CeBE Centre for the Built Environment

Whole House Heat Loss Test Method (Coheating)

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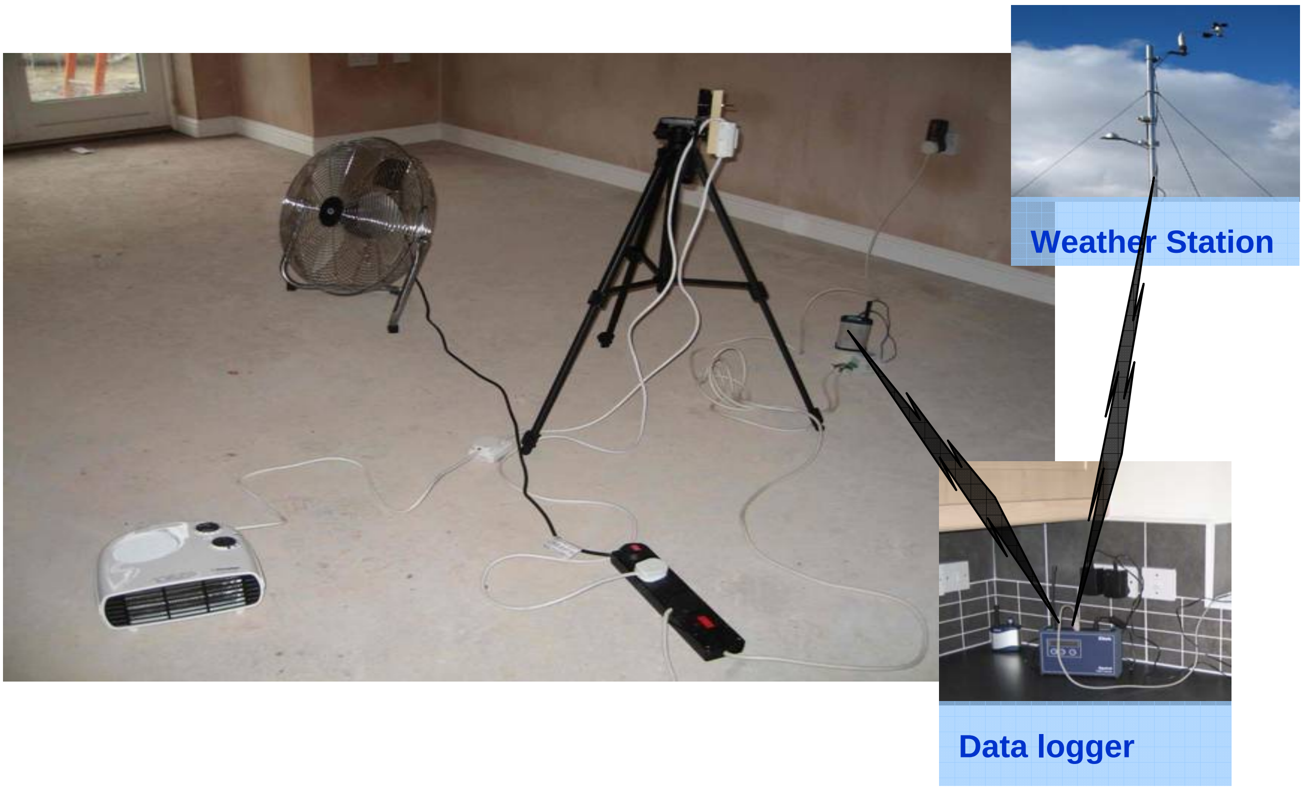

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Introduction

1 A coheating test is a method of measuring the heat loss (both fabric and background ventilation) in W/K attributable to an unoccupied dwelling. It involves heating the inside of a dwelling electrically, using electric resistance point heaters, to an elevated mean internal temperature (typically 25 °C) over a specified period of time, typically between 1 to 3 weeks. By measuring the amount of electrical energy that is required to maintain the elevated mean internal temperature each day, the daily heat input (in Watts) to the dwelling can be determined. The heat loss coefficient for the dwelling can then be calculated by plotting the daily heat input against the daily difference in temperature between the inside and outside of the dwelling (ΔT). The resulting slope of the plot gives the heat loss coefficient in W/K.

