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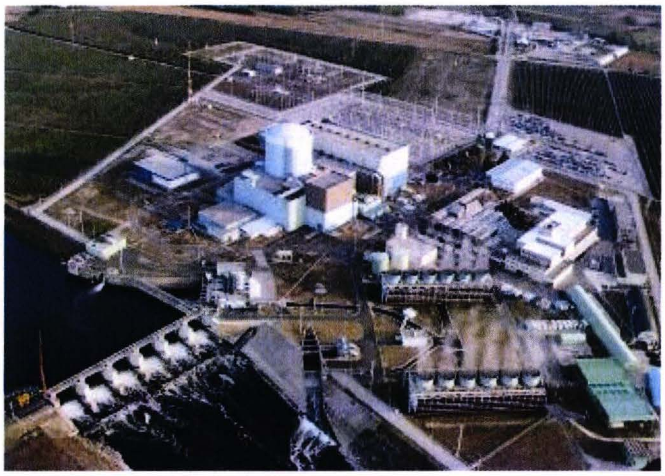
ENGINEERIGN SERVICE MANUAL
NUCLEAR POWER PLANT KRŠKO



ED-18

SEISMIC QUALIFICATION PROGRAM

(Rev. 3)

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Revision Log

Rev. 0	Original issue
Rev. 1	The following parts of the documents are revised: 3.1.2) Seismic categorization for structures, systems and components; 3.4.c): Evidence of successful completion of a qualification; 3.4.d) Documentation and Archiving; 3.4.e): Installation of equipment; 3.5 Maintenance of seismically qualified equipment.
Rev. 2	The Section 3.1 is extended. A new paragraph is added, describing technical bases and terminology for implementation of increased seismic requirements for modifications and safety upgrades. The title and text of 3.1.4 is revised. An explanation at the beginning of Section 3.1.5 regarding the seismic input to the BB1 design is added. Section 3.1.6 is revised. A section 3.4 and Appendix I describing pre-aging effects are added. Other editorial changes are made.
Rev. 3	Section 3.1.2 is revised with inclusion of definition of safety impact (or two over one) items in accordance with PSR3 actions (PSR3 1.3-005/006, PSR3 1.2-024). In Section 3.1.5, abbreviation BB2 is used instead Bunkered Building 2. Section Abbreviations is revised (abbreviation BB2 added). Terms of use of SP-S702 Appendix A FRS are revised in Section 3.1.6. The scope of SP-S702 given in Section 7.1 in extended also to Seismic Safety impact Items.

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ABBREVIATIONS

ANSI	American National Standards Institute
BB1	Bunkered Building 1
BB2	Bunkered Building 2
CFR	Code of Federal Regulations
DEC	Design Extension Condition
DGB	Diesel Generator Building
ESWIS	Essential Service Water Intake Structure
FRS	Floor Response Spectra
GDC	General Design Criteria
MC	Main Complex
OBE	Operating Basis Earthquake
NEK	Nuklearna Elektrarna Krško
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
NUREG	US Nuclear Regulatory Commission Regulation
PSR	Periodic Safety Review
PGA	Peak Ground Acceleration
RG	Regulatory Guide
RWS	Radwaste Storage
SSC	Structures, Systems and Components
SSE	Safe Shutdown Earthquake
SUP	Safety Upgrade Program
USAR	Updated Safety Analysis Report
ZPA	Zero Period Acceleration

1.0 PURPOSE

1.1 Background

GDC 2 »Design Basis for protection against natural phenomena« of Appendix A to 10 CFR Part 50 »General design criteria for nuclear power plants« requires that nuclear power plant structures, systems, and components (SSC) [1] important to safety be designed to withstand the effects of earthquakes without loss of capability to perform their safety functions. Specifically, paragraph (a) (1) of Section VI of Appendix A to 10 CFR Part 100 »Seismic and geologic sitting criteria for nuclear power plants« requires that all nuclear power plants be designed so that, if the Safe Shutdown Earthquake (SSE) occurs, all structures, systems and components important to safety remain functional. These plant features are those necessary to assure (1) the integrity of the reactor coolant pressure boundary, (2) the capability to shut down the reactor and maintain it in a safe shutdown condition, or (3) the capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the guideline exposures of 10 CFR Part 100. NRC Regulatory Guide 1.29 [2] designates those structures, systems and components which must be designed to withstands the effects and remain functional during the SSE as Seismic Category I.

Similarly, paragraph (a) (2) of the Section VI of Appendix A to 10 CFR Part 100 requires that all structures, systems, and components of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public shall be designed to remain functional and within applicable stress and deformation limits when subjected to the effects of the vibratory motion of the Operating Basis Earthquake (OBE) in combination with normal operating loads.

Paragraphs (a)(1) and (a)(2) above mentioned require that the engineering method used to ensure that the required safety functions are maintained during and after the vibratory ground motion associated with the OBE or SSE shall involve the use of either a suitable analysis or a suitable qualification test to demonstrate that structures, systems and components can withstand the seismic and other concurrent loads. Criterion III »Design Control« of Appendix B »Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants« to 10 CFR 50 requires, among other things, that the design control measures shall provide for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculation methods, or by the performance of a suitable testing program. Where a test program is used to verify the adequacy of a specific design feature in lieu of other verifying or checking processes, it shall include suitable qualifications testing of a prototype unit under the most adverse design conditions.

1.2 Objective

The purpose of this document is to provide seismic qualification program for systems and components of Krško Nuclear Power Plant (NPP). The purpose is to describe the seismic design inputs, specify seismic classification of systems and components, and define basic design criteria. General technical guidance on an application of the seismic qualification procedure in Krško NPP is given. The program addresses existing and future structures, systems and components. A conformance is given with the codes, standards, specifications and regulatory guides compliant to the plant's licensing basis. The use of modern codes, standards and regulatory guides are recommended for use for seismic qualification of new structures, systems and components.

This seismic qualification program is prepared according to the 2nd NEK PSR recommendation (PSR2-1.3-03: Plant Specific Seismic Qualification Program need to be developed, applied and discussed in the applicable USAR section. Qualification program shall consider original seismic design bases and shall include design changes control that is already assured through NEK modification process procedures and specification SP-S702) [18].

1.3 Scope

This program is applicable to the Seismic Category I SSC. Those are these SSC, which are important to safety and other SSC which are not safety-related but may have earthquake induced interaction (due to collapse) with the safety-related SSC as it is specified in RG 1.29, Seismic design and classification [2]. Seismic design inputs for design basis and design extension condition events are described.

2.0 REFERENCES

The codes, regulatory guides, NUREGs, standards and plant documents listed below have been used to obtain this seismic qualification program.

[1] 10 CFR Part 50, Domestic Licensing of Production and Utilization Facilities, U.S. Nuclear Regulatory Commission, Washington, DC.

[2] Regulatory Guide 1.29, Seismic design classification, U.S. Atomic Energy Commission, Rev. 4, March 2007.

[3] Regulatory Guide 1.60, Design response spectra for seismic design of nuclear power plants, U.S. Atomic Energy Commission, Rev. 1, December 1973.

[4] Regulatory Guide 1.61, Damping Values for Seismic Design of Nuclear Power Plants, U.S. Atomic Energy Commission, October 1973.

[5] Regulatory Guide RG 1.100, Seismic qualification of electrical and active mechanical equipment and functional qualification of active mechanical equipment for nuclear power plants, U.S. Nuclear Regulatory Commission, Rev. 3, September 2009.

