

Key comparison CCM.P-K13

MEASURAND : Effective area $A'(p', 20\text{ °C})$ of piston-cylinder unit DH-Budenberg 4603 mounted in a DH-Budenberg pressure balance model 5306 determined from comparisons against participants primary pressure standards

NOMINAL VALUE : 2 mm^2

x_i : result of measurement of $A'(p', 20\text{ °C})$ taken as the arithmetic average of 10 values obtained by laboratory i and corrected for drift

u_i : combined standard uncertainty of x_i as reported by laboratory i (without including uncertainty of the drift correction)

u_{DC} : standard uncertainty of the drift correction of x_i

	NIST, Jan 2009		CENAM, Mar 2009		NPLI, May 2009		NIM, Jun 2009		NMIJ, Oct 2009		LNE, Feb 2010		PTB, Mar 2010		
p' / MPa	x_i / mm^2	u_i / x_i / 10^{-6}	x_i / mm^2	u_i / x_i / 10^{-6}	x_i / mm^2	u_i / x_i / 10^{-6}	x_i / mm^2	u_i / x_i / 10^{-6}	x_i / mm^2	u_i / x_i / 10^{-6}	x_i / mm^2	u_i / x_i / 10^{-6}	x_i / mm^2	$u_i / x_i / 10^{-6}$	u_{DC} / x_i / 10^{-6}
50	1.961187	17	1.961171	85	1.961104	44	1.961098	17	1.961152	17	1.961191	11	1.961148	15	0.5
100	1.961285	17	1.961258	85	1.961244	44	1.961175	17	1.961269	17	1.961273	13	1.961261	15	0.5
150	1.961409	17	1.961367	85	1.961376	44	1.961280	17	1.961386	19	1.961373	16	1.961378	16	0.6
200	1.961519	17	1.961481	85	1.961493	44	1.961381	18	1.961495	20	1.961474	18	1.961486	17	0.2
250	1.961607	17	1.961589	85	1.961603	44	1.961477	19	1.961597	22	1.961574	20	1.961589	18	0.4
300	-	-	1.961699	85	1.961705	44	1.961564	20	1.961692	24	1.961671	23	1.961685	20	1.2
350	-	-	1.961802	85	1.961802	44	1.961646	21	1.961782	27	1.961766	25	1.961777	22	1.4
400	-	-	1.961905	85	1.961887	44	1.961729	22	1.961871	30	1.961856	28	1.961866	24	1.6
450	-	-	1.962013	85	1.961987	44	1.961774	23	1.961956	33	1.961945	30	1.961953	26	2.1
500	-	-	1.962120	85	1.962093	44	1.961853	25	1.962041	36	1.962040	33	1.962040	28	2.2

Key comparison APMP.M.P-K13

The results of the participating laboratories in key comparison APMP.M.P-K13 are given in Section 6 of the Final Report. Measurements were carried out between 2010 and 2013.

Key comparison EURAMET.M.P-K13

The results of the participating laboratories in key comparison EURAMET.M.P-K13 are given in Section 6 of the Final Report. Measurements were carried out between 2009 and 2011.

Key comparison CCM.P-K13

MEASURAND : Effective area $A'(p', 20\text{ °C})$ of piston-cylinder unit DH-Budenberg 4603 mounted in a DH-Budenberg pressure balance model 5306 determined from comparisons against participants primary pressure standards

NOMINAL VALUE : 2 mm²

The key comparison reference value, x_R , is calculated at each pressure p' as the median of the participants' values obtained at this pressure. The standard uncertainty of the reference value at each pressure, u_R , is calculated by the formula $u_R = [(1.858 \times \text{MED}|x_i - x_R|)^2 / (n-1)]^{1/2}$, where MED is median and n is number of participants.

For each value of the pressure, the degree of equivalence of each laboratory i with respect to the key comparison reference value is given by: $D_i = (x_i - x_R) / x_R$, the relative deviation from the reference value, and $U_i = 2 (u_i^2 + u_{DC}^2 + u_R^2)^{1/2} / x_R$, its expanded uncertainty ($k = 2$).

p' / MPa	x_R / mm ²	u_R / x_R / 10 ⁻⁶
50	1.961152	13.5
100	1.961261	4.6
150	1.961376	3.4
200	1.961486	3.4
250	1.961589	5.4
300	1.961688	5.9
350	1.961780	7.7
400	1.961868	6.7
450	1.961955	8.8
500	1.962041	11.1

Key comparison APMP.M.P-K13

The results of the participants in APMP.M.P-K13 are linked to those of CCM.P-K13 through the results of the two linking laboratories, NMIJ and NPLI, as explained in Section 7 of the Final Report.

Key comparison EURAMET.M.P-K13

The results of the participants in EURAMET.M.P-K13 are linked to those of CCM.P-K13 through the results of the linking laboratory, PTB, as explained in Section 7 of the Final Report.

Key comparisons CCM.P-K13, APMP.M.P-K13 and EURAMET.M.P-K13

Degrees of equivalence relative to the CCM.P-K13 key comparison reference values

50 MPa			100 MPa			150 MPa			200 MPa		
Lab <i>i</i>	D_i / 10 ⁻⁶	U_i / 10 ⁻⁶	Lab <i>i</i>	D_i / 10 ⁻⁶	U_i / 10 ⁻⁶	Lab <i>i</i>	D_i / 10 ⁻⁶	U_i / 10 ⁻⁶	Lab <i>i</i>	D_i / 10 ⁻⁶	U_i / 10 ⁻⁶
NIST	17.8	44	NIST	12.3	35	NIST	16.6	34	NIST	17.1	34
CENAM	9.6	173	CENAM	-1.8	169	CENAM	-4.5	169	CENAM	-2.3	169
NPLI	-24.5	92	NPLI	-9.1	88	NPLI	0.0	88	NPLI	3.5	88
NIM	-27.6	43	NIM	-43.8	35	NIM	-48.9	35	NIM	-53.6	37
NMIJ	0.0	43	NMIJ	3.9	36	NMIJ	5.0	38	NMIJ	4.5	41
LNE	20.1	35	LNE	6.1	28	LNE	-1.4	32	LNE	-6.0	37
PTB	-2.0	40	PTB	0.0	31	PTB	0.7	33	PTB	0.0	35
NMIJ	-1.2	44	NMIJ	-1.0	36	NMIJ	0.0	38	NMIJ	0.0	41
NPLI	-10.0	87	NPLI	-6.5	83	NPLI	-4.2	82	NPLI	-2.3	82
NMC, A*STAR	12.9	57	NMC, A*STAR	4.0	57	NMC, A*STAR	-1.7	65	NMC, A*STAR	-9.3	78
NIMT	-22.8	51	NIMT	-21.1	48	NIMT	-13.2	54	NIMT	-11.4	63
NMIA	5.2	37	NMIA	2.8	30	NMIA	6.1	34	NMIA	9.0	39
NIM	4.2	48	NIM	-0.7	43	NIM	3.6	45	NIM	4.4	49
CMS	9.8	81	CMS	3.3	77	CMS	3.9	77	CMS	3.7	77
Puslit KIM-LIPI	-13.3	53	Puslit KIM-LIPI	-13.8	49	Puslit KIM-LIPI	-12.0	56	Puslit KIM-LIPI	-25.6	65
KRISS	7.5	49	KRISS	4.0	44	KRISS	-0.4	45	KRISS	-6.6	49
PTB	-2.0	41	PTB	0.0	32	PTB	0.7	33	PTB	0.0	37
INRIM	7.2	56	INRIM	-17.0	51	INRIM	-36.1	51	INRIM	-44.1	53
NIS	-18.8	46	NIS	-14.3	41	NIS	-12.4	45	NIS	-7.7	50
NMISA	9.7	59	NMISA	-6.6	59	NMISA	-17.6	36	NMISA	-33.6	37
SMU	1.6	44	SMU	5.7	41	SMU	0.0	46	SMU	-1.6	46
MIRS/IMT/LMT	-19.9	39	MIRS/IMT/LMT	-10.1	31	MIRS/IMT/LMT	-11.9	32	MIRS/IMT/LMT	-13.0	36
NPL	-40.8	44	NPL	-9.6	35	NPL	5.1	35	NPL	21.1	35
UME	-37.0	41	UME	-19.8	31	UME	-22.8	33	UME	-22.5	34

