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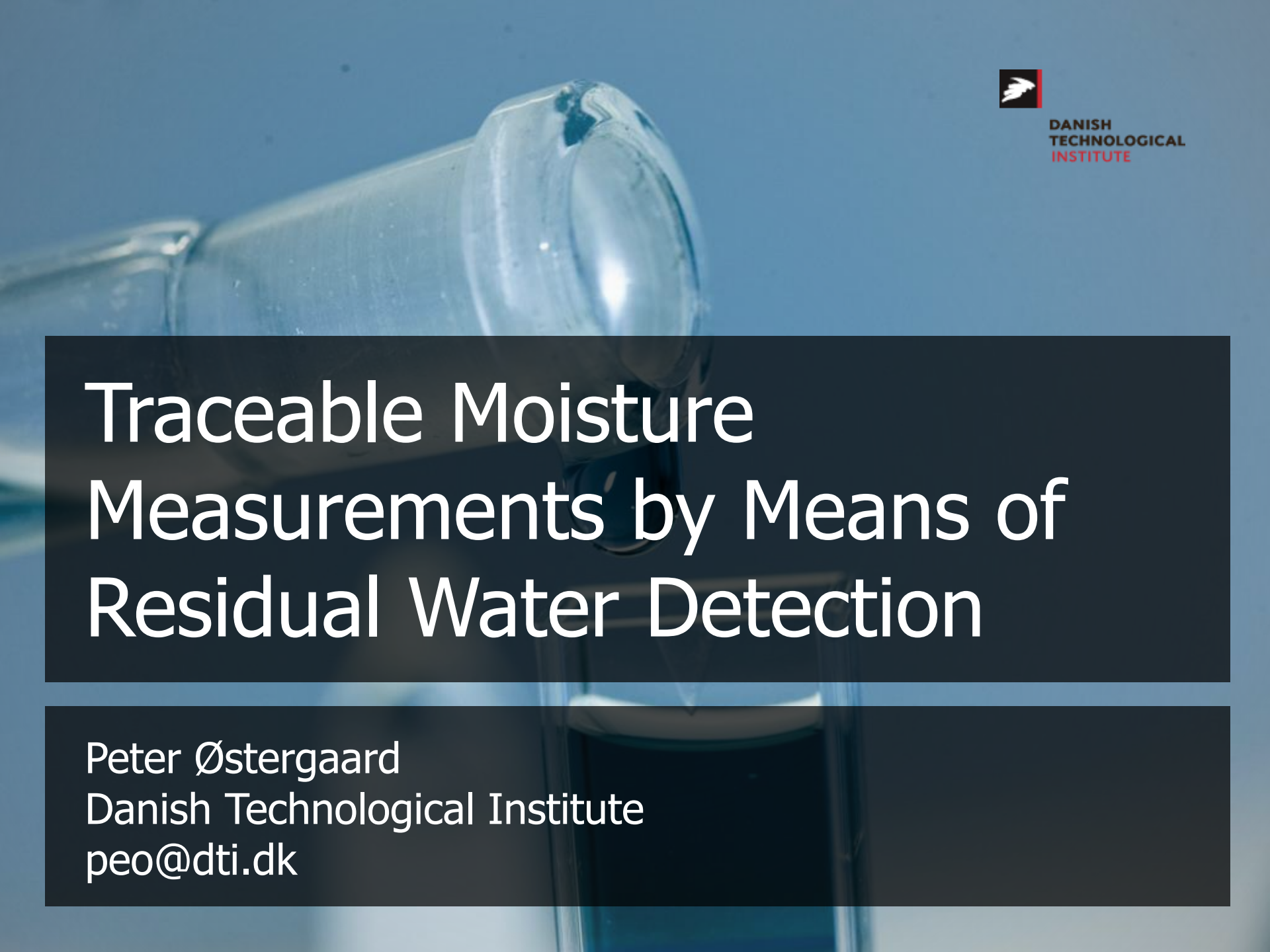
it's all about innovation



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Traceable Moisture Measurements by Means of Residual Water Detection

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What you will learn from this presentation

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- Why SI traceability is important
- How SI traceability can be accomplished within moisture measurements
- Why some existing methods are not necessarily SI traceable
- How we manage SI traceability in moisture measurements at DTI
- Results obtained at DTI
- Conclusions

What is SI traceability?

