# Annex B - Results Experiment 2

belonging to MSc thesis report:
***Experimental and numerical analysis of a silica gel packed bed for passive humidity control in museum rooms***

by

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# Contents

# 1 | Samples

Following samples are included in Experiment 2:

| No. | Name | Supplier | Type | Bulk density (kg/m3) | Beads / Irregular | Grain size (mm) |
|---|---|---|---|---|---|---|
| 6 | SIOGEL, small pored, white | Oker-Chemie | microporous | 680 - 780 | Beads | 2.5 - 4.0 |
| 11 | SIOGEL, mesoporous, white | Oker-Chemie | mesoporous | 500 - 600 | Irregular | 1.5 - 2.5 |
| 12 | Silica Gel White | DDC | microporous | 720 | Beads | 3.0 - 5.0 |
| 14 | PROSorb | Long Life for Art | microporous | 750 | Beads | ± 3 - 5 |

Table 1.1: Silica gel types included in Experiment 2

# 2 | Trial runs

## 2.1 Run A: Sample 12, step from 20 to 50 %RH.

Run 1 is used to get confident with the data acquisition in Matlab. In this run a step from 20 to 50 $\%RH$ is taken. Data is recorded during 4 intervals.
The following parameters are used in Run 1:

| | |
|---|---|
| Height of silica in column [$m$] | 0.50 |
| Volumetric flow rate [$dm^3/min$] | 90 |
| Silica gel sample | 12 |
| Relative humidity initial [%RH] | $\pm$ 19 |
| Relative humidity before step [%RH] | 16.9 |
| Relative humidity after step [%RH] | 46.6 |
| Duration [$sec$] | 8,950, 25,540, 56,408 and 10,252 |
| Half cycle time $\tau$ | - |

Table 2.1: Experiment parameters Run 1

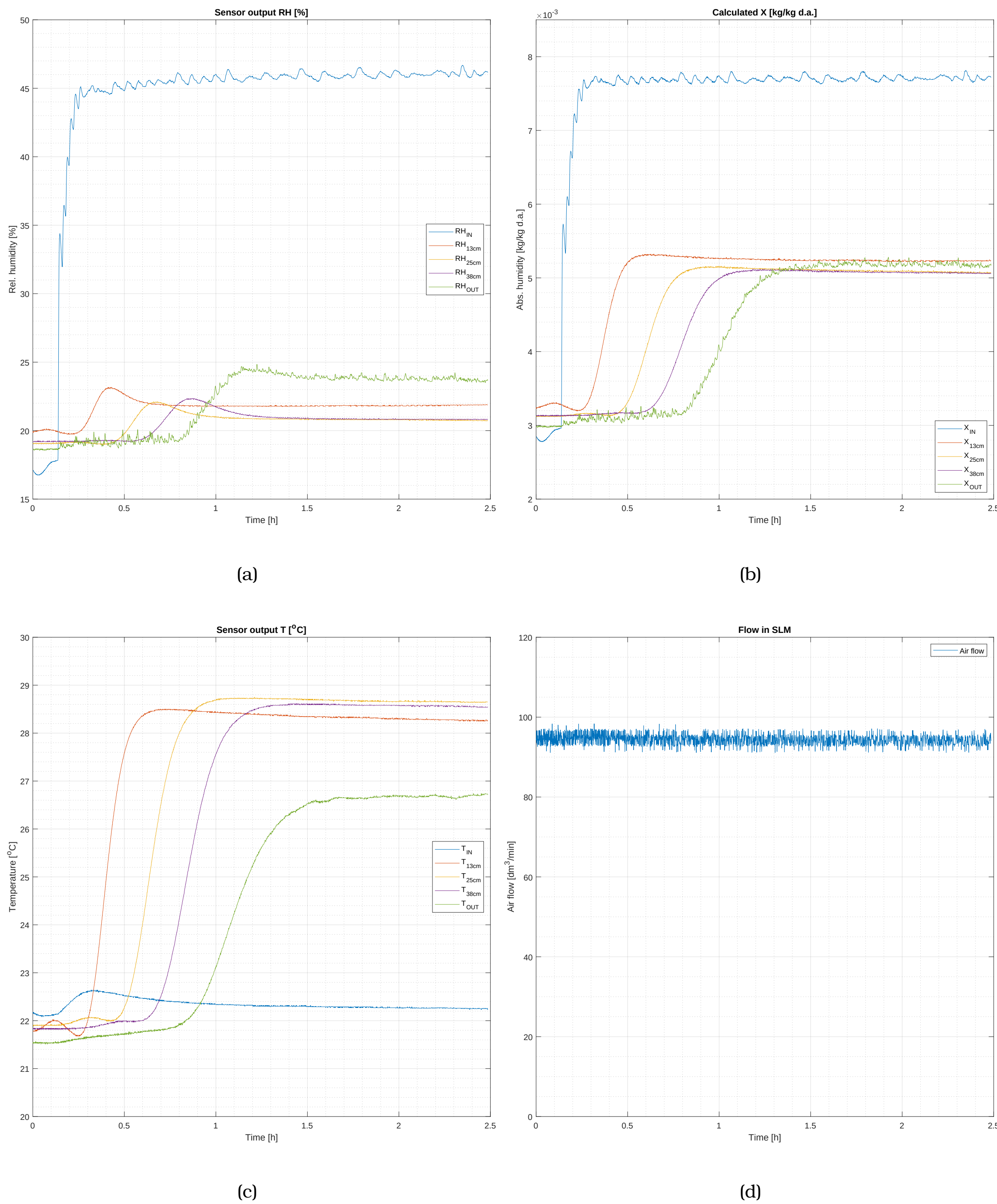
Resulting data is presented in Figures 2.1 up to 2.4. Since there are four intervals in which data is logged, the time is plotted in hours relative to the starting point.

### Discussion of Run A

The first relevant thing to mention is the response is as expected, based on theory and model study. After a step in relative humidity, the temperature rises, due to latent heat released at the silica gel surface.

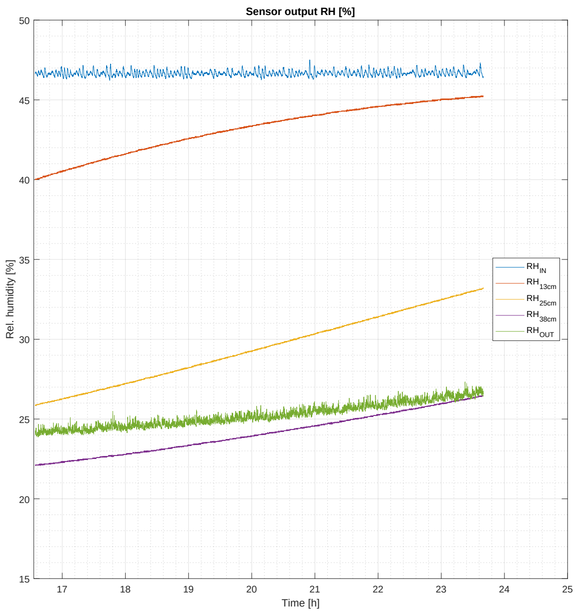
Worth mentioning is that the relative humidity measured at the outlet exceeds the relative humidity measured in the silica. This is likely explained by the fact that the air at outlet cools down, after leaving the silica. For the cooler air, the saturation humidity is lower, and thus the relative humidity will be higher.

To ensure the sensor measuring outlet air is not affected by the cabinet temperature and humidity, the column exit is extended with a piece of cloth to shield the sensor. It is not likely that the sensor is affected: a rise in RH should be measured directly after the step in RH.

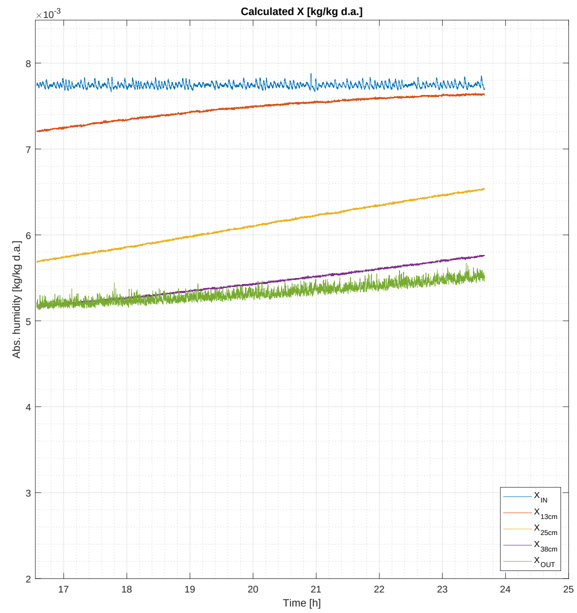



(a) (b) (c) (d)

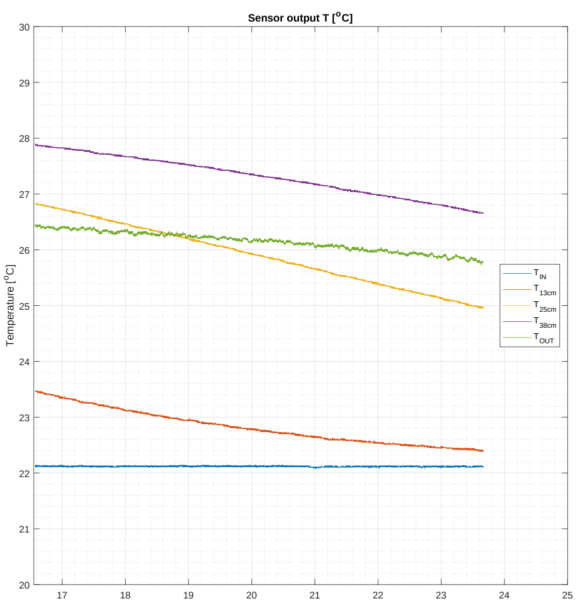
Figure 2.1: Results from Run A, February 28, $16.57h$ till $19.27h$




(a)




(b)

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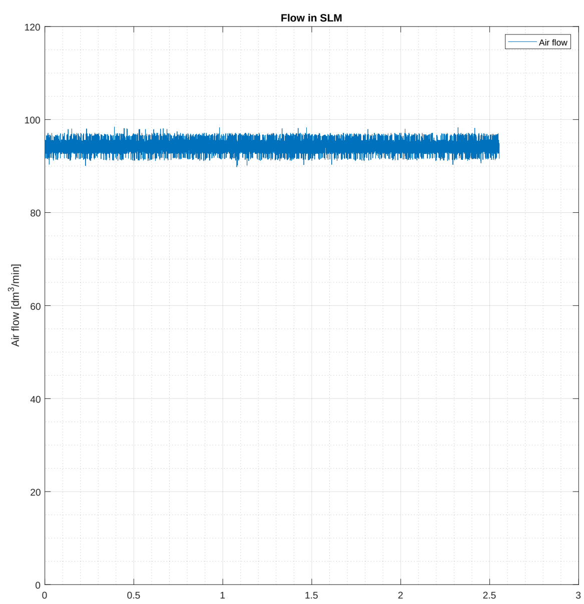
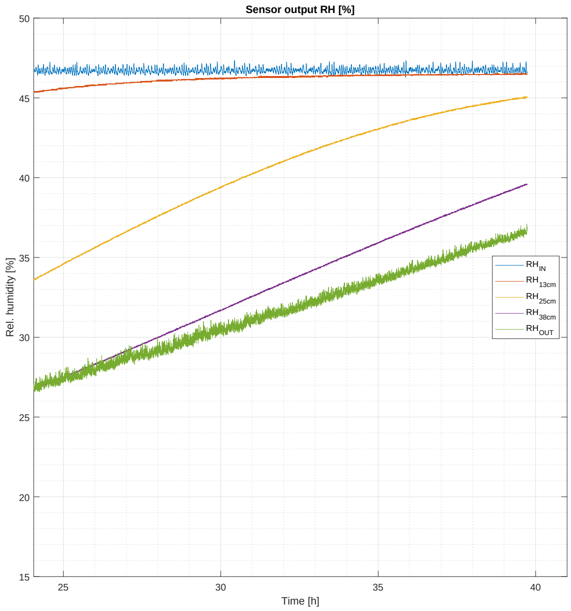
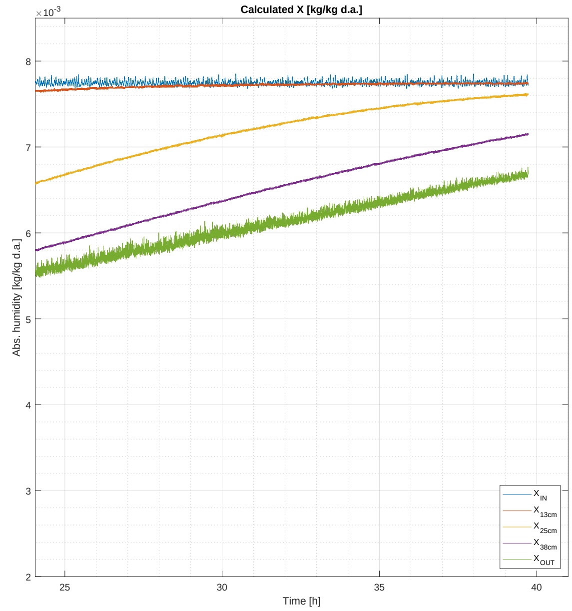



(d)

Figure 2.2: Results from Run A, February 29, $09:32h$ till $16.38h$




(a)

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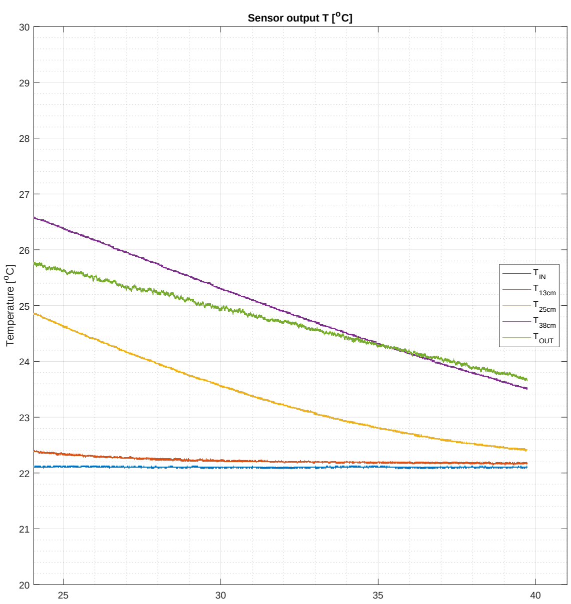
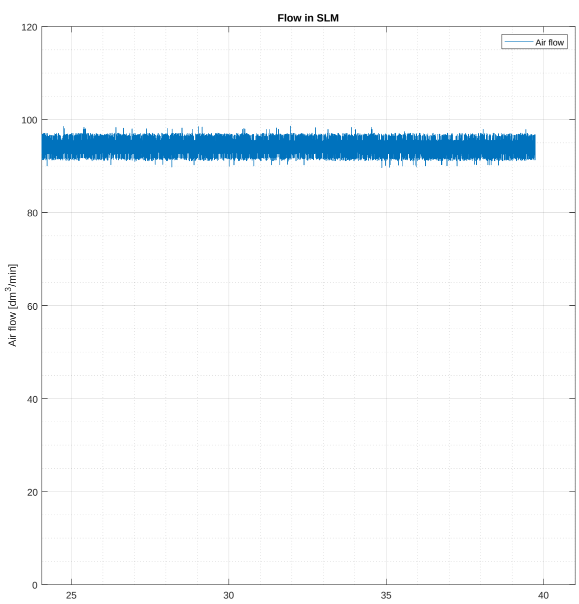
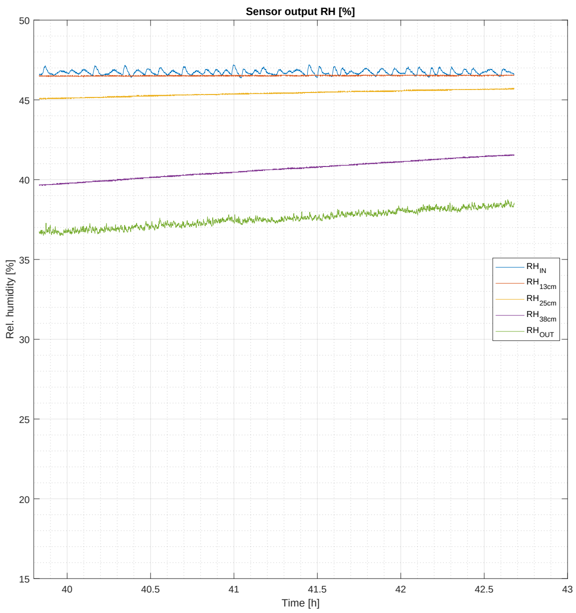



(c)

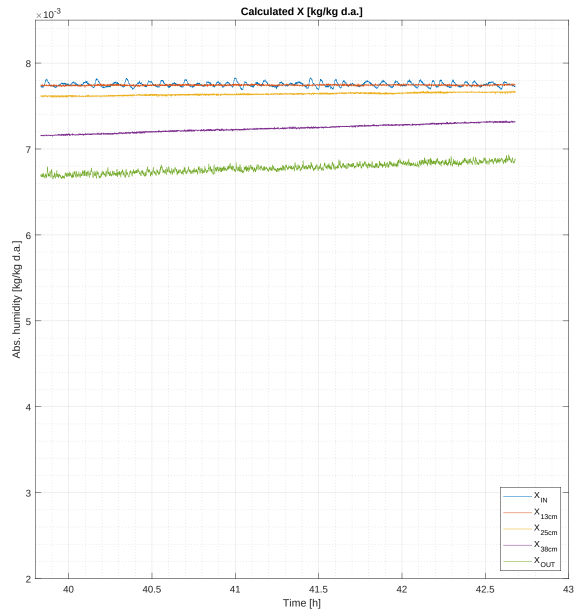



(d)

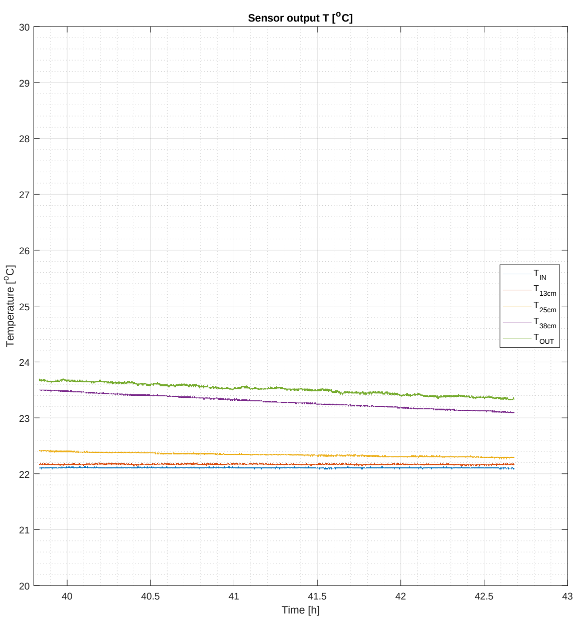
Figure 2.3: Results from Run A, March 1, $17.01h$ till March 2, $08.42h$




(a)




(b)

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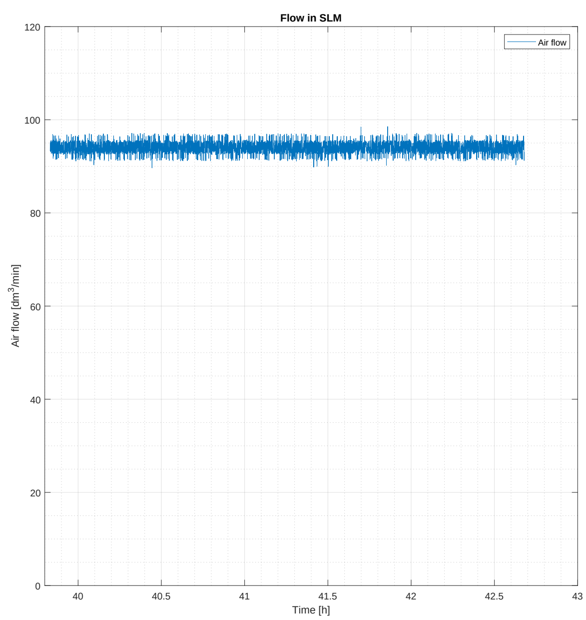


(d)

Figure 2.4: Results from Run A, March 2, $08.48h$ till $11.38h$

## 2.2 Run B: Sample 12, cyclic between 50 and 60 %RH.

In Run 2 the column is completely filled, and exposed to a cyclic input between 50 and 60 %RH. The initial state of the column was not completely equilibrium. The inlet of the column was in equilibrium at 56.0 %RH, decreasing to 52.0 %RH at the outlet.

| | |
|---|---|
| Height of silica in column [$m$] | 0.50 |
| Volumetric flow rate [$dm^3/min$] | 90 |
| Silica gel sample | 12 |
| Relative humidity initial [%RH] | 56.0 (1 & 2), 54.5 (3) and 52.0 (Outlet) |
| Relative humidity low [%RH] | 47.0 |
| Relative humidity high [%RH] | 56.2 |
| Duration [$sec$] | 31,516 |
| Half cycle time $\tau$ | 2 $h$ |

Table 2.2: Experiment parameters Run B

### Discussion of Run B

In this run a short cycle is inserted in the column. The bed shows transient behaviour. An important observation is that the initial condition is at the upper value of the alternative RH input. Due to this initial condition, and the relatively high column, the water stored in the first part of the column, is released later in the experiment. The outlet RH (green) is thus increasing throughout the whole experiment.

The first part of the column (red) is reaching its cyclic equilibrium just at the end of this run. with time, it goes towards the mean value of the cyclic RH input. The next part (yellow) is just starting to decrease at the end.

The temperature plot also shows the first part, in red, is reaching its cyclic equilibrium at the end of the experiment. On the long term, the temperature will fluctuate around the input value of around 22 $^oC$.

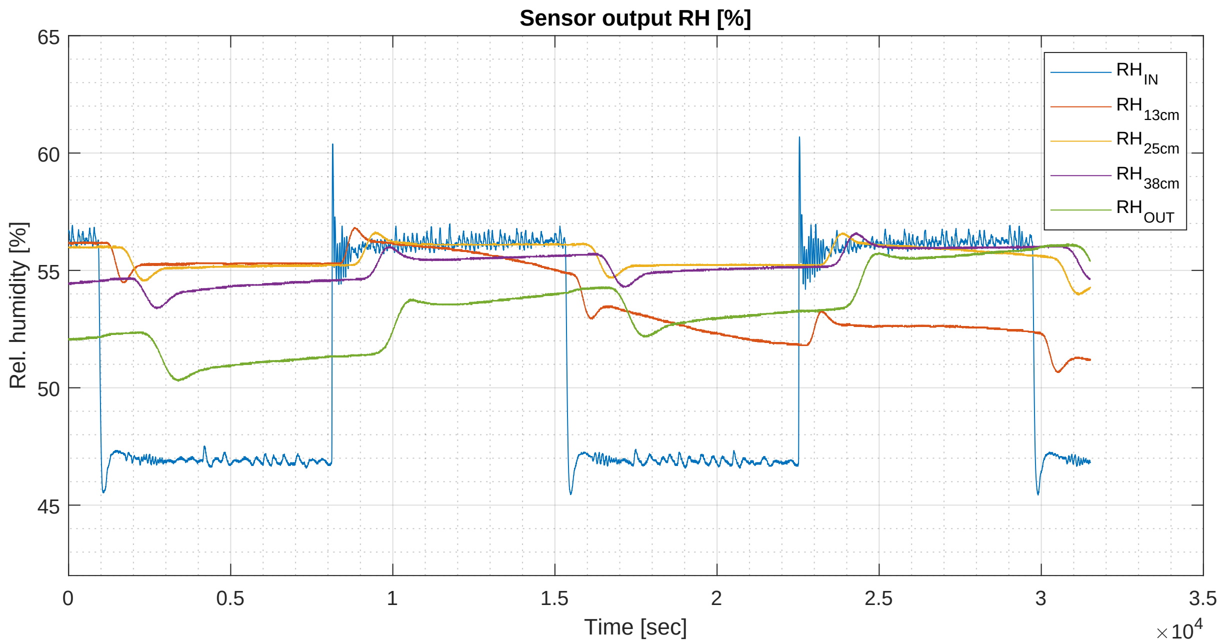


Figure 2.5: Relative humidity measurements in Run B.

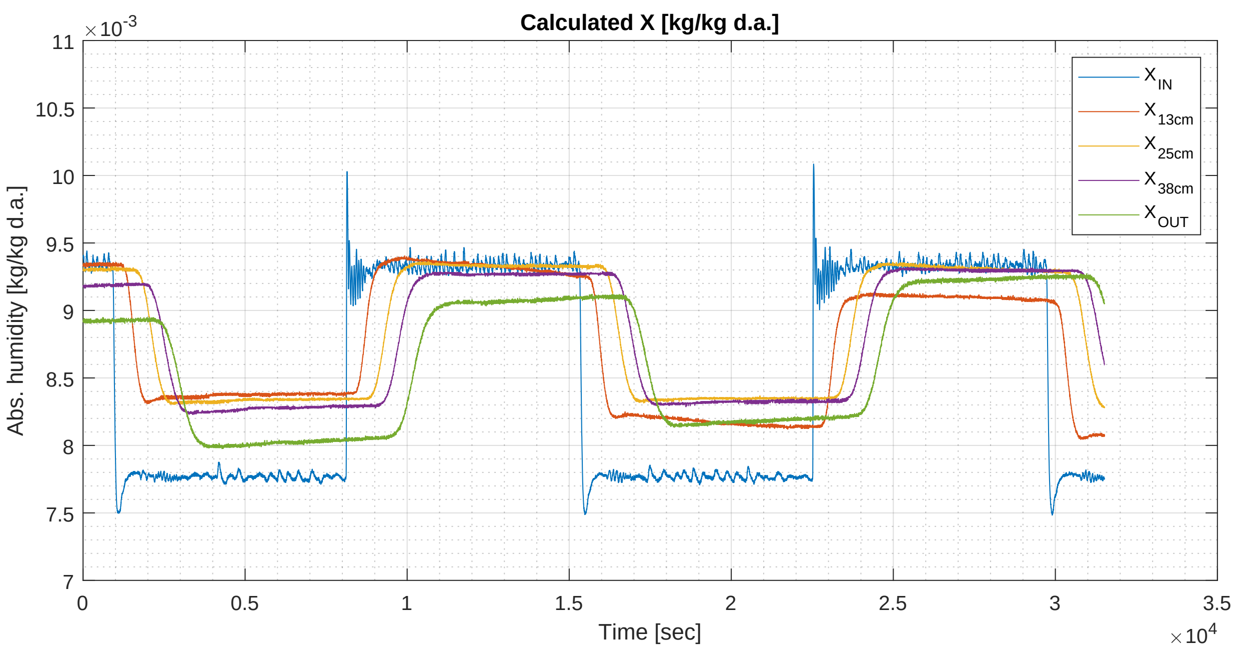


Figure 2.6: Absolute humidity calculated from RH and T in Run B.

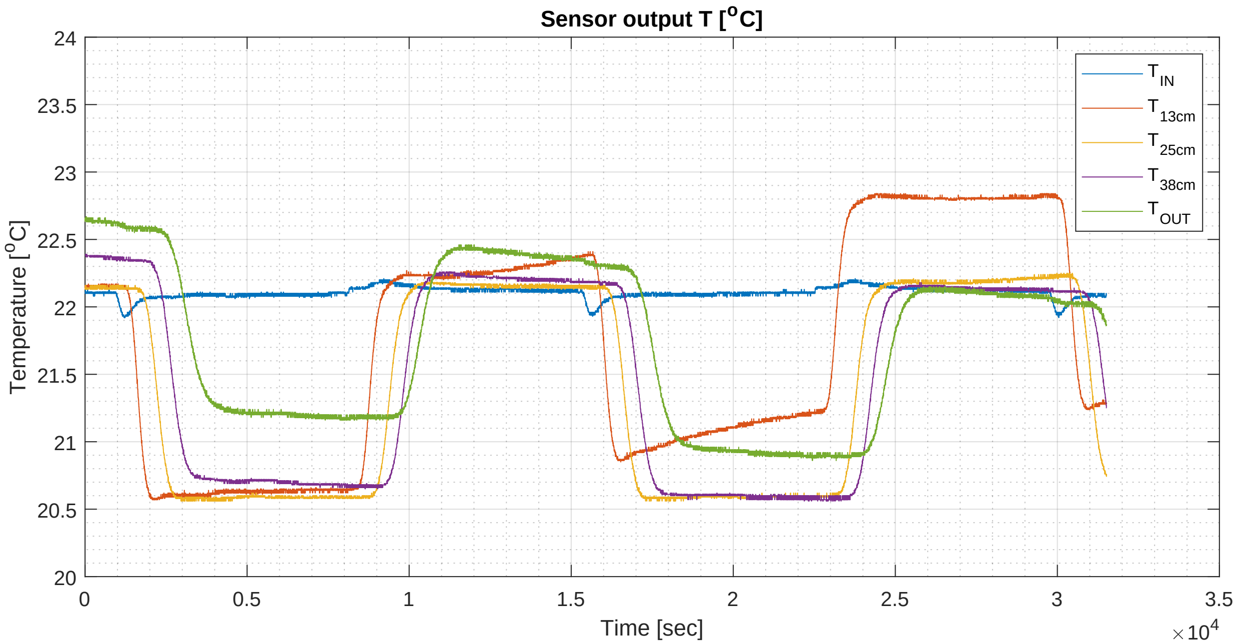


Figure 2.7: Temperature measurements in Run B.

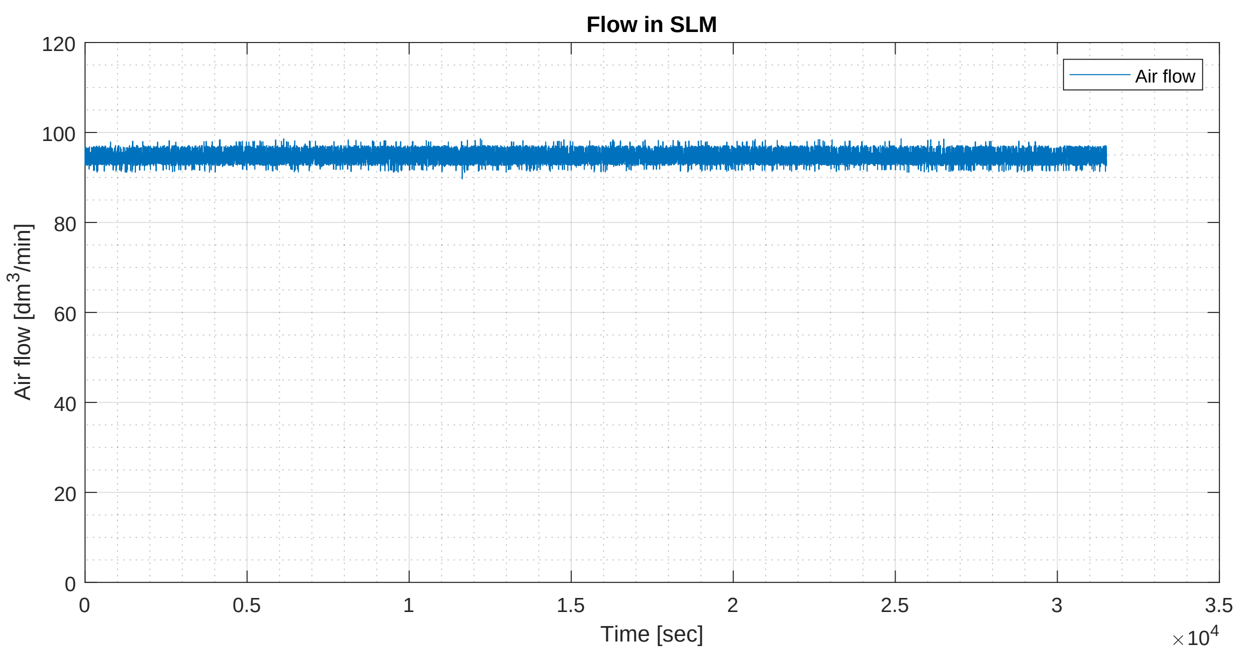


Figure 2.8: Flow measurements in Run B.

## 2.3 Run C: Sample 11, cyclic between 36 and 56 %RH.

In Run 2 the column is filled half, and exposed to a cyclic input between 36 and 56 %RH.

| | |
|---|---|
| Height of silica in column [$m$] | 0.31 |
| Volumetric flow rate [$dm^3/min$] | 112.1 |
| Silica gel sample | 11 |
| Relative humidity initial [%RH] | 45.0 |
| Relative humidity low [%RH] | 35.0 |
| Relative humidity high [%RH] | 52.2 |
| Duration [$sec$] | 24,302 |
| Half cycle time $\tau$ | 1 $h$ |

Table 2.3: Experiment parameters Run C

### Discussion of Run C

The relative humidity of air inserted in the column is lower than the setpoint of the climatic cabinet. Lower and upper value for relative humidity setpoint in this run were exactly $40.0$ and $60.0$ %RH. The measured lower and upper value are $35.0$ and $52.2$ %RH.

The height of the column in this run is only $33$ $cm$. This seems more suitable for the cyclic experiment.

