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METHODOLOGY TO EVALUATE CALIBRATIONS: A CASE STUDY ON THE INTERLABORATORIAL COMPARISON PROGRAM.

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Abstract – This work presents a method to evaluate measurement results of calibrations of an itinerary energy standard (Wh) performed by laboratories that participate in an interlaboratorial comparison program. It is based in the methodology of linearization of the normal function distribution. This tool compares data of a laboratory under analysis to data of the reference laboratory using beta values of each laboratory within a specific period of the program. If any of these measures is outside stipulated ranges it is a sign that the laboratory under analysis needs to investigate its process.

Keywords: Beta values, Beta ranges.

1. INTRODUCTION

Calibration laboratories have at their disposal a number of ways to demonstrate their technical competence and ability to maintain the quality of their services, for example, through audits, through intermediate calibrations and through its participation in interlaboratory comparison programs, etc.

In these programs an itinerary standard circulates among the laboratories in order to be calibrated by all of them. The results of theses calibrations are to be compared to the results of the calibration performed by a laboratory considered as a reference.

This program typically uses rules already accepted internationally [1]. The assessment of a laboratory performance using the value of the standard error (En) have a punctual characteristic, ie it evaluates the laboratory within a specific period of the program in which it participates. In our case we have a one year period, involving more than twenty laboratories.

For assessing the performance of laboratories over a longer period of time it is more appropriate to use a tool that is called *linearization of a normal distribution* [3]. Linear Regression is applied to data sorted is ascending order. The parameters of the straight line are compared with established limits. It is a tool widely used in other technical areas.

2. PRELIMINARY CONSIDERATIONS

Data analyzed here came from the interlaboratory comparison program maintained by the Brazilian Electric Sector, in the period 2000 to 2005 [2], which are represented in Table-1 The reference laboratory is Inmetro, which is legally established as National Reference for legal metrology and for scientific and industrial metrology.

Uncertainties (class of accuracy) relative to calibration standards of all laboratories that participate in the program vary from 70μWh/Wh (reference) to 500μWh/Wh.

The class of accuracy of the itinerant standard is 500μWh/Wh.

3. TECHNICAL CONSIDERATIONS

3.1. Methodology

The tool of *linearization of the normal distribution* uses the error and the uncertainty, for k = 2, for each annual measurement They are added in module, and this value is called e(max). During the period of analysis, from 2000 to 2005, there are six e(max) values. They are then sorted in ascending order and placed in the X-axis. In the Y-axis are placed the median ranks [8] (Benard's approximation).

These values are presented in Table-1 for the reference laboratory (Inmetro) and for the laboratory under analysis (Chesf).

Table 1. Sorted e(max) and Median Rank

Inmetro		chesf	
e(max)-X	Rank-Y	e(max)-X	Rank-Y
0.011%	0.109	0.020%	0.109
0.017%	0.266	0.021%	0.266
0.018%	0.422	0.023%	0.422
0.019%	0.578	0.032%	0.578
0.020%	0.734	0.033%	0.734
0.023%	0.891	0.060%	0.891

Now the data are plotted in a dispersion-YX graph using a spreadsheet (Excel, for instance) and then a trend line is generated. This is the regression line (y = ax + b), whose parameters, called measures in this work, are representative of each laboratory. These measures are obtained through the following procedures.

3.2. Setting out the measures

The measure-1 is obtained from the intersection of the regression line with the line y = 0.5, being a measurement of the average of data. These measures are called µLR for the reference laboratory and µLA for the laboratory under analysis.

The measure-2 is obtained from the slope of the regression line (variableX1 from Excel) and represents the dispersion of data around the average, being a measurement of the homogeneity of the process of the laboratory.

The measure-3 is obtained through the correlation coefficient (r-multiple of Excel) of the regression line, being a measurement of the conformity of data, relative to normal distribution.

These measures are shown in Fig-1.

