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Kozloduy Nuclear Power Plant

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PLENARY SESSION

Bulgarian Institute of Metrology's last year activities in the field of scientific metrology

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***Abstract*—Bulgarian Institute of Metrology (BIM) performing its duties as Bulgarian National Metrology Institute has a key role in metrology infrastructure. The main activities of BIM support the quality of life and the development of the economy. This is done by providing metrological traceability for national measurements using national standards and certified reference materials that BIM develops and maintains.**

Keywords—metrology, BIM, BIPM, EURAMET, EMPIR, calibration and measurement capabilities (CMC).

I. Introduction

In its activity, Bulgarian Institute of Metrology (BIM) follows the policies, recommendations and strategies of the international metrological organizations in which the Republic of Bulgaria is a member.

The main objectives of BIM are to support the development and reliability of measurements for the benefit of society, science and economy. It is achieved through the following main activities:

- maintaining and developing national standards to ensure their international equivalence;
- producing certified reference materials;
- ensuring traceability to BIPM or to other NMIs for those units for which national primary standards are not supported;
- dissemination of units to accredited laboratories, other industrial and commercial laboratories and costumers;
- ensuring traceability of standards used in legal metrology;
- participation in international comparisons to demonstrate their international equivalence;
- maintaining a quality system (EN ISO/IEC 17025 and ISO Guide 34);
- cooperation with other NMIs, with regional and international organizations and representation of the country in these organizations;
- organization of proficiency testing;
- other activities arising from the responsibilities of BIM as a national metrology institute.

The achievement of strategic goals and the implementation of operational actions in recent years is a solid basis and a guarantee for the realization of the mission and vision of BIM.

These activities lead to:

- development and maintenance of modern reference laboratories in the main measurement areas of BIM;
- participation in international comparisons to demonstrate international equivalence of standards and to support calibration and measurement capabilities (CMCs) [2];
- maintaining, improving and expanding internationally recognized calibration and measurement capabilities;
- capacity building for research projects and participation in the European research program EMPIR [3];
- improving the metrological control activities;
- provision of new and improved services;
- human resources development in BIM;
- strengthening the links with stakeholders.

II. National Reference Laboratories

BIM currently maintains reference laboratories at the modern level in the following measurement areas:

- Acoustics and vibrations,
- Time and frequency;
- Length and angle;
- Electroenergy measurements;
- Electromagnetic measurements;
- Chemical measurements;
- Ionizing radiation;
- Mass and volume;
- Pressure, force and hardness;
- Flow;
- Temperature and relative humidity;
- Photometry and radiometry.

III. International Comparisons and Calibration and Measurement Capabilities

Another major activity is participating in international comparisons to support the calibration and measurement capabilities (CMC). At present BIM has over 80 participations in international comparisons. Thanks to the good results of the comparisons, BIM has submitted and published 227 CMC entries in the BIPM database. The final reports for two comparisons were published in 2020. The main results are shown in Fig. 1 and Fig. 2 - respectively in the field of volume measurement and temperature measurements.

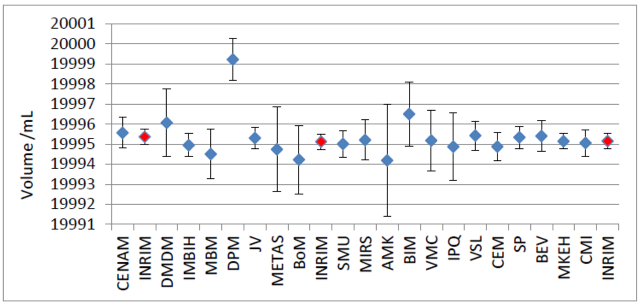

Fig. 1. Results as reported by the participants. Results from the INRIM pivot laboratory in red.

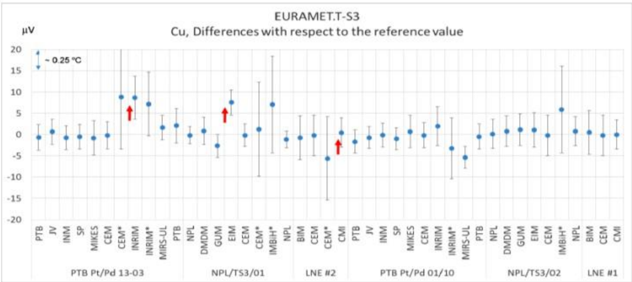

Fig. 2. Reported e.m.f. for Cu thermocouple (difference with respect to the reference value).

IV. PT Provider

Since 2012 BIM has been accredited as PT Provider by the Dutch Accreditation Body RvA according to EN ISO 17043 for Mass, Temperature, Electrical and Chemical Measurements. Outside of these measurement areas, BIM also organizes interlaboratory comparisons in line with the requirements of this standard.

V. Project for QMS Peer Visits and Reviews

In 2011, EURAMET project 1208 for peer visit was launched with the participation of BIM and the Serbian NMI - DMDM. Later the NMIs of Montenegro, Bosnia and Herzegovina, North Macedonia and Latvia joined the project.

VI. Quality Management System

BIM maintains and develops a quality management system (EN ISO / IEC 17025 and ISO Guide 34). According to EURAMET's rules, once every 5 years, the system is presented at the TC – Quality [4]. A change is currently in progress according to the requirements of the new version of the standard.

VII. Participation in Projects of the European Research Program EMPIR

Bulgarian Institute of Metrology joined the European Metrology Program for Innovation and Research EMPIR in 2013. BIM is currently one of the 28 EMPIR participants.

At present, BIM participates in the following projects:

18RPT03 MetForTC - Traceable measurement capabilities for monitoring thermocouple performance

- Project start date and duration: June 2019, 36 months
- Partners - TUBITAK, Turkey; BFKH, Hungary; BIM, Bulgaria; BRML, Romania; CMI, Czech Republic; FSB, Croatia, IMBiH; Bosnia and Herzegovina; JV, Norway; INM, Moldova; MER, Montenegro; [5]
- Objectives [5]

The general aim of this project is to develop novel scientific and technical capabilities providing both the dissemination of the International Temperature Scale ITS-90, and accurate low uncertainty temperature measurements by thermocouple, which is the most frequently used temperature sensing instrument.

This objective will be achieved by developing novel practical methods and devices for checking thermocouple drift performance to determine the inhomogeneity of thermocouples for primary and secondary calibration laboratories.

For high precision calibration, primary and secondary calibration laboratories are required to determine the inhomogeneity of thermocouples while performing their calibrations. Unfortunately, standardised, easy-to-use methods and devices are not currently available for the task. At the level of primary laboratories, new and extended traceable measurement methods and devices that will provide confidence in the verification of thermocouple performance are needed.

This project will develop novel methods and techniques, traceable to the ITS-90 that will significantly improve knowledge on drift and homogeneity as well as confidence in the verification of thermocouple performance.

The specific objectives are:

1. To develop and test novel methods and devices for the monitoring of thermocouple drift in-situ in the temperature range up to 1100 °C. These methods have to be suitable for implementation in critical industrial processes in order to assist the users in maintenance and replacement decisions.

2. To develop and test easy-to-operate methods and instruments for the assessment of inhomogeneity of thermocouples for secondary calibration laboratories in the temperature range from 230 °C to 1100 °C.

3. To design and construct novel measurement facilities that can provide confidence in the verification of thermocouple performance and to identify and quantify the range of drift of the thermocouples.

4. for each participant, to develop an individual strategy for the long-term operation of the capacity developed. The individual strategies will lead to an overall strategy document to be presented to the EURAMET TC-T, to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole.

- Impact

This project will have an impact on a wide range of industries where temperature measurement and control are vitally important, as well as on healthcare, climate change and global warming monitoring. Control of temperature is critical to many industrial processes, yet the relevant sensors require regular calibration.

1. Impact on industrial and other user communities

By organising workshops for accredited laboratories and industry stakeholders, the dissemination of knowledge will be extended to the end user. Ultimately this will facilitate the dissemination of traceable temperature measurements in ranges relevant for high value manufacturing in the participating countries.

Additionally, the NMIs/DIs will have closer relations and strengthen the collaboration with the users' associations, manufacturers, and other stakeholders, and will provide guidance to traceability and good practice in thermometry.

2. Impact on the metrology and scientific communities

The Consultative Committee for Thermometry (CCT) felt the need to establish the Working Group for Secondary Thermometry (WG2) and recommends research at NMIs on novel secondary techniques, monitoring stakeholder needs.

The project will be presented to the accreditation authorities in Europe as well as to end users and manufacturers of thermocouples.

There are a number of smaller NMIs in the consortium and their participation in this project will substantially contribute to capacity building, particularly in the area of thermocouple calibration and the facilities and skills required assessing thermocouple performance.

3. Impact on relevant standards

The project will support active participation and influencing in key European temperature related committees such as the Consultative Committee for Thermometry (CCT) and CCT Task Group for Guides on Thermometry, EURAMET Technical Committee on Thermometry TC-T, EURAMET Technical Committee for Quality TC-Q, and COOMET TC1.10.

4. Longer-term economic, social and environmental impacts

Establishing traceable measurements in the temperature field and collaboration in research (construction of miniature fixed-point cells and new facilities for characterisation of artefacts) will enable important inputs for areas of research, innovation and patenting in this field in future European research.

18RPT01 ProbeTrace - Traceability for contact probe and stylus instrument measurements

- Project start date and duration: June 2019, 36 months
- Partners - TUBITAK, Turkey; BIM, Bulgaria; CEM, Spanish; DMDM, Serbia; FSB, Croatia; GUM, Poland; INRIM, Italy; IPQ, Portugal; NIS, Egypt; SASO-NMCC, Saudi Arabia; [6]
- Objectives [6]

The general aim of this project is to develop traceable and cost-effective measurement capabilities for the calibration of form and surface roughness standards with uncertainties in the range 10 nm - 100 nm. Surface finish and form of products are important features to be examined for engineering and scientific purposes. Such characteristics of surfaces include wear resistance, bearing, sliding and lubricating properties, fatigue and corrosion resistance, functionality etc. Form and surface measurement devices with contact probes and stylus are used to characterize such surfaces. This project will improve the scientific knowledge, instruments, methods and research capability in metrology for contact measurement probes and stylus instruments and enable calibration labs to develop new capabilities for self-provision of traceability to the SI unit of length, the meter.

The specific objectives of the project are:

1. To calibrate reference stylus instruments for surface roughness measurements using novel portable displacement generators with uncertainties in the range 10 nm–100 nm and to evaluate the efficacy of displacement generators vs existing methods for calibration of stylus devices. Further, to develop novel software for the calibration of stylus devices using sphere standards.

2. To calibrate reference probes for form measurements in static and dynamic mode using novel portable displacement generators and to evaluate the current state of the art for calibration of flick standards.

3. To investigate the traceable calibration of transducers to be used as portable displacement generators under static (+/- 1000 μm) and dynamic (+/- 100 μm) measurement conditions. Further, to prepare two best practice guides on their use in the calibration of stylus instruments and form measurement probes.

4. To develop noise reduction software, including the use of numerical methods for random noise bias reduction, that can be used to reduce the uncertainties down to a level of 10 nm in roughness and roundness measurements.

5. For each project partner, to develop an individual strategy for the long-term operation of the capacity developed. The individual strategies will ensure that a coordinated and optimized approach to the establishment of traceability in this field is developed for Europe as a whole.

- Impact

1. Impact on industrial and other user communities

The NMIs will establish new services for calibration of form and surface roughness standards using the traceability route established with the novel methods developed in the project. In addition, newly developed guides will facilitate the application of the new methods for Coordinate Measuring Machines, form and stylus instrument users and manufacturers.

2. Impact on the metrology and scientific communities.

Newly developed methods, which will provide alternatives to the conventional ones, will create an impact on calibration laboratories end users and manufacturers.

Knowledge transfer from experienced NMIs to those less experienced on how to use these new types of standards will be very beneficial. The project will strengthen the collaboration of European NMIs and will increase their competitiveness and consistency by producing a draft calibration guide for the use of portable displacement generators for calibration of stylus instruments and contact measurement probes.

3. Impact on relevant standards

After its end, the project will contribute to a further revision of ISO 12179 [7], use of depth setting standards for calibration of contact stylus instruments. The results will be promoted within the standardization community and will provide input into the standardization process. A contact will be made with the EMPIR project 17NRM03 EUCoM - Standards for the evaluation of the uncertainty of coordinate measurements in industry [8] to share the project outputs.

4. Longer-term economic, social and environmental impacts

Measurement of form and surface finish parameters relate to functionality of manufactured parts. Better achievements for the desired tolerances on automotive parts will provide better engine parts working more efficiently with improved fuel savings, longer life time, reduction in waste and production time, which altogether will have a positive impact on the environment.

The project will provide this for surface roughness and form measurements, which will in turn result in improvements of manufacturing processes. This will increase economic growth in Europe and its neighbouring region(s) and enhance industry competitiveness and will therefore be instrumental for creating jobs particularly in the production of parts in a cost-effective way.

19RPT02 RealMass "Improvement of the realisation of the mass scale"

Participants: CMI, Czech Republic; BEV-PTP, Austria; BIM, Bulgaria; BRML, Romania; DMDM, Serbia; IMBiH, Bosnia and Herzegovina; INRIM, Italy; NSAI, Ireland; SMD, Belgium; [9]

Project started in 2020, duration – 36 months.

The scientific and technical objectives of the project are:

1. To analyse 3 selected calibration methods for the realisation and dissemination of the mass scale (e.g. 1 mg – 20 kg with uncertainties of 0.001 mg – 3 mg or better) including the impact from the recent redefinition of the kilogram, and to create an appropriate methodology in order to optimise different technical requirements and parameters (e.g. robustness, effectiveness, small uncertainty, properties of different weighing instruments, different types of weight sets, number of control weights or standards).

2. To develop and implement calibration methods to realise, improve and maintain the mass scale (e.g. from 1 mg to 20 kg with uncertainties of 0.001 mg – 3 mg or better) in countries where mass scale measurement capabilities are less developed, taking into account the requirements and the metrological needs of stakeholders. New or improved measurement capabilities should be validated by interlaboratory comparisons to establish the degree of equivalence.

3. To develop advanced mathematical and statistical tools and software solutions to calculate the results from the dissemination of the mass unit in the range 1 mg – 20 kg and to evaluate the associated uncertainties (including correlations between standards and measurements, and the handling of outliers). To validate developed mathematical and statistical tools for calculation of results (via a least squares method) and uncertainties (via an expanded model for covariance matrices and accounting for buoyancy corrections) via simulated and experimental data.

4. To develop a draft EURAMET calibration guideline for the realisation of the mass scale in the range from 1 mg to 20 kg with uncertainties of 0.001 mg – 3 mg or better, including the establishment of reliable dissemination schemes and methods to check and improve the long-term mass stability (including examples involving different equipment and methods to be used to extend or reduce the calibration range) and to submit it to EURAMET for approval.

5. For each participant, to develop an individual strategy for the long-term operation of the capacity developed, including regulatory support, research collaborations, quality schemes and accreditation. They should also develop a strategy for offering calibration services from the established facilities to their own country and neighbouring countries. The individual strategies should be discussed within the consortium and with other EURAMET NMIs/DIs including EURAMET TC-M, OIML TC SC9/SC3, COOMET TC 1.6, WELMEC WG2/WG6, and IMEKO TC3 and members of relevant EMNs or JRPs, to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole.

Impact:

1. Impact on industrial and other user communities

This project will establish an improved calibration service that will provide end users with access to calibrations in the range 1 mg – 20 kg with uncertainties of 0.001 mg – 3 mg or better. Such conditions will be beneficial, for example, for producers of weighing instruments. The guidance for the dissemination of the mass unit will enable emerging countries to further develop their calibration services which will be used by other calibration laboratories and industrial customers such as the chemical, pharmaceutical or automotive industry. These customers will be able to improve their internal processes which will lead to the improvement of the competitiveness of European industries. The outcomes will be disseminated to laboratories and industrial stakeholders by organising 1 general workshop for partners from Europe, 5 national workshops for local stakeholders and by presenting the project's results at 3 conferences and in 5 articles in peer reviewed scientific journals.

2. Impact on the metrological and scientific communities

Based on the project's results, the draft EURAMET guideline for the dissemination of the mass unit focusing on the 1 mg – 20 kg range with uncertainties of 0.001 mg – 3 mg or better will be developed. This will create a large impact on calibration laboratories and it will be presented to regional metrology organisations such as COOMET TC 1.6, accreditation organisations as well as to end users and manufacturers of weighing instruments.

The knowledge transfer from experienced NMIs to those less experienced in the process of dissemination of the mass unit will be very beneficial. The project will strengthen collaboration of the European mass laboratories and it will increase their competitiveness.

The EURAMET calibration guideline will describe 3 recommended procedures for selecting right combination of weighing cycles based on stability, robustness and statistical tools, methods for the calculation of the calibration results and uncertainty evaluation. The EURAMET guideline, covering all of these topics, will be beneficial for all Regional Metrology Organisations and for all NMIs worldwide. The draft EURAMET guideline will be submitted to EURAMET and it will be made available to users together with the developed software tools.

3. Impact on relevant standards

The consortium will promote the results of the project within the standardisation community and will provide input into the standardisation process e.g. COOMET TC 1.6 “Mass and related quantities”, OIML TC9/SC3 “Weights” or CCM-WGM. The project will have impact on future revision of OIML R111. One of the planned deliverables, the EURAMET guide on the dissemination of the mass unit, will become an official guide once approved by EURAMET. This will have an impact on other similar guides that are issued by other regional metrology organisations (such as COOMET, AFRIMETS or APMP).

4. Longer-term economic, social and environmental impacts

By improving the dissemination of the mass unit at the NMI level in the 1 mg – 20 kg range with uncertainties of 0.001 mg – 3 mg or better, this project will provide a better measurement capability for laboratories which are currently less developed in the field of mass. European calibration laboratories and industry should be able to engage with the new calibration services and to have their instruments calibrated within Europe as close as possible to the location of the respective laboratory. This will meet the demands of industry to obtain high accuracy calibration services in Europe. The expanded availability of the calibration service will reduce the time when the calibrated items are not available to the stakeholders and the travel distance of the equipment, which will reduce the risk of damage and travel costs. The increased availability of the calibration of the weights with state-of-the-art uncertainties in the 1 mg – 20 kg range will reduce calibration service costs for the industry. This will result in better competitiveness as they will be able to invest this budget in further research and services.

SCP-03 Smart PhoRa “Smart specialization and stakeholder linkage in Photometry and Radiometry”

Project started in 2021, duration – 18 months.

The scientific and technical objectives of the project are:

1. Investigation of the spectral and spatial distribution of rays harmful to human vision from various sources (for example, UV radiation from bactericidal lamps intended for disinfection of viral contaminants by Covid 19).

2. Two two-week trainings for two experts at the metrological institutes of Germany and France and two one-week trainings for two experts in Spain and Finland.

VIII. CONCLUSION

Bulgarian Institute of Metrology performing its activities as a National Metrology Institute has a substantial contribution to the maintenance and development of metrological infrastructure in Bulgaria. Following the policies, recommendations and strategies of the international metrological organizations BIM also has activities in collaboration with other NMIs, including participation in EURAMET projects.

Our participation in EMPIR projects, including RMG and capacity building training programs gives a great benefit to BIM - to increase the competence and confidence of our colleagues in the relevant areas.

These projects are not in the field of fundamental metrology, such as projects relating to the definition of physical constants and new definitions, but nevertheless they have a specific contribution to the development of metrology in Europe.

Also it is important to note that the active and successful participation in EMPIR projects affects the international prestige of BIM and the confidence in the measurements in Bulgaria.

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Temporological Analysis of the Distinguished Mathematicians

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***Abstract*— This study presents further exploration of the temporological approaches and four-elements models described in Cartography of Emotions and tested on the personal data of the Nobel laureates in literature [1-3]. Comparison of the characteristics of the recipients of prestigious prizes in mathematics (Fields, Wolf, Abel and Lobachevsky) with the Nobel laureates sheds new light on the processes of creativity and on our perception of the world in general. One of the results of this analysis reveals measurable differences between the Nobel laureates in literature and their mathematical counterparts.**

***Keywords*— Abel Prize, Nobel Prize, elements, mathematical thinking, measurements in humanities**

I. Introduction

Analyzing the personalities of mathematicians is much more difficult than analyzing the worldview of writers or poets, whose metaphors and imagery are reflected in their publications. Jacques Hadamard (1865-1963) was one of the first scientists to draw attention to the importance of studying the worldview of mathematicians and to contradict their stereotype as the absent-mind professor. He suggested that mathematical ideas, discoveries, and inventions are but a special case of a creative process in general, be it in sciences, in literature or in art. In his pioneer research "Psychology of Invention in the Mathematical Field" (1945) he discussed the results of a survey of a large number of his fellow mathematicians [4]. It turned out that mathematical thinking is not limited to a chain of logical reasoning but is the result of several complex and often intuitive processes of unknown nature. Like Pythagoras, most of the great mathematicians were also skilled in sciences, poetry and music. Mathematicians were also active in political life. For example, the French mathematician and statesman Paul Painlevé (1863-1933) served twice as Prime Minister of the Third Republic. Hadamard himself was not only a prominent mathematician, but also a professional violinist. He was also showing passion about social affairs, including taking a Dreyfusard stance and being an avid supporter of the Hebrew University of Jerusalem.

One of Hadamard's important observations was that mathematicians themselves often think differently and come to different conclusions. Hadamard's communication with Henri Lebesgue (1875-1941) led both mathematicians to accept their basic differences: "We could not avoid the conclusion that evidence – that starting point of certitude in every order of thinking – did not have the same meaning for him and for me. Only, of course, we were never tempted to despise each other merely because we recognized the impossibility of understanding each other" [4, p. 92].

Hadamard could not outline the most common types of thought for all mathematicians. Nevertheless, in the present work we are not studying all mathematicians, but only those of them who have achieved fame and the most prestigious awards. Significantly, the most impressive qualities of such mathematicians were also inherent in Hadamard, including his exceptionally long and active life. The following section reviews age dynamics in mathematical prizes (all data are updated for January 2021).

II. Mathematical Prizes and Age Dynamics of Laureates

It is symbolic that the first award of the prestigious Lobachevsky Prize took place in 1897, during the Phoenix Hour of 1885-1900 (i.e. during a period of radical and long-term historical changes [3, 5]). Since then, the prize has been awarded irregularly, and 28 people have become its laureates. Their average age at the time of award was 57, and the oldest of them was 91.

The Fields Medal is regarded as one of the highest honors a mathematician can receive, and has been described as the mathematician's Nobel Prize. It was established in 1936 by the Canadian mathematician John Fields (1863-1932), who demanded an age limit: a recipient must be under the age of 40 on the first of January, on the year in which the medal is awarded. The laureates receive a gold medal and ~ $ 11.000. Since 1950, the prize has been awarded every four years. 60 people have become its laureates, and their average age is 34.8.

The Wolf Prize in Mathematics, established in 1978 in Israel, is considered the most prestigious award after the Nobel Prize. The prize is $ 100,000 and is paid from a fund created by the chemist Ricardo Wolff (1887 - 1981) and his wife Francisca. 64 people became its laureates in mathematics. The average age of the laureates at the time of award is 66.5. The youngest laureate was 43 years old, and the oldest – 89 years old. The average age of 30 laureates, who had died before 2020, was 82.7 years; the oldest of them, Henri Cartan, who had died at the age of 104.

The annual Abel Prize is about $ 693,200 and it is named after the distinguished Norwegian mathematician Niels Henrik Abel (1802 - 1829). It was established in 2002 by the Norwegian government and modeled after the Nobel Prizes. The prize was first proposed in 1899 by the mathematician Sophus Lie (1842 - 1899) to be part of the celebration of the 100th anniversary of Abel's birth. The incentive was Nobel's decision to exclude mathematics from the areas in which the prize was awarded. Unfortunately, Lee's sudden death occurred at the very end of the Phoenix Hour of 1885-1900, and it took almost a century before the prize was finally established. All in all, 22 laureates have received the prize, of which four have already died. Their average life span was 91 years, which is higher than the current life expectancies (from 82.6 in Israel to 84.1 years in Japan).

The average age of the living laureates is 79.1 years. The oldest of them is 96 years old, and the youngest is 67. The average age of the laureates in the year they were awarded the Abel Prize is 77.1 years. The oldest recipient was 90 years old in the year of the award, and the youngest – 63 years old.

For comparison, the average age of Nobel Prize laureates in literature is 65; the youngest at the time of the award was 42 years old, and the oldest – 88 years old.

On the one hand, such data show that intensive math studies did not hurt health, but, on the contrary, contributed to longevity. On the other hand, each of the mathematical awards has its own preferred range, and together they cover almost the entire life span of scientists.

Temporological analysis of the laureates' birth data revealed several impressive coincidences. Traditionally, the first sign of the zodiac (Aries) is associated with youth and the pioneering of new beginnings. Indeed, the Aries-born mathematician Sir Andrew John Wiles became the youngest laureate of the Wolf Prize (43 years old) as well as the youngest laureate of the Abel Prize (63 years old). In physics, he was preceded by Sir William Lawrence Bragg, the youngest ever Nobel laureate in sciences (25 years). In addition, Aries-born Lars Ahlfors was the first Fields Prize recipient. Aries-born scientists were also the first to be awarded the Nobel prizes in physics (Wilhelm Roentgen) and in economics (Jan Tinbergen).

Pisces is the closing sign of the zodiac, and Pisces-born scientists usually wait longer to get recognition. At the most venerable age (90), the Abel Prize was received by Louis Nirenberg (1925 - 2020). Pisces-born John Torrance Tate (1925 - 2019), who was just two weeks younger than Nirenberg, got his Abel Prize at the age of 85. Both died 95 years old, with Nirenberg surviving Tate by just three months. As in the case of Ernest Hemingway and his translator Ivan Kashkin, the temporological indicators of the birth data of Nirenberg and Tate (their Theta factors) are so close that these laureates can be considered as partial celestial twins [6].

Mathematic laureates also demonstrate that pioneers often must wait for decades to be understood by others. For example, Fermat's last theorem waited 300 years to be proved by Wiles in 1994. and then Wiles waited another 22 years to be awarded the Abel Prize for this proof.

Back to Hadamard, at the venerable age of 91 he was awarded the highest scientific research award in France. He remained active until his death at the age of 97. It should be stressed that all the prizes are not awarded to discoveries, but to living people and to be awarded a prize a nominee must first of all stay alive and promote his ideas. It means that the longevity is an important quality for any scientist.

III. Citizens of the World

Like Hadamard, most mathematicians-laureates can be described as itinerant travelers, changing countries, universities, and even citizenships. For example, here is a partial list of places where the French mathematician and first Abel Prize winner Jean Pierre Serre (b. Virgo, Earth) taught: Sorbonne, Princeton, Harvard, Algeria, Bonn, Geneva, Göttningen, McGill, Mexico, Moscow, Singapore and Utrecht [7].

