FINAL REPORT on SUPPLEMENTARY COMPARISON in HYDRAULIC MEDIA in the RANGE from 10 MPA to 100 MPA at GAUGE MODE

EURAMET.M.P-S13 (EURAMET 1252)

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[1]UME, National Metrology Institute of Turkey, Turkey

[2]MKEH, Hungarian Trade Licensing Office, Hungary

[3]BoM, Bureau of Metrology, Macedonia

[4]DPM, Drejtoria e Pergjithshme e Metrologjise, Albania

[5]DMDM, Directorate of Measures and Precious Metals, Serbia

[6]MBM, Bureau of Metrology Montenegro, Montenegro

[7]QAF, Qatar Armed Forces Calibration Center, Qatar

[8]EMI, Emirates Metrology Institute, UAE

[9]SASO NMCC, National Measurements Calibration Center, Kingdom of Saudi Arabia

[10]VMC, Vilnius Metrology Centre, Lithuania

[11]GUM, Central Office of Measures, Poland

[12]IMT, Institute of Metals and Technology, Slovenia

[13]HMI/FSB-LPM, Croatian Metrology Institute/Faculty of Mechanical Engineering and Naval Architecture -Laboratory for Process Measurement, Croatia

[14]VSL, Netherlands

[15]VTT MIKES Metrology, VTT Technical Research Centre of Finland Ltd, Finland

[16]FORCE Technology, Denmark

[17]IMBiH, Institute of Metrology of Bosnia Herzegovina

[18]NSAI NML, Ireland

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Abstract

The regional supplementary comparison EURAMET.M.P-S13 for pressure measurements in liquid media from 10 MPa to 100 MPa was piloted by the TÜBİTAK UME Pressure Laboratory, Turkey. The transfer standard was a digital pressure gauge, serial number 116321, manufactured by Paroscientific Inc. Eighteen laboratories participated in this comparison. Fourteen laboratories are from EURAMET region; namely UME, MKEH, BoM, DPM, DMDM, MBM, GUM, IMT, HMI/FSB-LPM, VSL, VTT MIKES, FORCE Technology, IMBIH, NSAI NML. VMC is from COOMET and QAF, EMI, SASO NMCC are from GULFMET region. Participant laboratories and countries are given on the previous page.

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1. Introduction

Interlaboratory comparisons are a significant parameter for the calibration laboratories for assuring the quality of test and calibration results. Accredited laboratories and other laboratories that have a quality system for their working areas are expected to join into multi-participant intercomparisons in certain periods to show and assure their service quality.

The present comparison [1, 2] was planned at the EURAMET TC-M SC Pressure meeting held on 21st of March 2013 in Cavtat, Croatia. It was registered as Euramet project 1252 in the EURAMET projects database and as supplementary comparison EURAMET.M.P-S13 in the BIPM KCDB. The objective of this comparison is to state the degree of equivalence of measurements provided by National Metrology Institutes (NMIs) – the signatories of the Mutual Recognition Arrangement (MRA) [3]. Participating Laboratories will have the opportunity to support their uncertainty statements made in their Calibration Measurement Capability (CMC) Tables.

The pressure range up to 100 MPa in hydraulic media is the pressure range where many NMIs have measurement capability. After a discussion at the TC-M SC Pressure meeting dated 2013, 100 MPa pressure range was selected for the comparison. For the proposed comparison, eighteen participants applied to participate in the EURAMET 1252. Out of the eighteen applicants, fourteen institutes were members of EURAMET, three institutes were members of the Asian-Gulf (GULFMET) and one institute was the member of the Euro-Asian (COOMET) regional metrology organisation. The UME agreed to be the pilot laboratory for this comparison.

The comparison was conducted in accordance with the Technical Protocol prepared by the UME and approved by the participants.

Comparison reports – draft A, draft B and final report were prepared and distributed according to the "CCM Guidelines for approval and publication of the final reports of key and supplementary comparisons" [4]. In this guide in chapter 4, it is highlighted that information on pair-wise degrees of equivalence published in comparison reports be limited to the equations needed to calculate them, with the addition of any information on correlations that may be necessary to estimate them more accurately. The CCM stresses the importance of continuing to report the values and the graphs representing the degrees of equivalence relative to the comparison reference value. Due to the number of participants in this ILC, degrees of equivalence relative to the comparison reference value were presented while information on pair-wise degrees of equivalence was limited to the equations needed to calculate them.

2. Participants

2.1. Pilot laboratory

This comparison is piloted by TUBITAK UME. The pilot laboratory is responsible for preparing the measurement instructions, controlling the stability of the transfer standard, calculating the results and preparing the final report.

2.2. Participant laboratories

List of participating laboratories is given in Table 1.

Table 1. List of participating laboratories

No	Laboratory	Country	Contact Person	Measurement Date	Traceability	CMC
1	UME	Turkey	Yasin Durgut	2014.01.28	PTB	Yes
2	MKEH	Hungary	Csilla Vámossy	2014.02.19	PTB	Yes
3	BoM	Macedonia	Nenad Petrovski	2014.03.10	HIM	Yes
4	DPM	Albania	Bekim Tomçini	2014.04.09-11	HIM	Yes
5	DMDM	Serbia	Boris Ramač	2014.04.28 – 2014.05.09	LNE	Yes
6	MBM	Montenegro	Aleksandar Vulić	2014.05. 21- 28	PTB	Yes
7	QAF	Qatar	Nasser Al-Jattal	2014.07.15	NPL	No
8	EMI	United Arab Emirates	Brian K. Justice	2014.08.17	CMI	No
9	SASO–NMCC	Kingdom of Saudi Arabia	Homood M. Alotaibi	2014.10.01	FLUKE	No
10	VMC	Lıthuania	Ksaverija Dapkeviciene	2015.06.29	PTB	Yes
11	GUM	Poland	Adam Brzozowski	2015.05.19	PTB	Yes
12	IMT	Slovenia	Janez Setina	2015.06.08-12	PTB	Yes
13	HMI/FSB-LPM	Croatia	Lovorka Grgec Bermanec	2015.07.16	PTB	Yes
14	VSL	Netherlands	Jan Van Geel	2015.12.01	VSL	Yes
15	VTT MIKES	Finland	Sari Saxholm	2015.06.24-25	VTT MIKES	Yes
16	FORCE Technology	Denmark	Aykurt Altintas	2016.05.18	PTB	Yes
17	IMBIH	Bosnia and Herzegovina	Šejla Ališić	2017.03.10-15	PTB	No
18	NSAI NML	Ireland	Paul Hetherington	2015.10.19	PTB	Yes

3. Laboratory standards and measurement details of the participants

3.1. Measurement at UME

Details of performed measurement at UME are given in Table 2.

Table 2. Measurement details of UME

Participant laboratory name and address		National Metrology Institute of Turkey (UME) Gebze-Kocaeli/Turkey
Contact person name, e-mail, phone		Yasin Durgut yasin.durgut@tubitak.gov.tr +90 262 679 50 00
Notes of inspection of the package (e.g. Damage, missing items, any problems)		The transfer standard was free of damage.
Reference instrument information	Manufacturer	Budenberg
	Model	5304
	Serial no	8255
	Measurement range	10 to 1000 Bar
	Traceability information	PTB.
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		A description is given below
Date of receipt of transfer standards		20.01.2014
Date of dispatch		01.02.2014
Date of measurements		28.01.2014
Measurement environmental conditions	Temperature (°C)	(20.0 ± 1) °C
	Relative humidity (rh%)	(45 ± 15) rh%
	Atmospheric pressure (mbar)	(995 - 997) ± 0.1 mbar

The reference standard was a pressure balance manufactured by Budenberg with a piston-cylinder of 10 mm^2 nominal area. Its measurement range is up to 100 MPa. The piston-cylinders parameters (A_0 and λ) are traceable to the PTB. Loading masses are traceable to the UME. Di(2-Ethylhexyl) sebacate was used as the pressure transmitting medium. The density of sebacate at atmosphere is (912.30 ± 0.05) kg/m^3. The density of oil was re-calculated for each pressure point. The reference level of the transfer standard is the midpoint of the pressure connection port. The reference level of the reference standard is labelled on the base by the manufacturer. The height difference between the reference standard and the transfer standard was measured and taken into account. The measurements were performed per the instructions of section 6.2 of the Technical Protocol. The uncertainty of the calibration results was evaluated according to GUM, EA 4/02 and the guidance of Euramet CG-17 document. The measurement set-up is given in Figure 1.

Figure 1. Measurement set-up at UME

3.2. Measurement details of MKEH

Details of performed measurement at MKEH are given in Table 3.

Table 3. Measurement details of MKEH

Participant laboratory name and address		Hungarian Trade Licensing Office (MKEH), H-1124 Budapest, Németvölgyi út 37-39. / Hungary	
Contact person name, e-mail, phone		Csilla Vámossy, vamossycs@mkeh.hu +36 1 458 59 47	
Notes of inspection of the package (e.g. Damage, missing items, any problems)		The transfer standard was free of damage. There was no missing item.	
Reference instrument information	Manufacturer	Budenberg	Budenberg
	Model	380D	580HX
	Serial no	19593/S508	27033/515G
	Measurement range	(10 to 600) bar	(60 to 1200) bar
	Traceability information	PTB 2010	PTB 2001
A detailed description of how the measurements were performed (photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C.		See the description of measurements below and Figure 2	
Date of receipt of transfer standards		12.02.2014	
Date of dispatch		24.02.2014	
Date of measurements		19.02.2014	
Measurement environmental conditions	Temperature (°C)	(20.0 - 20.2) ± 0.2 °C	
	Relative humidity (rh%)	(39.9 - 43.7) ± 3.0 rh%	
	Atmospheric pressure (mbar)	(993.2 - 995.6) ± 0.1 mbar	

Description of the measurements

Two oil-operated pressure balances manufactured by Budenberg were used for the comparison. At the nominal pressure points of (10, 20, 30, 40, 50, 60) MPa we used the pressure standard type Budenberg 380D. The nominal area of the piston-cylinder assembly is 8.0 mm^2, the measuring range is (1 to 60) MPa. At the nominal pressure points of (70, 80, 90, 100) MPa we used the pressure standard type Budenberg 580HX. The nominal area of the piston-cylinder assembly is 4.0 mm^2, the measuring range is (6 to 120) MPa. The piston-cylinders parameters (A_0 and λ) are traceable to the pressure standards of the PTB (Germany). All masses are traceable to the Mass Laboratory of MKEH. 2-Ethylhexyl sebacate was used as a pressure-transmitting medium, density = (914.30 ± 0.05) kg/m^3. The reference level of the transfer standard is the midpoint of the pressure connection port. The reference levels of both reference standards are the piston lower edge. The height differences between the reference standard and the transfer standard were h_1 = (75.9 ± 1.0) mm and h_2 = (84.0 ± 1.0) mm. The height difference was measured by cathetometer. The measurements were performed per the instructions of section 6.2 of the Technical Protocol. The uncertainty of the calibration results was evaluated according to GUM, EA 4/02 and the guidance of Euramet CG-17 Calibration Guide. A schematic drawing of the experimental set-up is given in Figure 2.

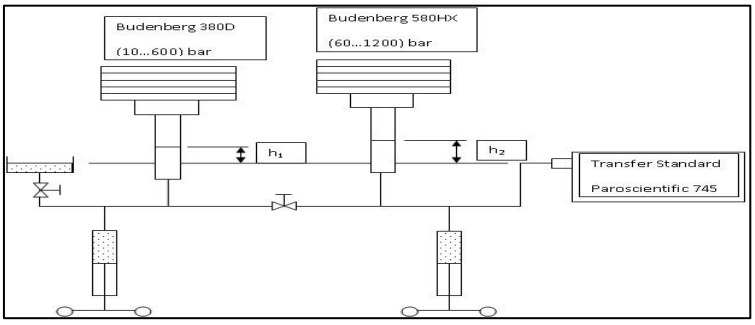

Figure 2. Measurement set-up at MKEH

3.3. Measurement details of BoM

Details of performed measurement at BoM are given in Table 4.

Table 4. Measurement details of BoM

Participant laboratory name and address		Bureau of the metrology-Pressure laboratory, Blvd. Jane Sandanski 109 a, Skopje
Contact person name, e-mail, phone		Nenad Petrovski nenad.petrovski@bom.gov.mk; Tel.+389 2 2403-676
Notes of inspection of the package (e.g.Damage, missing items, any problems)		Everything was OK, no damage
Reference instrument information	Manufacturer	DH-Budenberg
	Model	DWT-580
	Serial no.	Piston-cylinder Unit Serial No.: 830H
	Measurement range	(6-700) bar
	Traceability information	Certificate number: PRE-10-058_A, EIM-Greece
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		BOM Procedure: LP 04-P-01-Pressure calibration procedure for analogue and digital manometers (according: Euramet/cg-17/v. 2.0 - Guidelines on the Calibration of Electromechanical Manometers, 3/2011); see Figure 3. The temperature was measured with TESTO 650-Calibrated in EIM-Greece, the temperature was in the range of (20 ± 1) °C. The measurement set-up is given in Figure 3 below.
Date of receipt of transfer standards		28.02.2014
Date of dispatch		Probably on 03.04.2014, we will bring the instrument to the Pressure laboratory in Tirana by our car.
Date of measurements		10.03.2014
Measurement environmental conditions	Temperature (°C)	(20 ± 1) °C
	Relative humidity (rh%)	(50 ± 25) rh%
	Atmospheric pressure (mbar)	(980 ± 10) mbar

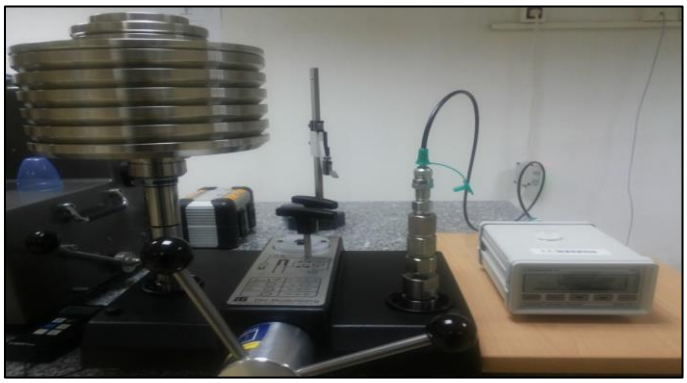

Figure 3. Measurement set-up at BoM

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3.4. Measurement details of DPM

Details of performed measurement at DPM are given in Table 5.

Table 5. Measurement details of DPM

Participant laboratory name and address		Pressure Laboratory Drejtoria e Pergjithshme e Metrologjise (DPM), Albania Address: Autostrada Tirane-Durres, Km 8, Kashar e-mail: metrology@dpm.gov.al
Contact person name, e-mail, phone		Bekim Tomçini bekim.tomcini@dpm.gov.al, +355 67 20 43 419
Notes of inspection of the package (e.g. Damage, missing items, any problems)		I received the instrument without any damage but 1 litre of sebacate oil was missing
Reference instrument information	Manufacturer	Dh – Budenberg
	Model	580 DX
	Serial no	297 K
	Measurement range	1 bar – 700 bar
	Traceability information	The standard was calibrated in EIM Greece on 09.02.2011; No. of calibration certificate PRE–11–015_A
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		The calibration was performed under the Technical Procedure LP – PT – 01 "Calibration of Pressure Gauges", according to DAkkS – DKD – R 6 – 1 "Calibration of pressure gauges", 06/2010 and EURAMET CG-17 "Guidelines on Calibration of Electrical Manometers", version 2, 03/2011. The measurement was performed under temperature conditions (20±1) °C for the whole calibration process. A photo of the measurement set-up is given in Figure 4 below.
Date of receipt of transfer standard		03.04.2014
Date of dispatch		11.04.2014
Date of measurements		09 – 11.04.2014
Measurement environmental conditions	Temperature (°C)	The measurements were performed under temperature (20 ± 1) °C
	Relative humidity (rh%)	The measurements were performed under a relative humidity of 51 rh%
	Atmospheric pressure (mbar)	The measurements were performed under a medium atmospheric pressure of 1011.15 mbar

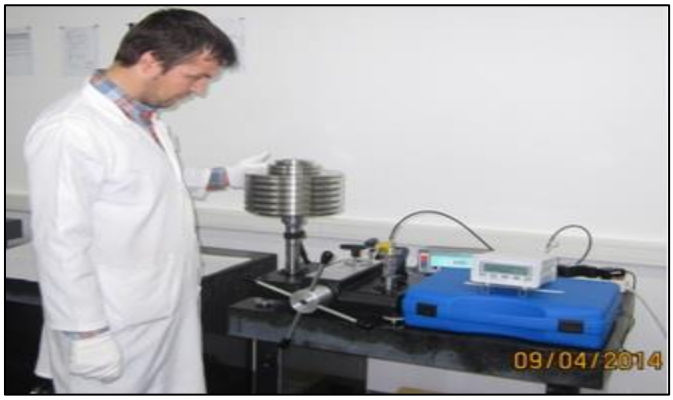

Figure 4. Measurement set-up at DPM

3.5. Measurement details of DMDM

Details of performed measurement at DMDM are given in Table 6.

Table 6. Measurement details of DMDM

Participant laboratory name and address		Directorate of Measures and Precious Metals (DMDM), Mike Alasa 14, 11000 Belgrade, Serbia
Contact person name, e-mail, phone		Predrag Djurić djuric@dmdm.rs +381 11 20 24 417
Notes of inspection of the package (e.g. Damage, missing items, any problems)		No damage, missing 1 L sebacate oil
Reference instrument information	Manufacturer	Desgranges et Huot
	Model	5303 S CP
	Serial no	base: 3401, PCU: 2496
	Measurement range	(20-1000) bar
	Traceability information	LNE - K080056, $U_{k=2}$=29 Pa + 1.9*10^{-5} x p
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		According to Technical Protocol points 6. Measurement procedure and DMDM calibration procedure for calibration of pressure gauges (RU M-03). Beside uncertainties listed in the protocol, were used all other relevant components (eg. u(hist), u(h), u(α+β), u(g), u(λ), u(tk),...), Δh=(0 ± 0.002) m
Date of receipt of transfer standard		25.04.2014
Date of dispatch		12.05.2014
Date of measurements		28.04.2014 - 09.05.2014
Measurement environmental conditions	Temperature (°C)	(20.0 - 21.7) °C
	Relative humidity (rh%)	(41.7 - 56.3) rh%
	Atmospheric pressure (mbar)	(995.7 - 1013.5) mbar

3.6. Measurement details MBM

Details of performed measurement at MBM are given in Table 7.

Table 7. Measurement details of MBM

Participant laboratory name and address		Zavod za metrologiju, Kralja Nikole 2, 81000 Podgorica, Crna Gora
Contact person name, e-mail, phone		Aleksandar Vulić, E-mail: aleksandar.vulic@metrologija.gov.me, Phone +382 20 601 360
Notes of inspection of the package (e.g. Damage, missing items, any problems)		The ATA carnet did not have enough empty pages for Montenegrin customs records. The TS was allowed to enter the Montenegro territory on a temporary import base.
Reference instrument information	Manufacturer	DH Budenberg
	Model	580 HXA
	Serial No	30421 (base); 437L (piston/cylinder); B0420 (weights); B0430 (weights)
	Measurement range	low range piston 1 bar to 60 bar; high range piston 60 bar to 1200 bar
	Traceability information	Calibration certificate issued by IMT, Laboratory of Pressure Metrology, Ljubljana, Slovenia
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		The measurement set up was established as it is demonstrated in the attached photo. The transfer standard (TS) input port was at the level of 75 mm over the laboratory standard reference level. A corresponding height difference correction was applied in measurement data treatment. 24 hours warm-up time was allowed for stabilisation at the temperature maintained at (20.0 ± 1.0) °C. The measurement was performed following the principles described in the Technical protocol. A photo of the measurement set-up is given in Figure 5 below
Date of the recipient of transfer standards		19.05.2014
Date of dispatch		02.06.2014
Date of measurements		21.05.2014 to 28.05.2014
Measurements environmental conditions	Temperature (°C)	(20 ± 0.7) °C
	Relative humidity (rh%)	(35 to 60) rh%
	Atmospheric pressure (mbar)	(1008.81 - 1007.42) mbar

Figure 5. Measurement set-up at MBM.