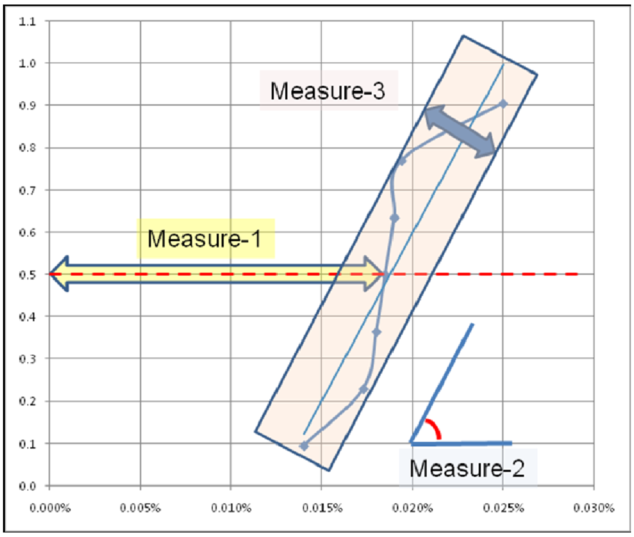

Fig. 1. Measures based in linear regression parameters.

3.3. Setting out Beta Values

These three measures, calculated for each laboratory, provide the beta-1 value, beta-2 value and beta-3 value, which will be used to analyze the performance of the laboratory by comparing them with values accepted as normal limits (range).

To obtain these measures it is plotted, in the same graph, data of the reference laboratory and data of the laboratory under analysis. In the next step the laboratory´s measures are determined according to 3.2.

3.3.1. Beta-1 value range

To obtain this range it is used (1) to calculate the ratio between the measure-1 of the reference laboratory (µLR) and the measure-1 of the laboratory under analysis (µLA).

$$\beta_1 = \frac{\mu_{LA} - \mu_{LR}}{\mu_{LR}} * 100\% \qquad (1)$$

This value will be compared with limit values (range), ie values that represent the best and the worst situation of uncertainty that this laboratory may have within the program of interlaboratorial comparison.

To determine these limits (range) it is assumed that the uncertainty of reference standard is 70µWh/Wh. Our laboratory has uncertainty of 100µWh/Wh. So, the limits for beta-1 are defined as follows:

a) Lower limit: Our standard, calibrated by the reference standard (70µWh/Wh), has a combined uncertainty of the order of 122µWh/Wh. By using (1) it is obtained a value for Beta-1 close to 74%, considering the itinerary standard has remained stable (zero error) during its circulation in the program.

$$\beta_1 = \frac{0.0122\% - 0.007\%}{0.007\%} * 100\% \approx 74\%$$

Note-1: In this situation it is not obeyed the criterion for TUR of at least 3:1

b) Upper limit: Here it is considered that the itinerary standard has not remained stable. The maximum error is its class of accuracy (500µWh/Wh). So, the upper limit will be the lower limit (122µWh/Wh) plus this error, giving an uncertainty of 622µWh/Wh (122µWh/Wh + 500µWh/Wh).
By using (1) it is obtained a value for Beta-1 close to 410%.

$$\beta_1 = \frac{0.0622\% - 0.0122\%}{0.0122\%} * 100\% \approx 410\%$$

Each laboratory will have, then, its lower and upper limits for Beta-1. In our case, specifically, the range for Beta-1 it is established in (2). Fig. 2 shows this range.

$$74\% < \beta_1 < 410\% \qquad (2)$$

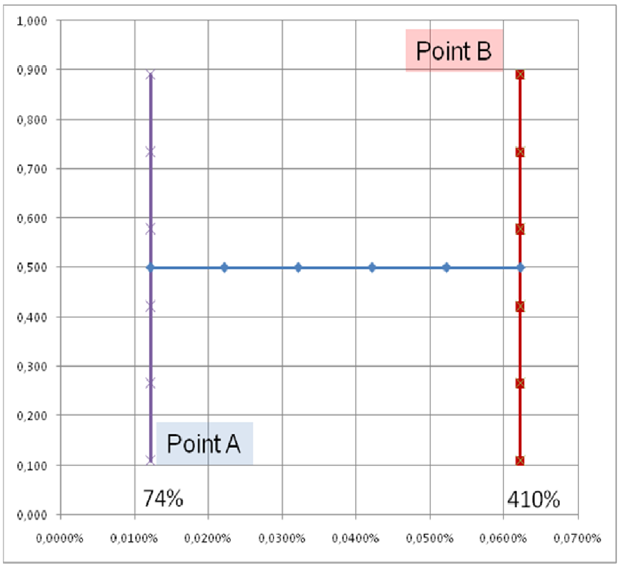

Fig. 2. β1-value range.

