

TECHNICAL REPORT

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Applicant

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Test

monitoring of hygrothermal comfort
(PMV and PPD indices) ante and post
operam at the Post Office in Scandicci
(FI)

Regulations

UNI EN ISO 7730:2006

Sample tested

VetroVentilato
(cf. description)

**The report consists of 38 pages and can be only reproduced in its entirety.
The results refer only to samples tested.**

Sampling date

date of samples delivery

Date of test

25 June-September 19,
2014**Description of the sample tested**

VetroVentilato technology offers an air intake system on top of the existing windows and doors.

Scandicci's intervention is necessary to improve the thermal and humidity comfort of working environments. The solution presents the concepts of VetroVentilato with a customization depending on the specific needs of the Office of *Poste Italiane*. The difference between the existing system and VetroVentilato is the ventilation system and the physical principle adopted for the air replacement. The Office has an air exchange system whose air intake vents are positioned about 30-50 cm high from the floor pulling fresh air. VetroVentilato system allows the exchange of air at a height greater than the existent one (above the window) ensuring better efficiency by extracting hot air. The intake is placed in a frame above the window that sucks in air between the window and the micro-perforated curtain which also shades the direct sunlight. For this purpose an aeraulic system and a traditional air puller have been installed to get, apart from the extraction of the heat in the ventilated room formed by lowering the motorized curtain depending on external brightness, an integration with the existing air conditioning system which was underpowered and inefficient.

Methodology used

The Danish senior professor P. Ole Fanger was the first to highlight the possible repercussions that thermal and air humidity discomfort conditions can cause on the human body: residential buildings can, on the long run, cause respiratory problems; in working spaces, however, could lead to a decisive reduction of the level of attention and the resulting performance.

To define the degree of hygrothermal comfort of an environment the standard UNI EN ISO 7730 is being used. Hygrothermal comfort is influenced by physical activity and clothing, as well as some measurable parameters in a living space: air temperature measured by a thermometer, radiant temperature measured through a globe thermometer, speed measured with an anemometer and relative humidity measured by a hygrometer.

Once these parameters have been measured you can predict the thermal sensation of a person by calculating the index PMV (Predicted Mean Vote). The PPD index (Predicted Percentage of Dissatisfied) provides information on thermal discomfort expecting the percentage of people who perceive a feeling of discomfort in a certain environment. The PMV is an index that ranges from +3 to -3 according to the following scale:

- +3 hot
- +2 warm
- +1 slightly warm
- 0 neutral
- 1 slightly cool
- 2 cool
- 3 cold

Results achieved

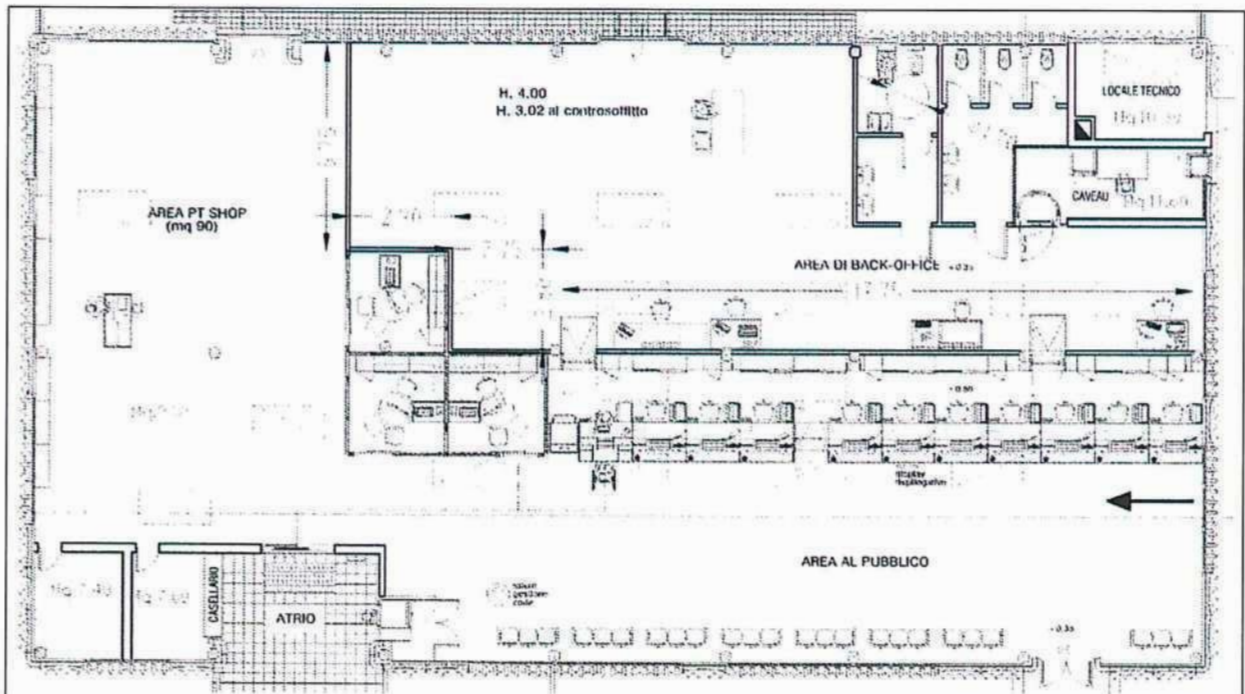
Monitoring campaign description

This experimental campaign aims to verify the correct operation of air conditioning and the resulting maintenance of hygrothermometric comfort conditions during working hours of the Post Office of Scandicci (FI). This campaign was required to determine the comfort index, obtained according to the norm UNI EN ISO 7730, after the refurbishment made by VetroVentilato srl.

For this purpose, a campaign was carried out prior to the intervention of the aforementioned company in order to determine the reference conditions of environmental well-being. This test was repeated at the end of the refurbishment in order to verify the fulfilment of proper comfort conditions.

Building Description

The building is built on a single floor divided into two areas: an area open to the public and a back-office. The walls are prefabricated and equipped with shutters along the Southwest and Northwest sides. The roof is covered with grey waterproofing material. There are skylights on the roof which does not contribute to the natural internal illuminance for the post Office because there is a false ceiling that reduces the usable building height from 4 meters to about 3 mt. The distribution of air-conditioning system is guaranteed by conical air diffusers on the ceiling. The air recycling is positioned at the bottom of the building at about 30-50 cm from the floor on two columns. The air conditioning is active from 7.00 am to 7.00 pm every day from Monday to Friday and Saturday only in the morning. During Sunday the system is turned off.



Experimental set-up

Sensors

The Post Office was properly equipped with an environmental monitoring system aimed at data acquisition to:

- determine the internal conditions of the environment;
- evaluate the achievement of internal comfort conditions.

The system consists of datalogger TMF500, representing the central unit of the system of remote control, monitoring and data acquisition. They are configured for data collection and each of them allows the connection of up to 24 different types of sensors.



Figure 1: datalogger TMF500 for data acquisition

The following parameters are detected:

-external monitoring:

- o wind speed and direction;
- o temperature;
- o relative humidity;
- o solar radiation in terms of coverage;

-internal monitoring:

- o air temperature;
- o radiant temperature;
- o relative humidity;
- o air speed;

The internal temperature was detected using temperature detector Ptl00 with a platinum resistance. These are sensors that estimate temperature through the measurement of the resistance of an element of Platinum: the Ptl00 probes feature a 100 Ohm resistor at room temperature of 0° C. The relationship between temperature and resistance can be considered linear for a relatively narrow range of temperature: the temperature range of these probes is -40° ÷ +60° C. Thermometers have been certified by the producer: this are class A sensors, which guarantee an accuracy of $\pm 0.15^{\circ}$ C at 0° C.



Figure 2. Resistance temperature sensor Ptl00

The relative humidity is detected through a capacitive transducer, consisting of a thin film element whose ability varies linearly with relative humidity: the signal returned by the sensor is a voltage between 0÷1 V.

The hygothermal sensor has a measuring range of $-40^{\circ}\text{C} \div +60^{\circ}\text{C}$ and an accuracy of $\pm 0.15^{\circ}\text{C}$ for measurement of temperature, whilst humidity range is from 0 to 100% RH, with an accuracy of $\pm 2\%$. All data are certified by the manufacturer.



Figure 3. Combined sensor of temperature and relative humidity for interiors spaces

The sensors were properly protected from direct solar radiation.

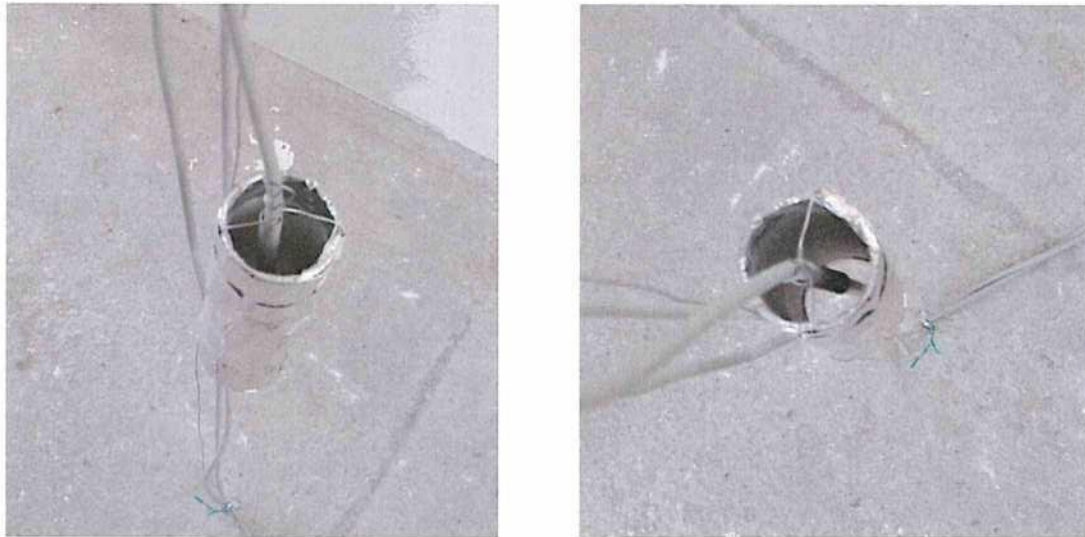


Figure 4. Protection system of temperature sensors

For the measurement of the radiant temperature, sensors with globe thermometers are used with Pt100 transducer. The characteristics of the sensing element are the same as described for the temperature probe, measuring range $-40^{\circ}\text{C} \div +60^{\circ}\text{C}$ and an accuracy of $\pm 0.15^{\circ}\text{C}$. The sensor is attached within a spherical copper screen painted Matt Black (diameter 15 cm) and the shielding is made to ensure anyway the heating of the sensitive element.



Figure 5. Globe thermometer for the measurement of the radiant temperature

Omnidirectional sensors with hot wire and temperature compensation are used for the measurement of the speed and temperature of the air flow inside the environments. The measuring range for air speed is 0-5 m/s, with typical sensitivity 0.01 m/s and accuracy of ± 0.02 m/s in the range between 0 and 1 m/s, and accuracy of ± 0.1 m/s between 1 and 5 m/s. The temperature instead is measured within the range $-20^{\circ}\text{C} \div +80^{\circ}\text{C}$ with an accuracy of $\pm 0.3^{\circ}\text{C}$.

The functioning of the sensor uses a heated wire: the decrease of wire temperature determines the speed of the air flow that touches the probe.

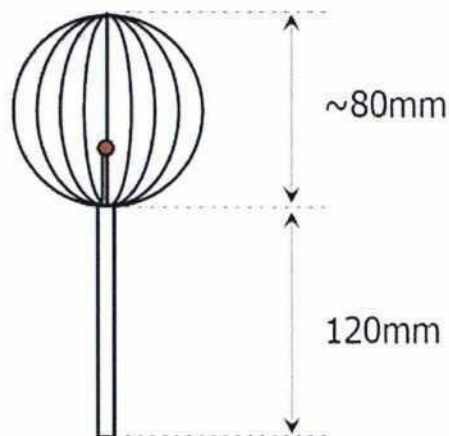


Figure 6. Hot-wired anemometer for the measurement of the speed and temperature of the air flow

A weather unit has been installed for monitoring climatic conditions. It is a system similar to that present inside the Post Office, consisting of a data logger TMF500 and with the following sensors:

- sensor for temperature and outdoor relative humidity;
- global solar radiation sensor;
- cup anemometer

The combined sensor for the measurement of relative humidity and temperature has the same features of those employed in the internal environment: the outer covering shall in this case not only repair by solar radiation, but also by weather events; the measuring range temperature is $-40^{\circ}\text{C} \div +60^{\circ}\text{C}$ with an accuracy of $\pm 0.15^{\circ}$, while humidity range is $0 \div 100\%$ RH with an accuracy of $\pm 2\%$.



