Abstracts
Journal "Problems of Nuclear Science and Engineering. Series: Physics of Nuclear Reactors", issue No.5, 2022

UDC 621.039

Technology Platform for the New Phase of Nuclear Energy Development

A.Yu. Gagarinskiy,
NRC "Kurchatov Institute", 1, Akademika Kurchatova sq., Moscow, 123182

Today, more and more experts look forward towards a new phase of nuclear energy use that would involve a longexpected transfer to low-carbon technologies coupled with growth of the nuclear sector. As regards renewable energy sources, the absence of available effective technologies of long-term energy storage would set back the predicted growth rates that largely depend on national decarbonization policies, and hence would create an incentive for "tandem" energy systems consisting of nuclear and renewables. This paper discusses the technology platform, which nuclear industry expects to rely upon in the new phase of development, as well as the "waiting list" of advanced reactor technologies.

Key Words: nuclear energy, reactor technology platform, water-cooled nuclear reactors, fast neutron reactors.

UDC 621.039.53; 621.039.633

Facility for Testing MSR Materials at the NRC "Kurchatov Institute"

S.S. Abalin, A.M. Berezov, V.A. Zagryadskiy, V.V. Ignatiev, P.N. Ivliev, S.A. Konakov, Ya.M. Kravets, T.Yu. Malamut, V.I. Novikov, A.V. Ovcharov, I.I. Skobelin, A.I. Surenkov, I.N. Trunkin, V.N. Unezhev, O.S. Feinberg, A.V. Shinkarev,
NRC "Kurchatov Institute", 1, Akademika Kurchatova sq., Moscow, 123182.

An experimental complex was created at the NRC "Kurchatov Institute" site to conduct multifactorial tests with MSR materials. The complex makes it possible to implant helium and (or) hydrogen into samples of materials at the U-150 cyclotron, simulating the result of long-term neutron exposure, to perform mechanical tests and microstructural studies before and after simulation exposure, to test the compatibility of structural materials before and after exposure with fuel salt in non-isothermal dynamic conditions at temperatures up to 750 °C with control of the melt redox potential. Preliminary tests with samples of nickel-molybdenum alloy XN80MT demonstrated the efficiency of the experimental technique proposed. The concentration of helium nuclei in the alloy samples reach ~150 ppm for approximately 10 hrs of irradiation.

Key Words: corrosion, Ni—Mo alloys, high-temperature He embrittlement, molten salt fluorides, molten salt reactor, cyclotron, ^{4}He nuclei, activation technique, gamma spectrometer, experimental complex, simulation effect.

UDC 621.039.5

Determination of Energy Release from Gamma Radiation in Experimental Channels of the IR-8 Reactor

V.V. Trofimchuk, V.A. Nasonov, D.Yu. Erak, Yu.E. Pesnya, A.E. Kruglikov, O.V. Mikhin,
NRC "Kurchatov Institute", 1, Akademika Kurchatova sq., Moscow, 123182.

The paper presents an approach to the computational and experimental determination of the energy release from the absorption of gamma radiation in various materials in the experimental channels of the IR-8 research reactor. The main parameters of irradiation are determined during the computational support of experiments, including the energy release due to the absorption of gamma radiation in samples and structural elements of irradiation rigs. The obtained values are used to preliminarily determine the irradiation temperature regime of samples, as well as to confirm the required irradiation conditions. A series of calorimetric experiments was carried out determining the gamma heat release in the experimental channels of the IR-8 reactor core and reflector to check the calculation of samples irradiation parameters.

Key Words: IR-8, irradiation experiments, calorimetric rigs, gamma radiation, radiation energy release, sample temperatures

UDC 621.039-78

Transmission of Neutrons by a Single Crystal of Bismuth Germanate

P.P. Parshin, P.A. Borisova, V.P. Glazkov, E.V. Dyuzheva-Maltseva, V.T. Em,
NRC “Kurchatov Institute”, 1, Akademika Kurchatova sq., Moscow, 123182

The effect of inelastic scattering on the transmission of neutrons by a single crystal $Bi_4Ge_3O_{12}$ (BGO) has been investigated experimentally and theoretically. The results of an experiment on measuring the temperature dependence of the transmission of monochromatic neutrons by a single crystal BGO are presented. The dependence obtained in the experiment is well described by a calculation based on taking into account inelastic neutron scattering on phonons. The analysis indicates the existence of a temperature-independent contribution to the total cross-section of neutrons interaction with a single crystal BGO. It is assumed that this contribution is due to the presence in the studied sample of a small amount of impurities that strongly absorb neutrons.

