ANNEX II

BASIC SAFETY PRINCIPLES AND SAFETY CULTURE

adapted excerpts from two reports of the
International Nuclear Safety Advisory Group

"Basic Safety Principles for Nuclear Power Plants"
(Safety Series No.75-INSAG-3, 1988)
and "Safety Culture" (Safety Series No. 75-INSAG-4, 1991)

INTRODUCTION

This compilation of commonly shared principles of safety and safety culture is based on two reports of the International Nuclear Safety Advisory Group "Basic Safety Principles for Nuclear Power Plants" (Safety Series No.75-INSAG-3, 1988) and "Safety Culture" (Safety Series No. 75-INSAG-4, 1991). Although these reports are directed at nuclear power plants, they are generally applicable to the design, operation and maintenance of radiation sources in general, and especially to large sources. Consequently, relevant principles have been extracted from INSAG-3, modified in some cases so as to be generally applicable, and assembled into a comprehensive compilation of principles for the safety of radiation sources which is presented in Part A of this Annex. Similarly, safety culture principles have been extracted from INSAG-4, modified so as to be generally applicable, and presented in Part B of this Annex.

In general, the concepts in this Annex are not new. Most of the ideas have been applied in different combinations in many safety programmes throughout the world. They are now consolidated and presented in a structured form. They do not differentiate between different types of source; it is up to the designers, manufacturers, constructors, regulators and operating organizations to decide how to apply the principles to each individual source

The safety objectives and principles set out in the remainder of this Annex are drafted in a style that reflects the situation that exists in well managed circumstances where the relevant principles have been applied.

PART A, BASIC SAFETY OBJECTIVES AND PRINCIPLES

GENERAL RADIATION SAFETY OBJECTIVES

To protect individuals, society and the environment by establishing and maintaining an effective defence against radiological hazards, and to ensure in normal operation that radiation exposure of members of the public within a plant and due to any release of radioactive material from the plant are kept as low as reasonably achievable and within prescribed limits, and to ensure mitigation of the extent of radiation exposures due to accidents.

TECHNICAL SAFETY OBJECTIVES

To prevent with high confidence accidents and to ensure that for all accidents taken into account in the design, even those of very low probability, any radiological consequences would be minor; and to ensure that the likelihood of severe accidents with serious radiological consequences is extremely small.

BASIC PRINCIPLES

1. Safety culture

A safety culture governs the actions and interactions of all individuals and organizations engaged in activities that involve or could involve exposure to radiation or radioactive substances.

2. Responsibility of the operating organization

The ultimate responsibility for safety rests with the operating organization. This is in no way diluted by the separate activities and responsibilities of designers, suppliers, constructors and regulators.

3. Regulatory control and independent verification

The government establishes a legal framework and an independent regulatory organization which is responsible for licensing and regulatory control and for enforcing the relevant regulations. The separation between the responsibilities of the regulatory organization and those of other parties is clear, so that the regulators retain their independence as a safety authority and are protected from undue pressure.

4. Defence in depth

To compensate for potential human and mechanical failures, a defence in depth concept is implemented, centred on several levels of protection including successive barriers which prevent the release of radioactive material to the environment. The concept includes protection of the barriers by averting damage to the plant and to the barriers themselves. It includes further measures to protect the public and the environment from harm in case these barriers are not fully effective.

5. Accident prevention

Principal emphasis is placed on the primary means of achieving safety, which is the prevention of accidents, particularly any which could cause severe damage to sources.

6. Accident mitigation

In-plant and off-site mitigation measures are maintained that would substantially reduce the effects of an accidental release of radioactive material.

GENERAL TECHNICAL PRINCIPLES

7. Proven engineering practices

Technology is based on engineering practices which are proven by testing and experience, and which are reflected in approved codes and standards and other appropriately documented statements.

8. Quality assurance

Quality assurance is applied throughout activities that involve or could involve exposure to radiation as part of a comprehensive system to ensure with high confidence that all items delivered and services and tasks performed meet specified requirements.

9. Human factors

Personnel engaged in activities bearing on safety are trained and qualified to perform their duties. The possibility of human error in operation is taken into account by facilitating correct decisions by operators and inhibiting wrong decisions, and by providing means for detecting and correcting or compensating for error.

10. Safety assessment and verification

Safety assessment is made before construction and operation of a plant begin. The assessment is well documented and independently reviewed. It is subsequently updated in the light of significant new safety information.

11. Radiation protection practices

A system of radiation protection practices, consistent with recommendations of the ICRP and the IAEA, is followed in the design, commissioning and operational phases of sources.

12. Operating experience and safety research

Organizations concerned ensure that operating experience and the results of research relevant to safety are exchanged, reviewed and analysed, and that lessons are learned and acted on.

13. External factors affecting a source

The choice of site takes into account the results of investigations of local factors which could adversely affect the safety of the sources.

14. Radiological impact on the public and the local environment

Sites are investigated from the standpoint of the radiological impact of the plant in normal operation and in accident conditions.

15. Feasibility of emergency plans

The site selected for a source is compatible with the off-site countermeasures that may be necessary to limit the effects of accidental releases of radioactive substances, and is expected to remain compatible with such measures.

DESIGN

16. Design management

The assignment and subdivision of responsibility for safety are kept well defined throughout the design phase of a project, and during any subsequent modifications.

17. Proven technology

Technologies incorporated into design have been proven by experience and testing. Significant new design features or new types of sources are introduced only after thorough research and prototype testing at the component, system or plant level, as appropriate.

18. General basis for design

A source is designed to cope with a set of events including normal conditions, anticipated operational occurrences, extreme external events and accident conditions. For this purpose, conservative rules and criteria incorporating safety margins are used to establish design requirements. Comprehensive analyses are carried out to evaluate the safety performance or capability of the various components and systems associated with a source.

19. Plant process control systems

Normal operation and anticipated operational occurrences are controlled so that plant and system variables remain within their operating ranges. This reduces the frequency of demands on the safety systems.

20. Automatic safety systems

Automatic systems are provided that would safely shut down a source, maintain it in a safe state, and limit any release of radioactive substances that might ensue if operating conditions were to exceed predetermined setpoints.

21. Reliability targets

Reliability targets are assigned to safety systems or functions. The targets are established on the basis of the safety objectives and are consistent with the roles of the systems or functions in different accident sequences. Provision is made for testing and inspection of components and systems for which reliability targets have been set.

