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RADIOACTIVE WASTE
MANAGEMENT IN CANADA

by

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Ottawa, Canada

June 3, 1976
ABSTRACT

Radioactive wastes are generated in the nuclear fuel cycle. Because these materials are radioactive, they are hazardous. The objectives of the Canadian radioactive waste management program are:

(1) to manage the wastes so that the potential hazards of the material are minimized;

(2) to manage the wastes in a manner which places the minimum possible burden on future generations.

The Atomic Energy Control Board regulates all activities in the nuclear field in Canada, including radioactive waste management facility licensing. The Atomic Energy Control Act authorizes the Board to make rules for regulating its proceedings and the performance of its functions. The Atomic Energy Control Regulations define basic regulatory requirements for the licensing of facilities, equipment and materials, including requirements for records and inspection, for security and for health and safety.
1. INTRODUCTION

The rapid growth of the nuclear industry has led to increasing public anxiety about the possible effects, upon man and his environment, of the liberation of radioactive contaminants. When the use of radioisotopes was confined mainly to hospitals and a few industrial concerns and when reactors were few, located in remote areas, and controlled by government agencies, the problem seemed to be a minor one. Now the Canadian public are faced with a developing nuclear industry. In these changed circumstances problems of radioactive waste management have aroused the interest and concern of politicians, the press and groups concerned with pollution, as well as members of the general public.

Knowledge in the field of radioactive waste management is more advanced than is popularly supposed. There is a general belief that a "problem" exists, in the sense that the future development of the nuclear industry is threatened by an ever-increasing volume of wastes that are a potential danger to the welfare of mankind. The problem that actually exists is how to choose the most economically effective method for disposing of the wastes.

2. GENERATION OF RADIOACTIVE WASTES

Radioactive waste is currently generated in the nuclear fuel cycle, in nuclear research, and in the production and use of radioisotopes. Radioactive waste may be produced in solid, liquid or gaseous forms. Radioactive waste generated in the nuclear fuel cycle arises as large volumes of uranium mill tailings contaminated with the natural decay products of uranium which includes radium 226, a long-lived radioisotope, wastes from uranium refining and fuel fabrication plants contaminated with uranium, and wastes from nuclear power reactor operation.

In a nuclear power reactor station almost all the radioactive material is contained within the fuel and consists of solid and gaseous by-products from fission reactions occurring within the fuel. Neutron activation products (radioactive substances that are formed as a result of neutron capture by the fuel material), such as plutonium,
are also contained within the fuel. Other activation products are formed in the coolant, moderator, reactor structures and gas systems.

Although most of the fission and activation products formed in the fuel remain inside the sealed fuel elements, small amounts leak into the coolant. The radioactive material in the coolant is continually removed by filters and ion exchange resins which periodically require replacement and thus become radioactive waste. Some radioactive material, however, remains attached to the piping and other components. Decontamination of these components may, from time to time, be necessary to permit routine maintenance; such decontamination also produces radioactive waste in the form of filters and ion exchange resins used in the clean-up procedure.

Leaks from the coolant system may result in some radioactive material becoming airborne inside the reactor building. The ventilation system is designed to prevent the spread of this material within the building and to clean-up the exhaust air leaving the reactor building. The filters and charcoal absorbers used are periodically replaced and are therefore another source of radioactive waste.

Other sources of radioactive waste associated with operation of reactors include contaminated scrap, tools, protective clothing, rags, mops and paper. These wastes arise mainly from routine maintenance and from the cleaning up of minor leaks, and their radioactive content is usually very low.

The production of radioactive waste during the mining, milling and fuel fabrication stages of the nuclear fuel cycle is small in radioactivity but large in volume compared to that generated in the fuel irradiation stage. This waste contains decay products of natural uranium some of which are radioactive.

Radioactive waste material is also produced at the Atomic Energy of Canada Limited (AECL) nuclear research laboratories. Much of the waste from these laboratories is associated with the operation of research reactors and is produced in the same manner as in commercial nuclear power reactors. A smaller amount of radioactive waste arises from the
production and processing of radioisotopes by AECL, and from the use of these radioisotopes in industry, medicine and education. Minor amounts of waste are produced from the operation of particle accelerators at universities and from the operation of a small number of university research reactors.

More than 99% of the radioactive waste from nuclear power stations is contained in the used fuel bundles, the nuclear "ashes" discharged from the reactors. In appearance a used bundle is identical to fresh fuel. It has spent about 1 1/2 years in the reactor core, and about 1.5% of the 20 kg of fuel per bundle has undergone a change. Each bundle, about the size of a fireplace log, has generated enough heat to warm a family dwelling in Northern Canada for about 100 years.

The fresh fuel contains two isotopes of uranium - U-238 and U-235 (0.7%). The fraction of the uranium which undergoes change in the reactor, most of the U-235 and only a small portion of the U-238, is converted to several hundred different isotopes. About one-third of this new material consists of atoms, such as plutonium, which are heavier than uranium. These atoms are very long-lived, requiring about 250,000 years to decay to 1/1000 of their initial amounts. The other two-thirds of the material produced in the reactor consists of fission products whose atomic weight is approximately half that of the uranium. Some of these "decay" to non-radioactive material in a few seconds or days. After one year has elapsed, only about 10% of the fission products are radioactive. The bulk of the activity at this point is due to strontium-90 and cesium-137. They "decay" to 1/1000 of their initial amounts in about 300 years.

