



Sustainable advanced flow meter calibration for the transport sector



Density and viscosity of alternative fuels



The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States



Collaborators



- Survey of diesel and gasoline surrogates
- Measurement plan
- First results
- Outlook



Imperial College
London



Diesel surrogates

- Biodiesel (FAME)
- Oxymethyl ether (OME)
- Hydrotreated vegetable oil (HVO)
- Dimethyl carbonate (DMC)
- Dimethyl ether (DME)
- Methanol (+ water impurity)
- Ethanol (+ water impurity)



Literature data and models available

Diesel surrogates

- EN 12214:
 - ν (1 bar, 40°C) = 3.5 – 5.0 mm²/s
 - ρ (1 bar, 15°C) = 860 – 900 kg/m³
- ASTM D6751:
 - ν (1 bar, 40°C) = 1.9 – 6.0 mm²/s

Name	ν [mm ² /s]	ρ [kg/m ³]	T_m [°C]
OME 3	1.89	1024	-20
OME 4	3.53	1068	12
OME 5	4.68	1100	

Name	ν [mm ² /s]	ρ [kg/m ³]	T_m [°C]
Ethyl decanoate	1.89	865	-20
E. dodecanoate	2.62	860	-10
E. tetradecanoate	3.53	860	12
E. hexadecanoate	4.68	865	24
E. octadecanoate	6.02	880	34
E. oleate	4.92	870	-32
Methyl octanoate	1.21	877	-37
M. Decanoate	1.73	873	-13
M. dodecanoate	2.43	870	5
M. tetradecanoate	3.33	867	18
M. hexadecanoate	4.41	852	30
M. octadecanoate	5.86	849	39
M. oleate	4.57	874	-20
M. lineoleate	3.70	895	-35

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Gasoline

- Unleaded gasoline EN228
- Multicomponent mixture in carbon number range from C4 to C10
- E-Fuels, Synfuels

Name	ρ (15°C) [kg/m ³]	RON	MON	p_v [kPa]
EN 228	720 – 775	min. 95	min. 85	40 – 60
STF CAC	720 – 760	92,5 – 95	83,5 – 85	50 – 60
n-heptane	680	0	-	4,74
isooctane	690	100	-	5,3

Measurement plan

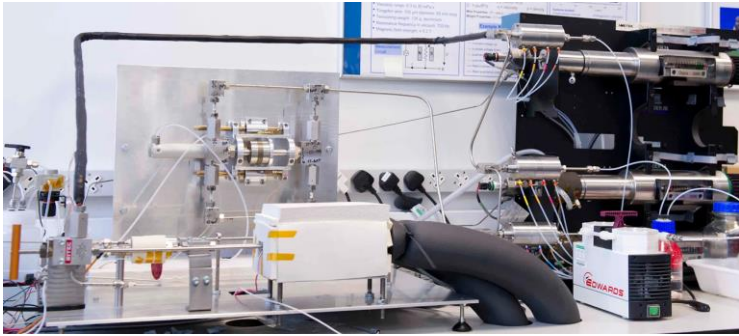
- Check calibration with CANNON N4 Standard – comparison between partners
- Wide p,T-range
 - Ethyl tetradecanoate (pure)
 - Methyl dodecanoate (pure)
 - Oxymethylether OME 3 (pure)
 - Oxymethylether OME 4 (pure)
 - 0.667 OME 3 + 0.333 OME 4 (mass-%)
- Atmospheric pressure, wide T-range
 - Oxymethylether OME 3 (pure)
 - Oxymethylether OME 4 (pure)
 - 0.667 OME 3 + 0.333 OME 4 (mass-%)
 - SYN E10 (Mixture of n-heptane + iso-octane + (bio-)ethanol (4,5/85,5/10) vol-%)
 - one or both of following mixtures (gasoline)
 - Mixture: n-Tetradecan + 2,2,4,4,6,8,8-Heptamethylnonane (75/25, 50/50, 25/75) mass-%
 - Mixture: Pentadecane + Hexadecane (75/25, 50/50, 25/75) mass-%