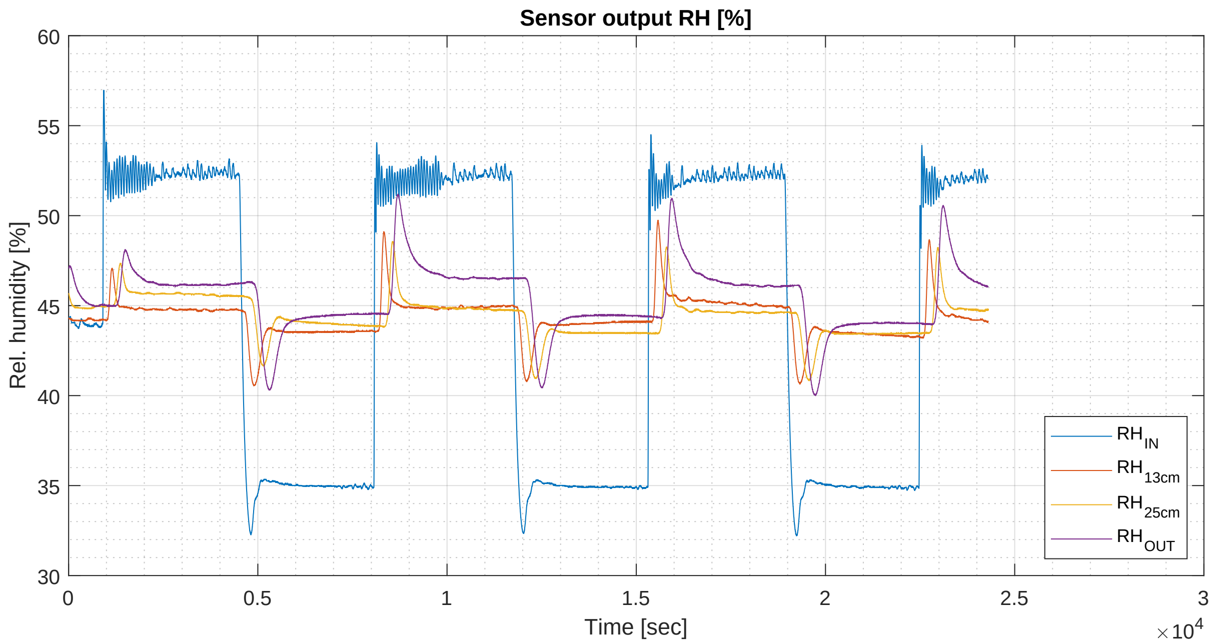


Figure 2.9: Relative humidity measurements in Run C.

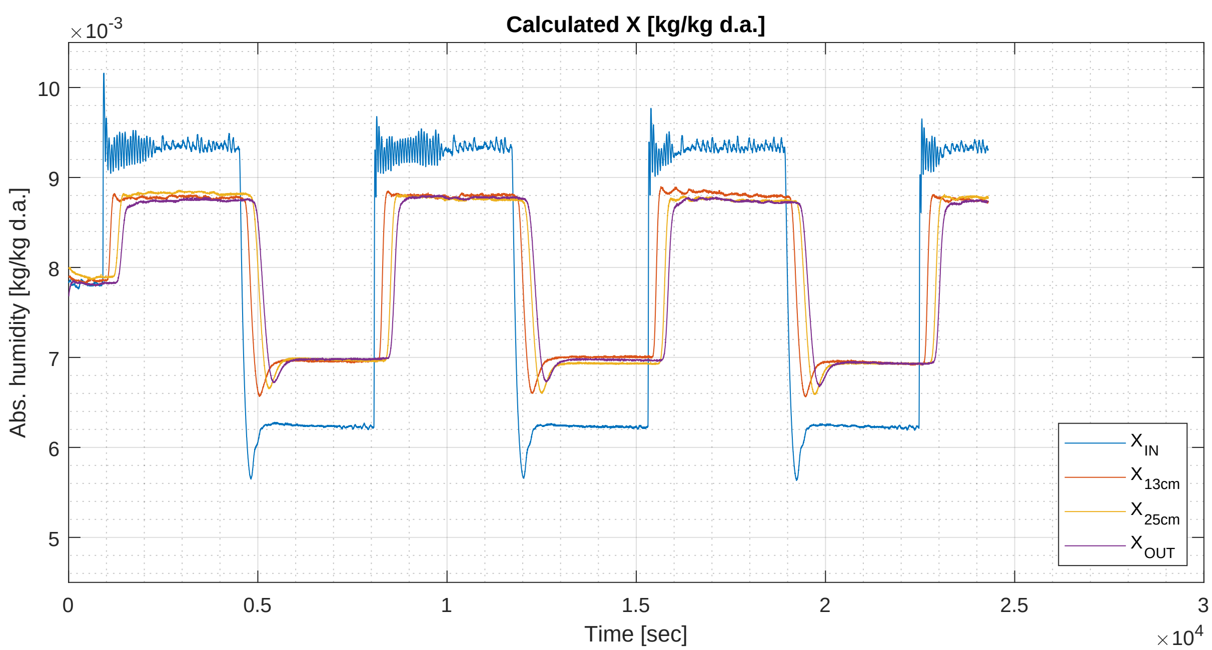


Figure 2.10: Absolute humidity calculated from RH and T in Run C.

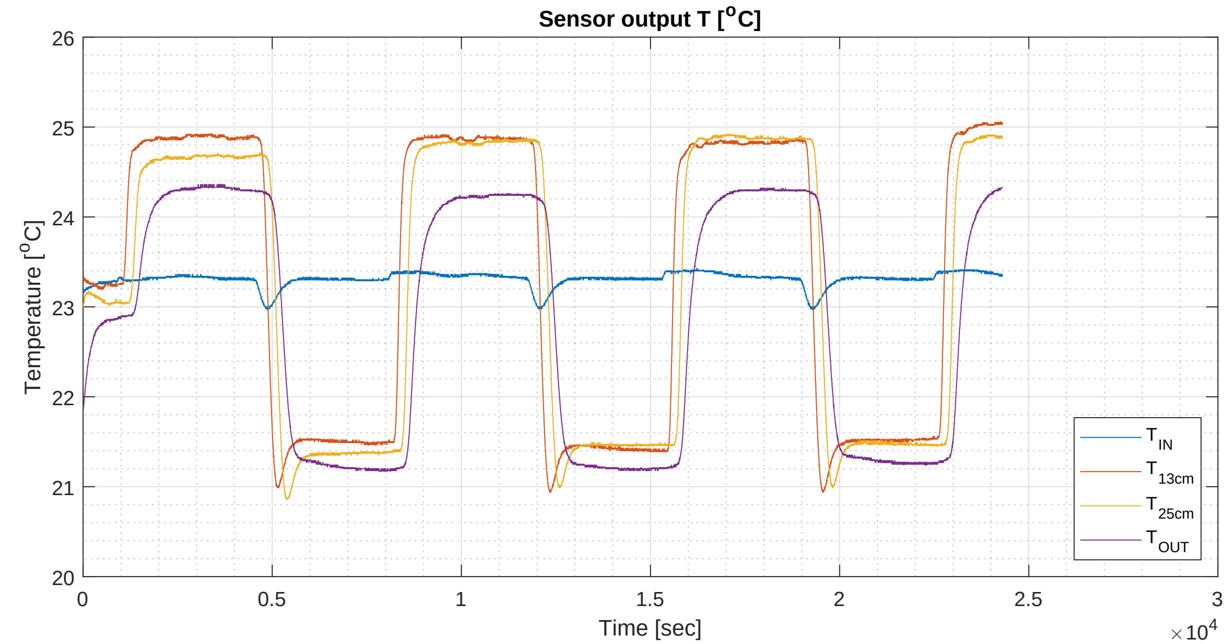


Figure 2.11: Temperature measurements in Run C.

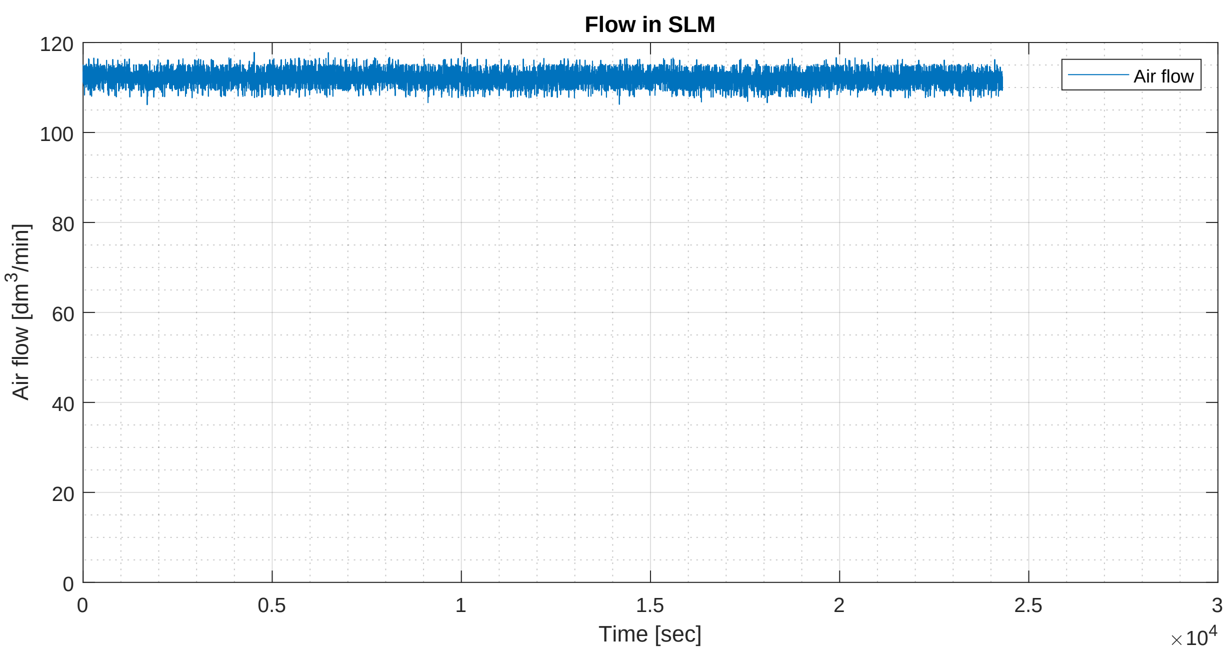


Figure 2.12: Flow measurements in Run C.

## 2.4 Run D: Sample 11, cyclic between 40 and 60 %RH.

In Run 2 the column is filled half, and exposed to a cyclic input between 40 and 60 %RH. The initial state of the column was not completely equilibrium. The inlet of the column was in equilibrium at 56.0 %RH, decreasing to 52.0 %RH at the outlet.

| | |
|---|---|
| Height of silica in column [$m$] | 0.31 |
| Volumetric flow rate [$dm^3/min$] | 91.6 |
| Silica gel sample | 11 |
| Relative humidity initial [%RH] | 47.3 |
| Relative humidity low [%RH] | 42.3 |
| Relative humidity high [%RH] | 60.6 |
| Duration [$sec$] | 29,378 |
| Half cycle time $\tau$ | 1 $h$ |

Table 2.4: Experiment parameters Run D

### Discussion of Run D

In this run, the measured setpoint values for relative humidity are closer to the intended values of $40.0$ and $60.0$ %RH. The initial condition is still at approximately $47$ %RH. Because the initial condition is not in the middle of lower and upper value, the relative humidity value around which is buffered is adjusting during the experiment; relative humidity is increasing and temperature is decreasing.

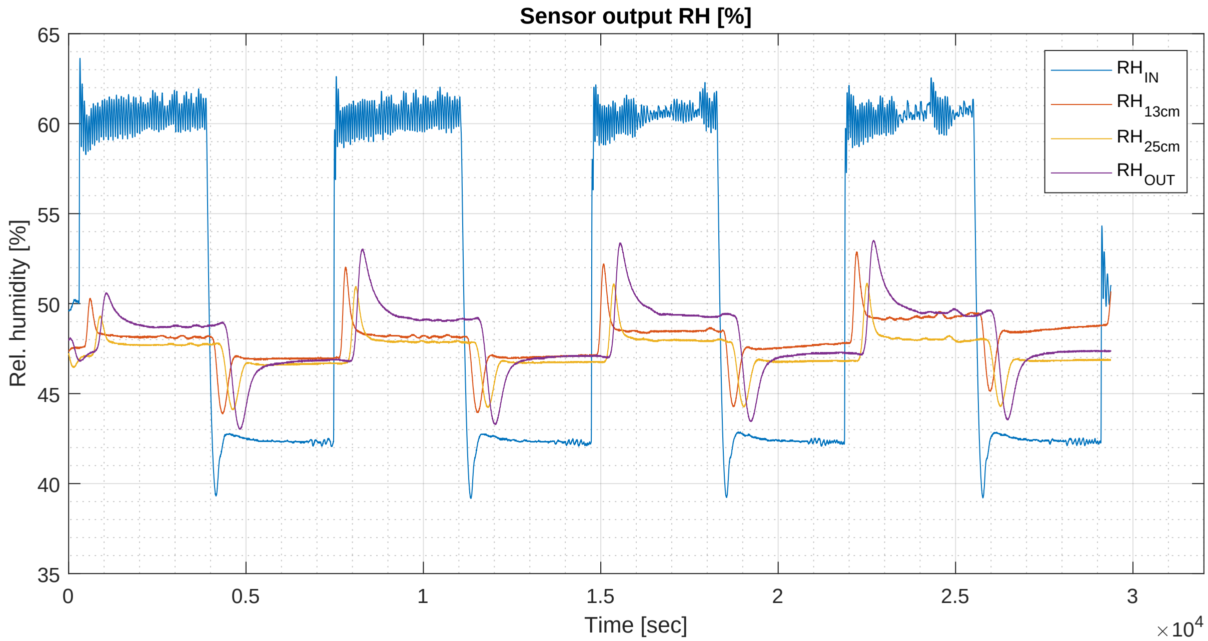


Figure 2.13: Relative humidity measurements in Run D.

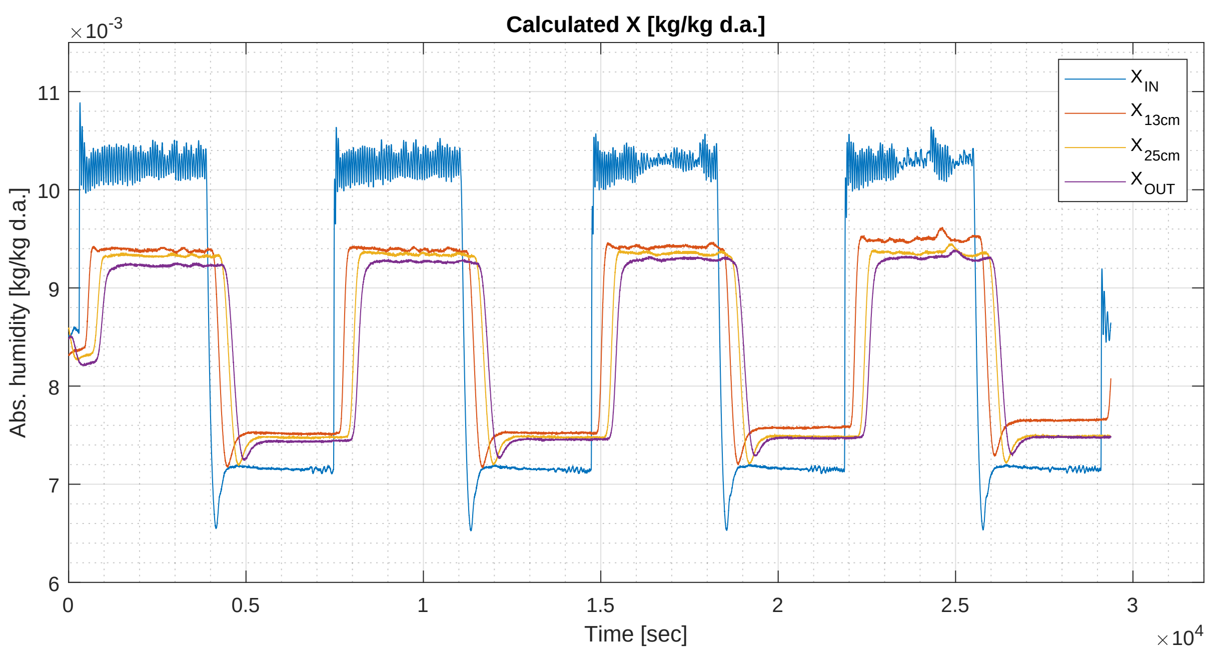


Figure 2.14: Absolute humidity calculated from RH and T in Run D.

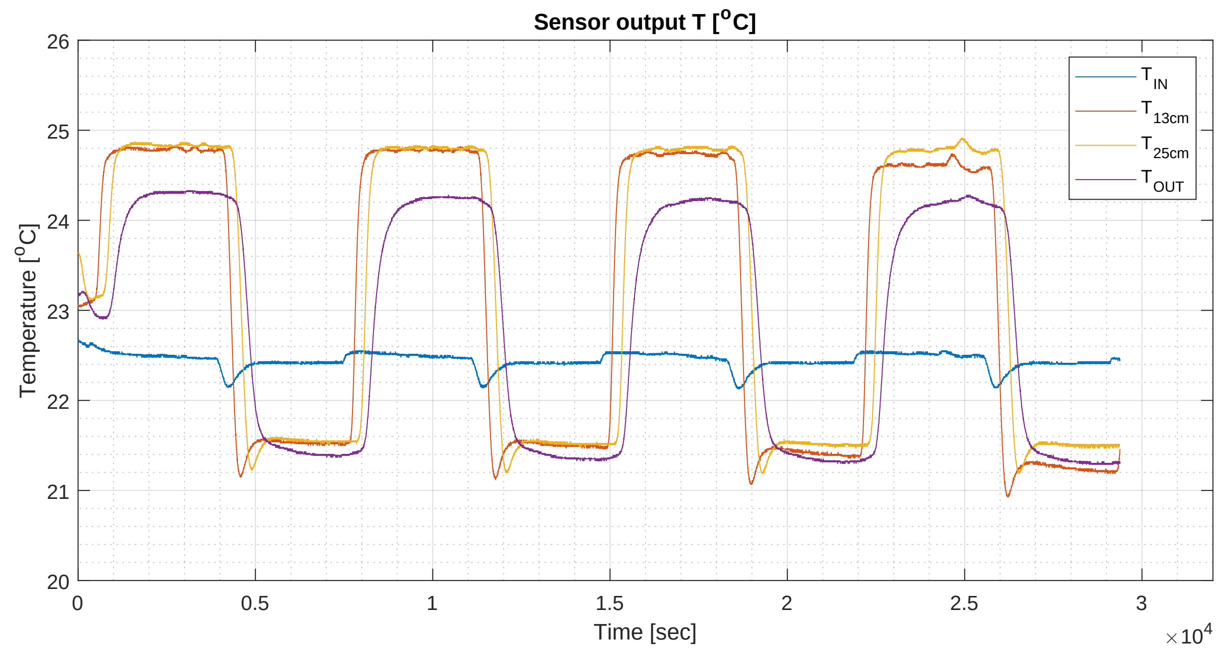


Figure 2.15: Temperature measurements in Run D.

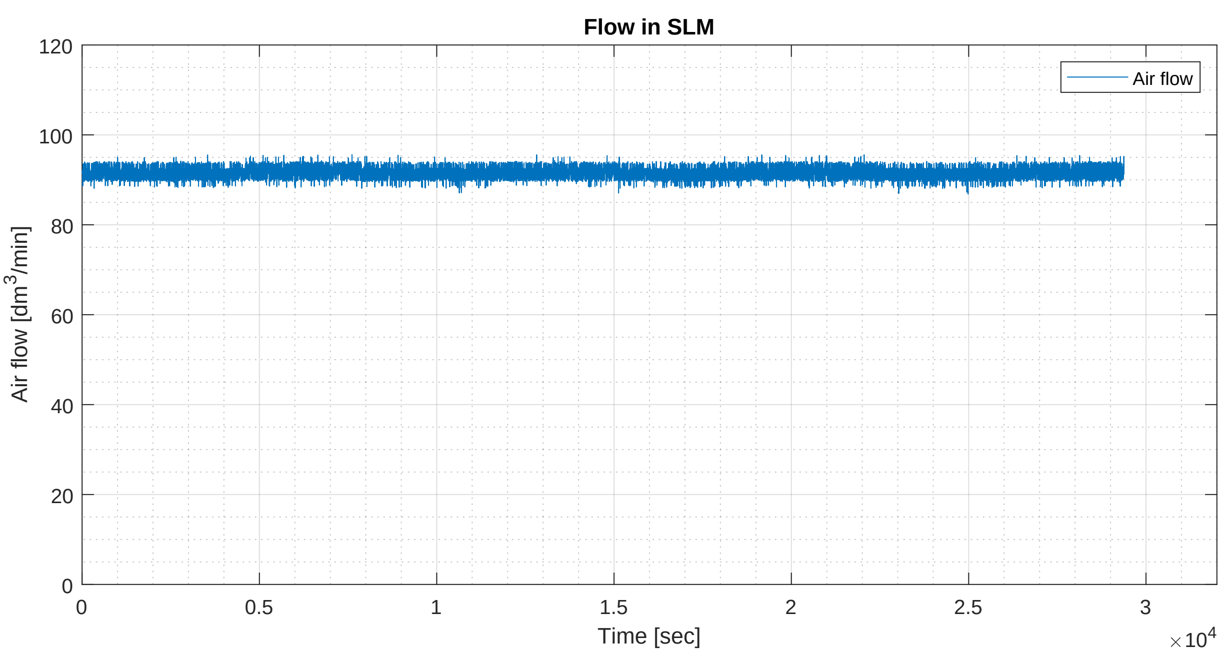


Figure 2.16: Flow measurements from RH and T in Run D.

# 3 | Results Experiment 2

## 3.1 Run 1: Sample 6, cyclic between 40 and 60 %RH.

| | |
|---|---|
| Height of silica in column [$m$] | 0.28 |
| Mass of silica in column [$g$] | 3,246 |
| Volumetric flow rate [$dm^3/min$] | 100.2 |
| Silica gel sample | 6 |
| Relative humidity initial [%RH] | 51.0 |
| Relative humidity low [%RH] | 39.0 |
| Relative humidity high [%RH] | 61.2 |
| Duration [$sec$] | 29,439 |
| Half cycle time $\tau$ | 1 $h$ |

Table 3.1: Experiment parameters Run 1

### Discussion of Run 1

Sample 6 is loaded in dry state in run 5 (long cycle). After run 5, when the silica had reached 50 %RH equilibrium again, run 1 is executed.

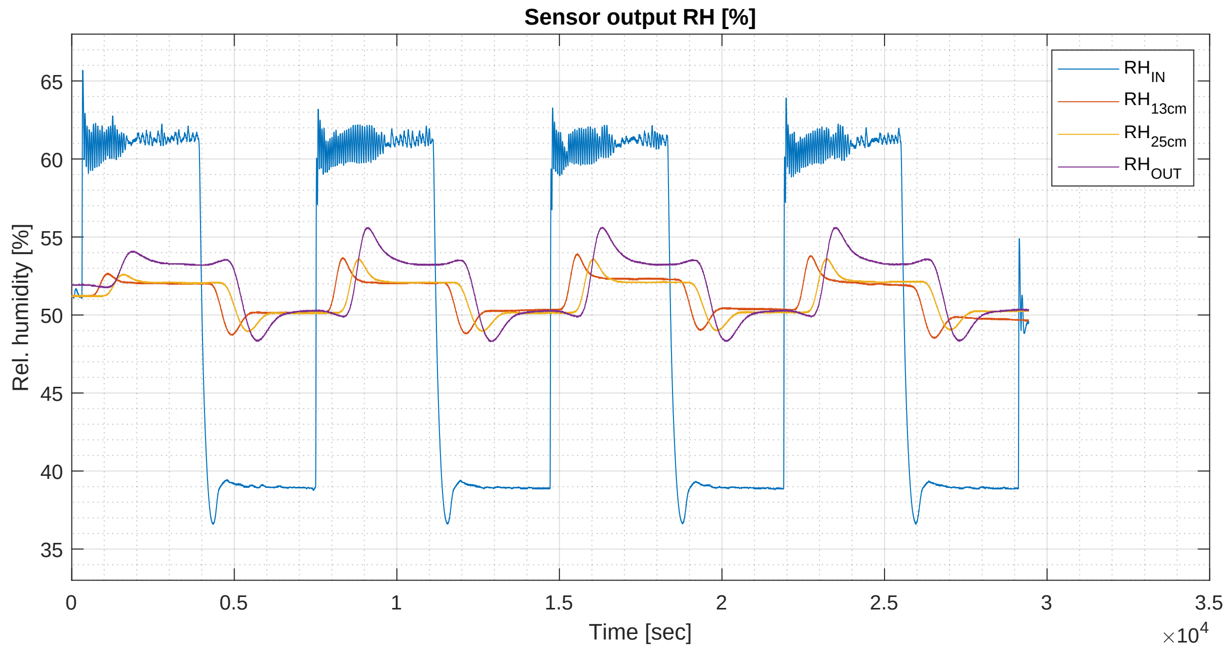


Figure 3.1: Relative humidity measurements in Run 1.

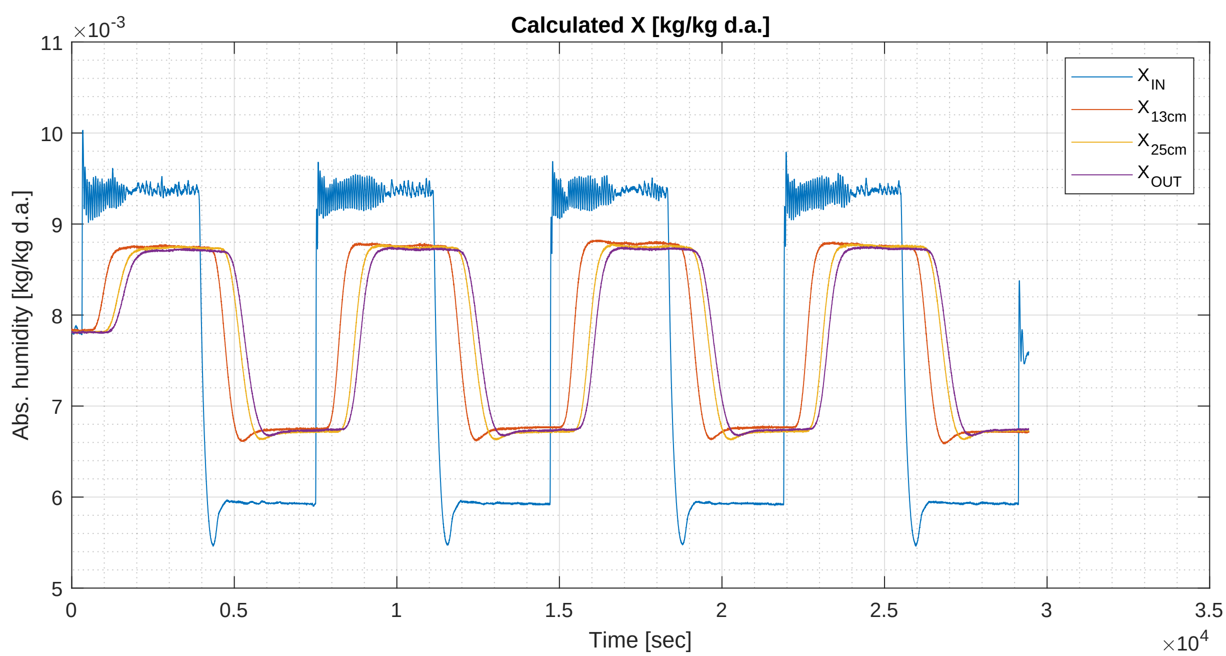


Figure 3.2: Absolute humidity calculated from RH and T in Run 1.

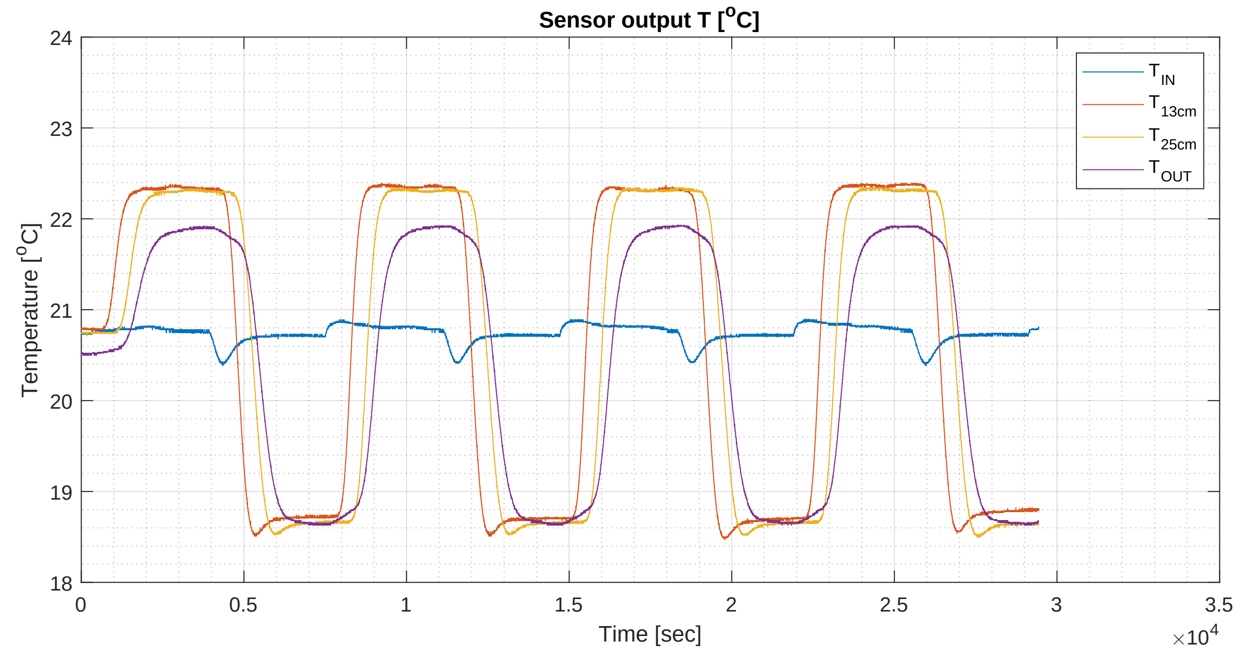


Figure 3.3: Temperature measurements in Run 1.

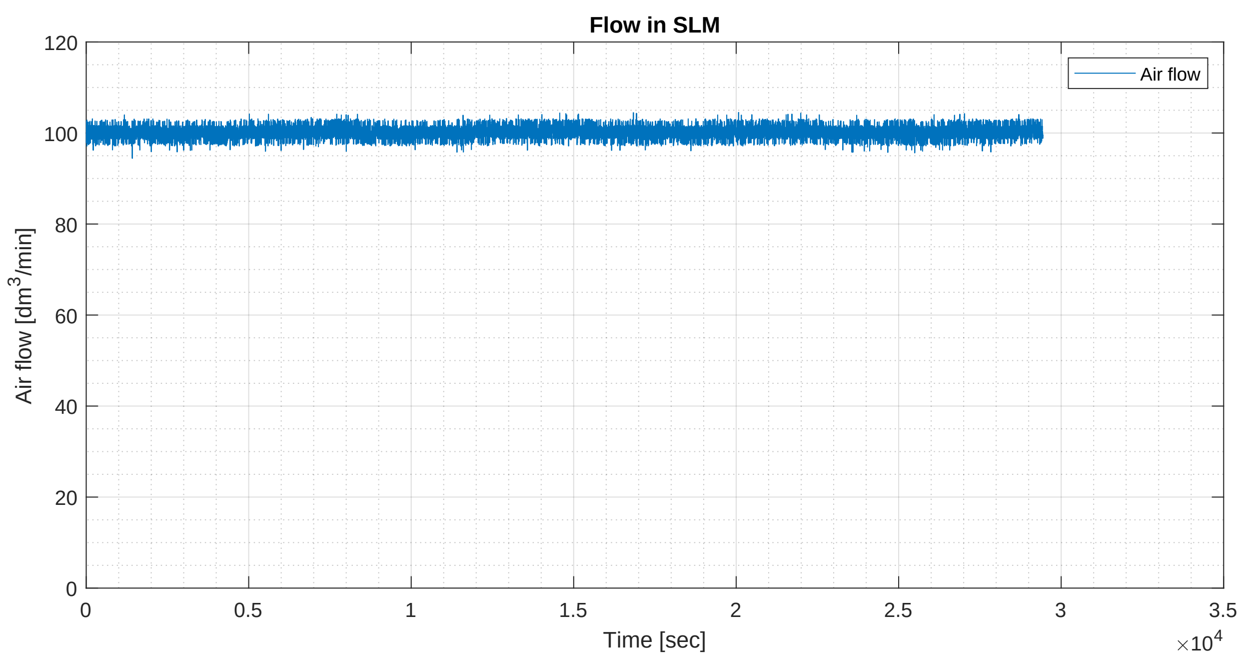


Figure 3.4: Flow measurements from RH and T in Run 1.

## 3.2 Run 2: Sample 11, cyclic between 40 and 60 %RH.

| | |
|---|---|
| Height of silica in column [$m$] | 0.31 |
| Mass of silica in column [$g$] | 2,267 |
| Volumetric flow rate [$dm^3/min$] | 97.5 |
| Silica gel sample | 11 |
| Relative humidity initial [%RH] | 49.2 |
| Relative humidity low [%RH] | 38.5 |
| Relative humidity high [%RH] | 59.0 |
| Duration [$sec$] | 29,383 |
| Half cycle time $\tau$ | 1 $h$ |

Table 3.2: Experiment parameters Run 2

### Discussion of Run 2

Sample 11 is loaded in dry state in run C. It has been subjected to the cyclic humidity input of runs C and D. The silica gel in run 2 is not following primary isotherm.

Compared to run 1, 3 and 4, this run has a faster rate of change of temperature. This sample is mesoporous silica gel, opposed to microporous silica gel in the other runs. A better explanation could be the smallar particle diameter.

The faster temperature change leads to a sharper and higher peak in relative humidity (purple line in $RH$ versus $time$ plot). After that, the relative humidity stay within a smaller RH range compared to run 1, 3 and 4.

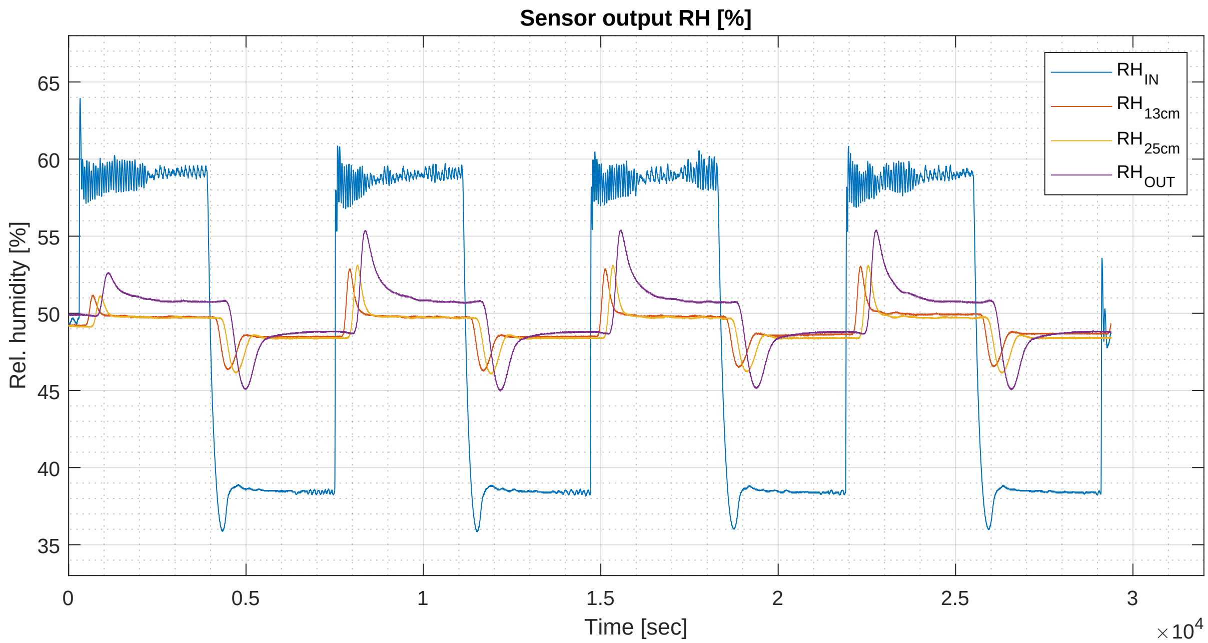


Figure 3.5: Relative humidity measurements in Run 2.

