DEVELOPMENT OF MATERIALS SPECIFICATIONS AND EMPLACEMENT PROCEDURES FOR BACKFILLING NUCLEAR FUEL WASTE VAULTS

ÉTABLISSEMENT DES PROPRIÉTÉS DES MATÉRIAUX ET MISE AU POINT DE TECHNIQUES DE MISE EN PLACE DU REMBLAI DANS LES ENCEintES DE STOCKAGE DE DÉCHETS DE COMBUSTIBLE NUCLEAIRE


Abstract

Atomic Energy of Canada Limited and Ontario Hydro are conducting a research program to assess the environmental impact and safety of the concept of disposal of nuclear fuel waste in an underground vault in plutonic rock of the Canadian Shield. The Vault Sealing Program, one of the components of the Nuclear Fuel Waste Management Program, is concerned with the development of materials specifications and emplacement procedures for backfilling the vault. Backfilling materials would surround the nuclear waste containers and fill all vault openings to minimize leaching and movement of radionuclides.

This paper presents the procedure followed to select candidate backfill materials, the integration of mathematical modelling studies and physical testing for the definition of materials specifications, and the principal elements of the recommended handling and emplacement systems.

Resume

l'Énergie Atomique du Canada Limitée et l'Ontario Hydro exécutent actuellement un programme de recherches dans le but d'évaluer la sûreté du concept d'évacuation (stockage) des déchets de combustible nucléaire dans une enceinte souterraine construite dans la roche plutonique du bouclier canadien et les conséquences pour l'environnement. Le programme de scellement de l'enceinte, une des parties du Programme de gestion des déchets de combustible nucléaire, porte sur l'établissement des propriétés des matériaux et la mise au point de techniques de mise en place du remblai dans l'enceinte. Les matériaux de remblayage entoureraient les conteneurs de déchets nucléaires et combleraient toutes les ouvertures de l'enceinte pour minimiser la lixiviation et le transport des radionucléides par les eaux souterraines.

Cet article présente la technique suivie pour choisir les matériaux à retenir comme remblai, l'intégration de la modélisation et des essais physiques pour définir les propriétés des matériaux ainsi que les éléments principaux des systèmes de manutention et mise en place recommandés.

Introduction

The main objective of the Canadian Nuclear Fuel Waste Management Program (CNFWMP), a research and development program of the Government of Canada (also supported by the Government, and the provincial utility of Ontario), is the environmental and safety assessment of the concept of disposal of nuclear fuel waste in a deep underground vault excavated in plutonic rock of the Canadian Shield. The program evaluates primarily the disposal of used (spent) nuclear fuel discharged by Canada's CANDU(1) reactors. As an alternative, the Program also evaluates the disposal of vitrified fuel recycle waste, although the Government of Canada has not made a decision regarding recycling of the current used fuel inventory (Rummery and Lisle, 1983; Green et al., 1985; Lyon, 1985).

The Canadian concept, illustrated schematically in Figure 1, considers as its main alternative, the disposal of used fuel in cylindrical containers of titanium, placed in boreholes drilled in the floor of a disposal vault. The vault would be excavated by room-and-pillar methods, in granitic rock of the Canadian Shield, at depth of between 500 m and 1,000 m. In addition to the geologic formation, several engineered barriers would surround the vault, and would be relied upon to retard the release of radionuclides to the geosphere; these barriers are (Nuttall et al., 1986):

(1) A trade name of Atomic Energy of Canada Limited (AECL) for its natural uranium fuelled, heavy water moderated and cooled power reactor (Canada Deuterium-Uranium).
1) the containers, designed for a lifetime of about 500 years;
2) the buffer, a mixture of swelling clay and sand-size aggregate that surrounds the containers, designed for a very low permeability to water and radionuclide flow; and
3) the backfill of tunnels, shafts and exploration boreholes.

Leaching of radionuclides would also be inhibited by the inherently low solubility of the waste forms.

**Vault design concepts**

Several design concepts for an underground disposal vault have been evaluated during the past few years. These include single-level vaults, multiple-level vaults, and emplacement of waste containers in long boreholes between two tunnels at different elevations (Baumgartner and Simmons, 1985). The concept of a multi-level vault is attractive for sites where the plutonic host rock might be of limited size; however, the evaluation studies have concluded that for used fuel, the multi-level vault results in higher disposal costs per unit of waste, because of the need for lower thermal loading in each level: (vertical stacking in a multi-level vault leads to addition of thermal energy from each level, resulting in higher container-skin and rock-pillar temperatures when compared with a single-level vault). The studies have also concluded that emplacement in long boreholes could result in higher unit costs than either a single-level, or a multi-level vault, because of the difficulties in emplacement of containers and buffer.

The reference design concept in the Canadian Program is a single-level vault, approximately 1,700 m by 3,600 m, consisting of 822 rooms arranged in 16 rectangular arrays (panels). Each room would be 195 m long, 7.5 m wide, and 5.0 m high. The overall extraction ratio in the room-and-pillar configuration is approximately 25 % (Acres Consulting Services Limited et al., 1980). The vault could accommodate approximately 250,000 used fuel containers, or 18 million CANDU fuel bundles. From current forecasts of the growth of electric energy demand from nuclear sources, a vault would not start operation until the 21st century, and would have an operating life of approximately 50 years before being permanently sealed. Figure 2 illustrates a general plan of the vault.

Each room of the vault would hold approximately 300 containers, arranged in rows of three containers, at approximately 1.850 mm centre to centre (Figure 3). The standard container (designated as TEC-2 by EACL), is approximately 600 mm diameter and 2,200 mm tall, with a capacity of 72 fuel bundles. The emplacement boreholes would be approximately 1,100 mm diameter and 4,950 mm long.

**Vault sealing**

The Canadian studies on closure and sealing of the vault are concerned with the development or specifications for materials composition, quality, and emplacement procedures, for the various sealing features (buffer, backfill, shaft seals, and borehole seals). The Vault Sealing Program has been described by Lopez et al. (1984) and Lopez and Johnson (1986).