

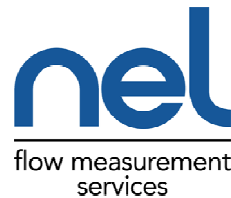
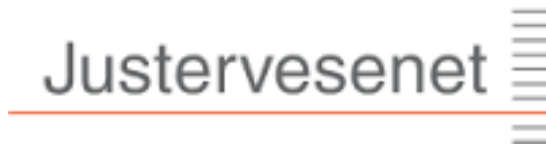
METROLOGY *for* HYDROGEN VEHICLES

Investigations on pressure dependence of Coriolis Mass Flow Meters used at Hydrogen Refuelling Stations

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Project Team – EMPIR Project 16ENG01 “MetroHyVe”



Hydrogen Refueling Station (HRS)



Table: 70 MPa Hydrogen Fueling Specifications

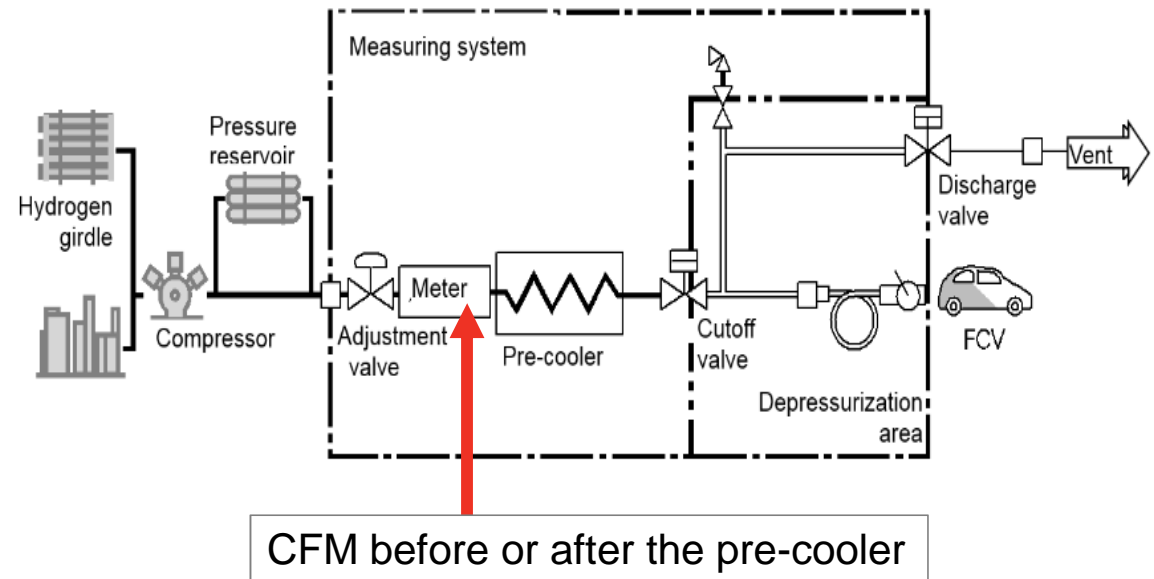
Parameter	Limit
Min. gas temperature (pre-cooling)	-40 °C
Max. gas temperature (tank)	+85 °C
Ambient temperature	-40 °C to +50 °C
Min. tank storage capacity	2 kg
Max. tank storage capacity	10 kg
Min. pressure (tank)	0.5 MPa
Max. pressure (tank)	87.5 MPa
Max. flow rate	60 g/s (3.6 kg/min)

Fast filling:

- 5 kg hydrogen can be filled in 3 min
- To avoid tank overheating the hydrogen is cooled down to -40 degC
- The pressure in the tank exceeds 70 MPa at the end of the fast fill process to ensure a filling at 70 MPa after cooling down.

