Calibration of Physikalisch-Technischen Bundesanstalt two-stage current transformer PTB 9/70

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CALIBRATION OF PHYSIKALISCH-TECHNISCHEN BUNDESANSTALT TWO-STAGE CURRENT TRANSFORMER PTB 9/70

-W. J. M. MOORE-

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ABSTRACT

The calibration of Physikalisch-Technischen Bundesanstalt (PTB) two-stage audio frequency current transformer at ratios 10/1 and unity, and frequencies 10, 5, and 1 kilohertz (kHz), by the National Research Council of Canada is presented. A comparison with a previous calibration by PTB indicates agreement to better than 1 part per million (ppm) at 10 kHz, 0.3 ppm at 5 kHz, and 0.06 ppm at 1 kHz.

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CALIBRATION OF PHYSIKALISCH-TECHNISCHEN BUNDESANSTALT TWO-STAGE CURRENT TRANSFORMER PTB 9/70

– W.J.M. Moore –

Introduction

In 1969, the Physikalisch-Technischen Bundesanstalt (PTB), Berlin, proposed that a comparison be made between their calibrations of audio-frequency current transformers and those of the National Research Council of Canada (NRC). A two-stage current transformer, constructed by PTB and shown in Fig. 1, was chosen for this comparison. This report presents the results of the NRC calibration of this transformer and compares them with the PTB calibrations made prior to its being sent to NRC.

NRC Calibration Procedure

The NRC calibration followed the procedure established in 1965 [1], with audio-frequency current comparator No. 4 as the ratio standard. The physical arrangement for 10/1 ratio is shown in Fig. 2.

