Condition Monitoring for the Use of Silicone Oil as a Heat Transfer Medium

June 9th, 2020_DLR Sonnenkolloquium

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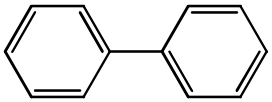
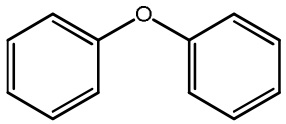
HELISOL® shows clear Advantages over BP/DPO

BP/DPO*

- 25 - 28% BP, 72 - 75% DPO
  (Diphyl® , Dowtherm® A, Therminol® VP-1)



Biphenyl



Diphenyl oxide

- Working temp.: 60 °C bis 400 °C
- Freezing point: 12 °C
- Vapor pressure (400 °C): 11 bar
- Self-ignition temp.: ~ 599 °C
- GHS classification for unused HTF

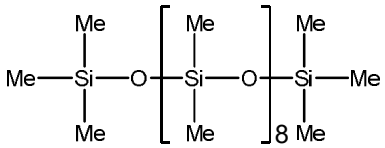
Harmful

Skin irritation - Category 2
Eye irritation - Category 2B
Specific target organ toxicity - single exposure - Category 3

Environmental hazard

HELISOL® XLP

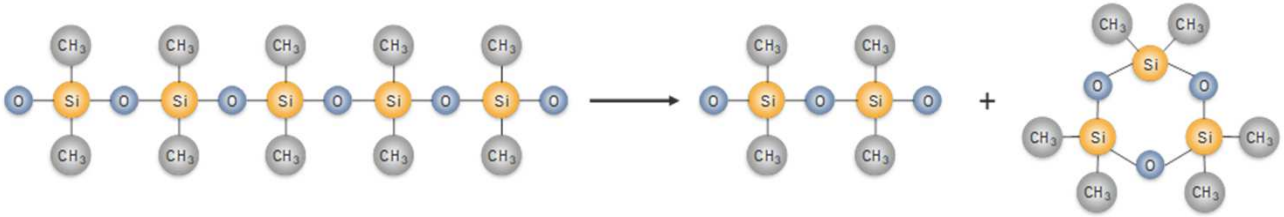
- Low viscosity silicone based HTF



- Working temp.: −40 °C to 425 °C
- Pour point: −51 °C
- Vapor pressure (400 °C): ~11 bar
- Self-ignition temp.: ~370 °C
- Lower H2 formation
- No fouling
- No GHS classification for unused HTF

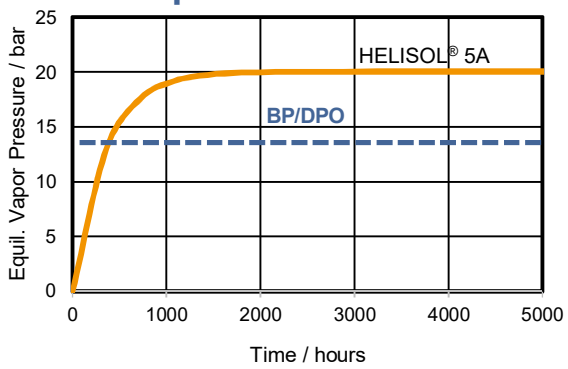
*BP/DPO (Biphenyl/diphenyl oxide)

HELISOL® fluids Equilibrate when used at High Temperatures

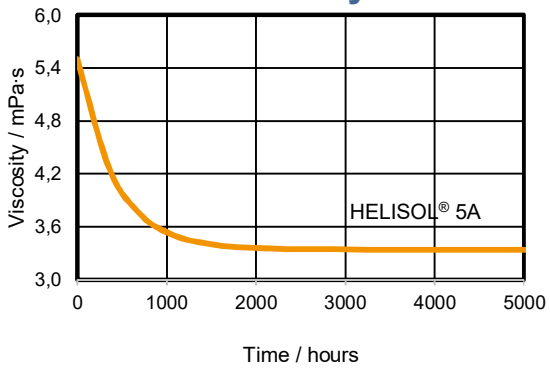


Representation of the equilibrium reaction of silicone fluids at high temperatures

