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Long-Term Loading Effect on Stability and Spatial Uniformity of Climatic Chambers

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***Abstract* – In this work, a study of the impact that the commonly-known 'loading effect' has over the determination of inhomogeneity and temporal stability of a climatic chamber is presented. Consecutive yearly characterizations of a two-pressure humidity generator treated as a climatic chamber revealed that the spatial inhomogeneity strongly depends on the environmental conditions of the laboratory as well as the percentage of the work volume occupied by 'loading devices', such as capacitive thermohygrometers. Results show that temperature and relative humidity measurements can vary as much as 0.4 °C and 0.1 %HR, respectively, if the load occupies at least 40% of the work volume. The effect on stability is considerably lower and in the worst case is 0.01 °C and 0.06 %HR.**

Keywords* – *Climatic chamber, characterization, uniformity, stability.

I. INTRODUCTION

Climatic chamber characterization is a process that allows the determination of the performance parameters of an enclosure with controlled temperature and relative humidity. This activity becomes relevant, for example, in the calibration of instruments used to register the environmental conditions of a certain region or enclosed space, also in aging studies, sensitivity analysis, and other areas.

For the purpose of climatic chamber characterization, some usually employed guides are the IEC 60068 [1], the Calibration Guide No. 20 from EURAMET [2] and the DKD R-5-7 [3], the latter is widely used by calibration laboratories in Colombia. One of the parameters contemplated in this guide corresponds to the loading effect, which must be determined separately for both the Temperature and Relative Humidity characterizations. This effect is generally estimated by introducing into the chamber a 'load' which simulates similar characteristics as those used in a normal calibration process, afterwards, depending on the characterization being performed (Temperature or Relative Humidity), the difference in indication of a single sensor relative to its same indication without loading must be determined and the result is taken as the loading effect of the chamber, the sensor used for this determination is generally placed on the center of the chamber volume.

The loading effect can, in turn, have an effect on other characterization parameters like spatial uniformity and temporal stability. Uniformity and Stability can be reported relative to the empty chamber (Method A [3]) and to the loaded chamber (Method B [3]). In this work, the differences that can be obtained between these two methods are presented using the measurement chamber of a two-pressure humidity generator. This work had not been yet carried out within the Colombian framework of operation therefore making its results and subsequent socialization fundamental for the network of secondary accredited laboratories who have implemented humidity measurements among its calibration and measurement capabilities. The Instituto Nacional de Metrología de Colombia has the obligation to aid in the enhancement of the measurement capabilities of secondary laboratories in order to further increase the competitiveness of Colombian laboratories and the quality of products produced in the country.

II. DESCRIPTION OF THE METHOD

In order to perform the study of the loading effect, the subject of evaluation was the measurement chamber of a two-pressure humidity generator (Thunder Scientific, model 2500) from the Temperature and Humidity Laboratory of the Instituto Nacional de Metrología, INM de Colombia.

Initially, the work volume was established by using a cubic metallic grid and placing 8 thermometers (PRT Pt100) on each of its edges as can be seen in Figure 1, these devices were used to monitor the spatial and temporal temperature changes within the work volume; an additional reference thermometer was placed on the center of the work volume, this position, labelled as 'C' in Figure 1, is known as the reference point. The chamber overall volume is 0.04 m^3, whilst the work volume was 0.005 m^3. The reading of the thermometer placed in the 'C' point from Figure 1 is subtracted to the readings of the 8 thermometers located at the edges of the work volume in order to calculate the Uniformity according to equation (1). A dew point hygrometer was also placed in the reference position for the purpose of determining the relative humidity values using the dew point temperature and the air temperature inside the chamber.

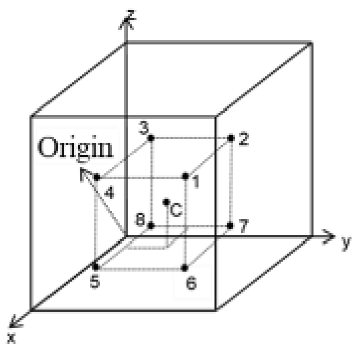

Fig. 1. Work volume employed in the characterization process

$$Unif = Max|t_i - t_c| \tag{1}$$

In equation (1), t_i is the temperature of the *i-th* thermometer placed on the edges of the metallic grid and t_c is the temperature indicated in the reference point. The overall uniformity of the chamber is taken as the maximum difference found within the work volume.

