REPORT to the CCT on Key Comparison «COOMET.T-K3.3»

(COOMET Project 593/RU/13)

Realizations of the ITS-90 from 273.16 K to 933.473 K

2014 - 2018

Prepared by
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CONTENT

Introduction

Regional key comparison of the ITS-90 of the national standards of temperature in the range from 273.16 K to 933.473 K was initiated by COOMET TC1.10.(the technical committee of COOMET "Thermometry and thermal physics"). The purpose of the comparison is to evaluate the equivalence of the realization of the ITS-90 in National Metrology Institutes (NMI) of COOMET for the most common temperature range from the triple point of water (0,01°C) to Al freezing point (660,323°C). Unlike prior COOMET regional comparisons, the temperature range was expanded and the composition of the participants was changed.

Six National Metrology Institutes of COOMET take part in the comparison: D.I. Mendeleev Institute for Metrology «VNIIM» (Russian Federation), Belarusian State Institute for Metrology «BelGIM» (the Republic of Belarus), National Scientific Centre Institute of Metrology «NSC IM» (Ukraine), Republic State Enterprise Kazakhstan Institute of Metrology «KazInMetr» (Republic of Kazakhstan), Georgian National Agency for Standards and Metrology «GEOSTM» (Georgia), National Institute of Standardization and Metrology, «NIM» (Republic of Moldova).

VNIIM (Russian Federation) is the coordinator of the regional comparison as a participant of the K3, K4 and K7 Key Comparisons.

The 25-Ohm standard platinum resistance thermometers (SPRT) are used as the transfer standards. The results of the comparisons should interrelate the equivalence of the national standards and their relation to the K3 Key Comparison results for inclusion in the CMC tables.

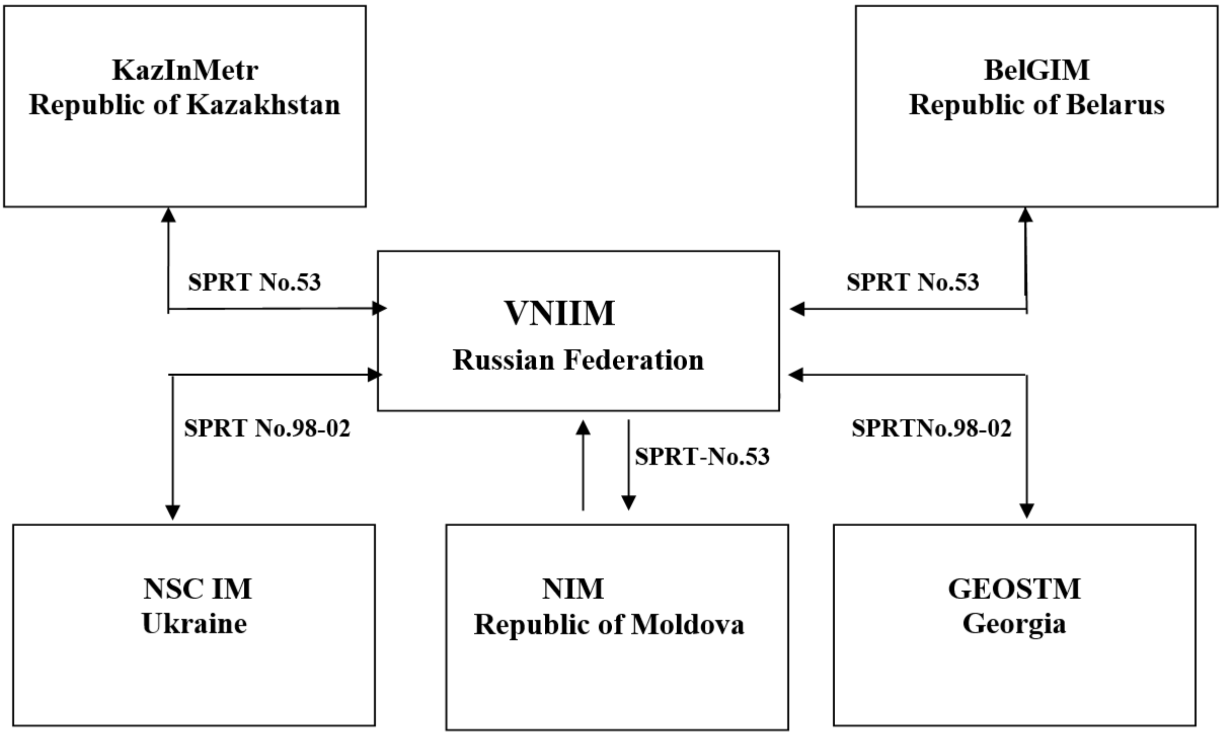
Each participant of the comparisons must use the accepted practice of ITS-90 realization.

The instruction is drawn up in accordance with Appendix 1 of the Summary of CCT Key Comparison CCT-K3 (D.W. Mangum et al. of NIST, November 1999). The comparisons carefully follow the protocols, given in Guidelines for CIPM Key Comparisons, in the Appendix F to the Mutual Recognition Agreement, March 1999.

Coordinator selects 2 SPRT-25 of high stability: No.53 and No.98-02, calibrates them in all of the ITS-90 fixed-points of the comparisons' range. Complete list of the ITS-90 fixed-points of these comparisons: the triple point of water, Ga melting-point, In, Sn, Zn and Al freezing-points. After SPRT calibration coordinator transfers the thermometer to the participating laboratories in turn: No.53 to BelGIM, KazInMetr, NIM and No.98-02 to NSC IM, and GEOSTEM. The SPRT stability is controlled by VNIIM after measurements are taken in each of the laboratories.

Participating laboratories must calibrate the SPRT in the ITS-90 fixed-points, for inclusion in the CMC tables, using National Standard's equipment and accepted procedure for ITS-90 fixed-points' realization.

1. Organization of comparison



2. Participating laboratories

Name of Laboratory	Contact person	Adress
VNIIM - Russian Federation	Pokhodun A.I. a.i.pokhodun@vniim.ru	Moskovsky pr., 19, 190005, St. Petersburg
BelGIM - Republic of Belarus	Krivonos P. krivonos@belgim.by	93, Starovilensky trakt, Minsk
NSC IM - Ukraine	Ivanova E.P. katerina.ivanova@metrology.kharkov.ua	Mironosickaya str., 42, 61002, Kharkov
KazInMetr – Republic of Kazakhstan	Dysebaeva K.K. kuralay_12@mail.ru	Left bank, 35thStreet, building11, 010000, Astana,
NIM - Republic of Moldova	Bordianu C. bordianuc@gmail.com	28, E. Coca Str., Chisinau, MD-2064
GEOSTM - Georgia	Chelidze I. iurichelidze.geostm@yahoo.com	67, Chargalskya st., Tbilisi

3. The bilateral equivalence of the NMIs standards relatively to the VNIIM standards

3.1. The measurement results of BelGIM, KazInMetr, NIM

The standard platinum resistance thermometer SPRT No.53, manufactured by VNIIM, was used as the transfer standard for this comparison.

The measurement results of W_i,, corresponding differences

$\Delta T_i = T_{NMI} - T_{VNIIM}$ and their uncertainties U (ΔT)(k=2) in according to the uncertainties submitted by NMIs are presented in Tables 1, 2, 3.

All the information about the uncertainty budgets are presented in Appendix 3.

Table 1. The measurement results of VNIIM and BelGIM,

W_{FP}	**VNIIM**	**BelGIM**	T_{NMI}-T_{VNIIM} **mK**	**U** (T_{NMI}-T_{VNIIM}) **mK**
W_{Ga}	1.118 126 1	1.118 124 6	- 0.37	0.27
W_{In}	1.609 732 1	1.609 728 7	- 0.89	0.87
W_{Sn}	1.892 701 2	1.892 700 2	- 0.27	1.07
W_{Zn}	2.568 730 9	2.568 724 0	- 1.98	1.47
W_{Al}	3.375 726 4	3.375 725 9	- 0.16	2.83

Table 2. The measurement results of VNIIM and KazInMetr

W_{FP}	**VNIIM**	**KazInMetr**	T_{NMI}-T_{VNIIM} **mK**	**U** (T_{NMI}-T_{VNIIM}) **mK**
W_{Sn}	1.892 700 5	1.892 698 1	- 0.64	1.57
W_{Zn}	2.568 731 6	2.568 736 4	1.37	2.38
W_{Al}	3.375 725 8	3.375 717 5	- 2.59	7.94

Table 3. The measurement results of VNIIM and NIM,

W_{FP}	VNIIM	NIM	T_{NMI}-T_{VNIIM} mK	U (T_{NMI}-T_{VNIIM}) mK
W_{Ga}	1.118 128 1	1.118 129 1	0.25	0.38
W_{In}	1.609 734 1	1.609 732 9	- 0.32	0.94
W_{Sn}	1.892 699 2	1.892 695 2	- 1.10	0.95
W_{Zn}	2.568 743 1	2.568 743 6	0.14	1.76
W_{Al}	3.375 728 7	3.375 728 4	- 0.09	2.82

In addition to the uncertainties reported by laboratories the uncertainty of possible changes in the transfer thermometer SPRT No.53 over the course of the comparison has to be taken into account for temperature difference uncertainty. The uncertainty of the measurement results due to instability of the transfer standard, u_{PRT} was calculated under the assumption that the distribution of the thermometer drift in time was rectangular and asymmetrical:

$$u_{prt} = \left[\left(W_{VNIIM}\right)_{end} - \left(W_{VNIIM}\right)_{begin}\right] \times \frac{\partial T}{\partial W} \times \frac{1}{\sqrt{3}}$$

The calculation results are presented in Tables 4, 5, 6.

Table 4. Evaluation of the SPRT No.53 instability in VNIIM- BelGIM period

Fixed point	$(W_{VNIIM})_{befor}$	$(W_{VNIIM})_{after}$	ΔT mK	u_{PRT}, mK (k=1)
Ga	1.118126 1	1.118125 8	0.08	0.04
In	1.609 732 1	1.609 731 4	0.18	0.11
Sn	1.892 701 2	1.892 702 0	0.22	0.13
Zn	2.568 730 9	2.568 732 1	0.34	0.20
Al	3.375 726 4	3.375 724 1	0.72	0.42

Table 5. Evaluation of the SPRT No.53 instability in VNIIM- KazInMetr period

Fixed point	**$(W_{VNIIM})_{befor}$**	**$(W_{VNIIM})_{after}$**	**ΔT mК**	**u_{PRT}, mК (k=1)**
Sn	1.892 700 5	1.892 701 8	0.30	0.17
Zn	2.568 731 6	2.568 730 5	0.31	0.17
Al	3.375 725 8	3.375 723 4	0.75	0.44

Table 6. Evaluation of the SPRT No.53 instability in VNIIM- NIM period

Fixed point	**$(W_{VNIIM})_{befor}$**	**$(W_{VNIIM})_{after}$**	**ΔT mК**	**u_{PRT}, mК (k=1)**
Ga	1.118127 8	1.118128 2	0.10	0.06
In	1.609 732 4	1.609 733 1	0.18	0.10
Sn	1.892 699 8	1.892 701 0	0.32	0.19
Zn	2.568 741 6	2.568 743 5	0.54	0.31
Al	3.375 726 4	3.375 729 1	0.84	0.49

For a direct comparison between two laboratories using a single transfer thermometer the uncertainty can be calculated

$$U^2(T_{NMI} - T_{VNIIM}) = U^2(T_{NMI}) + U^2(T_{VNIIM}) + U^2(prt)$$

Table 7. The bilateral equivalence results **ΔT** and **U (ΔT) (k=2)** taking into account SPRT instability

Fixed point	**BelGIM – VNIIM** mK	**U (ΔT)** mK	**KazInMetr - VNIIM** mK	**U (ΔT)** mK	**NIM – VNIIM** mK	**U (ΔT)** mK
Ga	- 0.37	0.28	-	-	0.25	0.40
In	- 0.89	0.90	-	-	- 0.32	0.96
Sn	- 0.27	1.10	- 0.64	1.61	- 1.10	1.02
Zn	- 1.98	1.52	1.37	2.26	0.14	1.87
Al	- 0.15	2.95	- 2.59	7.99	- 0.09	3.02

3.2. The measurement results of NSC IM, GEOSTM

The standard platinum resistance thermometer SPRT No.98-02, manufactured by VNIIM, was used as the transfer standard in NSC IM and GEOSTM.

The measurement results W_i, the differences $\Delta W_i = W_{NMI} - W_{VNIIM}$ **,** their uncertainties U(W_i)(k=2**),** submitted by NMIs, corresponding differences $\Delta T_i = T_{NMI} - T_{VNIIM}$ and results taking into account SPRT instability are presented in Tables 8-12.

Table 8. The measurement results of VNIIM and NSC IM,

W_{FP}	VNIIM	NSC IM	T_{NMI}-T_{VNIIM} mK	U (T_{NMI}-T_{VNIIM}) mK
W_{Ga}	1.118 100 8	1.118 099 7	- 0.27	0.27
W_{In}	1.609 595 2	1.609 587 8	- 1.68	0,87
W_{Sn}	1.892 487 6	1.892 486 1	- 0.35	0.93
W_{Zn}	2.568 367 1	2.568 358 7	- 2.4	1.20
W_{Al}	3.375 153 2	3.375144 9	-2.6	2.86

Table 9. The measurement results of VNIIM and GEOSTM

W_{FP}	VNIIM	GEOSTM	T_{NMI}-T_{VNIIM} mK	U (T_{NMI}-T_{VNIIM}) mK
W_{Sn}	1.892 495 5	1.892 496 3	0.22	1.15
W_{Zn}	2.568 370 1	2.568 376 1	1.14	1.82

Table 10. Evaluation of the SPRT No.98-02 instability in VNIIM- NSC IM period

Fixed point	$(W_{VNIIM})_{befo}$	$(W_{VNIIM})_{after}$	ΔT mК	u_{PRT} (k=1) mК
Ga	1.118 100 8	1.118 100 5	0.07	0.04
In	1.609 595 2	1.609 594 5	0.18	0.11
Sn	1.892 487 6	1.892 486 7	0.24	0.14
Zn	2.568 367 1	2.568 365 9	0.34	0.20
Al	3.375 153 2	3.375 150 8	0.75	0.44

Table 11. Evaluation of the SPRT No.98-02 instability in VNIIM- GEOSTM period

Fixed point	**$(W_{VNIIM})_{befor}$**	**$(W_{VNIIM})_{after}$**	**ΔT mK**	**u_{PRT}, mK (k=1)**
Sn	1.892 495 5	1.892 494 3	0.33	0.19
Zn	2.568 370 1	2.568 369 2	0.28	0.16

Table 12. The bilateral equivalence results taking into account SPRT instability

Fixed point	**NSC IM – VNIIM mK**	**U (ΔT) (k=2) mK**	**GEOSTM-- VNIIM** mK	**U (ΔT) (k=2) mK**
Ga	- 0.27	0.28	-	-
In	- 1.68	0.90	-	-
Sn	- 0.35	0.97	0.22	1.19
Zn	- 2.4	1.26	1.14	1.86
Al	- 2.6	2.99	-	-

4 Linkage of the COOMET comparison results with the CCT-K3 results

The results of the COOMET comparisons were estimated in accordance with the document "*Guide on Estimation of the COOMET Key Comparison Data*", COOMET, R/GM/14:2006. This document allows to link the results of the COOMET regional comparisons with those of the CIPM key comparisons, in this case with the results of the CCT comparisons K3.
The results of the key comparisons K3 in the protocol of WG8 "Inter-RMO CMC review committee 3-26-03 " are presented as differences [T_{NMI} – ARV (K3)] with the evaluations of their uncertainties for each reference point and NMI.

The degree of equivalence "***d***" of the NMIs results can be calculated on the corresponding relationship:

$$\mathbf{d_{NMI} = (T_{NMI} - T_{VNIIM}) + (T_{VNIIM} - ARV\ K3)},$$

the uncertainty of U(d)

$$U^2(d) = U^2(T_{NMI} - T_{VNIIM}) + U^2(T_{VNIIM} - ARV)$$

The results of VNIIM in CCT-K3 used in the calculations are presented in the Table 13.

Table 13. Results of CCT-K3

NMI	Fixed point	T_{VNIIM} – ARV mK	U(T_{VNIIM}-ARV) (к=2) mK
VNIIM	Ga	0.05	0.25
	In	0.54	1.14
	Sn	0.59	0.99
	Zn	0.52	1.85
	Al	0.05	1.85

Linkage of the BelGIM comparison results with the CCT-K3 results is presented in Table 14 and on fig.1

Table 14.

NMI	Fixed point	T_{BelGIM} – ARV mK	U(T_{BelGIM} - T_{VNIIM}) (k=2) mK	U(T_{BelGIM}-ARV) (к=2) mK
BelGIM	Ga	- 0.32	0.28	0.37
	In	- 0.35	0.90	1.45
	Sn	0.32	1.10	1.48
	Zn	- 1.46	1.52	2.39
	Al	- 0.10	2.95	3.48

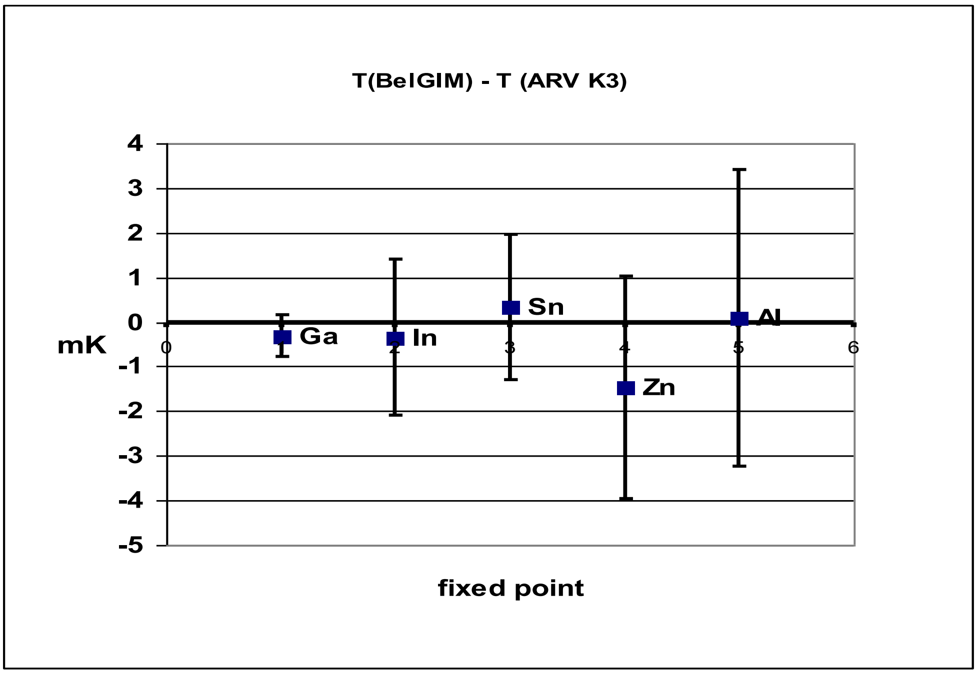


Fig.1 The differences [T_{BelGIM} – ARV(K3)] for the fixed points with their expanded uncertainties (k=2).

