New Fluids and Greases That Help Drive Electric Mobility

Dairene Uy

Shell Global Solutions (US) Inc.

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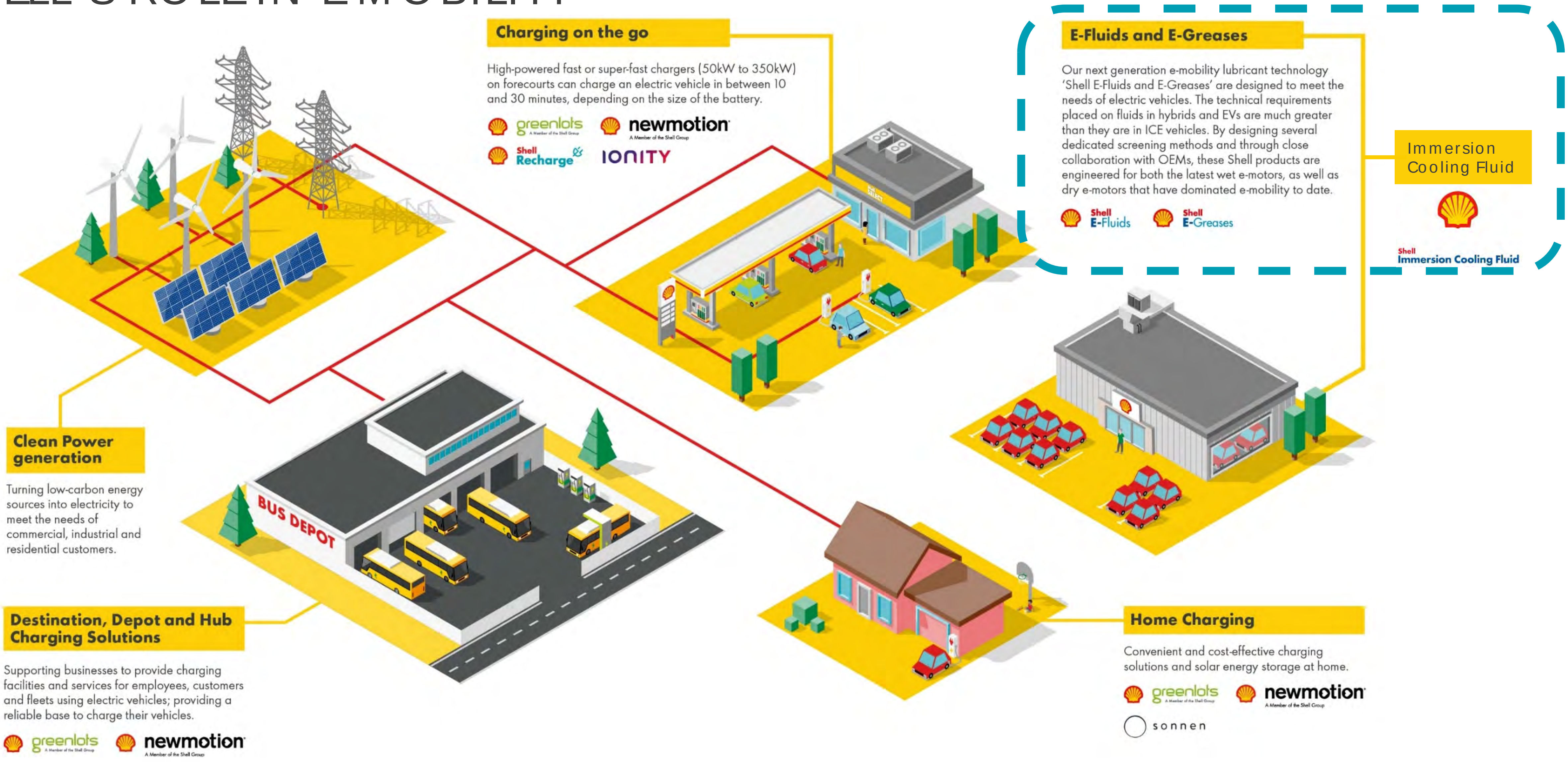
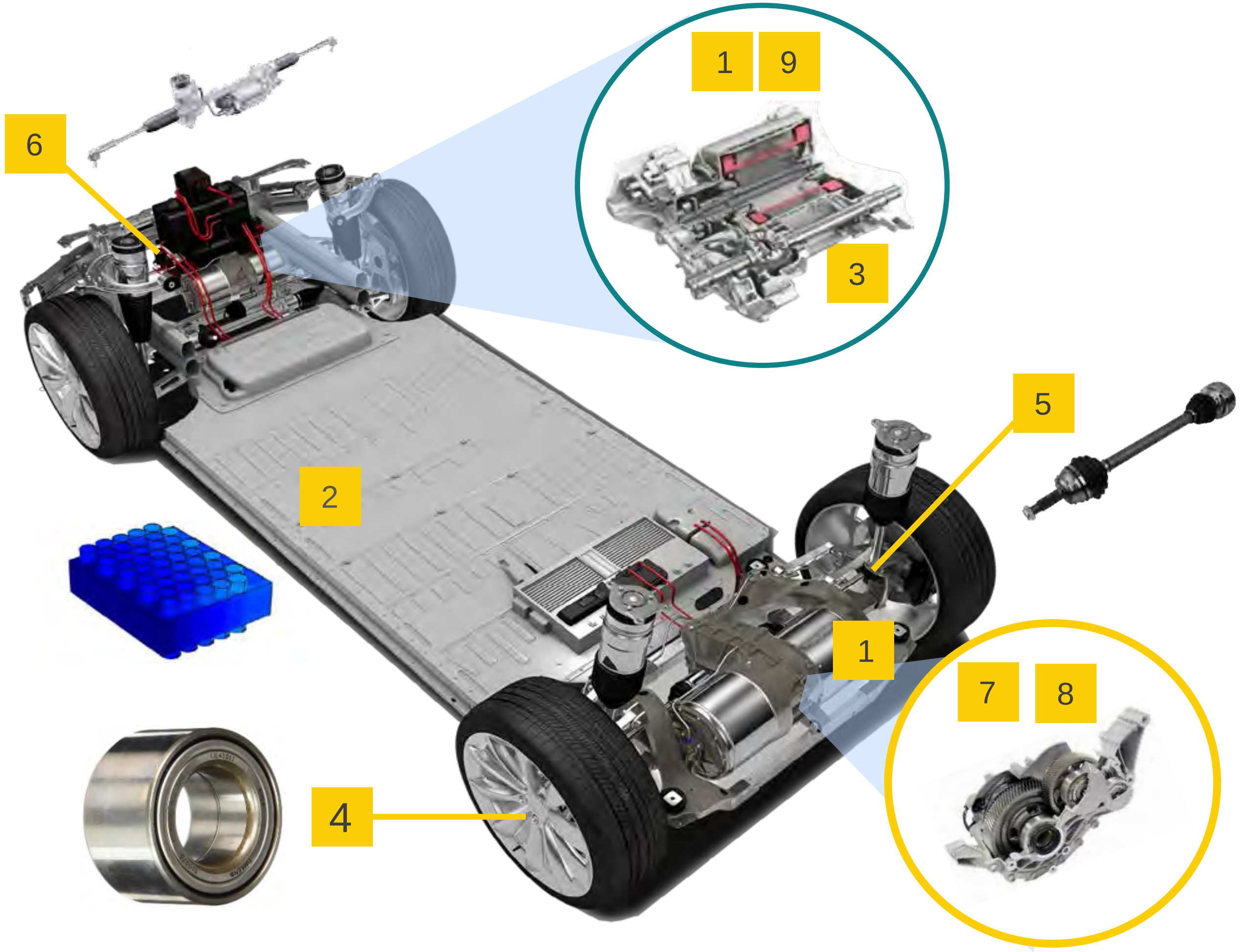
SHELL'S ROLE IN E-MOBILITY



LUBRICANTS AND GREASES IN ELECTRIC VEHICLES

What is an E-Fluid: Fluids & Greases specifically designed for electric vehicle applications. While they prevent wear, reduce friction, and are efficient, also ensure electrical compatibility and thermal management.



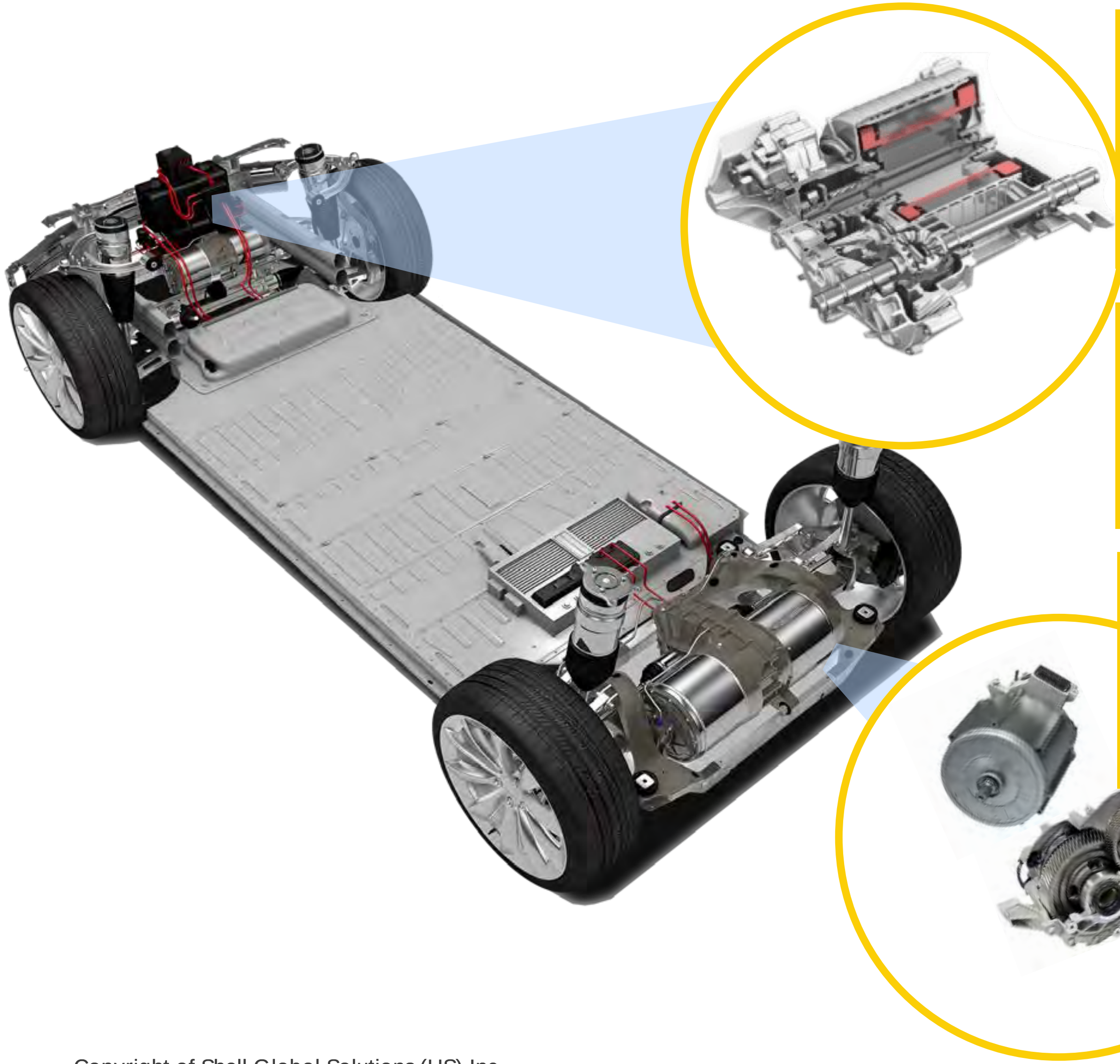
1 E-motor cooling
2 Battery thermal management
3 E-motor bearing lubrication
4 Wheel bearings
5 Constant Velocity Joints
6 Steering lubrication
7 Reduction gear lubrication
8 Differential lubrication
9 Potential direct cooling of e-motor windings

