INTERNATIONAL STANDARD

ISO 17657-4

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Resistance welding — Welding current measurement for resistance welding —

Part 4: Calibration system

Soudage par résistance — Mesurage des courants en soudage par résistance —

Partie 4: Système d'étalonnage

Reference number
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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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.

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 17657-4 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 6, *Resistance welding*.

ISO 17657 consists of the following parts, under the general title *Resistance welding — Welding current measurement for resistance welding*:

— *Part 1: Guidelines for measurement*

— *Part 2: Welding current meter with current sensing coil*

— *Part 3: Current sensing coil*

— *Part 4: Calibration system*

— *Part 5: Verification of welding current measuring system*

Introduction

Requests for official interpretations of any aspect of this part of ISO 17657 should be directed to the Secretariat of ISO/TC 44/SC 6 via your national standards body. A complete listing of these bodies can be found at http://www.iso.org.

Resistance welding — Welding current measurement for resistance welding —

Part 4: Calibration system

1 Scope

This part of ISO 17657 specifies calibration systems and calibration procedures for welding current measuring systems, current sensors, welding current meters and monitoring devices with current sensor used for measuring welding current in resistance welding with alternating current of 50 Hz or 60 Hz, or with direct current.

The procedures are applicable for a current range between 0,5 kA and 25 kA.

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.

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

ISO 17657-2, *Resistance welding — Welding current measurement for resistance welding — Part 2: Welding current meter with current sensing coil*

ISO 17657-3:2005, *Resistance welding — Welding current measurement for resistance welding — Part 3: Current sensing coil*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 669 and the following apply.

3.1
test (current) sensor
current sensor to be calibrated

3.2
reference (current) sensor
current sensor calibrated in highly accurate condition, used for calibration of current sensors

3.3
test welding current meter
welding current meter to be calibrated

3.4
non-inductive shunt
high precision and low value resistance with a very low inductive component

3.5
analog-to-digital converter
ADC
device to convert analog input signals into digital signals

3.6
data acquisition device
instrument or device used to acquire analog data, which tracks changes in physical variables such as voltage, current and temperature

3.7
measuring accuracy of reference welding current measuring system
sum of measuring accuracy values of each component calibrated by a certified reference equipment (e.g. reference sensor, integrator, ADC etc.)

4 Construction of calibration system

4.1 Reference welding current measuring system

Components of a reference welding current measuring system shall be calibrated by certified reference equipment in accordance with Clause 6. The reference welding current measuring system consists of a calibrated current sensor, a data acquisition system and a display unit or a recorder.

4.2 Test set-up

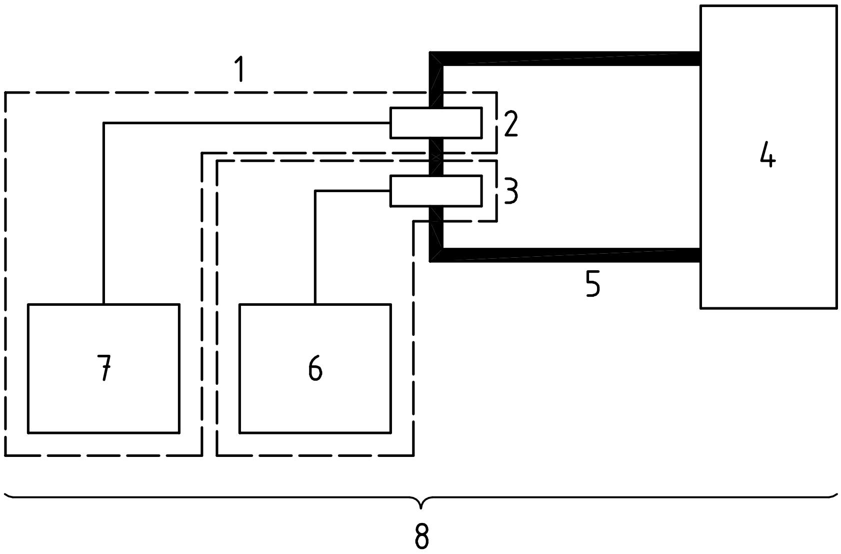
The test set-up consists of a test stage or an appropriate circuit for conducting high current, and a power source with a current control unit for supplying a test current.

All signal cables shall be twisted and shielded. The cable resistance shall be very small and negligible compared to the impedance of the current sensor. Typical examples of the test set-up are shown in Annex A.

NOTE A resistance welding machine/transformer can be used as a test set-up.

4.3 Basic feature for calibration of welding current measuring system

A welding current meter with a current sensor should be calibrated in a set consisting of the meter and the sensor. Calibration systems for a welding current meter with its sensor consist of a test set-up, a reference welding current measuring system and the welding current measuring system to be tested. The function of a reference welding current meter can be replaced with a calibrated data acquisition device. Figure 1 shows the basic features required for calibration of welding current measuring system.



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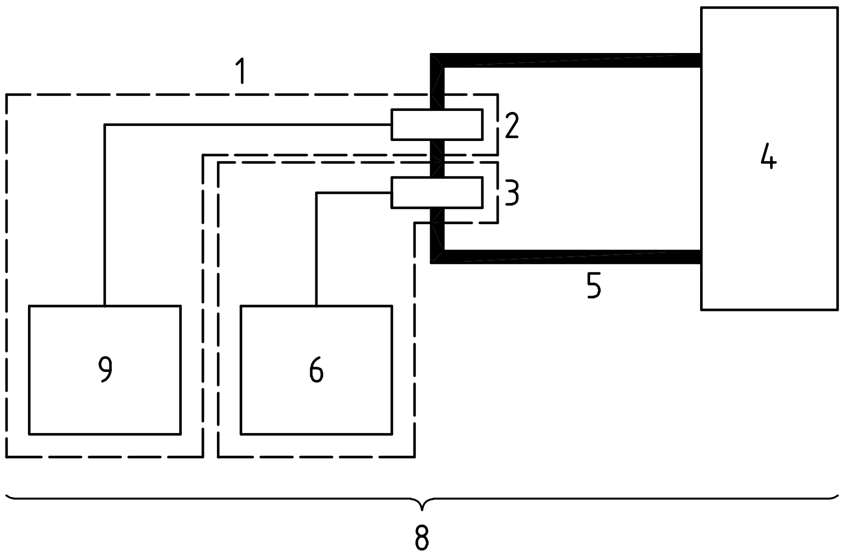


b)

