FINAL REPORT

of

APMP Supplementary Comparison APMP-T- S3-03

over the range – 40.0 °C to 250.0 °C using
Industrial Platinum Resistance &
Liquid in Glass Thermometers

Prepared by
Dr. Mark John Ballico
Mong Kim Nguyen
National Measurement Institute (Australia), NMIA
and
Uthai Norranim
National Institute of Metrology (Thailand), NIMT

Date 15 March 2006

TABLE OF CONTENTS

1. INTRODUCTION

The Comite Consulatif de Thermometrie has organized several key comparisons to provide comparison of temperature measurements performed by different laboratories practicing different techniques and instrumentation in realizing the ITS-90. Although there have been several Key Comparisons(KC) and Regional Key Comparisons they are limited to direct realizations of ITS-90. The National Institute of Measurement, Thailand (NIMT) agreed to organize an **APMP Supplementary Comparison (SC)** using Industrial Platinum Resistance (IPRT) and Liquid-in-glass (LIG) Thermometers, opened to APMP members and particularly the Developing Economy Countries who would like to improve their CMCs (Calibration and Measurement Capabilities).

The comparison ran from February 2004 to October 2004, and covered a temperature range from –40 °C to 250 °C based on the capability of participants from APMP DEC. The artifacts were six Liquid In Glass Thermometers (LIGT) and two Industrial Platinum Resistance Thermometers (IPRT) which were tested and characterized by NIMT, the coordinating laboratory, before circulation. To shorten the circulation time, this SC was performed concurrently in two loops (see circulation schedule in Appendix A)

The protocols (given in Appendix C) provide guidance for preparation, annealing criteria and the measurement sequence to be performed.

To clarify the objectives and measurement procedures before the comparison was started, a Seminar and Workshop was held at NIMT, Bangkok by NIMA and NIMT, attended by most of the participants. After release of the draft-A report, another seminar and workshop was held at NIMT, to discuss the comparison results and measurement issues arising during the comparison.

2. PARTICIPANTS

Participant details including affiliation, name and e-mail address of the contact person are listed as follows:

NMI	Country	Contact	e-mail address
NMIA (formerly NML-CSIRO)	Australia	Dr. Mark Ballico Mrs. Mong Kim Nguyen	Mark.Ballico@measurement.gov.au Kim.Nguyen@measurement.gov.au,
NIMT	Thailand	Mr. Uthai Norranim	uthai@nimt.or.th
ITDI	Philippines	Ms. Rosalinda G. Principe	nmlpill@dost.gov.ph
KIM-LIPI	Indonesia	Mr. Ghufron Zaid Mr. Suherlan	gzaid01@yahoo.com, suherlan75@yahoo.com
MSL	New Zealand	Mr. D. R. White	r.white@irl.cri.nz
NBSM	Nepal	Dr. Sita Ram Joshi	nbsm@nbsm.gov.np, ozone@ntc.net.np
SCL	Hong Kong	Mr. C. M. Tsui	cmtsui@itc.gov.hk
SIRIM	Malaysia	Mrs. Hafidzah Othman	hafidzah_othman@sirim.my
SPRING	Singapore	Mr. Kho Hao Yuan	khohy@spring.gov.sg
VMI	Vietnam	Mr. Vu Quang Cuong	vmi@fpt.vn

3. ARTIFACTS

Industrial Platinum Resistance Thermometers

Three good quality 100 Ω metal sheath IPRTs, with the following specifications, were used (two for circulation and one spare).

Model	:	5626-12-S	
Serial Number	:	0817	[Loop A]
Serial Number	:	0833	[Loop B]
Serial Number	:	0811	[Spare]
Manufacturer	:	Hart Scientific	

Before the measurements for this program was started, the stability with thermal cycling of the artifacts were assessed by NIMT to determining the change in its R(IP) values after being heated to 270 ^{o}C. See Graph 1.

Liquid in Glass Thermometers

Three sets of good quality ASTM class LIGTs, with the following specifications were used (two sets for circulation and one spare).

Serial No	Model	Range	Subdivision	Immersion	Loop
9714076	ASTM 62C	-38 ^{o}C to 2 ^{o}C	0.1 ^{o}C	total	Loop A
9714085	ASTM 62C	-38 ^{o}C to 2 ^{o}C	0.1 ^{o}C	total	Loop B
9981749	ASTM 120C	38.6 ^{o}C to 41.4 ^{o}C	0.05^{o}C	total	Loop A
9981771	ASTM 120C	38.6 ^{o}C to 41.4 ^{o}C	0.05^{o}C	total	Loop B
59-405	ASTM 40C	72 ^{o}C to 126 ^{o}C	0.2^{o}C	Partial 100 mm	Loop A
59-999	ASTM 40C	72 ^{o}C to 126 ^{o}C	0.2^{o}C	Partial 100 mm	Loop B

No special annealing or stabilization procedures were applied to the LIGT artifacts.

4. COMPARISON SCHEDULE

The planned comparison schedule, artifact transport and handling, and instructions to participants are reproduced in Appendix-C.

Note: NBSL was moved from loop-A to loop-B due to delays in loop A arising from customs clearance difficulties. The schedule actually achieved was as follows:

Feb 16-19, 2004	Initial workshop
Mar 24, 2004	Artifacts at NMIA and dispatched on Apr06, 2004
Apr 08, 2004	Artifacts at SPRING and dispatched on Apr29, 2004
Apr 09, 2004	Artifacts at SIRIM and dispatched on Apr30,2004
Apr 27, 2004	Rearrange schedule for NBSM
May 04, 2004	Artifacts at SCL and dispatched on June09, 2004
May 15, 2004	Artifacts at ITDI and dispatched on June16, 2004
June 17, 2004	Artifacts at VMI and dispatched on July09, 2004
June17, 2004	Artifacts at KIM-LIPI
July 20,2004	Artifacts at NIMT to rearrange schedule for both MSL and NBSM
Aug 2, 2004	Artifacts at NBSM (LIGT ASTM 120C)
Aug 11, 2004	Artifacts at MSL
Oct. 2004	All artifacts at NIMT for final measurements
Oct.19, 2004	Draft-A report (2004 TCT meeting, Beijing)
Feb 2-4, 2005	Closing seminar and workshop at NIMT
	Draft-B v0 released for approval by participants

5. MEASUREMENT PROCEDURES

Each laboratory measured and reported the R(IP) upon receipt, and if a change equivalent to more than 2 mΩ from the previous participant was found, the lab was instructed to further annealing the IPRT. This was found necessary only at two laboratories, NIMT as initial measurement and KIM-LIPI with large drift of R(IP).

Measurements at were taken in order of increasing temperature. Most participating laboratories had the capability to perform the comparison over the entire temperature range, with the exceptions:

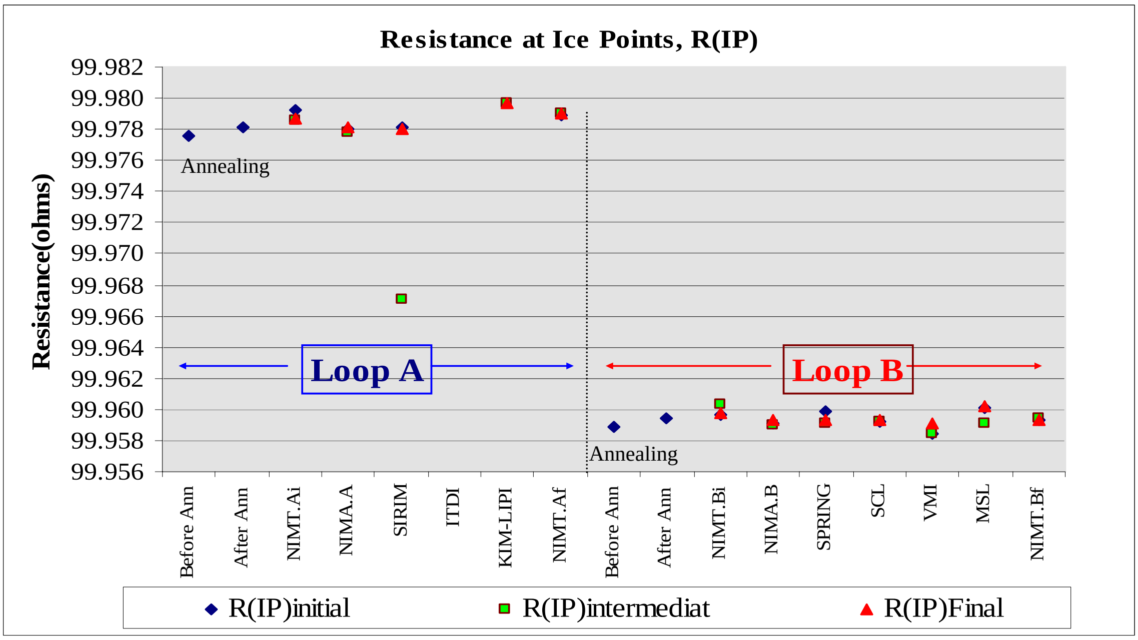
- MSL were (i) unable to perform LIGT measurement due to restrictions on the transport of Hg, and (ii) bath malfunction limited IPRT measurement to 200°C
- KIM-LIPI had no facilities for below 0 °C
- VMI had no facilities for below - 20 °C
- NBSL participated only with one LIGT, over 38.6 °C to 41.4 °C.
- ITDI participated only in LIGT measurements.

All laboratories' submitted raw data are listed in the Appendix D.

6. ANALYSIS of RESULTS

6.1 IPRT stability

The stability of the artifacts during the comparison was assessed by tracking the R(IP). The three R(IP) values: initial (before -40^{o}C), intermediate (after -40^{o}C) and final (after 250^{o}C data) are plotted in Graph 1. Note: the R(TPW) data submitted by some participants were corrected to R(IP). R(IP) from the initial annealing procedures done by NIMT before the circulation started were added to Graph 1.



Graph 1

6.2 Correction of IPRT data back to nominal temperatures:

IPRT (T,R) pairs of data were supplied by the participants at temperature values near to, but not exactly equal to the specified nominal temperatures. The participant data were therefore interpolated back to the nominal temperatures in order to be compared (see Table 2). This was done by fitting a cubic polynomial to each of the participants' data, and using the slope of this fitted curve to interpolate the data back to the agreed nominal temperatures. The uncertainty incurred by this extrapolation is estimated by considering (i) the maximum temperature extrapolation (ii) the uncertainty of the slope of the R(T) curve for the thermometer. The maximum extrapolation was less than 0.15^{o}C for all temperatures for all labs except -40^{o}C for MSL, which required a 1.2^{o}C extrapolation, and the uncertainty of the R(T) slope was estimated by considering the relative standard deviation of the slopes determined from each laboratories data (see Table 1). The relative uncertainty in slope was 0.013% at -40^{o}C, and no more than 0.08% at other temperatures. From this, we can calculate that the maximum error due to extrapolation is lower than 0.2mK, which is negligible and not included as a separate uncertainty term. In the calculation of differences to the link laboratory, resistance differences were converted into mK using the slope of the R(T) curve for the IPRT, and again, the error due to slope of R(T) makes a negligible contribution.

Table 1: ∂T/∂R of each set of Laboratory results

T ^{o}C	NIMTi	NMIA	SIRIM	ITDI	KIMLIPI	NIMTf	NIMTi	NMIA	SPRING	SCL	VMI	MSL	NIMTf
-40^{o}C	2.4778	2.4778	2.4779	-	-	2.4778	2.4782	2.4783	2.4784	2.4784	-	2.4786	2.4785
0^{o}C	2.5082	2.5082	2.5086	-	2.5022	2.5083	2.5086	2.5087	2.5087	2.5087	2.5095	2.5088	2.5086
50^{o}C	2.5461	2.5462	2.5467	-	2.5445	2.5462	2.5466	2.5466	2.5466	2.5466	2.5466	2.5466	2.5464
100^{o}C	2.5864	2.5865	2.5871	-	2.5876	2.5865	2.5869	2.5869	2.5869	2.5869	2.5867	2.5869	2.5866
150^{o}C	2.6267	2.6268	2.6274	-	2.6288	2.6267	2.6271	2.6273	2.6272	2.6272	2.6275	2.6273	2.6271
200^{o}C	2.6677	2.6680	2.6684	-	2.6688	2.6677	2.6682	2.6684	2.6684	2.6685	2.6699	2.6686	2.6686
250^{o}C	2.7096	2.7100	2.7101	-	2.7075	2.7095	2.7101	2.7105	2.7105	2.7107	2.7140	-	2.7111

Table 2: Participants IPRT (R,T) data corrected back to nominal temperatures

	Resistance associated with each Temperature								
	0^{o}C	-40 ^{o}C	0 ^{o}C	50 ^{o}C	100 ^{o}C	150 ^{o}C	200 ^{o}C	250 ^{o}C	0 ^{o}C
Loop A									
NIMT Ai	99.9792	83.9293	99.9785	119.7619	139.2493	158.4361	177.3267	195.9274	99.9787
NIMA A	99.9780	83.9299	99.9778	119.7628	139.2472	158.4327	177.3231	195.9212	99.9781
SIRIM	99.9781	83.9213	99.9671	119.7504	139.2275	158.4188	177.3029	195.8962	99.9780
ITDI	-								
KIM-LIPI	-	-	99.9797	119.8007	139.2757	158.4527	177.3359	195.9334	99.9797
NIMT.Af	99.9789	83.9307	99.9790	119.7646	139.2462	158.4330	177.3261	195.9251	99.9790
Loop B									
NIMT.Bi	99.9597	83.9134	99.9603	119.7407	139.2220	158.4062	177.2944	195.8909	99.9598
NIMA.B	99.9591	83.9137	99.9590	119.7403	139.2212	158.4037	177.2911	195.8854	99.9593
SPRING	99.9598	83.9148	99.9591	119.7404	139.2219	158.4052	177.2917	195.8869	99.9594
SCL	99.9592	83.9144	99.9592	119.7406	139.2221	158.4047	177.2917	195.8855	99.9593
VMI	99.9584	-	99.9584	119.7408	139.2183	158.4038	177.2888	195.8684	99.9591
MSL	99.9601	83.9158	99.9591	119.7397	139.2220	158.4048	177.2906	-	99.9602
NIMT.Bf	99.9593	83.9147	99.9594	119.7409	139.2273	158.4088	177.2965	195.8892	99.9593

6.3 LIGTs

For the ASTM 62C and ASTM12C thermometers no corrections were applied. For the ASTM 40C partial immersion thermometers, data were corrected back to the measured NIMT emergent stem temperature using the equation below.

$$\delta = Knt$$

where ***K***=0.00016, ***n*** is the number of degrees of mercury above the bath, and ***t*** is the average stem temperature difference to that of NIMT values.

Note: ITDI did not submit the emergent stem temperature, so these corrections could not be made, resulting in significant apparent differences. Tables 3-5 give a summary of the corrected data.

Table 3: Corrected ASTM 40C data.

	Temperature Correction at each Temperature						
	75	90	100	105	110	125	75
Loop A							
NIMT Ai	0.038	-0.037	-0.036	-0.023	-0.034	-0.026	0.000
NIMA A	0.034	-0.058	-0.050	-0.036	-0.037	-0.069	0.032
SIRIM	0.061	-0.004	-0.064	-0.091	-0.072	-0.123	0.053
ITDI	-0.084	-0.188	-0.262	0.090	-0.288	-0.459	-0.182
KIM-LIPI	-0.007	-0.036	-0.091	-0.066	-0.073	-0.045	0.003
NIMT.Af	0.009	-0.077	-0.084	-0.079	-0.075	-0.095	-0.030
Loop B							
NIMT.Bi	-0.018	-0.065	-0.079	-0.094	-0.076	0.005	-0.012
NIMA.B	0.003	-0.029	-0.045	-0.053	-0.075	-0.034	-0.011
SPRING	-0.016	-0.049	-0.057	-0.091	-0.121	-0.078	-0.032
SCL	-0.014	-0.069	-0.067	-0.101	-0.135	-0.108	-0.019
VMI	-0.027	-0.135	-0.088	-0.135	-0.210	-0.114	-0.056
NIMT.Bf	-0.041	-0.057	-0.079	-0.069	-0.113	-0.044	-0.084

Table 4: ASTM 62C data (no stem correction required)

	Temperature Correction at each Temperature						
	0	-37	-30	-25	-20	-10	0
Loop A							
NIMT Ai	-0.021	-0.070	-0.021	-0.064	-0.031	-0.021	-0.020
NIMA A	0.000	-0.064	-0.041	-0.076	-0.070	-0.037	-0.002
SIRIM	-0.040	0.010	-0.050	-0.070	-0.060	-0.030	-0.040
ITDI	-0.010	-0.010	-0.020	-0.020	-0.030	0.020	-0.010
KIM-LIPI	-	-	-	-	-	-	-
NIMT.Af	-0.005	-0.063	-0.027	-0.055	-0.056	-0.024	-0.016
Loop B							
NIMT.Bi	0.004	-0.049	0.014	-0.039	-0.008	-0.016	-0.004
NIMA.B	-0.002	-0.040	0.004	-0.030	-0.032	-0.019	0.000
SPRING	-0.010	-0.060	-0.030	-0.040	-0.030	-0.020	-0.010
SCL	0.000	-0.060	-0.020	-0.040	-0.020	-0.030	0.000
VMI	-0.006	-	-	-0.028	-0.017	-0.042	-0.006
NIMT.Bf	0.005	-0.066	-0.013	-0.022	-0.005	0.000	0.007

Table 5: ASTM 120C data (no stem correction required)

	Temperature Correction at each Temperature				
	0	39	40	41	0
Loop A					
NIMT Ai	-0.020	0.004	-0.001	-0.020	-0.020
NIMA A	-0.021	0.004	-0.001	-0.013	-0.023
SIRIM	-0.010	0.010	0.000	-0.020	-0.010
ITDI	-0.030	-0.020	-0.030	-0.040	-0.030
KIM-LIPI	-0.020	0.000	-0.020	-0.020	-0.020
NIMT.Af	-0.020	0.010	-0.001	-0.020	-0.021
Loop B					
NIMT.Bi	-0.027	-0.006	-0.011	-0.011	-0.024
NIMA.B	-0.023	-0.010	-0.007	-0.008	-0.024
SPRING	-0.025	-0.015	-0.010	-0.015	-0.025
SCL	-0.030	-0.010	-0.010	-0.010	-0.030
VMI	-0.035	-0.012	-0.008	-0.011	-0.035
NBSM	0.000	0.050	0.050	0.050	0.000
NIMT.Bf	-0.020	-0.005	-0.008	-0.011	-0.024

7. COMPARISON DATA ANALYSIS

There were 4 different types of artefact being used in the comparison (ASTS40C, ATSM120C & ASTM 62C Liquid in glass thermometers and an IPRT). In order to reduce the time required for the comparison, 2 of each type of artefact were circulated: one for loop A and one for loop B. This section discusses how the two loops were joined together and how a reference value was calculated for each artefact.

Note: In the following analysis, all uncertainties were reduced to standard uncertainties (u_i) (i.e. at k=1), by dividing the participants stated uncertainty by their stated coverage factor.

7.1 Linking loop A and loop B

NMIA and NIMT participated in both loop A and B measurements, so in principle can be used to link the two loops. As the NMIA uncertainties were significantly lower than the NIMT uncertainties, the NMIA data were used to link the loops, and the NIMT data used as a check on the consistency of the linking process. The first step was to reference measurements within each loop to the link laboratory value.

