

**The Swedish Nuclear Power Inspectorate's
Regulations concerning Safety in connection with
the Disposal of Nuclear Material and Nuclear
Waste**

**General Recommendations concerning
the Application of the Swedish Nuclear Power
Inspectorate's Regulations above**

Decided on October 24, 2001

(In all cases concerning interpretation the Swedish version takes precedence.)

The Swedish Nuclear Power Inspectorate's Regulations concerning Safety in connection with the Disposal of Nuclear Material and Nuclear Waste

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On the basis of 20 a and 21 §§ of the Ordinance (1984:14) on Nuclear Activities, the Swedish Nuclear Power Inspectorate has issued the following regulations and decided on the following general recommendations.

Application

1 § These regulations apply to facilities for the disposal of spent nuclear fuel and nuclear waste (repositories).

The regulations do not apply to facilities for landfill disposal of low-level nuclear waste in accordance with 19 § of the Ordinance (1984:14) on Nuclear Activities.

The regulations contain supplementary provisions to the Swedish Nuclear Power Inspectorate's regulations (SKIFS 1998:1) concerning Safety in Certain Nuclear Facilities.

Barriers and their Functions

2 § Safety after the closure of a repository shall be maintained through a system of passive barriers.

3 § The function of each barrier shall be to, in one or several ways, contribute to the containment, prevention or retention of dispersion of radioactive substances, either directly, or indirectly by protecting other barriers in the barrier system.

4 § A deficiency in any of the repository's barrier functions that is detected during the construction or operational surveillance of the repository and that can lead to a deterioration in safety after closure in addition to that anticipated in the safety report¹, shall be reported to the Swedish Nuclear Power Inspectorate without delay². The same applies if such a deficiency is suspected to occur or if the possibility that such a deficiency can occur in the future is suspected.

Design and Construction

5 § The barrier system shall be able to withstand such features, events and processes that can affect the post-closure performance of the barriers.

6 § The barrier system shall be designed and constructed taking into account the best available technique³.

7 § The barrier system shall comprise several barriers so that, as far as possible, the necessary safety is maintained in spite of a single deficiency in a barrier.

8 § The impact on safety of such measures that are adopted to facilitate the monitoring or retrieval of disposed nuclear material or nuclear waste from the repository, or to make access to the repository difficult, shall be analysed and reported to the Swedish Nuclear Power Inspectorate.

Safety Assessment

9 § In addition to the provisions of Chapter 4. 1 § of the Swedish Nuclear Power Inspectorate's Regulations (SKIFS 1998:1) concerning the Safety in Certain Nuclear Facilities, the safety assessments shall also comprise

¹ Cf Chapter 4. 2 § of the Swedish Nuclear Power Inspectorate's regulations (SKIFS 1998:1) concerning Safety in Certain Nuclear Facilities.

² Cf Chapter 2. 2 § of the Swedish Nuclear Power Inspectorate's regulations (SKIFS 1998:1) concerning Safety in Certain Nuclear Facilities.

³ Cf Chapter 2. 3 § of the Swedish Environmental Code.

features, events and processes which can lead to the dispersion of radioactive substances after closure, and such analyses shall be made before repository construction, before repository operation and before repository closure.

10 § A safety assessment shall comprise as long time as barrier functions are required, but at least ten thousand years.

Safety Report

11 § The safety report for a repository shall, in addition what is required in Chapter 4. 2 § of the Swedish Nuclear Power Inspectorate's Regulations (SKIFS 1998:1) concerning Safety in Certain Nuclear facilities, contain the information required in Appendix 1 of these regulations and which concerns the time after closure.

Prior to repository closure, the final safety assessment must be renewed and subjected to a safety review in accordance with Chapter 4. 3 § of the Swedish Nuclear Power Inspectorate's regulations (SKIFS 1998:1) Concerning Safety in Certain Nuclear Facilities and must be reviewed and approved by the Swedish Nuclear Power Inspectorate.