Figure 7. Combined sensor of temperature and relative humidity for outdoor use

A class 1 pyranometer measures the global solar radiation: the sensor is consisting of a thermopile transducer, protected by a glass dome that can guarantee a high sensitivity spectrum between $0.3\text{ }\mu\text{m} \div 3.0\text{ }\mu\text{m}$.

The sensor's output signal is $0 \div 2\text{ V}$ in a measuring range of $0 \div 1300\text{ W/m}^2$.



Figure 8. Sensor for the measurement of the global solar radiation

Concerning the wind conditions of the external part of the Post Office, they are measured with an anemometer: it is a tool that returns information about wind speed and direction.

The wind speed is measured with an accuracy of 0.1 m/s within the 30 m/s, and with an accuracy of $\pm 2\%$ within the range 30÷60 m/s.



Figure 9. Anemometric sensor

The data logger acquires data from different sensors with a sampling interval of 10 seconds.

However, in order not to generate an amount of data hardly manageable, a measurement is

recorded every 5 minutes; within the range of acquisition, data are collected and the equipment calculates maximum value, minimum value and average value: the most significant value on which are developed all the analysis is the average value.

1st Phase: monitoring ante operam

The first stage of monitoring is aimed at measuring the hygrothermal comfort conditions inside the Office before carrying out the refurbishing.

The test started the 25th of June 2014 and ended up the 7th of July 2014.

Attendance data

The recorded data are divided by days:

June 30 from 600 to 700 people

July 01 from 680 to 780 people

02 July from 630 to 730 people

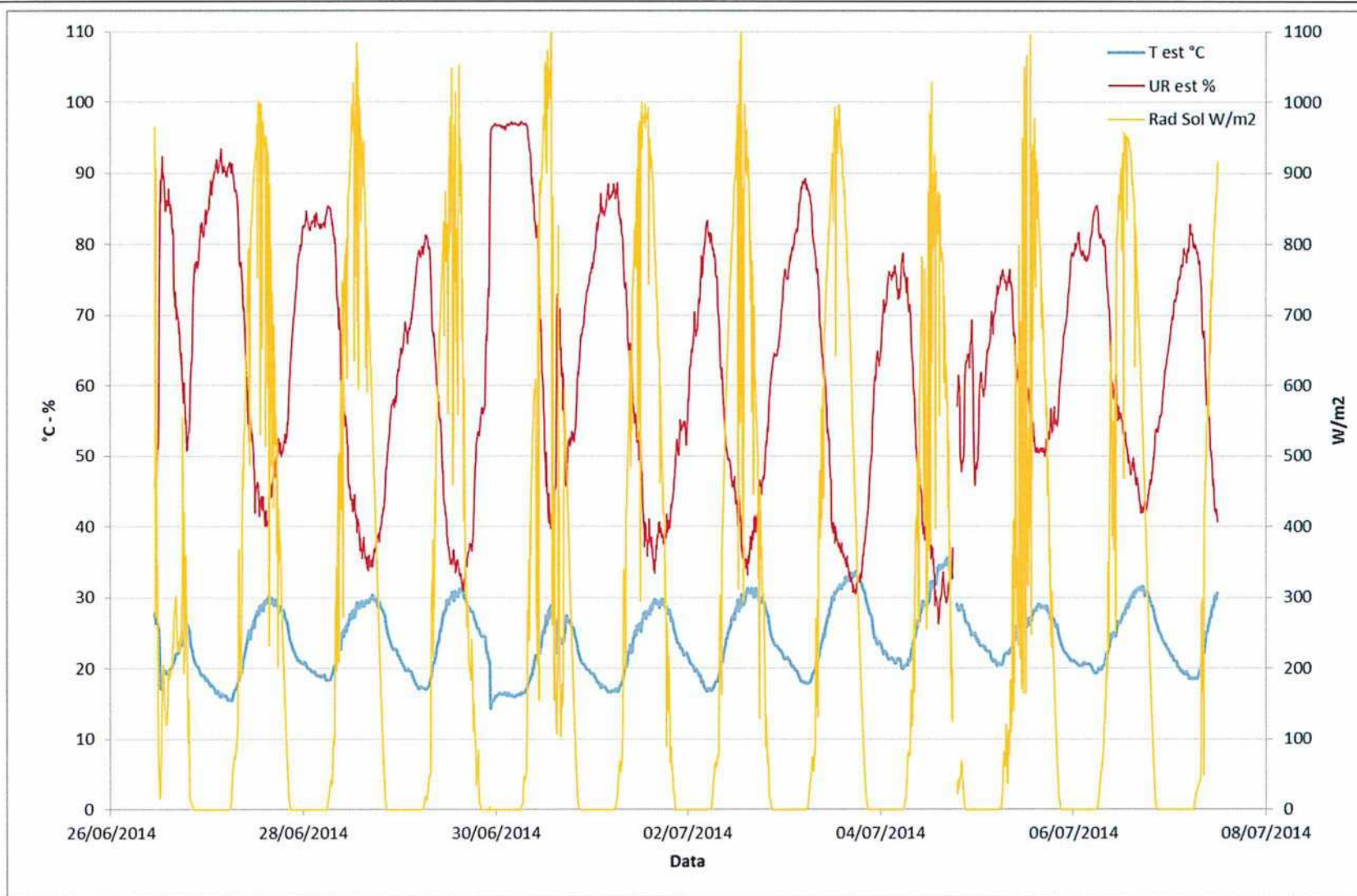
03 July from 536 to 636 people

04 July from 506 to 606 people

05 July from 239 to 300 people

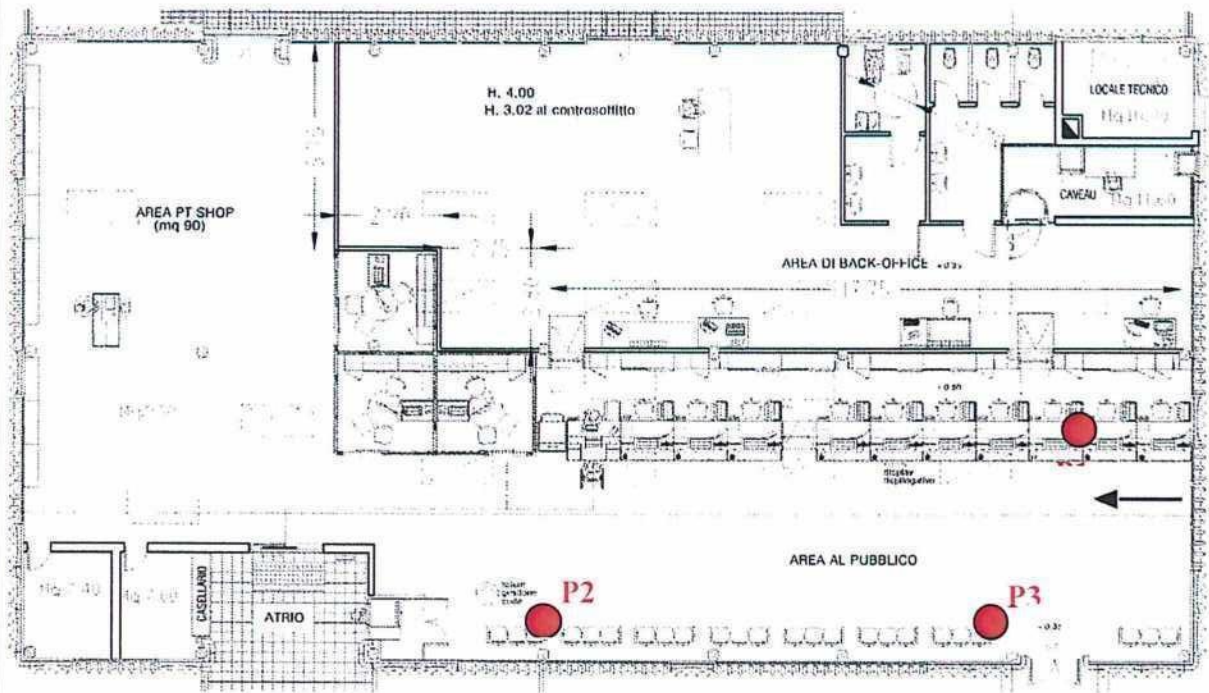
Weather Conditions

The weather conditions during the experimental period are summarized in the following chart. On average, there are sunny days with maximum temperatures up to 30° C; only on days 2, 3 and 4 July the temperatures will exceed 30° C.