Key Words: single crystal bismuth germanate, neutron transmission, partial thermal vibrations spectra of atoms, cross section of inelastic neutron scattering.

UDC 621.039.517

Energy Release of Fissile Isotopes of Uranium and Plutonium in the Nuclear Reactor Core

V.I. Kopeikin,
NRC “Kurchatov Institute”, 1, Akademika Kurchatova sq., Moscow, 123182,
D.V. Popov, M.D. Skorokhvatov,
NRC “Kurchatov Institute”, 1, Akademika Kurchatova sq., Moscow, 123182,
NRNU MEPhI, 31, Kashirskoe shosse, Moscow, 115049

A new calculation of the energy released in the fission processes of isotopes ^{235}U, ^{238}U, ^{239}Pu and ^{241}Pu in the nuclear reactor’s core, based on the revision of the reactor antineutrinos energy characteristics, was performed. The calculation used data from the reconstruction of antineutrino spectra [1] based on the results of the NRC “Kurchatov Institute” experiment [2] at the IR-8 research reactor, as well as calculated antineutrino spectra [3, 4] and updated information from nuclear databases [5—8].

Key Words: fission energy, nuclear reactor, reactor power, antineutrino.

UDC 621.039.52

About Requirements for Development of Neutron-Physical Mechanisms of Instability on a Part of Groups of Emitters of Delayed Neutrons

D.G. Kresov,
JSC “Afrikantov OKBM”, 15, Burnakovsky travel, Nizhny Novgorod, 603074

It is theoretically confirmed a possibility of oscillatory instability on a part of groups of delayed neutrons with short period of decay for some known models-mechanisms formed by a chain of the negative feedback “power — temperature (density) — reactivity — power”. The larger feedback gain is required for instability occurrence on smaller number of groups. The parametric and regime requirements which stabilize the system are discussed.

Key Words: kinetics, delayed neutrons emitter group, phase lag, instability, thermohydraulic inertia.

UDC 621.039.562

Optimal Stabilization of the Reactor Power with Preliminary Identification of its Characteristics under Conditions of Uncontrolled External Influences

A.M. Degtyarev,

NRC “Kurchatov Institute”, 1, Akademika Kurchatova sq., Moscow, 123182

The fundamental possibility of identifying the kinetic characteristics of a reactor under quasi-stationary operating conditions by observing fluctuations in its power under the influence of controlled changes in reactivity, as well as the possibility of optimal stabilization of the reactor power, is considered. The analysis is carried out under conditions of influencing the reactivity of the reactor and measuring its power of interfering disturbances in the form of uncontrolled random processes. A model of point reactor kinetics with one group of delayed neutrons and instantaneous power feedback is used. Examples are presented that illustrate the proposed identification method and the efficiency of the optimal controller.

Key Words: reactor, identification, power stabilization, control optimization, random noise.

UDC 621.039.51

Validation of ENDF/B-7.1 Library for PIK-04 Critical Experiments

M.S. Onegin,

National Research Center “Kurchatov Institute” — PNPI, 1, Orlova Roscha, Gatchina, 188300

Effective neutron multiplication coefficients k_{eff} were calculated for critical assemblies of PIK-04 series. The circular type cores contain PIK type fuel elements. It is demonstrated that the mean value of k_{eff} for 7 critical assemblies calculated using MCNP-6.1 and SCALE-6.2.4 codes with ENDF/B-7.1 nuclear data library is equal to 1.0016 with the mean square scatter $\pm$ 0.0004. The mean value of k_{ef} calculated using ENDF/B-6.2 nuclear data library is 0.0023 larger.

Key Words: critical assemblies, PIK type fuel elements, ENDF/B-7.1 library, validation.

UDC 621.039.55

Comparison of the Effect of Nuclear Data Uncertainty on the Accuracy of Prediction of the Isotope Composition for UO2 and MOX Fuel in Burnup Calculations for a PWR Cell

A.N. Pisarev, V.V. Kolesov,

NRC “Kurchatov Institute”, 1, Akademika Kurchatova sq., Moscow, 123182

The uncertainty of the quantification of the nuclide density is estimated in the calculations of the burnup of UO_2 and MOX fuel in the PWR cell due to the neutron flux density error and the uncertainties of the cross sections from the JEFF-3.3 library. It is shown that there is a difference between the constant components of the error for the indicated types of fuel. This difference decreases with fuel burnup increasing.

