Atomic Energy Control Board | Commission de contrôle de l'énergie atomique

R-99

Regulatory Document

Reporting Requirements for Operating Nuclear Power Facilities

A Regulatory Policy Statement

In effect: January 1, 1995

Canada

PREFACE

The Atomic Energy Control Board has three levels of Regulatory Documents, graduated in terms of their rigidity of application.

Level 1: Regulatory Guides

This is the most flexible form of regulatory document, providing advice or guidelines on certain aspects of the regulatory process.

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These contain firm requirements and guidelines for compliance. However, the AECB may allow variations, or consider alternative means of attaining the same objectives where a satisfactory case is made.

Level 3: Regulations

These are instruments by which the AECB establishes prohibitions, rights, obligations and powers pursuant to the *Atomic Energy Control Act*. Regulations possess the full force of law; they leave little room for interpretation.

All Regulatory Documents are initially issued in draft form as Consultative Documents, for comments by the public, special interest groups and those potentially affected by the content such as licensees and their employees.

Suggestions for new Regulatory Documents and for improvement to those that exist are encouraged and should be directed to the AECB Office of Public Information, as should requests for technical information on and interpretation of Regulatory Documents, if a subject matter specialist is not specified in the text.

Copies of Regulatory Documents are available in both English and French from the:

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If you wish to appear on the mailing list for the receipt of Consultative Documents or Notices announcing their release, requests can be sent to the same address.

NOTICE

A draft of this Regulatory Document was issued for public comment as a Consultative Document (C-99) on September 9, 1991. On completion of the comment review and text revision process, the content was made effective on January 1, 1995.

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Reporting Requirements for Operating Nuclear Power Facilities

A. PURPOSE

This regulatory document consolidates in a single document the requirements for reports that operating nuclear power facilities must make to the Atomic Energy Control Board (AECB). Additional reporting requirements are imposed on individual licensees through specific licence conditions and Regulations made under the *Atomic Energy Control Act.*

B. INTRODUCTION

A licensee who operates a nuclear power facility in Canada shall submit the following reports on the facility to the AECB:

a) event reports,
b) quarterly reports,
c) safety report updates,
d) annual radiological environmental monitoring reports,
e) annual research and development reports,
f) periodic inspection reports,
g) annual reliability reports, and
h) fissionable and fertile substances reports

C. DEFINITIONS

In this document,

"defined specifications" means the criteria set out in the licensing documents for a special safety system or a safety-related system that designate the minimum functional capability and performance levels required for effectiveness; (*critères établis*)

"discovery of a safety problem" means the earliest time when the licensee uncovers a situation revealing a safety problem or decides that specific resources should be allocated to ascertain whether or not a safety problem exists; *(découverte d'un problème de sûreté)*

"impairment report" means a report of the impairment history of the system for a given time, and includes, for each impairment, its duration and an assessment of the ability of the system to perform with respect to the reliability measures in the licensing documents; (*rapport de défaillance*)

"Operating Policies and Principles" means a document identified as the Operating Policies and Principles in the licensing documents, that sets out the authorities and responsibilities of managerial and operating staff, and the principles and guidelines to be followed for safe operation of the facility systems; *(ligne de conduite pour l'exploitation)*

"oral report" means information transmitted in a verbal or other form acceptable to the AECB; *(rapport oral)*

"potential serious process failure" means an event that could have become a serious process failure, but did not, due to fortuitous circumstances rather than design provisions or approved procedures; *(défaillance grave possible de système fonctionnel)*

"predicted reliability" means the reliability of a system in its nominal state during some future period and/or, for poised systems, at some future time; (*fiabilité prévue*)

"pressure boundary" means any pressure-retaining vessel or system component that is subject to registration or that is registered under the applicable boiler and pressure vessel legislation, whether a conventional system or a nuclear system; *(enveloppe de pression)*

"reliability" means the probability that a system in a given state will be able to perform a stated mission under stated conditions according to its defined specifications for a stated mission time and/or, for poised systems, when required to do so; *(fiabilité)*

"safety-related system" means those structures, systems, and components that either are identified as safety related in the licensing documents, or whose malfunction or failure could lead directly to radiation exposure of site personnel or the public, or could directly increase the severity of accidental releases of radioactive material from the facility; *(système relié à la sûreté)*

"security incident" means:

(a) an actual, attempted, or threatened act of sabotage,

(b) a failure of the procedures, or a breach or malfunction of the security system that results in a failure to comply with the *Physical Security Regulations* or the power reactor operating licence, or

(c) an actual or impending civil demonstration at the facility; *(atteinte à la sécurité matérielle)*

"serious process failure" means a failure of a process system, component, structure, or an inappropriate procedure or human action:

(a) that led to a systematic fuel failure or to a significant release from the facility, or

(b) that could have led to a systematic fuel failure or a significant release in the absence of action by any special safety system; *(défaillance grave de système fonctionnel)*

"significant release" means a release of radioactive material that arises from an event and that results in a whole body or committed effective dose in excess of 0.0005 Sv (50 mrem) or a committed or received thyroid dose of 0.005 Sv (500 mrem) to the most exposed member of the public at or beyond the exclusion boundary; *(rejet important)*

"special safety system" means the shutdown system no.1, the shutdown system no. 2, the containment system, or the emergency core cooling system; *(système spécial de sûreté)*

"systematic fuel failure" means that fuel that has no defect prior to an event, fails or exceeds the fuel integrity criteria defined in the licensing documents as a result of the event; *(défaillance systématique du combustible)*

"unacceptable decline in reliability" means that a safety-related system, subsystem or component:

(a) does not meet the predicted reliability targets that are set out in the licensing documents or

(b) shows a continued trend of reduced reliability such that those targets will not be met; *(baisse inacceptable de la fiabilité)*

"violation of a licence condition" means a violation of a condition of the reactor operating licence, the *Physical Security Regulations*, the *Transport Packaging of Radioactive Materials Regulations*, or the *Atomic Energy Control Regulations* and, without limiting the generality of the foregoing, includes:

(a) a failure to comply with any document specifically referenced in the operating licence such as the Operating Policies and Principles or,

(b) an interference with the operation of any safeguards equipment installed by or on behalf of the International Atomic Energy Agency; *(infraction au permis)*

"written report" means information transmitted in a written or electronic form acceptable to the AECB; *(rapport écrit)*

D. REPORTING REQUIREMENTS

1. Event Reports

Every licensee who operates a nuclear power reactor shall make event reports to the Project Officer or to the Director of the Power Reactor division designated by the AECB for the facility involved, at the times required by subsections 1.2 and 1.3 or, for each event that is described in 1.2(a) and 1.2(b), to the AECB Duty Officer, if the Project Officer or Director cannot be contacted within the allotted times.

