Approved by   
Order of the Federal Environmental, Industrial and Nuclear Supervision Service  
No. 228 dated May 6, 2011

PROVISION   
FOR THE TOPIC "NEUTRONIC CALCULATIONS" VERIFICATION AND SOFTWARE EXAMINATION

(RB-061-11)

I. General

1. The Provision for the topic "Neutronic calculations" verification and software examination (hereinafter - the Provision) is reckoned among safety guides, serves as guidelines and represents no law or regulation.

2. This Provision contains the recommendations of the Federal Environmental, Industrial and Nuclear Supervision Service (hereinafter Rostechnadzor) for verification and review of the Core Neutronic Computation Codes (hereinafter SW) used on justification and/or safety assurance of the nuclear facilities (hereinafter NF), including the recommendations for development and review of individual sections of the report on verification and justification of SW (hereinafter SW verification report) and for development of appendix to the SW qualification datasheet.

3. The terms and definitions used in this document are given in Appendix No. 1 to the Provision and are recommended for use in the SW verification report and documents on SW review of the Core Neutronic Computation Codes.

II. Organization of software verification and review

4. The results of verification performed by the SW applicant are embodied in the SW verification report. The SW verification report should be performed in accordance with the stipulated recommendations to the scope and content of the SW verification report used during safety justification of the NF. The SW verification report is developed in such manner so that it contained all the sections provided for by these recommendations. If the authors of the SW verification report do not include the material on any section, the relevant explanation is recommended to given under the number of this section. The form of the list of contents of the SW verification report is given in Appendix No. 2 to this Provision.

5. Basic conclusions of the SW verification report are presented by the SW applicant in the draft of the SW qualification data sheet an appendices to it. The form of appendix to qualification datasheet is given in Appendix No. 3 to this Provision.

6. The procedure of SW review of the Core Neutronic Computation Codes is determined by the work regulation of the expert council for qualification of SW under Rostechnadzor (hereinafter the Council), work regulation of the Council section of the Core Neutronic Computation Codes (hereinafter section No. 1) and the regulations of other sections, if the SW undergoes qualification for several sections of the Council.

7. The review results are available in the following materials:

1) expert conclusions of individual experts appointed by the section No. 1;

2) replies of the developers of SW verification report for the comments of experts;

3) minutes of the meetings of experts with the representatives of the developers of the SW verification report;

4) joint expert conclusions of several experts (as a rule represented after the meeting of experts with the representatives of the developers of SW verification report);

5) minutes (extracts from the minutes) of the meetings of section N 1;

6) exception reports of the members of the section No. 1;

7) minutes (extracts from the minutes) of the Council meetings.

If the SW is reviewed at several Council sections, the materials of sub-items a), e) and f) are supplemented respectively by the conclusions of experts appointed by the other sections, extracts from the minutes of other sections and exception reports of the members of other sections. The SW review materials are documented in the form of an individual document and provided to the Council and the SW applicant.

III. Recommendations for methodology of software verification

8. The general recommendations on the SW verification methodology used in various fields of the neutron and physical calculations are given in this section. Additional recommendations on verification methodology of SW designated for calculation of the space energy distribution of neutrons and gamma-ray radiation, SW-imitators of reactor core operation, neutron and physical parts of the joint non-stationary full scale neutron-physical and thermo-hydraulic calculation of the breach of normal operating conditions and accidents are presented in the sections IV, V, VI and VII of this Provision.

9. The SW verification methodology shall be presented in the section "Purpose and scope of SW" of the SW verification report. The methodology includes the methods of determining all the parameters and their accuracies listed in the item 2.6 of the appendix to the SW qualification datasheet. The parameters and methods of determining their accuracies in the form of table or group of table shall be presented in the section "Verification matrix" of SW verification report. It is recommended to include in item 2.1 of the appendix to the qualification datasheet "Purpose and scope of SW application" only those parameters, the accuracy thereof are determined in the item 2.6 of the appendix to the qualification data sheet.

