

**BIPM Capacity Building & Knowledge Transfer Programme
2018 BIPM - TÜBİTAK UME Project Placement**

REPORT

Project Name	Study of Extreme Pressure Measurements
Description	The theoretical and practical aspects of the calibration of cargo pressure gauges were studied.
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Motivation & Introduction

This project is aimed to improve the quality of measurements of excess pressure and improving Kazakhstan's national system for ensuring the uniformity of measurements in the field of pressure.

The result of the work should be the development of the technical task for the modernization of the state standard of the pressure unit, the development and testing of the method of obtaining a unit of pressure from the basic SI units, the development of a scheme for transferring the unit size of the magnitude of excess pressure from the state standard to the working measuring instruments with metrological traceability through a continuous calibrating circuit.

Research

The pressure-measuring instrument (Model 745) was calibrated by a calibration device (P9302A).

In the process of calibration, the following data is recorded:

- The mass and temperature values of the piston gage;
- An indication of measuring instrument to be calibrated.

The following data also be recorded:

- Values of the energizing quantities (temperature, atmosphere pressure);
- The ID parameter of the pressure-measuring instrument to is calibrated.

Calibration calculating of pressure-measuring instruments shown in Figures 1-4.

Reference Instrument	P9302A	Mass Set (3386)			
		#	True mass(g)	Corrected (kg)	Bel (mg)
±V _{portam} g(kg m/s ²)	0	1	4999,995	4,999	9
		2	4999,975	4,999	9
σ _C (kg m/s ²)	2,43E-04	3	4999,977	4,999	9
		4	5000,006	4,999	9
2α) ref(K ⁻¹)	9,00E-06	5	4999,973	4,999	9
		6	4999,972	4,999	9
±Δh (m)	0,050	7	4999,976	4,999	9
		8	4999,992	4,999	9
A _{0.ref} m ²	4,90209E-06	9	5000,020	4,999	9
		10	4999,989	4,999	9
λ _{ref} MPa ⁻¹	6,70E-07	11	4999,983	4,999	9
		12	4999,990	4,999	9
temperature(1537)	0,11	13	4999,990	4,999	9
		14	4999,986	4,999	9
		4 kg	4000,003	3,999	7
		2 kg -1-	1999,993	2,000	4
t _{lab}	20,25	2 kg -2-	2000,002	2,000	4
		1 kg	1000,001	1,000	2
p _{lab} (mbar)	990,2	500 g	500,001	0,500	2
		200 g -1-	199,999	0,200	1
p _{air}	1,170	200 g -2-	199,999	0,200	1
		100 g	100,001	0,100	1
ρ _{mass}	7920	bell	799,995	0,800	1
		piston	200,003	0,200	0,4
g	9,80227703				

