MEASUREMENT AND CALIBRATION FOR TIGHTENING SYSTEMS

New: with a chapter on **hydraulic torque wrenches** for the installation of wind turbines and plant construction
Calibration services from Atlas Copco Tools

With its calibration laboratories accredited by local accreditation bodies (e.g. DAkkS for Germany), Atlas Copco Tools has a special position among tool manufacturers. However, the calibration services offered are not limited to tightening systems. Atlas Copco Tools is a single-source provider of calibration services and also offers calibration in other fields such as temperature, pressure, electrical values, force and many other dimensions.

Atlas Copco Tools operates calibration laboratories in many different countries across the globe. Of course, calibration services and machine and process capability analysis can also be carried out at customers’ plants. Customers often request these on-site services to minimize downtimes. Our accredited laboratories are certified according to ISO/IEC 17 025:2005 and meet all the requirements of quality standards including ISO 9001, ISO 10012 and ISO/TS 16 949.

You will find contact addresses for measurement and calibration services on page 37.
Measurement and Calibration for Tightening Systems

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1. Introduction

This pocket guide is intended to help you achieve reliability, quality and security in the use of bolted assembly tools – for example considering product liability issues. The guide defines key terms in the field of measurement and calibration regarding industrial tools and provides a large number of suggestions, for example on the intervals and methods for control measurements of electric and pneumatic nutrunners. Also issues such as who should carry out the calibration work on the measuring equipment and relevant calibration procedures are covered.

2. Why are measurements and calibration required?

Pneumatic and electric tools need to be measured and verified at regular intervals. Calibrated measuring equipment is used for this purpose. This ensures that the tools function correctly and precisely. With present quality requirements, this procedure is essential due to the ultimate product responsibility of the manufacturers. Only tools that have been properly adjusted can avoid incorrect measurements which might be expensive and safety-critical. With regular measurements and calibration, manufacturers can avoid production problems and possible legal consequences – regarding product liability.

Measurements are a fundamental and essential element of industrial quality assurance. This applies not only to the international standards for quality management systems (e.g. ISO 9000 ff., VDA 6.4, QS 9000, ISO/TS 16 949) but also concerns product liability (see page 31) and environmental protection.

Accuracy is ensured by calibrating and if necessary adjusting the measuring equipment. A number of standards state requirements concerning equipment calibration; some quality standards call for regular calibration so that the deviation between the actual reading and the correct value is known at all times. Equipment must be appropriately calibrated to reach the accuracy required in its field of application.
3. Definitions

This section explains the definitions of a few key terms in order to avoid misunderstandings. In practice, these terms are often used in incorrect contexts or are understood incorrectly.

**Calibration**

Calibration is the determination and documentation of the deviation between the reading of a measuring instrument or a control unit to the value indicated by a higher-level reference device. This means that two values are compared with each other, one of which is known and fixed.

During the calibration of a measuring instrument, the correlation between the input and the output is determined and documented under defined conditions. The input is the physical parameter to be measured, for example torque or rotational angle. The output is often an electrical signal of the measuring instrument but may also be a displayed value.

**Adjustment**

Adjustment is the process of setting a measuring instrument in such a way that the deviation between the actual and the required measured value is as small as possible and is within the equipment specification. Adjustment represents a permanent change to the measuring instrument.

Adjustment is often closely connected with calibration. The objective of the two processes is to detect and document deviations. If the reading given by a measurement device or the output of a controller is found to be outside the admissible tolerance limits during calibration, the equipment must be adjusted until the measured values are within these tolerance limits.

**Measurement**

Measurement means determining whether a requirement, such as the correct functionality or precision of a system or measuring instrument, is met. Normally, the result of a measurement is a measured value or a series of measured values. A measurement result always represents an estimation that is more or less precise and includes a measurement deviation. The objective of measurement is to make a clear statement regarding an unknown factor.
Standards (measurement standards)

In English, the term “standard” is used both to refer to a written document stating requirements and to a standard measurement instrument used in calibration processes. This paragraph deals solely with measurement standards.

A standard is a realization of a given quantity that is used as a definition for a measure – i.e. as a sort of reference. A well-known standard in this sense is the atomic clock kept by the German National Institute (PTB) in Brunswick. This effectively “standardizes” time by defining a second using a constant in atomic physics. This constant is realized using caesium atomic clocks. On this basis, we all know how long a second or an hour is and whether our clock runs properly or needs adjustment.

There are also standards for other physical dimensions such as mass (the primary kilogram), force, temperature or torque. Most countries have their own national standards which apply to the specific country but are also compared on an international level. Standards used in the production process are referred to as working standards.

Certification

Certification is a verification of processes and routines concerning norms and standards by an independent, accredited certification body. The certificate issued by the certification body is a confirmation of compliances with standards. Certificates are often issued with expiry dates and are verified independently to ensure compliance.

Accuracy

Accuracy describes the ability of a measuring instrument or a machine to deliver values of an output that are near to the true value. The machine capability indices Cm and Cmk are often mentioned in connection with accuracy. These indices were established in the automotive industry as a method of assessing the quality and suitability of power tools.
The *machine capability index* ($C_m$ value) is a measure of the general ability of the tool to produce required quality at the operating point. The operating point shall be at the center of the specified range. The index indicates the repeatability of the machine. Systematic errors are not taken into consideration. The *critical machine capability index* ($C_{mk}$ value) however, indicates the deviation between the operating point of the tool and the target value. In other words it gives an indication of compliance with the required operating point. This index also takes systematic errors of the machine into consideration.

The lower the standard deviation in relation to the specified range, the higher the $C_m$ value and the more reliable the production process. The tool always delivers very similar values. In other words, if you throw three darts at the board, they will always hit a specific field but this will not always be the bull’s-eye. If the machine is set precisely to the center of the specified range, the $C_{mk}$ value will be equal to the $C_m$ value. As the setting moves away from the center of the specified range, the $C_{mk}$ value will be reduced.

The aim is to achieve $C_m$ and $C_{mk}$ values that are as high as possible. The diagram with the darts boards gives a graphic illustration of this point.

A high $C_{mk}$ value can only be reached with a high $C_m$ value!
**Measurement uncertainty**

Measurement uncertainty is a measure of the accuracy of a measuring instrument at operating conditions. Measurement uncertainty is not a fixed quantity but is determined individually for each measuring instrument. It is used to determine whether a measuring instrument is suitable for the required quality process. The optimal choice of a measuring instrument saves costs as excessive accuracy may be expensive.

**Tolerance**

The tolerance is the difference between the upper and lower limit, i.e. the admissible deviation from a target value. In other words, deviations from a target value are permitted as long as the measured value is within the defined tolerance.

**Traceability**

Traceability describes a process by which the value indicated by a measuring instrument is compared with the national standard through one or more steps. In each step, a measurement system is compared with a measuring standard which has been calibrated using a higher level measuring standard.