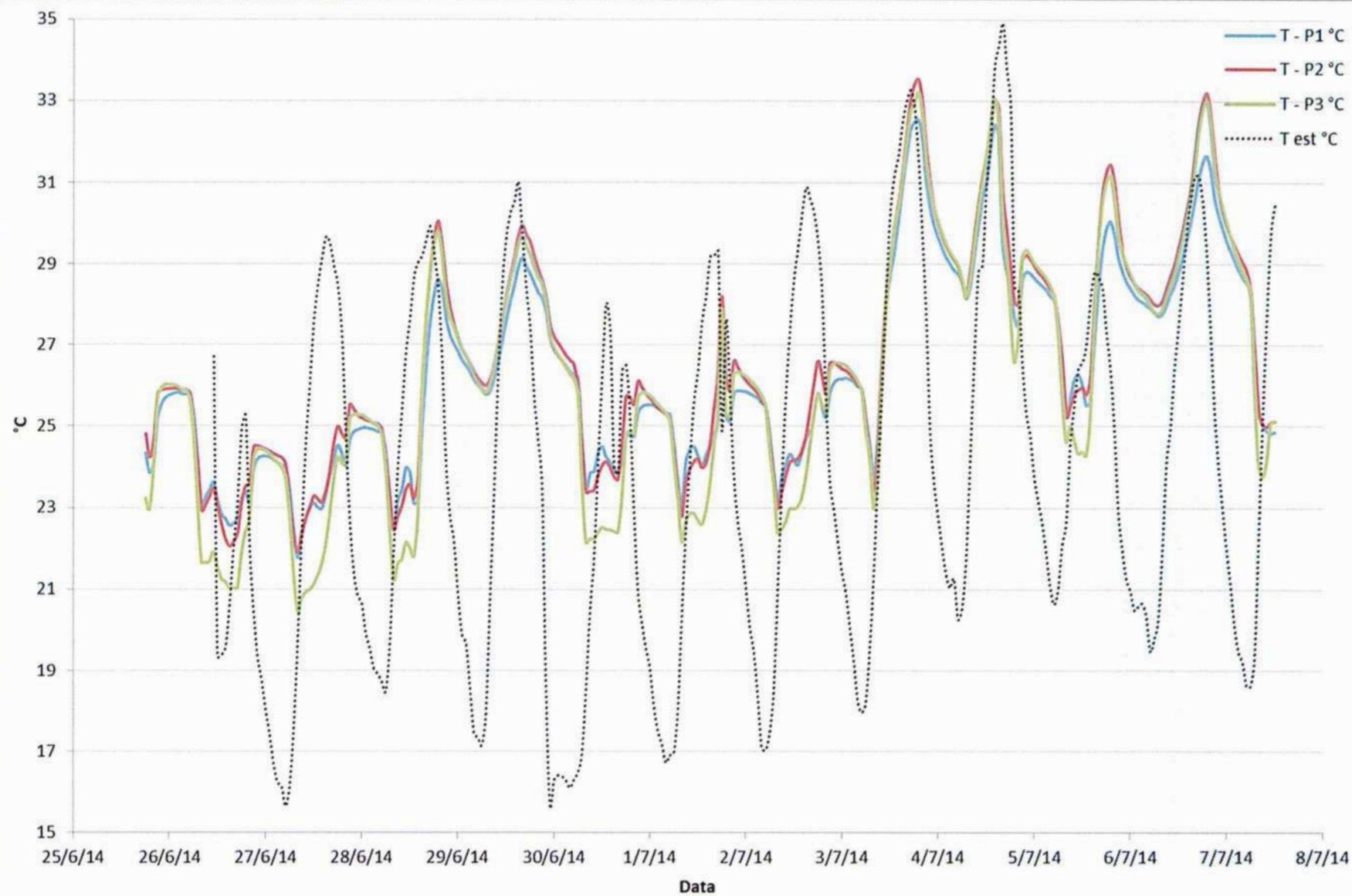
Internal environmental conditions

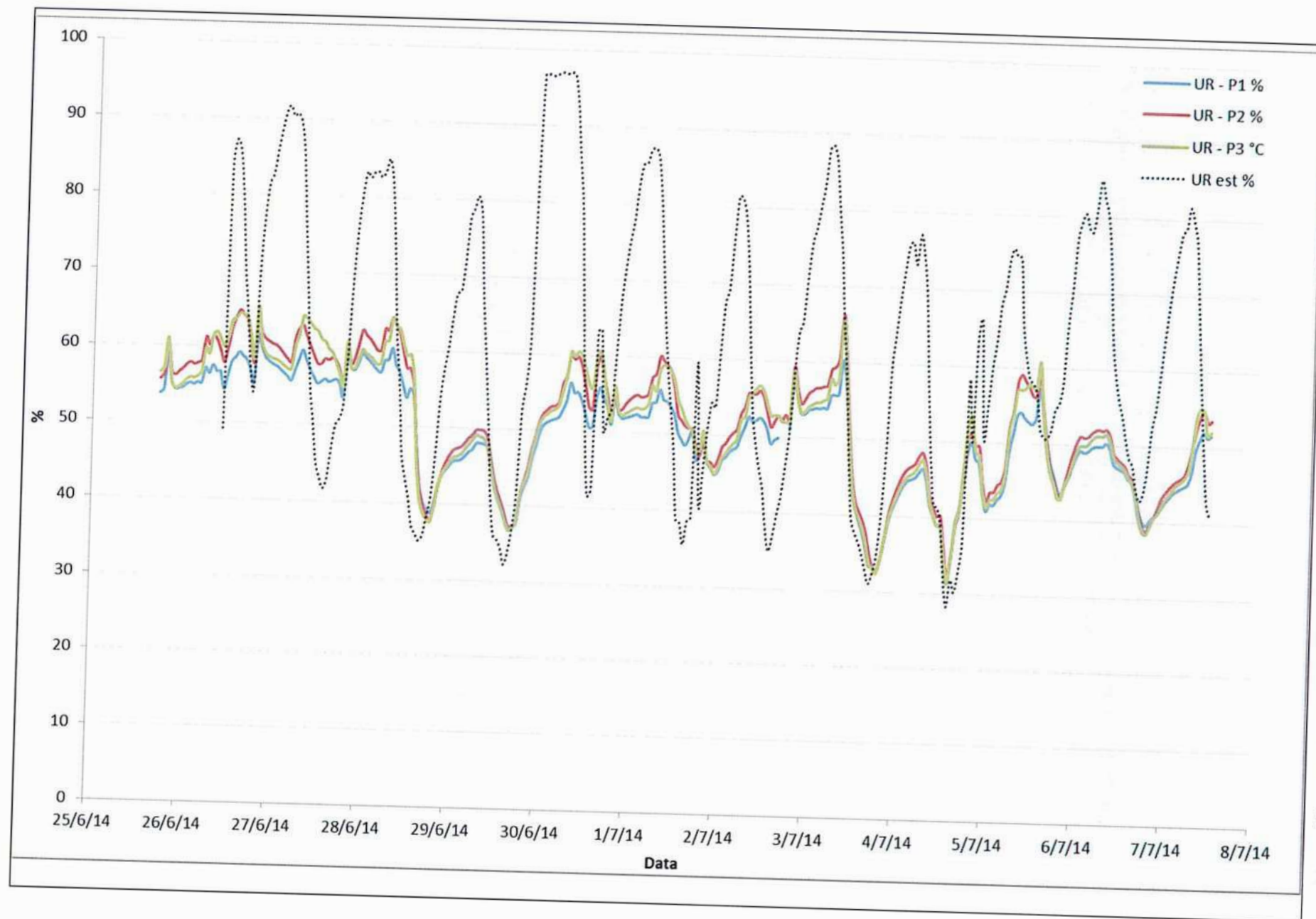
The drawing below shows the position of the data capture stations installed in the Office.

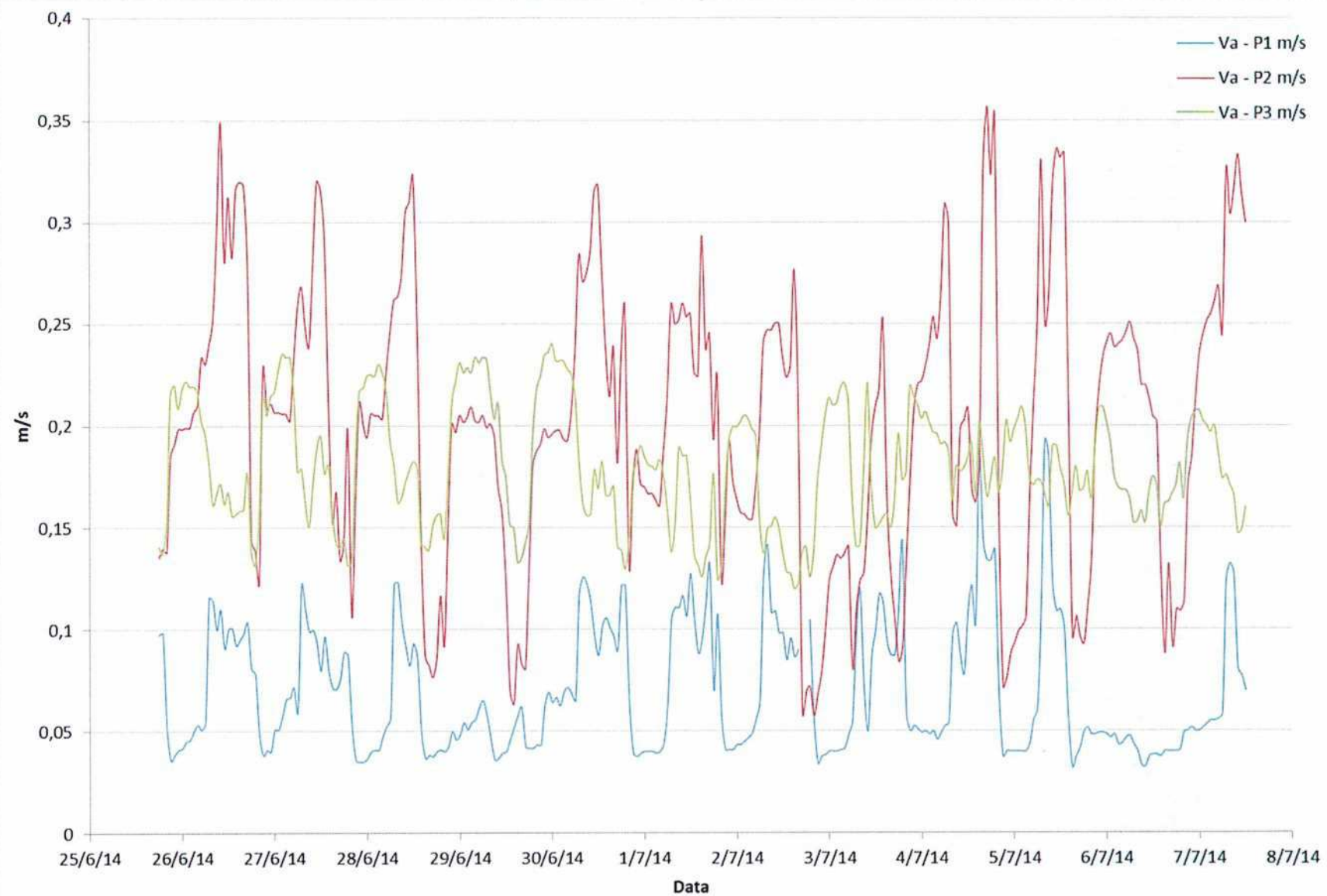


The following charts summarize the data progress, respectively, of temperatures, humidity and air speed collected by the three stations.

The temperatures recorded inside the Office at night, when air conditioning is off, increase significantly until they stabilize during the hours before the restart of the air conditioning system. Observing the outside temperature, it is evident how, despite it reaches rather low values and always below 20° C, there is no interaction between exterior and interior. This means that the internal environment at night stores thermal energy that it is disposed once the system is turned on. Among the three locations there are no big differences. The peaks are more high for the station no. 1 close to counters, while the station no. 3 is affected by external conditions; indeed there is the greater thermal gradient.







The air speed measured at station no. 2 is higher than other stations.

Analysis of the results

During the test, except for the closing days and malfunctioning of the system, the feeling of well-being of the occupants is classified as "slightly warm".

Observing the day 3rd of July on which air conditioning is not running, the discomfort reach a feeling of "hot".

At position no.1, close to the counters, acceptable values of average PPD are observed, except for the period when the system did not work and within some hours after Office opening and Office closing.

The collected data in the station no. 2, located at the main entrance of the Post Office, show worst values in terms of comfort. At first, during the week until the 29th of June there was a feeling a of "slightly cool". In fact the PPD achieves the 40% value of discomfort. The first days of July show (with temperatures that reach and exceed 30° C) a significant degree of discomfort due to feelings of both "slightly cool" and "slightly warm", with PPD exceeding 25%.

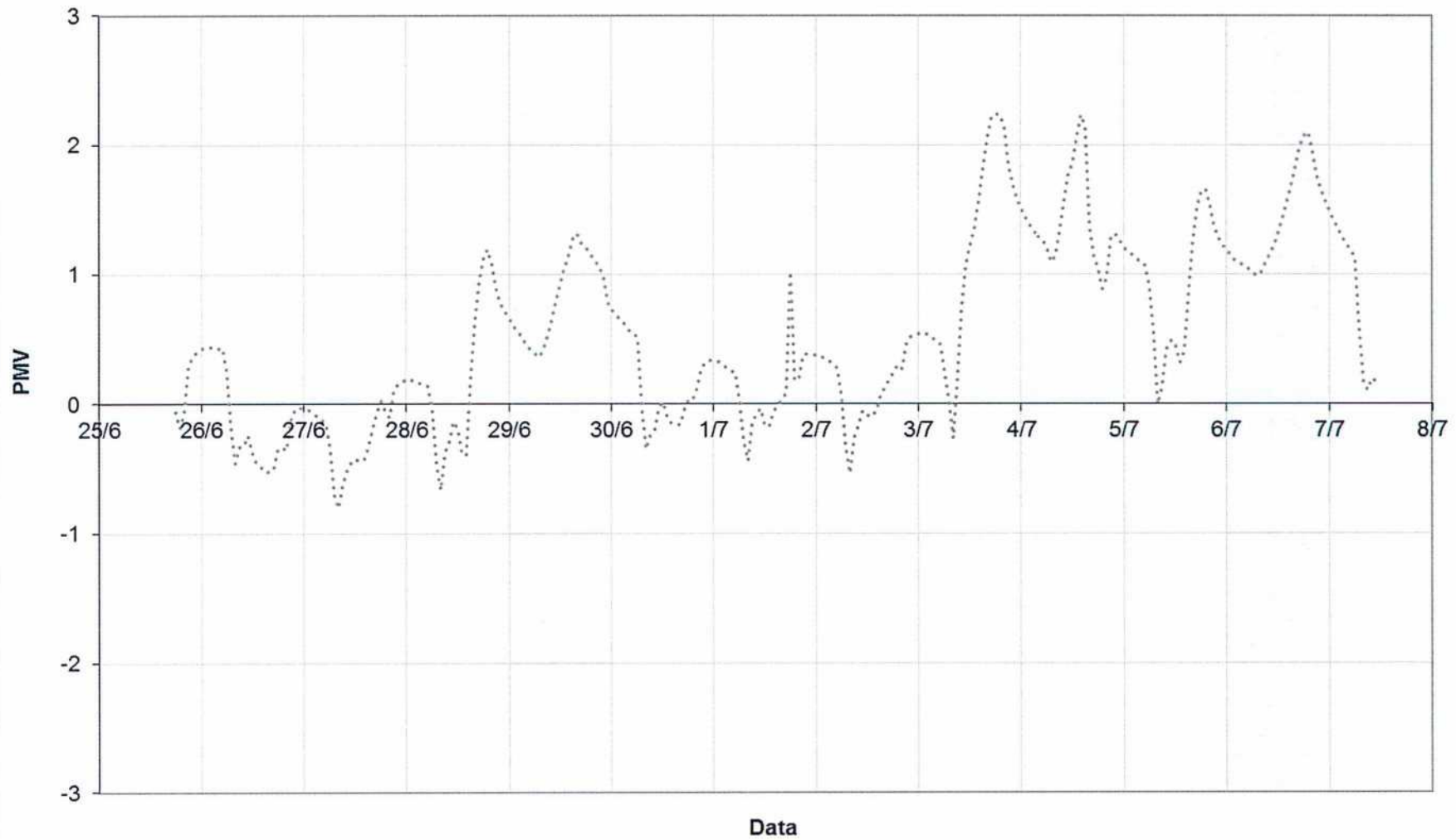
On the 3rd of July, with the malfunctioning of the air conditioning system, the highest degree of discomfort has been reached, equal to 95% of dissatisfied people.

As for the station no. 3, as I mentioned earlier, it is similar to station no. 2 but with more attenuated highs, because the proximity of the emergency exit brings more climatic variation.