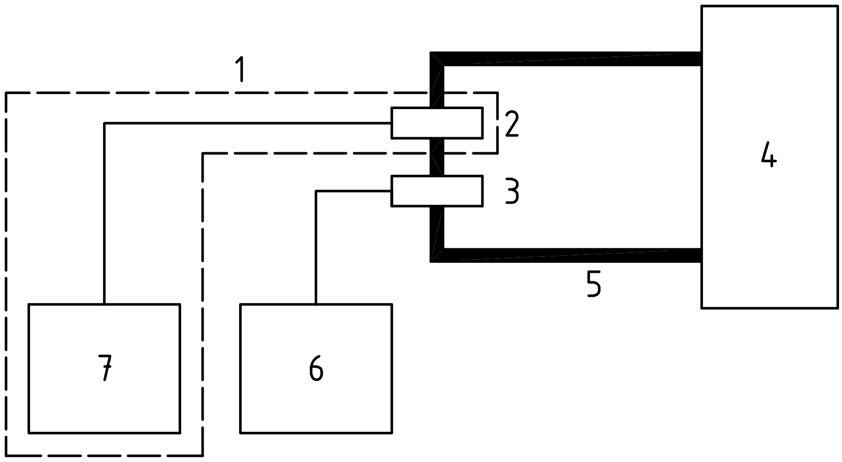
Key

1 reference welding current measuring system
2 reference sensor
3 test sensor
4 alternating current or direct current power source
5 secondary circuit
6 test welding current meter
7 reference welding current meter
8 test set-up
9 data acquisition device

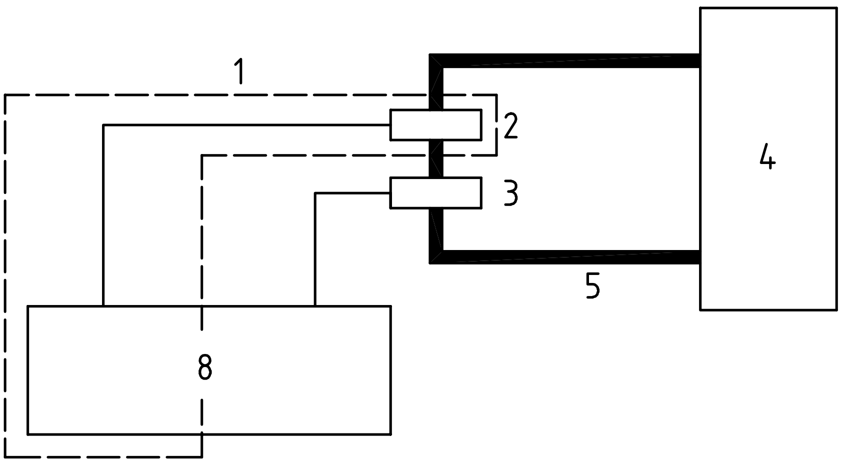
Figure 1 — Basic feature for calibration of welding current measuring system

4.4 Basic feature for calibration of current sensor

A calibration system for a current sensor consists of a test set-up, a reference welding current measuring system and a calibrated data acquisition device connected to the current sensor to be tested. The function of the reference welding current meter can be replaced by using another channel of the data acquisition device. Figure 2 shows the basic feature required for the calibration of current sensor.



a)



b)

Key

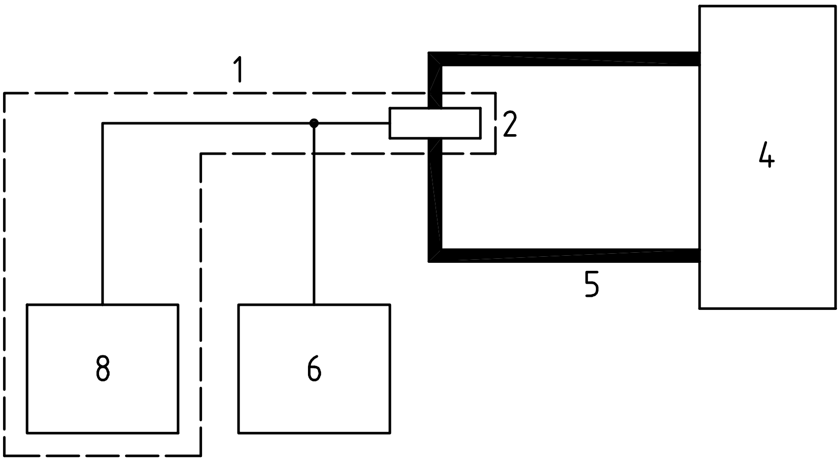
1 reference welding current measuring system
2 reference sensor
3 test sensor
4 alternating current power source
5 secondary circuit
6 data acquisition device
7 reference welding current meter
8 data acquisition device