10. The calculation accuracies of all the quantities included in the item 2.6 of the appendix to the SW qualification data sheet shall be determined and justified in the section "Results of verification and justification" of the SW verification report. The determination of accuracy concept accepted by the developer of the SW verification report shall be given in this section, as well as in the item 2.6 of the appendix to the SW certification passport.

11. The deviations of the calculated parameter from the measured quantity, collection of measured quantities (subject to primary processing) and values calculated under a different (qualified) SW shall be used as the calculation measure of error. The accuracy value may be the result of processing the deviations of the calculated quantities from the compared in conformance with the algorithms defined by the developer of SW verification report (for example, algorithms of mathematical statistics etc.) and may be characterized by the parameters accepted in this respect (for example, root mean square deviation, confidence probability, confidence interval etc.). The accuracy of the quantity with which comparison is made shall be considered on determination of the accuracy.

12. The methodological and stuck components of SW accuracy shall be assessed. These accuracy components may be assessed both together as well as individually.

13. The methodological accuracy components related to the applied approximation when resolving the transfer equation is recommended to determine using the verified SW itself, i.e. by increasing the approximation order of the transfer equation using the agreed stuck assurance.

14. The methodological accuracy component of the numerical implementation of the transfer equation is recommended to determine by using the verification SW itself (for example, by increasing the number of space points, energy groups).

15. The assessment of the methodological and stuck accuracy component for engineering SW (item 23 of this Provision) shall be made by comparing the results of calculations with the relevant results obtained for reference SW (item 22 of this Provision).

16. The correspondence of the calculated and measured quantities shall be established when assessing the error of calculation results by the comparison with the measured quantities and use the design-basis simulation of the measurements. The link between the outright measured quantities and derivative quantities from them, which are used for comparison with the calculation results, is described in the design-basis simulation process of the measurements.

17. The accuracy of measured quantities shall be set and considered on accuracy assessment by comparing the calculation quantities with the measured quantities. Information on the accuracy of measured quantities and methods of its determination is given in the section "Description of experimental facilities and presentation of experimental data" of verification report of SW. The definition and accuracy value of the calculation of the same parameters for the earlier qualified SW shall be compared during SW verification and review. For this purpose it is recommended to use the data based for SW qualification data sheets as the official source of the Federal Budgetary Institution "Research and Development Center for nuclear and radiation safety" (hereinafter FBU NTTs YaRB).

18. When using statistical processing for accuracy assessment it is recommended in the section "Results of verification and justification" of SW verification report the legitimacy of statistical processing is to be justified and the choice of statistical distribution is to be justified by the justified approaches accepted for this purpose (for example, accepted in mathematical statistics).

19. The justification of its applicability and confidence factor, confidence interval, significance level and other characteristics shall be given when using the normal distribution for accuracy assessment.

IV. Verification and review of software designed for calculation of space energy distribution of neutrons and gamma-ray radiation

20. The solution of the linear equation of transfer in different approximations shall be implemented as a rule in the SW calculation of space-energy distribution of neutrons and gamma radiation.

21. On verification and review of these SW it is recommended to establish for what type of calculations this SW is designed for:

1) Neutron-physical calculations of the unit or fragment of the nuclear reactor core for preparation of the few-group constants (grid coefficients) for SW-imitators of the reactor and neutron and physical modules of dynamic SW;

2) neutron-physical calculations of the reactor fragment or reactor overall for development of design tests for SW-imitators of the reactor and SW neutron and physical calculation being independent modules of dynamic SW;

3) neutron flow density distribution calculations in the nuclear reactor fragment of nuclear reactor overall for determining individual characteristics such as effects and reactivity coefficients, efficiency of the control rods etc.;

4) calculations of neutron flow density and gamma-ray radiation for determining the thermal and radiation characteristics, attenuation of radiations in the protection, and fluence of neutrons impacting the reactor structure;

