National Nuclear Regulator

Requirements
Document

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RD-0024	**Requirements on Risk Assessment and Compliance with Principal Safety Criteria for Nuclear Installations**	**0**

Approved:

GA Clapisson
Acting Chief Executive Officer

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APPROVAL RECORD

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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.

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.

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

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;

- 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)

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].

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 μSv year^{-1} site^{-1} individual dose limit for the average representative of the critical group.	5 x 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 x 10^{-5} fatalities year^{-1} (one fatality per twenty thousand year).

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

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:

$$< N >= \frac{1}{N_p} \int_1^{N_p} F(N) N \mathrm{d}N$$

$$= \frac{1}{N_p} \int_1^{N_p} \frac{A}{N^2} N \mathrm{d}N$$

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

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:

$$f(N) = \int_N^{N_p} F(N') \mathrm{d}N'$$

$$= A\left(\frac{1}{N} - \frac{1}{N_p}\right)$$

which gives the required reciprocal relation between f and N.

The quantity, A, is determined by the condition:

$$< N >= C$$

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.:

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

A1. Title of the Circular

RD-0024 REV 0 "REQUIREMENTS ON RISK ASSESSMENT AND COMPLIANCE WITH PRINCIPAL SAFETY CRITERIA FOR NUCLEAR INSTALLATIONS"

A2. Purpose

To obtain approval of RD-0024 Rev 0.

A3. Issue

LD-1091 Rev 3 needs to be updated to comply with the regulations:

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.

A4. Discussion

Extensive changes were made to the document in terms of definitions, dose limits for consistency with the SSRP, as indicated in the attachment to this circular. These were communicated by letter to Eskom and Necsa. Comments received from Eskom and Necsa on the first draft were far reaching, particularly with regard to the following:

- Approach to multiple sites (whether the dose and risk criteria apply to all facilities on a site together or separately)
- The distinction between "normal" and "accident" conditions
- Whether the risk criteria apply to normal operations as well as accident conditions.

These issues impact on the KNPS, PBMR, the Necsa sites and the proposed regulation for nuclear sites. After discussion with the holders it appears that a completely consistent position will not be achieved in the short term. In addition, the NNR has identified the need to reconsider its regulatory approach given the prospect of an expanding nuclear programme, and has included this as a strategic objective for the 2009-2012 Strategic Plan. As this may take several years, it has been decided to issue RD-0024 Rev 0 to align them to the SSRP, but keeping them sufficiently general to allow flexibility to deal with the existing technologies (ie KNPS, PBMR, Necsa, and New Build) on a case-by-case basis.

In this regard for example the position has now been taken that whereas the dose constraint of 0.25 mSv and public risk criteria will apply to the Necsa facilities collectively, they will apply to Koeberg and PBMR separately. This is acceptable as there are only two sites in the case of Koeberg and PBMR, whereas there are approximately 46 facilities on the Necsa site. As regards the definition of "normal" and "accident" conditions the main issue is that the dose limits applicable for normal operations need to make allowance for possible upset conditions which have to be included in the scope of normal operations. How this is achieved will be addressed for the various technologies on a case-by-case basis.

As regards the third bullet above, the SSRP is not specific as to whether the risk criteria apply to normal operations as well as accident conditions. The problem is that the dose limits for normal operation are not consistent with the corresponding risk criteria. For example the dose limits of 1 mSv and 20 mSv equate to risks of $4x10^{-5}$ pa and $8x10^{-4}$ pa respectively which exceed the risk criteria of $5x10^{-6}$ pa and $5x10^{-5}$ pa for the public and workforce respectively. The approach taken in RD-0024 is to apply the risk criteria to accident conditions only.

In summary, the purpose of Rev 0 of RD-0024 is merely to incorporate the requirements of the SSRP applicable to the various technologies (Koeberg, PBMR, Necsa, New Build). The issues referred to above are addressed on a case-by-case basis in the respective authorizations. The approach being followed is that more stringent requirements are being placed on new applications (viz. PBMR). A more consistent approach will be sought in the longer term in accordance with the Strategic Plan for 2009-2012.

The RD was corrected to clarify the points raised by Eskom and Necsa and submitted to them again giving them two weeks to respond. The responses have been positive, except for the following comments both from Necsa:

1. Request for criteria for screening out events
2. Risk to public (individual risk) due to all nuclear installations (within 50 km? or within SA?).

As regards point 1 the position taken is that it is preferable not to specify the screening criteria in the RD as there could be many scenarios of low risk which contribute cumulatively.
On point 2 the holder should be able to justify that the risk is due to plants in the immediate vicinity.

LD-1091 is being reissued as RD-0024 Rev 0. The changes are given in the attachment.

A5. Recommendation

It is recommended that RD-0024 Rev 0 be signed by the CEO.

A6. Financial Implication

None

A7. Other Implications

Eskom and Necsa will submit documents in conformance with the new requirements, which will need to be assessed.