Figure 2 — Basic feature for the calibration of current sensor

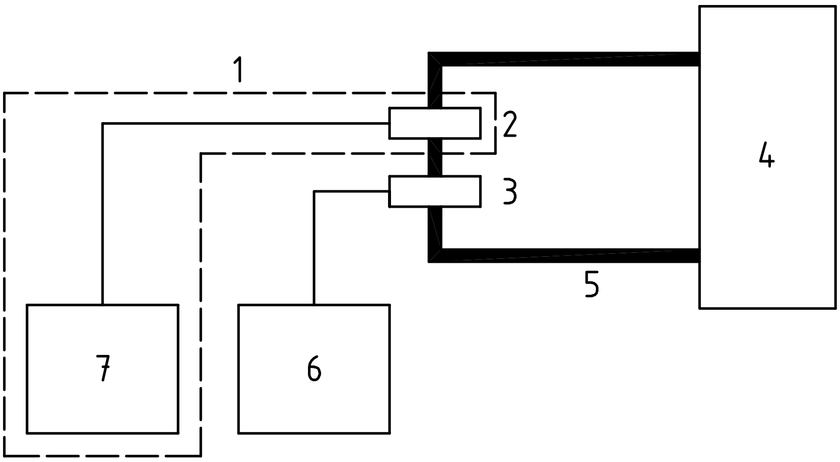
4.5 Basic feature for calibration of welding current meter without sensor

A calibration system for a welding current meter of the high-impedance integrator type without current sensor consists of a calibrated data acquisition device of the high-input-impedance integrator type, a calibrated reference sensor, and the test welding current meter. See Figure 3 a). The welding current meter to be tested is connected to the same output port of the reference current sensor. The data acquisition device shall not be replaced by a reference welding current meter of the low-impedance integrator type.

For calibration of a welding current meter with the low impedance integrator unit, and when two reference coils are used for the calibration, the calibration system shall consist of a calibrated reference welding current measuring system and a calibrated second reference sensor connected to the welding current meter to be tested. See Figure 3 b).



a)



b)

Key

1 reference welding current measuring system
2 reference sensor
3 second reference sensor
4 alternating current or direct current power source
5 secondary circuit
6 test welding current meter
7 reference welding current meter
8 data acquisition device

Figure 3 — Basic feature for calibration of welding current meter without sensor

5 Physical environment and operating conditions

Unless otherwise specified, the calibration system shall be capable of operating under the following conditions without any adverse effect on its accuracy. Any deviation from these conditions shall be agreed upon between the test laboratory and the client.

— at an ambient air temperature between +5 °C and +40 °C;

— in relative humidity up to 95 %;

— at altitudes up to 1 000 m above mean sea level.

6 Calibration requirements

6.1 Reference welding current measuring system

Components of the reference welding current measuring system shall be calibrated by using certified reference equipment at least once a year. The total measuring accuracy is defined as the sum of measuring accuracy of each component of the reference welding current measuring system and shall be better than that stipulated for the highly accurate class stipulated in ISO 17657-2.

The specification, name of certifying test body and relevant data for the reference welding current measuring system, including the data acquisition device, and the reference current sensor shall be recorded on all documentation. See Annex B.

6.2 Reference current sensor

Properties of reference current sensor shall be measured accurately with no external influences (e.g. strong magnetic field caused by the high current) and calibrated by using certified reference equipment at a full wave alternating current of 50 Hz or 60 Hz, or direct current.

In the case of using a non-inductive shunt as the reference current sensor, the conversion coefficient shall be between 10 mV/kA and 150 mV/kA, and the error shall be less than ± 0,25 %. The phase shift between a measured welding current and the output voltage shall be less than 1° for a sinusoidal wave current of 10 kHz.

Measuring accuracy of the reference current sensor including positioning error shall be within ± 0,5 %, or the position should be fixed with pre-mounted current sensors on the current conductor to prevent any positioning error.

NOTE A current sensing coil used as a reference current sensor should be made with as low internal impedance as possible. Recommended specifications for a current sensing coil to be cased as a reference current sensor are shown below:

— toroidal coil with return winding known as a Rogowski-type coil;

— $L < 250$ μH;

— $r_i < 50$ Ω;

— K: measuring accuracy shall be within ± 0,25 %;

— $R_L = 1\,000$ Ω (± 0,2 % and non-inductive type).

6.3 Data acquisition device

The data acquisition device shall be designed with an ADC (analog to digital converter) of the 12-bit type or higher, and with at least two channels as the input port. Each channel datum shall be simultaneously captured, and sampled. The sampling rate per channel shall be equal to or faster than 10 000 samples, and the input impedance shall be higher than 500 kΩ.

Calibration of the data acquisition device shall be carried out by using certified reference equipment. The measuring accuracy for each gain of each channel shall be reported as a document.

6.4 Test stage and power sources

The test set-up shall be capable of delivering the necessary current value for the calibration. This depends on the final application and the limits of the test set-up. The test set-up shall be capable of delivering at least four current values within range of the final application between the minimum and maximum current values of the described range of calibration.

A multi-turn secondary circuit is applicable to reduce the power source capacity. Examples of test set-up are given in Annex A.

An alternating current resistance welding machine can be used as the power source on condition that the current value can be controlled by changing the primary tap of the transformer, etc., and the current shall be delivered in different r.m.s. (root mean square) levels. A direct-current resistance welding machine can be also used as the power source.

7 Test report

7.1 Test report for calibration of welding current measuring systems

The following shall be recorded during calibration of a welding current measuring system including monitoring devices with its coil for measuring welding current:

a) type and name of the reference welding current measuring system, the full scale and the measuring accuracy;

b) type, model and manufacturer's name of the welding current measuring system to be tested, and its full scale(s);

c) sensor position (for current sensing coil, see Figure 1 of ISO 17657-3:2005);

d) frequency of power source (50 Hz or 60 Hz);

e) current waveform for the test (alternating current or direct current);

f) time of current application, in seconds or cycles;

g) room temperature;

also each measurement of:

h) read-out of the reference welding current meter expressed as an r.m.s. value, in kiloamps (kA);

i) read-out of the test welding current meter expressed as an r.m.s. value, in kiloamps (kA);

j) deviation from the indication of reference meter expressed as an r.m.s. value (kA); if the deviation is expressed as a percentage, the deviation shall be calculated as a ratio for the full scale of test meter;

and for information:

k) estimated measuring accuracy of the test current meter expressed as a percentage of full scale of the test meter, and the calculation form;

l) test date, name and signature of the testing or examining person.