Atoms which are radioactive "decay" because they are unstable and are transformed to stable lower energy states by the emission of energy. The way in which they shed this excess energy determines how they must be handled.

The principal mode is by beta decay - the ejection of electrons from the nucleus of the decaying atoms. A large fraction of these electrons are absorbed within the fuel, dissipating their energy as heat, and making it necessary to provide cooling. One year after
discharge from the reactor, a single bundle produces about 100 watts of heat from this process. Within 100 years, the heat has dropped to 1 watt.

Intense gamma radiation, which is similar to X-rays, is also emitted from the decaying nuclei. It can penetrate through the fuel and requires thick-walled shielding material, e.g., 3 to 5 feet of concrete, to attenuate the radiation to safe levels for human exposure. Heat generated by this radiation does not contribute significantly to the total heat load.

The heavy isotopes such as plutonium decay primarily by a third mode - alpha particle emission. Alpha particles are positively charged fragments with a mass four times that of the hydrogen atom. Because of their mass, they are readily slowed down and are completely absorbed within the fuel. They also contribute to the decay heat which must be removed from stored fuel, but in the first few hundred years their contribution is small compared to that of the beta particles. The major concern in handling alpha active materials is not external exposure, but the risk of inhaling or ingesting the material. The alpha particles emitted from the material deposit their energy in the body tissues and this can lead to chemical changes in the cells. To avoid this risk, the wastes must be prevented from spreading into the biosphere.

Thus, in handling radioactive wastes, three main requirements must be met - cooling, shielding, and isolation.

3. OBJECTIVES OF WASTE MANAGEMENT

The wastes generated in the nuclear fuel cycle are radioactive and therefore hazardous. If radiation passes through living cells, some of the molecules that are excited can cause chemical changes that are harmful to the cell. Large amounts of radiation can cause the death of a cell. (This is the way in which radiation is used to treat cancer, some cancerous cells are more susceptible to radiation than normal cells). Small amounts of radiation do not kill healthy cells immediately but may change their internal chemistry so that they grow in an uncontrolled
fashion, producing a cancer; or they may produce genetic defects. The long-term result may be death of the organism from the growth of a cancer. Many genetic defects are also lethal in subsequent generations.

The hazards from different radioactive materials vary widely. The hazard depends first on the energy left behind in cells by the radiation. As we have seen, alpha rays cause more chemical changes in their tracks than low energy beta rays. Materials emitting alpha rays can be particularly hazardous if their radiation is absorbed in certain parts of the body, bone marrow for instance, which is very sensitive to radiation.

The hazard depends also on how quickly a radioactive material decays. Radioactive materials with short half-lives are hazardous because they are likely to be very intense radiation sources. They release more energy in a fixed period of time than long-lived ones and thus cause more chemical and biological changes.

Radioactive materials with half-lives of ten to thousands of years emit energy at a lower rate but are of more concern because they will persist over many human lifetimes.

The hazard depends also on where the radioactive material is, inside or outside the body. Alpha particles from a source outside the body will barely penetrate the outer layer of the skin and are consequently of no concern. Beta particles penetrate a short distance and gamma rays pass right through the body. The external hazard is greatest from materials emitting the most penetrating radiation, gamma rays.

If the material is inside the body, the opposite is true. Gamma rays would pass out of the body leaving only a small amount of energy spread over a large number of cells; an alpha ray would lose all its energy in a fraction of a centimeter, in just a few cells. The internal hazard is thus greatest from materials emitting the least penetrating radiation.
Radioactive waste management is a term which embraces all the things that are being done, to ensure that radioactive materials are always handled and stored so carefully that only insignificant amounts could ever escape to the environment.

Because of the long radioactive decay time of some of these materials, this is a demanding exercise. It is not just a technical matter; it has policy implications at all levels of government, provincial, federal and international. Moreover, the time scales involved also raise questions about the responsibilities we have towards future generations who will be living on this planet.

It is for these reasons that it was found useful to identify two objectives for radioactive waste management:

(a) **Health and Safety Objective**

"Radioactive materials should be managed so that the health hazards are negligible".

(b) **Responsibility Objective**

"Radioactive waste products should be managed so that the trouble and concern to future generations will be minimized".

It should be noted that these two objectives can conflict. For example, one way to meet the safety objective is to place the material in a continuously monitored double-walled container. If leakage through the first wall is ever detected, the material would be moved to another container. In concept the technique is faultless. It does, however, conflict with the responsibility objective in putting us to the trouble of monitoring and maintenance for a very long time.

