VTT TECHNICAL RESEARCH CENTRE OF FINLAND LTD
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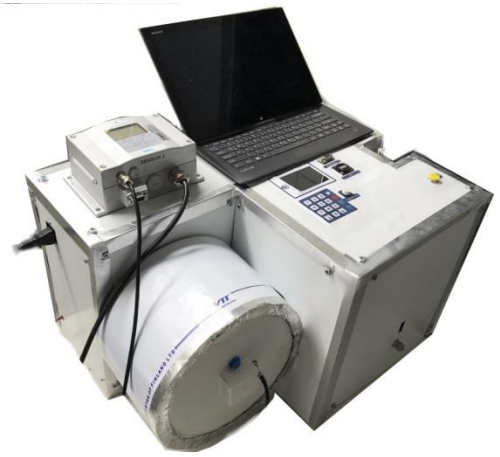

New approach to calibrate a RH probe and its application to field calibrations

HIT workshop , PTB, Braunschweig, Germany 16 to 17 November 2017

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EMPIR EURAMET
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Outline

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- Non-static calibration
  - Calibration coefficient redefinition for ramps
  - Generalization
  - Calibration by comparison of slopes
  - Temperature contribution
  - 2D calibration
- Calibrator design
  - Kinetic design
  - Dynamic design
  - Dehumidifier design
  - Humidifier design
- Calibrator Prototyping and testing
  - Time stability
  - Operating features

Non-static calibration

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Classical calibration by comparison

$$C = \frac{RHr}{RHc} = \frac{Ar}{Ac}$$

Non-static calibration by comparison

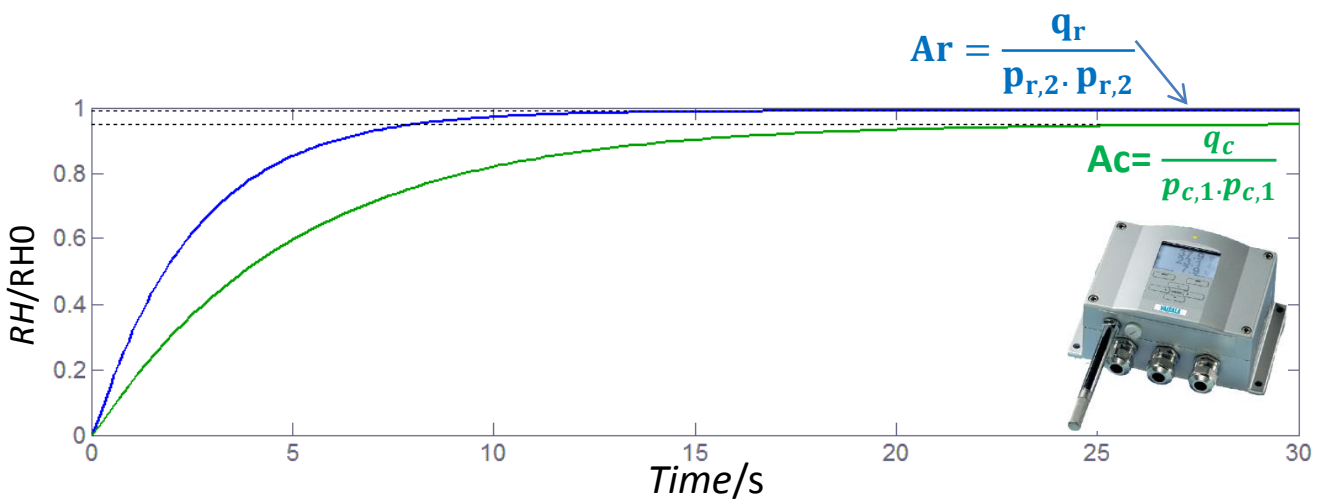
$$C = \frac{Ar}{Ac} = \frac{y4r}{y4c} = \frac{y_r - y_{r,1} - y_{r,2} - y_{r,3}}{y_c - y_{c,1} - y_{c,2} - y_{c,3}}$$

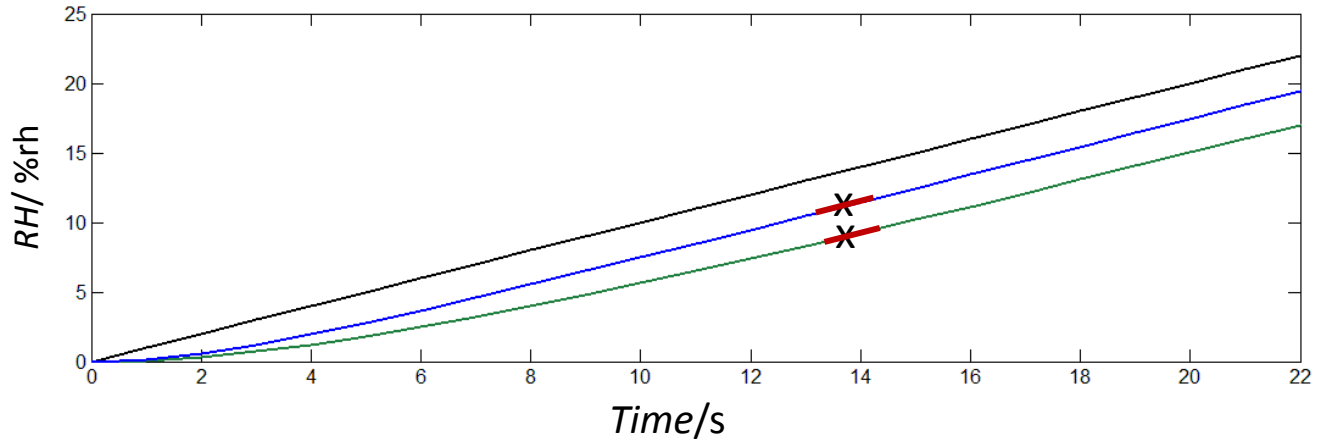
$$C = \frac{Ar}{Ac} = \frac{\dot{y_{4r}}}{\dot{y_{4c}}} = \frac{\dot{y_r} - \dot{y_{r,1}} - \dot{y_{r,2}}}{\dot{y_c} - \dot{y_{c,1}} - \dot{y_{c,2}}}$$

Where:

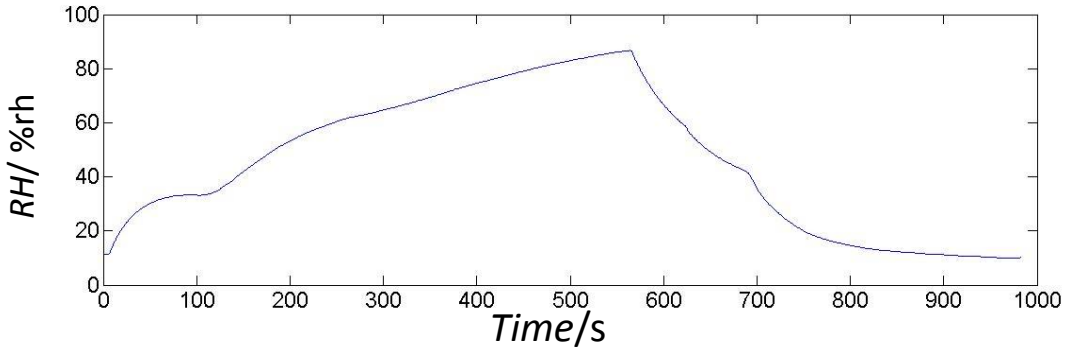
$$y1 = \frac{\alpha q e^{p1t}}{p1^2.(p1 - p2)} \qquad y3 = \frac{\alpha q (p1 + p2)}{p1^2.p2^2}$$

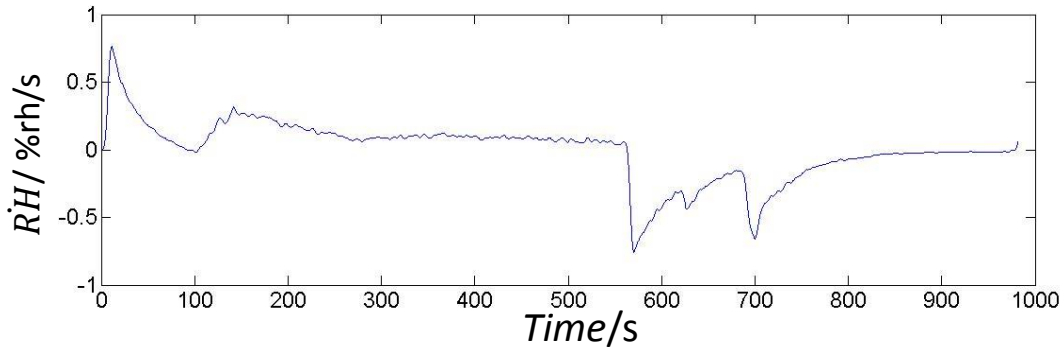
$$y2 = -\frac{\alpha q e^{p2t}}{p2^2.(p1 - p2)} \qquad y4 = \frac{\alpha q t}{P1.P2}$$