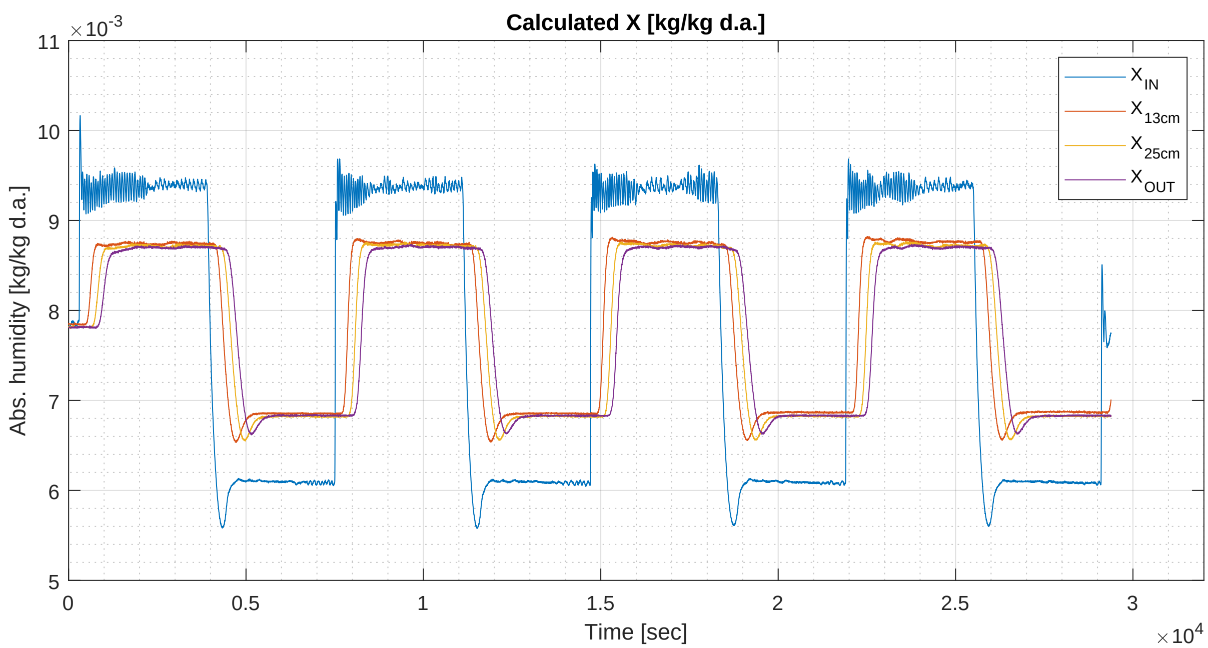


Figure 3.6: Absolute humidity calculated from RH and T in Run 2.

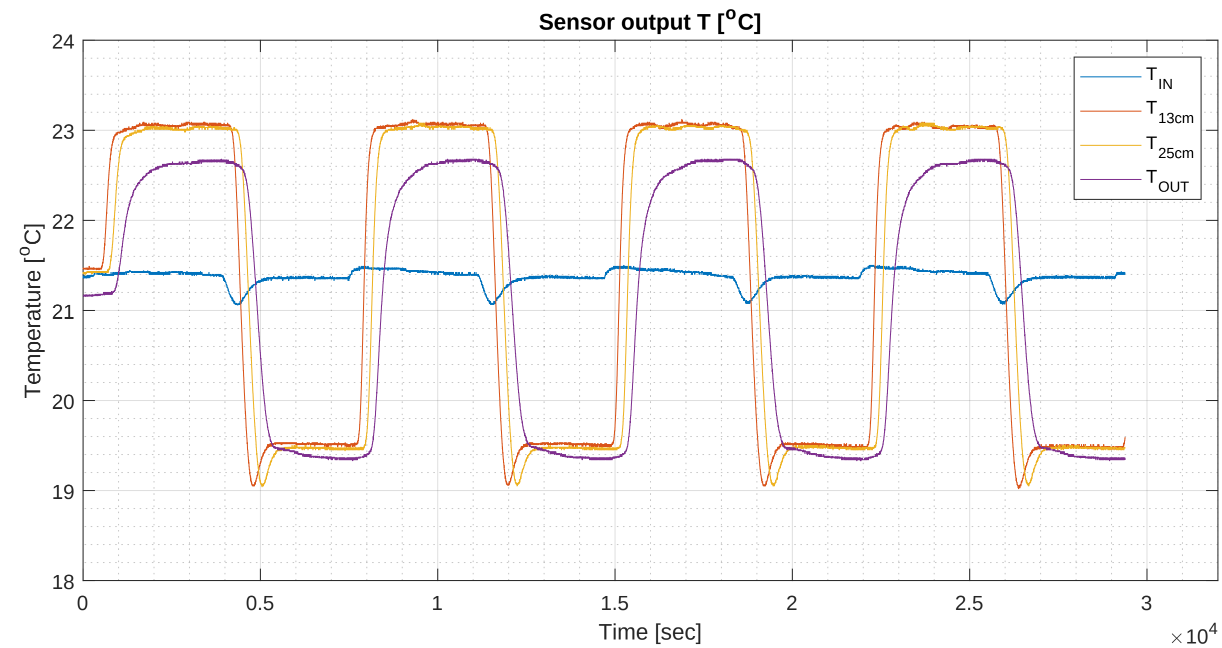


Figure 3.7: Temperature measurements in Run 2.

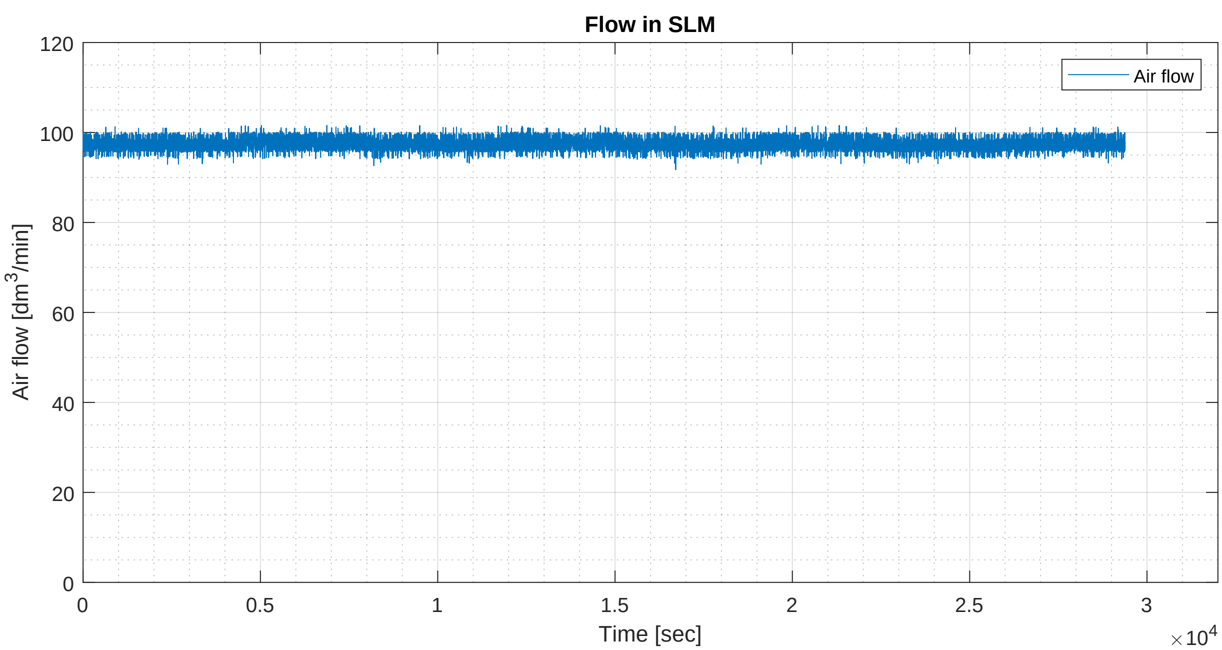


Figure 3.8: Flow measurements from RH and T in Run 2.

## 3.3 Run 3: Sample 12, cyclic between 40 and 60 %RH.

| | |
|---|---|
| Height of silica in column [$m$] | 0.30 |
| Mass of silica in column [$g$] | 3,547 |
| Volumetric flow rate [$dm^3/min$] | 102.4 |
| Silica gel sample | 12 |
| Relative humidity initial [%RH] | 51.0 |
| Relative humidity low [%RH] | 40.4 |
| Relative humidity high [%RH] | 60.9 |
| Duration [$sec$] | 29,400 |
| Half cycle time $\tau$ | 1 $h$ |

Table 3.3: Experiment parameters Run 3

### Discussion of Run 3

Sample 12 is loaded in dry state in run A. It has then been subjected to run B, a cyclic run between 50 and 60 %RH. The sample is thus not following the primary isotherm.

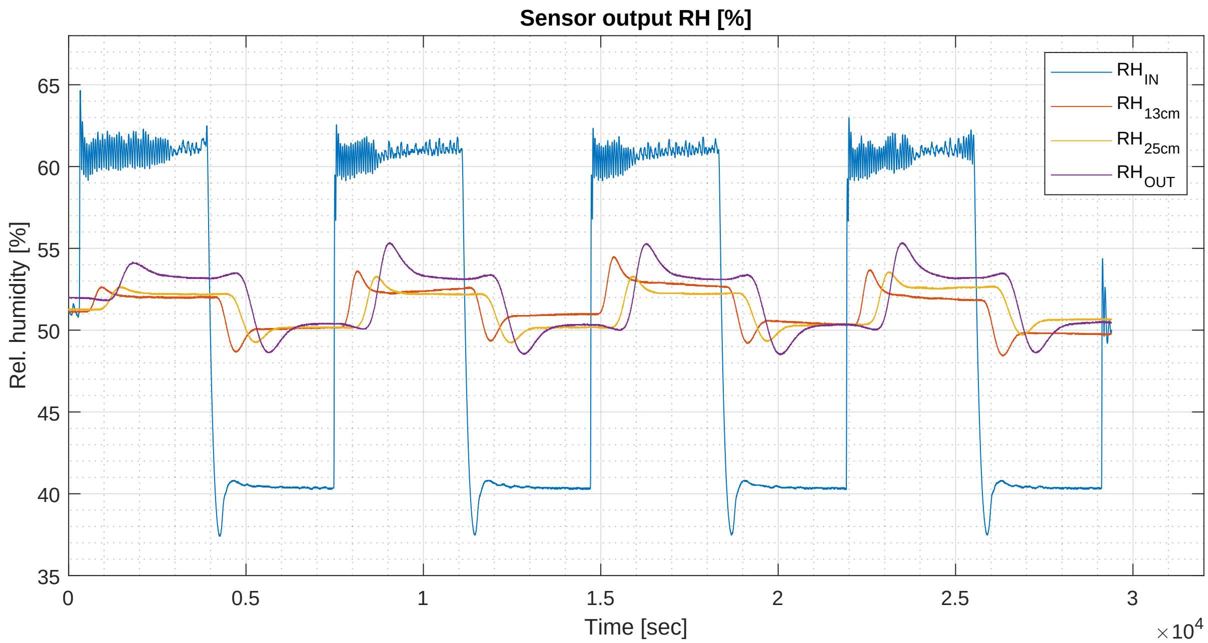


Figure 3.9: Relative humidity measurements in Run 3.

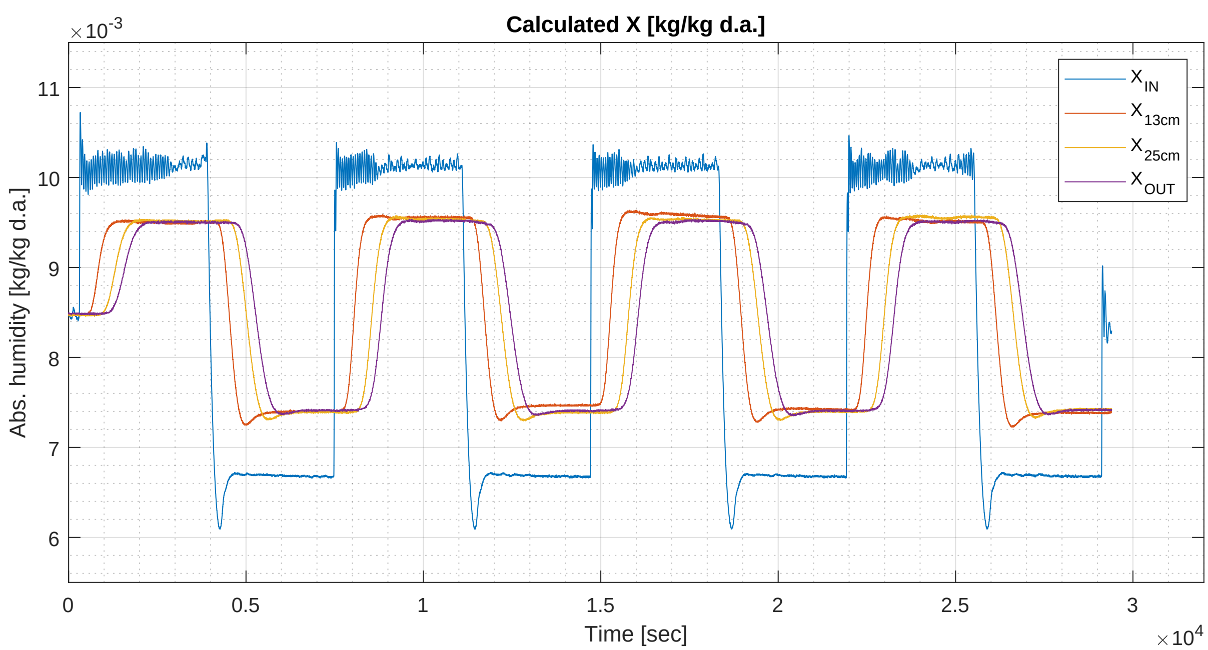


Figure 3.10: Absolute humidity calculated from RH and T in Run 3.

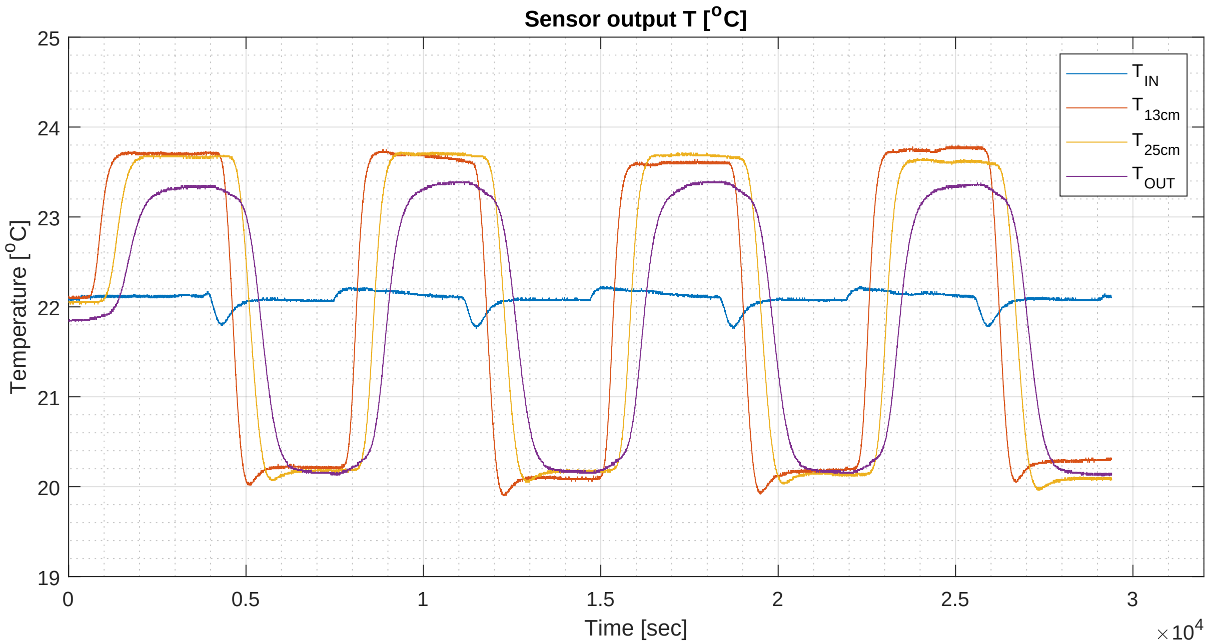


Figure 3.11: Temperature measurements in Run 3.

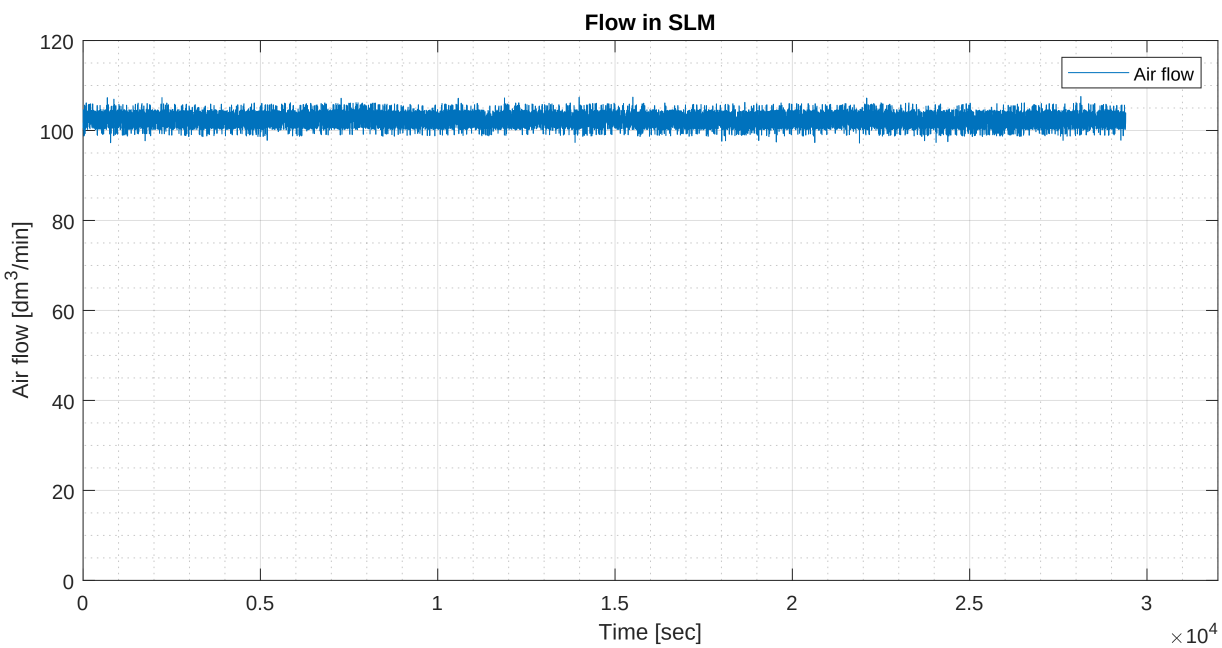


Figure 3.12: Flow measurements from RH and T in Run 3.

## 3.4 Run 4: Sample 14, cyclic between 40 and 60 %RH.

| | |
|---|---|
| Height of silica in column [$m$] | 0.31 |
| Mass of silica in column [$g$] | 3,482 |
| Volumetric flow rate [$dm^3/min$] | 97.6 |
| Silica gel sample | 14 |
| Relative humidity initial [%RH] | 50.5 |
| Relative humidity low [%RH] | 39.5 |
| Relative humidity high [%RH] | 61.5 |
| Duration [$sec$] | 29,405 |
| Half cycle time $\tau$ | 1 $h$ |

Table 3.4: Experiment parameters Run 4

### Discussion of Run 4

Sample 14 (ProSorb) is conditioned at 50 %RH. The difference between primary and secondary isotherm is likely less dominant.

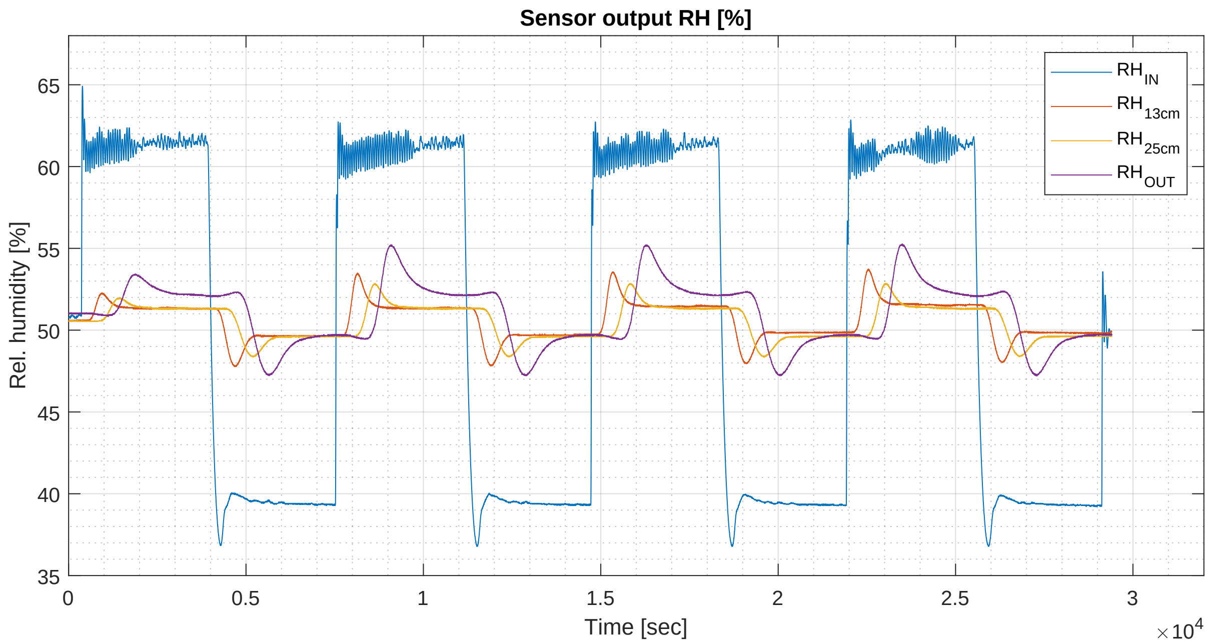


Figure 3.13: Relative humidity measurements in Run 4.

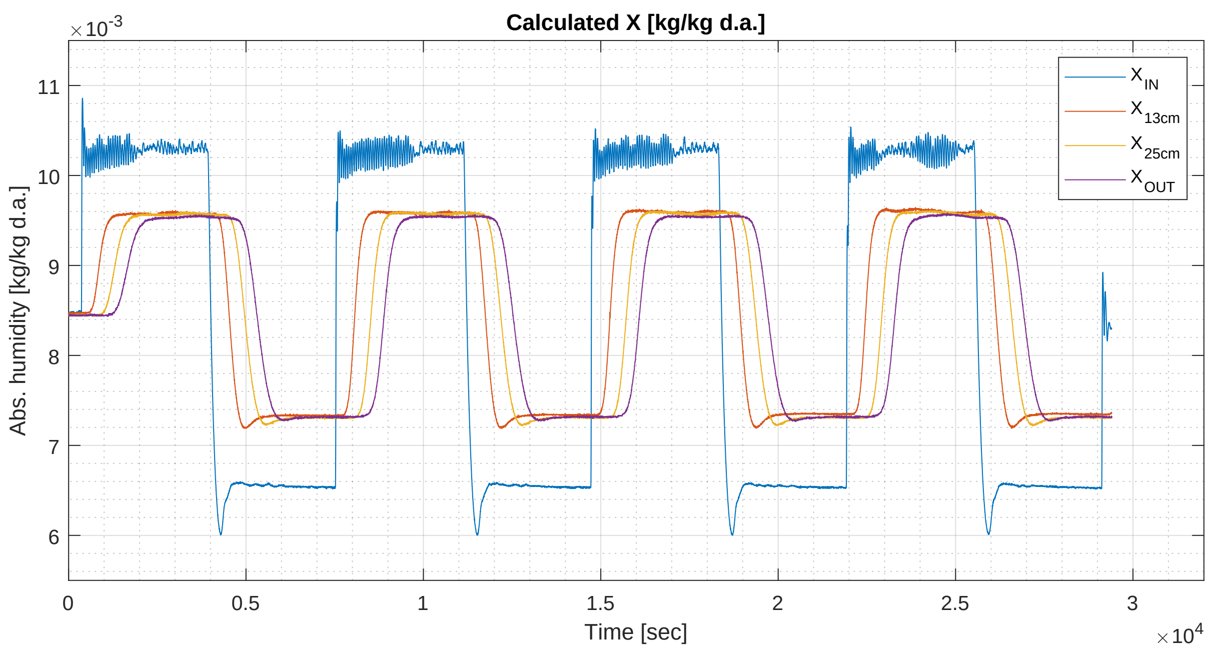


Figure 3.14: Absolute humidity calculated from RH and T in Run 4.

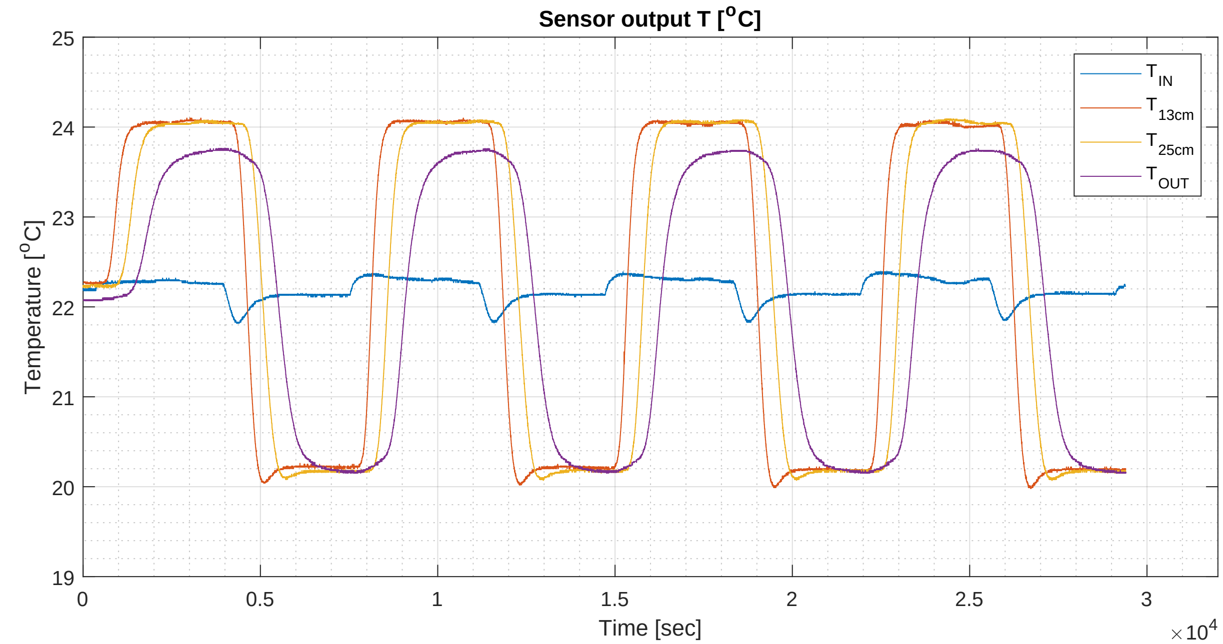


Figure 3.15: Temperature measurements in Run 4.

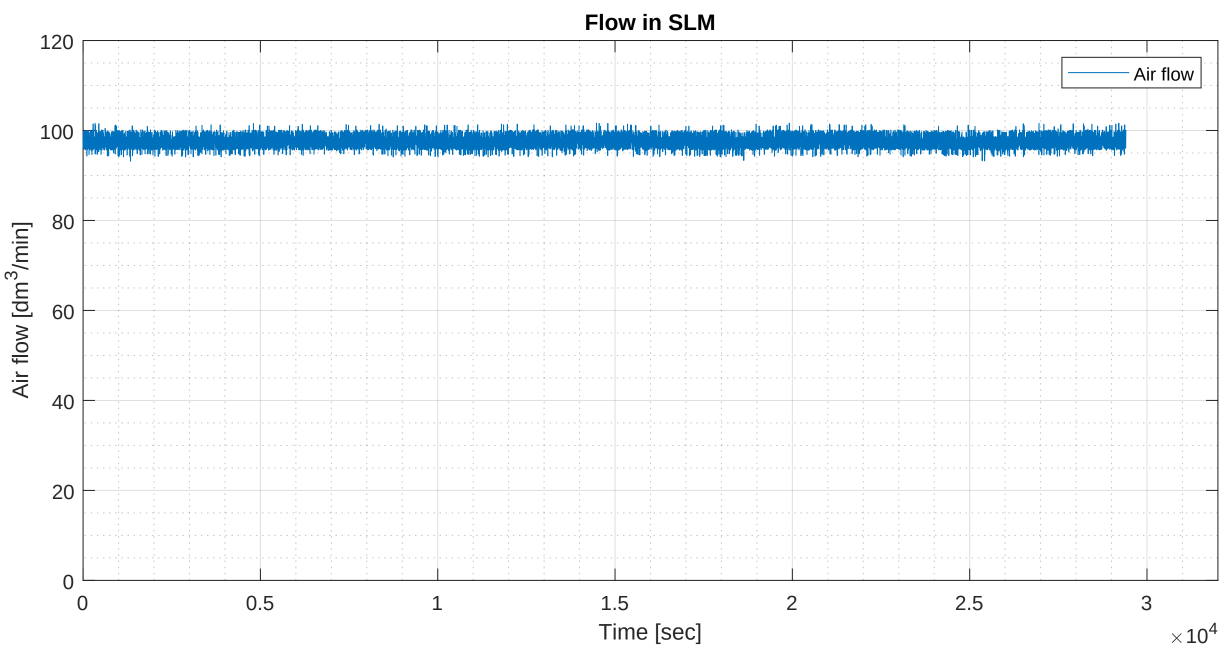


Figure 3.16: Flow measurements from RH and T in Run 4.

## 3.5 Run 5: Sample 6, long cycle between 50 and 60 %RH.

| | |
|---|---|
| Height of silica in column [$m$] | 0.50 |
| Mass of silica in column [$g$] | 5,011 |
| Volumetric flow rate [$dm^3/min$] | 104.4 |
| Silica gel sample | 6 |
| Relative humidity initial [%RH] | 48.3 |
| Relative humidity low [%RH] | 48.4 |
| Relative humidity high [%RH] | 58.3 |
| Duration [$sec$] | 85,598, 85,814, 85,470 |
| Half cycle time $\tau$ | 8 / 16 $h$ |

Table 3.5: Experiment parameters Run 5

### Discussion of Run 5

Sample 6 is loaded in dry state in run 5. The experiment was started when the silica gel had reached the 50 %RH equilibrium.

Because the sample is loaded in dry state, the silica gel is following primary isotherm in cycle **1**. The sorption capacity in the first cycle is higher compared to cycle **2**. This difference is discussed in the main thesis report.

**First 24h cycle;**

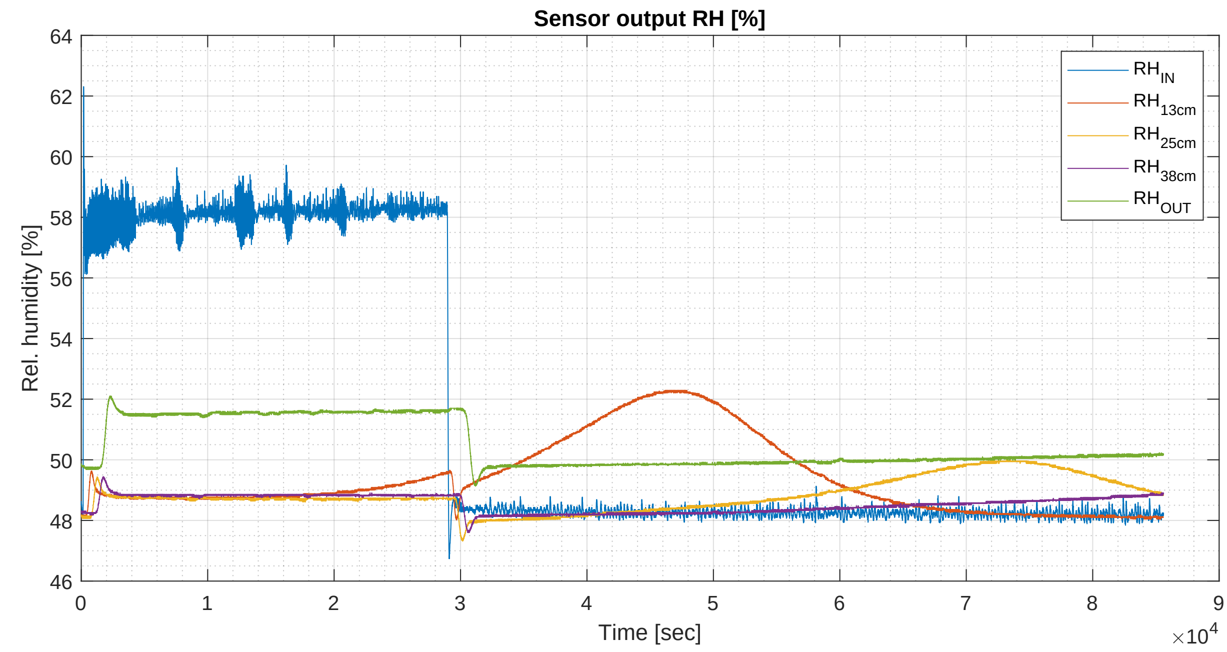


Figure 3.17: Relative humidity measurements in Run 5, cycle 1.

