Application Note: GMW Current Transducer Calibration Certificates *Frequently Asked Questions*

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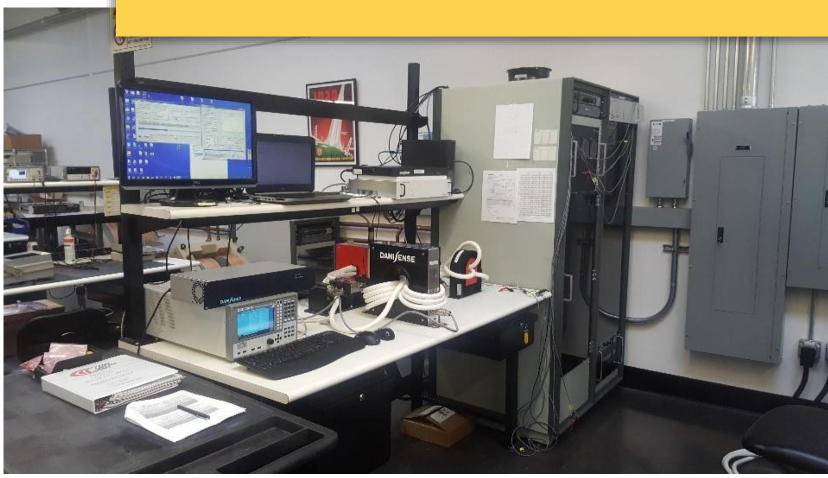

Equipment

- Current Transducer with Current or Voltage output

Overview

GMW Associates offers ISO 17025 Accredited Calibrations of Current Transducers at DC and AC up to 400 Hz; AC calibrations include both amplitude and phase information. We often receive questions about the order of magnitude difference between the uncertainties reported in GMW calibration certificates and manufacturers' specifications, especially Danisense that specifies ppm-level accuracy. This Application Note provides answers to several Frequently Asked Questions about the GMW Current Transducer Calibration Certificates.

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How do I use a GMW Calibration Certificate?

There are two primary use cases for the GMW Calibration Certificates:

1. Traceability: Several customers need NIST-Traceable or 17025 Accredited Calibration Certificates to satisfy their internal traceability requirements; this is often the case with Automotive or Aerospace customers.
2. Precision Measurements: Other customers need to know the true ratio or sensitivity of a current transducer to use with their measurement instrument, such as a power analyzer, for precision measurement. Customers can either convert the Accredited Ratio Error at nominal current from Table 1 of the GMW Certificate into a Transformer Ratio and enter that number in their power analyzer. Alternatively, customers can use the NIST-Traceable Transformer Ratio in the Calibration Results Summary section of the certificate.

How does the reported Ratio Error on the GMW Certificates relate to the manufacturer Accuracy specifications?

With reference to Figure 1, a current transducer with either secondary current or voltage output X_o, DC offset X_{Off} when the primary current $I_P = 0$ (for DC measurements only), has rated transformer ratio K_r and actual ratio

$$K = \frac{I_p}{X_o - X_{Off}}. \quad (1)$$

The GMW Calibration Certificates report the measurement of the *Ratio Error*

$$\varepsilon = \frac{K_r - K}{K} = \frac{K_r(X_o - X_{Off}) - I_P}{I_P}. \quad (2)$$

Numerical Example: With reference to the Danisense DN1000ID datasheet that has a rated ratio $K_r = 1500$, suppose we are trying to measure a true primary current of $I_P = 498.97\ \mathrm{A}$ that results in a secondary current of $X_o = 332.649\ \mathrm{mA}$. We also take a measurement of the DN1000ID output with zero primary current and the result is $X_{Off} = 1.83\ \mu\mathrm{A}$. Plugging these numbers into (1) and (2) yields $K = 1499.998$ and $\epsilon = 1.5\ \mathrm{ppm}$.

$$X_o = \frac{I_P}{\mathrm{K}} + X_{Off}$$

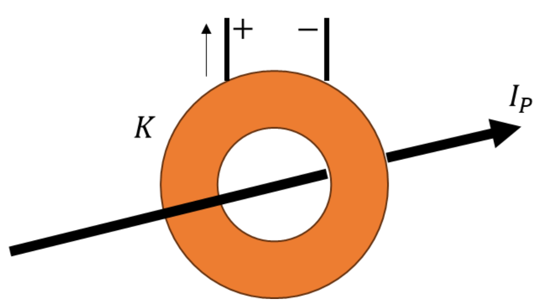


Figure 1: Current transducer schematic.

