

APPENDIX 3

**THE RESULTS AND ANALYSIS OF THE SSE, GAIN/ RANGE RATIO
AND AMBIENT CONDITIONS MEASUREMENTS**

**EURAMET 658 EXTENSION PROJECT TO EXAMINE UNDERLYING
PARAMETERS IN RADIANCE TEMPERATURE SCALE REALISATION
FROM 156 °C TO 1000 °C**

JANUARY 2018

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Conditions Measurements

EURAMET 658 Extension Project to Examine Underlying Parameters in
Radiance Temperature Scale Realisation from 156 °C to 1000 °C

Helen McEvoy
Engineering, Materials & Electrical Science

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National Physical Laboratory
Hampton Road, Teddington, Middlesex, TW11 0LW

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Approved on behalf of NPL by
Dr Stephanie Bell, Science Area Leader.

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1 THE SSE MEASUREMENTS

1.1 SSE APPARATUS USED AT EACH INSTITUTE

The size-of-source effect (SSE) measurements were made using either the ‘indirect’ method (with the central portion of the field-of-view of the thermometer obscured by means of a blackened spot or disc) or the ‘direct’ method (using a blackbody source and a series of apertures) or both methods. For the ‘indirect’ measurements, the spot size for the INRiM thermometer measurements was to be 6 mm in diameter; the spot sizes for the LP5 thermometer measurements were to be 3 mm and 6 mm in diameter. A summary of the apparatus used at each institute is given in Table 1. Full details can be found in Appendices 7 to 13.

Institute	Method used	Brief description of apparatus
PTB	Direct	Caesium heatpipe blackbody source at nominally 500 °C
NPL	Direct	Sodium heatpipe blackbody source at nominally 500 °C
NPL	Indirect	Integrating sphere with 3 mm and 6 mm blackbodies
CEM	Indirect	Integrating sphere with 3 mm and 6 mm spots
UME	Indirect	Integrating sphere with 3 mm and 6 mm spots
METAS	Direct	Caesium heatpipe blackbody source at nominally 500 °C
LNE	Indirect	Integrating sphere with 4 mm and 6.82 mm spots
INRiM	Indirect	Integrating sphere with 3 mm and 6 mm flattened discs

Table 1: details of the SSE methods used in each of the institutes

1.2 THE RESULTS OF THE SSE MEASUREMENTS

The results of the SSE measurements made at each institute are given in Tables 2 to 22. For the direct measurements, the SSE at each aperture diameter, x , is given by:

$$SSE(x) = \frac{\{Signal\ with\ aperture\ (x) - background\ signal\}}{\{Signal\ with\ maximum\ diameter\ aperture - background\ signal\}}$$

For the indirect measurements, the SSE is given by:

$$SSE = \frac{\{Signal\ viewing\ spot - background\ signal\}}{\{Signal\ viewing\ sphere - background\ signal\}}$$

Plots of the results of the measurements are given in Figures 1 to 13, along with the $k = 2$ uncertainty bars.

1.2.1 Results of the SSE measurements for the INRiM thermometer

PTB results: INRiM thermometer, direct method					
Aperture size \varnothing /mm	SSE (\varnothing 40 mm) without e-correction	Cs-bb e-correction (\varnothing 40 mm)	SSE (\varnothing 40 mm) with e-correction	std. dev. $k=1$	U_{SSE} $k=2$
40.0	1.000000	1.000000	1.00000	2.7E-05	6E-05
30.0	1.000094	1.000429	0.99967	2.8E-05	6E-05
20.0	1.00006	1.000736	0.99933	3.0E-05	6E-05
17.5	1.00014	1.000794	0.99934	3.0E-05	7E-05
15.0	1.00004	1.000844	0.99920	3.0E-05	7E-05
12.5	1.00004	1.000886	0.99915	3.2E-05	7E-05
10.0	0.99994	1.000921	0.99902	3.4E-05	7E-05
7.5	0.99997	1.000948	0.99902	4.6E-05	1E-04
5.0	0.9982	1.000967	0.9973	5.2E-04	2E-03

Table 2: the PTB SSE results with the INRiM thermometer (direct method)

NPL measurements: INRiM thermometer, direct method [†]						
Aperture diameter / mm	SSE run 1	SSE run 2	SSE run 3	SSE run 4	Average SSE	Uncertainty ($k=2$)
3	0.47239	0.47224	0.47247	-	0.47237	0.00023
4	0.82178	0.82382	0.82315	0.82310	0.82296	0.00171
5	0.99856	0.99861	0.99852	0.99867	0.99859	0.00013
7	0.99968	0.99980	0.99989	0.99981	0.99979	0.00018
9	0.99976	0.99987	0.99993	0.99991	0.99987	0.00016
12	0.99984	0.99996	1.00004	1.00001	0.99996	0.00017
15	0.99991	1.00002	1.00003	1.00007	1.00001	0.00014
20	0.99996	1.00005	1.00006	1.00012	1.00005	0.00013
25	1.00003	1.00012	1.00014	1.00015	1.00011	0.00011
30	1.00002	1.00006	1.00003	1.00011	1.00005	0.00008
40	1.00000	1.00000	1.00000	1.00000	1.00000	0.00000

Table 3: the NPL SSE results with the INRiM thermometer (direct method)

[†] in the calculation of the SSE, the thermometer signals were corrected to compensate for the change in emissivity of the source as the aperture size was increased.

NPL measurements: INRiM thermometer, indirect method , 6 mm blackbody						
Aperture diameter / mm	SSE run 1	SSE run 2	SSE run 3	SSE run 4	Average SSE	Uncertainty ($k=2$)
7	9.173E-05	9.042E-05	8.838E-05	8.963E-05	9.004E-05	2.811E-06
9	2.070E-04	2.093E-04	2.069E-04	2.094E-04	2.081E-04	2.755E-06
12	3.207E-04	3.203E-04	3.202E-04	3.201E-04	3.203E-04	4.865E-07
15	4.015E-04	3.991E-04	3.975E-04	4.002E-04	3.996E-04	3.334E-06
18	4.681E-04	4.656E-04	4.668E-04	4.670E-04	4.669E-04	2.025E-06
20	5.053E-04	5.031E-04	5.048E-04	5.042E-04	5.044E-04	1.884E-06
25	5.933E-04	5.922E-04	5.942E-04	5.930E-04	5.932E-04	1.622E-06
30	6.716E-04	6.695E-04	6.715E-04	6.703E-04	6.707E-04	2.043E-06
40	8.116E-04	8.075E-04	8.102E-04	8.091E-04	8.096E-04	3.393E-06
50	9.120E-04	9.114E-04	9.110E-04	9.111E-04	9.114E-04	9.018E-07

Table 4: the NPL SSE results with the INRiM thermometer (indirect method)

CEM results: INRiM thermometer, indirect , 6 mm spot		
Aperture diameter / mm	SSE	U ($k=2$)
6.3	0.000000	-
10.4	0.000265	0.000050
14.1	0.000406	0.000044
19.5	0.000501	0.000034
24.1	0.000591	0.000030
28.9	0.000681	0.000029
33.8	0.000751	0.000028
39.1	0.000827	0.000030
49.1	0.000946	0.000035
59.0	0.001062	0.000046
63.3	0.001220	0.000061
100.0	0.001810	0.000110

Table 5: the CEM SSE results with the INRiM thermometer (indirect method)

UME results: INRiM thermometer, indirect , 6 mm spot			
Aperture size / mm	SSE	$U_{SSE (k=1.0)}$	U / %
50	0.001264	3.1E-05	2.49
40	0.001097	2.8E-05	2.52
30	0.000876	2.3E-05	2.63
20	0.000620	1.4E-05	2.32
15	0.000472	8.7E-06	1.85
10	0.000276	4.3E-06	1.55
8	0.000161	2.5E-06	1.57

Table 6: the UME SSE results with the INRiM thermometer (indirect method)

METAS results: INRiM thermometer, direct method		
Aperture diameter/ mm	SSE	U (k=2) / °C
50	1.000000	0.00043
40	1.000025	0.00043
35	1.000252	0.00043
30	1.000174	0.00043
27	0.999849	0.00043
23	0.999965	0.00043
20	1.000110	0.00043
17	1.000060	0.00043
13	0.999851	0.00043
10	0.999667	0.00043
7	0.999632	0.00043
5	0.988740	0.00043

Table 7: the METAS SSE results with the INRiM thermometer (direct method)

LNE results: INRiM, indirect method, 6.82 mm spot		
Aperture diameter/ mm	SSE	U (k=2)
6	0.000001	1.311E-4
8	0.000110	6.227E-5
10	0.000260	1.052E-4
12	0.000369	1.880E-4
15	0.000513	1.319E-4
20	0.000736	1.961E-4
30	0.001264	2.331E-4
40	0.001756	1.757E-4
50	0.002303	1.585E-4
60	0.002883	2.920E-4
70	0.003440	3.703E-4
6	-0.000001	1.311E-4

Table 8: the LNE SSE results with the INRiM thermometer (indirect method)

INRiM results: INRiM thermometer, indirect , 6 mm spot		
Aperture diameter/ mm	SSE (%)	U (%) ($k=2$)
8	0.0194	0.0007
10	0.0315	0.0011
12	0.0405	0.0014
15	0.0508	0.0017
15 rpt	0.0507	0.0017
20	0.0650	0.0022
25	0.0788	0.0027
30	0.0892	0.0030
35	0.0990	0.0034
40	0.1079	0.0037
50	0.1226	0.0042
60	0.1369	0.0047
70	0.1534	0.0052
80	0.1723	0.0059
90	0.1907	0.0065
100	0.2078	0.0071

Table 9: the INRiM SSE results with the INRiM thermometer (indirect method)

1.2.2 Results of the SSE measurements for the LP5 thermometer

PTB results: LP5 thermometer, direct method					
aperture size \varnothing /mm	SSE ($\varnothing 40$ mm) without e- correction	Cs-bb e-correction ($\varnothing 40$ mm)	SSE ($\varnothing 40$ mm) with e- correction	Std. dev. $k=1$	U_{SSE} $k=2$
40.0	1.000000	1.000000	1.000000	9.9E-06	2E-05
30.0	1.000211	1.000429	0.999782	1.2E-05	3E-05
20.0	1.000405	1.000736	0.999669	1.3E-05	3E-05
15.0	1.000476	1.000844	0.999632	1.4E-05	3E-05
10.0	1.000550	1.000921	0.999629	1.4E-05	3E-05
7.5	1.000680	1.000948	0.999732	1.4E-05	3E-05
5.0	1.000541	1.000967	0.999574	1.5E-05	4E-05
4.0	1.000628	1.000973	0.999656	1.5E-05	4E-05
3.0	1.000591	1.000977	0.999614	1.6E-05	4E-05
2.0	0.99860	1.000980	0.99763	1.3E-04	3E-04

Table 10: the PTB SSE results with the LP5 thermometer (direct method)

NPL measurements: LP5 thermometer, direct method [†]						
Aperture diameter / mm	SSE run 1	SSE run 2	SSE run 3	SSE run 4	Average SSE	Uncertainty (k=2)
1.5	-	0.85652	0.84410	0.85969	0.8534	0.0165
2	0.99706	0.99653	0.99741	0.99429	0.9963	0.0028
2.5	0.99943	0.99937	0.99954	0.99962	0.9995	0.0002
3	0.99950	0.99942	0.99959	0.99969	0.9996	0.0002
4	0.99956	0.99944	0.99963	0.99967	0.9996	0.0002
5	0.99953	0.99957	0.99961	0.99966	0.9996	0.0001
7	0.99954	0.99956	0.99969	0.99958	0.9996	0.0001
9	0.99954	0.99958	0.99968	0.99963	0.9996	0.0001
12	0.99954	0.99968	0.99967	0.99965	0.9996	0.0001
15	0.99950	0.99970	0.99966	0.99970	0.9996	0.0002
20	0.99949	0.99973	0.99969	0.99974	0.9997	0.0002
25	0.99966	0.99984	0.99981	0.99989	0.9998	0.0002
30	0.99963	0.99984	0.99981	0.99990	0.9998	0.0002
40	1.00000	1.00000	1.00000	1.00000	1.0000	0.0000

Table 11: the NPL SSE results with the LP5 thermometer (direct method)

[†] in the calculation of the SSE, the thermometer signals were corrected to compensate for the change in emissivity of the source as the aperture size was increased.

NPL measurements: LP5 thermometer, indirect method, 3 mm diameter blackbody						
Aperture diameter / mm	SSE run 1	SSE run 2	SSE run 3	SSE run 4	Average SSE	Uncertainty (k=2)
4	0.0000513	0.0000547	0.0000571	0.0000605	0.0000559	0.0000078
5	0.0000558	0.0000598	0.0000613	0.0000605	0.0000594	0.0000049
6	0.0000661	0.0000688	0.0000706	0.0000725	0.0000695	0.0000055
7	0.0000683	0.0000743	0.0000778	0.0000824	0.0000757	0.0000118
9	0.0000848	0.0000840	0.0000826	0.0000915	0.0000857	0.0000079
12	0.0000913	0.0000899	0.0000942	0.0000988	0.0000936	0.0000078
15	0.0000984	0.0001037	0.0001035	0.0001065	0.0001030	0.0000068
18	0.0001052	0.0001095	0.0001071	0.0001084	0.0001075	0.0000037
20	0.0001100	0.0001126	0.0001137	0.0001159	0.0001131	0.0000049
25	0.0001146	0.0001182	0.0001234	0.0001198	0.0001190	0.0000073
30	0.0001300	0.0001324	0.0001292	0.0001260	0.0001294	0.0000053
40	0.0001437	0.0001466	0.0001443	0.0001427	0.0001443	0.0000033
50	0.0001605	0.0001612	0.0001597	0.0001590	0.0001601	0.0000020

Table 12: the NPL SSE results with the LP5 thermometer (indirect method, 3 mm blackbody)

NPL measurements: LP5 thermometer, indirect method, 6 mm diameter blackbody						
Aperture diameter / mm	SSE run 1	SSE run 2	SSE run 3	SSE run 4	Average SSE	Uncertainty ($k=2$)
7	0.0000221	0.0000152	0.0000167	0.0000105	0.0000161	0.0000095
9	0.0000281	0.0000209	0.0000228	0.0000221	0.0000235	0.0000064
12	0.0000356	0.0000306	0.0000328	0.0000324	0.0000329	0.0000042
15	0.0000432	0.0000407	0.0000411	0.0000444	0.0000423	0.0000035
18	0.0000523	0.0000477	0.0000509	0.0000536	0.0000511	0.0000051
20	0.0000500[†]	0.0000556	0.0000567	0.0000591	0.0000571	0.0000036
25	0.0000663	0.0000674	0.0000670	0.0000712	0.0000680	0.0000044
30	0.0000802	0.0000821	0.0000812	0.0000848	0.0000821	0.0000039
40	0.0001085	0.0001108	0.0001105	0.0001134	0.0001108	0.0000041
50	0.0001353	0.0001394	0.0001369	0.0001394	0.0001378	0.0000040

Table 13: the NPL SSE results with the LP5 thermometer (indirect method, 6 mm blackbody)

[†] this value is not consistent with the others and has therefore not been included in the average.

CEM results: LP5 thermometer, indirect , 3 mm spot		
Aperture diameter / mm	SSE	U ($k=2$)
6.3	0.000000	-
10.4	0.000059	0.000008
14.1	0.000076	0.000007
19.5	0.000101	0.000005
24.1	0.000117	0.000005
28.9	0.000122	0.000004
33.8	0.000127	0.000004
39.1	0.000131	0.000004
49.1	0.000140	0.000005
59.0	0.000181	0.000008
63.3	0.000207	0.000023
100.0	0.000342	0.000043

Table 14: the CEM SSE results with the LP5 thermometer (indirect method, 3 mm spot)

CEM results: LP5 thermometer, indirect , 6 mm spot		
Aperture diameter/ mm	SSE	U ($k=2$)
6.3	0.000000	-
10.4	0.000018	0.000004
14.1	0.000018	0.000004
19.5	0.000039	0.000004
24.1	0.000054	0.000004
28.9	0.000070	0.000004
33.8	0.000079	0.000004
39.1	0.000086	0.000004
49.1	0.000110	0.000004
59.0	0.000138	0.000005
63.3	0.000169	0.000007
100.0	0.000280	0.000020

Table 15: the CEM SSE results with the LP5 thermometer (indirect method, 6 mm spot)

UME results: LP5 thermometer, indirect , 3 mm spot			
Aperture size/ mm	SSE	$U_{SSE (k=1.0)}$	U/ %
50	0.000767	1.3E-05	1.69
40	0.000634	1.2E-05	1.91
30	0.000472	1.0E-05	2.13
20	0.000296	1.2E-05	4.05
15	0.000226	1.3E-05	5.64
10	0.000152	1.4E-05	9.02
8	0.000140	1.0E-05	7.26
5	0.000088	1.1E-05	12.22

Table 16: the UME SSE results with the LP5 thermometer (indirect method, 3 mm spot)

UME results: LP5 thermometer, indirect , 6 mm spot			
Aperture size/ mm	SSE	$U_{SSE (k=1.0)}$	U/ %
50	0.000677	9.1E-06	1.35
40	0.000544	9.1E-06	1.66
30	0.000365	8.9E-06	2.44
20	0.000204	8.7E-06	4.29
15	0.000141	8.7E-06	6.15
10	0.000061	8.6E-06	14.14
8	0.000043	8.6E-06	20.20

Table 17: the UME SSE results with the LP5 thermometer (indirect method, 6 mm spot)

METAS results: LP5 thermometer, direct method		
Aperture diameter/ mm	SSE	U ($k=2$) / °C
50	1.000000	0.00043
40	1.000008	0.00043
35	1.000058	0.00043
30	1.000008	0.00043
27	1.000023	0.00043
23	1.000104	0.00043
20	1.000150	0.00043
17	1.000116	0.00043
13	1.000092	0.00043
10	1.000286	0.00043
7	1.000311	0.00043
5	1.000236	0.00043

Table 18: the METAS SSE results with the LP5 thermometer (direct method)

LNE results: LP5 thermometer, indirect method, 4 mm spot		
Aperture diameter / mm	SSE	U ($k=2$)
4	0.000004	1.135E-4
6	0.000058	7.929E-4
8	0.000104	9.487E-5
10	0.000146	1.076E-4
12	0.000192	1.810E-4
15	0.000272	6.603E-5
20	0.000408	1.272E-4
30	0.000735	3.393E-4
40	0.001119	1.469E-4
50	0.001553	3.673E-4
60	0.001983	6.053E-4
70	0.002574	8.958E-4
4	-0.000004	1.135E-4

Table 19: the LNE SSE results with the LP5 thermometer (indirect method, 4 mm spot)

LNE results: LP5, indirect method, 6.82 mm spot		
Aperture diameter/ mm	SSE	U ($k=2$)
6	-0.00000198	5.178E-06
8	0.00001688	6.346E-05
10	0.00005975	4.280E-05
12	0.00010119	5.094E-05
15	0.00015316	6.190E-05
20	0.00026058	7.539E-05
30	0.00051823	4.275E-04
40	0.00078841	8.068E-04
50	0.00107212	1.485E-03
60	0.00140196	1.723E-03
70	0.00173278	3.130E-03
6	0.00000198	5.178E-06

Table 20: the LNE SSE results with the LP5 thermometer (indirect method, 6.82 mm spot)

INRiM results: LP5 thermometer, indirect method, 3 mm spot		
Aperture diameter/ mm	SSE/ %	U ($k=2$)/ %
4	0.0041	0.0001
5	0.0073	0.0002
6	0.0091	0.0003
8	0.0118	0.0004
10	0.0150	0.0005
10 rpt	0.0158	0.0005
12	0.0186	0.0006
15	0.0229	0.0007
20	0.0294	0.0009
25	0.0370	0.0012
30	0.0436	0.0014
35	0.0494	0.0016
40	0.0550	0.0018
50	0.0659	0.0021
60	0.0762	0.0024
70	0.0851	0.0027
80	0.0945	0.0030
90	0.1027	0.0033
100	0.1106	0.0035

Table 21: the INRiM SSE results with the LP5 thermometer (indirect method, 3mm spot)

INRiM results: LP5 thermometer, indirect method, 6 mm spot		
Aperture diameter/ mm	SSE/ %	U (k=2)/ %
8	0.0035	0.0001
10	0.0065	0.0002
12	0.0093	0.0003
12 rpt	0.0091	0.0003
15	0.0133	0.0004
20	0.0198	0.0006
25	0.0275	0.0009
30	0.0335	0.0011
35	0.0398	0.0013
40	0.0452	0.0014
50	0.0559	0.0018
60	0.0665	0.0021
70	0.0754	0.0024
80	0.0842	0.0027
90	0.0918	0.0029
100	0.0997	0.0032

Table 22: the INRiM SSE results with the LP5 thermometer (indirect method, 6 mm spot)

1.3 THE PLOTS OF THE RESULTS OF THE MEASUREMENTS

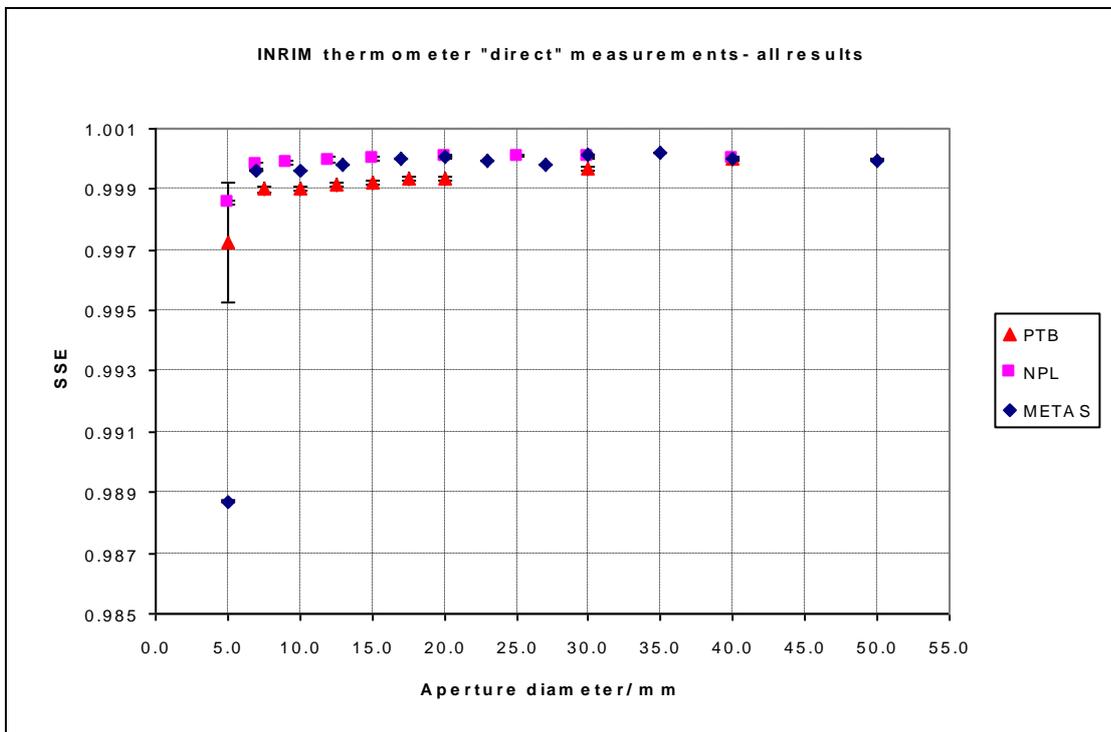


Figure 1: the results of the 'direct' SSE measurements with the INRiM thermometer

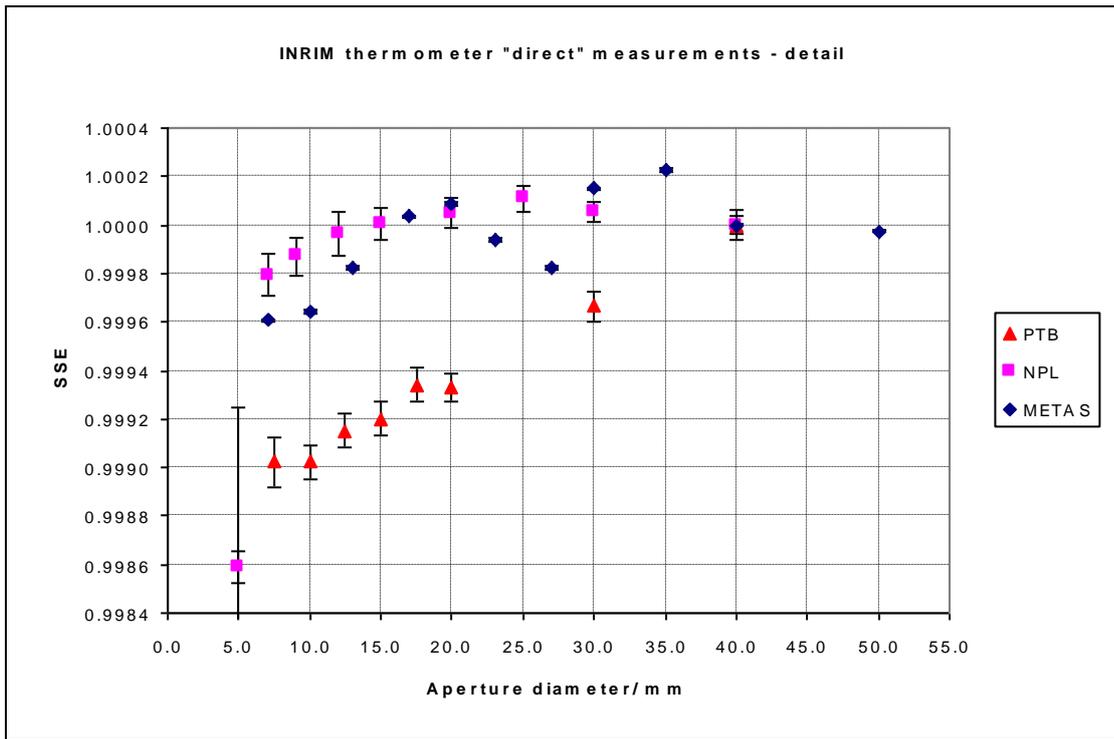


Figure 2: the detailed results of the 'direct' SSE measurements for the INRiM thermometer

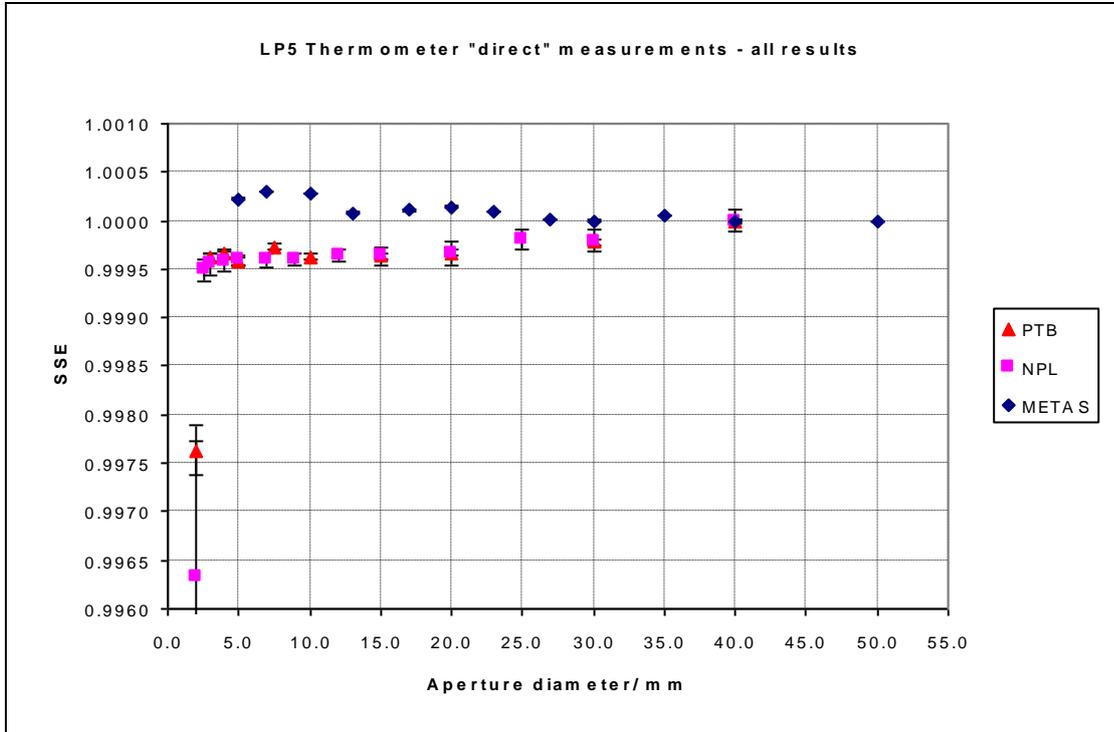


Figure 3: the results of the 'direct' SSE measurements for the LP5

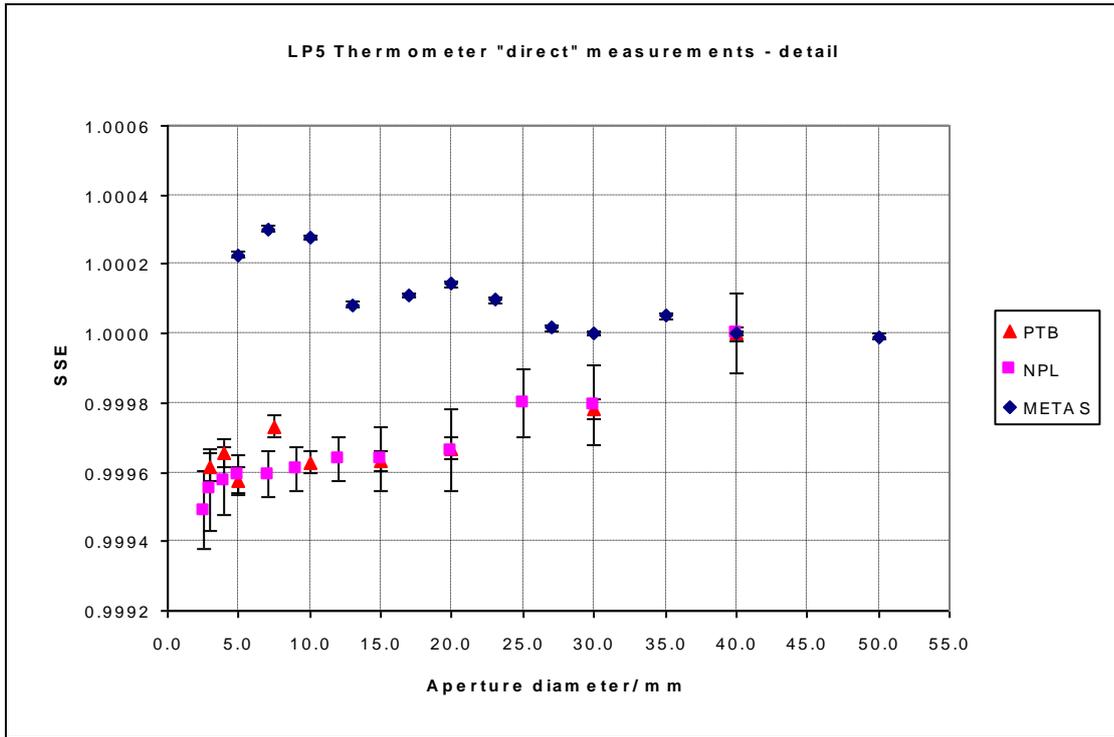


Figure 4: the detailed results of the 'direct' SSE measurements for the LP5

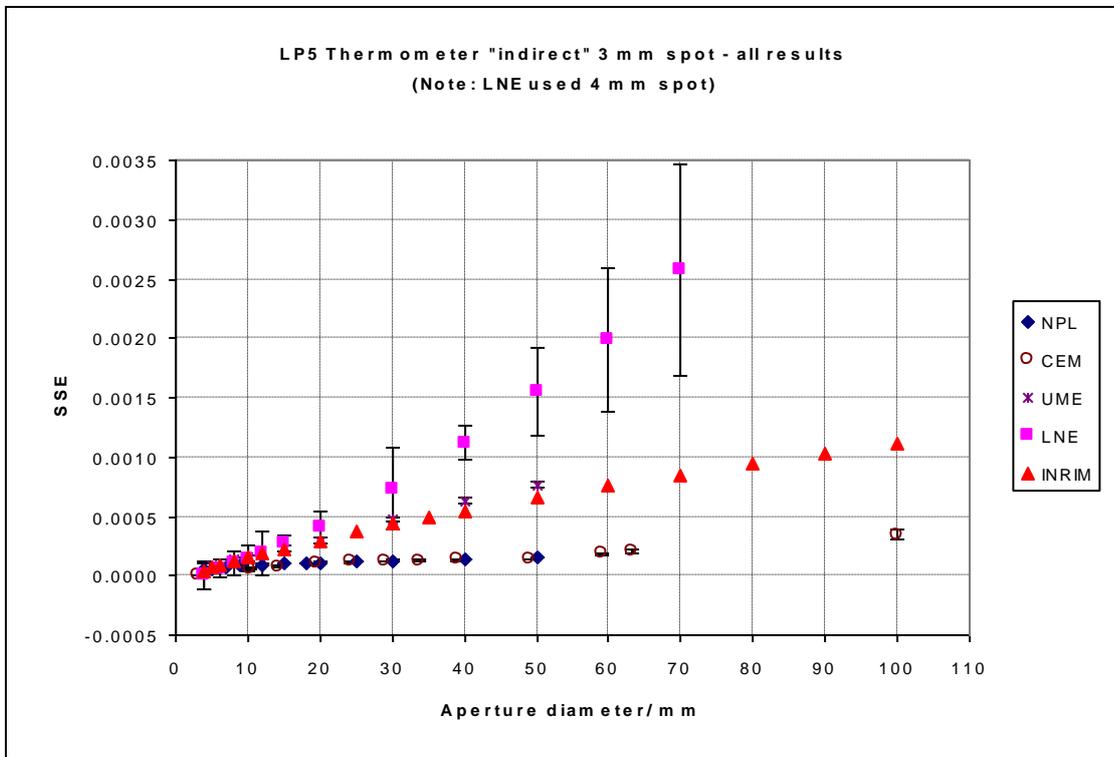


Figure 5: the results of the 'indirect' SSE measurements for the LP5 (3 mm spot)

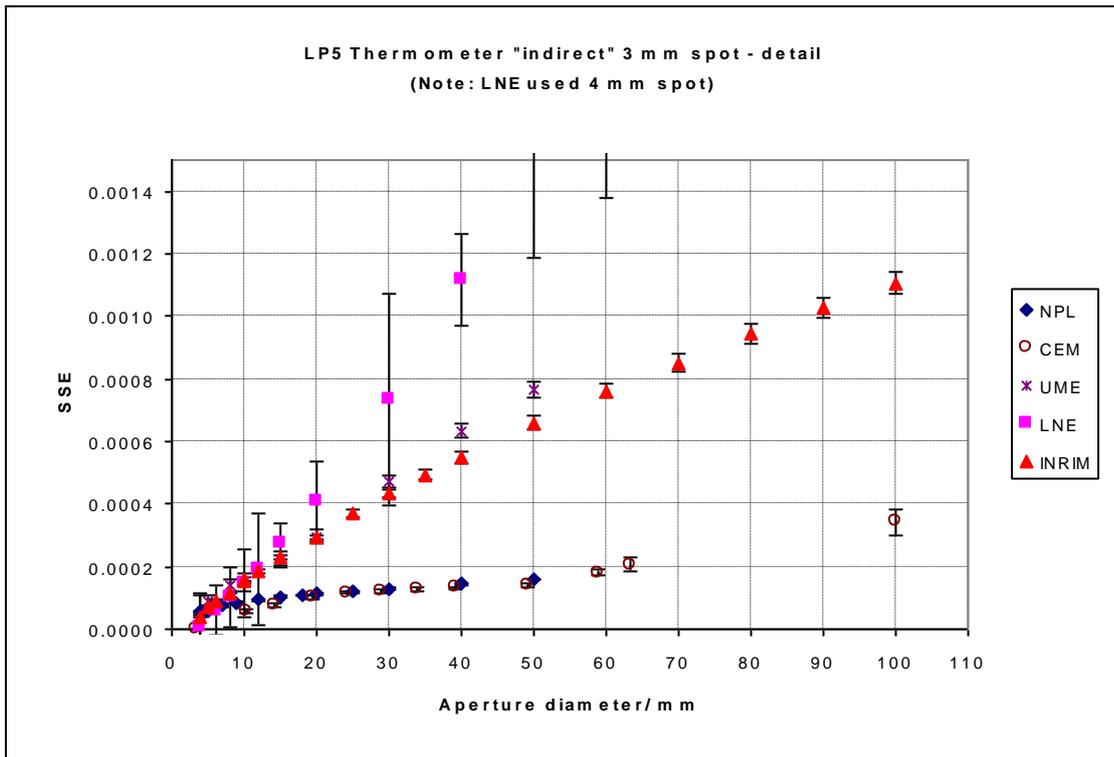


Figure 6: the detailed results of the 'indirect' SSE measurements for the LP5 (3 mm spot)

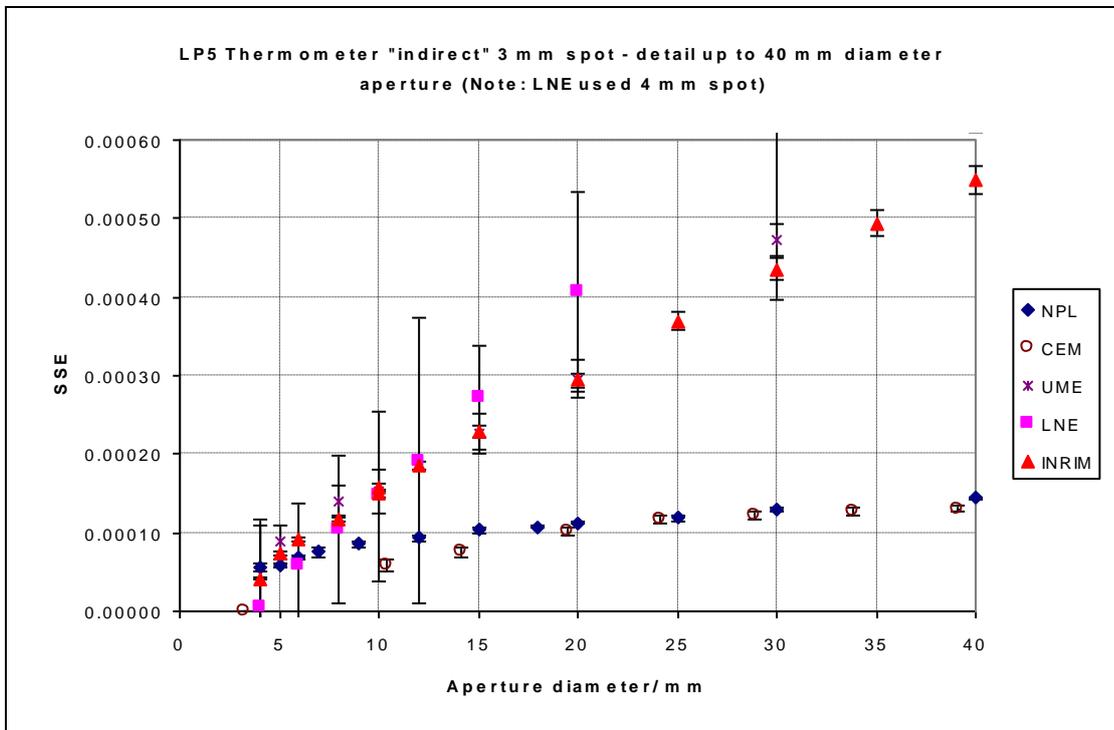


Figure 7: detailed results of the 'indirect' SSE measurements for the LP5 up to 40 mm diameter (3 mm spot)

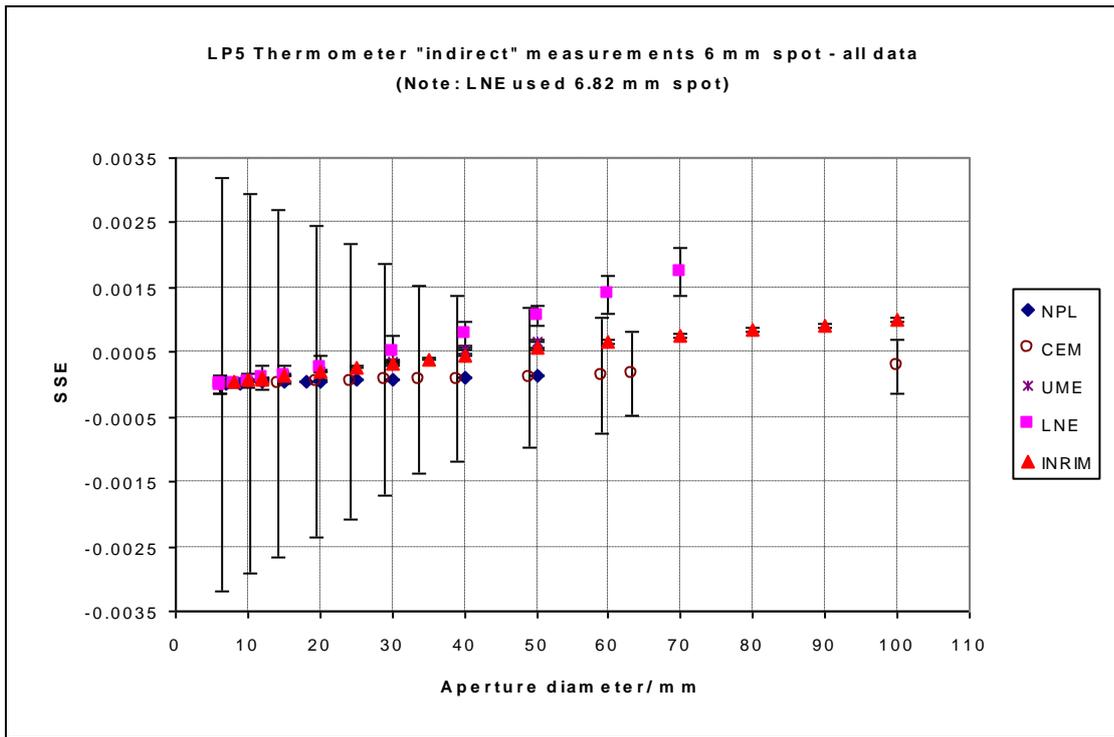


Figure 8: results of the 'indirect' SSE measurements for the LP5 (6 mm spot)

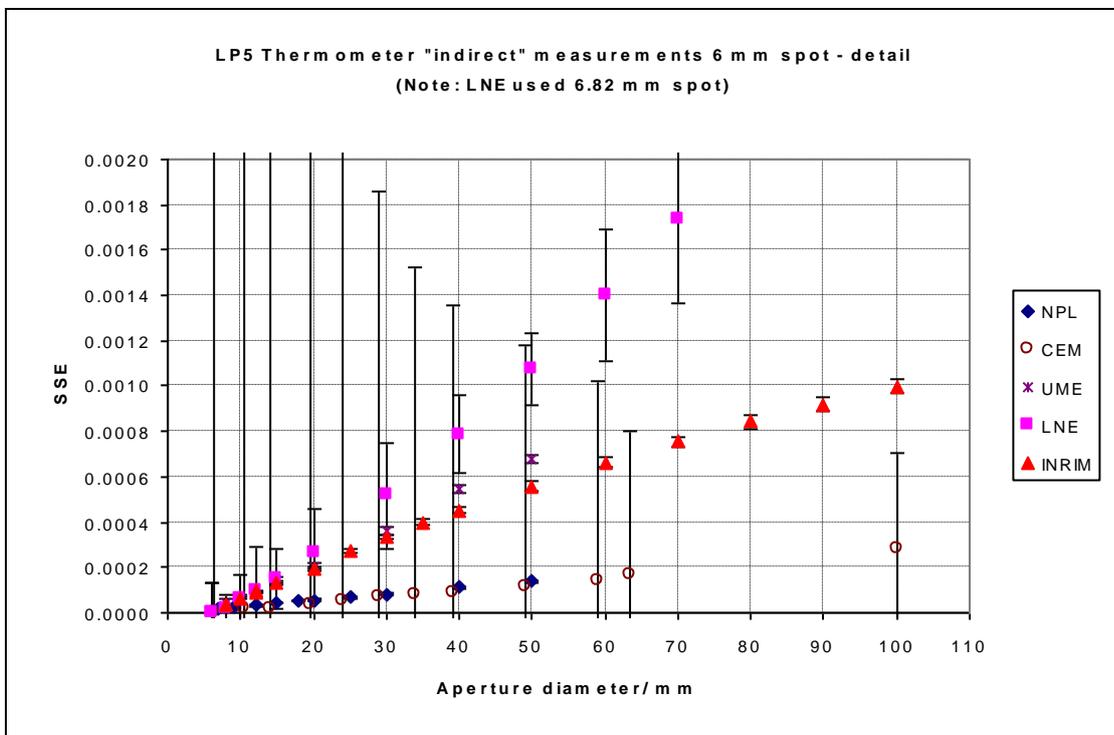


Figure 9: detailed results of the 'indirect' SSE measurements for the LP5 (6 mm spot)

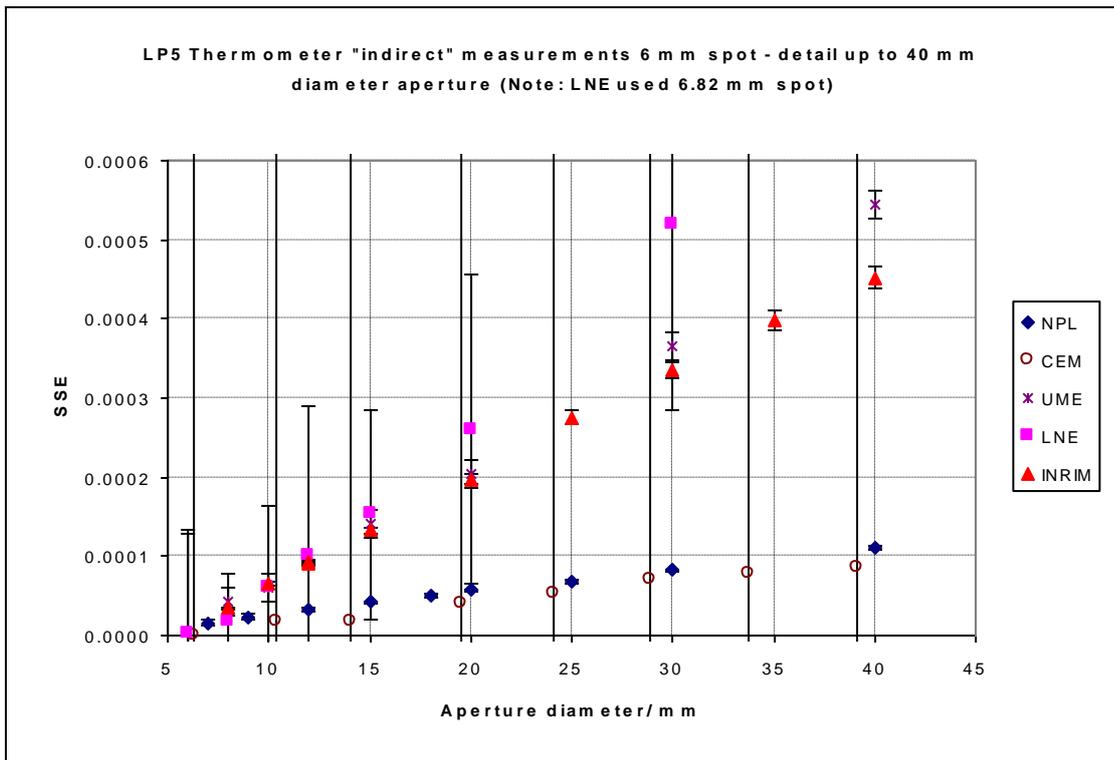


Figure 10: detailed results of the 'indirect' SSE measurements for the LP5 up to 40 mm diameter (6 mm spot)

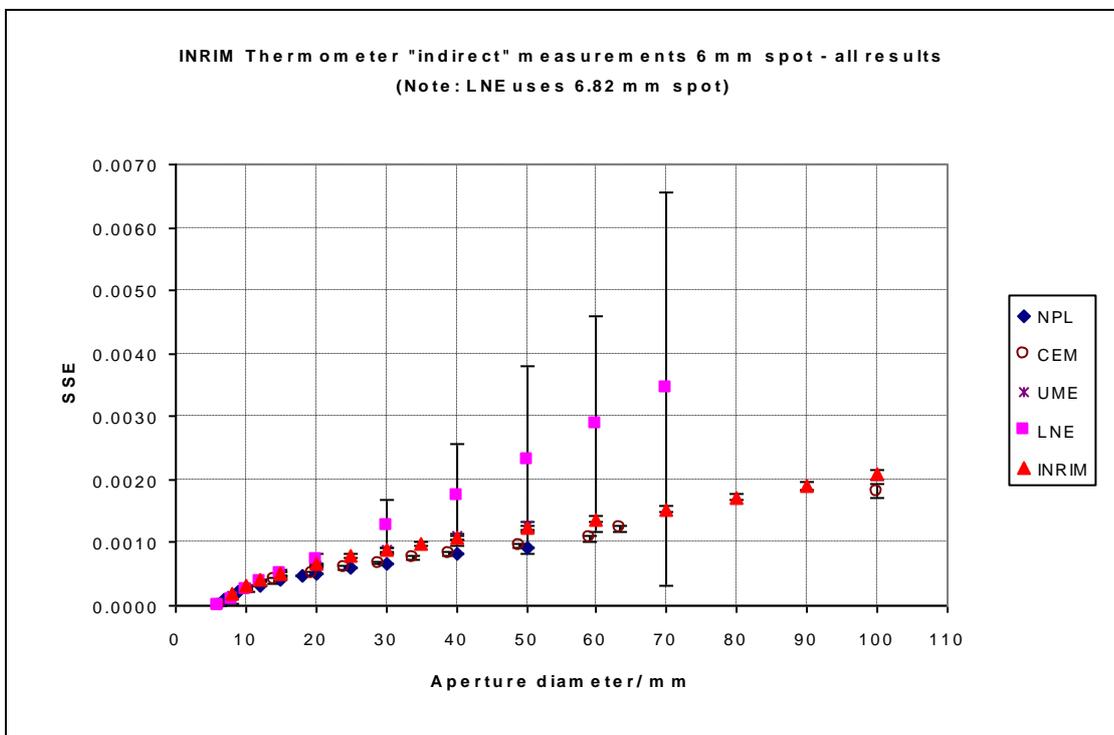


Figure 11: results of the 'indirect' SSE measurements for the INRiM thermometer (6 mm spot)

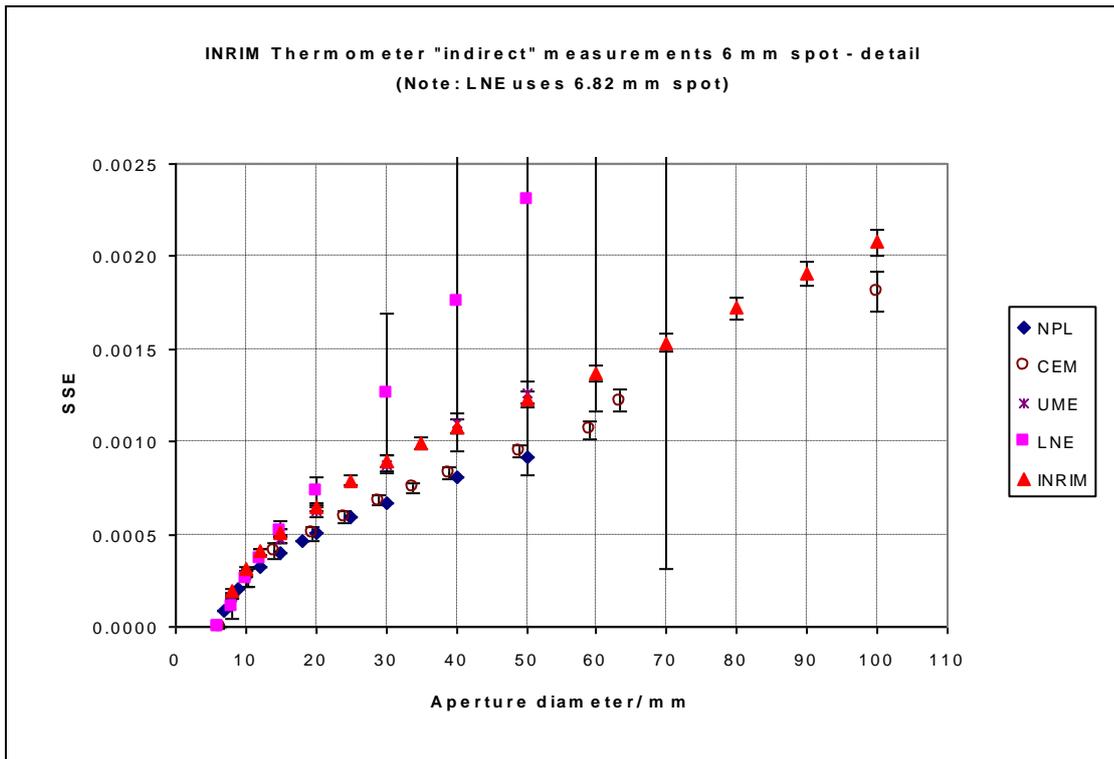


Figure 12: detailed results of the 'indirect' SSE measurements for the INRiM thermometer (6 mm spot)

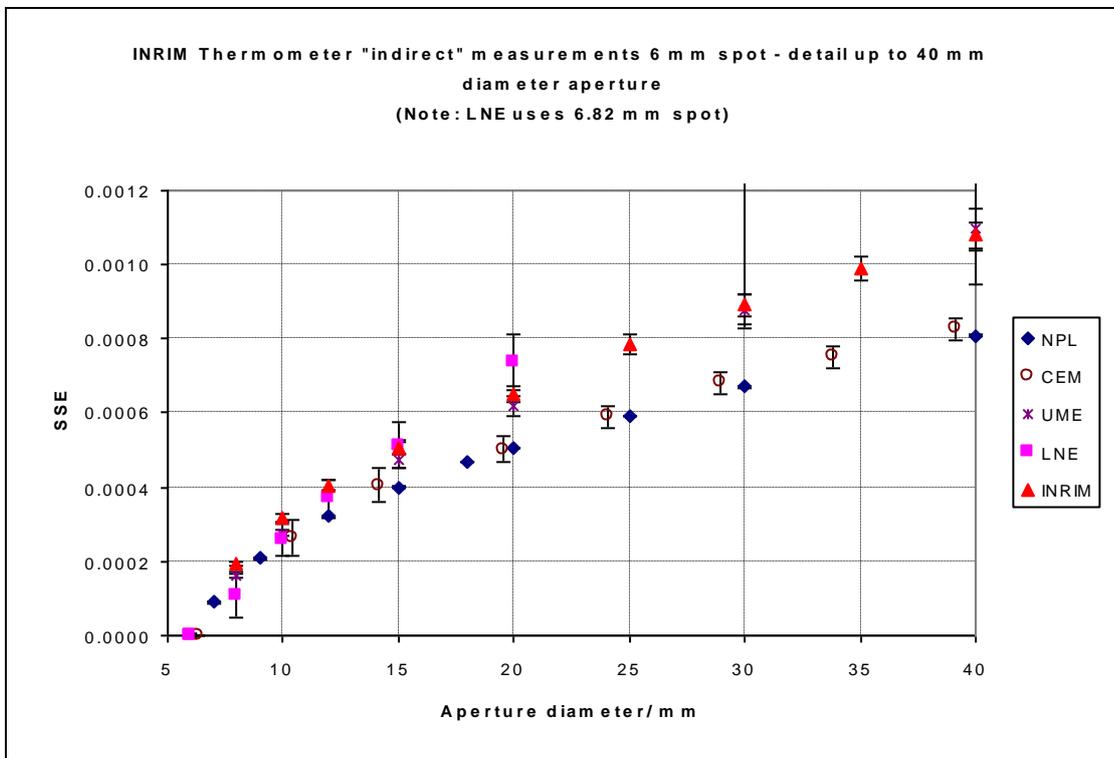


Figure 13: detailed results of the 'indirect' SSE measurements for the INRiM thermometer up to 40 mm diameter (6 mm spot)

1.4 ANALYSIS OF THE SSE RESULTS, DISCUSSIONS AND CONCLUSIONS

1.4.1 Analysis of the results

The SSE measurements were made using the aperture sizes available at each institute. This resulted in the measurements being made at a range of different aperture sizes, with only some overlap between institutes. In order to be able to directly compare all the results, and so that a comparison reference value could be calculated, the data sets from each participant were initially fitted using a Chebyshev polynomial expression¹ [1]. This polynomial expression was then used to provide, for each participant, an interpolated SSE over the range of apertures used by that participant. The average SSE value could then be calculated for specific aperture diameters in order to provide a comparison reference value at these diameters. The specific aperture diameters chosen for the indirect method were 5 mm (for the measurements with the 3 mm diameter spot) then (for both spots) 7 mm, 10 mm, every 5 mm to 30 mm, and then 40 mm, 50 mm, 60 mm, 70 mm, 80 mm and 100 mm. The specific aperture diameters chosen for the direct method were 3 mm (for the LP5), 5 mm (for both thermometers), 10 mm, and then every 5 mm to 40 mm.

The order of the polynomial fit for each participant was generally chosen to be $\leq n/2$, with n being the number of supplied data pairs (aperture diameter, SSE) from that participant, and ensuring that the fit was a good approximation to the data considering the estimated uncertainties of the measurements. The root mean square (rms) residual for each fit was used as an additional uncertainty component and was combined in quadrature with the participant's measurement uncertainty. The total uncertainty values were interpolated, where necessary, to give the values at each of the chosen aperture diameters. Information about the fitting, including Chebyshev coefficients and residuals and total combined uncertainties, is given in Tables 23 to 64.

In order to compare the results more rigorously a comparison reference value was needed. For each chosen aperture diameter the mean, weighted mean (weighted with respect to the laboratory measurement uncertainty) and median SSE values were calculated from the fitted data. The differences (laboratory – mean or median) were then calculated and the results are shown in Tables 65 to 105 and in the accompanying Figures. Discontinuities occur when the number of data sets (participants) changes. Since the LNE indirect measurements were carried out using spots that were different sizes from the other laboratories (although the measured SSE values were consistently higher than those of the other laboratories), the mean/ median/ weighted mean values and the laboratory differences were calculated both with and without the LNE data.

The arithmetic mean was chosen as the reference value for both thermometers and for both SSE methods. Since it was simply being used as a tool to facilitate the comparison of the results it was not assigned an uncertainty.

The calculated degrees of equivalence (DOE) and quantified demonstrated equivalence (QDE_{95}^2) values for pairs of participants are given in Tables 106 to 196 (DOE and QDE_{95} values are, respectively, top right and bottom left sections of the Tables). The QDE_{95} values for each pair of labs (i,j) were calculated from the equation:

¹ The Chebyshev coefficients are obtained using values of x transformed to lie in the range $(-1/+1)$ by the equation: $xx = ((x - xmin) - (xmax - x))/(xmax - xmin)$, $xmin$ and $xmax$ being the minimum and maximum aperture diameters respectively.

The coefficients $a(0)$, $a(1)$, ..., $a(n)$ are given for the Chebyshev series:

$$y = 0.5 * a(0) + \sum_{j=1}^n (a(j) * T(j))$$

where $T(j)$ is defined as $\cos(j*z)$ and where $\cos(z) = xx$

² For example, Wood, B. M., Douglas, R. J., *Metrologia*, 1998, **35**, pp 187-196

$$QDE_{95(i,j)} = \left| \Delta SSE \right|_{(i,j)} + \left\{ 1.645 + 0.3295 \exp \left(\frac{-4.05 \left| \Delta SSE \right|_{(i,j)}}{u_{(i,j)}} \right) \right\} u_{(i,j)} \quad \text{Equation 1}$$

where $\left| \Delta SSE \right|_{(i,j)}$ is the absolute difference in the SSE values between the two laboratories and $u_{(i,j)}$ is the combined $k = 1$ uncertainty.

The difference between each laboratory and the mean value at each aperture diameter, along with the estimated $k = 2$ measurement uncertainties, are given in the Figures accompanying the Tables.

1.4.2 Discussion of the results

It should be noted that some of the observed differences are due to the fitting function (as evidenced by the residuals of the fits – see Sections 1.5 and 1.6) and are not a real effect. It should also be noted that there is a considerable spread in the uncertainty values of the different participants (for example there is about a factor of ten spread in the uncertainties for the INRiM thermometer using the direct method), as well as inconsistencies in the results of the participants. It would be interesting to understand the reason(s) behind some of these inconsistencies, and whether some laboratories have maybe over- or under-estimated any uncertainty components.

Measurements using the ‘direct’ method:

1) For the INRiM thermometer, the NPL and METAS results are in reasonably good agreement, although not within the measurement uncertainties, whereas the PTB results are consistently lower and not within the measurement uncertainties. For the LP5 thermometer, the PTB and NPL results are in good agreement within the measurement uncertainties whereas the METAS results are consistently higher and not within the measurement uncertainties.

Measurements using the ‘indirect’ method:

1) As has been stated earlier, LNE used spots that were of a larger diameter than those of the other laboratories. However, the LNE SSE values are consistently higher, for both thermometers, compared to the results of the other laboratories, which is counterintuitive. LNE has suggested that this is possibly due to the arrangement of the LNE SSE apparatus, which has a diaphragm aperture some distance in front of the integrating sphere and could have resulted in light leakage. Alternatively, it might be that the metal spots have a not-insignificant transmission.

2) For both the INRiM thermometer and the LP5, the NPL and CEM results are in good agreement with each other, whereas the UME and INRiM results are consistently higher but in close agreement with each other. The results, apart from those of LNE, are in better agreement for the INRiM thermometer than for the LP5.

Comparison between the two methods:

The ‘direct’ and ‘indirect’ methods each provide an assessment of the SSE of a radiation thermometer but the methodology is different. The ‘direct’ method shows the relative change in signal of the radiation thermometer as the aperture size is varied, with the results normalised to the signal at the maximum diameter aperture. The ‘indirect’ method shows the change in ‘residual’ signal (most of the field-of-view of the radiation thermometer is obscured) relative to the radiance of the integrating sphere and the results are not normalised to a particular aperture size. Thus the two methods give different values: for a radiation thermometer with good SSE characteristics the values will be near 1 for the ‘direct’ method and small for the ‘indirect method’. Although initially an attempt was made to directly compare the results between the

two methods it was found to be overly complex and this was not done. Instead the comparison was limited to those laboratories using the same method.

1.5 THE FITTING DATA FOR THE INRIM THERMOMETER SSE MEASUREMENTS

1.5.1 Direct SSE measurements

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
5	0.997250	0.997258	0.000008
7.5	0.999022	0.998980	-0.000042
10	0.999025	0.999111	0.000086
12.5	0.999150	0.999073	-0.000077
15	0.999201	0.999211	0.000010
17.5	0.999342	0.999371	0.000029
20	0.999329	0.999314	-0.000015
30	0.999665	0.999665	0.000000
40	1.000000	1.000000	0.000000
Root mean square residual =			0.000090

Table 23 – the PTB direct SSE measurements with the INRiM thermometer

Table 24 – the Chebyshev polynomial coefficients (PTB, direct measurements with INRiM thermometer)

Index	Chebyshev coefficient
0	2.00049019E+00
1	2.50729091E-03
2	6.17030851E-04
3	-3.46389633E-05
4	-1.43854827E-03
5	-1.10147284E-03
6	-7.94785071E-04

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
5	0.998590	0.998619	0.000029
7	0.999790	0.999682	-0.000108
9	0.999870	0.999982	0.000112
12	0.999960	0.999960	0.000000
15	1.000010	0.999942	-0.000068
20	1.000050	1.000107	0.000057
25	1.000110	1.000082	-0.000028
30	1.000050	1.000057	0.000007
40	1.000000	1.000000	0.000000
Root mean square residual =			0.000130

Table 25 – the NPL direct SSE measurements with the INRiM thermometer

Index	Chebyshev coefficient
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Table 26 – the Chebyshev polynomial coefficients (NPL, direct measurements with INRiM thermometer)

0	2.00004441E+00
1	5.74066672E-04
2	-1.85389736E-04
3	1.59177763E-04
4	-3.01357881E-04
5	-4.29280819E-05
6	-2.26001315E-04

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
5	0.988715	0.988741	0.000025
7	0.999607	0.999505	-0.000102
10	0.999643	0.999883	0.000240
13	0.999826	0.999517	-0.000309
17	1.000035	1.000269	0.000234
20	1.000086	1.000080	-0.000005
23	0.999940	0.999749	-0.000191
27	0.999824	1.000014	0.000190
30	1.000149	1.000056	-0.000093
35	1.000227	1.000240	0.000012
40	1.000000	0.999999	-0.000001
Root mean square residual =			0.000388

Table 27 – the METAS direct SSE measurements with the INRiM thermometer

(Note that the METAS data has been adjusted to give the SSE values relative to a 40 mm diameter aperture to be consistent with the maximum diameter apertures of NPL and PTB.)

Table 28 – the Chebyshev polynomial coefficients (METAS, direct measurements with INRiM thermometer)

Index	Chebyshev coefficient
0	1.99861248E+00
1	2.53117720E-03
2	-1.37947063E-03
3	1.79094451E-03
4	-1.46746192E-03
5	9.00800389E-04
6	-1.32309191E-03
7	4.06293619E-04
8	-7.66480785E-04

1.5.2 Indirect measurements – 6 mm diameter spot

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
7	0.000090	0.000093	0.000003
9	0.000208	0.000203	-0.000005
12	0.000320	0.000321	0.000001
15	0.000400	0.000404	0.000004
18	0.000467	0.000467	0.000000
20	0.000504	0.000504	-0.000001
25	0.000593	0.000590	-0.000003
30	0.000671	0.000674	0.000003
40	0.000810	0.000809	-0.000001
50	0.000911	0.000911	0.000000
Root mean square residual =			0.000004

Table 29 – the NPL indirect SSE measurements with the INRiM thermometer

Table 30 - the Chebyshev polynomial coefficients (NPL, indirect measurements with INRiM thermometer)

Index	Chebyshev coefficient
0	1.17690672E-03
1	3.75400915E-04
2	-7.33357043E-05
3	2.33295642E-05
4	-1.29803075E-05
5	1.06044545E-05

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
6.3	0.000000	-0.000001	-0.000001
10.4	0.000265	0.000269	0.000004
14.1	0.000406	0.000399	-0.000007
19.5	0.000501	0.000510	0.000009
24.1	0.000591	0.000588	-0.000003
28.9	0.000681	0.000671	-0.000010
33.8	0.000751	0.000756	0.000005
39.1	0.000827	0.000836	0.000009
49.1	0.000946	0.000934	-0.000012
59.0	0.001062	0.001072	0.000010
63.3	0.001220	0.001215	-0.000005
100.0	0.001810	0.001810	0.000000
Root mean square residual =			0.000011

Table 31 – the CEM indirect SSE measurements with the INRiM thermometer

Table 32 - the Chebyshev polynomial coefficients (CEM, indirect measurements with INRiM thermometer)

Index	Chebyshev coefficient
0	2.84505341E-03
1	1.43377163E-03
2	1.11161150E-04
3	-2.17265280E-04
4	-4.84241062E-04
5	-3.11065800E-04
6	-1.44878010E-04

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
8	0.000161	0.000166	0.000005
10	0.000276	0.000268	-0.000008
15	0.000472	0.000472	0.000000
20	0.000620	0.000625	0.000005
30	0.000876	0.000872	-0.000004
40	0.001097	0.001099	0.000002
50	0.001264	0.001264	0.000000
Root mean square residual =			0.000008

Table 33 - the UME indirect SSE measurements with the INRiM thermometer

Table 34 - the Chebyshev polynomial coefficients (UME, indirect measurements with INRiM thermometer)

Index	Chebyshev coefficient
0	1.59065746E-03
1	5.34242855E-04
2	-6.67330627E-05
3	1.44838459E-05
4	-1.36965957E-05

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
6	0.000000	0.000003	0.000003
8	0.000110	0.000125	0.000016
10	0.000260	0.000242	-0.000018
12	0.000369	0.000353	-0.000016
15	0.000513	0.000512	-0.000001
20	0.000736	0.000764	0.000028
30	0.001264	0.001250	-0.000014
40	0.001756	0.001757	0.000001
50	0.002303	0.002305	0.000002
60	0.002883	0.002883	0.000000
70	0.003440	0.003440	0.000000
Root mean square residual =			0.000017

Table 35 - the LNE indirect SSE measurements with the INRiM thermometer (6.82 mm spot)

Table 36 - the Chebyshev polynomial coefficients (LNE, indirect measurements with INRiM thermometer)

Index	Chebyshev coefficient
0	3.41197415E-03
1	1.70325069E-03
2	3.47455017E-05
3	1.49968337E-05
4	-1.91977895E-05

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
8	0.000194	0.000214	0.000020
10	0.000315	0.000305	-0.000010
12	0.000405	0.000388	-0.000017
15	0.000508	0.000501	-0.000007
20	0.000650	0.000661	0.000011
25	0.000788	0.000791	0.000003
30	0.000892	0.000899	0.000007
35	0.000990	0.000991	0.000001
40	0.001079	0.001073	-0.000006
50	0.001226	0.001221	-0.000005
60	0.001369	0.001371	0.000002
70	0.001534	0.001537	0.000003
80	0.001723	0.001720	-0.000003
90	0.001907	0.001909	0.000002
100	0.002078	0.002077	-0.000001
Root mean square residual =			0.000010

Table 37 - INRiM indirect SSE measurements with the INRiM thermometer

Table 38 - the Chebyshev polynomial coefficients (INRiM, indirect measurements with INRiM thermometer)

Index	Chebyshev coefficient
0	2.48548674E-03
1	8.69673574E-04
2	-6.70436839E-05
3	6.21703860E-05
4	-3.00531075E-05

1.6 THE FITTING DATA FOR THE LP5 SSE MEASUREMENTS

1.6.1 Direct SSE measurements

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
3	0.999614	0.999627	0.000013
4	0.999656	0.999632	-0.000024
5	0.999574	0.999635	0.000061
7.5	0.999732	0.999642	-0.000090
10	0.999629	0.999647	0.000018
15	0.999632	0.999658	0.000026
20	0.999669	0.999675	0.000006
30	0.999782	0.999768	-0.000014
40	1.000000	1.000004	0.000004
Root mean square residual =			0.000053

Table 39 – the PTB direct SSE measurements with the LP5

Table 40 – the Chebyshev polynomial coefficients (PTB, direct measurements with LP5 thermometer)

Index	Chebyshev coefficient
0	1.99949828E+00
1	1.68306680E-04
2	6.65231462E-05
3	1.99795384E-05

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
2.5	0.999490	0.999499	0.000009
3	0.999551	0.999537	-0.000014
4	0.999575	0.999579	0.000004
5	0.999593	0.999593	0.000000
7	0.999593	0.999597	0.000004
9	0.999609	0.999606	-0.000003
12	0.999637	0.999633	-0.000004
15	0.999639	0.999645	0.000006
20	0.999662	0.999659	-0.000003
25	0.999800	0.999801	0.000001
30	0.999794	0.999794	0.000000
40	1.000000	1.000000	0.000000
Root mean square residual =			0.000010

Table 41 – the NPL direct SSE measurements with the LP5

Table 42 – the Chebyshev polynomial coefficients (NPL, direct measurements with LP5 thermometer)

Index	Chebyshev coefficient
0	1.99910719E+00
1	-9.20282317E-05
2	-1.21613373E-04
3	4.53050143E-05
4	1.61771234E-04
5	2.27249438E-04
6	1.55604450E-04
7	7.01209419E-05

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
5	1.000228	1.000270	0.000041
7	1.000303	1.000251	-0.000052
10	1.000278	1.000218	-0.000060
13	1.000084	1.000180	0.000096
17	1.000109	1.000130	0.000022
20	1.000143	1.000096	-0.000046
23	1.000096	1.000067	-0.000029
27	1.000016	1.000039	0.000023
30	1.000000	1.000025	0.000025
35	1.000050	1.000016	-0.000034
40	1.000000	1.000016	0.000016
Root mean square residual =			0.000058

Table 43 – the METAS direct SSE measurements with the LP5

(Note that the METAS data has been adjusted to give the SSE values relative to a 40 mm diameter aperture to be consistent with the maximum diameter apertures of NPL and PTB.)