3.7. Measurement details of QAF

Details of performed measurement at QAF are given in Table 8.

Table 8. Measurement details of QAF

Participant laboratory name and address		Qatar Armed Forces Calibration Center, PO Box 24129, Doha, Qatar
Contact Person Name, e-mail, phone		Brigadier (Tech./Air) Nasser Al-Jattal Tel: +974 44 616 500 / 900 / 906, Fax:+974 44 616 901 / 921 e-mail:ccqaf@yahoo.com, data1124@hotmail.com
Notes of inspection of the package (e.g. Damage, missing items, any problems)		Equipment received in good condition
Reference Instrument Information	Manufacturer	Desgranges et Huot
	Model	DH 5306
	Serial No.	6546
	Measurement range	0 – 2000 bar
	Traceability Information	National Physical Laboratory, United Kingdom.
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		- The transfer standard (UUT) was placed in a laboratory near the reference standard for 24 hours before starting the measurement. The UUT was placed horizontally, near to the reference standard in such a way that the datum line of the standard and input connection point of the UUT was in the same level to minimize the uncertainty due to height difference (a photo of the set-up is placed at enclosure). The UUT was kept switched on for 2 hours to warm up and stabilization before the commencement of measurements. The resolution of the UUT was adjusted to 1 mbar. The transfer standard was loaded to the full range three times, maintaining a waiting time of 2 min between loadings and 1 min at full scale. - After preloading exercises, 5 min waiting time was observed before measurements. The UUT was zeroed as described in the user manual - Measurements were performed in three cycles comprising 11 points in ascending and 10 points in descending order. The nominal pressure was applied to the reference standard and corresponding UUT readings were recorded after maintaining 30 sec for stabilization and 15 sec for UUT display. Measurements were performed in gauge mode. A photo of the measurement set-up is given in Figure 6 below.
Date of receipt of transfer standard		13.07.2014
Date of dispatch		21.07.2014
Date of measurements		15.07.2014
Measurement environmental conditions	Temperature (°C)	19.45 °C
	Relative Humidity (rh%)	45 %rh
	Atmospheric Pressure (mbar)	998.6 mbar

Figure 6. Measurement set-up at QAF

3.8. Measurement details of EMI

Details of performed measurement at EMI are given in Table 9.

Table 9. Measurement details of EMI

Participant laboratory name and address		Emirates Metrology Institute Block H, CERT Technology Park Sultan Bin Zayed The First Street PO Box 853, Abu Dhabi, UAE
Contact person name, e-mail, phone		Mr Brian K. Justice Brian.Justice@qcc.abudhabi.ae Direct: +971 2 406 6540 Mobile: +971 50 383 8491
Notes of inspection of the package (e.g. Damage, missing items, any problems)		Equipment received with packaging in good condition. No sign of damage. However, the adaptor provided for connection was not appropriate and there was a leak of oil at maximum pressure. The problem was solved by connecting the reference standard directly to the connector at the rear of the instrument.
Reference instrument information	Manufacturer	DHI
	Model	PG7302 Base MS-AMH-100 Mass Set 7300-1 3070063 Piston/Cylinder
	Serial no	953 2791 1845
	Measurement range	10 MPa - 100 MPa
	Traceability information	Czech Metrology Institute certificates: 6012-KL-H0024-13; 2013.03.11 Mass Set 6013-KL-P0080-12; 2012.12.12 P/Cylinder Local gravity measured using gravity comparator and three absolute gravity reference stations
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		Calibration was undertaken using Compass software for calibrating a Paroscientific transducer. The centre of the connection to the transducer was at the same height as the reference plane of the PG7302. The procedure given in the Protocol dated 2014.05.09 was followed. A period of 24 h was allowed to obtain thermal equilibrium. Before commencing each calibration run, the transfer standard was disconnected from the reference standard and the indicator reading set to zero by following the tare procedure.
Date of receipt of transfer standard		19.07.2014
Date of dispatch		17.09.2014
Date of measurements		17.08.2014
Measurement environmental conditions	Temperature (°C)	(20.4 ± 0.4) °C
	Relative humidity (rh%)	(54 ± 7) %rh
	Atmospheric pressure (mbar)	(995.5 ± 0.6) mbar

3.9. Measurement details of SASO-NMCC

Details of performed measurement at SASO-NMCC are given in Table 10.

Table 10. Measurement details of SASO-NMCC

Participant laboratory name and address		National Measurements Calibration Center (SASO–NMCC) P.O. Box 3437, Riyadh 11471, Kingdom of Saudi Arabia
Contact person name, e-mail, phone		Homood M. Alotaibi h.otaibi@saso.gov.sa +966505474746
Notes of inspection of the package (e.g. Damage, missing items, any problems)		Some glue on the back One liter of sebacate is missing
Reference instrument information	Manufacturer	Fluke
	Model	PC-7300-1
	Serial no	1961
	Measurement range	100 MPa
	Traceability information	NVlab
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		Three cycles, 10 points increasing and decreasing without zero point Temperature stability during the calibration is (20±0.3) °C A photo of the measurement set-up is given in Figure 7 below.
Date of receipt of transfer standard		21.9.2014
Date of dispatch		08.10.2014
Date of measurements		01.10.2014
Measurement environmental conditions	Temperature (°C)	21.2 °C
	Relative humidity (rh%)	43 %rh
	Atmospheric pressure (mbar)	942.4 mbar

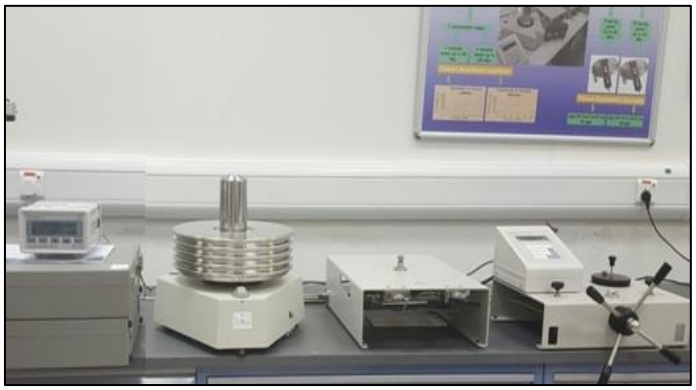

Figure 7. Measurement set-up at SASO NMCC

3.10. Measurement details of VMC

Details of performed measurement at VMC are given in Table 11.

Table 11. Measurement details of VMC

Participant laboratory name and address		Vilnius Metrology Center Dariaus and Gireno str. 23, Vilnius, LT-02189, Lithuania
Contact person name, e-mail, phone		Ksaverija Dapkeviciene k.dapkeviciene@vmc.lt Tel: +370 5 230 6538 Fax: +370 5 230 6364
Notes of inspection of the package (e.g. Damage, missing items, any problems)		No damages. Missing items: 1 ltr. sebacate oil.
Reference instrument information	Manufacturer	DHI
	Model	PG7302-M
	Serial no	297, PC unit Nr.0531
	Measurement range	(5 to 500) MPa
	Traceability information	PTB
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		Vilnius metrology centre is accredited by Lithuanian National Accreditation Bureau. Accreditation No. LA.02.023. Quality system equipped by requirements of standard ISO/IEC 17025:2005. The measurements were performed using the "Calibration procedure S2 for mechanical and electromechanical manometers". The temperature in the laboratory at (20 ± 1) °C is maintained with air conditioner. A photo of the measurement set-up is given in Figure 8 below.
Date of receipt of transfer standard		22.06.2015
Date of dispatch		02.07.2015
Date of measurements		29.06.2015
Measurement environmental conditions	Temperature (°C)	(20.14 - 20.93) °C
	Relative humidity (rh%)	(53 ± 5) %rh
	Atmospheric pressure (mbar)	(996 – 998) mbar

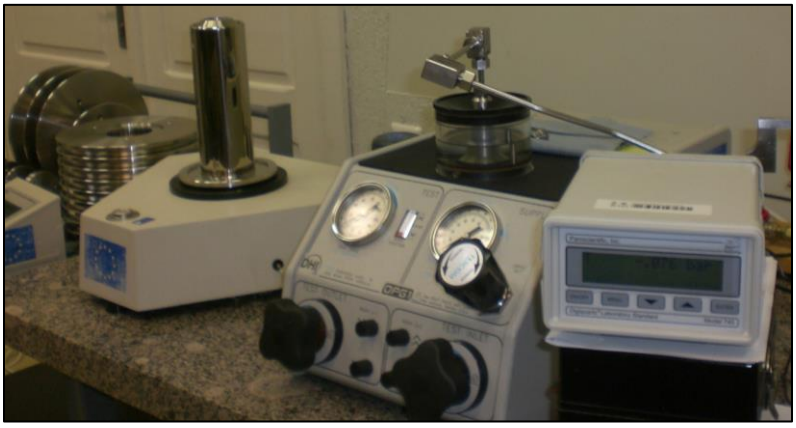

Figure 8. Measurement set-up at VMC

3.11. Measurement details of GUM

Details of performed measurement at GUM are given in Table 12.

Table 12. Measurement details of GUM

Participant laboratory name and adress		Central Office of Measures (GUM) 2 Elektoralna Str., 00-139 Warsaw, Poland
Contact person name, e-mail, phone		Adam Brzozowski Tel: (+48 22) 581 92 00 Fax: (+48 22) 851 93 80 a.brzozowski@gum.gov.pl
Notes of inspection of the package (e.g. Damage, missing items, any problems		Package free from damages, no items missing.
Reference instrument information	Manufacturer	Desgranges et Huot, Aubervilliers, France
	Model	5404S
	Serial no	base no.: 4244 piston-cylinder unit no.: 6664
	Measurement range	(1 ÷ 100) MPa
	Traceability information	calibrated at PTB, Germany 07.2014
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		Transfer standard has been connected directly to the reference standard with a steel tube. Reference levels of both instruments has been adjusted to be at the same height. Temperature was monitored at every measuring point, it didn't exceed (20.3 - 20.7) °C including thermometer's uncertainty
Date of receipt of the transfer standards		11.05.2015
Date of dispatch		29.05.2015
Date of measurements		19.05.2015
Measurement environmental conditions	Temperature (°C)	(20.3 - 20.7) °C
	Relative humidity (rh%)	(43 - 48) %rh
	Atmospheric pressure (mbar)	(993.2 - 993.5) mbar

3.12. Measurement details of IMT

Details of performed measurement at IMT are given in Table 13.

Table 13. Measurement details of IMT

Participant laboratory name and address		Institute of Metals and Technology (IMT) Lepi pot 11, SI-1000 Ljubljana, Slovenia
Contact person name, e-mail, phone		Janez Setina, janez.setina@imt.si Tel.: +386 1 4701 900
Notes of inspection of the package (e.g. Damage, missing items, any problems		no damages no missing parts
Reference instrument information	Manufacturer	DH Instruments USA
	Model	Pressure balance PG7302-M 2 MPa/kg piston PC-7300-2
	Serial no	261 (PG7302-M), 1380 (PC-7300-2)
	Measurement range	2 MPa to 200 MPa
	Traceability information	Traceable to PTB, 30252 PTB 11
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		Transfer standard was connected to the output of the reference instrument and the pressure points were generated by a pressure balance according to the operation manual of the manufacturer. Transfer standard was stabilized under laboratory conditions for more than 24 hours. A photo of the measurement set-up is given in Figure 9 below.
Date of receipt of transfer standards		04.06.2015
Date of dispatch		19.06.2015
Date of measurements		08.06.2015 to 12.06.2015
Measurement environmental conditions	Temperature (°C)	(21.5 ± 0.6) °C
	Relative humidity (rh%)	(55 ± 10) rh%
	Atmospheric pressure (mbar)	(983 ± 5) mbar

Figure 9. Measurement set-up at IMT

3.13. Measurement details of HMI/FSB-LPM

Details of performed measurement at HMI/FSB-LPM are given in Table 14.

Table 14. Measurement details of HMI/FSB-LPM

Participant laboratory name and address		Croatian Metrology Institute/Faculty of Mechanical Engineering and Naval Architecture -Laboratory for Process Measurement (HMI/FSB-LPM) Ivana Lucica 5, 10000 Zagreb, Croatia
Contact person name, e-mail, phone		Lovorka Grgec Bermanec lovorka.grgec@fsb.hr Tel: +385 1 6168 488
Notes of inspection of the package (e.g. Damage, missing items, any problems		No damages. No problems.
Reference instrument information	Manufacturer	Pressurements LTD
	Model	Oil pressure balance
	Serial no	Piston/cylinder unit X00467
	Measurement range	3 up to 140 MPa
	Traceability information	Traceable to PTB (Cert. No. PTB 30242/11)
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		Measurements were performed according to the procedure described in Technical Protocol for EURAMET 1252 and DKD R6-1 procedure. A photo of the measurement set-up is given in Figure 10 below.
Date of receipt of transfer standard		10.7.2015
Date of dispatch		17.9.2015 (to MIKES Finland)
Date of measurements		16.7.2015
Measurement environmental conditions	Temperature (°C)	(21 ± 0.5) °C
	Relative humidity (rh%)	(45 – 49) rh%
	Atmospheric pressure (mbar)	(1005 – 1007) mbar

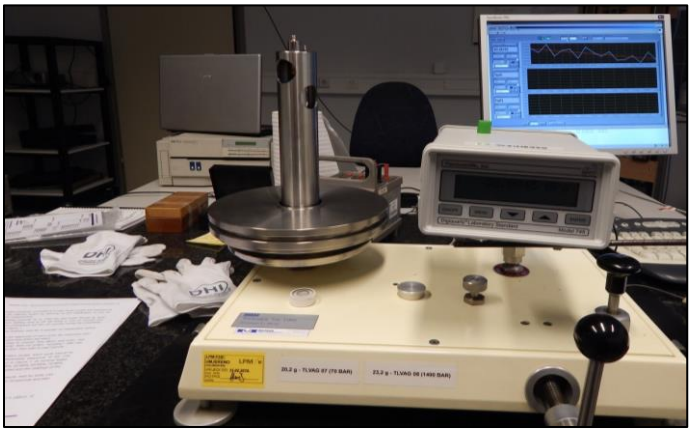

Figure 10. Measurement set-up HMI/FSB-LPM

3.14. Measurement details of VSL

Details of performed measurement at VSL are given in Table 15.

Table 15. Measurement details of VSL

Participant laboratory name and address		VSL, Thijsseweg 11, 2628 JA Delft, The Netherlands
Contact person name, e-mail, phone		Jan van Geel jvangeel@vsl.nl +31 152691729
Notes of inspection of the package (e.g. Damage, missing items, any problems		None
Reference instrument information	Manufacturer	Desgranges & Huot
	Model	5403 GS / 5305
	Serial no	2667 / 4069
	Measurement range	80 MPa / 500 MPa
	Traceability information	VSL dimensional calibration
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		The pressure gauge has been calibrated with a reference pressure balance for gauge pressure with oil (Sebacate) as a medium The deviations have been determined at increasing and decreasing pressure. The pressure gauge has been calibrated in a horizontal position, as reference level the pressure connector was taken. Before calibration, the pressure gauge was adjusted at zero. Acclimatisation time before measurements were 24 hours.
Date of receipt 0f transfer standard		11.11.2015
Date of dispatch		10.12.2015
Date of measurements		01.12.2015

3.15. Measurement details of VTT MIKES Metrology

Details of performed measurement at VTT MIKES are given in Table 16.

Table 16. Measurement details of VTT MIKES

Participant laboratory name and address		VTT MIKES Metrology, Tekniikantie 1, FI-02150 Espoo, FINLAND
Contact person name, e-mail, phone		Sari Saxholm sari.saxholm@vtt.fi +358 50 4105499
Notes of inspection of the package (e.g. Damage, missing items, any problems		None
Reference instrument information	Manufacturer	Desgranges & Huot
	Model	5306
	Serial no	Base no. 4572 and Piston-cylinder unit no. 6998
	Measurement range	2 MPa to 200 MPa
	Traceability information	Primary
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		The measurements were performed according to the given Measurement Procedure for EURAMET 1252. The object instrument was allowed to stabilise in the laboratory room for more than 24 hours before the measurements. During this time the instrument was switched on and pressure connector was open to atmosphere. During the measurements, the object-instrument and the measurement standard were connected to the same pressure line. Before the measurements were started, the instrument was pre-loaded and zeroed according to the instructions in Measurement Procedure. Each pressure point was repeated six times: three times both increasing and decreasing directions of pressure.
Date of receipt 0f transfer standard		
Date of dispatch		06.10.2015
Date of measurements		24.09.2015 – 25.9.2015
Measurement environmental conditions	Temperature (°C)	21 °C
	Relative humidity (rh%)	44 rh%
	Atmospheric pressure (mbar)	1015 mbar

3.16. Measurement details of FORCE Technology

Details of performed measurement at FORCE Technology are given in Table 17.

Table 17. Measurement details of FORCE Technology

Participant laboratory name and address		FORCE Technology, Park Alle 345, 2605 Brøndby, Denmark
Contact person name, e-mail, phone		Aykurt Altintas, aya@force.dk, +4522697641
Notes of inspection of the package (e.g. Damage, missing items, any problems		
Reference instrument information	Manufacturer	Budenberg
	Model	580
	Serial no	28340
	Measurement range	120 MPa
	Traceability information	PTB
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		
Date of receipt of transfer standard		16.05.2016
Date of dispatch		06.06.2016
Date of measurements		18.05.2016
Measurement environmental conditions	Temperature (°C)	(22.31 – 22.47) °C
	Relative humidity (rh%)	-
	Atmospheric pressure (mbar)	1011.17 mbar

3.17. Measurement details of IMBIH

Details of performed measurement at IMBIH are given in Table 18.