7.2 Test report for calibration of current sensors

The following should be recorded and reported before calibration of a current sensor:

a) type and name of reference measuring system, full scale and the measuring accuracy;

b) full scale of a data acquisition system and the measuring accuracy;

c) type, model and manufacturer's name of test current sensor and the rated conversion coefficient;

d) sensor position (for current sensing coil, see Figure 1 of ISO 17657-3:2005);

e) frequency of power source (50 Hz or 60 Hz);

f) time of current application, in seconds or cycles;

g) room temperature;

also each measurement of:

h) read-out of the reference (current) meter expressed as an r.m.s. value, in kiloamps or millivolts (kA or mV);

i) read-out of the test sensor expressed as an r.m.s. value, in millivolts (mV);

j) conversion coefficient of test current sensor, or deviation from the rated value expressed as a percentage of the rated value;

and for information:

k) conversion coefficient, the measuring accuracy and calculation forms;

l) test date, name and signature of the testing or examining person.

7.3 Test report for calibration of welding current meters without sensors

The following should be recorded during calibration of a welding current meter including monitoring devices for measuring welding current:

a) type and name of reference welding current measuring system, the full scale and the measuring accuracy;

b) conversion coefficient of the reference current sensor(s) and the measuring accuracy;

c) type, model and manufacturer's name of the welding current meter to be tested and its full scale;

d) sensor position (for current sensing coil, see Figure 1 of ISO 17657-3:2005);

e) frequency of the power source (50 Hz or 60 Hz);

f) current waveform for the test (alternating current or direct current);

g) time of current application, seconds or cycles;

h) room temperature;

also each measurement of:

i) read-out of the reference welding current meter expressed as an r.m.s. value, in kiloamps (kA);

j) read-out of the test welding current meter expressed as an r.m.s. value, in kiloamps (kA);

k) deviation from the indication of the reference meter expressed as an r.m.s. value, kiloamps (kA); if the deviation is expressed as a percentage, the deviation shall be calculated as a ratio for the full scale of test meter;

and for information:

l) measuring accuracy of the test current meter expressed as a percentage of full scale of the test meter and the calculation form;

m) test date, name and signature of the testing or examining person.

8 Test procedure

8.1 General

All equipment shall be switched on before calibration begins. Each range of the measuring instruments shall be adapted to the required current level in order to improve the measured accuracy. The room temperature at the beginning and the end of calibration shall be recorded.

Measurements for each setting of the test sequence shall be recorded as shown in tables as in Annex C.

8.2 Calibration of welding current measuring system

Calibration of a welding current measuring system shall be carried out with a measuring set-up as illustrated in Figure 1.

The appearance of the test sensor should be checked for any damage before the calibration. The deviation of read-out displayed on the test welding current meter relative to the reference measuring system shall be measured, followed by the determination of the measuring accuracy of the test welding current measuring system.

When calibrating the measuring system, the test shall be carried out at positions of the current sensing coil conforming to common practice.

NOTE 1 In order to calibrate the accurate class, and highly accurate class of a welding current meter with its coil, it is recommended to check at the four sensor positions B, D, E and H illustrated in Figure 1 of ISO 17657-3:2005.

The measuring accuracy should be determined using the maximum value of all the measured deviations. Each deviation should be expressed as an r.m.s. value. If the deviation is expressed as a percentage, the value shall be calculated as a ratio for the full scale of test meter.

The calibration shall be carried out at at least four current levels including the near full scale current condition of test meter. The measurements shall be carried out with either an alternating current of 50 Hz or 60 Hz, and/or with direct current. Current flow time for the test shall be longer than 0,1 s in order to reduce the initial transitions on the measured result.

NOTE 2 When the measured result is outside the required measuring accuracy, the meter should be adjusted or repaired.

NOTE 3 If the power source of the calibration system cannot supply the maximum current as shown on the test welding current meter label, it is recommended that a multi-turn circuit be used as the current conductor as shown in Figure A.3.

8.3 Calibration of current sensor

Calibration of a current sensor shall be carried out with a measuring set-up as illustrated in Figure 2. The test sensor should be rejected if damaged. Any deviation of the output voltage or current displayed on the data acquisition device relative to the reference value should be measured. The conversion coefficient and the measuring accuracy of test sensor shall be determined.

NOTE In order to calibrate the accurate class, and highly accurate class of welding current meter, it is recommended to check at four sensor positions of B, D, E and H illustrated in Figure 1 of ISO 17657-3:2005.

The calibration shall be carried out by measuring four current levels with an alternating current of 50 Hz or 60 Hz. Three measurements shall be performed at each current level. The procedure with a reference welding current measuring system shown in Figure 2 a) requires full-wave alternating current with no wave distortion to guarantee the measuring accuracy. Current flow time for the test shall be longer than 0,1 s in order to reduce the initial transitions on the test result.

When the test is carried out with an alternating current of either 50 Hz or 60 Hz, and a conversion coefficient in the other frequency is to be described in the documentation, the coefficient value shall be converted using Equation (1) described in ISO 17657-3:2005.

8.4 Calibration of welding current meter without sensor

Calibration of a welding current meter without current sensor shall be carried out with a measuring set-up as illustrated in Figure 3. When a welding current meter with low-impedance integrator unit is calibrated, a two-coil system shall be used for the calibration.

The deviation of welding current value should be calculated together with the determination of the measuring accuracy of test current meter.