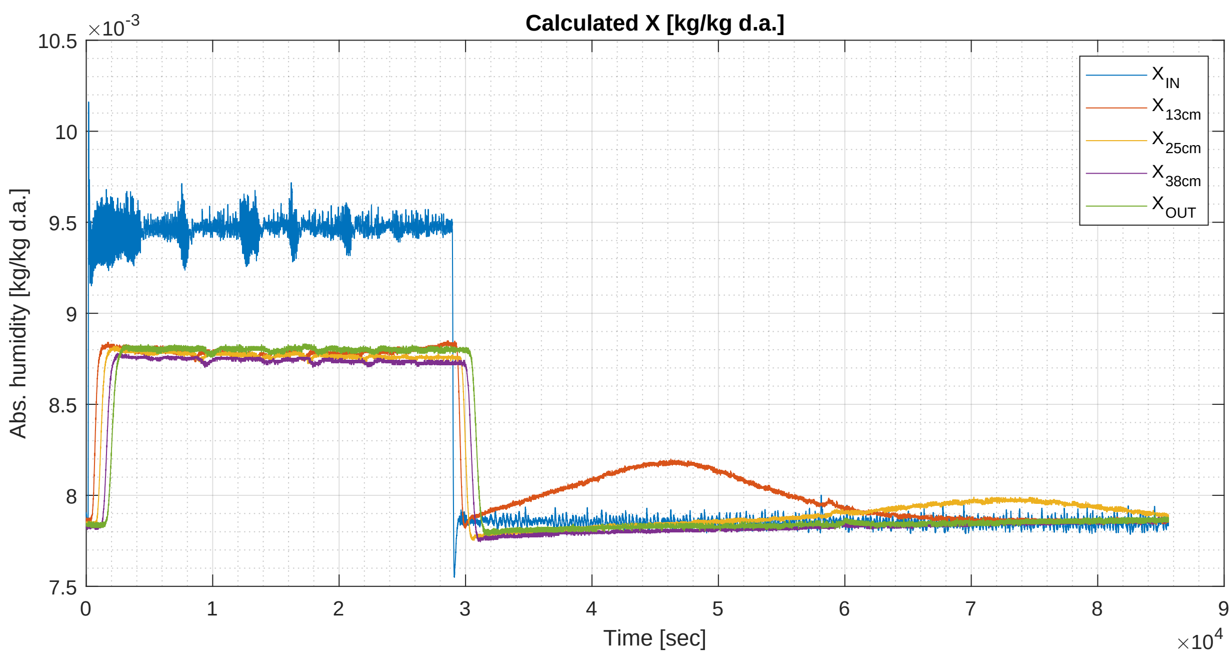


Figure 3.18: Absolute humidity calculated from RH and T in Run 5, cycle 1.

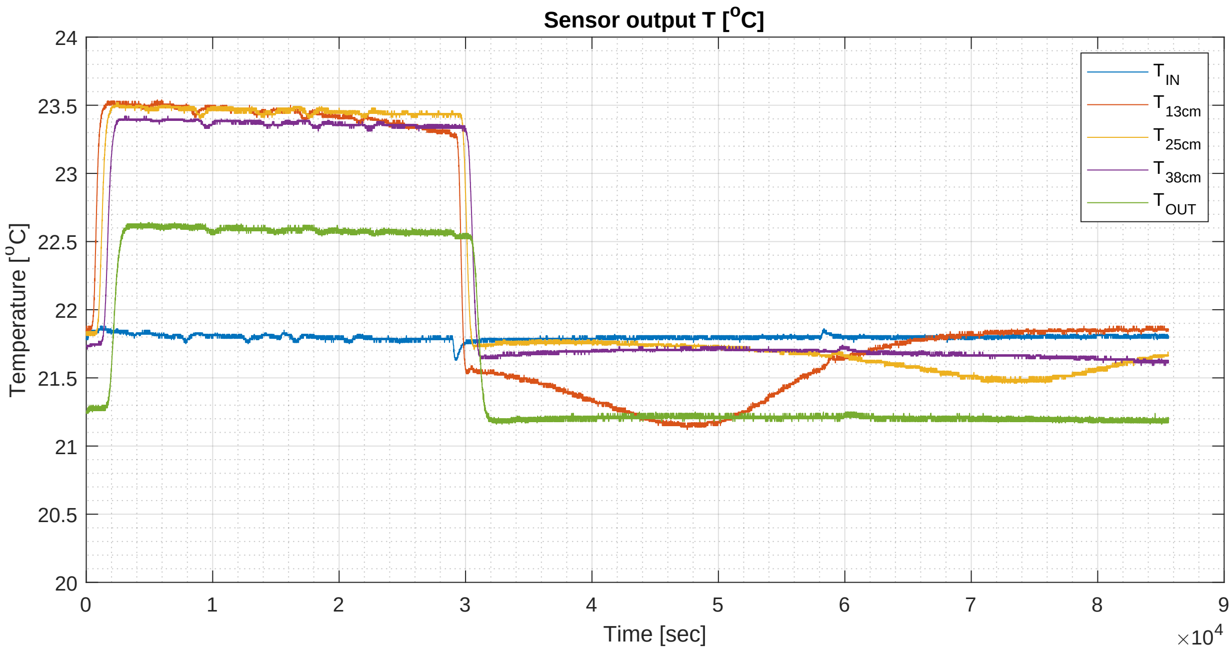


Figure 3.19: Temperature measurements in Run 5, cycle 1.

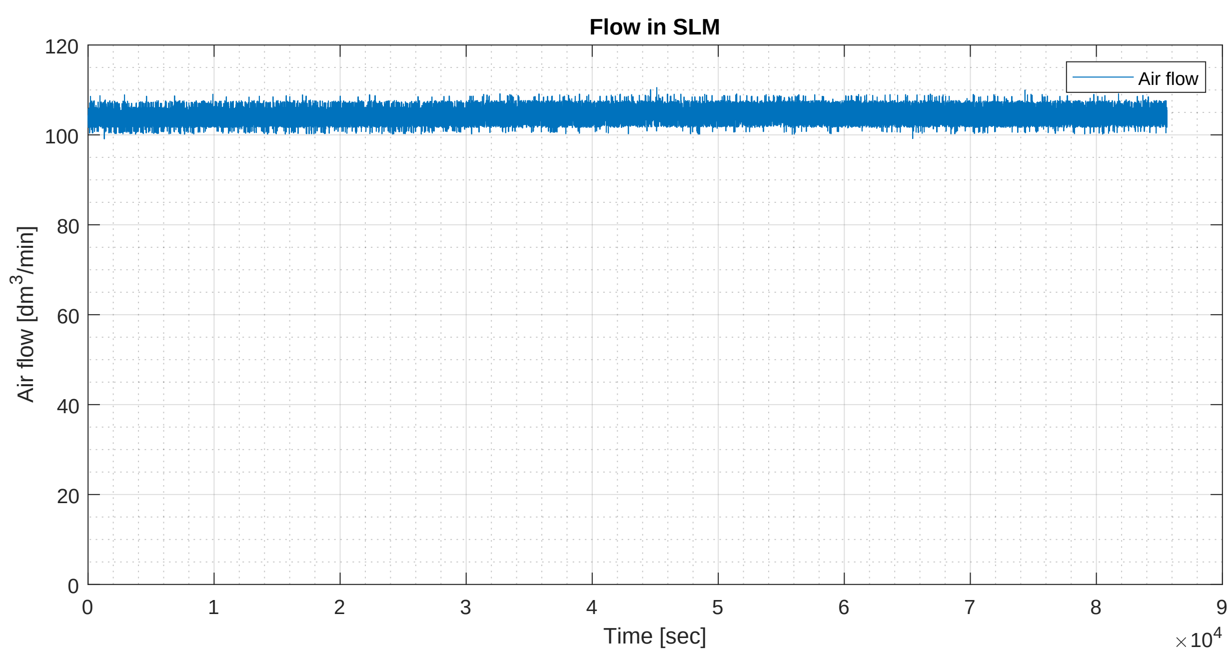


Figure 3.20: Flow measurements from RH and T in Run 5, cycle 1.

### Second 24h cycle;

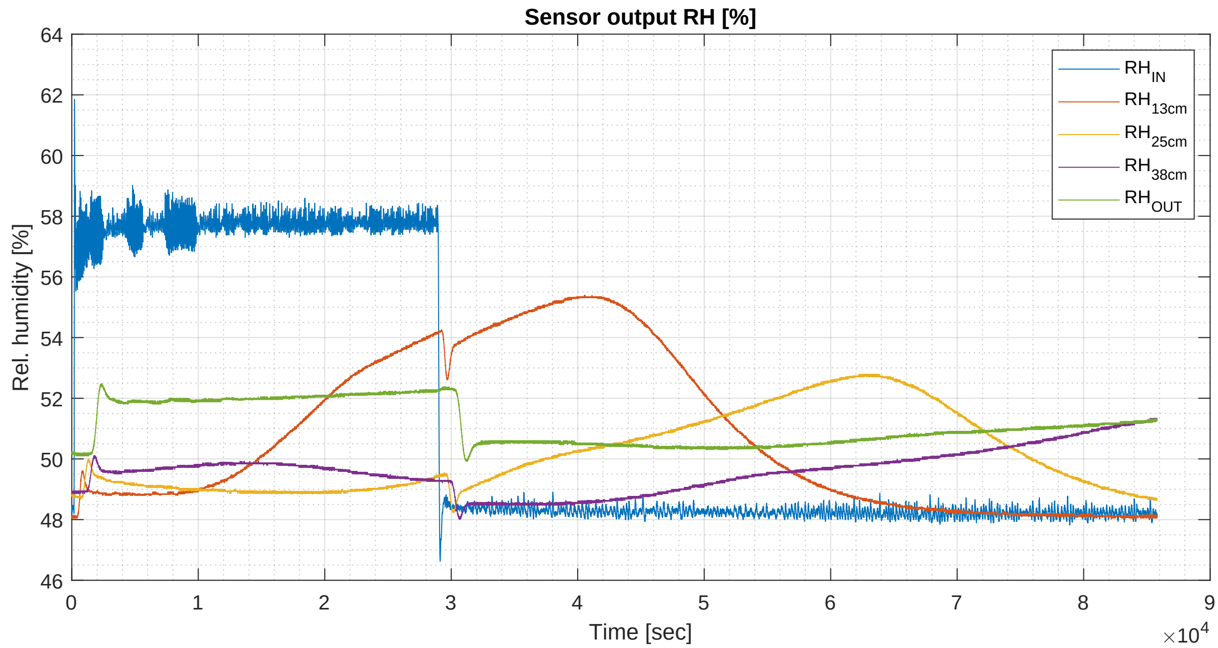


Figure 3.21: Relative humidity measurements in Run 5, cycle 2.

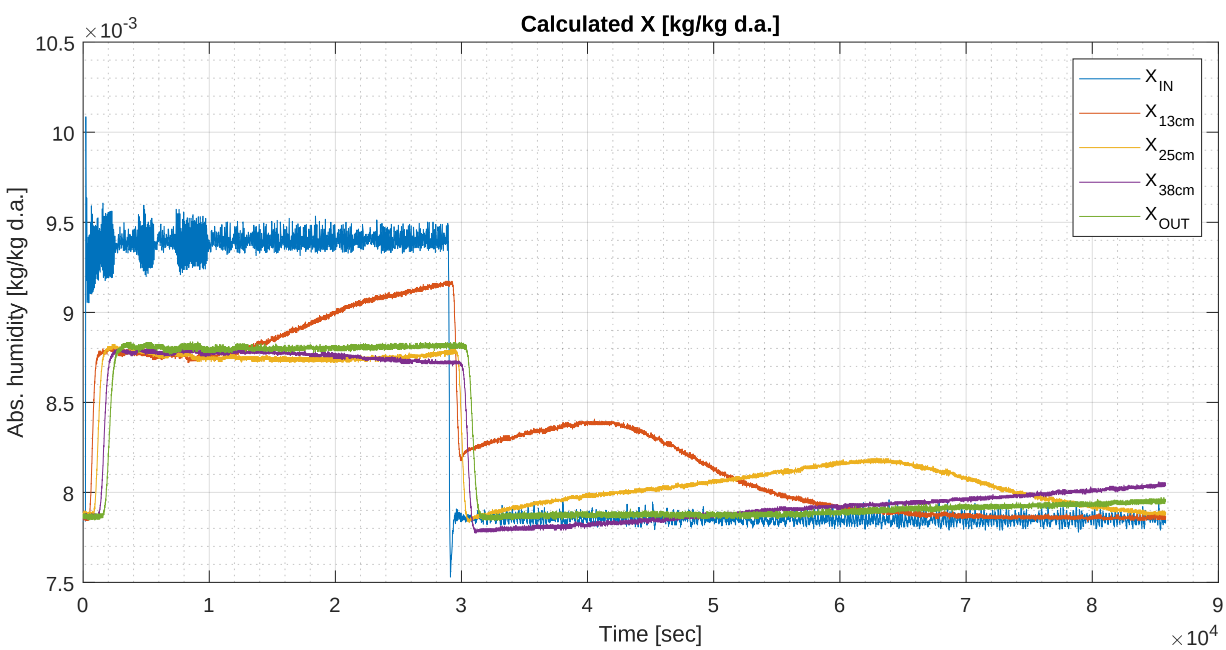


Figure 3.22: Absolute humidity calculated from RH and T in Run 5, cycle 2.

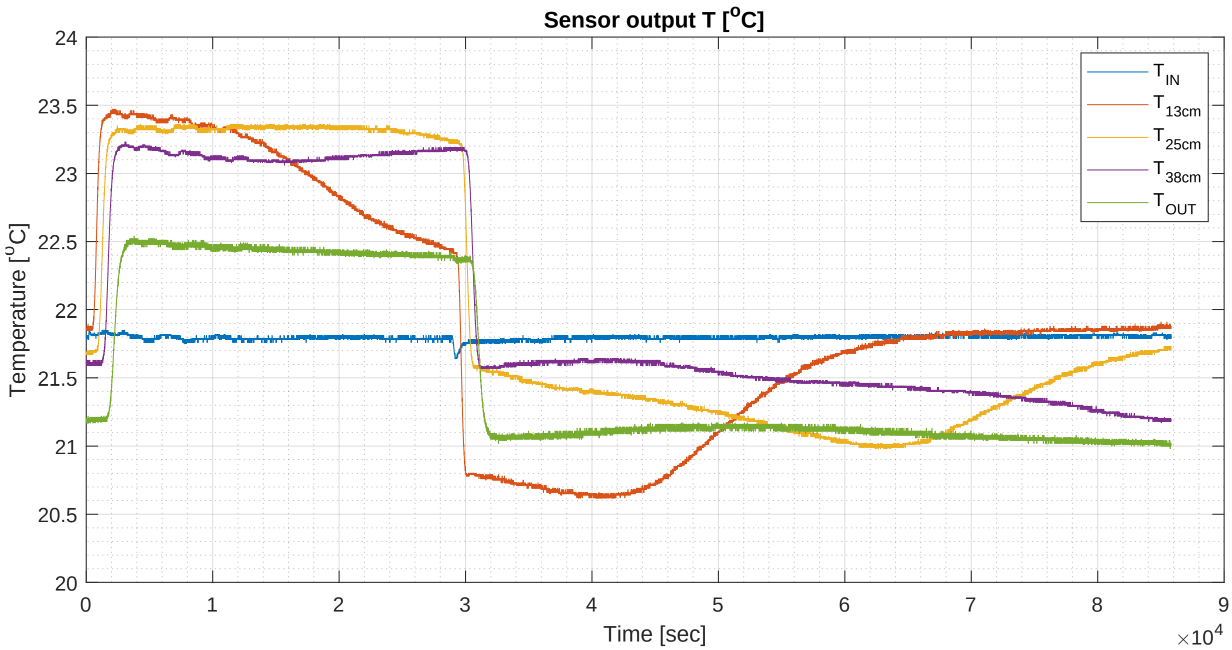


Figure 3.23: Temperature measurements in Run 5, cycle 2.

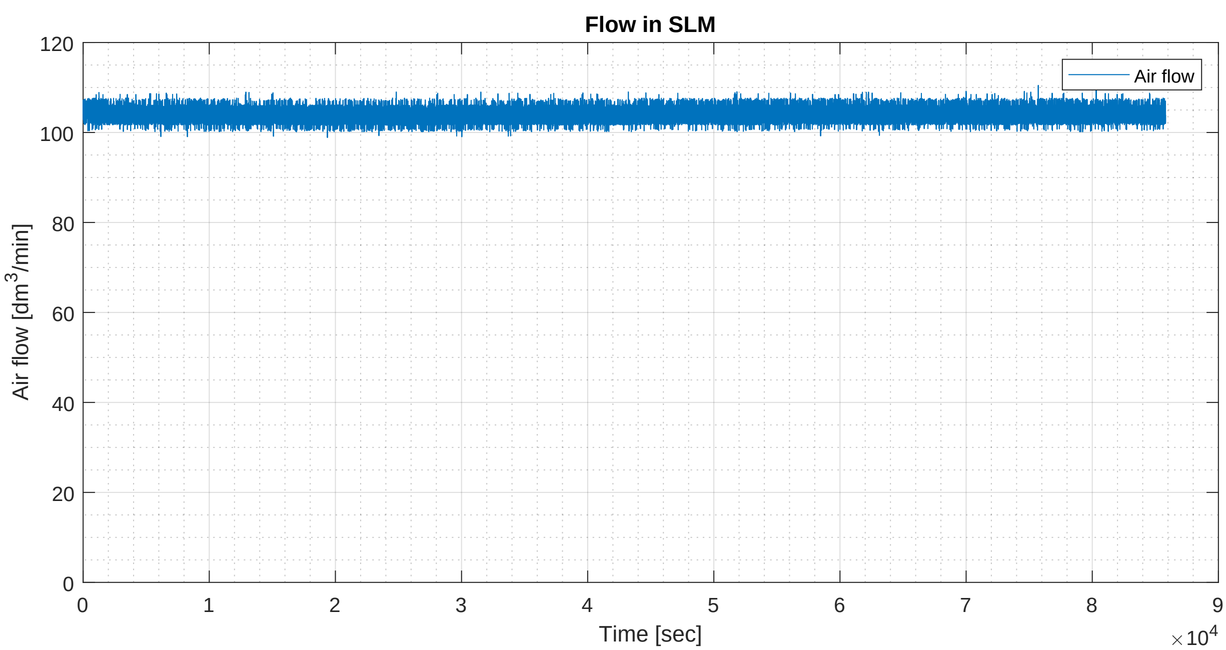


Figure 3.24: Flow measurements from RH and T in Run 5, cycle 2.

## Third 24h cycle;

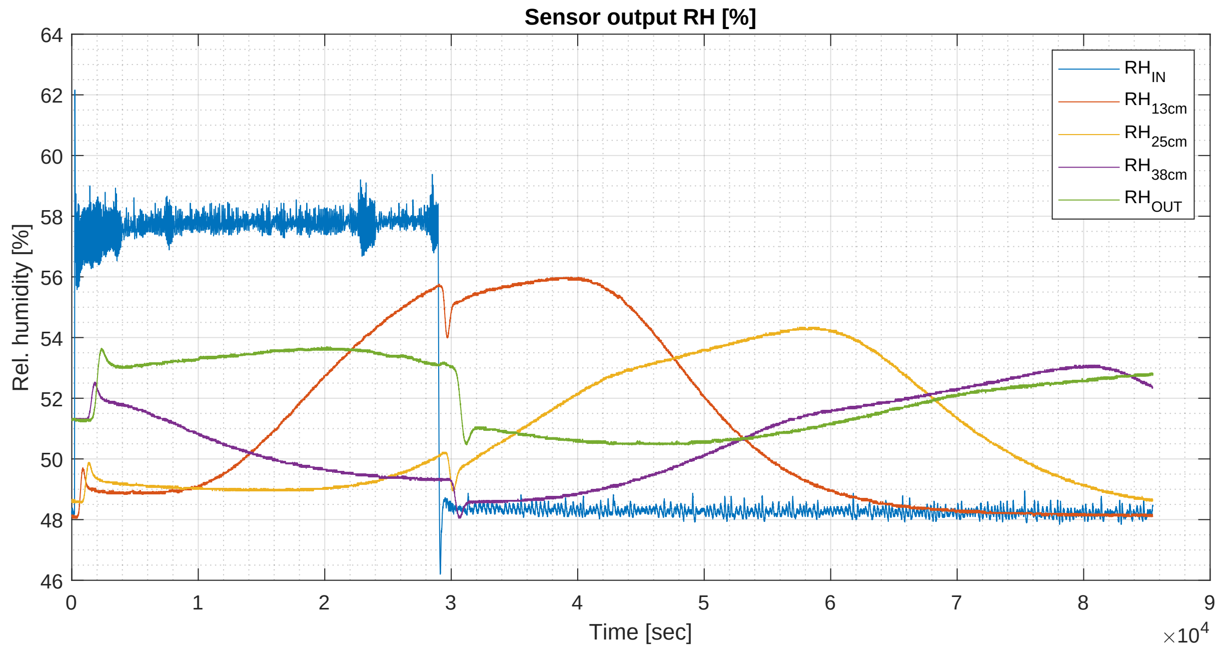


Figure 3.25: Relative humidity measurements in Run 5, cycle 3.

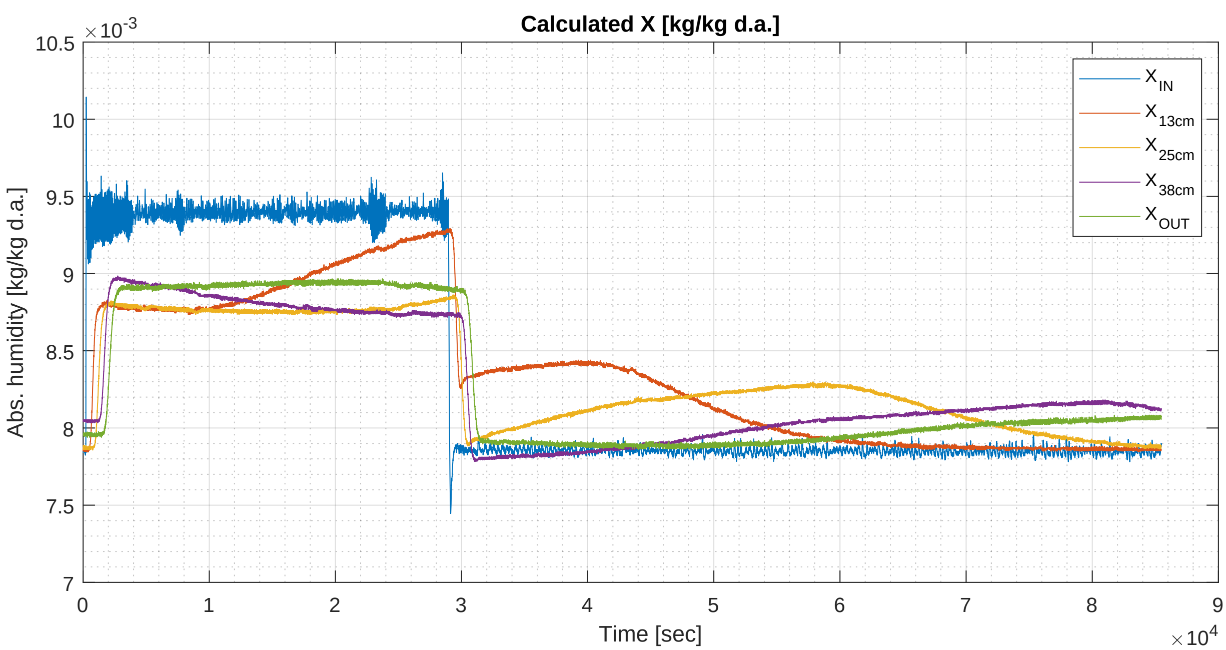


Figure 3.26: Absolute humidity calculated from RH and T in Run 5, cycle 3.

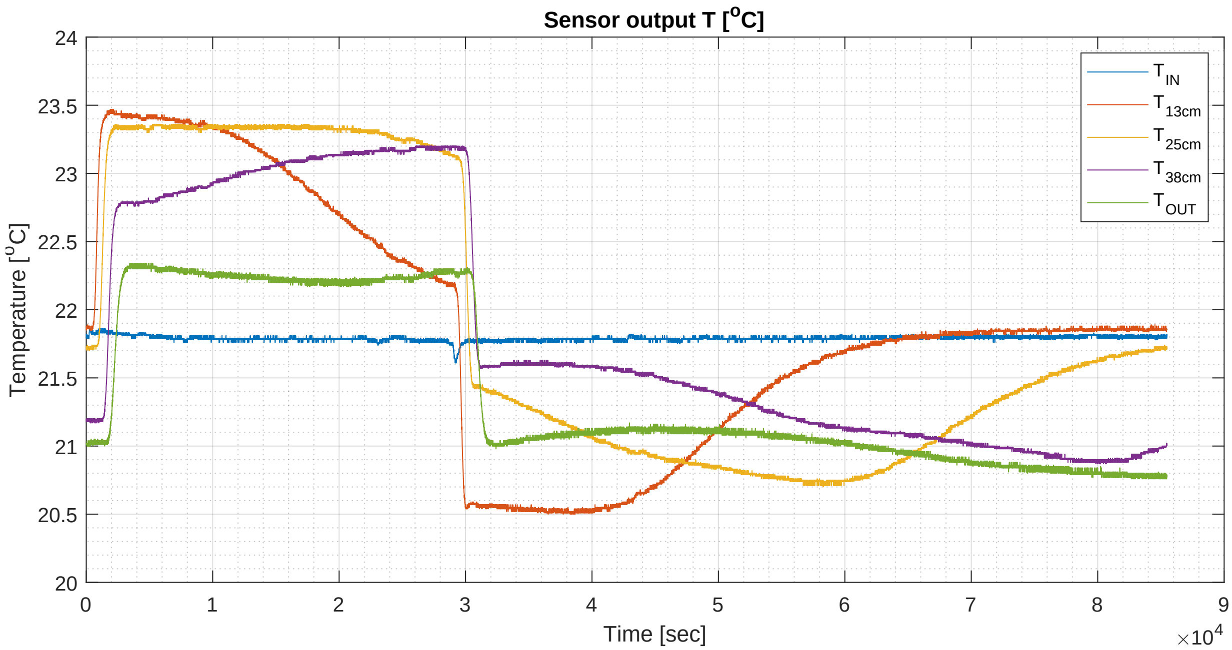


Figure 3.27: Temperature measurements in Run 5, cycle 3.

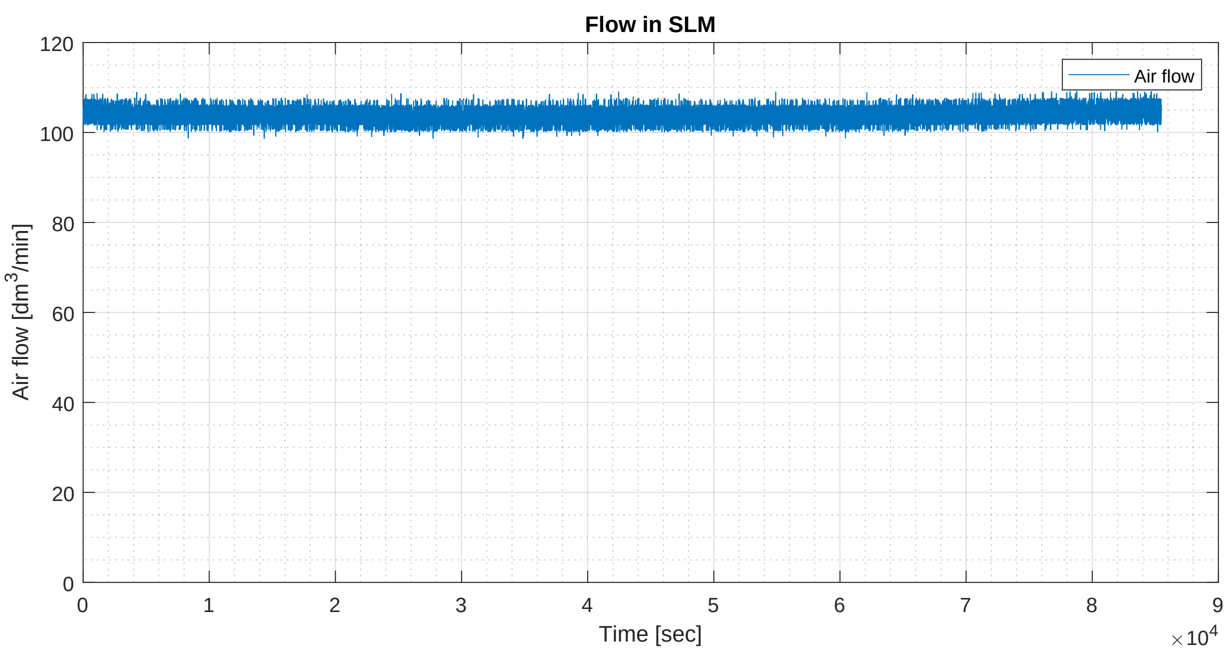


Figure 3.28: Flow measurements from RH and T in Run 5, cycle 3.

## 3.6 Run 6: Sample 11, long cycle between 50 and 60 %RH.

| | |
|---|---|
| Height of silica in column [$m$] | 0.31 |
| Mass of silica in column [$g$] | 2,267 |
| Volumetric flow rate [$dm^3/min$] | 97.5 |
| Silica gel sample | 11 |
| Relative humidity initial [%RH] | 49.1 / 48.5 |
| Relative humidity low [%RH] | 49.5 |
| Relative humidity high [%RH] | 58.8 |
| Duration [$sec$] | 86,153, 85,788, 94,203 |
| Half cycle time $\tau$ | 8 / 16 $h$ |

Table 3.6: Experiment parameters Run 6

### Discussion of Run 6

Run 6 is executed after run C, D and 2. It is therefor following secondary isotherm.

The absolute humidity is not rising much during the high part of the cycle. This means the silica gel has a high sorption capacity: it is not saturating during this time.

The step in absolute humidity after the input step (due to temperature increase) differs a bit in height for the different parts of the packed bed, because the packed bed has not reached initial conditions everywhere.

# First 24h cycle;

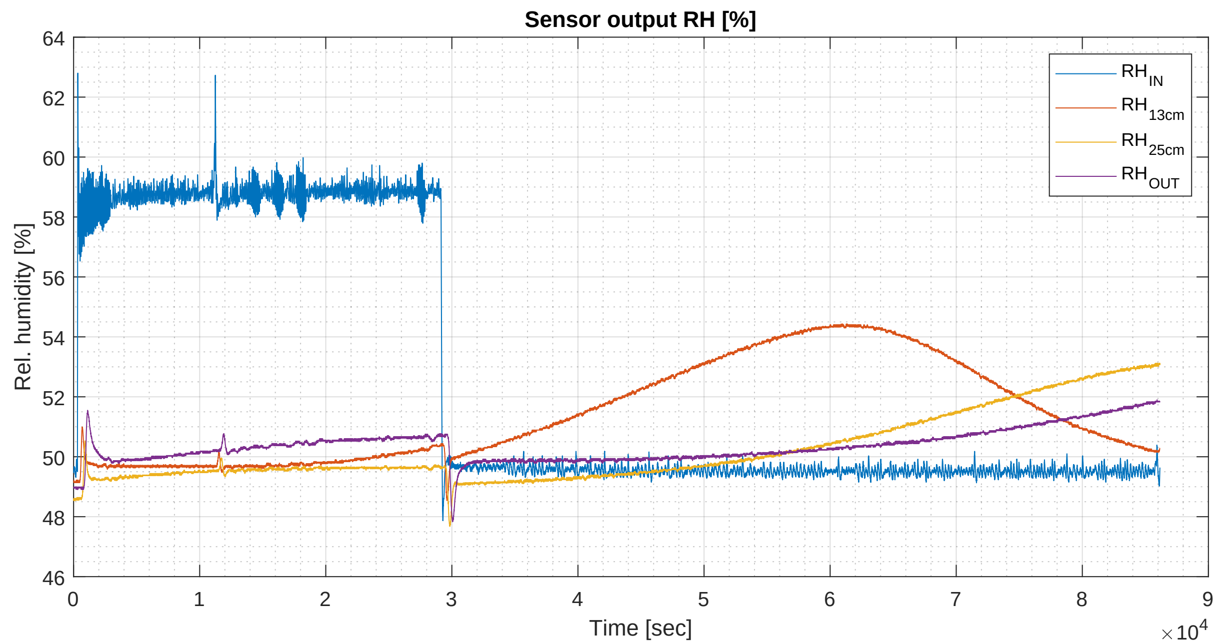


Figure 3.29: Relative humidity measurements in Run 6, cycle 1.

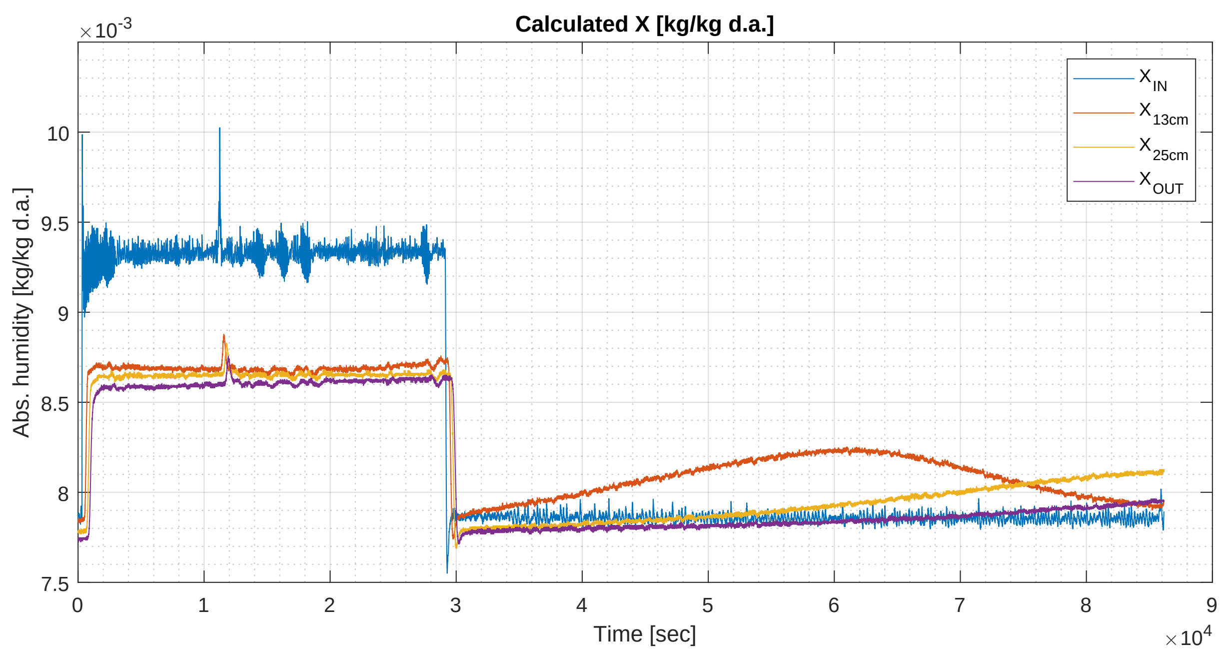


Figure 3.30: Absolute humidity calculated from RH and T in Run 6, cycle 1.

