Approved by
Order of the Federal Environmental, Industrial and Nuclear Supervision Service
No. \_\_\_ dated \_\_\_\_\_\_\_\_\_\_\_\_ 20\_\_

SAFETY GUIDE
IN THE USE OF ATOMIC ENERGY "ESTABLISHMENT AND MONITORING METHODS OF THE LIFE CHARACTERISTICS OF PUMPS FOR NUCLEAR POWER PLANTS"

(RB-133-17)

I. General

1. The safety guide in the use of atomic energy "Establishment and monitoring methods of the life of characteristics of pumps for nuclear power plants" (RB-133-17) (hereinafter referred to as the Safety Guide) has been developed in accordance with article 6 of the Federal law No. 170-FZ dated November 21, 1995 "On the use of atomic energy" for facilitating compliance with the requirements of the following Federal Rules and Regulationsfor the use of atomic energy: "Rules for design and safe operation of equipment and piping of nuclear power installations" (NP-089-15) approved by the order of the Federal Environmental, Industrial and Nuclear Supervision Service No. 521 dated December 17, 2015 (registered by the Ministry of Justice of the Russian Federation on February 9, 2106, registration No. 41010) (hereinafter No-089-15); "Requirements for life management of the equipment and piping of nuclear power plants. Principal provisions" (NP-096-15) approved by the Order of the Federal Environmental, Industrial and Nuclear Supervision Service No. 410 dated October 15, 2015 (registered by the Ministry of Justice of the Russian Federation on November 11, 2015, registration No. 39666) (hereinafter referred to as NP-096-15).

2. This Safety Guide contains the recommendations of the Federal Environmental, Industrial and Nuclear Supervision Service for the establishment and monitoring methods of the life characteristics of pumps for nuclear power plants during their design, engineering, and operation.

3. This Safety Guide applies to the casing and mechanical equipment of pumps and pump units of nuclear power plants included in the life management program according to the requirments of NP-096-15 <1>.

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<1> The establishment and methods of monitoring the life characteristics of electrical equipment of NPP pumps are regulated by the safety guide "Establishment and monitoring methods of life characteristics of electrical equipment of nuclear power plants".

4. This Safety Guide is not applicable to the thermal and mechanical equipment, reactor pressure vessel, pumps, valves of nuclear power plants.

6. This Safety Guide have been developed taking into account domestic and foreign experience in the life management of pumps for nuclear power plants.

6. The list of the abbreviations used in this Safety Guide is given in Appendix No. 1, and the terms and definitions are given in Appendix No. 2.

7. The suggested list of NPP equipment and piping included in the life management program and falling under this Safety Guide is given in Appendix No. 3. The operator may supplement the specified list by agreement with the developers of RP and NPP design developers.

II. Recommendations for establishing life characteristics

8. The life characteristics of NPP pumps is recommended to establish and justify either by the engineering (design) organization at the design stage or by the operator if at the engineering (design) stage these characteristics were not stipulated.

9. The suggested list of parameters based thereof the life characteristics of NPP pumps may be determined is given in Appendix No. 4 to this Safety Guide. It is recommended to determine the life characteristics required for life managements of the pumps is based on the parameters of the specified list or if the parameters given in it are not sufficient for determining the life characteristics, assign other parameters in addition.

10. The life characteristics of NPP pumps are determined as the maximum permissible values of the parameters given in Appendix No. 4 to this Safety Guide, the attainment thereof corresponds to the exhaustion of life according to the life assessment criteria (refer section IV of this Safety Guide).

11. The list of life characteristics of pumps, stipulated by the engineering (design) organization is recommended to justify, besides the following may serve as justification:

references to the operation and life management experience of similar pumps at the nuclear power plants;

results of trial operation of the prototypes having the maximum operating hours and operated in the worst-case for fluid parameters, external and internal impacts;

predictive pump degradation mechanisms <2>.

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<2> For new developments.

13. In cases when the life characteristics of pumps are stipulated by the operator, the list of life characteristics is recommended to agree with the organization that performed design engineering (designing) of the specified pump (excluding the cases when the design organizations ceased to exist or are foreign legal entities).