→ @ ICL and TUC

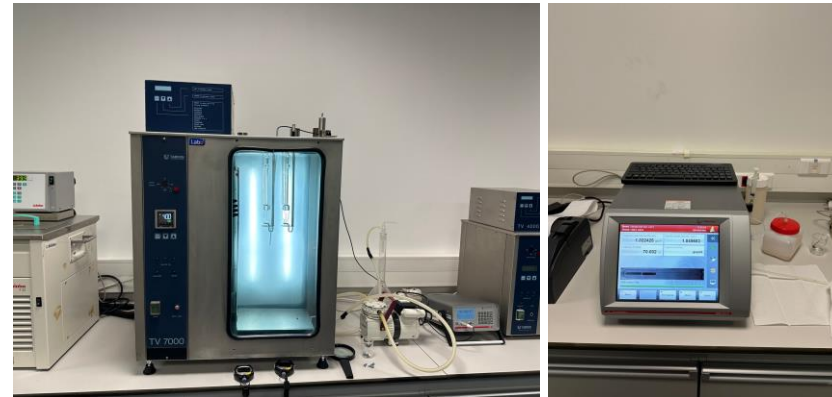
→ @ INRIM and TUBITAK

Measurement plan

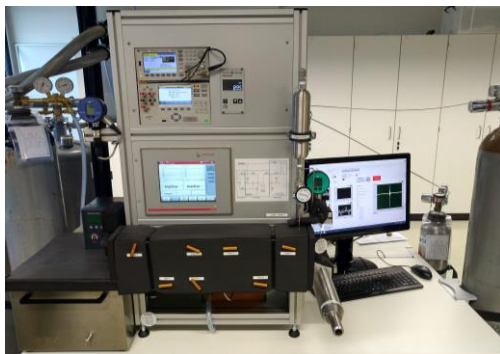
ICL



TUBITAK



TUC

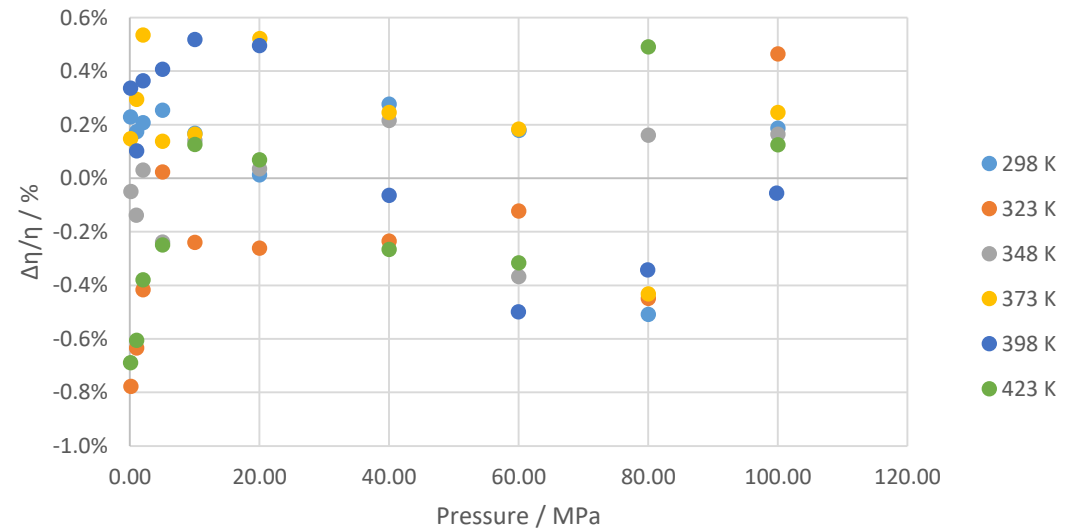
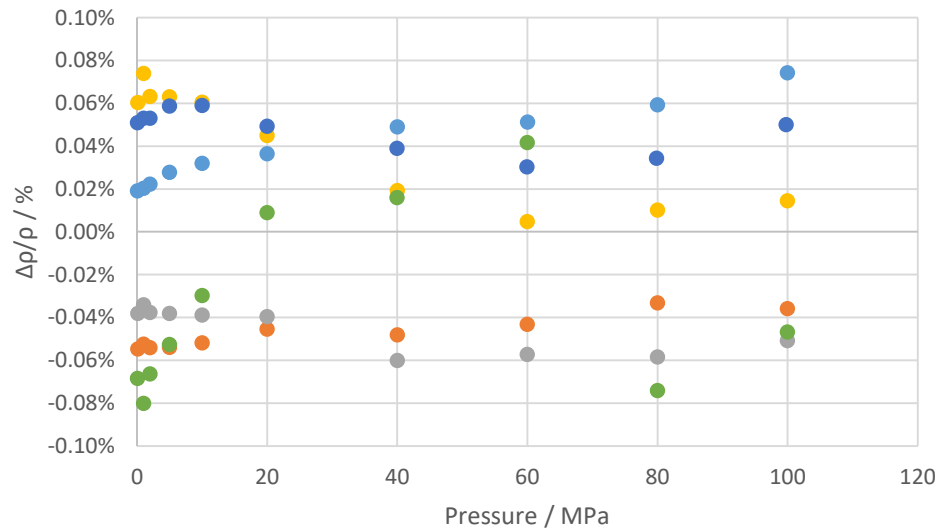


