National Institute of Metrology
(Thailand)

Final Report

NIMT Mica capacitance standard
Inter-Laboratory Comparison
No. EE-01/06

Electrical Metrology
Department

1. Abstract

This report summaries the results of an inter-laboratory comparison for mica capacitance standard conducted between seven participating laboratories. The comparison programme commenced in February 2006 and concluded in July 2006. The commercial mica capacitance standards were used as travelling artefact. The National Institute of Metrology (Thailand), Electrical Metrology Department, acted as coordinating laboratory on the programme and carried out to check the results on the artefacts before and after circulation of each loop.

2. Introduction

The NIMT Electrical Inter-Laboratory Comparison Programme is designed and organised by Electrical Metrology Department. The objectives of the program are to provide means for participant laboratories to compare their measurement results and measurement uncertainty evaluations, which aims ultimately at improvements of laboratories in carrying the measurements and handling the results.

The circulation of the capacitors will be organised in loops of four laboratories to allow close monitoring of the behavior of the standard capacitors at the end of each loop the artefacts were return to Electrical Metrology Department for checking the results.

The one week period starts when the travelling artefact arrives in the participant's laboratory and ends when the travelling artefact arrives in the following participant's laboratory so all participants will have at least three days for measurement period.

3. Participants

There were eight participant laboratories from five private companies and three state enterprises and one of them withdraw the programme because of the technical reason. The Electrical Metrology Department was responsible for providing and preparing the standards and the coordination of the schedule and also responsible for collecting and analyzing the comparison data and preparing the report. The participating laboratories and contact persons were listed in table 1.

Table 1 List of participating laboratories and contact persons

Organization	Contact Name	Address	Contact no.
Thai Airways International Plc.	Mr. Sumnouw Thorngmun	Bangkok International Airport, Vibhavadi Rangsit Rd., Donmuang, Bangkok 10210	Tel: 0 2563 8851 Fax: 0 2563 9183
NEC Corporation (Thailand) Ltd.	Mr. Yanyong Pithong	9/33-37 Moo 19 Navanakorn IND.EST., Klong 1, Klong Luang, Pathumthani 12120	Tel: 0 2529 2460 Fax: 0 2529 2466
Technology Promotion Association (Thailand-Japan)	Mr. Mitr Veeratham	534/4 Pattanakarn Soi 18, Suanluang, Bangkok 10250	Tel.0-2717-3000 Fax : 0-2719-9484

Organization	Contact Name	Address	Contact no.
Siam Cement Industry	Mr. Nuttapong Imbumrung	1 Siam Cement Road, Bangsue, Bangkok 10800	Tel. 0-2586-5380 Fax : 0-2586-5791
Metrology Co., Ltd.	Mr. Rungsan Panpunya	7/150 Moo 14 Bangna-Trad Road, Bangkeaw, Bangplee, Samutprakarn 10540	Tel.0-2316-3362 Fax : 0-2316-4390
Electricity Generating Authority of Thailand	Mr. Pasit Sagganayok	53 Jaransanitwong Road, Bangkrui, Nonthaburi	Tel.0-2436-6224 Fax : 0-2436-6297
Industrial Metrology and Testing Centre	Mr. Tawikiat Iamsamran	Thailand Institute of Scientific and Technological Research, 196 Phanonyothin Road, Chatuchak, Bangkok 10900	Tel. 0-23231672 Ext. 218 , Fax : 0-2323-9165
Bangpakong Training Center Calibration Laboratory	Mr. Detudom Mekviwattanawomg	8/4 Moo 8 , Thakam, Bangpakong, Chachoengsao	0-2436 8729, 038 573683 ext. 133 Fax : 0-2436 8729

4. Measurement Defining Conditions

Instructions were issued to each participant to help avoid any confusion about the defining condition of the measurement. These instructions stated that each standard capacitor was to be measured as a three-terminal configuration, which was measured with the G terminal unconnected to the L terminal.

Laboratory may use any of leads and adapters suitable to these artifacts and determining any necessary corrections for leads and/or adapters to obtain the corrected value of the capacitance standard.

To avoid problems with voltage coefficient, the maximum voltage was specified to be 1 volt rms. across both standard capacitors and these voltage was to be used at 1 kHz.

