



## MECHANICAL ENGINEERING TECHNOLOGY

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**DETERMINATION OF THE MAXIMUM COOLING CAPACITIES OF TWO-STAGE COOLERS WITH A VARIATION IN THE GEOMETRY OF BRANCHES IN STAGES**

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**Zaykov Vladimir**, PhD, Chief of Sector, Research Institute «STORM», Odessa, Ukraine, e-mail: gradan@i.ua, ORCID: <http://orcid.org/0000-0002-4078-3519>

**Mescheryakov Vladimir**, Doctor of Technical Sciences, Professor, Head of the Department of Informatics, Odessa State Environmental University, Ukraine, e-mail: gradan@ua.fm, ORCID: <http://orcid.org/0000-0003-0499-827X>

**Zhuravlov Yurii**, PhD, Senior Lecturer, Department of Technology of Materials and Ship Repair, National University «Odessa Maritime Academy», Ukraine, ORCID: <http://orcid.org/0000-0001-7342-1031>

A model of the relationship between the reliability indices of two-stage TECs of various designs with the geometry of the branches of thermoelements in cascades in the  $\Delta T_{\max}$  mode with electrical series of cascades (stages) is proposed and analyzed. Relations are obtained for determining the optimal geometry of the branches of thermoelements in cascades corresponding to the maximum temperature difference. The expression allows to estimate both the maximum cooling capacities and the reliability indices of two-stage thermoelectric cooling devices of various designs. The possibility of increasing the maximum temperature drop to 4 % is shown by choosing the optimal geometry of the branches of thermoelements in cascades (stages). This is achieved under the condition that the ratio of the length to the cross-sectional area of the elements of the first stage is greater than the ratio of the length to the cross-sectional area of the second stage, which differs from the traditional equality of these ratios for a given working current. The proposed approach makes it possible to estimate the maximum temperature drop and to predict the reliability indices of two-stage thermoelectric coolers of various designs for various operating conditions and to conduct an optimized design of radio electronic equipment using cascade thermoelectric cooling devices.

**Keywords:** thermoelectric cooling device, geometry of the branch of thermoelements, maximum temperature drop, cooler designs.

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**INVESTIGATION OF THE METHOD OF DECOMPOSITION OF A COMPLEX SCIENCE-INTENSIVE INSTRUMENT-MAKING DEVICE FOR THE FORMATION OF A RATIONAL STRATEGY FOR ITS MODERNIZATION**

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**Shevchenko Tetiana**, Department of Theoretical Mechanics, Mechanical Engineering and Robotic Systems, Zhukovsky National Aerospace University «Kharkiv Aviation Institute», Ukraine, ORCID: <http://orcid.org/0000-0003-1296-4600>

**Sobchak Andrey**, PhD, Associate Professor, Department of Management, Zhukovsky National Aerospace University «Kharkiv

Aviation Institute», Ukraine, e-mail: sobchak@ukr.net, ORCID: <http://orcid.org/0000-0002-0006-6240>

**Shostak Igor**, Doctor of Technical Sciences, Professor, Department of Computer Engineering, Zhukovskiy National Aerospace University «Kharkiv Aviation Institute», Ukraine, e-mail: iv.shostak@ukr.net, ORCID: <http://orcid.org/0000-0002-6428-2831>

**Popova Olga**, Commercial Director, Limited Liability Company Scientific-Production Enterprise «KIATON», Kharkiv, Ukraine, e-mail: Batbkivna@ukr.net, ORCID: <http://orcid.org/0000-0002-0310-4388>

**Morozova Olga**, PhD, Associate Professor, Department of Theoretical Mechanics, Mechanical Engineering and Robotic Systems, Zhukovskiy National Aerospace University «Kharkiv Aviation Institute», Ukraine, e-mail: oligmorozova@gmail.com, ORCID: <http://orcid.org/0000-0002-0604-9927>

