Intercomparison Results of UME Force Standard Machines with PTB After 1999 Marmara Earthquake

Sinan FANK*, Bernd Gloeckner**, Cihan KUZU*, Ercan PELIT*,
Bülent AYDEMIR*, Baris CAL*

** TÜBİTAK, Ulusal Metroloji Enstitüsü (UME)*

Gebze – Kocaeli, Turkey

*** PTB, Physikalisch Technische Bundesanastalt, Germany*

Abstract

UME force standard machines, 11 kN and 110 kN dead-weight and 1.1 MN lever amplification, were installed into UME Force Laboratory in 1995. During commissioning of these machines in 1995 and 1997, two intecomparison measurements were realized between UME and PTB. Uncertainty level was $2x10^{-5}$ for dead-weight machines and is $1x10^{-4}$ for lever amplification machine. Marmara Earthquake influenced the force standard machines in August 1999. The epicentre of earthquake is 30 km to UME. Some connection points, welded parts and position of mass stacks were affected from this earthquake. After all repairment and adjustment was completed, a new intercomparison was realized with PTB in 2000. The measurements show that the uncertainty level is satisfactory and not changed due to earthquake.

1. Introduction

In 1995, three force standard machines (FSM) constructed by GTM have been installed into UME Force Measurement Laboratory. First FSM is a fully dead weight machine having a capacity of 11 kN in range between 100 N and 11 kN. Second FSM is a lever-type machine having capacities of 110 kN in dead weight side in range between 2 kN and 110 kN and of 1.1 MN in lever side in range between 20 kN and 1.1 MN. After installation of these machines into the UME Force Laboratory on date of July 1995, intercomparison measurement between UME and PTB Force Standard Machines was realized using with PTB force transfer standards in 1995 and 1997. These are reported in different IMEKO TC3 conferences and at UME as Internal Report [1-2]

On August 17,1999, an earthquake measuring 7.4 on the Richter scale devastated the Marmara region of Turkey. Over 15,000 people have lost and there was an extensive damage on the region. Ulusal Metroloji Enstitüsü is located in Marmara region and 30 km near to epicenter of earthquake. After the Marmara earthquake-taking place, UME Machines subjected to great swinging during earthquake. Some connection and welded part broken and deformed and all mass of stacks shifted a little bit from axial position. UME took a decision to make intercomparison measurements with PTB after this earthquake to see the effect of earthquake on the results. Then, an international comparison measurement realized by PTB and UME force laboratories is to determine the comparability of the forces generated by the force standard machines of PTB and UME over a capacity range of 1 kN to 1 MN after the earthquake.

The protocol of these intercomparison measurements, which is developed by PTB, was used in this study. The results which were obtained in the intercomparison study in 2000 indicate that the 11 kN dead weight machine and 110/1.1 MN lever amplification dead weight force standard machine at UME and, 20 kN, 100 kN and 1 MN dead weight machines at PTB, over a range of 200 N to 100 kN for dead weight machine are in agreement within $2 \cdot 10^{-5}$ and within $1 \cdot 10^{-4}$ up to 1 MN lever amplification machine.

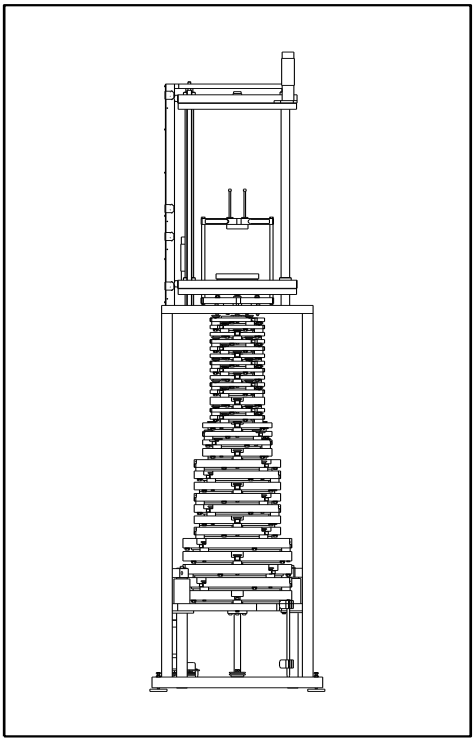


Figure 1. 11 kN Dead Weight Force Standard Machine

Total ten force transducers belonging to UME were used in this intercomparison. Initial measurements of all force transducers were carried out first at UME. These measurements were repeated by a set of similar measurements at PTB and then again at UME in 2000.