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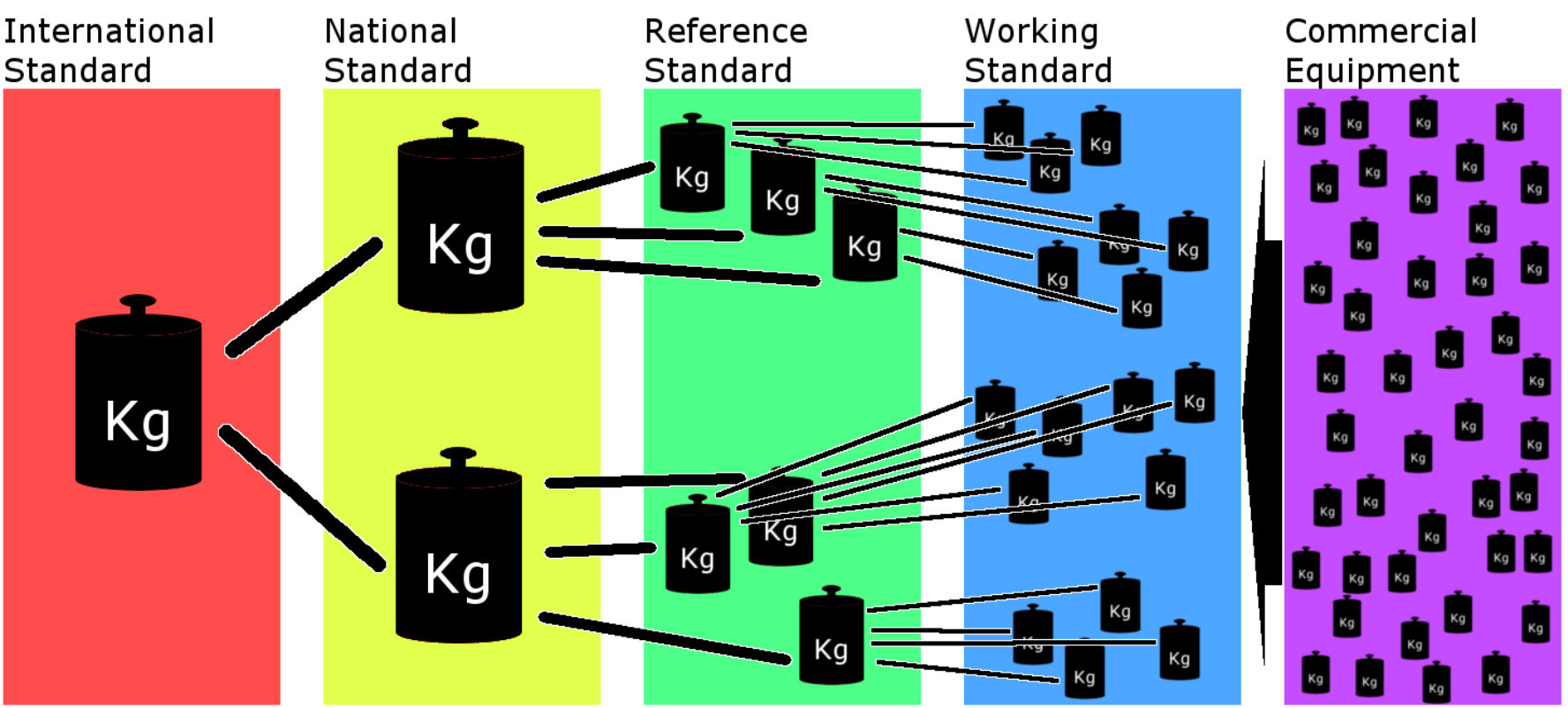

- We all refer to the same unit
- We know the uncertainty of the measured value

SI Traceability and why it is important

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Correct and coherent measurements are essential within

- Trading
- Manufacturing
- Rules and Regulations
- Transfer of Protocols

Moisture SI?

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- Mol fraction
  - H_2O molecules / substrate molecules
- Weight fraction
  - H_2O content / weight of substrate
- Should ALL water be included as part of the water content?
  - Free water
  - Capillary bound water & structurally integrated water
  - Chemically bound water

Moisture measuring methods

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Several ways of measuring moisture in materials

- Measure the water in-line
  - NIR, µ-waves
- Extract all water from the sample and then measure
  - cKF, LoD, water traps
- Do these methods measure ALL the water and ONLY the water?