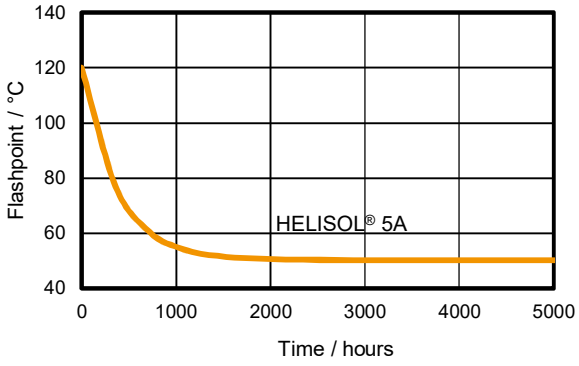
Vapor Pressure



Viscosity



Flash Point



- **Equilibration is not a degradation and does not affect fluid life time!**
- **Stable fluid composition after 720 hours (30 days) at 425 °C (“in use”)**
- **Auto ignition temperature remains constant**

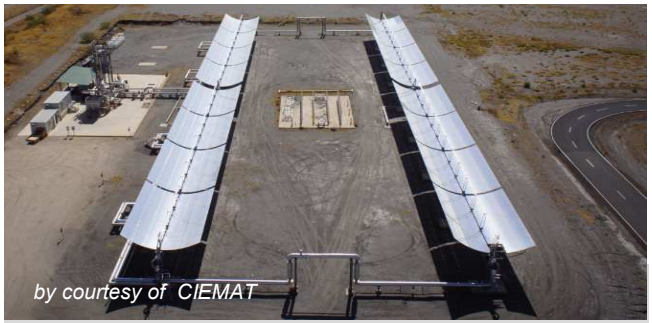
HELISOL® Development - from Lab to Loop in Cooperation with Experts in several Public Funded Projects

PAS** (2011 - 2012) → **Si-HTF** (BMWI 2012 - 2015) → **SITEF** (SEN*** 2015 - 2017) → **SIMON** (SEN 2017 - 2019) → **SING** (BMWI 2020 - 2022)

HELISOL® 5A	▪ excellent thermal stability ▪ no freezing ▪ lower hydrogen formation
HELISOL® XA	▪ lower vapor pressure
HELISOL® XLP	▪ optimized vapor pressure ▪ useable for existing technology

*TRL…technology readiness level,
**PAS…Pre Assessment Study
***SEN… SolarEra.NET

Loop-Scale (TRL 7)

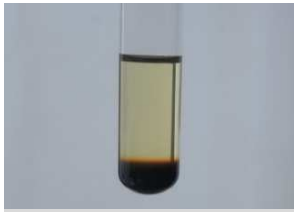


- Proof of Concept
- HTF volume 8 m^3
- > 480 h solar @ 425°C (450 °C)

+ No supercritical behavior, density, vapor pressure, heat conductivity, flash point
~ Heat capacity, thermal stability
o/- Viscosity, low temperature behavior → pumpability

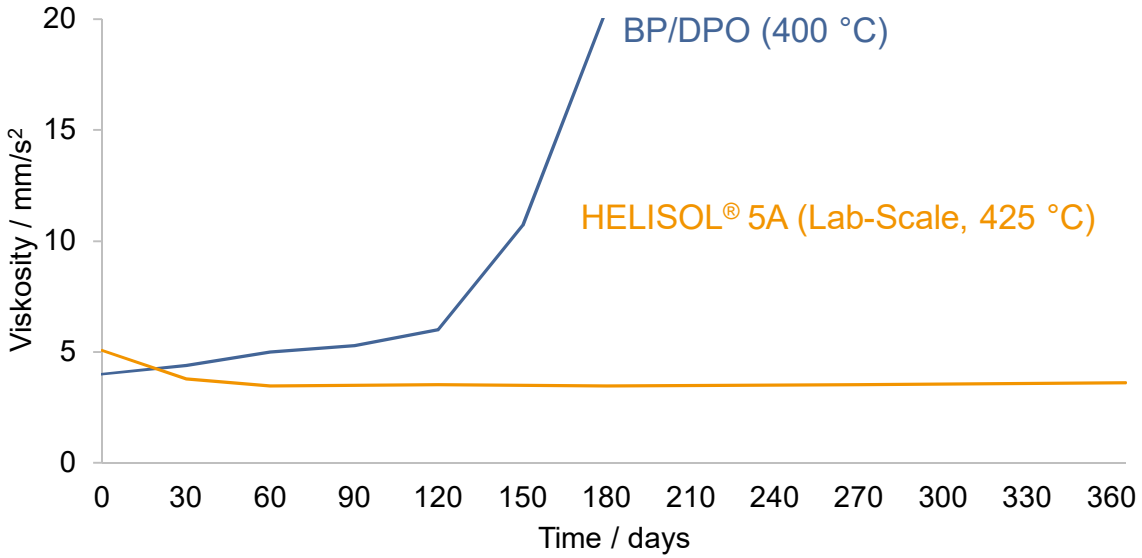
HELISOL® 5A shows an Outstanding Thermal Stability