5) calculations of neutron flow density and gamma-ray radiation for determining the radiation and thermal characteristics, and testing the radiation and nuclear safety criteria of the fresh fuel and spent nuclear fuel storage facility are met, long-term storage means, spent fuel pools, refueling devices, means of transportation and other nuclear fuel cycle facilities (such as the systems containing nuclear materials and designed for their processing, fuel fabrication);

6) neutron flow density calculations and gamma-ray radiation in the unit or core fragment for determining the isotopic abundance of nuclear fuel in the burn-out process during its presence in the core and change of isotopic abundance in the process of nuclear transformations during its presence outside the core;

7) calculations of other quantities being functional solutions of the transfer equation.

Information indicated above shall be presented in the item 2.1 of the appendix to the SW qualification data sheet.

22. SW for resolving the homogeneous or non-homogeneous linear equation of transfer, accuracy thereof in the applicability area is determined only by the accuracy of the used files of assessed nuclear data (without considering the accuracy of initial process data, for example, geometric dimensions, material composition) are considered as SW benchmarks. Besides the files of assessed nuclear data may be used in the calculation either directly or in the form of libraries, stipulated by the SW format. The ROSFUND Library shall be used as the file library of the assessed nuclear data. The relevant explanations shall be given if other file libraries of assessed nuclear data are used in the SW verification report and item 4 of the appendix to the SW qualification datasheet.

23. SW not being datum are related to engineering SW. The engineering SW implementing the resolution of the transition equation, may have own libraries of multi-group (or presented in another format) constants being inherent parts of the SW, or may use the problem-oriented library of constants existing in the form of individual software products. The review and verification of the engineering SW is made jointly with the above libraries of constants.

24. In the section "SW description" of the SW verification report information on the presence with the file libraries of assessed nuclear data and problem oriented libraries of constants, mentioned in the items 22 and 23 of this Provision, certificates of the Russian, foreign and international organizations.

25. In the section "Purpose and scope of SW application" of the SW verification report it is recommended to indicate whether the verified SW is referred to reference or engineering

26. The reference SW shall be verified using the results of benchmark experiments (reference class experiments). Moreover, it is recommended to perform comparison with the calculation results for qualified reference SW and verificatio foreign SW pf this class.

27. On verification of the engineering SW the results of calculations directly with the results of measurements made at the NF (considering the estimate errors of these measurements), comparison with calculations according to reference SW, comparison of the calculation on certified engineering SW with the theoretical assessments.

28. The determination of the accuracies accepted during verification of engineering SW is given in the section "Results of verification and justification" of the verification report of SW and briefy repeated in the item 2.6 of the appendix to the qualification data sheet. Herewith it is recommended that indicate how the methodological accuracy component should be specified. Information about it are given in the item 6 of the appendix to the qualification datasheet.

29.The comparison of calculated values of the multiplication factor (own value of the linear equation of transfer in the used approximation) shall be made on SW verification for calculation of few-group constants (grid coefficients), space energy distribution of neutron flow density for the units or fragment of reactor, effects and reactivity coefficients with the corresponding quantities calculated with relevant quantities calculated for the reference SW

30. The published results of determining the isotopic abundance of fuel by radiochemical methods shall be used during verification of SW, calculating the isotopic abundance of fuel by the following radiochemical methods.

31. The qualified reference SW data of the calculation of space energy distribution of neutrons and reference data of the chain of nuclear transformations shall be used as the basis of reference SW of the calculation of change of isotopic fuel composition.

32. The following sources of calculation results shall be used for verification and review of the calculation SW of space energy distribution of neutrons and gamma-ray irradiation.

1) domestic and foreign documented banks and databases of the estimated experiments including the use of estimated nuclear data and verification SW;

2) estimated experiments under the performance of international projects and the calculation tests created on their basis;

3) estimated experiments and database of design tests created on their basis, use of the qualification SW used earlier during the development of verification reports of the qualified SW;

4) published materials on appraised experiments and texts developed on their basis;

5) International Handbook of Evaluated Criticality Safety Benchmark Experiments. NEA/NSC/DOC (95), 03 September 2003 Edition);

6) experimental data bank of FBU NTS YaRB;

7) experiments and tests prepared on their basis, proposed by the developer of SW verification report.

