INTERNATIONAL STANDARD

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Welding — Calibration, verification and validation of equipment used for welding, including ancillary activities

Soudage — Étalonnage, vérification et validation du matériel utilisé pour le soudage, y compris pour les procédés connexes

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 17662 was prepared by the European Committee for Standardization (CEN) in collaboration with Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 10, *Unification of requirements in the field of metal welding*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Throughout the text of this document, read "...this European Standard..." to mean "...this International Standard...".

Annex ZA provides a list of corresponding International and European Standards for which equivalents are not given in the text.

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Foreword

This document (EN ISO 17662:2005) has been prepared by Technical Committee CEN/TC 121 “Welding”, the secretariat of which is held by DIN, in collaboration with Technical Committee ISO/TC 44 "Welding and allied processes".

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2005, and conflicting national standards shall be withdrawn at the latest by September 2005.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

This standard specifies requirements to calibration, verification and validation of equipment used for:

– control of process variables during fabrication,

or

– control of the properties of equipment used for welding or welding allied processes,

where the resulting output cannot be readily or economically documented by subsequent monitoring, inspection and testing. This regards process variables influencing the fitness-for-purpose and in particular the safety of the fabricated product.

NOTE 1 The standard is based on the lists of process variables stated in standards for specification of welding procedures, in particular, but not exclusively on the EN ISO 15609 series of standards. Future revisions of these standards can result in addition or deletion of parameters considered necessary to specify.

Some guidance is, in addition, given in annex B as regards requirements to calibration; verification and validation as part of acceptance testing of equipment used for welding or allied processes.

Requirements to calibration, verification and validation as part of inspection, testing, non-destructive testing or measuring of final welded products performed in order to verify product compliance are outside the scope of the present standard.

The subject of the standard is limited to calibration, verification and validation of equipment after installation, as part of the workshops' schemes for maintenance and/or operation.

NOTE 2 It should be stressed that the standard has nothing to do with manufacture and installation of equipment for welding. Requirements to new equipment are formulated in directives and product codes (standards), as necessary.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 562, *Gas welding equipment — Pressure gauges used in welding, cutting and allied processes*

EN 729-1, *Quality requirements for welding — Fusion welding of metallic materials — Part 1: Guidelines for selection and use*

EN 729-2, *Quality requirements for welding — Fusion welding of metallic materials — Part 2: Comprehensive quality requirements*

EN 729-3, *Quality requirements for welding — Fusion welding of metallic materials — Part 3: Standard quality requirements*

EN 729-4, *Quality requirements for welding — Fusion welding of metallic materials — Part 4: Elementary quality requirements*

EN 970, *Non-destructive examination of fusion welds — Visual examination*

EN 1321, *Destructive tests on welds in metallic materials — Macroscopic and microscopic examination of welds*

CR 12361, *Destructive tests on welds in metallic materials — Etchants for macroscopic and microscopic examination*

EN 13134, *Brazing — Procedure approval*

ENV 50184, *Validation of arc welding equipment*

EN ISO 14554-1, *Quality requirements for welding — Resistance welding of metallic materials — Part 1: Comprehensive quality requirements (ISO 14554-1:2000)*

EN ISO 14554-2, *Quality requirements for welding — Resistance welding of metallic materials — Part 2: Elementary quality requirements (ISO 14554-2:2000)*

EN ISO 14555, *Welding — Arc stud welding of metallic materials (ISO 14555:1998)*

EN ISO 14744-5, *Welding — Acceptance inspection of electron beam welding machines — Part 5: Measurement of run-out accuracy (ISO 14744-5:2000)*

EN ISO 15609-1, *Specification and qualification of welding procedures for metallic materials - Welding procedure specification - Part 1: Arc welding (ISO 15609-1:2004)*

EN ISO 15609-2, *Specification and qualification of welding procedures for metallic materials - Welding procedure specification - Part 2: Gas welding (ISO 15609-2:2001)*

EN ISO 15609-3, *Specification and qualification of welding procedures for metallic materials - Welding procedure specification - Part 3: Electron beam welding (ISO 15609-3:2004)*

EN ISO 15609-4, *Specification and qualification of welding procedures for metallic materials - Welding procedure specification - Part 4: Laser beam welding (ISO 15609-4:2004)*

EN ISO 15609-5, *Specification and qualification of welding procedures for metallic materials - Welding procedure specification - Part 5: Resistance welding (ISO 15609-5:2004)*

EN ISO 15620, *Welding — Friction welding of metallic materials (ISO 15620:2000)*

ISO 669, *Resistance welding — Resistance welding equipment — Mechanical and electrical requirements*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
accuracy class
class of measuring instruments that meet certain metrological requirements that are intended to keep errors within specified limits
[1]

3.2
accuracy of measurand
closeness of the agreement between the result of a measurement and a true value of the measurement
[1]

3.3
calibration
set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards
[1]

3.4
measurement
set of operations having the object of determining a value of a quantity
[1]

3.5
measuring instrument
device intended to be used to make measurements, alone or in conjunction with supplementary device(s)
[1]

3.6
material measure
device intended to reproduce or supply, in a permanent manner during its use, one or more known values of a given quantity

3.7
measuring system
complete set of measuring instruments and other equipment assembled to carry out specified measurements
[1]

3.8
repeatability (of results of measurements)
closeness of the agreement between the results of successive measurements of the same measurand carried out under the same conditions of measurement
[1]

3.9
reproducibility (of results of measurement)
closeness of the agreement between the results of measurements of the same measurand carried out under changed conditions of measurement
[1]

3.10
tractability
property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties
[1]

3.11
validation
confirmation, through the provision of objective evidence that the requirements for a specific intended use or application have been fulfilled
[EN ISO 9000:2000]

3.12
verification
confirmation, through the provision of objective evidence that specified requirements have been fulfilled
[EN ISO 9000:2000]

4 General requirements

4.1 General

Measuring, inspection and test equipment are used for many purposes and as part of many work operations during welding fabrication. However, the purposes can be grouped as follows:

1) demonstration of conformance of product to specified requirements;

2) control of processes where the resulting output cannot be readily or economically verified by subsequent monitoring, inspection and testing;

3) general process control.