22. Dependent failures

Design provisions seek to prevent the loss of safety functions due to damage to more than one component, system or structure resulting from a common cause.

23. Equipment qualification

Safety components and systems are chosen which are qualified for the environmental conditions that would prevail if they were required to function. The effects of ageing on normal and abnormal functioning are considered in design and qualification.

24. Inspectability of safety equipment

Safety related components, systems and structures are designed and constructed so that they can be inspected throughout their operating lives to verify their continued acceptability for service with an adequate safety margin.

25. Radiation protection in design

At the design stage, radiation protection features are incorporated to protect plant personnel from radiation exposure and to keep emissions of radioactive effluents as low as reasonably achievable and within prescribed constraints.

26. Protection against power transient accidents

Sources are designed so that fission chain reactions are prevented with a conservative margin of safety.

27. Source integrity

Sources are designed to have mechanical stability and to tolerate an appropriate range of anticipated variations in operational parameters. Source design is such that the expected distortion or movement during an accident within the design basis would not impair the shielding or other protective features of the source.

28. Automatic shutdown systems

Rapidly responding and highly reliable protective devices are designed to be independent of the equipment and processes used for normal operation.

29. Ultimate heat sink provisions

The site selected for heat generating sources has a reliable heat sink that can remove energy generated in the source during use and when not in use.

30. Normal heat removal

Heat transport systems are designed for highly reliable heat removal in normal operation. They would also provide means for the removal of heat during anticipated operational occurrences and during most types of accidents that might occur.

31. Emergency heat removal

Provision is made for alternative means to restore and maintain cooling under accident conditions, even if normal heat removal fails or the integrity of the cooling system boundary is lost.

32. Coolant system integrity

Codes and standards for vessels and piping are supplemented by additional measures to prevent conditions arising that could lead to a rupture of the coolant system boundary at any time during the operational life of the source.

33. Confinement of radioactive material

The plant is designed to be capable of retaining the bulk of the radioactive material that might be released, for the entire range of accidents considered in the design.

34. Protection of confinement structure

If specific and inherent features of a source would not prevent detrimental effects on the confinement structure in a severe accident, special protection against the effects of such accidents is provided, to the extent needed to meet the general safety objective.

35. Monitoring of plant safety status

Parameters to be monitored in the control room are selected, and their displays are arranged, to ensure that operators have clear and unambiguous indications of the status of plant conditions important for safety, especially for the purpose of identifying and diagnosing the automatic actuation and operation of a safety system or the degradation of defence in depth.

36. Preservation of control capability

The control room is designed to remain habitable under normal operating conditions, anticipated abnormal occurrences and accidents considered in the design. Independent monitoring and the essential capability for control needed to maintain ultimate cooling, shutdown and confinement are provided remote from the main control room for circumstances in which the main control room may be uninhabitable or damaged.

37. Loss of power

Sources are so designed that the simultaneous loss of normal on-site and off-site electrical power will not soon lead to source damage.

38. Control of accidents within the design basis

Provisions are made at the design stage for the control of accidents within the design basis, including the specification of information and instrumentation needed by the plant staff for following and intervening in the course of accidents.

MANUFACTURING AND CONSTRUCTION

39. Safety evaluation of design

Construction of a source is begun only after the operating organization and the regulatory organization have satisfied themselves by appropriate assessments that the main safety issues have been satisfactorily resolved and that the remainder are amenable to solution before operations are scheduled to begin.

40. Achievement of quality

The plant manufacturers and constructors discharge their responsibilities for the provision of equipment and for high quality construction by using well proven and established techniques and procedures supported by quality assurance practices.

COMMISSIONING

41. Verification of design and construction

A commissioning programme is established and followed to demonstrate that the entire plant, especially items important to safety and radiation protection, has been constructed and functions according to the design intent, and to ensure that weaknesses are detected and corrected.

42. Validation of operating and functional test procedures

Procedures for normal operation of plant and systems and for functional tests to be performed during the operating phase are validated as part of the commissioning programme.

43. Collecting baseline data

During commissioning tests, detailed diagnostic data are collected on components having special safety significance and the initial operating parameters of the systems are recorded.

44. Pre-operational plant adjustments

During the commissioning programme, the as-built operating characteristics of safety and process systems are determined and documented. Operating points are adjusted to conform to design values and to safety analyses. Training procedures and limiting conditions for operation are modified to reflect accurately the operating characteristics of the systems as built.

OPERATION

45. Organization, responsibilities and staffing

The operating organization exerts full responsibility for the safe operation of a source through a strong organizational structure under the line authority. The plant manager ensures that all elements for safe plant operation are in place, including an adequate number of qualified and experienced personnel.

46. Safety review procedures

Safety review procedures are maintained by the operating organization to provide a continuing surveillance and audit of plant operational safety and to support the plant manager in his overall safety responsibilities.

47. Conduct of operations

Operation of the plant is conducted by authorized personnel, according to strict administrative controls and observing procedural discipline.

48. Training

Programmes are established for training and retraining operating and maintenance personnel to enable them to perform their duties safely and efficiently.

49. Operational limits and conditions

A set of operational limits and conditions is defined to identify safe boundaries for plant operation. Minimum requirements are also set for the availability of staff and equipment.

50. Normal operating procedures

Normal plant operation is controlled by detailed, validated and formally approved procedures.

51. Emergency operating procedures

Emergency operating procedures are established, documented and approved to provide a basis for suitable response to abnormal events.

52. Radiation protection procedures

The radiation protection staff establish written procedures for the control, guidance and protection of personnel, carry out routine monitoring of in-plant radiological conditions, monitor the exposure of plant personnel, and also monitor releases of radioactive effluents.

53. Engineering and technical support of operations

Engineering and technical support staff competent in all disciplines important for safety are available throughout the life of a source.

55. Feedback of operating experience

Plant management institutes measures to ensure that events significant for safety are detected and evaluated in depth, that any necessary corrective measures are taken promptly, and that information on them is disseminated. The plant management has access to operational experience relevant to source safety from other sources worldwide.

56. Maintenance, testing and inspection

Safety related structures, components and systems are subjected to regular preventive maintenance, inspection, testing and servicing to ensure that they remain capable of meeting their design requirements throughout the life of the source. Such activities are carried out in accordance with written procedures and supported by quality assurance measures.