Any measured value is subject to a measurement uncertainty. The uncertainty grows with increasing distance from the highest-level standard in the hierarchy (see diagram on next page). Each standard or measuring instrument should be calibrated using higher-level standards. As a rule of thumb, each standard in the hierarchy has only one-fifth of the uncertainty of the standard on the next level downwards.
Both, the devices used for measurements and the standards used for verifying these devices, are measuring instruments. In addition, a distinction is often made between instruments used for quality assurance and those which are used for other purposes.

**Traceability:**

Even measurement standards are not always absolutely accurate. Within the calibration hierarchy, the measurement uncertainty of the standards used increases from top to bottom.

Each measurement standard or measuring instrument should therefore be calibrated using standards on a higher level of the hierarchy.

**Measuring instrument**

Measuring instruments used for quality assurance, such as the transducer shown on the left, installed on an analyzer, or the torque/angle wrench shown on the right, must always be properly calibrated.
4. Norms and standards

The most important norms and standards for quality assurance and industrial production are briefly explained below. This list does not claim to be exhaustive.

ISO 9000: This international standard defines basic principles and terms for quality management systems. The standard describes the requirements to be met by the management of the company in order to comply with a certain standard in the implementation of quality management. It may be used both for the implementation of quality management within a company and to demonstrate to third parties that the company complies with certain requirements.

ISO 9001: This international standard states requirements to be met by the quality management system in the event that an organization needs to demonstrate that its products conform to the requirements of customers and legislation and that it aims to improve customer satisfaction. The standard outlines a model for an entire quality management system.

QS 9000: This American standard was developed to meet special requirements of car manufacturers on the US market. It also adapts the ISO 9001 system to the special needs of the automotive industry.

VDA 6.1–6.4: These codes of practice of the German automotive industry are binding on suppliers of German car manufacturers.

ISO/TS 16949: Technical Specifications for Quality Management Systems. This specification describes special requirements for the application of ISO 9001 to vehicle and spare part production in the automotive industry.

ISO/IEC 17025: This standard defines general requirements for the competence of measurement and calibration laboratories.

ISO 10012: This standard describes quality management requirements for measurement management systems. The standard provides support for the effective management of measuring equipment and helps in ensuring that measuring equipment and measurement processes are suitable for the intended purpose.
The following norms and standards describe the most important calibration and measurement procedures used in connection with tightening systems:

**DIN 51 309**: This is one of the most important standards for torque calibration. It describes calibration procedures for torque measuring instruments. The results of the calibration process are classified. The class indicates the accuracy of the measuring equipment concerned.

**VDI/VDE 2646**: This standard defines the minimum requirements for the calibration of torque measuring equipment. It is often referred to as a factory standard as the procedure is considerably simpler than the DIN 51 309. Other than in DIN 51 309, the measurement results are not classified.

**VDI/VDE 2647**: Although this standard does not directly concern calibration of measuring equipment, it should still be mentioned here as it defines the procedure for machine capability testing (see page 15). As this standard is very comprehensive, a simplified version is normally used for testing of tightening tools.

**VDI/VDE 2645**: This new standard describes very comprehensive procedures for machine capability testing on manual and power tools used in tightening systems. The stability and reproducibility of a tightening tool can be determined by machine capability analyses in accordance with VDI/VDE 2645. This standard can be regarded as a further development of VDI/VDE 2647 and is even more comprehensive than its predecessor. It is therefore rather questionable whether VDI/VDE 2645 will actually be implemented in full in everyday work.

**VDI/VDE 2648**: This standard defines procedures for the traceable calibration of rotational angle sensors and measuring equipment which measure the rotational angle either directly (part 1) or indirectly via a gyroscope (part 2).

**ISO 6789**: This norm defines the calibration procedure for simple torque wrenches, such as click-type wrenches or torque wrenches with dials. A key disadvantage of this standard in the current form is the fact that the measurement uncertainty of the calibration results is not taken into account.

**DKD-R 3-7**: This standard describes the calibration procedure for higher accuracy (electronic) torque wrenches than those covered by ISO 6789. The measurement results are classified using a procedure similar to the one outlined in the DIN 51 309.
In the calibration laboratory.
5. Measurement and calibration laboratories

Users have a choice between many different calibration laboratories and a number of different calibration and measurement procedures. It is not always easy to find the laboratory or procedure that is appropriate for a specific purpose.

Almost every country has an accreditation body that is responsible for ensuring the quality of national calibration laboratories. Accredited laboratories are subject to continuous impartial assessment and monitoring. This ensures the high quality and reliability of the calibration services performed by accredited laboratories.

In general, it is necessary to distinguish between accredited calibration laboratories and non-accredited factory calibration laboratories.

Accredited calibration laboratories perform calibration work on measuring equipment for the measured dimensions and within the measuring ranges defined by their accreditation. The calibration certificates issued confirm that the calibration work performed is traceable to national measurement standards. This traceability is required by the ISO 9000 family of standards and by ISO/IEC 17025.

Most national accreditation bodies are members of ILAC (the International Laboratory Accreditation Cooperation). This means that calibration certificates are recognized in other ILAC member countries as well.

Non-accredited factory calibration laboratories are often owned by the concerned companies and are normally not accredited by a national authority or institution. Factory calibration laboratories perform calibration work on measuring equipment for the measured dimensions and measurement ranges defined in their accreditation.

Factory calibration laboratories are not accredited by a national authority or institution. They perform measurements and calibration work in accordance with their own procedures. Strict compliance with the applicable norms and standards is not necessarily ensured. The measuring references used may or may not be calibrated in a traceable way. The quality of these laboratories is normally not supervised by any independent institute. It is therefore questionable whether calibration certificates issued by these laboratories would be recognized by a court of law in product liability proceedings. In such liability proceedings, the court has to determine whether appropriate quality assurance was applied and if they are in accordance with the state of the art. Factory calibration laboratories meet these requirements only in exceptional cases.
6. Measurement and calibration possibilities

Factory calibration laboratories and especially accredited calibration laboratories often offer a wide variety of measurement and calibration services.

**Accredited calibration**

Accredited calibrations are performed in accordance with defined norms and standards using validated measurement procedures which are only applied by accredited calibration laboratories. In the case of tightening tools, calibration may be carried out clockwise and/or counter clockwise direction. The measuring equipment used for calibration must be traceable to national standards. In addition the measurement uncertainty must be stated. Accredited calibration laboratories have considerable metrological expertise. For this reason, an accredited calibration certificate is not only valid internationally but also provides evidence and security for any product liability issues (see page 31).

Accredited calibrations of torque measuring instruments are performed in accordance with the European standard EA-10/14. Accredited angle calibrations are carried out according to VDI/VDE 2648 (see page 11).

