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Resistance welding — Welding current measurement for resistance welding —

Part 1:
Guidelines for measurement

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

Partie 1: Lignes directrices pour le mesurage

Reference number
ISO 17657-1:2005(E)

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Foreword

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ISO 17657-1 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*

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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.

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Resistance welding — Welding current measurement for resistance welding —

Part 1: Guidelines for measurement

1 Scope

This part of ISO 17657 specifies equipment for the calibration of measuring systems of welding current and indicating weld time in resistance welding using single-phase alternating current of frequency 50 Hz or 60 Hz, or direct current.

The guidelines define various basic terms for the measurement of welding current, and give some basic information for users of welding current measuring systems including welding current meters with current sensing coil.

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 17657-2:2005, *Resistance welding — Welding current measurement for resistance welding — Part 2: Welding current meter with current sensing coil*

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

ISO 17657-4, *Resistance welding — Welding current measurement for resistance welding — Part 4: Calibration system*

ISO 17657-5, *Resistance welding — Welding current measurement for resistance welding — Part 5: Verification of welding current measuring system*

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
technical operation that consists of the determination of one or more characteristics or performance of a given product or equipment according to a specified procedure

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3.2
verification
confirmation by examination and provision of evidence that specified requirements have been met

3.3
calibration
set of operations that establish, under specified conditions, the relationship between values indicated by the measuring instrument or measuring system, and the corresponding values of a measuring instrument or measuring system with confirmed higher accuracy

3.4
welding current measuring system
⟨resistance welding⟩
measuring system that measures the welding current value and/or welding current waveform at the primary or secondary circuit of a welding transformer by using a sensing coil, non-inductive shunt or other suitable sensors

3.5
welding current meter
⟨resistance welding⟩
meter of portable type, or built into the weld controller for measuring short period current and which consists of at least a data capturing and calculating unit (e.g. integrator and accumulating unit) and a display unit

3.6
master welding current meter
welding current meter calibrated against a reference welding current meter

3.7
reference welding current meter
welding current meter which is sufficiently well-established to be used for the calibration of welding measuring systems or welding current meters

3.8
certified reference equipment
reference equipment which is certified by a technically valid procedure, accompanied by, or traceable to, a certificate or other documentation issued by a certifying body

3.9
current sensing coil (toroidal coil or **Rogowski coil)**
multi-wound coils, in which wire is wound around a non-magnetic core of constant cross section, for detecting the magnetic flux generated by current

3.10
weld time
time during which the welding current is applied, expressed as a number of cycles or a length of time in milliseconds

NOTE Annex A gives further information on the definition of weld time.

3.11
current flow time
duration defined from the start time of current conduction to the time when its current has decreased to a 10 % level of the measured welding current value, which is applied only to direct current for determination of minimum value of the hold time

NOTE 1 Annex A gives further information on the definition of current flow time.

NOTE 2 Current flow time is applicable only to direct current.

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3.12
welding current
current value accumulated over the weld time and indicated by the r.m.s. value, which is applicable for alternating and direct current

NOTE 1 In the case of capacitor discharge current, the welding current can be indicated by the r.m.s. or the peak value.

NOTE 2 Annex A in ISO 17657-2:2005 gives further information on how to calculate the welding current values.

3.13
phase control
typical current control technique in resistance welding, e.g. by changing the firing angle in each half-weld cycle of alternating current

4 Welding current measuring system

4.1 General

Welding current measuring systems consist of a welding current meter, a current sensor (e.g. current sensing coil, non-inductive shunt, or any suitable sensors) and display.

4.2 Applicability

The welding current measuring system shall be selected based on a consideration of the following factors, in order to guarantee highly accurate measurement:

- type of current sensor (coil, shunt, other suitable sensors);
- type of welding current (alternating, direct or pulsed current);
- current level or current range;
- frequency of current or current waveform;
- location of current sensor (primary or secondary of circuit).

Welding current measuring systems are classified into two types. One is used for measurement of alternating current only, which does not apply correctly to measurements of direct current. The other is a multi-purpose type applicable for the measurement of all current types, including continuous direct and pulsed direct current in addition to alternating current.

4.3 Accuracy

The scatter in measured current value is caused by the following factors:

- manufacturing variations of current sensor and existence of distortion caused by incorrect use, or excessive repeat bending in fitting and detaching the coil;
- setting position of current sensor;
- magnetic noise affecting the connection parts of cables and connecting leads;
- temperature variations;
- design differences in the integrator/amplifier used to convert the output signal of the current sensor to a current waveform, and different calculation algorithms for welding current value in the data processing

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unit, in particular different definitions of the start time and finish time for calculation of r.m.s. current values;

— variation of the input impedance and gain setting of the integrator if the combination of the current sensor and the integrator has been changed (when using a current sensing coil).