Table 44 – the Chebyshev polynomial coefficients (METAS, direct measurements with LP5 thermometer)

Index	Chebyshev coefficient
0	2.00018998E+000
1	-1.34251133E-004
2	4.70046345E-005
3	-5.30560445E-006
4	-1.20254445E-005

1.6.2 Indirect measurements – 3 mm diameter spot

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
4	0.000056	0.000056	0.000000
5	0.000059	0.000062	0.000003
6	0.000069	0.000069	-0.000001
7	0.000076	0.000074	-0.000002
9	0.000086	0.000084	-0.000002
12	0.000094	0.000095	0.000001
15	0.000103	0.000103	0.000000
18	0.000107	0.000109	0.000002
20	0.000113	0.000113	-0.000001
25	0.000119	0.000120	0.000001
30	0.000129	0.000127	-0.000002
40	0.000144	0.000145	0.000001
50	0.000160	0.000160	0.000000
Root mean square residual =			0.000002

Table 45 – the NPL indirect SSE measurements with the LP5

Table 46 – the Chebyshev polynomial coefficients (NPL, indirect measurements with LP5 thermometer)

Index	Chebyshev coefficient
0	2.36172801E-04
1	4.75469723E-05
2	-7.51575789E-06
3	4.64102214E-06
4	-2.85082027E-06

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
3.2	0.000000	0.000001	0.000001
10.4	0.000059	0.000056	-0.000003
14.1	0.000076	0.000078	0.000002
19.5	0.000101	0.000102	0.000001
24.1	0.000117	0.000115	-0.000002
28.9	0.000122	0.000123	0.000001
33.8	0.000127	0.000127	0.000000
39.1	0.000131	0.000129	-0.000002
49.1	0.000140	0.000142	0.000002
59.0	0.000181	0.000180	-0.000001
63.3	0.000207	0.000207	0.000000
100.0	0.000342	0.000342	0.000000
Root mean square residual =			0.000002

Table 47 – the CEM indirect SSE measurements with the LP5

Table 48– the Chebyshev polynomial coefficients (CEM, indirect measurements with LP5 thermometer)

Index	Chebyshev coefficient
0	4.05069880E-04
1	1.92217845E-04
2	1.14309484E-05
3	-7.75393161E-06
4	-4.26797850E-05
5	-1.37467689E-05

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
5	0.000088	0.000095	0.000007
8	0.000140	0.000129	-0.000011
10	0.000152	0.000154	0.000002
15	0.000226	0.000224	-0.000002
20	0.000296	0.000302	0.000006
30	0.000472	0.000470	-0.000002
40	0.000634	0.000633	-0.000001
50	0.000767	0.000768	0.000001
Root mean square residual =			0.000007

Table 49 – the UME indirect SSE measurements with the LP5

Table 50 – the Chebyshev polynomial coefficients (UME, indirect measurements with LP5 thermometer)

Index	Chebyshev coefficient
0	8.58752344E-04
1	3.47817375E-04
2	1.74197800E-06
3	-1.14132592E-05

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
4	0.000000	0.000001	0.000001
6	0.000058	0.000054	-0.000004
8	0.000104	0.000103	-0.000001
10	0.000146	0.000150	0.000004
12	0.000192	0.000197	0.000005
15	0.000272	0.000270	-0.000002
20	0.000408	0.000404	-0.000004
30	0.000735	0.000733	-0.000002
40	0.001119	0.001127	0.000008
50	0.001553	0.001544	-0.000009
60	0.001983	0.001987	0.000004
70	0.002574	0.002573	-0.000001
Root mean square residual =			0.000006

Table 51 – the LNE indirect SSE measurements with the LP5 (4 mm spot)

Table 52 - the Chebyshev polynomial coefficients (LNE, indirect measurements with LP5 thermometer)

Index	Chebyshev coefficient
0	2.26626131E-03
1	1.26735708E-03
2	1.41212001E-04
3	3.57999058E-06
4	1.30203021E-05
5	1.49742250E-05

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
4	0.000041	0.000051	0.000010
5	0.000073	0.000068	-0.000005
6	0.000091	0.000085	-0.000006
8	0.000118	0.000119	0.000001
10	0.000154	0.000152	-0.000002
12	0.000186	0.000183	-0.000003
15	0.000229	0.000229	0.000000
20	0.000294	0.000302	0.000008
25	0.000370	0.000369	-0.000001
30	0.000436	0.000433	-0.000003
35	0.000494	0.000494	0.000000
40	0.000550	0.000551	0.000001
50	0.000659	0.000659	0.000000
60	0.000762	0.000759	-0.000003
70	0.000851	0.000854	0.000003
80	0.000945	0.000943	-0.000002
90	0.001027	0.001028	0.000001
100	0.001106	0.001106	0.000000
Root mean square residual =			0.000004

Table 53 – the INRiM indirect SSE measurements with the LP5

Table 54 – the Chebyshev polynomial coefficients (INRiM, indirect measurements with LP5 thermometer)

Index	Chebyshev coefficient
0	1.26307904E-03
1	5.18372779E-04
2	-5.07067929E-05
3	9.12601710E-06
4	-2.57555545E-06

1.6.3 Indirect measurements – 6 mm diameter spot

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
7	0.000016	0.000016	0.000000
9	0.000023	0.000023	0.000000
12	0.000033	0.000034	0.000001
15	0.000042	0.000043	0.000000
18	0.000051	0.000051	0.000000
20	0.000057	0.000056	-0.000001
25	0.000068	0.000069	0.000001
30	0.000082	0.000082	0.000000
40	0.000111	0.000111	0.000000
50	0.000138	0.000138	0.000000
Root mean square residual =			0.000001

Table 55– the NPL indirect SSE measurements with the LP5

Table 56– the Chebyshev polynomial coefficients (NPL, indirect measurements with LP5 thermometer)

Index	Chebyshev coefficient
0	1.56924523E-04
1	6.01122606E-05
2	-6.17954252E-07
3	8.72674441E-07
4	-9.94456357E-07

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
6.3	0.000000	0.000003	0.000003
10.4	0.000018	0.000011	-0.000007
14.1	0.000018	0.000022	0.000004
19.5	0.000039	0.000040	0.000001
24.1	0.000054	0.000055	0.000001
28.9	0.000070	0.000068	-0.000002
33.8	0.000079	0.000078	-0.000001
39.1	0.000086	0.000088	0.000002
49.1	0.000110	0.000107	-0.000003
59.0	0.000138	0.000143	0.000005
63.3	0.000169	0.000166	-0.000003
100.0	0.000280	0.000280	0.000000
Root mean square residual =			0.000005

Table 57– the CEM indirect SSE measurements with the LP5

Table 58– the Chebyshev polynomial coefficients (CEM, indirect measurements with LP5 thermometer)

Index	Chebyshev coefficient
0	3.17645999E-04
1	1.72114524E-04
2	1.11943495E-05
3	-1.89165499E-05
4	-2.86640582E-05
5	-1.45344305E-05

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
8	0.000043	0.000039	-0.000004
10	0.000061	0.000068	0.000007
15	0.000141	0.000136	-0.000005
20	0.000204	0.000206	0.000002
30	0.000365	0.000365	0.000000
40	0.000544	0.000544	0.000000
50	0.000677	0.000677	0.000000
Root mean square residual =			0.000007

Table 59 – the UME indirect SSE measurements with the LP5

Table 60 – the Chebyshev polynomial coefficients (UME, indirect measurements with LP5 thermometer)

Index	Chebyshev coefficient
0	7.18282595E-04
1	3.29562367E-04
2	5.04331611E-06
3	-1.06244237E-05
4	-6.04600305E-06

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
6	0.000000	-0.000006	-0.000006
8	0.000017	0.000025	0.000008
10	0.000060	0.000059	-0.000001
12	0.000100	0.000095	-0.000005
15	0.000150	0.000154	0.000004
20	0.000260	0.000263	0.000003
30	0.000520	0.000513	-0.000007
40	0.000790	0.000795	0.000005
50	0.001100	0.001097	-0.000003
60	0.001400	0.001403	0.000003
70	0.001700	0.001699	-0.000001
Root mean square residual =			0.000006

Table 61 – the LNE indirect SSE measurements with the LP5 (6.82 mm spot)

Table 62 – the Chebyshev polynomial coefficients (LNE, indirect measurements with LP5 thermometer)

Index	Chebyshev coefficient
0	1.58341705E-03
1	8.71683019E-04
2	5.48251774E-05
3	-1.91595489E-05

Aperture diameter/ mm	SSE (raw data)	SSE (fitted data)	Residual
8	0.000035	0.000033	-0.000002
10	0.000065	0.000063	-0.000002
12	0.000092	0.000092	0.000000
15	0.000133	0.000135	0.000002
20	0.000198	0.000205	0.000007
25	0.000275	0.000271	-0.000004
30	0.000335	0.000334	-0.000001
35	0.000398	0.000395	-0.000003
40	0.000452	0.000453	0.000001
50	0.000559	0.000562	0.000003
60	0.000665	0.000662	-0.000003
70	0.000754	0.000755	0.000001
80	0.000842	0.000841	-0.000001
90	0.000918	0.000921	0.000003
100	0.000997	0.000996	-0.000001
Root mean square residual =			0.000003

Table 63 – the INRiM indirect SSE measurements with the LP5

Table 64 – the Chebyshev polynomial coefficients (INRiM, indirect measurements with LP5 thermometer)

Index	Chebyshev coefficient
0	1.11776914E-03
1	4.77153218E-04
2	-4.43026562E-05
3	4.04405319E-06

1.7 THE ANALYSIS OF THE DIFFERENCES BETWEEN THE SSE RESULTS

1.7.1 Results for the INRiM thermometer – direct measurements

Aperture diameter/ mm	Weighted mean SSE value	Arithmetic mean SSE value	Median SSE value
5	0.998191	0.994872	0.997258
7	0.999361	0.999378	0.999505
10	0.999571	0.999585	0.999643
15	0.999611	0.999703	0.999942
20	0.999740	0.999834	1.000080
25	0.999417	0.999501	0.999809
30	0.999886	0.999926	1.000056
40	1.000000	1.000000	1.000000

Table 65 – the calculated arithmetic and weighted mean and the median SSE values for the direct measurements with the INRiM thermometer

Aperture diameter/ mm	Difference (PTB - weighted mean SSE)	Difference (PTB - mean SSE)	Difference (PTB - median SSE)	Total ($k = 2$) uncertainty (fitted data)
5	-0.000934	0.002385	0.000000	0.002007
7	-0.000525	-0.000543	-0.000670	0.000190
10	-0.000459	-0.000473	-0.000531	0.000176
15	-0.000399	-0.000492	-0.000731	0.000176
20	-0.000426	-0.000520	-0.000766	0.000173
25	-0.000805	-0.000889	-0.001196	0.000173
30	-0.000220	-0.000261	-0.000391	0.000173
40	0.000000	0.000000	0.000000	0.000173

Table 66 – differences between PTB results and averages, direct measurements with the INRiM thermometer

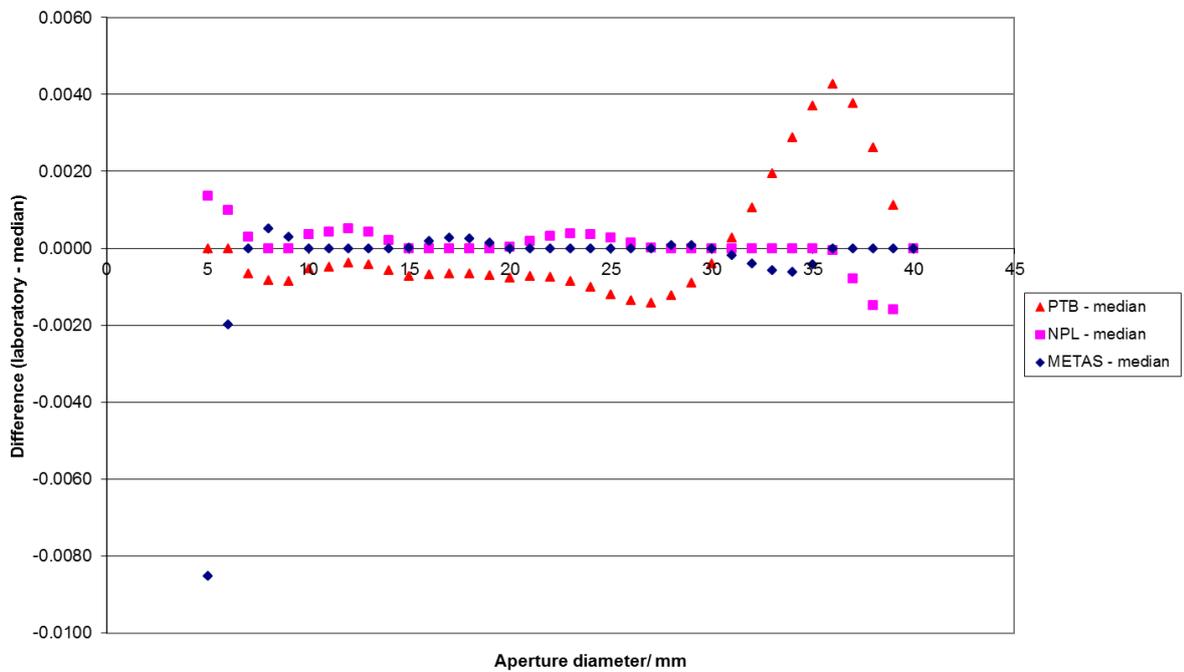
Aperture diameter/ mm	Difference (NPL - weighted mean SSE)	Difference (NPL - mean SSE)	Difference (NPL - median SSE)	Total ($k = 2$) uncertainty (fitted data)
5	0.000428	0.003747	0.001362	0.000164
7	0.000434	0.000416	0.000290	0.000174
10	0.000430	0.000416	0.000358	0.000171
15	0.000332	0.000239	0.000000	0.000165
20	0.000367	0.000273	0.000026	0.000165
25	0.000665	0.000581	0.000273	0.000159
30	0.000171	0.000131	0.000001	0.000155
40	0.000000	0.000000	0.000000	0.000155

Table 67 – differences between NPL results and averages, direct measurements with the INRiM thermometer

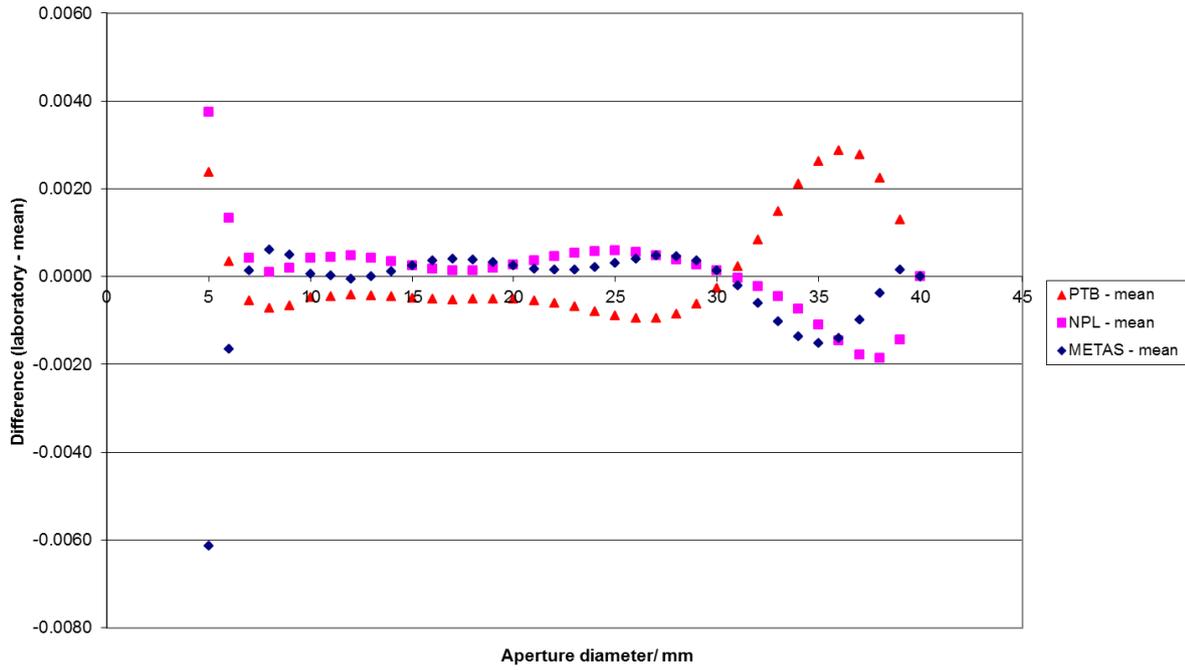
Aperture diameter/ mm	Difference (METAS - weighted mean SSE)	Difference (METAS - mean SSE)	Difference (METAS - median SSE)	Total ($k = 2$) uncertainty (fitted data)
5	-0.009451	-0.006132	-0.008517	0.000776
7	0.000144	0.000127	0.000000	0.000776
10	0.000072	0.000058	0.000000	0.000776
15	0.000346	0.000253	0.000014	0.000776
20	0.000340	0.000247	0.000000	0.000776
25	0.000392	0.000308	0.000000	0.000776
30	0.000170	0.000130	0.000000	0.000776
40	-0.000001	-0.000001	-0.000001	0.000776

Table 68 – differences between METAS results and averages, direct measurements with the INRiM thermometer

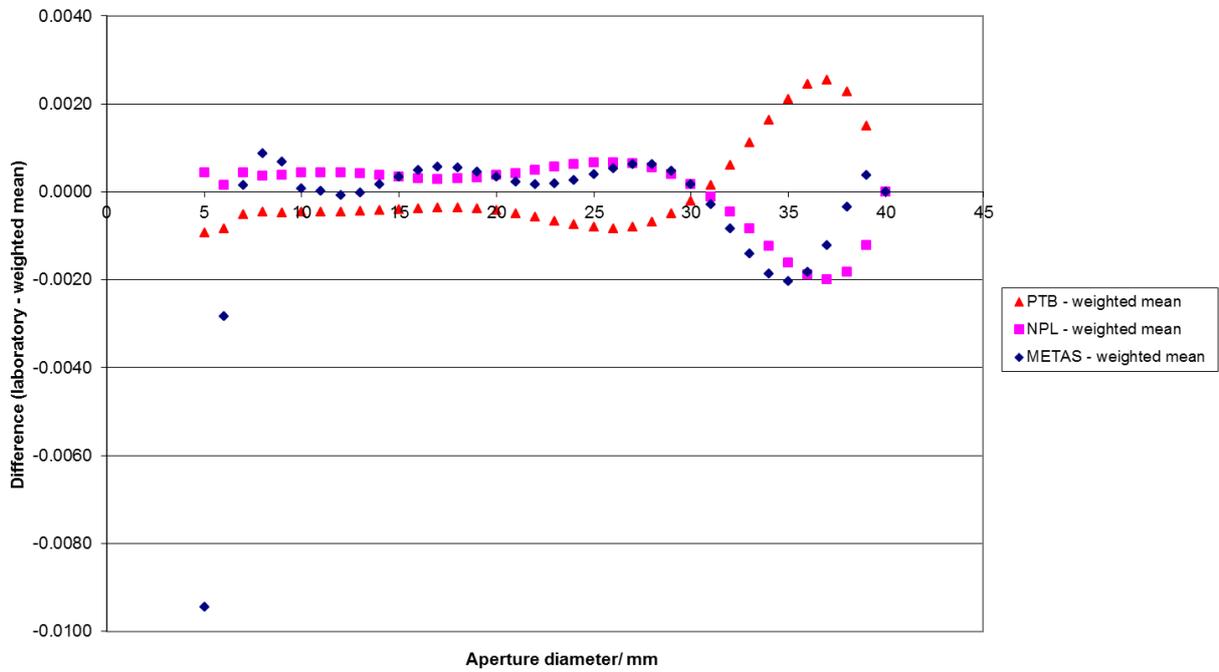
Plot of differences (laboratory - median) for INRiM thermometer SSE direct measurements



Plot of differences (laboratory - mean) for INRiM thermometer SSE direct measurements



Plot of differences (laboratory - weighted mean) for INRiM thermometer direct SSE measurements



1.7.2 Results for the LP5 thermometer – direct measurements

Aperture diameter/ mm	Weighted mean SSE value	Arithmetic mean SSE value	Median SSE value
3	0.999585	0.999582	0.999582
5	0.999723	0.999836	0.999635
7	0.999749	0.999827	0.999641
10	0.999740	0.999817	0.999647
15	0.999789	0.999807	0.999657
20	0.999807	0.999800	0.999675
25	0.999843	0.999846	0.999801
30	0.999859	0.999856	0.999794
40	1.000000	1.000000	1.000000

Table 69 – the calculated arithmetic and weighted mean and the median SSE values for the direct measurements with the LP5 thermometer

Aperture diameter/ mm	Difference (PTB - weighted mean SSE)	Difference (PTB - mean SSE)	Difference (PTB - median SSE)	Total ($k = 2$) uncertainty (fitted data)
3	0.000043	0.000045	0.000045	0.000113
5	-0.000088	-0.000201	0.000000	0.000113
7	-0.000108	-0.000186	0.000000	0.000112
10	-0.000093	-0.000170	0.000000	0.000110
15	-0.000132	-0.000149	0.000000	0.000110
20	-0.000132	-0.000125	0.000000	0.000110
25	-0.000135	-0.000138	-0.000093	0.000110
30	-0.000090	-0.000088	-0.000026	0.000109
40	0.000004	0.000004	0.000004	0.000108

Table 70 – differences between PTB results and averages, direct measurements with the LP5 thermometer

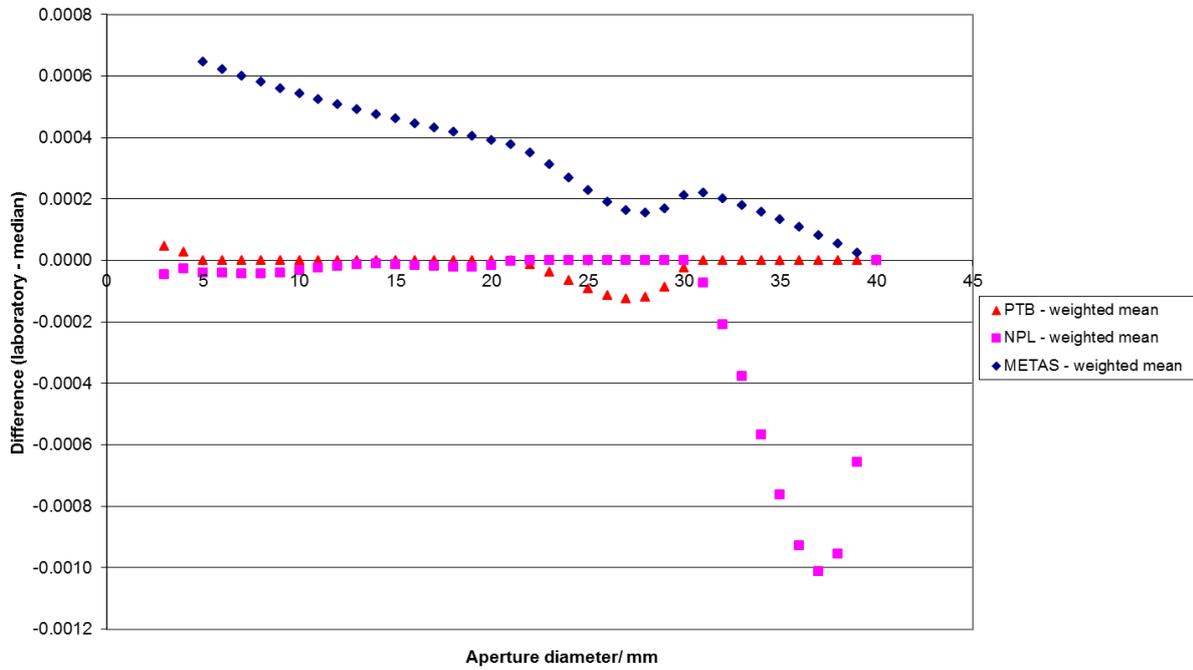
Aperture diameter/ mm	Difference (NPL - weighted mean SSE)	Difference (NPL - mean SSE)	Difference (NPL - median SSE)	Total ($k = 2$) uncertainty (fitted data)
3	-0.000047	-0.000045	-0.000045	0.000119
5	-0.000130	-0.000243	-0.000042	0.000058
7	-0.000152	-0.000229	-0.000044	0.000069
10	-0.000126	-0.000203	-0.000033	0.000065
15	-0.000144	-0.000162	-0.000013	0.000094
20	-0.000148	-0.000141	-0.000015	0.000119
25	-0.000042	-0.000045	0.000000	0.000101
30	-0.000065	-0.000062	0.000000	0.000119
40	0.000000	0.000000	0.000000	0.000119

Table 71 – differences between NPL results and averages, direct measurements with the LP5 thermometer

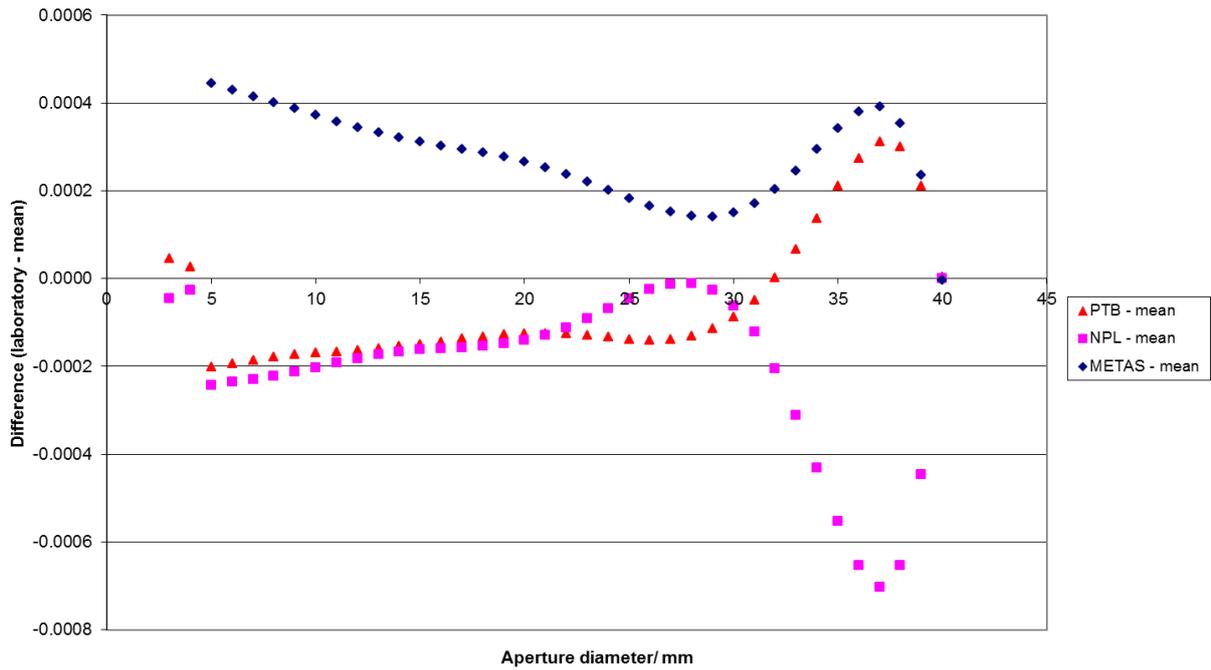
Aperture diameter/ mm	Difference (METAS - weighted mean SSE)	Difference (METAS - mean SSE)	Difference (METAS - median SSE)	Total ($k = 2$) uncertainty (fitted data)
5	0.000558	0.000444	0.000646	0.000110
7	0.000492	0.000415	0.000601	0.000110
10	0.000449	0.000372	0.000542	0.000110
15	0.000329	0.000311	0.000461	0.000110
20	0.000259	0.000266	0.000391	0.000110
25	0.000186	0.000183	0.000228	0.000110
30	0.000148	0.000150	0.000213	0.000110
40	-0.000004	-0.000004	-0.000004	0.000110

Table 72 – differences between METAS results and averages, direct measurements with the LP5 thermometer

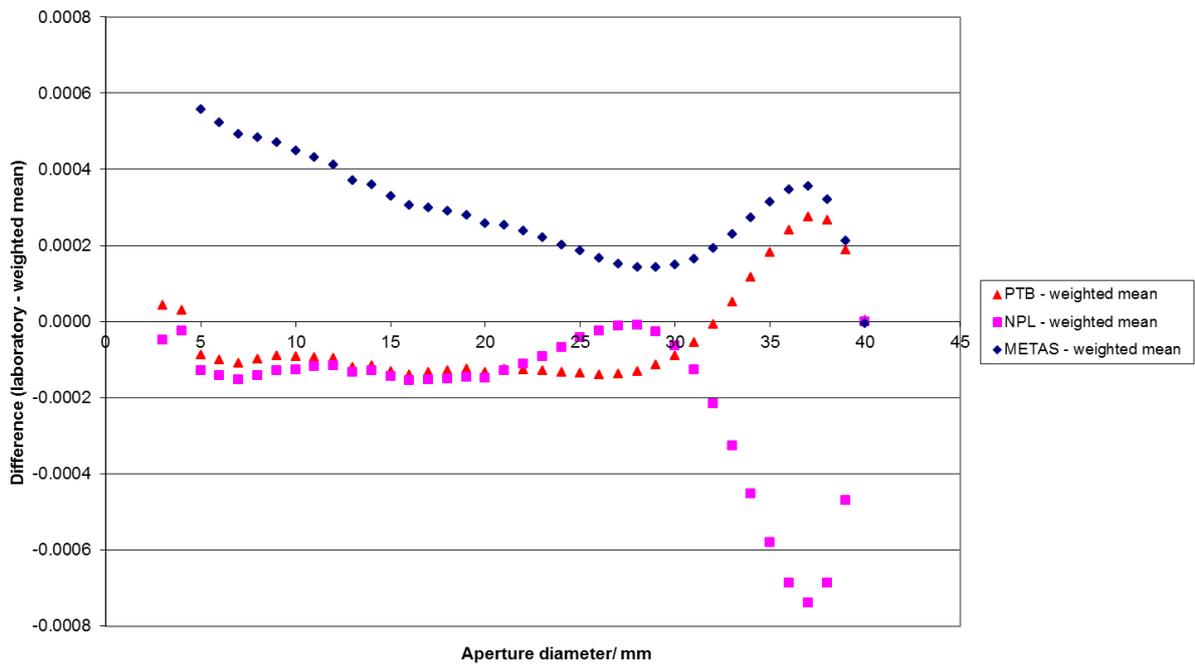
Plot of differences (laboratory - median) for LP5 direct SSE measurements



Plot of differences (laboratory - mean) for LP5 direct SSE measurements



Plot of differences (laboratory - weighted mean) for LP5 direct SSE measurements



1.7.3 Results for the INRiM thermometer – indirect measurements

Aperture diameter/ mm	Weighted mean SSE value	Arithmetic mean SSE value	Median SSE value
7	9.1342E-05	7.2240E-05	6.5150E-05
10	2.5562E-04	2.6237E-04	2.4972E-04
15	4.1904E-04	4.6210E-04	4.7174E-04
20	5.2228E-04	6.1449E-04	6.2538E-04
25	6.0650E-04	7.4881E-04	7.5347E-04
30	6.8918E-04	8.7694E-04	8.7169E-04
40	8.2507E-04	1.1170E-03	1.0726E-03
50	9.2620E-04	1.3286E-03	1.2210E-03
60	1.2455E-03	1.7843E-03	1.3711E-03
70	1.5663E-03	2.1976E-03	1.6158E-03
80	2.0299E-03	2.1764E-03	2.1764E-03
100	1.9973E-03	1.9437E-03	1.9437E-03

Table 73 – the calculated arithmetic and weighted mean and the median SSE values for the indirect measurements with the INRiM thermometer – 6 mm diameter spot, including all data

Aperture diameter/ mm	Difference (NPL - weighted mean SSE)	Difference (NPL - mean SSE)	Difference (NPL - median SSE)	Total ($k = 2$) uncertainty (fitted data)
7	1.4606E-06	2.0563E-05	2.7652E-05	0.000008
10	-8.2384E-06	-1.4982E-05	-2.3313E-06	0.000008
15	-1.5483E-05	-5.8542E-05	-6.8182E-05	0.000008
20	-1.8706E-05	-1.1092E-04	-1.2181E-04	0.000008
25	-1.6752E-05	-1.5907E-04	-1.6373E-04	0.000008
30	-1.5618E-05	-2.0337E-04	-1.9812E-04	0.000008
40	-1.6040E-05	-3.0792E-04	-2.6356E-04	0.000008
50	-1.4731E-05	-4.1712E-04	-3.0948E-04	0.000008

Table 74 – differences between NPL results and averages, indirect measurements with the INRiM thermometer, 6 mm diameter spot, including all data

Aperture diameter/ mm	Difference (CEM - weighted mean SSE)	Difference (CEM - mean SSE)	Difference (CEM - median SSE)	Total ($k = 2$) uncertainty (fitted data)
7	-3.2575E-05	-1.3473E-05	-6.3834E-06	0.000055
10	-5.9070E-06	-1.2651E-05	0.0000E+00	0.000055
15	2.8278E-06	-4.0232E-05	-4.9872E-05	0.000047
20	-3.2998E-06	-9.5510E-05	-1.0640E-04	0.000040
25	-3.6572E-06	-1.4597E-04	-1.5063E-04	0.000037
30	1.2568E-06	-1.8650E-04	-1.8125E-04	0.000036
40	2.2536E-05	-2.6935E-04	-2.2499E-04	0.000038
50	1.5319E-05	-3.8707E-04	-2.7943E-04	0.000042
60	-1.4639E-04	-6.8521E-04	-2.7203E-04	0.000054
70	4.9528E-05	-5.8178E-04	0.0000E+00	0.000074
80	6.0266E-04	4.5618E-04	4.5618E-04	0.000086
100	-1.8727E-04	-1.3374E-04	-1.3374E-04	0.000112

Table 75 – differences between CEM results and averages, indirect measurements with the INRiM thermometer, 6 mm diameter spot, including all data

Aperture diameter/ mm	Difference (UME - weighted mean SSE)	Difference (UME - mean SSE)	Difference (UME - median SSE)	Total ($k = 2$) uncertainty (fitted data)
10	1.2800E-05	6.0558E-06	1.8707E-05	0.000018
15	5.2700E-05	9.6398E-06	0.0000E+00	0.000024
20	1.0310E-04	1.0892E-05	0.0000E+00	0.000032
25	1.4697E-04	4.6581E-06	0.0000E+00	0.000040
30	1.8251E-04	-5.2501E-06	0.0000E+00	0.000049
40	2.7390E-04	-1.7984E-05	2.6377E-05	0.000058
50	3.3742E-04	-6.4967E-05	4.2670E-05	0.000064

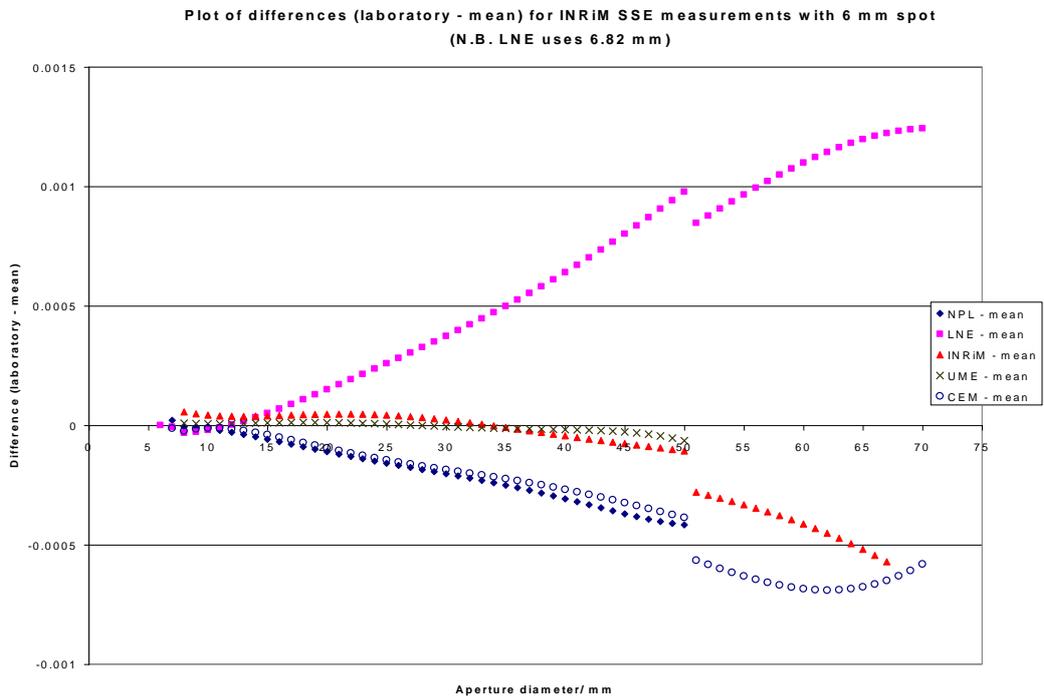
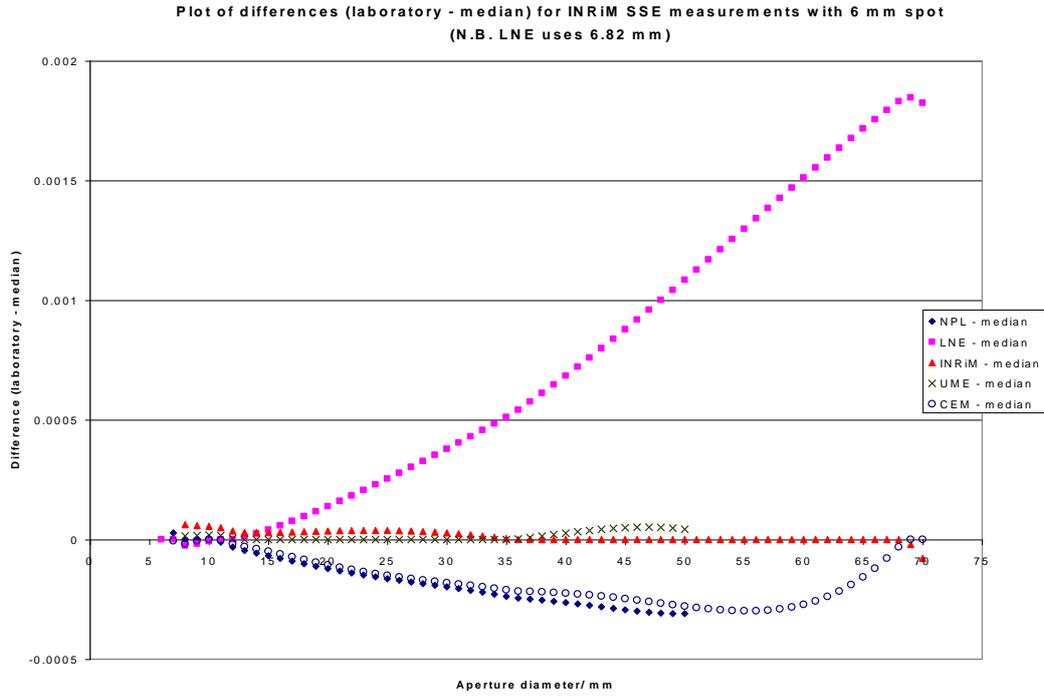
Table 76 – differences between UME results and averages, indirect measurements with the INRiM thermometer, 6 mm diameter spot, including all data

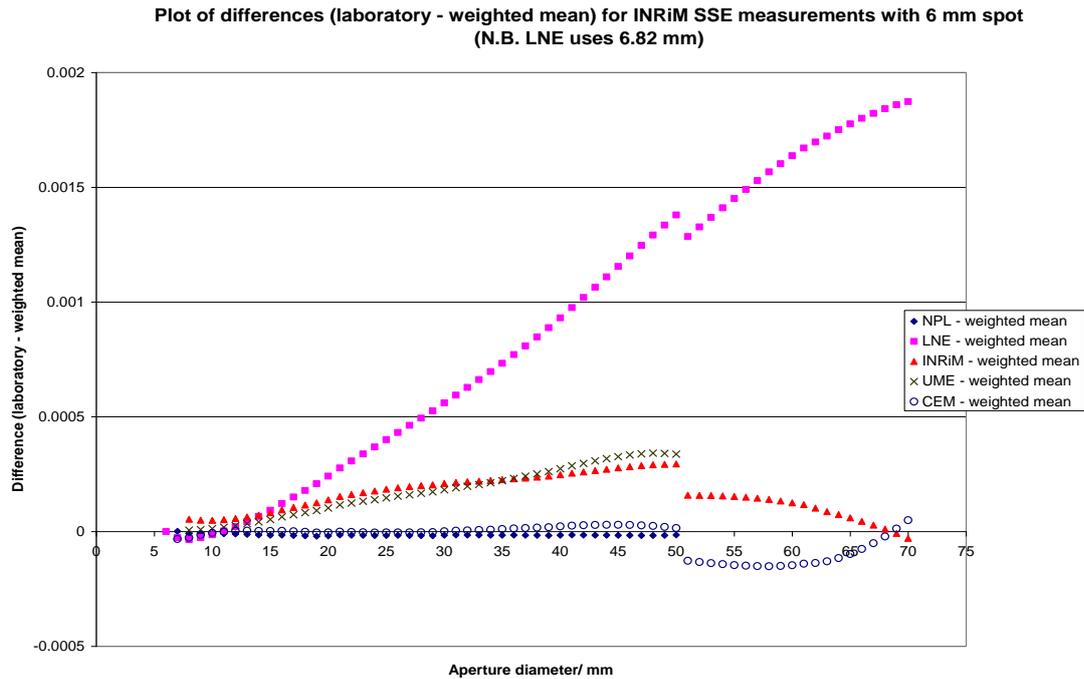
Aperture diameter/ mm	Difference (LNE - weighted mean SSE)	Difference (LNE - mean SSE)	Difference (LNE - median SSE)	Total ($k = 2$) uncertainty (fitted data)
7	-2.6192E-05	-7.0897E-06	0.0000E+00	0.000048
10	-1.3981E-05	-2.0725E-05	-8.0743E-06	0.000055
15	9.3106E-05	5.0046E-05	4.0406E-05	0.000071
20	2.4152E-04	1.4931E-04	1.3842E-04	0.000083
25	4.0049E-04	2.5817E-04	2.5352E-04	0.000254
30	5.6070E-04	3.7295E-04	3.7820E-04	0.000429
40	9.3150E-04	6.3962E-04	6.8398E-04	0.000808
50	1.3792E-03	9.7679E-04	1.0844E-03	0.001485
60	1.6372E-03	1.0984E-03	1.5116E-03	0.001724
70	1.8735E-03	1.2422E-03	1.8240E-03	0.003131

Table 77 – differences between LNE results and averages, indirect measurements with the INRiM thermometer, 6 mm diameter spot, including all data

Aperture diameter/ mm	Difference (INRiM- weighted mean SSE)	Difference (INRiM - mean SSE)	Difference (INRiM - median SSE)	Total ($k = 2$) uncertainty (fitted data)
10	4.9047E-05	4.2303E-05	5.4954E-05	0.000023
15	8.2148E-05	3.9088E-05	2.9449E-05	0.000026
20	1.3843E-04	4.6220E-05	3.5327E-05	0.000030
25	1.8452E-04	4.2207E-05	3.7549E-05	0.000033
30	2.0993E-04	2.2176E-05	2.7426E-05	0.000036
40	2.4752E-04	-4.4361E-05	0.0000E+00	0.000042
50	2.9475E-04	-1.0764E-04	0.0000E+00	0.000046
60	1.2563E-04	-4.1319E-04	0.0000E+00	0.000051
70	-2.9108E-05	-6.6042E-04	-7.8636E-05	0.000056
80	-3.0969E-04	-4.5618E-04	-4.5618E-04	0.000062
100	8.0214E-05	1.3374E-04	1.3374E-04	0.000073

Table 78 – differences between INRiM results and averages, indirect measurements with the INRiM thermometer, 6 mm diameter spot, including all data





Aperture diameter/ mm	Weighted mean SSE value	Arithmetic mean SSE value	Median SSE value
7	9.2066E-05	7.5785E-05	7.5785E-05
10	2.5585E-04	2.6755E-04	2.5907E-04
15	4.1804E-04	4.4959E-04	4.4681E-04
20	5.2033E-04	5.7716E-04	5.7218E-04
25	6.0615E-04	6.8427E-04	6.7815E-04
30	6.8901E-04	7.8370E-04	7.8106E-04
40	8.2498E-04	9.5705E-04	9.6010E-04
50	9.2617E-04	1.0844E-03	1.0812E-03
60	1.2447E-03	1.2351E-03	1.2351E-03
70	1.5659E-03	1.5765E-03	1.5765E-03
80	2.0299E-03	2.1764E-03	2.1764E-03
100	1.9973E-03	1.9437E-03	1.9437E-03

Table 79 – the calculated arithmetic and weighted mean and the median SSE values for the indirect measurements with the INRiM thermometer – 6 mm diameter spot **excluding LNE data**

Aperture diameter/ mm	Difference (NPL - weighted mean SSE)	Difference (NPL - mean SSE)	Difference (NPL - median SSE)	Total ($k = 2$) uncertainty (fitted data)
7	7.3624E-07	1.7018E-05	1.7018E-05	0.000008
10	-8.4637E-06	-2.0164E-05	-1.1685E-05	0.000008
15	-1.4481E-05	-4.6031E-05	-4.3246E-05	0.000008
20	-1.6758E-05	-7.3588E-05	-6.8608E-05	0.000008
25	-1.6401E-05	-9.4524E-05	-8.8410E-05	0.000008
30	-1.5442E-05	-1.1014E-04	-1.0750E-04	0.000008
40	-1.5954E-05	-1.4802E-04	-1.5107E-04	0.000008
50	-1.4694E-05	-1.7292E-04	-1.6977E-04	0.000008

Table 80 – differences between NPL results and averages, indirect measurements with the INRiM thermometer, 6 mm diameter spot **excluding LNE data**

Aperture diameter/ mm	Difference (CEM - weighted mean SSE)	Difference (CEM - mean SSE)	Difference (CEM - median SSE)	Total ($k = 2$) uncertainty (fitted data)
7	-3.3299E-05	-1.7018E-05	-1.7018E-05	0.000055
10	-6.1323E-06	-1.7832E-05	-9.3534E-06	0.000055
15	3.8293E-06	-2.7720E-05	-2.4936E-05	0.000047
20	-1.3519E-06	-5.8181E-05	-5.3201E-05	0.000040
25	-3.3058E-06	-8.1429E-05	-7.5315E-05	0.000037
30	1.4329E-06	-9.3262E-05	-9.0624E-05	0.000036
40	2.2622E-05	-1.0944E-04	-1.1249E-04	0.000038
50	1.5356E-05	-1.4287E-04	-1.3972E-04	0.000042
60	-1.4564E-04	-1.3601E-04	-1.3601E-04	0.000054
70	4.9907E-05	3.9318E-05	3.9318E-05	0.000074
80	6.0266E-04	4.5618E-04	4.5618E-04	0.000086
100	-1.8727E-04	-1.3374E-04	-1.3374E-04	0.000112

Table 81 – differences between CEM results and averages, indirect measurements with the INRiM thermometer, 6 mm diameter spot **excluding LNE data**

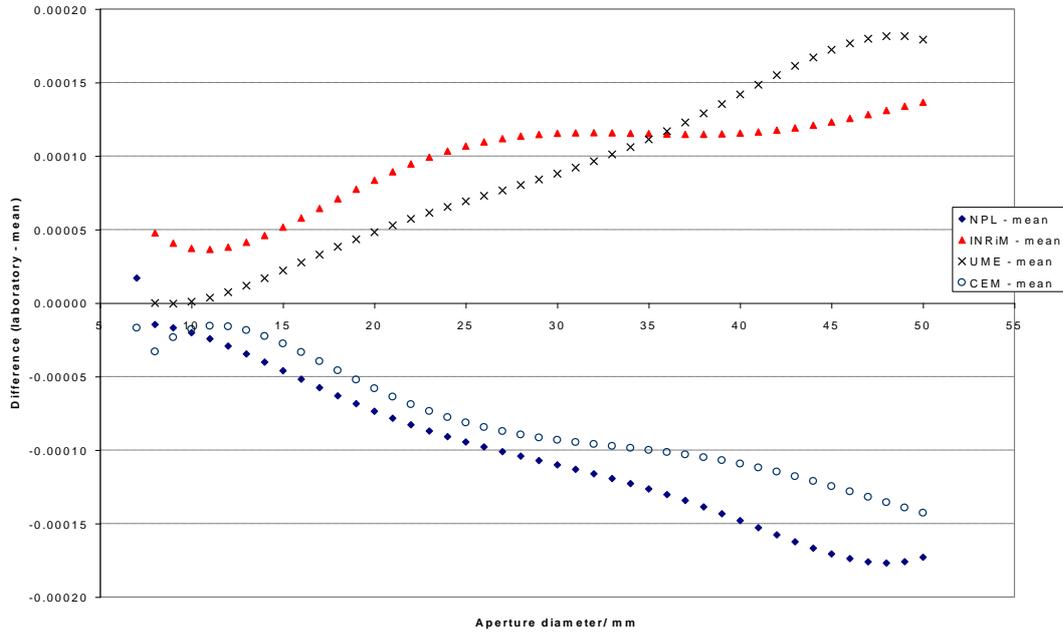
Aperture diameter/ mm	Difference (UME - weighted mean SSE)	Difference (UME - mean SSE)	Difference (UME - median SSE)	Total ($k = 2$) uncertainty (fitted data)
10	1.2574E-05	8.7449E-07	9.3534E-06	0.000018
15	5.3701E-05	2.2151E-05	2.4936E-05	0.000024
20	1.0505E-04	4.8221E-05	5.3201E-05	0.000032
25	1.4732E-04	6.9202E-05	7.5315E-05	0.000040
30	1.8268E-04	8.7986E-05	9.0624E-05	0.000049
40	2.7399E-04	1.4192E-04	1.3887E-04	0.000058
50	3.3746E-04	1.7923E-04	1.8239E-04	0.000064

Table 82 – differences between UME results and averages, indirect measurements with the INRiM thermometer, 6 mm diameter spot **excluding LNE data**

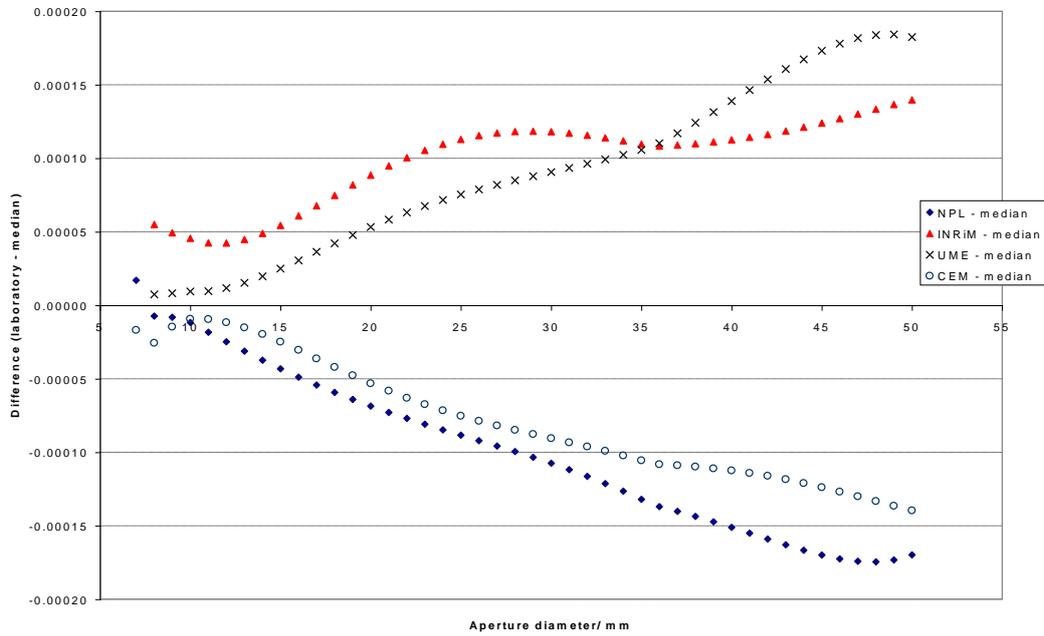
Aperture diameter/ mm	Difference (INRiM- weighted mean SSE)	Difference (INRiM - mean SSE)	Difference (INRiM - median SSE)	Total ($k = 2$) uncertainty (fitted data)
10	4.8821E-05	3.7121E-05	4.5600E-05	0.000023
15	8.3150E-05	5.1600E-05	5.4385E-05	0.000026
20	1.4038E-04	8.3548E-05	8.8528E-05	0.000030
25	1.8487E-04	1.0675E-04	1.1286E-04	0.000033
30	2.1011E-04	1.1541E-04	1.1805E-04	0.000036
40	2.4761E-04	1.1554E-04	1.1249E-04	0.000042
50	2.9479E-04	1.3656E-04	1.3972E-04	0.000046
60	1.2639E-04	1.3601E-04	1.3601E-04	0.000051
70	-2.8729E-05	-3.9318E-05	-3.9318E-05	0.000056
80	-3.0969E-04	-4.5618E-04	-4.5618E-04	0.000062
100	8.0214E-05	1.3374E-04	1.3374E-04	0.000073

Table 83 – differences between INRiM results and averages, indirect measurements with the INRiM thermometer, 6 mm diameter spot **excluding LNE data**

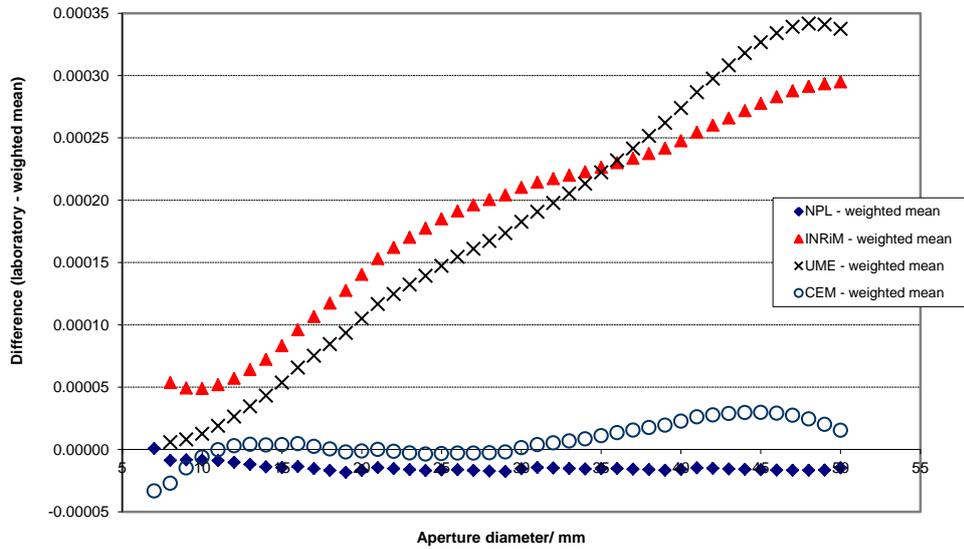
Plot of differences (laboratory - mean) for INRiM SSE with 6 mm spot
(excluding LNE data)



Plot of differences (laboratory - median) for INRiM SSE with 6 mm spot
(excluding LNE data)



Plot of differences (laboratory - weighted mean) for INRiM SSE with 6 mm spot (excluding LNE data)



1.7.4 LP5 Results – indirect measurements with 3 mm diameter spot

Aperture diameter/ mm	Weighted mean SSE value	Arithmetic mean SSE value	Median SSE value
5	5.6519E-05	5.3824E-05	6.2365E-05
7	7.2728E-05	8.0705E-05	7.8446E-05
10	9.4810E-05	1.1937E-04	1.4989E-04
15	1.1827E-04	1.8191E-04	2.2428E-04
20	1.2921E-04	2.4489E-04	3.0154E-04
25	1.4384E-04	3.1001E-04	3.6936E-04
30	1.4803E-04	3.7762E-04	4.3323E-04
40	1.5973E-04	5.1735E-04	5.5122E-04
50	1.7555E-04	6.5499E-04	6.5907E-04
60	2.9518E-04	9.7739E-04	7.5941E-04
70	5.4476E-04	1.2295E-03	8.5395E-04
80	6.5926E-04	6.4846E-04	6.4846E-04
100	7.8960E-04	7.2388E-04	7.2388E-04

Table 84 – the calculated arithmetic and weighted mean and the median SSE values for the indirect measurements with the LP5 thermometer, 3 mm diameter spot, including all data

Aperture diameter/ mm	Difference (NPL - weighted mean SSE)	Difference (NPL - mean SSE)	Difference (NPL - median SSE)	Total ($k = 2$) uncertainty (fitted data)
5	5.8466E-06	8.5407E-06	0.0000E+00	0.000005
7	1.4181E-06	-6.5591E-06	-4.3001E-06	0.000007
10	-6.9667E-06	-3.1522E-05	-6.2049E-05	0.000006
15	-1.5273E-05	-7.8908E-05	-1.2129E-04	0.000005
20	-1.6694E-05	-1.3237E-04	-1.8902E-04	0.000005
25	-2.3965E-05	-1.9014E-04	-2.4949E-04	0.000005
30	-2.0726E-05	-2.5032E-04	-3.0593E-04	0.000005
40	-1.4470E-05	-3.7208E-04	-4.0596E-04	0.000004
50	-1.5641E-05	-4.9508E-04	-4.9916E-04	0.000004

Table 85 – differences between NPL results and averages, indirect measurements with the LP5 thermometer, 3 mm diameter spot, including all data

Aperture diameter/ mm	Difference (CEM- weighted mean SSE)	Difference (CEM - mean SSE)	Difference (CEM - median SSE)	Total ($k = 2$) uncertainty (fitted data)
5	-4.0810E-05	-3.8116E-05	-4.6657E-05	0.000009
7	-4.1097E-05	-4.9074E-05	-4.6815E-05	0.000009
10	-4.1435E-05	-6.5990E-05	-9.6517E-05	0.000009
15	-3.5234E-05	-9.8869E-05	-1.4125E-04	0.000008
20	-2.5141E-05	-1.4082E-04	-1.9747E-04	0.000006
25	-2.6641E-05	-1.9281E-04	-2.5216E-04	0.000006
30	-2.3870E-05	-2.5346E-04	-3.0907E-04	0.000006
40	-2.9866E-05	-3.8748E-04	-4.2135E-04	0.000006
50	-3.1587E-05	-5.1103E-04	-5.1511E-04	0.000007
60	-1.0938E-04	-7.9160E-04	-5.7362E-04	0.000012
70	-2.8337E-04	-9.6815E-04	-5.9256E-04	0.000027
80	-3.0579E-04	-2.9499E-04	-2.9499E-04	0.000032
100	-4.4759E-04	-3.8188E-04	-3.8188E-04	0.000043

Table 86 – differences between CEM results and averages, indirect measurements with the LP5 thermometer, 3 mm diameter spot, including all data

Aperture diameter/ mm	Difference (UME - weighted mean SSE)	Difference (UME - mean SSE)	Difference (UME - median SSE)	Total ($k = 2$) uncertainty (fitted data)
5	3.8196E-05	4.0890E-05	3.2349E-05	0.000026
7	4.4231E-05	3.6253E-05	3.8512E-05	0.000025
10	5.9256E-05	3.4701E-05	4.1741E-06	0.000031
15	1.0601E-04	4.2377E-05	0.0000E+00	0.000030
20	1.7315E-04	5.7470E-05	8.2004E-07	0.000028
25	2.4145E-04	7.5277E-05	1.5931E-05	0.000026
30	3.2204E-04	9.2443E-05	3.6833E-05	0.000024
40	4.7340E-04	1.1579E-04	8.1915E-05	0.000028
50	5.9197E-04	1.1253E-04	1.0845E-04	0.000030

Table 87 – differences between UME results and averages, indirect measurements with the LP5 thermometer, 3 mm diameter spot, including all data

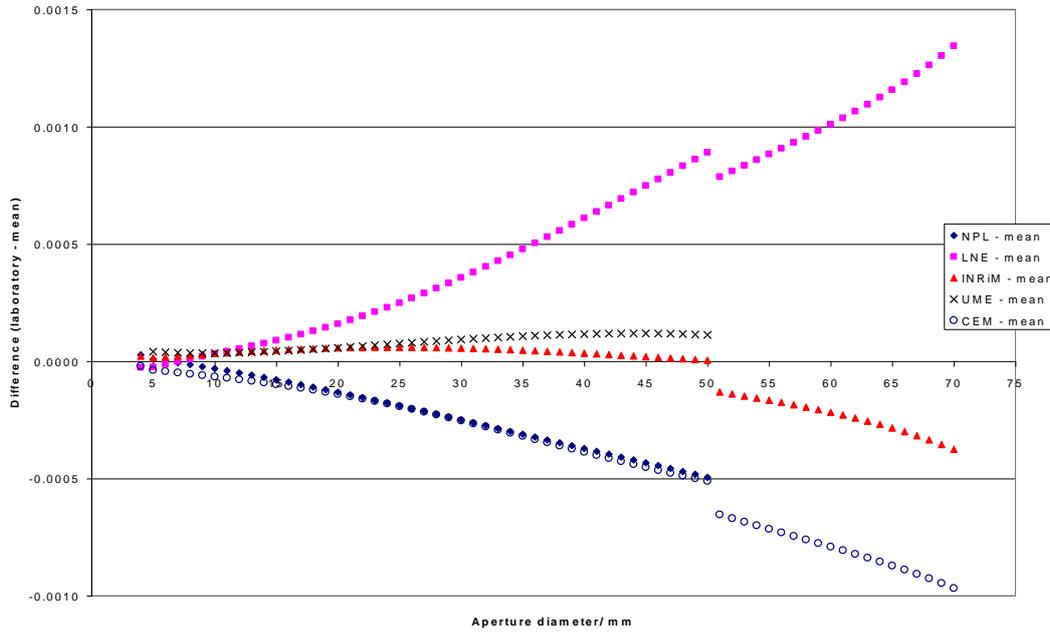
Aperture diameter/ mm	Difference (LNE - weighted mean SSE)	Difference (LNE - mean SSE)	Difference (LNE - median SSE)	Total ($k = 2$) uncertainty (fitted data)
5	-2.8402E-05	-2.5708E-05	-3.4248E-05	0.000097
7	5.7182E-06	-2.2591E-06	0.0000E+00	0.000088
10	5.5082E-05	3.0527E-05	0.0000E+00	0.000108
15	1.5175E-04	8.8119E-05	4.5742E-05	0.000067
20	2.7474E-04	1.5907E-04	1.0242E-04	0.000128
25	4.1450E-04	2.4833E-04	1.8899E-04	0.000234
30	5.8532E-04	3.5573E-04	3.0012E-04	0.000340
40	9.6752E-04	6.0990E-04	5.7603E-04	0.000147
50	1.3689E-03	8.8949E-04	8.8541E-04	0.000367
60	1.6918E-03	1.0096E-03	1.2276E-03	0.000605
70	2.0285E-03	1.3437E-03	1.7193E-03	0.000896

Table 88 – differences between LNE results and averages, indirect measurements with the LP5 thermometer, 3 mm diameter spot, including all data

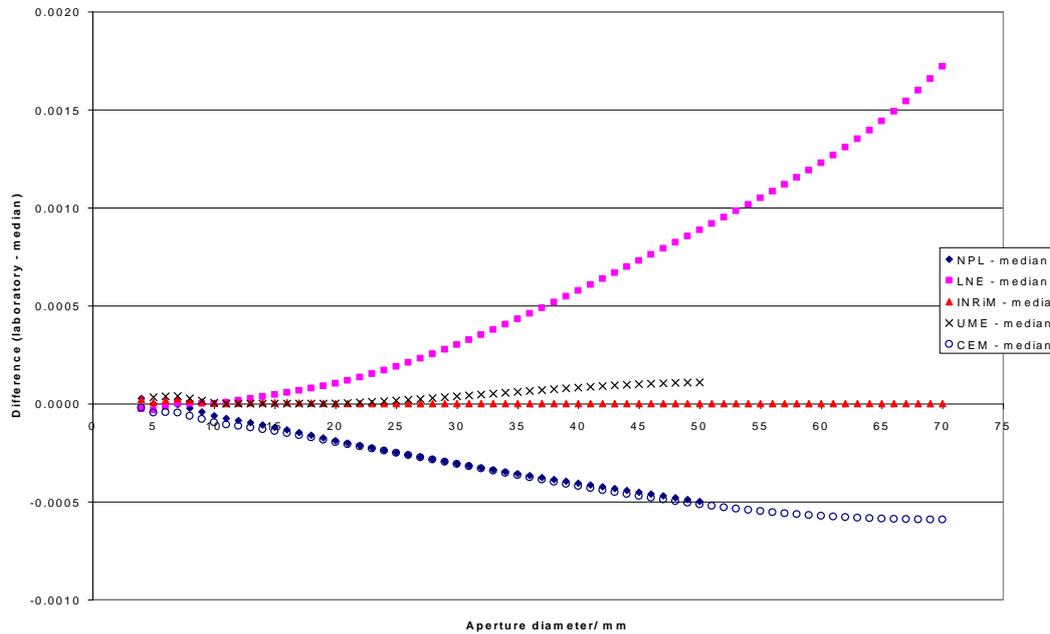
Aperture diameter/ mm	Difference (INRiM - weighted mean SSE)	Difference (INRiM - mean SSE)	Difference (INRiM - median SSE)	Total ($k = 2$) uncertainty (fitted data)
5	1.1699E-05	1.4393E-05	5.8527E-06	0.000008
7	2.9616E-05	2.1639E-05	2.3898E-05	0.000009
10	5.6838E-05	3.2283E-05	1.7559E-06	0.000009
15	1.1092E-04	4.7280E-05	4.9026E-06	0.000011
20	1.7233E-04	5.6650E-05	0.0000E+00	0.000012
25	2.2552E-04	5.9346E-05	0.0000E+00	0.000014
30	2.8520E-04	5.5609E-05	0.0000E+00	0.000016
40	3.9149E-04	3.3873E-05	0.0000E+00	0.000019
50	4.8352E-04	4.0819E-06	0.0000E+00	0.000023
60	4.6424E-04	-2.1798E-04	0.0000E+00	0.000026
70	3.0919E-04	-3.7559E-04	0.0000E+00	0.000028
80	2.8419E-04	2.9499E-04	2.9499E-04	0.000031
100	3.1616E-04	3.8188E-04	3.8188E-04	0.000036

Table 89 – differences between INRiM results and averages, indirect measurements with the LP5 thermometer, 3 mm diameter spot, including all data

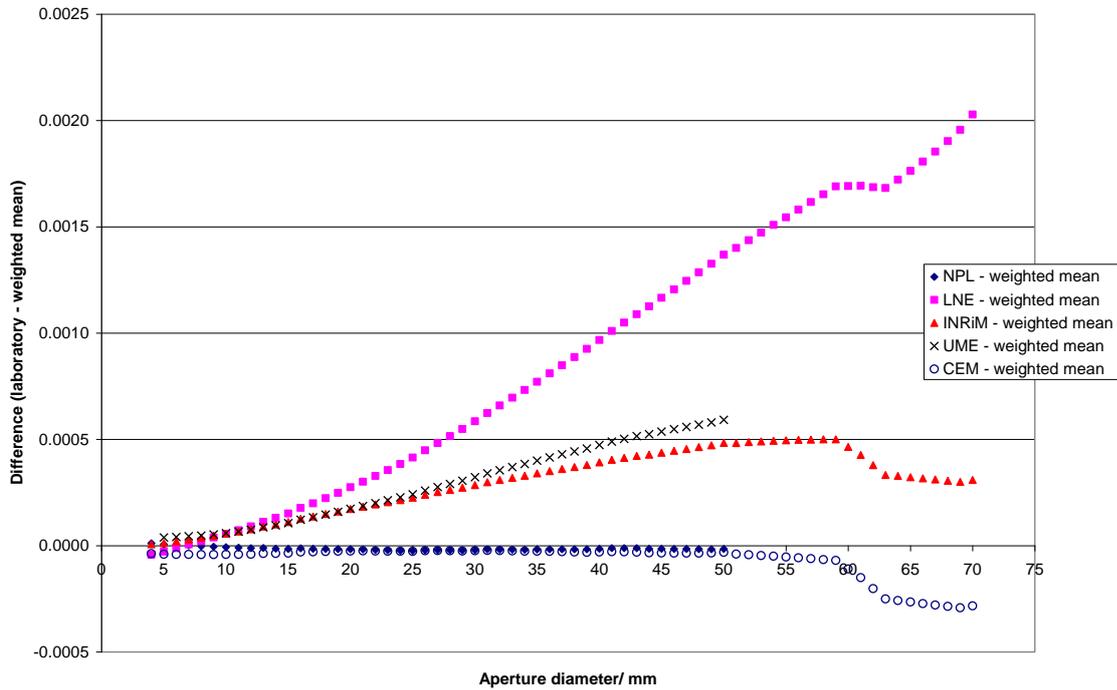
Plot of differences (laboratory - mean) for LP5 SSE measurements with 3 mm spot
(N.B. LNE uses 4 mm)



Plot of differences (laboratory - median) for LP5 SSE measurements with 3 mm spot
(N.B. LNE uses 4 mm)



Plot of differences (laboratory - weighted mean) for LP5 SSE measurements with 3 mm spot
(N.B. LNE uses 4 mm)



Aperture diameter/ mm	Weighted mean SSE value	Arithmetic mean SSE value	Median SSE value
5	5.6559E-05	6.0251E-05	6.5291E-05
10	7.2712E-05	8.1270E-05	8.8245E-05
15	9.4727E-05	1.1173E-04	1.1975E-04
20	1.1772E-04	1.5988E-04	1.6364E-04
25	1.2900E-04	2.0512E-04	2.0703E-04
30	1.4372E-04	2.4793E-04	2.4462E-04
40	1.4797E-04	2.8869E-04	2.8027E-04
50	1.5923E-04	3.6487E-04	3.4824E-04
60	1.7543E-04	4.3262E-04	4.0949E-04
70	2.9460E-04	4.7260E-04	4.7260E-04
80	5.4379E-04	5.5767E-04	5.5767E-04
90	6.5926E-04	6.4846E-04	6.4846E-04
100	7.8960E-04	7.2388E-04	7.2388E-04

Table 90 – the calculated arithmetic and weighted mean and the median SSE values for the indirect measurements with the LP5 thermometer – 3 mm diameter spot **excluding LNE data**

Aperture diameter/ mm	Difference (NPL - weighted mean SSE)	Difference (NPL - mean SSE)	Difference (NPL - median SSE)	Total ($k = 2$) uncertainty (fitted data)
5	5.8056E-06	2.1137E-06	-2.9264E-06	0.000005
7	1.4340E-06	-7.1239E-06	-1.4099E-05	0.000007
10	-6.8833E-06	-2.3890E-05	-3.1902E-05	0.000006
15	-1.4724E-05	-5.6878E-05	-6.0643E-05	0.000005
20	-1.6478E-05	-9.2604E-05	-9.4510E-05	0.000005
25	-2.3848E-05	-1.2806E-04	-1.2474E-04	0.000005
30	-2.0663E-05	-1.6139E-04	-1.5296E-04	0.000005
40	-1.3968E-05	-2.1961E-04	-2.0298E-04	0.000004
50	-1.5522E-05	-2.7271E-04	-2.4958E-04	0.000004

Table 91 – differences between NPL results and averages, indirect measurements with the LP5 thermometer, 3 mm diameter spot **excluding LNE data**

Aperture diameter/ mm	Difference (CEM- weighted mean SSE)	Difference (CEM - mean SSE)	Difference (CEM - median SSE)	Total ($k = 2$) uncertainty (fitted data)
5	-4.0851E-05	-4.4543E-05	-4.9583E-05	0.000009
7	-4.1081E-05	-4.9639E-05	-5.6614E-05	0.000009
10	-4.1351E-05	-5.8358E-05	-6.6370E-05	0.000009
15	-3.4685E-05	-7.6839E-05	-8.0603E-05	0.000008
20	-2.4925E-05	-1.0105E-04	-1.0296E-04	0.000006
25	-2.6524E-05	-1.3073E-04	-1.2742E-04	0.000006
30	-2.3807E-05	-1.6453E-04	-1.5611E-04	0.000006
40	-2.9363E-05	-2.3500E-04	-2.1837E-04	0.000006
50	-3.1467E-05	-2.8865E-04	-2.6553E-04	0.000007
60	-1.0880E-04	-2.8681E-04	-2.8681E-04	0.000012
70	-2.8240E-04	-2.9628E-04	-2.9628E-04	0.000027
80	-3.0579E-04	-2.9499E-04	-2.9499E-04	0.000032
100	-4.4759E-04	-3.8188E-04	-3.8188E-04	0.000043

Table 92 – differences between CEM results and averages, indirect measurements with the LP5 thermometer, 3 mm diameter spotexcluding LNE data****

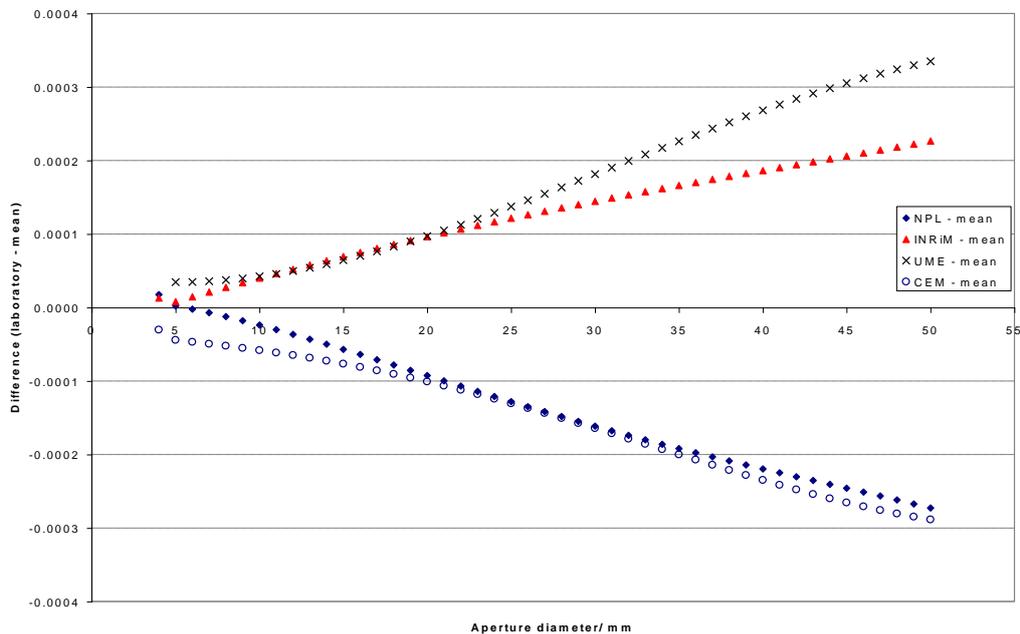
Aperture diameter/ mm	Difference (UME - weighted mean SSE)	Difference (UME - mean SSE)	Difference (UME - median SSE)	Total ($k = 2$) uncertainty (fitted data)
5	3.8155E-05	3.4463E-05	2.9423E-05	0.000026
7	4.4247E-05	3.5689E-05	2.8713E-05	0.000025
10	5.9339E-05	4.2333E-05	3.4321E-05	0.000031
15	1.0656E-04	6.4407E-05	6.0643E-05	0.000030
20	1.7336E-04	9.7237E-05	9.5330E-05	0.000028
25	2.4157E-04	1.3736E-04	1.4067E-04	0.000026
30	3.2210E-04	1.8138E-04	1.8980E-04	0.000024
40	4.7390E-04	2.6826E-04	2.8489E-04	0.000028
50	5.9209E-04	3.3491E-04	3.5803E-04	0.000030

Table 93 – differences between UME results and averages, indirect measurements with the LP5 thermometer, 3 mm diameter spot **excluding LNE data**

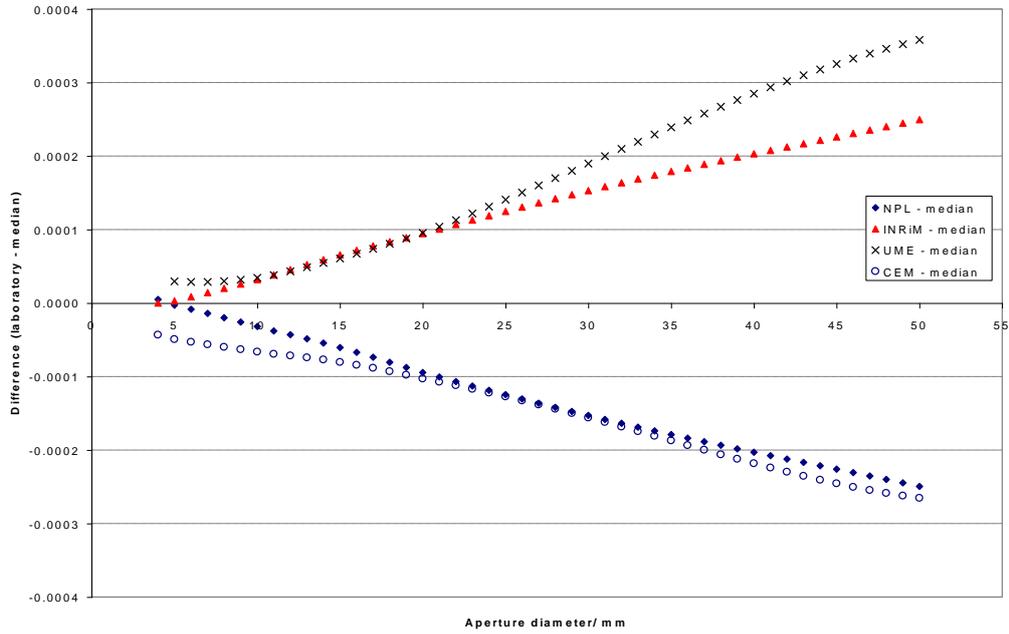
Aperture diameter/ mm	Difference (INRiM - weighted mean SSE)	Difference (INRiM - mean SSE)	Difference (INRiM - median SSE)	Total ($k = 2$) uncertainty (fitted data)
5	1.1658E-05	7.9665E-06	2.9264E-06	0.000008
7	2.9632E-05	2.1074E-05	1.4099E-05	0.000009
10	5.6921E-05	3.9915E-05	3.1902E-05	0.000009
15	1.1146E-04	6.9310E-05	6.5545E-05	0.000011
20	1.7254E-04	9.6417E-05	9.4510E-05	0.000012
25	2.2564E-04	1.2143E-04	1.2474E-04	0.000014
30	2.8527E-04	1.4454E-04	1.5296E-04	0.000016
40	3.9199E-04	1.8635E-04	2.0298E-04	0.000019
50	4.8364E-04	2.2645E-04	2.4958E-04	0.000023
60	4.6481E-04	2.8681E-04	2.8681E-04	0.000026
70	3.1016E-04	2.9628E-04	2.9628E-04	0.000028
80	2.8419E-04	2.9499E-04	2.9499E-04	0.000031
100	3.1616E-04	3.8188E-04	3.8188E-04	0.000036

Table 94 – differences between INRiM results and averages, indirect measurements with the LP5 thermometer, 3 mm diameter spot **excluding LNE data**