Primary standard at DTI

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- Extract water from sample
  - Heat up sample and remove the evaporated water
- Use chilled mirror hygrometer and capacitive sensor to monitor water evaporated from sample
  - Measure ONLY water
- Monitor water leaving the sample and stop when no more water appears at the sensor
  - Measure ALL water

Primary standard at DTI

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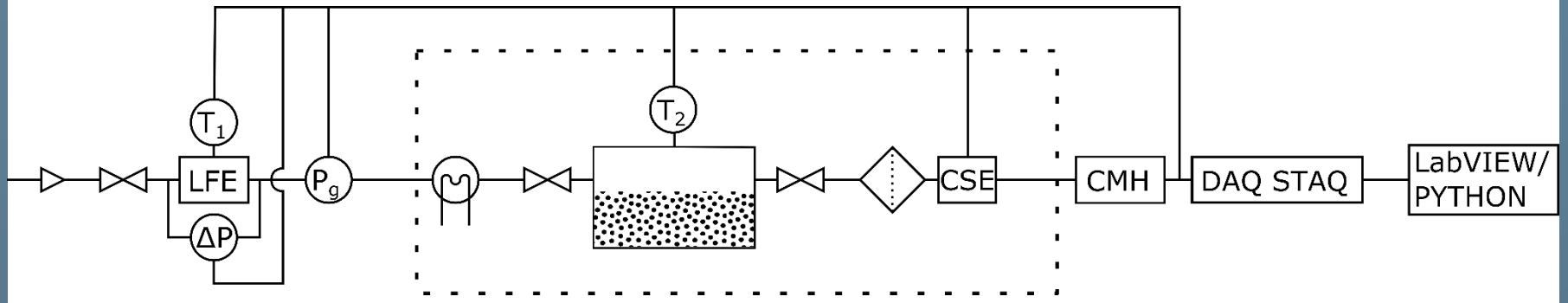
- Sample holder
  - Sealed during transportation, allowing air flow through it
- Air supply
  - Heat up chamber and have warm, dry air passing through sample
- Humidity measurement
  - Measure moisture content of air



Sample Chamber

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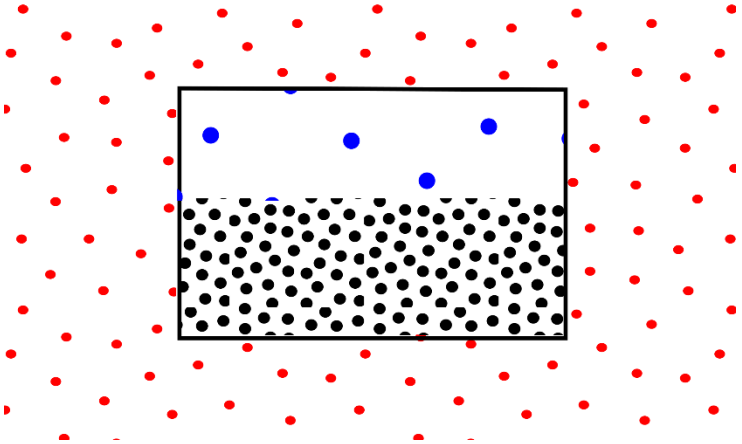
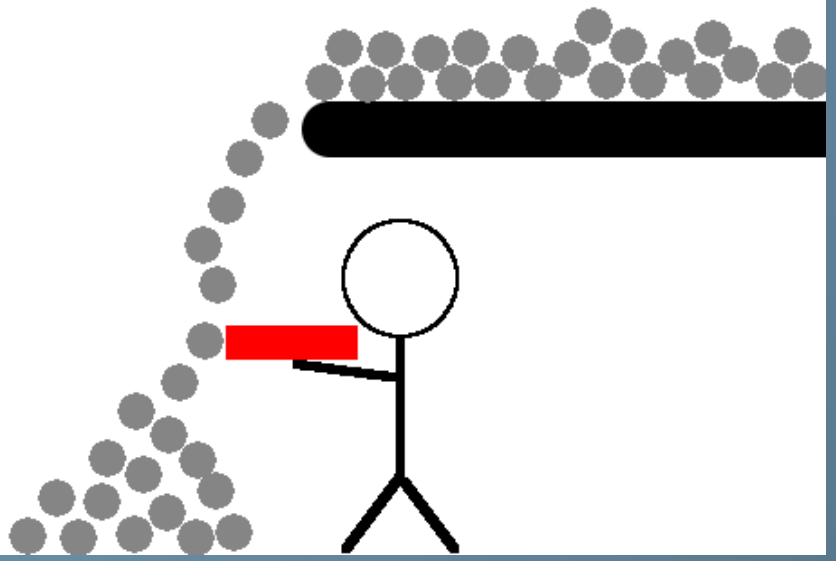
- Sampling on site
- Contain a large volume
- Seal chamber
- Transport to and from costumer