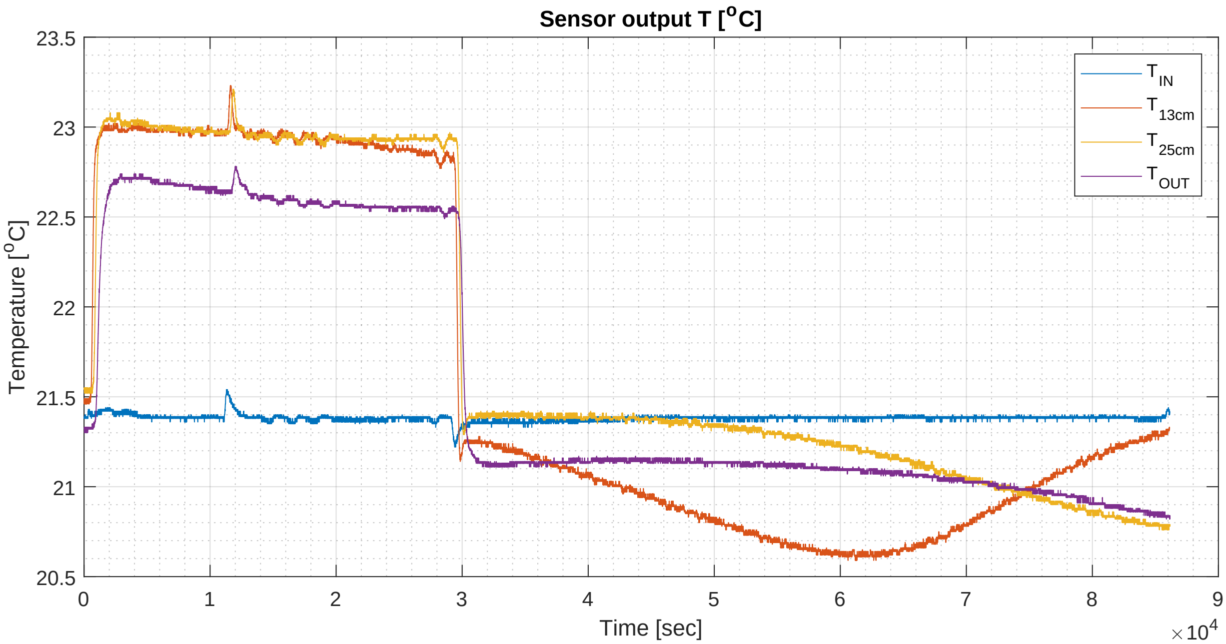


Figure 3.31: Temperature measurements in Run 6, cycle 1.

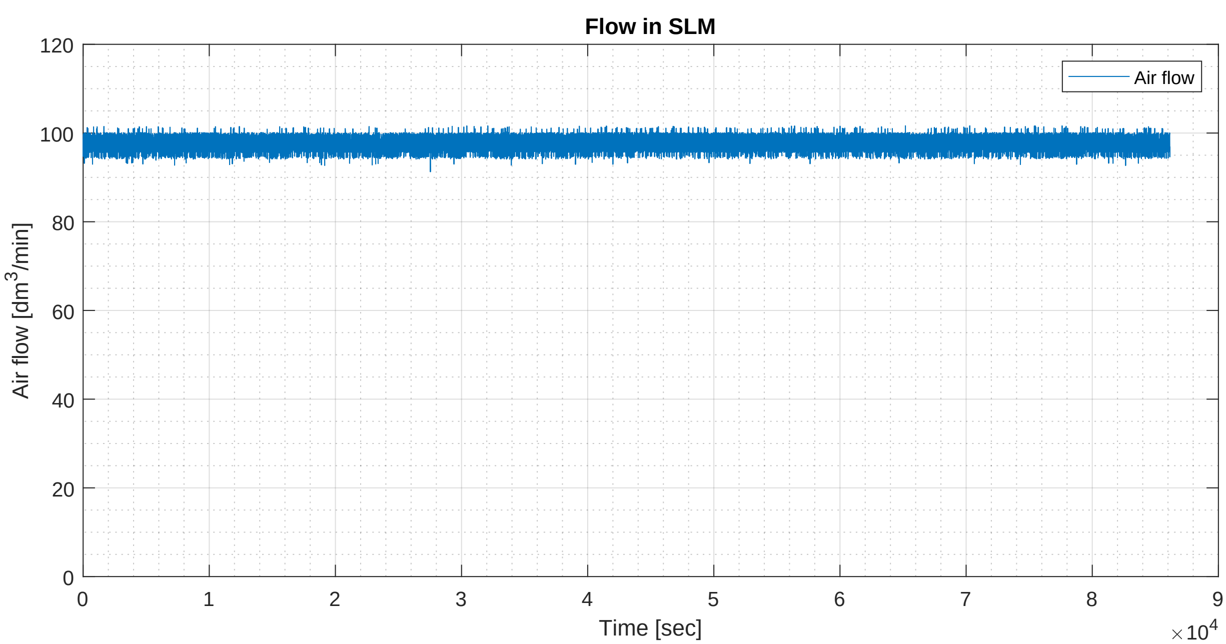


Figure 3.32: Flow measurements from RH and T in Run 6, cycle 1.

### Second 24h cycle;

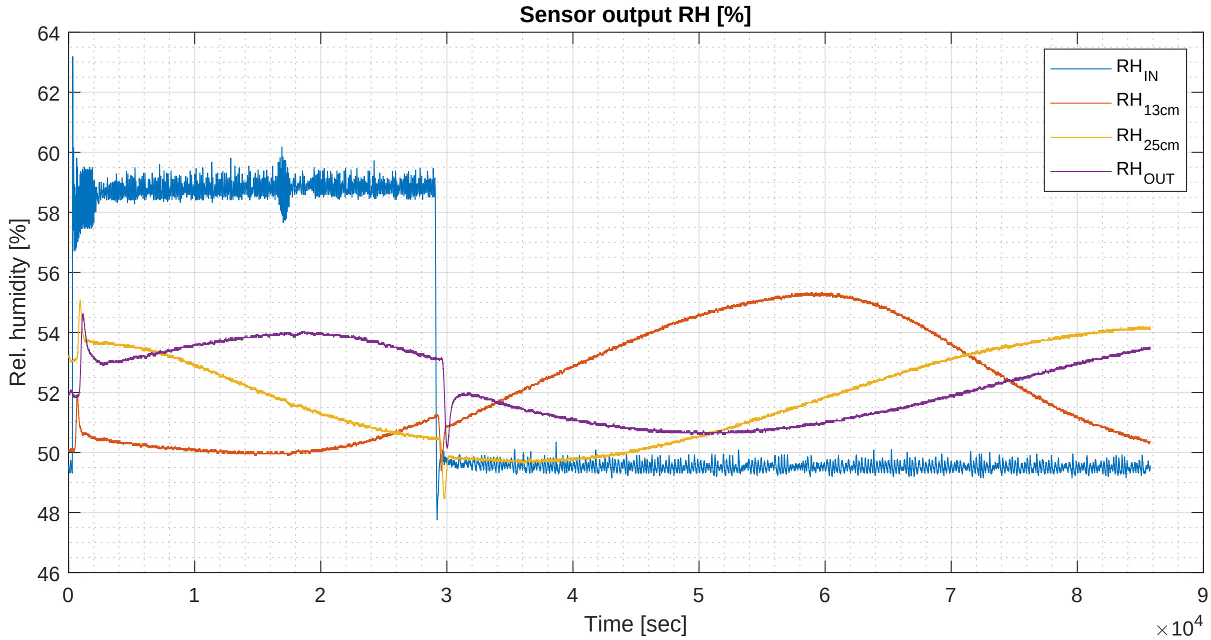


Figure 3.33: Relative humidity measurements in Run 6, cycle 2.

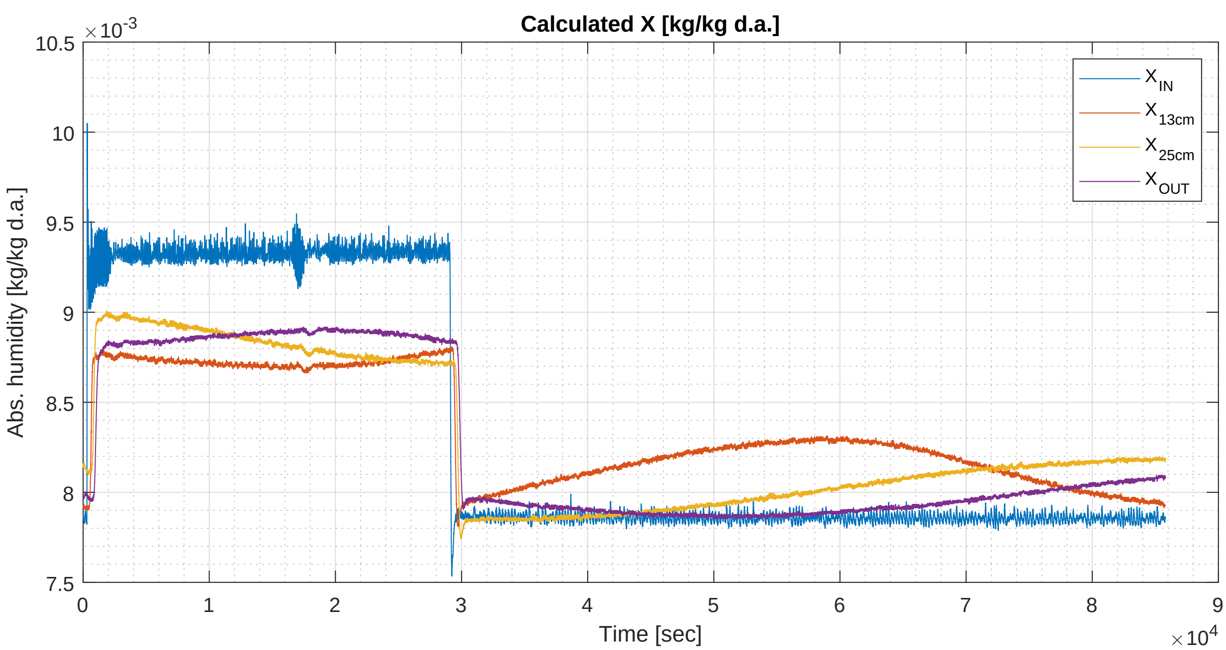


Figure 3.34: Absolute humidity calculated from RH and T in Run 6, cycle 2.

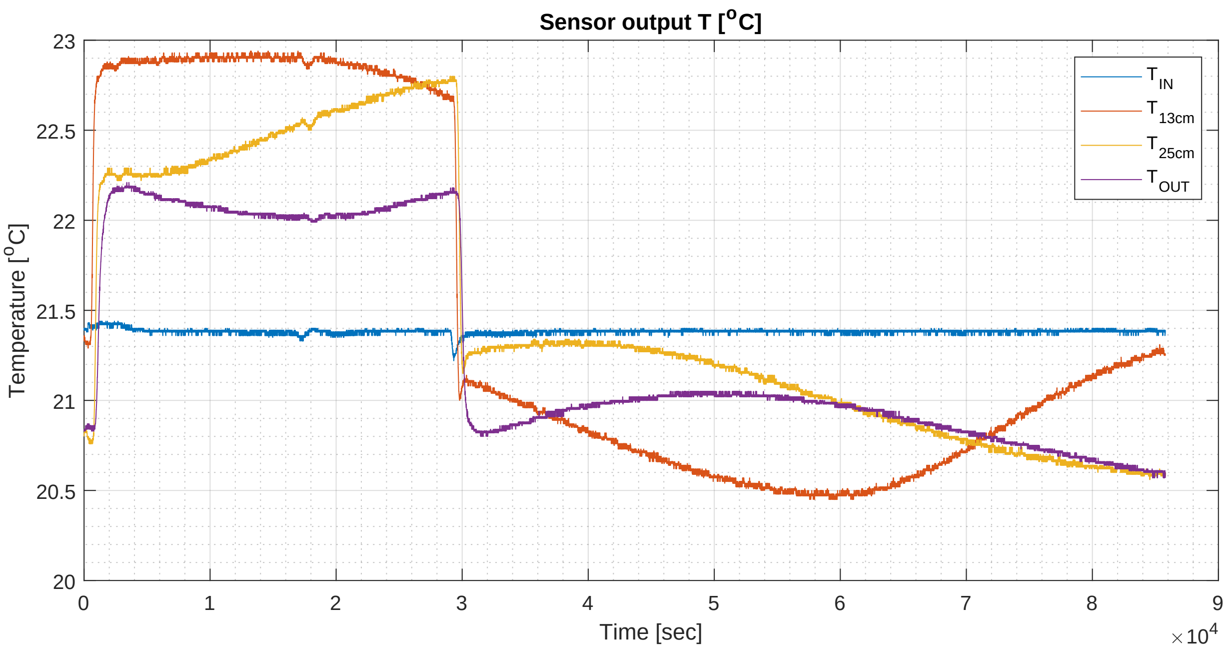


Figure 3.35: Temperature measurements in Run 6, cycle 2.

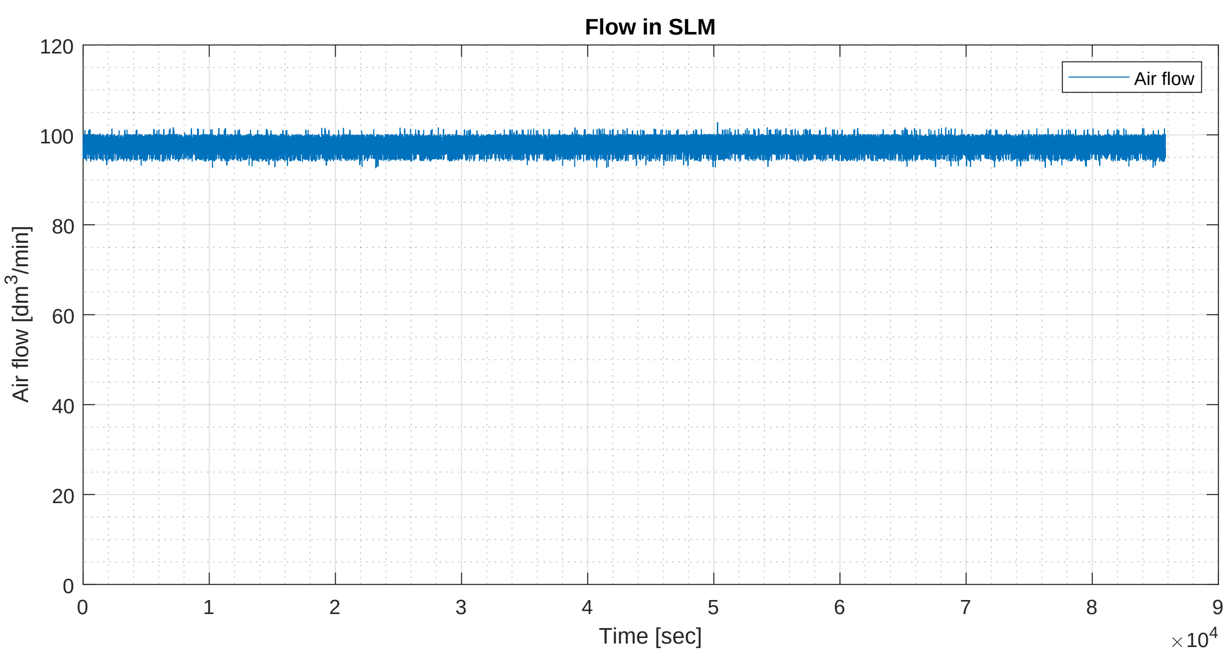


Figure 3.36: Flow measurements from RH and T in Run 6, cycle 2.

## Third 24h cycle;

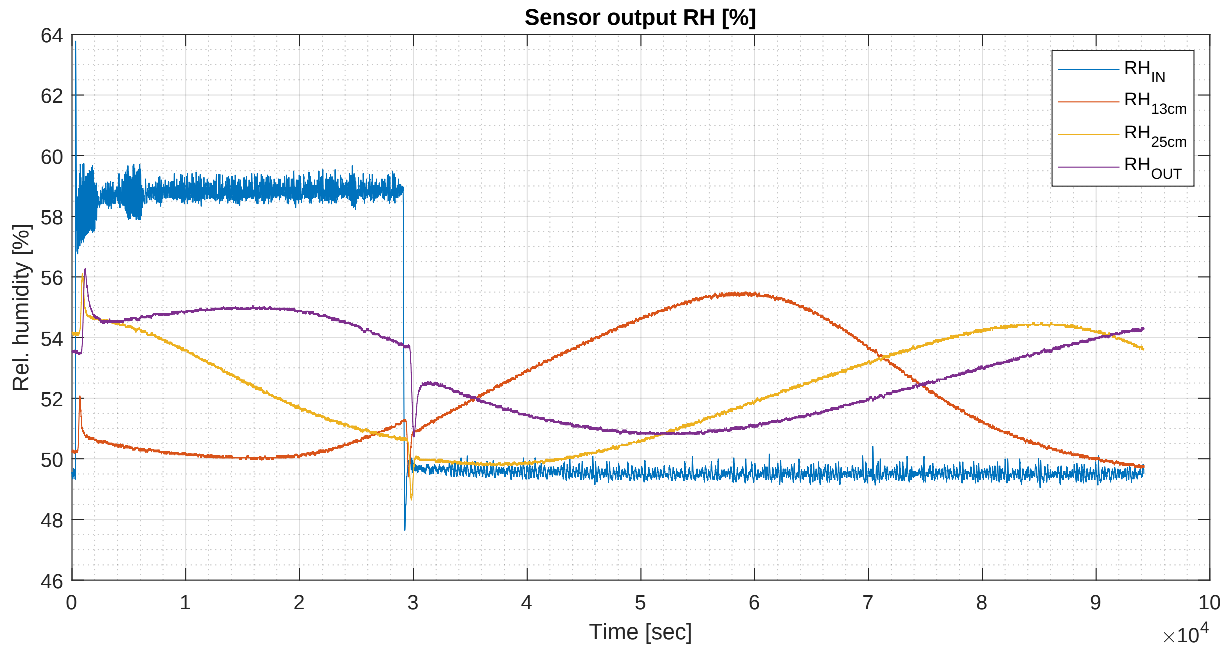


Figure 3.37: Relative humidity measurements in Run 6, cycle 3.

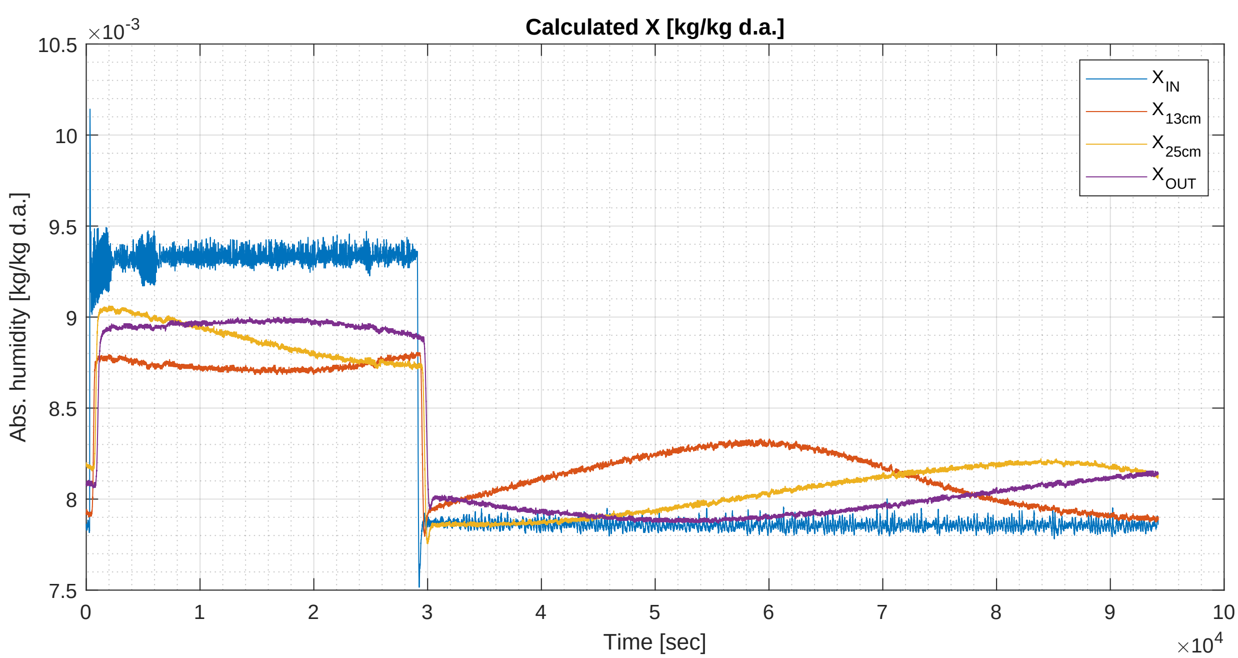


Figure 3.38: Absolute humidity calculated from RH and T in Run 6, cycle 3.

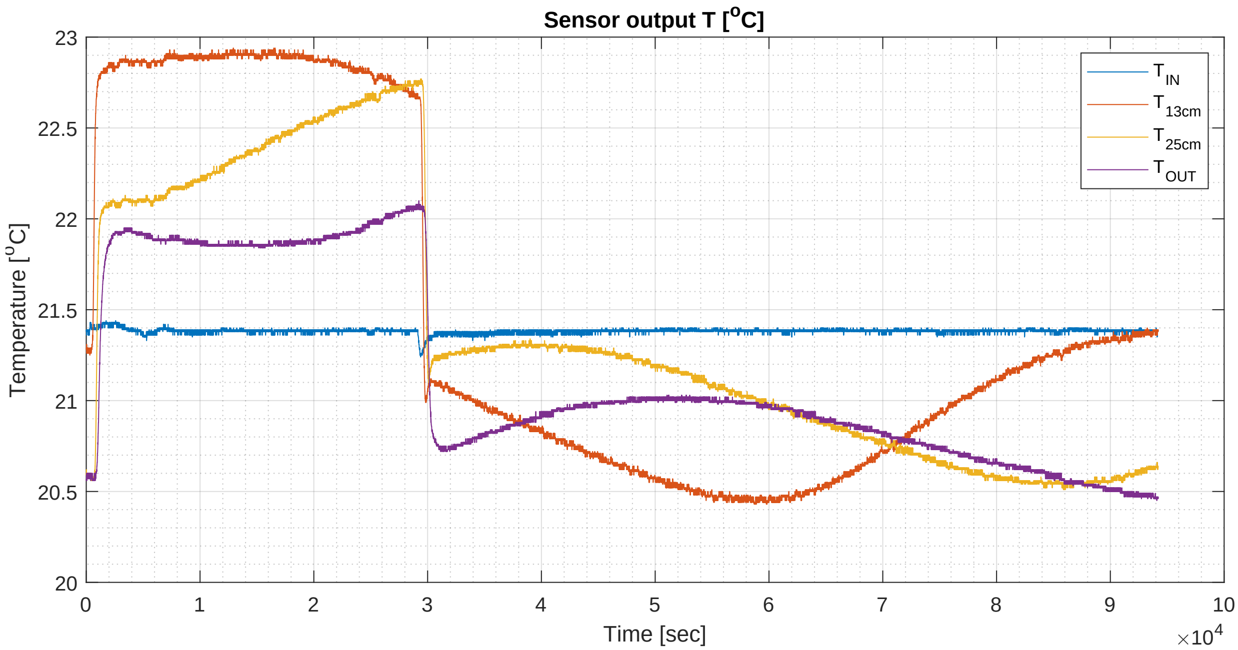


Figure 3.39: Temperature measurements in Run 6, cycle 3.

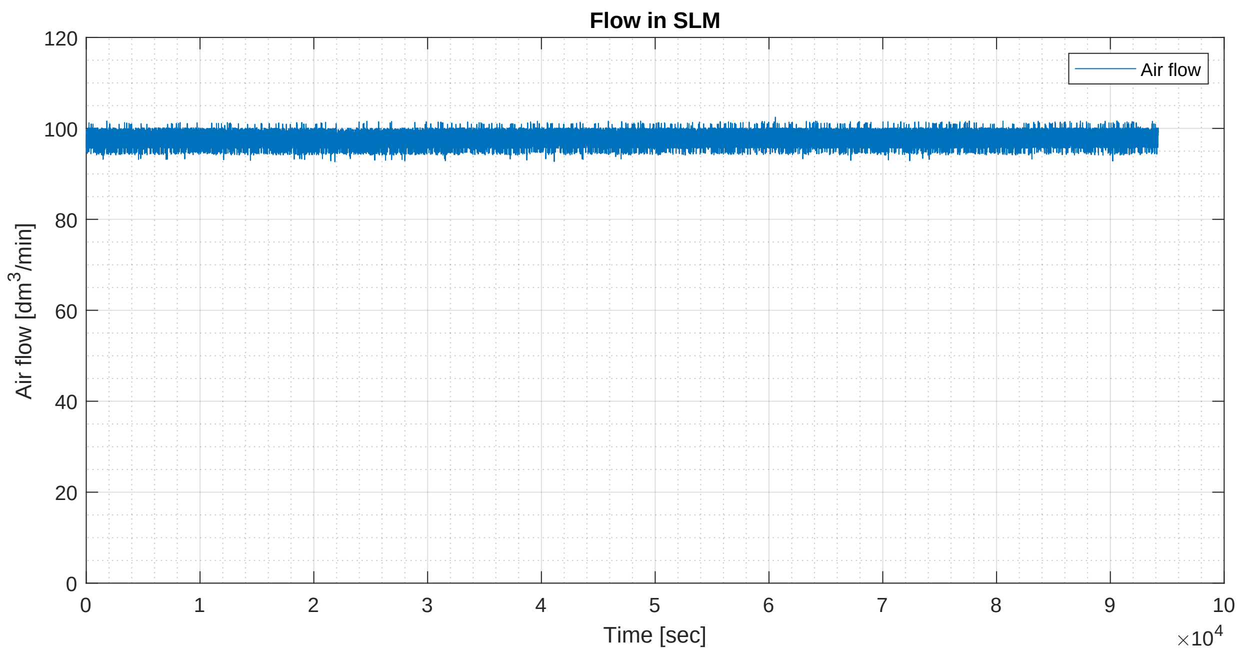


Figure 3.40: Flow measurements from RH and T in Run 6, cycle 3.

## 3.7 Run 7: Sample 12, long cycle between 50 and 60 %RH.

| | |
|---|---|
| Height of silica in column [$m$] | 0.260 |
| Mass of silica in column [$g$] | 3,193 |
| Volumetric flow rate [$dm^3/min$] | 103.5 |
| Silica gel sample | 12 |
| Relative humidity initial [%RH] | 50.9 |
| Relative humidity low [%RH] | 51.0 |
| Relative humidity high [%RH] | 61.1 |
| Duration [$sec$] | 86,793, 86,545, 90,664 |
| Half cycle time $\tau$ | 8 / 16 $h$ |

Table 3.7: Experiment parameters Run 7

### Discussion of Run 7

Run 7 is executed after run A, B and 3. Sample follows secondary isotherm.

Absolute humidity is rising in the first part of the column during the high part of the cycle (red line in $X$ vs. $time$ plot).

By the end of the 24-hour run the outlet air has reached inlet conditions, for both temperature and humidity. This is happening in all three cycles.

Since all cycles are started from equilibrium and the sample is always following secondary isotherm, the three cycles lead to similar results. The absolute humidity in the high part of the cycle rises a bit higher in every of the three cycles. This could indicate hysteresis is having a negative effect.

Another explanation could be that the sample is not strictly following secondary isotherm, as complete saturation at 60 %RH has not occurred. Stated different: the sample only follows secondary isotherm after complete saturation.

## First 24h cycle;

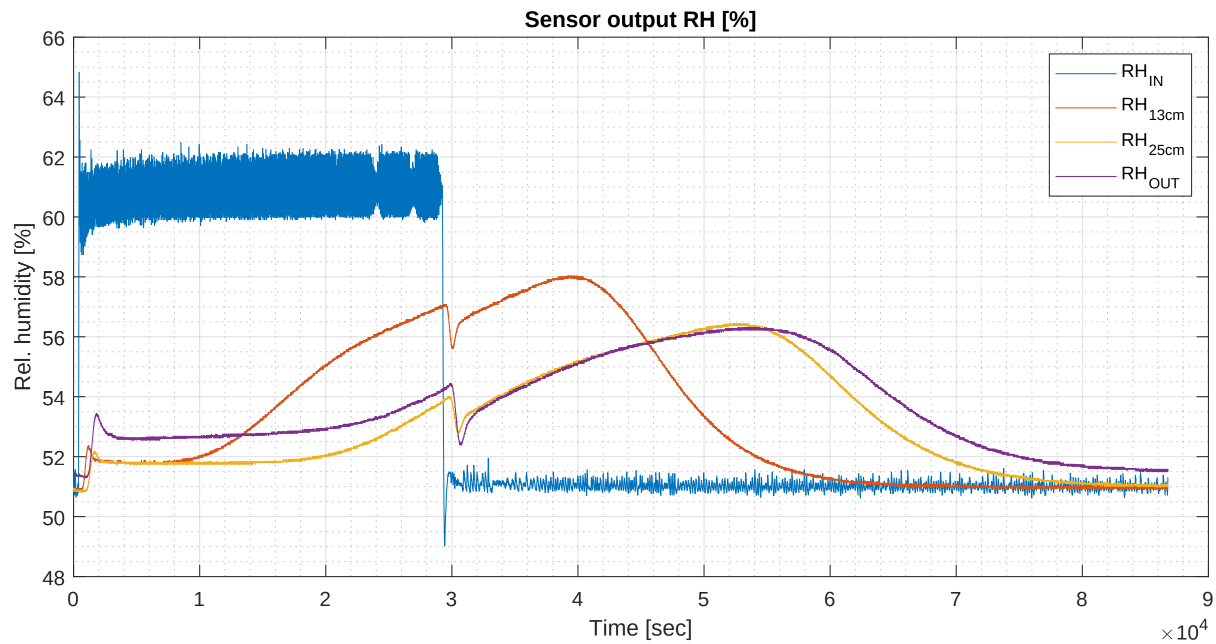


Figure 3.41: Relative humidity measurements in Run 7, cycle 1.

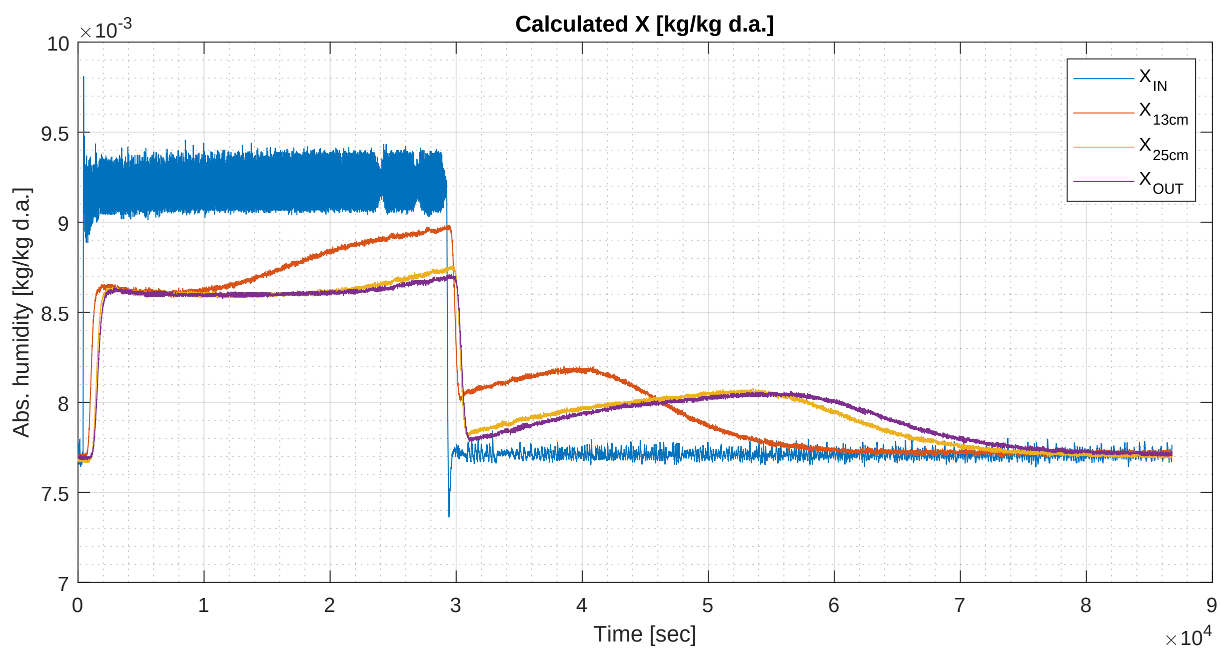


Figure 3.42: Absolute humidity calculated from RH and T in Run 7, cycle 1.

