

Final Report
on Bilateral (Supplementary)
Comparison in the Range 200 kN
to 1000 kN of TUBITAK UME and
INM Force Standard machines
(EURAMET 838 Project)

S. Fank¹. B. Aydemir¹. Cemal Vatan¹.

A. Gherasimov². M. Pomarlan². D. Hodor²

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TUBITAK UME, Turkey

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Abstract

The bilateral (Supplementary) comparison (EURAMET 838 Project) for the force measurements in the range between 200 kN and 1000 kN was realized between piloted by the TÜBİTAK UME (National Metrology Institute of Turkey) and INM (Institutul National de Metrologie. Romania). The transfer standards were 500 kN and 1 MN force transfer transducers have been used in this comparison measurements. TUBITAK UME was a pilot laboratory for the intercomparison of force standard machines with INM force standards.

The results of the participants were found to be consistent with the reference value of the actual comparison within their claimed uncertainties ($k = 2$). at all forces. Compared in pairs two laboratories with demonstrate their agreement with each other within the expanded uncertainties ($k = 2$) at all forces. The results are considered to be satisfactory.

¹ TUBITAK ME, Ulusal Metroloji Enstitüsü (National Metrology Institute of Turkey)ü, Turkey

² INM, Institutul National de Metrologie (National Metrology Institute of Romania), Romania

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ANNEX (Measurement Data for TUBITAK UME and INM Comparison)

1. Introduction

1.1 General

Force Laboratory of TUBITAK UME (National Metrology Institute of Turkey) as pilot laboratory and INM (National Metrology Institute of Romania) performed a bilateral (supplementary) comparison of force standard machines in the force interval from 200 kN to 1 000 kN according to EURAMET Project 838. This document comprises a report on the measurements carried out and the results of the bilateral comparison of force standard machines (FSM) of TUBITAK UME, Turkey and INM, Romania.

At the beginning, in accordance with EURAMET Project 838, it was decided that the interlaboratory comparison will cover the force interval from 2 kN to 1 000 kN involving the following standards:

TUBITAK UME:

- 10 kN dead weight force standard machine
- 110 kN dead weight force standard machine
- 110 kN/1.1 MN dead weight and lever amplification standard machine

INM:

- 10 kN dead weight force standard machine
- 100 kN dead weight force standard machine
- 1 MN comparator force standard machine

Due to some technical problems during measurements, comparison of INM 10 kN and 100 kN dead weight machines have been cancelled. Only the 1 MN comparator force standard machine of INM and the 110 kN /1.1 MN dead weight/ lever amplification standard machine of TUBITAK UME were compared to each other.

The comparison of force standard machines was carried out in compression mode in the interval from 200 kN to 1000 kN, using transfer force transducers provided by TUBITAK UME, having nominal force of 500 kN and 1000 kN.

Both participants used for the comparison the same transfer force transducers together with their own indicating instruments and equivalent comparison measurement procedures in appropriate ambient conditions.

Comparison was conducted between September 2008 and December 2009.

In this report, “**TUBITAK UME**” is shortened as “**UME**” in paragraphs and tables except headings.

1.2 Presentation of participation laboratories

UME Force laboratory was established the force scale in range between 0.5 N and 3 MN with five different FSMs in 1995 to 2002. All UME force standard machines were intercompared with different countries and their results were published in IMEKO TC3 conferences [1-5]. UME have been participated in several intercomparison measurement with PTB as a bilaterally and also CCM key comparisons. This comparisons have been connected the UME to Europe the USA, Asia and other countries to each other. Only the 1.1 MN UME FSM participated in UME and INM intercomparison. The UME FSM is lever type machine having capacity of 110 kN in dead weight side, in range between 2 kN and 110 kN, and 1.1 MN in lever side in the range between 20 kN and 1.1 MN.

INM Force laboratory, as a part of Romanian National Metrology Institute was established the force scale in range between 500 N and 1 MN with three different FSMs. First FSM is a dead weight machine having maximum force of 10 kN, in the interval from 0.5 kN to 10 kN. Second FSM is a dead weight machine having the interval from 5 kN to 100 kN and third FSM is an 1 MN comparator machine having the interval from 50 kN to 1 MN. Only the INM 1 MN comparator machine participated in comparison measurements.

2. Laboratory standards and measurement methods of the participants

All laboratory standards (LS) are the computer controlled force standard machines (FSM). 1.1 MN lever amplification type FSM of UME and 1 MN comparator type FSM of INM participated in this intercomparison measurement. All participants applied the international force comparison procedure (methods) given in detail below sections to compare their standards with transfer force standards (TS).

The uncertainties were estimated in respect of principles laid out in the Document "Expression of Uncertainty of the Measurement in Calibration", published EA 4/02. The principal components of the uncertainty budget to be evaluated are in accordance with the document "Calibration Guide EURAMET/cg-04/v.02 (03/2011)-Uncertainty of Force Measurements" or in accordance with equivalent consensus documents.

The uncertainty budget should also be given according to the parameters listed in Table 1.

Table 1. Uncertainty Contributions and Statistical Distribution

Uncertainty arising from	Approximate equation, Q	Statistical Distribution	Rel. Uncertainty contribution, (a= half width of Q)
Reproducibility, from 5 rotational measurement values, [a]	$b_{RP} = \frac{ X_{\max} - X_{\min} }{X_{AVE}}$ $X_{AVE} = \frac{X_1 + X_2 + X_3 + X_4 + X_5}{5}$	U shape distribution	$u_{(b_{RP})}^2 = \frac{a_{b_{RP}}^2}{2}$
Repeatability, in position zero, (not normally, for transfer transducer performance), [b]	$b_R = \frac{ X_2 - X_1 }{X_R}$ $X_R = \frac{X_1 + X_2}{2}$	Rectangular distribution	$u_{(b_R)}^2 = \frac{a_{b_R}^2}{3}$
Temperature effect of the sensitivity due change of temperature in both labs. (if needed, in case of the same lab. temperature), [c]	$S_{td} = \alpha \cdot (t_P - t_L)$ $\alpha \approx 5 \times 10^{-6} / ^\circ\text{C}$	Rectangular distribution	$u_{(S_{td})}^2 = \frac{a_{S_{td}}^2}{3}$
Standard uncertainty of applied force, [d]	U_{FSM}	Normal distribution	u_{FSM}^2
Hysteresis, will be applied only for comparator machine, [e]	$v = \frac{i' - i}{i}$	Rectangular distribution	$u_{(v)}^2 = \frac{a_v^2}{3}$
Resolution of indication, [f]	$e = \frac{r}{X_{AVE}}$	Rectangular distribution	$u_{(r)}^2 = \frac{a_r^2}{3}$
Rel. Expanded uncertainty of the measurements, (k=2)	$U = k \cdot \sqrt{a^2 + b^2 + c^2 + d^2 + e^2 + f^2}$		

X_{AVE} = Average values taken from five different rotational position of transfer transducer

X_i = Measured value for each lab

b_{RP} =Reproducibility of the measurements

b_R =Repeatability of the measurements

v = Hysteresis of the measurements

S_{td} = Temperature effect of the sensitivity due change of temperature

t_P = Ambient temperature of the pilot laboratory

t_L = Ambient temperature of the laboratory

α = temperature coefficient of the transfer force transducer

r = resolution of indicating instruments

e = resolution error of indicating instruments

U_{FSM} = Uncertainty of force standard machine of each laboratory

U = Relative expanded uncertainty of the measurements

k = Coverage factor ($k = 2$)

2.1. The Force Standard Machine of TUBITAK UME

110 kN / 1.1 MN Dead Weight /Lever Amplification Machine

Figure-1 shows the general view of the 110 kN/1.1 MN force standard machine. The dead weight side of the machine can be used as an independent force standard machine to generate forces of 2 kN up to 110 kN. The dead weight side has one stack of 25 weights is composed of: 4 x 1 kN; 8 x 2 kN; 1 x 3 kN; 7 x 5 kN; 5 x 10 kN, having 3 different force ranges to calibrate force proving instruments. These are 20 kN, 50 kN and 100 kN. Loading frame having a nominal value of 2 kN also realizes first step of force. Each one has also 10 steps with 10 % increment. The working principle and all other capabilities are the same with 11 kN dead weight machine explained above section. The lever amplification is realized with a single lever and transmission ratio of 1:10, With lever multiplication, the forces are generated of 20 kN up to 1.1 MN with force ranges 200 kN, 500 kN and 1 MN, A compression and tension space is provided on both the dead weight side and lever side. Conventional lever multiplication contains knife-edges and pans, thus the lever arms may deflect and rotate around the supporting knife-edges. The bearing mechanism with knife-edge and pan have some limitations, e.g. due to variation of fulcrum position inside the knife-edge contact area, long term- stability caused by wear and partial plastic deformation of the contact area due to large surface pressure. In this machine, newly developed strain controlled leaf spring joints by GTM company as a bearing instead of conventional knife-edge bearing mechanism in lever multiplication are used. The base frame consists of an adjustable cross head driven by a servomotor with low-friction planetary rolling spindles [1].

By means of supporting bearings the lever is connected with the upper cross head of the base frame. The location of the strain controlled joints in the lever is such that the fulcrum position remains in the neutral zone. To allow the length of the load arm of the lever to be kept very small (100 mm), the supporting bearing is equipped with two joints, the bearing on the force multiplication side with one joint. This ensures also good lateral guidance of the lever. Each leaf spring shaped joint has two strain gage bonded on the each side of the leaf springs and connected to Wheatstone bridge circuit in order to measure the bending moments applied to the lever by the joints.

The control unit maintains the lever in its zero-momentum position, irrespective of the load applied, so that the restoring momentum's of the flexible joints remains zero. At each force change, the loading system, including force proving instrument to be calibrated, is subject to a deformation which is a function of the force and which results in an inclination and deformation of the lever, the frame and supporting bearings. Via measuring amplifier, the strain gage type measuring bridge of the joints delivers a signal, proportional to the bending

momentum in the spring joints, to a control unit. This control unit then activates the servomotor so that the output of the bridge circuit of the joints becomes zero and the lever remains free of bending momentum, applied by the spring joints.