The Abel laureate Sathamangalam Varadhan (b. Capricorn, Earth) studied in Madras but worked at the Courant Institute in the USA. He wrote: "I like to travel. I like the pleasure and experience of visiting new places, seeing new things and having new experiences" [8].

Unlike Earth-born Varadhan, Pisces-born Nireneberg had a dominant Water element. Like Varadhan, Nirenebrrg was fond of travelling, but his reason for this was different: " One of the wonders of mathematics is you go somewhere in the world and you meet other mathematicians, and it's like one big family. This large family is a wonderful joy" [9].

Another Water-born prominent American laureate John Milnor (Pisces) at times lived in France and was also a member of the Russian Academy of Sciences. He believes that mathematicians are very fortunate because "ideas often travel from country to country very rapidly" and that in spite any political confrontations mathematics always stays "much more open than most scientific subjects" [10].

IV. Numerous Awards

Within the options of his times, Hadamard was awarded the most prestigious international awards, among them the Poncelet Prize and Feltrinelli Prize. The example of Abel laureates shows that this is not accidental: mathematicians who get the highest recognition are rewarded periodically and repeatedly throughout their life. Of the 22 Abel Prize laureates 16 (72.7%) have won at least two most prestigious prizes (14 – Wolf, 1 – Fields, and 1 (John Nash) – prior to Abel Prize had received the Nobel Prize in economics). Five laureates have won three most prestigious prizes (Wolf, Abel, and Fields). The remaining 6 laureates were awarded prior to Abel with such prestigious awards as the Lobachevsky, Leroy Steele, or Gauss Prize.

V. Personal Life

On average, Abel's laureates were married once and had 2 children. Behind these averages there are many creative couples and family dynasties. For example, Milnor's wife – Dusa McDuff – is an English mathematician, FRS and the first recipient of the Ruth Lyttle Satter Prize in Mathematics.

Jean Pierre Serre's wife Josiane is a professor and specialist in quantum chemistry. She has encouraged Serre to write a mathematical textbook for her chemical research.

VI. Laureates and their Celestial Twins

A quick search detects that each Abel Prize laureate has at least one well-known celestial twin ("celestial twins" – people who were born simultaneously or within an interval of 48 hours [11]). It suggests that such people are more predisposed for searching recognition. Each of these detected couples or groups of celestial twins deserves a separate study, but the scope of this work allows us to mention just a few striking examples.

John Nash (1928-2015) was the only person to be awarded both the Nobel Prize (economics) and the Abel Prize. In Belgium, his well-known celestial twin was the theoretical physicist Robert Braut (1928-2011), who received several prestigious awards, including the Wolf Prize in Physics. In Russia, their celestial twin Eduard Vladimirovich Evreinov (1928-2011) was a mathematician famous for his work in informatics. He was a laureate of the Lenin Prize and many international awards.

Jacques Tits is an influential French mathematician of Belgian origin. He has been awarded the Wolf and Abel

Prizes. Tits also served on the committee awarding the Fields Medal. His celestial twin is the Hungarian-born American influential investor and philanthropist George Soros who has studied economics at the University of London.

Grigory Margulis is a professor of mathematics at Yale University who has been awarded all the mathematical prizes known today. His celestial twin, Terry Allen Winograd, is a professor of computer science at Stanford University. Winograd is a recipient of the SIGCHI Lifetime Research Award. He is widely known as an adviser to a number of companies started by his students, including Google.

In 2020, Margulis shared the Abel Prize with Hillel Fürstenberg, professor of mathematics at the Hebrew University of Jerusalem. Fürstenberg's celestial twin was Walter Greiner, a renowned theoretical physicist. Like Fürstenberg, Greiner has an impressive list of awards, including the Max Born, Otto Hahn and Humboldt medals.

Celestial Twins reveals a story about two mathematicians (Hermann Weil and Theodore Kaluza) and their poetical celestial twin Velimir Khlebnikov [11]. Multitalented Khlebnikov as if mirrored both his celestial twins: Weyl (“a mathematician with a soul of poet”) and Kaluza (“a mathematician and consummate linguist”). Such mirroring effect presents also in the case of Hadamard, whose most famous celestial twin was the outstanding composer Jan Sibelius. As a child, Sibelius showed extraordinary abilities in mathematics, but then switched to music. On the contrary, Hadamard made his living in emigration by playing the violin.

Many Abel laureates were fond of music, literature and poetry. In the case of the distinguished American mathematician Isador Singer, we find that his famous celestial twin was the laureate of The Israel Prize, an outstanding poet and translator, Yehuda Amichai. It is indicative that Singer was fond of poetry too, and his first choice at the university was to take a poetry course [12]. Concluding this section, I would like to add that understanding our celestial twins can help each of us to discover oneself more fully.

VII. In Accordance with one's Elements

Previously it was shown that Nobel laureates in poetry have preferred metaphors in accordance with the basic concepts of their major element, be it Air, Fire, Water or Earth [1-3]. Similar differences between the representatives of the four basic elements are observed among mathematicians.

The first group includes representatives of the Fire element. In mathematics, they, like Hadamard, are attracted by the novelty of marvelous insights. For example, trying to solve Fermat's theorem – an enigma that mystified the greatest minds for centuries – Wiles (b. Aries, Fire) experienced exaltation: “suddenly, totally unexpectedly, I had this incredible revelation” [13].

The representatives of the Earth element see mathematics differently. For them it is most important to deal with the problems of applied mathematics. Jean-Pierre Serre (b. Virgo, Earth) – the laureate of Wolf, Abel and Fields prizes – wrote: "I don't know what "inspiration" really means. <...> Mathematics can be seen as a big warehouse full of shelves. Mathematicians put things on the shelves and guarantee that they are true. They also explain how to use them and how to reconstruct them. Other sciences come and help themselves from the shelves, mathematicians are not concerned with what they do with what they have taken, this metaphor is rather coarse, but it reflects the situation well enough" [7].

Representatives of the Air element are attracted to mathematics by the beauty of its language. Pierre Rene Deligne (b. Libra, Air) loves mathematics, "of course, because it is beautiful!" Robert Langlands (b. Libra, Air) is an enthusiastic learner of languages, both for a better understanding of foreign mathematical publications, and just "for fun."

Representatives of the Water element admire mathematics because for them, like for Louis Nirenberg (b. Pisces, Water) mathematics is a wonderful joy to be a member of a large family of mathematicians. Yves Meyer (b. Cancer, Water) said: "I like people. I like discussing with people – meeting, admiring people. I would say the pleasure to do mathematics is related to the pleasure of joint work" [14].

Different views of mathematics can provoke conflicts, similar to those between Hadamard (Fire) and Lebesgue (Water). For example, the Hungarian Abel Prize laureate, Endre Szemeredi (Fire), was encouraged by the Wolf laureate Pal Erdös (Fire) but was discouraged by his thesis adviser – another Wolf laureate, Israel Gelfand (Earth), who told Szemeredi: "Just try to find another profession; there are plenty in the world where you may be successful" [15].

Comparing his thinking with the Wolf laureate Luis Caffarelli (Fire), Luis Nirenberg (Water) felt himself inferior: "Fantastic intuition, just remarkable. I had a hard time keeping up with him" [9].

VIII. Comparing Abel and Nobel Laureates

In 2017, I discussed the uneven distribution between the elements in which the Nobel laureates in literature were born [3]. Meanwhile, a few names have been added, but the distribution of their birth data by element has not been changed. The Nobel Prize in Literature was first awarded in1901, and by 2020, 115 people with confirmed elements of birth became its laureates. 39 – more than one third of them – were born in the Air element. Fig.1 shows that they were twice as numerous than Earth-born recipients.

To compare similar periods of awarding the prizes and compatible number of mathematicians, the lists of the Lobachevsky, Wolf, Fields and Abel prizes were combined. As a result, 133 laureates with confirmed elements of birth were identified. The pattern of their distribution by elements, shown in Fig. 2, significantly differs from the previously obtained distribution of writers and poets.

For further comparison, I analyzed the birth data of the Nobel laureates in physics, chemistry, medicine and economics. Assuming the relative distribution of elements among mathematicians as a "standard," for each discipline the ratio of the specific weight of each element in relation to the selected standard was calculated (Table 1).

It turns out that physicists are closest to mathematicians in terms of the distribution of the elements. Perhaps this explains why modern physics is accused of excessive "mathematization."

We find the "earthliest" (predominance of Earth) laureates in chemistry, and the greatest dreamers (predominance of Air) in literature.

	Fire	Earth	Air	Water
Mathematics	1	1	1	1
Physics	0.97	1.03	1.19	0.86
Economics	1.12	1.09	1.11	0.75
Medicine	0.88	1.13	1.28	0.79
Chemistry	0.91	1.29	1.17	0.74
Literature	1.05	0.76	1.51	0.75

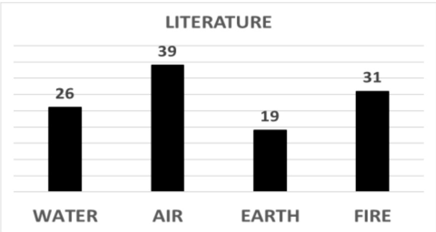

Fig. 1. Nobel laureates in literature by elements.

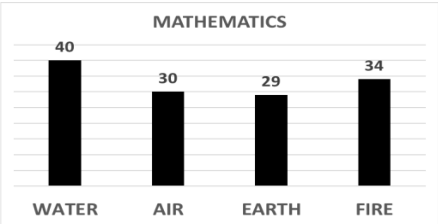

Fig. 2. Laureates in mathematics by elements.

This model suggests that the farthest from mathematics is the profile of the writer or poet. This suits the fact that the writers are free to create their own imaginary worlds and are least of all bound to adhere to the Truth.

In short, in comparison with literature, mathematical studies require from a laureate more practicality and reality (1.3 times more Earth), less imagination (almost 1.5 times less Air), more faith in success and the existence of Truth (1.3 times more Water).

This observation is consistent with Hadamard's appeal to mathematicians: "Although the truth is not yet known to us, it preexists and inescapably imposes on us the path we must follow under penalty of going astray" [4, p. xii].

IX. Conclusions

John F. Nash (b. Gemini, Air) supposed that "rationality of thought imposes a limit on a person's concept of his relation to the cosmos" [16].

Using alternative thinking, temporological approaches makes it possible to identify a number of common features of the mathematicians-laureates which are in accordance with Hadamard's earlier observations as well as with the philosophy of the four elements.

Ennio De Giorgi – a distinguished Italian mathematician – once noted that mathematics is the key to discovering the secrets of God. I hope that the application of the temporological methods to the study of the world's perception of outstanding mathematicians will help us to find such keys and establish a new logic that will bring us closer to the understanding of the cosmic laws.

Acknowledgment

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Establishment and Development of the Center for Competence in Mechatronics and Clean Technologies “MIRACLE” in TU-Sofia

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***Abstract*— The report presents a project for creation and development of a Center for Competence in Mechatronics and Clean Technologies MIRACle (Mechatronics, Innovation, Robotics, Automation, Clean technologies). The applicant of the Project is a consortium established by a partnership agreement between the Institute of Mechanics - BAS, as the lead organization and: the Institute of Information and Communication Technologies - BAS; Central Laboratory of Solar Energy and New Energy Sources - BAS; Technical University of Sofia; Sofia University "St. Kl. Ohridski "; University "Prof. Zlatarov " of Burgas; Higher School of Insurance and Finance; GIS "Transfer Center". The main task of the consortium is to bring together distinguished scientists and university professors for creation a unified infrastructure for high-tech innovative research aimed at business - a center of competence in the area "Mechatronics and clean technologies." In this area, it will be carried out research investigations on high contemporary level; will be developed methodologies for training and qualification; will be built strategic partnerships with leading research organizations in Europe and to work on projects with Bulgarian companies. Proposed for build the infrastructure in accordance to the project is distributed among the partners in the consortium. It consists of 4 bases with 15 laboratories, research activities of which are grouped into 6 work packages: • Innovative solutions in robotics and automation; • Bio mechatronic systems; • Smart environments, processes and technologies in mechatronics; • New methods and devices for control and testing of mechatronic components; • Mathematical support and modeling of complex systems and processes. Risk analysis; • 3D modeling, development and implementation of pilot models of mechatronic elements, details and systems.**

Keywords*— *Competence Center, Mechatronics, Clean Technologies, Robotics, Automation, Bio mechatronic Systems, Intelligent Environments, Processes and Technologies in Mechatronics, Methods and Means for Control and Testing of Mechatronic Elements, Mathematical Provision and Modeling of Complex Systems and Processes, 3D Modeling, Development of elements, details and systems for mechatronics.

I. INTRODUCTION

The objective of the project MIRACle is to establish a Center of Competence related to the thematic field “Mechatronic and Clean Technologies” of the Innovation Strategy for Smart Specialization of the Republic of Bulgaria, and consisting a critical mass of leading scientists and talented, successful researchers and inventors in all scientific fields in the pointed out thematic field, including the creation of the most modern research infrastructure with appropriate defined organization structure and own research and innovation programs in order to provide opportunities for competitive development of the scientific field “Mechatronics” and full scientific support to the economic sectors as regards that thematic field.

The applicant of the Project is a consortium (Fig.1) established by a partnership agreement between the Institute of Mechanics - BAS, as the lead organization and: the Institute of Information and Communication Technologies - BAS; Central Laboratory of Solar Energy and New Energy Sources - BAS; Technical University of Sofia; Sofia University "St. Kl. Ohridski "; University "Prof. Zlatarov " of Burgas; Higher School of Insurance and Finance; GIS "Transfer Center". The main task of the consortium is to bring together distinguished scientists and university professors for creation a unified infrastructure for high-tech innovative research aimed at business - a center of competence in the area "Mechatronics and clean technologies." In this area, it will be carried out research investigations on high contemporary level; will be developed methodologies for training and qualification; will be built strategic partnerships with leading research organizations in Europe and to work on projects with Bulgarian companies.

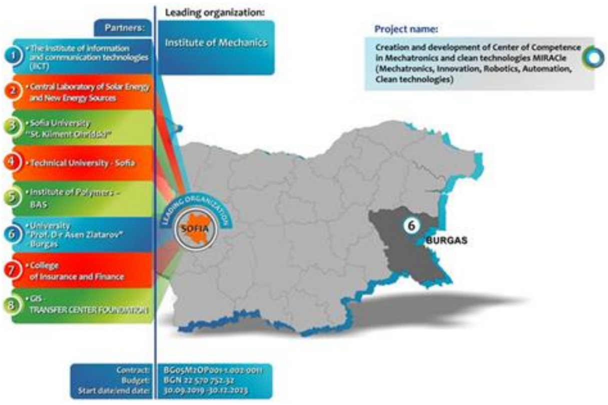

Fig. 1. Project consortium.

Specific objectives of the projects are to:

- Provide reproduction of scientific and research staff in the indicated thematic field by inviting leading scientists and researchers (from the country and abroad) to conduct scientific studies and to provide specialization of scientists and inventors at a high level;

- Create and introduce new training and educational methods and programs in the field of mechatronics and clean technologies including for scientists and representatives of business field;
- Establish sufficient favorable and attractive conditions for development of high qualified young scientists, specialization of researchers and inventors at a high level in the field of mechatronics and clean technologies, as well as for continuity of knowledge and experience among different generations of researchers;
- Establish strategical partnerships with leading technological institutions and companies in Europe related to initiation of scientific and research projects funded by EC framework programs;
- Achieve effective closing of a knowledge triangle “science-education-business” at the Center of Competence MIRACLe.

II. Center Structure

The scientific infrastructure is organized in laboratories which are consolidated **into 4 main bases:**

- **base 1** will be built on the territory of Bulgarian Academy of Science (including laboratories at IMeh, IICT, CL SENES),
- **base 2** – **on the territory of Technical University of Sofia with three laboratories:**
  - **Mechatronic systems for discrete production processes;**
  - **Intelligent mechatronic solutions in the field of textiles and clothing;**
  - **Metrological assurance, intelligent systems for measurement and quality control.**
- **base 3** will be developed on the territory of Sofia University “St. Climent Ohridski” and
- **base 4** will be exported within University "Prof. Dr. Assen Zlatarov" – Burgas.

The main bases include creation of new scientific laboratories and their modernization that best meet the priority direction of thematic field “Mechatronics and Clean Technologies”.

Scientific and research activities in the laboratories are grouped into **6 work packages (WP):**

- **WP 1** Innovation solutions in robotics and automation;
- **WP 2** Bio-mechatronic systems;
- **WP 3** Intelligent environment, processes and technologies in mechatronics;
- **WP 4** New methods and tools for controlling and testing mechatronic elements;
- **WP 5** Mathematical provision and modeling of complex systems and processes;
- **WP 6** 3D modeling, elaboration and implementation of pilot models of elements, details and systems related to mechatronics.

Under the project will be built and equipped 15 laboratories in the following areas:

1: Innovative solutions in robotics and automation - includes laboratories:

1.1. Mechatronic systems for discrete production processes - TU-Sofia

1.2. Automation of innovative technological processes - IICT-BAS; Intelligent Systems - University "Prof. Asen Zlatarov "- Burgas

1.3. Mechatronic micro-positioning and micro-fluid systems for biological cells and micro-objects - IMeh-BAS

1.4. Mechanics and control of robotic systems - IMeh-BAS

2: Biomechatronic systems. Study of human-machine systems

2.1. Mechatronic systems for rehabilitation and support of human movements - IMeh-BAS

2.2. Development of mechatronic systems applicable in medicine - Sofia University "St. Kliment Ohridski "

3: Intelligent environments, processes and technologies in mechatronics

3.1. Intelligent urban environment - Sofia University "Kl. Ohridski "

3.2. Development of functional coatings and their integration in mechatronic and biomechatronic systems - SENEI-BAS

3.3. Specialized laboratory for biochemical treatment of water and sludge - University "Prof. Asen Zlatarov "- Burgas

3.4. Intelligent mechatronic solutions in the field of textiles and clothing - TU-Sofia

3.5. Micro and nanomechanics of mechatronic systems - IMeh-BAS

4: New methods and means for control and testing of mechatronic elements and systems

4.1. Monitoring, non-destructive testing, testing and characterization of macromechatronic systems - IMeh-BAS

4.2. Metrological assurance, intelligent systems for measurement and quality control - TU-Sofia

5: Mathematical provision and modeling of complex systems and processes. Risk analysis - IMech-BAS.

6: Modeling, prototyping and reengineering of elements, details and systems for mechatronics - IMeh-BAS.

Conclusion

The successful project implementation will ensure opportunities for new solutions in the field of industrial robotics, automation of production processes, as well as for testing and optimizing innovation technological processes – high- speeded, high temperature using nanoelements and etc.; creation of innovative mechatronics systems for cell manipulation; construction of modern technological cells for production of special materials and alloys, as well as to replace the imported and expansive tools with such materials.

The successful project implementation will give opportunities to apply 3D visualization and digitalization of cultural and historical heritage, as well as to provide an access to disabled people (blind or partially sighted) to perception; to obtain new knowledge and applications in the field of intelligent systems and creation of intelligent urbanized environment.

The successful project implementation will provide opportunities for integration of specially elaborated lightweight sections, organic elements and textiles in mechatronics and bio mechatronics systems.

The successful project implementation will ensure opportunities for new quality as regards the control and testing the elements, units and systems in mechatronics, particularly in metrological assurance, intelligent sensors, devices and systems for measuring and quality control; monitoring and nondestructive testing; testing of macro mechatronic systems; studying micro and nanomechatronics of mechatronics systems.

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SECTION III

MEASUREMENT AND INFORMATION SYSTEMS AND TECHNOLOGIES

Web-service for Calculating the Efficiency of a Solar Power Station in a Given Location

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***Abstract*— A full-fledged system that makes it possible to effectively control solar power plants has been investigated, a web service that automates the process of calculating the energy production of a solar power plant per year and per every month has been created, it gives an idea of the effectiveness of its location and analysis of the climate in a given area.**

Keywords— power station, solar panels, control, statistics, api, ASP.NET, HTTP, MVC, REST, .NET.

I. Introduction

In the modern world, one of the most important tasks is to obtain energy that ensures the functioning of all technology used by humans. There are many different methods of generating energy, but many of them lead to environmental degradation, for example, thermal and nuclear power plants.

These prerequisites are forcing humanity to develop various technologies for obtaining energy from other sources, such as wind, geotherrmal and solar energy sources. Prospects for such a direction as obtaining electricity from solar radiation give new opportunities for improving the efficiency of power plants. It is also very important to create a web service that would incorporate all the advantages of this area and add a convenient interface for displaying information about the current state and statistics, since the analysis of the climate in a located territory can include the identification of many different parameters.

The main of these parameters are the intensity of solar radiation, the total energy of solar radiation and temperature. The use of solar power plants is one of the most promising methods of generating electricity from solar radiation [1].

II. Purpose and Objectives of Study

The purpose of the paper is the design and development of a web-service for calculating the efficiency of a solar farm in a specific location. The development methods are based on .NET technologies, ASP.NET MVC 5 and ASP.NET Web API 2 frameworks for creating web applications, MSSQL Server database and Visual Studio 2015 development environment.

The result of the work is the software implementation of the web service, which will help in choosing the location and parameters of the future solar farm.

III. Analysis of the Subject Domain

The modern world is developing rapidly and requires more and more energy to survive. This leads to the need to increase the capacity of various power plants. Since the problems of the climate change, environmental pollution and restrictions on mineral resources do not allow increasing the volume of generation through the construction of conventional nuclear or thermal power plants, mankind needs to use environmentally friendly methods of generating energy to preserve the environment. One of these ways is to obtain electricity from solar radiation using solar panels [2]. This also requires an assessment of the climatic conditions and characteristics of the region, as well as the correct choice of the location of the future system. These are fairly complex processes that require the necessary knowledge about geographic information systems, the characteristics of various types of solar power plants and the influence of climatic conditions on them. Therefore, when it is necessary to carry out preliminary planning of the location of a solar power plant in a given area, these processes take a lot of time and resources. That is why we need a system that would automate this process as much as possible.

The web service for intelligent monitoring of the state of the solar power plant will be a system for intelligent monitoring of the state of renewable energy sources, in particular, solar panels.

The service provides the following functionality:

- Registration, authentication and authorization of users;
- Using the map to determine the location and area of the solar power plant;
- Viewing the intensity map of the distribution of existing solar power plants;
- The ability to set various parameters of the solar power plant;
- Calculation of the energy production of a solar power plant per year and for each of the months;
- Downloading a report with the results of calculations and characteristics of a given power plant in the form of a PDF file.

The success of the service, first of all, will depend on the accuracy of the calculation of the energy production of the solar power plant. Also, the development of the industry of small and medium-sized solar power plants will be of great importance.

IV. The Description of the Adopted Design Decisions

At the design stage, the architecture of the system is developed, the technologies that will be used in the project are determined, the set of measures necessary for the implementation of the system and the most suitable design solutions are selected. The design of the system determines the list of developed software components, functional characteristics of the program, databases, etc. To simplify the visualization of the design process, the so-called notations are used – a schematic expression of the characteristics of a system using UML diagrams.

The functionality of the service is shown in the use case diagram (see Fig.1). It allows the user to interact with the system to obtain the necessary information about the solar power plant for timely response to changes in its state under the influence of negative factors and routine monitoring of the system.

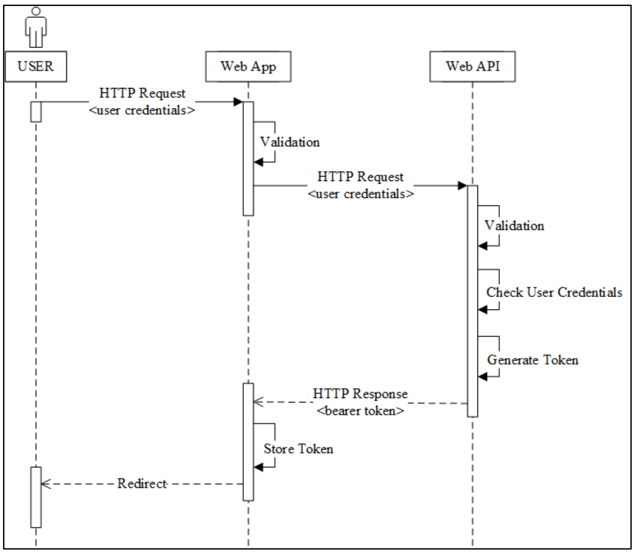

Fig. 1. Use case diagram.

A. *Examples of the Most Challenging Algorithms and Methods*

One of the main algorithms is the calculation of the output of a solar power plant. First of all, it is necessary to determine the main parameters:

- The average value of solar radiation, which is determined in kW*h/m^2/day;
- The average temperature value;
- The efficiency of the photoelectric converter;
- The area of solar power plant panels in square meters;
- Losses from the inverter, shade, equipment, panel pollution, etc.

Very often the specification of a solar power module includes a temperature coefficient, which is usually expressed as a percentage on the Centigrade scale. The standard temperature used for laboratory testing is 25ºC. This means that, for example, at the temperature of 40ºC and the temperature coefficient of -0.1% / ºC, the output of a solar power plant will decrease by 1.5%.

So, the final formula (3.1) for calculating the output of a solar power plant per day will be as follows.

$$E_{ps} = E_{se} * S * \mu * (1 - \mu l) \quad (3.1)$$

where:

- E_{ps} is the daily output of the solar power plant (kW * h / day),
- E_{se} is solar radiation (kW * h / m2 / day),
- S is the area of solar power plant panels (sq. m),
- μ is the coefficient of useful photoelectric converter,
- μ_l is the expense ratio.

Since the received data on solar radiation from the open source of WorldClim data have such units of measurement as kJ / m2 / day, they must be converted to kW * h / m2 / day. The following formula (3.2) reflects the relationship between kW and kJ.

$$1 \text{ kW} * \text{h} = 3600 \text{ kJ} \quad (3.2)$$

Then, the expense ratio is calculated using the formula (3.3).

$$\mu_l = \mu_{inv} + \mu_{sh} + \mu_{env} + \mu_{pol} + \mu_t, \quad (3.3)$$

where μ_{inv} is the inverter loss factor, μ_{sh} is the shadow loss factor, μ_{env} is the equipment loss factor, μ_{pol} is the pollution loss factor, μ_t is the temperature loss factor. In most cases, the expenses factor is calculated according to the parameters indicated in the specification for the purchased solar power plant. It is a very important parameter, as it gives an idea of the efficiency of the solar power plant system as a whole [3].

B. *The Architecture Description*

The software architecture consists of all-important design decisions concerning the program structures and interactions between these structures which make up the system. The design solutions provide the desired set functions that the system must support to be successful, they provide a conceptual framework for the development and maintenance of the system. When implementing the architecture, the following quality criteria must be considered:

- The system must be complete and effective, implementing, first of all, all the delivered tasks and requirements;
- The system must be flexible. This is needed for making quick and convenient changes. At the same time the number of errors must be reduced;
- The system must have the ability for extensions, namely the ability to add new models and functions into the system, not violating its basic structure. On the initial stage the system must include only the basic functionality, but at the same time the architecture must build up additional functionality easily;
- Scalability of the system and development process;
- The ability to reuse system components;

The functionality of the web server is given on the component diagram (see Fig.2). It allows representing the architecture of the system being developed by establishing dependencies between the software components.

