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DBHD 1.4 Materials

Advancements in the design of NUCLEAR WASTE REPOSITORIES

DBHD = Deep Big Hole Disposal / an example from Germany

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For decades the nuclear industry in Canada has studied the question of what to do with the radioactive waste products that result from nuclear power generation. The favored approaches include proposals to bury the waste products at great depths below ground as a form of geological disposal. There are challenges associated with such proposals including the risks during transportation to a site, validation of the long-term stability of a site, and the life expectancy of containment vessels for the waste.

The nuclear industry in Canada operates under the regulatory auspices of the Canadian Nuclear Safety Commission (CNSC) that defines radioactive waste as follows [1]: "Radioactive waste is any material (liquid, gas or solid) that contains a radioactive nuclear substance (as defined in section 2 of the Nuclear Safety and Control Act) and which the owner has determined to be waste (as per regulatory policy PP–229900, Managing Radioactive Waste). Radioactive waste produced in Canada is managed safely in specially designed facilities. The [CNSC] regulates and licenses these facilities, in order to protect the health, safety and security of Canadians and the environment."

The CNSC classifies nuclear waste as follows:

Low-level Radioactive Waste: "Low-level radioactive waste contains material that is more radioactive than clearance levels and exemption quantities allow. This type of waste loses most or all of its radioactivity within 300 years. It includes contaminated equipment from the operation of nuclear power plants (like protective shoe covers and clothing, rags, mops, equipment and tools). The owners of low-level radioactive waste are responsible for managing the waste they produce. This usually takes place onsite, within its own facility."

Figure 1: DBHD deep repository in a Canada rocksalt formation near New Brunswick.

Intermediate-level Radioactive Waste: "Waste that has been exposed to alpha radiation, or that contains long-lived radionuclides in concentrations that require isolation and containment for periods beyond several hundred years, is classified as intermediate-level radioactive waste. It typically requires shielding during handling and interim storage. This type of waste includes refurbishment waste, ion-exchange resins and some radioactive sources used in radiation therapy. The owners of intermediate-level radioactive waste are responsible for managing the waste they produce. This usually takes place onsite, within its own facility."

High-level Radioactive Waste: "High-level radioactive waste (HLW) in Canada is used (irradiated) nuclear fuel that has been declared as radioactive waste. This type of waste also includes small amounts of radioactive waste from medical isotope production and other applications that generate significant heat via radioactive decay. Used nuclear fuel produces ionizing radiation. This type of radiation has a strong ability to penetrate matter, so shielding against the radiation is required. Since used nuclear fuel contains significant quantities of radionuclides with long half-lives, it requires long-term management and isolation."

Currently, there are several alternative approaches that have been considered by the various entities that comprise the nuclear industry in Canada for repositories that can accommodate different waste. Ontario Power Generation (OPG) operates multiple nuclear power plants that generate over 50% of the province's electricity. OPG is proposing a storage facility near Kincardine and Lake Huron to inter low and intermediate wastes that is referred to as the Deep Geologic Repository (DGR). However, it is not intended to store high-level radioactive waste. Atomic Energy Canada Ltd. (AECL) has plans for geological disposal of research and operating waste at a location near to the Ottawa River beneath the Chalk River National Laboratory beside the Ottawa River. The Nuclear Waste Management Organization (NWMO), operating on behalf of Canadian utilities, is reviewing the viability of multiple sites to bury all of Canada's highly radioactive fuel waste. Currently, the NWMO is the only organization in Canada that is studying long-term solutions to the problems posed by high-level radioactive waste.

What initiatives are being taken in other countries with regard to the long-term storage of high-level radioactive waste? One example is the Deep Big Hole Repository (DBHD) — for High Level Waste (HLW) that has been developed by engineers in Germany.

The underlying success of such an advancement of repository technology (see Figure 1) is the placement of the site in an area with so-called rocksalt geology, also called Halit, where the gamma radiation is rendered safe after travelling only 30 cm through the surrounding rocksalt. Gamma rays are a form of ionizing radiation that is biologically hazardous and are a product of nuclear fission and fusion processes. They have a high penetration power and will damage bone marrow and internal organs. Unlike alpha and beta rays, they pass readily through the human body and are a challenge when it comes to protection. Due to their penetrating power, gamma rays require extensive amounts of shielding mass to attenuate them to levels which are not harmful to living cells, in contrast to alpha particles which can be stopped by paper or skin, and beta particles, which can be shielded by thin aluminum.

