THE REGULATORY CONTROL OF RADIOACTIVE EMISSIONS FROM NUCLEAR FACILITIES

by

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FOREWORD

The Atomic Energy Control Board was established in 1946 pursuant to the provisions of the Atomic Energy Control Act. It consists of one full-time member and four part-time members and a staff of 178. For the purposes of the Federal-Provincial Radioactivity Investigation and Remedial Action Program, an additional 7 temporary positions have been authorized.

In the administration of the Atomic Energy Control Act, the Board's activities include:

1. making regulations for developing, controlling and licensing the production, application and use of atomic energy;
2. regulating the mining, processing, refining, production, import, export, transport, possession, ownership, use or sale of prescribed substances;
3. defining standards to be met, assessing the capabilities of licence applicants to meet these standards and to assure their maintenance, and inspecting to ensure compliance;
4. funding and evaluating independent nuclear safety research and development work to obtain data essential to the effective implementation of licensing and compliance activities;
5. designating, under the Nuclear Liability Act, nuclear installations and prescribing the basic insurance to be carried by the operators of such installations;
6. developing specialized safeguards techniques and equipment in respect of CANDU reactors in Canada and abroad in cooperation with Atomic Energy of Canada Limited and the International Atomic Energy Agency in accordance with the Treaty of the Non-Proliferation of Nuclear Weapons; and
7. investigating, decontaminating and restoring sites which have been found to be radioactively contaminated as a result of the use of waste rock from uranium mines, uranium mill tailings and refinery residues.
With respect to the specific subject of radioactive emissions, the AECB evaluates, and if it is satisfied approves, the relevant design of and operating procedures for nuclear facilities and by means of its compliance program ensures that the emission limits derived according to the process outlined in this paper are enforced. For large facilities such as nuclear power stations, resident inspectors regularly review the performance of effluent control and monitoring systems with particular attention being paid to system upsets and unusual occurrences. Routine emissions are normally a small fraction (less than 1%) of the regulatory limits, thus any deviation from this norm results in careful investigation of the cause and followup enforcement of remedial actions.

The resident inspectors are assisted by a headquarters staff of nuclear safety analysts and health physicists. Facilities for which resident inspectors have not been appointed are inspected by headquarters and regional office staff.

A key element in the Board's licensing and compliance programs is extensive consultation and cooperation with other federal and provincial departments and agencies. Of the 137 persons appointed as inspectors under the Atomic Energy Control Regulations 80 are AECB employees and 57 are employees of provincial departments.
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1. INTRODUCTION

The fundamental objective of radiation protection is to minimize detrimental effects to mankind including the total environment in which man lives while still allowing necessary activities in which exposure to radiation is inherently involved to take place under strict control.

In Canada, as in most other countries, regulatory limits on exposure to ionizing radiation have been established on the basis of information and advice collected and analyzed over a period of many decades. The recommendations of the International Commission on Radiological Protection (ICRP) which was formed in 1928 (although then was called the International X-Ray and Radium Protection Committee of the International Congress of Radiology) and the findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) constitute a comprehensive source of information and advice upon which national regulatory authorities may draw in setting statutory limits for the maximum permissible exposure of individuals. Although limits are specified, no one should be exposed to radiation unless the total radiation detriment (i.e. the deleterious effects of exposure) is justifiable in terms of the benefit arising from the operation or practice causing the exposure. In addition, all exposures should be kept as far below the dose limits as is reasonably achievable, economic and social factors being taken into account (this is known as the ALARA principle).

The statutory dose limits for members of the public can generally not be applied directly, because the dose rates and concentrations of radioactive materials produced in the public domain due to the operation of nuclear facilities are generally too small to be differentiated from the natural background of radiation to which everyone is exposed. It is therefore necessary to derive limits for the rate of discharge of radioactive materials from a nuclear facility. These limits, often called derived emission limits (DEL), are related to the statutory dose limits such that
compliance with the DEL's will provide assurance of compliance with the dose limits.

The statutory dose limits specified in Schedule II of the Atomic Energy Control Regulations apply to the total radiation dose to individual members of the public from all sources, excluding natural background and exposure resulting from diagnostic or therapeutic treatment. Limits are specified for the relevant human organs and tissues for both occupational exposure (received by atomic radiation workers) and for exposure of individual members of the public. These limits are specified for annual and quarterly periods, for occupational exposure, and for annual exposure of members of the public. The limits for individual members of the public are one-tenth of the limits for atomic radiation workers.

In 1965, the ICRP recommended that the individual dose limits for members of the public be applied to a "critical group" defined as a representative group of people whose age, habits and diet cause them to receive doses higher than the average received by the rest of the population. This recommendation is commonly referred to as the "critical group concept".

2. DERIVED EMISSION LIMITS (DEL's)

Derived emission limits must be determined for both airborne and liquid-borne releases, and for each radionuclide of interest.