1.1 Reportable Events

An event report shall be submitted for:

(a) a violation of a licence condition;

(b) an emission of radioactive material that is:

(i) in excess of the limits that are specified in the licensing documents, or

(ii) unmonitored where the upper limit of the release cannot be estimated and shown to be below the limits set out in the licensing documents;

(c) an event that could have caused a reportable dose of ionizing radiation under the *Atomic Energy Control Regulations*, but did not, due to fortuitous circumstances rather than to approved procedures (this is in addition to the requirements set out in the AEC Regulations concerning the reporting of an occurrence resulting or likely to result in a dose of ionizing radiation in excess of any dose specified in the AEC Regulations);

(d) a serious process failure;

(e) a potential serious process failure;

(f) an automatic or intentional manual actuation of either shutdown system, or both, from any power level, except:

(i) a reactor trip that occurs while the unit is in a guaranteed shutdown state and where there is no failure or potential failure of the shutdown guarantee, or

(ii) a reactor trip that was part of a preplanned sequence;

(g) an event where the reactor is required to be shut down by the conditions of the licence or the Operating Policies and Principles;

(h) an unplanned actuation or series of actuations of the emergency core cooling system or subsystem;

(i) an unplanned actuation or series of actuations of the containment system or subsystem except for a spurious actuation of the containment isolation subsystem where there is no actual or potential significant release;

(j) a degradation of a special safety system or a relevant safety-related system that:

(i) is hazardous to the health and safety of any person, or

(ii) prevents a special safety system or a safety-related system from meeting its defined specifications;

(k) a degradation of the pressure boundary that exceeds a limit that is specified in the design analysis or in the applicable boiler and pressure vessel code, standard or act under which the pressure boundary was registered and includes:

(i) a pressure boundary deformation, crack, or rupture or a leakage in excess of a limit that is specified in the Operating Policies and Principles;

(ii) the occurrence of an abnormal loading transient that exceeds:

(A) a pressure boundary design condition, or

(B) a Service Level B condition, for any nuclear component that is designed in accordance with the rules of ASME III subsection NB;

(iii) a change to the size, rating or material property of the pressure boundary beyond that allowed for in the design;

(iv) a repair or modification that changes the strength of a component of the pressure boundary that did not receive the prior authorization required by CSA Standard N285.0;

(v) a reduction of the wall thickness beyond that allowed in the design by the applicable pressure vessel code, standard or act under which the pressure boundary was registered; and

(vi) degradation of the overpressure protection equipment for the pressure boundary that violates a limit of the overpressure protection report or any other licensing document;

(l) a reduction of the effectiveness of the systems for reactor power control, for the primary heat transport system pressure and inventory control or for turbine protection, below the defined specifications (whether caused by failure, equipment inadequacy, improper procedures, or inappropriate human action)

(m) an event that results in a loss of heavy water greater than 100 kg (in addition to the reporting requirements set out in the *Atomic Energy Control Regulations* for theft or loss of a prescribed substance);

(n) a security incident at the facility;

(o) an actual, threatened, or impending walkout, work disruption, slowdown, legal or illegal strike that can affect the safety or security of facility operations or the capability to maintain minimum staff complements;

(p) a declaration of an alert or emergency, within or beyond a unit of the facility, where personnel or resources are mobilized by the licensee in response to an unexpected occurrence of a radiological condition, chemical spill, fire, or potentially explosive mixture of gases that creates an actual hazard to the safe operation of the facility or to the safety of the public:

(q) a concentration of hydrogen and deuterium in any cover gas system in excess of 4% by volume;

(r) the occurrence of an earthquake that exceeds, at the site, the maximum free-field seismic instrumentation triggering level that is specified by Standard CAN/CSA N289.5 or, where appropriate instrumentation is not available, the occurrence of an earthquake that is greater than magnitude 5 on the Richter scale within 500 kilometers of the site;

(s) a failure to perform a test that is required by a licence condition, including any routine test of a safety-related system that is required in the licensing documents, except in accordance with approved procedures;

(t) a failure to monitor or control a release path of radioactive material that is required to be continuously monitored and controlled except in accordance with approved procedures;

(u) the discovery of a safety problem arising from operating experience that reveals a hazard to radiological health or nuclear safety that is different in nature, greater in probability, or greater in magnitude than was previously represented to the AECB in the licensing documents and includes:

(i) the discovery that a special safety system does not meet its defined specifications;

(ii) a case where the reactor is found to be operating in a state that was not considered in the safety analysis, or the occurrence of an event of a type that is not considered in the safety analysis;

(iii) an unexplained and unexpected reactor core behaviour;

(iv) an event where two or more systems or components, that were assumed in the safety analysis to be mutually independent, are proven to be interdependent;

(v) the discovery of a mistake in a licensing document that, if relied upon or acted upon, would increase the risk to radiological health or nuclear safety.

(v) the discovery of a safety problem that arises from research findings or improved methods for safety analysis, that reveals a hazard to radiological health or nuclear safety that is different in nature, greater in probability, or greater in magnitude than was previously represented to the AECB in the licensing documents and includes:

(i) the discovery that the assumptions, inputs, analytical methods or results of the safety analyses may be invalid;

(ii) information that reveals :

(A) that the limits in the Operating Policies and Principles document, or in the appendices to the document, are inadequate, or

(B) that the analyses from which the limits were derived may be invalid or uncertain, such that the minimum margins of safety are less than predicted;

(iii) information that reveals that the defined specifications of a special safety system or of a safety-related system are invalid and,

(iv) the discovery of a mistake in a licensing document that, if relied upon or acted upon, would increase the risk to radiological health or nuclear safety.