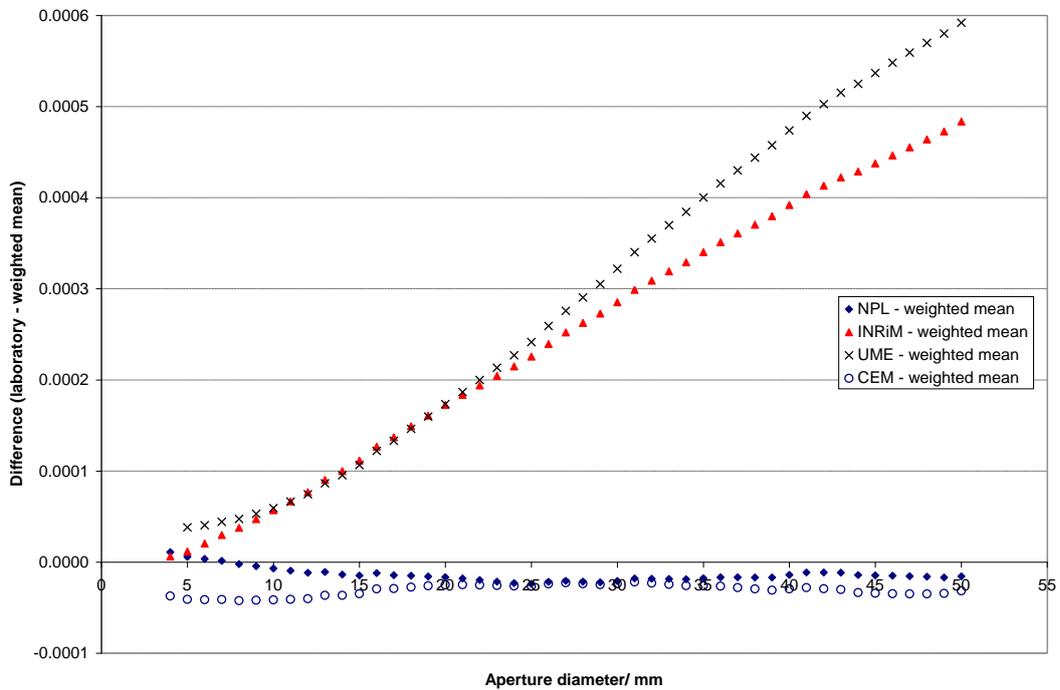
Plot of differences (laboratory - mean) for LP5 SSE with 3 mm spot (excluding LNE data)



Plot of differences (laboratory - median) for LP5 SSE with 3 mm spot
(excluding LNE data)



Plot of differences (laboratory - weighted mean) for LP5 SSE with 3 mm spot
(excluding LNE data)



1.7.5 LP5 Results – indirect measurements with 6 mm diameter spot

Aperture diameter/ mm	Weighted mean SSE value	Arithmetic mean SSE value	Median SSE value
7	1.3529E-05	9.5983E-06	9.3378E-06
10	3.3536E-05	4.5404E-05	5.9160E-05
15	5.2770E-05	9.8638E-05	1.3538E-04
20	6.9223E-05	1.5415E-04	2.0454E-04
25	8.4726E-05	2.1230E-04	2.7075E-04
30	9.6804E-05	2.7296E-04	3.3415E-04
40	1.2543E-04	3.9837E-04	4.5300E-04
50	1.5254E-04	5.1664E-04	5.6207E-04
60	2.5738E-04	7.3757E-04	6.6237E-04
70	3.4126E-04	8.8881E-04	7.5489E-04
80	4.3531E-04	5.6657E-04	5.6657E-04
100	5.1038E-04	6.3790E-04	6.3790E-04

Table 95 – the calculated arithmetic and weighted mean and the median SSE values for the indirect measurements with the LP5 thermometer – 6 mm diameter spot, including all data

Aperture diameter/ mm	Difference (NPL - weighted mean SSE)	Difference (NPL - mean SSE)	Difference (NPL - median SSE)	Total ($k = 2$) uncertainty (fitted data)
7	0.000002	0.000006	0.000007	0.000005
10	-0.000007	-0.000018	-0.000032	0.000003
15	-0.000010	-0.000056	-0.000093	0.000003
20	-0.000013	-0.000098	-0.000149	0.000003
25	-0.000016	-0.000143	-0.000202	0.000003
30	-0.000015	-0.000191	-0.000252	0.000003
40	-0.000015	-0.000288	-0.000342	0.000003
50	-0.000015	-0.000379	-0.000424	0.000003

Table 96 – differences between NPL results and averages, indirect measurements with the LP5 thermometer, 6 mm diameter spot, including all data

Aperture diameter/ mm	Difference (CEM - weighted mean SSE)	Difference (CEM - mean SSE)	Difference (CEM - median SSE)	Total ($k = 2$) uncertainty (fitted data)
7	-0.000010	-0.000006	-0.000006	0.000011
10	-0.000024	-0.000036	-0.000049	0.000011
15	-0.000028	-0.000074	-0.000110	0.000011
20	-0.000027	-0.000112	-0.000162	0.000011
25	-0.000027	-0.000155	-0.000213	0.000011
30	-0.000026	-0.000202	-0.000264	0.000011
40	-0.000036	-0.000309	-0.000364	0.000011
50	-0.000043	-0.000407	-0.000453	0.000011
60	-0.000110	-0.000590	-0.000515	0.000011
70	-0.000129	-0.000676	-0.000542	0.000014
80	-0.000143	-0.000274	-0.000274	0.000016
100	-0.000230	-0.000358	-0.000358	0.000022

Table 97 – differences between CEM results and averages, indirect measurements with the LP5 thermometer, 6 mm diameter spot, including all data

Aperture diameter/ mm	Difference (UME - weighted mean SSE)	Difference (UME - mean SSE)	Difference (UME - median SSE)	Total ($k = 2$) uncertainty (fitted data)
10	0.000034	0.000023	0.000009	0.000022
15	0.000083	0.000037	0.000001	0.000022
20	0.000136	0.000051	0.000001	0.000022
25	0.000197	0.000069	0.000011	0.000022
30	0.000269	0.000092	0.000031	0.000023
40	0.000418	0.000145	0.000091	0.000023
50	0.000525	0.000160	0.000115	0.000023

Table 98 – differences between UME results and averages, indirect measurements with the LP5 thermometer, 6 mm diameter spot, including all data

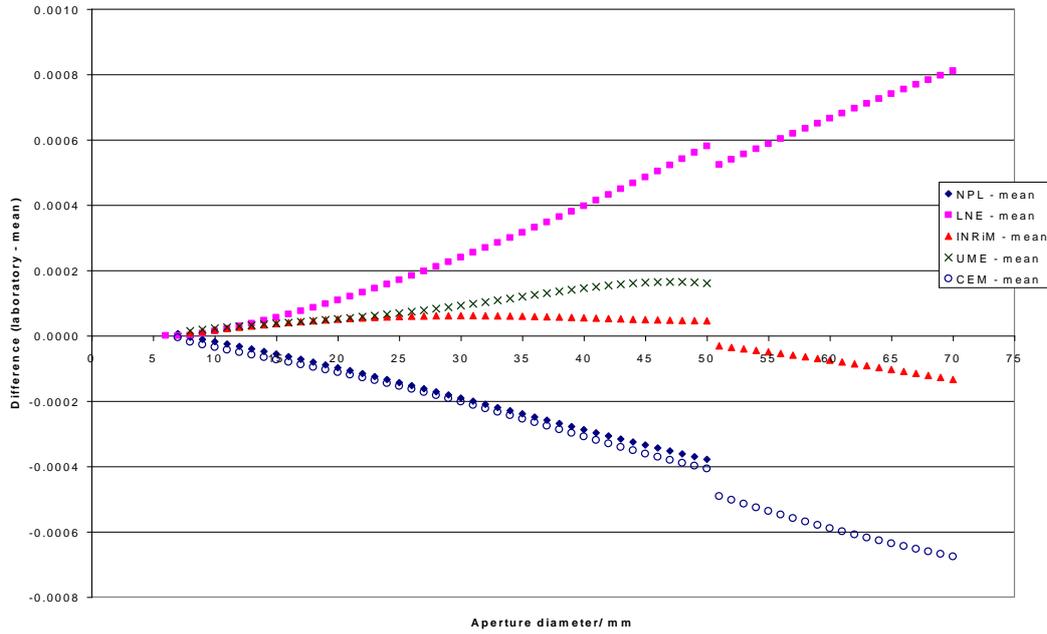
Aperture diameter/ mm	Difference (LNE - weighted mean SSE)	Difference (LNE - mean SSE)	Difference (LNE - median SSE)	Total ($k = 2$) uncertainty (fitted data)
7	-0.000004	0.000000	0.000000	0.000097
10	0.000026	0.000014	0.000000	0.000106
15	0.000101	0.000056	0.000019	0.000132
20	0.000193	0.000108	0.000058	0.000196
25	0.000298	0.000170	0.000112	0.000215
30	0.000416	0.000240	0.000178	0.000233
40	0.000670	0.000397	0.000342	0.000176
50	0.000944	0.000580	0.000535	0.000159
60	0.001145	0.000665	0.000740	0.000292
70	0.001358	0.000810	0.000944	0.000370

Table 99 – differences between LNE results and averages, indirect measurements with the LP5 thermometer, 6 mm diameter spot, including all data

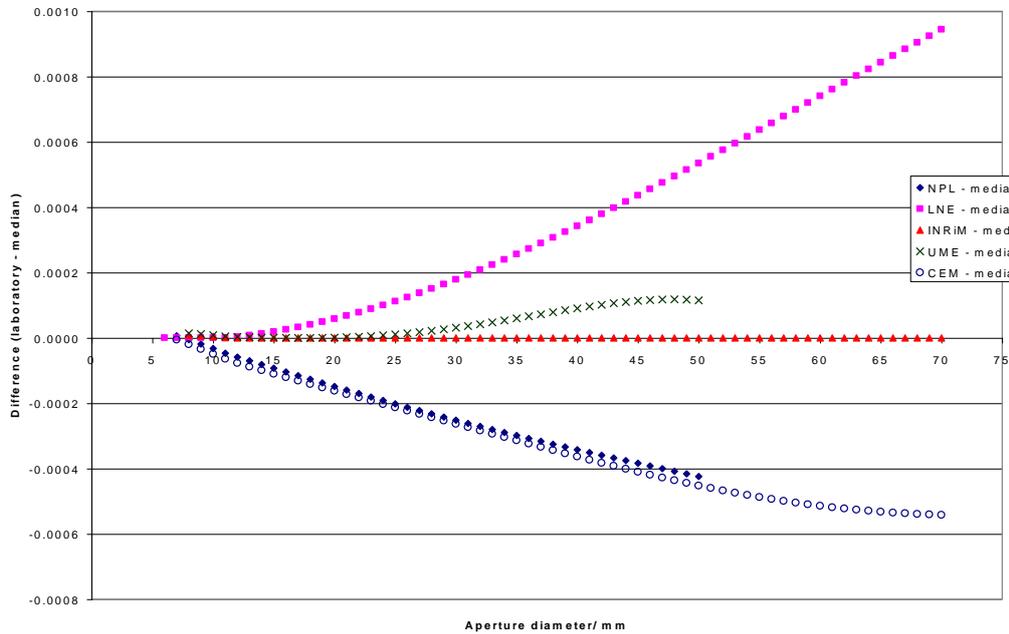
Aperture diameter/ mm	Difference (INRiM - weighted mean SSE)	Difference (INRiM - mean SSE)	Difference (INRiM - median SSE)	Total ($k = 2$) uncertainty (fitted data)
10	0.000030	0.000018	0.000004	0.000006
15	0.000083	0.000037	0.000000	0.000007
20	0.000135	0.000050	0.000000	0.000009
25	0.000186	0.000058	0.000000	0.000011
30	0.000237	0.000061	0.000000	0.000012
40	0.000328	0.000055	0.000000	0.000016
50	0.000410	0.000045	0.000000	0.000019
60	0.000405	-0.000075	0.000000	0.000022
70	0.000414	-0.000134	0.000000	0.000025
80	0.000405	0.000274	0.000274	0.000028
100	0.000485	0.000358	0.000358	0.000032

Table 100 – differences between INRiM results and averages, indirect measurements with the LP5 thermometer, 6 mm diameter spot, including all data

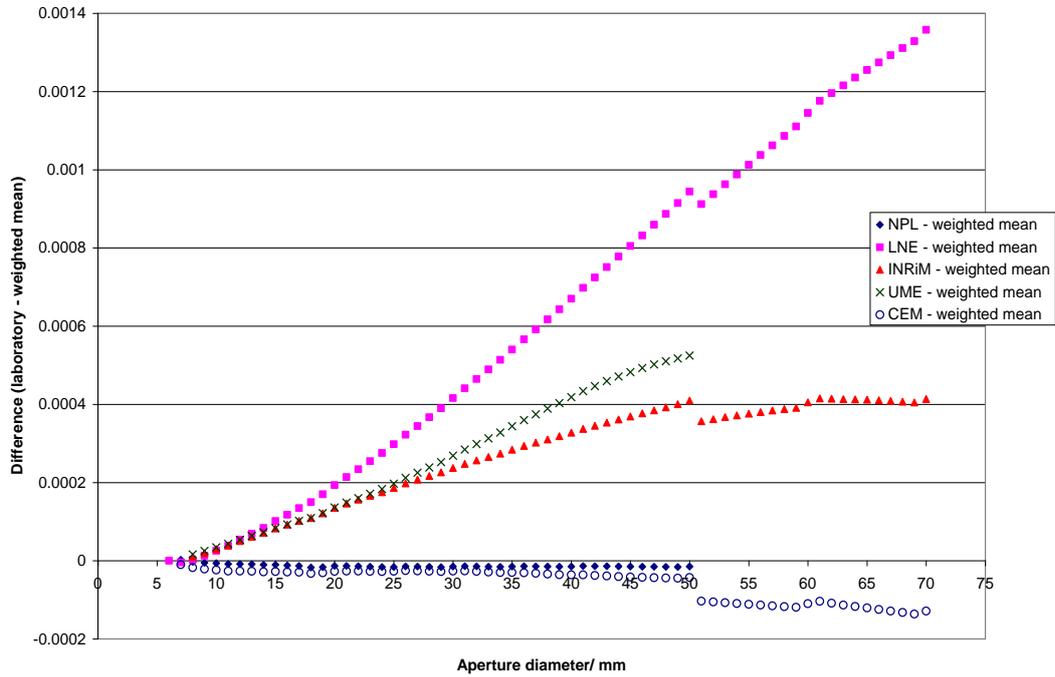
Plot of differences (laboratory - mean) for LP5 SSE measurements with 6 mm spot
(N.B. LNE uses 6.82 mm)



Plot of differences (laboratory - median) for LP5 SSE measurements with 6 mm spot
(N.B. LNE uses 6.82 mm)



Plot of differences (laboratory - weighted mean) for LP5 SSE measurements with 6 mm spot
(N.B. LNE uses 6.82 mm)



Aperture diameter/ mm	Weighted mean SSE value	Arithmetic mean SSE value	Median SSE value
7	1.3539E-05	9.7286E-06	9.7286E-06
10	3.3518E-05	4.1965E-05	4.5082E-05
15	5.2737E-05	8.4760E-05	8.8958E-05
20	6.9192E-05	1.2705E-04	1.3027E-04
25	8.4677E-05	1.6972E-04	1.6982E-04
30	9.6752E-05	2.1304E-04	2.0814E-04
40	1.2528E-04	2.9912E-04	2.8182E-04
50	1.5227E-04	3.7163E-04	3.4995E-04
60	2.5600E-04	4.0505E-04	4.0505E-04
70	3.3982E-04	4.8368E-04	4.8368E-04
80	4.3531E-04	5.6657E-04	5.6657E-04
100	5.1038E-04	6.3790E-04	6.3790E-04

Table 101 – the calculated arithmetic and weighted mean and the median SSE values for the indirect measurements with the LP5 thermometer – 6 mm diameter spot **excluding LNE data

Aperture diameter/ mm	Difference (NPL - weighted mean SSE)	Difference (NPL - mean SSE)	Difference (NPL - median SSE)	Total ($k = 2$) uncertainty (fitted data)
7	0.000002	0.000006	0.000006	0.000005
10	-0.000007	-0.000015	-0.000018	0.000003
15	-0.000010	-0.000042	-0.000046	0.000003
20	-0.000013	-0.000071	-0.000074	0.000003
25	-0.000016	-0.000101	-0.000101	0.000003
30	-0.000015	-0.000131	-0.000126	0.000003
40	-0.000015	-0.000188	-0.000171	0.000003
50	-0.000014	-0.000234	-0.000212	0.000003

Table 102 – differences between NPL results and averages, indirect measurements with the LP5 thermometer, 6 mm diameter spot **excluding LNE data **

Aperture diameter/ mm	Difference (CEM - weighted mean SSE)	Difference (CEM - mean SSE)	Difference (CEM - median SSE)	Total ($k = 2$) uncertainty (fitted data)
7	-0.000010	-0.000006	-0.000006	0.000011
10	-0.000024	-0.000032	-0.000035	0.000011
15	-0.000028	-0.000060	-0.000064	0.000011
20	-0.000027	-0.000085	-0.000088	0.000011
25	-0.000027	-0.000112	-0.000112	0.000011
30	-0.000026	-0.000143	-0.000138	0.000011
40	-0.000036	-0.000210	-0.000193	0.000011
50	-0.000043	-0.000262	-0.000240	0.000011
60	-0.000108	-0.000257	-0.000257	0.000011
70	-0.000127	-0.000271	-0.000271	0.000014
80	-0.000143	-0.000274	-0.000274	0.000016
100	-0.000230	-0.000358	-0.000358	0.000022

Table 103 – differences between CEM results and averages, indirect measurements with the LP5 thermometer, 6 mm diameter spot **excluding LNE data **

Aperture diameter/ mm	Difference (UME - weighted mean SSE)	Difference (UME - mean SSE)	Difference (UME - median SSE)	Total ($k = 2$) uncertainty (fitted data)
10	0.000034	0.000026	0.000023	0.000022
15	0.000083	0.000051	0.000047	0.000022
20	0.000136	0.000079	0.000075	0.000022
25	0.000197	0.000112	0.000112	0.000022
30	0.000269	0.000152	0.000157	0.000023
40	0.000418	0.000245	0.000262	0.000023
50	0.000525	0.000305	0.000327	0.000023

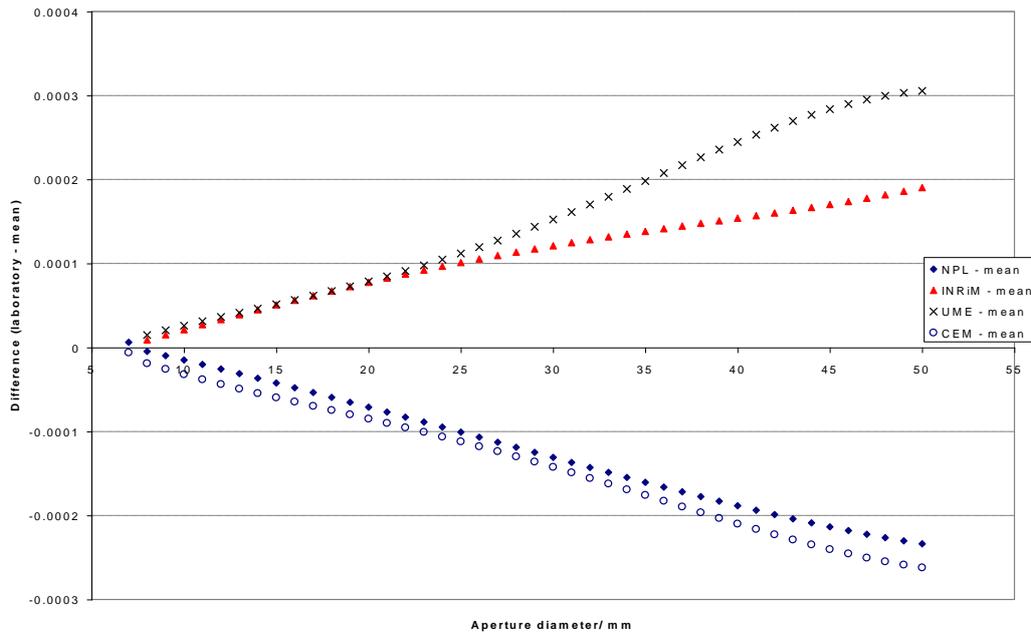
Table 104 – differences between UME results and averages, indirect measurements with the LP5 thermometer, 6 mm diameter spot **excluding LNE data **

Aperture diameter/ mm	Difference (INRiM - weighted mean SSE)	Difference (INRiM - mean SSE)	Difference (INRiM - median SSE)	Total ($k = 2$) uncertainty (fitted data)
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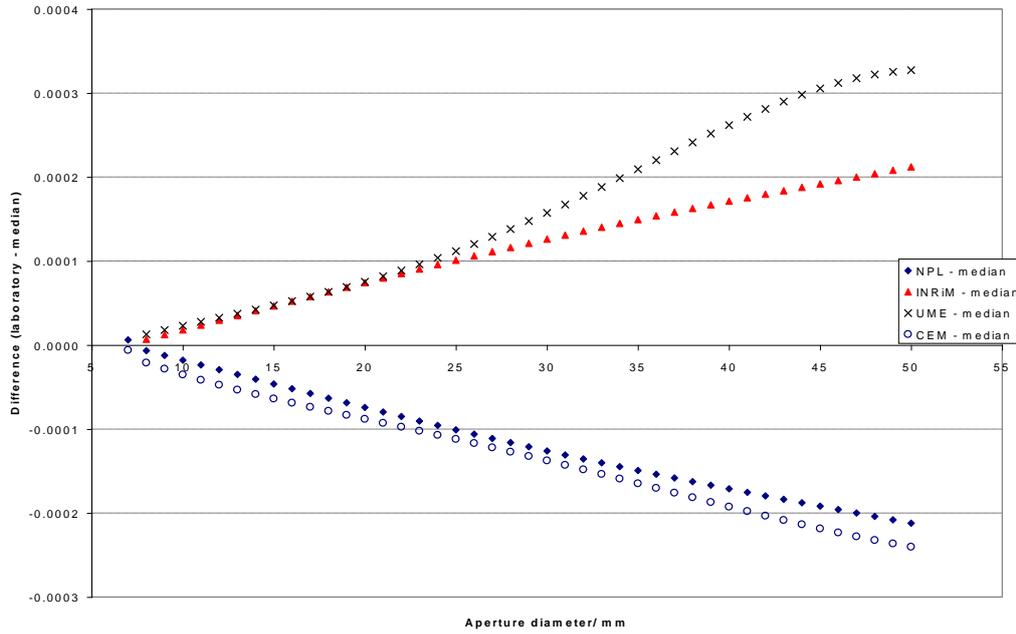
	SSE)			data)
10	0.000030	0.000021	0.000018	0.000006
15	0.000083	0.000051	0.000046	0.000007
20	0.000135	0.000077	0.000074	0.000009
25	0.000186	0.000101	0.000101	0.000011
30	0.000237	0.000121	0.000126	0.000012
40	0.000328	0.000154	0.000171	0.000016
50	0.000410	0.000190	0.000212	0.000019
60	0.000406	0.000257	0.000257	0.000022
70	0.000415	0.000271	0.000271	0.000025
80	0.000405	0.000274	0.000274	0.000028
100	0.000485	0.000358	0.000358	0.000032

Table 105 – differences between INRiM results and averages, indirect measurements with the LP5 thermometer, 6 mm diameter spot **excluding LNE data **

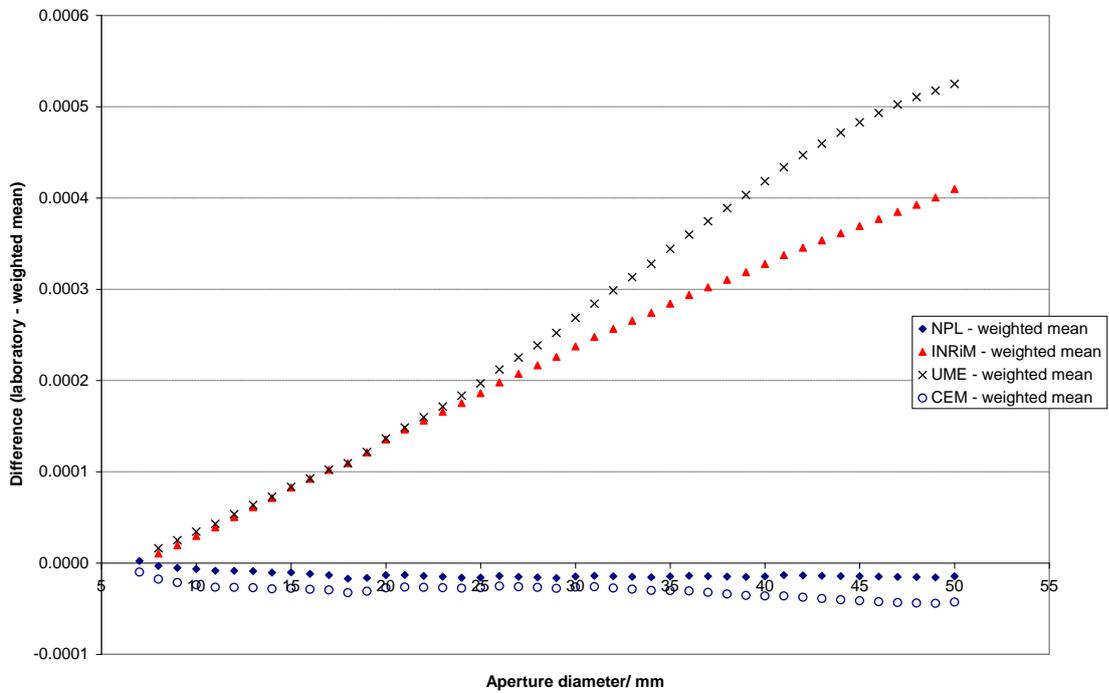
Plot of differences (laboratory - mean) for LP5 SSE with 6 mm spot (excluding LNE data)



Plot of differences (laboratory - median) for LP5 SSE with 6 mm spot
(excluding LNE data)



Plot of differences (laboratory - weighted mean) for LP5 SSE with 6 mm spot
(excluding LNE data)

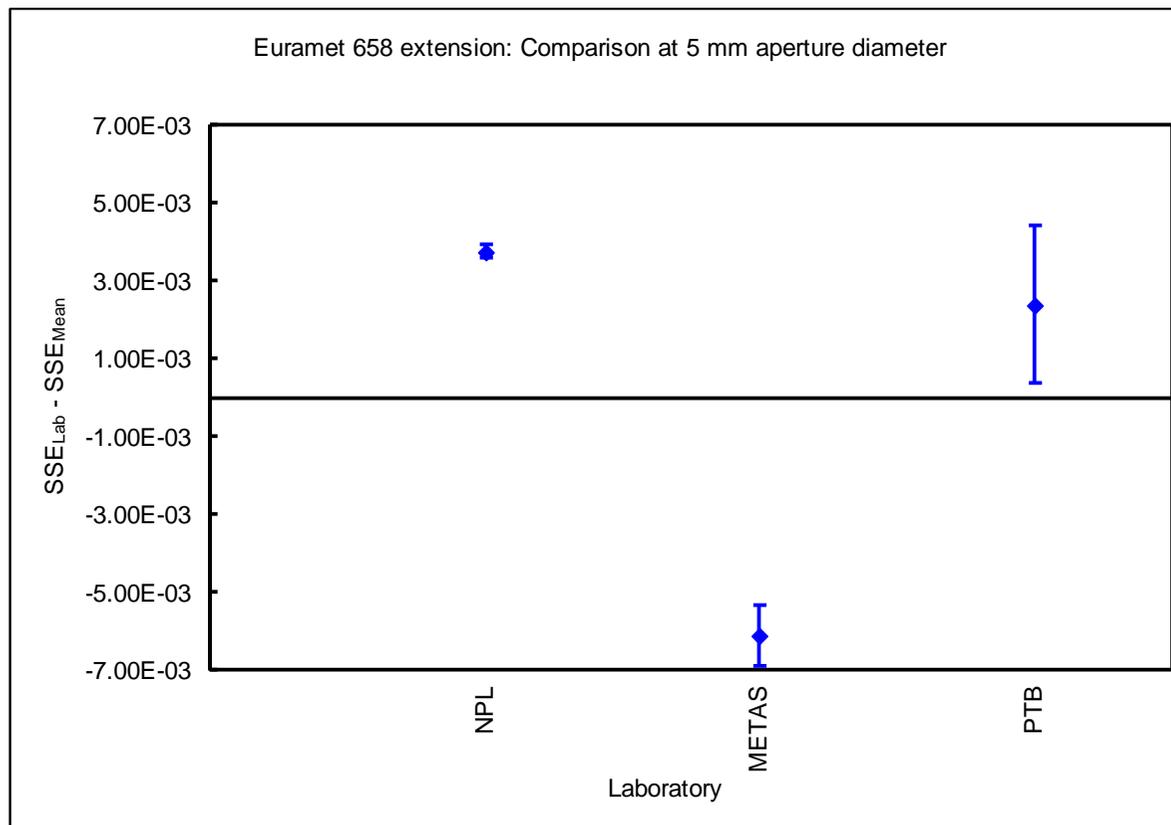


1.8 THE QDE₉₅ AND DOE VALUES FOR THE SSE RESULTS

1.8.1 The INRiM thermometer direct SSE results

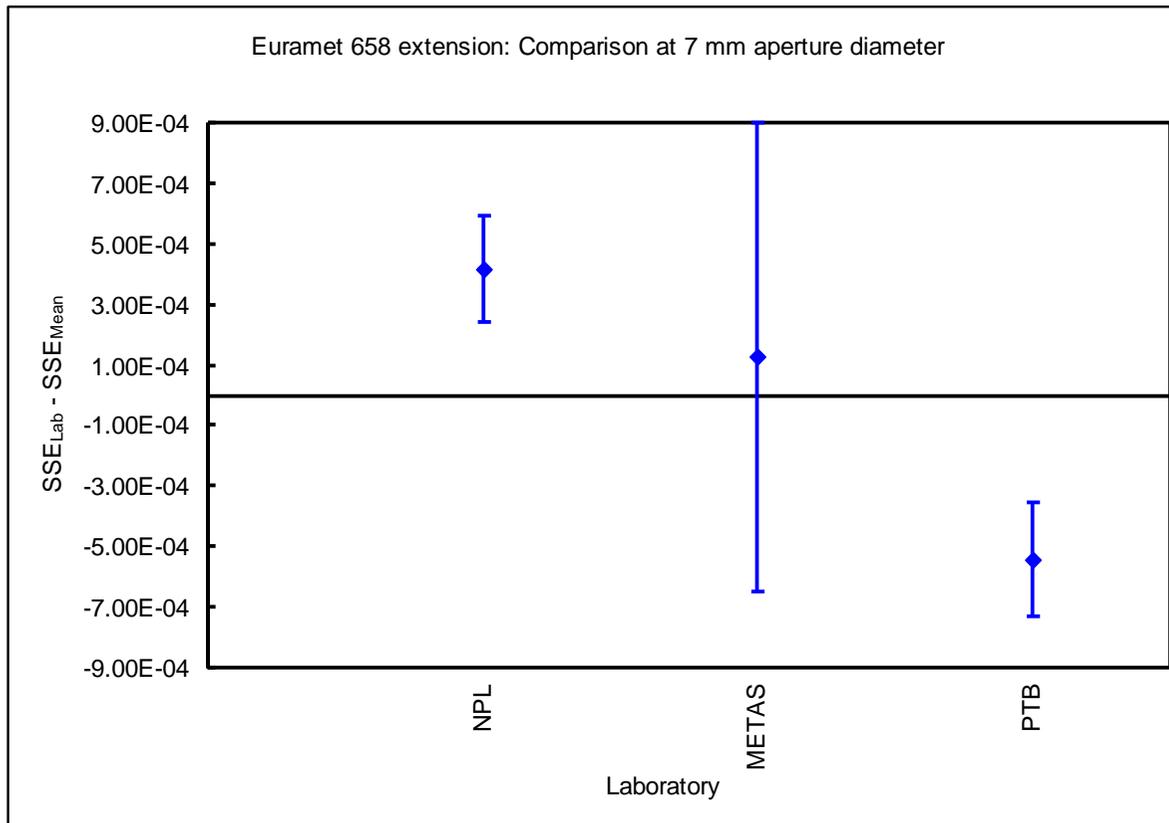
	NPL	METAS	PTB
NPL	-	0.009879 ± 7.931E-04	0.001362 ± 2.013E-03
METAS	0.010531	-	-0.008517 ± 2.151E-03
PTB	0.003019	0.010287	-

Table 106 – comparison of direct SSE measurements with the INRiM thermometer, 5 mm diameter aperture



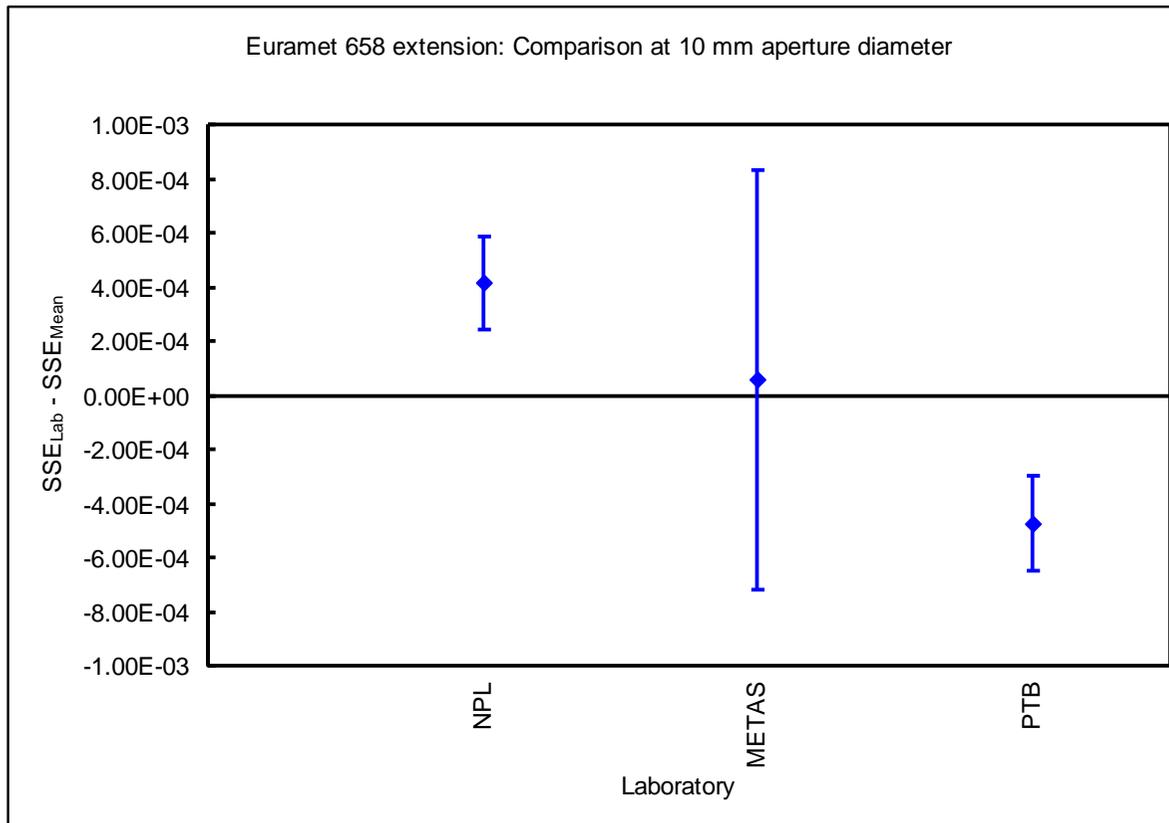
	NPL	METAS	PTB
NPL	-	0.000290 ± 7.954E-04	0.000959 ± 2.582E-04
METAS	0.000951	-	0.000670 ± 7.990E-04
PTB	0.001171	0.001327	-

Table 107 – comparison of direct SSE measurements with the INRiM thermometer, 7 mm diameter aperture



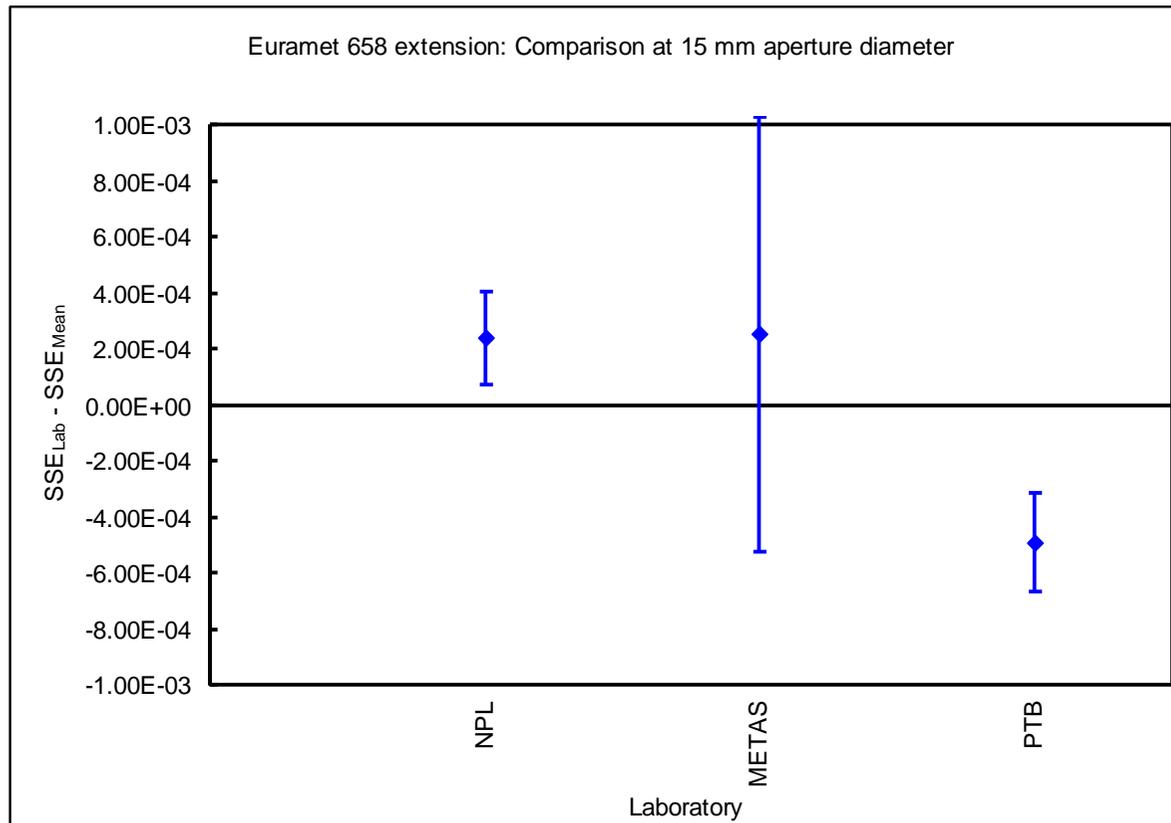
	NPL	METAS	PTB
NPL	-	0.000358 ± 7.947E-04	0.000889 ± 2.460E-04
METAS	0.001015	-	0.000531 ± 7.958E-04
PTB	0.001091	0.001186	-

Table 108 – comparison of direct SSE measurements with the INRiM thermometer, 10 mm diameter aperture



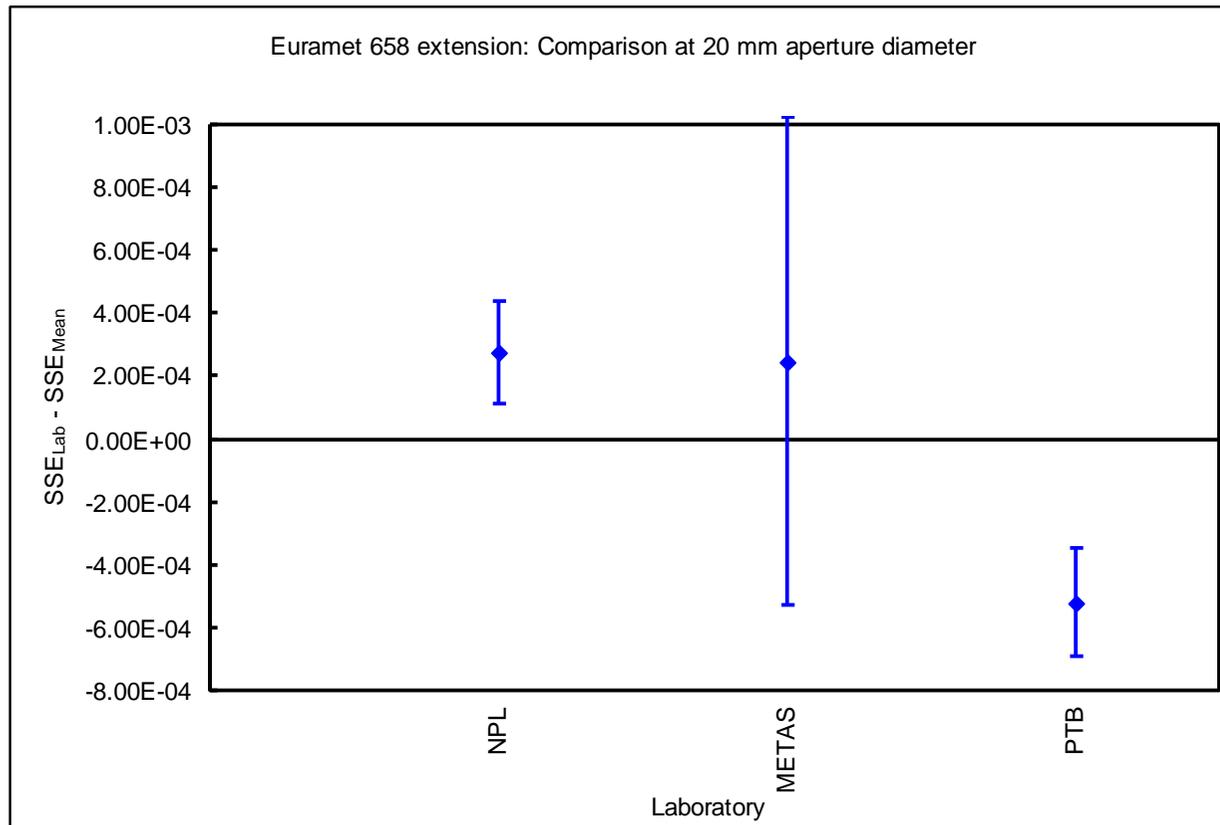
	NPL	METAS	PTB
NPL	-	-0.000014 ± 7.933E-04	0.000731 ± 2.413E-04
METAS	0.000780	-	0.000745 ± 7.958E-04
PTB	0.000930	0.001400	-

Table 109 – comparison of direct SSE measurements with the INRiM thermometer, 15 mm diameter aperture



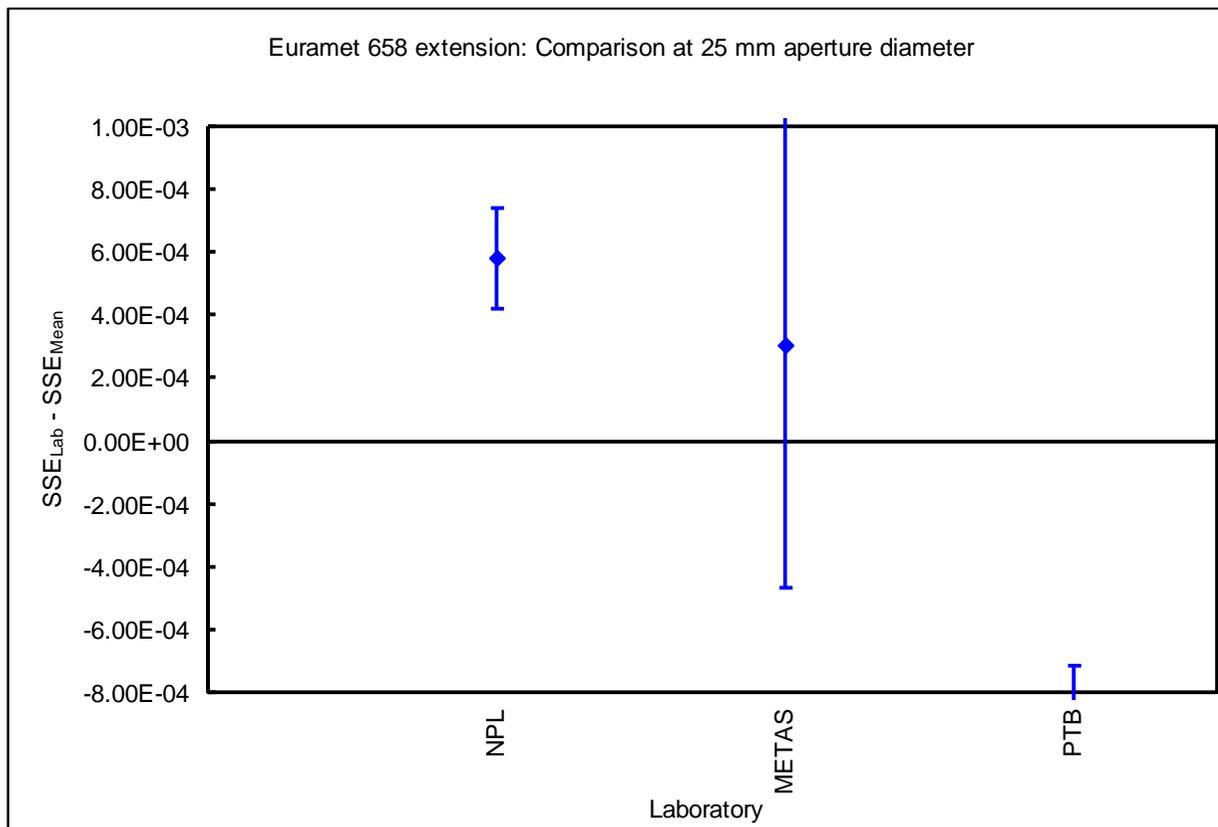
	NPL	METAS	PTB
NPL	-	0.000026 ± 7.931E-04	0.000793 ± 2.379E-04
METAS	0.000778	-	0.000766 ± 7.950E-04
PTB	0.000988	0.001420	-

Table 110 – comparison of direct SSE measurements with the INRiM thermometer, 20 mm diameter aperture



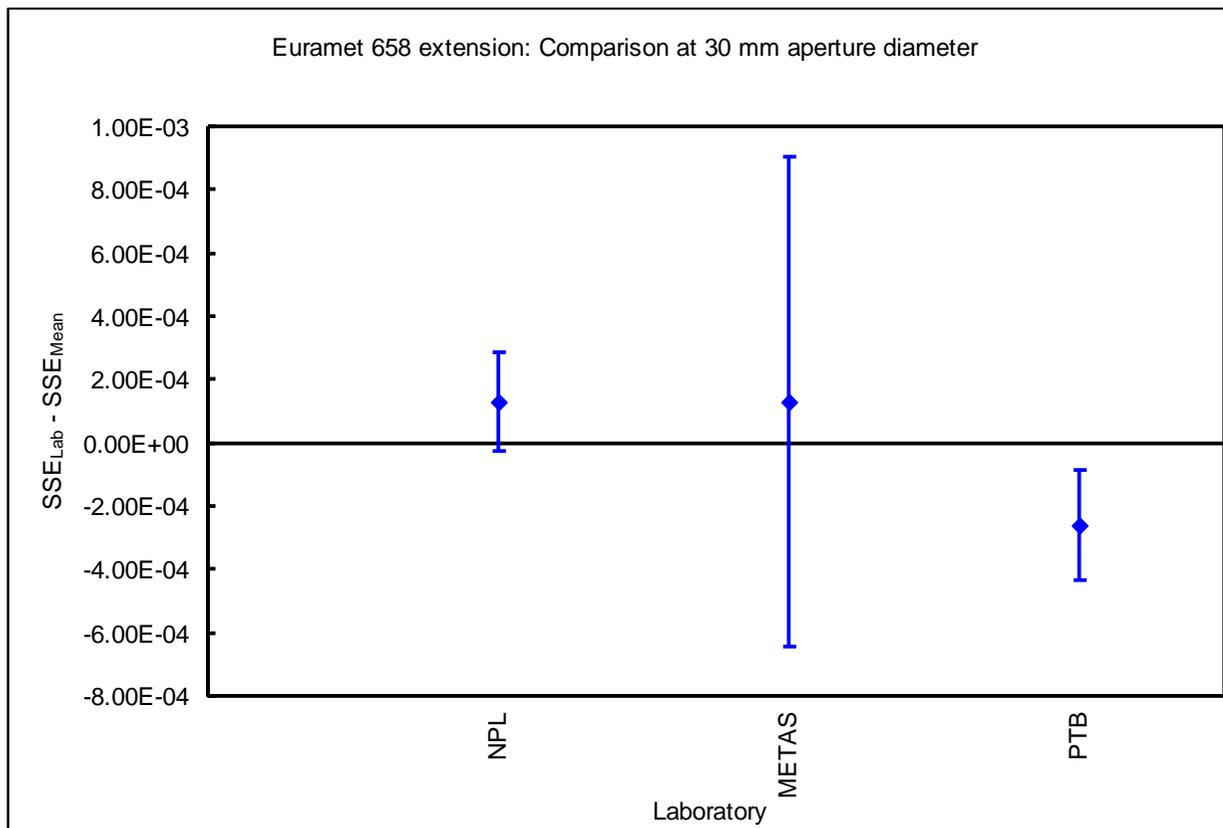
	NPL	METAS	PTB
NPL	-	0.000273 ± 7.921E-04	0.001469 ± 2.348E-04
METAS	0.000933	-	0.001196 ± 7.950E-04
PTB	0.001663	0.001850	-

Table 111 – comparison of direct SSE measurements with the INRiM thermometer, 25 mm diameter aperture



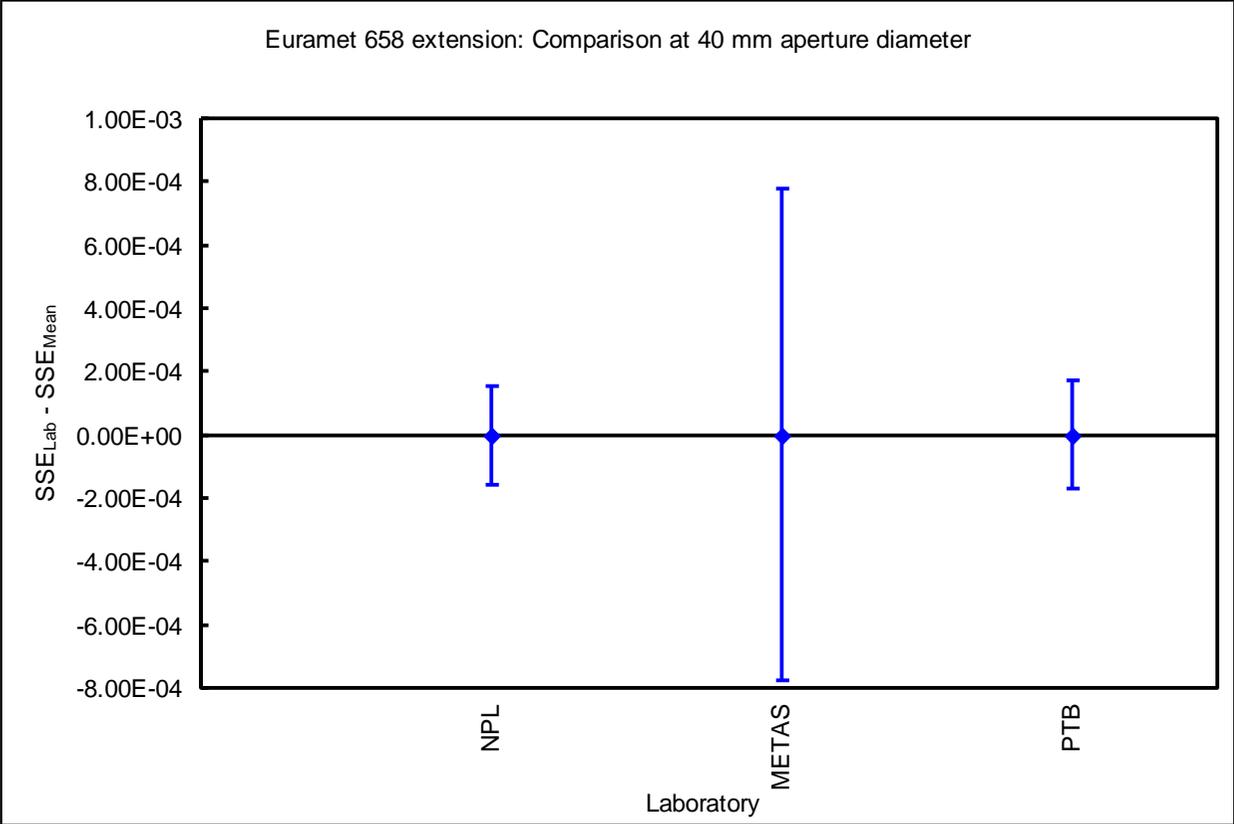
	NPL	METAS	PTB
NPL	-	0.000001 ± 7.914E-04	0.000391 ± 2.323E-04
METAS	0.000781	-	0.000391 ± 7.950E-04
PTB	0.000582	0.001047	-

Table 112 – comparison of direct SSE measurements with the INRiM thermometer, 30 mm diameter aperture



	NPL	METAS	PTB
NPL	-	0.000001 ± 7.914E-04	0.000000 ± 2.323E-04
METAS	0.000781	-	-0.000001 ± 7.950E-04
PTB	0.000229	0.000785	-

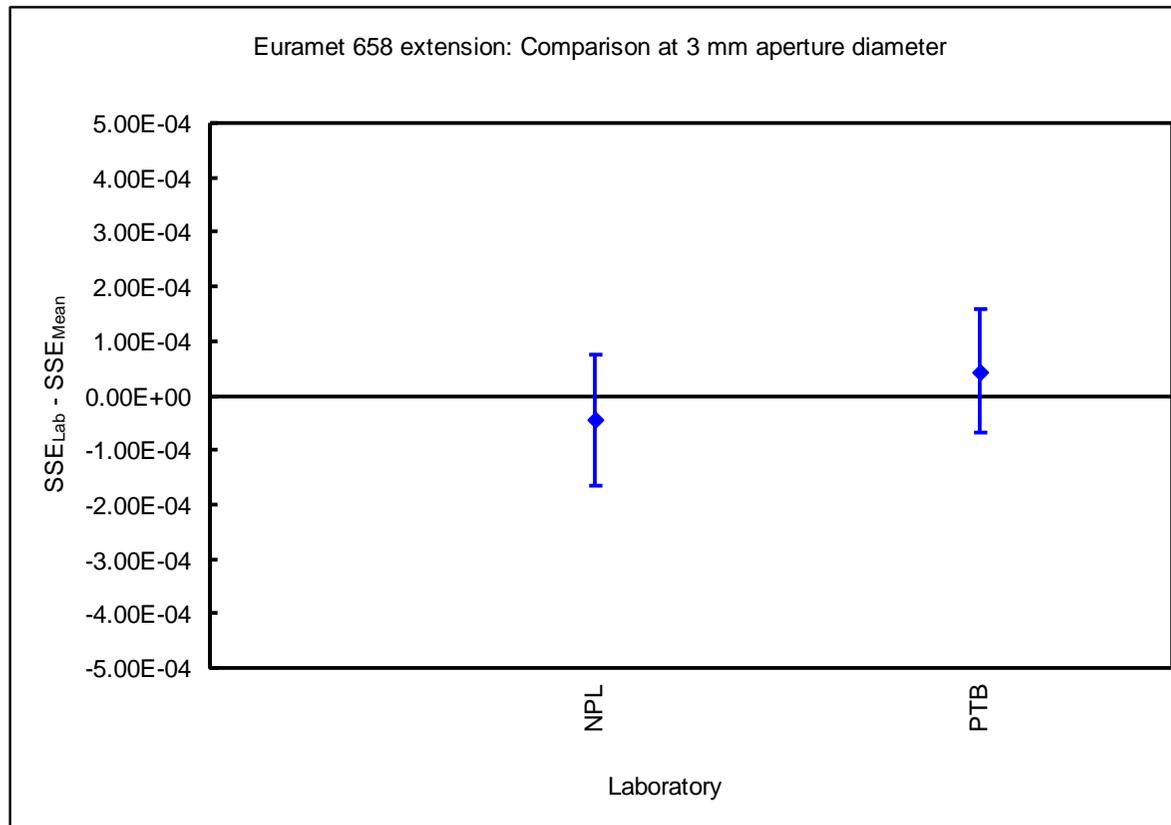
Table 113 – comparison of direct SSE measurements with the INRiM thermometer, 40 mm diameter aperture



1.8.2 The LP5 thermometer ‘direct’ SSE results

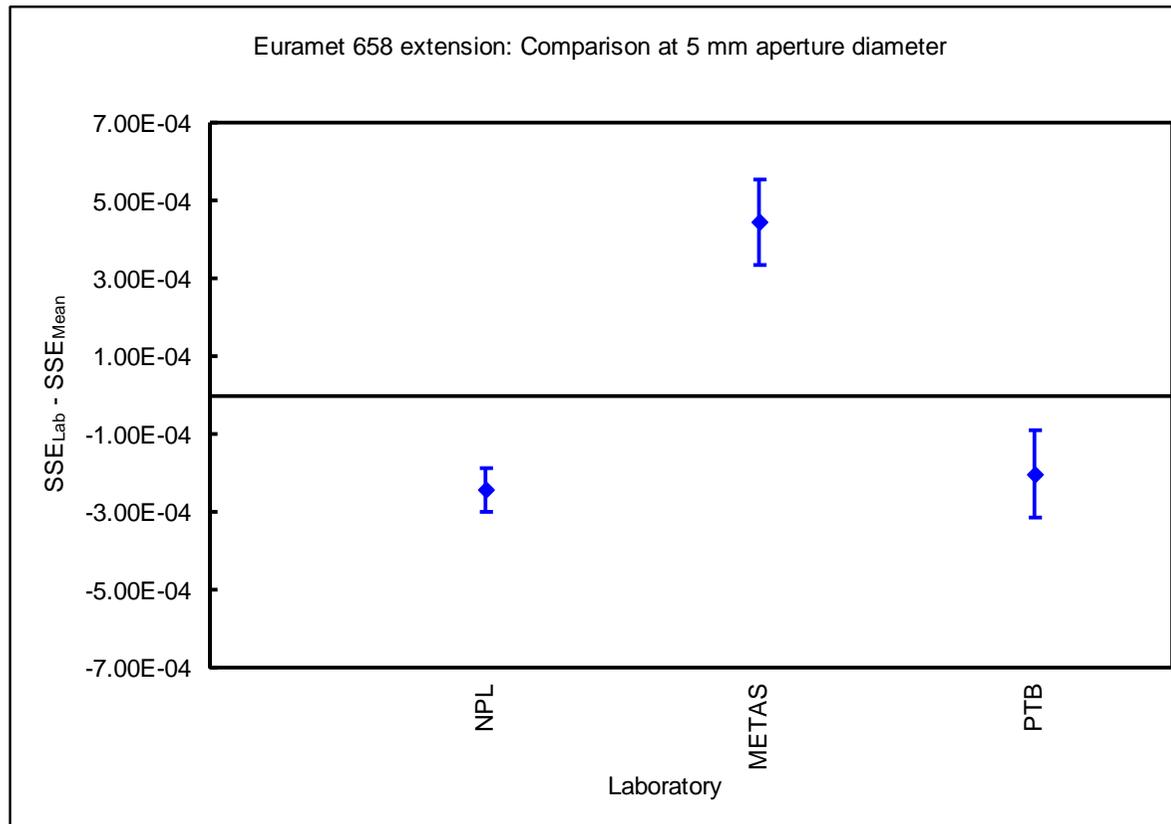
	NPL	PTB
NPL	-	-0.000090 ± 1.645E-04
PTB	0.000226	-

Table 114 – comparison of direct SSE measurements with the LP5 thermometer, 3 mm diameter aperture



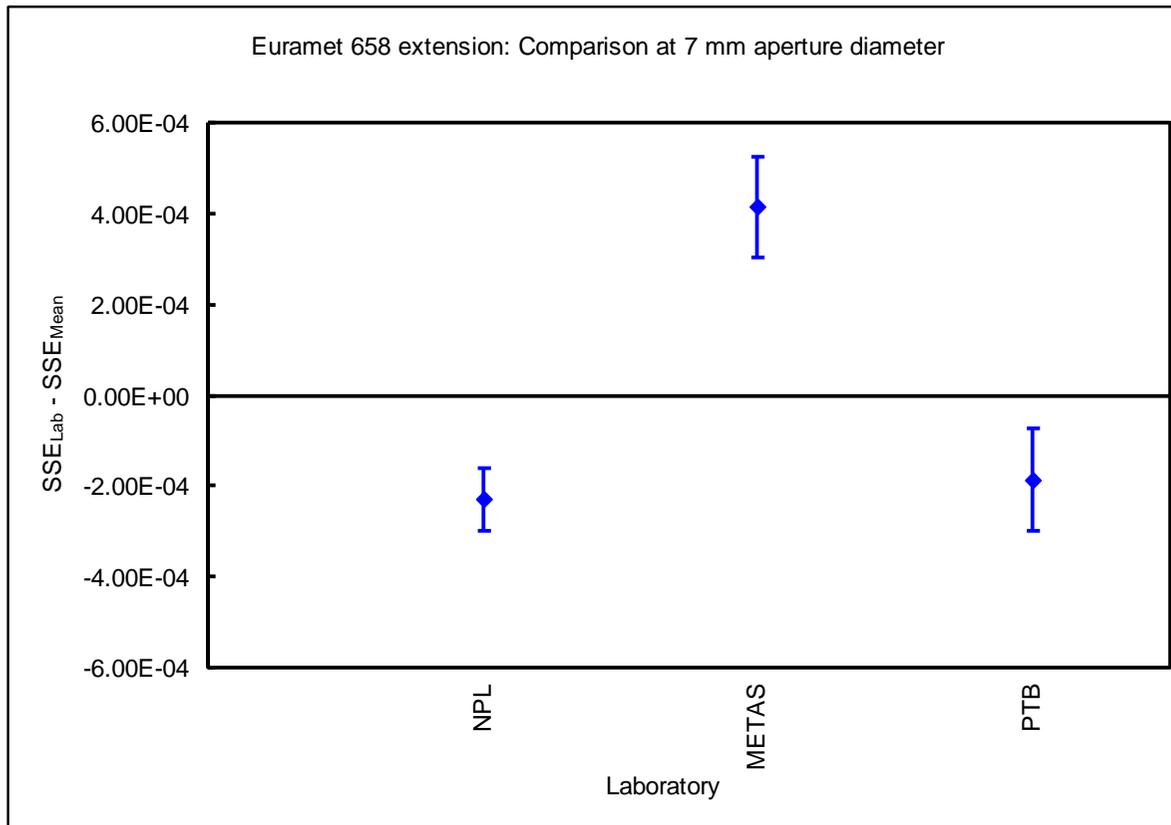
	NPL	METAS	PTB
NPL	-	$-0.000687 \pm 1.243E-04$	$-0.000042 \pm 1.271E-04$
METAS	0.000790	-	$0.000646 \pm 1.580E-04$
PTB	0.000148	0.000776	-

Table 115 – comparison of direct SSE measurements with the LP5 thermometer, 5 mm diameter aperture



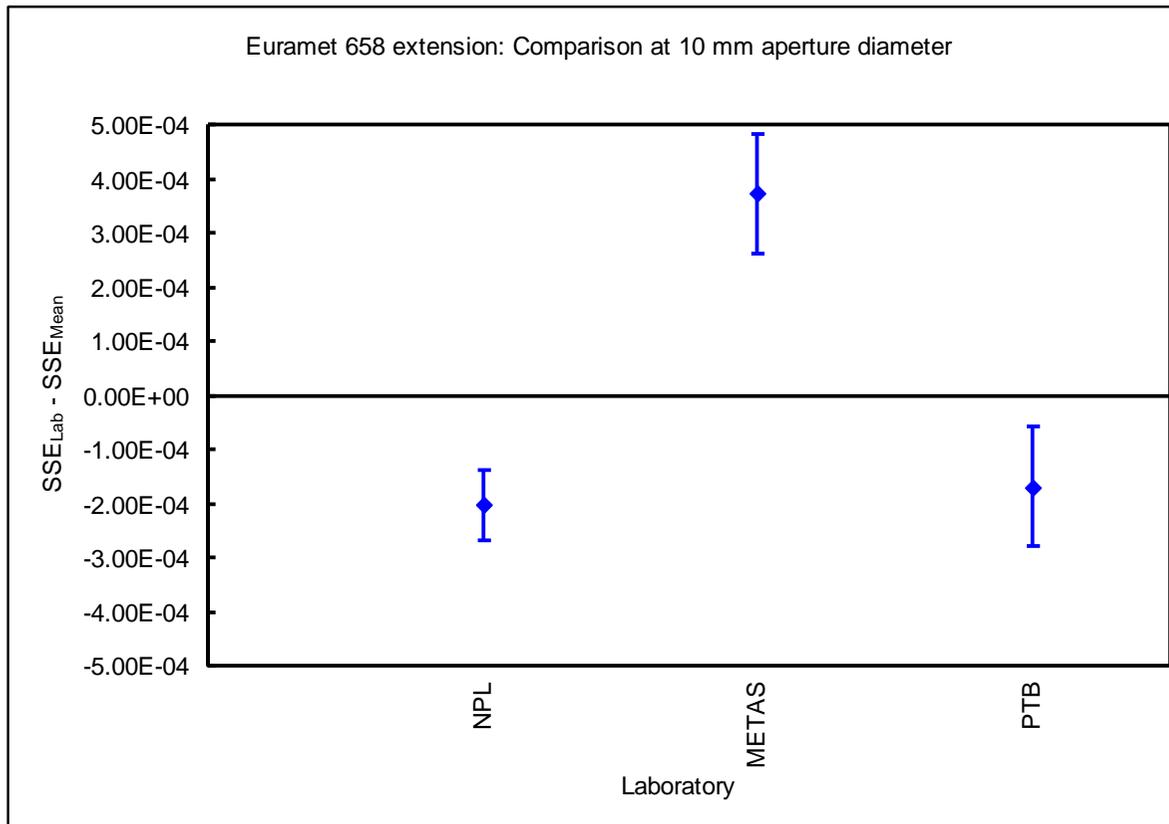
	NPL	METAS	PTB
NPL	-	-0.000644 ± 1.300E-04	-0.000044 ± 1.313E-04
METAS	0.000751	-	0.000601 ± 1.569E-04
PTB	0.000153	0.000730	-

Table 116 – comparison of direct SSE measurements with the LP5 thermometer, 7 mm diameter aperture



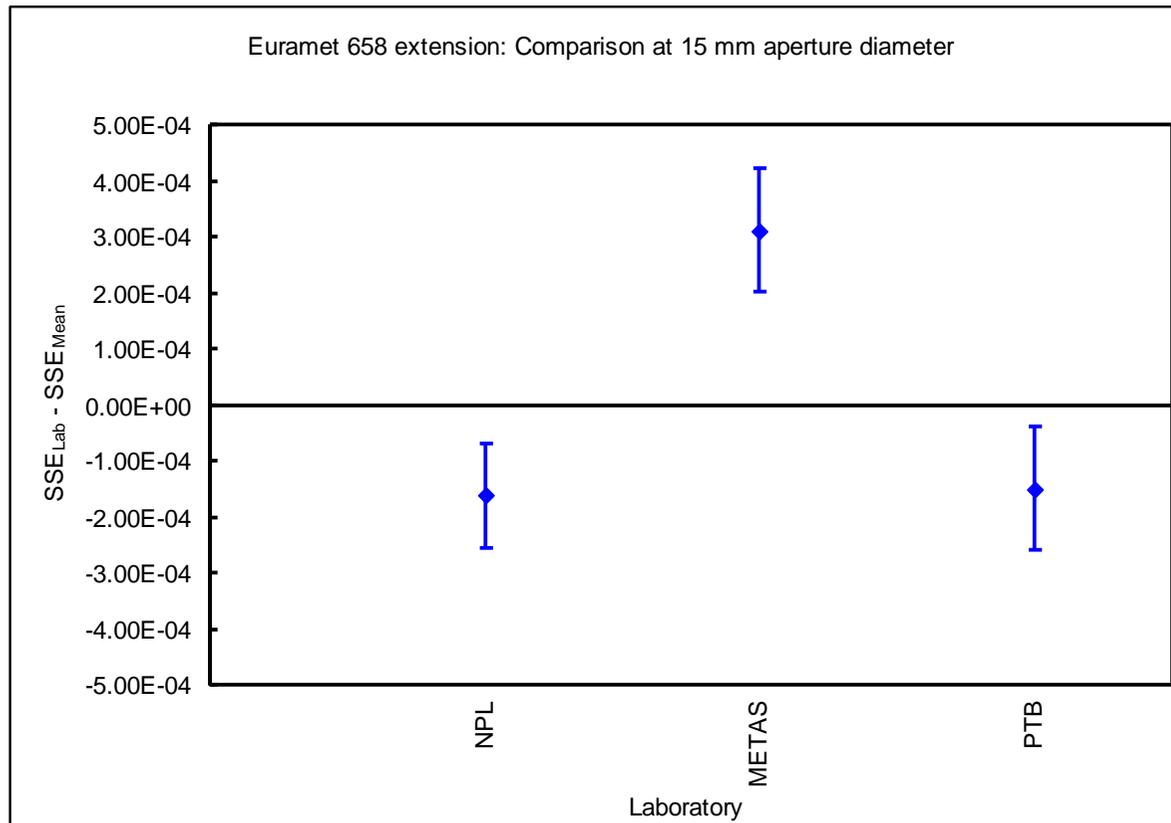
	NPL	METAS	PTB
NPL	-	-0.000575 ± 1.281E-04	-0.000033 ± 1.281E-04
METAS	0.000680	-	0.000542 ± 1.558E-04
PTB	0.000141	0.000670	-

Table 117 – comparison of direct SSE measurements with the LP5 thermometer, 10 mm diameter aperture



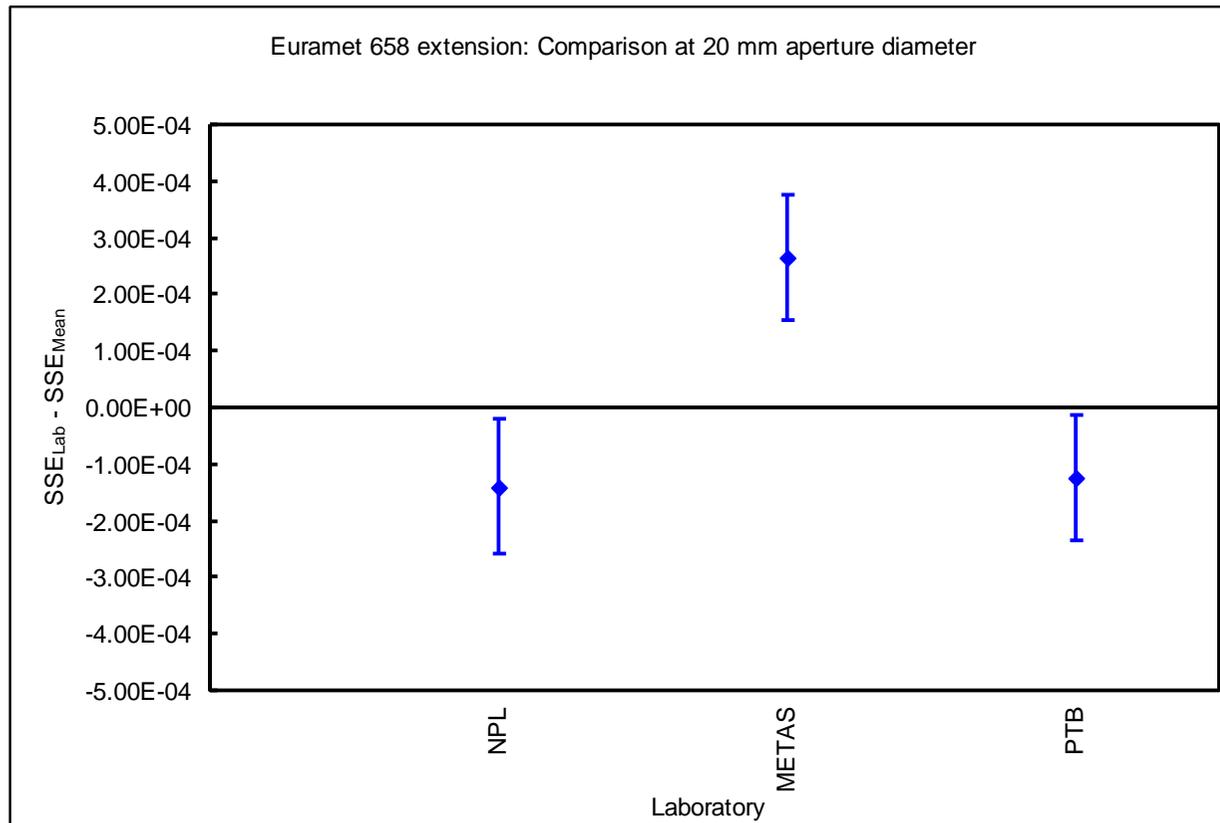
	NPL	METAS	PTB
NPL	-	-0.000474 ± 1.449E-04	-0.000013 ± 1.449E-04
METAS	0.000593	-	0.000461 ± 1.558E-04
PTB	0.000144	0.000589	-

Table 118 – comparison of direct SSE measurements with the LP5 thermometer, 15 mm diameter aperture



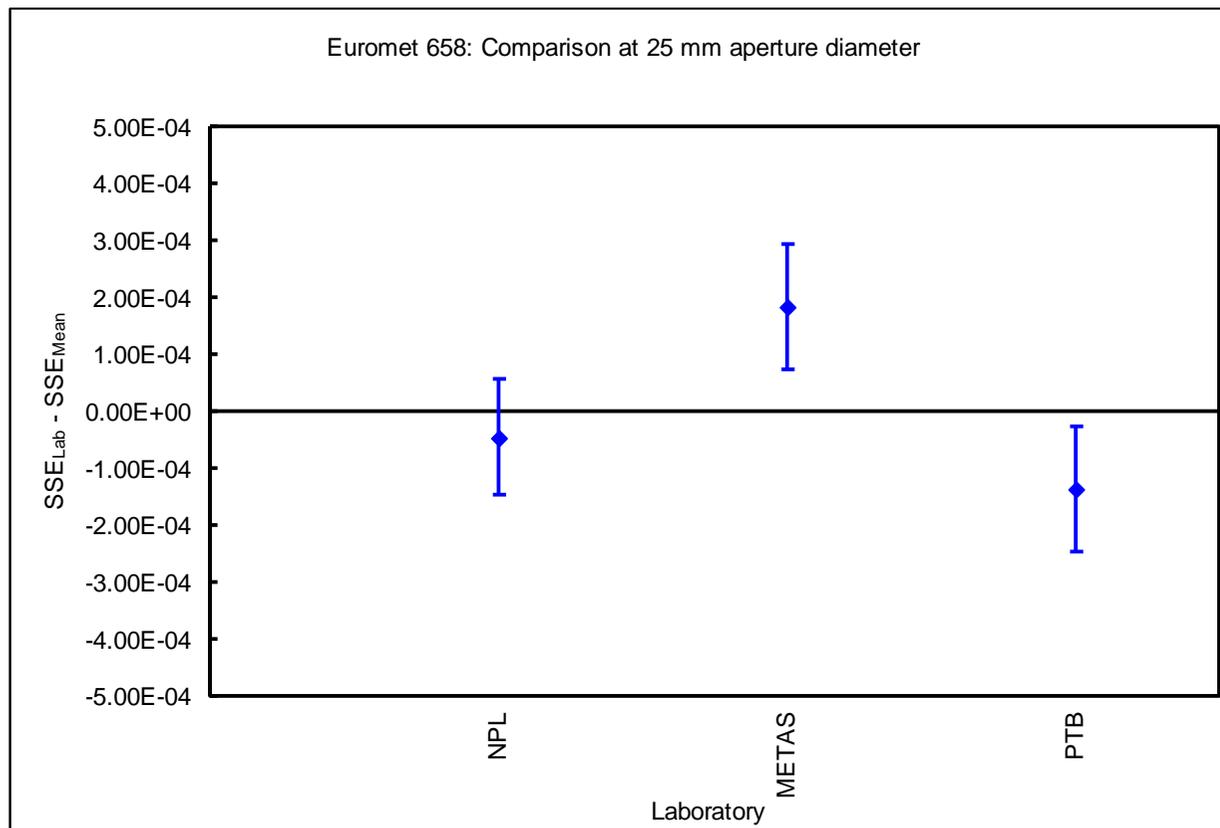
	NPL	METAS	PTB
NPL	-	-0.000406 ± 1.623E-04	-0.000015 ± 1.623E-04
METAS	0.000540	-	0.000391 ± 1.558E-04
PTB	0.000161	0.000519	-

