

THE CLIMATOGRAM OF LISBON FOLLOWING ETS STANDARD^(*)

Idalina Vieira Aoki⁽¹⁾, Teresa Cunha Diamantino⁽²⁾ ^(**) Maria João F. Marques⁽²⁾,
Isabel Figueira Vasques⁽²⁾ and Maria Elena Santos Taqueda⁽¹⁾

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ABSTRACT

A climatogram is an envelope of climatic conditions defined by the characteristic severity of these conditions. A characteristic severity of a climatic parameter is determined by the extreme values of the parameter obtained from a statistical distribution of the measured air temperature (T) and the relative air humidity (RH) in a specified location for a long monitoring period. The climatogram of Lisbon, in Portugal, is presented. Lisbon is classified as a temperate climate region, with short winter season and long and warm summer period. Lisbon is located at 38° 43' N of latitude and 9° 11' W of longitude and an average atmospheric pressure of 1.0043 bar. The relative humidity is commonly very high which makes its climate very special and somewhat similar to those of the tropical regions. In this work 8519 paired T and RH values acquired for five years, in a time frequency of four hours intervals starting from 2:00a.m., summing up a total of six recordings per day that were used for constructing the climatogram.

For every RH value there is an associated water partial pressure (p_A). Moreover, for each RH values an absolute humidity (AH) can be determined. So, with the known quantities T, RH and AH, the maximum and the minimum values with 1% and 10% probability of occurrence can be determined from the statistical distribution of the observed or calculated parameters using Minitab statistical software. Thus, the boundary values (extreme values of T and RH) of the climatogram square envelope can be obtained. In order to complete the envelope, a curve determined by the equation relating T and RH was drawn. There is an envelope for each percentile [1% (outer) or 10% (inner)] in the probability of occurrence plot. Comparisons between Lisbon climatogram and others obtained for regions of tropical climate are made, under the scope of the Tropicorr project, beneath the Cyted Programme in order to characterise the corrosivity of specific Ibero-American climates on materials used in electro-electronic devices to improve their reliability.

Key Words: Climatogram, Lisbon, Psychrometry, CYTED – Tropicorr Project

O CLIMATOGRAMA DE LISBOA SEGUNDO UMA NORMA ETS^(*)

RESUMO

Um climatograma é um diagrama das condições climáticas de uma região e é definido pela agressividade característica dessas condições. A agressividade característica de um parâmetro climático é determinada pelos valores extremos desse parâmetro que são obtidos a partir de uma distribuição estatística da temperatura do ar medida (T) e da humidade relativa do ar (RH) num local específico durante um período de monitorização longo. É apresentado aqui o climatograma de Lisboa, em Portugal. Lisboa é classificada como uma região de clima temperado, com uma estação curta de Inverno e período longo e temperado de Verão. Lisboa está situada a uma latitude de 38° 43' N e 9° 11' W de longitude e tem uma pressão atmosférica média de 1,0043 bar. A humidade relativa é geralmente muito elevada o que torna o seu clima muito especial e um tanto similar ao das regiões tropicais. Neste trabalho foram utilizados na construção do climatograma 8519 pares de valores de T e de RH, adquiridos num período de cinco anos, com uma frequência de tempo de quatro horas de intervalo, num total de seis valores por dia.

Para cada valor de RH está associada uma pressão parcial da água (p_A). Além disso, para cada valor de RH medido pode ser determinada uma humidade absoluta (AH). Então, conhecendo a T, a RH e a AH, os valores máximos e mínimos com probabilidade de 1% e de 10% de ocorrência podem ser determinados a partir da distribuição estatística dos parâmetros observados ou calculados usando o software estatístico Minitab. Deste modo, podem ser obtidos os valores limite (valores extremos de T e de RH) do diagrama do quadrado do climatograma. De forma a completar o diagrama, traçou-se uma curva determinada pela equação que relaciona T e RH. Há um diagrama para cada percentil [1% (exterior) e 10% (interior)] do gráfico de probabilidade de ocorrência. Foram efectuadas comparações entre o climatograma de Lisboa e outros obtidos em regiões de clima tropical, no âmbito do Projecto Tropicorr, ao abrigo do programa Cyted que tem como objectivo caracterizar a corrosividade de climas específicos Ibero-Americanos nos materiais usados em dispositivos electro-eletrónicos com vista a melhorar o seu desempenho e fiabilidade.