For laboratories in loop A

$$Y_{lab,i}=T_{lab,i}-T_{NMIA,a}$$

And similarly for laboratories in loop B

$$Y_{lab,i}=T_{lab,i}-T_{NMIA,b}$$

The Y_{labi} values are plotted in graphs B1 to B4 of Appendix B. The uncertainties on each of the data points from each laboratory are plotted at the k=2 level. Note that the NMIA values in each loop are zero (by definition). This should not be taken to mean that the NMIA values are the comparison reference value, which we will calculate later. Since NIMT has also provided 2 sets of measurements in loop A and 2 sets in loop B, there are 4 NIMT values plotted on each graph. By examining these 4 values we can see:

i. Each artefact was stable over its travel around the measurement loop: We can see that the NIMT initial and NIMT final values agree well within their measurement uncertainty.($Y_{NIMTa,initial}$ agrees with $Y_{NIMTa,final}$ and $Y_{NIMTb,initial}$, agrees with $Y_{NIMTb,final}$).

ii. The loop A to loop B link is robust: The NIMT data in loop A ($Y_{NIMTa,initial}$ & $Y_{NIMTa,final}$) agree with the NIMT data in loop B ($Y_{NIMTb,initial}$ & $Y_{NIMTba,final}$), well within the NIMT measurement uncertainties. This shows that the NIMT-NMIA difference measured for the artefact in loop A is consistent with the NIMT-NMIA difference measured by the artefact in loop B.

7.2 Calculation of a comparison reference value

The next step is to form an average of the values measured by each laboratory, to which results from each laboratory can be compared. Since NIMT and NMIA participated in both loops for each artefact, there are 4 "lab-pilot" differences for NIMT and 2 for NMIA. In order not to unfairly bias the calculation of the reference value to either of these laboratories, an average of these laboratories data points was used. Since any uncertainties in measurements made at the same laboratory are likely to be highly correlated, for the NMIA and NIMT multiple data we have taken the simple mean and used the formula for correlated uncertainties (i.e. taken the arithmetic sum of uncertainties, and not the quadrature sum).

For NIMT

$$X_{NIMT} = 1/4\ (Y_{NIMT,a,initial} + Y_{NIMT,a,final} + Y_{NIMT,b,initial} + Y_{NIMT,b,final})$$
$$u_{NIMT} = 1/4\ (u_{NIMT,a,initial} + u_{NIMT,a,final} + u_{NIMT,b,initial} + u_{NIMT,b,final})$$

For NMIA

$$X_{NMIA} = 1/2\ (Y_{NMIA,a} + Y_{NMIA,b})$$
$$u_{NMIA} = 1/2\ (u_{NMIA,a} + u_{NMIA,b})$$

For other labs

$$X_{lab,i} = Y_{lab,i}$$
$$U_{lab,i} = u_{lab,i}$$

The next step was to determine a comparison reference value, which is to be some form of the average of the differences and their uncertainties ($X_{lab,i}$, $u_{lab,i}$). Three different measures of the average have been computed: (a) the simple mean, (b) the median and (c) the weighted mean. The various averages and, and their uncertainties were thus calculated using the following formulae.

(a) Simple mean:

$$X_{simple} = \sum X_i / n$$
$$u_{simple}^2 = \sum u_i^2 \big/ n^2$$

(b) Median: computed using the MEDIAN function on Microsoft Excel. No uncertainty was calculated for this: it is for comparison purposes only.

(c) Weighed mean:

$$X_{weighted} = \sum X_i u_i^{-2} \Big/ \sum u_i^{-2}$$
$$u_{weighted}^2 = 1 \Big/ \sum u_i^{-2}$$

In the case of the weighted mean, we calculated the *Birge* ratio (Metrologia, 2002, 39, p.279-293, R. Kacker, R, A. Dalta and A. Parr), which is a measure of how well the estimated measurement uncertainties explain the measured dispersion of the actual data values.

$$Birge\ Ratio = \sqrt{\sum \left(X_i - X_{weighted}\right)^2 u_i^{-2} \Big/ (n-1)}$$

If the spread of the data points X_i is well within all the errors u_i on the data, then the Birge ratio will be less than 1, and if the spread of the data is larger than expected from the error bars, the Birge ratio will be greater than 1. A statistical criterion for a Birge ratio for *n* data points is given by:

$$Birge\ Criterion < \sqrt{1+\sqrt{8/(n-1)}}$$

which is approximately 1.5 for 7 labs and 1.4 for 8 laboratories.

When this was calculated for the comparison data here, the Birge ratio was generally much larger than this criterion, indicating that at least one laboratory has significantly underestimated their measurement uncertainty. Examination of the data indicated several clear "outliers" which were causing the Birge test to fail. These were:

i. LIGT ASTM40C: ITDI (as it is a clear outlier)
ii. IPRT: SIRIM (they have already acknowledged that the submitted data contained an error)
iii. IPRT: KIMLIPI (since the deviation is much greater than their uncertainty at most temperature points)

When these data points were removed from the calculation of the weighted mean, the Birge criterion was found to be satisfied for all temperatures on all 4 types of artefacts. So, since:

i. the Birge Criterion is satisfied,
ii. the uncertainty of the weighted mean is slightly lower (as it makes more use of the knowledge contained in the data set),

we have decided to use the weighted mean (without the outlier data mentioned) for the comparison reference value for all 4 types of artefact.

7.3 Additional Link Uncertainty

The estimated uncertainty of each of the "average" values calculated has been increased by an additional term, u_{link} to allow for the uncertainty in the link between loop A and loop B made by NMIA (recall that we calculated differences $Y_{labi}=T_{labi}-T_{NMIA}$). This additional uncertainty is taken as $u_{link}=u_{NMIA}$.

If we were to simply add this term into the uncertainty for the laboratory differences $Y_{lab,i}$, the simple formulae for the average and weighted mean, which implicitly assume that the uncertainties of the data points are uncorrelated, are incorrect: Any error in the NMIA data would lead to all the $Y_{lab,i}$ being wrong in the same direction, ie correlated. Adding the u_{link} to the u_{labi} would then result in artificially and incorrectly reducing the link error (by a factor of $\sqrt{n}$ for the simple mean).

Because of this, we add (in quadrature) this additional uncertainty term *after* the calculation of the average. The error bars plotted on the averages in graphs B1 to B4 include this additional term, as does the calculation of significant deviations from the comparison reference value.

7.4 Calculation of differences to the comparison reference value.

One of the requirements of Appendix-F of the MRA is to identify significant discrepancies amongst the data submitted from the participants. In this comparison we have chosen to do this by calculation of the quantity

$$E_n = \frac{X_{lab,i} - X_{average}}{\sqrt{U^2_{lab,i}(k=2) + U^2_{average}(k=2)}}$$

This has been tabulated in Appendix A for all laboratories, for each type of artefact, and at all measurement temperatures. The discrepancies are highlighted in bold font.

9. CONCLUSION

Data analysis for the artifacts are summarized in Appendix A. The results are presented in (i) Appendix A as Table of En Ratio Calculation with respect to a reference value based on weighted mean with outliers excluded, and (ii) Appendix B as graphs of T(Lab-NMIA)/ ^{o}C with simple mean, median and weighted mean on the same graph.

Appendix A

Liquid In Glass Thermometers Comparison ,ASTM 62C Result Analysis

Participants	0	U_i	k	-37	U_i	k	-30	U_i	k	-25	U_i	k	-20	U_i	k	-10	U_i	k	0	U_i	k
NIMT $_{.i}$ A	-0.021	0.100	2.00	-0.070	0.100	2.00	-0.021	0.100	2.00	-0.064	0.100	2.00	-0.031	0.100	2.00	-0.021	0.100	2.00	-0.020	0.100	2.00
NMIA.A	0.000	0.007	2.23	-0.064	0.016	2.09	-0.041	0.016	2.09	-0.076	0.016	2.09	-0.070	0.016	2.09	-0.037	0.016	2.09	-0.002	0.007	2.23
SIRIM	-0.040	0.120	2.00	0.010	0.120	2.00	-0.05	0.120	2.00	-0.07	0.120	2.00	-0.06	0.120	2.00	-0.03	0.120	2.00	-0.04	0.120	2.00
ITDI	-0.010	0.060	2.00	-0.010	0.060	2.00	-0.02	0.060	2.00	-0.020	0.060	2.00	-0.030	0.060	2.00	0.020	0.060	2.00	-0.010	0.060	2.00
KIM-LIPI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NIMT $_{.f}$ A	-0.005	0.100	2.00	-0.063	0.100	2.00	-0.027	0.100	2.00	-0.055	0.100	2.00	-0.056	0.100	2.00	-0.024	0.100	2.00	-0.016	0.100	2.00
NIMT $_{.i}$ B	0.004	0.100	2.00	-0.049	0.100	2.00	0.014	0.100	2.00	-0.039	0.100	2.00	-0.008	0.100	2.00	-0.016	0.100	2.00	-0.004	0.100	2.00
NMIA.B	-0.002	0.007	2.23	-0.040	0.016	2.09	0.004	0.016	2.09	-0.030	0.016	2.09	-0.032	0.016	2.09	-0.019	0.016	2.09	0.000	0.007	2.23
SPRING	-0.010	0.030	2.00	-0.060	0.030	2.00	-0.030	0.030	2.00	-0.040	0.030	2.00	-0.030	0.030	2.00	-0.02	0.030	2.00	-0.010	0.030	2.00
SCL	0.000	0.030	2.00	-0.060	0.050	1.98	-0.02	0.050	1.98	-0.04	0.050	1.98	-0.02	0.050	1.98	-0.03	0.050	1.98	0.00	0.030	2.00
VMI	-0.006	0.032	2.00	-	-	-	-	-	-	-0.028	0.032	2.00	-0.017	0.032	2.00	-0.042	0.032	2.00	-0.006	0.032	2.00
NIMT $_{.f}$ B	0.005	0.100	2.00	-0.066	0.100	2.00	-0.013	0.100	2.00	-0.022	0.100	2.00	-0.005	0.100	2.00	0.000	0.100	2.00	0.007	0.100	2.00
Loop A Reference	0.000	0.007	2.23	-0.064	0.016	2.09	-0.041	0.016	2.09	-0.076	0.016	2.09	-0.070	0.016	2.09	-0.037	0.016	2.09	-0.002	0.007	2.23
Loop B Reference	-0.002	0.007	2.23	-0.040	0.016	2.09	0.004	0.016	2.09	-0.030	0.016	2.09	-0.032	0.016	2.09	-0.019	0.016	2.09	0.000	0.007	2.23
Link Uncertainty	u_i	0.003			0.008			0.008			0.008			0.008			0.008			0.003	

NMIA is the reference lab, u_i at $k=1$, U_i at $k=2$

Lab-Ref	0	u_i	U_i	-37	u_i	U_i	-30	u_i	U_i	-25	u_i	U_i	-20	u_i	U_i	-10	u_i	U_i	0	u_i	U_i
NIMT$_{i.}$ A	-0.021	0.050	0.100	-0.006	0.050	0.100	0.020	0.050	0.100	0.012	0.050	0.100	0.039	0.050	0.100	0.016	0.050	0.100	-0.018	0.050	0.100
NMIA. A	0.000	0.003	0.006	0.000	0.008	0.015	0.000	0.008	0.015	0.000	0.008	0.015	0.000	0.008	0.015	0.000	0.008	0.015	0.000	0.003	0.006
SIRIM	-0.040	0.060	0.120	0.074	0.060	0.120	-0.009	0.060	0.120	0.006	0.060	0.120	0.010	0.060	0.120	0.007	0.060	0.120	-0.038	0.060	0.120
ITDI	-0.010	0.030	0.060	0.054	0.030	0.060	0.021	0.030	0.060	0.056	0.030	0.060	0.040	0.030	0.060	0.057	0.030	0.060	-0.008	0.030	0.060
KIM-LIPI																					
NIMT$_f$. A	-0.005	0.050	0.100	0.001	0.050	0.100	0.014	0.050	0.100	0.021	0.050	0.100	0.015	0.050	0.100	0.013	0.050	0.100	-0.014	0.050	0.100
NIMT$_i$. B	0.006	0.050	0.100	0.015	0.050	0.100	0.010	0.050	0.100	-0.009	0.050	0.100	0.024	0.050	0.100	0.003	0.050	0.100	-0.004	0.050	0.100
NMIA. B	0.000	0.003	0.006	0.024	0.008	0.015	0.000	0.008	0.015	0.000	0.008	0.015	0.000	0.008	0.015	0.000	0.008	0.015	0.000	0.003	0.006
SPRING	-0.008	0.015	0.030	0.004	0.015	0.030	-0.034	0.015	0.030	-0.010	0.015	0.030	0.002	0.015	0.030	-0.001	0.015	0.030	-0.010	0.015	0.030
SCL	0.002	0.015	0.030	0.004	0.025	0.051	-0.024	0.025	0.051	-0.010	0.025	0.051	0.012	0.025	0.051	-0.011	0.025	0.051	0.000	0.015	0.030
VMI	-0.004	0.016	0.032							0.002	0.016	0.032	0.015	0.016	0.032	-0.023	0.016	0.032	-0.006	0.016	0.032
NIMT$_f$. B	0.007	0.050	0.100	-0.002	0.050	0.100	-0.017	0.050	0.100	0.008	0.050	0.100	0.027	0.050	0.100	0.019	0.050	0.100	0.007	0.050	0.100
Simple	-0.009	0.013	0.026	0.025	0.017	0.033	-0.007	0.017	0.033	0.007	0.015	0.030	0.015	0.015	0.030	0.006	0.015	0.030	-0.010	0.013	0.026
Median	-0.004			0.008			-0.005			0.002			0.012			0.000			-0.007		
Weighted	-0.001	0.004	0.009	0.031	0.010	0.020	-0.016	0.010	0.020	0.001	0.010	0.019	0.013	0.010	0.019	-0.004	0.010	0.019	-0.002	0.004	0.009
No of labs	7			6			6			7			7			7			7		
NIMTAV	-0.003	0.050		0.002	0.050		0.007	0.050		0.008	0.050		0.026	0.050		0.013	0.050		-0.007	0.050	
NMIAAV	0.000	0.003		0.012	0.008		0.000	0.008		0.000	0.008		0.000	0.008		0.000	0.008		0.000	0.003	
Birge ratio	0.39			1.53			1.25			0.83			0.87			1.00			0.43		
Birge criteria		1.47			1.50			1.50			1.47			1.47			1.47			1.47	

Appendix A

Liquid In Glass Thermometers Comparison ,ASTM 120C Result Analysis

Participants	*0*	U_i	*k*	*39*	U_i	*k*	*40*	U_i	*k*	*41*	U_i	*k*	*0*	U_i	*k*
NIMT.$_i$ A	-0.020	0.020	2.00	0.004	0.020	2.00	-0.001	0.020	2.00	-0.020	0.020	2.00	-0.020	0.020	2.00
NMIA.A	-0.021	0.004	2.26	0.004	0.007	2.45	-0.001	0.007	2.31	-0.013	0.007	2.36	-0.023	0.004	2.23
SIRIM	-0.01	0.130	2.00	0.01	0.130	2.00	0.00	0.130	2.00	-0.02	0.130	2.00	-0.01	0.130	2.00
ITDI	-0.030	0.030	2.00	-0.020	0.030	2.00	-0.030	0.030	2.00	-0.040	0.030	2.00	-0.030	0.030	2.00
KIM-LIPI	-0.02	0.032	2.00	0.00	0.032	2.00	-0.02	0.032	2.00	-0.02	0.032	2.00	-0.02	0.032	2.00
NIMT.$_f$ A	-0.020	0.020	2.00	0.010	0.020	2.00	-0.001	0.020	2.00	-0.020	0.020	2.00	-0.021	0.020	2.00
NIMT.$_i$ B	-0.027	0.020	2.00	-0.006	0.020	2.00	-0.011	0.020	2.00	-0.011	0.020	2.00	-0.024	0.020	2.00
NMIA.B	-0.023	0.004	2.26	-0.010	0.008	2.31	-0.007	0.007	2.36	-0.008	0.007	2.36	-0.024	0.004	2.23
SPRING	-0.025	0.015	2.00	-0.015	0.015	2.00	-0.010	0.015	2.00	-0.015	0.015	2.00	-0.025	0.015	2.00
SCL	-0.030	0.015	1.99	-0.010	0.020	1.98	-0.010	0.020	1.98	-0.010	0.020	1.98	-0.030	0.015	1.99
VMI	-0.035	0.012	2.00	-0.012	0.012	2.00	-0.008	0.012	2.00	-0.011	0.012	2.00	-0.035	0.012	2.00
NBSM	0.00	0.16	2.45	0.05	0.16	2.45	0.05	0.16	2.45	0.05	0.16	2.45	0.00	0.16	2.45
NIMT.$_f$ B	-0.020	0.020	2.00	-0.005	0.020	2.00	-0.008	0.020	2.00	-0.011	0.020	2.00	-0.024	0.020	2.00
Loop A Reference	-0.021			0.004			-0.001			-0.013			-0.023		
Loop B Reference	-0.023			0.010			-0.007			-0.008			-0.024		
Link Uncertainty	u_i	0.002			0.003			0.003			0.003			0.002	

NMIA is the reference lab, u_i at $k=1$, U_i at $k=2$

Lab-Ref	*0*	u_i	U_i	*39*	u_i	U_i	*40*	u_i	U_i	*41*	u_i	U_i	*0*	u_i	U_i
NIMTi.A	0.001	0.010	0.020	0.000	0.010	0.020	0.000	0.010	0.020	-0.007	0.010	0.020	0.003	0.010	0.020
NMIA.A	0.000	0.002	0.004	0.000	0.003	0.006	0.000	0.003	0.006	0.000	0.003	0.006	0.000	0.002	0.004
SIRIM	0.011	0.065	0.130	0.006	0.065	0.130	0.001	0.065	0.130	-0.007	0.065	0.130	0.013	0.065	0.130
ITDI	-0.009	0.015	0.030	-0.024	0.015	0.030	-0.029	0.015	0.030	-0.027	0.015	0.030	-0.007	0.015	0.030
KIM-LIPI	0.001	0.016	0.032	-0.004	0.016	0.032	-0.019	0.016	0.032	-0.007	0.016	0.032	0.003	0.016	0.032
NIMTf.A	0.001	0.010	0.020	0.006	0.010	0.020	0.000	0.010	0.020	-0.007	0.010	0.020	0.002	0.010	0.020
NIMTi.B	-0.004	0.010	0.020	0.004	0.010	0.020	-0.004	0.010	0.020	-0.003	0.010	0.020	0.000	0.010	0.020
NMIA.B	0.000	0.002	0.004	0.000	0.003	0.007	0.000	0.003	0.006	0.000	0.003	0.006	0.000	0.002	0.004
SPRING	-0.002	0.008	0.015	-0.005	0.008	0.015	-0.003	0.008	0.015	-0.007	0.008	0.015	-0.001	0.008	0.015
SCL	-0.007	0.008	0.015	0.000	0.010	0.020	-0.003	0.010	0.020	-0.002	0.010	0.020	-0.006	0.008	0.015
VMI	-0.012	0.006	0.012	-0.002	0.006	0.012	-0.001	0.006	0.012	-0.003	0.006	0.012	-0.011	0.006	0.012
NBSM	0.023	0.065	0.131	0.060	0.065	0.131	0.057	0.065	0.131	0.058	0.065	0.131	0.024	0.065	0.131
NIMTf.B	0.003	0.010	0.020	0.005	0.010	0.020	-0.001	0.010	0.020	-0.003	0.010	0.020	0.000	0.010	0.020
Simple	0.001	0.011	0.022	0.004	0.011	0.022	0.000	0.011	0.022	0.000	0.011	0.022	0.002	0.011	0.022
Median	0.000			0.000			-0.001			-0.005			0.000		
Weighted	-0.003	0.002	0.005	-0.003	0.004	0.007	-0.005	0.004	0.008	-0.006	0.004	0.008	-0.002	0.002	0.005
No of labs	9			9			9			9			9		
NIMTAV	0.000	0.010		0.004	0.010		-0.001	0.010		-0.005	0.010		0.001	0.010	
NMIAAV	0.000	0.002		0.000	0.003		0.000	0.003		0.000	0.003		0.000	0.002	
Birge ratio	0.85			0.75			0.95			0.95			0.77		
Birge criteria		1.41			1.41			1.41			1.41			1.41	