III. Recommendations for the establishment of life assessment criteria

13. The pump life assessment criteria are recommended to stipulate for each life characteristics from the those intended for this pump based on:

the requirements of the Federal Rules and Regulations in the field of atomic energy use;

requirements of the national or industry standards included in the consolidated list of documents on standardization in the field of atomic energy use, applied on a mandatory basis;

requirements of engineering design (design) documentation.

14. A suggested list of criteria for assessment of the NPP pump life is given in Appendix 5 to this Safety Guide. It is recommended to determine the life assessment criteria necessary for managing the life of pumps using the specified list. If it is necessary to use other criteria for life assessment that are not specified in Appendix No. 5 to this Safety Guide or additional sources for the determination of numerical values of life criteria, it is suggested that the engineering (design) organization provide justification for the need to use alternative criteria.

IV. Recommendations for monitoring methods of the life characteristics of pumps

16. The life characteristics of NPP pumps are recommended to monitor for all the pumps included in the life management program and for all piping, the life thereof is to be managed according to NP-096-15, for the purpose of periodic or continuous (using automated systems to monitor residual life) assessment of technical condition and identification of the dominant (determining) mechanisms of aging, degradation and damages of these pumps.

16. The pump engineering design organization (designer) is recommended to the give the life characteristics and monitoring methods of the life characteristics in the operation manual specifying the periodicity of replacement of the in-vessel components of the pump with entry of the list of replaced components in the pump datasheet.

17. The life characteristics of the NPP pumps at the operation stage are monitored in accordance with the equipment and piping life management Program, which is developed by the operator for each NPP power unit and agreed with the developers of NF and NPP designs.

18. It is recommended to confirm, support and if there is technical possibility restore the life of NPP pumps by M&R with periodicity determined in the equipment and piping life management Program. The life of pump housing is confirmed by individual calculations.

19. In the cases when the residual life of a pump has ended, the pump shall be replaced. On pump replacement the relevant changes including the required life characteristics monitoring actions of the newly installed pump are entered in the Life Management Program of equipment and piping.

20. The operator is recommended to determine the list of non-replaceable pumps, the life thereof must be provided before the decommissioning of the power unit, as well as the pumps engaged during decommissioning of the NPP, the life must be ensured for the decommissioning period.

21. The required condition for performing life characteristics monitoring procedures subject to life management of NPP pumps is the monitoring of the actual operation conditions of these pumps, for which purpose it is recommended to monitor (by direct measurements or using indirect calculation assessment) the following parameters:

housing wall temperature;

temperature of coolant or other fluid;

number of cycles of heating and cooling down;

heating or cooldown rate and maximum values of these characteristics in the operation process;

pressure and rate of increase or drop of pressure of coolant or fluid;s

vibration characteristics (it is recommended to include the measurement periodicity of the measurement of vibration characteristics in the life management program);

coolant or fluid flow rate;

number of loading cycles.

22. In addition to the parameters given in the paragraph 21 it is recommended to record and account the operation time of pumps in one or other mode, and account the actual number of implementations of one or other mode of operation, including hydraulic (pneumatic) tests of pumps for strength and density taking account of the factory tests.

23. The parameters given in the paragraph 21 to this Safety Guide is recommended to monitor either by direct methods (regular or periodic measurement in the operation process), or by indirect methods (through recalculation, extrapolation or interpolation).

24. If it is impossible to directly or indirectly monitor the parameters given in paragraph 21 to this Safety Guide, it is recommended to stipulate the procedure for retrofitting the pumps of the NPP with the systems and/or methods to monitor necessary parameters from the above list.

25. The recommended methods for pump life characteristics monitoring using the parameters given in the paragraph 21 to this Safety Guide are specified in Appendix No. 6.

V. Recommendations for the collection, systematization and storage of data on pumps of nuclear power plants

26. For NPPs under construction and design, it is recommended that the operator organizes and adjusts the system of collection, processing, systematization, analysis and storage of information on damages of pumps, their accumulation and development, ageing mechanisms, failures and malfunctioning (considering startup and commissioning), as well as on operation modes, including transient modes, hydraulic (pneumatic) tests and emergency situations before commissioning a NPP power unit.

27. The specified information is recommended to store for the entire life of pump as a computer database allowing immediately get all the required parameters for assessment of the residual life of the pump if required.