The exact references and detailed abstract which includes the experimental errors and information about their certification by the Russian, foreign and international organizations shall be given for the above mentioned materials in the section "Experimental installations and presentation of experimental data" of the SW verification report. For the tests proposed by the developer of SW verification report for the first time, their detailed description shall be given.

33. The following sources of calculation results shall be used for verification and review of the calculation SW of space energy distribution of neutrons and gamma-ray irradiation.

1) the domestic and foreign systems of desing tests and their design appraisal for different codes including the tests used when creating the verification SW;

2) the design tests and their accounting estimates developed under the execution of international projects;

3) the design tests and their accounting estimates used during the development of verification reports for the SW qualified earlier;

4) published design tests and/or their assessments for different SW;

5) design tests developed by the developer of SW verification report specially for this verification.

The exact references and detailed abstract which includes the calculation errors of tests for different SW and information about their certification by the Russian, foreign and international organizations shall be given for the above mentioned materials in the section "Description of design tests" of the SW verification report.

A detailed description of the test allowing its independent calculation and assessment of the accuracies obtained following calculation of the quantities shall be given for the tests proposed by the developer of SW verification report for the first time in the section "Description of design tests".

V. Verification and review of the software - imitators of the reactor core operation

34. SW-imitators of the reactor are designed for justification of operation safety in the period of core operation with specific loading or for safety justification for a specific period for the reactors with continuous refuelling. Following the calculation for these SW it is shown that the limitation on the reactor plant (hereinafter RP) parameters stipulated by legal acts, federal rules and regulations in the field of atomic energy, operator rules and regulations including RP safe operation regulation are met.

35. The reactor SW-imitators are designed for calculations of the RP parameters, mainly the core in the process of fuel burn-up. The SW of the quasi-stationary reactor core calculation and thermo-hydraulic calculation programs required for this calculation shall be included in them. The temporary dependency in the reactor SW-imitator shall be included for accounting the fuel burn-up, which is compensated by the reduction of liquid (boron) poison in the core or displacement of compensating rods. The simulation of RP operation shall be performed in the SW, where the change of power occurs following change of xenon concentration in the fuel (in the process of xenon vibrations).

36. SW calculating the RP thermohydraulic parameters may be integral parts of the reactor SW-imitators or individual software product. In the latter case it is recommended to use the earlier qualified SW for calculation of the RP thermo-hydraulic parameters.

37. Neutron-physical calculation in the reactor core SW-imitator is made as a rule in the few-group diffusive approximation or in other similar approximations. The library of few-group diffusion constants (grid coefficients) with their parametric dependencies from the quantities required for the calculation is available in the SW for implementation of the calculation.

38. The library of few-group constants may be an integral part of the SW or individual software product prepared using the custom SW.

An individual qualification of SW for preparation of few-group constant in accordance with the recommendations of the section II of this Provision shall be made. Information about this is given in the section "Purpose and scope of SW application" of the SW verification report and in the item 4 of the appendix to the SW qualification data sheet.

39. The verification and review of the reactor core SW-imitator is recommended to perform jointly with the SW qualified earlier and used in this SW for thermo-hydraulic calculation and libraries of few-group constants or with corresponding thermo-hydraulic SW and libraries of few-group constants being integral parts of the reactor core SW-imitator. Information about it shall be presented in the item 1 of the appendix to the SW qualification data sheet.

40. Periodic measurements performed by the equipment stipulated by RP design, and temporarily used equipment designed for specific measurement not provide for by the RP design are stipulated by the regulatory legal acts for individual parameters calculated by the SW-imitators of reactor core operation (for example, effectiveness of emergency protection system, effectiveness of the groups or individual control rods of control and protection system, reactivity effects and coefficients). Regular monitoring by the in-core monitoring system environment and SW for archiving the measurement results are provided for such parameters as the distribution of energy release, temperature of individual core elements (component), coolant flow.