The manufacturer Accuracy specifications typically have the format of $\%\,Reading + \%\,Range$, where we are given two numbers, a fractional multiplier of the reading $\epsilon_{reading}$ and a fractional multiplier of the range ϵ_{range}. Assuming we are measuring a true primary current I_P with a transducer that has range $I_{P,nom}$ and the measurement result is $I_{P,meas}$, then the resulting measurement error is expected to be

$$\Delta I = I_{P,meas} - I_P = \epsilon_{reading} I_P + \epsilon_{range} I_{P,nom},$$

(3)

where the fractional multipliers, if given as percentages have been converted to absolute fractions by dividing by 100, and if given as parts-per-million (ppm) by dividing by 10^6. Equation (3) gives an absolute error in units of Amperes.

We can convert (3) into a fractional error by dividing by I_P:

$$\frac{\Delta I}{I_P} = \frac{I_{P,meas} - I_P}{I_P} = \frac{K(X_o - X_{Off}) - K_r(X_o - X_{Off})}{K_r(X_o - X_{Off})} = \frac{K - K_r}{K_r} = -\frac{\varepsilon}{1+\varepsilon} \approx -\varepsilon,$$

(4)

which has the opposite sign but same order of magnitude as the error ratio ϵ reported on the GMW Certificates and defined in equation (2).

Numerical Example: With reference to the Danisense DN1000ID datasheet, we are measuring $I_P = 500\ \mathrm{A}$ of current. The nominal DC current for the DN1000ID is $I_{P,nom} = 1000\ \mathrm{A}$, and the accuracy specification for under $10\ \mathrm{Hz}$ is $0.0001\% + 0.0001\%$, which translates to $\epsilon_{reading} = 10^{-6}$ and $\epsilon_{range} = 10^{-6}$. Plugging those numbers into (3) and (4) yields $\Delta I = 500 \cdot 10^{-6} + 1000 \cdot 10^{-6} = 1.5\ \mathrm{mA}$ and $\frac{\Delta I}{I_P} = 3\ \mathrm{ppm}$.

The manufacturer's Accuracy specification is on the order of 10 ppm but the reported Uncertainty is on the order of 0.1% or 1000 ppm; could you explain the discrepancy?

The Ratio Error is a quantity that normally is very close to zero. In measuring this quantity, we are limited by the instruments and the measurement setup: the accuracy of the meters, power supply stability, the reference transducer, environmental conditions, wiring etc. All these factors reduce our ability to measure this quantity accurately close to zero, and this is captured in the reported uncertainty next to Ratio Error in Table 1 of the calibration certificates. The GMW Calibration Certificates report the *best estimate* of the Error Ratio ε and its *uncertainty* $u(\varepsilon)$. The *true value* of the Error Ratio lies somewhere in the interval $\varepsilon \pm u(\varepsilon)$ with 95% probability. As can be seen in the attached sample certificates, there are data points where the best estimate of the Ratio Error is in single-digit ppm; however, the uncertainty is substantially larger. Note that the reported uncertainty is in line with our Accreditation scope:

https://gmw.com/wp-content/uploads/2023/04/2024_4349-01_A2LA-Scope-Cert.pdf

Several quantities in the GMW Calibration Certificates are marked as Non-Accredited; what is Accredited?

At the time of this writing, the accredited quantity is the Ratio Error (2). The non-accredited quantities are reported as additional information in case they are useful to the customer; these quantities, even though are not accredited, they are still NIST-Traceable. GMW plans to add some of these quantities in its future accreditation scope.

The manufacturer's specification for the Linearity Error is on the order of 10 ppm but the reported Linearity Error is higher; could you explain the discrepancy?

The reported linearity error is outside the scope of the accreditation and no uncertainty is reported. This number is deduced by a fit on the reported data points and its uncertainty is additionally affected by the number of points.

What is the difference between 17025 Accredited and NIST-Traceable Calibrations?