These artefacts will be transferred to the participants by hand carrying, in order to avoid excessive vibration or extreme temperature and humidity. In addition, During the transportation of the artefacts a temperature and humidity recorder was sent to monitoring that effect and we found that the temperature range and humidity range are 19 ^{o}C to 31 ^{o}C and 33 % RH to 90 % RH respectively.

5. Description of artefacts

The artefacts are mica capacitance standard which is hermetically sealed silvered mica and belongs to NIMT Electrical Metrology Department. Its specifications are shown in table 2.

Table 2 The specification of artefacts

Standard Capacitor	**0.001 μF**	**1 μF**
Manufacturer:	General Radio Company	
Model:	1409-F	1409-Y
Serial number:	27434	27288
Nominal Value:	0.001 μF ± 0.05 %	1 μF ± 0.05 %
Dissipation factor	0.000 3 @ 1 kHz	
Temperature coefficient:	<+ 35 ± 10 ppm/°C	
Stability:	< 0.01 % / year	
Temperature range:	10°C to 50 °C	
Maximum voltage:	500 V	

For more detailed information on this type of capacitance standard is available on the manufacturers web site: *www.ietlabs.com*

6. Calibration methodology

The mica capacitance standard is hermetically sealed silvered mica. Before making a measurement, the mica capacitance standard should be placed in an ambient temperature at least 12 hours to allow temperature stability.

- Capacitance value

  The mica capacitance standards must be measured in series capacitance (C_s) and dissipation factor (D) for three-terminal configuration.

- Applied voltage
  The measurement voltage must not exceed maximum voltage of 500 V.
  The preferred measuring voltage for both capacitors is 1V(rms).

- Applied frequency
  The preferred measurement frequency is 1000 Hz.

Other than specified above, the routine calibration procedures of the participating laboratory should be followed. In addition, the measurement methods for each participating laboratory were listed in table 3, appendix 1.

7. Results

The results reported by the participants, at a frequency of 1000 Hz and a voltage of 1 V_{rms} in series capacitance, are given in appendix 2 and 3. The table 4 and 5 give the reported results from each participating laboratory including the reference value with the values for each standard capacitor given as the relative difference in part per million (ppm) of its reference value with an associated uncertainty in ppm. All the uncertainties quoted in this report are expanded uncertainty, having a coverage factor k = 2 which provides a level of confidence of approximately 95 %.

The reported values from each laboratory have been plotted on the graph with their associated uncertainty and expressed as the relative difference in part per million (ppm) from the reference value that shown in figure 1 and 2, appendix 4 and 5.

The measurement results from participating laboratories were evaluated and normalized according to the ISO/IEC Guild 43-1:1997. The En value for each participant was calculated using the following equation to assist in identifying discrepant results.

$$E_n = \frac{\left| x_{lab} - X_{ref} \right|}{\sqrt{U_{lab}^2 + U_{ref}^2}}$$

where x_{lab} is the reported measurement result

X_{ref} is the reference value

U_{lab} is the expanded uncertainty of reported measurement result

U_{ref} is the expanded uncertainty of reference value

The reference value is the mean value of NIMT measurements of whole comparison within four months for both standard capacitors. Figure 3 and 4 show the NIMT measurements of the standard capacitors during the comparison. The standard capacitors have a large temperature coefficient so that we must keep them in the air bath for temperature control within $\pm$ 0.5 ^{o}C. The linear fit to the data shows the short-term stability of the standard capacitors and it is estimated from the poor maximum rate of changing capacitance over four months, 50 ppm for 0.001 μF s/n 27434 and 70 ppm for 1 μF s/n 27288. No correction is made for the drift value and then it was taken into account of the uncertainty budget.

8. Conclusions

The results appear to show that all participating laboratories were able to perform and carry out the measurements that means improving each laboratory's capabilities and measurement methods. The standard capacitors used in the comparison appear to have performed satisfactorily.

9. Acknowledgements

The author would like to thank all the laboratories who participated in this programm for their hard work in measuring the artefacts, their assistance in keeping the programme on schedule.

