Comparison of fresh and aged dielectric fluids for direct immersed battery cooling

March 2025

Agenda

APL Group

1. Introduction
    1.1 Pros & cons direct immersed cooling in automotive applications
    1.2 Fluid used for the test
2. Setup of the test rig
3. Test procedure
4. Test results
5. Conclusion

Pros direct immersion cooling	Cons direct immersion cooling
Efficiency	Complexity (due to additional fluid circuit)
Life span	Material compatibility
Charging cycle	
Safety	

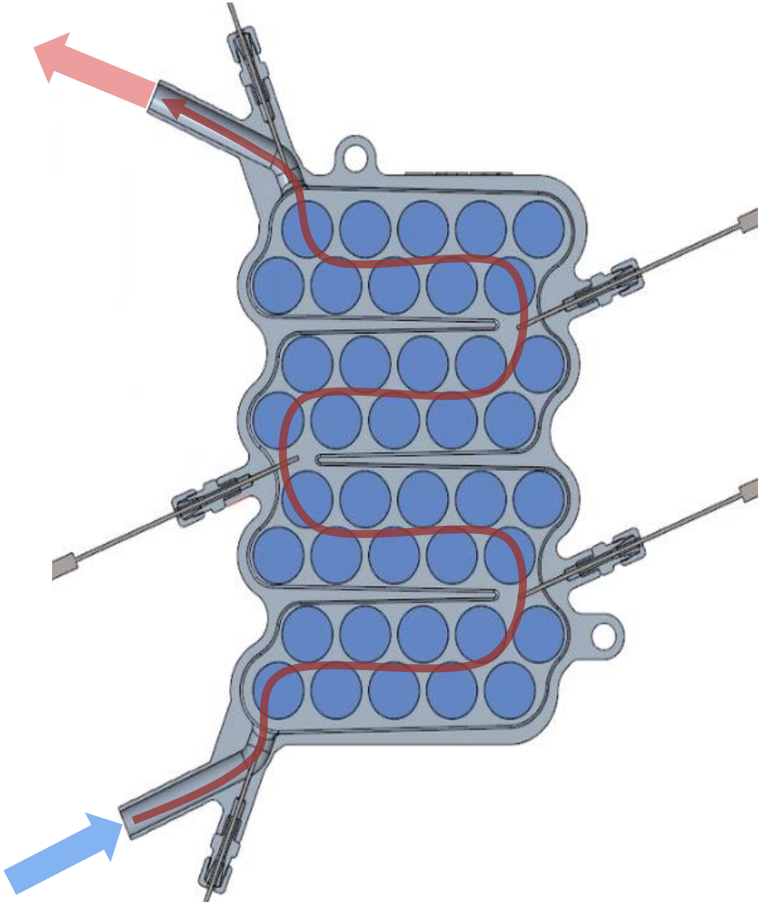
Parameter	Engineered Fluids AC-110
KV40	8,11 cSt
Flash Point	193 °C
Density (15,3 °C)	0,82 g/cm^3
Breakthrough voltage	> 60 kV
Resistivity	> 10^{14} Ω·cm
Thermal conductivity (40 °C)	0,1359 W/m·K
Specific heat capacity (40 °C)	2,2121 kJ/kg·K

Source: Technical data sheet (https://www.engineeredfluids.com/products/ampcool/) Date: 07.01.2025