*Bottom brackets for bicycles have right- and left-handed threads. In order to achieve the correct torque, nutrunners must therefore operate equally accurate in clockwise and counter clockwise directions.*
Factory calibration

Factory calibration (also misleadingly referred to as “ISO calibration”) normally involves a simplified measurement procedure under the sole responsibility of the calibration laboratory. The scope of calibration differs from laboratory to laboratory and may often be highly restricted. Factory calibration services do not necessarily comply with the requirements of national or international standards. The measuring instruments used might or might not be traceable to the national standard. Often, there is no statement of the measurement uncertainty. There is no formal obligation considering the content of the calibration certificate.

Many accredited calibration laboratories also offer factory calibrations as a simplified, low-cost alternative. Reputable calibration laboratories offering factory calibration services still operate in accordance with defined, validated measurement procedures. They are often based on national or international standards in a simplified form and apparent to the user. These accredited laboratories ensure the traceability of the reference equipment, also when performing factory calibrations.

The machine capability of tightening tools needs to be tested regularly using measuring equipment, which is traceable calibrated, such as this test bench.
Machine capability tests

A machine capability test (sometimes also referred to as a comparison or reference measurement) is performed over a relatively short period of time in order to determine the $C_m$ and $C_{mk}$ values of the tool (see page 7). On the basis of these values, it is possible to determine whether a tool is suitable for a specific application or not.

Well-equipped laboratories are in a position to simulate the actual tightening application (for example, using a test bench, see photo on page 15). Often, a series of “soft” and “hard” tightenings are simulated to determine whether the tool complies with the relevant requirements.

Homologation

Homologation is a tool type test. For this purpose, up to three machines of the same type are normally subjected to extremely time-consuming procedures. Some of the tests are performed under extreme conditions. The test period is considerably longer than for a machine capability test. The homologation procedure also determines the $C_m$ and $C_{mk}$ values of the tool.

Often, homologation is performed to obtain approval for the use of a machine type for a production process. In the automotive industry, homologation is often required and is performed according to VDI/VDE 2647.

Homologation may also be performed if there is reason to suspect that quality problems are caused by a specific type of tool. The objective in this case is to obtain comprehensive information on the behavior of the particular tool.

7. Calibration procedure

Typically, the calibration procedure is as follows (see diagram on next page):

1. Test of functions and visual inspection to identify any damage to the equipment to be calibrated. The objective is to identify any damage to the housing, cables and contacts of the equipment. The inspection also covers any accessories as well as the technical documentation required for the calibration (such as technical data, operating instructions, service documents).
Typical calibration procedure from visual inspection and test of functions through calibration and plausibility checking followed by documentation and labeling of instrument.
A test of functions is then performed on the equipment to be calibrated. This test investigates the proper functioning of the equipment and also covers basic settings, self-test functions and zero point alignment.

2. Following the inspection, it is necessary to decide whether the equipment is suitable for calibration in its current condition or needs to be repaired. If repair is necessary, the calibration laboratory contacts the customer in order to agree on the scope, cost and timing of repair work. If it is not feasible to repair the equipment, the laboratory suggests that the equipment should be scrapped and replaced.

3. If the equipment is suitable for calibration, a calibration routine according to the defined procedure (depending on the type of calibration required) is carried out. If the equipment needs to be adjusted and this has been agreed with the customer, the calibration procedure is again repeated after adjustment.

4. After calibration has been completed, the laboratory specialists check the plausibility of the measured data. In the event of deviations, the calibration procedure may be repeated or the equipment may be repaired.

5. If the results of the plausibility check are acceptable, a calibration certificate and documentation are issued in accordance with the applicable norms and standards. Finally, the equipment which has been calibrated is labeled. Labeling normally includes a recommendation of the next due date and clear identification of the laboratory which has performed the calibration.

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Factory calibration label

Accredited calibration label (scale: 1:1)
8. Calibration and machine capability certificates

Calibration certificates are issued for measuring instruments and machine capability certificates are issued for tools. What information should a certificate include?

The information to be included in an accredited calibration certificate is clearly defined. The minimum requirements are as follows:

- Unique identification of measuring instrument
- Calibration date
- Customer and customer’s address
- List of references and information on traceability to national standards
- Calibration procedure / norm
- Ambient conditions
- Achieved calibration results, if applicable, before and after adjustment or repair
- Measurement uncertainty
- Validity interval
- Adjustment value (calibration value) determined
- Possible restrictions on use (depending on results)
- Individual calibration number for the measuring instrument
- Unique identification of the accredited calibration laboratory
- Names and signatures of persons who performed calibration
- Name and signature of calibration laboratory manager or his deputy

As factory calibrations are the sole responsibility of the calibration laboratory, the factory calibration certificates issued may differ substantially. There are currently no binding requirements and the certificate issued may range from a simple sales slip without signature or stamp to a comprehensive calibration certificate of several pages.

You will find sample accredited calibration and machine capability test certificates in the appendix.
However, even in the case of a factory calibration, professional calibration laboratories offering a high-quality service will ensure that the certificates include at least the following information:

- Unique identification of measuring instrument
- Calibration date
- List of references
- Calibration procedure / norm
- Calibration results
- Individual calibration number for the measuring instrument
- Ambient conditions
- Identification of institute and signature of person who performed calibration

The certificate issued for a machine capability test (see page 15) should be similar to a calibration certificate and should include at least the following information:

- Unique identification of tool
- Customer and customer’s address
- Test date
- List of references
- Test procedure / standard
- Maximum, minimum, specified target and measured values
- Adjustment value
- Defined error limits
- Determined $C_m$ and $C_{mk}$ values
- Identification of institute and signature of person who performed calibration

Label for machine capability test and/or maintenance.
9. Calibration intervals

Frequently, customers ask about calibration intervals required for measuring instruments and test equipment. It is not possible to give a general answer to this question as calibration always represents a snapshot of current conditions. The calibration intervals required depend on a number of factors including the following:

- Quantity measured
- Admissible tolerances
- Conditions of measuring instruments and test equipment
- Stability of past calibrations
- Measurement accuracy required
- Quality assurance requirements
- Ambient conditions

This means that calibration intervals depend on the user and the specific application and need to be individually determined and monitored. Normally, the company’s quality manager is responsible for this task. In the case of new measuring equipment, it may be beneficial to change the calibration intervals gradually to reflect actual conditions. In this approach, calibration intervals are initially set to a relatively short period. The time interval for subsequent calibrations can then be extended or shortened, depending on the long-term stability of the calibration results. However, in many cases, annual calibration is appropriate for measuring instruments and references.
10. Who is allowed to carry out calibrations??

There are almost no limits on who can perform calibrations. When selecting a calibration company or laboratory, you should make sure that you select a professional partner that applies appropriate procedures. As calibration is not a legally protected procedure, there are many players on the market who do not offer a professional service. Rather, there are some low-budget calibration suppliers offering calibration services of highly dubious quality.

In fact, it is not just the calibration label on the equipment that is important. The following questions also need to be considered:

1. Have all the measuring ranges of the calibration object been correctly measured?

2. Are the results within the specific range of the laboratory? (Laboratories are certified with respect to measurement ranges and measurement uncertainties. If you indicate higher accuracy than you are actually able to measure, this does not indicate a professional approach.)

