Neue Erfahrungen aus Labor und Praxis zu GTL Transformatorenölen

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.

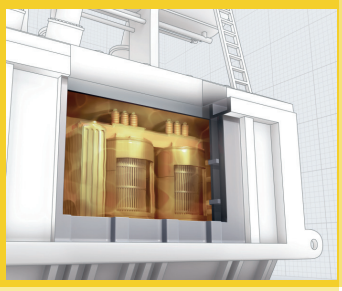
Neue Erfahrungen aus Labor und Praxis zu GTL Transformatorenölen

RECENT FINDINGS AND EXPERIENCES WITH GTL TRANSFORMER OILS

Transformer Life Management Conference

Neuss

08.- 09. September 2014



Dr. Joerg Friedel
Product Application Specialist

DEFINITIONS AND CAUTIONARY NOTE

The companies in which Royal Dutch Shell plc directly and indirectly owns investments are separate entities. In this presentation "Shell", "Shell group" and "Royal Dutch Shell" are sometimes used for convenience where references are made to Royal Dutch Shell plc and its subsidiaries in general. Likewise, the words "we", "us" and "our" are also used to refer to subsidiaries in general or to those who work for them. These expressions are also used where no useful purpose is served by identifying the particular company or companies. ''Subsidiaries'', "Shell subsidiaries" and "Shell companies" as used in this presentation refer to companies over which Royal Dutch Shell plc either directly or indirectly has control. Companies over which Shell has joint control are generally referred to "joint ventures" and companies over which Shell has significant influence but neither control nor joint control are referred to as "associates". In this presentation, joint ventures and associates may also be referred to as "equity-accounted investments". The term "Shell interest" is used for convenience to indicate the direct and/or indirect (for example, through our 23% shareholding in Woodside Petroleum Ltd.) ownership interest held by Shell in a venture, partnership or company, after exclusion of all third-party interest.

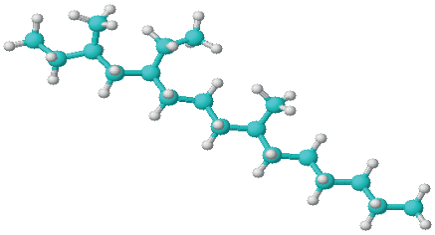
This presentation contains forward-looking statements concerning the financial condition, results of operations and businesses of Royal Dutch Shell. All statements other than statements of historical fact are, or may be deemed to be, forward-looking statements. Forward-looking statements are statements of future expectations that are based on management's current expectations and assumptions and involve known and unknown risks and uncertainties that could cause actual results, performance or events to differ materially from those expressed or implied in these statements. Forward-looking statements include, among other things, statements concerning the potential exposure of Royal Dutch Shell to market risks and statements expressing management's expectations, beliefs, estimates, forecasts, projections and assumptions. These forward-looking statements are identified by their use of terms and phrases such as ''anticipate'', ''believe'', ''could'', ''estimate'', ''expect'', ''goals'', ''intend'', ''may'', ''objectives'', ''outlook'', ''plan'', ''probably'', ''project'', ''risks'', "schedule", ''seek'', ''should'', ''target'', ''will'' and similar terms and phrases. There are a number of factors that could affect the future operations of Royal Dutch Shell and could cause those results to differ materially from those expressed in the forward-looking statements included in this presentation, including (without limitation): (a) price fluctuations in crude oil and natural gas; (b) changes in demand for Shell's products; (c) currency fluctuations; (d) drilling and production results; (e) reserves estimates; (f) loss of market share and industry competition; (g) environmental and physical risks; (h) risks associated with the identification of suitable potential acquisition properties and targets, and successful negotiation and completion of such transactions; (i) the risk of doing business in developing countries and countries subject to international sanctions; (j) legislative, fiscal and regulatory developments including regulatory measures addressing climate change; (k) economic and financial market conditions in various countries and regions; (l) political risks, including the risks of expropriation and renegotiation of the terms of contracts with governmental entities, delays or advancements in the approval of projects and delays in the reimbursement for shared costs; and (m) changes in trading conditions. All forward-looking statements contained in this presentation are expressly qualified in their entirety by the cautionary statements contained or referred to in this section. Readers should not place undue reliance on forward-looking statements. Additional risk factors that may affect future results are contained in Royal Dutch Shell's 20-F for the year ended December 31, 2012 (available at www.shell.com/investor and www.sec.gov). These risk factors also expressly qualify all forward looking statements contained in this presentation and should be considered by the reader. Each forward-looking statement speaks only as of the date of this presentation 23 September 2013 Neither Royal Dutch Shell plc nor any of its subsidiaries undertake any obligation to publicly update or revise any forward-looking statement as a result of new information, future events or other information. In light of these risks, results could differ materially from those stated, implied or inferred from the forward-looking statements contained in this presentation.