The object of research is the life cycle of products (a complex equipment object) of a manufacturing enterprise. Each product has its own life cycle, i. e., time interval, expiration date. In Ukraine, it is a period of 5 years. All the problems of enterprises lie in this fact. The current situation in the country does not allow enterprises to update their production capacity every 5 years, and therefore it is the most problematic place. To solve this problem, a method for decomposing an object of complex equipment (OCE), which allows to determine the necessary, morally outdated component in the OCE, and modernize it to a more modern – innovative. It also allows to extend such stage of the product life cycle as – operation, adding additional functions and (or) capabilities to the product. In this case, of course, there is a risk, which is to correctly identify the necessary element of modernization. For this purpose, a mathematical apparatus is applied in the work, which unlike others, allows to decompose the OCE with the greatest accuracy.

The author laid the foundation in the cardinal sense with respect to the ecological component, as well as the duration of the product life cycle, which theoretically can last for infinity and requires a deeper and more detailed study.

**Keywords:** complex science-intensive product, service life of the product, modernization path, object of complex equipment.

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## METALLURGICAL TECHNOLOGY

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### ANALYSIS OF TECHNOLOGICAL DAMAGEABILITY OF CASTINGS MANUFACTURED IN SAND MOLDS

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**Kuzin Oleg**, PhD, Associate Professor, Department of Applied Material Science and Materials Engineering, National University «Lviv Polytechnic», Ukraine, ORCID: <http://orcid.org/0000-0003-3669-0237>

**Kusyj Jaroslav**, PhD, Associate Professor, Department of Mechanical Engineering Technology, National University «Lviv Polytechnic», Ukraine, e-mail: jarkym@ukr.net, ORCID: <http://orcid.org/0000-0001-5741-486X>

**Kuzin Nikolai**, Doctor of Technical Sciences, Associate Professor, Lviv Branch of V. Lazaryan Dnipropetrovsk National

University of Railway Transport, Lviv, Ukraine, ORCID: <http://orcid.org/0000-0002-6032-4598>

In order to assess the process of accumulation of damages in billets obtained by casting in sand molds, studies of castings made from an aluminum alloy are conducted. Analysis of the physical heterogeneity of the material is carried out on the basis of the microstructural studies, as well as the LM hardness method. It is shown that it is expedient to evaluate the technological damageability of various zones of cast billets with complex spatial geometry that contain massive thermal assemblies and thin walls, according to the dispersion degree of the hardness characteristics. The technological damageability of billets obtained in sand molds varies widely and mainly depends on the conditions of crystallization of their individual volumes:

- distribution of temperature fields;
- direct heat reducing;

– features of the metal feeder with a liquid phase during crystallization.

The influence of the mold design on the formation of technological damage is analyzed. Increasing the distance from the feeder promotes growth, and accelerated crystallization and directed heat removing promote reduce in technological damage to the volume of the casting when cured. Damageability of the material of cast billets serves as a parameter that is quantitatively evaluates the reliability characteristics of products, and its definition allows to formulate new approaches to the selection of foundry alloys and improve casting technologies to increase their operational durability. On the basis of the conducted studies it is established that the technological damageability is 1.3–6.5 times higher than for the base material in the near-surface layer at a depth of 2 mm.

**Keywords:** technological damageability, Weibull homogeneity coefficient, accelerated crystallization, liquid phase, foundry defects.

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**DEVELOPMENT OF A SYSTEM FOR ORGANIZING A MODULAR DESIGN AND TECHNOLOGICAL PREPARATION FOR THE PRODUCTION OF CAST IRON PISTONS FOR INTERNAL COMBUSTION ENGINES**

page 23–27

*Puliaiev Anton*, Postgraduate Student, Department of Foundry Production, National Technical University «Kharkiv Polytechnic Institute», Ukraine, e-mail: antonpuliyae@gmail.com, ORCID: <http://orcid.org/0000-0002-8785-1582>

*Orendarchuk Julia*, Postgraduate Student, Department of Foundry Production, National Technical University «Kharkiv Polytechnic Institute», Ukraine, e-mail: Juliaorendarchuk@gmail.com, ORCID: <http://orcid.org/0000-0002-8184-906X>

