YOUR REFERENCE:	OUR REFERENCE: **2023-1325 _ STARKE & SOHN** - FINAL REPORT -	DATE: 06/07/2023
CONTACT PERSON: Steve Eeckhoudt	**E-MAIL:** OILS@laborelec.com steve.eeckhoudt@laborelec.com	

Dear Sir,

Enclosed you will find the FINAL REPORT of the acceptance tests as per most recent IEC 60296 (Ed. 5, 06/2020) and ENGIE Laborelec Purchase Specification (Ed. 01/2023) for mineral transformer oil for your reference sample **StaSo Transformer Oil I – batch 23265753**, received in our labs in May 2023.

We stay of course at your disposition for any further comments and remain,

Yours sincerely,

Steve Eeckhoudt
Senior Expert Insulating fluids & lubricants LABORELEC
Key Expert ENGIE

Author:	Verification:	Approbation:
Stijn Autru (06/07/2023)	Steve Eeckhoudt (06/07/2023)	Danielle Leemans (06/07/2023)

Description of the samples

LABORELEC-reference	Customer description
2305.2299	**StaSo Transformer Oil I – batch 23265753** (Received: May 17th 2023)

Conclusions and recommendations

The tested and reported oil analysis results on the next pages show that this reference sample **does comply** with the criteria mentioned in IEC 60296 (Ed. 5, 06/2020) for fully inhibited mineral transformer oil (TYPE A, as per table 3).

The tested and reported oil analysis results on the next pages show that this reference sample **does comply** with the criteria mentioned in ENGIE Laborelec Purchase Specification (Ed. 01/2023) for mineral transformer oil (High Grade type).

Analysis results (1)

LABORELEC-reference
2305.2299

Customer description
StaSo Transformer Oil I – batch 23265753
(Received: May 17th 2023)

Property	Unit	Test method	Minimum requirement IEC 60296 Ed.5 (table 3, TYPE A oil)	Minimum requirement Laborelec Purchase Specification for mineral transformer oil (version 01/2023 – high grade oil)	ANALYSIS RESULT
1 – Function					
Viscosity at -30°C	mm²/sec	ASTM D7042	*Max. 1800*	*Max. 1800*	**833.9**
Viscosity at 40°C	mm²/sec	ISO 3104	*Max. 12*	*Max. 12*	**9.3**
Pour point	°C	ISO 3016	*Max. -40*	*Max. -40*	**-51**
Breakdown voltage	kV	IEC 60156	*Min. 30*	*Min. 30*	**77**
Breakdown voltage after laboratory filtration (2)	kV	IEC 60156 / IEC 60296	*Min. 70*	*Min. 70*	**>80**
Water content	mg/kg	IEC 60814	*Max. 30/40*	*Max. 30*	**13**
Density at 20°C	kg/m³	ASTM D4052	*Max. 895*	*Max. 895*	**866**
DDF at 90°C		IEC 60247	*Max. 0.005*	*Max. 0.005*	**ND (<0.0003)**

Property	Unit	Test method	Minimum requirement IEC 60296 Ed.5 (table 3, TYPE A oil)	Minimum requirement Laborelec Purchase Specification for mineral transformer oil (version 01/2023 – high grade oil)	ANALYSIS RESULT
2 – Refining/stability					
Colour		ISO 2049	*< 0.5*	*Max. 0.5*	**< 0.5**
Appearance			*Clear*	*Clear*	**Clear**
Acidity	mg KOH/g	IEC 62021-1	*Max. 0.01*	*Max. 0.01*	**ND (<0.01)**
Interfacial tension	mN/m	ASTM D971	*Min. 43*	*Min. 43*	**48.3**
Total sulfur content	%	ISO 14596	*Max. 0.05*	*Max. 0.05*	**0.042**
Potentially corrosive sulfur		IEC 62535	*Non Corrosive*	*Non Corrosive*	**Non Corrosive**
Corrosive sulfur		DIN 51353	*Non Corrosive*	*Non Corrosive*	**Non Corrosive**
DBDS	mg/kg	IEC 62697	*ND (<5)*	*ND*	**ND (<3)**
Antioxidant additive (phenolic) HPLC	%	IEC 60666	*Min. 0.08 – Max. 0.4*	*Min. 0.20 - Max. 0.4*	**0.4**
Content of TTAA (metal passivator Irgamet 39®)	mg/kg	IEC 60666	*ND (<5)*	*ND*	**ND (<5)**
Content of TAA (metal passivator Irgamet 30®)	mg/kg	UPLC-MS/MS	*NGR*	*ND*	**ND (<1)**
Content of BTA (metal passivator)	mg/kg	IEC 60666	*ND (<5)*	*ND*	**ND (<1)**
Content of TTA (metal passivator)	mg/kg	IEC 60666	*ND (<5)*	*ND*	**ND (<1)**
2-Furfural content	mg/kg	IEC 61198	*Max. 0.05*	*Max. 0.025*	**ND (<0.025)**
Methanol	mg/kg	IEC PT63025	*NGR*	*Max. 0.025*	**ND (<0.025)**
Stray gassing		IEC 60296 ED.5 Annex A (AIR-stripped, presence of Cu)	*See annex 1*	*See annex 1*	**See annex 1**
Stray gassing		ASTM D7150 (method A, AIR-stripped)	*NGR*	*See annex 2*	**See annex 2**