Sample chamber version 1

with flaws

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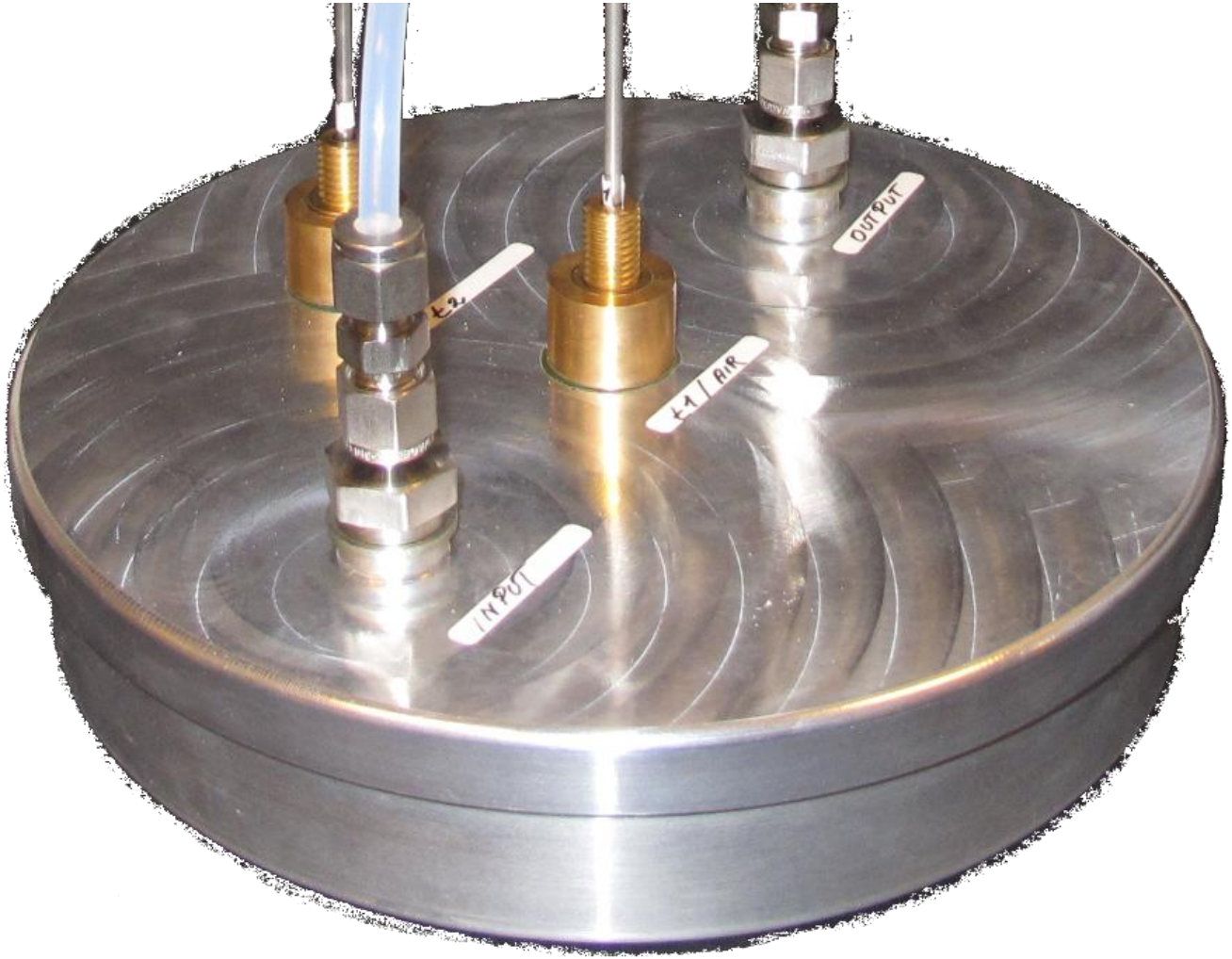