Appendix A

Liquid In Glass Thermometers Comparison ,ASTM 40C Result Analysis

Lab-Ref	75	u_i	U_i	90	u_i	U_i	100	u_i	U_i	105	u_i	U_i	110	u_i	U_i	125	u_i	U_i	75	u_i	U_i
$NIMT_i$ A	0.038	0.200	2.00	-0.037	0.200	2.00	-0.036	0.200	2.00	-0.023	0.200	2.00	-0.034	0.200	2.00	-0.026	0.200	2.00	0.000	0.200	2.00
NMIA A	0.034	0.017	2.45	-0.058	0.017	2.45	-0.050	0.017	2.45	-0.036	0.017	2.45	-0.037	0.018	2.36	-0.069	0.017	2.45	0.032	0.021	2.36
SIRIM	0.061	0.240	2.00	-0.004	0.240	2.00	-0.064	0.240	2.00	-0.091	0.24	2.00	-0.072	0.240	2.00	-0.123	0.240	2.00	0.053	0.24	2.00
ITDI	-0.084	0.090	2.00	-0.188	0.090	2.00	-0.262	0.090	2.00	0.09	0.09	2.00	-0.288	0.090	2.00	-0.459	0.090	2.00	-0.182	0.09	2.00
KIM-LIPI	-0.007	0.120	1.96	-0.036	0.120	1.96	-0.091	0.120	1.96	-0.066	0.12	1.96	-0.073	0.120	1.96	-0.045	0.120	1.96	0.003	0.12	1.96
$NIMT_{f.}$ A	0.009	0.200	2.00	-0.077	0.200	2.00	-0.084	0.200	2.00	-0.079	0.200	2.00	-0.075	0.200	2.00	-0.095	0.200	2.00	-0.030	0.200	2.00
Reference Loop A	0.034	0.017	2.450	-0.058	0.017	2.450	-0.050	0.017	2.450	-0.036	0.017	2.450	-0.037	0.018	2.360	-0.069	0.017	2.450	0.032	0.021	2.360
$NIMT_{i}$. B	-0.018	0.20	2.00	-0.065	0.20	2.00	-0.079	0.20	2.00	-0.094	0.20	2.00	-0.076	0.20	2.00	0.005	0.20	2.00	-0.012	0.20	2.00
NMIA B	0.003	0.017	2.45	-0.029	0.017	2.45	-0.045	0.017	2.45	-0.053	0.017	2.45	-0.075	0.017	2.45	-0.034	0.017	2.36	-0.011	0.017	2.45
SPRING	-0.016	0.04	2.00	-0.049	0.04	2.00	-0.057	0.04	2.00	-0.091	0.04	2.00	-0.121	0.04	2.00	-0.078	0.04	2.00	-0.032	0.04	2.00
SCL	-0.014	0.08	1.98	-0.069	0.08	1.98	-0.067	0.08	1.98	-0.101	0.08	1.98	-0.135	0.08	1.98	-0.108	0.08	1.98	-0.019	0.08	1.98
VMI	-0.027	0.069	2.00	-0.135	0.069	2.00	-0.088	0.069	2.00	-0.135	0.069	2.00	-0.210	0.069	2.00	-0.114	0.069	2.00	-0.056	0.069	2.00
$NIMT_{f}$. B	-0.041	0.20	2.00	-0.057	0.20	2.00	-0.079	0.20	2.00	-0.069	0.20	2.00	-0.113	0.20	2.00	-0.044	0.20	2.00	-0.084	0.20	2.00
Reference Loop B	0.003	0.017	2.450	-0.029	0.017	2.450	-0.045	0.017	2.450	-0.053	0.017	2.450	-0.075	0.017	2.450	-0.034	0.017	2.360	-0.011	0.017	2.450
LINK Uncertainty		0.0069			0.0069			0.0069			0.0069			0.0069			0.0072			0.0069	

NMIA is the reference lab, u_i at $k=1$, U_i at $k=2$

Lab-Ref	75	u_i	U_i	90	u_i	U_i	100	u_i	U_i	105	u_i	U_i	110	u_i	U_i	125	u_i	U_i	75	u_i	U_i
$NIMT_i$ A	0.003	0.100	0.200	0	0.100	0.200	0	0.100	0.200	0	0.100	0.200	0	0.100	0.200	0	0.100	0.200	0	0.100	0.200
NMIA A	0.000	0.007	0.014	0.000	0.007	0.014	0.000	0.007	0.014	0.000	0.007	0.014	0.000	0.008	0.015	0.000	0.007	0.014	0.000	0.009	0.018
SIRIM	0.026	0.120	0.240	0.053	0.120	0.240	-0.014	0.120	0.240	-0.055	0.120	0.240	-0.035	0.120	0.240	-0.054	0.120	0.240	0.021	0.120	0.240
ITDI	-0.119	0.045	0.090	-0.130	0.045	0.090	-0.212	0.045	0.090	0.126	0.045	0.090	-0.250	0.045	0.090	-0.390	0.045	0.090	-0.215	0.045	0.090
KIM-LIPI	-0.041	0.061	0.122	0.022	0.061	0.122	-0.042	0.061	0.122	-0.030	0.061	0.122	-0.036	0.061	0.122	0.024	0.061	0.122	-0.030	0.061	0.122
$NIMT_{f.}$ A	-0.026	0.100	0.200	-0.019	0.100	0.200	-0.034	0.100	0.200	-0.043	0.100	0.200	-0.038	0.100	0.200	-0.026	0.100	0.200	-0.062	0.100	0.200
$NIMT_{i}$. B	-0.021	0.100	0.200	-0.036	0.100	0.200	-0.034	0.100	0.200	-0.041	0.100	0.200	-0.001	0.100	0.200	0.039	0.100	0.200	-0.001	0.100	0.200
NMIA B	0.000	0.007	0.014	0.000	0.007	0.014	0.000	0.007	0.014	0.000	0.007	0.014	0.000	0.007	0.014	0.000	0.007	0.014	0.000	0.007	0.014
SPRING	-0.019	0.020	0.040	-0.020	0.020	0.040	-0.012	0.020	0.040	-0.038	0.020	0.040	-0.045	0.020	0.040	-0.044	0.020	0.040	-0.021	0.020	0.040
SCL	-0.017	0.040	0.081	-0.040	0.040	0.081	-0.022	0.040	0.081	-0.048	0.040	0.081	-0.060	0.040	0.081	-0.074	0.040	0.081	-0.007	0.040	0.081
VMI	-0.030	0.035	0.069	-0.106	0.035	0.069	-0.043	0.035	0.069	-0.081	0.035	0.069	-0.135	0.035	0.069	-0.080	0.035	0.069	-0.045	0.035	0.069
$NIMT_{f}$. B	-0.044	0.100	0.200	-0.028	0.100	0.200	-0.034	0.100	0.200	-0.016	0.100	0.200	-0.037	0.100	0.200	-0.010	0.100	0.200	-0.072	0.100	0.200
Simple	-0.028	0.024	0.048	-0.030	0.024	0.048	-0.046	0.024	0.048	-0.019	0.024	0.048	-0.073	0.024	0.048	-0.077	0.024	0.048	-0.041	0.024	0.048
Median	-0.020			-0.020			-0.024			-0.034			-0.041			-0.049			-0.025		
Weighted	-0.013	0.009	0.019	-0.019	0.009	0.019	-0.017	0.009	0.019	-0.013	0.009	0.019	-0.036	0.010	0.019	-0.038	0.010	0.019	-0.020	0.010	0.020
Wav-ITDI	-0.008	0.009	0.019	-0.014	0.009	0.019	-0.008	0.009	0.019	-0.018	0.009	0.019	-0.025	0.010	0.019	-0.020	0.010	0.019	-0.010	0.010	0.020
No of Labs		8			8			8			8			8			8			8	
NIMTAV	-0.022	0.100		-0.021	0.100		-0.026	0.100		-0.025	0.100		-0.019	0.100		0.001	0.100		-0.034	0.100	
NMIAAV	0.000	0.007		0.000	0.007		0.000	0.007		0.000	0.007		0.000	0.007		0.000	0.007		0.000	0.008	
Birge ratio			1.18			1.74			1.92			1.66			2.83			3.66			1.93
Birge criteria			1.44			1.44			1.44			1.44			1.44			1.44			1.44

Birge ratio w/o ITDI			0.65			1.43			0.70			1.41			2.00			1.58			0.73
Birge criteria w/o ITDI			1.47			1.47			1.47			1.47			1.47			1.47			1.47

Appendix A

Industrial Platinum Resistance Thermometers Comparison ,Model 5626-12S Result Analysis

Participants	*IP initial*	U_i	*k*	*-40*	U_i	*k*	*IP Itermed*	U_i	*k*	*50*	U_i	*k*	*100*	U_i	*k*	*150*	U_i	*k*	*200*	U_i	*k*	*250*	U_i	*k*	*IP Final*	U_i	*k*
NIMT.$_i$ A	99.97923	0.020	2.00	83.9293	0.020	2.00	99.97854	0.020	2.00	119.7619	0.020	2.00	139.2493	0.020	2.00	158.4361	0.020	2.00	177.3267	0.020	2.00	195.9274	0.020	2.00	99.97865	0.020	2.00
NMIA.A	99.978	0.001	1.95	83.92992	0.005	1.95	99.97780	0.001	1.95	119.7628	0.004	1.95	139.2472	0.004	1.95	158.4327	0.004	1.95	177.3231	0.004	1.95	195.9212	0.004	1.95	99.97810	0.001	1.95
SIRIM	99.97812	0.001	2.01	83.92131	0.025	2.01	99.96712	0.028	2.01	119.7504	0.028	2.01	139.2275	0.036	2.01	158.4188	0.013	2.01	177.3029	0.021	2.01	195.8962	0.030	2.01	99.97802	0.001	2.01
ITDI	-																										
KIM-LIPI	-			-			99.97966	0.013	2.03	119.8007	0.013	2.03	139.2756	0.013	2.03	158.4527	0.013	2.03	177.3359	0.013	2.03	195.9334	0.013	2.03	99.97969	0.013	2.03
NIMT.$_f$ A	99.97893	0.020	2.00	83.93066	0.020	2.00	99.97897	0.020	2.00	119.7646	0.020	2.00	139.2462	0.020	2.00	158.433	0.020	2.00	177.3261	0.020	2.00	195.9251	0.020	2.00	99.97897	0.020	2.00
NIMT.$_i$ B	99.9597	0.020	2.00	83.9134	0.020	2.00	99.96031	0.020	2.00	119.7407	0.020	2.00	139.2221	0.020	2.00	158.4062	0.020	2.00	177.2944	0.020	2.00	195.8909	0.020	2.00	99.95976	0.020	2.00
NMIA.B	99.9591	0.001	1.99	83.91373	0.005	1.99	99.95900	0.001	1.99	119.7403	0.004	1.99	139.2212	0.004	1.99	158.404	0.004	1.99	177.2911	0.004	1.99	195.8854	0.004	1.99	99.95930	0.001	1.99
SPRING	99.95984	0.004	2.00	83.91479	0.009	2.00	99.95907	0.004	2.00	119.7404	0.008	2.00	139.2219	0.009	2.00	158.4052	0.009	2.00	177.2917	0.008	2.00	195.8869	0.009	2.00	99.95936	0.004	2.00
SCL	99.95917	0.001	1.98	83.91438	0.013	2.00	99.95921	0.001	1.98	119.7406	0.006	1.97	139.2221	0.006	1.97	158.4047	0.006	1.97	177.2917	0.006	1.97	195.8855	0.033	2.00	99.95931	0.001	1.98
VMI	99.95844	0.007	1.96	-	-		99.95841	0.007	1.96	119.7408	0.011	1.96	139.2183	0.019	1.96	158.4038	0.017	1.96	177.2888	0.018	1.96	195.8684	0.017	1.96	99.95911	0.007	1.96
MSL	99.96011	0.0054	2.00	83.91578	0.0054	2.00	99.95909	0.0054	2.00	119.7397	0.0054	2.00	139.222	0.0054	2.00	158.4048	0.0054	2.00	177.2906	0.0054	2.00	-	-	-	99.96016	0.0054	2.00
NIMT.$_f$ B	99.95932	0.020	2.00	83.91471	0.020	2.00	99.95943	0.020	2.00	119.7409	0.020	2.00	139.2273	0.020	2.00	158.4088	0.020	2.00	177.2965	0.020	2.00	195.8892	0.020	2.00	99.95932	0.020	2.00
Loop A Reference	99.978	0.001	1.95	83.9299	0.005	1.95	99.9778	0.001	1.95	119.763	0.004	1.95	139.247	0.004	1.95	158.433	0.004	1.95	177.323	0.004	1.95	195.921	0.004	1.95	99.9781	0.001	1.95
Loop B Reference	99.9591	0.001	1.99	83.9137	0.005	1.99	99.959	0.001	1.99	119.74	0.004	1.99	139.221	0.004	1.99	158.404	0.004	1.99	177.291	0.004	1.99	195.885	0.004	1.99	99.9593	0.001	1.99
Link Uncertainty		0.001			0.003			0.001			0.002			0.002			0.002			0.002			0.002			0.001	
Link diff	1.69	mK		-0.69	mK		0.21	mK		-0.07	mK		-7.35	mK		-4.78	mK		-2.56	mK		0.96	mK		1.18	mK	

Lab-Ref	*T-T$_{Ref}$*	u_i /mK	U_i /mK	*T-T$_{Ref}$*	u_i /mK	U_i /mK	*T-T$_{Ref}$*	u_i /mK	U_i /mK	*T-T$_{Ref}$*	u_i /mK	U_i /mK	*T-T$_{Ref}$*	u_i /mK	U_i /mK	*T-T$_{Ref}$*	u_i /mK	U_i /mK	*T-T$_{Ref}$*	u_i /mK	U_i /mK	*T-T$_{Ref}$*	u_i /mK	U_i /mK	*T-T$_{Ref}$*	u_i /mK	U_i /mK
NIMT.$_i$ A	3.10	10.00	20.00	-1.55	10.00	20.00	1.86	10.00	20.00	-2.14	10.00	20.00	5.46	10.00	20.00	9.03	10.00	20.00	9.53	10.00	20.00	16.62	10.00	20.00	1.39	10.00	20.00
NMIA.A	0.00	0.51	1.03	0.00	2.56	5.13	0.00	0.51	1.03	0.00	2.05	4.10	0.00	2.05	4.10	0.00	2.05	4.10	0.00	2.05	4.10	0.00	2.05	4.10	0.00	0.51	1.03
SIRIM	0.29	0.50	1.00	-21.36	12.44	24.88	**-26.80**	13.93	27.86	-31.50	13.93	27.86	-50.92	17.91	35.82	-36.60	6.47	12.94	-54.04	10.45	20.90	-67.74	14.93	29.85	-0.21	0.50	1.00
ITDI																											
KIM-LIPI							4.65	6.40	12.81	96.50	6.40	12.81	73.56	6.40	12.81	52.63	6.40	12.81	34.17	6.40	12.81	32.88	6.40	12.81	3.97	6.40	12.81
NIMT.$_f$ A	2.33	10.00	20.00	1.81	10.00	20.00	2.93	10.00	20.00	4.77	10.00	20.00	-2.76	10.00	20.00	0.92	10.00	20.00	8.05	10.00	20.00	10.47	10.00	20.00	2.17	10.00	20.00
NIMT.$_i$ B	1.50	10.00	20.00	-0.81	10.00	20.00	3.29	10.00	20.00	1.20	10.00	20.00	2.14	10.00	20.00	6.61	10.00	20.00	8.74	10.00	20.00	14.74	10.00	20.00	1.15	10.00	20.00
NMIA.B	0.00	0.50	1.01	0.00	2.51	5.03	0.00	0.50	1.01	0.00	2.01	4.02	0.00	2.01	4.02	0.00	2.01	4.02	0.00	2.01	4.02	0.00	2.01	4.02	0.00	0.50	1.01
SPRING	1.86	2.00	4.00	2.63	4.50	9.00	0.17	2.00	4.00	0.26	4.00	8.00	1.83	4.50	9.00	3.95	4.50	9.00	1.55	4.00	8.00	4.00	4.50	9.00	0.15	2.00	4.00
SCL	0.16	0.51	1.01	1.63	6.50	13.00	0.54	0.51	1.01	0.77	3.05	6.09	2.23	3.05	6.09	2.57	3.05	6.09	1.51	3.05	6.09	0.31	16.50	33.00	0.03	0.51	1.01
VMI	-1.66	3.57	7.14				-1.49	3.57	7.14	1.43	5.61	11.22	-7.68	9.69	19.39	0.31	8.54	17.08	-6.28	9.18	18.37	-46.29	8.77	17.55	-0.47	3.57	7.14
MSL	2.54	2.69	5.39	5.09	2.69	5.39	0.24	2.69	5.39	-1.35	2.69	5.39	1.89	2.69	5.39	2.94	2.69	5.39	-1.30	2.69	5.39				2.17	2.69	5.39
NIMT.$_f$ B	0.54	10.00	20.00	2.44	10.00	20.00	1.08	10.00	20.00	1.58	10.00	20.00	15.79	10.00	20.00	13.37	10.00	20.00	14.31	10.00	20.00	10.27	10.00	20.00	0.04	10.00	20.00
Simple	0.72	1.60	3.19	-1.92	3.03	6.06	-2.55	2.37	4.74	8.43	2.51	5.02	3.26	3.05	6.11	4.16	2.15	4.31	-1.78	2.41	4.82	-9.12	3.88	7.76	0.85	1.73	3.46
Median	0.29			1.05			0.20			0.51			1.86			2.75			0.75			0.31			0.09		
Weighted	0.21	0.28	0.57	1.93	1.62	3.23	0.25	0.35	0.69	3.62	1.29	2.59	3.91	1.33	2.67	2.33	1.31	2.61	0.77	1.31	2.62	0.70	1.76	3.52	-0.05	0.34	0.69
Wav-KI,SIR	0.11	0.35	0.70	2.29	1.63	3.26	0.25	0.35	0.70	-0.05	1.30	2.60	1.00	1.34	2.68	1.63	1.33	2.67	0.18	1.32	2.64	-0.84	1.77	3.54	0.04	0.48	0.95
No of labs	7			6			8			8			8			8			8			7			8		
NIMTAV	1.87	10.00		0.47	10.00		2.29	10.00		1.35	10.00		5.16	10.00		7.48	10.00		10.16	10.00		13.02	10.00		1.19	10.00	
NMIAAV	0.00	0.51		0.00	2.54		0.00	0.51		0.00	2.03		0.00	2.03		0.00	2.03		0.00	2.03		0.00	2.03		0.00	0.51	
Birge ratio			0.57			1.05			0.85			**5.67**			**4.37**			**3.77**			**2.85**			**3.59**			0.42
Birge criteria			1.5			1.5			1.4			1.4			1.4			1.4			1.4			1.5			1.4
Birge ratio	without	SIRIM& KIM-L	0.69			0.70			0.41			0.28			0.55			0.57			0.65			**2.74**			0.37
Birge criteria	without	SIRIM& KIM-L	1.5			1.6			1.5			1.5			1.5			1.5			1.5			1.6			1.5

