Contents

1 Introduction

The metrological equivalence of national measurement standards and of calibration certificates issued by national metrology institutes is established by a set of key comparisons chosen and organized by the Consultative Committees of the CIPM or by the regional metrology organizations in collaboration with the Consultative Committees.

At its meeting in November 1997, the EUROMET Technical Committee for Length, TC-L, decided upon a key comparison on long gauge block measurements, numbered EUROMET.L-K2, with the National Physical Laboratory (NPL) as the pilot laboratory. This comparison would be the RMO equivalent of the comparison CCL-K2, which was also piloted by NPL.

The results of this international comparison contribute to the Mutual Recognition Arrangement (MRA) between the national metrology institutes of the Metre Convention [1]. This EUROMET key comparison is linked with the CCL and other RMO comparisons through mutual competence of participating laboratories. Laboratories participating in both the CIPM and the RMO comparisons establish the link between these comparisons and assure their equivalence.

2 Organisation

The protocol document for this comparison and this report have been based on the corresponding documents for key comparison CCL-K2 [2, 3]. The protocol document [4] was issued to all participants at the start of the comparison. A revised version was issued before commencing the second loop artefact circulation, to take into account the replacement of two failed gauge blocks and a revised timetable.

2.1 Participants

All members of EUROMET TC-L were invited to participate. 23 laboratories expressed an interest. The list of participants is given in Table 1.

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Table 1 Participating laboratories.

2.2 Schedule

The comparison was organised in two loops, the first being limited to laboratories able to make direct measurement by interferometry, with the second loop consisting of all other laboratories. The time schedule for the comparison is given in Table 2. Advantage was made of the change to membership of the EU, by scheduling laboratories of some of the new member states to make measurement after 1 May 2004, when they joined the EU. This reduced the carnet cost.

Each laboratory was allowed one month in which to make its measurements and to prepare for transportation to the next participant. The schedule was designed to fit with the preferences of the laboratories for scheduling the measurements and any changes to the schedule, after the start of the circulation, were discussed and agreed among the participants and the TC-L chairman.

Laboratory	Country	Final schedule	Results received
LOOP 1			
NPL	GB	Feb 2002	Feb 2002
SMD	BE	Mar 2002	June 2003
NMi-VSL	NL	Apr 2002	Jan 2003
MIKES	FI	May 2002	June 2002
SP	SE	June 2002	Aug 2002
BEV	AT	July 2002	Sept 2002 Rev. Oct 2002
IPQ	PT	Aug 2002	Jan 2003
METAS	CH	Sept 2002	Oct 2002
CEM	ES	Oct 2002	Nov 2002
IMGC	IT	Nov 2002	Apr 2005*
Pilot	*GB*	*Dec 2002*	*Dec 2002*
PTB	DE	Jan 2003	Mar 2003
LOOP 2			
PTB 2 replacements	DE	Apr 2003	July 2003
Pilot – 2 failed gauges	*GB*	*June 2003*	*June 2003*
Pilot - replacements	*GB*	*July 2003*	*July 2003*
Pilot	*GB*	*Jan 2004*	*Jan 2004*
UME	TR	May 2004	Jul 2004
NCM	BG	Jun 2004	Jul 2004
IMGC	IT	Jul 2004	Apr 2005*
NML	IE	Aug 2004	Aug 2005 Rev. August 2005
CMI	CZ	Sept 2004	Oct 2004
SMU	SK	Oct 2004	Dec 2004 Rev. Sep 2005
OMH	HU	Nov 2004	Mar 2005
INM	RO	Dec 2004	Feb 2005
GUM	PL	Jan 2005	Feb 2005
VNT/VMC	LT	Feb 2005	Mar 2005
LNMC	LV	Mar 2005	Apr 2005
MIRS-LTM	SI	Apr 2005	July 2005
LNE	FR	May 2005	July 2005
Pilot	*GB*	*Jun 2005*	*July 2005*

Shaded = NON EU, thus ATA carnet required on entry/exit of artefacts
Shaded = new EU member after 1 May 2004, ATA carnet was not required

Table 2 *Time schedule of the comparison. 'Final schedule' refers to the latest schedule agreed among the participants. 'Results received' refers to the first date of receipt, by the pilot laboratory, of the official results of the participant (paper or electronic report). * IMGC results sent together (loops 1&2).*

Towards the end of the first loop, significant problems were noticed on two gauge blocks (900 mm and 500 mm S/N 'B'). The CCL linking laboratories (IMGC, NPL and PTB) were asked at this time to attempt measurements of all the gauges, in order to close the first loop. On return of the gauges to the pilot laboratory at the end of loop 1, detailed repeat measurements confirmed the problem. The 500 mm gauge block faces were no longer parallel, showing a variation in length of 470 nm. Similarly the 900 mm gauge block exhibited a variation in length of 580 nm. There was also evidence to suggest that the 500 mm gauge block was changing size (from results received up to that date). It was therefore decided

to replace these two gauge blocks before starting loop 2. This resulted in a delay of around 1 year, whilst replacement gauges were supplied (from PTB) and characterised (PTB and NPL). The comparison re-started in April 2004. Apart from the problem at the end of loop 1, the timetable was followed strictly as per the plan.

2.3 Standards

Four gauge blocks made of steel were circulated in each loop. At the end of loop 1, two gauge blocks were replaced. The gauge blocks, which had been kindly donated by JV, PTB and NPL, were selected as having a stable history of measurement and good flatness and variation in length. The gauge blocks were of rectangular cross section, according to international standard ISO 3650 (1998). The thermal expansion coefficient of the gauge blocks had been measured by the pilot laboratory and another laboratory (PTB) before the comparison. The weighted mean of the pilot laboratory and PTB results of expansion measurement (and their calculated uncertainties) were given to the participating laboratories in the technical protocol. The participating laboratories were informed of the nominal length of the gauge blocks, the gauge material (steel), and the pre-determined expansion coefficients.

Loop	Serial number	Nominal length (mm)	α ($\times 10^{-6}$ K^{-1})	α uncertainty ($\times 10^{-6}$ K^{-1})
1 & 2	8728	150	11.407	0.072
1 & 2	AA/71001	500	10.766	0.025
1	B	500	10.510	0.028
1	EM/718	900	11.054	0.020
2	4 PTB 55	500	11.082	0.029
2	PTB 5.13 11/2001	900	10.943	0.022

Table 3 *Standards used in the comparison. The uncertainties for the thermal expansion coefficients are given at k = 2. Shaded cells indicate gauges that were replaced at the end of loop 1.*

The standards were supplied in a custom made transport case, fashioned from aluminium and steel, containing high density foam, sculpted to make a tight fit with the gauge blocks, to prevent any motion of the gauge blocks and generation of excessive bending forces. The case was designed to be suitable for either cabin or hold transportation. The desire was for cabin transportation (hand carriage) with a fall-back option of transportation in the hold. The gauge blocks were accessible and visible with the lid opened and a pair of chamois gloves were included in case of any request by customs to handle the gauge bocks. The transport case and gauge blocks had a total mass in excess of 10 kg. Despite this being greater than the advertised cabin baggage allowance of many airlines, most airlines involved did not object to the hand carriage of the case in the aircraft cabin, provided they had been informed in advance.