1.2 Oral Event Reports:

For all events referred to in Subsection 1.1, except paragraph 1.1(v), a licensee shall make an oral report to the AECB as follows:

(a) as soon as possible, for an emergency as described in paragraph 1.1(p) or for a security incident, where a hazard to safety or security continues to exist, (i.e. the oral report shall be made immediately after initiating the required response actions and alerting the required provincial, municipal authorities or station staff who are responsible for responding to an event);

(b) within 24 hours:

(i) the loss or theft of a prescribed substance, as described in paragraph 1.1(m),

(ii) an actual or potential dose of ionizing radiation, as described in paragraph 1.1 (c).

(iii) an emission of radioactive material in excess of the limits, as described in paragraph 1.1(b),

(iv) the occurrence of any seismic event that exceeds the maximum acceleration for the design basis earthquake;

(c) by the first business day following the discovery of an event that is described in subsection 1.1 and that is not referred to in paragraphs (a) and (b).

1.3 Written Event Reports

In addition to the oral event reports required by subsection 1.2, a licensee shall make one or more written reports for each event discussed in subsection 1.1 as follows:

Event Notification Report

For all events referred to Subsection 1.1, a licensee shall make an event report and submit to the AECB, an Event Notification Report within 15 calendar days after the discovery of the event. The Event Notification Report shall contain the following information:

(a) the date and time of the event;

(b) the facility and reactor unit(s) affected;

(c) where relevant, identification of the systems, components, functions or personnel that were affected;

(d) primary applicable paragraph(s) of subsection 1.1, licence condition(s) or regulations ;

(e) a brief description of the event and how the event was discovered;

(f) if relevant, a description of the condition of the event site and the operating conditions of the unit(s) including reactor power prior to the event;

(g) a description of the actions taken in immediate response to the event;

(h) a statement of the safety significance of the event, including, if the event is an automatic or intentional manual actuation of either shutdown system, a statement as to whether the event was a serious process failure or not;

(i) if relevant, the resulting doses or dose estimates to the personnel or to the public;

(j) if applicable, the municipal, provincial and federal authorities that were notified of the event;

(k) if applicable, a statement of whether or not there will be a root cause analysis and/or human performance evaluation done of the event;

(l) a statement whether the Event Notification Report constitutes a Detailed Event Report or not;

(m) the signature of the designated representative of the licensee.

Detailed Event Report

For all events referred to Subsection 1.1, except paragraph 1.1(v), a licensee shall submit to the AECB a Detailed Event Report within 45 calendar days after the discovery of the event unless the Event Notification Report previously forwarded to the AECB contains all the information required for a Detailed Event Report.

The Detailed Event Report shall include the following information:

(n) if relevant, an update of the information submitted in the Event Notification Report to correct any errors, changes or omissions;

(o) a detailed account of the event that sets out any causes or consequences, including, where relevant, those that have been established by an investigative process;

(p) if relevant, an evaluation of the degree of impairment of special safety systems or of a safety-related system;

(q) if applicable, a statement as to whether a review has been carried out and account has been taken of similar related events;

(r) the corrective actions taken or proposed to be taken to prevent a recurrence of the event or to correct the situation, including, for an event that involves human error, those actions that result from a human performance evaluation process;

(s) the comments and/or recommendations of the facility management, including, if relevant, their comments on the appropriateness of the actions taken by operating staff ;

(t) a statement whether the Detailed Event Report is believed to be complete or, that an Additional Report will be made and, if so, the Additional Report number that has been assigned and,

(u) the signature of the designated representative of the licensee.

Additional Report

Where the Detailed Event Report is incomplete due to the unavailability of the relevant information or due to an ongoing investigation, or due to the discovery of new information, the licensee shall make an Additional Report to the AECB as soon as the required information becomes available.

The Additional Report shall contain:

(v) the required information that is missing from the Detailed Event Report;

(w) if relevant, an update of the information in the Detailed Event Report to correct any errors, changes or omissions;

(x) a statement on the disposition of any action and recommendation, in the Detailed Event Report as per subparagraphs 1.3 (r) and 1.3 (s);

(y) a statement as to whether or not the Additional Report is believed to be complete and all necessary follow-up actions are taken; and,

(z) the signature of the designated representative of the licensee.

2. Quarterly Reports

Every licensee who operates a nuclear power facility shall make, each calendar year, four quarterly reports in writing to the AECB. The reports shall be submitted to the Project Officer or staff member designated by the AECB for the facility involved, at the time that is required by subsection 2.2.

2.1 Contents of Quarterly Reports

The quarterly report shall report the following:

(a) a change in station personnel organization and staffing, procedure, equipment, or fuel that could invalidate the information in the Safety Report or other documents that are referred to in the licensing documents;

(b) a list and/or a brief description of the events with report titles and numbers, of the events required to be reported under Subsection 1.1 that occurred during the reporting period, except for any security event referred to in Paragraph 1.1 (n);

(c) a list and/or brief description of the Additional Reports described in 1.3 that:

(i) were submitted during the quarter with the Detailed Event Report titles and numbers,

(ii) remain to be submitted with the Detailed Event Report titles and numbers;

(d) the results of routine radioactive effluent monitoring, including, for each month of the quarter, the total activity released and the cooling water flow volume;

(e) the results of non-routine off-site radiological monitoring that was triggered as a result of any unplanned emission of radioactive material;

(f) a summary of the results of routine surveys of the radiation field, or surface contamination and the concentration of airborne radioactive materials that were taken in various locations within the facility. This should include the results of any assessment to detect increases of radiation hazard over time;

(g) the dose received by any person that resulted from any event that is described in paragraph 1.1(c), the collective dose of all workers and dose statistics for different groups of workers;

(h) a summary of emergency exercises and drills that were carried out and a description of any change that was made to the emergency procedures and once per year, one of the quarterly reports shall also include the results of the annual review conducted by the licensee, of the off-site emergency procedures and the arrangements with off-site authorities;

(i) a summary of faults or combination of faults that prevented a special safety system and, where applicable, a safety-related system, from meeting its defined specifications;

(j) the acquisition and transfer of prescribed substances, including any revisions to the inventory to account for radioactive decay. The fourth quarterly report for each calendar year shall also include the inventory as of the end of the year;

(k) the number of fires that occurred at the facility with an evaluation of their safety significance, and

(l) the fourth quarterly report for each calendar year shall also include an annual review report of the safety-related station performance indicators for the operational and maintenance programs and documentation, that are used by the licensee to detect possible problems, backlogs or trends and to determine the appropriate priority for their resolution (the information may be presented in graphical form).

