

1. General objectives of the round robin experiment

The global objective of the Round Robin Experiment is to perform a well controlled comparative experiment on testing and data analysis. To this extent, a test box (a scale model of a simplified building) has been built by KU Leuven in the framework of the IEA-EBC Annex 58 project. Figure 3 and 9 give an impression of the test box. After construction, the box has been shipped to different sites (different climatic conditions and different acquisition equipment) with the aim to perform a full scale measurement of the test box under real climatic conditions. The obtained dynamic data is distributed to different institutes who will perform analysis to characterize the test box based on the provided experimental data. In this way, it is not a pure round robin experiment (inter-laboratory comparison performed independently by different institutes), but it is more a combination of a round robin test and data analysis comparison, somewhat comparable with e.g. the BESTEST for numerical modelling.

The aim of the experiment is first of all, to determine the state-of-the-art on experimental design, full scale measurements and dynamic data analysis: where are we as experts at the moment?

It can be seen as a first step before moving to more complex (real) buildings. Furthermore, the well-controlled experiment allows:

- investigating the capabilities, limitations and reliability of full scale testing
- investigating the capabilities, limitations and reliability of dynamic data analysis
- investigating the influence of variables such as climatic conditions on characterisation tools and at the same time, the experiment should
- provide a well documented data set for validation of data analysis tools.

2. Aim and general description of the exercise

The global objective is to characterize the Round Robin Test Box based on experimental data obtained during a measurement campaign during 2013, performed by CIEMAT at PSA in Almería, Spain. This campaign represents a second in a series of campaigns organised in different European climatic conditions and using different acquisition equipment depending on the institute performing the test.

This exercise intends to continue identifying strengths and weaknesses of different practiced analysis methodologies, applied on real full scale experimental data. Particularly taking into account the weather conditions at this test site, this exercise has the following specific objectives:

- Evaluate the capability to model and obtain accurate energy performance indicators of the test box under relative cold and sunny weather conditions (winter in Spain)
- Evaluate if implemented improvement in experiment set up and measurements lead to more accurate measurements.

The Round Robin Test Box is shortly described in section 3. The experiments performed at CIEMAT-PSA are illustrated in section 4. In Section 5, the collected data set is documented. Section 6 concludes with the expected outcomes of this common exercise.

This instruction document, together with the collected measurement data sets has been prepared for the DYNASTEE training webinars, replacing the physical Summer School 2020 and is based on the document provided by CIEMAT-PSA.

3. Round Robin Test Box description

The investigated test box has a cubic form (Fig 1, 3 and 4), with exterior dimensions of $120 \times 120 \times 120 \text{ cm}^3$. The floor, roof and wall components are all identical and exhibit a thickness of 12cm, leaving an inner volume of $96 \times 96 \times 96 \text{ cm}^3$. One wall contains a window component with dimensions $60 \times 60 \text{ cm}^2$, inside window frame (glazed part $52 \times 52 \text{ cm}^2$, outside frame $71 \times 71 \text{ cm}^2$). A structure is provided around the box, which allows the box to remain free from the thermal influence of the ground. Hence, the box can be considered as floating in free air.

4. Performed experiment

The experiments carried out at CIEMAT-PSA have been designed, taking as reference to the previous set of experiments carried out at BBRI in Belgium for the Round Robin experiment under the Annex 58 project. Particular measurement devices and test conditions in these new tests are described below.

4.1. Boundary conditions

The RR test box was tested at the LECE laboratory at Plataforma Solar de Almeria (PSA), in the South East of Spain (37.1°N, 2.4°W). The weather at this test site is dry and extremely hot in summer and cold in winter. Temperature swings largely between day and night. Global solar radiation on the south vertical surfaces is very strong in winter, and on the horizontal surfaces it is very strong in summer. Sky is usually very clear.

The experiments extended over a period of 33 days, starting the 6th of December 2013 and ending the 7th of January 2014.

Testing is done under real outdoor weather conditions.