Key comparisons CCM.P-K13, APMP.M.P-K13 and EURAMET.M.P-K13

Degrees of equivalence relative to the CCM.P-K13 key comparison reference values (Cont.)

250 MPa			300 MPa			350 MPa			400 MPa		
Lab <i>i</i>	D_i / 10 ⁻⁶	U_i / 10 ⁻⁶	Lab <i>i</i>	D_i / 10 ⁻⁶	U_i / 10 ⁻⁶	Lab <i>i</i>	D_i / 10 ⁻⁶	U_i / 10 ⁻⁶	Lab <i>i</i>	D_i / 10 ⁻⁶	U_i / 10 ⁻⁶
NIST	8.8	35	CENAM	5.4	170	CENAM	11.4	170	CENAM	18.9	170
CENAM	0.0	170	NPLI	8.8	89	NPLI	11.6	89	NPLI	9.7	89
NPLI	7.1	89	NIM	-63.6	42	NIM	-68.0	45	NIM	-70.8	46
NIM	-57.5	40	NMIJ	1.6	49	NMIJ	1.2	56	NMIJ	1.2	61
NMIJ	3.7	45	LNE	-9.1	47	LNE	-7.2	53	LNE	-6.4	57
LNE	-7.9	42	PTB	-1.6	42	PTB	-1.2	47	PTB	-1.2	50
PTB	-0.4	38									
NMIJ	0.1	45	NMIJ	0.1	51	NMIJ	0.2	56	NMIJ	0.5	62
NPLI	-1.3	83	NPLI	3.7	83	NPLI	3.3	83	NPLI	0.9	83
NMC, A*STAR	-15.0	88	NMC, A*STAR	-24.9	97	NMC, A*STAR	-26.3	110	NMC, A*STAR	-27.8	122
NIMT	-8.7	73	NIMT	-7.3	86	NIMT	-5.5	94	NIMT	-4.6	105
NMIA	11.7	45	NMIA	13.6	52	NMIA	19.0	59	NMIA	22.4	66
NIM	8.7	55	NIM	12.1	61	NIM	15.9	68	NIM	20.9	74
CMS	0.6	77	Puslit KIM-LIPI	-37.3	85	Puslit KIM-LIPI	-41.1	95	Puslit KIM-LIPI	-40.4	105
Puslit KIM-LIPI	-31.3	75	KRISS	-17.2	59	KRISS	-20.4	64	KRISS	-23.7	70
KRISS	-12.5	53									
PTB	-0.4	39	PTB	-1.6	43	PTB	-1.2	48	PTB	-1.2	51
INRIM	-48.0	55	INRIM	-52.8	58	INRIM	-53.9	61	INRIM	-53.9	64
NIS	-3.9	57	NIS	0.4	64	NIS	6.9	71	NIS	10.6	78
NMISA	-61.7	77	NMISA	-71.2	74	NMISA	-66.6	54	NMISA	-69.3	54
SMU	-3.9	54	SMU	-6.2	64	SMU	-2.5	75	SMU	-2.9	84
MIRS/IMT/LMT	-16.3	40	MIRS/IMT/LMT	-21.5	44	MIRS/IMT/LMT	-21.2	49	MIRS/IMT/LMT	-26.7	53
NPL	35.9	36	NPL	45.9	36	NPL	63.9	37	NPL	74.0	37
UME	-20.8	40	UME	-22.5	42	UME	-10.7	48	UME	-12.2	51

Key comparisons CCM.P-K13, APMP.M.P-K13 and EURAMET.M.P-K13

Degrees of equivalence relative to the CCM.P-K13 key comparison reference values (Cont.)

Lab <i>i</i>	450 MPa	
	D_i / 10^{-6}	U_i / 10^{-6}
CENAM	30.0	170
NPLI	16.7	90
NIM	-92.1	49
NMIJ	1.0	68
LNE	-4.6	63
PTB	-1.0	55