Linkage of the **KazInMetr** comparison results with the CCT-K3 results is presented in the Table 15 and on fig.2

Table 15

NMI	Fixed point	T_{KazIn} – ARV mK	$U(T_{KazIn} - T_{VNIIM})$ (k=2) mK	$U(T_{KazIn}$-ARV) (к=2) mK
KazInMetr	Sn	- 0.05	1.61	1.89
	Zn	1.89	2.26	2.92
	Al	-2.54	7.99	8.20

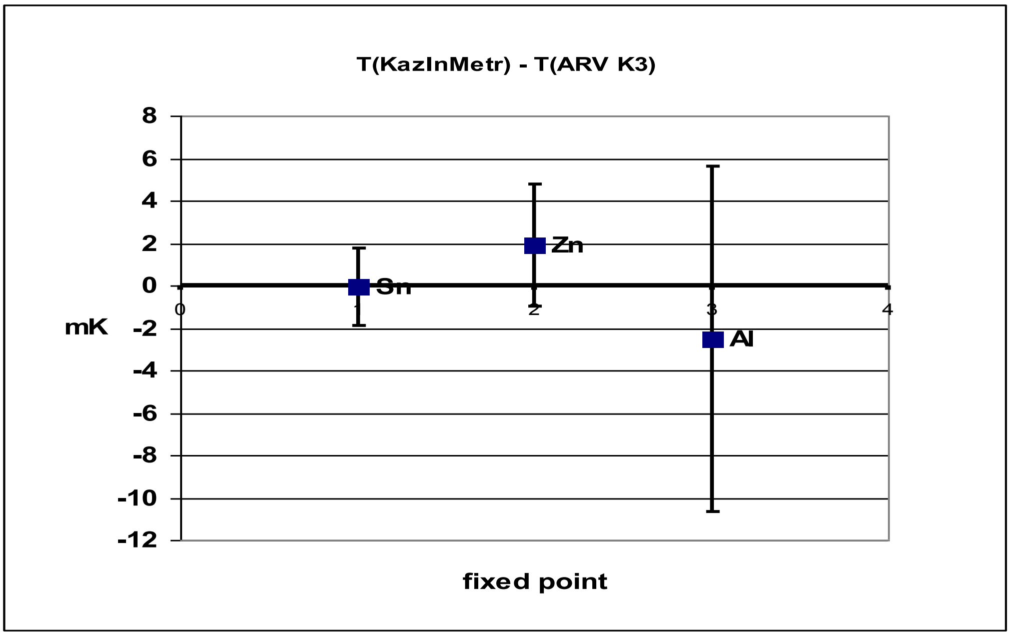


Fig.2 The differences [$T_{KazInMetr}$ – ARV(K3)] for the fixed points with their expanded uncertainties (k=2).

Linkage of the NIM comparison results with the CCT-K3 results is presented in Table 16 and on fig.3

Table 16.

NMI	Fixed point	T_{NIM} – ARV mK	$U(T_{NIM} - T_{VNIIM})$ (k=2) mK	$U(T_{NIM}$-ARV) (к=2) mK
NIM	Ga	0.30	0.40	0.47
	In	0.22	0.96	1.49
	Sn	- 0.51	1.02	1.42
	Zn	0.66	1.87	2.63
	Al	- 0.04	3.02	3.54

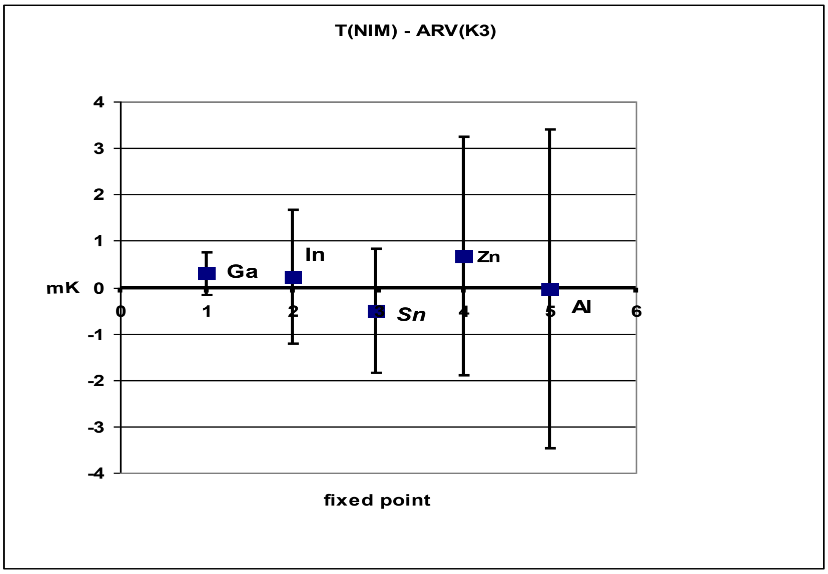


Fig.3 The differences [T_{NIM} – ARV(K3)] for the fixed points with their expanded uncertainties (k=2).

4.3. Linkage of the **NSC IM** comparison results with the CCT-K3 results is presented in the Table 17 and on fig.4

Table 17.

NMI	Fixed point	$T_{NSC\ IM}$ – ARV mK	U($T_{NSC\ IM}$ -T_{VNIIM}) (k=2) mK	U($T_{NSC\ IM}$- ARV) (к=2) mK
NSC IM	Ga	- 0.22	0.28	0.38
	In	- 1.14	0.90	1.45
	Sn	0.24	0.97	1.37
	Zn	- 1.88	1.26	2.24
	Al	- 2.55	2.99	3.52

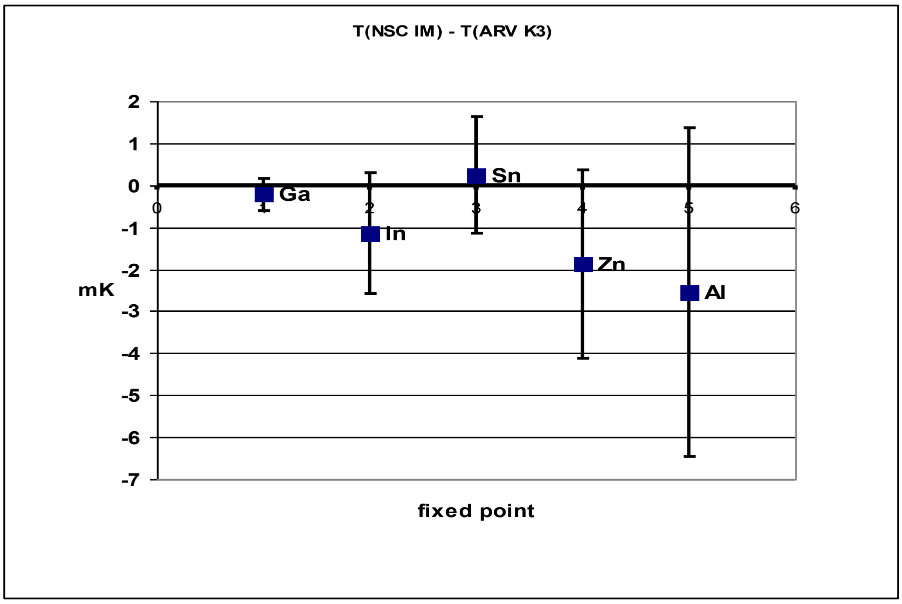


Fig.4 The differences [$T_{NSC\ IM}$ – ARV(K3)] for the fixed points and their expanded uncertainties (k=2).

Linkage of the **GEOSTM** comparison results with the CCT-K3 results is presented in the Table 18 and on fig.5

Table 18

NMI	**Fixed point**	**T_{GEOSTM} – ARV mK**	**$U(T_{GEOSTM} - T_{VNIIM})$ (k=2) mK**	**$U(T_{GEOSTM}$- ARV) (к=2) mK**
GEOSTM	Sn	0.81	1.19	1.55
	Zn	1.66	1.86	2.62

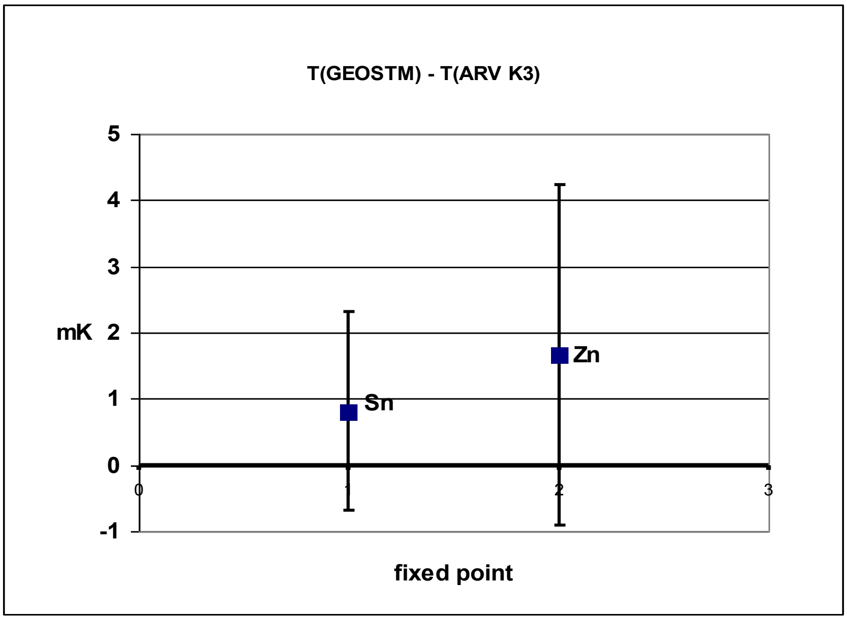


Fig. 5. The differences [T_{GEOSTM} – ARV(K3)] for the fixed points and their expanded uncertainties (k=2).

5. Conclusion

The purpose of the comparison is the determination the degree of equivalence of fixed point realizations of the 5 NMIs relatively to the CCT-K3 results and the confirmation of the uncertainties, claimed by NMIs for CMC.
Summary results of the comparison are presented in Tables 19-20.

Table 19. The degrees of equivalence “d” and their expanded uncertainties

Fixed point	BelGIM		NSC IM		NIM	
	d mK	U(d) (k=2), mK	**d** mK	U(d) (k=2), mK	**d** mK	U(d) (k=2), mK
Ga	- 0.32	0.37	- 0.22	0.38	0.30	0.47
In	- 0.35	1.45	- 1.14	1.45	0.22	1.49
Sn	0.32	1.48	0.24	1.37	- 0.51	1.42
Zn	- 1.46	2.39	- 1.88	2.24	0.66	2.63
Al	- 0.10	3.48	-2.55	3.52	- 0.04	3.54

Table 20. The degrees of equivalence “d” and their expanded uncertainties

Fixed point	KazInMetr		GEOSTM	
	d mK	U(d) (k=2), mK	**d** mK	U(d) (k=2), mK
Sn	- 0.05	1.89	0.81	1.55
Zn	1.89	2.92	1.66	2.62
Al	-2.54	8.20	-	-

The comparison results have confirmed the uncertainty values, claimed by NMIs, which are presented in Appendix 3 of the Report.
BelGIM, NSC IM and NIM have confirmed the uncertainty values for some fixed points, which were presented in CMC previously.

Appendix 1

Technical protocol

Regional key comparison COOMET.T-K3.3
Realizations of the ITS-90 from 273.16 K to 933.473 K
2014 - 2015

COOMET Project 593/RU/13

March 28, 2014

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Introduction

Regional key comparison of the ITS-90 of the national standards of temperature in the range from 273.16 K to 933.473 K was initiated by COOMET TC1.10.(the technical committee of COOMET "Thermometry and thermal physics"). The purpose of the comparison is to evaluate the equivalence of the realization of the ITS-90 in National Metrology Institutes (NMI) of COOMET for the most common temperature range from the triple point of water (0,01°C) to Al freezing point (660,323°C). Unlike prior COOMET regional comparisons, the temperature range was expanded and the composition of the participants was changed.

Six National Metrology Institutes of COOMET take part in the comparison: D.I. Mendeleev Institute for Metrology «VNIIM» (Russian Federation), Belarusian State Institute for Metrology «BelGIM» (the Republic of Belarus), National Scientific Centre Institute of Metrology «NSC IM» (Ukraine), Republic State Enterprise Kazakhstan Institute of Metrology «KazInMetr» (Republic of Kazakhstan), Georgian National Agency for Standards and Metrology «GEOSTM» (Georgia), National Institute of Standardization and Metrology, «NIM» (Republic of Moldova).

VNIIM (Russian Federation) is the coordinator of the regional comparison as a participant of the K3, K4 and K7 Key Comparisons.

The 25-Ohm standard platinum resistance thermometer (SPRT) is used as a transfer standard. The results of the comparisons should interrelate the equivalence of the national standards and their relation to the K3 Key Comparison results for inclusion in the CMC tables.

Each participant of the comparisons must use the accepted practice of ITS-90 realization. Comparisons' participants must act in accordance with the instructions below.

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Coordinator selects SPRT-25 of high stability, calibrates it in all of the ITS-90 fixed-points of the comparisons' range. Complete list of the ITS-90 fixed-points of these comparisons: the triple point of water, Ga melting-point, In, Sn, Zn and Al freezing-points. After SPRT calibration coordinator transfers the thermometer to the participating laboratories in turn. The SPRT stability is controlled by VNIIM after measurements are taken in each of the laboratories.

Participating laboratories must calibrate the SPRT in the ITS-90 fixed-points, for inclusion in the CMC tables, using National Standard's equipment and accepted procedure for ITS-90 fixed-points' realization.

2. Participating laboratories

Name of Laboratory	Contact person	Adress
VNIIM - Russian Federation	Pokhodun A.I. a.i.pokhodun@vniim.ru	Moskovsky pr., 19, 190005, St. Petersburg
BelGIM - Republic of Belarus	Krivonos P. krivonos@belgim.by	93, Starovilensky trakt, Minsk
NSC IM - Ukraine	Ivanova E.P. katerina.ivanova@metrology.kharkov.ua	Mironosickaya str., 42, 61002, Kharkov
KazInMetr – Republic of Kazakhstan	Dysebaeva K.K. kuralay_12@mail.ru	Left bank, 35thStreet, building11, 010000, Astana,
NIM - Republic of Moldova	Bordianu C. metrologie@metrologie.md bordianuc@gmail.com	28, E. Coca Str., Chisinau, MD-2064
GEOSTM - Georgia	Chelidze I. iurichelidze.geostm@yahoo.com	67, Chargalskya st., Tbilisi

Duration of the SPRT-25 calibration in the each participating laboratories is estimated roughly 6-7 weeks for Ga, In, Sn, Zn, Al fixed-points and 3-4 weeks for Sn, Zn, Al fixed-points.
Period for transferring thermometers between the laboratories, including intermediate control of the SPRT-25 stability in VNIIM is roughly 6-8 weeks.

3. Comparisons procedure

VNIIM is the coordinator.

VNIIM selects and calibrates ETS-25 in all points of ITS-90 of the comparison range; controls the stability of ETS-25 after the calibration in each of the laboratories; collects reports on the ETS-25 calibration results in the laboratories, analyzes the comparison results and prepares a final report on the comparisons.

Participating laboratories

After receiving the calibrated ETS-25 from VNIIIM the participating laboratories carries out the following procedures:

1. Measurement of the ETS-25 resistance at the triple point of water

First, pre-annealing should be carried out in the following sequence:

a. the ETS-25 is inserted in the furnace at a temperature of 500 °C,
b. the furnace temperature increases to 675°C,
c. the ETS-25 is kept in the furnace during 3 hours,
d. the furnace temperature is reduced to 450°C within 3 hours,
e. ETS-25 is quickly removed from the furnace to cool down to room temperature.

Then ETS-25 resistance in TPW is measured.
If the ETS-25 resistance change is less than 0.8 mK in temperature equivalent, its calibration in the fixed-points can be started.
If the ETS-25 resistance change in the TPW after the annealing is above or equal to 0.8 mK in temperature equivalent, the annealing must be repeated
If the ETS-25 resistance change in the TPW after the re-annealing is above 0.8 mK in temperature equivalent, coordinator’s advice is required.

2. The ETS-25 calibration

ETS-25 calibration must be carried out in the following sequence: TPW, Al, TPW, Zn, TPW, Sn, TPW, In, TPW, Ga, TPW. Laboratories should use its usual practices for each of the fixed-points.
For each fixed-point relative resistivity W is calculated: $W = R_t/R_{TPW}$, where R_{TPW} is ETS-25 resistance in the TPW, obtained directly after R_t measurement.
R_t and R_{TPW} values need to be corrected to overheating by measuring current, hydrostatic pressure and pressure in the cell, if pressure in cell differs from 101325 Pa.
Calibration cycle must be repeated at least 3 times: measuring cycle from Al to Ga and then two more times.

Values for W, obtained in 3 measuring cycles, and its average value for each fixed-point are transferred to VNIIM. After the calibration is complete, the ETS-25 must be returned to VNIIM for the stability control.

Submission of the information to the coordinator

a. Measurement results of $W = R_t/R_{TPW}$, where R_t is ETS-25 resistance in each fixed-point, R_{TPW} is ETS-25 resistance in the TPW, obtained after R_t measurement.
b. Characteristics of the fixed-points cells, furnaces, measuring instruments, used in the comparisons, according to the form in Appendix C.
c. Uncertainty budget for each fixed-point on the form in Appendix B, calculated in accordance with Appendix B of the Technical Protocol.

Appendix 2

Parameters of the cells of fixed points, furnaces, Instruments

Laboratory	VNIIM	KazInMetr	BelGIM
Bridge, potentiometer			
Manufacturer		ASL	ASL
Type	F 900	F-18	F-18
A.C. or D.C.		A.C.	A.C.
A.C. frequency		50 Гц	
D.C. period			
Normal measurement current	1 mA	1 mA	1 mA
Overheating current	1.414 mA	1.414 mA	1.414 mA
Reference resistor			
Manufacturer	ZIP, RF	ZIP, RF	Tinsley
Type	MC3020	MC3020	5685 A
Temperature control of reference resistor (yes/no)	yes	yes	yes
TPW cell	No.0/41		
Manufacturer	VNIIM	Fluke	VNIIM
Outer diameter	50 mm	50 mm	48 мм
Thermometer well diameter	11 mm	12 mm	13 мм
Immersion depth of the middle of the SPRT sensing element	260 mm	265 mm	212 мм
Thermostat for maintaining the TPW	HartScientific model 7312	Fluke model 7312	Cryostat TPW
Al fixed point cell			
Manufacturer	VNIIM	Fluke	Fluke
Open or closed	open	closed	closed
Outer diameter	48 mm	48 mm	48 mm
Thermometer well diameter	8 mm	8 mm	8 mm
Metal purity	99,9999 %	99,9999 %	99,9999 %
Immersion depth of the middle of the SPRT sensing element	190 mm	195 mm	207 mm
Furnace for the fixed point of Al		9114	
Manufacturer	VNIIM	Fluke	Fluke
Type (1, 2 or 3 zones)	3 zones	3 zones	Heat pipe
Melting plateau duration			8 hours

Freezing plateau duration	10 hours	9 hours	9 hours
Zn fixed point cell	No.12		
Manufacturer	VNIIM	Fluke	VNIIM
Open or closed	open	closed	closed
Outer diameter	52 mm	48 mm	52,8 mm
Thermometer well diameter	14 mm	8 mm	12,0 mm
Metal purity	99.9999m%	99,9999 %	99,9999%
Immersion depth of the middle of the SPRT sensing element	160 mm	195 mm	215 mm
Furnace for the fixed point of Zn		9114	
Manufacturer	VNIIM	Fluke	
Type (1, 2 or 3 zones)	3 zones	3 zones	3 zones
Melting plateau duration			2 hours
Freezing plateau duration	10 hours	9 hours	9 hours
Sn fixed point cell	No.88		
Manufacturer	VNIIM	9114 Fluke	VNIIM
Open or closed	open	closed	closed
Outer diameter	52 mm	48 mm	48,4 mm
Thermometer well diameter	14 mm	8 mm	9,7 mm
Metal purity	99.9999 %	99,99995 %	99.9999 %
Immersion depth of the middle of the SPRT sensing element	160 mm	195 mm	217 mm
Furnace for the fixed point of Sn			
Manufacturer	VNIIM	9114 Fluke	BelGIM
Type (1, 2 or 3 zones)	3 zones	3 zones	Heat pipe
Melting plateau duration			9 hours
Freezing plateau duration	11 hours	9 hours	9 hours
In fixed point cell	No.1		
Manufacturer	VNIIM		VNIIM
Open or closed	open		closed
Outer diameter	42 mm		49,3 mm
Thermometer well diameter	10 mm		12,4 mm
Metal purity	99.9999 %		
Immersion depth of the middle of the SPRT sensing element	173 mm		236 mm
Furnace for the fixed point of In			
Manufacturer	VNIIM		BelGIM
Type (1, 2 or 3 zones)	3 zones		2 zones
Melting plateau duration			9 hours
Freezing plateau duration	12 hours		9 hours
Ga fixed point cell	No.1		
Manufacturer	VNIIM		