Measuring, inspection and test equipment used for demonstration of conformance of product to specified requirements (1) should be properly calibrated, verified or validated. This is e.g. required in EN ISO 9001. Many of the procedures used for demonstration of conformance inspection are covered by standards, which typically include provisions for calibration, verification and validation. This is e.g. the case for standards for non-destructive testing and destructive testing of welds. Further, requirements to documentation of such quality characteristics (e.g. non-destructive testing) are stated in application standards and/or contracts. Calibration, verification and validation of measuring devices used for this category of application are not covered by this standard, apart from a few

comments on welding inspection and visual examination. The relevant standards for inspection and testing shall be consulted.

However, some quality characteristics (also related to safety) cannot be inspected or tested on the finished structure or product. This is e.g. the case for the materials properties of weld metals and to the heat-affected zones adjacent to welds. Such quality characteristics have to be documented indirectly by proper documentation of the fabrication process (2). The guidance given in this standard is limited mainly to calibration, verification and validation of measuring devices used for such indirect documentation of quality characteristics, influenced by welding. The measuring, inspection and test equipment can be separate measuring instruments or built-in instruments in e.g. the power sources used for welding.

Measuring, inspection and test equipment used for general process control may also have to be calibrated, verified or validated (3). This is, e.g. recommended in EN ISO 9004[1]. However, specification of such requirements are left entirely to the discretion of the manufacturer, the requirements cannot be standardized and they are not covered by the present standard.

A key issue of the standard is discussions of the influence of various process variables on the resulting output and in particular of the possibilities of verification of the output by subsequent monitoring, inspection and testing. The distinction between process variables in group (2) and group (3) is not always easy but essential for the interpretation of contractual and/or legal requirements. The main basis for selection of the relevant variables is the standards for specification of welding procedures.

The specific requirements to calibration, verification and validation of a particular instrument shall be derived from the required performance and shall be compatible with the permissible range as specified in the welding procedure specification (WPS) for the variable(s) in question. Many types of instruments used for control of welding such as ammeters, voltmeters, thermocouples, stop-watches etc. are also used for non-welding purposes. It should be noted that the requirements to accuracy, when used for welding purposes might be less stringent than for other applications of the instruments. “Normal” (standardized) procedures for calibration, verification and validation of the instruments can be too stringent and costly, if applied for welding purposes.

The formal requirements to calibration, verification and validation as regards control of welding and allied processes are specified in the EN 729 series of standards and the EN ISO 14554 series of standards. Some more specific supplementary requirements can, however, be found in structural codes and/or as contractual requirements.

4.2 Frequency

When a need for calibration, verification or validation of equipment has been identified then calibration, verification or validation shall be carried out once a year, unless otherwise specified. Where there is a proven record of repeatability and liability the frequency of calibration, verification and validation can be reduced. It can, however, be necessary to re-calibrate, re-verify or re-validate at more frequent intervals, depending upon the recommendation of the manufacturer of the instrument, the requirements of the user, or where there is reason to believe that the performances of the equipment have deteriorated. However, equipment shall be isolated and calibration, verification or validation carried out before the equipment is put back in use after the following cases:

— whenever there are indications that an instrument does not register properly;

— whenever the equipment has been visibly damaged and the damage can have influenced the function of one or more instruments;

— whenever the equipment has been misused, subject to severe stress (overloads, traffic accidents, etc.), or subject to any other event which can have resulted in damage to one or more instrument;

— whenever the equipment has been rebuilt or repaired.

[1] It should be noted that EN ISO 9004 is not intended for certification, regulatory or contractual use.

4.3 Requirements

Calibration, verification and validation shall, in principle, be carried out for all the instruments used for control of the welding process variables specified in the welding procedure specification. However, standards for specification of welding procedures provide comprehensive lists of variables but not all variables are essential for all applications. The following paragraphs give for all common welding processes some guidelines on relevant requirements.

Calibration, verification and validation can be omitted entirely in the following cases:

a) When verification of the process is not required.

Calibration, verification and validation can be omitted for all processes where there is no legal or contractual requirement for verification or validation of the process.

NOTE 1 This is usually the case for processes such as flame or plasma cutting and air arc gouging.

b) Mass production

Calibration, verification and validation can be omitted provided all the following conditions are fulfilled:

— production is controlled by pre-production testing, followed by testing of samples from the actual production at regular intervals;

— the control is supported by an adequate system for statistical quality control;

— the process is reasonably stable during the interval between testing of samples;

— pre-production testing and sampling are performed separately for each production line (welding cell).

c) Series and single piece production

Calibration, verification and validation can be omitted provided all the following conditions are fulfilled:

— the procedures are approved by procedure testing;

— the actual production is carried out by the same welding machine used during procedure testing.

NOTE 2 The manufacturer can, for managerial reasons, wish to perform much more comprehensive calibration, verification and validation. The main reasons are:
- more efficient control of processes resulting in higher productivity and more economical operation;
- possibility of transferring procedures from one equipment to another without adjustments, maintaining an uninterrupted production;
- higher process stability and therefore increased economic efficiency;
- control data becomes compatible with different types of equipment.

