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Justification of the material selection for LW-SMMR reactor and primary and secondary circuits; validation of strength and lifetime of the materials used

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Main issues related to the selection of materials for SNPP components



Operating conditions for the component:

- temperature;
- pressure;
- operation environment;
- cyclic loads;
- potential impact on other system components.

Selection of available component manufacturing technology.

Regulatory framework.

Selection of suitable materials :

- availability of material for purchase;
- availability of standardization documents in the selected regulatory framework;
- the material approved for use or the material is new and requires certification;
- availability of all material characteristics, taking into account operating conditions;
- conducting research to obtain the required characteristics of materials, taking into account the specifics of their application.

Principle of selection of materials for SNPP components

Materials are selected taking into account the following factors:

- mechanical and physical characteristics of the material concerned;
- influence of operating modes and operation environment on the material;
- the design and function of the component;
- margins of safety and reliability of the component;
- the impact of assembly operations on the material and the component as a whole, taking into account the subsequent assembly of components;
- both normal operating conditions and potential emergency conditions shall be taken into account.

Materials approved for use in the manufacture of NPP components in the Russian Federation



Materials used for components important to the safety of nuclear power plants, depending on the purpose of the component, must meet the requirements of the Federal rules and regulations in the field of atomic energy use of the Russian Federation - NP-089-15 and NP-104-18.

NP-089-15 and NP-104-18 regarding acceptable materials refer to the Consolidated List*, which is a list of materials approved by the Regulatory Authority.

Approved materials, with the associated conditions and restrictions (if any), are listed in:

- Section 1 of the Consolidated List* - for all components of the NPP;
- Appendix No. 1 to the Consolidated List* - for materials of components subject to NP-089-15;
- Appendix No. 3 to the Consolidated List* - for welding and surfacing materials of components subject to NP-104-18;
- Appendix No. 4 to the Consolidated List* - for surfacing materials of sealing and guiding surfaces of components subject to NP-089-1.

* The Consolidated List of documents on standardization in the field of atomic energy use, applied on a mandatory basis, is introduced in accordance with the Decree of the Government of the Russian Federation N 669 of July 12, 2016 "On approval of the Regulations on standardization in relation to products (works, services) for which requirements are established, related to ensuring safety in the field of atomic energy use, as well as processes and other standardization objects associated with such products" (with amendments and additions). It is provided on the ROSATOM website <https://www.rosatom.ru/about/tekhnicheskoe-regulirovanie/standartizatsiya-v-oblasti-ispolzovaniya-atomnoy-energii/>

New materials



New materials*, both basic and welding (surfacing), before being used in the field of atomic energy use, undergo conformity assessment in the form of certification tests in accordance with Federal rules and regulations in the field of atomic energy use – **NP-071-18**.

Certification tests are carried out according to the following standards of the Conformity Assessment System in the field of atomic energy use in the form of testing:

GOST R 50.04.01-2018 *Certification tests. General provisions*

GOST R 50.04.02-2018 *Certification tests of heat treatment technologies*

GOST R 50.04.04-2018 *Certification tests of billet forming technologies*

GOST R 50.04.05-2018 *Certification tests of technologies for smelting and casting steels and alloys*

GOST R 50.04.06-2018 *Certification tests of a new material (basic or welding)*

*New materials - basic and welding materials not listed in the Consolidated List of Standardization Documents (or supplied according to other standardization documents, or used at higher temperatures relative to those given in the Consolidated List) and not approved by Rostekhnadzor for use in the field of atomic energy use in the Russian Federation.



Certification testing of a new material

In accordance with the requirements of GOST R 50.04.01-2018

Certification tests of a new material are carried out by:

Leading materials science organization* that was not involved in the development of this material.

Certification tests are carried out in several stages:

- familiarization with information on the object of certification tests and the formation of a certification commission;
- development of a certification testing program;
- sampling and testing;
- generation of a certification report and issuance of a certificate.

* Leading materials science organization - An organization recognized by the authority governing the use of atomic energy (unless otherwise established by the legislation of the Russian Federation), which is competent to provide services to organizations in the field of its specialization in the selection and justification of the use of basic and welding materials, technologies for smelting and casting metal, processing of workpieces by pressure, welding, surfacing, heat treatment, non-destructive testing systems in the production, installation and operation of equipment, pipelines and other elements of nuclear power plants, for which requirements related to ensuring safety in the field of atomic energy use are established.



Certification commission

In accordance with the requirements of GOST R 50.04.01-2018

The certification commission, headed by the chairman of the commission, is formed by:
the Leading Materials Science Organization on the basis of the organization's administrative documents.

The certification commission must include at least three full-time employees of the Leading Materials Science Organization.

The certification commission may include representatives of:

- the applicant organization for material certification;
- developer of a new material;
- developer of the reactor installation (nuclear power plant) design, for the components of which it is planned to use the material;
- authority governing the use of atomic energy;
- operating organization;
- other interested organizations.



Certification testing program

In accordance with the requirements of GOST R 50.04.01-2018

The certification testing program is **developed** by the Leading Materials Science Organization.

The certification testing program is **approved** by the members and the chairman of the certification commission.

Certification tests of new materials are **carried out** in order to confirm the characteristics and properties of new materials, determine the possibility of their use in the manufacture of products, determine the quantitative characteristics of the properties of materials necessary for calculations when justifying the safety of products at all stages of their life cycle.