The stability of the *i-th* point is defined according to equation (2).

$$Est_i = \frac{(t_{max} - t_{min})}{2} \tag{2}$$

Where t_{max} and t_{min} represent the maximum and minimum temperatures, respectively, in the *i-th* point after a stable condition is reached within the chamber. The overall stability of the chamber is taken as the value found using equation (2) in the reference point 'C'.

The elements used as loading were 10 capacitive hygrometers with internal sensors which occupied approximately 40% of the work volume. These devices were used in order to simulate extreme working conditions for the chamber which can then justify the uncertainties reported to the users of the calibration services.

A total of three characterizations were realized distributed along three different years. The characterization processes were carried out by taking 30 temperature (or relative humidity) measurements during a 30 minute interval for each temperature and relative humidity point. The temperature characterizations were done at a 50 %RH constant value and the relative humidity characterizations were performed at a 20 °C constant temperature. The temperature points at which the chamber was characterized were 0 °C, 10 °C, 20 °C, 30 °C and 40 °C, whilst the Relative Humidity points were 10 %RH, 30 %RH, 50 %RH and 85 %RH.

Measurements were taken within the following environmental laboratory conditions:

Temperature: 22 °C ± 3 °C.
Relative Humidity: 50 %RH ± 15 %RH.

III. RESULTS AND DISCUSSIONS

Uniformity

Figure 2 presents the influence of the loading over the uniformity for relative humidity between 10 %RH and 85 %RH. It can be seen that the uniformity parameter increases with increasing relative humidity, both when the chamber is empty (without load) as well as when the load is inserted. This phenomenon is related to the difficulty of air circulation as the diluted water vapour increases, especially if there are flux barriers present, as is the case of the loaded chamber. The greatest change in the uniformity parameter due to the presence of the load was presented at a 30 %RH and it corresponds to a 0.10 %RH difference, meanwhile the smallest difference was obtained at a 10 %RH with a value of 0.03 %RH. The uncertainty that can be obtained in these types of systems is close to 0.8 %RH [4], implying that the loading contribution to the uncertainty is close to 13 %.

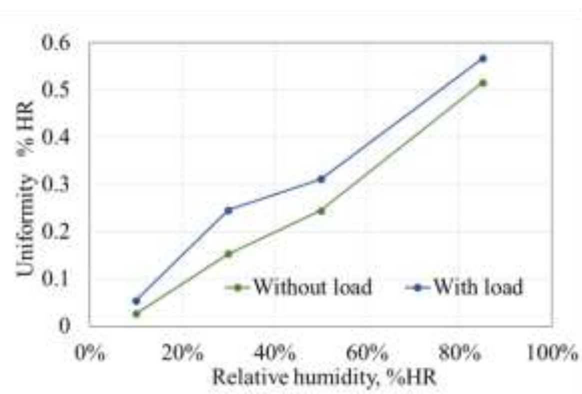

Fig. 2. Effect of the load over the Relative Humidity uniformity

Figure 3 presents the effect of the loading over the uniformity for temperatures between 0 °C and 40 °C. It can be observed that for temperatures smaller than 20 °C the uniformity parameter decreases with decreasing temperature, whilst for greater temperatures it increases. The greatest difference in uniformity due to the loading was evidenced at 10 °C with a value of 0.4 °C, meanwhile the smallest difference was 0.01 °C obtained at a 20 °C temperature. The fact that the smallest uniformity values are presented at 20 °C is related to the environmental conditions of the laboratory, which are of similar order (22 °C ± 3 °C). In temperatures close to ambient temperature, the heat transference between the measurement chamber and the exterior is reduced, generating fewer thermal disturbance and allowing the system to generate more uniform conditions. It is important to mention that for lower temperatures the uniformities are greater than the ones obtained at ambient temperature. The temperature uniformity of the humidity generator is 0.2 °C when the system is operated at 10 °C, which implies that the effect of the loading is up to three times greater when operating at temperatures lower than ambient temperature.