Comparison of Viscosity under Thermal Stress



BP/DPO
400 °C /180 d

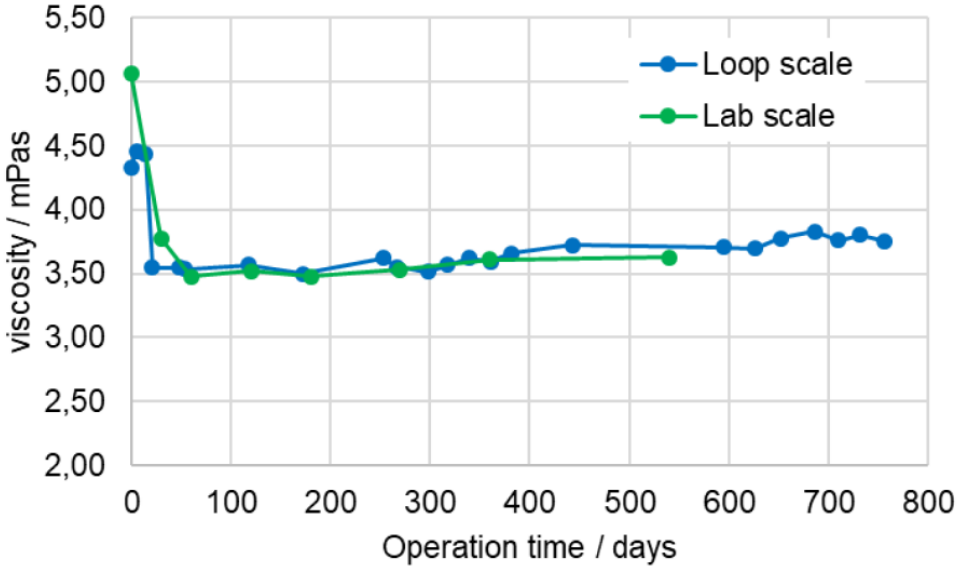
HELISOL®
425 °C / 180 d

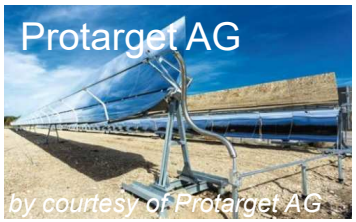


HELISOL® 5A shows an Outstanding Thermal Stability not only in the Lab but also on a Technical Scale