Thermal Fluids

Grease

Transmission Lubes

LUBRICANTS AND GREASES IN ELECTRIC VEHICLES - OUTLINE



1.	Transmission lubes	Complexity of electrification for powertrains
		Requirements for E-drive fluids
		Testing and optimization of E-drive fluids
2.	Grease	Requirements for E-drive applications
		Considerations in e-grease formulations
3.	Thermal fluids	Battery cooling concepts
		Key development areas for immersive battery cooling

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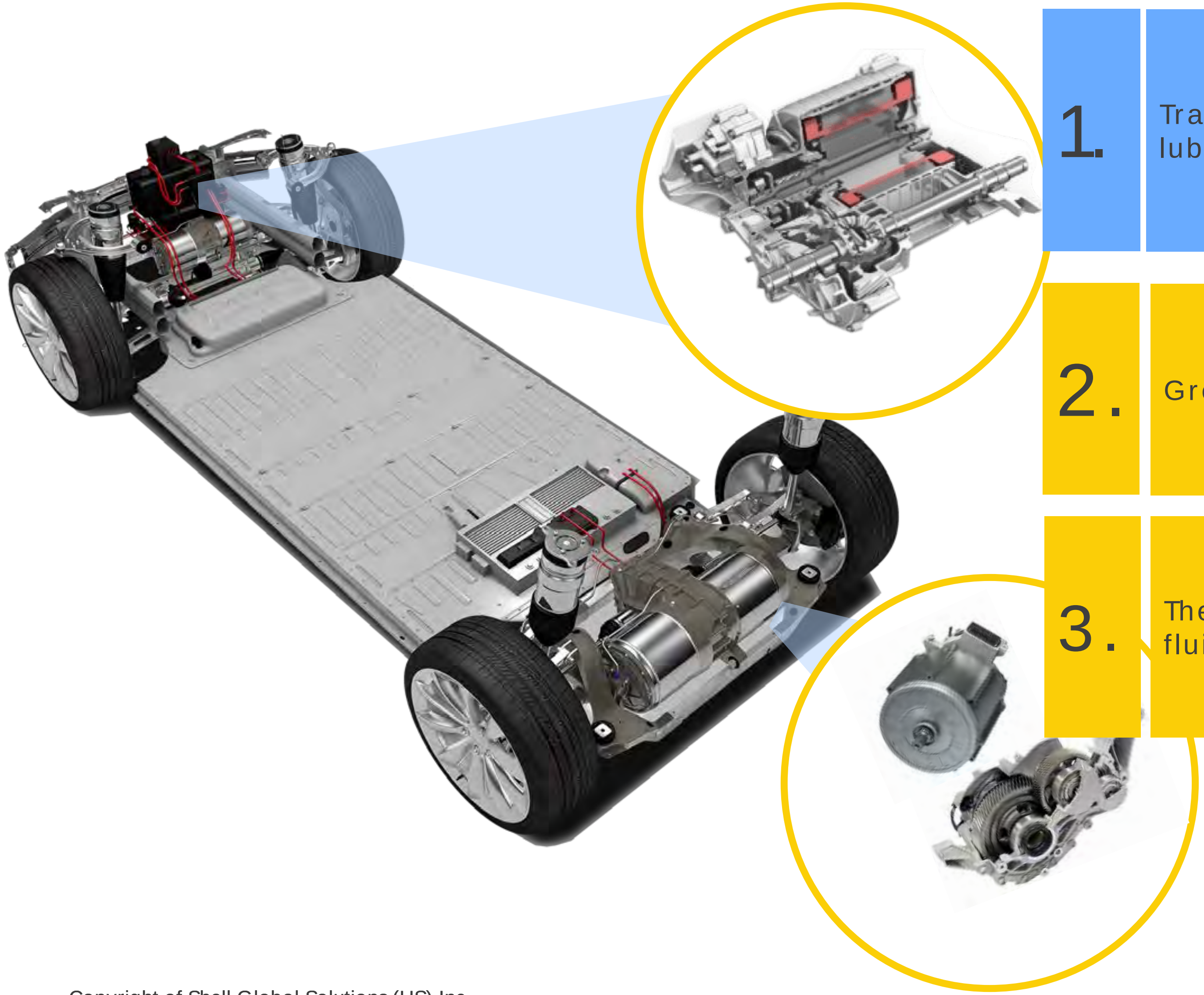

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DRIVETRAIN ELECTRIFICATION CONCEPTS – TECHNOLOGY DIFFERENTIATION

PHEV

ICE + E-Machine

Electricification of the Powertrain

PORTFOLIO DIVERSIFICATION AND SEGMENTATION

Full EV

BEV / FCEV

- AT
  Integrated e-drive
- DCT
  Integrated e-drive
- CVT
  Integrated e-drive
- MT
  E-Clutch System
- Axle
  Torque Vectoring by EM

- Single Speed E-Axle / E-Drive
- Multispeed E-Axle
- Direct Drive

Powertrain topology can add high complexity for selection of the right lubricant.

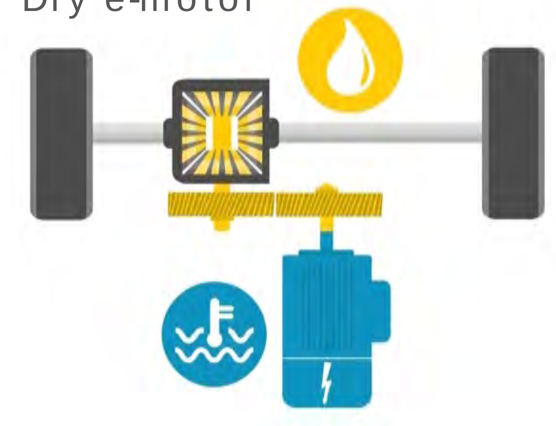
Important technical features to consider:

- Shifting elements, like clutch / synchronizer?
- Degree of electrification?
- Wet / dry E-motor?
- Viscosity limiting components?
- Gear design
- ...

Only considering above can easily lead to >100 different fluid options

ADDITIONAL DEMANDS FOR E-FLUIDS

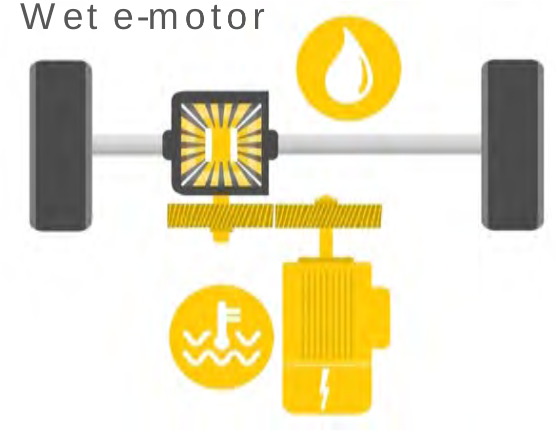
Dry e-motor



Electric motor is separate from transmission and differential.

- Differential lubrication
- Gear lubrication
- Bearing lubrication

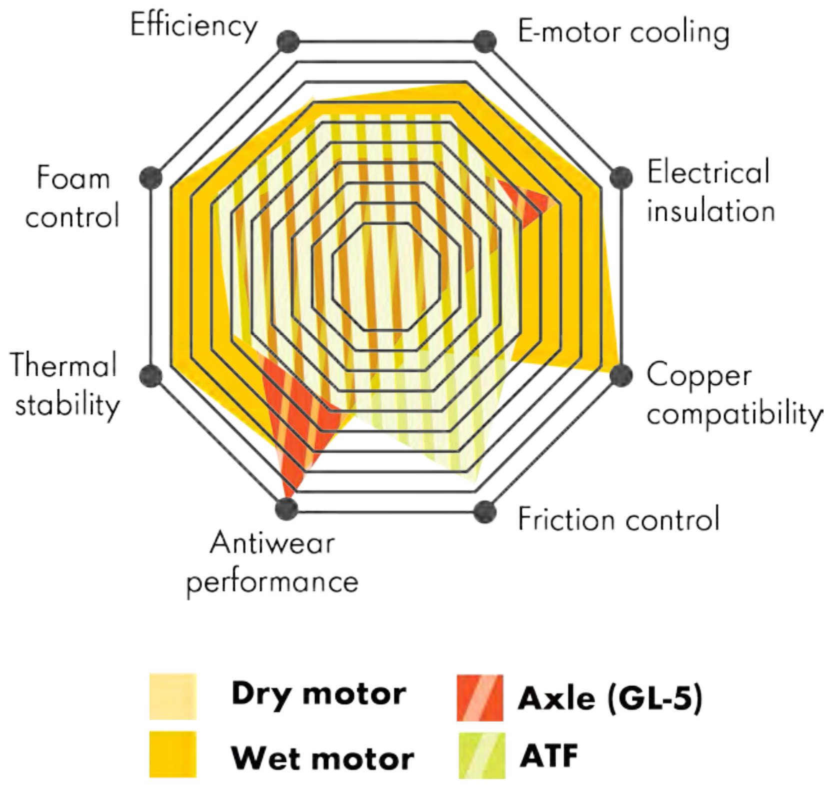
Wet e-motor



- Differential lubrication
- Gear lubrication
- Bearing lubrication
- + E-motor cooling