Table 18. Measurement details of IMBIH

Participant laboratory name and address		Institute of Metrology of Bosnia and Herzegovina/ Laboratory for Mass and Related Quantities
Contact person name, e-mail, phone		Šejla Ališić, sejla.alisic@met.gov.ba, +387 33 568 920 Alen Bošnjaković, alen.bosnjakovic@met.gov.ba, +387 33 568 931
Notes of inspection of the package (e.g. Damage, missing items, any problems		There are no visible damages.
Reference instrument information	Manufacturer	DH Instruments, USA
	Model	PG 7302 - Pressure Balance PC-7300-2 - Piston/Cylinder
	Serial no	Pressure Balance, No: 704, Piston/Cylinder, No: 1379 Set 35 kg, No:2532, Set 79 kg, No:2538
	Measurement range	2 MPa – 200 MPa
	Traceability information	**Pressure:** IMT-LMT – Slovenia No: IMT-LMT-57-2012 Expressed expended uncertainty for pressure at the moment of calibration indicated on the above mentioned certificate: $U(p) = 3{,}8 \times 10^{-5} \times p + (1{,}8 \times 10^{-13}\ /\text{Pa}) \times p^2 + 100$ Pa **Mass:** IMBIH-LM - Bosnia and Herzegovina No: 902; 02.03.2017, No: 902; 02.03.2017, No: 778; 04.04.2016, No: 884; 03.10.2016.
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		Performed according to internal procedure LM-P.08 which is based on EURAMET cg 17, version 2, as well as according to the protocol for ILC EURAMET 1252. Please see attached photo of the experimental set-up. The temperature in the laboratory was in a specified range according to the protocol (20±1) °C. A photo of the measurement set-up is given in Figure 11 below.
Date of receipt of transfer standard		21.2.2017
Date of dispatch		16.3.2017
Date of measurements		10.3.2017 - 15.3.2017
Measurement environmental conditions	Temperature (°C)	(20.26 ± 0.15) °C
	Relative humidity (rh%)	(38.97 ± 0.80) %rh
	Atmospheric pressure (mbar)	(960.7 ± 1.0) mbar

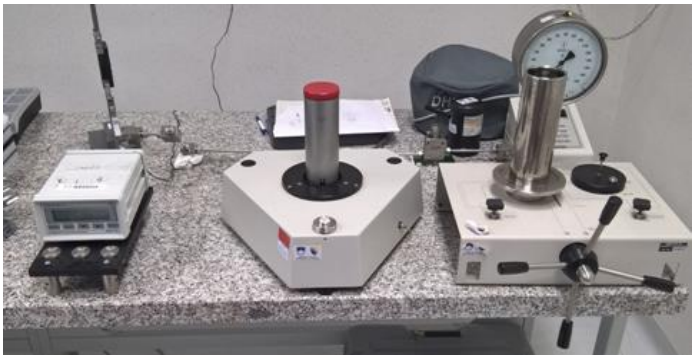

Figure 11. Measurement set-up at IMBIH

3.18. Measurement details of NSAI NML

Details of performed measurement at NSAI NML are given in Table 19.

Table 19. Measurement details of NSAI NML

Participant laboratory name and address		NSAI National Metrology Laboratory (NSAI NML) Griffith Avenue Ext Glasnevin, Dublin 11 Ireland
Contact person name, e-mail, phone		Paul Hetherington Paul.hetherington@nsai.ie
Notes of inspection of the package (e.g. Damage, missing items, any problems)		No problems
Reference instrument information	Manufacturer	Ruska
	Model	2485
	Serial no	Piston: J121
	Measurement range	1.4 to 140 MPa
	Traceability information	The effective area of the piston-cylinder assembly was determined by the PTB. The associated Ruska mass set was calibrated by PTB. The Troemner trim mass set was calibrated by NSAI/NML.
A detailed description of how the measurements were performed (general procedure, a schematic/photo of the experimental set-up, the duration of the temperature stabilisation at (20±1) °C etc.).		The TS was connected to the Ruska 2485 pressure balance as per technical protocol. See photo. The setup was allowed 24 hours for temperature stabilisation at (20 ± 1)°C. Three preloading exercises were carried out before readings were taken. A photo of the measurement set-up is given in Figure 12 below.
Date of receipt of transfer standards		07.10.2015
Date of dispatch		03.11.2015
Date of measurements		19.10.2015
Measurement environmental conditions	Temperature (°C)	20.0 °C
	Relative humidity (rh%)	52 rh%
	Atmospheric pressure (mbar)	1023 mbar

Figure 12. Measurement set-up at NSAI NML

4. Transfer standard

The transfer standard (TS) was a digital pressure gauge manufactured by Paroscientific, Inc. The serial number and model number are 116321 and 745-20K respectively. Battery charger (main power adaptor) and user manual guide were sent to participants together with the TS. Transfer standard details are given in Table 20 and Figure 13.

Table 20. Transfer standard

Name	Digital Pressure Gauge
Measurement Range	0 - 100 MPa (20000 psi)
Resolution	100 Pa (1 mbar)
Manufacturer	Paroscientific, Inc.
Model No	745-20K
Serial No	116321
Pressure Connection	NPT 1/4″ female
Pressure Media (operates with)	Oil (sebacate)
Measurement Points	(0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100) MPa
Transfer Standard Package Including List	Paroscientific digital pressure gauge with NPT1/4″

Figure 13. Transfer standard (TS)

4.1. Stability of the transfer standard

The transfer standard was selected as a digital pressure gauge manufactured by Paroscientific. Stability of transfer standard was analysed by five different measurements done at a different time starting from 2014 up to 2017 before, during and at the end of the comparison [5]. Calibrations were performed based on the EURAMET technical guide of "Guidelines on the Calibration of Electromechanical and Mechanical Manometers" [6]. Observed measurements results used to analyse the stability of the transfer standard during the comparison period is given in Table 21 and Figure 14. Stability of the transfer standard represented as u_{stab} was evaluated out of five measurements using by equation (1).

$$u_{\mathrm{stab}} = \text{standard deviation } (\mathrm{M}_1, \mathrm{M}_2, \mathrm{M}_3, \mathrm{M}_4, \mathrm{M}_5) \qquad (1)$$

where,

u_{stab} is the uncertainty due to transfer standard stability

$\mathrm{M}_1, \mathrm{M}_2, \mathrm{M}_3, \mathrm{M}_4, \mathrm{M}_5$ are the stability measurements of transfer standard

Table 21. Results of measurements of TS for stability evaluation

Nominal pressure / MPa	Date of measurements					u_{stab} standard deviation / MPa
	28.01.2014	24.06.2014	05.05.2016	23.12.2016	24.04.2017	
	Deviation of TS from the reference pressure / MPa					
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0376	0.0005	-0.0059	0.0068	0.0098	0.0017
20	0.0443	0.0008	-0.0035	0.0184	0.0147	0.0019
30	0.0479	0.0004	0.0030	0.0318	0.0191	0.0020
40	0.0529	0.0030	0.0071	0.0423	0.0199	0.0022
50	0.0577	0.0048	0.0104	0.0482	0.0202	0.0023
60	0.0603	0.0085	0.0141	0.0574	0.0230	0.0024
70	0.0675	0.0081	0.0191	0.0632	0.0246	0.0027
80	0.0685	0.0090	0.0213	0.0668	0.0259	0.0027
90	0.0705	0.0110	0.0221	0.0685	0.0290	0.0027
100	0.0717	0.0115	0.0236	0.0694	0.0280	0.0028
100	0.0617	0.0100	0.0183	0.0663	0.0283	0.0026
90	0.0577	0.0097	0.0140	0.0653	0.0300	0.0025
80	0.0557	0.0070	0.0133	0.0643	0.0260	0.0026
70	0.0497	0.0047	0.0090	0.0617	0.0250	0.0025
60	0.0453	-0.0017	0.0050	0.0560	0.0230	0.0025
50	0.0400	-0.0030	0.0017	0.0490	0.0207	0.0023
40	0.0347	-0.0050	-0.0017	0.0433	0.0197	0.0021
30	0.0287	-0.0070	-0.0047	0.0333	0.0197	0.0019
20	0.0230	-0.0125	-0.0097	0.0167	0.0153	0.0016
10	0.0177	-0.0100	-0.0157	0.0057	0.0100	0.0014
0	-0.0167	-0.0110	-0.0087	0.0007	0.0037	0.0008

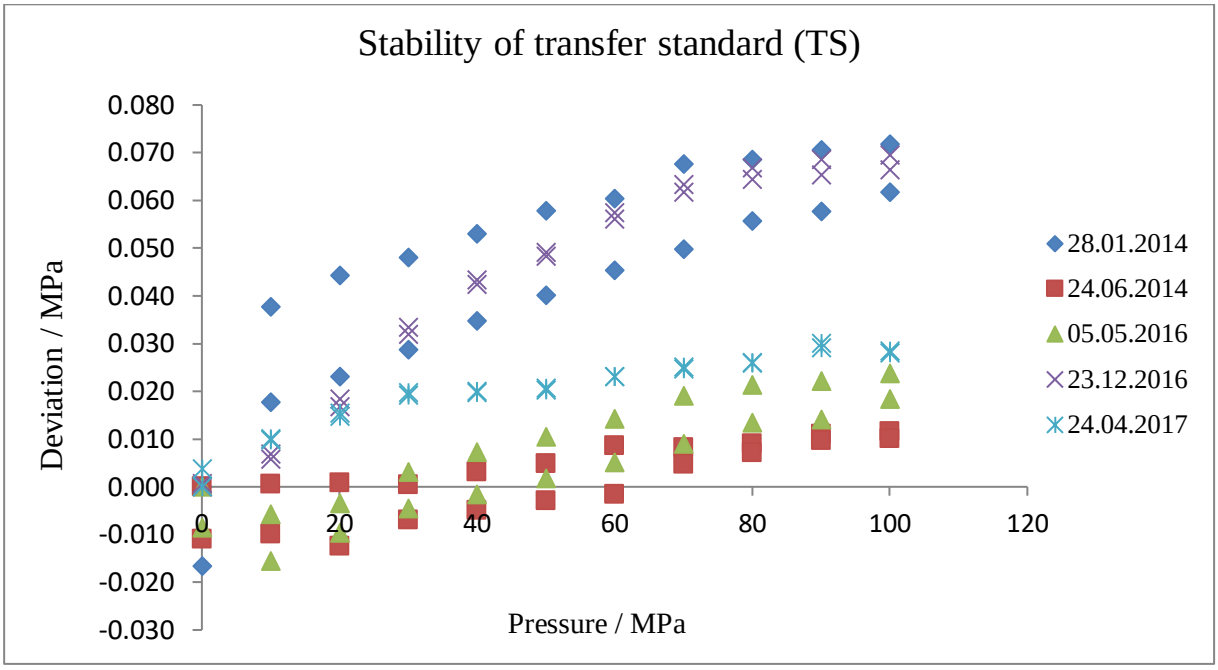

Figure 14. Stability of transfer standard (TS)

5. Measurement instructions

The measurement procedure was described in detail in the technical protocol. Unpacking, handling and care of the TS were explained. Some information about thermal stabilisation, using TS, measurement points were also supplied. The procedure for reporting results was also described in the technical protocol.

Measurements were (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100) MPa both in increasing and decreasing directions with 3 cycles.

6. Measurement results of participants

The mean deviations x_i measured by the participants and their standard uncertainties $u(x_i)$ are presented in Tables 22, 23, 24, 25, 26 and 27.

Table 22. Measurement results of participants

Nominal pressure	UME		MKEH		BoM	
	x_i	$u(x_i)$	x_i	$u(x_i)$	x_i	$u(x_i)$
(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)
0	0.0000	0.0010	0.0000	0.0003	0.0000	0.0032
10	0.0038	0.0016	0.0015	0.0005	0.0020	0.0033
20	0.0044	0.0017	0.0022	0.0007	0.0020	0.0037
30	0.0048	0.0018	0.0028	0.0008	0.0030	0.0051
40	0.0053	0.0018	0.0035	0.0010	0.0040	0.0059
50	0.0058	0.0020	0.0042	0.0013	0.0040	0.0068
60	0.0060	0.0022	0.0048	0.0015	0.0040	0.0077
70	0.0068	0.0023	0.0056	0.0028	0.0030	0.0086
80	0.0068	0.0025	0.0061	0.0032		
90	0.0071	0.0026	0.0063	0.0037		
100	0.0072	0.0028	0.0066	0.0041		
100	0.0062	0.0029	0.0066	0.0041		
90	0.0058	0.0027	0.0063	0.0037		
80	0.0056	0.0025	0.0059	0.0032		
70	0.0050	0.0025	0.0053	0.0028	0.0030	0.0086
60	0.0045	0.0021	0.0044	0.0015	0.0030	0.0077
50	0.0040	0.0021	0.0037	0.0013	0.0030	0.0068
40	0.0035	0.0019	0.0030	0.0010	0.0020	0.0059
30	0.0029	0.0020	0.0023	0.0008	0.0020	0.0051
20	0.0023	0.0019	0.0013	0.0007	0.0010	0.0037
10	0.0018	0.0017	0.0005	0.0005	0.0010	0.0033
0	-0.0017	0.0010	-0.0007	0.0003	0.0000	0.0032

Table 23. Measurement results of participants

Nominal pressure	DPM		DMDM		MBM	
	x_i	$u(x_i)$	x_i	$u(x_i)$	x_i	$u(x_i)$
(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)
0	0.0000	0.0005	0.0000	0.0004	0.0000	0.0001
10	0.0010	0.0010	0.0015	0.0013	0.0008	0.0004
20	0.0006	0.0012	0.0027	0.0013	0.0017	0.0004
30	0.0006	0.0015	0.0036	0.0013	0.0024	0.0006
40	0.0007	0.0018	0.0043	0.0014	0.0025	0.0007
50	0.0008	0.0022	0.0050	0.0014	0.0031	0.0010
60	0.0012	0.0026	0.0055	0.0015	0.0033	0.0013
70	0.0019	0.0030	0.0062	0.0016	0.0038	0.0020
80			0.0065	0.0018	0.0038	0.0020
90			0.0068	0.0019	0.0036	0.0026
100			0.0071		0.0036	0.0031
100			0.0069	0.0019	0.0037	0.0031
90			0.0065	0.0019	0.0040	0.0027
80			0.0061	0.0018	0.0041	0.0021
70	0.0018	0.0028	0.0056	0.0016	0.0039	0.0017
60	0.0010	0.0025	0.0049	0.0015	0.0034	0.0014
50	0.0004	0.0021	0.0040	0.0014	0.0027	0.0012
40	0.0002	0.0017	0.0032	0.0014	0.0021	0.0007
30	-0.0001	0.0016	0.0023	0.0013	0.0018	0.0008
20	0.0002	0.0013	0.0015	0.0013	0.0012	0.0004
10	0.0005	0.0011	0.0004	0.0013	0.0003	0.0004
0	0.0010	0.0006	-0.0007	0.0006	0.0001	0.0009

Table 24. Measurement results of participants

Nominal pressure	QAF		EMI		SASO NMCC	
	x_i	$u(x_i)$	x_i	$u(x_i)$	x_i	$u(x_i)$
(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)
0	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002
10	0.0002	0.0004	0.0009	0.0008	-0.0004	0.0004
20	0.0012	0.0006	0.0019	0.0009	0.0005	0.0005
30	0.0015	0.0009	0.0022	0.0009	0.0012	0.0005
40	0.0017	0.0012	0.0027	0.0010	0.0016	0.0006
50	0.0019	0.0014	0.0031	0.0012	0.0025	0.0007
60	0.0020	0.0017	0.0040	0.0013	0.0029	0.0008
70	0.0023	0.0019	0.0045	0.0015	0.0037	0.0009
80	0.0024	0.0022	0.0046	0.0017	0.0040	0.0011
90	-0.0018	0.0025	0.0052	0.0020	0.0045	0.0012
100	-0.0015	0.0027	0.0051	0.0023	0.0049	0.0013
100	-0.0004	0.0027			0.0047	0.0013
90	-0.0004	0.0025	0.0041	0.0020	0.0041	0.0012
80	0.0016	0.0022	0.0046	0.0017	0.0036	0.0011
70	0.0017	0.0019	0.0038	0.0015	0.0030	0.0009
60	0.0018	0.0017	0.0030	0.0013	0.0022	0.0008
50	0.0019	0.0014	0.0024	0.0012	0.0017	0.0007
40	0.0019	0.0012	0.0017	0.0010	0.0010	0.0006
30	0.0017	0.0009	0.0012	0.0009	0.0002	0.0005
20	0.0016	0.0006	0.0006	0.0009	-0.0005	0.0004
10	0.0005	0.0004	0.0002	0.0008	-0.0015	0.0004
0	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002

Table 25. Measurement results of participants

Nominal pressure	VMC		GUM		IMT	
	x_i	$u(x_i)$	x_i	$u(x_i)$	x_i	$u(x_i)$
(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)
0	0.0000	0.0000	0.0000	0.0001	0.0000	0.0006
10	0.0033	0.0007	0.0001	0.0002	-0.0004	0.0007
20	0.0053	0.0009	0.0008	0.0004	0.0001	0.0008
30	0.0062	0.0011	0.0011	0.0005	0.0005	0.0009
40	0.0065	0.0014	0.0014	0.0007	0.0007	0.0011
50	0.0070	0.0017	0.0016	0.0009	0.0009	0.0014
60	0.0075	0.0021	0.0020	0.0012	0.0010	0.0016
70	0.0079	0.0024	0.0026	0.0014	0.0013	0.0019
80	0.0080	0.0027	0.0031	0.0017	0.0012	0.0022
90	0.0080	0.0030	0.0036	0.0020	0.0010	0.0026
100	0.0080	0.0034	0.0042	0.0024	0.0013	0.0029
100	0.0080	0.0034	0.0039	0.0024	0.0013	0.0029
90	0.0079	0.0030	0.0031	0.0020	0.0012	0.0026
80	0.0075	0.0027	0.0025	0.0017	0.0011	0.0022
70	0.0074	0.0024	0.0021	0.0014	0.0009	0.0020
60	0.0069	0.0021	0.0016	0.0012	0.0005	0.0017
50	0.0066	0.0017	0.0012	0.0009	0.0004	0.0014
40	0.0060	0.0014	0.0010	0.0007	0.0000	0.0012
30	0.0052	0.0011	0.0007	0.0005	-0.0001	0.0010
20	0.0042	0.0009	0.0002	0.0003	-0.0005	0.0008
10	0.0021	0.0009	-0.0005	0.0002	-0.0008	0.0007
0	-0.0004	0.0002	-0.0004	0.0001	-0.0010	0.0006

Table 26. Measurement results of participants

Nominal pressure	HMIFSB-LPM		VSL		VTT MIKES	
	x_i	$u(x_i)$	x_i	$u(x_i)$	x_i	$u(x_i)$
(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)
0	0.0000	0.0002	0.0000	0.0000	0.0000	0.0007
10	-0.0009	0.0005	-0.0022	0.0003	0.0008	0.0007
20	-0.0003	0.0006	-0.0015	0.0003	0.0014	0.0007
30	0.0002	0.0009	-0.0011	0.0003	0.0015	0.0008
40	0.0010	0.0012	-0.0008	0.0004	0.0014	0.0008
50	0.0016	0.0014	-0.0007	0.0005	0.0009	0.0009
60	0.0022	0.0017	-0.0004	0.0006	0.0005	0.0010
70	0.0029	0.0021	0.0001	0.0007	-0.0001	0.0011
80	0.0035	0.0024	0.0002	0.0009	-0.0012	0.0012
90	0.0041	0.0026	0.0001	0.0010	-0.0020	0.0013
100	0.0040	0.0030	0.0002	0.0011	-0.0033	0.0015
100	0.0039	0.0030	0.0002	0.0011	-0.0034	0.0015
90	0.0038	0.0027	0.0000	0.0011	-0.0022	0.0013
80	0.0035	0.0027	-0.0001	0.0009	-0.0015	0.0012
70	0.0030	0.0022	-0.0001	0.0008	-0.0006	0.0011
60	0.0022	0.0019	-0.0005	0.0007	-0.0002	0.0010
50	0.0018	0.0018	-0.0008	0.0006	0.0002	0.0009
40	0.0010	0.0016	-0.0011	0.0005	0.0005	0.0008
30	0.0002	0.0013	-0.0013	0.0004	0.0007	0.0008
20	-0.0007	0.0011	-0.0018	0.0003	0.0004	0.0007
10	-0.0016	0.0009	-0.0024	0.0003	-0.0001	0.0007
0	-0.0009	0.0004	0.0001	0.0003	-0.0009	0.0008

