



The benefits of inhibited transformer oils using gas to liquid based technology

Joerg Friedel, Shell Technology Centre Hamburg



Joerg Friedel has a PhD degree in chemistry from the University of Halle in Germany. He joined Shell in 1995. His current role is a Global Product Application Specialist for Transformer and Hyper-compressor Oils. He is responsible for technical contacts to global customers, ensuring that products meets market requirements and acceptance. He is a member of IEC and CIGRÉ.

He has a wide experience of lubricants applications, including base oils and their use in finish lubricants, and in chemical products.





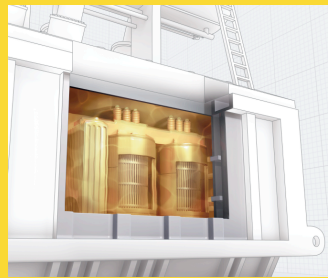
**TRANSFORMER-LIFE-MANAGEMENT
CONFERENCE**

The benefits of inhibited transformer oils using gas to liquid based technology



THE BENEFITS OF INHIBITED TRANSFORMER OILS USING GAS-TO- LIQUID BASED TECHNOLOGY

Transformer Life
Management
Conference
Dubai
22.-23. October 2013



Dr. Joerg Friedel
Senior Engineer

Shell Global Solution (Deutschland) GmbH

September 2013 1



TRANSFORMER-LIFE-MANAGEMENT CONFERENCE

The benefits of inhibited transformer oils using gas to liquid based technology

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, 5 June 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.



The benefits of inhibited transformer oils using gas to liquid based technology

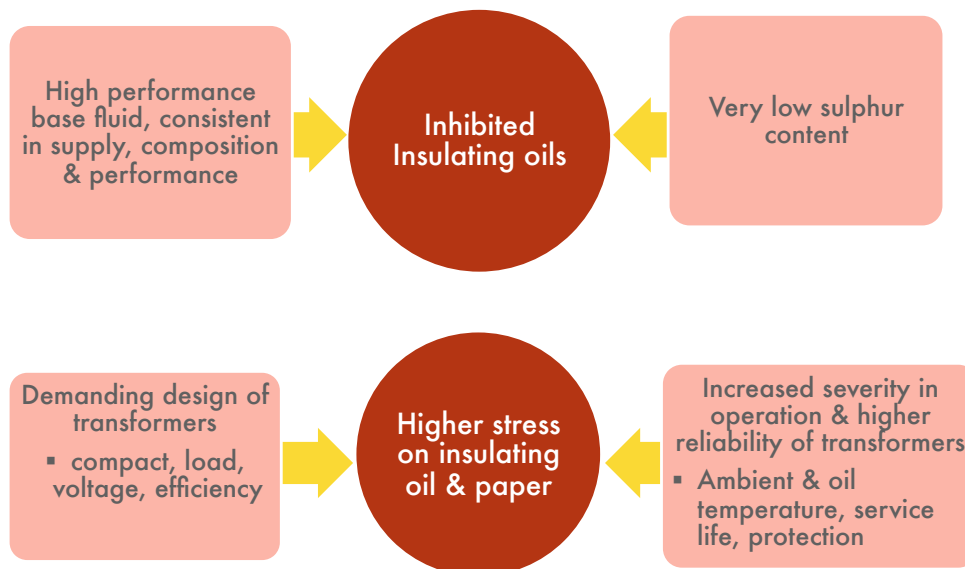
AGENDA

1. Benefits of using inhibited versus uninhibited transformer oils
2. Base Oils for transformer oil production
3. Shell Diala S4 ZX-I – inhibited transformer oil using GTL base fluid
 - Resistance to ageing & degradation in service
 - Cooling – thermal properties, fluidity
 - Ease of use – miscibility/compatibility with other oils
4. Conclusions – benefits of GTL based inhibited transformer oils over conventional products

Shell Global Solution (Deutschland) GmbH

September 2013 3

BASE FLUIDS – CHANGE AND CHALLENGE



Shell Global Solution (Deutschland) GmbH

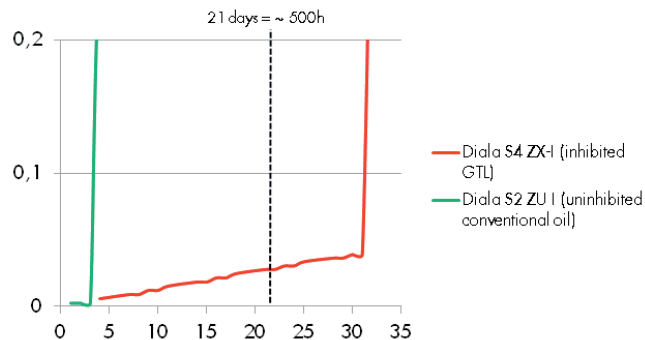
September 2013 4



The benefits of inhibited transformer oils using gas to liquid based technology

RESISTANCE TO DEGRADATION - INHIBITED GTL VERSUS CONVENTIONAL UNINHIBITED OIL

IEC 61125C = The induction period is reached when the volatile acidity significantly exceeds 0.1 mg KOH/g



