BS EN ISO 17662:2016

BSI Standards Publication

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

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National foreword

This British Standard is the UK implementation of EN ISO 17662:2016. It supersedes BS EN ISO 17662:2005 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee WEE/-/1, Briefing committee for welding.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Published by BSI Standards Limited 2016

ISBN 978 0 580 89185 4

ICS 25.160.30

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 March 2016.

Amendments/corrigenda issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN ISO 17662

March 2016

ICS 25.160.30

Supersedes EN ISO 17662:2005

English Version

Welding - Calibration, verification and validation of equipment used for welding, including ancillary activities (ISO 17662:2016)

Soudage - Étalonnage, vérification et validation du matériel utilisé pour le soudage, y compris pour les procédés connexes (ISO 17662:2016)

Schweißen - Kalibrierung, Verifizierung und Validierung von Einrichtungen einschließlich ergänzender Tätigkeiten, die beim Schweißen verwendet werden (ISO 17662:2016)

This European Standard was approved by CEN on 23 January 2016.

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Ref. No. EN ISO 17662:2016 E

European foreword

This document (EN ISO 17662:2016) has been prepared by Technical Committee ISO/TC 44 "Welding and allied processes" in collaboration with Technical Committee CEN/TC 121 “Welding” the secretariat of which is held by DIN.

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of an identical text or by endorsement, at the latest by September 2016, and conflicting national standards shall be withdrawn at the latest by September 2016.

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

This document supersedes EN ISO 17662:2005.

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Endorsement notice

The text of ISO 17662:2016 has been approved by CEN as EN ISO 17662:2016 without any modification.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 44, *Welding and allied processes*, Subcommittee SC 10, *Quality management in the field of welding*.

This second edition cancels and replaces the first edition (ISO 17662:2005), which has been technically revised.

Requests for official interpretations of any aspect of this International Standard should be directed to the Secretariat of ISO/TC 44/SC 10 via your national standards body. A complete listing of these bodies can be found at www.iso.org.

INTERNATIONAL STANDARD ISO 17662:2016(E)

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

1 Scope

This International Standard specifies requirements for calibration, verification and validation of equipment used for

— control of process variables during fabrication, and

— 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 involves process variables influencing the fitness-for-purpose and in particular the safety of the fabricated product.

NOTE 1 This International Standard is based on the lists of process variables stated in International Standards for specification of welding procedures, in particular, but not exclusively in the ISO 15609- series. Future revisions of these International 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 for calibration; verification and validation as part of acceptance testing of equipment used for welding or allied processes.

Requirements to calibrate, verify and validate as part of inspection, testing, non-destructive testing or measuring of final welded products performed in order to verify confirm product compliance are outside the scope of the present International Standard.

The subject of this International Standard is limited to calibration, verification and validation of equipment after installation, as part of the workshops' and site operations for maintenance and/or operation.

It needs to be stressed that this International Standard has nothing to do with manufacture and installation of equipment for welding. Requirements for new equipment are formulated in directives and product codes (standards), as necessary.

Annex C provides information when other parties are involved in calibration, verification and validation activities.

2 Normative references

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

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

ISO 5171, *Gas welding equipment — Pressure gauges used in welding, cutting and allied processes*

ISO 5172:2006, *Gas welding equipment — Blowpipes for gas welding, heating and cutting — Specifications and tests*

ISO 5826, *Resistance welding equipment — Transformers — General specifications applicable to all transformers*

3 Terms and definitions

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

3.1
accuracy class
class of measuring instruments or measuring systems that meets stated metrological requirements that are intended to keep measurement errors or instrumental measurement uncertainties within specified limits under specified operating conditions

[SOURCE: ISO/IEC Guide 99:2007, 4.25]

3.2
accuracy of measurement
closeness of agreement between a measured quantity value and a true quantity value of a measurand

Note 1 to entry: The term *measurand* is defined by the VIM (ISO/IEC Guide 99:2007, 2.3) as a "quantity intended to be measured".

[SOURCE: ISO/IEC Guide 99:2007, 2.13, modified — Note 1 to entry has been added.]