2 In order to obtain a sufficient value of ΔT (generally 10 K or more), the coheating test should be carried out in the winter months, usually between October/November and March/April.

Testing and monitoring equipment

3 A number of items of equipment are required to undertake a coheating test on a dwelling. The main items of equipment required within the dwelling to be tested (test dwelling) are as follows:

a) **Temperature and relative humidity sensors** – These are used to measure internal temperature and relative humidity within the dwelling. As a minimum, only the temperature sensors are required. However, the addition of the relative humidity sensors can be advantageous when analyzing the data obtained from the coheating test, as they can give an indication of how the dwelling has dried out during the test.

b) **Fan heaters** – These are used to heat the dwelling. A variable output model is preferred as it enables a degree of adjustment if required.

c) **Circulation fans** – These are used to mix the internal air within the dwelling. A variable speed fan is preferred as it enables a degree of adjustment if required.

d) **Thermostats** – These are used to regulate the heat output from the fan heaters.

e) **kWh meters** – These are used to measure the electrical energy consumption of the fan heaters, the circulation fans and the datalogger (if mains powered). The kWh meters should have a pulsed output that can be read by the datalogger.

f) **Datalogger** – This is used to record the data obtained from inside the dwelling. Careful consideration should be given to the choice of datalogger used to ensure that it is capable of recording all of the data that needs to be obtained from the dwelling. This data will include: temperature and humidity data from the temperature and humidity sensors and kWh data from the fan heaters and circulation fans.

g) **Extension leads** – These are used to supply mains power to the fan heaters and fans, as well as any other items of equipment, such as thermostatic controllers or dataloggers that require mains power.

4 A wireless battery powered monitoring system with a mains-powered datalogger is the preferred option within the dwelling as it removes the need for wiring between the sensors and the datalogger. This enables flexibility in the placement of the sensors and the equipment within the dwelling.

5 A photograph illustrating the main items of coheating test equipment installed within a test dwelling can be seen in Figure 1.

Figure 1 Coheating test equipment installed within a test dwelling.

6 It is important to note that additional items of equipment, such as transmitters, pulse counters, modems, etc. may also be required within the test dwelling depending upon the type of monitoring equipment used.

7 In addition to the above items of equipment, additional equipment is also required to collect external weather data. The weather data required for the coheating test consists of measurements of external temperature and relative humidity, vertical South facing solar radiation and wind speed. In order to obtain this data, the following items of equipment are required:

a) **Weather station** – This is used to measure the external temperature, relative humidity, wind speed, wind direction, rainfall and barometric pressure. As a minimum, only the external temperature and relative humidity sensors are required. However, the addition of the other sensors can give invaluable insights when analyzing the data obtained from the coheating test.

b) **Pyranometer** – This is used to measure the South facing solar radiation flux density in W/m^2.

c) **Datalogger** – A separate dedicated datalogger for the weather station (including pyranometer) may be required. This will be dependent upon whether the datalogger installed within the dwelling is capable of recording all of the inputs from the weather station. If a wireless system is used, it may also be dependent upon the proximity of the weather station to the dwelling.

8 A photograph illustrating the weather station can be seen in Figure 2.

Figure 2 Coheating test weather station installed on gable wall.