Polyamide material
➡ Good compatibility with test fluids

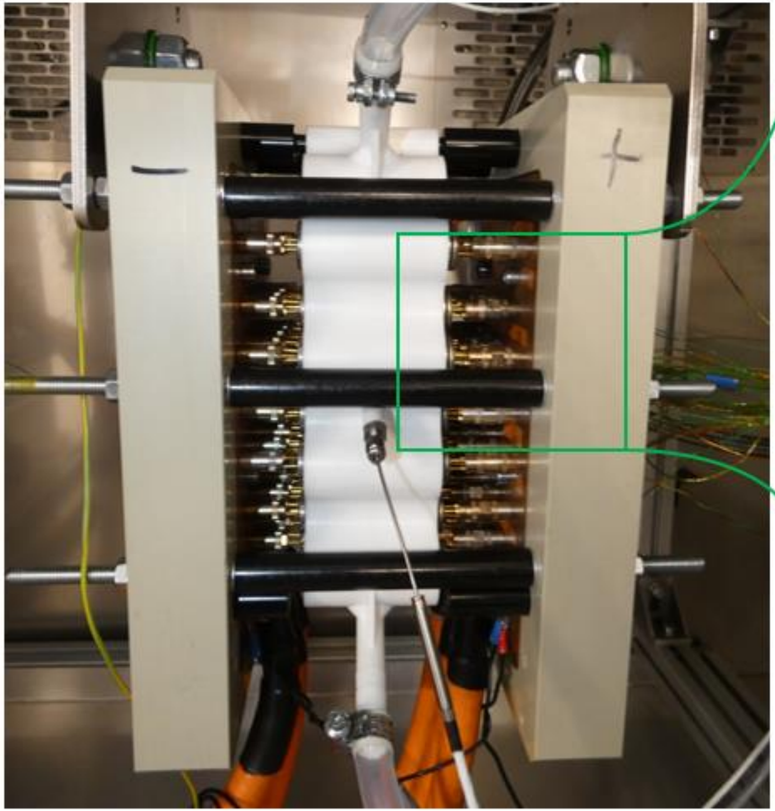
3D-printed
➡ Quick adaption to cell format and flow pattern

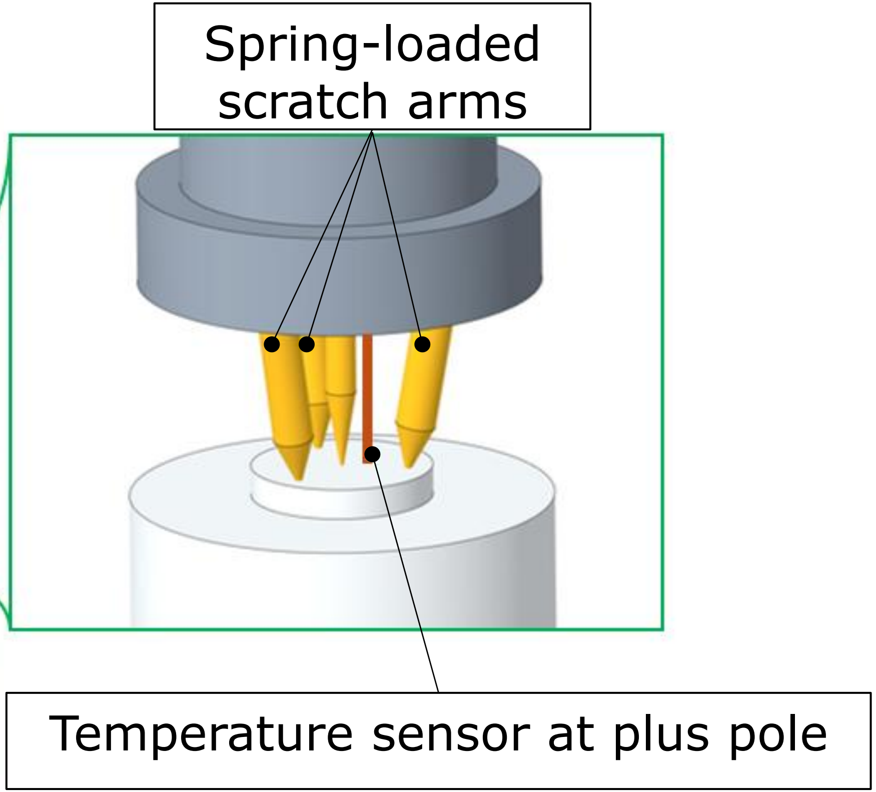
40 cells 1s40p
Samsung INR21700-40T
Module capacity: 160 Ah



