Accident management for NPPs with RBMK reactors

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PREFACE

Accident management is very important for prevention and mitigation of severe accidents in Nuclear Power Plants and is widely discussed in the world. The processes that could occur during severe accidents in vessel-type Light Water Reactors are rather well understood, however, some uncertainties remain. The knowledge about severe accidents is used for development of accident management strategies. Most of the Nuclear Power Plants that operate vessel-type reactors in the world have already developed or are developing severe accident management programs. The processes that could occur during severe accidents in channel-type reactors are not so well understood. The Chernobyl disaster demonstrated necessity to achieve the same level of knowledge and to develop accident management programs for RBMK-type reactors as well.

RBMK reactor belongs to a class of graphite-moderated nuclear power reactors that were designed in the Soviet Union in 1950s. Usage of materials with low neutron absorption in RBMK design allows improving the fuel cycle by using cheap, low-enriched nuclear fuel. In total there have been built 17 RBMK reactors and 1 reactor is still under construction at Kursk NPP. All three surviving reactors at Chernobyl NPP have been shutdown (the fourth was destroyed in the accident). Units 5 and 6 at Chernobyl NPP were under construction at the time of the accident, however further construction was stopped due to the high contamination level at the site and political pressure. One of two reactors at Ignalina NPP in Lithuania was shutdown in 2004. In 2009, there were 11 RBMK reactors operating in Russia (4 reactors in Saint Petersburg, 3 – in Smolensk and 4 – in Kursk) and 1 – in Lithuania, however there are no plans to build new RBMK type reactors.

At Ignalina NPP is the only Nuclear Power Plant located in Lithuania. It consists of two units, commissioned in December 1983 and August 1987 respectively. Both units are equipped with channel-type graphite-moderated reactors RBMK-1500. Ignalina NPP Unit 1 was shutdown for decommissioning at the end of 2004 and Unit 2 is to be operated until the end of 2009. Ignalina NPP has implemented symptom-based Emergency Operating Procedures that were developed in 2000 by RBMK reactor design institute NIKIET (Russia). These procedures together with the event-based Emergency Operating Procedures cover Design Basis Accidents and a range of Beyond Design Basis Accidents, which do not lead to reactor core damage, i.e. they do not include management of severe accidents. In order to ensure coverage of the whole spectrum of accidents and meet the requirements of IAEA the severe accident management guidelines have to be developed and integrated into the general accident management strategy of Ignalina NPP.

In order to ensure the safe operation of the Nuclear Power Plant a fundamental safety principle of defense-in-depth is applied. Accident management is one of the key components of effective defense-in-depth. The strategy for defense-in-depth is twofold: 1) to prevent accidents and 2) if prevention fails, to limit the potential consequences of accidents and to prevent their evolution to conditions that are more serious.

Around the world, there are several approaches to the accident management. The approach of Westinghouse Owners Group, which is developed for Pressurized Water Reactors, but is also applied to Boiling Water Reactors, is well known and widely applied. However, this approach is not easily applicable or transferable to channel-type RBMK-1500 reactors. The framework of the emergency response procedures at Ignalina NPP is also different from that in the NPPs developed by Westinghouse Owners Group. Therefore, a specific approach has to be developed for the accident management at RBMK-1500 reactors.

The objective of this book is to present the basic principles and approach to accident management at Ignalina NPP with

RBMK-1500 reactor. In general, this approach could be applied to NPPs with RBMK-1000 reactors, that are available in Russia and partially for other channel-type reactors, but the design differences should be taken into account. As well, this book presents the current status of knowledge regarding the severe accident phenomena and possibilities of accident management at NPPs with RBMK reactors. This book also includes the results of the performed severe accident analyses to justify the suggested accident management strategies as well as information on the suggested NPP improvements, which would enhance the safety of RBMK reactors.

The information presented in this book was mainly received in the frames of the project "Development of Manual on Management of Beyond Design Basis Accidents at Ignalina NPP" coordinated by the consortium Jacobsen Engineering Ltd (United Kingdom), SCIENTECH Inc. (USA), and Volian Enterprises Inc. (USA) and sponsored by the UK Department of Trading and Industry. The authors would like to express their gratitude to the sponsors, coordinators and staff of Ignalina NPP (Dr. G. Krivoshein and his team) who were involved in the development of BDBA management guidelines. Also the authors express sincere thanks to prof. J. Vilemas for the invaluable help and advice for preparation of the monograph, to colleagues of the Laboratory of Nuclear Installation Safety, who took part in severe accident research, and to Dr. R. Urbonas, Dr. J. V. Žiugžda, Mrs. A. Varnaitė and to all who helped to prepare the manuscript of the monograph.

