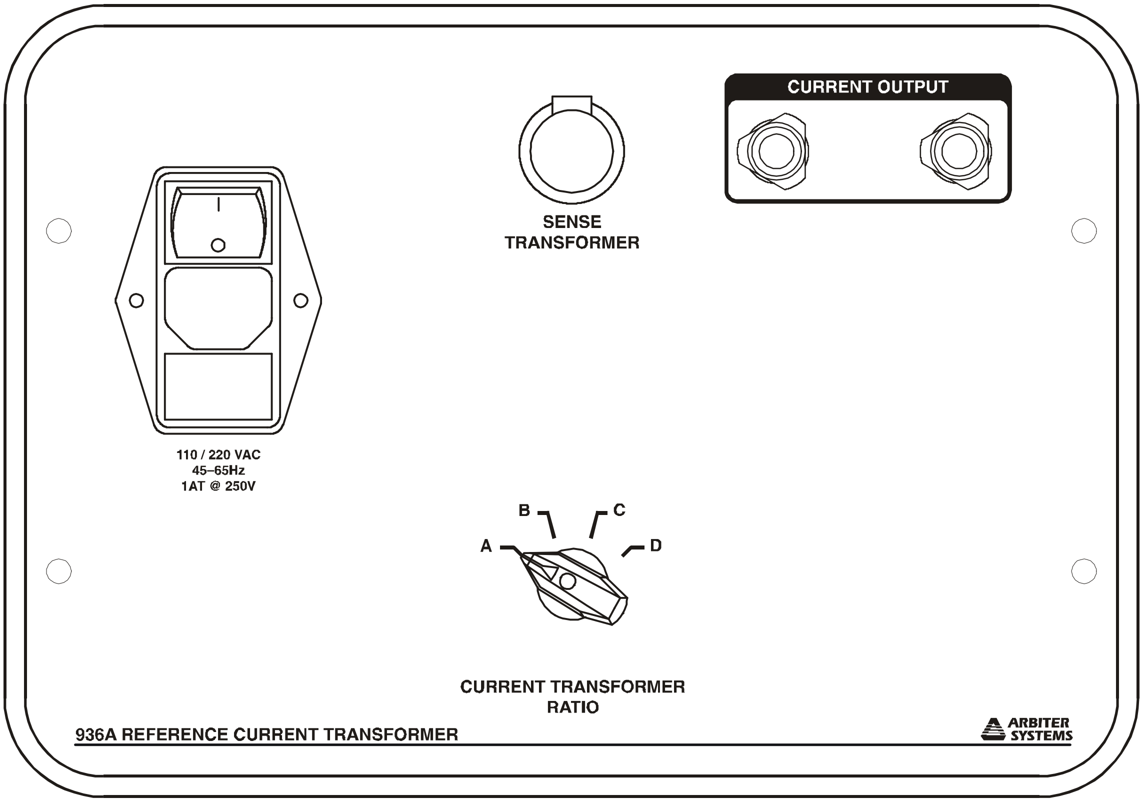
Model 936A
Reference Current Transformer
Operation Manual



ARBITER SYSTEMS, INC.
PASO ROBLES, CALIFORNIA
U.S.A.

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See contact information on page 2.

MODEL 936A
REFERENCE CURRENT TRANSFORMER
OPERATION MANUAL

- Product Description
- Specifications
- Recommended Usage
- Accurate CT Calibration for the Model 1133A
- NIST Sample Test Report

Product Description

This manual covers the use and specification of the Arbiter Systems Model 936A Reference Current Transformer. The Model 936A was designed primarily for use with the Model 935A Current Source and the Model 931A Power Systems Analyzer to calibrate current transformers used with the Model 1133A Power Sentinel. Operation with all of these devices is illustrated and described more fully later in this manual. While it is certainly possible to use the Model 936A Reference Current Transformer without these other devices, operation will be described with reference them.

The Arbiter Systems®, Inc. Model 936A Reference current Transformer provides laboratory grade accuracy in a small, portable, rugged case, making it ideal for field use. Multiple ratios of 1200:5, 1000:5, 800:5, and 600:5 are selectable via a front panel switch. The guaranteed accuracy over the full input range and operation conditions is 0.02% ratio and 0.01° phase (traceable to NIST - *see Appendix B*), ideal for calibrating other current transformers.