INRIM



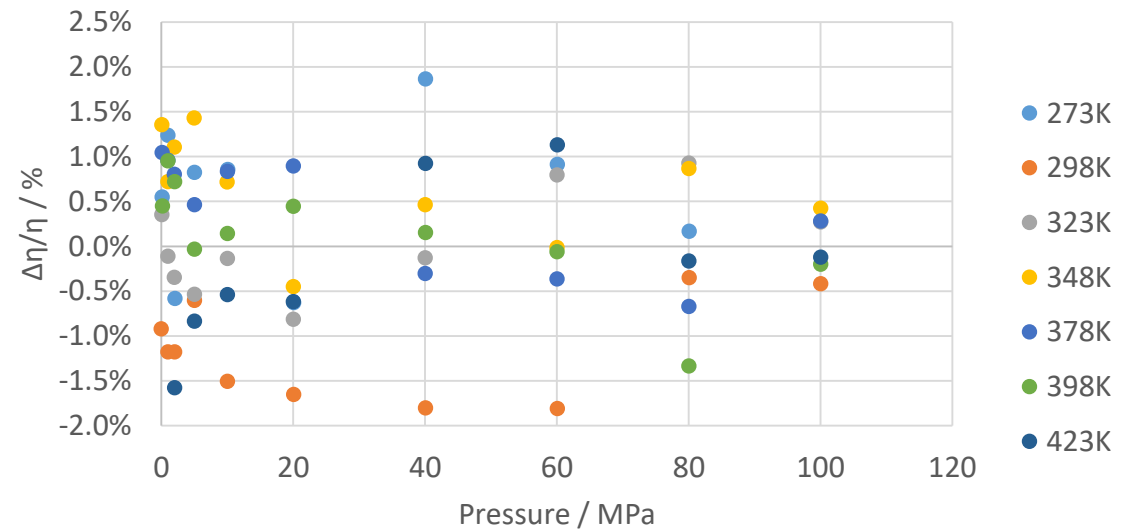
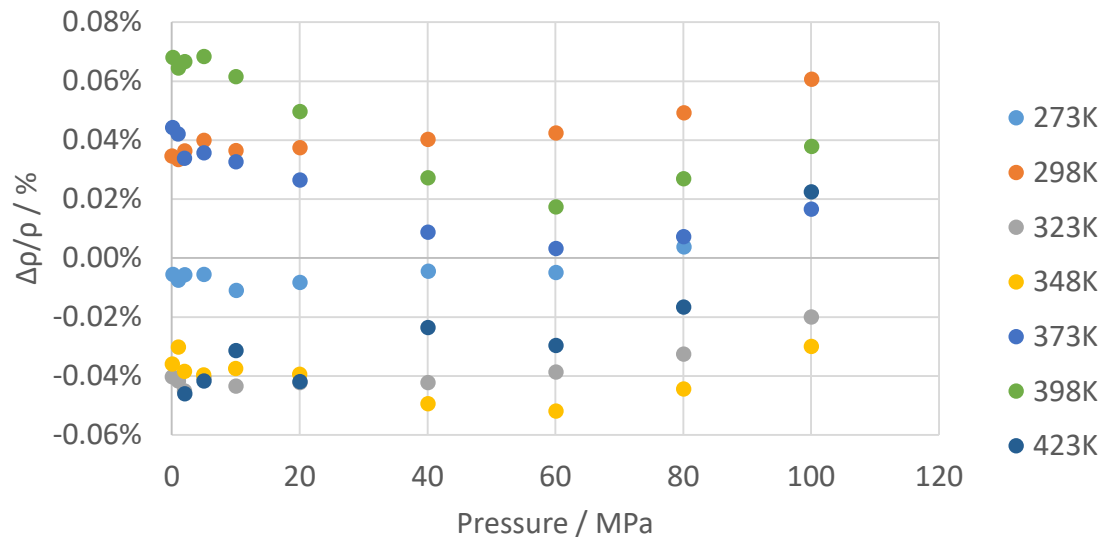
First results

