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# AUTOMATIC CONTROL SYSTEM FOR TORQUE NATIONAL STANDARD

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## ABSTRACT

The continuous development of the technology and the increase of its complexity demand wider measurement intervals, a greater exactness and a greater diversity of the standards used in order to establish the units or measuring systems. Torque metrology is of great importance and a magnitude is of common use for industry, technical development and research. The realization, quantification and dissemination of this magnitude are tasks assigned to the Metrology National Center (CENAM) Torque Laboratory, in Mexico.

For the dissemination of this magnitude the Torque National Standard relies on a system, which, in its original design, was operated manually originating high consumption of man-hours in the development of a calibration. This work presents the standard automation and the benefits of the automatic control system.

## RESUMEN

El desarrollo continuo de la tecnología y el aumento de su complejidad, demandan intervalos de medición más amplios, una mayor exactitud y una mayor diversidad de los patrones que se emplean para establecer las unidades o sistemas de medida. La metrología de Par Torsional es de gran importancia y es una magnitud de uso común en los sectores industriales, técnico y científico de nuestro país. La realización, cuantificación y diseminación de esta magnitud con los más altos niveles de confiabilidad en México, son tareas asignadas al Laboratorio de Par Torsional del Centro Nacional de Metrología (CENAM) de México.

Para la realización de esta magnitud se cuenta con el Patrón Nacional de Par Torsional el cual es un sistema, que en su diseño original era operado manualmente lo que originaba un elevado uso de horas-hombre en el desarrollo de una calibración. El presente trabajo muestra la automatización del patrón y los beneficios que se obtienen al contar con un sistema basado en el control automático.

**KEYWORDS:** Torque, Metrology and Control.

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## 1. INTRODUCTION

Torque is a derived magnitude of the applied force to a body at a perpendicular distance from an axis such that a rotation is generated. The realization of this magnitude is done by means of a machine design and constructed in cooperation with Phisikalisch Technische Bundesanstalt (PTB) from Germany. This was the first machine of its type in the world and is based on a transfer system formed by a set of high accuracy transducers, an engine – speed reducer, an alignment system, an air bearing as a support element, a counter reaction plate and an automatic control system [1].

The torque application is performed through a control system operated by an automatic program. In its original form, the system operated manually and the torque load required was achieved using motor start and stop control buttons, motor speed, applied torque load, motor spinning direction. Data acquisition was also made manually. This manual process required many man-hours for a calibration.

## 2. NATIONAL STANDARD TORQUE OPERATION

The operation is based on the direct coupling of the calibration instrument to the standard transducer. For this purpose, flexible and rigid couplings were used and the whole system is supported by an air bearing. The manual operation is performed using start-stop buttons of the motor, a 3 positions interrupter for spinning direction selection and 2 potentiometers, one to change the motor speed and the other to set engine load. All the process requires manual data acquisition.