2. Intercompared Force Standard Machines

2.1. UME Force Standard Machines

Specific characteristics of the 11 kN and 110 kN dead weight machines and 1.1 MN lever amplification FSM of UME described in references from [1-4] in detail. Short explanation and working principle of the FSMs have been given here.

Fig.1. shows the schematic drawing of the 11 kN dead weight machine. This machine has one stack of 30 weights composed of : 13 x 100 N; 4 x 200 N; 1 x 300 N; 7 x 500 N and 5 x 1 kN, to have 4 different force ranges to calibrate force proving instruments. These are 1 kN, 2 kN, 5 kN and 10 kN.

Fig.2. shows the general view of the 110 kN/1.1 MN lever amplification machine of UME. 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 with force ranges 20 kN, 50 kN and 100 kN. The dead weight side has one stack of 25 weights, which is produced by chemically nickel-plated mild steel discs. The lever amplification is realized with a single lever and a transmission ratio of 1:10. With lever multiplication, the forces are generated from 20 kN up to 1.1 MN with force ranges 200 kN, 500 kN and 1 MN.

Each force ranges in three machines have 10 steps with 10% increment and a compression and tension space is provided on all machines.

2.2. The PTB Force Standard Machines

To cover the force range included in the intercomparison, four PTB force standard machines were utilized. These are 2 kN, 20 kN, 100 kN and 1 MN dead weight machines (DWM). These machines had been described in detail in ref. [5], [6] and [7].

2 kN dead weight force standard machine has the force range from 50 N to 2000 N. Force steps are