9 If the dwelling to be tested is semi-detached, terraced or an apartment, then consideration will have to be given to any heat loss that may occur through any elements of construction that are shared with adjacent dwellings (such as party walls, party floors, etc.) or to any unoccupied spaces (such as stairwells, communal areas, etc). If access to adjacent dwellings or spaces can be obtained, then the ideal solution would be to maintain these spaces at the same mean internal temperature as the test dwelling. This can be achieved by installing additional fan heaters, circulation fans, thermostats and temperature and humidity sensors in the spaces. In doing so, any heat loss through elements of construction that is attributable to differences in temperature between the test dwelling and the adjacent spaces will be eliminated. However, it should be remembered that this will not necessary eliminate all of the heat losses through the elements of construction, as heat loss will still occur if any thermal bypasses in the construction exist.

10 If access to any adjacent dwellings or spaces cannot be achieved then an alternative approach would be to measure the internal temperature and relative humidity in all of the adjacent spaces and install heat flux sensors on the internal surface of the test dwelling to measure the heat flux through the elements of construction concerned. However, this approach has a number of limitations. These are as follows:

a) The heat flux measured by the heat flux sensors will relate only to the ΔT monitored. It may be that the heat flux will vary depending on the value of ΔT.

b) The heat flux measured will relate to a particular portion of construction and may not be representative of that construction as a whole.

11 An example equipment specification for a dwelling that has recently undergone a coheating test is contained within Appendix A.

Location and numbers of equipment

12 The location and number of items of equipment required to undertake a coheating test will vary and will be dependent upon the size, the form, the internal layout and the thermal performance of the dwelling. These factors will determine the number of zones that are required to be incorporated within the dwelling. As a minimum, each floor of a dwelling should be treated as a separate zone. For instance, in a two storey dwelling there would be a minimum of two zones; one zone for downstairs and one zone for upstairs. In apartments, where there is only one floor, the apartment

should be split into at least two zones; one zone for the living area and one zone for the master bedroom. However, in some dwellings, particularly large dwellings or those with poor thermal performance, more zones may be required in order to achieve the required elevated internal temperature throughout the dwelling.

13 The location and numbers of equipment that are likely to be required in a typical detached dwelling are as follows:

a) **Temperature and relative humidity sensors** – Ideally a temperature and relative humidity sensor should be installed in all of the habitable areas within the dwelling (living room, dining room, kitchen, bedrooms, toilets, bathrooms, en-suites, hallways, etc.). However, this is not always practical as it may require the installation of a large number of sensors. Therefore, as a minimum, one temperature and relative humidity sensor is required per zone. The sensors need to be strategically positioned to avoid direct sunlight and to minimise direct heating from the fan heaters.

b) **Fan heaters** – At least one fan heater is required per zone (more may be required if the elevated mean internal temperature cannot be reached). The fan heaters should be connected to the extension lead output of the kWh meter and positioned in such a way as to provide as much heating to the zone as possible. Care should be taken when selecting and installing the fan heaters to ensure that they do not overload the ring circuit that they are connect to and trip out the consumer unit if all the fan heaters and fans were switched on at once.

c) **Circulation fans** – At least one circulation fan is required per zone. The circulation fan should be connected to the extension lead output of the kWh meter and located to provide good mixing of the air both within and between the zones. Additional fans may be required if adequate mixing of the air throughout the dwelling cannot be achieved.

d) **Thermostats** – One thermostat is required per fan heater. The thermostat should be located at working plane height (approximately 0.85m above ground level) and be installed in-line with the fan heater. The thermostat should also be positioned to avoid direct sunlight and to minimise direct heating from the fan heaters.

e) **kWh meters** – At least one kWh meter is required per zone. It should be installed in-line with any extension lead that supplies power to the fan heaters, circulation fans and datalogger.

f) **Datalogger** – At least one datalogger will be required per dwelling. If mains powered, it should be connected to the extension lead output of the kWh meter.

g) **Heat flux sensors** – If required, the numbers and location of the sensors will be dependent upon the type of construction involved. An appropriate number of sensors should be installed to give an indication of the flux through the particular element of construction concerned.

h) **Extension leads** – At least one is required per zone. More may be required depending upon the numbers of equipment installed that require mains power. If additional extension leads are required, a kWh meter will have to be installed in-line to measure the electrical energy consumption of any appliances connected to the lead.

i) **Weather station** – Mounted horizontally above ground level on a mast. Positioned to avoid any possible overshading.

j) **Pyranometer** – Mounted vertically above ground level on a mast. Must be South facing and positioned to avoid any possible overshading.

