Short Report on AUV Activities at TÜBİTAK Ulusal Metroloji Enstitüsü

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Organization

TÜBİTAK Ulusal Metroloji Enstitüsü (UME) is the national metrology institute and the highest technical authority in Turkey for the field of scientific metrology. The work of TÜBİTAK UME is committed to excellence in measurement and testing for the benefit of industries and consumers alike. TÜBİTAK UME operates as national reference laboratory in metrology under the auspices of the Scientific and Technological Research Council of Turkey (TÜBİTAK) placed under the Ministry of Industry and Technology. It meets the requirements for calibration and testing laboratories as defined in the ISO/IEC 17025 standard employing a staff of 291 people (September 2019). It is a fundamental task of TÜBİTAK UME to realize and maintain the standards of the measurement units in compliance with the International System of Units (SI) and to disseminate them, above all within the framework of legal and industrial metrology as well as persuading its scientific and technological development in order to anticipate new measurement and testing requirements in the areas of energy, safety, health, and environmental protection. TÜBİTAK UME provides government authorities and key economic players with the technical assistance they require to draft new regulations and standards at national level.

In the overall, TÜBİTAK UME has 29 operational laboratories. Activities in the field of acoustics, ultrasound and vibration (AUV) metrology are carried out by two laboratories: Acoustics Laboratory and Medical Metrology Laboratory. Acoustics Laboratory has three different working areas, namely, acoustics, vibration and gravimetry. Ultrasound filed is covered by activities of Medical Metrology Laboratory. Acoustics Laboratory mainly performs primary and secondary calibration of devices used for acoustical and vibration measurements, e.g. microphones, sound level calibrators, accelerometers, calibration exciters etc. In addition, laboratory provides testing services such as sound power, sound intensity and sound absorption measurements. Acoustical tests (mainly sound power measurements) are performed in full compliance with relevant international standards and are accredited by Turkish Accreditation Agency (TÜRKAK), signatory of the ILAC MRA. Activities in the field of underwater acoustics are not covered by TÜBİTAK UME, but Underwater Acoustics Laboratory of Material Institute under Marmara Research Center is responsible for this field. The Laboratory is Designated Institute in this field since 2012. The Underwater Acoustics Laboratory is located in the same campus as TÜBİTAK UME.

National standards

Being responsible for realization, maintenance and dissemination of units TÜBİTAK UME has following calibration and measurement set-ups in the AUV field:

- Pressure reciprocity calibration of laboratory standard microphones from 1 Hz to 25 kHz
- Measurement of ultrasound power between 10 mW and 150 W
- Primary calibration of accelerometers with sinusoidal excitation in the range from 0.4 Hz to 20 kHz in both, magnitude and phase of the complex sensitivity
- Primary calibration of accelerometers with shock excitation in the range from 5 km/s^2 to 2000 km/s^2

In addition, TÜBİTAK UME has various calibration set-ups. Some of them are listed below:

- Calibration of sound level meters
- Calibration of sound calibrators and pistonphones
- Calibration and testing of mechanical couplers
- Calibration of vibration measuring chains
- Testing of acoustic couplers and ear simulators
- Calibration of impedance heads

and capability for verification of free-field and diffuse field environments.

Infrastructure

The laboratory is well equipped by various commercially available system and devices. However, there are few systems designed and constructed at TÜBİTAK UME, e.g. laser pistonphone, various reference sound sources, ultrasonic power transducers. TÜBİTAK UME has special acoustical facilities, Full Anechoic Room with 50 Hz cut-off frequency and Reverberation Room with 100 Hz cut-off frequency. These facilities used both for calibration/testing and research purposes.

Staff

Although activity of Acoustics and Medical Metrology Laboratories covers many subject fields there were permanent shortcoming with staff. From 4 to 5 people were working in the AUV field for a long time. This brought limitation to scope of activities with careful investigation of priorities. However, the situation was improved a little bit and new staff was hired both for Acoustics Laboratory and Medical Metrology Laboratory. Currently overall number of people working in two laboratories is 9, and four of them are chief researchers. Furthermore three out of 9 people have PhD degree. Work experience of the senior staff in the field of AUV metrology is more than 20 years.

