ITER

International Technical Meeting on Seismic Safety of Nuclear Power Plants

***25*-26 March 2010**

Tivoli, Italy

"SEISMIC HAZARDS IN SITE EVALUATION – OF NUCLEAR INSTALLATIONS - IAEA SAFETY GUIDE DS 422 FINAL DRAFT"

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IAEA

International Atomic Energy Agency

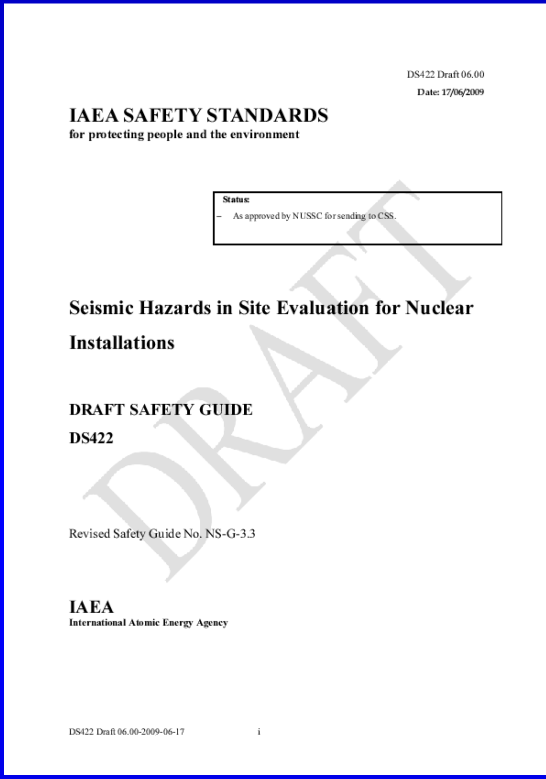
DS422 – BACKGROUND

The current version of the Safety Guide NS-G-3.3 on "*Evaluation of Seismic Hazards for Nuclear Power Plants*", was issued in 2002.

It has been extensively used and recognized by Member States.

DS422 – OBJECTIVES

- To provide guidance on evaluating seismic hazards at a nuclear installation site and, in particular, on how to determine: **(a) the vibratory ground motion hazards** in order to establish the design basis ground motions and other relevant parameters for both new and existing nuclear installations, and **(b) the potential for fault displacement** and the rate of fault displacement that could affect the feasibility of the site or safe operation of the installation at that site.
- It is intended for use by regulatory bodies and for operating organizations.



DS422 Draft 06.00
Date: 17/06/2009

IAEA SAFETY STANDARDS
for protecting people and the environment

Status:
– As approved by NUSSC for sending to CSS.

DRAFT

Seismic Hazards in Site Evaluation for Nuclear Installations

DRAFT SAFETY GUIDE
DS422

Revised Safety Guide No. NS-G-3.3

IAEA
International Atomic Energy Agency

DS422 Draft 06.00-2009-06-17 i

IAEA SAFETY STANDARDS ON SITE EVALUATION

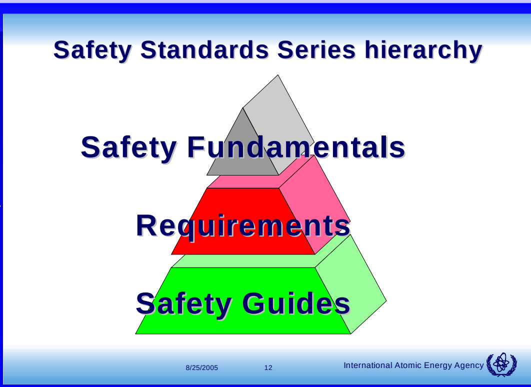
SITE EVALUATION

IAEA Safety Standards
for protecting people and the environment

Fundamental Safety Principles

Safety Fundamentals
No. SF-1

IAEA



IAEA SAFETY STANDARDS SERIES

Site Evaluation for Nuclear Installations

SAFETY REQUIREMENTS
No. NS-R-3

IAEA

REQUIREMENTS

SAFETY GUIDES

IAEA SAFETY STANDARDS SERIES
External Human Induced Events in Site Evaluation for Nuclear Power Plants
SAFETY GUIDE
No. NS-G-3.1