14 An example equipment layout for the temperature and humidity sensors, fan heaters and circulation fans can be found in Appendix B.

Estimating the background ventilation rate

15 When analysing the results obtained from a coheating test it is often useful to be able to separate out the heat losses attributable to the fabric and those attributable to background ventilation. This can be achieved by undertaking two pressurisation tests on the dwelling, one prior to undertaking the coheating test and one a soon as the test has been completed. The resulting average air leakage rate can then be used to give an estimate of the background ventilation rate for the dwelling. Alternatively, the background ventilation rate within the dwelling can be measured during the coheating test using tracer gas decay methods.

16 A range of tracer gases can be used. In some recent coheating tests undertaken by the LeedsMet research team, a CO_2 decay method was used. This method involved installation of the following items of equipment:

a) **CO_2 sensors** – These were used to measure the CO_2 concentration within the dwelling. The sensors were strategically located at different points throughout the building (2 on the ground floor, one on the second floor and one on the third floor) and out of the direct line of the circulation fans.

b) **CO_2 gas dispensing system** – This was used to inject CO_2 gas into the dwelling. The dispensing system was located on the ground floor of the dwelling. To aid mixing of the gas throughout the dwelling the outlet tube from the CO_2 gas dispensing system was attached to the casing of one of the ground floor circulation fans.

17 The method involved automatically injecting CO_2 gas into the dwelling at the same time, once per day, using a CO_2 gas dispensing system. The gas flow rate of the dispensing system was set such that the internal CO_2 levels throughout the dwelling were boosted to over 1000ppm. The CO_2 gas dispensing system was then switched off and gas decay rate was measured over time using the CO_2 sensors. The decay data was then used to calculate a background ventilation rate according to the method of Roulet and Foradini (2002).

18 An example equipment specification for CO_2 decay measurement is contained within Appendix A.

Transmit and logging intervals

19 The recommended transmit and logging intervals for each item of equipment are detailed in Table 1 below.

Component	**Logging interval**
Temperature and relative humidity sensors	Set at 5 minute transmit interval
kWh meter	1 Wh pulse output with a 5 minute transmit interval
Weather station	Set at 5 minute transmit interval
CO_2 sensors	Set at 5 minute transmit interval
Pyranometer	Set at 5 minute transmit interval
Datalogger	Set at 10 minute logging interval

Table 1 Coheating test equipment transmit and logging intervals.

Test procedure

20 Prior to undertaking the coheating test, a pressurisation test should be performed on the dwelling. The pressurisation test should be carried out in accordance with ATTMA Technical Standard 1 (ATTMA, 2007).

21 Following the pressurisation test, a number of measures are required to be put in place in order to minimise the contributions from other heat gain and heat loss mechanisms during the test. These measures are as follows:

a) All heating and electrical systems within the dwelling that are not used during the test need to be turned off. This should be done at the fuse box where applicable. For instance, the space and hot water heating system (including the hot water cylinder), lights, fridge, freezer, oven, hob and any mechanical extract fans.

b) All trickle vents, acoustic vents and mechanical supply/extract vents need to be adjusted to the closed position or temporarily sealed.

c) All flues and fire places need to be temporarily sealed.

d) All water traps and U-bends in kitchens, bathrooms, en-suites and toilets need to be filled with water; these will need topping-up throughout the test period due to evaporation.

e) All external doors and windows should be inspected to ensure that they are tightly closed.

f) All internal doors (including wardrobe and built-in cupboard doors) need to be temporarily wedged open to allow free movement of air around the dwelling.