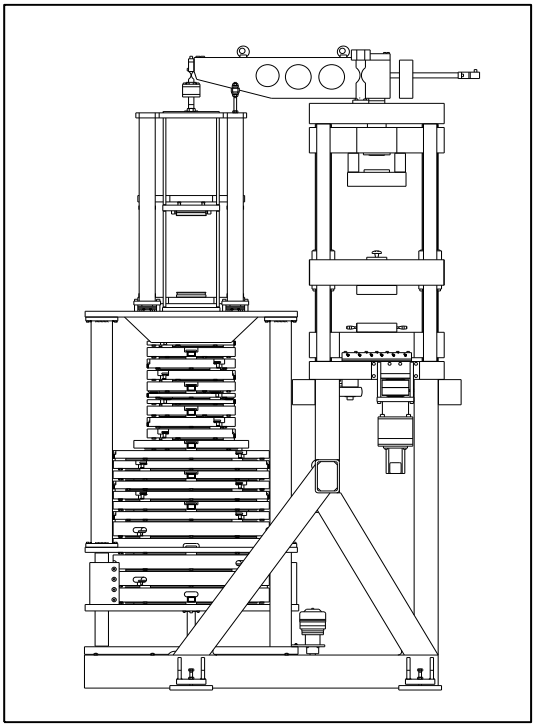


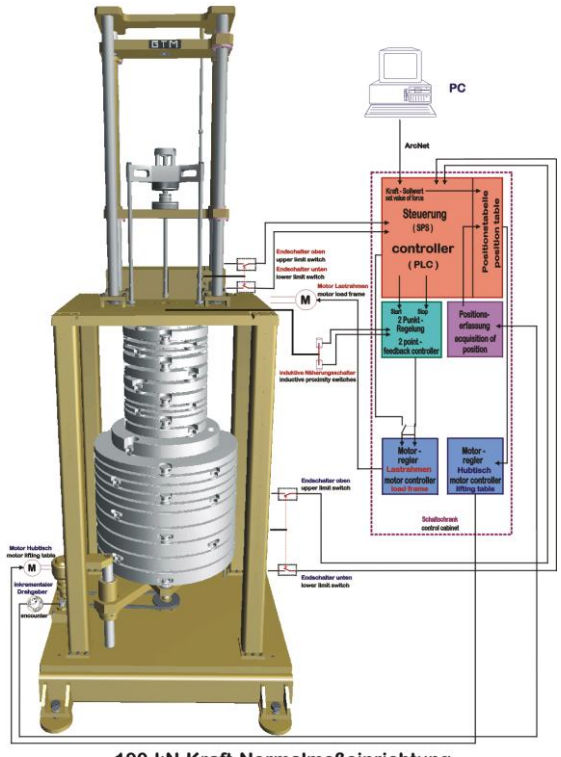
Figure 2. 110/1100 kN Lever Amplific. Dead Weight Force Standard Machine

50, 100, 110, 120, 140, 160, 180, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800 and 2000 N. 20 kN dead weight force standard machine has the force range from 0,25 kN to 20 kN. Force steps are 0,25; 0,5; 0,75; 1; 1,25; 1,5; 1,75; 2; 2,5; 3; 3,5; 4; 4,5; 5; 6; 7; 8; 9; 10; 12; 14; 16; 18 and 20. 100 kN force standard machine shown in Fig.3 has the force range: from 2 kN to 100 kN and its force steps are 2, 4, 5, 6, 8, 10, 12, 14, 15, 16, 18, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90 and100 kN. 1 MN Force Standard machine has the force range: from 20 KN to 1 MN and the force steps are 20, 40, 50, 60, 80, 100, 120, 140, 150, 160, 180, 200, 250, 300, 350, 400,

450, 500, 600, 700, 800, 900 and 1000 kN. Their relative measurement uncertainties are $\leq 2 \cdot 10^{-5}$.

3. Force Transfer Standards and Measurement Procedure

Compression type ten force transducers having capacities of 1, 2, 5, 10, 20, 50, 100 kN, 200 kN, 500 kN and 1 MN were used as force transfer standards in this intercomparison. All of them belong to UME had been used by UME in previous intercomparisons in five years. To minimize the uncertainty associated with the indicating instrument a high resolution, 1 ppm, indicator having good stability was used in this intercomparison.The measurement procedure applied in the intercomparison was developed by



100-kN-Kraft-Normalmeßeinrichtung
100 kN Force Standard Machine

PTB and have been used to perform the intercomparisons with national laboratories to minimize the effects of parameters such as time interval, machine-transducer interaction, ambient conditions and force steps that are known to contribute to the measurement uncertainty. The procedure has been described in ref [1], [5] and [6] have been used to perform the intercomparisons with national laboratories to minimize the effects of parameters such as time interval, machine-transducer interaction, ambient conditions and force steps that are known to contribute to the measurement uncertainty.

4. Measurement Results

The relative deviations between UME and PTB were determined by taking the UME mean values from the initial measurements. The relative deviations in the UME mean values relative to the PTB mean values for the force transducers included in the 500 N through the 10 kN range are shown in Fig.4. In a similar way, the relative deviations for the force transducers in the 1 kN through the 100 kN range and in the 80 kN and 1 MN range are shown in Fig.5 and Fig.6 respectively.

The force realized by the UME dead weight force standard machines over a range of 500 N to 100 kN was compared with PTB standards in 2000. The results of comparison show that the agreement between UME 10 kN dead weight machines and PTB 2 kN and 20 kN dead weight machines is better than $\pm 4.0 \cdot 10^{-5}$ over a range of

500 N to 10 kN except for 5 kN transducer results. These are also better than $\pm 5.0 \cdot 10^{-5}$. , This exception is due to force transducer behavior and overlapping effect. Because, 2 kN and 10 kN force transducers show better deviations than 5 kN in the identical force values. The force realized by the UME lever amplification FSM over a range of 80 kN to 1000 kN was compared with PTB dead weight machine in 2000.