Appendix A: En Ratio Calculation
Liquid In Glass Thermometers Comparison

LIGT- ASTM 62 C (-38°C to 2°C) , Total Immersion

En, k=2	0°C	-37°C	-30°C	-25°C	-20°C	-10°C	0°C
SIRIM	-0.32	0.36	0.06	0.04	-0.03	0.09	-0.30
ITDI	-0.14	0.37	0.59	0.87	0.42	0.97	-0.10
KIM-LIPI	-	-	-	-	-	-	-
SPRING	-0.22	-0.74	-0.49	-0.32	-0.32	0.08	-0.27
SCL	0.10	-0.49	-0.14	-0.21	-0.03	-0.13	0.05
VMI	-0.08	-	-	0.02	0.04	-0.51	-0.13
NIMT $_{Average}$	-0.02	-0.28	0.23	0.07	0.13	0.17	-0.05
NMIA $_{Average}$	0.11	-0.74	0.65	-0.06	-0.55	0.16	0.16

LIGT- ASTM 120 C (38.6°C to 41.4°C), Total Immersion

En, k=2	0°C	39°C	40°C	41°C	0°C
SIRIM	0.11	0.07	0.04	-0.01	0.12
ITDI	-0.20	-0.68	-0.79	-0.68	-0.15
KIM-LIPI	0.12	-0.03	-0.44	-0.04	0.17
SPRING	0.06	-0.12	0.09	-0.07	0.09
SCL	-0.26	0.14	0.07	0.18	-0.22
VMI	-0.70	0.07	0.25	0.20	-0.66
NBSM	0.20	0.48	0.47	0.49	0.20
NIMT $_{Average}$	0.15	0.32	0.16	0.04	0.18
NMIA $_{Average}$	0.49	0.30	0.47	0.61	0.41

LIGT- ASTM 40 C (72 °C to 126 °C), Partial Immersion

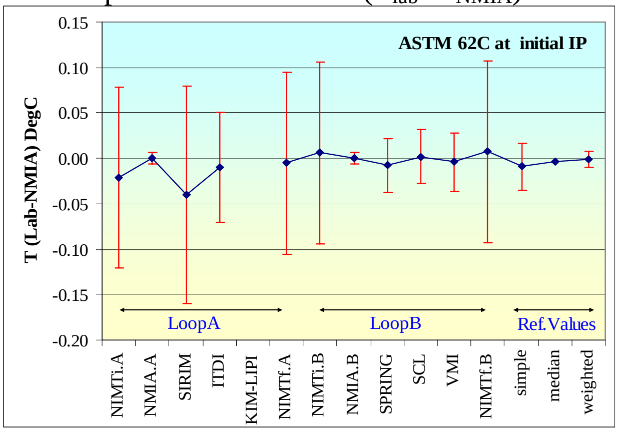
En, k=2	75°C	90°C	100°C	105°C	110°C	125°C	75°C
SIRIM	0.14	0.28	-0.02	-0.15	-0.04	-0.14	0.13
ITDI	**-1.20**	**-1.27**	**-2.22**	**1.57**	**-2.45**	**-4.02**	**-2.22**
KIM-LIPI	-0.27	0.28	-0.27	-0.10	-0.09	0.36	-0.16
SPRING	-0.24	-0.14	-0.09	-0.44	-0.45	-0.52	-0.24
SCL	-0.11	-0.31	-0.17	-0.36	-0.42	-0.65	0.03
VMI	-0.30	**-1.30**	-0.48	-0.88	**-1.53**	-0.83	-0.49
NIMT $_{Average}$	-0.07	-0.04	-0.09	-0.03	0.03	0.10	-0.12
NMIA $_{Average}$	0.35	0.59	0.36	0.78	**1.05**	0.85	0.40

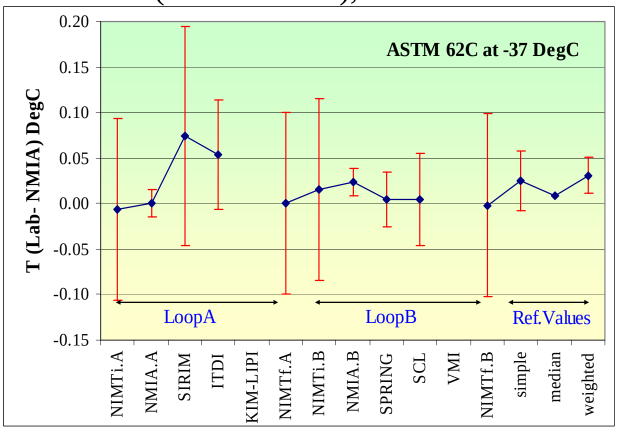
Appendix A: En Ratio Calculation
Industrial Platinum Resistance Thermometers Comparison

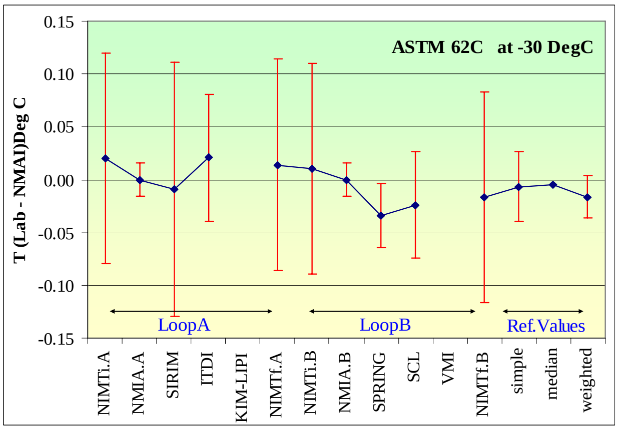
En, k=2	0°C	-40°C	0°C	50°C	100°C	150°C	200°C	250°C	0°C
SIRIM	0.15	-0.94	-0.97	**-1.12**	**-1.45**	**-2.89**	**-2.57**	**-2.23**	-0.20
ITDI	-	-	-	-	-	-	-	-	-
KIM-LIPI	-	-	0.34	**7.39**	**5.55**	**3.90**	**2.60**	**2.54**	0.31
SPRING	0.43	0.04	-0.02	0.04	0.09	0.25	0.16	0.50	0.03
SCL	0.04	-0.05	0.23	0.12	0.19	0.14	0.20	0.03	0.00
VMI	-0.25	-	-0.24	0.13	-0.44	-0.08	-0.35	**-2.54**	-0.07
MSL	0.45	0.45	0.00	-0.22	0.15	0.22	-0.25	-	0.39
$NIMT_{Average}$	0.09	-0.09	0.10	0.07	0.21	0.29	0.49	0.68	0.06
$NMIA_{Average}$	-0.09	-0.38	-0.20	0.01	-0.21	-0.34	-0.04	0.16	-0.03

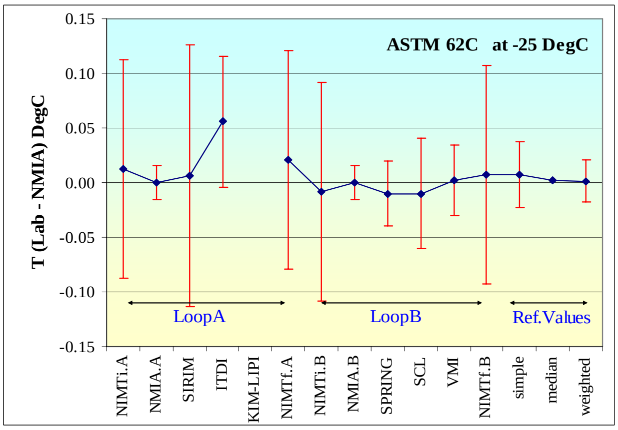
APPENDIX B
Measurement Results
Liquid In Glass Thermometers

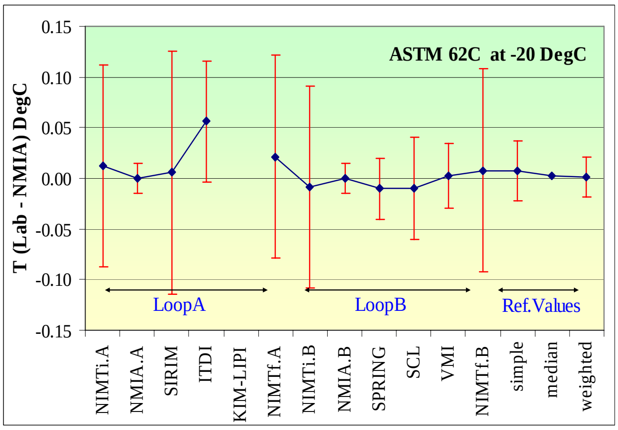
Temperature Difference ($T_{lab}–T_{NMIA}$) for LIGT- ASTM 62C (–38°C to 2°C), total immersion

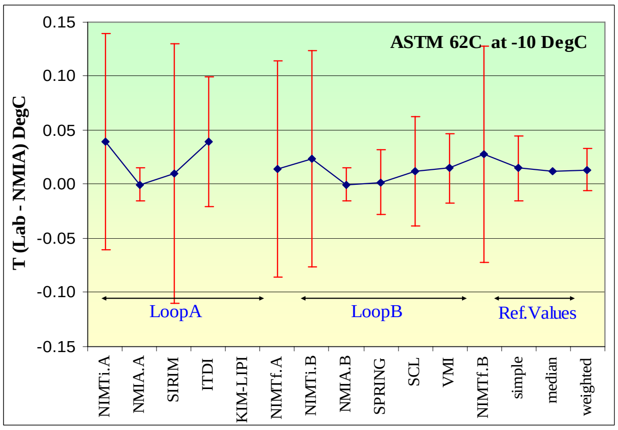


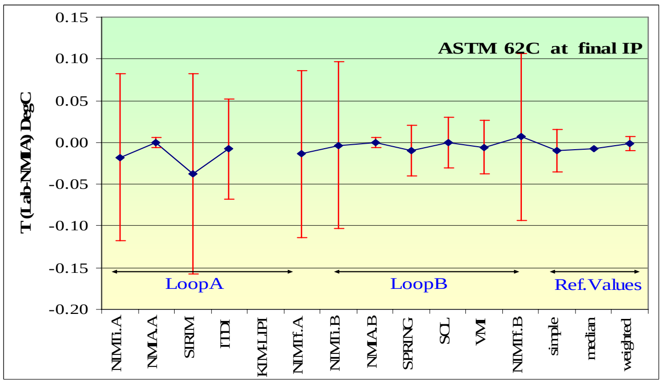








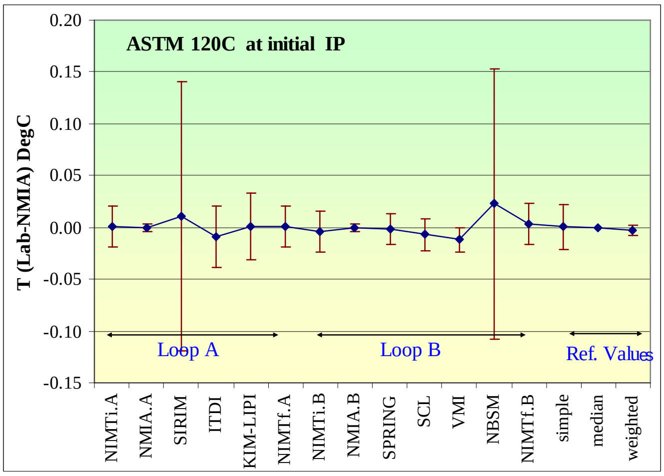


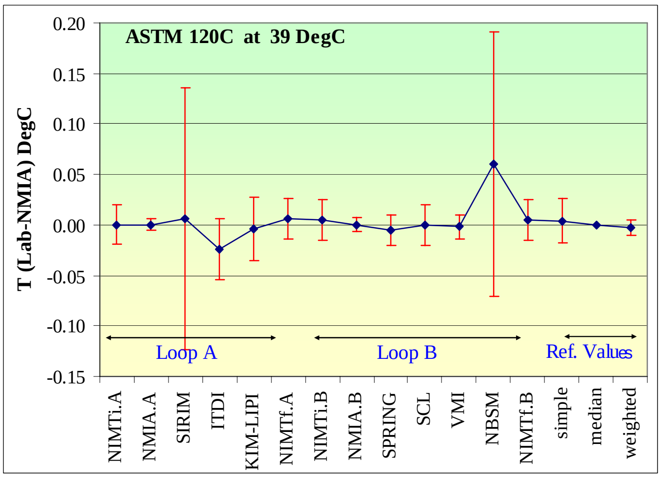


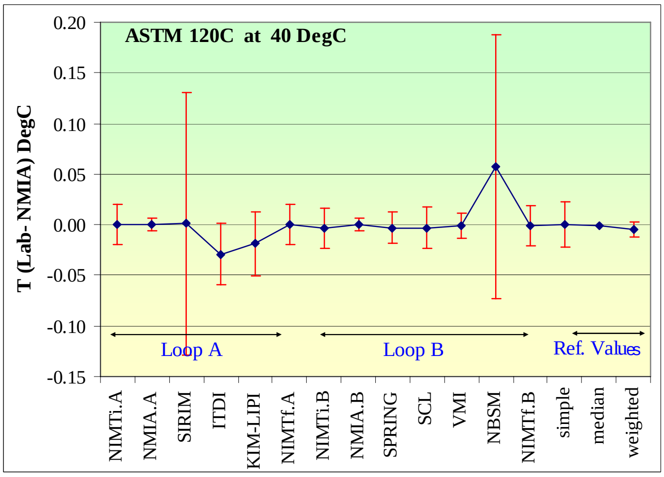
Graph B1 (LIGT ASTM 62C)

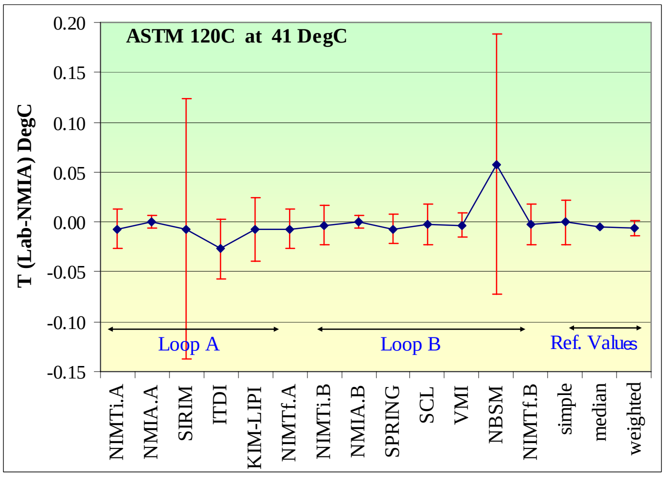
APPENDIX B
Measurement Results
Liquid In Glass Thermometers

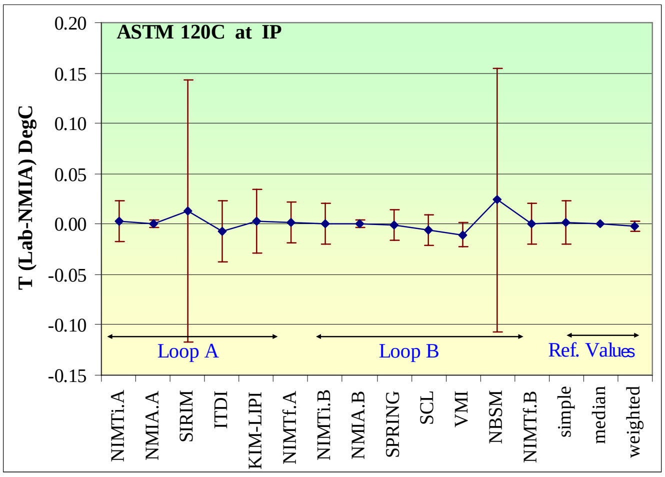
Temperature Difference (T_{lab}-T_{NMIA}) for LIGT- ASTM 120C (8.6°C to 41.4°C), total immersion







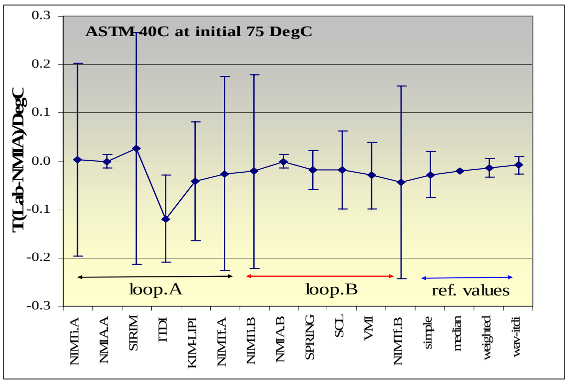


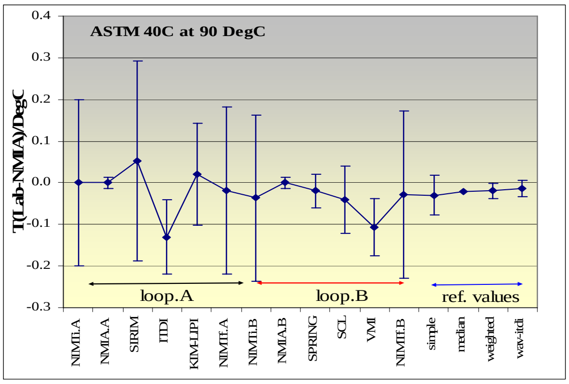


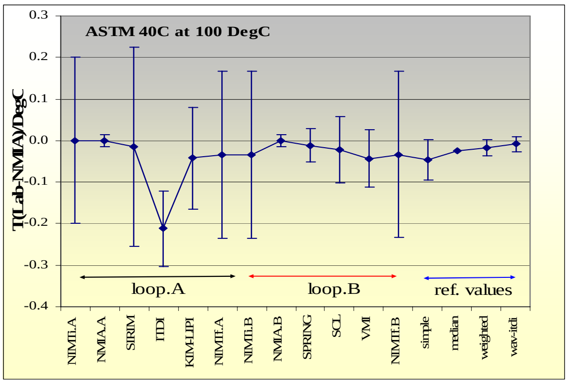
Graph B2 (LIGT ASTM 120C)

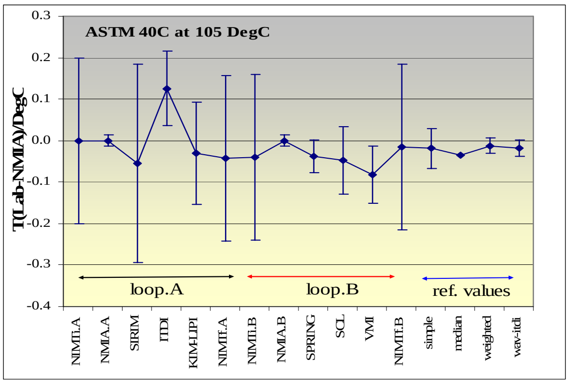
APPENDIX B
Measurement Results
Liquid In Glass Thermometers