- Viscosity and density measurements at ICL done
 - Simple fitting done (ρ : Tait equation; ν : Tait-Andrade equation)
- Methyl dodecanoate:



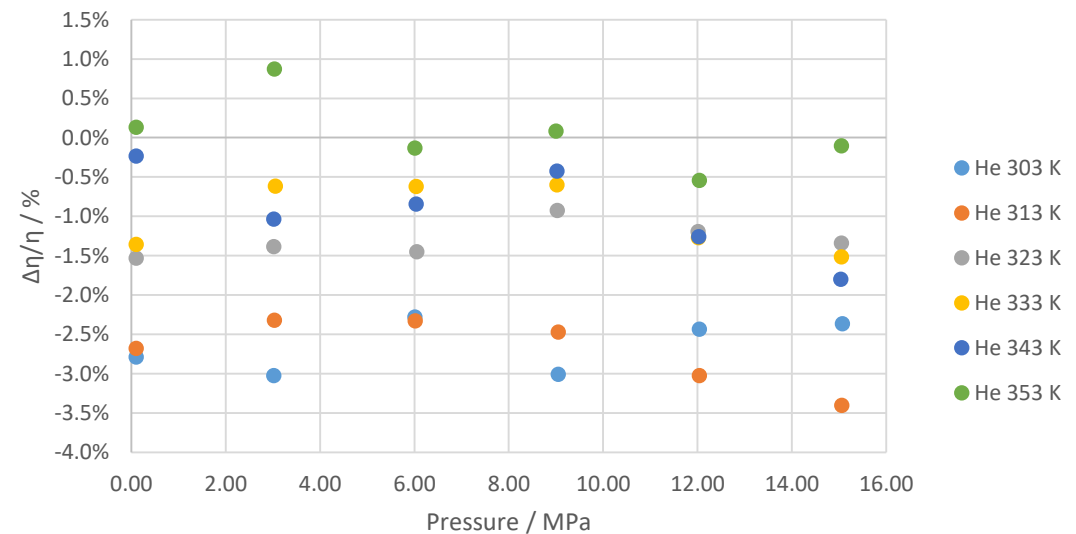
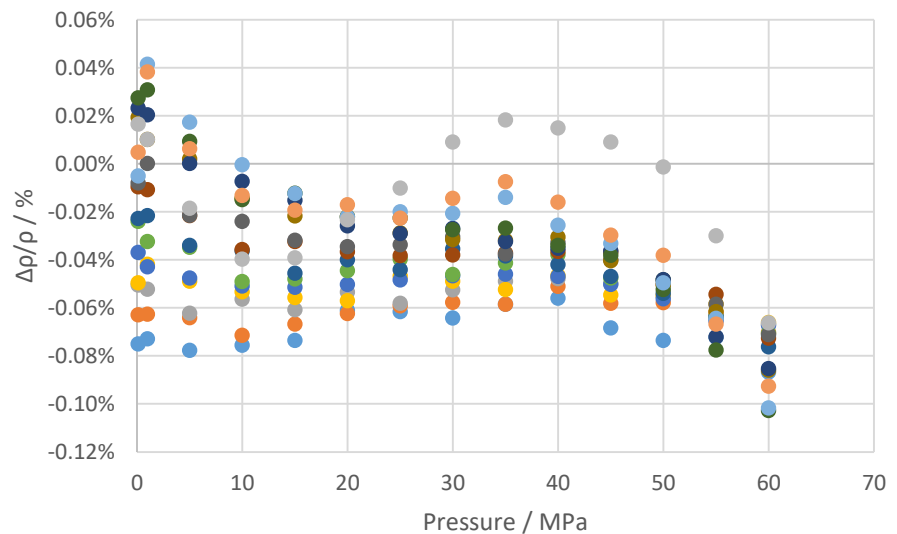
First results

