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CONTENTS

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UDC 62.039

Implementation stages of natural circulation for cooling down naval reactor plants

A.Ya. Blagoveshchensky, L.B. Gusev

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Abstract

The paper addresses the problems encountered in implementing new technologies and considers the ways to solve these problems so as to assure reliability, safety, and survivability of naval reactor plants in a total-loss-of-power scenario. The biggest problem for nuclear submarine conditions is limited capacity of the battery as a backup power supply. The paper shows the role of navy personnel and concerted action of the Customer, research organizations, and industry in successful solution to the problem, based on natural circulation of the coolant without use of powered machines.

Key words: nuclear submarine, reactor, emergency cooldown, steam generator, loop-type design, integral-type design, coolant natural circulation, self-regulation.

UDC 621.039.52.034.6

Analytical review of operating experience and modern developments of medium and small power liquid metal cooled nuclear reactors.

Part 1 (Operating experience)

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Abstract

Lead and lead-bismuth cooled reactors are a promising direction for the development of nuclear power. This paper presents a review of international and national experience in operation and development of liquid metal cooled nuclear reactors.

The paper describes liquid metal cooled reactor propulsion systems that were used in nuclear submarines of Projects 645, 705, 705K and in land-based prototype reactor plants 27/VT and KM-1. The key design solutions adopted in the mentioned projects are analyzed.

Key words: liquid metal coolant, lead-bismuth coolant, nuclear submarine, nuclear reactor propulsion plant.

UDC 621.039.51:006.91

Simulation of control rod worth experiments on a fast critical assembly facility

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Abstract

The paper presents results of simulation of control rod worth experiments performed with the "insertion" and "divergence" methods. A neutron model implemented in the SAPFIR_RF&RC program package was used in the simulation. The experiments were carried out on the critical assembly facility with a fast gas-cooled reactor core at FSUE "Alexandrov NITI". The purposes of the simulation were to verify the simulation model and assess the sensitivity of the simulation results to the inverse kinetics approach used for the measurement of reactivity.

Key words: fast neutron spectrum reactor, critical assembly facility, measurement of reactivity, delayed neutron parameters, spatial eff ects, neutron source, simulation of experiments, SAPFIR_RF&RC program package.

UDC 621.039.524:519.2

Analysis and evaluation of Groeneveld-Stewart correlation uncertainty in calculation of minimum wall wetting temperature

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Abstract

Based on comparison with results of reported experiments, the author has performed an uncertainty evaluation of the Groeneveld-Stewart correlation that is used as a closure relation in computer programs designed for thermal-hydraulic calculations – computer codes – for stimation of minimum wall-wetting temperature. The evaluation has shown that this correlation gives a conservative estimate of the mentioned parameter for the saturated water line and vapor-water flow.

The paper analyzes the infl uence that the correlation development methods and assumptions (indirect sources of uncertainty) have on quantifi ed discrepancy of calculation and experiment (RMS deviation). Results of mathematical analysis are used to develop a modifi ed Groeneveld-Stewart correlation that would reduce the discrepancy for the subcooled water region.

The paper addresses the problem of what software and technology should be used to account for indirect sources of uncertainty of multi-factor closure relations in calculations by the GRS
statistical method. A specifi c proposal of how to include this correlation uncertainty calculation in the KORSAR functional software is made.

The KORSAR code and PANDA programs and GRS method have been used to analyze numerically the eff ect of the Groeneveld-Stewart correlation uncertainty on calculation of the peak-clad temperature for the VVER-1000 LB LOCA scenario. It is found that consideration of the correlation uncertainty in this scenario leads to about 100 °C deviation in the calculated parameter value.

Key words: Groeneveld-Stewart correlation, minimum wall wetting temperature, KORSAR computer code, calculation uncertainty, LB LOCA, GRS.

UDC 621.039.548, 621.039.577

Development of procedures for fuel clad failure monitoring during testing of naval nuclear propulsion reactors

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Abstract

The paper reports the authors' experience of developing rapid procedures for integrity monitoring of fuel cladding during tests of naval nuclear propulsion reactor cores. The clad integrity is assessed via radiochemical analysis of coolant water samples taken after each reactor shutdown.

Such monitoring procedures are required because of transient test conditions of reactor operation, impossibility of taking coolant samples when the reactor is at power, and presence of activated corrosion products in reactor coolant water. Under these conditions, clad failures and stages of their evolution can be identifi ed from measurements of both short and long-lived activities present in cooling water immediately after reactor shutdown. In the practical test, coolant water samples were taken within the fi rst hours after shutdown and then subjected to radiochemical laboratory analysis. The method developed by the authors uses measurements of the eff ective masses of fuel to analyze and unify radiochemical data obtained from tests with varied reactor power and operation times. This approach relies on the observation that the activity of fuel fi ssion and activation products accumulated in fuel elements during the test is equal to the activity of the products released from failed fuel into the coolant water.

The paper presents an updated set of radiochemistry monitoring procedures for use in testing of naval nuclear reactor cores. This set includes new procedures for selective separation and concentrating of radionuclides. An algorithm for calculating the eff ective masse of fuel is described.

Key words: core, monitoring, fuel elements, clad integrity, clad failure, reference radionuclides, eff ective mass of fuel.

UDC 621

Technico-economic study of possible technologies for seawater desalination in the second power unit of Bushehr NPP (Iran

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Abstract

The problem of providing fresh water in many regions of the world is exacerbated every year. Seawater desalination is used as the main solution to meet the demand for water in the

countries of the Middle East and North Africa (MENA), which are severely aff ected by water shortage. Seawater desalination is an expensive process and needs a huge amount of energy. Currently, most of the existing water plants in the world are fossil-fuel based, which infl uenc-es the environment. Among all types of energy sources, nuclear energy can be considered as a proper alternative source of energy for supplying the required energy of water plants. Iran, as a country with shortage of fresh water, as a member state of the IAEA (International Atomic Energy Agency) has expressed its interest in developing the desalination plants based on the existing Bushehr nuclear power plant. The Bushehr atomic complex is the fi rst commercial nuclear reactor in the Middle East and can be used (and already partially used at the fi rst pow-er unit of the Bushehr NPP) as part of a multi-purpose nuclear complex to meet the demand for energy and drinking water in the arid territories of the south of the country. This article provides an economic and thermodynamic assessment of various desalination technologies at the second power unit of the Bushehr nuclear power plant. The relevance of the suggested topic is determined by the expediency (and even necessity) of the nuclear desalination tech-nologies development in Iran. Practical value of the article is its practical recommendations for choosing the concept and composition of desalination plant equipment for the second unit of Bushehr NPP in Iran.

Key words: seawater desalination, power plant, Desalination Economic Evaluation Program, Bushehr nuclear power plant, seawater desalination technologies, preheating the reverse os-mosis feed water, hybrid methods desalination, energy consumption.

UDC 544.344.2

$USiO_4$ stability analysis

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Abstract

The article analyzes the phase diagrams of a number of $Me^{IV}O_2$–SiO_2 binary systems, as well as the available structural and thermodynamic data of the $Me^{IV}SiO_4$ compounds (where *Me* is Zr, Th, Hf and U). The results of an experimental study of compositions corresponding to the composition of the compound $USiO_4$ presented. Obtained data are useful for improving the forecasting accuracy of scenarios for the Ex-Vessel stage of a severe accident at a nuclear power plant, for analyzing the fuel debris formed under these conditions, as well as for developing new materials for nuclear power, including nuclear fuel.

Key words: uranium dioxide, silica, uranium silicate, phase equilibria, phase diagram, induction melting in the cold crucible, severe accidents.