Figure 1. The property value of the calibration device

Nominal Pressure		PCU temperature	Temperature correction	Oil (Sesabate) density	Head correction	Air buoyancy	Mass uncertainty	F	Temperature effect	Pressure distortion coefficient	Effective area of PCU	Reference pressure			Tets pressure	error
Proximal	Proximal	T	Δt _{ref}	ρ	p _H	Σm(1-ρ)/ρ _{ref}	mg(1-.....)	1+2α Δt _{ref}	1+λ _{ref} p _{H,ref}	A(1+2αΔt) ² (1+λ _{ref} p _{H,ref})	m g/A _{ref} β _{ref} ρ _{ref} ρ _{air}			Pokusan		
bar	MPa	°C	°C	(kg/m ³)	Pa	kg	kg m/s ²				Pa	bar	MPa	bar	bar	
0	0	-	-	912.70	446.753	0.000000	0.000000	0.000000	0.000	0.0000000	0	0.00	0.00	0.000	0.00	
150	15	19.10	-0.79	923.61	452.103	7.498887	14	73.506412	1.000E+00	1.00	0.0000049	14995321	149.95	15.00	150.004	0.05
300	30	19.14	-0.75	933.82	457.104	14.997754	26	147.012395	1.000E+00	1.00	0.0000049	29989795	299.90	29.99	299.948	0.05
450	45	19.17	-0.72	943.34	461.771	22.496617	41	220.518329	1.000E+00	1.00	0.0000049	44983950	449.84	44.98	449.892	0.05
600	60	19.20	-0.69	952.21	466.119	29.995494	53	294.024401	1.000E+00	1.00	0.0000049	59977824	599.78	59.98	599.829	0.05
750	75	19.24	-0.65	960.46	470.162	37.494351	68	367.530286	1.000E+00	1.00	0.0000049	74971344	749.71	74.97	749.764	0.05
900	90	19.29	-0.60	968.12	473.914	44.993217	73	441.036250	1.000E+00	1.00	0.0000049	89964558	899.65	89.96	899.689	0.04
1050	105	19.32	-0.57	975.21	477.390	52.492123	88	514.542606	1.000E+00	1.00	0.0000049	104957557	1049.58	104.96	1049.616	0.04
1200	120	19.35	-0.54	981.77	480.604	59.990992	100	588.048609	1.000E+00	1.00	0.0000049	119950174	1199.50	119.95	1199.542	0.04
1350	135	19.39	-0.50	987.82	483.572	67.489868	115	661.554670	1.000E+00	1.00	0.0000049	134942481	1349.42	134.94	1349.467	0.04
1380	138	19.42	-0.47	988.98	484.137	68.989647	115	676.255924	1.000E+00	1.00	0.0000049	137940886	1379.41	137.94	1379.446	0.04
1380	138	19.50	-0.39	988.98	484.137	68.989647	115	676.255924	1.000E+00	1.00	0.0000049	137940786	1379.41	137.94	1379.445	0.04
1350	135	19.50	-0.39	987.82	483.572	67.489868	115	661.554670	1.000E+00	1.00	0.0000049	134942347	1349.42	134.94	1349.459	0.04
1200	120	19.52	-0.37	981.77	480.604	59.990992	100	588.048609	1.000E+00	1.00	0.0000049	119949990	1199.50	119.95	1199.597	0.10
1050	105	19.53	-0.36	975.21	477.390	52.492123	88	514.542606	1.000E+00	1.00	0.0000049	104957358	1049.57	104.96	1049.612	0.04
900	90	19.54	-0.35	968.12	473.914	44.993217	73	441.036250	1.000E+00	1.00	0.0000049	89964356	899.64	89.96	899.684	0.04
750	75	19.55	-0.34	960.46	470.162	37.494351	68	367.530286	1.000E+00	1.00	0.0000049	74971134	749.71	74.97	749.755	0.04
600	60	19.58	-0.31	952.21	466.119	29.995494	53	294.024401	1.000E+00	1.00	0.0000049	59977619	599.78	59.98	599.823	0.05
450	45	19.59	-0.30	943.34	461.771	22.496617	41	220.518329	1.000E+00	1.00	0.0000049	44983780	449.84	44.98	449.878	0.04
300	30	19.59	-0.30	933.82	457.104	14.997754	26	147.012395	1.000E+00	1.00	0.0000049	29989673	299.90	29.99	299.930	0.03
150	15	19.60	-0.29	923.61	452.103	7.498887	14	73.506412	1.000E+00	1.00	0.0000049	14995253	149.95	15.00	149.987	0.03
0	0	-	-	912.70	446.753						0	0.00	0.00	-0.039	-0.04	