Figure 1. 110/1100 kN Lever Amplification Force Standard Machine of UME

A tare weight driven by a stepping motor and highly precise spindle is installed in the neutral surface zone of the lever. After force proving instrument to be calibrated has been installed, the lever is brought into the horizontal position taking strain gage signal from elastic joints as a reference; in this way, weight of to be calibrated instrument cause deviation from the horizontal position of the lever, then tare weight is driven up to lever become horizontal position. Detail information about strain controlled joints, design, construction and working of the machine can be found in ref. [6-7].

2.2. The Force Standard Machines of INM

To cover the force range included in the intercomparison, 1 MN comparator force standard machine belonging to INM was utilized.

1 MN Comparator Type Force Standard Machine

Figure-2 is a view of the 1 MN comparator machine. A base frame supports a vertically adjustable yoke which carries reference force transducers for the control system. The reference force transducers mounted in the machine are used to calibrate force transducers coming from customer.



Figure 2. 1 MN INM Comparator type Force Standard Machine

The loading is managed by screw mechanism by PC control upon the lowering frame, 1 MN INM comparator machine have three different reference force transducers which are used as references of the machine are having the 500 kN and 1 MN capacities.

3. Transfer Standards

Two compression force transducers having capacities of 500 kN (GTM, SN: 43018) and 1 MN (GTM, SN: 45084) were used as the force transfer standards in this comparison measurements. These force transducers belonging to UME, have been used in previous interlaboratory comparisons with national laboratories of other countries as well. Accordingly, the long term stability behavior of these transducers was already well known.

To minimize the uncertainty associated with the indicating instrument a high resolution, 1 ppm, indicators having good stability (HBM, type DMP 40) were used in the comparison. The indicators are self calibrating. During an auto calibration cycle, the measuring voltage is replaced periodically by a zero signal and then by a highly- precise calibration voltage. A low frequency carrier frequency of 225 Hz is fed into the force transducers. In the DMP 40, the signal is amplified, demodulated, filtered and transformed into a digital value which is fed into a computer. For the DMP 40, the six-wire technique is used in the measuring line, i.e. the

supply voltage is taken of at the transducer and returned to the amplifier. The resolution of this indicating instrument used is 1 ppm and the relative accuracy of it is estimated by PTB to be 4 ppm [8].

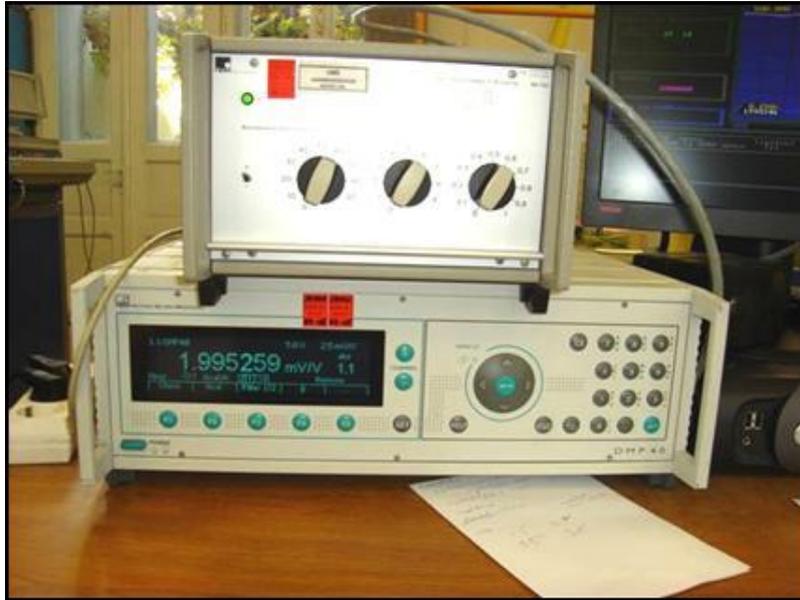


Figure 3. Precision indicating instrument (DMP 40) and BN 100 calibrator of UME

DPM 40 is adjusted as absolute value (ABS), 0.1 Hz Bessel filter, 5 V excitation voltage and ± 2.5 mV/V measuring range values during measurements.

At the same time, in order to check both DMP 40 indicating devices belonging to UME (HBM, DMP 40 S6: SN: 964720034) and INM (HBM, DMP 40: SN: 05132044), a BN 100 type HBM product calibrating device was used during comparison measurements (shown in Fig.3).

4. Organization, chronology and problems during the comparison

Initial measurements were carried out first at UME in September 2008. These measurements were performed at INM by a set of similar measurements in October 2008. To verify the stability of the force transducers used during the comparison, a final set of measurements was obtained at UME as well. This comparison measurement was made for to determine the relative deviations among the various forces realized by UME and INM.

At the beginning of the comparison, Force laboratory UME, as pilot laboratory, made the initial comparison measurements using the UME's transfer force transducers and UME's indicating instrument type DMP 40, operating the UME's 1.1 MN force standard machine. Then, UME staff moved the UME's transfer force transducers and the UME's calibrator type BN 100 to the force laboratory INM-Romania. INM staff carried out the measurements using the 1 MN comparator force standard machine, the same UME's transfer force transducers

and the INM's indicating instrument type DMP 40, under the supervision of UME staff. After measurements at INM. UME staff returned to UME for completing final measurements. Before starting each measurement, the indicating instruments type DMP 40 belonging to INM and UME were calibrated using the UME's calibrator type BN 100.

5. Measurement procedures

The procedure for performing the comparison measurements is described below.

To minimize the effect of creep, for each force transducer included in the comparison, the time required achieving a stable response following loading and unloading was determined prior to start of the comparison. In most instances it was found that a 3 min. time delay between the initiation of the loading (or unloading) and the actual reading was adequate. In addition this, after force transducer is loaded or unloaded, some drifts due to mechanical, thermal and electrical affects occur in the output of the transducer.

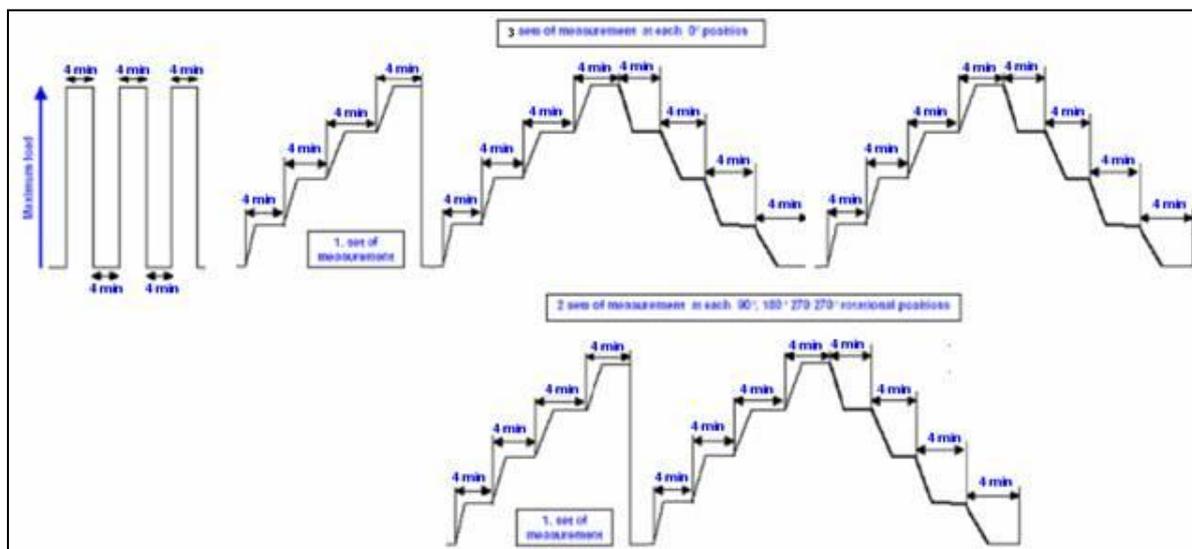


Figure 4. Loading diagram for 500 kN and 1000 kN transfer force transducers

Local heating due to electrical-power dissipation may cause this by the strain-measuring bridge. Many measurements and experience show that this effect on force transducer output stabilizes within about 3 minutes. For these reasons **4 minutes** time delay was selected as a time interval among each measurements.

Machine-transducer interactions can significantly influence measurement accuracy. Normal imperfections in alignment of loading machines and force transducers can result in significant bending, shear and twist components of deformation in the force transducers. To minimize

the errors due to these non-axial components of deformation, the response of each force transducer was obtained at five symmetrically distributed positions relative to the axis of the machine (0°, 90°, 180°, 270°, 360°). In order to get better results, prior to start measurement cycle, the force transducer was loaded with maximum test load three times at the 0° position.

Due to hysteresis effect of reference transducer of comparator machine of INM for 500 kN and 1000 kN transfer force transducer, three sets of measurements at 0°, two sets of measurements at 90°, 180°, 270° and 360° rotational positions were applied in increasing and decreasing loadings, as shown in Figure 4.

The measurements were carried out at (21±1) °C and relative humidity (45±10) % RH, the usual laboratory conditions at INM and UME. Due to equality of laboratory conditions, effect of temperature difference on uncertainty can be eliminated. Both the force transducers and indicator were kept in laboratories for at least 1 day prior to the initiation of measurements. Force steps selected for international comparison of the INM and UME Force Standard Machines are shown in below Table 2.

Table 2. Selected force steps for international comparison
of the INM and UME Force Standard Machines

UME Transfer Force Transducer			Selected force steps
Producer	Serial No	Capacity	
GTM	43018	500 kN	200 kN, 300 kN, 400 kN, 500 kN
GTM	45084	1000 kN	400, 600 kN, 800 kN, 1000 kN

6. Results of the participants

Measurement results are shortly presented in table 3. The full measurement data are annexed at the end of report. On the tables, below abbreviations are used.

UME_i = UME initial measurement results

UME_f = UME final measurement results

UME_{ave} = UME average (initial+final/2) measurement results

INM = INM measurement results

All measurement data given in annex, here the average measurement results taken from 500 kN and 1000 kN force transfer standards at UME and INM are given in Table 4 to 9.

