

National Nuclear Regulator



Requirements Document

No.	Title	Rev.
RD-0024	Requirements on Risk Assessment and Compliance with Principal Safety Criteria for Nuclear Installations	0

Approved:

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Acting Chief Executive Officer

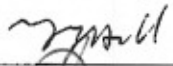

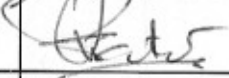
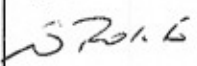
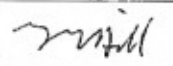
Date of issue: 05/08/2008

Revision Date:

Unrestricted

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REVISION HISTORY

Rev No.	Date Approved	Nature of Revision	Prepared by
3	27/07/2001	First issue Supersedes LD-1091 Rev 3	T Hill

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1 INTRODUCTION

Regulations [1] promulgated in terms of the National Nuclear Regulator Act, Act No. 47 of 1999 [2], lay down safety standards and regulatory practices applicable to holders of nuclear installation licences. These safety standards include inter alia principal radiation protection and nuclear safety requirements such as risk criteria and dose limits applicable to members of the public and workers.

2 PURPOSE

This Requirements Document (RD) specifies the principal safety criteria, in accordance with the regulations [1], and the requirements regarding demonstration of compliance with these criteria in respect of nuclear installations.

3 OBJECTIVES

The objectives of this Requirements Document are to specify the principal safety criteria applicable to nuclear installations, and requirements in terms of compliance to these criteria.

4 SCOPE

This Requirements Document applies to nuclear installations, and provides the NNR requirements on assessment of nuclear installations against the principal safety criteria relating to risk criteria, and dose limits for normal operating conditions, applicable to members of the public and workers. Dose limits resulting from normal operating conditions stipulated in the regulations [1] which are not referred to in this RD are specified in the nuclear installation licences on a case-by-case basis.

5 DEFINITIONS

5.1 Terms defined in references [1] and [2]

In this RD any word or expression to which a meaning has been assigned in references [1] and [2] shall have the meaning so assigned.

5.2 Terms not defined in references [1] and [2]

Many terms and definitions given in this RD are taken from ISO 9001:2000 [3] and are therefore not repeated in this section. Only additional terms, definitions and abbreviations are explained.

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5.3 Risk Management

A process to limit the risk impact of activities performed at the installation (eg maintenance).

6 GENERAL REQUIREMENTS

- (1) A methodology to demonstrate compliance with the Principal Safety Criteria, as given in Appendix 1, must be documented and implemented.
- (2) The process referred to in requirement (1) must take into consideration the impact of any change or issue (eg modifications), and identify those changes or issues requiring submission of a safety assessment to the NNR.
- (3) A system of risk management to ensure that the nuclear installation is operated in conformance with the Principal Safety Criteria must be implemented.
- (4) All activities with regard to safety analysis and risk management must be subjected to periodic review at a frequency acceptable to the NNR.
- (5) All activities with regard to safety analysis and risk management must be conducted in accordance with recognised standards and practices as available.

7. SPECIFIC REQUIREMENTS TO DEMONSTRATE COMPLIANCE WITH PRINCIPAL SAFETY CRITERIA

7.1 Identification of Normal Operations and Accident Conditions

- (6) All operating conditions and events which may give rise to risk to the population or workers as a result of exposure to radioactive material on site or released from the nuclear installation must be identified. All relevant sources of radioactive material, release mechanisms, release pathways, components, systems, processes, activities and events which could impact on risk must be identified. A screening analysis may be used to eliminate those conditions which are insignificant in terms of their cumulative effect in relation to the Principal Safety Criteria.
- (7) All the operating conditions and events identified in accordance with requirement (6) must be categorised either as *normal operations* or *accident conditions*.

Normal operations should include all conditions which are expected to occur during the lifetime of the nuclear installation and should include hypothetical events with expected mean frequencies greater than 0.01 per annum.

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7.2 Risk to the Public Due to Accident Conditions

- (8) For the *accident conditions* identified in accordance with section 7.1, the following must be determined:
- The average population risk, including the bias against larger accidents, due to the nuclear installation
 - The maximum individual risk due to all nuclear installations.

7.3 Dose to the Public Due to Normal Operations

- (9) The highest individual annual effective dose to the average representative of the critical group, due to the nuclear installation, from *normal operations* identified in accordance with section 7.1, must be determined [1].