Figure 2. Calculation of the first measurement

Nominal Pressure		PCU temperature	Temperature correction	Oil (Sebacate) density	Head correction	Air buoyancy	Mass uncertainty	F	Temperature effect	Pressure distortion coefficient	Effective area of PCU	Reference pressure			Tets pressure	error
P _{nominal}	P _{nominal}	T	ΔT _{ref}	ρ	p _H	Σm(1-ρ)/ρ _{ref}	mg	mg(1-.....)	1+2α _{ref} ΔT _{ref}	1+β _{ref} p _{ref}	A(1+2αΔT)(1+βp) _{ref}	m _g /A _{ref} (P _{ref} +P _{test})			Pokusan	
bar	MPa	°C	°C	(kg/m ³)	Pa	kg	mg	kg m/s ²				Pa	bar	MPa	bar	bar
0	0			912.70	446.753							0	0.00	0.00	0.000	0.00
150	15	19.76	-0.13	923.61	452.103	7.498887	14	73.506412	1.000E+00	1.00	0.0000049	14995232	149.95	15.00	150.016	0.06
300	30	19.77	-0.12	933.82	457.104	14.997754	26	147.012395	1.000E+00	1.00	0.0000049	29989625	299.90	29.99	299.965	0.07
450	45	19.78	-0.11	943.34	461.771	22.496617	41	220.518329	1.000E+00	1.00	0.0000049	44983703	449.84	44.98	449.916	0.08
600	60	19.79	-0.10	952.21	466.119	29.995494	53	294.024401	1.000E+00	1.00	0.0000049	59977506	599.78	59.98	599.852	0.08
750	75	19.80	-0.09	960.46	470.162	37.494351	68	367.530286	1.000E+00	1.00	0.0000049	74970966	749.71	74.97	749.790	0.08
900	90	19.81	-0.08	968.12	473.914	44.993217	73	441.036250	1.000E+00	1.00	0.0000049	89964137	899.64	89.96	899.720	0.08
1050	105	19.83	-0.06	975.21	477.390	52.492123	88	514.542606	1.000E+00	1.00	0.0000049	104957075	1049.57	104.96	1049.647	0.08
1200	120	19.83	-0.06	981.77	480.604	59.990992	100	588.048609	1.000E+00	1.00	0.0000049	119949655	1199.50	119.95	1199.564	0.07
1350	135	19.84	-0.05	987.82	483.572	67.489868	115	661.554670	1.000E+00	1.00	0.0000049	134941934	1349.42	134.94	1349.495	0.08
1380	138	19.84	-0.05	988.98	484.137	68.989647	115	676.255924	1.000E+00	1.00	0.0000049	137940364	1379.40	137.94	1379.474	0.07
1380	138	19.84	-0.05	988.98	484.137	68.989647	115	676.255924	1.000E+00	1.00	0.0000049	137940364	1379.40	137.94	1379.474	0.07
1350	135	19.84	-0.05	987.82	483.572	67.489868	115	661.554670	1.000E+00	1.00	0.0000049	134941934	1349.42	134.94	1349.487	0.07
1200	120	19.83	-0.06	981.77	480.604	59.990992	100	588.048609	1.000E+00	1.00	0.0000049	119949655	1199.50	119.95	1199.568	0.07
1050	105	19.82	-0.07	975.21	477.390	52.492123	88	514.542606	1.000E+00	1.00	0.0000049	104957085	1049.57	104.96	1049.641	0.07
900	90	19.82	-0.07	968.12	473.914	44.993217	73	441.036250	1.000E+00	1.00	0.0000049	89964129	899.64	89.96	899.719	0.08
750	75	19.82	-0.07	960.46	470.162	37.494351	68	367.530286	1.000E+00	1.00	0.0000049	74970952	749.71	74.97	749.782	0.07
600	60	19.81	-0.08	952.21	466.119	29.995494	53	294.024401	1.000E+00	1.00	0.0000049	59977495	599.77	59.98	599.849	0.07
450	45	19.81	-0.08	943.34	461.771	22.496617	41	220.518329	1.000E+00	1.00	0.0000049	44983691	449.84	44.98	449.906	0.07
300	30	19.80	-0.09	933.82	457.104	14.997754	26	147.012395	1.000E+00	1.00	0.0000049	29989617	299.90	29.99	299.967	0.07
150	15	19.80	-0.09	923.61	452.103	7.498887	14	73.506412	1.000E+00	1.00	0.0000049	14995226	149.95	15.00	149.019	-0.93
0	0			912.70	446.753							0	0.00	0.00	-0.005	-0.01