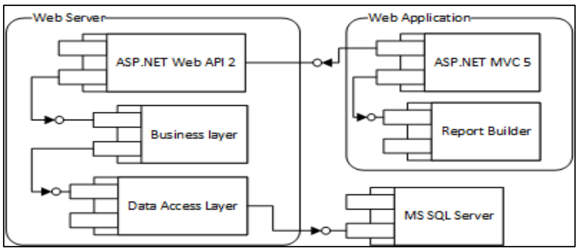

Fig. 2. Diagram of Web Server Components.

The software consists of a web application, a web server built using the REST architectural style, and a database.

A hierarchical decomposition of the web server was carried out; the result of it was that it was divided into logical levels, where each of them can interact only with the level which is below it:

- Presentation layer, which is an HTTP service, built using the ASP.NET Web API 2 technology [4];
- Business logic layer. It contains a set of components that are responsible for processing data received from the presentation layer, implements all the necessary application logic, all the calculations, and then transfers the processing result;
- Data access layer, which stores models describing the used entities.

During the design process, it was investigated that the system being developed must store the user data, the location of existing power plants and climatic data such as solar radiation and temperature on average per month. In this case, the data on the location of existing power plants will be stored in a .csv file, since they are needed only to read all the data, so this choice will increase the performance of the system. The database schema is shown in Fig. 3.

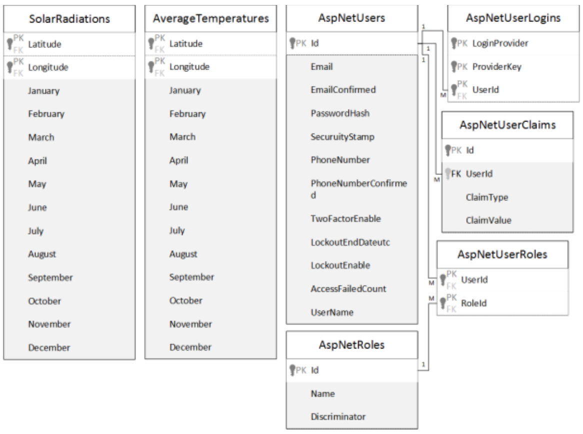

Fig. 3. Structure of the system database.

The database is normalized and has the third common form, since each table has a master key there are no replicates, atomicity is supported; the data stored in the tables with a composite key not depending only on a part of the key and the data in the table depend solely on the primary key.

1) Creating UI / UX or a different system design

When creating the web application interface, a lot of attention was paid to the page of calculating the production of a solar power plant, since almost all the main work on the system was concentrated there. The first thing that the user encounters when switching to this page is a small instruction on how to use the calculator in the form of animated slides that can be navigated using arrows or tabs (see Fig. 4).

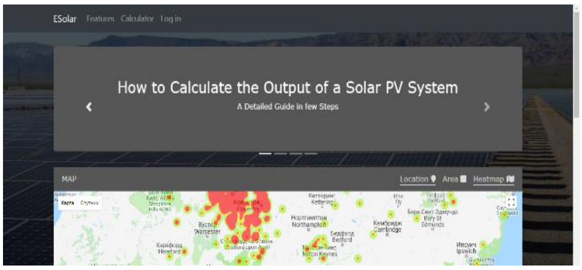

Fig. 4. Calculator instruction slides.

Next comes the card, which has quite a few functionalities, namely:

- The ability to view, zoom, change the view mode and move around the map;
- The ability to display and store the intensity map of the placement of existing solar power plants;
- The ability to install, edit and delete a marker on the map, indicating that a solar power plant will be located there;
- The ability to set, edit and delete a polygon on the map, which is the area occupied by a solar power plant;

The intensity map of the location of existing solar power plants is shown on the map in red and yellow areas (see Fig. 5). In order to hide or display it, you need to click on the "Heatmap" button.

Fig. 5. Displaying the intensity of the placement of existing solar power plants on the map.

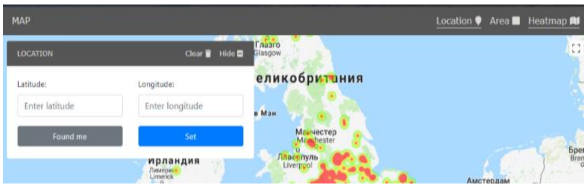

Fig. 6. Window for managing the location of the solar power plant.

In order to create a polygon on the map, which will represent the area of a solar power plant, you need to enter the location of its points in the corresponding fields in the window and press the "Set marker" button (see Fig. 6). There will be a list of the entered points, where we can delete them.

After the user clicks the "Set area" button, the polygon will be indicated on the map and at the same time its area will be calculated and set in the corresponding field of the calculator. In order to clear the window for managing the power plant area and the polygon on the map, press the "Clear" button.

The map is followed by the two forms (see Fig. 7), where the first one is for determining the parameters of a solar power plant, and the second one is for the loss due to various factors.

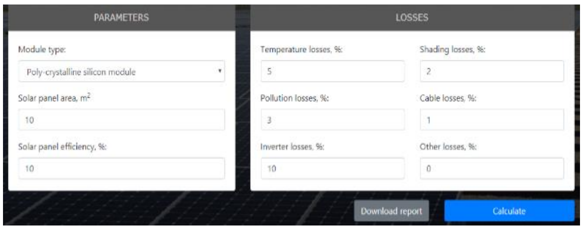

Fig. 7. Forms with different parameters.

After entering all the necessary parameters, press the "Calculate" button to calculate the output of the solar power plant. If some of the parameters are not defined correctly, errors will be displayed (see Fig. 8).

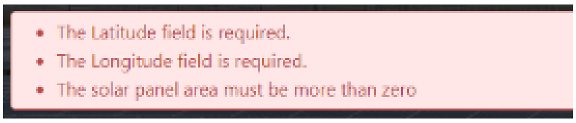

Fig. 8. Display of errors.

The calculation results are displayed in the form of a histogram (see Fig. 9).

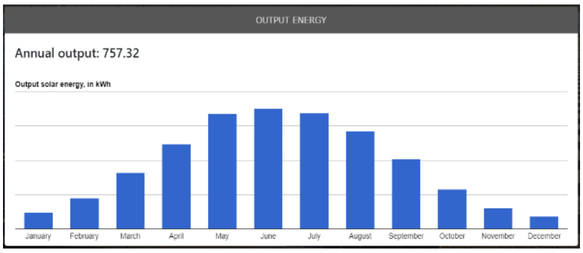

Fig. 9. Display of the calculation results.

The histogram shows the result for each of the months. In order to view the information on each of them, you need to move the mouse cursor over the corresponding column in the diagram (see Fig. 10).

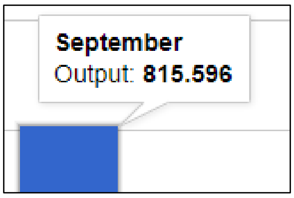

Fig. 10. Display of the result for September.

Also, in a separate field, the average annual result is displayed. The entire interface built has adaptive properties, which allows you to ensure the correct display of the site on various devices (see Fig. 11).

Photovoltaic System	
Position	52.0614860006336; -1.52958984375005
Module type	MonocrystallineSilicon
Area	10 m2
Efficiency	20 %
Photovoltaic System Losses (%)	
Temperature	5
Pollution	3
Inverter	10
Shading	2
Cable	1
Other	0
Output Energy By Month (kWh)	
January	182.598654701233
February	185.6539478302
March	270.760638427735
April	357.123439693451
May	522.549451446534
June	660.590080833436
July	768.472481918336
August	757.6179227829
September	629.258714103699
October	470.231690597534
November	308.372558498382
December	222.412639331818

Fig. 11. Average annual output of a solar power plant.

To obtain data on the location of the existing solar power plants, the application "Osmosis" was used, which allows to process data from an open geographic data source called "OpenStreetMap".

This data is presented in XML format allowing you to create and process data due to the presence of a predefined grammar, which, in turn, is presented in the form of a dictionary of tags and attributes, as well as a set of rules determining which attributes and elements can be included in other elements. Obviously, a set of objects and their corresponding tags are recommended in "OpenStreetMap" too.

All possible types of maps consist of basic elements, which are "point", "line" and "polygon". Each of the basic elements is associated with many of its properties or the so-called "tags". Many element properties can be empty. An ordered pair is used to describe a single property, the first element of the pair is the "key" and the second is the "value".

In order to get the objects with the required properties, you need to filter the data by the key and its value. From the official documentation of the OpenStreetMap project, it was determined that the pair, where the key is "generator: source" and its value is "solar", corresponds to a solar power plant. Obviously, a set of objects and their corresponding tags are recommended in "OpenStreetMap" too. All possible types of maps consist of basic elements, which are "point", "line" and "polygon".

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During the implementation of the software system, the principle of development by testing was used. This principle is a software development technology that uses unit tests. That is, tests are written first followed by the program code, which is enough to pass them successfully. To write unit tests, the MS Test framework was used, which is present by default in Visual Studio 2015.

When developing a web server, a unit testing project was added to its software solution. The testing itself was divided by purpose for various components of the software system. For example, the Controllers folder contains classes that are responsible for testing controller classes. One of these is the PhotovoltaicSystemControllerTest class. It is noticed by the TestClass attribute, which denotes the class containing the unit tests. Every method that passes testing is noticed by the TestMethod attribute.

Functional testing of the web application using the Selenium IDE tool was also performed. It is a plugin for the Google Chrome browser that is used to develop automated test scripts. One of these is the scenario for calculating the output of a solar power plant (see Fig. 12).

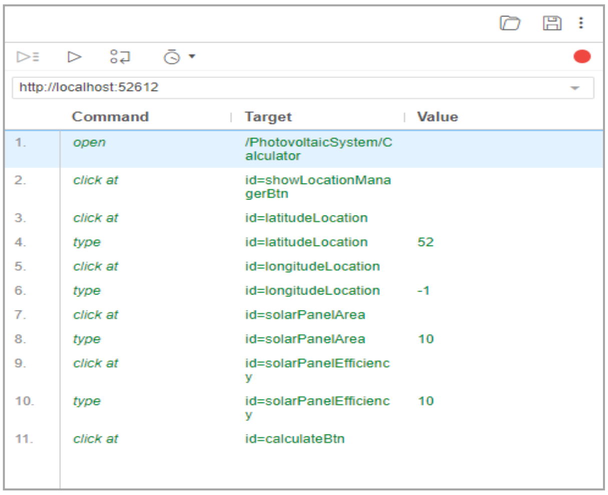

Fig. 12. Functional testing of a web application.

V. Conclusions

A web service was created to calculate the efficiency of a solar power plant on a given location. For this purpose, the subject area of solar power plants was investigated, namely, their capabilities, development prospects, features, factors affecting efficiency, etc.

Based on this knowledge, a formula for calculating the output of a solar power plant was derived. Considering the fact that the solar energy industry is constantly evolving and new methods of generating electricity from solar radiation appear, as well as the fact that there are factors affecting the generation which are difficult to calculate; one can affirm that this formula is not accurate enough and has many opportunities for further development.

The web server was developed based on the REST architectural style, which, in turn, allows third party applications to use most of the functionality and a web application that provides a convenient interface for interacting with the developed system.

All this is combined into a convenient and effective software system, and provides an opportunity for further development of the basic idea of automated calculations of various parameters for a solar power plant and the development of the entire industry as a whole.

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Universal mobile cartographic systems for geospatial data collection

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***Annotation*— The work of the mobile cartographic 3D scanning system Trimble MX 2 is considered. It is a spatial visualization complex that combines high-resolution laser scanning and precise positioning for capturing point clouds using georeferencing. Positioning accuracy is achieved through the combined use of GNSS and an Inertial Measurement Unit (IMU). The main components of the system are: the G360 high-resolution digital panoramic camera, which takes continuous color photography using five cameras located around the perimeter and one on top; laser system with one or two rotating lasers, which operate at a distance of up to 420 m, have a 360 ° viewing angle and allow data collection with an error of up to 3 mm; navigation subsystem Aplanix AP60 with a GNSS receiver and high-quality IMU, which are responsible for the accuracy of geolocation; odometer – a device for measuring distance in difficult GNSS conditions.**

***Key words*— 3D scanning; cartographic system; global navigation satellite system; inertial system; positioning accuracy**

I. Introduction

Recently, in connection with the development of modern geodetic technologies, equipment for collecting geospatial data has received its further improvement.

The above data are the basis for the normal and high-quality operation of the following industries: architecture, industry, construction, road infrastructure, geodesy, cartography, communications planning, railways, tunnel boring, mine surveying, archeology.

3D scanning technologies are one of the most productive and accurate measurement methods today.

The Building Information Model (BIM) is a kind of library, or resource potential, with the help of which the basis for making decisions, on its restructuring, or support for normal operation is formed.

Let's consider the operation of mobile cartographic systems using the example of the Trimble MX 9.

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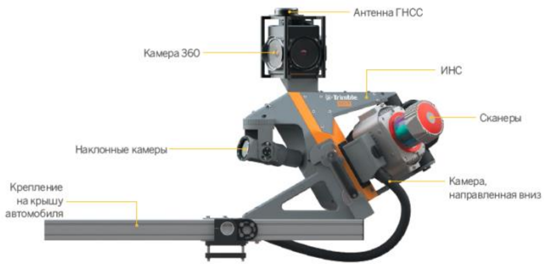
II. Principle Scheme of Operation and Implementation

Main components of the system are:

- high-resolution digital panoramic camera - a camera that takes continuous photography in color using five cameras located around the perimeter and one on top;
- laser system with one or two rotating lasers, which operate at a distance of up to 420 m and have a viewing angle of 360 °;
- navigation subsystems with a GNSS receiver and a high-quality IMU, which are responsible for the accuracy of geolocation;
- odometer, an instrument for measuring distances (DMI), under difficult GNSS conditions.

The system is installed on any moving device, be it: a car (Fig. 1), a railcar (railway platform) (Fig. 2), a boat or a tunnel trolley.



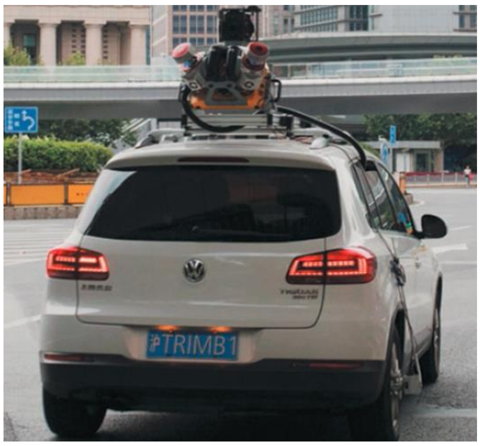


Fig. 1. Scheme of Trimble MX 9 System and its vehicle mounting option.

Fig. 2. Installation of a mobile cartographic system on a railcar.

The principle of operation of the main devices of the scanning system:

- Rotating scanner (scanners) with a full 360-degree viewing range, the principle of which is based on sending out laser pulses and receiving signals reflected from objects. Based on the obtained data (points of laser reflections), a three-dimensional information field is created that simulates the surrounding space.
- GNSS system for tracking and accumulating data received from global positioning satellites. Observations can be made in two modes: real-time kinematics (RTK) and post-processing kinematics (PPK).
- High-precision inertial module, with which the obtained data are synchronized and which makes it possible to more accurately build the trajectory of the cartographic system during analysis.
- Color panoramic camera, which is a logical addition to the complex and allows you to get a circular panorama, and then superimpose photogrammetric data on the point cloud (Fig. 3).
- Odometer, which, in addition to GNSS data of the inertial system, makes it possible to painlessly coordinate hard-to-reach places with no view of the sky (tunnels, overpasses) with minimal loss of trajectory quality.

Fig. 3. Urban survey data obtained while running the Trimble MX 9.

Unlike standard shooting methods, 2 people are enough to work with the scanner (for example, a car): a driver and an operator. It is advisable to plan routes with travel in both directions, in opposite directions, for the accumulation of greater data density.

Deployment time from transport position takes about 20 minutes. The versatility of the system allows installation on almost any vehicle, eliminating the need to purchase specialized vehicle.

Cameral processing is carried out in several stages:

- calculation and adjustment of the system trajectory points
- formation of point clouds, automatic or custom classification by objects, noise cleaning, alignment of passages (in the case of paired passage).
- creation of a realistic model of the captured object from point clouds and panoramic images.
- if necessary, further upload to the network software or databank (exchange with other project participants, BIM systems).

Any of the above tasks can be independent, depending on the goals and technical specifications of a particular project.

TABLE I. SHORT CHARACTERISTICS OF THE TRIMBLE MX 9 SYSTEM

PARAMETER	VALUE
Scanning rate	500 scans/sec
Amount of laser scanners	2
LASER CLASS	1, EYE SAFE
Maximum range, target reflectivity	420 m > 80%
Accuracy / error	5 mm / 3 mm
Field of view	360° "full circle"
360° "full circle"	IP64 (sensor module)
Operating temperature range	from 0 °C to +40 °C
Built-in inertial GNSS system Accuracy without loss of GNSS signals:	AP60 Coordinates X, Y (m): 0,020 0,020 Coordinate Z (m): 0,050 0,050 Speed (m/s): 0,005 0,005 Roll and pitch (degrees): 0,005 0,015 Course (degrees): 0,015

III. UNIFIED SOLUTION FOR MANY TASKS

Mobile cartographic systems are designed to perform a number of tasks:

✓ **Road infrastructure:** high-precision surveying at all stages of road construction and repair.

The main feature is that there is no need to block roads for work, the vehicle can travel in general traffic, minimizing the risks associated with employees being on the highway. Accurate data enable the production of varying quantities of outputs using powerful dedicated software packages (Trimble Trident, Trimble MX Asset Modeler).

- digital relief models, elevation maps;
- complex GIS databases for BIM implementation;
- calculation of volumes and planning of earthworks;
- obtaining up-to-date information on the condition of the road surface with the isolation of problem and emergency sections, filtration of damage, defects;
- creation of a basis for certification, including lists of objects;
- determination of geometrical parameters of roads and related objects (length of a section, width of a roadbed, width of each lane, lateral evenness, slopes from axial ones, angle of an arc of turn).
- the ability to implement CAD projects (design and project documentation, data catalogs in conjunction with CAD projects)

The software assumes in its functionality automatic recognition: hatches, cracks in the road surface, curbs, marking lines, which significantly speeds up the process of filtration and processing (fig. 4).

Fig. 4. Examples of point clouds for road construction.

After construction is completed, the materials of the executive survey can be used in the BIM environment throughout the entire life cycle of the object.

✓ **Railway infrastructure**

- monitoring of slopes and embankments in places of soil subsidence;
- survey of junctions, bridges, overpasses for condition monitoring and inventory;
- creation of a dimensional corridor during the construction of railways (fig. 5);
- survey of wires and objects of contact network;
- monitoring the condition of tracks, design and reconstruction of road facilities;
- survey of railway tracks to create digital track models (DMP). Determination of the actual values of the geometric parameters of the railway infrastructure, monitoring the condition of tracks, design and reconstruction of road facilities (fig. 6).

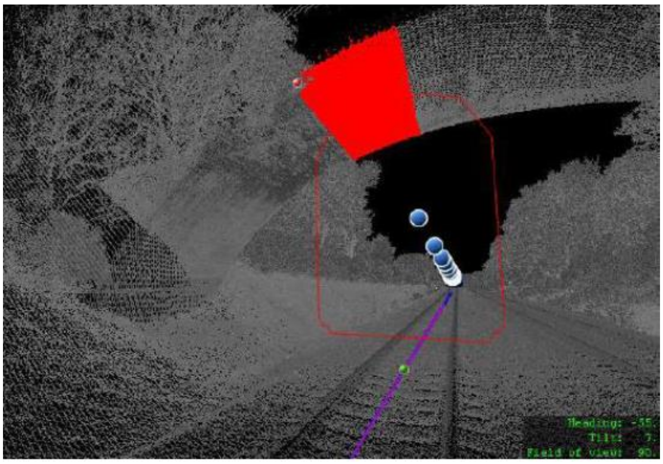


Fig. 5. An example of the overall passage of a car with a display of the risk zone on the railway.

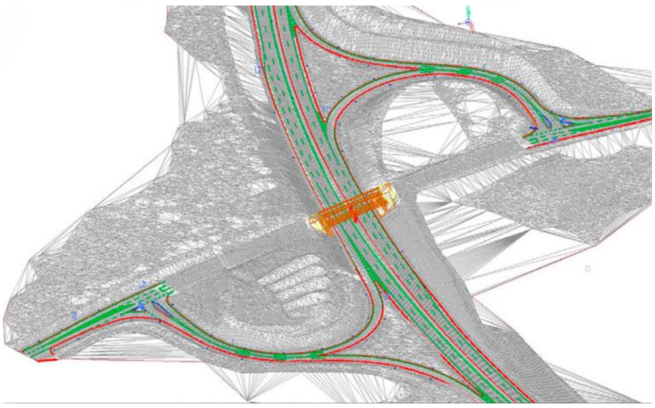


Fig.6. Displaying the road junction after connecting the processing vectors.

✓ **Urban infrastructure**

For large cities, in a rapidly developing rhythm, constant control over all urban processes is very important. Data obtained from mobile cartographic systems can be used for the following purposes:

- creation of 3D models of cities;
- inventory of trade objects (LFA), traffic lights, road signs;

- planning of repairs and inventory of buildings and structures for the architecture service;
- assessment of the current state of bridges, overpasses, junctions;
- assessment of the state of contact lines of urban land transport;
- assessment of the state of the tracks of urban land-based road transport.

For the full cycle of urban planning, mobile mapping systems allow you to efficiently create layers for GIS and working drawings in CAD.

Surveying large utility systems in a short time frame creates a unique environment for project planning, providing the basis for qualitative and quantitative analysis and prompt decision-making. Inventory and updating of the data of existing objects is carried out using special software procedures that provide communication with existing databases and schemes. Thanks to the convenient data exchange system, processing times are significantly reduced.

✓ **Other branches**

- determination of the volumes of production or stripping for quarries and ore mining and processing enterprises. Monitoring of subsidence of soil and rocks, control of boards;
- monitoring of slopes and movements of retaining walls on mountain roads;
- design and repair of overpasses, definition of security zones;
- survey of water infrastructure objects of hydroelectric power station, dams, berths, locks, canals. Inventory of port cranes and structures;
- survey of power lines (inventory, sagging of wires, assessment of damage to towers), distribution substations, glades.

Full use of cartographic mobile systems with the help of special software assumes a full cycle of data exchange with all city services. In this case, the street panorama is scanned, after processing and modeling, the obtained data is uploaded to the server, where each service will be able to work with filtered profile data for personal access.

Results and Discussion

With the ability to use mobile cartographic systems, large-scale survey projects that were previously too complex and costly for many organizations are now feasible.

Comparing traditional methods on the example of a road, where a team of 3 people can take a total station or GNSS receiver survey up to 4 kilometers per work shift, during the same period of time using a mobile cartographic system, it is possible to capture up to 100 km. roads with the surrounding situation.

This eliminates the high costs of traditional field crews. Having received a colossal amount of data, the risks associated with finding workers in hazardous field conditions are avoided. The work of the scanning system does not require stopping traffic or blocking roads, it makes it possible to work with inaccessible dangerous objects without risking the health of employees.

The ability to integrate the scanned results into network server programs allows you to optimize the work of any services and departments, avoiding additional costs in a well-defined time frame.

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SECTION VII

MEASUREMENTS IN THE ECOLOGY, BIOTECHNOLOGY,MEDICINE, AND SPORT

Analysis of Data from Scintigraphic Images and some Inflammatory Processes

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***Abstract*—Nuclear medicine diagnostics have many advantages over the other imaging methods. The most important of these advantages being the diagnosis of the earliest functional changes in an organism, before the development of structural-anatomical changes. In this article we are looking for the interrelationship between two groups of factors: group 1 (body temperature; leukocytes and erythrocyte sedimentation rate (ESR) and group 2 (presence and severity of an inflammatory process). Analysis of variance (ANOVA) is used for analyzing observations of the index of accumulation that depends on the effects of the factors as patient's temperature, leukocytes and ESR. The comparison of mean values of the statistically significant factors for the different categories of the index of accumulation and respectively activity of the inflammatory process is made. The study included 74 patients diagnosed in a hospital in Sofia, Bulgaria. However, ANOVA test results don't map out which groups are different from other groups.**

Keywords*—*ANOVA, Nuclear Medical Diagnostic

I. Introduction

Clinics often receive patients, who have had fever for a long time, without adequate response to ongoing therapy and without an established diagnosis. Petersdorf [1] defines the term "fever of unknown origin" (FUO) as "Fever with a body temperature above 38.3° C for more than 3 weeks without a final diagnosis, despite a one-week hospital stay ". According to leading experts, a differential diagnosis should be made between FUO and four groups of diseases: infectious, malignant, autoimmune and mixed. Infections remain the most common cause of FUO [2, 3, 4].

Over the last forty years, a small group of commercial radiopharmaceuticals have found their way into routine medical use, for the diagnostic imaging of patients with infection or inflammation. These molecular radiotracers usually participate in the immune response to an antigen, by tagging leukocytes or other molecules/cells that are endogenous to the process. Currently there is an advancing effort by researchers in the preclinical domain to design and develop new agents for this application. Nuclear medicine diagnostics have many advantages over the other imaging methods. The most important of these advantages being the diagnosis of the earliest functional changes in an organism, before the development of structural-anatomical changes. Nuclear medicine also allows for whole body scanning (without any omissions of body parts in the scan), as well as saving time.

Until now, using nuclear medicine diagnostics, there is some evidence in the Bulgarian scientific literature of a relationship between body temperature, leukocytes, erythrocyte sedimentation rate (ESR) and the presence and severity of the inflammatory process (IP) [5, 6], but the results based on a small samples (maximum size 54 patients).

That's why we decided to look for the existence of such a relationship by applying the diagnostic capacity of nuclear medicine based on the data from random sample of 74 patients.

Analysis of variance (ANOVA) is one of the most frequently used statistical methods in medical research [7]. Analysis of variance (ANOVA) is used for analyzing observations of the index of accumulation (in four groups) that depends on the effects of the factors as patient's body temperature, leukocytes and erythrocyte sedimentation rate (ESR).

The comparison of mean values of the statistically significant factors for the four categories of the index of accumulation and respectively activity of the inflammatory process will make it possible to apply the adequate treatment targeted at personalized medicine.

