EFAFLU case: cold start-up validation of transformers pumps by the use of a large climatic test chamber

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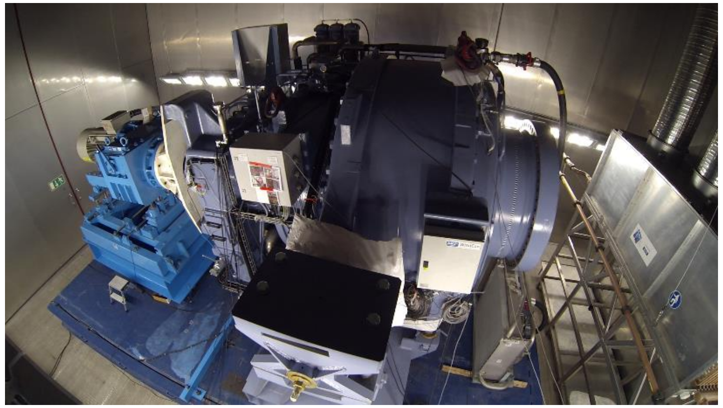
www.owi-lab.be | www.sirris.be

Winterwind
INTERNATIONAL WIND ENERGY CONFERENCE

Large climatic test chamber – example projects wind energy



Full size component testing of large and heavy machinery

Full size small & mid-range nacelle tests

Power electronics tests
Pitch & Yaw cold starts
Hydraulic brake tests
Generator tests

Full functional electrical tests with or without wind turbine auxiliaries (forced cooling, pumps, heating, expansion tank,…)

Smart solutions. Strong relationships.

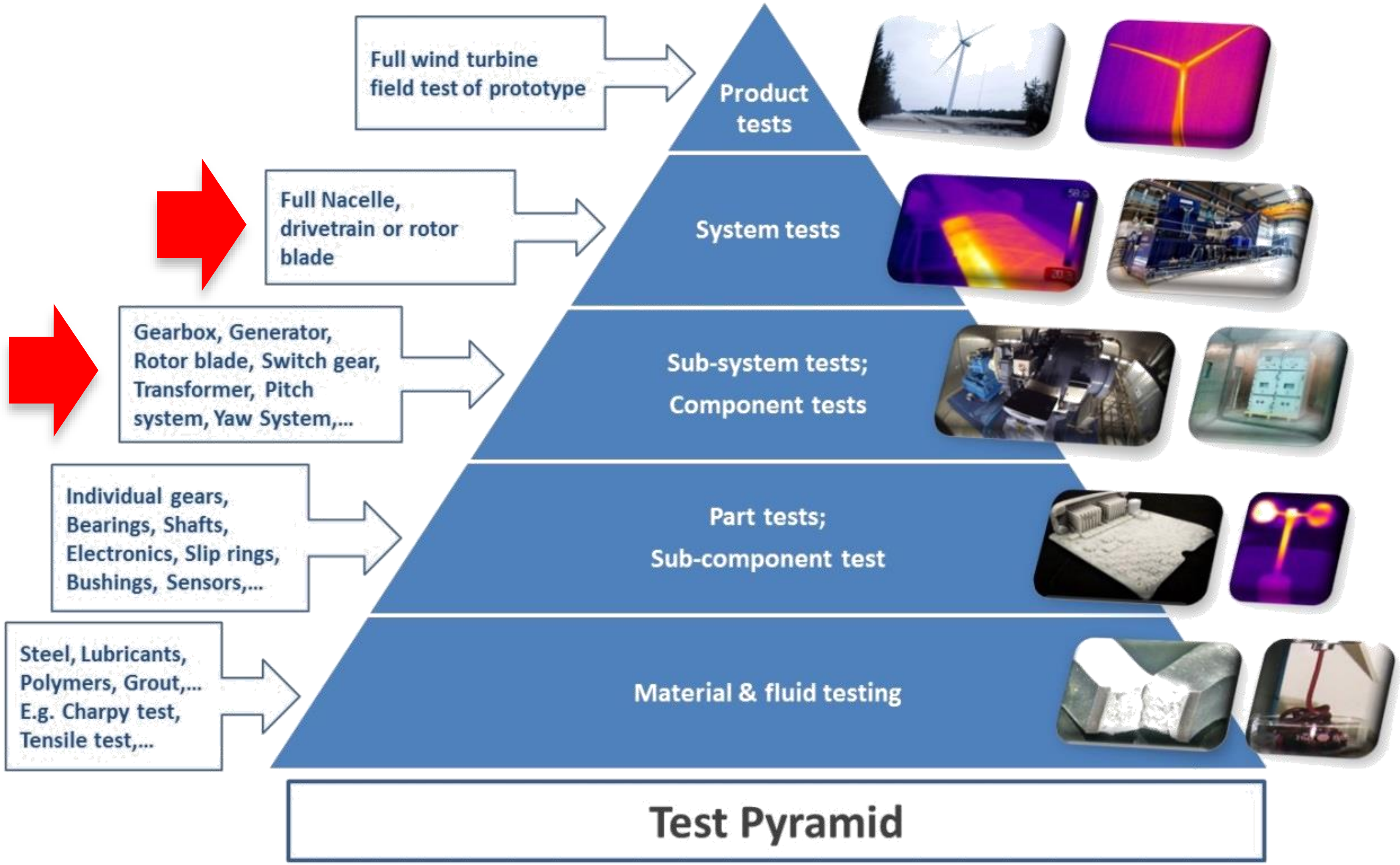
R&D tests on the behavior of fluids, oil and hydraulics in a full functional set-up

Smart solutions. Strong relationships.