Table 27. Measurement results of participants

Nominal pressure	FORCE		IMBIH		NSAI NML	
	x_i	$u(x_i)$	x_i	$u(x_i)$	x_i	$u(x_i)$
(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)
0	-0.0001	0.0000	0.0000	0.0006	0.0000	0.0001
10	-0.0010	0.0012	0.0032	0.0007	0.0006	0.0002
20	0.0008	0.0013	0.0037	0.0009	0.0014	0.0003
30	0.0013	0.0015	0.0042	0.0011	0.0021	0.0005
40	0.0017	0.0017	0.0045	0.0015	0.0026	0.0007
50	0.0022	0.0019	0.0050	0.0018	0.0030	0.0009
60	0.0024	0.0022	0.0054	0.0022	0.0035	0.0011
70	0.0028	0.0025	0.0060	0.0026	0.0041	0.0013
80	0.0036	0.0029	0.0064	0.0031	0.0041	0.0015
90	0.0036	0.0033	0.0067	0.0036	0.0043	0.0018
100	0.0042	0.0037	0.0070	0.0041	0.0044	0.0020
100	0.0042	0.0037	0.0068	0.0041	0.0044	0.0020
90	0.0028	0.0033	0.0064	0.0036	0.0043	0.0018
80	0.0025	0.0029	0.0060	0.0031	0.0040	0.0015
70	0.0027	0.0025	0.0057	0.0026	0.0036	0.0013
60	0.0018	0.0022	0.0052	0.0022	0.0031	0.0011
50	0.0017	0.0019	0.0046	0.0018	0.0025	0.0009
40	0.0015	0.0017	0.0042	0.0015	0.0020	0.0007
30	0.0011	0.0015	0.0038	0.0011	0.0015	0.0005
20	0.0006	0.0013	0.0032	0.0009	0.0008	0.0003
10	-0.0009	0.0012	0.0026	0.0007	-0.0001	0.0002
0	-0.0001	0.0000	-0.0005	0.0007	-0.0009	0.0001

7. Calculation of the reference value

For the calculation of the reference value and its assigned uncertainty, “non-weighted mean” method was used with the equations (2) and (3) below.

$$x_{\mathrm{ref}} = \sum_{i=1}^{n} \left(x_i \cdot \frac{1}{N_i} \right) / N \tag{2}$$

$$u(x_{\mathrm{ref}}) = \sqrt{\frac{1}{N^2} \sum_{i=1}^{n} \sum_{j=1}^{n} \frac{C_{ij}}{N_i N_j} \cdot u(x_i) \cdot u(x_j) + u_{\mathrm{stab}}^2} \tag{3}$$

where

x_{ref} is the reference value of the comparison

$u(x_{\mathrm{ref}})$ is standard uncertainty of the comparison reference value [7]

n is the total number of laboratories

N is number of laboratories having different traceability sources

i or j is laboratory number

N_i is the number of laboratories with the same traceability as laboratory i

x_i is the result of laboratory i

$u(x_i)$ is standard uncertainty of x_i

u_{stab} is standard uncertainty due to transfer standard instability

C_{ij} is the correlation coefficient:

$$C_{ij} = \begin{cases} 1, & \text{laboratories } i \text{ and } j \text{ have the same traceability source} \\ 0, & \text{laboratories } i \text{ and } j \text{ have different traceability sources.} \end{cases}$$

The reference values with assigned uncertainties are given in Table 28.

Table 28. Reference values with assigned standard uncertainties

Nominal pressure (MPa)	x_{ref} (MPa)	$u(x_{\mathrm{ref}})$ (MPa)
10	0.0004	0.0017
20	0.0012	0.0019
30	0.0017	0.0021
40	0.0020	0.0023
50	0.0023	0.0024
60	0.0026	0.0026
70	0.0029	0.0028
80	0.0035	0.0029
90	0.0029	0.0029
100	0.0029	0.0029
100	0.0026	0.0028
90	0.0028	0.0027
80	0.0031	0.0027
70	0.0025	0.0026
60	0.0021	0.0026
50	0.0017	0.0024
40	0.0013	0.0022
30	0.0009	0.0019
20	0.0005	0.0017
10	-0.0002	0.0014

8. Deviations from the reference value

In order to assess the equivalence of the measurements, the difference and the uncertainty of the participants' results in respect to the reference value are calculated. For i = 1,…, n, the degree of equivalence of institute i is given as the pair of values (d_i, ($U(d_i)$). For each pressure, the difference between the laboratories' and the reference values are given by equation (4), and its expanded and standard uncertainties are given by equations (5) and (6), respectively [7, 8].

$$d_i = x_i - x_{\mathrm{ref}} \tag{4}$$

$$U(d_i) = 2u(d_i) \tag{5}$$

$$u^2(d_i) = u^2[x_i - x_{\mathrm{ref}}]$$

$$u^2(d_i) = u^2\left[x_i - \sum_{j=1}^{n}(x_j \cdot \frac{1}{N_j})/N\right] + u_{\mathrm{stab}}^2$$

$$u^2(d_i) = u^2\left[x_i - \frac{x_i}{N_i \cdot N} - \sum_{j=1, j\neq i}^{n}(x_j \cdot \frac{1}{N_j})/N\right] + u_{\mathrm{stab}}^2$$

$$u^2(d_i) = u^2\left[x_i\left(1 - \frac{1}{N_i \cdot N}\right) - \sum_{j=1, j\neq i}^{n}(x_j \cdot \frac{1}{N_j})/N\right] + u_{\mathrm{stab}}^2$$

In the following, the uncertainties of x_i and x_j are handled as an independent. The results of the laboratories having the same traceability source are to some degree correlated, but the correlation coefficients of their uncertainties are unknown.

$$u^2(d_i) = u_i^2\left(1 - \frac{1}{N_i \cdot N}\right)^2 + \sum_{j=1, j\neq i}^{n}\left(\frac{u_j}{N_j}\right)^2 / N^2 + u_{\text{stab}}^2$$

$$u^2(d_i) = u_i^2\left(1 - \frac{1}{N_i \cdot N}\right)^2 + \sum_{j=1}^{n}\left(\frac{u_j}{N_j}\right)^2 / N^2 - \left(\frac{u_i}{N_i}\right)^2 / N^2 + u_{\text{stab}}^2$$

$$u^2(d_i) = u_i^2\left(1 - \frac{2}{N_i \cdot N} + \frac{1}{(N_i \cdot N)^2}\right) + \sum_{j=1}^{n}\left(\frac{u_j}{N_j}\right)^2 / N^2 - \left(\frac{u_i}{N_i}\right)^2 / N^2 + u_{\text{stab}}^2$$

$$u^2(d_i) = u_i^2\left(1 - \frac{2}{N_i \cdot N}\right) + \sum_{j=1}^{n}\left(\frac{u_j}{N_j}\right)^2 / N^2 + u_{\text{stab}}^2$$

$$u^2(d_i) = u_i^2\left(1 - \frac{2}{N_i \cdot N}\right) + u^2(x_{\text{ref}}). \qquad (6)$$

Herewith, $u^2(d_i)$ is always positive.

Deviations of participants from the reference value with assigned uncertainties are given in Tables 29, 30, 31, 32, 33, 34 and Figures 15 and 16.

Table 29. Deviations of participants from the reference value with expanded uncertainties

Nominal pressure	UME		MKEH		BoM	
	d_i	$U(d_i)$	d_i	$U(d_i)$	d_i	$U(d_i)$
(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)
10	0.0033	0.0047	0.0011	0.0036	0.0016	0.0071
20	0.0032	0.0051	0.0010	0.0041	0.0008	0.0080
30	0.0031	0.0054	0.0011	0.0044	0.0013	0.0104
40	0.0033	0.0058	0.0015	0.0049	0.0020	0.0120
50	0.0035	0.0063	0.0019	0.0055	0.0017	0.0136
60	0.0034	0.0067	0.0022	0.0059	0.0014	0.0153
70	0.0038	0.0073	0.0027	0.0079	0.0001	0.0171
80	0.0033	0.0075	0.0026	0.0085		
90	0.0041	0.0077	0.0034	0.0092		
100	0.0043	0.0080	0.0037	0.0100		
100	0.0036	0.0079	0.0040	0.0097		
90	0.0030	0.0075	0.0035	0.0089		
80	0.0025	0.0072	0.0028	0.0082		
70	0.0025	0.0072	0.0028	0.0077	0.0005	0.0169
60	0.0025	0.0066	0.0023	0.0060	0.0009	0.0153
50	0.0023	0.0063	0.0020	0.0054	0.0013	0.0136
40	0.0021	0.0058	0.0017	0.0049	0.0007	0.0119
30	0.0019	0.0056	0.0014	0.0042	0.0011	0.0103
20	0.0018	0.0050	0.0008	0.0036	0.0005	0.0078
10	0.0020	0.0045	0.0007	0.0030	0.0012	0.0068

Table 30. Deviations of participants from the reference value with expanded uncertainties

Nominal pressure	DPM		DMDM		MBM	
	d_i	$U(d_i)$	d_i	$U(d_i)$	d_i	$U(d_i)$
(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)
10	0.0005	0.0039	0.0011	0.0040	0.0004	0.0035
20	-0.0006	0.0044	0.0015	0.0045	0.0006	0.0039
30	-0.0011	0.0049	0.0019	0.0047	0.0007	0.0043
40	-0.0013	0.0057	0.0022	0.0051	0.0005	0.0047
50	-0.0015	0.0064	0.0027	0.0055	0.0008	0.0053
60	-0.0014	0.0071	0.0029	0.0057	0.0007	0.0058
70	-0.0011	0.0079	0.0032	0.0063	0.0009	0.0069
80			0.0030	0.0064	0.0002	0.0069
90			0.0039	0.0065	0.0007	0.0077
100			0.0042	0.0066	0.0007	0.0085
100			0.0043	0.0063	0.0012	0.0082
90			0.0037	0.0061	0.0012	0.0075
80			0.0030	0.0060	0.0010	0.0067
70	-0.0007	0.0075	0.0032	0.0060	0.0014	0.0062
60	-0.0011	0.0069	0.0028	0.0058	0.0014	0.0059
50	-0.0014	0.0061	0.0023	0.0053	0.0009	0.0053
40	-0.0012	0.0054	0.0018	0.0050	0.0008	0.0046
30	-0.0011	0.0049	0.0014	0.0045	0.0008	0.0042
20	-0.0003	0.0041	0.0010	0.0041	0.0007	0.0035
10	0.0007	0.0035	0.0006	0.0036	0.0005	0.0030

Table 31. Deviations of participants from the reference value with expanded uncertainties

Nominal pressure	QAF		EMI		SASO NMCC	
	d_i	$U(d_i)$	d_i	$U(d_i)$	d_i	$U(d_i)$
(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)
10	-0.0002	0.0035	0.0005	0.0037	-0.0008	0.0035
20	0.0000	0.0040	0.0007	0.0041	-0.0007	0.0039
30	-0.0001	0.0044	0.0006	0.0044	-0.0005	0.0042
40	-0.0003	0.0049	0.0007	0.0049	-0.0004	0.0046
50	-0.0004	0.0055	0.0007	0.0053	0.0002	0.0050
60	-0.0006	0.0059	0.0014	0.0056	0.0003	0.0053
70	-0.0006	0.0066	0.0016	0.0063	0.0008	0.0059
80	-0.0011	0.0067	0.0010	0.0064	0.0005	0.0060
90	-0.0047	0.0070	0.0022	0.0066	0.0016	0.0061
100	-0.0044	0.0074	0.0022	0.0069	0.0020	0.0063
100	-0.0030	0.0070			0.0021	0.0059
90	-0.0032	0.0067	0.0014	0.0062	0.0013	0.0057
80	-0.0015	0.0064	0.0015	0.0060	0.0005	0.0056
70	-0.0008	0.0063	0.0013	0.0059	0.0005	0.0055
60	-0.0003	0.0060	0.0009	0.0057	0.0001	0.0054
50	0.0001	0.0054	0.0006	0.0052	0.0000	0.0049
40	0.0006	0.0049	0.0003	0.0048	-0.0003	0.0046
30	0.0007	0.0042	0.0003	0.0042	-0.0007	0.0040
20	0.0011	0.0036	0.0001	0.0037	-0.0010	0.0035
10	0.0007	0.0030	0.0005	0.0032	-0.0013	0.0030

Table 32. Deviations of participants from the reference value with expanded uncertainties

Nominal pressure	VMC		GUM		IMT	
	d_i	$U(d_i)$	d_i	$U(d_i)$	d_i	$U(d_i)$
(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)
10	0.0028	0.0037	-0.0003	0.0034	-0.0008	0.0037
20	0.0041	0.0042	-0.0004	0.0039	-0.0011	0.0041
30	0.0045	0.0047	-0.0006	0.0042	-0.0012	0.0045
40	0.0045	0.0053	-0.0006	0.0047	-0.0013	0.0051
50	0.0047	0.0059	-0.0007	0.0052	-0.0014	0.0056
60	0.0049	0.0066	-0.0006	0.0056	-0.0016	0.0061
70	0.0050	0.0074	-0.0003	0.0064	-0.0016	0.0068
80	0.0045	0.0078	-0.0004	0.0066	-0.0023	0.0072
90	0.0051	0.0083	0.0007	0.0070	-0.0019	0.0077
100	0.0051	0.0088	0.0013	0.0075	-0.0016	0.0082
100	0.0055	0.0086	0.0013	0.0072	-0.0013	0.0080
90	0.0051	0.0080	0.0003	0.0066	-0.0016	0.0073
80	0.0045	0.0075	-0.0006	0.0063	-0.0019	0.0069
70	0.0049	0.0071	-0.0004	0.0060	-0.0016	0.0066
60	0.0048	0.0066	-0.0005	0.0057	-0.0015	0.0062
50	0.0048	0.0058	-0.0005	0.0051	-0.0014	0.0055
40	0.0047	0.0052	-0.0003	0.0047	-0.0013	0.0050
30	0.0042	0.0044	-0.0002	0.0040	-0.0011	0.0043
20	0.0038	0.0038	-0.0003	0.0034	-0.0009	0.0037
10	0.0023	0.0033	-0.0003	0.0029	-0.0006	0.0032

Table 33. Deviations of participants from the reference value with expanded uncertainties

Nominal pressure	HMIFSB-LPM		VSL		VTT MIKES	
	d_i	$U(d_i)$	d_i	$U(d_i)$	d_i	$U(d_i)$
(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)
10	-0.0013	0.0035	-0.0027	0.0035	0.0004	0.0036
20	-0.0015	0.0040	-0.0027	0.0039	0.0002	0.0041
30	-0.0014	0.0045	-0.0027	0.0042	-0.0002	0.0043
40	-0.0010	0.0051	-0.0028	0.0046	-0.0007	0.0047
50	-0.0007	0.0056	-0.0030	0.0050	-0.0014	0.0051
60	-0.0004	0.0061	-0.0030	0.0052	-0.0021	0.0054
70	0.0000	0.0070	-0.0029	0.0058	-0.0030	0.0060
80	0.0000	0.0074	-0.0033	0.0059	-0.0047	0.0060
90	0.0012	0.0077	-0.0028	0.0060	-0.0050	0.0061
100	0.0011	0.0083	-0.0028	0.0062	-0.0063	0.0063
100	0.0014	0.0081	-0.0024	0.0058	-0.0060	0.0060
90	0.0010	0.0076	-0.0028	0.0056	-0.0050	0.0057
80	0.0004	0.0075	-0.0032	0.0055	-0.0046	0.0057
70	0.0006	0.0068	-0.0026	0.0055	-0.0031	0.0056
60	0.0002	0.0064	-0.0026	0.0053	-0.0023	0.0055
50	0.0001	0.0059	-0.0026	0.0049	-0.0015	0.0050
40	-0.0004	0.0054	-0.0024	0.0045	-0.0008	0.0047
30	-0.0007	0.0046	-0.0023	0.0039	-0.0003	0.0041
20	-0.0011	0.0040	-0.0022	0.0034	0.0000	0.0036
10	-0.0014	0.0034	-0.0022	0.0029	0.0001	0.0031

Table 34. Deviations of participants from the reference value with expanded uncertainties

Nominal pressure	FORCE		IMBIH		NSAI NML	
	d_i	$U(d_i)$	d_i	$U(d_i)$	d_i	$U(d_i)$
(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)
10	-0,0009	0,0042	0.0027	0.0037	0.0002	0.0034
20	-0,0004	0,0047	0.0026	0.0042	0.0002	0.0039
30	-0,0004	0,0050	0.0025	0.0047	0.0004	0.0042
40	-0,0003	0,0056	0.0025	0.0054	0.0005	0.0047
50	-0,0001	0,0062	0.0027	0.0061	0.0007	0.0052
60	-0,0002	0,0067	0.0028	0.0067	0.0009	0.0055
70	-0,0001	0,0076	0.0031	0.0077	0.0011	0.0062
80	0,0001	0,0081	0.0028	0.0084	0.0006	0.0064
90	0,0007	0,0087	0.0037	0.0091	0.0014	0.0067
100	0,0013	0,0094	0.0041	0.0099	0.0015	0.0071
100	0,0016	0,0092	0.0042	0.0097	0.0018	0.0068
90	0,0000	0,0084	0.0037	0.0088	0.0015	0.0063
80	-0,0006	0,0079	0.0029	0.0081	0.0009	0.0061
70	0,0002	0,0073	0.0033	0.0074	0.0011	0.0059
60	-0,0003	0,0068	0.0031	0.0068	0.0010	0.0056
50	0,0000	0,0061	0.0029	0.0060	0.0008	0.0051
40	0,0002	0,0055	0.0029	0.0053	0.0007	0.0046
30	0,0002	0,0049	0.0029	0.0045	0.0005	0.0040
20	0,0001	0,0043	0.0028	0.0038	0.0003	0.0035
10	-0,0006	0,0038	0.0028	0.0032	0.0002	0.0029