II. Materials and Methods

The data are received from a random sample of 74 patients with fever of unknown origin (FUO): 30 (40.54%) men aged 15 to 71 years, and 44 (59.46%) women aged 7 to 74, all diagnosed in a hospital in Sofia. In 52,70% (39 persons) there was no initial working diagnosis and therefore they were united in a first subgroup - only fever, while 47,30% (35 persons) had an initial working diagnosis and were grouped into 9 subgroups, respectively: pyelonephritis - 8 (2 with + 6 without a classic clinical presentation (CCP)); post-operative complications - 6 (4 with + 2 without), sepsis - 5 (2 with + 3 without CCP); Crohn's disease - 5 (1 with + 4 without CCP); abscess - 4 (1 with + 3 without CCP); bronchopneumonia - 3 without CCP; pleurisy - 2 without CCP; alopecia- 2 without CCP; Lyme disease - 2 without CCP. The objectives of the nuclear medical diagnostic study are:

<u>First:</u> Evaluation of the quality of the technetium-99m hexa-methyl-propylene amine oxime (99mTc-HMPAO) ^{99m}Tc-HMPAO leukocyte tagging technique used. For this purpose, an "efficiency of tagging" (ET) of the leukocytes is used and is equal to: $(A_{sample})/[A_{sample}+A_{aspirated\ Plasma}]$, where A_{sample} is activity of the sample.

The value proves the quality of the used technique for isolation and labeling of leukocytes, which is a prerequisite for achieving a high quality of the obtained scintigraphic images and the in formativeness of the results.

Second: Evaluate the scintigraphic result by:

1. Qualitative assessment - according to the colors of the scintigraphic image, corresponding to the degree of accumulation of radiopharmaceuticals (RF). The fixation of radiopharmaceutical in a certain area alerts the nuclear physician to a possible focus of an inflammatory process;

2. Quantitative assessment - calculating the indicator "index of accumulation" (IA). An area of interest ROI_1 is determined from the region suspected to be a IP, and a substantially equal second zone located therein into the contralateral region of the body (ROI_2). Formula for calculating the "index of accumulation" is $(IA)=ROI_1/ROI_2$. The accumulation index (IA) indicates whether or not there is inflammatory process and what is the intensity of the inflammatory process – weak IA ≤1,1; medium IA = 1,1-1,3; strong ≥ 1,3

Third: Assess the sensitivity, specificity and accuracy of leukocyte scintigraphy in the diagnosis of FUO.

Fourth: For each patient, the effective dose (D_{ef}) from radiation exposure is assessed by a Swedish doscatolog [8].

First we choose the used radionuclide (99m-Technetium = ^{99m}Tc); then we selected radiopharmaceuticals (^{99m}Tc-hexamethylpropyleneamineoxime = ^{99m}Tc-HMPAO) and application mode (orally or intravenously); age of the patient (for adults, the dose is up to 15g to 10g to 7g), and application activity [MBq]

A. Statistical Methods

Analysis of variance (ANOVA) is a statistical technique for analyzing observation that depends on the effects of one (or more) classification variables (referred as factors) [9]. The analysis is done by partitioning the total variance in the observations into those variations attributable to the different explanatory variables or those attributable to random effects. Each factor or treatment occurs at two or more levels (particular category of a factor). The response variable is influenced not only by the levels of factor but also by external variation.

One-way analysis of variance can be viewed as a special case of bivariate analysis. The variable response variable *X* is assumed to be continuous random variable and the variable Y is assumed to be a classification variable with r categories. The interrelationship between the two variables therefore involves a comparison of means. The sampling model is the following: one column of the data matrix contains *N* observations on a variable *X*, a second column contains observations on a variable *Y* which classifies the *N* individuals into *r* categories (levels) or groups. The Y variable assumes one of the integer values $1, 2, ..., r$. The *N* individuals as a random sample from a population after classification according to *Y* resulted in totals of *n1, n2,...,nr* observations from the *r* groups respectively. Equivalently, one could view the sample of size *N* as the result of selecting random samples of sizes *n1, n2,...,nr*. The distribution of *X* is assumed to be normal for each group.

The objective in ANOVA is to use the sample information to test the null hypothesis: the population means of *r* mutually independent groups are the same.

The total variation in *X* over the sample is denoted by SST (total sum of squares) and this sum measures the variation in the *X* values around the grand mean or overall mean. The variation explained by the fitted model is given by SSA, the sum of squares among groups. This sum measures the variation among the group means. For all groups the total within-group sum of squares or Error Sum of squares (SSE) is given by

$$SSE=SST-SSA$$

Under the normality assumption the ratio

$$F=(SSA)(N-r)/(SSE)(r-1)$$

has a F distribution with $(r-1)$ and $(N-r)$ degree of freedom. For F-test the p-value less than 0,05 was considered statistically significant and null hypothesis is rejected.

III. Result and Discission

Calculated all the nuclear medical diagnostic metrics we received:

First: For "efficiency of tagging" (ET) we received 54,46%. The value proves the high quality of the used technique for isolation and labeling of leukocytes, which is a prerequisite for achieving a high quality of the obtained scintigraphic images and high informativeness of the results.

Second: We received "index of accumulation" IA=0 in 22 patients; IA less 1.1 in 12 patients; IA between 1.1 and 1.3 in 27 patients; and IA more than 1.3 in 13 patients. This means that in 22 patients there is no inflammatory process, in 12 patients there is an inflammatory process but very weak; in 27 patients, the inflammatory process was of a medium intensity, and in 13 patients - it was very intense.

Third: We received 91.07% sensitivity, 94.44% specificity and 91.89% accuracy of leukocyte scintigraphy in the diagnosis of FUO. These values are slightly above the published values we are familiar with.

Fourth: The effective dose (D_{ef}) obtained from patients are in the range of 1,72 mSv to 3,44 mSv. When comparing the data from the National Center for Radiobiology and Radiation Protection (NCRRP) with the obtained values for D_{ef} from nuclear methods (NM) we established:

D_{ef} Ro (0.01-1.3 mSv) < D_{ef} NM (1.72 mSv to 3.44 mSv) < D_{ef} CT (2.3-10.0 mSv) < D_{ef} therapeutic methods

In the study 74 patients are included, aged 7 to 75 years. The mean value±standard deviation and 95% confidence limits (CL) of the measured variables are the following: temperature (t) – 39.1^0 C ±0.81 [CL: 38.9^0 C; 39.3^0 C]; leukocytes (le) – 13.09 ±1.74 [CL: 12.7; 13.5]; ESR – 2.59 ±3.77 [CL: 19.7; 21.5].

All statistical analyses were conducted using Statistical Package STATISTICA 13.0 [10].

The variable Y (classification variable) is index of accumulation (*IA*) which classifies the activity of the inflammatory process in 4 categories:

Without inflammatory process – if $IA = 0$ – coded by '0";

Weak – if $IA < 1{,}1$ – coded by "1";

Medium – if $IA \in [1{,}1;\ 1{,}3]$ – coded by "2";

Strong – if $IA > 1{,}3$ – coded by ”3”.

In the first ANOVA analysis the response variable X is patient's temperature. The p-value for F statistic of 1.7914 with 3 and 70 degrees of freedom is 0.157. We conclude, therefore, that there no differences among mean values of the temperature.

The graph of the means values of temperature and 95% confidence limits for the four groups of *IA* are shown on Fig. 1.

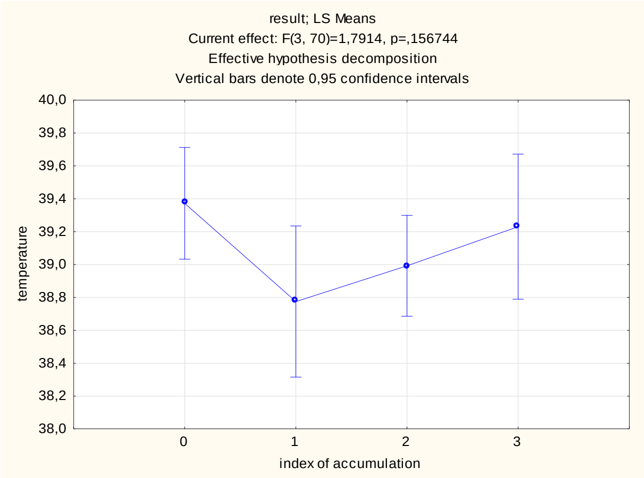

Fig. 1. The mean values and 95% confidence limits of temperature for the four groups of *IA*.

In the second analysis the response variable X is patient's value of leukocytes. The p-value for F statistic is 0.000001. Therefore, that there are some differences among mean values of the leukocytes. The graph of the mean values of leukocytes and it 95% confidence limits for the four groups of *IA* are shown on Fig. 2. Upon examination of the four sample means in Fig. 2 it would appear that the average value of leukocytes is larger for strong activity of the inflammatory process than for the other three groups.

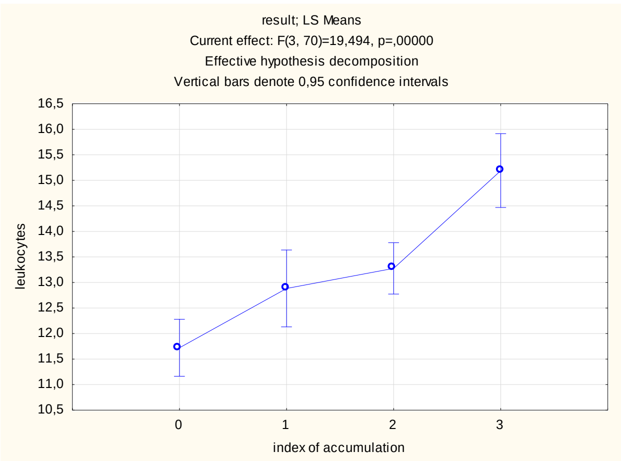

Fig. 2. The mean values and 95% confidence limits of leukocytes for the four groups of *IA*.

The last analysis is when the response variable is erythrocyte sedimentation rate. The p-value for F statistic is 0.000628. We conclude, therefore, that there are some differences among mean values of the ESR.

The graph of the mean values of erythrocyte sedimentation rate and it's 95% confidence limits for the four groups of *IA* are shown on Fig. 3.

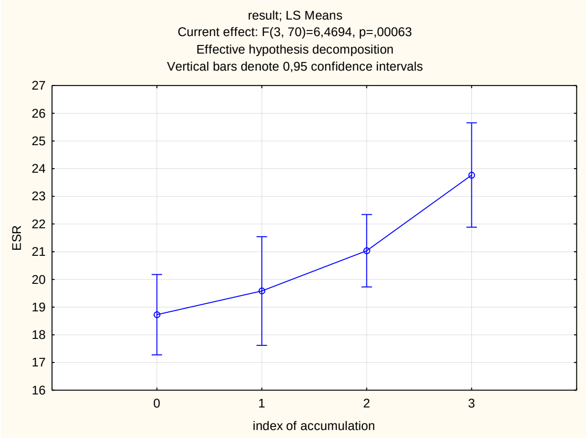

Fig. 3. The mean values and 95% confidence limits of ESR for the four groups of *IA*.

We conclude that there is some evidence that group "3" yields larger value of erythrocyte sedimentation rate than for the groups coded by "0" and "1".

IV. Conclusions

Fever of unknown origin is a life-threatening clinical condition, mainly because of the difficult diagnosis of the cause. Despite the numerous attempts by various specialists in this area, there is still no definite algorithm for diagnosis.

In this study, we demonstrated that there is a statistically significant relationship between leukocytes, erythrocyte sedimentation rate (ESR) and the inflammatory process. So we also took another small step on the difficult road to solving the big problem – diagnosis of the fever of unknown origin in Bulgarian.

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A Retrospective Analysis of Measurements in Sports During the Middle Ages and the Renaissance

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***Abstract*—The aim of the theoretical study is a retrospective analysis of the historical parallel development of two significant social activities - measurements and sports in the Middle Ages and the Renaissance. The research methods include historical analysis, document analysis, information research, comparative analysis, theoretical analysis and synthesis. It is found that during the Middle Ages and the Renaissance, measurements in sports followed the processes of parallel harmonious unity formed in Antiquity. During the analysed historical period, an objective basis for further development of the process was built through the adoption of an international treaty of major importance - the "Convention of the Meter". Historical facts suggest that measurements in sports have been qualitatively catalyzed by the advent of photography as a research method. In the restored Bulgarian state after 1878 an approach to measurement was adapted, adequate to the world and European trends in all areas of socio-economic activity.**

Keywords— measurement, sport, Middle Ages, Renaissance

I. INTRODUCTION

Historical analyses related to the measurement of sport in ancient Greece, Rome and the countries of the Ancient World give grounds that such measurements can be systematized in four directions: construction of sports facilities and creation of material and technical conditions for training and competitions; sports rules and dimensions of sports equipment; management of competition and training activities; recording of sports achievements and sports records [5].

The parallel development of these two significant social activities was naturally formed in a harmonious unity, which formed the starting point and objective basis for the subsequent development of the process and in the construction of civilized social formations after this historical period [6,20]. On the territory of the collapsed Roman Empire in its western part appeared Italy, and on the remaining parts many other state unions. The ignorance of these territories was ubiquitous and even the founder of one of the largest state structures in the 9th century - Charlemagne, an ardent defender of knowledge and ancient cultural heritage, managed to learn to read but not to write. But his work was an exception. Measurement and sport, which characteristics and integration process are the focus of our present study, also developed unevenly [1,2,21].

II. AIM, OBJECTIVES AND RESEARCH METHODOLOGY

A. *The aim of study*

The aim of the theoretical study is a retrospective analysis of the parallel historical development of the two significant social activities - measurement and sport in the Middle Ages and the Renaissance.

B. *Objectives*

As research objectives were set the following:

1. A retrospective study of the historical facts known so far in the development of measurements and units of measurement during the Middle Ages and the Renaissance.

2. Retrospective study of historical facts related to the most significant sports events and activities in the Middle Ages and the Renaissance.

3. Attempt to systematize and justify the integration between measurement and sport in the historical period under study.

C. *Research methods*

Historical analysis, document analysis, information research, comparative analyses, theoretical analysis, and synthesis.

III. PESULTS AND ANALYSES

The Middle Ages is a diverse historical era. There are conflicting assessments of it and distinct periods and geographical regions can be distinguished with different content. On the territory of central and western Europe in the period from the 4th to the 11th century, feudal restraint, warfare and a dominant religious scholasticism prevailed [4]. As a whole, the achievements of Greece and the greatness of Rome sank into oblivion during this time in these lands. The successful expansion of the Moors into the Iberian peninsula, the influence of the new religion that emerged in the 7th century, Islam, and the so-called "migration of peoples"- the total invasion from the East of pagan tribes and peoples-were catalysts of sorts for this negative process [14,19]. All this created a new content of the whole life of the society and undoubtedly of the sport, which ceased to exist independently [9].

At the same time, in the eastern part of Europe, one city was growing and flourishing - Constantinople and the associated Eastern Roman Empire, later called Byzantium. In this part of the world there was a partial continuity of antiquity, and this lasted until the 15th century. Sporting activities, as in ancient Greece and ancient Rome before that, were associated on the one hand with military training, and on the other hand they had albeit much less competitive appearances [3,16]. The expansionist policy of Byzantium also included the Christianization of the peoples coming from the East. This also led in the IX century to the creation, by the brothers of Slavic origin, the enlighteners Cyril and Methodius, of a new script through a new alphabet called Glagolitic [17].

After failure in Moravia, their disciples Clement, Nahum, Angelarius, Gorazd, Sava and the new Slavonic script found acceptance from the Bulgarian ruler Boris-I. With the help of this Bulgarian alphabet Christianity was established as the state religion in the country. Gradually in the period of the IX - XIth centuries in central and western Europe, the Christian religion managed to expand its influence in public life. During this time the knights also appeared. The first crusades were organized, which required a lot of physical effort and military training, which mainly included combat sports. Riding continued to develop as a way of fighting, but thanks to the knightly tournaments it also acquired new characteristics close to sport. Classical martial arts also developed as a means of offensive action, self-defense and, exceptionally, sporting performance [15]. From sword fighting skills there was a shift to new weapons, leading to the emergence of fencing and to specialized manuals for sport training. In the twelfth - fifteenth centuries a number of written sources appeared, preserved and reached the present day, such as the treatises on wrestling and fencing by Fiore de'Liberi" For di Battaglia", "Florius de Arte Luctandi", "Flos Duellatorum" published between 1400 and 1410. Other examples were the "Codex Wallerstein" compiled by Paulus Hector Mair in 1409, the "Opus Amplissimum de Arte Athletica" appearing in 1452 and the "Talhoffer Fechtbuch" by several authors published in 1459. In 1470 the "Paulus Kal Fechtbuch" was compiled, a manual on fencing and wrestling, and Albrecht Dürers wrote and richly illustrated the "Fechtbuch" in 1512 [18].

At the same time in the eastern part of continental Europe there was a reversal - the Turks conquered Constantinople and for centuries there was no place for classical sport in life there. Only military training was its territory. At the end of the fifteenth century the world witnessed the great geographical discoveries [7,13]. Christopher Columbus rediscovered the New World and events began again, that qualitatively changed the development of human history and civilization. The process of social stagnation in central and western Europe was actively changing and leading examples were the Italian cities of Florence, Urbani, Rome, Padua, Bologna and Venice. A period now known as the Renaissance. One of its leading characteristics was the integration of the world. This led to a natural need for a common language, not only in culture but also in measurement, to be used by builders, merchants, men of science and inhabitants of countries.

At the beginning of the 16th century, the mechanical clock was invented. Its creators are Peter Henlein-1504 and Christian Huygens, who in1656, based on the achievements of Galileo Galilei, developed a clock with a pendulum and high accuracy. In 1790, the Swiss company "Jacquet Droze and Leschot" created the first clock for mass use. The need for uniformity of measurements was first felt in Europe, where in the 16th and 17th centuries hundreds of different units of measurement were used in the many fragmented regions, duchies, states and countries (Fig.1).

Fig. 1. Measurements in Medieval Europe.

The need to integrate units of measurement led to a qualitatively new stage in the overall development of metrology. The advent of new tools for more precise measurements has also allowed such an approach to be applied in the world of sporting events. In many European countries, the leading ones being England, Germany, Greece, on the basis of personal initiatives, positive attitude of Christian religion and state policy, sports competitions in many sports-athletics, wrestling, rowing, cricket, etc.-were organized and started to be held annually. In 1731 (St Ducret at all.-2004) at equestrian competitions in England the ranking was for the first time also determined by measuring "time". For this purpose, mechanical clocks with a resolution of 1 (one) minute were used to record sporting achievements. Later such measurements with newer clocks were also made in various athletics disciplines (N. Ozolin et al. -1979). In athletes from Great Britain, a record in running one mile was recorded in 1792 - 5 m. 52 s. by F. Powell, and in 1830 in running 440 yards-2 m. 06 s. of A. Wood. At the same time measurements were made of sporting achievements connected with "length." In 1789 a record of 1 m. 83 cm. was recorded in the shepherd's jump by D. Busch-Germany in the high jump, in 1827 A. Wilson - Great Britain achieved 1 m. 57.5 cm., in 1838 the record achievement in the hammer throw was 19 m. 81 cm., of Rayon, Ireland, and in1839 in the shot put T. Carradis, Canada achieved -8 m. 61 cm. Such measurements were a natural reflection and result of the age of the Industrial Revolution which began in England in the seventeenth century, gradually swept across the globe and charted the development of human civilization in a new way. The catalyst for the process was the works, inventions and activities of Galileo Galilei -Italy, Nicolaus Copernicus - Poland, Robert Boyle, Robert Hooke, James Watt, Robert Stevenson - England, Thomas Jefferson, George Washington - USA and hundreds of other brilliant minds, among whom the great Isaac Newton undoubtedly stands out. In his "Mathematical Principles in Naturophilosophy" he presented for the first time in history the laws he discovered that govern the material world. The processes of industrialization and integration went through many interesting moments, and in the field of metrology had its new beginning in France (M.

Dodova-2017) [10]. Leading the way was the abandonment of natural measures and the move towards the creation of standards. In 1795, the French Parliament (Convent), passed a law to introduce throughout the country two compulsory units of measurement "meter"- for length and "kilogram"- for mass. The "metric system" of units appeared, and its founders presciently predicted its future and set as a guiding maxim "A tous les temps,a tous les peoples"-"For all times, for all peoples". The changes were imposed by the development of science and technology, and among the many discoveries, those of Michael Faraday on electricity gave new perspectives in the development of the world [8].

Significant for metrology was also the work defended in 1832 in Göttingen, Germany, "The Intensity of the Earth's Magnetic Force Reduced to a Unit of Measure", authored by the German scientist mathematician Karl Gauss. In his work, he introduced the concept of "system" and scientifically justified the need for the creation of an "absolute system" based on the units "millimeter", "kilogram" and "second". Developing a methodology for the construction of a system of units Gauss concluded that for all physical measurements it is sufficient to accept the three basic independent units, namely: for length, mass and time. All others can be defined by the basic ones. For example, the unit of surface is equal to the square with side equal to the unit of length; the unit of linear velocity-the speed of such uniform motion where the unit of length is completed in unit of time, etc. K Gauss was also the first to make measurements of the earth's magnetic field by means of three units of mechanical magnitudes-the millimeter, the gram, the second-and with K. Weber also made measurements of several electrical phenomena. These measurements in the field of electricity and magnetism were qualitatively improved in the 1860s by Maxwell and Thompson, who also laid the foundation for a coherent system of units of measurement. It was introduced in 1874 as the CGS (centimeter, gram, second) system. A century later (in 1980), the same was replaced by a mutually coherent system of practical units of measurement, including "ohm" for electrical resistance, "volt"-for electromotive voltage, "ampere"-for electric current. In the early and mid-19th century, other systems of physical education were being developed in many countries of Europe. These included nationally distinct methodological requirements for the application and dosage of physical exercise. Despite the overall military orientation of this activity, the process was actually linked to and based on compliance with metrological requirements and procedures. In England, the most widespread activities were games, in Germany gymnastic and structural exercises, in Sweden P. X. Ling (1776-1839) introduced four types of gymnastics: pedagogical, military, curative, aesthetic. The French system of Georges Ebert (1875-1957) included natural-applied exercises such as walking, climbing, balance and righting exercises, heights and supports, jumping, lifting and carrying, running and throwing, games of offense and defense. The Russian one was close to the French one and was based on the physiological research of I. M. Sechenov (1829-1905), the medical and pedagogical work of P. F. Lesgaft (1837-1909), and the hardening and all-round orientation of physical exercises were its characteristic features. At this time, a number of other activities began with marked activity, gradually but steadily shaping metrology in all its fields as a necessary, and from a modern point of view, as a very promising scientific discipline in international terms. One of the indirect examples is the establishment and increasing spread of a new independent method for registration, study and measurement of objects, processes and phenomena - photography. The method has a long history connected with the achievements of Avicenna (Jabir Ibn Hayam), Leonardo Da Vinci, I. Schulze and dozens of other researchers. As its creators, who managed to enrich the known with new solutions, Joseph Nicephorus Niepce, Jean Louis Daguerre, Isidore Niepce, Francoise Arago - in France and William Talbot - in England, established themselves in the period 1822-1839. Two decades later -1861. This gave a qualitative new impetus to measurements in every field, including sport. It became possible to measure both end results and the parts and phases making up different motor actions. In France, in 1870, where the new beginnings in the development of metrology were most prominent, it was decided that the new measures already introduced should be based on an unchanging prototype taken from nature, so that all nations could adopt them. The unit of length, the metre, was taken to be 1/10000000 part of the length of the quarter of the Paris meridian, and the unit of mass, the kilogram, 0.001 m3 of pure water of the greatest density at a temperature of 4 C [11].

To the metrological fragments of the above historical facts the adoption and implementation by law in the same year 1870 of the new units of measurement on the territory of the Ottoman Empire are added. Bulgaria was still under its rule at that time. The specific time limit for the changeover to their use was given as 01.03.1871 to 01.03.1874, after which the old measures were not to be used (Fig. 2).

Fig. 2. Law on New Weights and Measures in the Ottoman Empire - published in Bulgarian in 1870 in Constantinople in the printing house of A. H. Boyadzhiev.

At the beginning of May 1875 in the town of Nord, near Paris, another International Diplomatic Conference was held, called the Metric Conference. The result of the Conference was the adoption of a document of historical importance - the "Convention of the Meter". It was signed on 20.05.1875 by 17 countries, empires, and state unions. This date is also designated as World Metrology Day [12]. A number of international bodies were built on the basis of the Convention. Their tasks were defined - to consider and resolve all issues related to metrology (measures, units of measurement, standards and methods for their determination), and also issues related to the organization and activities of the relevant services, institutes and laboratories. "The 'meter' and the 'kilogram' were recognized as the basic units of measurement in the territories of the signatory countries. During the same historical period, national systems and institutions aimed at ensuring uniformity of measurement were actively being established in many countries of Europe, the world, the USA and Russia. At the time of the adoption of the "Meter Convention", measurements from the field of human locomotion were emphatically linked not only to the application of new units of measurement and rules, but also to a very active and explosively developing method of photography. Research centers were being built in various countries of the world: Marey established one in 1873 in France, Edweard Muybridje did so in Stanford USA in 1878, and in 1895 Braun, Fisher, Veber followed their example in Germany (Fig. 3). Measurements and characteristics of most natural movements and actions such as walking and running were originally in animals. Very soon afterwards, recordings in humans became leading. One example was the work of Eadweard Muybridje (1830-1904) at Stanoford University, USA. He developed a system of photography involving 12 cameras that were placed on a line side by side. Their photographic shutters were connected by wires and had an electrical mechanism. When a moving object passed in front of the camera lens, the corresponding photographic shutter was triggered... This gave new possibilities for measurements and determining the phase structure of a running stride. Partial quantitative values of kinematic characteristics such as "length" and "duration" were also measured.

Fig. 3. Sequence of photos of running stride.

Bulgaria was liberated in 1878 from Russia, after another victorious war with the Ottoman Empire, and very soon afterwards also officially joined the "Meter Convention". On 15.11.1888 the first "Law on Weights and Measures" was adopted at the Second Ordinary Session of the Vth National Assembly. By the Decree 278 issued by Prince Ferdinand I on 19.01.1889 and promulgated in State Gazette No. 7/1889, the law came into force on 01.06.1889 for food measures, and on 01.01.1892 for other weights and measures. It required the compulsory use of the new weights and measures in "government accounts" and in the accounts of "private persons having a claim on the government" and regulated the metrological control of measuring instruments.

Other significant metrological fragments are also found in the UK. This had implications for sport-related events. The emergence and development of football as a sport is one example. Competition rules, many of which survive to the present day, regulated from 1891 the taking of a 'penalty' for a flagrant foul in the goalmouth. The ball had to be, and still is, placed perpendicular to the goal line at 12 yards (1 yard = 0.914 m). This rule for the 11- yard penalty kick (1m = 1.094 yards) means that it is always taken from 10 m and 97 cm from the goal line!

IV. Conclusion

1. It is established that in the Middle Ages and the Renaissance, measurement and sport followed a parallel harmonious unity formed in Antiquity.

2. During the analyzed historical period an objective basis for the development of the process was established through the adoption of an international treaty of fundamental importance – the "Meter Convention".

3. Historical facts give grounds to point out that measurements in sport were qualitatively catalyzed by the advent of the mechanical clock and then photography as research tools and methods.

4. In the Bulgarian state, restored after 1878, an approach of measurements in the significant areas of social and economic activity, including sport, was adopted adequate to the world and European trends.