Table 3. Outputs for 500 kN and 1000 kN force transducers measured at INM and UME

Transfer Force Transducer	Force step	Average Measurements Data (without indicator difference and temperature difference corrections)			
		UME _i	UME _f	UME _{ave}	INM
kN	kN	mV/V	mV/V	mV/V	mV/V
500	200	0.800102	0.800099	0.800100	0.800106
	300	1.200279	1.200188	1.200234	1.200255
	400	1.600468	1.600106	1.600287	1.600415
	500	2.000632	2.000458	2.000545	2.000633
	400	1.600498	1.600344	1.600421	1.600377
	300	1.200332	1.200244	1.200288	1.200195
	200	0.800178	0.800142	0.800160	0.800065
1000	400	0.800699	0.800687	0.800693	0.800737
	600	1.201052	1.201002	1.201027	1.201101
	800	1.601479	1.601340	1.601410	1.601520
	1000	2.001851	2.001632	2.001742	2.001852
	800	1.601460	1.601326	1.601393	1.601436
	600	1.201101	1.201049	1.201075	1.200952
	400	0.800735	0.800720	0.800727	0.800497

Table.4. UME 500 kN Load cell-GTM-SN: 43018 Initial UME Measurements in 15.09.2008 in 110 kN/1100 kN Dead Weight Lever Amplification Force Standard Machine of UME

Applied Force	Average (UME _i) mV/V	Reproducibility. a	Repeteability at zero b	Std. Uncertainty of applied force. k=1 d	Temperature effect.S _{td} c	Resolution effect e	Hysteresis effect f	U _{UME-1} Uncertainty (UME initial) k=2
kN								
200	0.800102	6.38E-05	-4.52E-07	5.00E-05	2.5E-06	1.25E-06	-1.00E-04	1,24E-04
300	1.200279	2.33E-05	-2.49E-07	5.00E-05	2.5E-06	8.33E-07	-4.67E-05	1,05E-04
400	1.600468	1.62E-05	-2.71E-07	5.00E-05	2.5E-06	6.25E-07	-1.62E-05	1,01E-04
500	2.000632	7.90E-05	-2.20E-07	5.00E-05	2.5E-06	5.00E-07		1,15E-04
400	1.600498				t _{max} =21.65			
300	1.200332				t _{min} = 21.14			
200	0.800178				α=5.00E-06			

Table.5. UME 1000 kN Load cell-GTM-SN: 45084 Initial UME Measurements in 26.09.2008 in 110 kN/1100 kN Dead Weight Lever Amplification Force Standard Machine of UME

Applied Force	Average (UME _i) mV/V	Reproducibility. a	Repeteability at zero b	Std. Uncertainty of applied force. k=1 d	Temperature effect.S _{td} c	Resolution effect e	Hysteresis effect f	U _{UME-i} Uncertainty (UME initial) k=2
kN								
400	0.800699	3.50E-05	7.54E-07	5.00E-05	6.00E-07	1.25E-06	-4.00E-05	1,06E-04
600	1.201052	1.54E-04	7.69E-06	5.00E-05	6.00E-07	8.33E-07	-8.33E-06	1,48E-04
800	1.601479	4.06E-05	9.85E-07	5.00E-05	6.00E-07	6.24E-07	1.25E-05	1,04E-04
1000	2.001851	4.00E-05	1.22E-06	5.00E-05	6.00E-07	5.00E-07		1,04E-04
800	1.601460				t _{max} = 21.24			
600	1.201101				t _{min} = 21.12			
400	0.800735				α=5.00E-06			

Table.6. UME 500 kN Load cell-GTM-SN: 43018 INM Measurements in 22.10.2008 in 1000 kN Comparator type Force Standard Machine of INM

Applied Force	Average (INM) mV/V	Reproducibility. a	Repeteability at zero b	Std. Uncertainty of applied force. k=1 d	Temperature effect.S _{td} c	Resolution effect e	Hysteresis effect f	U _{INM} Uncertainty (NMI) k=2
kN								
200	0.800106	9.12E-05	4.37E-07	1.00E-04	2.00E-06	1.25E-06	5.10E-05	2,12E-04
300	1.200255	4.67E-05	1.48E-06	1.00E-04	2.00E-06	8.33E-07	4.98E-05	2,05E-04
400	1.600415	4.12E-05	1.89E-06	1.00E-04	2.00E-06	6.25E-07	2.39E-05	2,03E-04
500	2.000633	3.35E-05	1.00E-06	1.00E-04	2.00E-06	5.00E-07		2,01E-04
400	1.600377				t _{max} = 23.40			
300	1.200195				t _{min} =23.00			
200	0.800065				α=5.00E-06			

Table.7. UME 1000 kN Load cell-GTM-SN: 45084 INM Measurements in 23.10.2008 in 1000 kN Comparator type Force Standard Machine of INM

Applied Force	Average (INM)	Reproducibility.	Repeteability at zero	Std. Uncertainty of applied force. k=1	Temperature effect.S _{td}	Resolution effect	Hysteresis effect	U _{INM} Uncertainty (INMI)
kN	mV/V	a	b	d	c	e	f	k=2
400	0.800737	1.85E-04	3.45E-06	1.00E-04	1.5E-06	1.25E-06	2.99E-04	2,95E-04
600	1.201101	1.56E-04	2.98E-06	1.00E-04	1.5E-06	8.33E-07	1.24E-04	2,39E-04
800	1.601520	1.26E-04	3.54E-06	1.00E-04	1.5E-06	6.24E-07	5.21E-05	2,21E-04
1000	2.001852	1.27E-04	3.10E-06	1.00E-04	1.5E-06	5.00E-07		2,19E-04
800	1.601436				t _{max} = 22.90			
600	1.200952				t _{min} =22.60			
400	0.800497				α=5.00E-06			

Table.8. UME 500 kN Load cell-GTM-SN: 43018 Final UME Measurements in 23.03.2009 in 110 kN/1100 kN Dead Weight Lever Amplification Force Standard Machine

Applied Force	Average (UME _i)	Reproducibility.	Repeteability at zero	Std. Uncertainty of applied force. k=1	Temperature effect.S _{td}	Resolution effect	Hysteresis effect	U _{UME-f} Uncertainty (UME final)
kN	mV/V	a	b	d	c	e	f	k=2
200	0.800099	3.94E-05	-1.58E-06	5.00E-05	8.0E-07	1.25E-06	-4.00E-05	1,06E-04
300	1.200188	5.58E-05	-3.13E-06	5.00E-05	8.0E-07	8.33E-07	-7.17E-05	1,15E-04
400	1.600306	4.56E-05	-1.18E-06	5.00E-05	8.0E-07	6.25E-07	-2.06E-05	1,06E-04
500	2.000458	3.15E-05	-2.15E-06	5.00E-05	8.0E-07	5.00E-07		1,02E-04
400	1.600344				t max= 21.41			
300	1.200244				tmin = 21.25			
200	0.800142				α=5.00E-06			

Summary of measurement results and measurement uncertainties of UME and INM are given in Table 10 and table 11 shortly.

Table.9. UME 1000 kN Load cell-GTM-SN: 45084 Final UME Measurements in 25.03.2009 in 110 kN/1100 kN Dead Weight Lever Amplification Force Standard Machine

Applied Force	Average (UME _i) mV/V	Reproducibility. a	Repetability at zero b	Std. Uncertainty of applied force. k=1 d	Temperature effect.S _{td} c	Resolution effect e	Hysteresis effect f	U _{UME-f} Uncertainty (UME final) k=2
kN								
400	0.800687	4.00E-05	-7.79E-07	5.00E-05	6E-07	1.25E-06	-6.99E-05	1,11E-04
600	1.201002	4.62E-05	4.73E-07	5.00E-05	6E-07	8.33E-07	-4.66E-05	1,09E-04
800	1.601340	6.81E-05	2.86E-06	5.00E-05	6E-07	6.24E-07	7.49E-06	1,11E-04
1000	2.001632	1.00E-04	5.68E-06	5.00E-05	6E-07	5.00E-07		1,23E-04
800	1.601326				t _{max} = 21.43			
600	1.201049				t _{min} =21.31			
400	0.800720				α=5.00E-06			

Table.10. Measurement uncertainties of UME and INM measurements using 500 kN Load cell-GTM-SN: 43018

Force steps for 500 kN	UME _i	U _{UME-i} k=2	INM	U _{INM} k=2	UME _f	U _{UME-f} k=2
200	0.800102	1,24E-04	0.800106	2,12E-04	0.800099	1,06E-04
300	1.200279	1,05E-04	1.200255	2,05E-04	1.200188	1,15E-04
400	1.600468	1,01E-04	1.600415	2,03E-04	1.600306	1,06E-04
500	2.000632	1,15E-04	2.000633	2,01E-04	2.000458	1,02E-04

Table.11. Measurement uncertainties of UME and INM Measurements using 500 kN Load cell-GTM-SN: 45084

Force steps for 1000 kN	UME _i	U _{UME-i} k=2	INM	U _{INM} k=2	UME _f	U _{UME-f} k=2
400	0.800699	1,06E-04	0.800737	2,95E-04	0.800687	1,11E-04
600	1.201052	1,48E-04	1.201101	2,39E-04	1.201002	1,09E-04
800	1.601479	1,04E-04	1.601520	2,21E-04	1.601340	1,11E-04
1000	2.001851	1,04E-04	2.001852	2,19E-04	2.001632	1,23E-04

Before the calculation of relative deviation of INM force machine from UME force machine, below remarks will be taken into account as well;

- 1-) The values used for the comparison indicated by DMP 40s will be corrected by the indication of BN 100 comparator for both laboratories,
- 2-) The reference values established by pilot laboratory will be establish taking into account the value of the drift of the transfer force transducers,
- 3-) Effect of temperature difference INM laboratory from UME laboratory will be calculated according to temperature coefficient of transfer force transducers which are $\alpha=5.00E-06$ given in the data sheet of the producer and then corrected the output of the measured transducers at INM laboratory,

6.1. Stability of the transfer standard

In order to verify the stability of the force transducers used during the comparison, a final set of measurements was obtained at UME as well. Stability of the transfer force transducers are given in Table 12.