2.2 Timing of Quarterly Reports

Each quarterly report shall be submitted within three months of the end of the period covered by the report, except the fourth quarterly report for the calendar year, which shall be submitted by March 1 of the next calendar year.

3. Safety Reports

Every licensee who operates a nuclear power reactor shall make an update of the Safety Report in writing to the Project Officer or the staff member designated by the AECB.

The update of the Safety Report shall reflect design and procedural changes and new analyses. The updated report shall take into consideration any event or occurrence that was reported pursuant to paragraphs 1.1 (u) and 1.1 (v). If any event or occurrence brings the results of the Safety Report analyses into question, the analyses shall be repeated using current methods and information, and the results incorporated into the Safety Report revisions.

The description of the facility in the Safety Report shall be reviewed and updated where necessary, and submitted no more than every three years from the last update, unless otherwise permitted by the prior written approval of the AECB.

The Safety Report analyses for the facility shall be reviewed and updated, where necessary, every three years from the last update, unless otherwise approved in writing by the AECB, and shall be submitted by the date specified by the AECB.

4. Radiological Environmental Monitoring Reports

Every licensee who operates a nuclear power reactor shall make an annual report of the results of the off-site radiological environmental monitoring program in writing to the Project Officer or to the staff member designated by the AECB.

The reports shall include an analysis of the results of the off-site radiological environmental monitoring program, the individual doses that were calculated as doses to the critical group, a review of the radiological environmental monitoring quality assurance program, and any unusual findings during the calendar year.

The report shall be submitted by May 1 of the next calendar year, unless otherwise approved in writing by the AECB.

5. Research and Development Progress Reports

Every licensee who operates a nuclear power reactor shall make an annual research and development progress report in writing to the Project Officer or the staff member designated by the AECB.

The progress report shall describe research and development programs that are planned or are being carried out during the calendar year, or that are planned for future years, to resolve unresolved safety questions. The report shall describe schedules, milestones, and results of the programs.

The report shall be submitted by May 1 of the next calendar year, unless otherwise approved in writing by the AECB.

6. Periodic Inspection Program Reports

Every licensee who operates a nuclear power reactor shall make Periodic Inspection Program reports in writing to the Project Officer or the staff member designated by the AECB.

The Periodic Inspection Program reports shall describe the results of any inspection carried out in accordance with the Periodic Inspection Program requirements of CSA Standards N285.4 and N285.5

The reports shall be submitted within 90 days of the completion of any stage of the Periodic Inspection Program that is referred to in CSA Standards N285.4 and N285.5, unless otherwise approved in writing by the AECB.

7. Reliability Report

Every licensee who operates a nuclear power reactor shall make an annual Reliability Report in writing to the Project Officer or the staff member designated by the AECB. The requirement to report reliability on an annual basis does not relieve the licensee of its obligation to detect any unacceptable decline in reliability, and to respond to it on an ongoing basis.

The Reliability Report shall contain an evaluation, for the calendar year being reported, of the system reliability of each special safety system and of any other safety-related system that has a specific reliability requirement described in the licensing documents. The Reliability Report shall include:

(a) a report on the completion of all tests that were required to be carried out during the reporting period by a licence condition or that were required by a routine test program that was referred to in the licensing documents,

(b) an impairment report,

(c) a review of reliability indices for relevant safety-related systems (e.g. starting and running reliability of Class III power generators),

(d) an assessment of the predicted reliability of each special safety system and of any other relevant safety-related system. The assessment shall include a review of the changes that occurred between the information that was used in the existing reliability analysis and the current status of that information. The review shall take into consideration:

i) design changes that are anticipated in the reliability analysis but that have not yet been implemented;

ii) design changes that were made subsequent to the reliability analysis;

iii) differences between the actual operating or maintenance procedures and those assumed in the analysis;

iv) differences between the actual components and system performances and those assumed in the reliability analysis. Where relevant, the reliability analysis review shall take into consideration:

(A) the discovery of new failure modes not previously modeled in the reliability analysis;

(B) differences in the failure rates of components taking into account their environment and use;

(C) failure trends that affect the predicted reliability of the special safety systems and any other relevant safety-related system, and

(e) if the assessment indicates that the predicted reliability of a special safety system and any other relevant safety-related system is less than the target specified in the licensing documents, the Reliability Report shall also include:

i) an evaluation and discussion of the significance of these results,

ii) an identification of any action intended to be taken to increase the predicted system reliability to the limit specified in the licensing documents, and

iii) a schedule for implementation of the actions, where relevant.

If the review indicates differences that would invalidate the reliability analysis, the analysis shall be updated and the Reliability Report shall include the proposed schedule for updating the analysis.

The annual Reliability Report shall be submitted by April 1 of the year that follows the reporting period, unless otherwise approved in writing by the AECB.

8. Fissionable and Fertile Substances Report

Every licensee who operates a nuclear power reactor shall make reports on the inventory and transfer of fissionable and fertile substances in writing to the Project Officer or the staff member designated by the AECB.

The reports shall be made and submitted in accordance with the document AECB-1049, "Reporting Requirements for Fissionable and Fertile Substances" unless otherwise approved in writing by the AECB.

Regulatory Document

Texte de réglementation

Atomic Energy Control Board

Commission de contrôle de l'énergie atomique

REGULATORY DOCUMENT R-104

Regulatory Policy Statement

REGULATORY OBJECTIVES, REQUIREMENTS AND GUIDELINES FOR THE DISPOSAL OF RADIOACTIVE WASTES - LONG-TERM ASPECTS

Effective date:

June 5, 1987

Canada

R-104 REGULATORY OBJECTIVES, REQUIREMENTS AND GUIDELINES FOR THE DISPOSAL OF RADIOACTIVE WASTES - LONG-TERM ASPECTS

A draft of this document was issued for public comment as a Consultative Document (C-104) on April 30, 1986. On completion of the comment review and text revision process, the content was finalized and made effective on June 5, 1987.

