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NUCLEAR PROPULSION  
REACTOR PLANTS.  
LIFE CYCLE MANAGEMENT  
TECHNOLOGIES

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№ 4 (26) 2021

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# NUCLEAR PROPULSION REACTOR PLANTS. LIFE CYCLE MANAGEMENT TECHNOLOGIES

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## Detection of cavitation effects in VVER-1200 reactor coolant system from signals of pressure fluctuation sensors

*G.V. Arkadov<sup>1</sup>, V.I. Pavelko<sup>1</sup>, V.P. Povarov<sup>2</sup>, M.T. Slepov<sup>2</sup>*

<sup>1</sup>JSC “Joint Stock Company “Scientific and Technical Center “Diaprom”,  
Kaluga region, Obninsk, Russia

<sup>2</sup>Branch of JSC “Concern Rosenergoatom” Novovoronezh NPP,  
Novovoronezh, Voronezh region, Russia

### Abstract

The existing VVER 1200 reactors are equipped with diagnostic systems allowing for detection and identification of cavitation phenomena in the main coolant loops.

Based on analysis of large amounts of experimental data, the paper describes the conditions leading to cavitation in the VVER-1200 reactor coolant system. The data presented in the paper report the occurrence of cavitation phenomena in the VVER-1200 coolant loops.

The paper discusses the limitations of testing of reactor coolant pumps in special-purpose test facilities. These limitations are due to the inability of reproducing in full scale neither configuration of the coolant loop nor parameters of the processes occurring in this loop at real NPP.

**Key words:** VVER-1200, reactor coolant system, monitoring system, cavitation, pressure fluctuation sensor, accelerometer, resonance, diagnostic system, root-mean-square, autospectral power density, standing acoustic wave.

## **Optical spectrometry and multisensor potentiometry with chemometric processing of data for online monitoring in nuclear industry**

*<sup>1, 2, 3</sup>D.O. Kirsanov, <sup>1, 2</sup>A.V. Legin, <sup>2, 4</sup>V.A. Babain*

<sup>1</sup>Saint Petersburg State University, Institute of Chemistry, Saint Petersburg, Russia.

<sup>2</sup>Saint Petersburg National Research University ITMO, Laboratory of Artificial Sensor Systems,  
Saint Petersburg, Russia.

<sup>3</sup>ООО “Sensornye Sistemy”, Saint Petersburg, Russia.

<sup>4</sup>TriArk Mining Co., Saint Petersburg, Russia.

### **Abstract**

The nuclear fuel cycle is closed when used nuclear fuel is reprocessed. Uranium and plutonium are recovered by PUREX reprocessing, i.e. they are extracted from nitric acid solution with tributyl phosphate. The paper discusses the possibilities of on-line monitoring of the process solution composition by using optical spectroscopy methods (UV-Vis, Raman, and NIR spectroscopies) and multisensor potentiometric measurements. It is shown that the use of modern chemometric methods for processing of analytical signals produces reliable data on the concentration of analytes (actinides, lanthanides, and nitric acid) in the process solutions.

**Key words:** optical spectroscopy, NIR spectroscopy, process monitoring, potentiometry, chemometrics.

## Development of diagnosis algorithms for technical objects of different purpose

*V.A. Vasilenko<sup>1</sup>, A.M. Pankin<sup>1</sup>, I.A. Tutnov<sup>2</sup>*

<sup>1</sup> FSUE “Alexandrov NITI”, Sosnovy Bor, Leningrad region, Russia

<sup>2</sup> National Research Center “Kurchatov Institute”, Moscow, Russia

### Abstract

The paper describes the main steps of development of diagnosis algorithms for complex technical objects for which new generation diagnosis systems are expected to be designed. Previous diagnostic systems were mainly designed for non-destructive testing. However, non-destructive testing is not sufficient to adequately determine residual life of test objects. The in-service condition monitoring accuracy of components and systems can be improved if they are designed with features allowing acquisition of the most informative condition measurements. In view of this, diagnosis algorithms for new technical systems should include modules capable of selecting the most informative diagnostic indicators that can be obtained during diagnostic measurements. A special attention should be paid to the issues of uncertainty assessment of direct and indirect measurements because these issues are not completely resolved in metrology standards.

**Key words:** technical object, monitoring, diagnostics, condition, diagnostic indicator, mathematical model, diagnostic model, measurement information, diagnosis, uncertainty.