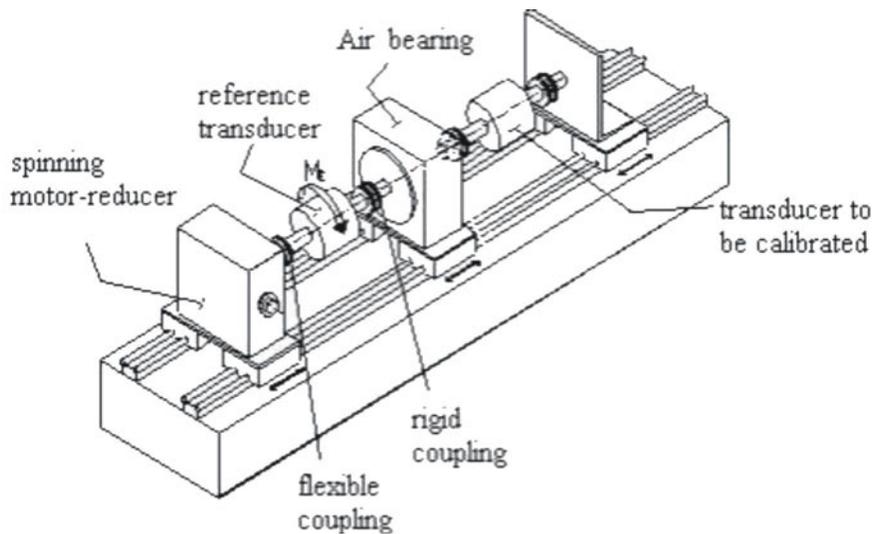


Figure 1. Torque national standard (Design)

### 2.1 Calibration procedure

Firstly, the standard transducer and the calibration instrument are coupled and mounted in the system using all required accessories, see figure [1]. Using the manual control system, the measuring points are set, see figure [2].

Eight points are selected on the calibration instrument's range (from 10% to 100%), all measurements are written down in a logbook. Preloads, at 100% load, are applied. This procedure is applied, increasing and then decreasing the load for three different mounting positions of the calibrating instrument and in clockwise and counterclockwise directions. A total of 112 measurements are made for one calibration. Since the process is manual the calibration is long and requires a large number of man-hours.

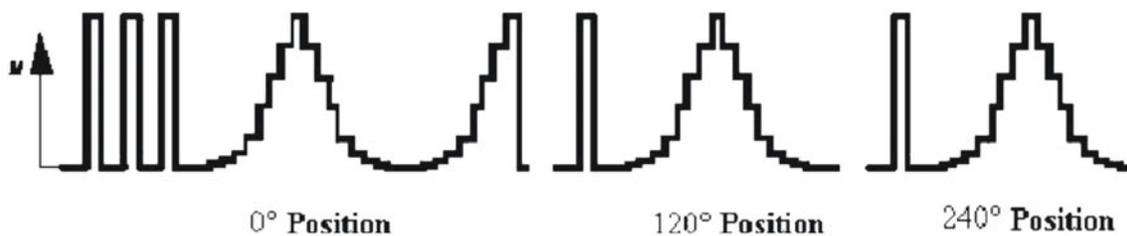


Figure 2. Torque calibration sequence

### 3. NATIONAL STANDARD TORQUE AUTOMATIZATION

#### 3.1 Control logics

The control logics frame was designed as follows:

1. Start the motor from 0 up to 100% of the calibrating instrument's range. Stop the motor. After 15 sec., start the motor in the opposite direction down to 0. Wait 15 sec., and repeat the cycle to perform 3 preloads.
2. Start the motor and stop at 10% of the instrument's range. Wait 15 sec. and take the measurement. Continue in this way up to 100%.
3. The previous activities are repeated in descendent mode from 100% to 0%.
4. The metrologist rotates the calibration instrument to 120° and performs the previously described work and does the same for 240°.
5. The same procedure is executed for clockwise and for counterclockwise directions, according to the sequence shown in figure 2.

#### 3.2. Equipment and material used

Software

Windows 95	Lab VIEW version 5.0	NI-DAQ version 6.1
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Hardware

PC Pentium	PC-DIO 24 PNP card	Interface card PC -control system	Power card
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##### 3.2.1 Programming software

The programming software used was Lab VIEW, as it is a versatile one easy to use. It works in Windows; uses blocks diagram notation and graphic language "G".

##### 3.2.2 Control stage

To develop the PC's interface with system, a digital input/output interface card PC-DIO24 PNP from National Instruments was used. The card works in a virtual instrumentation programming environment (Lab VIEW) and a power stage.

The card handles digital input and output; it has 3 ports (A, B y C) and 24 digital lines or 24 digital input and output channels. The ports can be configured as input or output, and is TTL logics compatible.