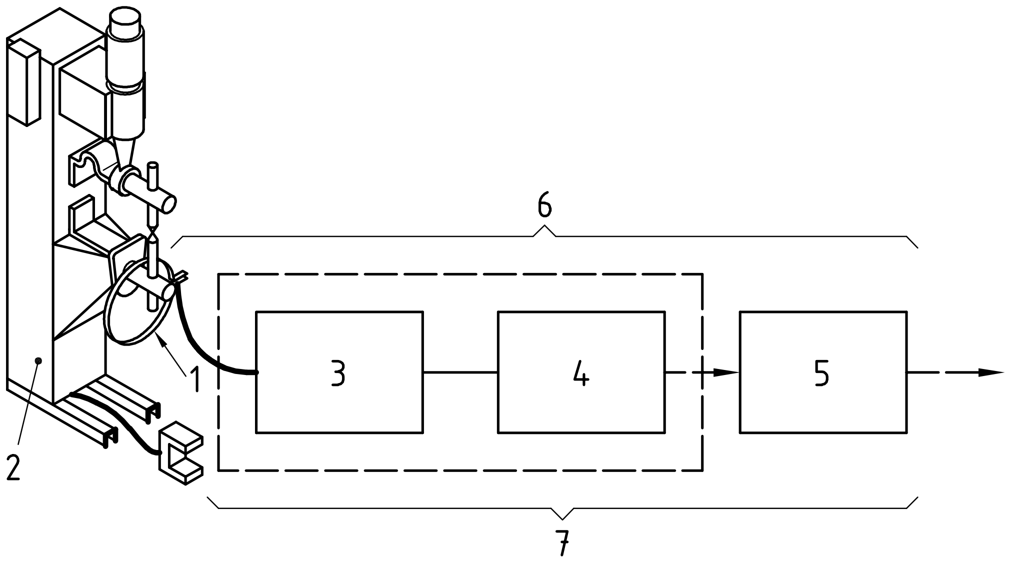
For high accurate measurements of welding current, i.e. less than ± 0,5 % error, the current sensing coil shall be located in the same position as that in which it was calibrated.

The welding current measuring system shall be calibrated as a set including the current sensor and integrator/amplifier in order to guarantee the accuracy. If calibration of the sensor alone is required, the input impedance of the calibration system shall be the same value as the input impedance of the welding current meter.

4.4 Welding current meter with current sensing coil

The welding current sensing system consists of at least a current sensing coil, an integrator, a data processing unit, and output devices for displaying or recording the welding current value and weld time. See Figure 1.

The current sensing coil is used for detecting the changing magnetic flux around the welding electrode or current conductor. The integrator converts a signal detected by the current sensing coil to the current waveform, and the data processing unit calculates the r.m.s. value of current over the weld time or for a fixed duration (see Annex A).



Key

1 current sensing coil

2 resistance welding machine

3 integrator

4 data processing unit

5 display unit, recorder, or control devices

6 welding current measuring system

7 welding current meter

Figure 1 — An example of welding current meter with current sensing coil

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5 Current sensors

5.1 Type of sensor

The following current sensors can be used in resistance welding:

— current sensing coil;

— non-inductive shunt;

— any other suitable sensors (e.g. hall devices).

The current sensing coils are predominantly used for current measurement, and classified into two main types, one is a flexible coil, the other is a rigid coil. The flexible coil type is usually used to measure the welding current set at the secondary circuit of a resistance welding machine. The rigid coil type can be mounted in any positions in the secondary or primary circuit, or built into the transformer.

5.2 Selection of current sensor

The following factors shall be checked when selecting the type of a current sensor to be used:

— sensitivity/conversion coefficient;

— maximum output voltage of the current sensor in the measuring range;

— frequency response;

— setting position error;

— temperature dependency of the sensitivity/conversion coefficient;

— current sensor output load required by manufacturer;

— influence of external magnetic flux on current sensing coil (especially affecting the connecting part and connecting lead);

— mechanical properties and design of winding, which closely related to the distortion of cross section, and any irregular winding of coil. The winding density can change as a consequence of repeat bending of the coil, e.g. when fitting and detaching a flexible current sensing coil.

