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VERIFICATION OF THE CONVERGENCE BETWEEN ISO GUM 95 vs MONTE CARLO METHOD REGARDING THE EXPANDAD UNCERTAINTY AT THE PRESSURE LABORATORY IN BRAZIL

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Abstract: This paper describes the way by which the National Pressure Laboratory in Brazil has been calculating its calibration measurement capabilities (CMC) using the uncertainty estimations contained in the ISO GUM 95 and declared in the appendix C of the BIPM, and verifying if there is any convergence and consistency between the measurements results calculate with both methods.

Keywords: ISO GUM 95, Monte Carlo, Uncertainty

1. INTRODUCTION

The measurement result is applied as an important parameter in a lot of situations: amount of a product on its commerce, loss in manufacture process, measure of product properties finding compare it with specifications of a quality level, medical and judicial decisions, adaptations in projects looking for reduce loss and increase the quality in products and industrial process, establishment of limits and directions on scientific research, etc. [3].

Mainly of the cases the measurement result is compared to an other value, frequently from standards, regulations or benchmarks. The condition for the comparison among different results is the use of the same model for the uncertainties calculation [3].

Since the beginning of the 90's, metrologists around the world have initiated studies that aimed to harmonize the methodologies of calculation of the measurement uncertainty estimation result. Thus, the Measurement Uncertainty Guide was accepted internationally (ISO GUM 95) [1] and adopted for many National Metrology Institutes (NMI) to calculate its Calibration Measurement Capabilities (CMC).

However, ISO GUM 95 begins from some considerations, which in many of the cases become limited for the measurement uncertainty estimation. The search for a more comprehensive mathematical model was made possible by via simulation by Monte Carlo Method [2, 4, 5], which in some cases, shows to effective than the ISO GUM method.

Monte Carlo Method is presented in this paper as a tool to evaluate the level of confiability gotten in measurement uncertainty estimation of the services of calibration carried through for the pressure quantity in the INMETRO/BRAZIL.

One of the principles of the National Metrology Institutes (NMI) is to allow that the measurement results in the country have confiability and comparability nationally and internationally, making easier the relations among enterprises on commerce or the exchange of different metrology laboratories [6, 7].

Thus, the comparison among the methods encourages us to question if the mathematical formularizations are adjusted for the different services of calibration in the pressure area.

2. METHODS

2.1. Peculiarities of the Methods

The uncertainty evaluations by ISO GUM [1] follow a widely known development script that can resume on the following stages:

a) Definition of mensurand.

b) Definition of the Cause/Effect diagram of the mensurand.

c) Estimation of the standard uncertainties to the mensurand uncertainty sources.

d) Calculation of the sensitivity coefficient of each input standard uncertainty.

e) Calculation of the mensurand uncertainty components.

f) Combination of the mensurand uncertainty components (calculation of the combined standard uncertainty).

g) Calculation of the effective degrees of liberty to the combined standard uncertainty.

h) Determination of the coverage factor.

i) Determination of expanded uncertainty (U).

However, this methodology has some limitations, mainly due to:

a) Linearization of mathematical models, through the cut of the Taylor series at the first order term;

b) Assumption about normality of the mensurand (Z-score);

c) Discrepancies in the determination of effective degrees of liberty, because in general the analysis of the degrees of liberty is a problem that remains without solution (Type B uncertainties with degrees of liberty unknown, being considered infinite).

Monte Carlo Method in many cases presents more appropriate [4, 8], in function of its versatility of allowing to combine different kinds of distribution not restricting the propagation of the uncertainties statistically. This method consists of generating numbers randomly [9, 10], in order to simulate the values of the varieties. Evidently, this was only possible favor to the increase of the processing speed of the personal computers [2].

The evaluation of the measurement uncertainty by the Monte Carlo simulation method can be resumed in the following stages [8, 11]:

a) Establishment of the mathematical model for the mensurand through the input quantities x_i (mensurand definition).

b) Estimation and selection of the significant sources of uncertainty.

c) Identification of the probability density functions $p(x_i)$ for each selected uncertainty source.

d) Selection of the Monte Carlo interactions number (M).

e) Simulation of M samples for each input uncertainty (x_{i1}, x_{i2} ..., x_{iM}), considering x_i an aleatory variety with a probability density function $p(x_i)$.

f) Calculation of the M results (Z_1, Z_2, ... Z_M) through the mathematical model of the mensurand, using the M varieties x_i.

From the understanding of the simulation by Monte Carlo Method, it was applied for all the calibration services offered by the LAPRE, with sufficiently conclusive results.

2.2 Results Gotten by both Methods

The Pressure Laboratory of INMETRO – LAPRE – offer calibrations of pressure measuring instruments from high vacuum to high pressure (form $2{,}7 \times 10^{-6}$Pa to 250 MPa), using fundamental and relative reference standards, giving traceability to vacuum measuring instruments, barometers, pressure balances, manometers, pressure transducers, etc.

The results obtained in the uncertainty estimation to some calibrations carried through by LAPRE, according to ISO GUM 95 and the Monte Carlo Simulation is presented in table 1.

Table 1. Comparison of the measurement uncertainties calculating by ISO GUM 95 and Monte Carlo methods

SERVICE	ISOGUM 95	MONTE CARLO
Vacuum	*$1{,}1 \times 10^{-5}$ Pa*	*8×10^{-6} Pa*
Barometry	*86 Pa*	*51 Pa*
Pressure Balance	*Pmin 29 Pa* *Pmax 31 Pa*	*Pmin 27 Pa* *Pmax 29 Pa*
Transducer	*710 Pa*	*600 Pa*
Manometer	*$2{,}35 \times 10^{4}$ Pa*	*$1{,}37 \times 10^{4}$ Pa*

The variation among both methods was quantified through the percentile difference of each measurement uncertainty estimated by the ISO GUM 95 method in relation to the Monte Carlo Simulation Method and is presented in table 2.

Table 2. Variation among the ISO GUM 95 and Monte Carlo methods.

MEASUREMENT	VARIATION
Vacuum	*38%*
Analogical Barometer	*69%*
Pressure Balance	*7%*
Pressure Transducer	*18%*
Analogical Manometer	*72%*

3. CONCLUSION

It can be observed that the values of the measurement uncertainty estimation in the pressure instruments calibrations gotten by the Monte Carlo Simulation Method presents smaller them those established by ISO GUM 95 methodology.

It was also verified that the biggest percentile variations between the methods were found in the analogical equipments (barometer and manometer) encouraging us to believe that the mathematical modeling could be rethought, considering the metrological features of these equipment.

On the other hand, if we consider the values calculated by Monte Carlo Method, we conclude that Pressure Laboratory of the INMETRO - LAPRE presents conservative in the results declared in appendix C of the BIPM.

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