57. Quality assurance in operation

An operational quality assurance programme is established by the operating organization to assist in ensuring satisfactory performance in all plant activities important to safety.

ACCIDENT MANAGEMENT

58. Strategy for accident management

The results of an analysis of the response of the plant to potential accidents beyond the design basis are used in preparing guidance on an accident management strategy.

59. Training and procedures for accident management

Plant staff are trained and retrained in the procedures to follow if an accident occurs that exceeds the design basis of the plant.

60. Engineered features for accident management

Equipment, instrumentation and diagnostic aids are available to operators who may at some time be faced with the need to control the course and consequences of accidents beyond the design basis.

EMERGENCY PREPAREDNESS

61. Emergency plans

Emergency plans are prepared before the startup of the plant and are exercised periodically to ensure that protection measures can be implemented in the event of an accident which results in, or has the potential for, significant releases of radioactive materials within and beyond the site boundary. Emergency planning zones around the plant allow for the use of a graded response.

62. Emergency response facilities

A permanently equipped emergency centre is available off the site for emergency response. On the site, a similar centre is provided for directing emergency activities within the plant and for communicating with the off-site emergency organization.

63. Assessment of accident consequences and radiological monitoring

Means are available to the responsible site staff to be used in early prediction of the extent and significance of any release of radioactive material if an accident were to occur, for rapid and continuous assessment of the radiological situation, and for determining the need for protective measures.

PART B. SAFETY CULTURE

Safety Culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, safety issues receive the attention warranted by their significance.

Safety Culture has two general components. The first is the necessary framework within an organization and is the responsibility of the management hierarchy. The second is the attitude of staff at all levels in responding to and benefiting from the framework.

Good practices in themselves, while an essential component of Safety Culture, are not sufficient if applied mechanically. There is a requirement to go beyond the strict implementation of good practices so that all duties important to safety are carried out correctly, with alertness, due thought, full knowledge, sound judgement and a proper sense of accountability. The highest level of safety is achieved only when everyone is dedicated to the common goal, which involves many elements:

- *Individual awareness of the importance of safety.*
- *Knowledge and competence conferred by training and instruction of personnel and by their self-education.*
- *Commitment which requires demonstration at senior management level of the high priority of safety and adoption by individuals of the common goal of safety.*
- *Motivation, through leadership, the setting of objectives and systems of rewards and sanctions, and through individuals' self-generated attitudes.*
- *Supervision, including audit and review practices, with readiness to respond to individuals' questioning attitudes*
- *Responsibility, through formal assignment and description of duties and their understanding by individuals.*

REQUIREMENTS AT POLICY LEVEL

In any important activity, the manner in which people act is conditioned by requirements set at a high level. The highest level affecting safety is the legislative level, at which the national basis for Safety Culture is set. Within an organization, similar considerations apply. Policies promoted at a high level create the working environment and condition individual behaviour. An organization pursuing activities with a bearing on safety makes its responsibilities well known and understood in a safety policy statement. This statement is provided as guidance to staff and declares the organization's objectives and the public commitment of corporate management to safety.

Management structures

Implementation of these safety policies requires that accountability in safety matters be clear. Strong lines of authority are established for those matters bearing on safety, by means of clear reporting lines and few and simple interfaces, supported by the definition and documentation of duties.

Large organizations with significant impact on safety provide independent internal management units with responsibility for the surveillance of safety activities These units have the role of scrutinizing safety practices. They report at a senior management level, ensuring the integration of safety responsibilities into the management chain with a prominence matching that of other main functions

Resources

Adequate sources are devoted to safety.

Sufficient experienced staff are available, supplemented as necessary by consultants or contractors, so that duties relevant to safety may be carried out without undue haste or pressure. Training of staff is recognized as vital and the necessary resources are devoted to it. Funding is sufficient to ensure that staff in all safety related tasks have available to them the necessary equipment, facilities and supporting technical infrastructure.

Self-regulation

As a matter of policy, all organizations arrange for regular review of those of their practices that contribute to safety.

The intent is to bring fresh judgement to bear and to allow new approaches to be suggested by involving fully competent individuals or bodies outside the normal chain of command. Such arrangements are promoted as natural and helpful aids to the practitioners, and they avoid the appearance of a punitive search for shortcomings.

Commitment

Corporate level commitment for success is publicly asserted and well known, shows the stance of corporate management in relation to its social responsibilities, and demonstrates also an organization's willingness to be open in safety matters.

Managers at the most senior level demonstrate their commitment by their attention to regular review of the processes that bear on safety, by taking direct interest in the more significant questions of safety or product quality as they arise, and by frequent citation of the importance of safety and quality in communications to the staff.

REQUIREMENTS ON MANAGERS

The key to an effective Safety Culture in individuals is found in the practices moulding the working environment and fostering attitudes conducive to safety It is the responsibility of managers to institute such practices in accordance with their organization's safety policy and objectives.

Definition of responsibilities

Discharge of individual responsibilities is facilitated by unique and clear lines of authority.

The responsibility assigned to individuals is defined and documented in sufficient detail to prevent ambiguity. Responsibilities and authority are reviewed to ensure that there are no overlaps and no problems of shared responsibility. Managers ensure that individuals understand not only their own responsibilities but also those of their immediate colleagues and of their management unit, and how these responsibilities complement those of other groups

Definition and control of working practices

Managers ensure that work on matters related to safety is carried out in a rigorous manner.

The basis is generally a hierarchy of up to date documents ranging from policy directives to detailed working procedures. These procedures are clear and unambiguous and they form an integral series. The documents receive formal

scrutiny, checking and testing under the organizations' quality assurance arrangements, and formal means are adopted for their control.

Qualification and training

Managers ensure that their staff are fully competent for their duties, and that any necessary training and periodic retraining are provided. Instruction instills more than technical skills or familiarity with detailed procedures to be followed rigorously. These essential requirements are supplemented by broader training, sufficient to ensure that individuals understand the significance of their duties and the consequences of mistakes arising from misconceptions or lack of diligence.

Without this additional understanding, safety issues arising may not receive the attention they warrant or wrong actions may be taken, out of lack of comprehension of the risks involved.

