



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

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Workshop on Hydrogen Quality and Flow Metering for Hydrogen Fuel Cell vehicles
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WP1 Flow Metering

Tasks

1. Identifying and assessing uncertainty sources for hydrogen metering
2. Investigate alternative methods for type approval testing using substitute substances to hydrogen
3. Investigate the influence of pressure on the mass flow measurement accuracy of CMFs using water
4. Develop 4 independent mobile gravimetric standards to deliver traceability to HRS at NWP of 350 and 700 bar
5. Develop uncertainty budgets for type approval testing, periodic verifications and gravimetric standards



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Overview

Table: 70 MPa Hydrogen Fuelling Specifications SAE J2601

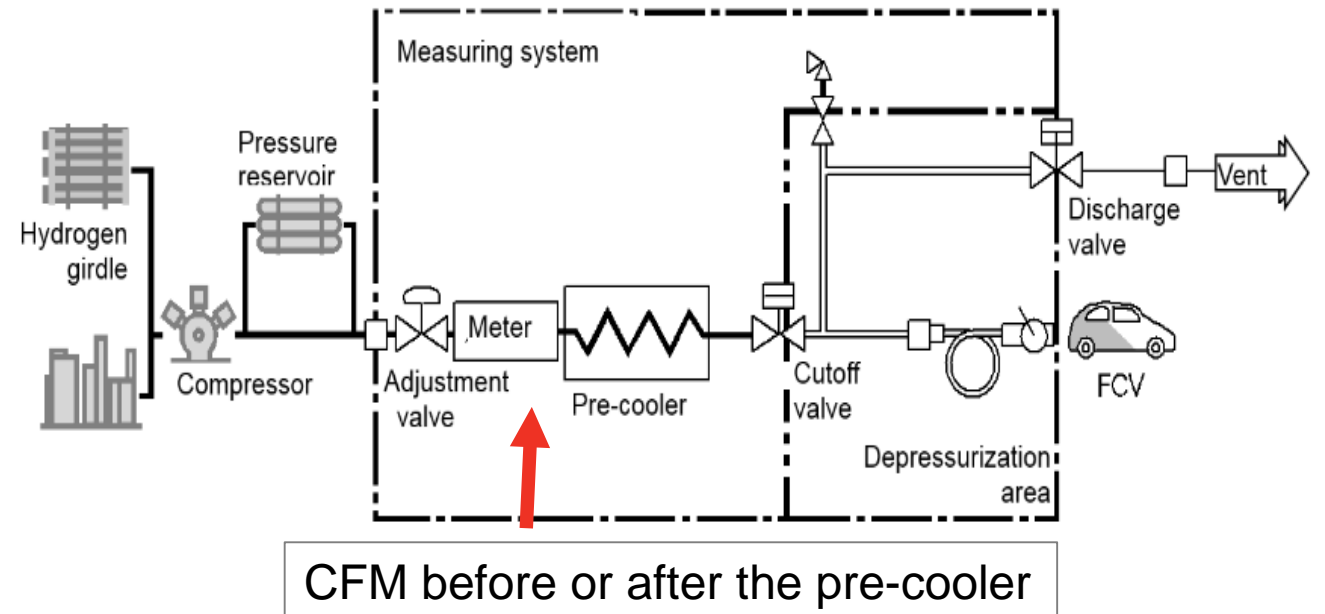
Parameter	Limit
Min. gas temperature (pre-cooling)	-40 °C
Max. gas temperature (tank)	+85 °C
Ambient temperature	-40 °C to +50 °C
Min. tank storage capacity	2 kg
Max. tank storage capacity	10 kg
Min. pressure (tank)	0.5 MPa
Max. pressure (tank)	87.5 MPa
Max. flow rate	60 g/s (3.6 kg/min)

Fast filling:

- 5 kg hydrogen can be filled in 3 min
- To avoid tank overheating the hydrogen is cooled down (-40 °C)