- Viscosity and density measurements at ICL done
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- OME 4:



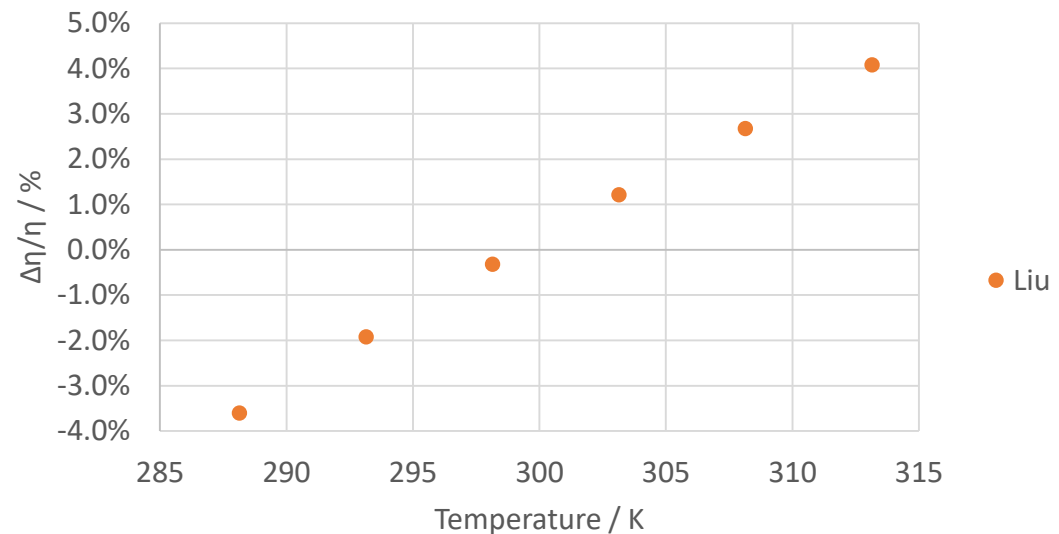
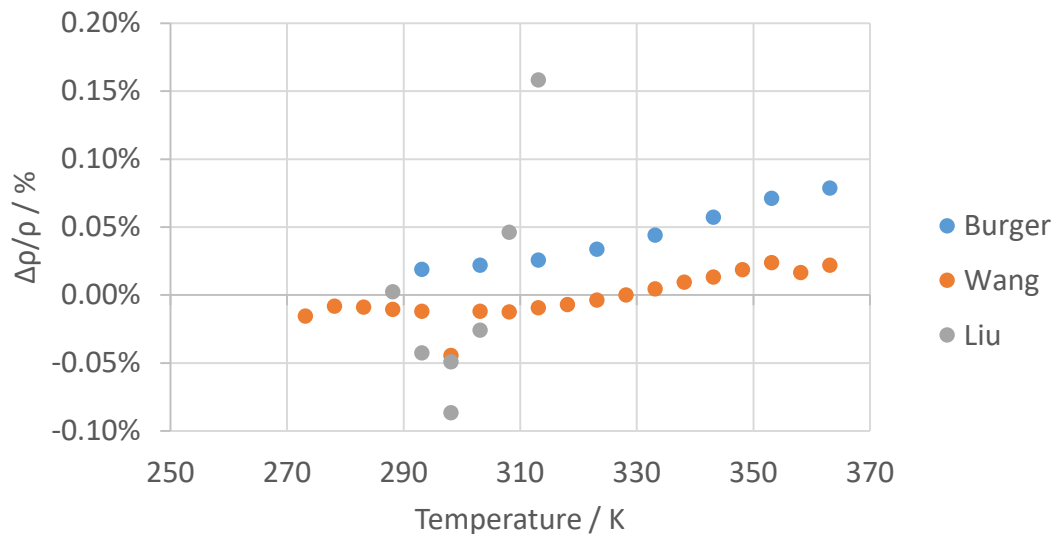
First results