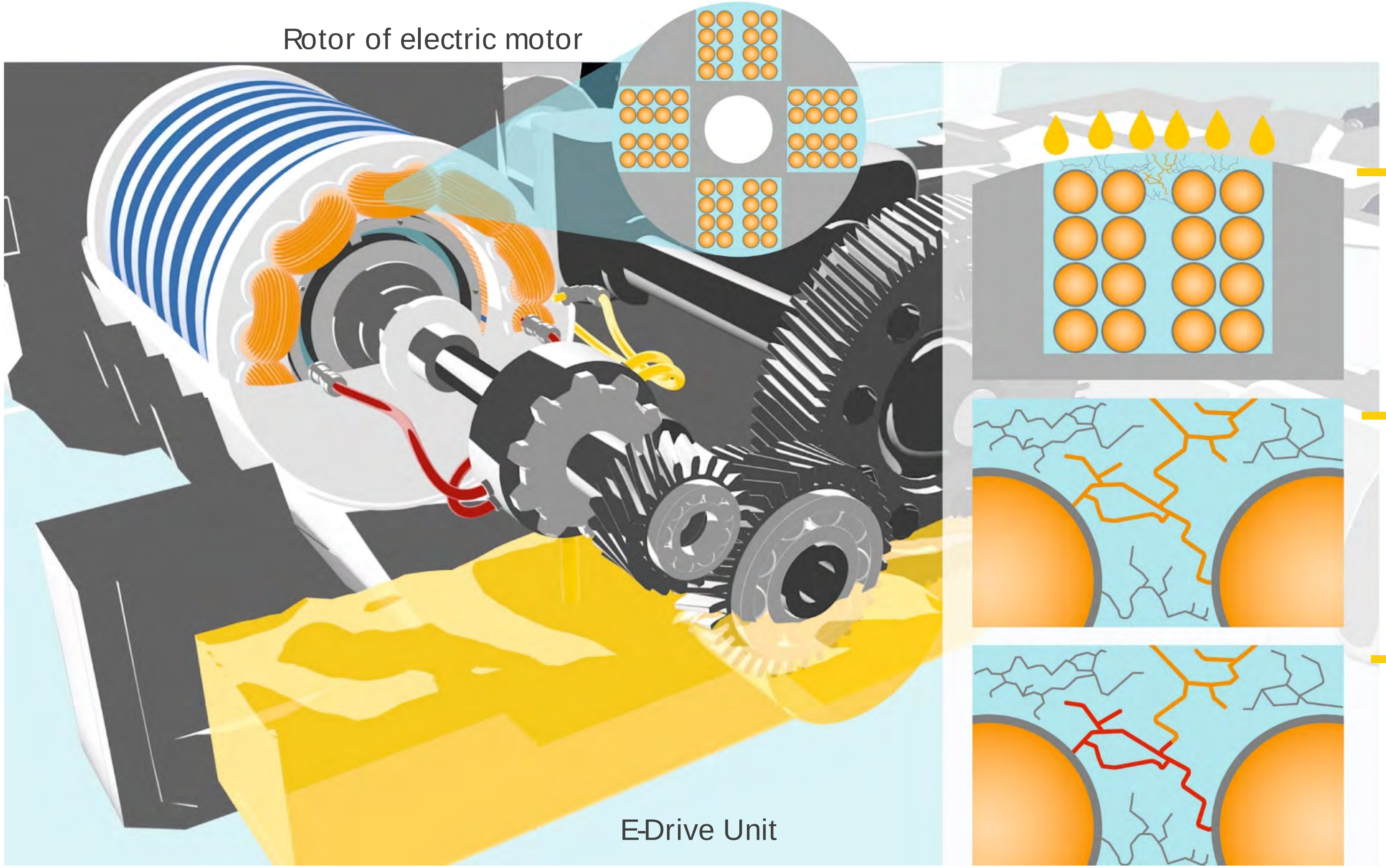
Operating conditions

- High Torque
- High Speed
- Recuper-ation



Electric motor, transmission and differential integrated into one housing for packaging efficiency

EXAMPLE OF TECHNICAL CHALLENGES FOR E-TRANSMISSION FLUIDS



Spinning rotor at high speeds
Cracks & damages of insulation

Oil leaking into cracks, contacting Cu-windings.
This may lead to any electrical short circuits or creeping currents.

Chemical reaction between lubricant and Cu-windings
This may cause corrosion and loss of power.

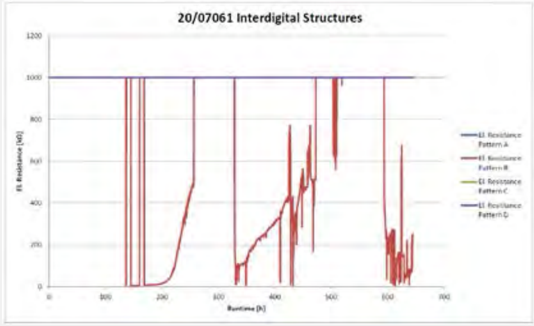
CIRCUIT BOARD SCREENER FOR VAPOR AND LIQUID PHASE CORROSION

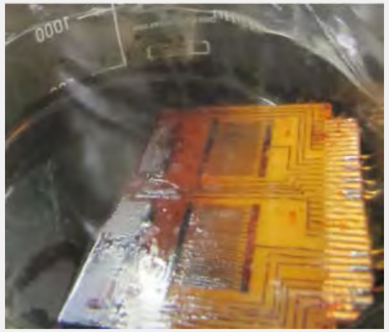
- Circuit board with four CAM-structures is being immersed in oil (half in / half out)
- Temperature and duration can be modified (here 1000hr/ 150° C)
- Electrical resistivity of CAM structures is being monitored
- Monitoring build up of conductive layers and formation of CuS_x

ATF Concept	E-Fluid Concept	DCTF Concept
		

Test with DCTF was stopped at 672hr

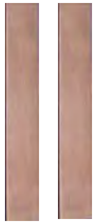
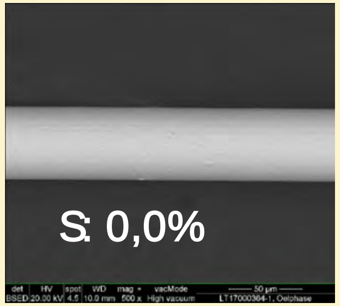
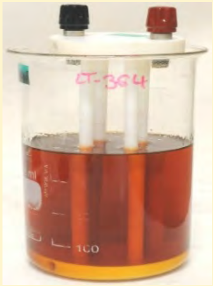
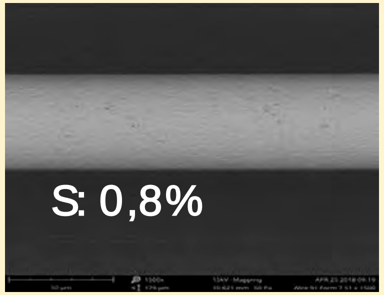
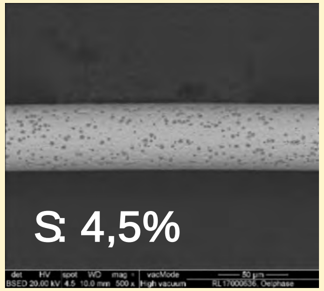
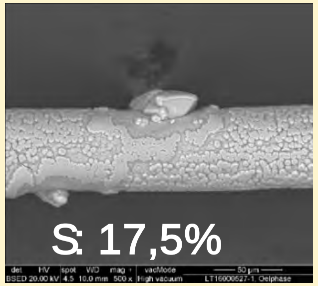
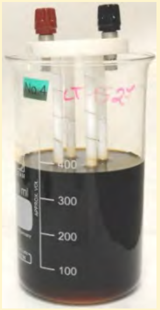
- Half of the oil volume has been evaporated
- High corrosion on the circuit board
- Base oil and additive system lead to failure of test





		ATF	E-Fluid	DCTF
Evaporation Loss Noack, 200° C, 1h	DIN 51581-1	2,5 %	4,7 %	8,7%
Flash Point	DIN EN ISO 2592	222° C	208° C	184° C

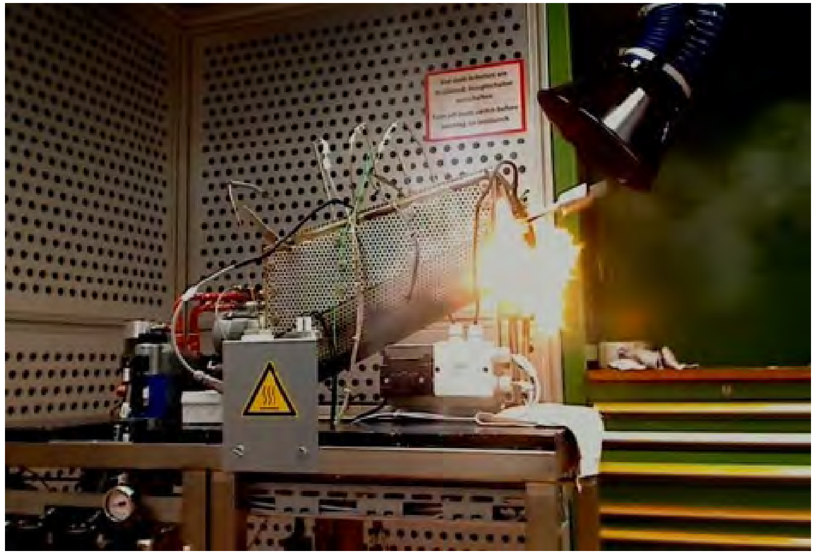
BALANCING CU-PROTECTION WITH SCUFFING PROTECTION