Almost all HRS meet the requirements according SAE J2601 fuelling protocols

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



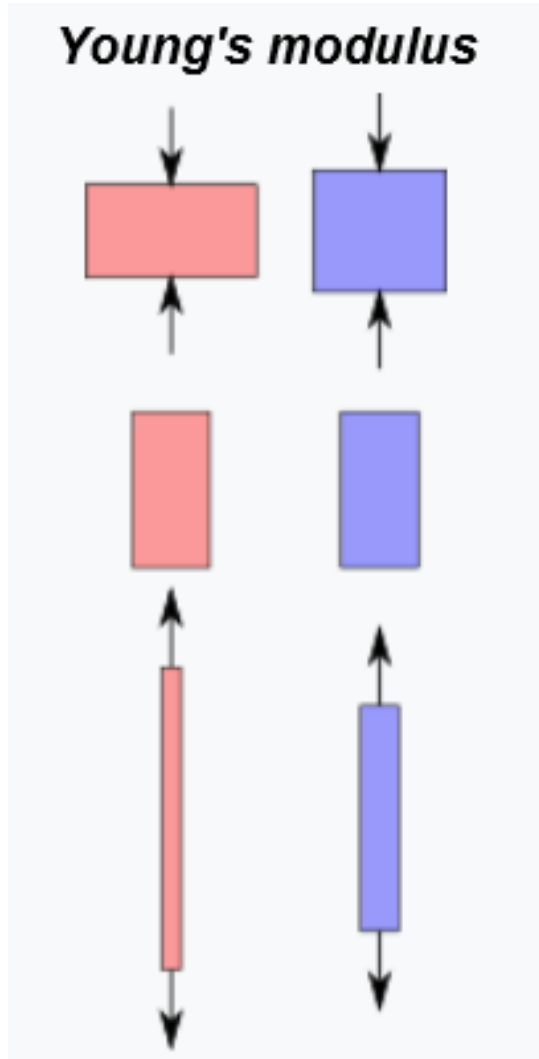
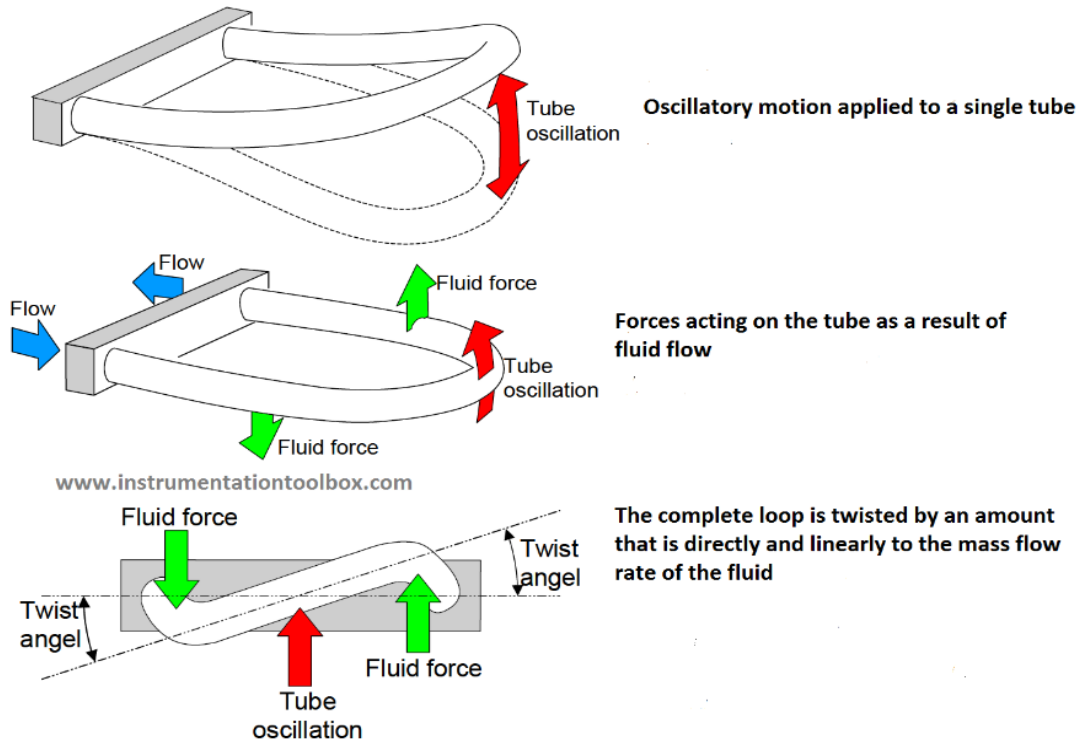
Overview

- RISE performed high-pressure measurements with high-pressure CMFs (three different brands: RHEONIK, HEINRICHS, KEM) at ambient temperature in a pressure range between 5 bar and 850 bar using water as test liquid.