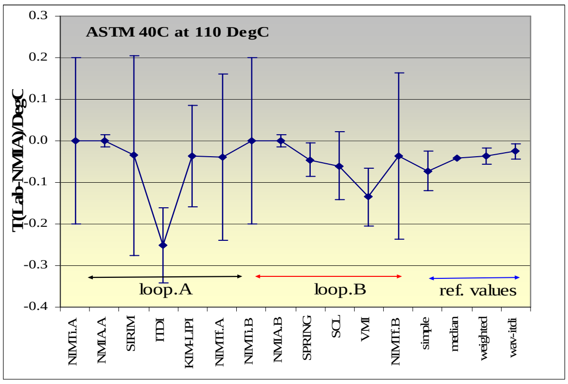
Temperature Difference (T_{lab}-T_{NMIA}) for LIGT- ASTM 40 C (75°C to 125°C), partial immersion

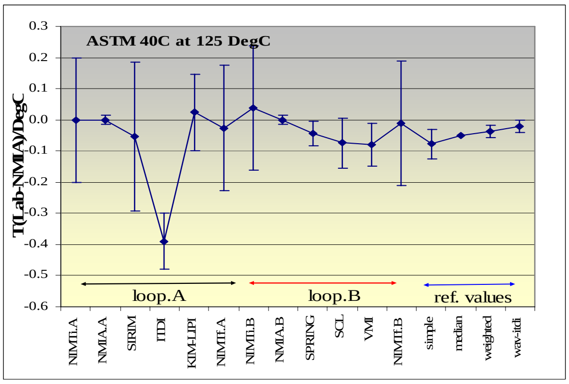


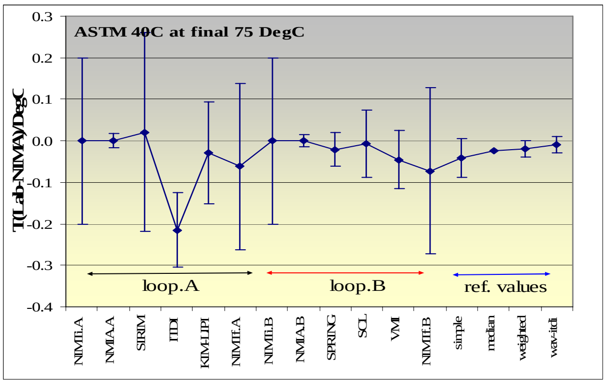






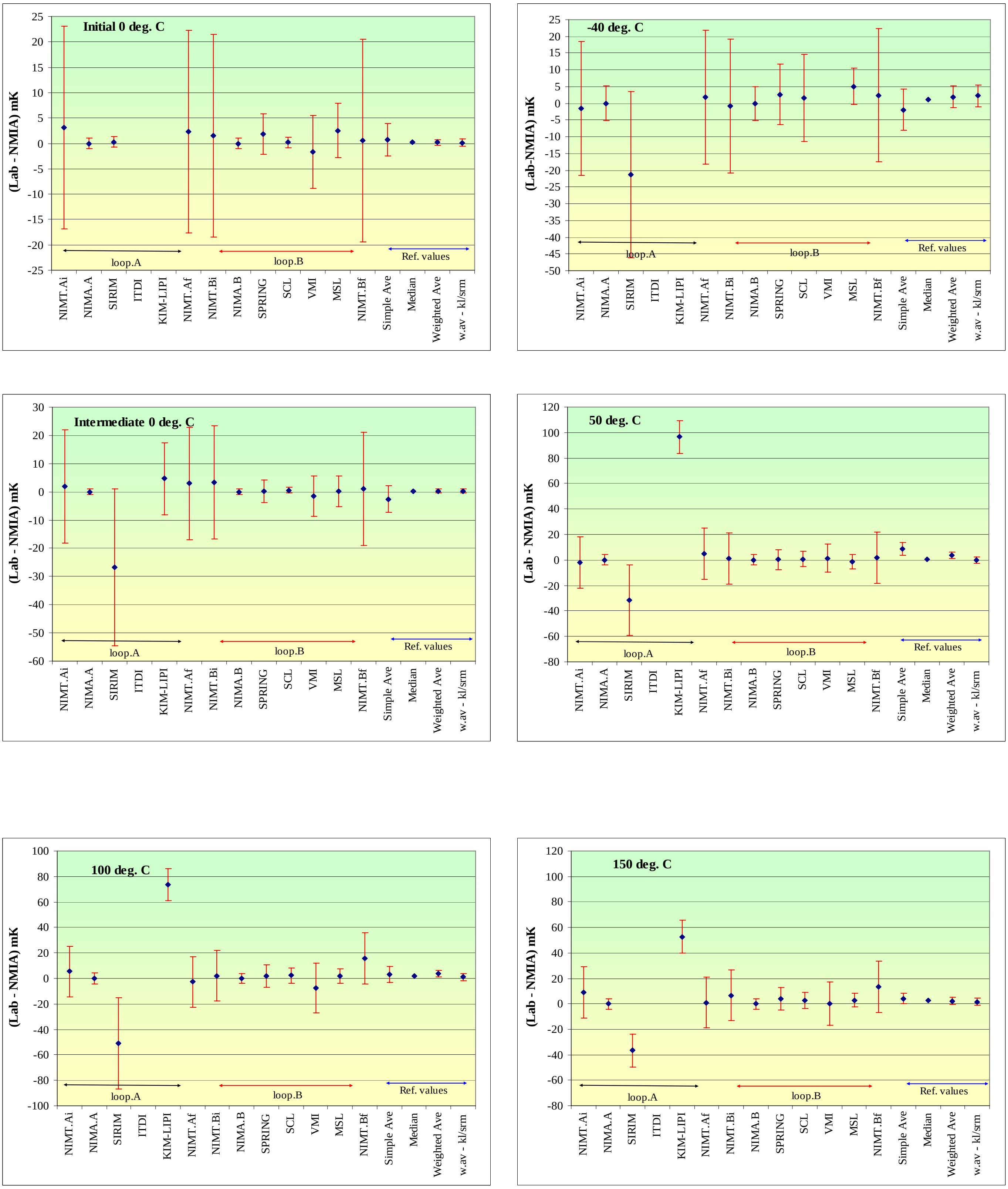






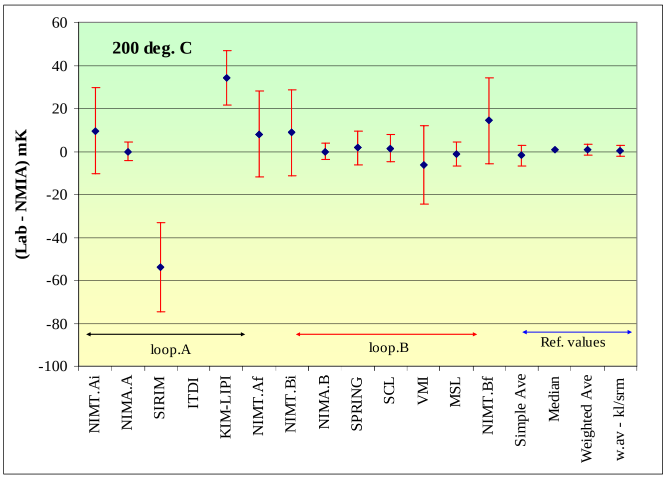
Graph B3 (LIGT ASTM 40C)

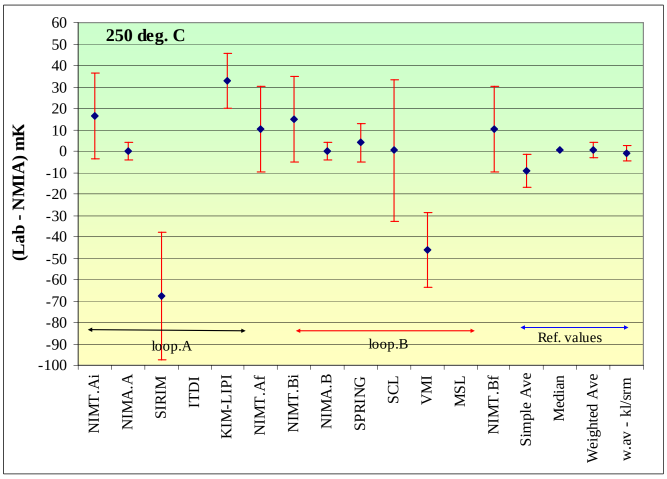
APPENDIX B
Measurement Results
Industrial Platinum Resistance Thermometers

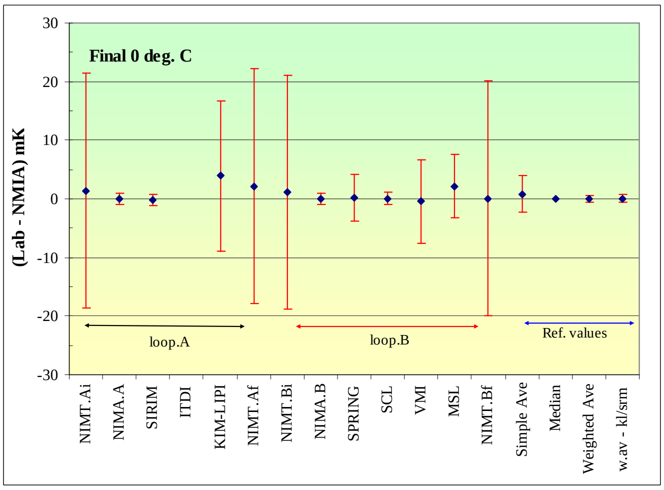


Graph B4 (IPRT Model 5626-12-S)

APPENDIX B
Measurement Results
Industrial Platinum Resistance Thermometers







Graph B4 (IPRT Model 5626-12-S)

APPENDIX C
The Protocol
for
APMP Industrial Platinum Resistance Thermometer Comparison

Part A: GENERAL INFORMATION

Introduction

The NIMT Temperature Inter-Laboratory Comparison Program is designed and organized by the Department of Thermometry Metrology, National Institute of Metrology (Thailand). The objectives of the program are, to provide the participating laboratories, the means for comparing of their measurement results and the opportunities for capability improvements.

An Industrial Platinum Resistance Thermometer, IPRT which approximately nominal resistance value 100 Ω at ice point is chosen as the artifact for the comparison. The procedures and instructions, which are given below, should be followed by participants in comparing range of -40 °C to 250 °C. The measurement results obtained from the participating laboratories will be evaluated by NIMT with assistance from NML and reported to the participating laboratories. Participating laboratories whose results significantly deviate from the average result wishing to improve their capabilities/techniques should contact NIMT for further collaboration if possible.

List of participants

There are 9 participating laboratories for the IPRT comparison program except NBSM (Nepal) whose capabilities are limited.

The artifact

The artifact circulation in each parallel loop is one of two 100 Ω IPRTs belonging to the NIMT Thermometry Department. Its specification and measuring points are shown below.

Industrial Platinum Resistance Thermometer

Model	:	5626-12-S	
S/N	:	0817	(for Loop A)
S/N	:	0833	(for Loop B)
Manufacturer	:	Hart Scientific	

Description of Artifacts

Nominal Resistance values approximately 100 Ω at 0 °C.
Metal sheath thermometer length is 305 mm with diameter 6.35 mm.
4 wires with spade terminals.
Calibration Range: -40 °C to 250 °C
Calibration point: 0 °C, - 40 °C, 0 °C, 50 °C, 100 °C,150 °C, 200 °C, 250 °C and 0 °C.

The Department of Thermometry Metrology, NIMT is the reference laboratory where the artifact is calibrated before and after circulation.

Apparatus

A.1 All participating laboratory should have stirred liquid baths and/or temperature furnaces whose working space are depth enough. The evidence of their instability and in-homogeneity should be available.

A.2 All participating laboratory should prepare at least one SPRTs to be used as the reference standard thermometer.

Circulation Schedule

To meet the time constraint, the IPRT Comparison has been organized to run in two parallel loops: A and B. Each laboratory should complete the measurement within approximately three weeks

For each loop, the specified schedule lists the serial number of the artifact, the circulation sequence of the artifact and the expected shipping date. All participants should refer to the Artifact Circulation. The IPRT artifact should be shipped in its original case by airfreight from the host laboratory to the next participating laboratory.

Each participant is responsible for Customs clearance, insurance and transportation cost to ship the artifact to the next laboratory.

Loop A: Artifact IPRT Model 5626-12-S , S/N 0817

NIMT	to NML	approximately 1 weeks after approval (Mar 22,2004)
NML	to SIRIM	approximately 4 weeks after approval (Apr 12,2004)
SIRIM	to ITDI	approximately 7 weeks after approval (May03,2004)
ITDI	to KIM-LIPI	approximately 10 weeks after approval (May24,2004)
KIM-LIPI	to NBSM	approximately 13 weeks after approval (June12,2004)
NBSM	to NIMT	approximately 20 weeks after approval (July 03,2004)

Loop B: Artifact IPRT Model 5626-12-S , S/N 0833

NIMT	to NML	approximately 1 weeks after approval (Mar 22,2004)
NML	to SPRING	approximately 4 weeks after approval (Apr 12,2004)
SPRING	to SCL	approximately 7 weeks after approval (May03,2004)
SCL	to VMI	approximately 10 weeks after approval (May24,2004)
VMI	to MSL	approximately 13 weeks after approval (June12,2004)
MSL	to NIMT	approximately 20 weeks after approval (July 03,2004)

If there is a delay during measurements, the laboratory has to inform NIMT immediately so that the schedule can be modified if necessary.

If unable to meet the planned schedule, the participant should inform NIMT before the arrival of the artifacts to decide on a more convenient time so that the artifact can be send to the next laboratory without further delay.

Instruction for Participating Laboratories

After receiving the artifacts, participating laboratories should complete the preliminary works outlined below before calibration started.

Artifact

Content of Package

1 Industrial Platinum Resistance Thermometer S/N: 0817 or S/N 0833

1 set of documentation consisting of

- the protocol which includes instruction to laboratories, a list of contact persons and the circulation schedule;
- result sheets;
- receipt form and dispatch form.

The Industrial Platinum Resistance Thermometer is housed in a box with foam protection. The net weight is approximately 1 kg.

Upon receipt

1. Upon receipt, the host laboratory must inspect the artifact for visual damage then complete the Artifact Received Form (Appendix 1) and forward to NIMT (by e-mail or FAX).
   If there is any damage, NIMT will advise of what to proceed.
   Make copies of result sheets for recording test data. Do not use the originals **Please handle the artifact with care.**
2. Perform the initial check for connection wire configuration, insulation leakage etc.
3. If no defect is found on the artifact, the participant should measure the resistance value of the IPRT at the ice point (or water triple point) using 1 mA and 1.414 mA sensing current as per **Preliminary measurement** step 1.

Part B: CALIBRATION PROCEDURE

Preliminary measurement

1 Measure and report the initial $R(IP)_1$ value to NIMT for further instruction. All ice point values reported to NIMT should be corrected for the self- heating effect and expressed in terms of the standards ohm.

2. NIMT after calculating the change in $R(IP)_1$ value after transit will advise the laboratory of the next step to be taken.
3. Anneal the artifact at 270 ^{o}C for 2 hours, re-measure and report the corrected ice point value $R(IP)_2$ to NIMT.
4. If $R(IP)_1 \geq R(IP)_2$ and:
   $R(IP)_1 - R(IP)2 \leq 2$ mΩ, go to calibration procedure.
   $R(IP)_1 - R(IP)2 \geq 2$ mΩ, contact NIMT for further instruction on the annealing procedure.
   If $R(IP)_2 \geq R(IP)_1$, no further annealing is required; go to calibration procedure**.**
5. Repeat step 3 until the difference in subsequence R(IP)s is less than 2 mΩ.

Calibration Procedure

1. Calibrate the artifact according to the host's normal calibration practice.
   The artifact should be calibrated from the lowest to the highest calibration point of the range and finish with the lowest
   Required calibrations points are 0 ^{o}C,- 40 ^{o}C, 0 ^{o}C, 50 ^{o}C, 100 ^{o}C,150 ^{o}C, 200 ^{o}C, 250 ^{o}C, 0 ^{o}C.

Ensure that the artifact is sufficiently immersed to minimize conduction error. The immersion depth and measurement results shall be recorded in the result sheets accompanying the artifact.

2. Record the ice point (0^oC) or WTP readings before and after the measurement cycle and the difference in the ice-point readings is the hysteresis (thermal cycling stability) mentioned in the uncertainty budget.
   The corrected value of the last ice point or WTP resistance measurement must be reported to NIMT.
3. The actual environmental conditions during measurement should be reported.

Reporting of the result

The following documents shall be submitted by the participating laboratory to the organizer within 2 weeks after completing the measurements.

Measurement results (see Appendix 2).
Uncertainty budget (see Appendix 3).

After completion of measurements

After the measurements are completed, pack the artifacts in the same manner as it was received using the original package, ensuring that the Carnet is together with but outside the package. Advise the next laboratory in the circulation schedule of the impeding arrival of the artifact. Forward the artifacts and the Carnet by airfreight to the next participant.

Complete and send the Artifact Dispatch Form (Appendix 1) to NIMT.

Evaluation of result

NIMT and NML will evaluate the result of the comparison within 3 months after the completion of the circulation and send the first draft reports to the participant for comment. The result will be reported at next APMP TCT meeting.

ARTIFACT RECEIVED

To: Thermometry Department Fax No. : 662-248-4485

Comparison of NIMT-IPRT S/No. ______________________

The Industrial Platinum Resistance Thermometer was received at ....

....

On:............./................../.................

The condition when it was received was

( ) in good physical and working order

( ) damaged (please explain)

____

____

____

Participating Laboratory: ______________________________________

____

Contact Person: ______________________________________

Tel: ______________________________________

Fax: ______________________________________

____

In order to monitor the comparison, we kindly ask each participating laboratory, upon arrival of the artifact, to fill in this confirmation form and return it to:

Ms. Ajchara Charoensook
Thermometry Department
National Institute of Metrology (Thailand)
75/7 Rama 6 Thungphayathai Rajthewee
Bangkok 10400
Tel : 662 – 2482181 ext. 210 and 241
Fax : 662 – 2484485
E-mail: ajchara@nimt.or.th

ARTIFACT DISPATCHED

To: Thermometry Department Fax No. : 662-248-4485

Comparison of NIMT-IPRT S/No. ______________________

The Industrial Platinum Resistance Thermometer was dispatched from ....
....
....

On:............./................../..................

The condition when it be dispatched was

( ) in good physical and working order

( ) damaged (please explain)

____
____
____

Participating Laboratory: ____
____

Contact Person: ____
____

Tel: ____

Fax: ____
____

In order to monitor the comparison, we kindly ask each participating laboratory, upon dispatched of the artifact, to fill in this confirmation form and return it to:

Ms. Ajchara Charoensook
Thermometry Department
National Institute of Metrology (Thailand)
75/7 Rama 6 Thungphayathai Rajthewee
Bangkok 10400
Tel : 662 – 2482181 ext. 210 and 241
Fax : 662 – 2484485
E-mail: ajchara@nimt.or.th

Result Sheets

Industrial Platinum Resistance Thermometer S/N: 0817 or 0833
Refer also to the attached certificate No. : ________

Name of participating laboratory : ____

Date of receipt : ____

Condition of the artifact when received : __________________________________

____

____

Remark : ____

____

Pre –condition preparation

Heat to the maximum test temperature
The Industrial Platinum Resistance Thermometer was heated to the maximum test temperature for two hours before calibration.
Environment Conditions during the measurement:
The ambient temperature: (_____ ± ___) °C
And relative humidity: (_____ ± ___) %RH

Other pre- condition preparation work conducted :
____

____

Immersion Depth : ______________________mm

Initial Check Resistance Value at Ice point or WTP : _____________________Ω

Final Check Resistance Value at Ice point or WTP : _____________________Ω

Result Sheets

Calibration results :

Equipment used :

Item	Description	Model	S/N	Traceability
1				
2				
3				
4				
5				
…				
…				
…				
…				
…				

Measurement Results:

Calibration point	**Standard** Reading	**Tested Thermometer** Reading	**Uncertainty** of Measurement	**Immersion Depth**
(^{o}C)	(^{o}C)	(Ω)	(^{o}C)	(mm)
0				
-40				
0				
50				
100				
150				
200				
250				
0				

Calibrated by : _______________ Checked by : ________________

Date of calibration : _______________

Proposed Uncertainty of Measurement

The uncertainties of measurement in the following table have been calculated by comparison against a Standard Platinum Resistance Thermometer (SPRT) as a reference standard.

