

1 Background

This document describes the method used to link the EUROMET.M.P-K4 and CCM.P-K7 Key Comparisons. The linking has been established by means of the laboratories taking part in both the EUROMET.M.P-K4 and CCM.P-K7 Key Comparisons. These comparisons may be readily compared as the type of transfer standard and the corresponding nominal pressures were the same.

1.1 EUROMET.M.P-K4

The comparison is described in detail in [1]. Fifteen laboratories in the EUROMET region participated, of whom twelve reported results. Four also participated in CCM.P-K7. The transfer standard was a commercially available piston-cylinder assembly manufactured by Desgranges et Huot, of nominal effective area 9.8 mm². Each participant determined the effective area at the nominal pressures of 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 MPa.

1.2 CCM.P-K7

The comparison is described in detail in [2]. Nine laboratories participated. The transfer standard was a commercially available piston-cylinder assembly manufactured by Desgranges et Huot, of nominal effective area 9.8 mm². Each participant determined the effective area at the nominal pressures of 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 MPa.

2 Weighted mean calculated from linking laboratories

The values used for the linking are calculated by using the combined differences. These have been calculated by a weighted mean method using the results of the corresponding differences of the linking laboratories in both comparisons CCM.P-K7 and EUROMET.M.P-K4. The four linking laboratories were INRIM (formerly CNR-IMGC), LNE, NPL and PTB.

The weighted mean obtained from the linking laboratories for CCM.P-K7, $X_{CCM}(i)$, was calculated from:

$$X_{CCM}(i) = \frac{x(INRIM,i)/u_c^2\{x(INRIM,i)\} + x(LNE,i)/u_c^2\{x(LNE,i)\} + x(NPL,i)/u_c^2\{x(NPL,i)\} + x(PTB,i)/u_c^2\{x(PTB,i)\}}{1/u_c^2\{x(INRIM,i)\} + 1/u_c^2\{x(LNE,i)\} + 1/u_c^2\{x(NPL,i)\} + 1/u_c^2\{x(PTB,i)\}}$$

where $x(J,i)$ and $u_c\{x(J,i)\}$ are respectively the relative deviations of the J -th institute from the CCM comparison reference values and their combined standard uncertainties.

Table 1 shows the results of the linking laboratories and the weighted mean obtained from the linking laboratories for CCM.P-K7 as a function of nominal pressure.

In a similar way, the weighted mean obtained from the linking laboratories for EUROMET.M.P-K4, $Y_{EUROMET}(i)$, was calculated from:

$$Y_{EUROMET}(i) = \frac{y(INRIM,i)/u_c^2\{y(INRIM,i)\} + y(LNE,i)/u_c^2\{y(LNE,i)\} + y(NPL,i)/u_c^2\{y(NPL,i)\} + y(PTB,i)/u_c^2\{y(PTB,i)\}}{1/u_c^2\{y(INRIM,i)\} + 1/u_c^2\{y(LNE,i)\} + 1/u_c^2\{y(NPL,i)\} + 1/u_c^2\{y(PTB,i)\}}$$

where $y(J,i)$ and $u_c\{y(J,i)\}$ are respectively the relative deviations of the J -th institute from the CCM comparison reference values and their combined standard uncertainties.

Table 2 shows the results of the linking laboratories and the weighted mean obtained from the linking laboratories for EUROMET.M.P-K4 as a function of nominal pressure.

3 Evaluation of degrees of equivalence

The degrees of equivalence of participating laboratories in EUROMET.M.P-K4 can be transferred to CCM.P-K7 as follows:

$$D(J,i) = X_{CCM}(i) - Y_{EUROMET}(i) + y(J,i)$$

where $D(J,i)$ is the relative deviation from the CCM.P-K7 reference value of the J -th participant in EUROMET.M.P-K4 and $y(J,i)$ is the relative deviation from the EUROMET.M.P-K4 reference value of the J -th participant.

For those participants in CCM.P-K7, the relative deviation from the CCM.P-K7 reference value $D(J,i)$ is as follows:

$$D(J,i) = x(J,i)$$

Table 3 shows the differences of the weighted mean values, $X_{CCM}(i) - Y_{EUROMET}(i)$ as a function of nominal pressure.