3. In technical terms, is the laboratory in a position and competent to perform the calibration?

4. Do you receive a comprehensive measurement report (see section 8, page 19) or only a calibration certificate that does not provide calibration results and measurement uncertainties?

5. Have safety tests and tests of functions been performed?

A good way of ensuring safe and reliable calibration services is to select an accredited calibration laboratory. However, you should pay attention to the measured dimensions (temperature, torque, force, etc.) for which the laboratory is accredited. Not every calibration carried out by an accredited laboratory is in fact an accredited calibration.

As a general principle, accredited laboratories offer considerable metrological competence. A conformity procedure ensures that only validated measurement methods and properly traceable measuring instruments are used for calibrations. Accredited laboratories are continuously monitored by national accreditation body and therefore ensure high quality in calibration services at all times.

You will find a check list for the selection of an appropriate calibration service provider in the appendix (page 50).
11. Special considerations for calibration work in connection with tightening systems

For calibration work on tightening systems, there are two measured dimensions that are especially important: torque and rotational angle. These two dimensions may be considered either separately or in combination.

**Torque**

In connection with tightening systems, torque calibration is the most widely used approach to ensure the proper functioning of the measuring instruments used and the quality of bolted joints. It is normal practice to use measuring instruments in production to determine the quality achieved by a tightening tool.

**Rotational angle**

Rotational angle calibration is important in connection with rotational angle-controlled tightening procedures. In practice, these procedures are not yet used as frequently as torque-controlled tightening procedures, but they are very useful in certain applications and are becoming increasingly important. If you use the rotational angle to control the tightening process, you must also calibrate the rotational angle in order to ensure that the measurements (and so the bolted joints) are correct.

**Torque and rotational angle**

As bolted joints become more complex, the topic of rotational angle calibration becomes more important for companies. Especially in the case of safety-critical joints (category A joints defined by VDI 2862), it is necessary to document a monitoring variable in addition to the control variable (for example, torque). In such cases, rotational angle is often the most practicable solution. Examples of safety-critical bolted joints can be found in safety belt or airbag installations in cars or on the rotor blades of wind turbines. If these bolted joints fail, there is a direct risk of injury or death.

Torque/rotational angle plots: the bolted joints can only be OK if both variables are OK at the same time (bottom graph). \( M_d \) stands for torque and the Greek letter phi (\( \phi \)) stands for rotational angle.
In the case of bolted joints tightened with a combined torque and rotational angle procedure, both values – torque and rotational angle – must be within the specified “window”; otherwise, the bolted joint as a whole cannot be rated as OK (see graphs on page 23).

Rotational angle calibration is performed according to the standard VDI/VDE 2648 (see page 11). A distinction is made between direct measuring systems such as torque and rotational angle sensors (VDI/VDE 2648, Part 1) and indirect measurement systems such as torque and rotational angle wrenches (VDI/VDE 2648, Part 2).

In the first case, with direct measurement systems, the procedure involves defining a 0° point and making measurements in different steps from this point.

In the case of indirect measurement systems, the matter is rather more complicated. High-quality torque and rotational angle wrenches operate with gyroscopes of the type used in aircraft. These instruments do not have a defined 0° point. For this reason, they are also referred to as no-reference systems. The calibration of such systems is highly complex and can only be carried out by a few accredited laboratories with special equipment. During such calibration work, the rotational angle is measured under a torque load.

Please make sure that rotational angle calibration of transducers or wrenches is only performed in connection with torque calibration. Torque calibration is used as a basis for the determination of certain key parameters.

Rotational angle calibration system for direct and indirect measurement systems.
12. Special case
hydraulic torque wrenches

Hydraulic torque wrenches are frequently used in plant construction, in the chemical and petrochemical industry, in pipeline construction and in the assembly of wind power systems. These tools use high oil pressures to achieve very high torque levels, which are often considerably above 20,000 N·m. However, hydraulic torque wrenches operate very slowly, which is why they are almost only used for final tightening stages. They are very different from the electric controlled nutrunner systems described in previous chapters. These controlled systems are normally operated in two stages, with a very fast rundown stage followed by a significantly slower and more accurate final tightening stage.

Hydraulic torque wrenches are driven and controlled by special pump units with oil pressure of up to 700 bar. The pump pressure itself is set using a pressure gauge; the pressure is used as a means for setting an approximate torque value. The pressure and torque relation is defined based on a table supplied with the wrench unit (pressure versus torque) (see next page).

Dynamic testing is not possible, still testing is crucial

These tools are often used for critical applications and therefore need to be inspected and tested just like normal electric or pneumatic nutrunners. However, dynamic testing in accordance with VDI/VDE 2647 or 2645 is not meaningful as dynamic processes cannot be directly measured, which would be the case with an electric control-
led tightening system. On the contrary, the tightening process is almost static as the final tightening stage only covers an angle of a few degrees.

As a result, there are many service providers on the market who work in very different ways, some of which are not professional. In addition, a variety of different test procedures are used which do not even meet the basic requirements for ensuring proper functioning and appropriate results.
**Testing norms and standards expected in the near future**

National committees are currently working intensively on a standard for the testing of hydraulic torque wrenches.

It is recommended to obtain regular updates to VDI/VDE and ISO standards. Until a standard has been issued, it is extremely important to ensure that the test procedures used, at least meet the requirements concerning the traceability and repeatability of the test results.

Some of the test procedures currently used, which are not recommended, test the hydraulic torque wrench in a single measurement series from minimum to maximum torque. The torque measured is then compared with the pressure indicated by the pressure gauge. These procedures are not suitable for verifying the repeatability and proper operation of the wrench. In addition, there are very few test systems which can perform measurements above 20,000 N·m. As a result, torque wrenches which operate above this torque range can only be tested up to the maximum torque level of the testing system. Higher torque levels are extrapolated.

It is clear that approaches of this type are unprofessional and also extremely dangerous because the user cannot be sure that the torque wrench will function properly in higher torque ranges. This also applies to testing procedures which only involve measurements at two or three measuring points and simply interpolate the other values in order to save time and money. As the test procedures used have not yet been standardized, approaches of this type are unfortunately very common on the market. Users therefore need to check their service providers closely.

If traceable measured values are not available and the testing procedure is not documented, it will be difficult to provide evidence that a manufacturer has ensured a secure process chain without any gaps in product liability proceedings.
A revised and expanded edition of VDI 2862 has been issued at the end of 2013. Apart from the use of tightening tools, this standard also defines requirements for the classification of tightening operations, not only for the automobile industry, as was previously the case, but also for the general industry, where hydraulic torque wrenches are frequently used.

Therefore, manufacturers are under an obligation to document tightening results of hydraulic nutrunners and to perform regular tests, especially if they are used for category A bolted joints (= classification of bolted joint as “safety-critical” because there is a risk of death or injury in the event of failure). Bolted joints are often crucially important for safety, not only in industrial plants and wind farms. In petrochemical plants too, faulty bolted joints pose a considerable risk of environmental damage that can lead to severe liability issues.

