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Multi-sensor calibration issues and characterisation concepts

Does the sensor output make sense?

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Technological advances for controlling indoor environment
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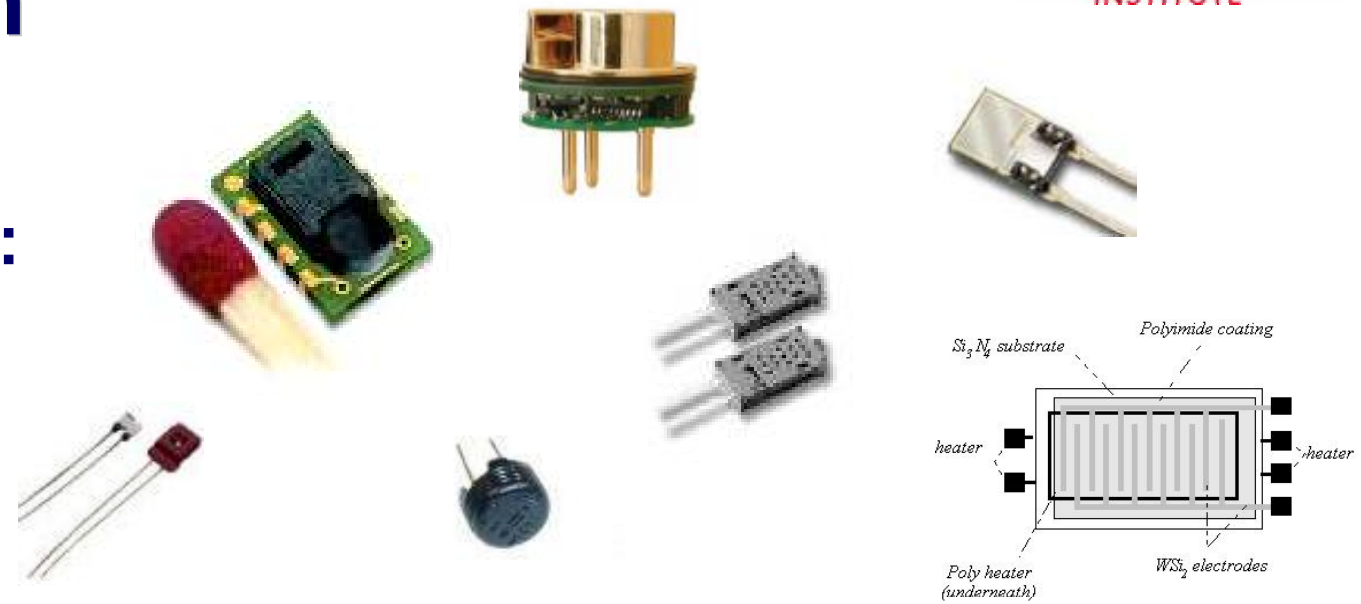
Introduction



What do we want:

- To measure
- To control

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- We wish know if of our measurement meet our demands (accuracy)
- We wish to linearise the sensor output (for control)

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- **We need to calibrate the sensor!**

Multi-sensors and calibration

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Survey by DTI calibration laboratories on indoor environment sensor manufacturers shows:

- Several sensor-types for t/rh measurement
- Few sensor-types for CO_2-measurement
- Sensors are mainly linearised based on single-parameter calibration such as:
  - CO_2 sensors with reference gas mixtures at fixed t, rh
  - Temperature sensors in liquid baths
  - Rh sensors at fixed temperature with salts or fixed-temperature rh-chambers

Is this the optimal way? <u>If not</u>, what are the consequences?