We can see another version of this conflict in the concept of geologic storage. By burying material deep underground we expect that we can more closely approach absolute safety by making the containment infinitely thick and requiring no maintenance. However, we cannot, from the nature of the problem, give an absolute guarantee that none of the material will ever escape. We can only make detailed safety and probability analyses to show that even an improbable escape would not violate the safety criterion.
We should not be apologetic or defensive about the need to recognize responsibilities to future generations. Both objectives are concerned with minimizing legacies to future generations, the first with a legacy of a potential hazard from radioactive materials, the second with a legacy of maintenance and responsibility. The ideal objectives, zero release of radioactivity and no future responsibility, are essentially unattainable because they are ideal and absolute. This is, however, a perennial human difficulty; such conflicts face us in many other activities. Every human activity leaves a legacy to the future some parts of which may be bad, some good. The oil and coal we burn today cannot be used by our grandchildren, but if our grandchildren inherit the need to manage our radioactive wastes, they should also benefit by having more oil and coal because we used nuclear energy.

At this point, I would like to point out the difference between interim and ultimate storage. Storage can be of two types:

(a) "Interim storage" where there is expectation or intent to move the material.

(b) "Ultimate storage or disposal" where there is no expectation or intent to move the material to another store.

Interim storage necessarily implies retrievability. Ultimate storage or disposal does not, in the logical sense, necessarily imply retrievability.

Retrievability is of course a relative term. Spent fuel stored in pools is plainly, readily retrievable. By contrast, the USA is considering a scheme to bury radioactive material in holes bored in the ocean bed perhaps 5000 feet from the surface of the sea. Retrieval, if possible, is plainly very difficult and expensive.

Large scale dispersion to the atmosphere, or to the sea, or shooting the material into outer space are plainly irreversible and irretrievable techniques.
4. **FUEL CYCLES AND STORAGE TECHNIQUES**

Waste management strategies and techniques are significantly altered by the choice of fuel cycle.

CANDU* reactors are, at present, operated with natural uranium fuel. No credit is taken in the fuel cycle for the value of the plutonium in the spent fuel, but it is a significant resource in its own right. The plutonium has an energy content, from fission, equal to about half the energy content of the uranium-235 originally in the fuel. At some time in the future it may become economic to reprocess the uranium fuel, extract the plutonium and recycle it. Uranium-238, if used in breeder reactors, has also a high potential energy content. While this isotope is a "waste" for the CANDU reactor, it is a potentially valuable resource for plutonium burning reactors.

At present, spent fuel is stored in interim storage facilities from which it can be retrieved for reprocessing when necessary. There is a possibility that reprocessing will never be implemented. In that case, the fuel would be put eventually in an ultimate repository. From that time on, fuel which had just been irradiated would be moved, after cooling, directly to the ultimate store.

If reprocessing is part of the fuel cycle, the wastes contain three principal materials, fission products, actinides (transuranics other than plutonium) and depleted uranium. The plutonium would be fabricated into fuel and returned to the reactor.

5. **PRESENT STORAGE METHODS**

5.1 **Ore Tailings**

The tailings from uranium ores are traditionally discharged to ponds adjacent to the mills. The concern with these wastes stems from their large volumes and from the potentially hazardous nature of the long-lived Ra-226 and other associated radionuclides in the event that they should become distributed in the environment by wind and water

*An acronym for Canada Deuterium Uranium, Canadian designed reactors moderated by heavy water and fuelled with natural uranium.
erosion. It is possible that this concern can be alleviated by increasing the thickness of earth cover over the tailings piles and revegetating the soil, in order to reduce the release of radon gas and windblown tailings dust, and by providing well engineered drainage of the storage areas.

5.2 Non-Fuel Reactor Wastes

Non-fuel reactor wastes are stored in concrete trenches or in "tile holes" (concrete pipes set vertically in concrete slabs). In many cases, the waste is treated prior to emplacement in storage either for conversion to solid form or for volume reduction. AECL and Ontario Hydro are currently studying and developing improved techniques of volume reduction involving incineration, reverse osmosis, and evaporation.

The isolation of radioactive materials in these facilities is controlled by two factors, the physical and chemical form of the waste and the properties of the site; the concrete structures and the soil provide a further important barrier between the emplaced activity and the environment.

5.3 Spent Fuel Waste

A 2000 megawatt power station - the size of Ontario Hydro's Pickering - is fed about 40 fuel bundles per day and discharges an equal amount of spent fuel. A coal fired station of the same size would require about 400 carloads of coal per day and would yield about 20 carloads of ashes per day. It is evident that the volume of waste arising from fuel is much smaller for the nuclear station. However, the nuclear waste must be handled with much greater care.

The discharged fuel from all Canadian reactors, and most reactors in the world, is stored under 3 to 4 m of water in deep water-filled pools constructed with thick concrete walls. Decay heat from the fuel is removed by circulating the water to a heat exchanger outside the pool. The water also helps to isolate the radioactivity from the biosphere. The water is kept clean by circulation through filters and ion exchange columns.
A nuclear power station may be designed with sufficient pool capacity to store, while the station operates, all the spent fuel produced over its expected 30 year service life. Alternatively, the spent fuel may be shipped from the power stations to central storage pool sites for interim storage.