- Comparison with literature data (Methyl Dodecanoate)
 - Density: Aissa et al. - Experimental Investigation and Modeling of Thermophysical Properties of Pure Methyl and Ethyl Esters at High Pressures
 - Viscosity: He et al. - Measurement and correlation of viscosities and densities of methyl dodecanoate and ethyl dodecanoate at elevated pressures



First results

- Comparison with literature data (OME 4)
 - Density: Wang et al. - High-cetane additives for diesel based on polyoxymethylene dimethyl ethers: Density behavior and prediction
 - Viscosity: Liu et al. - Densities and viscosities for binary mixtures of polyoxymethylene dimethyl ethers with different CH₂O chain length n = 2, 3, 4 at different temperatures



Whats next?

- Finishing measurements at TUC, INRIM and TUBITAK
- Compare results
- Fitting density and viscosity correlation

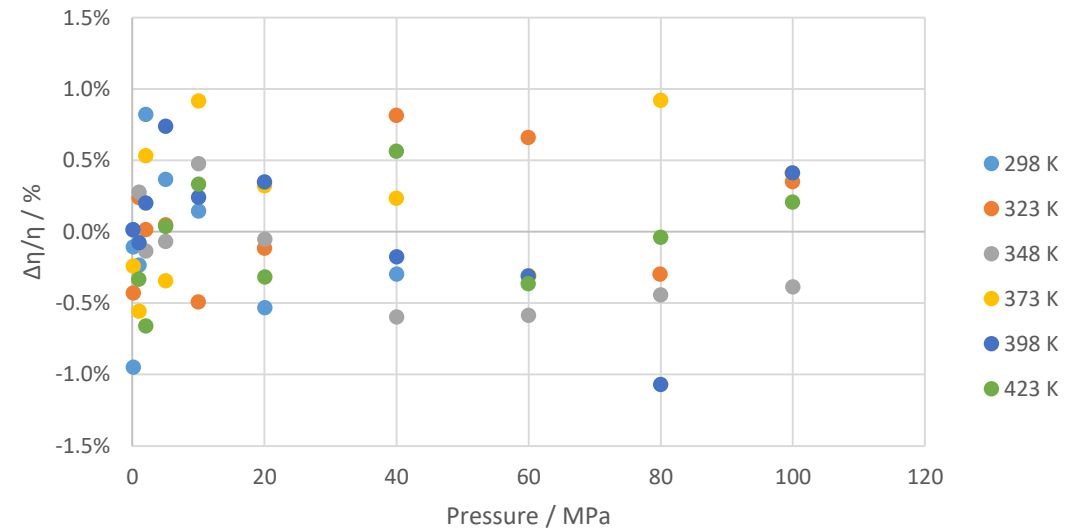
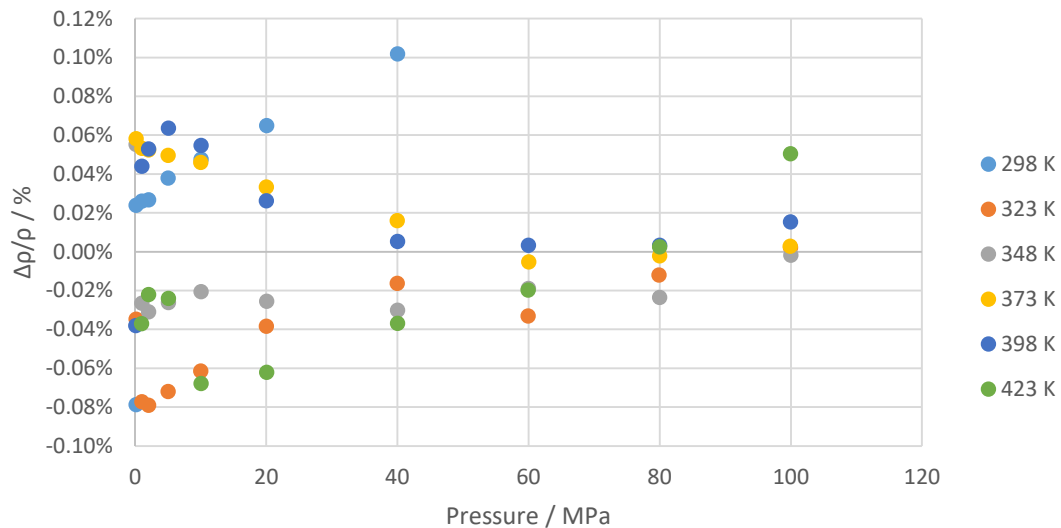
Thanks for your attention!