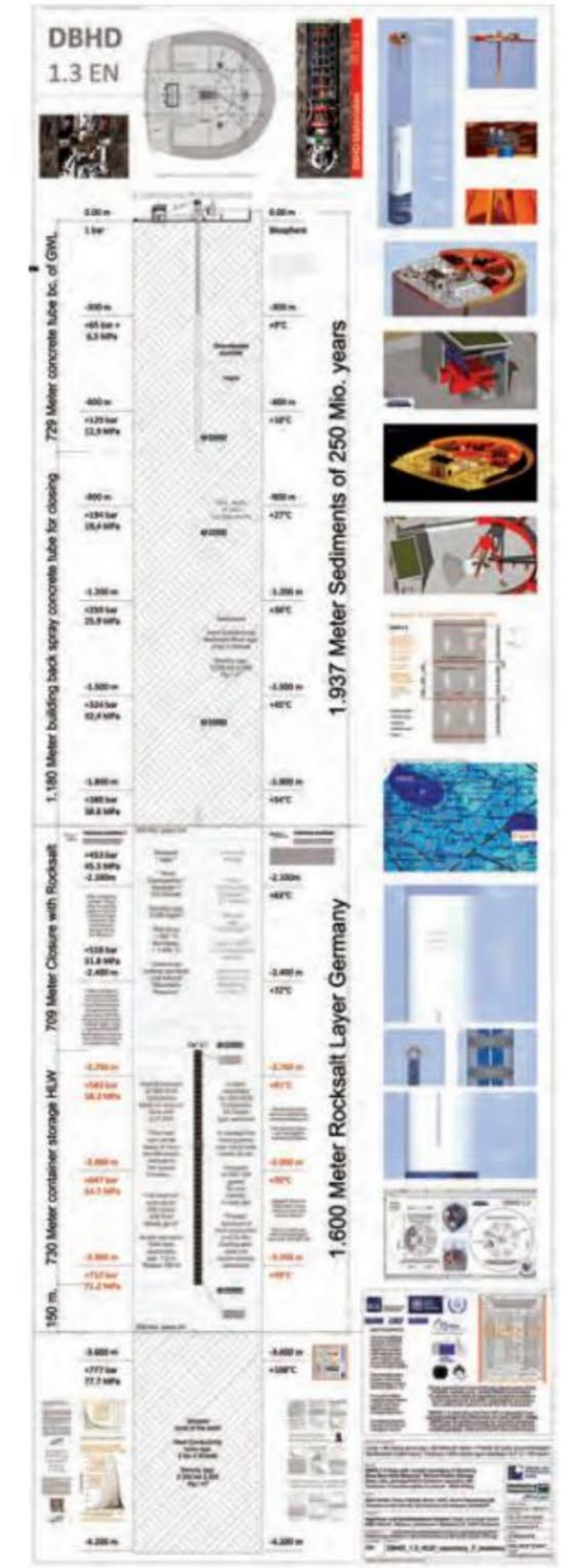

Figure 2: DBHD 1.3 EN Soil Stratification profile for a proposed site in Germany.

The DBHD process begins with the use of a shaft boring machine (SBM) from Herrenknecht AG / DE that is 12m in diameter to drill down to depths on the order of 3,350m. This deep shaft is then subject to further construction to install multiple layers, essentially a series of floors, each of which can support containers that encapsulate the HLW. A single DBHD can store up to eight "Castor" containers per floor with a total of up to 360 per site. The 12m diameter allows for a 113 sq.m. surface for all the ventilation pipes, Castor on steel cable, a staircase, a lift and a concrete tubbing ring to keep the hole open. Each Castor is able to take 10.5 tons of heavy metal (spent fuel).

The maximum temperature from waste heat from HLW after 25 years is 160 K — plus deep environmental temperatures of 105 C ranging up to a maximum of 265 C on the edge of shaft concrete to the surrounding rocksalt. As it turns out, the Castor container sealings are able to take up to +600 C. As such, the DBHD does not infringe on the limits of the Castor containers. Recent estimates from July 23, 2018 suggest that seven such repositories to accommodate 2520 Castor containers at sites in Germany would cost on the order of 5.65 billion Euros ($8.7 billion).

Why Canada? As it turns out, as shown in Figure 1, there are rocksalt formations in the Maritime provinces of Canada, including New Brunswick, Nova Scotia, and Prince Edward Island that are suitable candidates for the advanced repository performance offered by the DBHD technology. As a geologically viable region, it should be subject to consideration for the long-term storage problems associated with HLW. The authors also believe it to be a more cost-effective solution than those currently under consideration by the NWMO and believe its advancements offer improved performance and safety. **CCE**

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