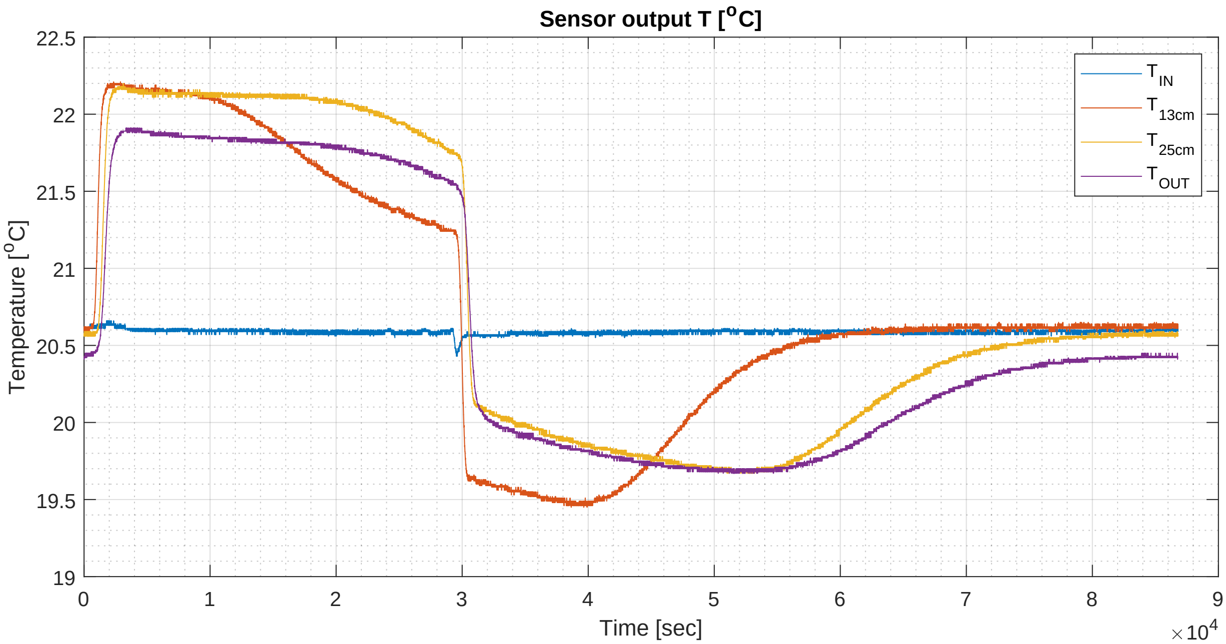


Figure 3.43: Temperature measurements in Run 7, cycle 1.

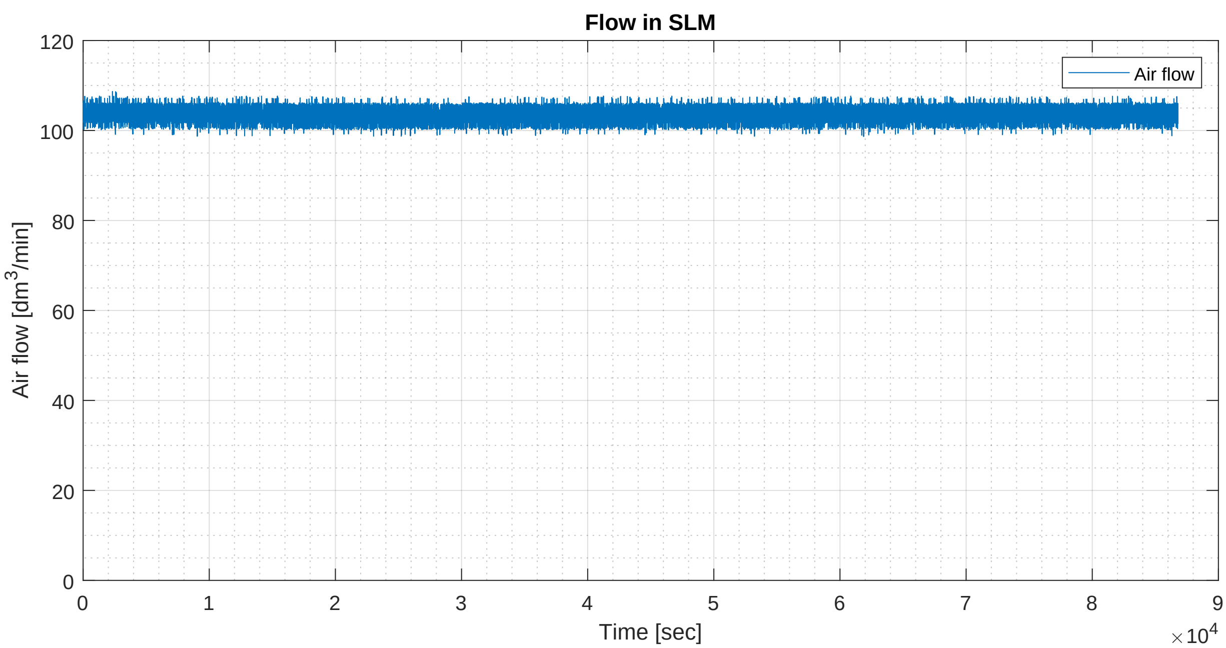


Figure 3.44: Flow measurements from RH and T in Run 7, cycle 1.

## Second 24h cycle;

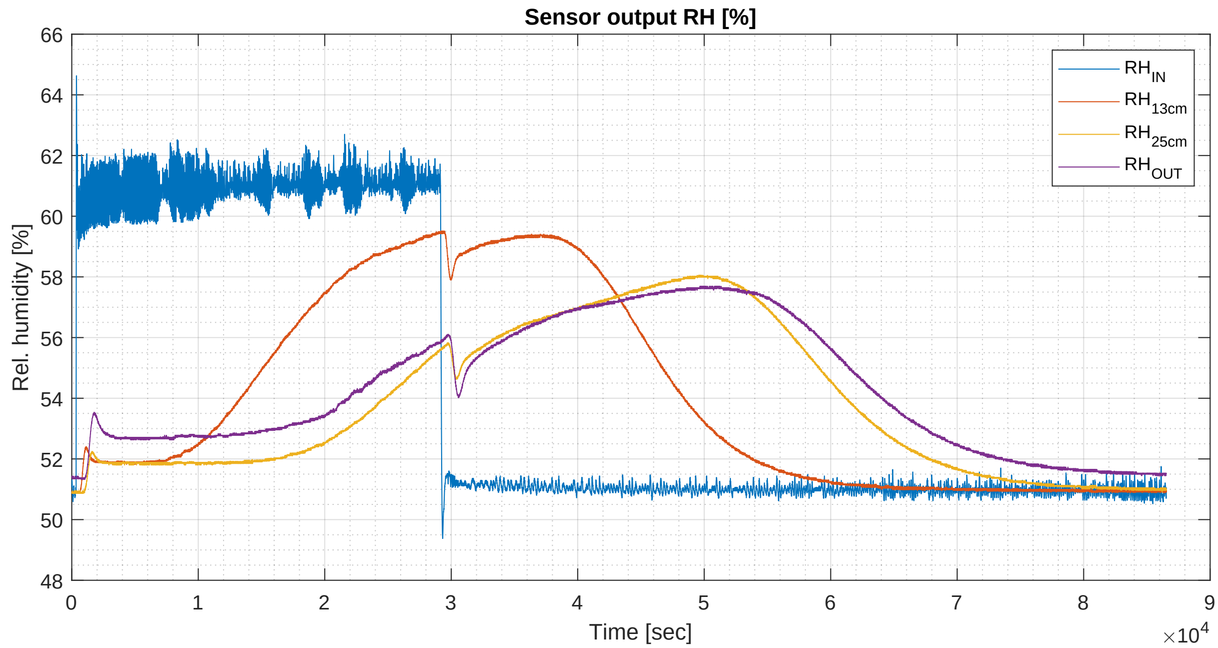


Figure 3.45: Relative humidity measurements in Run 7, cycle 2.

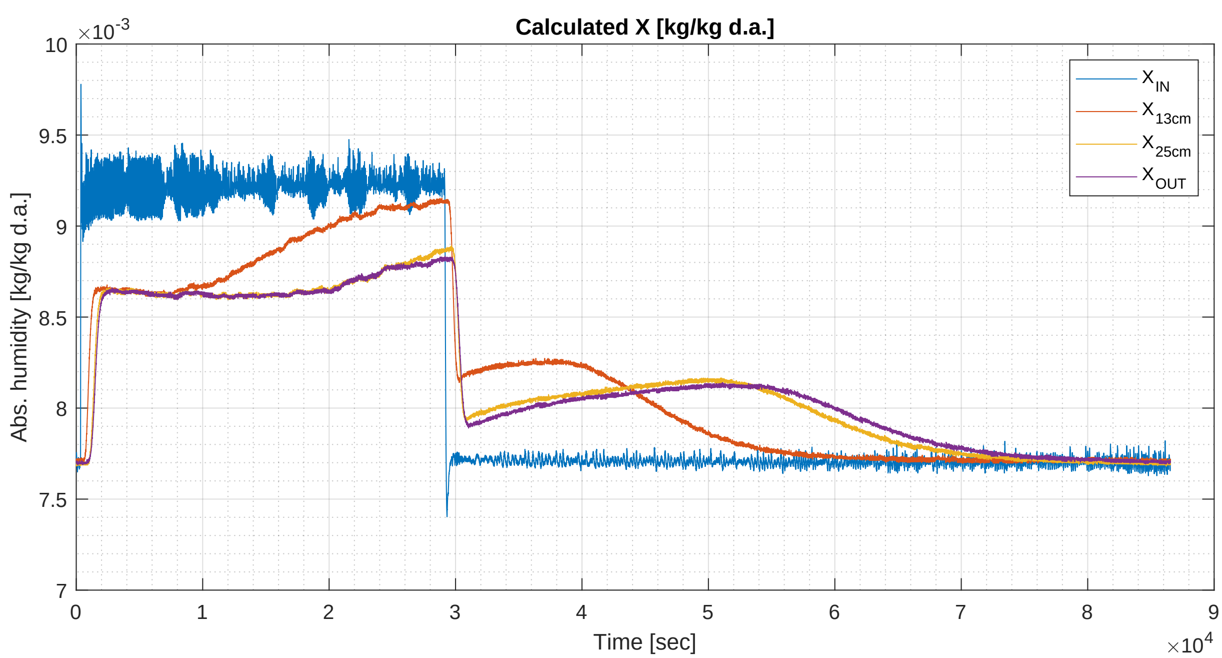


Figure 3.46: Absolute humidity calculated from RH and T in Run 7, cycle 2.

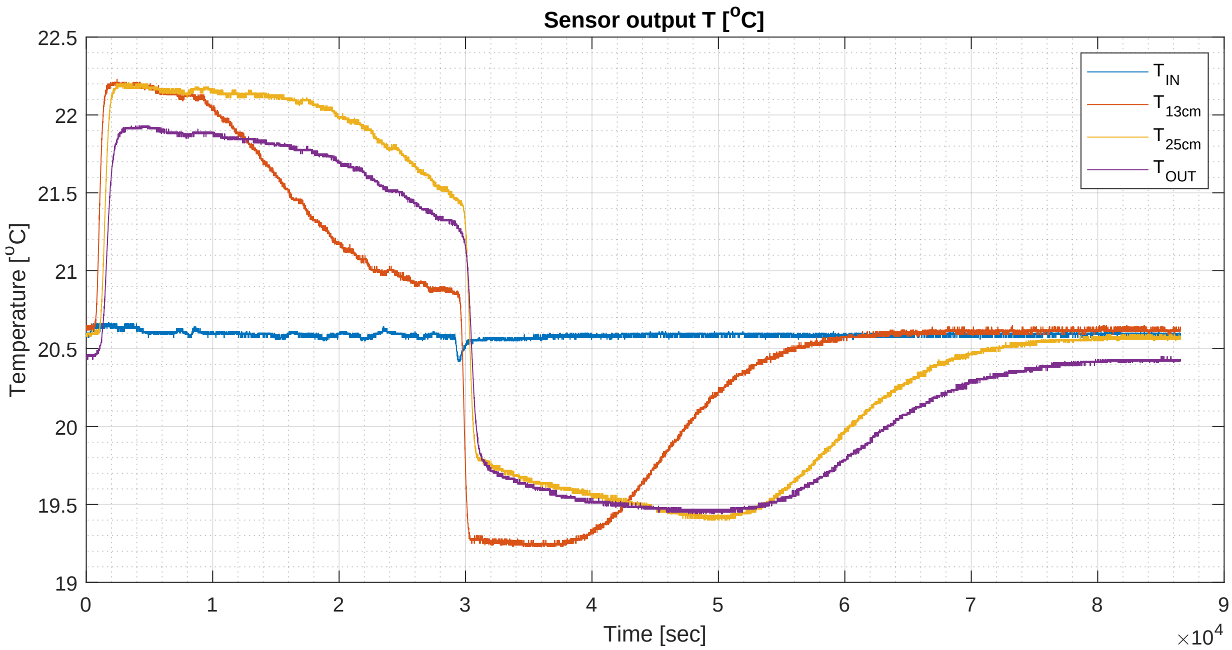


Figure 3.47: Temperature measurements in Run 7, cycle 2.

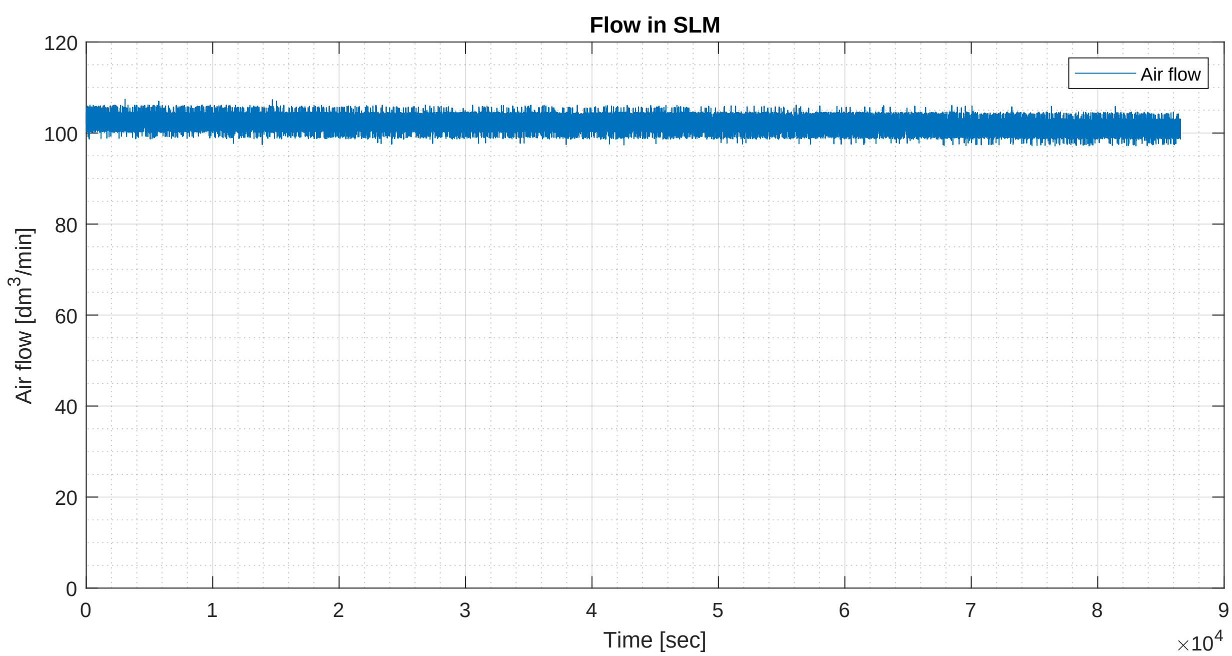


Figure 3.48: Flow measurements from RH and T in Run 7, cycle 2.

## Third 24h cycle;

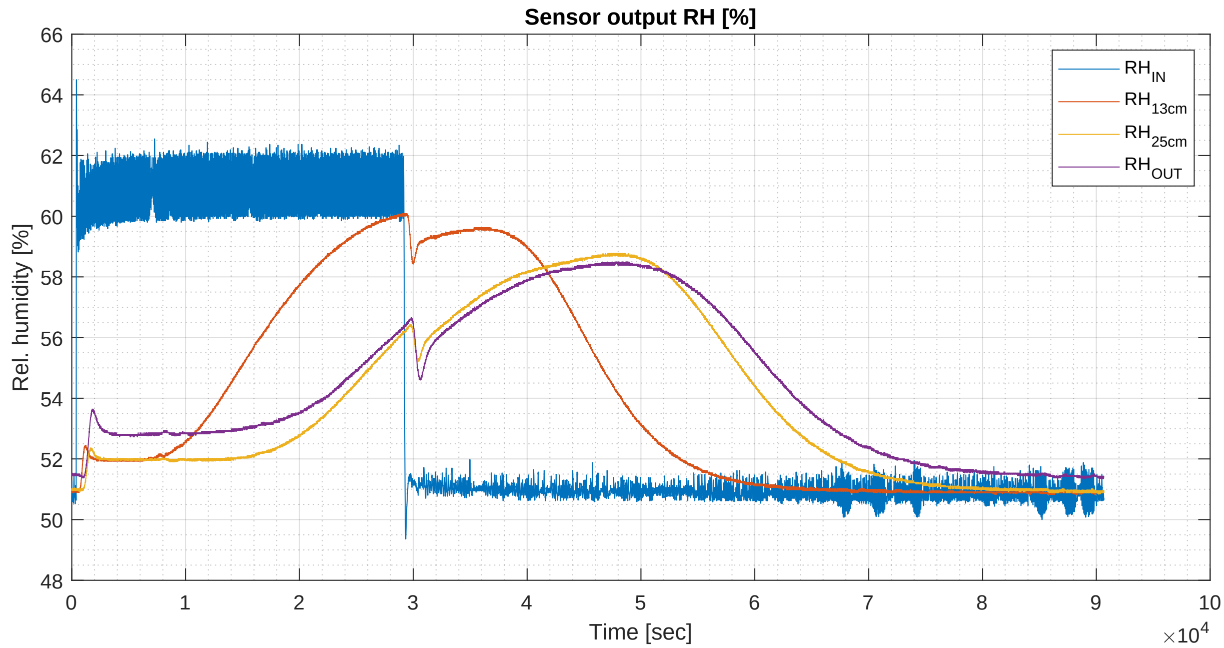


Figure 3.49: Relative humidity measurements in Run 7, cycle 3.

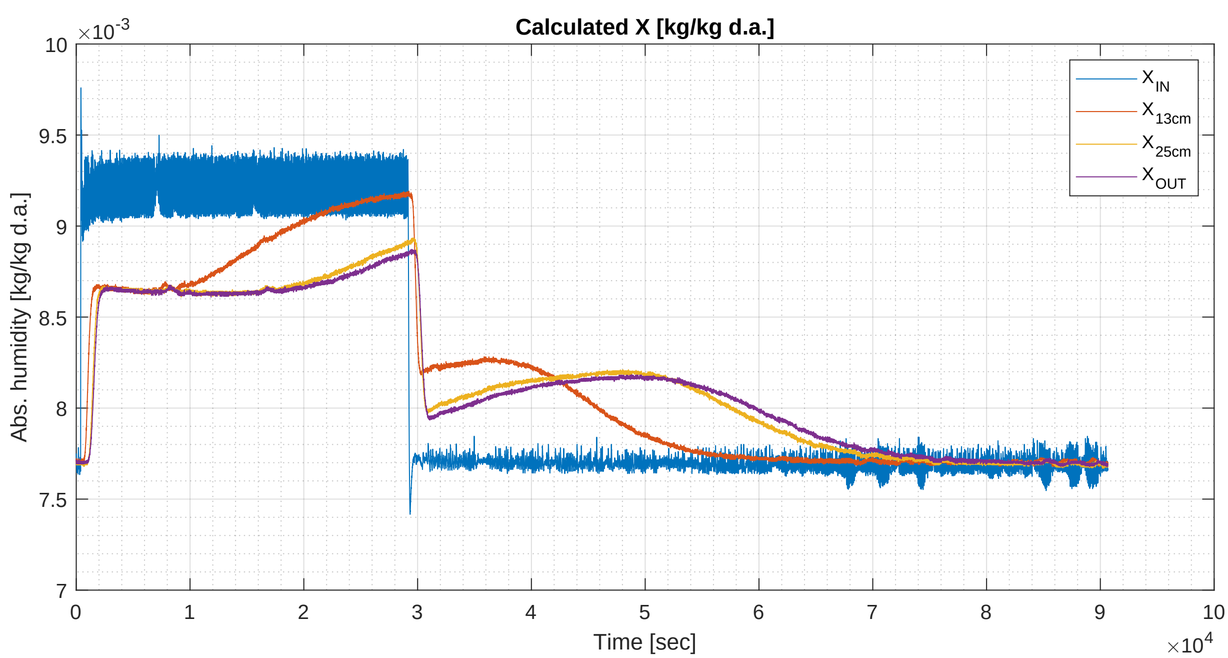


Figure 3.50: Absolute humidity calculated from RH and T in Run 7, cycle 3.

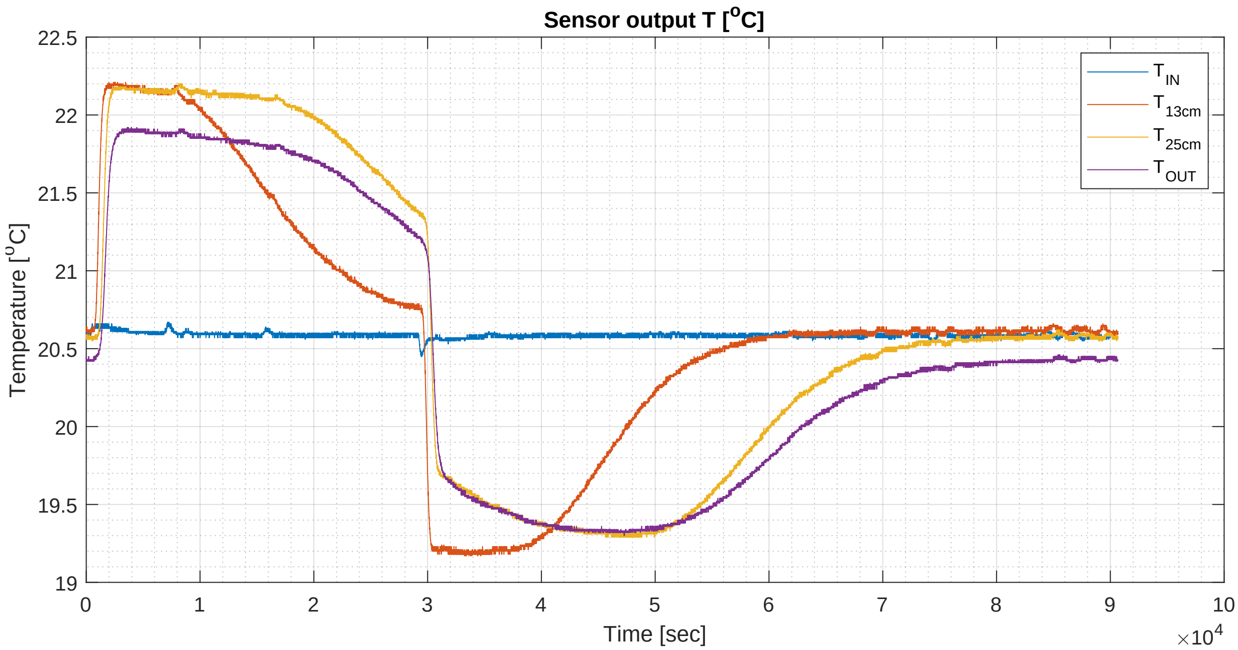


Figure 3.51: Temperature measurements in Run 7, cycle 3.

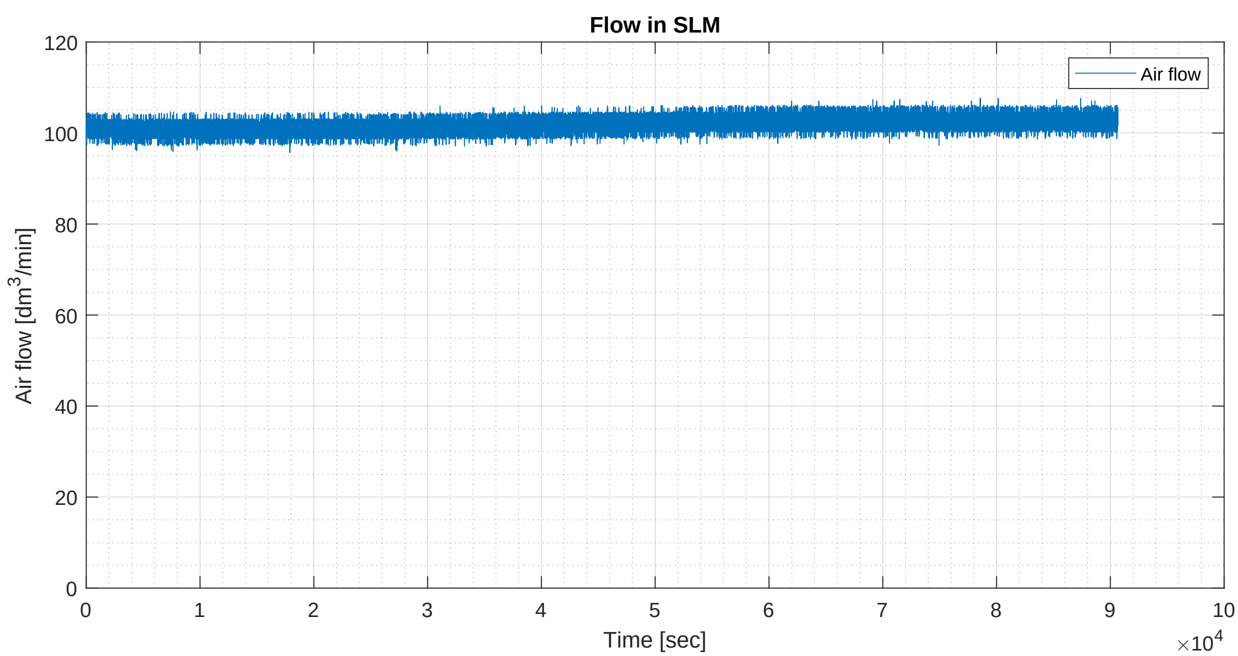


Figure 3.52: Flow measurements from RH and T in Run 7, cycle 3.

## 3.8 Run 8: Sample 14, long cycle between 50 and 60 %RH.

| | |
|---|---|
| Height of silica in column [$m$] | 0.285 |
| Mass of silica in column [$g$] | 3,041 |
| Volumetric flow rate [$dm^3/min$] | 103.4 |
| Silica gel sample | 14 |
| Relative humidity initial [%RH] | 50.8 |
| Relative humidity low [%RH] | 51.0 |
| Relative humidity high [%RH] | 61.1 |
| Duration [$sec$] | 86,425, 86,404, 91,078 |
| Half cycle time $\tau$ | 8 / 16 $h$ |

Table 3.8: Experiment parameters Run 8

### Discussion of Run 8

Sample 14 (ProSorb) is first subjected to run 4 (short cycle). There is no expected difference in primary and secondary isotherm.

The observed sorption capacity in run 8 is high: absolute humidity does not rise (after the initial step due to temperature increase) in all 3 cycles.

The gas flow sensor malfunctioned at the end of cycle **3**. This problem was solved by checking the wiring of the sensor. There is no reason to believe the actual air flow through the packed bed deviated during that time.

**First 24h cycle;**

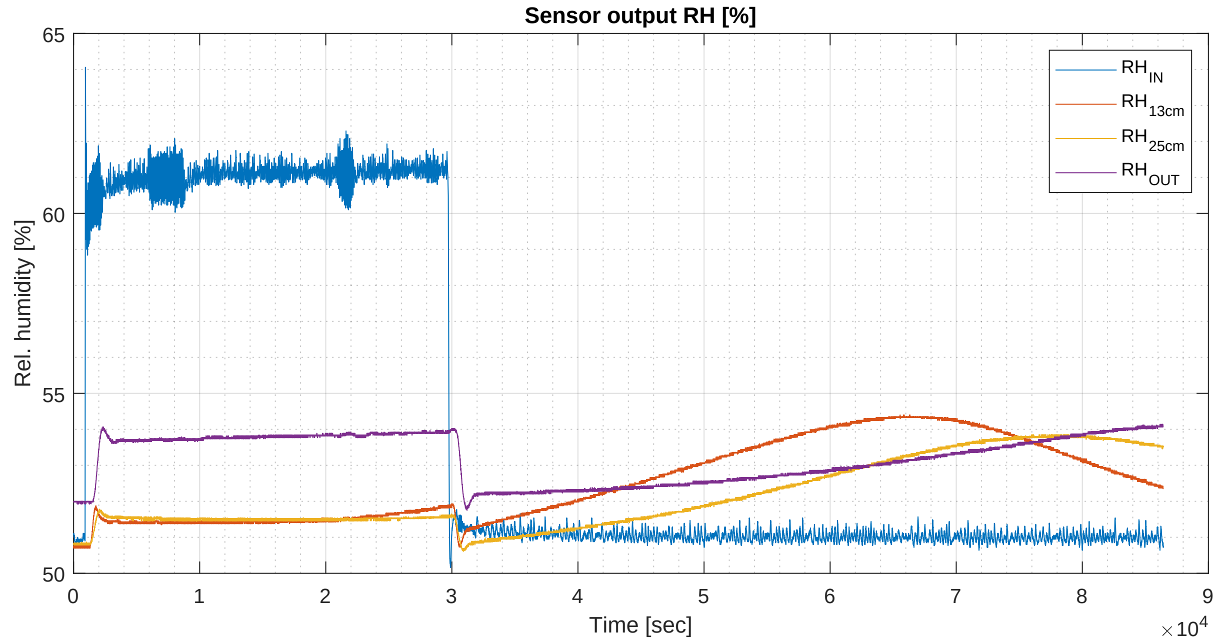


Figure 3.53: Relative humidity measurements in Run 8, cycle 1.

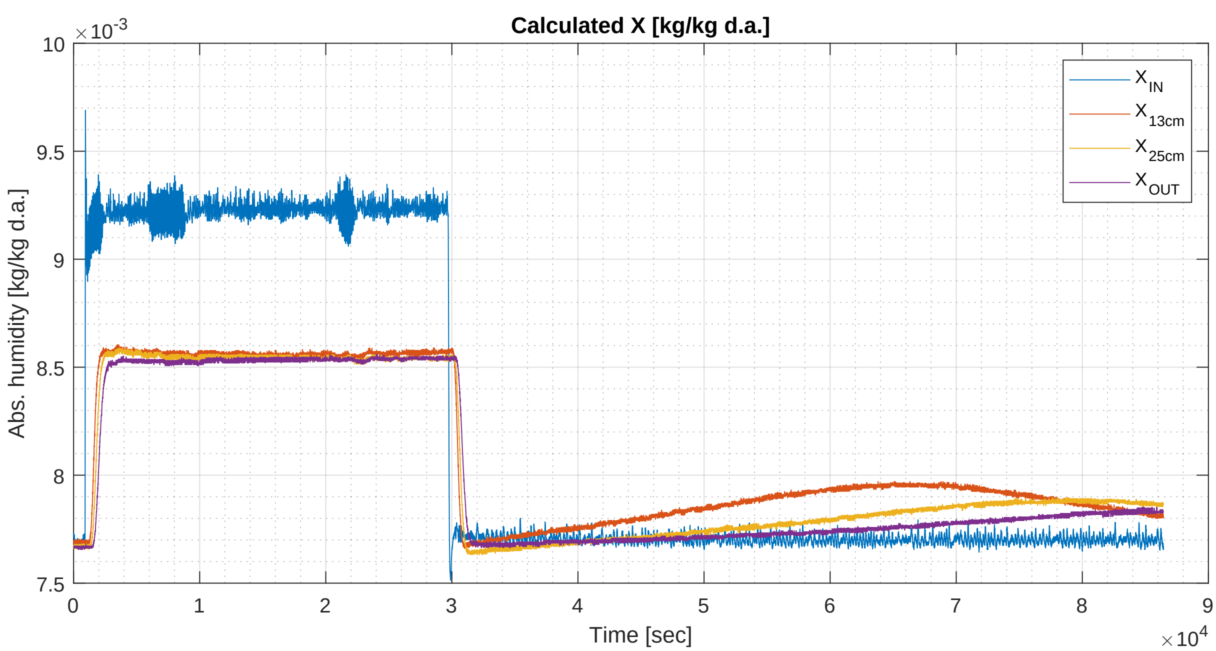


Figure 3.54: Absolute humidity calculated from RH and T in Run 8, cycle 1.

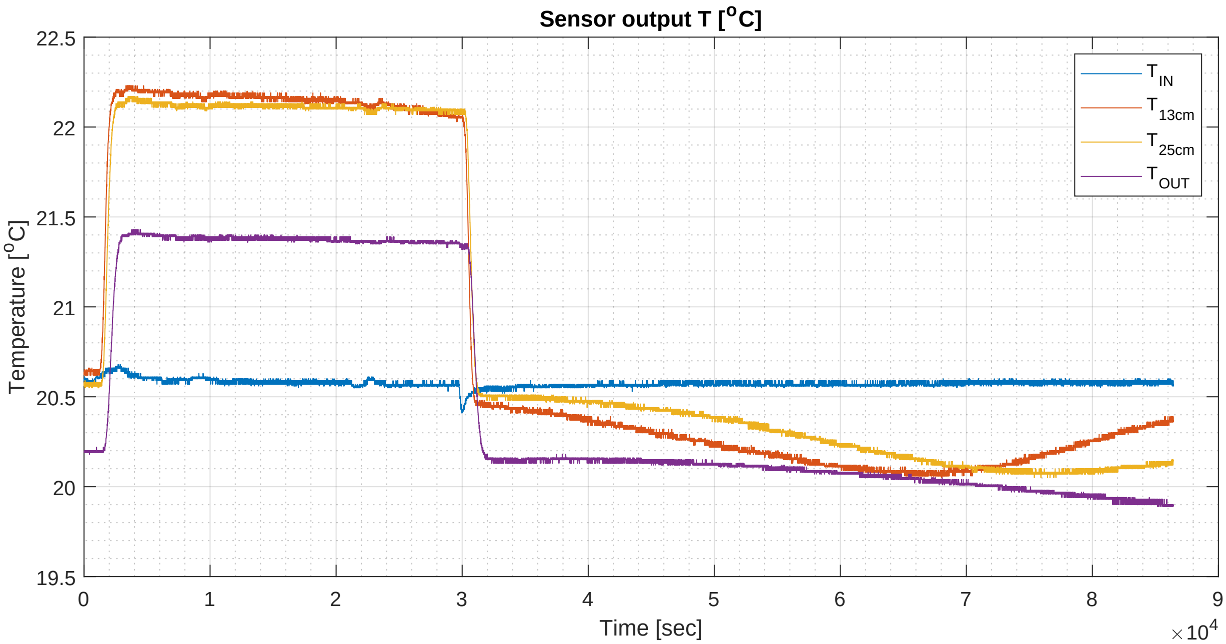


Figure 3.55: Temperature measurements in Run 8, cycle 1.