A pool is an elementary storage technique, but it does have advantages. The waste is contained within the fuel sheath which is corrosion resistant. If a fuel defect does occur, the small amount of activity escaping is retained within the pool water, which can be purged out if desired. The stainless steel liner and concrete are a further barrier. Furthermore, the system is not particularly sensitive to loss of coolant accidents. An accident resulting in entrainment of activity in the air (that is, where radioactivity is the most dangerous) seems to be incredible.

To date, this is more than 25 years of Canadian experience with storage of wastes in pools, and there has never been a significant escape of activity or an accident of any magnitude.

Storage under water is easy and convenient and is used at almost every reactor site in the world. The storage pool shown (Slide) is used for fuel as it is taken from the reactor when the need for cooling is greatest. After several years, it may be removed to larger pools sufficient for all the spent fuel produced by a reactor in its operating life. A design for such a facility is shown in the next (Slide). About 11 pools would suffice for all the spent fuel that could be produced in Canada until the end of the century.

5.4 Dry Storage

AECL and Ontario Hydro are studying alternatives to pools for interim storage of spent fuel. One scheme selected for development is the concrete canister concept (Slide). The fuel is stored dry in small quantities, 220 bundles per canister, in a steel can which is welded shut and surrounded by concrete shielding. The Canadian reference canister is a concrete container, about 5 meters high, and 2 1/2 meters in diameter, with an internal cavity of about 75 cm. in
diameter. The fuel is placed in steel cans, inside another steel can, and the space between the outer can and the concrete is filled with lead. The fuel is cooled by radiation and conduction to the concrete shell, and then by conduction through the concrete. The concrete is cooled by natural air convection over the outer surface. One canister will hold about 4.4 tons of fuel, about a week's production from a station the size of Pickering. The canister appears to have some advantages over pool storage. Once the fuel is in place, it needs minimal surveillance, essentially no maintenance, and produces no secondary wastes. However, there may be problems due to the temperature gradient across the wall of the concrete flask and with defected fuel. AECL's program is designed to quantify both advantages and disadvantages so that an objective comparison can be made. Test results to date are encouraging.

The canister is designed to contain fuel producing, when initially emplaced, 2 kW of heat. The calculated temperature difference across the concrete is about 65°C. The resulting thermal stresses in the concrete are within acceptable limits. There is, however, an economic incentive to shorten the cooling period of the fuel or to increase the fuel loading of the canister; measurements and tests are required to provide precise design criteria.

Four full scale test canisters are now built at WNRE, Pinawa, Manitoba. Two are electrically heated, with heaters capable of putting out up to 20 kW each. Two are loaded with fuel - one with bundles from Douglas Point Generating Station, one with bundles from WR-1. The canisters are instrumented with thermocouples and strain gauges. The electrically heated ones were put in service first.

The immediate value of the canister development program will be to provide an evaluated and demonstrated concept to which the water filled pool storage can be quantitatively compared. If the demonstrations are satisfactory and the design study shows that significant advantages can be gained, canisters rather than pools could be the preferred concept for facilities to be built in the late 1980's.
6. ULTIMATE STORAGE OR DISPOSAL

The form of the waste for long term management will not likely be spent fuel bundles. The reason lies in the value of the plutonium as an energy source. It is a fissionable material and if separated from the other components in the spent bundles can be used as reactor fuel. A further benefit is gained by the use of plutonium in this manner. It reduces the inventory of very long-lived waste that must be disposed of. Thus, the wastes to be managed are those components which remain after processing.

The timing of the decision to exploit the plutonium resource is dependent, among other things, on economics - the cost of recovering the plutonium - compared with the availability and price of natural uranium fuel. It is generally assumed that conditions will warrant the use of plutonium before 2000.

Storing wastes on an interim basis is not technically difficult. However, for the longer term we need to provide new engineering concepts. As with spent fuel, cooling, shielding, and isolation must be provided and in a manner that meets the two objectives previously mentioned.

We could continue to use man-made structures built on the surface of the earth. However, such structures deteriorate with time, and to ensure isolation, would have to be replaced many times. This places a burden on future generations, and is contrary to the second objective.

The option that appears to hold the best prospect for achieving the two objectives is the use of deep geologic formations that are known to have been stable over geologic timescales. The surrounding rock provides a giant heat sink for cooling. The overburden provides almost infinite shielding and isolation from the biosphere. It is difficult to think of anything, including ice ages and meteorites, which would remove this protection in a catastrophic fashion.

Salt beds, some of which are millions of years old, are one type of formation which has been investigated extensively in the USA and Germany for nuclear waste storage. Radioactive wastes emplaced at the birth of these beds would have long since decayed to levels at least
as low as those found in the rock of the earth's crust today. Since salt is highly soluble in water, the existence of a bed indicates the absence of flowing groundwater from the time that the bed was laid down. This is a very attractive feature since seeping groundwater appears to be the main mechanism by which waste might be transferred from its burial place. Further protection against this possibility can be afforded by storing the waste in a highly insoluble form.

Monolithic rock formations in regions such as the Canadian Shield have also been proposed for waste storage. These formations have not been extensively studied for this purpose, but appear to offer the degree of long term isolation required. It is important to study storage in several different geologic structures.