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

3.4
measurement
process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity

[SOURCE: ISO/IEC Guide 99:2007, 2.1]

3.5
measuring instrument
device used for making measurements, alone or in conjunction with one or more supplementary devices

[SOURCE: ISO/IEC Guide 99:2007, 3.1]

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
set of one or more measuring instruments and often other devices, including any reagent and supply, assembled and adopted to give information used to generate measured quantity values within specified intervals for quantities of specified kinds

[SOURCE: ISO/IEC Guide 99:2007, 3.2]

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

3.9
traceability
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

3.10
validation
confirmation through the provision of objective evidence that the requirements for a specific intended use (e.g. client specification) or application (e.g. product standard) have been fulfilled

3.11
verification
confirmation through the provision of objective evidence that specified requirements have been fulfilled

Note 1 to entry: Verification is also interpreted as a confirmation that an available process achieved an expected level of success.

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, for example, required in ISO 9001. Many of the procedures used for demonstration of conformance inspection are covered by standards, which typically include provisions for calibration, verification, or validation. This is, for example, the case for standards for non-destructive testing and/or destructive testing of welds. Further, requirements for 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, for example, 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, for example, 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, for example, recommended in ISO 9004[1)]. However, specifications 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 International Standard.

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

A key issue of the International 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 for 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 ISO 3834- series and the ISO 14554- series. 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 reliability 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. 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, 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.

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/brazing procedure specification. International Standards for specification of welding/brazing procedures provide comprehensive lists of variables, but not all variables are essential for all applications. The following are some guidelines on relevant requirements for all common welding/brazing processes.

Calibration, verification and validation may be omitted entirely in the following cases.

a) **When verification of the process is not required**

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

— the 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 may 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;

or the process is supported by a calibrated online-monitoring system for welding parameters.

NOTE 2 The manufacturer can, for managerial reasons, decide to perform much more comprehensive calibration, verification and validation. The main reasons are the following:

— 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/brazing processes, process data where calibration, verification, or validation are needed are stated in Clause 5. Calibration, verification, or validation is not needed for all other process data.

4.5 Material 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 this International Standard.

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

5 Process data common to more than one welding/brazing process

5.1 Process data common to all welding/brazing processes

The International Standards for specification of welding procedures require some data, which are common to all welding processes. Calibration, verification, or validation requirements are detailed 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 ISO 17637.
Welding position	Requirements for 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.	See ISO 6947.
Joint preparation	Instruments used for measurement and/or verification of joint dimension and outline shall be validated.	See ISO 17637.

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 the following: — 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. 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.	ISO 14744-5 and 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.
Practice	Instruments used for process control shall be calibrated, verified or validated, as appropriate, depending on the nature of the cleaning practice: Washing, pickling, abrasive blasting, etc.	Appropriate standards for the equipment shall be consulted.

5.2 Requirements specific to several welding/brazing 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 in the area where heat may have an influence of the surface.	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
Condition of storage	Instruments used, for example, 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. Validated against master instrument.
Baking oven, holding oven and quiver	Instruments for temperature control. Thermometers and other temperature indicators shall be validated. Requirement: max. ± 10 °C.	Appropriate standards for the equipment shall be consulted.
Treatment prior to welding/ brazing	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 (group 1)

During arc welding, it is simply impossible for the welder to observe any measuring instrument and he often welds by observations performed by “sound”, using his experience. He visually controls the welding process. This skill shall be verified through qualification testing of the welders for the used welding process.

Heat input is controlled by check of run-out-lengths and/or weld run cross section (see ISO/TR 18491).

Where heat input is an essential variable, all instruments used shall be calibrated, verified or validated.

Provisions for specification of welding procedures are laid down in 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.

Table 10 — Weaving for mechanized or automatic 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 EN 50504. Mean value of (rectified) current.
Arc voltage (mean)	Voltmeters shall be validated.	See EN 50504. Mean value of (rectified) tension.
Watt meter	Instantaneous energy or instantaneous power measurements shall be validated.	See ISO/TR 18491.
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 or automatic welding

Designation	Need for calibration, verification, or validation	Instruments and techniques
Travel speed	Measurements by means of stopwatches and tape measure/steel 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 EN 50504.
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 EN 50504.

6 Metal arc welding without gas protection (group 11)

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

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

Table 14 — Plasma arc welding (group 15)

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 between electrode and plasma gas nozzle and plasma gas nozzle to the workpiece surface	Distance between plasma gas nozzle to the workpiece surface is usually kept constant by: — arc sensor measuring with automatic voltage Control (AVC); — control by tactile device; — laser scanner. Distance between electrode and plasma gas nozzle is usually kept constant by: — gauge.	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 welding 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 new or repaired welding equipment, calibrated equipment shall be used, if agreed, when checking the real properties defined in ISO 669 and ISO 5826 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 welding 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, welding 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 upset (resistance butt) welding, welding current, the clamping force and the upset force shall be observed.

