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Contents

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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 2 (Modern developments)

[1]E.D. Fedorovich, [2]I.I. Kurdiukov

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Abstract

This paper is a continuation (the second part) of the review prepared by the authors with the aim to analyze the existing trends and experience in development and operation of liquid metal cooled nuclear reactors (the first part of the review was published in № 2(20)2020 of this Collection of Papers).

The paper gives information about modern developments of nuclear propulsion plants with heavy liquid metal cooled reactors in Russia and other countries: SVBR-100, BREST-OD-300, SSTAR, ELFR, URANUS-40, CLEAR, PBWFR, LFR-AS-200, SEALER, Gen4 Projects. A brief review of design solutions adopted in the mentioned projects is presented.

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

UDC 532.542:004.942

A numerical investigation in the behavior of coolant flow radially injected into the VVER reactor annulus via a pipe

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Abstract

The KORSAR/CFD calculation of simple tests shows anisotropic behavior of coolant fl ow in the annulus space of the VVER reactor where it is radially introduced via an injection pipe. The fl ow spreads around the annulus circumference in azimuthal directions. In the longitudinal direction fl ow choking occurs. The reason for anisotropic spreading behavior is explained. A three-dimensional fl ow pattern in the VVER reactor annulus determines spatial distributions of the coolant temperature and boron concentration at the inlet of fuel assemblies.

Key words: reactor, annulus, injection pipe, computer code, computational mesh, computational fl uid dynamics, coolant spreading

UDC 621.182.12 + 628.165

Modular membrane-sorption plant for preparation of high-purity coolant water for nuclear power plants

V.A. Vasilenko, V.N. Epimahov, I.V. Miroshnichenko, O.Yu. Pyhteev

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Abstract

The paper presents an automated modular membrane-sorption plant developed and manufactured in FSUE «Alexandrov NITI» for preparation of high-purity water used for filling and coolant makeup of the primary systems of naval reactor plants. The plant implements an improved four-stage water treatment technology which allows using both drinking water and saltish water of the Baltic Sea as source water.

The paper describes the results of plant testing and the improved features of water treatment technologies, such as alkalization, citrate washing, trilon treatment of membranes, and thermal decarbonization of sorbents. The results of life testing of both a mockup plant (NITI) and a prototype plant (LNPP) for high-purity water preparation are given. It is noted that the results of life testing confirm the perspectiveness of change-over from the traditional distillation and ion-exchange methods to membrane-sorption technology for preparation of high-purity coolant water used in naval reactor plants.

Key words: high-purity water, coolant, filtration, reverse osmosis, thermal decarbonization, membrane-sorption water treatment.

UDC 621. 039.534

Standardization and chemical control of coolant in the heavy water system of the PIK reactor

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Abstract

The design of the PIK reactor (NRC KI – PNPI) includes two heavy-water systems: a liquid control circuit and a heavy-water refl ector circuit. When standardizing the chemical parameters of such systems it is necessary to take into account that the physical and chemical properties of heavy water are slightly diff erent from those of light water.

The article proposes a technique to calculate the value of electrical conductivity of ideally pure heavy water. A list of control chemical parameters of the PIK reactor heavy water coolant has been recommended.

Key words: the PIK reactor, chemical control, water chemistry, liquid control circuit, heavy-water refl ector circuit, heavy water, deuterium.

UDC 621.039.577:628.165

The need for developing dual-purpose nuclear desalination complexes to provide electricity and fresh water in the arid territories of Iran

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Abstract

Nuclear energy has many advantages over other energy sources in supplying the required energy to the desalination plants; in particular, it is practically free of greenhouse gas emitting. Considering the fact that the freshwater defi cit is one of the key problems in some countries, the development of desalination technologies seems to be necessary in dealing with this diffi culty. Desalination processes are energy-intensive; therefore, its integration to the nuclear power plant further emphasizes its benefi ts. The growing demand for electricity and fresh water in Iran forces the country to investigate for eff ective alternatives. As a suitable option, the use of nuclear desalination complex can be suggested, in which the extracted steam from the turbine of the nuclear power plant is utilized to supply the thermal desalination systems and the generated electricity can be used to drive the high-pressure pumps of reverse osmosis membranes. In this paper, the status of desalination technologies and operating plants in Iran is described. Some possible coupling schemes between desalination plant and nuclear power plant are suggested. The results of a feasibility study of dual-purpose complexes in relation to the needs of Iran are presented. The calculation results indicate the competitiveness of the proposed complexes in comparison with fossil fuel-based desalination plants.

The relevance of the topic of this article is determined both by the need to develop dual-purpose nuclear desalination complexes for use in Iran, and by the fact that the Russian Federation can develop and supply such complexes to both Iran and other countries that need desalinated sea water.

The practical signifi cance of this article is determined by the fact that it gives practical recommendations on the choice of schemes and composition of equipment for dual-purpose complexes in relation to the Iranian needs.

Key words: seawater desalination; nuclear desalination complex; freshwater shortage in Iran; economic analysis of desalination plant operating in conjunction with a nuclear power plant.

UDC 544.45 + 621.039.58

Numerical simulation of thermokinetics during interaction of sacrificial material and corium melt during severe reactor accidents at nuclear power plants

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Abstract

The paper presents a three-dimensional model and the results of calculating the changes in thermal and phase state of the sacrifi cial material structural element interacting with the core melt in the cooled core catcher. The model is based on the Stefan's problem taking into account the residual radioactive corium heat release, the thermal eff ects from sacrifi cial material melting and from chemical reactions of the oxides recovery during oxidation of under oxidized elements of the melt, the heat transfer via natural convection in the melt, the heat transfer to cooling water through the walls of the vessel and thermal radiation in the internal space. The numerical methods of the COMSOL Multiphysics software package are used to unify discretization of a computational region, to automate the conditions for matching the thermal, hydrodynamic and chemical components of a model, to assure a pass-through calculation of these components for reduction of overall simulation uncertainties and for detailed description of thermokinetic characteristics of processes for core catcher designers.

Key words: core melt, core catcher, sacrificial material, thermal and phase state, simulation, thermokinetic processes, Stefan problem, three-dimensional model