The types of tests included in the program are determined taking into account the risk of harm and the severity of the consequences if they are not ensured under operating conditions [(mechanical load, operation environment, operating pressure, design temperature, neutron irradiation (fluence, damaging dose, temperature, neutron energy)], as well as the established service life of the product.



Certification test program. Scope of tests

In accordance with the requirements of GOST R 50.04.06-2018

The certification test program usually includes the determination of the following characteristics of the material in the as-delivered and aged state:

- micro-structure;
- physical properties;
- mechanical properties;
- characteristics of resistance to brittle fracture;
- characteristics of cyclic strength;
- characteristics of long-term static strength, long-term ductility and creep;
- corrosion rate in operation environments.

The exact list of determined characteristics of the material is established by the Leading Materials Science Organization, depending on the expected operating conditions and design of the component, taking into account ensuring strength and reliability for the entire service life of this component.



1/3 Report on certification tests

In accordance with the requirements of Appendix 2 to NP-089-15 and GOST R 50.04.06-2018

The report on the results of certification tests of basic materials shall reflect the following aspects:

- standard chemical composition (indicating the content of harmful impurities);
- type and method of obtaining semi-finished products;
- documents on material standardization;
- comprehensive information about the test object;
- the value of the maximum temperature T_{max} up to which the material can be used;
- information about the operation environments in which the material can be used;
- values of neutron fluence and irradiation temperature up to which the use of the material is justified;
- strength and plastic characteristics of the material at break;
- physical properties of the material.

2/3 Report on certification tests



In accordance with the requirements of Appendix 2 to NP-089-15 and GOST R 50.04.06-2018

The report on the results of certification tests of welding (surfacing) materials shall reflect the following aspects:

- welding method;
- combination of welding (surfacing) and basic materials (by brand);
- typical chemical composition of the deposited metal (weld metal), indicating the limits of the content of elements and harmful impurities;
- the need and modes of preliminary and accompanying heating, as well as post-welding heat treatment of welded joints and deposited products;
- documents on standardization for welding (surfacing) materials;
- comprehensive information about the test object;
- Tmax value up to which it is allowed to use the material in welded joints and deposited products;
- information about operation environments in which it is allowed to use the material in welded joints and deposited products;
- values of neutron fluence and irradiation temperature up to which the use of the material in welded joints and deposited products is justified.



3/3 Report on certification tests

In accordance with the requirements of Appendix 2 to NP-089-15 and GOST R 50.04.06-2018

For the base metal and the metal of the heat-affected zone of welding (surfacing), the report shall provide quantitative values:

- characteristics of resistance to brittle fracture;
- characteristics of cyclic strength;
- characteristics of plasticity, creep and long-term strength;
- corrosion resistance characteristics.

For all materials, quantitative data shall be provided characterizing the change over time (during the service life of the NPP) of the calculated characteristics or confirmation of the absence of changes in the characteristics of the material as a result of exposure to:

- thermal aging;
- operation environment;
- neutron irradiation (for relevant components, if applicable).

Participation of the nuclear energy supervisory authority in the matters of materials use

in accordance with Article 16 of the Decree of the Government of the Russian Federation
No. 669 of July 12, 2016



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Rostekhnadzor exercises control over the materials used during the process of approving materials for inclusion in the Consolidated List.

Proposals to include a New Material in the Consolidated List or other changes thereto may be formed by design, engineering, materials science and other interested organizations.

According to the relevant standard, to be included in the Consolidated List, a New Material in addition to receiving approval from Rostekhnadzor, shall also be approved by other materials science organizations, the list of which is determined by Rosatom.

Rostekhnadzor approval can be obtained based on the results of consideration of the Report on the results of certification tests of a new material.

Ensuring the strength and specified service life of SNPP components



The material is applicable if the components, taking into account the selected materials, satisfy strength calculations in accordance with PNAE G-7-002-86* for their entire service life.

When calculating strength, the following materials are used:

Approved materials

- minimum guaranteed properties from Appendix 1 of PNAE G-7-002-86
- corrosion allowances in accordance with Table 4.1 PNAE G-7-002-86

New materials

- minimum properties of materials, taking into account the expected operating conditions and specified service life, given in the Certification Report for the relevant material;
- corrosion allowances for the specified service life, taking into account the corrosion rate given in the Certification Report for the relevant material.

* PNAE G-7-002-86 - Rules and regulations in the nuclear power industry. Standards for calculating the strength of equipment and pipelines of nuclear power plants.

Conclusion

The selection of material significantly depends on the design of specific components and their operating conditions (operation environment parameters and operating modes).

The selection of materials is made from the list of materials approved by Rostekhnadzor included in the Consolidated List.

The use of New Materials is permitted after receiving approval from Rostekhnadzor based on review of the New Material Certification Test Report.

The strength and reliability of components over their entire service life is ensured by calculations according to PNAE G-7-002-86 and the use of minimum guaranteed characteristics of materials confirmed by application experience and/or results of certification tests.

The principles and approaches in the Russian Federation to justify the use of materials for nuclear power plants are the same as those established by the documents of regulatory authorities of countries with developed nuclear infrastructure, for example - 10 CFR 50.55a, NRC Regulatory Guide 1.84.

**Thank you for
your attention!**