Open or closed	open		closed
Outer diameter	42 mm		34,1 mm
Thermometer well diameter	10 mm		10,2 mm
Metal purity	99.99999 %		
Immersion depth of the middle of the SPRT sensing element	167 mm		201 mm
Furnace for the fixed point of Ga			"Termostat AS"
Manufacturer	VNIIM		BelGIM
Type (1, 2 or 3 zones)	2 zones		water thermostat
Melting plateau duration	17 hours		9 hours

laboratory	NIM	NSC IM	GEOSTEM
Bridge, potentiometer	Resistance Thermometry Bridge	Resistance Thermometry Bridge	”Super thermometer”
Manufacturer		ASL, England	Fluke
Type	6010 C	F900	1595 A
			-
A.C. or D.C.	D.C.	переменный	-
A.C. frequency		75 Гц	-
D.C. period	10s		-
			-
Normal measurement current	1 mA	1 mA	1 mA
Overheating current	1,414 mA	1,414 mA	1,414 mA
			-
			-
Reference resistor	100 Ω	100 Ω	25 Ω
Manufacturer	Tinsley	Tinsley USA	ASL
Type	5685 A	Wilkins Resistor	CER 6000
Temperature control of reference resistor (yes/no)	yes	yes	yes
TPW cell	5901 C-G	VNIIM	5901 D-G
Manufacturer	Hart Scientific		Fluke
Outer diameter	50 mm	50 mm	60 mm
Thermometer well diameter	14 mm	10 mm	12 mm
Immersion depth of the middle of the SPRT sensing element	265 mm	220 mm	240 mm
Thermostat for maintaining the TPW	Thermostat type 7312	Fluke 7312	Thermostat type 7312
Al fixed point cell	17672		-
Manufacturer	Isotech	NSC IM	-
Open or closed	closed	closed	-

Outer diameter	50 mm	50 mm	-
Thermometer well diameter	8 mm	10 mm	-
Metal purity	99,9999 %	99,9999 %	-
Immersion depth of the middle of the SPRT sensing element	200 mm	155 mm	-
			-
Furnace for the fixed point of Al	17703		-
Manufacturer	Isotech	NSC IM	-
Type (1, 2 or 3 zones)	3 zones	3 zones	-
Melting plateau duration		3,2 hours	-
Freezing plateau duration	9 hours	5,7 hours	-
Zn fixed point cell	Модель 5906		Модель 5906
Manufacturer	Hart Scientific	VNIIM	Fluke
Open or closed	closed	closed	closed
Outer diameter	48 mm	50 mm	48 mm
Thermometer well diameter	8 mm	10 mm	8 mm
Metal purity	99,9999 %	99,9999 %	99,9999 %
Immersion depth of the middle of the SPRT sensing element	195 mm	155 mm	195 mm
Furnace for the fixed point of Zn			Type 9114
Manufacturer	Hart Scientific	NSC IM	Fluke
Type (1, 2 or 3 zones)	3 zones	3 zones	3 zones
Melting plateau duration		4 hours	-
Freezing plateau duration	9 hours	7,8 hours	10 hours
Sn fixed point cell	5905		
Manufacturer	Hart Scientific	VNIIM	VNIIM
Open or closed	closed	closed	closed
Outer diameter	48 mm	50 mm	50 mm
Thermometer well diameter	8 mm	10 mm	10 mm
Metal purity	99,9999 %	99,9999 %	99,9999 %
Immersion depth of the middle of the SPRT sensing element	195 mm	155 mm	155 mm
Furnace for the fixed point of Sn	Type 9114	NSC IM	-
Manufacturer	Hart Scientific		-
Type (1, 2 or 3 zones)	3 zones	3 zones	-
Melting plateau duration		3,8 hours	-
Freezing plateau duration	9 hours	8,2 hours	-
			-
In fixed point cell	Type 5904		-
Manufacturer	Hart Scientific	NSC IM	-

Open or closed	Closed	Closed	-
Outer diameter	48 mm	50 mm	-
Thermometer well diameter	8 mm	10 mm	-
Metal purity	99,9999 %	99,9999 %	-
Immersion depth of the middle of the SPRT sensing element	195 mm	155 mm	-
Furnace for the fixed point of In	Type 9114		-
Manufacturer	Hart Scientific	NSC IM	-
Type (1, 2 or 3 zones)	3 zones	2 zones	-
Melting plateau duration		3,1 hours	-
Freezing plateau duration	12 hours	4,9 hours	-
			-
Ga fixed point cell	type 5943		-
Manufacturer	Hart Scientific	NSC IM	-
Open or closed	closed	closed	-
Outer diameter	38,1 mm	50 mm	-
Thermometer well diameter	8,2 mm	10 mm	-
Metal purity	99,99999 %	99,99999 %	-
Immersion depth of the middle of the SPRT sensing element	168 mm	155 mm	-
			-
Furnace for the fixed point of Ga	type 9230		-
Manufacturer	Hart Scientific	NSC IM	-
Type (1, 2 or 3 zones)		2 zones	-
Melting plateau duration	5 days	13 hours	-

Appendix 3

Uncertainty budgets

BelGIM

Uncertainty components	Type	Al	Zn	Sn	In	Ga
		mK	mK	mK	mK	mK
Repeatability of values W	A	0.745	0.256	0.146	0.246	0.046
Component due to metal purity	B	0.694	0.450	0.372	0.166	0.039
Component due to the hydrostatic pressure correction	B	0.005	0.008	0.006	0.01	0.003
Component due to the self-heating correction	B	0.174	0.169	0.139	0.204	0.020
Component due to the deviation from heat equilibrium	B	0.16	0.10	0.10	0.06	0.06
Component due to the pressure in the cell,	B	0.01	0.01	0.01	0.01	0.01
Component due to the resistance bridge non-linearity	B	0.014	0.014	0.014	0.014	0.014
Component due to the reference resistance temperature	B	0.012	0.012	0.011	0.011	0.005
Component due to the reference resistance stability	B	0.004	0.004	0.004	0.004	0.001
Component due to the uncertainty of TPW	B	0.37	0.26	0.18	0.15	0.10
Combined uncertainty		1.11	0.61	0.47	0.40	0.13
Expanded uncertainty (k=2)		2.22	1.22	0.94	0.80	0.26

Component due to R_{tpw} measurement, Tpe B	mK
Component due to the water purity and isotope composition	0.015
Component due to the hydrostatic pressure correction	0.002
Component due to the self-heating correction	0.071
Component due to the deviation from heat equilibrium	0.05
Component due to the resistance bridge non-linearity	0.014
Total uncertainty	0.089

NIM

Uncertainty components	Al mK	Zn mK	Sn mK	In mK	Ga mK
Repeatability of values, W_t	0.709	0.582	0.186	0.225	0.025
Component due to metal purity	0.427	0.264	0.16	0.26	0.010
Component due to the hydrostatic pressure correction	0.005	0.008	0.006	0.010	0.003
Component due to the self-heating correction	0.148	0.057	0.016	0.073	0.033
Component due to the deviation from heat equilibrium	0.400	0.150	0.100	0.100	0.05
Component due to the pressure in the cell	0.020	0.012	0.010	0.014	0.006
Component due to the resistance bridge non-linearity	0.102	0.093	0.088	0.086	0.082
Component due to the reference resistance temperature	0.0002	0.0003	0.0003	0.0003	0.0002
Component due to the reference resistance stability	0.018	0.017	0.016	0.016	0.015
Component due to R_{tpw} measurement					
Component due to the water purity and isotope composition	0.031	0.031	0.031	0.031	0.031
Component due to the hydrostatic pressure correction	0.002	0.002	0.002	0.002	0.002
Component due to the self-heating correction	0.024	0.051	0.012	0.017	0.062
Component due to the deviation from heat equilibrium	0.100	0.050	0.050	0.050	0.050
Component due to the resistance bridge non-linearity	0.082	0.082	0.082	0.082	0.082
Component due to the reference resistance temperature, u_R	0.0001	0.0003	0.0003	0.0003	0.0002
Component due to the reference resistance stability, u_t	0.018	0.017	0.016	0.016	0.015
Component due to the uncertainty of TPW	0.57	0.40	0.28	0.23	0.15
Combined uncertainty	1.10	0.78	0.40	0.44	0.18
Expanded uncertainty (k=2)	2.20	1.56	0.80	0.88	0.36

KazInMetr

Uncertainty components	Al mK	Zn mK	Sn mK
Type A			
Repeatability of values, W_t	3.732	0.518	0.220
Type B			
Component due to metal purity	0.194	0.709	0.16
Component due to the hydrostatic pressure correction	0.005	0.427	0.006
Component due to the self-heating correction	0.13	0.005	0.13
Component due to the deviation from heat equilibrium	0.80	0.148	0.60
Component due to the pressure in the cell	0	0.400	0
Component due to the resistance bridge non-linearity	0.42	0.020	0.21
Component due to the reference resistance temperature	0.014	0.102	0.014
Component due to the reference resistance stability	0.002	0.0002	0.002
Component due to the uncertainty of TPW	**0.46**	0.32	**0.22**
Combined uncertainty	**3.87**	**1.12**	**0.74**
Expanded uncertainty (k=2)	**7.74**	**2.24**	**1.48**

Component due to R_{tpw} measurement, Type B	mK
Component due to the water purity and isotope composition	0.010
Component due to the hydrostatic pressure correction	0.002
Component due to the self-heating correction	0.10
Component due to the deviation from heat equilibrium	0.050
Component due to the resistance bridge non-linearity	0.014
Total uncertainty	0.11

GEOSTM

Uncertainty component	**Zn** mK	**Sn** mK
Type A		
Repeatability of values, W_t	0.47	0.31
Type B		
Component due to metal purity	0.33	0.1
Component due to the hydrostatic pressure correction	0.08	0.01
Component due to the self-heating correction	0.04	0.03
Component due to the deviation from heat equilibrium	0.25	0.03
Component due to the pressure in the cell	0.1	-
Component due to the resistance bridge non-linearity	0.07	0.07
Component due to the reference resistance temperature	0.03	0.03
Component due to the reference resistance stability	0.08	0.03
Component due to the uncertainty of TPW,	0.49	0.40
Combined uncertainty	0.81	0.52
Expanded uncertainty (k=2)	1.62	1.04

Component due to R_{tpw} measurement **Type B**	mK
Component due to the water purity and isotope composition	0.11
Component due to the hydrostatic pressure correction	0.02
Component due to the self-heating correction	0.03
Component due to the deviation from heat equilibrium	0,1
Component due to the resistance bridge non-linearity	0,07
Total uncertainty	0.168

VNIIM

Uncertainty components	Al	Zn	Sn	In	Ga
	mK	mK	mK	mK	mK
Type A					
Repeatability of values, W_t	0.765	0.313	0.218	0.117	0.046
Type B					
Component due to metal purity	0.394	0.25	0.120	0.120	0.025
Component due to the hydrostatic pressure correction	0.005	0.010	0.003	0.005	0.003
Component due to the self-heating correction	0.12	0.025	0.015	0.012	0.020
Component due to the deviation from heat equilibrium	0.13	0.080	0.030	0.030	0.02
Component due to the pressure in the cell,	0.001	0.0012	0.001	0.0015	0.0006
Component due to the resistance bridge non-linearity	0.003	0.003	0.003	0.03	0.003
Component due to the reference resistance temperature	0.0001	0.0001	0.0001	0.0001	0.0001
Component due to the reference resistance stability	0.0001	0.0001	0.0001	0.0001	0.001
Component due to the uncertainty of TPW	0.080	0.056	0.039	0.032	0.021
Combined uncertainty	0.88	0.41	0.25	0.17	0.06
Expanded uncertainty (k=2)	1.76	0.82	0.50	0.34	0.12

Component due to R_{tpw} measurement	mK
Type B	
Component due to the water purity and isotope composition	0.01
Component due to the hydrostatic pressure correction	0.001
Component due to the self-heating correction	0.01
Component due to the deviation from heat equilibrium	0.013
Component due to the resistance bridge non-linearity	0.003
Total uncertainty	0.019

NSC IM

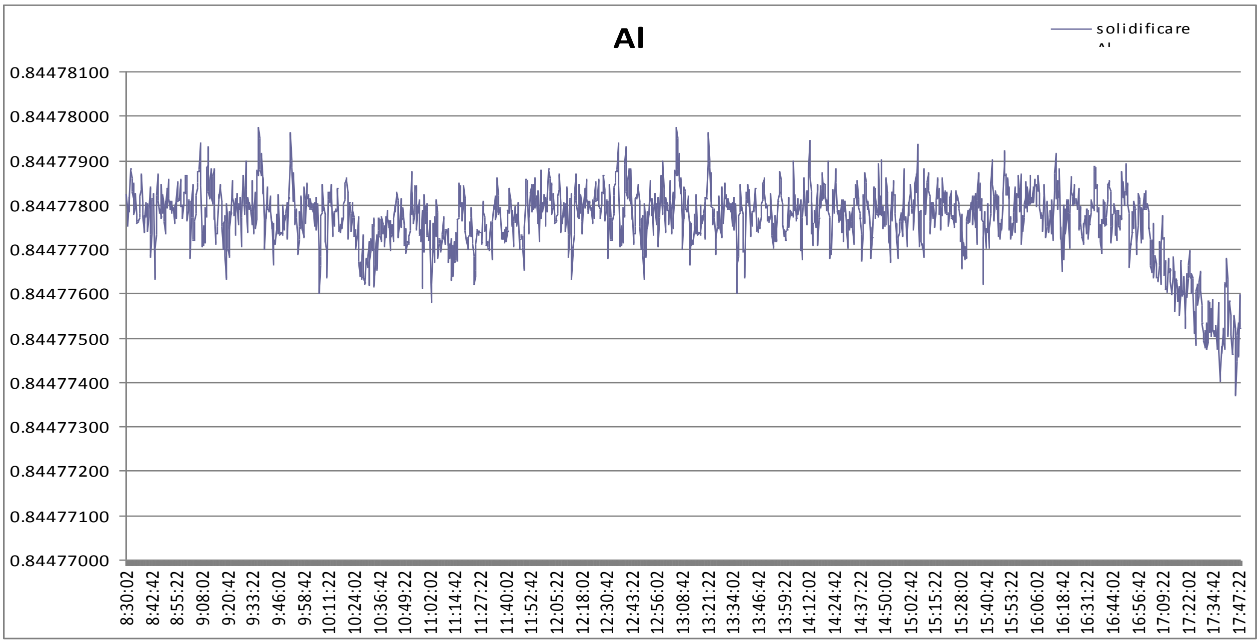
Uncertainty components	Al mK	Zn mK	Sn mK	In mK	Ga mK
Type A					
Repeatability of values,	0.96	0.29	0.22	0.29	0.042
Type B					
Component due to metal purity	0.45	0.2	0.2	0.200	0.07
Component due to the hydrostatic pressure correction	0.009	0.008	0.006	0.008	0.003
Component due to the self-heating correction	0.14	0.11	0.18	0.11	0.015
Component due to the deviation from heat equilibrium	0.16	0.070	0.060	0.07	0.02
Component due to the pressure in the cell,	0.012	0.006	0.005	0.006	0.003
Component due to the resistance bridge non-linearity	0.005	0.004	0.003	0.004	0.002
Component due to the reference resistance temperature	0.005	0.005	0.005	0.005	0.005
Component due to the uncertainty of TPW	0.327	0.228	0.158	0.131	0.088
Combined uncertainty	1.13	0.44	0.39	0.40	0.12
Expanded uncertainty (k=2)	2.26	0.88	0.78	0.80	0.24

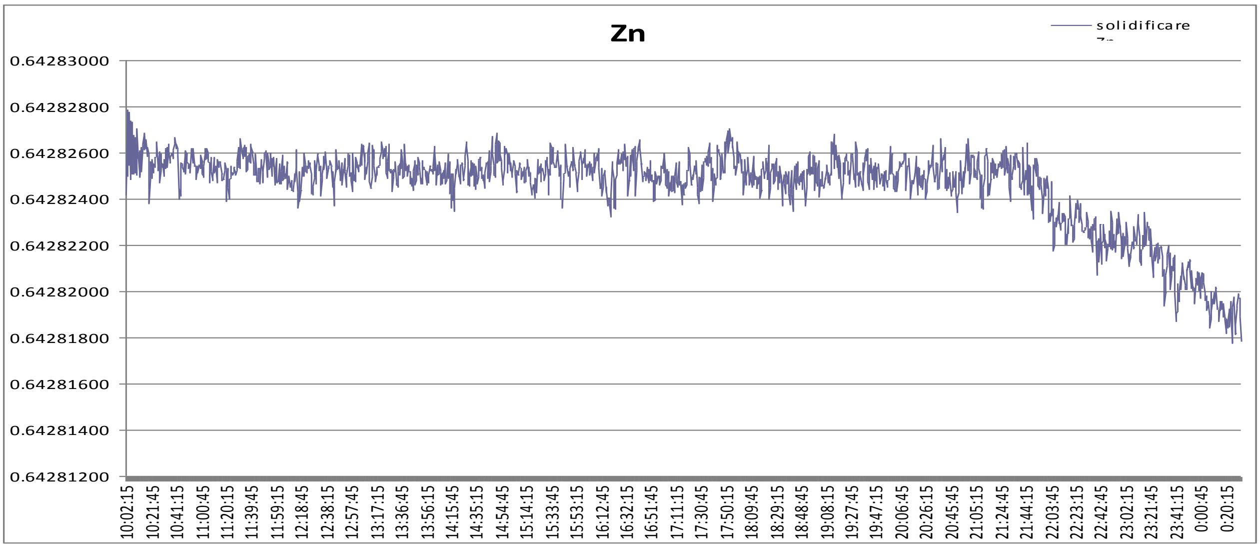
Component due to R_{tpw} measurement	mK
Type B	
Component due to the water purity and isotope composition	0.050
Component due to the hydrostatic pressure correction	0.002
Component due to the self-heating correction	0.017
Component due to the deviation from heat equilibrium	0.05
Component due to the resistance bridge non-linearity	0.029
Total uncertainty	0.078

