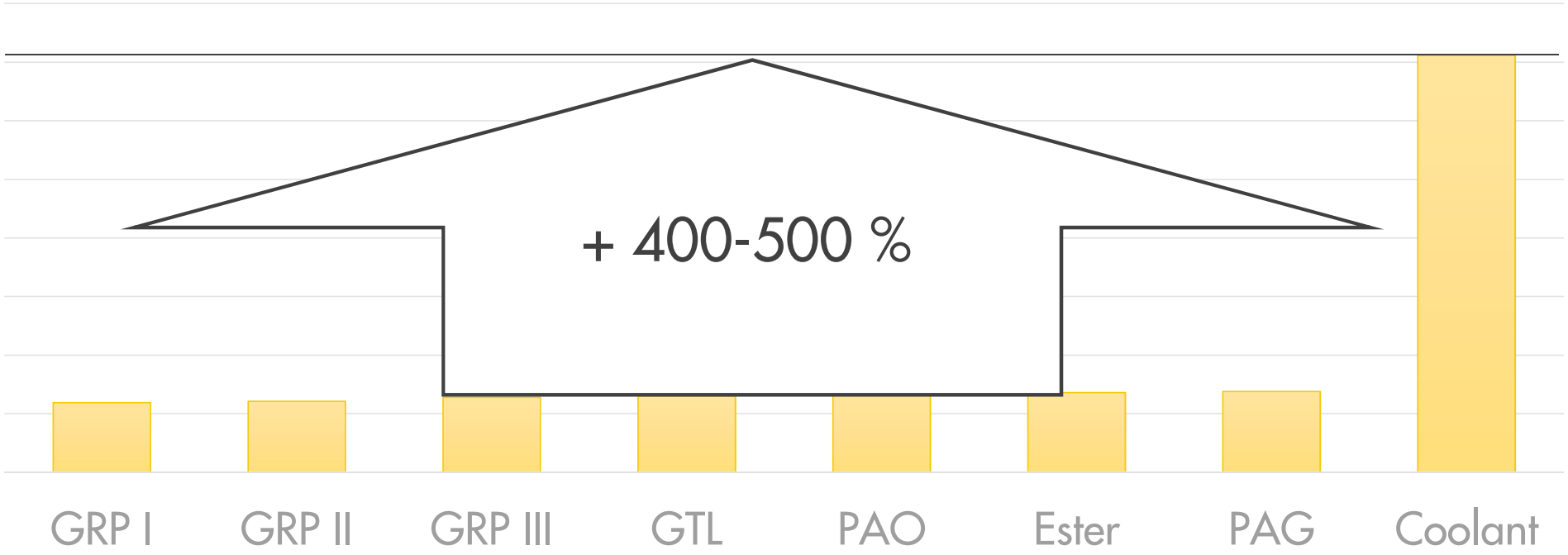
- The balanced formulation provides excellent oxidation and ageing stability
- Designed for fill for life application under high thermal stress conditions

Fluid formulation comparison for thermal properties





Comparison of Heat Conductivity at 100°C

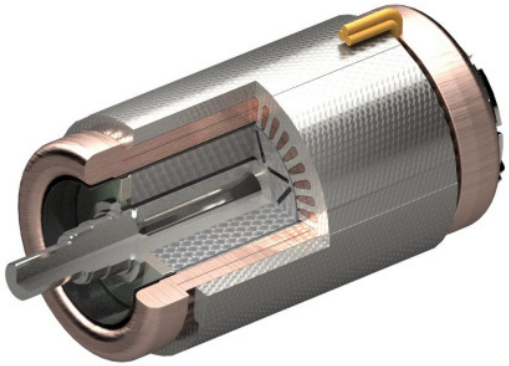


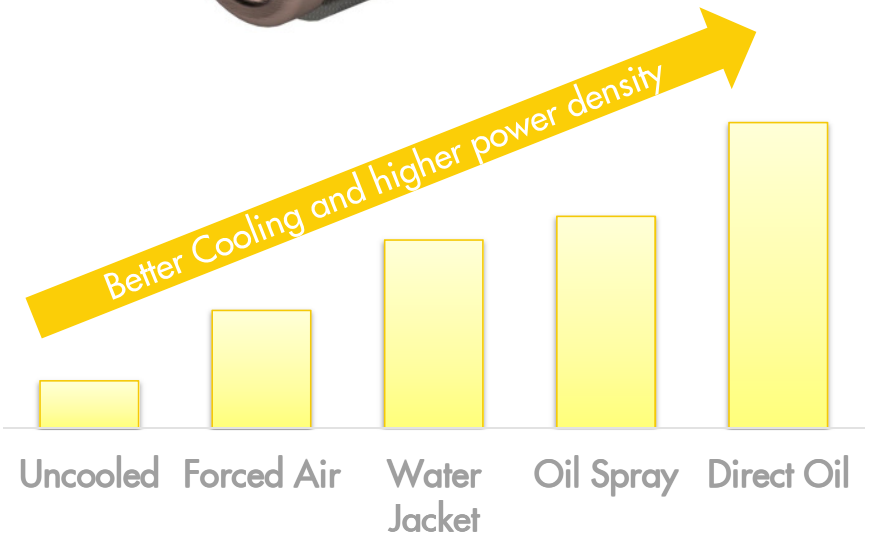
Comparison between Hydrocarbon based and Water/Glycol based fluids is an unrealistic match

Both fluid concepts are considered for different hardware designs which do have different requirements

SR.16.12924 „Heat Transfer Properties Review" Shell Internal report by K.Kamato

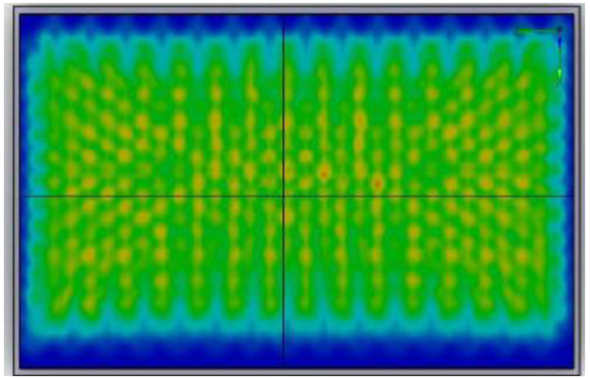
Direct Oil Cooling as a concept for future thermal management