[6] NUREG-800, 3.7.2, Seismic System Analyses, U.S. Nuclear Regulatory Commission Standard Review Plan, Rev. 3, March, 2007.

[7] NUREG-800, 3.9.3 ASME CODE Class 1, 2, and 3 components and component supports, and core support structures, U.S. Nuclear Regulatory Commission Standard Review Plan, Rev. 3, March, 2007.

[8] NUREG-800, 3.10 seismic and dynamic qualification of mechanical and electrical equipment, U.S. Nuclear Regulatory Commission Standard Review Plan, Rev. 3, March, 2007.

[9] ASME Boiler and Pressure Vessel Code, Section III, Rules for Construction of Nuclear Power Plant Components, 1971 edition.

[10] ASME QME Qualification of Active mechanical Equipment Used in Nuclear Power Plants, 2007 edition.

[11] IEEE 308, Criteria for Class 1E Power Systems for Nuclear Power Generating Stations, 1973 edition.

[12] IEEE 323, Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations, 1971 edition.

[13] IEEE 344, Guide for Seismic Qualification of Class 1 Electric Equipment for Nuclear Power Stations, 1971 edition.

[14] IEEE 344, Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations, 1987 edition.

[15] IEEE 344, Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations, 2004 edition.

[16] Krško Nuclear Power Plant, Updated Safety Analyses Report.

[17] PSR2-NEK-1.3, Equipment Qualification, The 2nd NEK Periodic Safety Review, Revision 0

[18] Krško Nuclear Power Plant, Seismic Analysis, Testing, and Documentation, Technical specification No. SP-S702-044687-000.

[19] Krško Nuclear Power Plant, Revised PSHA for NPP Krsko site, 2004.

[20] ARSO, Izdelava projektne in druge dokumentacije za odlagališče NSRAO Vrbina v občini Krško, Izvedba seizmološke analize lokacije (seizmološki del) za objekt odlagališče NSRAO Vrbina, Revizija 1, Marec 2015.

[21] Krško Nuclear Power Plant, Replacement Items, Technical Evaluations, ESP-2.202.

[22] Krško Nuclear Power Plant, Quality Assurance Plan, Management Manual QD-1.

[23] Krško Nuclear Power plant, Records Control Program, ED-3.

[24] WorleyParsons, Main Complex FRS for DEC (0.6g), KRSKO-1-DC-SE-0002, Revision 6, September, 2013.

[25] University of Ljubljana, Faculty of Civil and Geodetic Engineering, NEK – Main Complex FRS for DEC (0.6 g), Partial final independent evaluation, September 2013.

[26] EQE, Screening of seismic capacities of civil structures at the Krsko Nuclear Power Plant, March, 1995.

[27] EPRI 1021067, Nuclear Power Plant Equipment Qualification Reference Manual, Revision 1, 2010.

[28] EPRI NP 3326, Correlation between aging and seismic qualification for nuclear plant electrical components. Phase 1, 1983.

[29] EPRI NP 5024, Seismic Ruggedness of Aged Electrical Components, 1987.

[30] IEEE 334 Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations, 2006.

[31] IEEE 317, Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations, 1972.

[32] IEEE 382, Qualification of Actuators for Power-Operated Valve Assemblies with Safety-Related Functions for Nuclear Power Plants, 1972.

[33] IEEE 572, Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations, 1985.

[34] IEEE 535, Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Stations, 1986.

[36] IEEE 650, Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations, 2006.

[37] Regulatory Guide 1.40, Qualification of Continuous Duty Safety-Related Motors for Nuclear Power Plants, Revision 1, February 2010.

[38] Regulatory Guide 1.63, Electric Penetration Assemblies in Containment Structures for Water-Cooled Nuclear Power Plants, October 1973.

[39] Regulatory Guide 1.73, Qualification Tests of Electric Valve Operators Installed Inside the Containment of Nuclear Power Plants, January, 1974.

[40] Regulatory Guide 1.156, Environmental Qualification of Connection Assemblies for Nuclear Power Plants, November, 1987.

[41] Regulatory Guide 1.158, Qualification of Safety-Related Lead Storage Batteries for Nuclear Power Plants, February, 1989.

[43] Regulatory Guide 1.210, Qualification of Safety-Related Battery Chargers and Inverters for Nuclear Power Plants, January, 2008.

3.0 REQUIREMENTS

3.1 Design inputs

Design basis earthquake for the Krško nuclear power plant has been determined based on geophysical, geomechanical, hydrogeological and engineering seismological investigations performed during the period from 1971 to 1974. On the basis of the available data and the results of the investigations and measurements the maximum considered earthquake was considered an event with a peak ground acceleration of 0.3 g, which has been defined for the Safe Shut-down Earthquake. The design response spectrum has been defined according to the USAEC Regulatory Guide 1.60 of October 1973. The operating Basis Earthquake was set at 1/2 SSE with the maximum acceleration of 0.15 g.

Krško nuclear power plant was originally seismically qualified for SSE represented by Regulatory Guide 1.60 ground motion response spectrum. Seismic load was directly applied to the bottom of foundation without any deconvolution. In 2013, the FRS for earthquake with intensity twice the SSE (2×0.3g=0.6 g) have been calculated for main structures including Main Complex and Essential Service Water Intake Structure [24, 25]. Since the Main Complex and Essential Service Water Intake Structure foundation levels are below the ground surface, the synthetic ground acceleration time histories that are based on the Regulatory Guide 1.60 ground motion response spectra were deconvolved to determine a new time history that has been applied at the foundation levels. The Regulatory Guide 1.60 ground motion response spectra were defined by a specified PGA at the surface (0.6 g) and it was assumed that the ground motion response spectra are meant to represent motions recorded on the soil surface. It was found that so represented seismic load (0.6 g at the surface level) causes approximately equivalent FRS to those calculated for the original representation of seismic load (0.3 g at the foundation level) [24–26]. FRS for 0.6 g PGA represent increased seismic requirements and are defined to be used for the design of new systems and safety upgrades.

3.1.1 Design basis earthquakes

The SSE defines that earthquake which is based upon an evaluation of the maximum earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material. The OBE is that earthquake which, considering the regional and local geology and seismology and specific characteristics of local subsurface material, could reasonably be expected to affect the plant site during the operating life of the plant.

The definition of design basis earthquake includes maximum acceleration value, response spectrum and the time histories of accelerations. A peak ground acceleration of 0.3 g at the foundations of the original Krško NPP's structures is adopted as SSE. A certified design ground motion response spectrum for the horizontal component of SSE complies with Regulatory Guide 1.60 [3]. The vertical component used is equal to the horizontal component in all frequency regions. For the time histories of acceleration, artificial time histories corresponding to the RG 1.60 design spectrum are used.

According to the requirement of paragraph (a) (2) of Section V of Appendix A to 10 CFR Part 100, the OBE is taken one-half the maximum vibratory ground acceleration of the SSE (OBE=0.15 g PGA at the foundation level). The shape of the ground motion response spectrum for the OBE is defined so as to be completely adequate to the SSE ground motion response spectrum.

3.1.2 Seismic categorization for structures, systems and components

A. Original SSCs of Krško NPP are designed in accordance with ANSI-N18.2. Mechanical components and systems having the ANSI Safety Class 1, 2 or 3 designations, electrical components and systems having the IEEE-308 Class 1E designations [11], safety related instrumentation, and the structures housing the above-mentioned safety related systems and components, are classified as Seismic Category I. A list of the Seismic Category I structures and systems of Krško NPP is presented in USAR [16].