For the card operation we used NI-DAQ DRIVER Software of National Instruments, interface handler. NI-DAQ is a function library called by the program during its interface operation. Some included functions are:

Data acquisition	Digital, input/output	Counts/Operation time
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### 3.2.3 PC – control system interface card

To perform the connection between the output of the PC-DIO 24 card (installed in PC’s CPU) and the power stage an interface card was produced. In the 8 pin connector, 1 and 2 pins carry the electrical power difference (5 V dc) and the ground (electrical supply for the computer), 3 to 8 pins are for digital outputs (Figure 3).

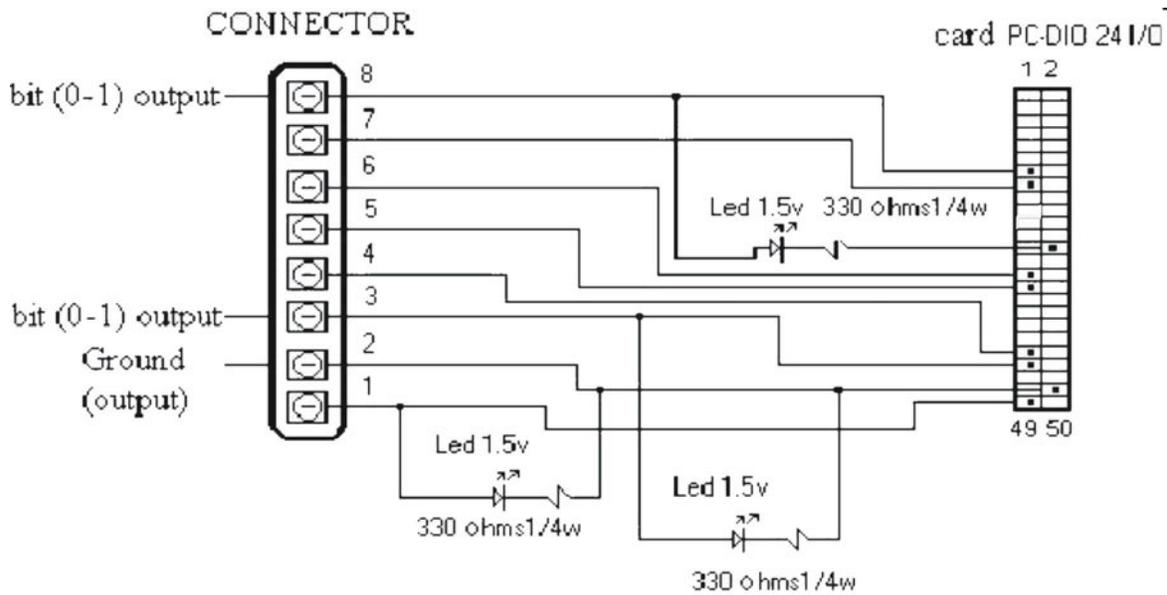


Figure 3. PC – control system interface card

### 3.2.4 Power stage

In the power stage 2 electrical contactors 127 V/60 Hz are integrated to the existing control system and are controlled by the power card (Figure 4).