- Saving weight
- More compact design, saving space
- Lower power losses
- Efficient cooling management
- Lower number of and smaller parts
- Lower material cost

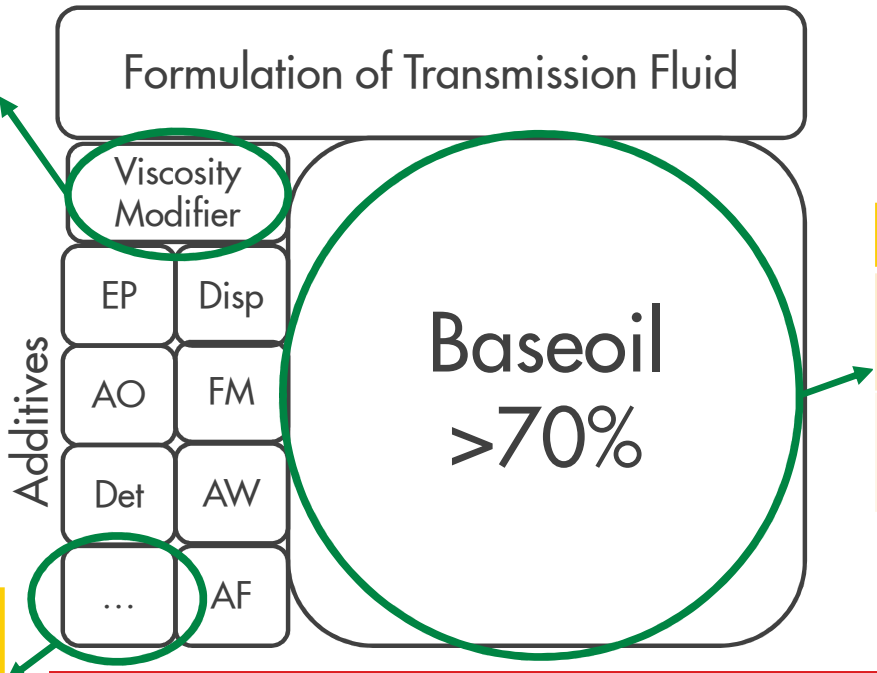
...Direct oil cooling also applies for batteries



Source: Roger Perthen, E-DRIVE: HIGHLY INTEGRATED AND HIGH EFFICIENT, AVL List GmbH; Dr. Cedric Rouaud, Ricardo plc, Battery Show Conference 2018

What possibilities do we have to boost Thermal Properties?

Concept	Cost impact
Increase VM	minor
VM molecular modification	?



Concept	Cost impact
Change to Grp III/ Grp IV	1,5-4 times
Change to Ester / PAG	2-8 times

Concept	Cost impact
Nano particles	> 30 times

Most cost-effective solutions for lubricants:
High Grade Base Oil Technology Grp III-IV

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- Baseoil selection for Efficency
- **Electric Properties & Corrosion Protection**
- Shell EV-Fluid Technology
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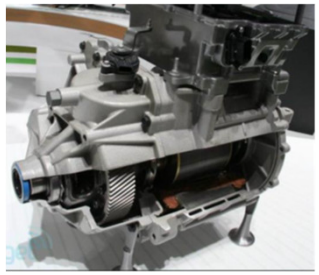
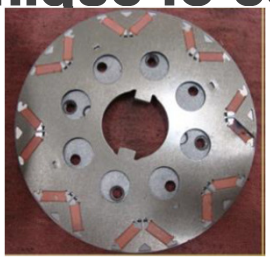
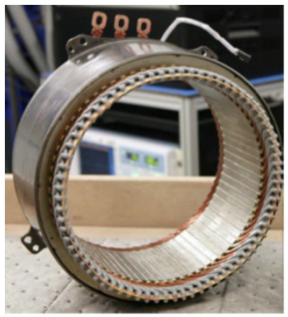
Electric Motor design is unique to each OEM

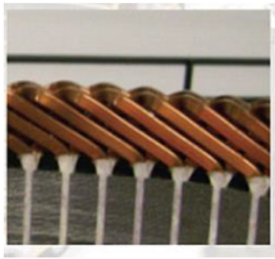


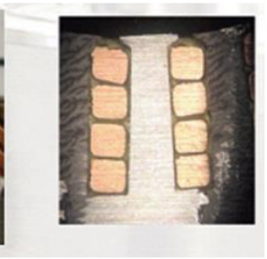
Ford Focus

Chevy Volt

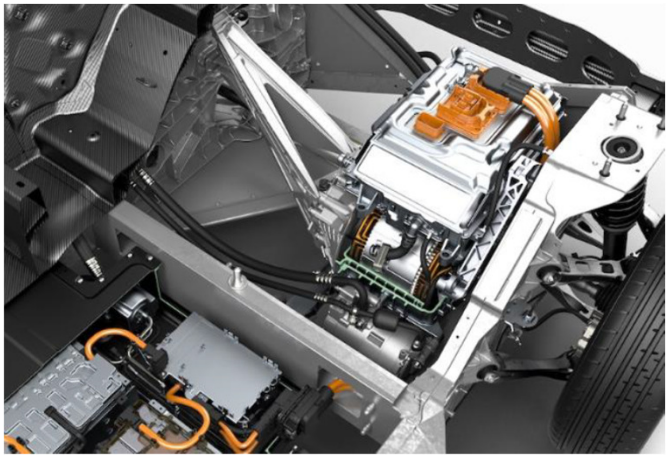




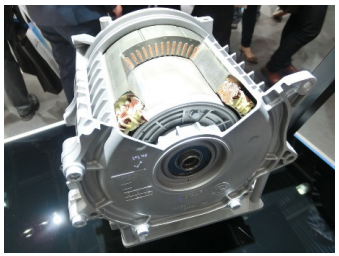


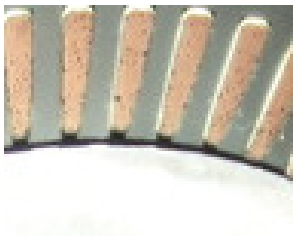


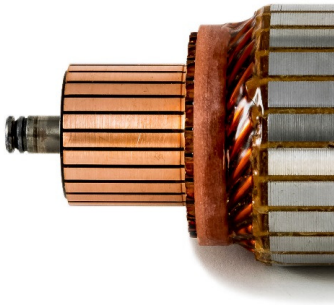
- Each OEM has a unique design of the electric motor
  - Insulation material
  - Winding technology
  - Rotor / Stator setup
  - …