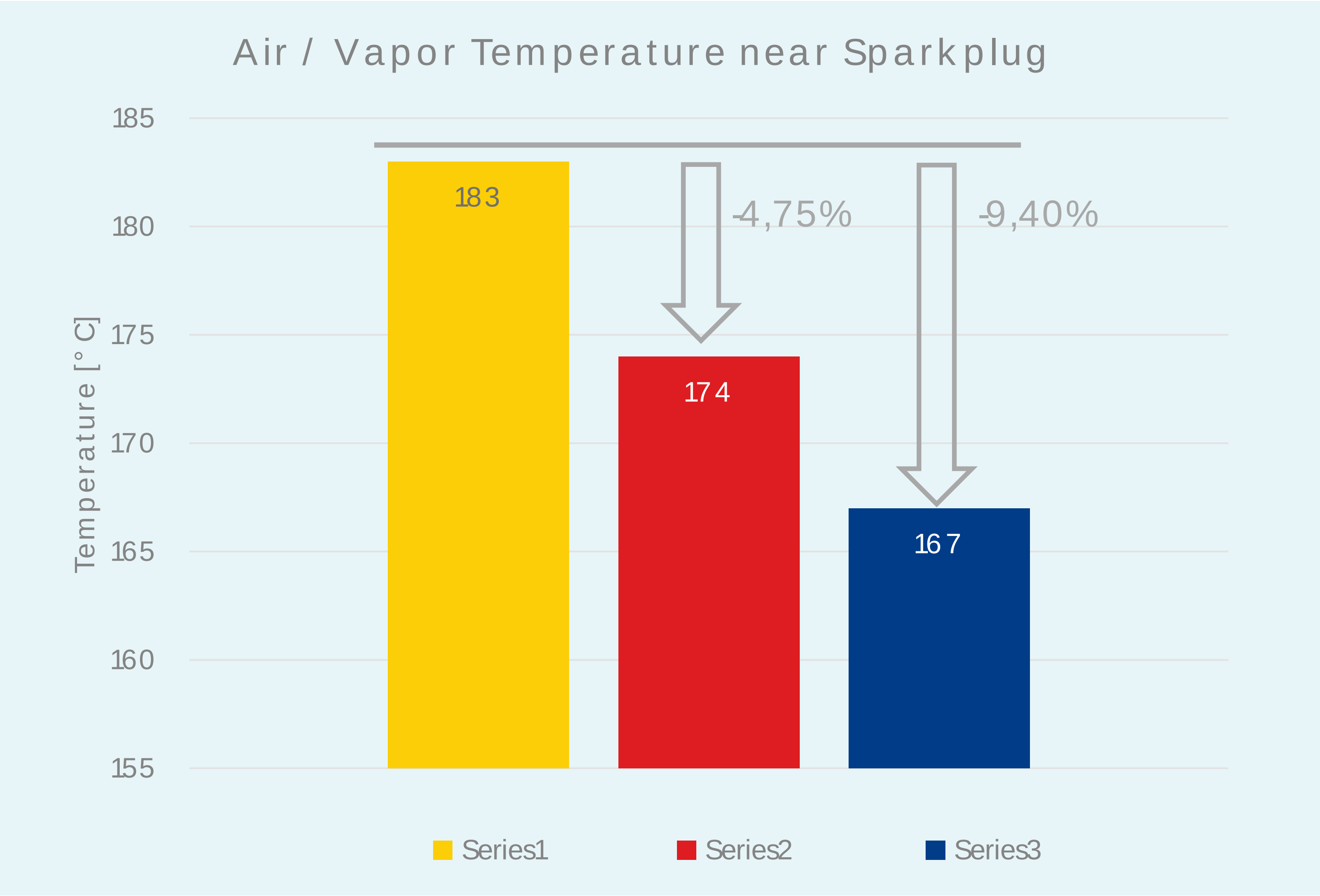
	Shell E-Fluid Technology A	Shell E-Fluid Technology B	ATF Technology	Gear Oil Technology
ASTM D130 150° C/ 168h - Copper in Oil	12 mg 	41 mg 	331 mg 	927 mg 
Copper Wire Corrosion Test 130° C / 240hr EDX: S-Content on Surface	 			 
FZG A10/16.6R/90 - Failure Load Stage	7	≥10	5	>10

OPTIMIZING THERMAL AND OXIDATIVE STABILITY (CEC L-48-A)

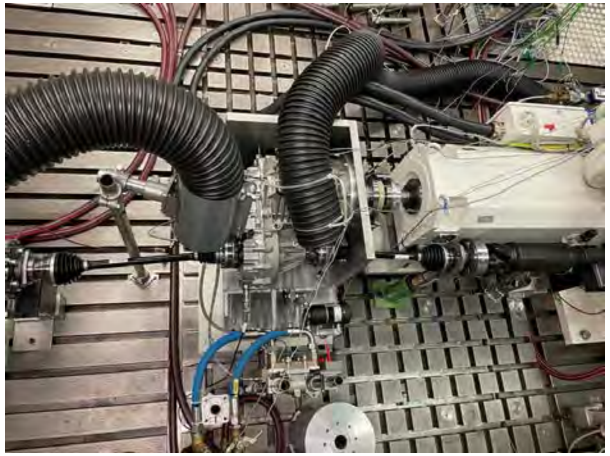
Test parameters	Shell E-Fluid	ATF	Gear Oil (MTF)
180°C, 192h - KV40 Increase % - KV100 Increase % - Delta TAN mgKOH/g	+4,0 +3,0 +0,55  		
170°C, 192h - KV40 Increase % - KV100 Increase % - Delta TAN		+ 9,9 + 7,3 + 1,6 	
150°C,192h - KV40 Increase % - KV100 Increase % - Delta TAN			+17,2 +8,6 +4,8 

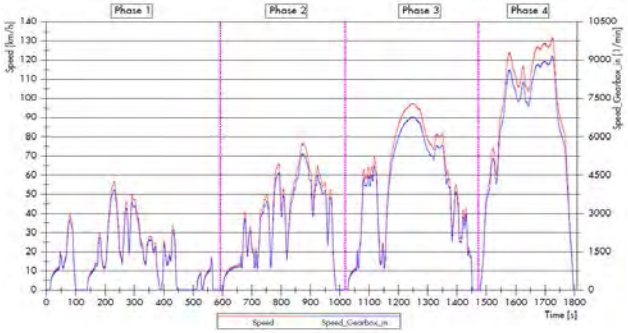
IN-HOUSE SAFETY ASSESSMENT OF LUBRICANTS FOR E-MOTOR COOLING





EFFICIENCY MAPPING

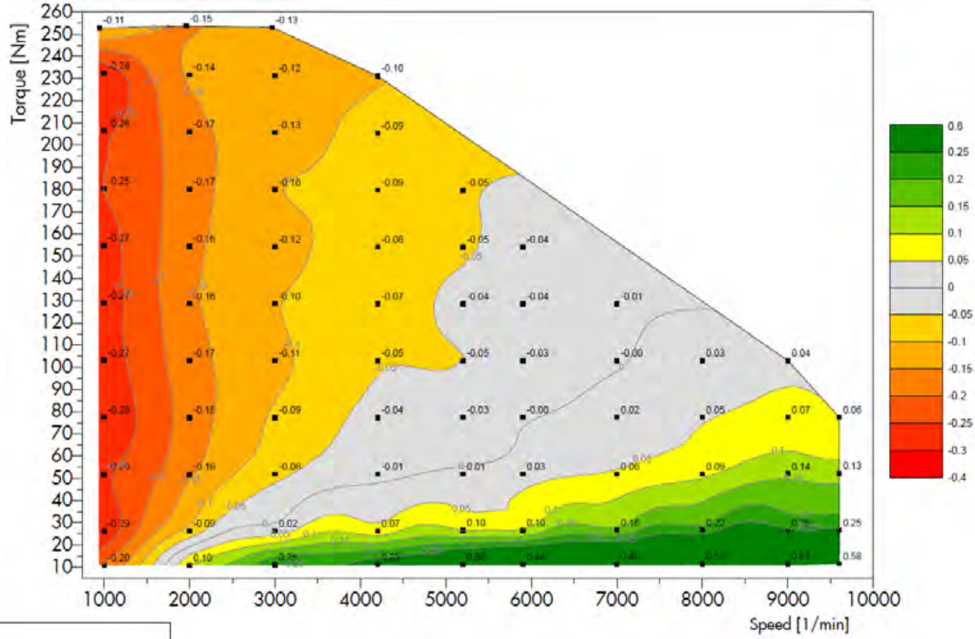


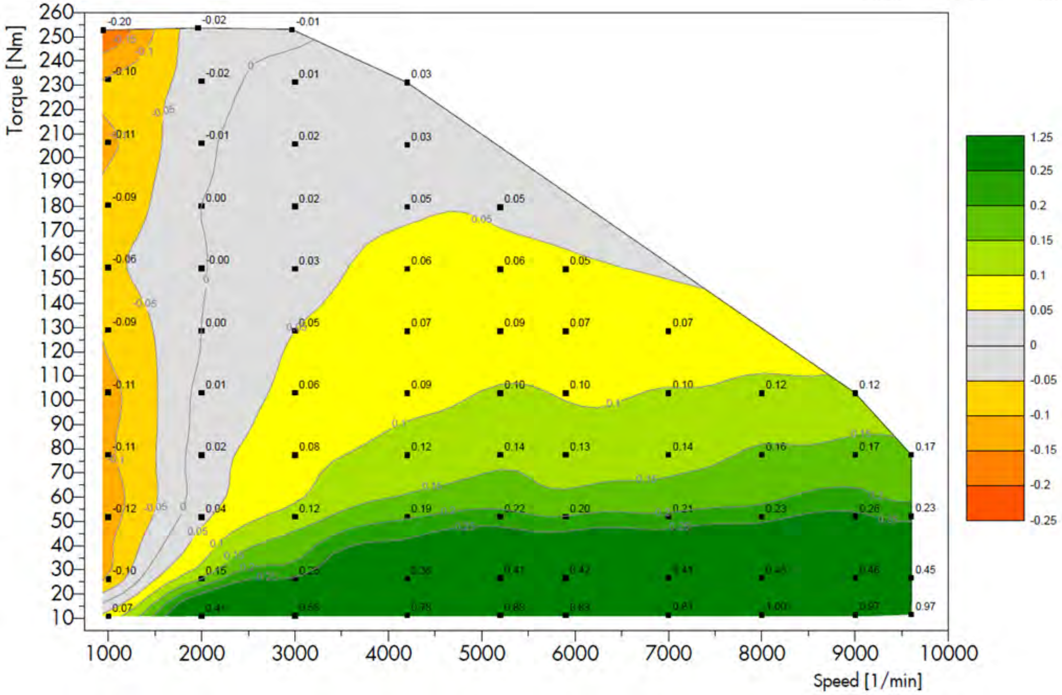


At 60˚C oil temperature:

Benefit of a 4 cSt fluid over a 6 cSt fluid.

☞ Efficiency is not seen at all conditions tested.





At 40˚C oil temperature:

Benefit of a fluid with optimized base oils and additives over a fluid of the same viscosity.

☞ Fluid chemistry can be optimized for efficiency at certain conditions.

