



**TRANSFORMER-LIFE-MANAGEMENT
CONFERENCE**

**Recent information about an inhibited transformer oil
based on Shell GTL technology**

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RECENT INFORMATION ABOUT AN INHIBITED TRANSFORMER OIL BASED ON SHELL GTL TECHNOLOGY

TLM Conference
Dubai, October 27-28, 2015



Dr. Joerg Friedel
Product Application Specialist

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DEFINITIONS AND CAUTIONARY NOTE

Cautionary Note

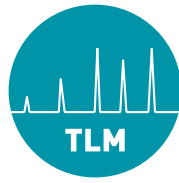
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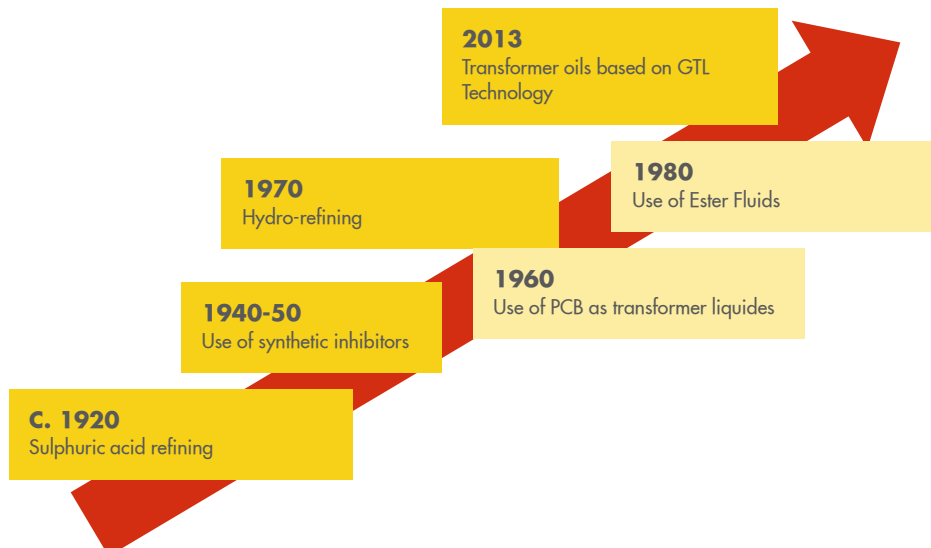
AGENDA

- GTL-process and use of GTL products
- History of transformer oils
- Diala S4 ZX-I properties
- Diala S4 ZX-I field experiences
- Diala S4 ZX-IG

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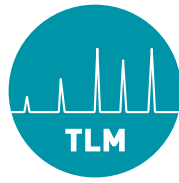
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THE EVOLUTION OF HYDROCARBON TRANSFORMER OILS