BMW i3

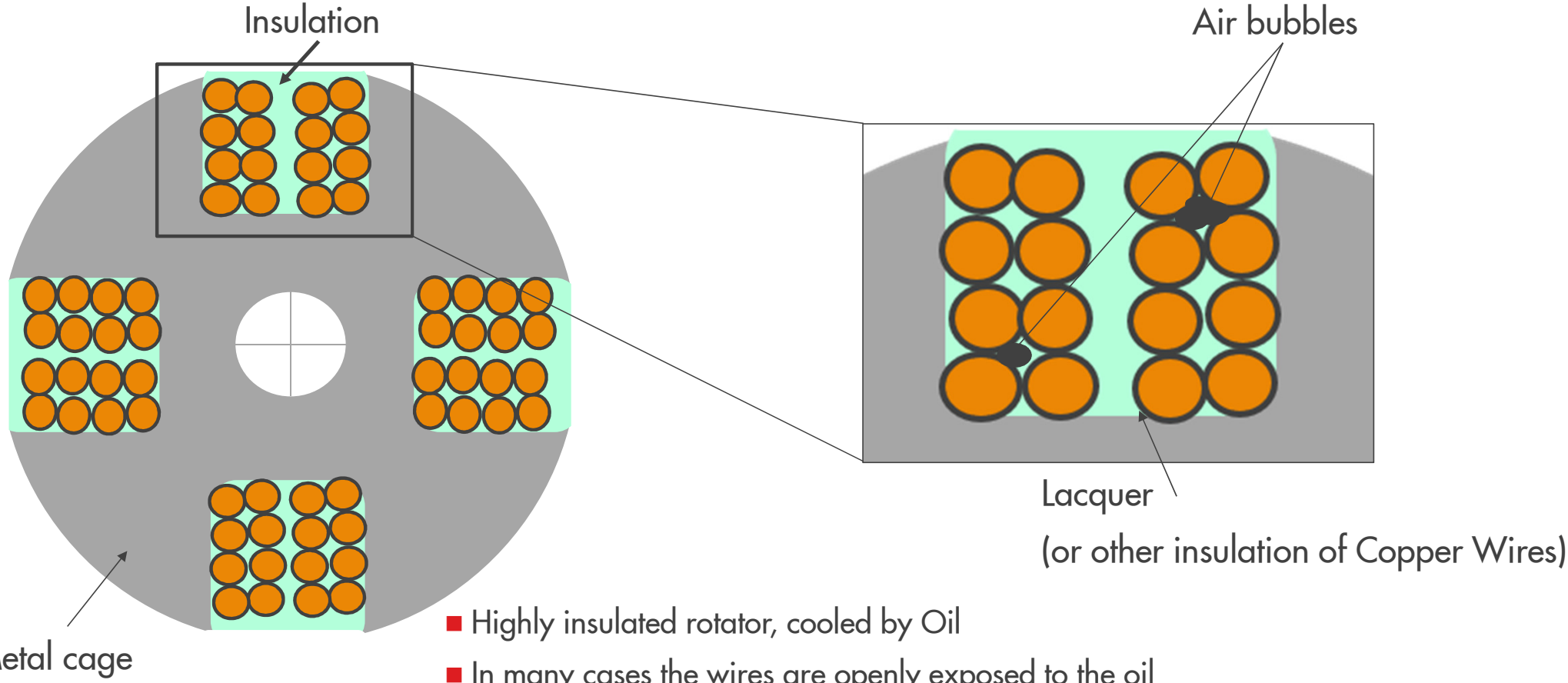






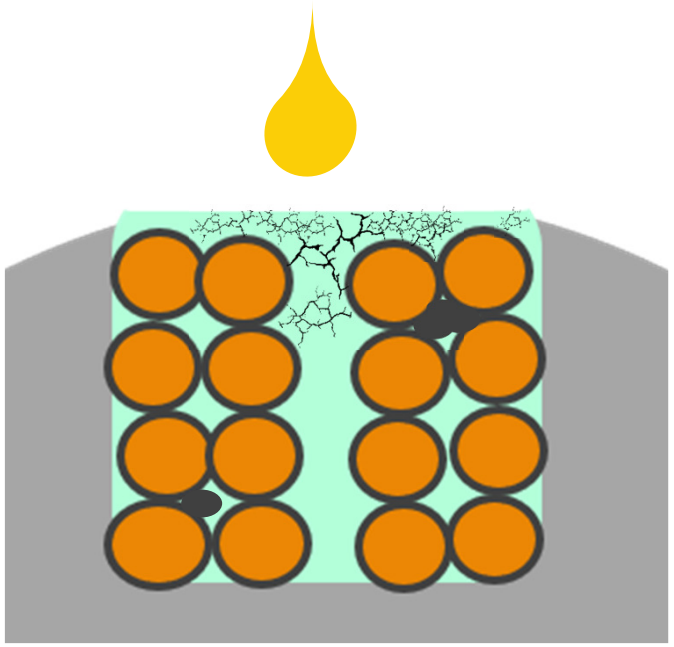
Source: James R. Hendershot, Nov 20th 2014, Florida International University; http://www.invetr.com/control-and-electronics/bmw-i3-electric-powertrain-machine

Example of incompatibility with integrated E-Components (Rotor)