Calibration/ Testing Services

Calibration and measurement capabilities of TÜBİTAK UME in AUV field as published on the BIPM KCDB includes 27 entries with the following breakdown in the subject fields: 16 in sound in air, 3 entries in ultrasound, and 8 entries in the field of mechanical vibration. No changes in CMCs were made during reporting period. However, TÜBİTAK UME is planning to revise CMC entries significantly on the base of results of EURAMET.AUV.A-K5 comparison in the nearest future.

On the average TÜBİTAK UME annually performs about 300 calibrations in AUV field for customers. The great majority of these calibrations are calibrations of microphones, sound calibrators, sound level meters, accelerometers and vibration measuring devices. The number of calibration certificates issued in the field of ultrasound is very limited. However, TÜBİTAK UME is strongly involved in research work in this field, especially on subjects related to characterization of HIFU transducers, development of transducers and devices for ultrasound power measurements. As five accredited calibration laboratories became operational in Turkey during past ten years, slight decrease in the number of calibrations performed by TÜBİTAK UME for customers occurred. These laboratories are accredited mainly for calibration of sound level meters, sound calibrators, microphones, accelerometers and noise dose meters.

Comparisons

BIPM Key Comparisons Database (KCDB) has records on 12 key comparisons participated by TÜBİTAK UME in AUV field. 3 other bilateral comparisons conducted with PTB (Germany) at the earliest stage of the establishment of Acoustics Laboratory are not registered at the BIPM KCDB, but their results are publicly available (e.g. Final Report of the EUROMET Project No: 736).

There were four official comparisons with TÜBİTAK UME involvement in the period from 2017 to 2019. They are following:

EURAMET.AUV.A-K5, Comparison of laboratory standard microphone calibrations
TÜBİTAK UME performed calibrations of microphones in the frequency range from 10 Hz to 10 kHz in February 2014 and reported results to pilot laboratory. Final report of the comparison was published in January 2019.

COOMET.AUV.V-K1, Comparison of accelerometer calibrations
Measurements within the comparison were completed in 2008. The final report of the comparison is still under consideration of the CCAUV KCWG.

CCAUV.A-K6, Primary pressure calibration of laboratory standard microphones LS2P
TÜBİTAK UME has just finished calibrations in September 2019. Measurements have been made in the full range from 2 Hz to 25 kHz both for magnitude and phase of complex pressure sensitivity. The evaluation of measurement results is in progress.

COOMET.AUV.A-S3, Determination of pressure sensitivity level of WS2F microphones by comparison method
Measurements within the comparison have been just started and TÜBİTAK UME will perform measurements in December 2019.

In addition, another supplementary comparison on calibration of single frequency sound calibrators were recently agreed within COOMET TC-AUV. The comparison will involve NMIs/Dis from 7 countries and will be piloted by TÜBİTAK UME.

Furthermore, TÜBİTAK UME was piloting bilateral comparison on ultrasound power measurements with Spanish research institute, having intention to be designated institute in future. The comparison was completed, and results were published in paper submitted to IEEE International Symposium on Medical Measurements and Applications (MeMeA) in June 2019.

Research and Other Projects

Since the establishment of basic calibration capabilities at the very beginning up to the recent years, TÜBİTAK UME has placed a growing emphasis on research activities that cross into areas that are outside its traditional remit as a national metrology institute. In AUV field TÜBİTAK has completed successfully or is currently active in the projects, which brief summary outlined below:

Metrology for a universal ear simulator and the perception of non-audible sound (Ears)

TÜBİTAK UME was involved in the tasks of characterization of novel universal ear simulator, which has the potential to significantly improve the calibration of audiological devices for better diagnosis and screening results mainly for newborns and children. The institute together with other partners performed measurements of transfer impedance of the universal ear simulator prototype. In addition, investigation of dependence of universal ear simulator on environmental conditions like static pressure and temperature were carried out. Furthermore, TÜBİTAK UME made clinical trials of universal ear simulator prototypes. The project was completed successfully in 2015.

Dosimetry for Ultrasound Therapy (DUTy)

The aim of the joint research project under European Metrology Research Programme (EMRP) was to develop the metrological infrastructure (definitions, validated measurement and modeling methods) which would underpin the specification of dose for therapeutic ultrasound applications allowing appropriate treatment planning and risk assessment. TÜBİTAK UME's activity was focused on the development of laboratory standards for thermal and non-thermal therapeutic dose parameters. TÜBİTAK UME worked on quantitative assessment of thermal and mechanical effects of therapeutic ultrasound by sonicating a joint-mimicking phantom, made of muscle-equivalent material. The project was completed in 2015.