Course of Viscosity under Thermal Stress

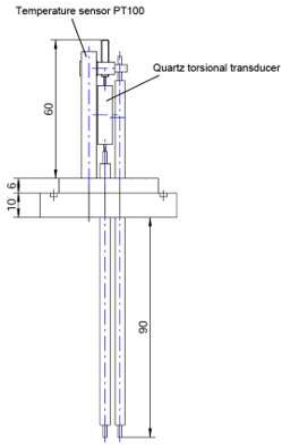
by courtesy of DLR

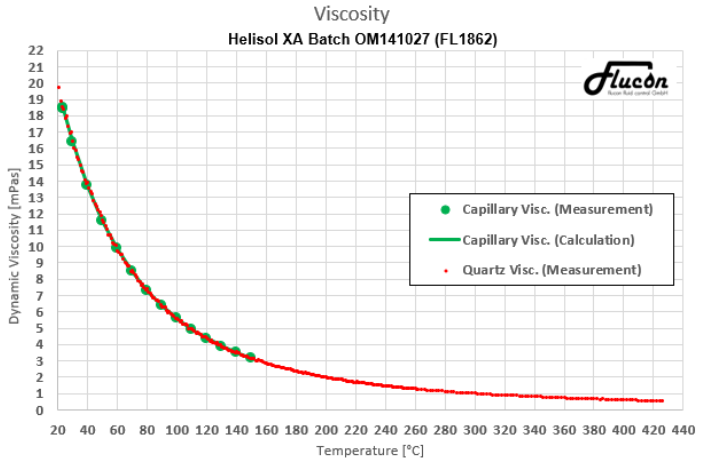




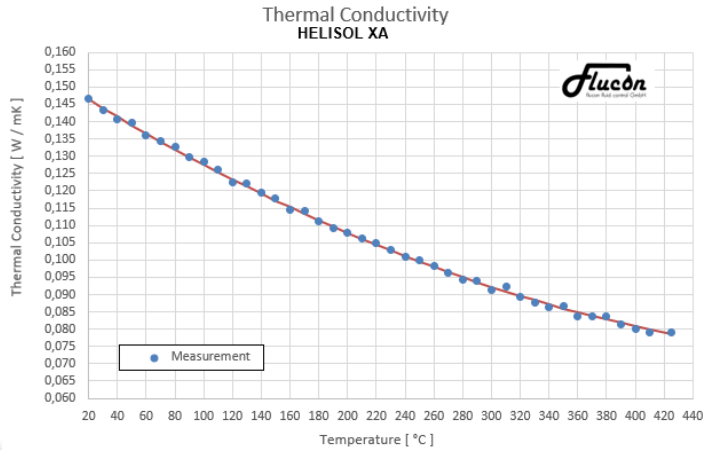
Planned Inline Monitoring of Viscosity & Thermal Conductivity by Flucon

Viscosity





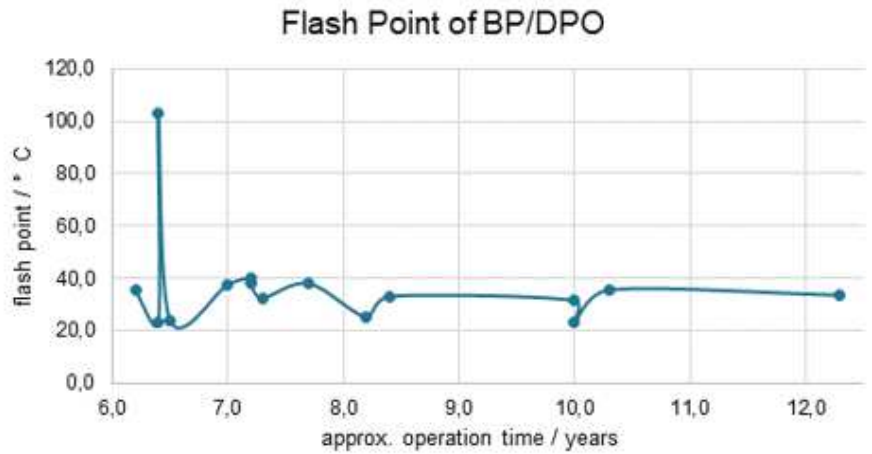
Thermal Conductivity



by courtesy of Flucon

The Course of the Flash Points (BP/DPO v.s. HELISOL®) is Widely Comparable…

Flash Points of BP/DPO out of different CSP-plants



Comparison of the Flash Point:

- **Flash Point of unused HTF**
  - BP/DPO: 113 °C
  - HELISOL® 5A: 120 °C
  - HELISOL® XLP: 220 °C
- **Flash Point of HTF in use***
  - BP/DPO: between 30 and 40 °C
  - HELISOL® 5A: between 30 and 50 °C
  - HELISOL® XLP: 67 °C

*…Heat transfer fluids that have been used in the heating system at least 720 h at 425 °C (~30 days).

