



**TRANSFORMER-LIFE-MANAGEMENT
CONFERENCE**

Diala Transformer oil based on GTL Technology

**Dr. Joerg Friedel,
Shell Technology Centre Hamburg**



Dr. Joerg Friedel studied Technical Chemistry at the Technical Colleague in Merseburg and the University of Aberdeen/Scotland. His PhD project was about environmental chemistry.

Mr. Friedel joined Shell in 1995 and got experiences in the application of lubricants and transformer oils, and the manufacturing and use of base oils. He works now as a Global Product Application Specialist for electrical oils and is responsible for technical support for transformer oil customers globally. He is located at Shell's research laboratory in Hamburg.





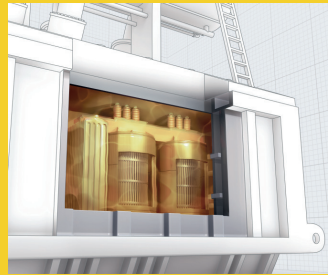
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RECENT FINDINGS AND EXPERIENCES WITH GTL TRANSFORMER OILS

Transformer Life
Management
Conference
Neuss
08.- 09. September 2014



Dr. Joerg Friedel
Product Application Specialist

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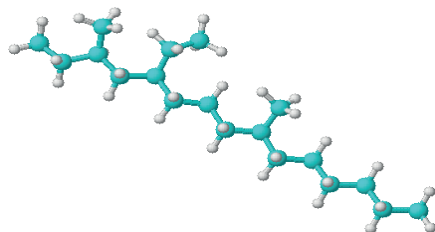


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SHELL DIALA S4 ZX-I: BASED ON SHELL GTL BASE OIL

Shell GTL base oil, primarily iso-paraffinic, virtually no impurities, excellent antioxidant response, narrow molecular distribution



Shell Diala S4 ZX-I =
Shell GTL Base Oil
+ anti-oxidant BHT

MAIN FEATURES OF SHELL DIALA S4 ZX-I:

- Excellent additive response causing outstanding oxidation resistance (surpass IEC 60296 § 7.1 limits)
- Low density (805 kg/m³)
- High flash point (190 °C)
- Pour point meets requirement of IEC 60296
- Sulphur content below detection limit (ASTM D 5185)

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SHELL DIALA S4 ZX-I

A transformer oil
based on GtL fluid +
inhibitor



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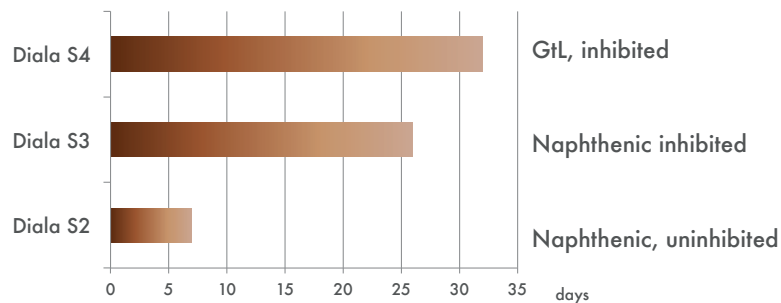
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OXIDATION STABILITY IEC 61125C



Time to reach the limit of acid number of IEC 60296 § 7.1 (0,3 mg KOH/g)

Typical RPVOT results (min) ASTM D 2112:

Diala S3 ZX-I 405 min

Diala S4 ZX-I 750 min

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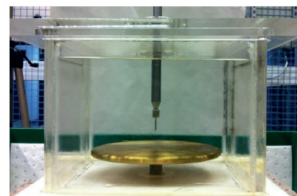
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ELECTRICAL PROPERTIES: LIGHTNING IMPULSE BREAKDOWN

- Lightning impulse breakdown voltage testing
- Needle-plane & needle-sphere electrode configurations (gap typically 25 mm, using positive & negative impulses)
- Testing run at the University of Manchester
- Diala S4 ZX-I (GTL) & Diala S3 ZX-I (naphth.), (water cont. <10 ppm)



