# SIM.M.T-S2

**CENAM - MEXICO / INM - COLOMBIA**

Supplementary Bilateral Comparison Calibration of a Reference Torque Wrench

Torque

0 N·m, 50 N·m, 100 N·m, 300 N·m, 500 N·m

Final Report


Pilot - CENAM, Mexico

José Jesús Galván Mancilla

Jorge C. Torres Guzman

Omar Segovia Arriola

Participant - INM, Colombia

Juan Alberto Arias

Iván David Betancur Pulido


May 2019

**Abstract**

A Regional Metrology Organization (RMO) Key Comparison on the calibration of a reference torque wrench was carried out between the Centro Nacional de Metrologia (CENAM, Mexico) and the Instituto Nacional de Metrologia (INM, Colombia), between September 2017 and October 2017. The results of this comparison are reported here, along with descriptions of torque standards used by CENAM and INM, and the uncertainty budget for these standards. This report also describes the protocol for the comparison and presents the data acquired. The results are analyze, determining the degree of equivalence between the torque measurements from CENAM and INM.

*Keywords: Comparison, Reference torque wrench, Degree of Equivalence.*

# Contents

1. Introduction ........ 3
2. Objetive ........ 3
3. Scope of the comparison ........ 3
4. List of Participants, Facilities Used, Circulation Scheme ........ 4
   1. Participants' details ........ 4
   2. Comparison Protocol ........ 4
      a. Environmental conditions of the measurement ........ 5
      b. Measurement sequence: ........ 5
   3. Transfer Standard ........ 7
5. Measurement results ........ 8
6. Conclusions ........ 10
7. References ........ 11

## 1. Introduction

Comparisons between national laboratories are being widely used by the National Institutes of Metrology as one of the main processes for the confirmation of technical competence. At the same time, comparisons allow to know the degree of equivalence between laboratories, constituting a requirement, both for the Mutual Recognition Arrangement (MRA) of the International Committee of Weights and Measures (CIPM), and for the publication of the Calibration and Measurement Capabilities (CMCs) of the laboratories. This comparison was coordinated and piloted by the torque laboratory of CENAM, Mexican NMI.

## 2. Objective

To establish the agreement of the results for the calibration of a high accuracy reference torque wrench, between the participating laboratories, through a comparison. The reference values were those established by the pilot laboratory (CENAM). The measurand of the reference torque wrench calibration for this comparison is the torque value (error and associated uncertainty for each torque measurement value) of the transfer standard (TS).

## 3. Scope of the Comparison

In this bilateral comparison only the results obtained are considered, no other technical characteristics were evaluated. The reference torque wrench was calibrated at the selected measuring points: 50 N·m, 100 N·m, 300 N·m and 500 N·m, according to the technical protocol SIM.M.T-S2 (based on with DIN 51309).

The present comparison was intentionally declared as a supplementary one since it was carried out with a reference torque wrench as a transfer standard (TS). The main motivation for using the reference torque wrench was its availability, simplicity of measurements and the fact that INM torque lab do not calibrate high accuracy transducers. It was expected that the uncertainties achievable with this reference torque wrench would be significantly higher than those of high accuracy transducers used as TS in CCM KCs. Indeed, the uncertainties of the present SC are (500 – 700) ppm, whereas those of CCM.T-K1 are (10 – 30) ppm only.

As a supplementary comparison, it does not formally need to be linked. The rather high uncertainties allow only very conservative statements of CMC uncertainties to be made, which can be accepted without any link, if necessary.

## 4. List of Participants, Facilities Used, Circulation Scheme

1. Participants' details

The participating laboratories were CENAM (Mexico, pilot) and INM (Colombia). The specifications of their facilities used and contact details are listed in Tables 1, 2 and 3, respectively. The 1 kN·m reference torque machine (TW-SYS, at INM) CMC was evaluated as 0.1% using torque transducers of 1 kN·m in the torque range from 100 N·m to 1 kN·m, which had been calibrated at CENAM.

2. Comparison Protocol

*Table 1. Torque Standard Machine*

| Participant | Type of reference standard | Capacity | Reference standard uncertainty (*k* = 2%) | Independent traceability? |
|---|---|---|---|---|
| CENAM | Reference torque machine CNM-PNM-23 | 2 kN·m | 0.05% | TT1 traceable to PTB |
| INM | Reference torque machine TW-SYS 1000 N·m | 1 kN·m | 0.1% | TTS traceable to - PTB |