Appendix 1

Table 3 The condition measurement and measurement method

Laboratory	Traceability Route	Environment Condition		Measurement Method	
		Relative Humidity	Ambient Temperature	0.001 µF	1 µF
National Institute of Metrology (Thailand)	BIPM	(50 ± 10) % RH	(23,0 ± 0,5) °C	Direct measurement by using Precision Capacitance Bridge AH 2700	Direct measurement by using Precision Capacitance Bridge AH 2700
Electricity Generating Authority of Thailand	NIMT	(50 ± 15) % RH	(23,0 ± 2,0) °C	Direct measurement by using Programmable Automatic RCL Meter PM 6304C	Direct measurement by using Programmable Automatic RCL Meter PM 6304C
Industrial Metrology and Testing Centre	NIMT	(50 ± 15) % RH	(23,0 ± 2,0) °C	Substitution measurement with Standard Air Capacitor HP 16384A using LCR Meter HP 4274A and Test Fixture Connector HP 16047C	Substitution measurement with Standard Air Capacitor HP 16387A using LCR Meter HP 4274A and Test Fixture Connector HP 16047C
NEC Corporation (Thailand) Ltd.	NMIJ, NIMT	(55 ± 15) % RH	(23,0 ± 3,0) °C	Direct measurement by using Precision LCR Meter 4284A	Direct measurement by using Precision LCR Meter 4284A
Thai Airways International Plc.	NMIA	(45 ± 10) % RH	(23,2 ± 0,5) °C	Direct measurement by using Capacitance Bridge 1615A	Direct measurement by using Capacitance Bridge 1615A
Siam Cement Industry	Withdrawn				
Metrology Co., Ltd.	NIMT	(45 ± 15)% RH	(23,0 ± 2,0) °C	Direct measurement by using LCR Meter SR 720	Direct measurement by using LCR Meter SR 720
Technology Promotion Association (Thailand-Japan)	NIMT	(50 ± 10)% RH	(23,0 ± 2,0)°C	Direct measurement by using Programmable Automatic RCL Meter PM 6304C	Direct measurement by using Programmable Automatic RCL Meter PM 6304C
Bangpakong Training Center Calibration Laboratory	NIMT	(45 ± 15) % RH	(23,0 ± 2,0) °C	Direct measurement by using Programmable Automatic RCL Meter PM 6304C	Direct measurement by Programmable Automatic RCL Meter PM 6304C

Appendix 2

Table 4 Laboratory's measurements x_{lab} of standard capacitor 0.001 μF s/n 27434, The reference value, X_{ref}, is the mean value of whole programme. The difference, $x_{lab} - X_{ref}$, between each laboratory's measurement and NIMT's measurement is listed. The measurement uncertainty, U_{lab}, reported by each laboratory and U_{ref} reported by reference laboratory are listed also.

Lab Code	x_{lab} (pF)	X_{ref} (pF)	U_{lab} (pF)	U_{ref} (ppm)	U_{lab} (ppm)	Difference (pF)	Difference (ppm)	E_n
05	990.361	990.651	1	59	1 010	-0.290	-292	0.29
01	990.81		1.16		1 171	0.159	161	0.14
03	990.780		0.140		141	0.129	131	0.85
04	990.57		0.23		232	-0.081	-81	0.34
06	990.63		0.18		182	-0.021	-21	0.11
07	990.512		1.16		1 170	-0.139	-140	0.12
02	990.75		3		3 028	0.099	100	0.03