Quantity	Type	Standard Uncertainty $u(x_I)$	Probability Distribution	Effective Degree of Freedom (ν_i)	Sensitivity coefficient c_i	Uncertainty Contribution $u_i(y)$
Contribution of UUC (IPRT)						
IPRT Reading (ohm)	A					
Drift of IPRT at iced point or @ 0°C (ohm)	B					
Self Heating of IPRT (ohm)	B					
Calibration of Indicator (ohm or °C)	B					
Drift of indicator (ohm or °C)	B					
Reference Standard						
Temperature Reading of Working Standard [SPRT/PRT] (°C)	A					
Calibration of Working Standard[SPRT/PRT](°C)	B					
Drift of Working Standard [SPRT/PRT] (°C)	B					
Calibration of Indicator (ohm or °C)	B					
Drift of indicator (ohm or °C)	B					
Temperature Source						
Axial Uniformity of liquid bath (°C)	B					
Radial Uniformity of liquid bath (°C)	B					
Instability of liquid bath (°C)	B					
Function						
Interpolation Function (°C)	B					
Others						
Combinded standard uncertainty						
Coverage factor k						
Expanded Uncertainty						

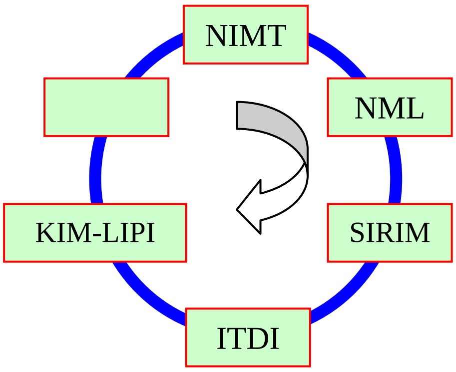
IPRT/LIGT Circulation Schedule

Loop A

1. Industrial Platinum Resistance Thermometer (IPRT)

Model 5626-12-S S/N 0817

NIMT(Thailand)	to NML(Australia)	Mar 22,2004
NML(Australia)	to SIRIM(Malaysia)	Apr 12,2004
SIRIM(Malaysia)	to ITDI(Philippines)	May 03,2004
ITDI(Philippines)	to KIM-LIPI(Indonesia)	May 24,2004
KIM-LIPI(Indonesia)	to NIMT(Thailand)	June 12,2004

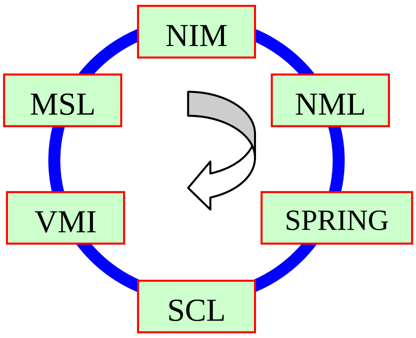


Loop B

1. Industrial Platinum Resistance Thermometer (IPRT)

Model 5626-12-S S/N 0833

NIMT(Thailand)	to NML(Australia)	Mar 22,2004
NML(Australia)	to SPRING (Singapore)	Apr 12,2004
SPRING (Singapore)	to SCL (Hongkong)	May 03,2004
SCL (Hongkong)	to VMI (Vietnam)	May 24,2004
VMI (Vietnam)	to MSL (New Zealand)	June 12,2004
MSL (New Zealand)	to NIMT (Thailand)	July 03,2004



APPENDIX C
The Protocol
for
APMP Liquid-in-Glass Thermometer Comparison

Introduction

The NIMT–Temperature Interlaboratory comparison program is organized by the Thermometry Department, The National Institute of Metrology (Thailand). The objectives of the program are to provide the participating laboratories the means for comparing of their measurement results and opportunity for improvement.

Liquid-in-Glass Thermometers are chosen as artifacts for circulation. All calibration laboratories meeting the capability of the said artifacts are encouraged to take part in this program.

The measurement results obtained from the participating laboratories will be evaluated and reported to the participating laboratories. Any lab with significant discrepancy wishing to investigate and to improve their capability may seek assistance from NIMT.

Organizer

The organizer of this program is Ms. Ajchara Charoensook, Head of Thermometry Metrology Department. All correspondence and enquirer should be addressed to:

Thermometry Department
National Institute of Metrology (Thailand)
75/7 Rama 6 Thungphayathai Rajthewee
Bangkok 10400
Tel : 662 – 2482181 ext. 210 and 241
Fax : 662 – 2484485
E-mail : **ajchara@nimt.or.th or** nimt@nimt.or.th

Time Schedule

Each laboratory has **three weeks** to calibrate the artifacts, including transportation. With its confirmation to participate, each laboratory has confirmed that it is capable of performing the measurements in the allocated time. If there is a delay during measurements, the laboratory shall inform NIMT immediately
If unable to meet the planned schedule, participant should inform NIMT before the arrival of the artifacts to decide on a more convenient time so that the artifact can be sent to the next laboratory without further delay.

Loop A: Artifact LIGT ASTM 62C S/N: 9714076 ASTM 120C S/N: 9981749
ASTM 40C S/N: 59-405

NIMT	to NML	approximately 1 weeks after approval (Mar 22,2004)
NML	to SIRIM	approximately 4 weeks after approval (Apr 12,2004)
SIRIM	to ITDI	approximately 7 weeks after approval (May03,2004)
ITDI	to KIM-LIPI	approximately 10 weeks after approval (May24,2004)
KIM-LIPI	to NBSM	approximately 13 weeks after approval (June12,2004)
NBSM	to NIMT	approximately 20 weeks after approval (July 03,2004)

Loop B: Artifact LIGT ASTM 62C S/N: 9714085 ASTM 120C S/N: 9981771
ASTM 40C S/N: 59-999

NIMT	to NML	approximately 1 weeks after approval (Mar 22,2004)
NML	to SPRING	approximately 4 weeks after approval (Apr 12,2004)
SPRING	to SCL	approximately 7 weeks after approval (May03,2004)
SCL	to VMI	approximately 10 weeks after approval (May24,2004)
VMI	to NIMT	approximately 13 weeks after approval (June12,2004)

The artifact

The artifacts are Liquid-in-Glass Thermometers belonging to NIMT Thermometry Department. Their specifications are shown below.

- Liquid-in-Glass Thermometer
- ASTM 62C S/N: 9714076 (for Loop A)
  ASTM 62C S/N: 9714085 (for Loop B)
  Range: -38 °C to 2 °C
  Subdivision: 0.1 °C
  Immersion: total

- Liquid-in-Glass Thermometer
- ASTM 120C S/N: 9981749 (for Loop A)
  ASTM 120C S/N: 9981771 (for Loop B)
  Range: IP, 38.6 °C to 41.4 °C
  Subdivision: 0.05°C
  Immersion: total

- Liquid-in-Glass Thermometer
- ASTM 40C S/N: 59-405 (for Loop A)
  ASTM 40C S/N: 59-999 (for Loop B)
  Range: 72 °C to 126 °C
  Subdivision: 0.2°C
  Immersion: partial 100 mm

General information on transfer standard

Packaging

The package contains the following items:

- three plastic boxes
- 1 copy of measurement instruction and result sheets
- ATA carnet, apart from the package

The Liquid-in-Glass Thermometers are housed in a plastic box ready to be shipped. Inside this box, the liquid-in-glass thermometers are enclosed in a plastic box with their serial numbers displayed so that they can be easily inspected by participants. The net weight is approximately 1 kg/box.

Shipment and insurance

Please handle the Liquid-in-Glass Thermometers with care.

The transfer LIGT can be shipped by air freight in their case to next participating laboratory. Shipping mercury thermometers may required special permit. For details, please contact the carrier/airline in advance.

The package is accompanied by an ATA carnet. The carnet shall always be shipped with the package, never inside the box, but apart. Please be certain, that when receiving the package, you also receive the carnet. If not hand carried, the box can be shipped with any appropriate carrier, preferably using a fast mail service such as DHL. After the measurement, the participating laboratory must inform the next laboratory in advance of the arrival of the artifact.

All costs for customs clearance of the artifact once it has landed in your country/territory, insurance and for the transport of the artifact from your laboratory to the next participating country/laboratory have to be borne by your laboratory.

Unpacking, Handling, Packing

The participating laboratory must forward the attached Artifact Received Form to NIMT to report the status of the artifacts. After the measurement, the artifacts have to be cleaned. Ensure that the content of the package is completed before shipment. Always used the original package.

Make copies of result sheets for recording test data. Do not use the originals.

Calibration Procedure

1 General visual inspection

Immediately after receipt of the thermometer, make a simple visual check and record the status of the artifacts. Next, the Artifact Received Form, attached in Appendix 1 has to be filled in and sent to NIMT without delay. If any damage is found upon receipt, **contact NIMT immediately.**

Besides checking for any broken glass or loose mercury, examine the column for any break. Rejoin any breaks found or consult with NIMT if you are likely to risk the integrity of the thermometer in the process of rejoining the column.

2 Pre-Condition and adjustment

Condition the artifacts by keeping them at room temperature for three days before measuring the ice point/reference point. The thermometers should be stored horizontally on trays in cabinets, with care being taken to avoid any weight or pressure on the bulbs.

The participating laboratories are to follow their own routine calibration procedure.

3 Ice point/ reference temperature measurement

Record the ice point (0^{o}C for ASTM 62C and ASTM 120C) or reference temperature(75^{o}C for ASTM 40C) readings before and after calibrations; the difference in the readings is the short term stability in the uncertainty budget

Measurement of the ice-point/reference temperature(75 ^{o}C) readings should be taken after keeping the artifacts for three days at room temperature.

4 Comparison

During the calibration process, total-immersion thermometers are required to be immersed so that just a few divisions around the test point are visible and the partial-immersion thermometer is immersed to a fixed distance from the bottom of the bulb to immersion line. The average reading of the emergent stem of the partial immersion thermometer should be recorded. The average readings of the Liquid-in-Glass Thermometers should be recorded in the comparison result sheets accompanying the Liquid-in-Glass Thermometers. The Liquid-in-Glass Thermometers should be calibrated from the lowest calibration point to the highest calibration point of the range.

The participating laboratories are to follow their own routine calibration procedure.

5 Measurement Point

The suggestion for measurement points are:

- Liquid-in-Glass Thermometer ASTM 62C S/N: 9714076 or 9714085
  Calibration points: 0 ^{o}C ,-37 ^{o}C, -30 ^{o}C, -25 ^{o}C, -20 ^{o}C, -10 ^{o}C, 0 ^{o}C
  Maximum error: 0.1 ^{o}C

- Liquid-in-Glass Thermometer ASTM 120C S/N: 9981749 or 9981771
  Calibration points: 0, 39 ^{o}C, 40 ^{o}C, 41^{o}C and 0 ^{o}C
  Maximum error: 0.1 ^{o}C

- Liquid-in-Glass Thermometer ASTM 40C S/N: 59-405 or 59-999
  Calibration points: 75 ^{o}C , 90 ^{o}C ,100 ^{o}C, 105 ^{o}C ,110 ^{o}C, 125 ^{o}C and 75 ^{o}C
  Maximum error: 0.2^{o}C

Environmental conditions

The temperature of the laboratory should be within (23 ± 3)^{o}C and relative humidity should be within (50±20)% during calibration.

The actual environmental conditions during measurement should be reported.

Reference Laboratory

The Temperature Laboratory, Thermometry Department is the reference laboratory. The laboratory will calibrate the Liquid-in-Glass Thermometer before and after circulation of each loop.

After completion of measurements

After the measurements are completed, clean the artifacts and pack them in the same manner as they were received using the original package, ensuring that the Carnet is together with but outside the package. Advise the next laboratory in the circulation schedule of the impending arrival of the artifacts. See Appendix 4 for artifact circulation. Forward the artifacts and the Carnet to the next participant.
Complete and send the Artifact Dispatched Form (Appendix 1) to NIMT.

Reporting of the results

The staff member of each participating laboratory should draft a report at the end of measurement. The reports shall be sent within **three** weeks after completing the measurements via fax or e-mail. The report is preferably in the format of MSWord 97 if it is sent via e-mail.
In any case, the signed report must also be sent in paper form by mail. In case of any differences, the paper forms are considered to be the valid version. The report must include the following information:

(1) completed comparison result sheets (Appendix 2);

(2) a copy of the laboratory's uncertainty budget (Appendix 3).

Evaluation of the results

NIMT and NML will evaluate the result of the comparison within 3 months after completion of the circulation and send the first draft reports to the participant for comment. The result will be reported to the next APMP TCT meeting.

APPENDIX 1

ARTIFACT RECEIVED

To: Thermometry Department   Fax No. : 0-2248-4485

Intercomparison of NIMT-Liquid-in-Glass Thermometer S/No. ______________________

The Liquid-in-Glass Thermometer was received at ....

....

On:................/......................./.......................

The condition when it was received was

( ) in good physical and working order

( ) damaged (please explain)

____

____

____

Participating Laboratory: ____

____

Contact Person: ____

Tel: ____

Fax: ____

____

In order to monitor the comparison, we kindly ask each participating laboratory, upon arrival of the artifact, to fill in this confirmation form and return it to:

Ms. Ajchara Charoensook
Thermometry Department
National Institute of Metrology (Thailand)
75/7 Rama 6 Thungphayathai Rajthewee
Bangkok 10400
Tel : 662 – 2482181 ext. 210 and 241
Fax : 662 – 2484485
E-mail: ajchara@nimt.or.th

Appendix 1

ARTIFACT DISPATCHED

To: Thermometry Department   Fax No. : 662-248-4485

Comparison of NIMT-LIGT S/No. ______________________

The Liquid-in-Glass Thermometer was dispatched from --

On:----------------/----------------------/----------------------

The condition when it be dispatched was

(   ) in good physical and working order

(   ) damaged (please explain)

____

____

____

Participating Laboratory: ____

____

Contact Person: ____

____

Tel: ____

Fax: ____

____

In order to monitor the comparison, we kindly ask each participating laboratory, upon dispatched of the artifact, to fill in this confirmation form and return it to:

Ms. Ajchara Charoensook
Thermometry Department
National Institute of Metrology (Thailand)
75/7 Rama 6 Thungphayathai Rajthewee
Bangkok 10400
Tel : 662 – 2482181 ext. 210 and 241
Fax : 662 – 2484485
E-mail: ajchara@nimt.or.th

APPENDIX 2

Calibration Result Sheets

Liquid-in-Glass Thermometer ASTM 62 C S/N: 9714076 or 9714085

Refer also the attached certificate no. : ____

Name of participating laboratory : ____

Date of receipt : ____

Condition of the artifact when received : ____

____

Remark : ____

____

Ambient condition

The ambient temperature was _____ ± ___ ^{o}C
the relative humidity was _____± _____%
and the absolute pressure ____± ____ mbar

Ice point measurement
First ice-point measurement ________ ^{o}C
And last ice-point measurement ________ ^{o}C

Pre–condition preparation
pre-condition preparation work conducted :

____

____

____

____

____

____

Calibration results :

Equipment used :

Item	Description	Model	S/N

Measurement Results: :

Calibration point (^{o}C)	Thermometer Reading (^{o}C)	**Correction** (^{o}C)
0		
- 37		
- 30		
-25		
- 20		
- 10		
0		

The estimated uncertainty of measurement is ____________ ^{o}C.

Calibrated by : ______________Checked by : _______________

Date of calibration : _______________

Calibration Result Sheets

Liquid-in-Glass Thermometer ASTM 120C S/N: 9981749 or 9981771

Refer also the attached certificate no. : ______________________________

Name of participating laboratory : ______________________________

Date of receipt : ______________________________

Condition of the artifact when received : ______________________________

____

Remark : ______________________________

____

Ambient condition

The ambient temperature was ______ ± ____ ^{o}C
the relative humidity was ______ ± _____%
and the absolute pressure _____ ± _____ mbar

Ice point measurement

First ice-point measurement _________ ^{o}C
And last ice-point measurement _________ ^{o}C

Pre–condition preparation

pre-condition preparation work conducted :

____

____

____

____

____

____

Calibration results :

Equipment used :

Item	Description	Model	S/N

Measurement Results:

Calibration point (^{o}C)	Thermometer Reading (^{o}C)	**Correction** (^{o}C)
0		
39		
40		
41		
0		

The estimated uncertainty of measurement is ____________ ^{o}C.

Calibrated by : ______________Checked by : _______________

Date of calibration : _______________

Calibration Result Sheets
Liquid-in-Glass Thermometer ASTM 40C S/N: 59-405 or 59-999

Refer also the attached certificate no. : ______________________________

Name of participating laboratory : ______________________________

Date of receipt : ______________________________

Condition of the artifact when received : ______________________________

____

Remark : ______________________________

____

Ambient condition

The ambient temperature was _____ ± ___ ^{o}C
the relative humidity was _____ ± ____%
and the absolute pressure ____ ± ____ mbar

Reference point measurement

First reference point(75 ^{o}C) measurement ________ ^{o}C
And reference point(75 ^{o}C) measurement ________ ^{o}C

Pre–condition preparation

pre-condition preparation work conducted :

____

____

____

____

____

____

Calibration results :

Equipment used :

Item	Description	Model	S/N

Measurement Results:

Calibration point (^{o}C)	Thermometer Reading (^{o}C)	**Correction** (^{o}C)	Stem Temperature Reading **(^{o}C)**
75			
90			
100			
105			
110			
125			
75			

The estimated uncertainty of measurement is ____________ ^{o}C.

