# ABSTRACT AND REFERENCES

## APPLIED PHYSICS

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### RATIONALE FOR CREATING DETONATION $CO_2$ LASER FOR RADIOACTIVE SURFACE DECONTAMINATION (p. 6-12)

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The laser decontamination method is based on the evaporation of oxide films under the influence of radiation. With the evaporation mechanism, laser radiation should heat the upper layer of the film to the boiling point during the pulse and evaporate it. It is relevant because of the growing environmental requirements in the world, which makes it possible to create a compact, energy-efficient laser installation. Unlike existing energy-efficient laser units, the detonation laser system will significantly affect and quickly decontaminate radioactive surfaces due to the evaporation of oxide films under the influence of radiation. Detonation technologies are critical and can be used for pulse detonation systems, such as pulse detonation engines, detonation lasers, magnetohydrodynamic generators with detonation combustion of fuel, volume explosion initiation systems. The introduction of these systems in armaments and military equipment can substantially change the scope of their application. The average laser power can exceed 100 kW and above. At the same time, the use of the mixture as a power source makes the system not only compact, but also light in weight with respect to the existing similar systems. The wavelength will be 10.6 μm due to radiation in the far infrared region. That is, combined power plants will provide not only actuation, but also electric power supply of machines. This will allow the creation of power detonation units with a periodic initiation frequency of at least 100 Hz, which will work on a liquefied mixture and insignificant use of oxygen in the incendiary portion.

**Keywords**: spark discharge, pre-ionization, current-conducting channel, lasers, detonation, decontamination, laser radiation, voltage.

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## DETERMINING HIGH QUASIHYDROSTATIC PRESSURE UP TO 7 GPa AT A TEMPERATURE TO 1,400 °C USING RESISTIVE SENSORS (p. 13-20)

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A differential method for measuring high quasi-hydrostatic pressures for six-punch pressing installations has been constructed by building a load-carrying characteristic p=f(Q), where p is the value for pressure in a quasi-hydrostatic cell of high-pressure, Q is the force of the press. Pressure in the cell is measured by using the measurement of a temperature difference between the polymorphic transformations into Co(α→β) and Fe(α→γ), melting of Cu and Ag; the measurements are performed by resistometry. The initial data used were the lines of polymorphic transitions in iron (BCC–FCC) and cobalt (FCC–HCP) within the ranges p=4–7 GPa and T=500–700 °C, examined in detail earlier in the p, T-diagrams, as well as copper and silver melting curves at p=4–7 and T==1,150–1,400 °C.

The database of initial data is represented in the analytical form, which has made it possible to use them to determine pressure in the cell at high temperatures based on the values for magnitudes of the differential temperature difference $\Delta T_d$, which was measured experimentally for the $Co^{\alpha-\beta}$–$Fe^{\alpha-\gamma}$ and $Ag^{L}$–$Cu^{L}$ sensors, designed in the current paper; we have described the features in assembling differential sensors and their electrical connections in order to perform the process of measuring the magnitudes for $\Delta T_d$. We have designed structures for the high-pressure cells to conduct experiments on measuring $\Delta T_d$ using thermocouples and a circuit that registers a change in the resistance of sensors at phase transformations.

The procedure applied has made it possible to determine pressure in the quasi-hydrostatic cells of six-punch setups by building load characteristics. The main benefits of the devised method for measuring quasi-hydrostatic pressures by resistometry are its relative simplicity and a significant increase in the accuracy of pressure determination. The latter is achieved through the mutual elimination of corrections of pressure impact and parasitic components for the magnitude of thermo-EMF of thermocouples in determining the values for a temperature of phase transformations in the resistive sensors Co–Fe and Ag–Cu.

The data obtained could be used for monitoring and measuring pressures in the cells of six-punch pressing installations with a plunger diameter of 560–950 mm.

**Keywords**: high quasi-hydrostatic pressures, six-punch high-pressure unit, resistive pressure sensor.

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## IDENTIFICATION OF ENERGY EFFICIENCY OF ORE GRINDING AND THE LINER WEAR BY A THREE-PHASE MOTION OF BALLS IN A MILL (p. 21-28)

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We have analytically derived an equation that relates the technological parameters of a ball mill, grinding material, to the parameters of a rod primary converter of energy efficiency of ore grinding. By using a method of applying a basic rod primary converter with a large cross-sectional area, at the side end of which large pieces of ore are destroyed at balls impacts, and an additional rod converter with identical parameters and a smaller cross-sectional area, which interacts only with balls, we have achieved invariance in determining the energy efficiency of ore grinding by a ball mill to a change in the motion speed of grinding bodies. We have analytically derived a mathematical model of energy-saving ore grinding by a ball mill with a three-phase motion of grinding bodies, invariant to a change in the length of rods during wear. The model can estimate the energy efficiency of grinding larger pieces of ore based on the resulting volume of crushed large-lump material. The mathematical model includes such constants as the cross-sectional areas of rod primary converters, the initial length of rod primary converters, the length of a basic section of strain gauges arrangement, the value for Young's modulus of the primary converters' material, as well as the changing constants that are defined by the ground material. In addition, the dependence has been derived analytically for determining the length of a main rod primary converter, based on which one can estimate the height of a liner, which wears out in the course of operation.