We may have used certain terms, such as resources, in this presentation that United States Securities and Exchange Commission (SEC) strictly prohibits us from including in our filings with the SEC. U.S. Investors are urged to consider closely the disclosure in our Form 20-F, File No 1-32575, available on the SEC website www.sec.gov. You can also obtain these forms from the SEC by calling 1-800-SEC-0330.

Neue Erfahrungen aus Labor und Praxis zu GTL Transformatorenölen

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)

Shell Global Solution (Deutschland) GmbH September 2014 5

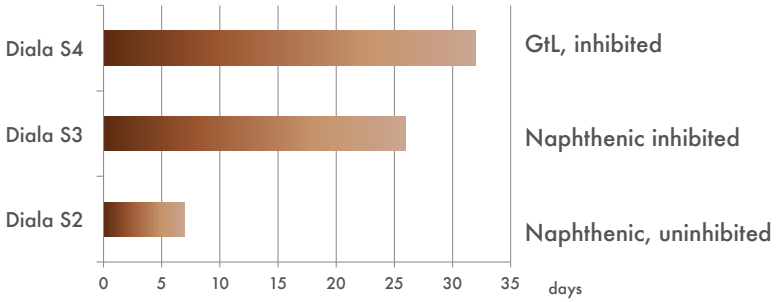
SHELL DIALA S4 ZX-I

A transformer oil based on GtL fluid + inhibitor

September 2014 6

Neue Erfahrungen aus Labor und Praxis zu GTL Transformatorenölen

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:

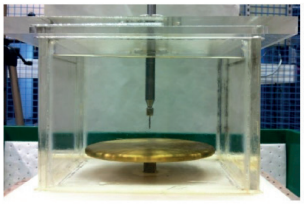
Diala S3 ZX-I 405 min

Diala S4 ZX-I 750 min

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 elipse
Brass sphere electrode 12.5 mm diameter

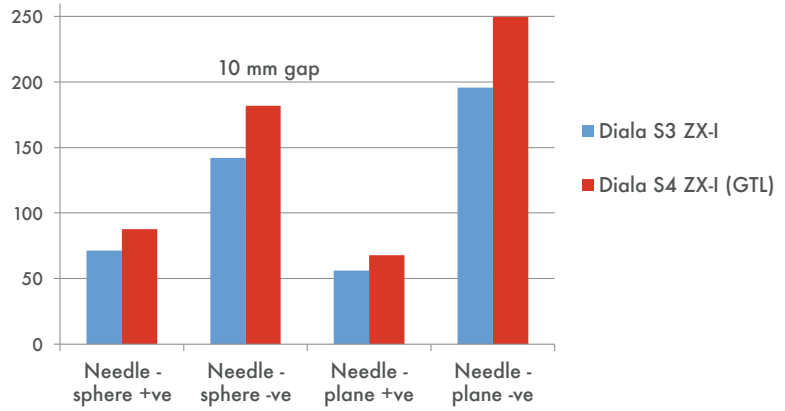


Needle – plane
12.5 litre oil
Tungsten needle tip radius 50 +/- 5 micron
Brass plane electrode 200 mm diameter

Neue Erfahrungen aus Labor und Praxis zu GTL Transformatorenölen

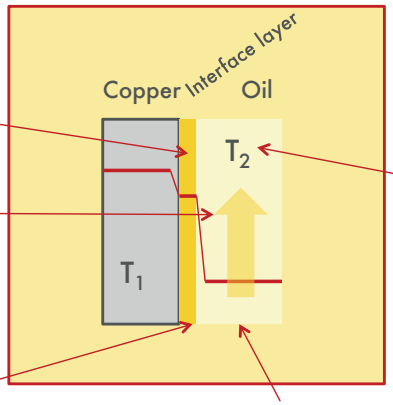
ELECTRICAL PROPERTIES: LIGHTNING IMPULSE BREAKDOWN

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



COOLING PROPERTIES: IMPORTANT CHARACTERISTICS

Efficiency depends on



Heat conductivity of oil

Heat capacity + **density** of oil

Depends e.g.on flow characteristics and flow rate (~ ν)

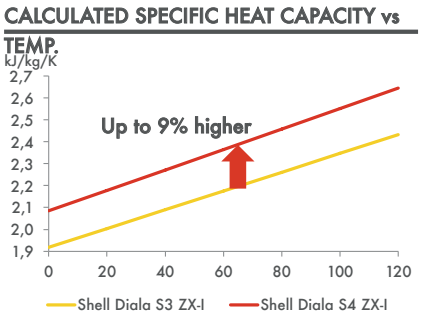
Thickness of interface layer (~ **kin. Viscosity**)

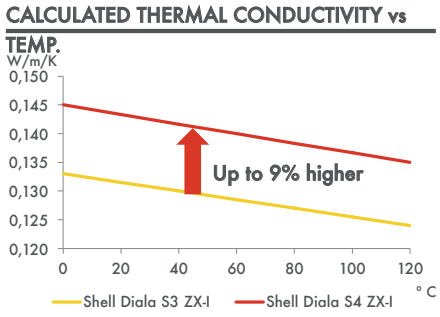
Oil flow in ONAN design depends e.g. on the **thermal expansion coefficient**