The Model 936A uses an active transformer to achieve the high accuracy needed for a primary reference. This design incorporates a dual core toroid with an amplifier-aided second stage. The active circuitry reduces the sense transformer core flux to zero and produces an accurate output current independent of burden. The Model 936A's multiple ratio selections allow other current transformers to be tested and calibrated across their entire operating range.

Usage Note

Included with the unit is a label that describes the specific settings with the actual turns ratios. These settings are labeled A B C and D. Place the label in an obvious location that will be easily seen for use.

Included Accessories

AC Power Cord - specify country (P01 – P09)

Unit Case and Cover

Reference CT with connection cable

Specifications

I/O Configuration

Input

Input Range	1 to 1200 Arms
Current Ratios	1200:5, 1000:5, 800:5, 600:5
Accuracy	±0.02%, 0.01°

Output

Current	5 Arms maximum
Voltage	5 Vrms maximum

Power Requirements

External Power

Range	110 or 220 Vac ±10%, 45 to 65 Hz, 15 VA max., 15 W maximum
Safety	Designed to meet UL, CSA, VDE Standards
Inlet	IEC–320 with fuse and mating cordset. Specify option P01 – P09

General

Physical

Case Size	205 x 305 x 225 mm (8 x 12 x 8.75 in.)
Weight	5.8 kg (12.8 lbs) maximum
Sense Transformer	51 mm (2.0 in.) ID Nominal

Environmental

Temperature	Operating: 0° to +40° C Nonoperating: -40° to +85° C
Humidity	Non-condensing

Accurate CT Calibration for the Model 1133A

Overview

The Model 1133A Power Sentinel™ offers accuracy in power measurement of 0.025%. Existing CTs provide accuracy of a few tenths of one percent. How then can the 1133A actually provide accuracy of 0.025% in the field?

The answer is by calibrating the existing CTs. By comparing each CT to an accurate reference CT, traceable to national standards (for example, NIST in the USA), the errors of the test CT can be determined at several currents and the correction factors entered into a table in the 1133A. The 1133A uses these correction factors, interpolating between them based on the measured current, to correct measured power (and current) to the actual values, in real time, within the instrument's stated accuracy.

For a pictorial schematic of this test configuration, see the next section entitled, "Recommended Usage."

Calibration Process

To calibrate the CTs requires three things: first, a calibrated reference CT; second, a source of high current; and third, some means of comparison. Each of these will be addressed below.

Calibrated Reference CT

Arbiter Systems now offers the Model 936A, Reference Current Transformer, suitable for these calibrations, and suitable for calibration by national standards laboratories at an accuracy which exceeds 0.02%. This CT has ratios of 1200:5, 1000:5, 800:5, and 600:5. It operates accurately at currents from 0 to 100% of rating, using a two-stage, amplifier-aided design.

By using a multi-turn primary through the center of the reference CT, current ratios of (1200/N):5, (1000/N):5, (800/N):5, and (600/N):5 can be provided as well (with N equal to the number of turns). By using a multi-turn primary on the CT under test, ratios of (1200*M):5, (1000*M):5, (800*M):5, and so on can also be provided. And finally, by using both N turns through the reference CT and M turns through the CT under test, ratios of (1000*M/N):5, (800*M/N):5, … can be provided. This allows a wide range of test CT ratios to be calibrated with a single accurate reference artifact.

Excitation Current Source

To provide the high currents (up to 1000 Amps) required to perform the calibration, Arbiter sells the Model 935A, an excitation current source. This will work on the principle of a "CT in reverse," that is, a 'donut' having a multi-turn primary excited at a reasonable current level (5 to 10 amps maximum). This device will allow a heavy-gauge winding to be placed through its center, exciting it at the high currents required (up to 1000 ampere-turns).