A NIST-Traceable calibration, or other general statement of traceability statement, indicates that the measurement standards are traceable to the International System of Units (SI); however, there is no uncertainty analysis or any statement about the technical competence of the calibration laboratory.

An ISO 17025 calibration is a higher level of calibration compared to a NIST-Traceable calibration. A 17025 accredited calibration certificate, in addition to being NIST-Traceable, includes the measurement uncertainty. To obtain and maintain a 17025 accreditation, the calibration laboratory goes through a bi-annual audit that reviews the compliance with the Standard, including the technical competence of the staff, the uncertainty analysis methodology and budget, and the various processes of the laboratory.

Are the Calibration Instruments & Standards listed in the sample certificates the same as what will be used in calibrating the customers' transducers?

The Calibration Instruments & Standards in the sample certificates will most likely be what will be used in a calibration of a customer's transducer; GMW has spare instruments that rotate to ensure continuity when instruments need to get re-calibrated.

How is Uncertainty calculated when multiple instruments are used for a calibration?

The following application note is a tutorial on how to perform uncertainty analysis in the context of current measurements using current transducers and some measurement instruments:

https://gmw.com/wp-content/uploads/2023/04/ftouf_CurrentUncertainty_AppNote_240925.pdf

This is not a thorough treatment of uncertainty analysis, as this is a very broad topic, but rather an introduction to get the reader thinking about their measurement and setup.

How does GMW determine whether the Unit is within the manufacturer's Tolerance?

GMW does not make a pass/fail determination during calibration; we only report the measurements and associated uncertainties. When calibrating closed-loop fluxgate transducers, the Ratio Error specification is typically lower than the uncertainty of our calibration system and as a result we cannot make a statistically significant pass/fail determination. Open-loop transducers typically have Ratio Error on the order of 1% that is higher than our uncertainties; however, we generally do not make a pass/fail determination. If the data indicates an issue with the transducer based on our experience with similar transducers, then we let the customer know via email.

Attachments

1. DC Calibration Certificate Sample.
2. AC 60 Hz Calibration Certificate Sample.
3. Copy of the GMW Accreditation Scope.

GMW Associates

ISO 17025 Accredited Certificate of Calibration

Customer Details

Customer	GMW Calibration Lab	**Order Number**	ILC-000012
Address	955 Industrial Road		
City, State	San Carlos, CA 94070, USA		

Instrument Details

Manufacturer	Danisense	**Date Received**	Apr 01, 2024
Model	DS200UB-10V	**Controller Model**	N/A
Serial Number	18490480022	**Controller SN**	N/A
Description	Current Transducer		

Calibration Details

Certificate #	GMW-CT-10048	**Calibration Date**	Apr 01, 2024
Calibration Level	Accredited	**Next Due Date**	N/A
Incoming Condition		**Outgoing Condition**	
Good		Good	

Test Details

Test Frequency	60 Hz	**Actual Frequency***	59.998 Hz
Temperature	22 °C	**Humidity**	42 %
REF Prim. Turns	1	**DUT Prim. Turns**	1
REF Meas. Instr. SN	06902402	**Channel / Input**	Ch. 1 / Current
DUT Meas. Instr. SN	06902402	**Channel / Input**	Ch. 2 / Voltage
Calibration Site	GMW Associates, 955 Industrial Rd, San Carlos, CA 94070		

Calibrated by	**Authorized by**
Sandro Renteria	Filippos Toufexis
Calibration Lab Manager	Applications Engineer
Apr 01, 2024	Apr 01, 2024

Notes

The customer is obligated to have the equipment calibrated at appropriate intervals.

This report applies only to the item(s) identified. This report shall not be reproduced without the written approval of GMW Associates. This report is only valid when signed.

This report cannot be used to claim product endorsement by A2LA or any other agencies.

*Non-Accredited Quantity.

Calibration Procedure

Reference Transducer Comparison Method: the customer's transducer (DUT) is compared against a reference transducer (REF).

Calibration Results Summary

Transformer Ratio[1,2]	$K = 20\,\mathrm{A}_{RMS}/\mathrm{V}_{RMS}$ (Primary/Output)
Linear Fit[1,3]	$X_o\,(\mathrm{V}_{RMS}) = 1.81 \cdot 10^{-4} + 5 \cdot 10^{-2} I_P\,(\mathrm{A}_{RMS})$ with $R^2 = 1$.
Linearity Error[1]	$\epsilon_L = 0.0022\,\%$
Accredited Data	Refer to Tables 1 and 2, and Figures 1, 2, and 3.
Past Data[4]	Refer to Figures 4 and 5.