Climatic test lab = Environmental testing of large / heavy electro-mechanical machinery
→ Functional testing under electrical, mechanical, hydraulic load during cold / hot / tropical / Humid environment

Focus = (functional) system & sub-system testing

EFAFLU
Bombas e Ventiladores



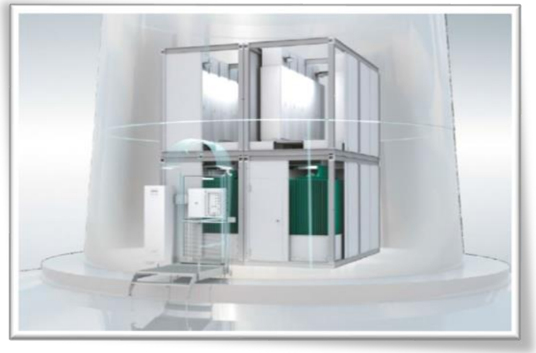
EFAFLU case (sub-system): cold start-up validation of transformer pumps

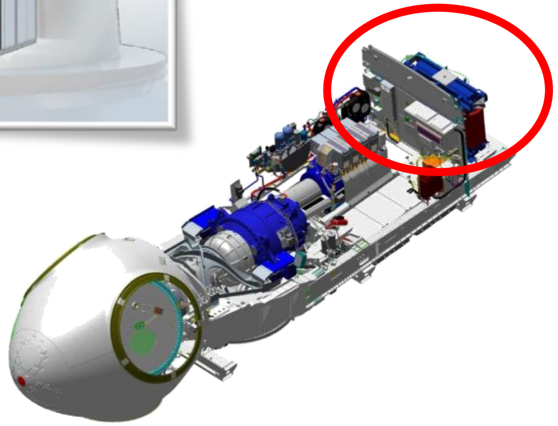
EFAFLU
Bombas e Ventiladores

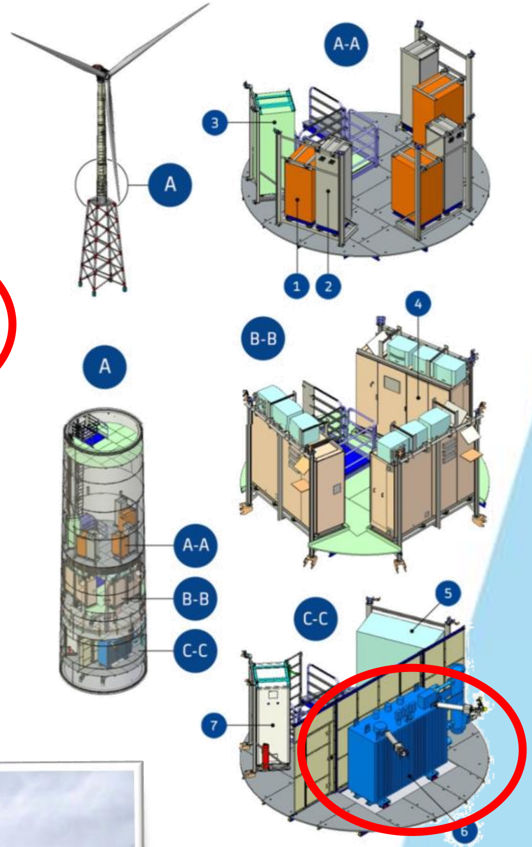
http://www.efaflu.pt/

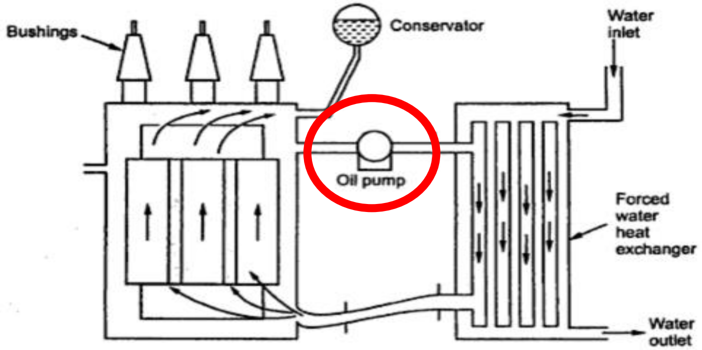
- Portuguese company founded in 1946
- Development, manufacture, marketing, technical support as well as after-sales service of pumps, pumping systems and fans
- Worldwide market → extreme environments (Canada, Russia,…)