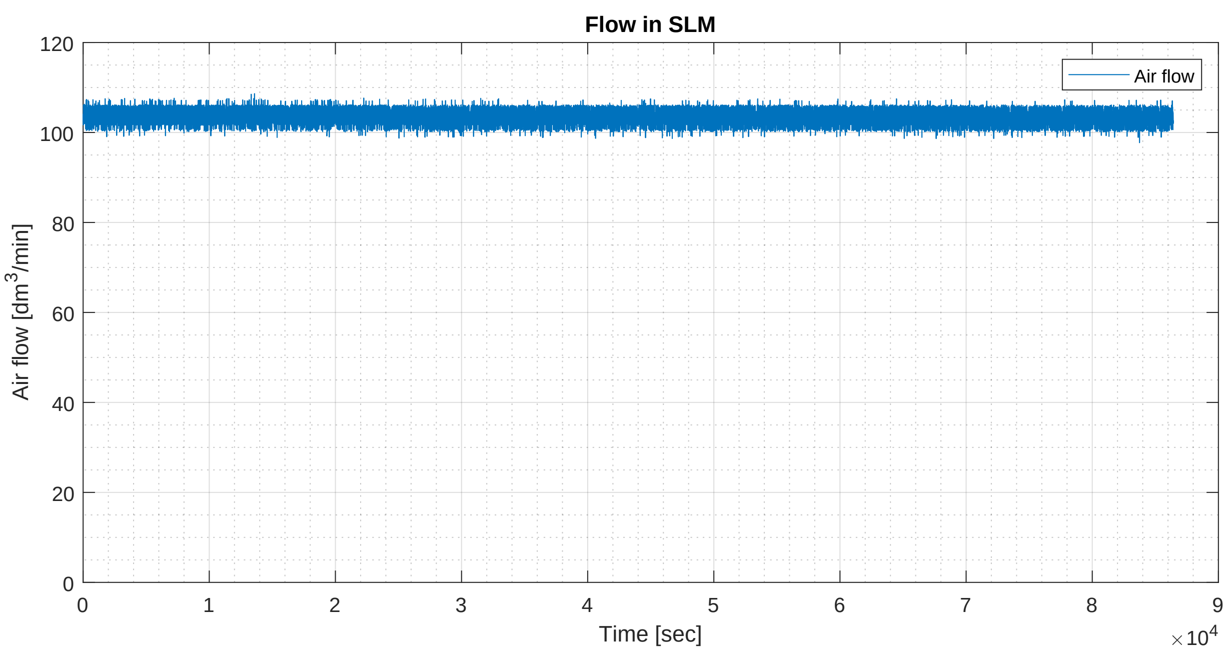


Figure 3.56: Flow measurements from RH and T in Run 8, cycle 1.

**Second 24h cycle;**

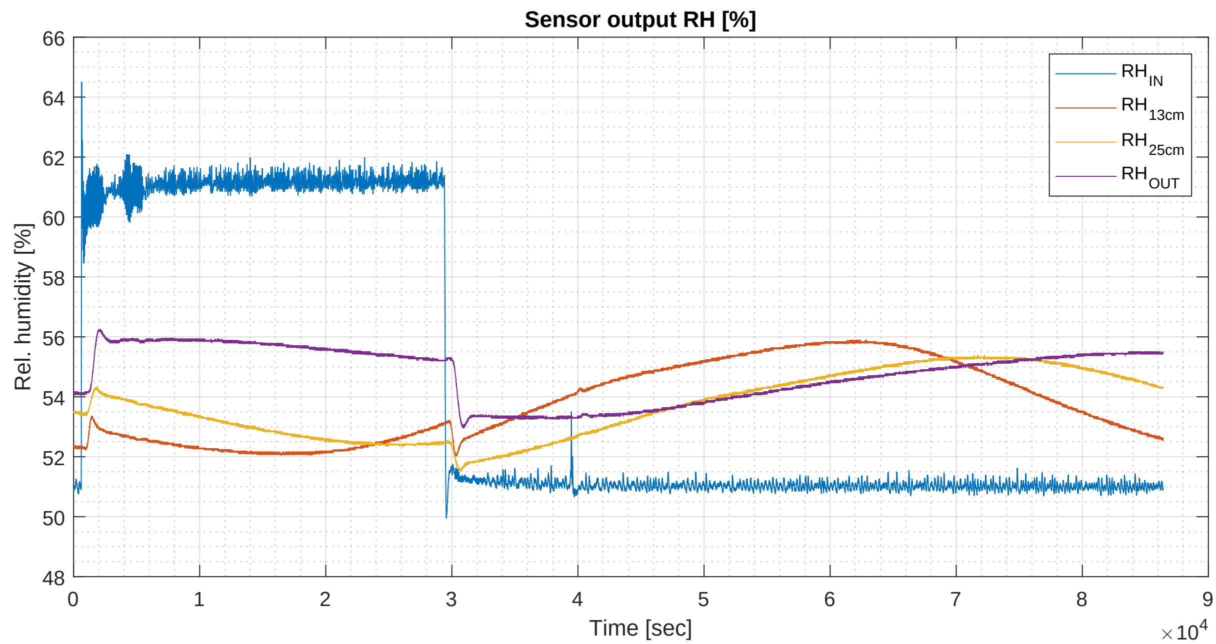


Figure 3.57: Relative humidity measurements in Run 8, cycle 2.

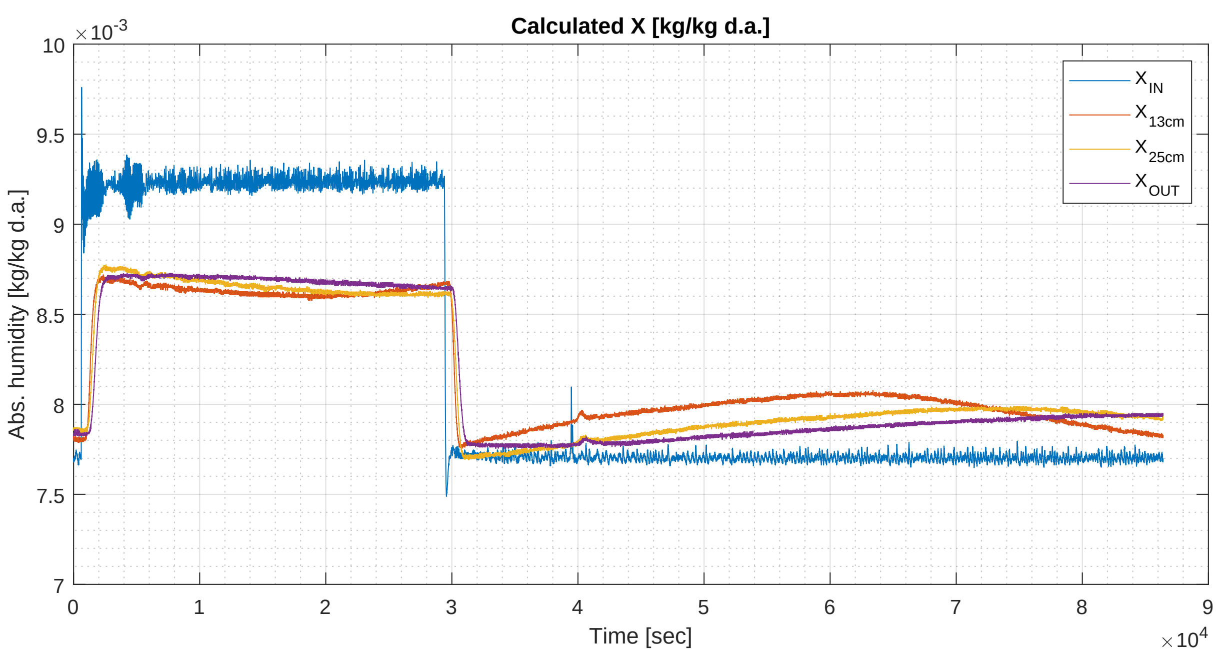


Figure 3.58: Absolute humidity calculated from RH and T in Run 8, cycle 2.

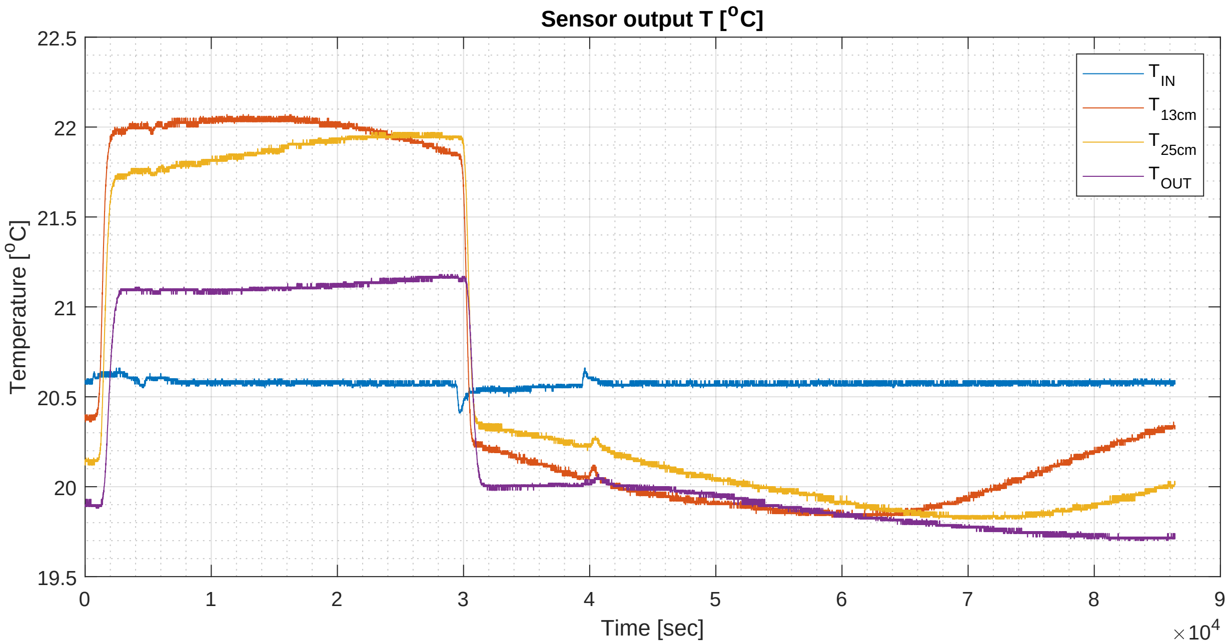


Figure 3.59: Temperature measurements in Run 8, cycle 2.

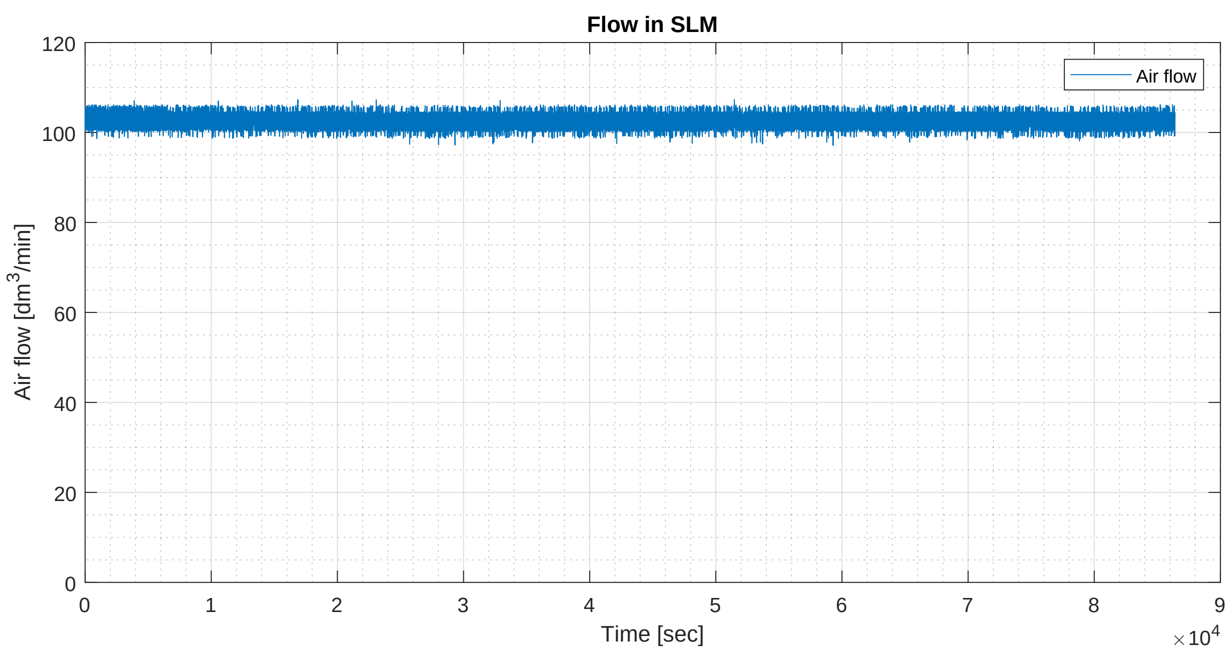


Figure 3.60: Flow measurements from RH and T in Run 8, cycle 2.

## Third 24h cycle;

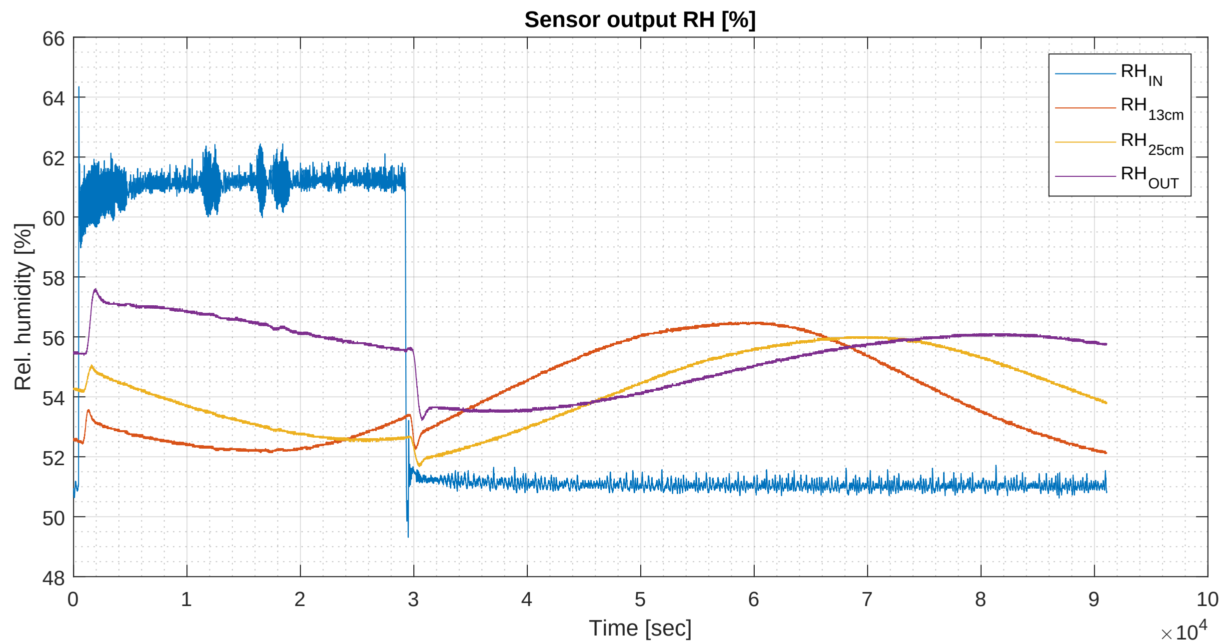


Figure 3.61: Relative humidity measurements in Run 8, cycle 3.

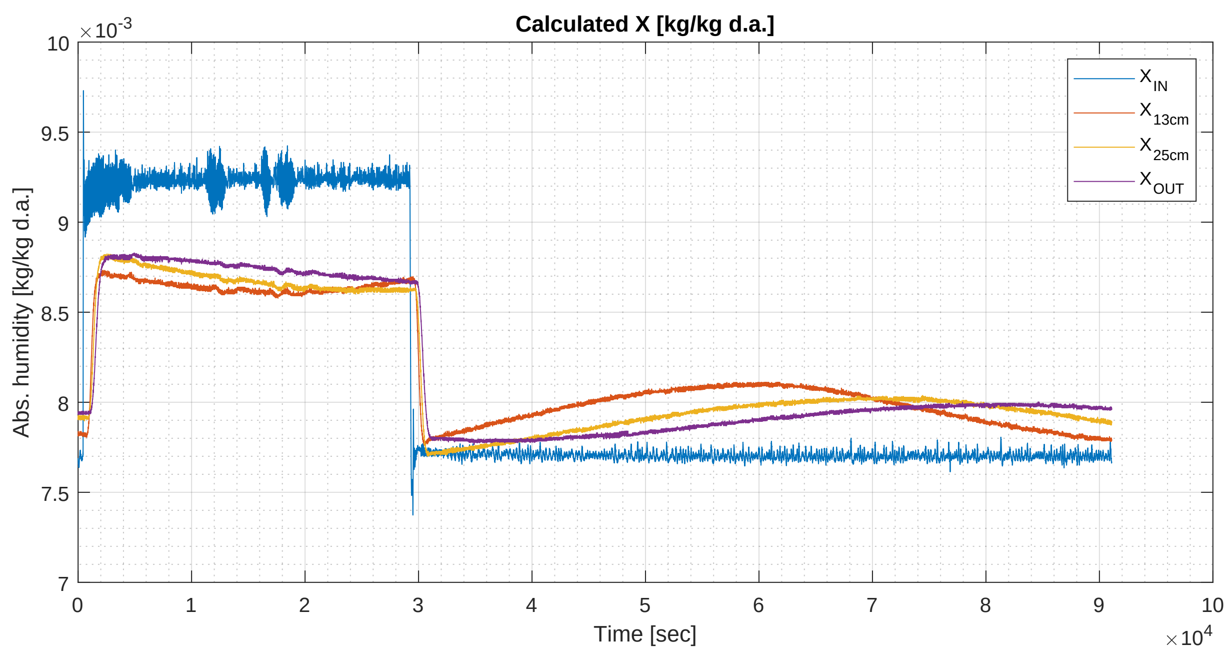


Figure 3.62: Absolute humidity calculated from RH and T in Run 8, cycle 3.

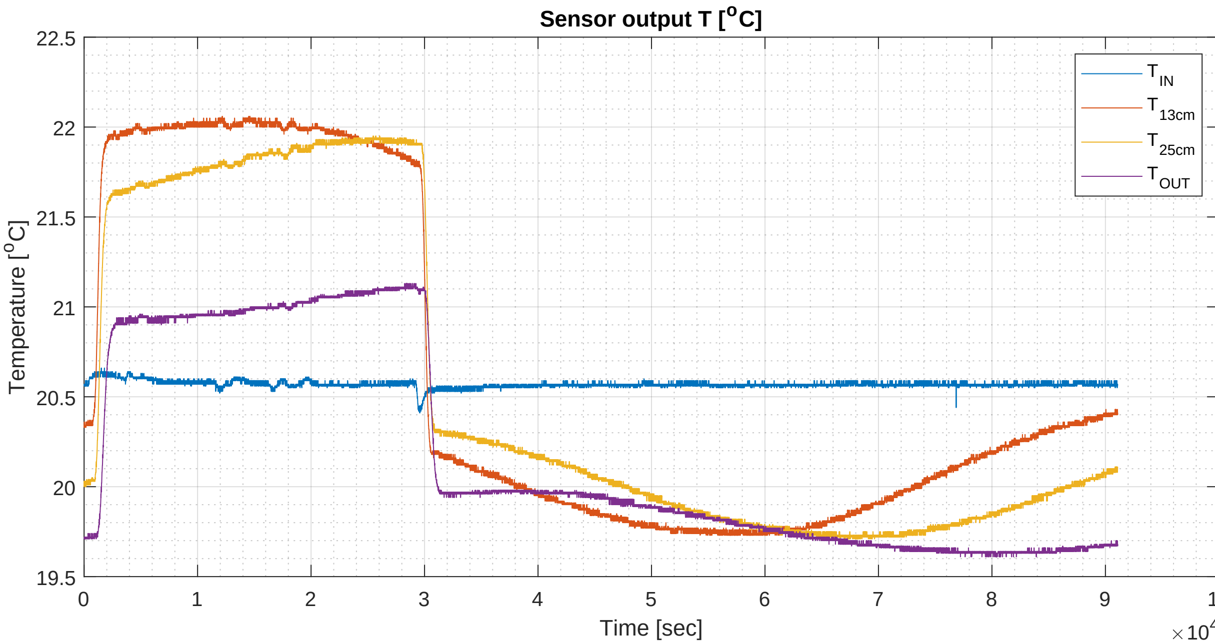


Figure 3.63: Temperature measurements in Run 8, cycle 3.

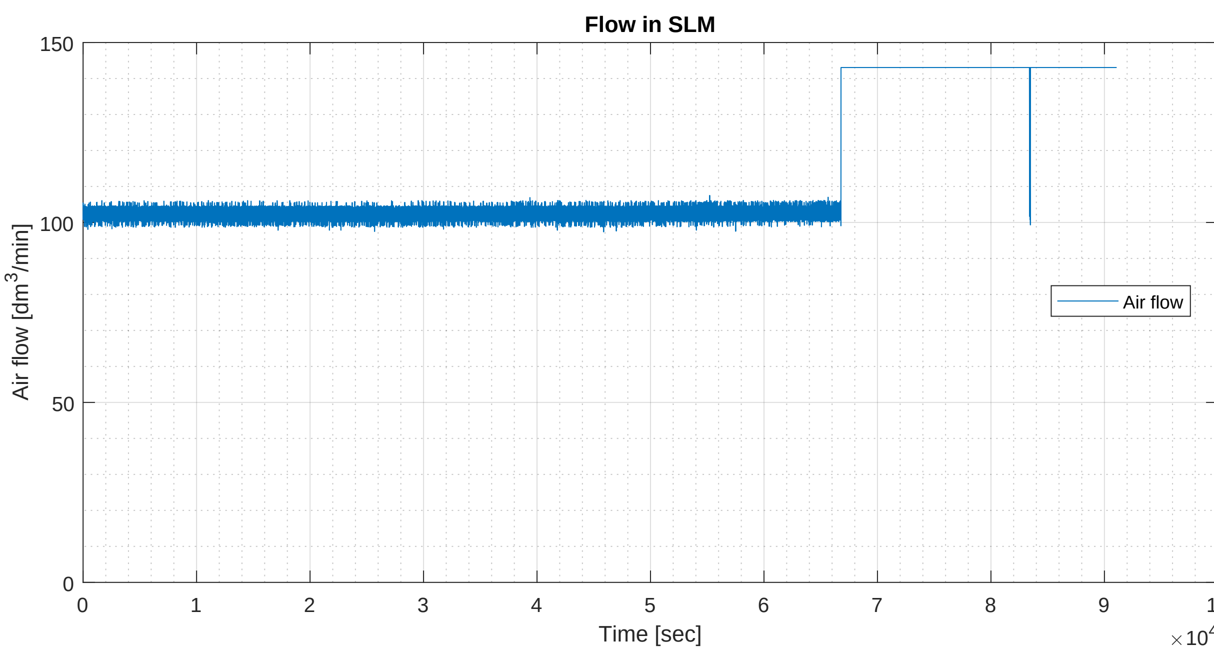


Figure 3.64: Flow measurements from RH and T in Run 8, cycle 3.

# 4 | Absolute (de)-humidification in Experiment 2

In this chapter, the (de)humidification of air in the packed bed is presented. The (de)humidification is expressed as:

$$x_{(de)hum} = x_{out} - x_{in} \tag{4.1}$$

Moisture uptake and release between $t_1$ and $t_2$ is given by:

$$+\Delta w = m_{ads} = -(x_{(de)hum,average}) * (t_2 - t_1) * \rho_{air} * Q \qquad [kg] \tag{4.2}$$

## Run 1

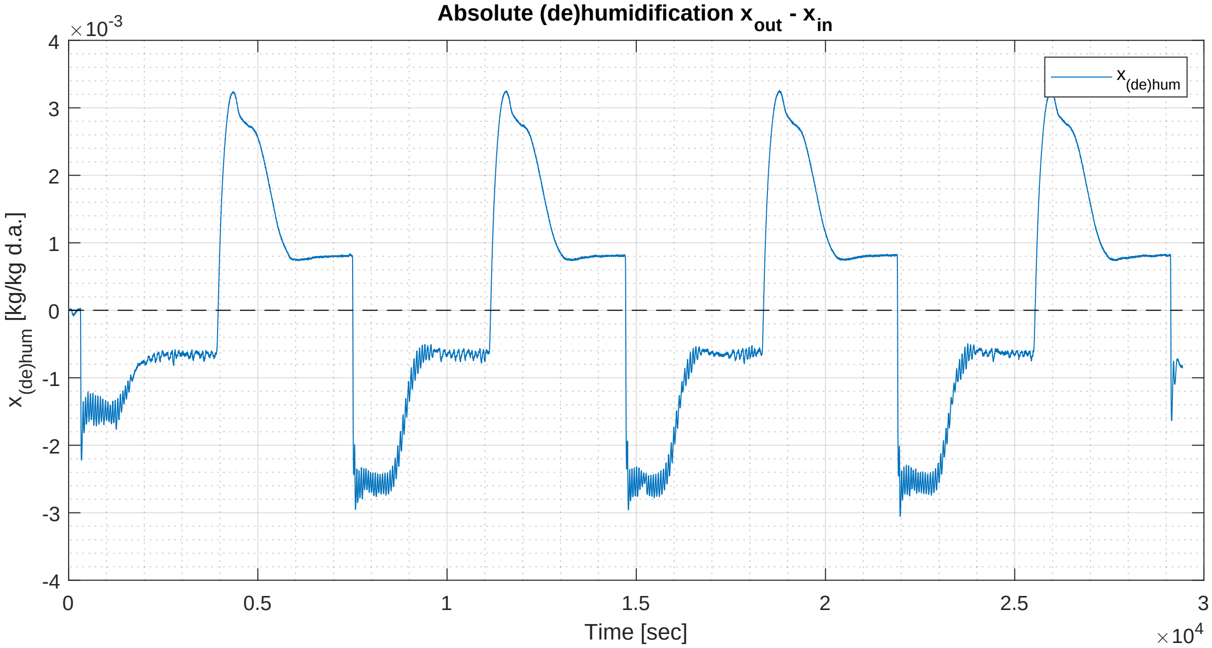


Figure 4.1: Absolute (de)-humidification of air in Run 1.

| **Run 1** | *Half cycle 1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* |
|---|---|---|---|---|---|---|---|---|
| $\Delta w$ | +0.0073 | -0.0112 | +0.0103 | -0.0112 | +0.0102 | -0.0112 | +0.0102 | -0.0113 |

Table 4.1: Moisture uptake and release during half cycles of Run 1

## Run 2

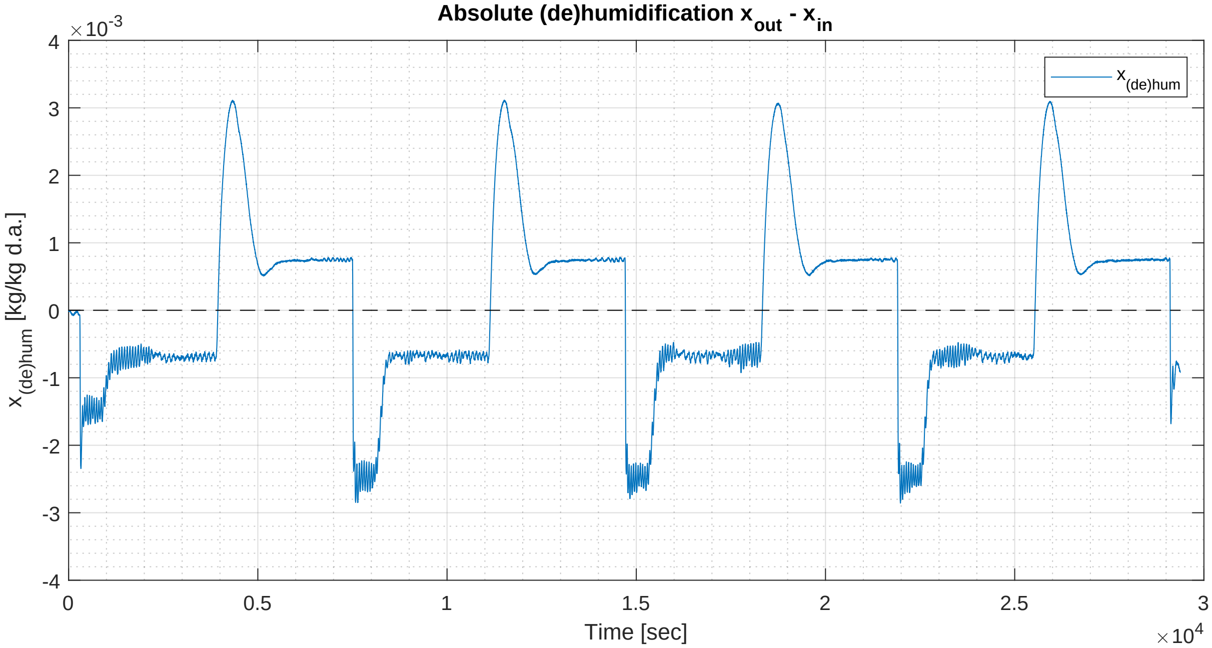


Figure 4.2: Absolute (de)-humidification of air in Run 2.

| **Run 2** | *Half cycle 1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* |
|---|---|---|---|---|---|---|---|---|
| $\Delta w$ | +0.0061 | -0.0076 | +0.0073 | -0.0077 | +0.0073 | -0.0077 | +0.0074 | -0.0077 |

Table 4.2: Moisture uptake and release during half cycles of Run 2

## Run 3

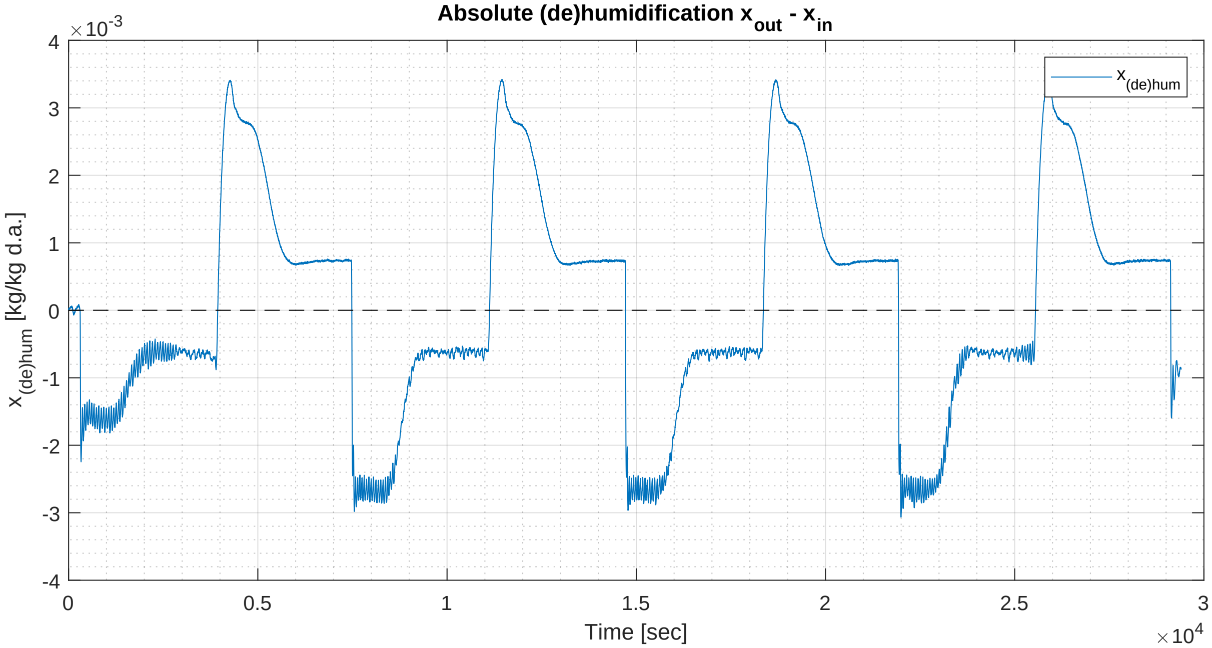


Figure 4.3: Absolute (de)-humidification of air in Run 3.

| **Run 3** | *Half cycle 1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* |
|---|---|---|---|---|---|---|---|---|
| $\Delta w$ | +0.0074 | -0.0109 | +0.0103 | -0.0109 | +0.0103 | -0.0109 | +0.0103 | -0.0109 |

Table 4.3: Moisture uptake and release during half cycles of Run 3

## Run 4

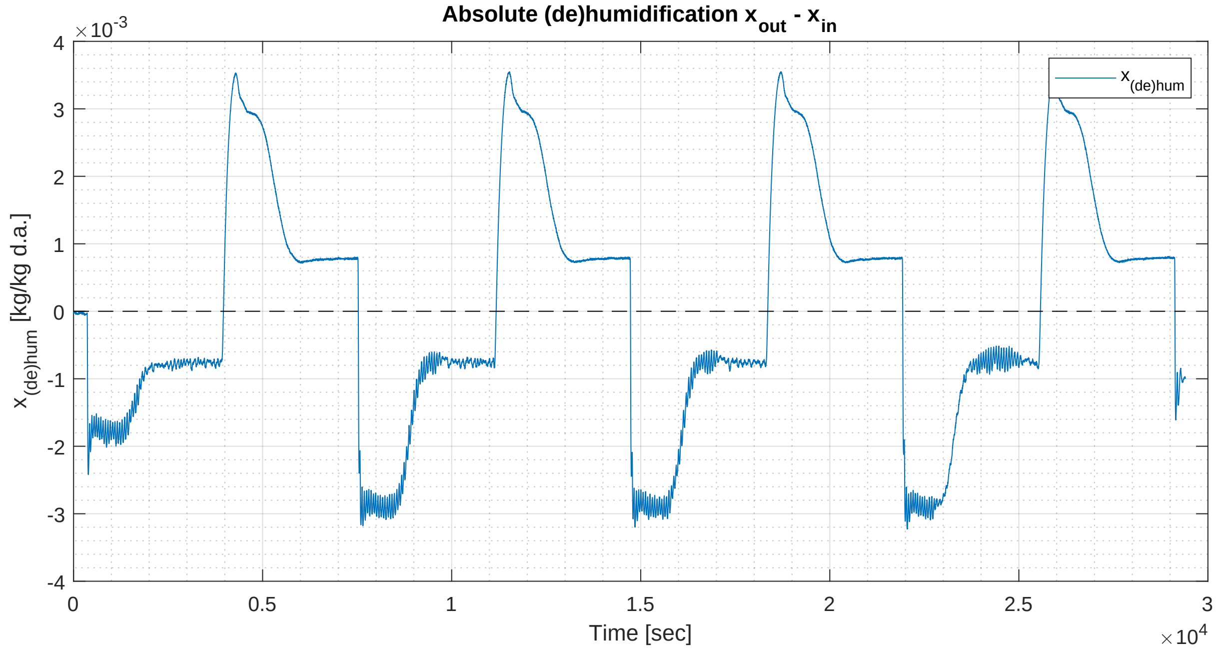


Figure 4.4: Absolute (de)-humidification of air in Run 4.

| **Run 4** | *Half cycle 1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* |
|---|---|---|---|---|---|---|---|---|
| $\Delta w$ | +0.0085 | -0.0116 | +0.0116 | -0.0116 | +0.0116 | -0.0117 | +0.0116 | -0.0116 |

Table 4.4: Moisture uptake and release during half cycles of Run 4

## Run 5

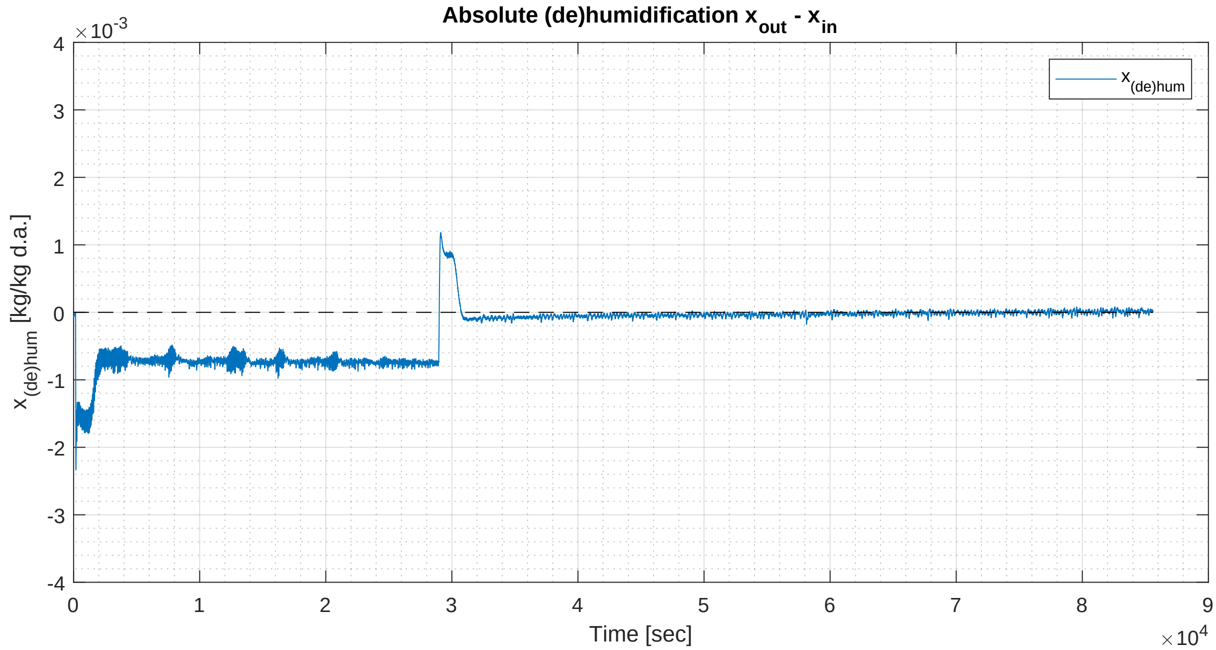


Figure 4.5: Absolute (de)-humidification of air in Run 5, cycle 1.