The Geological Survey of Canada are engaged with AECL in studies which will enable them to identify the more promising geologic formations. Formations will be evaluated in the context of the following requirements:

1. The rock should have low economic value and not be close to other formations with actual or potential economic value.
2. The formation should be large, accommodating a buffer zone of significant size.
3. The formation should have high integrity with a minimum of cracks, faults and joints.
4. The formation should be in a zone of low seismic activity.
5. The formation should be either impervious to and/or isolated from moving groundwater.

Besides these factors, there are a number of detailed considerations. The formation should be homogeneous and relatively free of internal stresses. The excavation of the cavity and the emplacement of the material and the heat load all place new stresses on the rock. It will have to be shown that the emplacement could not have any significant effect on the macroscopic stability of the formation and that the effects of future glaciation are acceptable.
This brief list shows that geologic storage will require a considerable development program. There is already some experience in using mined cavities for storage of various materials, petroleum fluids for example, so the idea is not entirely new. It is evident, however, that a predictive aspect of geology, a new scientific discipline in fact, may have to be developed over the next few years as the international geologic community gets involved in waste management. Many nations are engaged in studies similar to ours.

The USA National Academy of Sciences and the USAEC, nearly twenty years ago, identified bedded salt as a formation which met many of the requirements summarized above. The relatively high thermal conductivity of halites minimizes the thermal gradients. Salt deforms plastically under pressure so that the internal stresses are self-relieved and cracks and fissures tend to seal up. Since the halites are water soluble, existence of the bed demonstrates its isolation from groundwater over geologic time.

A great deal is known about all the relevant properties of halite deposits for waste disposal, far more than about any other formations. It is, however, recognized that other types of rocks may be equally suitable but the necessary research and development have not yet been done.

Storage in hard rock (e.g., granite) appears a promising alternative. The size of the Canadian Shield, the low economic value of granite and the congruence of the Shield with Ontario, the principal user of nuclear power for the next twenty-five years, are factors arguing in its favour.

The Geological Survey will be making a survey on hard rock, similar to that for salt and, in collaboration with AECL, will be developing a geophysical program on topics such as fracture density, thermal gradients, thermal stresses, radiation stability and so forth. The preliminary schedule is such that, by the end of 1978, there should be sufficient information to decide between salt and hard rock for the Canadian Demonstration site. Site selection for a demonstration emplacement should be made by 1983. Wastes could be emplaced in a mined cavity by 1987. For the demonstration, radioactive materials will be stored...
in retrievable form. The cost of this program in current dollars is estimated to be of the order of fifty million dollars.

7. SAFETY AND LOGISTIC STUDIES

Waste management impinges on many parts of the technology of the fuel cycle. It is important that these be identified, defined and studied so that nuclear energy can be developed in Canada in an orderly fashion. For convenience we use "safety and logistic studies" as an umbrella for all these considerations.

To give some examples:

The design of waste management schemes is an exercise in the safety analysis. For proper evaluation, the safety of the fuel cycle as a whole must be estimated. For instance, reprocessing has the apparent advantage that the inventory of plutonium to be managed for long periods of time can be significantly reduced. It has the disadvantage that fission products and actinides embedded in the fuel are dissolved. These solutions present handling problems as does the fabrication of the plutonium into fuel. The possibility of release of the hazardous material during the relatively short period of reprocessing and fuel fabrication is significantly greater than if the fuel had been left untouched for that time. How does this increased short-term hazard compare with the decreased long-term hazard? Hazards analysis of this type will be a continuing activity.

The requirements for waste management affect the techniques and economics of reprocessing and of the associated fuel cycles. The levels of separation and decontamination for fission product and actinide streams must be defined in terms of the specifications set by the hazards study. These levels of separation, in turn, define the cost and perhaps the practicability of some separations. The wastes from the fabricating plants must also be minimized and the burnup penalty of recycling actinides must be assessed. Analogous questions for the variants of the thorium cycle will also be analyzed.

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Transportation contributes a significant fraction to the cost of all waste management schemes. It is also possible that, even though radioactive material spends a very small fraction of its life in transit, this is the least safe part of the operation. For this reason and because of the logistical problems associated with transportation, and the interrelated matter of site selection, transportation is being studied as part of our waste management systems.

I have briefly described a wide ranging program of engineering developments and applications, in which AECL is a partner with the utilities and other organizations such as the Geological Survey of Canada. This program will help to provide the Canadian nuclear industry with the knowledge and expertise to conduct its waste management functions with the highest degree of safety and responsibility.

8. RESPONSIBILITIES FOR WASTE MANAGEMENT AND ITS DEVELOPMENT

Three agencies are today directly involved in waste management:

(1) The electric utilities produce the wastes through the operation of their generating stations. They own the spent fuel and the plutonium in it and are responsible for the safe management of the fuel and wastes.

(2) AECL, the development agency, is responsible for developing and recommending options on waste management techniques. Some of this development work will, of course, be done by the utilities themselves so that the overall effort is a cooperative program between AECL and the nuclear industry.

(3) The Atomic Energy Control Board is the licensing authority and is thus the ultimate arbiter on the safety and wisdom of any waste management technique.