Authors

CONTENT

ABBREVIATIONS

AGR	Advanced Gas-Cooled Reactor
ALS	Accident Localization System
AZ	Russian Acronym for "Emergency protection system"
BDBA	Beyond Design Basis Accident
BRU-B	Steam relief valve for steam discharge to ALS tower (Russian abbreviation)
BRU-K	Steam relief valve for steam discharge to turbine condensers (Russian abbreviation)
BSRC	Bottom Steam Reception Chamber
BSM	Russian Acronym for "Normal reactor shutdown system"
BWR	Boiling Water Reactor
CPS	Control and Protection System
CTCS	Condenser Tray Cooling System
DS	Drum Separator
DSS	Diverse Shutdown System
ECCS	Emergency Core Cooling System
EOP	Emergency Operating Procedure
EU	European Union
FC	Fuel Channel
FP	Fission Product
GDH	Group Distribution Header
IAEA	International Atomic Energy Agency
INPP	Ignalina Nuclear Power Plant
LOCA	Loss-of-Coolant Accident
LWR	Light Water Reactor
MCP	Main Circulation Pump
MSV	Main Safety Valve
NIKIET	Research and Development Institute of Power Engineering (Russian abbreviation)
NPP	Nuclear Power Plant
OECD	Organisation for Economic Co-operation and Development
PSA	Probabilistic Safety Analysis

PWR	Pressurized Water Reactor
RBMK	Russian abbreviation for "Large-power channel-type reactor"
RC	Reactor Cavity
RCS	Reactor Cooling System
SAG	Severe Accident Guide
SAMG	Severe Accident Management Guidelines
SRV	Steam Relief Valve
TSRC	Top Steam Reception Chamber
VATESI	Lithuanian abbreviation for "State Nuclear Power Safety Inspectorate"
VVER	Russian Abbreviation for "Water-cooled, Water-moderated Energy Reactor"

The notations are explained when they appear in the text.

1

Introduction. Accident Management at Nuclear Power Plants

In order to ensure the safe operation of the Nuclear Power Plant a fundamental safety principle of defense-in-depth is applied. The strategy of defense-in-depth is described in detail in IAEA document [1]. This document defines also two corollary principles of defense-in-depth: 1) accident prevention, and 2) accident mitigation. Defense-in-depth is achieved primarily by means of four successive barriers, which prevent the release of radioactive material (fuel matrix, fuel cladding, primary coolant boundary and containment). These barriers are protected by three levels of design measures: prevention of abnormal operation and failures (level 1), control of abnormal operation and detection of failures (level 2) and control of accidents within the design basis (level 3). If these first three levels fail to ensure the structural integrity of the core, e.g. due to beyond the design basis multiple failures, or due to extremely unlikely initiating events, additional efforts should be made at level 4 to further reduce the risks. The objective at the fourth level is to ensure that both the likelihood of an accident entailing significant core damage (severe accident) and the magnitude of radioactive releases following a severe accident are kept as low as reasonably achievable. Finally, level 5 includes off-site emergency response measures, with the objective of mitigating the radiological consequences of significant releases of radioactive material.

The fourth level of defense-in-depth relates to the management of Beyond Design Basis Accidents. These accidents could be grouped in two categories: 1) Beyond Design Basis Accidents without significant core degradation, and 2) severe accidents [2].

Accident management is one of the key components of effective defense-in-depth. The strategy for defense-in-depth is twofold: 1) to prevent accidents and 2) if prevention fails, to limit the potential consequences of accidents and to prevent their evolution to more serious conditions [1]. The elements that have to be addressed in development and implementation of accident management at NPPs are described in IAEA report [3].

In the Republic of Lithuania, the nuclear safety regulations require that the reactor plant technical design shall contain provisions for controlling the Beyond Design Basis Accidents and that for dealing with Beyond Design Basis Accidents the Operating Utility shall prepare in accordance with design documentation a special manual, which must be agreed in consultation with VATESI [4]. However, in the original RBMK design there are no specific procedures or guidance for management of BDBA leading to core damage, i.e. severe accidents. Furthermore, it does not include comprehensive RBMK specific analysis of severe accidents or approved strategies for dealing with such accidents. The NPPs with other types of reactors, e.g. PWR, BWR, have developed procedures or guidance, called Severe Accident Management Guidelines, for taking actions in the event of BDBA where the core damage is imminent or has occurred. In most cases, these SAMGs are based on extensive analyses of the phenomena associated with severe accidents.