Table 12. Stability of the 500 kN and 1000 kN force transfer transducers measured at UME before and after INM measurement

Transfer Force Transducer	Force step	Stability of the force transfer transducers		
		UME _i	UME _f	Relative Deviations
kN	kN	mV/V	mV/V	
500	200	0.800102	0.800099	3.63E-06
	300	1.200279	1.200188	7.55E-05
	400	1.600468	1.600306	1.01E-04
	500	2.000632	2.000458	8.67E-05
	400	1.600498	1.600344	9.62E-05
	300	1.200332	1.200244	7.34E-05
	200	0.800178	0.800142	4.55E-05
1000	400	0.800699	0.800687	1.49E-05
	600	1.201052	1.201002	4.15E-05
	800	1.601479	1.601340	8.68E-05
	1000	2.001851	2.001632	1.09E-04
	800	1.601460	1.601326	8.38E-05
	600	1.201101	1.201049	4.35E-05
	400	0.800735	0.800720	1.87E-05

Readings Corrections due to using different indicators at UME and INM

As it is explained in Section 3 that two different DPM 40 indicating instruments were used during comparison measurement due to causing the problem of DMP 40 instrument during air flight transfer. These are UME (HBM. DMP 40 S6: SN: 964720034) and INM (HBM. DMP 40: SN: 05132044). Instead of transferring the DMP 40s. BN 100 calibrator belonging to UME transferred to Romania to check both DMP 40s belonging to INM and UME. Measurement results and difference of them are given in tables 13 and 14.

Table.13. Check reading from both DMPs according to reference signals of BN 100 calibrator

DMP 40 Readings from BN 100 calibrator during comparison measurements for 500 kN and 1000 kN transfer transducers						
BN 100 Reference mV/V	500 kN UME-i mV/V	500 kN INM mV/V	500 kN UME-f mV/V	1000 kN UME-i mV/V	1000 kN INM mV/V	1000 kN UME-f mV/V
0.000 000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.400 000	0.400000	0.400005	0.400001	0.399998	0.400004	0.400001
0.600 000	0.600002	0.600005	0.600001	0.599997	0.600005	0.599997
0.800 000	0.799999	0.800004	0.799997	0.799997	0.800003	0.799999
1.000 000	1.000001	1.000008	0.999997	0.999998	1.000005	0.999993
1.200 000	1.199998	1.200007	1.199997	1.199996	1.200007	1.199992
1.400 000	1.399997	1.400009	1.399998	1.399997	1.400009	1.399991
1.600 000	1.599997	1.600012	1.599996	1.599995	1.600012	1.599990
1.800 000	1.799997	1.800014	1.799996	1.799994	1.800016	1.799990
2.000 000	1.999997	2.000015	1.999995	1.999994	2.000017	1.999989

Difference of indicating instruments (HBM DMP 40) can cause small deviations over the measurement results. For this reason. readings from DMP 40 indicators will be compensated as below table 15.

Table.14. Differences for DMP 40 Readings for 500 kN and 1000 kN transfer transducers

BN 100 Reference mV/V	Difference for DMP 40 Readings (mV/V)	
	UME-INM Difference for 500 kN transfer transducer	UME-INM Difference for 1000 kN transfer transducer
0.000000	0.000000	0.000000
0.400 000	-0.000004	-0.000005
0.600 000	-0.000004	-0.000008
0.800 000	-0.000 006	-0.000 005
1.000 000	-0.000009	-0.000009
1.200 000	-0.000 009	-0.000 013
1.400 000	-0.000012	-0.000015
1.600 000	-0.000 015	-0.000 020
1.800 000	-0.000017	-0.000023
2.000 000	-0.000 019	-0.000 025

Table.15. Indicator readings difference correction of UME and INM results for 500 kN transfer transducer

500 kN transducer	UME-1-2. Average results mV/V	INM Original results mV/V	INM Corrected results mV/V
200	0.800100	0.800106	0.800100
300	1.200234	1.200255	1.200246
400	1.600387	1.600415	1.600400
500	2.000545	2.000633	2.000614
400	1.600421	1.600377	1.600362
300	1.200288	1.200195	1.200186
200	0.800160	0.800065	0.800059

Table.16. Indicator readings difference correction of UME and INM results for 1000 kN transfer transducer

1000 kN transducer	UME-1-2. Average results mV/V	INM Original results mV/V	INM Corrected results mV/V
400	0.800693	0.800737	0.800731
600	1.201027	1.201101	1.201088
800	1.601410	1.601520	1.601500
1000	2.001742	2.001852	2.001826
800	1.601393	1.601436	1.601417
600	1.201075	1.200952	1.200939
400	0.800727	0.800497	0.800492

Temperature Corrections due to temperature difference at UME and INM

Temperature difference between INM and UME laboratories are corrected as below in Table 17 and Table 18.

Table.17. Temperature Correction due to temperature difference between UME and INM Laboratories during comparison measurements for 500 kN transfer transducer

500 kN	INM corrected results mV/V	UME measurements results			Temperature correction for INM measurements mV/V
		1. UME mV/V	2. UME mV/V	UME-1-2. Average mV/V	
200	0.800100	0.800102	0.800099	0.800100	0.800109
300	1.200246	1.200279	1.200188	1.200234	1.200259
400	1.600400	1.600468	1.600304	1.600386	1.600419
500	2.000614	2.000632	2.000458	2.000545	2.000637
400	1.600362	1.600498	1.600344	1.600421	1.600380
300	1.200186	1.200332	1.200244	1.200288	1.200200
200	0.800059	0.800178	0.800142	0.800160	0.800069
Laboratory temperature t_{max} (°C)	23.40	21.65	21.41	Formula for obtaining temperature corrected reading values $X_{tc} = X + [X \cdot \alpha (t_{UME} - t_{INM})]$	
Laboratory temperature t_{min} (°C)	23.00	21.12	21.25		
Tempr. Coefficient of force transducer	5.00E-06				
Average temperature (°C)	23.20	21.39	21.33		
Maximum temperature difference between UME and INM (°C)	2.28				

Table.18. Temperature Correction due to temperature difference between UME and INM Laboratories during comparison measurements for 1000 kN transfer transducer

1000 kN	INM corrected results mV/V	UME measurements results			Temperature correction for INM measurements mV/V
		1. UME mV/V	2. UME mV/V	UME-1-2. Average	
400	0.800731	0.800699	0.800687	0.800693	0.800738
600	1.201088	1.201052	1.201002	1.201027	1.201098
800	1.601500	1.601479	1.601340	1.601410	1.601514
1000	2.001826	2.001851	2.001632	2.001742	2.001844
800	1.601417	1.601460	1.601326	1.601393	1.601431
600	1.200939	1.201101	1.201049	1.201075	1.200950
400	0.800492	0.800735	0.800720	0.800727	0.800499
Laboratory temperature t_{max} (°C)	22.90	21.24	21.43	Formula for obtaining temperature corrected reading values $X_{tc} = X + [X \cdot \alpha (t_{UME} - t_{INM})]$	
Laboratory temperature t_{min} (°C)	22.60	21.11	21.21		
Tempr. Coefficient of force transducer	5.00E-06				
Average temperature (°C)	22.75	21.18	21.32		
Maximum temperature difference between UME and INM (°C)			1.79		

The new INM corrected results (including indicator difference correction and temperature difference corrections) will be used for the all calculations including relative deviations and E_n values after that.

6.2. Reference value calculation

This comparison is not a Key comparison, It can be identified as supplementary comparison due to having small differences (application of more force steps, decreasing forces and loading period) comparing to key comparison. Only two countries (Turkey and Romania) has been participated in this comparison measurements. As it is known that the weighted mean, non-weighted mean and median are 3 common methods which were considered for the calculation of the KC (Key Comparison) reference value (KCRV). Although this comparison is a supplementary comparison (not a Key Comparison), the abbreviation of the comparison reference value can be indicated as KCRV. In this comparison measurement, arithmetic mean value was used for the calculation of KCRV as shown in equation 2. Here, X_{UME} is average of initial (X_{UME-i}) and final (X_{UME-f}) measurement of UME (Equation.1) and X_{INM} is measured value of INM.

$$X_{UME} = \frac{X_{UME-i} + X_{UME-f}}{2} \quad (1)$$

$$X_{KCRV} = \frac{X_{UME} + X_{INM}}{2} \quad (2)$$

The relative uncertainty of KCRVs (U_{KCRV}) is calculated as taking the square root of relative measurement uncertainties of each laboratories shown as U_{UME} and U_{INM} . U_{UME} is calculated as taking the square root of relative measurement uncertainties ($k = 2$) of initial (U_{UME-i}) and final (U_{UME-f}) of UME given in equation 3. Relative combined uncertainty ($k = 2$) formula of KCRV is given in eq. (4).

$$U_{UME} = \sqrt{U_{UME-i}^2 + U_{UME-f}^2} \quad (3)$$

$$U_{KCRV} = \sqrt{U_{UME}^2 + U_{INM}^2} \quad (4)$$

Uncertainty associated with deviation for degree of equation for each laboratory, W_{i-UME} and W_{i-INM} ($k = 2$) are calculated with equation 5 and 6.

$$U_{i-UME} = \sqrt{U_{UME}^2 - U_{KCRV}^2} \quad (5)$$

$$U_{i-INM} = \sqrt{U_{INM}^2 - U_{KCRV}^2} \quad (6)$$

The KCRVs are given in Table 19 and Degree of Equivalence and their relative uncertainties ($k = 2$) are given in Table 20.

In this table X_{UME} is taken as the average value of initial UME ($X_{\text{UME-i}}$) and final UME ($X_{\text{UME-f}}$) measurements.

