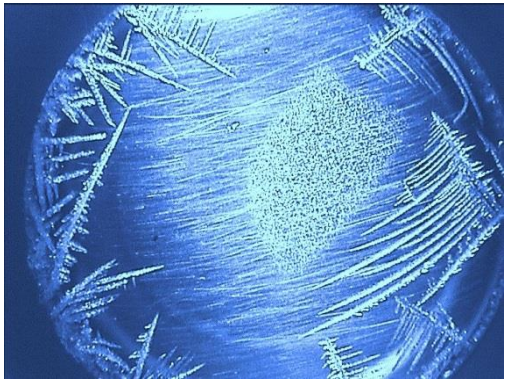
VTT TECHNICAL RESEARCH CENTRE OF FINLAND LTD
Centre for Metrology MIKES

MIKES METROLOGY



Improving the efficiency of humidity calibrations in a lab and on site

Workshop: Measurement and Control of Humidity and Moisture in Industry

DTI, Taastrup, Denmark, 10th April 2018

Martti Heinonen, VTT MIKES, Finland

HIT

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

Contents

- Motivation and Challenge
- Approaches to improve the efficiency
- Developments at VTT MIKES
  - Dynamic calibration procedures
  - Calibrators
- Conclusion

Contributors

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Introduction

- Calibrations are currently performed at static conditions:
  - Time consuming, i.e. expensive
    - Often a minimum number of measurement points to reduce costs: Representativeness to actual measurement conditions?
    - Hysteresis is often significant but often not included
  - In many cases RH probes are used at non-static conditions
- Target of this work:
  - Efficient but comprehensive calibration procedure based on measurements at non-static conditions

Motivation

- Companies e.g. in pharmaceutical manufacturing allocate significant resources in order to maintain high quality monitoring of humidity in their production premises and storage facilities.
- Companies are seeking more efficient calibration methods for humidity sensors to achieve savings both in costs and materials.
- Humidity calibrations are time consuming
  $\Rightarrow$ profitability is challenging for various calibration laboratories providing humidity calibration services
- Relative humidity calibrations should have appropriate coverage in terms of both relative humidity **and** temperature
- Hysteresis is often significant but often not included

Challenges

- Calibrations in a lab:
  - Defining appropriate calibration points is complex
    - Customer need (RH range, temperature range, uncertainty)
    - Price of calibration
  - Forecasting workload for calibration setups and operators
    - Variations in needed calibration schemes
  - Automatisation of measurements and analysis of results
    - Variations in needed calibration schemes
  - Profitability
- Calibrations on site
  - Time consuming
  - Limitations in applicability
  - Profitability

Approaches to improve the efficiency

- Automation
- Fixed calibration schemes
- Dynamic calibration

Developments at VTT MIKES

- **Dynamic calibration procedures**
  - Ascending and descending humidity ramps at fixed temperatures
  - Arbitrary humidity-temperature scheme

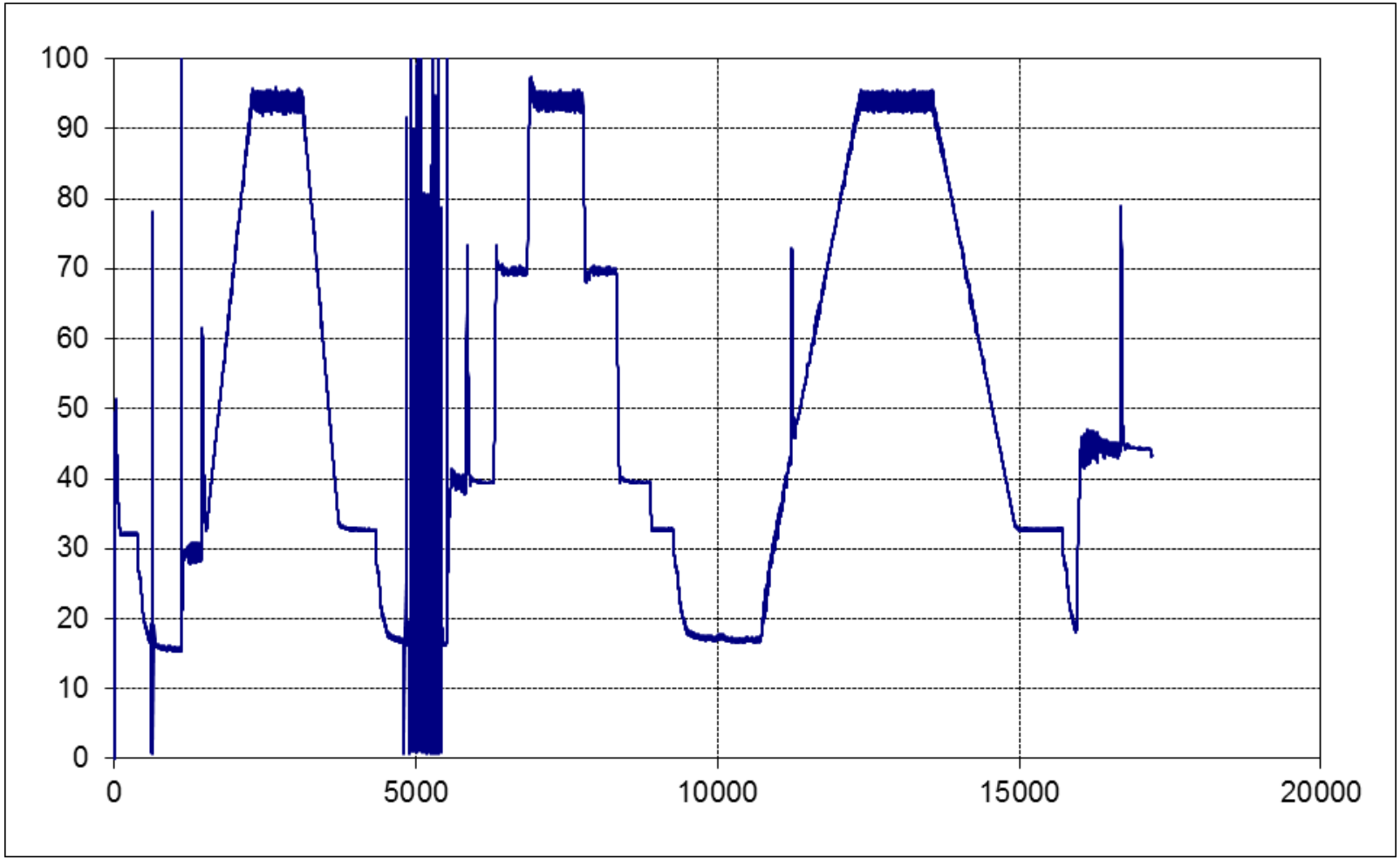
  ⇒ Feasible fixed full range calibrations
  ⇒ Fully automated
  ⇒ Cost efficient