The following outdoor climate sensors installed near the test box are included in the supplied data:

- air temperature (with a solar radiation shield and ventilated),
- vertical global solar radiation (parallel and next to the glazing)
- wind speed
- wind direction (North 0°, East 90°)

Additional meteorological sensors installed at the test site (80 m east from the test box) are also included in the data sets:

- horizontal global solar radiation
- beam solar radiation.
- diffuse solar radiation.
- vertical long wave radiation.
- relative humidity.

Other sensors installed at the test site (325 m north from the test box):

- horizontal long wave radiation from the sky.
- vertical global solar radiation facing north

4.2. Measurement devices

This section describes the measurement equipment and other considerations regarding their accuracy.

The following list summarises the used measurement transducers and sensors:

- Air temperature: Platinum thermos-resistance, PT100, 1/10 DIN, directly measured using a four-wire connection, with a solar radiation shield and ventilated for outdoor measurements. (Figure 5 and Figure 8).
- Surface temperature: Analogous sensors and connections as those used for air temperature. The used sensor consists in a very small sensing element embedded in a very slim semi-transparent substrate. These devices have been glued to the measured surfaces in their centre and covered with a tape of same colour of the surface, to integrate them as much as possible with the corresponding surface. (Figure 6 and Figure 7).

The internal temperature of the glass has been measured using the same device and two additional sensors: One using other type of PT100 with a very small and slim white substrate (named as Tsi glazing2), and other using a type T thermocouple (named as Tsi glazing3).

- Average surface temperature: Type T thermocouples class 1 according to IEC-584-1982, voltage directly measured using a differential connection, Nine sensors have been matrix distributed and glued in each internal surface of the Test Box. The average of the corresponding nine sensors is given for each surface.
- Heat flux density: Sensor model HFP01 manufactured by Hukseflux, accuracy of sensitivity coefficient 5%, voltage measured directly by differential connection. One of these devices has been glued to the centre of each internal surface of the Box and covered with a tape of the same colour of the surface (Figure 6).
- Horizontal and vertical global solar irradiance on the horizontal and south vertical surfaces respectively: Pyranometers, model CM11 manufactured by Kipp and Zonen, secondary standard according to ISO 9060:1990, voltage directly measured using a differential connection. (Figure 8 and Figure 9).

Analogous devices used for diffuse solar irradiance but installed in a two-axis sun tracker SOLYS 2. (Figure 9).

- Beam solar irradiance: Pyrhelimeter, model CHP1 manufactured by Kipp and Zonen, First Class according to ISO 9060:1990, installed in a two-axis sun tracker SOLYS 2 (Figure 9). Voltage directly measured using a differential connection.
- Horizontal and vertical long wave radiation on the horizontal and south vertical surfaces respectively: Pyrgeometers, model CGR-4 manufactured by Kipp and Zonen, voltage directly measured using a differential connection.
- Heating power: Power transducer, model SINEAX DME 440 manufactured by Camille Bauer Ltd. 4..20mA current loop directly measured.
- Wind speed: Sensor model WindSonic manufactured by GILL INSTRUMENTS LTD. 4..20mA current loop directly measured. (Figure 8).
- Outdoors relative humidity. Sensor model HMP45A/D manufactured by VAISALA. 4..20mA current loop directly measured.

A data acquisition system with the following characteristics has been implemented: 16-bit A/D resolution, range of measurements fitting sensor output, modules distributed to minimise wiring, based in Compact Field Point modules manufactured by NATIONAL INSTRUMENTS. Particularly the following list summarises the used modules (Figure 10):

- cFP-RTD-124: Four-Wire RTD and Resistance inputs. Range $-200\text{ }^{\circ}\text{C}$ to $850\text{ }^{\circ}\text{C}$ used for measurement of temperature.
- cFP-TC-125: Differential thermocouple or millivolt inputs. Range -20 mV to 80 mV used for measurement of global and long wave radiation and heat flux density.
- cFP-AI-111: Milliamp input. Range $4\text{--}20\text{ mA}$ used for measurement of wind speed.
- cFP-AI-110: Voltage or current input. Range $0\text{--}1\text{ V}$ used for measurement of relative humidity.

Twisted pairs and grounded shield are employed to reject noise and avoid perturbations from wiring.

4.2. Data acquisition

All data are read and recorded every minute in the GMT timeframe.