Mechanical properties of current sensing coil specified in ISO 17657-3, in addition to electrical properties, shall be considered, if necessary, to guarantee the measuring accuracy.

5.3 Conversion coefficient

The conversion coefficient shall be described as the ratio of output voltage to the welding current. The scatter in conversion coefficient depends on the type, structure, temperature sensitivity, and physical/dimensional change of the sensor.

The conversion coefficient of a current sensing coil is dependent on the frequency of measured current (Annex C gives further information on the conversion coefficient of current sensing coil). The scatter in conversion coefficient when using a coil is caused mainly by the irregular winding, and detected as a positional error and/or distortion of the coil cross section during long term use.

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6 Tests and calibration of the welding current measuring systems

The tests and calibration of new welding current measuring systems including welding current meters with current sensing coil etc., shall be achieved by the manufacturer using a reference welding current measuring system. Calibration of the devices or equipment after purchasing should be carried out in the laboratory of the manufacturer, the customer or an approved test body by using a reference welding current measuring system.

The verification of a welding current measuring system including a welding current meter can be carried out with a master welding current measuring system under shop-floor conditions if the master meter has been calibrated against a reference welding current measuring system.

Guidelines for the test and calibration are given in Table 1. The test and calibration shall be performed according to Table 1.

Results of the test are normally recorded in a test report or on a test certificate. The results of calibration shall be recorded in a document sometimes called a calibration report or a calibration certificate. The result of verification leads to a decision either to restore the unit to service or to perform adjustment, or repair. In all cases, it is required that a written trace of the verification performed is retained according to quality assurance manuals.

Table 1 — Systems of tests and calibrations

Target system to be calibrated or tested	For product tests	For calibration or verification after purchasing
(1) Welding current measuring system or components for daily use (welding current meters, welding timer with display for current, sensing coil, etc.)	Calibrated by an RWCM	Calibrated by an RWCM Verified by an MWCM
(2) Master welding current measuring system for use in shop-floor/workshop	Calibrated by an RWCM	Calibrated and verified by an RWCM
(3) Reference welding current measuring system for use in laboratory	Components shall be calibrated by a CRE	Components shall be calibrated or verified by a CRE
(4) Certified reference equipment	Certified by a certifying body	
MWCM: Master welding current measuring system.		
RWCM: Reference welding current measuring system.		
CRE: Certified reference equipment.		

7 Selection of requirements and test procedures for a welding current measuring system

Requirements and test procedures for welding current meters and current sensing coils are described in ISO 17657-2 and in ISO 17657-3. The measuring system should be verified or calibrated at least once every year according to Table 1. Requirements and procedures for calibration and verification are described in ISO 17657-4 and in ISO 17657-5. The components to be used in the reference welding current measuring system shall be calibrated against certified reference equipment at least once a year by a certifying body.

Guidelines in the selection of ISO 17657-2 to ISO 17657-5 are given in Table 2.

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Table 2 — Selection of requirements

Devices	References for requirements and test procedures	
	Tests for products	For calibration or verification
Welding current meters, Welding current measuring systems	ISO 17657-2	ISO 17657-2, ISO 17657-4 and ISO 17657-5
Current sensing coils	ISO 17657-3	ISO 17657-3 and ISO 17657-4
Reference welding current measuring system	ISO 17657-4	ISO 17657-4
Certified reference equipment	Documents by a certifying body	

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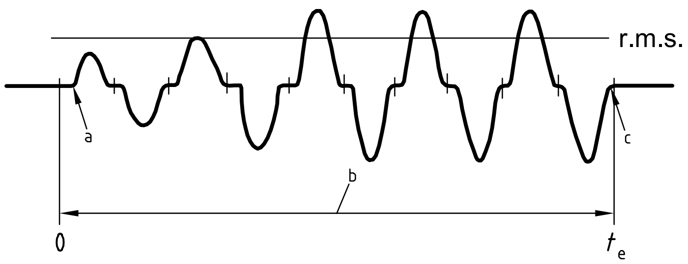
Annex A
(normative)

Definition of weld times

The definitions of weld time and current flow time are shown in Figure A.1.

