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Welding and allied processes — Guidelines for measurement of arc energies

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Foreword

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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, *Unification of requirements in the field of metal welding*.

Introduction

Welding “arc energy” or “heat input” are fundamental values used to manage the consistency of weld metal and heat-affected zone properties. ISO 15614 requires the measurement of the welding energies implemented during a welding procedure qualification, but it does not give details about the methods to be used. Likewise, during the construction of a welded assembly, inspectors should make sure that the welding energies comply with the Welding Procedure Specification (WPS). But again, the details of the methods to be used are not specified. As a consequence, there may be a lack of consistency between the methods used to measure the welding energies during welding of the test piece and the methods used during the manufacturing process. This is a potential source of error which could have implications on the safety or quality of a welded component or structure.

Moreover, the latest technological breakthroughs in microprocessors and electrical power manipulation have yielded welding power sources and control systems that are capable of generating complex waveforms. However, these control systems and waveforms increase the difficulties related to voltage and current intensity measurements, as their values are manipulated at frequencies which can reach thousands of Hertz. The measuring instruments generally used by inspectors, such as TRMS clamp meters, can no longer be relied on to correctly measure the welding energy since differences exceeding 30 % with respect to the true energy can sometimes be found.

This Technical Report provides guidance on how to accurately measure welding energy and calculate heat input, both in the case of traditional welding systems and those that employ complex waveforms.

Welding and allied processes — Guidelines for measurement of arc energies

1 Scope

This Technical Report presents the guidelines for measuring the parameters needed to calculate arc energies for arc welding processes.

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 15607, *Specification and qualification of welding procedures for metallic materials — General rules*

ISO 17662, *Welding — Calibration, verification and validation of equipment used for welding, including ancillary activities*

ISO/TR 17671 (all parts), *Welding — Recommendations for welding of metallic materials*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 15607 and ISO/TR 17671 (all parts) and the following apply.

3.1
arc energy
E
product of welding voltage and current divided by travel speed of welding

Note 1 to entry: The often-used term “heat input” is more correctly the arc energy modified by an arc efficiency factor.

3.2
waveform controlled welding
welding process modification of the voltage and/or current wave shape to control characteristics such as droplet shape, penetration, wetting, bead shape, or transfer mode(s)

3.3
instantaneous energy
IE
welding energy determined by summing the product of current and voltage measurements made at rapid intervals which capture brief changes in the welding waveform

3.4
instantaneous power
IP

welding power determined by averaging the product of current and voltage measurements made over time at rapid intervals which capture brief changes in the welding waveform

3.5
run out length
length of a run produced by the melting of a covered electrode

[SOURCE: ISO/TR 17671-2:2002, 3.2]

4 General

The term "heat input" is often used to describe two different concepts. In this Technical Report, these concepts are identified as heat input and as arc energy. Determination of heat input involves multiplication by a unitless thermal efficiency factor while arc energy does not. Other than that distinction, the measurement methods for both are identical. The arc energy is determined as shown in Formulae (1), (2), and (3). The symbols shown in Table 1 are used for all formulae.

Table 1 — Symbols of terms used

Abbreviations and symbols	Term	Unit
I	Arc welding current	A
L	Length of a run	mm
U	Arc voltage	V
v	Travel speed	mm/s
E	Arc energy	kJ/mm
IE	Instantaneous energy	J
IP	Instantaneous power	J/s

Formula (1) provides the arc energy using arc welding current and arc voltage.

$$E = \frac{U \times I}{v} \times 10^{-3} \quad (1)$$

Formula (2) gives the arc energy using instantaneous energy.

$$E = \frac{IE}{L} \times 10^{-3} \quad (2)$$

Formula (3) gives the arc energy using instantaneous power.

$$E = \frac{IP}{v} \times 10^{-3} \quad (3)$$

5 Apparatus

Usual equipment and, in particular, the following:

5.1 Clamp meter or any equivalent current, instantaneous energy, or power-measuring device.

5.2 Voltmeter.

5.3 Time-measuring device, such as stopwatch.

5.4 Distance-measuring device, such as steel rule, tape measure.

6 Determination of arc energy

Three methods can be used to determine arc energy:

— Method A: by calculation using arc welding current, arc voltage, and welding speed [Formula (1)];

— Method B: by calculation using instantaneous energy measurements and length of the run [Formula (2)];

— Method C: by calculation using instantaneous power measurements and welding speed [Formula (3)].

For non-waveform-controlled welding, method A, B, or C can be used indifferently.

For waveform-controlled welding, method B or C should be used as method A can introduce mistakes up to 70 %.

All pulsed welding processes, for example, pulsed gas metal arc welding, are waveform-controlled welding processes. Power sources that are sold as synergic, programmable, or microprocessor-controlled are generally capable of waveform-controlled welding. If any doubt exists on whether waveform-controlled welding is being performed, the welding equipment manufacturer should be consulted.