The differences listed in Table 3 are considerably smaller than the expanded uncertainties claimed by the participants in EUROMET.M.P-K4 and the results of the linking institutes in both comparisons are comparable.

The relative standard uncertainty of $D(J,i)$ for the participants in EUROMET.M.P-K4 is estimated from:

$$U\{D(J,i)\} = k \cdot u_c\{y(J,i)\}$$

where k is the coverage factor equal to 2.

The relative standard uncertainty of $D(J,i)$ for the participants in CCM.P-K7 is estimated from:

$$U\{D(J,i)\} = k \cdot u_c\{x(J,i)\}$$

Table 4 shows the relative deviations from the CCM KCRVs, $D(J,i)$, together with the expanded ($k=2$) uncertainties of the relative deviations, $U\{D(J,i)\}$. From Table 4 it can be seen that all participants in EUROMET.M.P-K4 are equivalent to the CCM KCRV.

4 References

- [1] M Perkin, NPL Report CMAM 54, 2000
- [2] W Sabuga *et al*, *Metrologia*, 2005, **42**, *Tech. Suppl.*, 07005

Table 1 Weighted mean calculated from the linking laboratories for CCM.P-K7.

Nominal pressure MPa	NPL		INRIM		BNM-LNE		PTB		Weighted mean $X_{CCM}(i)$
	$x(NPL,i)$	$u\{x(NPL,i)\}$	$x(INRIM,i)$	$u\{x(INRIM,i)\}$	$x(LNE,i)$	$u\{x(LNE,i)\}$	$x(PTB,i)$	$u\{x(PTB,i)\}$	
10	-3.5	11.5	8.5	11.5	-3.7	8.0	2.5	11.0	0.0
20	-1.7	11.0	1.1	11.0	-5.0	7.0	1.1	11.0	-2.2
30	-1.6	11.5	0.0	11.0	-5.5	7.0	0.3	11.0	-2.7
40	-1.3	11.5	0.5	11.0	-6.2	7.0	0.0	11.5	-3.0
50	0.0	11.5	2.4	11.0	-5.3	7.5	0.6	12.5	-1.8
60	0.4	12.0	2.1	11.5	-6.0	8.0	0.0	13.5	-2.1
70	2.6	12.0	4.3	11.0	-5.7	8.0	0.0	14.5	-1.0
80	4.5	12.0	4.5	11.5	-5.9	8.5	0.0	15.5	-0.5
90	6.5	12.5	5.2	11.5	-5.9	9.0	-0.1	16.5	0.3
100	8.3	12.5	7.2	11.5	-5.9	9.5	-0.1	18.0	1.5

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Table 2 Weighted mean calculated from the linking laboratories for EUROMET.M.P-K4.

Nominal pressure MPa	NPL		INRIM		BNM-LNE		PTB		Weighted mean $y_{EUROMET}(i)$
	$y(NPL,i)$	$u\{y(NPL,i)\}$	$y(INRIM,i)$	$u\{y(INRIM,i)\}$	$y(LNE,i)$	$u\{y(LNE,i)\}$	$y(PTB,i)$	$u\{y(PTB,i)\}$	
10	1.2	12.6	-1.2	13.9	3.9	8.5	-8.0	11.6	-0.1
20	4.4	13.8	-5.4	13.7	-5.3	7.8	-2.3	12.0	-3.2
30	2.8	14.7	-7.2	13.7	-10.4	7.7	-2.8	12.3	-6.6
40	2.5	15.8	-6.4	14.3	-14.5	8.1	-2.5	12.9	-8.6
50	3.0	16.4	-6.3	13.8	-14.8	7.5	-3.0	12.9	-9.3
60	3.3	17.4	-6.2	13.9	-14.8	7.9	-3.3	13.4	-9.2
70	4.3	18.1	-6.1	13.9	-13.9	7.6	-4.0	13.7	-9.1
80	3.9	19.1	-5.8	14.1	-14.0	8.0	-3.9	14.4	-9.1
90	6.1	20.0	-5.0	14.2	-12.5	8.1	-4.0	15.0	-8.0
100	6.5	20.9	-5.0	14.4	-11.5	8.5	-3.5	15.7	-7.3

Table 3 Differences of the weighted mean values, $X_{CCM}(i)-Y_{EUROMET}(i)$.

