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|  | APPROVED BYThe Order of Federal Environmental, Industrial and Nuclear Supervision Service\_\_\_\_\_\_\_\_\_\_ 20\_\_ No. \_\_\_\_ |

**Safety Guide**

**in the Use of Atomic Energy**

**“Emergency Monitoring Systems for Nuclear Power Plants with** W**ater-moderated Water-cooled Power Reactors. General Recommendations and Range of Monitored Parameters”**

**(RB-140-17)**

**I. General**

1. This Safety Guide in the use of atomic energy “Emergency Monitoring Systems for Nuclear Power Plants with Water-moderated Water-cooled Power Reactors. General Recommendations and Range of Monitored Parameters” (RB-140-17) (hereinafter – Safety Guide) has been developed in accordance with Article 6 of the Federal Law of 21 November 1995 No. 170-FZ "On the Use of Atomic Energy" and in order to ensure the compliance with the requirements of clause 3.1.5 of the federal codes and rules in the field of the use of atomic energy "General Provisions for Ensuring the Safety of Nuclear Power Plants" (NP-001-15), approved by the order of Federal Environmental, Industrial and Nuclear Supervision Service of 17 December 2015 No. 522 (the order was registered by the Ministry of Justice of Russia on 2 February 2016, Reg. No. 40939), requirements of paras 45, 45, 46, 46, 47, 47, 48 and 49 of the federal codes and rules in the field of the use of atomic energy "Requirements for Control Systems Important for Safety of Nuclear Power Plants" (NP-026-16), approved by the order of Federal Environmental, Industrial and Nuclear Supervision Service of 16 November 2016 No. 483 (the order of the Ministry of Justice of Russia of 14 December 2016, Reg. No. 44712 ), regarding the emergency monitoring of the parameters of nuclear power plants when managing beyond design basis accidents.

2. This Safety Guide contains general recommendations of Federal Environmental, Industrial and Nuclear Supervision Service to emergency monitoring systems that are applicable to the design and operation of the systems performing emergency monitoring at nuclear power plants with water-moderated water-cooled power reactors, and when analyzing and evaluating the safety of the adopted design solutions. In addition, this Safety Guide provides guidance on the range of controlled emergency monitoring parameters required for assessment of the state of a reactor, a unit of a nuclear plant and a nuclear plant as a whole when managing beyond design basis accidents.

3. This Safety Guide is intended for use by the operating organizations of nuclear plants and the organizations that perform and provide services to the operating organizations of nuclear plants in the development and design of emergency monitoring systems, and also for use by Rostechnadzor specialists when they implement licensing (authorization) activities or federal state supervision in the field of the use of atomic energy.

4. The recommendations in this Safety Guide take into account the accumulated international experience in the development of emergency monitoring requirements for accident management, in particular the IAEA recommendations as well as lessons learnt from the experience of management of beyond design basis accidents.

5. The requirements of the federal codes and rules in the field of the use of atomic energy can be met using other ways (methods) than those contained in this Safety Guide, when the chosen ways (methods) for ensuring safety are justified.

6. A list of abbreviations used in this Safety Guide is given in Appendix 1, terms and definitions in Appendix 2.

**II. General Recommendation for implementation of Emergency Monitoring**

7. In an NPP design, it is recommended to provide emergency monitoring systems needed to monitor the state of NRs and NPPs under conditions of beyond design basis accidents, including severe ones. It is recommended that the amount of control of the parameters of the state of an NR and an NPP, set in the design, take into account the recommendations of this Safety Guide and be sufficient for monitoring of the state of an NR and an NPP in the conditions of a BDBA. Instructions and manuals specifying the actions of personnel to manage BDBAs should be developed taking into account the design of the emergency monitoring system of each specific NPP unit.

8. It is recommended to display the parameters of NRs and NPPs controlled by the emergency monitoring system during the entire period of an accident and in the post-accident period until the NPP unit is brought into a controlled safe state. The composition of the parameters controlled at different stages of accidents is recommended to be justified in the NPP design and to be presented to the NPP SAR. It is recommended to ensure that the monitored parameters are displayed in the UCR, ECR and PERCP.

9. It is recommended to provide emergency monitoring system for all NPP units designed, constructed and in service. It is recommended to design the emergency monitoring system as an independent system of the normal operation control systems and safety control systems.

10. It is recommended to set a range of controlled parameters of emergency monitoring in the NR and NPP design, taking into account specific features of the design for each particular power unit. The structure of special technical means of emergency monitoring and their characteristics, such as the range and accuracy of measurements, speed, necessary duration of operation, resistance to external factors, redundancy, reliability, independence and separation, testability (maintainability), protection against unauthorized access, maintenance and repair procedure should be justified and set in the NPP design documentation of the AU (hereinafter − NPP design) and presented in the NPP SAR.

11. It is recommended that the classification of special technical emergency monitoring equipment be carried out in accordance with the requirements of FCR and presented in the NPP SAR.