Rewards and sanctions

Ultimately, satisfactory practice depends on the behaviour of individuals, as influenced by motivation and attitudes, both personal and group. Managers encourage and praise and seek to provide tangible reward for particularly commendable attitudes in safety matters.

Incentives are therefore not based on production levels alone but are also related to safety performance. Errors are seen as a source of experience from which benefit can be derived Individuals are encouraged to identify, report and correct imperfections in their own work in order to help others as well as themselves to avert future problems.

Audit, review and comparison

Managerial responsibilities include the implementation of a range of monitoring practices which go beyond the implementation of quality assurance measures and include, for example, regular reviews of training programmes, staff appointment procedures, working practices, document control and quality assurance systems

In design, manufacturing and operating organizations, they include scrutiny of the means by which design or engineering changes are controlled. In the operational context, they include scrutiny of changes to operating parameters, maintaining requirements, modifications to plant, plant configuration control and any non-routine operation. Managers make arrangements to benefit from all sources of relevant experience, research, technical developments, operational data and events of safety significance, all of which are carefully evaluated in their own contexts.

Commitment

Managers demonstrate their commitment to Safety Culture and encourage it in others.

It is the task of managers to ensure that their staff respond to and benefit from this established framework of practices and, by attitude and example, to ensure that their staff are continuously motivated towards high levels of personal performance in their duties.

RESPONSE OF INDIVIDUALS

It is the task of staff at all levels to respond to and benefit from the Safety Culture framework. Before an individual begins any safety related task, his or her questioning attitude raises issues such as the following:

- *Do I understand the task?*
- *What are my responsibilities?*
- *How do they relate to safety?*
- *Do I have the necessary knowledge to proceed?*
- *What are the responsibilities of others?*
- *Are there any unusual circumstances?*
- *Do I need any assistance?*
- *What can go wrong?*
- *What could be the consequences of failure or error?*
- *What should be done to prevent failures?*
- *What do I do if a fault occurs?*

In the case of relatively routine tasks, for which the individual has been fully trained, question and answer will be automatic to a large extent For tasks with a novel content, the thought process becomes more deliberate. New and unusual tasks which have an important safety content will be the subject of written procedures clarifying these matters.

Individuals adopt a rigorous and prudent approach This involves.

- *understanding the work procedures;*
- *complying with the procedures;*
- *being alert for the unexpected;*
- *stopping and thinking if a problem arises;*

- *seeking help if necessary;*
- *devoting attention to orderliness, timeliness and housekeeping;*
- *proceeding with deliberate care;*
- *forgoing shortcuts.*

Individuals recognize that a communicative approach is essential to safety. This involves:

- *obtaining useful information from others;*
- *transmitting information to others;*
- *reporting on and documenting results of work, both routine and unusual;*
- *suggesting new safety initiatives.*

GLOSSARY

GLOSSARY

DEFINITIONS

Abnormal Exposure Conditions:
Conditions in which a source or the radiation from it is not under control.

Accident:
Any unintended event, including operating errors, equipment failures and other mishaps, whose consequences or potential consequences cannot be ignored from radiation and safety point of view, and which could lead to potential exposure and subsequently to abnormal exposure conditions.

Activation:
The production of induced activity by nuclear reactions.

Agricultural Countermeasures:

Actions specifically taken to reduce contamination of food and forestry products that are to be produced, sold or consumed.

Annual Effective (or Equivalent) Dose Limit:
The value of the annual effective (or equivalent) dose that must not be exceeded for practices, and shall be regarded as the lower boundary of an unacceptable dose region for practices, according to these Standards.

Annual Limit on Intake:
The smaller of intake of a given radionuclide in a year by reference man which would result in either a committed effective dose equal to the annual effective dose limit or in a committed equivalent dose equal to the annual equivalent dose limit in any organ or tissue as established by these Standards

Applicant:
Any legal person or persons that intends to carry out any of the basic obligations of these Standards.

Application sources:
X ray apparatuses used in medical radiodiagnosis, dentistry and some industrial radiography; radioactive substances used in radiochemical laboratories and in diagnostic nuclear medicine; and, other radiation sources for which any conceivable potential scenario or sequence of potential exposure cannot lead to individual exposures able to cause serious deterministic radiation effects or significant contamination with radioactive substances and which may not sustain a nuclear reaction.

Approved:
Means approved by the regulatory authority

Approved Medical Practitioner:
A medical practitioner responsible for the health surveillance of Workers whose capacity to act in this respect is recognized by the Regulatory Authority.

Authorization, general:
A document by which the Regulatory Authority gives a general authorization to conduct a practice with Consumer Products requiring a specific requirement and with Application Sources

Authorization, specific:
A document by which the Regulatory Authority gives a specific authorization for the installation and the operation of any radiation installation.

Authorized:
Authorized by the Regulatory Authority

Consumer Products:
Items of general use that emit radiation or contain small amounts of radioactive substances, including: static electricity elimination devices; ion generating tubes, smoke detectors; devices for producing light or an ionized atmosphere, for in vitro clinical or laboratory testing, or making use of the luminizing properties of some radioactive materials, such as dials, time pieces, fishing floats, etc.; and electron tube and other devices able to generate relatively low fluxes of low energy X rays

Containment:
Either (1) the confinement of radioactive material in such a way that it is prevented from being dispersed into the environment or is only released at a specified rate, or (2) the device used to effect such confinement.

Contamination:
The presence of a radioactive substance or substances in or on a material or in a place where they are undesirable or could be harmful.

Controlled Area:
(a) Any area where special rules are needed for the purpose of occupational radiation protection for preventing the spread or dispersal of radioactive contamination, and
(b) Any area in which there is a risk of contamination arising from the use of unsealed radioactive substances.

Cost-Benefit Analysis (Differential)
Technique for optimization of radiation protection used to determine the point at which exposures have been decreased so far that any further decrease is considered less important than the additional necessary effort required to achieve it.

Critical Group:
For a given radiation source, the members of the public whose exposure is reasonably homogeneous and is typical of individuals receiving the highest effective dose or equivalent dose (whichever is relevant) from the source.

Critical Pathway:
.the dominant environmental pathway through which a given radionuclide reaches the critical group.