Typically, the BDBA may be the result of the following:

- an accident caused by initiating events not taken into account in the plant design basis, or
- an accident accompanied by additional safety system failures above and beyond the single failure assumed for design, or by erroneous personnel decisions.

Before proceeding to accident management several important definitions should be considered:

- Core Damage. In the IAEA report [5], it is mentioned that in different countries there are several definitions for the core damage, such as major loss of fuel cladding integrity, partial core melting and overall core melting. Considering the specifics of RBMK-1500 and assumptions made in PSA level 1 and level 2 studies of Ignalina NPP the core damage is defined as major loss of fuel cladding integrity.
- Core Degradation is a process that leads to core damage.

- Severe Accident – an accident more severe than a Design Basis Accident and involving significant core degradation.
- Severe Accident Management – a subset of accident management that:
    - terminates core damage once it has started,
    - maintains the capability of the containment as long as possible,
    - minimizes on-site and off-site releases,
    - returns the plant to a controlled safe state.
- Severe Accident Management Guidelines. A set of guidelines containing instructions for actions in the framework of severe accident management.
- Controlled safe state is a plant state in which:
    - The core is and remains subcritical.
    - The core is in a coolable geometry and there is no further fuel failure.
    - Heat is being removed by the appropriate heat removal systems.
    - Fission products release from containment has ceased, or further releases can be bounded.

These definitions are considered in SAMG development for Ignalina NPP and they comply with definitions given in the IAEA report [5].

Around the world, there are several approaches to the accident management. The approach of Westinghouse Owners Group, which is developed for Pressurized Water Reactors, but is also applied to Boiling Water Reactors, is well known and widely applied. Ignalina NPP is equipped with channel-type reactors RBMK-1500 and Westinghouse Owners Group approach is not easily applicable or transferable to such types of reactors. The framework of the emergency response procedures at Ignalina NPP is also different from that in the NPPs developed by Westinghouse Owners Group. Therefore, a specific approach has to be developed for the accident management at RBMK-1500 reactors.

In September 2003, the international project sponsored by UK Department of Trading and Industry has been initiated to develop guidelines for severe accident management that could occur in the RBMK-1500 reactor and in the spent fuel storage and transportation system of Ignalina NPP. These guidelines had to be integrated to the emergency response system of Ignalina NPP to cover the accidents that are not covered by the EOP that were implemented at that time.

Development of SAMG started from review of the existing international experience for Advanced Gas Cooled reactors, Boiling

Water Reactors, and Pressurized Water Reactors, which have procedures for taking actions following severe accidents and supporting analysis. At first, the BDBA list was developed based on results of Ignalina NPP Probabilistic Safety Analysis. Later this list was compared against BDBA list, which was previously developed by Ignalina NPP based on technical justification of the symptom-based EOPs. The information about the existing INPP capabilities, equipment, procedures, and responsibilities was collected in order to:

- Develop Candidate High Level Strategies, which can interrupt or mitigate challenges to the barriers to Fission Product release.
- Determine information / instruments needs to detect entry conditions to Severe Accident Guides (SAGs) and to determine if accident management strategies are being effective.
- Propose equipment and instrumentation improvements for Severe Accident Management.

The performed work was the basis to define the scope of the analyses for technical justification of SAMG. The selected accident sequences were analyzed to identify the expected NPP response, timing to key phenomena and to assess effectiveness of proposed accident management strategies.

- When all the required analyses were completed, the collected information was converted into the actual SAMG package, which consists of:
- User's guide. It describes the rules of usage and includes the Diagnostic flowchart, and the Exit checklist.
- Writer's guide. It describes the rules how the SAMG documentation has to be written in order to be understandable for the users of documents.
- Documentation of each Severe Accident Guide. Documentation of each guide consists of the Flowchart, the text procedure and the technical justification.

The verification and validation of the developed SAMG package was performed by the Ignalina NPP to check the guidelines for consistency and compatibility with the existing framework of the Emergency Operating Procedures.

At the end of the project, the training for the staff of the Ignalina NPP training centre was performed on how the SAMG should be implemented. The training centre will transfer the received knowledge to the operators of the Ignalina NPP.

The objective of this book is to present the basic principles and approach to accident management at Ignalina NPP with RBMK-1500 reactor. In general, this approach could be applied to NPPs with RBMK-1000 reactors, that are available in Russia, but the design differences should be taken into account. As well this book presents the current status of knowledge regarding the severe accident phenomena and possibilities of accident management at NPPs with RBMK reactors.

