6 Torque Tools as Measurement Equipment

6-4 Accuracy and Uncertainty

6-5 Tool control

6-1 Torque Tools are Measurement Equipment

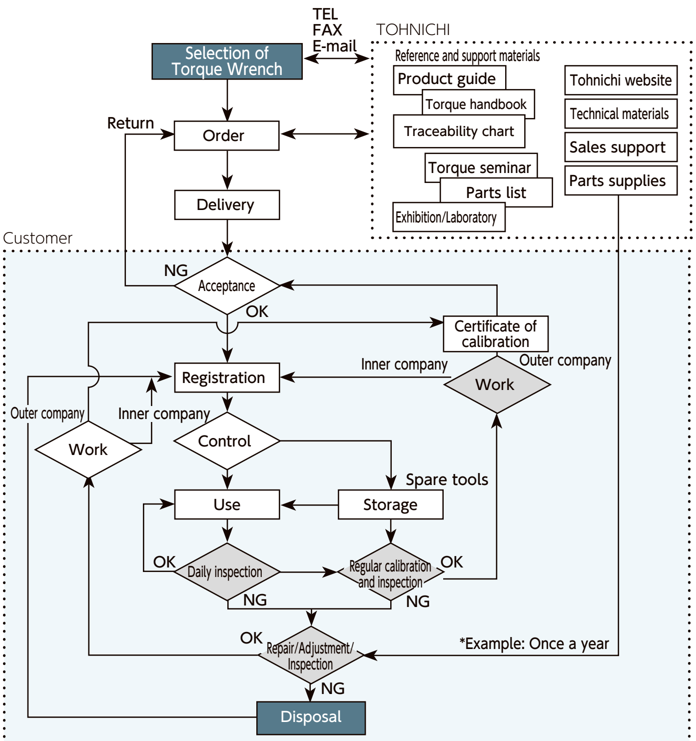
(1) Control of torque tools

The process for controlling torque tools (Figure 6-1) involves ascertaining the accuracy by adequately checking the measurement of the tools upon reception at the facility and on a daily basis. The decision of how to set up the process for the control should assess the following factors: importance, usage frequency, and usage torque capacity of the measuring instruments, by referring to the ISO standards (ISO 6789), JIS standards (JIS B 4652), and the manufacturer' s nominal accuracies.

The periodic calibration cycle depends on the same factors, but normally this is set between 3 months and a year. If possible this cycle should be readjusted as the tool ages to allow more effective control.

Due to torque tools are precision measurement equipment contrast to standard hand tools, take care for storage and management to maintain accuracy and durability.

Figure 6-1. Control system for torque tools



(2) Calibration

Calibrating a measuring device involves inspecting and verifying the extent to which the device deviates from what it should show, using as reference the upper measurement range value. Measurement range values must have a higher level of precision than the device used for measuring. The highest measurement standard applied within a company or organization is called the "reference standard."

Tools requiring calibration are calibrated periodically at a public institution. National standards and traceability must be maintained without interruption.

It is understood that calibration attests to a status only when it is performed. It does not provide Pass/Fail judgments. Therefore, adjustment and repair is not involved in calibration service. As a general rule, Tohnichi products come with a Calibration Certificate. Relevant documentation, such as an Inspection Report or Traceability System Diagram, will be issued upon request.

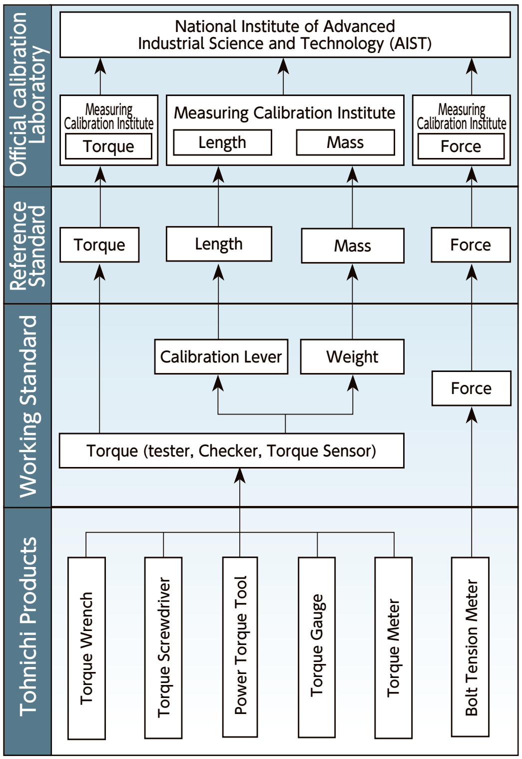
We keep inspection records on file for predetermined periods of time. Contact us if you need information regarding a record for a former product.

6-2 Traceability

(1) Traceability system

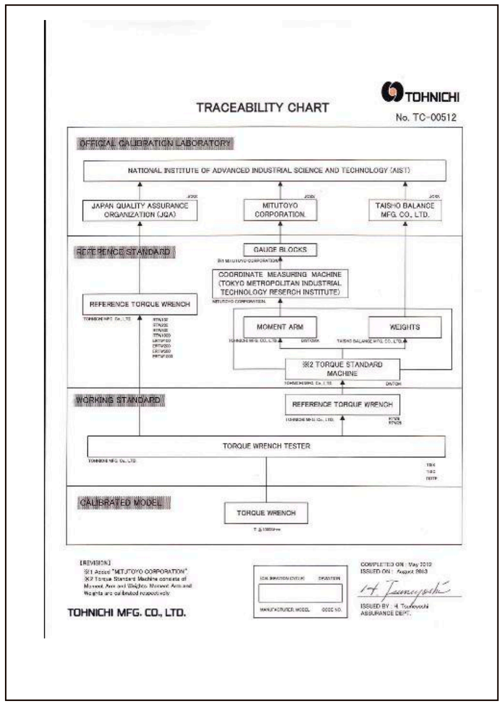
Generally, measurement equipment will be calibrated with more precise standard equipment and the standard equipment also calibrated by a higher level of standard devices. Eventually, it chains consecutively to National standard and when it certified, it can be described as traceable for National standard.
Torque can be resolved into length by the force. As the units of length and force are approved by official calibration laboratory respectively these units, or in part of country, torque itself chains directory to the National standard.

Figure 6-2. Traceability of Tohnichi products



Tohnichi is inspecting a wide variety of torque tools based on the traceability system (Figure 6-2). Services, such as calibration and repair, are very important and necessary factors in the control process. All of these services required for internal company controls of torque tools, such as calibration certificates, inspection sheets, and traceability charts (Figure 6-3), are available upon request. Use the Traceability Issue Request forms from Tohnichi agents and included with the general product information for such traceability requests.

Figure 6-3. Traceability chart



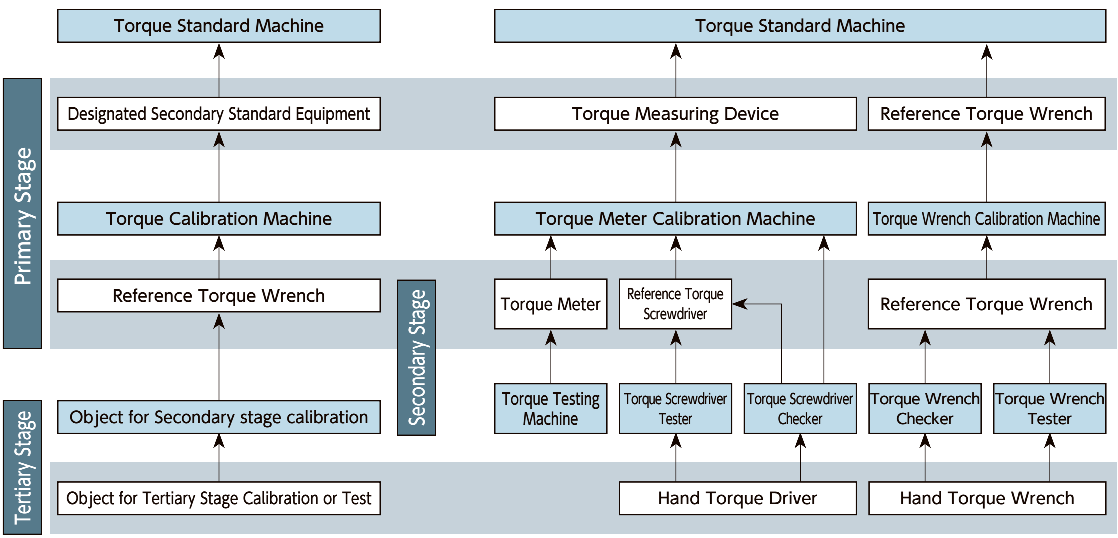
TECHNICAL DATA
6
Torque Tools as Measurement Equipment