22 Once the above measures are in place, the test can commence. The test procedure is as follows:

a) Adjust all of the thermostats to 25°C.

b) Switch on all of the fan heaters and adjust them such that they are operating on their maximum heat and fan speed setting.

c) Switch on all of the circulation fans and adjust to an appropriate angle and their maximum fan speed setting.

d) Switch on the CO_2 gas dispensing system.

e) Activate all of the dataloggers to record the internal and external data at 10 minute intervals.

f) Observe the CO_2 concentrations for the first couple of days to ensure that the gas dispensing system is capable of producing a relatively constant concentration of CO_2 gas throughout the dwelling each day before the dispensing system is switched off and the decay of the gas is monitored.

g) Observe the internal temperatures obtained from the temperature sensors for the first couple of days to ensure that they are increasing towards the setpoint on the thermostats (25°C).

h) Once the setpoint temperature has been reached, observe all of the internal temperatures obtained from the temperature sensors to determine whether there is a relatively uniform mean internal temperature throughout the dwelling.

i) If the mean internal temperature observed throughout the dwelling is not uniform, adjust the thermostats in each zone as necessary to obtain a uniform mean internal temperature. If a uniform mean internal temperature can still not be achieved, it may be necessary to change the position of the fan heaters and circulation fans in the zones. It may also be necessary to adjust the heat output from the fan heaters, the speed of the circulation fans and the angle of the circulation fans.

j) If a relatively uniform mean internal temperature is observed throughout the dwelling, but it is marginally different to the setpoint temperature on the thermostats, then the test should be allowed to continue at the different mean internal temperature.

k) Once a relatively uniform mean internal temperature is achieved, continue to log all of the data for a sufficient period of time such that a range of internal to external temperature differences (ΔT's) are recorded. Generally speaking, this should be for at least one week, but preferably two or three.

l) Download the data from the datalogger/s daily.

23 After completion of the coheating a test, a second pressurisation test should be undertaken on the dwelling once the dwelling has been allowed to cool down.

Points to note

24 Consideration should be given to the following when undertaking the coheating test:

a) Ensure that if power is to be taken off the domestic socket ring main, it is not overloaded. In new multi-floor dwellings, one ring circuit is normally installed per floor and at least two ring circuits are normally installed in apartments. The ring circuit is likely to be rated at 30 amps (7200 Watts) and will be protected by a 32 amp RCD connected to the consumer unit. In addition, each socket on the ring circuit will be rated at 13 amps. This will limit the number of items of equipment that can be connected to each ring main, particularly fan heaters which may be rated at 3kW each.

b) The location of the equipment within the rooms is not an exact science and is likely to involve a degree of trial and error. It is not uncommon to have to move equipment around or adjust equipment during the early stages of a test to achieve even temperatures throughout the dwelling.

c) Throughout the test, entry to the dwelling should be kept to a minimum and limited to those times when adjustments are required to be made to equipment. If entry to the dwelling is required, it should be for as short a time as possible and the use of any electrical equipment within the dwelling, such as lights, should be minimised where possible.

References

ATTMA (2007) *Technical Standard 1. Measuring Air Permeability of Building Envelopes* [Internet]. Airtightness Testing and Measurement Association. Issue 2, 13th July 2007. Available from: http://www.attma.org [Accessed 6th October 2009].

ROULET, C-A. & FORADINI, F. (2002) *Simple and Cheap Air Change Rate Measurements Using* CO_2 *Concentration Decay*, International Journal of Ventilation, Volume 1, No.2, pp 39-44

APPENDIX A

Component	Equipment Used
Temperature and Relative Humidity Sensor	Eltek GC-10 Temp/RH Transmitter
Fan Heater	Delonghi THE332-3 3kW Fan Heater or Dimplex DLB503 3kW Fan Heater, 3kW max heat output
Circulation Fan	Prem-I-Air HPF-4500 Air Circulator 18" fan blade
Thermostat	Honeywell T4360B Thermostat or Sunvic TLM 2253 Thermostat, 16A load capacity
kWh Meter	Elster A100C, 1 Wh pulse output
Pulse Transmitter	Eltek GS-62 Pulse Transmitter
Datalogger	Eltek RX250 Receiver Logger 250 channel radio receiver logger
GSM Modem	Wavecom Fastrak GSM Modem

Table A1 Co heating test equipment specification.