Wind turbine transformers – an essential component for energy harvesting

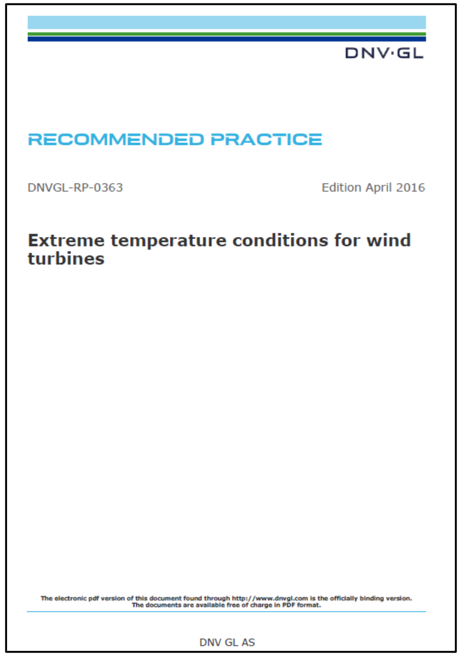








Wind turbine transformer pumps – part of the distribution transformer system


DNV·GL

RECOMMENDED PRACTICE

DNVGL-RP-0363 Edition April 2016

Extreme temperature conditions for wind turbines

The electronic pdf version of this document found through http://www.dnvgl.com is the officially binding version.
The documents are available free of charge in PDF format.

DNV GL AS

8.2.2 Start up procedure of wind turbine after long stand still during grid failure

A complete start up procedure concerning heating up or cooling down to operational temperature range should be given for the complete wind turbine after grid failure. The procedure should contain the measures for heating/cooling without grid power where necessary (e.g. for heating up the generator or main power transformer before switching on). The electrical installations (transformer, generator, converter and control cabinets etc.) are to be included in the procedure.

Main cooling medium

Mineral oil (fire point < 300 °C)	O
Ester/silicon (fire point > 300°C)	K

Circulation method

Forced	F
Natural	N
Directed into the windings	D

External cooling medium

Air	A
Water	W

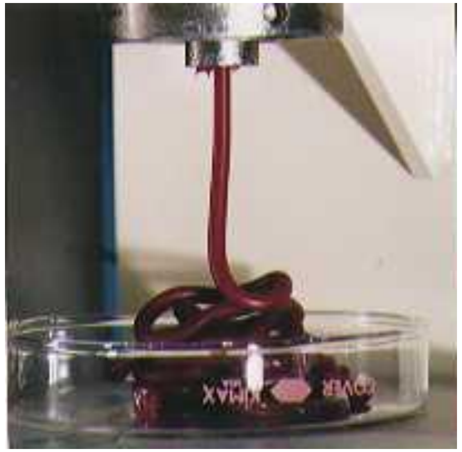
Circulation of external medium

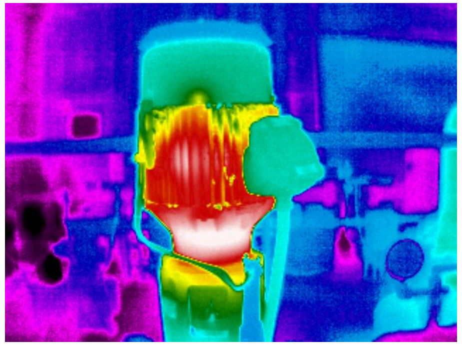
Forced	F
Natural	N

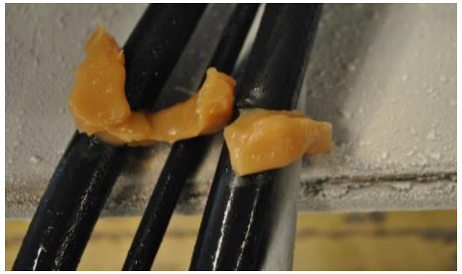
EFAFLU case: why performing a cold climate test?

Potential failure modes of a pump at extreme cold temperatures

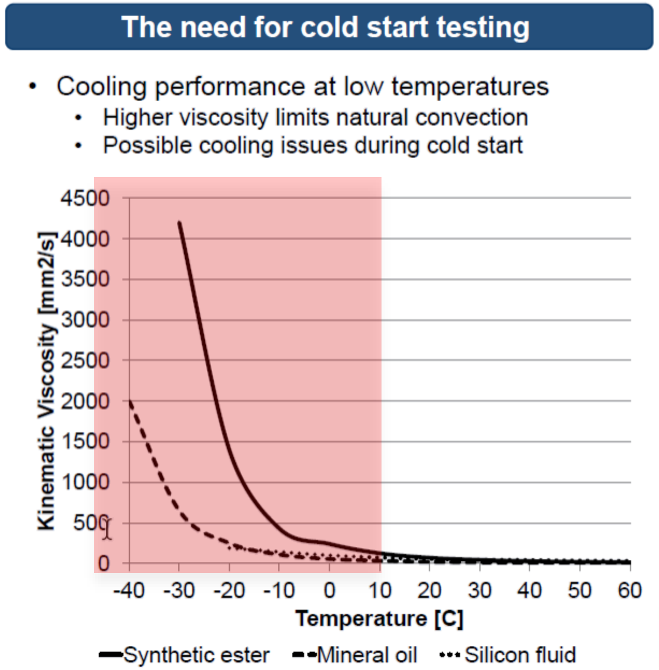
- **Lubricants become viscous and stiff**
  - ➔ exceptional load on the pump
- **Rotating elements at risk**
  - ➔ insufficient lubrication
  - ➔ different thermal expansion of sub components
- **Motor during long cold start-up at risk**
  - ➔ overheating cause by high current demand
- **Low temperatures effect on materials (plastics, metals, rubbers)**
  - ➔ brittle fracture of elements (sealings, cables, …)