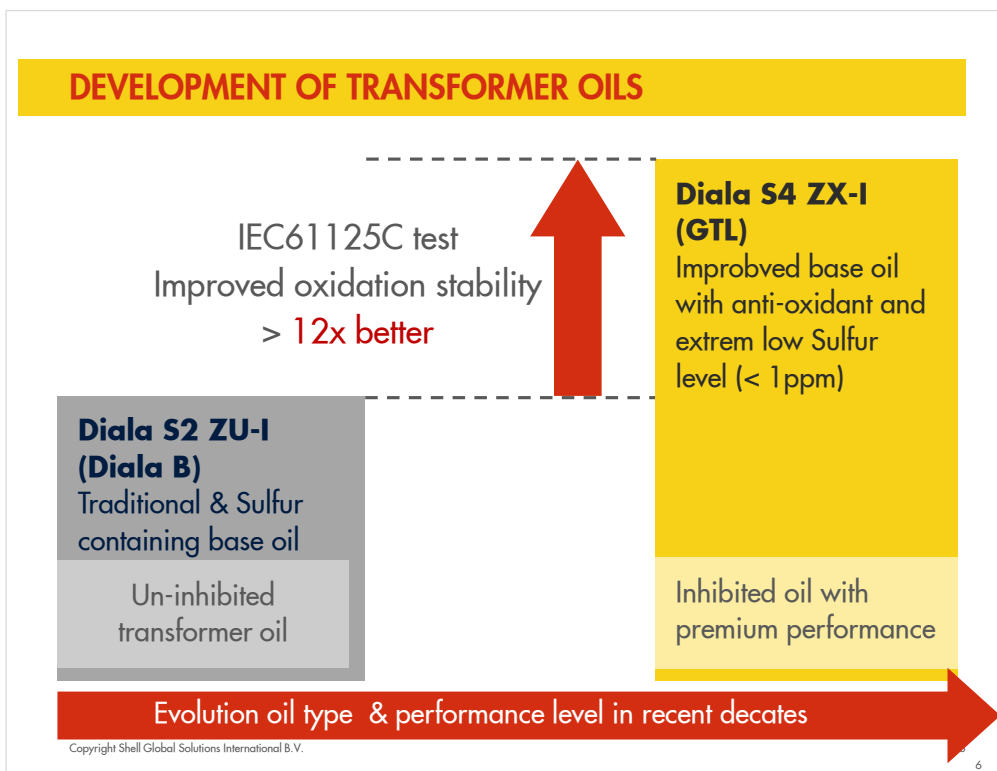
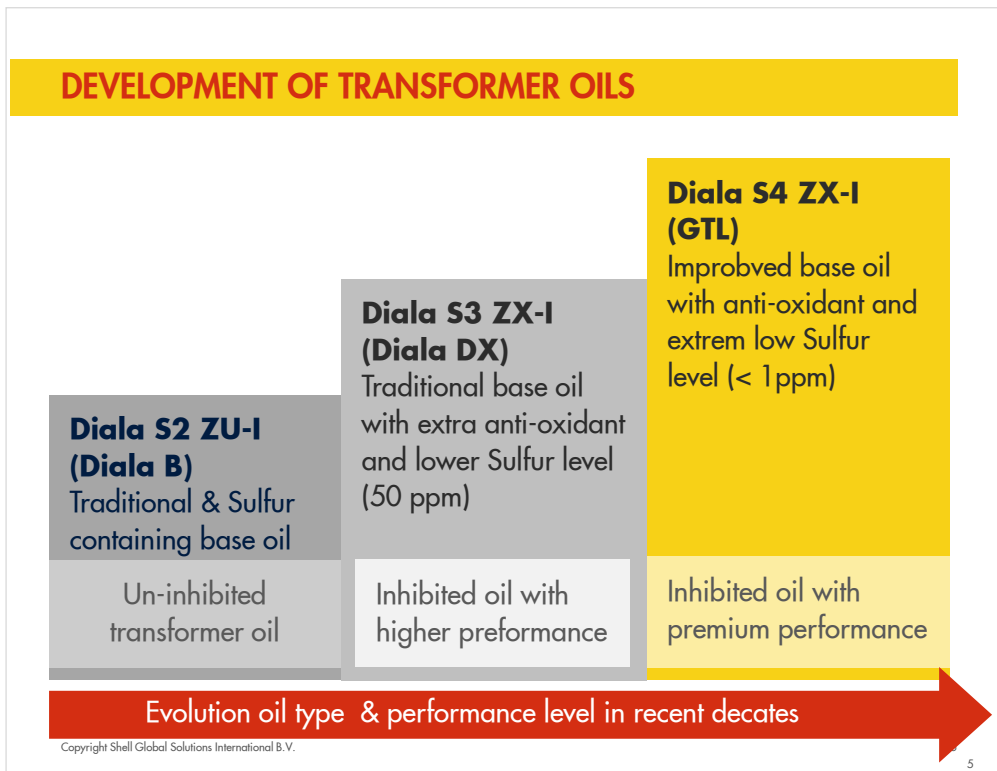
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DEVELOPMENT OF TRANSFORMER OILS