   Seismic Category I structures, systems and components must be designed to remain functional during and after the SSE. If a SSE occurs, all Seismic Category I structures, systems and components must withstand the effects of the SSE and assure the integrity of the reactor coolant pressure boundary, the capability to shut down the reactor and maintain it in a safe shutdown condition, and keep capability to prevent or mitigate the consequences of accidents which could result in potential off-site exposures comparable to the guideline exposures of Title 10 CFR Part 100.

B. Another group of SSC in terms of their importance to safety during and after an earthquake has to be seismically qualified as it is specified in RG 1.29 [2], paragraph C.2. These systems and components are defined seismic safety impact items and are those of which continued function is not required but which may have earthquake induced interaction (due to collapse) with the safety-related systems and components. It must be demonstrated that potential seismic effect due to the damage caused to non-safety related systems and components do not affect safety-related function or operator action. For such systems and components, the practice for design, installation and maintenance for nuclear applications are followed. In EAM MECL plant database, for the seismic safety impact items, the value of column »seismic« is set »II«.

C. In current revision of RG 1.29 [2], radioactive waste treatment, handling and disposal systems are not classified as Seismic Category I. Instead, RG 1.143 is recommended for use. RG 1.143 recommends qualifying such systems for earthquake ½ SSE. Note that in NEK, safety class components of the radioactive waste treatment, handling and disposal systems are designed for SSE.

3.1.3 Development of floor response spectra

Seismic loads for equipment are represented by Floor Response Spectra (FRS) curves, which represent maximum accelerations for various natural frequencies of single-degree-of-freedom systems. The FRS curves are calculated for all elevations and rooms of Seismic Category I structures where components under consideration are located. The account is taken for the effects of characteristics of the local soil conditions, soil-structure interaction, effects of dynamic characteristics of the plant structures including mass and stiffness, and the distribution of equipment within the plant.

FRS curves are calculated for horizontal and vertical directions of loading, different equipment damping values, and different seismic levels applicable to plant design basis (OBE, SSE) as well as increased seismic requirements (0.6 g PGA).

Methodologies that were used for development of FRS curves are described in USAR [16].

3.1.4 Consideration of increased seismic requirements for the systems and components in Main Complex and Essential Service Water Intake Structure

Artificial time histories generated in accordance with RG 1.60 [3] are basis for the seismic input to the structural model to develop the FRS in Krško NPP. In the methodology, which was used for the calculation of the FRS for the design basis conditions (OBE and SSE), the seismic input was determined using very conservative non-standard approach with the artificial ground surface time histories applied directly at the bottom of the foundation mat of Main Complex structures and Essential Service Water Intake Structure without any consideration of modification for depth below surface. This non-standard methodology introduced conservatism in estimating structural seismic response and FRS curves with respect to more realistic situation, where seismic ground motions at deeply buried foundation level are less amplified than that at the free surface.

In 2013, the FRS for earthquake with free-field peak ground acceleration of 0.6 g have been calculated for Main Complex structures, Essential Service Water Intake Structure to set forth the seismic input for the new built systems or plant's safety upgrade program. The free-field peak ground acceleration of 0.6 g was selected based on a probabilistic seismic hazard analysis for NEK's site [19] and roughly corresponds to the earthquake return period of 10 thousand years. In developing the FRS for free-field PGA of 0.6g, the credit of deconvolution of free surface time histories to the bottoms of Main Complex and Essential Service Water Intake Structure foundation mats was taken into account in order to more representatively calculate the seismic inputs to deeply buried buildings. Two sets of FRS for free-field PGA of 0.6 g have been developed: (1) the first set of FRS is based on the USAR soil damping, and (2) the second set of FRS is based on 20% limited composite modal damping in accordance with NUREG 0800, Section 3.7.2 applicable at a time [6]. The results showed that the first set of

FRS (based on the USAR soil damping) is approximately equivalent to the FRS calculated for the designed based earthquake (SSE). This is due to the fact that SSE artificial ground surface time histories, considered in the original SSE analysis, have not been modified for depth bellow surface. Therefore, the FRS, calculated based on the USAR soil damping, are prescribed for use in modifications on the SSC, while the second FRS set (which is based on 20% limited composite modal damping) is more stringent and is applicable to the seismic design of the systems and components under the Design Extension Condition (DEC) in the cases when these DEC systems and components are located either inside the Main Complex structures or Essential Service Water Intake Structure. In accordance with the definitions above, the FRS based on the USAR soil damping are designated "SSE FRS for modifications on existing SSC", while the FRS based on 20% limited composite modal damping are designated "Design Extension Condition FRS".

3.1.5 New facilities

The Bunkered Building 1 (BB1) was erected before general implementation of increased seismic requirements. In spite of that, BB1 is designed for the peak ground accelerations of 0.225g and 0.45 g. In case of BB1, the effect of embedment is negligible so that the deconvolution effect to define the input at the base of the foundation is also negligible. Therefore, the response spectra scaled to 0.225g and 0.45 g PGA were applied directly at the BB1 foundation. Seismic load for BB1 was defined based on engineering judgement at a time in order to guarantee seismic safety of BB1 at a reasonably high level. The FRS for earthquake with free-field PGA of 0.6 g based on 20% limited composite modal damping have been calculated for BB1 as well.

The Waste Manipulation Building is designed for peak ground acceleration of 0.6 g.

For Operating Support Centre, Spent Fuel Dry Storage and Bunkered Building 2 as well as safety related major equipment in-housed in BB2, the seismic design input is further extended in order to take approximately into account the uncertainties of the NPP Krško seismic hazard analysis [19]. It was required that the earthquake ground motion used for the seismic design of these buildings (and in-housed major DEC equipment) is defined with the design response spectrum for peak ground acceleration of $0.6\times1.3=0.78$ g. Multiplication factor of 1.3 on 0.6 g PGA was determined based on findings in [20]. The design peak ground acceleration for limit state of overturn of spent fuel casks inside Spent Fuel Dry Storage building is 1.2 g.

In the seismic design of Waste Manipulation Building, Operating Support Centre, Spent Fuel Dry Storage and Bunkered Building 2, a 20% limited composite modal damping was considered.

3.1.6 Selection of an appropriate seismic design input

OBE and SSE FRS for Main Complex (MC) structures, Essential Service Water Intake Structure (ESWIS), Diesel Generator Buildings (DGB) and RadWaste Storage building (RWS), FRS for Bunkered Building 1 (BB1) (for 0.225 g and 0.45 g PGA), and SSE FRS for modifications on existing SSC inside Main Complex (MC) structures and Essential Service Water Intake Structure (ESWIS) (free-field 0.6g PGA) are presented in USAR, Section 3.7. Design Extension Condition FRS (0.6g PGA with consideration of 20% limit on composite damping) are presented in USAR Section 20.

FRS curves are also part of technical specification SP-S702 for seismic analysis, testing and documentation of systems and components in Krško NPP [18]. Appendixes A to C contain FRS curves for MC structures, ESWIS, DGBs, RWS and BB1. FRS for design basis earthquake (0.15, 0.3g PGA) are presented in Appendix A, FRS for PGA of 0.6 g with consideration of USAR based damping are presented in Appendix B, and FRS for 0.6g PGA with 20% limit on composite damping are presented in Appendix C. FRS curves for other buildings are included in separated appendixes where each appendix is dedicated to a specific building.