We have devised a functional circuit for the automated control system of energy efficiency of ore grinding by a ball mill that makes it possible to obtain estimation parameters using modern microprocessor tools. According to the devised circuit, one can build algorithms for determining the volume of ore to be crushed, as well as the thickness of a liner in a ball mill, which open up an avenue for developing software products.

Computer simulation has proven the possibility of applying the proposed method in order to estimate energy efficiency of ore grinding by a ball mill with a three-phase ball motion. We have established high sensitivity of the proposed approach to a deviation in energy efficiency of ore grinding from the best value. A possibility to estimate the parameter with a relative error of ±2.5 % has been confirmed.

**Keywords**: energy efficiency, automated control, ore grinding, ball mill, elastic converters.

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## USING THE INTENSITY OF ABSORBED GAMMA RADIATION TO CONTROL THE CONTENT OF IRON IN ORE (p. 29-35)


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The paper reports results of mathematical modeling of the intensity of absorbed gamma radiation for determining the iron content in IOR. It was shown that to enhance the accuracy of rapid control of the iron content in IOR, it is advisable to use absorbed gamma radiation. This approach is the improvement of the nuclear-physical method for determining the iron content in IOR. Reflected gamma radiation is used in the existing nuclear-physical methods for determining the iron content in IOR. The gamma-gamma method, the feature of which is the use of "soft" gamma radiation, is used in this method. This leads to the fact that the irradiated surface reflects only a small part of the original flux of gamma radiation. As a result, measuring the intensity of the scattered gamma radiation is characterized by substantial relative errors and, consequently, low-precision of rapid control of iron content in IOR. The use of absorbed gamma radiation as the main part of gamma radiation, makes it possible to significantly reduce the relative error of measurement of the intensity of gamma radiation, that is, to enhance the accuracy of rapid control of the iron content in IOR.

The work considered the method of "central geometry" for measuring the intensity of gamma radiation as the most common. This method makes it possible to take into consideration in the mathematical model the dependence of the intensity of absorbed gamma radiation not only on the properties of irradiated surface of rock mass, but also on the geometric parameters in measurement. The main feature of the model is the use of albedo parameter, which allows linking the scattered and absorbed gamma radiation. Representation of the synthesized model in the dimensionless form enabled both simplification of calculations, and generalization of the results of mathematical modeling of the intensity of absorbed gamma radiation. In order to compare the values of intensities of reflected and absorbed gamma-radiation in terms of central geometry, the appropriate numerical calculations were performed. The results of the conducted calculations proved the effectiveness of using absorbed gamma radiation to determine the iron content in IOR. Thus, in the range of 50–60 percent of the iron content, the sensitivity of absorbed gamma-radiation is considerably higher (by two times) than sensitivity of scattered gamma radiation.


**Keywords**: rapid control, absorbed, scattered gamma-quanta, nuclear-physical method, detector, albedo.

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## STUDYING ADDITIONAL MEASUREMENT ERRORS FROM CONTROL TOOLS USING AN INTEGRAL FUNCTIONAL METHOD (p. 36-43)

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Our research has established that under industrial conditions the correction to the result of current measurements when an influencing parameter deviates from the rated value is rarely introduced. In a general case, the procedure for determining an additional measurement error implies that the measured values for an influencing parameter are applied to determine the degree of its deviation while a correction to the current measurement result is calculated as the product of this degree by its rated value.

In a general case, a procedure for determining an additional measurement error includes two stages. At the first stage, the measured values for an influencing parameter are used to determine the degree of its deviation from the rated value. At the second stage, correction is calculated as the product of this degree by the rated value for an additional error.

Such a technique to calculate a correction is time consuming and insufficiently precise, as it does not take into consideration the non-linear dependence of the additional error on a change in the influencing parameter, as well as the current value for the output signal of control tool. To determine the actual value for an influencing parameter and the additional measurement error under industrial operation of control tools, an integral functional method has been proposed. The method implies determining the difference of areas under the nominal and actual acreage static characteristics, limited to a range of measurement. The difference of areas is a function of the output signal of a control tool, a measured parameter and a change in the influencing parameter. It has been shown that the proposed method makes it possible to calculate the actual values for a technological parameter based on its measured and influencing parameters only. We have established regularities between the actual value for a measured parameter, the current value for the output signal from a control tool, and the measured value for an influencing parameter. The proposed method is important and valuable in the operation of computer-integrated control systems of technological parameters, as it makes it possible to determine the actual values for a measured parameter based on relevant algorithms without calculating corrections.