Methods to Determine the Aging Degree for BP/DPO Cannot be Transferred to SiHTF

Methods for BP/DPO

DIN51529

- Coke residue according Conradson

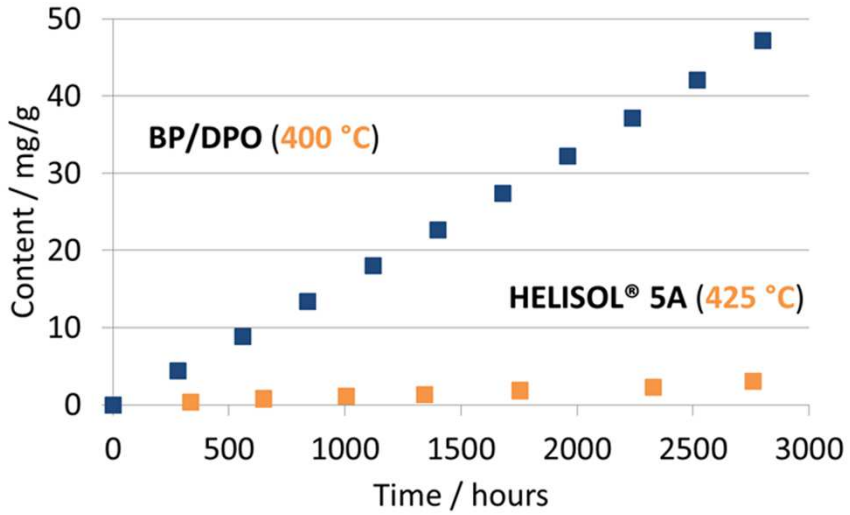
GB Code

- Ash content (mass fraction), %
- Carbon residue (mass fraction), %

UNE

- low boiler content <1%
- high boiler content <10%

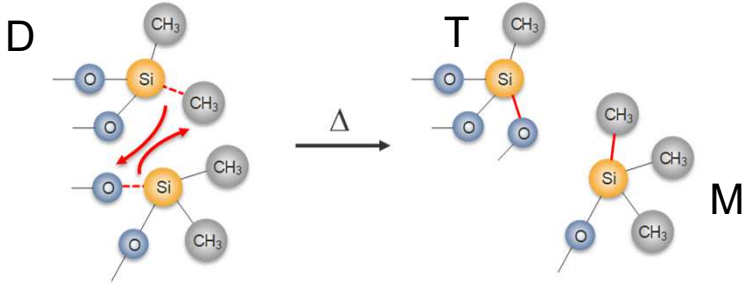
DLR: Aging Test based on Gaseous and Low Boiling Degradation Products



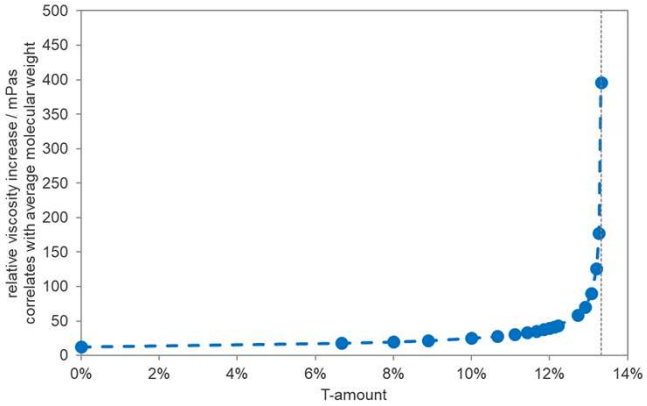
- New method needed to determine the aging degree for SiHTF