Palavras Chave: Climatograma, Lisboa, Psicrometria, CYTED – Projecto Tropicorr

⁽¹⁾ Departamento de Engenharia Química da Escola Politécnica da Universidade de São Paulo. Caixa postal: 61.548, CEP: 05424-970 – São Paulo – SP – Brasil, e-mail: idavaoki@usp.br.

⁽²⁾ INETI – Laboratório de Tratamento de Superfícies e Revestimentos – Estrada do Paço do Lumiar, 1649-038 – Portugal

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^(**) A quem a correspondência deve ser dirigida, e-mail: teresa.diamantino@ineti.pt.

1. INTRODUCTION

The establishment of environmental condition classification is the basis for specifying environmental tests for telecommunication or electronic equipment. The main purpose of environmental engineering is to make the equipment and the environment mutually compatible. Often the equipment has to be modified or protected to resist a given environment or, alternatively, the environment shall to be conditioned to match the equipment. This way, the environmental requirements related to equipment specification and design must be considered and stated in an early phase of a project. An over-specification, which results in over design is costly and may not lead to a more reliable product. In order to achieve an adequate test specification for the equipment, the environmental conditions of well-defined locations have to be known. The environmental conditions comprise climatic, biological and mechanical conditions and sometimes, typical environmental conditions have simple names such as "outdoors", "indoors", "in a room". However, these conditions involve many environmental parameters varying in severity and having complex interactions. These parameters (the significant ones) determine the actual influence of the environment on the equipment [1].

Environmental parameters are represented by those physical or chemical properties of an environment. They comprise air temperature, relative air humidity, called climatic parameters, and concentration of a chemical pollutant in the air and so on.

Determining the characteristic severity and extreme values of climatic parameters like air temperature and relative air humidity it is possible to construct a climatogram [2,8].

The climatogram of Lisbon, in Portugal, is presented and compared to other climatograms.

2. EXPERIMENTAL

2.1 Location

The measures of outdoor air temperature (T) and outdoor relative air humidity (RH) were acquired for five years in an outdoors location in Lisbon, Portugal, specifically the atmospheric corrosion site at INETI, Lisbon. The location is characterised by the co-ordinates north latitude of 38° 43' and west longitude of 9° 11'. The simultaneous acquisition of T and RH was taken at fixed times: 2:00 a.m., 6:00 a.m., 10:00 a.m., 2:00 p.m., 6:00 p.m. and 10:00 p.m., summing up a total of six recordings per day, for five consecutive years, starting from 1996. The whole data set summed up 8,519 pairs of simultaneous T and RH measures.

The historical average value of air pressure in Lisbon is 1.0043 bar or 100.43 kPa.

2.2 Calculations [8]

All the T and RH data were used to calculate the absolute humidity (AH), starting from the definition of relative humidity in order to find the water partial vapour pressure in the unsaturated air, in the conditions of T and RH of each data pair. Thus,

$$RH = \frac{P_A}{P'_A} \cdot 100 \quad \text{Eq. 1}$$

Where:

$$\begin{aligned} P_A &= \text{Partial water vapour pressure in the unsaturated air} \\ P'_A &= \text{Saturation water vapour pressure} \end{aligned}$$

$$P_A = \frac{RH}{100} \cdot P'_A \quad \text{Eq. 2}$$

The absolute humidity is defined as the ratio of mass of water vapour and mass of dry air. Considering this mixture water-air as an ideal gas, the AH expressed in terms of the partial water vapour pressure, P_A is given by:

$$AH = \frac{18}{29} \cdot \frac{P_A}{(P - P_A)} \quad \text{Eq. 3}$$

Substituting eq. 2 into eq. 3, it is obtained:

$$AH = \frac{18}{29} \cdot \frac{\frac{RH}{100} \cdot P'_A}{P - \frac{RH}{100} \cdot P'_A} \quad \text{Eq. 4}$$

The average barometric pressure of Lisbon, P, is 100.43 kPa.

Therefore, the AH can be estimated for each pair of air T and air RH measurements and P'_A determined from an exponential correlation with T using tabulated water thermodynamic properties [3].