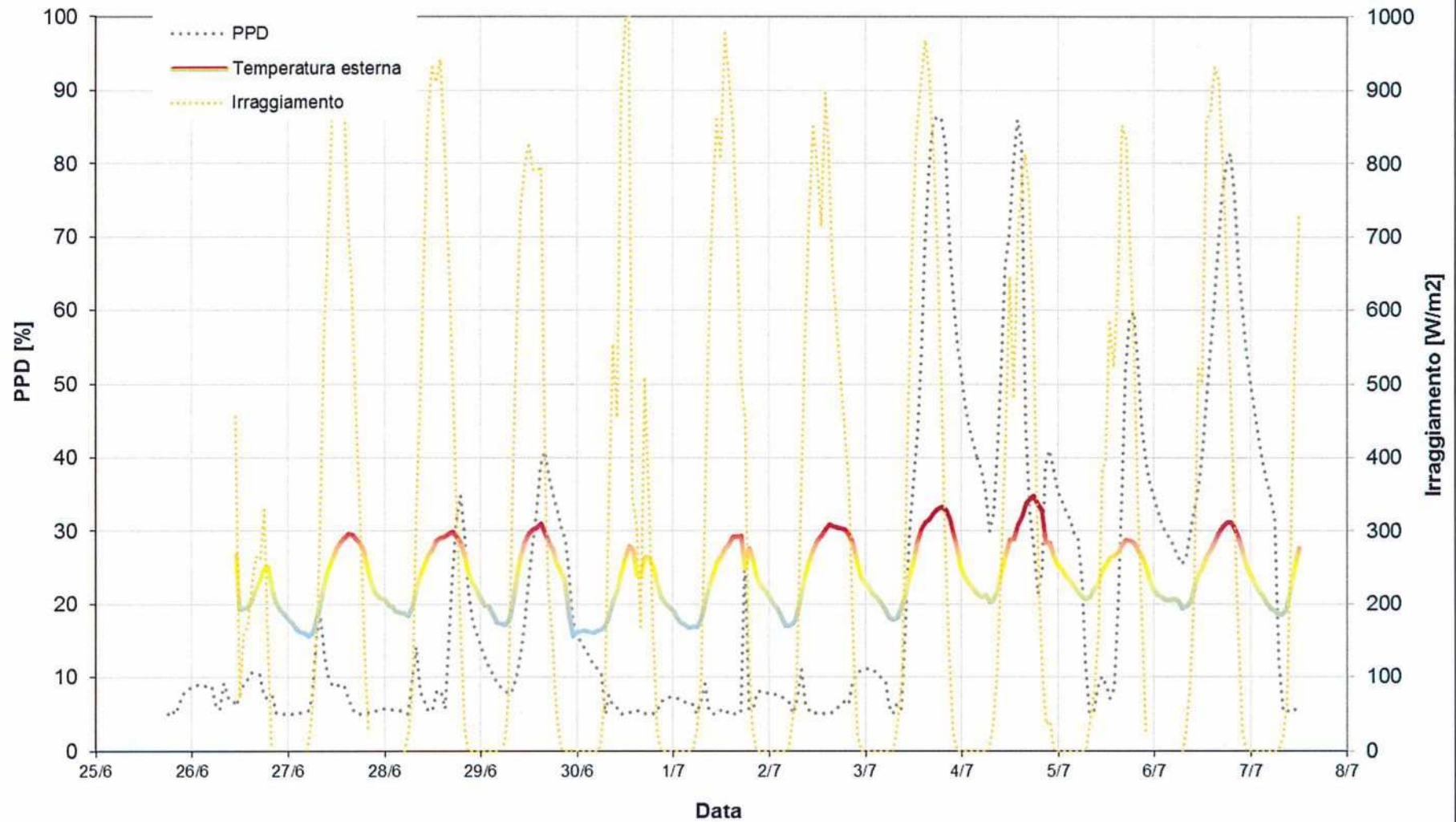
Taking into account the obtained data, it is believed that the air conditioning requires a most appropriate setting or a more adequate ventilation efficiency in the public area. It is also evident how the air-conditioning system crashes when the full power is required (for example during days 3 and 4 July).