IAEA SAFETY STANDARDS SERIES
Dispersion of Radioactive Material in Air and Water and Consideration of Population Distribution in Site Evaluation for Nuclear Power Plants
SAFETY GUIDE
No. NS-G-3.2

IAEA SAFETY STANDARDS SERIES
Evaluation of Seismic Hazards for Nuclear Power Plants
SAFETY GUIDE
No. NS-G-3.3

IAEA SAFETY STANDARDS SERIES
Meteorological Events in Site Evaluation for Nuclear Power Plants
SAFETY GUIDE
No. NS-G-3.4

IAEA SAFETY STANDARDS SERIES
Flood Hazard for Nuclear Power Plants on Coastal and River Sites
SAFETY GUIDE
No. NS-G-3.5

IAEA Safety Standards
for protecting people and the environment
Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants
Safety Guide
No. NS-G-3.6

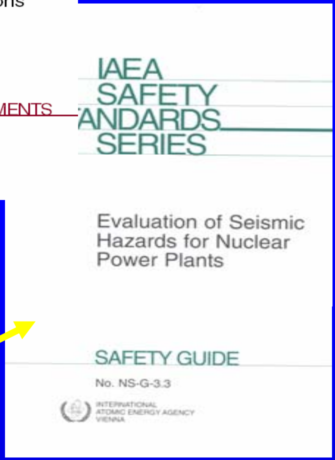
IAEA SAFETY STANDARDS
DRAFT
Volcanic Hazards in Site Evaluation for Nuclear Installations
DRAFT SAFETY GUIDE
DS405
IAEA

SG-S9
to be revised

DS422

IAEA SAFETY STANDARDS - SEISMIC SAFETY

SITE EVALUATION

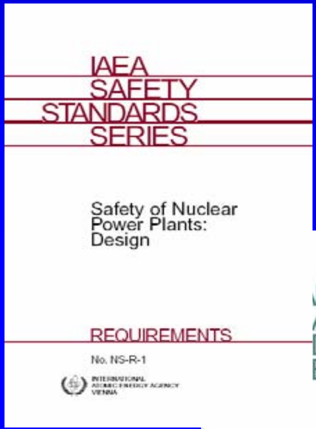


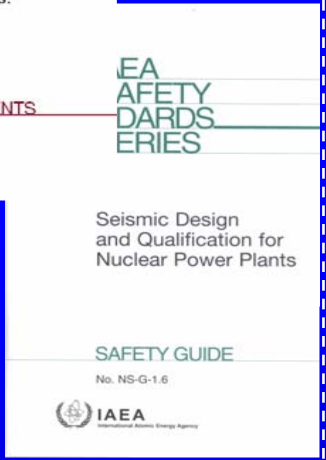
REVISION
DS422

Seismic Hazard NS-G-3.3

DESIGN

new installations



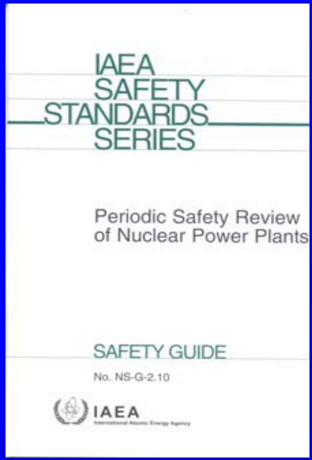


Seismic Design and Qualification NS-G-1.6

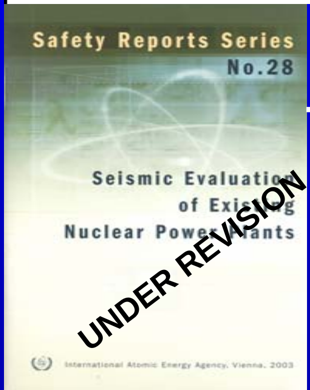
OPERATION

operating/existing installations

Evaluation of Seismic Safety - Existing NI NS-G-2.13



Periodic Safety Review



The complete lifetime of the installation *(t)*

Generation I – 50-SG-S1 (1979)

- Distinction between low and high seismicity countries (the Guide was valid for high seismicity countries)
- Confusion between probabilistic and statistical approaches
- Collection of varied and sometimes inconsistent national approaches
- Recommendation for generic response spectra (USNRC RG 1.60)

Generation II – 50-SG-S1 (Rev. 1, 1991)

