

Specification for Calibration and Performance Testing of Secondary Current Sensing Coils and Weld Current Monitors used in Single-Phase AC Resistance Welding



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Specification for Calibration and Performance Testing of Secondary Current Sensing Coils and Weld Current Monitors used in Single-Phase AC Resistance Welding

1st Edition

Prepared by the
American Welding Society (AWS) A10 Committee on Instrumentation for Welding

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This specification sets forth accepted methods for testing and describing the performance of Rogowski-type air core current sensing coils (CSC) and weld current monitors (WCM) used in the measurement of single-phase ac resistance welding currents. A definition of terms relevant to this measurement is included. CSC and system tests and calibration methods are described in detail. Detailed information that shall be made available to the user are prescribed.



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Dedication

Dr. V. Ananthanarayanan

This document is dedicated to Dr. V. Ananthanarayanan (Anthony). Without his vision, leadership, and persistence, neither this document nor the A10 Technical Committee would exist.

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Foreword

This foreword is not part of [AWS A10.1M:2007](#), *Specification for Calibration and Performance Testing of Secondary Current Sensing Coils and Weld Current Monitors Used in Single-Phase AC Resistance Welding*, but is included for informational purposes only.

Measurement of resistance weld current and calibration of the measurement devices have been performed for many decades. However, the indications, readings, or outputs of devices made by different manufacturers and sometimes, the same manufacturer, while measuring the same current differ from one another significantly. This Measurement and Calibration Specification was prepared to help equipment manufacturers and users take into account some of the common sources of measurement uncertainty and standardize the methods of testing/calibration of these devices. The information that shall be provided to the user upon the completion of the calibration effort is also clearly specified. The goal is to assure consistent weld current measurement results independent of measurement equipment and to provide the user with a quantitative estimate of the total measurement uncertainty.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS A10 Committee on Instrumentation for Resistance Welding, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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Specification for Calibration and Performance Testing of Secondary Current Sensing Coils and Weld Current Monitors Used in Single-Phase AC Resistance Welding

1. Scope

This specification sets forth accepted methods for testing and reporting the performance characteristics of Rogowski-type air core Current Sensing Coils (CSCs) and the Weld Current Monitors (WCMs) used in the measurement of secondary current in single-phase ac resistance welding. CSCs mounted inside transformers are not included in this specification. Traceability of measurements to National Standards as required by this specification is discussed. References regarding traceability concepts and requirements are provided. Sources of measurement uncertainty, methods of combining these uncertainties, and the manner in which the overall uncertainty is to be stated are discussed.

This standard makes sole use of SI units.

Safety and health issues and concerns are beyond the scope of this standard and therefore are not addressed herein. Safety and health information is available from other sources, including, but not limited to, applicable federal and state regulations.

2. Testing

This clause describes the accepted methods that are needed to evaluate common sources of measurement uncertainty. Each test will include a description of the purpose for the test, list the equipment needed, describe the test setup and the test procedure.

2.1 Measurement Standards. The calibration shall be done using appropriate Measurement Standards. The Measurement Standard shall be more accurate than the device being calibrated. The uncertainty of the Measurement Standard used shall be included in the documentation of the calibration. Further, to ensure that adequate calibration is performed, the Measurement Standards must be traceable to NIST or other acceptable national

metrology laboratory or nationally recognized standards. A more detailed explanation of traceability can be found in Annex F. Measurement Standards used must be calibrated and used in the range and type of currents in which they were intended to be used.

For example, to comply with this specification, it is not acceptable that a shunt calibrated by dc continuous current be used in a calibration of pulsed current at 20 kA. The shunt must be calibrated by ac methods at current levels for which the shunt will be used.

It is recommended that multiple sets of Measurement Standards with NIST or National Standards traceability be maintained by all calibrating organizations in order to periodically compare them against one another and assess any changes in the values of the standards.

2.2 Test Categories. There are no firmly established limits of uncertainties for the measurement applications of CSCs, or for the WCM-CSC combination. It is common to group the applications as shown below. The values of uncertainties may vary from one organization to the next, depending on their individual needs, capabilities, and economic considerations. Note that there may be overlap between the ranges of uncertainties. Uncertainties may be expressed as a percentage of full scale, or of reading.