The information presented in this book was mainly received in the frames of the above-mentioned international project "Development of Manual on Management of Beyond Design Basis Accidents at Ignalina NPP". In the frames of this project the accident management guidelines were developed not only for RBMK-1500 reactor, but for the spent fuel storage and transportation system of Ignalina NPP as well. For the project the consortium form Jacobsen Engineering Ltd. (United Kingdom), SCIENTECH Inc. (USA) and Volian Enterprises Inc. (USA) was created and coordinated by Jacobsen Engineering, Ltd. The Lithuanian Energy Institute was the subcontractor and participated in all tasks, performed within this project (development of BDBA list, compilation of information about the existing INPP capabilities, equipment, procedures, and responsibilities, determination of information and instrumentation needs to detect entry conditions, analysis of selected accident sequences, and other. The authors of the book were the tasks leaders in different works and took the responsibility for work management, performance of accident analysis, development of justification reports and others. The book authors and their colleagues in parallel participated in other international projects, networks of excellence in the frame of FP5 – FP7, related to integration of European research on severe accident phenomenology and management, e.g. SARNet (Severe Accident Research Network), Phebus, etc.

REFERENCES

1. INSAG-12, Basic safety principles for nuclear power plants, International Atomic Energy Agency, Vienna, 1999.
2. Safety Standards Series No. NS-R-1, Safety of nuclear power plants: Design: Safety requirements, International Atomic Energy Agency, Vienna, 2000.
3. Safety Reports Series No. 32, Implementation of accident management programmes in nuclear power plants. International Atomic Energy Agency, Vienna, 2004.
4. Nuclear Safety Regulations for Reactors of Nuclear Power Plants, Management Documents, VD-T-001-0-97, VATESI, Vilnius, Lithuania, 1997.
5. Safety Reports Series No. 23, Accident analysis for nuclear power plants. International Atomic Energy Agency, Vienna, 2002.
6. **Kaliatka A., Uspuras E.**, Accident and transient processes at NPPs with channel-type reactors: monography, Kaunas: Lithuanian Energy Institute. Thermophysics: 28. ISBN 9986-492-87-4. 2006. p. 298.
7. **Almenas K., Kaliatka A., Uspuras E.** Ignalina RBMK-1500. A Source Book. Extended and Updated Version. Lithuanian Energy Institute, Kaunas, Lithuania, 1998, 198 p.
8. **Afanasieva A., Burlakov E., Krayushkin A., Kubarev A.**, The characteristics of the RBMK core. Nuclear Technology. Vol. 103, Moscow, Russia, 1993, p. 1–9.
9. **Novoselsky O. Yu., Filinov V. N.**, Computational assessment of RBMK pressure tube rupture at accident heating. Proc. International Exchange Forum on Analytical Methods and Computational Tools for NPP Safety Assessment, Obninsk, Russia, 1996, pp. 1-10.
10. **Rimkevicius S., Urbonavicius E., Cesna B.**, Safety margins of RBMK-1500 Accident Localization System at Ignalina NPP. Safety margins of operating reactors. Analysis of uncertainties and

implications for decision making. International Atomic Energy Agency, TECDOC-1332, Vienna, 2003. pp. 95-106.

11. **Rimkevičius S., Uspuras E.,** Modelling of thermal hydraulic transient processes in nuclear power plants: Ignalina compartments, Kaunas: Lithuanian Energy Institute. 2007. ISBN 978-1-56700-247-8. p. 198.
12. **Povilaitis M., Urbonavičius E., Rimkevičius S.,** Confinements of nuclear power plants and processes in confinements // Energetika. ISSN 0235-7208 / 2005. No. 4, p. 18-27.
13. Pressure suppression system containments, A state-of-the-art report by a group of experts of the NEA/CSNI, CSNI report 126, 1986.
14. **In-depth safety assessment of Ignalina Nuclear Power Plant**. Ignalina NPP report, Visaginas, Lithuania, 1996.
15. **The analysis of steam-gas mixture release from the Reactor Cavity of RBMK-1500 reactor for determination of the boundaries**. Phase 3, methodology of the analysis. Report No. 74.063, NIKIET, Moscow, 1999 (in Russian).
16. **The analysis of steam-gas mixture release from the Reactor Cavity of RBMK-1500 reactor for determination of the boundaries**. Phase 4, results of the analysis. Report No. 74.069, NIKIET, Moscow, 2000 (in Russian).
17. **Level 2 PSA Methodology and Severe Accident Management**, Committee on the Safety of Nuclear Installations (CSNI) of the OECD Nuclear Energy Agency (NEA), OCDE/GD(97)198, 1997.
18. **Afremov D.A., Solovjev S.L.**, Development and application of design-theoretical methods of the analysis of certain severe accidents for RBMK reactor. Heat-and-power engineering. No. 4, Moscow, Russia. 2001. (In Russian).
19. **Safety Reports Series No. 43**, Accident analysis for nuclear power plants with graphite moderated boiling water RBMK reactors, International Atomic Energy Agency, Vienna, 2005.
20. **Cesna B., Rimkevicius S., Urbonavicius E., Babilas E.**, Reactor Cavity and ALS thermal-hydraulic evaluation in the case of Fuel Channels ruptures at Ignalina NPP // Nuclear Engineering and Design 232 (2004) 57–73.
21. **Vasilevskij V.P., Nikitin J.M., Petrov A.A., Potapov A.A., Tcherkashev J.M.** Features of RBMK severe accidents development and approaches to such accidents management//