- Seismotectonic modelling using a four-scale approach; regional, near regional, site vicinity, site area
- Applicable to all countries (no distinction between low/high seismicity)
- Seismogenic structures and zones of diffuse seismicity
- Deterministic with an option for probabilistic
- Minimum requirement for 0.1g design
- Clear definition of a “capable fault”
- Site specific response spectra

Seismic Hazard Evaluation – Scales of investigations

Geological, geophysical and geotechnical databases

Site vicinity

Objectives:
- **Neotectonic fault history**
- **Potential for surface faulting**

Near regional scale

Objectives:
- Detailed seismotectonic characterization
- Latest faults movements

Regional scale

Objectives:
- General geodynamic setting
- Characterization of geological features
- Delineation of seismogenic sources

Site area
(~1 km²)

Objectives:
- **Permanent ground displacement**
- **Dynamic properties of foundation materials**

5 km
(maps scale 1:5 000)

25 km
(maps scale 1:50 000)

>150 km
(maps scale 1:500 000)

A need for application of increased efforts

Generation III – NS-G-3.3 (2002)

- More emphasis on uncertainties
- More guidance on new topics of data generation such as paleoseismology
- More guidance on probabilistic seismic hazard analysis
- Decoupling of design response spectra and the hazard based response spectra (site specific)

Why we need a revision now?

- Feedback from seismic safety reviews since 2002 (about 30 missions) some involving PSHA
- Need to include other nuclear installations
- International experience on PSHA such as Pegasos AND PRP
- Recent strong motion recordings in California and especially Japan (exceeding 4g e.g.)
- Exceedance of hazard in Japan (Onagawa and K-K)
- Preparation for the new build

Why we need a revision now?

- Need for a better treatment of uncertainties in both deterministic and probabilistic analyses.
- Distinction between uncertainties that can be reduced through site specific investigations and those that are “imported”.
- Some recent PSHA studies have used approaches with significant human and financial resources. This is not always possible and alternative methodologies are needed to properly account for uncertainties. More attention is needed on organizational and management aspects.

Why we need a revision now?

- Evaluation of the potential for fault displacement in the site area or vicinity for existing nuclear installations using a probabilistic approach.

- This Safety Guide is included in the long-term structure of safety standards.

DS422 – CONTENTS

1. INTRODUCTION
2. GENERAL RECOMMENDATIONS
3. NECESSARY INFORMATION AND INVESTIGATIONS (DATABASE)
4. CONSTRUCTION OF A REGIONAL SEISMOTECTONIC MODEL
5. EVALUATION OF GROUND MOTION HAZARD
6. PROBABILISTIC SEISMIC HAZARD ANALYSIS
7. DETERMINISTIC SEISMIC HAZARD ANALYSIS
8. POTENTIAL FOR FAULT DISPLACEMENT AT THE SITE
9. DESIGN BASIS GROUND MOTION, FAULT DISPLACEMENT AND OTHER HAZARDS
10. EVALUATION OF SEISMIC HAZARDS FOR NUCLEAR INSTALLATIONS OTHER THAN NUCLEAR POWER PLANTS
11. PROJECT MANAGEMENT SYSTEM

REFERENCES / ANNEX-Examples PSHA/DEFINITIONS

DS422 – APPROVAL/DEVELOPMENT PHASES

- **Approval of DPP by CSS: May 2008**
- **Approval of Draft by NUSSC for submission to MSs: Oct 2008**
- **Experts Meeting-Tokyo, Japan: Feb 2009**
- **Comments received from MSs: April 2009**
- **3RD CSs to incorporate MSs comments: May 2009**
- **Approval by NUSSC/WASSC for submission to CSS: June 2009**
- **Endorsed by CSS: Oct 2009**
- Approval by Publications Committee: Dec 2009
- Target publication date: **Apr 2010**

DS422 - COMMENTS-NUSSC Meetings and MSs

- **Comments received during the development process:**

		N 25th	MSs	N 27th
1)	Austria	-	9	5
2)	Finland	1	2	-
3)	France	14	-	28
4)	Germany	33	26	-
5)	Hungary	-	3	-
6)	India	11	-	-
7)	Indonesia	-	5	-
8)	Japan	34	20	12
9)	Lithuania	-	8	-
10)	Mexico	-	1	-
11)	Morocco	-	3	-
12)	Pakistan	1	-	7
13)	Romania	-	22	-
14)	Russian Fed.-	-	57	-
15)	Spain	-	23	-
16)	Switzerland	-	12	7
17)	UK	-	30	16
18)	Ukraine	-	10	-
19)	USA	41	45	6
20)	WNA-CORDEL	-	6	-
21)	ENISS	6	9	-
Total:		141	291	81