Accurate Degradation Determination by Wacker T-Group Method

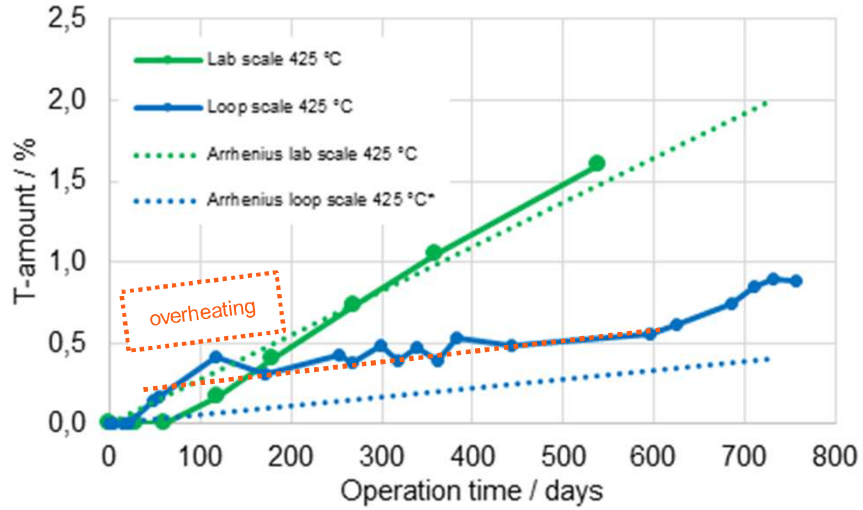
Thermally induced Disproportionation



Viscosity increase



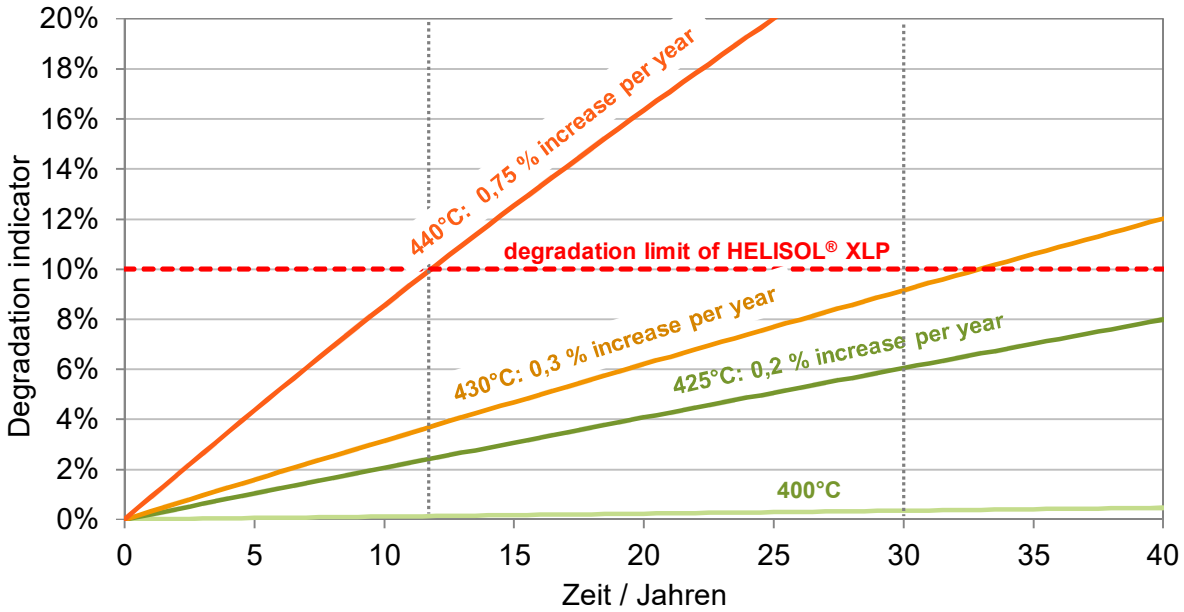
T-Group Comparison for 425°C

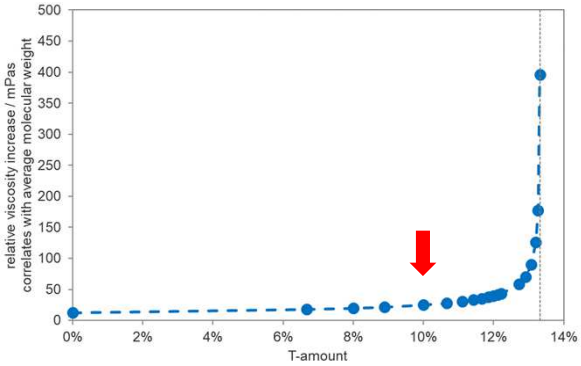


*calculated from lab scale kinetic data due to reduced thermal stress at plant of approx. factor 5

HELISOL®: No Fluid Exchange Needed up to 30 Years at Operation Temperature (425 °C)