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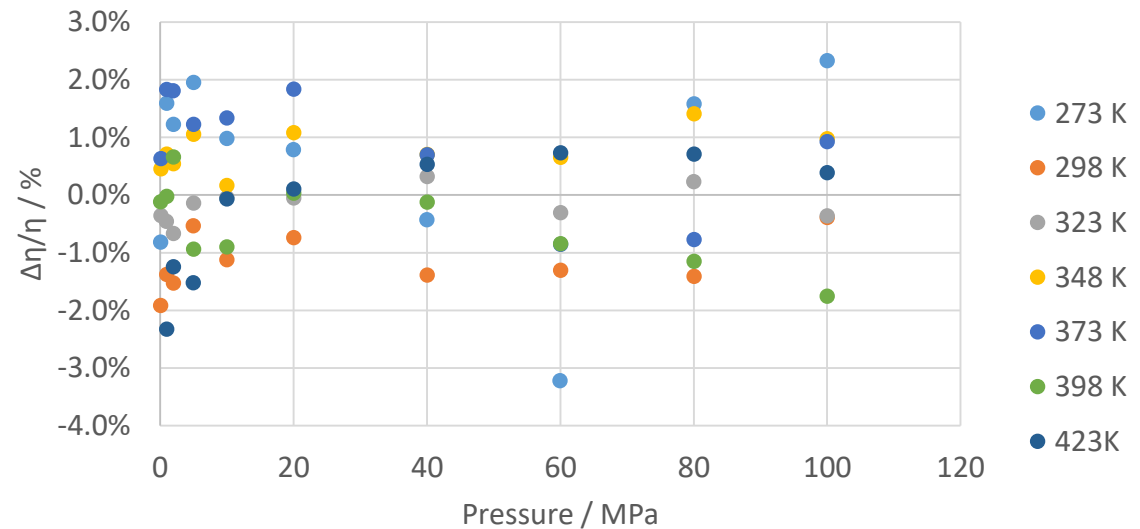
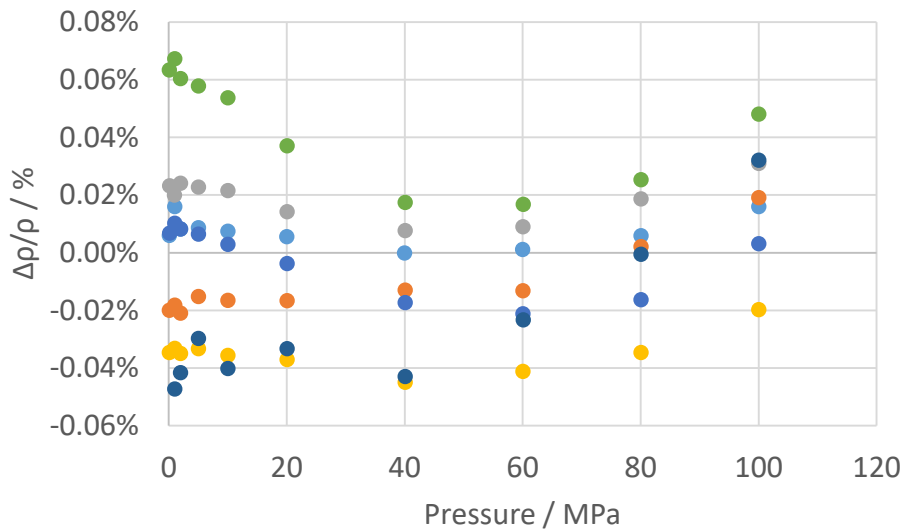
First results

- Viscosity and density measurements at ICL done
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- Ethyl tetradecanoate:



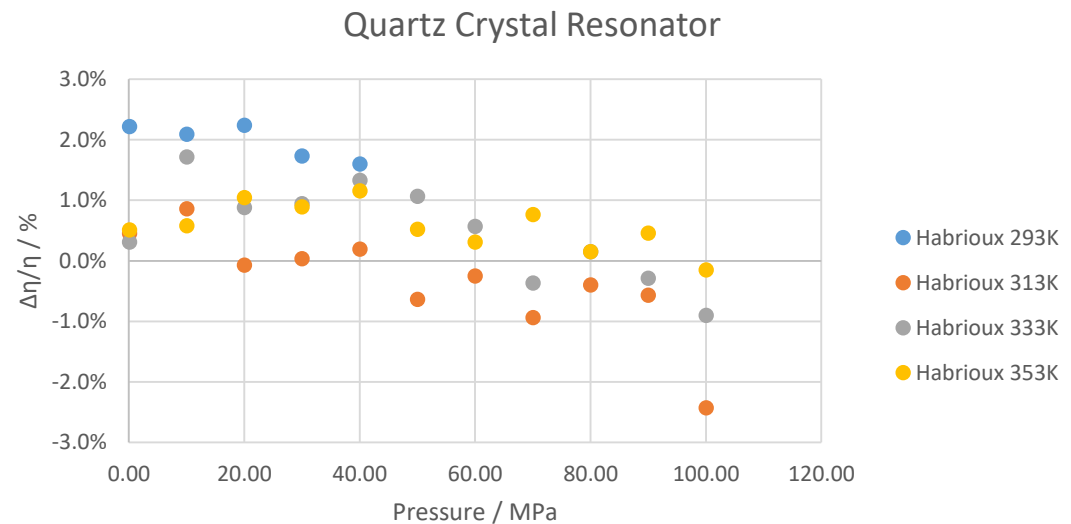
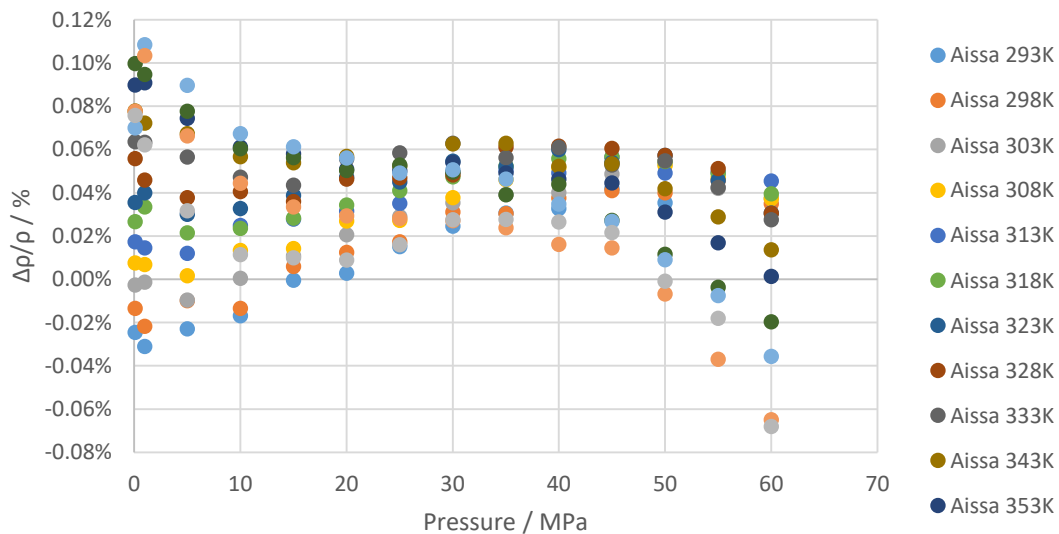
First results

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- OME 3:



First results

- Comparison with literature data (Ethyl tetradecanoate)
 - Density: Aissa et al. - Experimental Investigation and Modeling of Thermophysical Properties of Pure Methyl and Ethyl Esters at High Pressures
 - Viscosity: Habrioux et al. - Measurement of speed of sound, density compressibility and viscosity in liquid methyl laurate and ethyl laurate up to 200 MPa by using acoustic wave sensors



First results

- Comparison with literature data (OME 3)
 - Density: Burger et al. -A novel process for the production of diesel fuel additives by hierarchical design
 - Viscosity: Liu et al. - Densities and viscosities for binary mixtures of polyoxymethylene dimethyl ethers with different CH₂O chain length n = 2, 3, 4 at different temperatures