Now, with all T, RH and AH data, the maximum and the minimum values for these variables must be determined. It was done by first obtaining the statistical distribution or histogram and the probability of occurrence plot in order to determine the characteristic severities as the variable values with a probability of occurrence less than 1% and less than 10% [4].

2.3 Climatogram construction [8]

Using the statistically determined extreme values for T and RH, the outer (1%) and the inner (10%) square envelopes of the climatogram were constructed in a two-dimension plot using T as the left-hand ordinate and the RH as the abscissa. In a climatogram, the AH is the right-hand ordinate (for fixed AH values corresponding to isohumidity lines) and AH isohumidity lines have to be built for the maximum and for the minimum fixed AH values. The crossing points of the previous square envelope and the AH isohumidity lines define the final climatogram envelope which will be constituted by straight lines and AH isolines curves as shown in Fig. 4.

The AH isolines were obtained applying eq. 4 fixing the AH value as being the extreme value found in the statistical distribution. For each envelope two extreme values and hence two isohumidity lines are obtained.

Substituting the fixed AH value in eq. 4, an expression like eq. 5 is obtained.

$$P'_A = \frac{k}{RH} \quad \text{Eq. 5}$$

k being a numerical constant. In the other hand, an exponential correlation was obtained between P'_A and T using the literature water thermodynamical data [3] and the simplex estimation method employing the Statistica 5.0 software. The exponential correlation equation obtained was:

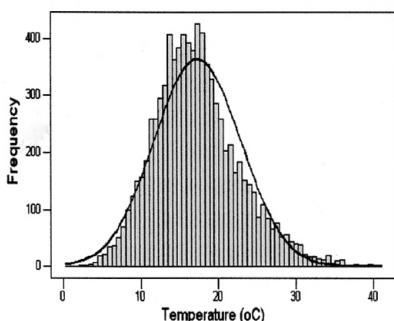
$$P'_A = -0.1796 \exp(0.0805T) + 0.9066 \exp(0.0641T) \quad \text{Eq. 6}$$

With a correlation coefficient $R=0.9999$ which is valid for T in °C and p'_A in kPa. The substitution of eq. 5 in eq. 6 results in eq. 7, which represents a specific AH isoline

$$\frac{k}{RH} = -0.1796 \exp(0.0805T) + 0.9066 \exp(0.0641T) \quad \text{Eq. 7}$$

3. RESULTS AND DISCUSSION

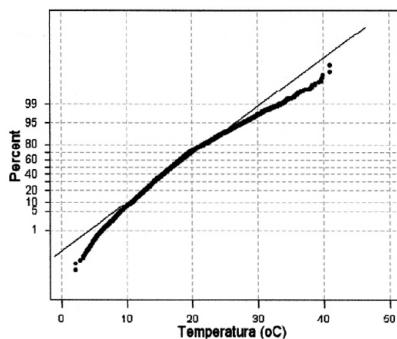
The quantitative measure of the stress introduced by the parameter is called severity and is stated as magnitude, rate or duration of occurrence. An example is the climatic parameter



(a) Histogram with Normal Curve

outdoor air temperature, whose statistical distribution or histogram is needed to see the appearance of the distribution, number of peaks and extreme values. Considering the definition of severity, both extreme values (maximum and minimum temperature) may induce stress with their own mechanisms leading to failure of the equipment. A temperature histogram generally shows a left-hand tail (minor values) and a right-hand tail (higher values).

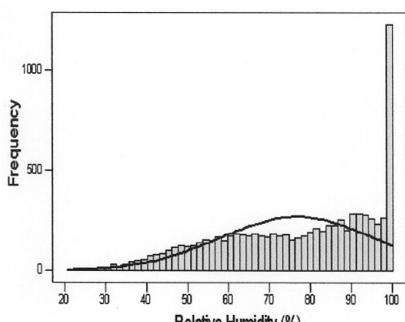
The statistical distribution or histogram for air temperature and its normal probability plot, in Lisbon, Portugal, are presented in Fig.1a and in Fig.1b, respectively.



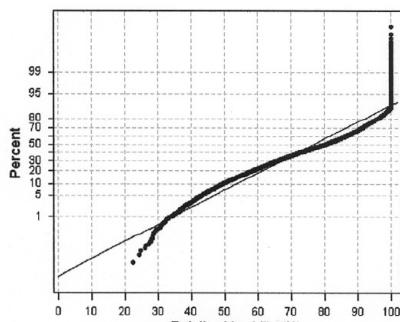
(b) Normal Probability Plot

Fig. 1 – Outdoor air temperature histogram showing the normal distribution
(a) and the normal probability plot (b) for Lisbon, Portugal.