9. AECB REGULATION OF RADIOACTIVE WASTE MANAGEMENT FACILITIES

9.1 Introduction

The Atomic Energy Control Board was established by the Atomic Energy Control Act, enacted in 1946. This Act indicates that the primary role of the Board is to make provision for the control and supervision .../17
of the development, application and use of atomic energy, in the national interest.

From its inception until approximately 1952, the Board was responsible for all aspects of the Canadian atomic energy program, including the original Chalk River project. Following the creation of Atomic Energy of Canada Limited in 1952 and an amendment to the Act in 1954, the Board has been responsible for only the regulatory and the granting aspects of the Canadian atomic energy program.

The basic functions of the Board are currently, the control of prescribed atomic energy materials and devices, and of nuclear facilities, in the interests of health and safety, the control of prescribed atomic energy materials, items and information in the interests of national and international security and the awarding of grants in aid of atomic energy research.

The Atomic Energy Control Act authorizes the Board to make rules for regulating its proceedings and the performance of its functions.

The Atomic Energy Control Board is responsible to Parliament through a designated Minister, currently the Minister of Energy, Mines and Resources, Mr. Alistair Gillespie.

The Atomic Energy Control Act provides for a five-member Board, including the President of the National Research Council (ex officio) and four other members appointed by the Governor-in-Council. One of the members is appointed by the Governor-in-Council to be the President and Chief Executive Officer of the Board.

9.2 Nuclear Licensing in Canada

I would, at this point, like to talk about the AECB's nuclear facility licensing process and to point out that facilities for the management of radioactive waste fall into the Board's nuclear facility category.

Under the authority of the Atomic Energy Control Act and Regulations, the Atomic Energy Control Board has developed a comprehensive licensing system which includes requirements for pre-licensing evaluation of an
application and its supporting documents, and for post-licensing compliance inspection. The Regulations and licensing system have evolved over the years and attempt to take into account the changing nature, scope and magnitude of activities in the nuclear field.

The Atomic Energy Control Regulations define basic regulatory requirements for the licensing of facilities, equipment and materials, including requirements for records and inspection, for security and for health and safety. The Regulations set limits on radiation doses both for members of the public and those who may be occupationally exposed. These limits are based on the recommendation of the International Commission of Radiological Protection (ICRP). (Slide on dose limits).

In keeping with the ICRP recommendation that radiation doses be kept as low as readily achievable the Board decided in 1973 that, for all new nuclear facilities, design and operating targets should be set such that no member of the public would be likely to receive more than 1 per cent of the regulatory limit. This would apply to any new reactor, waste management site or other nuclear facility.

Every application for a nuclear facility licence is evaluated in detail by Board staff and also by a safety advisory committee appointed by the Board. The committee is composed of senior scientists and engineers chosen for their technical competence and experience, together with representatives of relevant federal, provincial and municipal government departments. A safety advisory committee has the advantage of making available a greater breadth and depth of technical expertise and experience and also of co-ordinating the activities of the various federal, provincial and municipal departments and regulatory agencies, especially those concerned with health, industrial safety, environmental protection and emergency planning.

The Board staff assists the committee by performing detailed assessments of design and analysis, by reviewing submitted documents, and by providing advice on technical matters.

The nuclear facility evaluation process concludes with a recommendation to the Board relating to the issuance of a licence. The final decision

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on issuance of the licence rests with the Board itself and the licence may contain any conditions the Board feels are necessary in the interests of health, safety and security.

Primary responsibility for compliance with the terms of the Atomic Energy Control Regulations and with the Board's licence conditions rests with the licensee. The licensee's performance is monitored by the Board through its staff, advisers and designated inspectors. In addition, federal and provincial health and environmental agencies perform surveys of radioactivity in the environs of facilities. Each facility operator must submit an annual performance report which includes a complete compilation of personnel exposures, radioactive emissions and safety-related matters. This report is reviewed by the Board staff and by the relevant safety advisory committee.

When radioactive wastes are transported to a waste management site, the wastes must be packaged and shipped in accordance with the appropriate transportation regulations for the mode of transport involved. These regulations are based on the recommendations of the International Atomic Energy Agency.

9.3 Licensing Waste Management Facilities

The Atomic Energy Control Regulations concerning the licensing of radioactive waste management facilities may be summarized as follows:

(1) Unless exempted in writing by the Atomic Energy Control Board, no person shall operate a radioactive waste management facility except in accordance with a Waste Management Licence issued by the Board;

(2) The Board shall not issue a Waste Management Licence unless the approval in writing of the Board to construct or acquire the waste management facility has previously been obtained and the conditions of such approval have been complied with;

(3) A Waste Management Licence may contain such conditions as the Board deems necessary in the interests of health, safety and security.
Types of storage or management facilities which the Board is currently prepared to licence include:

(1) Facilities for the collection, processing packaging and temporary storage of radioactive wastes for periods of up to a few years;

(2) Facilities for storage of radioactive wastes for some intermediate period limited by the integrity of the facility;

(3) Facilities for very long term storage and management of radioactive wastes.