- **Calibrators**
  - A modular setup for climatic chambers
  - Low cost prototype calibrator enabling arbitrary humidity-temperature calibration scheme
  - Low cost prototype calibrator for on-site calibration of ambient air monitoring sensors

Developments:
A new approach for laboratory calibrations

- Starting point:
  - RH calibrations in a climatic chamber using a dew-point hygrometer and thermometer as the calibration standards
    - Widely applied in industrial calibration laboratories
    - Used also at VTT MIKES for secondary level RH calibrations
- Limitations at VTT MIKES:
  - Stability of humidity control
  - Humidity range
    - Discontinuation between dew-point temperature ranges below and above 5 °C
    - Low dew-point limit to humidity control around -10 °C

Example of a test measurement

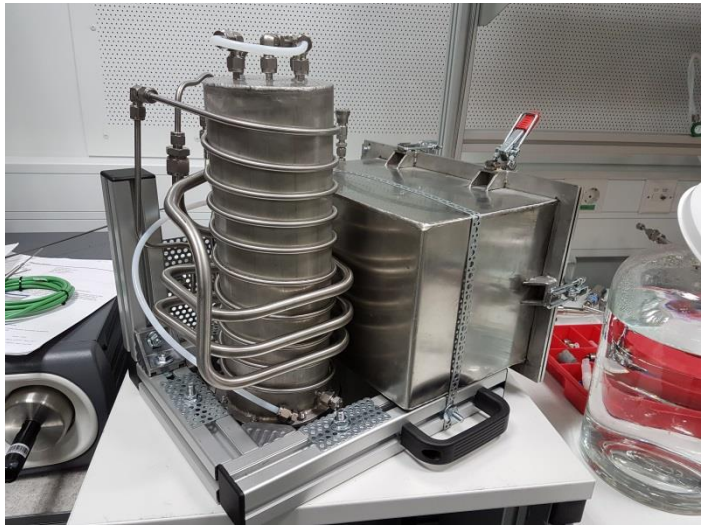


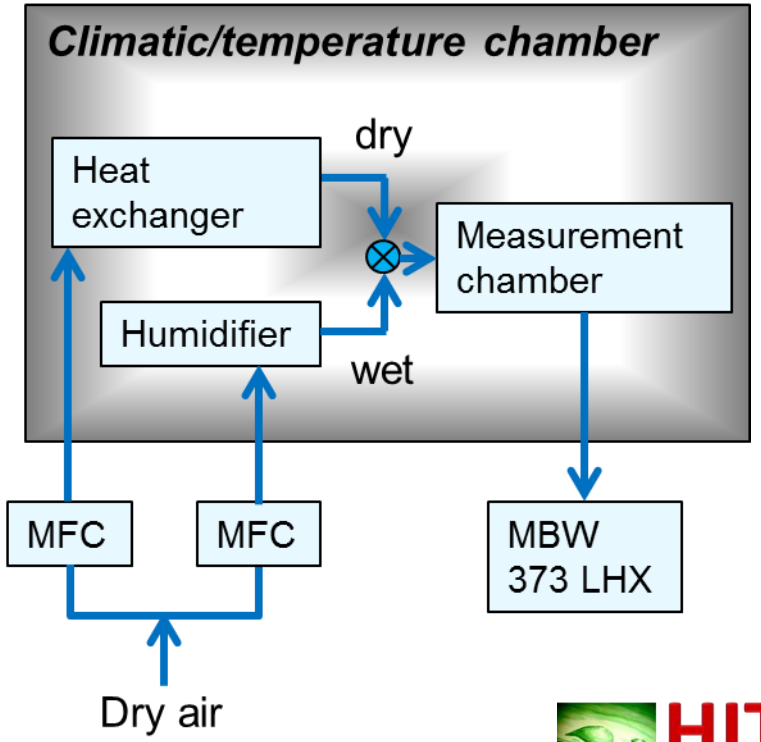
A new modular humidity calibration setup developed at VTT MIKES

- The system can easily be installed any commercial temperature test chamber with inner volume of 200 dm^3 or larger
- A LabView program enables automatic calibrations in static and non-static conditions

A new modular humidity calibration setup developed at VTT MIKES

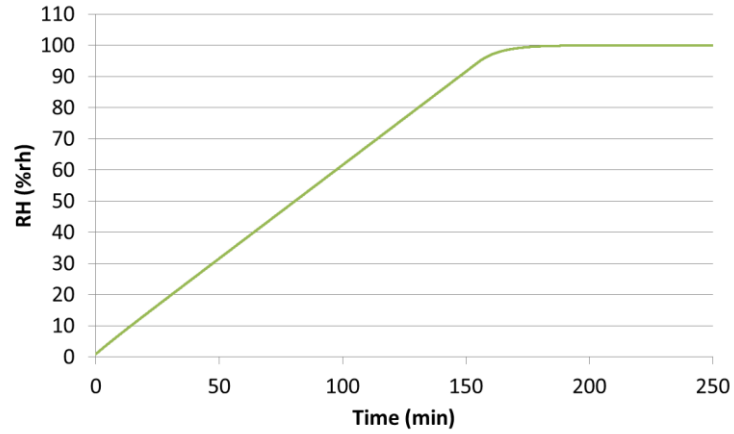
- Humidity is controlled by two mass flow controllers located outside the temperature test chamber
- Quick couplings for easy assembling
- Heater in the humidifier to compensate evaporative cooling