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COMPATIBILITY SCREENING OF INSULATION MATERIALS


Material A


Material B


Material C


Material D


Wire 1

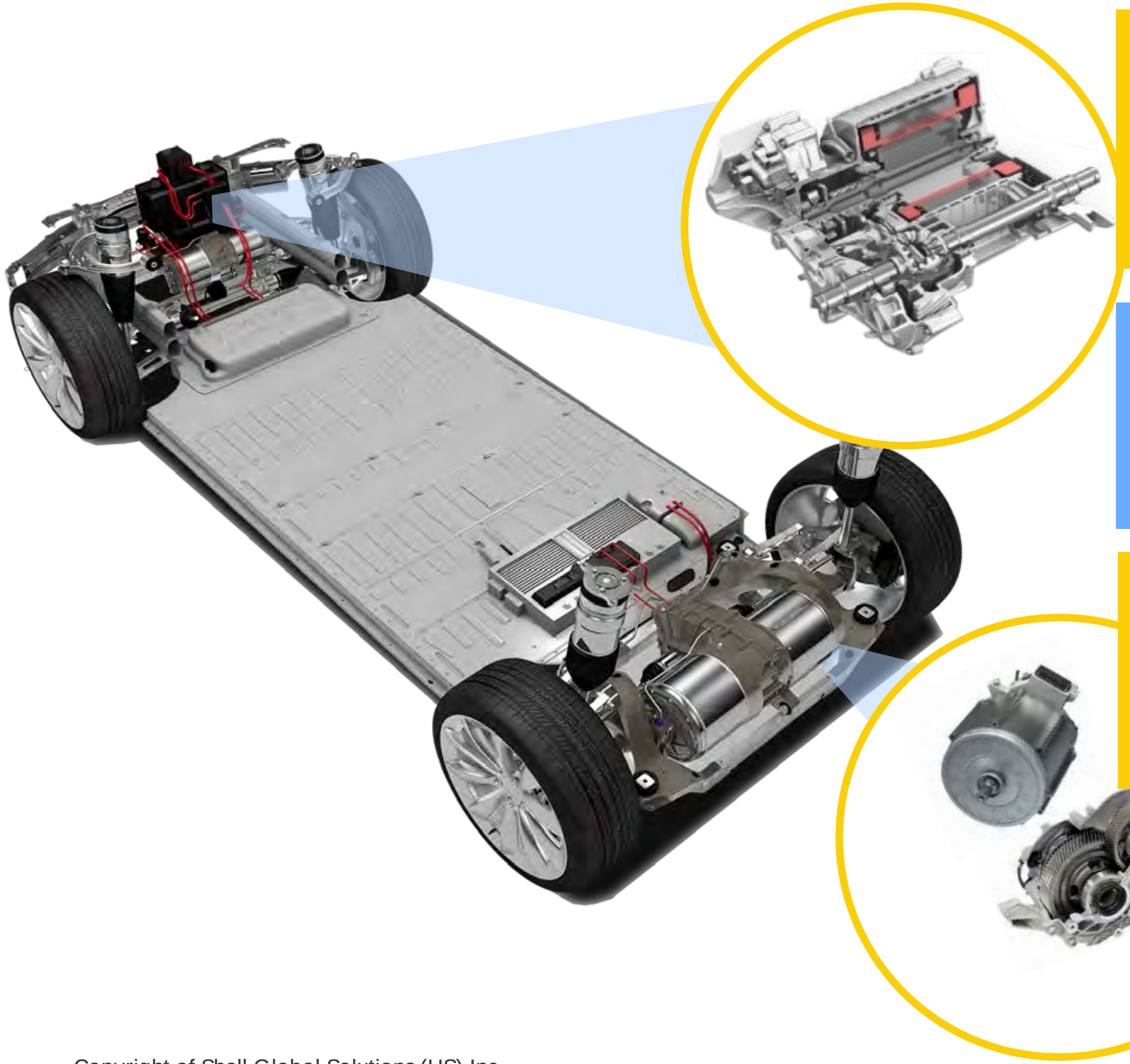

Wire 2


Wire 3


Wire 4

- To optimize insulation materials and improve e-motor reliability (*T/CEEIA 415*).
- Different insulation materials respond differently to the lubricant.

LUBRICANTS AND GREASES IN ELECTRIC VEHICLES - OUTLINE



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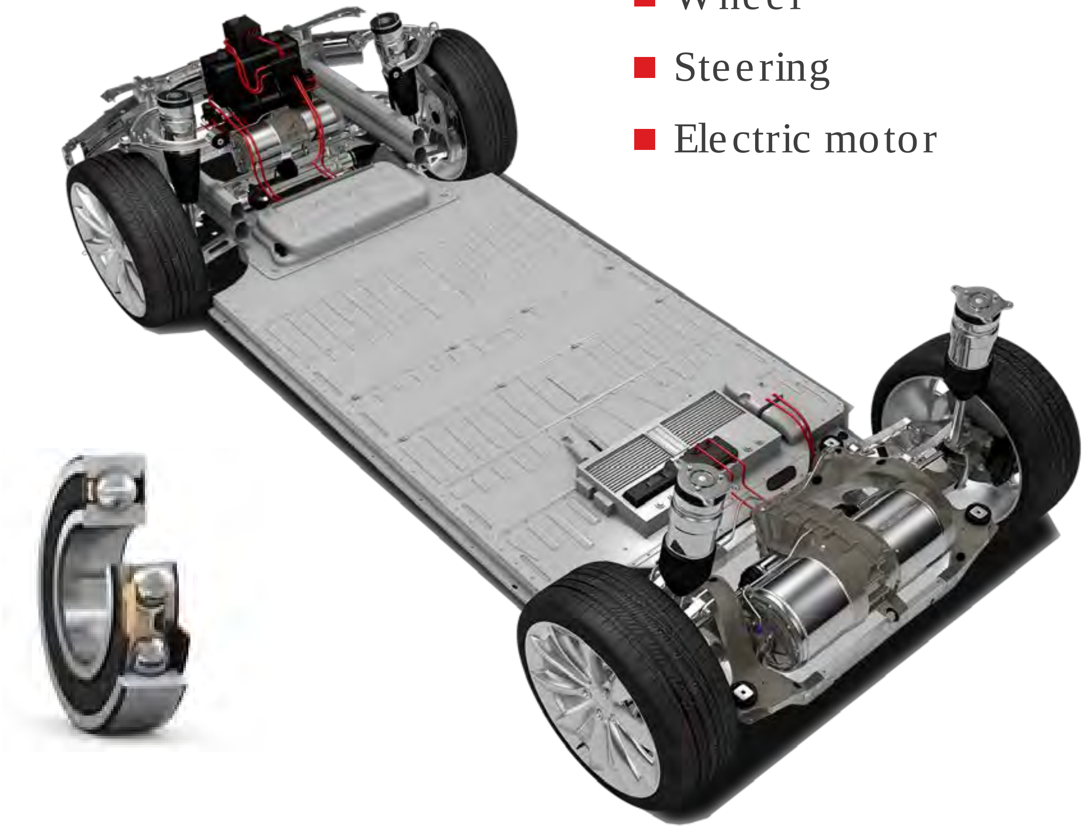
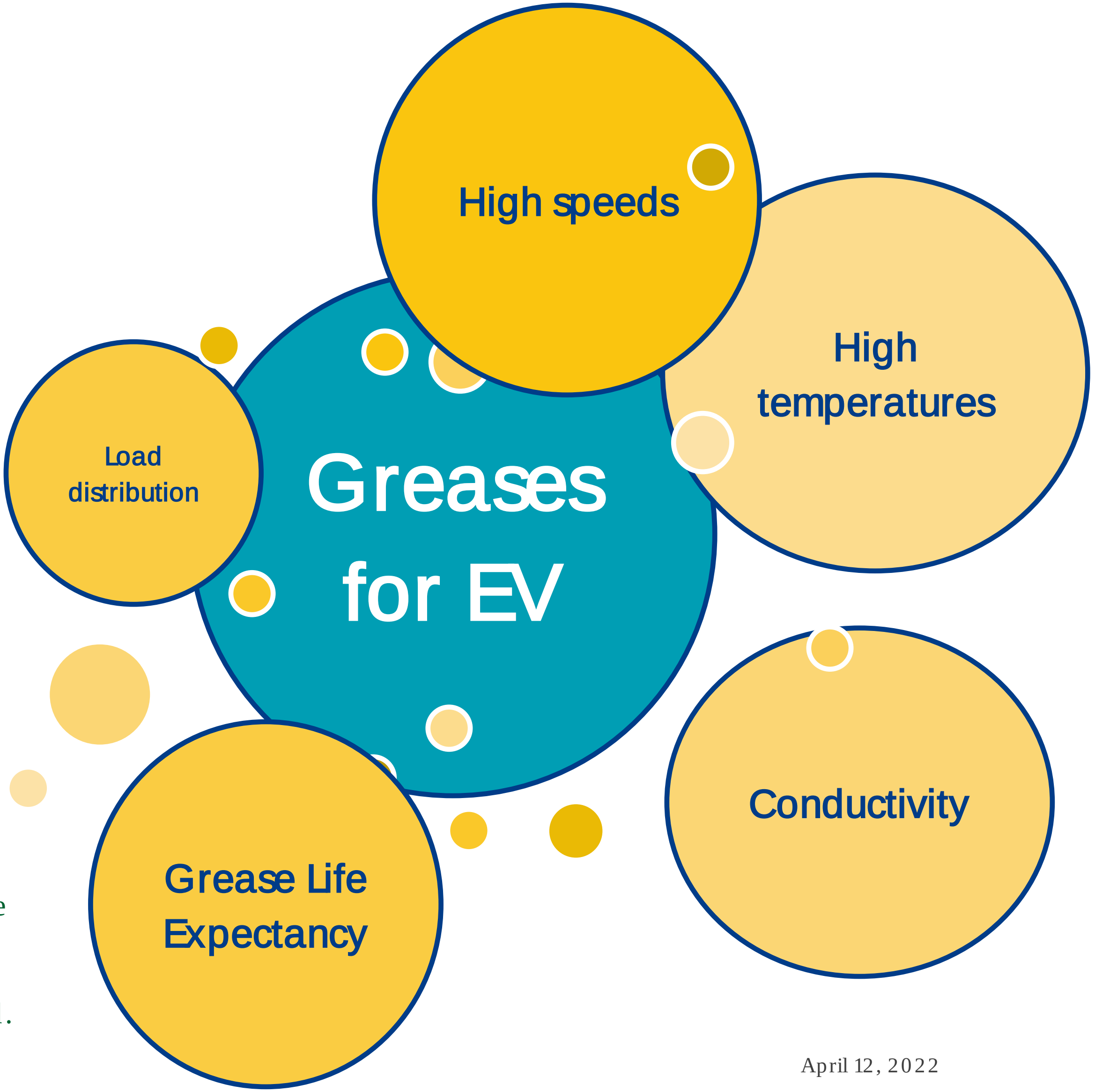
EV CONDITIONS THAT CHALLENGE GREASE FORMULATIONS TO CHANGE