4.4 Process data

For all welding processes, process data where calibration, verification or validation are needed are stated below. Calibration, verification or validation is not needed for all other process data.

4.5 Materials properties

Several kinds of materials are used in connection with production involving welding or ancillary activities. This includes parent metals and filler metals but also shielding gases, materials used for backing, etc. Occasionally incoming inspection and testing or check of stored materials may have to be performed, e.g. in order to identify a material. Such activities involve instruments and procedures for chemical analysis, positive material identification, etc. Provisions for calibration of instruments used for such purposes are outside the scope of the present standard.

Gas backing purity can be measured prior to welding, however, and is an exception.

5 Process data common to more than one welding process

5.1 Process data common to all welding processes

The standards for specification of welding procedures require some data, which are common to all welding processes. Calibration, verification or validation can be needed for the process data stated in Table 1 to Table 8.

Table 1 — Related to the parent material and filler metals

Designation	Need for calibration, verification or validation	Instruments and techniques
Material dimension	Instruments used for measurement and/or verification of material dimensions shall be calibrated, as necessary. Requirements depend on the specified tolerances, etc.	Measuring instruments such as vernier callipers, micrometer callipers, gauge blocks, rulers and straightedges, etc. are covered by several EN-, ISO- and national standards.

Table 2 — Related to the joint

Designation	Need for calibration, verification or validation	Instruments and techniques
Joint design	Instruments used for measurement and/or verification of joint dimension shall be validated.	See EN 970.
Welding position	Requirements to determination of welding position are, as a general rule, not very exacting. Instruments used for measurement and/or verification of welding position (e.g. spirit levels and instruments used for measurements of angles) do not have to be calibrated, verified or validated unless damaged, and after having been repaired.	Relevant instruments are covered by a number of standards.
Joint preparation	Instruments used for measurement and/or verification of joint dimension shall be validated.	See EN 970.

Table 3 — Welding machine

Designation	Need for calibration, verification or validation	Instruments and techniques
Characteristic dimensions, shape and configuration of welding machine and working conditions such as: — number and configuration of wire electrodes; — diameter of shielding gas nozzles and fixtures; — distance contact tip nozzle to the surface of the workpiece; — diameter of electrodes and wire electrodes; — dimensions, shape, position, etc. of back and front support.	Instruments used for measurement and/or verification of dimensions, shape, position, etc. of jigs, fixtures and tooling shall be calibrated, verified or validated, as appropriate.	Measuring instruments such as vernier callipers, micrometer callipers, gauge blocks, rulers and straightedges, etc. are covered by several EN-, ISO- and national standards.

Table 4 — Jigs, fixtures and tooling

Designation	Need for calibration, verification or validation	Instruments and techniques
Jigs and fixtures	Instruments used for measurement and/or verification of dimensions, shape, position, etc. of jigs, fixtures and tooling shall be calibrated, verified or validated, as appropriate.	Measuring instruments such as vernier callipers, micrometer callipers, gauge blocks, rulers and straightedges, etc. are covered by several EN-, ISO- and national standards.
Manipulators, x-y tables, etc.	Instruments used for control of movements shall be calibrated, verified or validated, as appropriate.	EN ISO 14744-5 and EN ISO 15616-2 may be used for general guidance (although the application is formally limited to beam welding).

Table 5 — Pre-welding cleaning

Designation	Need for calibration, verification or validation	Instruments and techniques
Surface conditions	Instruments used for control of surface conditions shall be validated.	Specific to instrument and surface characteristics. Appropriate standards for the equipment shall be consulted.
Process	Instruments used for process control shall be calibrated, verified or validated, as appropriate, depending on the nature of the cleaning process: Washing, pickling, abrasive blasting, etc.	Appropriate standards for the equipment shall be consulted.

5.2 Requirements specific to several welding processes

Table 6 — Gas backing

Designation	Need for calibration, verification or validation	Instruments and techniques
Gas flow rate	Instruments shall be validated. Required accuracy ± 20 % of gas flow rate.	Validated against master instrument.
Gas backing purity (oxygen content)	Instruments shall be validated. Required accuracy is ± 25 % of actual value. However, the purity can also be controlled by inspection of colour of protected side of weld HAZ zones.	Calibration by reference gases of known composition, covering at least the interval from 10 ppm to 30 ppm for argon and 50 ppm to 150 ppm for forming gas.

Table 7 — Consumables

Designation	Need for calibration, verification or validation	Instruments and techniques
Application of flux and filler metal, method, position, deposition rate, etc.	Instruments shall be calibrated, verified or validated, as appropriate.	Measuring instruments such as weighing instruments, vernier callipers, rulers and straightedges, etc. are covered by several EN-, ISO- and national standards. Stopwatches can be validated by comparison with any reasonably accurate clock.
Handling	Instruments used e.g. for control of storage conditions (temperature, humidity, etc.) shall be calibrated, verified or validated. Requirements ± 5 % for the instruments concerning humidity and ± 5 °C for thermometer.	Appropriate standards for the equipment shall be consulted.
Temperature in storage cabinet/room	Instruments for temperature control. Thermometers and other temperature indicators shall be validated. Requirement max. ± 5 °C.	Appropriate standards for the equipment shall be consulted.
Treatment prior to welding	Instruments used for process control shall be calibrated, verified or validated, as appropriate, depending on the nature of the treatment: Drying, cleaning, etc.	Appropriate standards for the equipment shall be consulted.