The measuring accuracy should be determined as indicated in C.5. Each deviation should be expressed as an r.m.s. value. If the deviation is expressed as a percentage, the value shall be calculated as a ratio for the full scale of test meter.

The calibration shall be carried out at at least four current levels including the near full scale setting condition of test meter. The measurements shall be carried out with either an alternating current of 50 Hz or 60 Hz, and/or with direct current. Current flow time for the test shall be longer than 0,1 s in order to reduce the initial transitions on the measured result.

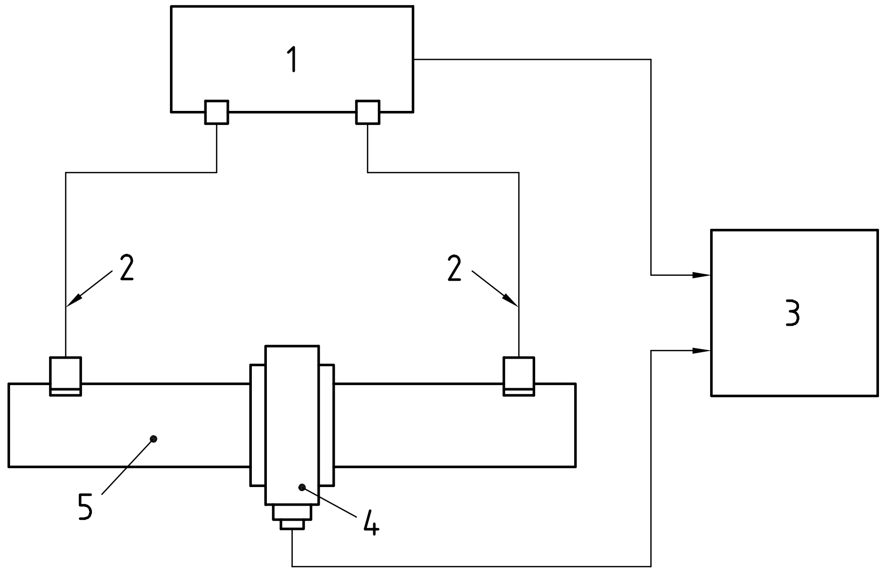
NOTE 1 When the measured result is outside the required measuring accuracy, the meter should be adjusted or repaired.

NOTE 2 If the power source of the calibration system cannot supply the maximum current as shown on the test welding current meter label, it is recommended that a multi-turn circuit be used as the current conductor as shown in Figure A.3.

8.5 Special calibration cases

8.5.1 Calibration of current sensors mounted within welding transformer

For the calibration of a built-in current sensor within a welding transformer, a copper rod pre-mounted reference sensing current sensor should be connected to the secondary circuit of the test welding transformer as shown in Figure 4. Alternatively, a similar test set-up as shown in Figure A.4 can be used.



Key

1 welding transformer

2 connecting cable

3 data acquisition system

4 reference coil

5 copper rod

Figure 4 — An example of measuring set-up for calibration of a current sensor mounted in a transformer

The calibration shall be carried out according to the procedure described in 8.3, and measuring accuracy and conversion coefficient shall be recorded on the documentation.

8.5.2 Calibration of current meters and sensors used for measuring the primary current

Calibration of a current sensor used for measurement of primary current of a welding transformer should also be carried out with the measuring set-up illustrated in Figure 1. A high-impedance secondary circuit can be used to realize a low test current condition at least between 0,5 kA to 1,0 kA to simulate the primary current range.

The calibration should be carried out according to the procedure described in 8.2 and 8.3 with a reference current sensor of the high conversion coefficient type (1,5 V/kA) as specified for the primary circuit in ISO 17657-3.

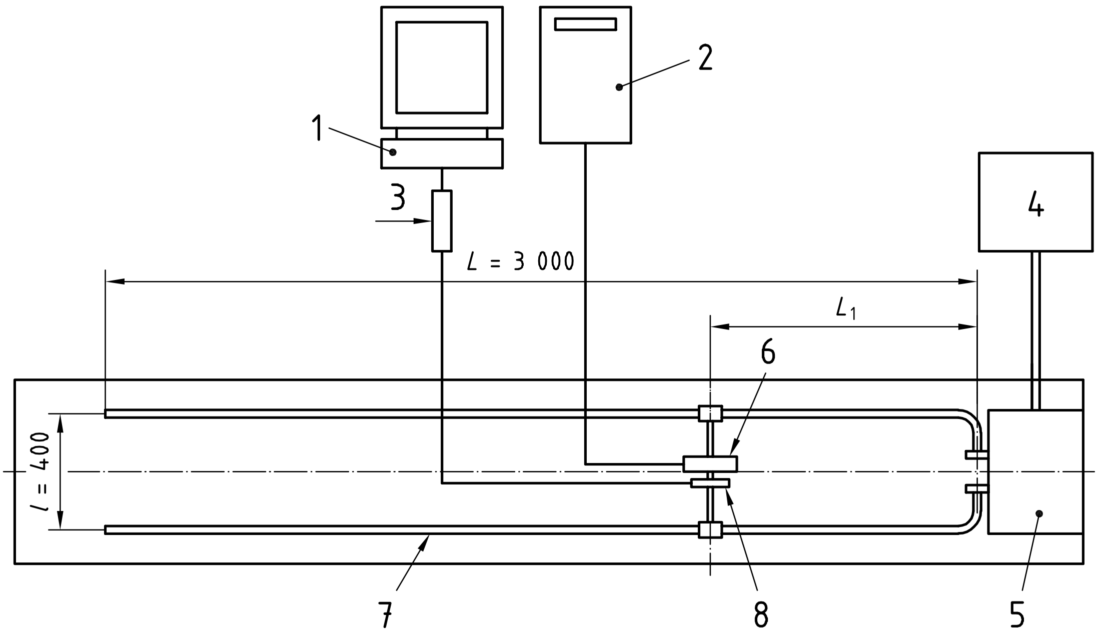
Annex A
(informative)

Measuring set-up

A.1 An example of test stage for checking current sensors and welding current meters

The test set-up consists of two parallel bars made of copper alloy arranged at a certain distance, and current sensors mounted on a transverse bar. The test set-up and a transverse bar are shown in Figure A.1 and A.2 that can be connected to either alternating current or a direct current power source.