For multi-arc welding, the arc energy is measured for each arc.

Table A.1 and Figure A.1 provide the range of power supply types and measurement methods that support production welding based on power supply type and measurement method used to weld the test piece.

7 Measurement parameters

7.1 General

When method A is used, measure arc voltage (7.2), welding current (7.3), and travel speed (7.5).

When method B is used, measure instantaneous energy (7.4) and length of the run (7.5).

When method C is used, measure instantaneous power (7.4) and travel speed (7.5).

7.2 Arc voltage

The voltage values should be measured as close to the arc as practical in order to prevent the measurement error due to voltage drop in the welding cables.

NOTE The voltage measurement is affected by cable size, length, and connection quality and has to be taken into account during measurement.

The position of the connectors shall be recorded in the WPQR to provide consistency of the measurement during production. The first one should be connected to the earth clamp on the work piece and the second one should be connected as described in Table 2.

Table 2 — Preferred arc voltage measurement locations

Process number according ISO 4063	Process	Measurement location

11(x)	Metal arc welding without gas protection (and all its subgroups)	Connection device on power source
12(x)	Submerge arc welding (and all its subgroups)	Welding head
13(x)	Gas-shielded metal arc welding (and all its subgroups)	Connection in wire feeder
14(x)	Gas-shielded arc welding with non-consumable tungsten electrode (and all its subgroups)	Connection device on power source
15(x)	Plasma arc welding (and all its subgroups)	Connection device on power source

7.3 Welding current

Measure the welding current using a shunt or a clamp meter on a straight portion of the welding cable.

The current measurement should include all earth-connection cables or current lead cables, if multiple earth-connection cables or current lead cables are used. It is inaccurate to measure the current intensity on a single cable and multiply by the total number of cables, or to mix the earth-connection cables and current lead cables in one measurement.

For measurements of arc welding current below the recommended range of the clamp meter, the cable may be looped through the clamp, in which case the measured value is divided by the number of loops.

7.4 Instantaneous energy or instantaneous power

Measurement of instantaneous energy or instantaneous power should utilize a welding power source or external meter that is capable of calculating and displaying energy or power. Both the sampling rate and the calculation rate should be sufficient to capture the changes in the welding waveform (typically, a sampling rate at least 10 times the frequency of the wave form is used).

When using external meters, the same guidelines as 7.2 and 7.3 apply.

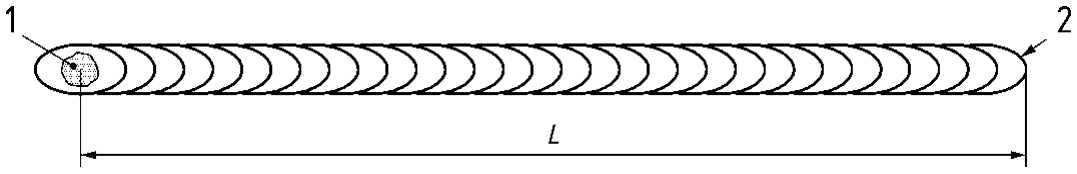
These meters are often identified by the terms “true energy”, “true power”, or “power factor”.

Meters identified by the terms “kVA”, “DC power”, or “average power” do not generally meet these requirements.

7.5 Travel speed and length

To determine the travel speed, a run is deposited and the time elapsed between arc starting and arc extinguishing is measured. After completion of the run, its length is measured (see Figure 1). The travel speed is obtained by dividing the length of the run by the elapsed time.

For mechanized and automatic welding, the travel speed can also be determined by measuring the time required to cover a distance without making a weld run or by using meters that are part of the equipment.



Key

1 crater at the end of the run

2 start of the run

L length of the run

Figure 1 — Length of the run

The length of the run corresponds to the distance between the start of the run and the middle of the crater at the end of the run, as illustrated in Figure 1.

8 Calibration and validation of measuring instruments

Calibrate or validate measuring equipment according to ISO 17662.

Annex A
(informative)

Range of power supply types and measurement methods

Table A.1 and Figure A.1 provide the range of power supply types and measurement methods that support production welding based on power supply type and measurement method used to weld the test piece.