[1] Non-Accredited quantity.
[2] Inferred from the Linear Fit.
[3] Performed on the data of Table 1.
[4] From GMW's archive for current transducer SN 18490480022.

Definitions

The **Transformer Ratio Error** ϵ, or simply **Ratio Error**, is defined as:

$$\epsilon = \frac{K_r - K}{K} = \frac{K_r X_o - I_P}{I_P}$$

and is expressed in %. K_r is the Rated Transformer Ratio per the manufacturer, K is the measured Transformer Ratio, X_o is the current transducer output, and I_P is the primary current (including primary turns).

The **Linearity Error** ϵ_L is defined as the RMS deviation of the data points from the identified linear fit, i.e. a line with slope $1/K$ and some offset, normalized to nominal current.

The **Phase Displacement** $\Delta\phi$ is defined as the difference between the phase of the transducer output and the phase of the primary current.

Measurement Uncertainty

The estimated uncertainties of the Ratio Errors $u\,(\epsilon)$ and Phase Displacements $u\,(\Delta\phi)$ listed in Tables 1 and 2 are expanded uncertainties for a coverage factor $k = 2$ that corresponds to confidence interval of approximately 95%, and includes Type A uncertainty and the Type B uncertainty of the GMW Calibration System. The uncertainty due to the effect of non-symmetrical primary return conductors is not included.

Statement of Traceability

This calibration was conducted using standards traceable to the International System of Units (SI) through either an accredited ISO laboratory or National Measurement Institute (NMI).

Calibration Instruments & Standards

Serial Number	Manufacturer	Model	Recall Date
17260290060	Danisense	DL2000ICLA	Feb 14, 2025
9953870	EXTECH	42280	Feb 18, 2025
06902402	ZES Zimmer	LMG641	Mar 12, 2025

GMW Associates 955 Industrial Rd, San Carlos, CA 94070, Tel (650) 802-8292

Table 1: Accredited Calibration Ratio Error Results for the Danisense DS200UB-10V with SN 18490480022.

Primary Current[1,2] (A_{RMS})	Output[2] (V_{RMS})	Ratio[2] K	Ratio Error ϵ (%)	$\pm u(\epsilon)$ (%)
28.8648	1.44346	19.997	0.015	0.05
55.8524	2.79304	19.997	0.015	0.05
83.881	4.19462	19.997	0.014	0.05
111.941	5.59757	19.998	0.0095	0.05
140.005	7.00089	19.998	0.0094	0.05

[1] Calculated using the reference transducer.
[2] Non-Accredited quantity.

Figure 1: Output versus Primary Current.

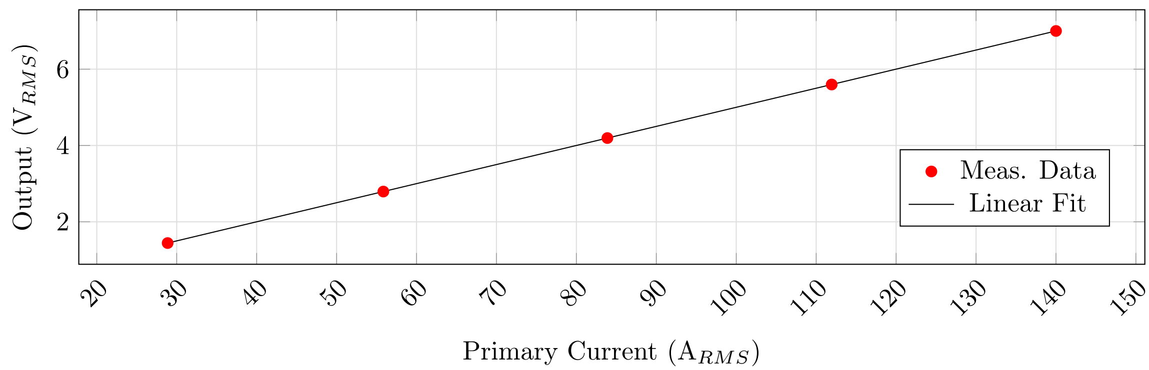


Figure 2: Transformer Ratio Error versus Primary Current.