Component	Equipment Used
Weather Station	Vaisala WXT520 Weather Transmitter With outputs for wind speed, wind direction, temperature, humidity, rainfall and barometric pressure
Pyranometer	Kipp & Sonnen CMP3 pyranometer Vertical Orientation, South Facing
Datalogger	Eltek 851-WXT Squirrel Datalogger 10 channel wired logger
GSM Modem	Wavecom Fastrak GSM Modem

Table A2 Weather station equipment specification.

Component	Equipment Used
Heat Flux Sensors	Hukseflux HFP01 Flux Sensor. Attached to wall using thermal paste and masking tape.
Thermal Paste	Corning 340 silicone heat sink compound. Used to improve thermal contact between sensor and wall.
Datalogger	Datataker DT80

Table A3 Heat flux equipment specification.

Component	Equipment Used
CO_2 Sensor	Vaisala GMW25 CO_2 sensor 0-2000 ppm CO_2 concentration range 4-20 mA current output
CO_2 Transmitter	Eltek GS-42 DC Current/Voltage Radio Transmitter. 4-20 mA current input
CO_2 Dispensing System	Disposable CO_2 Cylinder (600g), Valve Assembly, Solenoid Valve, 7 day/24 hour Timer, Needle Valve. Flow rate ~10 litres/min for 15 minutes

Table A4 CO_2 decay measurement equipment specification.