While it is possible, and perhaps even desirable on some accounts, to provide a regulated, solid-state source to drive the excitation coil, this would be very expensive and heavy considering the powers involved (up to 1000 VA). Due to the accurate ratiometric measurement technique to be proposed in the next section, it is not necessary to have the excitation current be particularly accurate or even stable. Therefore, we can use a much simpler 'brute-force' design based on a multi-tap autotransformer and Variac to set the current. The Model 935A offers settings for input voltage range (100, 120, 200, 220 and 240 Vrms) and output range (100, 50, 20, 10 and 5% of full-scale), and continuous adjustment from zero to the selected output range. The device is powered from the customer's AC-mains power.

Comparison Technique

The most direct method of comparison involves making a measurement using the reference CT, then using the unknown, and then calculating the ratio correction factor and phase angle from the data (Figure 1). This has the drawbacks that the current source and measurement device must be substantially more accurate and stable than the desired measurement result, typically by a factor of 4 or 5. If this were possible, it would greatly increase the cost and size of the equipment.

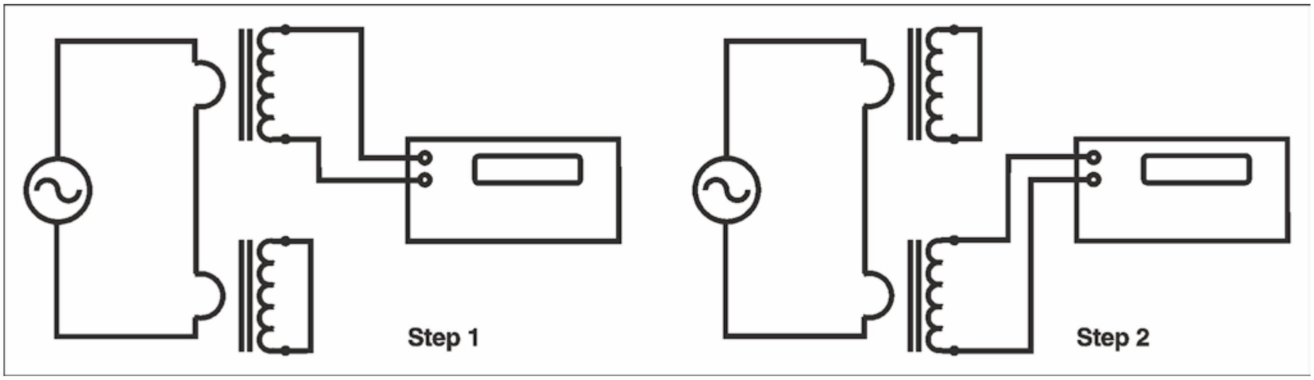


Figure 1

A better technique is called "nulling" (Figure 2). In this method, the outputs of the two CTs, reference and test, are subtracted electrically by using superposition (Kirchhoff's law), and the difference (error) measured directly. This subtraction is exact, and introduces no error. Using a second channel of the same measuring instrument, the actual secondary current can also be measured, and the ratio correction factor and phase angle are then determined mathematically. Best of all, if the measuring instrument can make the two measurements simultaneously, then effects of source variations cancel out. Furthermore, since the quantity being measured is a small error, equal to at most about 1% of the secondary current, then the accuracy required of the measuring instrument could be relaxed as well.