Andamento orario PMV - P1

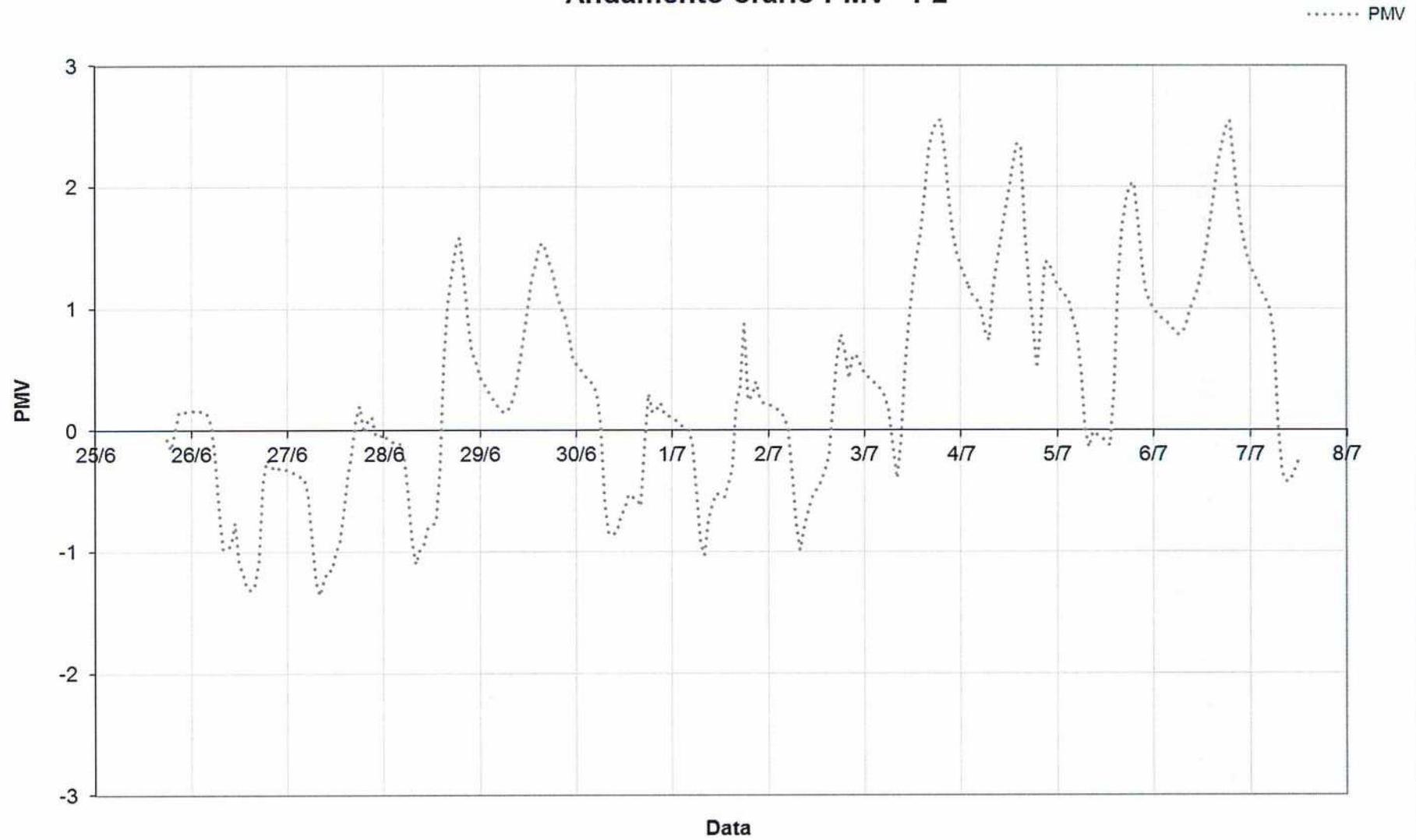
..... PMV



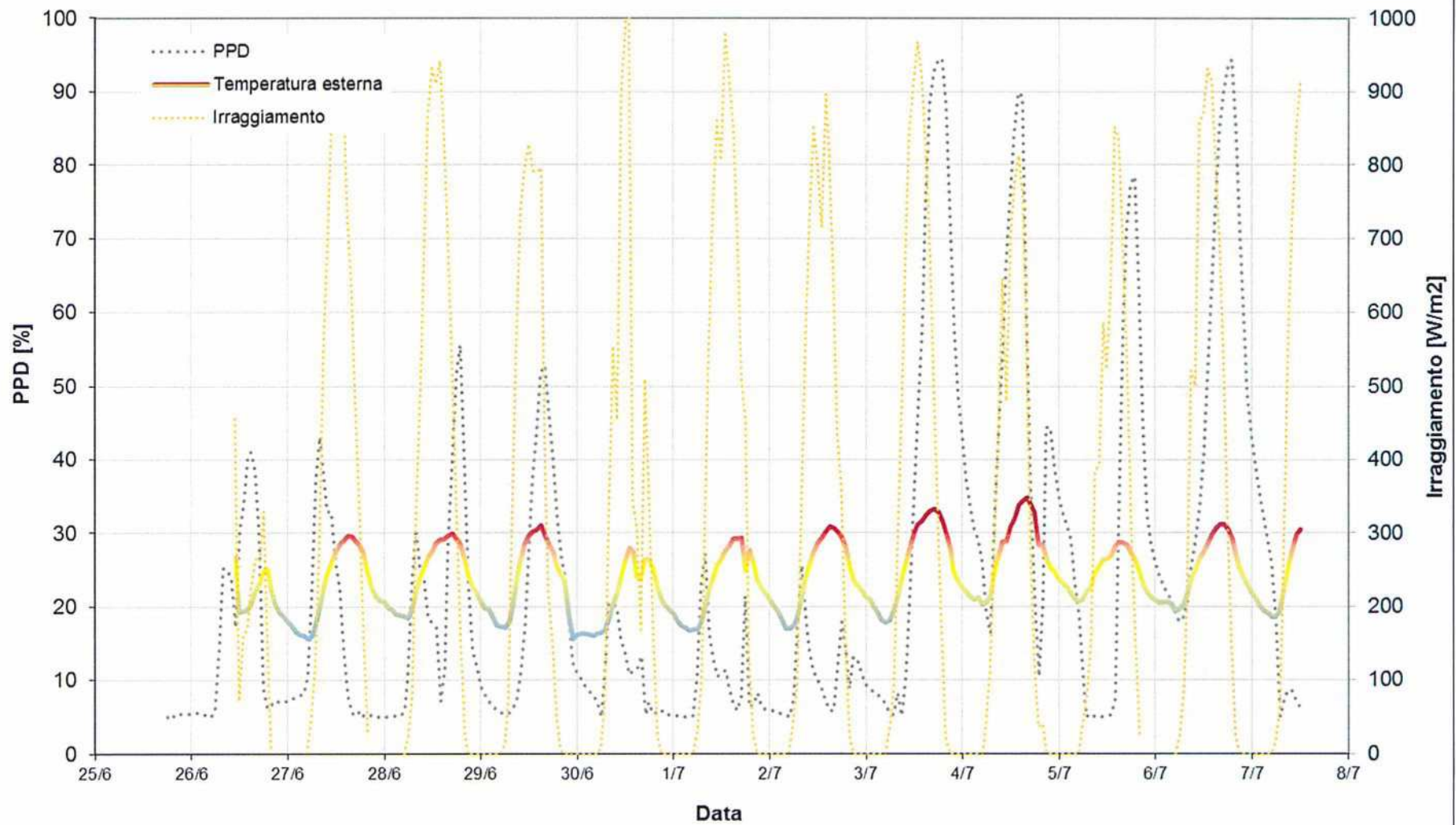
Andamento orario PPD - P1



Andamento orario PMV - P2

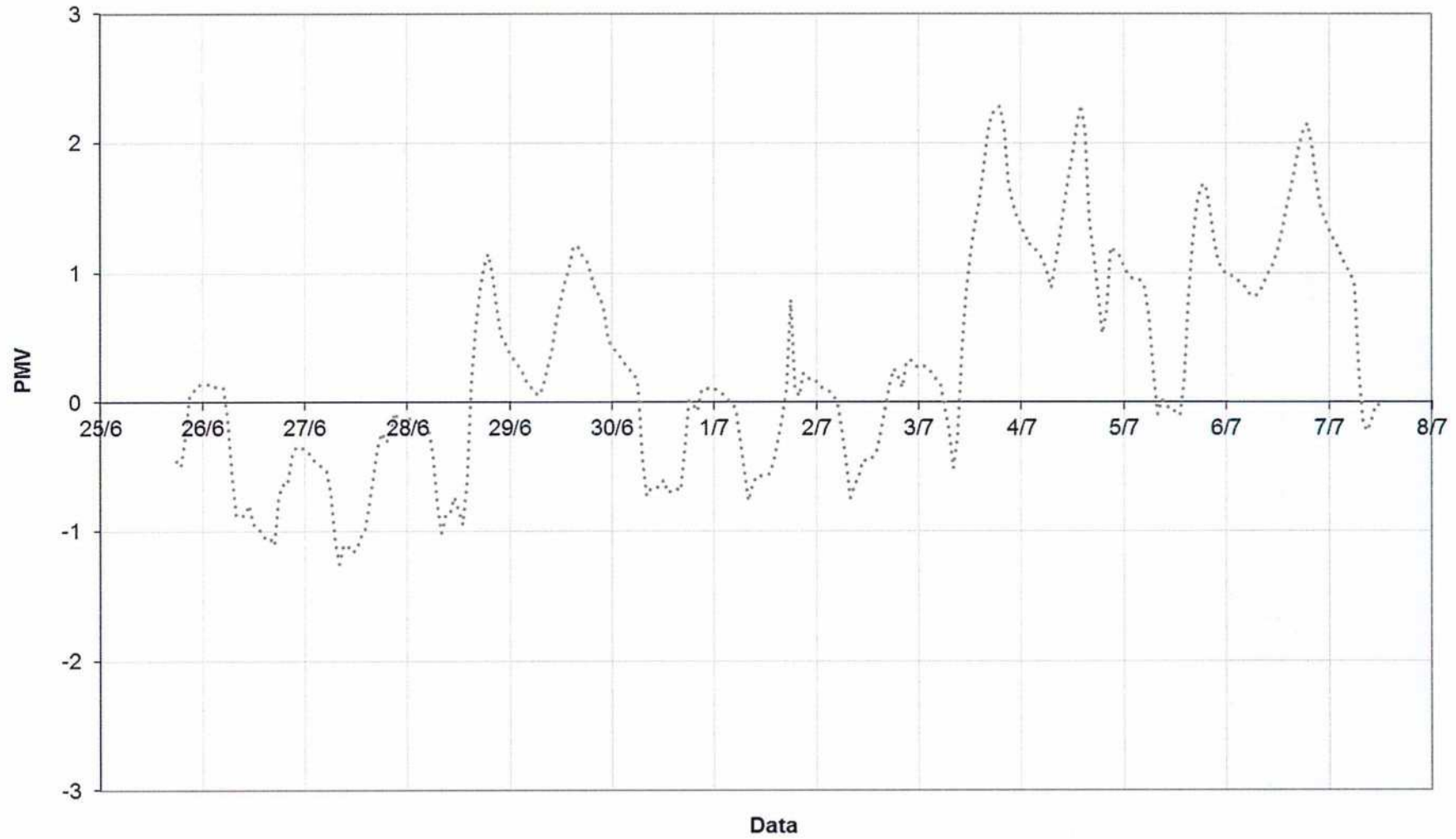


Andamento orario PPD - P2

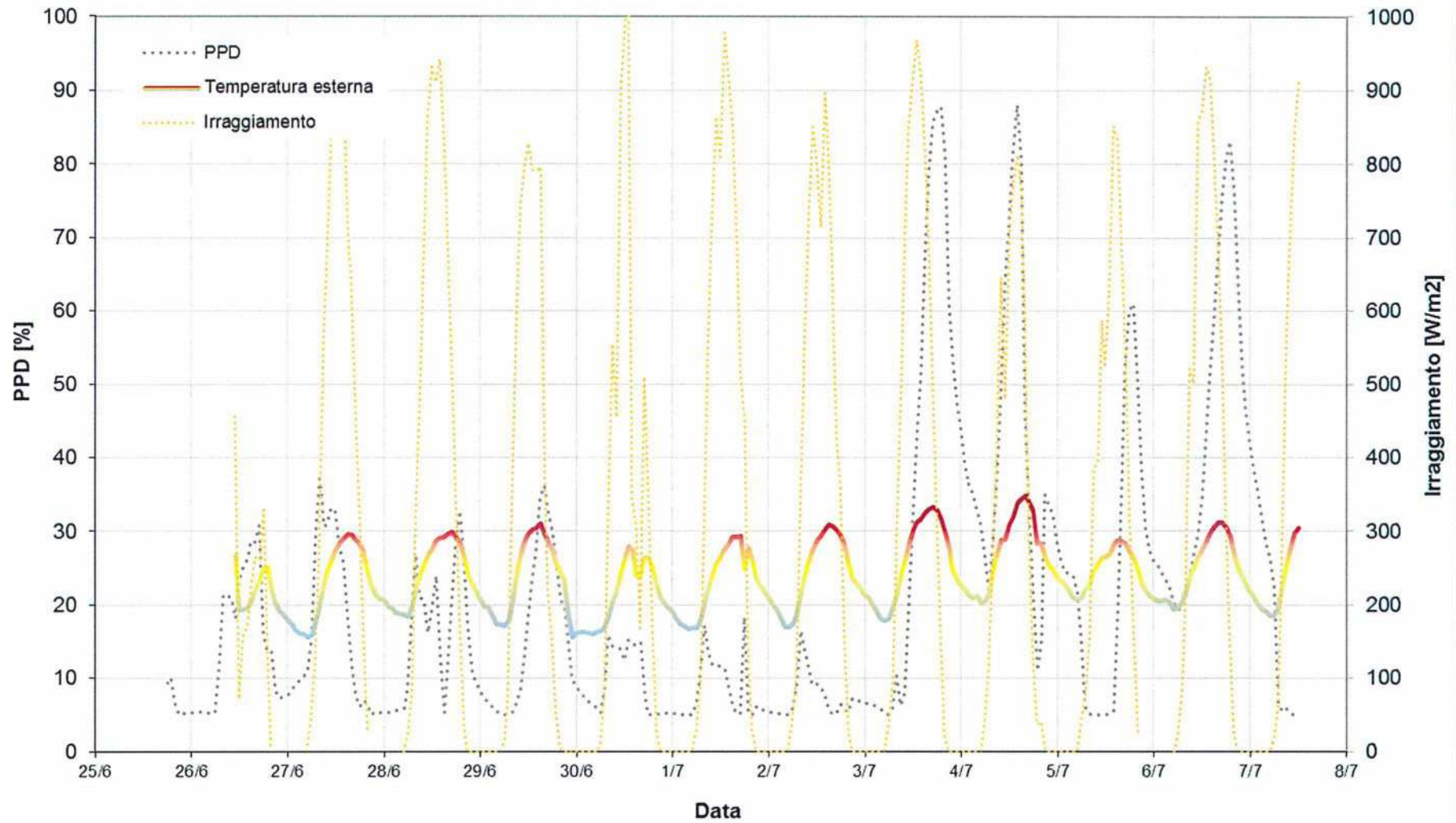


Andamento orario PMV - P3

..... PMV



Andamento orario PPD - P3



PHASE II: monitoring *post operam*

Monitoring post operam started on the 19th August and ended on 19th September 2014. In particular, a specific week from 25th to 31st August with the most critical summer conditions was analysed.

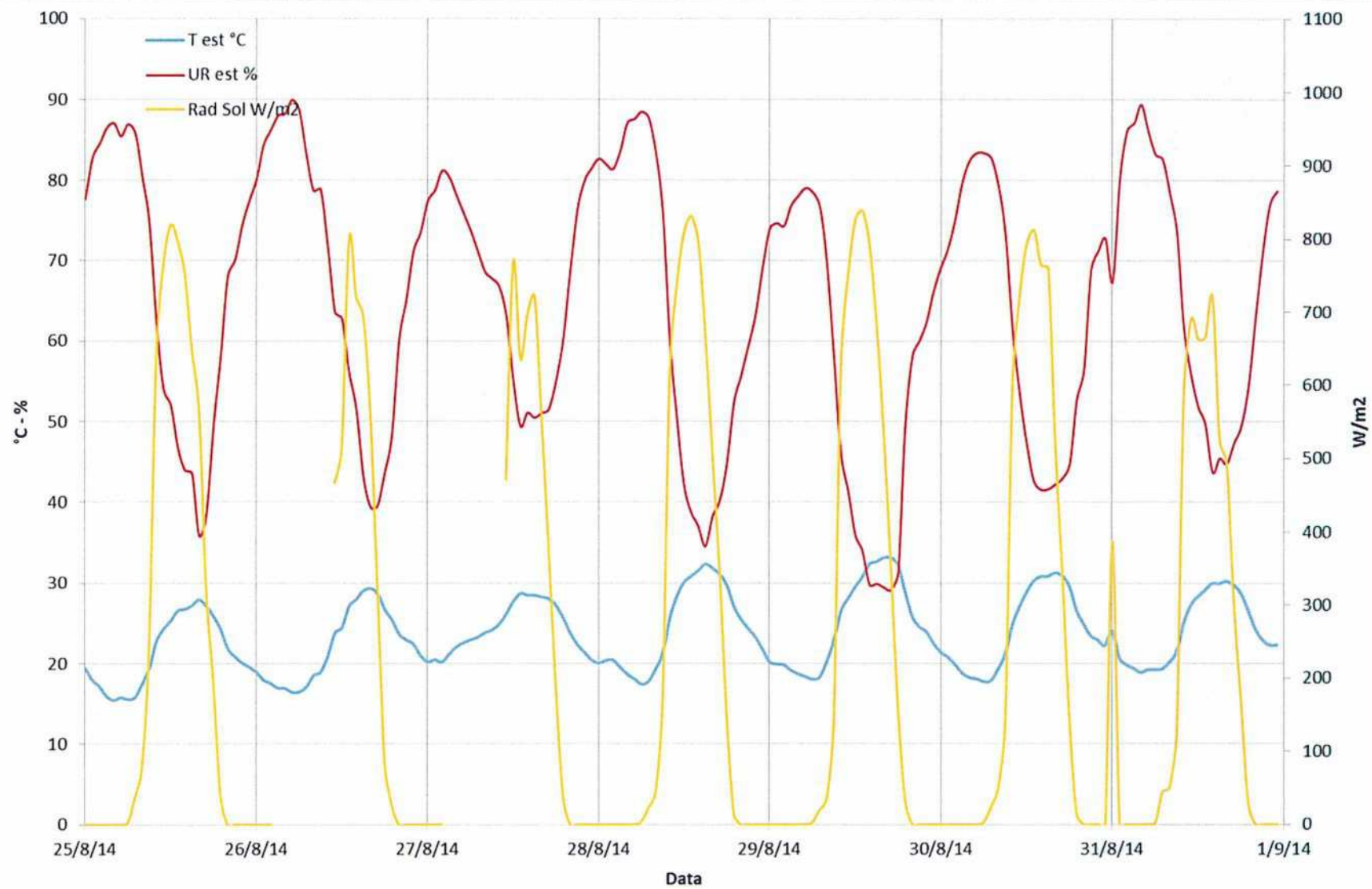
Attendance data

The recorded data by attendance are listed below.

19 August - 339 people	30 August - 254 people
20 August - 343 people	1 September - 741 people
21 August - 320 people	2 September - 587 people
22 August - 193 people	3 September - 488 people
23 August - 166 people	4 September - 460 people
25 August - 591 people	5 September - 474 people
26 August - 447 people	6 September - 237 people
27 August - 428 people	8 September - 518 people
28 August - 367 people	9 September - 444 people
29 August - 413 people	10 September - 409 people

Weather Conditions

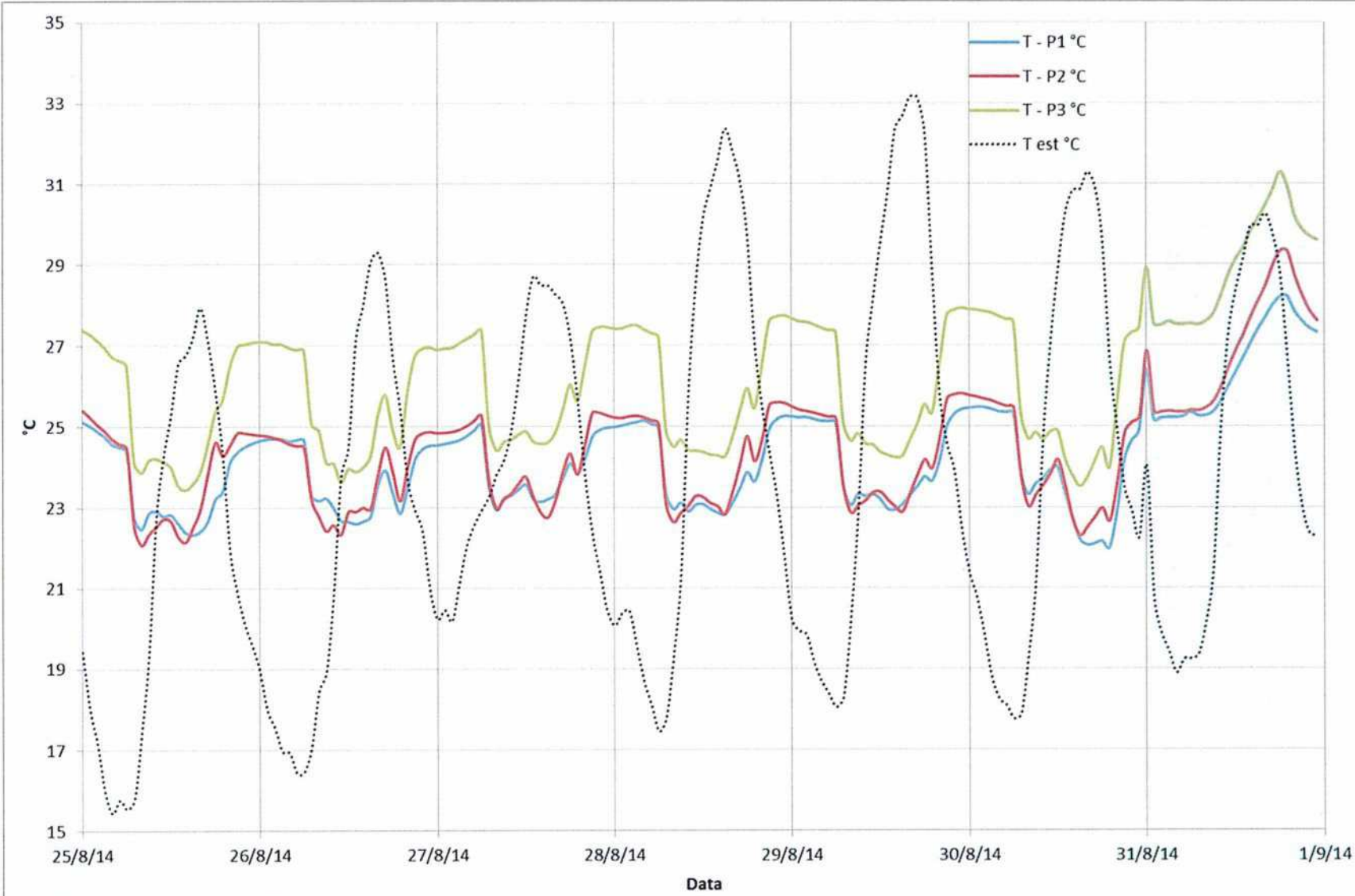
In the week deemed for analysis, the average temperatures are recorded growing with sunny days, especially on working days with maximum temperatures from about 28° C up to 34° C. The week from 25th to 31st August was chosen also to compare the hygrothermal comfort with equal external conditions compared to *ante operam* monitoring.

