Moisture Regulation of Wool and Polyester Based Insulation Material

Terra Lana Limited

CLR 14-28 (FBP 45103)

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Executive Summary

A preliminary trial (reported previously in CLR 12/46) demonstrated that a wool building insulation sample was capable of absorbing and releasing moisture to the surrounding environment as the humidity levels changed. In comparison a polyester sample exhibited limited ability to absorb and release moisture at an order of magnitude 10 times lower than the wool sample. This trial used a constant temperature with changing relative humidity which does not reflect actual conditions within a wall cavity. To generate data that more accurately reflects the actual conditions, the trial reported here incorporated cycles of changing temperature and humidity designed around winter, daytime and night time periods.

The data demonstrated that, on average, the wool sample absorbed almost 6 times more moisture than the polyester during the 10 hour night time cycle. In addition, on average, the wool sample released over 12 times more moisture than the polyester during the 10 hour daytime cycle.

These results further support wool's ability to respond to changes in the humidity of the environment and provide a buffering effect, by absorbing moisture in a high humidity environment and releasing it in a low humidity environment.

Whilst it is not possible to directly compare the two trials, a review of both indicates that changing the temperature has an impact on the samples' ability to absorb and release moisture. In particular the wool sample, demonstrated increases of both moisture absorption and release in excess of 50% when temperature and relative humidity were dynamic.

Contents

Page

1. Introduction

A preliminary trial, carried out in September 2012, demonstrated that a wool insulation sample was capable of absorbing and releasing moisture to the surrounding environment as the humidity levels changed [1]. The polyester sample exhibited limited ability to absorb and release moisture at an order of magnitude ten times less that the wool sample. This trial used a constant temperature with changing relative humidity (RH) which was not representative of actual conditions within a wall cavity. The current trial reported on here incorporated cycles of changing temperature and humidity designed around winter, daytime and night time periods.

2. Materials

Two samples of nonwoven insulation material were supplied by Terra Lana:

1. Wool blend
2. Polyester (NOVAtherm)

The samples were each cut to a sample size of 34 cm by 24 cm (0.0816 m^2) and placed in a conditioned environment of 20°C and 65% relative humidity for 48 hours.

3. Method

The conditioned samples were weighed and each was placed on a zeroed, three decimal place balance located inside a Contherm Precision environment chamber. A small temperature and humidity data logger (Hortplus, model TH) was inserted into the centre of each and the samples reweighed. Data loggers were set to record the temperature and humidity inside the samples every 15 minutes. This is provided, for reference, in the Appendix (Figure 5).

The chamber had been pre-conditioned to 89% relative humidity and 11°C. The samples were then subjected to 5 x 10 hour cycles of humidity and temperature change over a 5 day period. The cycles were designed to simulate the conditions (in a NZ South Island room) during winter. They included a daytime and a night time schedule based on data from a number of sources [2-5]. In addition, a brief check on conditions in two Lincoln-based, south-facing bedrooms in a modern (built in 2006), double glazed, single-story home was carried out. This was done using temperature and humidity data loggers set to record every 15 minutes for a period of 24 hours. An overview of the data obtained is provided in Table 1.

Table 1. Bedroom conditions recorded by data loggers.

Room	Temperature (°C)		Relative humidity (%)	
	Maximum	Minimum	Maximum	Minimum
Bedroom 1 (no occupant; heating off)	18.1	10.8	57.4	64.6
Bedroom 2 (one occupant; heated in evening)	25.4	10.9	72.7	37.8

Since the amount of water present in air at a given pressure is affected by the temperature, a calculation tool [6] was used to determine the alignment of changes in temperature and humidity. This allowed the trial conditions to be aligned to reflect realistic environmental conditions. An overview of the day and night time schedules is shown in Figure 1.