NMIJ	0.5	68
NPLI	5.3	84
NIMT	-5.5	114
NMIA	19.0	73
NIM	25.1	82
Puslit KIM-LIPI	-40.6	115
KRISS	-26.9	77

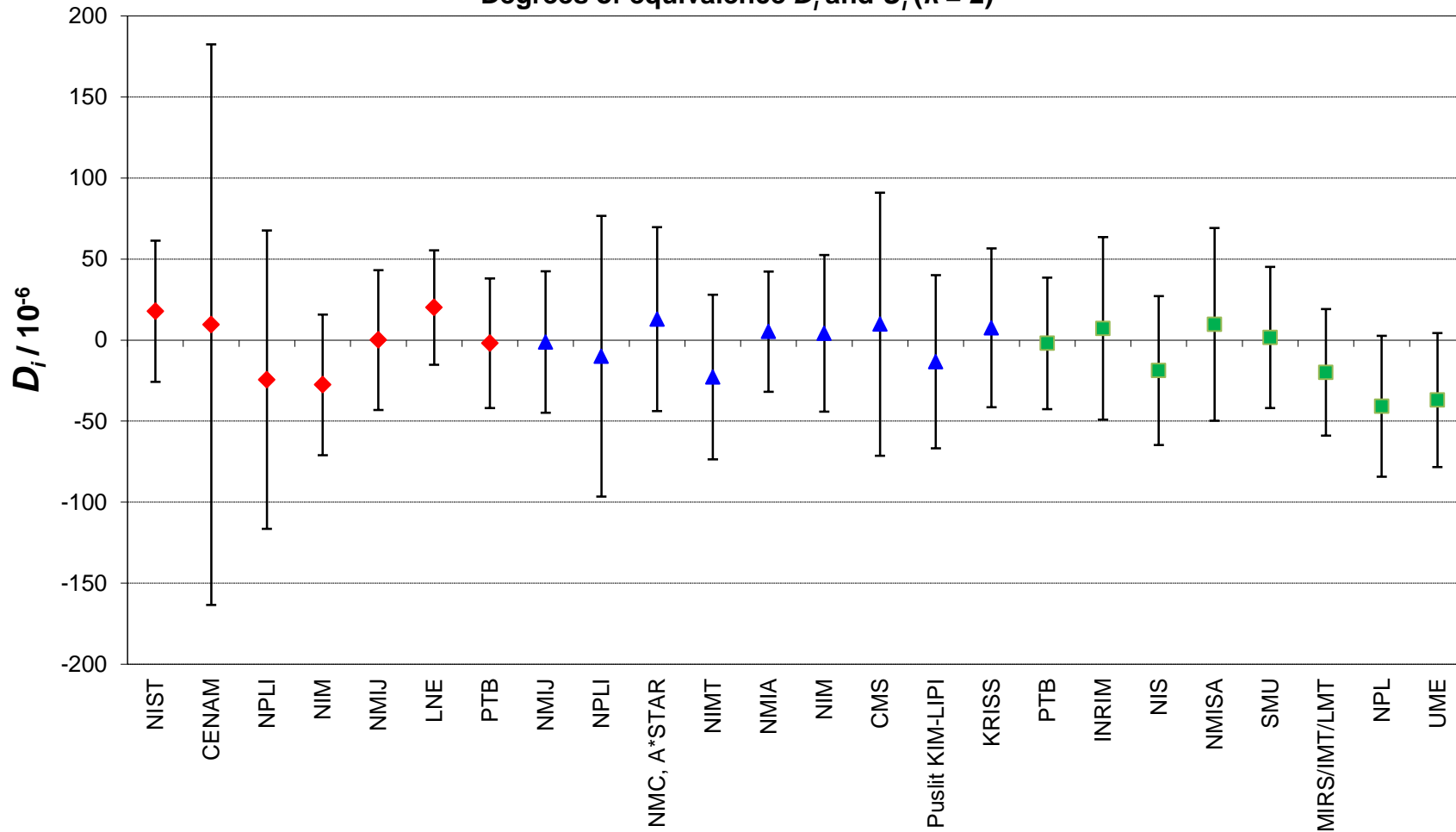
PTB	-10.0	56
INRIM	-53.4	68
NIS	12.4	86
NMISA	-63.8	37
SMU	-4.9	102
MIRS/IMT/LMT	-34.2	59
NPL	81.7	38
UME	-16.9	58

Lab <i>i</i>	500 MPa	
	D_i / 10^{-6}	U_i / 10^{-6}
CENAM	40.4	171
NPLI	26.6	91
NIM	-95.7	55
NMIJ	0.2	75
LNE	-0.2	69
PTB	-0.2	61

NMIJ	0.4	77
NPLI	1.0	85
NIMT	-8.3	125
NMIA	25.3	81
NIM	27.9	90
Puslit KIM-LIPI	-38.0	126
KRISS	-30.2	83

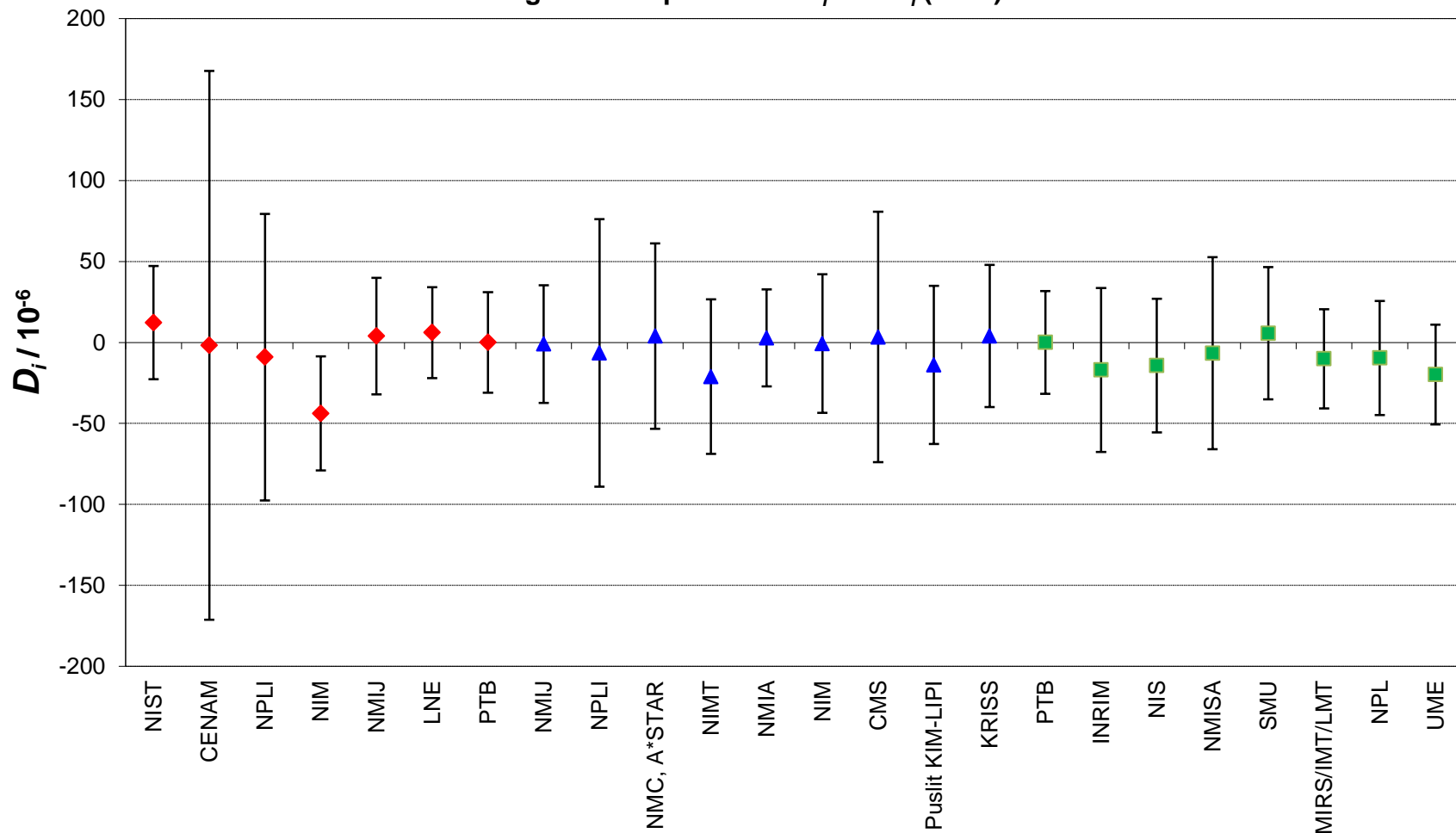
PTB	-0.2	61
INRIM	-56.9	73
NIS	19.2	95
NMISA	-76.7	39
SMU	-4.3	113
MIRS/IMT/LMT	-39.4	66
NPL	90.7	41
UME	-18.2	62