12. When determining the composition of special emergency monitoring equipment, it is recommended to take into account internal and external effects that may complicate the obtaining of information about the state of NRs and NPPs under BDBA, including emergency scenarios with long-term loss of power supply, loss of communication with the UCR and ECR, disruption of communication with the external infrastructure, and loss of resistance to external factors.

13. When determining the range of controlled parameters of emergency monitoring for a multi-unit NPP, it is recommended to take into account the possibility of occurrence of a beyond design basis accident, including a severe one, simultaneously at all NPP units.

14. It is recommended to choose special technical means of emergency monitoring taking into account the environmental conditions arising from accidents (for example, seismic impacts, air shock wave, ionizing radiation, temperature, humidity).

15. It is recommended to provide means of protection of the special technical means of the emergency monitoring system, including software, from unauthorized interference in operation.

16. It is allowed to use special technical means of the emergency monitoring system as an indicator of the presence or absence of a physical quantity. As special technical means of emergency monitoring, it is allowed to use the measuring channels of the normal operation control systems and safety control systems. The admissibility of the use of the normal operation control systems and safety control systems as special technical means of emergency monitoring should be substantiated in the NPP design and presented in the NPP SAR.

17. It is recommended to provide a self-diagnostic function for the special emergency monitoring equipment.

18. The power supply of the special emergency monitoring equipment should be performed in such a way that it remains operable during the time justified in the NPP design in the event of failure of the normal operation power supply sources, as well as the emergency power supply sources of the second group of the emergency power supply system.

19. Emergency monitoring for each of the controlled parameters should be carried out with several channels ensuring, if possible, their compliance with the principle of independence. Information from the emergency monitoring system is registered and stored in stand-alone means of information registration and storage.

20. When determining the range of controlled parameters, it is recommended to take into account all locations of nuclear fuel in an NPP such as the reactor, the spent fuel storage pool, nuclear fuel storage facilities, and the places where nuclear fuel is located when it is transported (FAs and SFAs).

21. It is recommended to take into account the mutual relationship between the BDBAMM and the composition of parameters of the emergency monitoring system, namely:

the BDBAMM is developed in accordance with the current state of an NPP (NPP unit) in terms of the composition and characteristics of the technical means of emergency monitoring;

for the introduction of a new BDBAMM in an operating NPP (NPP unit), a simultaneous modification of the design of the emergency monitoring system may be required.

**III. Recommendations for the Range of Emergency Monitoring Parameters**

22. When establishing the range of parameters and characteristics of special technical means of emergency monitoring, it is recommended to proceed from the fact that emergency monitoring should ensure that the personnel managing BDBAs are provided with information needed to:

a) determine the state of the basic safety functions, such as:

 emergency shutdown of the reactor and its maintenance in a subcritical state;

 emergency heat removal from the reactor (heat removal from the reactor core, as well as from the fuel elements located in the storage facilities and other places);

 retention of radioactive substances within the established boundaries and restriction of the release of radioactive substances into the environment (including ensuring the integrity of the containment);

 b) carry out the actions envisaged by the BDBAMM.

23. The range of parameters should be determined taking into account the need to identify the controlled parameters required to:

obtain information about a potential threat or actual violation of the integrity of physical barriers on the way of release of radioactive substances;

obtain information about the state of the safety systems and technical means for BDBA management;

estimate the amount of radioactive substances.

24. An approximate list of emergency monitoring parameters is given in Appendix 3 to this Safety Guide. The final list of parameters of emergency monitoring should be justified and established in the NPP design and presented in the NPP SAR.

25. As part of the special technical means of emergency monitoring, it is recommended to determine the minimum required set of technical devices that keep the working capacity, if a BDBA has passed into a severe stage. A complete list of parameters for monitoring in severe accident conditions is developed in the NPP design in accordance with the severe accident management strategy. In case of a severe BDBA, it is recommended to provide emergency monitoring of at least the following parameters:

temperature of the coolant at the outlet from the FAs;

pressure in the reactor vessel;

temperature of the bottom of the reactor vessel;

level and temperature of the coolant in the spent fuel pool;

pressure, humidity and temperature of the medium in the atmosphere inside the containment;

composition of explosive mixtures (hydrogen, carbon monoxide) in the atmosphere inside the containment;

 dose rate of gamma radiation inside the containment.

 For VVER NRs equipped with a molten core catcher, it is recommended to monitor the parameters characterizing the state of the MCC.

26. For additional information about the state of a NR and an NPP as a whole, in order to assess the potential threat of environmental contamination under a BDBA, it is recommended to use special technical means of the emergency and post-emergency sampling system, including means of emergency sampling of the reactor coolant, of the spent fuel pool and samples of the vapor-gas medium from the atmosphere under the containment in emergency conditions. Sampling provides early determination of the activity of radionuclides present in a sample, as well as monitoring of the following indicators:

concentration of hydrogen and oxygen in the premises inside the containment;

concentration of boric acid in the coolant, spent fuel and refueling pool, and ECCS tanks;

pH values of the water accumulated at the lower elevations of the sealed premises of a NR (water collectors and emergency sumps);

concentration of radionuclides of iodine, radioactive noble gases and aerosols inside the containment.