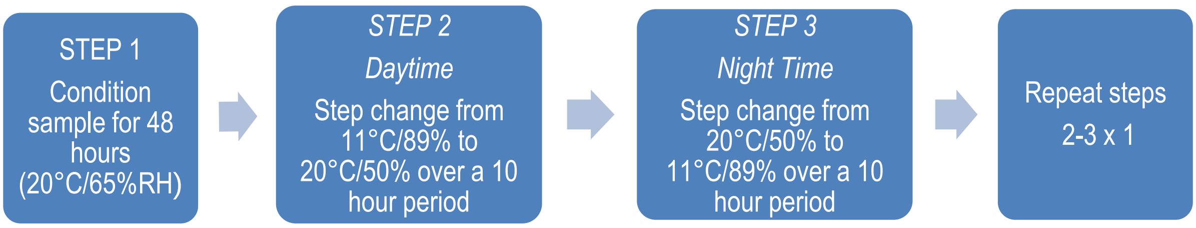

Figure 1. Temperature and humidity cycle schedule.

The sample mass, temperature and relative humidity were recorded every hour. In order to eliminate the issue of vibration on mass measurements, the Contherm was switched off whilst mass was recorded. The daily plan is given in Table 2. The first cycle was used as a lead in to allow the sample to come to equilibrium with the chamber. The data collected during this cycle was not used in any calculations.

Table 2. Daily plan.

Day	1 (Daytime) Lead in/buffer	2 (Night time)	*3* (Daytime)	4 (Night time)	5 (Daytime)
Activity	Change from 89% to 50% and 11°C to 20°C, over 10 hours. Leave overnight.	Change from 50% to 89% and 20°C to 11°C, over 10 hours. Leave overnight.	Change from 89% to 50% and 11°C to 20°C, over 10 hours. Leave overnight.	Change from 50% to 89% and 20°C to 11°C, over 10 hours. Leave overnight.	Change from 89% to 50% and 11°C to 20°C, over 10 hours.
Time (hours)	10	10	10	10	10
Measurements (2 samples)	22	22	22	22	22
Timing	8am-6pm	8am-6pm	8am-6pm	8am-6pm	8am-6pm

4. Results

The appendix contains the full data set obtained over the test period; this doesn't include any for the periods outside of the cycles. The buffer/lead in cycle data (from day 1) is included in the appendix. To facilitate interpretation the results have been graphically represented in Figures 2 to 4. For all cycles the results have been obtained by subtracting the cycle's initial sample mass from each of the subsequent measurements.

Figure 2 shows the change in mass of each sample throughout the night time cycles. The plots are the individual (not averaged) data sets for the two night time cycles. The trend, for both samples, during the night time schedule is for the samples to increase in mass. By capturing change in mass, as opposed to total mass, both wool and polyester samples can be shown on a single Y-axis. This chart clearly illustrates the difference in the magnitude of the changes in sample mass at different temperature and humidity levels. The mass of the wool sample increases to a much greater degree than the polyester's.

Figure 3 shows the change in mass of each sample throughout the daytime cycles. The plots are the individual (not averaged) data sets for the two daytime cycles. The trend, for both samples, during the daytime schedule is for the samples to decrease in mass. This chart clearly illustrates the difference in the magnitude of the changes in sample mass at different temperature and humidity levels, for wool and polyester samples.

Figure 4 contains the full set of day and night time cycles to provide an overview of the absorption and release of moisture of the two substrates during the measurement phases.