28. The following parameters are entered in the specified DB for each pump type, the life thereof is subject to management:

all nominal data for the pump in compliance with the requirements of NP-089-15;

data of manufacturers of NPP pumps and adjustment organizations on deviations or no deviations from the engineering (design) documentation for the NPP pumps and their manufacturing technologies, as well as data on repairs, heat treatments, additional tests;

information about deviations or no deviations from the engineering (design) documentation for NPP pumps during their storage, reconservation, shipment and handling operations;

technical characteristics of deviations (if any) during manufacture, storage, transportation, installation of pumps and during commissioning works;

data on the monitoring of actual operation conditions of pumps given in paragraph 21 of this Safety Guide;

data on damages of pumps (or metal of pumps), their accumulation and development, ageing mechanisms, failures and malfunctioning.

29. It is recommended to develop mathematical tool and software of the database so as to compare the initial and actual values of life characteristics of pumps at any stage of the life cycle of an NPP power unit, and to analyze information about the operating conditions of NPP pumps and impact of these conditions on the life.

30. DB is recommended to store using current data storage devices with mandatory duplication of information as backup copies allowing restoration of the full scope of information if lost or damaged. It is recommended to use information storage media not having link to the public access networks during storage of DB copies.

31. It is recommended for the operator to make a scheduled plan for development and commissioning of a computer database for the NPP in the operation stage.

Appendix No. 1
to the safety guide in the use of atomic energy "Establishment and monitoring methods of the life of pumps for nuclear power plants", approved by the order of the Federal Environmental, Industrial and Nuclear Supervision Service No. \_\_\_\_\_
dated \_\_\_\_ \_\_\_\_\_\_\_\_\_\_ 20\_\_

ABBREVIATIONS

The following abbreviations are used on this Safety Guide:

|  |  |  |
| --- | --- | --- |
| NPP | - | Nuclear Power Plant |
| NPF | - | Nuclear Power generating Facility |
| FNR | - | Sodium Cooled Fast Neutron Reactor |
| VVER | - | Water cooled, water moderated power reactor |
| AFEP | - | Auxiliary feedwater electric pump |
| RCP | - | Reactor coolant pump |
| RFCC | - | Repeated Forced Circulation (Coolant) Circuit |
| CEP | - | Condensate Electric Pump |
| RBMK | - | High Power Channel Type Reactor |
| RP | - | Reactor Plant |
| RLAMS | - | Residual lifetime automated monitoring system |
| CPS | - | Control and protection system |
| M&R | - | Maintenance and Repair |
| TFP | - | Turbine feed pump |
| EGP-6 | - | Heterogeneous Loop Type Power Reactor with 6 Coolant Circulation Loops |

Appendix No. 2
to the safety guide in the use of atomic energy "Establishment and monitoring methods of the life characteristics of pumps of nuclear power plants", approved by the Federal Environmental, Industrial and Nuclear Supervision Service order No. \_\_\_\_\_\_\_
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TERMS AND DEFINITIONS

The following terms and definitions are used in this Safety Guide:

1. The dominant mechanism of ageing, degradation, damages of pumps is one of several mechanisms of ageing, degradation, and damages to pump elements that leads to their fastest life depletion.

2. Cavitation margin is the excess of specific energy of fluid at the pump input over the energy corresponding to the pressure of saturated fluid vapors at pumping temperature.

3. Same=type pumps are pumps represented in the RP or NPP design as a minimum in several units (for example, RCP, high-pressure emergency spray pumps).

Appendix No. 3
to the safety guide in the use of atomic energy "Establishment and monitoring methods of the life of pumps for nuclear power plants", approved by the order of the Federal Environmental, Industrial and Nuclear Supervision Service No. \_\_\_\_\_
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SUGGESTED LIST
OF THE SAME TYPE PUMPS OF NPP INCLUDED IN THE LIFE MANAGEMENT PROGRAM

1. Pumps of NPP with VVER reactors included in the life management program:

RCP;

AFEP;

Stage I and I CEP;

High-pressure safety injection pump;

Low pressure safety injection pump;

Make-up pumps;

Boron control pumps;

Emergency boron injection pumps;

Emergency feedwater pumps;

Feed electric pump (for VVER-1200);

Spray pumps;

TFP.

2. NPP pumps w with RBMK reactors included in the life management program:

RCP.

3. NPP pumps with fast neutron reactors included in the life management program:

Primary circuit RCP;

Secondary circuit RCP;

Electromagnetic pumps.