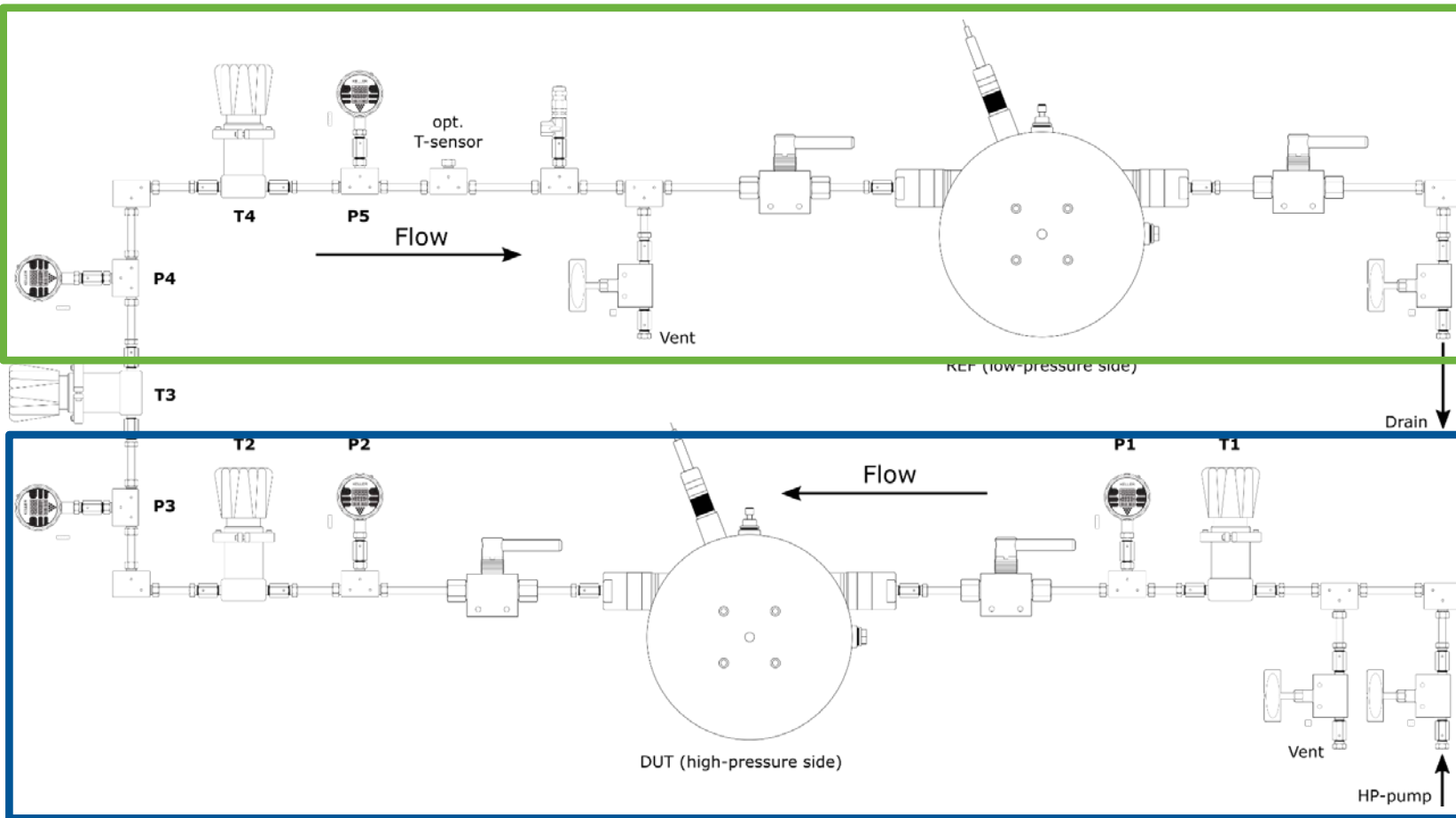
Overview

- Coriolis flow meters measure mass flow rate
- Oscillating tube, stainless steel
- Young's modulus: stiffness of a solid material
- depends on temperature and on pressure