Once established its own range for Beta-1, laboratory´s Beta-1 value outside this range it is an indicative that there is need for a more detailed analysis of its data, which, in principle, may point to a problem in the laboratory.

3.3.2. Beta-2 value range

To establish this range it is used the measure-2 of the reference laboratory and the measure-2 of the laboratory under analysis. The measure-2 is given by the slope of the regression line of data of each laboratory.

a) Lower limit: The minimum allowable slope is the slope of the line that connects points A e B of Fig.2. This value is 1694.

b) Upper limit: The maximum slope is been considered the measure-2 of the reference laboratory, whose value, in this case, was found to be approximately 6836.

Beta-2 value range (3) is shown in Fig.3.

$$1694 < \beta_2 < 6836 \quad (3)$$

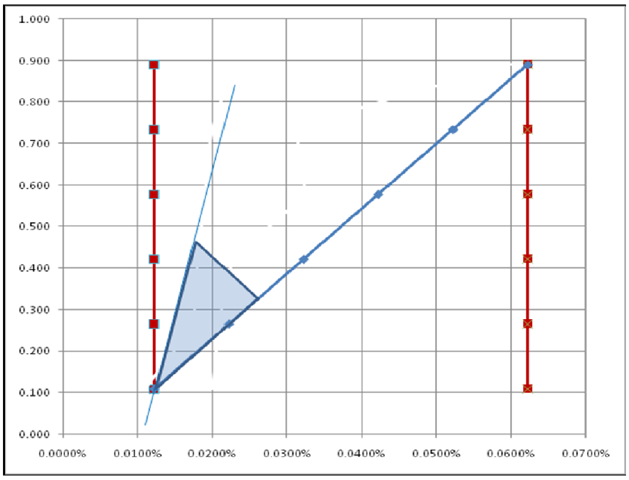

Fig. 3. β_2-value range.

Once established its own range for Beta-2, laboratory´s Beta-2 value outside this range it is an indicative that there is need for a more detailed analysis of its data, which, in principle, may point to a problem in the laboratory.

3.3.3. Beta-3 value range

To establish this range it is used the measure-3 of the reference laboratory and the measure-3 of the laboratory under analysis. The measure-3 is given by correlation coefficient of the regression line of data of each laboratory.

It is been considered bibliographic recommendations [6] about this coefficient. In this work we adopted the range given by (4). There are authors who, depending on the process, propose a wider limit.

$$0.8 \le \rho \le 1 \quad (4)$$

3.4. Analyzing laboratory performance

Data under analysis (Table-1), after applying all procedures presented so far, are now represented by straight lines (linear regression) whose parameters are the measures of each laboratory. These measures need now to be compared with Beta value ranges to evaluate laboratory performance.

3.4.1 Analyzing laboratory performance according to Beta-1 range

The measure-1 of the reference laboratory is 0.018% (μLR) and the measure-1 of the laboratory under analysis is 0.0315% (μLA). By using (1) is obtained the value of 75% for Beta-1 value. This value is within the range for Beta-1 (2), indicating that the laboratory has a satisfactory performance according to its average. The Fig.4 shows this situation.

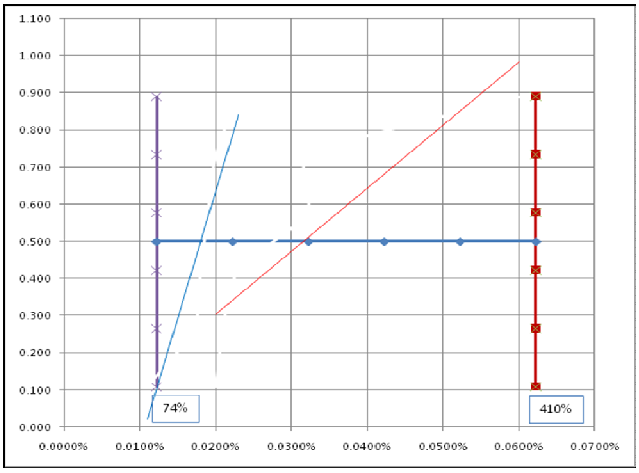

Fig. 4. Analysis of Beta-1.