(2) Diagram of torque traceability and National standard

In order to secure traceability system using torque SI units, the establishment of calibration methods using national torque standards is progressing worldwide. In Japan, a supply system using national torque standards has been prepared, in which “torque meters” that measure pure torsion are already being supplied in a range of 10 N･m to 20 kN･m, and “reference torque wrenches” that occupy the top standard of torque wrench testers are being provided in a range of 0.1 N･m to 5 kN･m (As of July 2018).

Items from the technical requirement application principles to the torque level structure for torque testing machines and torque wrenches measurement equipment disclosed by National Institute of Technology and Evaluation (NITE) shows in the figure 6-4. The layer composed of torque wrench and torque screwdriver and chains to torque tester and checker is "Tertiary Stage", the layer chains to reference torque wrench and reference torque screwdriver is "Secondary stage", and the layer chains from torque calibration machine to designated secondary standard equipment is "Primary stage".

Figure 6-4. Traceability System Diagram



Explanation of terms in JCSS (Hierarchy of torque wrench: from NITE issue technical requirements application guidelines)

■Designated standard equipment (Torque standard Machine) …… Equipment designated as the national standard that realizes the torque units.

■Designated secondary standard equipment (Reference torque wrench) …… A Reference torque wrench which is calibrated by designated standard equipment. It is a reference standard for the torque of the calibration laboratory and is used for maintenance of the calibration equipment.

■Working standard (Torque wrench calibration Machine) …… An actual load type, load cell type or build-up type torque wrench calibration machine. It is used for direct comparison calibration with a designated secondary standard equipment of a calibration service laboratory.

■Regular reference standard (Reference torque wrench) …… The most significant reference torque wrench in a calibration service laboratory. It has a torque wrench shaped sensor part (torque converter) provided with a lever and calibrated by linking to a designated secondary standard equipment. It is a reference standard of torque wrench testers and calibration target of the primal stage.

■Torque wrench tester …… A torque testing tool with a loading device to be given torque for calibrating hand torque wrenches. It is calibrated by a regular reference standard as the higher standard. It is a calibration target of the secondary stage.

■Hand torque tool …… The torque wrenches, those that apply load manually and also have function as screw tightening tools. The instruments can be calibrated by a torque wrench tester or torque wrench checker under JIS B 4652. It is the calibration target of the third stage of JCSS system.

Using these, through the establishing of a torque supply system by JCSS (refer to 6-3.), a traceability system for torque will be established similar to that for other units. However, depending on the torque range, it will performed conventional local calibration.

6-2 Traceability

(3) Hand torque tool standards

Requirements of ISO, International Organization for Standardization and JIS, Japanese Industrial Standards for manual torque wrenches and screwdrivers.

① ISO 6789:2017: Standards for assembly tools for screws and nuts -- Hand torque tools

Before adoption of these standards, standards in effect were listed under ISO 6789:2003 (Assembly tools for screws and nuts -- Hand torque tools -- Requirements and test methods for design conformance testing, quality conformance testing and recalibration procedure).
The standards underwent a number of changes, and are divided into Part 1 and Part 2, in response to the different needs of different users.The JIS version does not yet reflect these changes.

Part1

Part 1 specifies requirements for design and manufacture requirements, including the content of a declaration of conformity for hand torque tools.

- The classification of hand torque tools specified by the former standards (2003 version) was not changed.
- For scales and dials, maximums between graduation mark intervals were established. For electronic displays and indicators, resolution minimum requirements were established. In addition, applicable torque range must be specified.
- For high-order standard torque measurement devices, maximum measurement tolerances were established.
- Torque tool calibration procedures were made stricter than under the former standards.
- The calculation method for relative deviation (accuracy) was changed from that specified in the former standards (method returned to 1992 version).
- Some terminology and names were changed. (Reference to certificates was changed to declarations of conformity, inspection reports, etc., and their content is specified.)
- No reference is made to torque tool measurement uncertainty.

Part2

The following were established: Calibration and measurement specifications for hand torque tools; and requirements for traceable certificates of calibration. Calculation methods for uncertainty are included.

- Parameters were set for ratios between relative measurement uncertainty intervals for torque measurement devices and relative measurement uncertainty intervals for torque tools.
- The calculation method for relative measurement deviation (accuracy) is the same as that specified in the former standards (2003 version). Names are different from those in Part 1.
- Parameters were set for methods used to measure analog/dial graduation resolution.
- Stipulation of the need to evaluate variations caused by the reproducibility of a torque tool or the effect of an interface (e.g., interchangeable heads), or the output drive of a torque tool.
- Stipulation of the need to use actual torque tool calibration data when calculating reproducibility uncertainty.
- The above-mentioned data is to be used when calculating a torque tool's relative expansion uncertainty and relative measurement uncertainty intervals.
- A calibration certificate attests to the accreditation, and its content is described.

Tohnichi Manufacturing plans to introduce application of the above-mentioned standards in an orderly fashion.

② JIS B 4652:2008: Requirements and testing methods for hand torque tools

These JIS standards were compiled on the basis of the older ISO version (2003), which was later replaced by ISO 6789:2017 mentioned above. Applicable sections of the international standards were translated,
to form Japanese Industrial Standards issued in 2008 without change in the technical content.
Translated JIS, so content same as ISO: 6789:2003. Content is provided for torque tool types, tests and calibrations, and an explanation is given regarding calculation methods (including for uncertainty evaluations).

These standards are valid in Japan, so there is no problem with their application in this country. However, some sections differ from the content of the two-part ISO 6789:2017, making it urgent that new standards be drawn up.

Reference data: Terms and definitions of hand torque tool in JIS / ISO

Type Ⅰ: Indicating torque wrench Tool that indicates the applied torque by a mechanical scale, dial or electronic display		Permissive Deviation Maximum torque Below 10N・m	Permissive Deviation Maximum torque Above 10N・m
Class A	Twisting or deflection beam type wrench	±6%	
Class B	High rigidity housing type wrench with scale, dial, or display unit	±6%	±4%
Class C	High rigidity housing type wrench with electronic indicator		
Class D	Screwdriver with scale, dial, or display unit	±6%	
Class E	Screwdriver with electronic indicator	±6%	±4%

Type Ⅱ: Setting torque tool Tool that is set on a preset torque before use and it emits audibly,visibly or perceptibly signal when the torque reaches preset value.		Permissive Deviation Maximum torque Below 10N・m	Permissive Deviation Maximum torque Above 10N・m
Class A	Variable torque type wrench with graduations or display unit	±6%	±4%
Class B	Fixed torque type wrench		
Class C	Variable torque type wrench with no graduations		
Class D	Variable torque type screwdriver with graduations or display unit	±6%	
Class E	Fixed torque type screwdriver		
Class F	Variable torque type screwdriver with no graduations		
Class G	Deflection beam / variable torque type wrench with graduations		

6-2 Traceability

Special report

Torque Measurement Traceability Systems

National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology
Force and Torque Standards Group,
Hiroshi Ogushi, Research Group Director,

1. Introduction

Since the end of the last century, awareness has been growing of the importance of torque measurement traceability. This is reflected in the ISO 9000 series, ISO/IEC 17025, ISO/TS 16949,
the Fastener Quality Act (USA), and directives regarding American aircraft maintenance. In Japan, R&D for the further development of torque standards and traceability systems was begun 1997 by the National Institute of Advanced Industrial Science and Technology (AIST) and the National Metrology Institute of Japan (NMIJ, known at the time as the National Research Laboratory of Metrology, under the Agency of Industrial Science and Technology). This report compares current torque measurement traceability systems in two countries: Germany and the U.S.A.