Terms of use of Appendixes A to C of SP-S702 are as follows:

Appendix A, FLOOR RESPONSE SPECTRA CURVES FOR SAFETY RELATED BUILDINGS/STRUCTURES FOR OPERATING BASIS EARTHQUAKE (OBE) AND SAFE-SHUTDOWN EARTHQUAKE (SSE), contained in SP-S702, shall be applied in the case of:

- Seismic Category 1 buildings, which are part of the original plant scope (i.e., MC structures, DGBs, ESWIS, RWS) and embedment plates thereof. No re-qualification for higher seismic levels is required for these buildings and embedment plates (they remain qualified for OBE and SSE). Note that seismic fragility analyses [26] showed that High Confidence of Low Probability Factor (HCLPF) for all original structures exceed 0.6 g PGA.
- Procurement and qualification of spare parts or replacements of components, which were originally qualified for OBE and SSE. Included are alternate components, which may not be physically identical to the original but require an equivalency evaluation to ensure that they will perform the design function of the component they are replacing. Note that seismic input (loads) for qualification of replacements or alternate components of original components should be represented by an envelope of Appendix A FRS and original seismic accelerations reported in original qualification (analyses).
- Modifications of components or parts that are attached to or become a portion of larger component or system which is not subject of modification (for example, relays in existing panels/cabinets, etc.).
- Re-qualification of pipeline segments located between the tie-in point, where new pipeline is attached to the pipeline that is qualified for OBE and SSE, to the nearest anchorages on each side. These pipeline segments

remain qualified for OBE and SSE. It has been determined that no re-qualification for higher seismic levels is required in this case.
- Determination of operating basis seismic conditions (OBE) for all modifications on existing new systems and components or new DEC SSC that are to be constructed inside the MC structures, DGBs, ESWIS, RWS or will be attached on the Free Field Ground Surface.

Appendix A also contains FRS for BB1, although the BB1 building was designed for increased seismic loads comparing to original plant structures (seismic capacity of the BB1 structure in terms of PGA is higher than 0.6 g; SR equipment in-housed in BB1 is qualified for PGA of 0.6 g). The terms of use of BB1 FRS curves are the same as above stated for MC structures, DGBs, ESWIS and RWS except that they apply to the BB1.

Appendix B, FLOOR RESPONSE SPECTRA CURVES FOR SSE FOR MODIFICATIONS ON EXISTING SSCs ON MAIN COMPLEX STRUCTURES AND ESSENTIAL SERVICE WATER INTAKE STRUCTURE, contained in SP-S702, represent design-based earthquake loads for modifications on existing systems and components located in MC structures, ESWIS, or those attached to the Free Field Ground Surface. Appendix B shall be utilized for the following work:

- Analysis, design, and qualification of new systems and components that are part of modifications but not subjected to DEC. Included are connections (segments) from new systems and components to the tie-in points on the existing systems and components.
- Design of protective features for new systems and components that are part of modifications but not subjected to DEC in the cases in which new systems and components are designed in an area at which the non-seismically designed systems and components can represent potential "seismic two over-one" hazards.
- Design of new non-safety related systems and components that are part of modifications and which continued function is not required but may have earthquake induced interaction (due to collapse) with the safety-related systems and components.
- Procurement and qualification of spare parts or replacement parts of the components which had previously been qualified in accordance with Appendix B.
- Assessments of existing equipment (i.e., buildings, embedment plates, piping, electrical panels and cabinets, cable trays, conduits etc.), which are important for mechanical integrity and functionality of new safety-related components that are qualified in accordance with Appendix B.

Appendix C, FLOOR RESPONSE SPECTRA CURVES FOR MAIN COMPLEX STRUCTURES, ESSENTIAL SERVICE WATER INTAKE STRUCTURE, AND BUNKERED BUILDING 1 FOR DESIGN EXTENSION CONDITION (DEC), contained in SP-S702, represent design-based earthquake loads for new DEC systems and components for the cases when these DEC systems and equipment are located inside the MC structures, ESWIS or BB1 or are attached to the Free Field Ground Surface. Appendix C applies to the identical activities as noted above for the Appendix B FRS with an exception that they apply only to DEC systems and equipment.

3.2 Seismic load combinations, design features, codes and methodologies

For seismic design of Seismic Category I structures, systems and components loads from earthquakes shall be combined with:

a) plant loads during normal operation (e.g., thermal loads, pressure, self-weight, other sustained mechanical loads, electric loads), and
b) other plant conditions that may affect the safety function including effects caused by loads during either anticipated operational occurrences or accident conditions if these loads are caused by the earthquake or have a high probability of coinciding with the earthquake, which may be the case for the loads that occur sufficiently frequently and independently of an earthquake.

Mechanical systems, components and supports thereof are designed and analysed for normal, upset, emergency and faulted analysis conditions. Analyses conditions define correlation between load combinations, system operating conditions, plant conditions and allowable stress limits. Analysis conditions for original systems and components as specified in the equipment design specifications are related to the ASME B&PV Code, Section III, Edition 1971 [9]. The load from the OBE is combined with the occasional loads resulting from transients during normal plant conditions or those associated with upset plant condition that has a high probability of occurrence and which the design shall withstand without operational impairment. The load from the SSE is combined with occasional loads due to the transients existing during the faulted plant conditions associated with extremely low probability of occurrence whose consequences are such that the integrity and operability of the systems and components may be impaired.

According to ASME Code, the effects of cyclic loadings shall be taken into account. Five OBE occurrences in the life of the plant are assumed in the design of Balance of plant, while for the design of Nuclear Steam Supply Systems, the OBE is conservatively assumed to occur twenty times over the life of the plant. A time-history study indicates that ten maximum stress cycles for flexible equipment (natural frequencies less than 33 Hz) and five maximum stress cycles for rigid equipment (natural frequencies greater than 33 Hz) for each OBE occurrence shall be used for fatigue evaluation of systems and components [12]. The analyses or tests shall determine that the structural integrity of the equipment is maintained in combination with other applicable loads during the OBE. The analysis must show that OBE events followed by an SSE will not result in failure of the equipment to perform its safety function.

For the mechanical active components, it is generally required that the first natural frequencies are greater than 33 Hz, which is considered rigid frequency. The components having natural frequencies above rigid frequency do not resonate or amplify the seismic input motions. In cases such as rigid active Class 2 and 3 pumps and active Class 1, 2 or 3 valves, the equipment is allowed to be statically analysed for integrity and operability for the SSE acceleration coefficients as specified in equipment design specifications, provided that the resulting loads are equal or greater than postulated loads based on corresponding ZPA accelerations. In the case of valve design, the piping accelerations must be maintained to these levels. If the natural frequencies of pumps or valves are found to be below 33 Hz, an analysis shall be performed to determine the amplified input accelerations necessary to perform the static load equivalent analysis. Alternatively, dynamic analysis shall be performed for complex items to accurately predict the equipment's response resulting from a seismic disturbance. For active equipment whose operation is not affected by seismic accelerations (such as check valves without extended body structure), the operability is assured by equipment's design features and structural integrity.

Passive Seismic Category I equipment is qualified for integrity alone. Structural integrity may be checked in one of the following manners: (1) by analysis satisfying the stress criteria applicable to the particular piece of equipment according to ASME B&PV Code, Section III [9], or (2) by tests showing that the equipment retains its structural integrity under the simulated test environment.