Table 8 — Shielding gases

Designation	Need for calibration, verification or validation	Instruments and techniques
Shielding gas flow	Flow meters shall be validated. Requirement max. ± 20 % of actual value.	Appropriate standards for the equipment shall be consulted.

5.3 Requirements specific to arc welding

Welding production has been carried out by a large number of manufacturing companies not having any scheme for systematic calibration, verification and validation of instruments used in welding fabrication. Many have not used any instruments at all. Welders performing manual metal arc welding control the welding process by observations performed by 'sound and sight', using their experience. It is simply impossible for the welder to observe any instrument when he is looking at the bright arc through the darkened glass in his face shield. Measuring instruments have found little or no use [2]. Heat input is controlled by check of run-out-lengths and/or weld run cross section. This is e.g. the case when welding single run fillet welds. Maximum weld throat thickness (leg length) is directly related to minimum run-out-length, minimum throat thickness to maximum run-out-length (for a given type of electrode). Similar relations apply for butt welds welded with a small number of runs. The welding co-ordinator planning the production has, as a matter of fact, to exercise great care in order to avoid conflicts and inconsistencies between requirements to heat input and requirements to run cross section. Calibration, verification and validation are therefore not usually required for manual metal arc welding.

However, in a few - unusual - cases minimum and/or maximum welding current and sometimes also the arc voltage have to be strictly controlled. This is usually performed during some run-in tests, where the welding current is checked by means of a tong-test or other suitable means and the arc voltage measured by any means suitable with the type of welding current. Such instruments have to be calibrated, verified or validated.

Heat input during welding of a run is directly correlated with the total cross section of the run (weld metal cross section). The apparent cross section of the run (e.g. throat squared of a single run fillet weld) reflects, however, the amount of deposited weld metal. It is directly correlated to run-out length for a given type and dimension of manual metal arc electrode. Heat input during welding can be controlled by observation of apparent cross section, provided the ratio between the deposited weld metal and the total cross section of the joint is reasonably constant for the weld process. This is often the case for manual metal arc welding and for certain MIG/MAG weld processes, but not for all. It is not the case for submerged arc welding and for other welding processes/power sources which permit variation of the ratio between deposited weld metal and total cross sections (a high ratio corresponding to a “cold” process and a low ratio to a “hot” process). Processes where the ratio can be varied significantly necessitate instruments for control of heat input. These instruments shall be calibrated, verified or validated for all applications where heat input is an essential variable.

Provisions for specification of welding procedures are laid down in EN ISO 15609-1. Calibration, verification or validation can be needed for the welding data stated in Table 9 to Table 12.

Table 9 — Weaving for manual arc welding (if applied)

Designation	Need for calibration, verification or validation	Instruments and techniques
Maximum width of the run	Instruments used for measuring shall be calibrated, verified or validated, as appropriate.	Measuring instruments such as vernier callipers, micrometer callipers, etc. are covered by several EN-, ISO- and national standards.

[2] This does not conflict with the fact that control of welding is an inherently complex process. Training of welders can be a lengthy process involving “calibration” of some mental processes in the welder’s brain. Approval testing of the welder can be said to correspond to a verification of this “calibration”.

Table 10 — Weaving for mechanized welding (if applied)

Designation	Need for calibration, verification or validation	Instruments and techniques
Max. weaving or amplitude	Instruments used for measuring shall be calibrated, verified or validated, as appropriate.	Measuring instruments such as vernier callipers, micrometer callipers, etc. are covered by several EN-, ISO- and national standards.
Frequency	Calibration, verification or validation not required, provided size (penetration) and position of weld can be determined by non-destructive testing.	—
Dwell time of oscillation	Calibration, verification or validation not required, provided size (penetration) and position of weld can be determined by non-destructive testing.	—
Torch, electrode and/or wire angle	Instruments used for measuring shall be calibrated, verified or validated, as appropriate.	Measuring instruments such as vernier callipers, micrometer callipers, etc. are covered by several EN-, ISO- and national standards.

Table 11 — Electrical variables

Designation	Need for calibration, verification or validation	Instruments and techniques
Current (mean)	Ammeters shall be validated.	See ENV 50184. Mean value of (rectified) current.
Arc voltage (mean)	Voltmeters shall be validated.	See ENV 50184. Mean value of (rectified) tension.
NOTE The signal should be monitored continuously. The sampling time should be sufficient to give a reasonably stable reading. If tong-tests are used for measurement of current, the difference between mean value and RMS value measuring instruments should be taken into consideration.		

Table 12 — Mechanized welding

Designation	Need for calibration, verification or validation	Instruments and techniques
Travel speed	Measurements by means of stop-watches and rulers. Appropriate steel rulers need not to be calibrated, verified or validated provided the rulers are not visibly damaged.	Stopwatches can be validated by comparison with any reasonably accurate clock or watch. See also ENV 50184.
Wire feed speed	Measurements by means of stopwatches and rulers. Appropriate steel rulers need not to be calibrated, verified or validated provided the rulers are not visibly damaged.	Stopwatches can be validated by comparison with any reasonably accurate clock or watch. See also ENV 50184.

6 Metal arc welding without gas protection (group 11)

NOTE The explanation of the reference numbers for the processes are given in EN ISO 4063.

Provisions for specification of welding procedures are specified in EN ISO 15609-1. Calibration, verification or validation can be needed for the welding data stated in Table 13.