CCM.P-K13, APMP.M.P-K13 and EURAMET.M.P-K13 50 MPa
Degrees of equivalence D_i and U_i ($k = 2$)



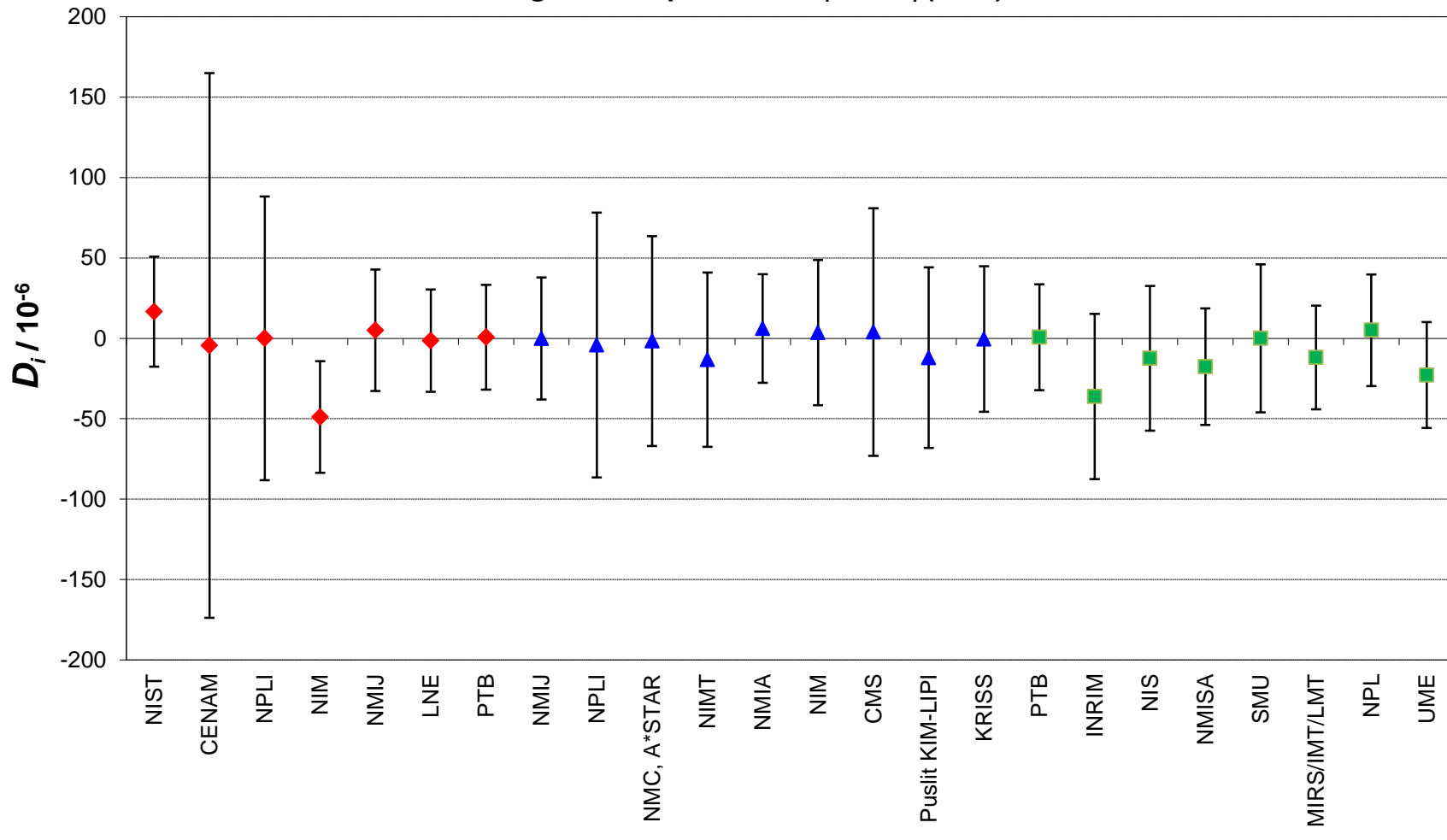
Red diamonds : participants in CCM.P-K13
Blue triangles : participants in APMP.M.P-K13
Green squares : participants in EURAMET.M.P-K13

CCM.P-K13, APMP.M.P-K13 and EURAMET.M.P-K13 100 MPa
Degrees of equivalence D_i and U_i ($k = 2$)



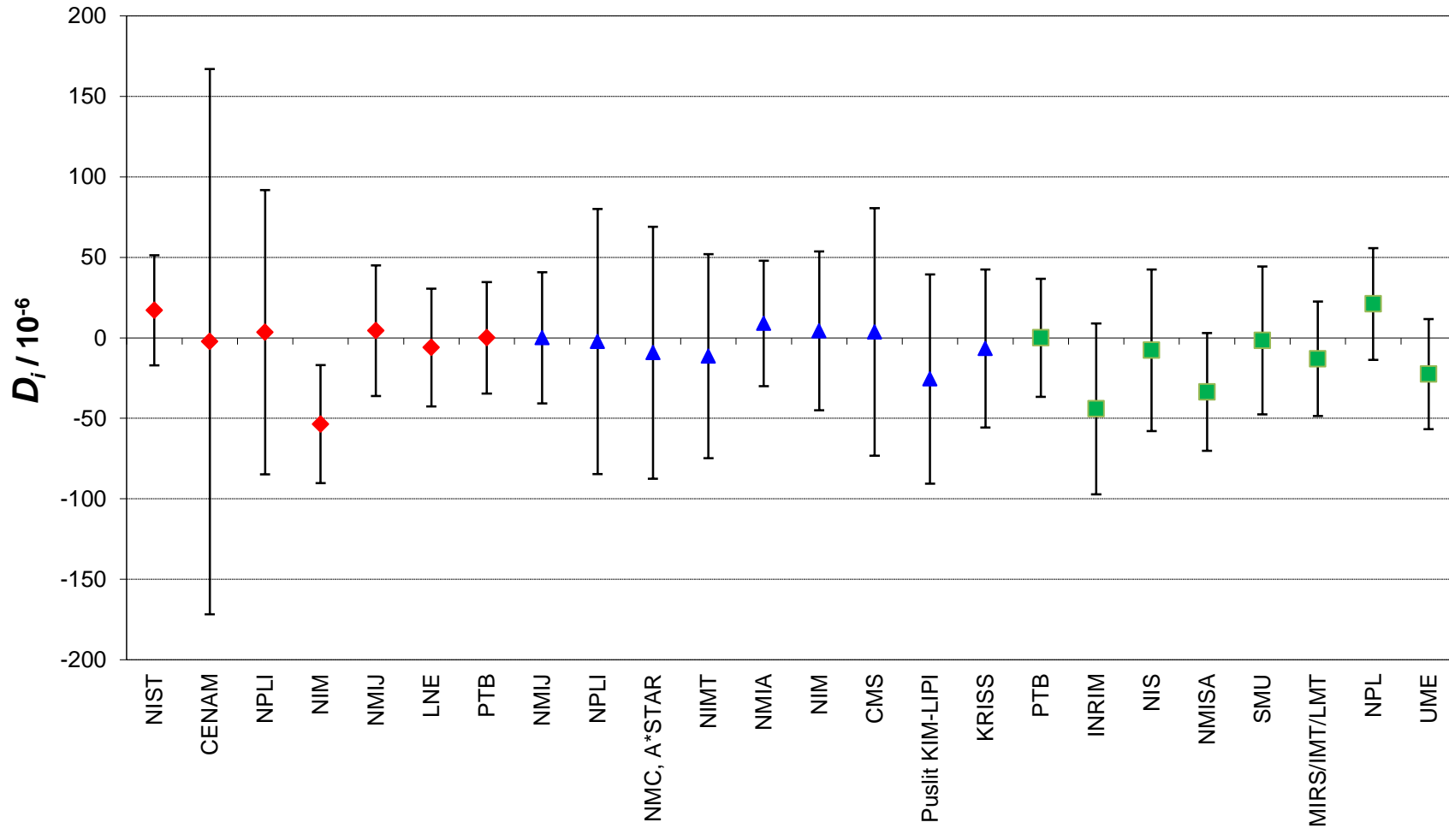
Red diamonds : participants in CCM.P-K13
Blue triangles : participants in APMP.M.P-K13
Green squares : participants in EURAMET.M.P-K13