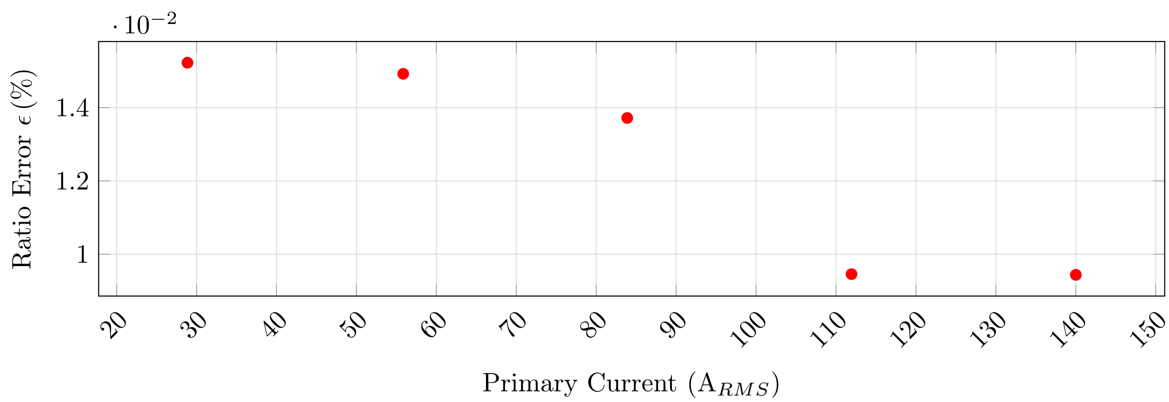


Table 2: Accredited Calibration Phase Displacement Results for the Danisense DS200UB-10V with SN 18490480022.

Primary Current[1] (A_{RMS})	Phase Displacement $\Delta\phi$ (deg)	$\pm u\,(\Delta\phi)$ (deg)
28.8648	−0.0066	0.09
55.8524	−0.0063	0.09
83.881	−0.0062	0.09
111.941	−0.0096	0.09
140.005	−0.01	0.09

[1] Calculated using the reference transducer, Non-Accredited quantity.

Figure 3: Phase Displacement versus Primary Current.

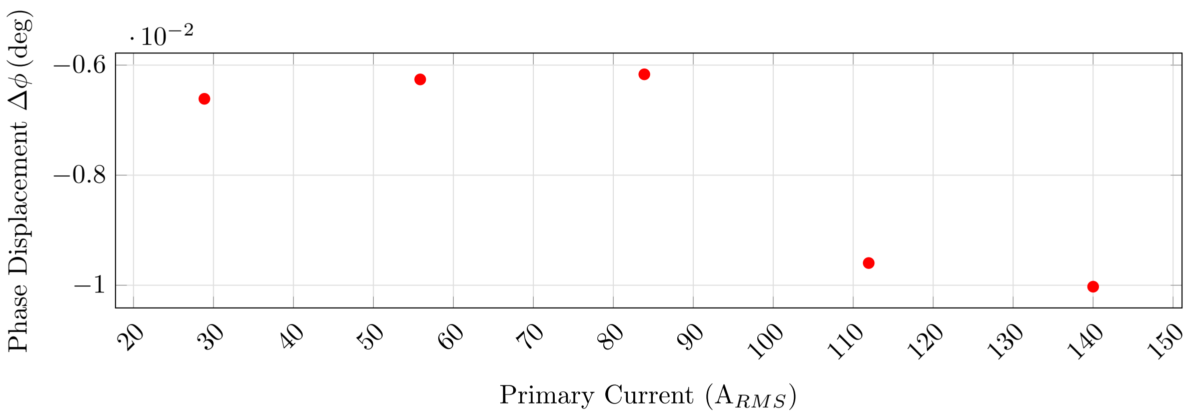


Figure 4: Transformer Ratio Error versus Primary Current History.