Realisation, dissemination and application of the unit watt in airborne sound (SIB56 SoundPwr)

The project, which is currently in progress, has the primary goal to establish traceability for the measurand sound power to SI units. Starting point is a primary standard for the unit Watt in airborne sound. TÜBİTAK UME among other four partners developed a primary standard for airborne sound power in the frequency range between 100 Hz and 20 kHz based on a vibrating solid body. Sound power of the source was determined on the base of velocity values measured by laser vibrometer and by conventional methods. Results for both methods agree in the order of 0.5 dB for the broad frequency range with exceptions at low frequencies below 125 Hz. The joint research project has been completed successfully in 2016.

Metrology for modern hearing assessment and protecting public health from emerging noise sources (Ears II)

The joint research project in the framework of the European Metrology Programme for Innovation and Research (EMPIR) has been started in 2016. The project is considered somehow as a continuation of the Ears project. There are many ambitious goals of the project involving 11 partners from 6 European countries, where PTB (Germany) acts as a coordinator. Partners will investigate how infrasound and ultrasound affect human beings. Different means with methods of audiology and imaging procedures of neurology will be applied by partners. Interest will particularly be focussed on the measurement and assessment of airborne ultrasound at workplaces. This includes

also the development of new hardware which is additionally granted by another project. Furthermore, the development of a novel universal ear simulator (family of devices) will be continued and finished. In connection with a newly developed calibration procedure for transient signal it has the potential to significantly improve the calibration of audiological devices for better diagnosis and screening results mainly for newborns and children. TÜBİTAK UME was involved in activities of four work packages out of 7. The joint research project has been completed successfully in 2019.

Radiotherapy coupled with hyperthermia - adapting the biological equivalent dose concept (RaCHy)

The joint research project in the framework of the European Metrology Programme for Innovation and Research (EMPIR) has been started in 2019. The project coordinated by the Italian National Metrology Institute (INRiM) Has many objectives. First new calibration devices, a new measurement framework and measurement techniques will be developed in the frame of the project. Furthermore, biological mechanisms will be assessed, for controlled and reproducible delivery of radiation and hyperthermia, and patient-specific prescriptions. Combinations of radiotherapies will be compared with different hyperthermia treatments, with and without heat, to quantify a dose modifying factor.

Development of Metrology Infrastructure at SASO (Saudi Arabia)

TÜBİTAK UME was involved in the joint project with Standardization Organization of Kingdom of Saudi Arabia (SASO) with the aim of establishment metrological infrastructure at the National Measurement and Calibration Center (NMCC). In the AUV field this activity mainly involved the following calibration systems:

- System for reciprocity calibration of microphones
- System for comparison calibration of microphones
- System for calibration of sound level meters and sound calibrators
- System for calibration of audiometers
- System for primary and secondary calibration of vibration pick-ups, calibration exciters and vibration measuring chains.

All systems were successfully designed, purchased and installed at SASO NMCC. Extensive training of SASO NMCC both at TÜBİTAK UME and SASO has been done. The project was successfully completed in 2018.

Renovation and Further Development of TÜBİTAK UME Research Infrastructure

5 years investment project has been started in May 2017 and is funded by Ministry of development of Turkish Republic. Although the core part of the project deals with an establishment of infrastructure for quantum metrology, the project itself consists of 22 work packages. 3 of them are concerning with establishment of new infrastructure for acoustics and vibration measurements. This includes extension of frequency range for primary microphone calibrations (both magnitude and phase) down to 1 Hz, extension of frequency range of primary calibration of vibration pick-ups down to 0,5 Hz and establishment of system for shock calibrations. Systems for acoustics and vibration calibrations were successfully installed and put into operation in 2018. View of few systems are presented in Figures 1 – 3