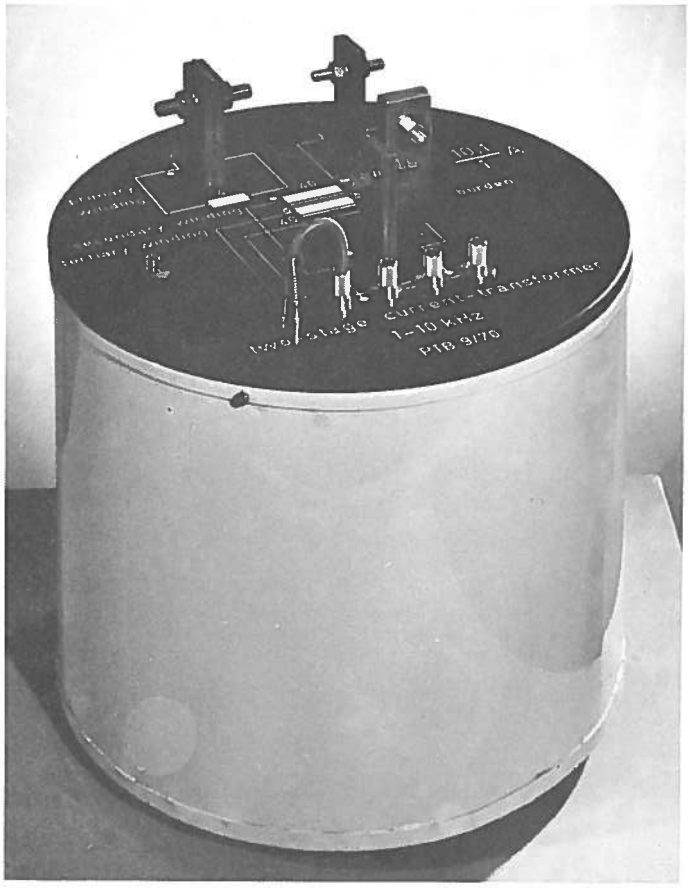

Fig. 1 PTB two-stage current transformer 9/70

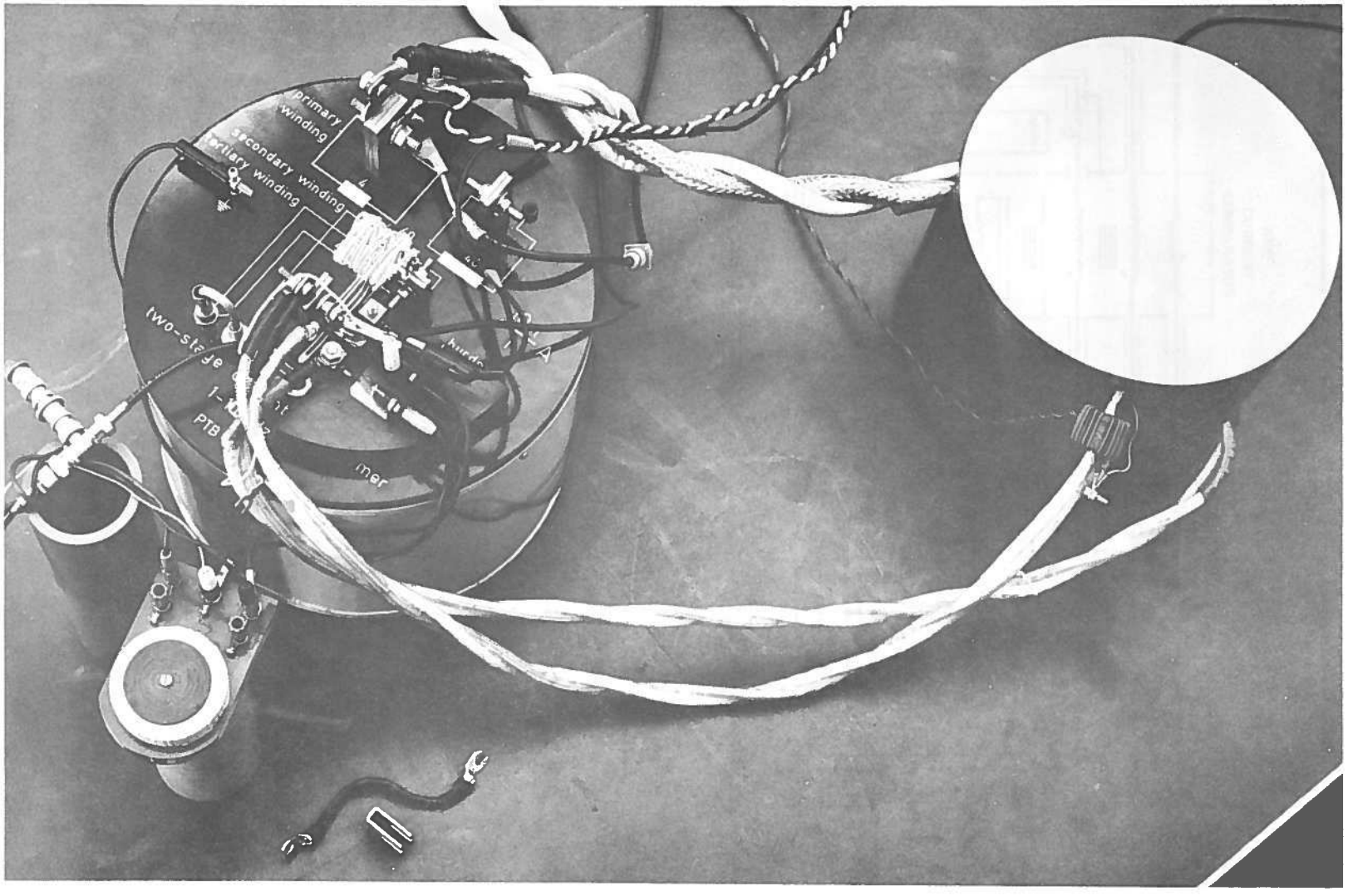

Fig. 2 Connection arrangement for 10/1 ratio calibration

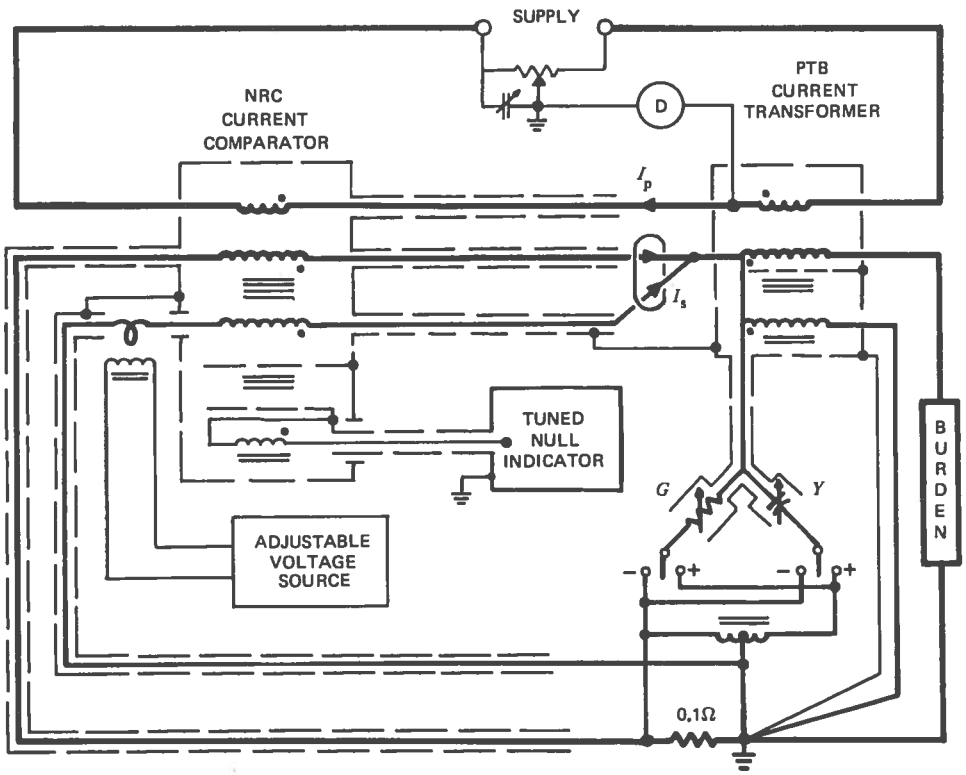

Fig. 3 NRC calibration circuit

The NRC calibration circuit is shown in Fig. 3. The relative error $(nI_s - I_p)/I_p$ between the NRC current comparator and the PTB current transformer as measured by this circuit, is given by

$$(nI_s - I_p)/I_p \cong 0.1\ (G + jY)$$

where n is the nominal ratio

I_p, I_s are the currents measured at the identified (marked) terminals of the primary and secondary windings, respectively, of the PTB current transformer

G is the conductance in mhos

and Y is the capacitive admittance in mhos.

The marked terminal of the primary winding of the PTB current transformer was maintained at ground potential by a Wagner ground circuit. The corresponding marked terminal of the secondary winding was also held at ground potential by insertion of a small adjustable voltage in series with the lead from the unmarked terminal of the compensation winding of the NRC current comparator. All measurements were made at room temperature, with a secondary current of approximately two amperes. The only burden imposed on the transformer was that connected between its 'burden' terminals.

The uncertainty in the relative error measurement is estimated to be not more than one percent of the vector sum of the indicated values of the two error components.

Results and Discussion

The results of the calibration are given in Table I, the NRC calibration being obtained by adding the relative error measurement to the error of the NRC standard. An indication of the uncertainty in the NRC measurements, exclusive of those due directly to the calibration of the NRC standard itself, was obtained from a comparison of the relative error measurements at unity ratio with those derived from separate self-calibrations performed at NRC on the NRC current comparator and the PTB current transformer. The closing discrepancies for these measurements, together with a similar set in which the 1965 calibrations of the NRC standard are substituted for those currently obtained, are given in Table II.