2. Torque measurement traceability systems

Figure 1 shows the outline of tractability system of Germany. It is classified "pure torsion torque calibration" and "Loading torque calibration"

Pure torsion torque measurement device calibrations are conducted under EU guidelines EURAMET/cg-14 and DIN 51309, or German industrial standards. On the other hand, for torque wrench load calibrations, domestic authorization system guideline DKD-R 3-7 is relevant for reference calibrations of torque wrenches, domestic guideline DKD-R 3-8 is relevant for torque wrench tester calibrations, and ISO 6789 is relevant for hand torque tool calibrations. The German authorization system promoted by DAkkS is used, and the SI traceability system for torque units has been established through the involvement of the national metrology institute (PTB), Germany's National Measurement Institute (NMI).

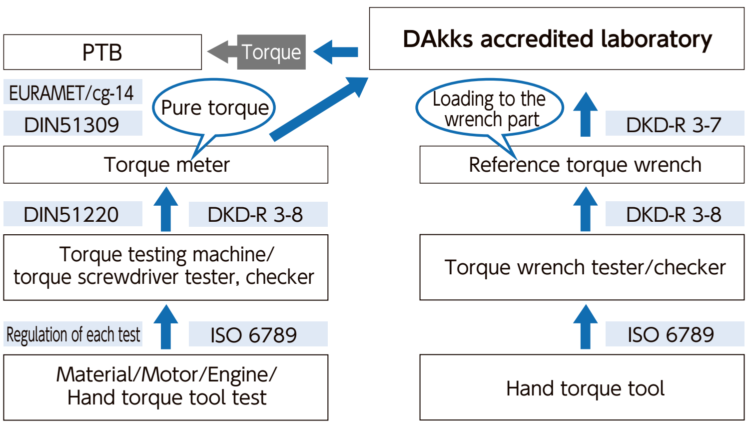


Figure 1. Germany torque traceability system and related standards

Figure 2 shows the outline of traceability system of USA. In the United States, there are many public service such as National Voluntary Laboratory Accreditation Program called NVLAP, A2LA organization and others. Both mass of weights and standard length for torque calibration services must be traceable to US national science laboratory, called the National Institute of Standard and Technology, NIST. Calibration performance of test equipment is referred to ASTM international, American Society for Testing and Materials. ASTM E2428 is standard practice for the calibration and verification of static torque measuring instruments, and ASTM E2624 is for torque calibration of testing machines. American Society of Mechanical Engineers, called ASME provides guidelines for manually operated torque instruments.

Figure 3 shows the outline of Japan. Public traceability system for Torque will be established soon with JCSS, Japan Calibration Service System. Japan Measuring Instruments Federation, JMIF provides guidelines JMIF015 for calibration service of torque meter and guidelines JMIF019 for torque wrench testers. For calibration of reference torque wrench and torque wrench tester/checker, JMIF016 and JMIF019 are referred. To calibrate manual torque instruments, JIS B 4652 by Japanese Industrial Standards Committee covers the requirement and procedure according to ISO 6789 2003. ISO 6789, however was significantly revised in 2017, it's categorized into two parts. The Part 1 is for examination and the another Part 2 for calibration.

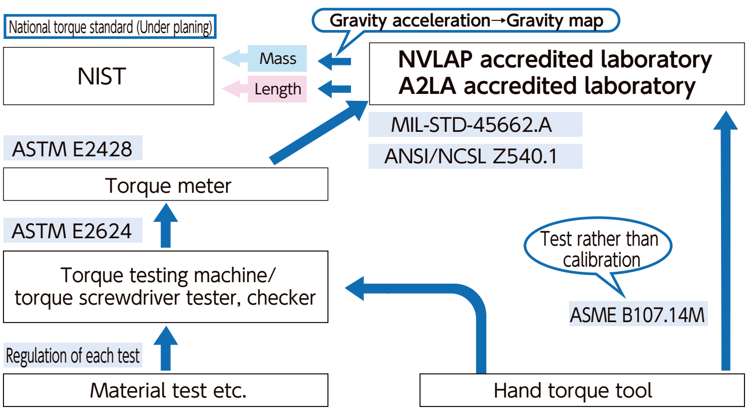


Figure 2. American torque traceability system and related standards

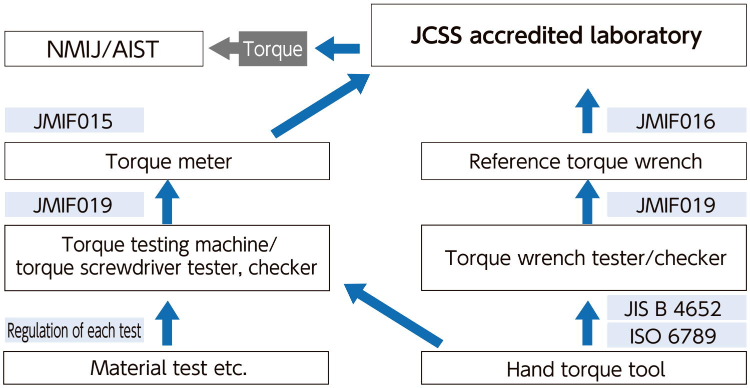


Figure 3. Japanese torque traceability system and related standards

3. Traceability stages

Here follows an explanation of traceability stages for a sample calibration, using JCSS terminology. For the first stage, using torque standard machines (TSM), which are classified as Specified Standard Instruments by the National Metrology Institute of Japan (NMIJ), calibrate a Specified Secondary Standard Instrument (either a torque measuring device [TMD] or a high precision reference torque wrench [HGRTW]). Next, using the TMD or HGRTW, calibrate the practical standards torque calibration machine (TCM) which is in the possession of the technician who performed the 1st stage calibration. Then, using the TCM, calibrate the working standard torque meter (TM), the reference torque screwdriver (RTS), and the reference torque wrench (RTW), which are in the possession of the technician who performed the 2nd stage calibration. And then, use the TM, RTS or RTW to calibrate the torque testing machine (TTM), the torque screwdriver tester (TST) / torque screwdriver checker (TSC), and the torque wrench tester (TWT) / torque wrench tester (TWC, which are in the possession of the technician who performed the 3rd stage calibration. Use the TTM, TST, TSC, TWT or TWC to test various materials or to calibrate (or test) hand torque tools. This will ensure traceability up to the end user.

4. Conclusion

My report has briefly examined torque standards and torque measurement traceability systems in Japan. Under government directive, accreditation programs ensure measurement traceability. Such practices have become a corporate responsibility, even a business strategy, and they are now considered common sense worldwide. It is to be hoped that this report will encourage industries in Japan to use the Japan Calibration Service System (JCSS), and strengthen their torque measurement traceability systems.

Traceability

(4) ISO 9000-related documents

Torque equipment is also required to be controlled, calibrated and have traceability with national standards as a measurement instrument according to ISO 9000. Tohnichi provides certificate of calibration shown in Figure 6-5. Alternatively, upon the customer' s request, we also issue an inspection certificate, traceability chart shown in Figure 6-3. Tohnichi stores the histories of these issued documents for a certain period and it helps maintain your torque management system base on ISO 9000.