4. NPP pumps with EGP-6 reactors included in the life management program:

Feedwater electric pump;

CPS channels cooling circuit pumps;

Emergency feedwater injection pumps;

Condensate pumps.

Appendix No. 4
to the safety guide in the use of atomic energy "Establishment and monitoring methods of the life of pumps for nuclear power plants", approved by the order of the Federal Environmental, Industrial and Nuclear Supervision Service No. \_\_\_\_\_
dated \_\_\_\_ \_\_\_\_\_\_\_\_\_\_ 20\_\_

SUGGESTED LIST OF
PARAMETERS BASED THEREOF THE LIFE CHARACTERISTICS OF NPP PUMPS MAY BE DETERMINED

1. Operation time.

2. Total wall thickness of the pump housing and other components.

3. In-situ wall thickness of the housing or other pump components.

4. Accumulated value of pump component metal fatigue during cyclic-repeated loads.

5. Offset of ductile to brittle transition temperature of metal of welded joints and basic metal of pump housing following temperature ageing and cyclic metal fatigue <1>.

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<1> The specified parameter is used only in the cases when the calculation of pump housing for brittle fracture resistance is mandatory.

6. Accumulated value of plastic deformations of the pump components.

7. Accumulated value of creep deformations of the pump component

8. Changes of the pump component dimensions or form following elastic and inelastic deformations.

9. Mechanical characteristics of structural materials of non-replaceable and replaceable pump components.

10. Quality change of pump component metal structure leading to appearance of new mechanisms of its degradation and accelerated end of life.

11. Maximum deviation of pump head from the value stipulated in the design engineering documentation.

12. Maximum deviation of pump injection from the value stipulated in the design engineering documentation.

13. Irreversible changes of the pump process parameters following depositions, wear or chafing, change of pump geometric dimensions or form.

14. Pump vibration characteristics.

15. Cavitation margin.

Appendix No. 5
to the safety guide in the use of atomic energy "Establishment and monitoring methods of the life of pumps for nuclear power plants", approved by the order of the Federal Environmental, Industrial and Nuclear Supervision Service No. \_\_\_\_\_
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SUGGESTED LIST OF
NPP PUMP LIFE ASSESSMENT CRITERIA

|  |  |  |  |
| --- | --- | --- | --- |
| S. No. | Parameter | Life assessment criteria | Note |
| 1. | Operation time | Limit value set in the design engineering documentation | It is recommended to enter in the data sheet and maintain record with entering of information in the data sheet. |
| 2. | Total wall thickness of the pump housing or other components | Minimum value for which the requirements of calculation for section of the basic dimensions regulated by the Federal Rules and Regulations for atomic energy use stipulating the norms of strength calculation of nuclear power generating facility equipment and piping <1>. | It is recommended to enter in the datasheet and monitor with entry of information in the datasheet (following the monitoring results in accordance with the Life management Program) |
| 3. | In-situ wall thickness of the pump housing or other components. | Limit value for which the strength conditions during verification analysis for mechanical strength,given in the Federal Rules and Regulations for atomic energy use establishing the norms of strength calculation of nuclear power generating facility equipment and piping <1> | It is recommended to enter in the datasheet and monitor with entry of information in the datasheet (following the monitoring results in accordance with the Life management Program) |
| 4. | Accumulated value of pump component metal fatigue during cyclic-repeated loads | Limit value given in the Federal Rules and Regulations in the field of atomic energy use establishing the norms of strength calculation of nuclear power generating facility equipment and piping <1> |  |
| 5. | Offset of ductile to brittle transition temperature of metal of welded joints and basic metal of pump housing following temperature ageing and cyclic metal fatigue <1>. | Limit value for which the strength conditions during brittle fracture resistance calculation given in the Federal Rules and Regulations for atomic energy use establishing the norms of strength calculation of nuclear power generating facility equipment and piping <1> |  |
| 6. | Accumulated value of plastic deformations of the pump components | Limit value for structural material set in the national or industry standards, included in the consolidated list of mandatory standardization documents in the field of atomic energy use |  |
| 7. | Accumulated value of plastic deformations of the pump components | Limit value for structural material set in the national or industry standards, included in the consolidated list of mandatory standardization documents in the field of atomic energy use |  |
| 8. | Changes of the pump component dimensions or form following elastic and inelastic deformations | Limit value set in the engineering (design) documentation |  |
| 9. | Mechanical characteristics of structural materials of non-replaceable and replaceable pump components | Limit values for engineering materials stipulated in the national or industry standards included in the consolidated list of mandatory standardization documents in the field of atomic energy use |  |
| 10. | Quality change of pump component metal structure leading to appearance of new mechanisms of its degradation and accelerated end of life | Set by the operator following in-service inspection of metal by agreement with the engineering organization (if any) and specialized material organization | It is recommended to enter in the data sheet (following monitoring in accordance with the Life Management Program) |
| 11. | Maximum deviation of pump injection from the value stipulated in the design engineering documentation | Stipulated in the engineering design documentation for the pump |  |
| 12. | Maximum deviation of pump injection from the value stipulated in the design engineering documentation | Stipulated in the engineering design documentation for the pump |  |
| 13. | Irreversible changes of the pump process parameters following depositions, wear or chafing, change of geometric dimensions or form | Limit values stipulated in the engineering design documentation for the pump |  |
| 14. | Pump vibration characteristics | Inadmissible frequencies or amplitude of vibrations of the pump or its components leading to non-compliances with the strength conditions of the pump, its components or associated piping.Determined from the strength conditions given in the Federal Rules and Regulations in the field of atomic energy use establishing the norms of strength calculation of nuclear power generating facility equipment and piping <1> |  |
| 15. | Cavitation margin | Limit value set in the design engineering documentation for the pump |  |
| 16. | State of replaced components | Limit value set in the design engineering documentation | It is recommended to enter the list of replaced components, periodicity of in-vessel components in the data sheet.It is recommended to maintain a record |