Figure 3. Calculation of the second measurement

Nominal Pressure		PCU temperature	Temperature correction	Oil (Sebacate) density	Head correction	Air buoyancy	Mass uncertainty	F	Temperature effect	Pressure distortion coefficient	Effective area of PCU	Reference pressure			Tets pressure	error
P _{nominal}	P _{nominal}	T	ΔT _{ref}	ρ	p _H	Σm(1-ρ)/ρ _{ref}	mg	mg(1-.....)	1+2α _{ref} ΔT _{ref}	1+β _{ref} p _{ref}	A(1+2αΔT)(1+βp) _{ref}	m _g /A _{ref} (P _{ref} +P _{test})			Pokusan	
bar	MPa	°C	°C	(kg/m ³)	Pa	kg	mg	kg m/s ²				Pa	bar	MPa	bar	bar
0	0			912.70	446.753							0	0.00	0.00	0.000	0.00
150	15	19.26	-0.63	923.61	452.103	7.498887	26	73.506412	1.000E+00	1.00	0.0000049	14995299	149.95	15.00	150.011	0.06
300	30	19.26	-0.63	933.82	457.104	14.997754	41	147.012395	1.000E+00	1.00	0.0000049	29989762	299.90	29.99	299.963	0.07
450	45	19.29	-0.60	943.34	461.771	22.496617	53	220.518329	1.000E+00	1.00	0.0000049	44983902	449.84	44.98	449.912	0.07
600	60	19.29	-0.60	952.21	466.119	29.995494	68	294.024401	1.000E+00	1.00	0.0000049	59977776	599.78	59.98	599.851	0.07
750	75	19.30	-0.59	960.46	470.162	37.494351	73	367.530286	1.000E+00	1.00	0.0000049	74971303	749.71	74.97	749.785	0.07
900	90	19.32	-0.57	968.12	473.914	44.993217	88	441.036250	1.000E+00	1.00	0.0000049	89964534	899.65	89.96	899.718	0.07
1050	105	19.33	-0.56	975.21	477.390	52.492123	100	514.542606	1.000E+00	1.00	0.0000049	104957547	1049.58	104.96	1049.642	0.07
1200	120	19.36	-0.53	981.77	480.604	59.990992	115	588.048609	1.000E+00	1.00	0.0000049	119950163	1199.50	119.95	1199.569	0.07
1350	135	19.37	-0.52	987.82	483.572	67.489868	115	661.554670	1.000E+00	1.00	0.0000049	134942505	1349.43	134.94	1349.492	0.07
1380	138	19.39	-0.50	988.98	484.137	68.989647	115	676.255924	1.000E+00	1.00	0.0000049	137940923	1379.41	137.94	1379.492	0.08
1380	138	19.39	-0.50	988.98	484.137	68.989647	115	676.255924	1.000E+00	1.00	0.0000049	137940923	1379.41	137.94	1379.471	0.06
1350	135	19.39	-0.50	987.82	483.572	67.489868	100	661.554670	1.000E+00	1.00	0.0000049	134942481	1349.42	134.94	1349.483	0.06
1200	120	19.40	-0.49	981.77	480.604	59.990992	88	588.048609	1.000E+00	1.00	0.0000049	119950120	1199.50	119.95	1199.568	0.07
1050	105	19.39	-0.50	975.21	477.390	52.492123	100	514.542606	1.000E+00	1.00	0.0000049	104957491	1049.57	104.96	1049.639	0.06
900	90	19.82	-0.07	968.12	473.914	44.993217	88	441.036250	1.000E+00	1.00	0.0000049	89964129	899.64	89.96	899.707	0.07
750	75	19.40	-0.49	960.46	470.162	37.494351	73	367.530286	1.000E+00	1.00	0.0000049	74971236	749.71	74.97	749.774	0.06
600	60	19.39	-0.50	952.21	466.119	29.995494	68	294.024401	1.000E+00	1.00	0.0000049	59977722	599.78	59.98	599.841	0.06
450	45	19.41	-0.48	943.34	461.771	22.496617	53	220.518329	1.000E+00	1.00	0.0000049	44983853	449.84	44.98	449.895	0.06
300	30	19.40	-0.49	933.82	457.104	14.997754	41	147.012395	1.000E+00	1.00	0.0000049	29989725	299.90	29.99	299.956	0.06
150	15	19.41	-0.48	923.61	452.103	7.498887	26	73.506412	1.000E+00	1.00	0.0000049	14995279	149.95	15.00	149.997	0.04
0	0			912.70	446.753							0	0.00	0.00	-0.011	-0.01

