

## SIM TORQUE COMPARISON BETWEEN CENAM (MEXICO) AND INMETRO (BRAZIL) UP TO 100 N·m

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**Abstract.** A torque comparison was carried out between the Centro Nacional de Metrología, CENAM (in Mexico) and the Instituto Nacional de Metrologia, Normalização e Qualidade Industrial, INMETRO (in Brazil), in order to estimate the level of agreement for the realization of the quantity and the uncertainty associated to its measurement. The comparison was carried out in a range starting at 20 N·m and up to 100 N·m. The results obtained, deviations graphs (including the uncertainty for each torque applied of each laboratory) and the normalized error equation application results are presented in this document. This constitutes the first torque comparison within the Sistema Interamericano de Metrologia (Interamerican Metrology System, SIM) and has the classification number SIM.7.27 BK.

**Keywords:** Comparison, torque, torque transducers, SIM.

### 1. INTRODUCTION

As part of many technical activities performed between the Instituto Nacional de Metrologia, Normalização e Qualidade Industrial, (INMETRO, Brazil) and the Centro Nacional de Metrología (CENAM, Mexico) [1, 2 and 3], a torque comparison was carried out in order to estimate the level of agreement for the realization of the quantity, and the uncertainty associated to its measurement. The measurements were carried out from August to December of 2004.

This constitutes the first torque comparison within the Sistema Interamericano de Metrologia (Interamerican Metrology System, SIM) and it is included in the SIM data base as comparison number SIM.7.27 BK. The analysis of comparability between the laboratories was performed by using the normalized error equation technique [4, 5 and 6].

### 2. SCOPE OF WORK

To compare torque measurements carried out by the two national laboratories in the range from 20 N·m and up to 100 N·m.

#### 2.1 Transfer standards (TS)

One torque transducer was used as transfer standard (TS). The general characteristics of the torque transducer, as stated by the manufacturer, are given in the following Table 1.

Table 1. Transfer standard data.

|                    |                        |
|--------------------|------------------------|
| Transfer Standard: | Torque Transducer      |
| Manufacturer:      | Route Precision OY     |
| Range:             | 10 N·m to 100 N·m      |
| Model:             | TT1-100 N·m            |
| Serial number:     | 36740-03               |
| Accuracy Class:    | ≤ 0,05% of the Reading |

#### 2.2 General Guidelines and Procedure

The torque measurement points selected were the four steps 20%, 40%, 60% and 100% of the nominal torque value of 100 N·m (the zero measurement was also to be taken for corrections). In Figure 1, the torques applied and the series for each torque transducer position are presented.

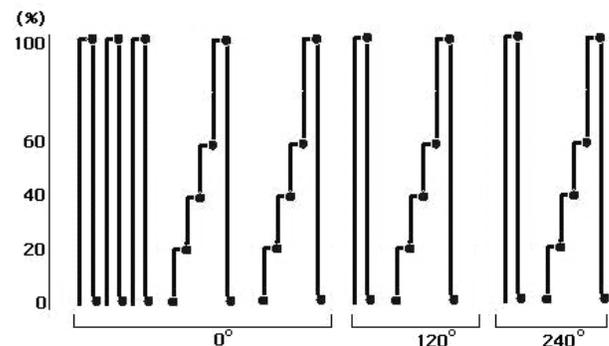


Figure 1. Torque application series for each torque transducer position.

The most important aspects of the measurement protocol, proposed and written by INMETRO, are:

- The pre-loads and measurement cycles were carried out in accordance to the sequence shown in Figure 1.
- The torque was applied on the measurements side of the torque transducer.
- The torque application directions were clockwise (CW) and counter clockwise (CCW).
- Three different torque transducer positions were used, 0°, 120° and 240°.
- The same period of time was chosen for the pre-loads and measurements, 90 s.
- All measurements were carried out at 21 °C ± 1 °C.
- Each laboratory used their own amplifier DMP 40 for their measurements. The bridge voltage was 5 V.
- All measurements were carried out in mV/V and in absolute mode.

The uncertainties calculated by each laboratory were based mainly on four contributing elements: the standard used by the laboratory, repeatability, reproducibility and resolution of the transfer standard (instrument).

### 3. PARTICIPATING LABORATORIES' STANDARDS

INMETRO used a Dead Weights Machine (DWM), CENAM used a Torque Transfer Standard Machine (TTSM). In Table 2, the laboratories standards general information is listed. The uncertainties declared are those included in the BIPM data base.

Table 2. Participating laboratories' standards general information.

| Laboratory      | Machine Type | Range          | Declared Uncertainty   |
|-----------------|--------------|----------------|------------------------|
| INMETRO, Brazil | DWM          | 2 N·m – 3 kN·m | 100 x 10 <sup>-6</sup> |
| CENAM, Mexico   | TTSM         | 1 N·m – 2 kN·m | 500 x 10 <sup>-6</sup> |

### 4. RESULTS

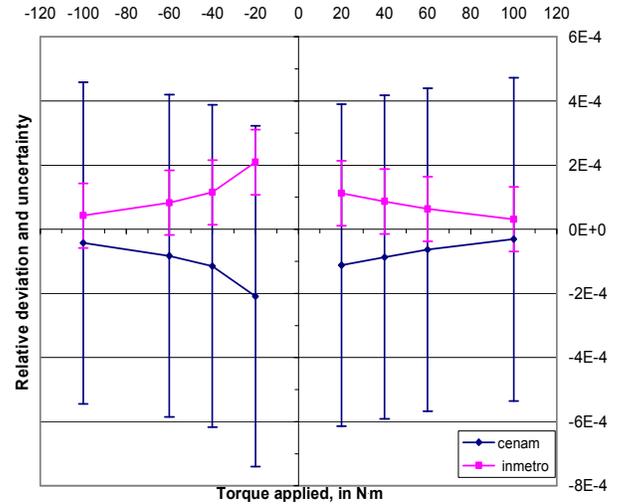
The results of the measurements made (average reading and expanded uncertainty) to the transfer standard, in both torque application directions, by the participating laboratories are presented in Table 3.