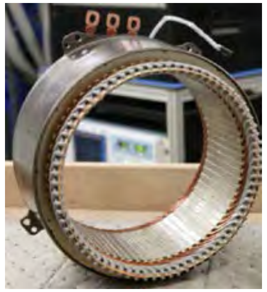
- Wheel
- Steering
- Electric motor

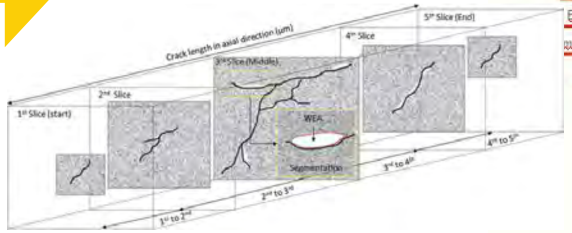


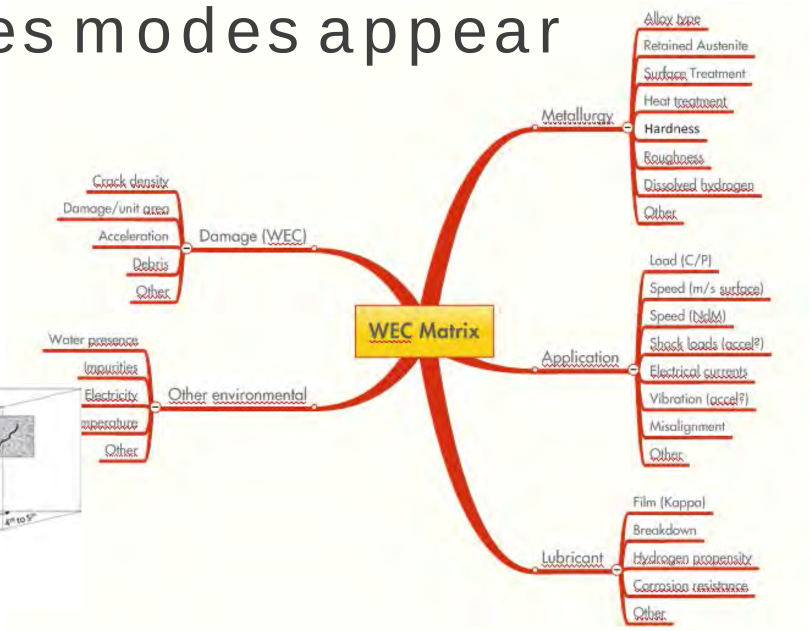
Bearing size and rotational speed during variable driving conditions need to be addressed in formulary design .

A high level of variability in OEM-to-OEM design and parameters is anticipated.

With E-Mobility known but more severe failures modes appear

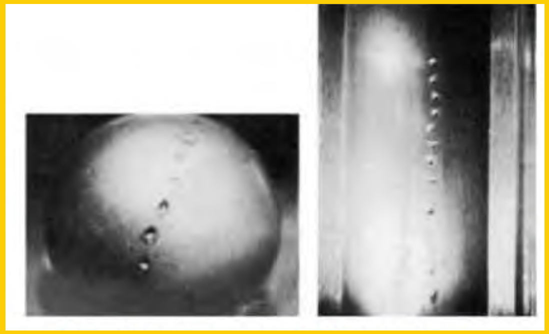






Electrical Discharges through high voltages

- Destroyed lubricant
- Grooves on the race outer ring
- Weld puddles on rollers and cage



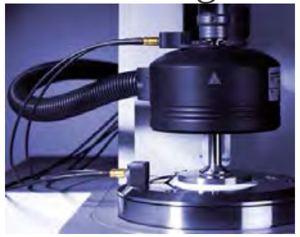
… and many more

… dedicated failure modes require dedicated testing and knowledge

Shell E-Greases

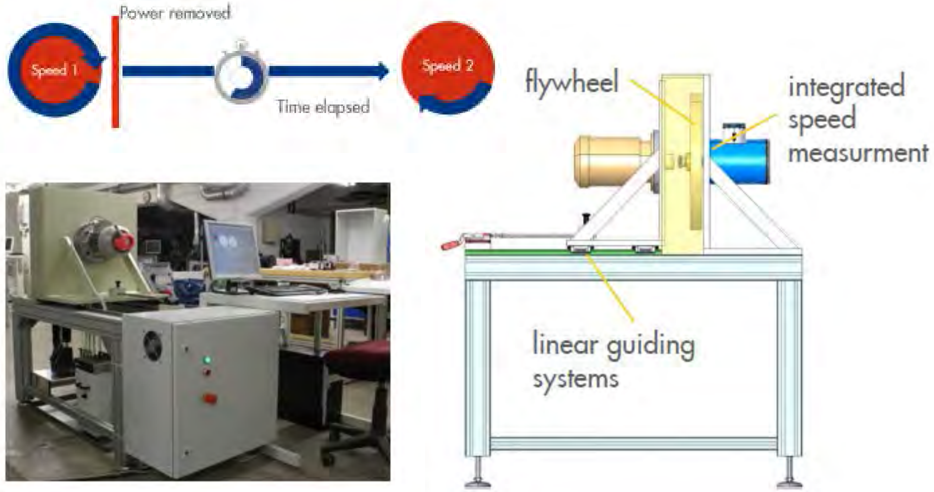
- Dedicated product line for E-Mobility
- Dedicated operating conditions
- Dedicated test rigs and tools

Lubricating film and electrical discharging

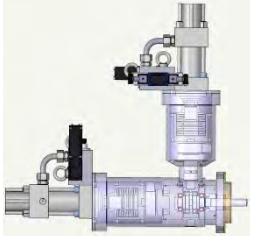


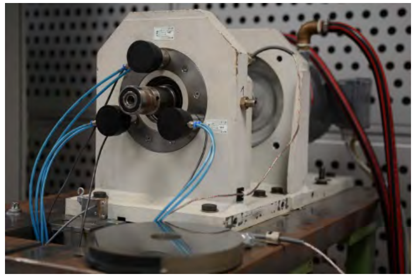
- Evaluating the effects of non- & Ionic fluids, graphite and alternative solids under tribological conditions

unique energy efficiency (EE) rig

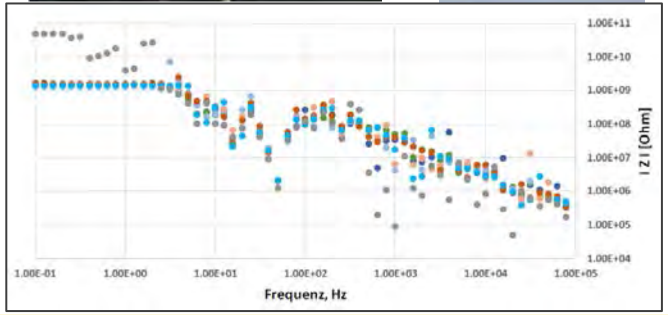


Bearing failure due to electric current





Impedance and electric conductivity



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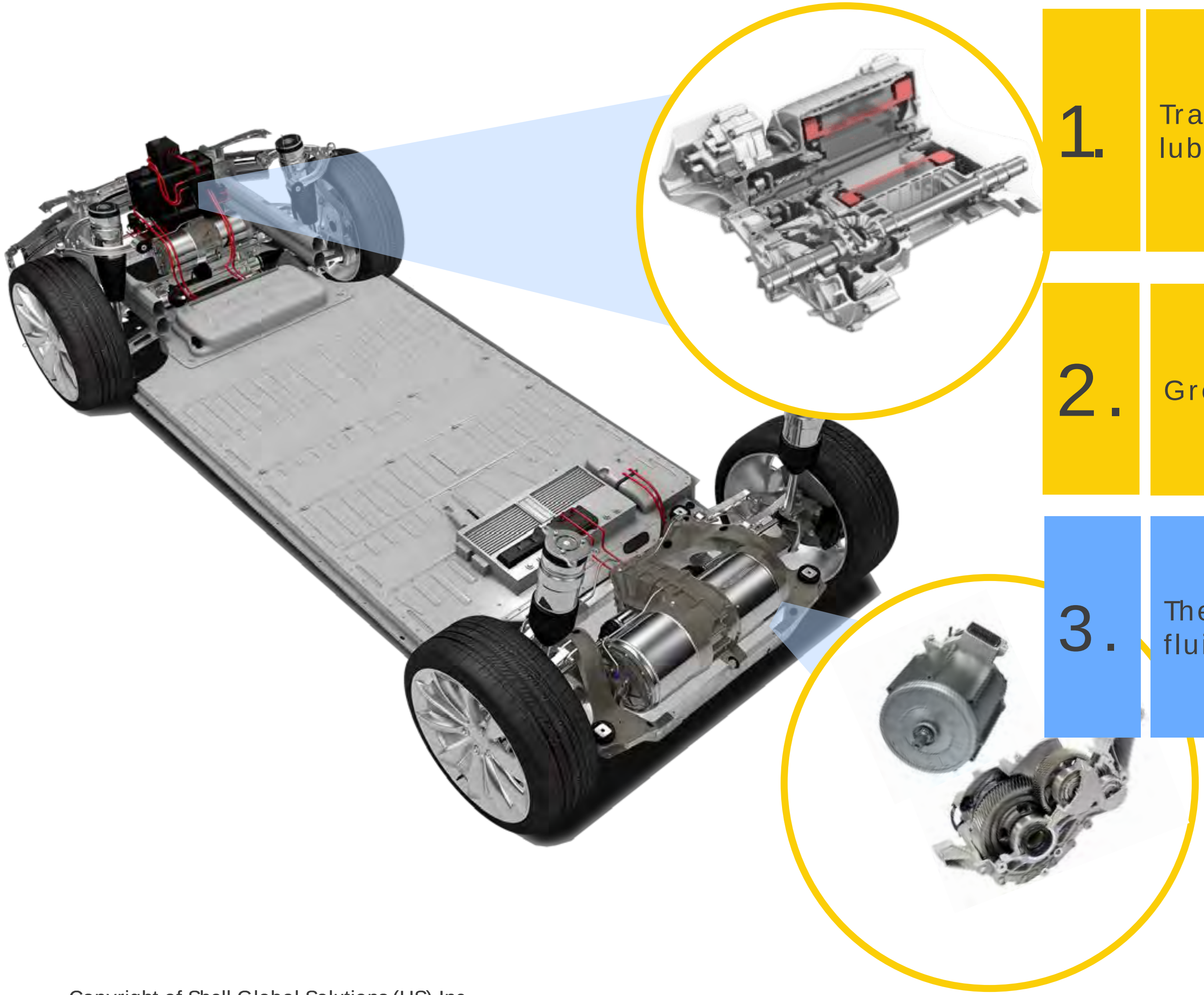