*Penziev Pavel*, Assistant, Department of Foundry Production, National Technical University «Kharkiv Polytechnic Institute», Ukraine, e-mail: djpenzev@gmail.com, ORCID: <http://orcid.org/0000-0003-0402-9575>

*Akimov Oleg*, Doctor of Technical Sciences, Professor, Head of the Department of Foundry Production, National Technical University «Kharkiv Polytechnic Institute», Ukraine, ORCID: <http://orcid.org/0000-0001-7583-9976>

*Marynenko Dmytro*, Department of Foundry Production, National Technical University «Kharkiv Polytechnic Institute», Ukraine, e-mail: prostooelementary@gmail.com, ORCID: <http://orcid.org/0000-0001-7720-9222>

*Marchenko Andriy*, Doctor of Technical Sciences, Professor, Vice-rector for Scientific-and-Research Work, National Technical University «Kharkiv Polytechnic Institute», Ukraine, ORCID: <http://orcid.org/0000-0001-9746-4634>

Modern engine building requires a significant increase in power, fuel efficiency and ensuring high environmental performance of internal combustion engines (ICE). When forcing the operating modes of diesel engines, one of the most loaded engine parts becomes a piston, due to a significant increase in mechanical and thermal stresses. With increasing load on the piston, the difficulty of meeting the high demands for them increases. When creating modern ICE and improving the quality of existing ones, special attention is paid to the design and technological preparation of the production of pistons, which is the object of research. Pistons determine the reliability and life of the engine as a whole.

To solve this problem, all the main works related to the design and manufacture of cast-iron pistons are proposed to divide into separate modules, performed simultaneously in three areas:

organizational, design and technological. These modules are integral sectors of a single modular system for organizing design and technological preparation for production of cast iron pistons. Modeling of the stressed-strain state of monolithic cast-iron pistons is considered for an example of implementation of one of the modules. The results of calculations of the stress-strain state and the temperature distribution field in the body of the piston are presented. The results show that the maximum temperature is 315 °C and concentrated on the edge of the combustion chamber. The stress does not exceed 617 MPa.

**Keywords:** modular system, ICE piston, vermicular graphite, stress-strain state, aluminum CGI.

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## MATERIALS SCIENCE

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### RESEARCH OF ELECTRICAL PROPERTIES OF EPOXY COMPOSITE WITH CARBON FILLERS

page 28–34

**Melnyk Liubov**, PhD, Senior Lecturer, Department of Chemical Technology of Composites, National Technical University of Ukraine «Ihor Sikorsky Kyiv Polytechnic Institute», Ukraine, e-mail: luba\_xtkm@ukr.net, ORCID: <http://orcid.org/0000-0001-5139-3105>

The object of research in this study is electroconductive epoxy compositions with carbon fillers. Based on the porous structure of the filler, the technology of manufacturing composite materials in the form of films using ultrasound is proposed. The effect of the type and content of the carbon filler on the electrical properties of the epoxy composite is investigated. It is found that the resistivity in the direction perpendicular to the axis of formation of samples with content of thermally expanded graphite (normal and after ultrasonic grinding at room temperature) can reach  $7.5 \cdot 10^{-6} \Omega \cdot m$ , while for carbon nanotubes is  $5.1 \cdot 10^{-8} \Omega \cdot m$ . It is found that the percolation threshold for systems of epoxy resin – thermally expanded graphite is ~5 wt. %, and for epoxy resin systems – carbon nanotubes is ~1 wt. %. Research results of the effect of carbon filler on the dielectric properties of epoxy composite are presented. It is experimentally established that as the filler concentration increases, the dielectric constant increases in the polymer matrix. A sharp increase in the dielectric constant of research systems is observed with a CNT concentration of 1 %. An increase in the dielectric losses of the orientational polarization is observed as the frequency of the alternating current increases to  $10^5$  Hz.