Nominal pressure MPa	$X_{CCM}(i)-Y_{EUROMET}(i)$
10	0.1
20	1.0
30	3.8
40	5.5
50	7.5
60	7.1
70	8.1
80	8.6
90	8.3
100	8.8

Table 4 Deviations of participants in EUROMET.M.P-K4 from the CCM KCRVs, $D(J,i)$ together with the expanded ($k=2$) uncertainties of the deviations, ($U\{D(J,i)\}$).

Participant	10 MPa		20 MPa		30 MPa		40 MPa		50 MPa		60 MPa		70 MPa		80 MPa		90 MPa		100 MPa	
	$D(J,i)$	$U\{D(J,i)\}$	$D(J,i)$	$U\{D(J,i)\}$	$D(J,i)$	$U\{D(J,i)\}$	$D(J,i)$	$U\{D(J,i)\}$	$D(J,i)$	$U\{D(J,i)\}$	$D(J,i)$	$U\{D(J,i)\}$	$D(J,i)$	$U\{D(J,i)\}$	$D(J,i)$	$U\{D(J,i)\}$	$D(J,i)$	$U\{D(J,i)\}$	$D(J,i)$	$U\{D(J,i)\}$
CEM	-5.4	15.8	-4.9	16.5	-3.3	16.8	-4.0	17.6	-3.7	16.6	-4.1	17.1	-4.2	16.4	-4.6	17.0	-5.1	17.0	-4.0	17.4
SP	-9.3	22.1	-9.5	21.9	-8.6	22.1	-7.9	23.7	0.6	41.0	2.6	40.3	2.7	40.0	-0.5	39.2	-1.0	39.2	-4.6	39.4
MIKES	-14.6	30.8	-6.9	31.3	-4.3	31.5	-2.0	31.9	0.4	31.4	-2.1	31.6	-2.1	31.3	-1.5	31.5	-2.0	31.6	-1.0	31.8
NPL	-3.5	23.0	-1.7	22.0	-1.6	23.0	-1.3	23.0	0.0	23.0	0.4	24.0	2.6	24.0	4.5	24.0	6.5	25.0	8.3	25.0
NMi	3.8	60.4	8.3	60.7	7.9	60.8	11.3	61.0	11.6	60.7	12.2	60.8	12.1	60.7	12.7	60.8	12.3	60.8	12.3	60.9
INRIM	8.5	23.0	1.1	22.0	0.0	22.0	0.5	22.0	2.4	22.0	2.1	23.0	4.3	22.0	4.5	23.0	5.2	23.0	7.2	23.0
UME	6.3	41.0	10.6	41.4	14.0	41.5	15.7	41.9	17.7	41.4	17.3	41.7	18.6	41.5	18.8	41.7	19.4	41.8	20.2	42.1
BNM-LNE	-3.7	16.0	-5.0	14.0	-5.5	14.0	-6.2	14.0	-5.3	15.0	-6.0	16.0	-5.7	16.0	-5.9	17.0	-5.9	18.0	-5.9	19.0
OFMET	-45.2	60.4	-38.6	60.7	-33.9	60.7	-31.6	61.0	-43.4	60.7	-41.9	60.8	-37.8	60.6	-36.2	60.8	-34.6	60.8	-33.6	60.9
PTB	2.5	22.0	1.1	22.0	0.3	22.0	0.0	23.0	0.6	25.0	0.0	27.0	0.0	29.0	0.0	31.0	-0.1	33.0	-0.1	36.0
IPQ	-4.0	56.4	4.0	56.7	7.5	56.8	10.9	57.1	13.4	56.7	13.6	56.9	15.2	56.7	16.5	56.8	17.9	56.9	19.0	57.0
CMI	-8.7	35.7	3.3	36.1	9.6	36.3	11.2	36.7	14.9	37.2	17.0	37.4	17.3	39.0	15.1	40.2	16.8	41.2	20.7	43.3