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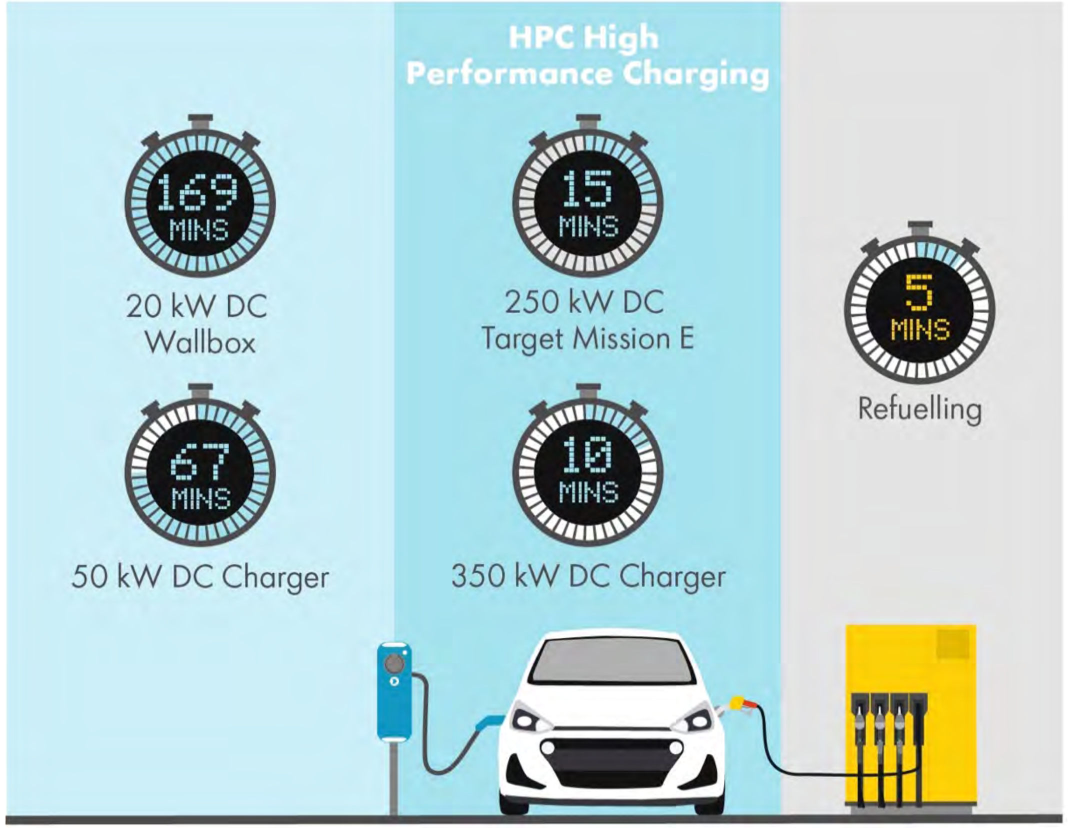
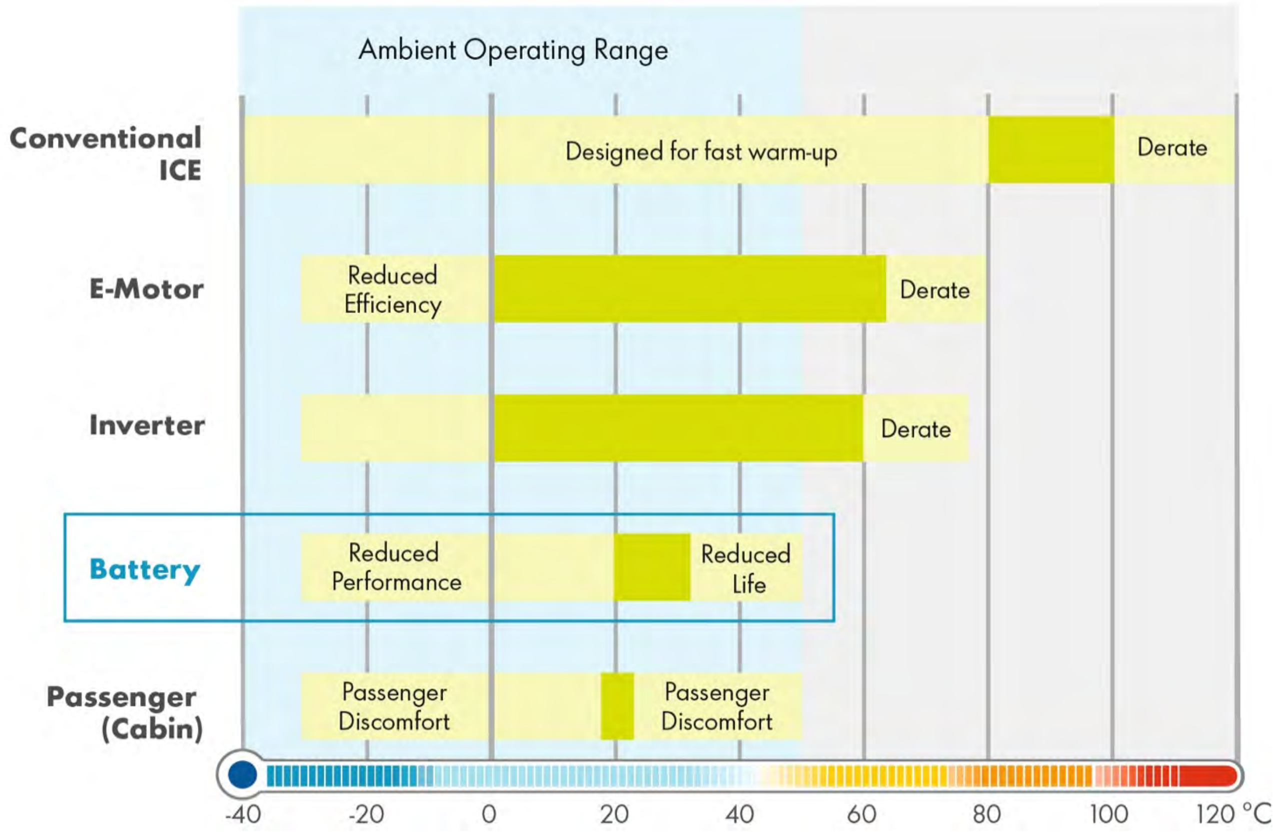
High performance charging will increase thermal stress to batteries

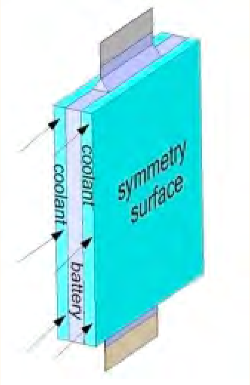
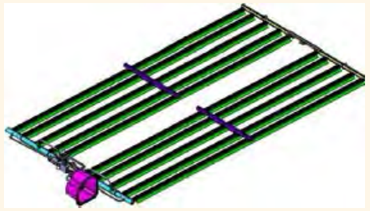
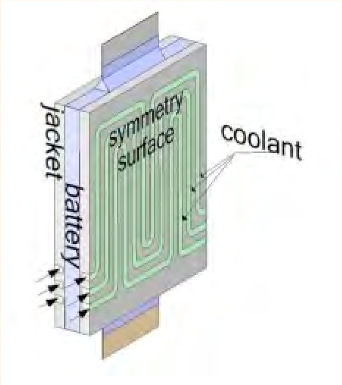
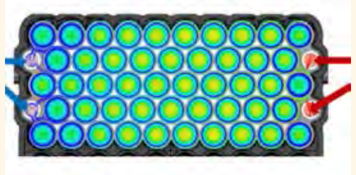
Charging times for 80 % battery capacity lift





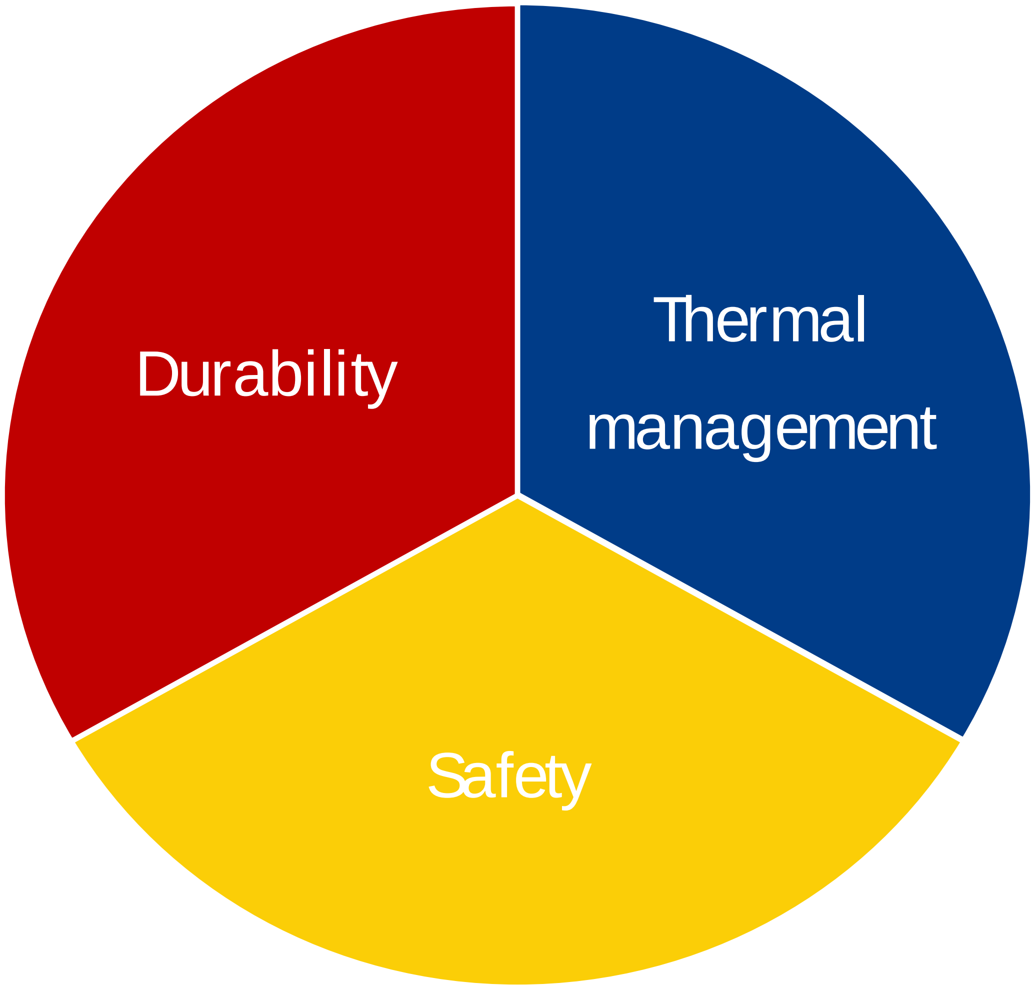
The battery system is one of the most valuable components in BEVs