Criticality:
the conditions in which a system is capable of sustaining a nuclear chain reaction

Countermeasure:
an action aimed at alleviating the consequences of an accidental release of radioactive material into the environment, primarily by reducing environmental contamination and collective dose commitment

Decontamination:
the removal of radioactive contaminants with the objective of reducing the residual radioactivity level in or on materials, persons or the environment.

Defence in Depth:

the application of more than a single protective measure for a given safety objective such that the objective is at least partially achieved even if one of the protective measures fails.

Deterministic Effect:

Radiation effects for which a threshold exists above which the severity of the effect varies with the dose

Deposition:

Amount of radioactive material incorporated into tissues and organs (see intake and uptake). Also used to denote the process.

Detriment:

The expectation of the harm (damage to health and other effects) incurred from the exposure of individuals or groups of persons in a human population to a radiation source, taking into account not only the probabilities but also the severity of each type of deleterious effect.

Dose:

A term used with two meanings.
(1) as a measure of the 'quantity of radiation' present in or 'given' by, a radiation field - a concept also known as exposure; and
(2) as a measure of the radiation 'received' or 'absorbed' by a target
The first meaning is a way of specifying the radiation field in terms of quantities such as exposure (for X rays and gamma rays) and kerma (for indirectly ionizing radiation). It can also be expressed as fluence or energy fluence.

The second meaning, which has the connotation of 'receiving' by a target, is expressed in terms of quantities such as absorbed dose, organ dose, equivalent dose, effective dose, committed equivalent dose, or committed effective dose, depending on the context, as they are defined in this Section. All these quantities have the dimensions of energy divided by mass. The modifying adjectives are often omitted when they are not absolutely necessary to define the quantity of interest

Dosimeter:

A device, instrument or system which can be used to measure or evaluate any quantity that can be related to the determination of dose.

Employer:

A person or legal entity with recognized responsibility, commitment and duties towards workers in their employment by virtue of a mutually agreed employer/employee relationship; particularly, in relation to occupational exposures, an Employer is any legal person that employs workers, either regularly or temporarily, for activities that may cause exposure to radiation, wherever such exposure can reasonably be regarded as being under the Employer's responsibility (a self-employed worker shall be regarded as having the responsibilities of an employer).

Enhanced Natural Sources:

Natural sources of radiation that increase the background exposure which the exposed people inevitably receive whenever they are elements of a practice, the continuation of which is not a matter of choice. Examples of such sources are cosmic radiation affecting occupationally exposed persons in high altitude flights, and terrestrial radiation sources in some new dwellings, in mines, in spas, etc.

Environment:

Everything outside the premises or other site of a radiation source, including the air, terrain, surface and underground water, flora and fauna.

Ethical Review Committee:

A committee of independent persons to advise on conditions of exposure and dose constraints to be applied to persons exposed for research purposes when there is no direct benefit to the exposed individual

Exposure:

A term used in radiation protection both in a specifically defined quantitative sense and in a general sense. In the general sense, it is the irradiation of persons or materials. Exposure of persons to ionizing radiation may be either.

(a) external exposure, irradiation by sources outside the body, or
(b) internal exposure, irradiation by sources inside the body

Exposure Pathways:

The routes by which radioactive material can reach or irradiate man

Industrial Gauges:

Devices designed and manufactured for the purpose of detecting, measuring, gauging or controlling thickness, density, level, interface, location, radiation, or qualitative chemical composition or calibration or reference sources, including ice detection devices.

Intake, Radioactive Nuclide:

Amount of radioactive material introduced into the body by inhalation or ingestion, or through the skin (see also uptake and deposition) Also used to denote the process.

Intervening Organization:

Any legal person with recognized rights and duties for prescribing intervention or intervening for reducing radiation exposures and, in some cases, for the preparation, development and/or execution of off-site emergency plans or parts of such emergency plans. (The Intervening Organization may, although not necessarily, be the Regulatory Authority itself.)

Intervention:

Any action intended to reduce exposures to existing sources due to de facto situations, altering existing causes of exposure, modifying the existing exposure pathways, changing people's habits, circumstances or actions so as to preclude their exposure.

Intervention Level:

A level, such as a level of contamination or dose rate, at which intervention, such as the introduction of countermeasures, should be carried out

Intervention Situation:

An intervention situation is deemed to exist:

(a) in long standing situations involving the presence of naturally occurring radioactive substances, including radon, and, where there is the feasibility to reduce the doses incurred because of such presence;
(b) where there is feasibility to reduce exposures from radioactive residues from previous events, such as contamination from previous accidents or fallout from nuclear weapon testing; and,
(c) when an accident or emergency situation has been declared or when an emergency plan or emergency procedures have been invoked, such as in cases involving accidents in Irradiation

Installations, and Nuclear Installations, or Radioactive Waste Facilities, the loss of application sources, or accidents during the transport of radioactive materials.

Irradiation Installations:

Particle accelerators and other large irradiators, such as enclosures with X ray apparatus for therapeutical uses or high activity sealed sources (i.e. large amounts of radioactive material encased in a capsule designed to prevent leakage or escape of the radioactive material) used for teletherapy, radiosterilization and other commercial product irradiatiors.

Legal Person:

Any individual, organization, corporation, partnership, firm, association, trust, estate, public or private institution, group or any political or administrative entity, who or which has full responsibility and commensurate authority for any action taken.

Level, reference (recording, investigation, intervention):

The value of a quantity which governs a particular course of action Such levels may be established for any of the quantities determined in the practice of radiation protection; when they are reached or exceeded, all relevant information is considered and the appropriate action may be taken Reference levels are not to be confused with the limits. They include:

(a) Recording level: a level defined by the Regulatory Authority or the Operator for nay relevant quantities above which recording of the information is taken to be necessary

(b) Investigation levels: values of quantities (such as equivalent dose, intake, contamination per unit area, etc.) above which further investigations are considered to be justified.

(c) Intervening levels: levels usually specified in advance by the Regulatory Authority or Operator for use in abnormal situations. if the value of the quantity of interest exceeds or is predicted to exceed a particular level, the appropriate remedial action may have to be taken Also referred to as Protective Actions Guides (PAG) or Emergency Reference Levels (ERL).

Licence:

A document by which the Regulatory Authority gives authority to site, design, manufacture, produce, construct, acquire, transport, receive, site, locate, commission, possess, use, operate, transfer, decommission or dispose any Nuclear Installation or any Radioactive Waste Facility, and
a document by which the Regulatory Authority gives authority to a Practitioner to deliver medical exposure.