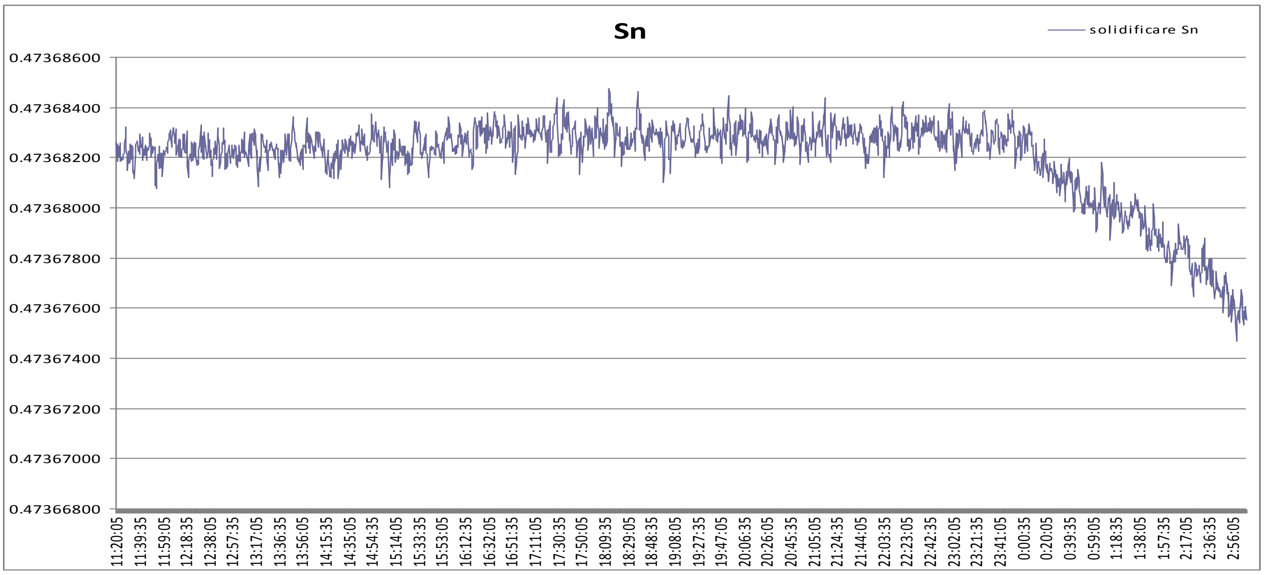
Appendix 4

Plateaus of the fixed points and immersion profiles

NIM



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0.47367200
0.47367000
0.47366800
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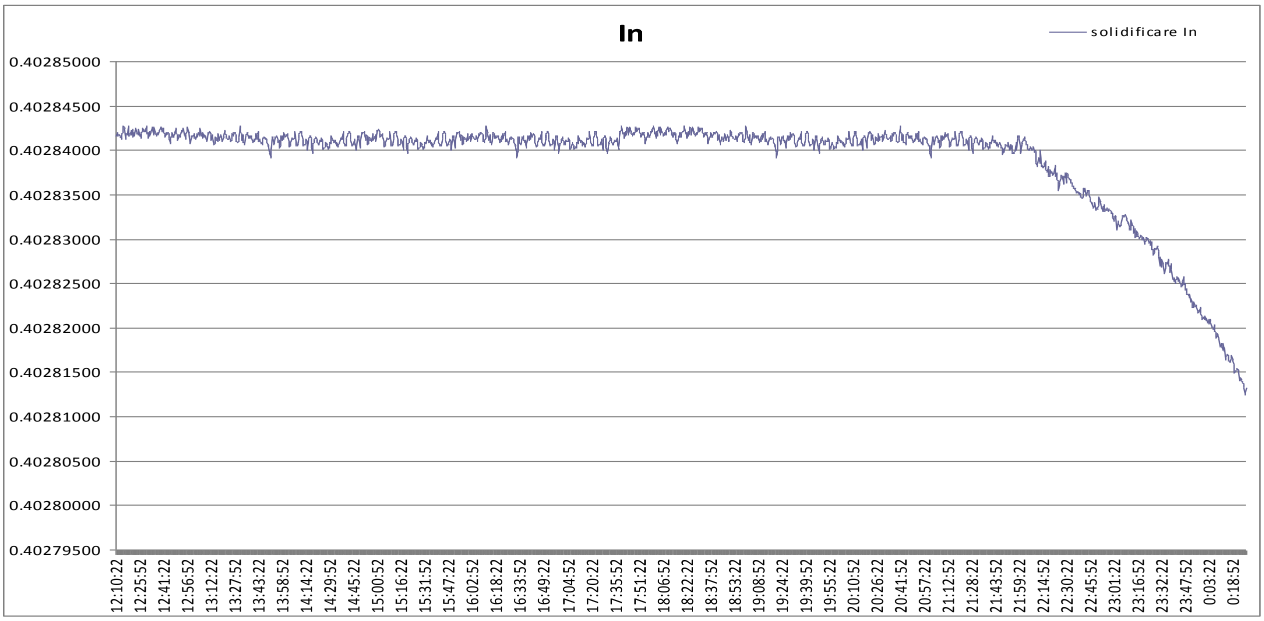
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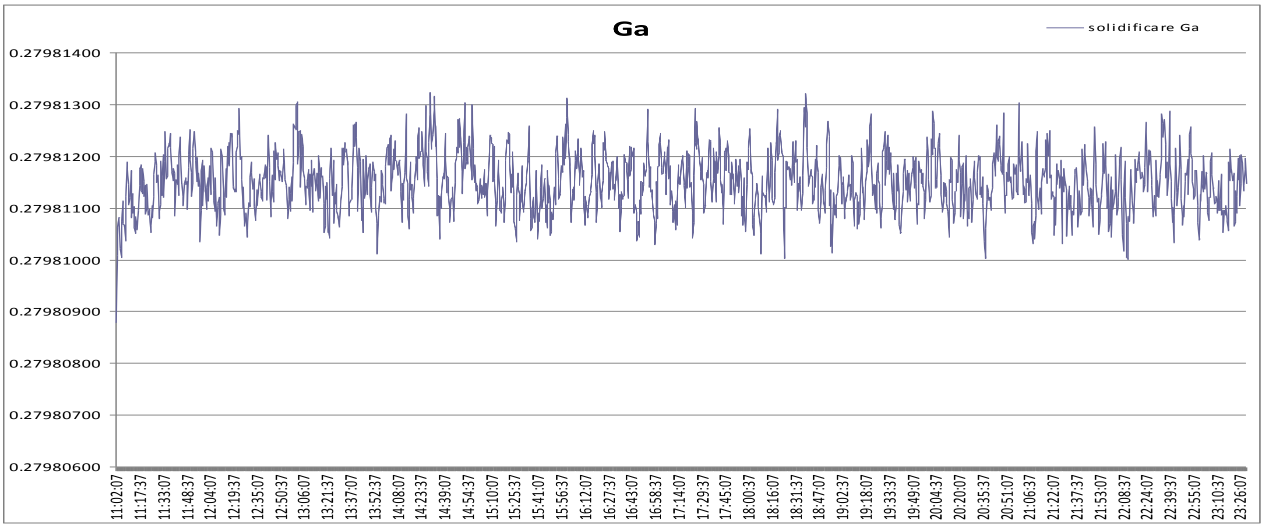
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0.27980600
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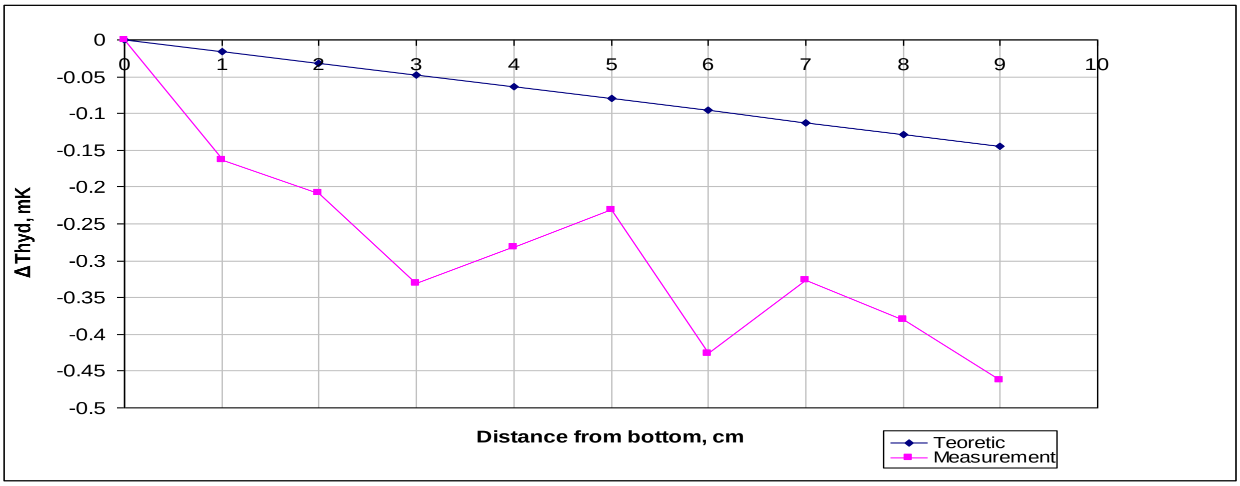
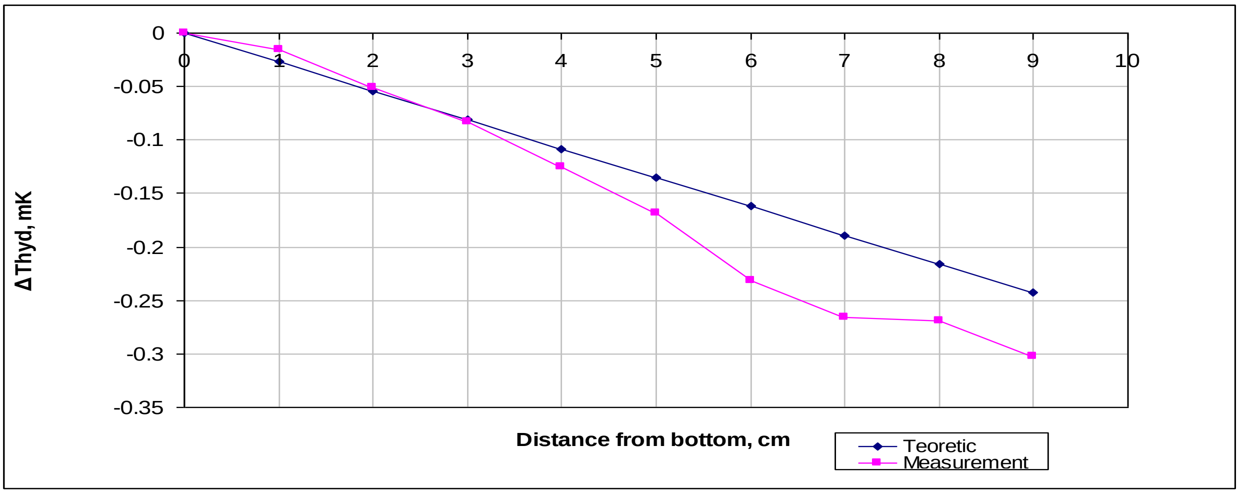
Al



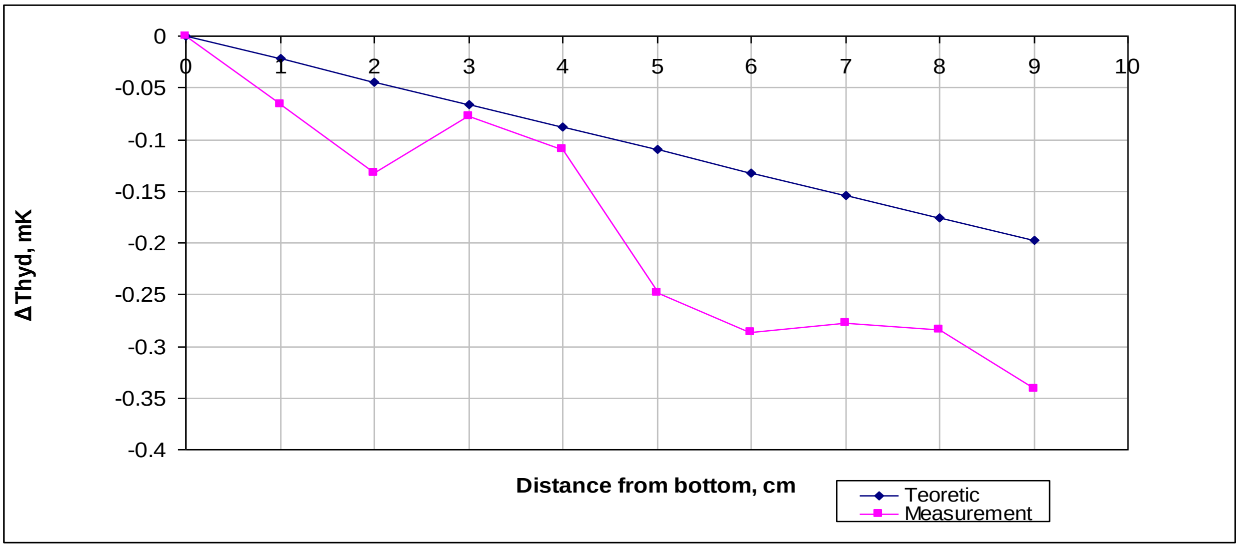
ΔThyd, mK
Distance from bottom, cm
Teoretic
Measurement

Zn



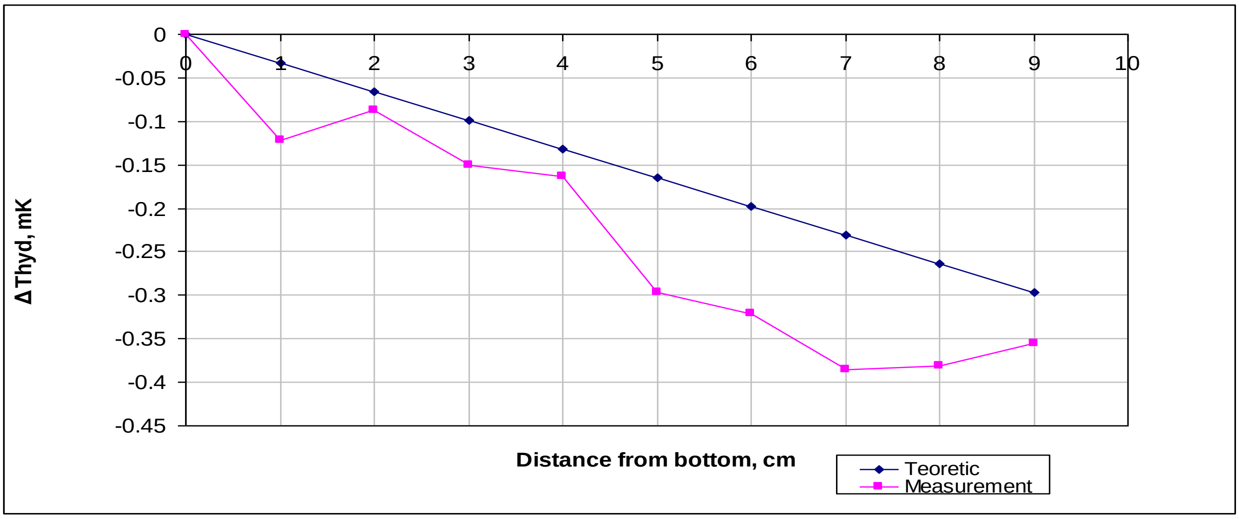
ΔThyd, mK
Distance from bottom, cm
Teoretic
Measurement

Sn



ΔThyd, mK
Distance from bottom, cm
Teoretic
Measurement

In



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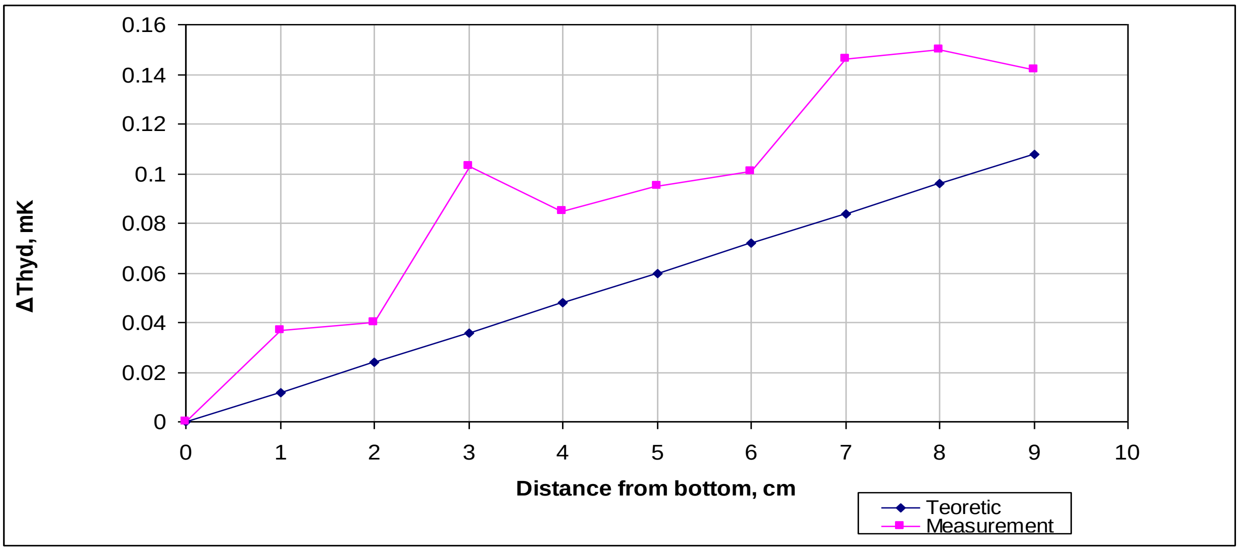
-0.2
-0.25
-0.3
-0.35
-0.4
-0.45
0 1 2 3 4 5 6 7 8 9 10
ΔThyd, mK
Distance from bottom, cm
Teoretic
Measurement

Ga



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0.14
0.12
0.1
0.08
0.06
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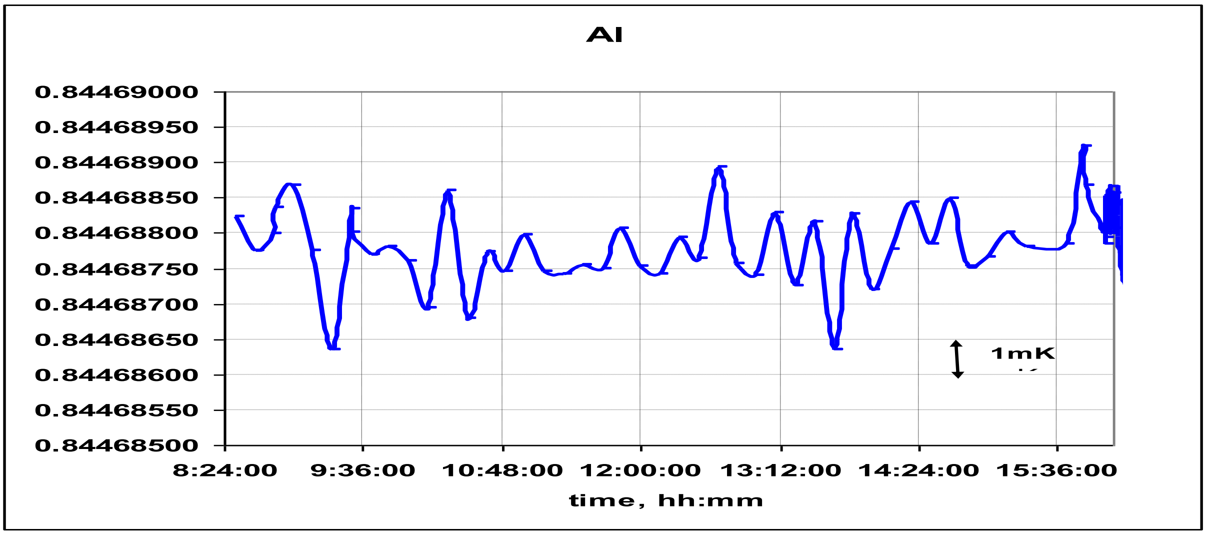
0.02
0
0 1 2 3 4 5 6 7 8 9 10
ΔThyd, mK
Distance from bottom, cm
Teoretic
Measurement