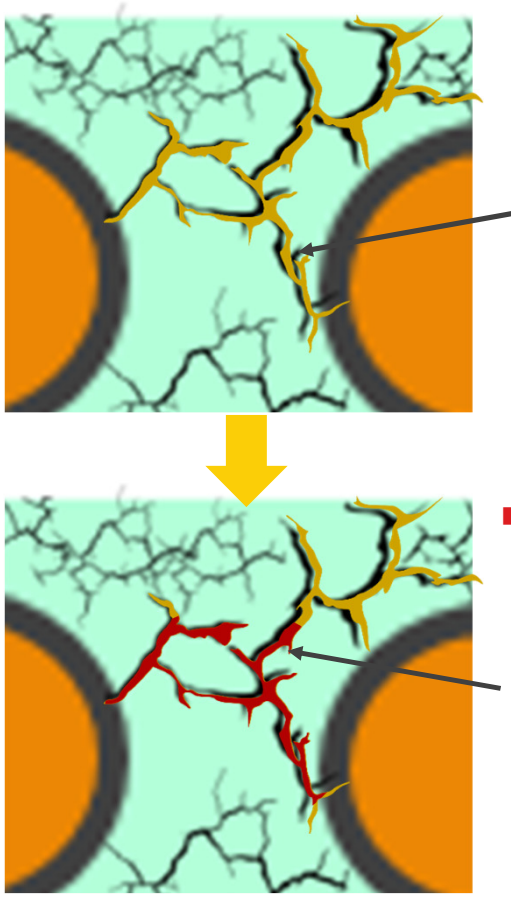


- Highly insulated rotator, cooled by Oil
- In many cases the wires are openly exposed to the oil

Example of incompatibility with integrated E-Components (Rotator)



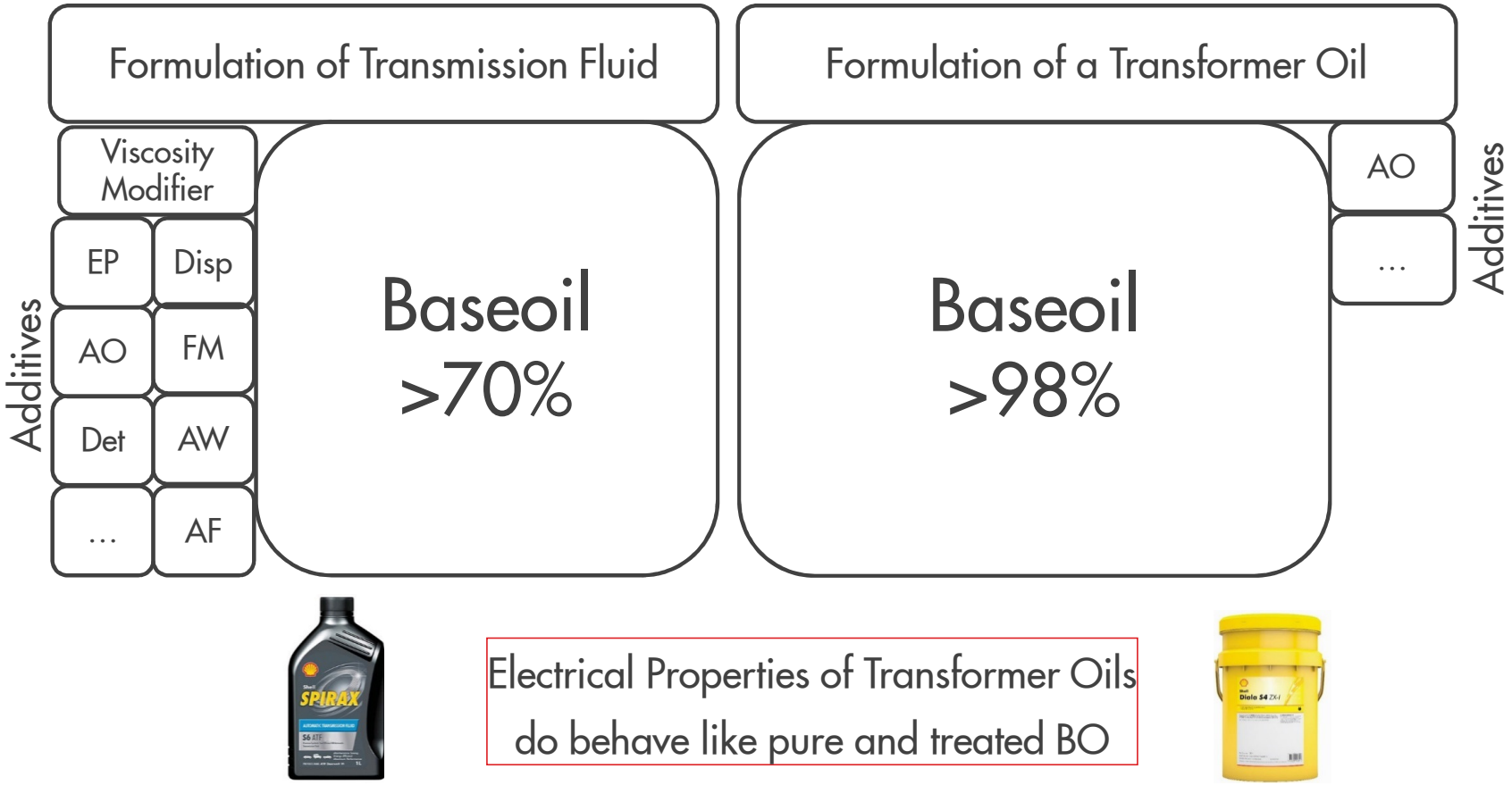
- Electric Rotator spinning with high speed, experiencing high dynamic load
  - Small Cracks in the insulation