Table 119 – comparison of direct SSE measurements with the LP5 thermometer, 20 mm diameter aperture



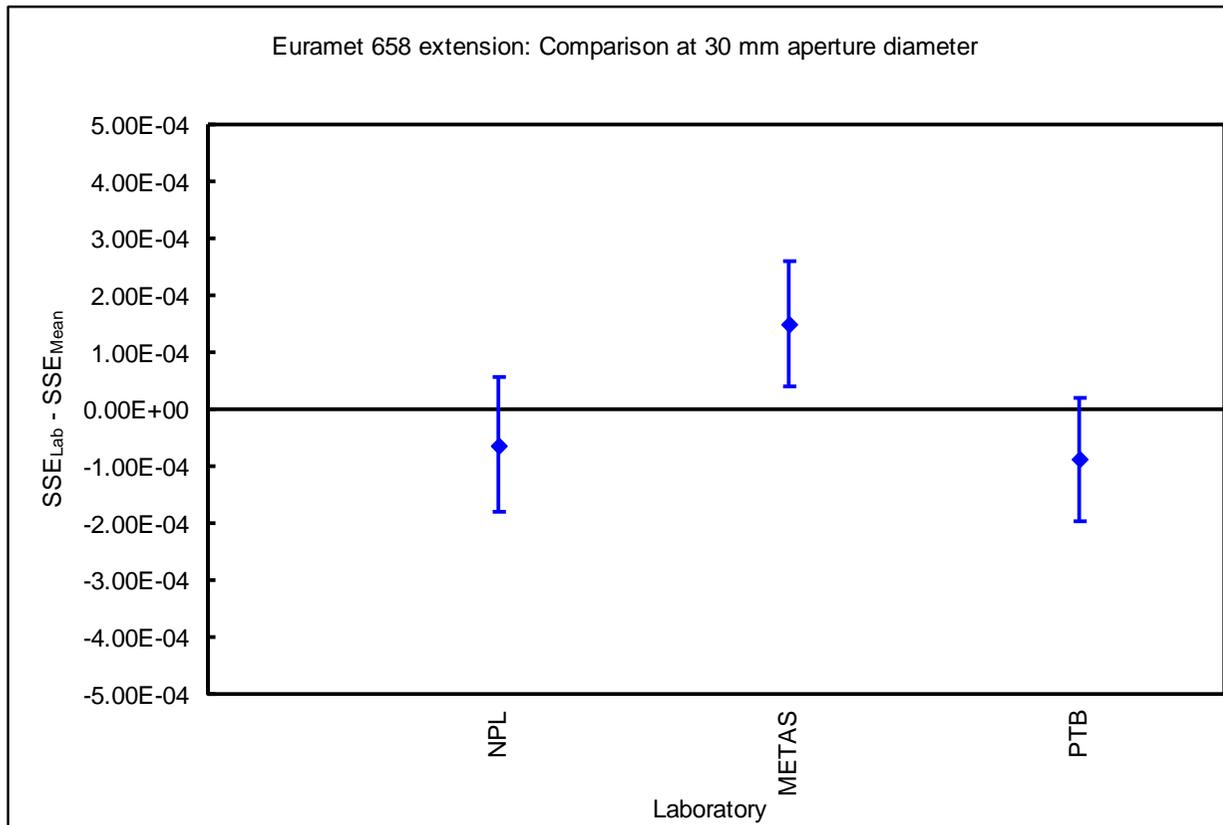
	NPL	METAS	PTB
NPL	-	$-0.000228 \pm 1.495E-04$	$0.000093 \pm 1.495E-04$
METAS	0.000351	-	$0.000321 \pm 1.558E-04$
PTB	0.000216	0.000449	-

Table 120 – comparison of direct SSE measurements with the LP5 thermometer, 25 mm diameter aperture



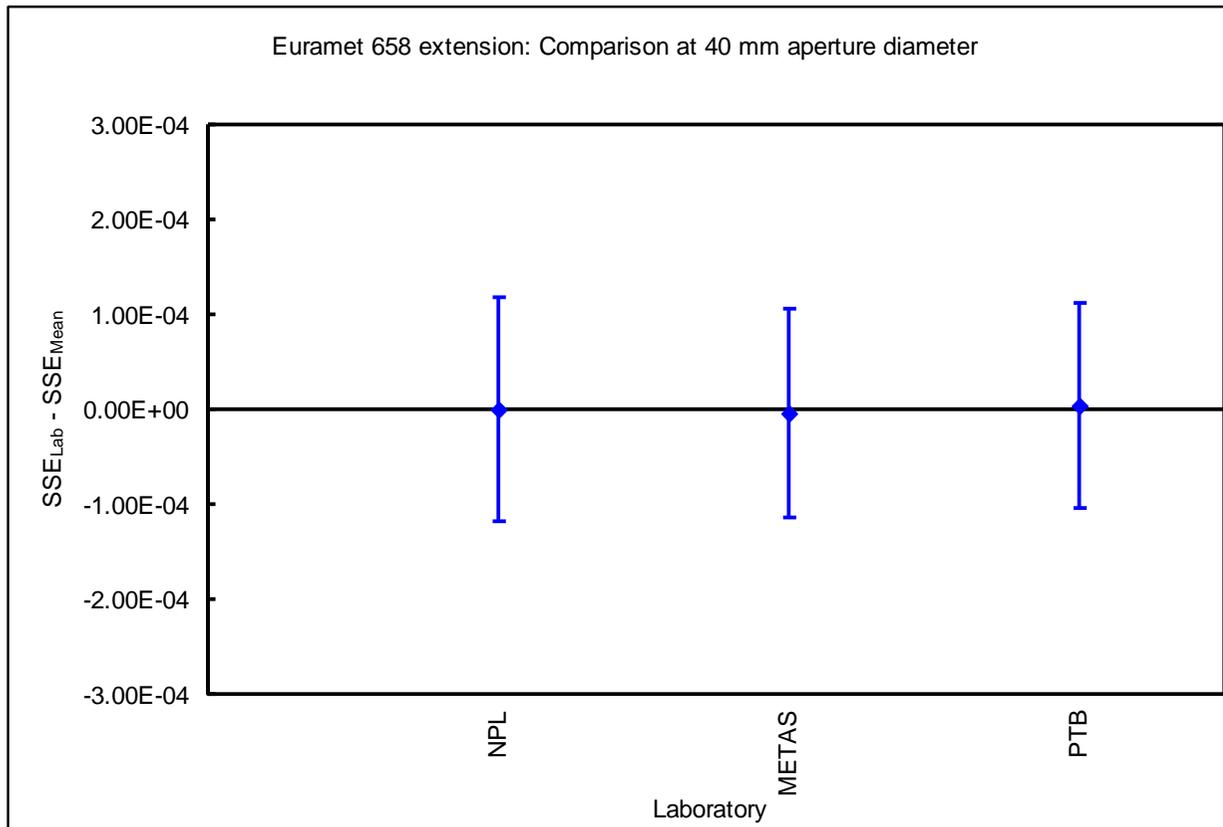
	NPL	METAS	PTB
NPL	-	-0.000213 ± 1.620E-04	0.000026 ± 1.611E-04
METAS	0.000346	-	0.000238 ± 1.549E-04
PTB	0.000165	0.000366	-

Table 121 – comparison of direct SSE measurements with the LP5 thermometer, 30 mm diameter aperture



	NPL	METAS	PTB
NPL	-	0.000004 ± 1.620E-04	-0.000004 ± 1.604E-04
METAS	0.000159	-	-0.000008 ± 1.542E-04
PTB	0.000158	0.000152	-

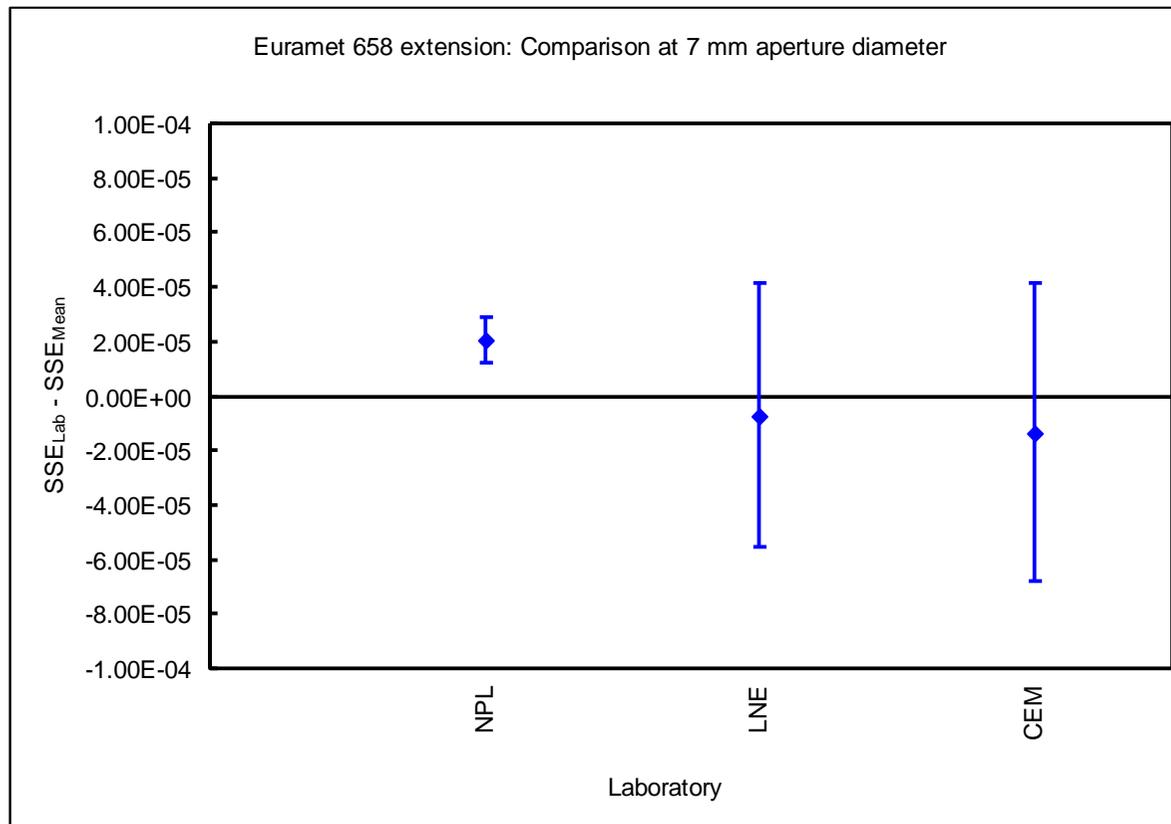
Table 122 – comparison of direct SSE measurements with the LP5 thermometer, 40 mm diameter aperture



1.8.3 The INRiM thermometer ‘indirect’ SSE results – 6 mm spot, all data

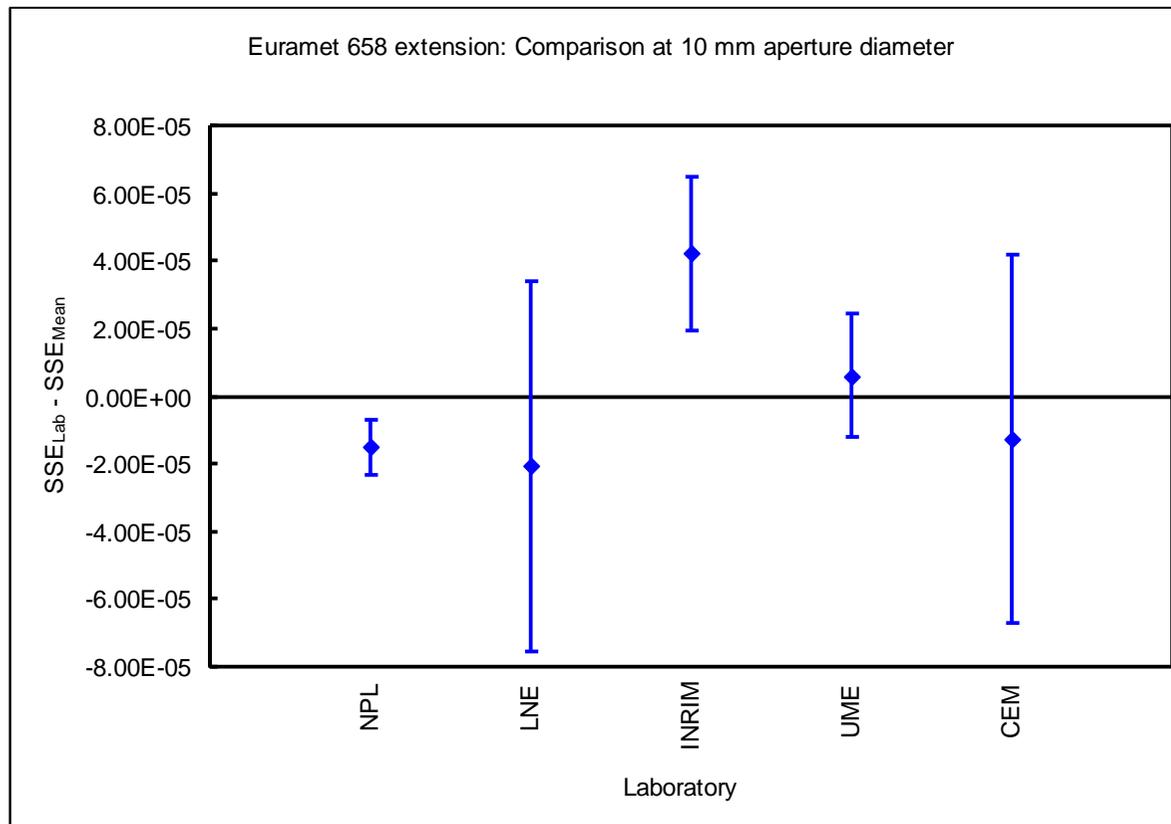
	NPL	LNE	CEM
NPL	-	2.7652E-05 ± 4.899E-05	3.4036E-05 ± 5.523E-05
LNE	6.8029E-05	-	6.3834E-06 ± 7.292E-05
CEM	7.9521E-05	7.2276E-05	-

Table 123 – comparison of indirect SSE measurements with the INRiM thermometer, with 6 mm diameter spot and 7 mm diameter aperture



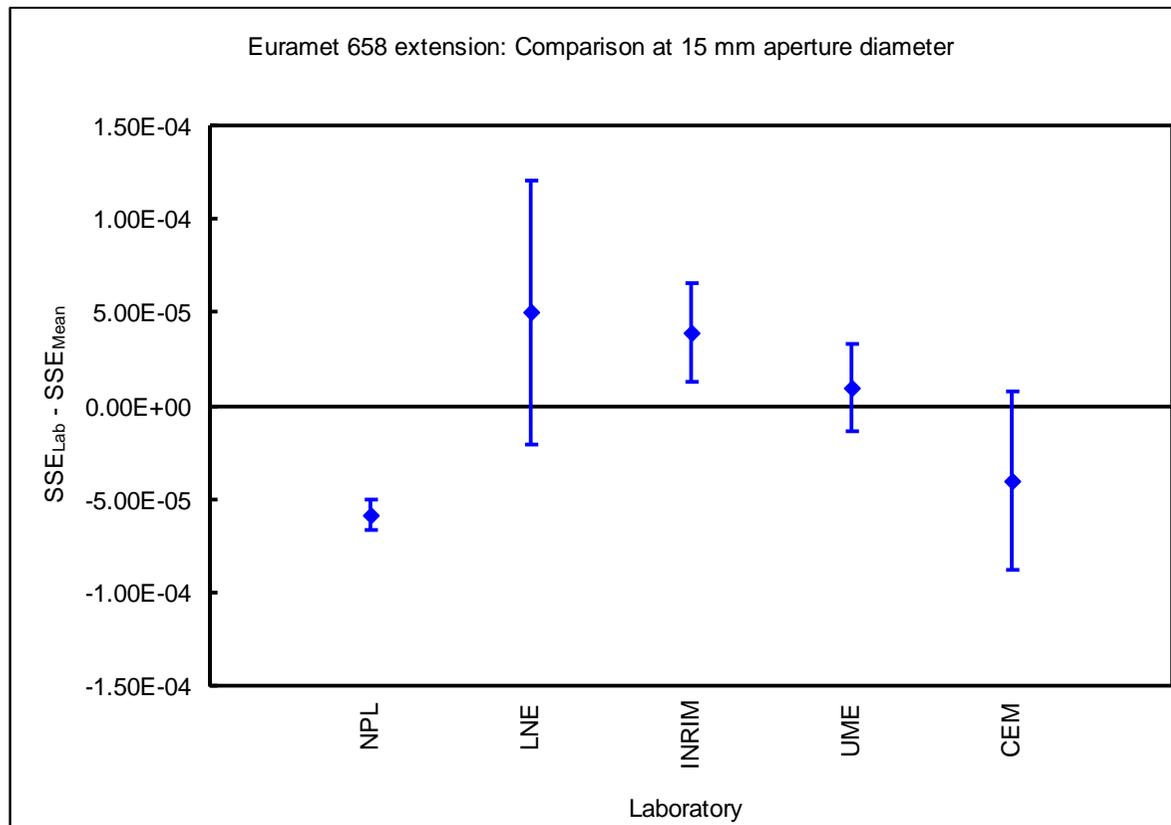
	NPL	LNE	INRIM	UME	CEM
NPL	-	5.7430E-06 ± 5.525E-05	-5.7285E-05 ± 2.407E-05	-2.1038E-05 ± 1.986E-05	-2.3313E-06 ± 5.521E-05
LNE	5.5104E-05	-	-6.3028E-05 ± 5.918E-05	-2.6781E-05 ± 5.760E-05	-8.0743E-06 ± 7.728E-05
INRIM	7.7083E-05	1.1170E-04	-	3.6247E-05 ± 2.906E-05	5.4954E-05 ± 5.915E-05
UME	3.7378E-05	7.4374E-05	6.0152E-05	-	1.8707E-05 ± 5.757E-05
CEM	5.4207E-05	7.7094E-05	1.0361E-04	6.6738E-05	-

Table 124 – comparison of indirect SSE measurements with the INRiM thermometer, with 6 mm diameter spot and 10 mm diameter aperture



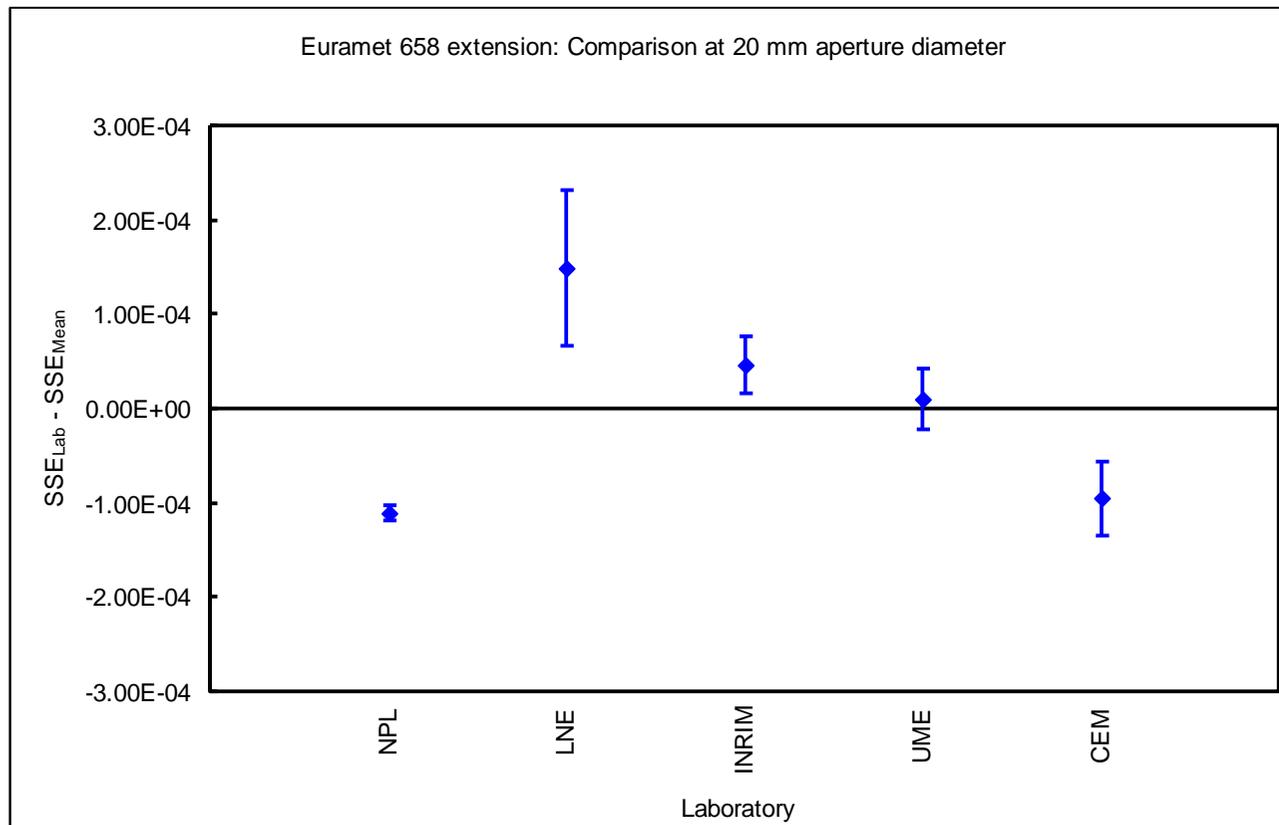
	NPL	LNE	INRIM	UME	CEM
NPL	-	-1.0859E-04 ± 7.108E-05	-9.7631E-05 ± 2.763E-05	-6.8182E-05 ± 2.497E-05	-1.8310E-05 ± 4.809E-05
LNE	1.6705E-04	-	1.0958E-05 ± 7.541E-05	4.0406E-05 ± 7.447E-05	9.0278E-05 ± 8.506E-05
INRIM	1.2036E-04	7.6808E-05	-	2.9449E-05 ± 3.546E-05	7.9320E-05 ± 5.428E-05
UME	8.8722E-05	1.0181E-04	5.8620E-05	-	4.9872E-05 ± 5.298E-05
CEM	5.8229E-05	1.6024E-04	1.2397E-04	9.3451E-05	-

Table 125 – comparison of indirect SSE measurements with the INRiM thermometer, with 6 mm diameter spot and 15 mm diameter aperture



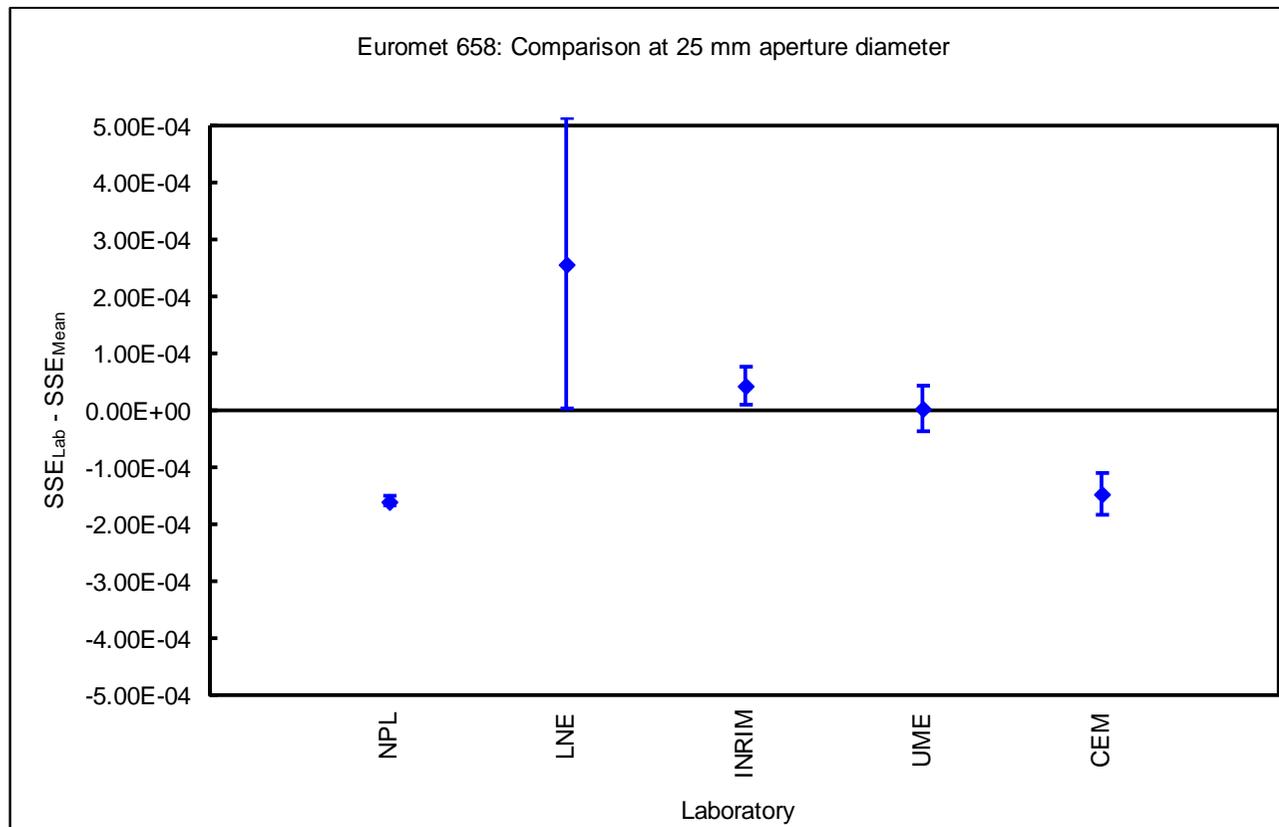
	NPL	LNE	INRIM	UME	CEM
NPL	-	-2.6023E-04 ± 8.309E-05	-1.5714E-04 ± 3.087E-05	-1.2181E-04 ± 3.324E-05	-1.5407E-05 ± 4.063E-05
LNE	3.2857E-04	-	1.0309E-04 ± 8.790E-05	1.3842E-04 ± 8.876E-05	2.4482E-04 ± 9.179E-05
INRIM	1.8252E-04	1.7540E-04	-	3.5327E-05 ± 4.391E-05	1.4173E-04 ± 4.974E-05
UME	1.4915E-04	2.1143E-04	7.1452E-05	-	1.0640E-04 ± 5.125E-05
CEM	4.9138E-05	3.2032E-04	1.8264E-04	1.4855E-04	-

Table 126 – comparison of indirect SSE measurements with the INRiM thermometer, with 6 mm diameter spot and 20 mm diameter aperture



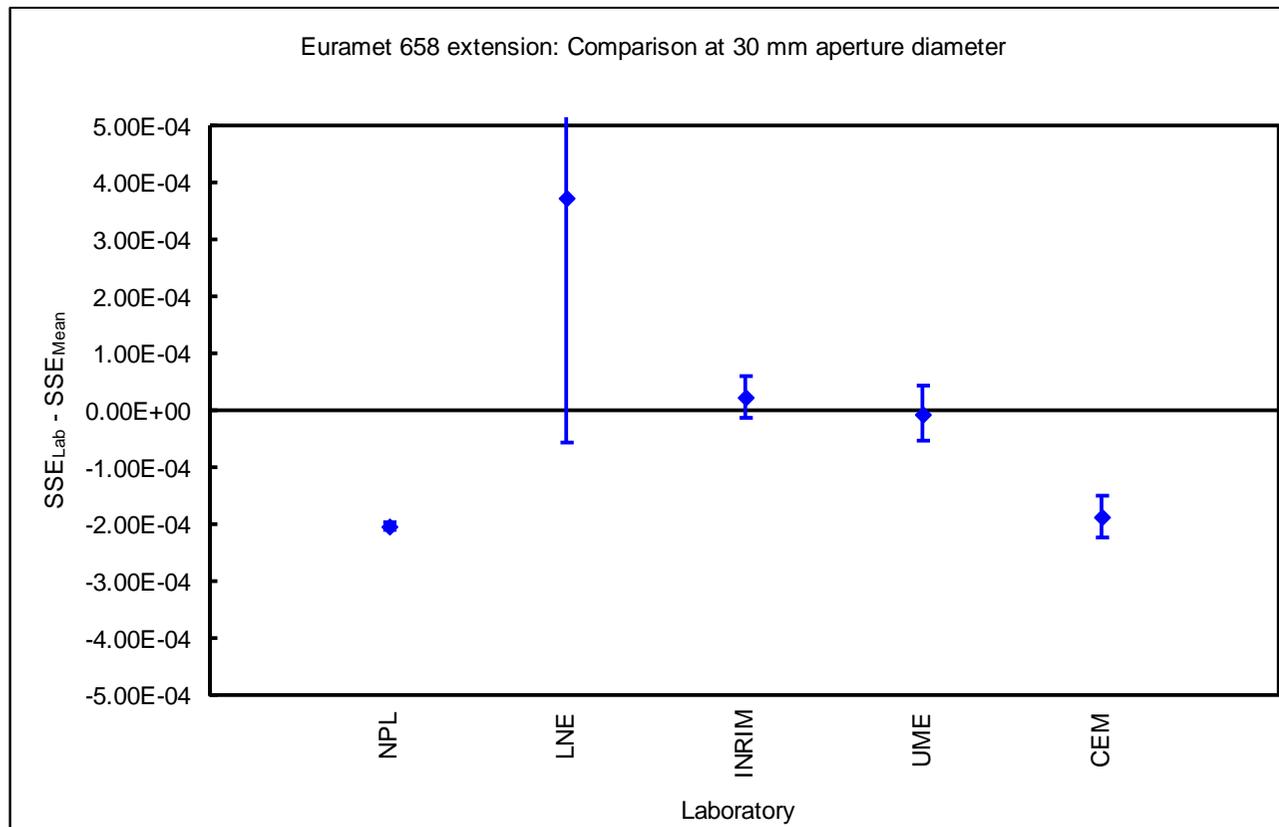
	NPL	LNE	INRIM	UME	CEM
NPL	-	-4.1724E-04 ± 2.538E-04	-2.0127E-04 ± 3.439E-05	-1.6373E-04 ± 4.111E-05	-1.3095E-05 ± 3.790E-05
LNE	6.2603E-04	-	2.1597E-04 ± 2.559E-04	2.5352E-04 ± 2.569E-04	4.0415E-04 ± 2.564E-04
INRIM	2.2956E-04	4.2650E-04	-	3.7549E-05 ± 5.237E-05	1.8818E-04 ± 4.990E-05
UME	1.9753E-04	4.6483E-04	8.0650E-05	-	1.5063E-04 ± 5.475E-05
CEM	4.4651E-05	6.1504E-04	2.2922E-04	1.9566E-04	-

Table 127 – comparison of indirect SSE measurements with the INRiM thermometer, with 6 mm diameter spot and 25 mm diameter aperture



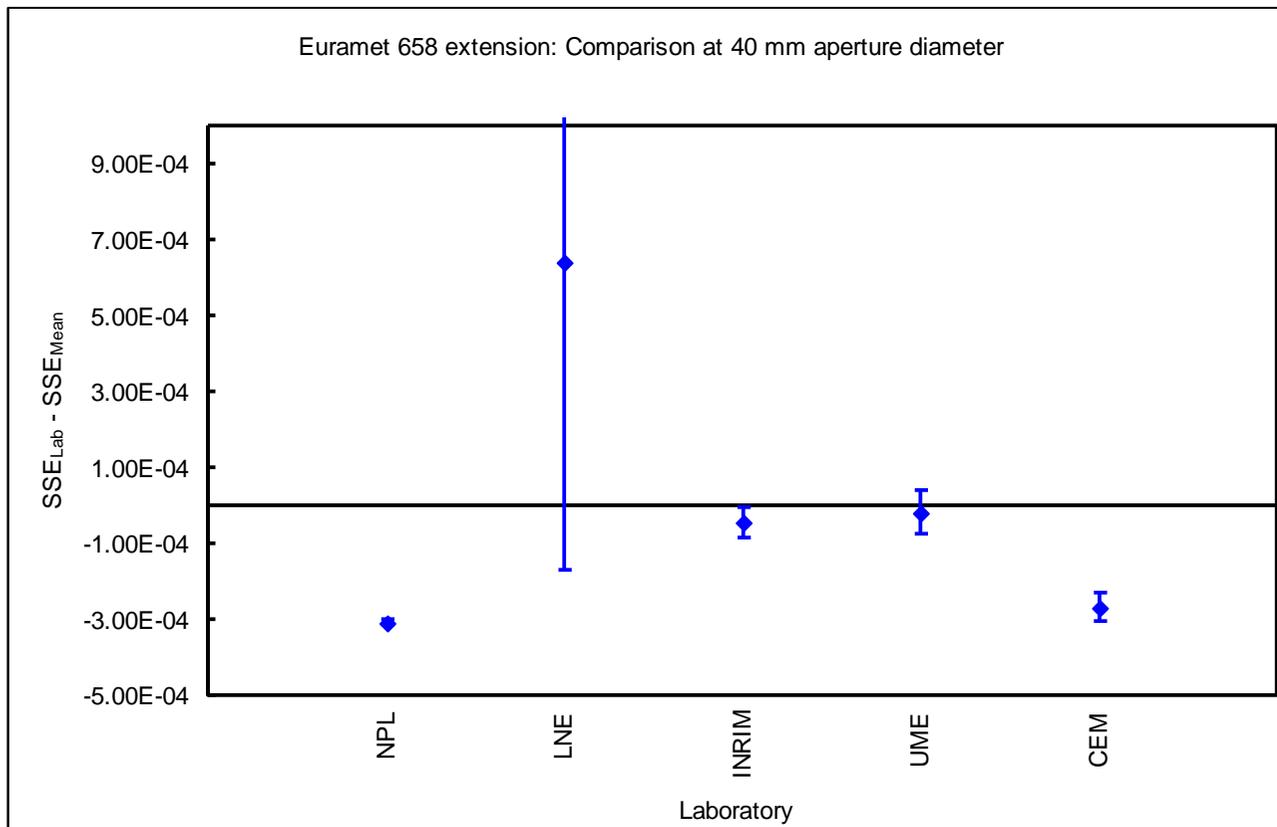
	NPL	LNE	INRIM	UME	CEM
NPL	-	-5.7632E-04 ± 4.289E-04	-2.2555E-04 ± 3.720E-05	-1.9812E-04 ± 4.937E-05	-1.6875E-05 ± 3.713E-05
LNE	9.2908E-04	-	3.5077E-04 ± 4.304E-04	3.7820E-04 ± 4.316E-04	5.5944E-04 ± 4.303E-04
INRIM	2.5615E-04	7.0483E-04	-	2.7426E-05 ± 6.075E-05	2.0867E-04 ± 5.131E-05
UME	2.3873E-04	7.3322E-04	7.7654E-05	-	1.8125E-04 ± 6.071E-05
CEM	4.7566E-05	9.1340E-04	2.5087E-04	2.3118E-04	-

Table 128 – comparison of indirect SSE measurements with the INRiM thermometer, with 6 mm diameter spot and 30 mm diameter aperture



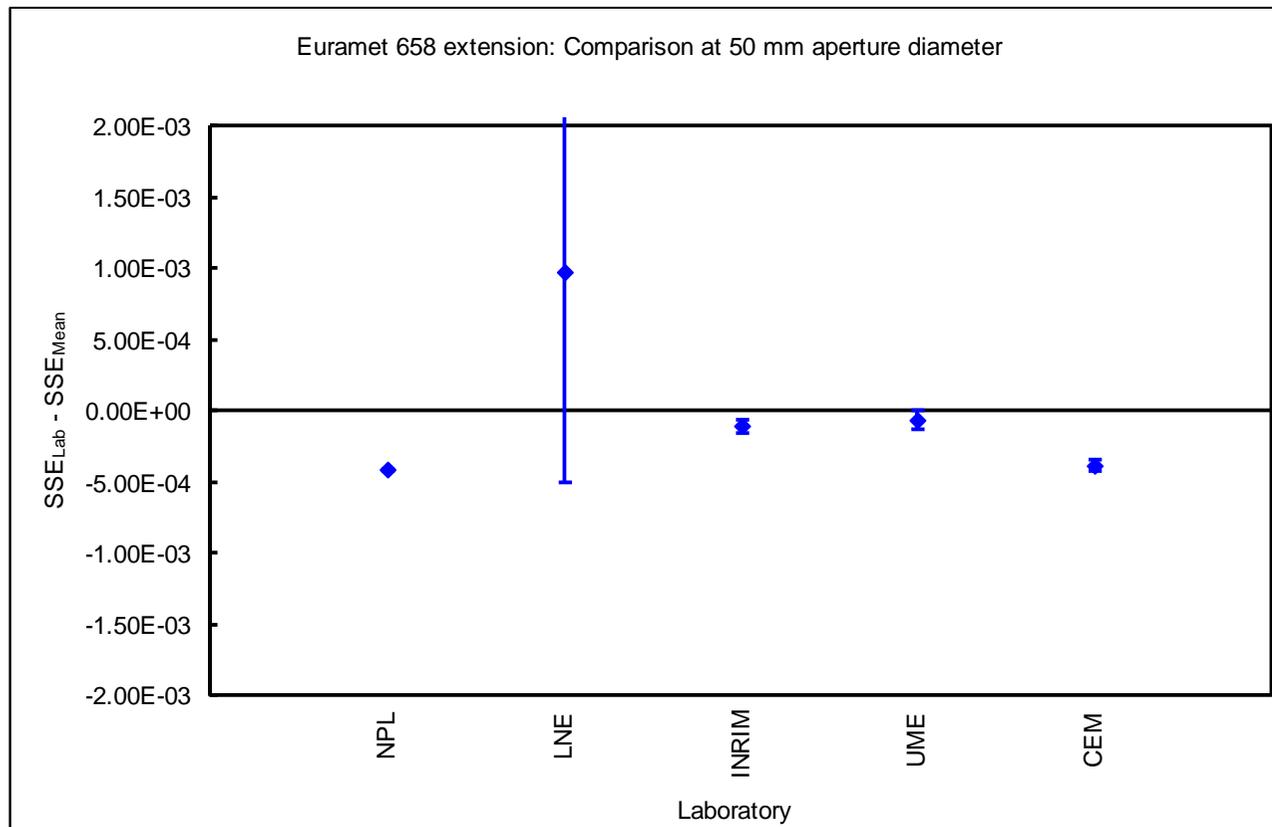
	NPL	LNE	INRIM	UME	CEM
NPL	-	-9.4754E-04 ± 8.076E-04	-2.6356E-04 ± 4.258E-05	-2.8994E-04 ± 5.881E-05	-3.8576E-05 ± 3.849E-05
LNE	1.6118E-03	-	6.8398E-04 ± 8.086E-04	6.5760E-04 ± 8.096E-04	9.0896E-04 ± 8.084E-04
INRIM	2.9859E-04	1.3492E-03	-	-2.6377E-05 ± 7.168E-05	2.2499E-04 ± 5.622E-05
UME	3.3831E-04	1.3237E-03	8.5936E-05	-	2.5136E-04 ± 6.933E-05
CEM	7.0232E-05	1.5739E-03	2.7123E-04	3.0838E-04	-

Table 129 – comparison of indirect SSE measurements with the INRiM thermometer, with 6 mm diameter spot and 40 mm diameter aperture



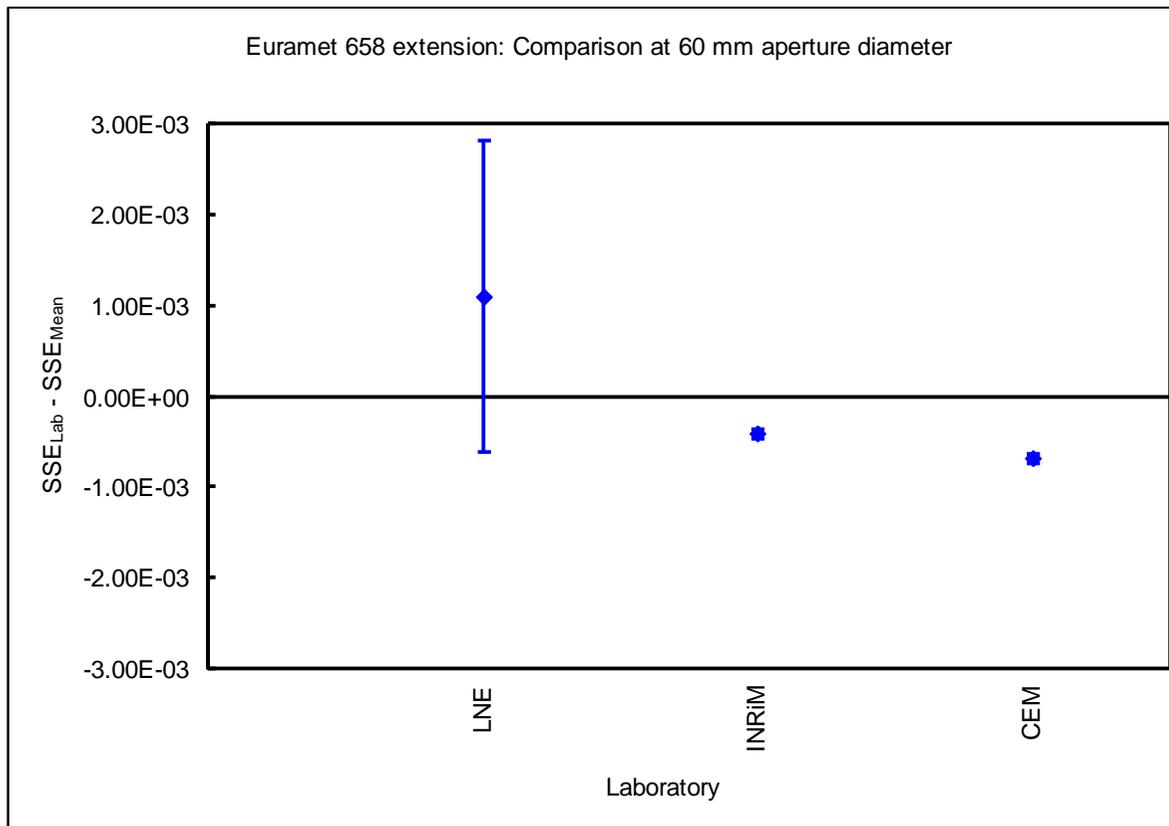
	NPL	LNE	INRIM	UME	CEM
NPL	-	-1.3939E-03 ± 1.485E-03	-3.0948E-04 ± 4.691E-05	-3.5215E-04 ± 6.453E-05	-3.0050E-05 ± 4.303E-05
LNE	2.6155E-03	-	1.0844E-03 ± 1.486E-03	1.0418E-03 ± 1.486E-03	1.3639E-03 ± 1.486E-03
INRIM	3.4807E-04	2.3071E-03	-	-4.2670E-05 ± 7.897E-05	2.7943E-04 ± 6.264E-05
UME	4.0523E-04	2.2652E-03	1.0779E-04	-	3.2210E-04 ± 7.673E-05
CEM	6.5466E-05	2.5859E-03	3.3095E-04	3.8521E-04	-

Table 130 – comparison of indirect SSE measurements with the INRiM thermometer, with 6 mm diameter spot and 50 mm diameter aperture



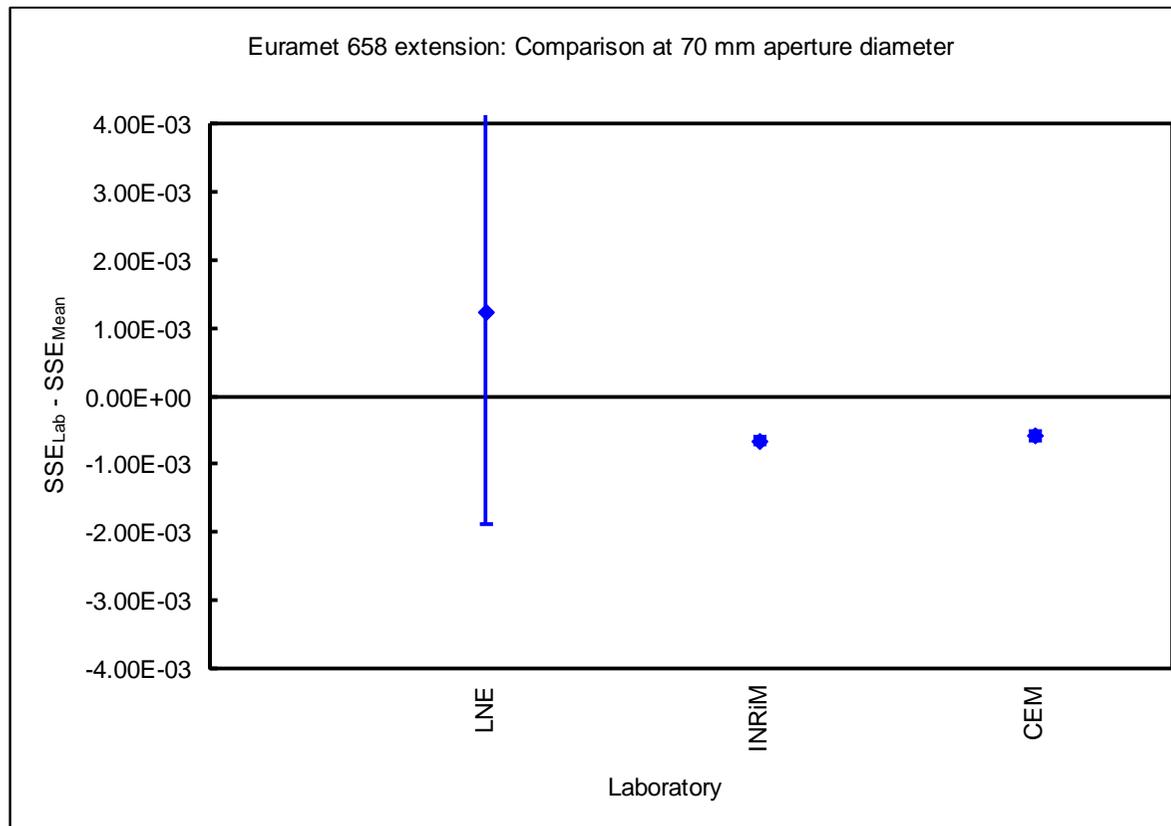
	LNE	INRiM	CEM
LNE	-	1.5116E-03 ± 1.725E-03	1.7836E-03 ± 1.725E-03
INRiM	2.9302E-03	-	2.7203E-04 ± 7.434E-05
CEM	3.2022E-03	3.3317E-04	-

Table 131 – comparison of indirect SSE measurements with the INRiM thermometer, with 6 mm diameter spot and 60 mm diameter aperture



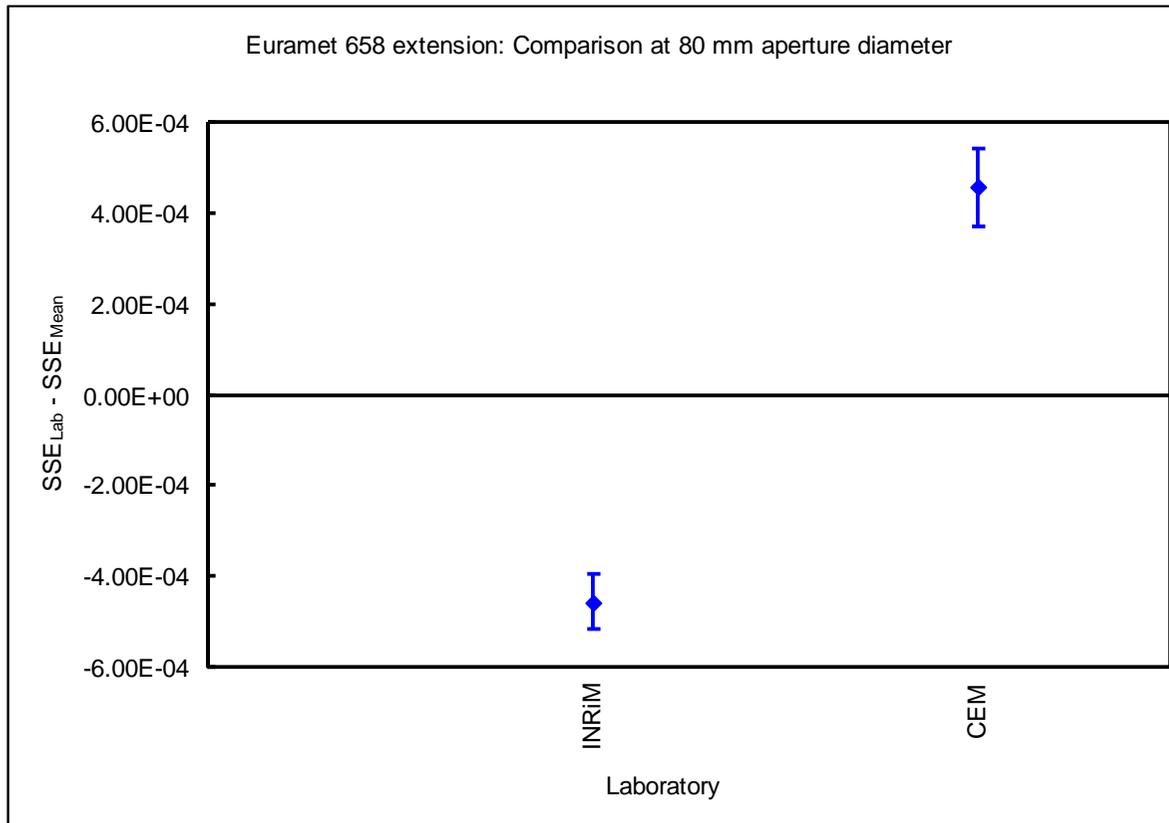
	LNE	INRiM	CEM
LNE	-	1.9026E-03 ± 3.131E-03	1.8240E-03 ± 3.131E-03
INRiM	4.4817E-03	-	-7.8636E-05 ± 9.243E-05
CEM	4.4042E-03	1.5467E-04	-

Table 132 – comparison of indirect SSE measurements with the INRiM thermometer, with 6 mm diameter spot and 70 mm diameter aperture



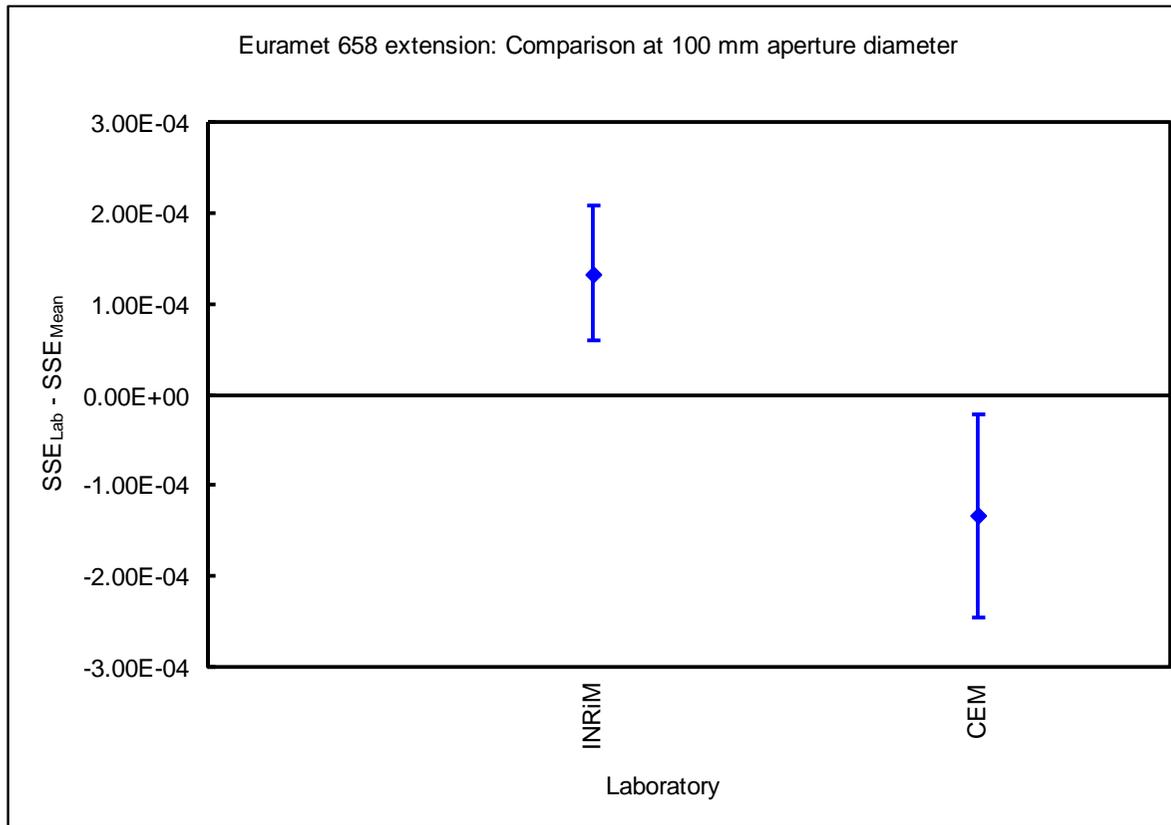
	INRiM	CEM
INRiM	-	-9.1236E-04 ± 1.063E-04
CEM	9.9976E-04	-

Table 133 – comparison of indirect SSE measurements with the INRiM thermometer, with 6 mm diameter spot and 80 mm diameter aperture



	INRiM	CEM
INRiM	-	2.6748E-04 ± 1.341E-04
CEM	3.7775E-04	-

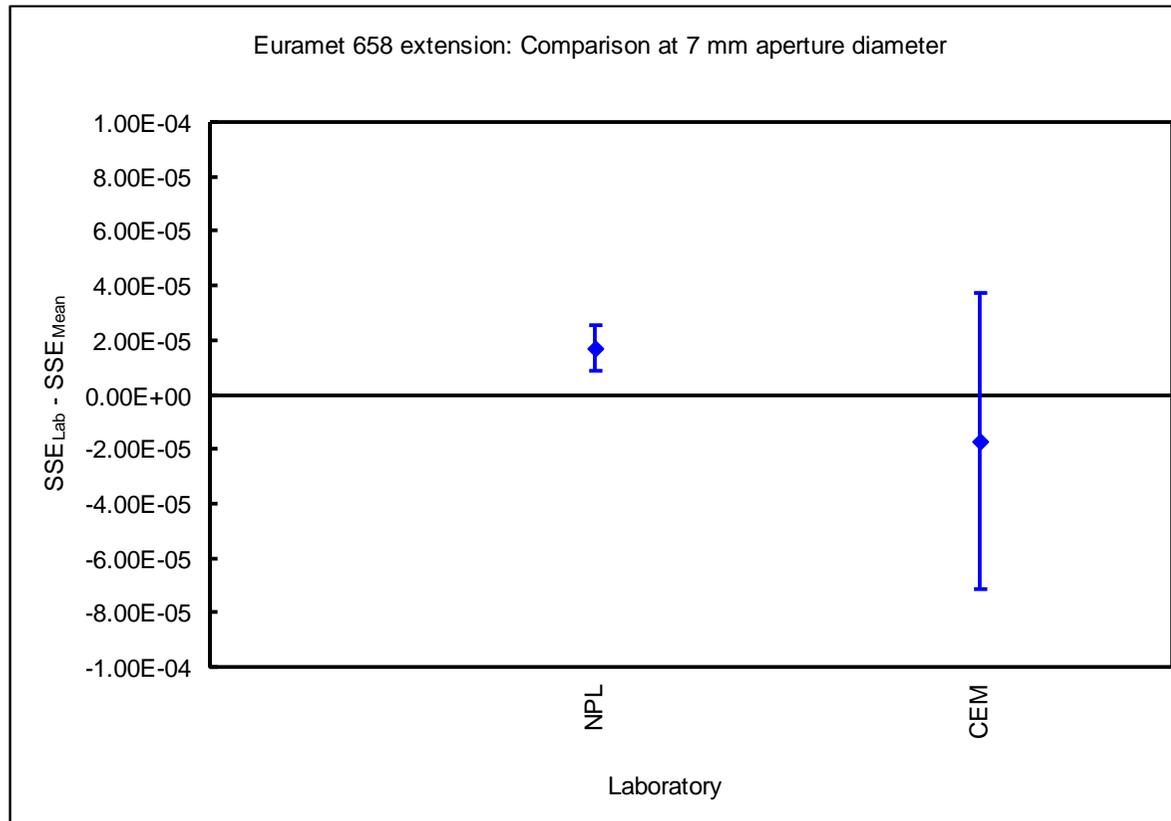
Table 134 – comparison of indirect SSE measurements with the INRiM thermometer, with 6 mm diameter spot and 100 mm diameter aperture



1.8.4 The INRiM thermometer ‘indirect’ SSE results – 6 mm spot, excl. LNE

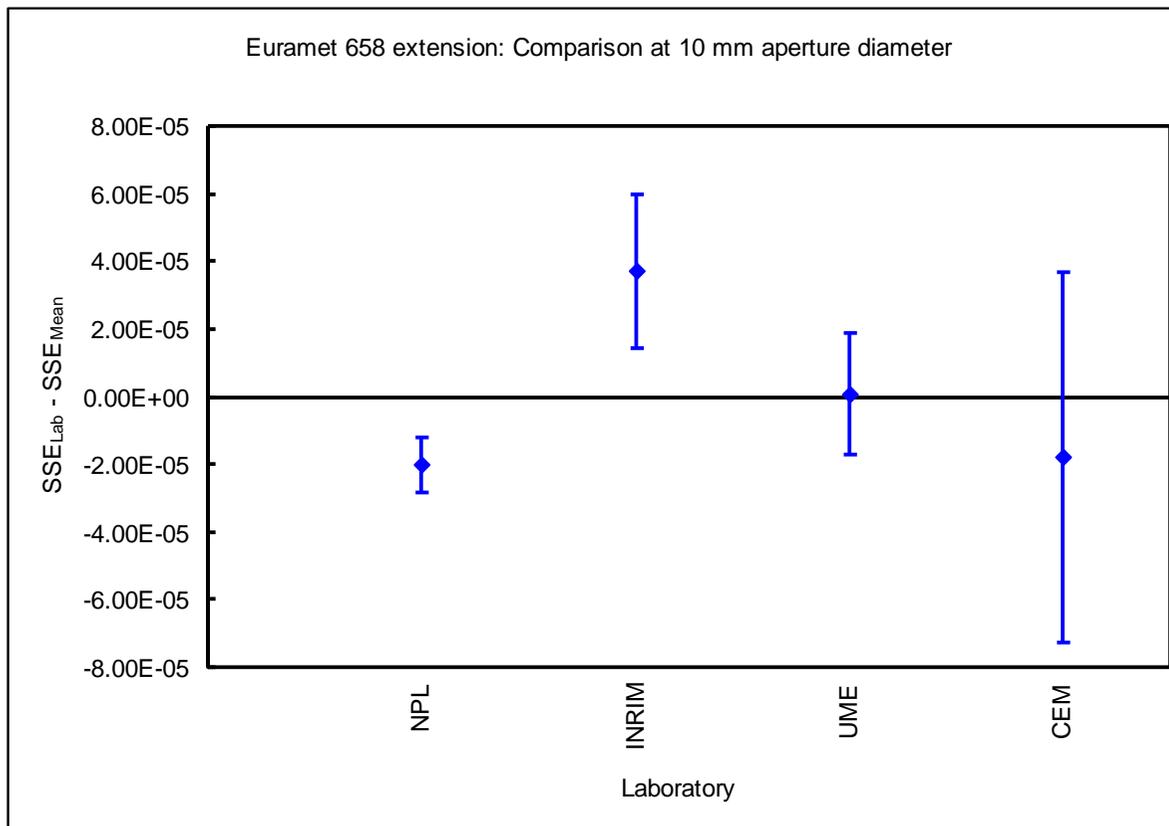
	NPL	CEM
NPL	-	3.4036E-05 ± 5.523E-05
CEM	7.9521E-05	-

Table 135 – comparison of indirect SSE measurements with the INRiM thermometer, excluding LNE data - 6 mm diameter spot and 7 mm diameter aperture



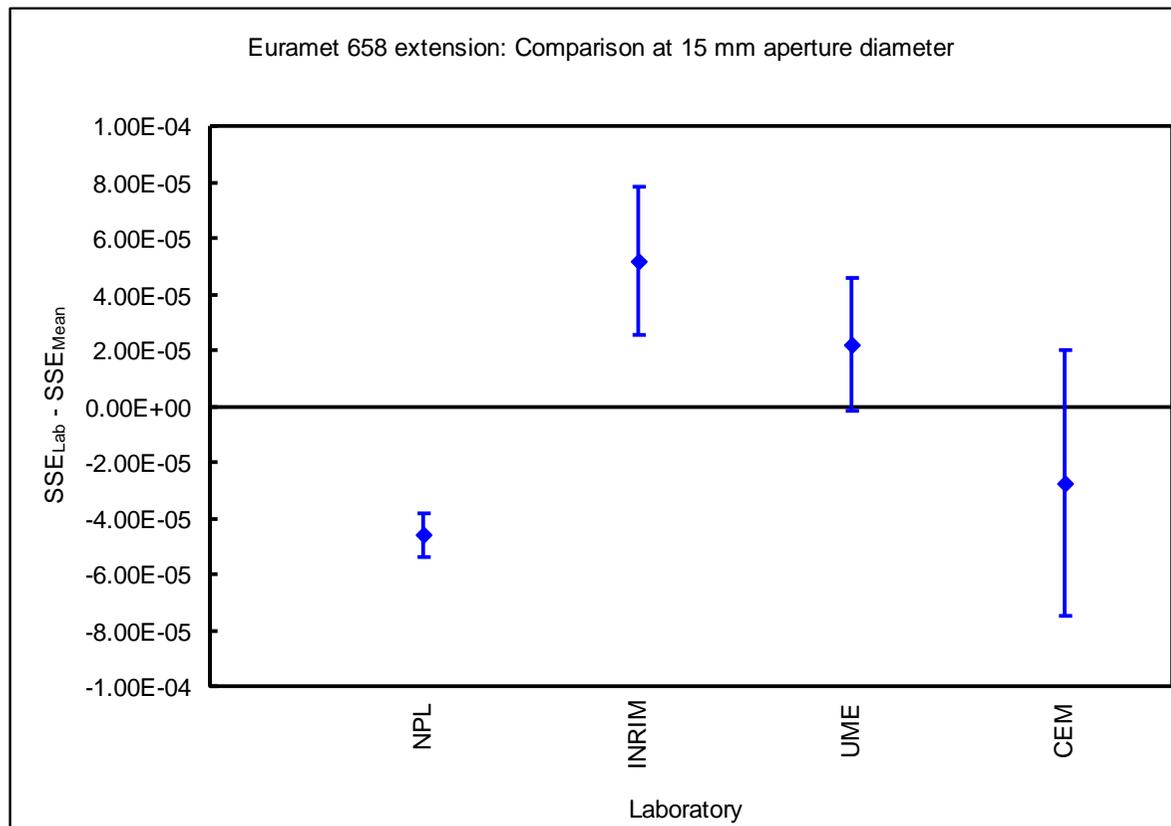
	NPL	INRIM	UME	CEM
NPL	-	-5.7285E-05 ± 2.407E-05	-2.1038E-05 ± 1.986E-05	-2.3313E-06 ± 5.521E-05
INRIM	7.7083E-05	-	3.6247E-05 ± 2.906E-05	5.4954E-05 ± 5.915E-05
UME	3.7378E-05	6.0152E-05	-	1.8707E-05 ± 5.757E-05
CEM	5.4207E-05	1.0361E-04	6.6738E-05	-

Table 136 – comparison of indirect SSE measurements with the INRiM thermometer, excluding LNE data - 6 mm diameter spot and 10 mm diameter aperture



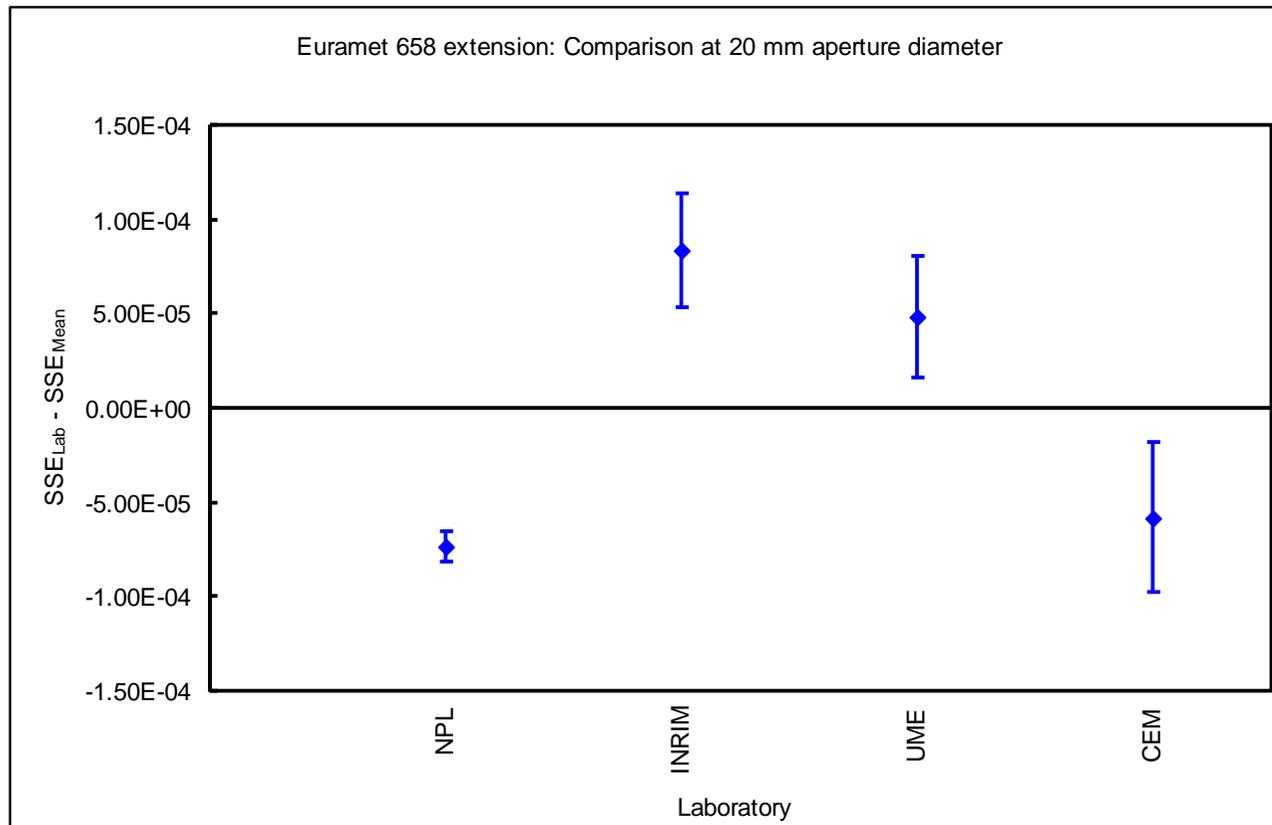
	NPL	INRIM	UME	CEM
NPL	-	-9.7631E-05 ± 2.763E-05	-6.8182E-05 ± 2.497E-05	-1.8310E-05 ± 4.809E-05
INRIM	1.2036E-04	-	2.9449E-05 ± 3.546E-05	7.9320E-05 ± 5.428E-05
UME	8.8722E-05	5.8620E-05	-	4.9872E-05 ± 5.298E-05
CEM	5.8229E-05	1.2397E-04	9.3451E-05	-

Table 137– comparison of indirect SSE measurements with the INRiM thermometer, excluding LNE data - 6 mm diameter spot and 15 mm diameter aperture



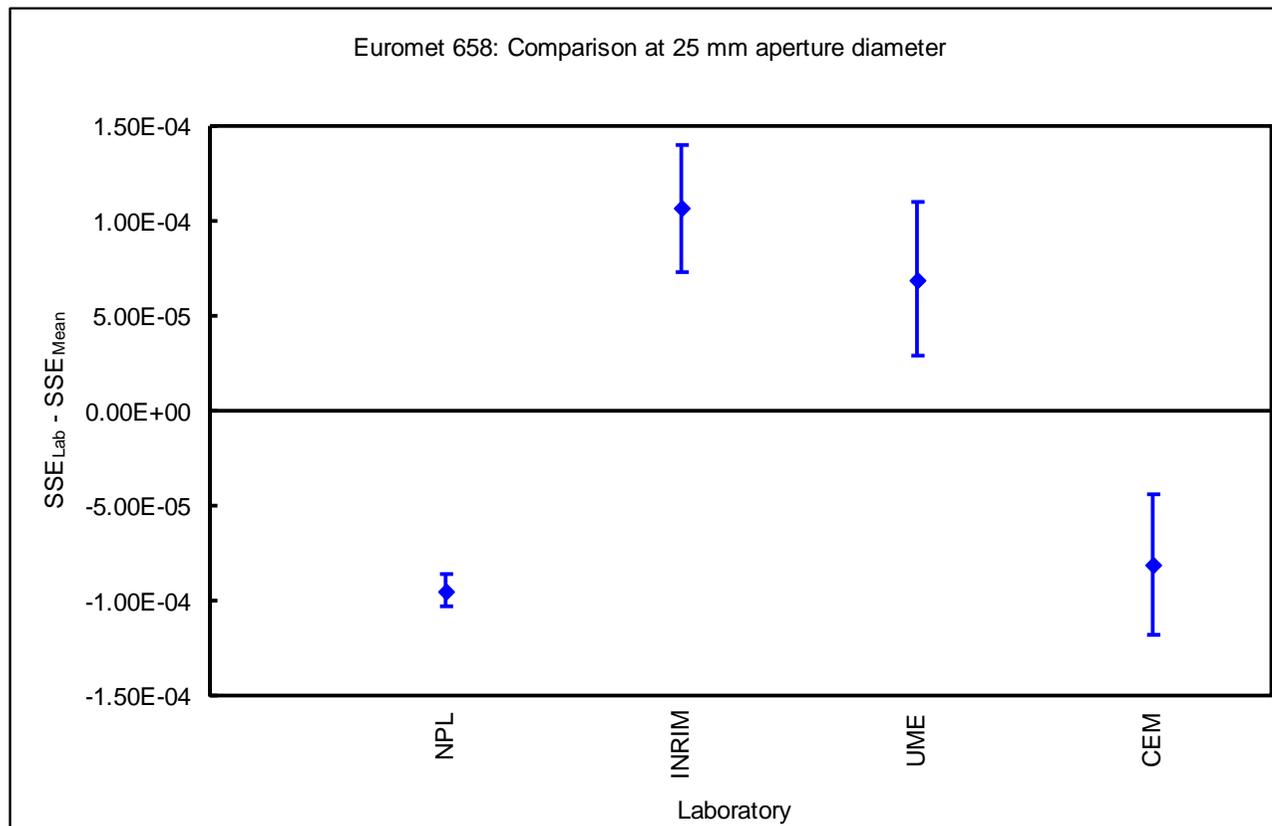
	NPL	INRIM	UME	CEM
NPL	-	-1.5714E-04 ± 3.087E-05	-1.2181E-04 ± 3.324E-05	-1.5407E-05 ± 4.063E-05
INRIM	1.8252E-04	-	3.5327E-05 ± 4.391E-05	1.4173E-04 ± 4.974E-05
UME	1.4915E-04	7.1452E-05	-	1.0640E-04 ± 5.125E-05
CEM	4.9138E-05	1.8264E-04	1.4855E-04	-

Table 138 – comparison of indirect SSE measurements with the INRiM thermometer, excluding LNE data - 6 mm diameter spot and 20 mm diameter aperture



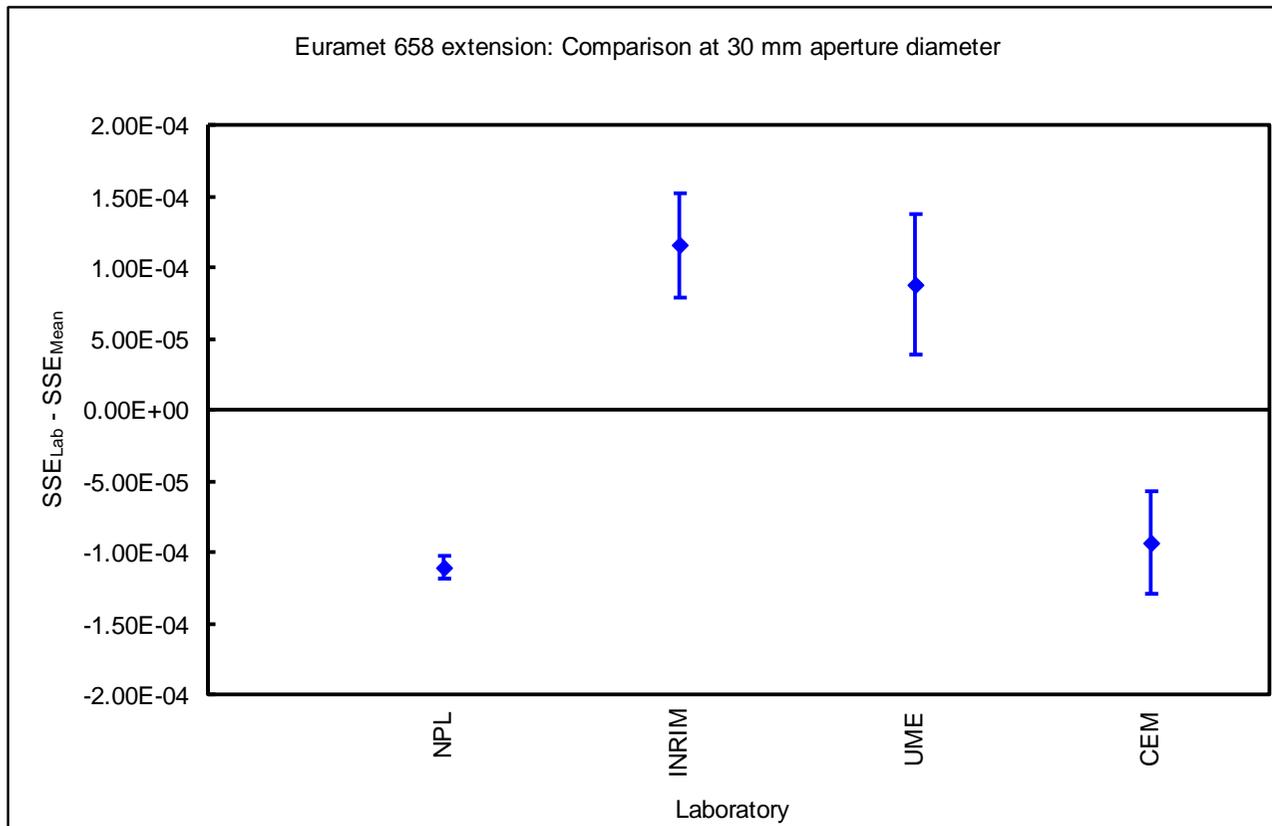
	NPL	INRIM	UME	CEM
NPL	-	$-2.0127\text{E-}04 \pm 3.439\text{E-}05$	$-1.6373\text{E-}04 \pm 4.111\text{E-}05$	$-1.3095\text{E-}05 \pm 3.790\text{E-}05$
INRIM	$2.2956\text{E-}04$	-	$3.7549\text{E-}05 \pm 5.237\text{E-}05$	$1.8818\text{E-}04 \pm 4.990\text{E-}05$
UME	$1.9753\text{E-}04$	$8.0650\text{E-}05$	-	$1.5063\text{E-}04 \pm 5.475\text{E-}05$
CEM	$4.4651\text{E-}05$	$2.2922\text{E-}04$	$1.9566\text{E-}04$	-

Table 139 – comparison of indirect SSE measurements with the INRiM thermometer, excluding LNE data - 6 mm diameter spot and 25 mm diameter aperture