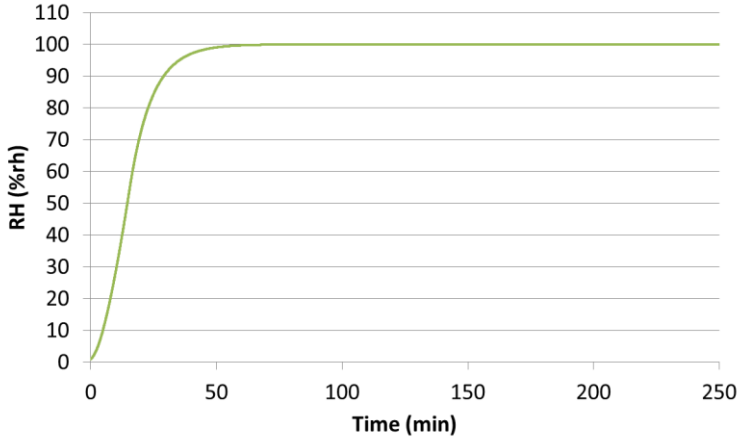




Slow ramp configuration

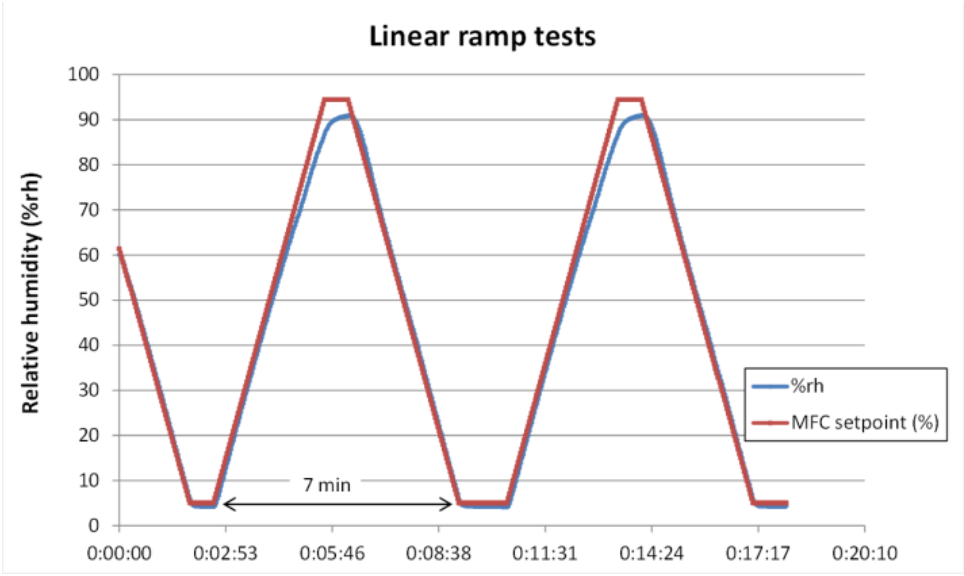
- Speed is limited by the volume (12 dm^3; flow rate 1 dm^3/min)