CCM.P-K13, APMP.M.P-K13 and EURAMET.M.P-K13 150 MPa
Degrees of equivalence D_i and U_i ($k = 2$)



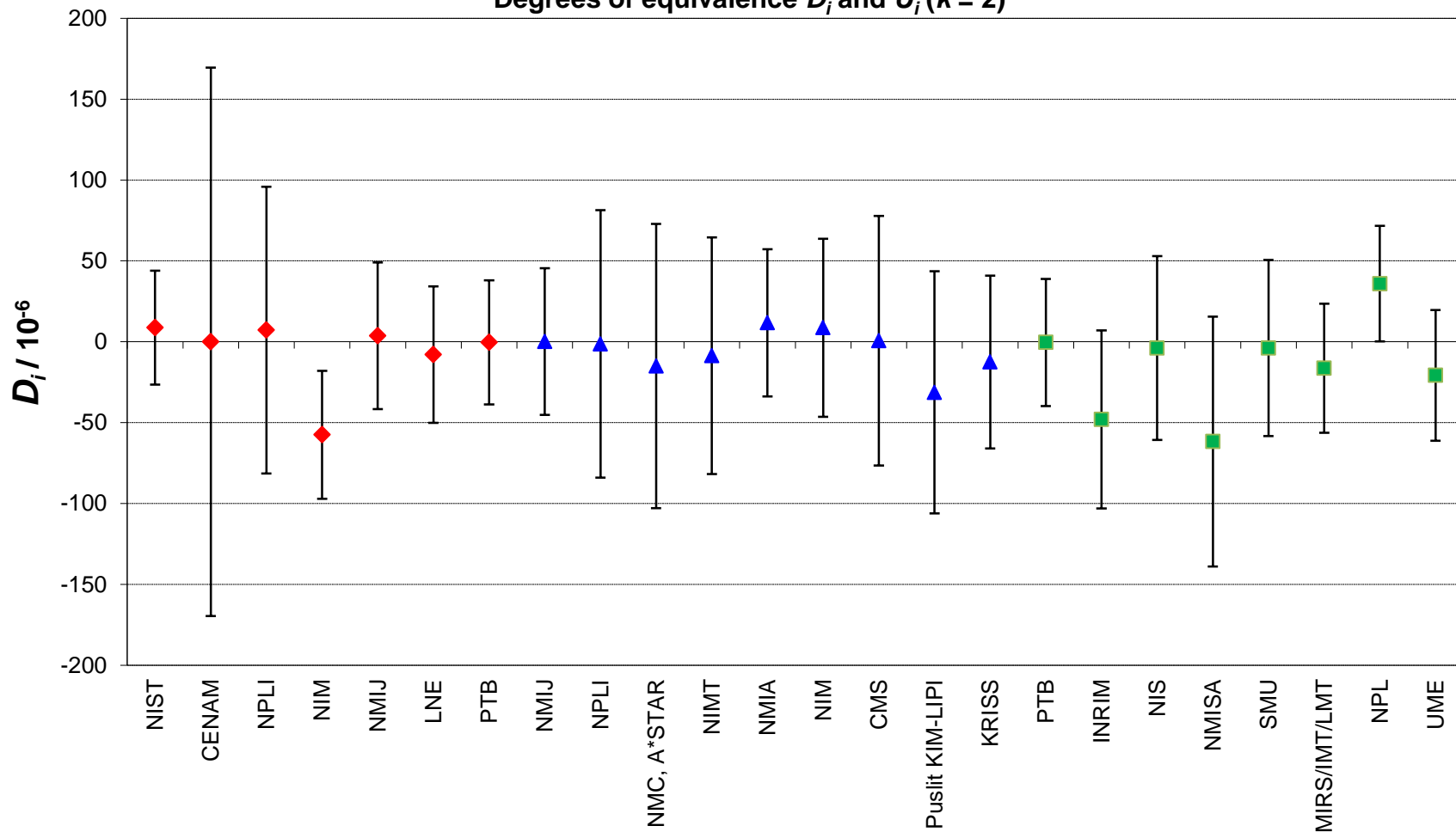
Red diamonds : participants in CCM.P-K13
Blue triangles : participants in APMP.M.P-K13
Green squares : participants in EURAMET.M.P-K13

CCM.P-K13, APMP.M.P-K13 and EURAMET.M.P-K13 200 MPa
Degrees of equivalence D_i and U_i ($k = 2$)