Figure 6-5. Certificate of calibration supplied with torque wrenches

TOHNICHI

Certificate of Calibration
校 正 証 明 書

		Date of First Used:	/ /
Name:	TORQUE WRENCH	Serial No.:	145490J
Model:	QL100N4	Accuracy ±(%):	3
Max.Capacity:	100	Temperature (℃):	26
Units:	N·m	Inspector:	E.AIZAWA
Date of Calibration: (Day/Month/Year)	05/09/2018		

Set Torque	Lower	Upper		Actual Readings				
20	19.5	20.6	CW	20.6	20.5	20.4	20.4	20.4
			CCW	---	---	---	---	---
60	58.3	61.8	CW	60.3	60.3	60.2	60.1	60.0
			CCW	---	---	---	---	---
100	97.1	103.0	CW	101.5	101.4	101.3	101.2	101.2
			CCW	---	---	---	---	---

上記製品は、国家標準にトレースされた参照標準を基準とした標準器を用い、当社の作業標準に従って校正が行われ、校正作業における検査または試験結果が製品仕様を満足していることを証明します。
We certify that product identified above was calibrated using reference standard
That is traceable to the national standards specifications and according to TOHNICHI STANDARDS.
We have verified that these test results comply with product specifications.
Measured values are within tolerance according to ISO6789.
The uncertainty of measurement of the reference standard use is ±1%.

標準器 Standard Equipment	Model	Serial No.
ﾄﾙｸﾚﾝﾁﾃｽﾀ TORQUE WRENCH TESTER	TISK1000N-2	706249F

参照標準 Reference Standard	公的機関 Official Facility	製造番号 Serial No.
参照用ﾄﾙｸﾚﾝﾁ RTW200 REFERENCE TORQUE WRENCH	(株)東日製作所 TOHNICHI MFG CO., LTD	701570Y
ﾄﾙｸ基準機 DWTCM25 TORQUE CALIBRATION MACHINE	(株)ﾐﾂﾄﾖ/(株)大正天びん製作所 MITUTOYO CORPORATION TAISHO BALANCE MFG.	706752B

株式会社東日製作所
TOHNICHI MFG. CO., LTD.
2-12, Omori-kita 2-Chome, Ota-ku, Tokyo 143-0016, Japan
TEL:03-3762-2452 FAX:03-3761-3852
00512

TOHNICHI MFG. CO., LTD. KOFU PLANT
ISO9001 JQA-1536
Head of Calibration
H. Tsuneyoshi

ISO Related document

1. Calibration Certificate
(Combined with inspection certificate)

2. Inspection Certificate

3. Traceability Chart

Torque Tools as Measurement Equipment

6-3 Engagement wit JCSS and development of services

The Torque Standards Calibration Laboratory of Tohnichi Manufacturing was awarded JCSS Second Grade (Torque Wrench Testers) accreditation in November 2011. By March 2018 the Laboratory had also been granted First Grade (Reference Torque Wrenches) and Third Grade (Hand Torque Tools) registration. This makes Tohnichi the first torque device calibration service provider in Japan to complete accreditation in all JCSS grades. (10N•m ~ 1000N•m)

(1) JCSS overview

JCSS (Japan Calibration Service System) covers measurement traceability systems under Japan's Measurement Law.

Its focus is twofold: the National Measurement Standards Provision System and the Calibration Laboratory Registration System. The latter system has been administered since November 1993 as the Calibration Laboratory Accreditation System by the National Institute of Technology and Evaluation (NITE: initially called the International Trade and Industry Inspection Institute). Then due to system changes introduced on 1 July 2005, JCSS has since been administered as a calibration service provider registration system.

Participation in the registration system is voluntary. Acceptance depends on whether the entity satisfies the requirements of the Measurement Law, relevant regulations and ISO/IEC 17025. Registration is offered for each of the 24 registration categories currently published. Audits are conducted by NITE. Upon an entity's application, NITE examines such factors as whether the entity's quality assurance system is administered appropriately, whether its calibration methods and uncertainty evaluations are appropriate, and whether its equipment, etc. are suitable for calibration performance. Audited entities deemed by the audit to be eligible for JCSS registration can be issued a calibration certificate that includes a special accreditation symbol (see Figure 6-6).

In December 1999 JCSS entered into a Mutual Recognition Arrangement (MRA) with Asia Pacific Laboratory Accreditation Cooperation (APLAC), and then in November 2000 it signed another MRA with International Laboratory Accreditation Cooperation (ILAC). Participation in these international MRAs brings JCSS another step closer to worldwide acceptance of calibrations conducted under its umbrella (One-Stop-Testing).

Figure 6-6. JCSS symbol

JCSS
0281

Figure 6-7. JCSS symbol with MRA compliant

ilac-MRA IAJapan JCSS 0281 JCSS

When JCSS-registered calibration service providers wish to be covered by the international MRAs, they sign a separate voluntary agreement and may then be issued a calibration certificate imprinted with JCSS accreditation symbols and ILAC MRA attestation (see Figure 6-7). International MRA-accredited entities are subjected to periodic inspections to verify international MRA compliance. The JCSS emblem, and calibration certificate with JCSS accreditation symbol, offer traceability assurance under Japan's national measurement standards, and provide the advantage of immediate recognition of the technical expertise of the calibration service provider.

Extract from National Institute of Technology and Evaluation (NITE)

6-3 Engagement with JCSS and development of services

Torque Tools as Measurement Equipment

(2) JCSS calibration service

Tohnichi has been registered to JCSS as "torque" part, figure 6-9. and it is accredited to issue a calibration certification with the JCSS and MRA (Mutual Recognition Arrangement) symbol which certified the torque to be traced directly to National standard with "torque" and the contents of conformity assessment are guaranteed internationally.

Figure 6-8 Traceability chart from the view point of calibration service

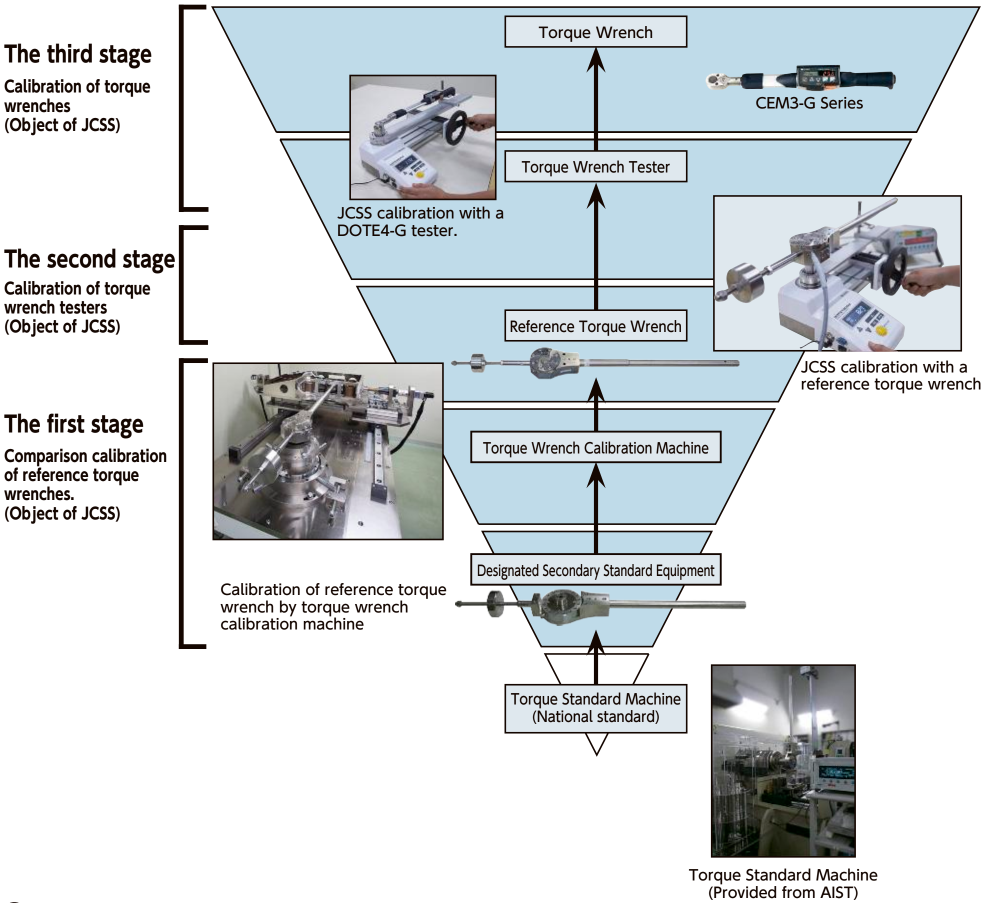
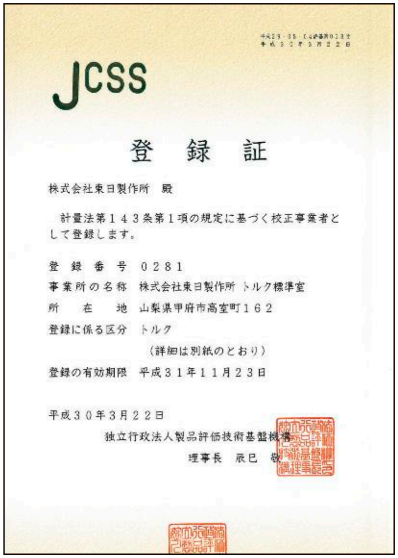