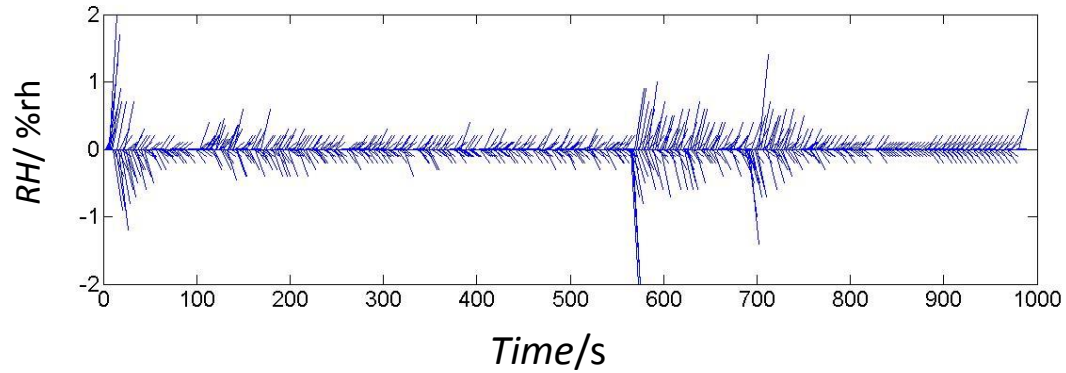


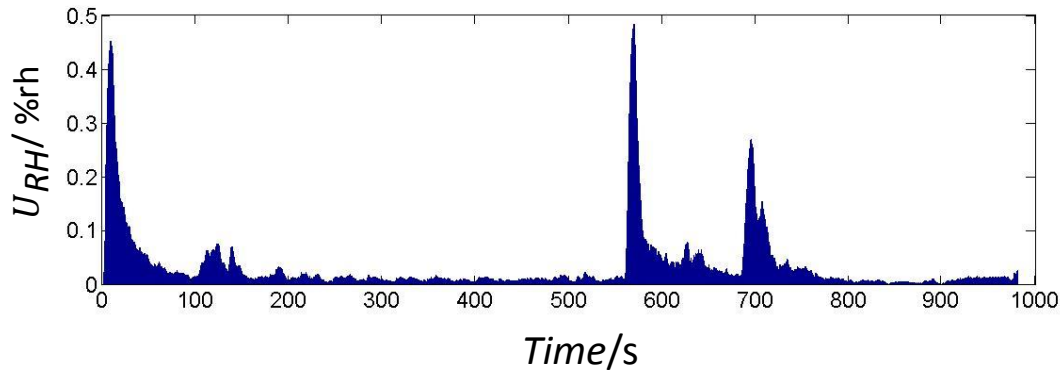


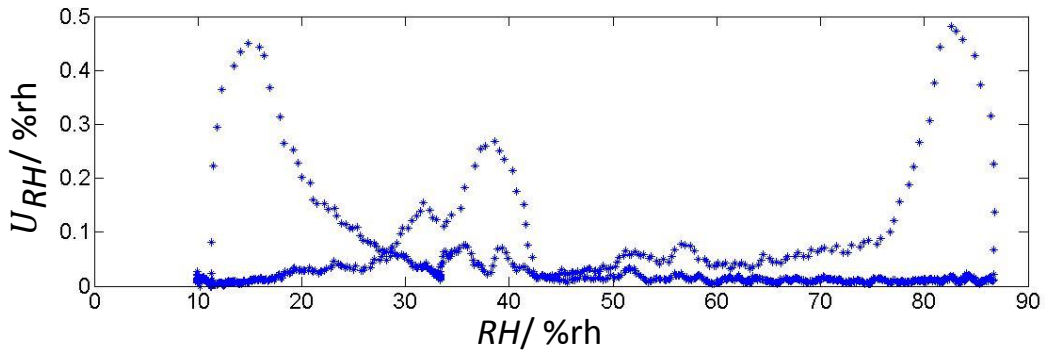
Generalization-arbitrary profiles



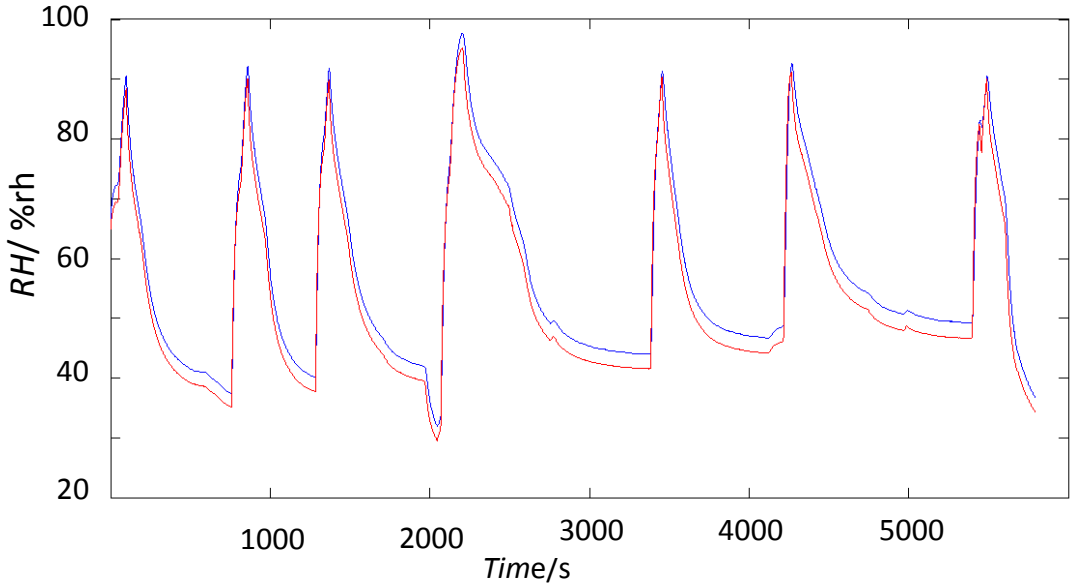




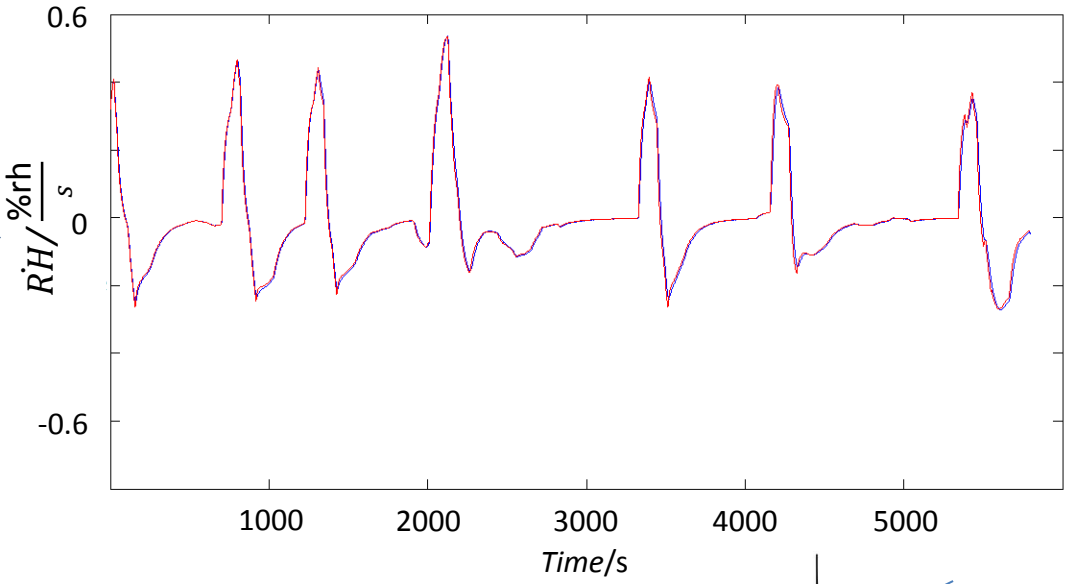




Calibration by comparison of slopes



$\frac{dRH}{dt}$

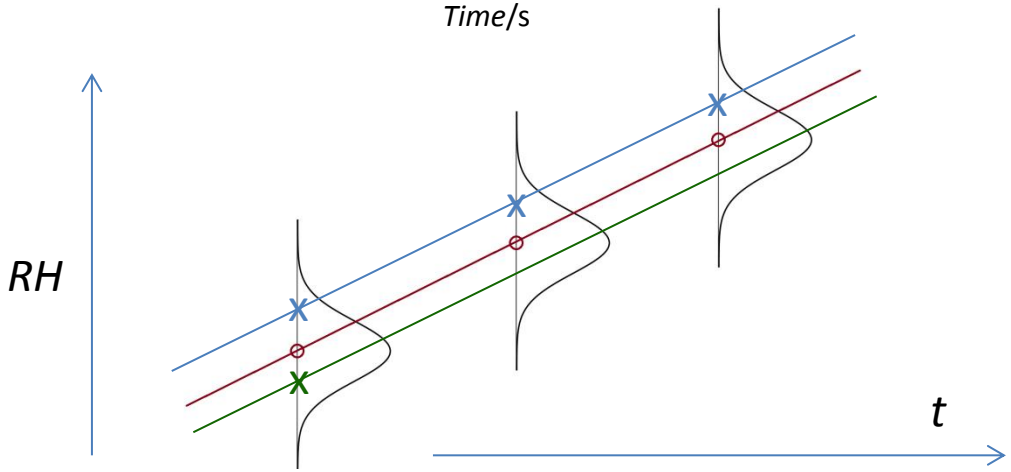


Advantages:

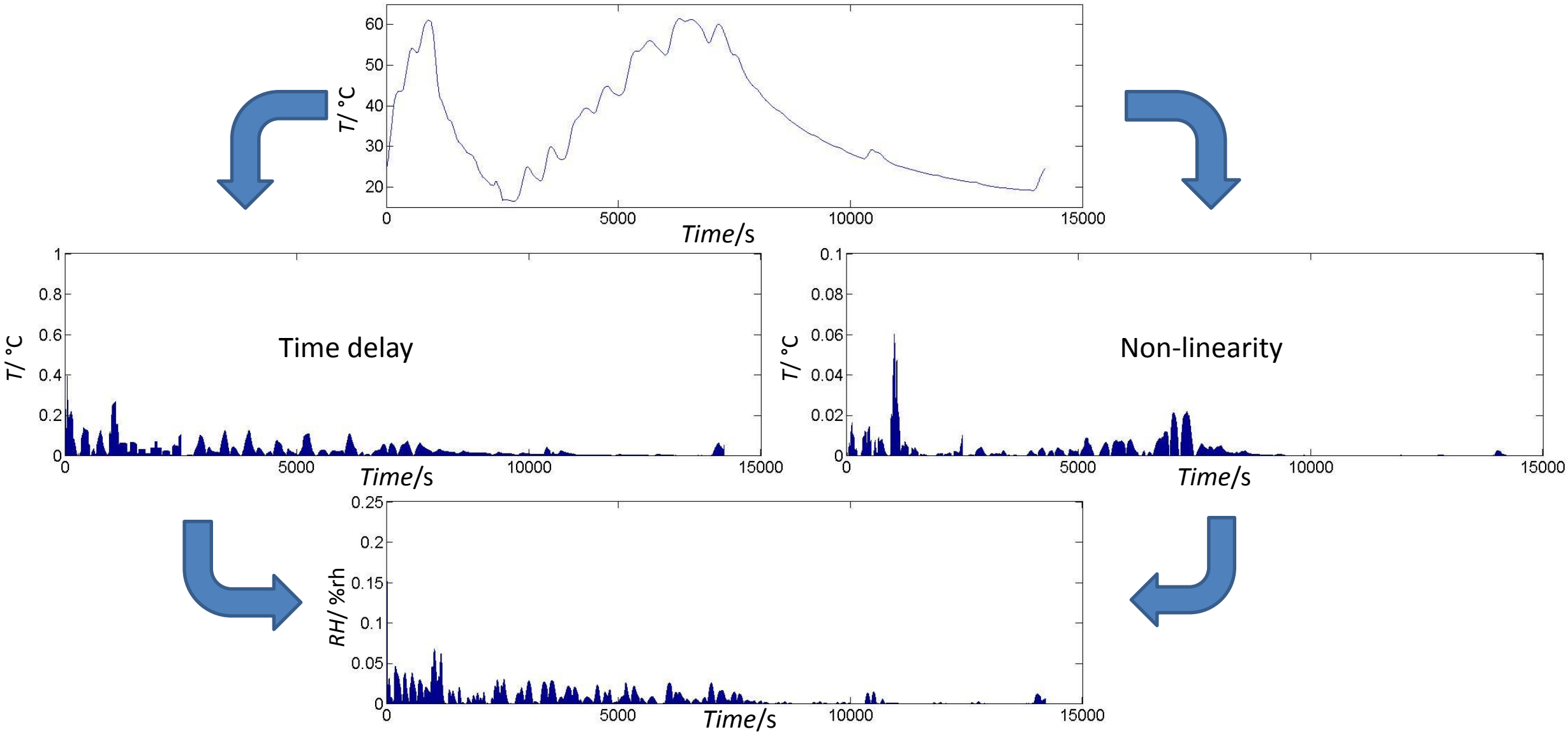
1) Time constant non-sensitivity
2) Improved temperature dependency
3) Perfect reproducibility

Disadvantage:

Slow slopes increase the uncertainty dramatically



Temperature contribution



2D calibration

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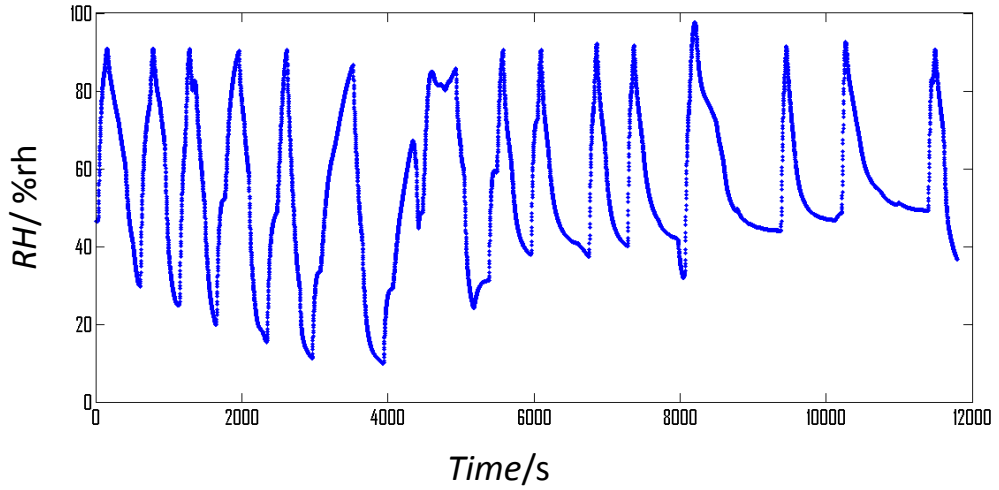
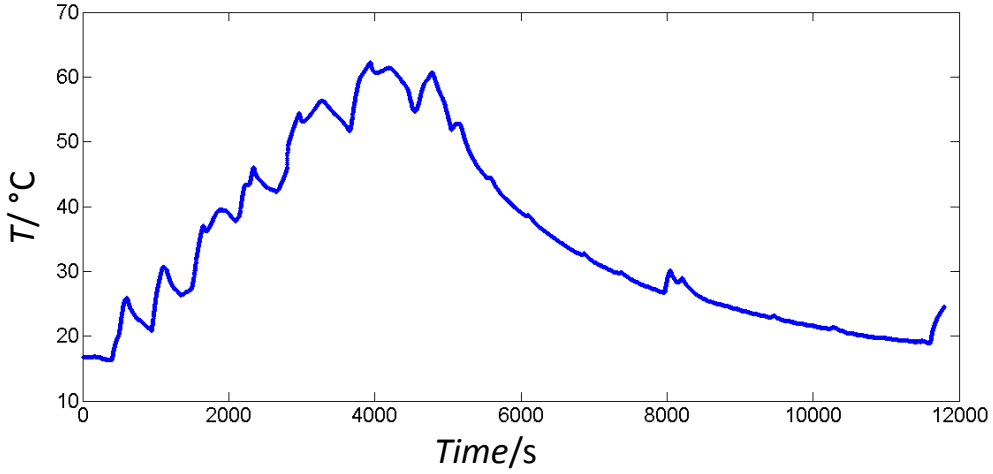
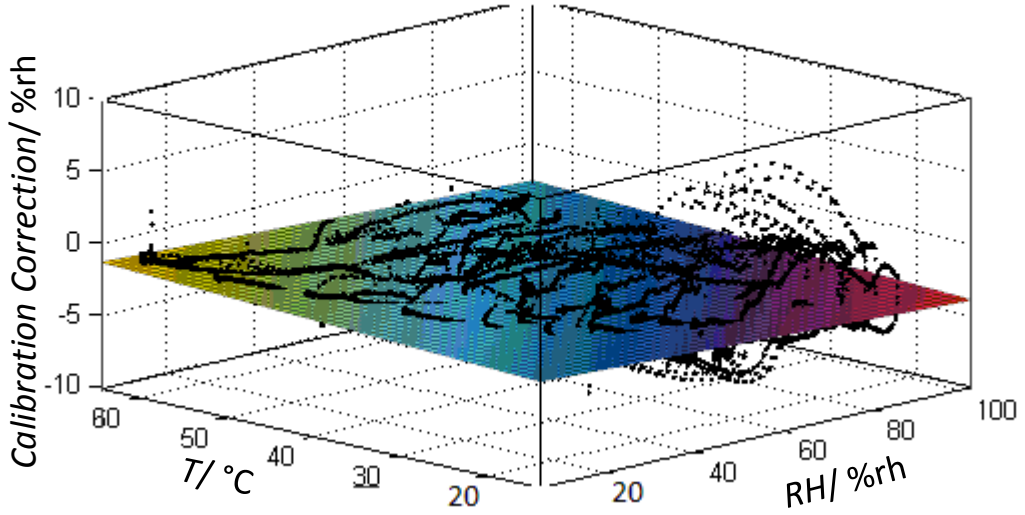
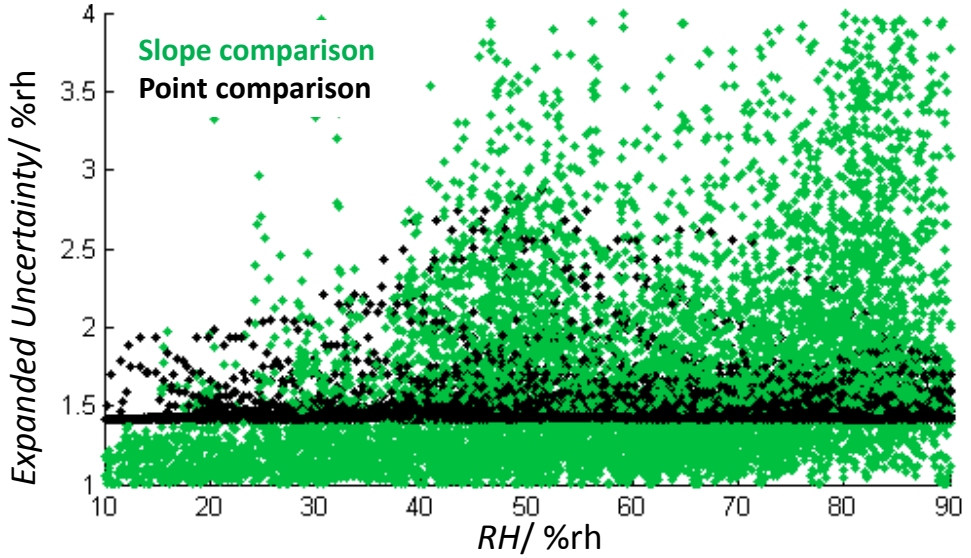
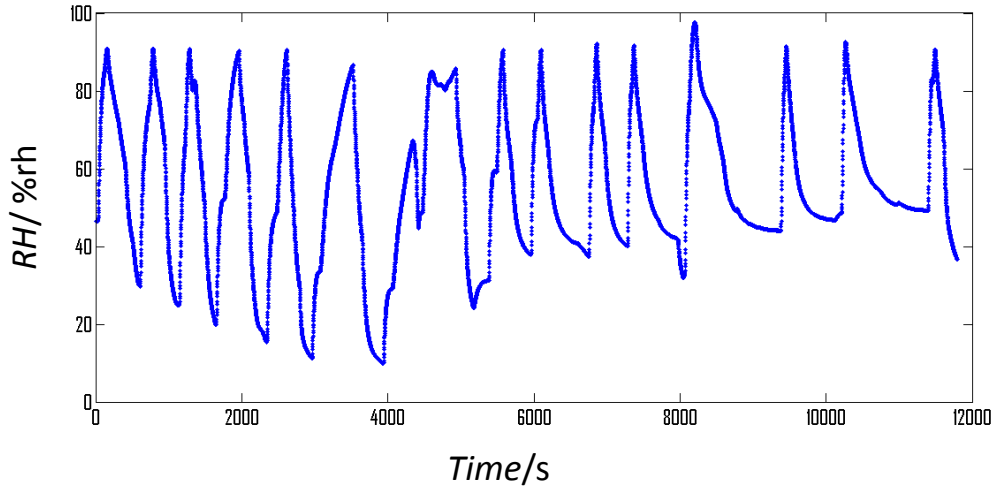