Sample chamber version 2

with fewer flaws

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Flow control

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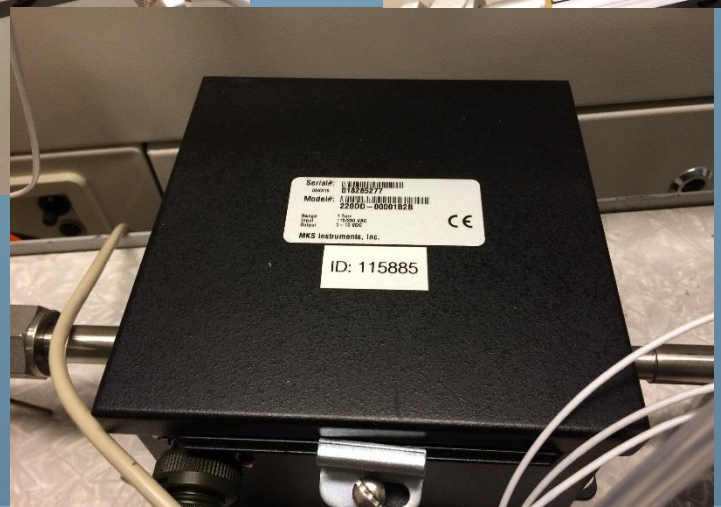
- Laminar flow element
- Differential pressure
- Temperature adjustment
- Pressure adjustment



Flow control

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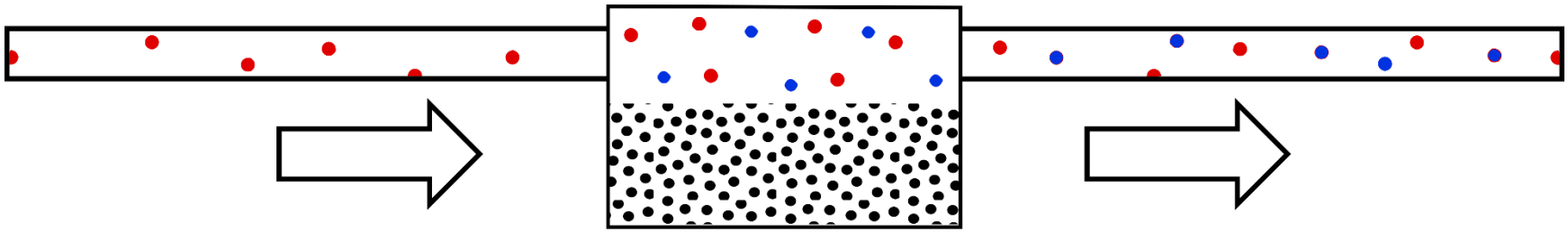
- Extra flow from water vapour released from sample



Humidity measurement

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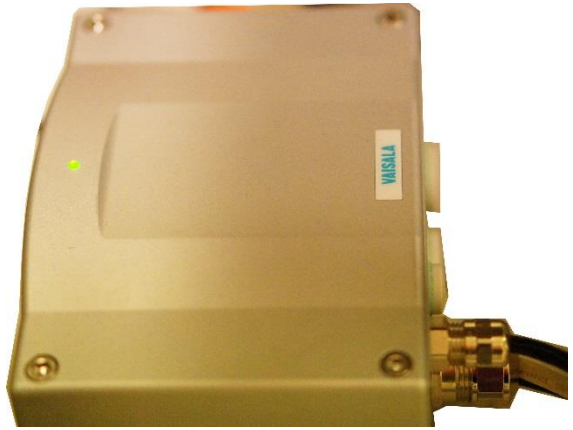
- Chilled mirror hygrometer
  - Low uncertainty
  - Water specific at low VOC-levels
  - Contamination
- Capacitive sensor element
  - Stable
  - Robust even at high VOC-levels
  - Higher uncertainty