The histogram for relative air humidity and its normal probability plot in Lisbon, Portugal, are presented in Fig. 2a and in Fig. 2b, respectively.

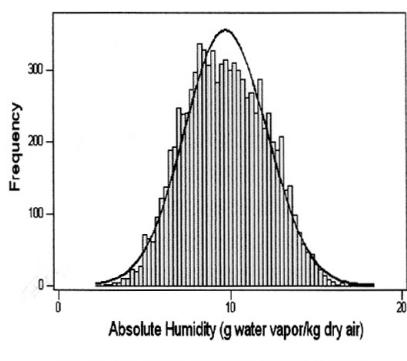


(a) Histogram with Normal Curve

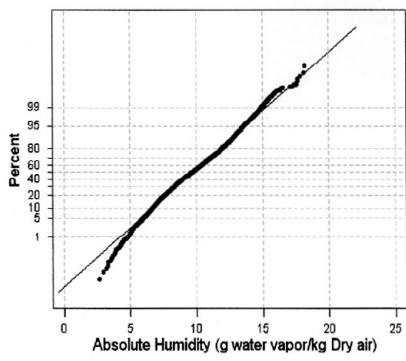


(b) Normal Probability Plot

Fig. 2 – Outdoors relative air humidity histogram showing the normal distribution curve
(a) and normal probability plot (b) for Lisbon, Portugal.



(a) Histogram with Normal Curve



(b) Normal Probability Plot

Fig. 3 – Outdoors absolute air humidity histogram showing the normal distribution curve
(a) and the normal probability plot (b) for Lisbon, Portugal.

Although the extreme points in the distribution tail does not rigorously fit to a normal distribution (see Fig. 1), all the data fit quite well to a straight line in the probability plot. The mean value and corresponding standard deviation of temperature determined from the 8519 data is $(17.3 \pm 5.6)^\circ\text{C}$. Lisbon is classified as a temperate climate region, with short winter season and long and warm summer period.

For relative humidity data the mean value and standard deviation is $(76.8 \pm 18.8)\%$. The distribution of relative humidity is special with high frequencies of occurrence for all humidity in the whole range what was evidenced by a high standard deviation for RH. Another characteristic feature is a high frequency of occurrence for the maximum 100%RH This can be explained by the fact that summer in Lisbon is characterized by long dried periods, high temperatures, low humidity, while in winter, high humidity, temperatures not too low and quite strong winds are recorded. During the data acquisition period, a long rainy period in 1996 and 1997 winter was verified, justifying the very high frequency observed for 100% relative humidity. Completing the

descriptive statistics the mean value of absolute humidity is $(9.7 \pm 2.4) \text{ g water vapour/kg dry air}$ that is lower than absolute humidity found in tropical locations.

The area bellow the distribution curves, beginning from a given temperature, represents the % probability of its occurrence. The so-called characteristic severity is in principle to be considered as an extreme point of the statistical distribution for each parameter. The probability of exceeding the characteristic severity is normally very low, less than 1%, but it is important to note that the characteristic severity, although an extreme, may be exceeded from time to time or from place to place.

From the probability plots for T, RH and AH, the extreme values, minimum (1%) and the maximum (99%) for the characteristic and other severity, are obtained.

The results of the extreme values, maximum and minimum, of T, RH and AH for characteristic severity, for exceptional climatic conditions and for special severity were put together in Table 1. A climatogram is an envelope of climatic conditions defined by the characteristic severity of these conditions. The final climatogram for Lisbon is presented in Fig. 4.