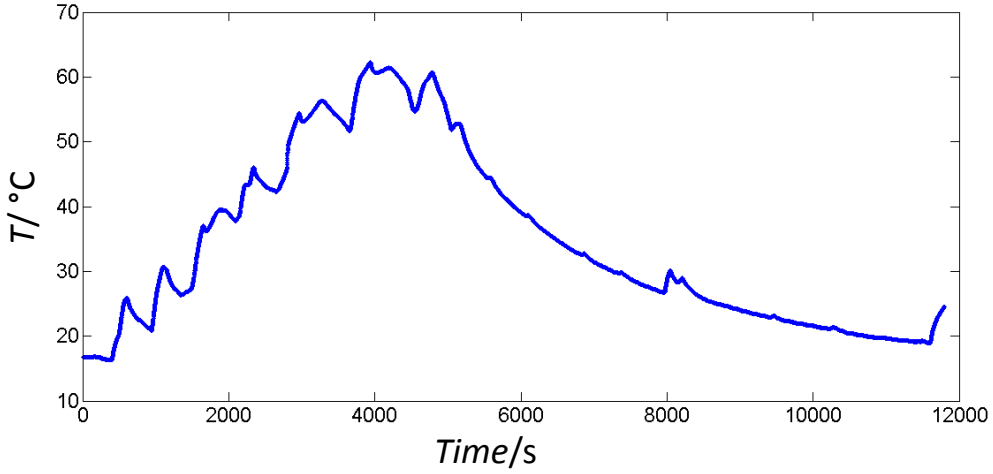


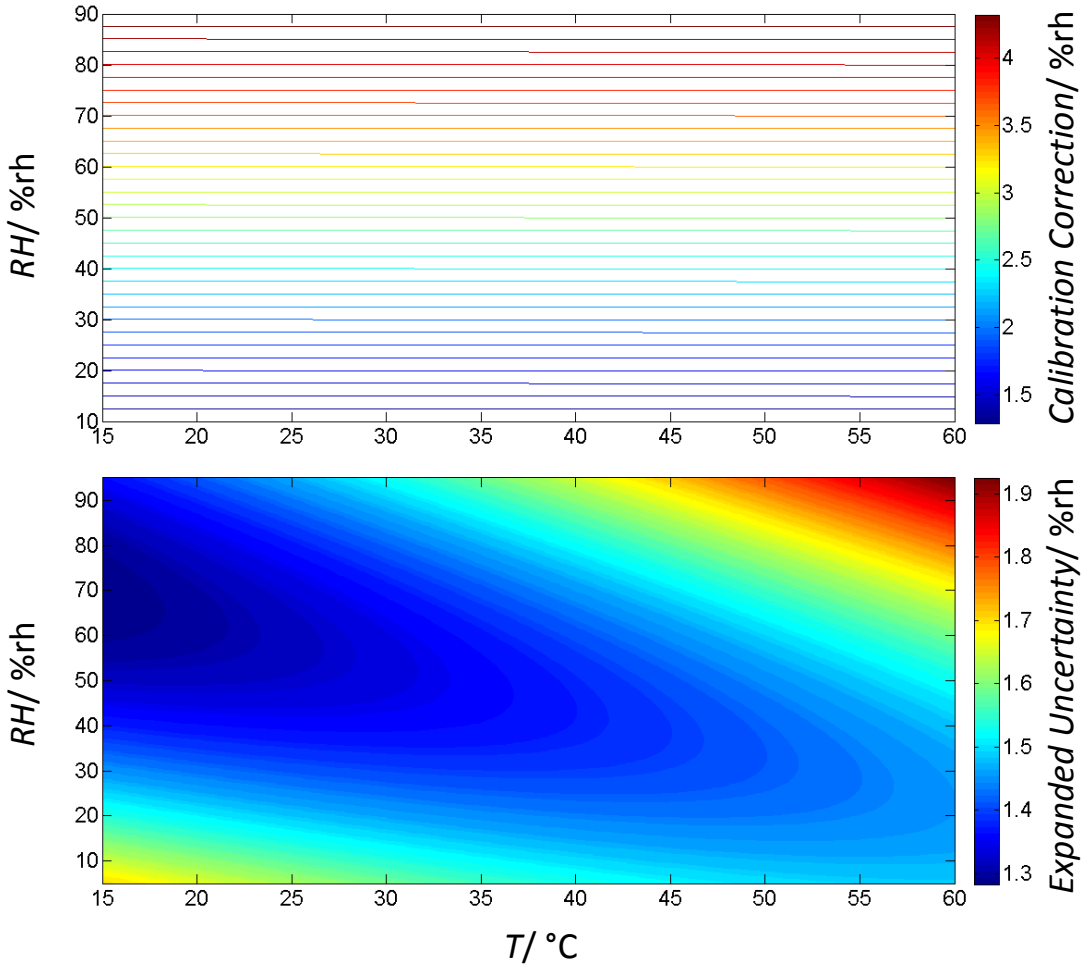




2D calibration







Design and prototyping of a humidity calibrator

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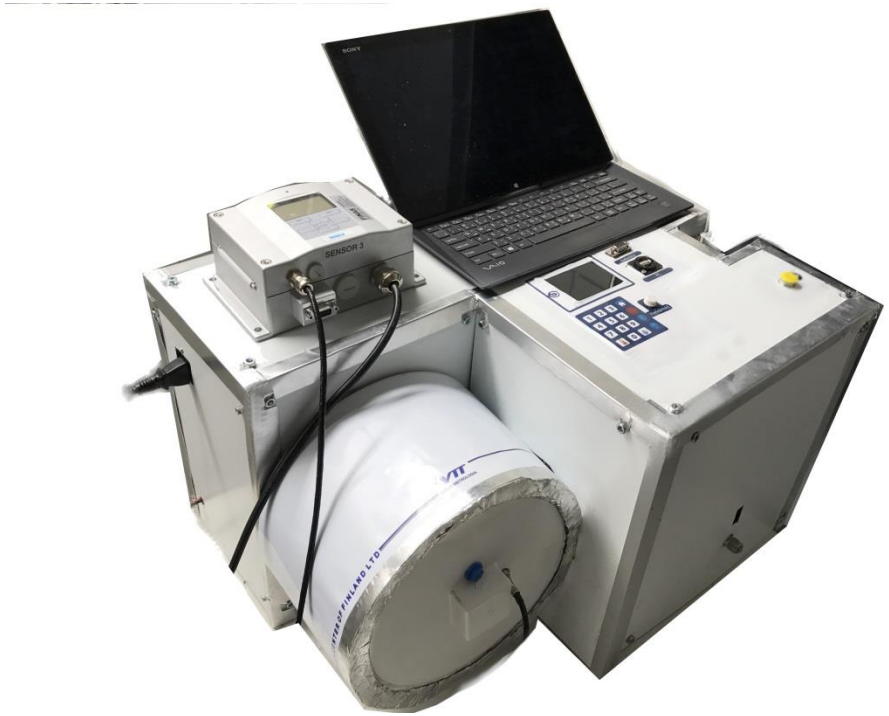
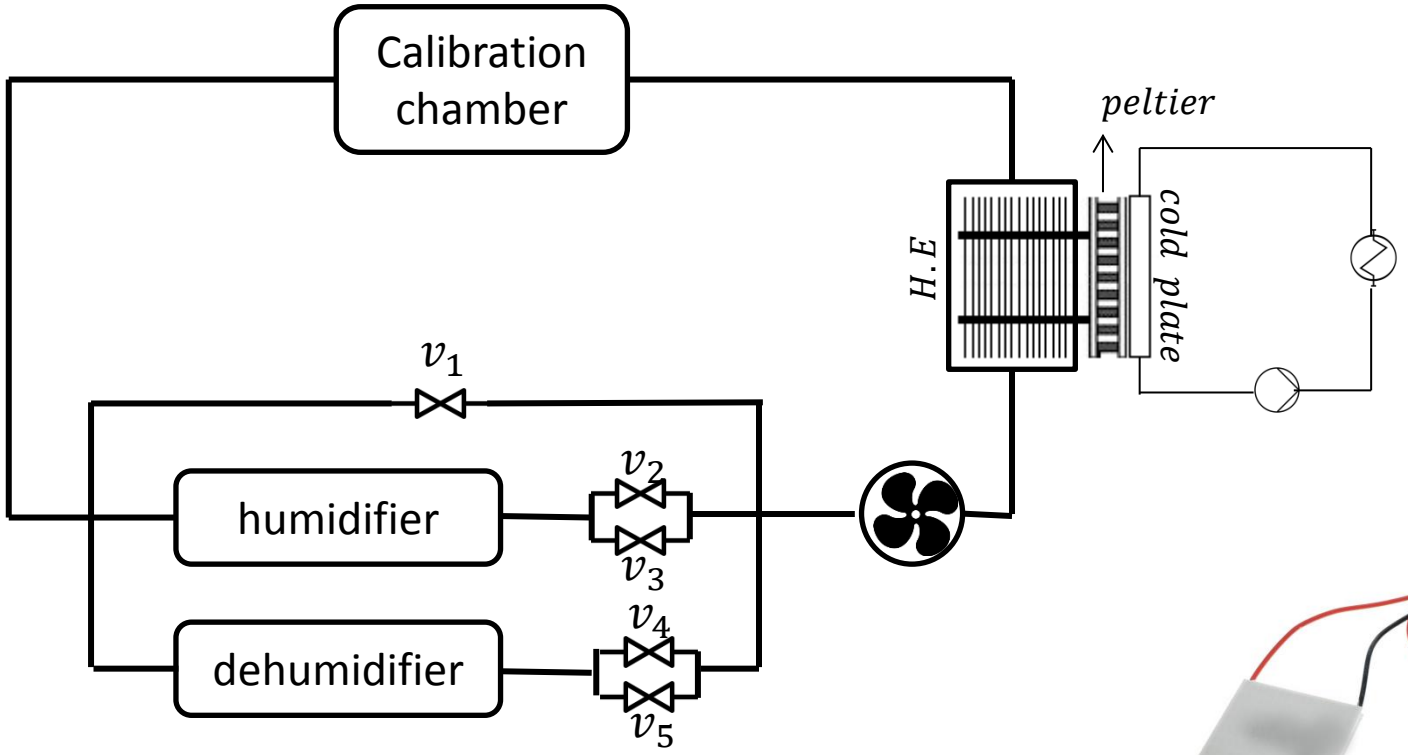
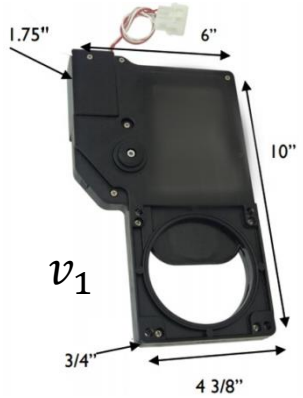
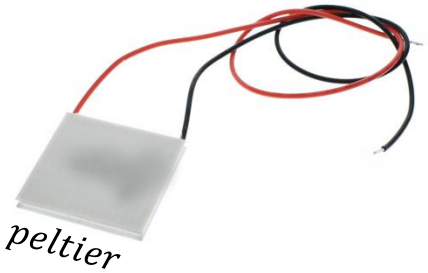
- Kinetic design of the system using CFD modeling
- Dynamic design of the system
- Controller simulation and design