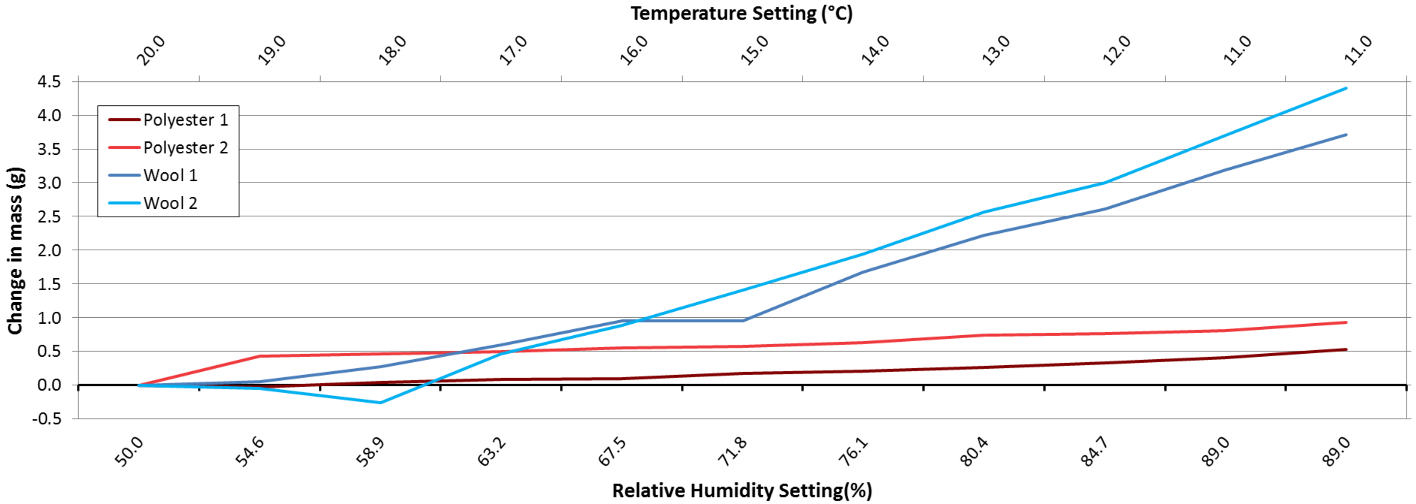

Figure 2. Night time schedule, sample mass difference.

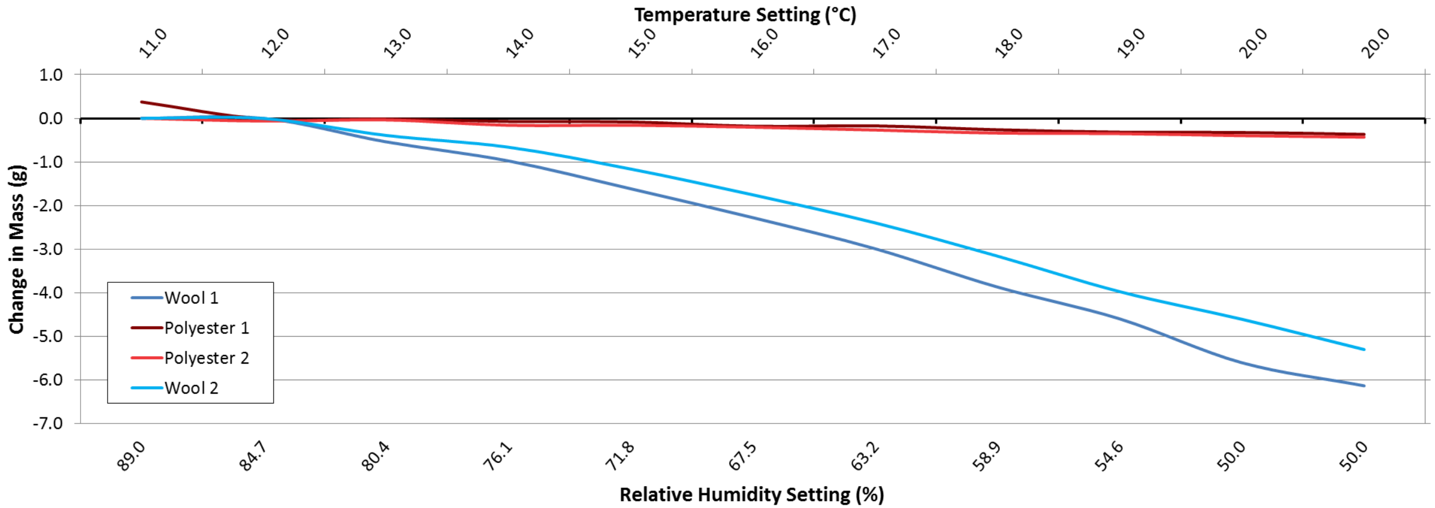

Figure 3. Daytime schedule, sample mass difference.