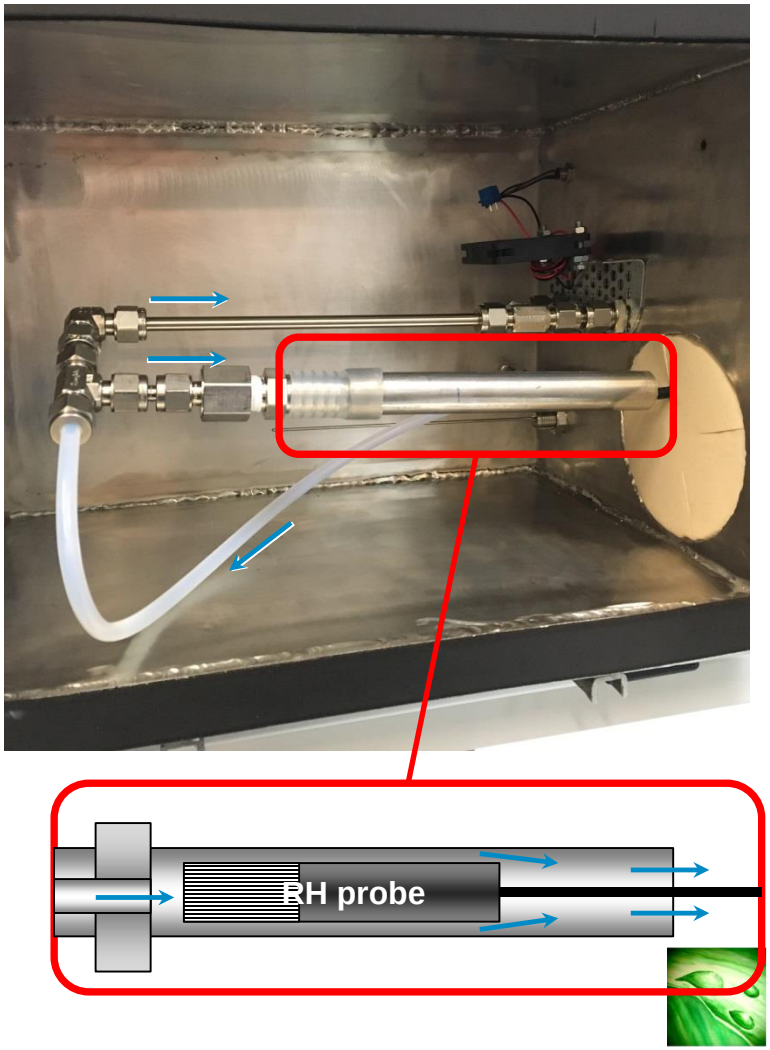




Fast ramp configuration

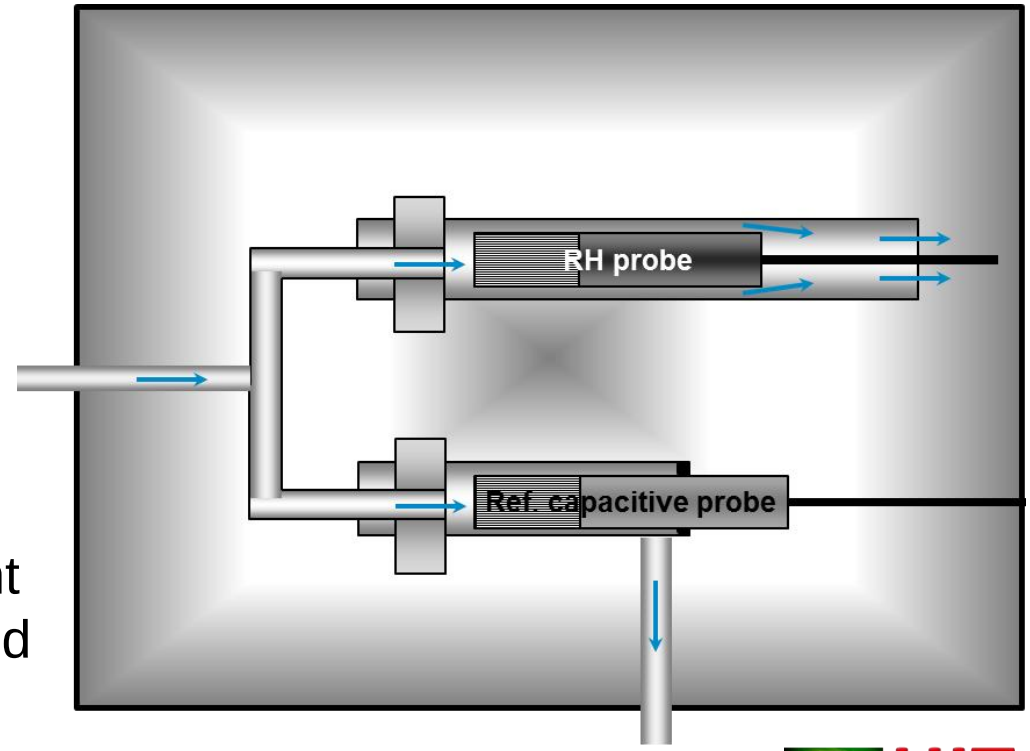
- Sensors have to be tested separately





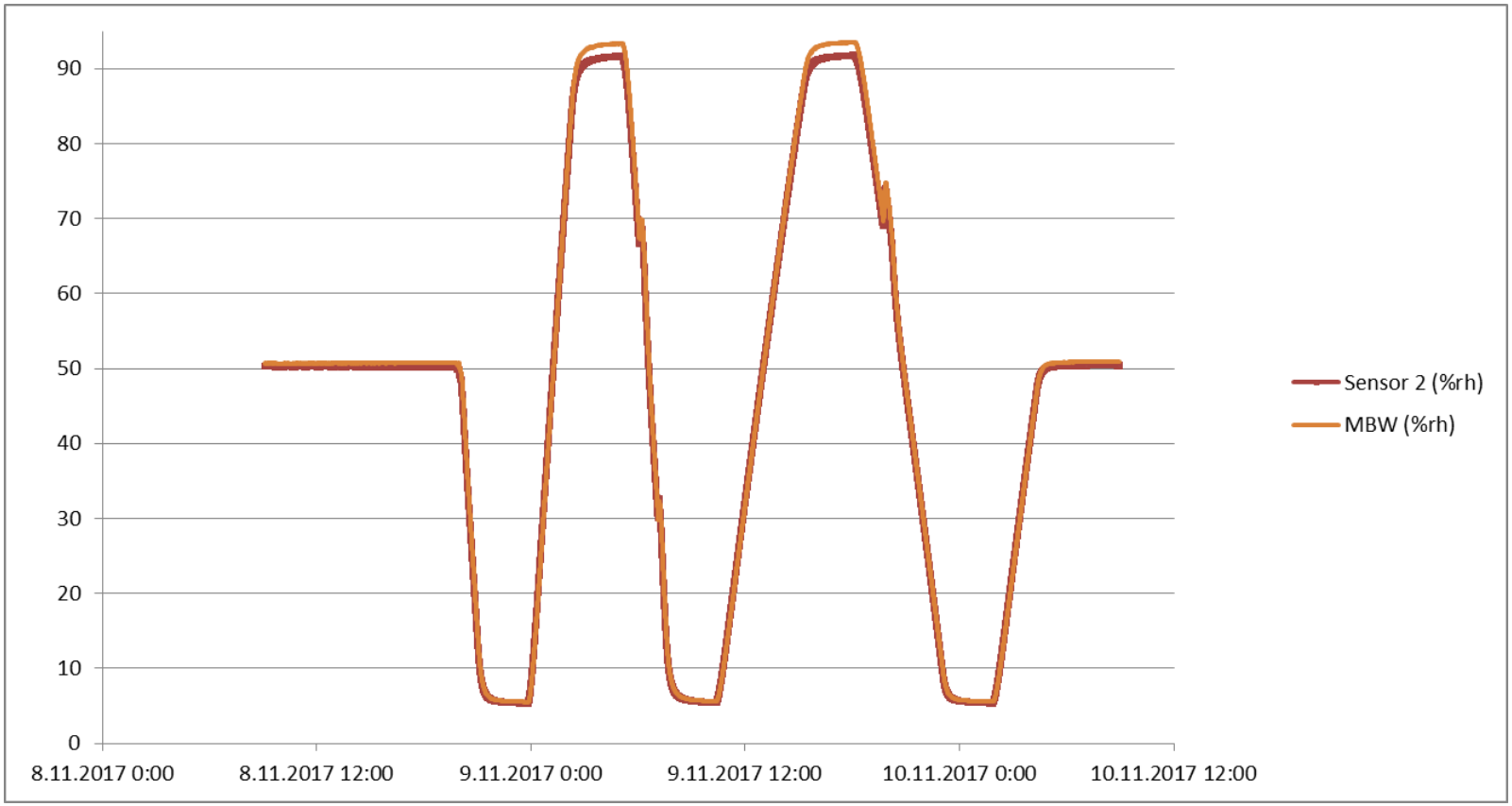
Dynamic characteristics of a reference

- Chilled mirror hygrometer:
  - Accurate but suffer from instabilities and limited speed in non-static measurements
- Capacitive sensors:
  - Can be fast but suffer from drift
- Solution:
  Combination of a chilled mirror hygrometer and a capacitive reference sensor
  - During calibration measurement the capacitive sensor is checked against the chilled mirror hygrometer at static conditions.