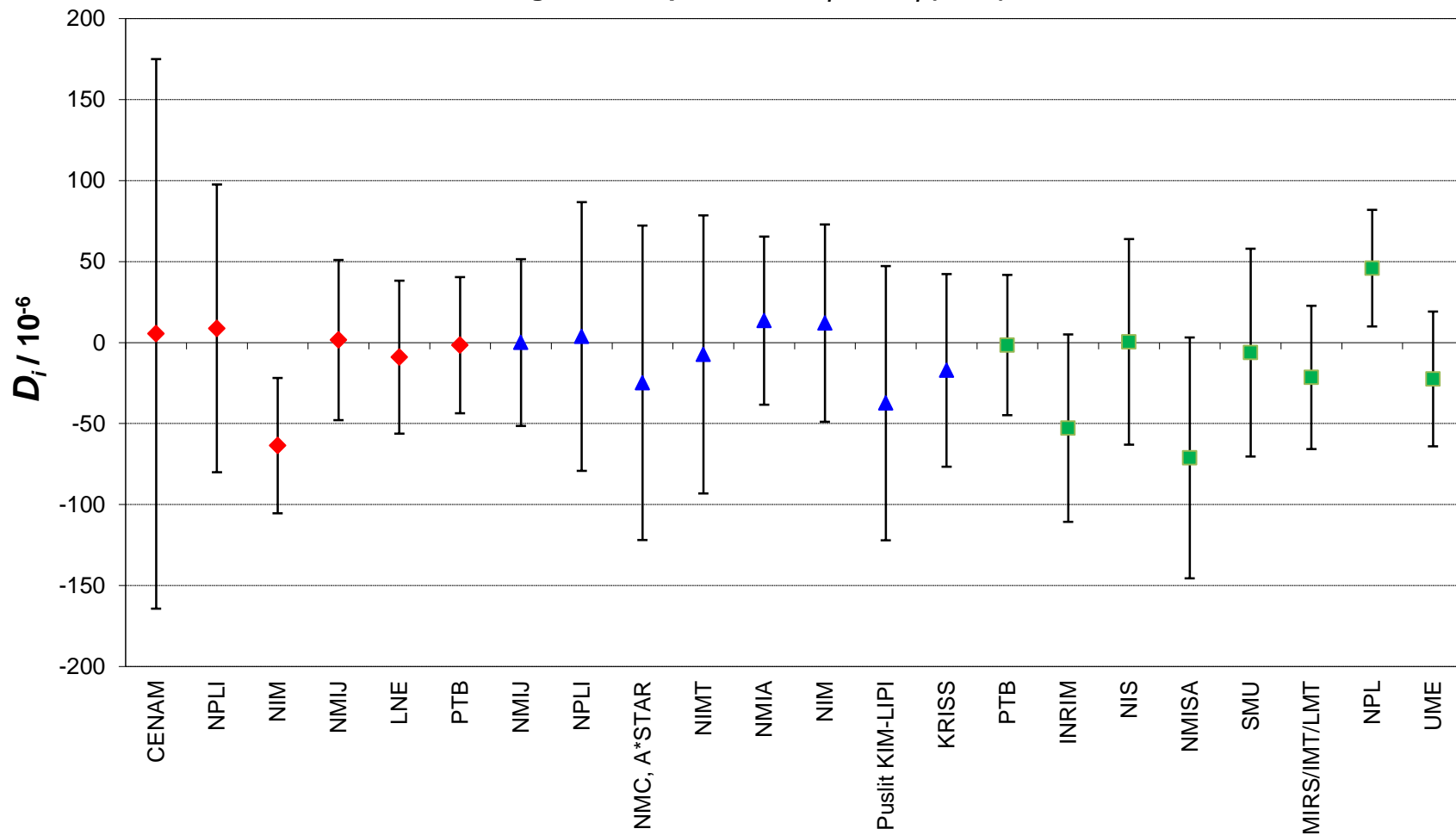
Red diamonds : participants in CCM.P-K13
Blue triangles : participants in APMP.M.P-K13
Green squares : participants in EURAMET.M.P-K13

CCM.P-K13, APMP.M.P-K13 and EURAMET.M.P-K13 250 MPa
Degrees of equivalence D_i and U_i ($k = 2$)



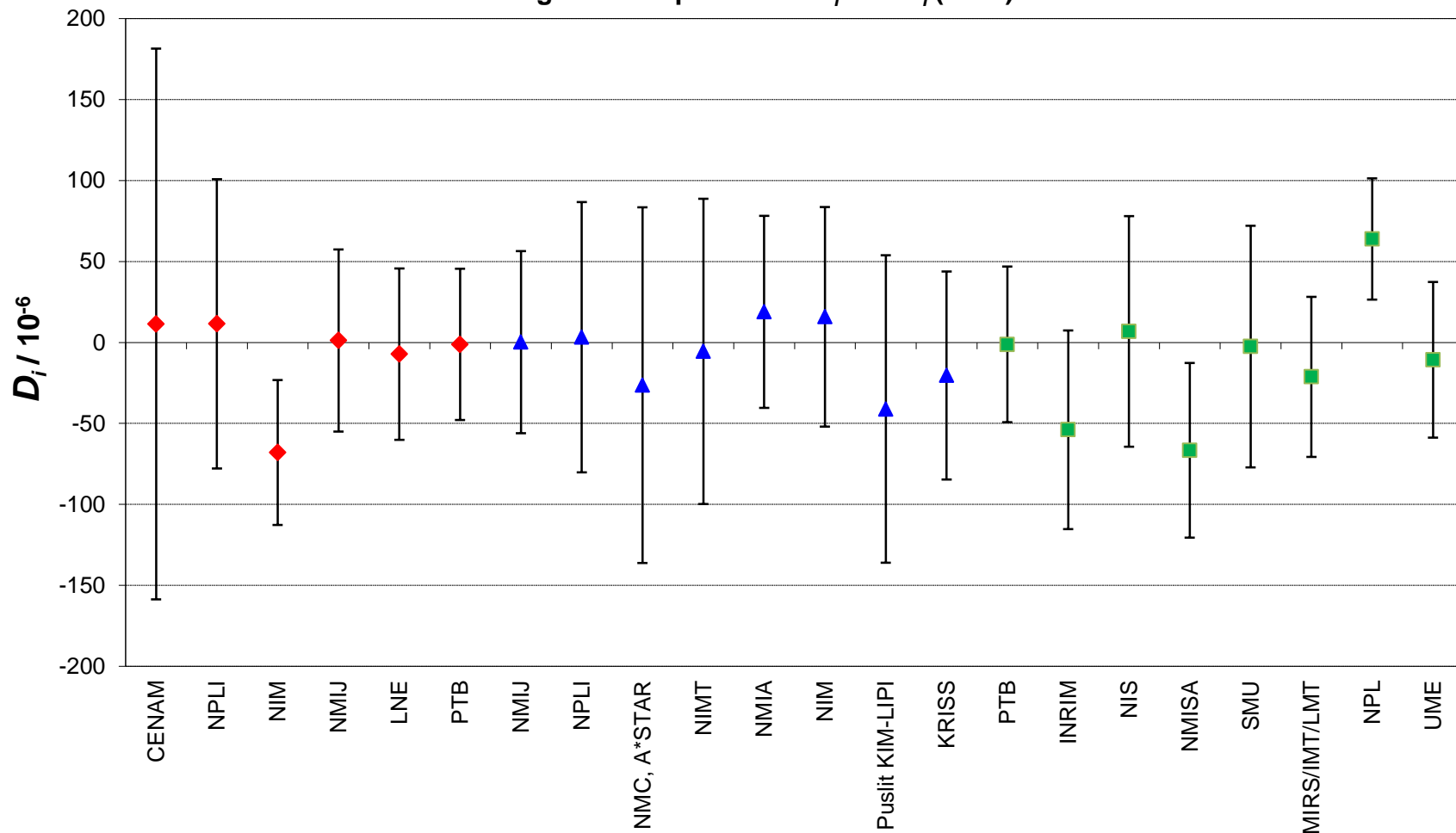
Red diamonds : participants in CCM.P-K13
Blue triangles : participants in APMP.M.P-K13
Green squares : participants in EURAMET.M.P-K13