Figure 4. Calculation of the third measurement



Figure 5. Digital Pressure Gauge Calibration

Estimation of Uncertainty Value:

The base values taken into account for the estimated uncertainty of pressure-measuring instrument calibrating are:

- the uncertainty of the reference device used;
- the uncertainty of reproducibility;
- the uncertainty of reversibility (hysteresis effect) of the measuring instruments under calibration;
- uncertainty definition of the quantity measured;
- -the uncertainty of the model operation (estimated square deviation of quantity to be measured);
- the uncertainty of correlation between reference device and the device to be calibrated.

CALIBRATION CERTIFICATE							
Increasing				Decreasing			
Pref	Ptest	Error	Uncertainty	Pref	Ptest	Error	Uncertainty
bar	bar	bar	bar	bar	bar	bar	bar
0,000	0,000	0,000	0,025	0,000	-0,018	-0,018	0,038
149,953	150,010	0,057	0,262	149,953	149,668	149,668	0,259
299,897	299,959	0,061	0,308	299,897	299,951	299,951	0,307
449,839	449,907	0,068	0,481	449,838	449,893	449,893	0,479
599,777	599,844	0,067	0,619	599,776	599,838	599,838	0,617
749,712	749,780	0,068	0,792	749,711	749,770	749,770	0,790
899,644	899,709	0,065	0,849	899,642	899,703	899,703	0,848
1049,574	1049,635	0,061	1,022	1049,573	1049,631	1049,631	1,021
1199,500	1199,558	0,058	1,160	1199,499	1199,578	1199,578	1,160
1349,423	1349,485	0,062	1,333	1349,423	1349,476	1349,476	1,333
1379,407	1379,471	0,063	1,333	1379,407	1379,463	1379,463	1,333

Figure 6. Certificate Values

Conclusions and Future Work

During the internship the following were accomplished:

1. Study of the composition, modes, device, traceability and schemes of transfer of unit for national measurement standard of extreme pressure in the Pressure Laboratory of TUBITAK UME;
2. Analysis of the calibration procedure of the national measurement standard of extreme pressure including traceability to the measurement standards of mass and length;
3. Investigation of the influence of structural and geometric parameters of the piston on the stability of metrological characteristics of piston gage;
4. Evaluation of environmental conditions and the uncertainty of geometric parameters of piston gage;
5. Construction of a mathematical model of measurement and estimation of the uncertainty of influencing factors for transfer of the unit of extreme pressure from national measurement standard to working measurement standards.

Participation in «BIPM - TUBITAK UME project placements» allowed me to improve my technical skills and build knowledge towards the goal of for improving the system of transfer of pressure unit size in Kazakhstan.

The measurement chain of national standard of pressure is to be revised and the calibration procedure of the pressure calibrator will be drafted in accordance with the requirements of

international document Euramet Calibration Guide No.17 Version 3.0 (04/2017) to ensure reliable measurement results.

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