CASE: Characterisation of an rh sensor

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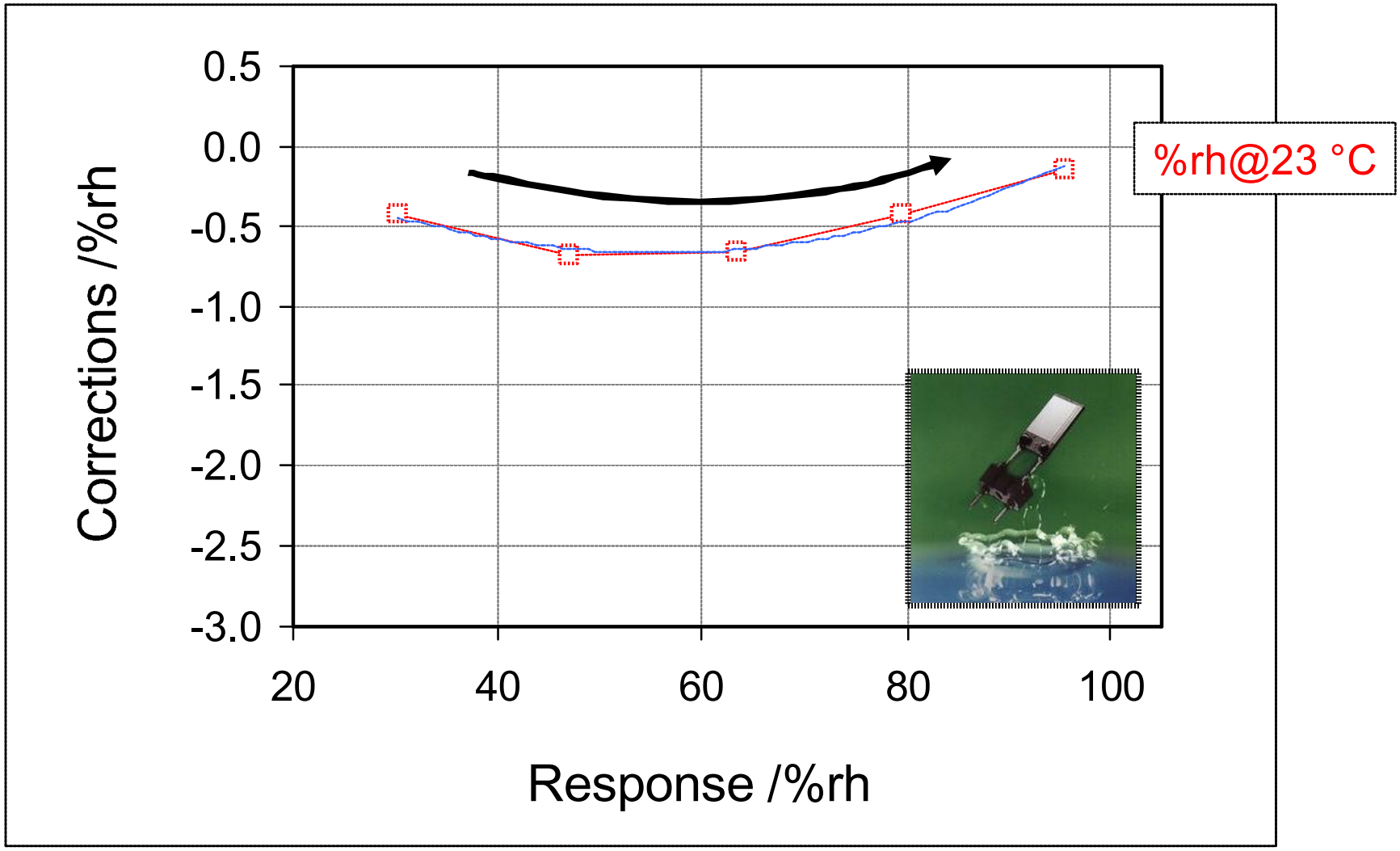
Rh/t sensor featuring:

- State-of-the-art thin film capacitive polymer sensor
- Built-in thermistor for temperature measurement
- Temperature-compensated
- Calibrated in 5 points from 11 %rh to 75 %rh @25 °C
- Linearised on basis of the calibration
- Size: 5x10 mm
- Price: 1100 € (including electronics)