CCM.P-K13, APMP.M.P-K13 and EURAMET.M.P-K13 300 MPa
Degrees of equivalence D_i and U_i ($k = 2$)



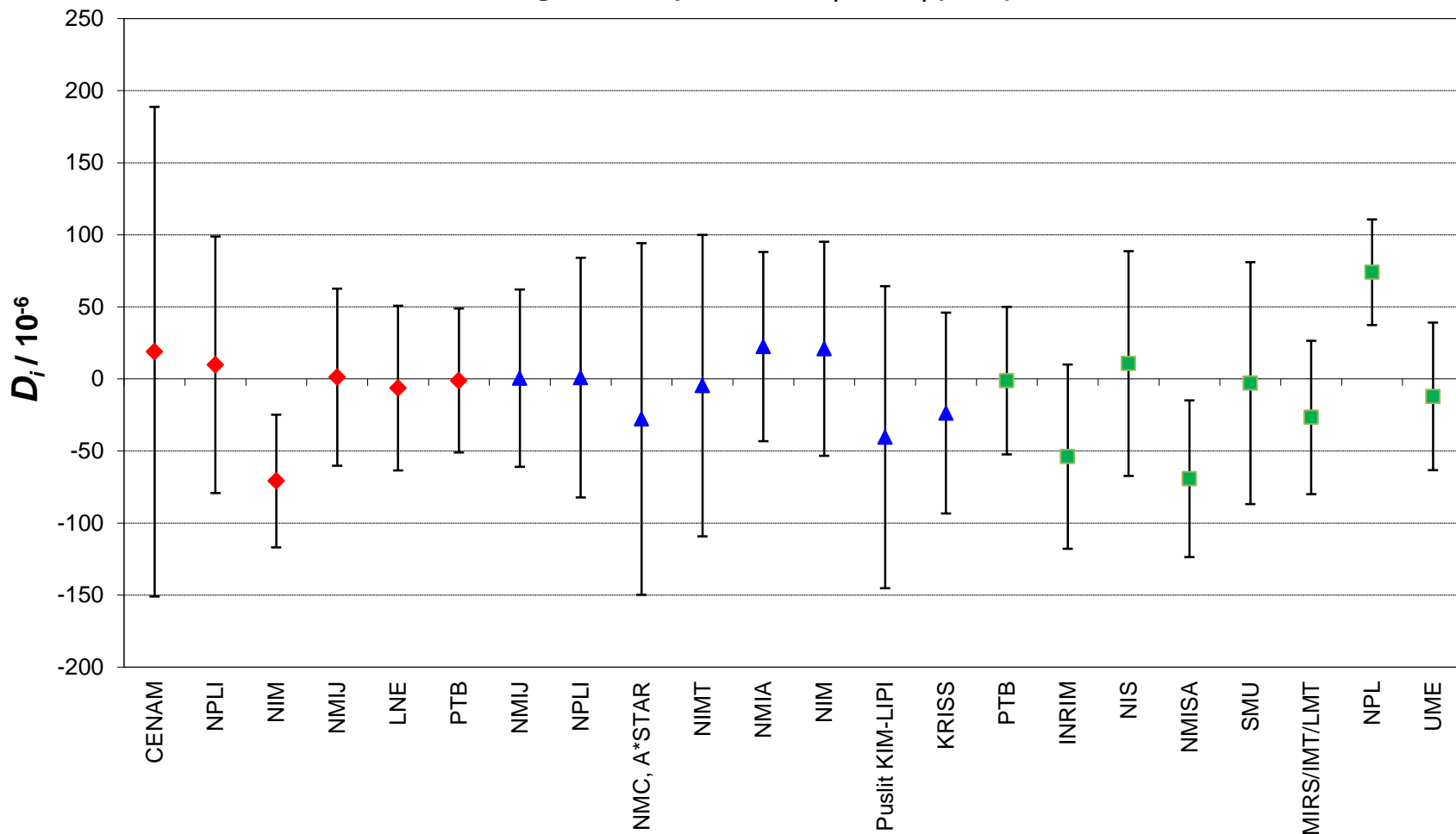
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Blue triangles : participants in APMP.M.P-K13
Green squares : participants in EURAMET.M.P-K13

CCM.P-K13, APMP.M.P-K13 and EURAMET.M.P-K13 350 MPa
Degrees of equivalence D_i and U_i ($k = 2$)