Layout of the HP-test rig

Low pressure side: 5 bar



	Pressure					
Flow rate kg/min	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	--	--	--

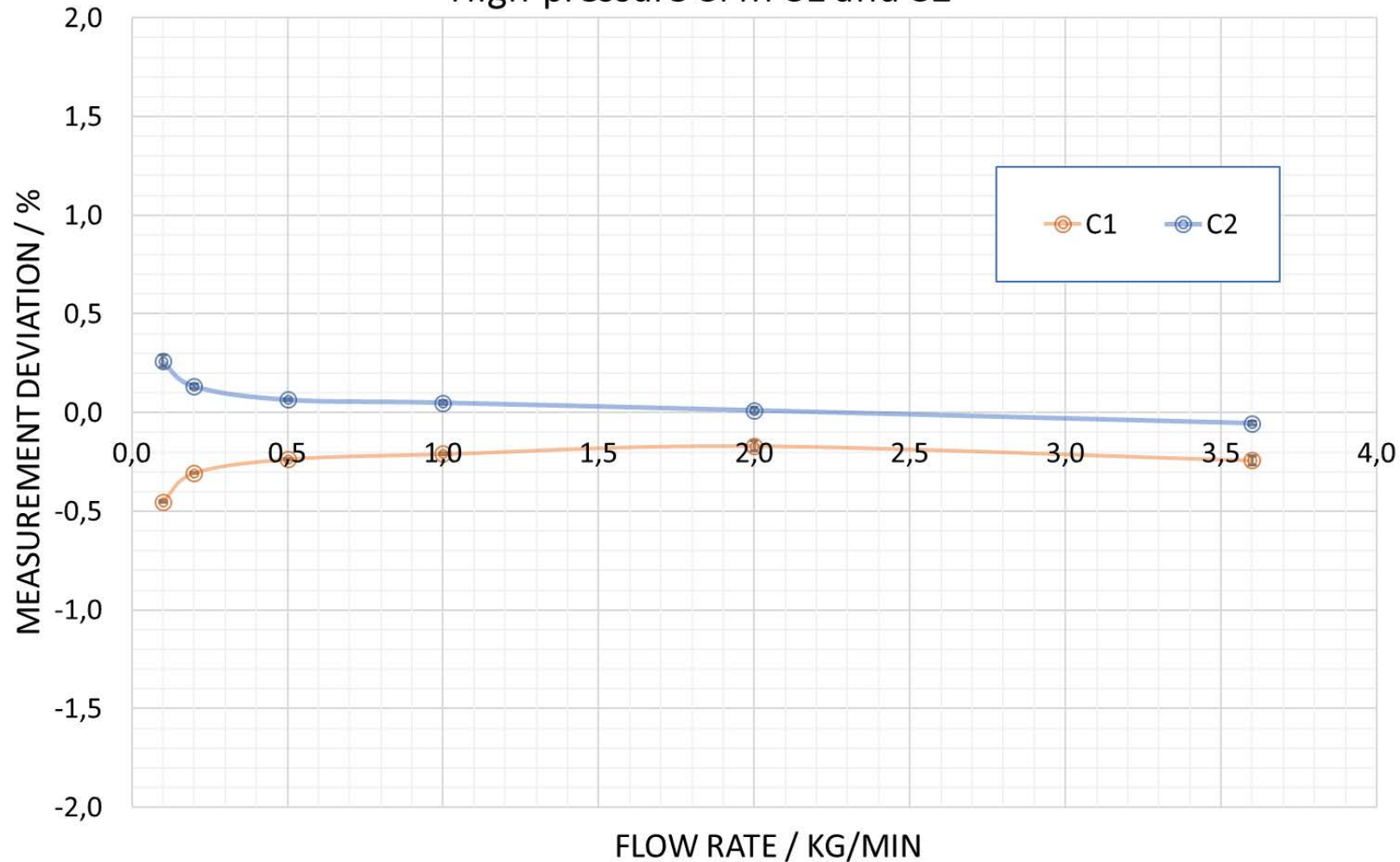
	Pressure					
Regulator No.	10 MPa	25 MPa	40 MPa	55 MPa	70 MPa	85 MPa
T1	100 bar	250 bar	400 bar	550 bar	700 bar	850 bar
T2	80 bar	125 bar	150 bar	150 bar	200 bar	200 bar ¹
T3	35 bar	35 bar	35 bar	35 bar	35 bar	35 bar
T4	5 bar	5 bar	5 bar	5 bar	5 bar	5 bar