- Inhibited oils show predictable & best resistance to degradation
- Monitoring antioxidant concentration gives indication of oil condition before significant quantities of acids are developed (and potentially attack the paper)

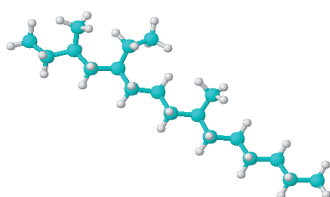
Shell Global Solution (Deutschland) GmbH

September 2013 5

BASE OILS USED FOR MANUFACTURING OF TRANSFORMER OILS

1. Naphthenic base oil – degree of raffination depends on crude, and inhibition
2. Paraffinic base oil – usually highly refined and inhibited

3. **GTL base oil**, primarily iso-paraffinic, no impurities, excellent antioxidant response, narrow molecular distribution



GtL base oil is produced in Qatar JV plant from Natural Gas using the Fischer-Tropsch Process

Shell Global Solution (Deutschland) GmbH

September 2013 6



The benefits of inhibited transformer oils using gas to liquid based technology

RESISTANCE TO DEGRADATION - INHIBITED GTL VERSUS CONVENTIONAL INHIBITED OIL

	Limits IEC 60296	IEC 60296 – sect 7.1 Higher oxid stab & low sulphur	Inhibited Shell Diala S3 ZX-1	Inhibited Shell Diala S4 ZX-1 (GTL)
Oxidation Stability IEC 61125 C	164/500 hours	500 hours	500 hours	500 hours
Total acidity, mgKOH/g	max 1.2	max 0.3	0.02	0.02
Sludge, % weight	max 0.8	max 0.05	0.01	<0.01
Dielectric dissipation factor (DDF) at 90 °C	max 0.5	Max 0.05	0.009	0.001

- GTL inhibited oils – exceptional resistance to degradation.

Shell Global Solution (Deutschland) GmbH

September 2013 7

POTENTIAL IMPROVEMENTS OVER CURRENTLY USED TRANSFORMER OILS

- Increased oxidation stability
- Improved cooling properties
- Oil should not promote corrosion – sulphur content should be minimized
- High flash point

Easy changeover and continued practice from currently used transformer oils:

- Dissolved Gas Analysis (DGA) for monitoring the transformer condition can be used.
- Comparable compatibility with construction materials (sealings, varnish)
- Comparable interaction with paper insulation (e.g. water solubility)
- Miscibility with current used transformer oils

Shell Global Solution (Deutschland) GmbH

September 2013 8



The benefits of inhibited transformer oils using gas to liquid based technology

RESISTANCE TO DEGRADATION - INHIBITED GTL VERSUS CONVENTIONAL INHIBITED OIL

IEC 61125 C extended oxidation stability test

- Test run for standard 500 hrs, when inhibitor content reduced to approx 50 % of initial value, antioxidant was topped up to initial level (refer to IEC 60422), later inhibitor topping up regularly. Test run for approx 2180 hrs (> 4X usual duration)

<p>Shell Diala S4 ZX-I (GTL)</p> <p>Acidity (mgKOH/g) 0.18</p> <p>Sludge <0.01 % wt</p> <p>Oil loss 0 % wt</p>		<p>Shell Diala S3 ZX-I</p> <p>Acidity (mgKOH/g) 0.96</p> <p>Sludge <0.01 % wt</p> <p>Oil loss 24 % wt</p>
--	--	---

- Extended resistance to degradation in normal service & when re-inhibited

RESISTANCE TO AGEING & DEGRADATION - CORROSIVE SULPHUR

Property	Units	Method	IEC 60296 Table 2 + section 7.1	Shell Diala S4 ZX-I	Shell Diala S3 ZX-I
Total Sulphur content	mg/kg	ASTM D 5185	Section 7.1 limit Max 500	<1	<40
Corrosive Sulphur		DIN 51353	Not corrosive	Not corrosive	Not corrosive
Corrosive Sulphur		IEC 62535	Not corrosive	Not corrosive	Not corrosive
Corrosive Sulphur		ASTM D 1275 B	-	Not corrosive	Not corrosive

- Essentially zero sulphur minimises risk of oil based corrosive sulphur failures.