A few more words on storage and disposal may be appropriate here; the disposal of short-lived isotopes is relatively simple since they need only be stored for short periods before they can be treated as non-radioactive waste. However, for long-lived wastes, which includes some isotopes produced in the nuclear fuel cycle, no method of permanent disposal has yet been authorized. Although several alternatives are receiving detailed study, as I previously mentioned, until the adequacy of any disposal method has been demonstrated in a controlled experiment, the Board is prepared to licence only waste storage facilities. These storage facilities must be designed so that the waste will be retrievable at some future date should additional processing of the material or its transfer to more permanent storage be required.

The Board recognizes that this emphasis on retrievability places a burden of surveillance and management on future generations and therefore supports the efforts currently being made by the nuclear industry to develop waste disposal techniques and to demonstrate their effectiveness. It is expected that these disposal techniques will minimize or eliminate any burden on future generations.

I will now expand on the types of waste management facilities, presently licensable by the AECB.

9.4 Types of Waste Management Facilities

As I previously mentioned, the types of waste management facilities which the Board is prepared to licence at the present time can be divided...
into three categories, each of which is a form of retrievable storage.

Short-term temporary storage facilities are for relatively short-lived isotopes which only require storage for short periods and also for collection depots for more long-lived wastes prior to their shipment to longer term storage facilities.

Interim term storage facilities are for the temporary storage of waste whose radioactivity is long-lived but where it is intended to retrieve the waste either because it may have some commercial value or because the ultimate disposition of the waste has not been finally decided. These facilities could also be used for wastes whose activity is too long-lived for a short term temporary storage facility but whose half-life is short compared to the lifetime of an interim storage facility. In this case, the waste could be treated as non-radioactive when the facility was being decommissioned.

The third type of facilities are those intended as long-term waste management facilities. The wastes in these facilities would have no commercial value but must be retrievable for safety reasons since the long-term integrity of such facilities has not been demonstrated.

A major difference between intermediate term facilities and very long-term facilities is that the intermediate facilities are intended to be taken out of service after their useful life is finished. At this time any waste which still needs to be treated as radioactive would be transferred to another waste management site. The decommissioned site should then be available for other uses without the need for any restrictions due to residual radioactivity.

The current thrust of Canadian research and development on radioactive waste management as mentioned earlier is towards the development of permanent disposal techniques. In the interim, while this research and development program is going on, wastes are being stored, temporarily, in intermediate term facilities. Development of a long-term facility, which essentially involves accepting the burden of an active waste management program on a permanent or indefinite basis, would only be considered if this research and development program failed to produce
an acceptable permanent disposal system. Facilities for the management of uranium mine wastes and U mill tailings may be considered an exception to this since they may be considered to be essentially long-term facilities, until new technology and policies for dealing with these wastes are developed. These are being studied at present.

I will now talk about the AECB criteria for licensing of waste management facilities:

(1) First, the considerations for short-term waste collection and temporary storage facilities:

Because only temporary storage is involved, waste will normally be stored in containers in buildings or similar structures. The facilities may include equipment to concentrate the radioactive waste or make it more suitable for long-term storage (for example, equipment for the baling of solid material or for the absorption of liquids on solid materials or their incorporation into solid blocks; equipment for the incineration of organic material contaminated with radioactive material; equipment for packaging of wastes for shipment to longer term waste storage facilities). After the waste has been transferred to other facilities, the facility may be used for other purposes after decontamination has been carried out to the satisfaction of the appropriate inspectors.

Information required by the Board to assess any particular application includes:

(1) A statement of the nature, form and quantity of radioactive material intended to be stored;

(2) A description of the storage facilities and any special equipment to be provided;

(3) A description of the procedures and surveillance planned to ensure that workers and members of the public do not receive doses of radiation in excess of the maximum permissible doses specified in the Atomic Energy Control Regulations; and

(4) An outline of planned procedures to cope with any emergency and particularly to minimize the escape of any material into the public domain.
In many cases, the information mentioned above will be included as part of the information submitted with an applicant's request for permission to obtain and use radioactive materials or to construct and operate nuclear installations such as reactors. Conditions governing the collection and temporary storage of radioactive waste may be included in the relevant licence.

The information will be reviewed by the Board's staff and expert advisers from appropriate federal and provincial departments and agencies. These advisers will make recommendations regarding the granting of the licence and any special health, safety and environmental conditions which they consider should be imposed in such a licence. For example, operation of an incinerator is likely to be licensed only if it is of an approved design, has suitable filters for the collection of particulate matters, and the gaseous effluents from the incineration operation will not pose any safety hazards for workers or nearby members of the public.

The licensee will be required to submit periodic reports of the nature and quantities of the radioactive wastes handled in the facility. Any wastes intended for transfer to intermediate or long-term facilities will have to meet the packaging requirements of the appropriate transportation authorities.