Table 19. Key comparison reference values (X_{KCRV})

	Force (kN)	X_{UME} (mV/V)	X_{INM} (mV/V)	X_{KCRV} (mV/V)
500 kN Force Transducer	200	0.800100	0.800106	0.800103
	300	1.200234	1.200255	1.200244
	400	1.600387	1.600415	1.600401
	500	2.000545	2.000633	2.000589
1000 kN Force Transducer	400	0.800693	0.800737	0.800715
	600	1.201027	1.201101	1.201064
	800	1.601410	1.601520	1.601465
	1000	2.001742	2.001852	2.001797

6.3. Degrees of equivalence

Degrees of equivalence (D_i) of the laboratories is expressed by the relative differences of the laboratories' results from the KCRVs (X_{KCRV}) of each laboratory calculated as eq.(7) and eq.(8).

$$D_{INM} = (X_{INM} - X_{KCRV}) \quad (7)$$

$$D_{UME} = (X_{UME} - X_{KCRV}) \quad (8)$$

Table 20. Degree of Equivalence and (D_i) and their relative expanded standard uncertainties, U_{UME} and U_{INM} , $k=2$

	Force (kN)	D_{UME}	U_{i-UME}	D_{INM}	U_{i-INM}
500 kN Force Transducer	200	-2.8E-06	2,1E-04	2.8E-06	1,6E-04
	300	-1.1E-05	2,0E-04	1.1E-05	1,6E-04
	400	-1.4E-05	2,0E-04	1.4E-05	1,5E-04
	500	-4.4E-05	2,0E-04	4.4E-05	1,5E-04
1000 kN Force Transducer	400	-2.2E-05	2,9E-04	2.2E-05	1,5E-04
	600	-3.7E-05	2,4E-04	3.7E-05	1,8E-04
	800	-5.5E-05	2,2E-04	5.5E-05	1,5E-04
	1000	-5.5E-05	2,2E-04	5.5E-05	1,6E-04

6.4. Relative deviations and E_n Numbers

In order to see possible relative deviation (RD_{UME}) between initial (i) and final (f) measurements of the pilot (UME) laboratory results, Table 21 and Table 22 are given in below using equation (7).

$$RD_{UME} = \frac{X_i - X_f}{X_i} \quad (7)$$

Table.21. UME 500 kN Load cell-GTM-SN: 43018 Relative deviation of $UME_i - UME_f$ measurements in 110 kN/1.1 MN force standard machine

500 kN	UME measurements			Relative deviation of $UME_i - UME_f$ measurements
	UME_i	UME_f	UME_{i-f} Average	
200	0.800102	0.800099	0.800100	3.63E-06
300	1.200279	1.200188	1.200234	7.55E-05
400	1.600468	1.600306	1.600387	1.01E-04
500	2.000632	2.000458	2.000545	8.67E-05

Table.22. UME 1000 kN Load cell-GTM-SN: 45084 Relative deviation of $UME_i - UME_f$ measurements in 110 kN/1.1 MN force standard machine

1000 kN	UME measurements			Relative deviation of $UME_i - UME_f$ measurements
	UME_i	UME_f	UME_{i-f} Average	
400	0.800699	0.800687	0.800693	1.49E-05
600	1.201052	1.201002	1.201027	4.15E-05
800	1.601479	1.601340	1.601410	8.68E-05
1000	2.001851	2.001632	2.001742	1.09E-04

Resulting relative deviation (RD) between pilot laboratory (UME) and conducted laboratory (INM) based on the corrected measurement results (indicator difference correction and temperature difference correction) can be calculated in accordance with equation (8).

$$RD = \frac{X_{INM} - X_{UME}}{X_{UME}} \quad (8)$$

Table 23. Relative deviation of UME-INM 1000 kN force standard machines comparison

Force steps for 500 kN	UME-INM measurements		Relative deviation of UME-INM mV/V
	INM Corrected mV/V	UME, Average mV/V	
200	0.800100	0.800100	5.96E-08
300	1.200246	1.200234	1.01E-05
400	1.600400	1.600387	8.53E-06
500	2.000614	2.000545	3.43E-05

Table.24. UME 1000 kN Load cell-GTM-SN: 45084

Relative deviation of UME-INM 1000 kN force standard machines comparison

Force steps for 1000 kN	UME-INM measurements		Relative deviation of UME-INM
	INM Corrected mV/V	UME, Average	
400	0.800731	0.800693	4.76E-05
600	1.201088	1.201027	5.07E-05
800	1.601500	1.601410	5.65E-05
1000	2.001826	2.001742	4.24E-05

The results of the intercomparison measurements can also be evaluated using the E_n number which is given in “ISO/IEC 17043 (2010) Conformity assessment “General requirements for proficiency testing” [9] which represent the figure of the merit of the INM laboratory, calculated for the each measuring point, expressing the degree of equivalence between UME as a reference laboratory and INM .

The E_n number was calculated using the equation (9) given in ref [9] as below.

$$E_n = \frac{X_{INM} - X_{UME}}{\sqrt{U_{INM}^2 + U_{UME}^2}} \quad (9)$$

X_{INM} = Measurement values of lab (INM)

X_{UME} = Measurement values of pilot lab (UME)

U_{INM} = Relative expanded uncertainty of INM force standard machine (2×10^{-4} , for $k=2$)

U_{UME} = Relative expanded uncertainty of UME force standard machine (1×10^{-4} , for $k=2$)

$|E_n| \leq 1$ = successful

$|E_n| > 1$ = unsuccessful

Table.25. E_n values for 500 kN force range between UME and INM

Force kN	UME_{AVE} mV/V	INM Corrected mV/V	U_{UME}	U_{INM}	E_n
200	0.800100	0.800100	1.00E-04	2.00E-04	0.00
300	1.200234	1.200246	1.00E-04	2.00E-04	0.05
400	1.600387	1.600400	1.00E-04	2.00E-04	0.06
500	2.000545	2.000614	1.00E-04	2.00E-04	0.31

Table.26. E_n values for 1000 kN force range between UME and INM

Force kN	UME_{AVE} mV/V	INM Corrected mV/V	$U_{UME-AVE}$	U_{INM}	E_n
400	0.800693	0.800731	1.00E-04	2.00E-04	0.17
600	1.201027	1.201088	1.00E-04	2.00E-04	0.27
800	1.601410	1.601500	1.00E-04	2.00E-04	0.40
1000	2.001742	2.001826	1.00E-04	2.00E-04	0.38

As it seen the E_n number for this comparison measurements given in table 25 and table 26 that this comparison is very successful due to rule given in “ISO/IEC 17043 as “ $|E_n| \leq 1$ = successful”.

6.5. Relation between Bilateral comparisons of TUBITAK UME and PTB

UME has participated CCM.F-K2-50-100 kN and CCM.F-K2-5-10 kN key comparison measurements. At the same time UME has participated bilateral comparison measurements with PTB-Germany and NIM-China in 1995, 1997, 1998, 2000, 2002, 2006, 2006 and 2010. Due to bilateral comparison measurements over the 100 kN, there is no direct link to EURAMET and CCM key comparison for 200-1000 kN range. However, it has been linked to the UME and PTB bilateral comparison results measurement held in 2005 and 2010 results with INM results as a relative deviation calculations given in Table 27-30.

Table.27. Linkage between bilateral comparison UME and PTB in 2005 for 500 kN Load cell-GTM-SN: 43018

500 kN Load cell	Measurement Data			Relative Deviation	Relative Deviation
	PTB results in 2005	UME result	INM corrected result	PTB-UME	PTB-INM
200	0.800072	0.800100	0.800100	-3.55E-05	-3.56E-05
300	1.200178	1.200234	1.200246	-4.62E-05	-5.63E-05
400	1.600324	1.600387	1.600400	-3.95E-05	-4.80E-05
500	2.000478	2.000545	2.000614	-3.37E-05	-6.80E-05

Table.28. Linkage between bilateral comparison UME and PTB in 2005 for 1000 kN Load cell-GTM-SN: 45084

1000 kN Load cell	Measurement Data			Relative Deviation	Relative Deviation
	PTB results in 2005	UME result	INM corrected result	PTB-UME	PTB-INM
400	0.800618	0.800693	0.800731	-9.41E-05	-1.42E-04
600	1.200958	1.201027	1.201088	-5.75E-05	-1.08E-04
800	1.601311	1.601410	1.601500	-6.16E-05	-1.18E-04
1000	2.001657	2.001742	2.001826	-4.21E-05	-8.45E-05

Table.29. Linkage between bilateral comparison UME and PTB in 2010
for 500 kN Load cell-GTM-SN: 43018

500 kN Load cell	Measurement Data			Relative Deviation	Relative Deviation
	PTB results in 2010	UME result	INM corrected result	PTB-UME	PTB-INM
200	0.800084	0.800100	0.800100	-1.99E-05	-1.99E-05
300	1.200206	1.200234	1.200246	-2.35E-05	-3.36E-05
400	1.600356	1.600387	1.600400	-1.92E-05	-2.77E-05
500	2.000524	2.000545	2.000614	-1.07E-05	-4.50E-05

Table.30. Linkage between bilateral comparison UME and PTB in 2010
for 1000 kN Load cell-GTM-SN: 45084

1000 kN Load cell	Measurement Data			Relative Deviation	Relative Deviation
	PTB results in 2010	UME result	INM corrected result	PTB-UME	PTB-INM
400	0.800639	0.800693	0.800731	-6.81E-05	-1.16E-04
600	1.200981	1.201027	1.201088	-3.81E-05	-8.89E-05
800	1.601337	1.601410	1.601500	-4.52E-05	-1.02E-04
1000	2.001684	2.001742	2.001826	-2.86E-05	-7.10E-05

7. Conclusion

The force realized by the UME force standard machines over a range from 200 kN to 1000 kN was compared with INM force standards. The key comparison reference value was calculated as a average due to bilateral comparison participating only two laboratories.

The results of comparison realized in the range from 200 kN to 1 MN show that the relative differences between UME 1.1 MN lever type force standard machine and INM 1 MN comparator type force standard machine are maximum $\pm 5.65 \times 10^{-5}$ over the range from 200 kN to 1000 kN.

Comparison results show that the best measurement uncertainty is achieved with comparator type force standard machine of INM as it declared in the level of 2×10^{-4} . This uncertainty Value of INM is approved by the E_n values given in Table 25 and Table 26 as $|E_n| \leq 1$ and results is called as "successful".

It may therefore be concluded that the force standards realized by INM in Romania are maintained on the international level of accuracy.