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

Provisions for welding procedure specifications are specified in 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 welding (23)]

Designation	Need for calibration, verification, or validation	Instruments and techniques
Shape, dimension, material of the electrodes	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.
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.
Welding current	Welding current usually measured by special instrument which shall be calibrated.	The producer's specified calibration procedure or appropriate standards for the equipment shall be consulted.
Welding time	Weld time usually measured by current meter or directly by 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 (upset) welding (25)

Designation	Need for calibration, verification, or validation	Instruments and techniques
Clamping force/pressure	Clamping 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.
Upset force/pressure	Upset 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.
Welding current	Welding 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 feedback 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 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
Nozzle size	Marking of the nozzle according to ISO 5172:2006, Annex J.	Nozzle size shall be checked by the visual inspection of the hard stamp nozzle size number.
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 ISO 5171.
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 ISO 5171.
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 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:

a) stringent requirements: Accuracy ±10 % of determined value;

b) medium requirements: Accuracy ±20 % of determined value;

c) 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.

ISO 15616-1, ISO 15616-2, ISO 15616-3 and ISO 15616-4 can be consulted (for CO_2 lasers). ISO 22827-1 and ISO 22827-2 can be consulted (for Nd:YAG laser). ISO 15616-1, ISO 15616-4 and ISO 22827-2 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 ISO 15609-4 and ISO 15614-11. 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 weld details	Requirements are the same as for ordinary welding.	—
Oscillation pattern, amplitude, frequency and dwell time (if applied, e.g. for cladding and surfacing)	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 ISO/TR 16060 as regards macro sectioning.
Laser beam orientation, polarization 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 ISO/TR 16060 as regards macro sectioning.

Table 20 — Mechanical variables

Designation	Need for calibration, verification, or validation	Instruments and techniques
Filler wire, particle size of powder, wire feed rate, powder 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 EN 50504, if needed.

Table 21 — Plasma suppression gas and shielding gas

Designation	Need for calibration, verification, or validation	Instruments and techniques
Gas flow rate	Instruments shall be validated.	See 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 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 oscillation, 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 (vacuum) 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 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 current sensor class 2.
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	In case there is no setpoint indication for the lift, the spread between the minimum and the maximum reading at a certain setpoint shall not exceed 1 mm at a minimum of 10 lifting cycles. The setpoints shall be selected at the minimum, the maximum and approximately in the middle of the adjustment range.	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 9)

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 42.

14.2 Manual and mechanized 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 Induction brazing (group 916)

Table 28 — 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 29 — 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.

14.4 Resistance brazing (group 918)

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

14.5 Furnace brazing in protective atmosphere (group 921)

Table 30 — 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 31 — Furnace type

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

Table 32 — 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).

14.6 Vacuum brazing (group 922)

Table 33 — 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 34 — Furnace type

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

Table 35 — 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 36 — 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).

14.7 Furnace brazing in open atmosphere (group 921)

Table 37 — 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 38 — Furnace type

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

14.8 Dip-bath brazing (group 923), salt-bath brazing (group 924) and flux-bath brazing (group 925)

Table 39 — 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 40 — Bath composition

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

14.9 Infrared brazing (group 941)

Table 41 — 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 42 — 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 43.

Table 43 — Temperature measurement

Designation	Need for calibration, verification, or validation	Instruments and techniques
Preheat temperature, interpass temperature and preheat maintenance temperature measurement	Surface contact thermometers, thermocouples, temperature sensitive materials (thermochrome crayons and paints), optical devices for contactless measurement and other thermal temperature indicators Surface contact thermometers and optical devices for contactless measurement shall be validated. Thermocouples are reasonably stable and accurate and do not usually need to be validated. The connected electrical instruments and in particular the entire set-up (except thermocouples) shall be validated. Temperature sensitive materials need not be verified, if manufactured by a reliable supplier.	This can, for normal preheat temperatures, be performed by validation at two fix-points: melting ice and boiling water. However, for high preheat temperatures and, in particular if the instrument range of measurement is changed, validation at a higher fix-point temperature is needed. A master thermocouple can be used.
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 is usually needed whenever the instrument settings have been changed.	Watches shall be considered sufficiently accurate unless obviously defective. Time recording instruments shall be validated by means of a watch.