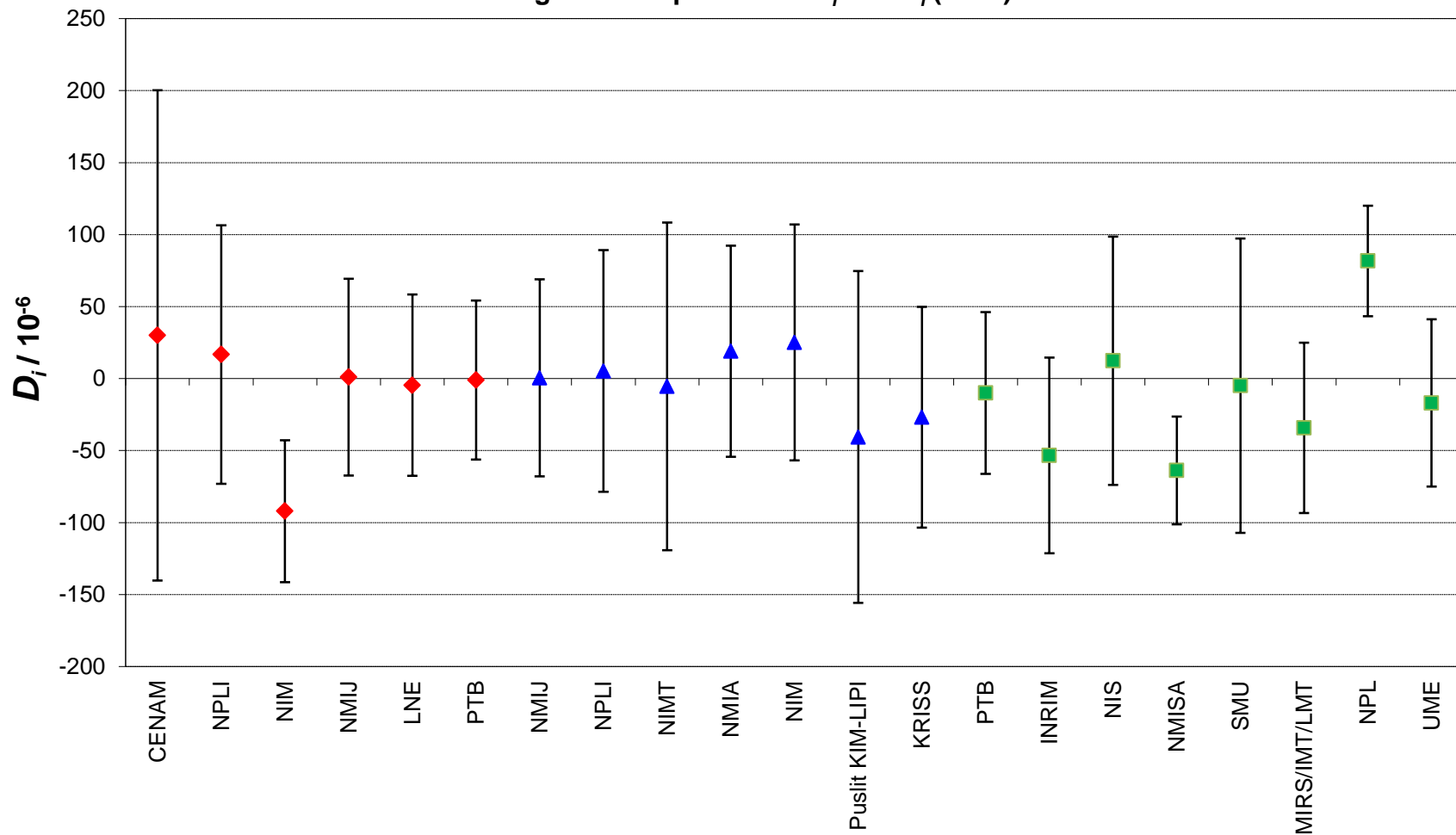
Red diamonds : participants in CCM.P-K13
Blue triangles : participants in APMP.M.P-K13
Green squares : participants in EURAMET.M.P-K13

CCM.P-K13, APMP.M.P-K13 and EURAMET.M.P-K13 400 MPa
Degrees of equivalence D_i and U_i ($k = 2$)



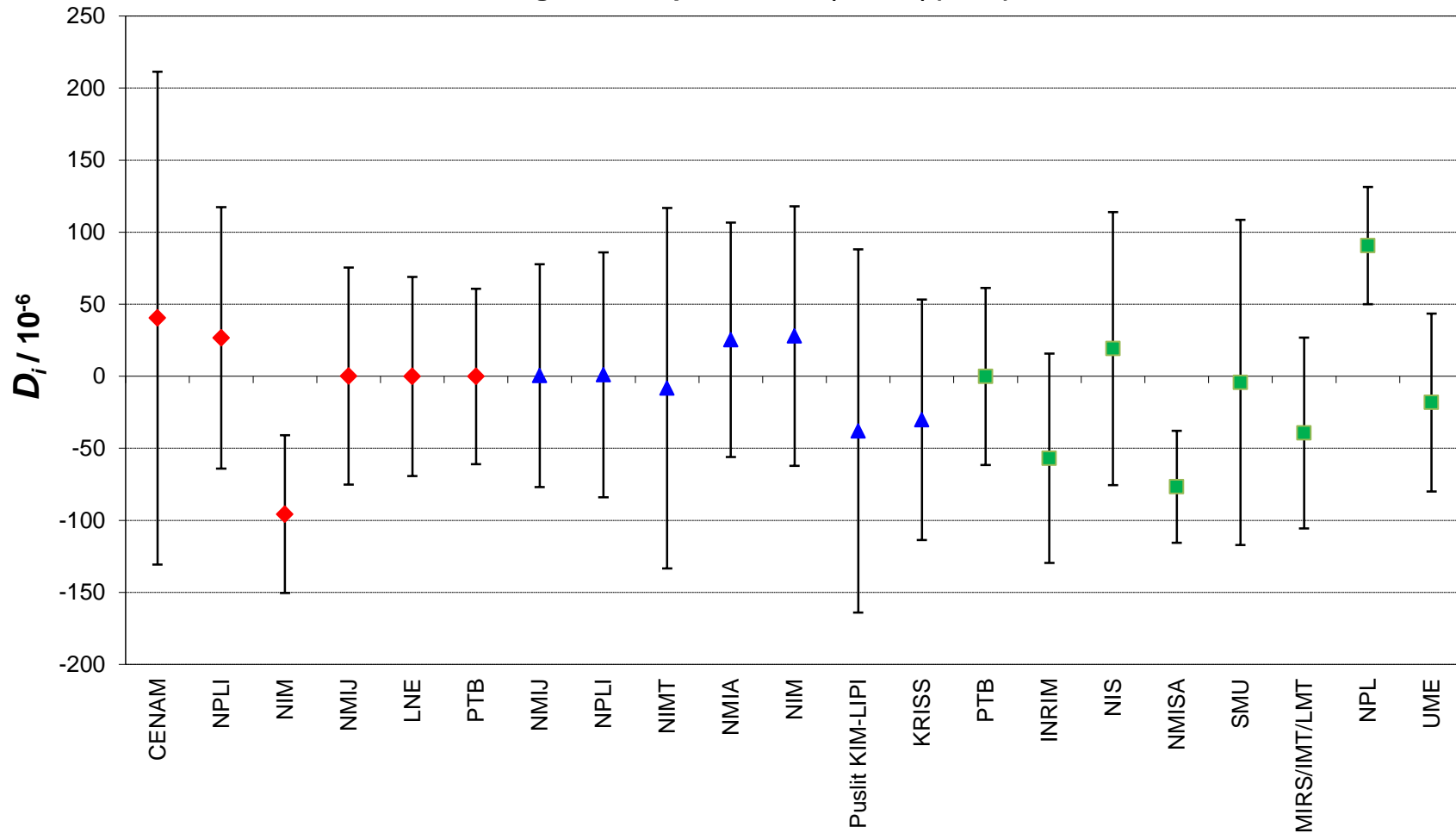
Red diamonds : participants in CCM.P-K13
Blue triangles : participants in APMP.M.P-K13
Green squares : participants in EURAMET.M.P-K13

CCM.P-K13, APMP.M.P-K13 and EURAMET.M.P-K13 450 MPa
Degrees of equivalence D_i and U_i ($k = 2$)



Red diamonds : participants in CCM.P-K13
Blue triangles : participants in APMP.M.P-K13
Green squares : participants in EURAMET.M.P-K13

CCM.P-K13, APMP.M.P-K13 and EURAMET.M.P-K13 500 MPa
Degrees of equivalence D_i and U_i ($k = 2$)



- ♦ : participants in CCM.P-K13
- ▲ : participants in APMP.M.P-K13
- : participants in EURAMET.M.P-K13