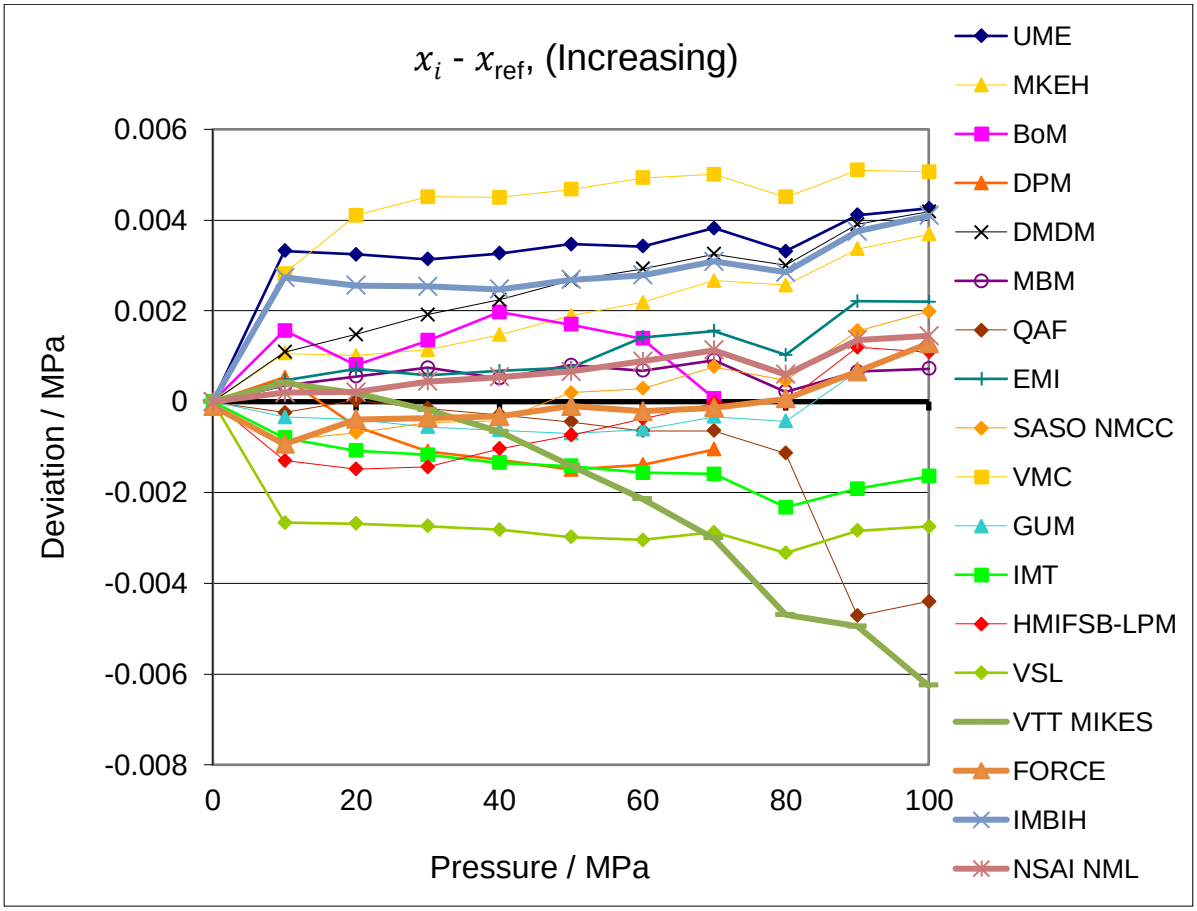

Figure 15. Deviations of participants vs. pressure for increasing pressure

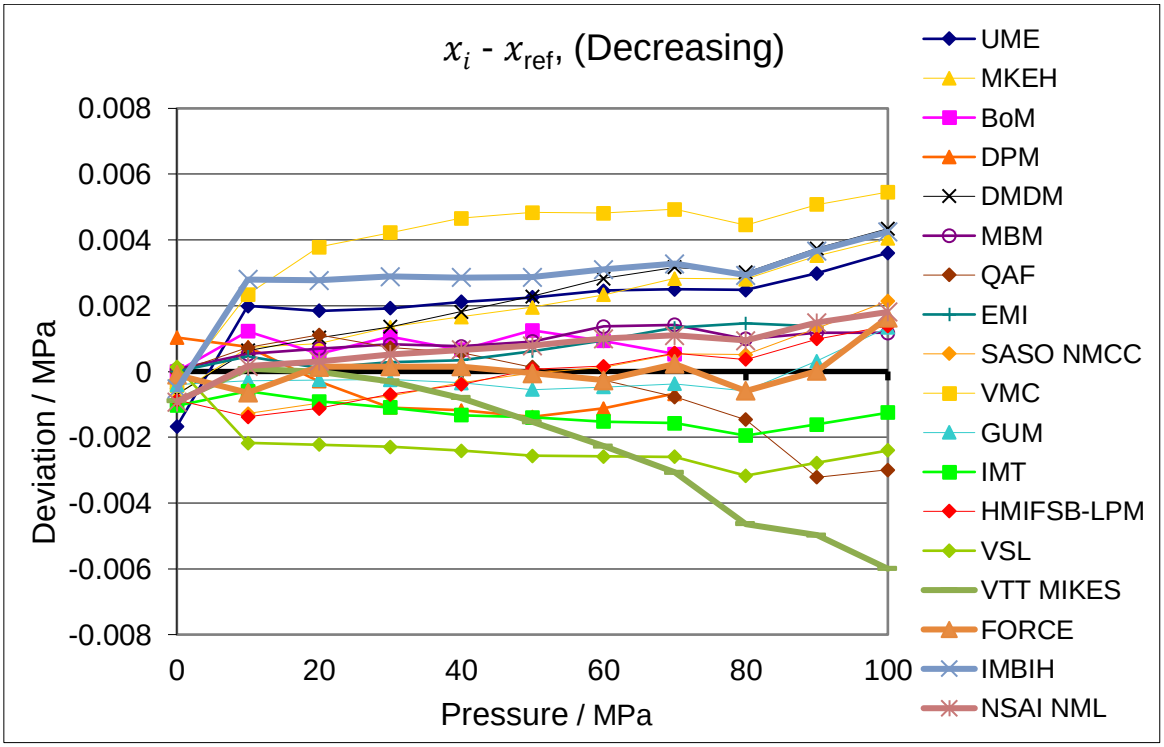

Figure 16. Deviations of participants vs. pressure for decreasing pressure

Deviations from the reference value with assigned expanded uncertainties are given in Figures from 17 to 36.