41. The comparison of the calculation results and results of measurements made on the RP (considering estimated accuracies of these measurements), comparison with the specially developed calculation tests, with calculations for similar SW besides preference is given to SW certified for calculations of this reactor.

42. The development of databases of the measured quantities prepared based on the periodic measurements of RP parameters, processing of the archives of RP parameters, measured by the in-core monitoring shall be recommended for verification of reactor SW-imitators. The calculation assessment obtained including by design simulation of the measurement process shall be performed for the parameters included in the database, including design simulation of the measurement process and perform accuracy assessments

VI. Verification and review of the neutron and physical parts of the programs of joint non-stationary full scale neutron physical and thermo-hydraulic calculation of the breach conditions of abnormal operation and accidents

43. The SW containing programs of joint non-stationary neutron and physical and thermo-hydraulic calculation shall be used for calculation of the non-stationary regimes of normal operation conditions and calculation of the emergency regimes. Such SW may simulate the operation of RP up to it shutdown following the actuation of emergency protection or for other reasons. This allows remove a series of conservative assumptions during assessment of RP safety. The above-mentioned SW may also contain (independent) parts performing strength calculations, simulation of the turbine generator operation, simulation of the control, safety systems, process parameters of the reactor plant and nuclear power plant, and simulation of the power grid loads.

44. SW of the joint non-stationary neutron and thermo-hydraulic calculation may be organized in the form of a common SW or may represent union of individually functioning SW using interfaces of different levels, including network interfaces.

45. It is recommended that all the independent SW modules may be individually qualified. At the same time the SW made from them all undergoes the qualification procedure.

46. The review of the joint non-stationary neutron-thermo-hydraulic calculation is recommended to perform with the engagement of experts for other directions (for example, the thermal hydraulics, thermomechanics).

47. The non-stationary few-group diffusive approximation considering the delayed neutrons and required feedbacks or other similar approximations as a rule are implemented in the neutron-physical parts of the non-stationary RP simulation SW. Individual feedbacks may be included in the mathematical model implemented in the SW in the form of equations or other ratios, and others in the form of dependency of neutron physical constants from the relevant quantities. In the latter case the values of the feedback parameters may be obtained from individual modules of the unified SW for which the results of calculation for neutron-physical part of SW (section V of this Provision) are the input quantities.

48. The library of few-group constants of diffusion approximation in the neutron physical part of SW shall be used for implementing the few-group diffusion approximation in the neutron physical part of SW.

The library may be included in the SW of the joint neutron-physical and thermal-hydraulic calculation as its integral part or be an independent software product prepared for the qualified SW designated for this purpose. These information are indicated in the item 1 of the appendix to the SW qualification datasheet.

49. The library of constants shall be supplemented by the constants of the delayed neutrons. The distributed constants of delayed neutrons shall be used. The use of common constants for the core of delayed neutrons shall be justified.

50. SW verification of accident modes, abnormal operation modes and transition processes include:

1) verification of the stationary part used in the SW, which provides calculation accuracy of the basic parameters, initial stationary state not above the accuracies of the relevant reactor simulator SW;

2) verification of each integrated SW jointly with the non-stationary neutron-physical and thermo-hydraulic calculation in the interval of parameters where the physical and other processes take place on development of the considered regimes using the relevant experiments, mathematic tests, comparisons with other SW, including the qualified;

3) calculations of specially setup experiments for complete or partial simulation of the relevant accidents, modes with breach of the normal operation conditions and transition processes;

4) comparison with specially developed design tests;

5) comparison with results of calculations with similar SW.