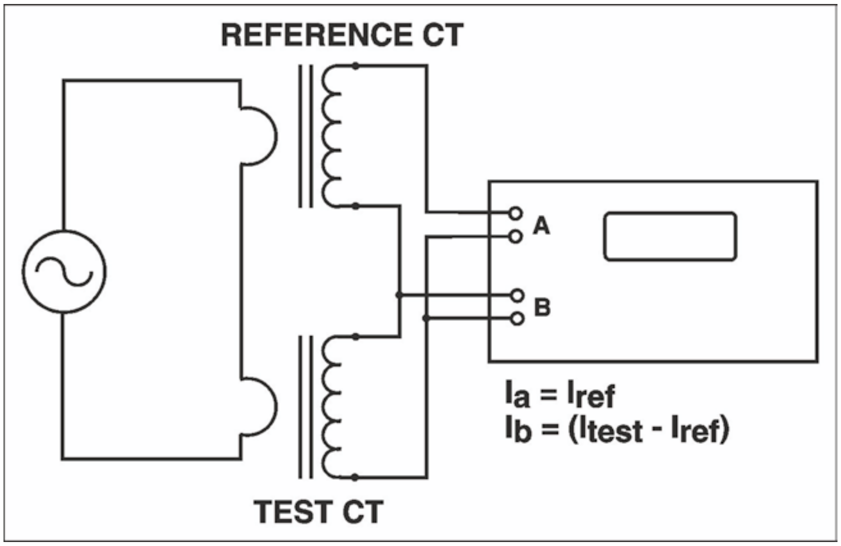


Figure 2

The ideal instrument to make this comparison is the Arbiter Systems Model 931A Power System Analyzer, or Model 933A Portable Power Sentinel. This instrument samples both of its selected input channels simultaneously, meeting the requirement stated above. Best of all, measuring the error current with 0.05% accuracy, the Model 931A is capable of making this comparison at a level of 5 ppm of the secondary current (0.05% of 1%). This standards-lab performance can readily be achieved in the field using rugged, portable equipment designed for field use, operated by service technicians with little or no training in metrology techniques.

Accessories

This setup will be provided with the necessary accessories to perform the required calibrations. The cable carrying the high primary current will be AWG 4/0 welding cable, capable of up to 500 amps current. For applications where the cable can be run through the center of the test CT, a single long length (about 15 m or 50 ft.) of cable will be provided, allowing for multi-turn setups. To perform a calibration of, for example, a 1000:5 CT at currents up to 2000 amperes, four turns are required through each of the excitation CT, the test CT, and the reference CT.

For applications where the current must be provided to a bar running through the test CT, four shorter (3 m or 10 ft.) cables will also be provided. The lugged ends of all of the cables are connected to the primary of the test CT. This would form a single-turn loop, with each cable carrying 500 of the 2000 amperes of current.

Software allows automation for the data gathering and reduction process, using a serial connection to the Model 931A and prompting the operator to perform the proper hookup and settings of the other equipment. The data could later be printed out, and it can be stored in a data file suitable for use when configuring the 1133A, eliminating a manual step where errors could enter into the process.

Hardware required for connecting the lugged ends of the cables together, completing the high-current loop, and tools to tighten the hardware to specification, will also be a part of the kit.

Selection of the Current Calibration Points

The proper choice of calibration points (test currents) satisfies two criteria: first, the points chosen should allow complete characterization of the CT; and second, the points should allow for accurate interpolation. Since CTs are magnetic devices, they have error curves, which are smooth and do not have jumps or break points. Usually, either a linear (1, 2, 3, 4, 5) or logarithmic (0.1, 0.2, 0.5, 1.0, 2.0) progression of the test current values will provide an accurate characterization of the CT performance.

Many interpolation algorithms do not easily deal with nonlinear input progressions, often yielding bizarre results. The algorithm chosen for the 1133A will operate well with either logarithmic or linear progression of test points. No algorithm can be expected to yield acceptable performance if the test points are not spaced out in some logical manner. For example, the test sequence (0.1, 0.2, 0.3, 10, 15, 20) might seem reasonable for a device which had relatively large errors at the ends of its range, and small, consistent errors in the midrange. However, the large ‘hole’ in the middle is certain to confound any general-purpose interpolation algorithm with more complex-than-linear interpolation. What will confuse the algorithm is the dramatic change in the ‘slope’ of the x-axis points at 0.3 and 10. Using points with a relatively predictable and consistent pattern, such as logarithmic or linear progression, will eliminate this potential problem.

To determine which is the best choice for a particular type of CT, you could characterize the CT initially using enough points to thoroughly describe its performance. Then, the points can be plotted on graph paper (or using a spreadsheet program) with log and linear axes for the current values. Whichever curve appears smoother and more representative of the CT to the eye is probably the best choice for the calibration point sequence. In general, logarithmic sequences (1, 2, 5, and 10) emphasize the lower current values and linear (1, 2, 3, 4, 5) sequences emphasize the higher current values. Where the errors are changing rapidly at the low end of the current range (usually due to changes in permeability of the core as a function of current level), a logarithmic progression will usually work best. When the errors are changing rapidly at the high end of the current range (usually due to incipient saturation of the core with increasing burden voltage), then a linear progression might be a better choice (although a reduction in burden will almost certainly improve overall performance).