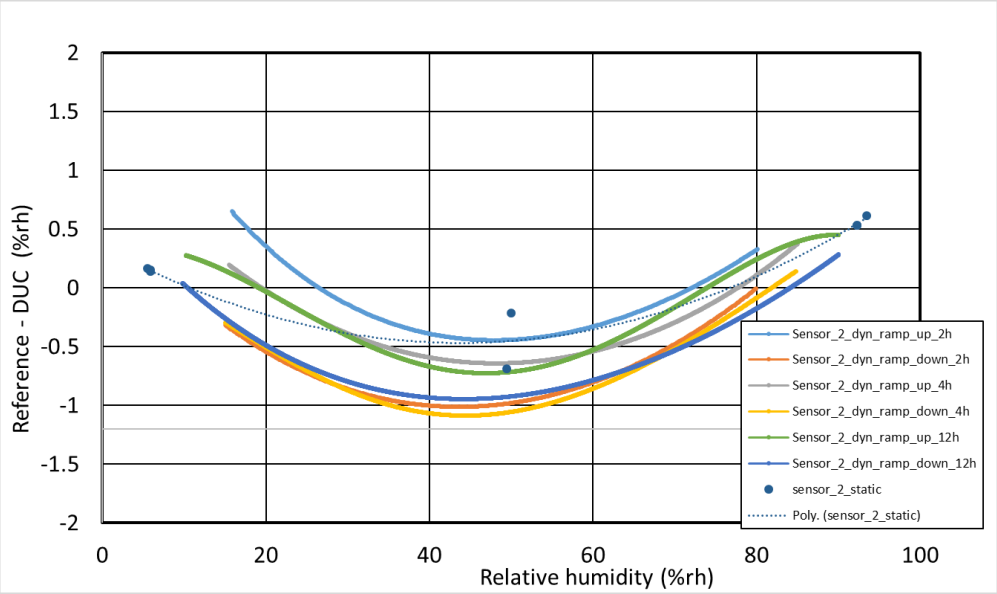


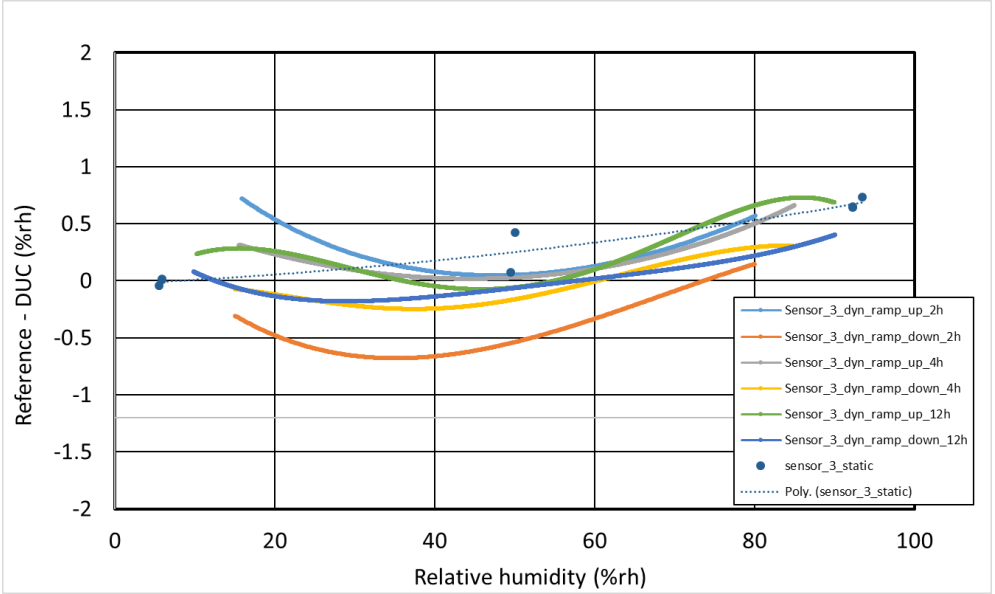
Measurements

- Measurement scheme (different speed rates)