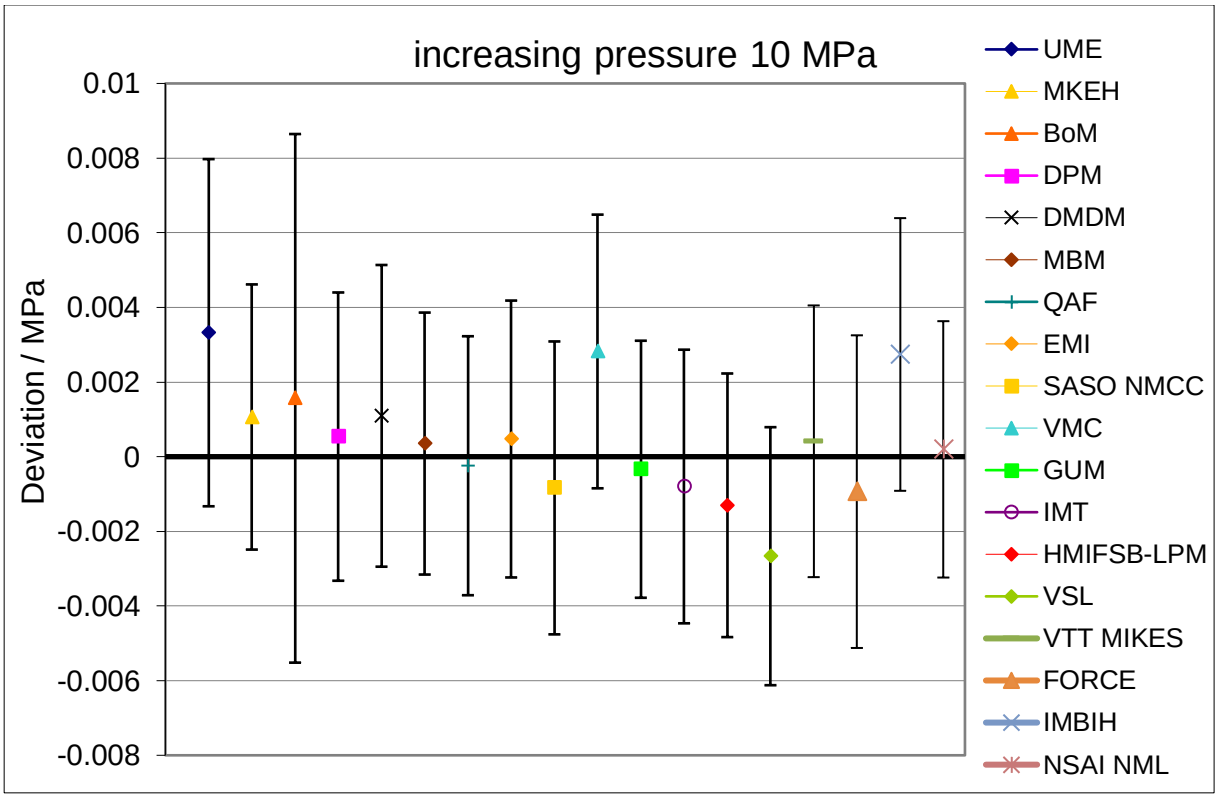

Figure 17. Deviations from the reference value with uncertainties at 10 MPa

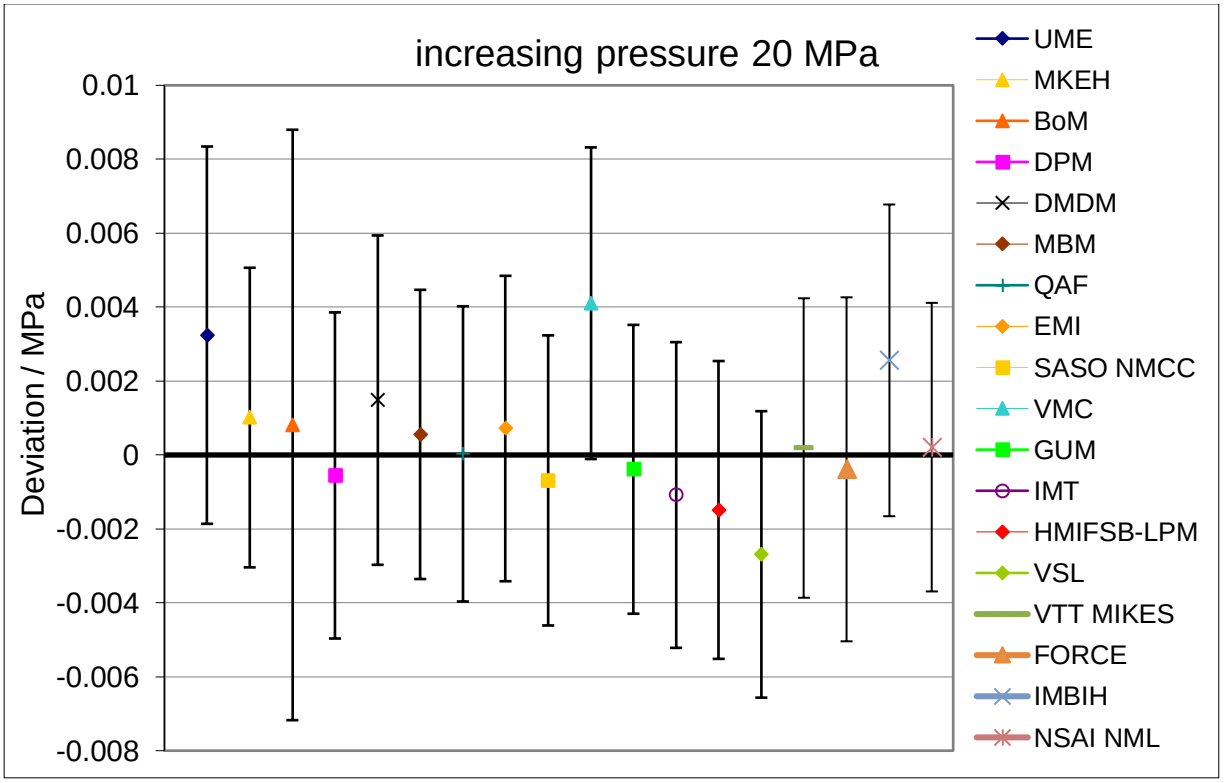

Figure 18. Deviations from the reference value with uncertainties at 20 MPa

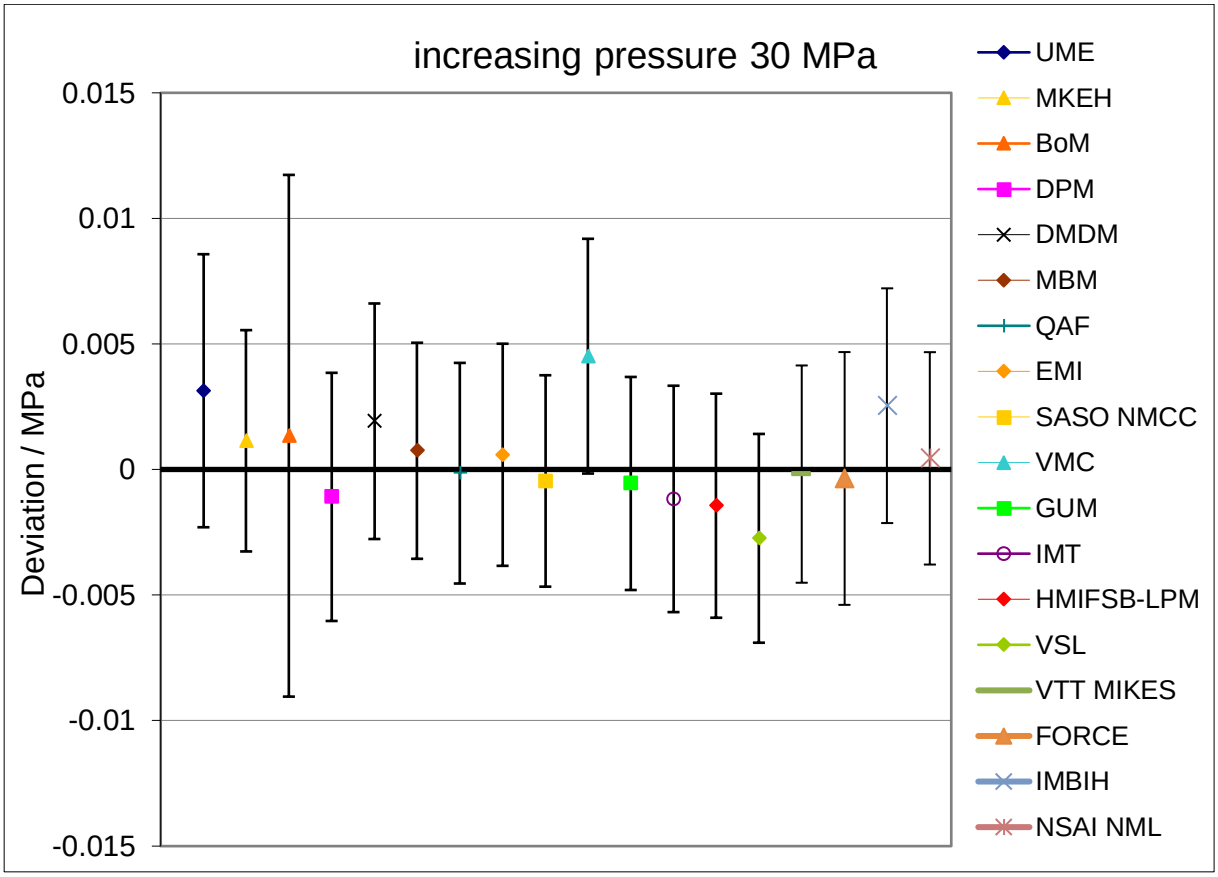

Figure 19. Deviations from the reference value with uncertainties at 30 MPa

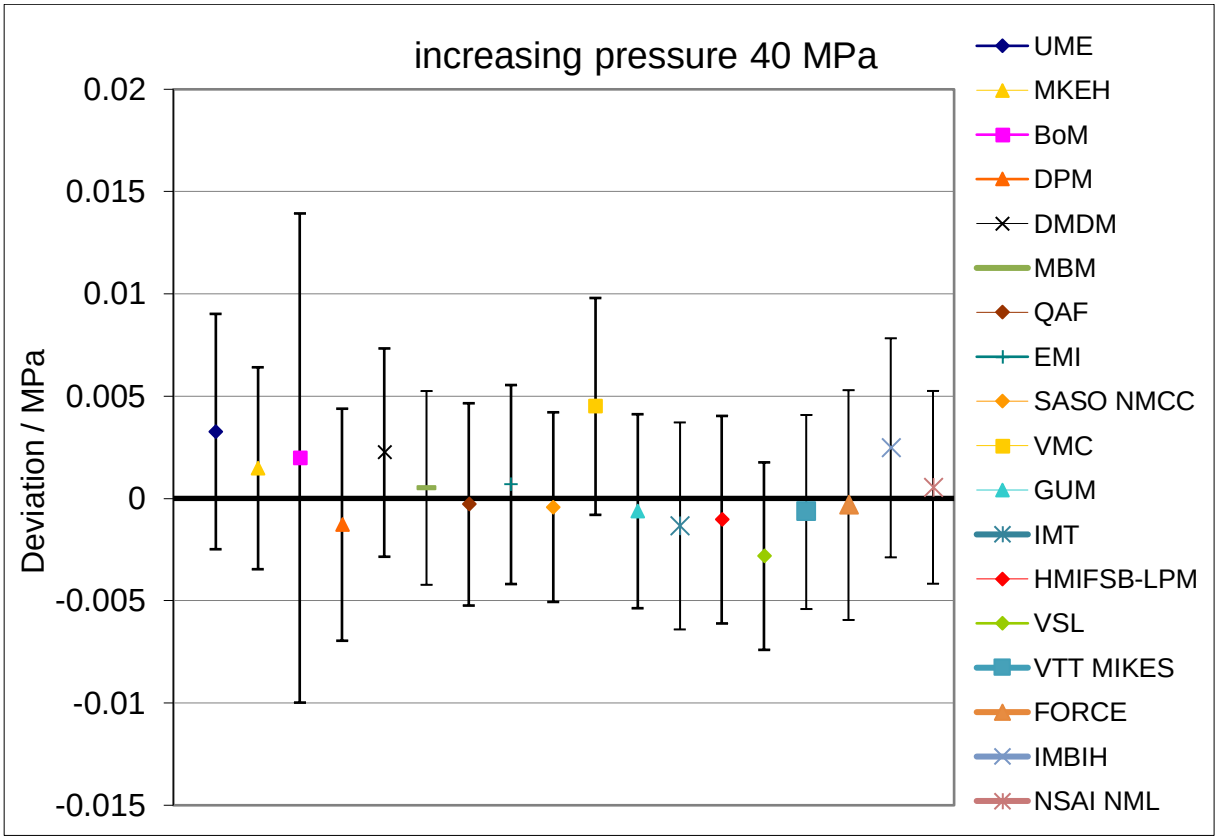

Figure 20. Deviations from the reference value with uncertainties at 40 MPa

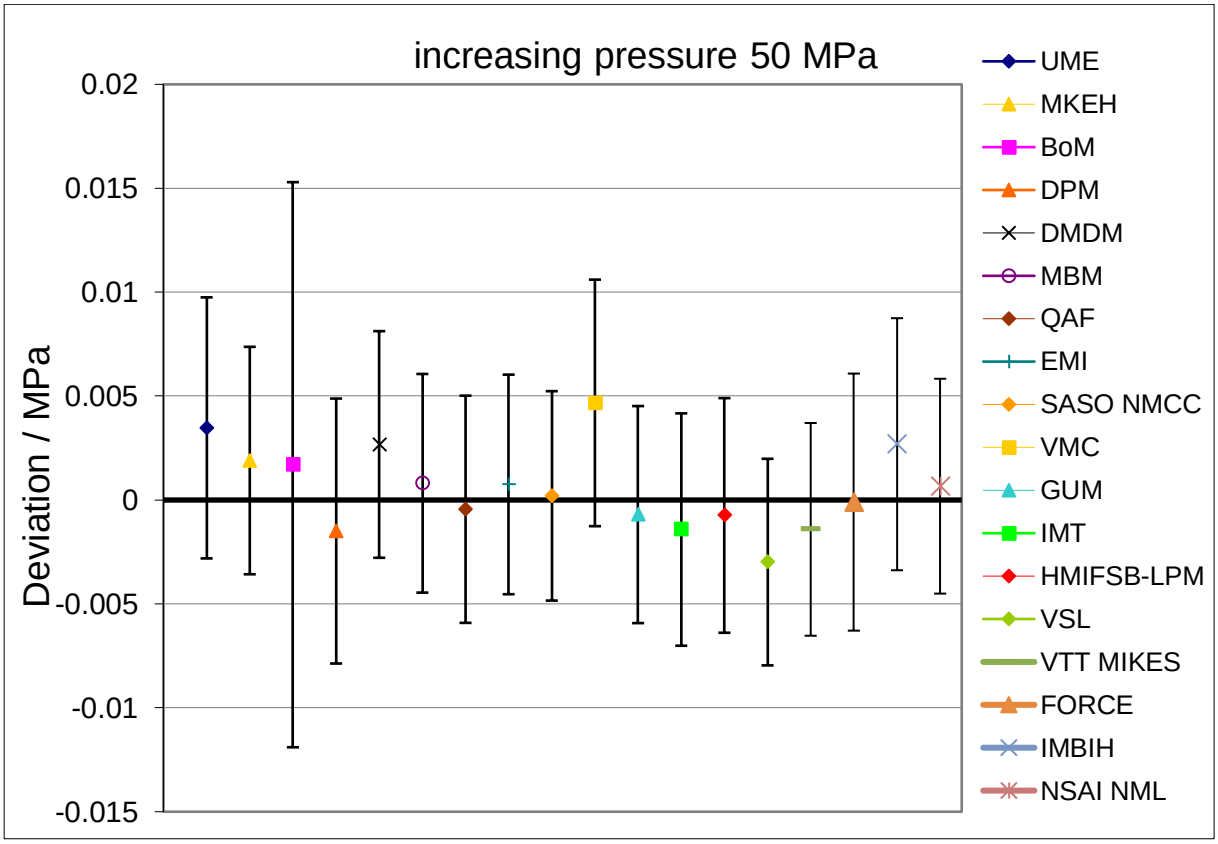

Figure 21. Deviations from the reference value with uncertainties at 50 MPa

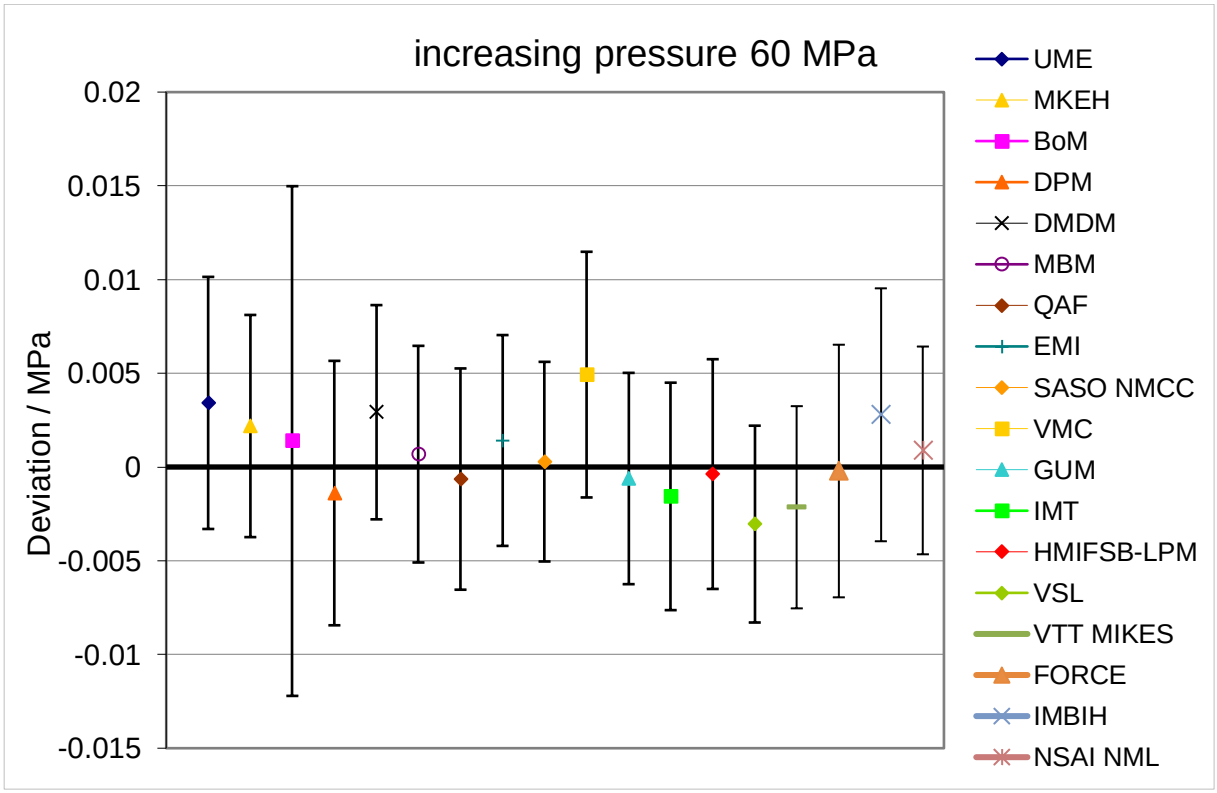

Figure 22. Deviations from the reference value with uncertainties at 60 MPa

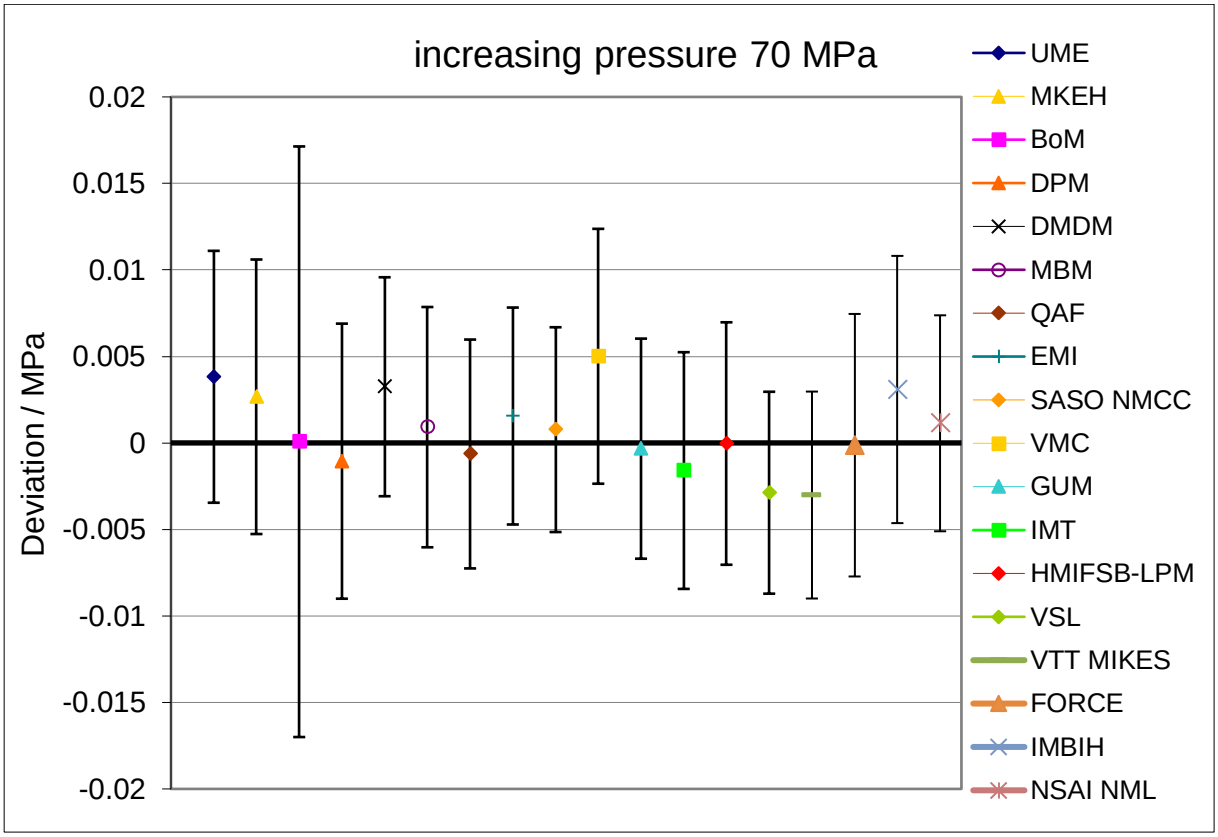

Figure 23. Deviations from the reference value with uncertainties at 70 MPa

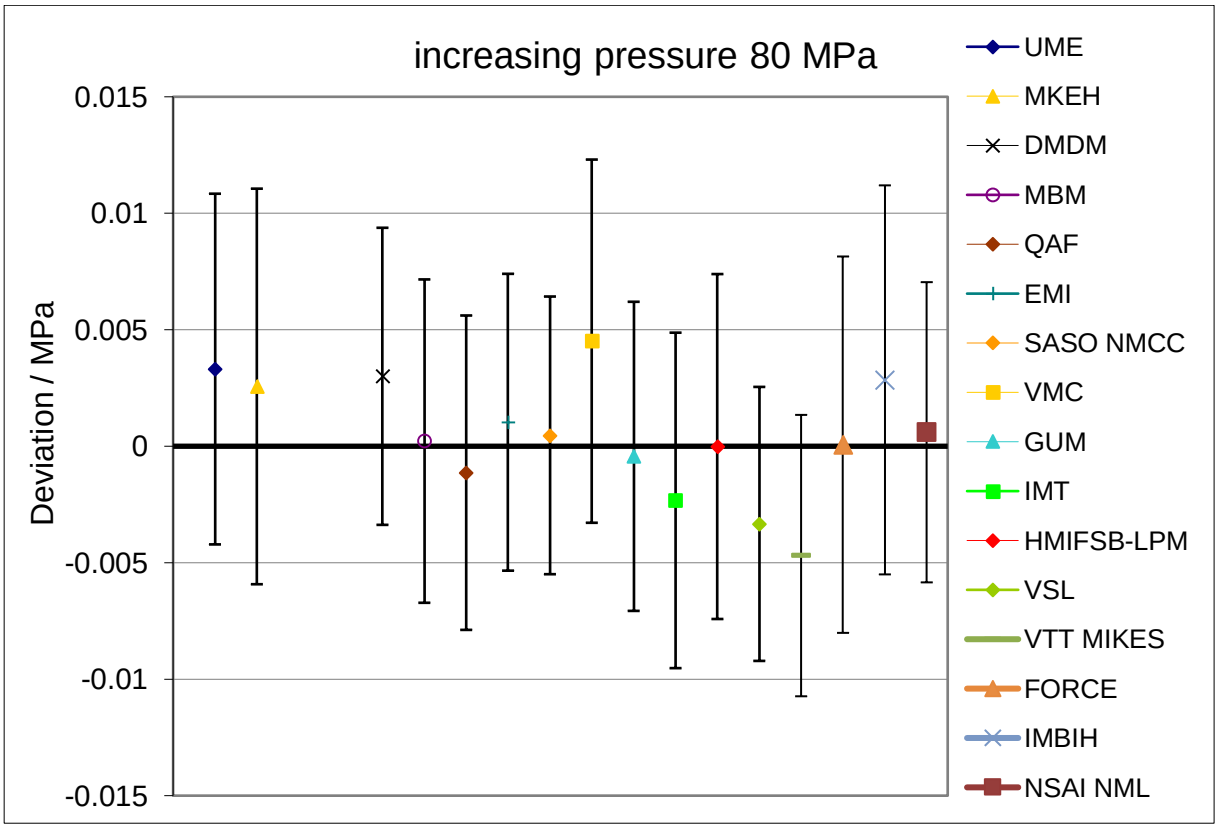

Figure 24. Deviations from the reference value with uncertainties at 80 MPa

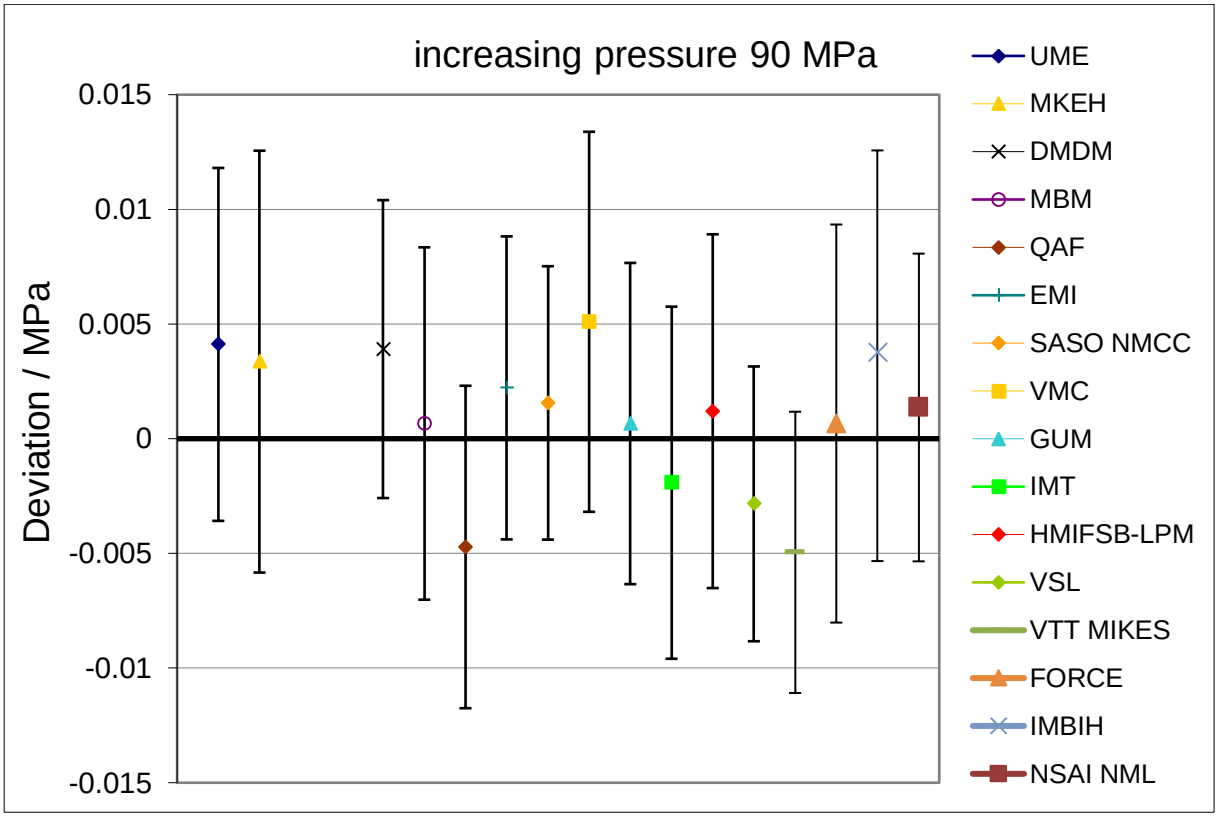

Figure 25. Deviations from the reference value with uncertainties at 90 MPa

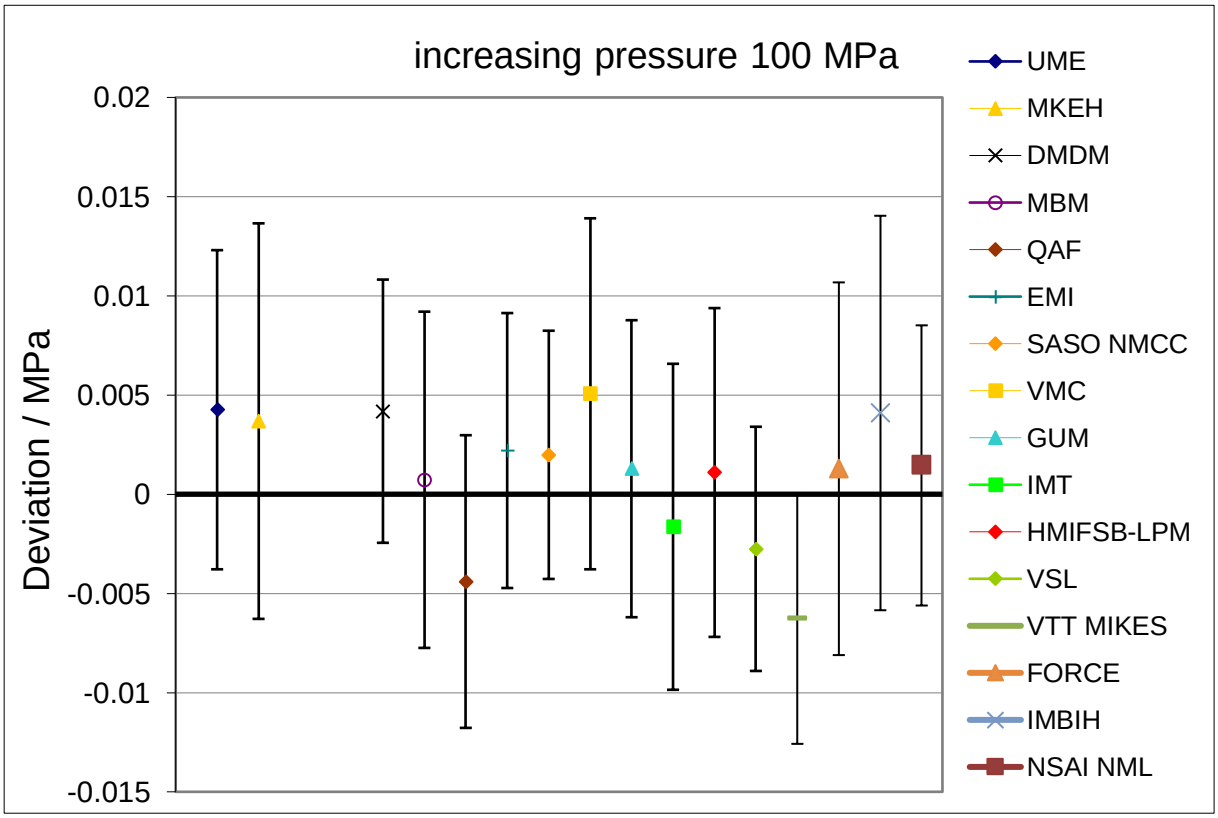

Figure 26. Deviations from the reference value with uncertainties at 100 MPa

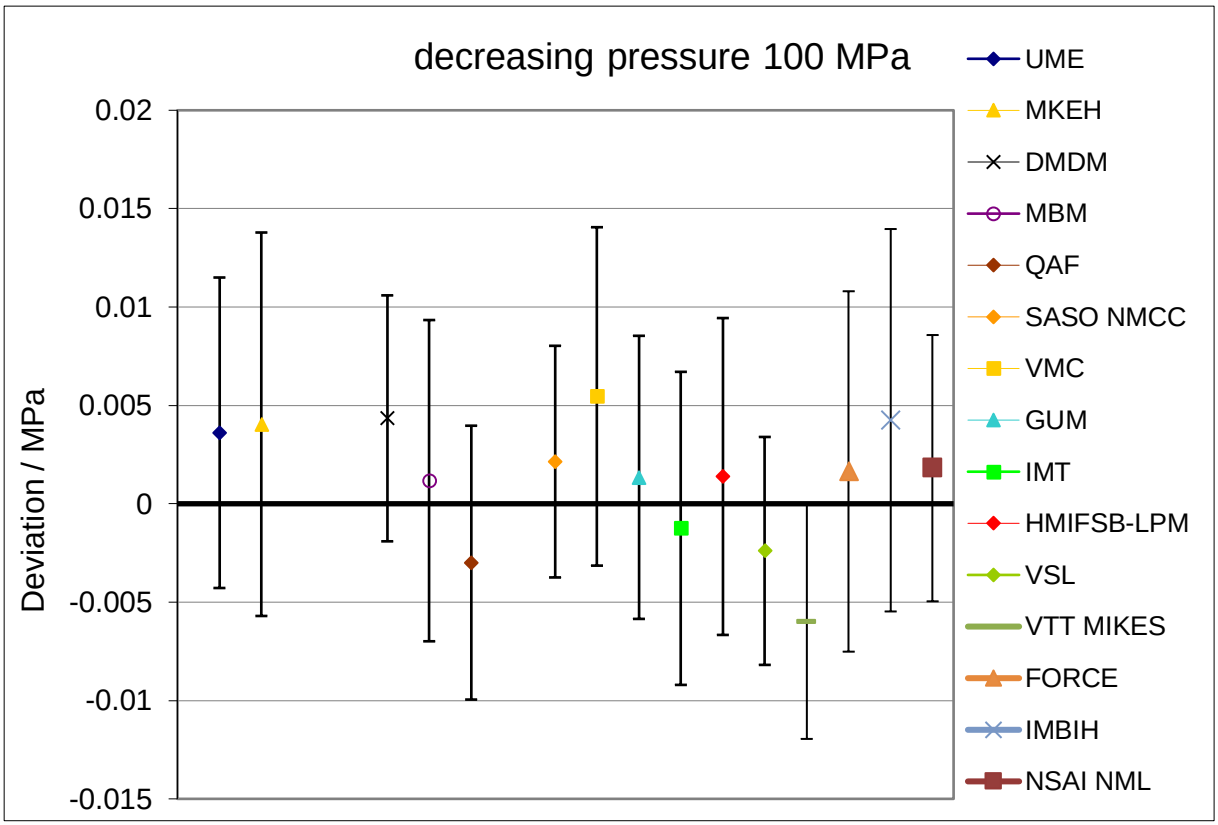

Figure 27. Deviations from the reference value with uncertainties at 100 MPa

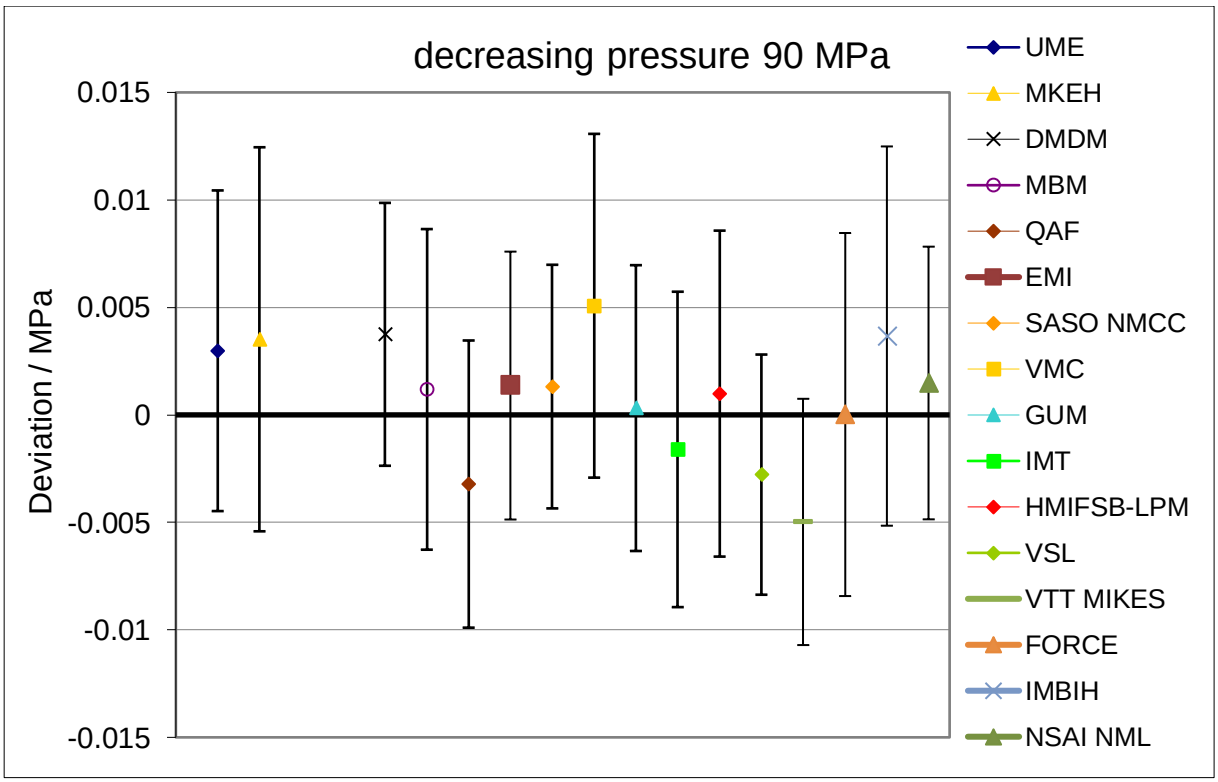

Figure 28. Deviations from the reference value with uncertainties at 90 MPa

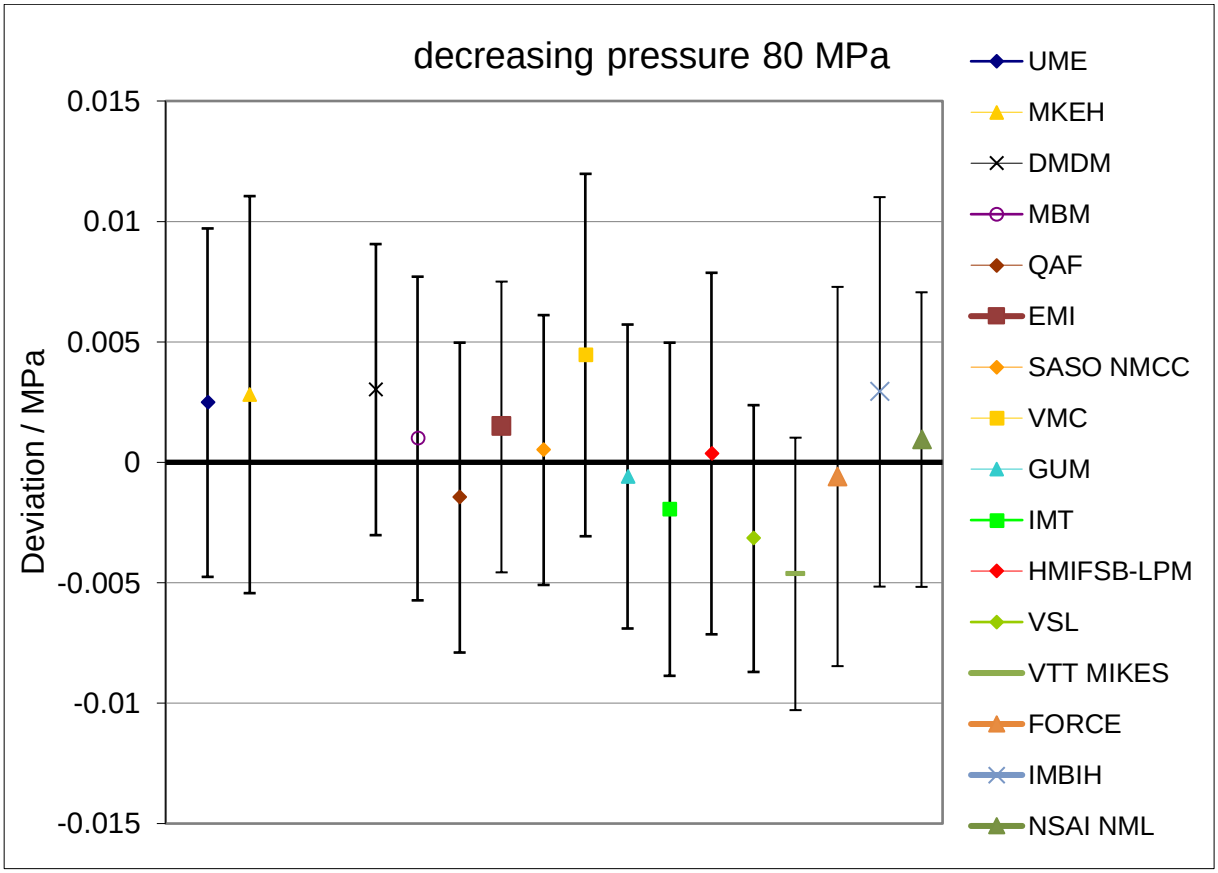

Figure 29. Deviations from the reference value with uncertainties at 80 MPa

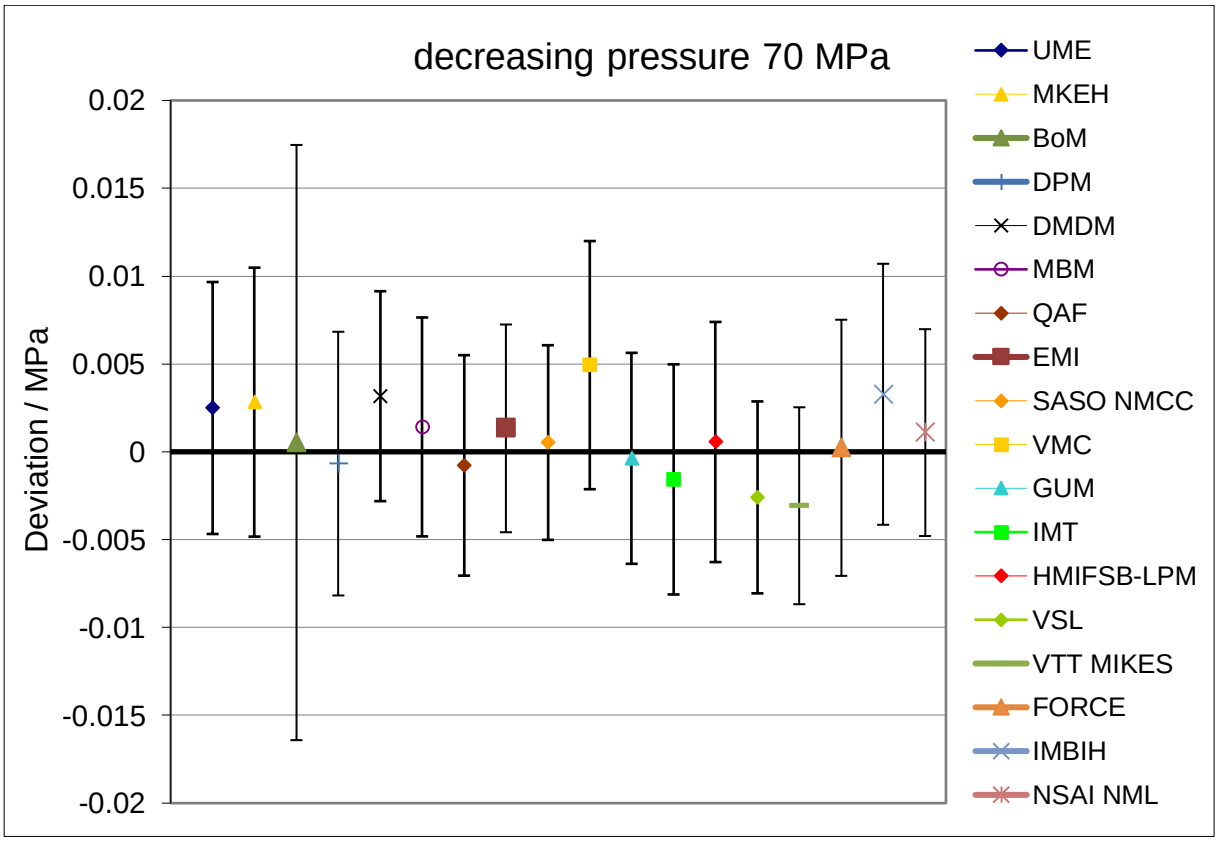

Figure 30. Deviations from the reference value with uncertainties at 70 MPa

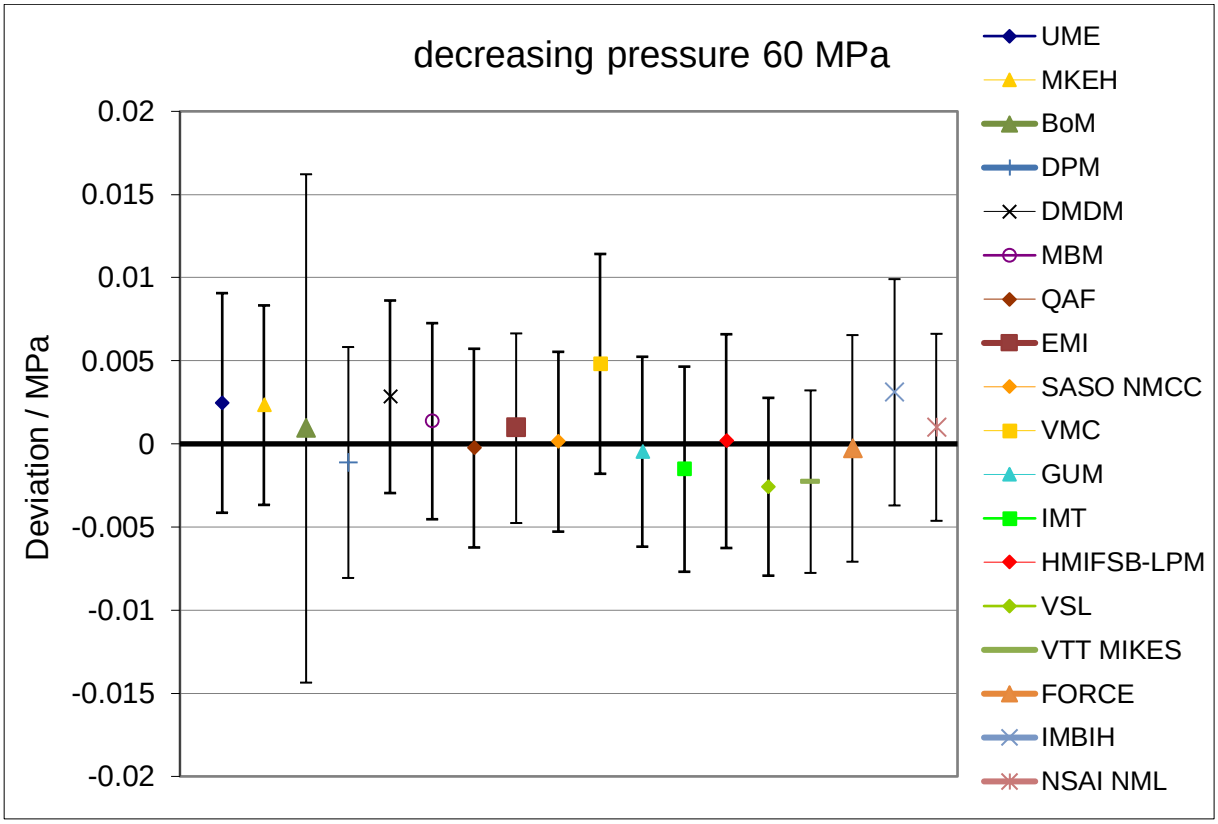

Figure 31. Deviations from the reference value with uncertainties at 60 MPa

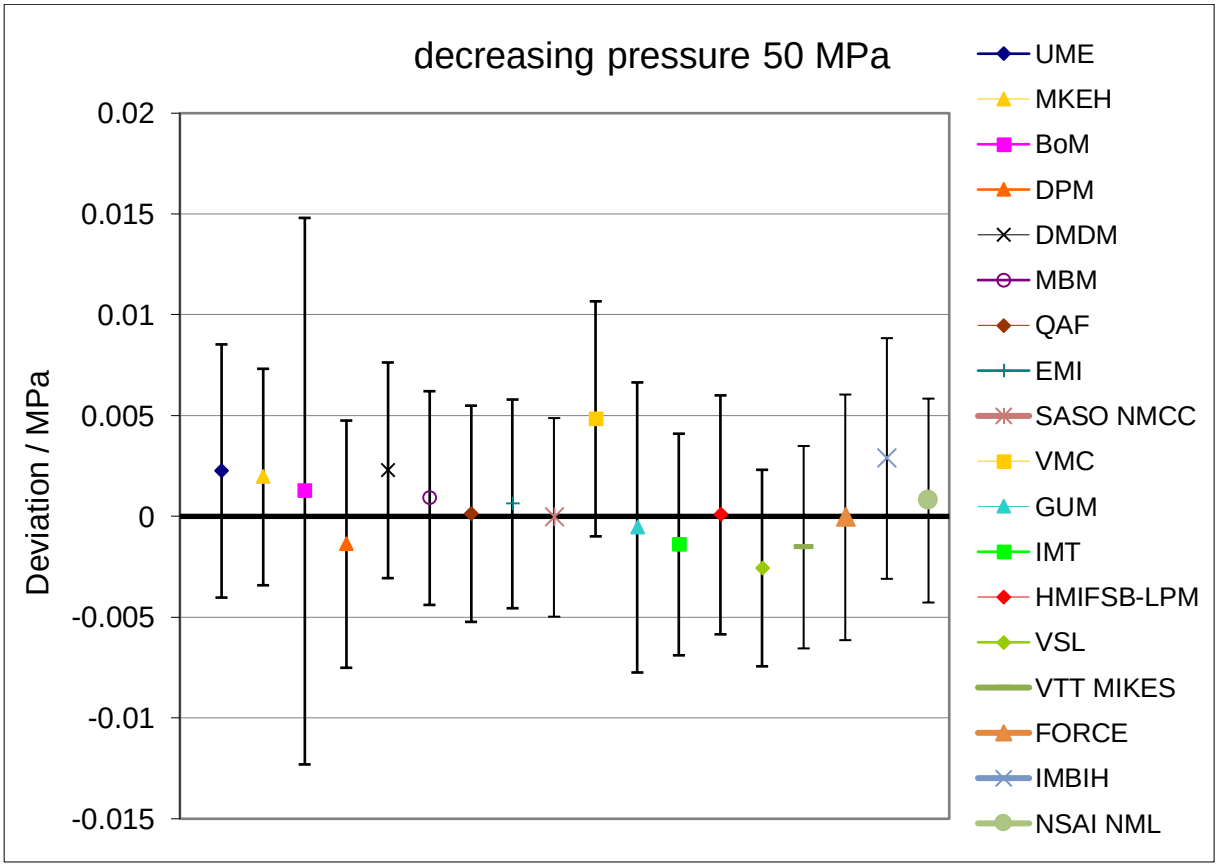

Figure 32. Deviations from the reference value with uncertainties at 50 MPa

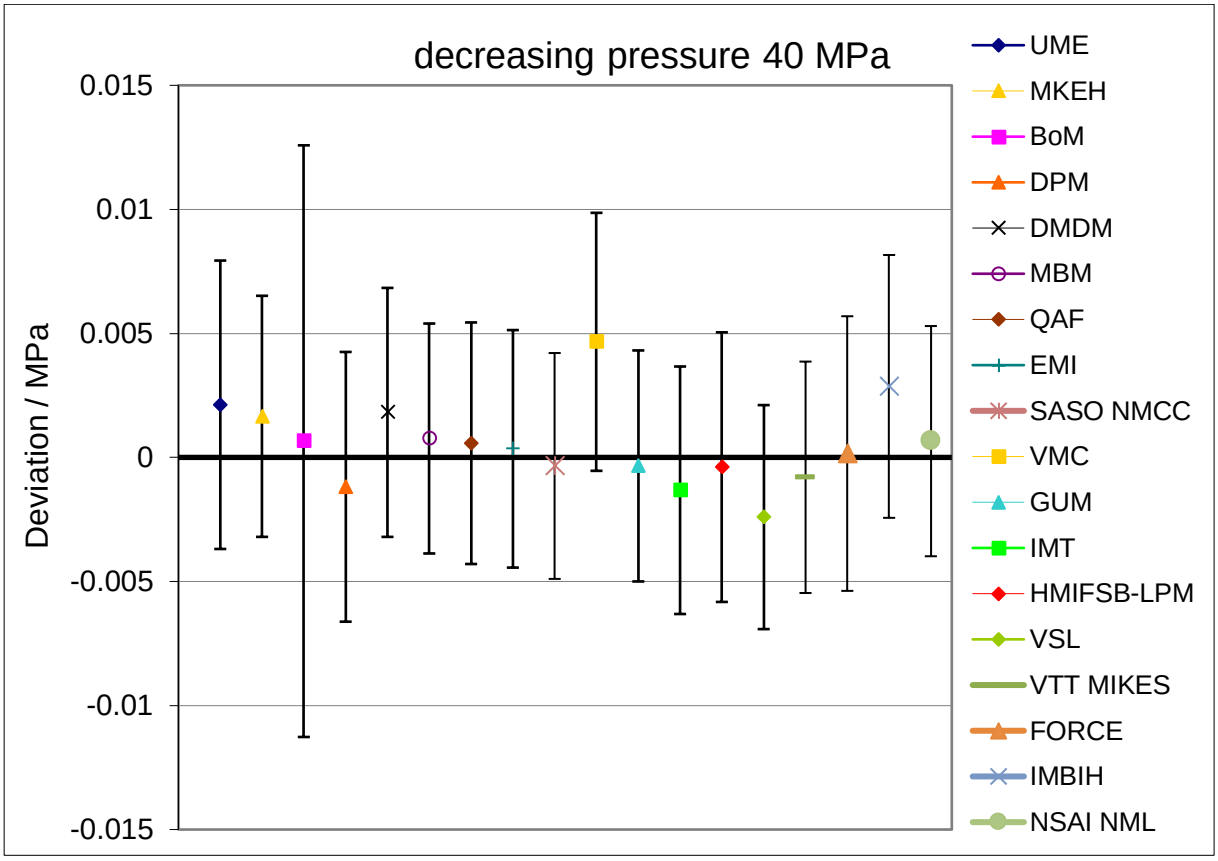

Figure 33. Deviations from the reference value with uncertainties at 40 MPa

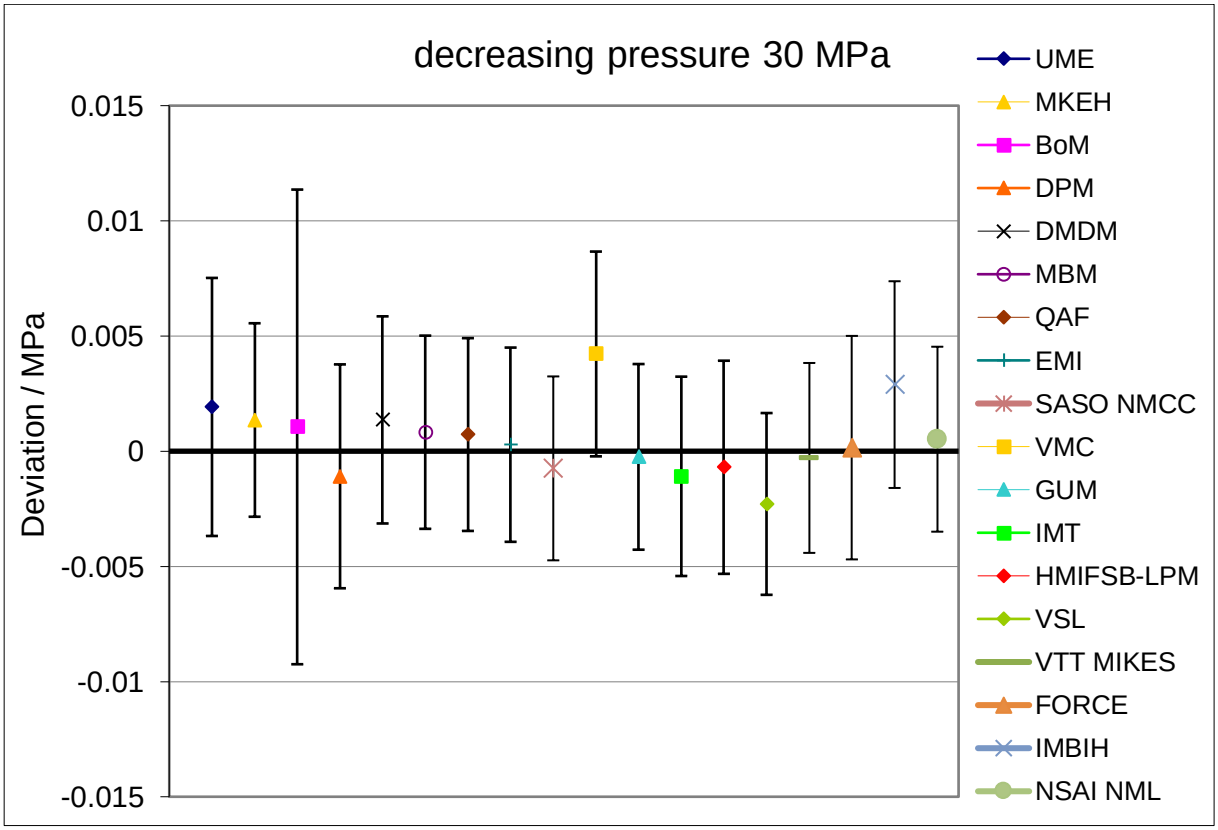

Figure 34. Deviations from the reference value with uncertainties at 30 MPa

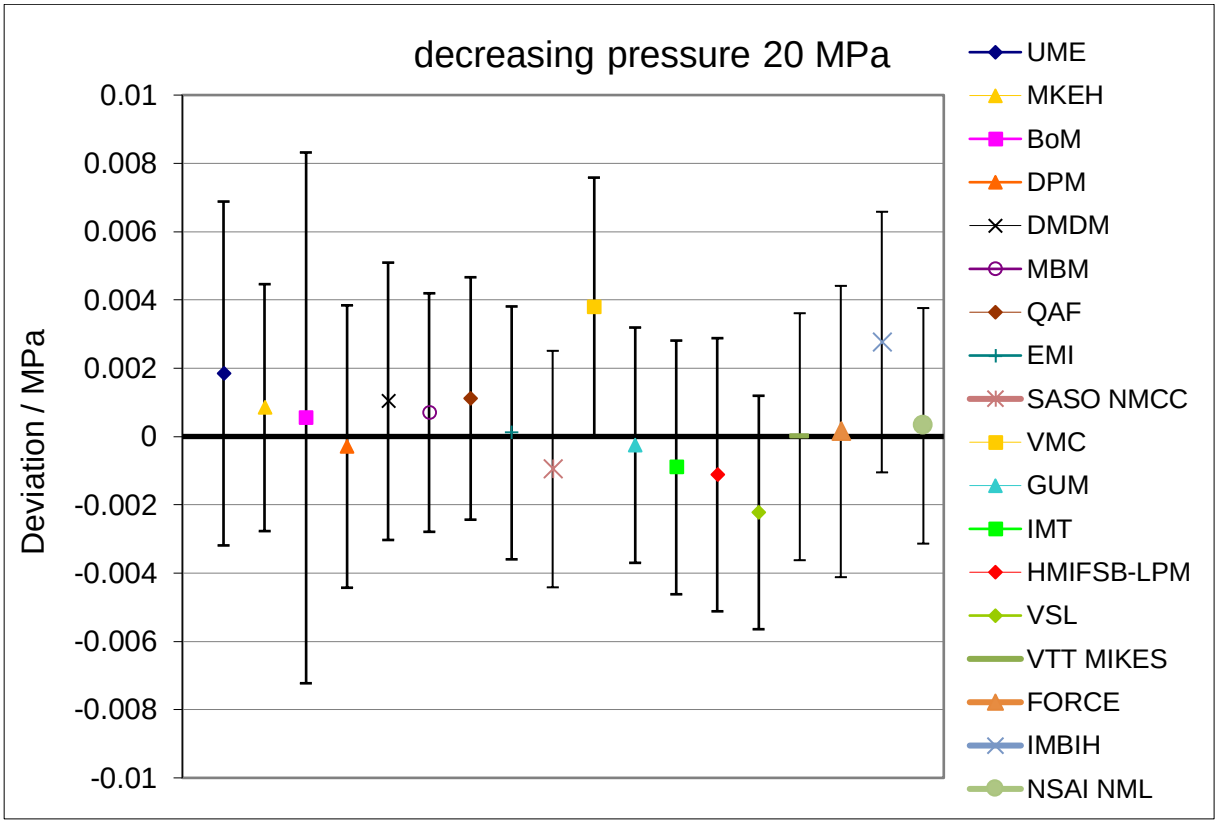

Figure 35. Deviations from the reference value with uncertainties at 20 MPa

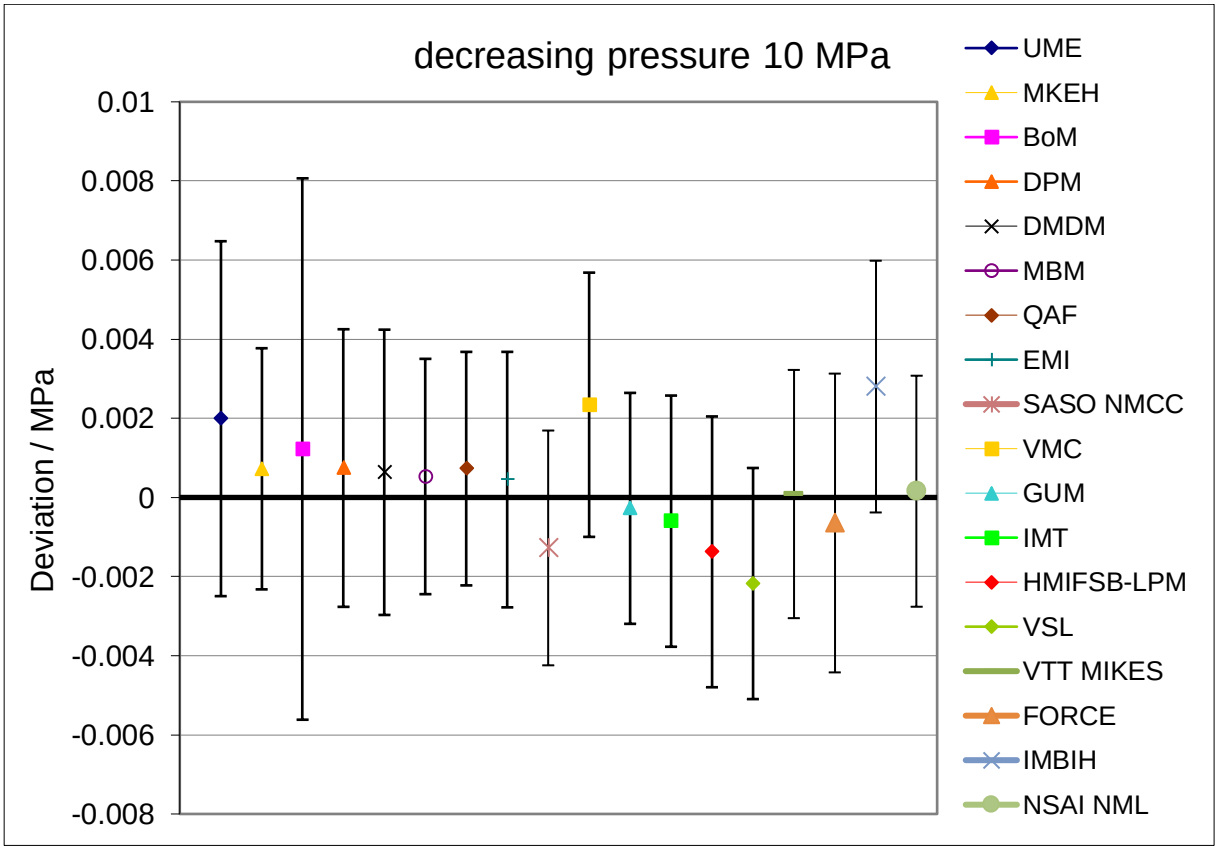

Figure 36. Deviations from the reference value with uncertainties at 10 MPa

9. Degree of equivalence