A8. Quality Assurance Trail

	Name	Designation	Signature	Date
Prepared by	T Hill	Acting Senior Manager: Power Reactor Division		14/7/2008
Reviewed by	P Bester	Manager: PBMR Programme	*	14/7/08
	T Pather	Manager: NTWP		14/07/2008
	S Rokita	Acting Manager: Koeberg Programme		14/07/2008
Recommended for approval by	T Hill	Acting Senior Manager: Power Reactor Division		14/7/2008

* It is my opinion that the current licensing basis for NL-1 is in violation of the RD.

ATTACHMENT

RD-0024 REQUIREMENTS ON RISK ASSESSMENT AND COMPLIANCE WITH PRINCIPAL SAFETY CRITERIA FOR NUCLEAR INSTALLATIONS
(Replacing LD-1091 "Requirements on Licensees of Nuclear Installations regarding Risk Assessment and Compliance with the Safety Criteria of the NNR")

Old Section	New Section	Change	Explanation
General		"acceptable to the NNR" removed from the document except in paragraph 6(4)	NNR does not necessarily accept codes and methodologies in writing, but would need to accept the frequency of periodic reviews.
		"NNR Safety Criteria" replaced by "Principal Safety Criteria"	Consistency with section 3 of Regulation R388
		"Plant" or "facility" replaced by "nuclear installation" where appropriate.	Consistency with NNR Act and Regulation R388
		"Plant personnel" replaced by "workers".	Consistency with Regulation R388
		Numbering of requirements	In accordance with AD-1039
Title	Title	Title simplified	Consistency with other LDs/RDs
4	5	Definitions	Definitions referred to NNRA, Reg R388 and ISO.
5	10	References to facility specific LDs removed	References to facility specific LDs removed as these will change, and the text changed to refer to these requirements in general terms.
6.1		Requirements on ALARA and Defence-in-Depth dropped.	Requirements removed as covered by specific licence conditions and not specific to risk assessment per se.
6.3	6 (2)	"risk assessment" changed to "safety assessment"	Wording changed to be more general.
6	6 (5)	Inclusion of (5) on compliance to recognized standards and practices.	Conformance to good international practice.
7.1	7.1	Improvement in wording.	Clarification.
7.2-7.5	7.2-7.5	Requirement changed simply to calculate the risks or doses as required.	Clarification.
7.2	7.2	Reference to NNR	NNR does not approve

		approved computer codes, models and methodology removed.	these items.
7.2	7.2	Wording changed to reflect that the average population risk and bias against larger accidents are due to the nuclear installation alone, while the maximum individual population risk is due to all nuclear installations.	Clarification
7.3, 7.4	7.3, 7.4	Reference to NNR guidelines removed.	Concept of critical group covered by Regulation R388
7.3	7.3	Wording changed to reflect that the public dose is due to the nuclear installation alone.	Clarification
7.4	7.4	Wording changed to reflect that the risk to workers due to accidents is due to all nuclear installations.	Clarification
7.5	7.5	Wording changed to reflect that the dose to workers due to normal operations is due to all nuclear installations.	Clarification
7.6	7.6	Removal of requirement regarding 12 month time interval.	Covered by requirement 6(3) on risk management.
7.6	7.6	Bullet items referring to LCOs, NCRs and PNRs replaced by requirements on performance and conformance of systems, structures and components.	Use of terminology common to all nuclear installations.
7.7	7.7	Wording changed to indicate that the use of mean values is an acceptable approach.	Clarification.
7.8	7.8	Reworded to cover dose calculations	Completeness
7.8	7.8	"Properties" inserted after "chemical"	Consistency with "material properties"
7.8	7.8	Bullet added to cover environmental impact modelling	Completeness
7.10		Section on off-site	Section 7.2 addresses risk

		consequence modeling removed.	to the public.
8	8	"Information" inserted before "security"	Clarification
8	8	"Training of relevant personnel" replaced by "Training of risk assessors"	Clarification
9	9	Replacement of references to facility specific requirements with general quality assurance requirements.	General applicability.
9	9	"competent personnel, accepted by designated officials" replaced by "competent personnel and accepted by designated officials"	Clarification that the work is accepted by designated officials.
Appendix 1 third paragraph	Appendix 1 third paragraph	Inserted "during the operational lifetime of the existing facilities"	To clarify the period of validity of the assumption of ten major nuclear sites.
Appendix 1 4th paragraph	Appendix 1	"peak-to-average ratio of 50 is to be used" replaced by "peak-to-average ratio of 50 is used"	Correction
4th paragraph		Inserted "applicable collectively to all authorised actions in South Africa"	Clarification
Table 1	Table in Appendix 1	Inclusion of "site^{-1} " as appropriate.	To clarify which criteria are applicable to a single authorized action or to all authorized actions.
Table 1	Table in Appendix 1	Inclusion of "person^{-1}" where appropriate.	Correction. (Note error in regulation R388).
Table 1	Table in Appendix 1	Inclusion of the 20 mSv and 50 mSv dose limits and the word "occupational".	Alignment to Regulation R388.
	Appendix 2	Appendix to provide the risk aversion criterion.	To avoid need for its inclusion in other RDs.