NSC IM



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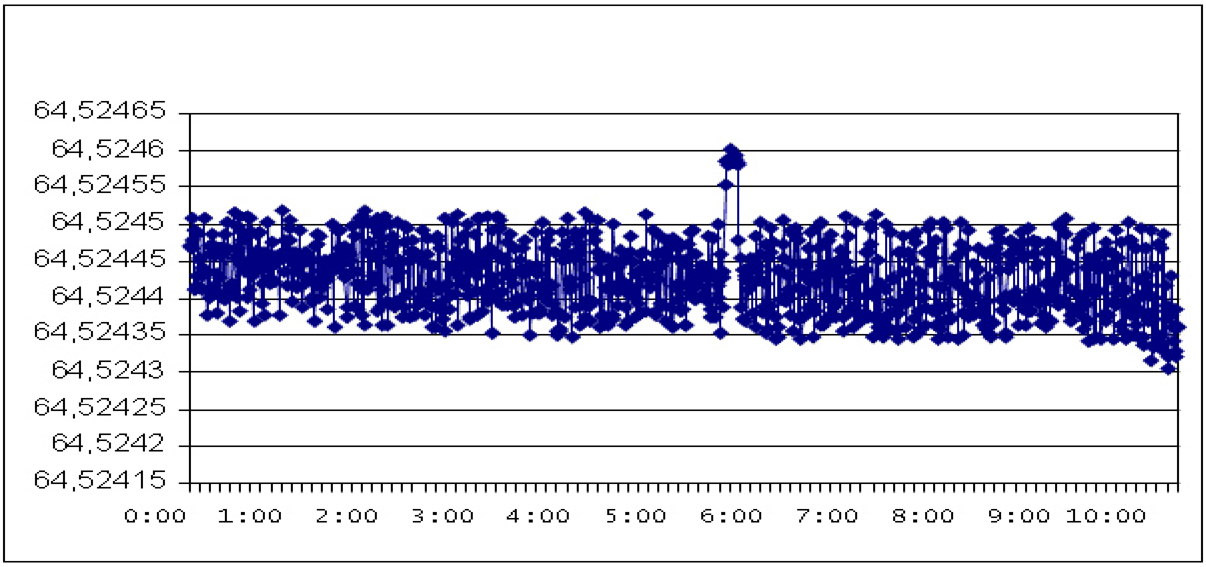
13:12:00
14:24:00
15:36:00
time, hh:mm

Zn



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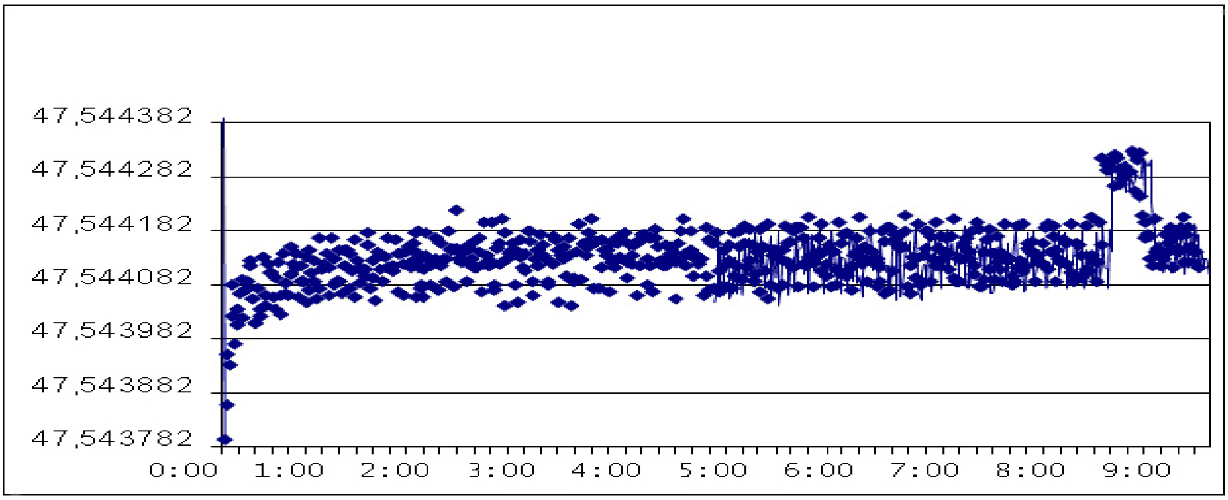
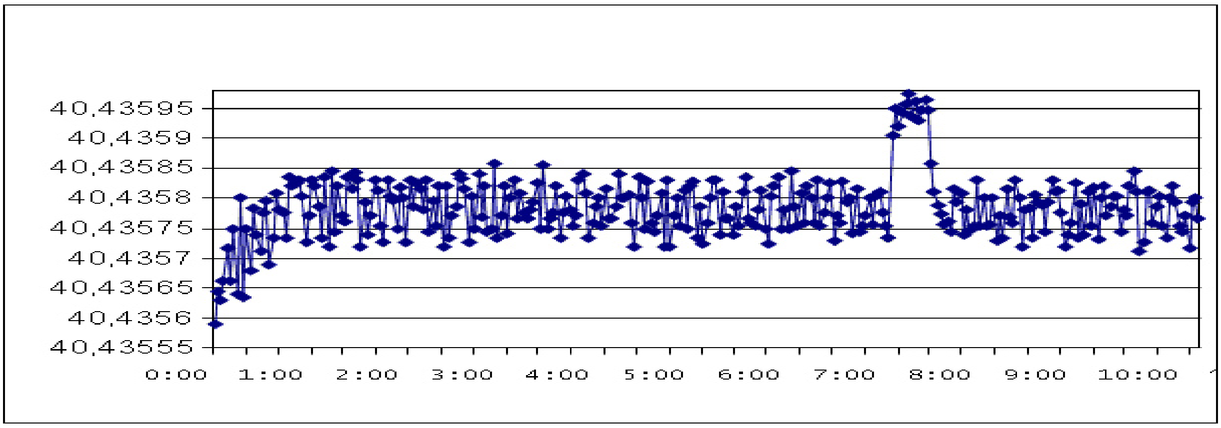
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00

Sn

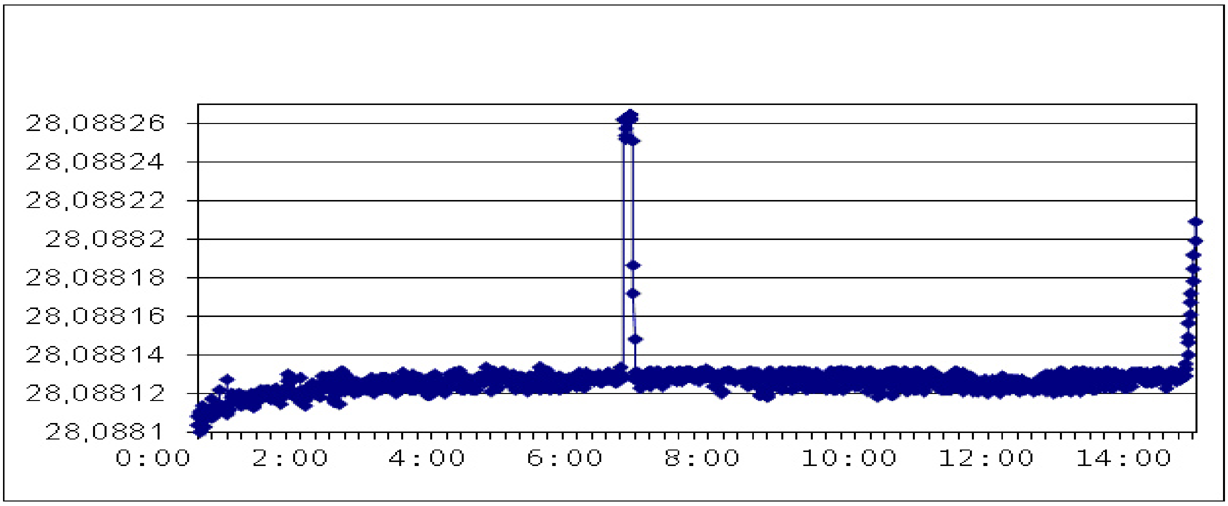


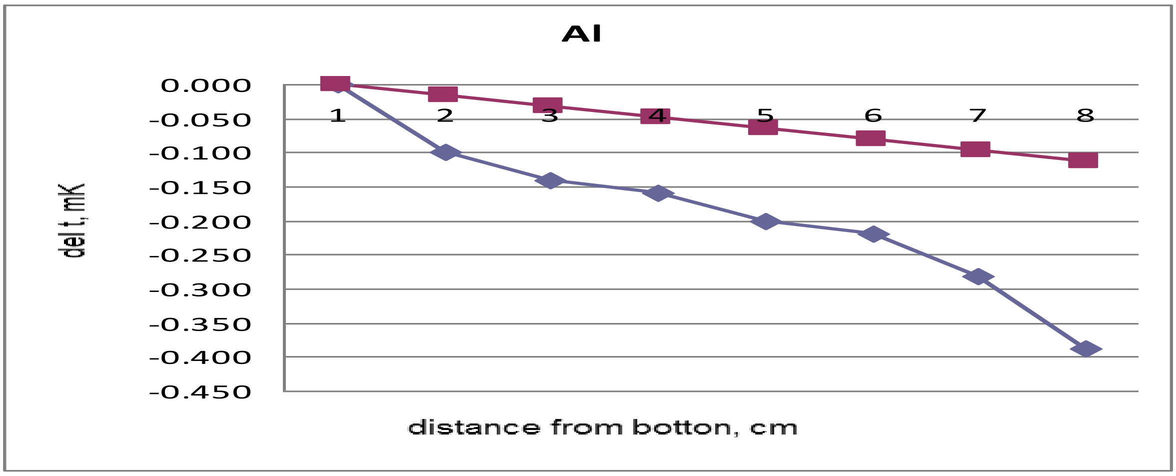
47,544382
47,544282
47,544182
47,544082
47,543982
47,543882
47,543782
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00

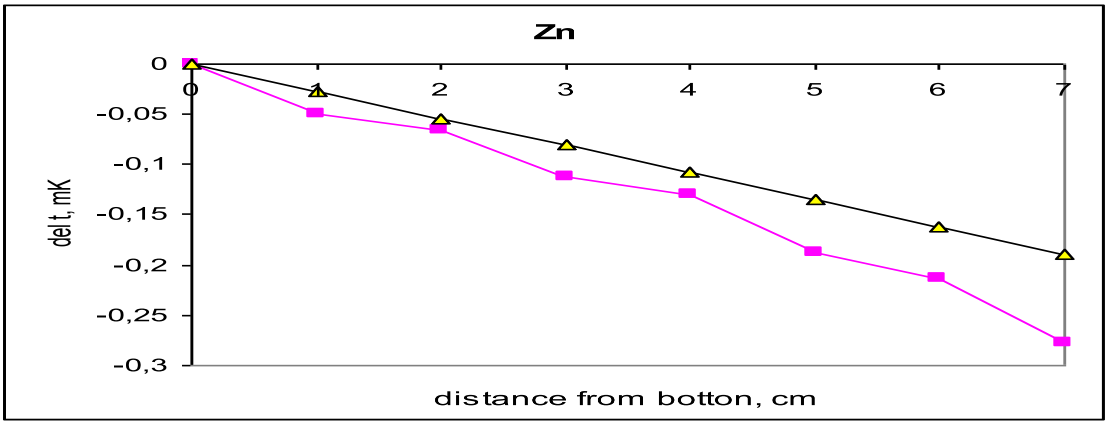
In

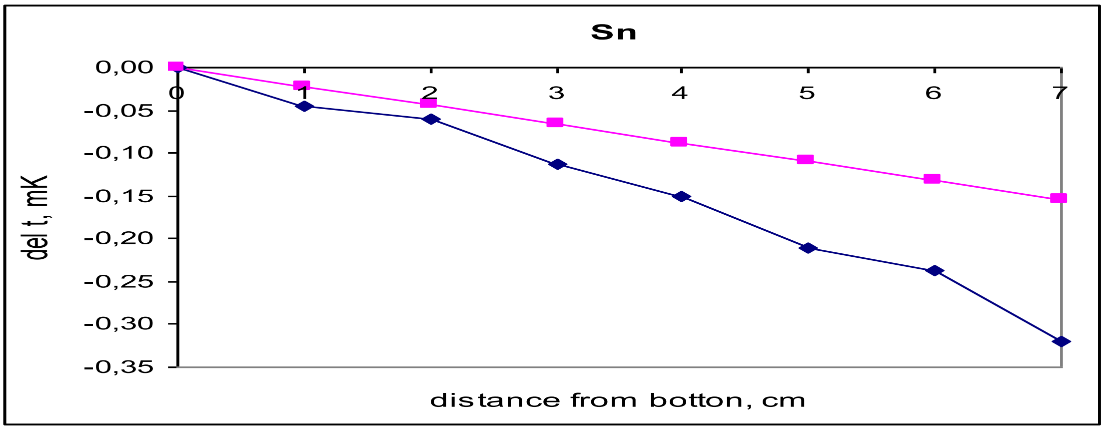

40,43595
40,4359
40,43585
40,4358
40,43575
40,4357
40,43565
40,4356
40,43555
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00

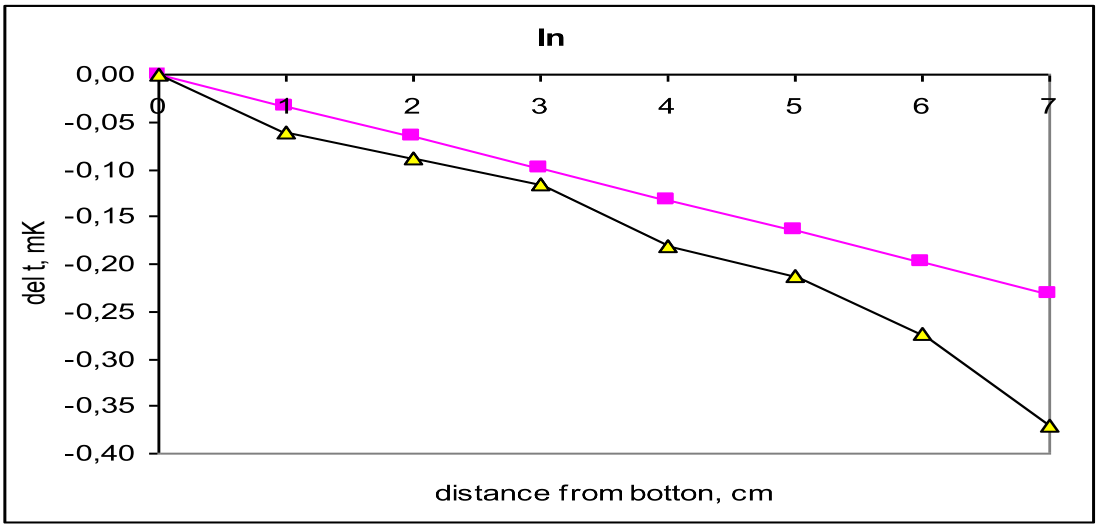
Ga

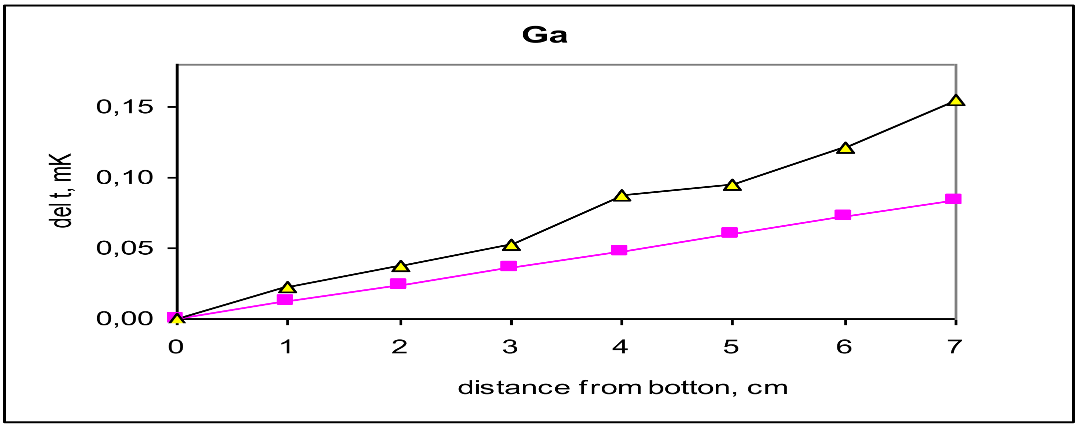

28,08826
28,08824
28,08822
28,0882
28,08818
28,08816
28,08814
28,08812
28,0881
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00


Al
0.000
-0.050
-0.100
-0.150
-0.200
-0.250
-0.300
-0.350
-0.400
-0.450
1
2
3
4
5
6
7
8
del t, mK
distance from botton, cm

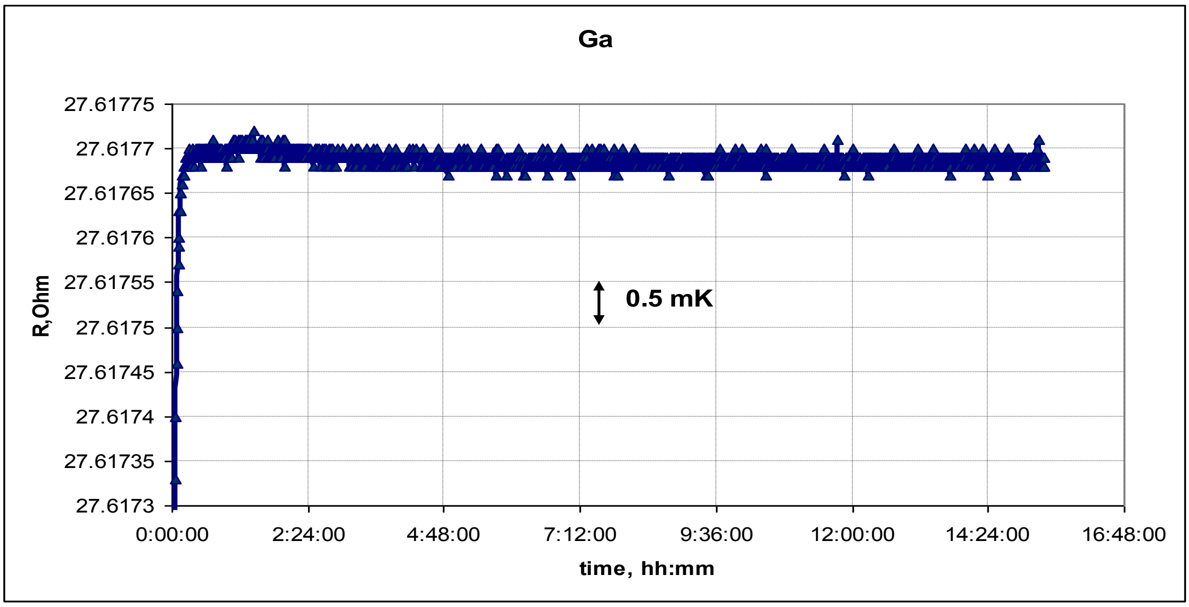

Zn
0
-0,05
-0,1
-0,15
-0,2
-0,25
-0,3
0 1 2 3 4 5 6 7
del t, mK
distance from botton, cm


Sn
0,00
-0,05
-0,10
-0,15
-0,20
-0,25
-0,30
-0,35
0 1 2 3 4 5 6 7
del t, mK
distance from botton, cm

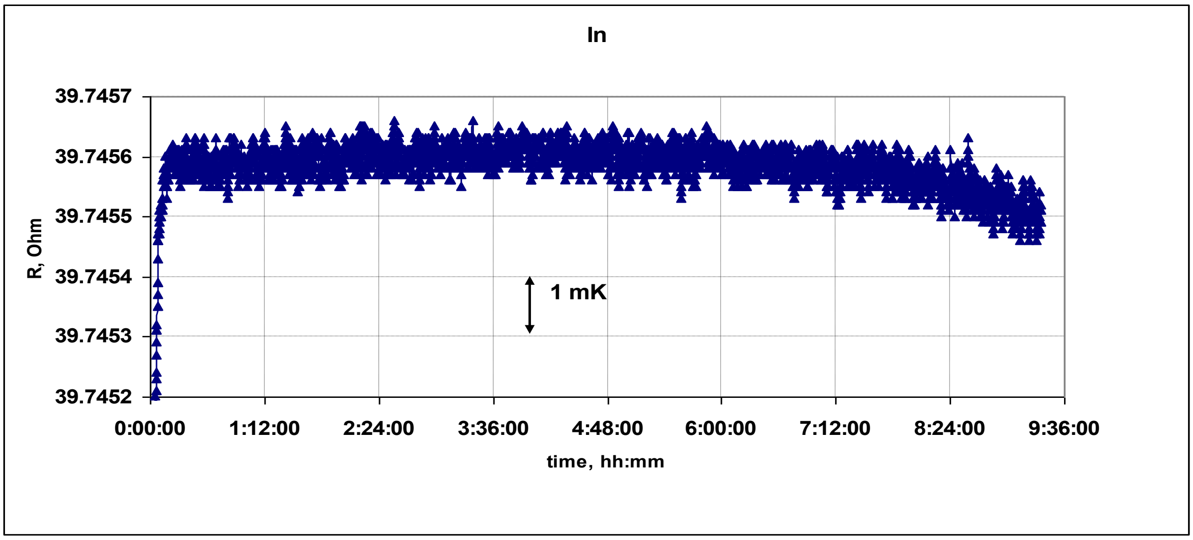

In
0,00
-0,05
-0,10
-0,15
-0,20
-0,25
-0,30
-0,35
-0,40
0 1 2 3 4 5 6 7
del t, mK
distance from botton, cm