8. References

- [1] S. Fank. A. Sawla. H.O.Özbay. H. Gassmann. Establishment of national force scale at TUBITAK UME and results of intercomparison measurements between TUBITAK UME and PTB. In: Proceedings IMEKO "Accuracy. Assurance in Force. Torque and Mass Measurements". Madrid. Spain 1996.
- [2] S. Fank. A. Sawla. H.O.Özbay. Long-Term Observation of Newly Developed 110 kN/1.1 MN Lever Amplification Dead Weight Force Standard Machine at UME. In: Proceedings IMEKO World Congress. Tampere. Finland 1997
- [3] S. Fank. C. Kuzu. E. Pelit. B. Aydemir. B. Çal. Intercomparison Results of UME Force Standard Machines with PTB After 1999 Marmara Earthquake. IMEKO TC3 Conference. 17-21 September 2001. İstanbul. Turkey 2001.
- [4] S. Fank. C. Kuzu. E. Pelit. B. Aydemir. B. Çal. H. Özbay. 3 MN Hydraulic Type Build-Up Force Standard Machine Installed at National Metrology Institute (UME). XVII IMEKO World Congress. June 22-27. Dubrovnik. Croatia. 2003
- [5] S. Fank. R. Kumme. B. Aydemir. E. Pelit. B. Glöckner. G. Haucke. Intercomparison of 3 MN Hydraulic Type Build-Up And 1.1MN Lever Amplification Force Standard Machine Between UME And PTB. XVIII IMEKO World Congress. September 17-22. Rio De Janeiro. Brazil. 2006
- [6] A. Sawla. H. Gassmann. K. Beathke. Investigation of measurement uncertainty achievable with strain controlled joints realized in a new lever type 100 kN force calibration machine. IMEKO TC3 Conference "Force and Mass Measurement". Helsinki. Finland. 1993
- [7] H.Gassmann. A. Sawla. Metrological characteristics of force standard machines equipped with strain controlled elastic joints for lever multiplication. IMEKO TC3 Conference "Force and Mass Measurement". Warszawa. Poland 1995.
- [8] A. Sawla. M. Peters. S. L. Yaniv. and R. A .Mitchell. Intercomparison of Force Standard machines of the National Institute of Standards and Technology. USA. and the Physikalisch Technische Bundesanstalt. Braunschweig. GERMANY. PTB-Bericht MA-20 .1991
- [9] ISO17043 (2010) Conformity assessment General requirements for proficiency testing”

ANNEX (Measurement Data for TUBITAK UME and INM Comparison)**500 kN Initial UME measurements**

Date	15.09.2008
Laboratory	UME
Machine Capacity	1 MN
Operator	B.Aydemir
BN 100	34714
DMP 40	964720034
Filter	0.10 Hz Bessel
Bridge Supply	5 V
Measuring Range	+/- 2.5 mV/V
Mode	Absolute
Transducer	GTM 43018
Capacity (kN)	500

Orientation degrees	Force kN	Time hh:mm	DMP 40 reading mV/V	Temperature °C	Deflection mV/V
0	0	0:00	-0.004170	21.65	
	500 (preload)	0:04	1.996498		2.000 668
	0	0:08	-0.004142		
	0	0:12	-0.004146		
	500 (preload)	0:16	1.996512		2.000 658
	0	0:20	-0.004142		
	0	0:24	-0.004147		
	500 (preload)	0:28	1.996544		2.000 691
	0	0:32	-0.004148		
	0	0:36	-0.004144	21.55	0.000 000
	200	0:40	0.795939		0.800 083
	300	0:44	1.196157		1.200 301
	400	0:48	1.596390		1.600 534
	500	0:52	1.996485		2.000 629
	0	0:56	-0.004137		
	0	1:00	-0.004144		0.000 000
	200	1:04	0.795949		0.800 093
	300	1:08	1.196164		1.200 308

	400		1:12	1.596354		1.600 498
	500		1:16	1.996515		2.000 659
	400		1:20	1.596384		1.600 528
	300		1:24	1.196186		1.200 330
	200		1:28	0.796026		0.800 170
	0		1:32	-0.004142		
	0		1:36	-0.004146		0.000 000
	200		1:40	0.795965		0.800 111
	300		1:44	1.196114		1.200 260
	400		1:48	1.596305		1.600 451
	500		1:52	1.996478		2.000 624
	400		1:56	1.596336		1.600 482
	300		2:00	1.196168		1.200 314
	200		2:04	0.796030		0.800 176
	0		2:08	-0.004140	21.52	
90	0		2:12	-0.004159	21.56	0.000 000
	200		2:16	0.795912		0.800 071
	300		2:20	1.196127		1.200 286
	400		2:24	1.596292		1.600 451
	500		2:28	1.996373		2.000 532
	0		2:32	-0.004152		
	0		2:36	-0.004150		0.000 000
	200		2:40	0.795921		0.800 071
	300		2:44	1.196136		1.200 286
	400		2:48	1.596331		1.600 481
	500		2:52	1.996391		2.000 541
	400		2:56	1.596376		1.600 526
	300		3:00	1.196202		1.200 352
	200		3:04	0.796004		0.800 154
	0		3:08	-0.004150	21.33	
180	0		3:12	-0.004162	21.23	0.000 000
	200		3:16	0.795957		0.800 119
	300		3:20	1.196115		1.200 277
	400		3:24	1.596281		1.600 443
	500		3:28	1.996407		2.000 569
	0		3:32	-0.004145		
	0		3:36	-0.004146		0.000 000
	200		3:40	0.795976		0.800 122

	300	3:44	1.196113		1.200 259
	400	3:48	1.596312		1.600 458
	500	3:52	1.996553		2.000 699
	400	3:56	1.596317		1.600 463
	300	4:00	1.196146		1.200 292
	200	4:04	0.796041		0.800 187
	0	4:08	-0.004149	21.12	
270	0	4:12	-0.004159	21.13	0.000 000
	200	4:16	0.795981		0.800 140
	300	4:20	1.196204		1.200 363
	400	4:24	1.596328		1.600 487
	500	4:28	1.996529		2.000 688
	0	4:32	-0.004144		
	0	4:36	-0.004148		0.000 000
	200	4:40	0.795972		0.800 120
	300	4:44	1.196139		1.200 287
	400	4:48	1.596307		1.600 455
	500	4:52	1.996493		2.000 641
	400	4:56	1.596355		1.600 503
	300	5:00	1.196213		1.200 361
	200	5:04	0.796055		0.800 203
	0	5:08	-0.004146	21.42	
360	0	5:12	-0.004176	21.25	0.000 000
	200	5:16	0.795981		0.800 157
	300	5:20	1.196100		1.200 276
	400	5:24	1.596372		1.600 548
	500	5:28	1.996477		2.000 653
	0	5:32	-0.004150		
	0	5:36	-0.004149		0.000 000
	200	5:40	0.795944		0.800 093
	300	5:44	1.196130		1.200 279
	400	5:48	1.596320		1.600 469
	500	5:52	1.996488		2.000 637
	400	5:56	1.596346		1.600 495
	300	6:00	1.196186		1.200 335
	200	6:04	0.796024		0.800 173
	0	6:08	-0.004147	21.14	

500 kN INM measurements

Date	22 Eki 2008
Laboratory	INM
Machine Capacity	1 MN
Operator	Mihai Pomarlan
BN 100	34714
DMP 40	05132044
Filter	1.7 Hz Bessel
Bridge Supply	5 V
Measuring Range	+/- 2.5 mV/V
Mode	Absolute
Transducer	GTM 43018
Capacity (kN)	500

Orientation degrees	Force kN	Time hh:mm	DMP 40 reading mV/V	Temperature °C	Deflection mV/V
0	0	00:00	-0.004117	23.00	
	500 (preload)	00:04	1.996636		2.000 753
	0	00:08	-0.004116		
	0	00:12	-0.004117		
	500 (preload)	00:16	1.996624		2.000 741
	0	00:20	-0.004119		
	0	00:24	-0.004117		
	500 (preload)	00:28	1.996608		2.000 725
	0	00:32	-0.004117		
	0	00:36	-0.004116	23.10	0.000 000
	200	00:40	0.796035		0.800 151
	300	00:44	1.196186		1.200 302
	400	00:48	1.596370		1.600 486
	500	00:52	1.996596		2.000 712
	0	00:56	-0.004114		
	0	01:00	-0.004115		0.000 000
	200	01:04	0.796031		0.800 146
	300	01:08	1.196191		1.200 306
	400	01:12	1.596347		1.600 462
	500	01:16	1.996540		2.000 655
400	01:20	1.596259		1.600 374	

	300		01:24	1.196060		1.200 175
	200		01:28	0.795926		0.800 041
	0		01:32	-0.004131		
	0		01:36	-0.004132		0.000 000
	200		01:40	0.795973		0.800 105
	300		01:44	1.196120		1.200 252
	400		01:48	1.596285		1.600 417
	500		01:52	1.996484		2.000 616
	400		01:56	1.596258		1.600 390
	300		02:00	1.196069		1.200 201
	200		02:04	0.795944		0.800 076
	0		02:08	-0.004122	23.10	
90	0		02:12	-0.004120	23.10	0.000 000
	200		02:16	0.795958		0.800 078
	300		02:20	1.196106		1.200 226
	400		02:24	1.596278		1.600 398
	500		02:28	1.996484		2.000 604
	0		02:32	-0.004125		
	0		02:36	-0.004110		0.000 000
	200		02:40	0.795987		0.800 097
	300		02:44	1.196115		1.200 225
	400		02:48	1.596267		1.600 377
	500		02:52	1.996502		2.000 612
	400		02:56	1.596248		1.600 358
	300		03:00	1.196070		1.200 180
	200		03:04	0.795950		0.800 060
	0		03:08	-0.004100	23.10	
180	0		03:12	-0.004100	23.10	0.000 000
	200		03:16	0.795971		0.800 071
	300		03:20	1.196110		1.200 210
	400		03:24	1.596280		1.600 380
	500		03:28	1.996494		2.000 594
	0		03:32	-0.004124		
	0		03:36	-0.004082		0.000 000
	200		03:40	0.795973		0.800 055
	300		03:44	1.196141		1.200 223
	400		03:48	1.596300		1.600 382
	500		03:52	1.996518		2.000 600