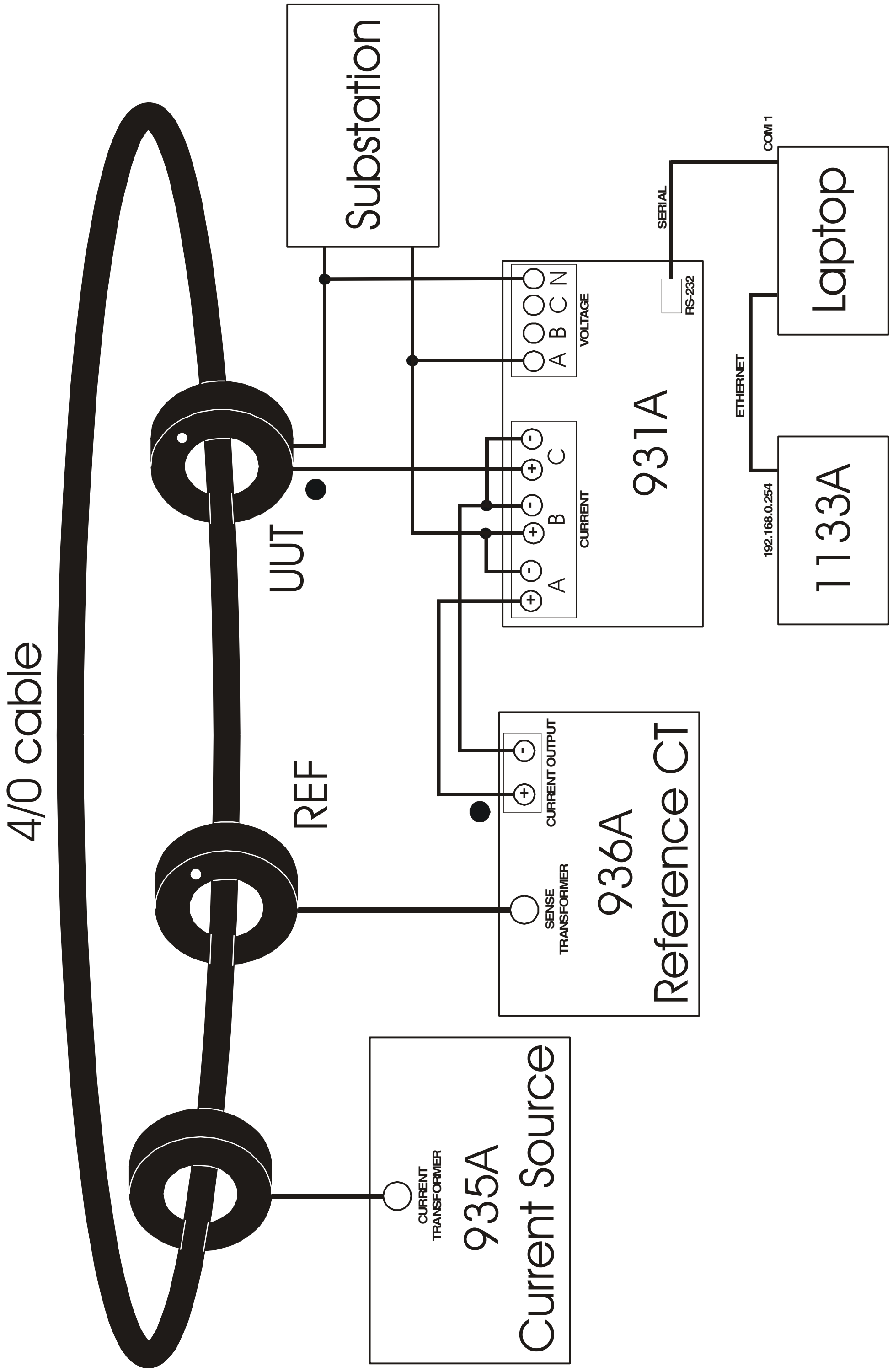
Conclusion

Taking advantage of the full accuracy of the 1133A Power Sentinel requires calibration of the user's CTs. This paper presents a method to perform these calibrations.