Figure 6-9 JCSS certification of registry and MRA attestation certification
(Registration the torque range from 10 N • m to 1000 N • m)



JCSS

登　録　証

株式会社東日製作所　殿

計量法第１４３条第１項の規定に基づく校正事業者として登録します。

登録番号　０２８１
事業所の名称　株式会社東日製作所 トルク標準室
所在地　山梨県甲府市高室町１６２
登録に係る区分　トルク
（詳細は別紙のとおり）
登録の有効期限　平成３１年１１月２３日

平成３０年３月２２日
独立行政法人製品評価技術基盤機構
理事長　辰巳　敬

(English Translation)

Certificate of Accreditation

To　Tohnichi Mfg. Co., Ltd.

IAJapan hereby accredits the following laboratory as a calibration laboratory based on the Measurement Law as it meets the requirements of relevant international standards. This laboratory also meets the requirements for Mutual Recognition Arrangements (MRA) of ILAC and APLAC.

Accreditation No.　ＪＣＳＳ０２８１

Name of Laboratory
Torque Standard Room, Tohnichi Mfg. Co., Ltd.

Address of Laboratory
162, Takamuro-Cho, Kofu, Yamanashi 400-0057, Japan

Accreditation Scope　Torque

Accreditation Criterion　ISO/IEC 17025:2005

Date of Issue: 2011-11-24
Dr. Koichi Nara
Chief Executive, IAJapan
National Institute of Technology and Evaluation

- International Accreditation Japan (IAJapan) is a laboratory accreditation body which has signed MRAs of ILAC(International Laboratory Accreditation Cooperation) and APLAC (Asia Pacific Laboratory Accreditation Cooperation).
- MRA requirements are, in addition to relevant international standards and guides, requirements for participation in proficiency testing programmes, surveillance and reassessment, and the policy for the traceability of measurement for MRA purpose.
- This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system. The management system requirements in ISO/IEC 17025:2005 meet the principles of ISO 9001:2008 and are alined with its pertinent requirements.

Figure 6-10. Example of JCSS calibration certificate (Initial page only)

TOHNICHI

JCSS

校正証明書

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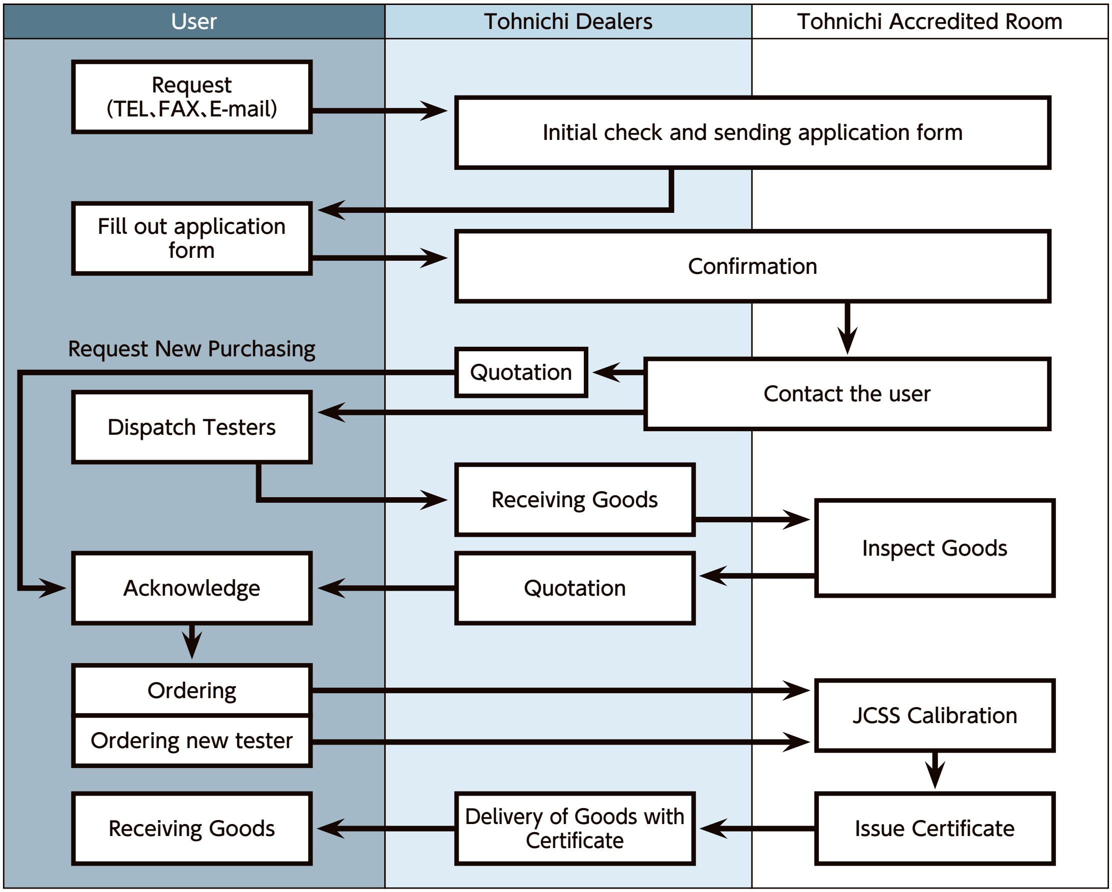
Engagement with JCSS and development of services

(3) Flow of JCSS calibration

Figure 6-11 shows a flowchart of JCSS calibration system. Application form is sent in advance to confirm requirements. "Tohnichi Accredited Room" performs calibration.

Under JCSS calibration system, not only newly purchasing Tohnichi torque equipment, also being used items can be calibrated. Contact Tohnichi for further information.

Figure 6-11 Flow of JCSS calibration



6-4 Accuracy and Uncertainty

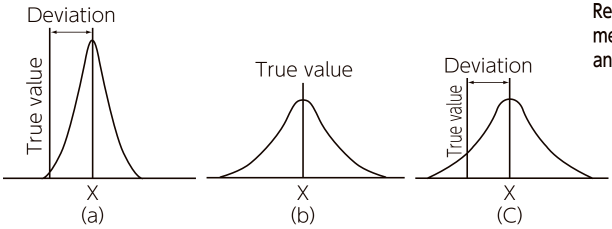
(1) Accuracy

Accuracy is the overall favorable condition including the correctness and precision of values shown by measuring equipment or measurement results. Further, correctness is the condition where there is little deviation, while precision is the condition where there is little dispersion.