The benefits of inhibited transformer oils using gas to liquid based technology

COOLING PROPERTIES OF OIL IN TRANSFORMER

Modeling of oil cooling in transformer can be undertaken from a knowledge of oil properties at different temperatures, such as:

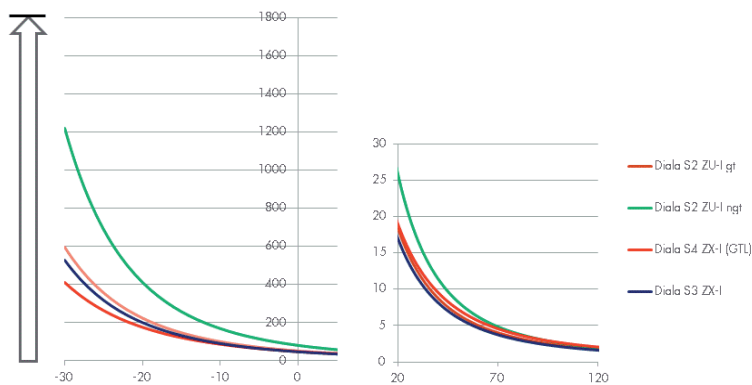
- Viscosity
- Specific heat capacity
- Thermal conductivity
- Density
- Thermal coefficient of expansion

Shell Global Solution (Deutschland) GmbH

September 2013 11

COOLING - VISCOSITY (FLUIDITY)

Shell Diala typical viscosity (cSt) versus temperature (°C)



- Good fluidity across broad temperature range, especially low temperatures down to -30 °C, facilitate a safe low temperature start.
- Comparable viscosity to conventional oils at higher temperatures.

Shell Global Solution (Deutschland) GmbH

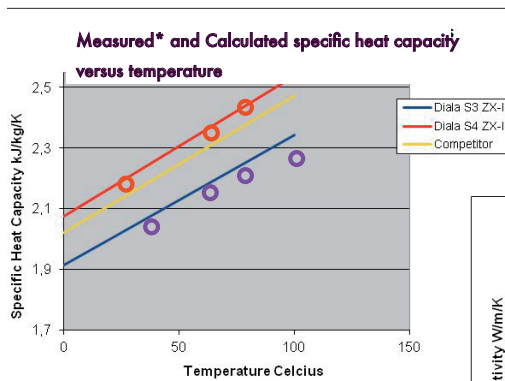
September 2013 12



TRANSFORMER-LIFE-MANAGEMENT
CONFERENCE

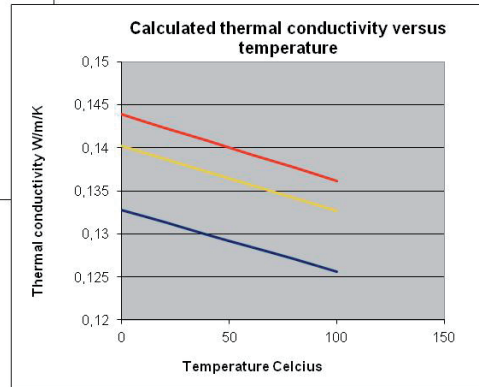
The benefits of inhibited transformer oils using gas to liquid based technology

COOLING - THERMAL PROPERTIES (APPROXIMATE)



*measured by ASTM E 1269 mod.

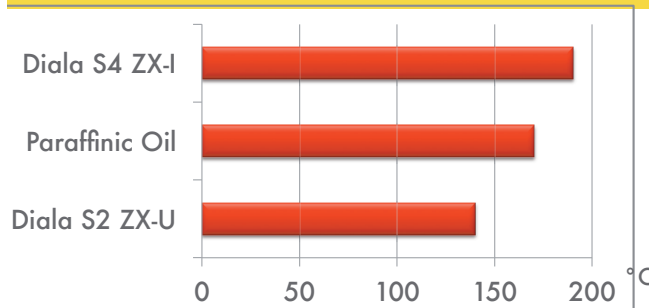
- Density app. 9 % lower compared to naphthenic transformer oils



Shell Global Solution (Deutschland) GmbH

September 2013 13

COMPARISON FLASH POINT COC AND EVAPORATION LOSS



Evaporation loss	ASTM D 972 22h at 107 °C	ASTM D 5800 1 h 250 °C
Naphthenic Oil	26%	100%
Diala S4 ZX-I	0,75%	40%

- Significantly higher flash point and reduced volatility provides additional safety.