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|  | APPENDIX 1to Safety Guide in the Use of Atomic Energy “Emergency Monitoring Systems for Nuclear Power Plants with Water-moderated Water-cooled Power Reactors. General Recommendations and Range of Monitored Parameters” approved by the Order of Federal Environmental, Industrial and Nuclear Supervision Service of \_\_\_\_\_\_\_\_\_\_\_\_ 20\_\_ No. \_\_\_\_\_ |

# List of Abbreviations

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| --- | --- |
| BDBA | * beyond design basis accident
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| BDBAMM | * beyond design basis accident management manual
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| ECCR | * emergency core cooling system
 |
| ECR | * emergency control room
 |
| FA | * fuel assembly
 |
| FCR | * Federal codes and rules in the field of the use of atomic energy
 |
| FE | * fuel assembly
 |
| IFA | * irradiated fuel assembly
 |
| MCC | * molten core catcher
 |
| NPP | * nuclear power plant
 |
| NPP SAR | * NNP unit safety analysis report
 |
| NR | * nuclear reactor
 |
| PERCP | * protected emergency response control post
 |
| PHRS | * passive heat removal system
 |
| SG | * steam generator
 |
| UCR | * unit control room
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| VVER | * (type of) water-moderated water-cooled power reactor
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|  | APPENDIX 2to Safety Guide in the Use of Atomic Energy “Emergency Monitoring Systems for Nuclear Power Plants with Water-moderated Water-cooled Power Reactors. General Recommendations and Range of Monitored Parameters” approved by the Order of Federal Environmental, Industrial and Nuclear Supervision Service of \_\_\_\_\_\_\_\_\_\_\_\_ 20\_\_ No. \_\_\_\_\_ |

# Terms and Definitions

This Safety Guides uses terms and definitions as follows.

**Controlled safety condition of the nuclear power plant** − a state of an NPP maintained for an unlimited time, at which the main safety functions of the NPP established by General Provisions for the Safety of Nuclear Power Plants are ensured.

**Monitoring** – acquisition, display, registration, storage and analysis of the parameters of a NR and an NPP, directly or indirectly characterizing the safety status of the NR and the NPP.

**Emergency monitoring system** – a set of special technical means designed to monitor the state of an NR and an NPP under BDBAs.

**Special technical means for management of beyond design basis accidents** − control systems (components) provided in the NPP design for management of beyond design basis accidents.

**Severe accident** – a BDBA with damage of fuel elements above the design limit.

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|  | APPENDIX 3to Safety Guide in the Use of Atomic Energy “Emergency Monitoring Systems for Nuclear Power Plants with Water-moderated Water-cooled Power Reactors. General Recommendations and Range of Monitored Parameters” approved by the Order of Federal Environmental, Industrial and Nuclear Supervision Service of \_\_\_\_\_\_\_\_\_\_\_\_ 20\_\_ No. \_\_\_\_\_ |

**Exemplary List of Emergency Monitoring Parameters**[[1]](#footnote-1)

1. Neutron power and reactor period.
2. Temperature of the coolant at the outlet from the fuel assemblies.
3. Water level in the reactor.
4. Temperature of the coolant in the "hot" legs of the main coolant pipeline.
5. Pressure in the reactor vessel (above the core).
6. Water level in the volume compensator.
7. Temperature of the bottom of the reactor vessel.
8. Concentration of boric acid in the coolant of the primary circuit in the reactor.
9. Levels of boiler water in steam generators.
10. Steam pressure in the steam lines of the steam generators.

11. Water level in the spent fuel pool.
12. Water temperature in the spent fuel pool.
13. Activity of the primary coolant.
14. Activity and concentration of boric acid in the pool water.
15. Water level in the containment sump (sump tank).
16. Level of boric acid solution in the ECCS accumulators, accumulators of the second (third) stage.
17. Pressure in the ECCS accumulators, accumulators of the second (third) stage.
18. Levels of boric acid solution in ECCS tanks.
19. Dose rate inside the containment.
20. Pressure inside the containment.

21. Flow rate of solution of the spray system.
22. Concentration of hydrogen inside the containment.
23. Concentration of oxygen and water vapor inside the containment.
24. Temperature of the atmosphere inside the containment.
25. Water level in the MCC shaft.

26. Water levels in the tanks used to supply emergency feed water to the steam generators.
27. Water level in the PHRS[[2]](#footnote-2) tanks (for the PHRS using water).
28. Flow rate of service water from responsible consumers.
29. Flow rate in the systems of the auxiliary coolant circuits related to safety systems.
30. Radiation parameters (dose rate inside the containment, in the auxiliary building of the reactor building, others).

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1. The list of emergency monitoring parameters is established in the NR and NPP design, taking into account the specifics of each concrete power unit and concrete lists of BDBA scenarios. [↑](#footnote-ref-1)
2. The list of emergency monitoring parameters has been compiled for the operating and newly designed NPPs. It should be taken into account that not all parameters of the newly designed NPPs are applicable for the operating ones. [↑](#footnote-ref-2)