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SECTION VIII

METROLOGY PRACTICE

Critical Analysis of the Taximeter Verification Methods

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***Abstract* — The metrological control of the taximeters (or the system "taximeter-car") guarantees protection of the users' rights of taxi services. At present in Bulgaria this control is carried out by comparing the distance travelled by the system "taximeter-car" to the length of a measured road section. Due to many limiting conditions in the application of this method, there is a need to apply a new one, based on a stationary test bench for verification of the system "taximeter-car". The implementation of the proposed new method for verification, already applied in other European countries, also requires the development of relevant documents for metrological assurance of the method.**

Keywords — taximeter, taxi, metrological control, measurement instrument, verification method.

I. Introduction

Movement of people, goods and ideas has always been vital for humanity. Movement is life. Since ancient times people use different means of transportation that only evolve as time goes by. Those means for moving people or goods from one place to another have further developed as the concept of not only owning, but also hiring those means.

The taxi service, an automobile driven by chauffeur available for hire to carry passengers between any two points within a city for a meter determined fare, is a convenient means of transportation that has spread around the globe in the twentieth century.

Article 5 of the Measurement Instrument Directive (Directive 2014/32/EU, MID) states that "Correct and traceable measuring instruments can be used for a variety of measurement tasks. Those responding to reasons of public interest, public health, safety and order, protection of the environment and the consumer, of levying taxes and duties and of fair trading, which directly and indirectly affect the daily life of citizens in many ways, may require the use of legally controlled measuring instruments." [1]

One of the means for providing the taxi service is the taximeter – a measurement instrument that falls into the scope of the Measurement Instrument Directive. Taxi services are part of the daily life of citizens for more than a century. The use of the taximeter secures that it will be a fair trade deal for both the consumer and the taxi service provider.

II. Taximeter Verification Methods

Two main methods can be defined for checking the distance travelled by the system "taximeter-car". They are based on the difference in the condition of the car during the verification. The same can be done for a car that is moving on a road or the road is simulated by means of a roller test bench.

The first method, which is historically older and more widespread, is called "basic" according to the current "Methodology for checking the system "electronic taximeter with fiscal memory – car" [2]. It is a kinematic method, as it is performed in conditions of natural movement of the verified taxi. It makes a "comparison of the distance travelled by the system "taximeter-car", registered by the electronic taximeter with fiscal memory for the respective working tariff, with the length of the measured road section" (the checked car is in motion on the measured road section).

During the verification, the vehicle is positioned at the beginning of the measured road section, ensuring the coincidence of a reference point on the car and the sign for beginning of the road section. The taximeter is switched to the appropriate mode and the car travels the distance of 1 000 m. When approaching the end of the measured road section, the speed gradually decreases and the car stops at the moment of finding a match of the reference point on it with the sign for the end of the road section. The distance travelled by the car is recorded by the taximeter and a fiscal receipt with the result is printed. After comparing the distance reported by the taximeter with the reference one of 1 000 m, the conformity of the measuring instrument with the requirements for maximum permissible error in distance measurement is established (Fig. 1).

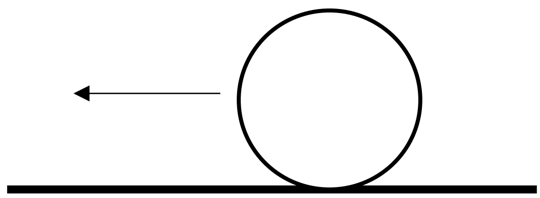


Fig. 1. A scheme of the basic method for travelled distance easurement.

In the second method, the measured road section is replaced by a roller test bench that simulates the movement of the car and the distance travelled. This method is defined as static.

According to the technical solutions of the designers of the roller test benches used for verification, a subsequent classification of the same can be made.

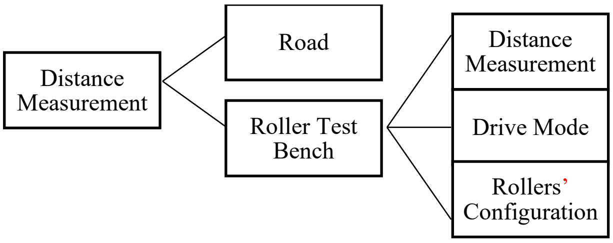
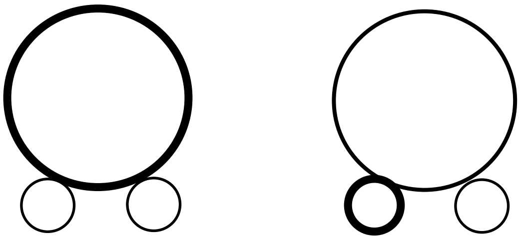


Fig. 2. Classification of distance measurement methods.

They can be distinguished according to the selected distance reading method, the drive mode or the configuration of the rollers of the test bench (Fig. 2).

The applicable method for realisation and measurement of the reference distance for the roller test bench is achieved indirectly by setting and reading the revolutions of a car wheel (circumference of a car tyre) or a roller of the test bench.

In the case of reading the revolutions of the car wheel, it is necessary to know or measure the diameter of the tyre, to respectively calculate its circumference and to put a reference mark on the wheel. Then the roller test bench is driven and transmitters count the revolutions made by the wheel (Fig. 3a). At the end of the simulation, a software application determines the distance travelled by the car.



3a 3b

Fig. 3. A scheme for distance measurement using a roller test bench.

In case the revolutions of a roller on the test bench are taken into account, the so-called method of measurement with a rolling roller is applied (Fig. 3b). Similar to the previous method, known diameters and circumferences of a roller of the test bench are used, as well as a reference mark is placed on the roller itself in this case. The convenience of this approach is that the diameter and circumference of the roller, as well as the location of the reference mark are permanently established, i.e. it is not necessary for each system "taximeter-car" checked to perform certain actions before every single measurement.

Depending on drive mode of the system "taximeter – car", the roller test benches can be externally or internally driven. Externally driven for the roller test bench and internally driven for the verified system "taximeter-car" is when the system is driven by the engine of the checked car (Fig. 4a).

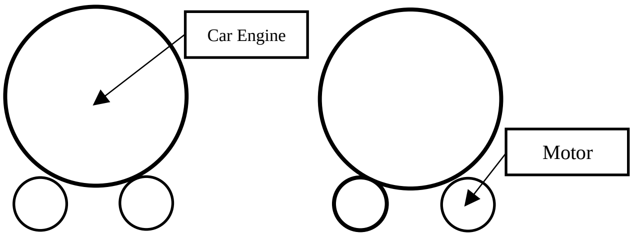


Fig. 4a Fig. 4b

Fig. 4. Different drive modes of test benches.

Similarly, internally driven for the roller test bench and externally driven for the verified system "taximeter-car" is when an electric motor drives the roller test bench (Fig. 4b).

The most common are roller test benches with two sets of two rollers located in one common or two separate modules, depending on the technical solution of the manufacturer. There are also solutions on the market with only one module with one set of two rollers, as well as with two extended modules with more than four rollers thus being able to mount both axes of the car on the test bench. For the "basic" method it is not relevant which is the drive wheel of the car for the verification of the system "taximeter-car". When using a roller test bench, it is necessary to take into account which is the drive wheel of the car, as the taximeter is connected to it, and to simulate its movement.

III. Critical Analsys of Methods

There are numerous technical solutions for roller test benches for taxi verification due to the different possible combinations among distance measurement method, how the system "taximeter-car" is driven, and the rollers' configuration. However, a key point in the taximeter verification is the distance measurement and it is therefore appropriate to make a comparison between the "basic" method (measured road) and the two methods for counting the number of revolutions (car wheel and roller of the test bench).

For the purposes of the critical analysis of those verification methods certain criteria for comparison should be established. In order to evaluate the three methods, they are compared according to the criteria of measurement error and range of measurement, measurement conditions, performance, metrological reliability, and type of measurement data [3].

The evaluation of the three methods is presented in Table 1, in which each of the methods is ranked from 1st to 3rd place according to each of the above criteria [4]. The error comparison and the measurement range provide information on the configurability of the method or in particular the reference used. In the case of measurement conditions, the necessary circumstances that need to be present to use the method shall be taken into account. The performance criterion compares the number of taximeter verifications that can be performed per unit of time. The metrological reliability characterises for how long the method, or the means by which it is carried out, maintains its error. The type of measurement information is how and what exactly is obtained as measurement data using each of the three methods.

TABLE I. METHODS' EVALUATION

Criteria	Methods		
	Measured Road	*Wheel Revolutions*	*Roller Revolutions*
Error and measurement range	3	2	1
Measurement conditions	3	1	1
Performance	3	1	1
Metrological reliability	1	3	2
Type of measurement data	3	2	1

The key aspects of the methods from the point of view of legal metrology are selected for the purposes of the analysis. The full feasibility study should include the cost and efficiency of the method, impact on environment and safety.

The criterion for a measurement error of a verification method depends on the accuracy of the measurement instrument being verified. In the case of periodic metrological verifications of the system "taximeter-car", the requirement for the value of the permissible error for distance travelled is up to 2%. For comparison, in the case of initial verification of taximeters, the requirement for the value of the permissible error is up to 0.2% for distance travelled [5]. A consequence of the requirement regarding the accuracy of the verified measurement instrument is that the verification methods (standards) used must be 4 to 5 times more accurate than the verified measurement instrument. Therefore, all three methods can be defined as accurate, as the error requirement of the verified measurement system is not so strict.

The serious potential advantage in terms of the accuracy of the third method – the "roller revolutions" method, should be pointed out. In this case, the distance is calculated by means of reading the revolutions of a calibrated roller on a stationary test bench. Its parameters are embedded into the software algorithm for working with the test bench and their accuracy is a key determinant. As a result of this technical solution, the subjective human factor is further eliminated, while it is dominant in the other two methods. The "measured road" method relies on the operator to set the "start" and "end" point of the measurement, as well as to assess absolutely subjectively whether the road section used meets the criteria for conducting the verifications. In the case of the "wheel revolutions" method, the operator has the key role of measuring the tyre diameter that is necessary for calculating the circumference of the tyre. This parameter may need to be calculated by the operator before each check, if a similar function is not provided in the software application for the roller test bench. Those actions may cause subjective technical errors.

In terms of the measurement range, the "measured road" method ranks last among the three methods, as it is limited by its methodology to a maximum distance of 1 000 m. At the same time, the other two methods allow setting a greater range of distance measurement.

The necessary measurement conditions are also of paramount importance when choosing a method for verifying the system "taximeter-car". It is clear that the verification by the "measured road" method is highly dependent on environmental conditions. The seasonal fluctuations of the atmospheric conditions and the length of the day affect not only the planning of the verification process, but also the condition of the road surface and car tyres. In the case of a roller test bench, where all components and controls of the test bench are intended to be protected for operation in a wide temperature range and higher than usual humidity, verifications may be carried out without depending heavily on atmospheric conditions.

The most time-consuming is the "measured road" method in terms of method performance. It takes time for the operators to consider a favourable moment to carry out the verifications in daylight, to find and move to a suitable road section and to travel the distance several times for the needs of all planned verifications. The placement of a roller test bench is possible indoors or on site, and verifications can be better organised and quicker without the need to deliberately wait for appropriate conditions.

The metrological reliability of each method is determined by the metrological reliability of the technical means used - their number, characteristics, and their ability to maintain their error over time. These are minimised by the "measured road" method - only a stopwatch and a measured road section of constant length are used. This method may be simple, but it is reliable in its simplicity. The "wheel revolutions" method relies on the use of a suitable transmitter to read the wheel revolutions and on technical means for measuring the tyre diameter. Some disadvantages of the commonly used optical sensors for counting the revolutions of the wheel are how they are attached to the wheel, and their changing characteristics over time due to the specifics of use (possible contamination, vibration, etc.). In the case of the "roller revolutions" method, an inductive transmitter is used to count the revolutions and it is installed in a way that minimises the risk of contamination or vibration.

Regarding the type of measurement information, the "wheel revolutions" and "roller revolutions" methods provide the same in digital form, and the "measured road" method relies on paper, pen and the operator's observations. The methods "wheel revolutions" and "roller revolutions" can also be called automated ones, because they use suitable transmitters for counting revolutions and microprocessor circuits with embedded algorithms for calculating the distance travelled. The ability to control the roller test bench, to monitor the measurement process, and to visualise the measurement data gives a significant advantage to those two methods.

IV. CONCLUSION

The paper classifies various methods for carrying out metrological verifications of the system "taximeter-car". A comparative analysis of three methods for measuring distance is performed and the methods were evaluated according to 5 criteria. The "roller revolutions" method or the one for measuring distance by a roller test bench and a circumference of a reference roller is ranked first among the three. An assessment of the overall efficiency of the equipment and development of relevant documents for metrological assurance of the method should also be made in order to complement the feasibility study of the chosen method.

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Automated Workbench for Metrological Verification of WCM G01÷G08 Measuring Converters (Westron Current Multiplicator)

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***Abstract*—The report deals with the automated workbench (AWB) for metrological verification of cards for pro-cessing and propagation of analogue input signals type WCM G01÷08.**

A brief description of the application built on the basis of the LabVIEW programming language is given.

The structure of the AWB, hardware components, programme modes and operating screens are discussed.

Keywords*— *LabVIEW, cDAQ, metrological verification, standards, communication interface

I. Introduction

Technological protections in NPP are part of the control system which in case of an emergency situation provides automatic implementation of discrete control operations for valves, mechanisms and other equipment in order to prevent a nuclear hazardous situation, equipment damage and evolution of accidents.

Measurement converters (cards) are part of these systems used for processing and propagation of analogue input signals and forming a digital signal to Ovation computer information and control system, WCM G01÷08 type. Metrological verification of more than 4500 cards delivered in 2020 and installed under the WWER-1000 lifetime extension project of the CIS systems – I circuit and NOS SSCs systems – II circuit is being carried out at the NPP.

II. Automated Workbench

Technological protections in NPP are part of the control system which in case of an emergency situation provides automatic implementation of discrete control operations for valves, mechanisms and other equipment in order to prevent a nuclear hazardous situation, equipment damage and evolution of accidents.

The automated workbenches have a number of advantages in comparison with the classical ones, such as:

- decreased probability of error occurring in the course of obtained results processing;
- absence of operator mistake;
- large volume of operations performed;
- high productivity;
- displays with friendly human-machine interface and possibilities for developing additional displays and modification of the present ones;
- Reliable data archiving and its visualization on graphical displays;
- Analysis of the data from the archive;
- Possibility to modify and supplement the software and the hardware without significant cost.

III. Products of National Instruments and CompactDAQ

- LabView (Laboratory Virtual Instrument Engineering Workbench) is a development environment based on the G graphics programming language designed for communications with GPIB, VXI, PXI, RS-232, RS-485, Field Point and data acquisition hardware.

- CompactDAQ (cDAQ) is a data acquisition platform built by National Instruments that includes a wide range of compatible hardware and software solutions. It integrates data input/output hardware with LabVIEW software.

IV. Structure of the AWB for Automated Verification

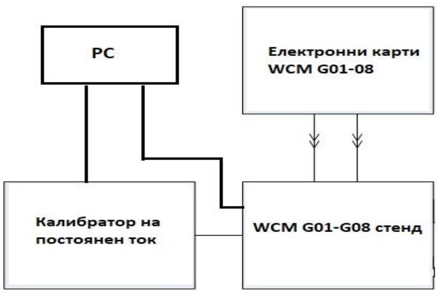

Fig. 1. Block diagram of workbench, cards WCM G01÷08 type.

Depending on the type of the measuring multiplicator, the circuit diagrams are presented in Fig. 2, 3 and 4.

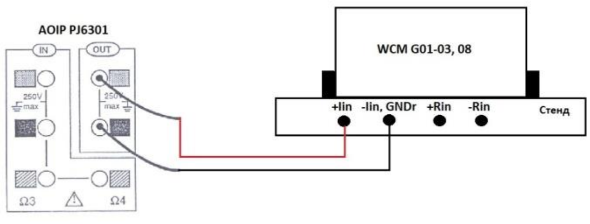

Fig. 2. Circuit diagram of WCM G01÷G03, G08 cards.

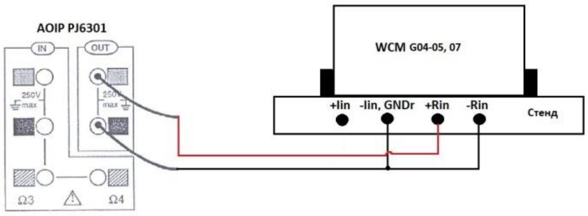

Fig. 3. Circuit diagram of WCM G04÷G05, G07 cards.

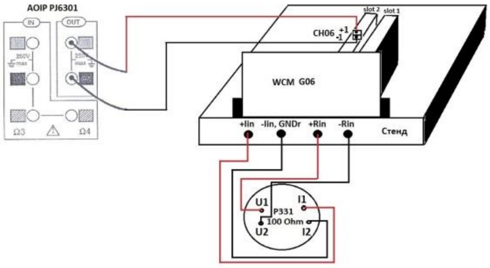

Fig. 4. Circuit diagram of WCM G06 card.

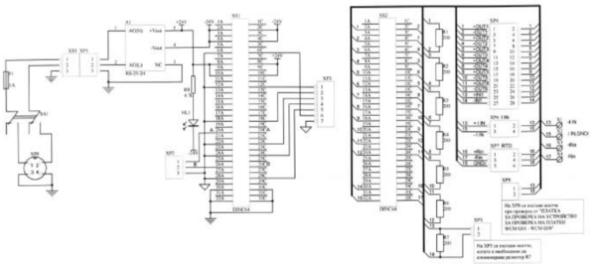

Fig. 5. Electrical diagram of a card checking stand WCM G01÷G08.

V. Components of the AWB

The automated workbench for checking analogue input signal propagation cards is composed of:

- a card verification device (stand);
- cDAQ system cDAQ-9174 and measuring modules NI-9239 with an accuracy class of ±(0,03Umeas+0,008Urange);
- Precision resistors VFR B1947 / S102K with an accuracy class of 0,005 %;
- GPIB communication interface;
- National Instruments LabView software package;
- AOIP PJ6301 current, voltage and resistance calibrator with an accuracy class of 0,02.

The AOIP PJ6301 calibrator provides a total uncertainty of 1/10 of the allowable basic absolute error of the WCM card being checked.

VI. Metrological Characteristics of Cards Type WCM G01 ÷ G08.

WCM G01 ÷ G08 – device for processing and propagation of analog input signals. They are designed to generate five (G06) or six (G07÷G08) galvanically isolated identical output signals from the input signal and to form a digital signal to the CIS-Ovation system.

The metrological characteristics of different types of WCM cards:

WCM Inputs:

- standard current (0÷5 mA) – cards G01÷G03 and G08;
- standard RTD (-50 ÷ +100 °C) – G04 and G07 cards (RTD 0879, RTD 0979, STB Pt50, RTD Pt100 and graduation 23) 3- and 4-wires;
- standard thermocouples (type J) – G06;
- Rheochords (up to 5 kΩ), cold junction compensation – G05;

- Sensors powering: 24 V, 36 V, 41 mA;
- Outputs: 0÷5, 4÷20 mA, 6 (5) channels;
- Signals multiplication boards;
- Converting time: 50 ms (current), 400 ms (thermocouples), 650 ms (rheochords), 990 ms (RTD);
- Converting accuracy 0,3 ÷ 0,5 %;
- Converting type: linear, nonlinear (square root);
- Upper level bus – RS485;
- 24 V power (2 inputs).

VII. 7. Metrological Characteristics of the AWB

The developed AWB has 2 measuring modules Fig.6 with metrological characteristics:

- 4 measuring channels;
- Measuring range -10÷10 V DC;
- Frequency of channel sampling 50 kS/s;
- Analogue input signal resolution 24 bits;
- Accuracy ±(0,03Umeas+0,008Urange);
- 1 MΩ input impedance.

Fig. 6. Measuring module NI-9239.

7 VFR B1947/S102K precision resistors, one per measurement channel and one reference with metrological characteristics:

- 200 Ω resistance;
- Dissipated power 600 mW;
- Temperature factor 1 ppm/C;

- Accuracy 0,005 %.

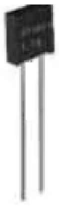

Fig. 7. B1947/S102K VFR resistor.

The precision resistors increase the accuracy of the measurement and ensure traceability of the measured values at the outputs of the WCM G01÷G08 cards.

VIII. WCM.VI VIRTUAL INSTRUMENT MAIN SCREEN

The number of checked channels and measuring points (5%, 25%, 50%, 75% and 95% of the card range) is fixed and set for each card in the virtual instrument in the LabView software environment.

The checked card is placed on the coupling of the stand. The current values set by the application WCM.vi are formed by a calibrator type AOIP PJ 6301. The input signal passes through a resistor (reference) at the input of the card, and the formed signals at the outputs, through the module NI-9239 the values are taken of the voltage drop across them and the reference resistor.

The virtual instrument user screen allows selection of:

- WCM G01÷ G08 card type;
- process position data entry and card serial number;
- verifier information and environmental conditions;
- by means of calibrator AOIP PJ 6301 the value of the current is sequentially established according to the set checkpoints;
- through the module NI-9239 the voltage drops are measured simultaneously at all channels of the unit with a speed of 1000 reports per second and a time delay of 15 seconds;
- it averages the read data for each channel separately;
- it calculates the measurement errors for each channel of the block (by comparison with the measured value of the reference channel);
- calculation of maximum error of the measurements and its comparison with the permissible error;
- visualisation of the measurements and graphical representation of their results;
- suitability/unsuitability conclusions for the card under test;
- visual indicator with three changing lights, depending on the result of the verification: red – the maximum error is greater than the allowable error, yellow – the maximum error is more than 75% of the allowable error and green when the maximum error is less than 75% of the allowable error;
- data back-up and presentation capability in Microsoft office.

Fig. 8. Main working screen of WCM.vi virtual tool.

The report generated by the virtual tool is shown in Figure 9.

Протокол за метрологична проверка № 1

1	Тип: G02 0-5 / 0-5 mA		Фабричен № 2006162			Шкаф: 5HS311/A01	
	X вх. действ.	Y изх. измерено					
	mA	Канал 1	Канал 2	Канал 3	Канал 4	Канал 5	Канал 6
	0,2500	0,2491	0,2497	0,2500	0,2491	0,2481	0,2506
	1,2500	1,2484	1,2492	1,2493	1,2483	1,2478	1,2503
	2,5000	2,4982	2,4992	2,4990	2,4980	2,4977	2,5004
	3,7500	3,7479	3,7492	3,7485	3,7475	3,7476	3,7504
	4,7500	4,7478	4,7494	4,7486	4,7475	4,7479	4,7506
	ЗАКЛЮЧЕНИЕ: Годен		Допустима грешка: 0.0150		Максимална грешка: -0.0025		
	16.02.2021г.		Проверител: Р. Евтимова				

Fig. 9. WCM G02 card metrological verification report.

Each WCM card G01 ÷ 08 is checked individually. Check time is ~ 10 minutes.

IX. CONCLUSION

The implementation of the automated workbench ensured limitation of the subjective factor for making errors in the evaluation and processing of the measurement results, reduction of the time of the metrological control and timely preparation of the activity reports. Conditions were created for the accumulation of data from metrological checks.

This development ensures the quality and optimised performance of metrological control activities for over 4500 cards and they are approved for use at the NPP.

REFERENCES

[1] 82.MO.00.MT.1743 Metrological verification of measuring converters WCM-G0x type

[2] http://www.ni.com.

National Interlaboratory Comparison of Calibration Laboratories in the Field of Mass Measurement, Bim-Mm-Nawi-2019-01

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***Abstract*— The report presents the results of the participation of the Mechanical and Physicochemical Measurements (MPCM) of the Metrological Support Department of Kozloduy NPP EAD in the national interlaboratory comparison conducted in the period from 08.07 to 23.08.2019, BIM-MM-NAWI-2019-01, for calibration of non-automatic weighing scales with a range of 200 g, class I accuracy.**

***Keywords*— interlaboratory comparison, subject of the comparison, reference laboratory, reference value, normalization of deviation of each laboratory's result toward the reference value**

I. Introduction

The interlaboratory comparison is organized by the Bulgarian Institute for Metrology, DG National Centre of Metrology, Mechanical Measurements Department.

The main goal of our participation in the interlaboratory comparison is to prove competence and build confidence for the results of the measurements in the clients of the laboratory for calibration in the field of mass measurement by comparison between the results of our measurements and the results of the reference laboratory with a follow-up analysis and identification of measures if necessary for work quality improvement (correction of the best uncertainty (CMC) stated by the laboratory for the relevant values, etc.).

II. Participants

Five accredited and two non-accredited laboratories took part in the comparison.

III. Object of Comparison

The object of comparison is an electronic non-automatic weighing scales, class I accuracy, AE 240S type, manufactured by Mettler Toledo Switzerland, with a range up to 200 g and a resolution of 0,1 mg.

The calibration points are 0,05 g, 0,1 g, 1 g, 10 g, 50 g, 100 g, 150 g and 200 g.

The stability of the comparison object was tested in the reference laboratory and it was found to be good enough for comparison purposes. We used a method of direct comparison of the reading when the scales are loaded with a test load, in this case reference weights, with the actual value of the conventional mass of the weights.

IV. Object of Comparison

4.1. Measurement results

The XREF reference value is determined by the reference laboratory and is the arithmetic mean of the before and after measurements of the participating laboratories.

The results of the two measurements indicate that for the period of the comparison, the reference object is sufficiently stable for the purpose of the comparison.

4.2. Uncertainty of the measurement

The combined root square uncertainty of the reference value is calculated in compliance with EA-4/02 Evaluation of the Uncertainty of Measurement in Calibration and is calculated according to the formula:

$$u_{REF} = \sqrt{u^2(X_{REF}) + u^2(X_{STAB})} \quad (1)$$

whereas:

$u(X_{REF})$ - measurement uncertainty of the reference laboratory;

$u(X_{STAB})$ - instability contribution from the object of comparison for the duration of the comparison.

The expanded uncertainty of the reference value is:

$$U_{REF} = 2 \cdot u_{REF} \quad (2)$$

V. Measurement and Processing of Results

For the calibration of non-automatic weighing scales, the MPCM laboratory uses a comparative measurement method in compliance with all the measurement instructions given in the technical report [1] and the requirements of the technical description of the object of comparison, and the results were processed according to the methodology for calibration of non-automatic weighing scales. The expanded uncertainty from a measurement is calculated as a product of the combined root square uncertainty and the coverage factor , k=2, which for a normal distribution corresponds to approximately 95 % confidence.

It contains contributions of uncertainty from:

- I -value reported from the repeatability measurements;
- δIecc - eccentric load correction;

- δId0 - correction from rounding of a scale mark without load;
- δIdT - correction from rounding of scale mark with load;
- mref - conventional reference mass;
- δmD - correction of the reference drift.

VI. Criterion for Assessing the Results of the Comparison

The evaluation of the results of the participating laboratories is performed through the criterion of the normalized deviation, En, which is calculated in compliance with БДС ISO/IEC 17043.