The degree of equivalence E_n for each participating laboratory at each nominal pressure is presented in Tables 35 and 36. The E_n calculation is performed using equation (7) below:

$$E_n = \frac{d_i}{U(d_i)} \quad (7)$$

where,

d_i is the difference between the result of laboratory i and the comparison reference value

$U(d_i)$ is the expanded uncertainty of d_i

The laboratories results are regarded as equivalent with the reference values if $-1 \leq E_n \leq 1$.

Table 35. The degree of equivalence E_n for each nominal pressure and each laboratory

Nominal pressure	E_n values								
(MPa)	UME	MKEH	BoM	DPM	DMDM	MBM	QAF	EMI	SASO NMCC
10	0.71	0.30	0.22	0.14	0.27	0.10	-0.07	0.13	-0.24
20	0.64	0.25	0.10	-0.13	0.33	0.14	0.01	0.17	-0.18
30	0.58	0.26	0.13	-0.22	0.41	0.17	-0.03	0.13	-0.11
40	0.57	0.30	0.17	-0.23	0.44	0.11	-0.06	0.14	-0.09
50	0.55	0.35	0.12	-0.23	0.49	0.15	-0.08	0.14	0.04
60	0.51	0.37	0.09	-0.20	0.51	0.12	-0.11	0.25	0.05
70	0.53	0.34	0.00	-0.13	0.51	0.13	-0.10	0.25	0.13
80	0.44	0.30	0.00	0.00	0.47	0.03	-0.17	0.16	0.08
90	0.53	0.37	0.00	0.00	0.60	0.09	-0.67	0.34	0.26
100	0.53	0.37	0.00	0.00	0.63	0.09	-0.60	0.32	0.32
100	0.46	0.41	0.00	0.00	0.69	0.14	-0.43	0.00	0.36
90	0.40	0.39	0.00	0.00	0.61	0.16	-0.48	0.22	0.23
80	0.34	0.34	0.00	0.00	0.50	0.15	-0.23	0.24	0.09
70	0.35	0.37	0.03	-0.09	0.53	0.23	-0.12	0.23	0.10
60	0.37	0.39	0.06	-0.16	0.49	0.23	-0.04	0.17	0.02
50	0.36	0.36	0.09	-0.22	0.43	0.17	0.02	0.12	-0.01
40	0.37	0.34	0.06	-0.22	0.36	0.16	0.12	0.07	-0.08
30	0.34	0.32	0.10	-0.22	0.30	0.20	0.17	0.07	-0.19
20	0.37	0.23	0.07	-0.07	0.25	0.20	0.31	0.03	-0.28
10	0.44	0.24	0.18	0.21	0.18	0.18	0.25	0.14	-0.43

Table 36. The degree of equivalence E_n for each nominal pressure and each laboratory

Nominal pressure	E_n values								
(MPa)	VMC	GUM	IMT	HMIFSB-LPM	VSL	MIKES VTT	FORCE	IMBIH	NSAI NML
10	0.77	-0.10	-0.22	-0.37	-0.77	0.11	-0.22	0.75	0.06
20	0.97	-0.10	-0.26	-0.37	-0.69	0.05	-0.08	0.61	0.05
30	0.97	-0.13	-0.26	-0.32	-0.66	-0.04	-0.07	0.54	0.10
40	0.85	-0.13	-0.27	-0.21	-0.62	-0.14	-0.06	0.46	0.11
50	0.79	-0.13	-0.25	-0.13	-0.60	-0.28	-0.02	0.44	0.13
60	0.75	-0.11	-0.26	-0.06	-0.58	-0.40	-0.03	0.41	0.16
70	0.68	-0.05	-0.23	-0.01	-0.49	-0.50	-0.02	0.40	0.18
80	0.58	-0.07	-0.32	0.00	-0.57	-0.78	0.01	0.34	0.09
90	0.62	0.09	-0.25	0.16	-0.47	-0.81	0.08	0.41	0.20
100	0.57	0.17	-0.20	0.13	-0.45	-0.99	0.14	0.41	0.21
100	0.63	0.19	-0.16	0.17	-0.41	-1.01	0.18	0.44	0.27
90	0.64	0.05	-0.22	0.13	-0.50	-0.87	0.00	0.42	0.23