Atomic energy. Vol. 90, Issue 6. Moscow, Russia. 2001. (In Russian).

22. **Kramerov A.J., Michailov D.A.** About the approach to severe accident studying in channel boiling reactors (basically at overheating by decay heat) // Proc. of the 5th International Information Exchange Forum "Safety Analysis for NPPs of VVER and RBMK Types Reactors". Obninsk, Russia .16-20 October 2000. 8 p. (In Russian).
23. **Final Safety Justification for Ignalina Nuclear Power Plant Diverse Shutdown System**. Safety justification for Additional Hold-down System, DS&S Report XE405-TEC188_Appendix-E, Ignalina NPP, 2004.
24. **Ignalina NPP Safety Analysis Report.** Volume 3 Task Group 5 "Assessment of Reactor Cavity Integrity", VATTENFALL, Ignalina NPP report, Visaginas, Lithuania, 1996.
25. **Fedorov V., Lipov M., Wang Z. et al.**, RELAP5/MOD3 Analysis of RBMK-1000 Reactor Fuel Channel Coolant Flow Decrease due to Stop Control Valve Destruction, RELAP5 International Users Seminar, Baltimore, Maryland, USA. 1994, p.16.
26. **Medvedeva N., Timkin S., Andrejev A., Zhilko V., Peshkov I., Marciniuk D., Poshtovaja O.**, "Analysis of piping behavior in the graphite stack of RBMK-1000 in case of single technological channel rupture", Annual report, Elektrogorsk research centre on safety of nuclear power plants, Elektrogorsk, pp. 11–21, 2004 (in Russian).
27. **Barselina Report**, Phase 5, final version. Visaginas, Ignalina NPP, Lithuania. 2001.
28. **Ušpuras E., Kaliatka A., Augutis J., Rimkevičius S., Urbonavičius E., Kopustinskas V.,** Probabilistic and deterministic analysis of BDBA in RBMK-1500 // Energetika. ISSN 0235-7208. 2006. No. 3, p. 8-23
29. **C. D. Fletcher et. al.,** RELAP5/MOD3 code manual user's guidelines, Idaho National Engineering Lab., NUREG/CR-5535, 1992.
30. **Urbonas R., Uspuras E., Kaliatka A.** State-of-the-art computer code RELAP5 validation with RBMK-related separate phenomena data, Nuclear Engineering and Design. ISSN 0029-5493. Vol. 225, 2003, p. 65-81.

31. **Allison C. M., Wagner R. J.**, RELAP5/SCDAPSIM/MOD3.2 Input Manual Supplemental. Innovative Systems Software. LLC, USA. 2001.

32. **Kaliatka A., Uspuras E.**, Benchmark analysis of Main Circulation Pump trip events at the Ignalina NPP using RELAP5 code, Nuclear Engineering and Design. ISSN 0029-5493. Vol. 202, 2000. p. 109-118.

33. **RELAP5-3D Code Manual**, Appendix A, RELAP5-3D Input Data Requirements, INEEL-EXT-98-00834-V2, 1998.

34. **Paik S.** RELAP5-3D multidimensional heat conduction enclosure model for RBMK reactor application. Nuclear Technology. 1999. Vol. 128, pp. 87-102.

35. **Ušpuras E., Kaliatka A.** Evaluation of Weak Heat Conduction Mechanism for Long-term LOCAs in RBMK-1500 // Nuclear Technology. 2007, Vol. 158, p. 18-25.