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REGULATORY OBJECTIVES, REQUIREMENTS AND GUIDELINES FOR THE DISPOSAL OF RADIOACTIVE WASTES - LONG-TERM ASPECTS

1. PURPOSE AND SCOPE

It is the purpose of this document to present the regulatory basis for judging the long-term acceptability of radioactive waste disposal options, assuming that the operational aspects of waste emplacement and facility closure satisfy the existing regulatory framework of requirements. Basic objectives of radioactive waste disposal are given, as are the regulatory requirements which must be satisfied in order to achieve these objectives. In addition, guidelines are given on the application of the radiological requirements to assist proponents in the preparation of submissions to the Atomic Energy Control Board (AECB).

The primary focus of the requirements is on radiation protection, although environmental protection and institutional controls are also addressed in a more general way since these factors stem directly from the overall objectives for radioactive waste disposal. Other types of regulatory requirements such as might concern other aspects of conceptual assessments, siting, design, construction, operation and decommissioning of facilities for the management of particular waste types are, or will be, addressed in separate regulatory documents. Examples of these documents are Regulatory Document R-71 on the concept for deep geological disposal of nuclear fuel waste and Consultative Document C-36 on the management of uranium and thorium mine and mill tailings.

2. INTRODUCTION

In Canada, a wide variety of radioactive wastes are generated at all steps in the nuclear fuel cycle from uranium mining and milling to reactor operations for electricity production, and from the use of radioisotopes in industry, research and hospitals. The bulk of these wastes are managed in a manner based on the principles of containment and isolation from people and the environment. However, the techniques employed rely on the continued need for human intervention and surveillance whether this be for monitoring, maintenance, treatment or restriction of public access to assure an acceptable level of radiological safety. The remaining wastes are disposed of either by controlled discharge to the environment as gaseous and liquid effluents, or in the case of small quantities of lightly contaminated material, by treatment as conventional wastes with no requirement for special radiological precautions.

The current operation of radioactive waste management facilities and the routine discharge of radioactive effluents from other nuclear facilities are strictly regulated by the AECB using a comprehensive system of licensing, compliance and enforcement activities. The specific radiological requirements applied by the AECB are derived from the system of dose limitation recommended by the International Commission on Radiological Protection (ICRP). The dose limits recommended by the ICRP are intended to apply to all practices in which radiation exposure of workers and the public can be influenced by active controls but do not apply to exposures from unusual events, medical irradiations and natural background radiation. For exposures from situations such as accidents and other unusual events during nuclear facility operations, the radiological requirements that are applied by the AECB acknowledge the expected frequency of occurrence of the unusual event or process causing the

exposure. In summary, for current operations a regulatory framework of radiological requirements is actively applied, such that procedures of various types are reliably maintained for monitoring environmental discharges, conducting remedial actions as necessary, and controlling exposure pathways.

For the long-term management of radioactive wastes, the preferred approach is disposal, a permanent method of management in which there is no intention of retrieval and which, ideally, uses techniques and designs that do not rely for their success on long-term institutional control beyond a reasonable period of time. The practical disposal options presently being studied usually involve containment of the wastes and their isolation from the biosphere for extended time periods. For some waste types, though, such as the large-volume wastes from uranium mining and milling, the ideal type of disposal may sometimes not be practicable: In such instances where there are no practical disposal options for achieving the ideal goal, there may be a long-term need for continued institutional controls to guard against particular exposure scenarios after the facility has ceased receiving waste and has been closed down.

Whichever option is implemented for the long-term containment and isolation of radioactive wastes, exposures after the closure of a disposal facility will be dependent on a range of events and processes with varying probabilities of occurrence and, in some cases, they will be delayed for considerable periods of time. Forecasts of the possible doses to humans are subject to additional uncertainties owing to the range of factors affecting the environmental transport of radionuclides and to changes which might occur in future living habits, lifestyles and population distributions. Also, in the case of disposal with no ongoing requirement for institutional controls, it is not possible to enforce compliance with present-day forecasts since there would be no operator for the facility in the future. There is consequently a need to establish alternative regulatory requirements to ensure the acceptability of waste disposal options for which there are potential long-term radiological impacts in the post-operational period. The basic purpose of this document is to establish these waste management requirements. For reasons of consistency, equity and fairness, the requirements are based upon an extension of the existing regulatory framework and should be broadly applicable to all waste types and disposal options in which long-term containment and isolation are employed.

It is intended that the requirements and guidelines presented here will come into effect immediately for those facilities designed specifically for the disposal of radioactive wastes. Where a facility may change from an operational storage facility to a disposal facility at some time in the future, the requirements and guidelines are intended to apply at the time disposal is considered to begin. This would normally occur as soon as practical after operations at the facility cease and would likely include a period of institutional control determined by waste and site-specific issues.

3. OBJECTIVES OF RADIOACTIVE WASTE DISPOSAL

The objectives of radioactive waste disposal are to:

- *minimize any burden placed on future generations,*
- *protect the environment,*
- *protect human health,*

taking into account social and economic factors.

Many factors must be considered in meeting these objectives in an effective and reliable way over the long term. The disposal of radioactive wastes on the basis of containment and isolation requires safety features to restrict the release of radionuclides into the environment and to reduce the likelihood of inadvertent public access to the waste. These safety features may incorporate a suitable combination of processes, barriers and institutional controls. The processes include radioactive decay, adsorption, chemical precipitation, dilution, dispersion and other phenomena which influence the transport of radionuclides. The barriers may be provided by engineered design or by the natural geological setting of the site. Such a system of passive multiple barriers gives an increased degree of assurance of containment and isolation and of assurance that any release of radioactive material to the environment will occur at an acceptably low rate. Institutional controls on the other hand are active mechanisms established by society to ensure the continued implementation and achievement of a desired course of action. These controls could include the monitoring and treatment of contaminated releases, the keeping of records, and the imposition of land-use restrictions registered in property deeds and by-laws.

4. BASIC REGULATORY REQUIREMENTS

4.1 Burden on Future Generations

The burden on future generations shall be minimized by:

(a) selecting disposal options for radioactive wastes which to the extent reasonably achievable do not rely on long-term institutional controls as a necessary safety feature;

(b) implementing these disposal options at an appropriate time, technical, social and economic factors being taken into account; and

(c) ensuring that there are no predicted future risks to human health and the environment that would not be currently accepted.