Table 13 — Manual metal arc welding (group 111)

Designation	Need for calibration, verification or validation	Instruments and techniques
The run-out length of electrode consumed	Calibration, verification and validation not required, provided appropriate steel rulers are used and the rulers are not visibly damaged.	—

7 Plasma arc welding (group 15)

Provisions for specification of welding procedures are laid down in EN ISO 15609-1. Calibration, verification or validation can be needed for the welding data stated in Table 14.

Table 14 — Plasma arc welding

Designation	Need for calibration, verification or validation	Instruments and techniques
Plasma gas flow rate	Validation to an accuracy of ± 0,1 l/min.	Appropriate standards for the equipment shall be consulted.
Plasma gas nozzle diameter	The welding operator usually detects wear of the nozzle by changes in the arc.	Nozzle changed, if required.
Distance electrode/work piece	Distance is usually kept constant by: — arc sensor measuring with AVC control; — control by tactile device; — laser scanner.	These instruments shall be validated, usually by ordinary measuring instruments such as vernier, callipers, micrometer callipers, etc.

8 Resistance welding (groups 21, 22, 23, 24 and 25)

Resistance welding is mainly used for mass production and calibration, verification and validation can then be omitted, see 4.3.

Production with resistance welding is used in industry by a large number of companies in a controlled process by simple workshop tests. Measuring of current, force and weld time is used in special cases by the weld-setter or maintenance experts to check the equipment or the weld conditions.

The measuring equipment is often used without a frequently specific calibration, verification and/or validation. The trends of measured values are often more important than the absolute values.

When needed for the acceptance of a new or repaired welding equipment, calibrated equipment shall be used, if agreed, when checking the real properties defined in ISO 669 and given on the name plate of the equipment.

Weld quality depends mainly of the type of material, surface conditions, electrical and mechanical properties of the weld equipment, the shape and dimension of the component, which shall be welded.

In the case of spot, projection and seam welding shape, dimension, material of the electrodes, weld current, electrode force and weld time and for seam welding the welding speed are the main control parameters of the process.

In the case of flash and resistance butt welding weld current, the clamping force and the upset force shall be observed.

The upset and follow up parameters of the electrodes for spot, projection and seam welding, respectively the upset speed for flash and resistance butt welding are very important parameters which cannot be adjusted directly at the equipment.

Provisions for welding procedure specifications are specified in EN ISO 15609-5. Calibration, verification or validation can be needed for the welding data stated in Table 15 and Table 16.

Table 15 — Resistance welding for overlapped sheets (spot welding (21), seam (22) and projection (23))

Designation	Need for calibration, verification or validation	Instruments and techniques
Electrode force	Electrode force usually measured by special electrode force meter which shall be calibrated.	The producer's specified calibration procedure or appropriate standards for the equipment shall be consulted.
Weld current	Current meter usually measured by special weld current which shall be calibrated.	The producer's specified calibration procedure or appropriate standards for the equipment shall be consulted.
Weld time	Weld time usually measured by current meter or directly by e.g. a timer.	The producer's specified calibration procedure or appropriate standards for the equipment shall be consulted.
Seam welding speed	Seam welding speed usually determined from rate of rotation and the diameter of the electrode. Instruments for determination of these parameters shall be calibrated.	The producer's specified calibration procedure or appropriate standards for the equipment shall be consulted.

Table 16 — Flash (24) and resistance butt welding (25)

Designation	Need for calibration, verification or validation	Instruments and techniques
Damping force / pressure	Damping force usually measured by special force meter / hydraulic pressure gauge which shall be calibrated.	The producer's specified calibration procedure or appropriate standards for the equipment shall be consulted.
Upsetting force / pressure	Upsetting force usually measured by special force meter / hydraulic pressure gauge which shall be calibrated.	The producer's specified calibration procedure or appropriate standards for the equipment shall be consulted.
Weld current	Weld current usually measured by special current meter which shall be calibrated.	The producer's specified calibration procedure or appropriate standards for the equipment shall be consulted.

For quality control monitoring and feed back control systems on the basis of current, electrode voltage, work piece resistance, electrode acceleration, speed and displacement measurement different incorporated calibration, verification and validation are in use.

9 Gas welding (group 3)

Provisions for specification of welding procedures are laid down in EN ISO 15609-2. Calibration, verification or validation can be needed for the welding data stated in Table 17.

Table 17 — Welding data

Designation	Need for calibration, verification or validation	Instruments and techniques
Fuel gas pressure	Pressure is often indicated by a pressure gauge. However, the pressure is usually not used as a primary variable for control of the flame. Pressure gauges do not need to be calibrated, verified or validated, unless required due to special conditions.	If required, pressure gauges shall be validated to the requirements stated in EN 562.
Oxygen-pressure	Pressure is often indicated by a pressure gauge. However, the pressure is usually not used as a primary valuable for control of the flame. Pressure gauges do not need to be calibrated, verified or validated, unless required due to special conditions.	If required, pressure gauges shall be validated to the requirements stated in EN 562.
Type of flame	Common practice does not include use of any instrument. The type of flame is checked by visual observation.	—

10 Friction welding (group 42)

Provisions for specification of welding procedures are laid down in EN ISO 15620. Calibration, verification or validation can be needed for the welding data stated in Table 18.

Table 18 — Welding data

Designation	Need for calibration, verification or validation	Instruments and techniques
Friction rotation speed	Instruments shall be calibrated or verified. Rotation speed is measured at the welding spindle.	Appropriate standards for the equipment shall be consulted.
Forge force	Instruments shall be calibrated or verified. Use an appropriate instrument for measurement. Force is measured at the axis of the component or the pressure can be measured as near as possible at the working cylinder.	Appropriate standards for the equipment shall be consulted.
Shortening	Instruments used for measuring shall be calibrated or verified. Shortening is measured at the working slide.	Appropriate standards for the equipment shall be consulted.