Key Words: standard deviations of nuclear concentrations of nuclides, fuel burnup, nuclear data uncertainties.

UDC 621.039

MNT-CUDA Program Verification Research on PWR and BFS Systems

V.A. Varfolomeeva, N.A. Grushin, I.E. Ivanov, S.A. Bychkov,
JSC “VNIIAES”, 25, Ferganskaya st., Moscow, 109507

The article presents the results on the first verification phase of a high-precision engineering code MNT-CUDA. Periodical lattices of VVER and BFS assemblies were calculated and results were compared with results of precision code MCU-6. The comparison of several neutron-physical characteristics (such as the multiplication factor, reaction rates in the multi-group approximation) is introduced. MNT-CUDA (version 2.0) solves the neutron transport equation using the Monte Carlo method and allows detailed system modeling (e.g. full-scale reactor or its separate parts). One of the notable program features is the possibility of running parallel calculations on graphic processors (GPUs) gaining a significant time benefit.

Key Words: Monte Carlo method, MNT-CUDA program, GPU, MCU, verification, neutron-physical characteristics.

UDC 621.039.58

About Radiocarbon in Uranium-Graphite Reactors

G.B. Davydova, A.V. Krayushkin, A.K. Smirnova,
NRC “Kurchatov Institute”, 1, Akademika Kurchatova sq., Moscow, 123182

The reactor graphite management is discussed. Comparison of the ^{14}C content in RBMK graphite and its natural content and release from other technogenic activities is performed. The limits of the natural oscillations of the ^{14}C natural content and their correlation with technogenic releases are discussed. The doses due to ^{14}C release from some hypothetic near surface storage of the reactor graphite under normal operation and accidents are estimated.

***Key Words*:** graphite, radiocarbon, uranium-graphite reactors.

UDC 629.039.58

Beyond Design Basis Accident with Complete Blackout of the RBMK. Analysis of the Recriticality Occurrence Possibility

A.V. Krayushkin, I.A. Tupotilov,
NRC “Kurchatov Institute”, 1, Akademika Kurchatova sq., Moscow, 123182

The influence of various accident events on the reactivity during the severe stage of the accident is studied using the three-dimensional program STEPAN-T, developed specifically for simulating an accident with a complete blackout of the RBMK. The maximum and average temperatures for graphite and fuel, the temperatures of the metal structures of the lower support and shielding (OR scheme), as well as the chronology of the destruction of the core elements before the start of the destruction of the fuel are given. The effect of reactivity from graphite heating is shown. The effects of reactivity from the melting of aluminum sleeves of cluster control (KRO) rods, shells of shortened control rods (USP) and emergency rods (AZ) rods are considered. An analysis was made of the scenario when, due to the departure of the aluminum sleeves of the KRO rods, the absorbing elements, losing their distance, form a dense bundle. The scenario with the breakage of the KRO rods servo drive cable and the fall of the absorbing elements under the core is considered, the impact of this incident on the reactivity is assessed. The influence on the reactivity of the formation of “fuel columns” resulting from the destruction of fuel assemblies is estimated. The effect of the yield of fission products and erbium on the reactivity was estimated. The reactivity was also calculated for all the cases described above at reduced temperatures, when the emergency reactor is cooled.

Key Words: severe accident, reactivity effects, RMBK, STEPAN-T.

UDC 621.039.564

Application of Fiber-Optic Measuring System for NPP RBMK-1000 Lifetime Management

A.N. Biryukov, A.V. Slobodchikov,
JSC “NIKIET, 2/8, Malaya Krasnosel’skaya st., Moscow, 107140,
I.N. Lozhnikov,
NRC “Kurchatov Institute”, 1, Akademika Kurchatova sq., Moscow, 123182,
A.V. Shutikov,
JSC “Rosenergoatom”, 3a, Kholodil’nyy pereulok, Moscow, 115191

Two methods of control of RBMK-1000 fuel (technological) channels curvature evaluation are discussed in this article. The control is performed in order to assess the graphite stack shape change at the final stages of NPP RBMK-1000 operation, to determine the necessity and scope of repair as part of the works on lifetime management (LTM), to plan the reactor unit operation period. The method based on using the IKS-49 fiber-optic system does not require the unloading of fuel assemblies from the channels and makes it possible to reduce significantly the duration of scheduled repair works at NPPs, while having a sufficient degree of accuracy. The paper describes the principle of operation and the main technical characteristics of the measuring system based on fiber-optic sensors. The assessment of actual reduction of reactor unit repair duration was performed and the obtained economic effect when applying the system IKS-49 for in-core monitoring at LTM of graphite stack of Leningrad NPP unit № 3 in 2020 was assessed.