The requirement to minimize the burdens on future generations is based on three matters of principle. The first reflects a pessimistic view of the longevity of institutional controls and concern for the possible consequences should they lapse. Where reasonable disposal alternatives clearly exist, those options which rely on monitoring, surveillance or other institutional controls as a primary safety feature for very long periods are not recommended. This is not because of concern that future generations will be technologically incompetent, but rather because methods of ensuring the continuity of controls are not considered very reliable beyond a few hundred years. Similarly, it is not meant to imply that means to preserve the identity and location of waste disposal facilities or to monitor their performance should not be attempted. It is expected that records will be kept and that in some cases monitoring will be carried out, but, where reasonably possible, safety should not rely on these measures.

The second principle concerns the responsibility of the present generation, as the primary beneficiary of the current exploitation of nuclear energy, to bear

the financial burden associated with the implementation of waste disposal options. It has also been argued, however, that it should be recognized that the current use of nuclear energy contributes to an improved standard of living that will benefit future generations. In any case, the timing of the implementation of waste disposal options will depend on a number of technical, social and economic factors. These include the availability and development of suitable sites and technology, the technical advantages to be gained from interim storage of short-lived wastes and, in the case of used nuclear fuel, the desire not to discard prematurely various constituents that are of potential value to future generations.

The third principle concerns the level of risk that may be imposed on future generations since it is not possible to ensure total containment and isolation and absolute safety. On ethical grounds, and in keeping with the recommendations of the ICRP, the radiological risks to future individuals should be limited on the same basis as are the risks to individuals living now. Moreover, the judgement is made that the level of protection to be afforded to future individuals shall not be less than that which is currently provided.

4.2 Protection of the Environment

> *Radioactive waste disposal options shall be implemented in a manner such that there are no predicted future impacts on the environment that would not be currently accepted and such that the future use of natural resources is not prevented by either radioactive or non-radioactive contaminants.*

One of the primary goals of environmental protection is to ensure appropriately safe conditions for human activities. This includes the impacts on human health arising from non-radioactive substances which may also be released from waste disposal facilities. It is thought likely that the level of radiation protection afforded all human individuals ensures adequate protection of other living species in the environment, although not necessarily individual members of those species. It follows then that by establishing the requirements found in this document concerning the radiation health burden on future generations, an appropriate requirement for environmental radiation protection is also formulated.

However, there is also a need to provide adequate protection for the general environment from the impacts that might arise from either radioactive or non-radioactive contaminants. The disposal of radioactive wastes must therefore comply with the appropriate requirements governing land-use and the protection of natural resources, such as water, wildlife, fish, soil, forests, minerals and other economically viable commodities. This basic requirement applies both to the environment surrounding a waste disposal facility and to the materials consumed in its construction and operation.

4.3 Protection of Human Health

The primary focus in this section is on radiological aspects of human health. It must however be recognized that some non-radioactive substances also may have detrimental effects on health. These effects have already been addressed in Section 4.2.

4.3.1 General Requirement

The predicted radiological risk to individuals from a waste disposal facility shall not exceed 10^{-6} fatal cancers and serious genetic effects in a year, calculated without taking advantage of long-term institutional controls as a safety feature.

In judging the acceptability of a disposal facility for which forecasts of hypothetical exposures of individuals in the future are made, it is not appropriate to apply dose limits in the manner practised today for the current operation of nuclear facilities. This is because it will not generally be possible in the long term to enforce compliance with any preselected dose limits. There is also considerable uncertainty as to whether the doses forecast will actually be received. This is due to the assumptions and uncertainties in predictive assessments concerning, for example, the location of the exposed individuals. It is also clear that waste disposal facilities may be subject to unlikely events and processes which could cause doses in excess of an individual dose limit. For example, seismic or tectonic phenomena can modify groundwater flow characteristics, and flooding and erosion may have a disruptive effect on near-surface facilities. Similarly, future human activities such as well-drilling, mineral exploitation, building and farming could give rise to immediate radiation impacts and could modify the characteristics of existing environmental pathways as well as introduce new pathways.

In order to take into account the hypothetical exposures committed in a year from both highly probable and less probable events and processes, the appropriate expression of the requirement is in terms of risk, where risk is defined as the probability that a fatal cancer or serious genetic effect will occur to an individual or his or her descendants. Risk, when defined in this way, is the sum over all significant scenarios of the products of the probability of the scenario, the magnitude of the resultant dose and the probability of the health effect per unit dose. Where it is reasonable to assume that the probability of the scenario approximates unity, the risk is simply the product of the dose and the probability of the health effect per unit dose. This is often assumed to be the case for groundwater transport of radionuclides to the human environment in the long term from a waste disposal facility.

For lifelong continuous exposures, the present view of the ICRP is that the principal limit on effective dose equivalent to members of the public should be 1 millisievert (1 mSv) in a year, taking into account exposures from all sources and facilities excluding medical irradiations and natural background radiation. Since the probability of fatal cancers and serious genetic effects is approximately 2×10^{-2} per sievert, the probability of these health effects associated with a dose of 1 mSv is 2×10^{-5}.

In the case of a single waste disposal facility, there is a need to ensure that the predicted radiological risks associated with it are sufficiently low so as to allow for uncertainties in exposure scenarios and their consequences, and also to allow for future nuclear activities which might impact on the same individuals. An appropriate and prudent risk level for individuals must therefore be chosen in keeping with the objective concerning the radiological

health burden on future generations. The level of risk selected, 1×10^{-6}, or 1 in a million, in a year, is a level of risk from other activities that is considered to be insignificant by individuals in their daily lives.

To put the foregoing into perspective, a risk of 10^{-6} in a year is the risk associated with a dose of 0.05 mSv in a year. Individual doses of 0.05 mSv in a year are a small fraction (approximately 2.5%) of the annual dose received by the general population in Canada from natural background radiation and are also of the same order of magnitude as the doses to critical groups predicted from the routine release of radioactive effluents from nuclear power reactors in Canada.