APPENDIX B

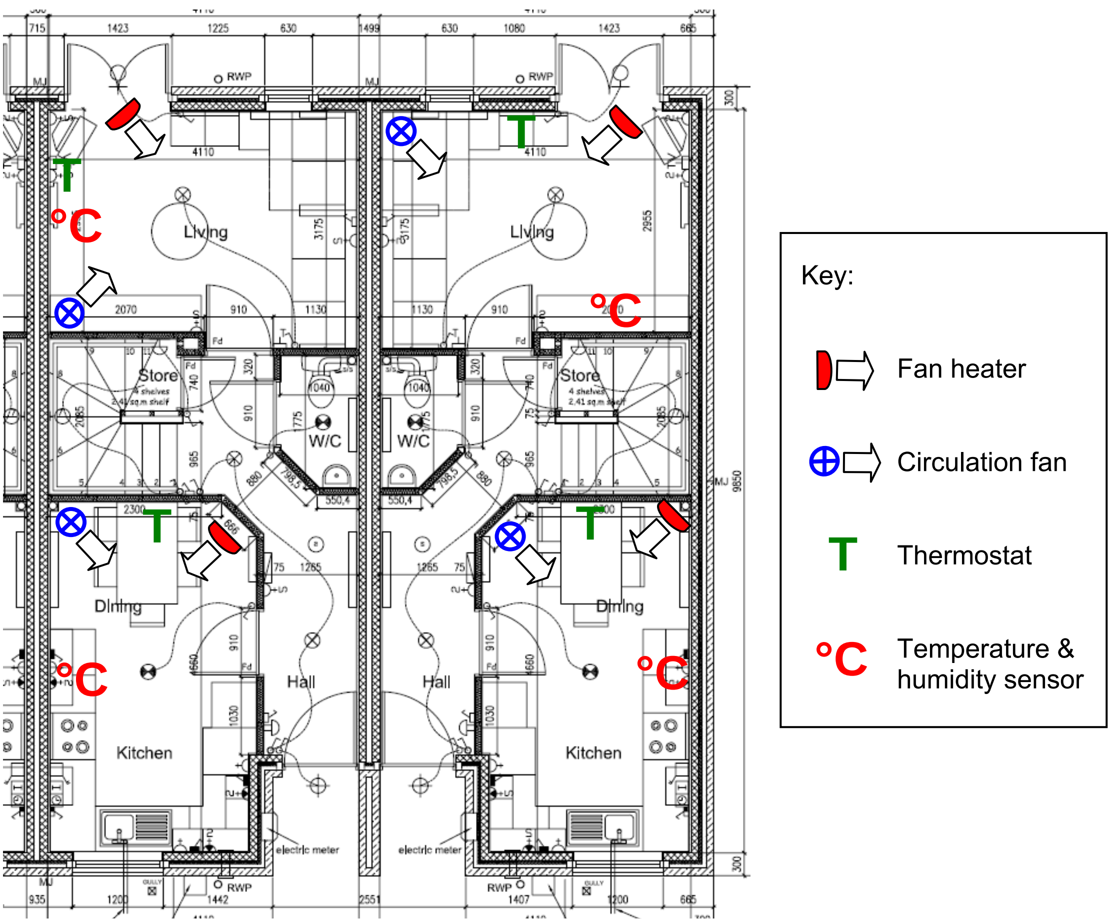

Figure B1 Ground floor plan.

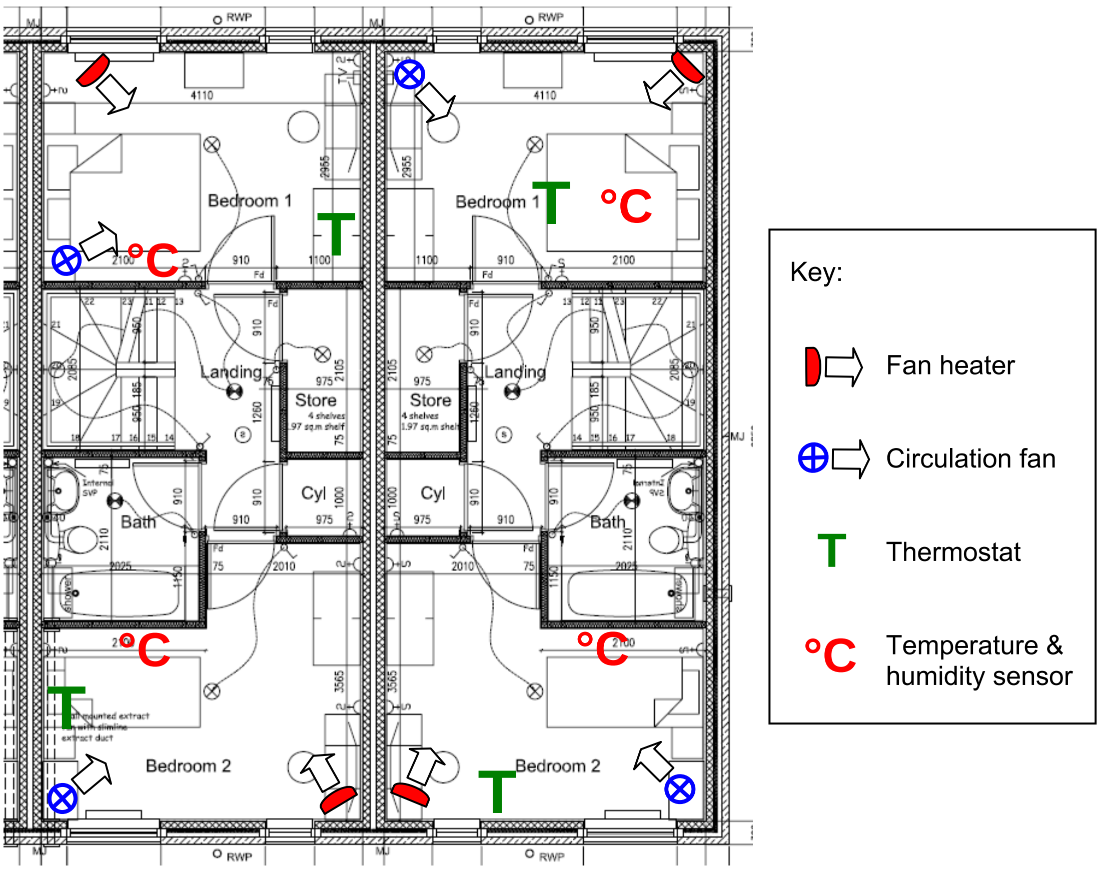

Figure B2 First floor plan.