Accuracy = Deviation + Dispersion

Deviation: In graduated torque measuring devices, this is the difference between the graduated values and the measured values. In torque measuring devices without graduation (preset type), this is the difference between the set torque value and the measured torque value.
Dispersion: The standard for the dispersion is taken as 2σ or 3σ.

Figure 6-12. Relation between deviation and dispersion



(a) Case where dispersion is small, but there is deviation
(b) Case where deviation is small, but there is dispersion
(C) Case where there is deviation and dispersion

Figure 6-13. Relation of measured value and true value

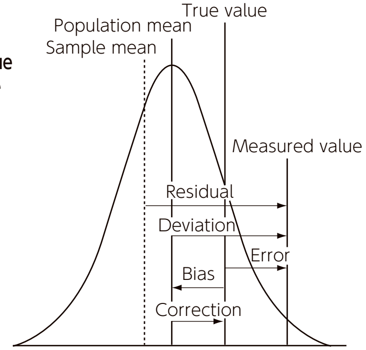


Table 6-1. Glossary of terms used in measurement(Extracted from JIS Z 8103, Glossary of terms used in measurement)

Term	Definition
True value	Value consistent with the definition of a given particular quantity. (refer to Figure 6-13) Remarks: Excluding particular cases, this is an ideal value it is unattainable practically.
Measured value	That value which has been obtained by a measurement. (refer to Figure 6-13)
Error	That value subtracted by the true value from a measured value. (refer to Figure 6-13) Remarks: The ratio of an error to the true value is called the relative error. However, in the case where it is not liable to be confused, it may also be called simply an error.
Bias	A subtracted value of population mean of measured value by a true value. (refer to Figure 6-13)
Deviation	A subtracted value by population mean from a measured value. (refer to Figure 6-13)
Residual	A subtracted value by sample mean from a measured value. (refer to Figure 6-13)
Correction	Value added algebraically to the uncorrected result of a measurement to compensate for systematic error. (refer to Figure 6-13) Remarks : 1. The correction is equal to the negative of the estimated systematic error. 2. The ratio of the correction to the read out value or calculated value is called the correction rate, and the value of correction rate expressed in percentage is called the percentage correction. 3. For the purpose of compensating the presumable systematic error, the factor to be multiplied to the measured result before correction is called the correction factor.
Dispersion	Unevenness of the magnitudes of measured values or the degree of irregularity.

6-4 Accuracy and Uncertainty

(2) Uncertainty

Without assuming the conventional concept of the true value (which is generally unknown), the uncertainty is obtained from the data dispersion (already known) in the data range, using the measured results themselves. (Figure 6-12) The methods of evaluating uncertainty are classified under the following two types:

① Evaluation method by statistical analysis from a series of measured values. (Uncertainty type A)

② Evaluation method by a means other than statistical analysis from a series of measured values. (Uncertainty type B)

Further, for both of type A and type B, the standard uncertainties and the standard deviations (or similar values) are estimated from the normal distribution, rectangular distribution and trapezoid distribution. Finally, these are combined by the propagation rule of errors. (The combined standard uncertainty) Under these procedures, the overall uncertainty is indicated as the Extended Uncertainty.

Table 6-14. Factors for uncertainty in general measurements

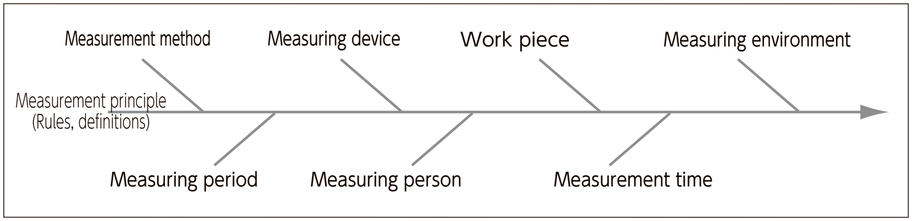
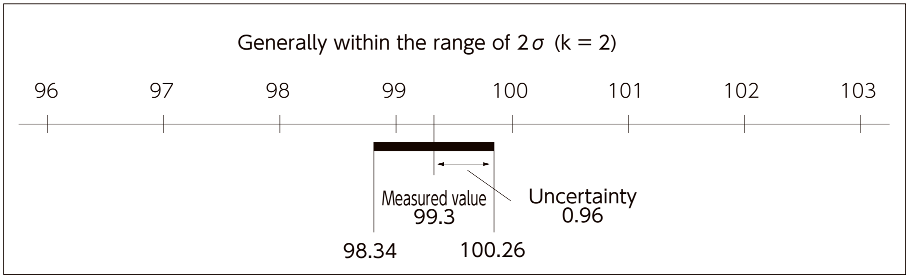
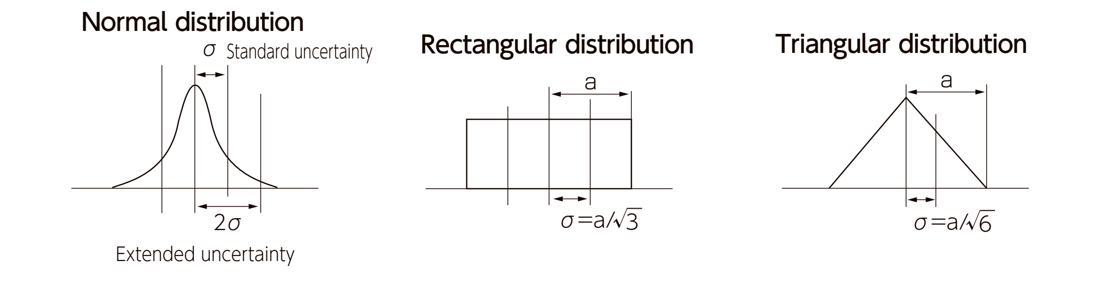


Table 6-15. Uncertainty



In normal distribution, σ (standard error) equals the standard uncertainty and generally, 2σ equals the extended uncertainty. In rectangular distribution, dividing the half width of distribution (a) by $\sqrt{3}$ equals the extended uncertainty ($a/\sqrt{3}$). In triangular distribution, dividing the half width of distribution by $\sqrt{6}$ equals the standard uncertainty ($a/\sqrt{6}$).

Table 6-16. How to estimate the uncertainty



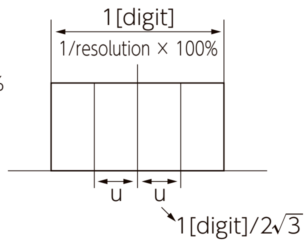
To obtain the resolution of a digital display for the uncertainty of 1 [digit], dividing 0.5 [digit] (half the width of 1 [digit]) by $\sqrt{3}$ equals the standard uncertainty (1 [digit]/$2\sqrt{3}$). For example, if the resolution (Nmin) using the minimum torque capacity (Tmin) is taken as 100, 1 [digit] equals 1% and the uncertainty of its resolution (Udigit) equals 0.29%.

Table 6-17. Example of estimating the uncertainty from the rectangular distribution

Resolution of digital display

Uncertainty for 1 [digit] (Udigit)
Resolution Nmin at Tmin
$\text{Udigit} = 1/(\text{Nmin} \times 2\sqrt{3}) \times 100\%$
1/resolution × 100%

Nmin	Udigit
100	0.29%
200	0.14%
400	0.07%



Accuracy and Uncertainty

(3) Analysis procedure for uncertainty in measurements

① Setting the method of measurement and calibration. (Describe the procedure concisely.) Describe the principles and measuring methods, measuring devices and instruments concisely.

② Construction of the mathematical model (Write the formulas or state the principal factors.)

a) Describe the formulas if they can express the uncertainty.

b) If the uncertainty cannot be expressed by numerical formulas, indicate the factors of the uncertainties and combine them by adding.

c) Execute the test of significance through experiments based upon the design of experiments and factor analysis. Then estimate the uncertainties of each factor.