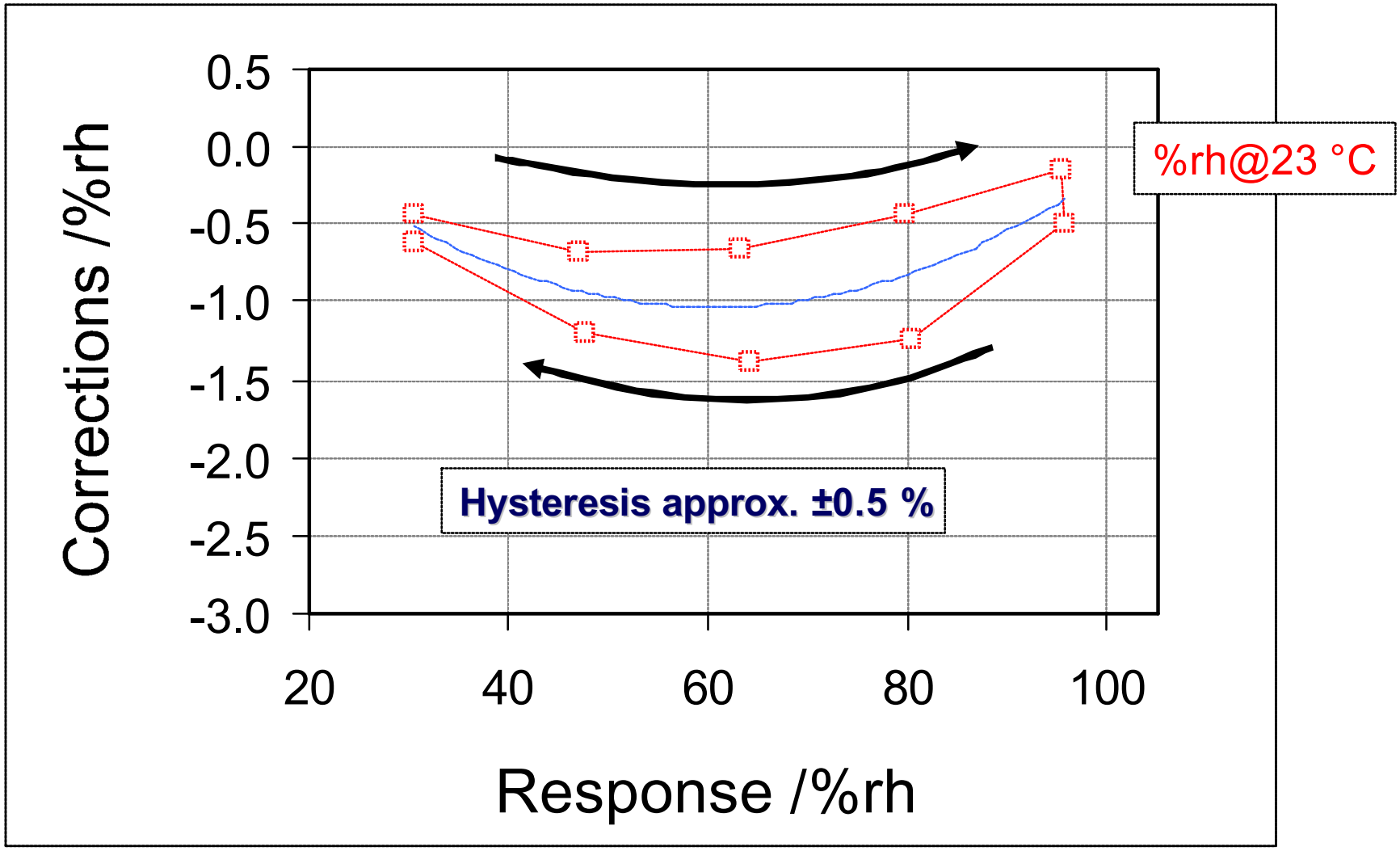
Manufacturers specification:

- Range: 0 %rh to 100 %rh, -10 °C to 50 °C
- Accuracy: ±1 %rh (15 °C to 30 °C) otherwise ±2 %rh
- Cross-sensitivity: 0.03 %rh/K (from scientific paper by the manufacturer)

