THERMAL CYCLING OF THE FIRST PRE-SERIES MODULES

CS Cluster

1. PREPARATION OF THE MODULES FOR CYCLING

The first pre-series modules were placed their bonding jig with no attachment other than the clamps holding the hybrid in place, and the precision pins preventing lateral movement. This avoids thermoelastic stresses due to the large shrinkage of the jig made of aluminium.

The jigs were placed, one at a time, nearly horizontally on the grille in the middle of the BiA climate cabinet. The Dallas digital thermometer (DS18S20) was placed between the edge of the jig and the grille, so that the weight of the jig rested on the sensor. The Honeywell humidity sensor (HIH-3610-003) was placed freely under the module at a distance of a few cm.

2. PREPARATION OF THE CLIMATE CABINET

The program of the climate cabinet featured continuous flow of dry nitrogen (purity 4.5) at a rate of 180 l/h, which is sufficient to compensate the dilatation of air in the 62 l volume of the cabinet during its cooldown. The humidity sensor was used for measuring the relative humidity of the nitrogen at room temperature; the result is compatible with zero within the accuracy of the sensor, quoted to be ±2 %.

The cycle involves cooldown and warmup of the cabinet at maximum rate, and soak periods of 30 min at +35 °C and at –30 °C. The cycle is started by warmup from room temperature to 35 °C, which deviates from the cycle suggested in the preliminary QA document ATL-IS-QA-0004 (this starts from the minimum temperature).

During cycling the cabinet is programmed to perform dryout at all times. This means that the refrigerator unit continues to operate at all times, so as to dry the air emerging from the heater unit which controls the temperature of the cabinet.

3. RAW DATA ON TEMPERATURE AND RELATIVE HUMIDITY DURING CYCLING

Figure 1 shows the data logged from the temperature and humidity sensors every 30 s for the first pre-series modules. The relative humidity of the sensor is temperature corrected using the measured temperature of the jig. It can be seen that the relative humidity is fairly stable from cycle to cycle, and that the jig temperature approaches the cabinet temperature at the ends of the soak periods.

The cabinet temperature (not shown) changes 3 to 4 times more rapidly than the temperature of the jig. The average cooldown and warmup rates of the jig are between ±3 °C/min and ±4 °C/min, apart from the initial cooldown which takes place at a rate of about –7 °C/min. The cooldown of the cabinet can be slowed down to a desired value, if needed.

4. DEW POINT AND FROST POINT DURING CYCLING

The dew point and the frost point of the ambient gas near the jig were determined using the measured relative humidity and the measured temperature of the jig. These are shown in Figure 2 together with the jig temperature. It can be seen that the gas is slightly dried during the first cycle, and then its humidity is repetitive from cycle to cycle. The frost point is determined by the air heat exchanger temperature of the refrigerator, and is more than 6 °C below the jig temperature during the coldest part of the cycle. It is concluded that there is no risk of frost formation on the jig, and even less for the module, even during the start of the warmup. The dew point is mostly below 0 °C, and is therefore irrelevant.

5. ABSOLUTE HUMIDITY AND MARGIN OF FROST POINT

The drying effects of the nitrogen flow and of the dryout function of the cabinet are most clearly visualised by plotting the absolute humidity of the air in cabinet during the thermal cycling, as shown in Figure 3. During the cold spell of the cycle the gas is freeze-dried by the exchanger, and the total amount of the humidity is visible only during the warm spell.

The plot shows also that the air in the room, initially filling the cabinet before the cycling starts, has a humidity content of about 6 to 9 g/m^3, and the nitrogen flow reduces it to about 3 g/m^3.

It is evident that the thermal cycling must be started by a warmup rather than cooldown. This enables to reduce the amount of humidity in the cabinet, both by bakeout of the inner surfaces, and by the effect of dry nitrogen flow. It may be useful that the first warmup is not made with the dryout option of the cabinet, because this stores much of the initial humidity on the surface of the exchanger.

Figure 3 also shows the difference of the temperature of the jig and the frost point of the surrounding gas. One can see that the margin of 6 °C is mainly due to the freeze-drying effect of the exchanger of the refrigerator, and this is the temperature difference between the gas in the cabinet and the exchanger, where the gas is saturated with water vapour.

6. METROLOGY RESULTS BEFORE AND AFTER THERMAL CYCLING

The modules were measured on the CMM MivroVu table before and after thermal cycling. No significant shift is observed in XY, as shown by the Tables on page 4 to 6 of the document http://dpnc.unige.ch/atlas/atlaspage/module/forward/Documents/Summary.pdf

The variation of the Z surfaces of up to16 microns lower relative to the mounting block was observed. The thickness variation of the module is 6 microns, which could be the result of the glue post-curing.

It is concluded that the modules are still in the specifications after thermal cycling, and that no substantial changes in the dimensions have happened.