Radioactivity released into the environment may lead to external exposure of the public directly and to internal exposure following inhalation of radioactive substances, and in the case of tritium from absorption through the skin, or indirectly via the food chain. These routes of exposure are called "exposure pathways".

By the use of well established systems analysis techniques, mathematically expressed environmental models are used to predict concentrations or levels of radioactivity in the environment resulting from short term, protracted and continuous releases of radioactivity. This permits the calculation of dose rates as a function of time and the determination of the total dose for the members of the critical group. Experimental data and operational experience have shown that when radioactive materials are introduced into the environment, a few nuclides and certain exposure pathways are much more significant than others and will be responsible for
most of the dose received by individual members of the public. These nuclides and pathways are designated "critical".

Thus, the basic requirement that the individual dose limits not be exceeded (i.e. that the average dose in the critical group not exceed the dose limits) is achieved by application of the derived emission limits. The DEL for release into the environment is defined as the annual input of radioactivity of specified composition which will result in a committed dose in the critical group equal to the statutory dose limit.

However, recognizing further that doses should be kept "as low as reasonably achievable" (i.e. the optimization of protection) design and operational targets are established. In other words, since there is a small risk of harm even below the dose limits, nuclear facilities should be designed and subsequently operated in such a way as to minimize exposure of workers, and the public. In Canada, experience has shown that nuclear power stations can be designed and operated in such a way as to limit the release of radionuclides to 1% or less of the emission limits derived from the statutory dose limits.

3. THE CALCULATION OF DERIVED EMISSION LIMITS FOR AIR-BORNE RELEASES

Although the primary criterion for deriving emission limits is avoidance of exposure in excess of the statutory dose limits (which, as explained earlier, are specified for annual periods) DEL's for air-borne releases are calculated in terms of a weekly limit. Weekly limits are necessary in order to ensure that the annual dose limits are respected even if releases occur during adverse atmospheric conditions. The derived limits are based on long-term average weather conditions, but if adverse weather occurs, the dose from a given release will be higher than assumed when deriving the limit. A one week period is short enough that if the allowable release for a week were to be released over a period of a few hours during adverse atmospheric conditions, the resultant dose would be well within the annual dose limit.

As would be expected, annual limits are also specified in order to provide an explicit basis for any regulatory action which may be required such as imposing a reduction on allowable release rates following a period in which the weekly limits had been ex-
ceeded.

In most countries, a combination of factors makes the ATMOSPHERE - PASTURE - COW - MILK - MAN chain the most important pathway leading to internal exposure. Milk is the major dietary component for the infant, whose relatively small organ masses cause him to receive doses significantly higher than those to the adult. The fission products of primary concern from the standpoint of the food chain are iodine, cesium and strontium.

If there is no agricultural production in the vicinity of a nuclear facility, the only significant pathway for internal exposure is by direct inhalation and, in the case of tritium, by absorption through the skin.

With respect to direct, external exposure by air-borne effluents, the fission product noble gases xenon and krypton are the principal nuclides of interest.

4. THE CALCULATION OF DERIVED EMISSION LIMITS FOR LIQUID-BORNE RELEASES

The potentially important pathways for exposure of the public due to liquid-borne releases are:

1. internal exposure resulting from the consumption of contaminated fish and other seafoods;
2. internal exposure resulting from the drinking of contaminated water; and
3. external exposure resulting from contaminated shoreline sediments and seaweeds.

As in the case of emission limits for air-borne releases, the calculation of limits for liquid-borne releases involves annual and short term (i.e. monthly) considerations. These calculations take into account the consumption of locally harvested fish and seafood, marine concentration factors for aquatic organisms, daily water intake in the case of fresh water, local dilution factors, and concentration factors for marine sediments.

5. THE COMBINED EFFECT OF AIR-BORNE AND LIQUID-BORNE RELEASES

Although derived emission limits are calculated separately for air-borne and liquid-borne releases, a summation rule is specified to ensure that the integrated effect of exposure from all nuclides and via all pathways does not exceed the statutory dose limits. For multi-unit nuclear power stations such as the
Pickering and Bruce Generating Stations limits are set for the entire station and the total releases from all units must not exceed these limits.

6. EFFLUENT AND ENVIRONMENTAL MONITORING

Emission limits for nuclear facilities are complied with by controlling and monitoring the releases at the source (i.e. at the point of release). However, as a further precaution and to provide confirmatory data each nuclear facility operator conducts an environmental monitoring program. These programs not only confirm that the derived emission limits are not exceeded but they also provide valuable information on the conservatism of the assumptions made in calculating the DEL's.

As a further backup, provincial and federal health and environmental agencies conduct monitoring programs which include the sampling and analysis of water, milk, flora and fauna in the environs of nuclear facilities.