The criterion represents the normalized deviation of the result of each laboratory towards the reference value.

En is calculated according to the formula:

$$E_n = \frac{X_{LAB} - X_{REF}}{\sqrt{U^2_{LAB} + U_{REF}^{2}}} \quad (3)$$

whereas:

X_{LAB} - the value of the error of the scale reading under increasing load obtained by the participating laboratory for the relevant point;

X_{REF} -the reference value, being the value of the error of the scale reading under increasing load, obtained from the reference laboratory for the relevant point;

U_{LAB} - expanded uncertainty of the result of the participating laboratory for the relevant point;

U_{REF} - expanded uncertainty of the reference value for the relevant point.

At fulfilment of the condition │En│≤1,0 the result of the comparison for the relevant participating laboratory is considered satisfactory.

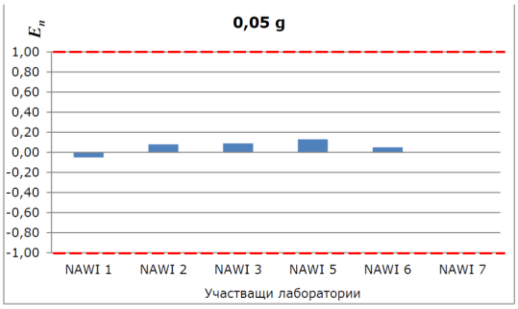
When │En│>1,0 – the result of the comparison is considered unsatisfactory.

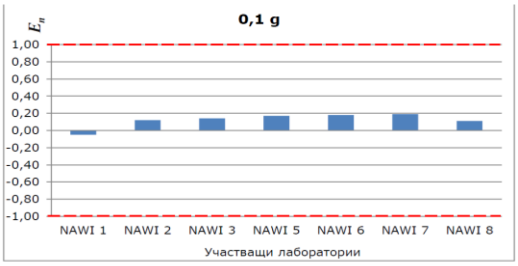
VII. Results of the Comparison

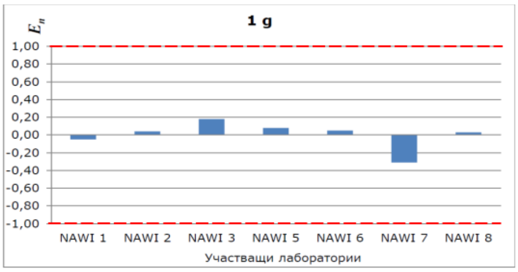
Participants in the comparison were randomly identified with NAWI 1; NAWI 2; NAWI 3; NAWI 5; NAWI 6; NAWI 7 and NAWI 8 codes.

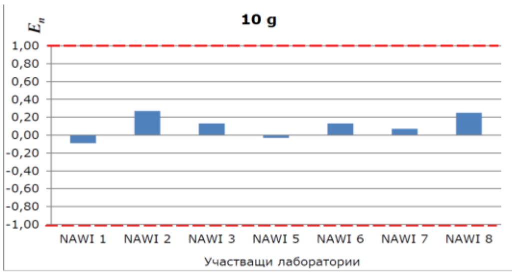
Mechanical and Physicochemical Measurements Laboratory is identified with NAWI 1.

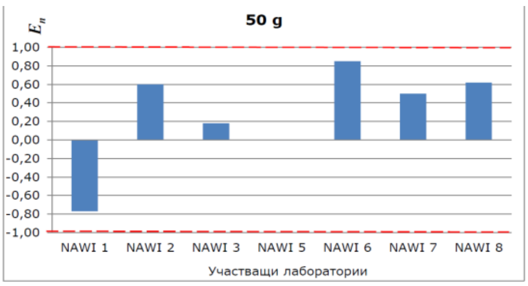
The results, according to the reports submitted by the participants, the reference values, En for each calibration point, are announced in the final report of 23.08.2019 of the suitability testing by interlaboratory comparison BIM-MM-NAWI-2019-01 for the calibration of non-automatic scales [2], and presented graphically as follows:

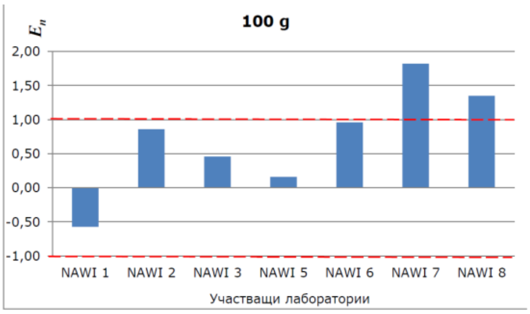


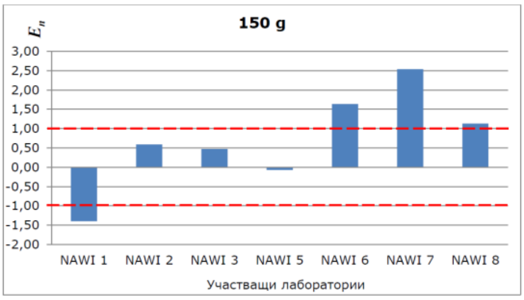


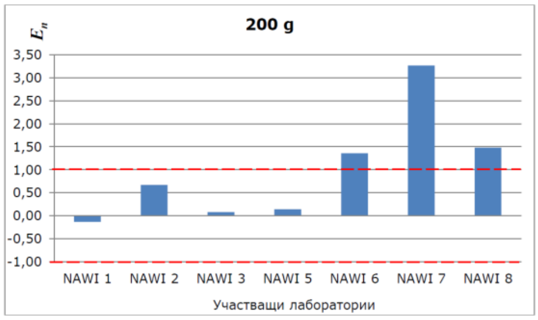












VIII. Conclusion

Seven laboratories participated in the inter-laboratory comparison for calibration of non-automated scales.

The results of the MPCM laboratory fulfilled the criterion for a satisfactory result $|E_n| \le 1$ for: items - 0,05 g, 0,1 g, 1 g, 10 g, 50 g, 100 g and 200 g.

The condition was not met for the 150 g range result.

Reassessment and analysis of the announced CMC have been made.

References

[1] Technical report for interlaboratory comparison BIM-MM-NAWI-2019-01

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Metrological Assurance of Personal Dosimetric Monitoring

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***Abstract*—The report discusses the method of implementation of personal dosimetric monitoring of occupational exposure of the staff of Kozloduy NPP EAD and the staff of external companies working under contract at the site, and the main tasks of its metrological assurance.**

A brief description is given of the method of ensuring metrological traceability and reliability of measurements of individual dose from internal and external irradiation carried out with different types of measuring instruments.

Keywords— Personal dosimetric monitoring, metrological assurance, calibration

I. INTRODUCTION

The measurement of ionizing radiation is performed in many areas of the production and monitoring activities carried out at Kozloduy NPP EAD the area of radiation protection is being of special importance for these measurements.

The metrological assurance of ionizing radiation measurements at Kozloduy NPP is performed by the "Measurement of ionizing radiation" laboratory which is an important prerequisite for compliance with:

- ALARA principle;
- technological regulations;
- radiation protection standards;
- regulatory requirements for radioactive discharges into the environment;
- the dose rate standards for the staff working in an ionising radiation environment;
- Act on Measurements.

At Kozloduy NPP EAD personal dosimetric monitoring of internal and external exposure of personnel is implemented as a part of the radiation control to ensure protection of humans from the harmful effects of ionizing radiation, in accordance with the requirements of the Regulation on radiation protection, promulgated by the State Gazette, No. 16 of 20.02.2018, in force since 20.02.2018, Regulation 32 on the conditions and procedure for personal dosimetric monitoring of persons working with sources of ionizing radiation.

II. PERSONAL DOSIMETRIC MONITORING

Personal dosimetric monitoring of occupational exposure consists of the determination of personal doses of the staff based on the results of individual measurements of the exposure characteristics of the body and individual organs and the individual uptake of radionuclides into the body of each monitored person.

Individual dosimetry monitoring determine the individual exposure of:

Individual dosimetry monitoring determine the individual exposure of:

- persons carrying out activities with sources of ionising radiation;
- persons undergoing training in an ionising radiation environment;
- persons from external organisations who carry out activities at the site and work in an ionising radiation environment;
- persons involved in the recovery from radiation incidents and accidents.

Depending on the nature of the work and the working conditions, personal dosimetric monitoring of external and/or internal exposure is carried out.

The personal dosimetric monitoring of occupational exposure of persons at Kozloduy NPP is carried out by:

1) Periodic control of the individual dose from internal exposure, carried out by whole-body measurement of the person with systems for measuring the activity incorporated in the human body (WBC);

Fig.1. Human body incorporated activity measurement systems.

2) Periodic monitoring of personal dose from external exposure by individual electronic dosimeters (IEDs) and

passive thermo luminescent dosimeters (PTLDs), the results of which are reported by a TLD system.

Fig.2. Passive thermo luminescent dosimeter and individual electronic dosimeter.

III. Metrological Assurance Activities

In order to provide anticipated high quality and reliability of the measurement results in compliance with the national and international requirements, metrology assurance of the measurement equipment for personal dosimetry control is conducted at Kozloduy NPP EAD.

The main metrological assurance activities include:

- organisation and performance of initial and subsequent metrological inspection;
- calibration of measurement equipment
- maintaining standards and ensuring traceability of measurements.

Metrology inspection is carried out in order to validate the metrological characteristics and their compliance with the requirements of the designed usage. It provides for accurate measurements.

Subsequent periodic inspections and calibration represent activities that are subject to scheduling and are performed for all instrumentation in use at Kozloduy NPP. Metrological Assurance Programme is prepared annually for the measuring instruments subject to periodic verification and calibration in the following calendar year.

IV. Metrological Assurance of the WBC

Kozloduy NPP uses three WBC systems for direct "in vivo" gamma spectrometric measurement of the activity of high-energy emitters incorporated into the human body. The measurements are performed without a shielded room with multilayer protection. The measurement geometry is a linear scan (vertically, where the person is positioned vertically and is stationary and the detector is moved in the vertical direction, and horizontally, with a stationary detector and a mobile bed that is moved in the horizontal direction), which is the most widely used configuration for determining whole-body activity of high-energy gamma emitters. The measurement systems are equipped with one detector each, which is a HPGe type.

The initial and subsequent metrological inspection of the measuring instruments is carried out by specialists of the Measures and Measuring Instruments General Directorate (MMIGD) of BIM, in accordance with Article 5 of the Measurement Act and in accordance with the Regulation on Measuring Instruments subject to metrological control. The periodicity of subsequent metrological inspections of WBC is 1 year.

The Metrological Assurance Department organises the subsequent metrological verification and assists the MMIGD specialists by providing standards with ensured metrological traceability and qualified personnel.

The calibration of the WBC is carried out by the operating unit of the Whole body count (WHB) section under the Type C Control Authority - Personal Dosimetry CC, complying with all the minimum requirements of BSS EN ISO/IEC 17025 and the BSA, as specified in BAS QR27 the calibration results are traceable to the activity unit according to the International SI System of Units.

The calibration of the WBC instruments is carried out to establish the relationships between the recorded values of the measurements (i.e. the readings of the technical measuring instrument) and their actual values realised from certified reference materials, and to assess the measurement uncertainty.

The calibration of gamma spectrometry systems for measuring whole-body activities includes:

- calibration by energy;
- resolution calibration of the measurement system;
- efficiency calibration at the peak of full absorption.

The WBC section of the Type C CA PDCC uses a certified reference material (modular phantom with MF2-02 production index) for calibration of gamma spectrometric instruments for measurement of activity incorporated in the human body, which is validated and recorded in the Register of Certified Reference Materials (CRM) manufactured in Bulgaria, Section 1.

The CRM Register is certified by the General Directorate of the National Metrology Centre, which ensures traceability to primary standards of the unit of measurement (Bq) of measurement results.

The use of the modular phantom enables modelling of human bodies with heights ranging from 150 cm to 190 cm and weights ranging from 40 kg to 120 kg. The CRM Register, in combination with the modelling of the human body by its modules, acts as an intra-departmental reference unit for the measurement of activity incorporated in the human body.

The single modules contain the same activity, homogeneously distributed over the volume of the modules at each stage of operation. The modules are constructed as conditionally sealed sources with 152Eu (5134 Bq) and 241Am (2792.6 Bq) radionuclides, and the activity within the modules is encapsulated to prevent leakage of activity from the modules, ensuring that their metrological performance is assured.

The CRM Register is stored in the Metrological Assurance Department's dedicated radioactive source storage, which ensures their metrological performance and excludes the possibility of surface radioactive contamination.

To ensure the quality of the measurements in the inter-calibration interval, the Type C CA PDCC section performs internal and external quality control. The internal quality control of the measurements is carried out periodically on a two week basis by checking the parameters and processes that influence the measurement result. External quality control of measurements is performed by conducting interlaboratory comparisons.

V. Metrological Assurance of the Individual Electronic Dosimeters (IED)

IEDs are used for operating personal dosimetric monitoring of the staff working in the EP-2 CA.

Depending on their type, IEDs are calibrated in the magnitude - personal equivalent dose Hp(10) for gamma radiation and/or neutrons.

The personal IED performs the function of an additional signal dosimeter. Preventive control of not exceeding the daily personal dose rate is performed by the IED.

In order to ensure the expected high quality and reliability of the measurement results, metrological assurance activities of the IED is performed, including: type approval, calibration, initial and subsequent metrological verification.

Type approval is performed at the manufacturing or import stages in accordance with the requirements of the BIM.

The initial and subsequent metrological verification of the IEDs is carried out by specialists of the Measures and Measuring Instruments General Directorate at BIM and authorized laboratories, in accordance with Article 5 of the Act and in accordance with the Regulation on Measuring Instruments Subject to Metrological Control.

The calibration of IEDs is carried out by the manufacturer and, if necessary, during the inspection, using specialised software.

After repairs affecting the accuracy of measurement, the IEDs are submitted for an additional metrological check.

Annually, the MA department plans and organises the submission of the IED for subsequent periodic inspection.

VI. Metrological Assurance of Personal Thermo Luminescence Dosimetry (TLD) Control

Personal thermo luminescence dosimetry control is achieved by monitoring the personal effective dose from external exposure by measuring the Hp(10) equivalent dose with an personal passive thermo luminescence dosimeter (PTLD).

At Kozloduy NPP the personal thermoluminescence dosimetry control is performed by the TPLD sector of the Type C CA PDCC. The section has four TLD-systems for measuring the personal effective dose from external irradiation [mSv], determined by measuring the personal equivalent dose Hp(10), [mSv] with personal thermo luminescence-fluorescent dosimeter. The TLD-systems are of an approved type listed in the register of approved types of measuring instruments.

In addition to passive TLDs the thermo luminescent dosimetry system includes also a readout device (readout unit) with a computer and appropriate control and data processing software.

Fig.3. Thermo luminescent dosimetry system.

Initial and follow-up verification of TLD systems is carried out by specialists of the Directorate General of MMI in accordance with the Regulation on Measuring Instruments Subject to Metrological Control.

The calibration of the TLD systems is carried out by the TPLD sector of the Type C CA PDCC in order to improve the measurement accuracy and to bring the metrological characteristics of the personal passive TLDs and the reading unit into line with the regulatory requirements.

The calibration of the passive TLDs is carried out by qualified personnel in the Ionizing Radiation Measurement Laboratory under defined conditions and established procedures, based on a validated Methodology for Calibration of Passive Thermo luminescent Dosimeters. The methodology prepared in the laboratory complies with the requirements of the methodology prepared in accordance with the regulatory requirements and IEC 62387:2012 Radiation protection instrumentation. Passive integrating dosimetry systems for personal and environmental monitoring of photon and beta radiation.

For the purpose of verification and calibration of TLD systems, calibration of reference series of passive TLDs prepared and requested by the TLD Branch of the Type C CA PDCC or MMI DG is performed in the Ionizing Radiation Measurement Laboratory.

The calibration of a batch of passive TLDs is part of the system calibration, since the detectors in them and the measuring instrument (readout device) are physically separate (distinct) instruments and each has its own characteristics. The calibrated passive TLDs are used to transmit the calibration unit of the TLD system.

A reference dosimeter with an ionisation chamber and a reference gamma irradiation line, which reproduces and transmits the individual equivalent dose unit Hp(10), is used to perform the metrological assurance activities. The reference dosimeter is traceable to the German national reference. The reference gamma irradiation line has been investigated and its parameters and metrological characteristics have been determined. All reference and auxiliary measuring instruments used have valid calibration certificates.

As recommended, calibration of the passive TLD should be performed on a homogeneous phantom of tissue-equivalent material.

Calibration is performed by the substitution method. The method consists of sequentially placing at the same calibration point in an attenuated radiation field along the beam axis a reference dosimeter with an ionisation chamber and the passive TLD group placed on the front surface of a tissue-equivalent phantom.

To determine the field characteristics at a given point on the metric line, a specialized software calculator (EasyCalc.mdb) has been developed by Ionizing Radiation Measurement Laboratory specialists, which allows to perform the necessary calculations easily and reliably.

The specialised software calculator is used to calculate the irradiation time at the selected point to obtain a given individual Hp(10) equivalent dose. We calculate the actual value obtained at the calibration point and its uncertainty.

The metrological assurance activities of personal thermo luminescence dosimetry monitoring is carried out in strict compliance with the conditions and requirements of regulatory documents, international publications and standards in the field of personal TLD monitoring.

VII. Conclusion

Laboratories for sources of ionizing radiation at Kozloduy NPP EAD are responsible for the metrology assurance of a large number of measurements and measurement instruments in the industrial and legal metrology. The principles and methods for metrology assurance which are applied by the laboratory comply with the modern international and national trends for development of metrology assurance.

The current Act on measurements, drafted in accordance with the requirements for harmonization of the legislation of the Republic of Bulgaria with the legislation of the European Union, requires:

- the metrological assurance of technological measurements to be the duty and responsibility of individual departments.
- maintenance and development of reference and material facilities is also the obligation and responsibility of the departments.

This reinforces the responsibility of individual departmental units for ensuring the quality of measurements. In the case of ionising radiation measurement - the responsibility for the environmentally sound and safe production of electricity.

Therefore, the Ionizing Radiation Measurement Laboratory at Kozloduy NPP has focused its efforts on the metrological assurance of process measurements: establishment of quality assurance programmes for single measurements, calibration of measuring instruments, improvement and development of the reference base, improvement of the quality of metrological checks, preparation of measurement methodologies, receipt inspection, etc.

References

[1] Act on Measurements

[2] Regulation on measuring instruments subject to metrological control

[3] ISO 4037-3, X and gamma reference radiation for calibrating dosimeters and dose rate meters and for determining their response as a function of photon energy-Part 3: Calibration of area and personal dosimeters and the measurement of their response as a function of energy and angle of incidence

[4] IEC 62387:2012 Radiation protection instrumentation - Passive integrating dosimetry systems for personal and environmental monitoring of photon and beta radiation

[5] DBC.MO.MT.1498 Methodology for calibration of passive thermo luminescent dosimeters.

SECTION X

QUALITY MANAGEMENT AND CONTROL, STANDARDIZATION, CERTIFICATION, ACCREDITATION

Shrinkage Compensating Concrete Admixtures – a Necessity to Start a Standardization Procedure

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***Abstract*— Shrinkage is an inherent characteristic of Portland cement concretes, leading to their volume reducing, which potentially create preconditions for the development of different types of cracking - prerequisites for integral decreasing of structure durability. The elimination of the negative processes from the development of shrinkage in all its varieties (autogenous, plastic, thermal and carbonization) is based on optimization of complex mix design and technological factors, including the use of innovative chemical products - mainly minimizing and/or compensating the volume changes during the concrete setting and hardening.**

In recent years, new innovative products have entered the world and Bulgarian practice aimed to compensate the shrinkage by initiating of additional hydration interactions. These processes give some attractive possibilities for manageable early age increasing of the concrete volume, leading to partial or complete compensation of the negative effect of later shrinkage. Unlike the well-known types of special shrinkage-compensating cements, these innovative chemical agents are not yet standardized (despite their presence in the product range of different manufacturers), which makes it difficult to use them effectively.

The report presents results for the effective action on the strength-deformation characteristics of concrete from the use of a special shrinkage-compensating modifier KEPTONITE. The product, in accordance with ACI Technical Report 223-10 Standard Practice for Use of Shrinkage Compensated Concrete, is specified as the so-called type G-agent. The using permission in Bulgaria is in accordance of respective BULGARIAN TECHNICAL APPROVAL (BTA) No 0192/01.03.2021, issued by Notified Body of University of Architecture, Civil Engineering and Geodesy, Sofia.

Successful implementation of this type of products obviously passes by respective standardization procedures. Nowadays stated lack of such standard in the world would be overcome in EC countries by possibilities for respective National, or European technical approval issuing. The latter has a big negative effect, connected to the fact that there is no unified technical characteristics for different products of this range and this makes it impossible to compare them correctly.

In our point of view, the time has come to develop a relevant standard. This is what both theory and real production practice already desperately need it.

***Keywords*— portland cement concrete, shrinkage, cracking, shrinkage-compensating cements, shrinkage-reducing admixtures, shrinkage-compensating agents, strength-deformation characteristics**

I. IINTRODUCTION

The shrinkage of Portland cement concretes is an inherent characteristic of them, leading to volumetric reducing, which potentially create preconditions for the development of crack formation processes. This leads to prerequisites for integral decreasing of the durability of the structural elements, constructions and facilities.

The shrinkage is an intrinsic phenomenon in the hardening processes of cement pastes and cement-containing composites (concrete, mortar, etc.). It is expressed in the reduction of the volume of the cement stone, respectively the concrete, and is due to the reduction of the water content and of complex physical-chemical processes during the hydration of the Portland cement. Shrinkage, according to the time and reasons for its formation, is classified as:

- **Plastic shrinkage**, which occurs while the concrete mixture is in a plastic state and is caused by the rapid loss of water from the concrete surface. If preventive measures (so called "curing") are not taken, the amount of plastic shrinkage can exceed several times another main component - moisture shrinkage. The topic of plastic shrinkage is not subject to national regulations, but there are a number of foreign documents dedicated to the problem. One of the best examples of this is the **ACI 305R-10 Guide to Hot Weather Concreting** [1].
  Plastic shrinkage leads to the formation of cracks of different width and depth, especially when concreting in hot, dry and windy weather. High temperature, wind speed, low humidity or a combination of these factors can cause rapid surface evaporation of water. The rate of water release is a function of the concrete mix design, the thickness of the concrete cross-section, the type and degree of compaction, etc.
  It is considered that if the rate of evaporation of water from the concrete surface exceeds 1,0 kg/m^2/h, preventive measures should be taken. Analytical, including nomograms dependences are well-known for determining the amount of evaporated water, influenced on temperature, wind speed and relative humidity [2].

- **Drying shrinkage** is active from the moment when the concrete curing (realized by different technological ways) at its early age is stopped. The process develops intensively in the initial period and gradually subsides within 2-5 years. Draying shrinkage leads to deformations and stresses in the structures, which, when the tensile strength of the concrete is exceeded, cause the formation of cracks. The factors that affect the draying shrinkage are the concrete mix design (type and amount of cement), geometrical sizes of the concrete element, the presence of reinforcement, relative humidity of the ambient air and others.

- **Contraction (chemical, autogenous) shrinkage** is an intrinsic process that accompanies the hydration of Portland cement. It is due to the fact that the volume of the solid phase, after the hydration process, is smaller than the total volume of the starting products (cement and water). Each clinker mineral in the composition of the cement has its own specific contraction shrinkage. Contraction shrinkage leads to the formation of so-called contractional micropores, which, due to their fine dimension, do not affect the permeability of concrete.

- **Carbonization shrinkage** is due to the carbonization of calcium hydroxide (Portlandite), a major product in the hydration of cement, in interactions with carbon dioxide from the atmosphere. The process proceeds relatively slowly from the surface to the depth of the concrete cross-section. The main factor that affects the rate of carbonization of concrete is its their permeability, which is strongly influenced by the water-cement ratio.
  The total effect of the different components of shrinkage causes corresponding stresses in the concrete body, and in the different phases of hardening and increasing the strength of concrete over time, they can lead to undesirable cracking and defects. This effect directly affects the direction of reducing the serviceability and durability of the elements and structures in general.
  There are several popular methods for numerical determination of concrete shrinkage, and undoubtedly the most used among them are those regulated in the **fib Model Code (1990, 2010)** [2], which is laid down in **EN 1992-1-1: 2004 (Eurocode 2)** [3] and the method described in **ACI 209.2R-08 Guide for Modeling and Calculating Shrinkage and Creep in Hardened Concrete** [4].

Generally speaking, quality and serviceability of industrial concrete floorings and pavement, mainly as a ground-supported slab on grade, are dramatically influenced from the shrinkage. These type of concrete structures designed and implemented to provide the main functions of logistics centers, production and parking areas, hypermarkets, retail centers, etc., can be specified as "***a poured type of construction site reinforced or non-reinforced concrete structures with geometric dimensions in plan many times exceeding the size in height, designed as a slab on an elastic base and surface finishing-made by power-floating, for long-term absorption of specific operating loads with ensured resistance to environmental and production factor"*** [5] Their serviceability directly depends on the size and speed of development of the shrinkage processes in the concrete used for their implementation.

In Table. I presented values for the deformations range from shrinkage as a function of the humidity of the medium of aging of the concrete. The marked area is representative of industrial concrete floors and pavements, where the problems caused by uncontrolled shrinkage have a very negative impact on their durability [6]. The concretes used for such concrete structures do not exceed those with a compressive strength class of 40/50 MPa, resp. the humidity range of the medium during performance and aging is usually within 40-80%.