Accuracy of all measurements for friction welding is classified into three categories:

1) Stringent requirements: Accuracy ± 10% of determined value;

2) Medium requirements: Accuracy ± 20% of determined value;

3) Low requirements: Calibration, verification or validation not required.

11 Laser beam welding (group 52)

It should be noted that deviations in many of the variables result in wrong size (penetration) or position of the weld, which usually can be detected on the finished welds by non-destructive testing.

Provided the size (penetration) and position of weld can be determined by non-destructive testing, calibration, verification or validation is not required for the following welding data:

— Laser beam power at the work piece;

— Peak power;

— Repetition rate;

— Pulse length;

— Power ramping details;

— Pulse variables (if used);

— F-number;

— Pulse shape.

Else, EN ISO 15616-1 can be consulted (for CO_2 lasers). EN ISO 15616-1 may be used for all types of lasers (if necessary) for the following welding data:

— Travel speed;

— Travel speed ramping details, if necessary.

It should be noted that deviations in variables related to oscillation can result in deviations of the properties in the heat-affected zones, weld metal composition, etc. which cannot be detected without destructive testing. Provisions for specification of welding procedures are laid down in EN ISO 15609-4. Calibration, verification or validation can be needed for the welding data stated in Table 19 to Table 22.

Table 19 — Beam variables

Designation	Need for calibration, verification or validation	Instruments and techniques
Tack pass details	Requirements are the same as for ordinary welding.	—
Oscillation pattern, amplitude, frequency and dwell time (if applied, e.g. for cladding and surface treatment)	Validation required. Validation can be performed by welding of a (simple) test piece, prior to actual production and measure the resulting weld.	Measuring instruments such as vernier callipers, micrometer callipers, gauge blocks, rulers and straightedges, etc. are covered by several EN-, ISO- and national standards. See CR 12361 and EN 1321 as regards macro sectioning.
Laser beam orientation, polarisation and position in relation to joint and welding direction. Angles (in two directions). Position in transverse direction (if relevant)	Calibration, verification or validation not required, provided size (penetration) and position of weld can be determined by non-destructive testing. Validation can be performed by welding of a (simple) test piece prior to actual production and measure the resulting weld.	Measuring instruments such as vernier callipers, micrometer callipers, gauge blocks, rulers and straightedges, etc. are covered by several EN-, ISO- and national standards. See CR 12361 and EN 1321 as regards macro sectioning.

Table 20 — Mechanical variables

Designation	Need for calibration, verification or validation	Instruments and techniques
Wire/filler, feed rate direction, position to be defined and angle (if any)	Measurements by means of stopwatches and rulers. Appropriate steel rulers need not to be validated provided the rulers are not visibly damaged.	Stopwatches can be validated by comparison with any reasonably accurate clock. See also ENV 50184, if needed.

Table 21 — Plasma suppression gas

Designation	Need for calibration, verification or validation	Instruments and techniques
Gas flow rate	Instruments shall be validated.	See EN ISO 15616-3.

Table 22 — Other variables

Designation	Need for calibration, verification or validation	Instruments and techniques
Working distance in millimetre	Instruments shall be calibrated or validated.	Measuring instruments such as vernier callipers, micrometer callipers, etc. are covered by several EN-, ISO- and national standards.
Location of shielding gas nozzle with respect to the work piece.	Instruments shall be calibrated or validated.	Measuring instruments such as vernier callipers, micrometer callipers, etc. are covered by several EN-, ISO- and national standards.

12 Electron beam welding (group 51)

Provisions for specification of welding procedures are laid down in EN ISO 15609-3.

It should be noted, that deviations in many of the variables result in wrong size (penetration) or position of the weld or physical imperfections (e.g. shrinkage cavity), which usually can be detected on the finished welds by non-destructive testing. Some deviations in variables can, however, result in deviations of the properties in the heat-affected zones, weld metal composition, etc. which can only be detected by destructive testing.

Calibration, verification or validation is not required for the following welding data, provided size (penetration) and position of weld can be determined by non-destructive testing:

— Accelerating voltage;

— Beam current;

— Lens current(s);

— Travel speed;

— Beam deflection, DC deflection, deflection amplitude;

— Beam deflection, AC oscillation, Signal shape;

— Orientation to the welding direction;

— Frequency;

— Signal amplitude, signal frequency.

Calibration, verification or validation can be needed for the welding data stated in Table 23 and Table 24.

Table 23 — Mechanical variables

Designation	Need for calibration, verification or validation	Instruments and techniques
Wire/filler feed rate	Measurements by means of stopwatches and rulers. Appropriate steel rulers need not to be calibrated, verified or validated, provided the rulers not are visibly damaged.	Measuring instruments such as vernier callipers, micrometer callipers, etc. are covered by several EN-, ISO- and national standards. Stopwatches can be validated by comparison with any reasonably accurate clock.
Wire/filler direction, position to be defined and angle	Instruments shall be calibrated, verified or validated, as appropriate.	Measuring instruments such as vernier callipers, micrometer callipers, etc. are covered by several EN-, ISO- and national standards.

Table 24 — Other variables

Designation	Need for calibration, verification or validation	Instruments and techniques
Pressure in the gun	Instruments shall be validated in case pressure control is essential for the properties of the weld.	Use a master instrument (pressure gauge).
Pressure in the chamber	Instruments shall be validated in case pressure control is essential for the properties of the weld.	Use a master instrument (pressure gauge).