**Keywords:** carbon nanotubes, epoxy composite, thermally expanded graphite, resistivity, dielectric constant.

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### INVESTIGATION OF SURFACED PRESS MOLDS MADE ITS WORKING RESOURCE

page 34–38

**Blokhina Inna**, Postgraduate Student, Department of Equipment and Technologies of Welding Production, Donbass State Machine-Building Academy, Kramatorsk, Donetsk region, Ukraine, ORCID: <http://orcid.org/0000-0003-4831-8870>

The object of research is the repair of press molds with the help of plasma-MIG surfacing. The weld metal on the repaired press molds wears out unevenly, has a different structure and hardness, which is characteristic of multi-layer surfacing of alloyed steels. The greatest way to manage the storage and quality of surfacing is a combined method – plasma-MIG surfacing. An analysis is made of all plasma-MIG surfacing options for surfacing in order to strengthen the surfaces in the repair and manufacture of products operating under thermal cyclic loads. It is established that when restoring press molds working under thermocyclic loads, to ensure uniform hardness over the cross-section of the welded metal layer, the surfacing should be carried out with a minimum step in the optimum operating regime:  $\alpha_H=16-19 \text{ g/A} \cdot \text{h}$ .  $\psi_{B,S}=4-5 \%$ ;  $K_V=91 \%$ . It has been experimentally proved that in order to reduce the width of the eutectic sections that is distinguished along the grain boundaries, and hence also the decrease in the probability of crack formation in the deposited layer, the plasma-MIG surfacing on the developed unit should be carried out at the lowest possible current  $I=75-90 \text{ A}$ . This will significantly increase the crystallization rate of the deposited metal.

**Keywords:** plasma-MIG surfacing, flux-cored wire, structural heterogeneity of surfaced metal, working capacity of press molds.

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### INVESTIGATION OF THE INFLUENCE OF ORGANOMINERAL ADDITIVES ON THE COLLOID-CHEMICAL PROPERTIES OF GEOCEMENT DISPERSION

page 38–43

**Guzii Sergii**, PhD, Senior Researcher, V. D. Glukhovskiy Scientific Research Institute for Binders and Materials, Kyiv National University of Construction and Architecture, Ukraine, e-mail: [sguziy@ukr.net](mailto:sguziy@ukr.net), ORCID: <http://orcid.org/0000-0003-0147-5035>

The object of research is the geocement dispersion of the heulandite-clinoptilolite composition of the structural formula  $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2 \cdot 20\text{H}_2\text{O}$ , modified with an organomineral additive

The results of the effect of an organomineral additive on the colloidal-chemical properties of geocement dispersion are presented. Mathematical models that characterize the effect of the concentrations of constituent organomineral additives on changes in its basic physical and colloidal chemical properties are obtained:

- conventional viscosity;
- density;
- wetting angle;

- surface tension;
- works of adhesion, cohesion and wetting of geocement dispersions, factors  $X_1...X_3$  have an influence that are significant. Also, the joint effect of factors, respectively,  $x_1x_2x_3$ ,  $x_1x_2$ ,  $x_1x_2$  and  $x_1x_3$  has a significant effect.

The coefficients of wetting and spreading of geocement dispersions are significantly influenced only by the joint action of the factors  $x_1x_2x_3$ .

Relationship is established between the conditional viscosity and the wetting coefficient, between the wetting angle, adhesion, wetting and spreading work and between the density, surface tension and work of cohesion. The composition of the organomineral additive is optimized and the areas of permissible concentrations of its constituents are determined:

- along the  $X_1$  axis, 2–2.3 % of polymer RI-551Z;
- along the  $X_2$  axis, 2.1–2.5 % of microcalcite;
- along the  $X_3$  axis, 4.5–6.5 % of aluminate cement, which, when introduced into a geocement dispersion, allows  $\text{Na}_2\text{O}\cdot\text{Al}_2\text{O}_3\cdot 6\text{SiO}_2\cdot 20\text{H}_2\text{O}$  to stabilize its colloidal-chemical properties.