TABLE I. DRYING SHRINKAGE NON-RESTRAINED DEFORMATION (ε_{CD}) FOR CONCRETE CLASSES (F_{CK}/ $F_{CK,CUBE}$) WITH CEM I, CLASS N

f_{ck}/ $f_{ck,cube}$, MPa	**Relative humidity, %**					
	20	**40**	**60**	**80**	**90**	**100**
20/25	0,62	**0,58**	**0,49**	**0,30**	0,17	0,00
40/50	0,48	**0,46**	**0,38**	**0,24**	0,13	0,00
60/75	0,38	0,36	0,30	0,19	0,10	0,00
80/95	0,30	0,28	0,24	0,15	0,08	0,00
90/105	0,27	0,25	0,21	0,13	0,07	0,00

Shrinkage causes free deformations caused by corresponding stresses in the concrete section, which can generally be calculated according to the methodology included in **TR34-3td Edition (2003)** [6], based on the understanding that drying shrinkage in the presence of restrain conditions for well-designed and executed fibre-reinforced concretes is in the range of $400\text{-}600.10^{-6}$ mm/m. The resulting shrinkage stress f_{sh} can be calculated as follows:

$$f_{sh} = E_{cm}\varepsilon_{sh} \qquad (1)$$

where:
E_{cm} – secant elastic modulus of fibre-reinforced concrete;
ε_{sh} – long-term drying shrinkage deformation

As far as the shrinkage is a function of the aging time of the concrete, obviously its value is subject to reduction from the realization of the accompanying long-term creep of the concrete with different intensity. This allows a threefold reduction in the values of the secant elastic modulus ***($E_{cm(t)}$= E_{cm}/3)***, which modifies the drying shrinkage stresses formula as follows:

$$f_{sh} = E_{cm(t)}\varepsilon_{sh} \qquad (2)$$

The application of suitable polyethylene membranes in the base-joint of the flooring/pavement allows reduction of the limiting factors of shrinkage, in which case the coefficient of friction μ varies from 1 to 2,5. Referring to **BS 8110-3 Structural use of concrete (Table 3.3 Values of restraint recorded in various structures**) [7] specifies the average value of the so-called limiting factor equal to 0,2. Then the shrinkage stress f_{sh} is determined by a modified formula, including the potential value of the limiting factor:

$$f_{sh} = 0{,}2E_{cm(t)}\varepsilon_{sh} \qquad (3)$$

In case of average value of long-term drying shrinkage deformation ε_{sh} in range of 500.10^{-6} mm/m, the shrinkage stress can be calculated:

$$f_{sh} = 0{,}2.33.10^3.500.10^{-6} = 1{,}1 \text{ N/mm}^2 \qquad (4)$$

It is seen that in a certain phase of concrete structure formation these stresses exceed the respective strength and it can lead to cracking. In conclusion of the above, it is clear that it is necessary to search and use different approaches to control the shrinkage, thus creating the necessary prerequisites to ensure its design durability.

II. Possibilities for Shrinkage Limitation and Controlling

There are currently several different approaches to minimizing the size of concrete shrinkage. Generally speaking, they represent focused efforts mainly on optimization in the concrete mix design and technological approaches for concrete curing after casting.

The approach in the design phase of the concrete composition consists in the use of quality aggregates, selected type of cement (ordinary and those with compensated shrinkage), the use of a combination of special chemical admixtures - mainly highly water-reducing, shrinkage-reducing and shrinkage-compensating ones.

The use of special shrinkage-compensated cements is relatively complicated, given the impossibility of concrete batching plants to keep in stock this special types of cement.

In **BDS EN 197-1: 2011** [8] includes 27 products in the group of ordinary cements and 7 products in the group of sulphate-resistant cements. The shrinkage-compensated cements are not specified.

This type of cements is included in USA standardization system - **ACI 223R-10 Guide for the use of shrinkage-compensated concrete** [9]. Three types of shrinkage-compensated cements are described in **ASTM 845** [10] are designated **K**, **M** and **S** – TABLE II.

TABLE II. Types Of Shrinkage-Compensating Cements And Their Constituents

Expansive type	**Principal constituents**	**Reactive aluminates available for ettringite formation**
K	(a) Portland cement (b) Calcium sulfate (c) Portland-like cement containing C_4A_3S	C_4A_3S
M	(a) Portland cement (b) Calcium sulfate (c) Calcium-aluminate cement CA and $C_{12}A_7$	CA and $C_{12}A_7$
S	(a) Portland cement high in C_3A (b) Calcium sulfate	C_3A
G	(a) Portland cement high in CaO (b) Calcinated pozzolan (SiO_2 and Al_2O_3)	$CA(OH)_2$, CaO and Al_2O_3

As far as the use of highly water-reducing (HRWRA) and shrinkage-reducing chemical admixtures (ShRA) has been established for years in the direction of shrinkage minimizing, the shrinkage-compensating (ShCA) ones are present relatively recently in research and construction practice.

In **BDS EN 934-2: 2009 + A1 Chemical admixtures for concrete, mortar and grout. Part 2: Chemical admixtures for concrete. Definitions, requirements, conformity, marking and labeling** [11], **table. 1, p. 9**, 12 types of chemical admixtures are defined, among which there are none with shrinkage compensating action.

Along with the apparent absence of these highly effective chemical admixtures from the current standardization system in Bulgaria, Europe and the world as a whole, in the real construction practice there is a well-grounded interest in their application in construction. The principle of their effective action is illustrated in Fig. 1.

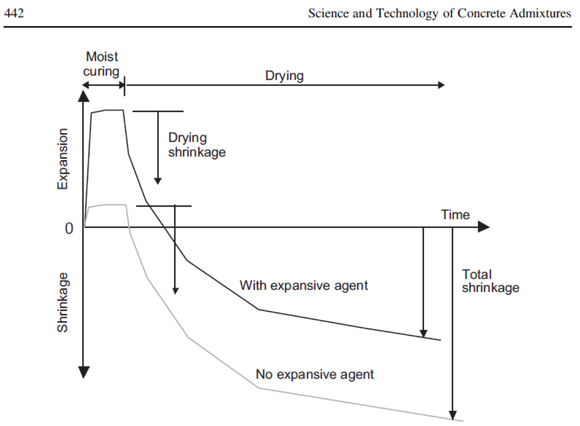

Fig.1. Schematic representation of the swelling and drying shrinkage of two concretes, one containing an expansive agent and another not contain this type of agent.

The mechanism of compensated shrinkage is based on the ability of these admixtures (expanding agents) to cause an initial increase in the volume of the concrete, which compensates to varying degrees for the decrease in volume due to the development of shrinkage processes over time. In this efficient way, concrete compositions with a predetermined maximum shrinkage range can be designed, including up to its complete elimination and / or to an optimal degree of self-stressing.

The internal expansion occurs dominantly during the first 1-3 (rarely up to 7) days of concrete curing and its size is not more than 0,1% from the initial volume of concrete. Generally speaking, the kinetics and intensity of internal expansion depend on some basic parameters - the chemical nature and dosage rate of the expansive agent, the type and duration of wet curing and cement dosage. These expanding agents are most often available in powder form, and it is necessary to optimize their consumption depending on the type and amount of cement and the required degree of shrinkage compensation [13].

III. Actual Bulgarian Practice

In actual BG-practice more often new chemical admixture KEPTONITE takes part in the special mix design for the concretes used for industrial ground flooring systems – especially for so called "joint-free" ones. The mixture is based on the peculiarities of the expansive agent Type G (a special type of dead-burn lime CaO) which results in the future portlandite $Ca(OH)_2$ crystals formation in case of contact with water. The expansion is quite rapid and reaches maximum value in range of first 24-48 hours after concrete mixing and casting. The dosage rate is in range of 10-20 kg/m^3 of concrete. There are a lot of original scientific results concerning the relationships between type of cement and KEPTINITE dosage [14]. Limited part of them is illustrated in Fig. 2.

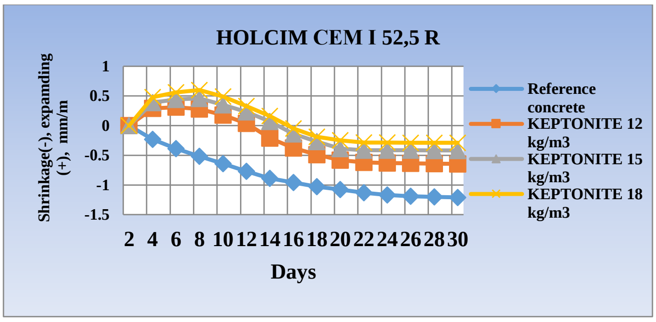

Fig. 2. Shrinkage/expanding kinetics of the concrete with cement HOLCIM CEM I 52,5r in function of KEPTONITE dosage.

The original scientific results obtained from the study [14] makes it possible to evaluate the application of ShCA KEPTONITE as particularly effective in reducing drying shrinkage of concrete produced on the basis of various typical for Bulgaria cement. The different cements in the composition of the tested concretes predetermine the different kinetics of free deformation, which, obviously, was provoked primarily by the different chemical and mineral composition of the base clinker.

The tested dosage range of the ShCA KEPTONITE is within the optimum ratio between technical characteristics and reasonable price.

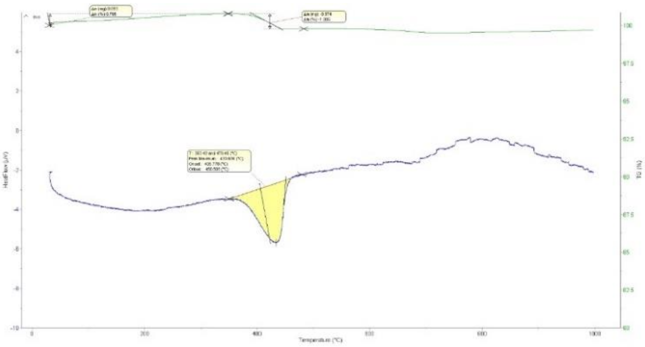

Fig. 3. KEPTONITE - Differential-thermal analysis CaO identification.

The very successful use ShCA KEPTONITE in the concrete mix design for joint-less industrial flooring innovating system is for BPD-LOGISTIC PARK in Varna with total area of 15 000 m^2. Due to the promising technical solution proposed whole area was divided to minimized one-day casting zones (limited with special type HCJ sinus expansion steel joints), as a biggest one was around the impressable 2074 m^2 without any saw-cut joints.

In conclusion, the use of ShCA KEPTONITE in the mix design for special concretes for industrial floorings and thin repair overlays for repair and restoration of defected reinforced concrete structures in industrial sites is particularly promising. Due to the fact of above discussed lack of an appropriate standard for the expansive agents, Bulgarian stakeholders assigned to Notified Body of University of Architecture, Civil Engineering and Geodesy, Sofia, the development of the respective BULGARIAN TECHNICAL APPROVAL (BTA) No 0192/01.03.2021 for expansive concrete modifier ShCA KEPTONITE.

TABLE III. KEPTONITE DRY POWDER CHARACTERISTICS

Technical characteristics	**Test method**	**Test result**	**Limits by BTA №0192**	**Compliance**
Appearance	visual	Dry powder material from 3 samples	Dry powder material	yes
Color	visual	Light beige from 3 samples	Beige-yellow to white	yes
Specific density, кg/m^3	BDS EN 459-2	3120, 3060,3115 Average: 3098	3000-3200	yes
Bulk volume density, кg/m^3	BDS EN 459-2	1340, 1280,1390 Average:1337	1200-1500	yes
Remain on standard sieve 125 μ, %	EN ISO 3310-1	4,2; 4,8; 4,6 Average: 4,53	≤ 5,0	yes
Remain on standard sieve 63 μ, %	EN ISO 3310-1	28; 31; 36 Average: 31,70	20-50	yes
Insoluble residue, %	BDS EN 196-2	3,7; 3,2; 4,1 Average: 3,43	≤ 5,0	yes
Loss on ignition, %	BDS EN 196-2	1,64; 1,48; 1,53 Average: 1,55	≤ 2,0	yes
Chloride content, %	BDS EN 196-2	0,03; 0,04; 0,02 Average: 0,03	≤ 0,1	yes
Reactive CaO - %	BDS EN 196-2 and/or DTA-test	Fig. 4 (≈ 100%)	≥ 95	yes

TABLE IV. KEPTONITE FRESH CONCRETE

Technical characteristics	**Test method**	**Test result**	**Limits by BTA №0192**	**Compliance**
Setting time, compared with reference concrete, min	BDS EN 196-3	Reference concrete: start: 3 h 28 min end: 5 h 15 min KEPTONITE concrete: start: 3 h 17 min (- 11 min = 5,3 %) end: 5 h 08 min (- 7 min = 2,2 %)	±15	yes
Slump test, compared to reference concrete, mm	BDS EN 12350-2:2009	Reference concrete 135; 143; 129 Average: 136 KEPTONITE concrete 142; 148; 153 Average: 148 (+12 mm)	±15	yes

Respective tests included in BTA content were performed to specify the essential product characteristics - TABLE III, IV and V, Fig. 3.

TABLE V. KEPTONITE HARDENED CONCRETE CHARACTERISTICS

Technical character-ristic	**Test method**	**Test result**	**Li-mits by BTA №01 92**	**Comp-liance**
Volume density, compared with reference concrete (kg/m^3), %	BDS EN 12390-7:2019	Reference concrete 2340; 2290; 2305 Average: 2312 KEPTONITE concrete 2350; 2320; 2330 Average: 2333 (100,9 %)	± 5	yes
Compressive strength, compared to reference concrete (MPa), %	BDS EN 12390-3:2009	Reference concrete 34,4; 36,2; 35,4 Average: 35,3 KEPTONITE concrete 35,7; 38,2; 36,6 Avarage: 36,8 (104,2 %)	≥95	yes
Splitting tensile strength, compared to reference concrete (MPa), %	BDS EN 12390-6:2009	Reference concrete 2,3; 2,2; 2,3 Average: 2,27 KEPTONITE concrete 2,4; 2,2; 2,2 Average: 2,27 (100 %)	≥95	yes
Secant modulus of elasticity in compression, compared to reference concrete (GPa), %	BDS EN 12390-13:2012	Reference concrete 28; 29; 28 Average: 28,3 KEPTONITE concrete 27; 29; 30 Average: 28,7 (101,4 %)	≥95	yes
Depth of penetration of water under pressure (mm), compared to reference concrete, %	BDS EN 12390-8:2009	Reference concrete 38; 40; 36 Average: 38 KEPTONITE concrete 34; 32; 35 Average: 33,7 (88,7 %)	≤100	yes
Frost resistance, compared to reference concrete – accelerated method, resistance of numbers of cycles, %	BDS EN 206:2013 +A1:2016/NA:2017 Annex NA.O, p.2	Reference concrete cycles :75; 75; 75 Average: 75 KEPTONITE concrete cycles: 100; 100; 100 Average: 100 (133,3 %)	≥95	yes
Shrinkage at 28-days of age, compared to reference concrete (mm/m), %	BS EN 12390-16	Reference concrete 0,4 mm/m KEPTONITE concrete 0,1 mm/m (25 %)	0-50	yes

IV. CONCLUSION

Based on innovative approach for elimination of negative effect to the concretes, provoked by intrinsic shrinkage processes, KEPTONITE could be promoted as a typical representative of new family (Type G) shrinkage-compensating agent.

Successful implementation of this type of products obviously passes by respective standardization procedures. Nowadays stated lack of such standard in the world would be overcome in EC countries by possibilities for respective National, or European Technical Approval issuing. The latter has a big negative effect, connected to the fact that there is no unified technical characteristics for different products of this range and this makes it impossible to compare them correctly.

From an objective point of view, the time has come to develop a relevant standard. This is what both theory and real production practice already desperately need it.

ACKNOWLEDGMENT

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Procedure for Evaluation of Measuring Systems in a Test Laboratory Using the MSA Method

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***Abstract*—An overview of used measuring systems in the metrological laboratory for the automotive industry is made. Using the MSA (Measurement statistical analysis) method, an assessment of basic measurement systems was performed. Based on the collected data, an analysis and evaluation of the capabilities of the measuring systems was performed using the MiniTab 19 software. A conclusion was made based on the obtained results with conclusions about the acceptability of the process and its improvement. A procedure for evaluation of measuring systems has been established.**

Keywords— quality, measurement, control, repeatability and reproducibility, statistics

I. Introduction

Secure measuring and control systems are used in the production processes and must be properly verified. A modern method for evaluation and verification of such systems is MSA [1], which examines the impact of equipment, method, materials, operator and environment [2] and evaluates their proper use. Many software products [3, 4] are used for assessment with MSA, in which there is a module for MSA assessment. The evaluation parameter is GRR%, which is a measure of the repeatability and reproducibility of the measuring system. Statistics and correlations determine the limits of GRR% at which measuring systems can be used or need to be improved. The main indicators of the quality of a measuring system that can be determined by MSA [5] are:

- Repeatability (EV);
- Reproducibility (AV);
- Repeatability and reproducibility (Gage R&R или GRR);
- Variation of details (PV);
- Complete (general) variation (TV);
- Number of district categories (ndc $\geqslant$ 5).

Deviations are caused by various problems - wear standard or error in the standard, worn components of the measuring instrument, improperly designed instrument or its incorrect application, incorrect measuring method or calculation, incorrect calibration of the instrument, environmental impact, untrained operators and others.

The creation of a procedure for evaluation of the measuring system in a test laboratory using the MSA method will ensure the measurement of valid data through which to manage a certain process. The procedure will also be used to assess the repeatability and performance indicators of the measuring system, which are important for determining the period for external calibration of the equipment.

Using the Ishikawa diagram to evaluate the measurement system aims to identify possible causes of a problem.

Using software to apply the method MSA facilitates the application of the method by reducing the possibility of human error and reduces the time for the overall use of the method.

II. Experiments

For the correct examination and verification of the measuring systems, the causal connection was used to analyze the reasons for incorrect use of the measuring systems by means of an Ishikawa diagram, which for the specific case is shown in fig. 1.

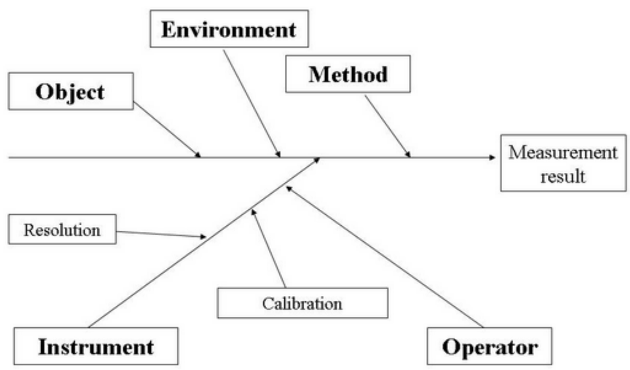

Fig. 1. Ishikawa diagram of a measuring system.

Table 1 is used to evaluate a measurement system using the MSA method.

TABLE 1.

GRR	Decision	Comment
<10%	It is usually considered a suitable measuring system.	Recommended; it is especially useful when sorting or classifying products or when intensive process control is required.
10-30%	The system may be suitable for some applications.	A decision must be made as to whether to apply measurement, to estimate the cost of the measuring instrument, the cost of processing and repair. It should be approved by the client.
>30%	It is considered an inappropriate measuring system.	Every effort must be made to improve the measurement system. An adequate measurement strategy must be implemented. For example, using the arithmetic mean of several readings of the same product indicator to reduce the final measurement variation.

The subject of the present work is a metrological laboratory of a manufacturer for the automotive industry, in which the following measuring equipment is used:

1. Non-destructive measurements:

1.1. Network Connection Analyzer;

1.2. High voltage meter for insulation and dielectric strength test, continuity test, resistance test;

1.3. Theraommeter and picoommeter;

1.4. LCR meter;

1.5. Micrometer;

1.6. Digital microscope;

1.7. High resolution camera;

1.8. Digital micrometer;

1.9. Digital caliper;

1.10. Measuring line;

1.11. X-ray inspection and computed tomography.

2. Destructive measurements:

2.1. Mechanical material testing machine - maximum tensile strength, maximum compressive strength, tear strength, maximum elongation and area reduction;

2.2. Cross-section system with measuring microscope.

III. RESULTS

The results and analysis were made for basic measurement systems using the MSA method by collecting and processing analysis data. A digital micrometer, a digital microscope and an X-ray measuring system were studied as basic measuring systems. The results were analyzed using the MiniTab 19 software product, which has the built-in MSA method.

A. Digital micrometer

For sufficiently reliable reliability of the results, a team of three evaluators (operators) measured the internal diameters of 10 parts in mm, which were collected in 2 pieces on 5 different days from different production orders in order to cover the entire production process. The specification of the details was for an outer diameter size of 5.60 ± 0.05mm. The collected database is shown in Table 2.

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TABLE 2.

RunOrder	Parts	Operators	Measurements
1	2	Tsvetoslava	5,600
2	5	Stilianos	5,618
3	9	Tsvetoslava	5,623
4	5	Tsvetoslava	5,617
5	3	Tsvetoslava	5,597
6	4	Stilianos	5,604
7	3	Veselka	5,598
8	7	Veselka	5,590
9	5	Veselka	5,617
10	5	Stilianos	5,618
11	6	Stilianos	5,603
12	5	Tsvetoslava	5,603
13	10	Tsvetoslava	5,612
14	8	Veselka	5,609
15	1	Tsvetoslava	5,602
16	3	Stilianos	5,597
17	4	Tsvetoslava	5,604
18	1	Stilianos	5,602
19	2	Stilianos	5,600
20	10	Veselka	5,612
21	7	Stilianos	5,591
22	4	Veselka	5,604
23	8	Stilianos	5,609
24	9	Stilianos	5,612
25	9	Veselka	5,623
26	6	Tsvetoslava	5,603
27	7	Stilianos	5,609
28	7	Tsvetoslava	5,590
29	7	Tsvetoslava	5,590
30	10	Stilianos	5,612
31	1	Veselka	5,602
32	3	Stilianos	5,598
33	9	Tsvetoslava	5,609
34	8	Tsvetoslava	5,609
35	2	Stilianos	5,600
36	1	Stilianos	5,612
37	4	Tsvetoslava	5,604
38	2	Veselka	5,600
39	6	Tsvetoslava	5,603
40	9	Veselka	5,623
41	1	Tsvetoslava	5,602
42	6	Veselka	5,603
43	6	Veselka	5,603
44	8	Stilianos	5,609
45	8	Tsvetoslava	5,609
46	6	Stilianos	5,603
47	8	Veselka	5,609
48	4	Stilianos	5,604
49	9	Stilianos	5,624
50	5	Veselka	5,618
51	10	Tsvetoslava	5,612
52	10	Veselka	5,612
53	4	Veselka	5,604
54	3	Tsvetoslava	5,598
55	2	Tsvetoslava	5,600
56	10	Stilianos	5,611
57	3	Veselka	5,598
58	2	Veselka	5,600
59	1	Veselka	5,602
60	7	Veselka	5,590

The results were processed with MiniTab 19 software and can be seen in fig. 2.

Two-Way ANOVA Table With Interaction

Source	DF	SS	MS	F	P
Parts	9	0,0051873	0,0005764	3939,70	0,000
Operators	2	0,0000000	0,0000000	0,11	0,893
Parts * Operators	18	0,0000026	0,0000001	1,46	0,174
Repeatability	30	0,0000030	0,0000001		
Total	59	0,0051929			

α to remove interaction term = 0,05

Two-Way ANOVA Table Without Interaction

Source	DF	SS	MS	F	P
Parts	9	0,0051873	0,0005764	4911,02	0,000
Operators	2	0,0000000	0,0000000	0,14	0,868
Repeatability	48	0,0000056	0,0000001		
Total	59	0,0051929			

Variance Components

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0,0000001	0,12
Repeatability	0,0000001	0,12
Reproducibility	0,0000000	0,00
Operators	0,0000000	0,00
Part-To-Part	0,0000960	99,88
Total Variation	0,0000962	100,00

Gage Evaluation

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)
Total Gage R&R	0,0003426	0,0020555	3,49
Repeatability	0,0003426	0,0020555	3,49
Reproducibility	0,0000000	0,0000000	0,00
Operators	0,0000000	0,0000000	0,00
Part-To-Part	0,0098000	0,0588003	99,94
Total Variation	0,0098060	0,0588362	100,00

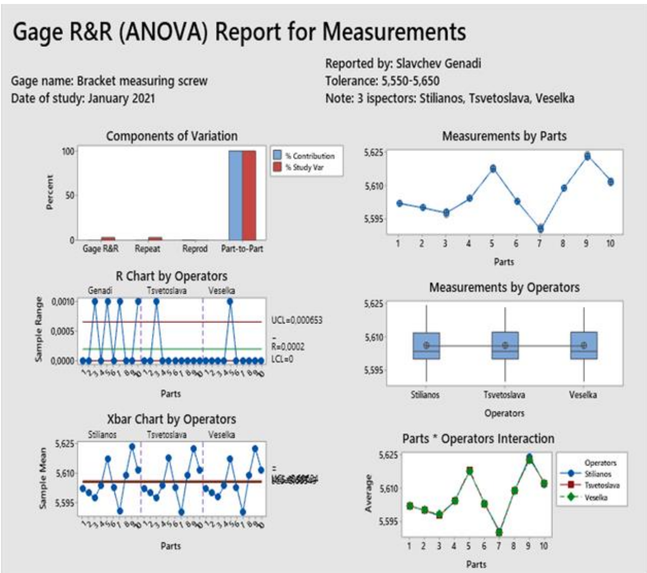

Fig. 2. Results of diameter control analysis with micrometer.

The results obtained are:

- Repeatability – 3,49%;
- Reproducibility – 0%;
- Gage R&R или GRR - 3,49%;
- Variation of details (PV) – 99,94%;
- Complete (general) variation (TV) – 100%;

* Number of district categories (ndc ⩾ 5) – 40.

The results are acceptable and since GRR% <10%, the measuring system is applicable without the need for improvement.

B. Digital microscope

In this case, the evaluation of a measurement with a digital microscope of internal diameter with a specification of 0.82 ± 0.03 mm was performed as in A. and the final results are shown in fig. 3.

Gage Evaluation

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)
Total Gage R&R	0,0017855	0,010713	10,01
Repeatability	0,0008165	0,004899	4,58
Reproducibility	0,0015879	0,009527	8,91
Operators	0,0000000	0,000000	0,00
Operators*Parts	0,0015879	0,009527	8,91
Part-To-Part	0,0177386	0,106432	99,50
Total Variation	0,0178282	0,106969	100,00

Number of Distinct Categories = 14

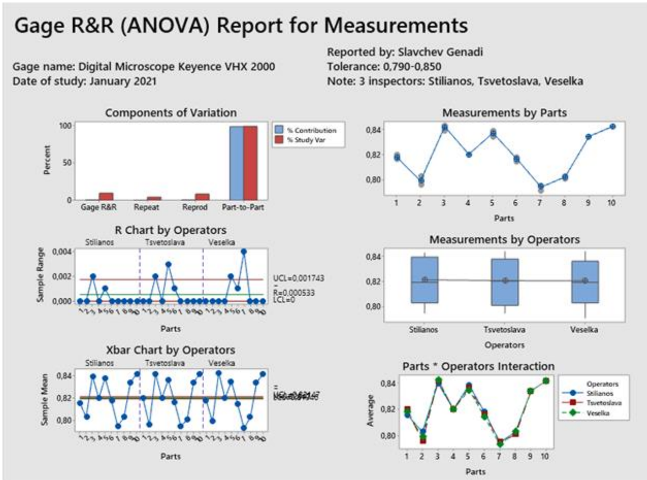

Fig. 3. Results of diameter control analysis with a microscope.

The results obtained are:

- Repeatability – 4,58%;
- Reproducibility – 8,91%;
- Gage R&R или GRR - 10,01%;
- Variation of details (PV) – 99,50%;
- Complete (general) variation (TV) – 100%;

* Number of district categories (ndc ≥ 5) – 14.

The results are usable and since GRR%> 10%, the measuring system is applicable, but needs to be improved.

C. X-ray measuring system

In the present case, for the evaluation of measurement with an X-ray system for the length of a hidden element of an article with a specification of 22.0 ± 0.6 mm, the procedure is as in A. and the results are shown in fig. 4.