## Experimental determination of spatial inversion point of coexisting molten phases in the U-Zr-Fe-O-B<sub>4</sub>C system

*V.B. Khabensky<sup>1</sup>, V.I. Almjashev<sup>1,2,3</sup>, A.V. Timchuk<sup>1</sup>, E.B. Shuvaeva<sup>1</sup>, E.V. Krushinov<sup>1</sup>, S.A. Vitol<sup>1</sup>, A.A. Sulatsky<sup>1</sup>, S.Yu. Kotova<sup>1</sup>, V.V. Gusarov<sup>4</sup>*

<sup>1</sup> FSUE “Alexandrov NITI”, Sosnovy Bor, Leningrad region, Russia

<sup>2</sup> Saint Petersburg Electrotechnical University “LETI”, Saint Petersburg, Russia

<sup>3</sup> I.V. Grebenshchikov Institute of Silicate Chemistry of RAS, Saint Petersburg, Russia

<sup>4</sup> Ioffe Institute, Saint Petersburg, Russia

### Abstract

The work studies the stage of a severe accident associated with the formation of a molten pool and a change in the spatial arrangement of two immiscible liquid phases (metallic and oxidic) in the U-Zr-Fe-O-B<sub>4</sub>C system, which is the base system for a severe accident at a nuclear power plant. In the experiment, the initial state was a two-liquid oxidic-metallic suboxidized molten pool of corium with a bottom position of metallic liquid and a U/Zr ratio typical of the accident conditions at the Fukushima-Daiichi NPP. During the experiment, in the U-Zr-Fe-O-B<sub>4</sub>C system, the mass fraction of B<sub>4</sub>C was successively increased in small portions, and the point of spatial inversion of the metallic and oxidic liquid was determined, at which the metallic liquid occupied a stable upper position in the molten pool. In the experiment, the monotectic temperature was also measured with a change in the B<sub>4</sub>C content in the melt, and the composition of the melt samples and melt products was determined. The obtained experimental results can be used to expand and refine the databases used for thermodynamic modeling of phase equilibria in multicomponent systems of molten corium at various stages of a severe accident at NPPs with pressurized and boiling water reactors.

**Key words:** uranium, zirconium, iron, oxygen, boron carbide, phase equilibria, miscibility gap, spatial inversion of liquid phases, induction melting in the cold crucible (IMCC), severe accidents.

## Determination of the thermal conductivity of the crust formed on the corium melt during a severe accident at a nuclear power plant

*V.B. Khabensky<sup>1</sup>, V.S. Granovsky<sup>1</sup>, V.A. Vasilenko<sup>1</sup>, V.I. Almjashev<sup>1,2,3</sup>,  
E.V. Krushinov<sup>1</sup>, S.A. Vitol<sup>1</sup>, A.A. Sulatsky<sup>1</sup>, V.V. Gusarov<sup>4</sup>*

<sup>1</sup> FSUE “Alexandrov NITI”, Sosnovy Bor, Leningrad region, Russia

<sup>2</sup> Saint Petersburg Electrotechnical University “LETI”, Saint Petersburg, Russia

<sup>3</sup> I.V. Grebenshchikov Institute of Silicate Chemistry of RAS, Saint Petersburg, Russia

<sup>4</sup> Ioffe Institute, Saint Petersburg, Russia

### Abstract

The article proposes a new method for determining the thermal conductivity of an oxidic crust formed on the surface of a molten pool of oxidic-metallic corium, which is a prototypic corium that forms during a severe accident at a nuclear power plant with VVER. In the proposed method, the way of crust formation, which determines its elemental and phase compositions, microstructural features, including the nature of porosity, is as close as possible to reactor conditions. A review of the known methods for determining the thermal conductivity of corium oxidic crusts is given with an analysis of the measurement accuracy and limitations associated with the technology of manufacturing experimental samples. Using the proposed method, the thermal conductivity of the oxidic crust formed on the melt surface in the CORDEB project experiments was determined. The good convergence of the experimental results and the performed estimates is demonstrated. The proposed method can be used to refine the thermal conductivity of the corium crust in the calculation analysis of the in-vessel stage of a severe accident at a nuclear power plant with pressurized water reactors.

**Key words:** corium melt, corium crust, thermal conductivity, severe accidents.