15.2 Post weld heat treatment

Post weld heat treatment is a critical operation (when needed) and proper control is essential for the properties of the welded joints and indeed the entire structure. Calibration, verification, or validation can be needed for the process data stated in Table 44.

Table 44 — Temperature-time 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 (except thermocouples) 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: ±10 °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. The required accuracy of the measuring system shall be defined by the manufacturer depending on the used components of the measuring system corresponding to the allowed range of annealing temperature of the materials to be annealed. The required accuracy of the measuring systems depends on the pwht tolerances given in the instruction for pwht.
Heat treatment time measurement	Watches, recording instruments. Watches shall be considered sufficiently accurate unless obviously defective and need not 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.
Temperature recorder	Temperature recorder shall be validated or calibrated. Recommended accuracy class 0,5.	Temperature simulator shall be used for calibration and validation.

16 Post weld cleaning

Calibration, verification, or validation can be needed for the process data stated in Table 45.

Table 45 — Post weld cleaning

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

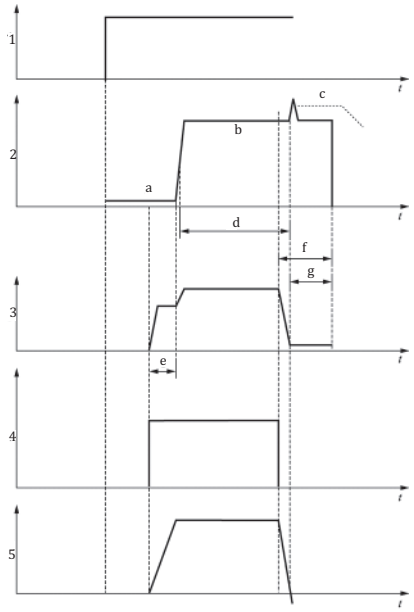
17 Flame cutting (group 81) and other ancillary processes

Flame cutting machines are similarly controlled by observing the quality (visual appearance) of the cut faces and not so much on measured gas pressures and flow rates. Calibration, verification, or validations are usually not needed, unless required due to special conditions, if not specified.

NOTE Procedure testing of flame cutting and other ancillary processes is usually not required.

Annex A
(informative)

Details for stud welding



Key

1 trigger
2 current
3 voltage
4 voltage at solenoid (pre-set welding time)
5 stud travel
a Pilot current.
b Main current.
c Short-circuit current.
d Welding time.
e Pilot arc.
f After-burning time.
g Short-circuit time.

Figure A.1 — Drawn arc stud welding process (783) (schematic)

Annex B
(informative)

Acceptance testing of equipment

Calibration, verification and validation of measuring devices used for manufacture and/or acceptance testing of equipment are, in general, outside the scope of the present International Standard. The following guidance can, however, be given:

Many types of equipment are covered by International Standards specifying requirements to outgoing inspection. The International Standards usually include provisions for verification, validation, or calibration of measuring instruments integrated into the equipment.

A number of International Standards specify requirements to acceptance testing of equipment. These International Standards typically relate to complex equipment where the installation phase is critical for the quality of the entire installation and/or the equipment is composed of components delivered from more than one supplier. At least parts of the final acceptance testing are usually performed after installation in the welding workshop.

Some of the International Standards for acceptance testing, in particular ISO 14744-1 to ISO 14744-6 and ISO 15616-1 to ISO 15616-3, include provisions for check of *x*-*y* tables, rotary tables, etc. These provisions can also, to some extent, be used for acceptance testing of similar equipment installed in combination with complex equipment for other welding processes.

Annex C
(informative)

Parties involved

Manufacturers should be aware of the fact that legal, contractual, or commercial requirements can restrict the choice of the organization performing calibration, verification, or validation. The organization may have to have a special status, e.g. as accredited third party. The requirements depend on the nature of the product and also on the customer. The manufacturer should consider all likely requirements in order to avoid unnecessary re-calibrations, etc.

Calibration, verification and validation necessitate an unbroken traceability chain all the way back to an object or phenomenon directly reflecting the definition of one or more units, using more and more accurate instruments. Few manufacturers are able to perform the entire chain of calibrations and verifications needed and have instead to rely on subcontractors (organizations specialized in fundamental calibration and verification). The manufacturer should note that requirements to the status of the calibrating organization (if any) usually applies to all subcontractors in the entire traceability chain.

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