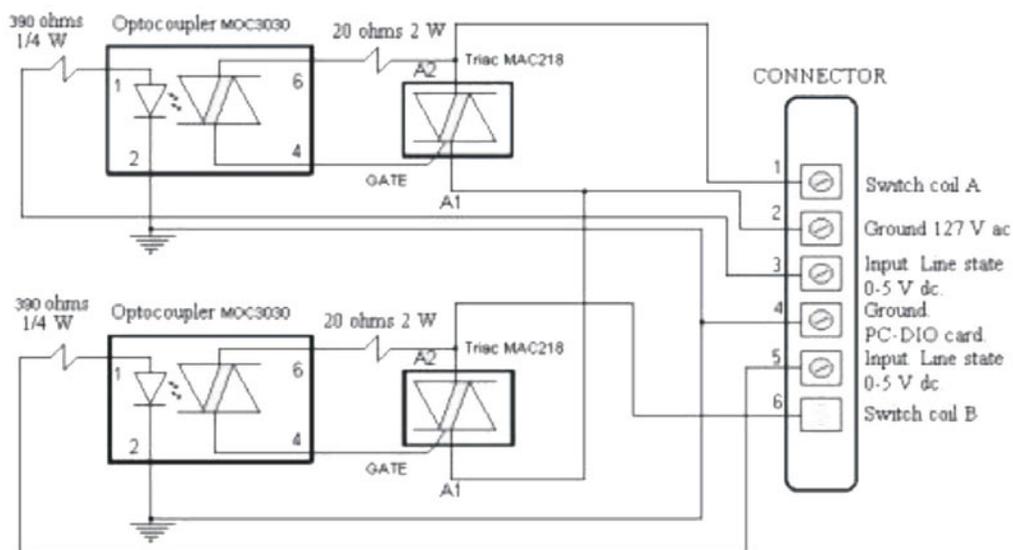


Figure 4. Power card

### 3.3 Control Program

The program follows the calibration procedure [2.1] and the control logics [3.1]. The calibration starts with the preloads (3 preloads at maximum load). The automatic program performs the 3 first series at 0° position. The measuring range is divided into 8 points proportional to the operation time and measurements are taken in each point (Fig. 6). The first reading is taken at 10% of the maximum range and the 8 points are evenly distributed up to 100% of the defined operation time [3].

The program stops after the 3 first series to allow the rotation of the instrument under calibration to 120° and then continuous according to the calibration procedure [2.1]. The same series is repeated for 240° (Figure 2).

The calibration process requires an open program, capable of performing the calibration in automatic mode but able to adjust itself to fit all different measurement ranges, from 1 Nm up to 2 kNm. The program also has a subroutine with elapsed times to be able to take reading in the measuring points (in mV/V or Nm).

#### 3.3.1 Programming mode

The programming was designed to execute the required subroutines for calibration. In the programming, sequences “false” “true” Boolean cases, “for” “while” cycles, counters, indicators and controllers were used. For data output to the port, a subprogram was included so that the line state of the port was written. The program repeats the same procedure; the subroutines put the bit in high or low state, in two directing different lines.

#### 3.3.2 Control program structure

The control program is structured in such a way that the operation logic is linked to the front panel (Figure 5) as well as the operation mode selection: either automatic or semiautomatic [4]