7. FIGURES AND TABLES

	Module 20220130000001			Module 20220130000002		
Measure	Before cycling	After cycling	Difference	Before cycling	After cycling	Difference
X Hole	-78.130	-78.127	0.003	-78.133	-78.133	0.000
Yhole	0.012	0.013	0.001	0.010	0.008	-0.002
X Slot	62.314	62.308	-0.006	62.283	62.284	0.002
Y Slot	0.000	-0.002	-0.002	-0.003	-0.007	-0.004
MidXf	-0.001	-0.001	0.001	-0.001	-0.001	0.000
MidYf	-0.041	-0.041	0.000	-0.039	-0.040	0.000
SepF	61.664	61.663	-0.001	61.665	61.665	0.000
SepB	61.664	61.664	0.000	61.668	61.668	0.000
Stereo	-19.981	-19.983	-0.002	-19.981	-19.983	-0.002
A1	0.006	-0.007	-0.013	0.006	-0.007	-0.013
A2	0.019	0.018	-0.001	0.019	0.018	-0.001
A3	0.004	0.001	-0.004	0.004	0.001	-0.004
A4	-0.030	-0.027	0.002	-0.030	-0.027	0.002
Z Aver F	0.858	0.843	-0.016	0.844	0.842	-0.002
Z Aver B	-0.400	-0.410	-0.010	-0.417	-0.422	-0.005
Z Max F	0.939	0.926	-0.014	0.915	0.917	0.002
Z Max B	-0.327	-0.332	-0.005	-0.358	-0.364	-0.006
Z Min F	0.812	0.796	-0.016	0.783	0.774	-0.009
Z Min B	-0.430	-0.439	-0.010	-0.462	-0.473	-0.011
Z RMS F	0.025	0.027	0.002	0.032	0.035	0.003
Z RMS B	0.021	0.023	0.002	0.027	0.030	0.003
Thickness	1.258	1.253	-0.006			

Table 1: Metrology results for the two pre-series modules before and after 10 thermal cycles between +35 °C and –30 °C. The measures are in mm with the exception for the stereo angle.