51. It is recommended to specify in the appendix to the SW qualification datasheet for calculation of what accidents (or groups of accidents), abnormal operation modes (or groups of regimes), transition processes is the SW designated. Their names are selected in accordance with the terminology accepted in the documents regulating the justification of NF safety. Different accuracies may be indicated for one and the same parameters for different accidents (transition processes) in the item 2.6 of the appendix to the qualification datasheet. These information are given in the item 2.3 of the appendix to the qualification datasheet.

VII. The verification and review of the neutron-physical parts of the software of the non-stationary calculation of transition processes in the reactor plants in normal operation conditions and for design simulation of the measurements

52. The review and verification of SW for non-stationary calculation of the transition processes in normal operation conditions is recommended to carry out:

1) by comparing the results of calculations with the measurements for operating RP with due regard to estimated accuracy of the measurement results;

2) by comparing the results of calculations with similar results obtained for other (qualified) SW;

3) by comparing with the calculations of specially prepared mathematical tests;

4) by comparing the results of calculations with the measurements for operating RP with due regard to estimated accuracy of the measurement results;

5) by comparing the results of calculations with similar results obtained for other (qualified) SW;

53. The design simulation of measurements shall be performed for determining the accuracy of measured quantities.

54. The communication between the calculated quantity, measured quantity and quantity obtained following design simulation of measurement shall be established on problem definition about simulation of measurements.

55. The values obtained following the calculation and following design simulation of measurement shall be obtained for one and the same SW or for SW with similar constant assurance.

56. The SW jointly with the neutron-physical and thermo-hydraulic calculation shall be used for design simulation of measurements, wherein the possibility of simulation of required RP systems and measuring instrument (for example, effectiveness of registration, signal lag, change of properties of sensor in the RP operation process).

57. The SW together with neutron-physical and thermo-hydraulic calculation shall be used for design simulation of measurements wherein the specification of the calculated parameters on the results of measurements of the simulated process and use of other aposteriori information has been implemented.

Appendix No 1   
to the Provision for the topic "Neutronic calculations" verification and software examination approved by the Federal Environmental, Industrial and Nuclear Supervision Service   
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TERMS AND DEFINITIONS

1. Software validation is the justification of the possibility of using the software in the declared scope and calculation accuracy of the parameters by comparing with the experimental data, calculation data obtained for other software, results of analytical tests, theoretical analysis. The concept "Software verification" used in this Regulation combines the concept "Software verification" and "Software validation".

2. Software applicant is a legal entity or individual providing the software for expert review.

3. Software verification methodology is group of tools and methods used when performing software verification.

4. Methodological component of calculation accuracy is the accuracy related with the calculation methodology using the approximation, its numerical implementation, preparation of neutron and physical constants

5. Software is a program (code) of complex programs, evaluated data files, independent program module or their package; the words "software", "program", "code" are synonyms in the text of this Provision.

Appendix No 2   
to the Provision for the topic "Neutronic calculations" verification and software examination approved by the Federal Environmental, Industrial and Nuclear Supervision Service   
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(Form)

List of contents of the software verification report

1. Introduction

2. Purpose and scope of software application.

3. Software description

4. Description of the calculation schemes and geometrical models

5. Justification of the calculation procedure

6. Verification matrix

7. Descriptio of calculation and analytical tests.

8. Description of experimental facilities and presentation of experimental data.

9. Verification and justification results

10. Conclusion (Draft of software qualification datasheet).

11. List of sources

Appendix No 3   
to the Provision for the topic "Neutronic calculations" verification and software examination approved by the Federal Environmental, Industrial and Nuclear Supervision Service   
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(Form)

Appendix   
to the software qualification datasheet

1. List of the registered program modules, their registration numbers

2. Purpose and scope of software application.

2.1. Purpose.

2.2. Type of nuclear facility

2.3. Modes

2.4. Limitations of application

2.5. Allowed values of parameters.

2.6. Error maintained within the range of allowed parameter values.

3. Information on the calculation methods used in the software

4. Information on databases (evaluated data files) used in the software.

5. List of organization, using the software

6. Additional Information.

7. Special terms and conditions

8. Official experts (Full name, place of work, occupied position).