Setup of testrig

Battery contacting

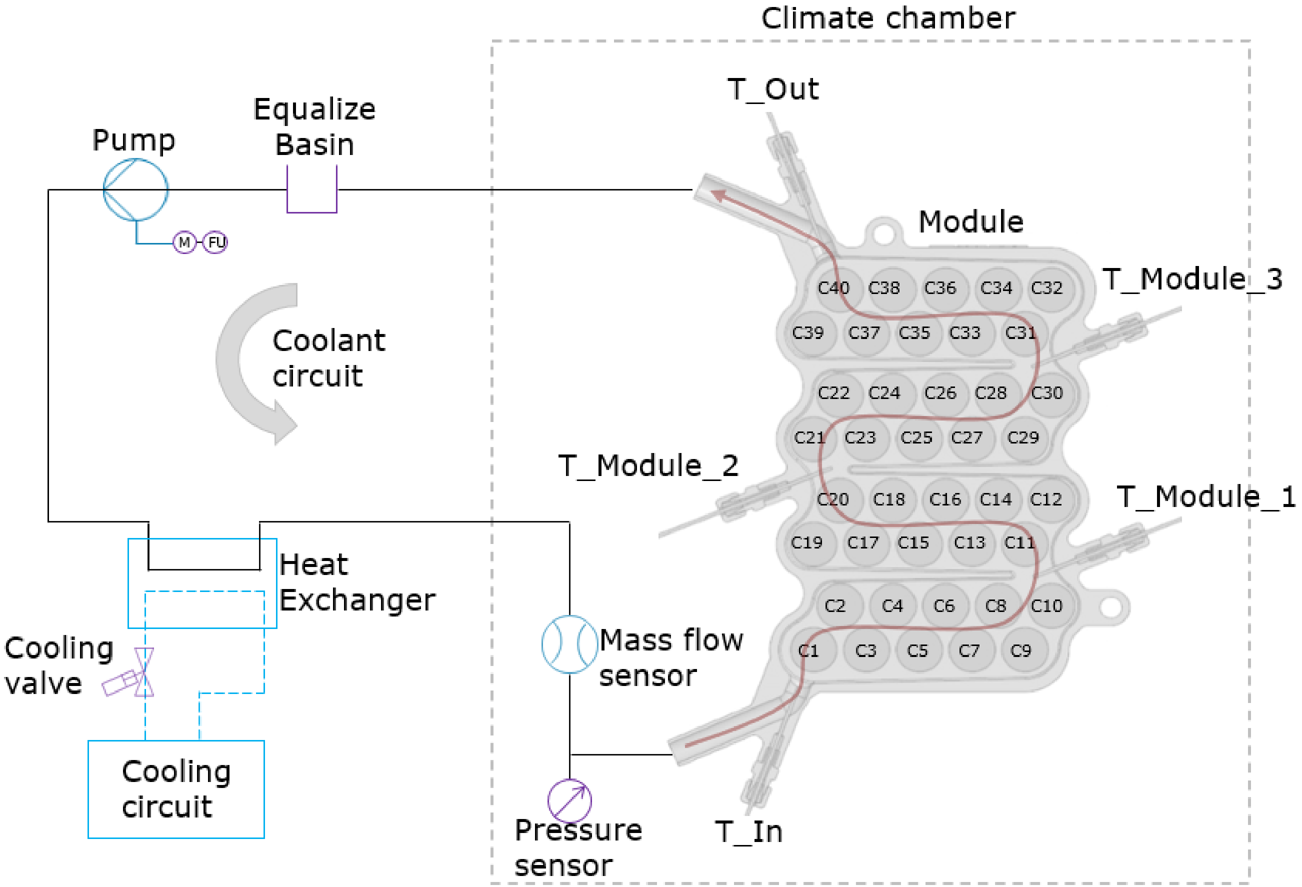




Setup of testrig

BatteRig test stand

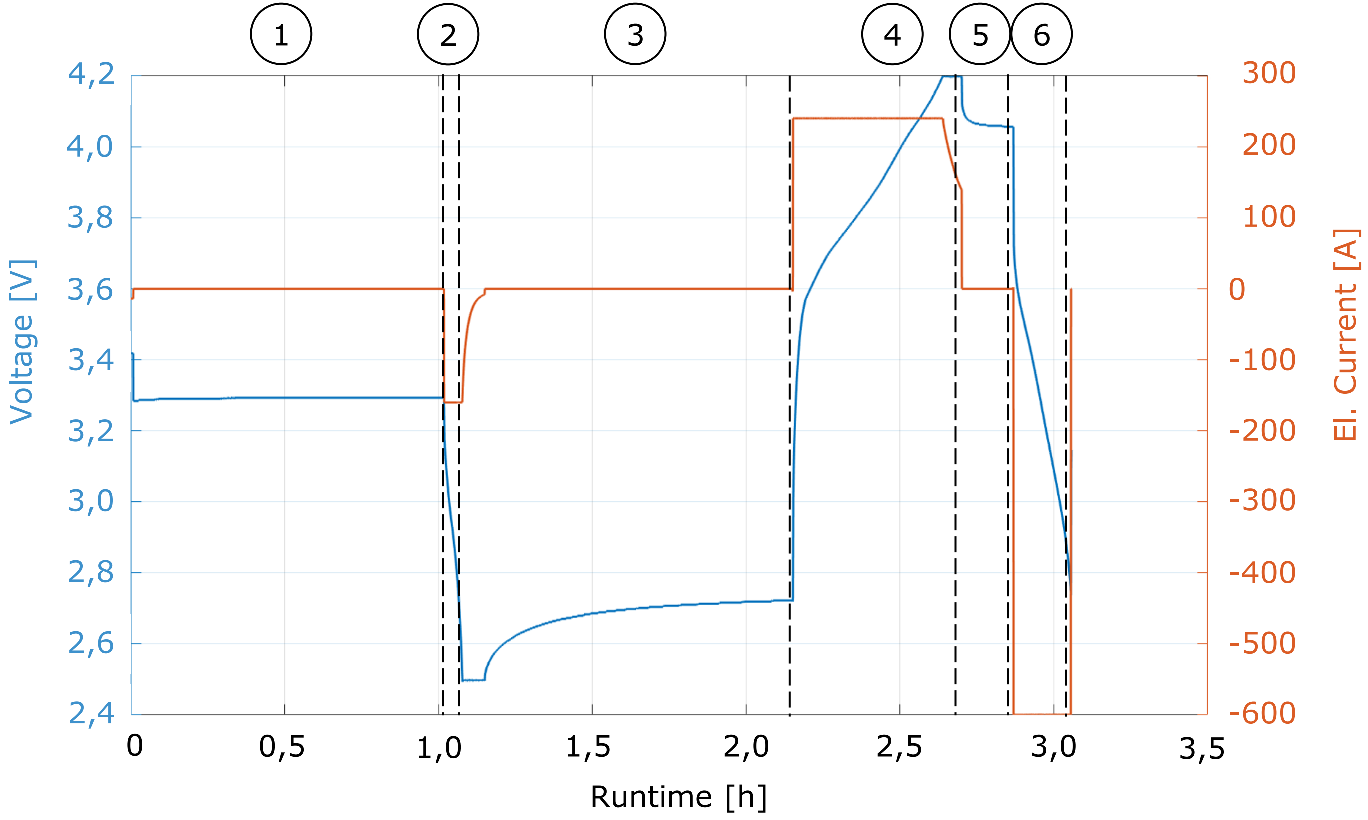
APL Group



Test procedure

Composition of one test cycle

1	Thermal balance 1 h
2	Discharging with -1 C to SOC 0
3	Thermal balance 1 h
4	Charging with 1,5 C to SOC 80
5	Relaxation 10 min
6	Discharge with -3,75C to SOC 10



Identification of two main problems:

1. Aging of battery cells

Conducting of RPT-cycles acc. to proven method

- Determination of cell state (residual capacity, inner resistance)

Definiton of the reference fluid AmpCool™ AC-110 by Engineered Fluids

- Each candidate is surrounded by reference runs
- If reference runs are correlating, the run is valid