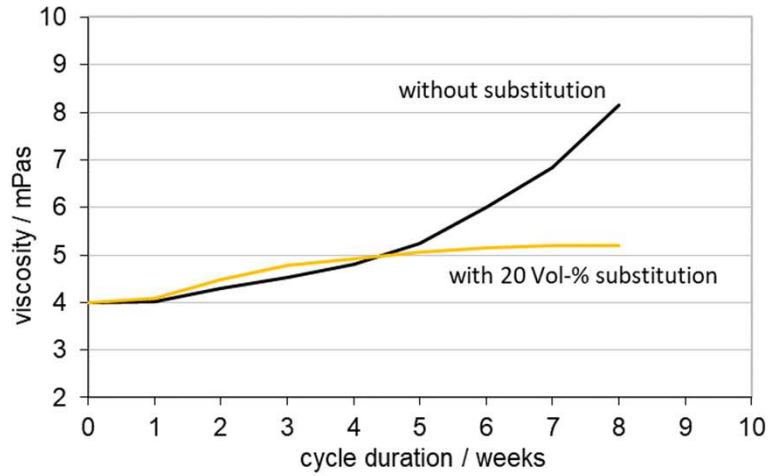
Aging Characteristics According to Arrhenius Kinetics





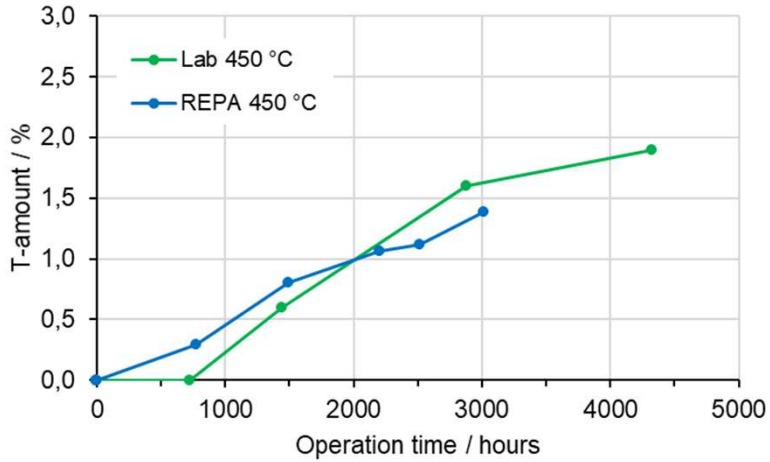
Refurbishment for Strongly Degraded Si-HTF Possible

HTF „Refurbishment“ at 465°C



- The effect is based on equilibration and dilution
- Patented principle : EP3146011B1