CASE: Characterisation of an rh sensor



CASE: Characterisation of an rh sensor



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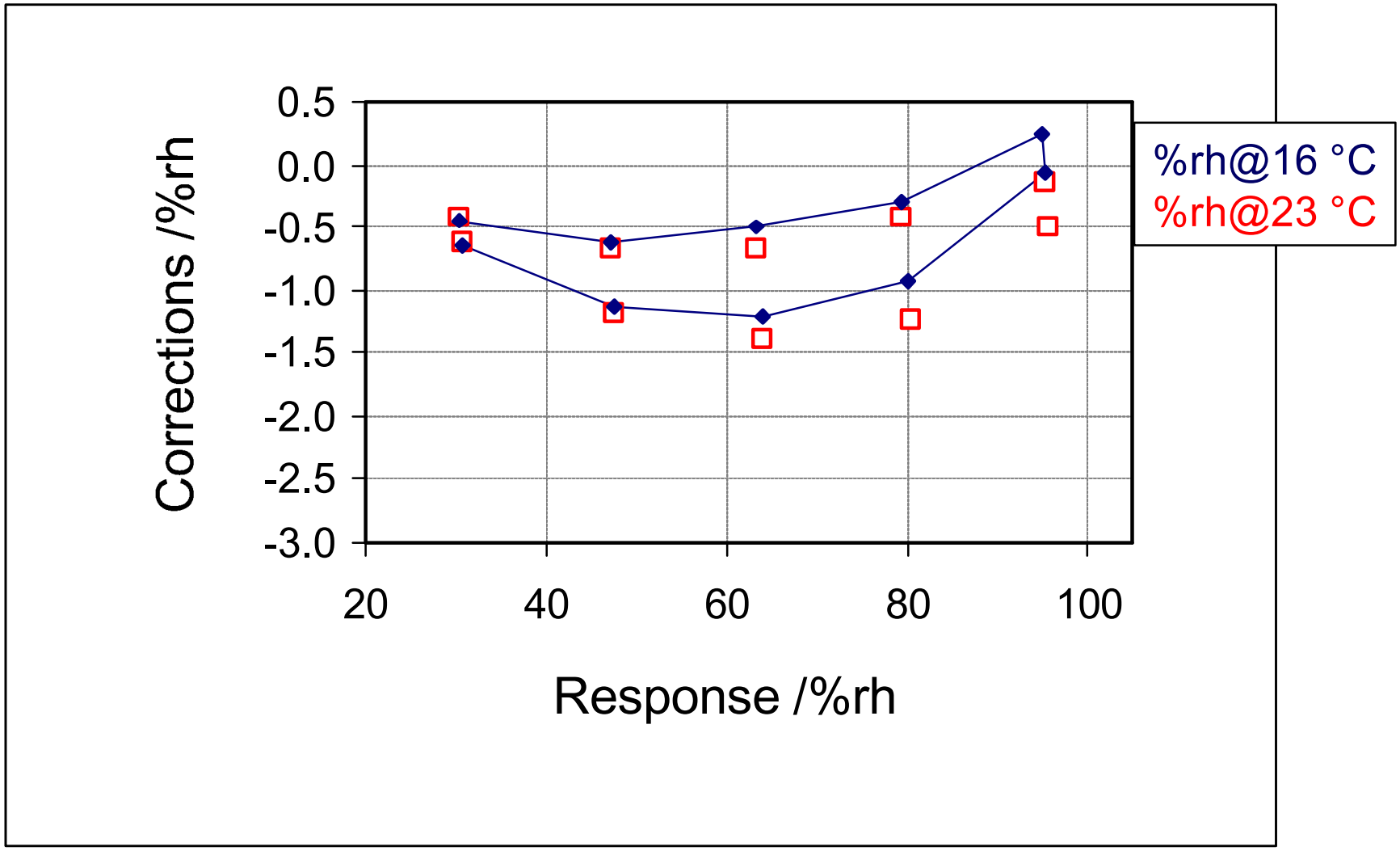