	400		03:56	1.596270		1.600 352
	300		04:00	1.196092		1.200 174
	200		04:04	0.795968		0.800 050
	0		04:08	-0.004080	23.20	
270	0		04:12	-0.004082	23.20	0.000 000
	200		04:16	0.796030		0.800 112
	300		04:20	1.196171		1.200 253
	400		04:24	1.596346		1.600 428
	500		04:28	1.996561		2.000 643
	0		04:32	-0.004084		
	0		04:36	-0.004072		0.000 000
	200		04:40	0.796051		0.800 123
	300		04:44	1.196199		1.200 271
	400		04:48	1.596371		1.600 443
	500		04:52	1.996595		2.000 667
	400		04:56	1.596336		1.600 408
	300		05:00	1.196151		1.200 223
	200		05:04	0.796007		0.800 079
	0		05:08	-0.004065	23.30	
360	0		05:12	-0.004063	23.30	0.000 000
	200		05:16	0.796050		0.800 113
	300		05:20	1.196197		1.200 260
	400		05:24	1.596355		1.600 418
	500		05:28	1.996565		2.000 628
	0		05:32	-0.004079		
	0		05:36	-0.004055		0.000 000
	200		05:40	0.796073		0.800 128
	300		05:44	1.196221		1.200 276
	400		05:48	1.596380		1.600 435
	500		05:52	1.996593		2.000 648
	400		05:56	1.596330		1.600 385
	300		06:00	1.196155		1.200 210
	200		06:04	0.796022		0.800 077
	0		06:08	-0.004055	23.40	

500 kN Final UME measurements

Date	24 Mar 2009
Laboratory	UME
Machine Capacity	1 MN
Operator	S. Fank
BN 100	34714
DMP 40	964720034
Filter	0.10 Hz Bessel
Bridge Supply	5 V
Measuring Range	+/- 2.5 mV/V
Mode	Absolute
Transducer	GTM 43018
Capacity (kN)	500

Orientation degrees	Force kN	Time hh:mm	DMP 40 reading mV/V	Temperature °C	Deflection mV/V
0	0	0:00	-0.007359	21.34	
	500 (preload)	0:04	1.993177		2.000 536
	0	0:08	-0.007358		
	0	0:12	-0.007355		
	500 (preload)	0:16	1.993127		2.000 482
	0	0:20	-0.007356		
	0	0:24	-0.007356		
	500 (preload)	0:28	1.993111		2.000 467
	0	0:32	-0.007357		
	0	0:36	-0.007355		21.34
	200	0:40	0.792754		0.800 109
	300	0:44	1.192874		1.200 229
	400	0:48	1.592978		1.600 333
	500	0:52	1.993094		2.000 449
	0	0:56	-0.007350		
	0	1:00	-0.007351		0.000 000
	200	1:04	0.792755		0.800 106
	300	1:08	1.192857		1.200 208
	400	1:12	1.592944		1.600 295
	500	1:16	1.993105		2.000 456
	400	1:20	1.592995		1.600 346
	300	1:24	1.192874		1.200 225

	200		1:28	0.792787		0.800 138
	0		1:32	-0.007351		
	0		1:36	-0.007357		0.000 000
	200		1:40	0.792752		0.800 109
	300		1:44	1.192837		1.200 194
	400		1:48	1.592962		1.600 319
	500		1:52	1.993147		2.000 504
	400		1:56	1.593027		1.600 384
	300		2:00	1.192929		1.200 286
	200		2:04	0.792801		0.800 158
	0		2:08	-0.007352	21.34	
90	0		2:12	-0.007384	21.25	0.000 000
	200		2:16	0.792740		0.800 124
	300		2:20	1.192825		1.200 209
	400		2:24	1.592964		1.600 348
	500		2:28	1.993114		2.000 498
	0		2:32	-0.007351		
	0		2:36	-0.007352		0.000 000
	200		2:40	0.792753		0.800 105
	300		2:44	1.192852		1.200 204
	400		2:48	1.593004		1.600 346
	500		2:52	1.993113		2.000 465
	400		2:56	1.592998		1.600 350
	300		3:00	1.192890		1.200 242
	200		3:04	0.792797		0.800 149
	0		3:08	-0.007344	21.25	
180	0		3:12	-0.007380	21.29	0.000 000
	200		3:16	0.792734		0.800 114
	300		3:20	1.192855		1.200 235
	400		3:24	1.592933		1.600 313
	500		3:28	1.993146		2.000 526
	0		3:32	-0.007342		
	0		3:36	-0.007343		0.000 000
	200		3:40	0.792755		0.800 098
	300		3:44	1.192862		1.200 205
	400		3:48	1.592942		1.600 285
	500		3:52	1.993144		2.000 487
	400		3:56	1.593019		1.600 362

	300		4:00	1.192894		1.200 237
	200		4:04	0.792799		0.800 142
	0		4:08	-0.007337	21.29	
270	0		4:12	-0.007387	21.41	0.000 000
	200		4:16	0.792760		0.800 147
	300		4:20	1.192856		1.200 243
	400		4:24	1.592988		1.600 375
	500		4:28	1.993205		2.000 592
	0		4:32	-0.007333		
	0		4:36	-0.007339		0.000 000
	200		4:40	0.792768		0.800 107
	300		4:44	1.192855		1.200 194
	400		4:48	1.592959		1.600 298
	500		4:52	1.993085		2.000 424
	400		4:56	1.592990		1.600 329
	300		5:00	1.192924		1.200 263
	200		5:04	0.792822		0.800 161
	0		5:08	-0.007330	21.41	
360	0		5:12	-0.007378	21.39	0.000 000
	200		5:16	0.792726		0.800 104
	300		5:20	1.192832		1.200 210
	400		5:24	1.592952		1.600 330
	500		5:28	1.993123		2.000 501
	0		5:32	-0.007333		
	0		5:36	-0.007339		0.000 000
	200		5:40	0.792737		0.800 076
	300		5:44	1.192799		1.200 138
	400		5:48	1.592944		1.600 283
	500		5:52	1.993097		2.000 436
	400		5:56	1.592977		1.600 316
	300		6:00	1.192885		1.200 224
	200		6:04	0.792769		0.800 108
	0		6:08	-0.007334	21.39	0.000 005

1000 kN Initial UME measurements

Date	26.09.2008
Laboratory	UME
Machine Capacity	1 MN
Operator	B.Aydemir
BN 100	34714
DMP 40	964720034
Filter	0.10 Hz Bessel
Bridge Supply	5 V
Measuring Range	+/- 2.5 mV/V
Mode	Absolute
Transducer	GTM 45084
Capacity (kN)	1000

Orientation degrees	Force kN	Time hh:mm	DMP 40 reading mV/V	Temperature °C	Deflection mV/V
0	0	0:00	0.068244	21.19	
	1000 (preload)	0:04	2.070223		2.001 979
	0	0:08	0.068289		
	0	0:12	0.068324		
	1000 (preload)	0:16	2.070192		2.001 868
	0	0:20	0.068288		
	0	0:24	0.068325		
	1000 (preload)	0:28	2.070188		2.001 863
	0	0:32	0.068288		
	0	0:36	0.068326		21.15
	400	0:40	0.869008		0.800 682
	600	0:44	1.269378		1.201 052
	800	0:48	1.669785		1.601 459
	1000	0:52	2.070144		2.001 818
	0	0:56	0.068290		
	0	1:00	0.068328		0.000 000
	400	1:04	0.869014		0.800 686
	600	1:08	1.269386		1.201 058
	800	1:12	1.669775		1.601 447
	1000	1:16	2.070141		2.001 813
800	1:20	1.669754		1.601 426	
600	1:24	1.269403		1.201 075	

	400		1:28	0.869050		0.800 722
	0		1:32	0.068317		
	0		1:36	0.068331		0.000 000
	400		1:40	0.869015		0.800 684
	600		1:44	1.269110		1.200 779
	800		1:48	1.669776		1.601 445
	1000		1:52	2.070140		2.001 809
	800		1:56	1.669754		1.601 423
	600		2:00	1.269400		1.201 069
	400		2:04	0.869052		0.800 721
	0		2:08	0.068319	21.13	
90	0		2:12	0.068315	21.12	0.000 000
	400		2:16	0.869013		0.800 698
	600		2:20	1.269406		1.201 091
	800		2:24	1.669816		1.601 501
	1000		2:28	2.070197		2.001 882
	0		2:32	0.068298		
	0		2:36	0.068335		0.000 000
	400		2:40	0.869048		0.800 713
	600		2:44	1.269434		1.201 099
	800		2:48	1.669842		1.601 507
	1000		2:52	2.070226		2.001 891
	800		2:56	1.669831		1.601 496
	600		3:00	1.269475		1.201 140
	400		3:04	0.869085		0.800 750
	0		3:08	0.068327	21.18	
180	0		3:12	0.068322	21.12	0.000 000
	400		3:16	0.869032		0.800 710
	600		3:20	1.269160		1.200 838
	800		3:24	1.669833		1.601 511
	1000		3:28	2.070217		2.001 895
	0		3:32	0.068299		
	0		3:36	0.068338		0.000 000
	400		3:40	0.869049		0.800 711
	600		3:44	1.269442		1.201 104
	800		3:48	1.669849		1.601 511
	1000		3:52	2.070221		2.001 883
	800		3:56	1.669812		1.601 474