Ga
0,15
0,10
0,05
0,00
0 1 2 3 4 5 6 7
del t, mK
distance from botton, cm

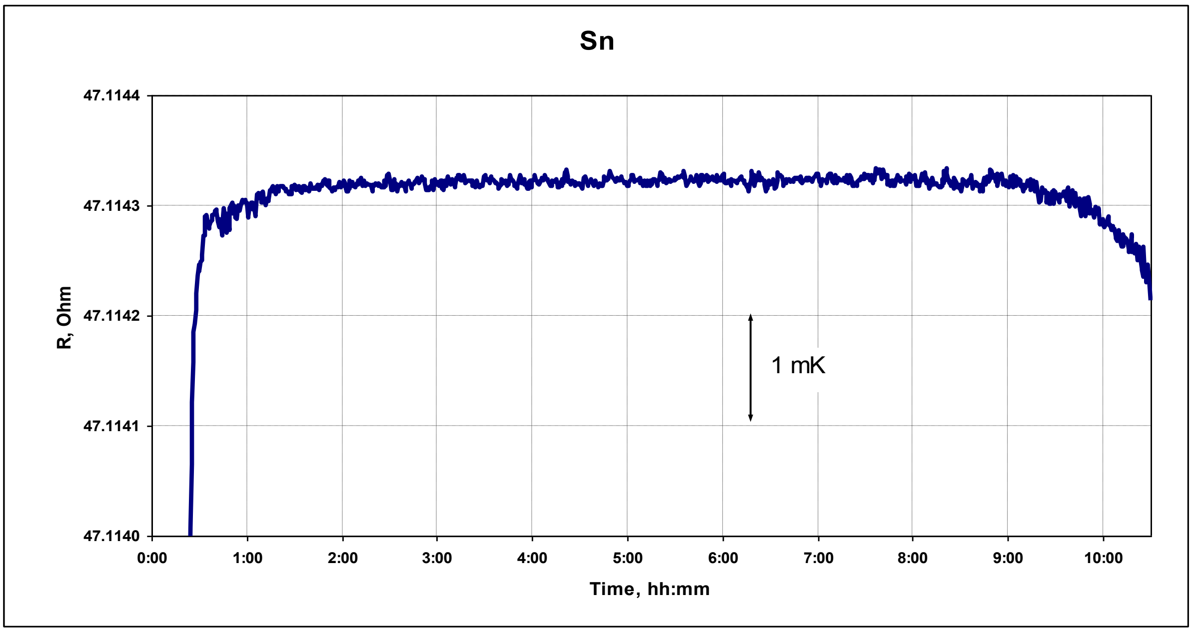
VNIIM



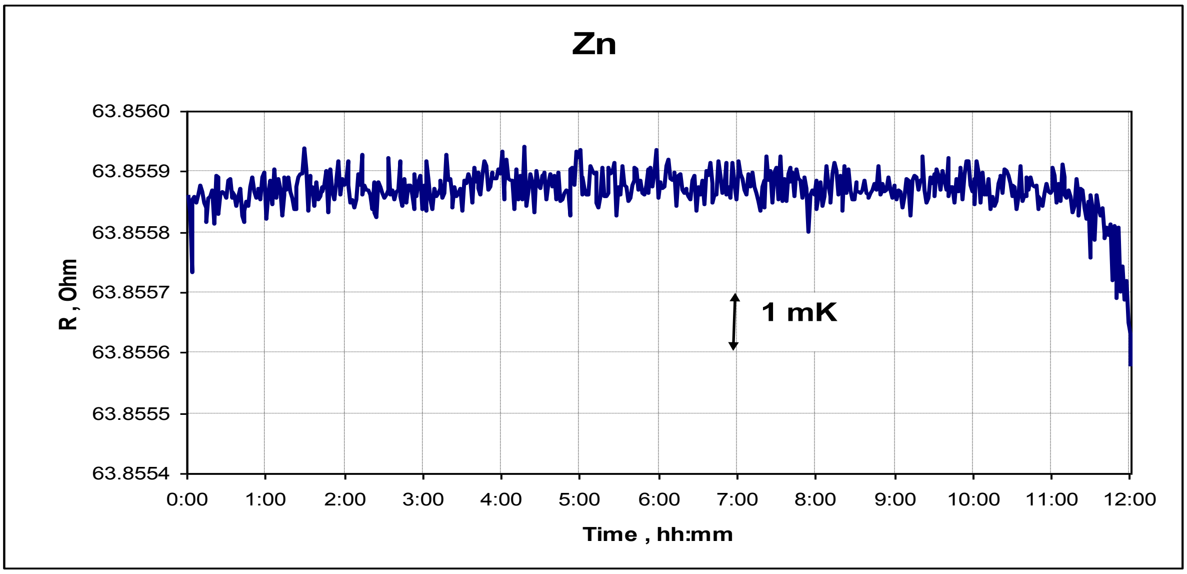
Ga
27.61775
27.6177
27.61765
27.6176
27.61755
27.6175
27.61745
27.6174
27.61735
27.6173
R,Ohm
0.5 mK
0:00:00
2:24:00
4:48:00
7:12:00
9:36:00
12:00:00
14:24:00
16:48:00
time, hh:mm

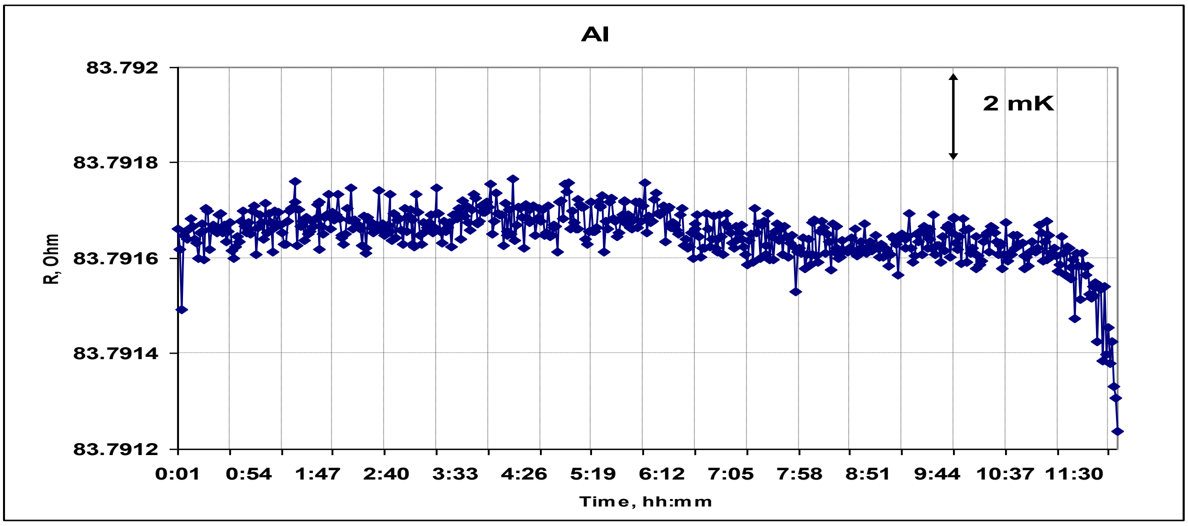


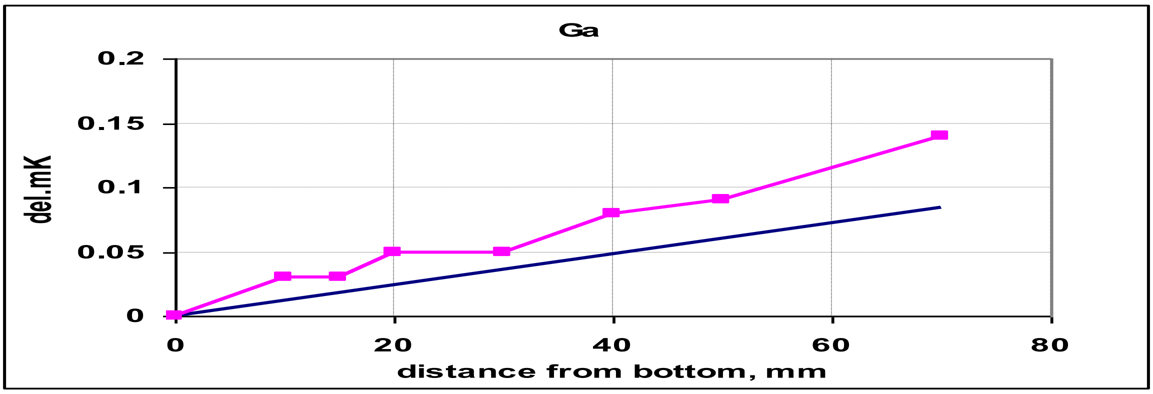
In
39.7457
39.7456
39.7455
39.7454
39.7453
39.7452
R, Ohm
1 mK
0:00:00
1:12:00
2:24:00
3:36:00
4:48:00
6:00:00
7:12:00
8:24:00
9:36:00
time, hh:mm

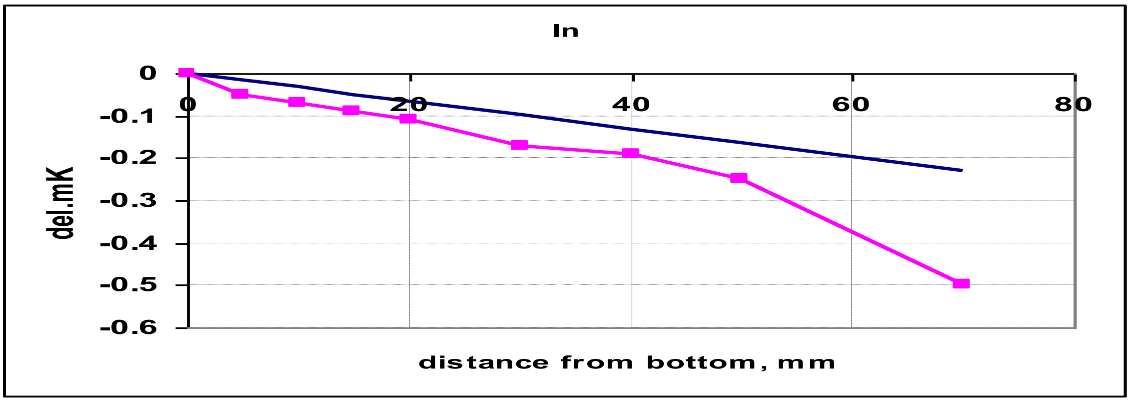


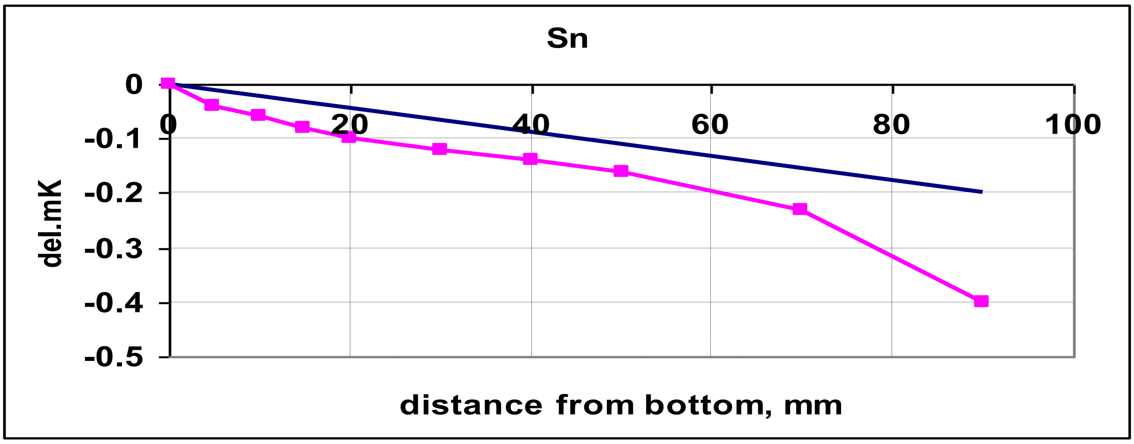
Sn
47.1144
47.1143
47.1142
47.1141
47.1140
R, Ohm
1 mK
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
Time, hh:mm

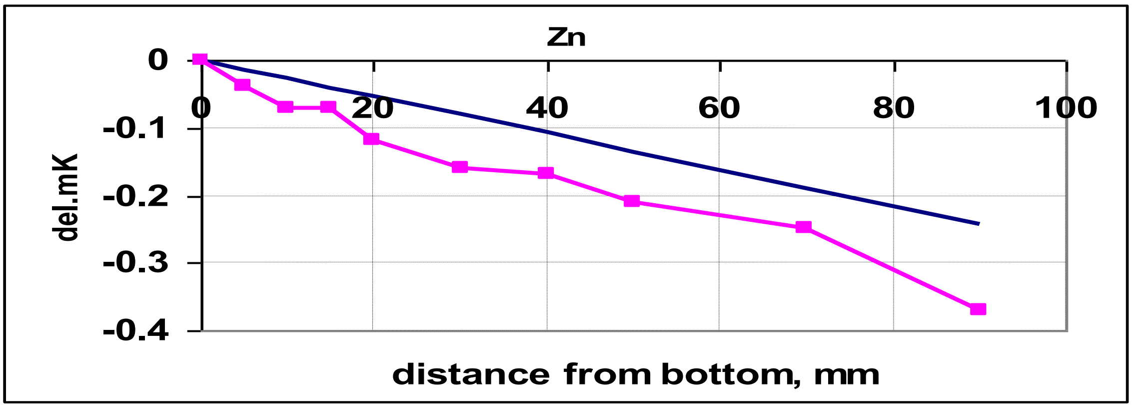

Zn
63.8560
63.8559
63.8558
63.8557
63.8556
63.8555
63.8554
R , Ohm
1 mK
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
Time , hh:mm

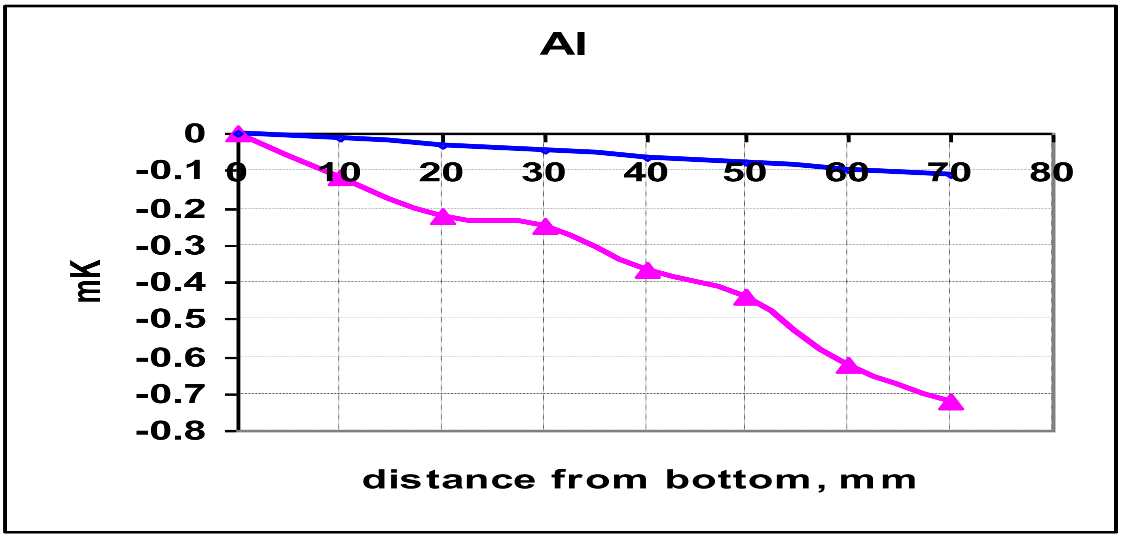

Al
83.792
83.7918
83.7916
83.7914
83.7912
R, Ohm
2 mK
0:01
0:54
1:47
2:40
3:33
4:26
5:19
6:12
7:05
7:58
8:51
9:44
10:37
11:30
Time, hh:mm


Ga
0.2
0.15
0.1
0.05
0
del.mK
0
20
40
60
80
distance from bottom, mm

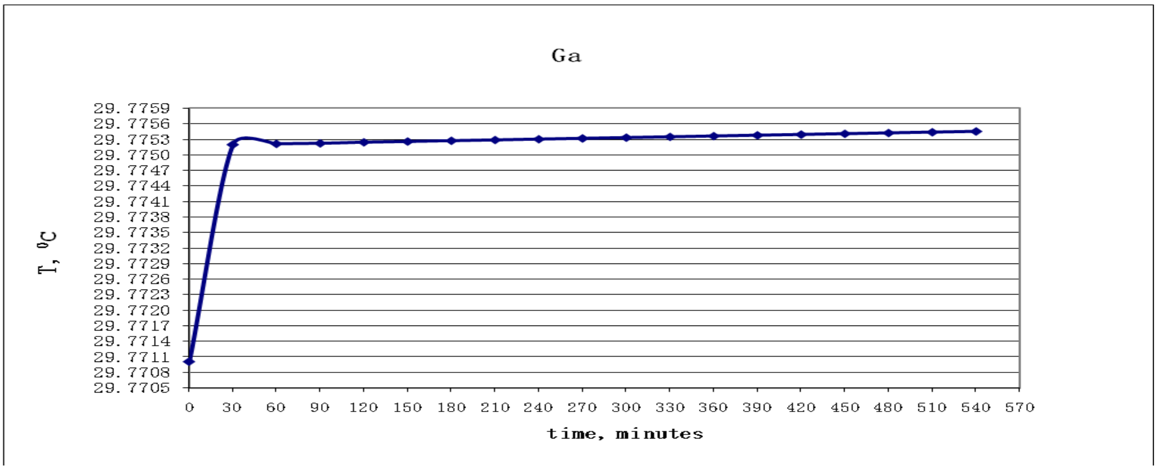

In
del.mK
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
0
20
40
60
80
distance from bottom, mm