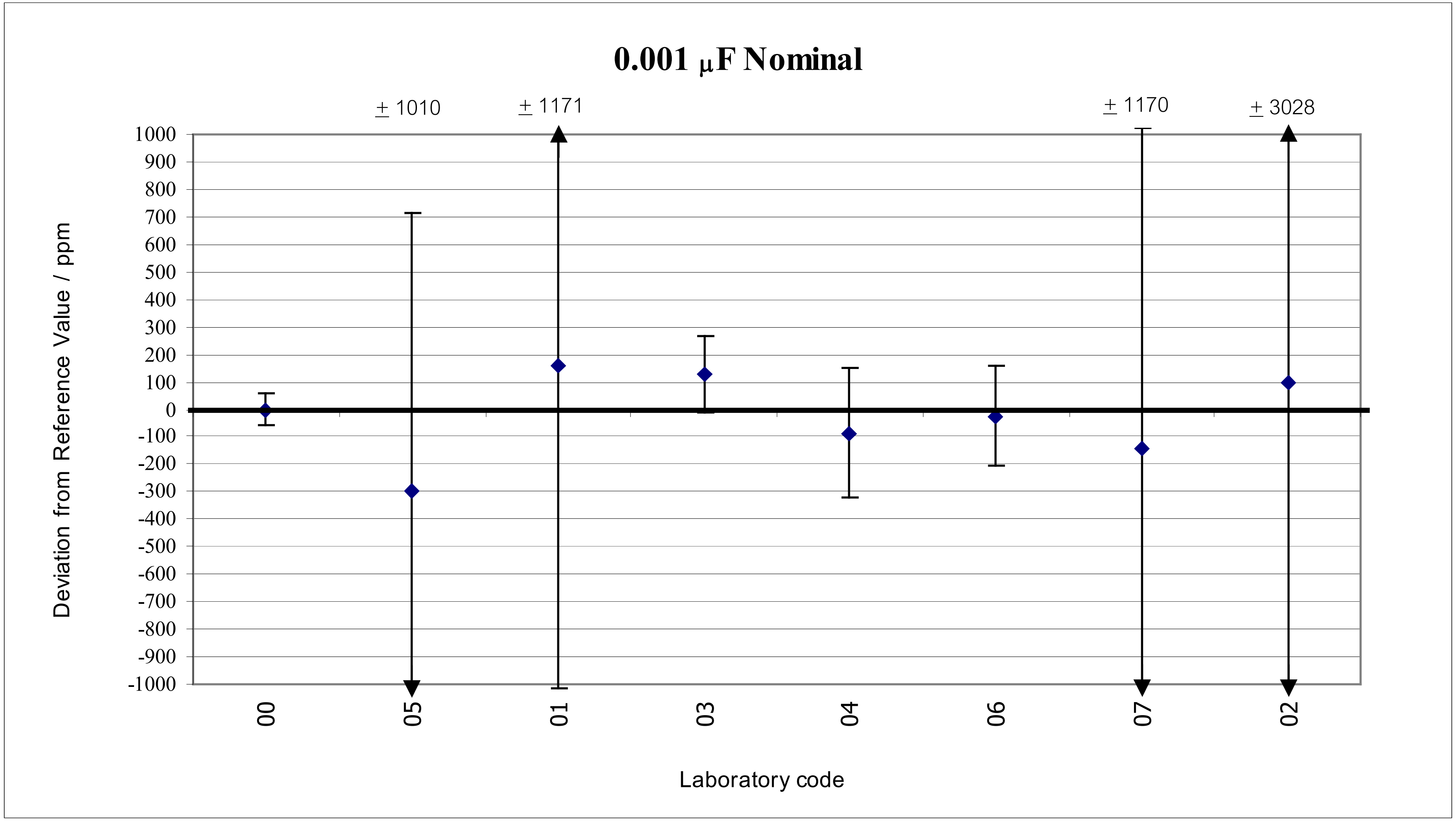
Appendix 3

Table 5 Laboratory's measurements x_{lab} of standard capacitor 1 μF s/n 27288, The reference value, X_{ref}, is the mean value of whole programme. The difference, $x_{lab} - X_{ref}$, between each laboratory's measurement and NIMT's measurement is listed. The measurement uncertainty, U_{lab}, reported by each laboratory and U_{ref} reported by reference laboratory are listed also.

Lab Code	x_{lab} (μF)	X_{ref} (μF)	U_{lab} (μF)	U_{ref} (ppm)	U_{lab} (ppm)	Difference (μF)	Difference (ppm)	E_n
05	1.003 42	1.003 18	0.003 4	114	3 400	0.000 24	239	0.07
01	1.003 3		0.000 58		578	0.000 12	119	0.20
03	1.003 226		0.000 14		140	0.000 05	46	0.25
04	1.003 14		0.000 24		240	-0.000 04	-40	0.15
06	1.003 08		0.000 15		150	-0.000 10	-100	0.53
07	1.003 16		0.000 70		700	-0.000 02	-20	0.03
02	1.003 2		0.003		2 990	0.000 02	20	0.01