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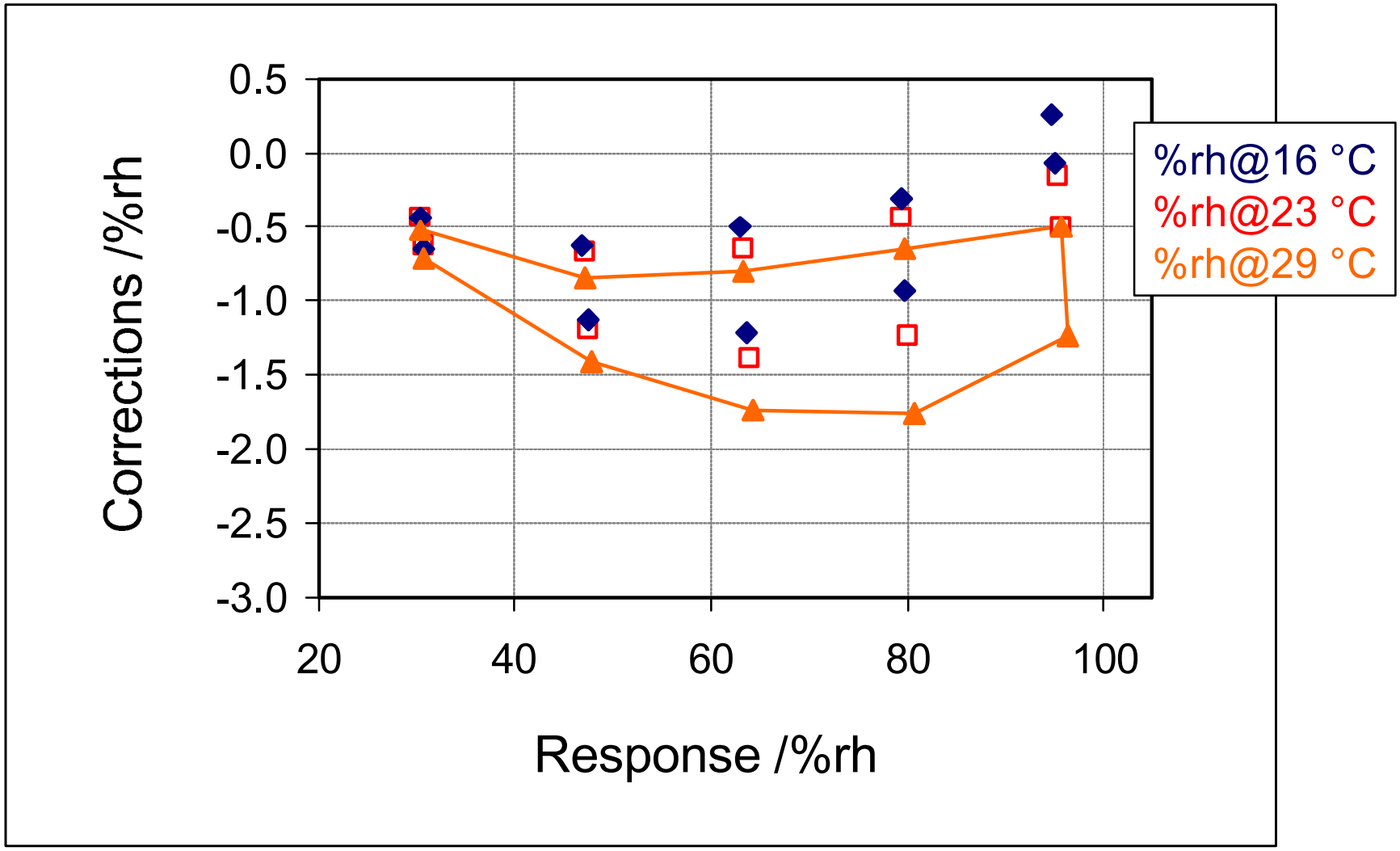
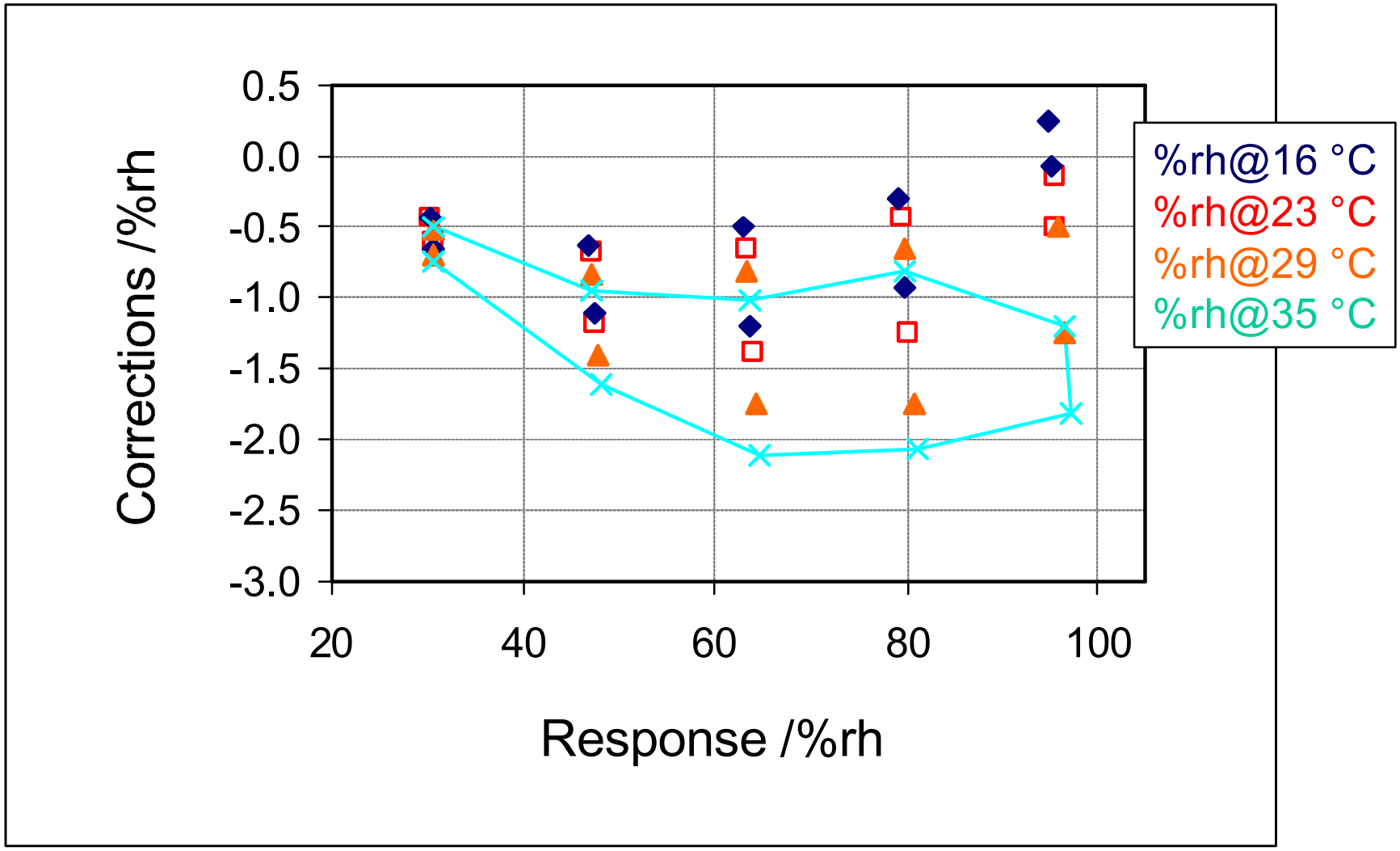