Licensee:

An Applicant who is granted a general or specific authorization or a licence for a practice or source and who has recognized rights and duties for such practice or source, particularly in relation to protection and safety.

Limit:

The value of a quantity which may not be exceeded

Medical Exposures:

Exposures incurred by: patients as part of their own medical diagnosis or treatment; persons while helping in the support and comfort of patients, excluding occupational exposure; and, volunteers in a programme of research involving their exposure.

Member of the Public:

An idealized person whose characteristics are equal to the mean of the critical group of the population exposed by a source, i.e. of the group which is representative of the individuals most exposed to radiation and homogeneous in respect of the parameters influencing the dose received

Member State:
Any Member State of the organizations sponsoring these Standards.

Monitoring:
The measurement of radiation or activity for reasons related to the assessment or control of exposure to radiation or radioactive material and the interpretation of such measurements.

Natural Sources:
Natural radiation sources that increase the background exposure which the exposed people would otherwise receive and provided they are elements of a deliberate practice, the continuation of which is a matter of choice. Examples of such sources are cosmic radiation affecting occupationally exposed people in aircraft during high altitude flights, and terrestrial radiation sources in some new dwellings, in mines, in spas, etc

Normal Exposures:
Exposures which are expected to be delivered with certainty.

Nuclear Fuel Cycle:
All the operations associated with the production of nuclear energy including mining, milling, processing and enrichment of uranium or thorium, manufacture of nuclear fuel; operation of nuclear reactors; reprocessing of nuclear fuel, decommissioning and relevant waste management and disposal activities and any related research and development activity arising from any of the foregoing

Nuclear Installations:
Mines and mills, and other processing installations for uranium and thorium, nuclear fuel fabrication plants, nuclear reactors (critical and subcritical facilities, research reactors and nuclear power plants), spent fuel storage and processing facilities.

Occupational Exposure:
Exposure incurred by workers as a result of temporary or regular employment, wherever such exposures are incurred as a result of situations that can reasonably be regarded as being the responsibility of the employer.

Operator (or Operating Organization):
A Registrant or Licensee with recognized rights and duties for operating a source and who has accepted the legal possession of the source and is in complete charge of it, with full responsibility and commensurate authority for its operation in approved activities

Potential Exposures:
Exposures that may or may not be delivered and to which a probability of occurrence can be assigned.

Practice:
The adoption and continuation of any activity that introduces additional sources of exposures, exposure pathways or scenarios, or extends exposure to additional people, or modifies the network of pathways from existing sources, so as to increase the exposure of people, or the likelihood of exposure, or the number of people exposed.

Practitioner:
A Licensee for delivering medical exposure who has been accredited for exercising the medical practice.

Protection and Safety:

The protection of health against ionizing radiations and the safety of radiation sources, including the means for achieving such protection and safety, such as the various procedures and devices for keeping people's doses and risks as low as they can reasonably be and within prescribed constraints, for preventing accidents, and for mitigating the consequences of accidents - should they occur. [The term encompasses the technical disciplines of nuclear safety and radiological protection (including radioactive waste management and disposal)].

Protection and Safety Culture:

Assembly of characteristics and attitudes in persons and organizations which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance

Public Exposure:

Exposure incurred by members of the public, excluding their occupational exposure or medical exposure.

Qualified Expert:

Any person duly recognized by the Regulatory Authority to possess the knowledge and training to properly measure ionizing radiation, evaluate safety techniques, or advise regarding protection against radiation and the safety of sources and to whom the Operating Organization has delegated these responsibilities.

Radiation:

In the context of this Standard means ionizing radiation, i.e radiation capable of producing ion pairs in biological material.

Radioactive Effluents:

Those radioactive materials arising from a source within a practice which are released with the purpose of diluting and dispersing them into the environment, regardless of the physical state of those materials.

Radioactive Waste:

Those radioactive materials arising from a source within a practice that are retained for the purpose of isolation from the biosphere, regardless of the physical state of those materials.

Radioactive Waste Facilities:

Waste management and disposal facilities which handle radioactive materials that will eventually be disposed in the biosphere and for which future institutional controls are not foreseen.

Radiography Devices:

X ray apparatus and other radiography sources used in medical diagnosis (including lixiscopes), dentistry, veterinary and industrial radiography.

Radon:

Radon or thoron (^{220}Rn or ^{222}Rn) and their short-lived radioactive daughters.

Recording Level:

A level of dose, exposure or intake specified by the regulatory authority at and above which values of dose, exposure or intake received by workers shall be entered in their individual exposure records In the absence of such an approved level the recording level can be assumed as (10% of the annual limit) x (monitoring period in days) ÷ 365

Reference Man:
A model of a hypothetical adult with the anatomical and physiological characteristics defined in the report of the ICRP Task Group on Reference Man, used in dosimetry for radiation protection purposes.

Registrant:
An applicant who is granted registration of a practice or source and has recognized rights and duties for such practice or source, particularly in relation to protection and safety

Regulatory Authority:
An authority designated or otherwise recognized by a government for specific purposes in connection with protection and safety.

Remedial Actions or Measures:
Actions taken to reduce radiation doses that might otherwise be received in an intervention situation. Remedial actions or measures are sometimes called protective actions or countermeasures

Remedial Action Plan:
A plan for initiating and carrying out countermeasures or other actions intended to reduce radiation doses that might otherwise be received in an intervention situation.

Risk:
A multi-attribute quantity expressing hazard, danger, or chance of harmful or injurious consequences that can be attributed to exposure. It relates to objective quantities such as the probability that specific deleterious consequences may arise and the magnitude and character of such consequences; it may also include subjective considerations such as familiarity with and voluntariness in incurring the risk, and knowledge of the consequences. For purposes of radiation protection, risk is usually taken to be the probability that a given individual will incur any given deleterious stochastic effect as a result of radiation exposure

Safety:
(See protection and safety.)

Safety Analysis:
A review of the aspects of design and operation which are relevant to the protection of persons and the safety of the source, including the analysis of risks and the analysis of safety and protection provisions established in the design and operation of the source.