Original Seismic Category I mechanical and electrical equipment, which is structurally to complex such that its response cannot be adequately predicted analytically (e.g., pump motors and valve's operators (motors), as well as corresponding auxiliary equipment) are qualified for integrity and operation during seismic event by meeting the requirements of IEEE 344, Edition 1971 [13]. In the evaluation of the Class 1E qualification test results, any sample equipment is considered to have failed when the equipment does not perform the Class 1E functions required by the equipment design specifications. The evaluation of the performance of relays and breakers during seismic testing requires documentation of the output effects. The criterion for output discontinuities is 2 ms chatter duration.

Seismic qualification by analysis, testing, or combined analysis and testing delineated in IEEE 344, Edition 2004 [15] and in Non-mandatory Appendix QR-A to ASME QME-1-2007 [10] endorsed by RG 1.100, Rev. 3, March 2009 [5] are acceptable methods for seismic qualifications of new Class 1E electrical equipment and new active mechanical equipment. The use of experience data (earthquake data) is not acceptable method to seismically qualify neither Class 1E electrical nor safety-related mechanical active equipment.

In addition to requirements of IEEE 344 or Appendix QR-A to ASME QME-1, the active mechanical equipment shall always comply with the requirements of the applicable construction code.

Reconciliation of changes to the design basis is required when replacement items (material, parts, and components) are produced, fabricated, or qualified to a later edition, addenda or section of the code than the original item.

3.3 Identification of the equipment

This seismic qualification program is applicable to Seismic Category I SSC. Those are these plant SSC which are necessary to assure (1) the integrity of the reactor coolant pressure boundary, (2) the capability to shut down the reactor and maintain it in a safe shutdown condition, or (3) the capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the guideline exposures of 10 CFR Part 100. Design basis and DEC Seismic Category I SSC have ANSI Safety Class 1, 2 or 3 or IEEE-308 Class 1E designations as specified in USAR, Table 3.2-1 [16].

Seismic qualification program is also applicable to the systems and components which are not safety related but may have earthquake induced interaction (due to collapse) with the safety-related systems and components as specified by RG 1.29 [2].

Seismic design input to the seismic qualification of design basis, modified and DEC SCC are defined in Section 3.1.5.

3.4 Pre-aging requirements in seismic qualification

Pre-aging must be addressed in seismic equipment qualification if it is estimated that aging mechanisms may cause seismic failure modes. The principal types of aging stressors are temperature, radiation, pressure, humidity, steam, submergence, chemicals, vibrations and earthquakes. Aging mechanisms are summarized below.

3.4.1 Temperature

As temperatures increase significantly above room temperature, physical, mechanical, electrical, and chemical properties of materials begin to change. Affected physical and mechanical properties can include failure strain, tensile strength, yield strength, shear strength, tensile and flexure modulus, creep and recovery, and impact resistance. Electrical property changes include changes in dielectric strength, conductor resistivity, insulator volume resistivity, dielectric constant, and dissipation factor. For organic materials, chemical reactions change properties gradually with prolonged exposure to heat. As a result, many material properties exhibit continued degradation with time. In general, higher temperatures cause accelerated degradation. The thermal aging of organic materials can affect hardness, brittleness, tensile strength, elongation, compressive strength, elastic modulus, insulation resistance, high-potential dielectric withstand strength, and other properties.

3.4.2 Radiation

There are four types of nuclear radiation in a nuclear power plant. Gamma is the principal type of radiation addressed in equipment qualification, although beta radiation is also considered. Alpha radiation, due to its extremely low penetrating power, plays no role in qualification. Neutron flux can affect electrical equipment in the vicinity of the reactor during power operation. Nuclear radiation causes changes in the atomic and molecular structure of materials. Radiation affects materials by two principal processes: physical displacement of atoms/electrons and ionization/excitation of atoms and molecules. Both processes occur for all materials, but the damage to metals and inorganics is principally through displacement effects. Damage to organic compounds occurs via chemical reactions resulting from the ionization/excitation processes.

3.4.3 Pressure

Pressure and rapid pressure changes can affect equipment by causing additional forces on parts and components. Excessive differential pressure, generally from high external pressure, can cause structural failure of sealed devices. Rapid pressurization can also cause structural failure of devices not fully sealed. The current-interrupting characteristics of electrical contacts can also be affected by varying pressure.

3.4.4 Humidity, Moisture and water spray

Humidity can directly cause degradation and can aggravate the effects of other stressors. Humidity causes corrosion and, at interfaces between dissimilar metals, galvanic effects. Corrosion can directly affect performance of metallic components. Electrical terminations and contact surfaces can be degraded by corrosive effects. The transfer of highly conductive corrosion products to other components can affect their electrical characteristics. Humidity can directly degrade organic materials, weakening their physical, mechanical, and electrical properties and distorting their shapes. Hygroscopic materials, such as polyimide, are particularly vulnerable. The absorption of water in many organic materials is both a physical and a chemical process. The presence of surface moisture significantly alters the resistivity and dielectric-withstand potential of insulating surfaces. Humidity can aggravate thermal and radiation effects in electrical insulating materials.

3.4.5 Steam

Exposure to high-temperature saturated steam combines temperature and humidity effects. The condensation of steam on colder surfaces results in rapid heating of the cooler surface (condensing heat transfer). This heat transfer is much more rapid than exposure to hot air. The condensed moisture can further degrade equipment by collecting on the equipment surface or accumulating in undrained areas. Qualification to steam conditions can also include exposure to superheated steam or a combination of saturated and superheated conditions.

3.4.6 Submergence

Submergence in water during accident conditions may promote the leaching of certain materials. Immersion in water also provides an immediate electrical ground plane that can affect electrical performance, particularly for partially damaged (for example, cracked) cables and splices. In addition, immersion in water may promote moisture intrusion into equipment, particularly if additional pressurization is caused by a significant hydrostatic pressure. Some organic materials may experience effect (like cracking) related to time, temperature, relative humidity or bending stresses.

3.4.7 Chemicals

Chemicals principally affect equipment by their presence in process fluid systems and their use in containment spray systems. Polymer degradation could release chemicals that attack surrounding components in elevated normal and accident temperatures and radiation environments. Chemicals can also react with materials, causing corrosion, the release of flammable or toxic gases, and other chemical reactions.

3.4.8 Vibration and Earthquakes

Vibration can cause fatigue and failure in both passive and active components. Vibration results in wear whenever it causes surface rubbing. It also promotes the loosening of parts, particularly fasteners, and rattling of loosely retained components (for example, cabinet doors). Another possible failure mechanism during vibration is cyclic fatigue damage. This may occur under high-level hydrodynamic or operating basis earthquake loads. Vibration stresses may be self-induced during equipment operation or transmitted to the equipment from external sources such as earthquakes. In normal service, vibration is generated by the operation of rotating and reciprocating machinery. Earthquakes produce random ground motion that is transmitted through buildings to all internal equipment and systems. The frequency range of this motion is typically between 1 and 33 Hz.

3.4.9 Equipment susceptible to aging effects

Based on the research performed by EPRI ([27-36]), the significant correlation between aging and seismic performances is confirmed for lead-acid batteries. Limited correlation exists for pressure switches, limit switches and rotary switches. The qualification requirements for aging preconditioning prior seismic test have to be defined for the following equipment if located in MILD environmental conditions:

- 1E Lead-Acid Batteries: Aging preconditioning must be performed prior seismic testing. Qualification (and certification) shall be performed per applicable RG 1.158, IEEE 344-1987 (or later edition) and IEEE 535-1986 (or later editions).
- 1E Pressure Switches: Aging preconditioning must be performed prior seismic testing if contact chattering during seismic event is defined a failure mode. Qualification (and certification) shall be performed per applicable IEEE 344-1987 (or later edition) and IEEE 323-1974 (or later edition).
- 1E Rotary Control/Selector Switches: Aging preconditioning must be performed prior seismic testing if contact chattering during seismic event is defined a failure mode. Qualification (and certification) shall be performed

per applicable IEEE 344-1987 (or later edition), IEEE 323-1974 (or later edition).