Calibrated by : ______________Checked by : _______________

Date of calibration : _______________

Appendix 3

Proposed uncertainty budget for Liquid-in-Glass Thermometer Contribution

Quantity	Type	Standard Uncertainty $u(x_I)$	Probability Distribution	Effective Degree of Freedom (ν_i)	Sensitivity coefficient c_i	Uncertainty Contribution $u_i(y)$
Contribution of UUC (LIGT)						
LIGT Reading (°C)	A					
Drift of LIGT(Temporary depression at reference point	B					
Resolution of LIGT (°C)	B					
LIG Scale error (°C)	B					
Reference Standard						
Temperature Reading of Working Standard [SPRT/PRT] (°C)	A					
Calibration of Working Standard[SPRT/PRT](°C)	B					
Drift of Working Standard [SPRT/PRT] (°C)	B					
Calibration of Indicator (ohm or °C)	B					
Drift of indicator (ohm or °C)	B					
Resolution of indicator (ohm or °C)	B					
Temperature Source						
Axial Uniformity of liquid bath (°C)	B					
Radial Uniformity of liquid bath (°C)	B					
Instability of liquid bath (°C)	B					
Other						
Combinded standard uncertainty						
Coverage factor k						
Expanded Uncertainty						

$U = k \times u_c(y)$ at approximately 95% Confidence Level

APPENDIX D
Measurement Results
For
LIGT Comparison Model ASTM 62C

Name of participating laboratory : NIMT, THAILAND (Initial) **S/N 9714076 (Loop A)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction** (°C)	**Uncertainty** (°C)	**k**
0	0.00	-0.021	0.100	2.00
-37	-37.00	-0.070	0.100	2.00
-30	-29.98	-0.021	0.100	2.00
-25	-25.00	-0.064	0.100	2.00
-20	-20.00	-0.031	0.100	2.00
-10	-10.00	-0.021	0.100	2.00
0	0.00	-0.020	0.100	2.00

Name of participating laboratory : NMIA, AUSTRALIA **S/N 9714076 (Loop A)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction** (°C)	**Uncertainty** (°C)	**k**
-37	-36.94	-0.064	0.016	2.09
-30	-29.96	-0.041	0.016	2.09
-25	-24.92	-0.076	0.016	2.09
-20	-19.93	-0.070	0.016	2.09
-10	9.96	-0.037	0.016	2.09
0	0.00	-0.002	0.007	2.23

Name of participating laboratory : SIRIM , MALAYSIA **S/N 9714076 (Loop A)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction** (°C)	**Uncertainty** (°C)	**k**
0	0.00	-0.04	0.12	2.00
-37	-37.05	0.01	0.12	2.00
-30	-30.00	-0.05	0.12	2.00
-25	-25.00	-0.07	0.12	2.00
-20	-20.00	-0.06	0.12	2.00
-10	-10.02	-0.03	0.12	2.00
0	0.00	-0.04	0.12	2.00

Name of participating laboratory : ITDI ,PHILIPPINES **S/N 9714076 (Loop A)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction** (°C)	**Uncertainty** (°C)	**k**
0	-0.0100	-0.010	0.060	2.00
-37	-36.99	-0.01	0.06	2.00
-30	-29.98	-0.02	0.06	2.00
-25	-24.98	-0.020	0.060	2.00
-20	-19.97	-0.030	0.060	2.00
-10	-9.98	0.020	0.060	2.00
0	-0.01	-0.010	0.060	2.00

Name of participating laboratory : KIM-LIPI, INDONESIA **S/N 9714076 (Loop A)**

No Results

Calibration point (°C)	Thermometer Reading (°C)	**Correction (°C)**	**Uncertainty (°C)**	**k**
0				
-37				
-30				
-25				
-20				
-10				
0				

Name of participating laboratory : NIMT, THAILAND (Final) **S/N 9714076 (Loop A)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction (°C)**	**Uncertainty (°C)**	**k**
0	0.00	-0.005	0.100	2.00
-37	-36.99	-0.063	0.100	2.00
-30	-30.00	-0.027	0.100	2.00
-25	-25.00	-0.055	0.100	2.00
-20	-20.00	-0.056	0.100	2.00
-10	-10.00	-0.024	0.100	2.00
0	0.00	-0.016	0.100	2.00

Name of participating laboratory : NIMT, THAILAND (Initial) **S/N 9714085(Loop B)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction (°C)**	**Uncertainty (°C)**	**k**
0	0.00	0.004	0.100	2.00
-37	-37.00	-0.049	0.100	2.00
-30	-30.02	0.014	0.100	2.00
-25	-25.00	-0.039	0.100	2.00
-20	-20.00	-0.008	0.100	2.00
-10	-10.00	-0.016	0.100	2.00
0	0.00	-0.004	0.100	2.00

Name of participating laboratory : NMIA, AUSTRALIA **S/N 9714085(Loop B)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction (°C)**	**Uncertainty (°C)**	**k**
-37	-36.96	-0.040	0.016	2.09
-30	-30.00	0.004	0.016	2.09
-25	-24.97	-0.030	0.016	2.09
-20	-19.97	-0.032	0.016	2.09
-10	-10.00	-0.019	0.016	2.09
0	0.00	0.000	0.007	2.23

Name of participating laboratory : **SPRING, SINGAPORE** **S/N 9714085(Loop B)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction** (°C)	**Uncertainty** (°C)	**k**
0	0.01	-0.010	0.030	2.00
-37	-36.94	-0.060	0.030	2.00
-30	-29.97	-0.030	0.030	2.00
-25	-24.96	-0.040	0.030	2.00
-20	-19.97	-0.030	0.030	2.00
-10	-9.98	-0.02	0.030	2.00
0	0.01	-0.010	0.030	2.00

Name of participating laboratory : **SCL, HONG KONG** **S/N 9714085(Loop B)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction** (°C)	**Uncertainty** (°C)	**k**
0	0.00	0.00	0.03	2.00
-37	-37.02	-0.06	0.05	1.98
-30	-30.02	-0.02	0.05	1.98
-25	-25.03	-0.04	0.05	1.98
-20	-20.02	-0.02	0.05	1.98
-10	-10.03	-0.03	0.05	1.98
0	0.00	0.00	0.03	2.00

Name of participating laboratory : **VMI, VIETNAM** **S/N 9714085(Loop B)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction** (°C)	**Uncertainty** (°C)	**k**
0	0.0075	-0.006	0.032	2.00
-37				
-30				
-25	-24.96	-0.028	0.032	2.00
-20	-19.97	-0.017	0.032	2.00
-10	-9.98	-0.042	0.032	2.00
0	0.01	-0.006	0.032	2.00

Name of participating laboratory : **NIMT, THAILAND (Final)** **S/N 9714085(Loop B)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction** (°C)	**Uncertainty** (°C)	**k**
0	0.00	0.005	0.100	2.00
-37	-37.01	-0.066	0.100	2.00
-30	-30.00	-0.013	0.100	2.00
-25	-25.00	-0.022	0.100	2.00
-20	-20.00	-0.005	0.100	2.00
-10	-10.00	0.000	0.100	2.00
0	0.00	0.007	0.100	2.00

APPENDIX D
Measurement Results For
LIGT Comparison Model ASTM 120C

Name of participating laboratory : **NIMT, THAILAND (Initial)** **S/N 9981749 (Loop A)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction (°C)**	**Uncertainty (°C)**	**k**
0	0.00	-0.020	0.020	2.00
39	39.00	0.004	0.020	2.00
40	40.00	-0.001	0.020	2.00
41	41.01	-0.020	0.020	2.00
0	0.00	-0.020	0.020	2.00

Name of participating laboratory : **NMIA, AUSTRALIA** **S/N 9981749 (Loop A)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction (°C)**	**Uncertainty (°C)**	**k**
0	0.02	-0.021	0.004	2.26
39	39.00	0.004	0.007	2.45
40	40.00	-0.001	0.007	2.31
41	41.01	-0.013	0.007	2.36
0	0.02	-0.023	0.004	2.23

Name of participating laboratory : **NML-SIRIM, MALAYSIA** **S/N 9981749 (Loop A)**

_Calibration point (°C)	Thermometer Reading (°C)	**Correction (°C)**	**Uncertainty (°C)**	**k**
0	0.0125	-0.01	0.130	2.00
39	39.025	0.01	0.130	2.00
40	40.025	0.00	0.130	2.00
41	41.050	-0.02	0.130	2.00
0	0.0125	-0.01	0.130	2.00

Name of participating laboratory : **ITDI, PHILIPPINES** **S/N 9981749 (Loop A)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction (°C)**	**Uncertainty (°C)**	**k**
0	-0.040	-0.030	0.030	2.00
39	38.980	-0.020	0.030	2.00
40	39.970	-0.030	0.030	2.00
41	40.960	-0.040	0.030	2.00
0	-0.030	-0.030	0.030	2.00

Name of participating laboratory : **KIM-LIPI, INDONESIA** **S/N 9981749 (Loop A)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction (°C)**	**Uncertainty (°C)**	**k**
0	0.01	-0.02	0.040	2.00
39	39.00	0.00	0.040	2.00
40	40.00	-0.02	0.040	2.00
41	41.00	-0.02	0.040	2.00
0	0.02	-0.02	0.040	2.00

Name of participating laboratory : **NIMT, THAILAND(Final)** **S/N 9981749 (Loop A)**

Calibration point (^oC)	Thermometer Reading (^oC)	**Correction** (^oC)	**Uncertainty** (^oC)	**k**
0	0.00	-0.020	0.020	2.00
39	39.00	0.010	0.020	2.00
40	40.00	-0.001	0.020	2.00
41	41.01	-0.020	0.020	2.00
0	0.00	-0.021	0.020	2.00

Name of participating laboratory : **NIMT, THAILAND (Initial)** **S/N 9981771 (Loop B)**

Calibration point (^oC)	Thermometer Reading (^oC)	**Correction** (^oC)	**Uncertainty** (^oC)	**k**
0	0.00	-0.027	0.020	2.00
39	38.99	-0.006	0.020	2.00
40	40.00	-0.011	0.020	2.00
41	41.00	-0.011	0.020	2.00
0	0.00	-0.024	0.020	2.00

Name of participating laboratory : **NMIA, AUSTRALIA** **S/N 9981771 (Loop B)**

Calibration point (^oC)	Thermometer Reading (^oC)	**Correction** (^oC)	**Uncertainty** (^oC)	**k**
0	0.023	-0.023	0.004	2.26
39	39.010	- 0.010	0.008	2.31
40	40.007	-0.007	0.007	2.36
41	41.008	-0.008	0.007	2.36
0	0.024	-0.024	0.004	2.23

Name of participating laboratory : **SPRING, SINGAPORE** **S/N 9981771 (Loop B)**

Calibration point (^oC)	Thermometer Reading (^oC)	**Correction** (^oC)	**Uncertainty** (^oC)	**k**
0	0.025	-0.025	0.015	2.00
39	39.015	-0.015	0.015	2.00
40	40.010	-0.010	0.015	2.00
41	41.015	-0.015	0.015	2.00
0	0.025	-0.025	0.015	2.00

Name of participating laboratory : **SCL, HONG KONG** **S/N 9981771 (Loop B)**

Calibration point (^oC)	Thermometer Reading (^oC)	**Correction** (^oC)	**Uncertainty** (^oC)	**k**
0	0.030	-0.030	0.015	1.99
39	39.000	-0.010	0.020	1.98
40	40.005	-0.010	0.020	1.98
41	41.000	-0.010	0.020	1.98
0	0.030	-0.030	0.015	1.99

Name of participating laboratory : **VMI, VIETNAM** **S/N 9981771 (Loop B)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction** (°C)	**Uncertainty** (°C)	**k**
0	0.0360	-0.035	0.012	2.00
39	39.011	-0.012	0.012	2.00
40	40.019	-0.008	0.012	2.00
41	41.014	-0.011	0.012	2.00
0	0.0370	-0.035	0.012	2.00

Name of participating laboratory : **NBSM, NEPAL** **S/N 9981771 (Loop B)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction** (°C)	**Uncertainty** (°C)	**k**
0	0	0.00	0.16	2.45
39	39	0.05	0.16	2.45
40	40	0.05	0.16	2.45
41	41	0.05	0.16	2.45
0	0	0.00	0.16	2.45

Name of participating laboratory : **NIMT, THAILAND (Final)** **S/N 9981771 (Loop B)**

Calibration point (°C)	Thermometer Reading (°C)	**Correction** (°C)	**Uncertainty** (°C)	**k**
0	0.00	-0.020	0.020	2.00
39	39.00	-0.005	0.020	2.00
40	40.00	-0.008	0.020	2.00
41	41.00	-0.011	0.020	2.00
0	0.00	-0.024	0.020	2.00

APPENDIX D
Measurement Results For
LIGT Comparison Model ASTM 40C

Name of participating laboratory : NIMT, THAILAND (Initial) **S/N 59-405(Loop A)**

Calibration point (°C)	Thermometer Reading (°C)	Correction (°C)	**ELC** Correction (°C)	Uncertainty (°C)	**k**	ELC (°C)
75	75.00	0.038	0.038	0.200	2.00	30.0
90	90.00	-0.037	-0.037	0.200	2.00	32.0
100	100.00	-0.036	-0.036	0.200	2.00	34.0
105	105.00	-0.023	-0.023	0.200	2.00	35.0
110	110.00	-0.034	-0.034	0.200	2.00	35.6
125	124.98	-0.026	-0.026	0.200	2.00	37.6
75	75.04	0.000	0.000	0.200	2.00	30.2

Name of participating laboratory : NMIA, AUSTRALIA **S/N 59-405(Loop A)**

Calibration point (°C)	Thermometer Reading (°C)	Correction (°C)	**ELC** Correction (°C)	Uncertainty (°C)	**k**	ELC (°C)
75	74.971	0.029	0.034	0.017	2.45	32.82
90	90.038	-0.038	-0.058	0.017	2.45	27.47
100	100.030	-0.030	-0.050	0.017	2.45	30.68
105	105.007	-0.007	-0.036	0.017	2.45	30.68
110	109.981	0.019	-0.037	0.018	2.36	28.12
125	124.963	0.037	-0.069	0.017	2.45	26.88
75	74.963	0.037	0.032	0.021	2.36	27.78

Name of participating laboratory : NML-SIRIM, MALAYSIA **S/N 59-405(Loop A)**

Calibration point (°C)	Thermometer Reading (°C)	Correction (°C)	**ELC** Correction (°C)	Uncertainty (°C)	**k**	ELC (°C)
75	75.00	0.04	0.061	0.24	2.00	40.73
90	90.10	-0.04	-0.004	0.24	2.00	40.21
100	100.10	-0.07	-0.064	0.24	2.00	35.08
105	105.20	-0.08	-0.091	0.24	2.00	33.33
110	110.20	-0.08	-0.072	0.24	2.00	36.64
125	125.20	-0.10	-0.123	0.24	2.00	35.27
75	75.00	0.04	0.053	0.24	2.00	37.00

Name of participating laboratory : ITDI, PHILIPPINES **S/N 59-405(Loop A)**

Calibration point (°C)	Thermometer Reading (°C)	Correction (°C)	**ELC** Correction (°C)	Uncertainty (°C)	**k**	ELC (°C)
75	74.973	-0.027		0.09	2.00	
90	89.950	-0.050		0.09	2.00	
100	99.935	-0.061		0.09	2.00	
105	104.937	-0.063		0.09	2.00	
110	109.980	-0.020		0.09	2.00	
125	124.913	-0.087		0.09	2.00	
75	94.972	-0.028		0.09	2.00	

Name of participating laboratory : **KIM-LIPI, INDONESIA** **S/N 59-405(Loop A)**

Calibration point (°C)	Thermometer Reading (°C)	Correction (°C)	**ELC** Correction (°C)	Uncertainty (°C)	**k**	ELC (°C)
75	75.000	-0.080	-0.007	0.12	1.96	68.00
90	90.000	-0.120	-0.036	0.12	1.96	51.43
100	100.000	-0.200	-0.091	0.12	1.96	52.35
105	105.000	-0.190	-0.066	0.12	1.96	53.42
110	110.000	-0.170	-0.073	0.12	1.96	48.43
125	125.000	-0.220	-0.045	0.12	1.96	55.25
75	75.000	-0.070	0.003	0.12	1.96	68.00

Name of participating laboratory : **NIMT, THAILAND (Final)** **S/N 59-405(Loop A)**

Calibration point (°C)	Thermometer Reading (°C)	Correction (°C)	**ELC** Correction (°C)	Uncertainty (°C)	**k**	ELC (°C)
75	74.98	0.015	0.009	0.200	2.00	26.60
90	90.00	-0.072	-0.077	0.200	2.00	31.00
100	100.00	-0.067	-0.084	0.200	2.00	31.20
105	104.97	-0.065	-0.079	0.200	2.00	33.00
110	109.97	-0.069	-0.075	0.200	2.00	34.80
125	124.96	-0.085	-0.095	0.200	2.00	36.60
75	75.04	-0.027	-0.030	0.200	2.00	28.60

Name of participating laboratory : **NIMT, THAILAND(Initial)** **S/N 59-999(Loop B)**

Calibration point (°C)	Thermometer Reading (°C)	Correction (°C)	**ELC** Correction (°C)	Uncertainty (°C)	**k**	ELC (°C)
75	75.00	-0.018	-0.018	0.200	2.00	26.60
90	90.00	-0.065	-0.065	0.200	2.00	29.80
100	100.00	-0.079	-0.079	0.200	2.00	31.00
105	105.00	-0.094	-0.094	0.200	2.00	32.20
110	110.04	-0.076	-0.076	0.200	2.00	36.40
125	124.94	0.005	0.005	0.200	2.00	38.80
75	75.02	-0.012	-0.012	0.200	2.00	30.00

Name of participating laboratory : **NMIA, AUSTRALIA** **S/N 59-999(Loop B)**

Calibration point (°C)	Thermometer Reading (°C)	Correction (°C)	**ELC** Correction (°C)	Uncertainty (°C)	**k**	ELC (°C)
75	75.009	-0.009	0.003	0.017	2.45	32.82
90	90.019	-0.019	-0.029	0.017	2.45	27.47
100	100.043	-0.043	-0.045	0.017	2.45	30.68
105	105.043	-0.043	-0.053	0.017	2.45	30.68
110	110.013	-0.013	-0.075	0.017	2.45	28.12
125	124.916	0.084	-0.034	0.017	2.36	26.88
75	75.007	-0.007	-0.011	0.017	2.45	27.78

Name of participating laboratory : **SPRING, SINGAPORE** **S/N 59-999(Loop B)**

Calibration point (°C)	Thermometer Reading (°C)	Correction (°C)	**ELC** Correction (°C)	Uncertainty (°C)	**k**	ELC (°C)
75	75.04	-0.04	-0.016	0.040	2.00	39.20
90	90.08	-0.08	-0.049	0.040	2.00	37.00
100	100.10	-0.10	-0.057	0.040	2.00	38.20
105	105.12	-0.12	-0.091	0.040	2.00	36.50
110	110.12	-0.12	-0.121	0.040	2.00	36.30
125	125.04	-0.04	-0.078	0.040	2.00	35.00
75	75.04	-0.04	-0.032	0.040	2.00	34.20

Name of participating laboratory : **SCL, HONG KONG** **S/N 59-999(Loop B)**

Calibration point (°C)	Thermometer Reading (°C)	Correction (°C)	**ELC** Correction (°C)	Uncertainty (°C)	**k**	ELC (°C)
75	74.94	-0.04	-0.014	0.08	1.98	40.00
90	90.02	-0.08	-0.069	0.08	1.98	32.40
100	99.98	-0.08	-0.067	0.08	1.98	33.20
105	105.02	-0.10	-0.101	0.08	1.98	32.00
110	109.98	-0.10	-0.135	0.08	1.98	31.70
125	125.02	-0.04	-0.108	0.08	1.98	31.90
75	74.98	-0.04	-0.019	0.08	1.98	41.10

Name of participating laboratory : **VMI, VIETNAM** **S/N 59-999(Loop B)**

Calibration point (°C)	Thermometer Reading (°C)	Correction (°C)	**ELC** Correction (°C)	Uncertainty (°C)	**k**	ELC (°C)
75	75.078	-0.030	-0.027	0.069	2.00	28.30
90	90.118	-0.125	-0.135	0.069	2.00	27.40
100	100.090	-0.083	-0.088	0.069	2.00	30.20
105	105.010	-0.111	-0.135	0.069	2.00	28.70
110	110.158	-0.152	-0.210	0.069	2.00	28.70
125	124.970	-0.009	-0.114	0.069	2.00	28.20
75	75.090	-0.057	-0.056	0.069	2.00	30.30

Name of participating laboratory : **NIMT, THAILAND (Final)** **S/N 59-999(Loop B)**