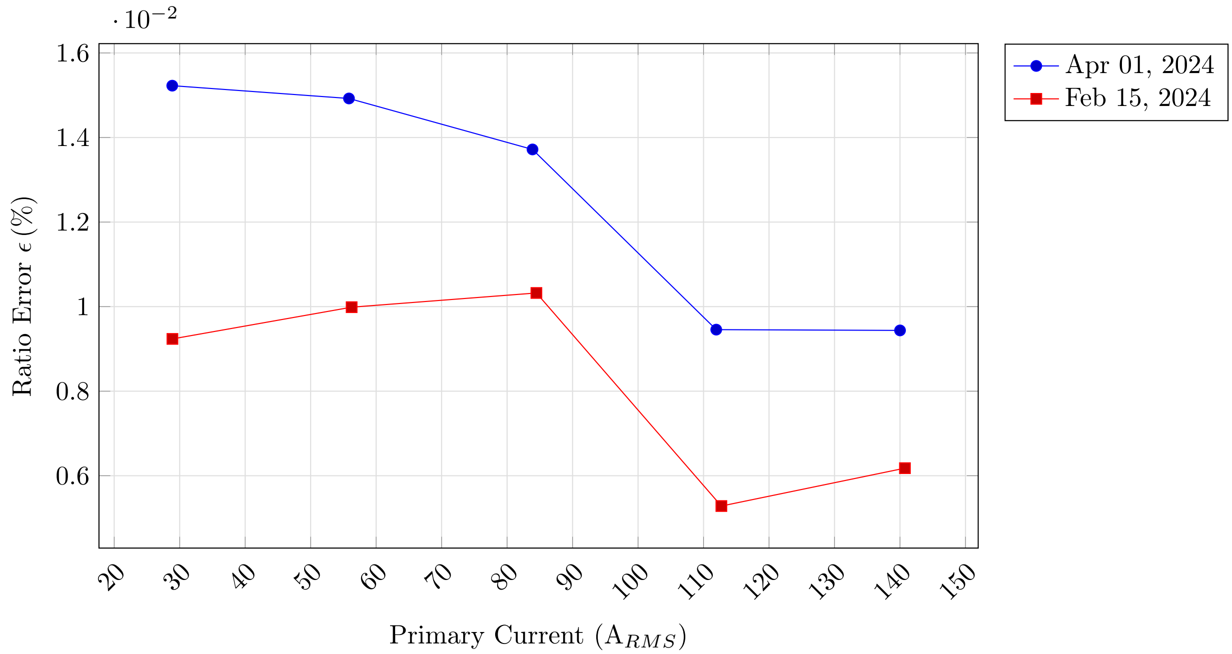
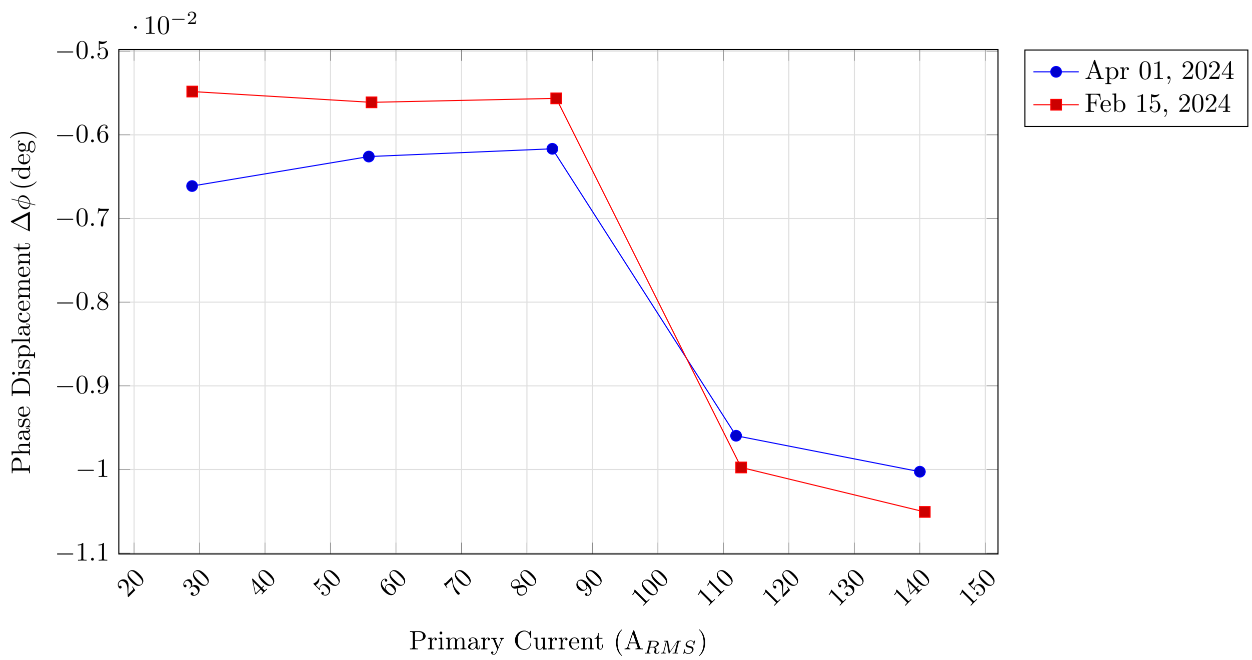