The measurements corresponding sensors in the test box and near it and in Meteo 1 are collected using the same distributed data acquisition system. Measurements corresponding to Meteo 2 are recorded using an independent data acquisition system with the same characteristics as the one used for the test box. Both data acquisition systems are synchronised to the main time server at PSA.

4.2. Initial preparation of the test box

4.2.1. Heating power and its measurement

Heating power is necessary to produce a delta T high enough to produce a heat flux through walls that allow to see the phenomena to characterize.

Several actions have been taken to improve the accuracy and resolution in amplitude and time of the measurement of heating power regarding previous test as explained below. In order to improve the resolution in amplitude a very accurate measurement device, which accuracy is 0.25% of reading, has been used.

Even using a so accurate device time resolution can be very poor if temperature control is very accurate and the switching frequency is higher than the sampling frequency (see figure 31, Report ST3a Annex 58).

Switching frequency depends highly on the control dead band: dead band must be low enough to maintain stable indoor air temperature and high enough to avoid high frequency switching that can lead to low resolution measurement of heating power.

Power supplied by the heating device must be high enough to maintain the indoor air temperature set point taking into account that outdoor air temperature can vary from day to night (differences up to 20°C between day and night), and not too high to avoid indoor air stratification and also to avoid fast switching (see figures 29 and 30 Report ST3a Annex 58).

Taking all these conditions into account, several heating devices, dead bands and set points for indoor air

temperature have been examined, with the final goal of achieving (see figures 11 to 15):

- A heat flux through the opaque walls high enough for identification.
- Switching frequency low enough to allow enough time resolution for accurate power measurement.
- Indoor air temperature that is stable enough and at the same time avoiding stratification.

Finally a 100W incandescent lamp has been used as heating device, with 40°C as set point and 0.5°C dead band. Indoor air temperature shows acceptable stability and low stratification, measurement of heating power has enough resolution, and heat flux through the opaque walls is high enough for identification.

4.3. Performed experiments

Each of the three data series has 46 columns. The signals are described in the next section. The three periods have different characteristics when it concerns the auxiliary heating and indoor temperature setting

- PSA_data_Series 16: 6/012/2013 to 17/12/2013 (12 days; 17280 records of observations). One ROLBS power sequences. Heating power using a 100W incandescent lamp.
- PSA_data_Series 17: 18/12/2013 to 26/12/2013 (9 days; 12960 records of observations). Co-heating test. Indoor air temperature set point 35°C and dead band is 0.5°C. Heating power using a 100W incandescent lamp.
- PSA_data_Series 18: 27/12/2013 to 7/01/2014 (12 days; 17280 records of observations): Co-heating test. Indoor air temperature set point 21°C and dead band is 0.8°C. Heating power using a 100W incandescent lamp.

5. Measurement data

For all these tests, the surface of the box equipped with the glazing is oriented to the South.

On each surface of the box (5 opaque surfaces and 1 glazing), the following sensors have been installed:

- Heat flux at the internal surface (in the centre of the surface)
- External surface temperature (in the centre of the surface)
- Internal surface temperature (in the centre of the surface)
- Average of the internal surface temperature (from a matrix of nine measurement points, only in opaque surfaces)

The indoor air temperature has been measured along the vertical symmetry axis of the box at 1/3 and 2/3 of the total height of the box.

An 100W incandescent lamp has been chosen as heating device. It allows to maintain a stable indoor air temperature and at the same time exhibiting a switching frequency lower than the sampling interval to allow for accurate monitoring of heating power.

Three data files (series 16, 17 and 18) are supplied, one for each test. The data files are text files organized in rows and columns and can be inserted directly in programs such as EXCEL. Each column corresponds to a variable. The first row represents the headers of the respective columns and refers to the recorded variables. Data are read and recorded in each row every minute. It is strongly suggested to plot data to control the behaviour of the signals.

The text “_1” and “_2” has been added at the end of the name of variables to indicate that these measurements correspond to Meteo 1 or Meteo 2 respectively (see Figure 2).

The text “N/A” has been used in the data files in records for which the corresponding measurement are not available..



Figure 1: the test box and meteorological devices near to it (left), indoor air temperature (right-top), heat flux and internal and external surface temperature sensors (right-bottom).