Table A.1 — Range of power supply types and measurements

Qualification measurement method	Range of support
Non-waveform controlled welding using volt and ammeters and method A	— Non-waveform controlled welding with power supply using volt meters and ammeters and method A. — Non-waveform controlled welding displaying instantaneous energy or power measurement and method B or C. — Waveform-controlled welding displaying instantaneous energy or power measurement and method B or C. — Waveform-controlled welding which does not display instantaneous energy or power measurement using external meters that display instantaneous power or energy measurements and method B or C.
Non-waveform controlled welding using instantaneous energy or power and method B or C	— Non-waveform-controlled welding with power supply using volt meters and ammeters and method A. — Non-waveform-controlled welding displaying instantaneous energy or power measurement and method B or C. — Waveform-controlled welding displaying instantaneous energy or power measurement and method B or C. — Waveform-controlled welding which does not display instantaneous energy or power measurement using external meters that display instantaneous power or energy measurements and method B or C.
Waveform controlled welding using instantaneous energy or power and method B or C	— Non-waveform-controlled welding with power supply using volt meters and ammeters and method A. — Non-waveform-controlled welding displaying instantaneous energy or power measurement and method B or C. — Waveform-controlled welding displaying instantaneous energy or power measurement and method B or C. — Waveform-controlled welding which does not display instantaneous energy or power measurement using external meters that display instantaneous power or energy measurements and method B or C.
Waveform controlled welding using volt and ammeters and method A	— Non-waveform-controlled welding with power supply using volt meters and ammeters and method A. — Non-waveform-controlled welding displaying instantaneous energy or power measurement and method B or C. — Waveform-controlled welding displaying instantaneous energy or power measurement and method B or C. — Waveform-controlled welding which does not display instantaneous energy or power measurement using external meters that display instantaneous power or energy measurements and method B or C.

	The WPQR should be appended to show the heat input calculated using instantaneous power or energy. This can be done by welding a simple bead on plate using the same parameters (mode or program, voltage, current, etc.) as were used in the procedure qualification. Utilizing either a welding power source or external meter that displays instantaneous energy or power, the arc energy can be calculated per method B or C based on those readings.

NOTE A waveform-controlled power supply can also be able to provide non-waveform controlled welding.

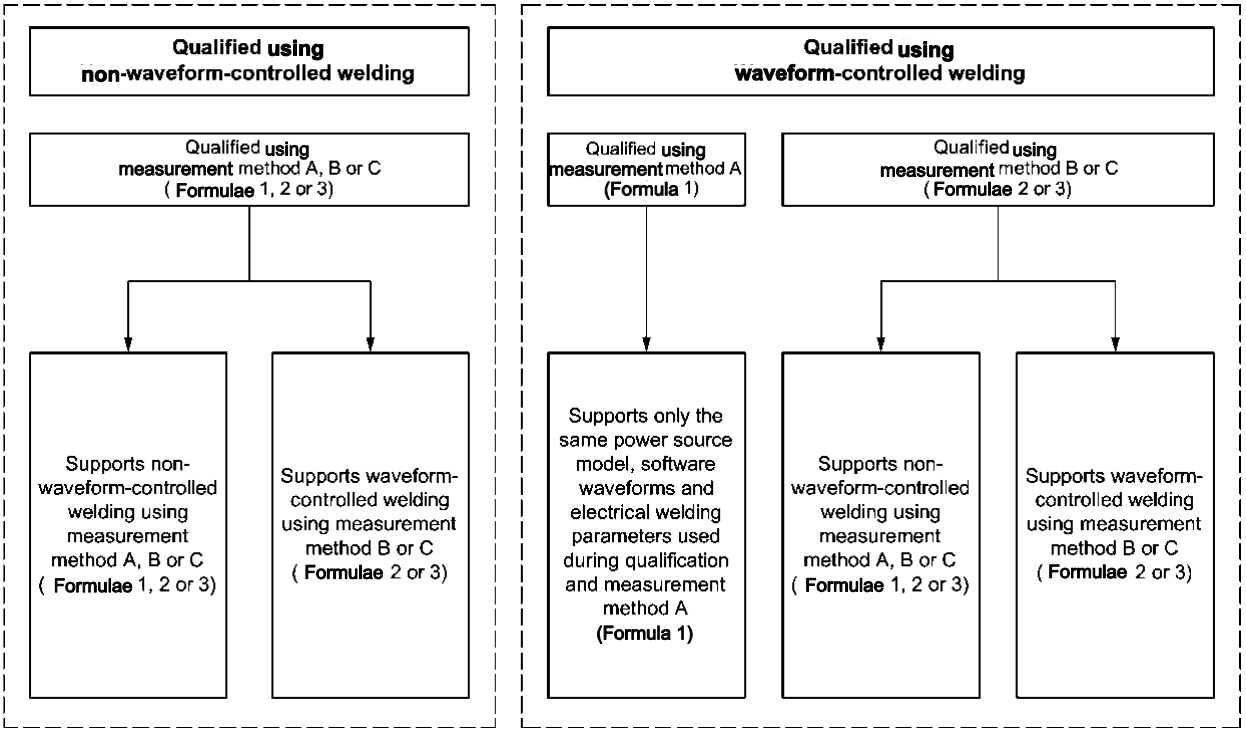


Figure A.1 — Logigram for qualification and production measurement method

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