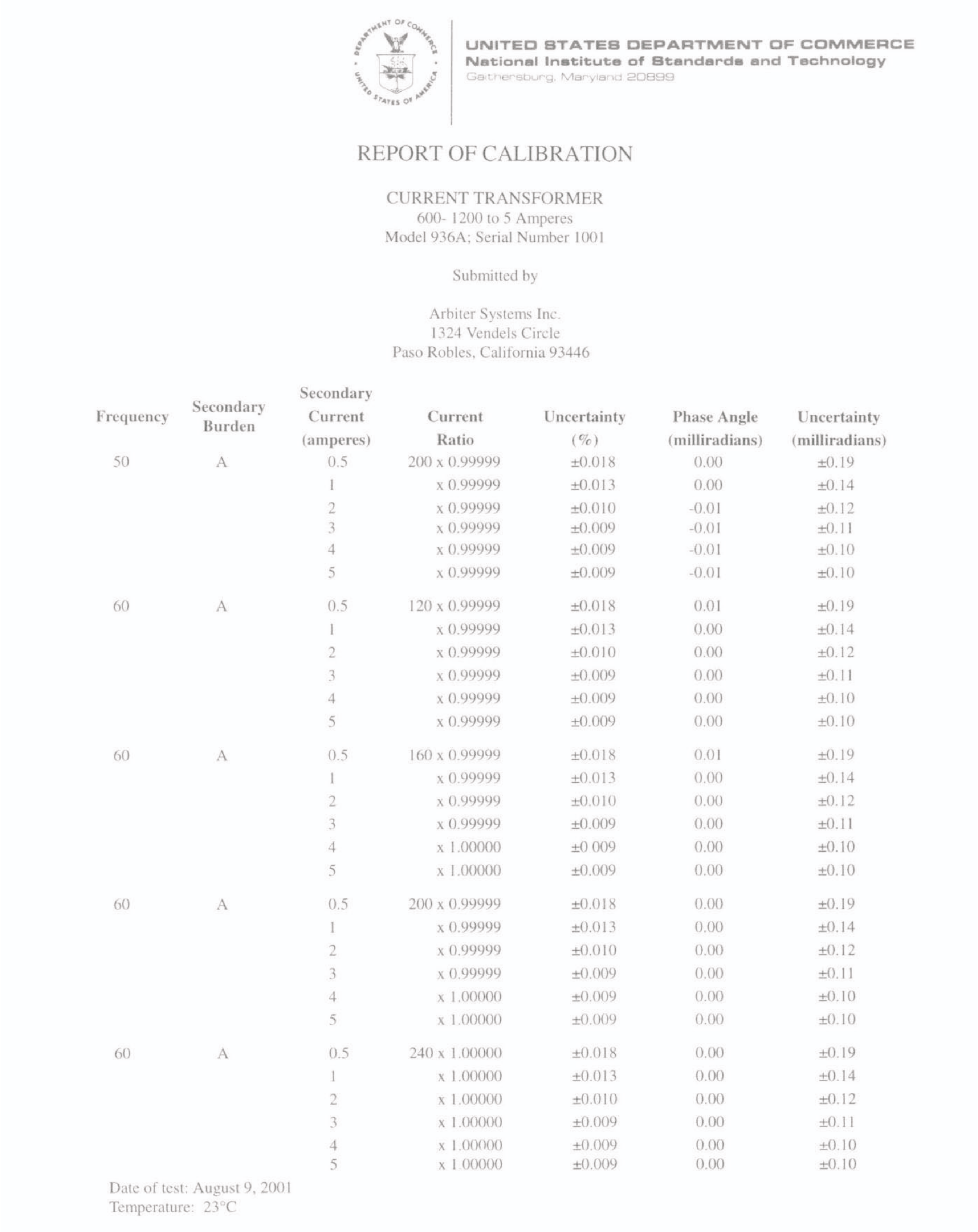
Calibrating existing CTs requires three extra pieces of equipment: a reference CT, an excitation current source and a current comparator. Two new products developed by Arbiter Systems should provide users with these tools for on site calibrations. The Model 935 Current Source and Model 936 Reference CT are now available. The popular Arbiter Systems Model 931 Power System Analyzer can accept three-phase primary currents up to 2000 amperes (higher under some conditions), with a transfer accuracy of 5 ppm and an overall traceable accuracy of 0.01%, or better.