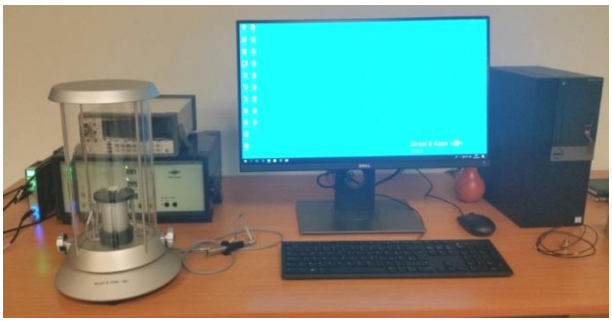

Figure 1. Upgraded system for reciprocity calibration of microphones

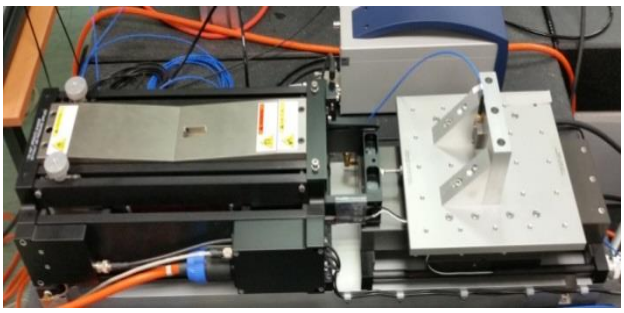

Figure 2. System for low frequency calibration of accelerometers

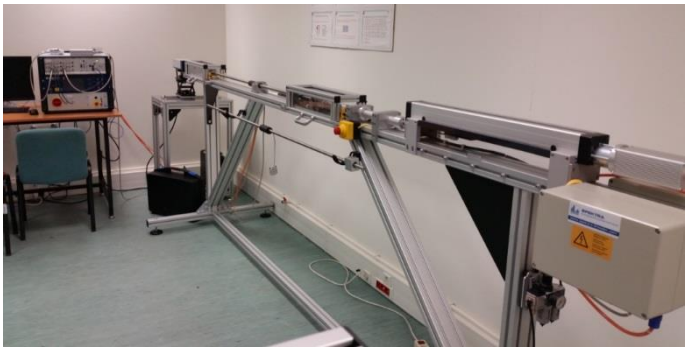

Figure 3. System for calibration of accelerometers with shock excitation

Publications

The list of publications of TÜBİTAK UME in AUV field in the period from 2017 to 2019 is given below:

Sound in air

1. E.Sadıkoğlu, E.Bilgiç, C.Kırbaş, İ. Coşkun, **Example of Cooperation in the European Union for Strengthening the Metrology Basis for Hearing Assessment**, 12th National Acoustics Congress, 14-15 September 2017, İzmir, Turkey (in Turkish)
2. E.Bilgiç, E.Sadıkoğlu, C.Kırbaş, İ. Coşkun, S. Beşiroğlu, **Sensor and Signal Conditioner Calibrations for Acoustics and Vibration Field Applications**, 12th National Acoustics Congress, 14-15 September 2017, İzmir, Turkey (in Turkish)
3. C.Kırbaş, E.Bilgiç, E.Sadıkoğlu, **Characterization of Reference Sound Sources**, 12th National Acoustics Congress, 14-15 September 2017, İzmir, Turkey (in Turkish)
4. K.Saher, S.Nas, B.Karaböce, C.Kırbaş, E.Sadıkoğlu, **Comparison of Measured and Simulation Values of Reverberation Time in Reverberation Room**, 12th National Acoustics Congress, 14-15 September 2017, İzmir, Turkey (in Turkish)
5. E.Bilgiç, H.Mutaf, C.Kırbaş, E.Sadıkoğlu, **Evaluation of Uncertainty Contributions of Measurement Surface and Number of Microphone Positions in Determination of Sound Power Levels**, Acta Physica Polonica A, 132:3 (2017) : 642-649

6. E.Sadıkoğlu, E.Bilgiç, **Metrological Traceability and Reliability of Audiological Measurements**, 9th National Audiology and Speech Disorders Congress, 11-13 October 2018, İstanbul, Turkey (in Turkish)

7. E.Sadıkoğlu, E.Bilgiç, C.Kırbaş, İ.Coşkun, **New Initiative for Reliability of Hearing Assessment: Development of an Universal Ear Simulator**, 9th National Audiology and Speech Disorders Congress, 11-13 October 2018, İstanbul, Turkey (in Turkish)

8. E.Bilgiç, E.Sadıkoğlu, C.Kırbaş, İ.Coşkun, **Establishment, Verification and Application of THD+Noise Measurement System for Sound Calibrator and Field Vibration Calibrator**, International Conference on Computational and Experimental Science and Engineering (ICCESEN 2018), 12 – 16 October 2018, Antalya, Turkey