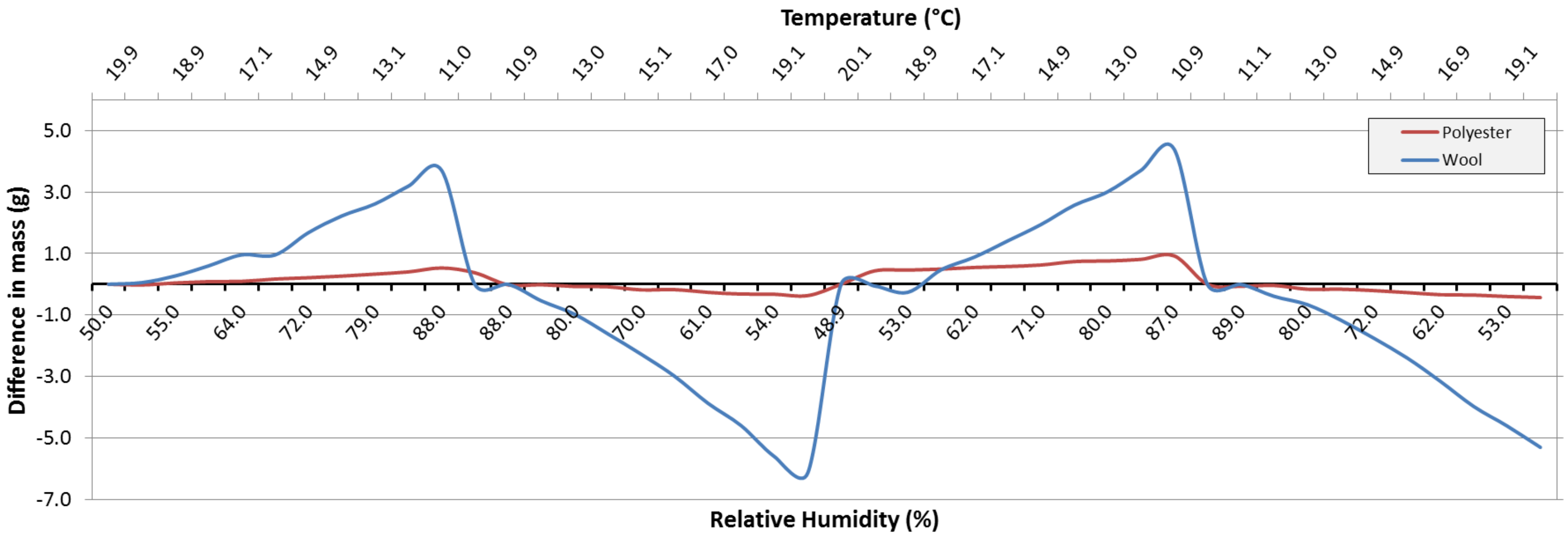

Figure 4. Full trial cycle, sample mass difference.

It was also noted that overnight, when the samples were held at constant temperature and humidity, the wool sample continued to absorb (2.82 g) or release moisture (1.169 g), whilst the polyester exhibited negligible change (0.20 g absorbed, 0.45 g released).

5. Discussion

During the night time cycles, on average the wool absorbed a maximum of 4.05 g of water and the polyester sample absorbed a maximum 0.73 g. In terms of percentage the wool samples' (average) overall increase in mass was 3.79% and for polyester it was 0.66%. On average the wool sample absorbed almost 6 times more moisture than the polyester during the 10 hour night time cycle.