7.4 Risk to Workers Due to Accident Conditions

- (10) For the *accident conditions* identified in accordance with section 7.1, the maximum and average annual risk to the workers due to all nuclear installations must be quantified.

7.5 Dose to Workers Due to Normal Operations

- (11) The average annual effective occupational dose and maximum individual annual effective occupational dose, due to all nuclear installations, from *normal operations* identified in accordance with section 7.1, must be determined [1].

7.6 Accident Frequencies

- (12) The calculation of the frequencies of the operating conditions and events referred to in section 7.1 must take into account the following factors as appropriate:
- scheduled activities (eg maintenance, outages, modifications);
 - actual events (eg occurrences, unscheduled activities);
 - all relevant configurations (eg system lineups);
 - operational states (eg operation and shutdown states);
 - activities performed on site (eg fuel handling and storage);
 - internal and external events (eg fire, flooding, sabotage);
 - degradation and ageing;
 - performance/conformance of systems, structures and components.

7.7 Statistical Considerations

- (13) With regard to the calculation of risk due to *accident conditions* in accordance with sections 7.1, 7.2, 7.4 and 7.6, the mean value of the risk would be acceptable. Justification for the mean values must however be provided. The use of an

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uncertainty analysis or a sensitivity analysis in this regard is an acceptable approach.

7.8 Sources of Data

- (14) All sources of data relevant to the risk and dose calculations referred to in sections 7.1 to 7.6 must be identified, including generic data and plant specific data on, inter alia:

- Reliability data
 - Component
 - System
 - Human
- Fragility data
 - Civil
 - Mechanical
 - Electrical
- Event frequencies
 - Internal events
 - External events
- Parameters used in accident analysis modelling
 - Plant engineering description
 - Material properties
 - Chemical properties
- Common cause data
- Data used in environmental impact modelling

7.9 Data Acquisition and Analysis

- (15) A documented process to obtain plant-specific data, for items identified in section 7.8 must be implemented. All appropriate sources of information for the processing of this data for use in the risk analysis must be identified. A means to provide validation of the data used must be implemented. This may include trending of occurrences, test failures, the use of safety indicators, and/or accident precursor analysis. Where applicable, the process used for deriving reliability data from generic data and plant specific data must be documented.

8. PROCESS DOCUMENTATION

- (16) The activities in respect of this Requirements Document must be carried out using written, authorised procedures. These procedures must address the following areas:
- controls on changes to the PRA and/or risk management system;
 - data acquisition, validation and control;

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- identification of changes that require NNR approval and the approval cycle for such changes;
- computer hardware and software quality assurance;
- testing and validation of computational models and associated hardware;
- information security aspects, including access control to the database, software and hardware;
- training of risk assessors.

9. QUALITY ASSURANCE

- (17) All activities relevant to conformance to this Requirements Document must be conducted in accordance with a quality management system in compliance with the conditions of licence.
- (18) All activities in respect of this Requirements Document must be carried out by technically competent personnel and accepted by designated individuals.

10. REFERENCES

- [1] Regulations R 388 (28 April 2006) in terms of Section 36, read with Section 47 of the National Nuclear Regulator Act (Act No. 47 of 1999) on Safety Standards and Regulatory Practices
- [2] National Nuclear Regulator Act, Act No. 47 of 1999
- [3] ISO 9001:2000 Series
- [4] LD-1091 Requirements on licensees of nuclear installations regarding risk assessment and compliance with the Safety Criteria of the NNR (Revision 3)

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APPENDIX 1: PRINCIPAL SAFETY CRITERIA

The principal safety criteria refer to limits on the annual risk/dose to members of the public and workers due to exposure to radioactive material as a result of *accident conditions/normal operations*.

These limits are discussed in more detail and summarised in the table below.

Risk to Members of the Public Due to Accident Conditions

The limit of 10^{-7} fatalities per person per annum refers to the average risk to the national population due to all nuclear installations in the South Africa. This figure is based on comparison with other risks imposed on society by industry and various natural disasters. Based on a projection of ten nuclear sites in South Africa during the operational lifetime of the existing nuclear installations, a factor of 0.1 is applied to this figure to obtain the risk limit of 10^{-8} fatalities per person per annum for each site. The risk to the public is to be computed using projections on the relevant site-specific data (eg demographic, agricultural, farming practices, food consumption data).