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<1> For the components not falling under the Federal Rules and Regulations for atomic energy use, the strength calculation is made in accordance with the current development level of science and technology.

Appendix No. 6
to the safety guide in the use of atomic energy "Establishment and monitoring methods of the life of pumps for nuclear power plants", approved by the order of the Federal Environmental, Industrial and Nuclear Supervision Service No. \_\_\_\_\_
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RECOMMENDED MONITORING
METHODS OF PUMP LIFE CHARACTERISTICS

|  |  |  |
| --- | --- | --- |
| S. No. | Life characteristic | Recommended monitoring methods |
| 1. | Total wall thickness of the pump housing or other components | Ultrasonic wall thickness test; Visual and measuring control |
| 2. | In-situ wall thickness of the pump housing or other components. | Ultrasonic wall thickness test; Visual and measuring control |
| 3. | Accumulated value of pump component metal fatigue during cyclic-repeated loads | Calculation or automatic method (on use of AMRLS) |
| 4. | Offset of ductile to brittle transition temperature of metal of welded joints and basic metal of pump housing following temperature ageing and cyclic metal fatigue <1>. | Calculation or experiment (following tests of metal samples) |
| 5. | Accumulated value of plastic deformations of the pump components | Calculation or measurement |
| 6. | Accumulated value of plastic deformations of the pump components | Calculation or measurement |
| 7. | Changes of the pump component dimensions or form following elastic and inelastic deformations | Calculation or measurement |
| 8. | Mechanical characteristics of structural materials of non-replaceable and replaceable pump components | Measurements (direct or indirect methods), tests and/or study on metal samples |
| 10. | Quality change of pump component metal structure leading to appearance of new mechanisms of its degradation and accelerated end of life | Examination of metal samples |
| 11. | Maximum value of external leakage established in the design engineering documentation | Measurements (direct or indirect methods) in the operation process or during examinations |
| 12. | Maximum deviation of pump injection from the value stipulated in the design engineering documentation | Estimate |
| 13. | Maximum deviation of pump injection from the value stipulated in the design engineering documentation | Estimate |
| 15. | Irreversible changes of the pump process parameters following depositions, wear or chafing, change of geometric dimensions or form | Calculation or measurement |
| 16. | Pump vibration characteristics | Calculation or measurement |
| 17. | Cavitation margin | Estimate |

Note.

It is recommended to apply the methods, which are included in the norms and rules in atomic energy use, national standards (preliminary national standards), safety guides, metal control procedures, vibration characteristics control procedure for control and monitoring the life characteristics.