During the daytime cycles, on average the wool sample released a maximum of 4.95 g of moisture whilst the polyester released a maximum of 0.40 g of water. This equates to 3.51% for the wool and 0.37% for the polyester. The wool sample released over 12 times more moisture than the polyester during the 10 hour daytime cycle.

These results further support wool's ability to respond to changes in the humidity of the environment and provide a buffering effect, by absorbing moisture in a high humidity environment and releasing it in a low humidity environment.

The previous trial focussed on maintaining a temperature of 20°C and having relative humidity change from 90% down to 50% (simulating night time) and then back up to 90% (daytime). Although different samples were used for this trial, the percentage difference in mass during this period has been compared to the current trial in Table 3.

Table 3. Comparison of data between trials.

	Wool 2012	Wool 2014	Polyester 2012	Polyester 2014
Night time: Average% change in mass	2.40	3.79	0.30	0.66
Daytime: Average% change in mass	-2.17	-3.51	-0.30	-0.37

It is not possible to directly compare these samples but they do indicate that changing the temperature has had an impact on the samples' ability to absorb and release moisture. In particular the wool sample which demonstrated increases of both moisture absorption and release in excess of 50% compared to the previous trial (with fixed temperature).

6. References

1. A Hodgson, AgResearch Client Report CLR 12-46, Moisture regulation of wool and polyester based insulation materials, September 2012
2. N Isaacs *et al* BRANZ Study Report, Energy use in New Zealand households, No. SR155 (2006), pp 53-57
3. C R Lloyd, M F Callau, T Bishop and I J Smith, The Efficacy of an energy efficient upgrade program in New Zealand, Energy and Buildings, Vol 40, 2008, pp.1228-1239
4. M Shen and C R Lloyd, Monitoring of energy efficiency upgrades of public housing in Southern New Zealand, University of Otago, Department of Physics, Energy Management Programme. In Sayigh, A. (Ed.) (2004) Proceedings of the 8th World Renewable Energy Congress (WREC VIII) 28th August - 3rd September 2004, Denver, Colorado, USA.
5. M Boulic I Hosie and R Phipps, Student Paper: Effects on indoor environment in 30 Auckland homes from the installation of a positive pressure ventilation unit, Proceedings: SB10 Wellington - Innovation and Transformation, May 2010, Wellington, New Zealand
6. Website: https://ready.arl.noaa.gov/READYmoistcal.php (viewed 5th August 2014).