③ Correction of values (Describe the correction items and the methods, if any.) If corrections are made, the estimation of uncertainties should be carried out after the data correction.

④ Analysis and estimation of uncertainty elements (Including type A and type B classification) point out and classify the uncertainty elements, and estimate the standard deviation (or similar values) per element as follows:

a) Uncertainty of standard. (Described as the standard uncertainty.)

b) The uncertainty compared to the standard. Uncertainty resulting from factors such as the calibration equipment, calibration environment, calibration period, work piece, etc.(Described in the standard uncertainty; show the basis of the method of determination).

⑤ Calculation of combined standard uncertainty (Square root of sum of squares)

$$uc = \left(\sum_{i=1}^{n} ui^2\right)^{1/2} = \sqrt{u1^2+u2^2+\cdots un^2}$$

(The apparent differences between type A and type B will disappear.)

⑥ Calculation of extended uncertainty

$$u = k \cdot uc$$

k: Coverage factor

(Generally, k = 2 is taken. If not, describe the reason for this.)

(4) Example of uncertainty

① Theoretical formula

Torque [N·m] = Mass of dead weight [kg] x Gravitational acceleration [m/s^2] x Effective length of calibration lever L [mm]

② Hypothetical models

・Torque calibration kit	DOTCL100N
・Torque wrench tester	DOTE100N4-G

③ Uncertainty of calibration of torque wrench tester

Extended uncertainty of torque calibration kit: UIA

Extended uncertainty of torque calibration work: UIB

Extended uncertainty of measured torque: UIT ($UIT^2 = UIA^2 + UIB^2$)

Extended uncertainty of torque wrench tester: UC

Extended uncertainty of calibration of torque wrench tester: UT ($UT^2 = UIT^2 + UC^2$)

④ Uncertainty of torque calibration kit

Factors	Standard uncertainty
・Mass (standard dead weight)	0.0004%
・Mass for measurement	0.01%
・Gravitational acceleration	0.005%
＊(Refer to P. 27, "Acceleration of gravity")	
・Corrections of specific gravity	0.015%
・Vertical/horizontal conversion	0.014%
・Scale (calibration)	0.006%
・Length of lever (process tolerance)	0.02%
・Diameter of wire	0.02%
・Elongation of lever	0.014%

Combined standard uncertainty for force

$$uf = \sqrt{0.0004^2+0.01^2+0.005^2+0.015^2+0.014^2} = 0.023\%$$

Combined standard uncertainty of length of lever

$$ul = \sqrt{0.006^2+0.02^2+0.02^2+0.014^2} = 0.032\%$$

Combined standard uncertainty of torque calibration kit

$$ua = \sqrt{uf^2+ul^2} = \sqrt{0.023^2+0.032^2} = 0.04\%$$

Extended standard uncertainty of torque calibration kit (k = 2)

$$UIA = 2\times ua = 0.08\%$$

6-4 Accuracy and Uncertainty

⑤ Uncertainty of torque calibration

Factors	Standard uncertainty
・Horizontality of wire	0.06%
・Inclination of lever (horizontality)	0.06%
・Length of lever (angle of drive)	0.03%
・Newton conversion	0.03%
・Repeated uncertainty	0.1%

Combined standard uncertainty of torque calibration work:

$$ub = \sqrt{0.06^2+0.06^2+0.03^2+0.03^2+0.1^2} = 0.14\%$$

Extended uncertainty of torque calibration work:

$$UIB = 2 \times ub = 0.28\%$$

Extended uncertainty of calibration torque:

$$UIT = \sqrt{UIA^2+UIB^2} = 0.29\%$$

⑥ Uncertainty of calibration of torque wrench tester

Factors	Standard uncertainty
・Resolution of torque wrench tester (zero point)	0.06%
・Resolution of torque wrench tester (display)	0.06%
・Friction of axis bearing area	0.005%
・Uncertainty of gauge	0.14%
・Uncertainty of display	0.14%

Combined standard uncertainty of torque wrench tester:

$$uc = \sqrt{0.06^2+0.06^2+0.005^2+0.14^2+0.14^2} = 0.22\%$$

Extended uncertainty of torque wrench tester:

$$UC = 2 \times uc = 0.44\%$$

Extended uncertainty of calibration of torque wrench tester:

$$UT = \sqrt{UIT^2+UC^2} = 0.52\%$$

⑦ Traceability of torque tools

The extended uncertainty of the torque wrench tester is required to be below ±1% (k = 2).
The extended uncertainty of the torque of the torque calibration kit should be below ±0.3% (k = 2).
Therefore, the standard uncertainty of the calibration kit is expected to be below 0.15%.
Each standard uncertainty of inferior characteristics that is below 0.015% can be ignored.

(5) Accuracy of Torque Tools (JIS B 4652：2008)

Situation where calibration of a torque wrench or torque screwdriver is being carried out using a measuring instrument, match the indicated value on the index of the graduated scale of the measuring instrument being calibrated with the measuring point, and read the numbers on the measuring instrument.

$$As(\%) = \frac{(\chi_a - \chi_r)}{\chi_r} \times 100$$

As(%)：Deviation of the torque tool
Xa：Indicated value of torque tool
Reference value of Calibration Equipment
Xr：Reference value of Calibration Equipment

$$\text{Deviation of the torque tool} = \frac{\text{Indicating value of torque tool} - \text{Measuring value of calibration equipment}}{\text{Measuring Value of Calibration Equipment}} \times 100$$

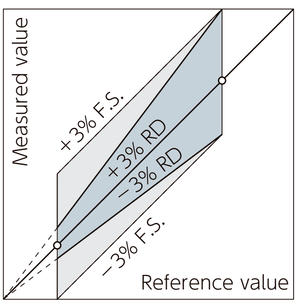
Indicated value of torque tool

Reference value of Calibration equipment

Calculation example　As(%)　$\chi a = 50$　$\chi r = 52$

$$As = \frac{(50-52)\times 100}{52} = -3.85\%$$

Figure 6-18. Difference in accuracy between RD and FS



Tohnichi adopts RD (Reading) for accuracy of torque products, not F.S (Full Scale).
Figure 6-18 shows the concept of difference of Reading and Full Scale accuracy.
For Full Scale +/-3% accuracy, the +/-3% error at the maximum range is applied on all measuring point. In contrast, Reading +/-3% error will be applied against each indicating points, so the more lower the measuring point, error will be larger in Full Scale.

Accuracy and Uncertainty

Table 6-2. List of Torque Equipment Accuracy

Description	Model Name	Accuracy
Digital Torque Wrench Tester	TF, TCC2-G, DOTE4-G	± 1% + digit
Digital Torque Meter	TME2	
Digital Torque Screwdriver Tester	TDT3-G	
Digital Torque Wrench Checker	LC3-G	
Digital Rotary Torque Checker	ST3-G	
Digital Torque Screwdriver	STC2-G	± 1%
Digital Torque Wrench	CEM3-G, CTA2-G, CTB2-G	
Digital Torque Gauge	ATGE-G, BTGE-G	± 2% +1digit
Torque Meter	TM	± 2%
Torque Gauge	ATG, BTG	
Torque Wrench Tester	DOT	
Digital Torque Wrench	CPT-G	± 3%
Torque Screwdriver	RTD, LTD, NTD, FTD, MTD, RNTD, A/BMRD, A/BMLD etc.	
Torque Wrench	QL (E2), CL (E2), DQL (E2), TW2, SP2, QSP, PQL, MPQL etc.	
Semi-automatic Torque Wrench	A3、AC3	
Torque Wrench	QSPCA12N ~ 70N	± 4%
Power Torque Tool	U, UR, AUR, DU, AP2 ME, MC2, etc.	± 5%
Torque Wrench	QSPCA6N	± 6%

(6) Durability Accuracy of Tohnichi Standard

■Manual Torque Tools

Guaranteed accuracy and durability on 100,000 cycle operations at maximum torque set or one year from the first use. With proper maintenance, calibration, adjustment and parts replacement every 100,000 cycles, Tohnichi torque wrenches, upto 420N・m models can be used 1,000,000 times. Upto 1000N・m models 500,000 times, and more than 1000N・m 250,000 times.