- Valve mounted 1E Limit Switches: Aging preconditioning must be performed prior seismic testing if contact chattering during seismic event is defined a failure mode. Qualification (and certification) shall be performed per applicable IEEE 344-1987 (or later edition), IEEE 323-1974 and/or 382-1972 (or later edition).

Regulatory Guides and associated IEEE standards by default require aging pre-conditioning for following types of equipment (aging preconditioning will be considered in test procedure):

- 1E Connection Assemblies: Qualification (and certification) shall be performed per RG 1.156, IEEE 344-1987 (or later edition) and IEEE 572-1985 (or later edition).
- SR/1E Valve Actuators: Qualification (and certification) shall be performed per RG 1.73, IEEE 344-1987 (or later edition) and IEEE 382-1972 (or later edition).
- 1E Electrical Penetration Assemblies: Qualification (and certification) shall be performed per RG 1.63, IEEE 344-1987 (or later edition) and IEEE 317-1972 (or later edition).
- 1E Battery Chargers and Inverters: Qualification (and certification) shall be performed per RG 1.210 and IEEE 650-2006

Above listed types of equipment shall be aging preconditioned prior seismic tests. More detailed description of the requirements for aging preconditioning for the above listed equipment are in Appendix I of this document. Additionally, aging preconditioning shall be performed also for other types of equipment if correlation between aging and seismic performances is recognized.

3.5 Qualification procedure

Qualification of the equipment shall include the following activities and services:

a) Specification of qualification requirements. Qualification requirements are contained in equipment design specifications that are under NEK responsibility. The content of design specification shall include (but is not limited to) the following:
    - Description of the equipment including components that are inside the equipment boundary and auxiliary components that are important for functionality of the equipment under consideration
    - Description of the equipment function and performance requirements
    - Service conditions and concurrent loads for operating modes that shall be considered during the qualification process
    - Codes, standards and regulatory requirements
    - Significant aging mechanisms
    - Acceptance criteria

b) A process to demonstrate that the equipment under consideration satisfies the qualification requirements by analysis, test, similarity, or a combination of these methods. Pre-aging effects have to be taken into account where applicable. Refer to the requirements specified in Krško NPP technical specification for analysis, testing and documentation for seismic qualification.

c) Evidence of successful completion of a qualification. The test is successful if tested equipment satisfies defined acceptance criteria. In case of qualification by analysis, the acceptance criteria are defined by codes and standards that are prescribed in technical specification for the equipment. In case of dynamic tests, the acceptance criteria are included in qualification procedure, which is prepared and issued by supplier of the equipment. The procedure is reviewed and approved by NEK.

d) Documentation and Archiving. For documentation refer to the requirements specified in Krško NPP technical specification for analysis, testing and documentation. Archiving of seismic qualification reports is responsibility of Engineering Service Division. Records Control Program, ED-3 [23], defines key archiving activities including receiving, storage, maintenance, replacement and/or supplement and disposal as required, of plant records submitted to the Document Center. Records Control Program also tracks records affected by plant design changes to assist in support of plant configuration management. In order to support design control management and determination of operation and maintenance history, the Records Control Program interfaces with the Master Component List (MECL) program. In MECL, qualification reports are indexed with the corresponding Seismic Category I plant SSCs. MECL is linked the Document Control Module (DCM) and Quality Record Management (QRM) databases.

e) Installation of equipment. SSCs are installed in accordance with Installation Package, which is part of design change documentation. Any changes in installation necessary to successful completion of seismic qualification are documented in seismic qualification report. Final installation is in accordance with installation package and qualification report.

During the qualification process to satisfy (b) above, the equipment shall not be degraded to the point so that it cannot perform its specified safety function.

In the case of seismic qualification by testing an appropriate table motion without introducing excessive ZPA levels shall be used.

Equivalency evaluation is required in cases when original component or part is no longer available or new component is not physically identical to the original to determine if replacement items are identical or alternative. Engineering

Service Procedure ESP-2.202 [21] provides instructions for performing an equivalency technical evaluation to ensure that replacement item will perform the design function of the item it is replacing. It shall be demonstrated that replacement items are equivalent in excitation and critical design characteristic to the previously qualified component it is replacing.

3.6 Maintenance of seismically qualified equipment

New equipment is supplied with manuals for installation, usage and maintenance. Manuals are part of turn over package which is submitted to the DCM (Document Control Module). Maintenance requirements are integrated in preventive and surveillance maintenance procedures (Preventive Maintenance (Mechanical), Preventive Maintenance (Civil), Preventive Maintenance (Electrical), Preventive Maintenance (I&C)) to assure compliance with original design and seismic qualification.

3.7 The content of the USAR

Krško NPP USAR [16] contains all information regarding the seismic qualification of mechanical and electrical equipment:

- Section 2.5 describes plant site characteristics, including geology and seismology.
- Section 3.7 presents the plant seismic design basis and inputs to the structural design and seismic qualification of the equipment, discusses the seismic system analysis applicable to structures and seismic subsystem analysis applicable to systems and components, and describes seismic control program.
- Section 3.8 describes seismic design of Seismic Category I structures (i.e., codes, standards and specifications, loads and load combinations, design and analysis procedures, and structural acceptance criteria).
- Section 3.9 describes methods and standards used for dynamic analysis and testing, including seismic analysis and testing of safety related mechanical systems and components.
- Section 3.10 specifies seismic analysis, codes and testing procedures for safety related instrumentation and electrical equipment.
- Section 20 presents, among other descriptions of DEC SSCs, the seismic input to qualification of DEC systems and components.

4.0 PARTICIPATING ORGANIZATIONS

Listed below are the principal divisions/departments which are directly involved in seismic qualification program:

ING.MOD	Engineering Service Division / Design Change Department
ING.DOV	Engineering Service Division / Licencing Department
ING.PDO	Engineering Service Division / Engineering Support for Long Term Operation
TO.VZ	Technical Division / Maintenance Department
SKV.QA	Quality and Nuclear Oversight / Quality Assurance

5.0 RESPONSIBILITIES

ENGINEERING DIRECTOR is responsible for establishing and implementing the Seismic Qualification Program.

SUPERINTENDENTS are responsible for coordination and supervision of activities on Seismic Qualification Program within their respective departments.

RESPONSIBLE ENGINEER of the Design Change Department or Maintenance Department is responsible for implementation of seismic qualification process for the equipment under consideration in accordance with the requirements set forth in Section 3 of this qualification program.

ING.MOD — ENGINEERING SERVICE DIVISION /
DESIGN CHANGE DEPARTMENT:
Involved in seismic qualification program through the process of implementing plant design changes related to Seismic Category I structures, systems and components and is responsible for preparation of design specifications, qualification equivalency evaluation and installation of new (and modified) equipment.

ING.DOV — ENGINEERING SERVICE DIVISION /
LICENCING DEPARTMENT:
Responsible for identification, preparation, and approval of USAR change package describing the Seismic Category I structures, systems and components.

ING.PDO — ENGINEERING SERVICE DIVISION /
ENGINEERING SUPPORT for LONG TERM OPERATION:
Has responsibility for the implementation of qualification requirements as a support to the procurement and configuration control process.