MAIN ISSUES DISCUSSED DURING DEVELOPMENT AND APPROVAL PHASES

- **Recommended minimum value for the seismic hazard (para. 2.10).**
- **Graded approach (para. 1.8, last sentence).**
- **Use of source simulation for ground motion prediction models (current methodology in Japan / nearby faults).**
- **Logic tree and Monte Carlo methods (para. 6.5).**
- **“*Sanity*” check (para. 6.3), finally deleted.**

Example Paragraphs

The following slides provide some examples of the new or emphasized topics of the Generation IV Draft

Scope

1.10 For the purpose of this Safety Guide, existing NIs are those installations that are either (a) in the operational stage (including long term operation) or (b) in pre-operational stages for which the construction of structures, manufacturing, installation and/or assembly of components and systems, and commissioning activities are significantly advanced or fully completed.

1.11 The PSHA recommended in this Safety Guide also addresses the needs for PSAs conducted for NIs.

Uncertainties (site specific vs imported)

- 2.6. The general approach to seismic hazard evaluation should be directed towards reducing the uncertainties at various stages of the evaluation process in order to get reliable results driven by data. Experience shows that the most effective way of achieving this is to collect a sufficient amount of reliable and relevant data. There is generally a trade-off between the time and effort needed to compile a detailed, reliable and relevant database and the degree of uncertainty that the analyst should take into consideration at each step of the process.

Uncertainties

- 2.7 The collection of site specific data tends to reduce uncertainties. However, part of the data that is used indirectly in seismic hazard evaluation may not be site specific; for example, in many cases the strong motion data used to develop the attenuation relationships. There may, therefore, be a part of the uncertainty which is irreducible with respect to site specific investigations. This should be recognized and taken into consideration by including aleatory and epistemic uncertainties within the framework of seismic hazard evaluation.

Minimum seismic design

2.10 Uncertainties that cannot be reduced by means of site investigations (e.g. uncertainties arising from the use of ground motion attenuation relationships derived for other parts of the world) do not permit hazard values to decrease below certain threshold values. For this reason and regardless of any lower apparent exposure to seismic hazard, a minimum level should be recognized as the lower bound to any seismic hazard study performed for a nuclear power plant using this Safety Guide.

Minimum seismic design

2.11 In that regard, generically, this level should be represented by a horizontal free field standardized response spectrum anchored to a peak ground acceleration value of 0.1g. It should also be recognized that when geological and seismological data have deficiencies in comparison with what is recommended in Section 3, the value of 0.1g will not represent a sufficiently conservative estimate of the hazard. This fact should be properly represented in defining the design basis and re-evaluation parameters in Refs [5] and [6], respectively.

Current tectonic regime

3.12 …The tectonic history should be thoroughly defined for the current tectonic regime, the length of which will depend on the rate of activity. For example, the tectonic information through the Upper Pleistocene-Holocene may be adequate for interplate regions and through Pliocene-Quaternary for intraplate regions….

Seismic Instrumentation

3.30 To acquire more detailed information on potential seismic sources, it is recommended that a network of sensitive seismographs having a recording capability for micro-earthquakes be installed and operated…

3.32 Strong motion accelerographs should be installed permanently within the site area in order to record small and large earthquakes…

Seismic source simulation

5.14 In seismically active regions where data from ground motion caused by identifiable faults is available in sufficient quantity and detail, simulation of the fault rupture as well as the wave propagation path is a recommended procedure to follow. In cases where nearby faults contribute significantly to the hazard, this procedure may be especially effective…..

More guidance on PSHA

6.2 The smallest annual exceedance frequency of interest will depend on the eventual use of the PSHA (i.e., for design or for input to a seismic PSA) and can be as low as 10-8. which are appropriate for seismic PSA studies where the nuclear power plant has a very low Core Damage Frequency in relation to non-seismic initiators (e.g., innovative reactors). In such cases, additional caution should be exercised to assess the suitability and validity of the database, the seismotectonic model and the basis of the expert opinion, since uncertainties associated with these can significantly bias the hazard results.