- Oil immersing into cracks of Insulation
  - Electrical Properties of Lubricant

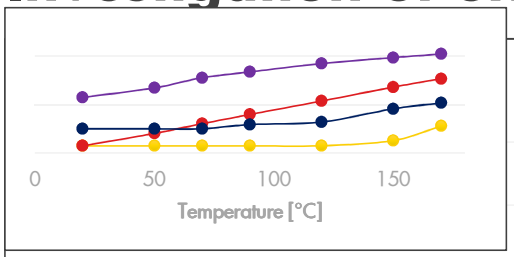
- Chemical reaction with Copper to build up „CuS Bridges“ leading to short circuits, decreasing efficency of E-Motor
  - Copper Compatibilty of Lubricant
  - Compatibility with insulation material of hairpins

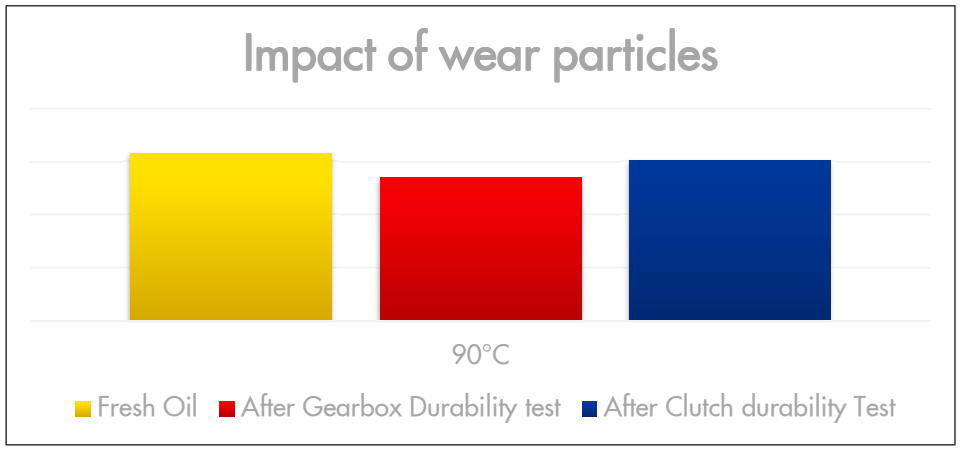
Fluid Formulation Comparison for electrical properties

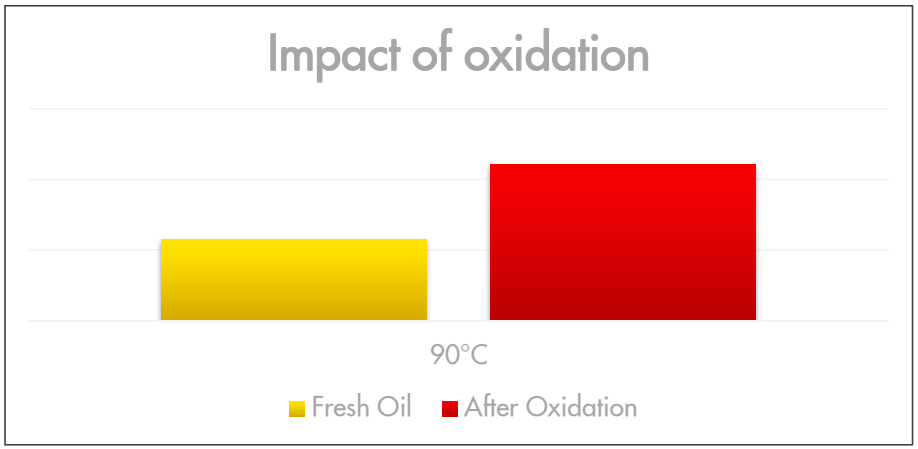


Electrical Properties of Transformer Oils do behave like pure and treated BO

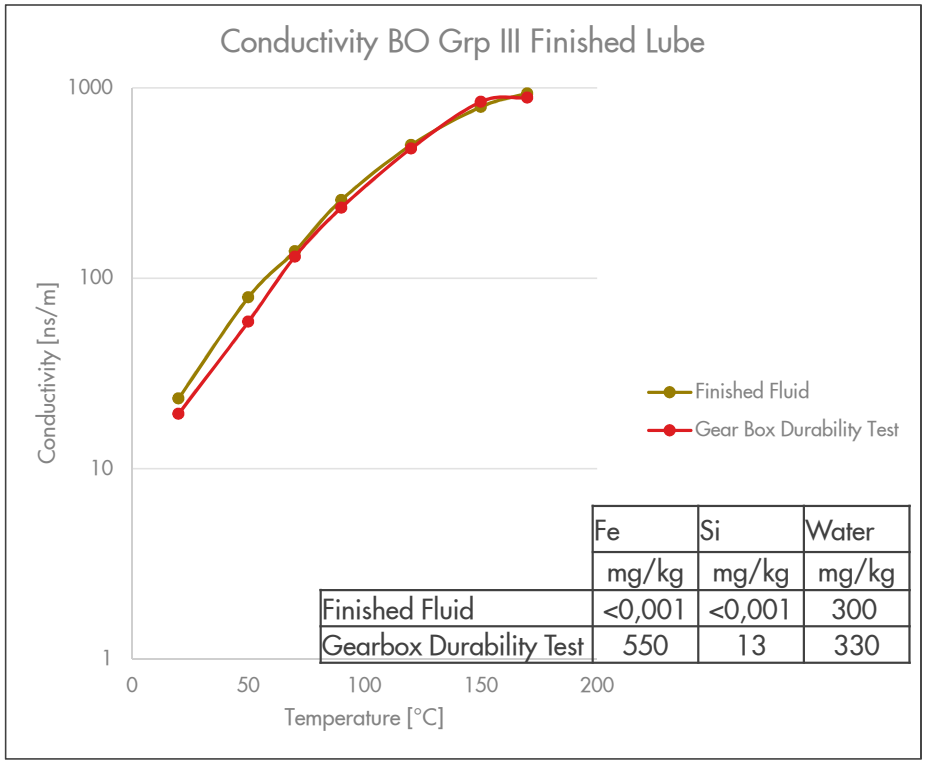
Investigation of effects on electrical conductivity (IEC 60247)