Hydraulic torque wrenches are frequently used in the process and wind power industry.
13. What type of testing or calibration makes sense?

In order to answer the question of what type of testing or calibration service makes sense for an individual user, it is necessary to draw a distinction between nutrunners used for dynamic processes on the one hand and measuring and testing equipment on the other hand. By definition, it is not possible to “calibrate” a tool. In most cases, “tool calibration” refers to a comparison measurement or a machine capability test (see page 15). On the other hand, both accredited and factory calibrations can be performed on measuring and testing equipment such as torque transducers.

As a general recommendation, tests should be carried out at regular intervals on all machines and tools used for a production process. Preferably, a machine capability test should be performed.

Homologation (see page 16) is only recommended if it is specifically required or if there are reasons to suspect that the tool has caused quality problems. Homologation tests are very extensive and provide information that are far more comprehensive than a machine capability test. Homologations are performed in accordance with VDI/VDE 2647 and can be used for the type approval of a specific tool type.

In the case of transducers, accredited calibrations are normally recommended. ISO 9000/9001 requires measuring equipment to be calibrated in a traceable way. Accredited calibrations meet these requirements at all times and the calibration certificates issued are internationally recognized; this often saves additional costs.

Where there is no specific requirement for calibration based on quality standards, factory calibrations are recommended. In addition, there are some measuring dimensions for which the accreditation bodies do not yet issue accreditations, such as ultrasound. In this case too, factory calibration is a feasible alternative.

Transducers and other measuring equipment that are used as reference standards must always be subject to accredited calibration. Otherwise, traceability to national reference standards is not ensured. This traceability is normally the sole purpose of reference equipment.
14. Quality assurance, liability and environmental protection

“Quality” is a term that is widely used in a number of very different contexts. Sometimes, the term is even used to deliberately mislead customers and to give them a false sense of security. The introduction of the ISO 9000 ff. standards at least provided a first definition which is of considerable importance for manufacturing industry. On this basis, it is possible to assess quality using defined benchmarks and to make comparisons. For both, consumers and producers, this means greater security.

How can you ensure continuously high quality? The ISO 9000 ff. standards provide answers and practical hints. Organizations and companies certified on the basis of this series of standards commit to comply with defined procedures. For example, properly working measuring equipment is an essential requirement. All measuring equipment and references must be calibrated at regular intervals and such calibrations must be documented.

Quality assurance lays the foundation for product liability. Product liability describes the liability to pay damages for delivering defective goods and for damages caused by such. Initially, every customer might claim compensation if it can be proven, that the manufacturer is responsible for the faulty goods. The Product Liability Act is based on EC Directive 85/374 EC, which has now been implemented in all the member states of the EU; similar laws are implemented in other countries worldwide.

The Product Liability Act applies to all companies and organizations selling or distributing products in the European Union. The effects of product liability are especially dramatic in the USA, where huge amounts of damages may be awarded in the case of defective goods or products. Less spectacular but often equally costly are the recall campaigns frequently announced by manufacturers and importers. Product liability for a period of up to 60 years is not unusual in the automotive and aerospace industries. In connection with the Product Liability Act, manufacturers must select suitable measuring equipment for the measurement tasks involved, need to keep full documentation of the proper use of such equipment and need to implement systematic measuring equipment control procedures. This obligation also calls for companies to keep precise documentation and to maintain measurement standards which have been used. Producers who have complied with all these requirements will find it easier to defend themselves against product liability claims.
Quality is not only connected with product safety and responsibility, but also with environmental aspects. Properly tested measuring equipment and tools are also a prerequisite for efficient, environmental friendly production. This is why environmental protection is increasingly becoming an integral component of the entire product life cycle from design and development through use to disposal and recycling. Environmental management systems are audited and certified in accordance with ISO 14 001.
15. Industry requirements

In industry, mainly carmakers have played a pioneering role in quality assurance and safety. Automobile industry requirements are often gradually accepted and implemented as standard procedure in other sectors of industry.

What does industry actually require? One of the key elements, in accordance with the standards series ISO 9000 to 9004 concerning quality assurance, is the management of measuring equipment. This approach is intended to ensure that all the measuring instruments relevant for product quality actually function properly. For this purpose, measuring equipment needs to be calibrated regularly. Such calibrations must be traceable to national standards. In addition, the measured results must be documented.

The traceability of calibration results to the national standards is often attested by many laboratories issuing a factory calibration certificate. However, the international recognition of such certificates became increasingly questionable in view of the proliferation of unqualified calibration service providers. For this reason, ISO 9000 auditors increasingly call for calibration certificates issued by an organization participating in the International Laboratory Accreditation Cooperation (ILAC, see page 37).

For instance, DAkkS is accredited as the German member organization and is accepted not only within the European Union but also in most countries worldwide. This ensures compliance with all relevant requirements concerning the competence of calibration providers.

Even though certification to ISO 9001 is regarded as a minimum requirement in most sectors, such certification is often insufficient. In the automobile industry the main trend is towards ISO/TS 16 949. This standard combines the requirements of various national standards and is based on ISO 9001. The standard is recognized by virtually all the world’s carmakers and indicates a way out of the certification maze apparent in the automobile industry. Formerly, multiple certifications were often required as different standards applied in various European countries and America (for example QS 9000 in the USA, VDA 6.1 in Germany, EAQS in France and AVSQ in Italy).
Major carmakers such as Daimler, General Motors and Ford have decided only to award contracts to suppliers who are certified to ISO/TS 16 949 (see box below). As a result, ISO/TS 16 949 automatically applies to the entire automobile industry supply chain and to both direct and indirect suppliers. Transitional periods have been allowed for existing certificates. The validity of these certificates is also limited by the expiry of other standards. A changeover to ISO/TS 16 949 is therefore urgently recommended in view of the need for worldwide recognition by major carmakers.

ISO/TS 16 949 contains a direct reference to ISO/IEC 17 025 (General requirements for the competence of testing and calibration laboratories), a standard which states clear requirements for calibration laboratories. In the standard, it is stressed that the introduction of a quality management system in accordance with ISO 9001 is not sufficient for a calibration laboratory because ISO/IEC 17 025 lays down technical competence requirements which are not covered by ISO 9001. The calibration laboratory must therefore not only operate a quality management system but also demonstrate that it is technically competent. This means that the laboratory must be in a position to meet minimum technical requirements and to achieve technically well-founded results.

The standard also states that top management must ensure that suitable communication processes are in place within the laboratory and that communications concerning the effectiveness of the management system take place. The laboratory must also ensure that feedback is received from its customers; this refers to both positive and negative information. This information flow is intended to ensure the improvement of the management system, testing and calibration activities and the benefits to customers. ISO/IEC 17 025 specifically requires the continuous improvement of the entire laboratory management system.
Asset Management

Apart from the standards mentioned previously, it is also necessary to refer to ISO 10 012 in the context of measurement and calibration for tightening systems.

