Eskom	Standard	Nuclear Operating Unit

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1. INTRODUCTION

This standard specifies the radiation protection dose and risk limits for the Eskom Generation Division in terms of the Eskom Radiation Protection Policy 32-227 and Standard 32-226. Eskom is committed to ensure that nuclear and radiation safety receives the highest priority to provide for the protection of persons and the environment against harmful ionising radiation in accordance with the safety principles and requirements addressed in the Eskom Radiation Protection Policy and Standard.

2. SCOPE

2.1 PURPOSE

This standard specifies the radiation protection dose and risk limits in terms of Eskom Policy 32-227, Eskom standard 32-226 and the Generation Division Radiation Protection Manual, 238-19 relating to radiation protection and safety of radiation sources.

2.2 APPLICABILITY

This procedure is applicable to Group III hazardous substances (electronic products), Group IV hazardous substances (radioactive sources), radioactive material, restricted material, special nuclear material and radioactive waste defined in the Generation Division Radiation Protection Manual, 238-19.

3. NORMATIVE/INFORMATIVE REFERENCES

The following normative references contain provisions that, through reference in the text, constitute requirements listed in this document. Parties using this document shall apply the most recent edition of the documents listed below, unless otherwise specified in the applicable statutory and regulatory requirements:

3.1 NORMATIVE

[1] 238-19: Generation Division Radiation Protection Manual.

[2] 238-43: Requirements for Radiation Workers.

[3] 32-226: Eskom Standard, Radiation Protection and safety of radiation sources.

[4] 32-227: Eskom Policy, Radiation Protection and safety of radiation sources.

[5] ICRP 68: Dose Coefficients for Intakes of Radionuclides by Workers

[6] ICRP 72: Age-dependent Doses to Members of the Public from Intake of Radionuclides

3.2 INFORMATIVE

The following informative references were used during the development of this document. Although listed, the informative references are not mandatory requirements.

[7] 238-1: Nuclear Division Integrated Management System.

4. DEFINITIONS AND ABBREVIATIONS

4.1 DEFINITIONS

4.1.1 **Assessment:** The process and the result, of analysing systematically the hazards associated with sources and actions, and associated protection and safety measures, aimed at quantifying performance measures for comparison with criteria.

4.1.2 **Authorisation(s):** See authority and licence(s).

4.1.3 **Authorised action:** An action authorised in terms of the Nuclear Regulator Act, 1999 (Act No. 47 of 1999).

4.1.4 **Authority:** Written authority or Authorisations issued by the relevant regulator.

4.1.5 **Collective dose:** An expression for the total radiation dose incurred by a population, defined as the product of the number of individuals exposed to a source and their average radiation dose. The units of collective dose are termed person-sievert.

4.1.6 **Critical group:** A group of members of the public which is reasonably homogeneous with respect to its exposure for a given radiation source and given exposure pathway and is typical of individuals receiving the highest effective dose or equivalent dose (as applicable) by the given exposure pathway from the given source.

4.1.7 **Deterministic effects:** Those effects for which the severity of the effect varies with dose, and for which a threshold generally exists.

4.1.8 **Dose constraint:** a prospective and source-related restriction on the individual dose arising from the prescribed operation of the Authorised action which serves exclusively as a bound on the optimization of radiation and nuclear safety.

4.1.9 **Dose limit:** The value of the effective dose or the equivalent dose of radiation to individuals, from Authorised actions and controlled practices that shall not be exceeded.

4.1.10 **Dose:** The amount of radiation received, where the use of a more specific term such as effective dose or equivalent dose is not necessary for defining the quantity of interest.

4.1.11 **Effective dose:** A summation of the tissue equivalent doses, each multiplied by an appropriate tissue-weighting factor. The units of effective dose are termed sievert.

4.1.12 **Electronic product:** Any electronic product that emits ionising electro-magnetic, particulate radiation or any sonic, infrasonic or ultrasonic wave.

4.1.13 **Emergency exposure:** The act or condition of being subject to irradiation during radiological emergencies.

4.1.14 **Equivalent dose:** The product of the absorbed dose delivered by radiation averaged over the tissue or organ and the radiation-weighting factor. The units of equivalent dose are termed sievert and/or rem.

4.1.15 **Eskom:** is used for Eskom SOC Holdings Limited, its divisions and wholly owned subsidiaries.