Source:
Any body or physical entity that may cause radiation exposure, e.g by emitting ionizing radiation or releasing radioactive materials. Sources can be existing or be introduced or used as elements within a practice. (For example: while radon emitting materials are sources existing in the environment, a sterilization gamma irradiation unit is a source for the practice of radiation preservation of food, an X ray unit is a source for the practice of radiodiagnosis, a nuclear power plant is a source for the practice of generating electricity by nuclear power)

Sponsoring Organizations:
FAO, IAEA, ILO, OECD/NEA, PAHO and WHO

Stochastic Radiation Effects:
Radiation effects, the severity of which is independent of dose and the probability of which is assumed by the ICRP to be proportional to the dose without threshold at the low doses of interest in radiation protection

Supervised Area:
Any area not already designated as a controlled area where the occupational radiation protection conditions need to be kept under review even though specific occupational radiation protection provisions are not normally needed.

Supplier:
Any legal person to whom the Operator has delegated his duties in relation to their design, manufacture, production or construction of a source (an importer of a source shall be considered a supplier of the source).

Surveillance:
All planned activities performed to ensure compliance with operational specifications established for a particular source.

Unsealed Sources:
Radioactive substances used in radiochemical laboratories, in diagnostic nuclear medicine and in biological and human metabolic research; and, other unsealed sources for which any conceivable potential scenario or sequence of potential exposures cannot lead to individual exposures able to cause lethal deterministic radiation effects or serious contamination with radioactive substances.

Uptake:
Amount of radioactive material absorbed into the extracellular fluids (see intake and deposition). Also used to denote the process.

Worker:
Any person who works, either regularly or temporarily, for an Employer and who has recognized rights and duties in relation to occupational radiation protection (a working Employer shall be regarded as having the duties of a worker).

Working Level:
A unit for potential alpha energy concentration (i e the sum of the total energy per unit volume of air carried by alpha particles emitted during the complete decay of each atom and its progeny in a unit volume of air) resulting from the presence of radon daughters or thoron daughters equal to emission of 1.3×10^5 MeV of alpha energy per litre of air. In SI units the WL corresponds to 2.1×10^5 J·m^{-3}

Working Level Month:
A unit of exposure to radon or thoron daughters
1 WLM = 170 WL·h
One working level month equals 3.5 mJ·h·m^{-3}.

QUANTITIES AND UNITS

( ) These standards adopt the quantities recommended in ICRP Publication 60 for purposes of specifying the limits and constraints for individuals. For purposes of monitoring, these standards continue the use of the quantities recommended by ICRU in Publication 39. The monitoring quantities should be such that they can be related to ICRP quantities.

Basic Dosimetric Quantities

Absorbed Dose

( ) The fundamental dosimetric quantity in these standards is the Absorbed Dose Its general definition is:

$$D=\frac{d\bar{e}}{dm}$$

where D is the absorbed dose, $d\bar{e}$ is the mean energy imparted by the ionizing radiation to matter in a volume element, and dm is the mass of the matter in this volume element. Dose can be averaged over any defined volume, the average being equal to the total energy imparted in the volume divided by the mass of the volume. The SI unit of absorbed dose is joule per kilogram ($J\ kg^{-1}$) and its special name is gray (Gy).

Organ Dose

( ) When referring to the tissues of human body these Standards use the Organ Dose D_T, which is the mean absorbed dose in a specified tissue or organ given by:

$$D_T=(1/m_T)\int_{m_T} D dm,$$

where m_T is the mass of the tissue or organ, and D is the absorbed dose in the mass element dm

Equivalent Dose

( ) Since the biological effects in organs or tissues also depends on type and energy of the radiation, these standards make use of the Equivalent Dose in an organ or tissue. The equivalent dose,is.

$$H_{T,R} = W_R \,.\, D_{T,R}$$

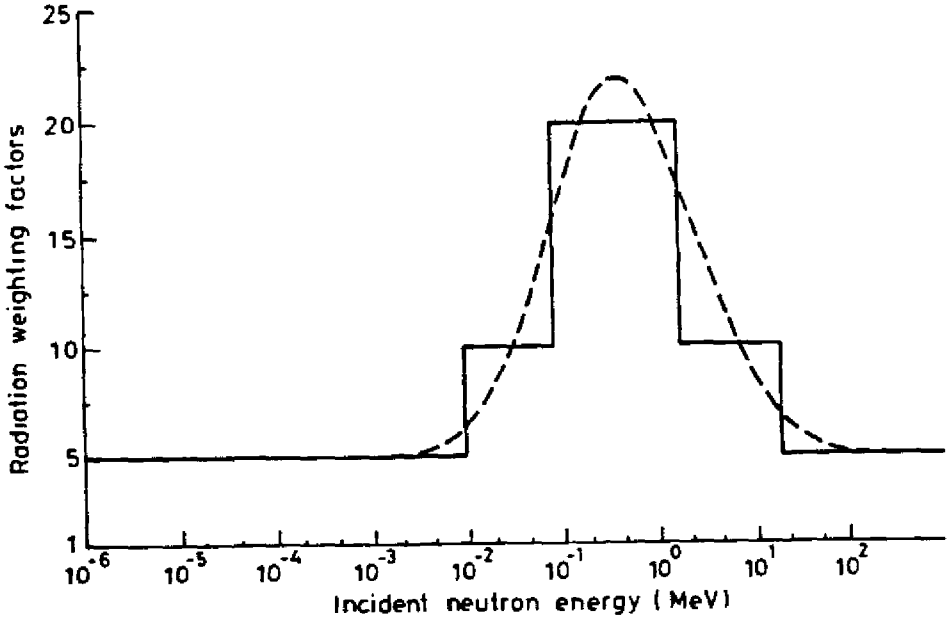
where $D_{T,R}$ is the average absorbed dose from radiation R in the organ or tissue T and W_R is the Radiation Weighting Factor for radiation R, defined below.

( ) The radiation weighting factors are the values specified by ICRP according to the type and quality of the external radiation incident on the body or of the radiation emitted by internally deposited radionuclides. The values are:

Type and energy range		Radiation weighting factor, W_R
Photons, all energies		1
Electrons and muons, all energies *		1
Neutrons, energy	<10 keV	5
	10 keV to 100 keV	10
	>100 keV to 2 MeV	20
	>2 MeV to 20 MeV	10
	>20 MeV	5
Protons, other than recoil protons, energy >2 MeV		5
Alpha particles, fission fragments, heavy nuclei		20

* Excluding Auger electrons emitted from nuclei bound to DNA

When calculations for neutrons require a continuous function, the approximation represented by the line in the following figure can be used:



Radiation weighting factors for neutrons. The smooth curve is to be treated as an approximation

$$W_R = 5 + 17.e^{-(\ln(2E))^2/6}$$

Where E is the neutron energy in MeV.