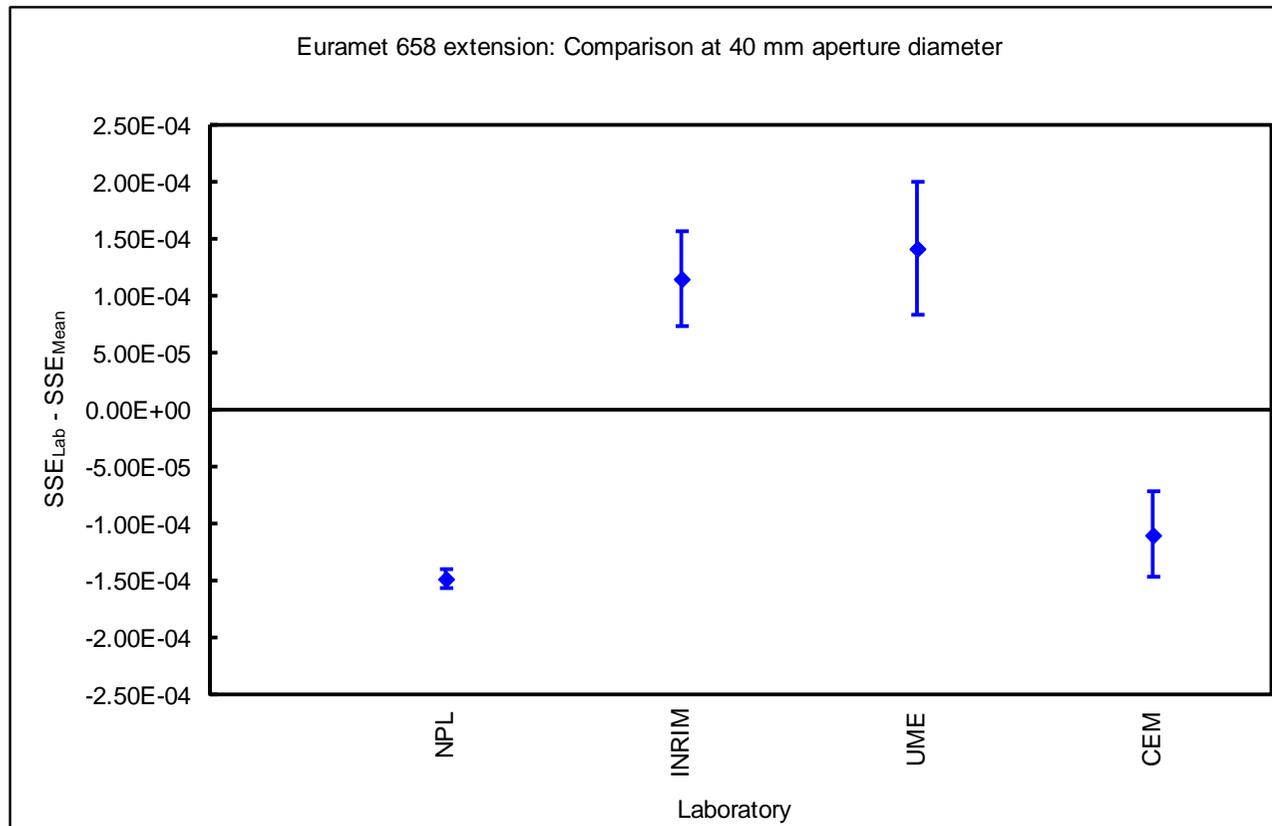
	NPL	INRIM	UME	CEM
NPL	-	-2.2555E-04 ± 3.720E-05	-1.9812E-04 ± 4.937E-05	-1.6875E-05 ± 3.713E-05
INRIM	2.5615E-04	-	2.7426E-05 ± 6.075E-05	2.0867E-04 ± 5.131E-05
UME	2.3873E-04	7.7654E-05	-	1.8125E-04 ± 6.071E-05
CEM	4.7566E-05	2.5087E-04	2.3118E-04	-

Table 140 – comparison of indirect SSE measurements with the INRiM thermometer, excluding LNE data - 6 mm diameter spot and 30 mm diameter aperture



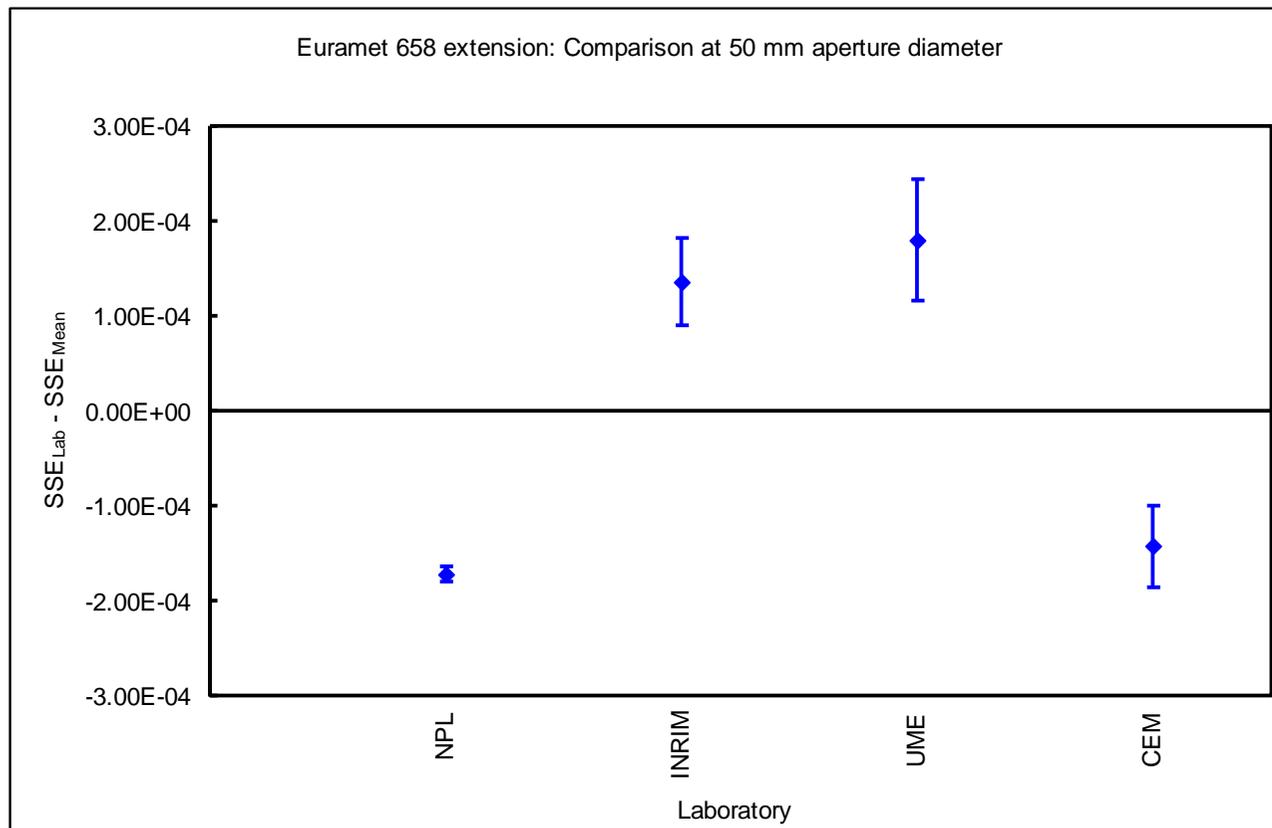
	NPL	INRIM	UME	CEM
NPL	-	-2.6356E-04 ± 4.258E-05	-2.8994E-04 ± 5.881E-05	-3.8576E-05 ± 3.849E-05
INRIM	2.9859E-04	-	-2.6377E-05 ± 7.168E-05	2.2499E-04 ± 5.622E-05
UME	3.3831E-04	8.5936E-05	-	2.5136E-04 ± 6.933E-05
CEM	7.0232E-05	2.7123E-04	3.0838E-04	-

Table 141 – comparison of indirect SSE measurements with the INRiM thermometer, excluding LNE data - 6 mm diameter spot and 40 mm diameter aperture



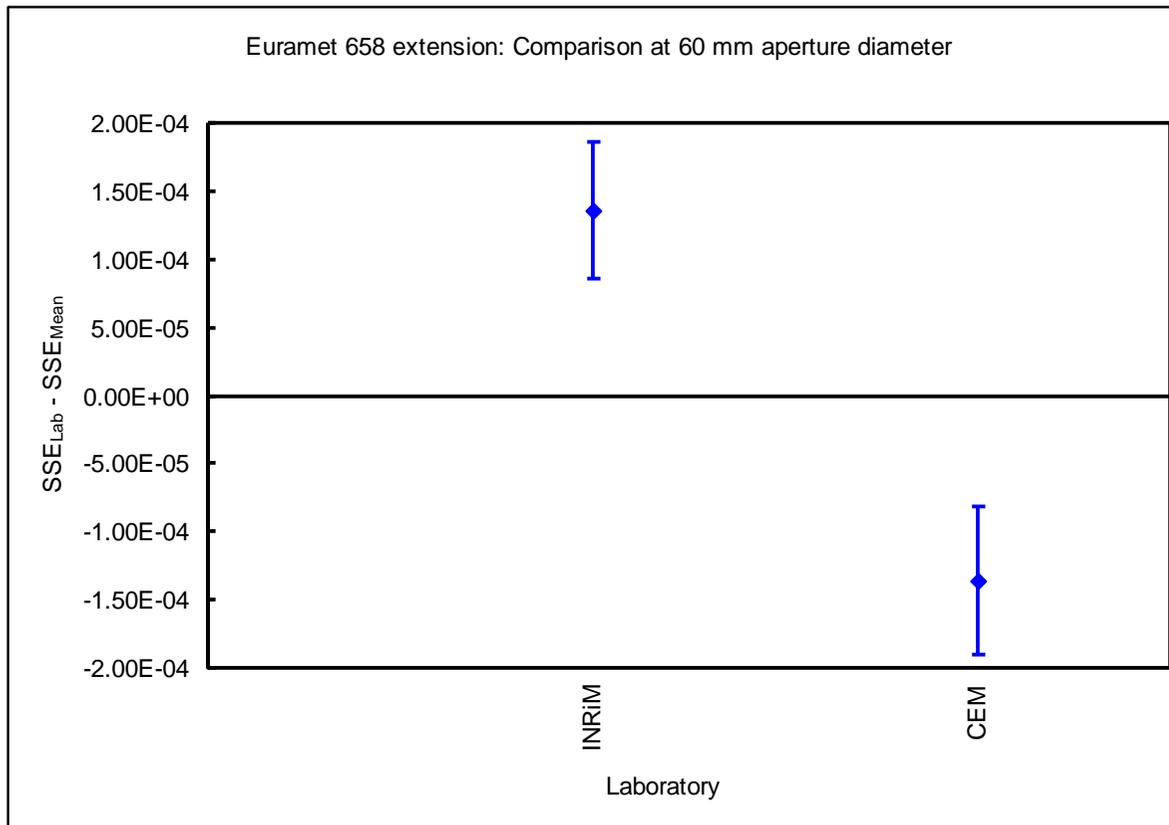
	NPL	INRIM	UME	CEM
NPL	-	$-3.0948E-04 \pm 4.691E-05$	$-3.5215E-04 \pm 6.453E-05$	$-3.0050E-05 \pm 4.303E-05$
INRIM	$3.4807E-04$	-	$-4.2670E-05 \pm 7.897E-05$	$2.7943E-04 \pm 6.264E-05$
UME	$4.0523E-04$	$1.0779E-04$	-	$3.2210E-04 \pm 7.673E-05$
CEM	$6.5466E-05$	$3.3095E-04$	$3.8521E-04$	-

Table 142 – comparison of indirect SSE measurements with the INRiM thermometer, excluding LNE data - 6 mm diameter spot and 50 mm diameter aperture



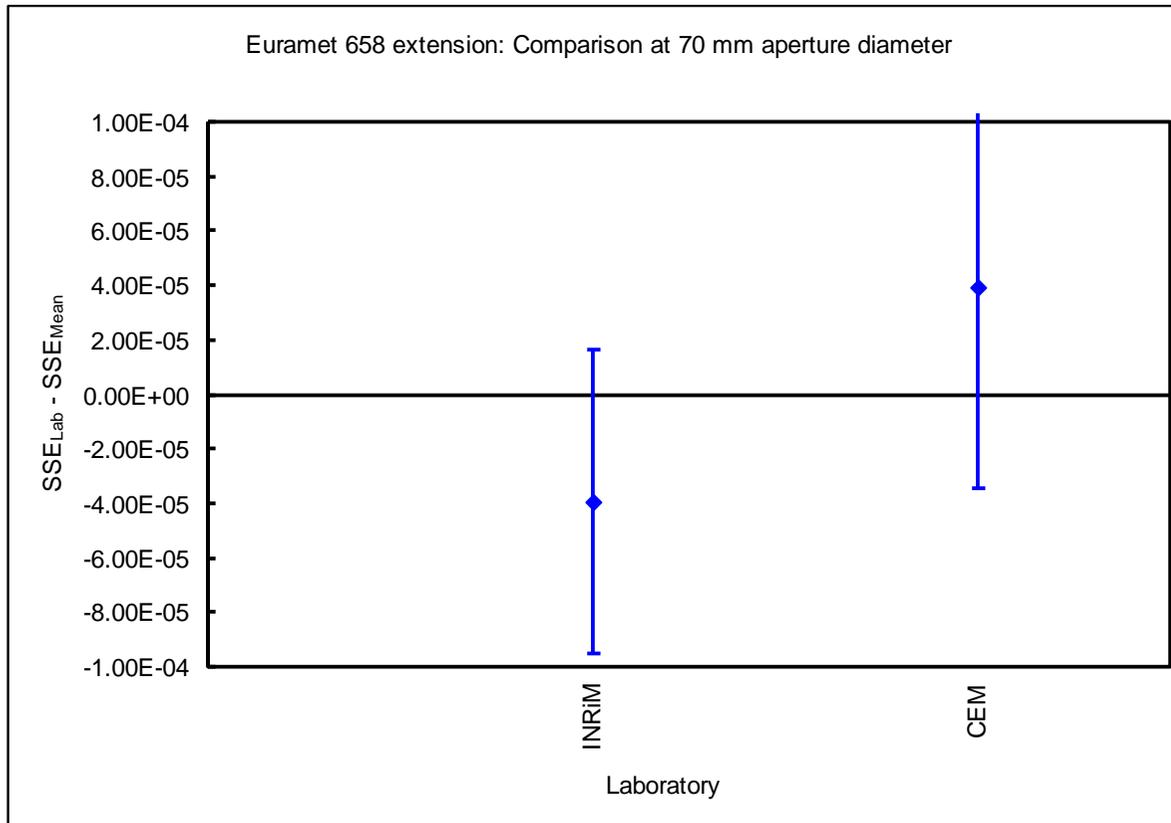
	INRiM	CEM
INRiM	-	2.7203E-04 ± 7.434E-05
CEM	3.3317E-04	-

Table 143 – comparison of indirect SSE measurements with the INRiM thermometer, excluding LNE data - 6 mm diameter spot and 60 mm diameter aperture



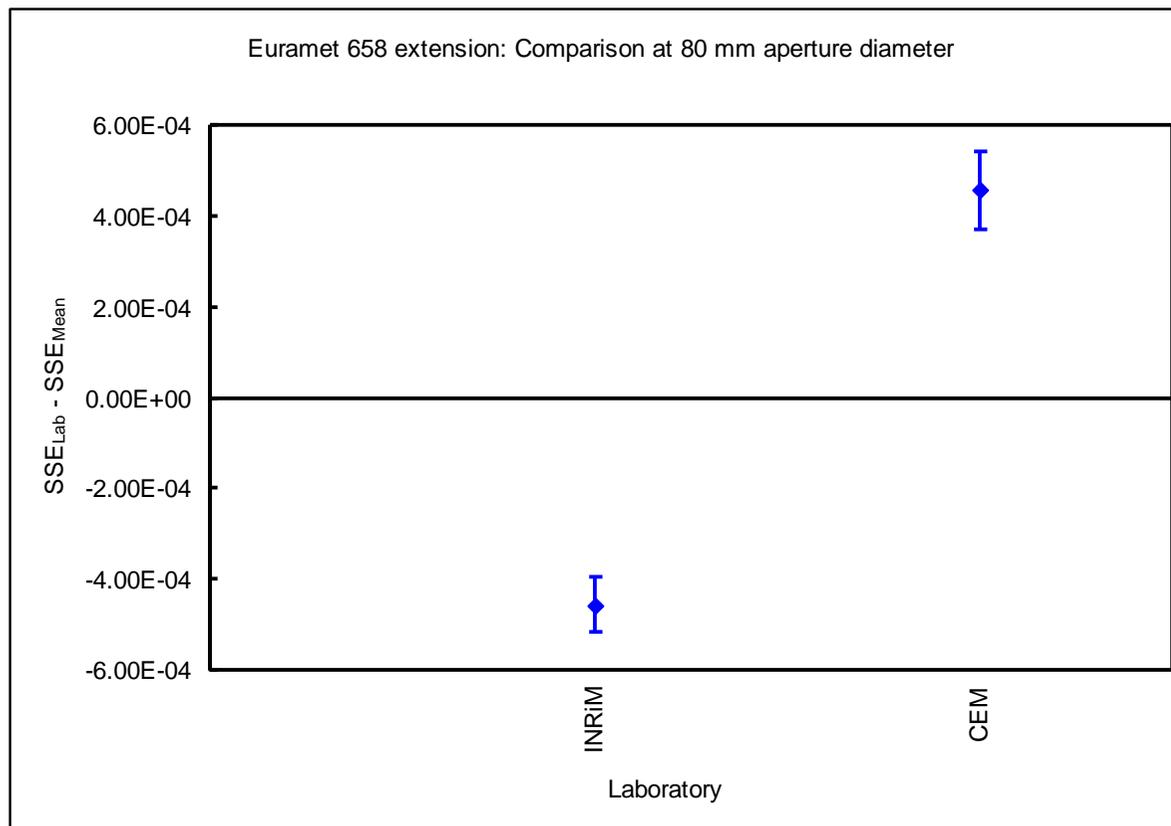
	INRiM	CEM
INRiM	-	-7.8636E-05 ± 9.243E-05
CEM	1.5467E-04	-

Table 144 – comparison of indirect SSE measurements with the INRiM thermometer, excluding LNE data - 6 mm diameter spot and 70 mm diameter aperture



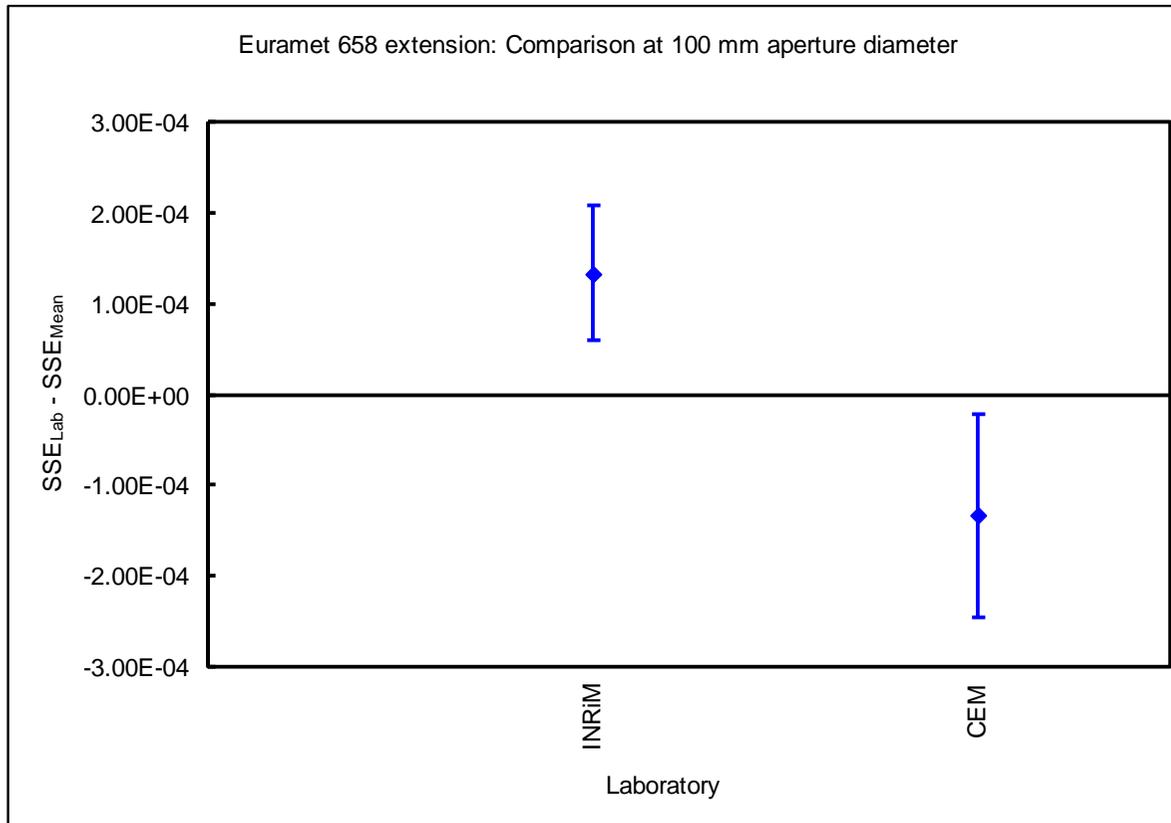
	INRiM	CEM
INRiM	-	-9.1236E-04 ± 1.063E-04
CEM	9.9976E-04	-

Table 145 – comparison of indirect SSE measurements with the INRiM thermometer, excluding LNE data - 6 mm diameter spot and 80 mm diameter aperture



	INRiM	CEM
INRiM	-	2.6748E-04 ± 1.341E-04
CEM	3.7775E-04	-

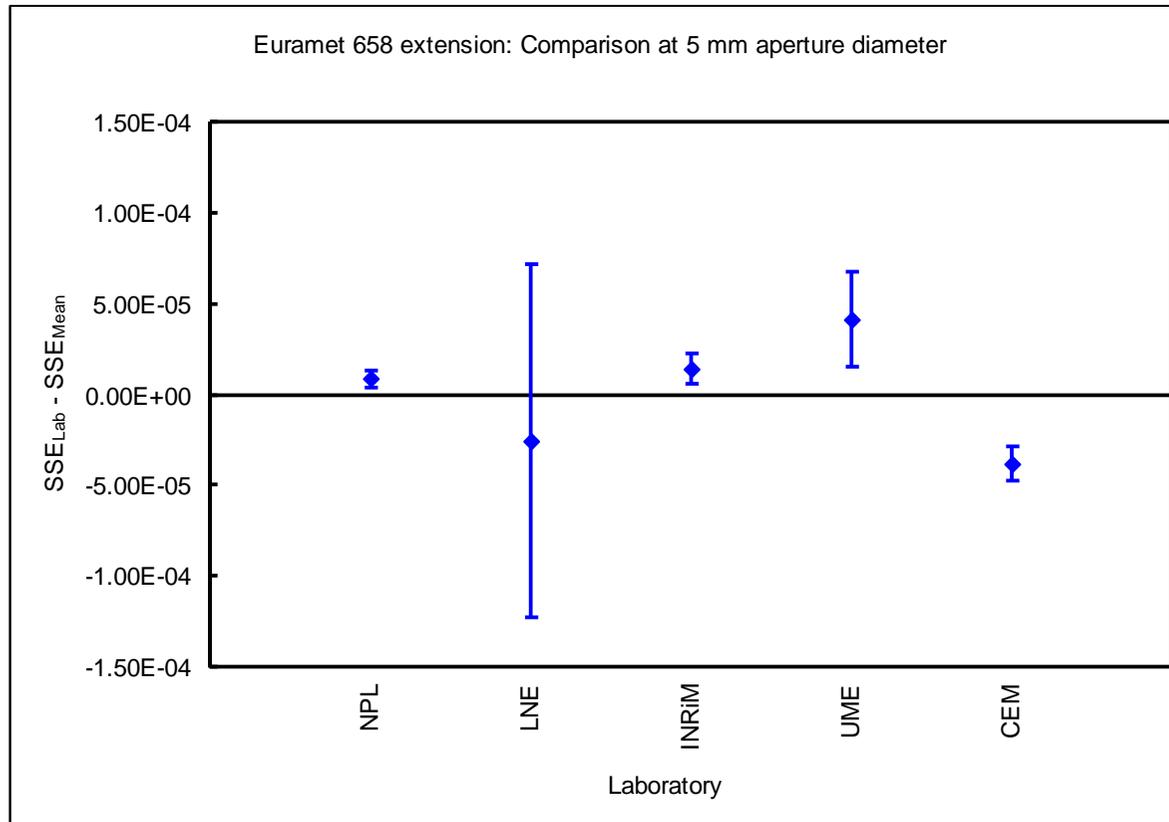
Table 146 – comparison of indirect SSE measurements with the INRiM thermometer, excluding LNE data - 6 mm diameter spot and 100 mm diameter aperture



1.8.5 The LP5 thermometer ‘indirect’ SSE results – 3 mm spot

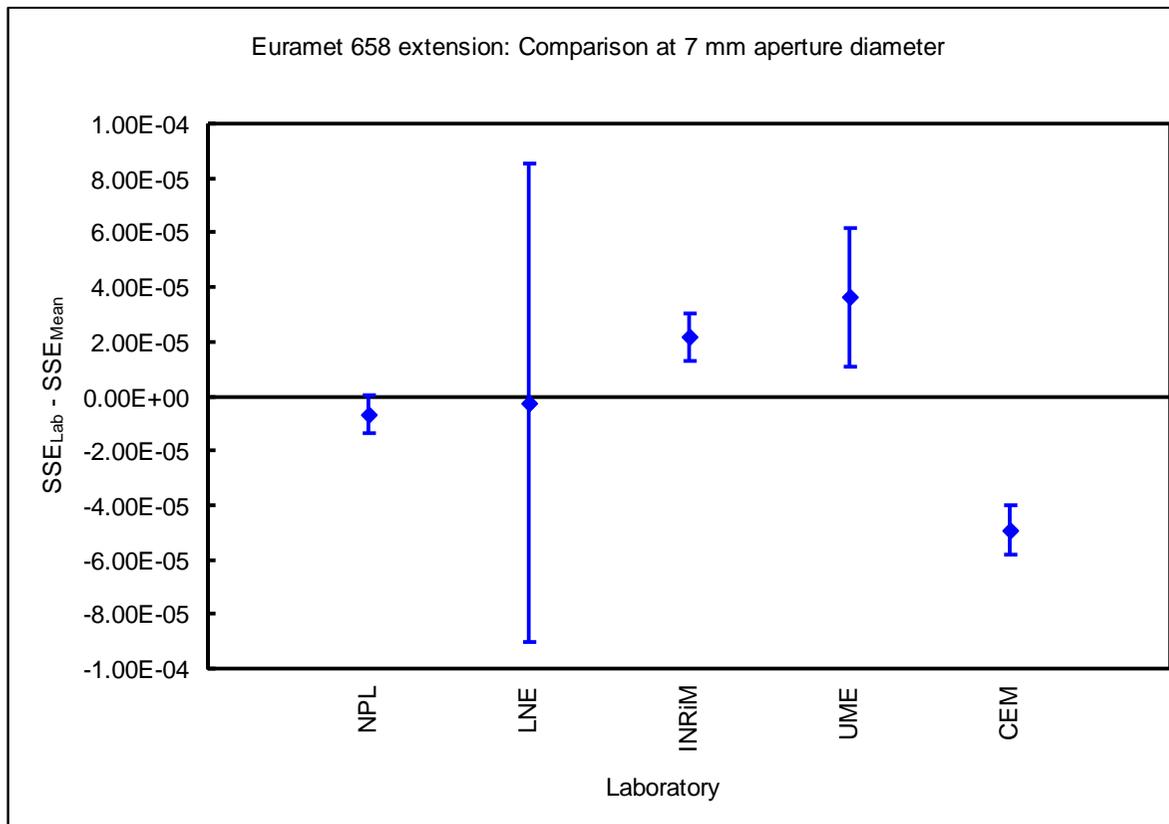
	NPL	LNE	INRiM	UME	CEM
NPL	-	3.4248E-05 ± 9.727E-05	-5.8527E-06 ± 9.559E-06	-3.2349E-05 ± 2.649E-05	4.6657E-05 ± 1.027E-05
LNE	1.1518E-04	-	-4.0101E-05 ± 9.751E-05	-6.6597E-05 ± 1.006E-04	1.2408E-05 ± 9.758E-05
INRiM	1.3726E-05	1.2088E-04	-	-2.6496E-05 ± 2.738E-05	5.2509E-05 ± 1.237E-05
UME	5.4140E-05	1.4941E-04	4.9015E-05	-	7.9006E-05 ± 2.763E-05
CEM	5.5103E-05	9.8411E-05	6.2684E-05	1.0173E-04	-

Table 147 – comparison of indirect SSE measurements with the LP5 thermometer, 3 mm diameter spot and 5 mm diameter aperture



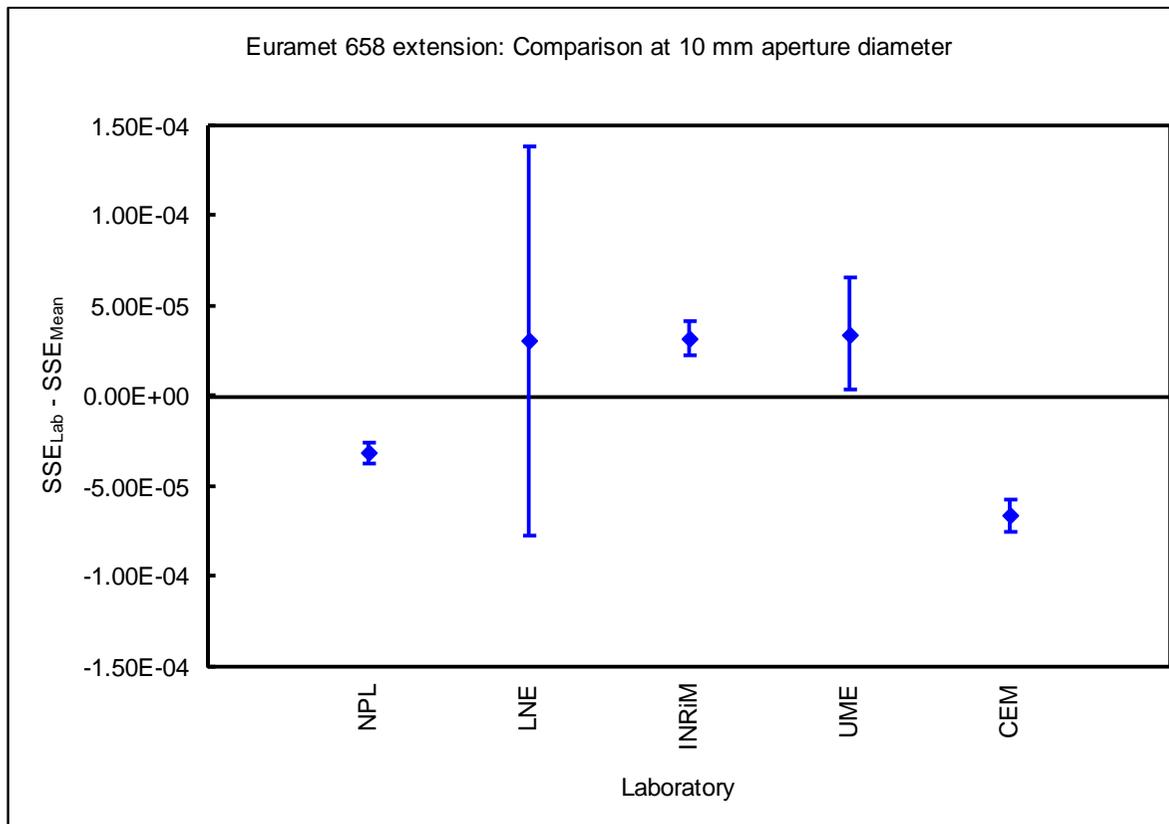
	NPL	LNE	INRiM	UME	CEM
NPL	-	-4.3001E-06 ± 8.819E-05	-2.8198E-05 ± 1.124E-05	-4.2812E-05 ± 2.623E-05	4.2515E-05 ± 1.160E-05
LNE	8.6626E-05	-	-2.3898E-05 ± 8.833E-05	-3.8512E-05 ± 9.145E-05	4.6815E-05 ± 8.838E-05
INRiM	3.7440E-05	9.8174E-05	-	-1.4614E-05 ± 2.669E-05	7.0714E-05 ± 1.260E-05
UME	6.4387E-05	1.1423E-04	3.6616E-05	-	8.5328E-05 ± 2.684E-05
CEM	5.2058E-05	1.1970E-04	8.1076E-05	1.0741E-04	-

Table 148 – comparison of indirect SSE measurements with the LP5 thermometer, 3 mm diameter spot and 7 mm diameter aperture



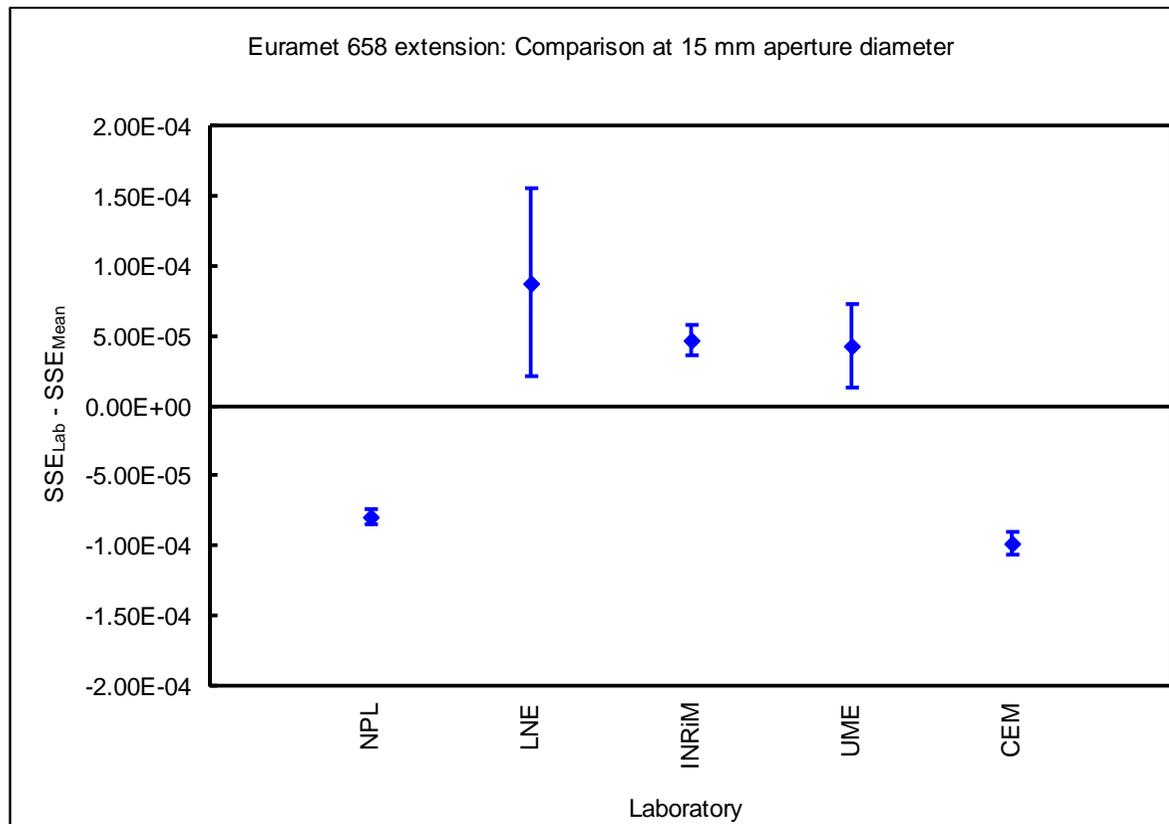
	NPL	LNE	INRiM	UME	CEM
NPL	-	$-6.2049\text{E-}05 \pm 1.084\text{E-}04$	$-6.3804\text{E-}05 \pm 1.089\text{E-}05$	$-6.6223\text{E-}05 \pm 3.180\text{E-}05$	$3.4468\text{E-}05 \pm 1.072\text{E-}05$
LNE	$1.5142\text{E-}04$	-	$-1.7559\text{E-}06 \pm 1.087\text{E-}04$	$-4.1741\text{E-}06 \pm 1.127\text{E-}04$	$9.6517\text{E-}05 \pm 1.087\text{E-}04$
INRiM	$7.2758\text{E-}05$	$1.0687\text{E-}04$	-	$-2.4183\text{E-}06 \pm 3.267\text{E-}05$	$9.8272\text{E-}05 \pm 1.306\text{E-}05$
UME	$9.2380\text{E-}05$	$1.1066\text{E-}04$	$3.2241\text{E-}05$	-	$1.0069\text{E-}04 \pm 3.261\text{E-}05$
CEM	$4.3286\text{E-}05$	$1.8592\text{E-}04$	$1.0902\text{E-}04$	$1.2751\text{E-}04$	-

Table 149 – comparison of indirect SSE measurements with the LP5 thermometer, 3 mm diameter spot and 10 mm diameter aperture



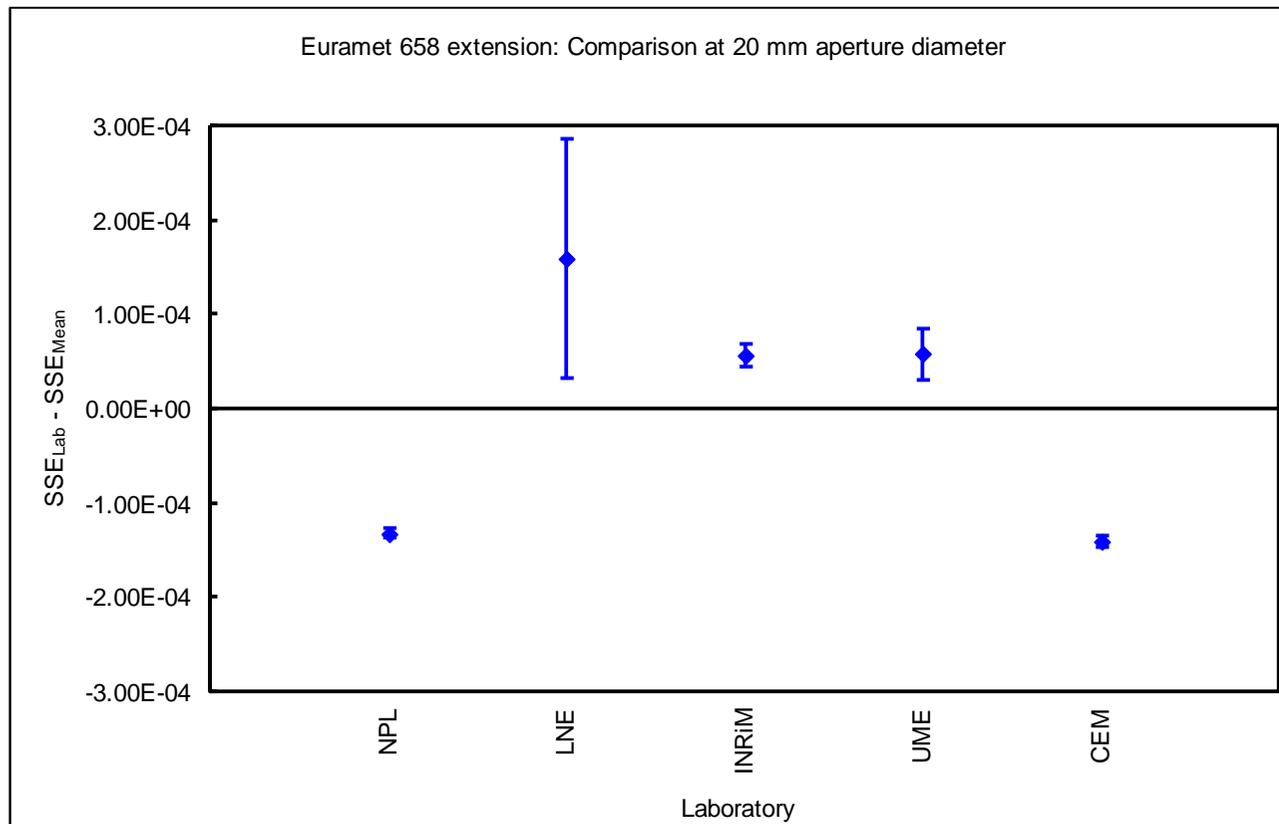
	NPL	LNE	INRiM	UME	CEM
NPL	-	-1.6703E-04 ± 6.731E-05	-1.2619E-04 ± 1.205E-05	-1.2129E-04 ± 2.999E-05	1.9961E-05 ± 9.618E-06
LNE	2.2239E-04	-	4.0839E-05 ± 6.798E-05	4.5742E-05 ± 7.332E-05	1.8699E-04 ± 6.759E-05
INRiM	1.3610E-04	9.6841E-05	-	4.9026E-06 ± 3.146E-05	1.4615E-04 ± 1.352E-05
UME	1.4595E-04	1.0612E-04	3.2246E-05	-	1.4125E-04 ± 3.061E-05
CEM	2.7872E-05	2.4258E-04	1.5727E-04	1.6642E-04	-

Table 150 – comparison of indirect SSE measurements with the LP5 thermometer, 3 mm diameter spot and 15 mm diameter aperture



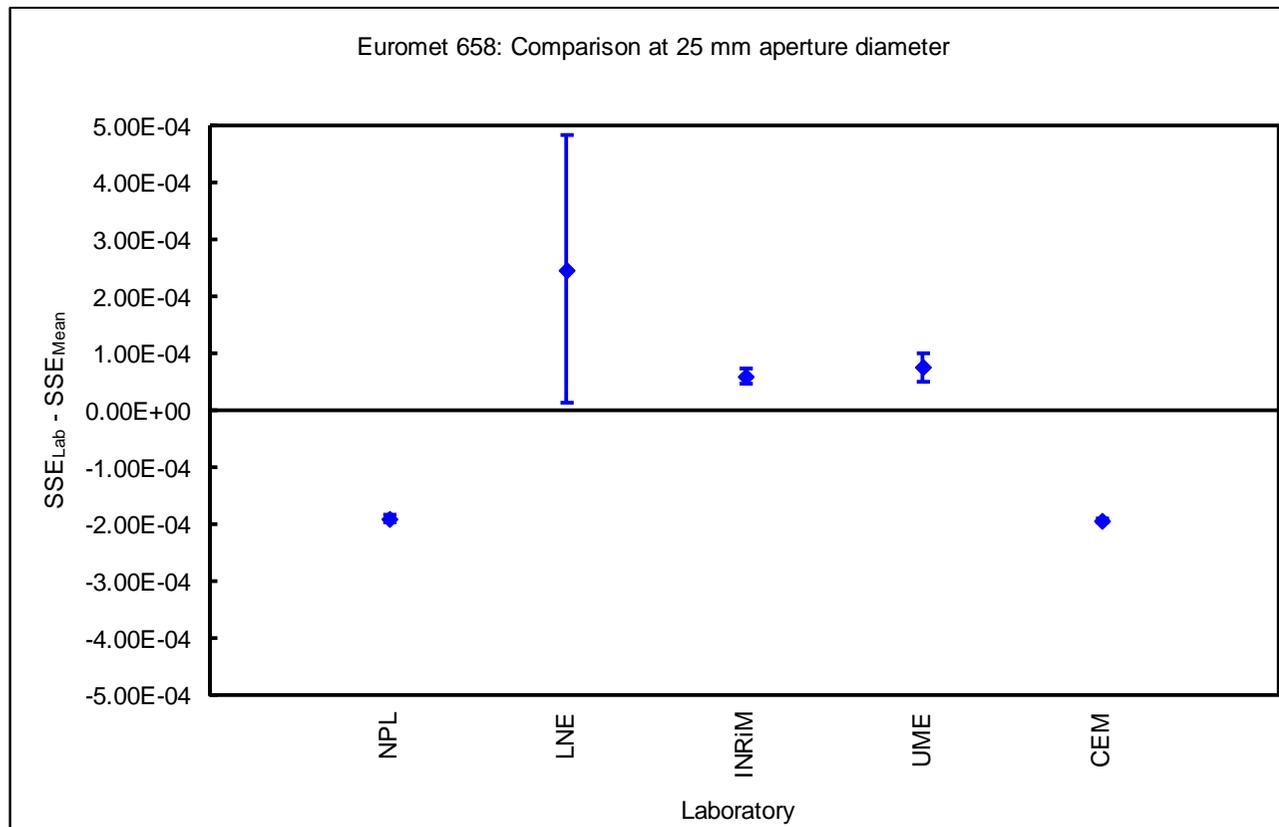
	NPL	LNE	INRiM	UME	CEM
NPL	-	$-2.9144E-04 \pm 1.278E-04$	$-1.8902E-04 \pm 1.320E-05$	$-1.8984E-04 \pm 2.818E-05$	$8.4469E-06 \pm 7.937E-06$
LNE	$3.9657E-04$	-	$1.0242E-04 \pm 1.283E-04$	$1.0160E-04 \pm 1.307E-04$	$2.9988E-04 \pm 1.279E-04$
INRiM	$1.9988E-04$	$2.0801E-04$	-	$-8.2004E-07 \pm 3.040E-05$	$1.9747E-04 \pm 1.390E-05$
UME	$2.1302E-04$	$2.0916E-04$	$2.9852E-05$	-	$1.9829E-04 \pm 2.851E-05$
CEM	$1.4975E-05$	$4.0508E-04$	$2.0890E-04$	$2.2174E-04$	-

Table 151 – comparison of indirect SSE measurements with the LP5 thermometer, 3 mm diameter spot and 20 mm diameter aperture



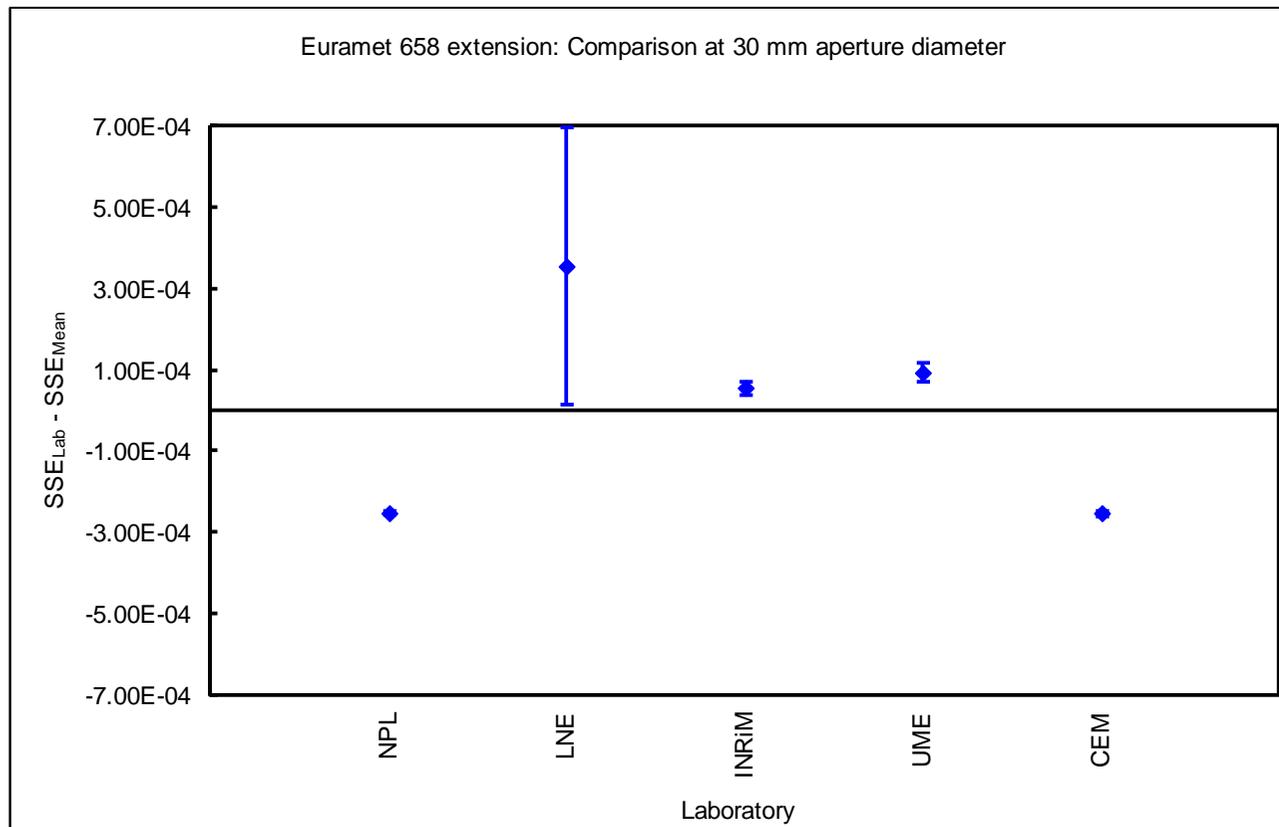
	NPL	LNE	INRiM	UME	CEM
NPL	-	-4.3847E-04 ± 2.336E-04	-2.4949E-04 ± 1.527E-05	-2.6542E-04 ± 2.663E-05	2.6754E-06 ± 8.292E-06
LNE	6.3062E-04	-	1.8899E-04 ± 2.340E-04	1.7305E-04 ± 2.350E-04	4.4115E-04 ± 2.336E-04
INRiM	2.6204E-04	3.8150E-04	-	-1.5931E-05 ± 2.973E-05	2.5216E-04 ± 1.560E-05
UME	2.8732E-04	3.6645E-04	4.0447E-05	-	2.6809E-04 ± 2.682E-05
CEM	9.5959E-06	6.3332E-04	2.6499E-04	2.9015E-04	-

Table 152 – comparison of indirect SSE measurements with the LP5 thermometer, 3 mm diameter spot and 25 mm diameter aperture



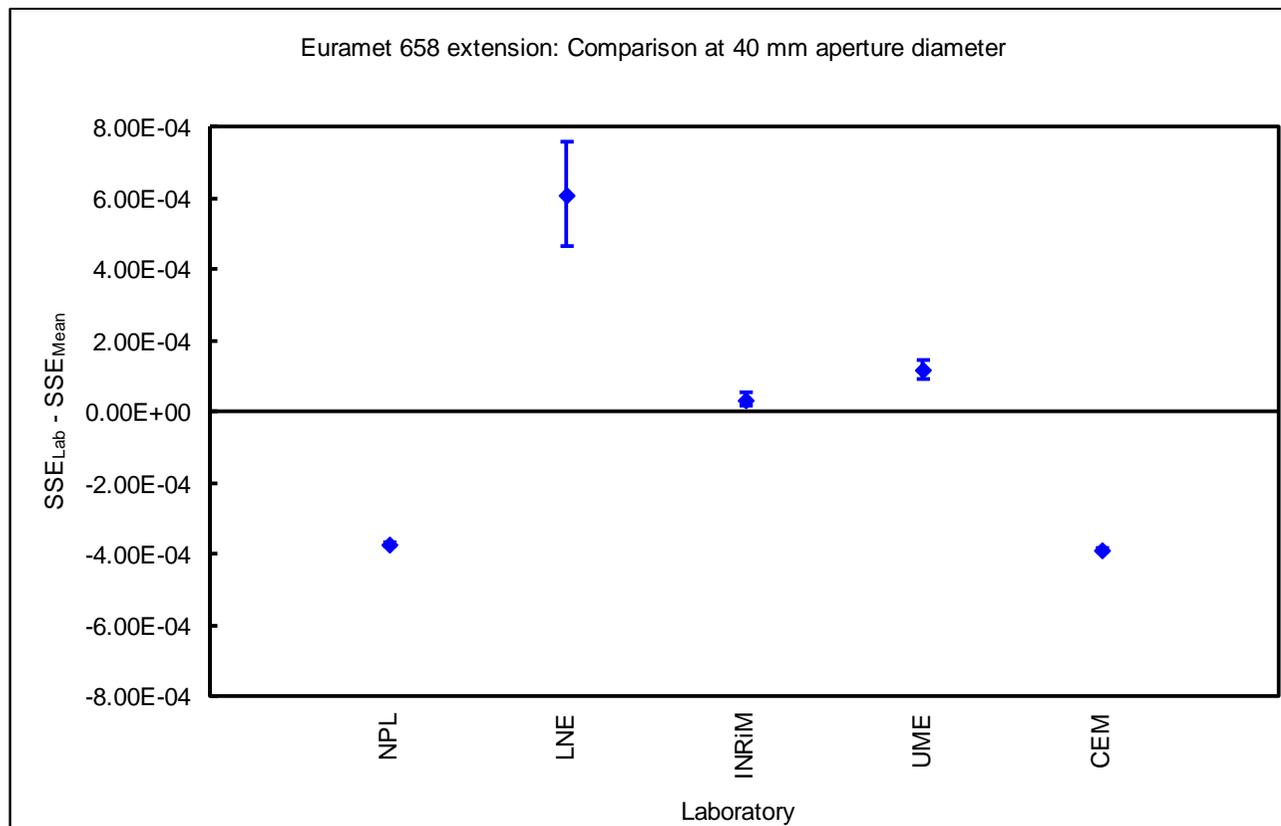
	NPL	LNE	INRiM	UME	CEM
NPL	-	$-6.0605E-04 \pm 3.396E-04$	$-3.0593E-04 \pm 1.677E-05$	$-3.4276E-04 \pm 2.488E-05$	$3.1440E-06 \pm 7.412E-06$
LNE	$8.8535E-04$	-	$3.0012E-04 \pm 3.399E-04$	$2.6329E-04 \pm 3.404E-04$	$6.0919E-04 \pm 3.396E-04$
INRiM	$3.1972E-04$	$5.7975E-04$	-	$-3.6833E-05 \pm 2.923E-05$	$3.0907E-04 \pm 1.704E-05$
UME	$3.6322E-04$	$5.4338E-04$	$6.0875E-05$	-	$3.4591E-04 \pm 2.506E-05$
CEM	$9.2799E-06$	$8.8850E-04$	$3.2309E-04$	$3.6652E-04$	-

Table 153 – comparison of indirect SSE measurements with the LP5 thermometer, 3 mm diameter spot and 30 mm diameter aperture



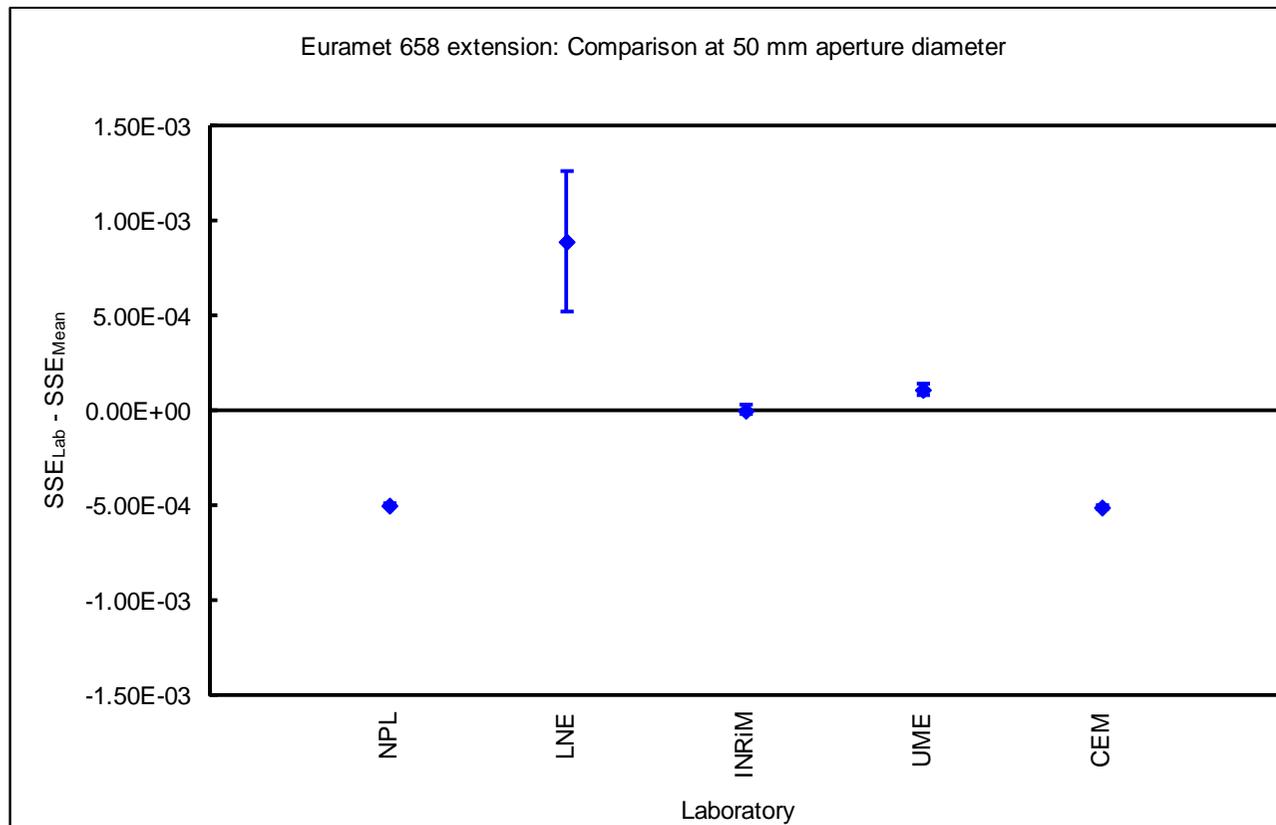
	NPL	LNE	INRiM	UME	CEM
NPL	-	$-9.8199E-04 \pm 1.474E-04$	$-4.0596E-04 \pm 1.980E-05$	$-4.8787E-04 \pm 2.812E-05$	$1.5396E-05 \pm 7.122E-06$
LNE	$1.1032E-03$	-	$5.7603E-04 \pm 1.486E-04$	$4.9412E-04 \pm 1.499E-04$	$9.9738E-04 \pm 1.475E-04$
INRiM	$4.2224E-04$	$6.9826E-04$	-	$-8.1915E-05 \pm 3.384E-05$	$4.2135E-04 \pm 2.014E-05$
UME	$5.1100E-04$	$6.1745E-04$	$1.0975E-04$	-	$5.0327E-04 \pm 2.835E-05$
CEM	$2.1253E-05$	$1.1187E-03$	$4.3791E-04$	$5.2659E-04$	-

Table 154 – comparison of indirect SSE measurements with the LP5 thermometer, 3 mm diameter spot and 40 mm diameter aperture



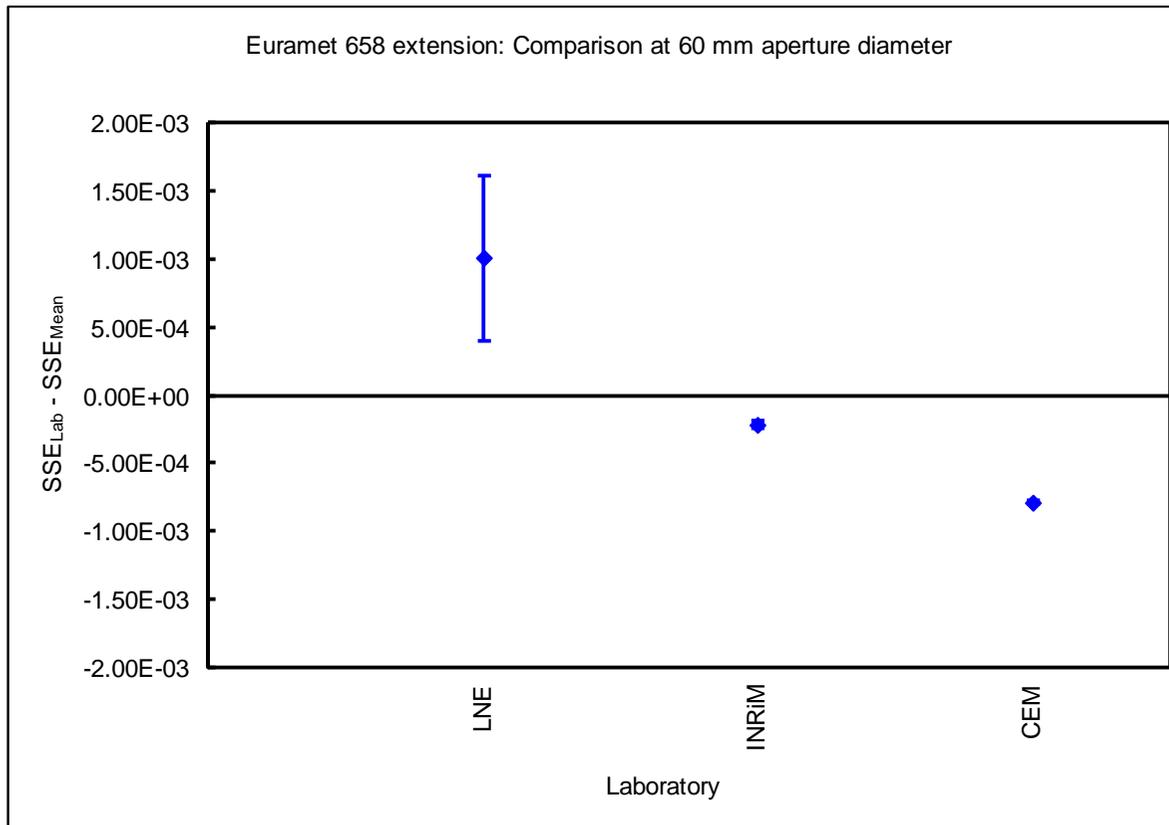
	NPL	LNE	INRiM	UME	CEM
NPL	-	$-1.3846E-03 \pm 3.675E-04$	$-4.9916E-04 \pm 2.294E-05$	$-6.0761E-04 \pm 2.982E-05$	$1.5946E-05 \pm 7.814E-06$
LNE	$1.6868E-03$	-	$8.8541E-04 \pm 3.681E-04$	$7.7695E-04 \pm 3.686E-04$	$1.4005E-03 \pm 3.675E-04$
INRiM	$5.1803E-04$	$1.1882E-03$	-	$-1.0845E-04 \pm 3.717E-05$	$5.1511E-04 \pm 2.353E-05$
UME	$6.3214E-04$	$1.0802E-03$	$1.3902E-04$	-	$6.2356E-04 \pm 3.027E-05$
CEM	$2.2373E-05$	$1.7028E-03$	$5.3446E-04$	$6.4845E-04$	-

Table 155 – comparison of indirect SSE measurements with the LP5 thermometer, 3 mm diameter spot and 50 mm diameter aperture



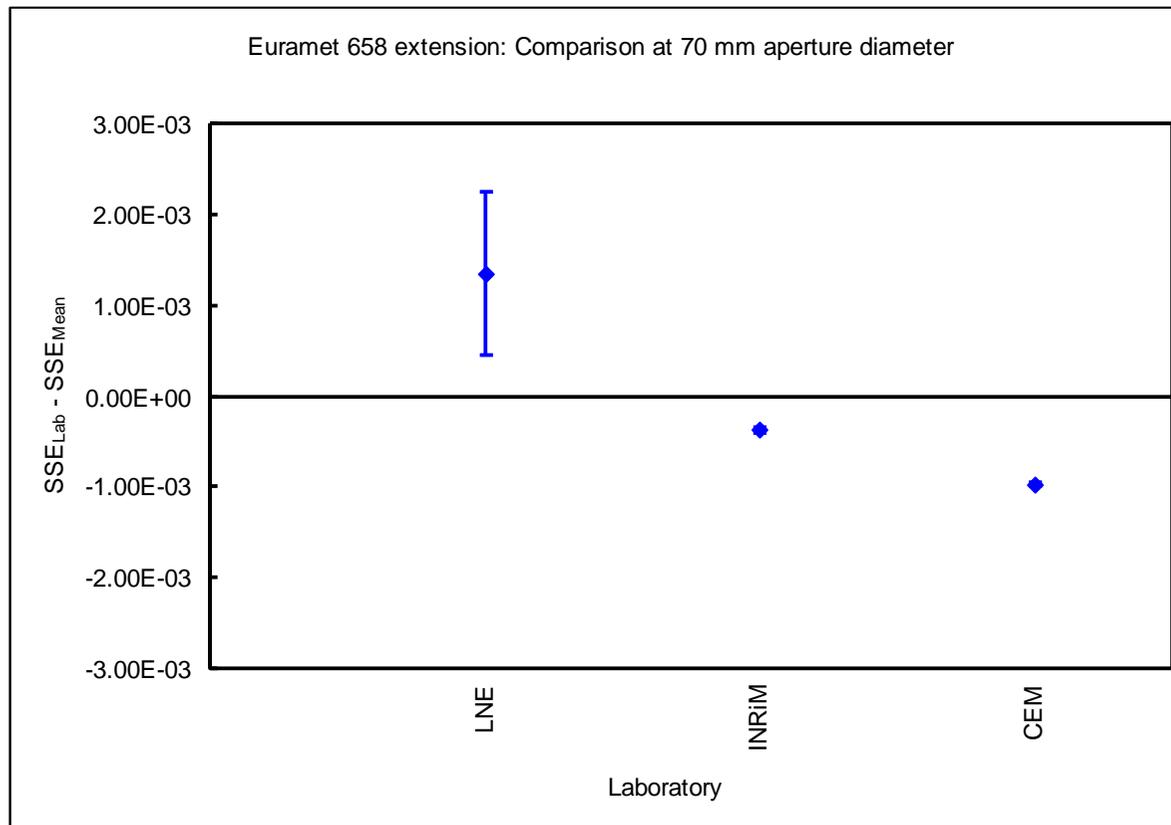
	LNE	INRiM	CEM
LNE	-	1.2276E-03 ± 6.060E-04	1.8012E-03 ± 6.056E-04
INRiM	1.7260E-03	-	5.7362E-04 ± 2.850E-05
CEM	2.2993E-03	5.9706E-04	-

Table 156 – comparison of indirect SSE measurements with the LP5 thermometer, 3 mm diameter spot and 60 mm diameter aperture



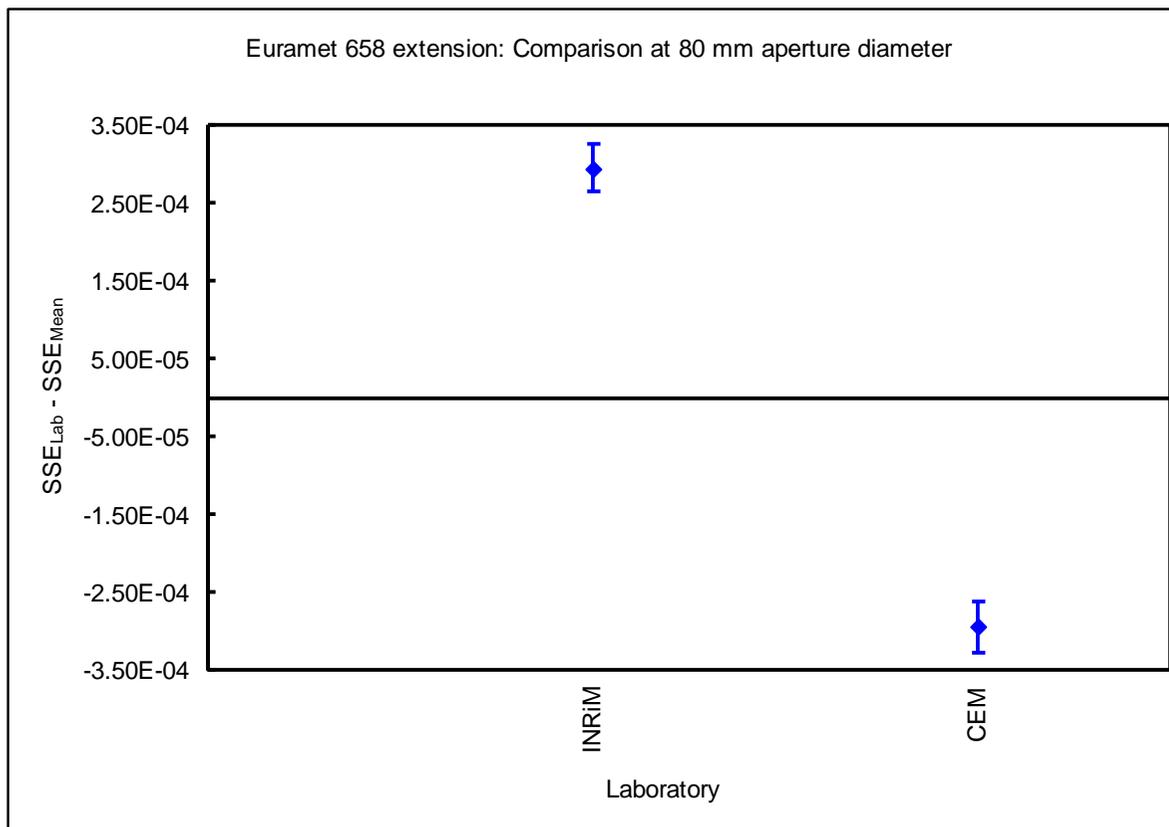
	LNE	INRiM	CEM
LNE	-	1.7193E-03 ± 8.963E-04	2.3119E-03 ± 8.963E-04
INRiM	2.4565E-03	-	5.9256E-04 ± 3.923E-05
CEM	3.0491E-03	6.2483E-04	-

Table 157 – comparison of indirect SSE measurements with the LP5 thermometer, 3 mm diameter spot and 70 mm diameter aperture



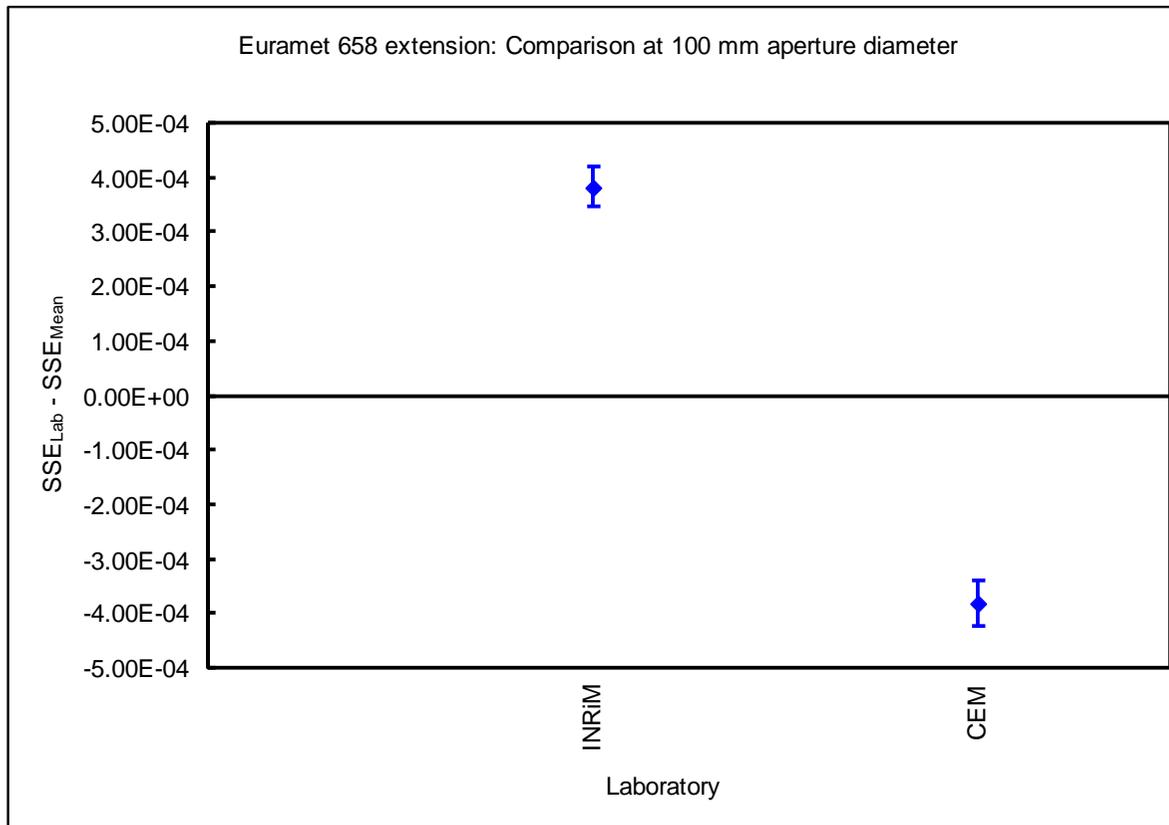
	INRiM	CEM
INRiM	-	5.8998E-04 ± 4.506E-05
CEM	6.2704E-04	-

Table 158 – comparison of indirect SSE measurements with the LP5 thermometer, 3 mm diameter spot and 80 mm diameter aperture



	INRiM	CEM
INRiM	-	7.6375E-04 ± 5.641E-05
CEM	8.1015E-04	-

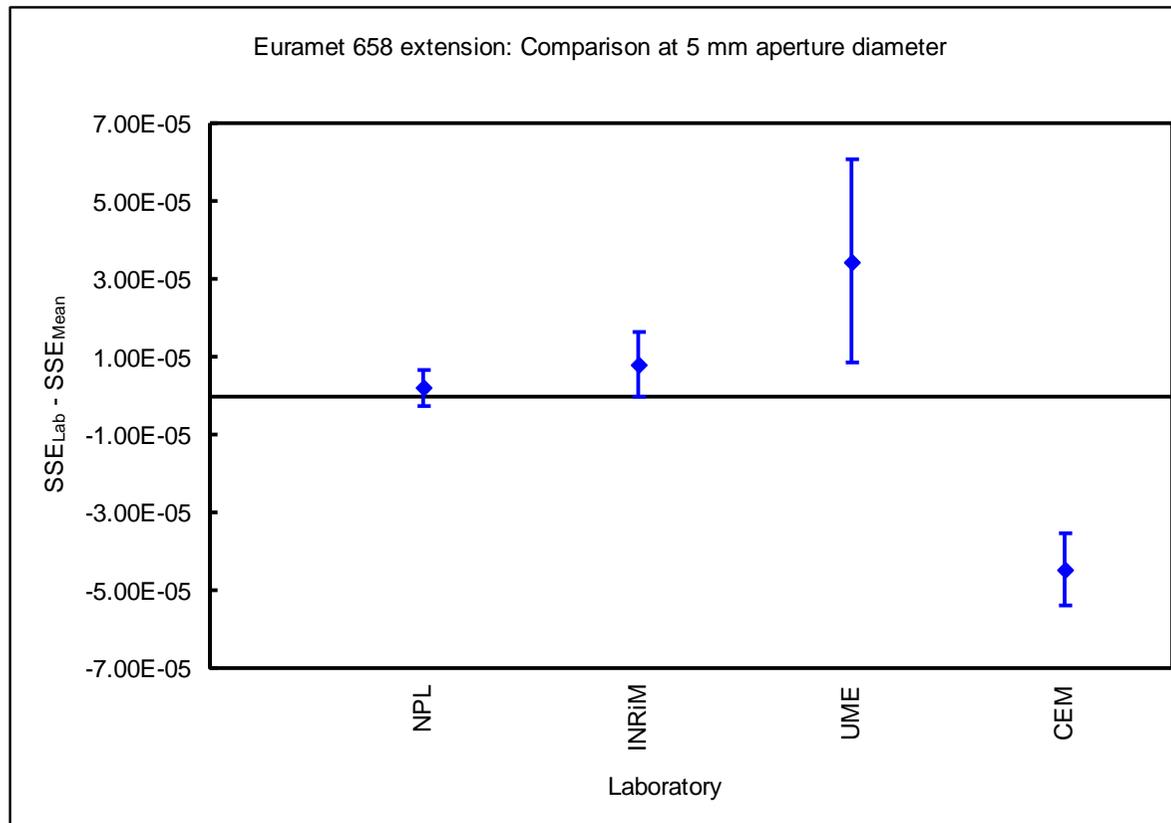
Table 159 – comparison of indirect SSE measurements with the LP5 thermometer, 3 mm diameter spot and 100 mm diameter aperture