4.1.16 **Exposure:** The act or condition of being subject to irradiation. Exposure can be either external exposure (irradiation by sources outside the body) or internal exposure (irradiation by sources inside the body). Exposure should be classified as normal exposure, potential exposure, occupational exposure, public exposure or emergency exposure.

4.1.17 **Group III hazardous substance:** Any electronic product that emits ionising and non-ionising radiation.

4.1.18 **Group IV hazardous substance:** Any fabricated radio-isotopes.

4.1.19 **Intake:** The process of taking radioactive nuclides into the body by inhalation or ingestion or through the skin.

4.1.20 **Ionising radiation:** Radiation capable of producing ion pairs in biological material(s).

4.1.21 **Licence(s):** An authorisation granted by the relevant regulatory authority, accompanied by specific requirements and conditions to be complied with.

4.1.22 **Non-radiation worker:** Is a person with duties at an Eskom nuclear installation. A non-radiation worker shall comply with requirements prescribed in Eskom standard, 238-43: Requirements for Radiation Workers.

4.1.23 **Occupational exposure:** All exposures of radiation to workers incurred in the course of their work.

4.1.24 **Potential exposure:** Exposure to radiation that is not expected with certainty to be delivered, but that may result from an incident at a source or owing to an event or sequence of events of a probabilistic nature, including equipment failures and operating errors.

4.1.25 **Practice:** Any human activity that introduces sources of exposure or exposure pathways, in addition to those of natural background radiation levels, or extends exposure to additional people, or modifies the network of exposure pathways from existing sources; so as to increase the exposure or the likelihood of exposure to people, or the number of people exposed.

4.1.26 **Protection and safety:** The protection of people against exposure to ionising radiation or radioactive substances and the safety of radiation sources, including the means for achieving such protection and safety, such as the various procedures and devices for keeping peoples' doses and risks as low as reasonably achievable.

4.1.27 **Public exposure:** Exposure incurred by members of the public from radiation sources.

4.1.28 **Radiation worker:** Any person who is potentially exposed to radiation through his/her occupation to more than 1 mSv per annum

4.1.29 **Radiation:** See ionising radiation.

4.1.30 **Regulatory authority:** Authorities designated by government for regulatory purposes in connection with radiological protection and occupational health and safety i.e. the National Nuclear Regulator and the Directorate: Radiation Control, Department of Health.

4.1.31 **Risk:** The probability of a specified health effect occurring in a person or group as a result of exposure to radiation or (quantitatively expressed) a quantity expressing hazard, danger or chance of harmful consequences associated with actual or potential exposures relating to quantities such as the probability that specific consequences may arise and the magnitude and character thereof.

4.1.32 **Source:** Anything that may cause radiation exposure, by emitting ionising radiation or releasing radioactive substances or materials.

4.2 ABBREVIATIONS

Abbreviation	Description
ESKOM	Eskom Holdings SOC Limited, its divisions and wholly owned subsidiaries
mSv	Millisievert

5. REQUIREMENTS

5.1 DOSE LIMITATION

5.1.1 A system of dose limitation is laid down whereby:

5.1.1.1 No practice involving exposures to radiation shall be adopted or continued unless it produces sufficient benefit to the exposed individuals or society to offset the radiation detriment it causes;

5.1.1.2 All exposures shall be kept as low as reasonably achievable (ALARA) with economic and social factors being taken into account. This procedure shall be constrained by appropriate restrictions on the doses to individuals; (Footnote 1).

5.1.1.3 The normal operational exposure of individuals shall be restricted to ensure that neither the effective dose nor the equivalent dose to relevant organs or tissues, caused by the possible combination of authorised actions, exceeds any relevant dose limit specified in this standard;

5.1.1.4 (Footnote 2). In special circumstances, provided that the radiation protection in the action has been optimised as required, the relevant regulator should approve a temporary change in the dose limits.

5.1.1.5 The previous occupational exposure history of workers who are not Eskom employees shall be obtained as a precondition for engagement.

5.1.1.6 The requirements for radiation workers in Eskom employment are defined in Eskom Standard, 238-43, Requirements for Radiation Workers.

5.2 DOSE CONTRAINTS

5.2.1 Prior safety assessments

5.2.1.1 Where applicable in terms of the prior safety assessment, the optimisation of radiation protection shall be subject to dose constraints specific to the authorised action, which shall not exceed values that can cause the relevant dose limits to be exceeded and which will ensure as far as practicable that doses are restricted by application of the ALARA principle on a source-specific basis rather than by dose limits.