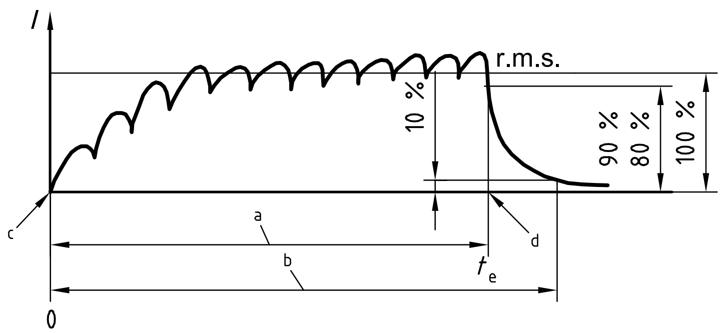


a Start of measuring.

b Weld time.

c Current finish time.

a) single-phase alternating current



a Weld time.

b Current flow time.

c Current start time.

d End of time for calculation of welding current.

b) direct current

Figure A.1 — Definition of the weld times and current flow time

In the case of single-phase alternating current, the weld time is indicated by the number of cycles of current conduction time. In the case of direct current, the weld time is determined from the start time of the current conduction to the time when the current has not decreased below a certain level (e.g. 90 %) of the measured value of welding current. A notation t_e described in Figure A.1 defines the end of the weld time in each welding current wave form. In the case of alternating current, the weld time shall be defined in cycle number(s), or the time expressed in milliseconds, which is calculated as a product of the duration of 1 cycle and the number of cycles.

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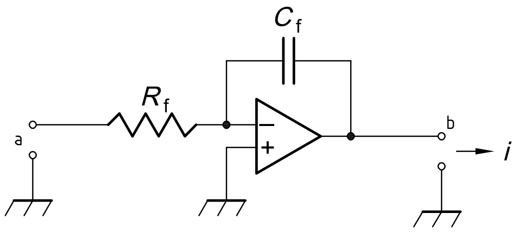
Annex B
(informative)

Types of integrator and equivalent current sensing coil circuits

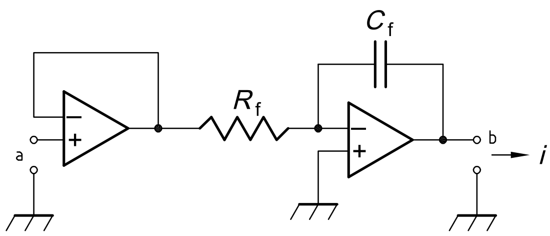
The integrators used for welding current meters or welding current monitoring systems with their current sensing coil are classified into three types. An analog integrator without a pre-amplifier or an analog integrator but with pre-amplifier to increase the input impedance is available. Another type is a digital integrator with an analog-to-digital converter. Typical circuits are illustrated in Figure B.1.



[a] To current sensing coil.

[b] Current waveform.

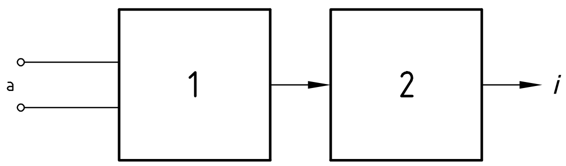
a) Analog integrator without pre-amplifier



[a] To current sensing coil.

[b] Current waveform.

b) Analog integrator with pre-amplifier



Key

1 A/D converter

2 data processing unit

[a] To current sensing coil.

c) Digital integrator with analog to digital converter (A/D converter)

Figure B.1 — Constructions of integrators

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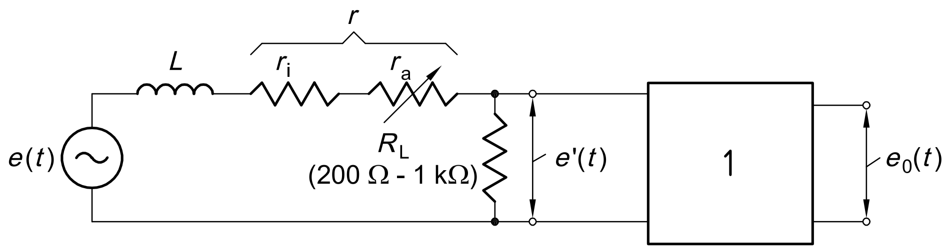
The analog integrator shown in Figure B.1 a) has a relatively low impedance feature, but the dynamic input range is wide. On the other hand, the analog integrator with a pre-amplifier shown in Figure B.1 b), and the digital integrator type has high input impedance features. This means that connection of the integrator to the current sensing coil does not affect the conversion coefficient. However, the supply voltage limits the dynamic input range when using high impedance integrator types [see Figure B.1 b) and c)]. The applicable frequency range of welding current (target current) is narrower than in the case of the analog integrator without pre-amplifier type. An equivalent circuit of the current sensing coil with an output load is shown in Figure B.2.