3.4.2 Analyzing laboratory performance according to Beta-2 range

The Beta-2 value of the laboratory under analysis is 1694.61. This value is closed to lower limit for Beta-2 (1694), but within the limits established (3), indicating a homogeneous behavior of the laboratory. It is important to remember that the maximum slope of the line of the laboratory under analysis should not exceed the limit given by the slope of the line of the reference laboratory. Fig.5 shows this situation.

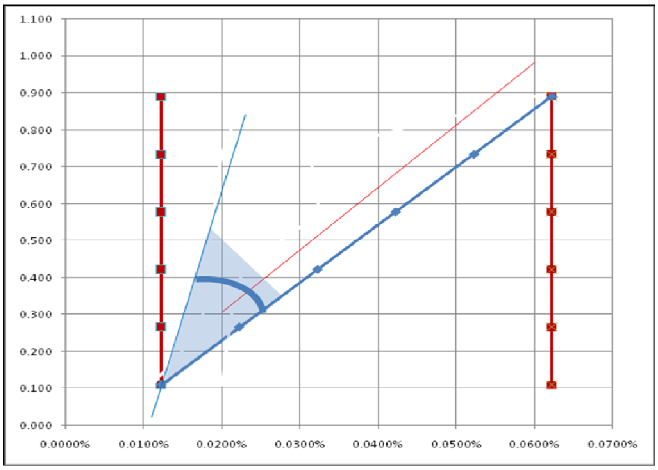

Fig. 5. Analysis of Beta-2.

3.4.3 Analyzing laboratory performance according to Beta-3 range

The value of Beta-3 of the reference laboratory is 0.9354 and the value of Beta-3 of the laboratory under analysis is 0.8713. These values are within the limits established (4), which may be a sign of conformity, ie normality of data of both laboratories. Fig.6 shows this situation.

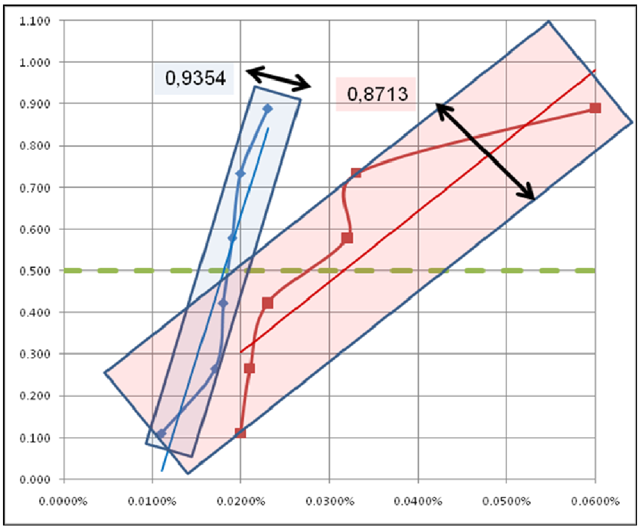

Fig. 6. Analysis of Beta-3.

4. CONCLUSIONS

Interlaboratory comparison programs use standards already established and accepted internationally. Normalized error (En) is a tool to evaluate laboratory´s performance during a period of a single circulation.

This work purposes the use of a tool called *linearization of normal distribution* to evaluate the performance of a laboratory over a slightly longer period of time, by comparing the measures of the laboratory under analysis to its Beta values ranges.

If any of these measures is outside stipulated ranges it is a sign that the laboratory needs to investigate its process.

It is observed, nowadays, laboratories with uncertainties close to the national reference. This brings, as a consequence, the breach of the rule 3:1 for TUR [7].

Finally, it is emphasized that this tool compares data of a laboratory to data of reference laboratory. It is because each laboratory, during its participation in the program of interlaboratory comparison, has its own values, which represents its process.

Nevertheless, it is suggested for future work the use of this tool to evaluate the performance of all laboratories belonging to a program of interlaboratorial comparison, by stipulating Beta ranges for the group.

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