5.2.2 Members of the Critical Group

5.2.2.1 For members of the public, the dose constraint applicable to the average member of the critical group within the exposed population is 2.5×10^{-2} mSv per year specific to the authorised action unless otherwise agreed by the relevant regulator on a case-by-case basis, taking into account the dose limit specified for exposed members of the public from all sources.

5.3 OCCUPATIONAL EXPOSURE

5.3.1 Effective dose limit

5.3.1.1 In order to limit the occurrence of stochastic effects, the effective dose to a worker shall not exceed 20 mSv per year; averaged over 5 consecutive years (100 mSv in 5 years), with a further provision that the maximum effective dose should not exceed 50 mSv in any single year. (Footnote 3).

5.3.2 Non-uniform exposure

5.3.2.1 In the case of non-uniform or partial exposures, account shall be taken of the contribution of different organs to the overall stochastic effects on the body by calculating the effective dose

[1] Keeping doses as low as reasonably achievable (optimisation of protection) is particularly important and dose constraints shall be applied to ensure adequate protection of the individual.

[2] The dose limit represents the upper bounds of acceptability and shall not necessarily be interpreted as allowable limits.

[3] The effective dose limits specified apply to the sum of the relevant doses from external exposure in the specified period and the relevant committed doses from intakes in the same period: the period for calculating the committed dose shall normally be 50 years for intakes by adults. Administrative dose limits for external and internal exposure shall be established and shall specify the authorisations required in order for a person to exceed those limits when required.

using tissue-weighting factors recommended by the International Commission on Radiological Protection.

5.3.3 Equivalent dose levels

5.3.3.1 In order to avoid deterministic effects, the annual equivalent dose limits are 1.5×10^2 mSv for the lens of the eye and 5×10^2 mSv for extremities (hands and feet) and skin averaged over 1 cm^2 regardless of the area exposed.

5.3.4 Annual limits on intake

5.3.4.1 Annual limits on intake based on a committed effective dose of 20 mSv shall be used as recommended by the International Commission on Radiological Protection in Publications 68 and 72.

5.3.5 Derived Air Concentrations

5.3.5.1 Derived Air Concentrations shall be based on rate of committed effective dose of 2.5×10^{-2} mSv/h based on effective dose coefficients recommended by the International Commission on Radiological Protection in Publications 68 and 72.

5.3.6 Rate of dose accumulation

5.3.6.1 No further restrictions are placed on the instantaneous rate, or the rate at which the equivalent dose may be accumulated, except in the case of pregnant women.

5.3.7 Previous exposure

5.3.7.1 If the previous exposure cannot be derived conclusively, it shall be assumed that the worker has received a dose equal to the effective dose limit (20 mSv) each year of any given period.

5.3.8 Exposure of women of reproductive capacity

5.3.8.1 The prescribed dose limits for the control of the occupational exposure of women who are not pregnant are the same as those for men.

5.3.9 Exposure of pregnant women

5.3.9.1 When pregnancy has been diagnosed and/or declared, the conceptus shall be protected by applying a supplementary equivalent dose limit to the surface of the women's abdomen (lower trunk) of 1 mSv for the remainder of the pregnancy, and by limiting intakes of radionuclides to less than 1 mSv. Arrangements shall be made to ensure that the pregnant woman performs work that is of a type that does not carry a significant probability of high accidental doses and intakes.

5.3.9.2 Following declaration of pregnancy, a dose limit on the equivalent dose to the abdomen of 2 mSv for the remainder of the pregnancy applies.

5.3.10 Abnormal exposures

5.3.10.1 Doses received under abnormal circumstances such as emergencies or accidents shall be recorded together with, and clearly distinguished from, normal exposures.

5.3.11 Potential exposures

5.3.11.1 Dose limits do not apply directly to potential exposures. For potential exposures, risk limits (which take account of both probability of incurring a dose and the detriment associated with the dose) shall be applied.

5.3.12 Exposure of apprentices and students

5.3.12.1 The following dose limits are applicable for apprentices and students of 16 years to 18 years at Eskom facilities (Footnote 6).