Table 3. Torque transducer calibration results.

| Nominal Torque | CENAM      |                   | INMETRO          |                   |                  |
|----------------|------------|-------------------|------------------|-------------------|------------------|
|                | Reading    | U<br><i>k</i> = 2 | Reading          | U<br><i>k</i> = 2 |                  |
| CW             | N·m        | mV/V              | 10 <sup>-4</sup> | mV/V              | 10 <sup>-4</sup> |
|                | 100        | 1,330 857         | 5,04             | 1,330 940         | 1,01             |
|                | 60         | 0,798 409         | 5,03             | 0,798 510         | 1,00             |
|                | 40         | 0,532 228         | 5,04             | 0,532 321         | 1,01             |
| CCW            | 20         | 0,266 092         | 5,02             | 0,266 151         | 1,02             |
|                | -20        | -0,266 099        | 5,31             | -0,266 154        | 1,02             |
|                | -40        | -0,532 260        | 5,03             | -0,532 321        | 1,01             |
|                | -60        | -0,798 438        | 5,02             | -0,798 504        | 1,01             |
| -100           | -1,330 866 | 5,01              | -1,330 923       | 1,01              |                  |

The readings included in Table 3 are the average lectures obtained for each applied torque and corrected by the zero reading for each corresponding torque application series, for each laboratory.

The relative deviations between the measurements made by INMETRO and those from CENAM are shown in Graph 1. In this graph, the uncertainties declared for each measuring torque by each laboratory are included. The results for clockwise (CW) and counter clockwise (CCW) torque application directions are included in the same graph.



Graph 1. Relative deviations for the torque transducer measurements from INMETRO and CENAM.

The reference values for Graph 1 are the calibration results average from those of INMETRO and CENAM included in Table 3.

### 5. DISCUSSION

The degree of equivalence among the results of the measurements made by the participating laboratories was evaluated using the normalized error equation according to the expression of Equation 1.

$$e_n = \left| \frac{E_{CENAM} - E_{INMETRO}}{\sqrt{(U_{CENAM})^2 + (U_{INMETRO})^2}} \right| \quad (1)$$

Where,

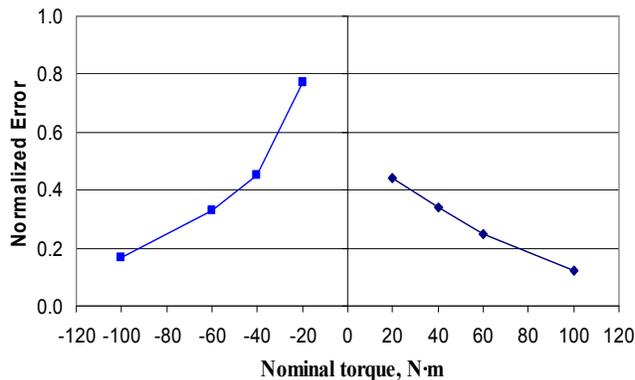
- $e_n$  - normalized error calculated at each torque,
- $E_{CENAM}$  - estimated errors found by CENAM,
- $E_{INMETRO}$  - estimated errors found by INMETRO,
- $U_{CENAM}$  - estimated expanded uncertainty declared by CENAM,
- $U_{INMETRO}$  - estimated expanded uncertainty declared by INMETRO.

The normalized error equation application values for each torque and for both load directions are included in Table 4.

**Table 4. Normalized error equation degree of equivalence between INMETRO and CENAM.**

| Nominal Torque<br>N·m |      | Normalized Error<br>$e_n$ |
|-----------------------|------|---------------------------|
| CW                    | 100  | 0,12                      |
|                       | 60   | 0,25                      |
|                       | 40   | 0,34                      |
|                       | 20   | 0,44                      |
| CCW                   | -20  | 0,77                      |
|                       | -40  | 0,45                      |
|                       | -60  | 0,33                      |
|                       | -100 | 0,17                      |

A graphical representation of the normalized error equation application is shown in Graph 2. Nominal torque positive values are those for clockwise direction and negative nominal torque values are those obtained for the counter clockwise direction.



**Graph 2. Relative deviations for the torque transducer measurements from INMETRO and CENAM.**

From Table 4 and Graph 2, it is important to notice that between INMETRO and CENAM, the values were in agreement throughout the entire comparison measuring torque range. The agreement seems to be better at higher torques, as can be seen in Graph 2. Nevertheless, the normalized error equation values were below 1, for all applied torques.

There is a difference between the results for the two directions of torque application, having the anti clockwise direction higher values of normalized error. Although, both load application directions have values below 0,8; for the clockwise direction the normalized error values were below 0,5.

## 6. CONCLUSIONS

From the results of the analysis of comparability, by means of the normalized error equation technique, it can be concluded that good agreement exists between the torque measurements carried out at INMETRO and those performed at CENAM for the entire chosen range of this comparison (i. e. from 20 N·m up to 100 N·m), on both torque application directions, clockwise and anti clockwise.

## REFERENCES

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