*Table 2. Torque Transducer used*

| | CENAM | INM |
|---|---|---|
| Manufacturer | Raute | HBM |
| Type / Model: | TT1 / 500 N·m | TTS / 500 N·m |
| Serial N° | 36753-02 | 091630001 |
| Measurement range | 500 N·m | 500 N·m |
| Uncertainty | 0.021%L | 0.077% |
| Calibration date | 2011-03-21 | 2016-09-14 |
| Certificate number | 12031_11-03 | PTB12555_16-09 |
| Traceability | PTB-1.22_10-016 | PTB-1.22_16-032 |

*Table 3. Contact Details*

| CENAM | INM |
|---|---|
| J Jesús Galván Mancilla<br>e-mail; jgalvan@cenam.mx<br>Tel: +52 442 211 05 00 Ext. 3746<br>Centro Nacional de Metrología (CENAM)<br>km 4.5 carretera a los Cués<br>El Marqués, Qro., C. P. 76241, Mexico | Juan Alberto Arias Prieto<br>Instituto Nacional de Metrologia de Colombia<br>Subdirección de Metrología Física<br>Tel: +571 2542222 Ext.1613<br>e-mail: jarias@inm.gov.co<br>Av. Cra. 50 No. 26-55 Int. 2 CAN, Bogotá, Colombia |

a. Environmental conditions of the measurement

The measurements were made under stable environmental conditions at a temperature of (22 ± 1) °C and a relative humidity of (45 ± 15)%. The data was recorded. See table 4

*Table 4. Environmental conditions*

| Environmental conditions | | | |
|---|---|---|---|
| | **Temperature (°C)** | **Relative Humidity (%)** | **Pressure (hPa)** |
| **CENAM** | 21.3 | 47.0 | 80.8 |
| | ±0.3 | ±13.0 | ±0.4 |
| **INM** | 21.2 | 46.0 | 75.01 |
| | ±0.2 | ±1.0 | ±0.3 |
| **CENAM** | 21.9 | 42.5 | 81.2 |
| | ±0.5 | ±12.0 | ±0.2 |

b. Measurement sequence:

the same time interval was used for preloads and measurement series, this is, the readings were taken 3 minutes after the reaching the load point to be measured, to achieve a stabilization of the reading and to decrease effects of short-term drift.

The sequence of the measurement points is presented in Table 5. In total, in addition to the zero measurement, 4 points were measured in ascending order and in 4 mounting positions

(0°, 90°, 180° and 270°). The calibration points were 50 N·m, 100 N·m, 300 N·m, and 500 N·m.

In the initial assembly position (0°), 3 preloads and 3 measurement series were performed for repeatability evaluation.

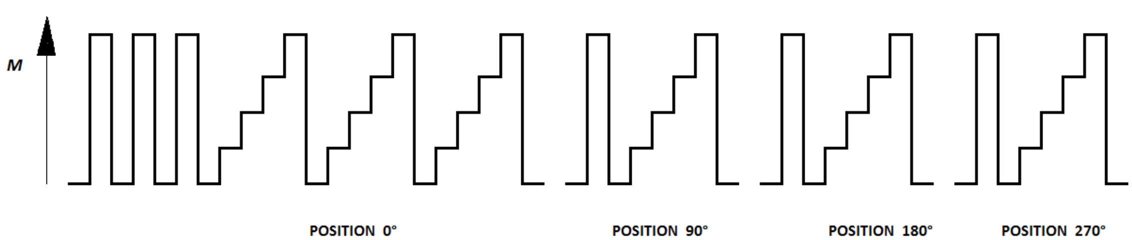
For reproducibility evaluation, the readings were taken in 4 mounting positions (0°, 90°, 180° and 270°) taking as reference the line marked on the TT control panel, a preload was apply each change of position.

The following is a summary of the calibration sequence (Table 5 and Figure 1).

*Table 5. Measurement sequence of the comparison*

| Position | Loads | Measuring points |
|---|---|---|
| 0° | 3 preloads<br>3 measurement series | 0 N·m, 50 N·m, 100 N·m, 300 N·m, 500 N·m |
| 90° | 1 preload<br>1 measurement series | 0 N·m, 50 N·m, 100 N·m, 300 N·m, 500 N·m |
| 180° | 1 preload<br>1 measurement series | 0 N·m, 50 N·m, 100 N·m, 300 N·m, 500 N·m |
| 270° | 1 preload<br>1 measurement series | 0 N·m, 50 N·m, 100 N·m, 300 N·m, 500 N·m |

*Figure 1. Measured torque measurement sequence diagram.*



3. Transfer Standard

For the comparison, the following reference torque wrench was used:

| | |
|---|---|
| Manufacturer | CEH |
| Type / Model | TTW |
| Serial N°: | S/N |
| Measurement range | 500 N·m |
| Cable | Connector DB-15. 3 m length |
| Packaging | Special transportation suitcase |

The standard indication has been recorded by means of a measuring amplifier DMP40 (manufactured by HBM). The same type of amplifier was used by the laboratories; each laboratory used its own amplifier.