4.3.2 Variance From the General Requirement

> *If there is no practicable method of fully meeting the requirements of Section 4.3.1, an optimization study shall be performed in order to determine the preferred option. A disposal facility, under these circumstances, shall be:*
>
> *(a) compatible with the results of such a study, and*
>
> *(b) such that the predicted risk to individuals does not exceed that which is presently accepted from current operations involving the same wastes.*

It is clearly the intent of this document to have the general requirement used as the basis for judging the acceptability of human health protection to the greatest extent practicable. However, for some waste types in a site-specific situation, there may be no realistic alternative to their disposal in a manner which requires long-term institutional controls as a safety feature. Uranium mill tailings are a general class of wastes which are generated in large volumes and which, in most practicable disposal options, require some form of long-term institutional control to guard against the occurrence of particular exposure scenarios. This need arises since the tailings disposal options usually involve some variation of surface or near-surface containment. In this case, measures must be implemented to deter inadvertent public access to or misuse of the waste material. However, monitoring, surveillance and maintenance may be needed to controls may also permit future societies to take remedial action if that is considered desirable. However, in keeping with the requirement concerning the burden on future generations, the need for such controls must be minimized to the extent reasonably achievable. The process of determining what is reasonabl achievable is called optimization and is discussed in greater detail in Section 5.5. The stipulation that the predicted risk to individuals not exceed that which is presently accepted from current operations involving the same wastes follows from the requirement concerning the burden on future generations It should be ensured that when the long-term risk predicted to arise from a waste disposal facility is compared to presently-accepted risks, a similar set of scenarios, critical groups and overall assumptions are used, so that artificial differences between predictions of consequences for today's practice and those in the future are avoided.

5. GUIDELINES FOR APPLICATION OF THE BASIC RADIOLOGICAL REQUIREMENTS

5.1 Identifying the Individual of Concern

The individual risk requirements in the long term should be applied to a group of people that is assumed to be located at a time and place where the risks are likely to be the greatest, irrespective of national boundaries.

The concept of the critical group is commonly employed when applying individual dose limits to members of the public affected by existing nuclear facilities. This concept involves the identification of a relatively homogeneous group of people that is expected to receive the greatest exposure because of its location, age, habits and diet. Owing to the conservative assumptions usually made in selecting critical groups and in defining their lifestyles, the doses actually received by members of the group will in most cases be lower than the estimated mean dose of the critical group. It follows that doses to individuals outside the critical group are even lower.

When considering potential exposures in the future, the precise identification of critical groups and their lifestyles is not possible because of uncertainties about population distributions, living habits, climate and other aspects of the environment. In these circumstances, the individual risk requirements in the long term should be applied to a critical group of people that is assumed to be located at a time and place where the risks are likely to be the greatest regardless of national boundaries. This ensures that individuals beyond the national border are afforded a level of radiation protection at least as stringent as the level afforded residents of Canada.

Definition of the lifestyle of the hypothetical group of people should be based on present human behaviour using conservative, yet reasonable, assumptions. Similarly, the diet and metabolic characteristics of the group should be based on present knowledge, making the assumption that the basic dietary requirements of future individuals will be the same as those of people at present.

5.2 Probabilities of Exposure Scenarios

The probabilities of exposure scenarios should be assigned numerical values either on the basis of relative frequency of occurrence or through best estimates and engineering judgements.

In order to apply the risk requirements it is necessary to express the probabilities of exposure scenarios quantitatively. While the term "probability" is usually defined in terms of relative frequency of occurrence, the conventional system for assigning probabilities breaks down as the frequency of occurrence decreases, since little information exists on which to base predictions. Low probability exposure scenarios should therefore be assigned values through best estimates and engineering judgements. These values can be determined using a subjective probability approach in which a number is assigned to the likelihood of an event occurring in a defined period of time, as a measure of the degree of belief that the event will actually occur during that time. The assignment should be made using quantitative analytical techniques to

assess as broad a base of expert opinion as reasonably possible. The use of subjective probability is appropriate as long as the quantitative values assigned through best estimates and engineering judgements are consistent with the quantitative values of the actual relative frequencies in situations where more information is available. The uncertainty of the probability assigned should also be estimated.

5.3 Timescale of Concern

> *The period for demonstrating compliance with the individual risk requirements using predictive mathematical models need not exceed 10,000 years. Where predicted risks do not peak before 10,000 years, there must be reasoned arguments that beyond 10,000 years the rate of radionuclide release to the environment will not suddenly and dramatically increase, and acute radiological risks will not be encountered by individuals.*

Demonstration that a radioactive waste disposal facility complies with the individual risk requirements can only be done by forecasting future impacts using predictive mathematical modelling techniques. In any assessment of the performance of waste disposal options there are several general sources of uncertainty associated with parameter values, the mathematical models and the specification of environmental pathways and exposure scenarios. In general, these uncertainties will increase as the period of prediction increases. On the other hand, the uncertainties are partially offset in that the potential hazard associated with radioactive wastes usually decreases with time owing to radioactive decay of the source, unlike the potential hazard from many types of toxic chemical wastes which do not decay.

In view of the increasingly speculative and uncertain environmental conditions that might exist in the future, estimates of individual risk in the far future may be subject to considerable error, given that environmental modelling is a key part of risk assessment. For example, if severe changes in global climate were to occur, the human environment would also drastically change from that which exists today. It is therefore considered appropriate for regulatory decision-making purposes to establish an upper bound on the timespan for individual risk calculations.

Selection of an upper bound, however, is a matter of judgement since there does not appear to be any objective way of limiting the assessments in a scientifically satisfying manner. Taking into account the characteristics of radioactive wastes, the options for their disposal, and the uncertainties in long-term predictions, it is considered that 10,000 years after the time of waste emplacement is a reasonable maximum period for assessments of individual risk.

For some waste types and disposal options, shorter time periods than 10,000 years for predictive modelling are all that are necessary. This is particularly true where radioactive decay or radionuclide release and dispersion are predicted to occur to the extent that risks to individuals are clearly on the decline. For other situations, assessments may show that the predicted risks to individuals do not peak before 10,000 years. This might occur where long-lived wastes are contained and isolated in geological formations that are relatively unaffected by natural surface phenomena and that are likely to remain stable

over extended timescales. In these cases, there must be reasoned argument leading to the conclusion that beyond 10,000 years sudden and dramatic increases in the rate of release to the environment will not occur, acute doses will not be encountered by individuals and that major impacts will not be imposed on the biosphere.