1.8.6 The LP5 thermometer ‘indirect’ SSE results – 3 mm spot excl. LNE

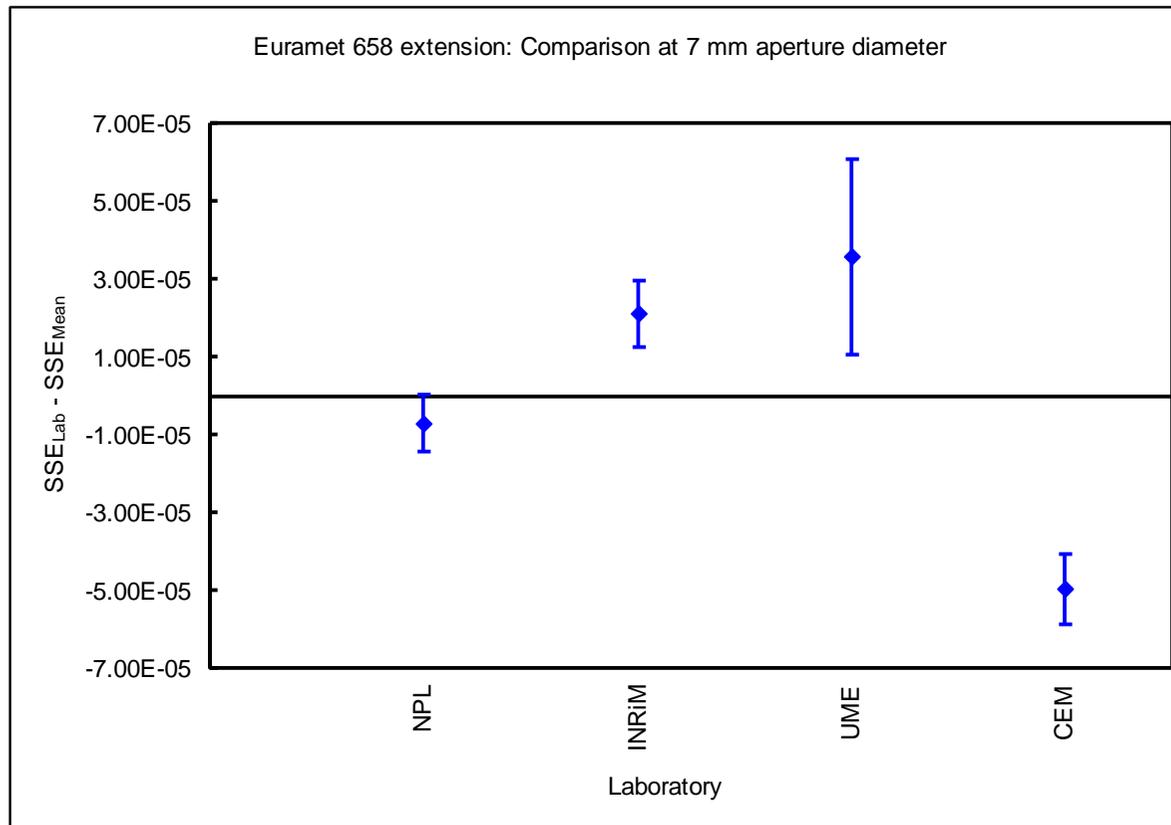
	NPL	INRiM	UME	CEM
NPL	-	$-5.8527\text{E-}06 \pm 9.559\text{E-}06$	$-3.2349\text{E-}05 \pm 2.649\text{E-}05$	$4.6657\text{E-}05 \pm 1.027\text{E-}05$
INRiM	$1.3726\text{E-}05$	-	$-2.6496\text{E-}05 \pm 2.738\text{E-}05$	$5.2509\text{E-}05 \pm 1.237\text{E-}05$
UME	$5.4140\text{E-}05$	$4.9015\text{E-}05$	-	$7.9006\text{E-}05 \pm 2.763\text{E-}05$
CEM	$5.5103\text{E-}05$	$6.2684\text{E-}05$	$1.0173\text{E-}04$	-

Table 160 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 3 mm diameter spot and 5 mm diameter aperture



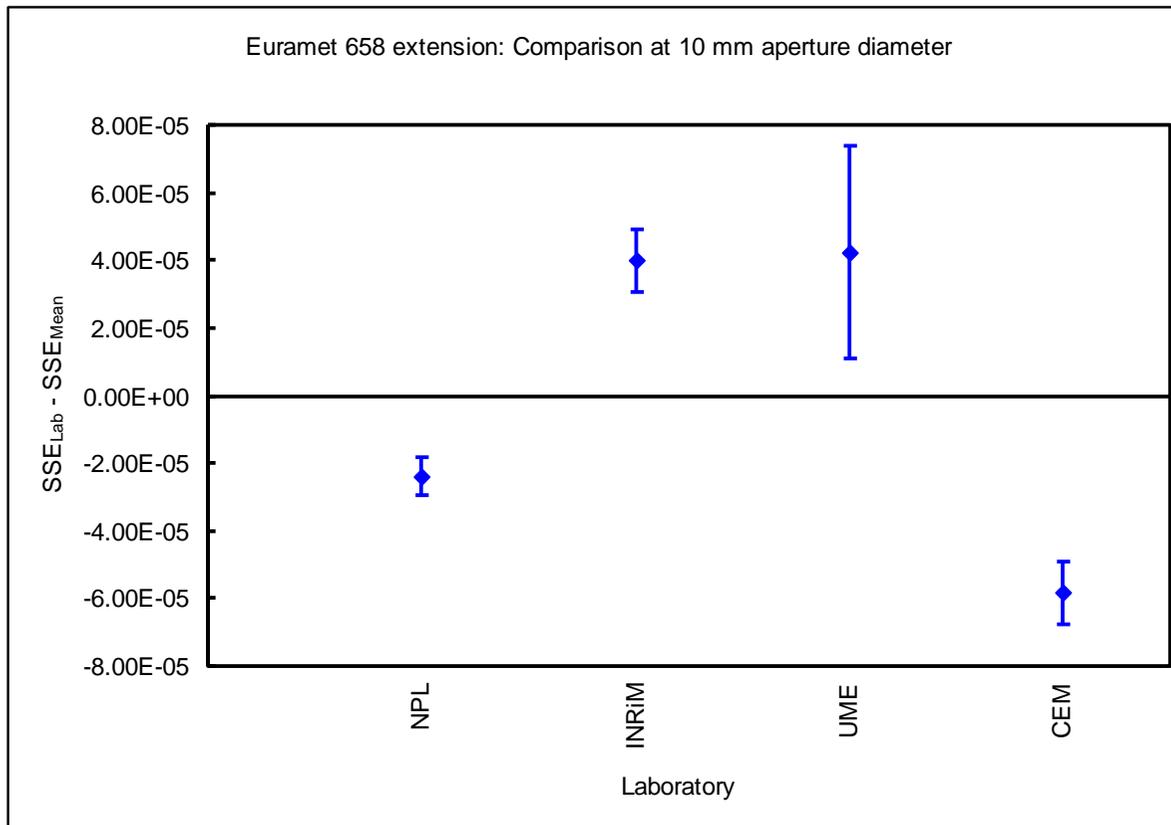
	NPL	INRiM	UME	CEM
NPL	-	$-2.8198E-05 \pm 1.124E-05$	$-4.2812E-05 \pm 2.623E-05$	$4.2515E-05 \pm 1.160E-05$
INRiM	$3.7440E-05$	-	$-1.4614E-05 \pm 2.669E-05$	$7.0714E-05 \pm 1.260E-05$
UME	$6.4387E-05$	$3.6616E-05$	-	$8.5328E-05 \pm 2.684E-05$
CEM	$5.2058E-05$	$8.1076E-05$	$1.0741E-04$	-

Table 161 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 3 mm diameter spot and 7 mm diameter aperture



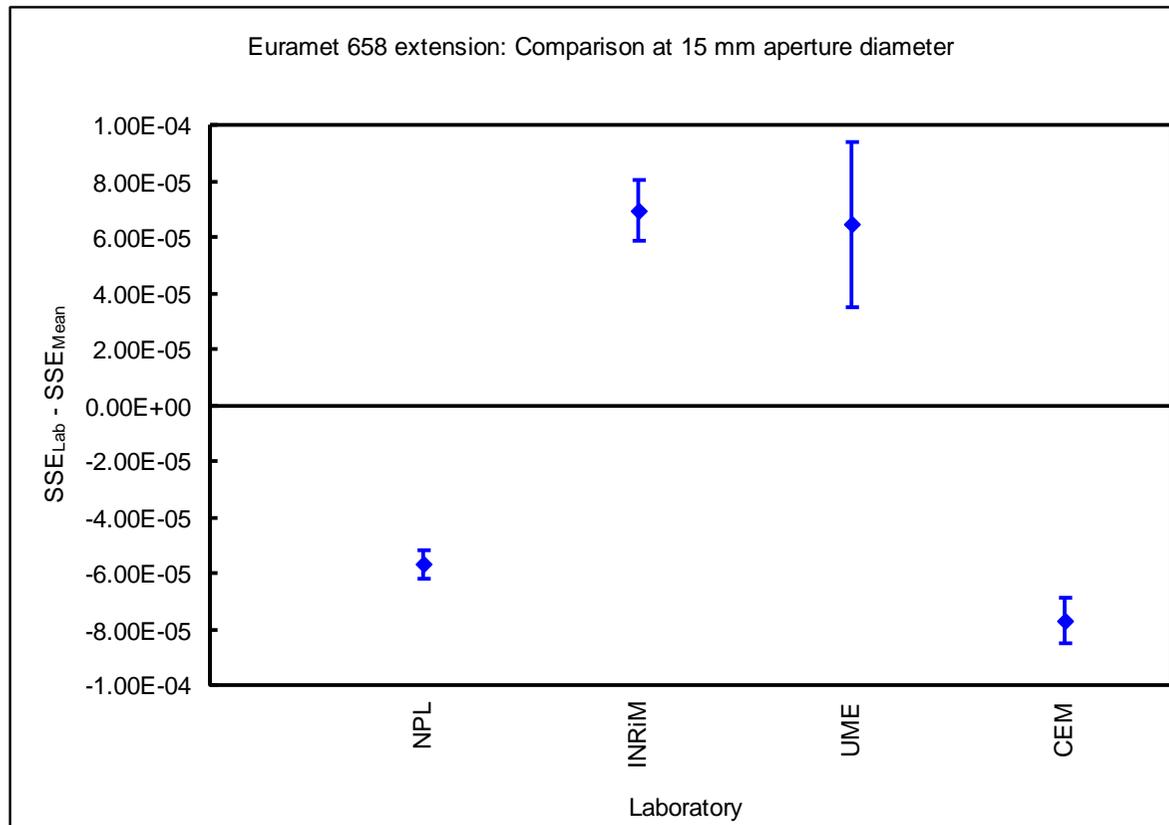
	NPL	INRiM	UME	CEM
NPL	-	$-6.3804E-05 \pm 1.089E-05$	$-6.6223E-05 \pm 3.180E-05$	$3.4468E-05 \pm 1.072E-05$
INRiM	$7.2758E-05$	-	$-2.4183E-06 \pm 3.267E-05$	$9.8272E-05 \pm 1.306E-05$
UME	$9.2380E-05$	$3.2241E-05$	-	$1.0069E-04 \pm 3.261E-05$
CEM	$4.3286E-05$	$1.0902E-04$	$1.2751E-04$	-

Table 162 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 3 mm diameter spot and 10 mm diameter aperture



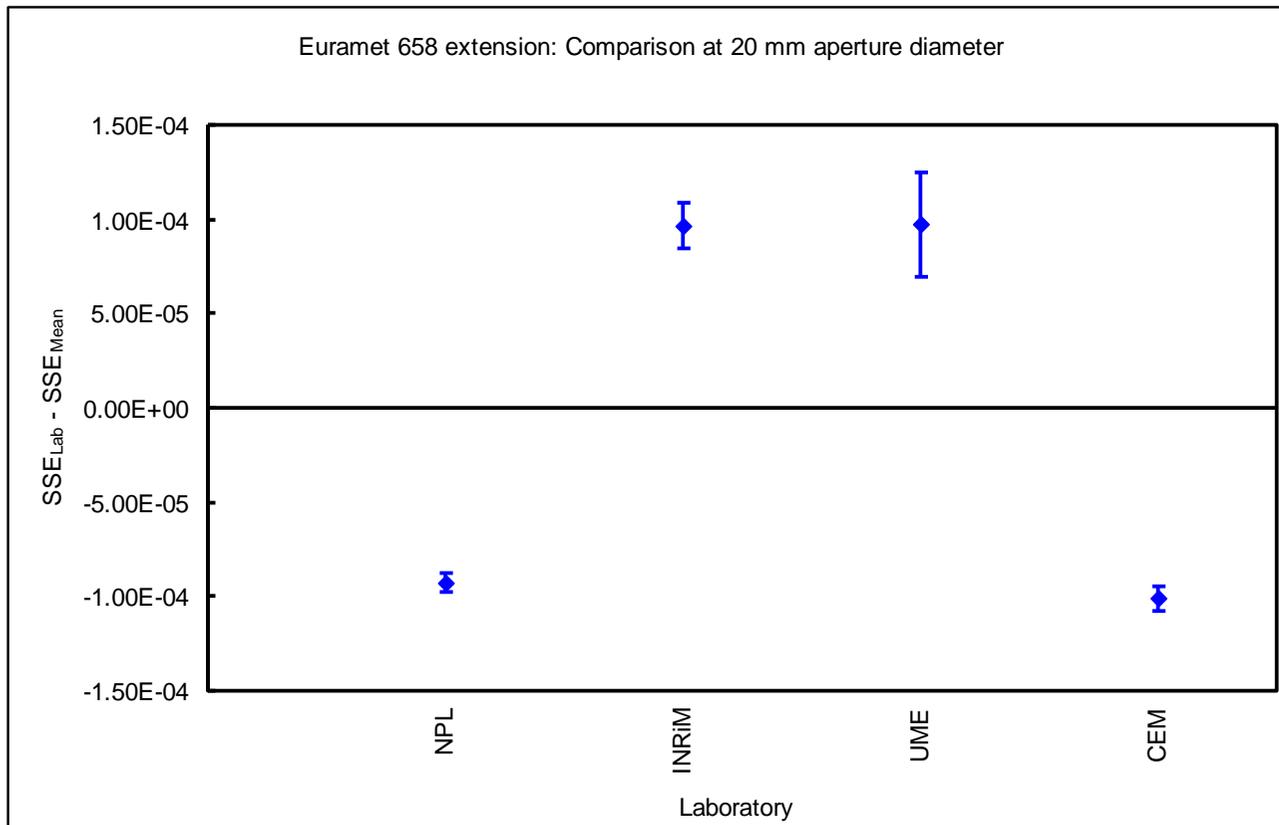
	NPL	INRiM	UME	CEM
NPL	-	$-1.2619E-04 \pm 1.205E-05$	$-1.2129E-04 \pm 2.999E-05$	$1.9961E-05 \pm 9.618E-06$
INRiM	$1.3610E-04$	-	$4.9026E-06 \pm 3.146E-05$	$1.4615E-04 \pm 1.352E-05$
UME	$1.4595E-04$	$3.2246E-05$	-	$1.4125E-04 \pm 3.061E-05$
CEM	$2.7872E-05$	$1.5727E-04$	$1.6642E-04$	-

Table 163 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 3 mm diameter spot and 15 mm diameter aperture



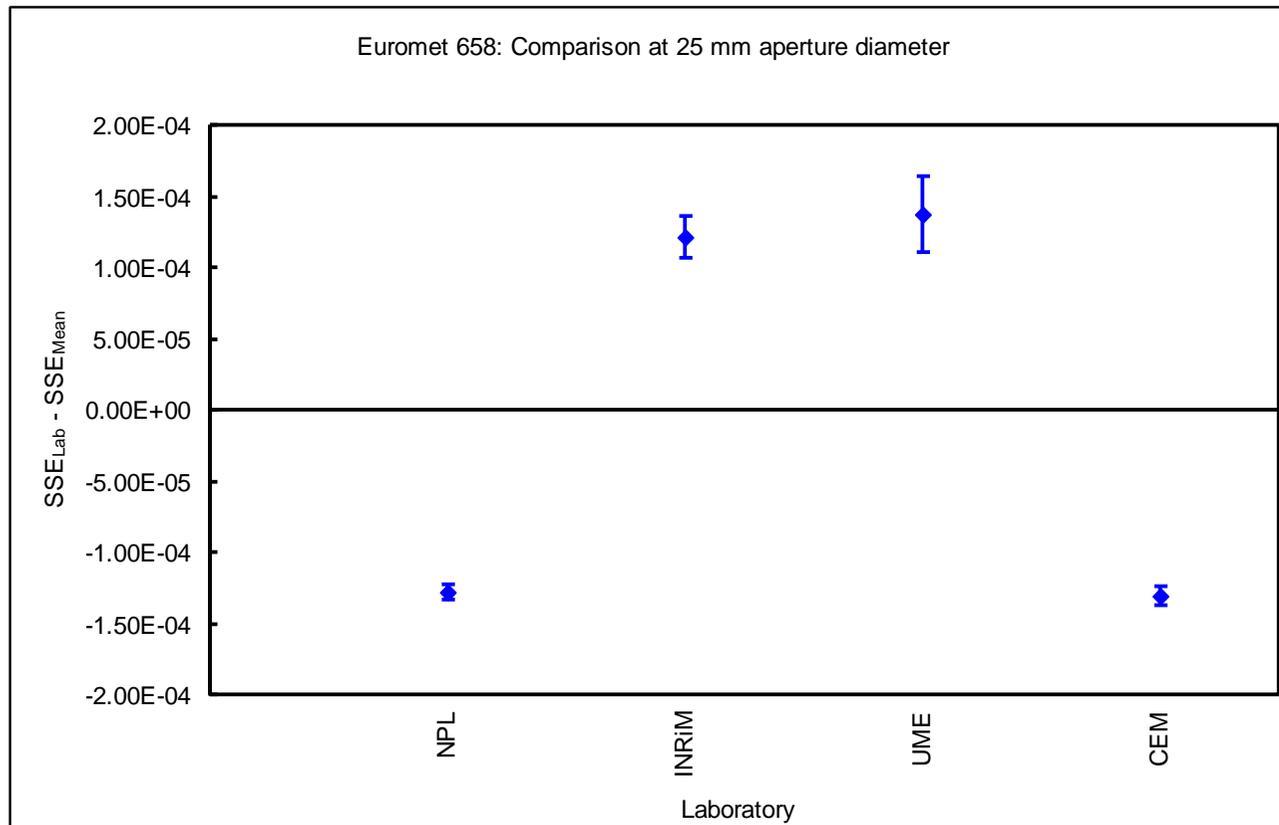
	NPL	INRiM	UME	CEM
NPL	-	$-1.8902E-04 \pm 1.320E-05$	$-1.8984E-04 \pm 2.818E-05$	$8.4469E-06 \pm 7.937E-06$
INRiM	$1.9988E-04$	-	$-8.2004E-07 \pm 3.040E-05$	$1.9747E-04 \pm 1.390E-05$
UME	$2.1302E-04$	$2.9852E-05$	-	$1.9829E-04 \pm 2.851E-05$
CEM	$1.4975E-05$	$2.0890E-04$	$2.2174E-04$	-

Table 164 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 3 mm diameter spot and 20 mm diameter aperture



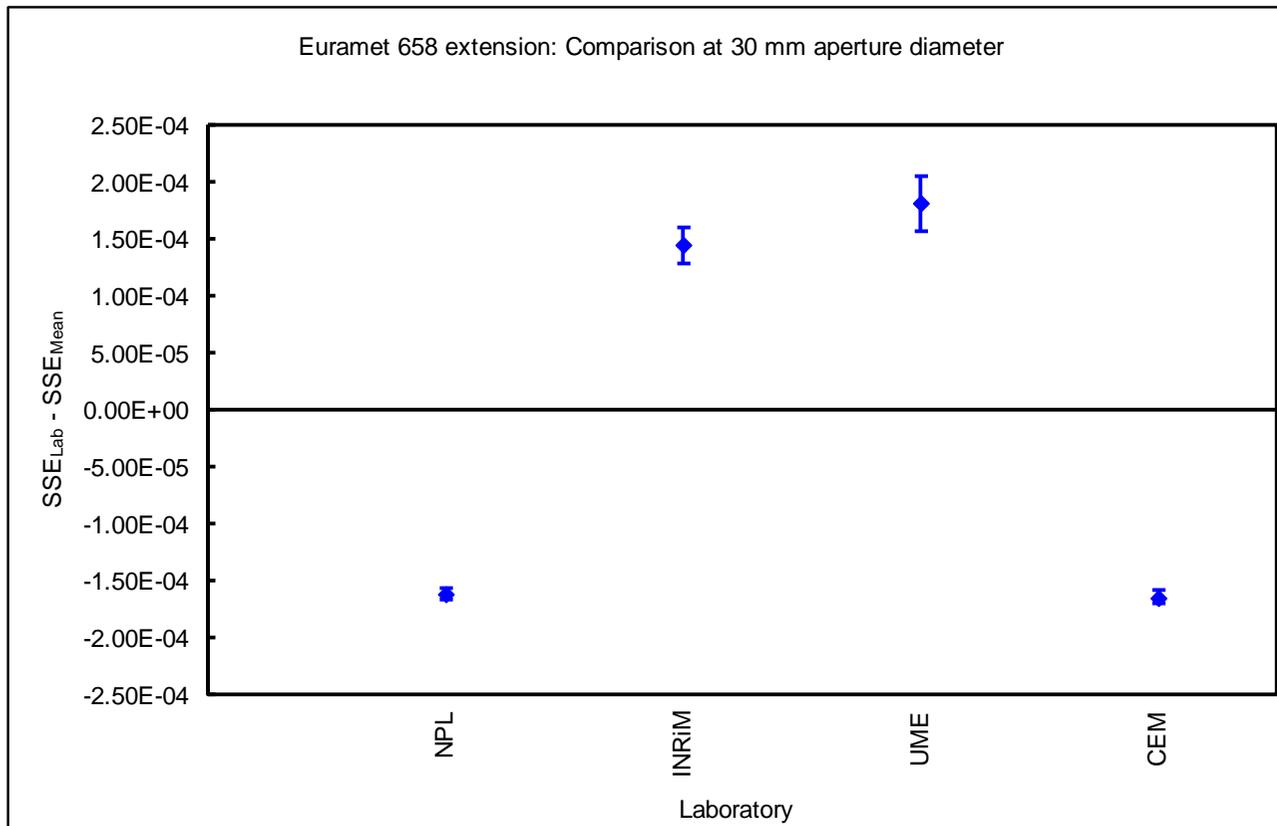
	NPL	INRiM	UME	CEM
NPL	-	-2.4949E-04 ± 1.527E-05	-2.6542E-04 ± 2.663E-05	2.6754E-06 ± 8.382E-06
INRiM	2.6204E-04	-	-1.5931E-05 ± 2.973E-05	2.5216E-04 ± 1.565E-05
UME	2.8732E-04	4.0447E-05	-	2.6809E-04 ± 2.685E-05
CEM	9.6735E-06	2.6503E-04	2.9018E-04	-

Table 165 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 3 mm diameter spot and 25 mm diameter aperture



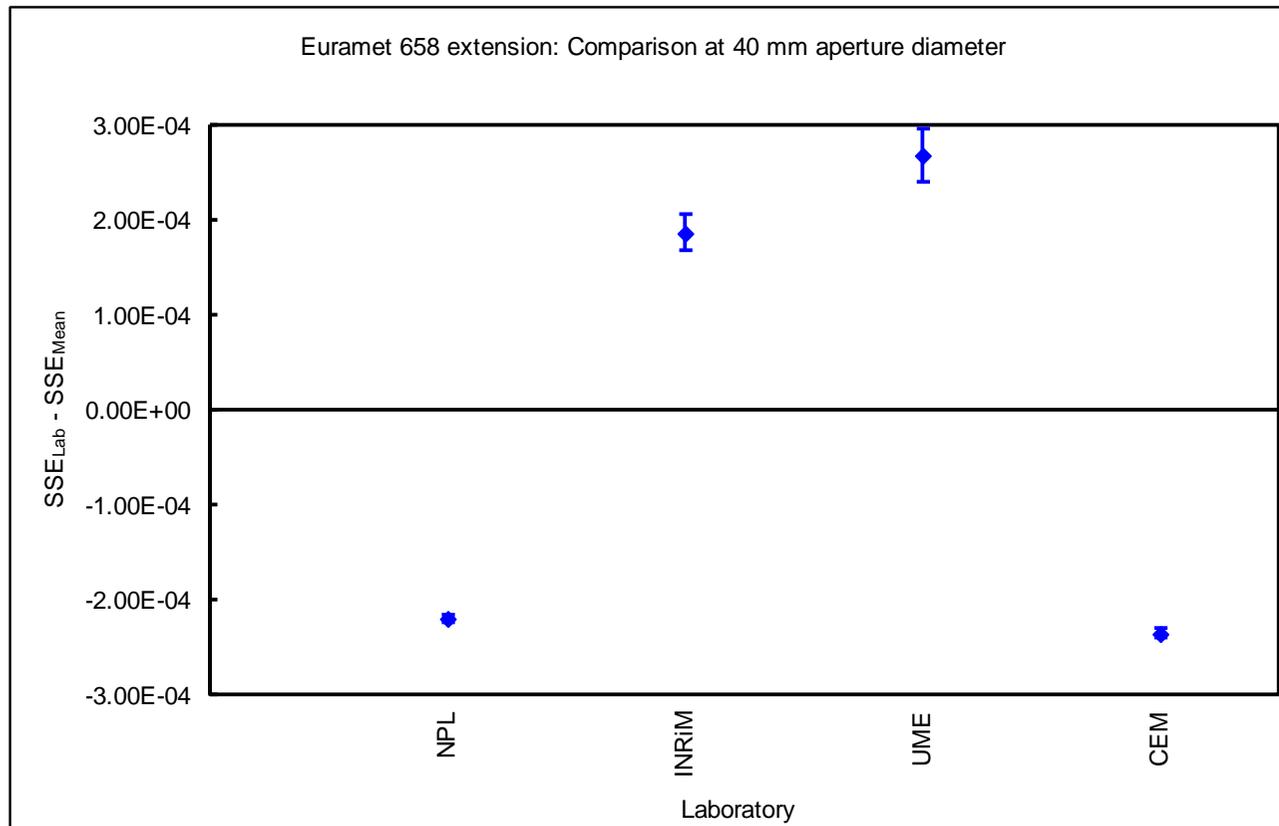
	NPL	INRiM	UME	CEM
NPL	-	$-3.0593E-04 \pm 1.677E-05$	$-3.4276E-04 \pm 2.488E-05$	$3.1440E-06 \pm 7.412E-06$
INRiM	$3.1972E-04$	-	$-3.6833E-05 \pm 2.923E-05$	$3.0907E-04 \pm 1.704E-05$
UME	$3.6322E-04$	$6.0875E-05$	-	$3.4591E-04 \pm 2.506E-05$
CEM	$9.2799E-06$	$3.2309E-04$	$3.6652E-04$	-

Table 166 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 3 mm diameter spot and 30 mm diameter aperture



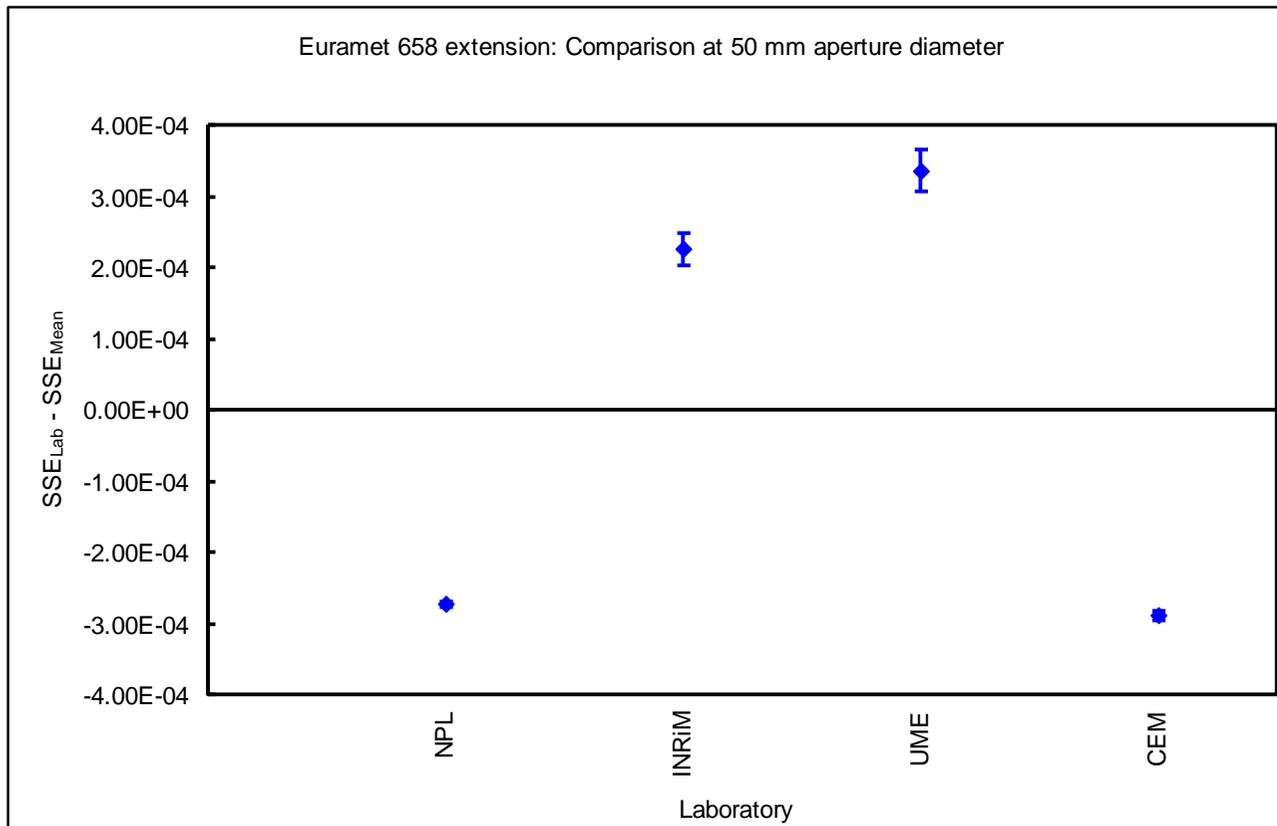
	NPL	INRiM	UME	CEM
NPL	-	$-4.0596E-04 \pm 1.980E-05$	$-4.8787E-04 \pm 2.812E-05$	$1.5396E-05 \pm 7.122E-06$
INRiM	$4.2224E-04$	-	$-8.1915E-05 \pm 3.384E-05$	$4.2135E-04 \pm 2.014E-05$
UME	$5.1100E-04$	$1.0975E-04$	-	$5.0327E-04 \pm 2.835E-05$
CEM	$2.1253E-05$	$4.3791E-04$	$5.2659E-04$	-

Table 167 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 3 mm diameter spot and 40 mm diameter aperture



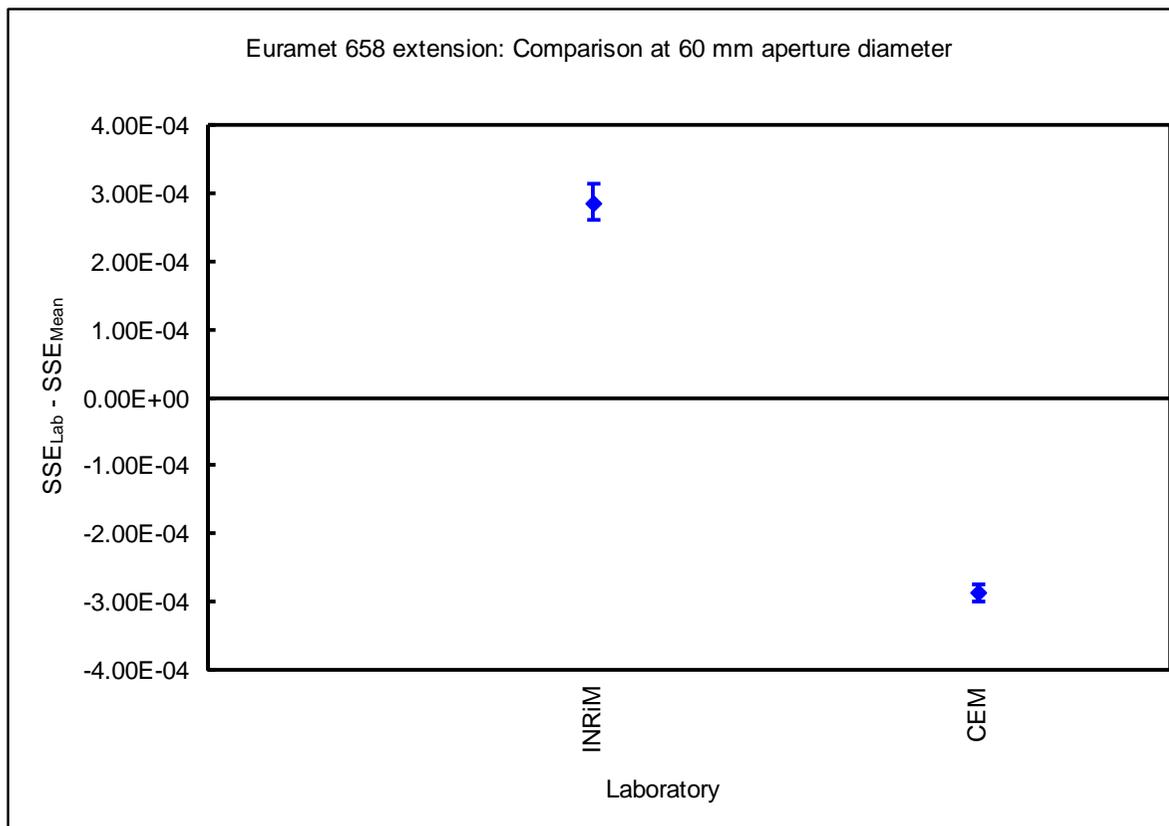
	NPL	INRiM	UME	CEM
NPL	-	$-4.9916E-04 \pm 2.294E-05$	$-6.0761E-04 \pm 2.982E-05$	$1.5946E-05 \pm 7.814E-06$
INRiM	$5.1803E-04$	-	$-1.0845E-04 \pm 3.717E-05$	$5.1511E-04 \pm 2.353E-05$
UME	$6.3214E-04$	$1.3902E-04$	-	$6.2356E-04 \pm 3.027E-05$
CEM	$2.2373E-05$	$5.3446E-04$	$6.4845E-04$	-

Table 168 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 3 mm diameter spot and 50 mm diameter aperture



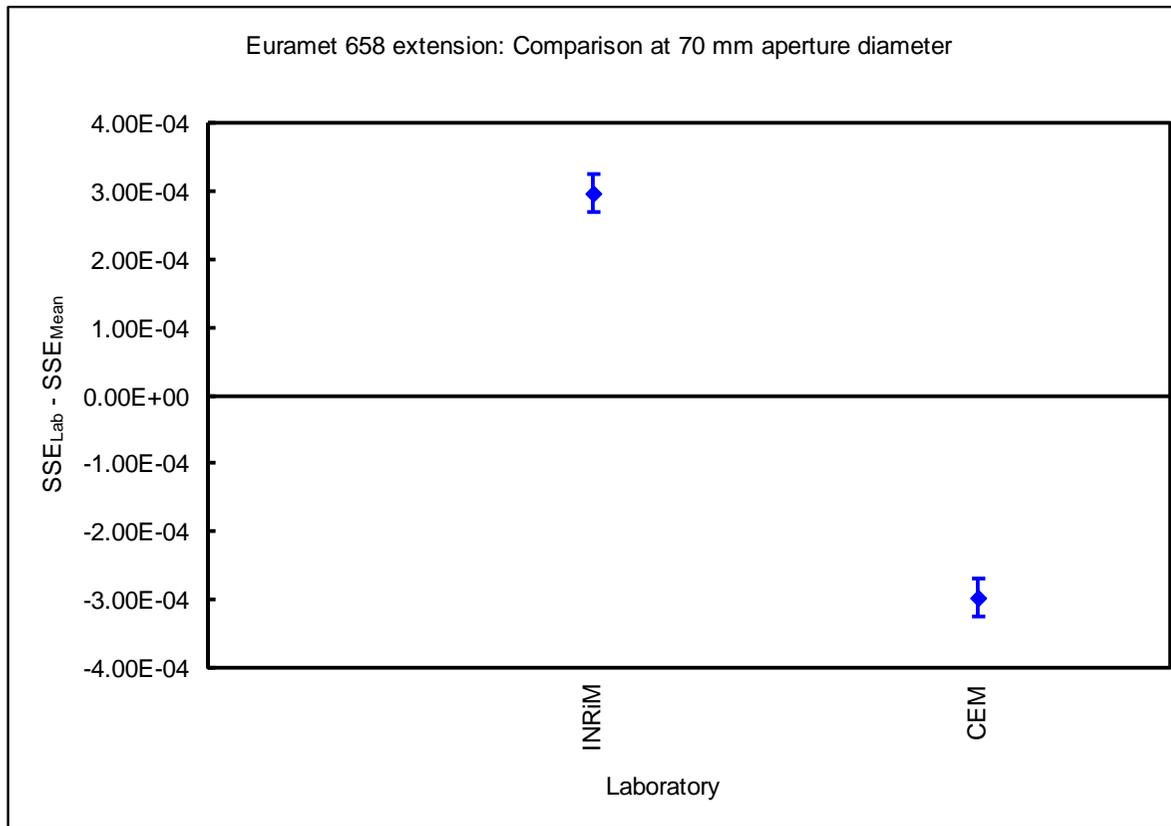
	INRiM	CEM
INRiM	-	5.7362E-04 ± 2.850E-05
CEM	5.9706E-04	-

Table 169 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 3 mm diameter spot and 60 mm diameter aperture



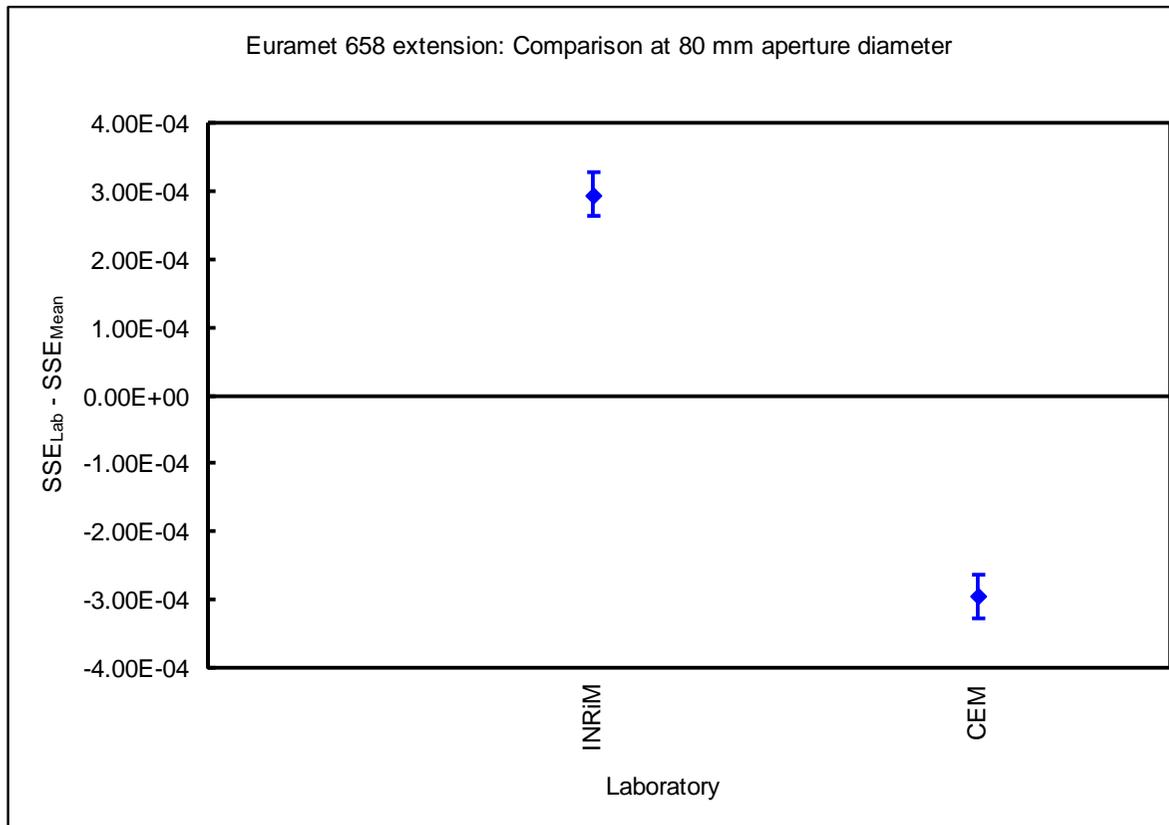
	INRiM	CEM
INRiM	-	5.9256E-04 ± 3.923E-05
CEM	6.2483E-04	-

Table 170 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 3 mm diameter spot and 70 mm diameter aperture



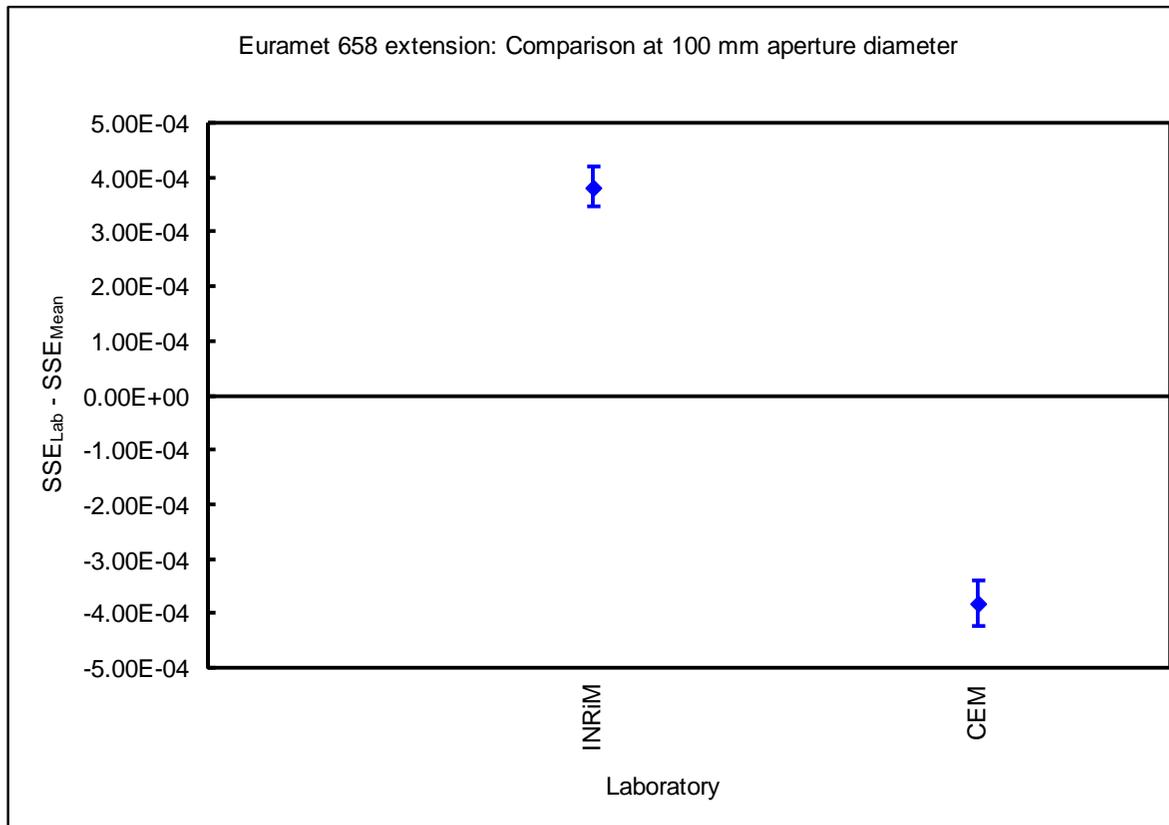
	INRiM	CEM
INRiM	-	5.8998E-04 ± 4.506E-05
CEM	6.2704E-04	-

Table 171 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 3 mm diameter spot and 80 mm diameter aperture



	INRiM	CEM
INRiM	-	7.6375E-04 ± 5.641E-05
CEM	8.1015E-04	-

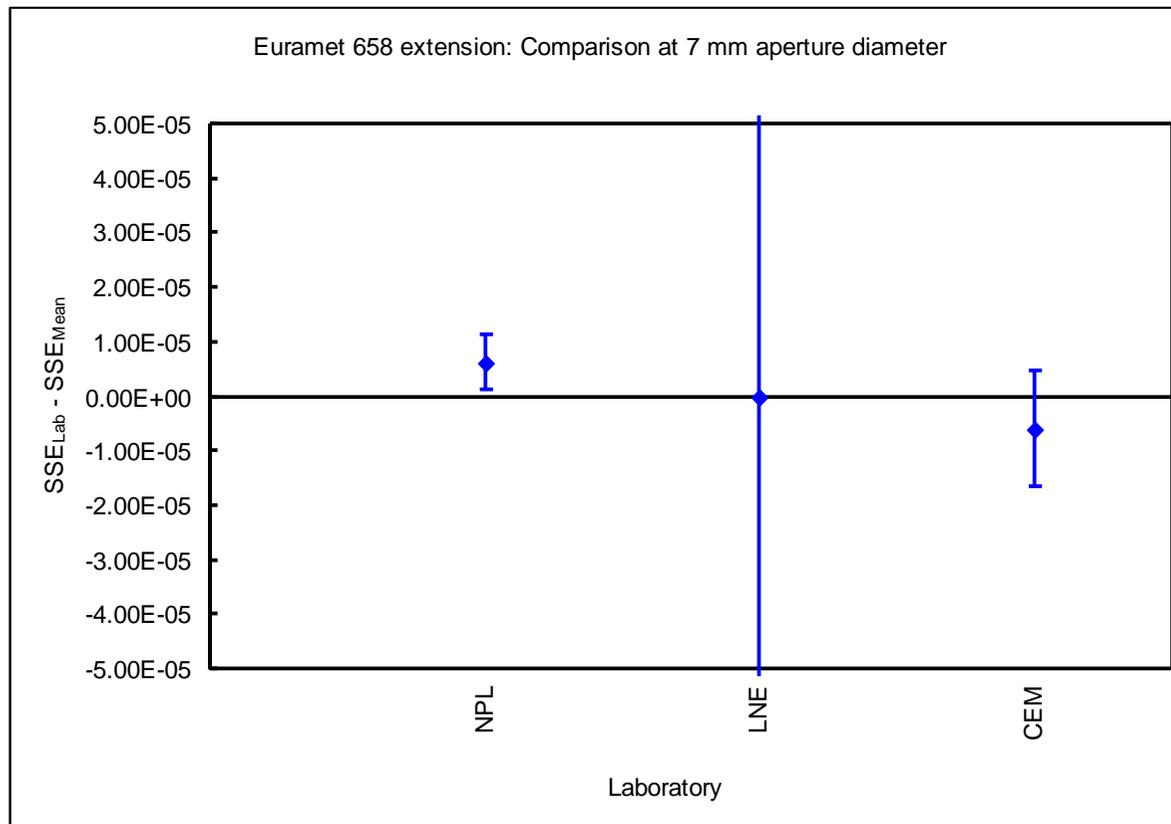
Table 172 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 3 mm diameter spot and 100 mm diameter aperture



1.8.7 The LP5 thermometer ‘indirect’ SSE results – 6 mm spot

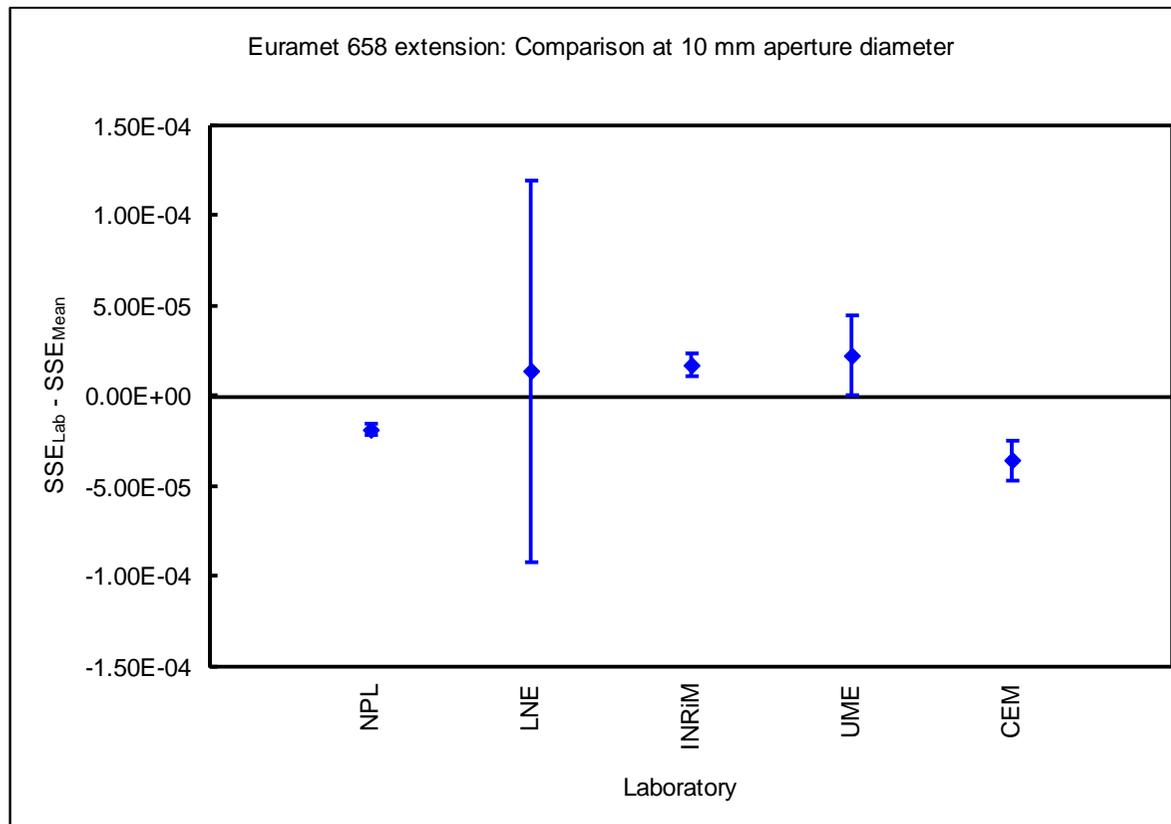
	NPL	LNE	CEM
NPL	-	0.000007 ± 9.757E-05	0.000012 ± 1.186E-05
LNE	0.000096	-	0.000006 ± 9.802E-05
CEM	0.000022	0.000096	-

Table 173 – comparison of indirect SSE measurements with the LP5 thermometer with 6 mm diameter spot and 7 mm diameter aperture



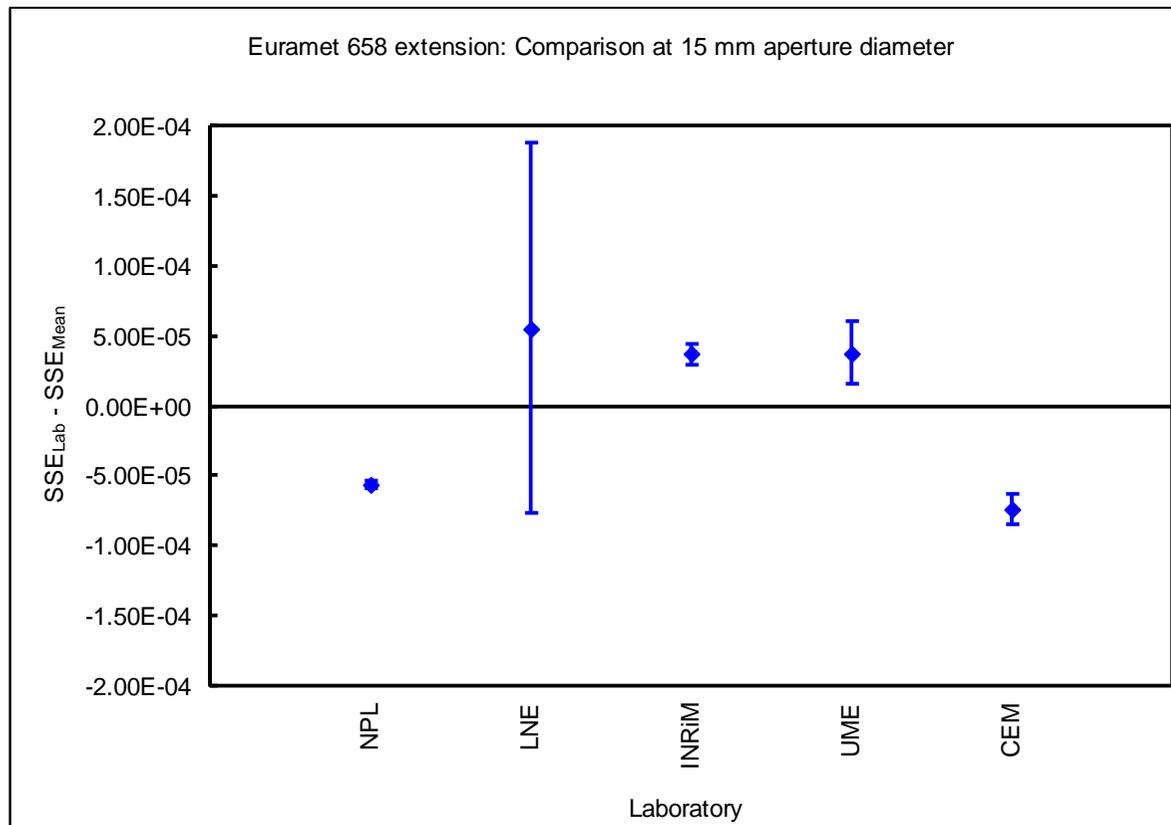
	NPL	LNE	INRiM	UME	CEM
NPL	-	-0.000032 ± 1.059E-04	-0.000036 ± 7.165E-06	-0.000041 ± 2.242E-05	0.000017 ± 1.116E-05
LNE	0.000121	-	-0.000004 ± 1.060E-04	-0.000009 ± 1.081E-04	0.000049 ± 1.064E-04
INRiM	0.000042	0.000104	-	-0.000005 ± 2.307E-05	0.000053 ± 1.241E-05
UME	0.000059	0.000107	0.000024	-	0.000058 ± 2.460E-05
CEM	0.000026	0.000137	0.000064	0.000078	-

Table 174 – comparison of indirect SSE measurements with the LP5 thermometer with 6 mm diameter spot and 10 mm diameter aperture



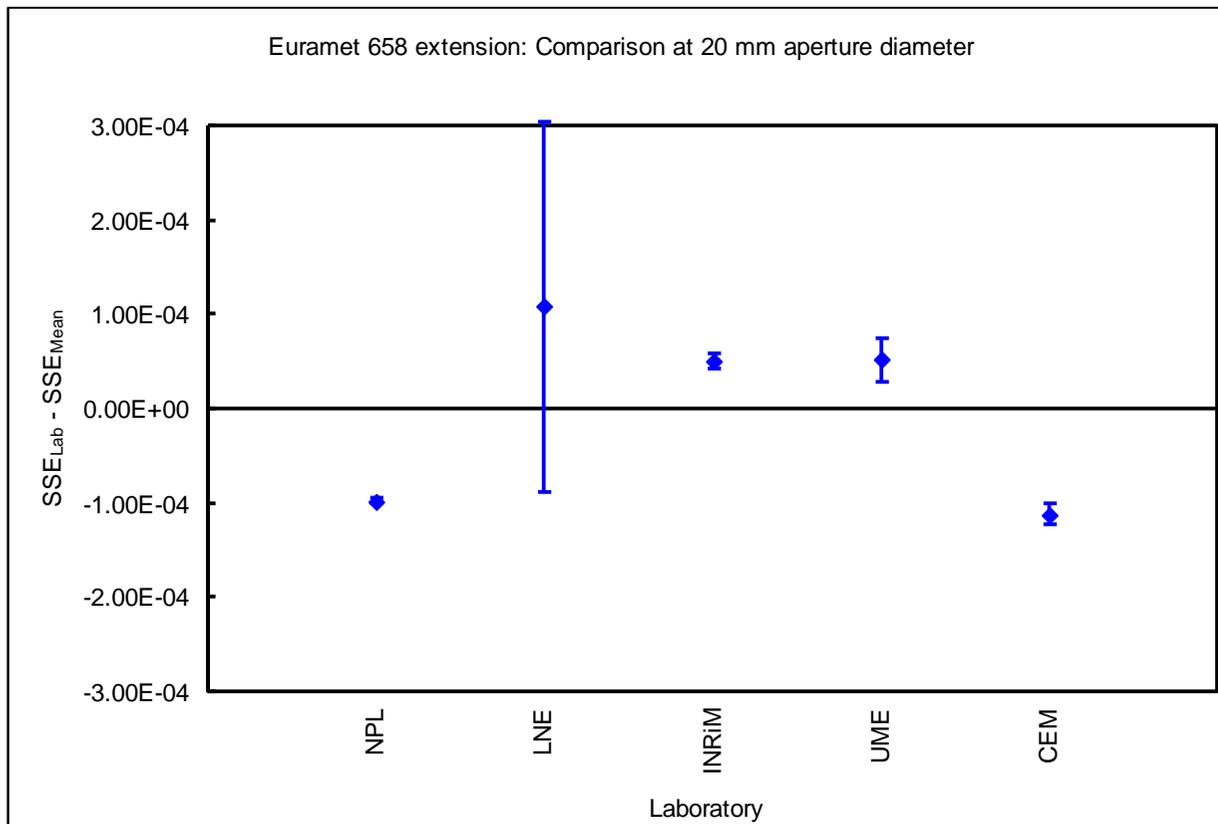
	NPL	LNE	INRiM	UME	CEM
NPL	-	-0.000112 ± 1.325E-04	-0.000093 ± 7.821E-06	-0.000094 ± 2.249E-05	0.000018 ± 1.100E-05
LNE	0.000221	-	0.000019 ± 1.327E-04	0.000018 ± 1.343E-04	0.000129 ± 1.329E-04
INRiM	0.000099	0.000135	-	-0.000001 ± 2.351E-05	0.000110 ± 1.296E-05
UME	0.000112	0.000136	0.000023	-	0.000111 ± 2.475E-05
CEM	0.000027	0.000238	0.000121	0.000131	-

Table 175 – comparison of indirect SSE measurements with the LP5 thermometer with 6 mm diameter spot and 15 mm diameter aperture



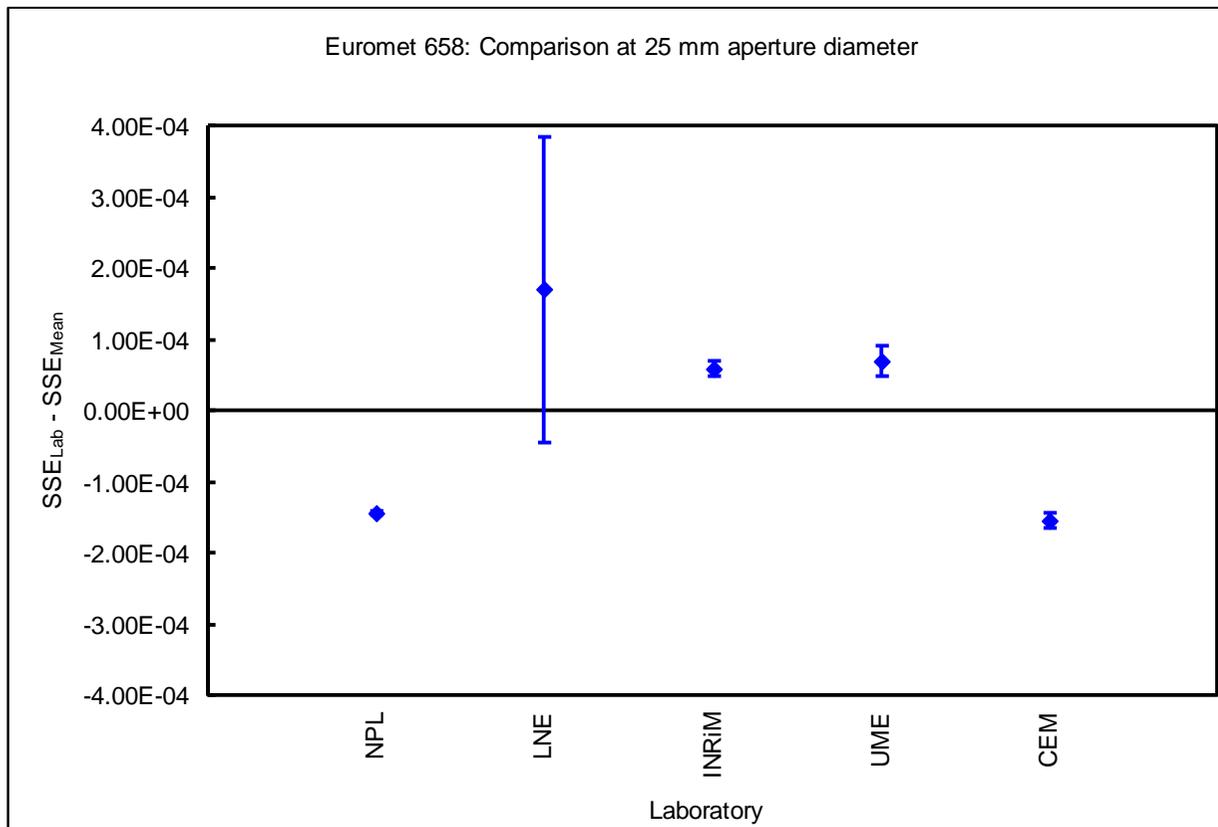
	NPL	LNE	INRiM	UME	CEM
NPL	-	-0.000207 ± 1.965E-04	-0.000149 ± 9.127E-06	-0.000150 ± 2.249E-05	0.000014 ± 1.110E-05
LNE	0.000368	-	0.000058 ± 1.967E-04	0.000057 ± 1.977E-04	0.000221 ± 1.968E-04
INRiM	0.000156	0.000223	-	-0.000001 ± 2.398E-05	0.000162 ± 1.386E-05
UME	0.000168	0.000223	0.000024	-	0.000164 ± 2.479E-05
CEM	0.000023	0.000382	0.000174	0.000184	-

Table 176 – comparison of indirect SSE measurements with the LP5 thermometer with 6 mm diameter spot and 20 mm diameter aperture



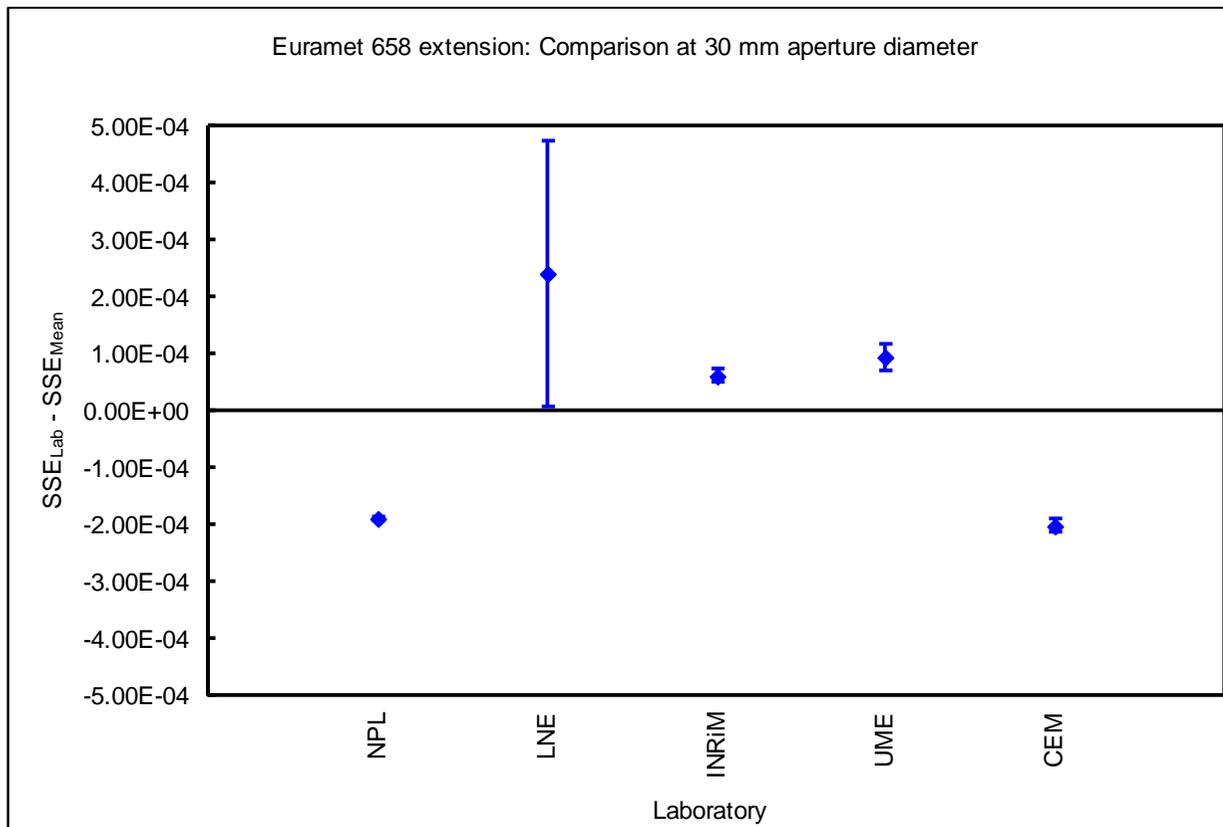
	NPL	LNE	INRiM	UME	CEM
NPL	-	-0.000314 ± 2.149E-04	-0.000202 ± 1.106E-05	-0.000213 ± 2.268E-05	0.000011 ± 1.123E-05
LNE	0.000491	-	0.000112 ± 2.152E-04	0.000101 ± 2.161E-04	0.000325 ± 2.152E-04
INRiM	0.000211	0.000289	-	-0.000011 ± 2.489E-05	0.000213 ± 1.520E-05
UME	0.000231	0.000280	0.000031	-	0.000224 ± 2.496E-05
CEM	0.000020	0.000502	0.000226	0.000244	-

Table 177 – comparison of indirect SSE measurements with the LP5 thermometer with 6 mm diameter spot and 25 mm diameter aperture



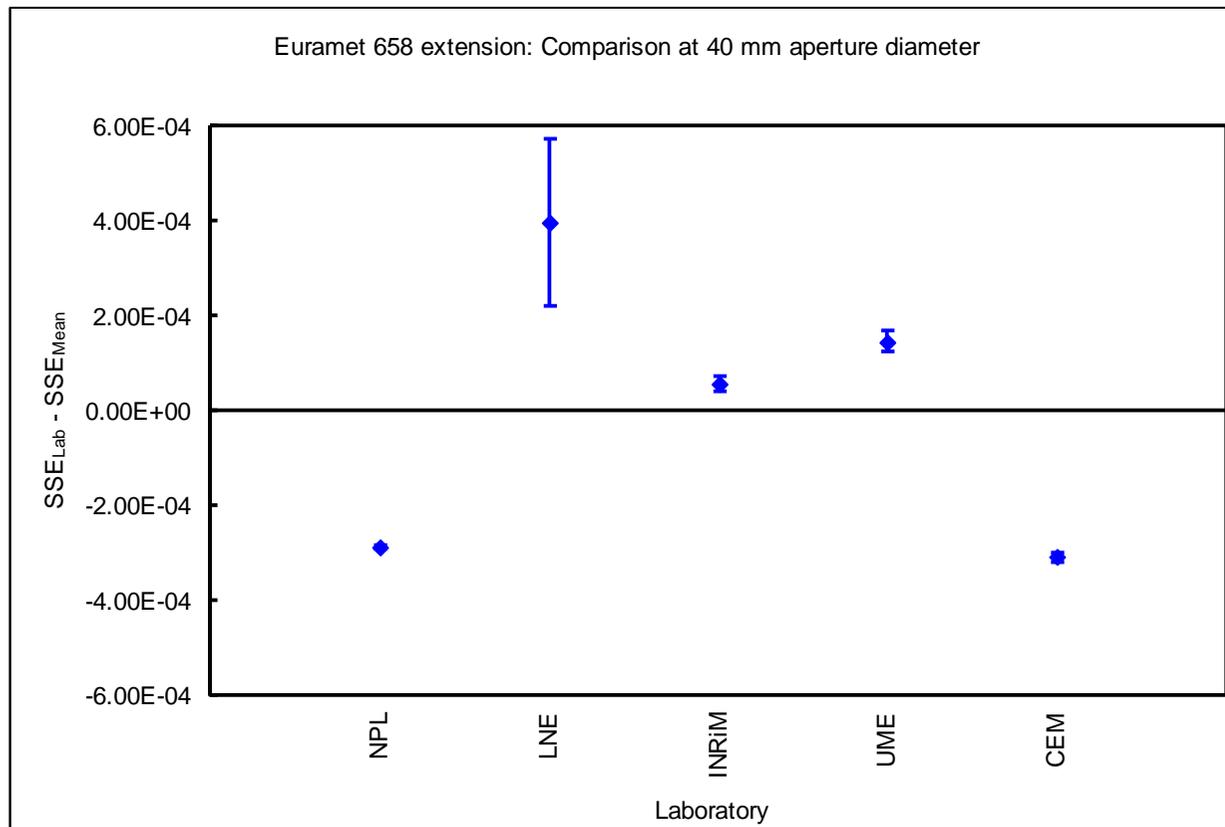
	NPL	LNE	INRiM	UME	CEM
NPL	-	-0.000431 ± 2.334E-04	-0.000252 ± 1.260E-05	-0.000283 ± 2.282E-05	0.000012 ± 1.119E-05
LNE	0.000622	-	0.000178 ± 2.337E-04	0.000147 ± 2.345E-04	0.000442 ± 2.336E-04
INRiM	0.000262	0.000371	-	-0.000031 ± 2.576E-05	0.000264 ± 1.638E-05
UME	0.000302	0.000340	0.000052	-	0.000295 ± 2.510E-05
CEM	0.000021	0.000634	0.000277	0.000316	-

Table 178 – comparison of indirect SSE measurements with the LP5 thermometer with 6 mm diameter spot and 30 mm diameter aperture



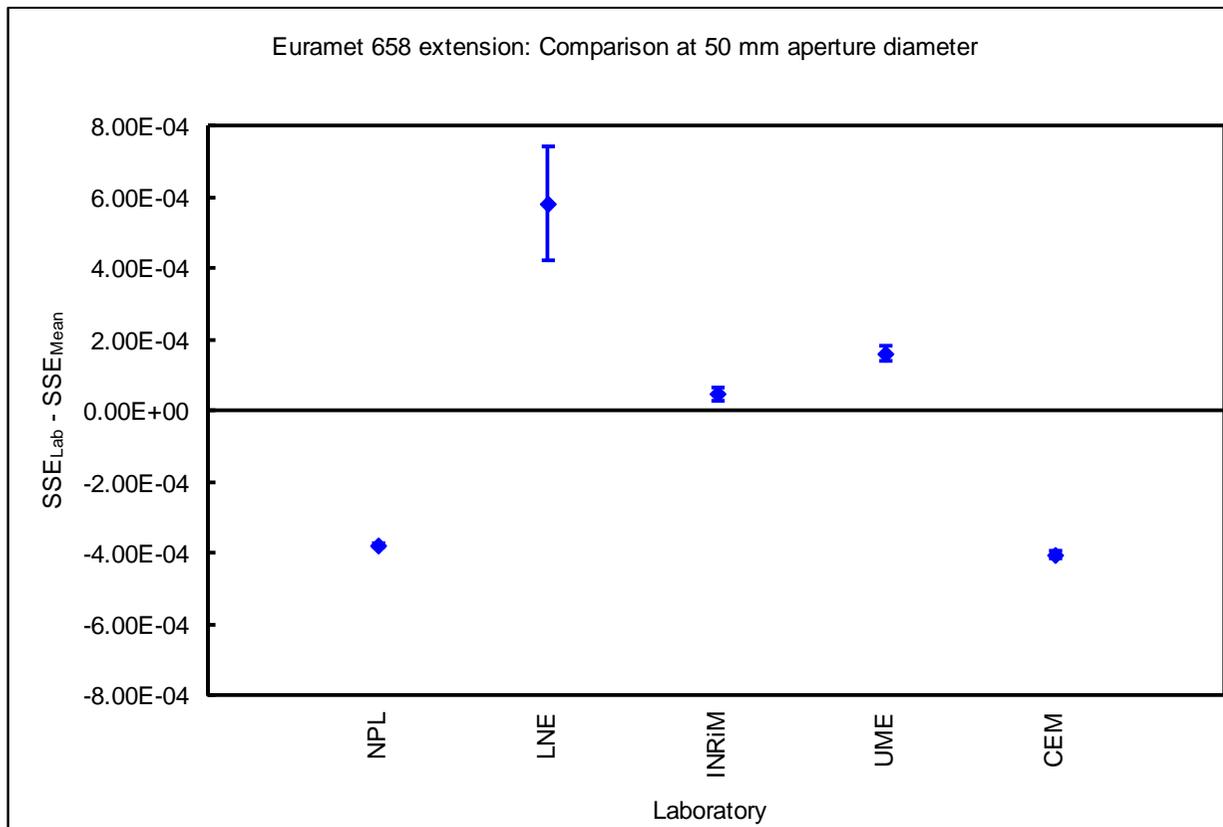
	NPL	LNE	INRiM	UME	CEM
NPL	-	-0.000685 ± 1.762E-04	-0.000342 ± 1.591E-05	-0.000433 ± 2.314E-05	0.000021 ± 1.120E-05
LNE	0.000830	-	0.000342 ± 1.768E-04	0.000252 ± 1.776E-04	0.000706 ± 1.765E-04
INRiM	0.000355	0.000488	-	-0.000091 ± 2.779E-05	0.000364 ± 1.904E-05
UME	0.000452	0.000398	0.000114	-	0.000454 ± 2.539E-05
CEM	0.000031	0.000851	0.000379	0.000475	-

Table 179 – comparison of indirect SSE measurements with the LP5 thermometer with 6 mm diameter spot and 40 mm diameter aperture



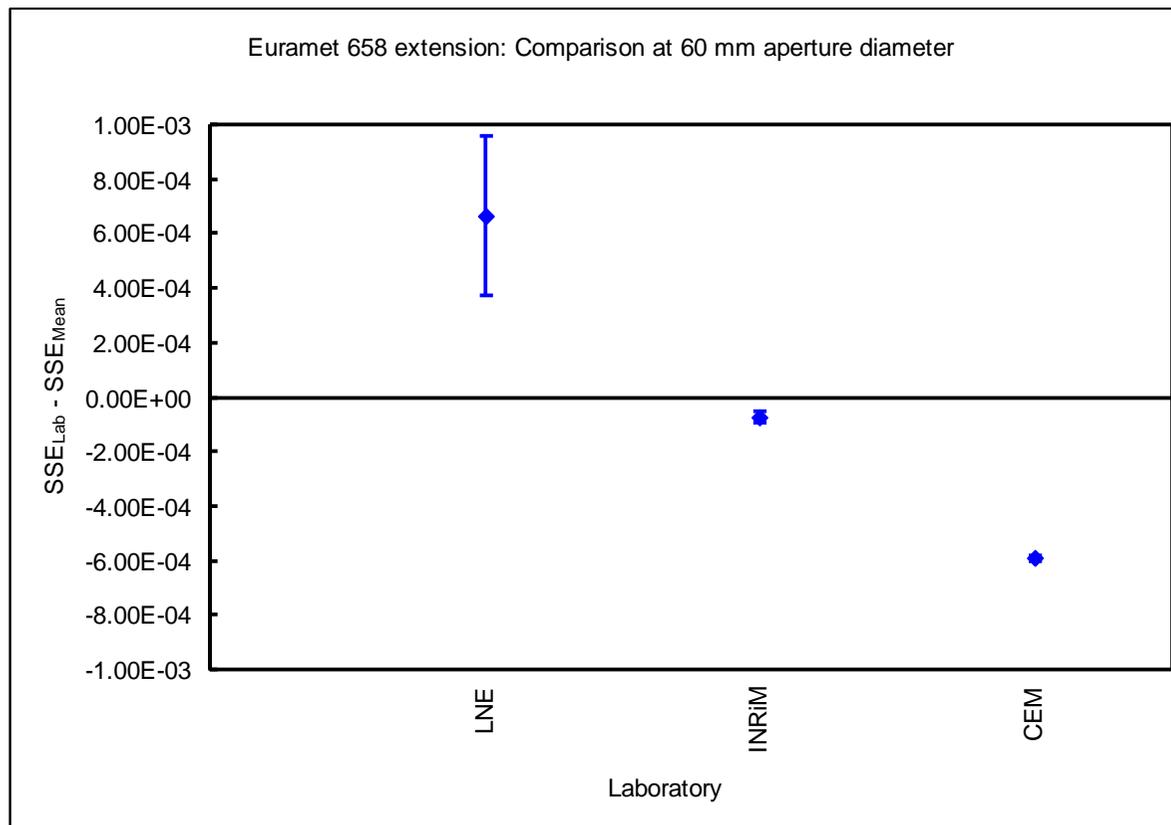
	NPL	LNE	INRiM	UME	CEM
NPL	-	-0.000959 ± 1.590E-04	-0.000424 ± 1.909E-05	-0.000539 ± 2.314E-05	0.000028 ± 1.123E-05
LNE	0.001090	-	0.000535 ± 1.601E-04	0.000420 ± 1.606E-04	0.000987 ± 1.593E-04
INRiM	0.000440	0.000666	-	-0.000115 ± 2.973E-05	0.000453 ± 2.179E-05
UME	0.000558	0.000552	0.000139	-	0.000568 ± 2.540E-05
CEM	0.000038	0.001118	0.000470	0.000588	-