| | |
|---|---|
| Manufacturer | Hottinger Baldwin Messtechnik GmbH, Germany |
| Type / Model | DMP40 |
| Serial N° | 962720029 (CENAM) / 121020084 (INM) |
| Filter | 0.22 Hz Bessel |
| Signal reading | Absolute |
| Measuring range | 2.5 mV/V |
| Excitation voltage | 5 V |

Only the square drive adapter mounted at the reference toque wrench was rotated, couplings and mounting accessories were not changed from their position. The size of the square drive adaptor was 20 mm (3/4 “) for the standard torque wrench. The standard was mounted in horizontal position so that the torque was always applied on the fixed arm length of 1 000 mm. The change of mounting positions (0°, 90°, 180° and 270°) has been realize by rotating the male square drive adapter of the reference torque wrench. The standard have been kept in the laboratory for environmental conditioning for at least 24 hours before measuring (22 °C ± 1 °C; 45 %rH ± 15 %rH)

Circulation scheme

The round of measurements was make according to the program established in Table 6

*Table 6. Comparison schedule*

| Torque comparison measurements program. SIM.M.T-S2 | | | | |
|---|---|---|---|---|
| **No** | **LABORATORY** | **PLACE** | **START** | **FINNISH** |
| | | | September 2017 | |
| 1 | CENAM | Querétaro, Mexico. | 26 | 28 |
| | | | October 2017 | |
| 2 | INM | Bogotá, Colombia. | 4 | 6 |
| 3 | CENAM | Querétaro, Mexico. | 11 | 13 |

## 5. Measurement Results

For the comparison results evaluation the normalized error equation value ($E_n$) was used, and was determined according to the following equation:

$$E_n = \frac{\bar{X}_{INM} - \bar{X}_{CENAM}}{\sqrt{{W_{INM}}^2 + {W_{CENAM}}^2}} \qquad \text{Equation 1}$$

Where:

$\bar{X}_{INM}$ is the value obtained by INM

$\bar{X}_{CENAM}$ is the reference value obtained by CENAM

$W_{INM}$ is the expanded uncertainty estimated by INM and

$W_{CENAM}$ is the expanded uncertainty obtained by CENAM.

According to the normalized error equation model, if -1 ≤ $E_n$ ≤ +1 the results of the laboratories are compatible, and if -1> $E_n$ > +1 the results are not compatible. (ISO / IEC-17043: 2010).

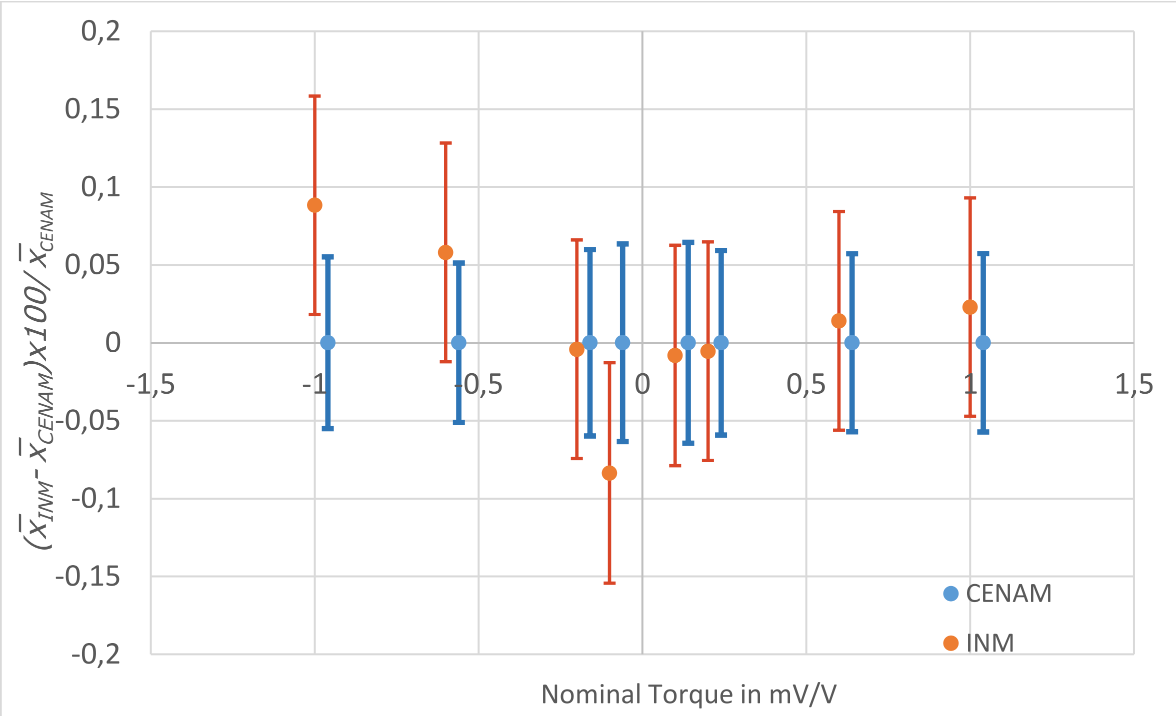
Table 7 shows the results of the measurements made by the participating laboratories. The values obtained from the application of the normalized error equation method are also included in the last column.