Table 1: Nomenclature and units.

Name	Measurement	Unit
TIME	GMT Time	DD/MM/AAAA hh:mm
Tsi glazing	Internal surface temperature	°C
Tsi left		°C
Tsi back		°C
Tsi right		°C
Tsi ceiling		°C
Tsi floor		°C
Ti down	Indoors air temperature (1/3 height of the box)	°C
Ti up	Indoors air temperature (2/3 height of the box)	°C
Tse glazing	External surface temperature	°C
Tse left		°C
Tse back		°C
Tse right		°C
Tse ceiling		°C
Tse floor		°C
Te down	Outdoors air temperature se figure below the box (Figure 1)	°C
Te middle	Outdoors air temperature se figure mid height of the box (Figure 1)	°C
Øi glazing	Heat flux density in the internal surface.	W/m ²
Øi left		W/m ²
Øi back		W/m ²
Øi right		W/m ²
Øi ceiling		W/m ²
Øi floor		W/m ²
P heating	Heating power	W
Gv	Vertical south global solar radiation (plane of the glazing).	W/m ²

Gh_1	Horizontal global solar radiation.	W/m ²
Gh, dif_1	Diffuse solar radiation	W/m ²
Glw-h_2	Horizontal long wave radiation	W/m ²
Glw-v_1	Vertical south long wave radiation	W/m ²
WD	Wind direction	°
WV	Wind speed	m/s
H_1	Relative humidity	%

Table 2: Nomenclature and units. Additional variables.

Name	Measurement	Unit
Tsi glazing2	Internal glass surface temperature (small size PT100).	°C
Tsi glazing3	Internal glass surface temperature. (type T thermocouple).	°C
Tsi left avg	Average of the internal surface temperature	°C
Tsi back avg		°C
Tsi right avg		°C
Tsi ceiling avg		°C
Tsi floor avg		°C
Tsi frame avg		°C
Tsi front avg		°C
Gb_1	Beam solar radiation	W/m ²
Ggr_1	Ground reflected solar radiation	W/m ²
Gvn_2	Vertical north global solar radiation	W/m ²
Patm	Atmospheric pressure	Pa
Tsi floor2	Internal surface temperature of the floor (additional PT100)	°C

6. Aim of the Exercise

This exercise consists of two independent parts. Contributions can be to either one or both.

Analysis of Series 16 17 to 18 could be used for the whole period, however it would be wise to split the data for validation purposes and examination of particular conditions, indoor as well as exterior. Take into account that some of the provided data may not be necessary.

6.1. Part 1: Obtain the energy performance indicators

The aim of this part is to obtain the energy performance indicators using the data recorded at CIEMAT-PSA.

Participants are given the freedom to choose which physical characteristics (overall heat loss coefficient, solar aperture, effective heat capacities, time constants ...) of the RR Box to assess. However, at least one of the following performances should be extracted from the analysis:

- U value (W/m²K) of each opaque wall of the test box
- overall heat loss (W/K) of the test box
- solar gains (m²)
- dynamic behaviour of the test box

The suitability of each data series (16, 17 and 18) to fit the objective must be discussed.

Hint: start with data derived from the rear wall and use the result for assessing the other walls that may be affected by solar radiation.

6.2. Part 2: Cross validation of identified models

The aim of this part is to analyse the capability of a model identified on the basis of one data set to predict the box's behaviour during another period, for which only the inputs are available. Using models identified on the basis of data recorded at CIEMAT-PSA, predict the output during a measurement period different from the one used to identify model.

Discuss difference between predicted and simulated output in both cases.

6.3. Reporting

The submitted reports need to comprise a detailed description of the applied analysis and validation carried out. Try to be as clear and illustrative as possible in all steps.

The report must consider at least the following items:

- Pre-processing (Data overview, discussion about quality of data and suitability to fit objectives, etc.)
- Modelling (Hypotheses and approximation about the physics behind the model used, statistical and mathematical approach, software tools, etc.)
- Validation (statistical criteria and physical consistency).
- Clear indication of results and uncertainty in each parameter estimate. Motivate the reported results.
- Conclusions (about results themselves, about the experiment set up and measurement campaign, etc).