Exceptions

12 § The Swedish Nuclear Power Inspectorate may grant exceptions, if particular grounds exist, from these regulations if this can be achieved without departing from the purpose of the regulations and on condition that safety can be maintained.

These regulations enter into force on April 1, 2002.

On behalf of the Swedish Nuclear Power Inspectorate

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Appendix 1

The following shall be reported with regard to analysis methods:

- how one or several methods have been used to describe the passive system of barriers in the repository, its performance and evolution over time; the method or methods shall contribute to providing a clear view of the features, events and processes that can affect the performance of the barriers and the links between these features, events and processes,
- how one or several methods have been used to identify and describe relevant scenarios for sequences of events and conditions that can affect the future evolution of the repository; the scenarios shall include a main scenario that takes into account the most probable changes in the repository and its environment,
- the applicability of models, parameter values and other conditions used for the description and quantification of repository performance as far as reasonably achievable,
- how uncertainties in the description of the functions, scenarios, calculation models and calculation parameters used in the description as well as variations in barrier properties have been handled in the safety assessment, including the reporting of a sensitivity analysis which shows how the uncertainties affect the description of barrier performance and the analysis of consequences to human health and the environment.

The following shall be reported with respect to the analysis of post-closure conditions:

- the safety assessment in accordance with 9 § comprising descriptions of the evolution in the biosphere, geosphere and repository for selected scenarios; the environmental impact of the repository for selected scenarios, including the main scenario, with respect to defects in engineered barriers and other identified uncertainties.

GENERAL RECOMMENDATIONS

**The Swedish Nuclear Power Inspectorate's
General Recommendations concerning the
Application of the Regulations concerning
Safety in connection with the Disposal
of Nuclear Material and Nuclear Waste
(SKIFS 2002:1)**

General Recommendations:

Such general recommendations on the application of regulations that stipulate how someone can or should act in a certain respect.

[1 § Ordinance on Regulatory Codes (1976:725)]

The Swedish Nuclear Power Inspectorate's General Recommendations concerning the Application of the Regulations concerning Safety in connection with the Disposal of Nuclear Material and Nuclear Waste (SKIFS 2002:1)

Comments on Certain Paragraphs

On 1 §

According to 10 § of the Act (1984:3) on Nuclear Activities, the holder of a license to conduct nuclear activities is responsible for ensuring that the necessary measures are implemented to safely dispose of nuclear waste or nuclear material that are generated by operations and are not re-used.

The Act stipulates that the Government can relieve a licensee of the obligations of 10 § of the Act on Nuclear Activities⁴. One condition for being relieved of these obligations is that it should be at the same time established that the obligations can be fulfilled in a satisfactory manner by another licensee.

According to 14 § of the Act on Nuclear Activities, licensees retain their obligations to dispose of the nuclear waste and nuclear material in a safe manner until these obligations have been fulfilled. In accordance with 16 § of the Act on Nuclear Activities, SKI determines whether these obligations are fulfilled. With respect to a repository, this can be achieved after SKI has approved the closure of the repository. As soon as SKI can establish that a licensee has fulfilled its obligations with respect to a repository, the obligations to comply with the provisions in these regulations for the repository also cease.

The purpose of the regulations is to promote the safety of a repository so that the dispersion of radioactive substances is prevented or delayed. Thus, the

4 Cf 14 § of the Act (1984:3) on Nuclear Activities

safety intended by the regulations should be interpreted as the ability of a repository to prevent the dispersion of radioactive substances.

The regulations assume that operational surveillance and maintenance of a repository will be conducted in accordance with the provisions of the Swedish Nuclear Power Inspectorate's Regulations (SKIFS 1998:1) concerning Safety in Certain Nuclear Facilities until the time that the repository has been closed. Closure entails backfilling of tunnels and shafts up to the surface level, in accordance with the safety report for the facility (cf 9 and 11 §§). The backfilling of, for example, emplacement cavities that is conducted during the repository operating period (operational closure) is not considered to be closure in this respect.