*Table 7. Results obtained by the participating laboratories*

| Nominal Torque N·m | INM Colombia | | | CENAM, Mexico | | | Normalized error *En* |
|---|---|---|---|---|---|---|---|
| | $\bar{X}$ [mV/V] | *W, k = 2* [mV/V] | *W, k = 2* [%L] | $\bar{X}$ [mV/V] | *W, k = 2* [mV/V] | *W, k = 2* [%L] | |
| 0.00 | ----- | | ----- | ----- | | ----- | ----- |
| 50.00 | 0.100 026 | 0.000 071 | 0.071 | 0.100 034 | 0.000 065 | 0.064 | -0.09 |
| 100.00 | 0.200 057 | 0.000 140 | 0.070 | 0.200 067 | 0.000 119 | 0.059 | -0.06 |
| 300.00 | 0.600 355 | 0.000 421 | 0.070 | 0.600 270 | 0.000 343 | 0.057 | 0.16 |
| 500.00 | 1.000 729 | 0.000 701 | 0.070 | 1.000 499 | 0.000 573 | 0.057 | 0.25 |
| 0.00 | ----- | | ----- | ----- | | ----- | ----- |
| -50.00 | -0.099 880 | 0.000 071 | 0.071 | -0.099 964 | 0.000 063 | 0.063 | -0.88 |
| -100.00 | -0.200 001 | 0.000 140 | 0.070 | -0.200 009 | 0.000 120 | 0.060 | -0.05 |
| -300.00 | -0.600 519 | 0.000 422 | 0.070 | -0.600 171 | 0.000 307 | 0.051 | 0.67 |
| -500.00 | -1.001 127 | 0.000 702 | 0.070 | -1.000 243 | 0.000 552 | 0.055 | 0.99 |

In Figure 2, the comparison between the measurements made by both institutes is graphed. In the conclusions, situations that can be the cause of the differences in the measurement or in the calculations of the results are mention in a general way. This analysis only aims to find opportunities for improvement.

*Figure 2. Comparison between the results obtained by the laboratories. The average error and uncertainty is included.*




## 6. Conclusions

Based on the results obtained, it is convenient to comment separately the clockwise and the anticlockwise directions:

A. In the clockwise direction, the error estimated for the reference torque wrench is fully compatible, as can be seen in Figure 2 and quantitatively in Table 7 by the estimated normalized error.

B. In the case of the anticlockwise direction, it can be seen that the results obtained by the INM show slight deviations from CENAM, mainly at the extremes of the measurement interval (at 50 N·m and 500 N·m), which is manifested in the normalized error with values of -0.88 and 0.99 respectively. It should be mentioned that the INM detected a deviation in its results in anticlockwise direction, due to a shift in the "zero" programmed in the indicator. The results used in this study (Table 7) correspond to the corrected values after the detection of the shift.

Table 8 presents the results of the comparison by torque direction application.

*Table 8. Final result of the comparison*

| Torque direction | Comparison Results | Observation |
|---|---|---|
| Clockwise | **COMPATIBLE** | ---- |
| Anticlockwise | **COMPATIBLE** | ---- |

## 7. References

[1] *Measurement comparisons in the CIPM MRA*, CIPM MRA-D-05, http://www.bipm.org/utils/common/CIPM_MRA/CIPM_MRA-D-05.pdf.

[2] *Guidelines for CIPM Key Comparisons*, CIPM KC guidelines, http://www1.bipm.org/utils/en/pdf/guidelines.pdf.

[3] *CIPM MRA Guidelines for Authorship of Key Supplementary and Pilot Study Comparison Reports,* CIPM MRA-G-04, http://www.bipm.org/utils/common/CIPM_MRA/CIPM_MRA-G-

[4] *CCM Guidelines for approval and publication of the final reports of key and supplementary comparisons*, https://www.bipm.org/utils/en/pdf/CCM_Guidelines_on_Final_Reports.pdf, CCM-Working Group on Strategy and MRA coordination.

[5] Guide to the expression of uncertainty in measurement, https://www.bipm.org/en/publications/guides/gum.html