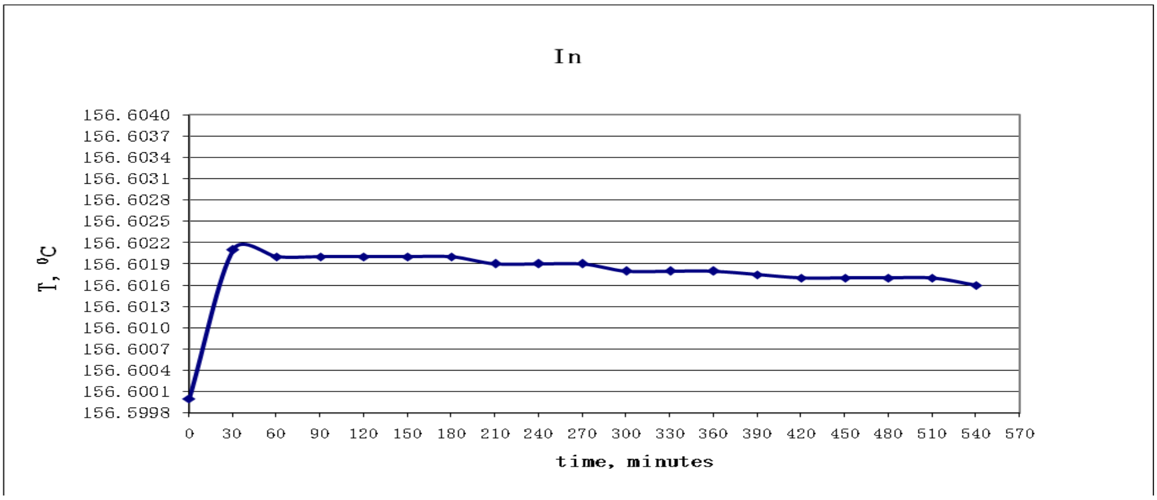

Sn
del.mK
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
20
40
60
80
100
distance from bottom, mm

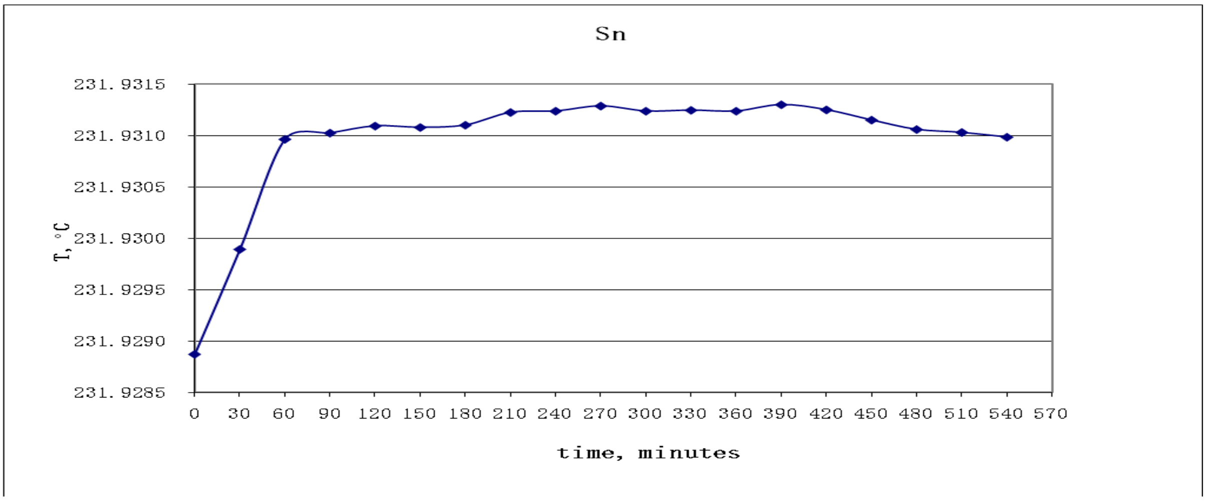

Zn
del.mK
0
-0.1
-0.2
-0.3
-0.4
0
20
40
60
80
100
distance from bottom, mm

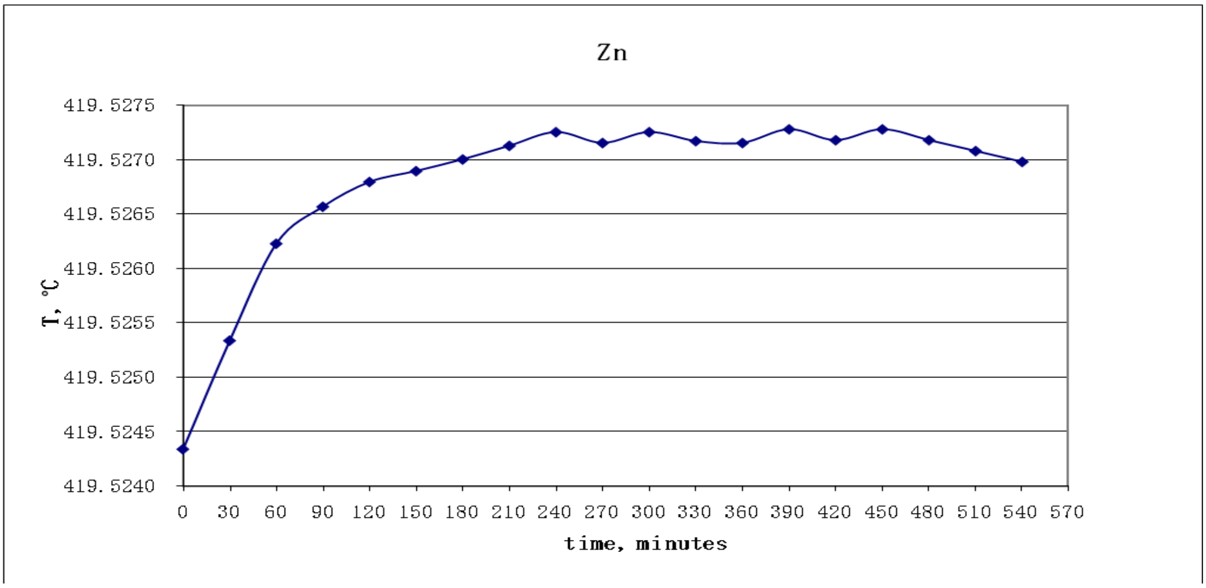

Al
mK
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
0
10
20
30
40
50
60
70
80
distance from bottom, mm

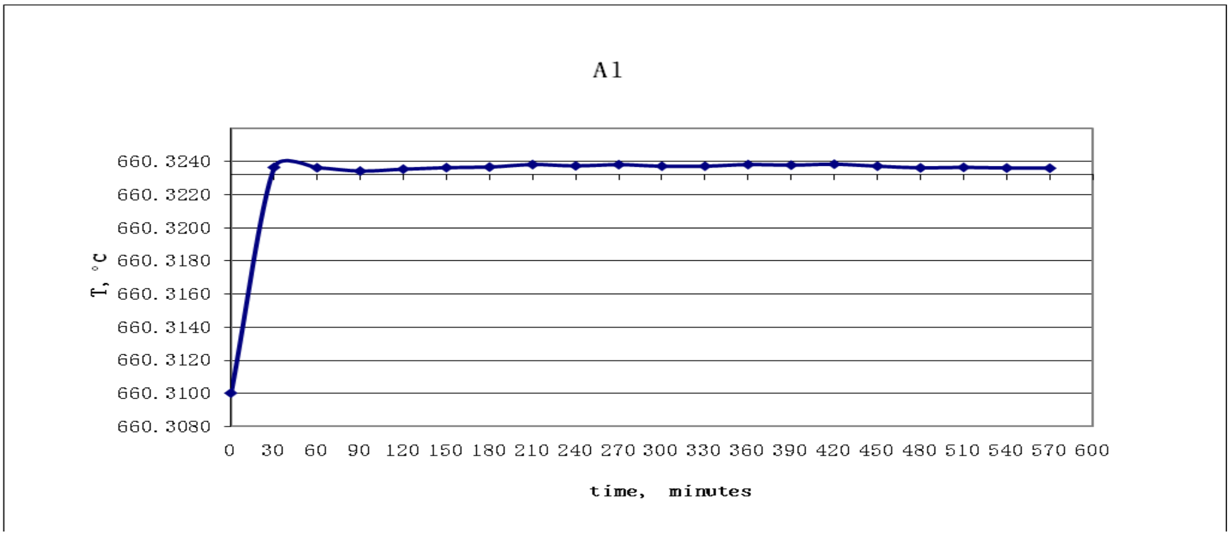
BelGIM

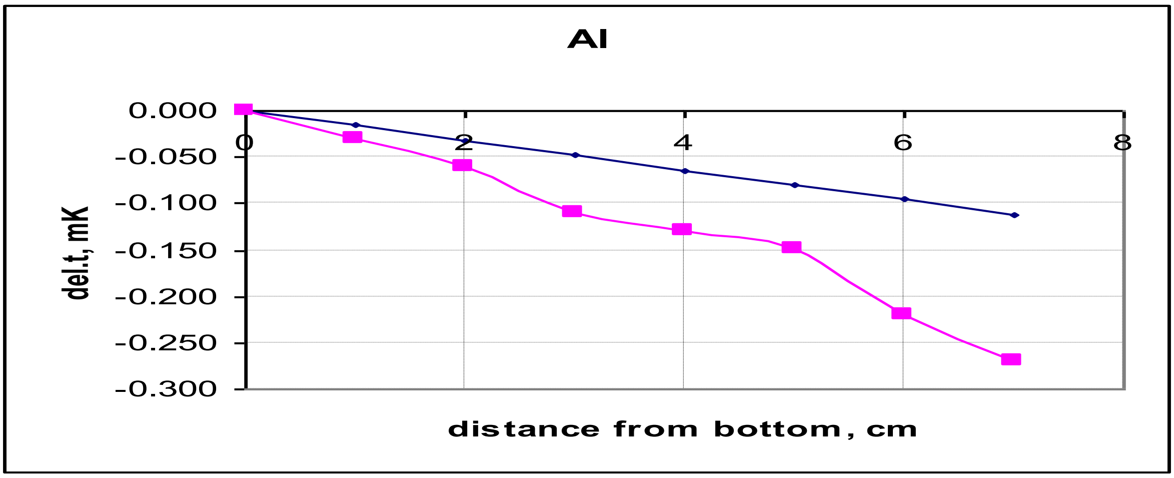

Ga
T, °C
29.7759
29.7756
29.7753
29.7750
29.7747
29.7744
29.7741
29.7738
29.7735
29.7732
29.7729
29.7726
29.7723
29.7720
29.7717
29.7714
29.7711
29.7708
29.7705
0 30 60 90 120 150 180 210 240 270 300 330 360 390 420 450 480 510 540 570
time, minutes

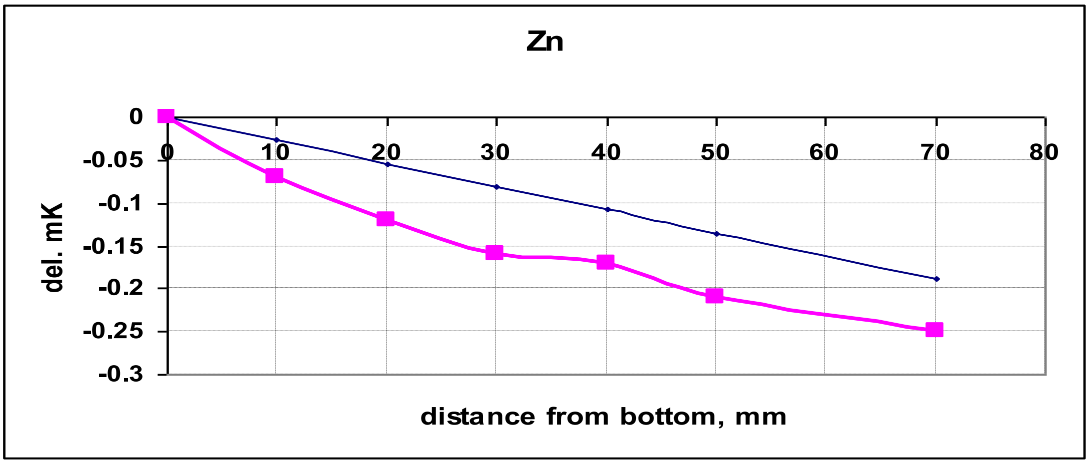

In
T, °C
156.6040
156.6037
156.6034
156.6031
156.6028
156.6025
156.6022
156.6019
156.6016
156.6013
156.6010
156.6007
156.6004
156.6001
156.5998
0 30 60 90 120 150 180 210 240 270 300 330 360 390 420 450 480 510 540 570
time, minutes

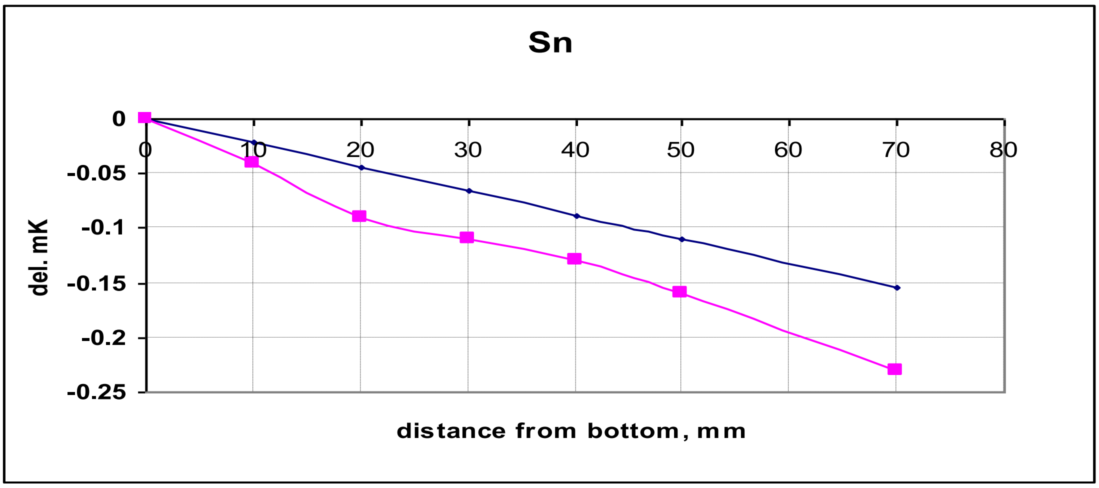

Sn
T, °C
231.9315
231.9310
231.9305
231.9300
231.9295
231.9290
231.9285
0 30 60 90 120 150 180 210 240 270 300 330 360 390 420 450 480 510 540 570
time, minutes

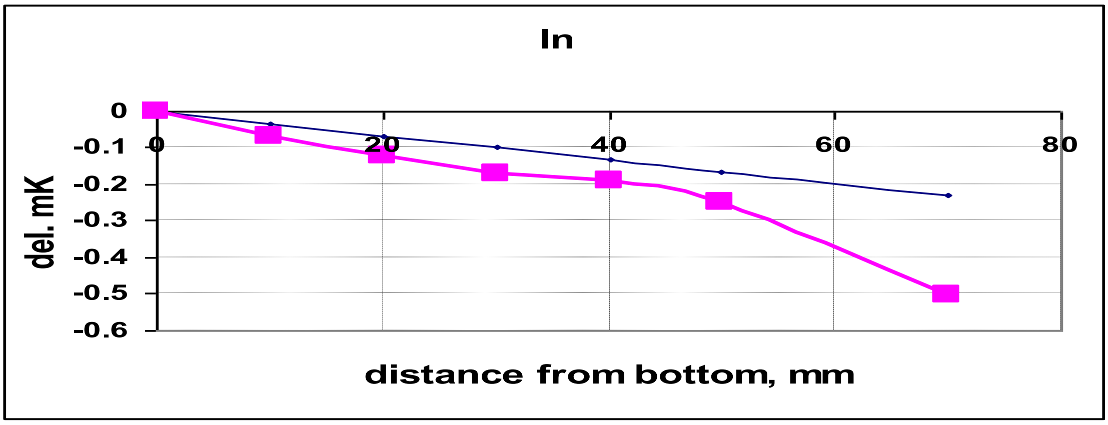

Zn
419.5275
419.5270
419.5265
419.5260
419.5255
419.5250
419.5245
419.5240
T, °C
0 30 60 90 120 150 180 210 240 270 300 330 360 390 420 450 480 510 540 570
time, minutes

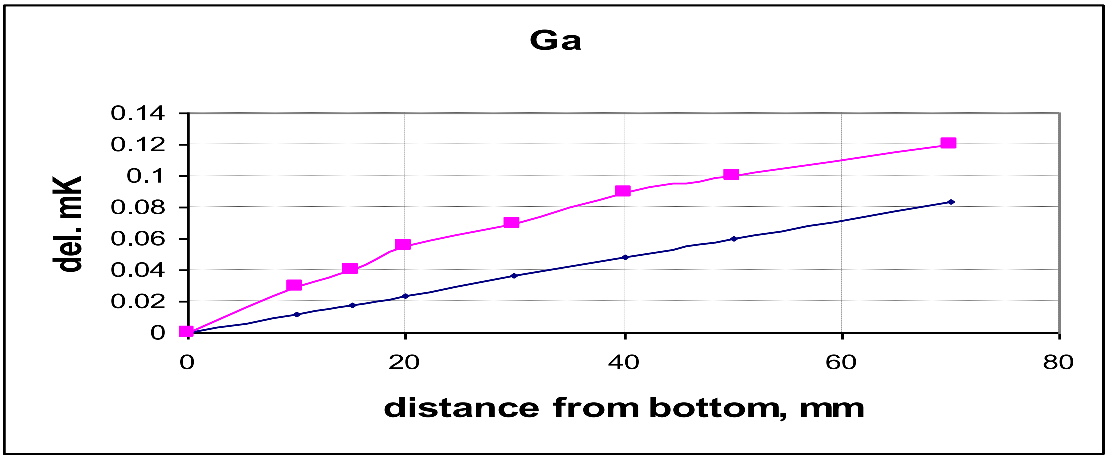

Al
660.3240
660.3220
660.3200
660.3180
660.3160
660.3140
660.3120
660.3100
660.3080
T, °c
0 30 60 90 120 150 180 210 240 270 300 330 360 390 420 450 480 510 540 570 600
time, minutes


Al
0.000
-0.050
-0.100
-0.150
-0.200
-0.250
-0.300
del.t, mK
0 2 4 6 8
distance from bottom, cm

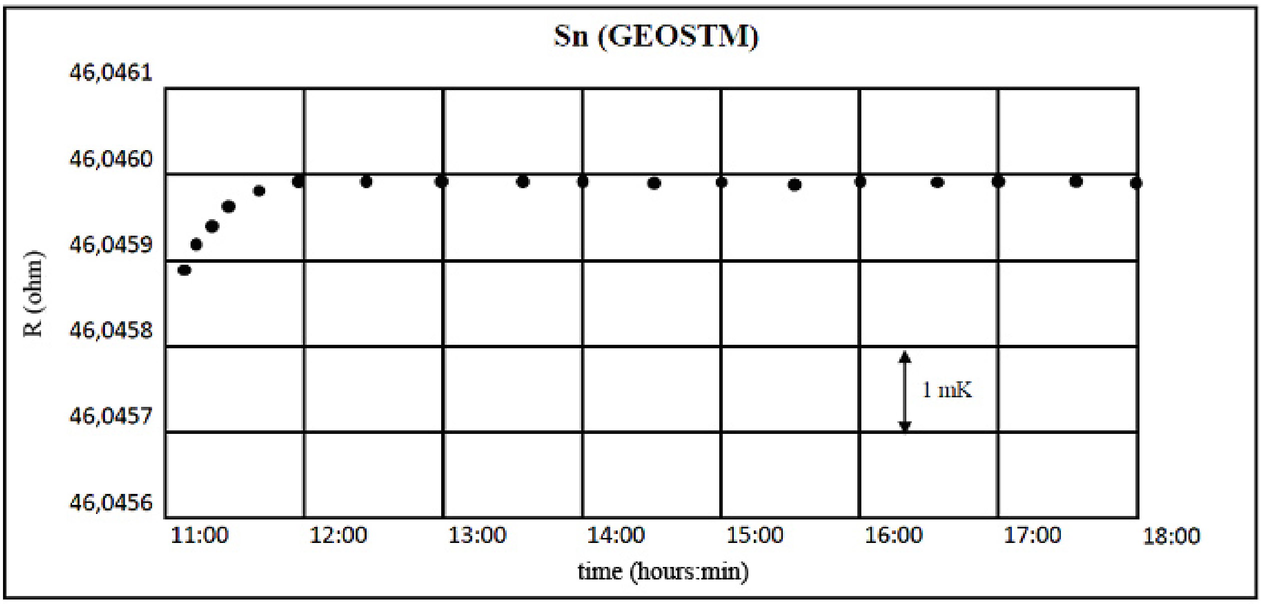

Zn
del. mK
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
0
10
20
30
40
50
60
70
80
distance from bottom, mm