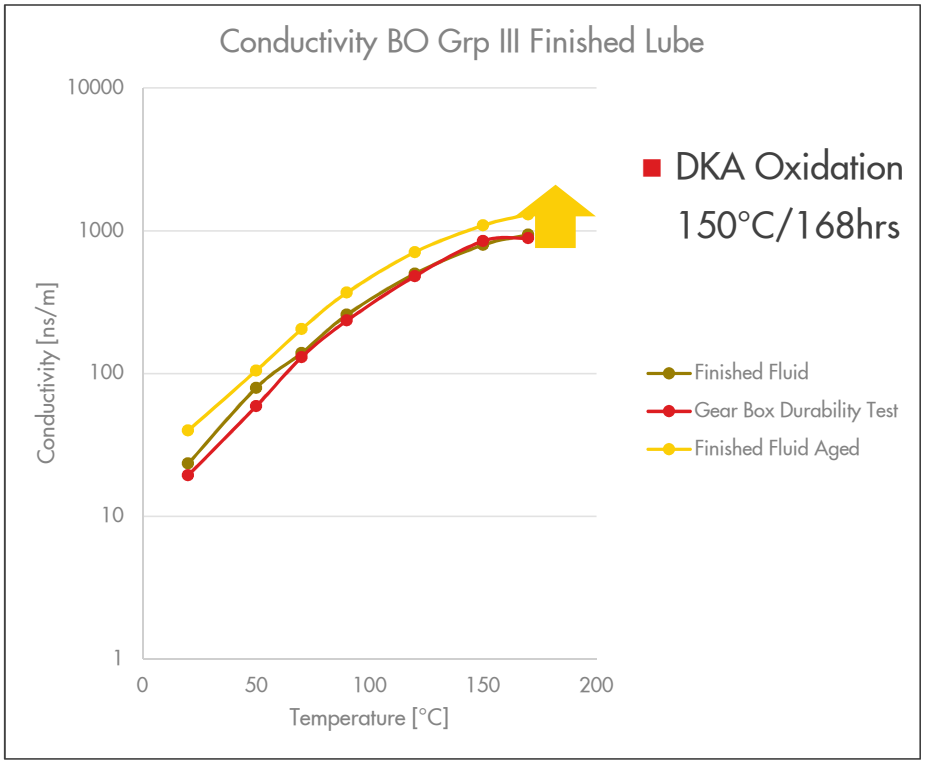




Ageing effect on electrical properties - oxidation of lubricants



	Fe	Si	Water
	mg/kg	mg/kg	mg/kg
Finished Fluid	<0,001	<0,001	300
Gearbox Durability Test	550	13	330



Oxidation of lubricants has higher effects on conductivity as wear particles

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New Screening tests to enable
Shell EV-Fluid Technology

- Formulating successful future E-Mobility lubricants requires to use new, alternative chemistries and base stocks:

Dry E-Motor

- High wear protection
- Low viscosity with high VI for efficency

Shell E-Fluid Gear Oil

Wet E-Motor

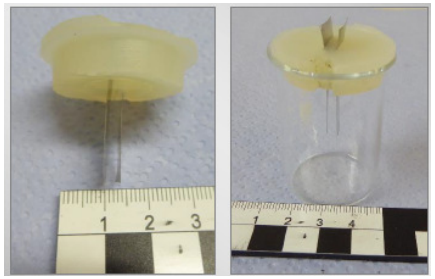
- Electrical properties,
- Clutch compatibility
- Excellent Copper compatibility

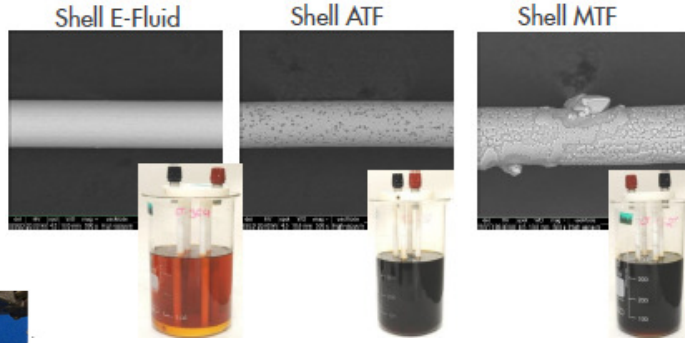
Shell E-Fluid integrated

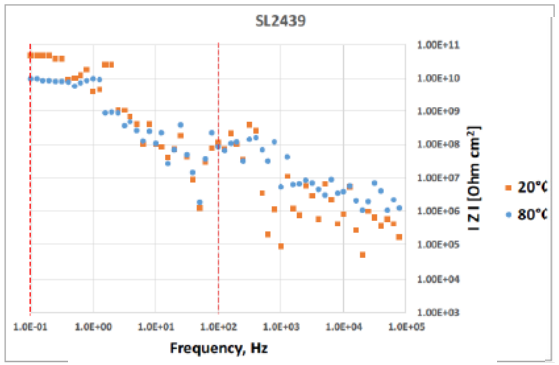
- High wear protection
- Excellent Copper compatibility

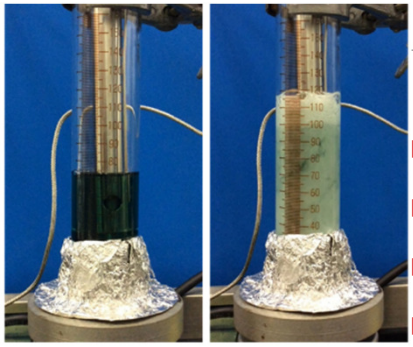
Shell E-Fluid i PLUS

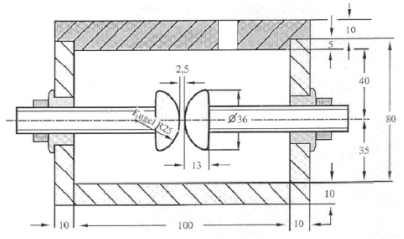
Screening methods for future E-Mobility lubricants development