( ) For radiation types and energies not included in the table, W_R can be taken to be equal to Q calculated at 10 mm depth in the ICRU sphere and can be obtained as follows:

$$\bar{Q} = \frac{1}{D}\int Q(L)D(L)dL$$

where D is the absorbed dose and Q(L) is the quality factor in terms of the unrestricted line as energy transfer, L, in water specified by ICRP (ICRP Publication 60)

$$Q(L) = \begin{cases} 1 & \text{for } L \leq 10, \\ 0.32L-2.2 & \text{for } 10 \leq L \leq 100, \\ 300/\sqrt{L} & \text{for } L \geq 100, \end{cases}$$

where L is expressed in keV μm^{-1}.

( ) When the radiation field is composed of radiations with different values of W_R, the calculation of equivalent dose is carried out by subdividing the organ absorbed dose in blocks (given in 4.1), multiplying each by its own value of W_R, and summing the results

$$H_T = \sum_R W_R \quad D_{T,R}$$

The unit of equivalent dose is J kg^{-1}, with the special name sievert (Sv).

Effective Dose

( ) Usually more than one organ or tissue is exposed to radiation, receiving different equivalent doses In most cases the requirements of these Standards refer to the quantity Effective dose, namely a summation of the tissue equivalent doses, multiplied by the tissue weighting factors, which corresponds numerically to the equivalent dose of the uniformly irradiated whole body. The effective dose, E, is defined as.

$$E = \sum_T W_T \cdot H_T$$

where H_T is the equivalent dose in tissue T and W_T is the tissue weighting factor for tissue T, as specified in the table below.

It follows that:

$$E = \sum_T W_T \cdot \sum_R W_R \cdot D_{T,R} = \sum_R W_R \cdot \sum_T W_T \cdot D_{T,R}$$

The unit of effective dose is J kg^{-1}, with the special name sievert (Sv).

Tissue or organ	Tissue weighting factor, H_T
Gonads	0.20
Bone marrow (red)	0 12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Oesophagus	0 05
Thyroid	0.05
Skin	0.01
Bone surface	0 01
Remainder	0 05

For the purposes of calculation, the remainder is composed of the following organs: adrenal glands, brain, upper large intestine, small intestine, kidney, muscle, pancreas, spleen, thymus and uterus. In those exceptional cases in which a single one of the remainder tissues or organs receives an equivalent dose in excess of the highest dose in any of the twelve organs for which a weighting factor is specified, a weighting factor of 0.025 should be applied to that tissue or organ and a weighting factor of 0.025 to the average dose in the rest of the remainder as defined above.

Committed Equivalent Dose

( ) Organ or tissue irradiation from internal emitters is spread in time, from the energy deposition that occurs as the radionuclide decays The Committed Equivalent Dose, $H_T(\tau)$, at elapsed time, τ, following a single intake of radioactive material is defined as

$$H_T(\tau) = \int_{t_0}^{t_0+\tau} \dot{H}_T(t)\,dt$$

where t_o is the time of intake and $H_T(t)$ is the equivalent dose rate at time t in an organ or tissue T When τ is not specified it will be taken to be 50 years for adults and 70 years for children.

Committed Effective Dose

( ) The Committed Effective Dose, $E(\tau)$ for whole body irradiation from the single uptake of radioactive material is defined as:

$$E(\tau) = \sum_T W_T \cdot H_T(\tau)$$

Dosimetric Quantities for Monitoring

( ) A joint task group of ICRP and ICRU is currently examining these relationships, and the correlation between the new ICRP quantities and the recommended ICRU quantities. Further consideration, and update as appropriate, of these factors and quantities will be made when the work of the task group is completed.

Individual Monitoring

( ) For individual monitoring the personal dose equivalent, Hp(d) is defined for both strongly and weakly penetrating radiations Hp(d) is the dose equivalent in soft tissue below a specified point on the body at an appropriate depth, d.

d = 10 mm for strongly penetrating radiation and

d = 0.07 mm for weakly penetrating radiation are recommended

Area Monitoring

( ) For area monitoring, the Ambient Dose Equivalent and the Directional Dose Equivalent are defined:

Ambient dose equivalent, H*(d), at a point in a radiation field is the dose equivalent that would be produced by the corresponding aligned and expanded field in the ICRU sphere at a depth d on the radius opposing the direction of the aligned field. d = 10 mm is recommended for strongly penetrating radiation

Directional dose equivalent, H'(d,Ω), at a point in a radiation field, is the dose equivalent that would be produced by the corresponding expanded field in the ICRU sphere at depth d, on a radius in a specified direction, Ω. d = 0.07 mm is recommended for weakly penetrating radiation

Collective Dosimetric Quantities

Collective Effective Dose

( ) As an expression of the total radiation exposure in a population the Collective Effective Dose, S, is defined as

$$S = \Sigma E_i \cdot N_i$$

where E_i is the average effective dose in the population sub-group i and N_i is the number of individuals in the sub-group. It can also be defined by the integration

$$S = \int_0^\infty E\left[\frac{dN}{dE}\right] dE$$

where $\frac{dN}{DE}$ dE is the number of individuals receiving an effective dose between E and E+dE If collective effective dose is committed by an event, decision or a finite portion of a practices, k, then the collective effective dose commitment, S_K is the total collective effective dose that will result from k. S_K is then also given by

$$S_K(t) = \int_0^\infty \dot{S}_K(t)\, dt$$

where $S_K(t)$ is the collective effective dose rate at time t, caused by k.

Other Radiological Quantities

Activity

( ) The Activity, A, of an amount of radionuclide in a particular energy state at a given time is defined as

$$A = \frac{dN}{dt}$$

where dN is the expectation value of the number of spontaneous nuclear transformations from that energy states in the time interval dt. The SI unit of activity is the reciprocal second, S^{-1}, with the special name becquerel (Bq).