(1) Laboratory Standards: uncertainty typically $\pm 0.25\%$ to $\pm 1\%$,

(2) Working Standards: uncertainty typically $\pm 1\%$ to $\pm 2\%$, and

(3) Production Instruments: uncertainty typically $\pm 2\%$ and greater.

Tests described in this specification are divided into three categories: "Type Tests," "Routine Tests," and "Optional Tests."

(1) Type tests are carried out to characterize the product design and manufacturing process. It is also being done when uncertainty requirements are less demanding.

(2) Routine tests shall be done on every piece of hardware because test results depend on manufacturing differences from CSC to CSC. It is required when uncertainty requirements cannot be met with type tests alone.

(3) Optional tests are conducted when more rigorous estimates of the measurement uncertainties are required.

The categories are shown for 3 typical classes of instruments, namely instruments used as Laboratory Standards, Working Standards, and Production Instruments. Laboratory Standards are usually maintained at a company standards laboratory for the purpose of establishing a uniform and traceable basis of measurements. Working

Standards typically are used to disseminate the calibration from the standards laboratory to the field, shop, or production areas of a company. Production instruments typically are the instrumentation in the field, shops, or production areas of a company.

Table 1 lists all the tests included in this specification and their categories. Under the Test Category columns, there may be a “double listing” of the test category, such as “Type/Routine” or “Type/Optional.” In these instances, the test category may depend on the uncertainty that is trying to be achieved, or conversely, the uncertainty is acceptably large enough so as not to require the test. Furthermore, considerations have to be given to whether the CSC is being tested by the original manufacturer (in which case, Type Testing may be appropriate) or whether the CSC is being tested by a user

Table 1
CSC and WCM-CSC Combination Tests and Their Categories

Test No. (Clause No.)	Test	Test Categories			Comments
		Lab. Std.	Work Std.	Prod. Instr.	
1 (3.1)	Mutual inductance calibration at manufacturer recommended load	Routine	Routine	Type/ Routine	The most important characteristic of the CSC. It is used to describe the relationship between the CSC output voltage and the current it is being used to measure when connected to the WCM for which it was designed.
2 (3.1)	Mutual inductance calibration at no load	Routine	Optional	Optional	The results of this test help evaluate the CSC interchangeability since the manufacturer recommended load might differ from WCM to WCM.
3 (3.2)	Position sensitivity	Routine	Type/ Routine	Type	Often the single highest source of uncertainty in measurements made with Rogowski-type CSCs.
4 (3.3)	Tilt tests for position sensitivity	Routine	Type/ Routine	Type/ Optional	These additional tests are needed to provide a more rigorous estimate of the uncertainties due to position sensitivity.
5 (3.4)	Sensitivity to external magnetic fields	Optional	Type/ Optional	Type/ Optional	These additional tests are needed to provide a more rigorous estimate of the uncertainties due to position sensitivity. Particularly relevant when CSCs are placed in smaller secondary loops.
6 (3.5)	Temperature coefficient of a CSC	Routine	Type/ Routine	Type	It is important to know the temperature coefficient since CSCs are commonly used at temperatures different from where they are calibrated.
7 (3.6)	Frequency Response Testing of a CSC	Type/ Routine	Type	Type	Frequency response of CSC must be evaluated with respect to the spectrum of the current waveform being measured.
8 (4)	WCM-CSC combination calibration	Routine	Routine	Routine	Commonly performed, but the uncertainties and traceability aspects are usually not taken into account.

to verify performance (in which case, Routine or Optional Tests are more appropriate). Comments are provided to clarify the need for each test.

2.3 Physical Environment for Testing. All tests shall be performed with the Unit Under Test (UUT) at a temperature of $20^{\circ}\text{C} \pm 5^{\circ}\text{C}$, except when the temperature coefficient of the CSC is being determined. The relative humidity shall be no higher than 95%.

3. CSC Tests

Rigid closed, rigid hinged, and flexible CSCs are covered by this specification. The common CSC shapes covered are round, oval, and tear-drop. Other shapes, such as square, rectangular, or “racetrack” are not excluded from use. When testing these other shapes, the test methods described in this specification may not be directly applicable. This specification may be used as a guide in these instances.

3.1 Mutual Inductance Calibration. The CSC’s output signal is a function of its mutual inductance, M_{CSC} . The CSC shall be calibrated and the value of mutual inductance provided to the user. It is usually expressed in units of *micro henries* (abbreviated μH ; 1×10^{-6} henries) or *nanohenries* (abbreviated nH ; 1×10^{-9} henries). For CSCs used with weld current monitors, the CSC mutual inductance is typically in the range of 0.2 μH to 0.7 μH . For the purposes of this specification, the mutual inductance of the CSC is considered to be independent of frequency.