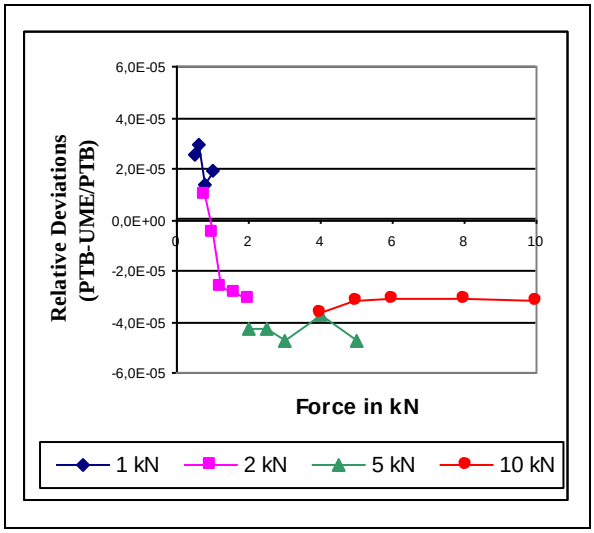


Figure 3. Intercomparison Results of 11kN dead weight FSM of UME

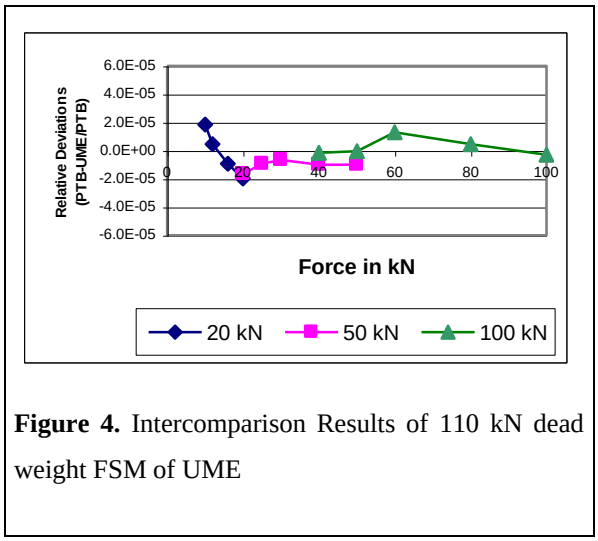


Figure 4. Intercomparison Results of 110 kN dead weight FSM of UME

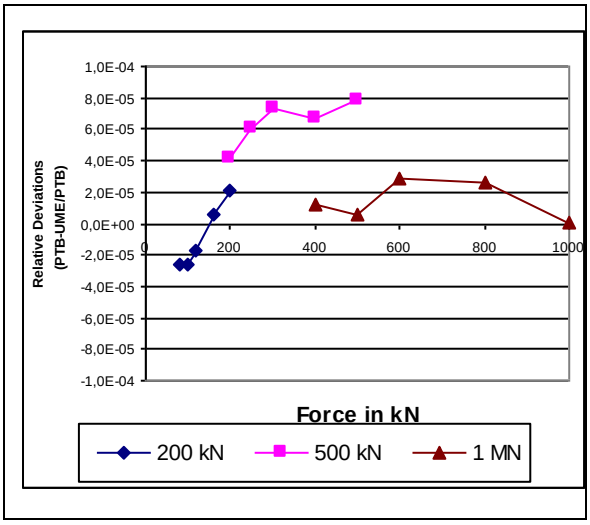


Figure 5. Intercomparison Results of 1.1 MN lever amplification FSM of UME

Table 1. Relative Deviations Between UME and PTB FSMs for 1 kN, 2 kN, 5 kN and 10 kN Transducers Measured in 2000

Force Step KN	1 kN Transducer	2 kN Transducer	5 kN Transducer	10 kN Transducer
0,5	2,6E-05			
0,6	2,9E-05			
0,8	1,4E-05	9,7E-06		
1,0	1,9E-05	-5,4E-06		
1,2		-2,6E-05		
1,6		-2,9E-05		
2,0		-3,1E-05	-4,3E-05	
2,5			-4,3E-05	
3,0			-4,8E-05	
4,0			-3,7E-05	-3,7E-05
5,0			-4,7E-05	-3,2E-05
6,0				-3,1E-05
8,0				-3,1E-05
10,0				-3,2E-05