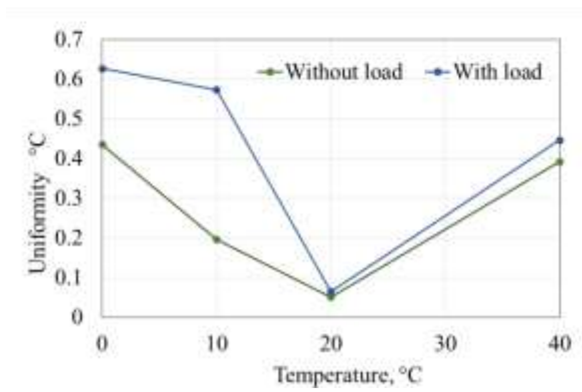

Fig. 3. Effect of the load over the Temperature Uniformity

Stability

Figure 4 presents the effect of the load over the stability calculated in the Relative Humidity quantity for values within 10 %RH and 85 %RH. Similar to the behavior for the uniformity, the stability parameter increases with increasing relative humidity and greater values are obtained once the load is inserted. The difference in the stability parameter was approximately constant and around 0.06 %RH.

Figure 5 presents the effect of the load over the stability for temperatures ranging between 10 °C and 40 °C. Similar to the uniformity case, the stability was lower for temperatures close to the ambient temperature (~1 mK) and then it increased for lower temperatures (10 mK).

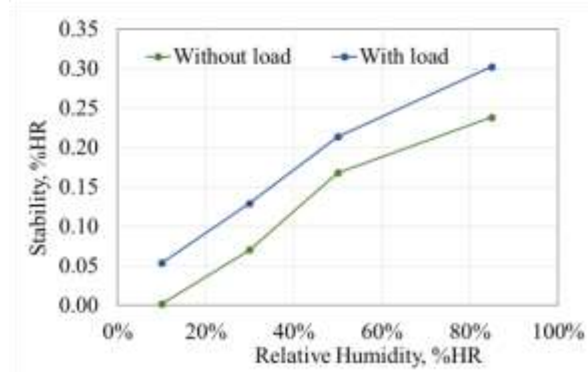

Fig. 4. Effect of the load over the Stability in Relative Humidity.

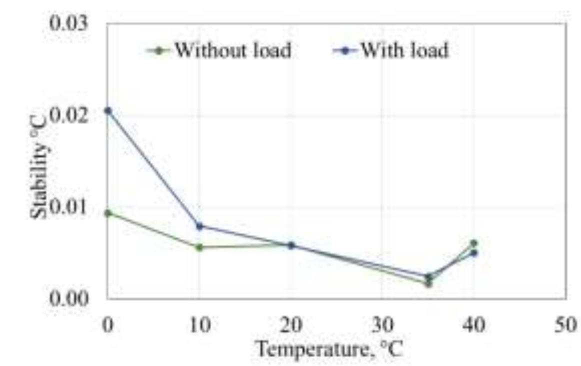

Fig. 5. Effect of the load over the Temperature Stability

IV. CONCLUSIONS AND OUTLOOK

The effect of introducing a load over the determination of the uniformity and stability of a climatic chamber was compared according to guide DKD R-5-7. It was found that the loading effect has an important contribution in the characterization of climatic chambers and that it has an influence on other characterization parameters.

Regarding the Relative Humidity quantity, the effect of the load over the uniformity depends on the environmental conditions. For temperatures lower than 20 °C, a difference of up to 0.4 °C was obtained, which corresponds to a variation of three times the determined value at conditions close to ambient temperature. The effect over the stability is considerably smaller and of the order of 0.01 °C.

For both Temperature and Relative Humidity quantities, the loading effect is more relevant for the spatial uniformity than for the stability, which is consistent with the experimental setup given that the air flux barriers tend to impose a greater difficulty for the spatial distribution of the air/water mix to be homogenous within the chamber, regardless of any given stabilization time. In the case of temporal stability, it is enough to adjust at least a two-hour time-period for the dispersion of the readings to be appropriate for the laboratory procedures.

V. ACKNOWLEDGMENTS

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