The CSC manufacturer needs to know the input impedance of the WCM to which the output of the CSC shall be connected. Only then can the CSC output be properly trimmed to provide the expected effective mutual inductance. It is common practice to adjust the *effective mutual inductance* of a CSC with the use of added resistor(s). These resistors are often physically located in the electrical connector of the CSC’s output cable. Series and/or parallel adjusting schemes are commonly used. The effective mutual inductance of the CSC is dependent upon the external electrical load impedance to which it is connected. The effective mutual inductance at the WCM manufacturer’s recommended load impedance shall be stated. In addition, the effective mutual inductance at no-load impedance may be stated. The no-load impedance is defined as a load equal to or greater than 1 $\text{M}\Omega$.

A value of CSC *transimpedance* may be provided, but shall not be used as a sole characteristic that describes the CSC sensitivity. In all instances, if a *transimpedance* value is given, it shall be accompanied with a value for frequency and load impedance under which it applies.

The value of transimpedance, if used, shall be stated in units of ohms, milliohms, or microohms, as appropriate. This value is commonly expressed as “millivolts per thousand amperes” at a stated frequency which is equivalent to units of microohms. The internationally accepted scientific units of ohms, milliohms, or microohms are preferred over the use of the expression “millivolts per thousand amperes.”

The mutual inductance calibration shall be performed in a 1/R-type magnetic field. A 1/R-type magnetic field is only created by an infinitely long straight conductor with a circular cross section when a current is flowing along the length of the conductor. The field is purely tangential to the single center conductor. The magnetic field beyond the outside of the conductor varies inversely with the distance R to the center of the conductor in a radial direction. Ideally, there are no other field contributions from any other source, especially the return conductor.

It is difficult to generate an ideal 1/R field. A practical, proven and suggested means to implement the generation of a suitable approximation of a 1/R-type magnetic field is with the use of a coaxial cage arrangement. The coaxial cage, which may be cylindrical or comprised of large flat rectangular conductors and a rigid straight center conductor with a round cross section. Sections through typical hexagonal and circular coaxial cages are shown in Figure 1. The coaxial cage geometry shall be such as to develop a suitable 1/R-type magnetic field approximation in the test envelope during the mutual inductance calibration test.

The sizes of the central and return conductors shall be appropriate for the current range used. Typical diameter of the center conductor is 38 mm to 50 mm. Practical cage diameters range from 300 mm to 600 mm, and the inside length range from 300 mm to 900 mm. The thickness of the outer walls and end plates of the cage is typically 6 mm to 12 mm thick. The inside of the cage must be sufficiently large to permit mounting the center of the CSC around the center conductor while maintaining a suitable clearance between the CSC and the inside walls of the cage. The opposing design criteria are to keep the cage small to minimize the insertion impedance of the cage in the high current path, while simultaneously providing sufficient working volume inside the cage to accommodate the CSC being calibrated. Smaller cages are less expensive to fabricate and are more portable. Additionally, the thick outside walls of the cage provides eddy-current shielding from external fields.

The CSC mutual inductance calibration shall be performed in a 1/R-type magnetic field equal to or better than that generated by a coaxial cage as described herein. If a coaxial cage is not used, it is the responsibility of the user to ensure, either through measurement or modeling