Measurements at room temperature





Reference value based on MBW 373 LHX reading

Measurements at +40 °C

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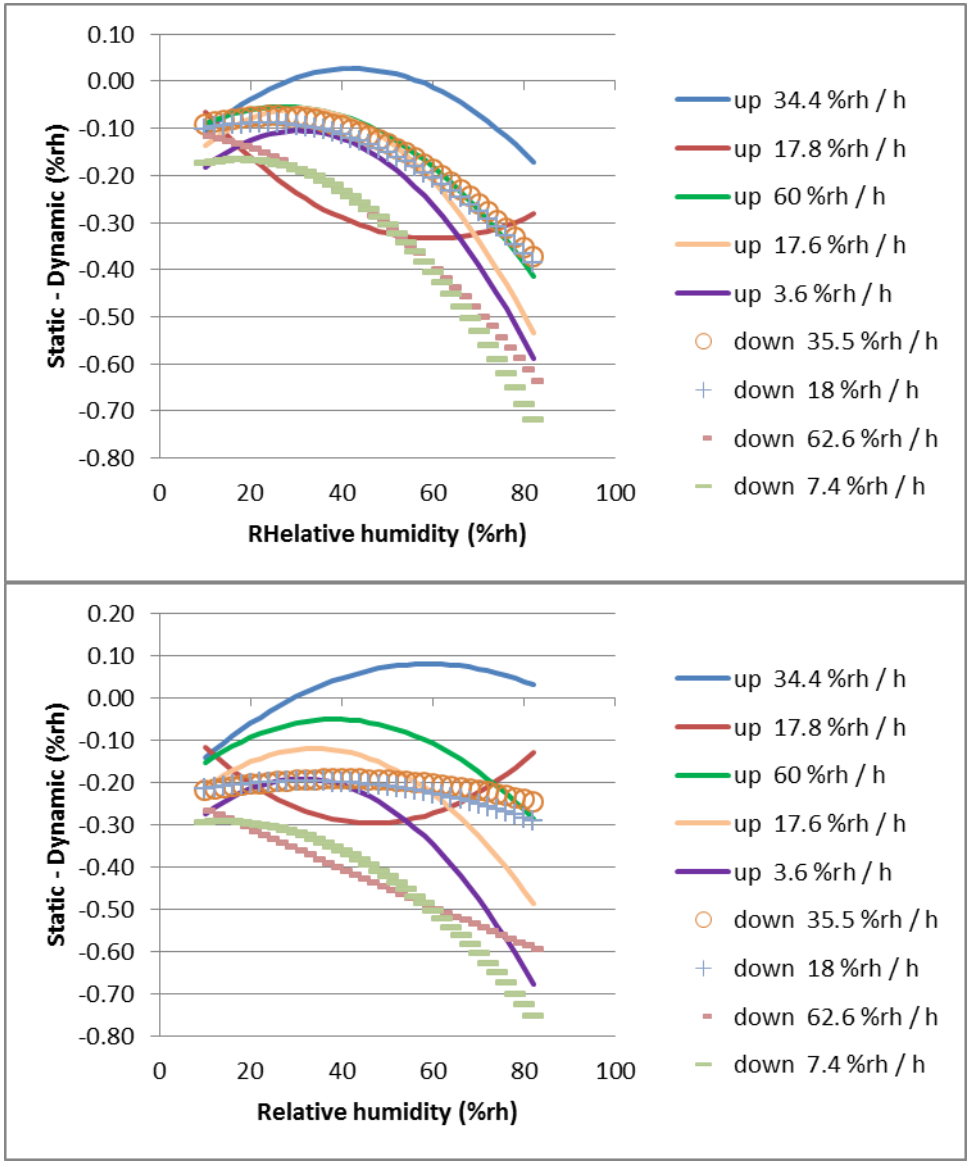
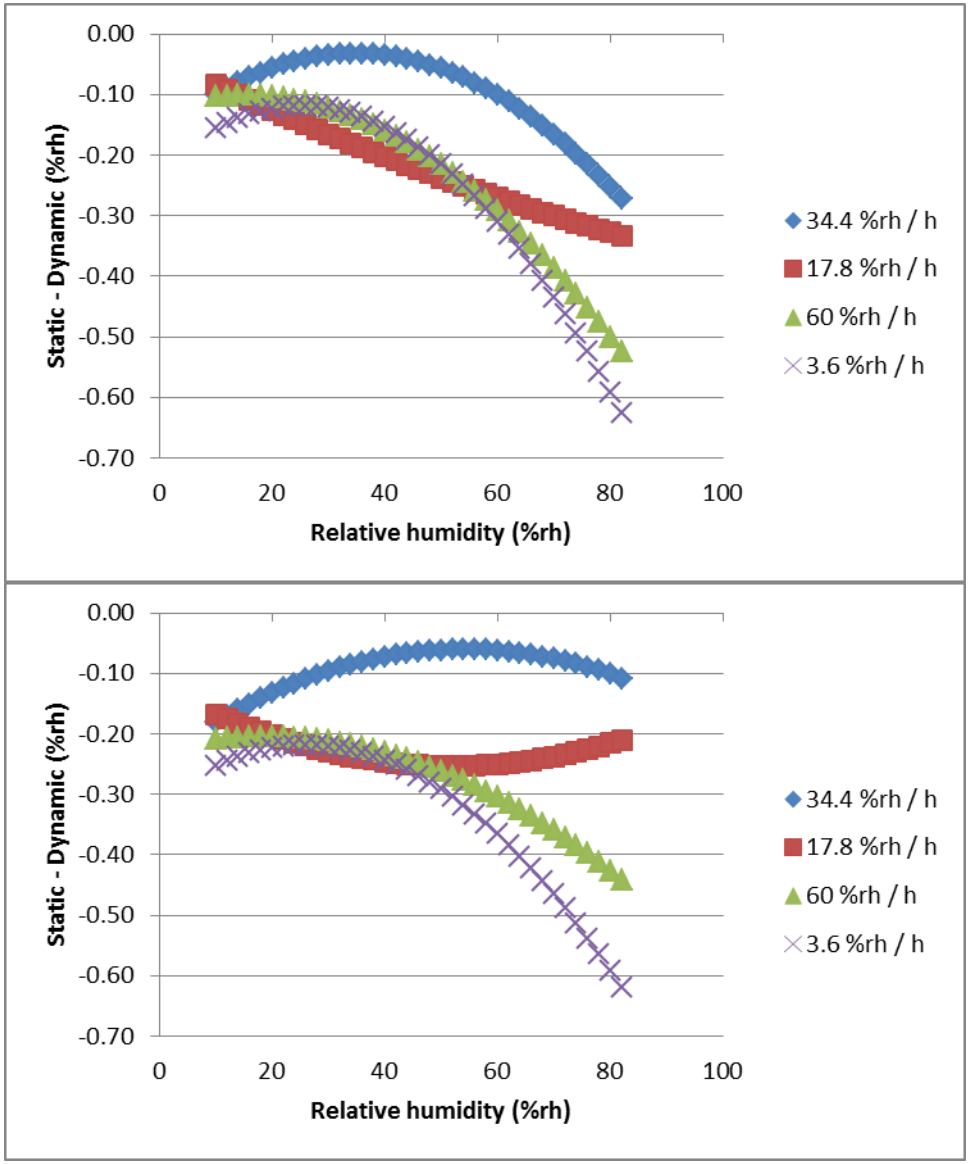
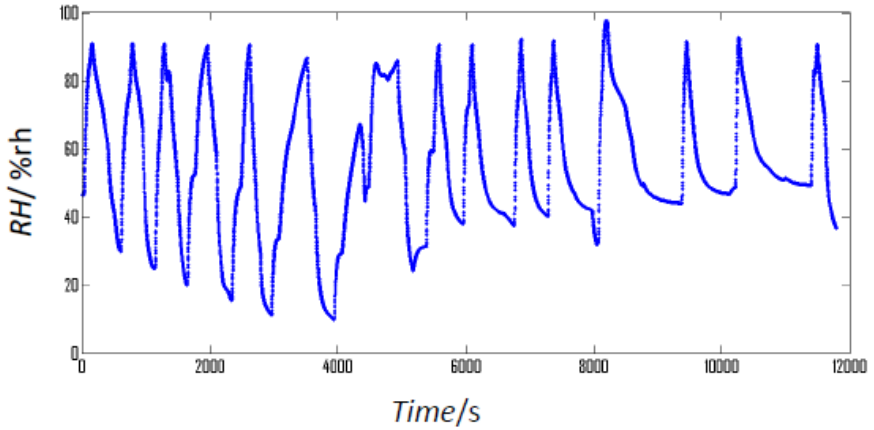