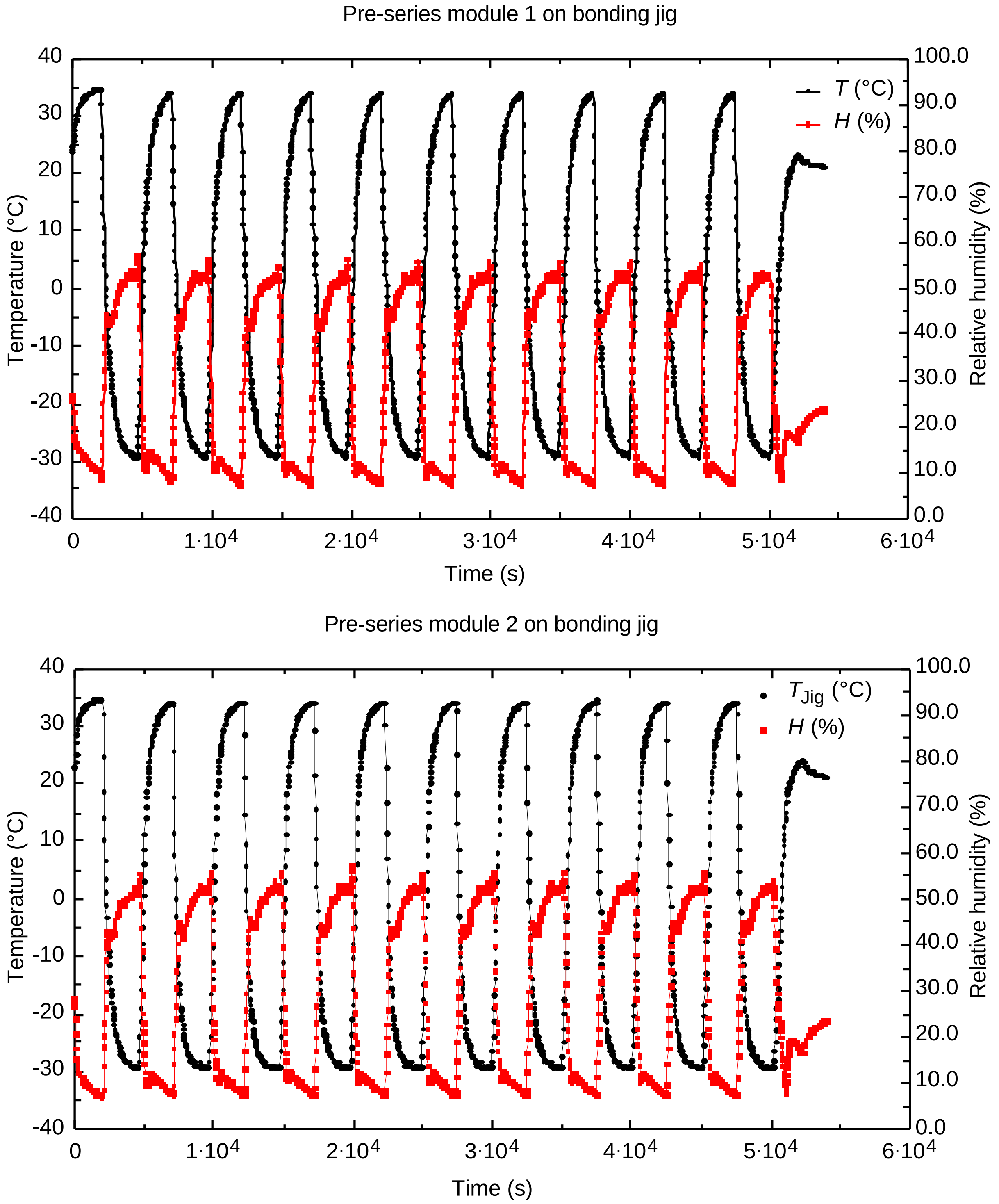

Figure 1: Records of the jig temperature and relative humidity of the ambient gas (nitrogen enriched air) during the thermal cycling of the two first pre-series modules.

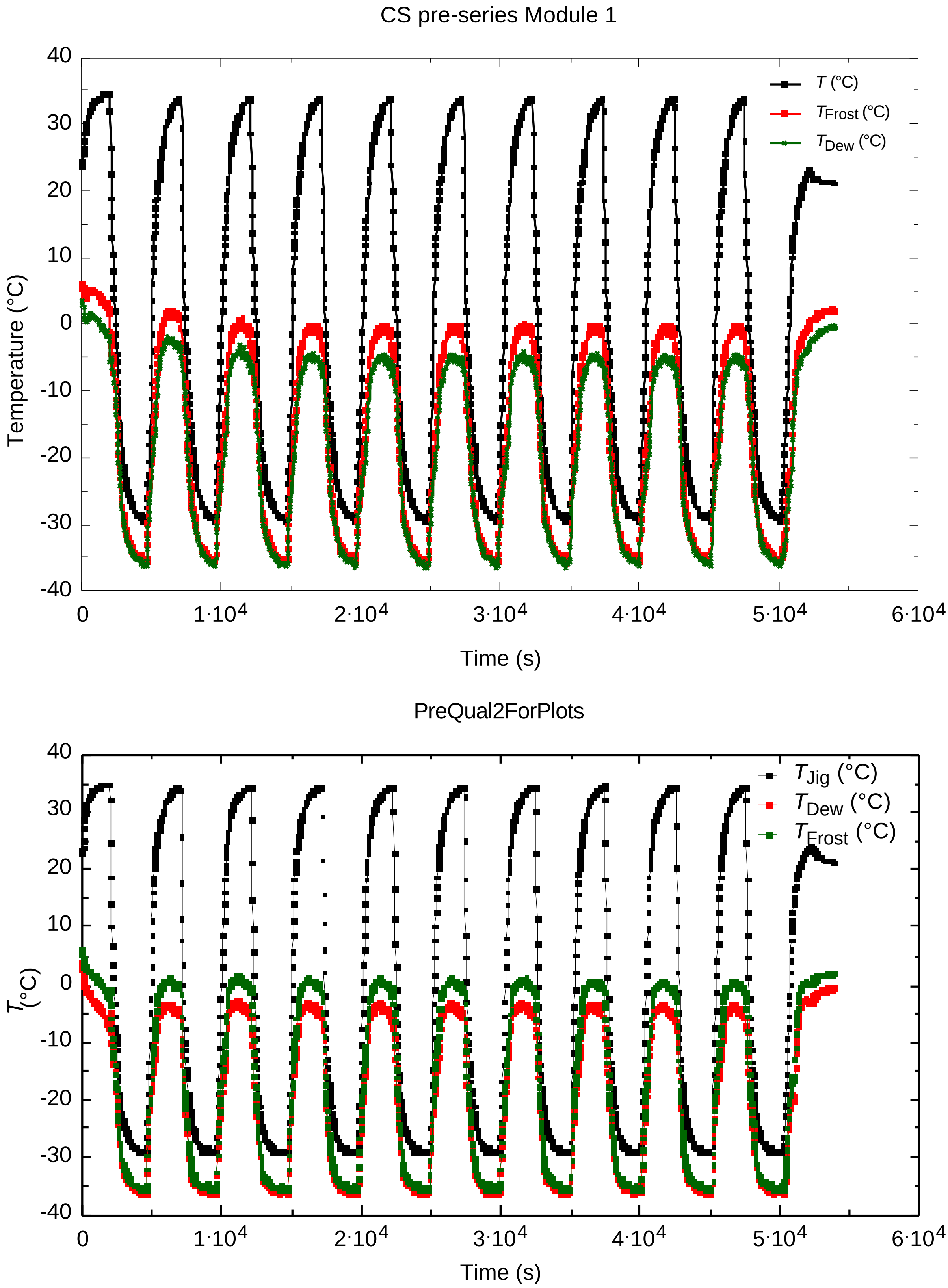

Figure 2: The dew point and frost point of the ambient gas near the bonding jig supporting the modules during thermal cycling. The jig temperature is also shown.