5.3.12.1.1 The effective dose limit is 6 mSv in a year;

5.3.12.1.2 The equivalent dose limit to the lens of the eye is 50 mSv in a year; and

5.3.12.1.3 The equivalent dose limit to the extremities (hands, feet) or the skin is 1.5 $x10^2$ mSv in a year.

5.4 PUBLIC EXPOSURE

5.4.1 Exposure of visitors and non-occupationally exposed workers at sites

5.4.1.1 The annual effective dose limit for visitors and non-radiation workers to the sites and those not deemed to be occupationally exposed is 1 mSv. The annual dose equivalent limit for individual organs and tissues of such person is 10 mSv.

5.4.2 Exposure of members of the public

5.4.2.1 The annual effective dose limit for members of the public from all authorised actions is 1 mSv.

5.4.2.2 No action should be authorised which would give rise to any member of the public receiving a radiation dose from all authorised actions exceeding 1 mSv in a year.

5.5 EMERGENCY EXPOSURE

5.5.1 In the event of an emergency or when responding to an accident, a worker who undertakes emergency measures may be exposed to a dose in excess of the annual dose limit for persons occupationally exposed for the following interventions:

5.5.1.1 for the purpose of saving life or preventing serious injury;

5.5.1.2 if undertaking actions intended to avert a large collective dose; or

5.5.1.3 if undertaking actions to prevent the development of catastrophic conditions.

5.5.2 The effective dose to any emergency worker engaged in saving life or preventing serious injury; shall be controlled to ensure that a dose limit of 5 x 10^2 mSv is not exceeded (Footnote 5).

5.5.3 The effective dose to any emergency worker undertaking actions intended to avert a large collective dose or to prevent the development of catastrophic conditions shall be controlled to ensure that a dose limit of 10^2 mSv is not exceeded (Footnote 5).

5.5.4 The equivalent dose to skin of any emergency worker undertaking actions during an emergency shall be controlled to ensure that a dose limit of 5 x 10^3 mSv is not exceeded (Footnote 5).

5.6 ACCIDENTAL EXPOSURE

5.6.1 Accidental exposures in excess of the dose limits recommended for normal practice differ from emergency exposures in that they are unavoidable and unforeseen. For this reason no dose limits are set for such exposures.

5.6.2 Accidental exposures in excess of the dose limits, shall be reviewed by an appointed medical practitioner.

5.7 RISK LIMITS

5.7.1 The risk limits for workers and members of the public listed in Appendix A for normal operations and accident conditions shall be complied with.

5.8 RECORDS AND REPORTS

5.8.1 Records and reports relating to radiation protection dose limits shall be established, implemented, retained, maintained and made available for reference.

5.8.2 Records and reports relating to radiation protection dose limits shall be submitted to the relevant regulator at predetermined periods as required.

5.8.3 A reporting mechanism shall be established, implemented and maintained for recording incident and accidents of any events that the relevant regulator should specify relating to radiation protection dose limits.

5.9 QUALITY MANAGEMENT

5.9.1 A quality management programme shall be established, implemented and maintained in order to ensure on-going compliance with this standard.

5.10 FOOTNOTES

5.10.1 Footnote 1

Keeping doses as low as reasonably achievable (optimisation of protection) is particularly important and dose constraints shall be applied to ensure adequate protection of the individual.

5.10.2 Footnote 2

The dose limit represents the upper bounds of acceptability and shall not necessarily be interpreted as allowable limits.

5.10.3 Footnote 3

The effective dose limits specified apply to the sum of the relevant doses from external exposure in the specified period and the relevant committed doses from intakes in the same period. The period for calculating the committed dose shall normally be 50 years for intakes by adults. Administrative dose limits for external and internal exposure shall be established and shall specify the authorisations required in order for a person to exceed those limits when required.

5.10.4 Footnote 4

This limit applies to the average member of the critical group within the exposed population. No practice shall be authorised which would give rise to any member of the public receiving a dose from all sources in excess of 1 mSv per year.

5.10.5 Footnote 5

All reasonable efforts shall be made to keep doses to the worker below twice the maximum annual dose limit. In respect to life-saving interventions every effort shall be made to keep doses to the worker below ten times the maximum annual dose limit. In addition, workers undertaking interventions which may result in their doses approaching or exceeding ten times the annual dose limit may only do so when the benefits to others clearly outweigh their own risk.

5.10.6 Footnote 6

Apprentices and students between 16 to 18 years of age who are training for employment involving exposure to radiation and who are required to handle sources in the course of their training should be registered as radiation workers and their dose shall be managed in accordance with the dose limits listed in section 5.3.12.

5.10.7 Footnote 7

The average and maximum annual individual public risk limits for accidental conditions are based on the assumption that 10 nuclear installation sites in South Africa exist.