Appendix

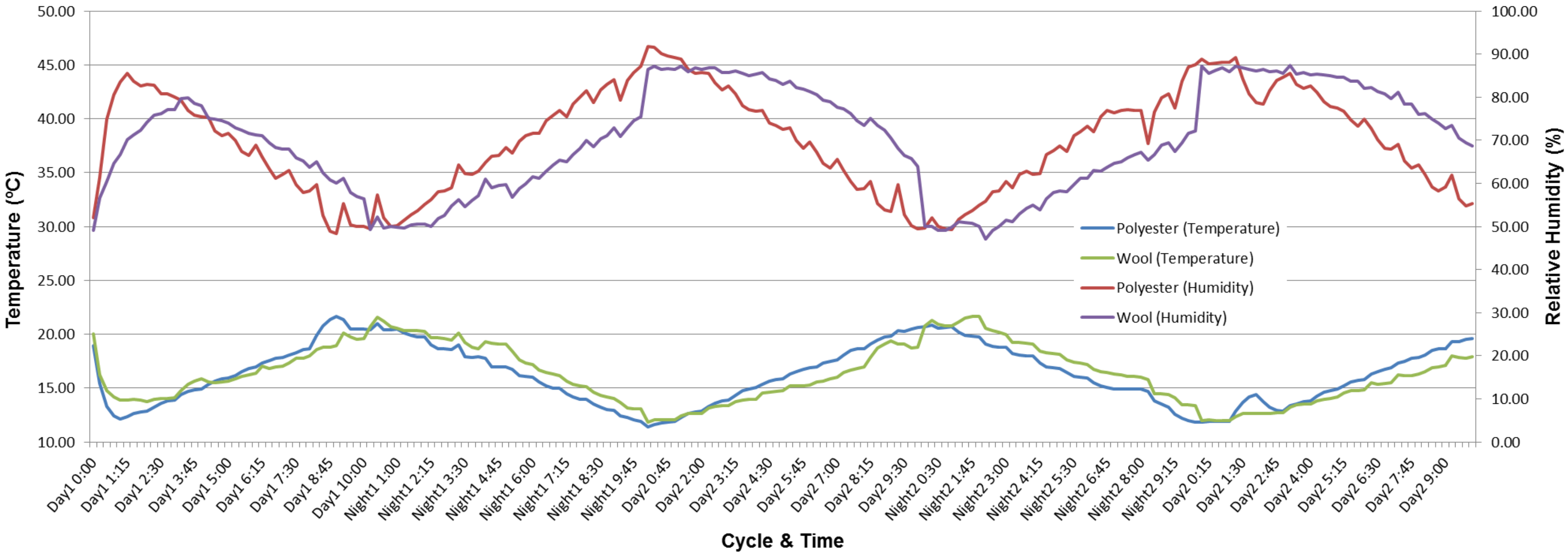

Figure 5. Internal data logger data.

Table 4. Sample mass data.

Day 1 (Daytime)				
Measurement Time	Actual Temperature	Actual Humidity	Wool Sample Mass (g)	Polyester Sample Mass (g)
08:00a.m.	11.9	88.0	160.394	108.729
09:00a.m.	11.0	88.0	161.715	109.065
10:00a.m.	12.0	84.0	161.805	108.932
11:00a.m.	13.1	80.0	162.258	109.216
12:00p.m.	13.9	75.0	161.524	109.170
01:00p.m.	15.1	71.6	161.586	109.205
02:00p.m.	16.0	66.0	161.214	109.119
03:00p.m.	17.0	63.0	160.862	109.049
04:00p.m.	18.1	58.0	160.490	109.047
05:00p.m.	18.9	52.0	160.063	108.946
06:00p.m.	Not measured	Not measured	159.697	108.988

Day 2 (Night time)								
Measurement time	Actual temperature	Actual humidity	Wool sample mass (g)	Difference in mass (g)	% Difference	Polyester sample mass (g)	Difference in mass (g)	% Difference
08:00a.m.	19.9	50.0	159.055	0.000	0.00	108.949	0.000	0.00
09:00a.m.	20.0	52.0	159.109	0.054	0.03	108.926	-0.023	-0.02
10:00a.m.	18.9	55.0	159.323	0.268	0.17	108.993	0.044	0.04
11:00a.m.	18.1	58.0	159.652	0.597	0.38	109.033	0.084	0.08
12:00p.m.	17.1	64.0	160.011	0.956	0.61	109.042	0.093	0.09
01:00p.m.	16.1	67.0	160.008	0.953	0.61	109.119	0.170	0.16
02:00p.m.	14.9	72.0	160.731	1.676	1.07	109.160	0.211	0.20
03:00p.m.	13.9	75.0	161.275	2.220	1.42	109.215	0.266	0.25
04:00p.m.	13.1	79.0	161.667	2.612	1.67	109.279	0.330	0.31
05:00p.m.	12.1	83.0	162.243	3.188	2.04	109.350	0.401	0.38
06:00p.m.	11.0	88.0	162.765	3.710	2.38	109.479	0.530	0.50