Needle - sphere (IEC 60897 method A)
300 ml oil
Steel needle tip radius 7.2 micron ellipse
Brass sphere electrode 12.5 mm diameter



Needle - plane
12.5 litre oil
Tungsten needle tip radius 50 +/- 5 micron
Brass plane electrode 200 mm diameter

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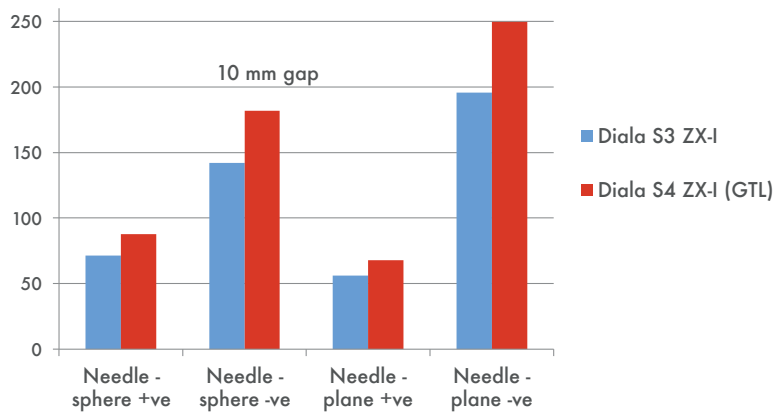


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ELECTRICAL PROPERTIES: LIGHTNING IMPULSE BREAKDOWN

Average breakdown voltage in kV (Gap 25 mm unless specified)



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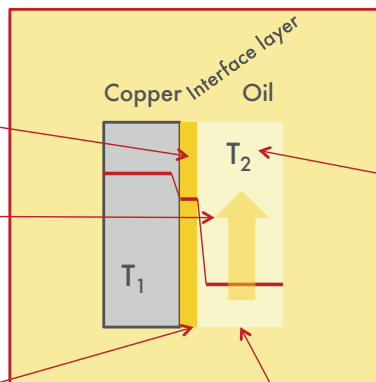
COOLING PROPERTIES: IMPORTANT CHARACTERISTICS

Efficiency depends on

Heat conductivity of oil

Heat capacity + density of oil

Thickness of interface layer (~ kin. Viscosity)



Depends e.g. on flow characteristics and flow rate ($\sim \nu$)

Oil flow in ONAN design depends e.g. on the thermal expansion coefficient

ν - Dynamic viscosity of the oil
P - Oil density

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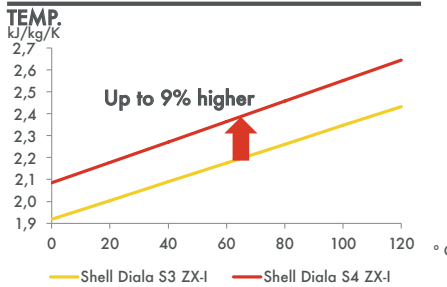


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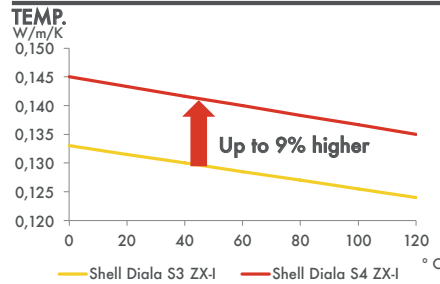
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COOLING PROPERTIES: BETTER THAN NAPHTHENICS

CALCULATED SPECIFIC HEAT CAPACITY vs



CALCULATED THERMAL CONDUCTIVITY vs



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COOLING PROPERTIES OF TRANSFORMER OILS