Participants are requested to provide a full analysis report in a .doc-file or .pdf-file (yourname_country_.doc/pdf).

7. Deadline

Interested participants are asked to submit their contribution to Mjose.jimenez@psa.es or hans.bloem@in-ive.org

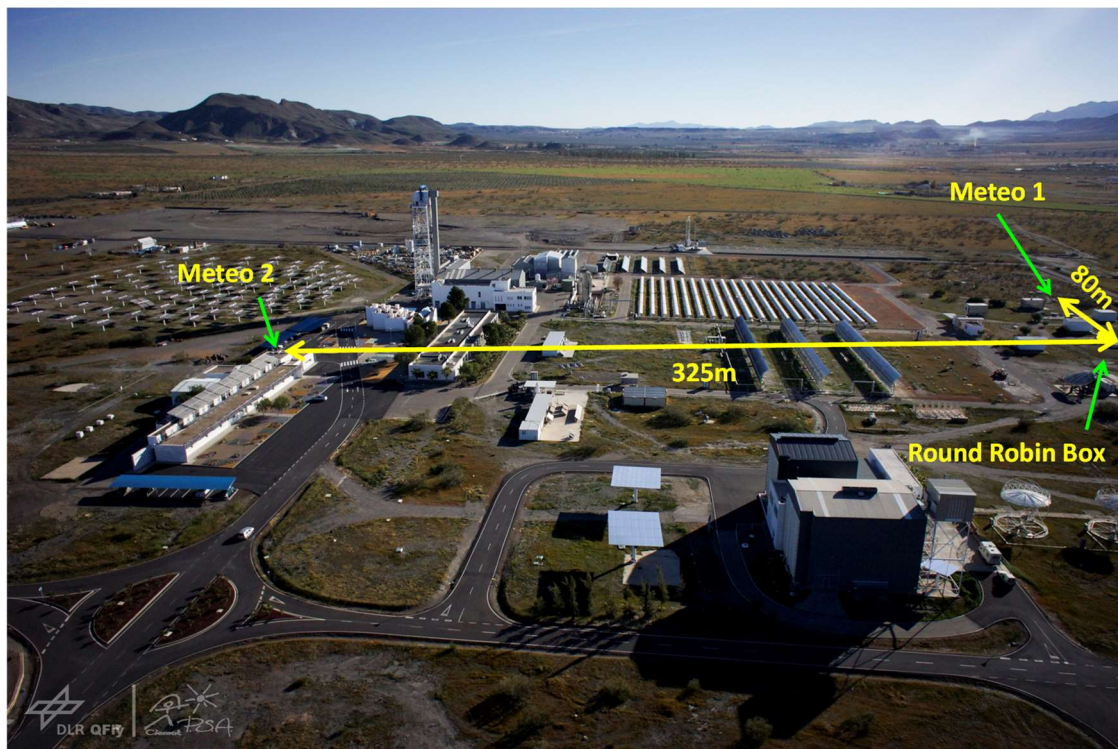


Figure 2: Location of the test box and the other meteorological devices at Plataforma Solar de Almería (PSA).



Figure 3: Placement. Facing south in an open area.



Figure 4: Anchoring additional to the brakes, to prevent damage due to strong winds which are very frequent in the test site



Figure 5: Indoors air temperature and shielding devices

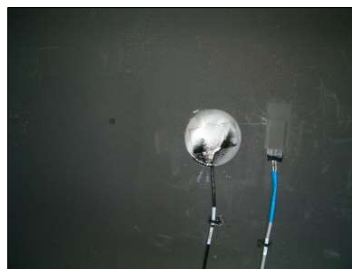


Figure 6: Installation of internal heat flux density and surface temperature sensors. First glued to the internal surfaces and then covered with a tape of same colour of the internal surface.



Figure 7: Installation of external surface temperature. First glued to the internal surfaces and then covered with a tape of same colour of the internal surface.



Figure 8: Meteorological sensors near the test box: Outdoors air temperature, global vertical solar radiation, wind speed and direction.



Figure 9: The test box and meteorological devices near to it (left), meteorological devices at meteo 1 (right)



Figure 10: Data acquisition modules