This standard states general requirements for the handling and metrological confirmation of measuring equipment. The standard also contributes to effective management of measuring equipment and to determine whether this equipment and measurement processes are suitable for the intended purpose. A sufficient asset management system is essential for product quality and in order to minimize the risk of incorrect measurement results.

The purpose of management of measuring equipment is to create confidence in the measuring results. In this way, quality fluctuations in products and services are prevented. ISO 10 012 is often used for the definition of product properties and for the assessment and auditing of asset management systems.

In particular, ISO 10 012 states specific requirements for the calibration of all measuring instruments using traceable standards. Companies are required to maintain documentation of all calibrations performed within the traceability chain. It is also necessary to ensure that all measuring instruments are securely and permanently marked in order to indicate the status of calibration. Such marking must clearly indicate the deadline for the next calibration of the measuring instrument. The standard also defines minimum requirements for the information to be provided in calibration certificates.

Annual accredited calibrations meet all the requirements of industry stated previously as well as many other requirements and save a considerable amount of effort and trouble. Calibrations by accredited laboratories give the user confidence that the measurement results are reliable, and also enhance confidence levels among customers and the competitiveness of the companies concerned on the national and international market. Accredited calibration ensures results that are internationally comparable and are audit proof.
16. Benefits of measurement and calibration

Measurements and calibrations indeed cost some time and money, which is why it is important to know what the effects are and what specific benefits these services bring to your company.

The main benefits are as follows:

- Security for the manufacturer or supplier
- Security for the user
- Defined measurement uncertainty
- Quality assurance in production
- Compliance with quality standards
- Higher customer satisfaction
- International recognition (with accredited certificates)
- Compliance with stringent requirements such as those of the automobile industry

However, the most important point is probably:

- Evidence in connection with product liability

These benefits are essential for virtually any company.

At first glance, measurements and calibrations are often seen as a waste of time and a cost factor. However, this view changes as soon as a manufacturer has to bear liability for its products. In comparison with impending claims for damages, the cost of thorough testing or calibration is of secondary importance and can be seen as a highly cost-effective investment. This means that the high-quality testing of tools and the calibration of measuring equipment are essential for companies who want to operate professionally on the market in the long term and at the same time maintaining high levels of customer satisfaction.
17. Further information sources

Further information on calibration is available on the Internet:

**www.atlascopco.com**  
Atlas Copco, your competent one-stop calibration service provider, offers a full service including measuring equipment management.

**www.european-accreditation.org**  
Association of the European certification organizations with the objective of mutual recognition. DAkkS is a member of EA.

**www.ilac.org**  
ILAC: International Laboratory Accreditation Cooperation. The EA is a member of the ILAC. As a result, accredited certificates are recognized by the ILAC members.

If you have any questions concerning this topic, please do not hesitate to contact your Atlas Copco Service contact: [www.atlascopco.com](http://www.atlascopco.com)

We will be pleased to inform you about our professional training in topics including calibration measurement. These and other courses can be adapted to your specific requirements and can also be held on site at your facilities (*see also page 40*).

**Appendix:** from page 42, you will find sample machine capability tests and accredited calibration certificates as well as a check list for the selection of calibration service providers.
18. Your calibration service: 
with guaranteed certification and 
accreditation

Atlas Copco Tools is your calibration partner. As an expert in tightening tools and quality assurance equipment, we want to support you in calibrating your measurement equipment so that you can concentrate on your core activities. We perform both accredited and factory calibrations.

All the references and standards used by Atlas Copco Tools for calibration are calibrated on a regular basis, directly traceable to the national standards and measurement systems.
19. Our logistics solutions

Re-usable transport system and collection service

Atlas Copco Tools offers transport options tailored to meet your specific needs, from insured shipment with tracking functions through to collection and delivery services. We ensure that your valuable measurement equipment is handled safely, efficiently and environmentally friendly.

We offer the following options:

Standard shipment: You can check the shipment status of your measurement equipment at all times. Upon request, we can also ship equipment by overnight express.

Re-usable transport system: You just call us and we collect your equipment, which is shipped and returned to you in a re-usable shipment box. You retain the box until you need it the next time. We assume full responsibility for shipment. This solution is easy to use and reduces administrative expenses for our customers.

Collection and delivery service: If you require special attention for your measurement equipment, we offer a collection and delivery service with trained drivers. You can be sure that your measurement equipment is in safe hands.
20. Training, seminars and workshops

Atlas Copco offers a large number of training courses, seminars and workshops to refresh and enhance the expert knowledge of our customers. For example, we hold a seminar on “quality management – calibration for tightening systems”.

Seminar: quality management – calibration for tightening systems

This seminar deals with the calibration of measurement equipment in connection with machine capability tests on tightening tools. The program includes presentations and practical exercises. Participants enhance their specialist knowledge in the following fields: calibration and machine capability tests; norms, standards and regulations for tightening and calibration systems; calibration with reference to product liability and product safety; tightening processes with reference to calibration; measurement equipment capability; check measurements; basic principles of statistics in this area.

Main focuses of seminar:
- Significance of calibration and machine capability test
- Types of calibration and tests
- Norms and standards
- Calibration and testing in practice
- Differences between machine capability test, calibration and adjustment
- Reading and interpreting certificates
- How to distinguish between good, professional certificates and suspect certificates

Experts from Atlas Copco Tools prepare participants for impending ISO or certification audits in workshops tailored to customers’ specific requirements.
Zertifikat

Kunde: Muster GmbH
Zertifikat-Nr.: 40092304

Gegenstand der Prüfung
Test Object

Hersteller: ATLAS COPCO TOOLS AB
Maschinentyp: ETV E561-100-B13
Steuerung: Serien-Nr.: 5699378
Controller: Serien-Nr.: A4450252
Sonderantrieb: Serien-Nr.: -
Crawfort: -

Mfd- min 40 Nm
max 100 Nm
Test-Mfd 100 Nm

Motor: Serien-Nr.: -
Motor: Serien-Nr.: -
DrehmomentSensor: Serien-Nr.: -
Drehwinkelsensor: Serien-Nr.: -
Angle encoder: Serien-Nr.: -

Artikelnr.: Artikelnummer:
TC-Factor: 0,000

Referenz (Gebrauchsnormal)
Reference:

Hersteller: ATLAS COPCO
Prüferät: JSB 3800 (Local)
Sensor: 3 - Brake - 25-250 Nm

* Die Messunsicherheit der Gegenmessung beträgt 1%. Die Ergebniswerke wurden mit der oben genannten Gegenmessung ermittelt.
* The uncertainty of the measuring device is 1%. All results are measured with the testing device mentioned above.

Die Prüfung des Werkzeuges erfolgte auf einer Messbank. Das Werkzeug wurde in der Messvorrichtung werkseitig und unabhängig fixiert. Das Tool of the tool was performed on a simulator bench. The test object was fixed on a mounting plate.