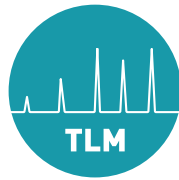
- The heat transfer coefficient for GTL based TFO is higher than naphthenic based TFO – for forced and natural cooling. The differences are small.
- Effect in a real transformer depends on design and temperature range
- Back-to-back tests with naphthenics in real transformers (IEC 60076-2) have shown an average 2,5 K lower temperature level can be achieved with Shell Diala S4 ZX-I

Heat Run test 1600 kVA, 5 kV, ONAN, hermetic	Naphthenic Oil A	Shell Diala S4 ZX-I
Average gradient of primary winding	22,6 K	20,5 K
Average gradient of secondary 1 winding	24,1 K	20,3 K
Average gradient of secondary 2 winding	21,1 K	19,2 K

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

	Diala S4 ZX-I
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 what can be used for mineral oil based transformer 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

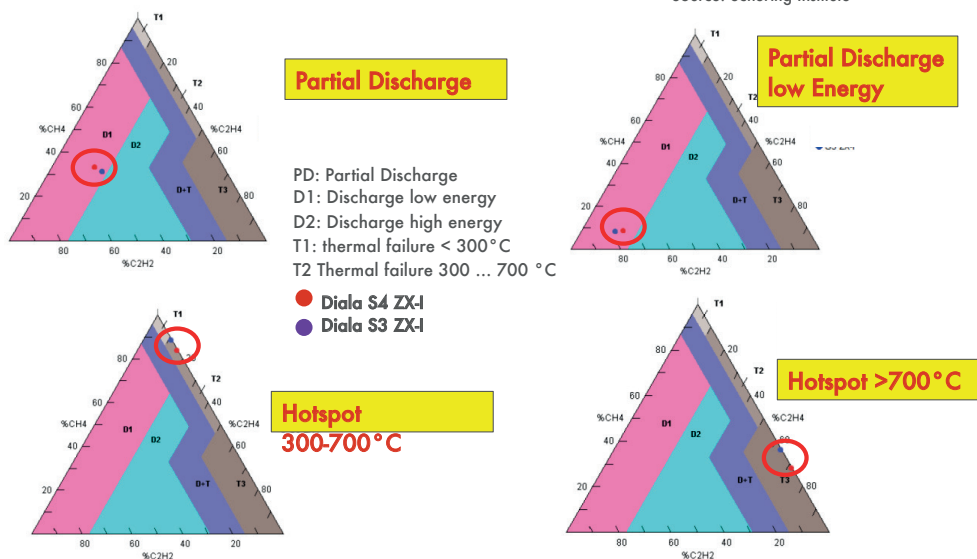
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DGA EVALUATION - DUVAL DIAGRAMS

Source: Schering Institute



Absolute gas concentration lower for Diala S3 ZX-I in comparison to Diala S3 ZX-I.

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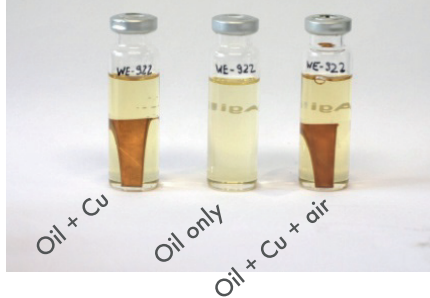
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EASE OF USE: COMPATIBLE & MISCIBLE

Topped up with Diala S4 ZX-I



Oven test, 35 days at 100 °C,
used Diala D

Topped up with Diala S2 ZU-I

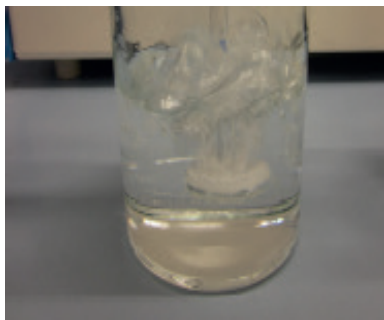


- No miscibility, compatibility, solvency issues found
- GTL based transformer oils can be used alongside traditional oils
- Top-up performance even better than Diala S3 ZX-I