The results of comparison show that the agreement between UME and PTB FSMs is better than $\pm 8.0 \cdot 10^{-5}$ over a range of 80 kN to 1000 kN. Table 1. , Table. 2. and Table 3. show the results of intercomparisons as relative deviations between UME and PTB which were obtained from 1 kN, 2 kN, 5 kN

and 10 kN, 20 kN, 50 kN and 100 kN, 200 kN, 500 kN and 1000 kN force transducers.

Table 2. Relative Deviations Between UME and PTB FSMs for 20 kN, 50 kN and 100 kN Transducers Measured in 2000.

Force Step KN	20 kN Transducer	50 kN Transducer	100 kN Transducer
10	1,9E-05		
12	4,6E-06		
16	-9,4E-06		
20	-2,0E-05	-1,7E-05	
25		-9,2E-06	
30		-6,6E-06	
40		-1,0E-05	-1,6E-06
50		-1,0E-05	-3,8E-07
60			1,3E-05
80			4,5E-06
100			-2,8E-06

Table 3. Relative Deviations Between UME and PTB FSMs for 100 kN, 200 kN, 500 kN and 1 MN Transducers Measured in 2000.

Force Step kN	200 kN Transducer	500 kN Transducer	1 MN Transducer
80	-2,6E-05		
100	-2,6E-05		
120	-1,7E-05		
160	6,4E-06		
200	2,1E-05	4,2E-05	
250		6,0E-05	
300		7,3E-05	
400		6,6E-05	1,2E-05
500		7,9E-05	6,2E-06
600			2,9E-05
800			2,5E-05
1000			1,0E-06

5. Conclusions

Two intercomparison measurements were realized between UME and PTB in 1995 and 2000. The same measurement procedure using with same four-force transducer belonging to PTB were applied in these intercomparisons.

As shown in Fig.4. Fig.5. and Fig.6 or in Table 1., Table 2. and Table 3. that UME force standard machines show similar behavior comparing to 1995 results in ref.[1] after the Marmara earthquake. All adjustments and repairements after the earthquake give acceptable results in intercomparison measurements.

The force realized by the UME dead weight force standard machines over a range of 500 N to 1000 kN was compared with PTB standards in 2000.

The results of the two intercomparison measurements show that the agreement between UME and PTB dead weight force standard machines is better than $\pm 4 \cdot 10^{-5}$. over a range 50N kN to 100 kN except for 2.5 kN and 3 kN force steps show maximum $4.8 \cdot 10^{-5}$ relative deviation. These exceptions are due to force transducer and overlapping effect. Dead weight force standard machines that have theoretical uncertainty on the order of $\pm 2 \cdot 10^{-5}$ examined exhibit $\pm 5 \cdot 10^{-5}$ relative deviations from PTB machine in international comparison measurements and more precise statements cannot be made [7].

The results of comparison also show that the agreement between UME lever amplification machine and and PTB dead weight machine is better than $\pm 8.0 \cdot 10^{-5}$ over a range of 80 kN to

1000 kN. Maximum relative uncertainty of measurements for lever type machines amounts to $\pm 2.0 \cdot 10^{-4}$ and the mean relative deviations from the PTB's 1 MN dead weight machine lie between $+1.0 \cdot 10^{-4}$ to $-5.0 \cdot 10^{-4}$ [7]. As a result of this statement that lever amplification machine of UME has the measurement uncertainty of $< \pm 1.0 \cdot 10^{-4}$.

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

6. References

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Contact Person for Paper:

Sinan Fank,

TÜBİTAK-Ulusal Metroloji Enstitüsü,
P.O. Box 21, 41470 Gebze Kocaeli -TURKEY,
Phone: + 90 262 646 63 55,
Fax: + 90 262 646 59 14,
e-mail: sinan.fank@ume.tubitak.gov.tr