	600		4:00	1.269436		1.201 098
	400		4:04	0.869075		0.800 737
	0		4:08	0.068291	21.11	
270	0		4:12	0.06832	21.22	0.000 000
	400		4:16	0.86902		0.800 696
	600		4:20	1.26938		1.201 064
	800		4:24	1.66978		1.601 455
	1000		4:28	2.07015		2.001 825
	0		4:32	0.06830		
	0		4:36	0.06834		0.000 000
	400		4:40	0.86902		0.800 686
	600		4:44	1.26940		1.201 064
	800		4:48	1.66980		1.601 466
	1000		4:52	2.07017		2.001 834
	800		4:56	1.66980		1.601 460
	600		5:00	1.26945		1.201 112
	400		5:04	0.86907		0.800 733
	0		5:08	0.06833	21.21	
360	0		5:12	0.068335	21.22	0.000 000
	400		5:16	0.869026		0.800 691
	600		5:20	1.269405		1.201 070
	800		5:24	1.669831		1.601 496
	1000		5:28	2.070177		2.001 842
	0		5:32	0.068314		
	0		5:36	0.068359		0.000 000
	400		5:40	0.869059		0.800 700
	600		5:44	1.269432		1.201 073
	800		5:48	1.669825		1.601 466
	1000		5:52	2.070195		2.001 836
	800		5:56	1.669805		1.601 446
	600		6:00	1.269442		1.201 083
	400		6:04	0.869091		0.800 732
	0		6:08	0.068348	21.24	

1000 kN INM measurements

Date	23.10.2008
Laboratory	INM
Machine Capacity	1 MN
Operator	Dan Hodor
BN 100	34714
DMP 40	05132044
Filter	1.7 Hz Bessel
Bridge Supply	5 V
Measuring Range	+/- 2.5 mV/V
Mode	Absolute
Transducer	GTM 45084
Capacity (kN)	1000

Orientation degrees	Force kN	Time hh:mm	DMP 40 reading mV/V	Temperature °C	Deflection mV/V
0	0	00:00	0.068976	22.60	
	1000 (preload)	00:04	2.070814		2.001 838
	0	00:08	0.068959		
	0	00:12	0.068964		
	1000 (preload)	00:16	2.070788		2.001 824
	0	00:20	0.068900		
	0	00:24	0.068965		
	1000 (preload)	00:28	2.070919		2.001 954
	0	00:32	0.068912		
	0	00:36	0.068971	22.60	0.000 000
	400	00:40	0.869632		0.800 661
	600	00:44	1.269988		1.201 017
	800	00:48	1.670424		1.601 453
	1000	00:52	2.070763		2.001 792
	0	00:56	0.068871		
	0	01:00	0.068961		0.000 000
	400	01:04	0.869672		0.800 711
	600	01:08	1.270028		1.201 067
	800	01:12	1.670446		1.601 485

	1000		01:16	2.070791		2.001 830
	800		01:20	1.670356		1.601 395
	600		01:24	1.269874		1.200 913
	400		01:28	0.869429		0.800 468
	0		01:32	0.068948		
	0		01:36	0.068977		0.000 000
	400		01:40	0.869677		0.800 700
	600		01:44	1.270018		1.201 041
	800		01:48	1.670437		1.601 460
	1000		01:52	2.070731		2.001 754
	800		01:56	1.670346		1.601 369
	600		02:00	1.269854		1.200 877
	400		02:04	0.869410		0.800 433
	0		02:08	0.068951	22.60	
90	0		02:12	0.068961	22.60	0.000 000
	400		02:16	0.869631		0.800 670
	600		02:20	1.269972		1.201 011
	800		02:24	1.670411		1.601 450
	1000		02:28	2.070747		2.001 786
	0		02:32	0.068900		
	0		02:36	0.068965		0.000 000
	400		02:40	0.869633		0.800 668
	600		02:44	1.270006		1.201 041
	800		02:48	1.670413		1.601 448
	1000		02:52	2.070753		2.001 788
	800		02:56	1.670360		1.601 395
	600		03:00	1.269865		1.200 900
	400		03:04	0.869381		0.800 416
	0		03:08	0.068935	22.70	
180	0		03:12	0.068966	22.70	0.000 000
	400		03:16	0.869727		0.800 761
	600		03:20	1.270136		1.201 170
	800		03:24	1.670597		1.601 631
	1000		03:28	2.070969		2.002 003
	0		03:32	0.068883		
	0		03:36	0.068961		0.000 000
	400		03:40	0.869777		0.800 816
	600		03:44	1.270170		1.201 209

180	800		03:48	1.670605		1.601 644
	1000		03:52	2.070963		2.002 002
	800		03:56	1.670512		1.601 551
	600		04:00	1.270006		1.201 045
	400		04:04	0.869553		0.800 592
	0		04:08	0.068942	22.70	
270	0		04:12	0.06897	22.70	0.000 000
	400		04:16	0.86976		0.800 786
	600		04:20	1.27014		1.201 166
	800		04:24	1.67056		1.601 593
	1000		04:28	2.07091		2.001 940
	0		04:32	0.06888		
	0		04:36	0.06896		0.000 000
	400		04:40	0.86976		0.800 800
	600		04:44	1.27014		1.201 179
	800		04:48	1.67056		1.601 593
	1000		04:52	2.07089		2.001 929
	800		04:56	1.67046		1.601 498
	600		05:00	1.26999		1.201 031
	400		05:04	0.86953		0.800 571
	0		05:08	0.06894	22.80	
	360	0		05:12	0.068968	22.80
400			05:16	0.869673		0.800 705
600			05:20	1.270026		1.201 058
800			05:24	1.670417		1.601 449
1000			05:28	2.070731		2.001 763
0			05:32	0.068907		
0			05:36	0.068978		0.000 000
400			05:40	0.869672		0.800 694
600			05:44	1.270000		1.201 022
800			05:48	1.670420		1.601 442
1000			05:52	2.070725		2.001 747
800			05:56	1.670334		1.601 356
600			06:00	1.269868		1.200 890
400			06:04	0.869435		0.800 457
0			06:08	0.068960	22.90	

1000 kN Final UME measurements

Date	25.03.2009
Laboratory	UME
Machine Capacity	1 MN
Operator	S. Fank
BN 100	34714
DMP 40	964720034
Filter	0.10 Hz Bessel
Bridge Supply	5 V
Measuring Range	+/- 2.5 mV/V
Mode	Absolute
Transducer	GTM 45084
Capacity (kN)	1000

Orientation degrees	Force kN	Time hh:mm	DMP 40 reading mV/V	Temperature °C	Deflection mV/V
0	0	0:00	0.082428	21.31	
	1000 (preload)	0:04	2.084137		2.001 709
	0	0:08	0.082452		
	0	0:12	0.082494		
	1000 (preload)	0:16	2.084062		2.001 568
	0	0:20	0.082454		
	0	0:24	0.082504		
	1000 (preload)	0:28	2.084124		2.001 620
	0	0:32	0.082466		
	0	0:36	0.082520		21.31
	400	0:40	0.883185		0.800 665
	600	0:44	1.283565		1.201 045
	800	0:48	1.683735		1.601 215
	1000	0:52	2.083865		2.001 345
	0	0:56	0.082483		-0.000 037
	0	1:00	0.082538		0.000 000
	400	1:04	0.883177		0.800 639
	600	1:08	1.283499		1.200 961
	800	1:12	1.683824		1.601 286
	1000	1:16	2.083987		2.001 449
800	1:20	1.683810		1.601 272	

	600		1:24	1.283568		1.201 030
	400		1:28	0.883254		0.800 716
	0		1:32	0.082533		-0.000 005
	0		1:36	0.082553		0.000 000
	400		1:40	0.883297		0.800 744
	600		1:44	1.283545		1.200 992
	800		1:48	1.683821		1.601 268
	1000		1:52	2.084125		2.001 572
	800		1:56	1.683800		1.601 247
	600		2:00	1.283534		1.200 981
	400		2:04	0.883258		0.800 705
	0		2:08	0.082541	21.31	-0.000 012
90	0		2:12	0.082528	21.35	0.000 000
	400		2:16	0.883179		0.800 651
	600		2:20	1.283556		1.201 028
	800		2:24	1.683938		1.601 410
	1000		2:28	2.084218		2.001 690
	0		2:32	0.082514		-0.000 014
	0		2:36	0.082569		0.000 000
	400		2:40	0.883251		0.800 682
	600		2:44	1.283601		1.201 032
	800		2:48	1.683955		1.601 386
	1000		2:52	2.084280		2.001 711
	800		2:56	1.683928		1.601 359
	600		3:00	1.283659		1.201 090
	400		3:04	0.883293		0.800 724
	0		3:08	0.082557	21.35	-0.000 012
180	0		3:12	0.082530	21.41	0.000 000
	400		3:16	0.883173		0.800 643
	600		3:20	1.283561		1.201 031
	800		3:24	1.683924		1.601 394
	1000		3:28	2.084218		2.001 688
	0		3:32	0.082510		-0.000 020
	0		3:36	0.082567		0.000 000
	400		3:40	0.883275		0.800 708
	600		3:44	1.283585		1.201 018
	800		3:48	1.683951		1.601 384
	1000		3:52	2.084220		2.001 653

	800		3:56	1.683932		1.601 365
	600		4:00	1.283621		1.201 054
	400		4:04	0.883303		0.800 736
	0		4:08	0.082551	21.41	-0.000 016
270	0		4:12	0.082539	21.43	0.000 000
	400		4:16	0.883200		0.800 661
	600		4:20	1.283534		1.200 995
	800		4:24	1.863931		1.781 392
	1000		4:28	2.084193		2.001 654
	0		4:32	0.082521		-0.000 018
	0		4:36	0.082567		0.000 000
	400		4:40	0.883245		0.800 678
	600		4:44	1.283564		1.200 997
	800		4:48	1.683886		1.601 319
	1000		4:52	2.084226		2.001 659
	800		4:56	1.683890		1.601 323
	600		5:00	1.283619		1.201 052
	400		5:04	0.883263		0.800 696
	0		5:08	0.082554	21.43	-0.000 013
360	0		5:12	0.082519	21.42	0.000 000
	400		5:16	0.883181		0.800 662
	600		5:20	1.283626		1.201 107
	800		5:24	1.683886		1.601 367
	1000		5:28	2.084086		2.001 567
	0		5:32	0.082531		
	0		5:36	0.082591		0.000 000
	400		5:40	0.883267		0.800 676
	600		5:44	1.283577		1.200 986
	800		5:48	1.683926		1.601 335
	1000		5:52	2.084218		2.001 627
	800		5:56	1.683914		1.601 323
	600		6:00	1.283633		1.201 042
	400		6:04	0.883323		0.800 732
	0		6:08	-0.082577	21.42	-0.000 014