Dimensions in millimetres



Key

1 data acquisition board

2 system to be checked

3 input resistance (1 kΩ ± 0,2 %)

4 welding control unit

5 transformer

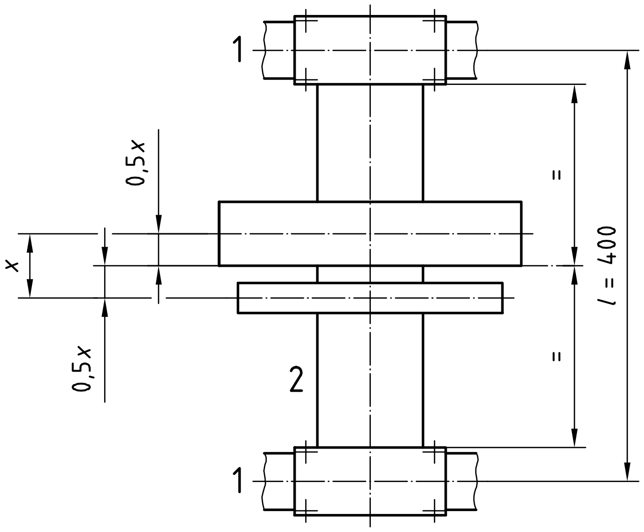
6 current sensing coil

7 copper circuit

8 reference coil

Figure A.1 — A measuring set-up of test stage type

Dimensions in millimetres



Key

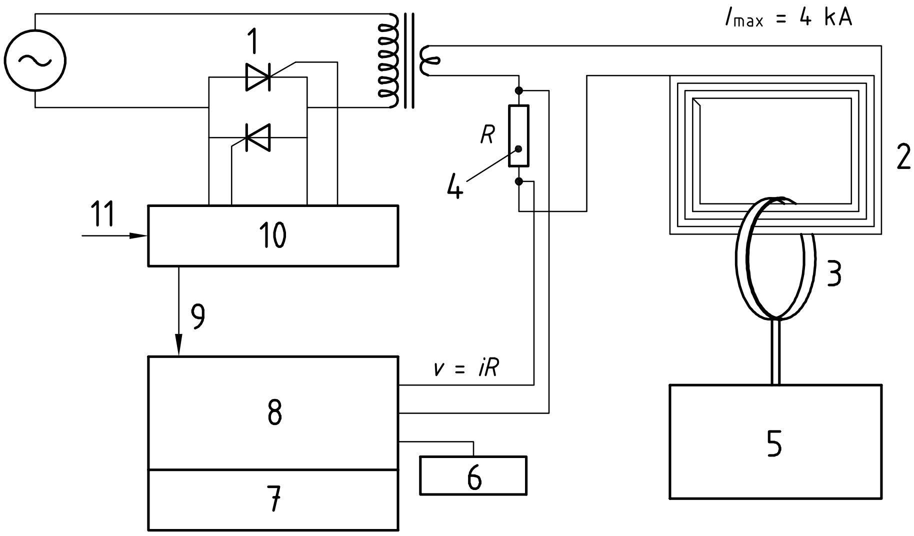
1 longitudinal bar

2 transverse bar

Figure A.2 — A transverse bar made of copper alloy to control the test current value

A.2 Example of measuring set-up with a non-inductive shunt

The test set-up consists of a data acquisition device, a non-inductive shunt, multi-turn secondary current circuit and a power source (see Figure A.3).



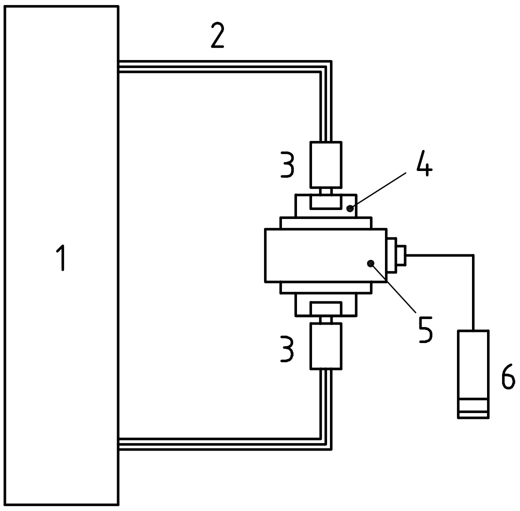
Key

1 thyristor
2 secondary conductor
3 test coil
4 shunt
5 test welding current meter
6 printer
7 display
8 m.s. operation – data acquisition device
9 synchronized signal
10 weld control
11 start switch

Figure A.3 — An example with non-inductive shunt as a current sensor

A.3 Examples of measuring set-up with a resistance welding machine

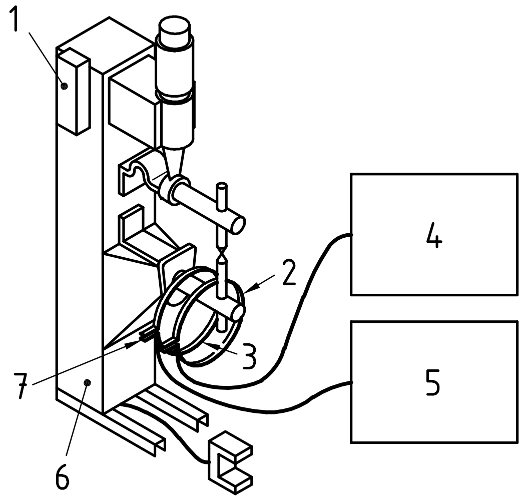
A reference current sensor pre-mounted on a short copper bar is available as shown in Figure A.4. The bar can set up between electrode tips of a resistance spot welding machine. An example where the resistance welding machine is used as a power source and test stage is shown in Figure A.5. These systems can apply to calibrate a monitoring device mounted in the welding machine.