- Conceptual prototyping
- Microcontroller programming
- Testing



Working principle

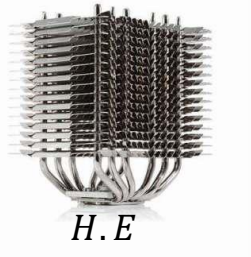






$$RH(t+\Delta t) = \frac{(V - Q_v \Delta t) RH + (Q_v \Delta t) RH_{up}}{V}$$

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

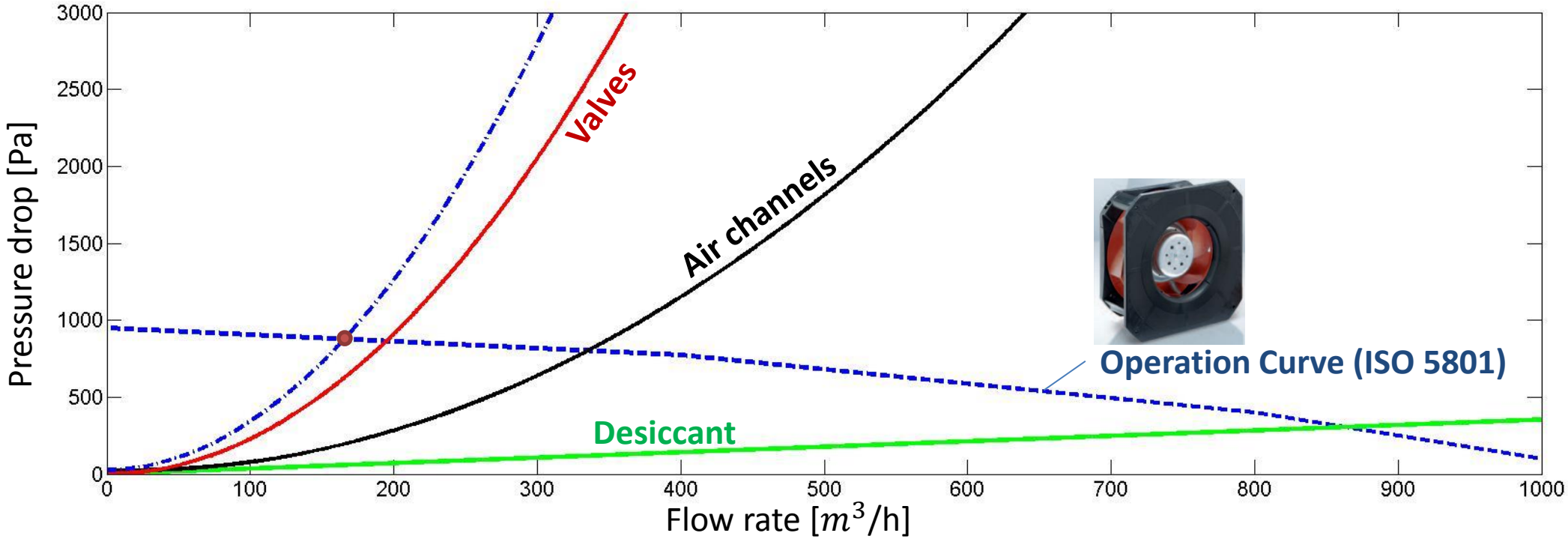


Kinetic design

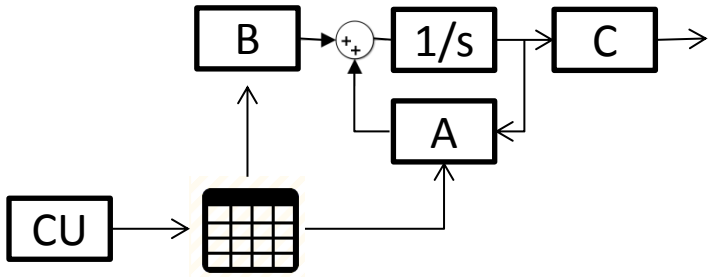
Pressure drop over the dehumidifier box and air channels are estimated by CFD models.

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.