36. **Ušpuras E., Urbonavičius E., Kaliatka A.** Specific features of the RBMK-1500 reactor and BDBA management // Energetika. ISSN 0235-7208. 2005, Nr. 3, P. 1–9.

37. **Ušpuras E., Kaliatka A., Augutis J., Rimkevičius S., Urbonavičius E., Kopustinskas V.** Safety analysis of beyond design basis accidents in RBMK-1500 reactors // Annals of Nuclear Energy. ISSN 0306-4549. 2007, Vol. 34, p. 356-373.

38. **Kaliatka A., Uspuras E.,** Thermal-hydraulic analysis of accidents leading to local coolant flow decrease in the Reactor Cooling System of RBMK-1500. Nuclear Engineering and Design, 2002. Vol. 217, N 1–2, 91–101.

39. **Allelein H.J., Arndt S., Klein-Hessling W., Schwarz S., Spengler C., Weber G.,** COCOSYS: Status of development and validation of the German containment code system, Nuclear Engineering and Design, 238 (4), p.872-889, 2008

40. **Urbonavicius E., Rimkevicius S.**, RALOC4 Code Validation Against Measured Data at Ignalina NPP During Single Main Safety Valve Opening, Nuclear Engineering and Design. 2002, 216, p. 89-97.

41. **Fedorov V., Lipov M., Wang Z. et al.**, RELAP5/MOD3 Analysis of RBMK-1000 reactor Fuel Channel coolant flow decrease due to stop control valve destruction. Proc. of RELAP5 International Users Seminar, Baltimore, Maryland, USA, 1994. pp. 1-12.

42. **Medvedeva N. Y., Andreev A. V., Peshkov I. et al.**, Multiscale experimental test facilities on RBMK multiple pressure tube rupture problem. Proc. of 6th Int. Topical Meeting on Nuclear Reactor Thermal Hydraulics, Operations and Safety, NUTHOS-6, Nara, Japan, 2004. pp. 1-16.
43. **Wickham A.J.**, Oxidation reactions of graphite in Ignalina RBMK reactors under fault conditions. Jacobsen Engineering report, Jacobsen Engineering, 2005.
44. **Uspuras E., Urbonavičius E., Kaliatka A.** The specifics of RBMK core cooling at overheated conditions // Fourteenth international conference on nuclear engineering ICONE 14, Miami, Florida, USA, July 17-20, 2006. USA: ASME, 2006. ISBN 0-7918-3783-1, p. 1-9.
45. **Van Dorsselaere J.P.**, Overview of progress of ASTEC Topic, Conference ERMSAR-07, Session "Code and method development activities", Overview of progress of ASTEC Topic, Karlsruhe, 12-14 June 2007.
46. **Urbonavicius E., Uspuras E., Rimkevicius S., Kaliatka A.**, Application of RELAP/SCDAPSIM and COCOSYS Codes for Severe Accident Analysis in RBMK-1500 Reactor, Proceedings of ICAPP '06, Reno, NV USA, June 4-8, 2006, Paper 6174.
47. **Safety substantiation of Reactor Cooling System**, Lithuanian Energy Institute, Kaunas, Lithuania, 1999.
48. **E. Uspuras, A. Kaliatka, V. Vileiniskis**, Development of accident management measures for RBMK-1500 in the case of loss of long-term core cooling, Nuclear Engineering and Design, **236**, 47, 2006.
49. **Technical Support for the Debris Coolability Requirements for Advanced Light Water Reactors in the Utility/EPRI Light Water Reactor Requirements Document**, Fauske & Associates, June 1990.
50. **EU co-sponsored research on reactor safety/severe accidents**, Final summary reports – "Source Term (ST)" cluster projects, EURATOM, EUR 19963, European Commission, Brussels, 2003.
51. **Dutton L.M.C., et al.**, Iodine behaviour in severe accidents, Proceedings of the fourth CSNI workshop on the chemistry of iodine in reactor safety, Wurenlingen, Switzerland, June 10-12, 1996, NEA/CSNI/R(96)6, Nuclear Energy Agency, 1996.

52. **A simplified approach to estimating reference source terms for LWR designs**, TECDOC-1125, International Atomic Energy Agency, Vienna, 1999.

53. **Impact of short-term severe accident management actions in a long-term perspective**, Final report, NEA/CSNI/R(2000)8, Nuclear Energy Agency, 2000.

54. **Libmann J.**, Elements of nuclear safety, Les editions de physique, 1996.