Properties	IEC 60296 spec (7.1)	Diala S4 ZX-I	Diala S4 ZX-I (GTL + 0,2 % DBPC)
BDV	30+ kV	60-75 kV	Reliability
Flashpoint	> 135°C	191°C	Safety
Viscosity -30oC	< 1800 cSt	523 cSt	Fast cold start up
Pourpoint	< - 40°C	- 42°C	Allround applicable
Sulfur %	< 0,05%	Sulfur free	No risk on Cuper / Silver & Sulfur corrosion
Oxidation test (500 hours)			
*Acid nr (TAN)	< 0,3	0,02	Very high oxidation resistant
*Deposit / sludge	< 0,05	< 0,01	
*DDF	< 0,05	0,001	

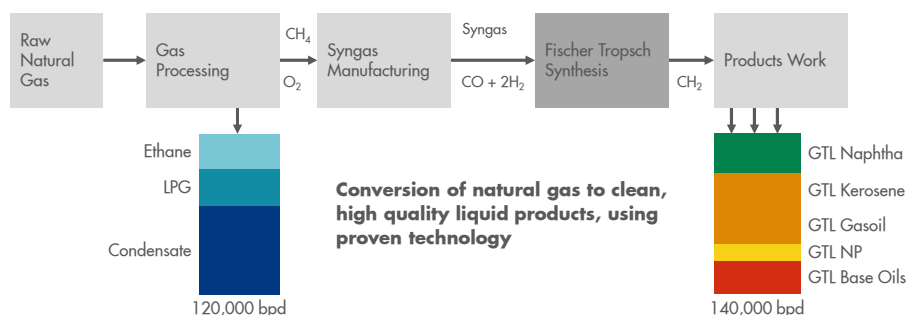
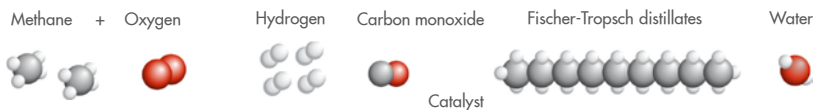
Evolution oil type & performance level in recent decates

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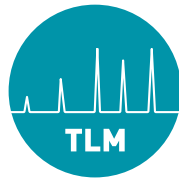
SHELL GAS TO LIQUID PROCESS

The Shell GTL process transforms natural gas into liquid and solid hydrocarbons with high purity.



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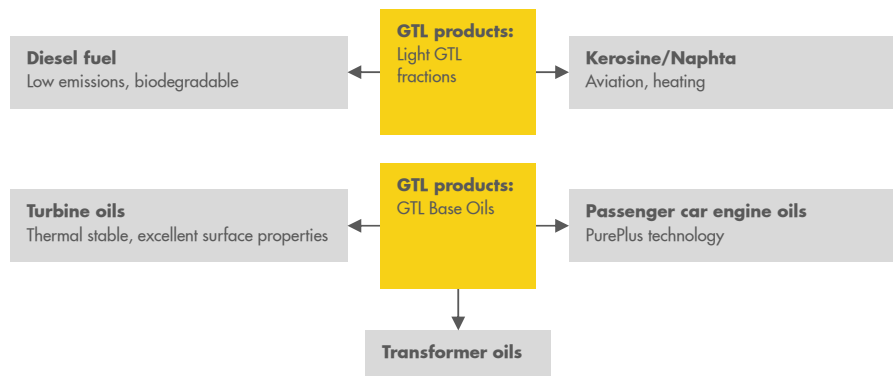
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CURRENT USE OF GTL PRODUCTS



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**EXCEPTIONAL RESISTANCE TO OXIDATION VERSUS LEADING
COMPETITOR TECHNOLOGY**

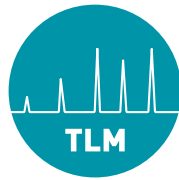
IEC 61125C	Metric	Competitor Oil X 670 hours	Competitor Oil X 690 hours	Diala S4 ZX I 690 hours	Diala S4 ZX I 980 hours
Total Acidity	mg KOH/g	1,71	2,15	0,01	1,05
Sludge	m%	0,10	0,14	<0,01	<0,01
DDF	-	0,035	0,035	0,0017	0,0063

Table shows Shell data

- Procedure: Oxidation IEC 61125C – samples in parallel testing, volatile acidity is monitored.
- Standard test time in IEC 61125C for inhibited products is 500hours.
- Oil X is an „ultra grade“ naphthenic oil.

