# Abstracts
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## Vibrations and Oscillatory Instability of the IBR-2M Pulsed Reactor

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As a result of the studies on the statistical characteristics of pulse energy fluctuations and vibrations of the blades of the movable reflectors at the IBR-2 and IBR-2M reactors, as well as studies of pulse energy fluctuations with a change in the sodium flow through the cores of these reactors, it has been shown that the appearance low-frequency oscillations of pulse energy in both reactors is not related with vibrations of the reactivity modulator or reactor core elements.
***Key Words:*** IBR-2M, pulse energy fluctuations, instability, movable reflectors.

EDN: LYZLOQ

UDC 621.039.5

## Spatial Neutron Kinetics. Summing Up

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The article is a detailed author's abstract of the recently published book "Spatial Neutron Kinetics. Benchmarks", on which the author has been working with varying degrees of intensity for the last ten years. What has been done:

— a formula for the reversed solution of the kinetic equation with a differential shape of the delayed neutron source has been introduced into the calculations, which does not contain an integral and has proved the feasibility of achieving the ideantity of the reactivity values obtained from the reversed solution and in direct criticality calculations. This justified the possibility of using the latter as a reference when evaluating the accuracy of different variants of the reactivity assessment;

— it was shown that the theoretically postulated identity of the reactivity values obtained from the generalized solution of the kinetic equation and direct calculations of criticality at the time of the end of the disturbance is confirmed with good accuracy in practice;

— obtaining accurate results provided by using separate sources of prompt and delayed neutrons at all steps of calculation, including stationary calculations of neutron flux and importance;

— formulas for averaging kinetic parameters over nuclides and physical zones have been derived and tested in practice;

— the informativeness of modeling the instantaneous dropping of control rods was investigated;

— simulation of the movement of control rods with variable time steps has been implemented;

— codes have been created to select the location of ionization chambers based on the results of modeling several scenarios of the movement of control rods;

— a system of nine benchmarks for spatial neutron kinetics with a reasonable combination of accuracy and calculation time has been studied. All test calculations were performed using the ShIPR intelligent software system briefly described in the book.
***Key Words:*** spatial kinetics, benchmarks, reactivity, control rods, delayed neutrons, ShIPR intelligent software system.

EDN: NAOBDY

UDC 621.039.51...17

## Modification of the Frank-Kamenetsky Algorithm for Parallel Calculations

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The paper proposes a description of the developed parallel Frank-Kamenetsky algorithm for regulating the number of neutrons at the beginning of the generation in the calculations of neutron-physical stationary transfer problems by the Monte-Carlo method. Its justification is given, proving its consistency with the standard Frank-Kamenetsky algorithm. The algorithm opens the opportunity of optimizing the load between parallel processes and can be used to effectively reduce the systematic error of the first kind associated with the size of the neutron generation. The results of calculations of test problems using a local cluster and a supercomputer are presented.
***Key Words***: parallel algorithm, method Monte-Carlo, MPI-interface, neutron-physics calculations, stationary processes, optimization, supercomputer calculations.

EDN: OAJWQE

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## Implementation of a Grid Method for Neutron-Physical Calculations

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The article describes the grid method applied to solving the neutron transfer equation in the two-group diffusion approximation implemented in the RAINBOW-TPP software package. The results of the method validation are presented and the possibilities of its application to modern designs of reactor plants are analyzed.

***Key Words:*** grid method, VVER, modeling, RAINBOW-TPP, verification of calculation codes.

EDN: SFOYBX

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## Dynamical Component of the In-Core Temperature Sensors' Error (Analog Modeling)

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The article presents the results of analysis of the error dynamic component for in-core temperature measurements using the example of temperature sensors installed in the VVER reactor plant. The analytical analog temperature sensor is modeled. The analytical expression for evaluation of the time constant of the temperature sensor inertia depending on eigenvalues of the analog model is obtained. The inertia time constant is presented as a function of the design parameters of the temperature sensor.