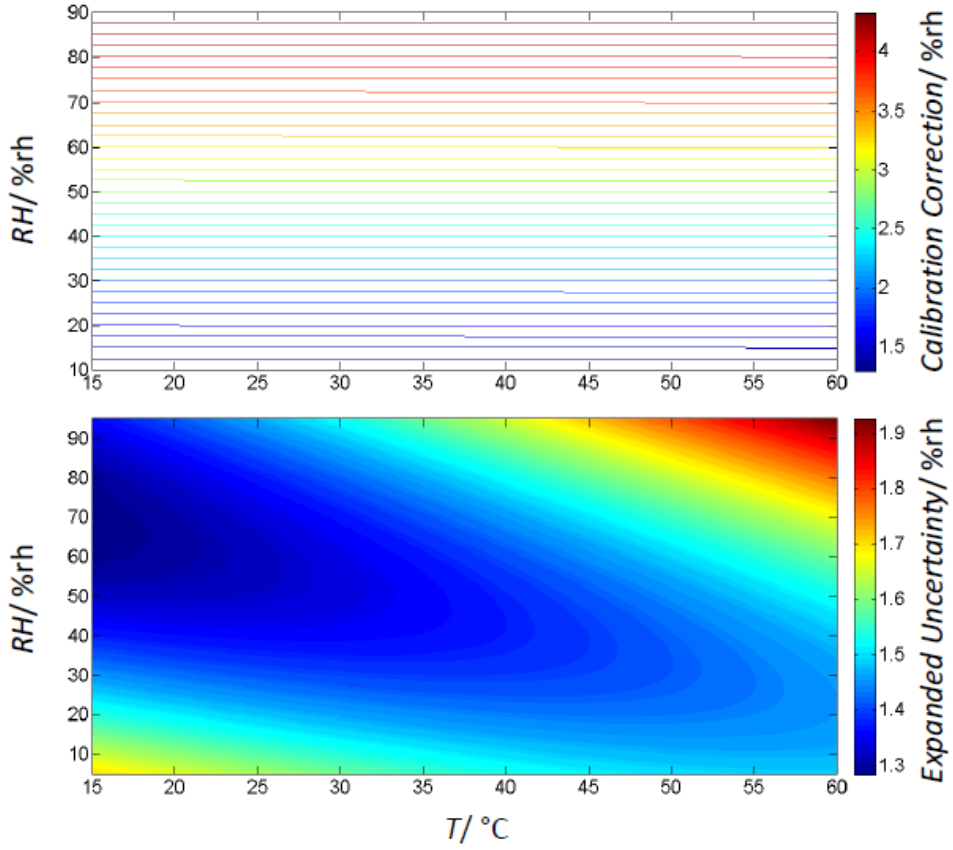


Developing calibrators for on-site measurements

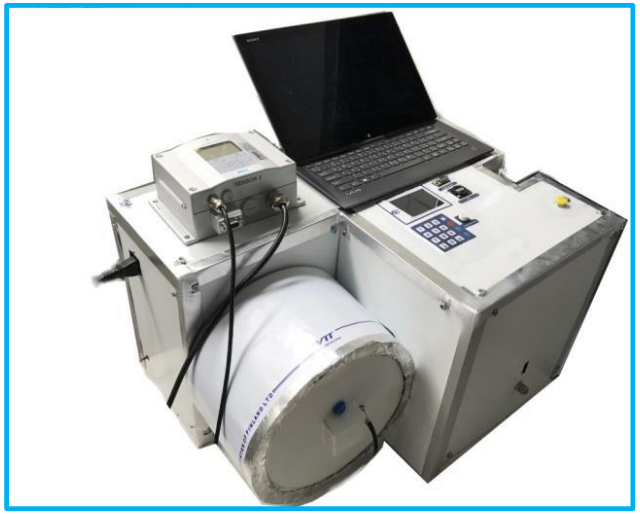
- Technical challenges:
  - Reduce time needed for a calibration
  - Reduce manual work (incl. setting up the system on site)
  - Low cost

Arbitrary humidity-temperature calibration scheme

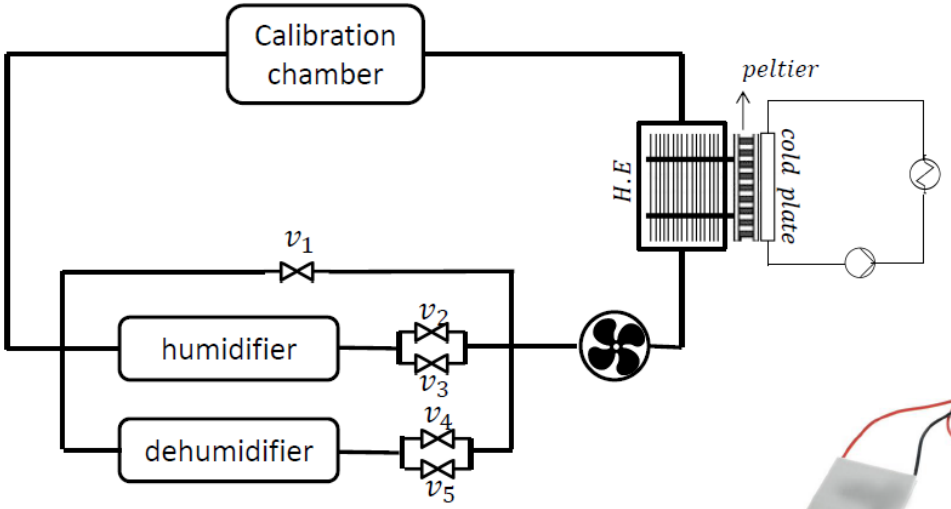


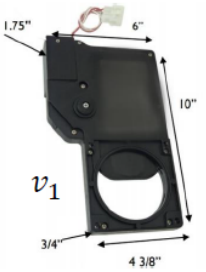


A calibrator prototype enabling arbitrary humidity-temperature calibration schemes



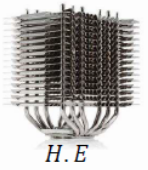
Capacitive humidity sensor as the reference





$$RH(t+\Delta t) = \frac{(V - Q_v \Delta t) RH + (Q_v \Delta t) RH_{up}}{V}$$

$$\dot{RH} = \lim_{\Delta t \to 0} \frac{RH(t+\Delta t) - RH(t)}{\Delta t} = \frac{Q_v}{V}(RH_{UP} - RH(t))$$



A calibrator prototype enabling arbitrary humidity-temperature calibration schemes

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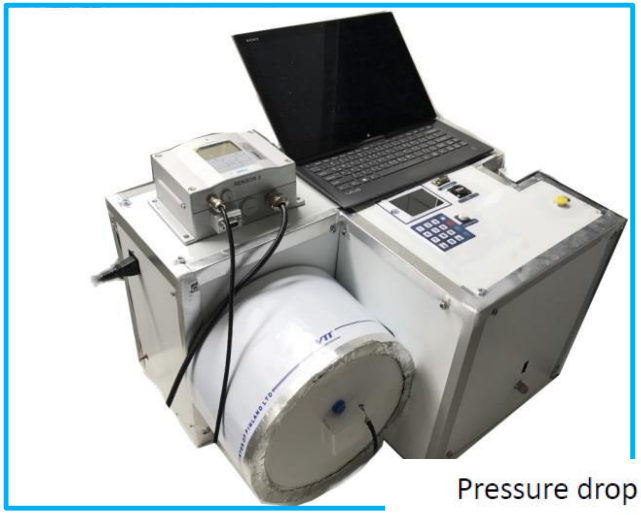
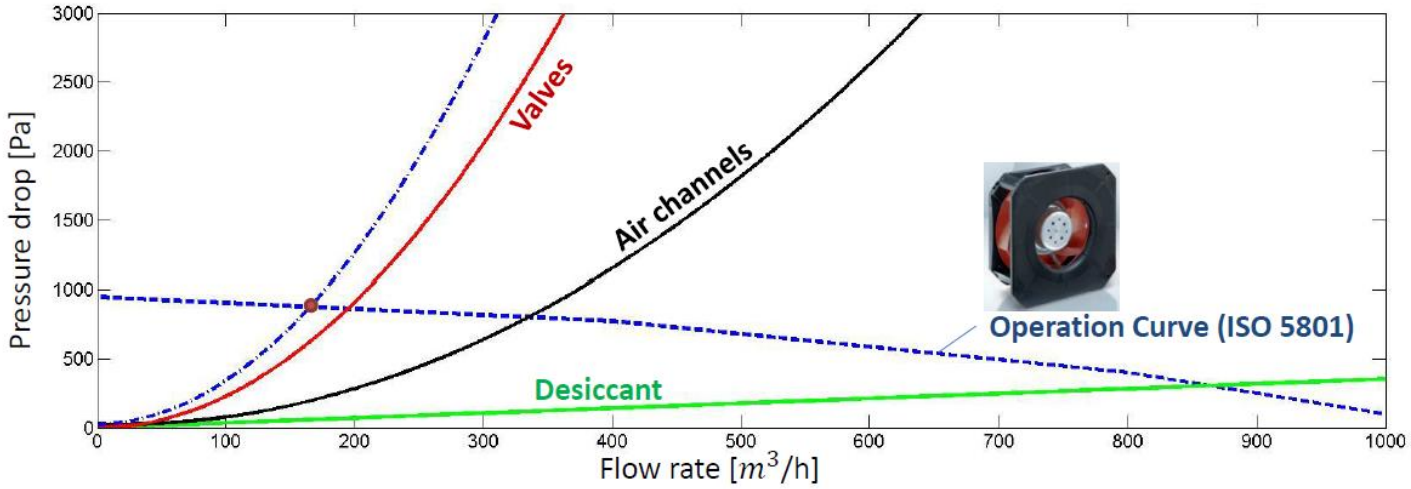