How DTI ensures SI traceability

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- Chamber
  - Sealed
  - Enables representative sampling
  - Reduces possibility of contaminating the sample
- Flow
  - Laminar flow element
  - Differential pressure
  - Temperature
  - Line pressure
- Humidity
  - Chilled mirror hygrometer
  - Capacitive sensor element

Main sources of uncertainty

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- $m_{H_2O} = \sum_i \frac{Q_{LFE,i}}{T_{LFE,i}} \cdot \frac{\eta_{std}}{\eta_{cg}} \cdot \frac{p_{chamber,i}}{p_{chamber,i} - e_{chamber,i}} \cdot \frac{e_{chamber,i}}{R_v} \cdot \delta t_i$

- Flow
  - linearly dependent on this value
    - Laminar flow element
    - Differential pressure

- Dew point
  - Linearly dependent on $e_{chamber}(T_d)$

Main sources of uncertainty

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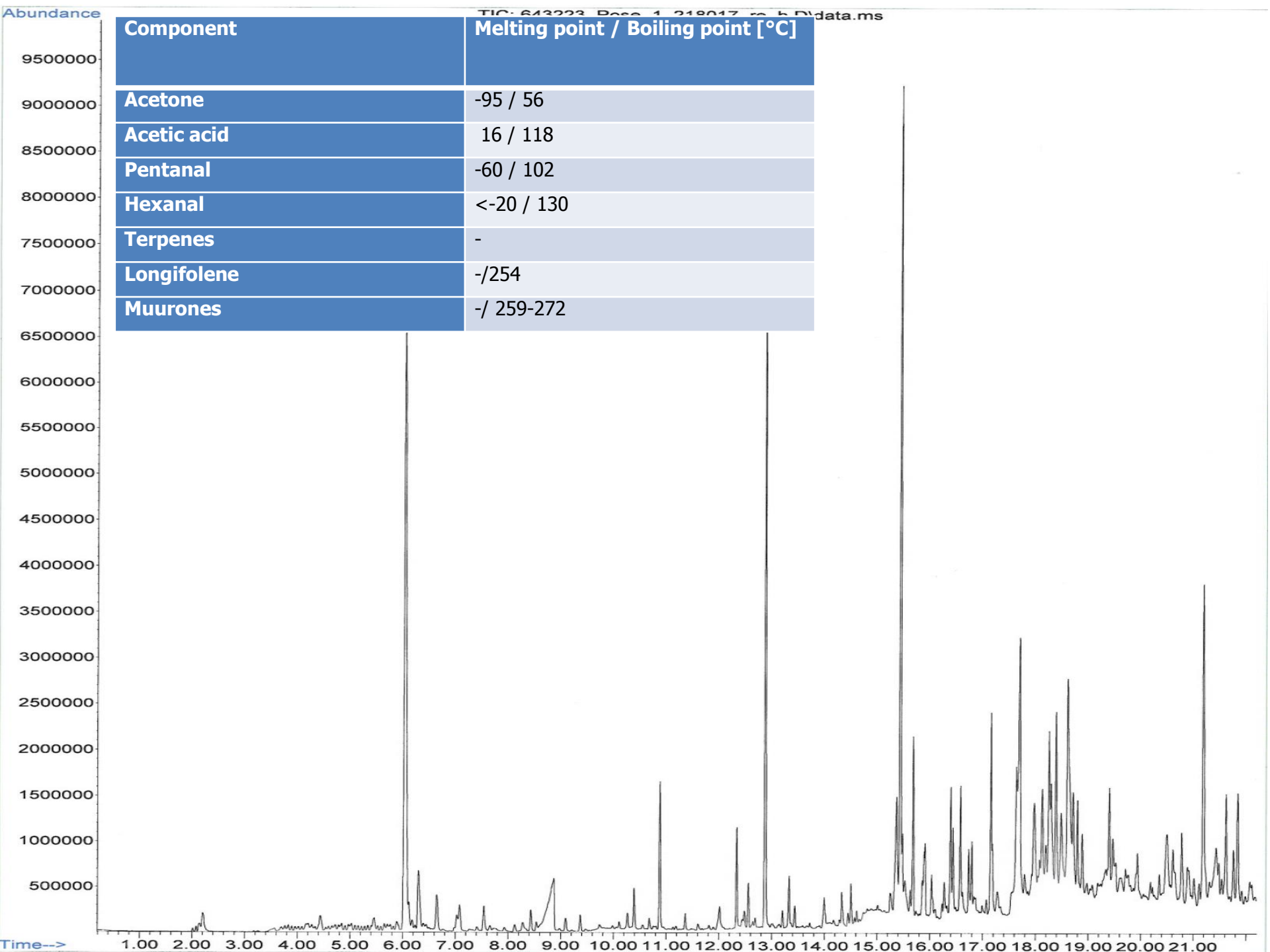
- Dew point temperature