¹ from 0.5 kg/min: 300 bar

High pressure side: (100...850) bar

1. Low-pressure calibrations

High-pressure CFM C1 and C2



2. High-pressure measurements

High-pressure hose

compressed air tank

Diesel-powered air compressor

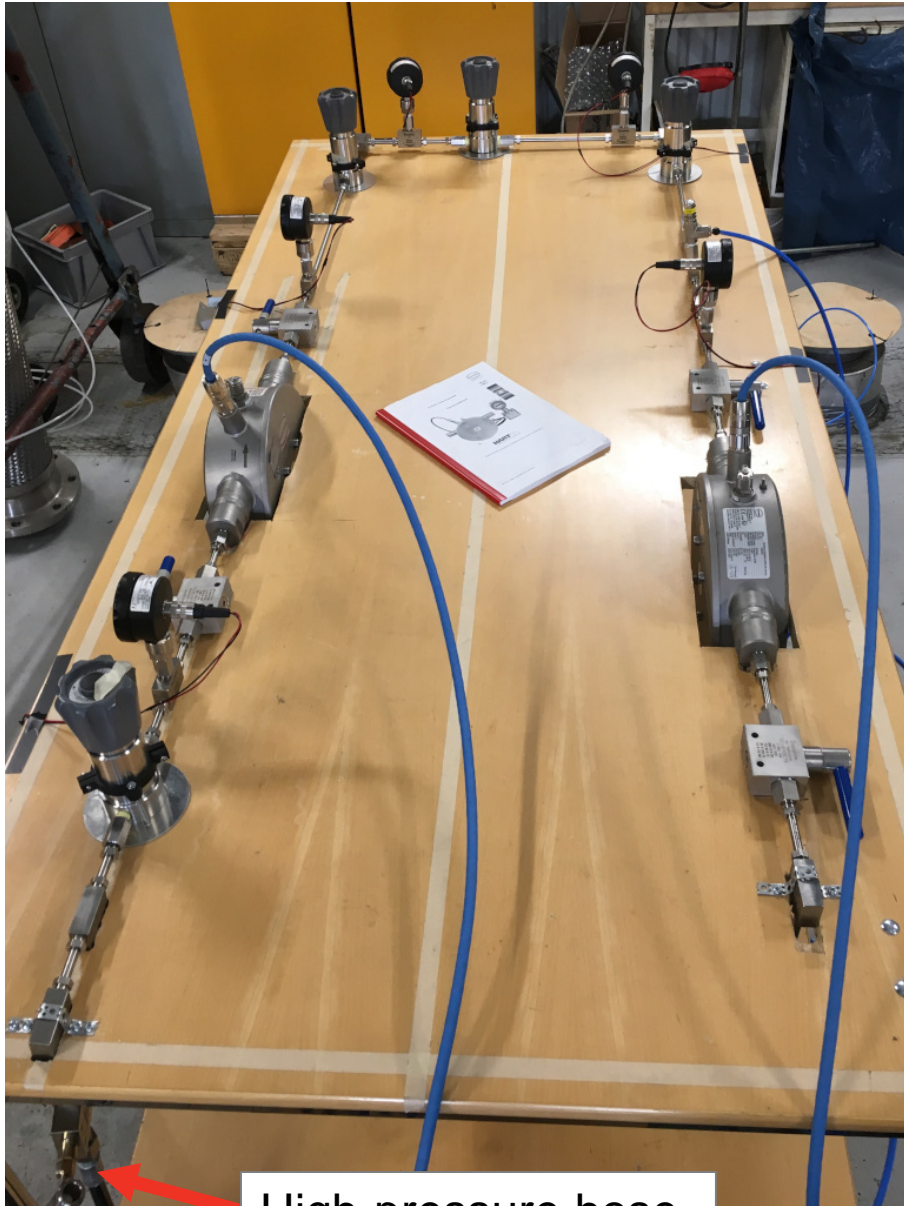
compressed air filter

High-pressure pump (PARKER AHL66-2D series)

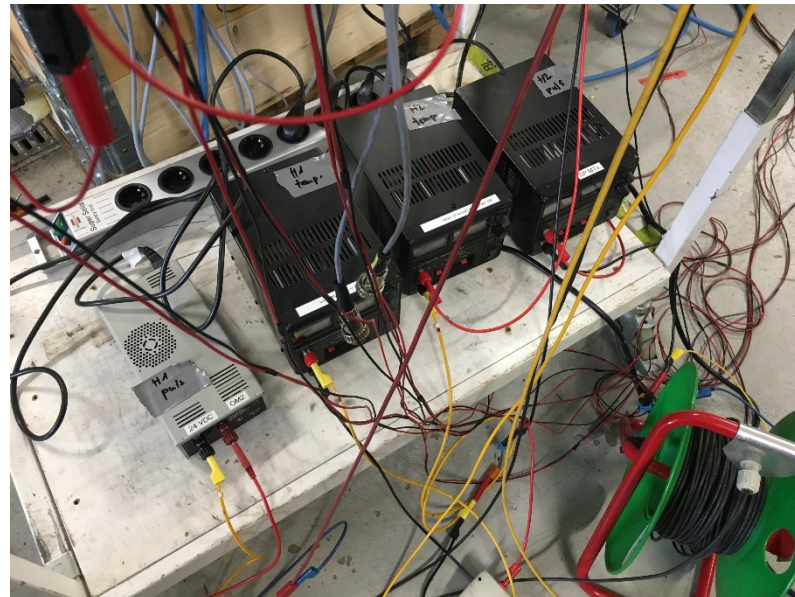
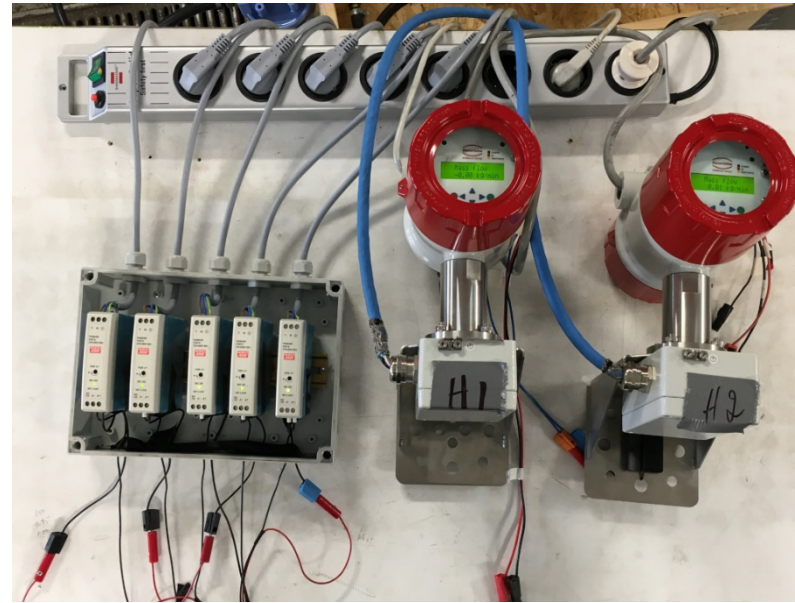
Storage tanks (200 L) filled with deionized and filtered water