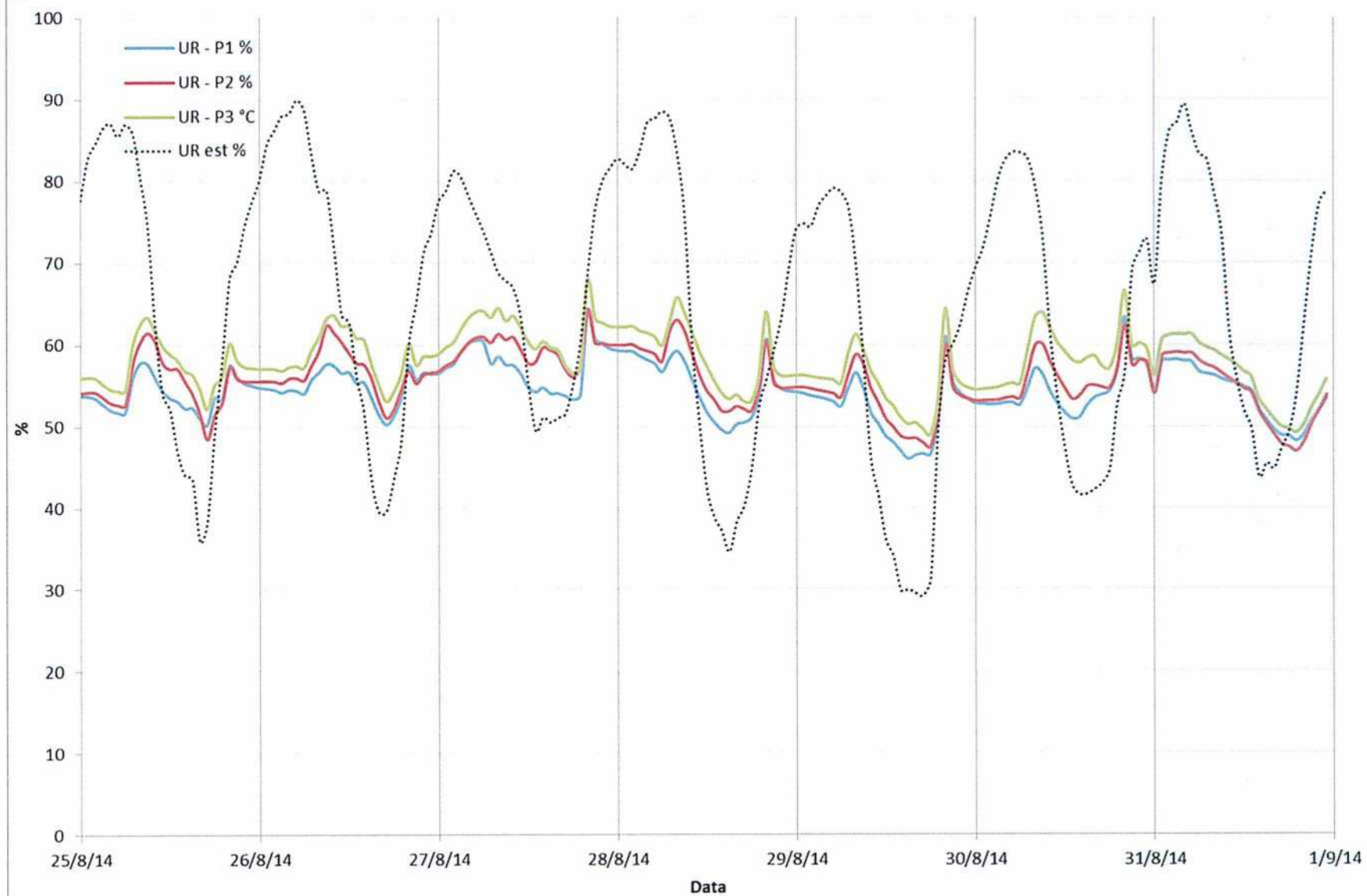


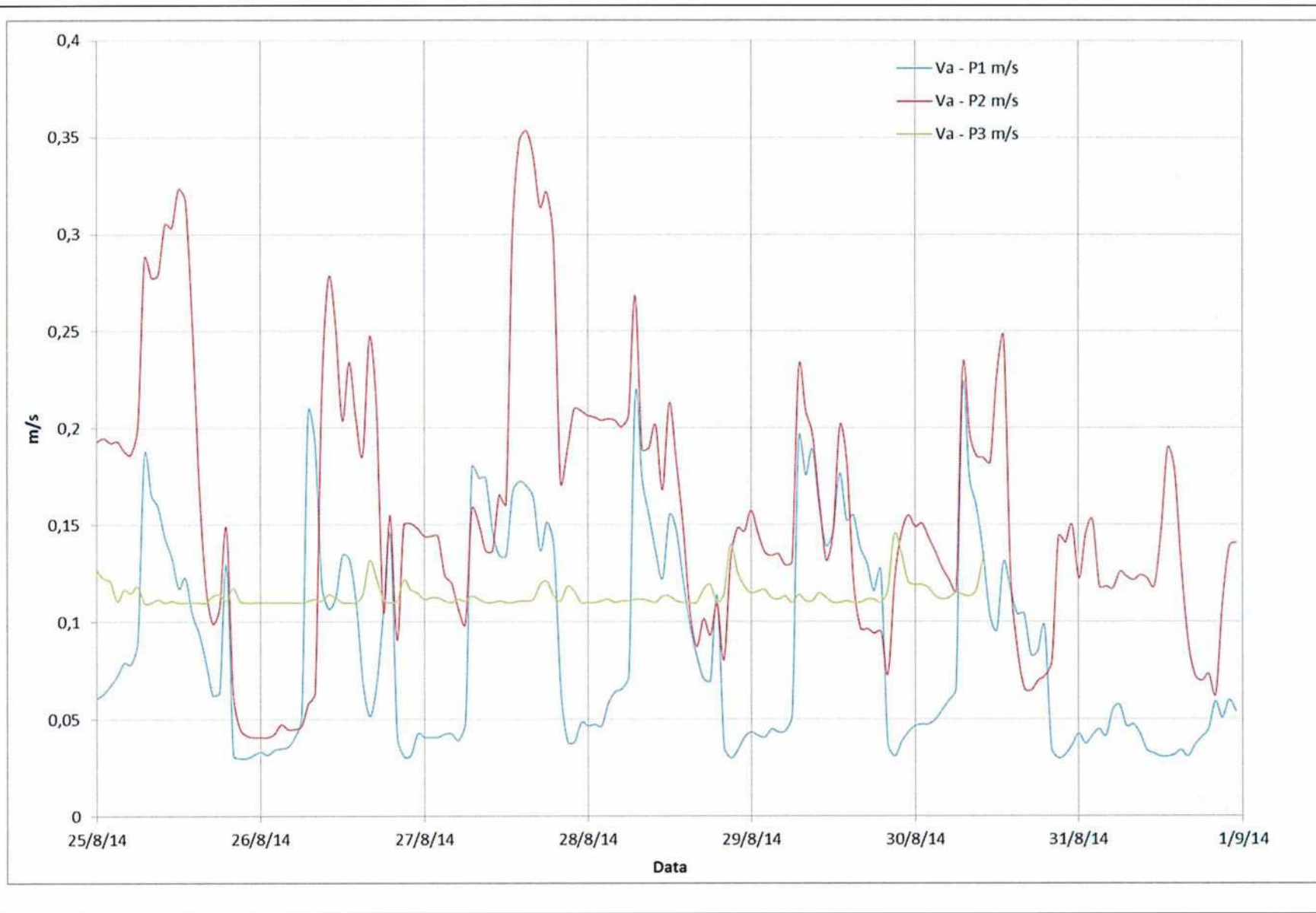
Internal environmental conditions

The data acquisition stations were installed in the same positions before the refurbishing. The following charts summarize the progress of, respectively, temperatures, humidity and air speed at the three data stations. The temperatures recorded internally at night do not increase excessively; on average (relative to the station no. 2) hovering around 25° C thanks to night ventilation and thermal inversion. This behaviour allows at 07:00 in the morning to have offices with a temperature of 23°-25° C (depending on the measuring point). Vice versa, the average temperature recorded during the night monitoring *ante operam* (related to station 2) is 26.7° C.

There is also a significant difference between positions 1 and 2 compared to position 3. Such a difference is mainly due to the location of the station near the window. Indeed, the dependence of the recorded data is closely linked to the external climatic conditions and therefore limited locally as it is shown by the data of the other two stations whose temperatures are noticeably lower. This difference cannot be seen in *ante operam* monitoring as the temperature distribution was closely linked to external conditions, regardless of location.







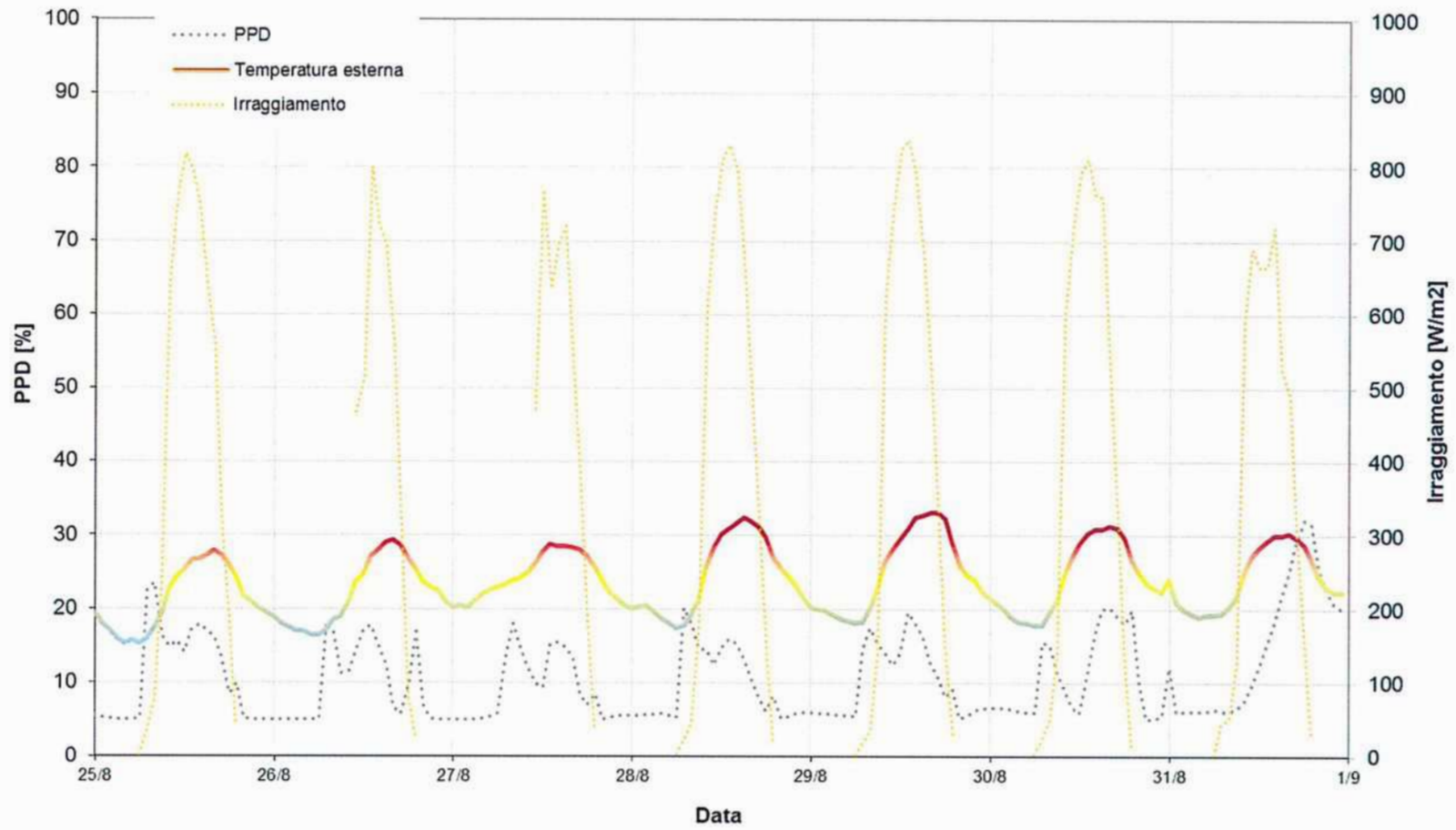
Measured speeds are significantly lower than the previous monitoring.