Almost all HRS meet the requirements according SAE J2601 fueling protocols

- Direct filling or cascade filling
- Flow meter (CFM) before of after pre-cooler



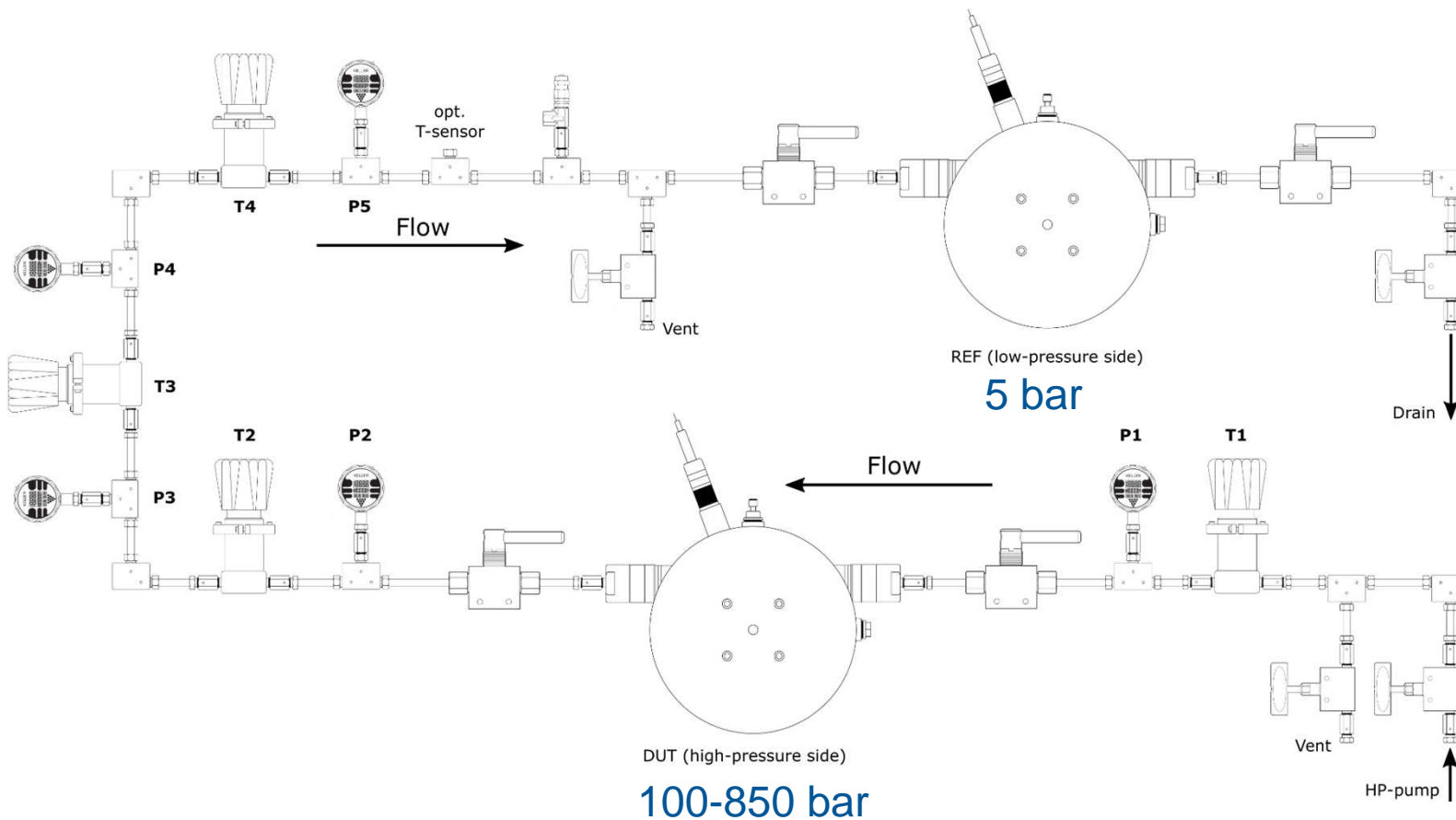
Scope of the work



- The aim of this work was to investigate the influence of pressure on the measurement accuracy of high-pressure CFMs.
- Particularly for measurement of hydrogen with very high operation pressures (up to 875 bar) it is necessary to take the influence of pressure into account.
- RISE performed high-pressure measurements with high-pressure CFMs (three different brands: RHEONIK, HEINRICHS, KEM) at ambient temperature in a pressure range between 5 bar and 850 bar using water as test liquid.