Air dryer

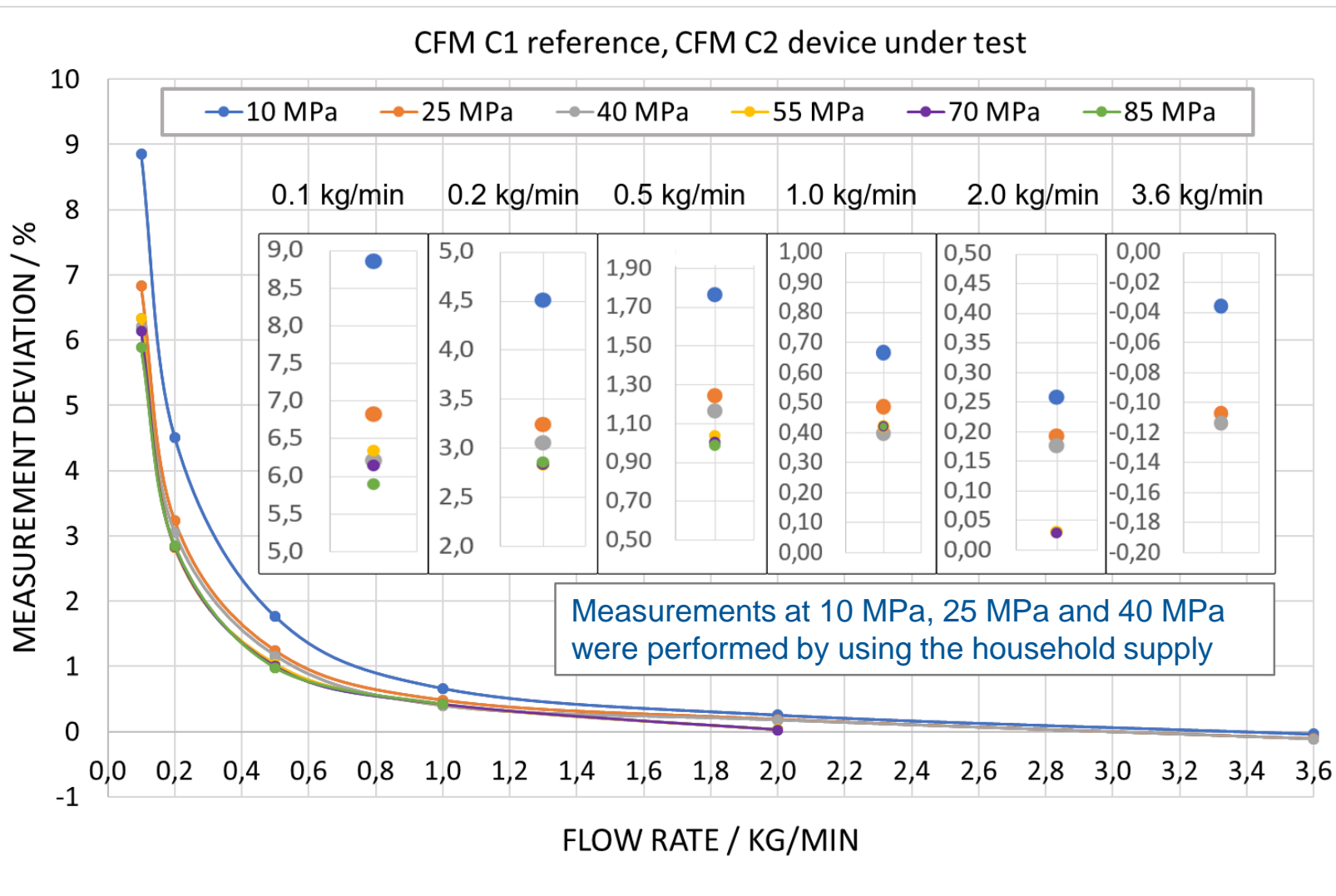
2. High-pressure measurements



High-pressure hose



2. High-pressure measurements



- The water temperature was stable up to 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

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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