The licensee of a repository should ensure that the measures implemented to comply with quality assurance, safety review, safety programme and periodic safety review requirements in accordance with SKIFS 1998:1 are also adequate with respect to post-closure safety.

On 2 and 3 §§

The containment of radioactive substances that is provided by individual barriers in a repository does not have to be as complete as, for example, that for a leaktight container. Porous materials can also function as barriers through a low permeability to water (low hydraulic conductivity) and substances dissolved in the water (high resistance to diffusion). Parts of the repository or materials in the repository can also be counted as barriers without necessarily comprising an obstacle to physical transport. For example, this could be the case for materials which contribute to providing a chemical environment that counteracts the transport of radioactive substances. Examples of this include a chemical environment that results in low solubility and a high sorption of radioactive substances. Barrier function is the term used to designate the different ways that barriers function and the ability of a barrier to protect and preserve the function of other barriers. In this way, a single barrier can have several barrier functions and several barriers can have the same or similar barrier functions.

Barriers in a repository can be engineered (man-made) or natural.

Examples of engineered barriers include containers for nuclear material and nuclear waste, concrete structures and backfill materials made of clay, sand or concrete. Examples of engineered barrier functions include mechanical

protection of other barriers, complete containment of radioactive substances in leaktight containers, resistance to water flow and resistance to the diffusion of various substances as well as chemical properties that protect other barriers or contribute to the prevention of the dispersion of radioactive materials.

The geological formation at the repository site can itself be a natural barrier. The formation (such as rock) can have several barrier functions, for example, the isolation of the nuclear waste from the environment at the surface, including rendering human intrusion difficult, the limitation of the damaging impact of air and water on engineered barriers, the limitation of hydraulic flux in the repository and the contribution to a favourable chemical environment inside and in the vicinity of the repository which counteracts the transport of radioactive substances in the groundwater.

The barriers or barrier functions that are necessary in a repository are dependent on the radioactive inventory of the repository, on the other substances that affect the safety performance of the barriers and on the design and location of the repository. These needs and how they are satisfied by the barrier system should be clearly described in the safety report for the repository, in accordance with 9-11 §§.

The repository site and repository depth should be chosen so that the geological formation provides adequately stable and favourable conditions to ensure that the repository barriers perform as intended over an adequate period of time. The conditions intended primarily concern temperature-related, hydrological, mechanical (for example, rock mechanics and seismology) and chemical (geochemistry, including groundwater chemistry) factors. Furthermore, the repository site should be located at a secure distance from natural resources exploited today or which can be exploited in the future.

On 4 §

In accordance with the provisions of Chapter 4. 4 § of SKIFS 1998:1 it is the responsibility of the licensee, as long as the repository is in operation, to continuously keep informed of the conditions of importance to the assessment of repository safety, also after closure. If, during the continuous analysis and safety assessment, a degradation in barrier performance compared to that stated in the safety report (in accordance with Chapter 4. 2 § of SKIFS 1998:1) should be detected or suspected after repository closure, the Swedish Nuclear Power Inspectorate should be notified without delay apart from the time required to collect and process the necessary information.

On 6 §

In this context, construction means excavation of geological formations (such as rock or soil layers), the construction of facilities above or below ground and the manufacturing, application, control and testing of engineered barriers.

The use of the best available technique means that the technology, from a technical and economic standpoint, shall be industrially feasible for application within this area. This means that the technique must be available and not merely at the experimental stage. However, the technique does not have to be available in Sweden (see bill 1997/98:45, Part I, p. 215 ff for details).

On 7 §

The provision of this paragraph can be fulfilled by showing, in the safety assessment prepared in accordance with 9 §, how different types of deficiencies in barriers and barrier performance cannot on their own lead to unacceptable risks from the dispersion of radioactive substances from the repository. It should be possible to show how this dispersion is limited by other barriers and barrier functions besides those affected by the deficiencies that have arisen. In order for the provision to be fulfilled, several barriers may be necessary, especially with respect to the final disposal of spent nuclear fuel.