Two factors may account for the difference between the NRC and PTB calibrations given in Table I. First, the PTB transformer suffered some minor damage in transit and the repairs made at NRC might not have been sufficient to restore it to the original condition. Second, the location of the lead connecting the unmarked terminal of the PTB transformer to the internal mumetal shield was found to affect the error measurements by as much as ±0.07 parts per million (ppm) at 10 kHz. The results given in this report apply to the condition where this lead is located around the side of the transformer case adjacent to the secondary winding current terminals, as shown in Fig. 2.

Some indication of the consistency of the measurements made by the two laboratories may be obtained from a comparison of the shifts due to burden shown in Table III. The only serious discrepancy appears to be in the in-phase component of the unity ratio measurements at 10 kHz.

Conclusion

A comparison has been made between NRC and PTB current transformer calibrations at 10, 5, and 1 kHz, at ratios of 10/1 and unity. The results indicate differences in the vector sum of the two error components no greater than 0.63 ppm at 10 kHz, 0.17 ppm at 5 kHz, and 0.03 ppm at 1 kHz. Tests indicate that the uncertainties in the measurements vary from about 30 percent of these differences at 10 kHz to 100 percent at 1 kHz. It appears therefore that subject to the confirmation of the PTB calibrations after the transformer has been returned to PTB, the agreement between the two laboratories is better than one ppm at 10 kHz, 0.3 ppm at 5 kHz, and 0.06 ppm at 1 kHz.

Reference

1. Kusters, N.L. and Moore, W.J.M. The development and performance of current comparators for audio frequencies. IEEE Trans., IM-14 (4): 178–190; 1965.