Day 3 (Daytime)								
Measurement time	Actual temperature	Actual humidity	Wool sample mass (g)	Difference in mass (g)	% Difference	Polyester sample mass (g)	Difference in mass (g)	% Difference
08:00a.m.	11.1	88.0	166.300	0.000	0.00	109.324	0.375	0.35
09:00a.m.	10.9	88.0	166.299	-0.001	0.00	109.306	-0.018	-0.02
10:00a.m.	11.9	83.0	165.760	-0.540	-0.33	109.308	-0.016	-0.01
11:00a.m.	13.0	80.0	165.323	-0.977	-0.60	109.252	-0.072	-0.07
12:00p.m.	13.9	76.0	164.685	-1.615	-0.99	109.240	-0.084	-0.08
01:00p.m.	15.1	70.0	164.022	-2.278	-1.39	109.142	-0.182	-0.17
02:00p.m.	15.9	67.0	163.309	-2.991	-1.83	109.150	-0.174	-0.16
03:00p.m.	17.0	61.0	162.431	-3.869	-2.37	109.061	-0.263	-0.24
04:00p.m.	17.9	58.0	161.701	-4.599	-2.82	109.006	-0.318	-0.29
05:00p.m.	19.1	54.0	160.695	-5.605	-3.43	108.999	-0.325	-0.30
06:00p.m.	19.9	50.0	160.165	-6.135	-3.76	108.956	-0.368	-0.34

Day 4 (Night time)								
Measurement time	Actual temperature	Actual humidity	Wool sample mass (g)	Difference in mass (g)	% Difference	Polyester sample mass (g)	Difference in mass (g)	% Difference
08:00a.m.	20.1	48.9	158.996	0.000	0.00	108.497	0.000	0.00
09:00a.m.	19.9	50.0	158.941	-0.055	-0.04	108.930	0.433	0.41
10:00a.m.	18.9	53.0	158.733	-0.263	-0.17	108.957	0.460	0.44
11:00a.m.	18.1	59.0	159.463	0.467	0.30	108.989	0.492	0.47
12:00p.m.	17.1	62.0	159.877	0.881	0.56	109.044	0.547	0.52
01:00p.m.	16.1	66.0	160.404	1.408	0.90	109.074	0.577	0.55
02:00p.m.	14.9	71.0	160.936	1.940	1.24	109.124	0.627	0.59
03:00p.m.	13.9	76.0	161.564	2.568	1.65	109.234	0.737	0.70
04:00p.m.	13.0	80.0	162.000	3.004	1.93	109.255	0.758	0.72
05:00p.m.	11.9	85.0	162.695	3.699	2.37	109.306	0.809	0.77
06:00p.m.	10.9	87.0	163.395	4.399	2.82	109.422	0.925	0.88

Day 5 (Day time)								
Measurement time	Actual temperature	Actual humidity	Wool sample mass (g)	Difference in mass (g)	% Difference	Polyester sample mass (g)	Difference in mass (g)	% Difference
08:00a.m.	11.1	89.0	165.511	0.000	0.00	109.375	0.000	0.00
09:00a.m.	11.1	89.0	165.506	-0.005	0.00	109.311	-0.064	-0.06
10:00a.m.	12.1	85.0	165.119	-0.392	-0.24	109.337	-0.038	-0.04
11:00a.m.	13.0	80.0	164.849	-0.662	-0.41	109.214	-0.161	-0.15
12:00p.m.	13.9	75.0	164.348	-1.163	-0.72	109.215	-0.160	-0.15
01:00p.m.	14.9	72.0	163.756	-1.755	-1.08	109.170	-0.205	-0.19
02:00p.m.	16.1	67.0	163.113	-2.398	-1.48	109.105	-0.270	-0.25
03:00p.m.	16.9	62.0	162.351	-3.160	-1.94	109.036	-0.339	-0.32
04:00p.m.	18.1	60.0	161.536	-3.975	-2.45	109.023	-0.352	-0.33
05:00p.m.	19.1	53.0	160.902	-4.609	-2.84	108.976	-0.399	-0.38
06:00p.m.	19.9	52.0	160.208	-5.303	-3.26	108.943	-0.432	-0.41