Table 180 – comparison of indirect SSE measurements with the LP5 thermometer with 6 mm diameter spot and 50 mm diameter aperture



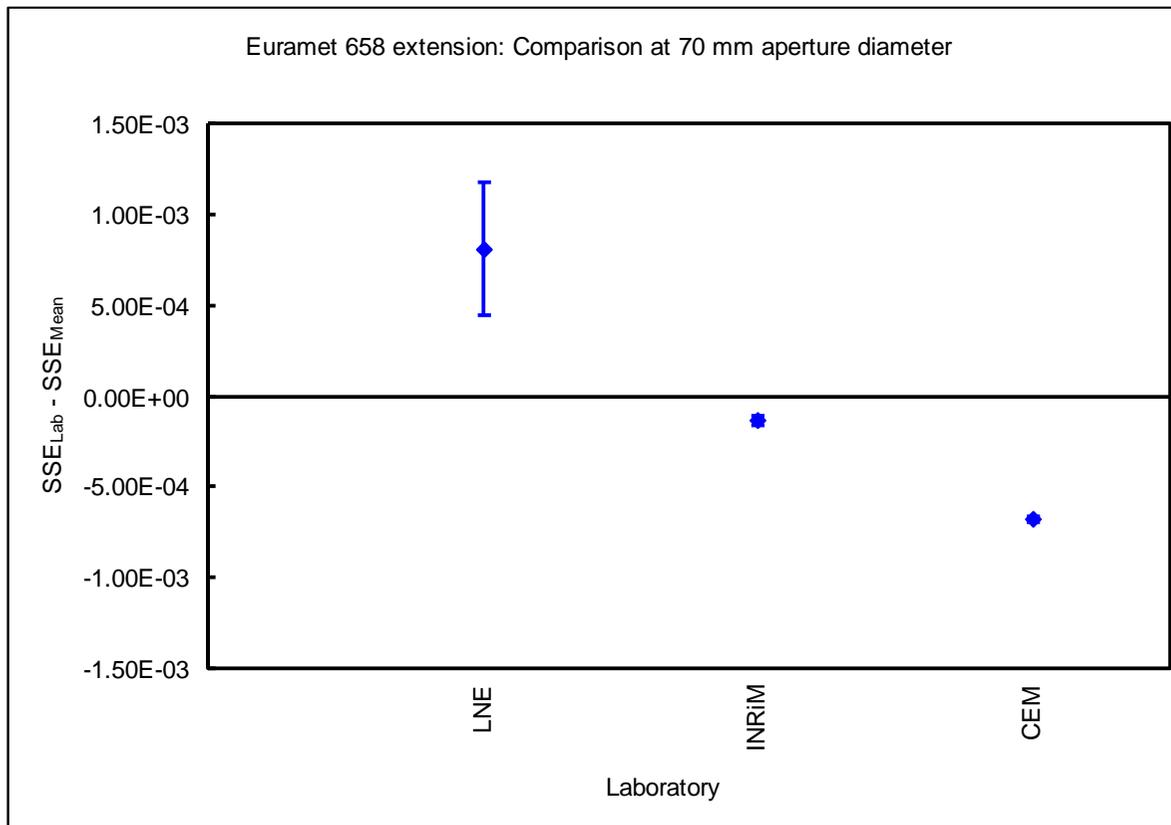
	LNE	INRiM	CEM
LNE	-	0.000740 ± 2.931E-04	0.001255 ± 2.925E-04
INRiM	0.000981	-	0.000515 ± 2.488E-05
CEM	0.001495	0.000535	-

Table 181 – comparison of indirect SSE measurements with the LP5 thermometer with 6 mm diameter spot and 60 mm diameter aperture



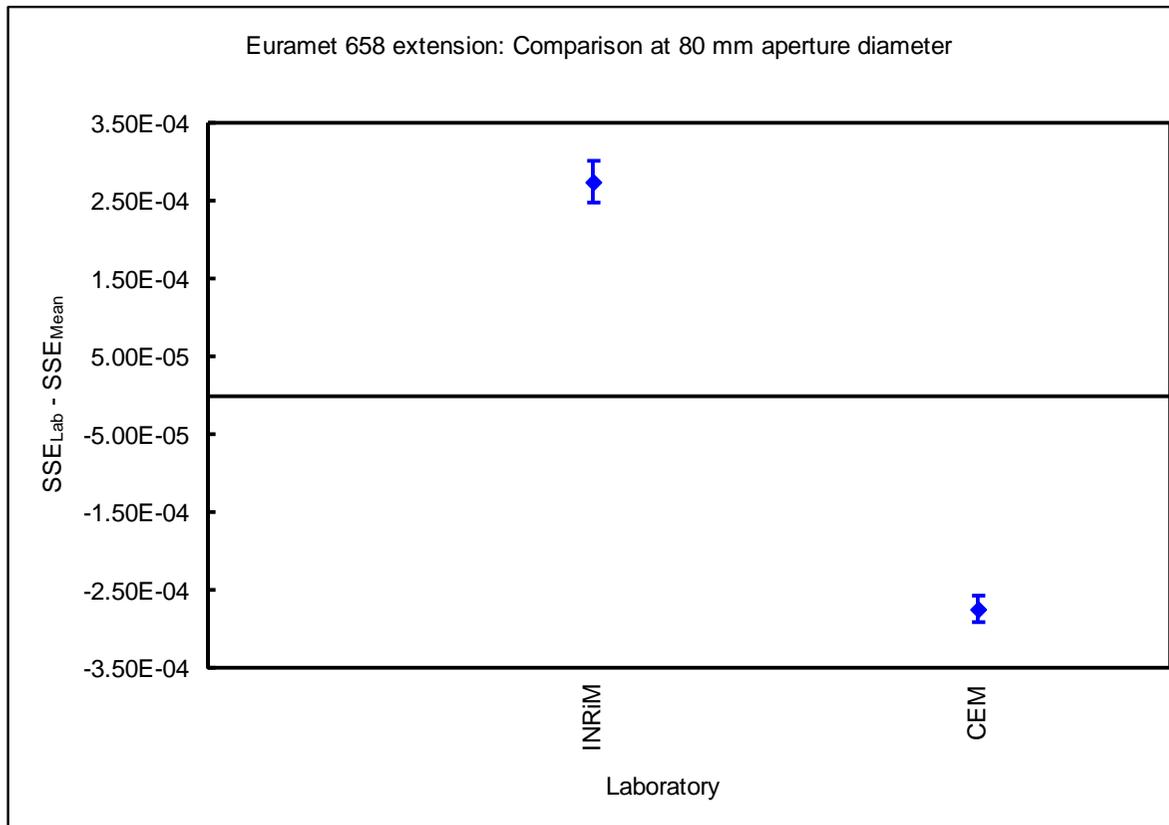
	LNE	INRiM	CEM
LNE	-	0.000944 ± 3.713E-04	0.001487 ± 3.707E-04
INRiM	0.001250	-	0.000542 ± 2.841E-05
CEM	0.001792	0.000566	-

Table 182 – comparison of indirect SSE measurements with the LP5 thermometer with 6 mm diameter spot and 70 mm diameter aperture



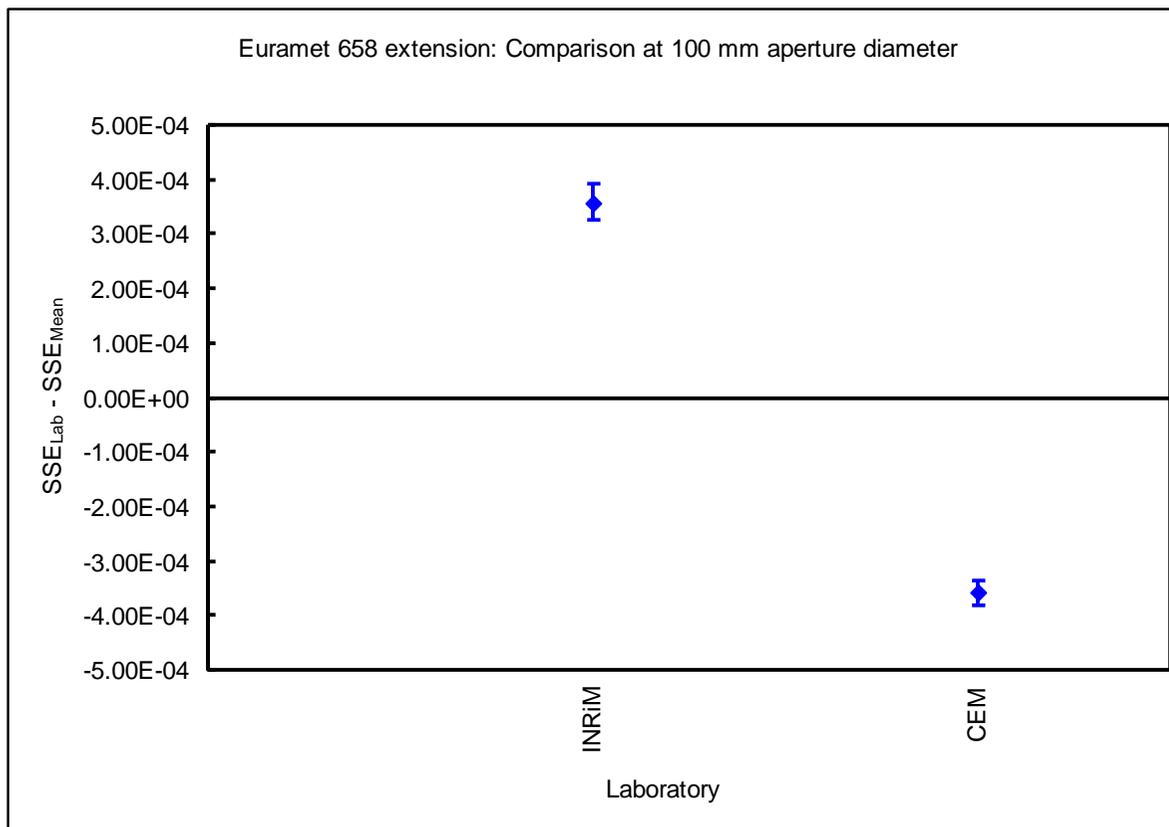
	INRiM	CEM
INRiM	-	0.000548 ± 3.209E-05
CEM	0.000575	-

Table 183 – comparison of indirect SSE measurements with the LP5 thermometer with 6 mm diameter spot and 80 mm diameter aperture



	INRiM	CEM
INRiM	-	0.000716 ± 3.942E-05
CEM	0.000748	-

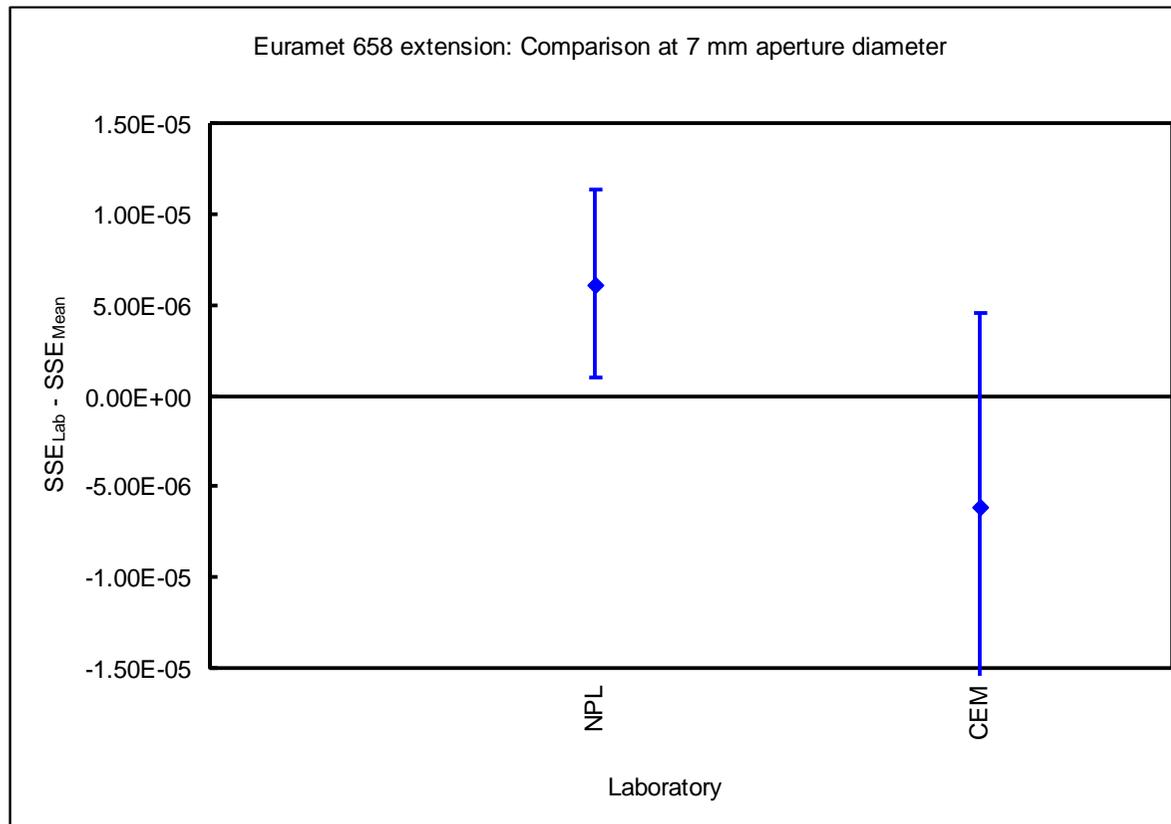
Table 184 – comparison of indirect SSE measurements with the LP5 thermometer with 6 mm diameter spot and 100 mm diameter aperture



1.8.8 The LP5 thermometer ‘indirect’ SSE results – 6 mm spot, excl. LNE

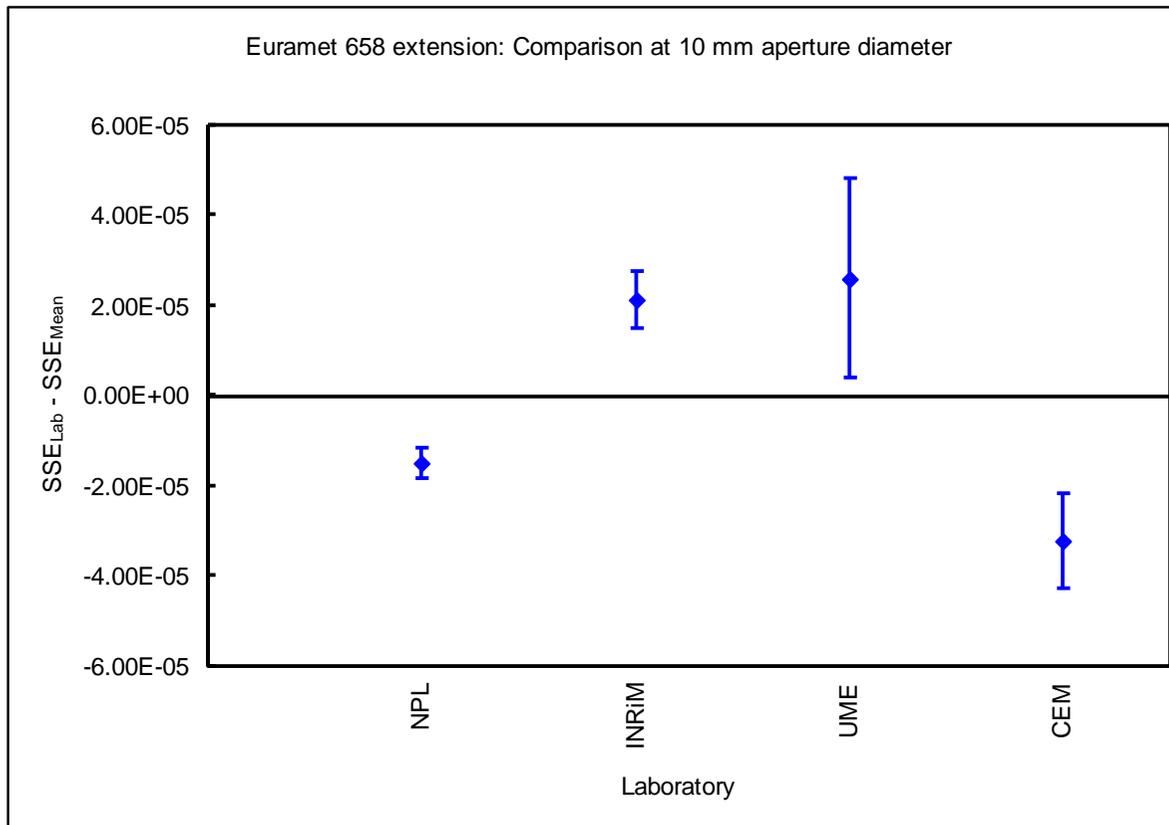
	NPL	CEM
NPL	-	0.000012 ± 1.186E-05
CEM	0.000022	-

Table 185 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 6 mm diameter spot and 7 mm diameter aperture



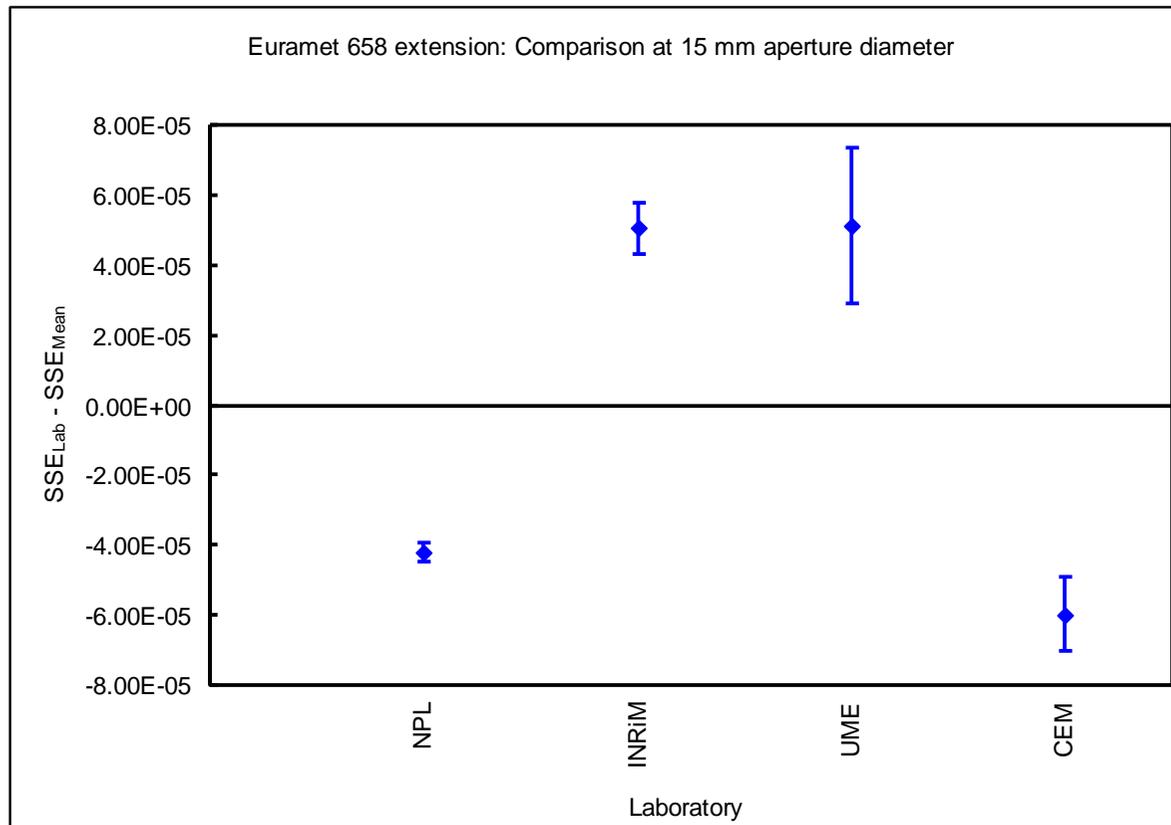
	NPL	INRiM	UME	CEM
NPL	-	$-0.000036 \pm 7.165E-06$	$-0.000041 \pm 2.242E-05$	$0.000017 \pm 1.116E-05$
INRiM	0.000042	-	$-0.000005 \pm 2.307E-05$	$0.000053 \pm 1.241E-05$
UME	0.000059	0.000024	-	$0.000058 \pm 2.460E-05$
CEM	0.000026	0.000064	0.000078	-

Table 186 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 6 mm diameter spot and 10 mm diameter aperture



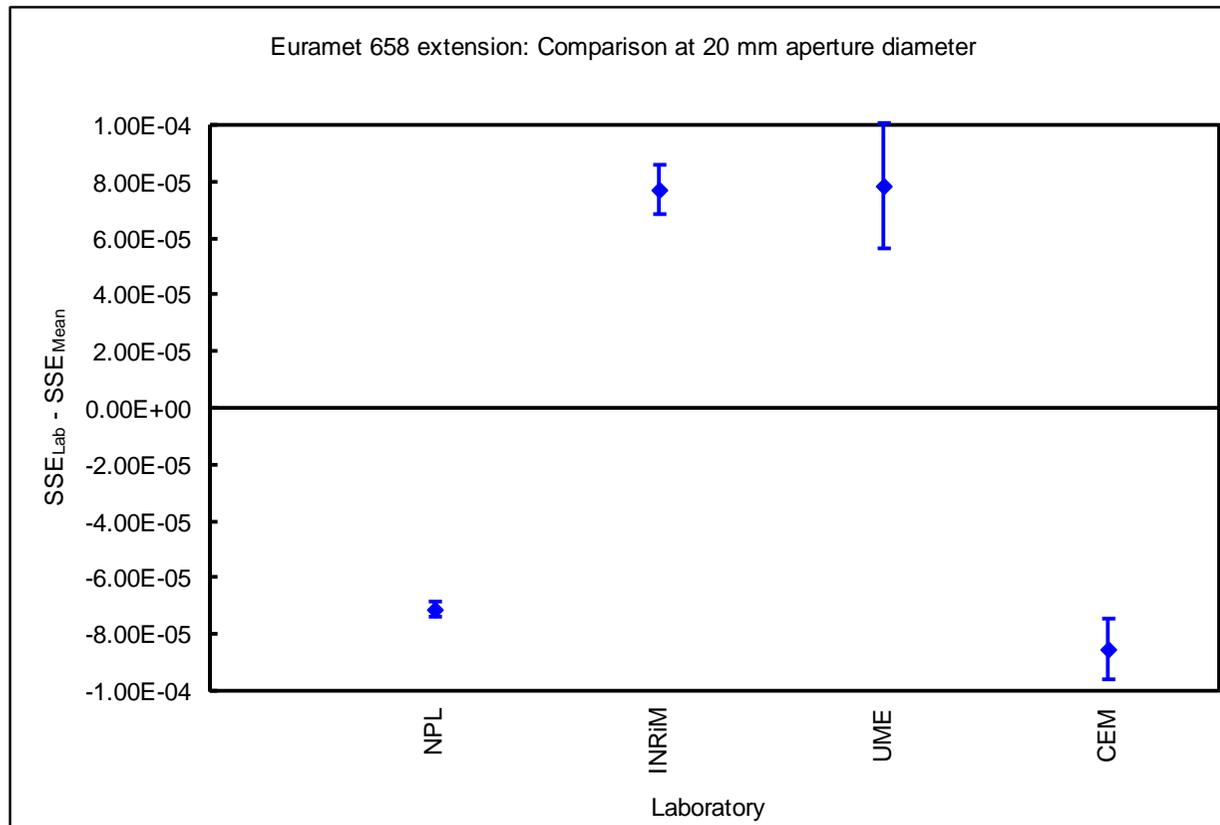
	NPL	INRiM	UME	CEM
NPL	-	-0.000093 ± 7.821E-06	-0.000094 ± 2.249E-05	0.000018 ± 1.100E-05
INRiM	0.000099	-	-0.000001 ± 2.351E-05	0.000110 ± 1.296E-05
UME	0.000112	0.000023	-	0.000111 ± 2.475E-05
CEM	0.000027	0.000121	0.000131	-

Table 187 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 6 mm diameter spot and 15 mm diameter aperture



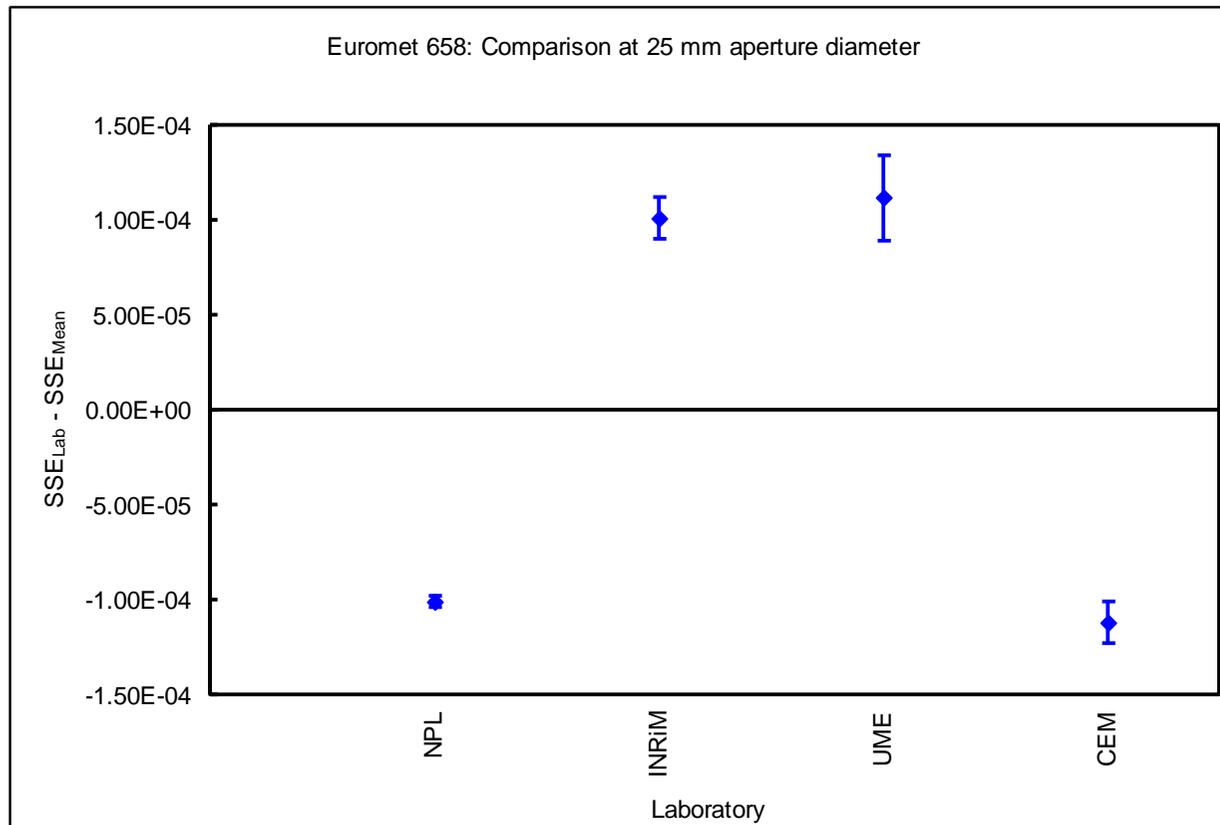
	NPL	INRiM	UME	CEM
NPL	-	-0.000149 ± 9.127E-06	-0.000150 ± 2.249E-05	0.000014 ± 1.110E-05
INRiM	0.000156	-	-0.000001 ± 2.398E-05	0.000162 ± 1.386E-05
UME	0.000168	0.000024	-	0.000164 ± 2.479E-05
CEM	0.000023	0.000174	0.000184	-

Table 188 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 6 mm diameter spot and 20 mm diameter aperture



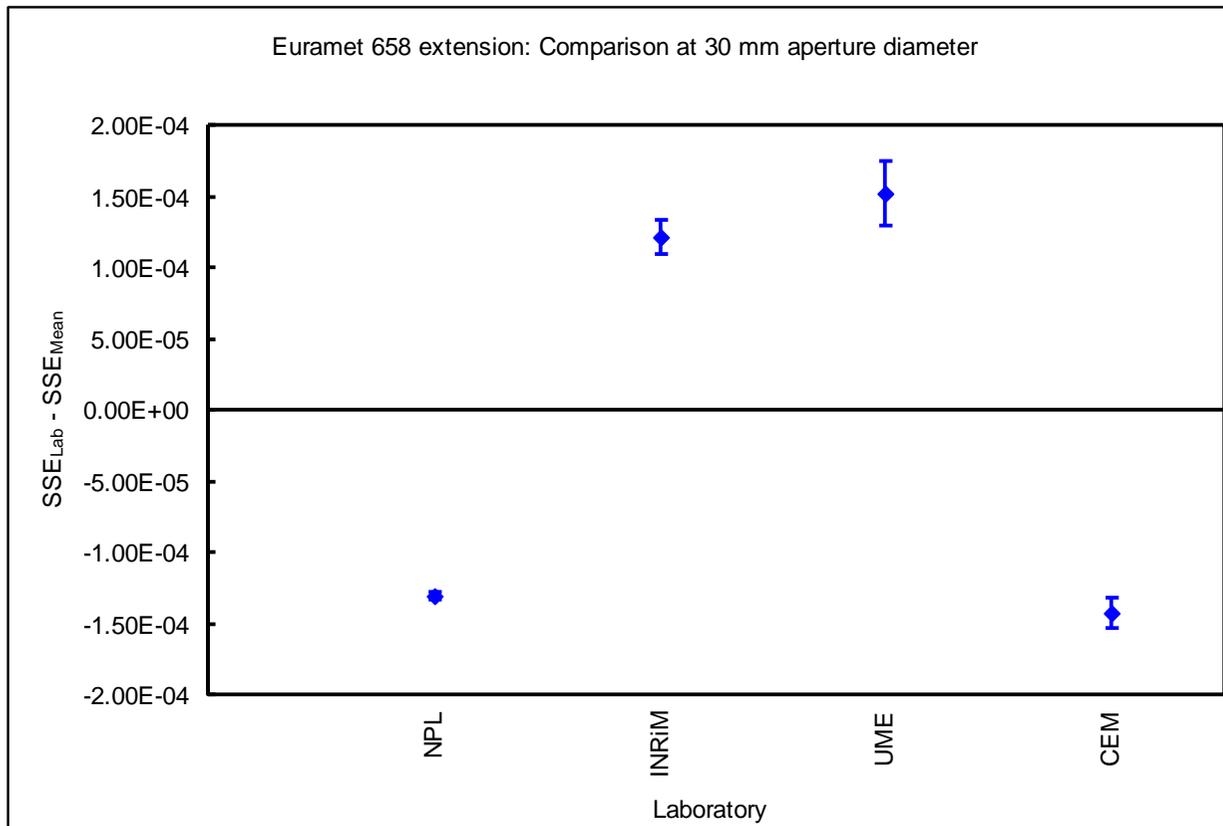
	NPL	INRiM	UME	CEM
NPL	-	$-0.000202 \pm 1.106E-05$	$-0.000213 \pm 2.268E-05$	$0.000011 \pm 1.123E-05$
INRiM	0.000211	-	$-0.000011 \pm 2.489E-05$	$0.000213 \pm 1.520E-05$
UME	0.000231	0.000031	-	$0.000224 \pm 2.496E-05$
CEM	0.000020	0.000226	0.000244	-

Table 189 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 6 mm diameter spot and 25 mm diameter aperture



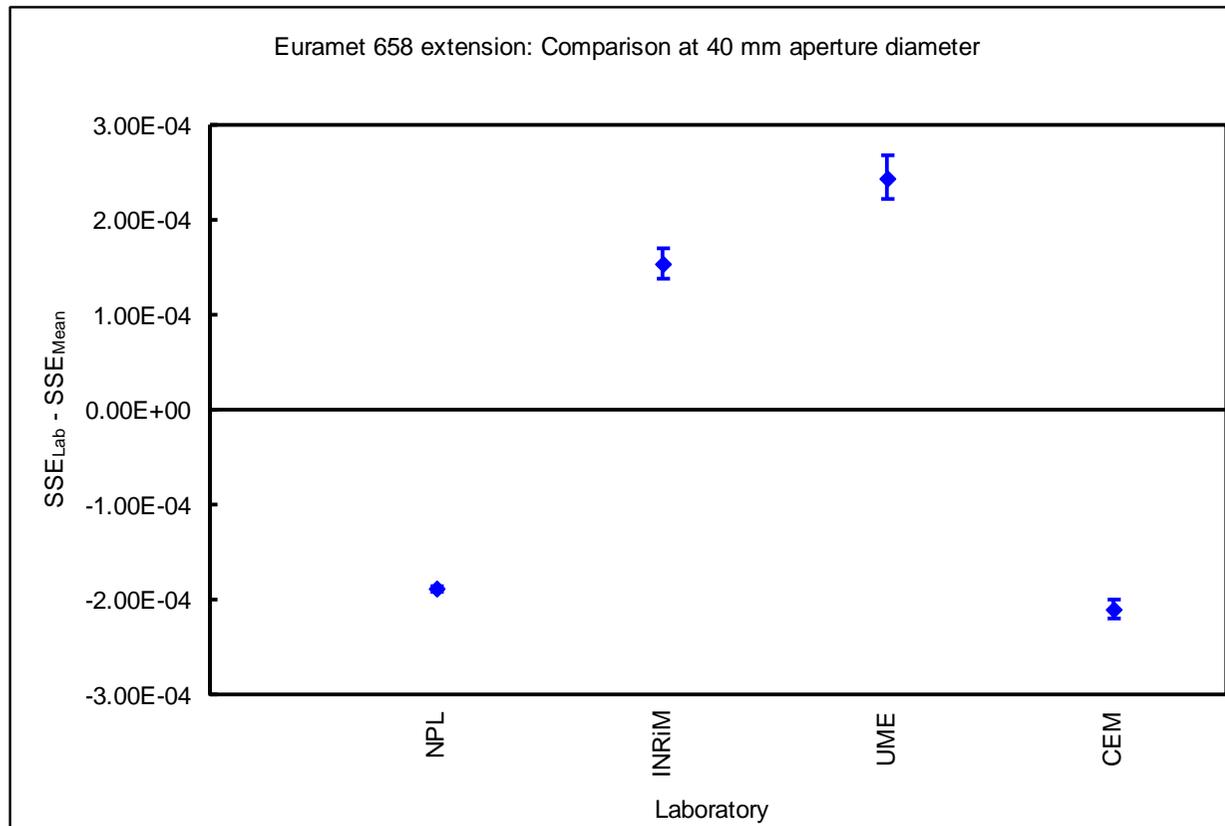
	NPL	INRiM	UME	CEM
NPL	-	$-0.000252 \pm 1.260E-05$	$-0.000283 \pm 2.282E-05$	$0.000012 \pm 1.119E-05$
INRiM	0.000262	-	$-0.000031 \pm 2.576E-05$	$0.000264 \pm 1.638E-05$
UME	0.000302	0.000052	-	$0.000295 \pm 2.510E-05$
CEM	0.000021	0.000277	0.000316	-

Table 190 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 6 mm diameter spot and 30 mm diameter aperture



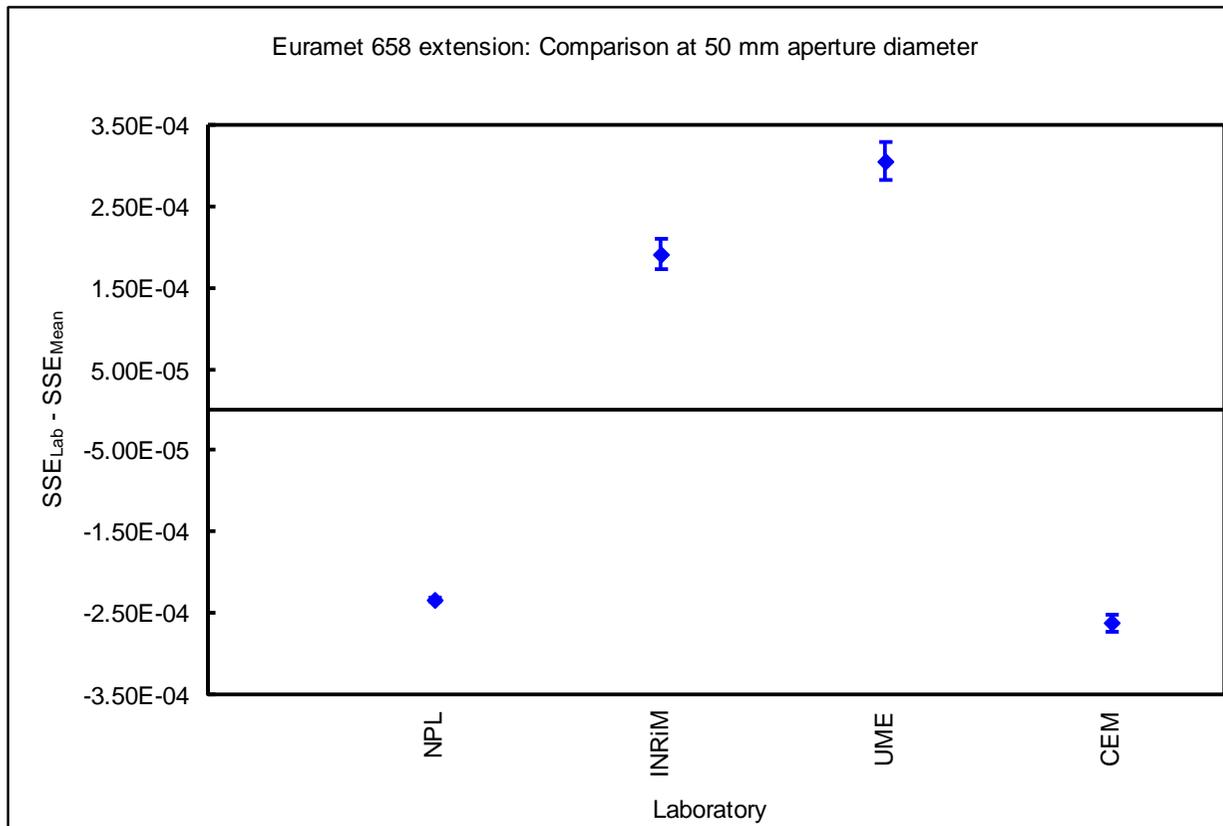
	NPL	INRiM	UME	CEM
NPL	-	-0.000342 ± 1.591E-05	-0.000433 ± 2.314E-05	0.000021 ± 1.120E-05
INRiM	0.000355	-	-0.000091 ± 2.779E-05	0.000364 ± 1.904E-05
UME	0.000452	0.000114	-	0.000454 ± 2.539E-05
CEM	0.000031	0.000379	0.000475	-

Table 191 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 6 mm diameter spot and 40 mm diameter aperture



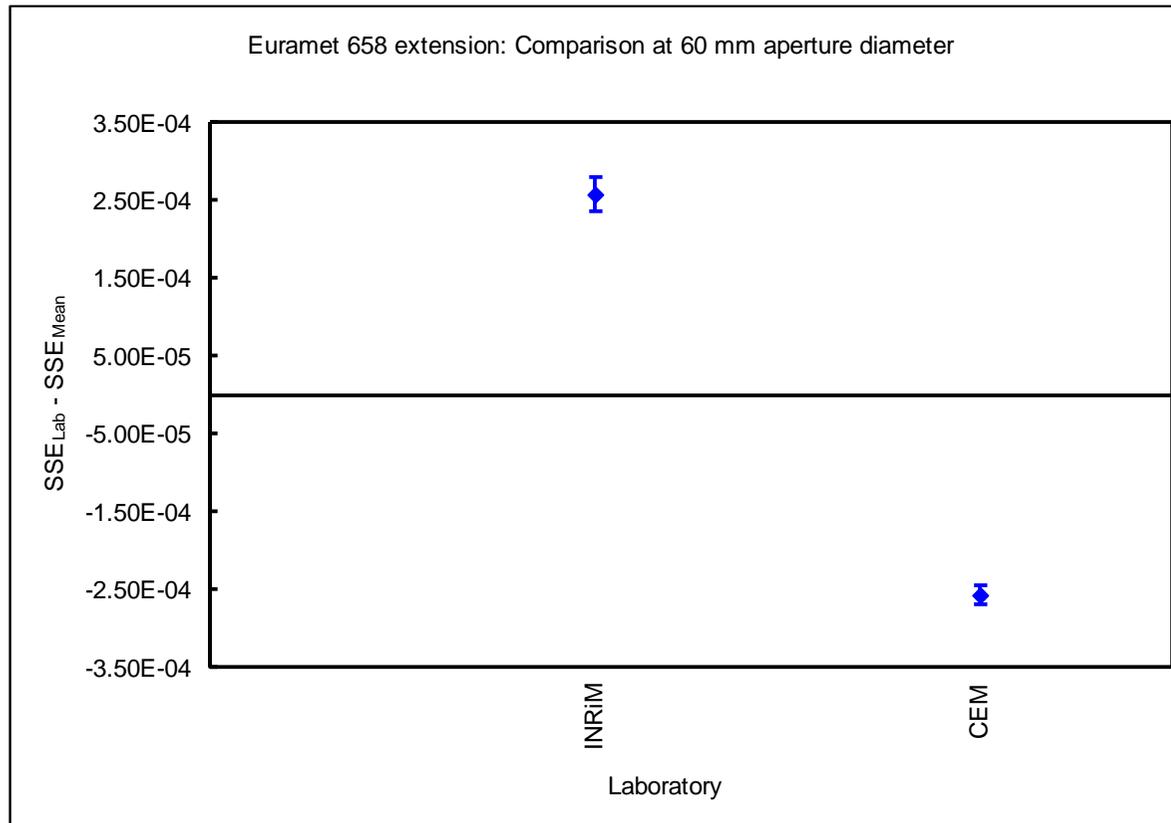
	NPL	INRiM	UME	CEM
NPL	-	-0.000424 ± 1.909E-05	-0.000539 ± 2.314E-05	0.000028 ± 1.123E-05
INRiM	0.000440	-	-0.000115 ± 2.973E-05	0.000453 ± 2.179E-05
UME	0.000558	0.000139	-	0.000568 ± 2.540E-05
CEM	0.000038	0.000470	0.000588	-

Table 192 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 6 mm diameter spot and 50 mm diameter aperture



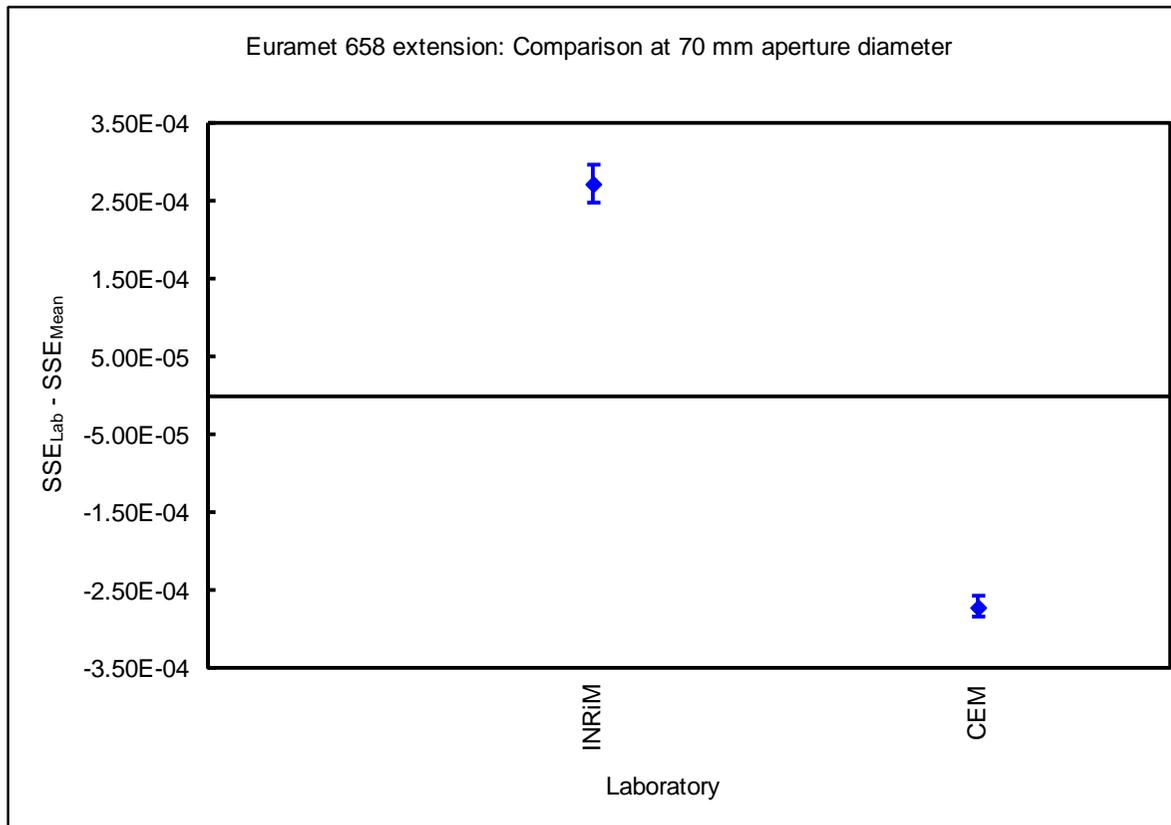
	INRiM	CEM
INRiM	-	0.000515 ± 2.488E-05
CEM	0.000535	-

Table 193 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 6 mm diameter spot and 60 mm diameter aperture



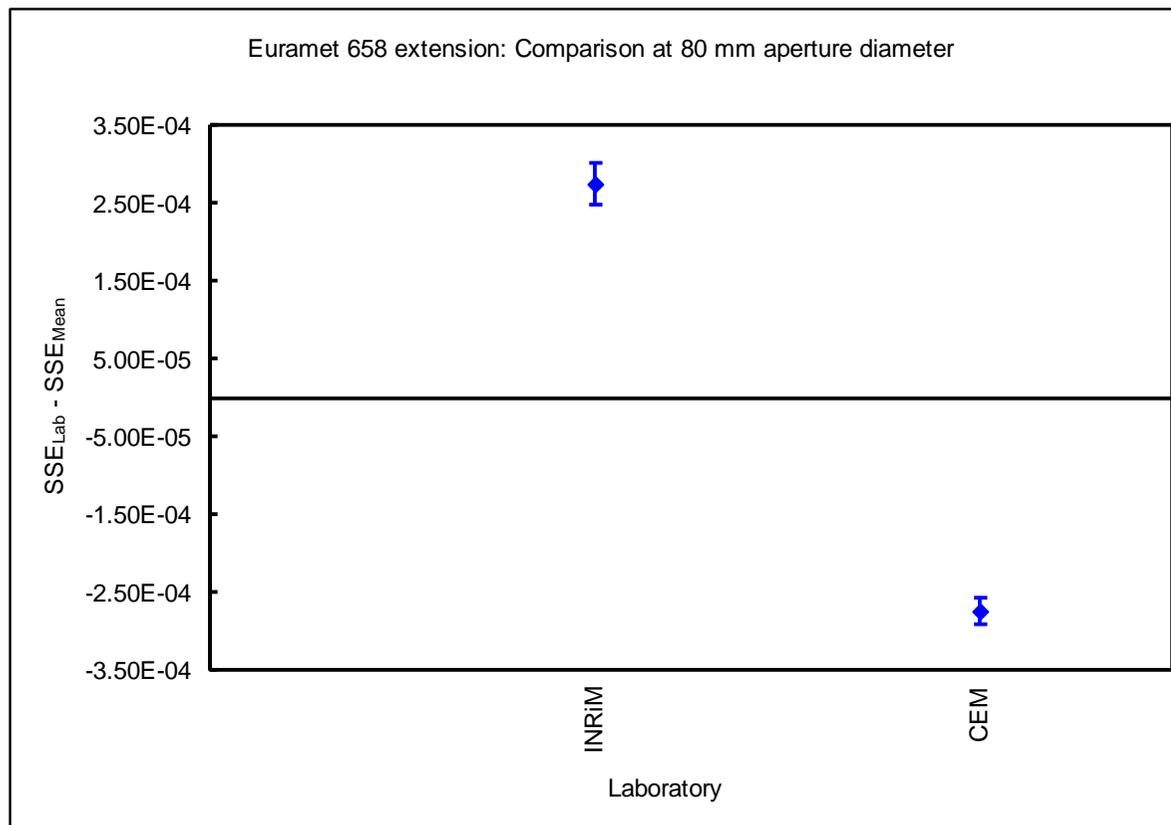
	INRiM	CEM
INRiM	-	0.000542 ± 2.841E-05
CEM	0.000566	-

Table 194 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 6 mm diameter spot and 70 mm diameter aperture



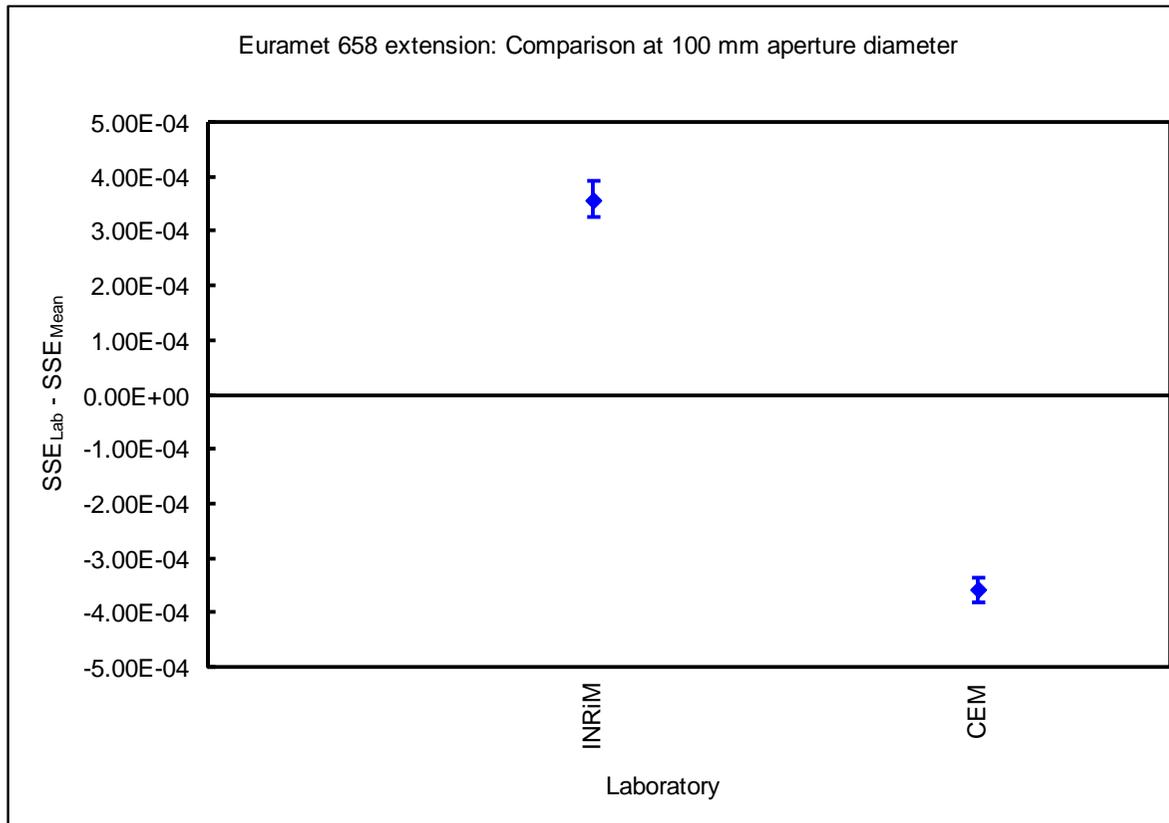
	INRiM	CEM
INRiM	-	0.000548 ± 3.209E-05
CEM	0.000575	-

Table 195 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 6 mm diameter spot and 80 mm diameter aperture



	INRiM	CEM
INRiM	-	0.000716 ± 3.942E-05
CEM	0.000748	-

Table 196 – comparison of indirect SSE measurements with the LP5 thermometer, excluding LNE data - 6 mm diameter spot and 100 mm diameter aperture



2 THE GAIN RATIO MEASUREMENTS

2.1 APPARATUS USED FOR GAIN RATIO MEASUREMENTS

The results of the measurements of the gain and range ratios of the two thermometers are given in Tables 197 to 203. The majority of the laboratories measured the gain ratios using a stable reference blackbody source set at appropriate temperatures. The INRiM measurements were made using a high stability tungsten ribbon lamp and/or an integrating sphere with suitable neutral filters mounted on the front of the objective of the thermometers.

2.2 RESULTS OF THE MEASUREMENTS

2.2.1 The results for the LP5 thermometer

Laboratory	Nominal source temperature/ °C	Range ratio R2/ R1	Uncertainty ($k=2$)
PTB	420	0.999822 [†]	1 E ⁻¹³ A
PTB	600	1.000063	8 E ⁻¹⁴ A
NPL	500	1.000352	0.000204
CEM	400 to 600	1.000452	0.00106
UME	232	0.982026	0.083850
UME	250	0.997150	0.031816
LNE	600	0.009907*	0.018392
METAS	420	1.000552	0.00105 °C
INRiM	N/A	1.001268	0.000094

Table 197: the results of the range ratio measurements with the LP5 thermometer

[†] This is the average of two values

*The LNE value was measured using the LP5 analogue output (voltage) rather than the photocurrent, and is not consistent with the other values. It has therefore not been included in the subsequent analysis. (This only affects the range ratio measurements; the other measurements were carried out using the photocurrent.)

2.2.2 The results for the INRiM thermometer

CEM calculated the gain ratios by converting the thermometer signals from voltage to current using the value of the amplifier gain setting, leading to gain ratios of ~1.0. In order to compare the CEM results with those of the other laboratories, the values have been re-calculated by converting the signals back to the 'raw' voltage values. The CEM values in square brackets are the original values.

Laboratory	INRiM gain ratio $\times 10^{10}/ \times 10^9$	Uncertainty ($k=2$)
PTB	9.21948	0.00080
NPL	9.21781	0.00303
CEM	[0.92143] 9.21425	[0.02401] 0.24014
UME	9.21615	0.02642
LNE	-	-
METAS	9.22504	0.00105 °C
INRiM	-	-

Table 198: the results of the gain ratio measurements for the INRiM thermometer ($\times 10^{10}/ \times 10^9$ gains)

Laboratory	INRiM gain ratio $\times 10^9 / \times 10^8$	Uncertainty ($k=2$)
PTB	10.89522	0.00090
NPL	10.88970	0.00615
CEM	[1.08874] 10.88744	[0.00128] 0.1278
UME	10.88964	0.00071
LNE	-	-
METAS	10.89079	0.00105 °C
INRiM	10.88963	0.00102

Table 199: the results of the gain ratio measurements for the INRiM thermometer ($\times 10^9 / \times 10^8$ gains)

Laboratory	INRiM gain ratio $\times 10^8 / \times 10^7$	Uncertainty ($k=2$)
PTB	10.05744	0.00001
NPL	10.05739	0.00137
CEM	[1.00575] 10.05747	[0.00014] 0.00137
UME	-	-
LNE	10.06362	0.00302
METAS	-	-
INRiM	10.05765	0.00095

Table 200: the results of the gain ratio measurements for the INRiM thermometer ($\times 10^8 / \times 10^7$ gains)

Laboratory	INRiM gain ratio $\times 10^7 / \times 10^6$	Uncertainty ($k=2$)
PTB	9.99478	0.00002
NPL	9.99382	0.00097
CEM	[0.99948] 9.99482	[0.00020] 0.00203
UME	9.99496	0.00095
LNE	9.99980	0.00127
METAS	9.99241	0.00105 °C
INRiM	9.99524	0.00094

Table 201: the results of the gain ratio measurements for the INRiM thermometer ($\times 10^7 / \times 10^6$ gains)

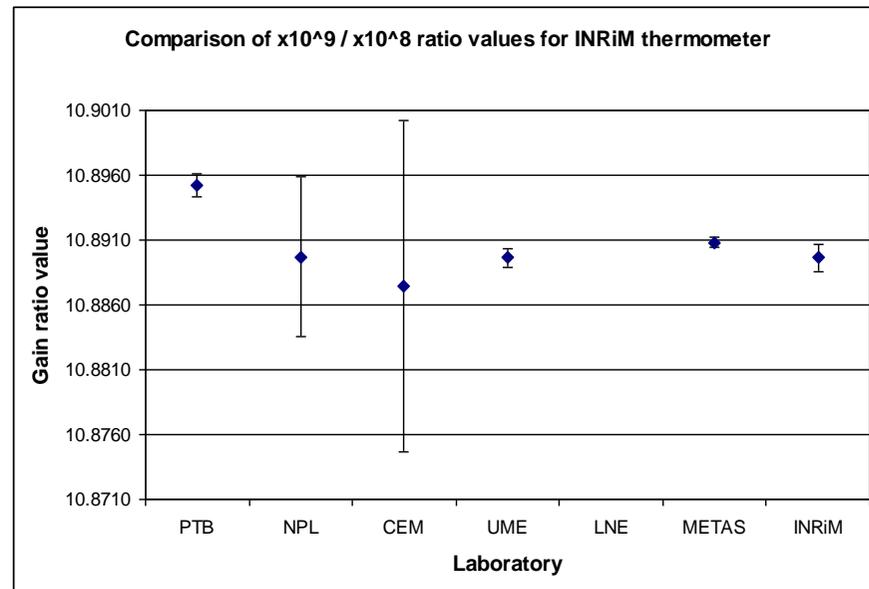
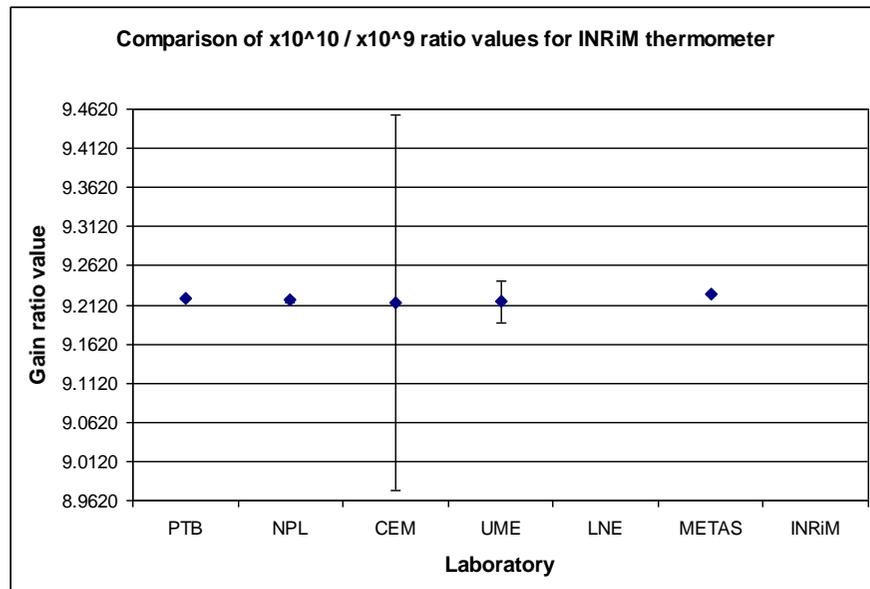
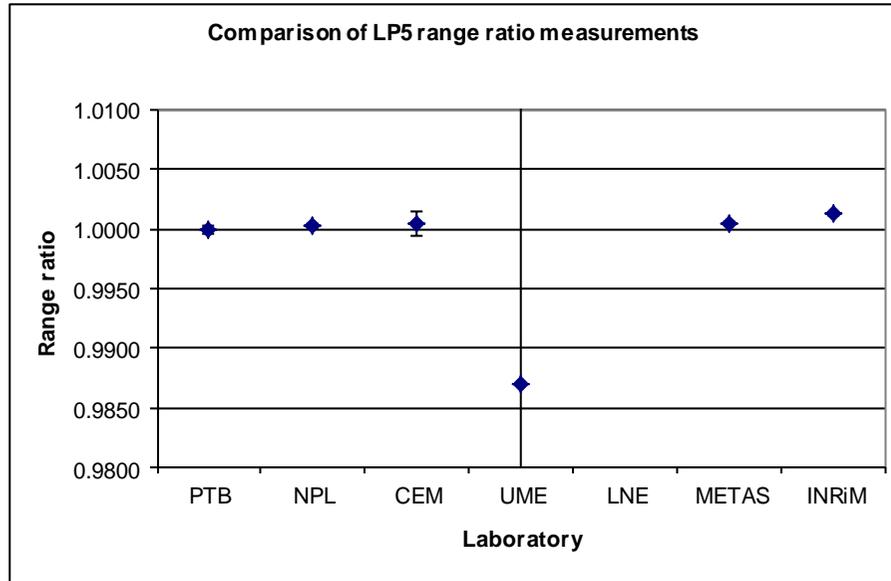
Laboratory	INRiM gain ratio $\times 10^6 / \times 10^5$	Uncertainty ($k=2$)
PTB	10.00859	0.00002
NPL	10.00861	0.00053
CEM	[1.00034] 10.00335	[0.00010] 0.00097
UME	9.97569	0.00721
LNE	10.00582	0.00080
METAS	10.00498	0.00105 °C
INRiM	10.00430	0.00094

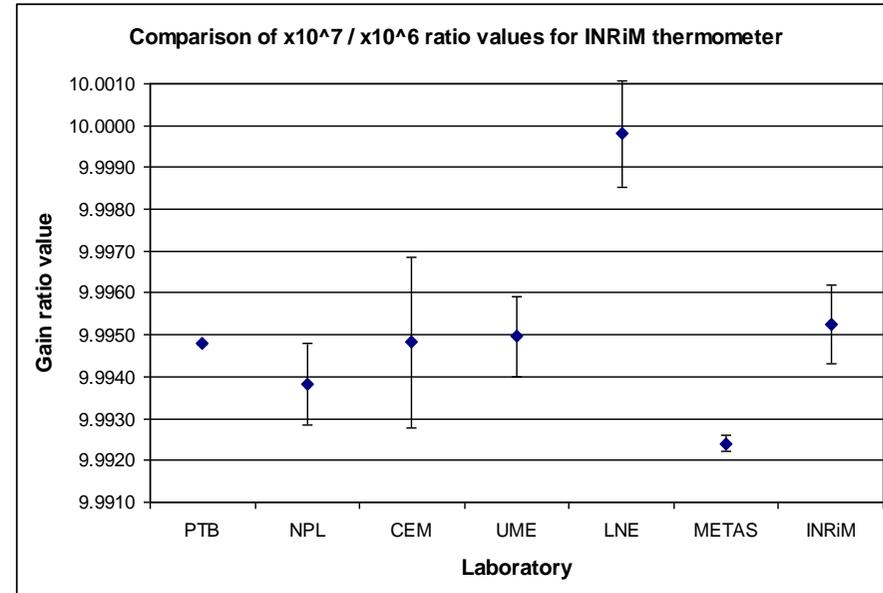
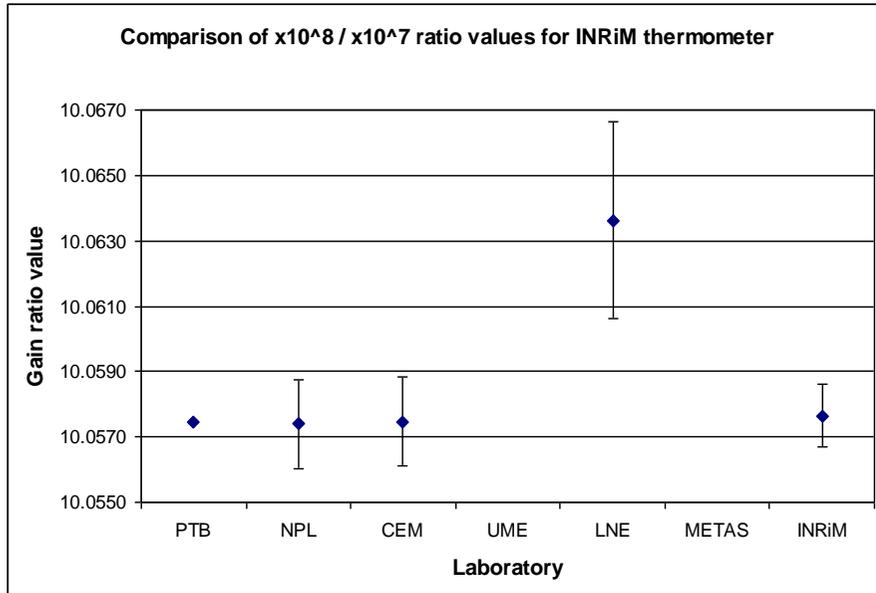
Table 202: the results of the gain ratio measurements for the INRiM thermometer ($\times 10^6 / \times 10^5$ gains)

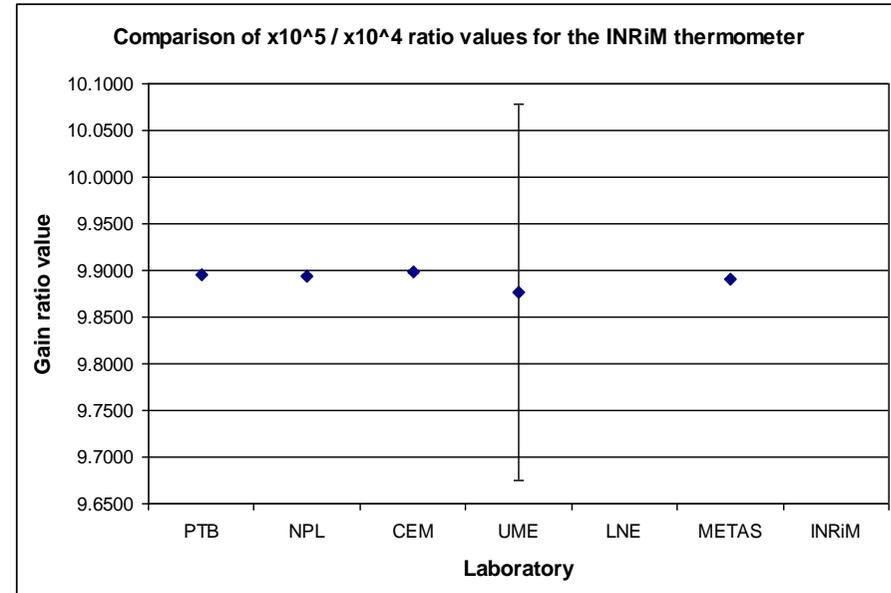
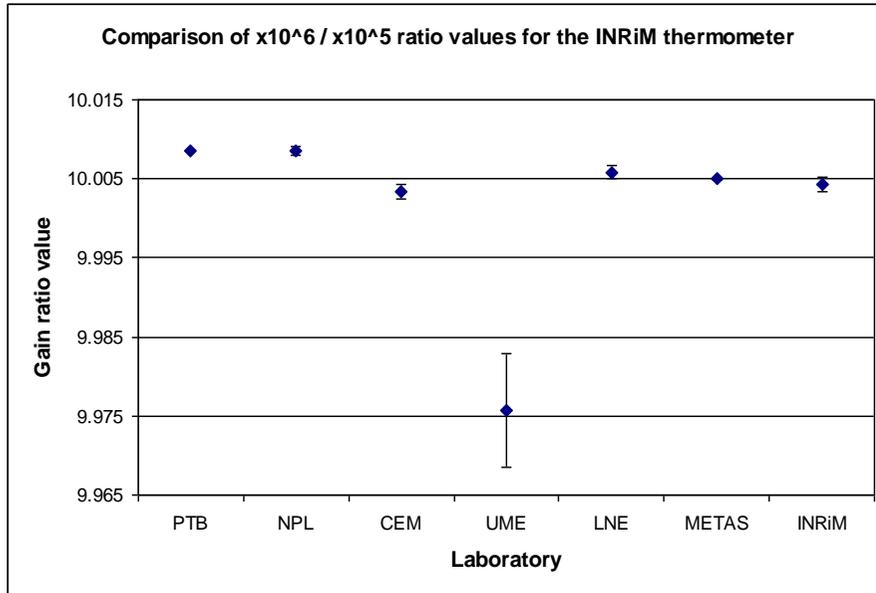
Laboratory	INRiM gain ratio $\times 10^5 / \times 10^4$	Uncertainty ($k=2$)
PTB	9.89589	0.00003
NPL	9.89421	0.00049
CEM	[0.98984] 9.89844	[0.00020] 0.00199
UME	9.87689	0.20126
LNE	-	-
METAS	9.89060	0.00105 °C
INRiM	-	-

Table 203: the results of the gain ratio measurements for the INRiM thermometer ($\times 10^5 / \times 10^4$ gains)

The results are plotted graphically in the seven Figures below, along with the $k = 2$ uncertainty bars. Where the gain/ range ratio uncertainty was given in terms of a different unit (for example, the METAS uncertainties were given in terms of an equivalent temperature uncertainty) the values were converted to be in terms of the gain/ range ratio value, so that all the results could be plotted and compared consistently.







2.3 ANALYSIS OF THE GAIN RATIO RESULTS

For the LP5 thermometer, when a laboratory had provided two or more values for the range ratio, measured at different source temperatures, the average value for that laboratory was calculated.

The mean and median values of the participant results were then calculated for each of the measured gain or range ratios. As was noted previously, the LNE result for the LP5 was not consistent with those of the other laboratories, due to it having been measured using the analogue (voltage) signal rather than the photocurrent, and so it has not been included in any of the analysis.

Summaries of the mean and median values are given in Tables 204 to 210 below, along with the difference (laboratory – mean or median). The differences are also plotted in the Figures following Table 210. Two uncertainty values ($k = 2$) are given: the first is the laboratory uncertainty; the other is the laboratory uncertainty combined with the standard deviation (stdev) of the mean (i.e. the standard deviation divided by $\sqrt{(\text{number of measurements})}$).

It was felt to be inappropriate to analyse the results further by calculating the DOE and QDE₉₅ values.

2.3.1 Average results for the LP5

Laboratory	R2/R1	Diff from mean	Diff from median	Laboratory		U ($k=2$) with stdev of mean of all results
				u ($k=1$)	U ($k=2$)	
PTB	0.999902*	0.001645	-0.000500	0.000169	0.000337*	0.004523
NPL	1.000352	0.002095	-0.000050	0.000102	0.000204	0.004515
CEM	1.000452	0.002195	0.000050	0.000530	0.001060	0.004634
UME	0.987016*	-0.011241	-0.013386	0.021888	0.043776*	0.044008
LNE	0.009907	-0.988350	-0.990495		0.018392	
METAS	1.000552	0.002295	0.000150	0.000011	0.000022	0.004511
INRiM	1.001268	0.003011	0.000866	0.000047	0.000094	0.004512
Average	0.998257					
Stdev	0.005525					
$1/\sqrt{n}$	0.002255					
Median	1.000402					

Table 204: the differences from the mean and median for the LP5 range ratio results

* average values calculated. The total laboratory uncertainty includes the stated laboratory uncertainty plus additional uncertainty for the standard deviation of the mean laboratory value.