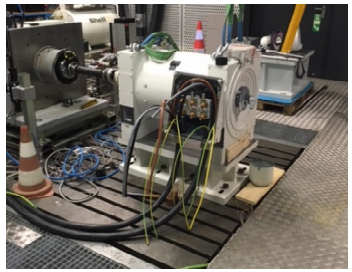






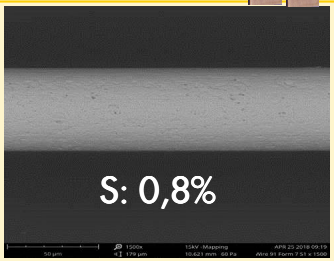
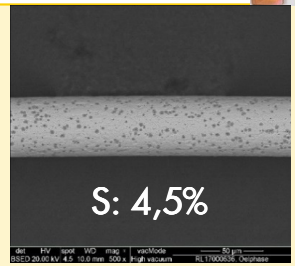
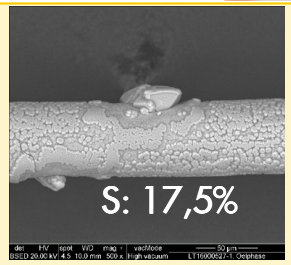




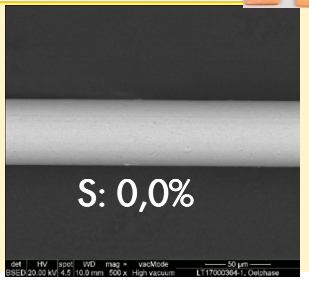
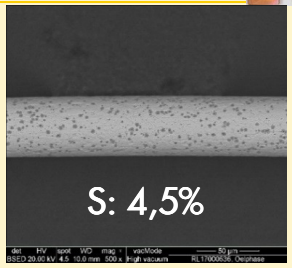
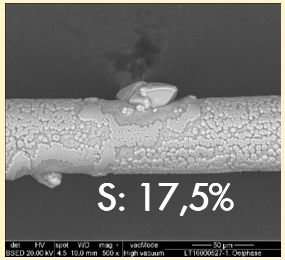


- Understanding frequency effects on lubricants behaviour
- Dielectric breakdown measurements
- Electrical Conductivity
- Copper Wire Corrosion testing
- Hairpin immersion in oil
- Foaming test for 20.000 rpm
- Updating test rigs for high speed E-Drive Units
- …

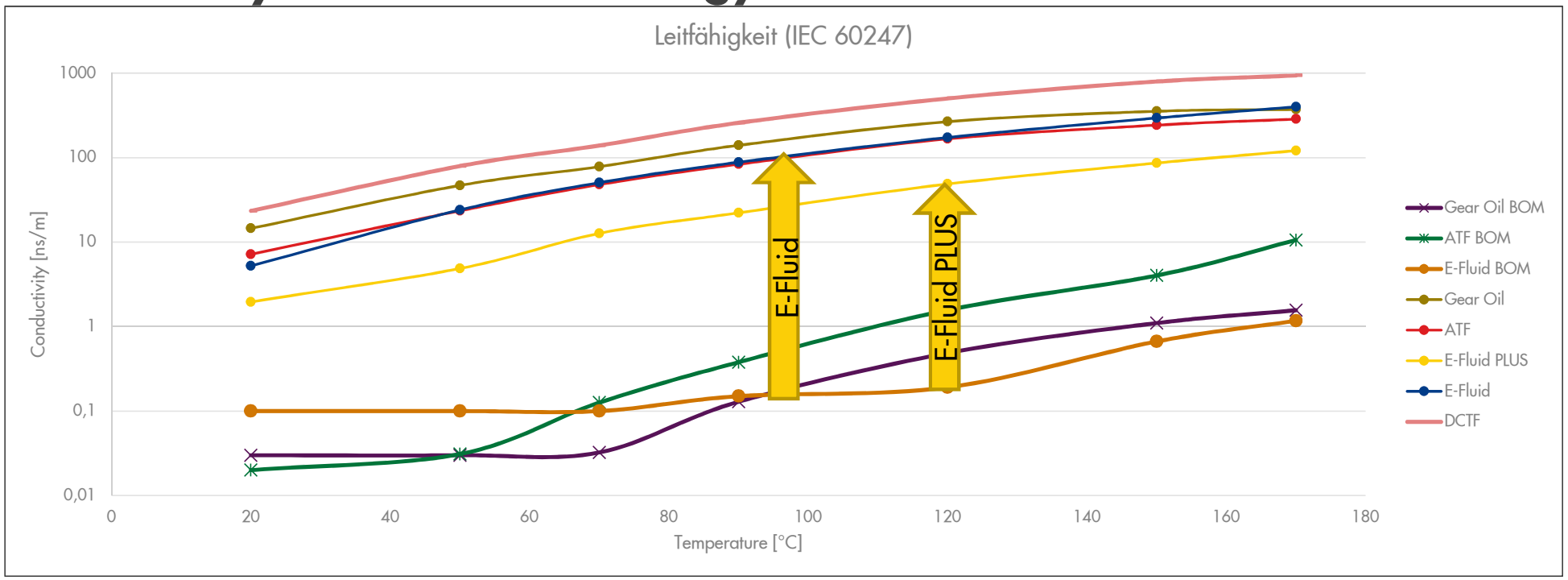
Balancing Cu-Protection with Scuffing Protection
Shell E-Fluids i Technology

	Shell E-Fluid i	Conv. ATF Technology	Conv. Gear Oil Technology
P-Content [%]	<0,04	<0,04	<0,1
S-Content [%]	≤0,15	≤0,15	>0,5
ASTM D 130 150C / 168h - Rating - Copper in Oil	41 mg 	331 mg 	927mg 
Copper Wire Corrosion Test 130°C / 240hr - EDX: S-Content on Surface			
FZG A10/ 16,6R/90 - Fail Load Stage	>10	5	>10

Balancing Cu-Protection with Scuffing Protection

	Shell E-Fluid	ATF Technology	Gear Oil Technology
P-Content [%]	≤0,04	<0,04	<0,1
S-Content [%]	≤0,06	≤0,15	>0,5
ASTM D 130 150C / 168h - Rating - Copper in Oil	1B 12 mg 	3B 331 mg 	4C 927mg 
Copper Wire Corrosion Test 130°C / 240hr - EDX: S-Content on Surface			
FZG A10/ 16,6R/90 - Fail Load Stage	7	5	>10