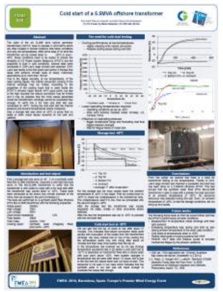






(illustrative examples)





Poster and Paper available
EWEA 2014: Cold start of a 5.5MVA offshore transformer


SGB-SMIT
Group
Synthetic Este
-40°C
SGB-SMIT
Group
Natural Ester
-40°C
CANADA GOOSE
ARCTIC PROGRAM

EFAFLU test specifications

- According to EN 50216-7 standard:

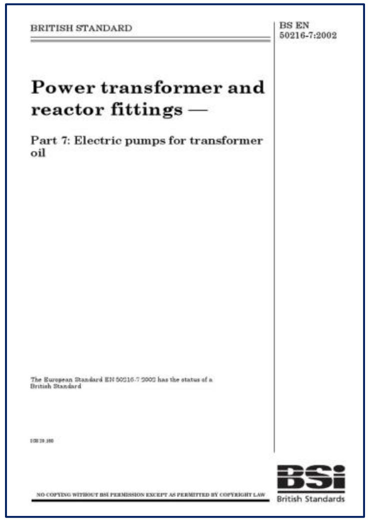
"Power transformer and reactor fittings; Part 7: Electric pumps for transformer oil"

➔ pumps required to perform cold start-up test <u>at -25°C</u>

- During the test the pump shall reach full running speed following the conditions:
  - At minimum voltage with oil at minimum temperature
  - Without overheating or other adverse observations

EFAFLU extends standard requirements to a more severe scenario of <u>-45°C !</u>

- Extreme locations worldwide (China, Russia, Canada,…)
- Robustness & Reliability → 'the new quality'


BRITISH STANDARD

BS EN 50216-7:2002

Power transformer and reactor fittings —

Part 7: Electric pumps for transformer oil

The European Standard EN 50216-7:2002 has the status of a British Standard

BSI British Standards

1:05 p.m. ET, January 30, 2019

Chicago will be colder than parts of Alaska — and parts of Antarctica

Polar vortex brings coldest air in a generation

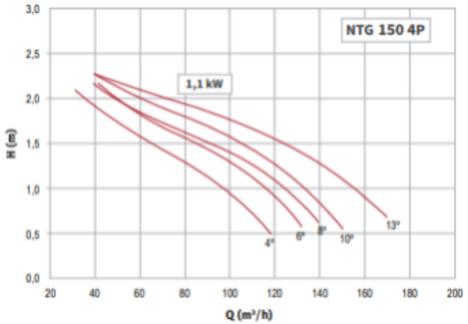
By Meg Wagner, Brian Ries, Amanda Wills and Veronica Rocha, CNN

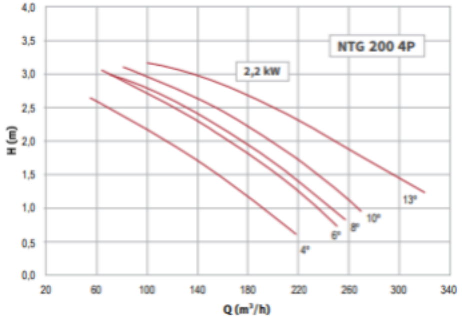
Updated 22 hr 43 min ago 8:01 a.m. ET, February 1, 2019