Key

1 resistance welding machine
2 secondary circuit
3 electrodes
4 copper rod
5 current sensing coil
6 connecting plug

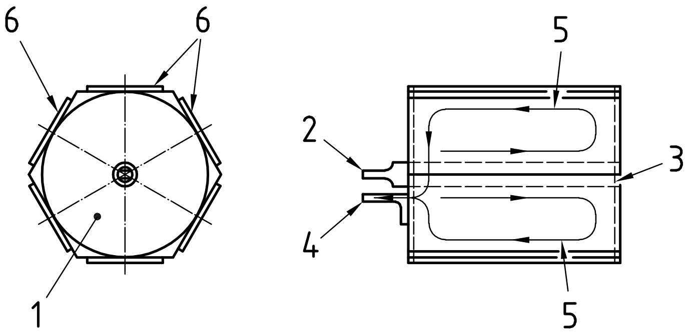
Figure A.4 — Example of clamped type of reference sensing current sensor



Key

1 welding controller
2 reference coil
3 test coil
4 reference welding current meter
5 test welding current meter
6 resistance welding machine
7 fixing

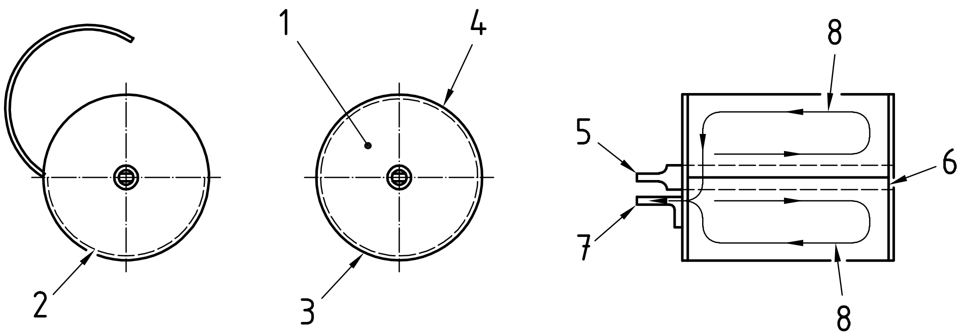
Figure A.5 — Example using a resistance spot welding machine as the test stage



Key

1 round central conductor
2 centre bus current in
3 centre bus connected to end plate
4 end plate return current
5 current paths
6 return current plates, upper three plates removable (six plates total)

a) Hexagonal current cage



Key

1 round central conductor
2 view open cage
3 view closed cage
4 upper half shell hinged to open
5 centre bus current in
6 centre bus connected to end plate
7 end plate return current
8 current paths

b) Circular coaxial current cage

Figure A.6 — Example of measuring set-up with hexagonal and circular coaxial current cages

Annex B
(informative)

Items to be recorded or filed as reference documentation for calibration

B.1 Reference welding current meter

The following items should be recorded and filed as the reference documents:

a) model;

b) type;

c) type of measuring current (alternating or direct);

d) maximum measuring current, kiloamps or amps (kA or A);

e) maximum measuring time, in cycles or milliseconds (ms);

f) measuring accuracy, percent (%);

g) setting requirements to guarantee the accuracy;

h) permissible temperature range, in degree centigrade (°C);

i) manufacturer's name and name of certifying test body.

B.2 Reference sensor

The following items should be recorded and filed as the reference documents:

a) model;

b) type;

c) rated conversion coefficient, in millivolts per kiloamp (mV/kA) and the frequency, in hertz (Hz);

d) measuring accuracy, percent (%);

e) frequency response, in kilohertz (kHz);

f) pre-connected output load of current sensor, ohms (Ω);

g) required input impedance of integrator, in kilohms (kΩ);

h) setting requirements to guarantee the accuracy;

i) allowable temperature range, in degrees centigrade (°C);

j) manufacturer's name and name of certifying test body.

B.3 Data acquisition device

The following items should be recorded and filed as the reference documents:

a) model of the device;

b) rated dynamic input range of each channel (±V);

c) resolution of ADC (bits);

d) rated sampling rate of ADC (number of samples/channel);

e) measuring accuracy, in percent (%);

f) maximum input voltage for each channel guarded (V);

g) manufacturer's name and name of certifying test body.

B.4 Non-inductive shunt

The following items should be recorded and filed as the reference documents:

a) model of the shunt;

b) sensitivity, in millivolts per kiloamp (mV/kA);

c) measuring accuracy, in percent (%);

d) frequency response, in kilohertz (kHz);

e) rated current, in kiloamps (kA);

f) rated flow rate of cooling water, litres per minute (l/min);

g) manufacturer's name and name of certifying test body.