***Key Words:*** VVER, thermocouple, resistance thermometer, dynamical error.

EDN: UTCLYK

UDC 621.039.5, 621.039.586

## Development of a Package of Codes for the Analysis of Radiation Safety During Severe Accidents at NPPs with VVER Reactors

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Modern regulatory documents impose strict requirements to justification of NPP safety under severe accidents, which cannot be satisfied by conservative approaches and require the development of new, realistic models. The article describes the approach developed and applied at the NRC "Kurchatov Institute" to the analysis of radiation safety of NPPs with VVER reactors under conditions of severe accidents, including those involving fuel melting, namely: the phenomenology of fission products behavior under severe accident conditions, the description of approaches to fission products behavior modelling, description of NRC "Kurchatov Institute" codes for modelling of fission products behavior during severe accident. The final part of the article presents the results of modeling the behavior of fission products for the accident scenario "Double-ended guillotine break of the main circulation pipeline with simultaneous complete blackout" for the AES-2006 project.

***Key Words:*** fission products, severe accident, VVER, safety.

EDN: VQTXVF

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## Analysis of Accidents with CPS CR Ejection at VVER RP with Regard to Actual Hydrodynamic Forces

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The work is aimed at justifying the conservative approach used in the analysis of the accident at the VVER RP (AES-2006 project) with the ejection of one cluster of absorbing elements (AEL) from the core. The task of finding the law of motion of the control and protection system control rod (CPS CR) at its postulated ejection in an accident with a rupture of the driver casing is solved. For this, a mathematical model of CPS CR is used, which takes into account the geometric characteristics of AEL and the hydrodynamic situation in the core in the event of a leak. The analysis of the affect of the movement law of one CPS CR cluster on the introduced disturbances in the reactor is performed for different initial states of the RP.

***Key Words:*** design basis accident, CPS CR ejection, reactivity and power distribution change, spatial kinetics, code KORSAR/GP.

EDN: XCZDPQ

UDC 621.039.5

## Justification of the Selection of Physical Characteristics and Power of a Multipurpose Test Research Reactor with a Supercritical Light-Water Coolant

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The methodology for selecting the main parameters of the multi-purpose low-power research reactor with a lightwater coolant of supercritical parameters MTIR-SKD, and the calculated characteristics of the reactor core are presented. The conditions under which the main operating parameters, physical properties and reactivity effects of the VVER-SCP power reactor are reproduced are shown. The possibilities of effective irradiation of structural materials and fuel compositions for the WWER-SKD power reactors depending on the maximum power of the MTIR-SKD are considered. An assessment of the overall dimensions of the reactor vessel depending on the volume of the reactor core is presented.

It is shown that the minimum volume of the reactor core at which the MTIR-SKD will have reference characteristics in relation to the WWER-SKD is equal to 500 liters. In addition, such volume of the core makes it possible to place two loop facilities, which will allow experimental studies of the behavior of fuel rods surrounded by a light-water at sub- and supercritical pressures in a wide temperature range, as well as simulate of reactor accidents with loss of coolant, depressurization and unapproved power increase.

***Key Words:*** MTIR-SKD, WWER-SKD, light-water SCP-coolant, test reactor, research reactor, reactor power.

EDN: XNREPI

UDC 621.039.54

## Modeling of Coupled Processes of Coolant Thermal Hydraulics and Thermal Mechanics of Cylindrical Fuel Elements of Power Reactors of VVER and BN Type in Quasi Steady State and Transient Operation Modes. Part 1. Peculiar Features of Modeling and Structure of the FRB Code

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Presents a brief description of the main models and the structure of the FRB code for calculating the coupled processes of coolant thermal hydraulics and thermomechanics of cylindrical fuel elements of VVER and BN power reactors in quasi steady state and transient operating modes using neutronic data calculated by the third-party software tools.

***Key Words:*** code, coupled calculation, thermal hydraulics, thermomechanics, model of thermo-viscous-elastic behavior of cylindrical bodies, fuel element, power reactor.

EDN: XUNBKF

UDC 621.039.531:620.186.1

## Estimation of the Influence of Structure Parameters of High-Nickel Steels for Future VVER-type Reactor Pressure Vessels on their Stress Rupture Strength Characteristics

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The results of comparative structure studies of the high-nickel steel for pressure vessel of the reactor with supercritical coolant parameters ($T \geq 400$ °C, pressure ≥25 MPa) after stress rupture tests are presented. Structural factors that affect stress rupture strength characteristics are revealed for samples of different types. Recommendations are provided in order to increase the stress rupture strength characteristics of the high-nickel reactor pressure vessel steel.