Das Verfahren zur Prüfung der Maschinenfahigkeit erfolgte dynamisch und in Anlehnung an die Richtlinie VDI/VDE 2547.
The process of testing the machine capability was done dynamically and in accordance with the guideline VDI/VDE 2547.

This certificate documents the traceability to national standards which implement the unit of measurement according to the International System of Units (SI). Traceability of the stated results is given through the accredited laboratory D-K-17447-01.

Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich. Es wird empfohlen diese aber alle 12 Monate zu wiederholen.
The user is obliged to have the device recalibrated at appropriate intervals. It is recommended to repeat this every 12 months.

Prüfdatum: 28.01.2015
Bearbeiter: D. Kubulik
Druckdatum: 29.01.2015

Internet: www.atlascopco.de
Fax: +49 (0) 201 - 21 77 - 197
Tel.: +49 (0) 201 - 21 77 - 0

Kaltnerdienst.de
cal-service@de.atlascopco.com

Atlas Copco Tools Central Europe GmbH
Langenmarckstraße 35
45141 Essen
# Zertifikat

**Certificate**

**Hersteller**: ATLAS COPCO TOOLS AB  
**Manufacturer**: 

**Maschinenmodell**: ETV ES61-100-813  
**Machine model**: 

**Steuerung**: Power Focus 600  
**Controller**: 

## Vorgegebene Werte zum Schraubfall [N·m]

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## Statische der Referenz

**Statische der Referenz**

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## Toleranzklasse

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<th>Cm</th>
<th>Cerr</th>
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**Ergebnisse [N·m] für den Schraubfall 30°**

**Ergebnisse [Grad] für den Schraubfall 30°**

**Statische der Referenz**

**Toleranzklasse**

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**Measurement and Calibration for Tightening Systems**
Kalibrierlaboratorium für mechanische, elektrische, thermodynamische und dimensionelle Messgrössen
Calibration laboratory for mechanical, electrical, thermodynamic and dimensional measuring quantities

Atlas Copco
Sustainable Productivity

akkreditiert durch die / accredited by the
Deutsche Akkreditierungsstelle GmbH
als Kalibrierlaboratorium im / as calibration laboratory in the
Deutschen Kalibrierdienst

DKD

Kalibrierschein

Calibration certificate

Kalibrierzeichen
Calibration mark

<table>
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<tr>
<th>EN376</th>
<th>D-K-17447-01-02</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>2013-05</td>
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Gegenstand:
Object:
Drehmomentsensor

Hersteller:
Manufacturer:
Atlas Copco BLM

Typ:
Type:
IRT-B 500A-20

Fabrikat/Serien-Nr.
Serial number:
43300080

Auftraggeber:
Customer:
Musterfirma GmbH
Teststrasse 12
D - 35578 Wetzlar

Auftragsnummer:
Order no.:
40000944

Anzahl der Seiten:
Number of pages:
4

Datum der Kalibrierung:
Date of calibration:
2013-05-14

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normen zur Darstellung

Die DAkkS ist Unterzeichner der multilateralen Übereinkommen der European cooperation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.

Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der

Benutzer verantwortlich.

This calibration certificate documents the traceability to national standards, which realize

the units of measurement according to the International System of Units (SI).

The DAkkS is a signatory to the multilateral agreements of the European cooperation for Accreditation (EA) and the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.

The user is obliged to have the object recalibrated at appropriate intervals.

Datum
Date
2013-05-23

Leiter des Kalibrierlaboratoriums
Head of the calibration laboratory

Annika Kranz

Person in charge

Atlas Copco Tools Central Europe GmbH
cal-service@de.atlasconcopco.com
cal-service@de.atlasconcopco.com
Langenmarktstr. 35
D - 45141 Essen
Fon: +49 (0)201 / 2177 - 767
Fax: +49 (0)201 / 2177 - 197

www.kalibrierdienst.de
www.atlasconcopco.de
## Measurement and Calibration for Tightening Systems

**EN376**

D-K-
17447-01-02

2013-05

**Seite 2 zum Kalibrierschein vom 2013-05-23**

**Page 2 of the calibration certificate from 2013-05-23**

---

**In case of doubt the German text of this certificate is valid.**

### 1 Kalibrierverfahren / Calibration Procedure:

DIN 51300:2005-12 Klasse 1

### 2 Kalibrierbezeichnung / Calibration device:

2M-m - Drehmoment-Bezugsnormalmessung

#### 2.1 Messunsicherheit für jede Drehmomentwerte in % / Uncertainty of measurement related to torque in %:

<table>
<thead>
<tr>
<th>Torque in N-m</th>
<th>Exp. Uncertainty ( (k = 2) ) in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0,1</td>
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<tr>
<td>200</td>
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<tr>
<td>400</td>
<td>0,1</td>
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<tr>
<td>500</td>
<td>0,1</td>
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</table>

#### 2.2 DKD Bezugsnormal / Reference transducer:

TT 1 - 1 000 Nm, 36762-04

#### 2.3 Anzeigegerät / Indication device:

MCG+ mit ML30, Ch1

##### Hersteller / Manufacturer:

DNF #010008

##### Speiseanspannung / Supply voltage:

5V

##### Filtereinstellung / Filter settings:

1,5 Hz Bessel

##### Auflösung / Resolution:

0,000001

##### Anzeigeinheit / Indication unit:

mV/V

### 3 Kalibriergegenstand / Calibration device:

IPTT-B 500A-20, 43300980

#### 3.1 Anzeigegerät / Indication device:

MCG+ mit ML30, Ch2

##### Hersteller / Manufacturer:

DNF #010008

##### Speiseanspannung / Supply voltage:

5V

##### Ziffernansicht / Numerical resolution:

0,01

##### Anzeigeinheit / Indication unit:

N-m

### 4 Kalibrierwert alt / calibration value old:

453,40 Nm

### 5 Kalibrierwert neu / calibration value new:

454,03 Nm

---

**Atlas Copco Tools Central Europe GmbH**

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www.kalibrierdienst.de

www.atlascopco.de

---

Measurement and Calibration for Tightening Systems 45
8 Auswertung / Analysis
8.1 Kalibrierergebnis / Calibration results

<table>
<thead>
<tr>
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<th>Fall II / case II</th>
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<tbody>
<tr>
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<td>rel. Uns.-interval/ rel. uncert. interval k = 2</td>
<td></td>
</tr>
<tr>
<td>Signal / signal</td>
<td>in Nm</td>
<td>in %</td>
</tr>
<tr>
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<td>-----------------</td>
<td>-----------------</td>
</tr>
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Entriegelwinkel / anti-clockwise torque