Shell Global Solution (Deutschland) GmbH

September 2013 14



The benefits of inhibited transformer oils using gas to liquid based technology

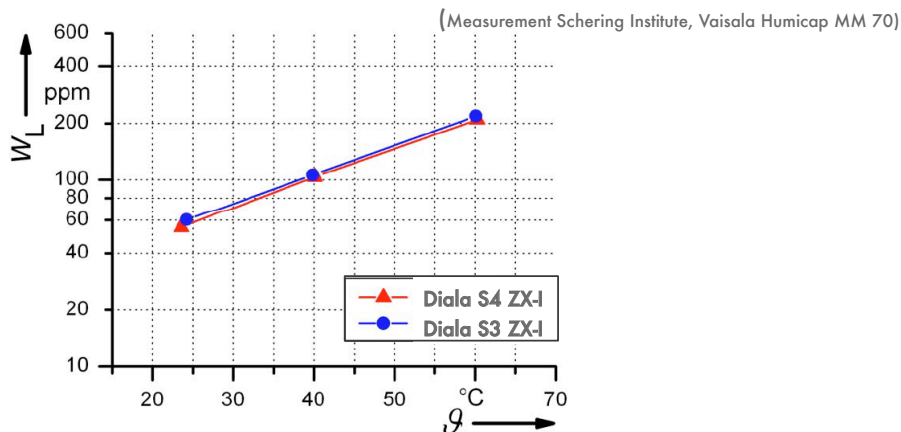
STRAY GASSING RESULTS WITH SHELL DIALA S4 ZX-I VS. SHELL DIALA S3

Stray Gassing Results ASTM D 7150
164 hrs at 120 °C , 30 min air stripped before test [ppm v/v]

	Diala S4 ZX-I	Diala S3 ZX-I
Hydrogen	40	54
Carbon Monoxide	249	229
Carbon Dioxide	304	176
Methane	5	2
Ethan	16	< 1
Ethylene	4	< 1
Acetylene	< 1	< 1

- DGA experience from currently used transformer oils might be transferred to Diala S4 ZX-I

WATER SATURATION VS. TEMPERATURE



- No significant difference in water solubility to conventional transformer oils.



TRANSFORMER-LIFE-MANAGEMENT
CONFERENCE

The benefits of inhibited transformer oils using gas to liquid based technology

EASE OF USE - COMPATIBILITY WITH AGED OIL (TOP UP SCENARIO, 5%, SLUDGE FILTERED OUT)

	Field sample, uninhibited	Field sample, uninhibited +5% Diala S4 ZX-I	Field sample, plus 5% Diala S3 ZX
fresh			
7 days			
15 days			

* air access through a tube

Shell Global Solution (Deutschland) GmbH
September 2013 17

EASE OF USE - COMPATIBILITY WITH AGED OIL (SLUDGE FILTERED OUT; OIL DRAIN SCENARIO, 85%)

	Field sample, uninhibited	Field sample, 85% Diala S4	Field sample, plus 85% Diala S3
fresh			
7 days			
15 days			

* air access through a tube

Shell Global Solution (Deutschland) GmbH
September 2013 18



The benefits of inhibited transformer oils using gas to liquid based technology

EASE OF USE - COMPATIBILITY/MISCIBILITY CONCLUSIONS



- 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 2013 19

COMPATIBILITY WITH SEALING ELASTOMERS

	Type	Hardness change Shore A	Weight change %	Volume change %
NBR	ANT 6800	-2 (68/66)	+ 0,33	+ 1,43
FPM	S 161/19-69	0 (76/76)	+ 0,2	+ 0,26
MFQ	A-SK 65-16	0 (62/62)	+ 0,23	+ 0,29

- No sealing compatibility issues, GTL fluids are compatible with typical sealants and components used in transformers.

Shell Global Solution (Deutschland) GmbH

September 2013 20



The benefits of inhibited transformer oils using gas to liquid based technology

CONCLUSIONS – BENEFITS OF INHIBITED TRANSFORMER OILS BASED ON GTL

- Diala S4 ZX-I meets & exceeds IEC 60296:Ed 4 2012 highest oxidation stability, low sulphur specification.
- Exceptional resistance to ageing & degradation.
- Modeling predicts good to superior cooling in service .
- Essentially zero sulphur minimises risks due to corrosive sulphur.
- Safety benefits due to higher flash point and lower volatility.
- Easy to use with other oils, no miscibility/compatibility/solvency issues found.
- Praxis experiences with conventional products can be used.
- Product being evaluated & approved by OEMs & utilities, a rising number have confirmed acceptance and approved, and the product is being successful used in transformers.