ND : Not Detectable (if not mentioned specifically in table above, detection limit of used analysis standard is applicable)
NGR : No general requirement in IEC 60296
AGREED : To be agreed upon between supplier and user
- : Not determined yet
/ : Not requested by customer
(1) : To be agreed between supplier and customer in specific very hot/cold climates. Pour point should be at least 10°C under Lowest Cold Start Energizing Temperature of the transformer.
(2) : Filtration of oil before measuring breakdown voltage consists of filtration of oil at 60°C under vacuum pressure of max. 2.5 kPa, using a sintered glass filter with a maximum pore size of 2.5 µm.

Analysis results (2)

LABORELEC-reference
2305.2299

Customer description
StaSo Transformer Oil I – batch 23265753
(Received: May 17th 2023)

Property	Unit	Test method	Minimum requirement IEC 60296 Ed.5 (table 3, TYPE A oil)	Minimum requirement Laborelec Purchase Specification for mineral transformer oil (version 01/2023 – high grade oil)	ANALYSIS RESULT
3 – Performance					
Oxidation stability		IEC 61125			
• Volatile acidity	mg KOH/g				**0.08**
• Soluble acidity	mg KOH/g	uninhibited: 164h			**0.00**
• Total acidity	mg KOH/g	trace-inhibited: 322h	*Max. 0.3*	*Max. 0.3*	**0.08**
• Sludge	%	**inhibited: 500h**	*Max. 0.05*	*Max. 0.05*	**0.05**
• DDF at 90°C			*Max. 0.050*	*Max. 0.050*	**ND (<0.01)**
RPVOT	minutes	ASTM D2112	*NGR*	*Min. 350*	**402**

Property	Unit	Test method	Minimum requirement IEC 60296 Ed.5 (table 3, TYPE A oil)	Minimum requirement Laborelec Purchase Specification for mineral transformer oil (version 01/2023 – high grade oil)	ANALYSIS RESULT
4 – HSE					
Flash point (PMCC-method)	°C	ISO 2719	*Min. 135*	*Min. 135*	**145**
PCA content	%	IP 346	*Max. 3*	*Max. 3*	**1.42**
PAH content	mg/kg	DIN ISO 18287	*NGR*	*Report values*	
• Naphthalin					**7.5**
• Acenaphthylen					**2.1**
• Acenaphthen					**1.8**
• Fluoren					**3.2**
• Phenanthren					**3.3**
• Anthracen					**0.37**
• Fluoranthen					**0.36**
• Pyren					**1.3**
• Benz(a)anthracen					**0.091**
• Chrysen					**0.41**
• Benzo(b)fluoranthen					**<0.050**
• Benzo(k)fluoranthen					**<0.050**
• Benzo(a)pyren					**<0.050**
• Indeno(1,2,3-cd)pyren					**<0.050**
• Dibenz(a,h)anthracen					**<0.050**
• Benzo(g,h,i-perylen					**<0.050**
PCB content	mg/kg	IEC 61619	*ND (<2)*	*ND (<2)*	**ND (<2)**

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Property	Unit	Test method	Minimum requirement IEC 60296 Ed.5 (table 3, TYPE A oil)	Minimum requirement Laborelec Purchase Specification for mineral transformer oil (version 01/2023 – high grade oil)	ANALYSIS RESULT
5 – Optional					
Viscosity at -40°C	mm²/sec	IEC 61868	*NGR/AGREED*	*NGR/AGREED*	*/*
Viscosity at -50°C	mm²/sec	IEC 61868	*NGR/AGREED*	*NGR/AGREED*	*/*
Structural analysis • Naphthenics • Aromatics • Paraffinics	 % % %	IEC 60590 / Brandes / BDS 05-50-651	 *NGR/AGREED* *NGR/AGREED* *NGR/AGREED*	*Report values*	 **41.3** **7.1** **51.6**
Particle counting		IERC 60970	*NGR/AGREED*	*NGR/AGREED*	*/*
Gassing Tendency	µl/minute	IEC 60628 method A	*NGR/AGREED*	*NGR/AGREED*	*/*
Individual PAH compounds		EN 16143	*NGR/AGREED*	*NGR/AGREED*	*/*
Biodegradability		OECD 301B	*NGR/AGREED*	*NGR/AGREED*	*/*