2. Cross-contamination due to fluid changes

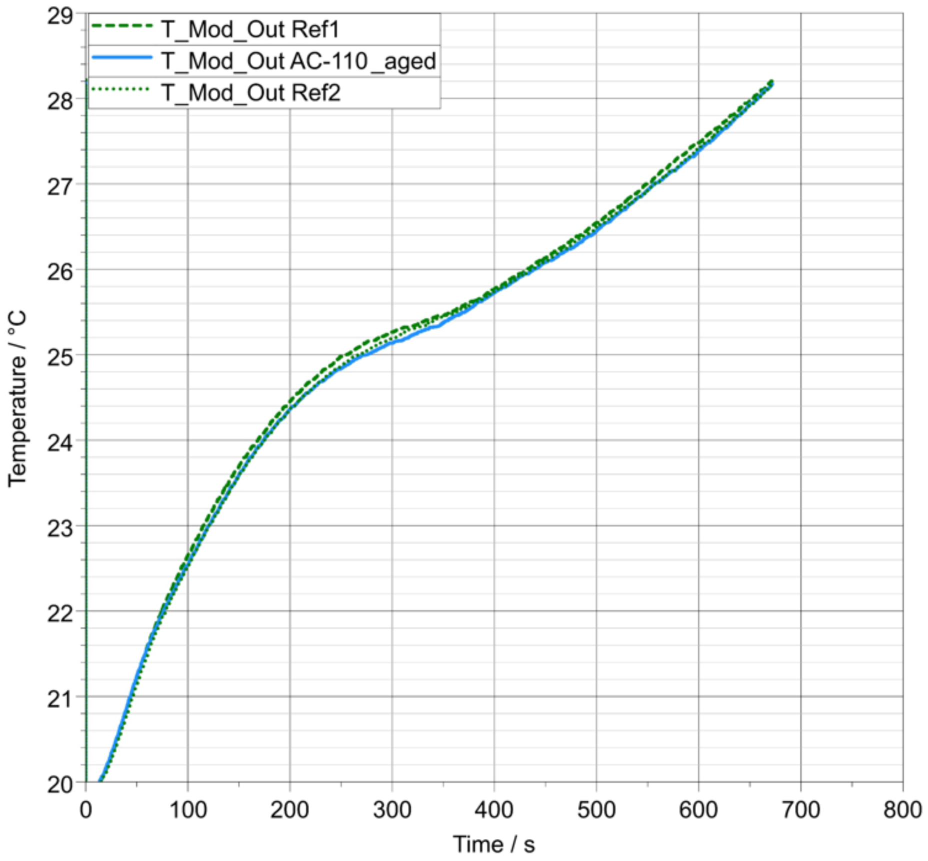
Requires proper flushing of the rig between different fluids

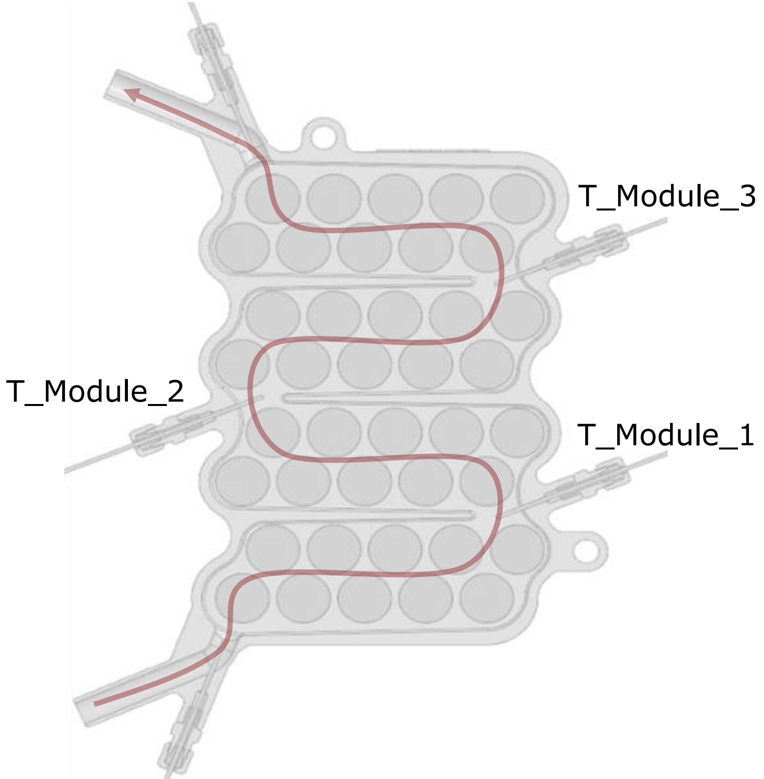
- Development of a standard work sequence for fluid exchanges
- Includes 3x flushings with respective new candidate
- Density measurement before candidate run for validation of flushing