On 8 §

Measures can be adopted during construction and operation for the possible monitoring of a repository's integrity and its barrier performance after closure. Such measures can also be adopted to maintain safeguards. Measures can also be adopted during construction and operation with the primary aim of facilitating the retrieval of deposited nuclear materials and nuclear waste from the repository, during the operating period or after closure. Furthermore, measures can be adopted to make intrusion into the repository difficult or to caution against intrusion. The safety report for the facility, in accordance with 9 § should show that these measures either have a minor or negligible impact on repository safety, or that the measures result in an improvement of safety, compared with the situation that would arise if the measures were not adopted. These provisions are in agreement with the provisions of the Swedish Radiation Protection Authority's regulations SSIFS 1998:1.

On 9 § and Appendix

The safety of a repository after closure is analysed quantitatively, primarily by estimating the possible dispersion of radioactive substances and how it

is distributed in time for a relevant selection of future possible sequences of events (scenarios). The purpose of the safety assessment is to show, inter alia, that the risks from these scenarios are acceptable in relation to the requirements on the protection of human health and the environment issued by the Swedish Radiation Protection Authority (SSIFS 1998:1). The safety assessment should also aim at providing a basic understanding of the repository performance on different time-periods and at identifying requirements regarding the performance and design of different repository components.

A *scenario* in the safety assessment comprises a description of how a given combination of external and internal conditions affect repository performance.

Two groups of such conditions are:

- external conditions in the form of features, events and processes which occur outside repository barriers; this includes climate changes and their consequential impact on the repository environment, such as permafrost, glaciation, land subsidence and elevation as well as the impact of human activities,
- internal conditions in the form of features, events and processes which occur inside the repository; this includes properties, including defects, of nuclear material, nuclear waste and engineered barriers and related processes as well as properties of the surrounding geological formation and related processes.

Based on an analysis of the probability of occurrence of different types of scenarios in different time-periods, scenarios with a significant impact on repository performance should be divided into different categories:

- main scenario,
- less probable scenarios,
- other scenarios or residual scenarios.

The main scenario should be based on the probable evolution of external conditions and realistic, or where justified, pessimistic assumptions with respect to the internal conditions. It should comprise future external events which have a significant probability of occurrence or which cannot be shown to have a low probability of occurrence during the time covered in the safety assessment. Furthermore, it should be based, as far as possible, on credible assumptions with respect to internal conditions, including substantiated assumptions concerning the occurrence of manufacturing defects and other

imperfections, and which allow for an analysis of the repository barrier functions (it is, for example, not sufficient to always base the analysis leaktight waste containers, even if this can be shown to be the most probable case). The main scenario should be used as the starting point for an analysis of the impact of uncertainties (see below), which means that the analysis of the main scenario also includes a number of calculation cases.

Less probable scenarios should be prepared for the evaluation of scenario uncertainty (see also below). This includes variations on the main scenario with alternative sequences of events as well as scenarios that take into account the impact of future human activities such as damage inflicted on barriers. (Damage to humans intruding into the repository is illustrated by residual scenarios, see below). The analysis of less probable scenarios should include analyses of such uncertainties that are not evaluated within the framework of the main scenario.

Residual scenarios should include sequences of events and conditions that are selected and studied independently of probabilities in order to, inter alia, illustrate the significance of individual barriers and barrier functions. The residual scenarios should also include cases to illustrate damage to humans intruding into the repository as well as cases to illustrate the consequences of an unclosed repository that is not monitored.