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TYPICAL DATA SHOWS THE PROPERTIES THAT DIFFERENTIATE SHELL DIALA S4 ZX-I

	Unit	Standard	IEC 60296 Table 2 + section 7.1	
Density 20 °C	kg/m ³	ISO 3675	max. 895	805
kin. Viscosity 40 °C	mm ² /s	ISO 3104	max. 12	9,6
kin. Viscosity -30°C	mm ² /s	ISO 3104	max. 1800	382
Flashpoint PM	°C	ISO 2719	min. 135	191
Pour Point	°C	ISO 3016	max. -40	-42
Total Sulphur content	mg/kg	ASTM D 5185	max. 500	< 1
DBPC content	%		0,4	0,2
Volatility 107 °V, 22 h	% m	ASTM D 2007		0,75
Dielectric dissipation factor (DDF) 90 °C		IEC 60247	max. 0,005	< 0,001
Oxidation stability (500h/120 °C)		IEC 61125C		
Total Acidity	mg KOH/g		max. 0,3	0,02
Sludge	% m		max. 0,05	< 0,01
DDF at 90 °C			max. 0,05	0,001

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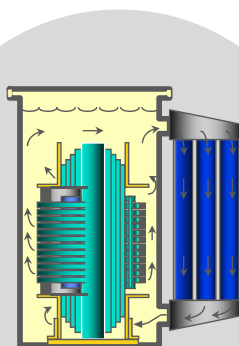
TRANSFORMER OIL REQUIREMENTS

Dissipate heat

- High heat conductivity (9 % higher)*
- Low viscosity in the cold (200 mm²/s lower at -30°C)*

Protection

- Prevention of copper corrosion (< 1 ppm sulphur)
- Maintaining low acidity to protect paper insulation



Electrical insulation

- High impulse breakdown voltage (app. 50 kV higher)*
- Low conductivity

Carry information

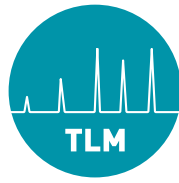
- Detect impurities via measurement of interfacial tension
- Detect heat or electrical issues using DGA – Duval triangle

Ageing resistance: must be maintained over oil life time. Therefore oxidation stability is key (GtL based oil has 5x higher oxidation stability).*

*comparison against naphthenic high grade Diala S3 ZX-I

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SHELL DIALA S4 ZX-I COOLING PROPERTIES

- Customer Transformer trials* showed comparable or better cooling properties for GtL based oils compared to conventional oils.
- Calculation of the heat transfer coefficient α in a tube:
 α is higher for GTL based oils. TFO is higher than naphthenic based TFO – for laminar and turbulent flow. The differences are small.
- Modeling showed advantages for GtL based oil especially on high stress conditions
- Parameter influencing cooling properties:
 - Specific Heat Capacity
 - Thermal Conductivity
 - Viscosity
 - Density

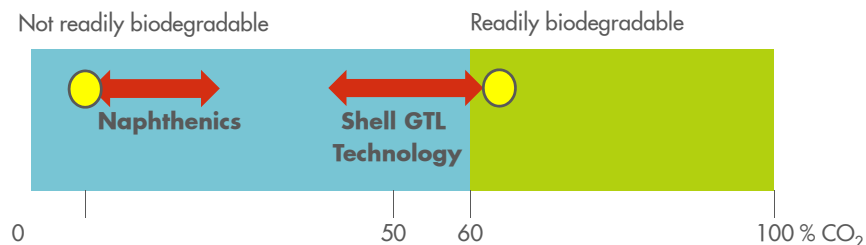
*Customer trials run by OEMs & Utilities

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BIODEGRADABILITY OF BASE OILS OECD 301B

Fluids with Shell GTL Technology can be more quickly consumed by microorganisms than naphthenic oils.