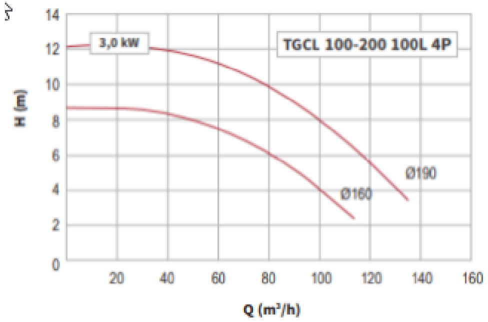
EFAFLU pump specifications

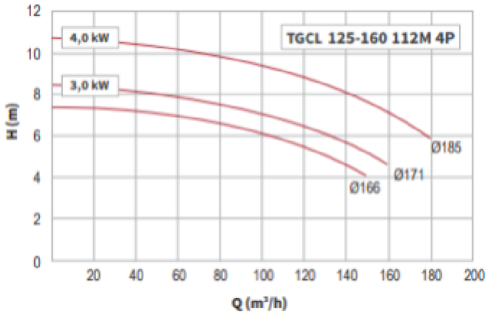
EFAFLU PUMPS SPECIFICATIONS					
Model	NTG 150	NTG 200	TGCL 100-200 100L	TGCL 125-160 112M	TGCL 150-200 132M
Type	IN-LINE	IN-LINE	END-SUCTION	END-SUCTION	END-SUCTION
DN (mm)	150	200	100	125	150
Power (kW)	1.1	2.2	3.0	4.0	7.5
Frequency (Hz)	50	50	50	50	50
I (A)	2.6	4.5	6.4	8.0	14.1
RPM (at 400V)	1440	1440	1450	1450	1450
Impeller Diameter (mm)	148	199	190	185	215
Blade Angle (°)	13	13	-	-	-

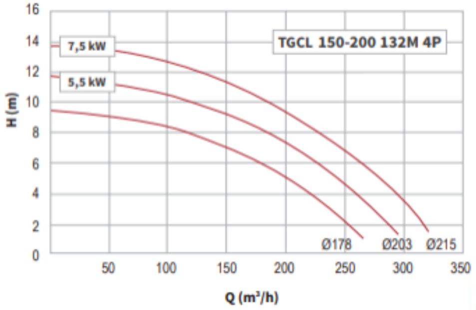
OIL SPECIFICATIONS	
Manufacturer	Nynas AB
Name	Nytro 10XN
Type	Transformer Mineral Oil
Density (kg/m³)	874
Viscosity at -30°C (mm²/s)	730
Viscosity at 40°C (mm²/s)	7.6











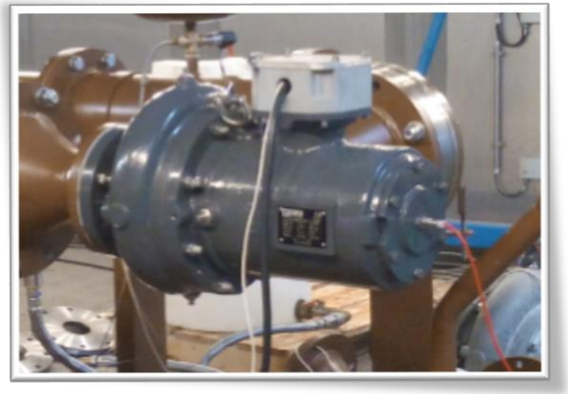
EFAFLU test description

- Test setup to simulate the sub-system resistance

  → Sub-system test approach

  (= mimic the functional behavior in the wind turbine setting)

- Measurements during the test:
  - Current
  - Rotational speed
  - Inlet oil temperature and pressure
  - Outlet oil temperature and pressure
  - Winding temperature



EFAFLU test set-up – functional sub-system test

- Closed loop test setup placed in the climate chamber
- Sensors to monitor temperature, pressure and rotational speed
- Orifice plates with different diameters for different flow rates

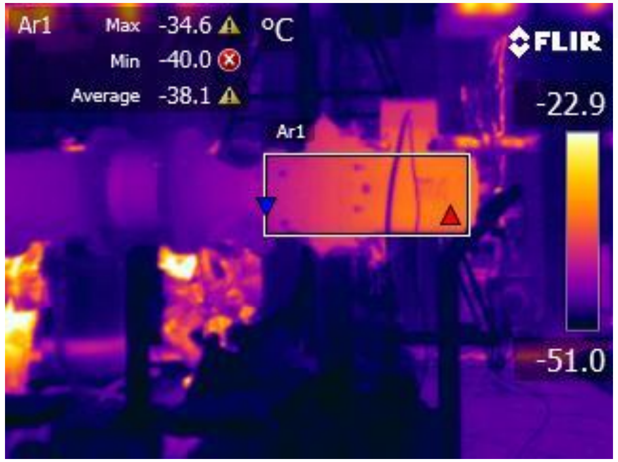
EFAFLU test procedure (1)

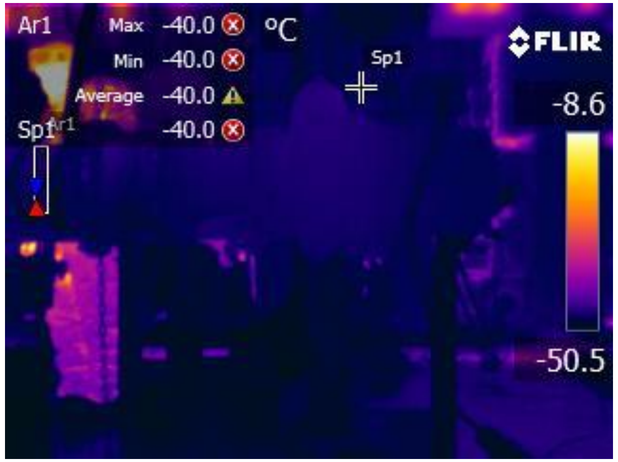
For each pump under test the following procedure was executed:

1. Pump A is mounted in the test setup with orifice plate
2. Cooling down of the chamber
3. Oil temperature stabilization at -45°C
4. Pump start-up at minimum voltage

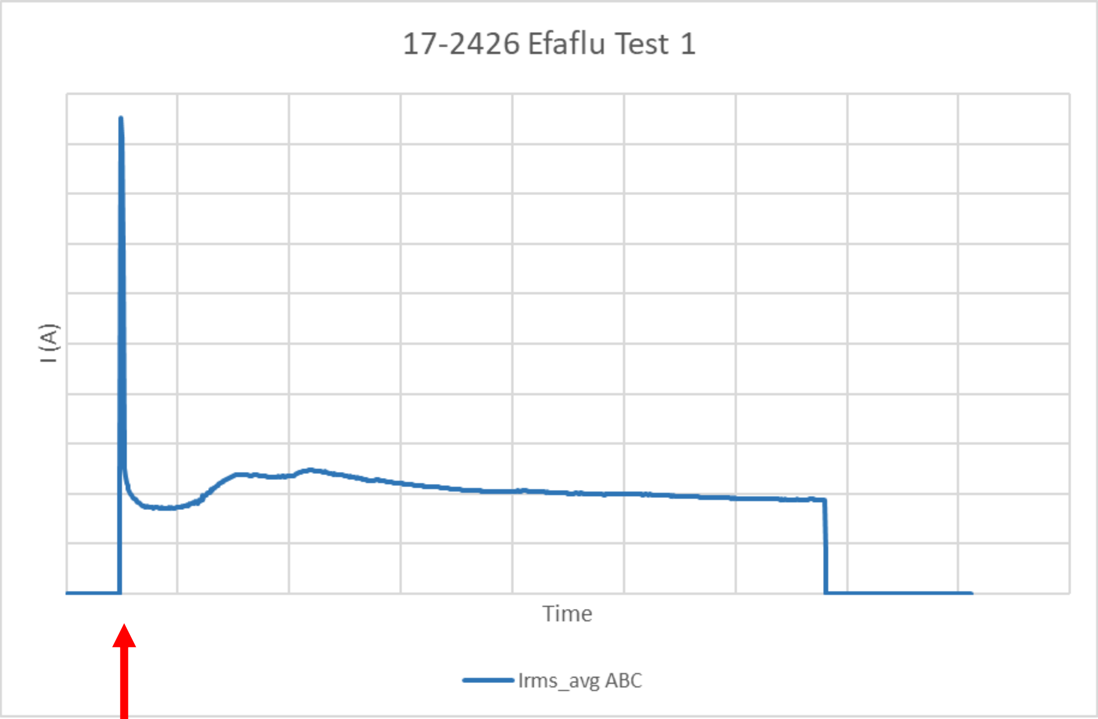
EFAFLU test procedure (2)

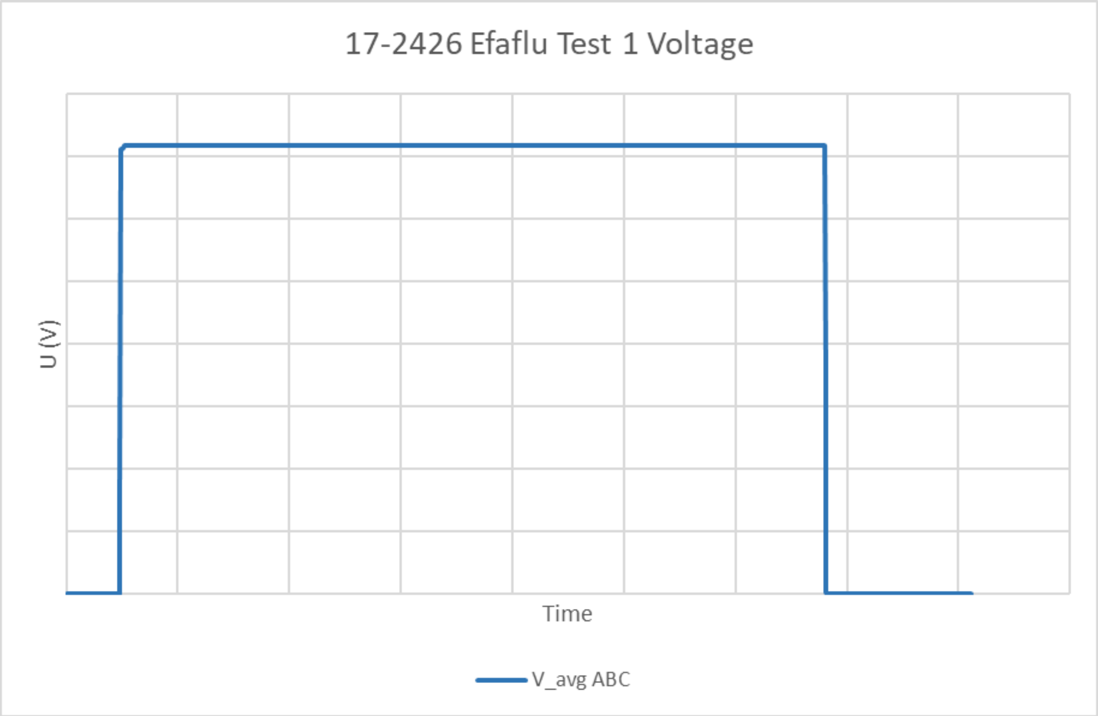
5. Pump reaches nominal speed
6. A, rpm, p, oil and winding T are recorded during the test
7. Pump A dismounted – Pump B mounted
8. Repeat 2-7