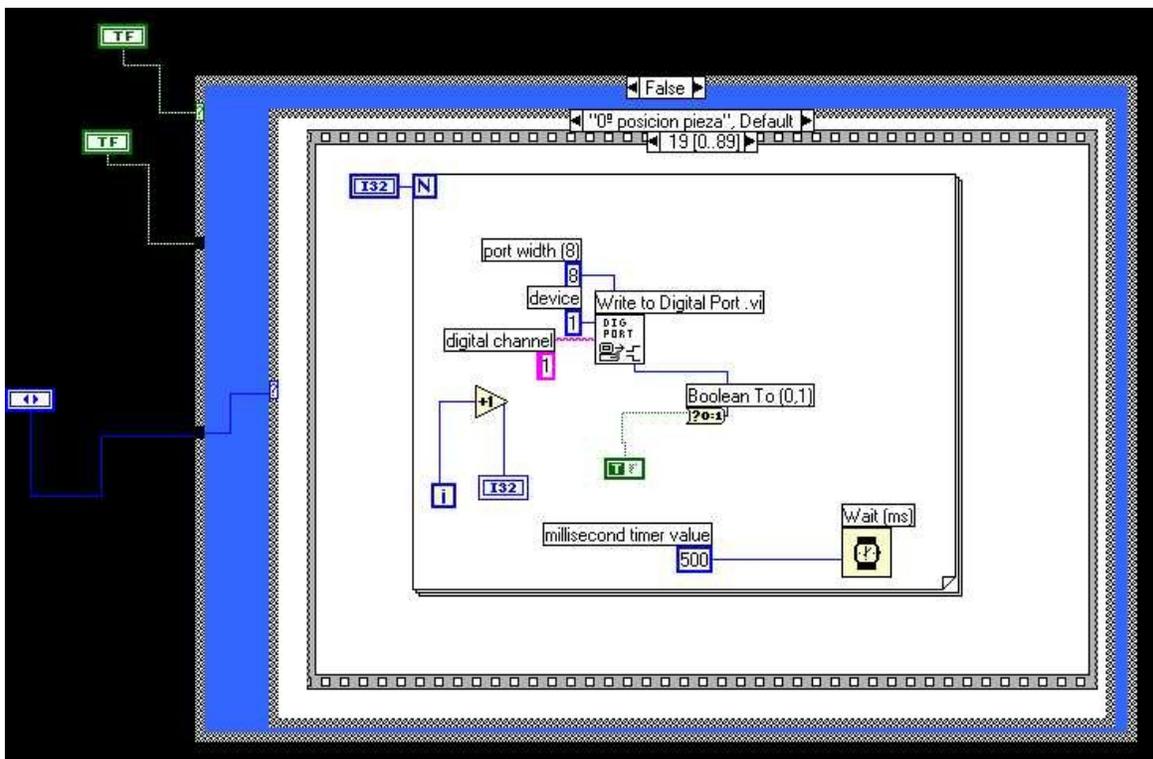


Figure 5. Control program blocks diagram for one subroutine

When automatic or semiautomatic modes are selected, the program calls a "case". If automatic mode is selected, it sends a *False* and calls a subprogram with three options. Option 1 runs the operation program for 0°, option 2 for 120° and option 3 for 240°. For each option, a program sends one bit to the port in high or low state, with variable time subroutines. If semiautomatic mode is selected, it sends a *True* and executes a subprogram which asks the spin direction, enter as Boolean *True* or *False*; if it is *False* operates the clockwise direction, if it is *True* operates the counterclockwise direction. To operate this options a Boolean button is included, the button starts and stops the motor directly. The automation was integrated to the existing control system, which operated manually the torque standard (Figure 7).

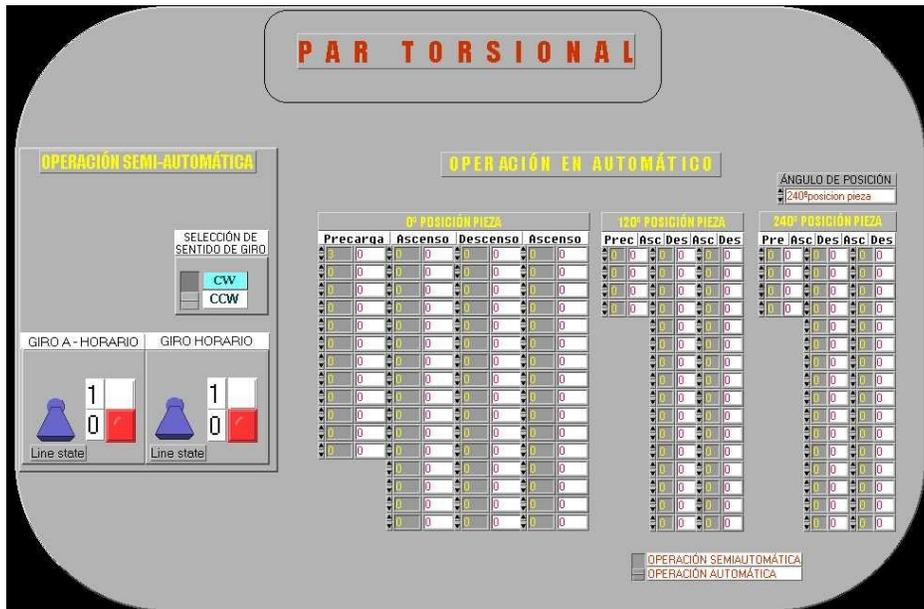
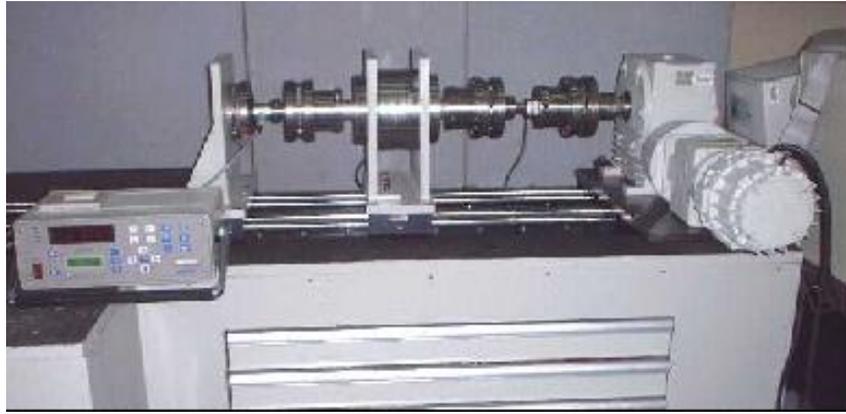