Key Words: RBMK, curvature, lifetime management, in-core monitoring, fiber-optic measuring system.

UDC 621.3.002

Analysis of Readings of Background Cores of in-Reactor Detectors

A.M. Musihin, N.V. Mil'to, A.Yu. Kurchenkov, D.N. Skorohodov, D.A. Karasev, A.I. Vereschaka, D.S. Markov,
NRC “Kurchatov Institute”, 1, Akademika Kurchatova sq., Moscow, 123182

Readings of background cores of SPND are analyzed. It is proposed the new method of independent evaluation of reactor thermal power.

***Key Words*:** self-powered neutron detector (SPND), background detector, in-core noise diagnostic systems (ICND).

UDC 621.039.5

The RC Code for Doses Calculations from Radioactive Emissions to the Atmosphere

I.N. Geraskin, A.V. Krayushkin, A.K. Smirnova,
NRC “Kurchatov Institute”, 1, Akademika Kurchatova sq., Moscow, 123182

It is presented a description of the model for calculating the doses of external exposure from the surface and the cloud, internal exposure due to inhalation and for the food chains in the RC code, which is used for doses calculations during emergency short-term releases and continuous releases during normal operation of nuclear facilities. The article describes the features of the code, such as aerodynamic shadow and the line source model accountings. The results of code verification with experimental data on aerosol transfer and NOSTRADAMUS code are presented. A comparison is also made with the results of dose measurements after the Chernobyl accident and continuous emissions from NIIAR reactors.

Key Words: radiation doses, accident, radiation safety, radioactive release.

UDC 621.039.536.2

Grain Refinement of HAZ Metal Due to Multi-Pass Welding

A.A. Chernobaeva, D.Yu. Erak, R.O. Polyakova, O.D. Chebotaryov, Yu.E. Pesnya, V.V. Trofimchuk,

NRC "Kurchatov Institute", 1, Academika Kurchatova sq., Moscow, 1123182

The size distribution of former austenite grains in the HAZ metal of a welded joint made of steel 15Kh2NMFAA has been studied in detail. Computational modeling of the thermal cycle of welding was carried out in order to evaluate the distribution of the maximum values of temperature and heating rate in the heat-affected zone. The work is aimed at analyzing the causes of grinding of the austenite grain of the shell metal in the HAZ due to the thermal cycle of welding.

Key Words: reactor pressure vessel, heat-affected zone, welding cycle modeling.

UDC 621.039.56

Peculiarities of the Organization and Execution Experience during NPP Units Decommissioning Abroad: Analysis, Conclusions and Recommendations

Yu.M. Semchenkov, B.K. Bylkin, Yu.A. Zverkov,

NRC "Kurchatov Institute", 1, Akademika Kurchatova sq., Moscow, 123182,

P.L. Ipatov, V.G. Volkov, F.T. Morozov,

Joint-Stock Company "Rosenergoatom", 25, Ferganskaya str., Moscow, 109507,

N.N. Safronova,

Association of Organizations of the Construction Complex of the Nuclear Industry, 65/1, Profsoyuznaya str., Moscow, 117342,

I.I. Korneev,

Joint-Stock Company "VNIIAES", 25, Ferganskaya str., Moscow, 109507

The article presents final results of the analysis of peculiarities of the organization and execution experience during NPP units decommissioning abroad. Among foreign countries, the USA, Germany, France, Great Britain, Sweden and some others were considered as reference countries. Conclusions are drawn and recommendations are given on taking into account accumulated foreign experience in relation to decommission of the Russian nuclear power plants.

Key Words: NPP, decommissioning, growth of work and service market, IAEA recommendations, implemented approaches and technical solutions, integration of innovative technical solutions and technologies, power companies, operating organizations, organizational and structural transformation.