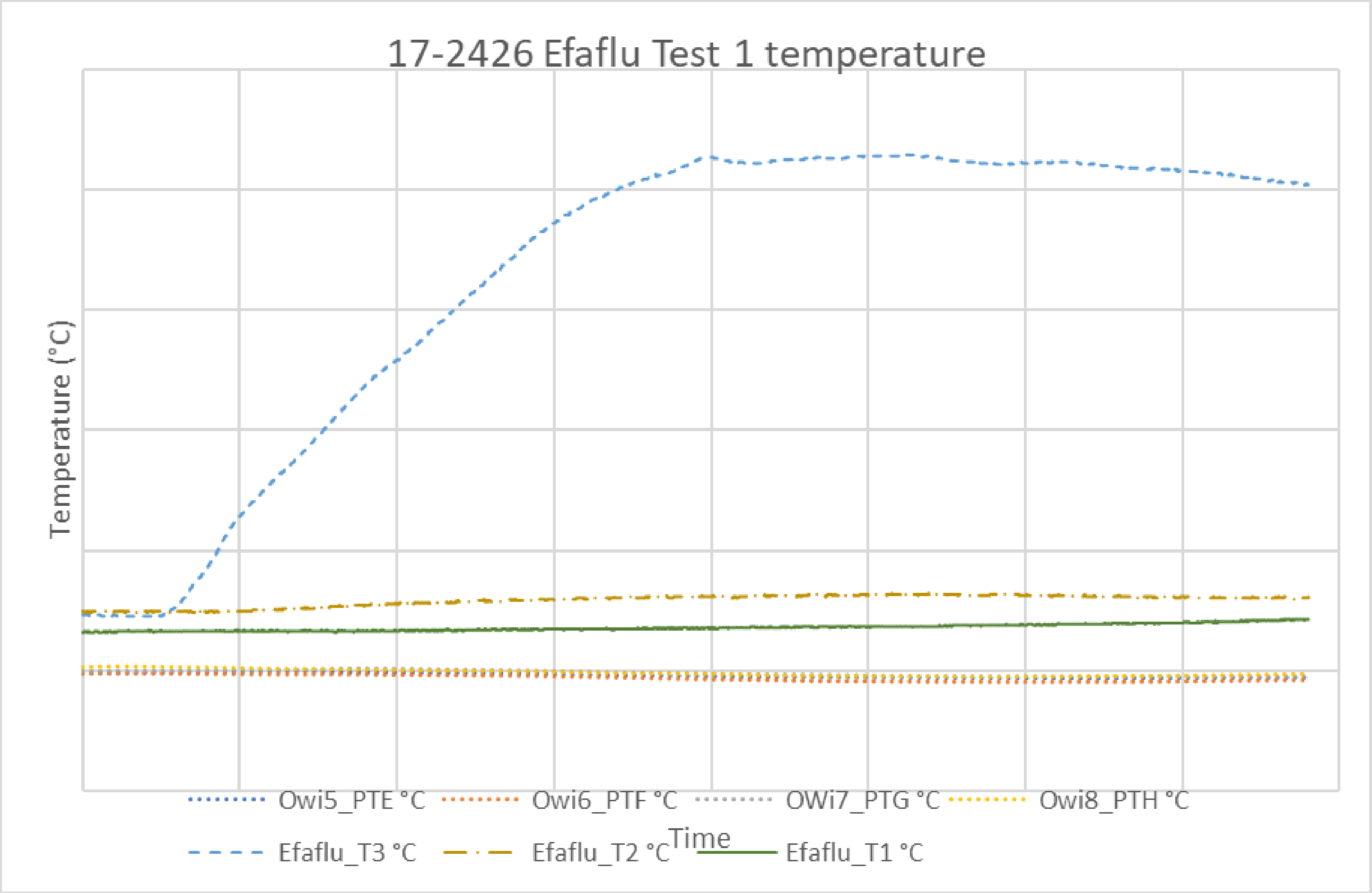


EFAFLU measurement results – current & voltage





EFAFLU measurement results – temperature



EFAFLU conclusions

Having completed all the tests with success, a full report for each pump was elaborated