The lack of knowledge and other uncertainties in the calculation conditions (assumptions, models, data) is denoted in this context as **uncertainties**⁵. These uncertainties can be classified as follows:

- scenario uncertainty: uncertainty with respect to external and internal conditions in terms of type, degree and time sequence,
- system uncertainty: uncertainty as to the completeness of the description of the system of features, events and processes used in the analysis of both individual barrier performance and the performance of repository as a whole,
- model uncertainty: uncertainty in the calculation models used in the analysis,
- parameter uncertainty: uncertainty in the parameter values (input data) used in the calculations,
- spatial variation in the parameters used to describe the barrier performance of the rock (primarily with respect to hydraulic, mechanical and chemical conditions).

⁵ This explanation of the term *uncertainty* only makes sense in Swedish where the same word (säkerhet) is used to denote both *certainty* and *safety*.

There are often no clear boundaries between the different types of uncertainties. The most important requirement is that the uncertainties should be described and handled in a consistent and structured manner.

The evaluation of uncertainties is an important part of the safety assessment. This means that uncertainties should be discussed and examined in depth when selecting calculation cases, calculation models and parameters values as well as when evaluating calculation results.

The assumptions and calculation models used should be carefully selected with respect to the principle that the application and the selection should be justified through a discussion of alternatives and with reference to scientific data. In cases where there is doubt as to a suitable model, several models should be used to illustrate the impact of the uncertainty involved in the choice of model.

Both deterministic and probabilistic methods should be used so that they complement each other and, consequently, provide as comprehensive a picture of the risks as possible.

The probabilities that the scenarios and calculation cases will actually occur should be estimated as far as possible in order to calculate risk. Such estimates cannot be exact. Consequently, the estimates should be substantiated through the use of several methods, for example, assessments by several independent experts. This can be done, for example, through estimates of when different events can be expected to have occurred.

Based on scenarios that can be shown to be especially important from the standpoint of risk, a number of *design basis cases* should be identified. Together with other information, such as on manufacturing method and controllability, these cases should be used to substantiate the design basis such as requirements on barrier properties.

Particularly in the case of disposal of nuclear material, for example spent nuclear fuel, it should be shown that criticality cannot occur in the initial configuration of the nuclear material. With respect to the redistribution of the nuclear material through physical and chemical processes, which can lead to criticality, it should be shown that such a redistribution is very improbable.

The result of calculations in the safety assessment should contain such information and should be presented in such a way that an overall judgement of safety compliance with the requirements can be made.

The validity of assumptions used, such as models and parameter values, should be supported, for example through the citing of references to scientific literature, special investigations and research results, laboratory experiments on different scales, field experiments and studies of natural phenomena (natural analogues).

Scientific background material and expert assessments should be documented in a traceable manner by thoroughly referring to scientific literature and other material.

On 10 §

The time-period for which safety has to be maintained and demonstrated should be a starting point for the safety assessment. One way of discussing and justifying the establishment of such a time period is to start from a comparison of the hazard of the radioactive inventory of the repository with the hazard of radioactive substances occurring in nature. However, it should also be possible to take into consideration the difficulties of conducting meaningful analyses for extremely long time-periods, beyond one million years, in any other way than through showing how the hazard of the radioactive substances in the repository declines with time.


In the case of a repository for long-lived waste, the safety assessment may have to include scenarios which take into account greater expected climate changes, primarily in the form of future glaciations. For example, the next complete glacial cycle which is currently estimated to be on the order of 100,000 years, should be particularly taken into account.

In the case of periods up to 1,000 years after closure, in accordance with the regulations of SSIFS 1998:1, the dose and risk calculated for current conditions in the biosphere constitute the basis for the assessment of repository safety and its protective capabilities.

Furthermore, in the case of longer periods, the assessment can be made using dose as one of several safety indicators. This should be taken into account in connection with the calculations as well as the presentation of analysis results. Examples of such supplementary safety indicators are the concentrations of

radioactive substances from the repository which can build up in soils and near-surface groundwater or the calculated flow of radioactive substances to the biosphere.

(Compare SSIFS 1998:1 and SSI's comments on those regulations).



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