Sn
del. mK
0
-0.05
-0.1
-0.15
-0.2
-0.25
0
10
20
30
40
50
60
70
80
distance from bottom, mm

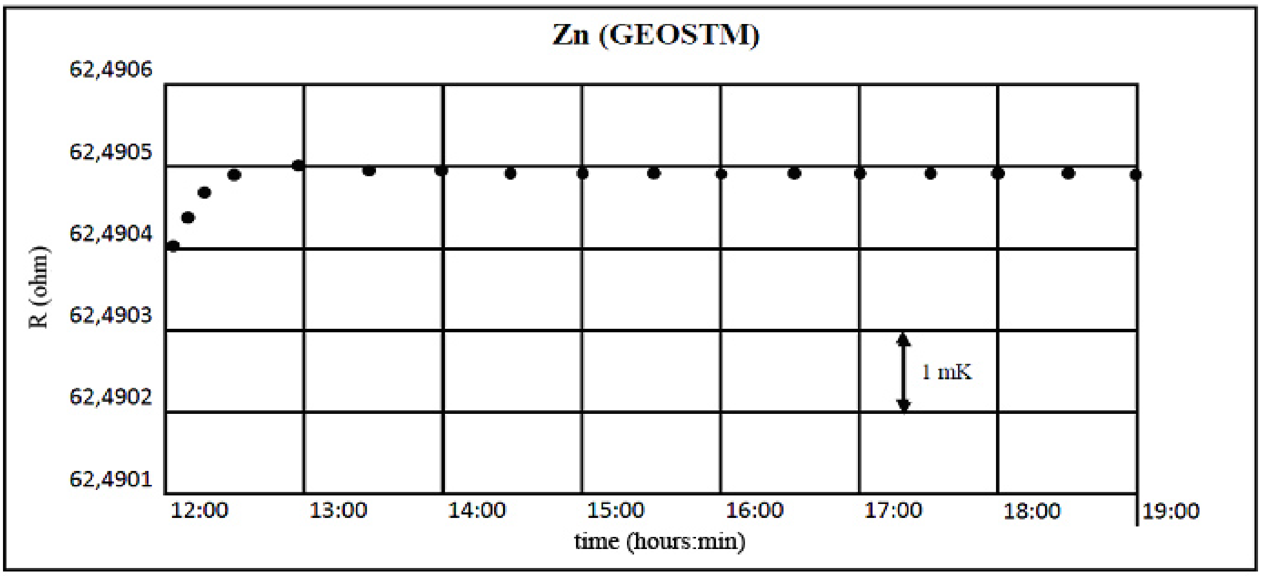

In
del. mK
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
0
20
40
60
80
distance from bottom, mm


Ga
del. mK
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
20
40
60
80
distance from bottom, mm

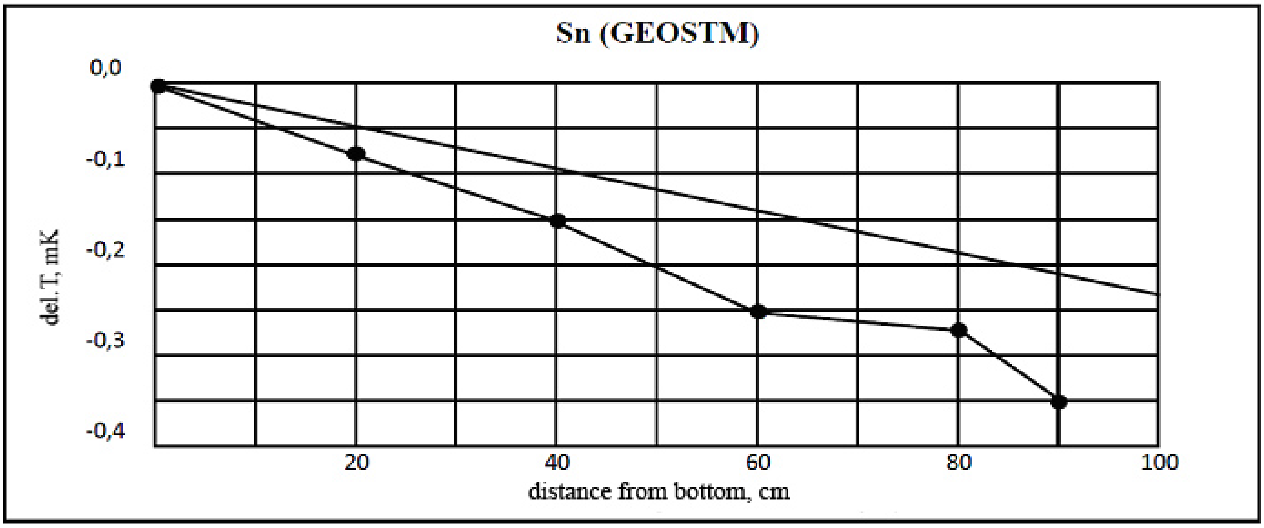
GEOSTM



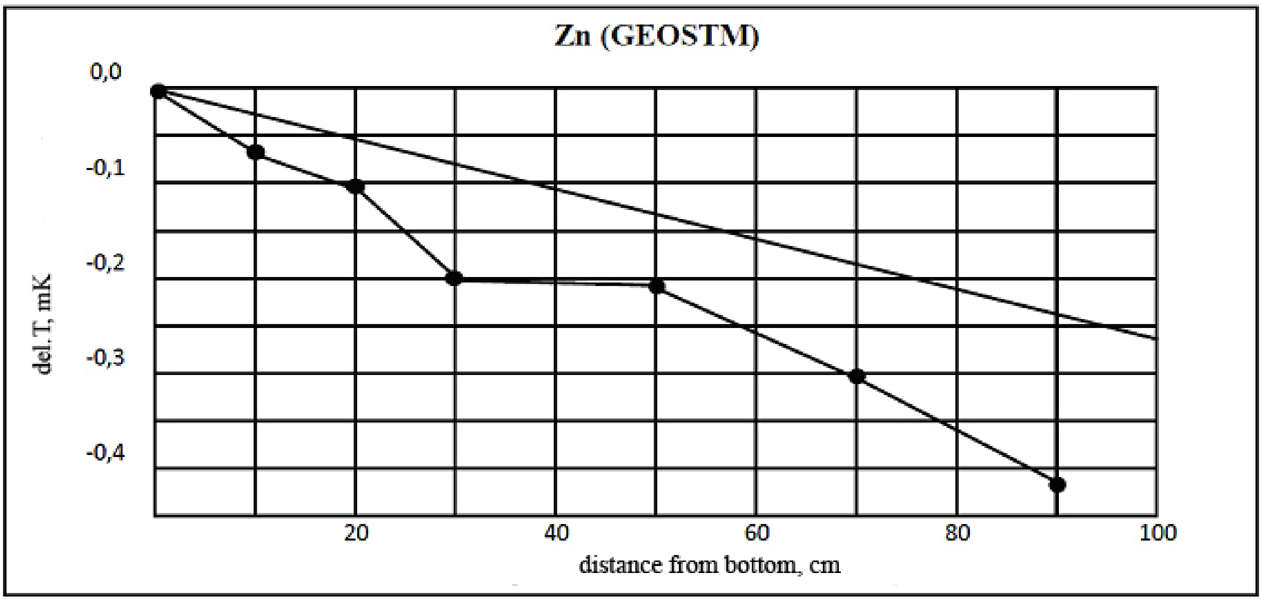
Sn (GEOSTM)
46,0461
46,0460
46,0459
46,0458
46,0457
46,0456
R (ohm)
1 mK
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
time (hours:min)



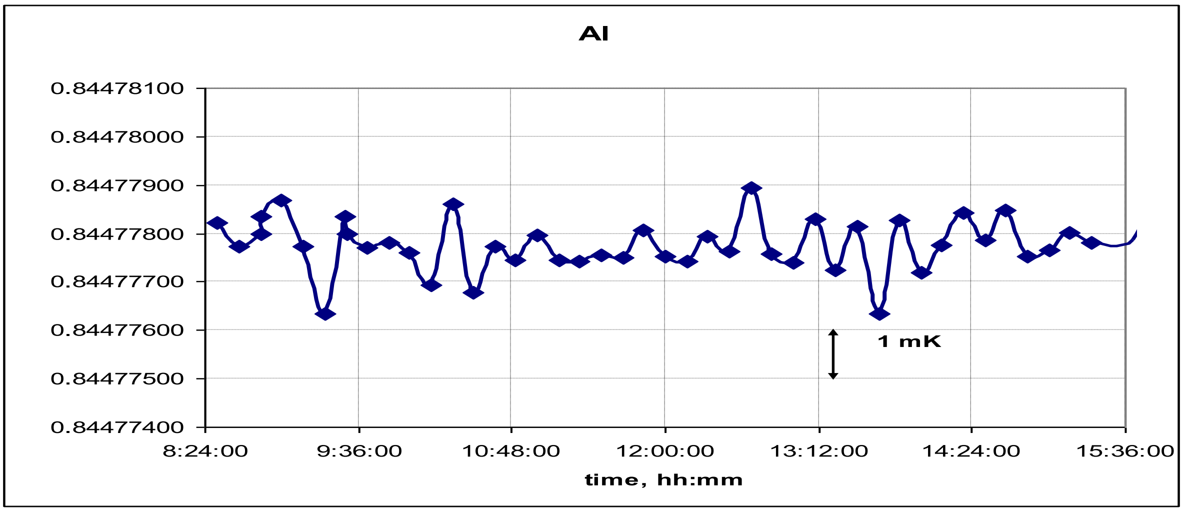
Zn (GEOSTM)
62,4906
62,4905
62,4904
62,4903
62,4902
62,4901
R (ohm)
1 mK
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
time (hours:min)



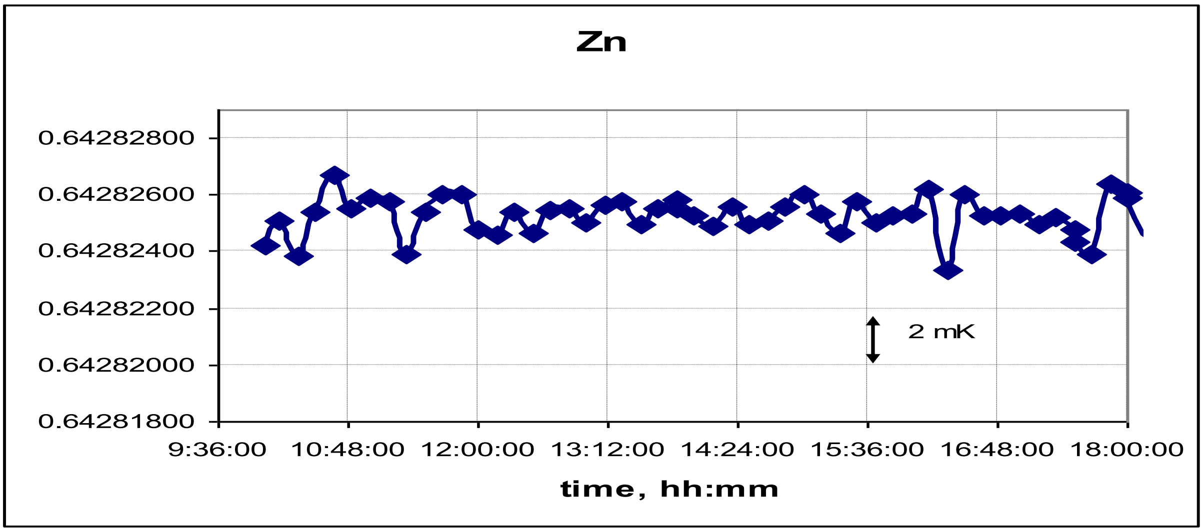
Sn (GEOSTM)
0,0
-0,1
-0,2
-0,3
-0,4
del.T, mK
20
40
60
80
100
distance from bottom, cm


Zn (GEOSTM)
0,0
-0,1
-0,2
-0,3
-0,4
del.T, mK
20
40
60
80
100
distance from bottom, cm

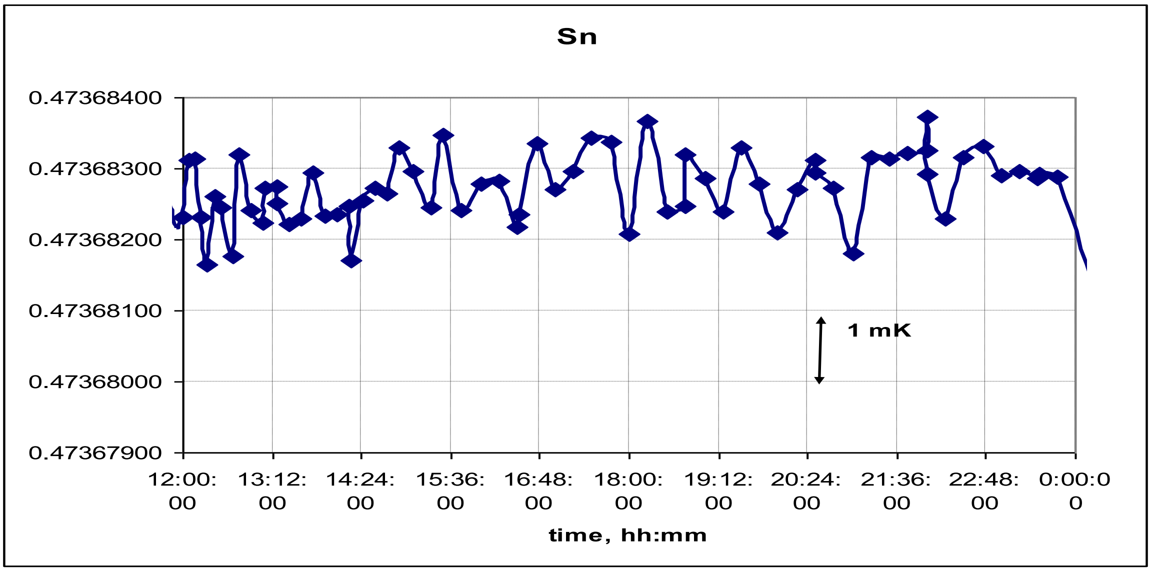
KazInMetr



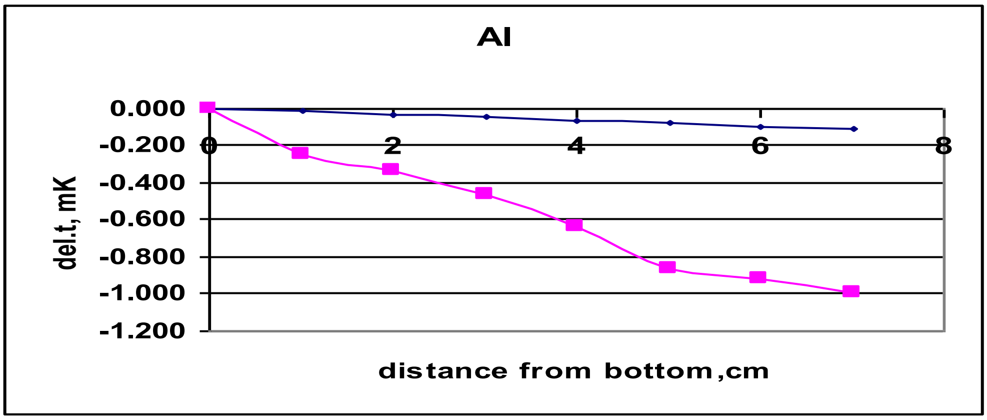
Al
0.84478100
0.84478000
0.84477900
0.84477800
0.84477700
0.84477600
0.84477500
0.84477400
8:24:00
9:36:00
10:48:00
12:00:00
13:12:00
14:24:00
15:36:00
time, hh:mm
1 mK

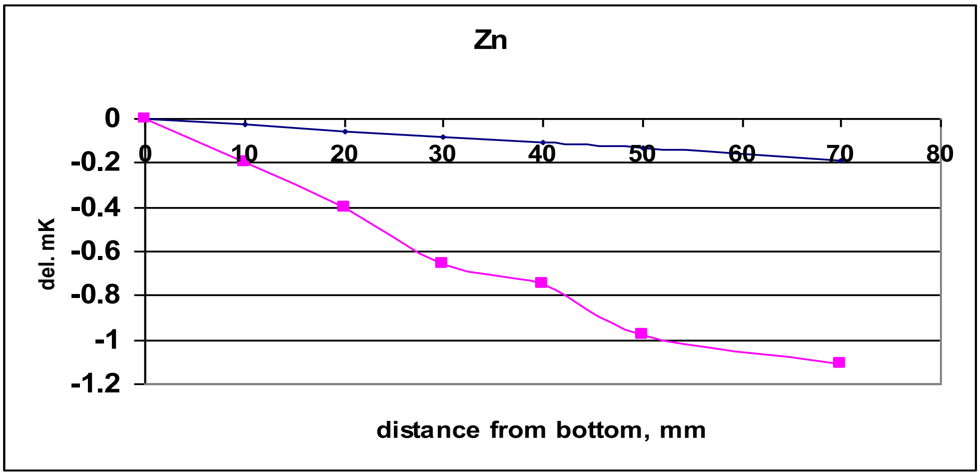


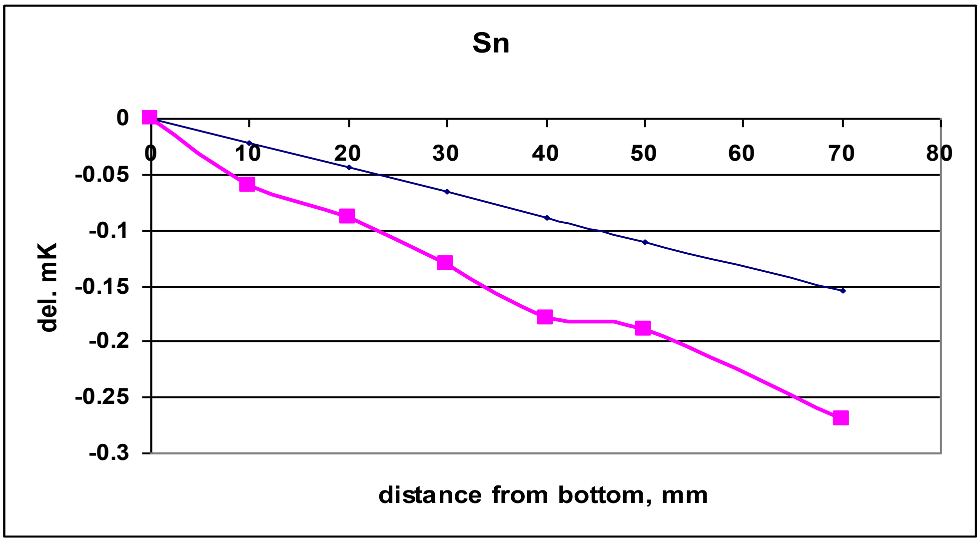
Zn
0.64282800
0.64282600
0.64282400
0.64282200
0.64282000
0.64281800
9:36:00
10:48:00
12:00:00
13:12:00
14:24:00
15:36:00
16:48:00
18:00:00
time, hh:mm
2 mK



Sn
0.47368400
0.47368300
0.47368200
0.47368100
0.47368000
0.47367900
12:00:00
13:12:00
14:24:00
15:36:00
16:48:00
18:00:00
19:12:00
20:24:00
21:36:00
22:48:00
0:00:00
time, hh:mm
1 mK


Al
0.000
-0.200
-0.400
-0.600
-0.800
-1.000
-1.200
0
2
4
6
8
del.t, mK
distance from bottom,cm


Zn
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
0
10
20
30
40
50
60
70
80
del. mK
distance from bottom, mm


Sn
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
0
10
20
30
40
50
60
70
80
del. mK
distance from bottom, mm