Table I

Calibration of Physikalisch-Technischen Bundesanstalt Two-Stage Current Transformer PTB 9/70

parts per million

Ratio	Frequency kHz	Burden ohms*	Error of NRC standard†	Relative error measurement§	NRC calibration	PTB calibration‡	Difference (PTB – NRC)
10/1	10	zero	+0.03 + j0.42	+4.95 – j1.26	+4.98 – j0.84	+5.50 – j0.50	+0.52 + j0.34
	5		+0.03 + j0.20	+1.15 – j0.54	+1.18 – j0.34	+1.28 – j0.21	+0.10 + j0.13
	1		+0.00 + j0.06	–0.02 – j0.09	–0.02 – j0.03	+0.00 – j0.02	+0.02 + j0.01
	10	0.1122	+0.03 + j0.42	+5.02 – j2.82	+5.05 – j2.40	+5.60 – j2.10	+0.55 + j0.30
	5		+0.03 + j0.20	+1.15 – j1.31	+1.18 – j1.11	+1.30 – j1.02	+0.12 + j0.09
	1		+0.00 + j0.06	–0.03 – j0.22	–0.03 – j0.16	–0.01 – j0.16	+0.02 + j0.00
1/1	10	zero	–1.90 + j1.06	+5.11 – j2.62	+3.21 – j1.56	+3.55 – j1.42	+0.34 + j0.14
	5		–0.50 + j0.45	+1.28 – j1.18	+0.78 – j0.73	+0.88 – j0.69	+0.10 + j0.04
	1		–0.02 + j0.09	+0.04 – j0.21	+0.02 – j0.12	+0.03 – j0.13	+0.01 – j0.01
	10	0.1122	–1.90 + j1.06	+5.20 – j4.81	+3.30 – j3.75	+3.90 – j3.60	+0.60 + j0.15
	5		–0.50 + j0.45	+1.27 – j2.27	+0.77 – j1.82	+0.92 – j1.82	+0.15 + j0.00
	1		–0.02 + j0.09	+0.02 – j0.43	+0.00 – j0.34	+0.02 – j0.34	+0.02 + j0.00

* Burden – as measured at the burden terminals of the PTB transformer

† Error of NRC standard – as determined in 1965 calibration of NRC standards

§ Relative error measurement – measured at the secondary winding current terminals of the PTB transformer, with both terminals at ground potential.

‡ PTB calibration – from Mr. H. Schlinke's letter dated December 4, 1970.

Table II

Comparison of self-calibrations with relative error measurements at unity ratio

parts per million

A. Using 1970 self-calibration of NRC standard

Burden ohms	Operation*	Frequency 10 kHz	5 kHz	1 kHz
zero	Self-NRC STD	- 1.83 + j1.12	- 0.47 + j0.49	- 0.02 + j0.09
	Relative-(PTB–NRC)	+5.11 - j2.62	+1.28 - j1.18	+0.04 - j0.21
	Self-PTB CT	+3.23 - j1.51	+0.80 - j0.68	+0.02 - j0.12
	Discrepancy	+0.05 + j0.01	+0.01 - j0.01	+0.00 + j0.00
0.1122	Self-NRC STD	- 1.83 + j1.12	- 0.47 + j0.49	- 0.02 + j0.09
	Relative-(PTB–NRC)	+5.20 - j4.81	+1.27 - j2.27	+0.02 - j0.43
	Self-PTB CT	+3.29 - j3.67	+0.79 - j1.76	+0.01 - j0.32
	Discrepancy	+0.08 - j0.02	+0.01 - j0.02	- 0.01 - j0.02

B. Using 1965 self-calibration of NRC standard

zero	Self-NRC STD	- 1.90 + j1.06	- 0.50 + j0.45	- 0.02 + j0.09
	Relative-(PTB–NRC)	+5.11 - j2.62	+1.28 - j1.18	+0.04 - j0.21
	Self-PTB CT	+3.23 - j1.51	+0.80 - j0.68	+0.02 - j0.12
	Discrepancy	- 0.02 - j0.05	- 0.02 - j0.05	+0.00 + j0.00
0.1122	Self-NRC STD	- 1.90 + j1.06	- 0.50 + j0.45	- 0.02 + j0.09
	Relative-(PTB–NRC)	+5.20 - j4.81	+1.27 - j2.27	+0.02 - j0.43
	Self-PTB CT	+3.29 - j3.67	+0.79 - j1.76	+0.01 - j0.32
	Discrepancy	+0.01 - j0.08	- 0.02 - j0.06	- 0.01 - j0.02

*Discrepancy = (Self-NRC STD) + (Relative-(PTB–NRC) - (Self-PTB CT)

Table III

Comparison of error shifts due to burden

parts per million

Ratio	Frequency kHz	NRC Calibration	PTB Calibration
10/1	10	+ 0.07 - j1.56	+0.10 - j1.60
	5	+ 0.00 - j0.77	+ 0.02 - j0.81
	1	- 0.01 - j0.13	- 0.01 - j0.14
1/1	10	+ 0.09 - j2.19	+0.35 - j2.18
	5	- 0.01 - j1.09	+0.04 - j1.13
	1	- 0.02 - j0.22	- 0.01 - j0.21