Gage Evaluation

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)
Total Gage R&R	0,049610	0,29766	38,76
Repeatability	0,049610	0,29766	38,76
	0,000000	0,00000	0,00
Reproducibility			
Operator	0,000000	0,00000	0,00
Part-To-Part	0,259766	1,55859	98,22
Total Variation	0,264460	1,58676	100,00

Number of Distinct Categories = 5

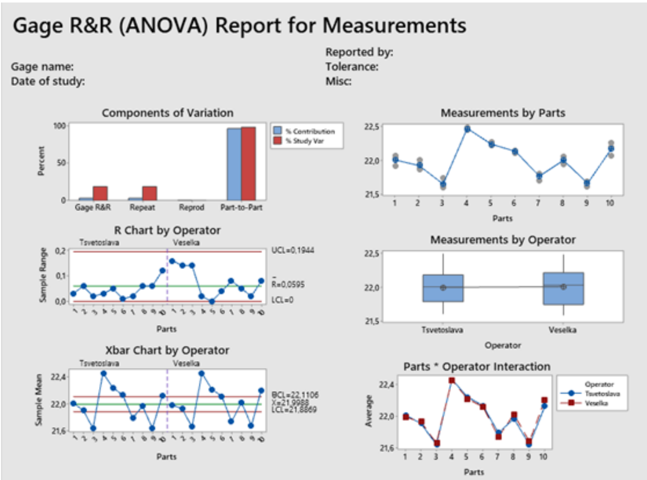

Fig. 4. Results of analysis of length control with X-ray meter.

The results obtained are:

- Repeatabilit) – 38,76%;
- Reproducibility – 0%;
- Gage R&R или GRR - 38,76%;
- Variation of details (PV) – 98,22%;
- Complete (general) variation (TV) – 100%;

* Number of district categories (ndc ≥ 5) – 4.

The results are biased and since GRR%> 30% the measuring system is not applicable and needs to be changed.

IV. Conclusion

MSA is defined as an experimental and mathematical method for determining the variation that exists within a measurement process. Variation in the measurement process can directly contribute to our overall process variability. It is used to certify the measuring system by assessing the accuracy and stability of the system. An effective MSA process can help ensure that the data being collected is accurate and the data collection system is appropriate for the process. Reliable data can prevent waste of time, labor and marriage in the production process. Processes, among other parameters that they can lead to, must be evaluated both in terms of their quality and in terms of quantitative characteristics. The assessment is made on the basis of existing data and data to be collected.

As a result of the present study, a procedure for evaluation of a measuring system by the MSA method for a metrological laboratory consisting of:

1. Plan the approach that will be used when measuring Determining the owner of the procedure and team leader
2. Determining the number of assessors, the number of test items and the number of repeated readings.
3. Selection of a tool that allows at least one tenth of the expected change in the controlled characteristic to be read directly.
5. Choice of measurement method.
6. Preparation of data collection forms and software for data processing and analysis of results.
7. Determining the form for presenting the obtained results.
8. Continuous improvement through the use of the Ishikawa diagram.

The creation of a procedure for evaluation of the measuring system in a test laboratory using the MSA method will ensure the measurement of valid data through which to manage a certain process. The procedure will also be used to assess the repeatability and performance indicators of the measuring system, which are important for determining the period for external calibration of the equipment.

Using the Ishikawa diagram to evaluate the measurement system, the possible causes of a problem are identified.

Using software to apply the MSA method facilitates future application of the method by reducing the possibility of human error and reducing the time to complete the method.

Acknowledgment

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State of Art of Radon and Thoron Volume Activity Measurements

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***Abstract*— A control, monitoring and reduction of the dose load from ionizing radiation to the population is a national task, which is determined and coordinated by a number of Laws and Resolutions of the Cabinet of Ministers of Ukraine.**

Based on the accumulated experience in the creation and operation of the state primary standard for the unit of volumetric activity ^{222}Rn, a methodology for creating the state primary standard for the unit of volumetric activity ^{222}Rn (radon) and ^{220}Rn (thoron) is proposed.

The natural background radiation consists of cosmic radiation and radiation from natural radionuclides (^{232}Th, ^{226}Ra, ^{40}K) common in the Earth's crust, soil, air, water and other objects of the external environment. Some part of the territory of Ukraine is located on the Ukrainian crystal shield with significant reserves of ^{226}Ra and ^{232}Th and, as a result, ^{222}Rn (radon) and ^{220}Rn (thoron) emanations from the soil surface into the environment, housing and industrial premises.

The purpose of this work is to develop the structure and concept of constructing the state primary standard of the unit of volumetric activity ^{222}Rn and ^{220}Rn based on the accumulated experience in the creation and operation of the state primary standard of the unit of volumetric activity ^{222}Rn.

Keywords*— *state primary standard, radon chamber, thoron chamber, volumetric activity, radon generator, thoron generator.

I. Introduction

The greatest contribution to the irradiation of the body, primarily of its bronchopulmonary system, is made by the radioactive gas ^{222}Rn and its decay products, due to which certain groups of professionals and the population can receive extremely high radiation doses exceeding the maximum permissible levels.

Radiation safety standards of Ukraine regulate the average annual Equivalent Equilibrium Volumetric Activity (EEVA) of radon isotopes in the air of buildings:

– in the premises of buildings and structures under construction and reconstructed for operation with the constant presence of people, the level of action for the average annual EEVA of radon-222 in the air is 50 Bq/m^{-3}, the average annual EEVA of radon-220 is 3 Bq/m^{-3};

– the level of actions for the average annual EEVA of radon-222 in the breathing zone in the air of premises operated with the constant presence of people is 100 Bq/m^{-3}; and for EEVA radon-220 - 6 Bq/m^{-3};

– if the specified action levels are exceeded, countermeasures for children's, sanatorium and health resorts and health-care institutions, as well as public premises are mandatory: for residential premises - only with the consent of the owner of the home. In this case, the latter should be provided with complete information on radiation doses and health risks;

– if the average annual total EEVA of radon-222 and radon-220, after carrying out anti radon activities, cannot be reduced below the level of 400 Bq/m^{-3} (the level of actions of unconditionally justified intervention), then the decision on further actions belongs to the relevant state bodies, the order of which is regulated by a separate document.

Thus, one of the units of such physical quantities in the field of ionizing radiation and nuclear constants is the volumetric activity of ^{222}Rn and ^{220}Rn. The existing fleet of working measuring equipment contains equipment for determining both the volumetric activity of the initial radionuclide and its daughter decay products (DDP).

II. Measurements Standards and Chambers in the Field of Radon and Thoron Measurements

The state primary standard of the unit of volumetric activity ^{222}Rn was created in 1997 and improved in 2011 at the National Scientific Centre “Institute of Metrology” (Kharkiv, Ukraine).

In the period from 2004 to 2006, the standard participated in international comparisons on the topic COOMET.RI (II)-S1, ^{222}Rn (169 /UA/98) “^{222}Rn VOLUME ACTIVITY COMPARISON”. As a result of comparisons, the metrological characteristics were confirmed, which allowed Ukraine to confirm line CMC, which is necessary for the mutual recognition of certificates issued by national metrological institutes [1, 2]. In world practice, the basis for creating a radon or thoron atmosphere is chamber-rooms with different volumes. A liquid, solid-state or gaseous standard (standard) ^{222}Rn or ^{220}Rn is used as a source (generator) of radon or thoron.

The national standard for the unit of volumetric activity ^{222}Rn was created by specialists from the Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany in 1991.

Compare to other national standards of the unit of volumetric activity ^{222}Rn, it reproduces the standard radon atmosphere and the programmed radon atmosphere with the ability to set thermodynamic characteristics (temperature, pressure, humidity, aerosol concentration). The internal structure of a radon chamber with an internal volume of 21.035 m^3 is shown in fig. 1.

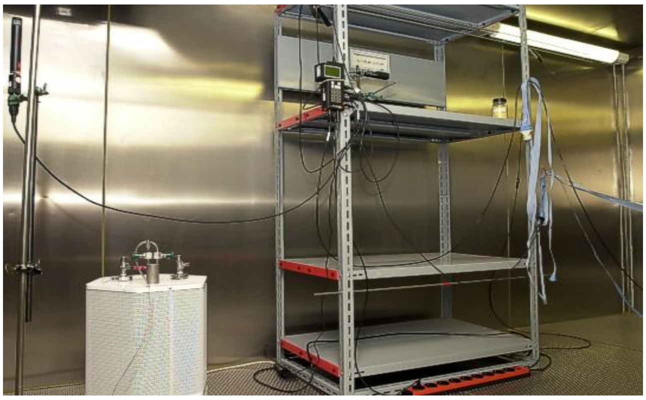

Fig. 1. Radon chamber of the National standard of Germany of the unit of volumetric activity ^{222}Rn.

The radon atmosphere in the radon chamber can be set warm, cold, dry, humid and standard for the possibility of researching measuring instruments (MI) created in Germany of volumetric activity and equivalent equilibrium volumetric activity ^{222}Rn [3].

The climatic system of the radon chamber operates in two modes with the temperature of the radon atmosphere from -20 °C to 10 °C and with the temperature of the radon atmosphere stable at any point in the range from 10 °C to 40 °C.

To reduce humidity, the condenser lowers the temperature. Thus, the humidity in the radon chamber can vary from 95 % to 5 %.

In addition to changing the thermodynamic characteristics of the radon atmosphere, the radon chamber allows experiments with aerosols of various sizes and concentrations [4]. The aerosol source is “Carnauba” wax. This material contains carbon-hydrogen molecules. “Carnauba” wax allows the production of aerosol particles of various sizes from 10 nm to 1 µm. “Carnauba” wax aerosols have unique medical and chemical properties in terms of shape, size; density and acidity of the environment. From a theoretical and experimental point of view, they are the ideal choice for working in a radon chamber. The spherical shape of wax aerosols is advantageous for adsorption by charged ions. The radon chamber was designed and created to provide stable environmental parameters during the calibration of ^{222}Rn measuring instruments and its DDP, which is achieved by an atmosphere control system, an effective aerosol generator and an aerosol cleaning air system. Environmental parameters are determined and measured within an uncertainty range of 0.5 % to 5.0 %. This provides ideal conditions for the calibration of both passive and active ^{222}Rn measuring devices with forced circulation of the investigated atmosphere. In addition, it makes it possible to change the equilibrium factor F between ^{222}Rn and its DDP.

When reproducing a unit of volumetric activity ^{222}Rn, a ^{222}Rn generator and a pulsed ionization chamber are used.

As part of the national standard of Germany, three pulse ionization chambers with different structures of the internal electrode are used. Also, as in the national standard of the United States, the international standards for the mass 226Ra [5, 6] were included in the national standard of Germany. A distinctive feature is the use of the absolute method for determining the activity of ^{222}Rn in the known "solid angle" (Picolo method). Gaseous radon enters the "solid angle" and, spreading over the volume, condenses. The alpha particles emitted by the radon atmosphere are measured with an alpha spectrometer, the detection efficiency depends only on the geometry of the volume and the detector efficiency is determined by the ratio of the "solid angle" through which the detector counts alpha particles.

The characteristics of the national standard of Germany are presented in table. 1.

The expanded uncertainty of this National Standard for the unit of volumetric activity ^{222}Rn is 2.5 % with a confidence level p = 0.95.

The reference installation for measuring the volumetric activity of radon (Republic of Belarus, Minsk, BelGIM) [7] consists of two chambers with a volume of 0.142 m^3 and 3.087 m^3. Both cameras are equipped with windows for visual observation, connectors for power, equipment, sensors and sampling systems. The reference installation is completed with six exemplary radon generators of various activity, which are certified on the basis of an exemplary ^{226}Ra solution. The created installation provides calibration and verification of working instruments of measuring equipment in the range from 15 to 50 % with a confidence level of 0.95. The range of reproduction of a unit of radon volumetric activity is from 20 Bq×m^{-3} to 60 kBq×m^{-3} with an expanded uncertainty of no more than 10 % at a confidence level p = 0.95.

The complex of impulse chambers of the Environmental Measurement Laboratory, New York [8, 9] is a stainless steel room with a volume of 19.2 m^3. The volumetric activity of ^{222}Rn is created in the range from 50 Bq×m^{-3} to 3700 Bq×m^{-3}, the temperature is set and maintained in the range from 0 °C to 45 °C and the humidity is from 20 % to 90 %.

Pulsed ionization chambers certified by the National Institute of Standards and Technology (NIST, USA) using a ^{226}Ra reference solution are used as a reference device.

The US Bureau of Mines Radon test Chamber, Colorado [10] is a cylinder 2.13 m long and 1.52 m in diameter, respectively, has a volume of 3.9 m^3. The design of the chamber allows the selection of the generated volumetric activity. The volumetric activity of ^{222}Rn is created in the range from 37 Bq×m^{-3} to 37000 Bq×m^{-3}. The concentration of aerosols is possible in the range from 5000 cm^{-3} to 200000 cm^{-3}.

The radon chamber of the U.K. National Radiological Protection Board [11] allows creating and maintaining a volumetric activity of ^{222}Rn up to 2000 Bq×m^{-3} in a volume of 43 m^3. The auxiliary equipment makes it possible to simulate a radon atmosphere with aerosol particles in the range from 100 nm to 300 nm with a concentration of up to 3×10^4 cm^{-3}. The chamber ensures uniformity of the volumetric activity of ^{222}Rn throughout the entire volume with the ability to control the temperature and humidity of the created radon atmosphere.

TABLE I. CHARACTERISTICS OF THE GERMAN NATIONAL STANDARD

Characteristic	Value
Temperature range, °C	from -20 to + 45
Relative humidity, %	from 5 to 95
Aerosol diameter, μm	from 30 to 300
Aerosol concentration, m^{-3}	from 10^6 to 10^{13}
Volume activity ^{222}Rn, $Bq{\times}m^{-3}$	from 10 to 100000
Volumetric activity of DDP ^{222}Rn, $Bq{\times}m^{-3}$	from 10 to 100000
Equilibrium coefficient, F	from 0,1 to 1

The radon chamber of the Australian Radiation Laboratory (Victoria) [12] is a chamber with an internal volume of 7.2 m^3 and the ability to create a volumetric activity of ^{222}Rn up to 60,000 $Bq{\times}m^{-3}$. Auxiliary equipment provides control and maintenance of humidity in the range from 20 % to 50 %.

The calibration chamber of the Institute for Nuclear Protection (BACCARA, Saclay, France) [13] has a cylindrical shape and an internal volume of 1 m^3. Volumetric activity is provided in the range from 40 $Bq{\times}m^{-3}$ to 40 $kBq{\times}m^{-3}$.

The radon chamber of the Elliot Laboratory (CANMET, EMR, Ontario, Canada) [14] is a pressurized room with an internal volume of 30 m^3 and a transition sluice with a volume of 3 m^3. The range of measurement and maintenance of temperature is from 10 °C to 35 °C, relative humidity is controlled in the range from 5 % to 99 %. Thermodynamic parameters are measured and maintained using a microcontroller air conditioning system. In addition to providing the volumetric activity of ^{222}Rn, the radon chamber allows the creation of the volumetric activity of ^{220}Rn. 6 radium standards with activities of hundreds to thousands of kBq are used as ^{222}Rn generators. Six thorium standards with activities of hundreds to thousands of kBq are used as Thoron generators.

The calibration radon chamber of the Paul Scherrer Institute, Switzerland [15] represents a sealed volume of 12.6 m^3 with a 1.6 m^3 transition sluice. A liquid radium source with the ability to create a radon atmosphere is used as a ^{222}Rn generator up to 15 $kBq{\times}m^{-3}$. The microprocessor-based air conditioning system measures and maintains the following thermodynamic parameters: temperature from 5 °C to 40 °C, humidity from 20 % to 95 %.

The radon chamber of the Radiological Protection Institute of Ireland, Dublin [16, 17] is a complex of three modules: a chamber, a gateway, and a working compartment. The total volume of 8 m^3 is provided with a system for monitoring thermodynamic parameters and emergency ventilation. The radon chamber is equipped with an observation window, sensors for monitoring the radon atmosphere, and rubber gloves for working inside the working compartment. The microprocessor system provides information exchange between the equipment in the working chamber and external devices. As a ^{222}Rn generator, a solid-state (dry, powdery) radium source with a volume of 5 liters, representing a powder of ^{226}Ra salt with a 100 % yield of ^{222}Rn, was used.

One of the last known ones created to date is the Thoron-Folgeprodukt-Kammer (PTB, Germany) daughter decay product chamber [18]. Thoron daughter decay product chamber (TKF) is The "Vötsch" sealed chamber with a volume of 6 m^3 with the ability to measure and control temperature in the range from 10 °C to 70 °C and humidity from 10 % to 95 % (fig. 2).

Ten lead cubes with ^{228}Th sources are evenly distributed over the TFK volume (fig. 3). The internal structure and arrangement of the apparatus in the chamber of the daughter products of thoron decay is shown in fig. 4. Each source can be controlled separately, independently of the others. Each source extends and retracts by means of a threaded mechanism. Positioning is controlled by limit switches. At the same time, the generator control system ensures the homogeneity (uniformity) of the thoron atmosphere with a range of reproducible activities from 400 $Bq{\times}m^{-3}$ to 8 $kBq{\times}m^{-3}$. With the possibility of increasing the activity up to 10 $kBq{\times}m^{-3}$ (^{220}Rn and ^{222}Rn) of a single applied activity.

Fig. 2. Chamber of Thoron decay daughter products (PTB, Germany).

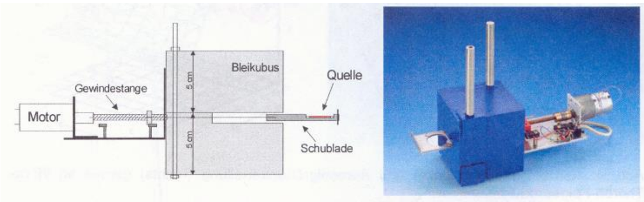

Fig. 3. Generator of ^{228}Th.

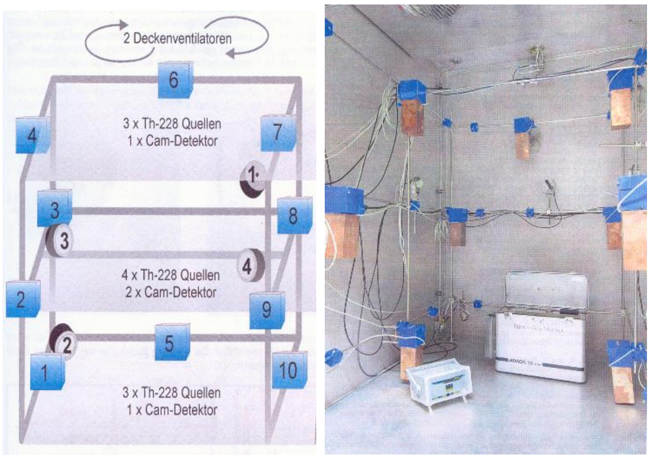

Fig. 4. Internal structure of the chamber of daughter decay products of thoron.

Thus, the establishment of additional sources to increase the activity of the created atmosphere is ensured. In addition to calibration and safety, the production of a reference atmosphere must ensure its homogeneity. In the study of the radon atmosphere, this problem is not, due to the long half-life of ^{222}Rn.

The provision and elimination of the temperature gradient is also not a concern for ^{222}Rn and its daughter products. However, ^{220}Rn has a short half-life of 55.6 s. Therefore, the source control system must provide constant replenishment and circulation of the thoron atmosphere. The simplest ventilation system, in the future, will be able to ensure circulation and uniformity. This can be proved by continuous monitoring by means of an air monitoring system using 4 detectors (fig. 5), by means of local measurements of ^{216}Po.

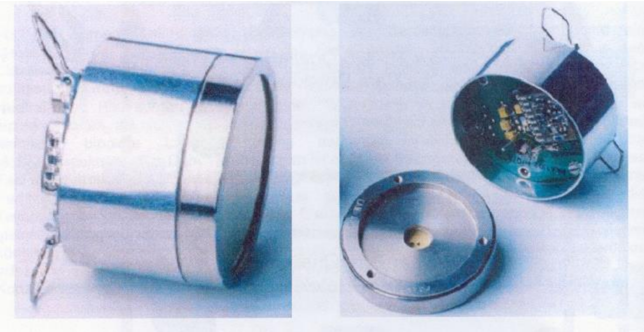

Fig. 5. Detector ^{216}Po.

Here, ^{216}Po, due to a half-life of 0.15 s, is constantly in equilibrium with ^{220}Rn, which in turn is proof of the homogeneity of the ^{220}Rn atmosphere. Signals are fed from 4 detectors to one ADC unit, where they are processed. The alpha spectrometer determines the values and generates a signal for constructing a spectrum with 0.3 MeV resolution, this allows you to select ^{216}Po (6.778 MeV, 0.16 s). The Atmos 12 DPX radon monitor, modernized for measuring 220Rn, and the universal ^{222}Rn and ^{220}Rn meter - RTM 1688-2, were used as recording devices.

One of the absolute methods for determining the ^{220}Rn concentration and ^{220}Rn DDP is the “double filter” method [19]. The method is insensitive to the presence of any concentration of ^{222}Rn. Turbulence, humidity and air temperature do not affect the measurement. This method was primarily developed for measuring ^{220}Rn and ^{212}Pb concentrations in work places in underground environments with high (^{222}Rn) concentration, but this methodology can be used for reference measurement of ^{220}Rn concentration in calibrators.

It is known that ^{222}Rn and its daughter products of its decay make a significant contribution to the dose load on the population. ^{220}Rn does not pose a significant problem due to its short half-life, but its DDPs make a significant contribution with long half-lives. The measurement of the ^{222}Rn concentration can be replaced by the measurement of its DPR using the equilibrium factor, which is usually used to estimate the ^{222}Rn dose. However, this principle cannot be used to determine the ^{220}Rn concentration. This is due to the fact that the equilibrium between ^{220}Rn and its DDP is influenced by many factors, such as the concentration of aerosols in the air and air flows, as well as the influence of the short-lived ^{220}Rn and the relative long-lived ^{212}Pb. To estimate the dose from ^{220}Rn and its DDP, it is necessary to measure both ^{220}Rn and ^{212}Pb.

The “double filter method” is based on the collection of DDP ^{220}Rn. The unit consists of a branch pipe, an inlet filter and an outlet filter (fig. 6). Air is drawn in through the inlet filter at a constant rate. Inside the nozzle, ^{220}Rn disintegrates and its DDP settles on the inner wall of the nozzle as well as on the outlet filter. A thin-walled plastic tube is used inside the nozzle, which can be compressed to a standard geometric shape (fig. 7) for subsequent measurement on a gamma spectrometer.

This method is implemented in an Italian toron calibration facility developed at ENEA (BAS-ION Instituto di Radioprotezione) (fig. 8).

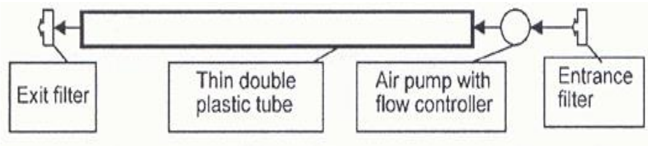

Fig. 6. Schematic representation of the "double filter" method.

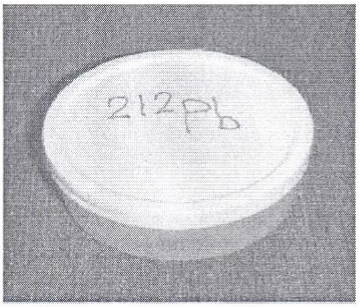

Fig. 7. Standard vial for gamma measurements.

Fig. 8. Aluminum cassette implementing the "double filter" method.

III. Results and Discussion

Thus, the analysis performed allows us to conclude that the existing radon or thoron chambers consist of a complex of systems and modules. Based on the review of sources [3, 7–18], it is possible to determine the main systems and modules of the structural diagram:

1. Chamber-room for creating an air mixture "radon atmosphere", "thoron atmosphere" with a sealed volume from 0.1 m^3 to 78 m^3. The size and equipment of the cell rooms varies depending on the purpose of use. Chambers with a volume of up to 3 m3 are relatively small and are used to calibrate and transfer a unit of volumetric activity to measuring instruments that measure only ^{222}Rn or ^{220}Rn without taking into account DDP. Chambers-rooms oriented to work with the equipment measuring the DDP have a larger volume and, as a rule, have a system of aerosol generators with a system for monitoring the concentration of aerosols [4].

2. Generators ^{222}Rn or generators ^{220}Rn exist in three types: liquid, solid and gaseous.

Liquid generators consist of an acidic solution of ^{226}Ra or ^{228}Th salts to produce ^{222}Rn or ^{220}Rn, respectively. The salt solution is placed in a glass vessel, in which equilibrium is reached between ^{222}Rn, ^{220}Rn and their DDP during ten half-lives. Then, the accumulated ^{222}Rn or ^{220}Rn is pumped into the chamber-room.

Solid-state sources consist of ^{226}Ra or ^{228}Th dry salts. The salt can be mixed with the carrier and placed on the backing of the container where ^{222}Rn or ^{220}Rn accumulates.

Vessels with condensed ^{222}Rn are used as gaseous radon generators [6].

3. A system for measuring and monitoring thermodynamic parameters (temperature, humidity) of the air environment is necessary to simulate the natural operating conditions of devices, as well as to take into account the influence of environmental parameters on the formation of DPR.

4. The system for ensuring the uniformity of the volumetric activity of ^{222}Rn or ^{220}Rn in the entire volume consists of a complex of fans located in the volume of the chamber-room or a distributed system of ^{220}Rn generators.

5. The control system of the ^{222}Rn or ^{220}Rn generators provides opening/closing of the generators during work.

6. The system for determining the volumetric activity of ^{222}Rn or ^{220}Rn consists of transfer standards and/or α-, β-spectrometers that determine the presence of either ^{222}Rn/ ^{220}Rn or their DPR.

7. Control system of the external environment.

8. Control system.

IV. Summary

Having got acquainted in detail with the execution of the state standard of the unit of volumetric activity 222Rn, it can be stated with confidence that such conditions can be realized on its basis, i.e. By improving the existing one, reproduction, storage and transmission of not only the volumetric activity unit ^{222}Rn, but also the reproduction, storage and transmission of the volumetric activity unit ^{220}Rn can be provided.

To do this, you only need to perform the following modifications on it:

- equip the reference measuring chamber (RMC) with a system of electromechanical opening / closing of the cover for placement inside the RMC equipment;
- to place temperature and pressure sensors inside RMC;
- to equip RMC with mounts to accommodate equipment;
- to equip the internal volume of the chamber with a system of video cameras for reading readings from equipment during research;
- to replace obsolete valves on the vacuum system and on the ^{222}Rn generators;
- to develop an electronic system and an algorithm for programmed control of the state primary standard of the unit of volumetric activity ^{220}Rn;
- to create the thoron chamber as a separate complex of systems and modules for reproducing, storing and transferring the unit of volumetric activity ^{220}Rn into the state primary standard of the unit of volumetric activity ^{220}Rn and evaluate uncertainty of radon and thoron volumetric activity according to [20].

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