DSHA – negative evidence

7.1 (4) (b) The maximum potential magnitude in a zone of diffuse seismicity which includes the NI site should be assumed to occur at some identified specific horizontal distance from the site. This distance should be determined on the basis of detailed seismological, geological and geophysical investigations (both onshore and offshore) with the goal of ensuring that there are no seismogenic structures within this distance, and therefore, that the related probability of earthquakes occurring therein is negligibly low….

DSHA Uncertainties

7.1 (5) Both aleatory and epistemic uncertainties should be appropriately taken into account at each step of the evaluation with the consideration that the conservative procedure described in (4) is already introduced to cover uncertainties and therefore double counting should be avoided.

Fault displacement

8.9 In view of the extensive site investigation required for a nuclear plant before construction, in general, the situation should not arise in which further consideration has to be given to the potential for fault displacement at the site of an existing installation. However, it may be the case that information comes to light that requires that a new assessment for fault displacement potential is made.

8.10 In such circumstances, efforts should first be made to acquire further data relating to the fault of concern. If, using the definition and the methodology described in paras. 8.3 to 8.8 does not provide a sufficient basis to decide conclusively that the fault is not capable, then, with the totality of the available data, probabilistic methods analogous to and consistent with those used for the ground motion hazard should be used to obtain an estimate of the annual probability of exceedance of various amounts of displacement at or near the surface.

Fault Displacement

8.2 Fault displacement can occur as a result of an earthquake (either directly or indirectly). It should be noted that tectonic displacements caused by folds (synclines and anticlines) are also included in the term “fault displacement”.

Capable Faults

8.4 …In highly active areas, where both earthquake data and geological data consistently reveal short earthquake recurrence intervals, periods of the order of tens of thousands of years (e.g. Upper Pleistocene-Holocene) may be appropriate for the assessment of capable faults. In less active areas, it is likely that much longer periods (e.g. Pliocene-Quaternary) are appropriate.

Fault displacement

8.11 The probabilistic fault displacement hazard analysis (PFDHA) should consider the following two types of possible displacements: (a) primary displacement, typically in the form of direct seismogenic fault rupture, and (b) secondary displacement (also called indirect or subsidiary displacement), typically associated with induced movement along pre-existing seismogenic slip planes (e.g., triggered slip on an existing fault or bedding plane from an earthquake on another fault) and non-seismogenic slip planes (e.g., localized fractures, weak clay seams, etc.). In addition, the displacement should generally be characterized as a three-dimensional displacement vector, and should be resolved into components of slip along the fault trace and along the fault dip, with resulting amplitude equal to the total evaluated slip (for given annual exceedance frequency and given fractile of hazard). The evaluation should adequately address epistemic uncertainties.

Response Spectra

9.8 It is possible to have low to moderate magnitude near field earthquakes that have a relatively rich high frequency content and short duration. Using the peak acceleration from such an earthquake to scale a broad banded standardized response spectrum could lead to an unrealistic response spectral shape. In such a case, it might be preferable to use multiple response spectra for design purposes to reflect properly the different types of seismic sources.

Project organization

11.2 A Project Plan should be prepared prior to, and as basis for, execution of the seismic hazard analysis project. The Project Plan should convey the complete set of general requirements of the project, including applicable regulatory requirements. …In addition to such general requirements, the SHA project plan should delineate the following specific elements: personnel and their responsibilities, work breakdown structure and project tasks, schedule and milestones, deliverables and reports, etc.

Present Status

- Receive further feedback from countries with PSHA experience (**Done Nov 2007)**
- Finalize the draft taking into consideration all feedback **(Done)**
- Present the draft in various international technical and scientific for a including EBP activities (also the Scientific Committee of the EBP) (**Done also in NEA WS in Lyon April 2008)**
- Present the draft and get feedback from MS in a meeting dedicated to DS 422 **(done in February 09 in Tokyo)**
- Go through the required IAEA process for publication (Steering Comm, NUSSC, CSS, etc) **(Done)**

READY FOR PUBLICATION

Emerging Issues

- Can DSHA and PSHA be treated within the same study?
- Are regional studies compatible with the 4 scaled approach?
- Is it reasonable to expect the regional studies and site specific studies to produce similar results? (differences in the details of database and larger sigmas for regional studies)

Thank you for your attention