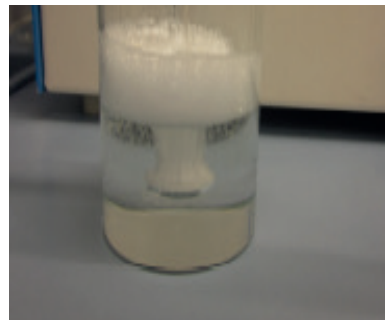
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EASE OF USE: LESS FOAMING WITH SHELL DIALA S4 ZX-I



Shell Diala S4 ZX-I



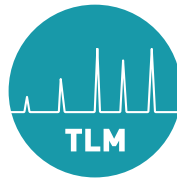
Shell Diala S3 ZX-I

Less Foaming, quicker vacuum treatment might be possible

Source: Siemens

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OXIDATION STABILITY IEC 61125C (500H, 120 °C): SHELL DIALA S4 ZX-I WITH INHIBITED NAPHTHENIC OIL B

Shell Diala S4 ZX-I	%			5	50	85	100
Naphthenic oil B	%		100	95	50	15	
Density	kg/m ³	ISO 3675	869,2	866	837,4	816,4	
Flash Point PM	°C	DIN EN 22719	138	143	151	167	188
kin. Viscosity 40 °C	mm ² /s	ISO 3104	8,95	8,958	9,183	9,483	9,560
Breakdown Voltage	kV	IEC 60156	72	78	75	66	80
DDF 90 °C		IEC 60247	0,0005	0,0004	0,0008	0,0007	0,0002
Oxidation Stability		IEC 61125C 500 hrs					
Acidity	mg KOH/g		0,14	0,03	0,02	0,02	0,02
Sludge	m%		<0,01	< 0,01	0,02	0,01	< 0,01
DDF 90 °C			0,023	0,020	0,005	0,001	0,001

tested in Shell Technology Centre Hamburg laboratory
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OXIDATION STABILITY IEC 61125C (500H, 120 °C): SHELL DIALA S4 ZX-I WITH UNINHIBITED NAPHTHENIC OIL A

Shell Diala S4 ZX-I	%			5	50	85	100
Naphthenic oil A	%		100*	95	50	15	
Density	kg/m ³	ISO 3675	873	868,2	838,5	816,7	
Flash Point PM	°C	DIN EN 22719	135	143	159	171	188
kin. Viscosity 40 °C	mm ² /s	ISO 3104	10	10,08	9,72	9,64	9,56
Breakdown Voltage	kV	IEC 60156	72	77	82	80	80
DDF 90 °C		IEC 60247	0,0005	0,0004	0,0007	0,0007	0,0002
Oxidation Stability		IEC 61125C 500 hrs					
Acidity	mg KOH/g			1,12	0,52	0,02	0,02
Sludge	m%			0,35	0,04	< 0,01	< 0,01
DDF 90 °C				0,052	0,016	0,009	0,001

tested in Shell Technology Centre Hamburg laboratory *based on TDS
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SHELL DIALA S4 ZX-I: TYPICAL DATA

The key highlights of the specification are as follows:

1. It is an inhibited grade meeting the specification IEC 60296, (Edition 4.0 2012-02); Meets the specific requirements for special applications, higher oxidation stability and low sulphur content
2. Sulphur levels are **below detection limits**
3. Offers **extended oil life**
4. **Exceptional flashpoint**