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Annex 1

Stray gassing as per method IEC 60296 (Annex A, Ed. 5, 06/2020)

DGA before stray gassing test [1] (according IEC 60567)				
H_2	in µl/l	**ND (<5)**		
O_2	in µl/l	**>20000**		
N_2	in µl/l	**>50000**		
CO	in µl/l	**ND (<25)**		
CO_2	in µl/l	**ND (<25)**		
CH_4	in µl/l	**ND (<1)**		
C_2H_2	in µl/l	**ND (<1)**		
C_2H_4	in µl/l	**ND (<1)**		
C_2H_6	in µl/l	**ND (<1)**		
DGA after stray gassing test [2] (according IEC 60567)		**ANALYSIS RESULT**	**Minimum requirement IEC 60296 Ed.5 (table 3, TYPE A oil)**	**Minimum requirement Laborelec Purchase Specification for mineral transformer oil (version 01/2023 – high grade oil)**
H_2	in µl/l	**ND (<5)**	***< 50***	***Max. 50***
O_2	in µl/l	**>20000**	*NGR*	*NGR*
N_2	in µl/l	**>50000**	*NGR*	*NGR*
CO	in µl/l	**56**	*NGR*	*NGR*
CO_2	in µl/l	**83**	*NGR*	*NGR*
CH_4	in µl/l	**1**	***< 50***	***Max. 50***
C_2H_2	in µl/l	**ND (<1)**	*NGR*	*NGR*
C_2H_4	in µl/l	**1**	*NGR*	*NGR*
C_2H_6	in µl/l	**ND (<1)**	***< 50***	***Max. 50***
DGA after stray gassing test [3] (according IEC 60567)		**ANALYSIS RESULT**		
H_2	in µl/l	***/***	*NGR*	*NGR*
O_2	in µl/l	***/***	*NGR*	*NGR*
N_2	in µl/l	***/***	*NGR*	*NGR*
CO	in µl/l	***/***	*NGR*	*NGR*
CO_2	in µl/l	***/***	*NGR*	*NGR*
CH_4	in µl/l	***/***	*NGR*	*NGR*
C_2H_2	in µl/l	***/***	*NGR*	*NGR*
C_2H_4	in µl/l	***/***	*NGR*	*NGR*
C_2H_6	in µl/l	***/***	*NGR*	*NGR*

ND : Not Detectable (if not mentioned specifically in table above, detection limit of used analysis standard is applicable)
NGR : No general requirement
- : Not determined yet
/ : Not requested by customer

(1): AIR-stripped conditions, 0h incubation, 100ml syringes, all tests performed in duplo
(2): AIR-stripped conditions, **48 h incubation at 105°C with presence of Cu-strip**, 100ml syringes, all tests performed in duplo
(3): AIR-stripped conditions, **48 h incubation at 105°C without Cu-strip**, 100ml syringes, all tests performed in duplo

Annex 2

Stray gassing as per method ASTM D7150

DGA before stray gassing test (1) (according IEC 60567)				
H_2	in µl/l	**ND (<5)**		
O_2	in µl/l	**>20000**		
N_2	in µl/l	**>50000**		
CO	in µl/l	**ND (<25)**		
CO_2	in µl/l	**ND (<25)**		
CH_4	in µl/l	**ND (<1)**		
C_2H_2	in µl/l	**ND (<1)**		
C_2H_4	in µl/l	**ND (<1)**		
C_2H_6	in µl/l	**ND (<1)**		
DGA after stray gassing test (2) (according IEC 60567)		**ANALYSIS RESULT**	**Minimum requirement IEC 60296 Ed.5 (table 3, TYPE A oil)**	**Minimum requirement Laborelec Purchase Specification for mineral transformer oil (version 01/2023 – high grade oil)**
H_2	in µl/l	**97**	*NGR*	***Max. 100***
O_2	in µl/l	**>20000**	*NGR*	*NGR*
N_2	in µl/l	**>50000**	*NGR*	*NGR*
CO	in µl/l	**312**	*NGR*	*NGR*
CO_2	in µl/l	**209**	*NGR*	*NGR*
CH_4	in µl/l	**2**	*NGR*	***Max. 20***
C_2H_2	in µl/l	**ND (<1)**	*NGR*	*NGR*
C_2H_4	in µl/l	**3**	*NGR*	*NGR*
C_2H_6	in µl/l	**ND (<1)**	*NGR*	***Max. 20***

ND : Not Detectable (if not mentioned specifically in table above, detection limit of used analysis standard is applicable)
NGR : No general requirement
\- : Not determined yet
/ : Not requested by customer

(1): AIR-stripped conditions, 0h incubation, 100ml syringes, all tests performed in duplo
(2): AIR-stripped conditions, **164 h incubation at 120°C without presence of Cu-strip**, 100ml syringes, all tests performed in duplo