Figure 6. Front control panel



Figure 7. Control system for Torque National Standard



*Figure 8. Torque National Standard*

#### 4. CONCLUSIONS

The automatic control system brought a number of benefits to the operation and use of the torque standard. Some of the benefits are:

- Considerable calibration time reduction of instruments,
- Minimum metrologist intervention during a calibration,
- Better control over the process influence variables,
- Better control on the data acquisition, ensuring better measurement quality.

It is recommended to improve the operation sequence to start and stop the engine at the desired measurement points. At the moment the program works in time assignments. The sequence should be set according to the electrical power difference (mV/V) to the quantity measurement units (Nm). Another improvement could be to change into automatic data acquisition.

#### 5. BIBLIOGRAPHY

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#### Authors Biography

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Jesús Galván got a Bachelor Degree in Instrumentation and Processes Control Engineering from the Universidad Autónoma de Querétaro (UAQ), Querétaro, México. He worked six years in charge of the Torque Laboratory, Force and Pressure Metrology Division at Centro Nacional de Metrología (CENAM, México). He is a Technical Expert in laboratory accreditation processes, as well as advisor in the building industry. Jesús has imparted 5 metrology courses, has dictated 5 conferences and written 3 papers and organized one national comparison. J. Jesus Galvan is member of SOMI.



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He obtained a Mechanical Engineering Doctorate (Ph.D.) and Master in Science, in Advanced Applied Mechanics at the Imperial College of Science, Technology and Medicine (ICST&M), London, England. As well as Mechanical and Electrical Engineering title at Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM), Monterrey, Mexico. Since December 1993, he has been working at Centro Nacional de Metrología (CENAM, Mexico) as Force and Pressure Metrology Division Head. From June to November 1996 was responsible for the Mechanical Metrology Area. He worked ten years as Researcher and Project Leader in the Mechanical Engineering Department, Instituto de Investigaciones Eléctricas (IIE), Cuernavaca, Mexico. Three years as Plant Services Engineer in the Engineering Division at HyL (Grupo ALFA), Monterrey, Mexico, and has other work experience at Procter & Gamble de México, Mexico City and at MARHINO, auto parts, Monterrey, Mexico. As well he worked one year as Lecturer on Strength of Materials at ITESM, Queretaro, Mexico; three and a half years as Laboratory Instructor on Electricity and Magnetism, on Manufacturing Processes and on Physical Metallurgy at ITESM, Monterrey, Mexico. He has dictated more than 60 conferences, given more than 65 short courses and written more than 45 papers. Has organized 15 international comparisons and 20 national, and he holds two patents and has written 4 workbooks. Has been honored with several national and international awards.