CASE: Characterisation of an rh sensor



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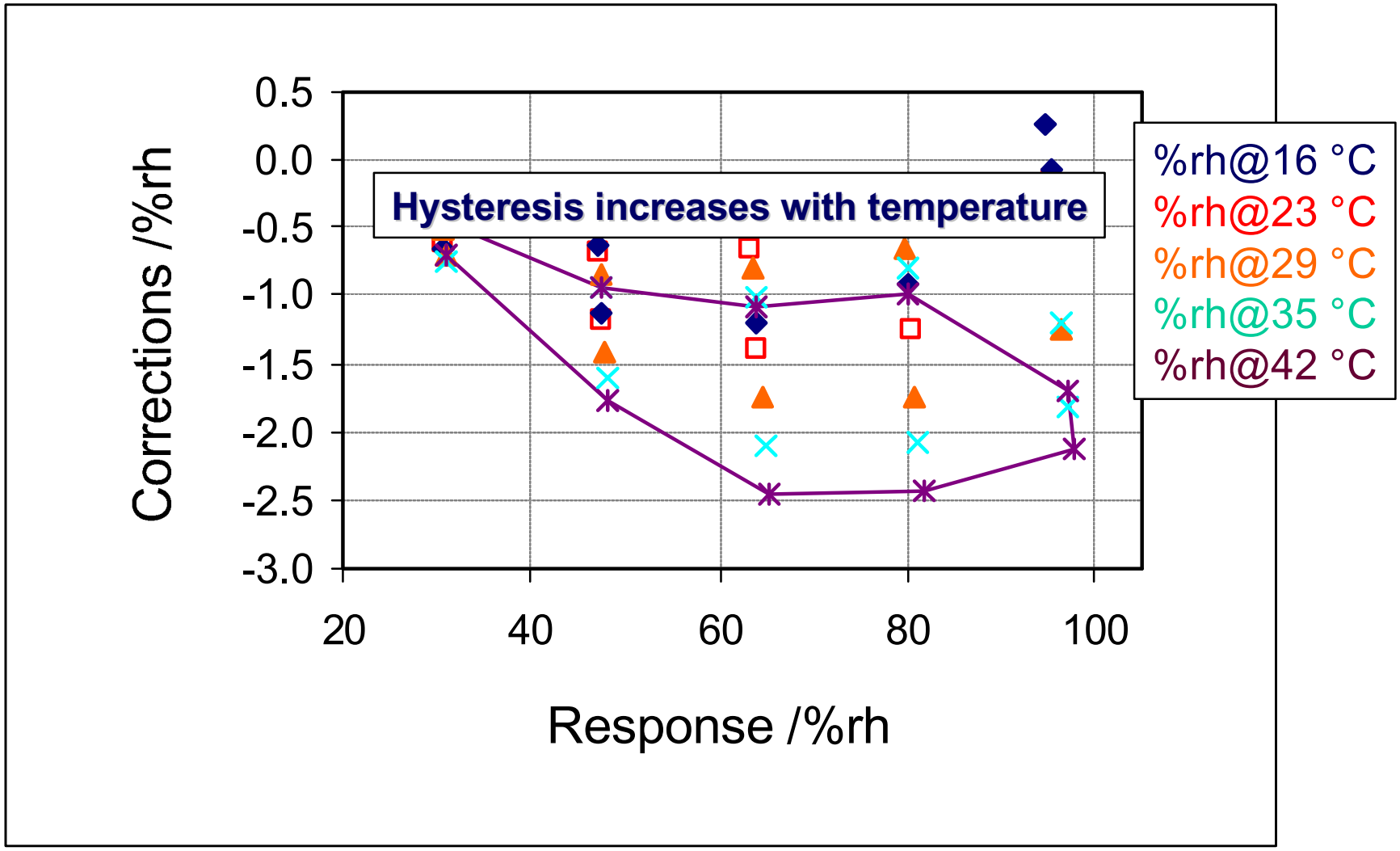
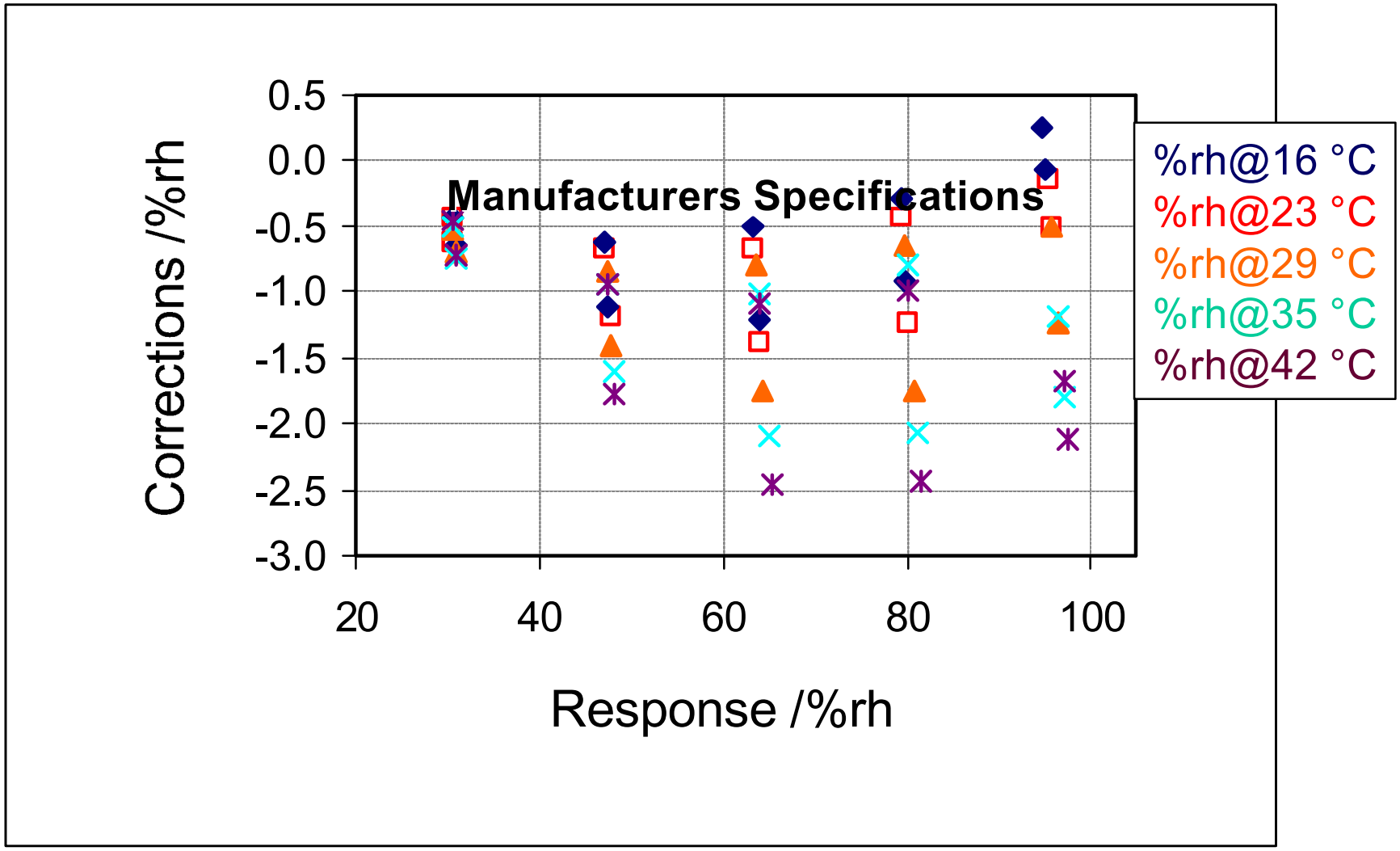