Analysis of the results

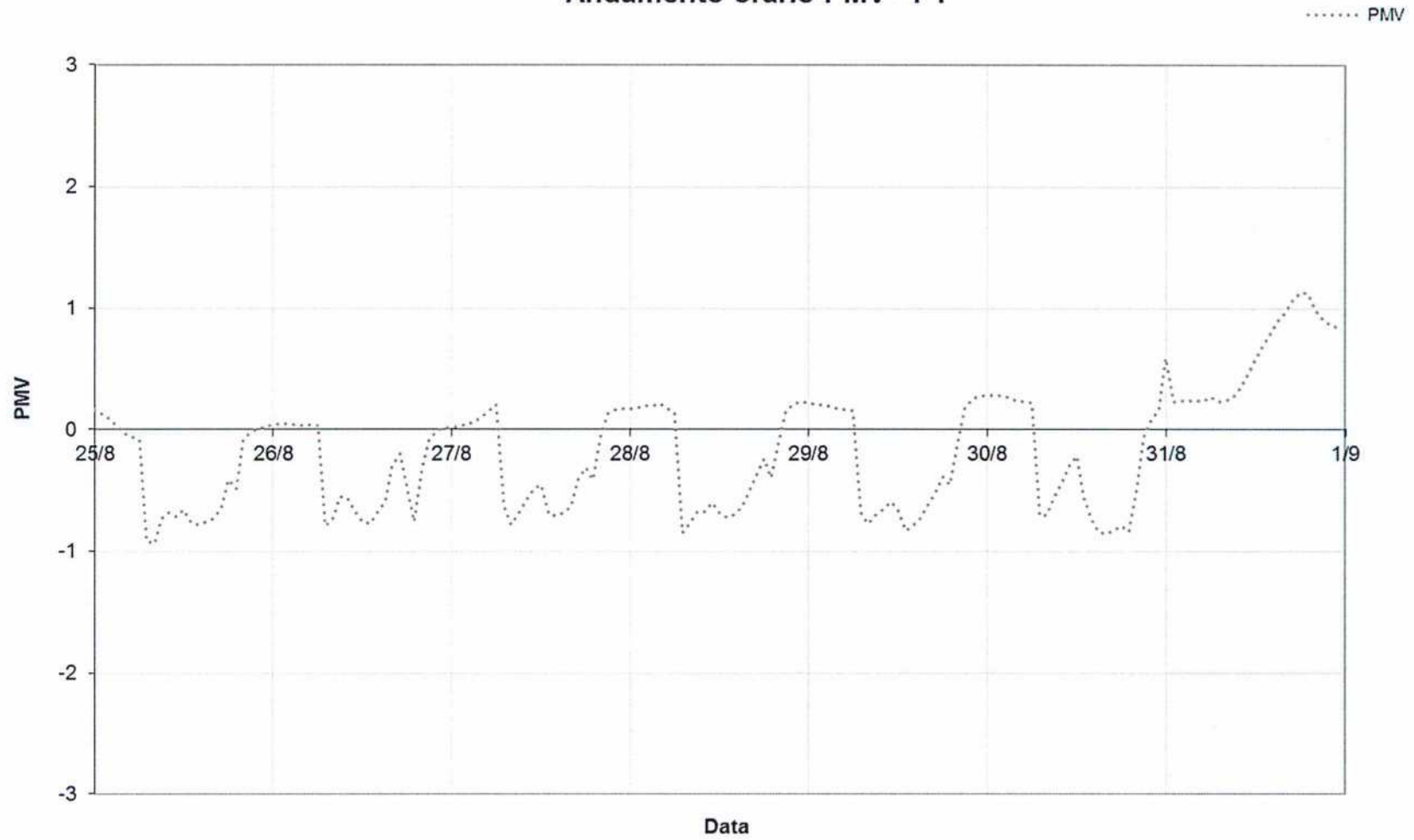
The well-being feeling of the occupants is improved and essentially attenuated compared to the peaks detected during the first monitoring.

The predicted percentage of dissatisfied is quite high but this is coming from the type of air conditioning adjustment. Although the PPD is sometimes higher than 30%, the pattern is visible in the PMV index, where a feeling of "slightly cool" can be seen during daylight hours. This result applies to positions no. 1 and no. 2 but not for no. 3. The latter maintains a sense of well-being within the parameters of comfort caused by, as already mentioned, the overheating located near the window.