To put the maximum period of 10,000 years for assessment into perspective, it should be recognized that a number of experts believe that the next glacial episode will commence as early as several to tens of thousands of years from now. In the event of glaciation, it can be expected that near-surface wastes in Canada will be dispersed and diluted in the environment by the movement of ice sheets. It is also reasonable to assume that humans would avoid a heavily glaciated region during an ice age although they would likely repopulate the region when glaciers recede many thousands of years later. Wastes at greater depth will be less affected by glaciation, depending on their depth below the surface and the nature of the geological host formation. For example, the evidence suggests that a deep geological repository for nuclear fuel wastes in hard crystalline rock would not be breached by the erosional effects of glaciation, although the regional groundwater flow system would likely be modified.

5.4 Output From Predictive Modelling

Calculations of individual risks should be made by using the risk conversion factor of 2 x 10^{-2} per sievert and the probability of the exposure scenario with either:

(a) the annual individual dose calculated as the output from deterministic pathways analysis; or*

(b) the arithmetic mean value of annual individual dose from the distribution of individual doses in a year calculated as the output from probabilistic analysis.

There are two general approaches to mathematically modelling the long-term performance of waste disposal facilities, but it must be recognized that in either the deterministic or the probabilistic approach the results can only represent an approximation of the consequences, were releases of radionuclides to occur. Confidence in the modelling output must then derive from a thorough examination of the assumptions, input data and mathematical models constructed to represent the release and transport of radionuclides and the subsequent exposure of individuals. Such an examination can be accomplished by a combination of several complementary methods. These include:

(a) the use of an appropriate quality assurance program in the development, application and maintenance of computer models and in the gathering, interpretation and incorporation of data;

(b) the use of experimental laboratory and field techniques for the validation of models and parameter values to the extent possible;

*dose means the effective dose equivalent committed per year of exposure

(c) peer review by independent experts; and

(d) intercomparison of various modelling approaches.

In the traditional deterministic approach, a single value for each of the model parameters is selected from a range of input values to produce a single value of model output, usually in terms of annual individual dose which is the consequence of primary interest. When using this technique, conservative assumptions are usually made to compensate for the uncertainty in modelling and to ensure that the calculations overestimate the potential doses from possible releases from a facility. Excessive conservatism however is not to be used and a balanced choice of assumptions is to be made to ensure that the overall assessment describes reasonable situations encompassing the full spectrum of exposure pathways, and assesses their impacts in a rational manner. Where complex systems are being modelled, sensitivity analyses should be conducted to investigate the effect of changes in the values of model parameters on the magnitude of the dose estimate, particularly when the estimated dose is judged to be significant. Comparisons with the risk requirements are then straightforward provided that the probabilities of exposure scenarios have been properly assigned.

Another approach now available involves probabilistic assessment techniques in which each parameter value is randomly selected from its probability distribution for input to the model. By repeating the analysis many times, a distribution of consequences is obtained which represents the spread and variation of outcomes as a result of variability and uncertainty in input parameter values for a particular scenario. This approach has certain advantages over the traditional deterministic approach by providing more information. A frequency distribution of individual dose will usually display a most probable dose value and a maximum dose value in the high-tail extremity of the distribution and thus it is necessary to specify a means of comparing the output to the risk requirement. In this case, the arithmetic mean value of the distribution should be calculated and should be taken as being representative of the consequences predicted for an exposure scenario, such as that involving groundwater transport of radionuclides to the environment. In the same way as for deterministic assessments, sensitivity analyses should also be conducted to investigate the effect of changes in input assumptions and model parameters on the mean value of dose. The latter should then be combined with both the probability of the exposure scenario and the risk conversion factor for comparison with the individual risk requirements.

By calculating the arithmetic mean value of the frequency distribution of dose, the significance of the extreme values may be overlooked. Since some of these could conceivably result from combinations of reasonable parameter values, this would clearly be undesirable even though the fact that such combinations generate consequences in the tail-end of the distribution is indicative that their relative frequency of occurrence is low. Nonetheless, the relative frequencies of occurrence of high consequences may differ significantly between frequency distributions having the same mean value. An additional criterion appears to be needed to help judge the acceptability of an option for which probabilistic environmental pathways analysis calculates high doses, albeit with a low relative frequency. It is judged acceptable to allow 5% of the estimated doses to exceed a dose of 1 mSv per year to take account of normal statistical variations which are inherent in the probabilistic assessment process. However

the choice of the general risk requirement takes account of this since a 5% occurrence of a dose of 1 mSv corresponds to an average dose of 0.05 mSv. If more than a 5% level of occurrence is predicted at 1 mSv or higher doses, then the criterion for the arithmetic average itself cannot be met. Thus for the numbers chosen in this regulatory policy statement a secondary requirement is not specifically needed but is implied and needs to be specifically addressed in proposals.

5.5 Optimization

> *When an optimization study is required in accordance with Section 4.3.2, it should take account of all relevant radiological and non-radiological factors.*

The ICRP principle that all exposures should be as low as reasonably achievable, taking social and economic factors into account, may be regarded as being generally applicable. However, for the purposes of this regulatory document it is to be applied only to the disposal of radioactive wastes where the general risk requirement is not likely to be met and thus where continuing long-term institutional controls are necessary. In other cases, the risk limit is sufficiently low to be the primary requirement with optimization playing at most a secondary role to help guide broader choices between options. Application of the optimization principle is intended to ensure that all reasonable or practical opportunities to reduce doses are explored in a broad way. The factors to be considered may include both radiological and non-radiological aspects, human health and environmental protection, as well as a broad range of social and economic issues. For example, it is appropriate to consider both public and worker risks associated with each step of the sequence of activities involved in waste disposal and not simply the risks to individuals in the long term. Also it may be necessary to weight some factors to take account of preferences such as might apply to spatial and temporal distributions of risk and other radiological parameters. Some non-radiological factors include, but are not limited to, conventional safety, environmental impacts, transportation, the nature and length of any institutional controls and the susceptibility of disposal options to naturally occurring disruptive events and to human intrusion. Some of these factors will not be amenable to rigorous quantification and thus a full optimization study will require the use of considered judgement. There are various techniques which can help structure this type of analysis so that the choices which need to be made are clear and the rationale for each choice can be fully documented. Generally, optimization in this broad sense does not result in clear or unambiguous choices between disposal options in the long term. It is for this reason, and the fact that the general risk requirement is so low, that optimzation has not been given a prominent role in this document.