Dynamic design

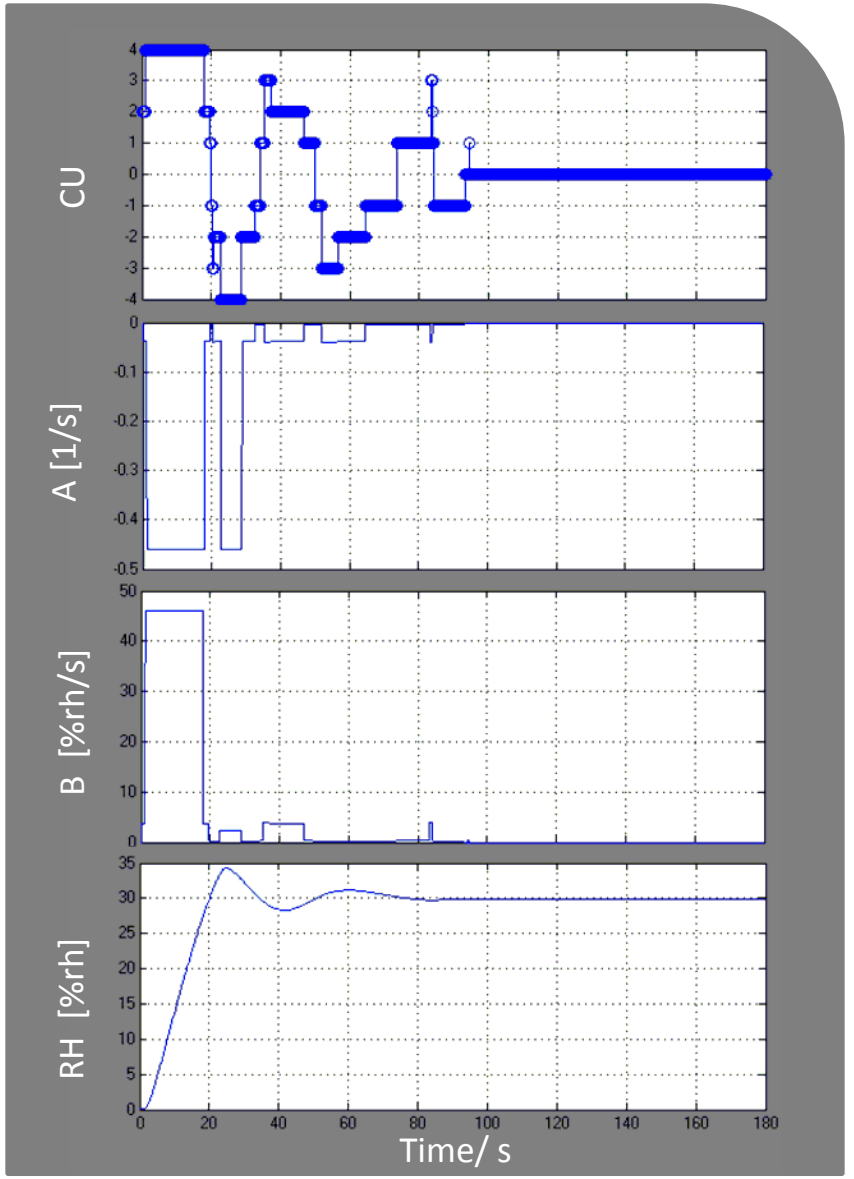


$$A = \frac{-Q_v}{V * 3.6} \qquad B = \frac{RH_{up} * Q_v}{V * 3.6} \qquad C = 1$$

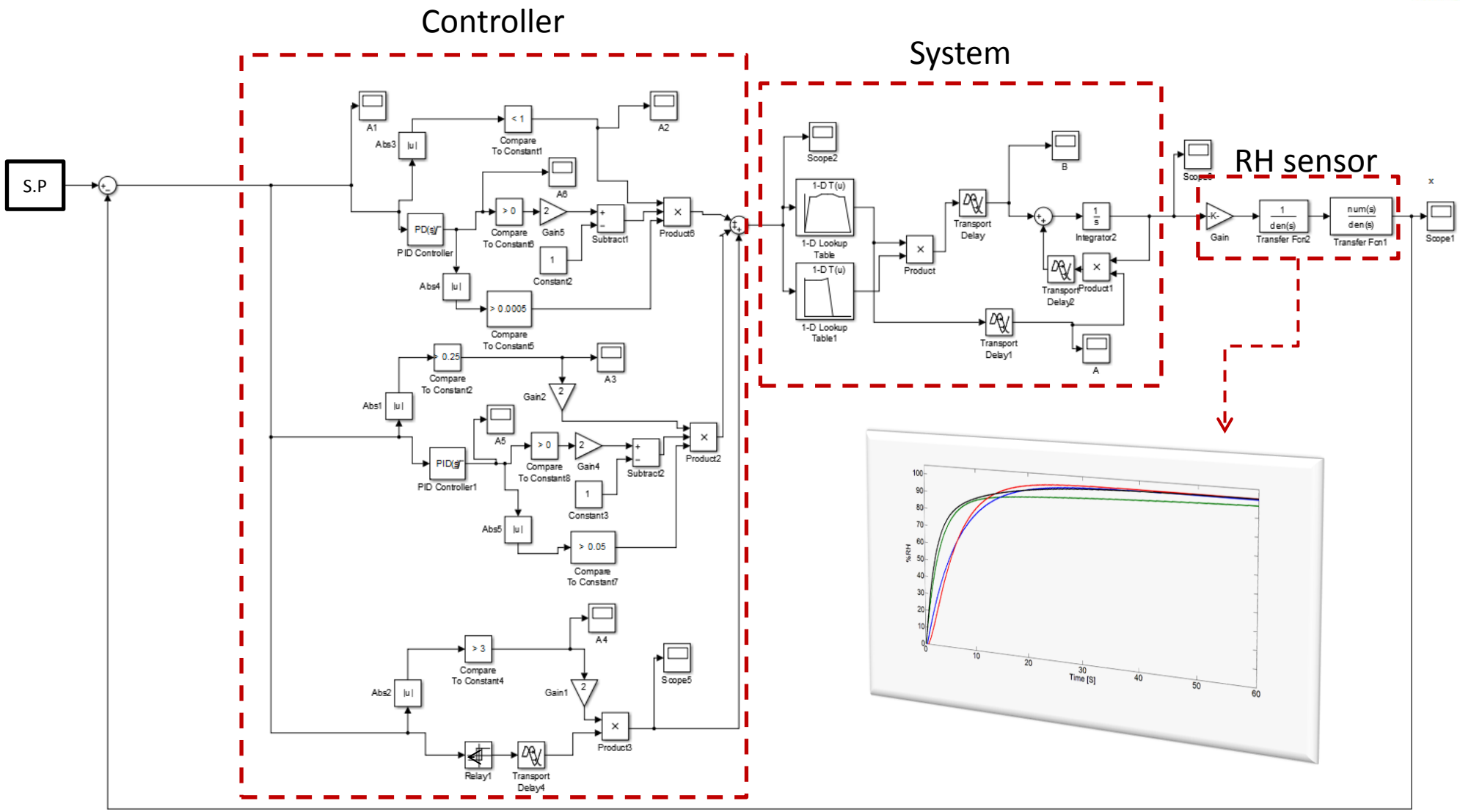
to dry

to humidify

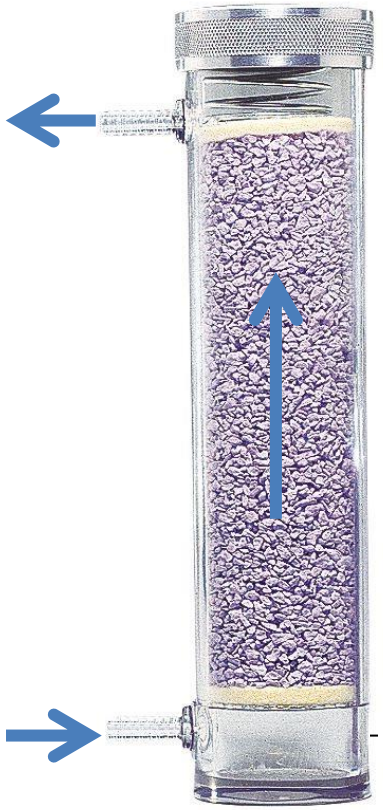
Position of the Valvles	Qv of BDV [m3/h]	Qv of SDV [m3/h]	Qv of SHV [m3/h]	Qv of BHV [m3/h]
-4	28.18	0	0	0
-3	2.295	0.19	0	0
-2	2.295	0	0	0
-1	0	0.19	0	0
0	0	0	0	0
1	0	0	0.19	0
2	0	0	0	2.295
3	0	0	0.19	2.295
4	0	0	0	28.18