CASE: Characterisation of an rh sensor



CASE: Characterisation of an rh sensor

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Observation:

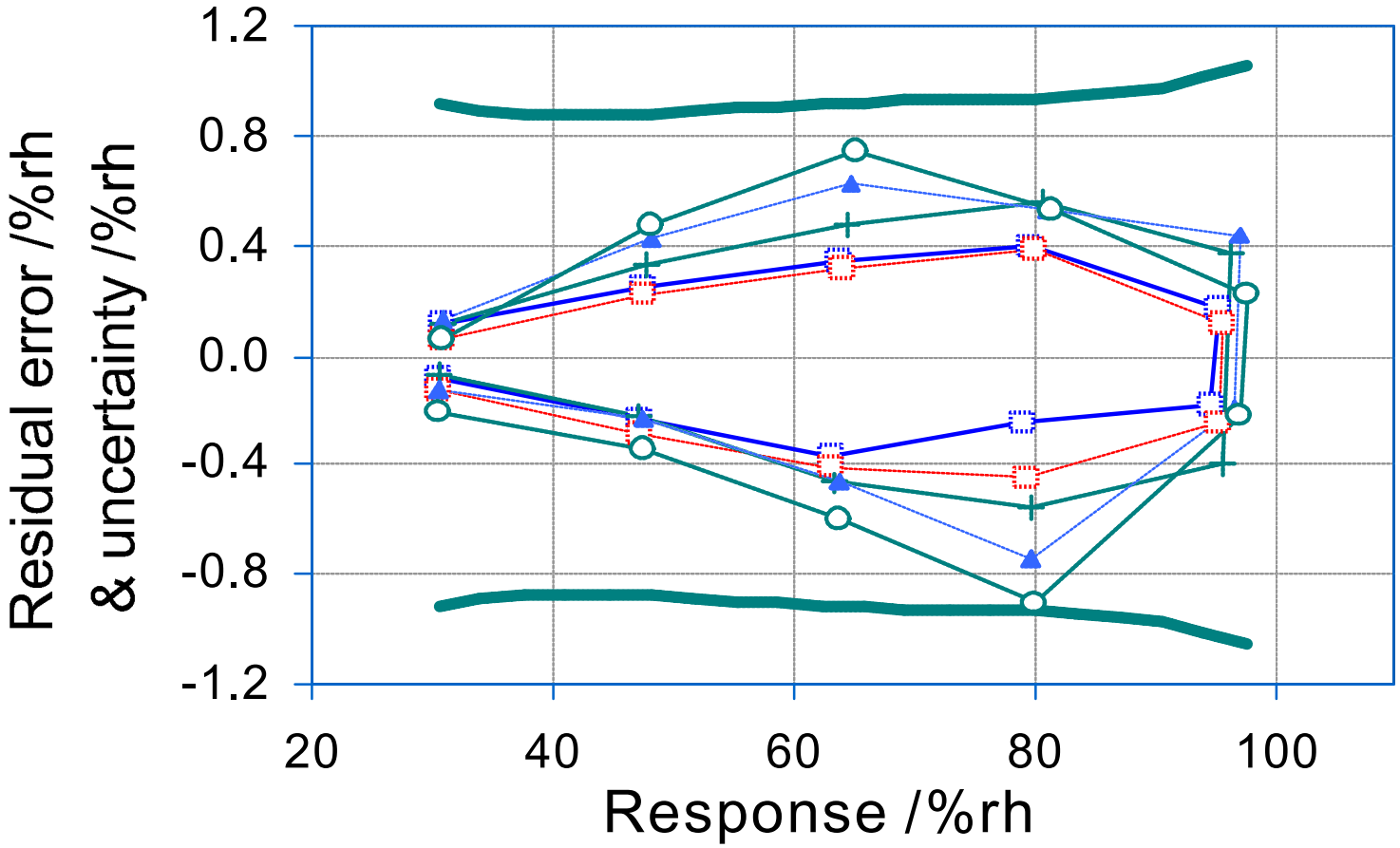
- The sensor response is clearly dependant on the temperature
- The sensor exhibits a significant hysteresis
- The manufacturers linearisation using a correction curve based on a single temperature and 5 rh values is insufficient to meet specs.

Suggested improvement:

- Better model based on more calibration data (t /°C, R /%rh)
- Example: $H(R, t)=(a_0+a_1R+a_2R^2)(b_0+b_1t)$

  (this model is based on experience from the calibration of a large number of rh sensors)

CASE: Characterisation of an rh sensor



Improvement: approx. a factor 3!

Multi-sensor calibration issues

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When designing the sensor be aware that the sensor responds to several influence parameters:

- Sensor temperature is affected by:
  - self-heating
  - heat-conduction
  - air-flow rate
- Thermal gradients influence electronics:
  - signal-conditioning, temperature-compensating and adjustment electronics
- Contamination and condensation can cause shift in response, acting differently over the range

The problems tend to increase as the sensor size decrease!

Multi-sensor calibration issues

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Consider:

- Physical “built-in” limitations such as hysteresis
- Limitations in the physical models
  - i.e. the vapour-pressure equations are for synthetic air
- Cross-sensitivity with respect to:
  - temperature
  - gases in the air (H_2O, Ar, CO_2, …)
  - pressure
  - contaminants such as dust
- Adequate selection of calibration points ? Improve the uncertainty!
- Good calibration and modelling saves you money.....

..... A lot of money!

Thanks to:

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Jeremy Lovell-Smith, MSL, Wellington, New Zealand

More about modelling sensors:

J. Lovell-Smith & J. Nielsen, *"Calibration equations for humidity applications",* Proceedings on TEMPMEKO 2004

Bernieri A., Betta G., Dell'Isola M., "*Statistical problems in calibration design*", Advanced Mathematical Tools in Metrology II, 1996, pp 100-109