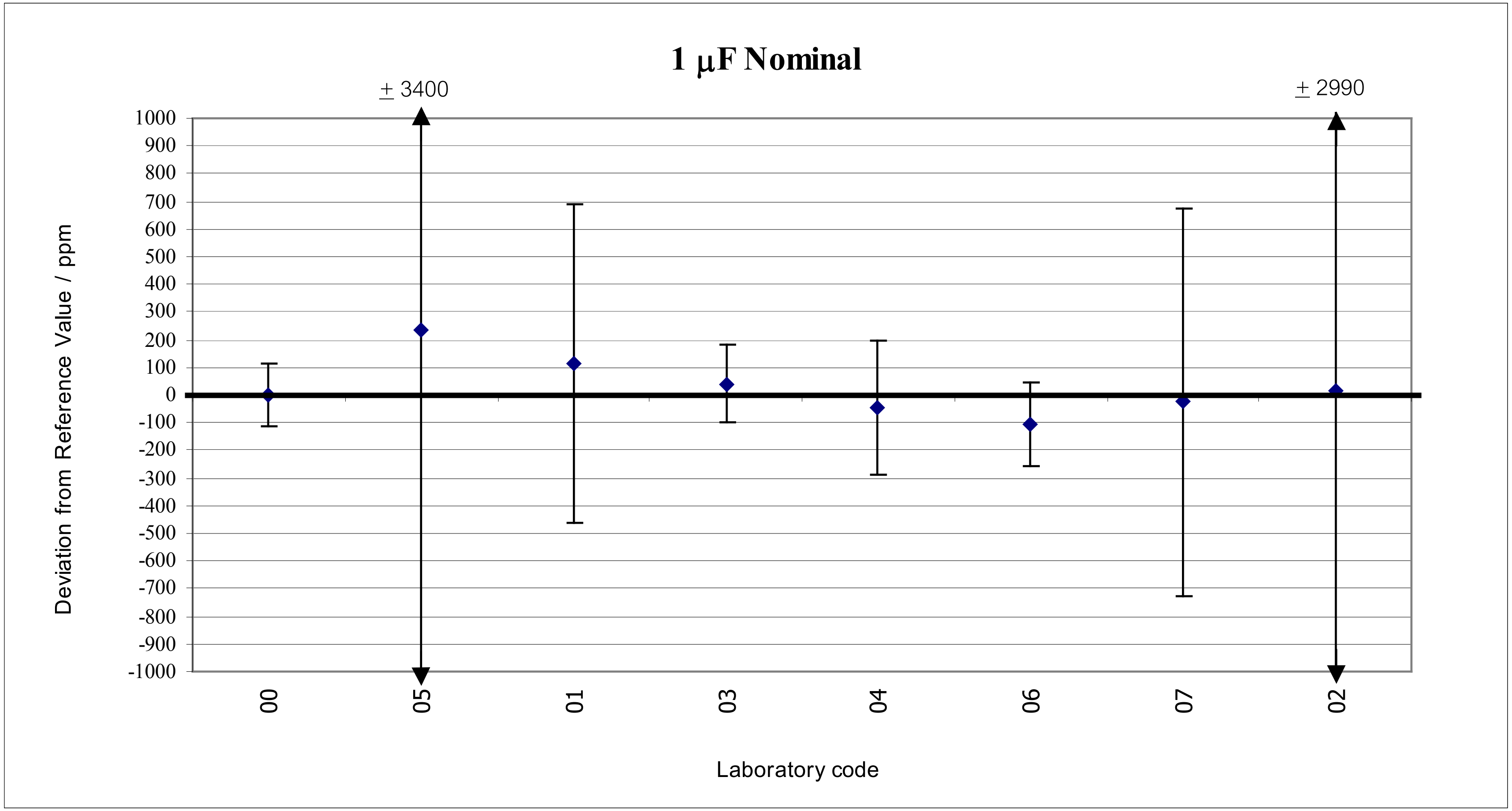
Appendix 4

Figure 1 : The results of measuring the standard capacitor 0.001 μF s/n 27434 with associated 2σ uncertainty bars by various laboratories expressed as the relative difference in part per million (ppm) from the reference value