$$\left.\begin{array}{l} T_d = 34.00\,^{\circ}\mathrm{C} \Rightarrow 32.83\,\mathrm{g/m^3} \\ T_d = 35.00\,^{\circ}\mathrm{C} \Rightarrow 34.70\,\mathrm{g/m^3} \end{array}\right\} \Rightarrow \delta\rho_{H_2O} = 1.87\,\mathrm{g/m^3}$$

$$\left.\begin{array}{l} T_d = -30.00\,^{\circ}\mathrm{C} \Rightarrow 0.23\,\mathrm{g/m^3} \\ T_d = -29.00\,^{\circ}\mathrm{C} \Rightarrow 0.26\,\mathrm{g/m^3} \end{array}\right\} \Rightarrow \delta\rho_{H_2O} = 0.03\,\mathrm{g/m^3}$$

- Low uncertainties are most important at the beginning of the test

Component	Melting point / Boiling point [°C]
Acetone	-95 / 56
Acetic acid	16 / 118
Pentanal	-60 / 102
Hexanal	<-20 / 130
Terpenes	-
Longifolene	-/254
Muurones	-/ 259-272



Challenges/Limitations

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- Equipment
  - Contamination
  - Accuracy
- Time
- Materials
  - Containing large quantities of VOCs
- Samples
  - Representative?

Results

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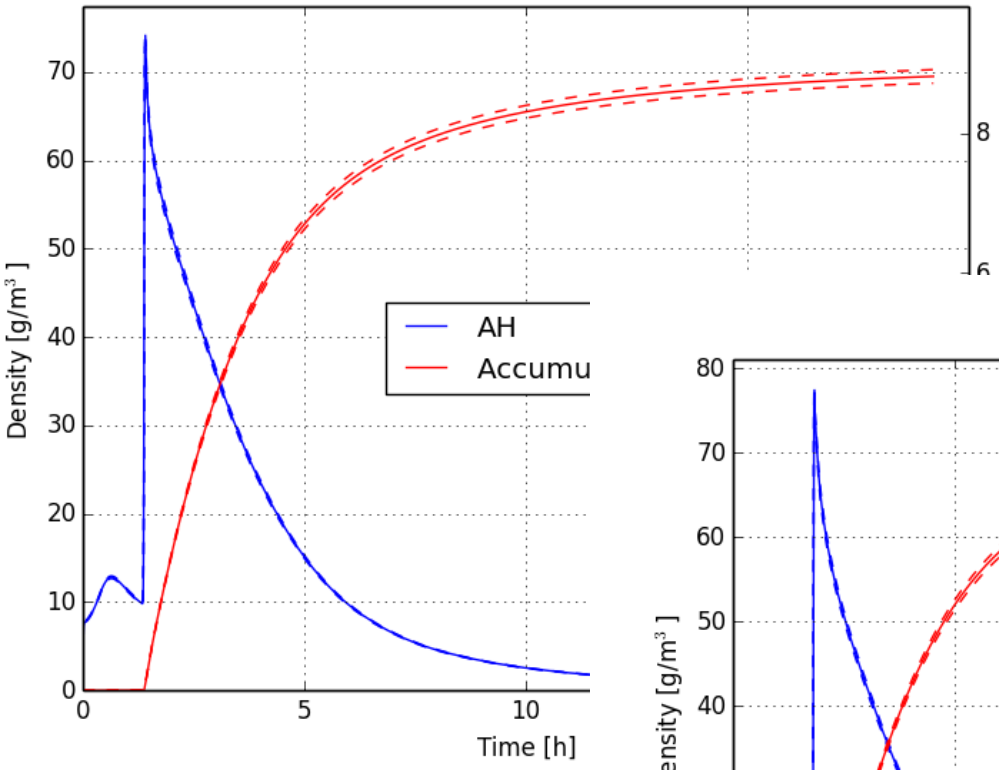