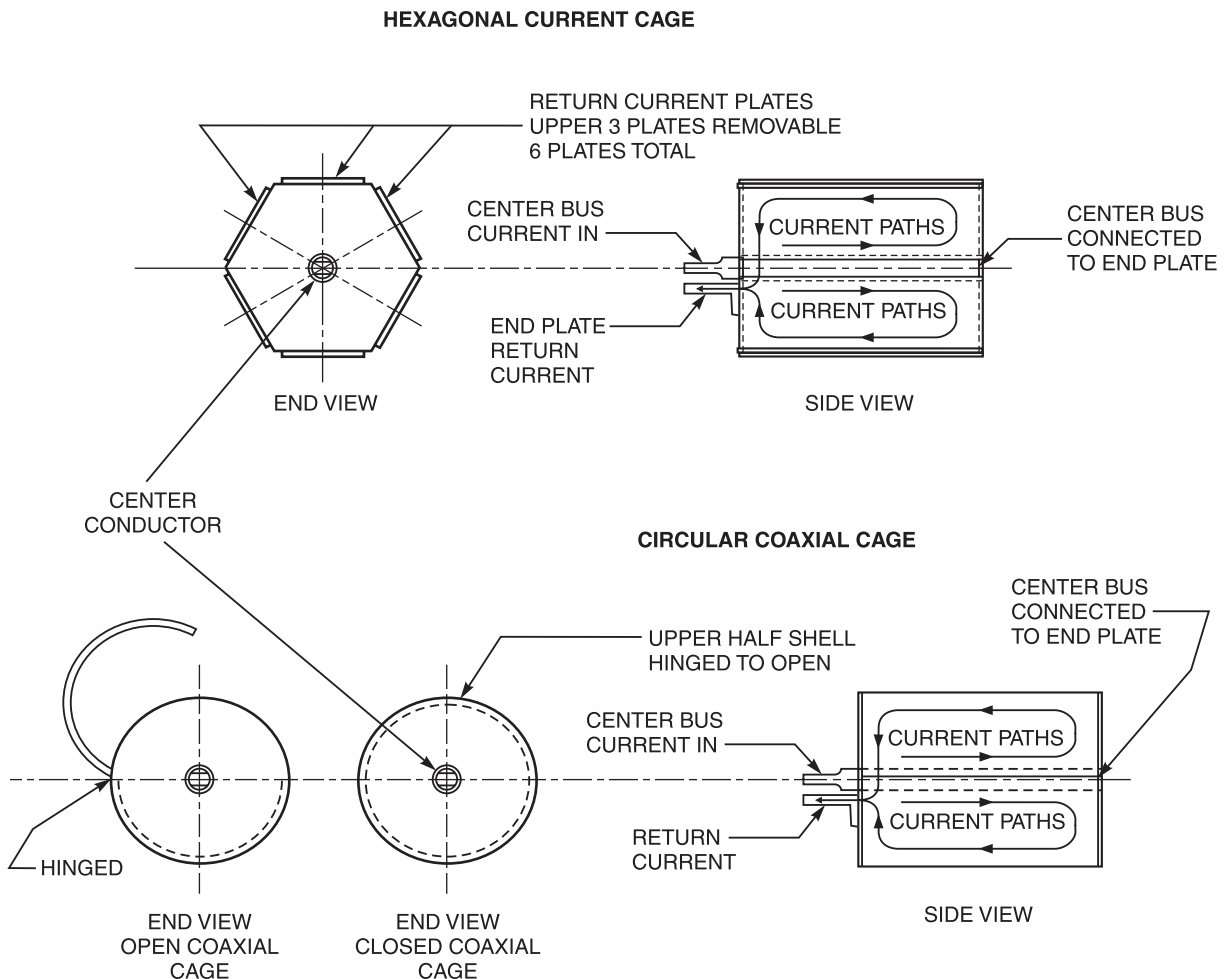


Figure 1—Hexagonal and Circular Coaxial Cages Typically Used for Mutual Inductance Testing of a CSC

of the magnetic field, that the magnetic field is a suitable approximation of the field produced by a coaxial cage, or that of an ideal $1/R$ field.

3.1.1 Equipment

(1) Current source. *This is either a calibrated current source, or an uncalibrated current source used with the calibrated current sensor listed next. In either instance, the source or the sensor must be calibrated in the frequency and current ranges used for the tests. The current waveform must be nominally a full-wave sinusoid. Waveforms other than sinusoidal will introduce frequency dependant errors.*

(2) Reference Current Sensor and Display. *Not required if the current source is calibrated.*

(3) Coaxial cage as in Figure 1.

(4) Frequency counter.

(5) AC voltmeter capable of measuring the output of CSC with an input impedance of 1 megohm or greater.

(6) Load resistor, value recommended by the WCM manufacturer, typically 1000 ohms $\pm$ 1% low inductance resistor. (Recommend the use of a metal film resistor; avoid using a wire wound resistor.) When the mutual inductance is being determined for a “no load” test condition, this load resistor is not used.

3.1.2 Setup. For the mutual inductance calibration, the CSC shall be placed in the coaxial cage during testing so that the following conditions are met. The distance from the end plates to any part of the CSC shall be no