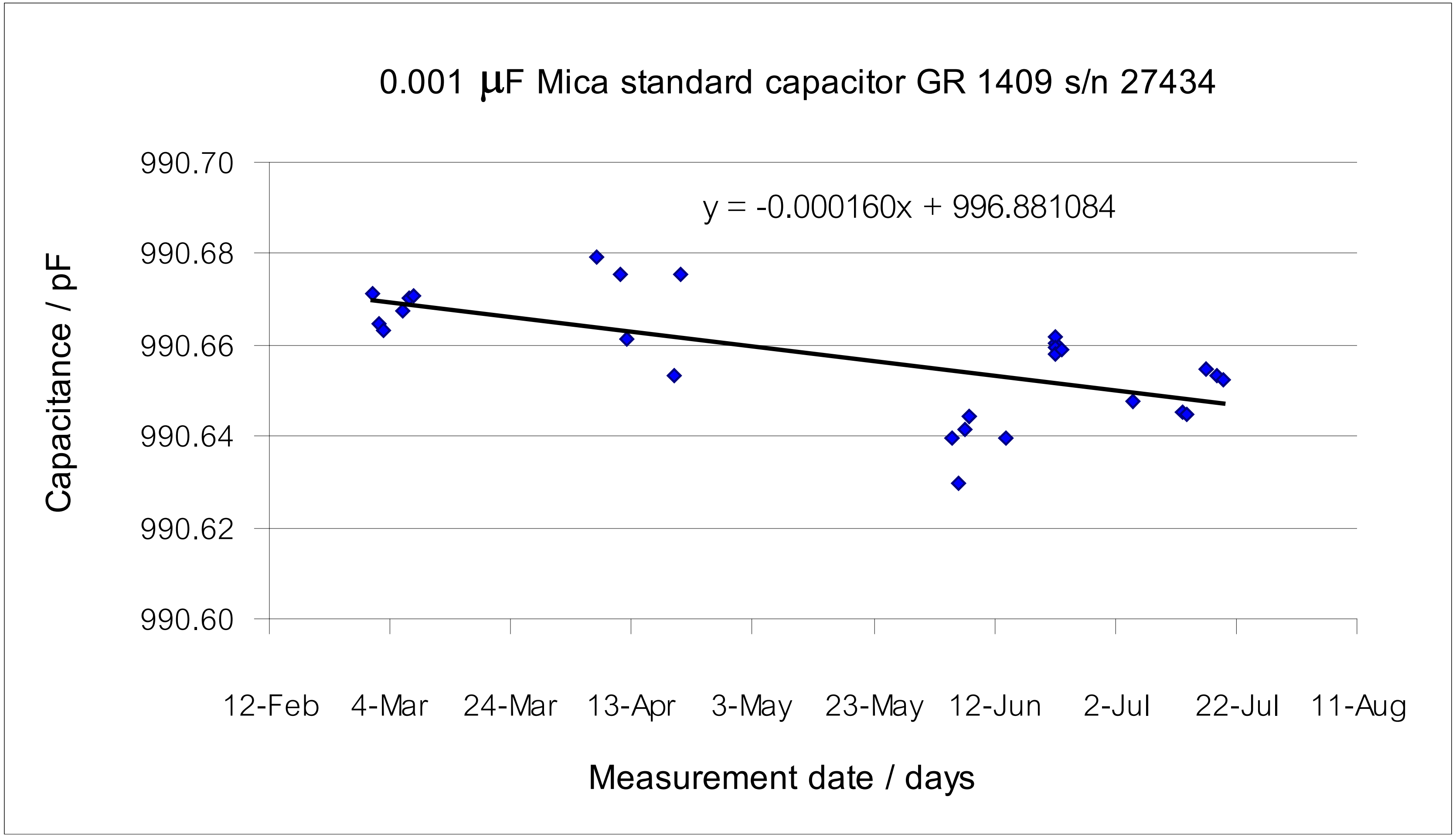
Appendix 5

Figure 2 : The results of measuring the standard capacitor 1 μF s/n 27288 with associated 2σ uncertainty bars by various laboratories expressed as the relative difference in part per million (ppm) from the reference value



Appendix 6

Figure 3 : NIMT measurements of standard capacitor s/n 27434 during the comparison. The solid line is a linear fit to the data



Appendix 7

Figure 4 : NIMT measurements of standard capacitor s/n 27288 during the comparison. The solid line is a linear fit to the data