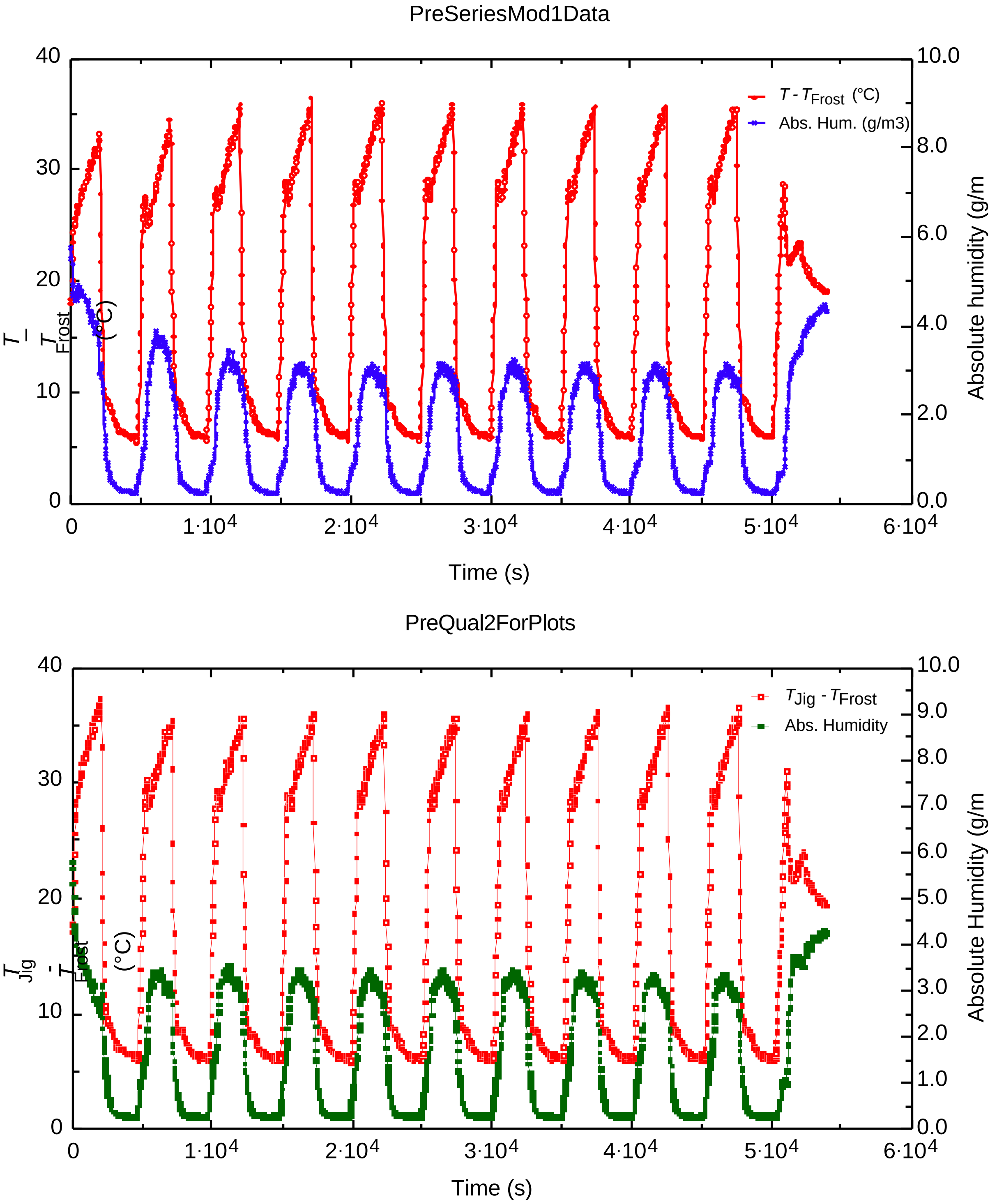

Figure 3: The difference between the temperature of the jig and the frost point of the surrounding gas, plotted together with the absolute humidity determined from the measured relative humidity and jig temperature. The evolution of the absolute humidity features initial reduction due to the flow of dry nitrogen gas at a rate of 3 volumes/hour, and storage of the residual humidity on the surfaces of the exchanger during the cold part of the cycle.