9. J. Avison, P. Harris, S. Robinson, D. Rodrigues, C. Guglielmone, C. Hof, E. Sadıkoğlu, M. Chushkov, S. Zelenika, P. Rosenkrantz, H. Andersson, T. Fedtke, C. Koch, N. Medina Martin, S. Ruiz, H. Shawky, **Final Report: Key Comparison EURAMET.AUV.A-K5**, Metrologia, 56:1A, Technical Supplement (2019): 09001

10. C. Kırbaş, M.Yu. Seyidov, **Influence of Native Structural Defects Activated by Illumination and under the Memory Effect Conditions on Ultrasonic Wave Propagation in $TlInS_2$ Ferroelectric-Semiconductor with Incommensurate Phase**, Material Research Express, 6:8 (2019): 085914

11. E. Sadıkoğlu, E. Bilgic, **Characterization Measurements of New Family of Ear Simulators at TÜBİTAK UME**, The 14th edition of IEEE International Symposium on Medical Measurements and Applications (MeMeA), 26-28 June 2019, İstanbul, Turkey

Ultrasound

1. B.Karaböce, H.O.Durmuş, E.Çetin, M.Özdingiş, **Power Calibration of Therapeutic Ultrasonic Transducers**, 12th National Acoustics Congress, 14-15 September 2017, İzmir, Turkey (in Turkish)

2. B.Karaböce, M.Özdingiş, H.O.Durmuş, E.Çetin, **Portable Ultrasonic Power Meter System**, 12th National Acoustics Congress, 14-15 September 2017, İzmir, Turkey (in Turkish)

3. B.Karaböce, E.Çetin, H.O.Durmuş, **Thermal Effects of High Intensity Focused Ultrasound, National Biophysics Congress**, 6-9 September 2017, İstanbul, Turkey

4. B.Karaböce, E.Çetin, H.O.Durmuş, M.Özdingiş, **Investigation of Viscous Heating Effect of Thermocouples under HIFU Applications**, National Congress of Medical Technologies (TIPTEKNO'17), 12 – 14 October 2017, Trabzon, Turkey (in Turkish)

5. B.Karaböce, E.Çetin, M.Özdingiş, H.O.Durmuş, **Image Measurement Verification Studies of Different Objects in Tissue-Mimicking Phantom**, National Congress of Medical Technologies (TIPTEKNO'17), 12 – 14 October 2017, Trabzon, Turkey (in Turkish)

6. E.Çetin, B.Karaböce, O.Kılınç, O.Orun, **Biological Effects of HIFU on HT-29 Colon Cancer Cell Lines**, 2018 IEEE International Symposium on Medical Measurements and Applications (MeMeA), 11 – 13 June 2018, Rome, Italy

7. M.Özdingiş, B.Karaböce, Y.E.Erdemli, **Production of Probes to Characterize Acoustic Field Effects Due to the Geometry of Piezoelectric Transducers: Rectangular and**

Rhomboid Transducers, 2018 IEEE International Symposium on Medical Measurements and Applications (MeMeA), 11 – 13 June 2018, Rome, Italy