It is determined that the changes in the values of the other output parameters are tied to the change:

- the conditional viscosity and their values are in the following limits:  
 $\rho = 1.571\text{--}1.766 \text{ g/cm}^3$ ,  $\cos\Theta = 0.50\text{--}0.67$ ;
- surface tension  $\sigma = 114\text{--}128 \text{ mN/m}$ ;
- works of adhesion, wetting and cohesion, respectively, 184–204 mN/m;
- coefficients of wetting and spreading  $-0.77\text{--}(-)0.84$ ,  $-37\text{--}(-)55 \text{ mN/m}$ .

**Keywords:** geocement dispersion, optimization of organomineral additive composition, colloid-chemical properties.

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# ELECTRICAL ENGINEERING AND INDUSTRIAL ELECTRONICS

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## CIRCUIT SIMULATION OF ELECTRICAL BREAKDOWN IN AIR USING KIND'S EQUAL-AREA CRITERION

page 44–49

**Trotsenko Yevgeniy**, PhD, Associate Professor, Department of High Voltage Engineering and Electrophysics, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Ukraine, e-mail: y.trotsenko@kpi.ua, ORCID: <http://orcid.org/0000-0001-9379-0061>

**Brzhezitsky Volodymyr**, Doctor of Technical Sciences, Professor, Department of High Voltage Engineering and Electrophysics, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Ukraine, e-mail: v.brzhezitsky@kpi.ua, ORCID: <http://orcid.org/0000-0002-9768-7544>

**Masluchenko Igor**, PhD, Associate Professor, Department of High Voltage Engineering and Electrophysics, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Ukraine, e-mail: i.masluchenko@kpi.ua, ORCID: <http://orcid.org/0000-0001-6073-9649>

The object of the research is the circuit simulation model of a streamer breakdown of a rod-rod air gap when exposed to positive voltage pulses. One of the most problematic places in this task is determination of the time interval of the streamer propagation. The lower bound of this interval corresponds to the beginning of the streamer propagation, and the upper bound corresponds to the time when the streamer reaches the opposite electrode. To create such model, it is not enough to take into account only the functional relationship between the breakdown voltage and the spacing between the electrodes.

With the help of Kind's equal-area criterion in the circuit simulation programs it is possible to create the model of electrical breakdown of any air gap, including the rod-rod configuration.

The article shows how to create the model of electrical breakdown of the air gap in the evaluation version of the Micro-Cap 11 circuit simulator. Using the model, the breakdown time of the air gap is determined when subjected to the lightning pulses of positive polarity with different amplitudes. Wherein, the moments of breakdown of the air gap both at the front and at the tail of the applied voltage pulse are measured. Simulation results are compared with experimental data. It is determined that the simulation relative error does not exceed 10 %. As experimental data, the experimentally obtained expression for the volt-time characteristic of the rod-rod air gap subjected to the positive polarity voltage pulses is used.

The proposed model allows to predict the volt-time characteristic of various air gaps in a virtual experiment. The model can be used in scientific work or in the educational process as an auxiliary tool for visual demonstration of the conditions for the electric breakdown in long air gaps.

**Keywords:** circuit simulation, high voltage engineering, electrical breakdown, volt-time characteristic, equal-area criterion.

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## RESEARCH OF OPERATION OF ANISOTROPIC OPTICAL THERMOELEMENT WITH LATERAL TEMPERATURE REGULATION

page 49–53

**Khabiuk Andrii**, Postgraduate Student, Department of Psychology, Pedagogics and Social Management, National University «Lviv Polytechnic», Ukraine, e-mail: kym-ua@ukr.net, ORCID: <http://orcid.org/0000-0001-7151-9043>

**Danalakiy Oleh**, PhD, Associate Professor, Department of Information Systems, Chernivtsi Faculty of the National Techni-

cal University «Kharkiv Polytechnic Institute», Ukraine, e-mail: ogdanalaki@gmail.com, ORCID: <http://orcid.org/0000-0002-6602-9506>

The object of research is a direct mutual conversion of thermal and electrical energy using anisotropic optical thermoelectric elements (AOTE). Receivers of through-type radiant flux, containing optically transparent heat sinks, to which the AOTE attach with the help of an adhesive dielectric layer, lead to a significant distortion of the amplitude-phase characteristics of the transmitted radiant flux. This is limited the energy and timing characteristics of receivers. Therefore, the task of creating such design of the receiver, which would be free of these shortcomings, is necessary.