TO.VZ — TECHNICAL DIVISION /
MAINTENANCE DEPARTMENT:
Involved through the maintenance process and is responsible for preparation of equipment specifications, qualification, equivalency evaluation and installation of the replacement items.

SKV.QA — QUALITY AND NUCLEAR OVERSIGHT /
QUALITY ASSURANCE:
Participates with quality assurance plan in case of safety-related and seismic related SSC as per QD-1 [22] and is responsible for a review of the design and equipment specifications.

6.0 ADMINISTRATIVE IMPLEMENTING PROCEDURES

Administrative implementing procedures of Krško NPP are not applicable to this seismic qualification program.

All safety-related replacements items as well as new (and modified) structures, systems and components are seismically qualified in accordance with this seismic qualification program. Performance indicators that would be used to monitor and measure the program performance are not meaningful and are therefore not established.

7.0 TECHNICAL IMPLEMENTIVE PROCEDURES

7.1 Technical specifications

SP-S702, Technical Specification, Seismic Analysis, Testing, and Documentation

The specification SP-S702 sets forth the general criteria and procedures which shall be used to verify that Seismic Category I mechanical and electrical equipment for the Krško NPP can meet seismic performance requirements during and following the Operating Basis Earthquake (OBE), Safe Shutdown Earthquake (SSE), and Design Extension Conditions (DEC), and that seismic safety impact items can meet integrity requirements during SSE or DEC. SP-S702 shall be used for design assessment and qualification of safety related equipment and seismic safety impact items for seismic loads by analysis and/or testing methods for Krško NPP. This specification shall be used for revisions or changes to existing qualifications and for completely new qualifications.

7.2 Engineering Services Procedures (ESP)

Technical procedures of Krško NPP are not directly applicable to the seismic qualification program. Described below are the procedures that are indirectly involved in the seismic qualification program through the plant design change and procurement process.

ESP-2.201, Component/Part safety Classifications

Procedure EPS-2.201 provides instructions to determine safety class of components and parts based on the function during and post-accident of the subject item and plant licencing basis. Included are instructions for seismic design classification.

ESP-2.202, Replacement items technical evaluation

Procedure ESP-2.202 provides instructions for performing an equivalency evaluation for alternative items. Guidelines are given for determining critical design characteristics for alternate replacement items intended to provide those functions which assure that seismic qualification is properly performed.

ESP-2.206, Procurement, management and use of ASME code material, parts and components

Among other instructions to the procurement of ASME code materials, parts and components, the procedure ESP-2.206 provides direction for reconciliation of code edition. Reconciliation of changes to the design basis is required when replacement items (material, parts, and components) are produced, fabricated, or qualified to a later edition, addenda or section of the code than the original item. Included is requirement for reconciliation of changes to the seismic design and qualification basis codes and standards.

ESP-2.207, Specification and dedication of commercial grade items

Procedure ESP-2.207 provides instructions for dedicating commercial grade items intended for safety related applications and to meet the intent of 10CFR50. The process requires seismic technical evaluation of seismically sensitive replacement items.

ESP-2.601 Preparation of conceptual design packages (CDP) for the modification

Procedure ESP-2.601 establishes guidelines and instructions for preparation and documentation of principle/conceptual technical solution for the particular plant modification. In section 3 of the CDP, seismic requirements shall be defined for a particular design change in addition to standards, methodologies, operation and maintenance requirements, licensing requirements, standard engineering practices and other requirements (like environmental, internal and external events etc.).

ESP-2.602, Plant design modification

This procedure sets forth the requirements for preparing, processing and controlling modifications and design changes to power plant structures, systems, and components. It also provides the means for initiating needed changes to documents and programs resulting from modifications. The main purpose is to provide a consistent and transparent approach to modifications to assure updated configuration control of the plant and a sound basis for licensing following any plant modifications. In section 5.3.2 (Design Impact evaluation), the procedure gives instructions for evaluating impact of modification on selected program.

ESP-2.604, Design consideration, bases and inputs

Procedure ESP-2.604 establishes a method to identify design inputs utilized in the preparation of design specifications, analyses, calculations and design modifications. The design seismic loads and the impact of the design modification to the qualification of the existing or new equipment or component is assessed and described in design input continuation sheet.

ESP-2.617, Engineering services, material, and equipment technical specifications

Procedure ESP-2.617 establishes a method for preparation of technical and quality requirements to the procurement process of new item or engineering services. The requirements for seismic classification and qualification are part of the design specifications.

ESP-2.624, Design impact evaluation

Procedure ESP 2-624 determines whether the plant design modification affects or is affected by key plant design analyses or regulatory program requirements. If an evaluation identifies an impact of the selected plant's program, the impact evaluation analysis, calculation or detailed description shall be included in the modification process.

8.0 APPENDIX I: THE QUAILIFICATION REQUIREMENTS FOR AGING PRECONDITIONING PRIOR SEISMIC TESTING

8.1 Evaluation of EPRI documents

EPRI technical report 1021067, Nuclear Power Plant Equipment Qualification Reference Manual, Revision 1:

Report among other topics discusses qualification of equipment located in MILD environmental locations. It is important to determine for specific types of equipment whether subject aging mechanisms can affect seismic resistance.

EPRI and Westinghouse sponsored shake-table tests on side-by-side artificially aged and unaged components. The tests showed that for most small components such as motors, solenoid valves, relays, circuit breakers, capacitors, resistors, and integrated circuits, aging degradation does not affect seismic resistance. The lack of an aging-seismic correlation relates to the first criterion for significant aging mechanisms, since these aging mechanisms (producing mainly electrical degradation) do not promote seismic failure modes (mainly mechanical in nature). However, lead-acid batteries have been found to possess a strong aging-seismic correlation.

It is concluded that:

a) there is no correlation between aging and seismic performances for:
   - motors,
   - MCC components, control panels (relays, starters including contactors and overcurrent protection devices, circuit breakers),
   - electronic components (resistors, capacitors, integrated circuits),
   - solenoid valves,
   - other small electrical components.

b) there is correlation between aging and seismic performances for:
   - lead-acid batteries.

EPRI technical report NP-3326, Correlation Between Aging and Seismic Qualification for Nuclear Plant Electrical Components (Phase I research):

Based on the literature research and extensive testing program, the effects of aging on the ability of equipment to perform its safety function in a seismic environment were determined. The documented research provides information on existence of correlation between aging and seismic performances for various types of electrical and electronic equipment. Different aging effects like thermal aging, mechanical cycling and also radiation aging are addressed.

It is concluded that there is no correlation between aging and seismic performances:

- electronic components (resistors, diodes, integrated circuits, transistors, optical couplers, capacitors, printed circuits, IC sockets, transistor sockets, soldered connections, wire-wrapped connections and other electronic connections/interfaces),
- terminal blocks,
- capacitors,
- electric switching devices (circuit breakers, relays, time-delay relays, starters and current limiting fuses/fuse blocks).

EPRI technical report NP-5024, Seismic Ruggedness of Aged Electrical Components (Phase II research):

The objective of this technical report was to demonstrate generically that, for certain classes of equipment (equipment not included in NP-3326 research), aging does not degrade seismic performance. Similar to Phase I research (NP-3326), the report addressed effects of thermal aging, mechanical cycling and radiation aging. Test samples were selected which contained nonmetallic materials in critical functions, which are most age sensitive. Test samples were representative samples of a worst-case age sensitivity. The artificially aged equipment was aged to equivalent of 50 years. Fifty years was chosen to conservatively envelope the 40-year plant design life.