A peak-to-average ratio of 50 is used to obtain an acceptable variation in risk in the country. This gives an upper risk limit for an individual of 5×10^{-6} fatalities per annum applicable cumulatively to all nuclear installations in the country.

A bias against larger accidents is imposed by the requirement that the annual average frequency $f(N)$ of accident conditions resulting in more than N fatalities be less than the risk aversion criterion $f(N)$ given in Appendix 2.

Risk to Workers Due to Accident Conditions

Similar considerations apply to the risk due to *accident conditions* to the occupationally exposed workers, resulting in a limit on the average risk of 10^{-5} fatalities per annum, and a maximum individual risk of 5×10^{-5} fatalities per annum, based on a maximum peak to average value of 5 for the workers. Both criteria apply cumulatively to all nuclear installations in South Africa.

Dose to Members of the Public Due to Normal Operations

Whereas for *accident conditions* the corresponding safety criteria relate directly to risk as determined using a probabilistic risk assessment methodology, the relevant criteria for *normal operations* refer directly to deterministic dose levels to the average representative of the critical group [1].

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Dose to Workers Due to Normal Operations

Similarly for the workers, the relevant criteria for *normal operations* refer directly to deterministic dose levels to the average representative of the critical group [1].

	NORMAL OPERATIONS	ACCIDENT CONDITIONS
ASSESSMENT TYPE	DETERMINISTIC	PROBABILISTIC
PUBLIC		
Average Annual Population Risk	Risk to be controlled to a trivial level by application of the ALARA principle.	10^{-8} fatalities person ⁻¹ year ⁻¹ site ⁻¹ (one fatality per person per one hundred million year per site) ⁽¹⁾
Maximum Annual Individual Risk	$250 \mu\text{Sv year}^{-1} \text{ site}^{-1}$ individual dose limit for the average representative of the critical group.	5×10^{-6} fatalities year ⁻¹ (one fatality per two hundred thousand year).
WORKERS		
Average Annual Risk to Workers	Risk to be controlled by the application of the ALARA principle. An ALARA target for the annual average individual dose is required which must not exceed 4 mSv.	10^{-5} fatalities person ⁻¹ year ⁻¹ (one fatality per person per one hundred thousand year).
Maximum Annual Individual Risk to Workers	The occupational exposure of any worker shall not exceed the following: - An average effective dose of 20 mSv per year averaged over five consecutive years. - A maximum effective dose of 50 mSv in any single year.	5×10^{-5} fatalities year ⁻¹ (one fatality per twenty thousand year).

⁽¹⁾ Subject to a maximum of 10 nuclear installation sites in South Africa.

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APPENDIX 2: RISK AVERSION CRITERION

A bias against larger accidents is imposed by the requirement that the annual average frequency of accident conditions resulting in more than N fatalities be less than a risk aversion criterion $f(N)$ which is inversely proportional to N . This criterion reflects a lower tolerance of risk due to more severe accidents and is derived as follows:

The probability density function, $F(N)$, for having N fatalities per annum is chosen with the following form:

$$F(N) = \frac{A}{N^2}.$$

Where A is a constant determined by limiting the mean number of fatalities per person per annum to 10^{-8} in the range $1 < N < N_p$, where N_p is a projection of the national population.

The individual fatality risk per person per annum is then given by:

$$\begin{aligned} \langle N \rangle &= \frac{1}{N_p} \int_1^{N_p} F(N) N dN \\ &= \frac{1}{N_p} \int_1^{N_p} \frac{A}{N^2} N dN \\ &= A \frac{\ln N_p}{N_p} \end{aligned}$$

where $N_p \equiv$ Acceptable projection of the population at risk.

The annual frequency of events in which N is equal or exceeded is given by:

The criterion $f(N)$ is related to $F(N)$ as follows:

$$\begin{aligned} f(N) &= \int_N^{N_p} F(N') dN' \\ &= A \left(\frac{1}{N} - \frac{1}{N_p} \right) \end{aligned}$$

which gives the required reciprocal relation between f and N .

The quantity, A , is determined by the condition:

$$\langle N \rangle = C$$

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where C is the required limit of the average number of fatalities per person per annum due to all nuclear facilities and -sites, i.e.:

$$A = \frac{CN_p}{\ln N_p}$$