Battery cooling concepts

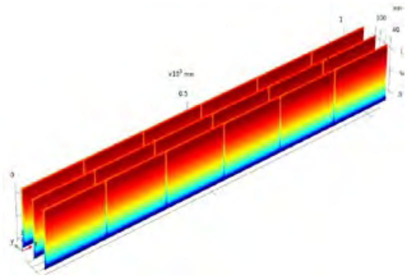
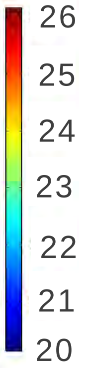
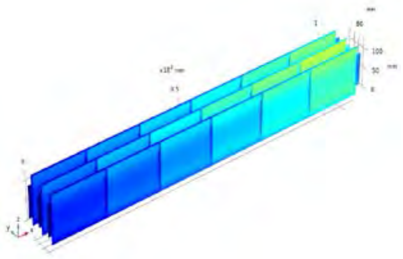
	Air cooling	Evaporative	Liquid	Liquid	Phase change
Type	active / passive	indirect	indirect	immersive	direct
Working media	Air	Refrigerant	Water/ glycol	Dielectric fluid	Phase change material
Cooling	-	0	0	+	0
Heating	-	-	0	+	-
Design complexity	+	-	0	0	+
Fast charging	-	0	+	+	0
Safety / Abuse performance	-	+	0	+	0
Examples	 Source b)	 Source a)	 Source b)		 Source c)

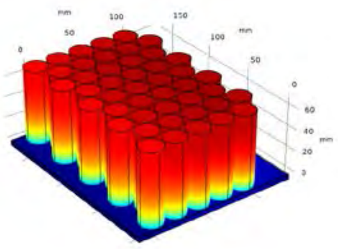
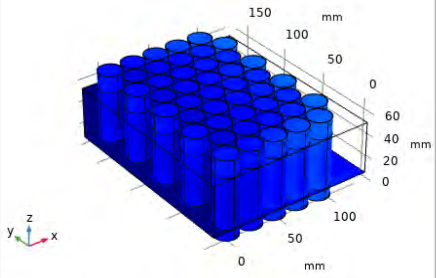
Source a) F.Schoewel, E. Hockgeiger, BMW, AABC 2014, February 3TH-7TH, Atlanta
Source b) Applied Thermal Engineering, Volume 94, 5 February 2016, Pages 846-854, DafenChen JiuchunJiang Gi-HeonKim ChuanboYang AhmadPesaran[b]
Source c) https://allcelltech.com/#section-about2

Key development areas for immersive battery cooling



Comparison of conventional and immersive cooling by CFD Modelling

Battery module with prismatic cells and 2W per cell		
Conventional Water/glycol (50/50)	T [°C]	Immersive Shell Thermal Fluid E5 TM 410
		

Battery module with cylindrical cells and 2W per cell		
Conventional Water/glycol (50/50)	T [°C]	Immersive Shell Thermal Fluid E5 TM 410
		

Advantages of immersive cooling:
- Better cooling and better temperature homogeneity within cell and module
- Can enable faster charging & can extend battery life

Abuse test GB 38031-2020 with Prismatic Cell Immersion Cooling

Prismatic cells	Parameter
Anode	Graphite
Cathode	NMC 622
Energy density	176 Wh/kg
Rating voltage	3,7 V

Test conditions

- Static conditions
- No thermal insulating material
- No flame retardant

Collaboration

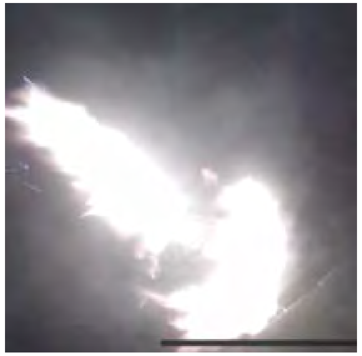
清華大學 苏州汽车研究院
Tsinghua University Suzhou Automotive Research Institute

国内某 / Tier 1 OEM

Module

No fluid (air)

T = 0
Thermal Runaway



0 < t < 5 mins

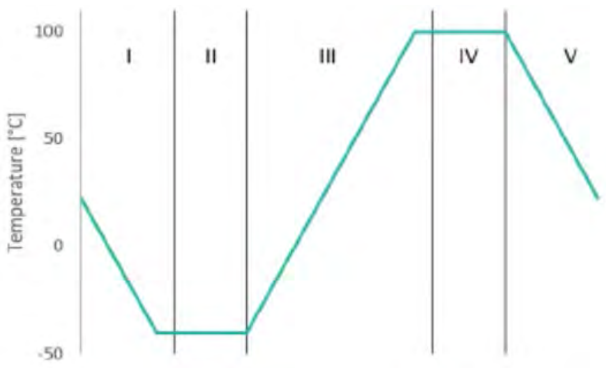
Immersed with Shell Thermal Fluid E5 TM 410

T = 0
Thermal Runaway

0 < t < 5 mins

t > 5 mins

Lifetime assessment of Kreisel battery & Shell Thermal Fluid



Temperature cycle

5 x 2S stacks (10 hollowblocks) with dummy cells (limiting samples), filled with cooling liquid at maximum steady system pressure (P_{rel} = 1 bar)

Parameters

- Different modes (driving, loading, on- and off-grid parking
- Coffin-Manson equation taking into account statistical significance

$$N_{Lab} = N_{Field} \cdot \left(\frac{\Delta T_{Field}}{\Delta T_{Lab}}\right)^{c} \cdot \left(\frac{ln(1-P_A)}{n \cdot ln(R)_r}\right)^{1/\beta}$$

Comparison of key fluid data before and after test

Test	Unit	Fresh fluid	Used fluid	Result	Limits
Visual inspection		Clear & bright	Clear & bright	pass	Dark & turbid*
Break down voltage	kV	>30	58	pass	<30*
Tan delta @ 90° C		<0,005	0,025	pass	>0,5*
Resistivity @ 90° C	GOhm* m	12000	20	pass	<4*
Acidity	mg KOH/ g	<0,01	0,1	pass	>0,30*
Water	mg/ kg	5	11	pass	>40*
KV 40	mm2/ s	9,8	9,9	pass	+/ - 5%

Data source: Kreisel Electric

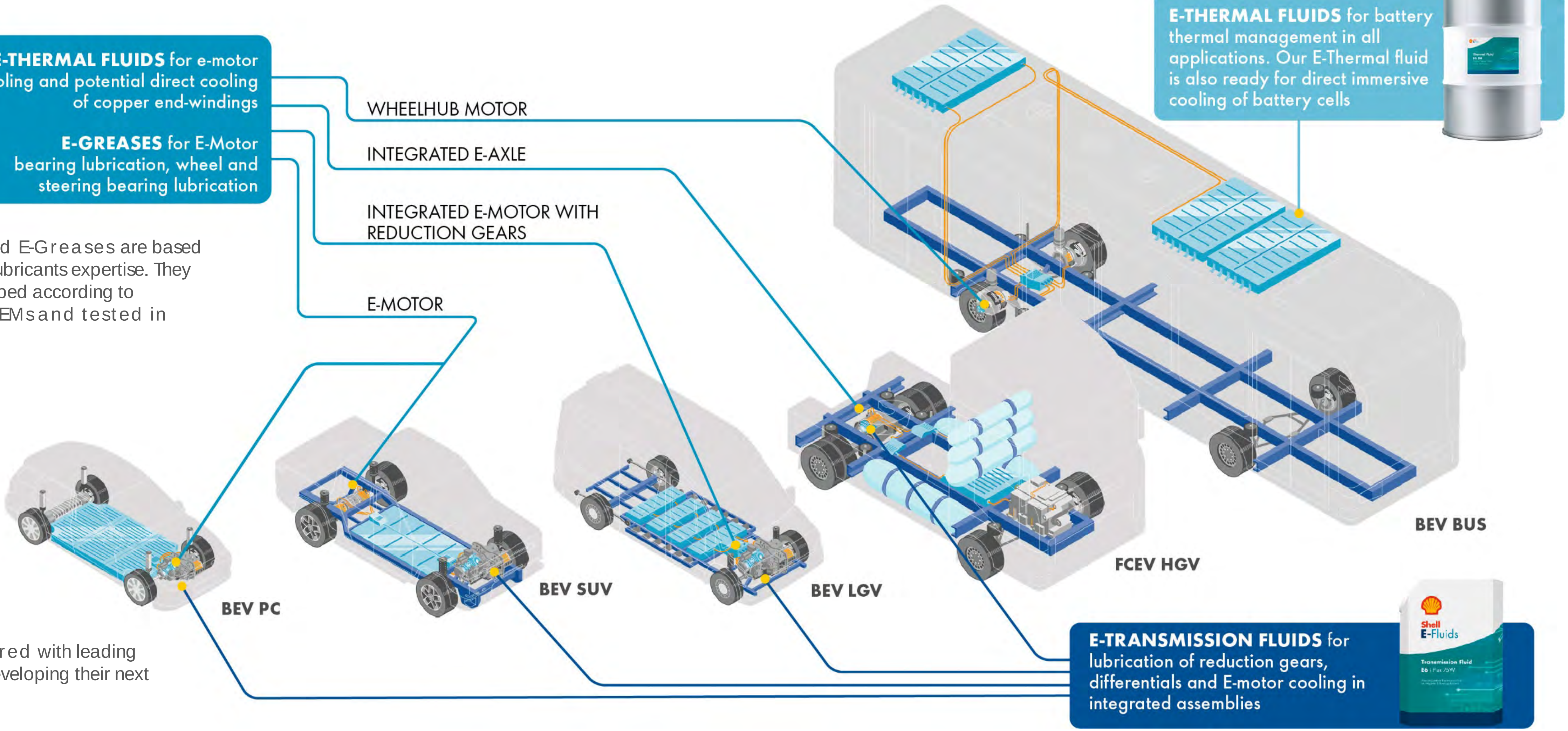
* From IEC 60422 maintenance guide

APPLYING OUR SHELL E-FLUIDS AND E-GREASE PORTFOLIO

E-THERMAL FLUIDS for e-motor cooling and potential direct cooling of copper end-windings

E-GREASES for E-Motor bearing lubrication, wheel and steering bearing lubrication

Shell E-Fluids and E-Greases are based on our extensive lubricants expertise. They have been developed according to requirements of OEMs and tested in Formula E.



We have partnered with leading OEMs who are developing their next generation of EVs