- 28 day test
- Mineralisation of test material to CO₂
- Pass level is > 60% theoretical CO₂ evolution

Newest Results from BFB Oil Research:
Diala S4 ZX-I: 61,5 %
Diala S3 ZX-I: 11,2 %

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**IN MANY WAYS, SHELL DIALA S4 ZX-I REMAINS SIMILAR TO
MINERAL BASED TRANSFORMER OILS...**

	GtL based transformer oil
Dissolved gas analysis	DGA interpretation can use same tools as for traditional hydrocarbon oils (e.g. with Duval diagram)
Failure Detection	In case of a transformer failure (e.g. due to PD) Hydrogen will be generated, Buchholz relay can release an alarm
Material compatibility	Compatibility given for materials which are compatible with mineral oils - Same substance class as mineral oils (hydrocarbons)
Water solubility	Comparable with naphthenic transformer oils
Compatibility with naphthenic oils	Given (used and unused oils), no issue observed in many tests

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POSITIVE EXPERIENCES WITH GTL TRANSFORMER OIL

Since 2013 GtL transformer oil has been used to fill thousands of transformers across three continents, more than 25 Mio litre has been sold.

For applications in

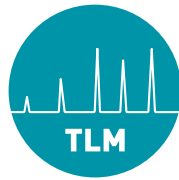
- Distribution transformers
- Power transformers
- Reactors
- Instrument transformers
- Traction transformers



- Good Performance – no issues observed, function as expected for an high grade oil
- No design or maintenance changes required (possible optimization and maintenance reduction being explored!)
- Proven to be able to detect failures in transformers by initiating Buchholz relay alarm

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PERFORMANCE AFTER ONE YEAR IN SERVICE

- New transformers filled with Diala S4 ZX-I –first oil analysis after one year in service

Type	N2	O2	CO2	CO	H2	CH4	C2H2	C2H4	C2H6	C3H6	C3H8	TAN	BDV	DDF	BHT	IFT
380kV-grid transformer (350 MVA)	53423	24974	226	114	2	1	0	0	0	10	0					
380kV-grid transformer (350 MVA)	6849	4262	191	51	0	1	0	0	0	0	0	0	75	0,001	0,21	48
380kV-grid transformer (350 MVA)	3006	1639	74	18	0	0	0	0	0	0	0					
30kV-reactor (50MVA)	62753	31889	429	74	3	0	0	0	0	0	0					
30kV-reactor (50MVA)	38678	15444	178	36	0	1	1	1	1	0	0	0	78	0,0009	0,22	47
30kV-reactor (50MVA)	63935	31640	436	88	3	7	0	12	0	3	0					
30kV-reactor (50MVA)	57350	28661	131	41	4	7	0	8	0	0	0	0	86	0,004		44
30kV-reactor (50MVA)	68358	34739	378	85	4	7	0	0	0	0	0					
30kV-reactor (50MVA)	54609	24606	888	69	7	6	0	2	18	0	0	0	72	0,0002	0,2	46
30kV-reactor (50MVA)	5788	3422	95	42	1	0	0	1	0	0	0	0	86	0,004	0,23	42

Source: Amprion/Siemens

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PERFORMANCE IN A TRANSFORMER REFILLED WITH DIALA S4 ZX-I

- GTL oil still bright with no signs of sludge after 18 months

Date	CO ₂	CO	H ₂	CH ₄	C ₂ H ₂	C ₂ H ₄	C ₂ H ₆	TAN	BDV	DDF	IFT
10 Jul 12	1,178	221	164	3.5	0.01	2.3	1.4	0.06	61	0.207	22.2
23 Oct 12	1,595	126	6.2	5.3	0.01	3.9	3.5	0.06	73	0.264	22.6
30 Jan 13	1,342	100	202	2.4	0.01	2.4	1.9	0.06	60	0.299	
15 May 13	1,153	139	174	2.8	0.01	2.1	1.7	0.06	83	0.121	23.6
04 Jul 13	79	2	3.1	0.6	0.01	0.1	0.1	0.01	88	0.061	37.4
28 Aug 13	182	17	12	1.2	0.01	0.4	0.3	0.01	83	0.021	36.3
11 Dec 13	547	43	89	1.9	0.01	0.6	0.5	0.01	89	0.034	36.4
26 Jan 14	79	2	0.5	1	0.01	0.2	0.1	0.01	78	0.034	32.2
24 Mar 14	169	35	6.1	1.5	0.01	0.3	0.3	0.01	84	0.022	32.2
02 Jul 14	625	75	9.8	2.7	0.01	0.3	0.2	0.01	72	0.022	35.2
25 Nov 14	473	76	1.9	1.8	0.43	0.4	0.4	0.01	66	0.034	33.7