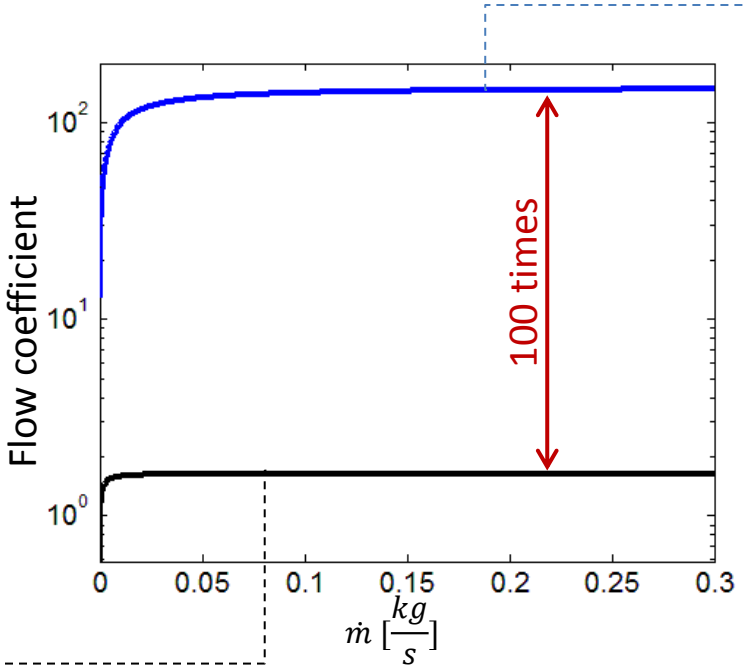


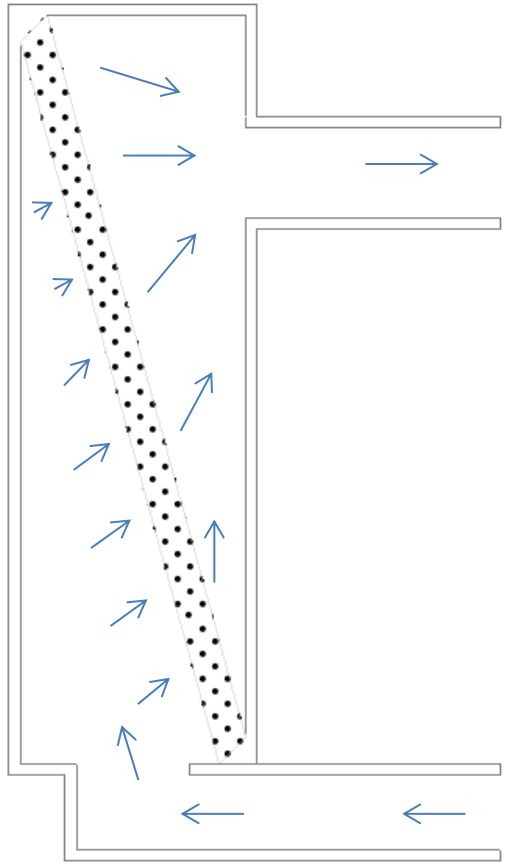
Dynamic design



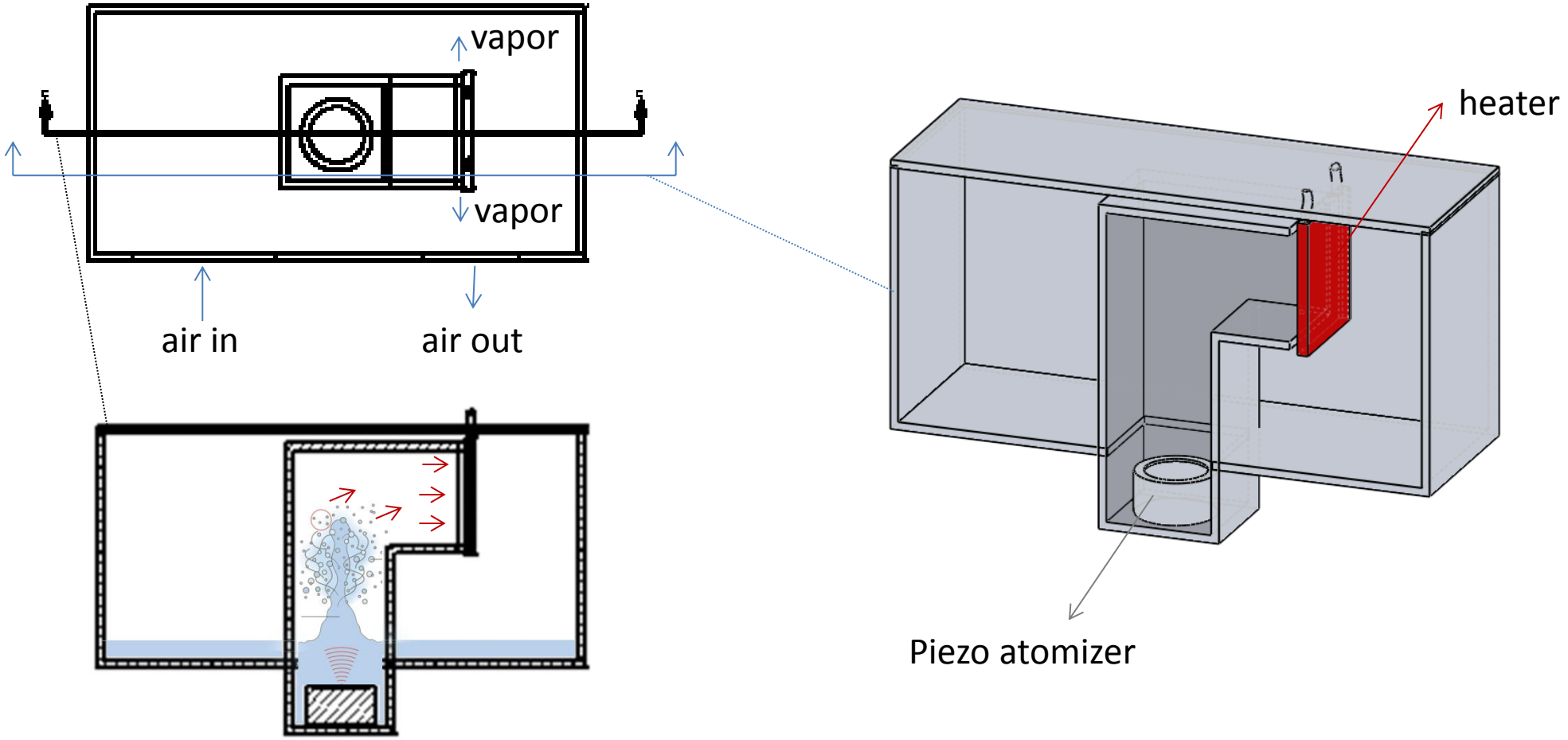
Dehumidifier



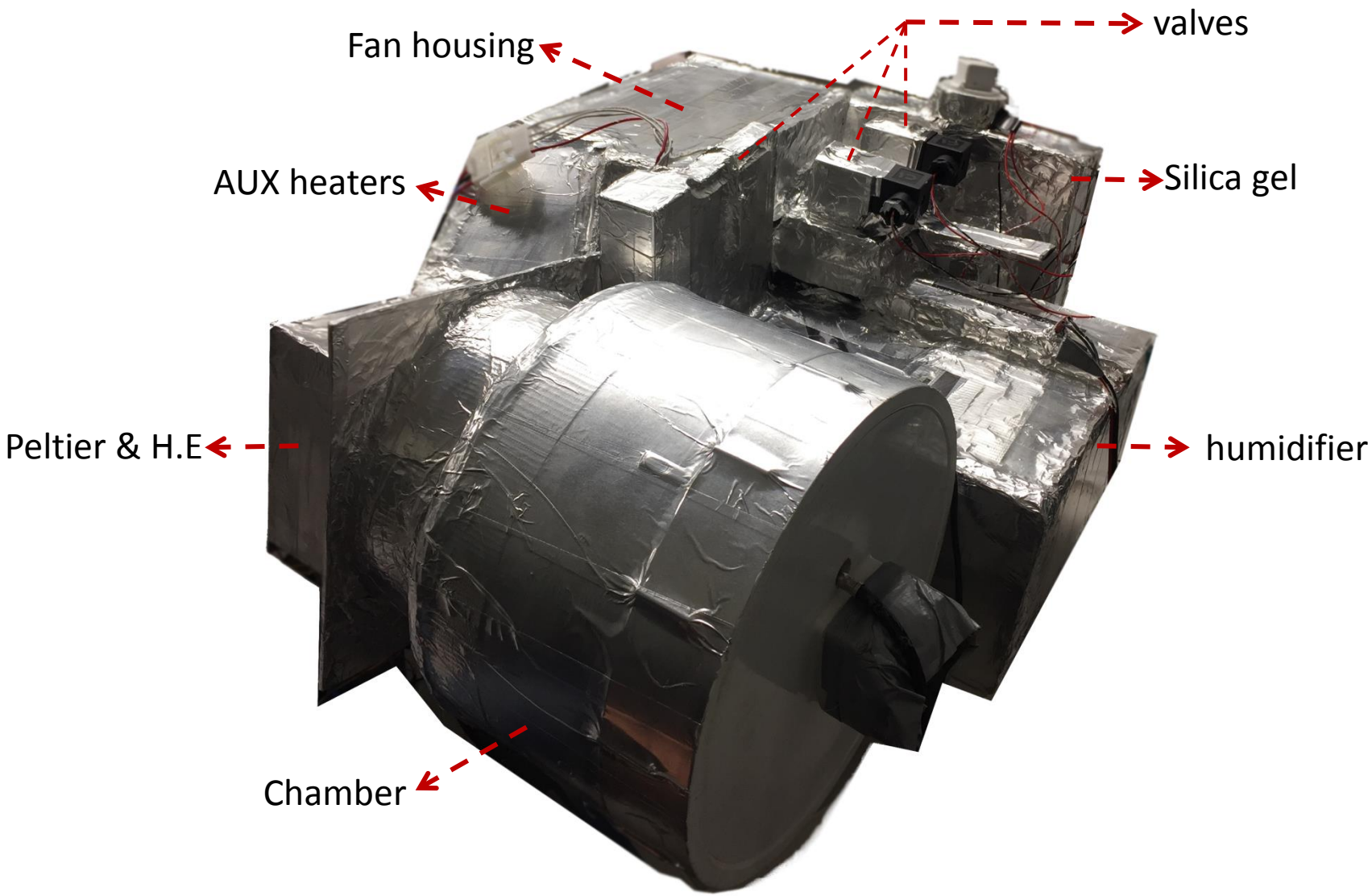




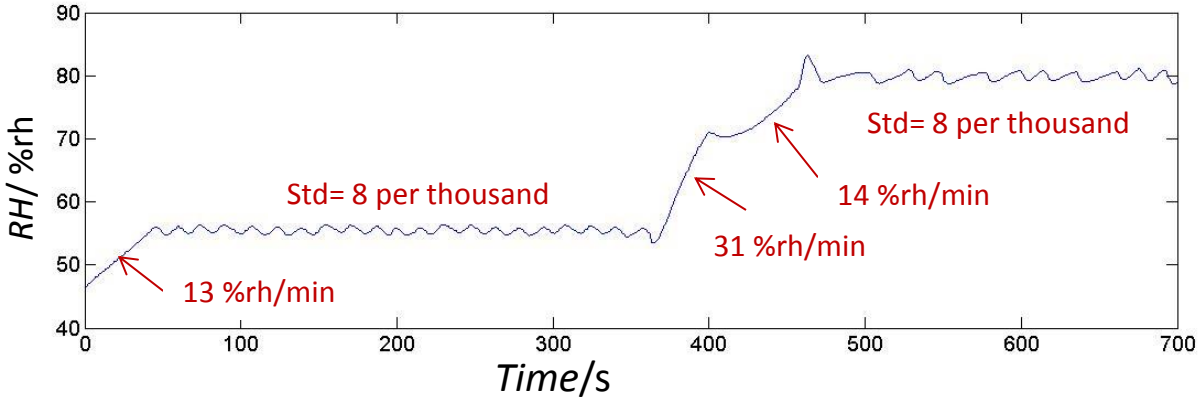
Humidifier

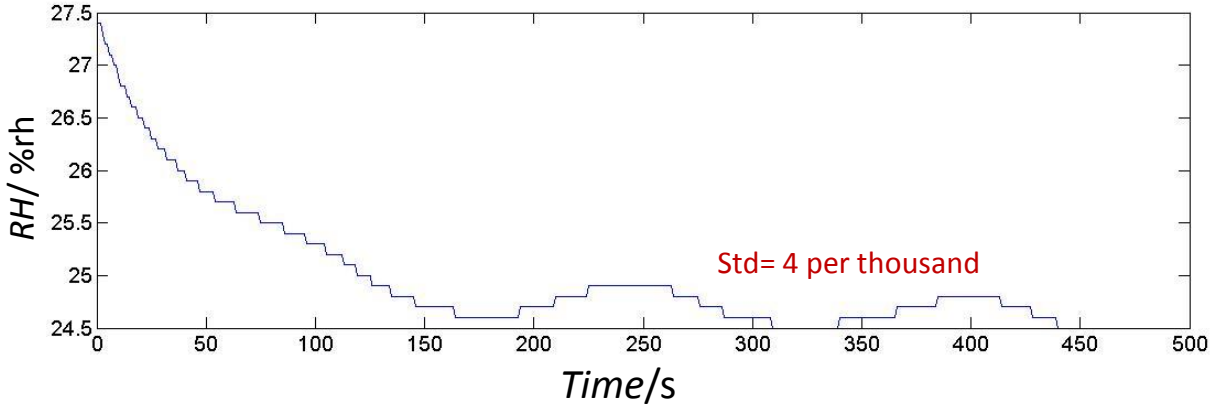


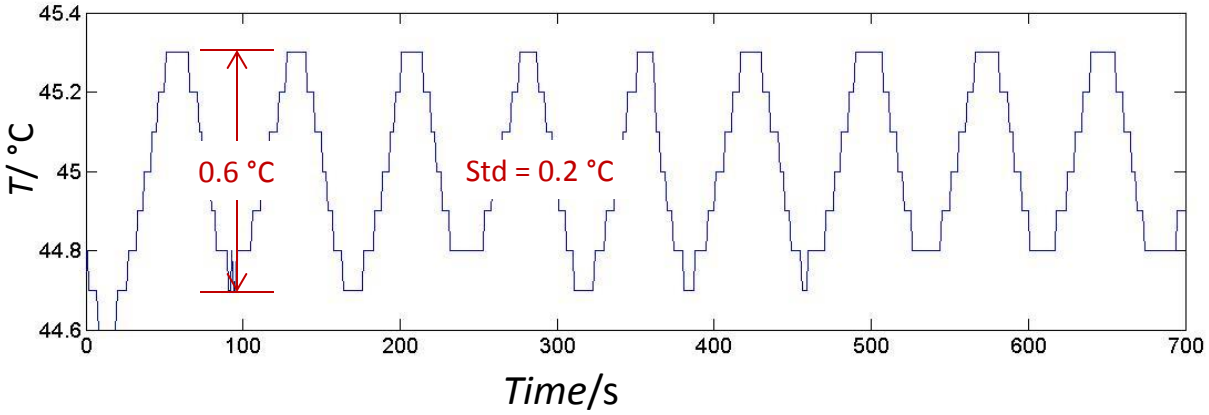
Prototyping

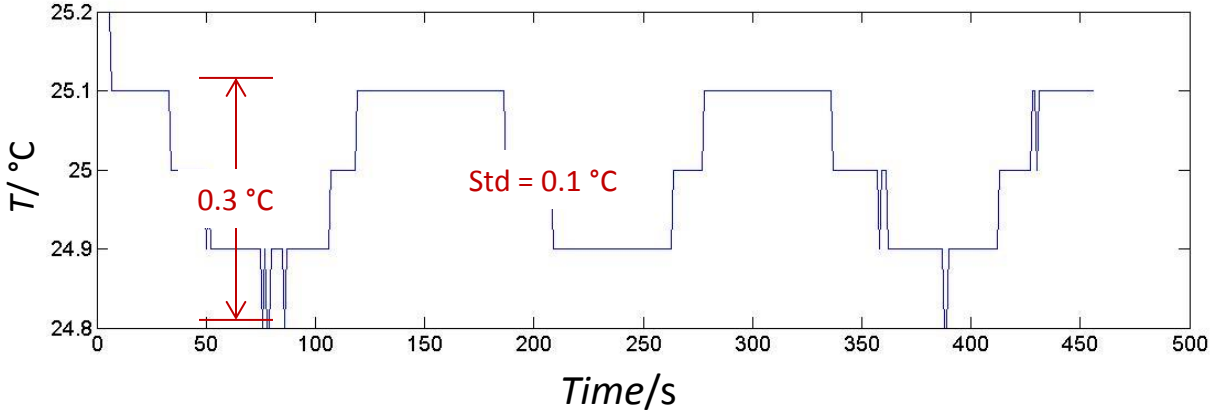


Operation


RH/ %rh
Time/s
Std= 8 per thousand
Std= 8 per thousand
14 %rh/min
31 %rh/min
13 %rh/min


RH/ %rh
Time/s
Std= 4 per thousand


T/ °C
Time/s
0.6 °C
Std = 0.2 °C


T/ °C
Time/s
0.3 °C
Std = 0.1 °C

Specifications