The design of a radiant flux receiver based on an anisotropic optical thermoelement is developed and tested, and the amplitude-phase characteristics of the flux do not change during its passage. The receiver can be used as a filter or a semitransparent mirror of an optical resonator. Such effect is due to the fact that at a thickness of 1 cm AOTE is selected with parameters  $\alpha = 10^{-4}$  V/K,  $\chi = 10^{-2}$  W/(cm·K),  $\rho = 10^{-3}\Omega$ , current  $I = 10$  A and temperature of the thermostat 300 K cm gives the minimum temperature of 239 K.

A separate anisotropic thermoelement, which is made of a material with the same kinetic parameters under the same conditions, yields 265 K. Thus AOTE leads to an increase in the temperature drop.

**Keywords:** anisotropic optical thermoelectric elements (AOTE), transverse thermoelectric power, AOTE with lateral temperature regulation.

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## ANALYSIS OF MODERN GRAVIMETERS OF THE AVIATION GRAVIMETRIC SYSTEM

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**Bezvesilna Olena**, Doctor of Technical Sciences, Department of Instrumentation, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Ukraine, e-mail: [tinfaand@ukr.net](mailto:tinfaand@ukr.net), ORCID: <http://orcid.org/0000-0002-6951-1242>

**Chepyuk Larina**, PhD, Department of Automation and Computer-Integrated Technologies named after prof. B. B. Samotokin, Zhytomyr State Technological University, Ukraine, ORCID: <http://orcid.org/0000-0002-8072-8186>

**Tkachuk Andriy**, PhD, Department of Automation and Computer-Integrated Technologies named after prof. B. B. Samotokin, Zhytomyr State Technological University, Ukraine, e-mail: [andrew\\_tkachuk@i.ua](mailto:andrew_tkachuk@i.ua), ORCID: <http://orcid.org/0000-0003-2466-6299>

**Nechai Sergii**, PhD, Associate Professor, Department of Instrumentation, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Ukraine, e-mail: [snechai@mail.ru](mailto:snechai@mail.ru), ORCID: <http://orcid.org/0000-0002-7821-6472>

**Khylchenko Tetiana**, Postgraduate Student, Department of Automation and Computer-Integrated Technologies named after prof. B. B. Samotokin, Zhytomyr State Technological University, Ukraine, e-mail: [xvulunka@i.ua](mailto:xvulunka@i.ua), ORCID: <http://orcid.org/0000-0003-0029-2114>

The analysis of existing gravimeters of aviation gravimetric systems (AGS) is carried out. Their main disadvantages are identified: low accuracy of measurement (3–10 mGal), mandatory necessity of application of filtration procedure of output signal of AGS gravimeter; instability of the static transfer coefficient of the AGS gravimeter; low speed. The expediency of using AGS for carrying out gravimetric measurements and obtaining information about the Earth's gravitational field is substantiated. Aero-gravimetric surveying requires a significant increase in the accuracy and speed of aviation gravity measurements. Therefore, the study of this issue remains an important problem. To date, there are already theoretical developments and prototypes that almost completely solve all the main disadvantages. Modern advanced developments in the field of aircraft gravimeters are considered: gyroscopic, ballistic, piezoelectric, capacitive, string gravimeters. They are distinguished by high accuracy (1–2 mGal) and speed. It is proposed to use a two-channel (differential) method for GA measurement in all gravimeter designs. Then the useful signal is doubled 2g, and the signals of the main disturbing vertical acceleration, instrumental errors from the influence of changes in temperature, pressure and other environmental factors are canceled.

**Keywords:** sensing element, gravimeter, gravity acceleration, gravitational field of the Earth.



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