The report contains:

- Full explanation of the test performed
- Test setup schemes
- Values recorded during cooling and during test
- Results and conclusions

<u>Value driver = risk mitigation</u>

➔ EFAFLU encloses OWI-lab's report among the pump documentation as certification for application in cold climates – proof for customers (OEM's, transformer suppliers, O&M managers) that the product can survive & operate in -45°C

Credits to the project team – example: replacing parts in extreme temperatures

João Pinto
R&D Engineer at EFAFLU Bombas e Ventiladores, S.A.
8h

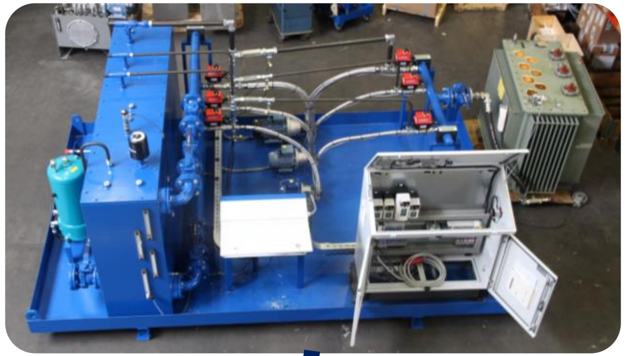
During the last month of April, **EFAFLU Bombas e Ventiladores, S.A.** successfully cold start tested five transformer oil pumps at -45 °C. These tests were performed in **OWI-Lab**. It was a tough week yet rewarding and a privilege to be part of this project. We faced extreme conditions and overcame several challenges to achieve our goals.

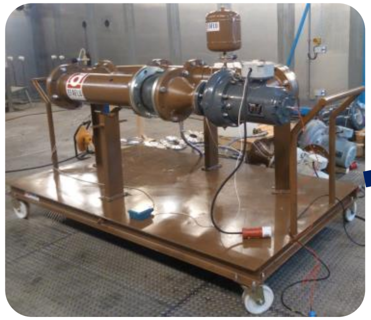
I would like to thank my colleague **Benedita Vasconcellos Ferreira** for all the ideas, technical discussions and help during this project, it was fundamental for the success of these tests.

Future R&D topics – risk mitigation topic / robustness & reliability topic

- **Durability test in harsh environment (cold climate)**
  - cold start-up cycles at different T, …
- **Fatigue tests in extreme temperatures**

➔ **assessment of component lifetime**





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Future R&D topics – risk mitigation topic / robustness & reliability topic

Climate chamber testing of integrated systems with components and sub-components from different partners

➔ Validation of **Digital Twin** approach in extreme temperatures

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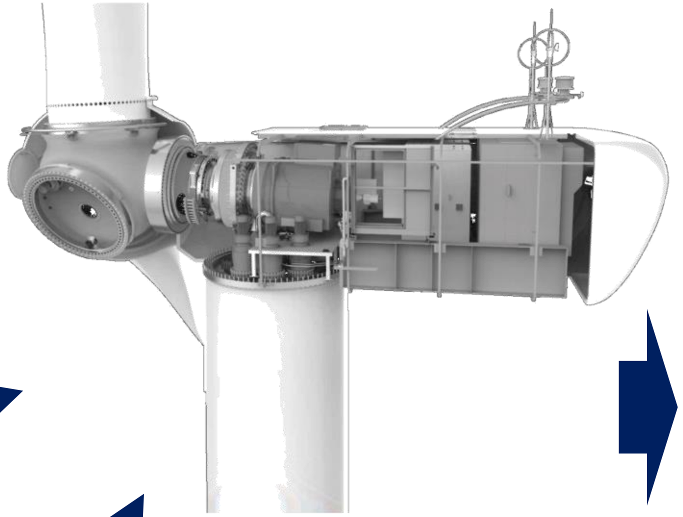
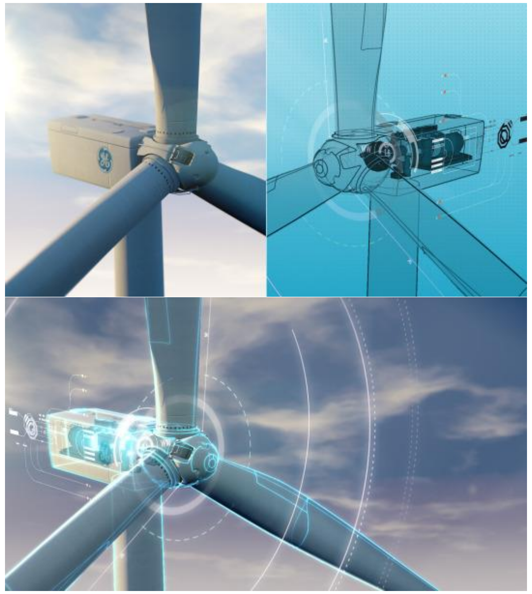
+ …





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