ν -Dynamic viscosity of the oil
ρ - Oil density

Neue Erfahrungen aus Labor und Praxis zu GTL Transformatorenölen

COOLING PROPERTIES: BETTER THAN NAPHTHENICS





Shell Global Solution (Deutschland) GmbH September 2014 11

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

Shell Global Solution (Deutschland) GmbH September 2014 12

Neue Erfahrungen aus Labor und Praxis zu GTL Transformatorenölen

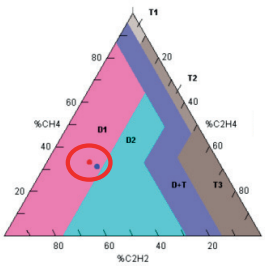
IN MANY WAYS, SHELL DIALA S4 ZX-I REMAINS SIMILAR TO MINERAL BASED TRANSFORMER OILS...

	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

Shell Global Solution (Deutschland) GmbH September 2014 13

DGA EVALUATION - DUVAL DIAGRAMS

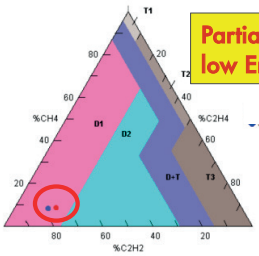
Source: Schering Institute



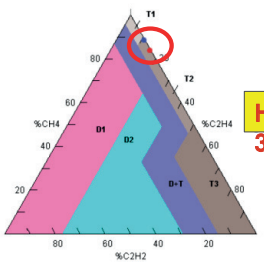
Partial Discharge

PD: Partial Discharge
D1: Discharge low energy
D2: Discharge high energy
T1: thermal failure < 300°C
T2 Thermal failure 300 ... 700 °C

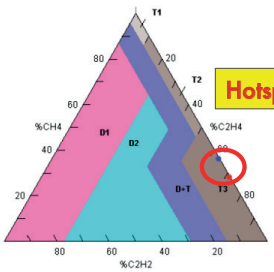
Diala S4 ZX-I
Diala S3 ZX-I



Partial Discharge low Energy



Hotspot 300-700°C



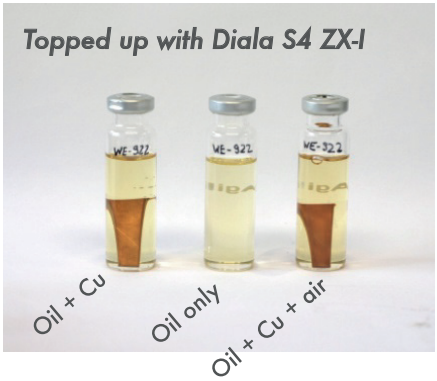
Hotspot >700°C

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

Shell Global Solution (Deutschland) GmbH September 2014 14

Neue Erfahrungen aus Labor und Praxis zu GTL Transformatorenölen

EASE OF USE: COMPATIBLE & MISCIBLE

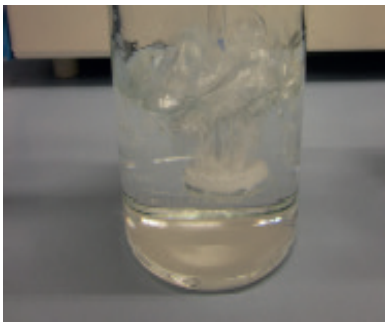


Oven test, 35 days at 100°C, used Diala D

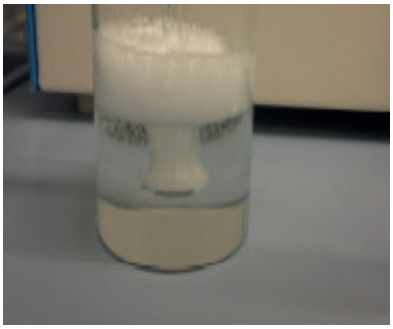
- No miscibility, compatibility, solvency issues found
- GTL based transformer oils can be used alongside traditional oils
- Top-up performance even better than Diala S3 ZX-I

Shell Global Solution (Deutschland) GmbH September 2014 15

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

Shell Global Solution (Deutschland) GmbH September 2014 16

Neue Erfahrungen aus Labor und Praxis zu GTL Transformatorenölen

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/m³	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	mm²/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

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/m³	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	mm²/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

Neue Erfahrungen aus Labor und Praxis zu GTL Transformatorenölen

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 Table 2 + section 7.1	Diala S4 ZX-I
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

Shell Global Solution (Deutschland) GmbH September 2014 19

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

Shell Global Solution (Deutschland) GmbH September 2014 20

Neue Erfahrungen aus Labor und Praxis zu GTL Transformatorenölen

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 *(<=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

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)

Neue Erfahrungen aus Labor und Praxis zu GTL Transformatorenölen

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***

Neue Erfahrungen aus Labor und Praxis zu GTL Transformatorenölen