■Power Torque Tools

Guaranteed 500,000 cycle operations or one year from the first use under proper operation.
Required periodical calibration and overhauling.

6-5 Tool Control

(1) Tool Control

Any torque equipments break down and cause malfunction as they are used for a long time. To prevent it, periodical check and calibration are required.
Daily inspection serves as a basis for the validity to use, and periodic calibration is effective for external report by securing traceability. By combining these, corresponds to measurement equipment management requirements of various standards including ISO.

Table 6-3. Daily Check and Periodic Calibration

	Daily check	Periodic calibration
Inspector	Operators	QC section, Calibration providers
Time	Before or after the operation	Periodic sequence
Testing equipment	Torque wrench checker	Torque wrench testers, Calibration equipment
Anomaly detection	Possible to detect an error at an early stage	Evaluable the uncertainty and long term variation
Failure and trouble	Possible to find abnormal trends at early stage	Difficult to find an error at early, need a report from line side for repairing

(2) Select Testers

Checker for Daily Check ···
Prevents numerous defective products beforehand

- Required to zero adjust since weight of torque wrench itself is add to vertical loading direction.
- Direct manual loading doesn't provide stable Loading speed, force position and direction.

Tester for Calibration ······
Quality control and securing traceability of torque equipment

- Horizontal loading direction is not affected by the acceleration of gravity.
- Loading device can keep stable operation speed, force position and loading direction.

Table 6-4. Select Testers

Type / Article	Checker		Tester			
	LC3-G	ST3-G	TDT3-G	DOT	DOTE4-G	TF, TCC2-G
Object	Torque Wrench	Power Tool, Torque Wrench	Torque Screwdriver	Torque Wrench	Torque Wrench	Torque Wrench
Accuracy	± 1%+1digit	± 1%+1digit	± 1%+1digit	± 2%	± 1%+1digit	± 1%+1digit
Torque Range	Small-Medium-Large	Small-Medium-Large	Small	Small-Medium	Small-Medium-Large	Small-Medium-Large
Analog	×	×	×	○	×	×
Digital	○	○	○	×	○	○
Manual	○	○	○	○	○	○ (TCC2-G)
Power	×	×	×	○ (DOT-MD)	○ (DITE4-G-MD2)	○ (TF)
Direction	Right	Right/Left	Right/Left	Right	Right/Left	Right/Left

Tool Control

(3) Testers for torque tools

Table 6-5. Example of Torque tools and Testers/Checkers

Torque tools	Representative Model	Tester / Checker
Pneumatic torque screwdriver	U、UR、AUR	TCF＋TP＋Display
Semi-automatic airtork	A3, AC3	DOT・DOTE4-G・LC3-G・TF・TCC2-G Torque wrench tester
Fully automatic airtork	HAT, AP2	TCF＋TP＋Display、ST
Multiple unit	ME, MC2, MG	TCF＋TP＋Display、ST
Manual torque screwdriver	RTD、LTD、AMRD、BMRD	TDT、ATGE、TCF＋Display
Manual torque wrench	QL、SP、QSP、TW、QSPCA	DOT・DOTE4-G・LC3-G・TF・TCC2-G Torque wrench tester
Tester, Checker, Torque meter	DOTE4-G, LC3-G, TF, TDT3-G, TME2	Calibration kit (weight + calibration lever/pulley)

(4) Standards of Tohnichi, ISO, JIS (ISO 6789:2003, JIS B 4652:2008)

Table 6-6. Permissible deviation of torque value

A. Dial indicating type	Tohnichi standard	Wrench、Screwdriver	± 3%	
	ISO、JIS standard	Wrench	Below 10 N·m ± 6%	Above 10 N·m ± 4%
		Screwdriver	± 6%	
B. Adjustable type	Tohnichi standard	Wrench、Screwdriver	± 3%	
	ISO、JIS standard	Wrench	Below 10 N·m ± 6%	Above 10 N·m ± 4%
		Screwdriver	± 6%	
C. Preset type	Tohnichi standard	Wrench、Screwdriver	± 3%※	
	ISO、JIS standard	Wrench	Below 10 N·m ± 6%	Above 10 N·m ± 4%
		Screwdriver	± 6%	

Permissible deviation of JIS, ISO sectionalize by the maximum torque range of torque tools. ※QSPCA is based on ISO and JIS standard

Table 6-7. Measurement procedure

A. Dial indicating type	1. Tohnichi standard	Preliminary loading at maximum capacity → Release loading → Zero adjustment → Measure 5 times at each measuring point
	2. ISO standard	
	3. JIS standard	
B. Adjustable type	1. Tohnichi standard	5 times preliminary loading at maximum capacity → Measure 5 times at each measuring point
	2. ISO standard	
	3. JIS standard	
C. Preset type	1. Tohnichi standard	5 times preliminary loading at torque set value → Measure 5 times
	2. ISO standard	5 times preliminary loading at torque set value → Measure 10 times
	3. JIS standard	

Table 6-8. Measurement point

A. Dial indicating type	Tohnichi standard	20% 60% 100% ※ of maximum torque value
	ISO、JIS standard	
B. Adjustable type	Tohnichi standard	
	ISO、JIS standard	
C. Preset type	Tohnichi standard	Torque set value
	ISO、JIS standard	

Adjustable Minimum value, 60% and 100% of the maximum torque range.
There are case to calibrate at 20% of the maximum range even if it is not the minimum scale value.

(5) Naming of hand torque tools

Table 6-9. Naming of torque tools

Type I Indicating type torque tool (ISO, JIS)		Tohnichi equivalent model
Class A	Twisting or deflection beam type wrench	F、CF
Class B	High rigidity housing type wrench with scale, dial, or display unit	DB、CDB、T-S
Class C	High rigidity housing type wrench with electronic indicator	CEM3-G
Class D	Screwdriver with scale, dial, or display unit	FTD
Class E	Screwdriver with electronic indicator	STC2-G

Type II Adjustable type torque tool (ISO, JIS)		Tohnichi equivalent model
Class A	Variable torque type wrench with graduations or display unit	QL、CL、PQL
Class B	Fixed torque type wrench	–
Class C	Variable torque type wrench with no graduations	QSP、CSP、QSPCA
Class D	Variable torque type screwdriver with graduations or display unit	LTD、RTD
Class E	Fixed torque type screwdriver	NTD、RNTD
Class F	Variable torque type screwdriver with no graduations	–
Class G	Deflection beam / variable torque type wrench with graduations	–

(6) Cautions for calibration of hand torque tools (ISO 6789 : 2003、JIS B 4652 : 2008)

Common items	Calibration Device	The maximum permissible uncertainty of the calibration equipment: measurement should be ±1% of the indicated value. (including coefficient k = 2)
	Calibration Temperature	Should be in the range of 18 to 28°C and should have a temperature variation of less than ±1°C. (The maximum relative humidity should be 90%)
Type I Indicating type torque tools	Installation	Torque wrench: incline within ±3° and loading incidence angle within ±10°. torque screwdriver: tilt within ±5°.
	Preliminary Loading	Carry out preliminary loading one time up to the maximum value in the working direction, and set to zero after releasing the load.
	Loading Method	Load gradually with increasing force until the indicated torque value is reached.
Type II Adjustable type torque tools	Installation	Torque wrench: incline within ±3° and loading incidence angle within ±10°, torque screwdriver: tilt within ±5°.
	Preliminary Loading	Carry out loading five times to the maximum capacity (torque tool nominal capacity) in the working direction, and carry out averaging.
	Loading Method	After loading gradually with increasing force up to 80% of the target torque value, slowly apply a final loading evenly over 0.5 to 4 seconds to reach the target torque value.