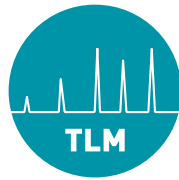
Source: EDF UK

Power plant station unit transformer (10 years old)

Hawker Siddeley (1986), 132 kV, 90 MVA, free breathing. Changed to Shell GTL oil June/July 2013. Vacuum applied January 2014. No issues

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SHELL RECOMMENDATION FOR USE OF SHELL DIALA S4 ZX-I

In the case of a change from Shell Diala S2/Shell Diala S3 to Shell Diala S4 ZX-I

Vacuum Treatment and Filtration	No change to Shell Diala S3
Oil Reclamation	No change to Shell Diala S2/S3
Top up Diala S2/S4	Up to 10 % no objection*
Fill old transformers	15 % remaining oil acceptable*
Oil monitoring	As described in IEC 60422
Interpretation of DGA	As described in IEC 60599
Concentration measurement of Antioxidant	As described in IEC 60666

* Assuming that the oil is not heavily aged

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Shell Diala S4 ZX-IG

	Diala S3 ZX-IG	Diala S4 ZX-IG	Diala S4 ZX-I
Density [kg/m ³]	886	806	805
V40 [mm ² /s]	8,0	9,4	9,6
Flash Point [°C]	136	158	191
Pourpoint [°C]	-57	-42	-42
Oxidation 500h/120°C TAN [mgKOH/g]	1,0 Limit 0,3*	0,02	0,02
Sludge [m%]	0,45 Limit 0,05*	< 0,05	<0,01
DDF	0,12 Limit 0,05*	0,001	<0,0003
Gassing tendency IEC	-10	-5	30

■ Fulfils IEC 60296 high grade specification (§ 7.1)

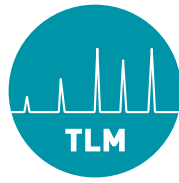
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■ Fulfils ASTM D 3487 type II specification including gassing tendency

* High grade limits

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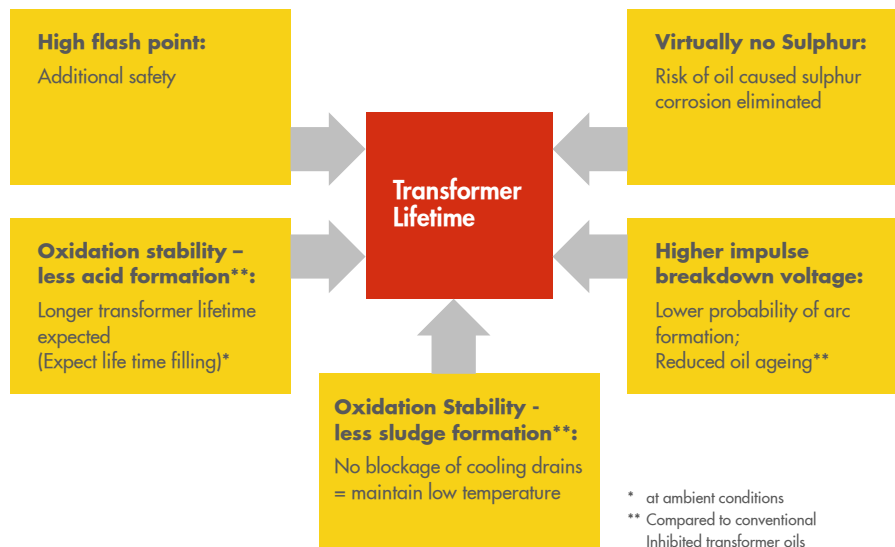
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SHELL DIALA S4 ZX-I OFFERS INCREASED OXIDATION STABILITY AND REDUCED RISK OF FAILURE



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