**Keywords**: control tool, additional error, influencing parameter, integral functional, measurement, static characteristics.

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**DETERMINING THE REGIONS FOR EFFICIENT USE OF ELECTROJET LOWTHRUST ENGINES (p. 43-50)**

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This work addresses the issues on determining the optimal regions for using propulsion system for spacecraft at low near-Earth orbits. An analysis of spacecraft launches over the past 5 years has been performed. The result of analyzing the launches is the type of spacecraft, selected for subsequent calculations, specifically a remote sensing satellite at low near-Earth orbit. We have solved the problem on determining parameters for the trajectory of a spacecraft motion, exposed to external non-permanent forces. Based on an analysis of the external influence, the scope of possible future application of spacecraft propulsion systems has been defined. A comparative analysis has been performed for the mass criterion of efficiency of using propulsion systems based on the chemical mono-component and electro-jet engines in order to solve tasks on maintaining the circular orbit parameters over a long time.

For orbit altitudes below 300 km, as was established based on the calculation results, the application of a propulsion system proved to be inefficient due to the need for a large reserve of fuel aboard and a large required engine thrust. For satellites at circular orbits from 350 to 450 km, a propulsion system that includes the Hall-effect-based engine ST-25, manufactured by SETS, proved to be more effective than the chemical propulsion unit. Application of chemical engines to maintain the orbit parameters at altitude above 500 km would be preferable to electro-jet ones due to a relatively small mass of the chemical propulsion system and a sufficient resource of engines operation in order to maintain the orbit.

We have obtained parameters for the propulsion system that uses the Hall-effect-based engine ST-25 in order to maintain orbital parameters within different ranges of altitudes, solar activity, and geometrical parameters for a satellite. The result of calculation is the determined necessary resource of operation and the fuel stock to maintain parameters of the orbit.

The calculation results obtained could be used to design new satellites and to modify satellite platforms.

**Keywords**: flight dynamics, low orbits, electro-jet engine, mono-component engine, maintaining the orbit.

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## IMPROVEMENT OF AN ENGINEERING PROCEDURE FOR CALCULATING THE NONISOTHERMAL TRANSPORTATION OF A GASLIQUID MIXTURE (p. 51-60)

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The study that we conducted into the process of transportation of a gas-condensate mixture from a well bottom to the separation production plant has revealed the features of isothermal and non-isothermal flow. It was proved that during non-isothermal flow, hydraulic losses in the product pipeline are significantly affected by throttle effect and energy accommodation effect. The influence of velocity and volumetric flow rate of the gas-liquid mixtures on hydraulic resistance and pressure drop on a section of product pipeline, taking into consideration non-isothermal flow was analyzed. It was found that the assessment of hydraulic resistance and pressure drop in the proposed dependences converges with standardized ones by 95 %. The result was obtained based on the developed system of equations of the mathematical model for non-isothermal non-stationary one-dimensional motion of the gas-liquid mixture of hydrocarbons in the pipeline. The proposed system beneficially differs from the known ones by the fact that it takes into consideration the inner convective heat exchange, estimated by the combined effect of Joule-Thomson.

A distinctive feature of the improved procedure for calculation was the introduction of temperature correction and accommodation coefficient in the calculation of hydraulic resistance of a pipeline as a system with distributed parameters. Due to this, it became possible to improve the procedure for the calculation of non-isothermal transportation of a homogeneous gas-condensate mixture. Based on the analysis of calculation curves by the known procedures (formulas of Thomas Colebrooke, Leibenson and VNIIgas) for isothermal and non-isothermal processes and the proposed procedure, rational areas of their applications were shown. All calculations were performed at the velocity of a gas-liquid flow within the range 0–50 m/s, pipe roughness of 0.01–0.05 mm and their diameter of 100–300 mm, the data from actual production pipelines of Novotroitsk oil-gas condensate field were used. Comparison of the theoretical and industrial experiments showed sufficient for engineering practice accuracy of calculation of pressure drop on the stretches of oil and gas lead lines and allowed recommending the developed analytical dependences for the introduction in industrial engineering.

**Keywords**: non-isothermal fluid, pipeline transportation, gas-liquid mixture of hydrocarbons, hydraulic losses, coefficient of hydraulic resistance.

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