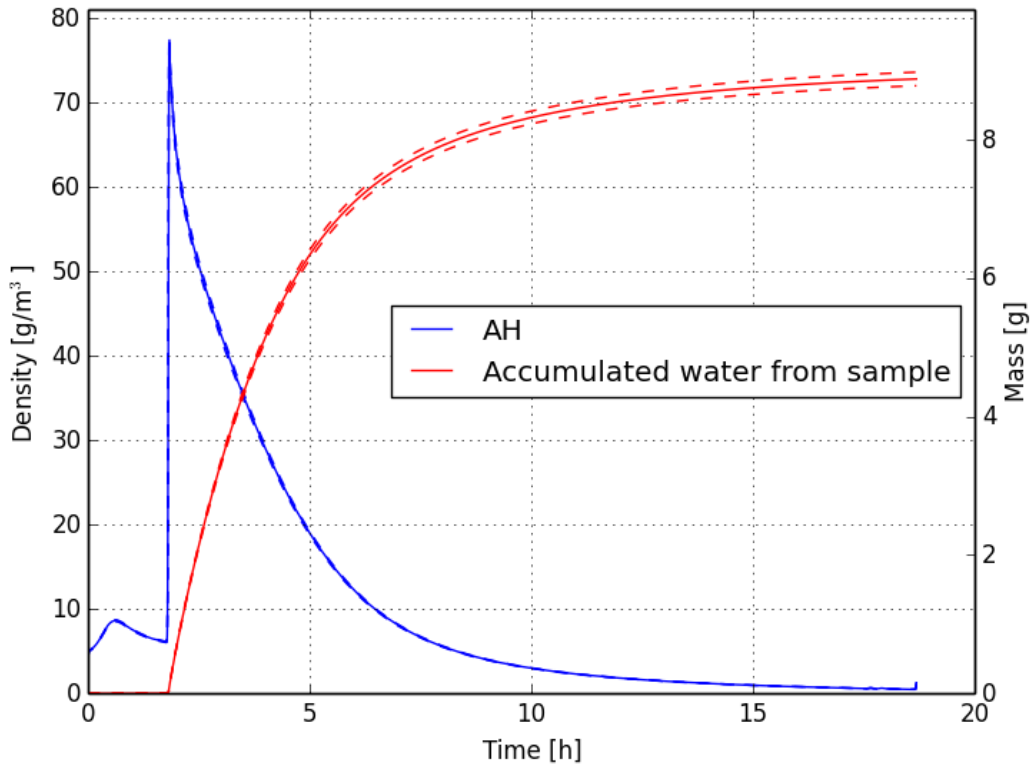

Results

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- Comparison of LoD and DTI primary standard on drying of wood pellets

Initial Weight	Water Content from DPM	Water Percentage from DPM	Water Content from LoD	Water percentage from LoD
232.080 g ± 0,058 g	17.73 g ± 0.19 g	7,640 % ± 0,084 %	17,706 g ± 0,058 g	7,629 % ± 0,025 %
241,396 g ± 0,051 g	18,16 g ± 0,20 g	7,524 % ± 0,083 %	18,203 g ± 0,051 g	7,541 % ± 0,021 %
227,574 g ± 0,049 g	17,88 g ± 0,20 g	7,856 % ± 0,087 %	17,805 g ± 0,053 g	7,824 % ± 0,024 %
213,217 g ± 0,055 g	16,33 g ± 0,18 g	7,659 % ± 0,084 %	16,282 g ± 0,055 g	7,636 % ± 0,026 %

- DTI primary standard generally measures slightly higher values, but always within standard deviation

Conclusion

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- Primary standard created, measuring ALL the water and ONLY the water
- Test chamber is important for obtaining representative sample and proper sample handling
- Small uncertainties are most important in the beginning of the test
- Handle contaminants without ruining the test

- We are ready for customers by the end of the year

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