Figure 5: Phase Displacement versus Primary Current History.



SCOPE OF ACCREDITATION TO ISO/IEC 17025:2017

GMW ASSOCIATES
955 Industrial Road
San Carlos, CA 94070
Sandro Renteria Phone: 650 802 8292

CALIBRATION

Valid To: March 31, 2026 Certificate Number: 4349.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following calibrations[1, 6]:

I. Electrical – DC/Low Frequency

Parameter/Range[5]	Frequency	CMC[2] (±)	Comments
DC Ratio Error[3] – Current & Voltage Output (15 to 600) A 600 A to 11 kA		 0.2 % of ratio 0.1 % of ratio	Calibration of DC current transducers using reference transducer comparison method
AC Ratio Error[3, 4] – Current & Voltage Output 5A to 2kA (2 to 8) kA 5A to 8kA	 (5 to 100) Hz (5 to 100) Hz (100 to 400) Hz	 0.05 % of ratio 0.1 % of ratio 0.2 % of ratio	Calibration of AC current transducers using reference transducer comparison method
AC Phase Displacement[3] – Current & Voltage Output 5A – 8kA	 (5 to 100) Hz (100 to 400) Hz	 0.09 ° 0.11 °	Calibration of AC current transducers using reference transducer comparison method

[1] This laboratory offers commercial calibration service and field calibration service.

[2] Calibration and Measurement Capability Uncertainty (CMC) is the smallest uncertainty of measurement that a laboratory can achieve within its scope of accreditation when performing more or less routine calibrations of nearly ideal measurement standards or nearly ideal measuring equipment. CMC's represent expanded uncertainties expressed at approximately the 95 % level of confidence, usually using a coverage factor of $k = 2$. The actual measurement uncertainty of a specific calibration performed by the laboratory may be greater than the CMC due to the behavior of the customer's device and to influences from the circumstances of the specific calibration.

[3] Field calibration service is available for this calibration. Please note the actual measurement uncertainties achievable on a customer's site can normally be expected to be larger than the CMC found on the A2LA Scope. Allowance must be made for aspects such as the environment at the place of calibration and for other possible adverse effects such as those caused by transportation of the calibration equipment. The usual allowance for the actual uncertainty introduced by the item being calibrated, (e.g. resolution) must also be considered and this, on its own, could result in the actual measurement uncertainty achievable on a customer's site being larger than the CMC.

[4] AC Current Range values are RMS (sinusoidal) values. Limited to 2 kA at 400 Hz.

[5] The current range refers to the Transducer's Nominal Current.

[6] This scope meets A2LA's *P112 Flexible Scope Policy*.

Accredited Laboratory

A2LA has accredited

GMW ASSOCIATES

San Carlos, CA

for technical competence in the field of

Calibration

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017 *General requirements for the competence of testing and calibration laboratories*. This laboratory also meets R205 – Specific Requirements: Calibration Laboratory Accreditation Program. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (*refer to joint ISO-ILAC-IAF Communiqué dated April 2017*).

American Association for Laboratory Accreditation
CORPORATE SEAL 1978
DISTRICT OF COLUMBIA
A2LA

Presented this 20th day of February 2024.

Mr. Trace McInturff, Vice President, Accreditation Services
For the Accreditation Council
Certificate Number 4349.01
Valid to March 31, 2026

For the calibrations to which this accreditation applies, please refer to the laboratory's Calibration Scope of Accreditation.