Table 1
Extreme values for the climatic parameters in Lisbon

		Climatic parameters		
Severity grade	Reference Value	Temperature ($^\circ\text{C}$)	Relative Humidity (%)	Absolute Humidity (g water vapor/kg dry air)
Exceptional climatic limits	Exceptional minimum	2.1	23.4	2.6
	Exceptional maximum	40.9	100.0	18.2
Characteristic severity: probability of occurrence less than 1%	Minimum 1%	6.1	33.4	4.8
	Maximum 99%	33.3	100.0	14.9
Normal climatic limits: probability of occurrence of less than 10%	Minimum 10%	10.8	50.7	6.7
	Maximum 90%	24.6	100.0	12.9

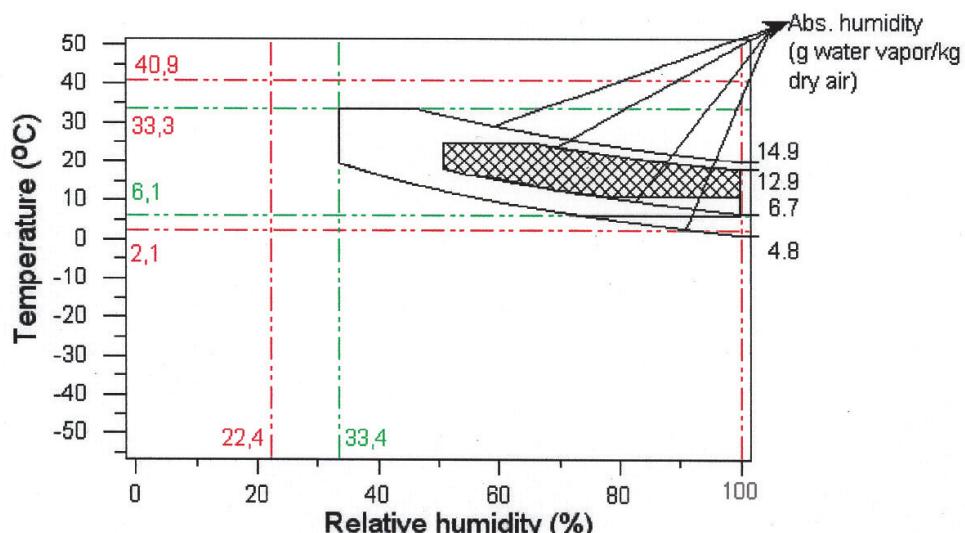


Fig. 4 – Climatogram of outdoors air in Lisbon, Portugal, including exceptional climatic conditions (in long dashed red lines), the characteristic severity in the outer (green) envelope and the normal climatic conditions in the inner envelope.

3.1 Comparison among different climatograms in the scope of Tropicorr Cyted Project

The comparison becomes easier to be made when the climatograms are overlaid inside standard envelopes like those from ETS Standard 300 019-1-3 typical for 4.1 and 4.1E environmental classes for unsheltered outdoors environment.

The climatogram from Lisbon was put inside the EIS climatogram and is shown in Figure 5.

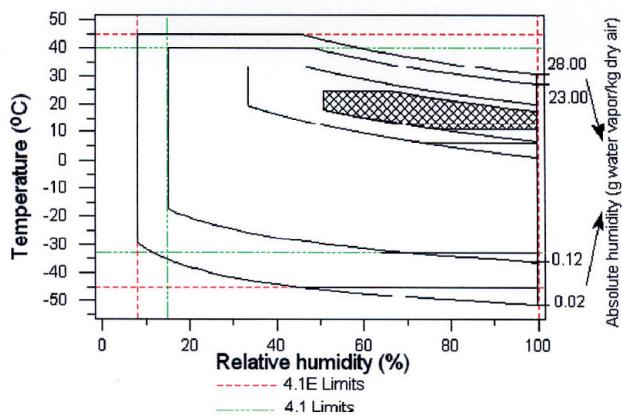


Fig. 5 – Overlay of typical ETS Standard 4.1 and 4.1E environmental classes (external envelopes with extremes values shown by limiting lines 4.1 and 4.1E) and Lisbon climatogram (internal continuous line and cross slant).

All the climatograms are inside the ETS Standard envelope what means that it is well specified. The differences between them are related to the type of climate of the specific location. The climatograms from Lisbon, a temperate climate site, São Paulo and Santa Cruz de la Sierra, moderate tropical climate locations, are very similar in general, but the great difference appears when we compare the three with that from Limón, in Costa Rica, a typical humid tropical climate. An observer can also verify a similarity between Lisbon and Limón climatograms