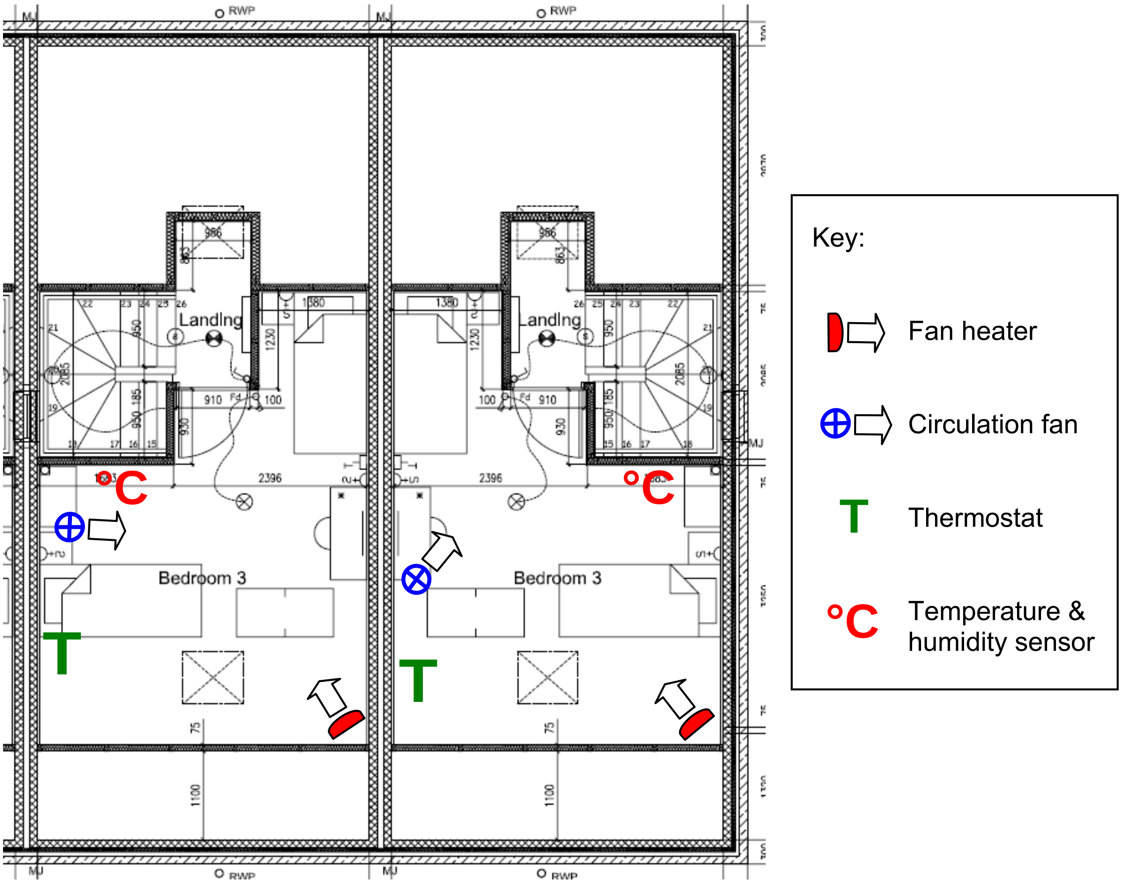

Figure B3 Second floor plan.