Conductivity of E-Fluid Technology vs. conventional

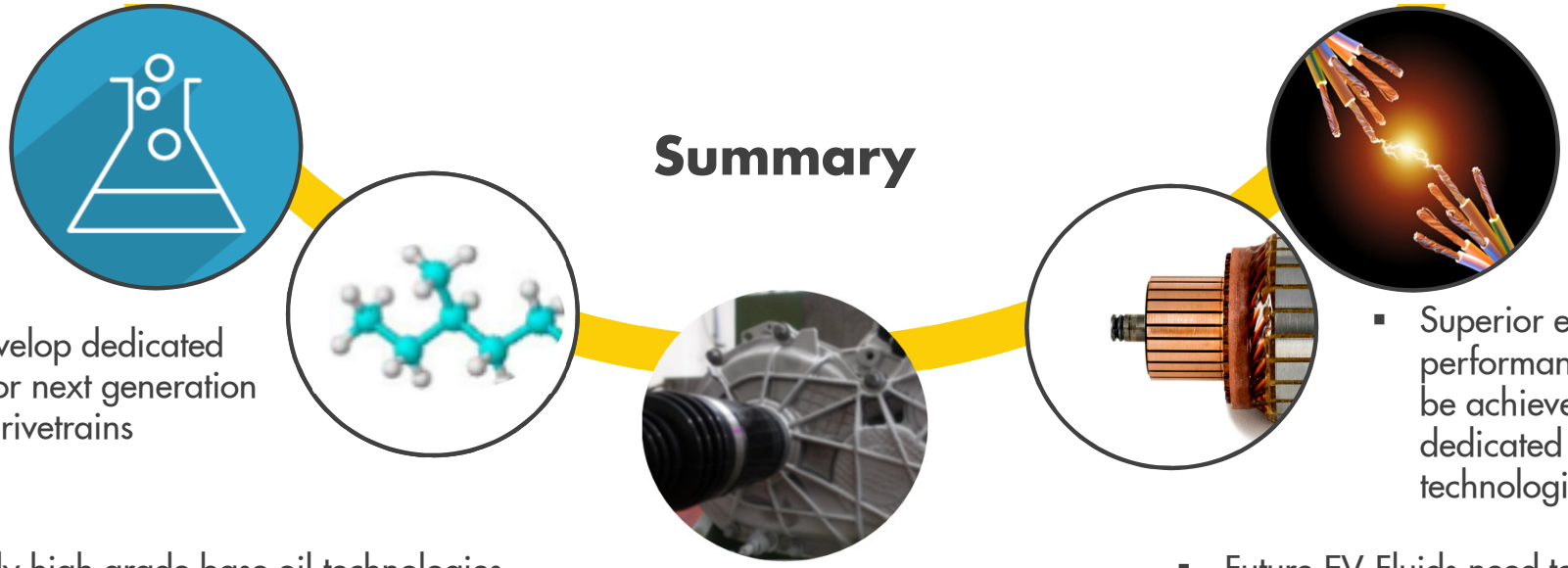


- Baseoil composition for E-Fluid Technology - extra low conductive due to VM / Baseoil selection
- Shell E-Fluid Core Technology shows comparable conductivity as conv. ATF
- Shell E-Fluid Plus Technology shows significant improvement for electrical conductivity

Agenda

- Market and Hardware Trends
- Baseoil selection for efficency
- Electric Properties and Corrosion Protection
- Shell EV-Fluid Technology
- Summary

Summary



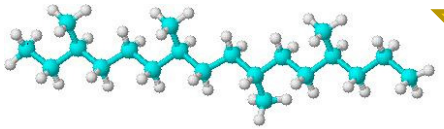
- Need to develop dedicated lubricants for next generation electrified drivetrains
- Only high grade base oil technologies are fit for purpose, balancing commercial value vs. technical performance
- Evaluating successful the new E Fluids, requires to investe into test methods and alternative chemistries and base stocks
- Future EV-Fluids need to deliver excellent compatibility with electric components, while achieving higher gear protection compared to conv. technologies
- Superior electrical performance benefits can be achieved with dedicated lubricants technologies

Thank You

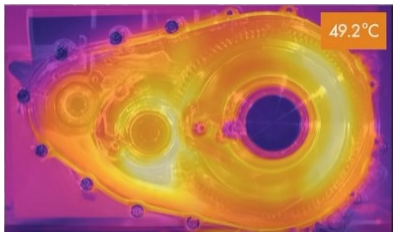
Shell E-Fluids key enabler: GTL Base oil with fine selected additive technology

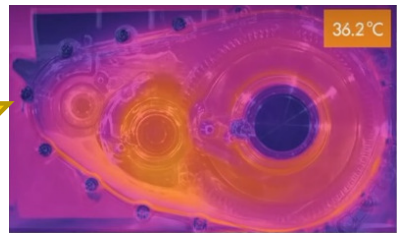
GTL enabling

Shell E-Fluids

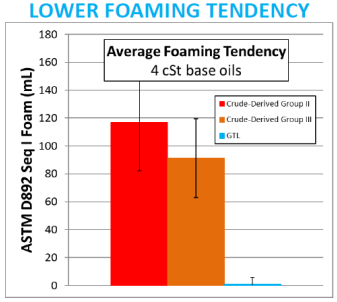


Lower Viscosity combined with GTL-Technology

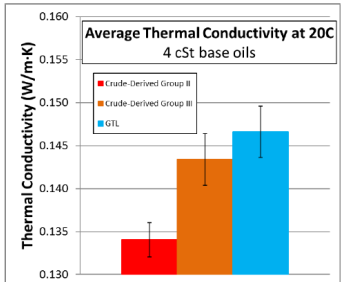




LOWER FOAMING TENDENCY



GREATER THERMAL CONDUCTIVITY



GREATER HEAT CAPACITY