13 Stud welding (group 78)

Stud welding is a process in which one or more parameters occasionally do not reach their set values due to the short time of the welding. This is the reason why considerable deviations from the set values can occur. Any calibration, verification and validation have to take this into consideration. For details of the process see annex A.

Provisions for specification of welding procedures are laid down in EN ISO 14555. Calibration, verification or validation can be needed for the welding data stated in Table 25 and Table 26.

Table 25 — Drawn arc stud welding (groups 783 and 784)

Designation	Need for calibration, verification or validation	Instruments and techniques
Welding current	Instruments used for measuring shall be validated. Welding current is the mean current, disregarding the up-slope, down-slope and short circuit at the end of the welding cycle. Required accuracy ± 10 % of nominal value.	Validation by means of shunt class 0,5.
Set time of current flow	Instruments used for measuring of the time of current flow shall be validated. The time of current flow shall be measured as the time between the start of the welding current (50 % of the set value) and the start of the plunging movement (switch-off of the solenoid). Required accuracy is ± 10 % of nominal value. NOTE The total welding time depends on the type of the welding gun, welding position, plunging speed, lift, etc and is not used for process control (no validation).	Validation can be performed by storage oscilloscope ± 5 % minimum.
Lift	Validation of settings is performed by lifting the backwards movement of the piston when the lifting mechanism is activated. Accuracy ± 0,5 mm at a minimum nominal lift of 1,5 mm.	Measurement by means of vernier callipers, steel rulers, etc. Calibration or verification of such measuring instruments are covered by several EN-, ISO- and national standards.

Table 26 — Capacitor discharge stud welding (groups 785 and 786)

Designation	Need for calibration, verification or validation	Instruments and techniques
Charging voltage	Instruments used for measuring shall be validated. Voltage between the terminals of the capacitor bank after expiry of charging. Required accuracy ± 5 V.	Use a master instrument (voltmeter).

14 Brazing (group 91)

14.1 General

Provisions for specification of brazing procedures are laid down in EN 13134. Calibration, verification or validation can be needed for the brazing data stated in Table 27 to Table 43.

14.2 Manual flame brazing (group 912)

Table 27 — Heating gas

Designation	Need for calibration, verification or validation	Instruments and techniques
Type	Common practice does not include use of any instrument, unless incoming inspection of delivered gas is required. Required accuracy shall be compatible with the composition of the gas.	Use recognized method for gas analysis.
Flow	Flow measuring instruments shall be validated, if fitted. Required accuracy ± 20 % of gas flow rate.	Use a master instrument (flowmeter).
Pressure	The pressure gauges shall be validated. Required accuracy corresponding to class 2.5, that is with a maximum deviation of ± 2,5 % over the entire scale.	Use a master instrument (pressure gauge).
Nozzle size and number	Check of nozzle type and number is usually sufficient. Instruments not required.	—

14.3 Mechanized flame brazing (group 912)

Table 28 — Heating gas

Designation	Need for calibration, verification or validation	Instruments and techniques
Type	Common practice does not include use of any instrument, unless incoming inspection of delivered gas is required. Required accuracy shall be compatible with the composition of the gas.	Use recognized method for gas analysis.
Flow	Flow measuring instruments shall be validated, if fitted. Required accuracy ± 20 % of gas flow rate.	Use a master instrument (flowmeter).
Pressure	The pressure gauges shall be validated. Required accuracy corresponding to class 2.5, that is with a maximum deviation of ± 2,5 % over the entire scale.	Use a master instrument (pressure gauge).
Nozzle/burner size and number	Check of nozzle/burner type and number is usually sufficient. Instruments not required.	—

14.4 Induction brazing (group 916)

Table 29 — Time-temperature cycle

Designation	Need for calibration, verification or validation	Instruments and techniques
Temperature measurement	Common practice does not include use of any specific instrument.	—
Time measurement	Check by stopwatches.	Watches shall be considered sufficiently accurate unless obviously defective.

Table 30 — Induction coil

Designation	Need for calibration, verification or validation	Instruments and techniques
Position	Instruments used for measuring shall be calibrated, verified or validated, as appropriate.	Measuring instruments such as vernier callipers, micrometer callipers, etc. are covered by several EN-, ISO- and national standards.

14.5 Resistance brazing (group 918)

Use provisions specified in Clause 8 for resistance welding, as appropriate.

14.6 Furnace brazing in protective atmosphere (group 913)

Table 31 — Time-temperature cycle

Designation	Need for calibration, verification or validation	Instruments and techniques
Temperature measurement	Thermocouples are stable and accurate and do not need calibration, verification or validation. The connected electrical instruments and in particular the entire measuring system shall be validated, however. If control is established by measurement of oven temperatures (and not by thermocouples directly placed on the heat-treated structure), then the temperature distribution in the oven shall be checked. Required accuracy ± 5 °C. It should be noted that re-validation usually is needed whenever the electrical connections have been changed.	Validation of the entire measuring system can be performed by checks at a reasonable number of temperature gaugings by a master thermocouple.

Time measurement	Watches, recording instruments. Watches shall be considered sufficiently accurate unless obviously defective and need not to be validated. The main risk consists in misinterpretation of the scale and re-validation usually is needed whenever the instrument settings have been changed.	Time recording instruments should be validated by means of a watch.

Table 32 — Furnace type

Designation	Need for calibration, verification or validation	Instruments and techniques
Furnace type	See 5.1	—

Table 33 — Furnace atmosphere

Designation	Need for calibration, verification or validation	Instruments and techniques
Type	Common practice does not include use of any instrument, unless incoming specific inspection of delivered gas is required. Required accuracy shall be compatible with the composition of the gas.	Use recognized method for gas analysis.
Purity	Common practice does not include use of any specific instrument.	—
Gas flow rate	Instruments shall be validated. Required accuracy ± 20 % of gas flow rate.	Use a master instrument (flowmeter).