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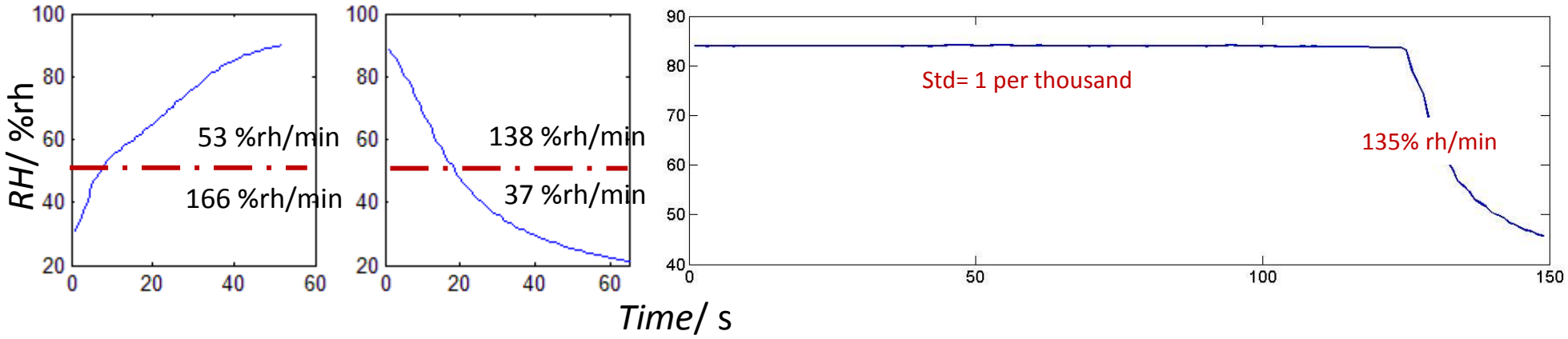
	RHapidCal (fluke)	VTT calibrator
Cooling rate	1.5 °C/minute (Typical)	1.5 to 2.2 °C /minute
Heating rate	10 °C /minute (Typical)	10 °C /minute (Avg)
Dehumidification rate	**5 % rh/minute (Typical)**	**60% rh/minute (Avg)**
Humidification rate	**10 % rh/minute (Typical)**	**63 % rh/minute (Avg)**
Max T_{dp}	**32 °C**	**59 °C**
Min T_{dp}	**Not reported**	**3 °C**
RH time stability	**2-7% of Reading**	**0.8% of Reading**
T time stability	**1% of Reading**	**0.4% of Reading**



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