(2) Secondly, there are the intermediate term storage facilities:

The following are the criteria currently used for design and operation of intermediate term storage facilities:

(1) All radioactive waste should be managed in such a way as to prevent exposure of any person to ionizing radiation in excess of the maximum permissible doses specified in Section 19 of the Atomic Energy Control Regulations under foreseeable conditions;

(2) The dose which could be received by any individual due to the normal operation of a waste management facility should be kept as low as is reasonably achievable; the target levels for both design and operation should be such that no member of the public

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is likely to be exposed to more than 1% of the maximum doses specified in Section 19 of the Atomic Energy Control Regulations;

(3) Radioactive wastes should be processed, packaged and stored so that they may be retrieved at any time and transported in accordance with the packaging and shipping requirements of the appropriate transport regulatory authorities;

(4) The waste should be stored in solid form in near-surface engineered structures;

(5) The facilities should be designed to prevent the escape of the contained radioactive material to the surroundings;

(6) Provision should be made to detect the escape of radioactive material into the immediate surroundings of the facilities;

(7) Provision should be made to allow corrective action in the event that unacceptably high levels of activity are detected in the surroundings, including provision to retrieve the radioactive material safely from any of the facilities in a form suitable for ordinary commercial transport to another location;

(8) Provision for surface water run-off to be monitored and controlled before discharge, should be provided;

(9) It is desirable that there should be at least two levels of containment to prevent escape of radioactive material to the public domain.

The following are regarded as interim term storage facility siting requirements:

(a) A location remote from a large population;

(b) Groundwater conditions which prevent contact between waste management facilities and groundwater;

(c) Soil with favourable ion-exchange properties and capacity;

(d) Located in a geologic formation which minimizes or controls groundwater movement out of the area; and

(e) Inaccessible to the public.
The siting and design of the proposed facility will be reviewed by the Board's staff and by appointed advisers, prior to any radioactive material being brought on site, to ensure that the facility will not create an unacceptable burden of radiation dose either for the present or for future generations. This review will encompass not only consideration of the adequacy under normal circumstances of the provisions built into the facility for containment of radioactivity but also the effects of accidental or naturally-occurring events, such as aircraft crashes and floods. The environmental factors which would dictate the consequences of a release, should one occur, would also be taken into account.

In addition to reviewing the siting and design of these facilities the Board's staff will review the operation of each facility after it is placed in service and assess the results of the routine environmental monitoring program in the surrounding area in order to ensure that the operational targets set in the design stage are being met.

Since intermediate term storage facilities are intended to be decommissioned and decontaminated, to the point where unrestricted use of the site could be allowed, one of the factors which will be considered in approval of a site for such a facility is ease of decontamination.

(3) Thirdly, there are the long term radwaste management facilities:

The criteria for approval of long term facilities would be similar to those for intermediate term facilities. In addition, since the long-term facility is by definition a permanent waste management site, it would have to be demonstrated that the cost to future generations of having this facility permanently unavailable for other uses would not be excessive.

Finally, I will briefly mention the current status of waste management facilities licensed by the AECB:

(1) Temporary Storage Facilities

It is the responsibility of individual licensees, that is, those licensed by the Board to possess any prescribed substance, to arrange
temporary storage for any radioactive waste until it can be safely
disposed of as non-radioactive or shipped to a licensed waste
management site. The health and safety considerations of whatever
temporary storage the licensee provides are covered by the terms of
the prescribed substance licence.

(2) Under Intermediate Term Storage Facilities

There are two utility-operated waste management facilities in
Canada: one at the Bruce Nuclear Power Development, Douglas Point,
Ontario and one at Gentilly, Quebec, which are licensed as intermediate
term facilities. These are located on land owned by Ontario Hydro
and Hydro-Quebec, respectively, and are associated with and on the
same sites as nuclear power plants.

AECL currently operates waste management facilities both at its
Chalk River Nuclear Laboratories, Chalk River, Ontario and at the
Whiteshell Nuclear Research Establishment, Pinawa, Manitoba.

There is also a licensed waste management site owned and operated
by the Department of National Defence Research Establishment at
Suffield, Alberta. This facility is primarily for military wastes.
It does, however, handle civilian wastes by agreement with provincial
authorities.

ENL are licensed to operate their Port Granby residue area as
an intermediate term storage facility for refinery and uranium
hexafluoride plant residues.

(3) Under Long-Term Storage Facilities

The only long-term facilities currently licensed by the AECB
are the U mine waste sites and mill tailings piles, the health and
safety considerations of whatever storage is required to be provided
by the licensee is covered by the terms of the mine permit issued by
the AECB. This is likely to change in the near future since the
method of licensing mine waste and mill tailings facilities is currently
under review by the AECB.
To conclude, I will say that the production of radioactive wastes, and especially spent fuel is expected to increase significantly in the near future. To ensure that such an increase will not degrade the high level of safety required and will not unduly burden future generations with the responsibilities of perpetual storage, it is important that regulatory requirements governing the management of radioactive wastes, including fuel and non-fuel wastes take into account the changes associated with the rapidly expanding Canadian nuclear program. The development of these requirements is the responsibility of the Atomic Energy Control Board in consultation with the nuclear industry, national research laboratories and appropriate provincial and federal agencies as well as elected representatives of the three levels of government, municipal, provincial and federal.
REFERENCES