Recommended Usage

In the figure below, the Model 936A is shown in a pictorial-type schematic with the Model 935A Current Source, the Model 931A Power Systems Analyzer and other equipment. In this configuration, the Model 936A serves as the reference CT in a scheme to calibrate the CT (UUT in the figure below). This method uses the “error vector” method of calibrating that is more fully explained in the Appendix A that follows.



NIST Sample Test Report



UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Gaithersburg, Maryland 20899

REPORT OF CALIBRATION

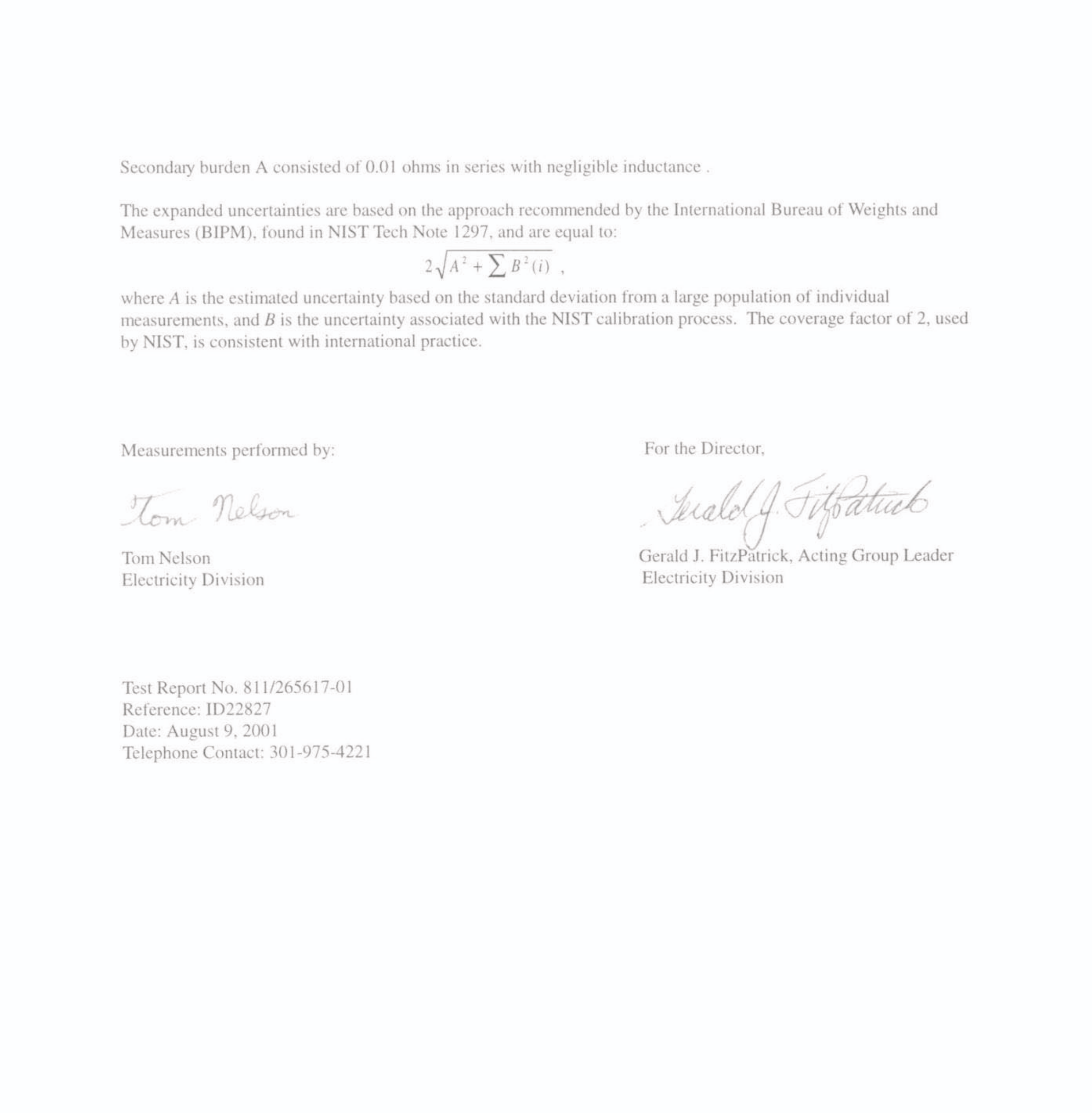
CURRENT TRANSFORMER
600- 1200 to 5 Amperes
Model 936A; Serial Number 1001