REPA Test-Loop: Accelerated Aging of HELISOL® XA

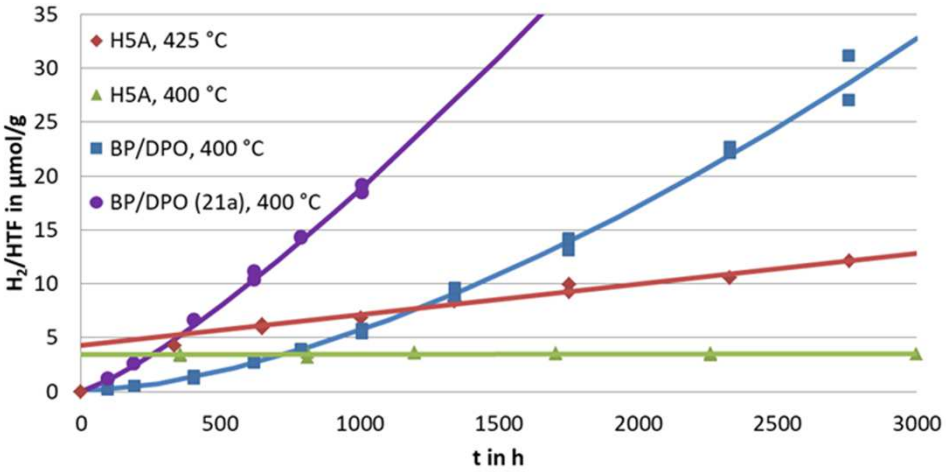


- Refurbishment concept to be tested

- **Substitution may balancing increased ageing rates**

Almost no Hydrogen Formation of HELISOL® at 400 °C

Comparison of Hydrogen Formation



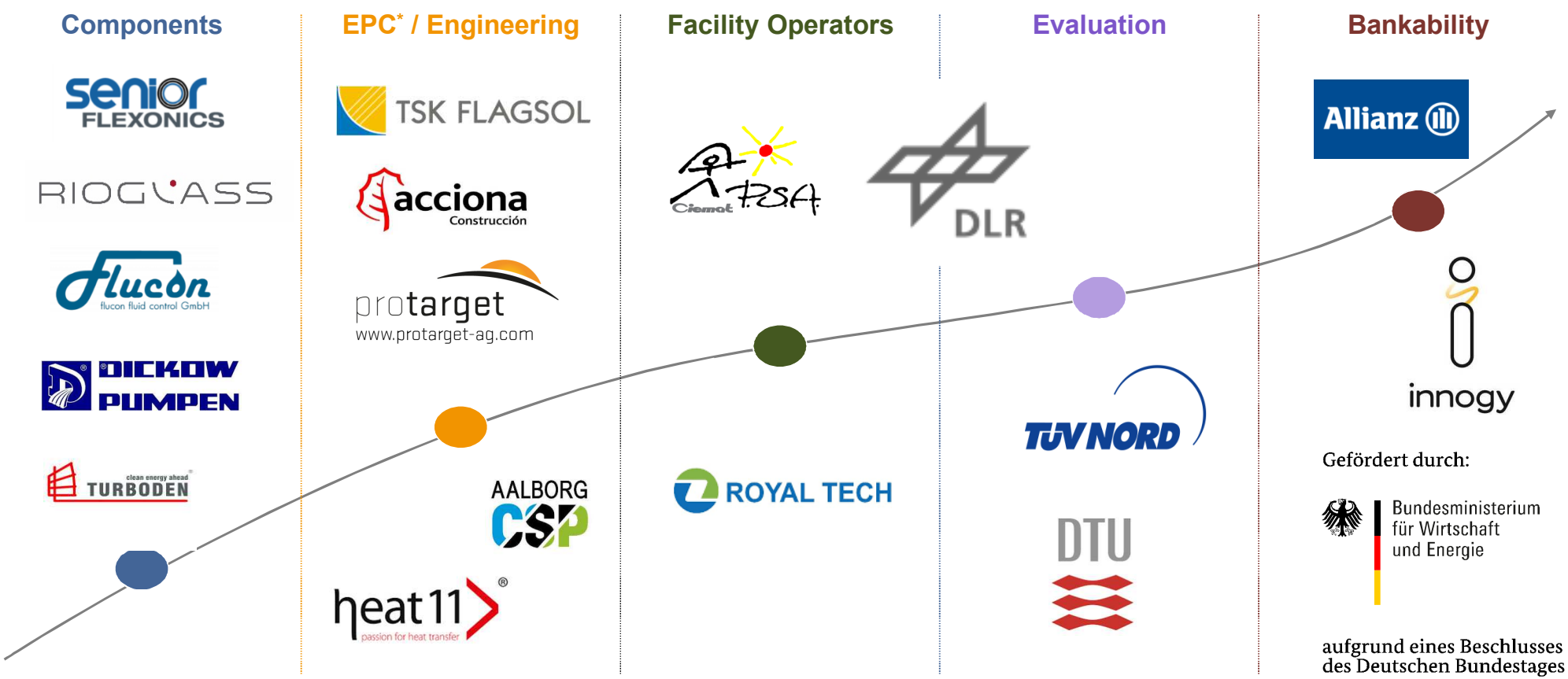
BP/DPO (21a): regular operation at 350°C

Aspects for Future R&I Projects:

- Examination of the applicability of an HTF exchange scenario to existing power plants
  - HTF exchange demonstration (loop-scale)
  - Economic assessment e.g. operation temp. from 393 °C to 410 °C
  - Investigation of hydrogen removal mechanism
  - Investigation of the recovery of HCEs* saturated with hydrogen using silicon based HTF

* Heat Collecting Elements

Thank you!!



*…engineering-procurement-construction