Layout of the HP-test rig



Flow rate kg/min	Pressure					
	10 MPa	25 MPa	40 MPa	55 MPa	70 MPa	85 MPa
0.1	x	x	x	x	x	x
0.2	x	x	x	x	x	x
0.5	x	x	x	x	x	x
1.0	x	x	x	x	x	(*)
2.0	x	x	x	x	(*)	--
3.6	x	x	x	--	--	--

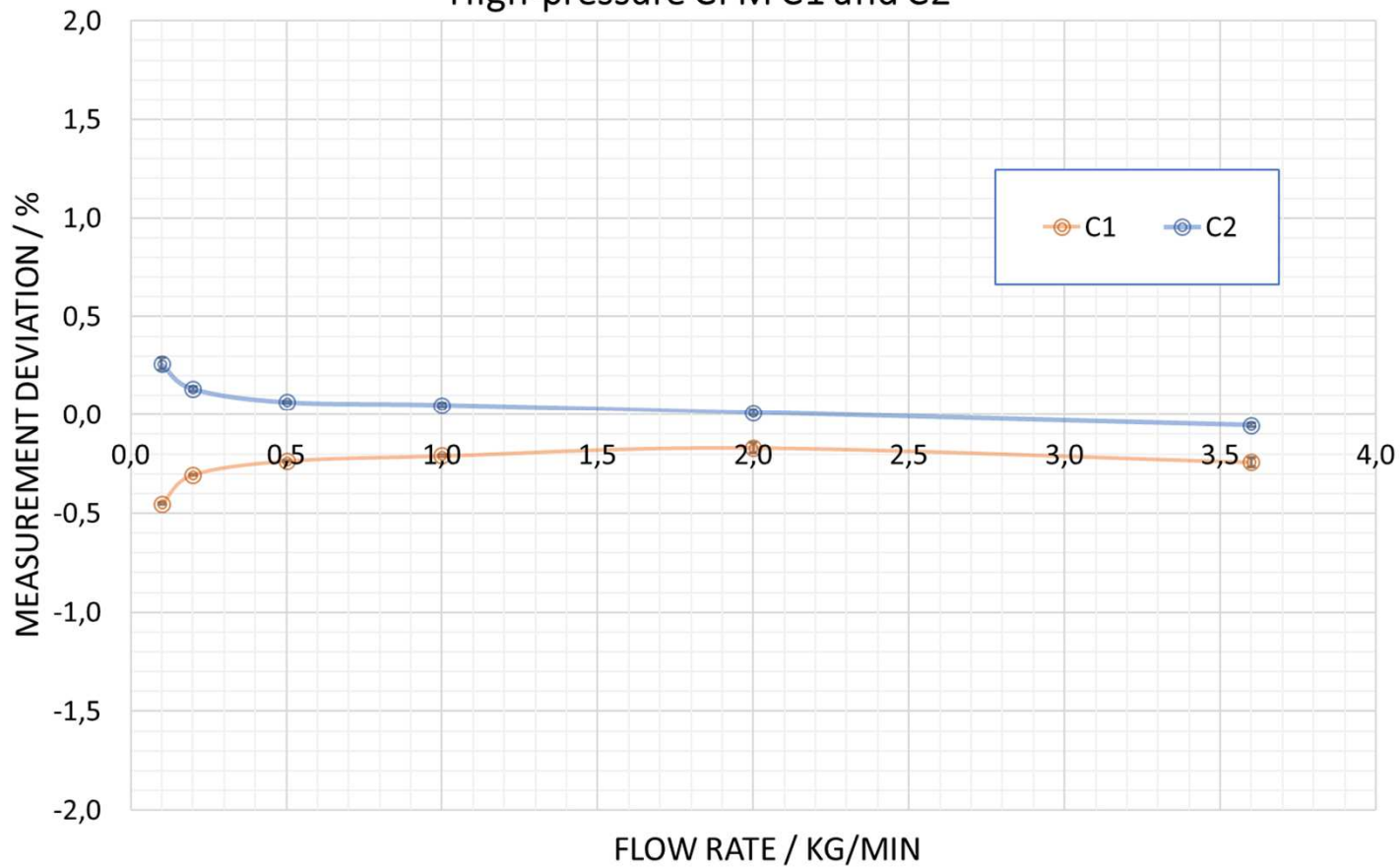
Regul ator No.	Pressure					
	10 MPa	25 MPa	40 MPa	55 MPa	70 MPa	85 MPa
T1	100 bar	250 bar	400 bar	550 bar	700 bar	850 bar
T2	80 bar	125 bar	150 bar	150 bar	200 bar	200 bar ¹
T3	35 bar	35 bar	35 bar	35 bar	35 bar	35 bar
T4	5 bar	5 bar	5 bar	5 bar	5 bar	5 bar