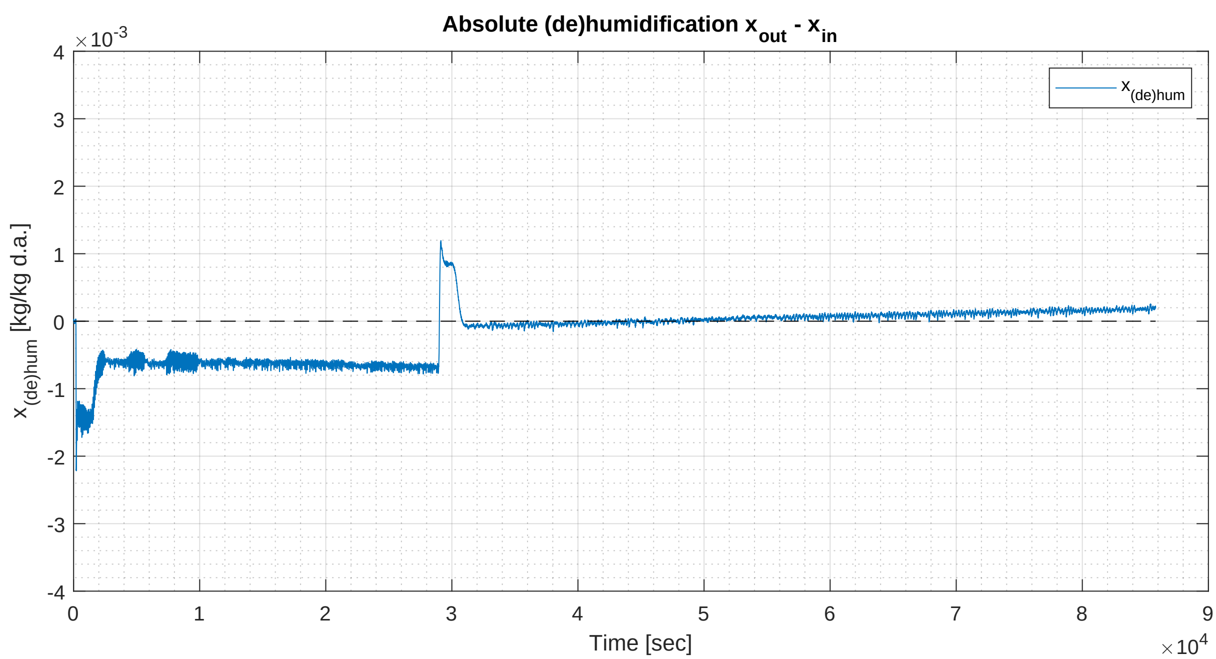


Figure 4.6: Absolute (de)-humidification of air in Run 5, cycle 2.

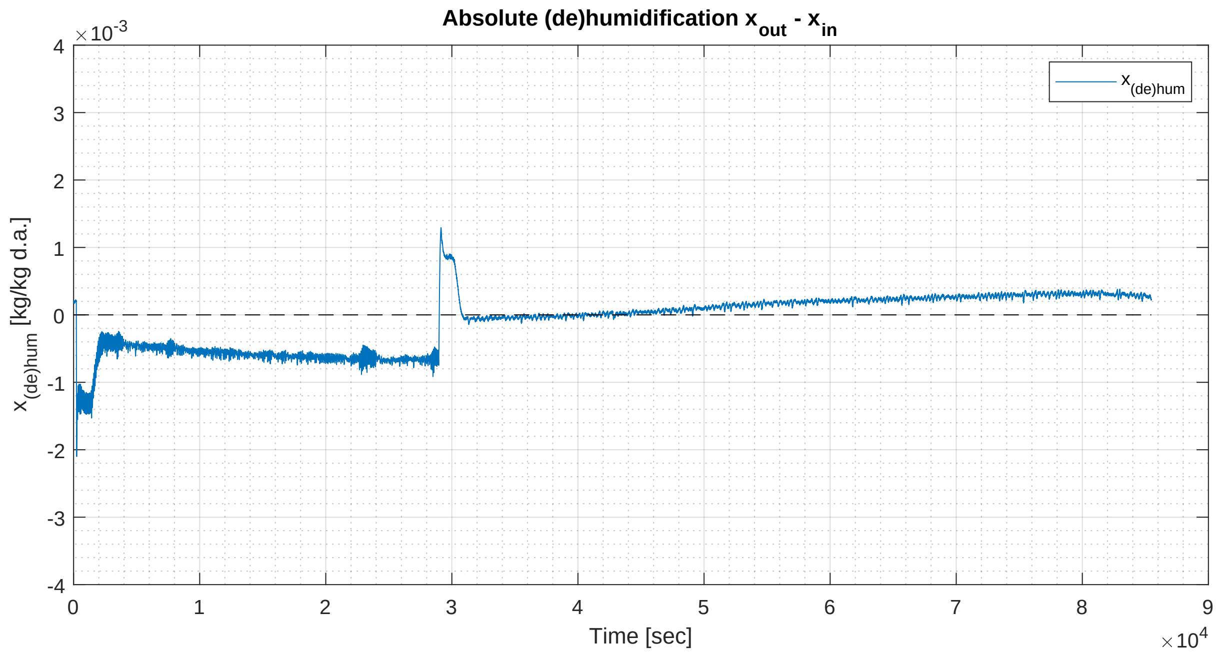


Figure 4.7: Absolute (de)-humidification of air in Run 5, cycle 3.

| **Run 5** | *Half cycle 1* | *2* | *3* | *4* | *5* | *6* |
|---|---|---|---|---|---|---|
| $\Delta w$ | +0.0462 | +0.0008 | +0.0405 | -0.0091 | +0.0368 | -0.0204 |

Table 4.5: Moisture uptake and release during half cycles of Run 5

## Run 6

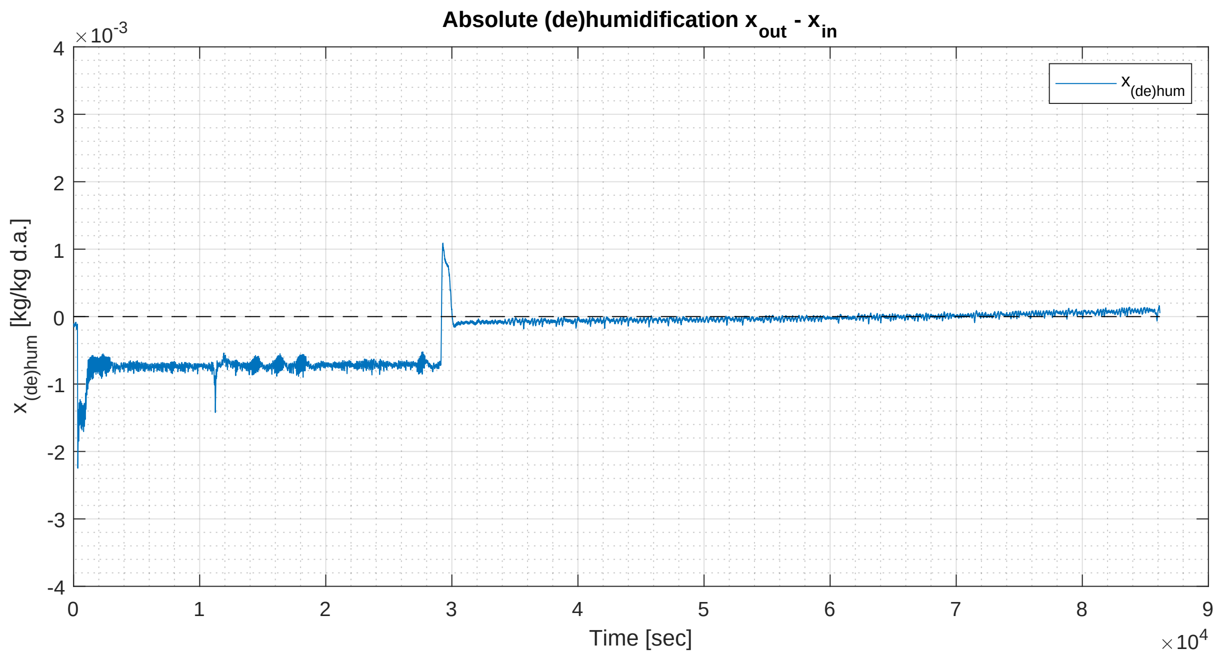


Figure 4.8: Absolute (de)-humidification of air in Run 6, cycle 1.

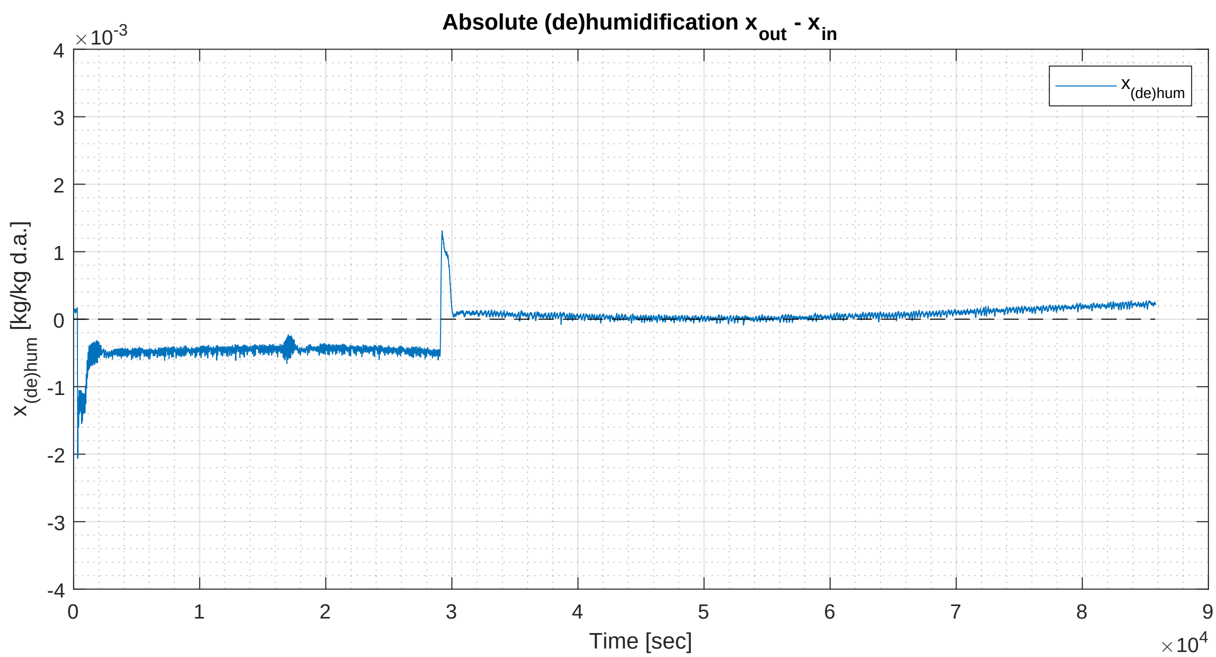


Figure 4.9: Absolute (de)-humidification of air in Run 6, cycle 2.

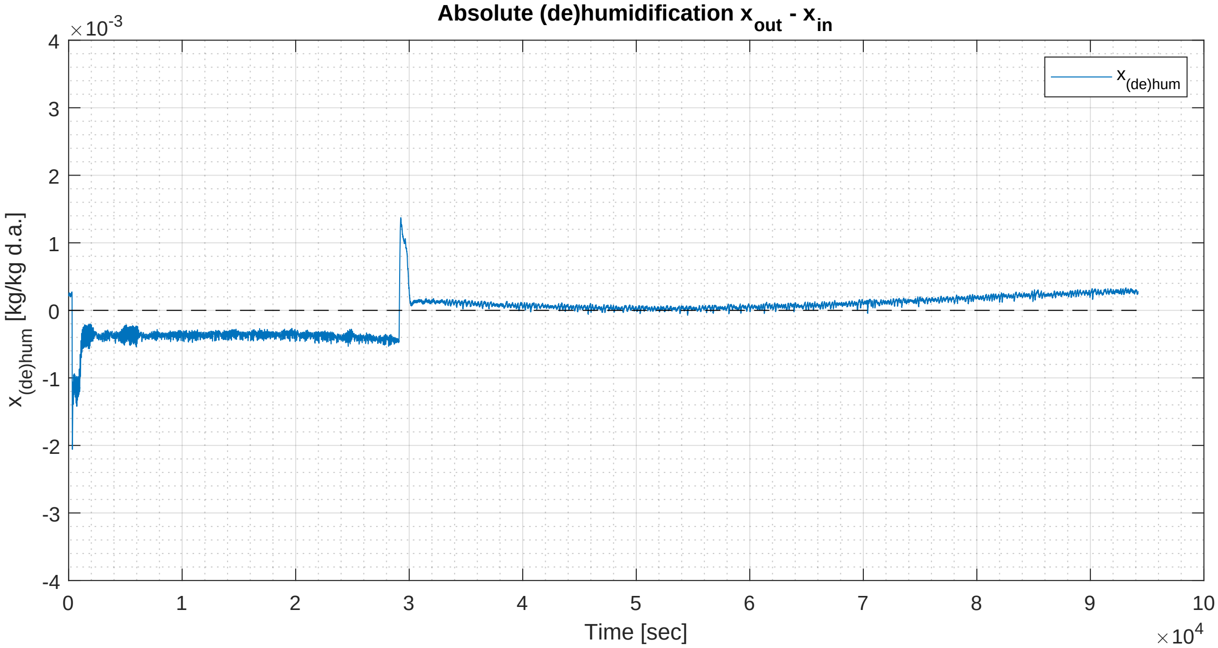


Figure 4.10: Absolute (de)-humidification of air in Run 6, cycle 3.

| **Run 6** | *Half cycle 1* | *2* | *3* | *4* | *5* | *6* |
|---|---|---|---|---|---|---|
| $\Delta w$ | +0.0447 | +0.0007 | +0.0291 | -0.0103 | +0.0238 | -0.0168 |

Table 4.6: Moisture uptake and release during half cycles of Run 6.

## Run 7

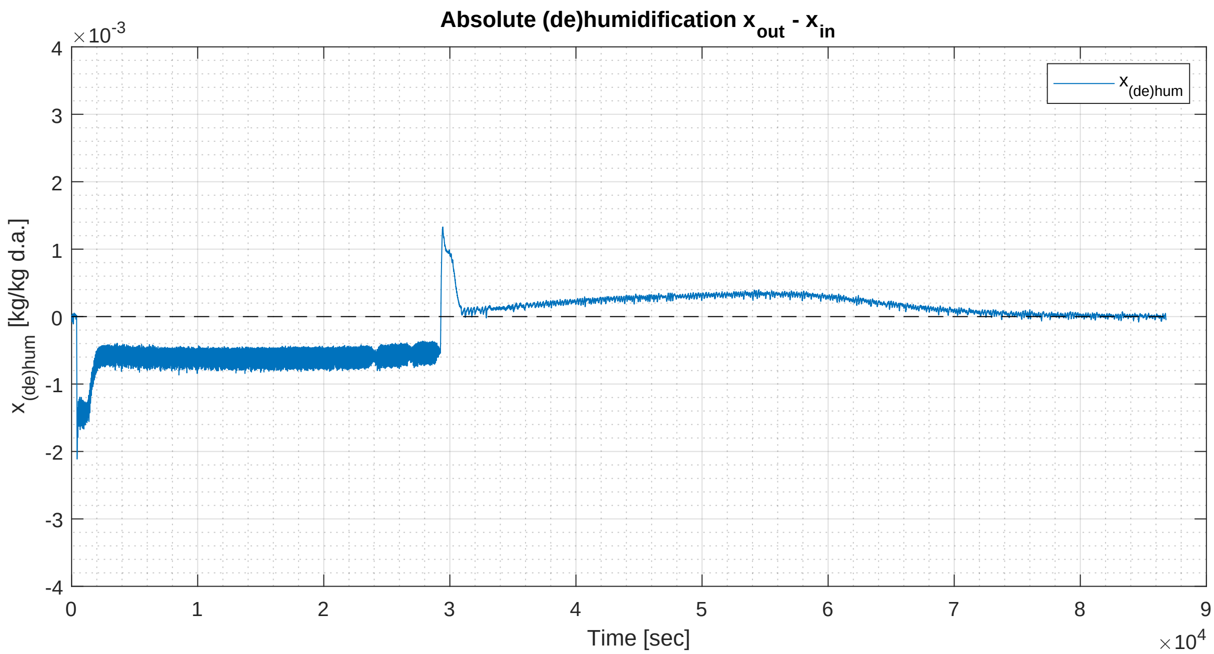


Figure 4.11: Absolute (de)-humidification of air in Run 7, cycle 1.

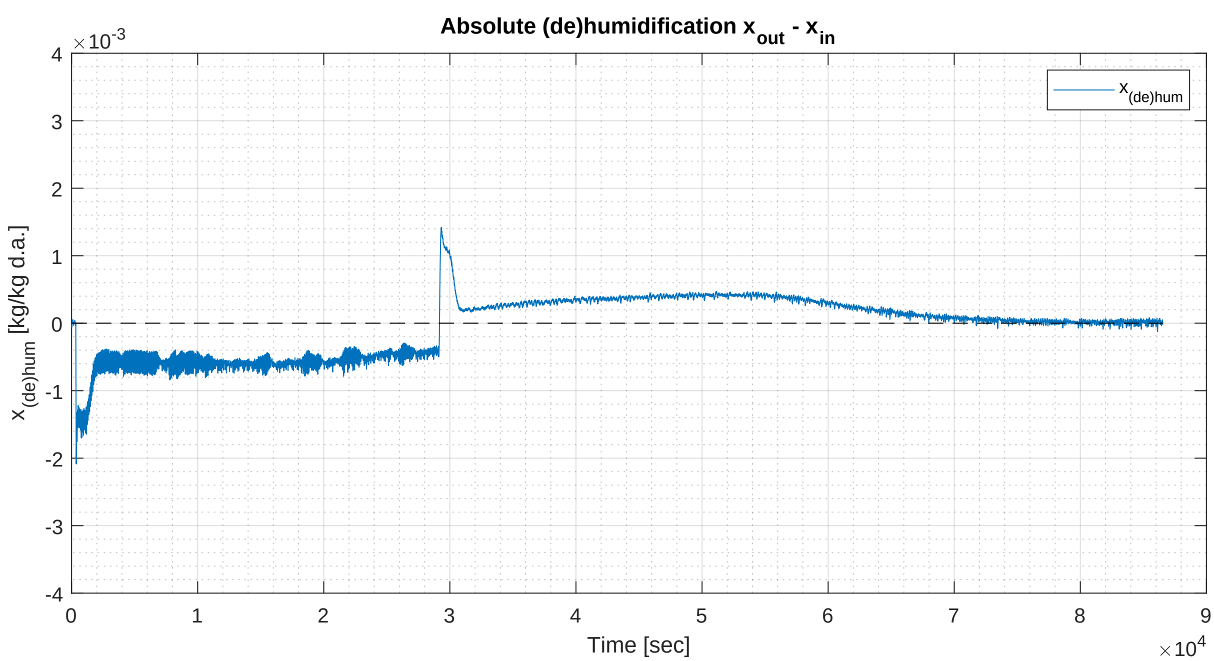


Figure 4.12: Absolute (de)-humidification of air in Run 7, cycle 2.

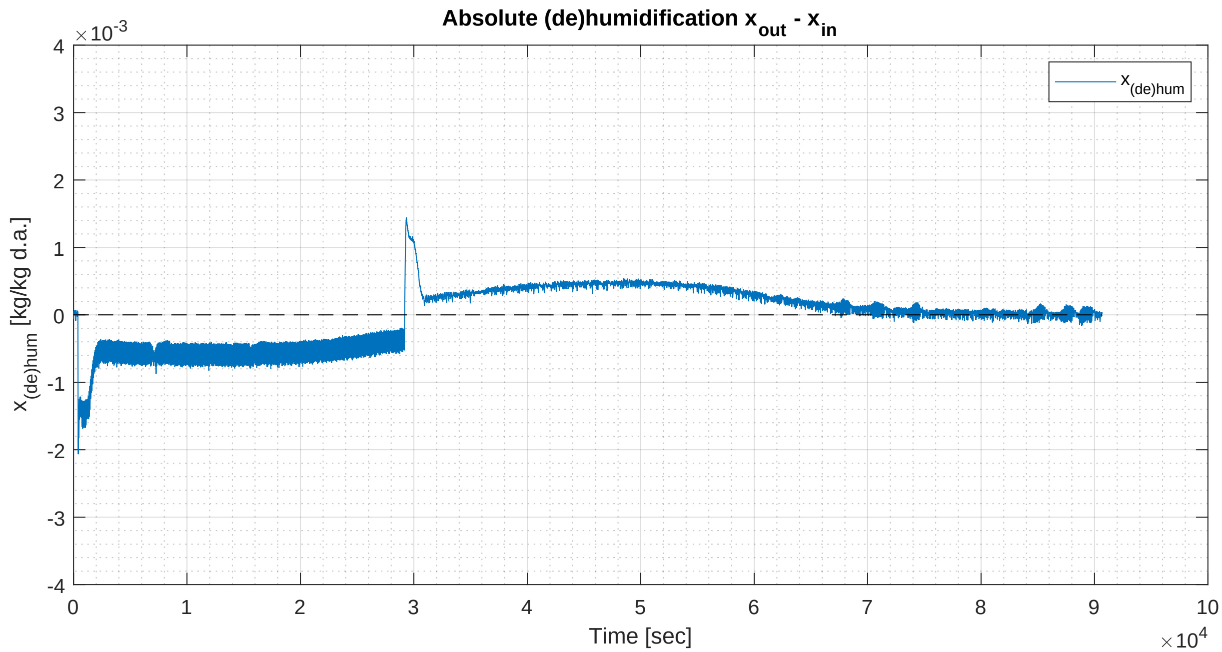


Figure 4.13: Absolute (de)-humidification of air in Run 7, cycle 3.

| **Run 7** | *Half cycle 1* | *2* | *3* | *4* | *5* | *6* |
|---|---|---|---|---|---|---|
| $\Delta w$ | +0.0389 | -0.0223 | +0.0360 | -0.0282 | +0.0353 | -0.0309 |

Table 4.7: Moisture uptake and release during half cycles of Run 7.

## Run 8

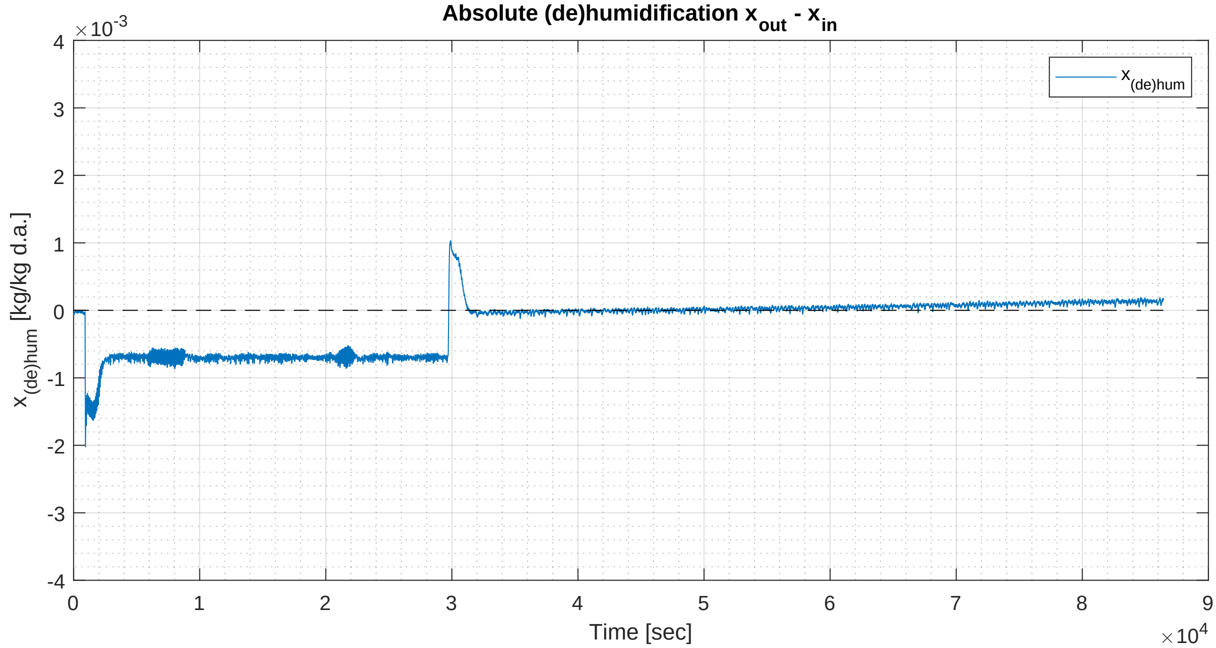


Figure 4.14: Absolute (de)-humidification of air in Run 8, cycle 1.

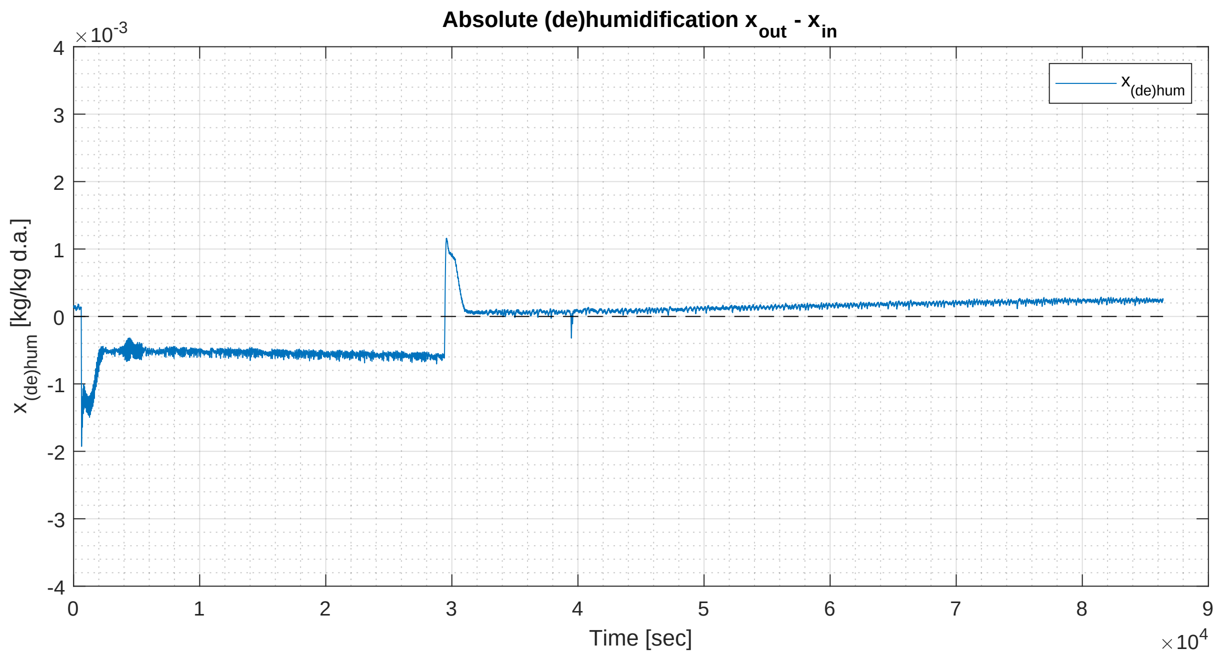


Figure 4.15: Absolute (de)-humidification of air in Run 8, cycle 2.

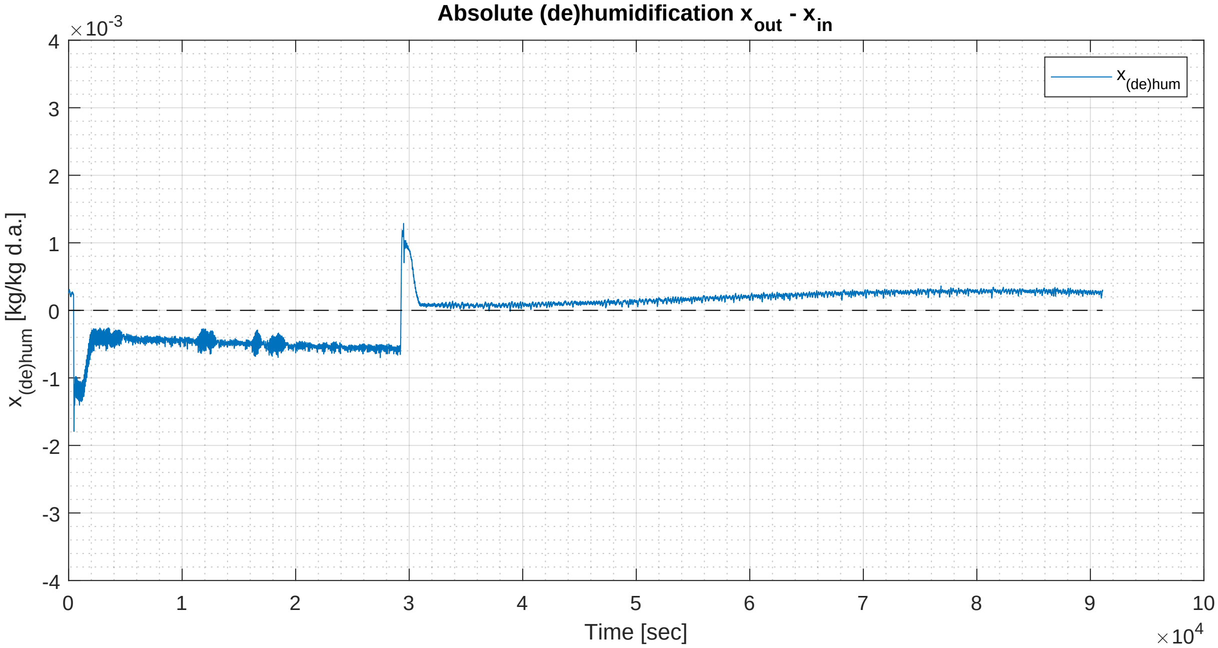


Figure 4.16: Absolute (de)-humidification of air in Run 8, cycle 3.

| **Run 8** | *Half cycle 1* | *2* | *3* | *4* | *5* | *6* |
|---|---|---|---|---|---|---|
| $\Delta w$ | +0.0436 | -0.0067 | +0.0345 | -0.0194 | +0.0311 | -0.0260 |

Table 4.8: Moisture uptake and release during half cycles of Run 8.