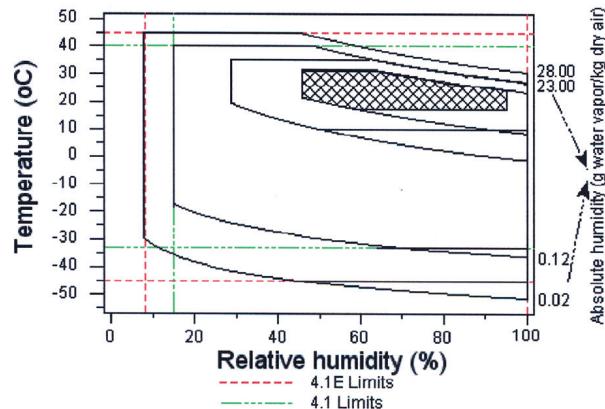


Fig. 6 – Overlay of typical ETS Standard 4.1 and 4.1E environmental classes (external envelopes with extremes values shown by limiting lines 4.1 and 4.1E) and Santa Cruz de la Sierra, Bolivia, climatogram (internal continuous line and cross slant).

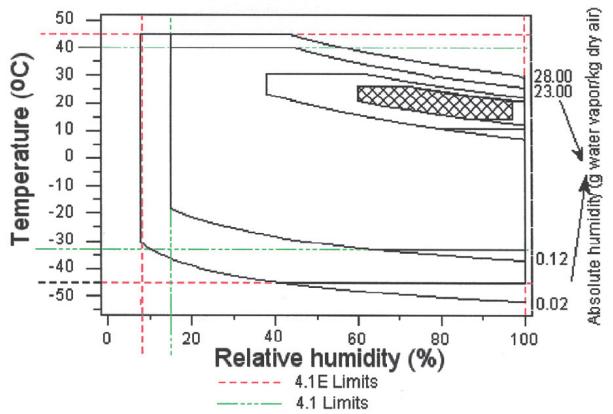


Fig. 7 – Overlay of typical ETS Standard 4.1 and 4.1E environmental classes (external envelopes with extremes values shown by limiting lines 4.1 and 4.1E) and São Paulo, Brazil, climatogram (internal continuous line and cross slant).

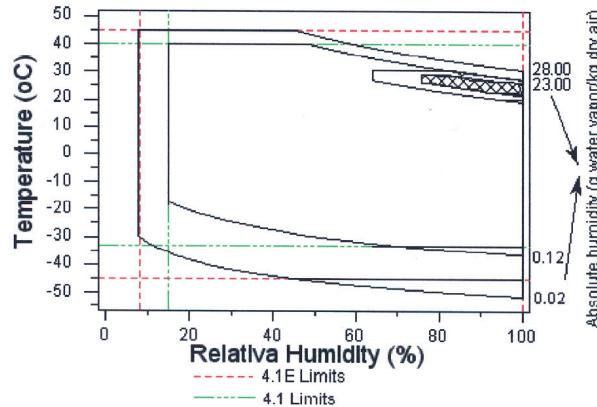


Fig. 8 – Overlay of typical ETS Standard 4.1 and 4.1E environmental classes (external envelopes with extremes values shown by limiting lines 4.1 and 4.1E) and Limón, Costa Rica, climatogram (internal continuous line and cross slant).

due to the fact that both present the inner envelope corresponding to normal climatic limits (10%) with the maximum RH at 100% what is typical for coastal locations. This does not happen to São Paulo or Santa Cruz climatograms. The thinner form of Limón climatogram is due to a narrow distribution of temperature and RH. The other climatograms are larger due to more spread distribution for temperature and RH at the referred locations. The main point is that when the producer must specify the conditions for a test for the electronic equipment, the cyclic test lasts for a long time in conditions never found in that region. As the test duration is fixed, it could be advisable to perform a test over a real

climatogram from the location and not only for an ETS standard climatogram. This is the reason for so much defective electronic equipment when used in tropical climate regions or similar ones.

4. CONCLUSIONS

This work allows the following conclusions:

- Starting from basic concepts in thermodynamics, statistics and psychrometry, it is possible to construct the climatogram in a simple way.

2. Lisbon climatogram is close to other climatograms from moderate tropical climate regions like São Paulo, in Brazil and Santa Cruz de la Sierra, in Bolivia.

3. The climatograms are useful to specify conditions for performing accelerated tests for electronic devices avoiding over-specification or over-designing.

4. It is possible to construct similar climatograms taking also in account the pollutants level in the location where the monitoring is been performed.

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