Test results

Measured temperatures

Aged = stored at 95 °C for 2.780 h ≙ 10 years in duty

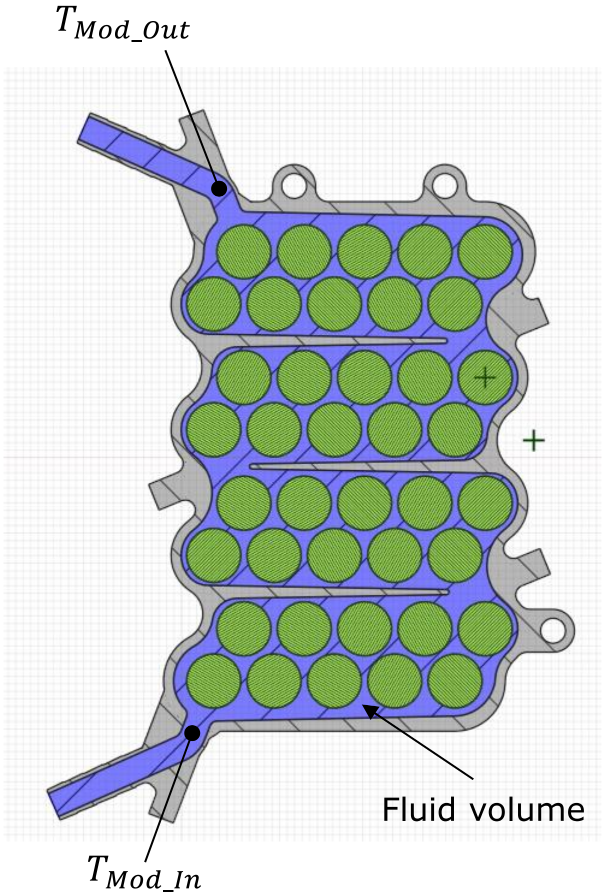




T_In = 20 °C ± 0,1 °C

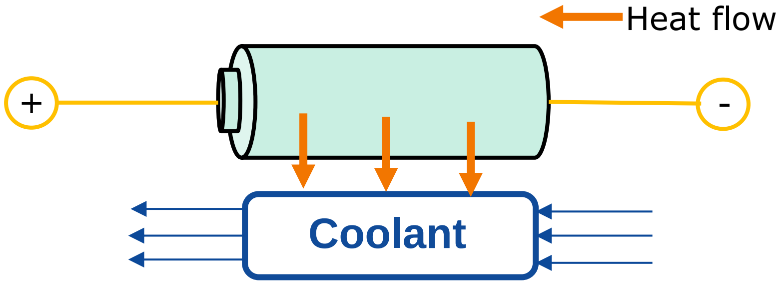
Test results

Calculation of heat flow



Heat transfer via housing is not considered

- Evaluation of dissipated heat via coolant
- Heat transfer battery to coolant



$\dot{Q} = const$

$\alpha = f(c_p, \rho, \lambda, \ldots)$

α : heat transfer coefficient

Coolant: $\dot{Q} = c_{p,mean} \cdot \dot{m} \cdot \Delta T$

with

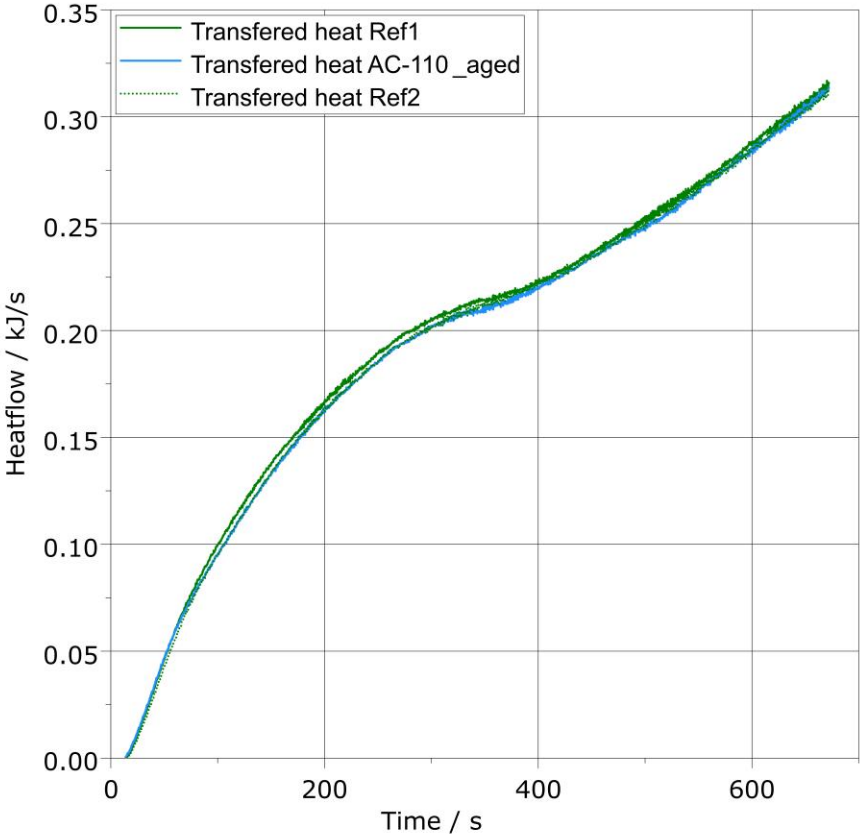
$$c_{p,mean} = f(T)$$

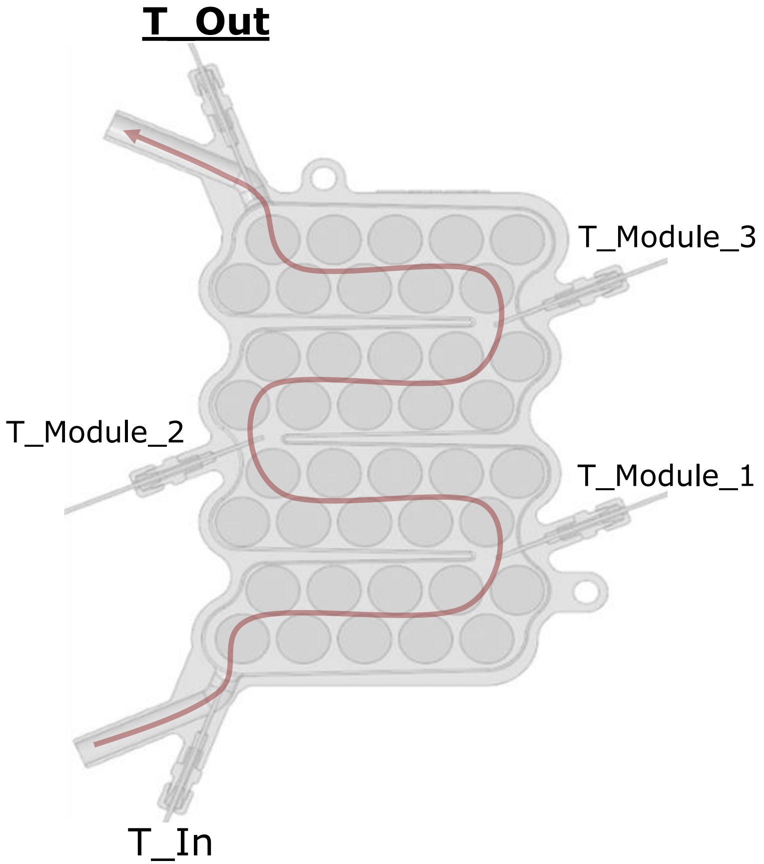
$$\Delta T = T_{Mod\_Out} - T_{Mod\_In}$$

Test results

Heat flows

Aged = stored at 95 °C for 2.780 h ≙ 10 years in duty





Conclusion & outlook

Interpretation of results

- No significant difference between fresh and aged fluid measureable

➡ Aging process does not affect heat absorption capability of AC-110

- Further testing possible
  - Investigation of impact of different influences under varying test conditions, e.g. temperature cycles, flow variations
  - Determination of a fluid ranking based on cooling perferomance
  - Development of optimal test application of a selected fluid to show ideal parameters for utilization of the fluid

APL Group

Passion becomes drive!

Contact:

Dr. Gunther Müller
gunther.mueller@apl-landau.de
+49 (0) 6341 991 4623

M. Sc. Rico Pelz
rico.pelz@apl-landau.de
+49 (0) 6341 991 2236

E-Fluide@apl-landau.de

APL Automobil-Prüftechnik Landau GmbH | Am Hölzel 11 | 76829 Landau in der Pfalz | Germany
Phone: +49 (0) 6341 991-0 | E-mail: info@apl-landau.de | www.apl-landau.de