6. ACCEPTANCE:

This following people were informed of the request submitted to the National Nuclear Regulator (NNR) via letter K-28414-E and the NNR response via letter k28414N relating to implementation of administrative changes to this document.

Name	Designation
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Marcus Nemadodzi	Arnot Power Station Manager
Maserati Lesolang	Matla Power Station Manager
Morongwe Raphasha	Kriel Power Station Manager
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Obakeng Mabotja	Matimba Power Station Manager
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7. REVISIONS

Date	Rev.	Compiler	Remarks
March 2022	1	M Maree	Administrative changes implemented in accordance with letter k28414N dated, 22 March 2022.
December 2019	0B	M Maree	NNR approval via letter k26060N dated 6 December 2019 for extension of review date from October 2019 to May 2020.
September 2018	0A	M Maree	NNR approval via letter k24608N dated, 4 September 2018 for implementation of administrative changes.
March 2012	0	M Maree	NNR approval via letter k20275N dated, 12 March 2012 for implementation of Radiation Protection Standards.

8. DEVELOPMENT TEAM

This document has been developed by Marc Maree.

9. ACKNOWLEDGEMENTS

- E Flanagan
- K Featherstone
- MV Moduka

10. APPENDICES

A – Summary Of Risk And Dose Limits

B – Acceptance and Authorisation

APPENDIX A: SUMMARY OF RISK AND DOSE LIMITS

		NORMAL OPERATIONS	ACCIDENT CONDITIONS
PUBLIC	Average Annual Individual Risk	Risk to be controlled to a trivial level through the application of the ALARA principle.	10^{-8} fatalities per person per year per site (Footnote 7).
	Maximum Annual Individual Risk	250 µSv per person per year per site effective dose limit for the average representative of the critical group.	5×10^{-6} fatalities per person per year per site (Footnote 7).
RADIATION WORKERS	Average Annual Individual Risk	Risk to be controlled by the application of the ALARA principle. The ALARA target for average annual individual dose will not exceed 4 mSv.	10^{-5} fatalities per person per year
	Maximum Annual Individual Risk	Radiological exposure per person will not exceed: a) an effective dose of 20 mSv per year averaged over 5 consecutive years; b) a maximum effective dose of 50 mSv in any single year; c) an equivalent dose to the lens of the eye of 150 mSv per year; and d) an equivalent dose to the extremities (hands and feet) of 500 mSv per year.	5×10^{-5} fatalities per person per year
	Maximum Annual Individual Risk for Pregnant Women	Following declaration of pregnancy, the following additional limit will apply: An equivalent dose to the abdomen not to exceed 2 mSv (for the remainder of the pregnancy).	N/A
VISITORS AND NON-RADIATION WORKERS	Average Annual Individual Risk	Risk to be controlled to a trivial level through the application of the ALARA principle.	N/A
	Maximum Annual Individual Risk	Radiological exposure per person will not exceed: a) an effective dose of 1 mSv per year; b) an equivalent dose to individual organs and tissues of 10 mSv per year.	N/A

		NORMAL OPERATIONS	ACCIDENT CONDITIONS
APPRENTICES AND STUDENTS (Footnote 6)	Average Annual Individual Risk	Risk to be controlled to a trivial level through the application of the ALARA principle.	N/A
	Maximum Annual Individual Risk	Radiological exposure per person will not exceed: a) an effective dose of 6 mSv per year; b) an equivalent dose to the lens of the eye of 50 mSv per year; and c) an equivalent dose to the extremities (hands and feet) or the skin of 150 mSv per year.	N/A
EMERGENCIES	Maximum Annual Individual Risk	N/A	All reasonable effort will be made to limit worker dose to below 100 mSv per year in the event of: a) actions to prevent a large collective dose; or b) actions to prevent the development of catastrophic conditions. c) All reasonable effort will be made to limit worker dose to below 500 mSv per year for the purpose of saving life or preventing serious injury.

Eskom imposes a bias against more severe accidents in accordance with the requirements in RD-0024. The average annual frequency of accident conditions that result in more than *N* fatalities shall be less than the risk aversion criterion *f*(*N*):

$$f(N) = C\frac{N_p}{\ln N_p}\left(\frac{1}{N} - \frac{1}{N_p}\right)$$

where:

C = 10^{-7} fatalities per person per year for the national population due to all nuclear installations in South Africa; and Np is a projection of the national population.