It is concluded that:

a) there is no correlation (or not statistically significant correlation) between aging and seismic performances for:
   - transformers,
   - solenoid valves,
   - RTDs,
   - pressure transmitters,
   - power supplies,
   - meters,
   - indicating lams and lamp sockets,
   - time delay relays,
   - contactors and motor starters,
   - electronic alarms,
   - motors,
   - electronics,
   - capacitors,
   - terminal blocks,
   - fuse blocks,
   - fuses,
   - circuit breakers,
   - indicators,
   - relays,
   - snap acting switches.

b) Differences in seismic performance of aged and unaged pressure switches, rotary switches and limit switches were noted only during the extremely high excitation levels at which testing was performed. These aged equipment types experienced contact chatter. The same report also states that specific equipment performances (limit switches) of aged equipment was not significantly different from unaged equipment at seismic levels less than 100% design based earthquake. The generic response spectrum applied in testing didn't represent a known environment for any component in a plant. Applied test response accelerations were approximately 5 – 10 times higher than typical accelerations of NEK Floor Response Spectrum.

It is concluded that aging preconditioning is not required for 1E MILD applications for pressure switches, rotary switches and limit switches – this conclusion is specifically applicable for applications where contact chattering during seismic event is not defined a failure. For all tested samples from this group of equipment types, aging was not observed to have an effect on the post seismic capability.

The following equipment was excluded from research:

- power cables, penetrations, valve actuators, which are usually qualified for HARSH environment;
- switchgear, motor control centers, control panels, diesel generators;
- batteries – industry consensus (IEEE Std. 535-1979) is that batteries are considered to be more susceptible to seismic performance degradation after aging and therefore, aging needs to be addressed prior to seismic qualification;
- recorders – a multitude of designs and applications limit the practicality of generic type testing.

8.2 Evaluation of various qualification Regulatory Guides

Safety Related electrical equipment is required to be qualified by IEEE Standard 323-1974 (or newer editions). Qualification includes demonstration that Safety Related equipment will perform properly during a seismic event, when equipment is in an aged condition. Various types of SR 1E classified equipment are ordered, qualified and certified to specific IEEE daughter standard which is prescribed in applicable NRC Regulatory Guide (see USAR section 3, Appendix 3A).

Following Regulatory Guides and applicable IEEE standards are applicable and define specific qualification requirements including aging preconditioning requirements (if applicable).

RG 1.40, Qualification of Continuous Duty Safety-Related Motors for Nuclear Power Plants; **IEEE 334-2006**, IEEE Standard for Qualifying Continuous Duty 1E Motors for Nuclear Power Generating Stations:

Regulatory Guide references IEEE 334 for qualifying 1E motors located in MILD and HARSH environment. It does not specify if aging/preconditioning is required before seismic test. IEEE 334 standard specifically states the following (Chapter 5.2): A qualified life is not required for motors that are located in a MILD environment and have no significant aging mechanisms. A design life shall be defined as an alternative to determining qualified life for motors and/or insulation systems in a mild environment where seismic is the only design basis event under consideration. The standard recognizes these capabilities and design features and does not require that an age conditioning subprogram be performed as part of a qualification program for motors in a mild environment. It is concluded that SR 1E Motors are not required to be aged before seismic test - there is no correlation between aging and seismic performances.

RG 1.63, Electric Penetration Assemblies in Containment Structures for Nuclear Power Plants; **IEEE 317-1972**, IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations:

Regulatory Guide refers to IEEE 317 for qualifying Electrical Penetration Assemblies. It does not distinguish between MILD and HARSH qualification. It does not specifically discuss aging. Standard IEEE 317 specifically requires preconditioning before seismic tests. Required preconditioning includes shipping and storage simulation, thermal operating cycle simulation, thermal age conditioning and radiation exposure simulation. Normally, electrical penetration assemblies are qualified for HARSH environment. It is concluded that electrical penetration assemblies (in containment structures) are required to be aged before seismic test - aging is a must operation in test sequence. Note that all NEK Electrical Penetration Assemblies are located in HARSH environment and included in EQ program (there is no penetrations located in MILD environment), which includes aging preconditioning in qualification test sequence.

RG 1.73, Qualification Tests for Safety-Related Actuators in Nuclear Power Plants; **IEEE 382-1972**, IEEE Standard for Qualification of Actuators for Power-Operated Valve Assemblies with Safety-Related Functions for Nuclear Power Plants:

Regulatory Guide refers to IEEE 382 for qualifying Safety-Related actuators. It does not distinguish between MILD and HARSH qualification. It specifies qualification activities such as aging (e.g., thermal, cycling, radiation, and vibration). Similarly, IEEE 382 standard does not distinguish between MILD and HARSH qualification. On the other hand, test sequence is specified in Chapter 6.3.2 where it is required to perform aging tests (normal thermal aging, normal pressurization cycle test, normal radiation aging test and vibration aging test) before seismic simulation test. Normally, SR valve actuators are qualified for HARSH environment. It is concluded that SR Actuators are required to be aged before seismic test – aging is a must operation in test sequence. Normally are 1E valve actuators also located in HARSH environment and therefore typically included in EQ program, which includes aging preconditioning in qualification test sequence.

RG 1.156, Qualification of Connection Assemblies for Nuclear Power Plants; **IEEE 572-1985**, IEEE Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations:

Regulatory Guide refers to IEEE 572 for qualifying 1E connection assemblies. It does not distinguish between MILD and HARSH qualification. It does not specifically discuss aging. IEEE 572 standard in Chapter 4 states that connection assemblies located in areas where the environment does not exceed the postulated normal and abnormal conditions during a DBE (except seismic) may not require pre-aging prior to seismic testing to establish a qualified life. It is concluded that 1E connectors are normally not required to be aged before seismic test – there is no correlation between aging and seismic performances. Note that NEK typically uses 1E connection assemblies which are environmentally qualified for HARSH environment. Aging preconditioning is part of qualification testing for these 1E connectors.

RG 1.158, Qualification of Safety-Related Lead Storage Batteries for Nuclear Power Plants; **IEEE 535-1986**, IEEE Standard for Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Stations:

Regulator Guide specifically requires that batteries qualified by test should be preconditioned by natural or artificial (accelerated) aging. IEEE 535 standard does not distinguish between MILD and HARSH qualification. It specifically requires aging prior seismic test (to qualify a battery, it shall be aged). It is concluded that SR 1E lead batteries must be aged before seismic test - there exists clear correlation between aging and seismic performances.

RG 1.210, Qualification of Safety-Related Battery Chargers and Inverters for Nuclear Power Plants; IEEE 650-2006, IEEE Standard for Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations:

Regulatory Guide refers to IEEE 650 for qualifying 1E Battery Chargers and Inverters. It does not distinguish between MILD and HARSH qualification. It does not specifically discuss aging. IEEE 650 specifically discuss aging requirements. It discusses components for which aging is or is not failure mechanism. Standard provides various methodologies to address aging requirements. Section 5.2 of IEEE 650 requires that components with significant aging mechanisms need not to be aged prior to the type test if they can be addressed by periodic in-service surveillance/maintenance. If the qualified life of the component is expected to be less than that of the equipment, then the component shall be aged to its qualified life (prior to the type test) based on either operating experience or component-life test data. Qualification procedure defined in IEEE 650-2006 provides alternative activities to preconditioning which address aging. It is concluded that aging preconditioning is not strictly required. Implementation of IEEE 650-2006 guidance will assure that aging will be adequately addressed in MILD qualifications.