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<th>Drehmoment / torque</th>
<th>Fall I / case I</th>
<th>Fall II / case II</th>
</tr>
</thead>
<tbody>
<tr>
<td>in Nm</td>
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<tr>
<td>Signal / signal</td>
<td>in Nm</td>
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</tr>
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<td>200</td>
<td>199.86</td>
<td>0.345</td>
</tr>
<tr>
<td>300</td>
<td>299.94</td>
<td>0.226</td>
</tr>
<tr>
<td>400</td>
<td>400.08</td>
<td>0.106</td>
</tr>
<tr>
<td>500</td>
<td>500.28</td>
<td>0.020</td>
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</table>

Entriegelwinkel / anti-clockwise torque

8.2 Klasseneinstufung nach DIN 51309:2005 / Classification according to DIN 51309:2005

<table>
<thead>
<tr>
<th>Klasse / Class</th>
<th>ven / from</th>
<th>bis / to</th>
<th>ven / from</th>
<th>bis / to</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in Nm</td>
<td></td>
<td>in Nm</td>
<td></td>
</tr>
<tr>
<td>Rechtsdrehmoment / clockwise torque</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>500</td>
<td>100</td>
<td>500</td>
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<table>
<thead>
<tr>
<th>Klasse / Class</th>
<th>ven / from</th>
<th>bis / to</th>
<th>ven / from</th>
<th>bis / to</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in Nm</td>
<td></td>
<td>in Nm</td>
<td></td>
</tr>
<tr>
<td>Linksdrrehmoment / anti-clockwise torque</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
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<tr>
<td>5</td>
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</table>

9 Kennwerte nach DIN 51309:2005 / Classification criteria according to DIN 51309:2005

<table>
<thead>
<tr>
<th>Fall I / case I</th>
<th>Fall II / case II</th>
</tr>
</thead>
<tbody>
<tr>
<td>M_K in Nm</td>
<td>D / \gamma</td>
</tr>
<tr>
<td></td>
<td>\gamma E / \gamma E</td>
</tr>
<tr>
<td></td>
<td>\gamma R / \gamma R</td>
</tr>
<tr>
<td>500</td>
<td>0.134</td>
</tr>
<tr>
<td>400</td>
<td>0.175</td>
</tr>
<tr>
<td>300</td>
<td>0.217</td>
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<tr>
<td>200</td>
<td>0.201</td>
</tr>
<tr>
<td>100</td>
<td>0.401</td>
</tr>
<tr>
<td>0</td>
<td>0.090</td>
</tr>
</tbody>
</table>

Angenommen ist die erweiterte Messunsicherheit, die sich aus der Standardmessunsicherheit durch Multiplikation mit dem Erweiterungsfaktor k=2 ergibt. Sie wurde gemäß DAkkS-DKD-3 ermittelt. Der Wert der Messgröße liegt im Regelfall mit einer Wahrscheinlichkeit von annähernd 95% im zugeordneten Wertebereich.

Stated is the extended measurement uncertainty which results from the standard measurement uncertainty multiplied by the extension factor k=2. Determined according to DAkkS-DKD-3. Generally, the reading is located in the associated range with a probability of approx. 95%.

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Fax: +49 (0) 201 / 2177 - 197
cal-service@de.atlascopco.com
www.atlascopco.de
**Measurement and Calibration for Tightening Systems**

**Sample calibration certificate, page 4**

10 **Messdaten / measuring data in N·m / Rechtsdrehmoment / clockwise torque**

<table>
<thead>
<tr>
<th>N·m</th>
<th>0</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0,01</td>
<td>0,06</td>
<td>0,06</td>
<td>0,00</td>
<td>0,24</td>
<td>0,54</td>
</tr>
<tr>
<td>1</td>
<td>0,00</td>
<td>99,55</td>
<td>199,55</td>
<td>299,61</td>
<td>399,73</td>
<td>500,55</td>
</tr>
<tr>
<td>2</td>
<td>0,00</td>
<td>99,73</td>
<td>199,85</td>
<td>300,06</td>
<td>400,26</td>
<td>500,45</td>
</tr>
<tr>
<td>3</td>
<td>0,00</td>
<td>100,04</td>
<td>200,17</td>
<td>300,26</td>
<td>400,45</td>
<td>500,53</td>
</tr>
<tr>
<td>4</td>
<td>0,00</td>
<td>100,19</td>
<td>200,35</td>
<td>300,45</td>
<td>400,6</td>
<td>500,53</td>
</tr>
</tbody>
</table>

**Linksdrehmoment / anticlockwise torque**

11 **Darstellung der Ergebnisse in Diagrammen / Results in diagrams**

**Bezugswert / Reference value:** 500,00 N·m

- Abweichungen bezogen auf den Endwert / deviation relative to max. calibration torque
- Interpolationsabweichung v. M. / interpolation error relative to actual value

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Fon: +49 (0)201 / 2177 - 767  
Fax: +49 (0)201 / 2177 - 197

www.kalibrierdienste.de  
www.atlascopco.de

**cal-service@de.atlascopco.com**
<table>
<thead>
<tr>
<th>Check list for selection of calibration service providers</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conformity with standards</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Is the calibration service provider accredited to ISO/IEC 17 025? (Requirement of ISO/TS 16 949)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Does the calibration service provider have an accredited quality management system (for example in accordance with ISO 9001)?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Is calibration carried out precisely in accordance with norms and standards (and not “on the basis of…”)?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Is the calibration laboratory accredited for the dimensions required by the customer, such as torque or rotational angle?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Is the calibration procedure validated (for example in accordance with DIN 51 309)?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Are safety tests and tests of functions performed prior to calibration?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td><strong>Measurement uncertainty</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Is measurement uncertainty indicated?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Is measurement uncertainty confirmed by a calculation model?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Is measurement uncertainty adequate in view of the customer’s application?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Are the items to be calibrated and calibration systems acclimatized prior to calibration??</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Is the traceability of the transfer standards ensured?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Are the transfer standards recalibrated following each shipment?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Are the measured values within the accredited range of the laboratory (for example 1 to 5,000 N·m)?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td><strong>Personnel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Are there any documents concerning the metrological expertise of the service provider?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Do the qualifications of the laboratory manager and laboratory personnel meet the requirements of ISO/IEC 17025?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Is the qualification status of the calibration laboratory documented?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Have the employees been examined by independent experts?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>• Does the service provider have several years of calibration experience?</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

(continued on page 51)
### Check list for selection of calibration service providers

(Continued from page 50)

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

#### Certificate

Does the calibration certificate include all the information required?

- Identification of measuring instrument
- Calibration date
- Information on traceability
- List of calibration equipment
- Written standard used for calibration
- Information on measurement uncertainty
- Calibration results
- Defined error limits
- Ambient conditions
- Name and signature of person who performed calibration

#### Insurance

- Does the calibration service provider hold product liability insurance that also covers recall campaigns?

---

*There is no need to worry about the quality and reliability of your calibration service provider if (and only if) you can answer virtually all these questions with “yes”.*
COMMITTED TO SUSTAINABLE PRODUCTIVITY

We stand by our responsibilities towards our customers, towards the environment and the people around us. We make performance stand the test of time. This is what we call – Sustainable Productivity.

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www.atlascopco.com