***Key Words:*** high-nickel steel, pressure vessel of the reactor with supercritical coolant parameters, structure studies, phase composition, fractography, metallography, transmission electron microscopy, scanning electron microscopy, stress rupture.

EDN: OVQLFD

UDC 621.039.531:620.186.1

## Special Features of the Macro- and Microstructure of the Weld Metal for the VVER Reactor Pressure Vessel Made using Ceramic Flux in the Initial and Irradiated States

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This work presents the comparative analysis of special features of the macro- and microstructure of the weld metal for the VVER reactor pressure vessel made using ceramic flux in the initial and irradiated states compared to the weld metal made according to the standard technology. It is shown that the weld made using ceramic flux is characterized by the reduced yield strength of metal and lower level of grain boundary segregation. Calculation and experimental evaluation of radiation hardening showed an increase in yield strength by 108 MPa. This value of radiation hardening turned out to be equal to the characteristic value for the metals of welds for VVER-1000 RV with a close content of nickel irradiated to the fast neutron fluence corresponding to the design value for the service life of 60 years. As a result, it was concluded that the tendency of the studied weld material to radiation embrittlement is reduced.

***Key Words:*** welds, ceramic flux, reactor pressure vessel, neutron irradiation, radiation embrittlement, radiation hardening, grain boundary segregations, carbides, dislocation loops, radiation-induced precipitates, transmission electron microscopy.

EDN: QJXSKH

UDC 544.3; 621.039.53

## Some Features of Nitride Fuel Interaction with Fuel Rod Claddings of Austenitic and Ferritic-Martensitic Steel

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The paper presents a comparative analysis of the results of computational studies of thermodynamics of austenitic ChS68-ID and ferritic-martensitic EP823-Sh steels during their interaction with carbon and oxygen. Particular attention is paid to the behavior of unbound chromium depending on the content of oxygen and carbon impurities, since the unbound chromium appears to be the main protector of intergranular corrosion. Results of this study show that EP823-Sh ferriticmartensitic steel is significantly less sensitive to carbon introduction into the fuel compared to ChS68-ID austenitic steel. Relative stabilization of the unbound Cr concentration in the EP823-Sh steel cladding may be due to carbon redistribution between chromium and silicon. It has been established that oxygen produces quite different effects on the unbound chromium content in the “EP823-Sh steel cladding + fuel” and “EP823-Sh steel cladding + oxygen” systems. According to the calculations, chromium silicide oxidation in the “EP823-Sh steel cladding + oxygen” system yields a lot of unbound Cr, while oxygen binds with silicon. In the “EP823-Sh steel cladding + fuel” system, oxygen binds with fuel components, and the concentration of unbound Cr in the cladding does not increase.

***Key Words:*** thermodynamics, corrosion, ferrite, austenite, martensite, steel.

EDN: EZOOHE

UDC 621.039;620.19

## Sacrificial Protection Application for Structural Materials in the Water Reactor Coolant

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The possibility of the sacrificial protection application in the light-water reactor coolant in a wide range of temperatures has been analysed. The need for additional experimental investigations has been demonstrated. The approximate design for such experiments has been proposed.

***Key Words:*** sacrificial protection, corrosive medium, nuclear power installation, water coolant.

EDN: OOKPEI

UDC 621.039.58

## Reduction of Tritium Release During Operation of Fast Neutron Reactors

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This paper considers the reduction of tritium emissions from fast reactors taking into account devices that convert tritium from a gaseous form into the form of tritiated water vapor, which has less permeability through the walls of equipment and pipelines and facilitates further processing and conditioning of tritium-containing radioactive waste. An example of a mathematical model of release formation is given. Using this model, we carried out an assessment of the influence of “tritium drain” devices on tritium activity in process systems and releases of a power unit with a fast neutron reactor. It is shown that when choosing certain operating modes of these devices, it is possible to reduce tritium releases to a significantly low level.

***Key Words:*** fast reactor, tritium, radioactive release, radioactive wastes, radiation safety, mathematical modeling.

EDN: NBINWA