14.7 Vacuum brazing (group 924)

Table 34 — Time-temperature cycle

Designation	Need for calibration, verification or validation	Instruments and techniques
Temperature measurement	Thermocouples are stable and accurate and do not need calibration, verification or validation. The connected electrical instruments and in particular the entire measuring system shall be validated, however. If control is established by measurement of oven temperatures (and not by thermocouples directly placed on the heat-treated structure), then the temperature distribution in the oven shall be checked. Required accuracy ± 5 °C. It should be noted that re-validation usually is needed whenever the electrical connections have been changed.	Validation of the entire measuring system can be performed by checks at a reasonable number of temperature gaugings by a master thermocouple.

Time measurement	Watches, recording instruments. Watches shall be considered sufficiently accurate unless obviously defective and need not to be validated. The main risk consists in misinterpretation of the scale and re-validation usually is needed whenever the instrument settings have been changed.	Time recording instruments shall be validated by means of a watch.

Table 35 — Furnace type

Designation	Need for calibration, verification or validation	Instruments and techniques
Furnace type	See 5.1	—

Table 36 — Vacuum pressure

Designation	Need for calibration, verification or validation	Instruments and techniques
Pressure in the furnace	Instruments shall be validated in cases where pressure control is essential for the purposes of the brazed joint.	Use a master instrument (pressure gauge).

Table 37 — Accelerated cooling gas

Designation	Need for calibration, verification or validation	Instruments and techniques
Type	Common practice does not include use of any instrument, unless incoming inspection of delivered gas is required. Required accuracy shall be compatible with the composition of the gas.	Use recognized method for gas analysis.
Pressure	The pressure gauges shall be validated.	Use a master instrument (pressure gauge).

14.8 Furnace brazing in open atmosphere (group 913)

Table 38 — Time-temperature cycle

Designation	Need for calibration, verification or validation	Instruments and techniques
Temperature measurement	Thermocouples are stable and accurate and do not need calibration, verification or validation. The connected electrical instruments and in particular the entire measuring system shall be validated, however. If control is established by measurement of oven temperatures (and not by thermocouples directly placed on the heat-treated structure), then the temperature distribution in the oven shall be checked. Required accuracy ± 5 °C. It should be noted that re-validation usually is needed whenever the electrical connections have been changed.	Validation of the entire measuring system can be performed by checks at a reasonable number of temperature gaugings by a master thermocouple.
Time measurement	Watches, recording instruments. Watches shall be considered sufficiently accurate unless obviously defective and need not to be validated. The main risk consists in misinterpretation of the scale and re-validation usually is needed whenever the instrument settings have been changed.	Time recording instruments shall be validated by means of a watch.

Table 39 — Furnace type

Designation	Need for calibration, verification or validation	Instruments and techniques
Furnace type	See 5.1	—

14.9 Dip brazing (group 914), salt-bath brazing (group 915) and flux brazing (group 93)

Table 40 — Time-temperature cycle

Designation	Need for calibration, verification or validation	Instruments and techniques
Temperature measurement	Thermocouples are stable and accurate and do not need calibration, verification or validation. The connected electrical instruments and in particular the entire measuring system shall be validated, however. If control is established by measurement of oven temperatures (and not by thermocouples directly placed on the heat-treated structure), then the temperature distribution in the oven shall be checked. Required accuracy ± 5 °C. It should be noted that re-validation usually is needed whenever the electrical connections have been changed.	Validation of the entire measuring system can be performed by checks at a reasonable number of temperature gaugings by a master thermocouple.
Time measurement	Watches, recording instruments. Watches shall be considered sufficiently accurate unless obviously defective and need not to be validated. The main risk consists in misinterpretation of the scale and re-validation usually is needed whenever the instrument settings have been changed.	Time recording instruments shall be validated by means of a watch.

Table 41 — Bath composition

Designation	Need for calibration, verification or validation	Instruments and techniques
Bath composition	Common practice does not include use of any specific instrument.	—

14.10 Infrared brazing (group 911)

Table 42 — Temperature measurement

Designation	Need for calibration, verification or validation	Instruments and techniques
Temperature measurement	Thermocouples are stable and accurate and do not need calibration, verification or validation. The connected electrical instruments and in particular the entire measuring system shall be validated, however. If control is established by measurement of oven temperatures (and not by thermocouples directly placed on the heat-treated structure), then the temperature distribution in the oven shall be checked. Required accuracy ± 5 °C. It should be noted that re-validation usually is needed whenever the electrical connections have been changed.	Validation of the entire measuring system can be performed by checks at a reasonable number of temperature gaugings by a master thermocouple.

Table 43 — Atmosphere

Designation	Need for calibration, verification or validation	Instruments and techniques
Type	Common practice does not include use of any specific instrument, unless incoming inspection of delivered gas is required. Required accuracy shall be compatible with the composition of the gas.	Use recognized method for gas analysis.
Purity	Common practice does not include use of any specific instrument.	—
Gas flow rate	Instruments shall be validated. Required accuracy ± 20 % of gas flow rate.	Use a master instrument (flowmeter).

15 Preheat and/or post weld heat treatment

15.1 Preheat

Preheating is a critical operation (when needed) and proper control of preheating is essential for the properties of the welds. Calibration, verification or validation can be needed for the process data stated in Table 44.