8. B.Karaböce, E.Çetin, H.O.Durmuş, M.Özdingiş, H.Öztürk, K.Mahmat, M.A.Güler, **Investigation of Different TMMs in High Intensity Focused Ultrasound Applications**, 2018 IEEE International Symposium on Medical Measurements and Applications (MeMeA), 11 – 13 June 2018, Rome, Italy
9. B.Karaböce, **Establishment of Ultrasonic Power Measurements Standard at TÜBİTAK UME and Bilateral Comparison Results**, International Journal of Acoustics and Ultrasonics, Volume 1:1 - 2 (2018): pp.13-18
10. E.Çetin, H.O.Durmuş, B.Karaböce, **Inspection of an Ultrasonography Device by Using Ultrasound Phantom: An Example of Operator Proficiency Test**, National Congress of Medical Technologies (TIPTEKNO'18), 8 – 10 November 2018, Gazi Magosa (in Turkish)
11. B.Karaböce, E.Çetin, H.O.Durmuş, H.Öztürk, K.Mahmat, M.A.Güler, H.Korkmaz, **Variation of Temperature Responses Resulting from HIFU Application According to Acoustic Parameters**, National Congress of Medical Technologies (TIPTEKNO'18), 8 – 10 November 2018, Gazi Magosa (in Turkish)
12. B.Karaböce, H.O.Durmuş, E.Çetin, M.Özdingiş, **Investigation of Hardness of Backing Material Used in Piezoelectric Transducers**, National Congress of Medical Technologies (TIPTEKNO'18), 8 – 10 November 2018, Gazi Magosa (in Turkish)
13. M.Özdingiş, B.Karaböce, K.Bostan, H.Korkmaz, **Increasing Power Transmission Efficiency of Ultrasonic Transducers Used in Physiotherapy**, National Congress of Medical Technologies (TIPTEKNO'18), 8 – 10 November 2018, Gazi Magosa (in Turkish)
14. B.Karaböce, H.O.Durmuş, E. Çetin, **Establishment of Measurement System for Hearing Aids at TÜBİTAK UME**, International Conference on Medical and Biological Engineering (CMBEBIH 2019), 16 – 18 May 2019, Banja Luka, Bosnia and Herzegovina
15. E. Çetin, B. Karaböce, H.O. Durmuş, H. Gürbüz, S. Altınay, **Determination of Thermal Lesions Formed by HIFU Using Polyacrylamide Based Phantom Containing Egg White**, The 14th edition of IEEE International Symposium on Medical Measurements and Applications (MeMeA), 26-28 June 2019, İstanbul, Turkey
16. E. Çetin, H.O. Durmuş, B. Karaböce, N. Kavaklı, **Acoustical Characterization of Tissue - Mimicking Materials**, The 14th edition of IEEE International Symposium on Medical Measurements and Applications (MeMeA), 26-28 June 2019, İstanbul, Turkey
17. B. Karaboce, M. Özdingiş, M., H.O. Durmuş, E. Çetin, **Load Cell Based Ultrasonic Wattmeter for Ultrasonic Probe Calibration**, The 14th edition of IEEE International Symposium on Medical Measurements and Applications (MeMeA), 26-28 June 2019, İstanbul, Turkey
18. H.O. Durmuş, B. Karaböce, E. Çetin, M. Ozdingiş, E. Toprak, S.S. Topşar, Ş. Balcı, **Investigation of the Effect of Tungsten Used in Backing Materials of Ultrasound Probes on Acoustical Parameters**, The 14th edition of IEEE International Symposium on Medical Measurements and Applications (MeMeA), 26-28 June 2019, İstanbul, Turkey
19. H.O.Durmuş, E.Çetin, B.Karaböce, **An Evaluation of Performance Tests of In-Ear Hearing Aids**, The 14th edition of IEEE International Symposium on Medical Measurements and Applications (MeMeA), 26-28 June 2019, İstanbul, Turkey

20. G. Durando, B. Karaböce, G.T. Haar, A. Denkova, P. Miloro, J.D. Pooter, B. Caccia, R. Dijkema, V. Wilkens, G.V. Rhoon, A. Spinelli, RaCHy - **Radiotherapy Coupled with Hyperthermia - 18HLT06 EURAMET EMPIR Project**, The 14th edition of IEEE International Symposium on Medical Measurements and Applications (MeMeA), 26-28 June 2019, İstanbul, Turkey

21. B. Karaböce, H.O. Durmuş, E. Çetin, M. Özdingiş, F.M. de Espinosa, F. Chinchurreta, A. Alvarez, **Bilateral Intercomparison of Ultrasound Power Standards Used for Calibrations in Medical Field**, The 14th edition of IEEE International Symposium on Medical Measurements and Applications (MeMeA), 26-28 June 2019, İstanbul, Turkey

22. M. Özdingiş, B. Karaböce, H.O. Durmuş, E. Çetin, **Automatic Measurement Software Algorithm for Embedded System Used in Portable Ultrasonic Power Meter**, The 14th edition of IEEE International Symposium on Medical Measurements and Applications (MeMeA), 26-28 June 2019, İstanbul, Turkey

Vibration and Acceleration

1. E.Bilgiç, **Determination of Pulse Width and Pulse Amplitude Characteristics of Materials Used in Pendulum Type Shock Calibration Device**, Acta Physica Polonica A, 132:3 (2017) : 857-860