Property	Units	Method	IEC 60296	Diala S4 ZX-I
			Table 2 + section 7.1	
Appearance		IEC 60296	Clear, free from sediment and suspended matters	Complies
Density at 20 °C	kg/m ³	ISO 3675	Max. 895	805
Kinematic viscosity at 40 °C	mm ² /s	ISO 3104	Max. 12	9,6
Kinematic viscosity at -30 °C	mm ² /s	ISO 3104	IEC 60296=Max. 1.800	382
Flashpoint P.M.	°C	ISO 2719	Min. 135	191
Pourpoint	°C	ISO 3016	IEC 60296=Max. -40	-42
Neutralisation value	mg KOH/g	IEC 62021-1	Max. 0,01	<0,01
Total Sulphur content	mg/kg	ASTM D 5185	Section 7.1 limit Max 500	<1
Corrosive Sulphur		DIN 51353	Not corrosive	Not corrosive
Corrosive Sulphur		IEC 62535	Not corrosive	Not corrosive
Corrosive Sulphur		ASTM D 1275 B	-	Not corrosive
Breakdown voltage	kV	IEC 60156		
Untreated			Min. 30	>30
After treatment			Min. 70	>70
Dielectric dissipation factor (DDF) at 90 °C		IEC 60247	Max. 0,005	<0,001
Oxidation Stability (500 h / 120 °C)		IEC 61125 C	Section 7.1 Limits	
Total acidity	mg KOH/g		Max. 0,3	0,02
Sludge	%m		Max. 0,05	<0,01
Dielectric dissipation factor (DDF) at 90 °C			Max 0,05	0,001

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MANY OEMS HAVE APPROVED SHELL DIALA S4 ZX-I

Some of the OEM approvals include:

- ABB*
- Alstom**
- CG Pauwells
- MR
- Siemens
- SGB
- TBEA
- Celduc
- EFACEC
- Zaporoshe Transformer
- Huapeng

Note: 'Approved' in this context may mean any one of a range of possible endorsements, from formal written approval having been granted, to self certification that product meets relevant specs

* Up to 72.5KVA

** provisional technical approval

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SUPPORT CONTINUING TO GROW FROM GRID COMPANIES FOR SHELL DIALA S4 ZX-I

SELECTION OF COMPANIES THAT HAVE APPROVED SHELL DIALA S4 ZX-I:

- RWE, Germany
- Amprion, Germany
- 50 Hertz, Germany
- Vattenfall, Germany
- TenneT GmbH, Germany (*onshore*)
- GDF-Suez /Electrabel
- EDF Luminus, Belgium
- Elia, Belgium
- EDF (for new transformers)
- Scottish Power, UK (*HV applications*)
- Vietnam Northern Power, Vietnam
- EGAT, Thailand
- SGCC, China ($\leq 220KV$)
- PLN, Indonesia

Note: 'Approved' in this context may mean any one of a range of possible endorsements, from formal written approval having been granted, to self certification that product meets relevant specifications

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EVALUATION BY LABORATORIES & UNIVERSITIES

EUROPE & update summary (updated February 2014)

country	Laboratory / University	status
Belgium & France	Laborelec	Tested & Approved
Croatia	Koncar Institute	Tested & comply
France	University of Poitiers	Run extensive tests (ESD)
Italia	TERNA	Tested & comply
Germany	Schering Institute / University Hannover	Run extensive tests (DGA)
Netherlands	KEMA	Evaluated & comply
Spain	ENDESA	Tested & comply
Slovenia	EIMV	Tested & comply
UK	University of Manchester	Run extensive tests (lighting impulse)

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EXPERIENCES WITH SHELL DIALA S4 ZX-I

Since its launch, Shell has supplied > 6,000,000 L of Shell Diala S4 ZX-I in 3 continents to more than 40 customers

For applications in

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



- Satisfactory Performance – no issues observed, function as expected of high quality oil
- No design or maintenance changes required (*possible optimisation and maintenance reduction being explored!*)
- Proven to be able to detect mechanical failures of transformers

NEW DEVELOPMENTS

ONGOING TESTING

- Long term ageing
- Paper impregnation properties
- Collecting and analysing oil analysis results from field

Further developments with Shell GTL baseoil planned e.g.

- New transformer oil with gas absorbing properties – for special applications as bushing or instrument transformers - to be available later this year → **Shell Diala S4 ZX-IG**



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SHELL DIALA S4 ZX-I OFFERS INCREASED TRANSFORMER LIFETIME AND REDUCED RISK OF FAILURE