80	0.59	-0.09	-0.28	0.05	-0.57	-0.82	-0.08	0.36	0.15
70	0.70	-0.06	-0.24	0.08	-0.48	-0.55	0.03	0.44	0.19
60	0.73	-0.08	-0.25	0.03	-0.48	-0.41	-0.04	0.46	0.18
50	0.83	-0.11	-0.25	0.01	-0.53	-0.30	-0.01	0.48	0.16
40	0.90	-0.07	-0.27	-0.07	-0.53	-0.17	0.03	0.54	0.14
30	0.95	-0.06	-0.25	-0.15	-0.58	-0.07	0.03	0.64	0.13
20	1.00	-0.07	-0.24	-0.28	-0.65	0.00	0.03	0.72	0.09
10	0.70	-0.09	-0.19	-0.40	-0.74	0.03	-0.17	0.88	0.05

10. Conclusion

The EURAMET.M.P-S13 (EURAMET 1252) inter-laboratory comparison project was organized as a supplementary comparison to provide a degree of equivalence for each participating laboratory. The comparison was performed in gauge mode in oil pressure up to 100 MPa. Eighteen laboratories from the EURAMET, COOMET and GULFMET Regional Metrology Organisations participated in the comparison.

The transfer standard was a digital pressure gauge manufactured by Paroscientific, which was circulated without major problems from January 2015 to April 2017. Due to the high number of participants, the comparison has taken a longer period.

The reference value of the comparison has been determined based on the non-weighted mean of the measurement results provided by the participants.

Stability of the transfer standard was analysed by five different interim measurements in different time slots during the comparison life cycle.

Instability of TS is included in the uncertainty of the reference value of this comparison and consequently, the uncertainty of the reference value is slightly larger than expected due to the instability of the TS. The uncertainties achieved in this comparison are quite conservative. They are strongly affected by the performance of the TS and are much bigger than the uncertainties stated by the participants for their standards.

BoM and DPM did the measurements up to 70 MPa both in decreasing and increasing directions. EMI did not do the measurement at 100 MPa in decreasing direction. The equivalence of the participants with the reference value, in gauge pressure, was realized by all 18 participants at the vast majority of nominal pressure points. The only exceptions being for VTT MIKES at 100 MPa decreasing pressure (E_n of 1.01) where the difference from an E_n value of 1.0 is marginal. So, in summary, the equivalence respective to the reference value is demonstrated by all 18 participants for specified nominal pressures.

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