Submitted by

Arbiter Systems Inc.
1324 Vendels Circle
Paso Robles, California 93446

Frequency	Secondary Burden	Secondary Current (amperes)	Current Ratio	Uncertainty (%)	Phase Angle (milliradians)	Uncertainty (milliradians)
50	A	0.5	200 x 0.99999	±0.018	0.00	±0.19
		1	x 0.99999	±0.013	0.00	±0.14
		2	x 0.99999	±0.010	-0.01	±0.12
		3	x 0.99999	±0.009	-0.01	±0.11
		4	x 0.99999	±0.009	-0.01	±0.10
		5	x 0.99999	±0.009	-0.01	±0.10
60	A	0.5	120 x 0.99999	±0.018	0.01	±0.19
		1	x 0.99999	±0.013	0.00	±0.14
		2	x 0.99999	±0.010	0.00	±0.12
		3	x 0.99999	±0.009	0.00	±0.11
		4	x 0.99999	±0.009	0.00	±0.10
		5	x 0.99999	±0.009	0.00	±0.10
60	A	0.5	160 x 0.99999	±0.018	0.01	±0.19
		1	x 0.99999	±0.013	0.00	±0.14
		2	x 0.99999	±0.010	0.00	±0.12
		3	x 0.99999	±0.009	0.00	±0.11
		4	x 1.00000	±0.009	0.00	±0.10
		5	x 1.00000	±0.009	0.00	±0.10
60	A	0.5	200 x 0.99999	±0.018	0.00	±0.19
		1	x 0.99999	±0.013	0.00	±0.14
		2	x 0.99999	±0.010	0.00	±0.12
		3	x 0.99999	±0.009	0.00	±0.11
		4	x 1.00000	±0.009	0.00	±0.10
		5	x 1.00000	±0.009	0.00	±0.10
60	A	0.5	240 x 1.00000	±0.018	0.00	±0.19
		1	x 1.00000	±0.013	0.00	±0.14
		2	x 1.00000	±0.010	0.00	±0.12
		3	x 1.00000	±0.009	0.00	±0.11
		4	x 1.00000	±0.009	0.00	±0.10
		5	x 1.00000	±0.009	0.00	±0.10

Date of test: August 9, 2001
Temperature: 23°C



Secondary burden A consisted of 0.01 ohms in series with negligible inductance .

The expanded uncertainties are based on the approach recommended by the International Bureau of Weights and Measures (BIPM), found in NIST Tech Note 1297, and are equal to:

$$2\sqrt{A^2 + \sum B^2(i)}\ ,$$

where *A* is the estimated uncertainty based on the standard deviation from a large population of individual measurements, and *B* is the uncertainty associated with the NIST calibration process. The coverage factor of 2, used by NIST, is consistent with international practice.

Measurements performed by:

Tom Nelson

Tom Nelson
Electricity Division

For the Director,

Gerald J. Fitzpatrick

Gerald J. FitzPatrick, Acting Group Leader
Electricity Division

Test Report No. 811/265617-01
Reference: ID22827
Date: August 9, 2001
Telephone Contact: 301-975-4221