2.3.2 Average results for the INRiM thermometer

Laboratory	$10^{10}/10^9$	Diff from mean	Diff from median	u (k=1)	U (k=2)	U (k=2) with stdev of mean of all results
PTB	9.21948	0.00094	0.00167	0.00040	0.00080	0.00377
NPL	9.21781	-0.00073	0.00000	0.00152	0.00303	0.00477
CEM	9.21425	-0.00430	-0.00356	0.12007	0.24014	0.24017
UME	9.21615	-0.00240	-0.00167	0.01321	0.02642	0.02668
LNE						
METAS	9.22504	0.00650	0.00723	0.00024	0.00047	0.00371
INRiM						
Average 9.21855 Stdev 0.00412 $1/\sqrt{(n)}$ 0.00184 Median 9.21781						

Table 205: the differences from the mean and median for the INRiM $\times 10^{10}/\times 10^9$ gain ratio results

Laboratory	$10^9/10^8$	Diff from mean	Diff from median	u (k=1)	U (k=2)	U (k=2) with stdev of mean of all results
PTB	10.89522	0.00482	0.00555	0.00045	0.00090	0.00231
NPL	10.88970	-0.00070	0.00003	0.00308	0.00615	0.00651
CEM	10.88744	-0.00296	-0.00223	0.00639	0.01278	0.01295
UME	10.88964	-0.00076	-0.00003	0.00035	0.00071	0.00224
LNE						
METAS	10.89079	0.00039	0.00112	0.00020	0.00040	0.00216
INRiM	10.88963	-0.00077	-0.00004	0.00051	0.00102	0.00236
Average 10.89040 Stdev 0.00260 $1/\sqrt{(n)}$ 0.00106 Median 10.88967						

Table 206: the differences from the mean and median for the INRiM $\times 10^9/\times 10^8$ gain ratio results

Laboratory	10 ⁸ /10 ⁷	Diff from mean	Diff from median	u (k=1)	U (k=2)	U (k=2) with stdev of mean of all results
PTB	10.05744	-0.00127	-0.00003	0.00000	0.00001	0.00246
NPL	10.05739	-0.00133	-0.00008	0.00069	0.00137	0.00281
CEM	10.05747	-0.00125	0.00000	0.00068	0.00137	0.00281
UME						
LNE	10.06362	0.00491	0.00615	0.00151	0.00302	0.00389
METAS						
INRiM	10.05765	-0.00107	0.00018	0.00047	0.00095	0.00263
Average 10.05872 Stdev 0.00275 /√(n) 0.00123						
Median 10.05747						

Table 207: the differences from the mean and median for the INRiM $\times 10^8 / \times 10^7$ gain ratio results

Laboratory	10 ⁷ /10 ⁶	Diff from mean	Diff from median	u (k=1)	U (k=2)	U (k=2) with stdev of mean of all results
PTB	9.99478	-0.00033	-0.00003	0.00001	0.00002	0.00172
NPL	9.99382	-0.00130	-0.00100	0.00049	0.00097	0.00198
CEM	9.99482	-0.00030	0.00000	0.00102	0.00203	0.00266
UME	9.99496	-0.00016	0.00014	0.00048	0.00095	0.00197
LNE	9.99980	0.00468	0.00498	0.00063	0.00127	0.00214
METAS	9.99241	-0.00271	-0.00241	0.00010	0.00020	0.00174
INRiM	9.99524	0.00012	0.00042	0.00047	0.00094	0.00196
Average 9.99512 Stdev 0.00228 /√(n) 0.00086						
Median 9.99482						

Table 208: the differences from the mean and median for the INRiM $\times 10^7 / \times 10^6$ gain ratio results

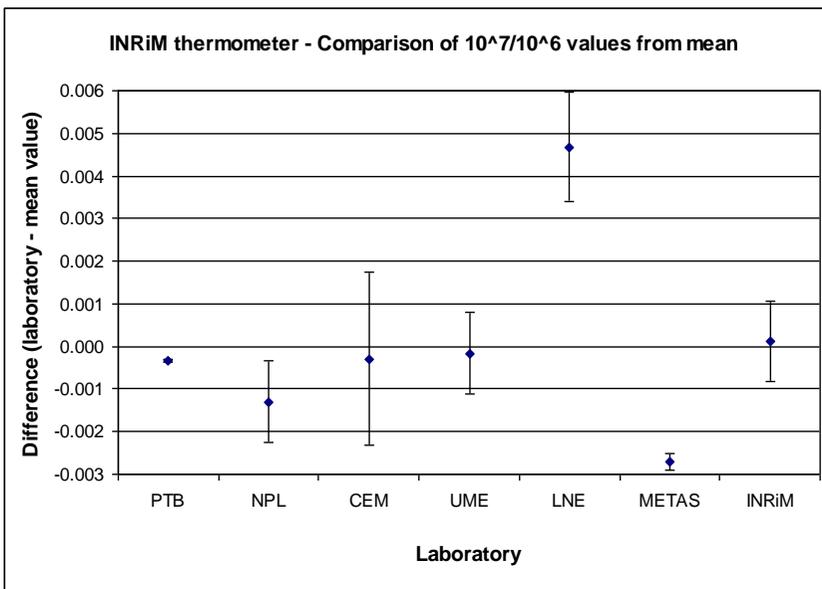
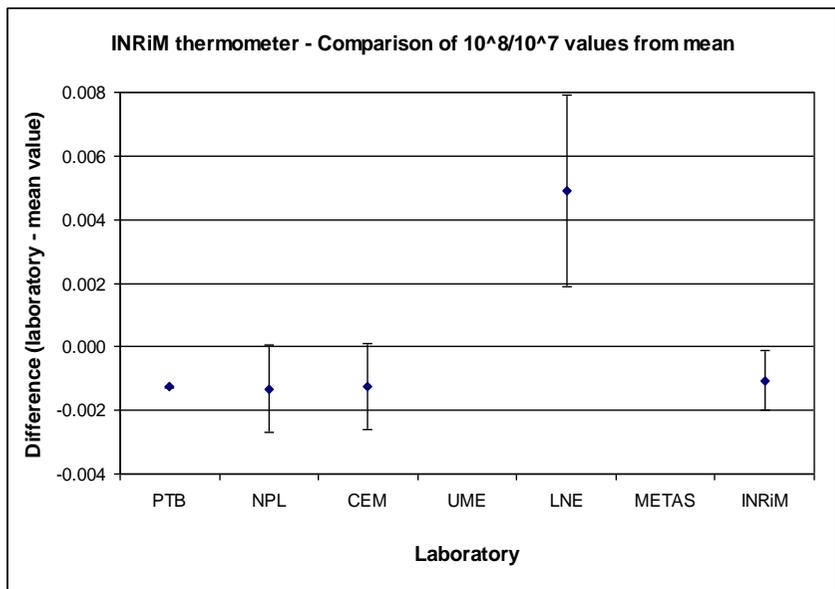
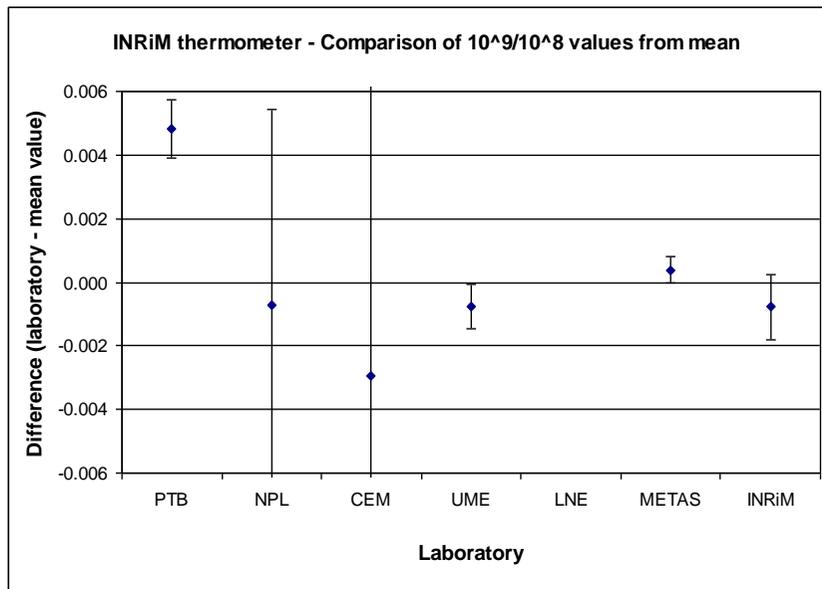
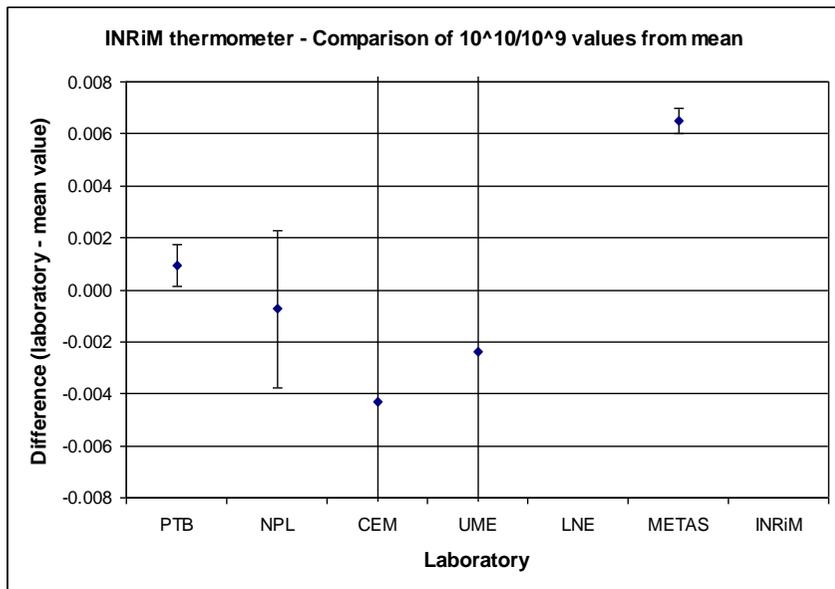
Laboratory	$10^6/10^5$	Diff from mean	Diff from median	u (k=1)	U (k=2)	U (k=2) with stdev of mean of all results
PTB	10.00859	0.00697	0.00361	0.00001	0.00002	0.00878
NPL	10.00861	0.00699	0.00363	0.00027	0.00053	0.00879
CEM	10.00335	0.00173	-0.00163	0.00048	0.00097	0.00883
UME	9.97569	-0.02593	-0.02929	0.00360	0.00721	0.01136
LNE	10.00582	0.00420	0.00084	0.00040	0.00080	0.00881
METAS	10.00498	0.00336	0.00000	0.00006	0.00011	0.00878
INRiM	10.00430	0.00268	-0.00068	0.00047	0.00094	0.00883
Average 10.00162 Stdev 0.01161 $1/\sqrt{(n)}$ 0.00439						
Median 10.00498						

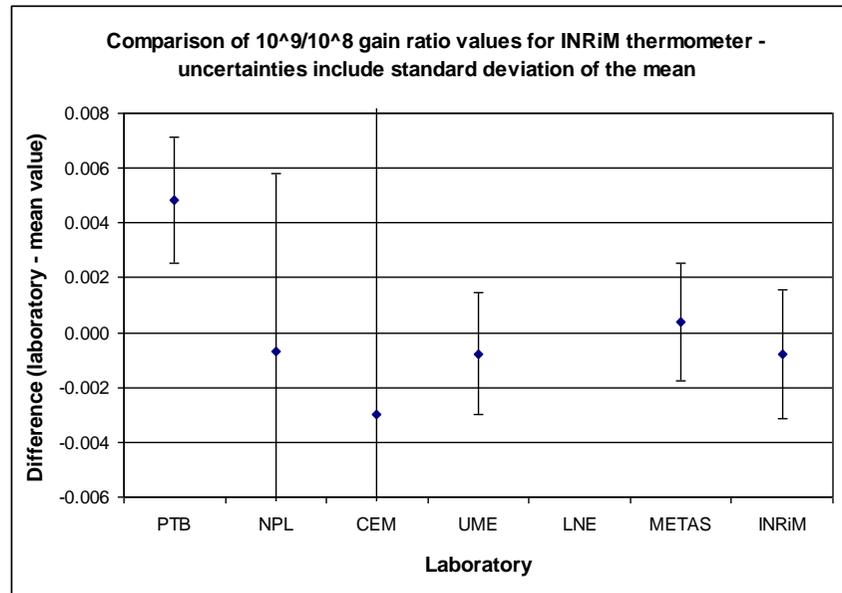
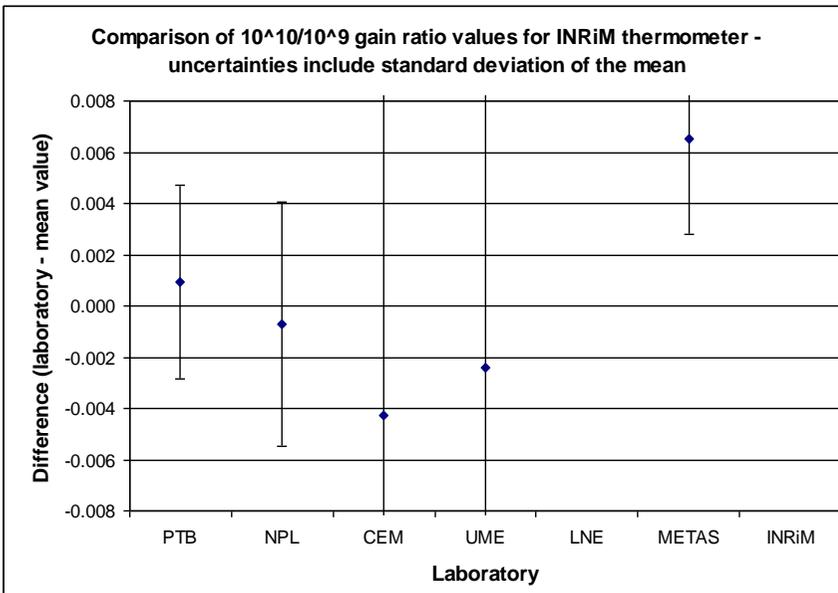
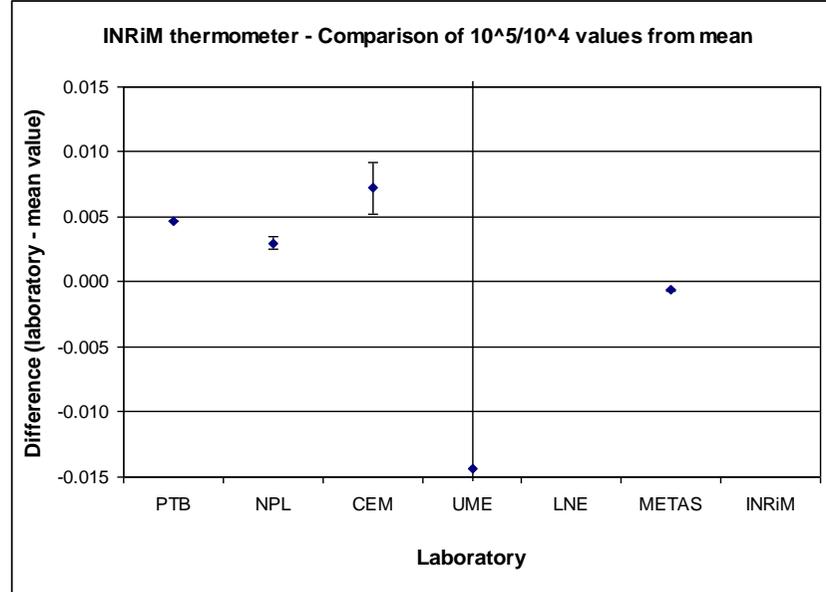
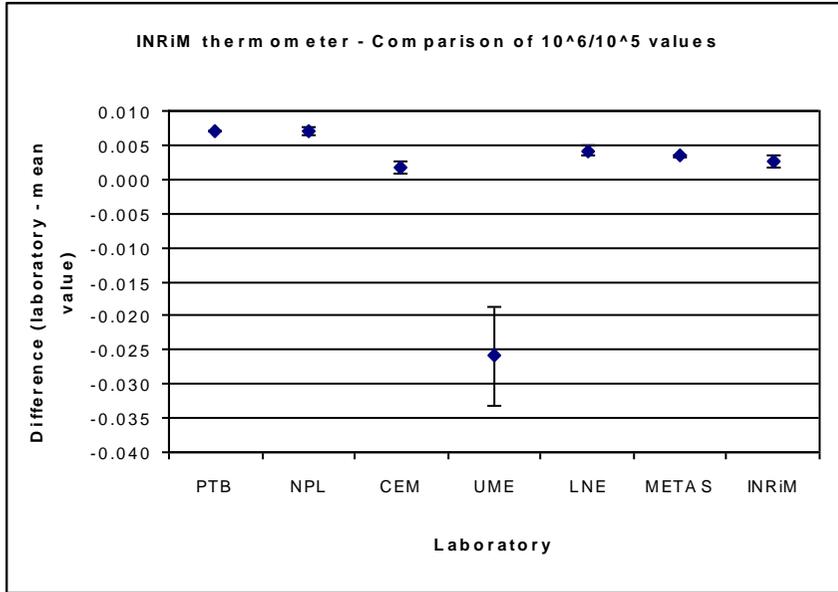
Table 209: the differences from the mean and median for the INRiM $\times 10^6/ \times 10^5$ gain ratio results

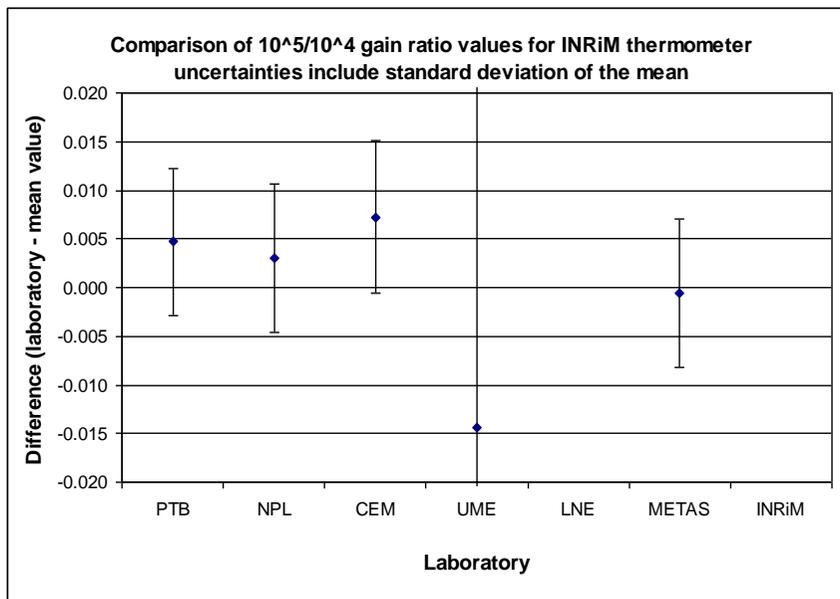
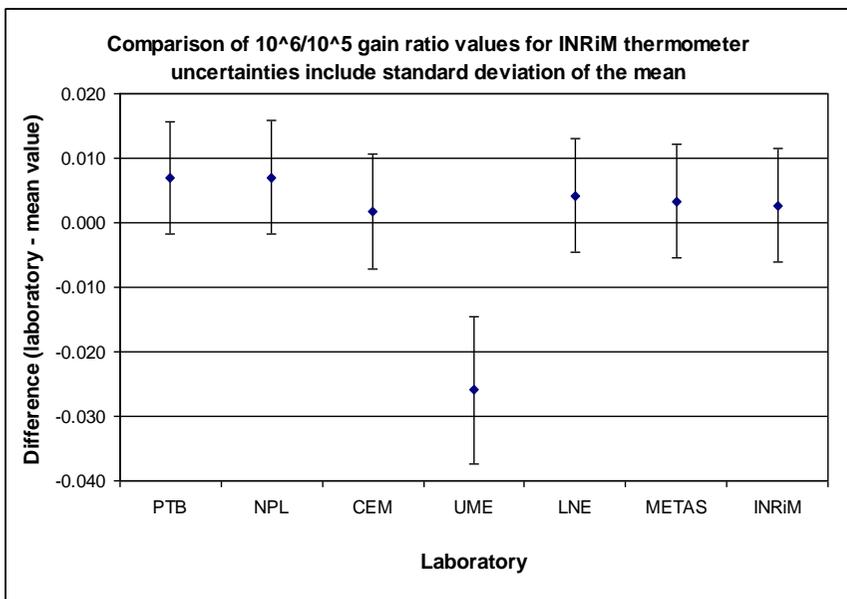
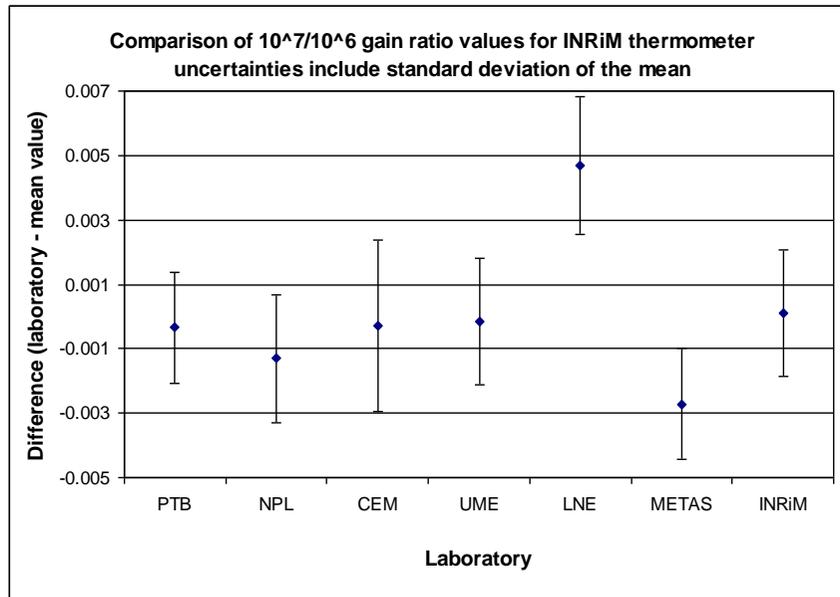
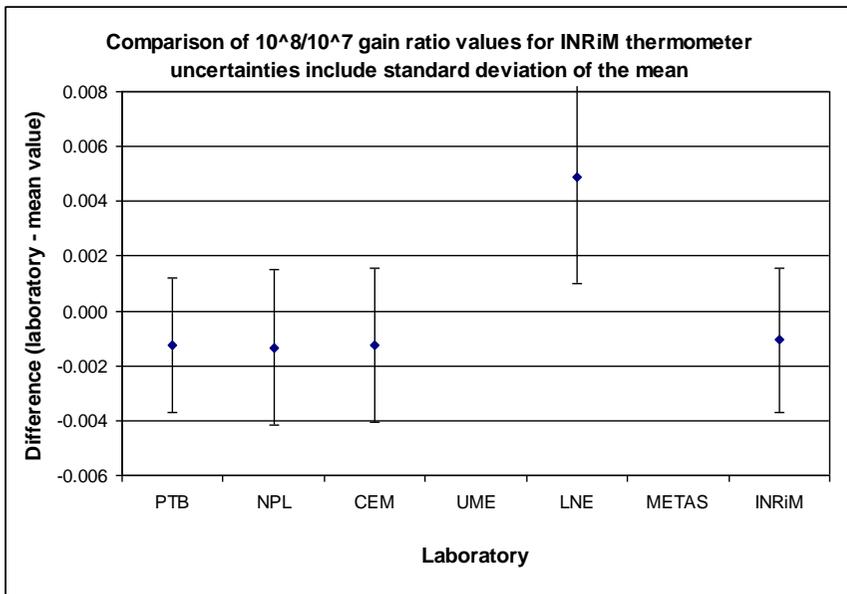
Laboratory	$10^5/10^4$	Diff from mean	Diff from median	u (k=1)	U (k=2)	U (k=2) with stdev of mean of all results
PTB	9.89589	0.00469	0.00168	0.00002	0.00003	0.00760
NPL	9.89421	0.00301	0.00000	0.00025	0.00049	0.00761
CEM	9.89844	0.00723	0.00423	0.00100	0.00199	0.00786
UME	9.87689	-0.01432	-0.01732	0.10063	0.20126	0.20141
LNE						
METAS	9.89060	-0.00061	-0.00361	0.00003	0.00006	0.00760
INRiM						
Average 9.89120 Stdev 0.00850 $1/\sqrt{(n)}$ 0.00380						
Median 9.89421						

Table 210: the differences from the mean and median for the INRiM $\times 10^5/ \times 10^4$ gain ratio results

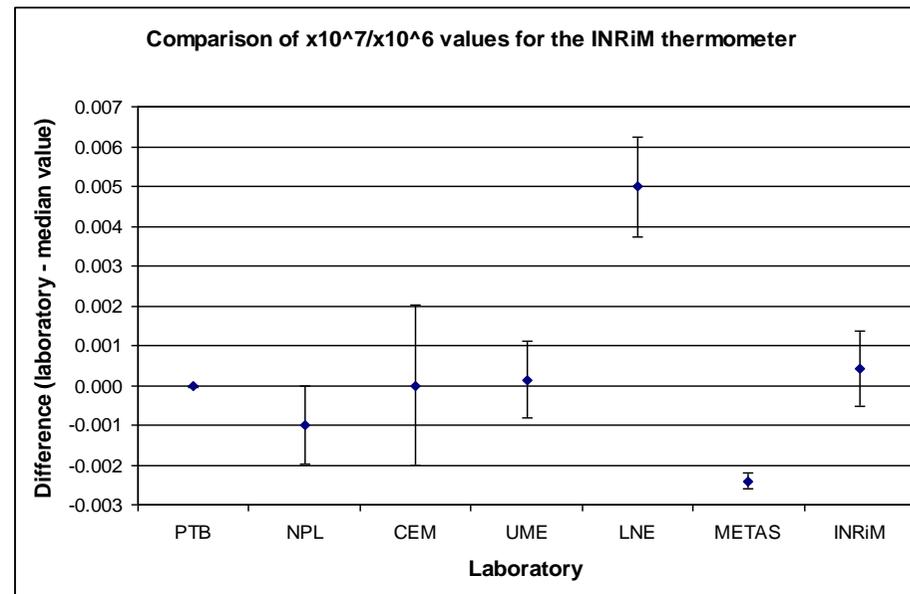
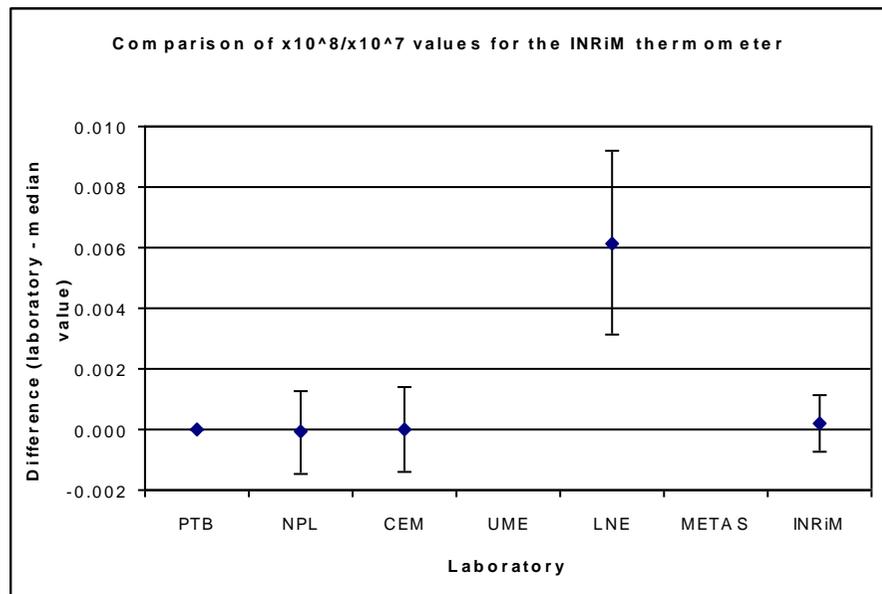
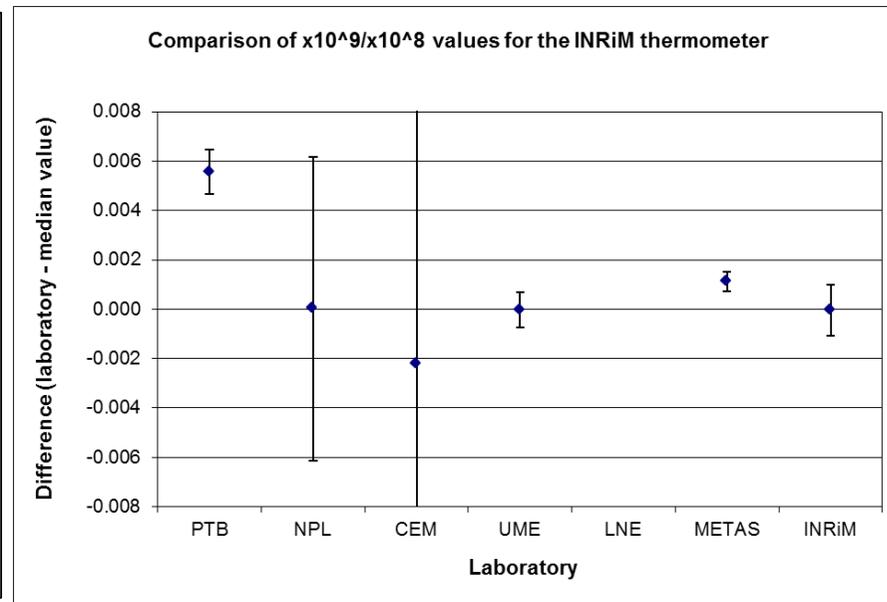
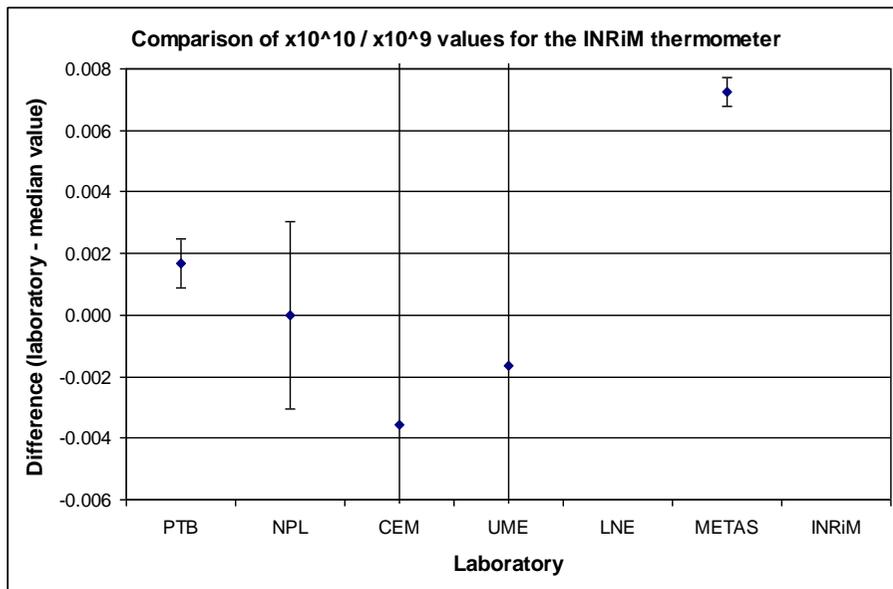
2.3.3 Comparison of the INRiM thermometer results: differences from the mean value

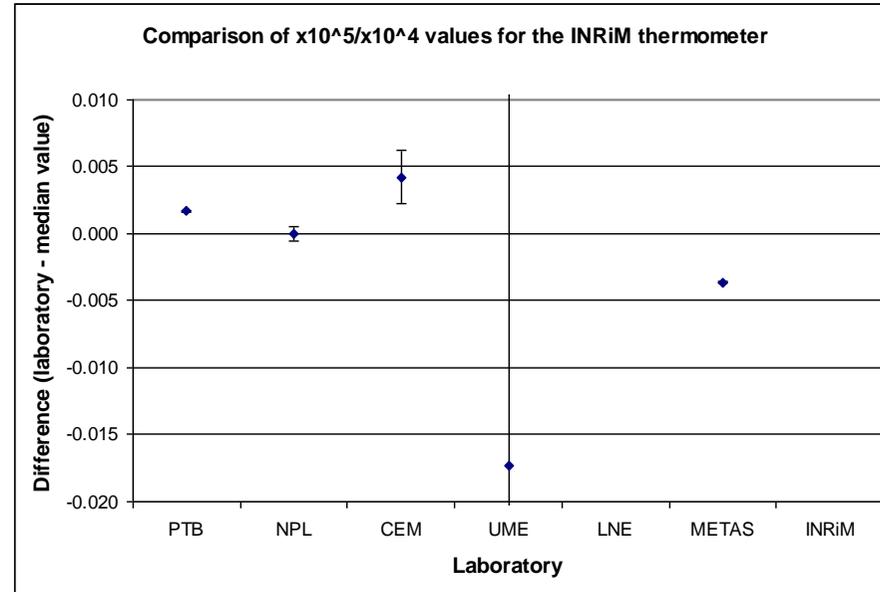
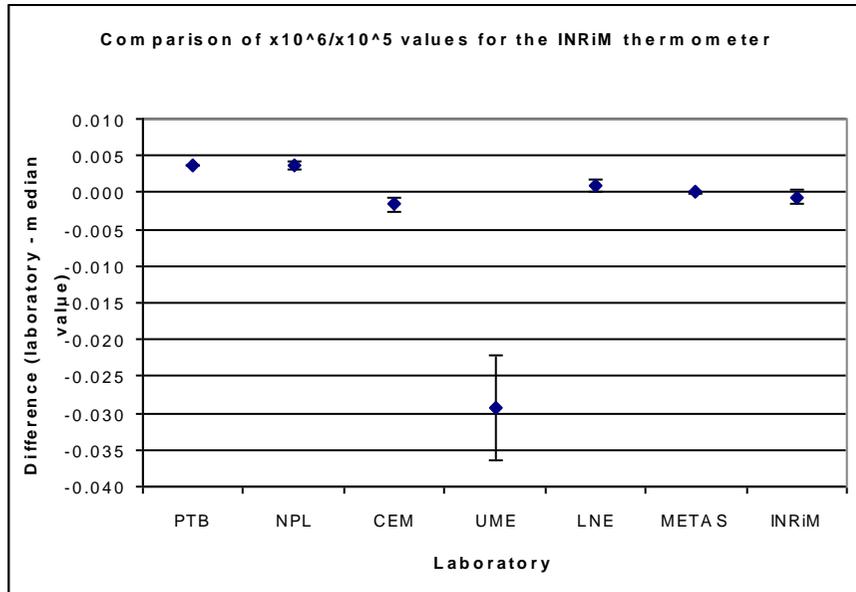




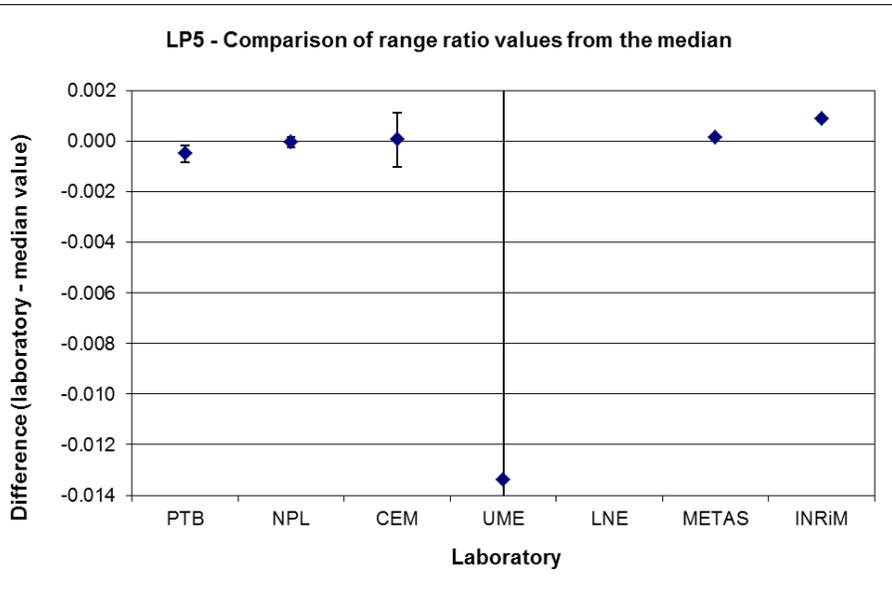
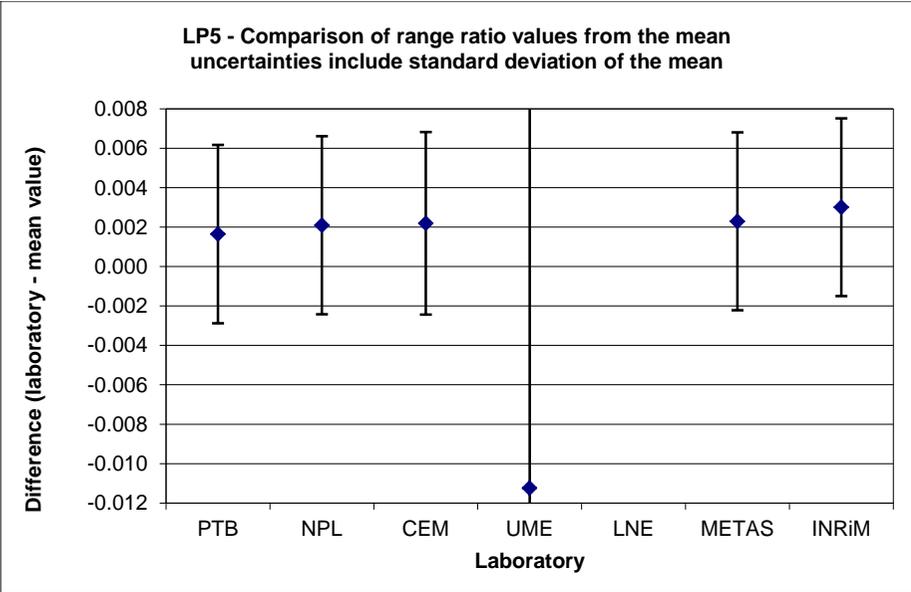
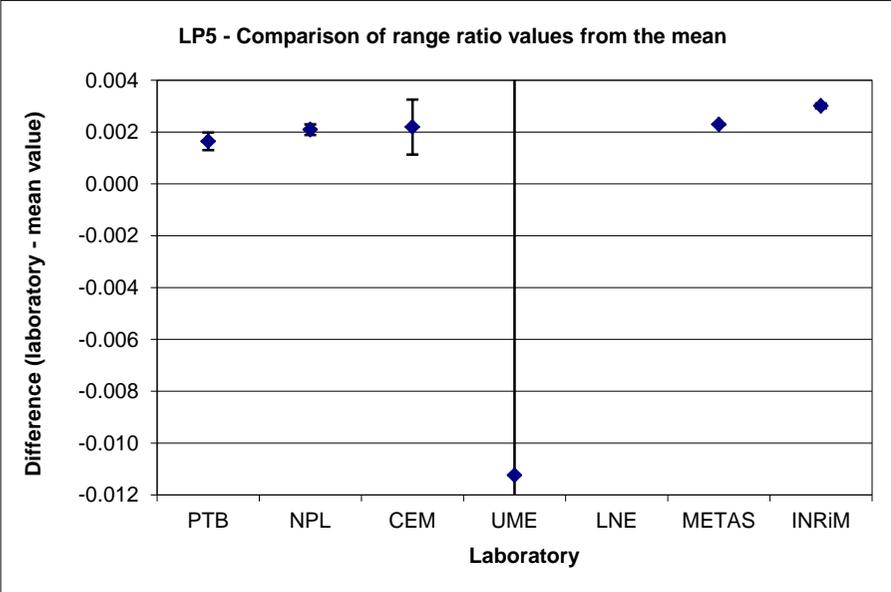


2.3.4 Comparison of the INRiM thermometer results: differences from the median value





2.3.5 Comparison of the LP5 results: differences from the mean and median values



2.4 DISCUSSION OF THE RESULTS

2.4.1 The INRiM thermometer results

The majority of the measurement results are in reasonably good agreement, taking into account the quoted measurement uncertainties, with the occasional outlying data point.

2.4.2 The LP5 results

The range ratio value from LNE was measured using the LP5 analogue output, rather than the photocurrent, and was completely inconsistent with the values from the other laboratories. The results from the other laboratories were in good agreement with the exception of the UME value, which was significantly lower. UME measured the range ratio very close to the bottom of the LP5 temperature range, where the background on range R2 was a significant component of the overall signal level. This could have impacted on the results. However, the UME value does agree with those of the other laboratories within the quoted measurement uncertainties.

3 EFFECT OF AMBIENT TEMPERATURE AND RELATIVE HUMIDITY

Only CEM, INRiM and NPL carried out the measurements of the effect of changing ambient temperature and relative humidity. CEM and INRiM carried out the full range of measurements. The NPL laboratory only has a small amount of temperature adjustment and no humidity control, so the measurements at NPL were somewhat limited. The results of all the measurements are given in the following tables.

3.1 THE RESULTS OF THE MEASUREMENTS

The results of the measurements made at CEM, INRiM and NPL are given in Tables 211 to 218 and Figures 14 to 17 below.

Amplifier Gain Setting / V/A	Average temperature of the source / °C	St. dev. of the temperature source / °C	Average Output Signal / mV	Average Background Signal / mV	Background Corrected Signal / mV	Measurement Standard Deviation / mV	Ambient Temperature t_{amb} / °C	Relative Humidity RH_{amb} / %rh	Internal Temperature t_{int} / °C	$U_{teffect}$ (k=2) / %
10 ⁹	231.35	0.01	1794.10	-2.84	1796.94	0.40	17.7	75	18.4	12
			1802.80	4.04	1798.76	0.45	27.7	55	28.6	
10 ⁷	412.85	0.01	1757.64	-0.49	1758.13	0.10	17.9	58	18.6	12
			1754.21	-0.47	1754.68	0.12	27.8	37	28.7	
10 ⁶	670.4	0.05	6124.8	-0.45	6125.3	2.9	17.8	52	18.6	12
			6109.9	-0.53	6110.4	2.2	27.8	62	28.8	
10 ⁵	963.6	0.05	5717.8	-0.45	5718.3	1.4	17.9	72	18.8	12
			5696.8	-0.54	5697.3	1.5	27.9	53	29.0	

Table 211: Results of the INRiM measurements of the ambient temperature effect for the INRiM thermometer

Amplifier Gain Setting / V/A	Average temperature of the source / °C	St. dev. of the temperature source / °C	Average Output Signal / mV	Average Background Signal / mV	Background Corrected Signal / mV	Measurement Standard Deviation / mV	Ambient Temperature t_{amb} / °C	Relative Humidity RH_{amb} / %rh	Internal Temperature t_{int} / °C	$U_{RHeffect}$ (k=2) / %
10 ⁹	232.35	0.01	1860.75	-0.25	1861.00	0.23	22.9	32	23.7	32
			1859.50	-0.22	1859.72	0.32		72		
10 ⁷	412.80	0.01	1756.60	-0.48	1757.08	0.12	22.9	32	23.7	32
			1755.47	-0.48	1755.95	0.15		69		
10 ⁶	670.5	0.05	6127.3	-0.48	6127.8	2.8	22.8	31	23.7	32
			6123.7	-0.49	6124.2	2.8		72		
10 ⁵	964.0	0.06	5722.5	-0.49	5723.0	1.5	22.9	33	23.9	32
			5719.4	-0.50	5719.9	1.9		70		

Table 212: Results of the INRiM measurements of the humidity effect for the INRiM thermometer

Amplifier Gain Setting (range)	Average temperature of the source / °C	St. dev. of the temperature source / °C	Average Output Signal / nA	Average Background Signal / pA	Background Corrected Signal / nA	Measurement Standard Deviation / nA	Ambient Temperature t_{amb} / °C	Relative Humidity RH_{amb} / %rh	Internal Temperature t_{int} / °C	$U_{teffect}$ ($k=2$) / %
R2	659.83	0.02	12.465	-1.6	12.467	0.003	18.3	55	25.15	18
	659.68		12.427	0.9	12.426		20.3	47	27.08	
	659.67		12.452	3.2	12.448		22.0	51	28.90	18
	659.71		12.464	3.8	12.460		24.0	49	29.20	
	659.64		12.444	4.1	12.440		25.9	50	29.20	
R2	960.14	0.02	137.184	-1.6	137.186	0.02	18.7	55	25.06	13
	959.81		136.559	4.0	136.555		23.2	52	29.21	
	959.76		136.423	4.4	136.419		26.0	54	29.21	15

Table 213: Results of the INRiM measurements of the ambient temperature effect for the LP5 thermometer

Note: the yellow shading indicates where the thermometer cell temperature was below the specified limits.

Amplifier Gain Setting (range)	Average temperature of the source / °C	St. dev. of the temperature source / °C	Average Output Signal / nA	Average Background Signal / pA	Background Corrected Signal / nA	Measurement Standard Deviation / nA	Ambient Temperature t_{amb} / °C	Relative Humidity RH_{amb} / %rh	Internal Temperature t_{int} / °C	$U_{RHeffect}$ ($k=2$) / %
R2	659.15	0.02	12.430	3.4	12.426	0.003	23.8	29	29.21	32
			12.393	4.5	12.389			73	29.21	
R2	959.16	0.02	136.377	3.4	136.374	0.02	23.6	25	29.23	32
			135.953	4.6	135.948			71	29.22	

Table 214: Results of the INRiM measurements of the humidity effect for the LP5 thermometer

t_{nom} / °C	RH_{nom} / %rh	t_{R} / °C	$s(t_{\text{Au/Pt}})$ / °C	dark current, S_0 / A	average signal, S / A	$S_{\text{extr a}}$ 660,32 °C / A	$S_{\text{extr}}-S_0$ / A	Standard deviation / A	t_{amb} / °C	$s(t_{\text{amb}})$ / °C	RH_{amb} / %rh	$s(\text{RH}_{\text{amb}})$ / %rh	t_{int} / °C	$U(S)$ / A	$U(S)$ / °C
18	50	660.22	0.0014	-5.1330E-10	5.4849E-06	5.4913E-06	5.4918E-06	1.8320E-10	17.67	0.13	55.99	0.25	19.47	1.768E-08	0.28
19	50	660.38	0.0023	-5.1130E-10	5.4944E-06	5.4906E-06	5.4911E-06	6.1362E-11	19.03	0.15	56.93	0.47	20.22	1.769E-08	0.28
20	50	660.16	0.0016	-5.3340E-10	5.4796E-06	5.4898E-06	5.4904E-06	5.0449E-11	20.21	0.10	48.96	0.38	21.38	1.768E-08	0.28
21	50	660.35	0.0034	-5.6570E-10	5.4873E-06	5.4854E-06	5.4860E-06	2.1107E-10	21.37	0.35	45.20	0.72	23.57	1.771E-08	0.28
22	50	660.31	0.0038	-5.5360E-10	5.4867E-06	5.4873E-06	5.4879E-06	9.9133E-11	22.16	0.21	43.73	0.46	23.52	1.769E-08	0.28
24	50	660.39	0.0017	-5.6020E-10	5.4881E-06	5.4836E-06	5.4842E-06	4.0333E-11	23.69	0.10	48.40	0.23	24.63	1.768E-08	0.28
24	50	660.26	0.0019	-5.7090E-10	5.4800E-06	5.4838E-06	5.4844E-06	1.8378E-10	24.04	0.15	40.29	0.30	25.46	1.769E-08	0.28
26	50	660.36	0.0015	-5.9030E-10	5.4848E-06	5.4823E-06	5.4829E-06	1.6450E-11	26.22	0.07	42.04	1.78	27.39	1.768E-08	0.28
26	50	660.35	0.0016	-5.8700E-10	5.4855E-06	5.4836E-06	5.4842E-06	2.0851E-10	25.97	0.09	42.51	0.29	27.52	1.769E-08	0.28
23	40	660.36	0.0014	-5.5350E-10	5.4865E-06	5.4840E-06	5.4845E-06	3.9213E-11	22.78	0.11	39.63	0.32	23.88	1.768E-08	0.28
23	50	660.44	0.0012	-5.5110E-10	5.4934E-06	5.4857E-06	5.4863E-06	6.4629E-11	22.70	0.08	50.48	0.46	24.23	1.768E-08	0.28
23	70	660.38	0.0008	-5.5290E-10	5.4885E-06	5.4847E-06	5.4853E-06	4.8281E-11	22.76	0.09	72.03	0.81	23.88	1.768E-08	0.28

Table 215: Results of the CEM measurements for the INRiM thermometer

(Note that the signal, which was given in terms of voltage, has been converted to current using the amplifier gain setting).

The results are plotted graphically in Figures 14 and 15.

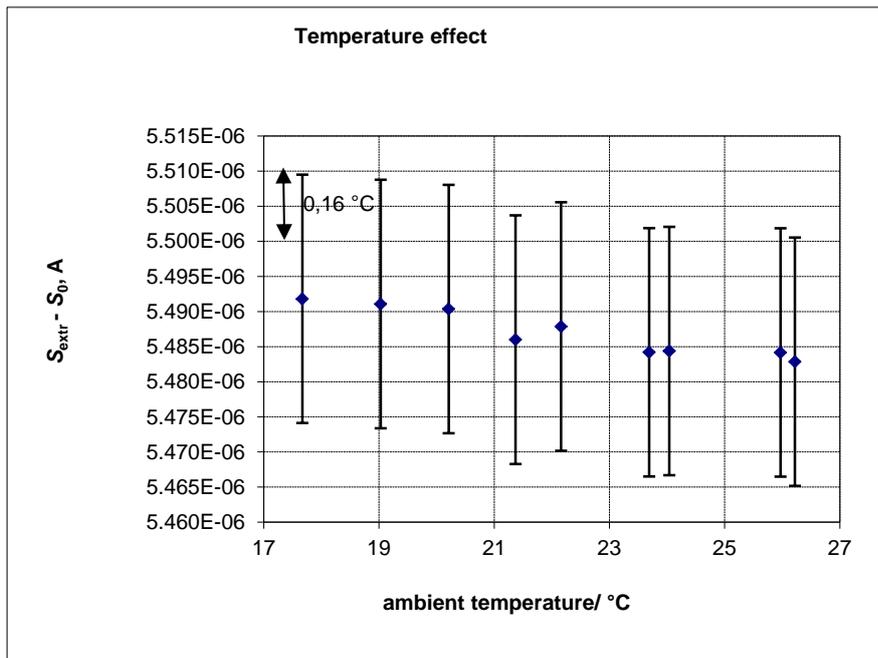


Figure 14: the CEM results for the effect of ambient temperature on the INRiM thermometer

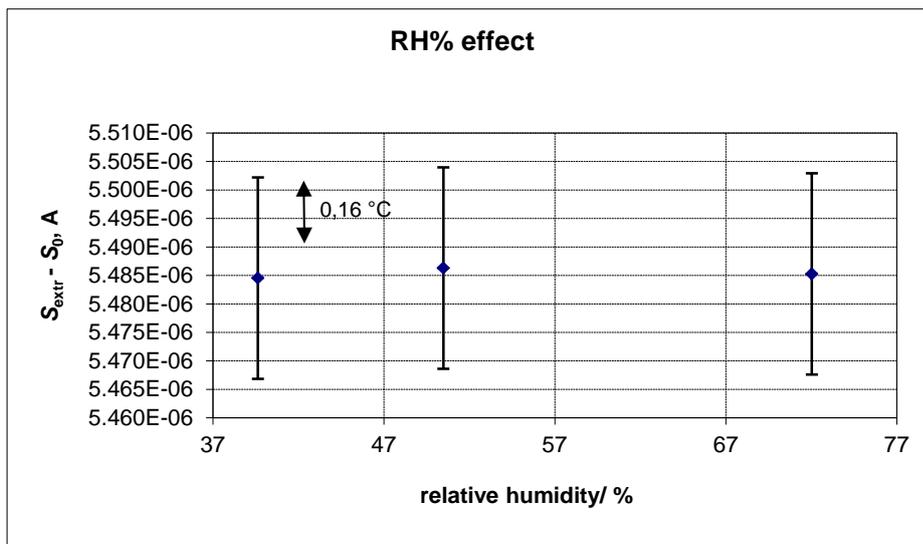


Figure 15: the CEM results for the effect of relative humidity on the INRiM thermometer

t_{nom} / °C	RH _{nom} / %rh	t_R / °C	$s(t_{Au/Pt})$ / °C	dark current, S_0 / A	average signal, S / A	S_{extr} a 660,32 °C / A	$S_{extr}-S_0$ / A	Standard deviation / A	t_{amb} / °C	$s(t_{amb})$ / °C	RH _{amb} / %rh	$s(RH_{amb})$ / %rh	t_{int} / °C	$U(S)$ / A	$U(S)$ / °C
18	50	660.28	0.0026	5.7877E-13	1.2535E-08	1.2540E-08	1.2540E-08	3.2641E-13	17.67	0.13	55.99	0.25	27.61	3.33E-11	0.25
19	50	660.43	0.0024	8.6042E-13	1.2567E-08	1.2552E-08	1.2552E-08	1.0815E-13	19.03	0.15	56.93	0.47	28.03	3.33E-11	0.25
20	50	660.2	0.0022	2.6086E-12	1.2545E-08	1.2561E-08	1.2558E-08	1.1231E-13	20.21	0.1	48.96	0.38	29.06	3.33E-11	0.25
21	50	660.41	0.0018	2.7102E-12	1.2597E-08	1.2585E-08	1.2582E-08	1.9541E-13	21.37	0.35	45.2	0.72	29.22	3.35E-11	0.25
22	50	660.37	0.0034	2.6609E-12	1.2585E-08	1.2578E-08	1.2576E-08	2.4928E-13	22.16	0.21	43.73	0.46	29.22	3.34E-11	0.25
24	50	660.43	0.0031	2.8120E-12	1.2563E-08	1.2548E-08	1.2545E-08	3.5487E-13	23.69	0.1	48.4	0.23	29.22	3.33E-11	0.25
24	50	660.31	0.0038	2.6388E-12	1.2558E-08	1.2559E-08	1.2557E-08	3.5487E-13	24.04	0.15	40.29	0.3	29.22	3.33E-11	0.25
26	50	660.4	0.0017	2.8121E-12	1.2576E-08	1.2565E-08	1.2563E-08	9.8759E-14	26.22	0.07	42.04	1.78	29.22	3.33E-11	0.25
26	50	660.37	0.0021	2.8095E-12	1.2577E-08	1.2570E-08	1.2567E-08	2.2766E-13	25.97	0.09	42.51	0.29	29.22	3.33E-11	0.25
23	40	660.41	0.0028	2.5981E-12	1.2567E-08	1.2555E-08	1.2553E-08	1.7380E-13	22.78	0.11	39.63	0.32	29.22	3.33E-11	0.25
23	50	660.51	0.0023	2.6837E-12	1.2584E-08	1.2559E-08	1.2556E-08	4.1867E-13	22.7	0.08	50.48	0.46	29.22	3.33E-11	0.25
23	70	660.42	0.0039	2.8430E-12	1.2560E-08	1.2547E-08	1.2544E-08	2.0647E-13	22.76	0.09	72.03	0.81	29.22	3.33E-11	0.25

Table 216: the CEM results for the effect of ambient temperature on the LP5 thermometer

Note: the yellow shading indicates where the cell temperature was below the specified limits.

The results are plotted graphically in Figures 16 and 17.

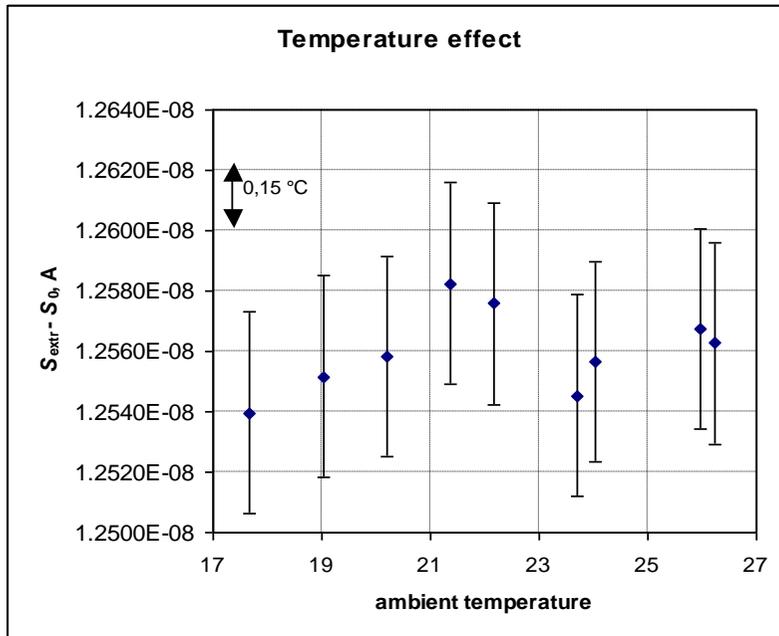


Figure 16: CEM results for the effect of temperature on the LP5

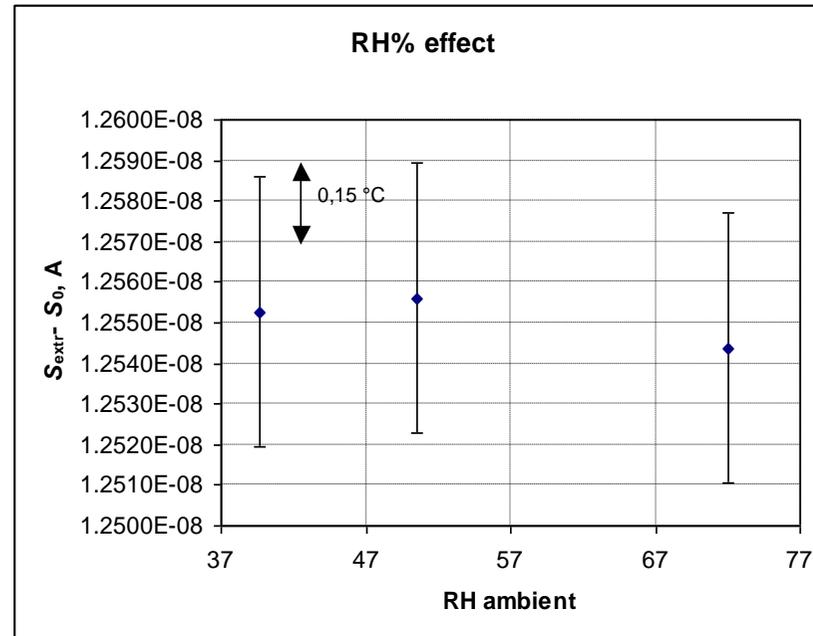


Figure 17: CEM results for the effect of relative humidity on the LP5

Ambient temp. / °C & RH / %rh	Internal temp / °C	t_{BB} / °C	t_{BB} std dev / °C	Signal / V	Bgrd signal / V	Bgrd corrected signal/ V	Signal std deviation/ V
21.1 / 29	22.00	659.87	0.00	5.471272	-0.000525	5.471797	8.210E-05
21.1 / 29	22.02	659.87	0.00	5.471048	-0.000525	5.471573	6.867E-05
23.8 / 37	24.92	659.86	0.00	5.468346	-0.000553	5.468899	1.105E-04
23.8 / 37	24.93	659.86	0.00	5.468231	-0.000553	5.468784	1.518E-04
23.9 / 37	24.88	660.86	0.01	5.524544	-0.000553	5.525097	4.796E-04
23.9 / 37	24.89	660.84	0.01	5.524014	-0.000553	5.524567	1.189E-04
22.1 / 43	23.19	660.82	0.00	5.525029	-0.000536	5.525565	1.850E-04
22.1 / 43	23.19	660.82	0.00	5.525250	-0.000536	5.525786	5.450E-05
22.2 / 43	23.12	659.88	0.00	5.471235	-0.000535	5.471770	3.233E-04
22.2 / 43	23.13	659.88	0.01	5.471019	-0.000535	5.471554	2.657E-04

Table 217: Results of the NPL measurements for the INRiM thermometer

Ambient temp. / °C & RH / %rh	Internal temp / °C	t_{BB} / °C	t_{BB} std dev / °C	Signal / A	Bgrd signal / A	Bgrd corrected signal/ A	Signal std deviation/ A
21.1 / 28	28.66	659.88	0.00	1.255691E-08	1.03821E-12	1.255587E-08	4.9964E-13
21.1 / 28	28.67	659.87	0.00	1.255584E-08	1.03821E-12	1.255481E-08	3.7411E-13
23.8 / 38	29.22	659.87	0.00	1.256291E-08	2.04829E-12	1.256086E-08	8.9812E-13
23.8 / 38	29.22	659.87	0.01	1.256297E-08	2.04829E-12	1.256092E-08	9.4297E-13
23.7 / 38	29.22	660.86	0.01	1.269432E-08	2.04813E-12	1.269227E-08	5.8258E-13
23.7 / 38	29.22	660.85	0.00	1.269283E-08	2.04813E-12	1.269078E-08	5.8479E-13
22.1 / 43	29.21	660.83	0.01	1.268954E-08	1.95133E-12	1.268759E-08	6.4780E-13
22.1 / 43	29.21	660.84	0.00	1.269078E-08	1.95133E-12	1.268883E-08	8.2813E-13

Table 218: Results of the NPL measurements for the LP5 thermometer

Note: the yellow shading again indicates where the thermometer cell temperature was below the specified limits.

The INRiM measurements with the LP5 were adjusted to correct for the small changes in the reference blackbody temperature during the measurements. The thermometer signal sensitivities in terms of V/ °C or A/ °C, or V/ %rh or A/ %rh were then calculated. The sensitivities in terms of an equivalent temperature were also calculated for more clarity.

The LP5 measurements made with the cell temperature out of specification are given for indication only.

The results of the calculations are given in Tables 219 to 226. Again, the yellow shading indicates where the LP5 cell temperature was below the specified limits.

3.2 THE RESULTS IN TERMS OF SENSITIVITIES

Amplifier Gain Setting / V/A	Average Temperature Of the source / °C	Background Corrected Signal / mV	Ambient Temperature t_{amb} / °C	Relative Humidity RH_{amb} / %rh	Internal Temperature t_{int} / °C	Ambient Temperature Sensitivity/ V/ °C _{amb}	Sensitivity in Terms of Equivalent Temperature/ °C/ °C _{amb}	Internal Temperature Sensitivity/ V/ °C _{int}	Sensitivity in Terms of Equivalent Temperature/ °C/ °C _{int}	$U_{teffect}$ (k=2) / %
10 ⁹	231.35	1796.94	17.7	75	18.4	0.00018	0.003	0.00018	0.003	12
		1798.76	27.7	55	28.6					
10 ⁷	412.85	1758.13	17.9	58	18.6	-0.00035	-0.010	-0.00034	-0.010	12
		1754.68	27.8	37	28.7					
10 ⁶	670.4	6125.3	17.8	52	18.6	-0.00148	-0.024	-0.00145	-0.023	12
		6110.4	27.8	62	28.8					
10 ⁵	963.6	5718.3	17.9	72	18.8	-0.00209	-0.014	-0.00205	-0.013	12
		5697.3	27.9	53	29.0					

Table 219: INRiM measurements of the temperature effect with the INRiM thermometer

Note that the relative humidity also varied during the measurements and this could have had an impact on the results.

Amplifier Gain Setting/ V/A	Average Temperature Of the source / °C	Background Corrected Signal / mV	Ambient Temperature t_{amb} / °C	Relative Humidity RH_{amb} / %rh	Internal Temperature t_{int} / °C	Relative Humidity Sensitivity/ V/ %rh	Sensitivity in Terms of Equivalent Temperature/ °C/ %rh	$U_{RHeffect}$ (k=2) /
10 ⁹	232.35	1861.00	22.9	32	23.7	-0.00003	0.000	32
		1859.72		72				
10 ⁷	412.80	1757.08	22.9	32	23.7	-0.00003	-0.001	32
		1755.95		69				
10 ⁶	670.5	6127.8	22.8	31	23.7	-0.00009	-0.001	32
		6124.2		72				
10 ⁵	964.0	5723.0	22.9	33	23.9	-0.00008	-0.002	32
		5719.9		70				

Table 220: INRiM measurements of the humidity effect with the INRiM thermometer

Amplifier gain setting (range)	Average temperature of the source / °C	Background corrected signal / nA	Signal corrected for changes in source temp [‡] . / nA	Ambient temperature t _{amb} / °C	Relative humidity RH _{amb} / %rh	Internal temperature t _{int} / °C	Ambient temperature sensitivity [†] / nA/ °C _{amb}	Sensitivity in terms of equivalent temperature [†] / °C/ °C _{amb}	Ambient temperature sensitivity*/ nA/ °C _{amb}	Sensitivity in terms of equivalent temperature*/ °C/ °C _{amb}	U _{teffect} (k=2) / %
R2	659.83	12.467	12.467	18.3	55	25.15	-	-	-	-	18
	659.68	12.426	12.446	20.3	47	27.08	-0.010	-0.08	-	-	
	659.67	12.448	12.469	22.0	51	28.90	0.001	0.01	-	-	
	659.71	12.460	12.476	24.0	49	29.20	0.002	0.01	-	-	
	659.64	12.440	12.465	25.9	50	29.20	0.000	0.00	-0.006	-0.04	18
R2	960.14	137.186	137.186	18.7	55	25.06	-	-	-	-	13
	959.81	136.555	136.827	23.2	52	29.21	-0.081	-0.10	-	-	
	959.76	136.419	136.731	26.0	54	29.21	-0.062	-0.08	-0.034	-0.04	15

Table 221: INRiM measurements of the ambient temperature effect with the LP5 thermometer

[‡] relative to the blackbody temperature during the first measurement set

[†] Calculated relative to the results at the lowest ambient temperature/ relative humidity

* Ignoring the values where the cell temperature was out of specification.

Amplifier Gain Setting (range)	Average temperature of the source / °C	Background Corrected Signal / nA	Ambient Temperature t _{amb} / °C	Relative Humidity RH _{amb} / %rh	Internal Temperature t _{int} / °C	Relative Humidity Sensitivity / nA/ %rh	Sensitivity in Terms of Equivalent Temperature/ °C/ %rh	U _{RHeffect} (k=2) / %
R2	659.15	12.426	23.8	29	29.21	-0.001	-0.007	32
		12.389		73	29.21			
R2	959.16	136.374	23.6	25	29.23	-0.009	-0.011	32
		135.948		71	29.22			

Table 222: INRiM measurements of the humidity effect with the LP5 thermometer

t_{nom}	RH_{nom}	t_{R}	$S_{\text{extr}}-S_0$	t_{amb}	RH_{amb}	t_{int}	$S_{\text{extr}}-S_0$	Ambient temperature sensitivity [†] / V/ °C _{amb}	Sensitivity in terms of equivalent temperature difference [†] / °C/ °C _{amb}	Internal temperature sensitivity [†] / V/ °C _{int}	Sensitivity in terms of equivalent temperature difference [†] / °C/ °C _{int}	U (k=2)
/ °C	/ %rh	/ °C	/ A	/ °C	/ %rh	/ °C	/ V					/ °C
18	50	660.22	5.4918E-06	17.67	55.99	19.47	5.4918	-	-	-	-	
19	50	660.38	5.4911E-06	19.03	56.93	20.22	5.4911	-0.00054	-0.010	-0.00098	-0.017	0.28
20	50	660.16	5.4904E-06	20.21	48.96	21.38	5.4904	-0.00057	-0.010	-0.00076	-0.013	0.28
21	50	660.35	5.4860E-06	21.37	45.20	23.57	5.4860	-0.00157	-0.028	-0.00142	-0.025	0.28
22	50	660.31	5.4879E-06	22.16	43.73	23.52	5.4879	-0.00088	-0.015	-0.00097	-0.017	0.28
24	50	660.39	5.4842E-06	23.69	48.40	24.63	5.4842	-0.00126	-0.022	-0.00147	-0.026	0.28
24	50	660.26	5.4844E-06	24.04	40.29	25.46	5.4844	-0.00116	-0.021	-0.00124	-0.022	0.28
26	50	660.36	5.4829E-06	26.22	42.04	27.39	5.4829	-0.00105	-0.018	-0.00113	-0.020	0.28
26	50	660.35	5.4842E-06	25.97	42.51	27.52	5.4842	-0.00092	-0.016	-0.00095	-0.017	0.28
t_{nom}	RH_{nom}	t_{R}	$S_{\text{extr}}-S_0$	t_{amb}	RH_{amb}	t_{int}	$S_{\text{extr}}-S_0$	Relative humidity sensitivity [†] / V/ %rh	Sensitivity in terms of equivalent temperature difference [†] / °C/ %rh	U (k=2)		
/ °C	/ %rh	/ °C	/ A	/ °C	/ %rh	/ °C	/ V			/ °C		
23	40	660.36	5.4845E-06	22.78	39.63	23.88	5.4845	-	-	0.28		
23	50	660.44	5.4863E-06	22.70	50.48	24.23	5.4863	0.00016	0.003	0.28		
23	70	660.38	5.4853E-06	22.76	72.03	23.88	5.4853	0.00002	0.000	0.28		

Table 223: CEM measurements with the INRiM thermometer

[†] Calculated relative to the results at the lowest ambient temperature/ relative humidity

t_{nom} / °C	RH_{nom} / %rh	t_R / °C	$S_{extr}-S_0$ / A	t_{amb} / °C	RH_{amb} / %rh	t_{int} / °C	Ambient temperature sensitivity [†] / nA/ °C _{amb}	Sensitivity in terms of equivalent temperature difference [†] / °C/ °C _{amb}	Ambient temperature sensitivity*/ nA/ °C _{amb}	Sensitivity in terms of equivalent temperature difference*/ °C/ °C _{amb}	U (k=2) / °C
18	50	660.28	1.2540E-08	17.67	55.99	27.61	-	-	-	-	
19	50	660.43	1.2552E-08	19.03	56.93	28.03	0.009	0.07	-	-	
20	50	660.20	1.2558E-08	20.21	48.96	29.06	0.007	0.06	-	-	
21	50	660.41	1.2582E-08	21.37	45.20	29.22	0.012	0.09	-	-	
22	50	660.37	1.2576E-08	22.16	43.73	29.22	0.008	0.06	-0.008	-0.07	0.25
24	50	660.43	1.2545E-08	23.69	48.40	29.22	0.001	0.01	-0.016	-0.12	0.25
24	50	660.31	1.2557E-08	24.04	40.29	29.22	0.003	0.02	-0.010	-0.07	0.25
26	50	660.40	1.2563E-08	26.22	42.04	29.22	0.003	0.02	-0.004	-0.03	0.25
26	50	660.37	1.2567E-08	25.97	42.51	29.22	0.003	0.03	-0.003	-0.03	0.25
t_{nom} / °C	RH_{nom} / %rh	t_R / °C	$S_{extr}-S_0$ / A	t_{amb} / °C	RH_{amb} / %rh	t_{int} / °C	Relative humidity sensitivity [†] / nA/ %rh	Sensitivity in terms of equivalent temperature difference [†] / °C/ %rh	U (k=2) / °C		
23	40	660.41	1.2553E-08	22.78	39.63	29.22	-	-			
23	50	660.51	1.2556E-08	22.70	50.48	29.22	0.000	+0.002	0.25		
23	70	660.42	1.2544E-08	22.76	72.03	29.22	0.000	-0.002	0.25		

Table 224: CEM measurements with the LP5 thermometer

[†] Calculated relative to the results at the lowest ambient temperature/ relative humidity

* Ignoring the values where the cell temperature was out of specification.

Ambient temp./ °C & RH/ %rh	Internal temp / °C	t_{BB} / °C	Bgrd corrected signal/ V	Signal corrected for changes in source temp. [‡] / V	Ambient temperature sensitivity [†] / V/ °C _{amb}	Sensitivity in terms of equivalent temperature difference [†] / °C/ °C _{amb}	Internal temperature sensitivity [†] / V/ °C _{int}	Sensitivity in terms of equivalent temperature difference [†] / °C/ °C _{int}
21.1 / 29	22.00	659.87	5.471797	5.471797	-0.00076	-0.01	-0.00070	-0.01
21.1 / 29	22.02	659.87	5.471573	5.471394	-0.00090	-0.02	-0.00083	-0.02
23.8 / 37	24.92	659.86	5.468899	5.469551	-0.00105	-0.02	-0.00102	-0.02
23.8 / 37	24.93	659.86	5.468784	5.469170	-0.00090	-0.01	-0.00088	-0.01
23.9 / 37	24.88	660.86	5.525097	5.468657	-0.00042	0.00	-0.00035	0.00
23.9 / 37	24.89	660.84	5.524567	5.469064	-0.00011	0.00	-0.00009	0.00
22.1 / 43	23.19	660.82	5.525565	5.471175	-0.00076	-0.02	-0.00074	-0.02
22.1 / 43	23.19	660.82	5.525786	5.471488	-0.00095	-0.02	-0.00093	-0.02
22.2 / 43	23.12	659.88	5.471770	5.470765	-0.00076	-0.01	-0.00070	-0.01
22.2 / 43	23.13	659.88	5.471554	5.470549	-0.00090	-0.02	-0.00083	-0.02

Table 225: NPL measurements with the INRiM thermometer

[‡] relative to the blackbody temperature during the first measurement set

[†] Calculated relative to the results at the lowest ambient temperature/ relative humidity

Note that the relative humidity also varied during the measurements and this could have had an impact on the results.

Ambient temp./ °C & RH/ %rh	Internal temp / °C	t_{BB} / °C	Bgrd corrected signal/ A	Signal corrected for changes in source temp. [‡] / A	Ambient temperature sensitivity [†] / nA/ °C _{amb}	Sensitivity in terms of equivalent temperature difference [†] / °C/ °C _{amb}	Ambient temperature sensitivity*/ nA/ °C _{amb}	Sensitivity in terms of equivalent temperature difference*/ °C/ °C _{amb}
21.1 / 28	28.66	659.88	1.255587E-08	1.255587E-08	-	-	-	-
21.1 / 28	28.67	659.87	1.255481E-08	1.255579E-08	0.000	0.00	-	-
23.8 / 38	29.22	659.87	1.256086E-08	1.256147E-08	0.002	0.02	-	-
23.8 / 38	29.22	659.87	1.256092E-08	1.256198E-08	0.002	0.02	-	-
23.7 / 38	29.22	660.86	1.269227E-08	1.256301E-08	0.003	0.02	-	-
23.7 / 38	29.22	660.85	1.269078E-08	1.256298E-08	0.003	0.02	-	-
22.1 / 43	29.21	660.83	1.268759E-08	1.256248E-08	0.007	0.05	0.00	-0.001
22.1 / 43	29.21	660.84	1.268883E-08	1.256232E-08	0.006	0.05	0.00	-0.001

Table 226: NPL measurements with the LP5 thermometer

[‡] relative to the blackbody temperature during the first measurement set

[†] Calculated relative to the results at the lowest ambient temperature

* Ignoring the values where the cell temperature was out of specification.

Note that the relative humidity also varied during the measurements and this could have had an impact on the results.

3.3 DISCUSSION OF THE RESULTS AND CONCLUSIONS

The NPL results have been ignored in the following discussion, because the number of measurement data points was very limited. It should also be noted that the uncertainties of the CEM and INRiM measurements are large compared to the magnitude of the observed effect, making it difficult to see any clear dependence of the thermometers' signals on changes in room temperature and relative humidity.

3.3.1 Results for the INRiM thermometer:

The INRiM thermometer results show a small negative coefficient for both ambient temperature and relative humidity changes.

Temperature coefficient: The INRiM measurements showed a temperature coefficient, over nominally the 18 °C to 29 °C internal temperature range, equivalent to between approximately -0.00 °C per °C_{int} and -0.02 °C per °C_{int}, depending on the reference source temperature. The CEM measurements showed a temperature coefficient, over nominally the 19.5 °C to 27.5 °C internal temperature range, equivalent to approximately -0.02 °C per °C_{int} at a reference source temperature of 660 °C. The INRiM results at 660 °C were equivalent to the average CEM results at 660 °C.

Looking at the participant measurements of the fixed-point and variable temperature blackbody sources (Sections 6, 7 and 8 of the main comparison report), the typical internal temperature range for the INRiM thermometer was 23 °C to 28 °C (the overall range was from 22.8 °C to 28.1 °C). The uncertainty/required correction due to these variations in the internal temperature would equate to a maximum value equivalent to approximately ± 0.05 °C, which is negligible compared to the overall laboratory uncertainties and the repeatability of the measurements.

Humidity coefficient: The INRiM results showed a humidity coefficient, over the ~30 %rh to 70 %rh humidity range, equivalent to approximately 0.000 °C per %rh to -0.002 °C per %rh depending on the reference source temperature. The CEM measurement results showed a humidity coefficient, over the ~40 %rh to 72 %rh humidity range, equivalent to approximately 0.000 °C per %rh to $+0.003$ °C per %rh at a reference source temperature of 660 °C.

The typical laboratory relative humidity range for the variable temperature and fixed-point measurements was 25 %rh to 50 %rh, with the overall range from 18 %rh to 76 %rh. The uncertainty/required correction due to these variations in the relative humidity would equate, typically, to a maximum value equivalent to approximately ± 0.04 °C. No correction was applied to any of the results, due to the discrepancy in the measured values (negative for the INRiM results and positive for the CEM results), and the fact that the relative humidity tended to fluctuate during the variable temperature blackbody (VTBB) and fixed point (FP) measurements in each laboratory: this means that any effect has already been taken into account within the repeatability of the measurements.

3.3.2 Results for the LP5 thermometer:

No laboratory submitted results for measurements with the fixed-point and variable temperature blackbody sources where the LP5 cell temperature was outside its specification. Therefore, in the following analysis, only those values where the cell temperature was within its specification have been considered.

Temperature coefficient: The INRiM measurements showed a temperature coefficient, over the ~23 °C to 26 °C ambient temperature range, equivalent to -0.04 °C per °C_{amb}. The CEM measurements showed a temperature coefficient, over the ~21 °C to 26 °C ambient temperature range, of

approximately $-0.03\text{ }^{\circ}\text{C per }^{\circ}\text{C}_{\text{amb}}$ to $-0.12\text{ }^{\circ}\text{C per }^{\circ}\text{C}_{\text{amb}}$ at a source temperature of $660\text{ }^{\circ}\text{C}$.

The typical laboratory temperature range for the variable temperature and fixed-point measurements with the LP5 was $22\text{ }^{\circ}\text{C}$ to $24\text{ }^{\circ}\text{C}$, with the overall range from $21.6\text{ }^{\circ}\text{C}$ to $24.9\text{ }^{\circ}\text{C}$. The uncertainty/required correction due to these variations would equate generally from approximately $\pm 0.03\text{ }^{\circ}\text{C}$ to $\pm 0.10\text{ }^{\circ}\text{C}$ depending on the sensitivity value chosen. No correction has been applied to the results to take this into account: it is assumed that this will be covered by the laboratory uncertainty and the repeatability of the measurements.

Humidity coefficient: The INRiM measurement results showed a humidity coefficient, over the $\sim 25\text{ }^{\circ}\text{rh}$ to $70\text{ }^{\circ}\text{rh}$ humidity range, of approximately $-0.007\text{ }^{\circ}\text{C per }^{\circ}\text{rh}$ to $-0.011\text{ }^{\circ}\text{C per }^{\circ}\text{rh}$ depending on the reference source temperature. The CEM measurement results showed a humidity coefficient, over the $\sim 40\text{ }^{\circ}\text{rh}$ to $72\text{ }^{\circ}\text{rh}$ humidity range, of approximately $\pm 0.002\text{ }^{\circ}\text{C per }^{\circ}\text{rh}$ at a reference source temperature of $660\text{ }^{\circ}\text{C}$.

The typical laboratory relative humidity range for the variable temperature and fixed-point measurements was $25\text{ }^{\circ}\text{rh}$ to $50\text{ }^{\circ}\text{rh}$, with the overall range from $18\text{ }^{\circ}\text{rh}$ to $76\text{ }^{\circ}\text{rh}$. The uncertainty/required correction due to these variations in the relative humidity would generally equate to approximately from $\pm 0.03\text{ }^{\circ}\text{C}$ to $\pm 0.13\text{ }^{\circ}\text{C}$ depending on the sensitivity value chosen. No correction was applied to any of the results, due to the discrepancy in the measured values, and the fact that the relative humidity tended to fluctuate during the measurement process in each laboratory; therefore any effect has already been taken into account within the repeatability of the measurements.