Key

1 integrator

Figure B.2 — An equivalent circuit of the current sensing coil and an integrator

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Annex C
(informative)

Conversion coefficient and maximum output voltage of current sensing coils

If the target current waveform is assumed to be a simple sinusoidal curve, $I = I_{\mathrm{m}} \sin\omega t$, the conversion coefficient K of the current sensing coil can be defined by the following equation:

$$K = \frac{R_{\mathrm{L}}}{R_{\mathrm{L}} + r} N A \mu_0 \omega \quad \text{(V/A)} \tag{C.1}$$

where

μ_0	is the permeability of the core materials used for the current sensing coil [$= 4\pi \times 10^{-7}$ H/m (henry per metre)];
N	is the number of coil windings per unit length (1/m);
A	is the cross section of the current sensing coil (not for loop length of the current sensing coil) in square metres;
r	is the sum of a resistance of current sensing coil r_{i} and a small adjustment resistance r_{a} in ohms;
R_{L}	is the resistance connected at the sensing coil ends as an output load/burden (hereafter referred to as the "output load" of the current sensing coil) in ohms;
$\omega = 2\pi f$	is the angular frequency;
f	is the frequency of target (measured) current in hertz.

The maximum output voltage of the current sensing coil is the product of K and I_{m}. The output voltage of the current sensing coil is proportional to the frequency. A similar phenomenon appears when the firing angle is controlled. A typical calculated result is shown in Figure C.1. This figure shows a calculation result as a function of firing angle in a circuit condition of 50 % power factor. The broken line shows the relationships between the firing angle and r.m.s. value of welding current, the solid line indicates the relation between the angle and maximum output voltage of the current sensing coil.

The welding current value reduces proportionally with the firing angle although the output voltage changes little. This means that the output voltage increases with the firing angle if the welding current value keeps constant. In the case of a 45° firing angle, the actual output voltage is almost twice that of the full wave condition.

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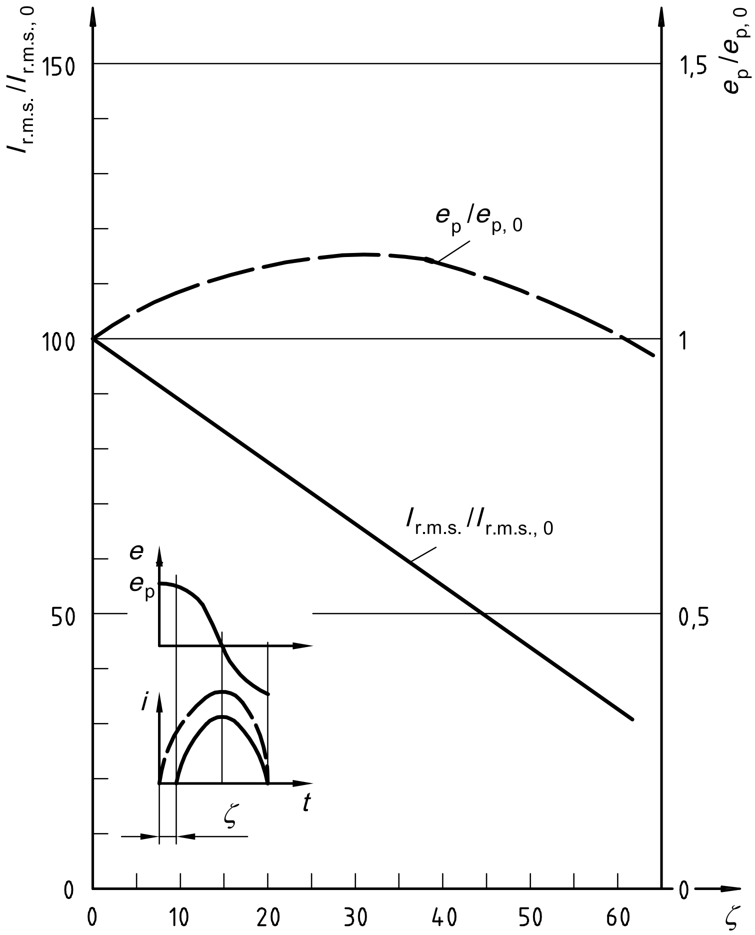

where

e is the maximum output voltage;

$I_{r.m.s.}$ is the welding current expressed as the r.m.s. value.

Figure C.1 — Influence of firing angle on the maximum output voltage (power factor 50 %)

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