Calibration point (°C)	Thermometer Reading (°C)	Correction (°C)	**ELC** Correction (°C)	Uncertainty (°C)	**k**	ELC (°C)
75	74.95	-0.047	-0.041	0.200	2.00	30.0
90	90.00	-0.067	-0.057	0.200	2.00	32.0
100	99.98	-0.097	-0.079	0.200	2.00	34.0
105	104.96	-0.088	-0.069	0.200	2.00	35.0
110	110.00	-0.107	-0.113	0.200	2.00	35.6
125	124.94	-0.032	-0.044	0.200	2.00	37.6
75	75.00	-0.084	-0.084	0.200	2.00	30.2

APPENDIX D
Measurement Results For
Industrial Platinum Resistance Thermometers, Model 5626

Name of participating laboratory : NIMT, THAILAND (Initial) S/N 0817 (Loop A)

Calibration point	**Standard** Reading	**Tested Thermometer** Reading	**Uncertainty** of Measurement	**Immersion Depth**
(°C)	(°C)	(Ω)	(°C)	(mm)
0	- 0.0004	99.979 06	0.020	200
-40	-40.0006	83.929 08	0.020	200
0	0.0001	99.978 59	0.020	200
50	49.9936	119.759 41	0.020	200
100	99.9973	139.248 27	0.020	200
150	150.0011	158.436 53	0.020	200
200	199.9998	177.326 62	0.020	200
250	250.0043	195.928 94	0.020	200
0	0.0002	99.978 74	0.020	200

Name of participating laboratory : NMIA, AUSTRALIA S/N 0817 (Loop A)

Calibration point	**Standard** Reading	**Tested Thermometer** Reading	**Uncertainty** of Measurement	**Immersion Depth**
(°C)	(°C)	(Ω)	(°C)	(mm)
0	0.0000	99.978 0	0.001	280
-40	-39.9510	83.949 7	0.005	255
0	0.0000	99.977 8	0.001	280
0	0.0000	99.977 5	0.001	280
50	50.0016	119.763 4	0.004	280
100	100.0002	139.247 3	0.004	280
150	149.9969	158.431 5	0.004	280
200	199.9954	177.321 4	0.004	280
250	249.9948	195.919 3	0.004	280
0	0.0000	99.978 1	0.001	280

Name of participating laboratory : NML-SIRIM, MALAYSIA S/N 0817 (Loop A)

Calibration point	**Standard** Reading	**Tested Thermometer** Reading	**Uncertainty** of Measurement	**Immersion Depth**
(°C)	(°C)	(Ω)	(°C)	(mm)
0	0.00071	99.978 4	0.001	250
-40	-40.07881	83.889 5	0.025	250
0	0.00071	99.967 4	0.028	250
50	50.07028	119.778 0	0.028	250
100	100.06845	139.254 0	0.036	250
150	150.06371	158.443 0	0.013	250
200	200.07772	177.332 0	0.021	250
250	249.94004	195.874 1	0.030	250
0	0.00071	99.978 3	0.001	250

Name of participating laboratory : ITDI, PHILIPPINES **S/N 0817 (Loop A)**

Measurement Results: Not Received

Calibration point	**Standard** Reading	**Tested Thermometer** Reading	**Uncertainty** of Measurement	**Immersion Depth**
(°C)	(°C)	(Ω)	(°C)	(mm)
0				
-40				
0				
50				
100				
150				
200				
250				
0				

Name of participating laboratory : KIM-LIPI, INDONESIA **S/N 0817 (Loop A)**

Calibration point	**Standard** Reading	**Tested Thermometer** Reading	**Uncertainty** of Measurement	**Immersion Depth**
(°C)	(°C)	(Ω)	(°C)	(mm)
0				
-40				
0	0.0064	99.982 22	0.013	300
50	49.9742	119.790 55	0.013	300
100	100.0177	139.282 50	0.013	300
150	150.0773	158.482 11	0.013	300
200	200.1218	177.381 56	0.013	300
250	250.1435	195.986 36	0.013	300
0	0.0064	99.982 25	0.013	300

Name of participating laboratory : NIMT, THAILAND (Final) **S/N 0817 (Loop A)**

Calibration point	**Standard** Reading	**Tested Thermometer** Reading	**Uncertainty** of Measurement	**Immersion Depth**
(°C)	(°C)	(Ω)	(°C)	(mm)
0	0.0002	99.979 00	0.020	200
-40	-40.0126	83.925 59	0.020	200
0	0.0104	99.983 12	0.020	200
50	50.0403	119.780 48	0.020	200
100	100.0286	139.257 23	0.020	200
150	150.0155	158.438 93	0.020	200
200	200.0074	177.328 91	0.020	200
250	250.0205	195.932 64	0.020	200
0	0.0006	99.979 19	0.020	200

Name of participating laboratory : NIMT, THAILAND (Initial) S/N 0833 (Loop B)

Calibration point	**Standard** Reading	**Tested Thermometer** Reading	**Uncertainty** of Measurement	**Immersion Depth**
(°C)	(°C)	(Ω)	(°C)	(mm)
0	0.0005	99.959 88	0.02	200
-40	-40.0020	83.912 59	0.02	200
0	-0.0013	99.959 79	0.02	200
50	49.9981	119.740 01	0.02	200
100	99.9995	139.221 86	0.02	200
150	150.0010	158.406 57	0.02	200
200	200.0013	177.294 89	0.02	200
250	250.0004	195.891 00	0.02	200
0	-0.0001	99.959 74	0.02	200

Name of participating laboratory : NMIA, AUSTRALIA S/N 0833 (Loop B)

Calibration point	**Standard** Reading	**Tested Thermometer** Reading	**Uncertainty** of Measurement	**Immersion Depth**
(°C)	(°C)	(Ω)	(°C)	(mm)
0	0.0000	99.959 1	0.001	280
-40	-39.9510	83.933 5	0.005	255
0	0.0000	99.959 0	0.001	280
0	0.0000	99.958 8	0.001	280
50	50.0016	119.740 9	0.004	280
100	100.0002	139.221 3	0.004	280
150	149.9969	158.402 5	0.004	280
200	199.9954	177.289 4	0.004	280
250	249.9948	195.883 5	0.004	280
0	0.0000	99.959 3	0.001	280

Name of participating laboratory : SPRING, SINGAPORE S/N 0833 (Loop B)

Calibration point	**Standard** Reading	**Tested Thermometer** Reading	**Uncertainty** of Measurement	**Immersion Depth**
(°C)	(°C)	(Ω)	(°C)	(mm)
0	0.000 0	99.959 840	0.004	250
-40	- 40.179	83.842 564	0.009	250
0	0.000	99.959 068	0.004	250
50	50.342	119.874 668	0.008	250
100	100.110	139.264 453	0.009	250
150	150.000	158.405 183	0.009	250
200	200.001	177.292 079	0.008	250
250	250.130	195.934 857	0.009	250
0	0.000	99.959 358	0.004	250

Name of participating laboratory : SCL, HONG KONG **S/N 0833 (Loop B)**

Calibration point	**Standard** Reading	**Tested Thermometer** Reading	**Uncertainty** of Measurement	**Immersion Depth**
(°C)	(°C)	(Ω)	(°C)	(mm)
0	0.0100	99.963 2	0.001	280
-40	-40.0126	83.909 3	0.013	280
0	0.0100	99.963 2	0.001	280
50	49.9993	119.740 3	0.006	280
100	99.9796	139.214 2	0.006	280
150	149.9896	158.400 7	0.006	280
200	200.0067	177.294 2	0.006	280
250	249.9850	195.880 0	0.033	260
0	0.0100	99.963 3	0.001	280

Name of participating laboratory : **VMI, VIETNAM** **S/N 0833 (Loop B)**

Calibration point	**Standard** Reading	**Tested Thermometer** Reading	**Uncertainty** of Measurement	**Immersion Depth**
(°C)	(°C)	(Ω)	(°C)	(mm)
0	0.0011	99.958 88	0.007	225
-40				
-20	-19.9876	91.964 42	0.010	225
0	0.0011	99.958 85	0.007	225
50	50.0128	119.745 86	0.011	225
100	100.0112	139.222 58	0.019	225
150	149.9960	158.402 28	0.017	225
200	200.0037	177.290 16	0.018	225
250	249.9453	195.848 21	0.017	225
0	0.0016	99.959 75	0.007	225

Name of participating laboratory : MSL, NEW ZEALAND **S/N 0833 (Loop B)**

Calibration point	**Standard** Reading	**Tested Thermometer** Reading	**Uncertainty** of Measurement	**Immersion Depth**
(°C)	(°C)	(Ω)	(°C)	(mm)
0.01	0.0100	99.964 10	0.0054	200
-40	-38.8355	84.385 60	0.0054	150
0.01	0.1094	100.002 70	0.0054	200
50	50.0740	119.768 80	0.0054	200
100	100.0917	139.257 40	0.0054	200
150	150.0092	158.408 30	0.0054	200
200	199.8582	177.237 50	0.0054	200
250				
0	0.0100	99.964 15	0.0054	200

Name of participating laboratory : NIMT, THAILAND (Final) S/N 0833 (Loop B)

Calibration point	**Standard** Reading	**Tested Thermometer** Reading	**Uncertainty** of Measurement	**Immersion Depth**
(°C)	(°C)	(Ω)	(°C)	(mm)
0	-0.000 27	99.959 21	0.020	200
-40	-40.041 0	83.898 17	0.020	200
0	0.000 25	99.959 53	0.020	200
50	49.971 6	119.729 74	0.020	200
100	99.990 7	139.223 73	0.020	200
150	150.001 6	158.409 38	0.020	200
200	199.973 7	177.286 63	0.020	200
250	250.105 8	195.928 23	0.020	200
0	0.000 33	99.959 87	0.020	200

APPENDIX F
Equipment used :
For
LIGT Comparison

Laboratory : **NIMT ,THAILAND**

Item	Description	Model	S/N	Traceability
1	SPRT	Hart 5681	1301	NIMT, Thailand
2	SPRT	ISOTECH 670	138	NIMT, Thailand
3	Super Thermometer II	Hart 1590	97045	NIMT, Thailand
4	Liquid Calibration Bath (Alcohol)	Hart 7081	A07014	NIMT, Thailand
5	Liquid Calibration Bath (Oil)	Hart 6022	A03098	NIMT, Thailand
6	Liquid Calibration Bath (Water)	HETO CB216	8806298	NIMT, Thailand
	Controller	02 PG 000	88060689	NIMT, Thailand

Laboratory : **NMIA, AUSTRALIA**

Item	Description	Model	S/N	Traceability
1	Standard PRT	NML	377	NML
2	AC resistance bridge	ASL F700	7358004560	NML
3	Reference Resistor	25 ohm	RRS3	NML
4	Isotech alcohol bath		E12 18743-1	NML
5	Ice bath	NML	N/A	
6	Water bath	NML	E3	NML
7	Standard PRT	NML	378-S899	NML

Name of participating laboratory : **SPRING, Singapore**

Item	Description	Model	S/N	Traceability
1	Precision Thermometer Bridge	ASL F700	1349-008	SPRING Singapore
2	SPRT (low temperature)	5187SA	275053	SPRING Singapore
3	SPRT (high temperature)	5187SA	250303	SPRING Singapore
4	Alcohol Bath (-40°C to 5°C)	KB25	496905-B	SPRING Singapore
5	Water Bath (-40°C to 5°C)	KB22	67296000	SPRING Singapore
6	Oil Bath (-40°C to 5°C)	KB12	67297000	SPRING Singapore
7	Camera	XC-50CE		

Name of participating laboratory : **VMI, VIETNAM**

Item	Description	Model	S/N	Traceability
1	SPRT (25 Ω)	5681	1248	KRISS
2	Ratio Resistance Bridge	1590	A11118	Hart Scientific /USA
3	Air STD. Resistor 100 Ω	5420-100	A252923	Hart Scientific /USA
4	Liquid Bath DENMARK	Heto-KB22	8203140	VMI
5	Oil Bath	915H	18915/1	VMI

Laboratory : **SCL, Hong Kong**

_Item	Description	Model	S/N	Traceability
1	SPRT	Tinsley 5187SA	259761	SCL
2	SPRT	Tinsley 5187SA	269562	SCL
3	SPRT	Tinsley 5187SA	269563	SCL
4	SPRT	Tinsley 5187SC	275061	SCL
5	Resistance bridge	ASL F17A	1029-3/215	SCL
6	Standard Resistor	Tinsley 5685A	248795	SCL
7	Constant Temperature Bath	Heto Lab KB22-2	93070851	N/A
8	Constant Temperature Bath	Heto Lab KB25	9011858	N/A
9	Constant Temperature Bath	Heto Lab KB12	8309	N/A
10	Farden Thermometer	K. Schneider	869111	SCL
11	Farden Thermometer	K. Schneider	869117	SCL
12	Farden Thermometer	K. Schneider	869121	SCL
13	Farden Thermometer	K. Schneider	869123	SCL
14	Farden Thermometer	K. Schneider	869125	SCL
15	Farden Thermometer	K. Schneider	869131	SCL

Laboratory : **NML-SIRIM ,MALAYSIA**

Item	Description	Model	S/N	Traceability
1	SPRT	5680	1161	NML-SIRIM
2	Standard PRT	R800-2	RS-907-3	NML-SIRIM
3	Resistance bridge	F17	1157-6/302	NML-SIRIM
4	Low Temp. Calibration Bath	KB25	9209956	NML-SIRIM
5	Oil bath	JH03	452385	NML-SIRIM

Laboratory : **ITDI ,PHILIPPINES**

Item	Description	Model	S/N	Traceability
1	SPRT	3614		
2	SPRT, Sensing Technology	670/25	670/58	
3	RTD Indicator	850C	A16464	
4	ASL, Bridge	F700	1669-006-470	
5	Cryostatic Bath	BK-40		
6	Oil Bath			

Laboratory : **KIM-LIPI ,INDONESIA**

Item	Description	Model	S/N	Traceability
1	SPRT	Kunming		
2	AC Bridge	ASL F16		
3	Ice Bath			
4	Water Bath	Tamson		
5	Oil Bath	Tamson		

APPENDIX F
Equipment used :
For
IPRT Comparison

Name of participating laboratory : **NIMT ,THAILAND**

Item	Description	Model	S/N	Traceability
1	SPRT	Hart 5681	1301	NIMT, Thailand
2	SPRT	ISOTECH 670	138	NIMT, Thailand
3	Super Thermometer II	Hart 1590	97045	NIMT, Thailand
4	Liquid Calibration Bath (Alcohol)	Hart 7081	A07014	NIMT, Thailand
5	Liquid Calibration Bath (Oil)	Hart 6022	A03098	NIMT, Thailand
6	Liquid Calibration Bath (Water)	HETO CB216	8806298	NIMT, Thailand
	Controller	02 PG 000	88060689	NIMT, Thailand

Name of participating laboratory : **NMIA, AUSTRALIA**

Item	Description	Model	S/N	Traceability
1	SPRT	DSL	T10	NML
2	ASL AC bridge	F17	F17/2 111-2/276	NML
3	Oil Bath	NML	E2	NML
4	Reference resistor	25 ohm	RRS2	NML
5	Ice bath	NML	N/A	NML

Name of participating laboratory : **SPRING, Singapore**

Item	Description	Model	S/N	Traceability
1	F17 Bridge	F17	742/8-141	SPRING Singapore
2	SPRT (high temperature)	5187SA	250303	SPRING Singapore
3	SPRT (high temperature)	5187SA	253126	SPRING Singapore
4	SPRT (low temperature)	5187SA	275053	SPRING Singapore
5	SPRT (low temperature)	5187SA	280123	SPRING Singapore
6	Alcohol Bath (-40°C to 5°C)	KB25	496905-B	SPRING Singapore
7	Water Bath (5°C to 75°C)	KB22	67296000	SPRING Singapore
8	Oil Bath (75°C to 250°C)	KB12	67297000	SPRING Singapore
9	MI Bridge	6010A	920303	SPRING Singapore
10	Standard Resistor 100 ohm	5685A	248872	SPRING Singapore

Name of participating laboratory : VMI, VIETNAM

Item	Description	Model	S/N	Traceability
1	SPRT (25 Ω)	5681	1248	KRISS
2	Ratio Resistance Bridge	1590	A11118	Hart Scientific /USA
3	Air STD. Resistor 100 Ω	5420-100	A252923	Hart Scientific /USA
4	Ice Point	-	V10.TB1.20	VMI
5	Liquid Bath	Heto-KB22	8203140	VMI
6	Oil Bath	915H	18915/1	VMI

Name of participating laboratory : **SCL, Hong Kong**

Item	Description	Model	S/N	Traceability
1	Triple point of water cell	Jarrett A13	1297	SCL
2	Triple point of water cell	Jarrett A13	1588	SCL
3	SPRT	Tinsley 5187SA	24508	SCL
4	SPRT	Tinsley 5187SA	253085	SCL
5	SPRT	Tinsley 5187SA	259761	SCL
6	SPRT	Tinsley 5187SA	269562	SCL
7	SPRT	Tinsley 5187SA	269563	SCL
8	SPRT	Tinsley 5187SC	275061	SCL
9	SPRT	Isotech 935-14-77	082	SCL
10	SPRT	Isotech 935-14-77	084	SCL
11	Standard Resistor	Tinsley 5685A	242104	SCL
12	Standard Resistor	Tinsley 5685A	242902	SCL
13	Resistance bridge	ASL F17A	520-2/055	SCL
14	Resistance bridge	ASL F17A	520-1/054	SCL
15	Resistance bridge	ASL F17A	1029-3/215	N/A
16	Constant Temperature Bath	Heto Lab KB12	8309	N/A
17	Constant Temperature Bath	Heto Lab KB22-2	93070851	N/A
18	Constant Temperature Bath	Heto Lab KB25	9011858	N/A
19	Constant Temperature Bath	Hart 6055	A13039	N/A

Name of participating laboratory : **MSL, NEW ZEALAND**

Item	Description	Model	S/N	Traceability
1	ASL Resistance Bridge	F18/IEEE	756-3/032	NZ National Standards
2	ASL Resistance Bridge	F700B	9392 001 579	NZ National Standards
3	Leeds and Northrop SPRT	8163Q	1748541	NZ National Standards (fixed points)
4	100-Ohm Standard Resistor	5685A	243501	NZ National Standards
5	Custom-built oil bath for standard resistor	-	-	-
6	Custom-built oil bath (-25 ºC to 55 ºC)	-	-	-
7	Custom-built oil bath (55 ºC to 200 ºC)	-	-	-
8	Isotech mercury triple point cell	ITL-M-17924	M029	NZ National Standard
9	Isotech mercury triple point apparatus	ITL-M-17925	101411/1	-
10	Triple point of water cell	-	PEL 84/5	NZ National Standard

Name of participating laboratory : **NML-SIRIM ,MALAYSIA**

Item	Description	Model	S/N	Traceability
1	SPRT	5680	1161	NML-SIRIM
2	SPRT	5699	0155	NML-SIRIM
3	Resistance bridge	F17	1157-6/801	NML-SIRIM
4	Low Temp. Calibration Bath	KB25	9209956	NML-SIRIM
5	Oil bath	JH03	452385	NML-SIRIM
…				

Name of participating laboratory : **KIM-LIPI ,INDONESIA**

Item	Description	Model	S/N	Traceability
1	SPRT	Kunming		
2	AC Bridge	ASL F16		
3	Ice Bath			
4	Water Bath	Tamson		
5	Oil Bath	Tamson		