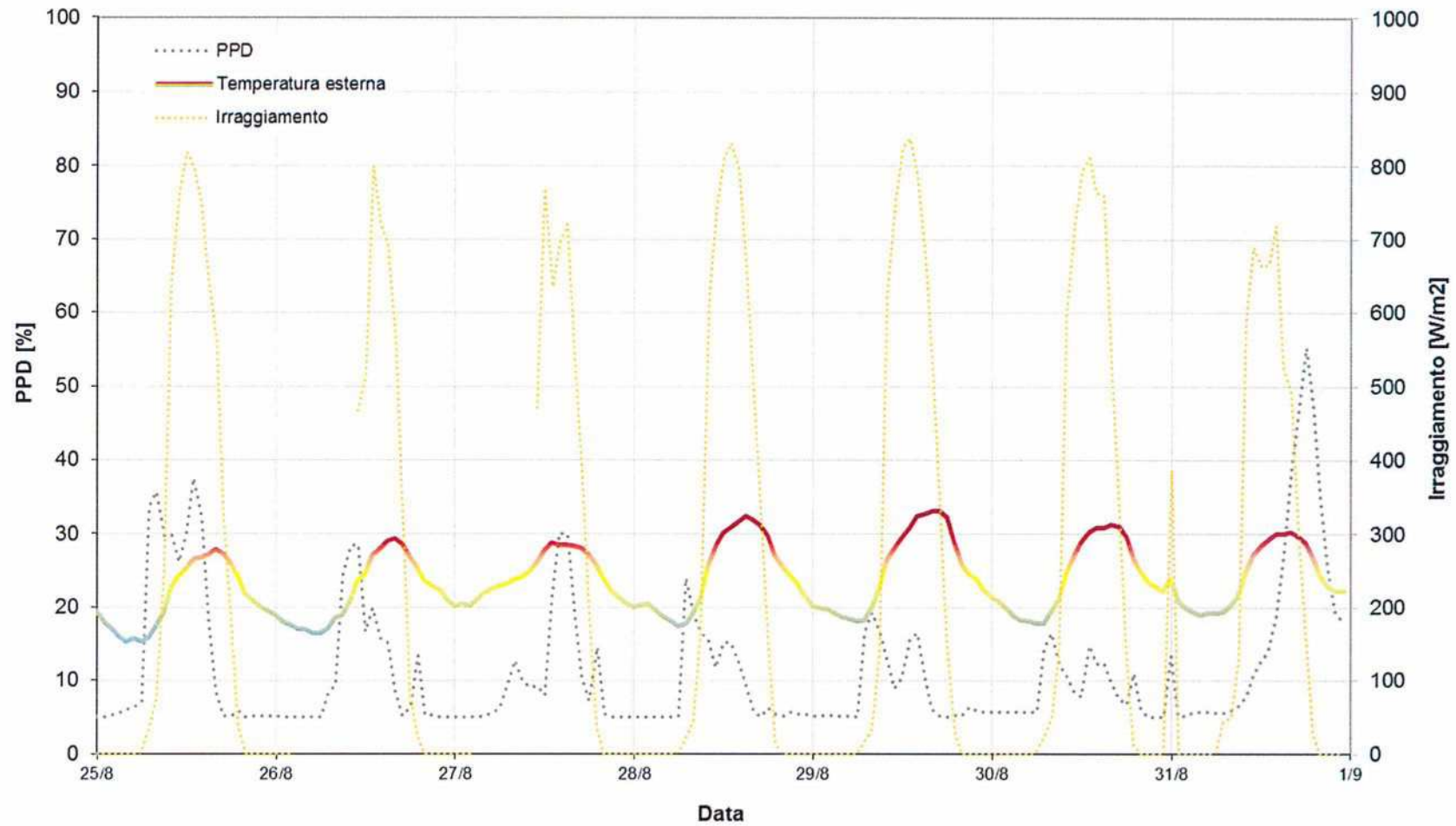
Andamento orario PPD - P1



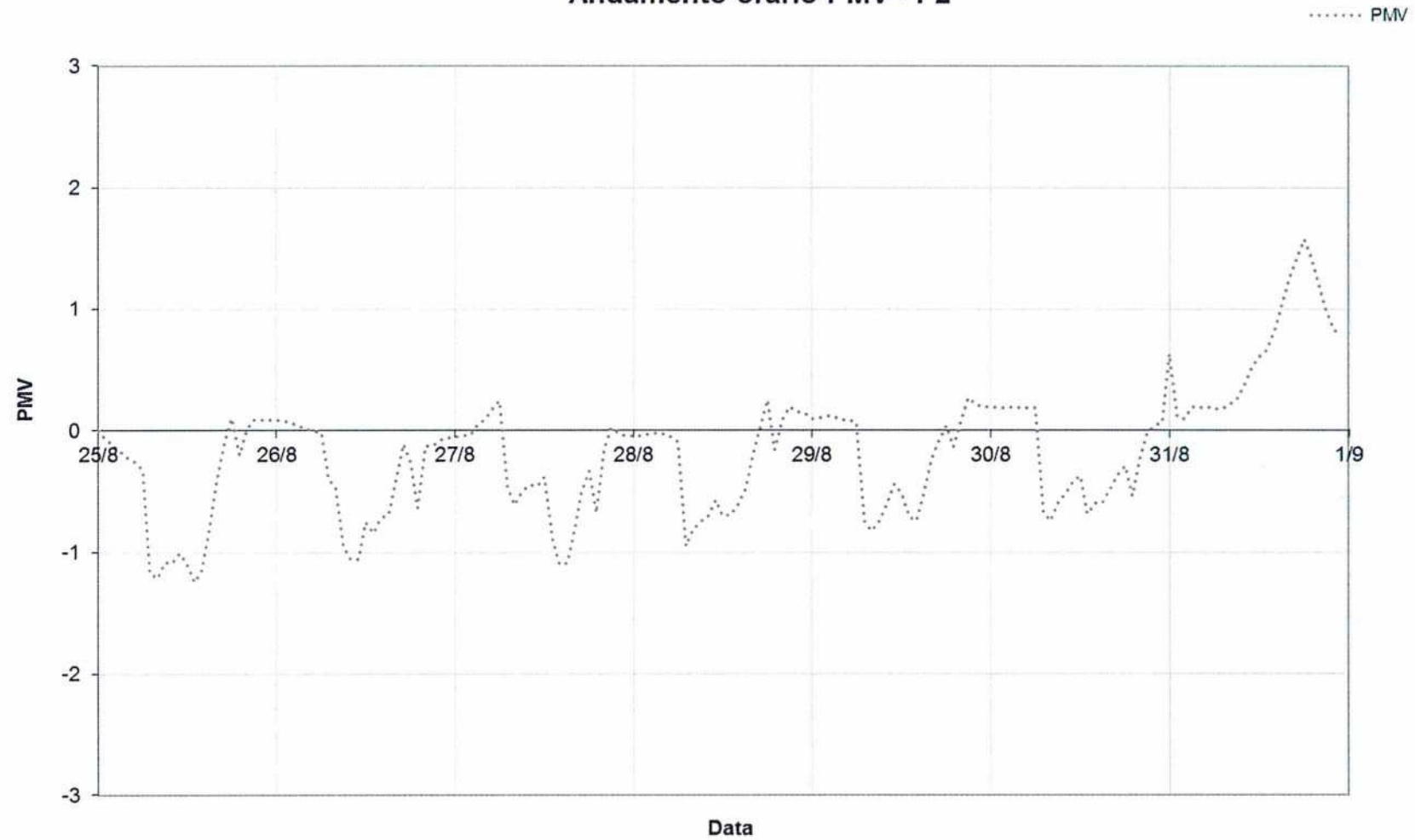
Andamento orario PMV - P1



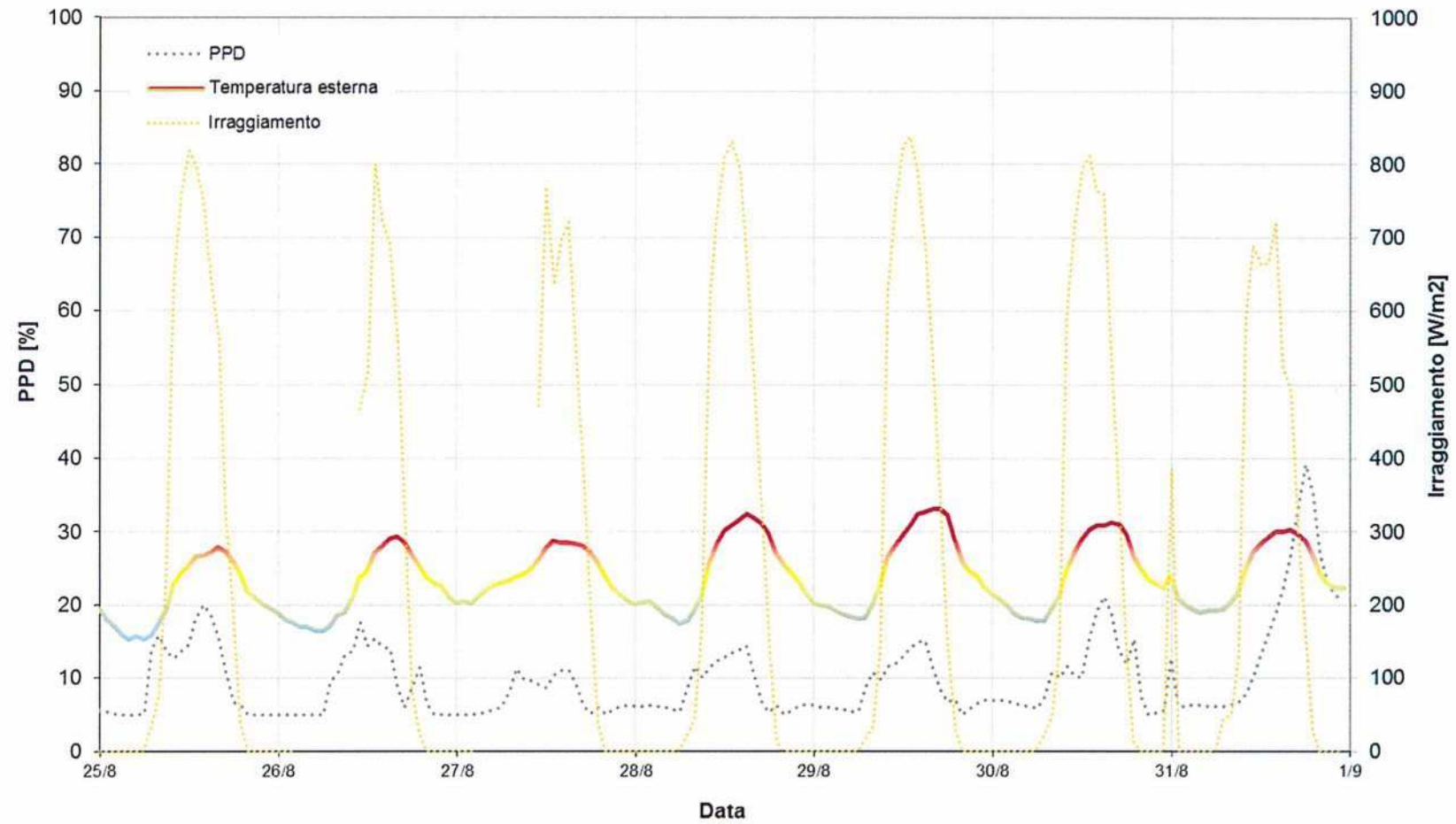
Andamento orario PPD - P2



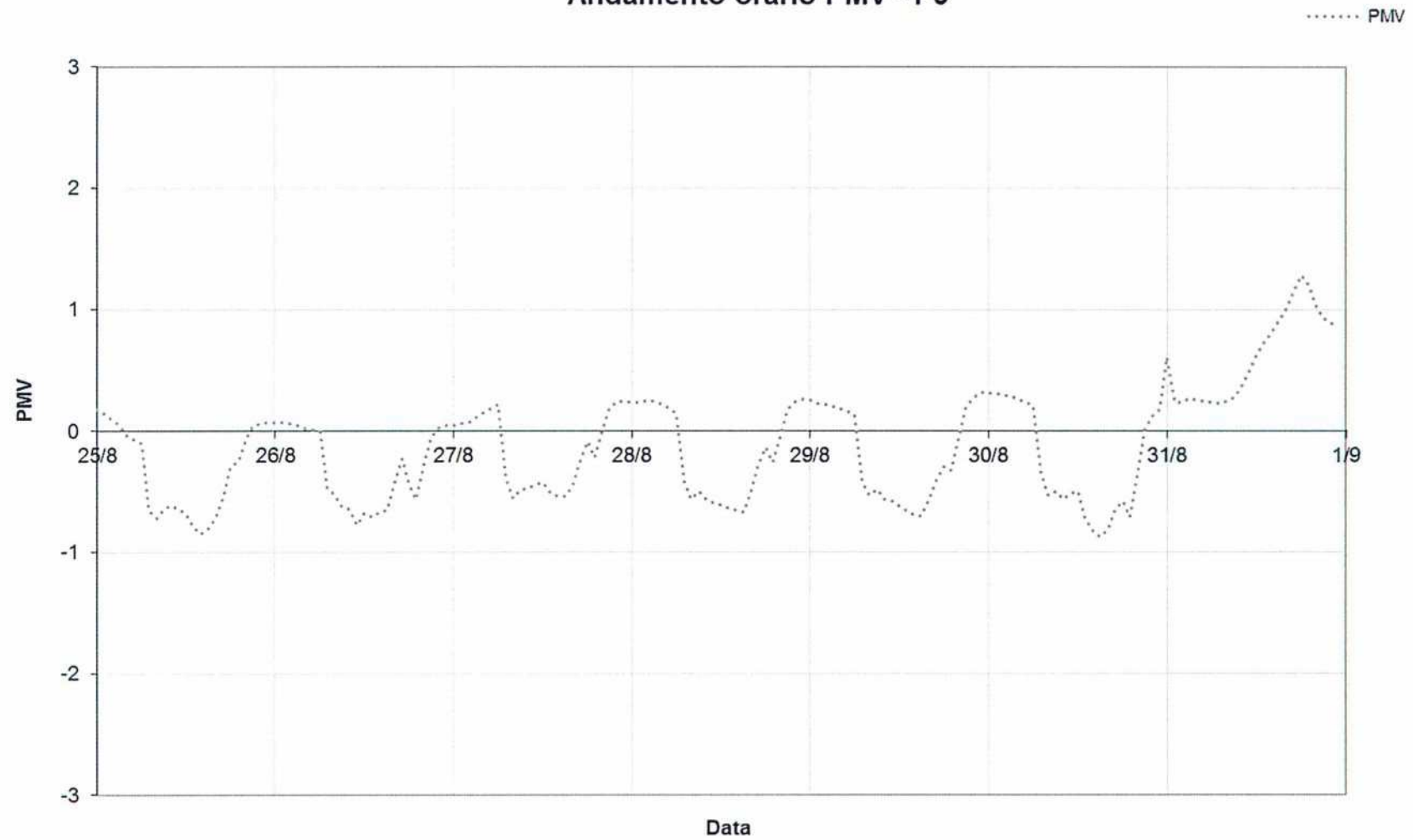
Andamento orario PMV - P2



Andamento orario PPD - P3

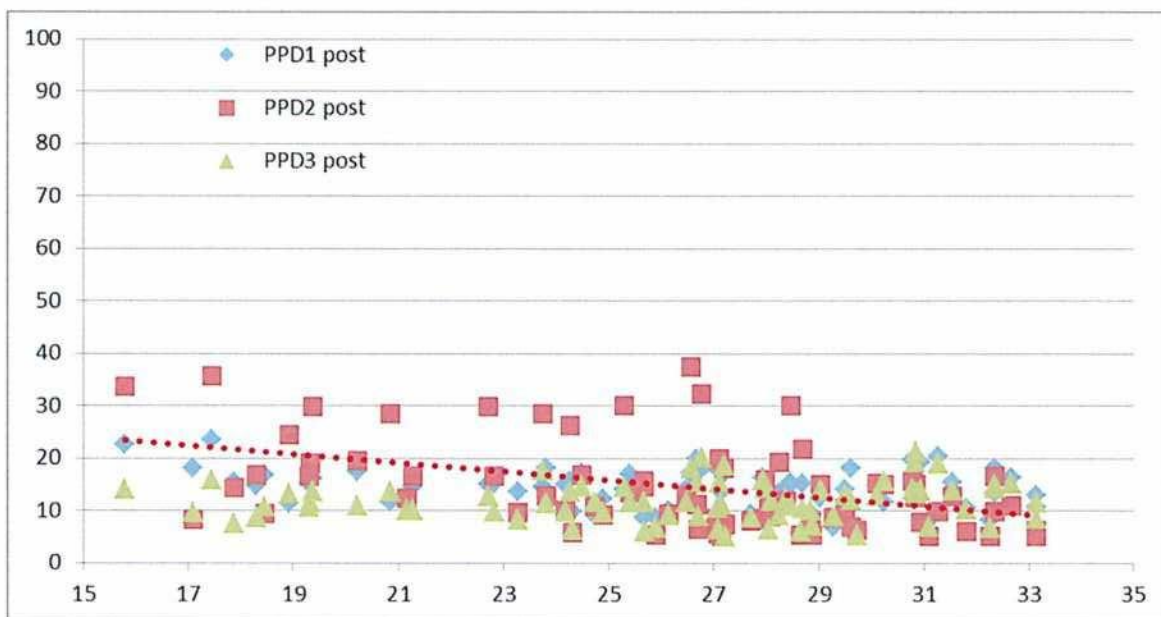
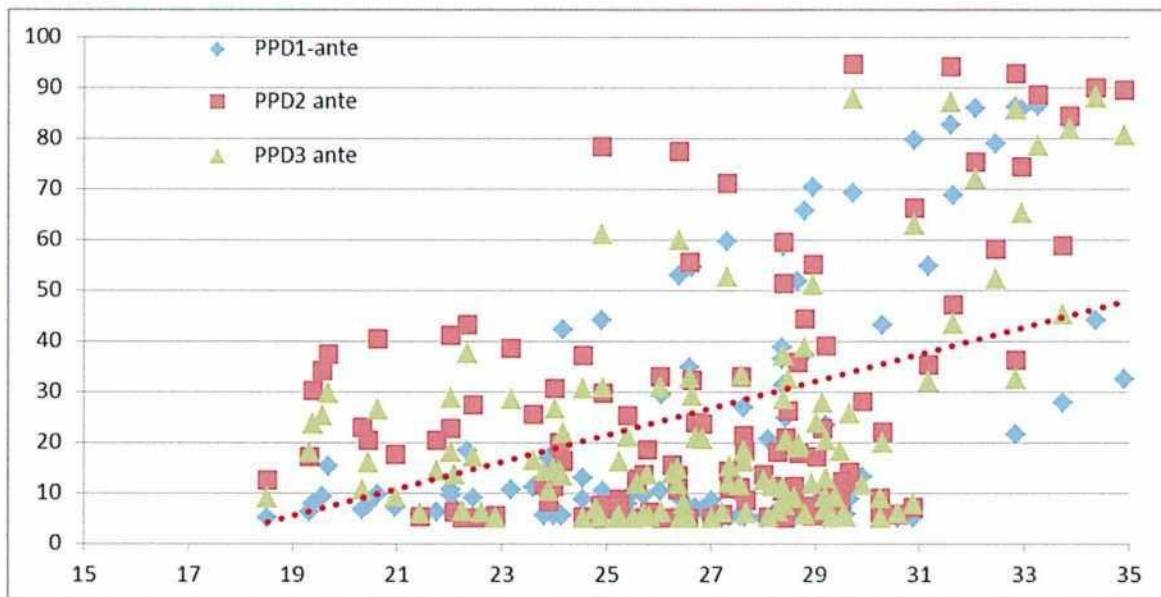


Andamento orario PMV - P3



With the same cooling capacity, because the air conditioning system has not been modified, the sensation of "slightly cool" is due to the increase in cooling efficiency caused by the use of the air intake system introduced by VetroVentilato.

Therefore, a more appropriate adjustment to new efficiency parameters is required. This can be achieved modifying the temperature control, for example, by lowering down the set-point temperature.



The previous two graphs show that the introduction of the air intake ventilation system significantly improves efficiency by making independent the hygrothermal comfort from outside temperature. Indeed, the first trend line of the first graph increases as the outside temperature increases. Vice versa with the introduction of air intake system, the PPD index in the second graph is independent from environmental conditions.

The experimenters

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