Annex C
(informative)

Examples of the test report in accordance with this part of ISO 17657

C.1 Test report for calibration of a welding current measuring system

Welding current measuring system to be tested	**Test set-up**	**Reference current measuring system**
Model:	Model or type:	Model or type:
Type:	**Power source**	Full scale: kA
Manufacturer:	Type:	Measuring accuracy: %
Full scale: kA	Frequency: Hz	

Test conditions		
Time of current application	cycles or ms	
Sensor position:	Test sensor:	Reference sensor:
Room temperature:	Beginning:	End:

Test No.	**Read-out of reference meter** kA	**Read-out of test meter** kA	**Deviation from reference meter** kA or %	**Note** (Test sensor position)
1	(I_{max})			
2	(I_{max})			
3				
4				
5				
6				
7				
8				
9	(I_{min})			
10	(I_{min})			

Test result	
Measuring accuracy:	%

Checked by:	Date:	Signature:

NOTE The value of estimated measuring accuracy was calculated using the following equation:

< Description of the equation to calculate the measuring accuracy here >

C.2 Test report for calibration of a current sensor with a reference welding current measuring system

Current sensor to be tested	**Test set-up**	**Data acquisition device**
Model:	Model or type:	Model or type:
Type:		Full scale: kA
Manufacturer:	**Power source**	Measuring accuracy: %
Rated conversion coefficient: mv/kA and Hz	Type:	**Reference current measuring system**
	Frequency: Hz	Model or type:
		Full scale: kA
		Measuring accuracy: %

Test conditions		
Time of current application	cycles or ms	
Sensor position:	Test sensor:	Reference sensor:
Room temperature:	Beginning:	End:

Test No.	**Read-out of reference meter** kA	**Read-out of test sensor** mV	**Conversion coefficient of test sensor** mV/kA	**Note** (Test sensor position)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Test result

Conversion coefficient: mv/kA and Hz Measuring accuracy: %

Checked by:	Date:	Signature:

NOTE The value of conversion coefficient estimated measuring accuracy was calculated using the following equation:

< Description of the equation to calculate the conversion coefficient and the measuring accuracy here >

C.3 Test report for calibration of a current sensor with measuring output voltages

Current sensor to be tested	**Test set-up**	**Data acquisition device**
Model:	Model or type:	Model or type:
Type:		Full scale: kA
Manufacturer:	**Power source**	Measuring accuracy: %
Rated conversion coefficient: mV/kA and Hz	Type:	**Reference sensor**
	Frequency: Hz	Conversion coefficient: mV/kA and Hz
		Measuring accuracy: %

Test conditions

Time of current application cycles or ms

Sensor position: Test sensor: Reference sensor:

Room temperature: Beginning: End:

Test No.	Read-out of reference sensor mV	Test current [a] kA	Read-out of test sensor mV	Conversion coefficient of test sensor mV/kA	Deviation from the rated value %	Note (Test sensor position)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Test result

Conversion coefficient: mV/kA and Hz Measuring tolerance: %

Checked by:	Date:	Signature:

NOTE The value of conversion coefficient estimated measuring accuracy was calculated using the following equation:

< Description of the equation to calculate the conversion coefficient and the measuring accuracy here >

[a] This calculated value is for information only and can be omitted by agreement between the contracting parties.

C.4 Test report for calibration of a welding current meter without sensor

Welding current measuring system to be tested	**Test set-up**	**Reference current measuring system**
Model:	Model or type:	Model or type:
Type:		Full scale: kA
Manufacturer:	**Power source**	Measuring accuracy: %
Full scale: kA	Type:	**Reference sensor**
Rated conversion coefficient of sensor connected	Frequency: Hz	Conversion coefficient: mV/kA and Hz
to the meter: mV/kA and Hz		Measuring accuracy: %

Test conditions		
Time of current application	cycles or ms	
Sensor position:	Test sensor:	Reference sensor:
Room temperature:	Beginning:	End:

Test No.	**Read-out of reference meter** kA	**Read-out of test meter** kA	**Deviation from reference meter** kA or %	**Note** (Test sensor position)
1	(I_{max})			
2	(I_{max})			
3				
4				
5				
6				
7				
8				
9	(I_{min})			
10	(I_{min})			

Test result

Measuring accuracy: %

Checked by:	Date:	Signature:

NOTE The value of estimated measuring accuracy was calculated using the following equation:

< Description of the equation to calculate the measuring accuracy here >

C.5 Examples of equation for the calculation of test results

C.5.1 General

The following equations are recommended for calculating the measuring accuracy and conversion coefficient:

C.5.2 Test reports for calibration of welding current meter with and without sensor

$$\text{Measuring accuracy} = \frac{\text{Maximum deviation (kA)}}{\text{FS of TWCM (kA)}} \times 100 + \text{MA of RWCM} \times \frac{\text{FS of RWCM}}{\text{FS of TWCM}} \ (\%)$$

where

MA is the measuring accuracy

FS is full scale

RWCM is the reference welding current measuring system

TWCM is the test welding current meter with or without sensor

C.5.3 Test report for calibration of current sensor with measuring output voltage

$$\text{Conversion coefficent} = \left(1 + \frac{\text{Mean value of all deviations}}{100}\right) \times \text{Conversion coefficient of RWCS (mV/kA)}$$

$$\text{Measuring accuracy} = \sqrt{\frac{\Sigma(\text{Deviation from the rated value})^2}{\text{Test data number}}} + \text{MA of DAD} \times \frac{\text{FS of DAD}}{\text{Measured input level}} + 1\text{LSB } (\%)$$

where

MA is the measuring accuracy

FS is full scale

RWCS is the reference welding current sensor

DAD is the data acquisition device

LSB is the least significant bit

C.5.4 Test report for calibration of current sensor with reference welding current meter

$$\text{Conversion coefficient} = \frac{\Sigma \text{Each conversion coefficient value}}{\text{Test data number}} \text{ (mV/kA)}$$

$$\text{Measuring accuracy} = \sqrt{\frac{\Sigma(\text{Each conversion coefficient} - \text{rated conversion coefficient})^2}{\text{Test data number} \times \text{rated conversion coefficient}}} +$$

$$+ \text{MA of DAD} \times \frac{\text{FS of DAD}}{\text{Measured input level}} + 1\text{LSB (\%)}$$

where

MA is the measuring accuracy

FS is full scale

DAD is the data acquisition device

LSB is the least significant bit

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