¹ from 0.5 kg/min: 300 bar

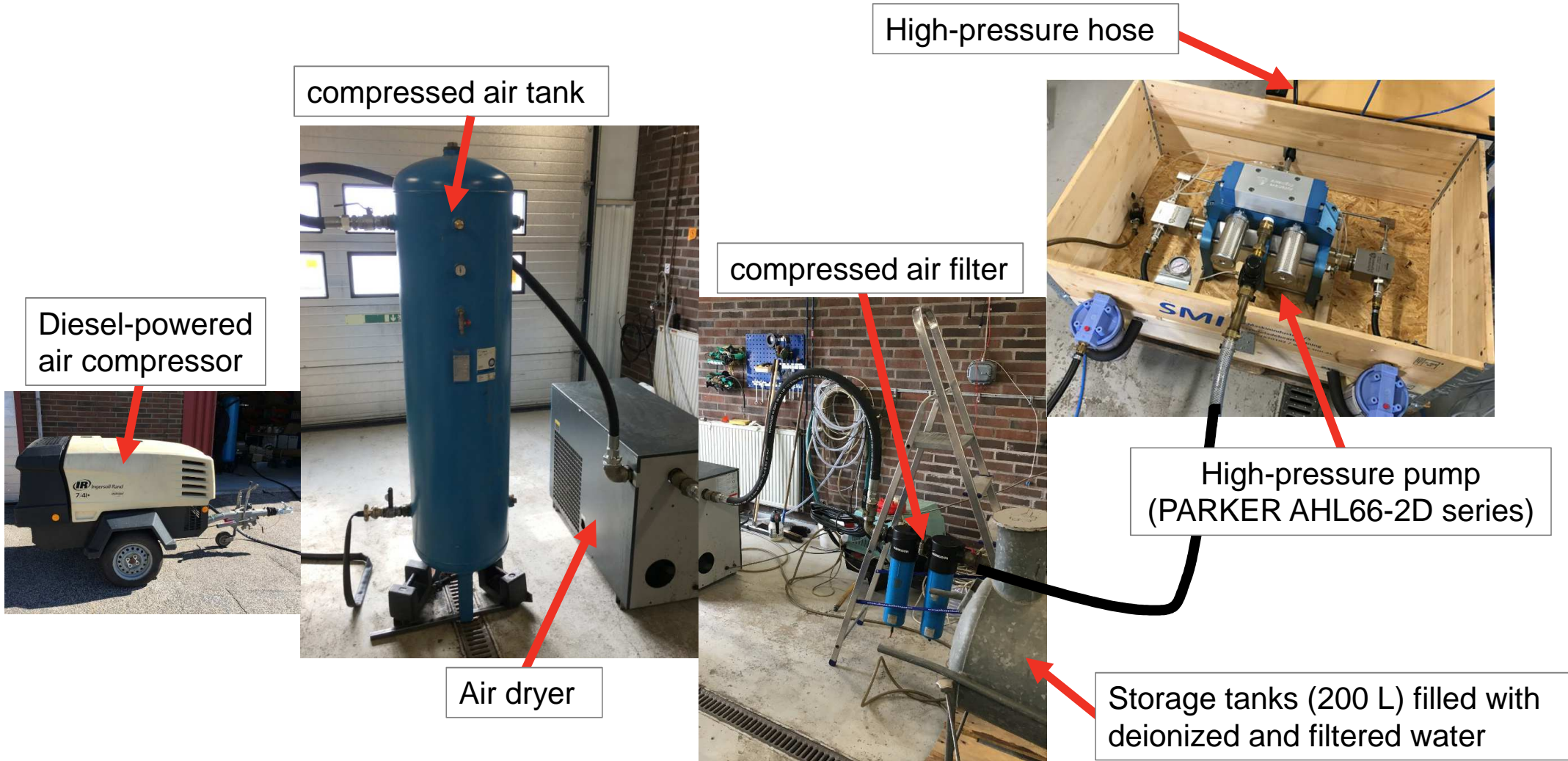
1. Low-pressure calibrations



High-pressure CFM C1 and C2



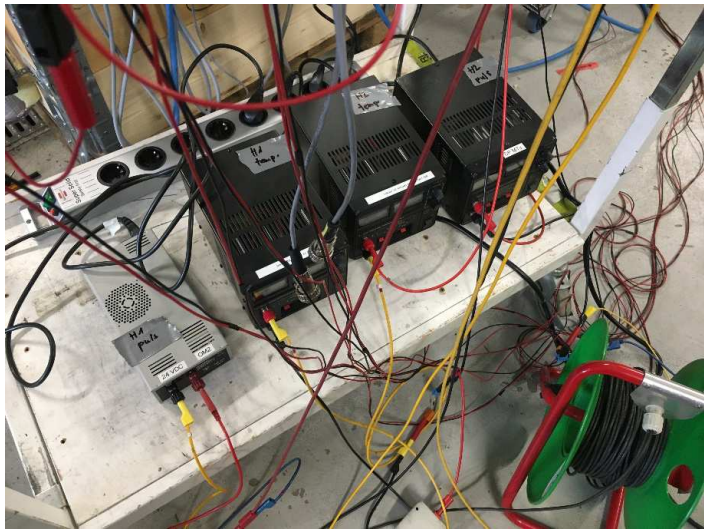
2. High-pressure measurements



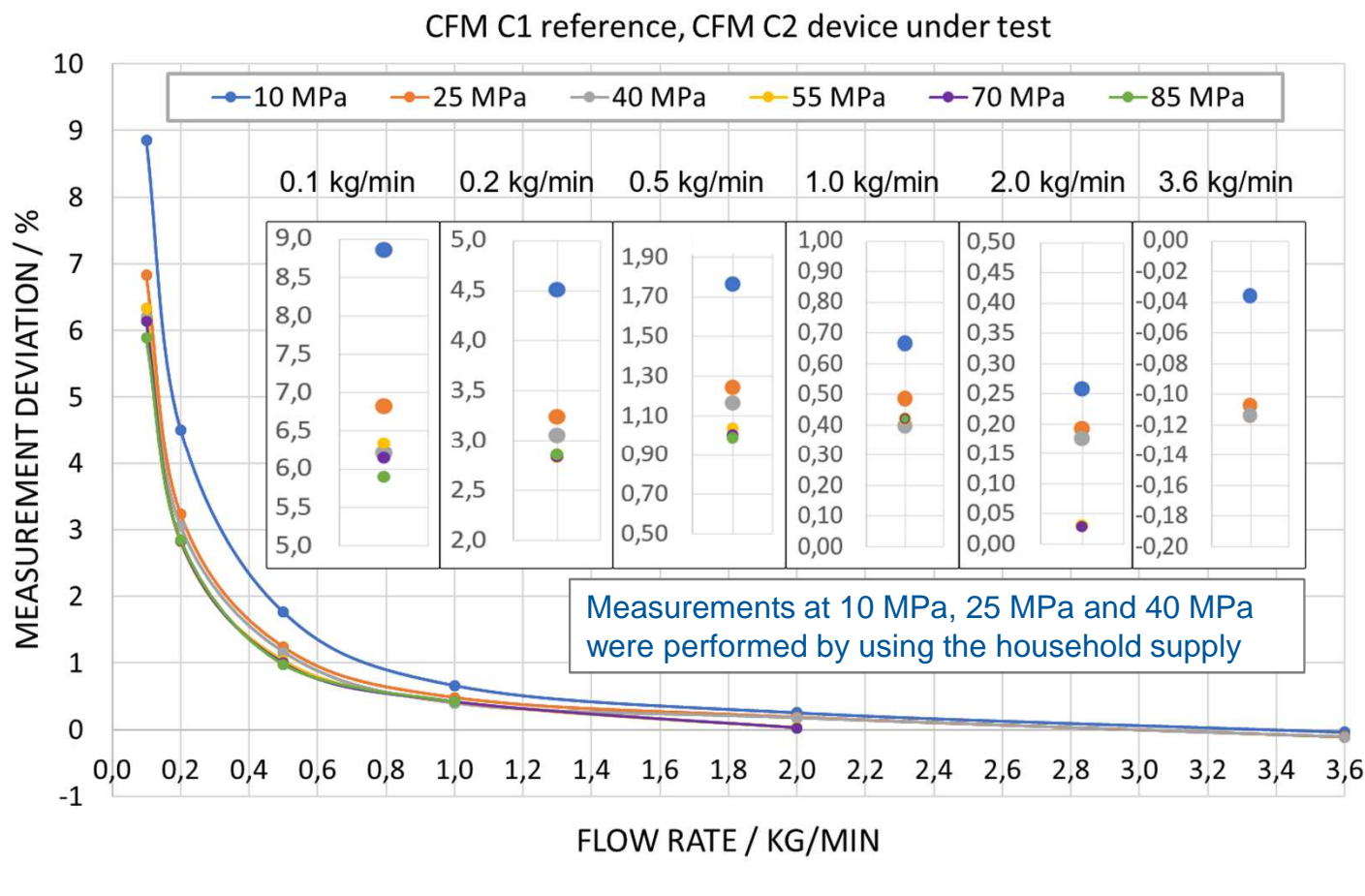
2. High-pressure measurements



High-pressure hose



2. High-pressure measurements



- The water temperature was stable for a certain pressure level
- With increasing pressure the water temperature at the low-pressure side was increasing
- The water temperature at the low-pressure side was depending on the compressed air supply



→ Additional low-pressure calibrations in the temperature range between 20 degC to 30 degC are needed !!!

Conclusions

- A novel high-pressure flow test facility was built at RISE.
- The test rig allows measurements with water and base oils under the conditions prevailing at 70 MPa HRS regarding mass flows (up to 3.6 kg min^{-1}) and pressures (up to 87.5 MPa).
- Measurements have been performed with high-pressure CFMs from three different manufacturers.
- Additional (low-pressure) calibrations need to be performed in order to correct for the temperature effect and hence to separate temperature and pressure effects.
- A complete data set regarding the influence of pressure on mass flow measurement accuracy for all three CFMs will be published.



THANK YOU



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