Pressure drop over the dehumidifier box and air channels are estimated by CFD models.

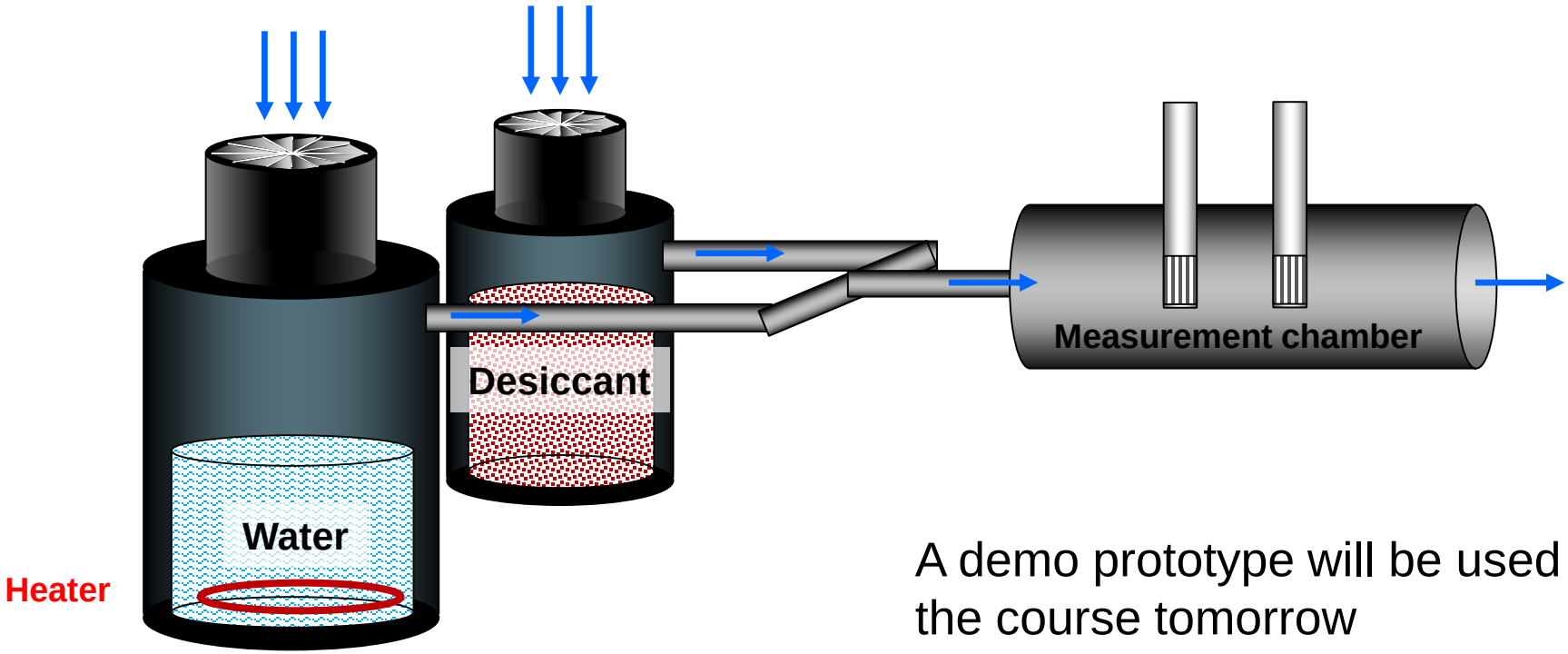
The operation point is 2.7 m^3/min which guaranties a fast and homogeneous temperature and humidity changes.

A low pressure drop (i.e. 875 Pa) gives the opportunity of having a light and cheap impeller.



Low cost approach to a field calibrator

- Wet-dry mixing using two fans controlled by a computer
- Designed to operate at ambient temperature
- For both static and dynamic calibrations



A demo prototype will be used in the course tomorrow

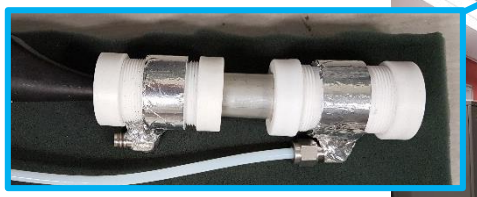
Probe fittings and measurement chamber

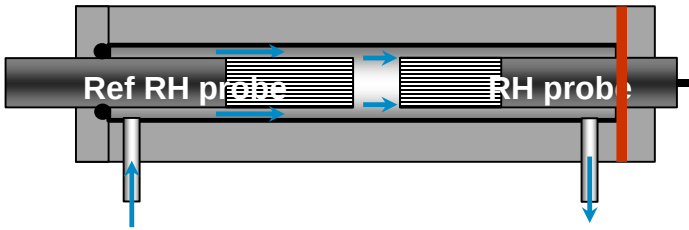
- For full immersion
  - large measurement volume needed ⇒ slower

- Electrical cable fittings
  - Low cost, suitable for a range of diameters
  - Durability?
  - Some leaks possible

- Open end measurement tube
  - Very easy to operate
  - Tube inner diam. must be close to the probe diameter

- Rubber flange sealed chamber tube
  - Suitable for a range of diameters
  - Durability?
  - Some leaks possible





Conclusion

- To improve the efficiency of humidity calibrations at a laboratory and in the field, we have developed:
  - Dynamic calibration procedures
  - New calibrators
- Dynamic calibration procedure
  - Limited by response times of sensors and air volume
    - Measurement procedure should include a response time test
  - Requires automatic recording
  - Best results achieved applying linear ramps
- New calibrator approaches
  - Low cost
  - Practical in use
  - Further development needed before commercialisation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Thank you