ELECTROMAGNETIC PROBLEMS IN NUCLEAR WASTE DISPOSAL

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Electromagnetism is needed when final disposal of nuclear waste is planned and carried out. The present disposal plans include the encapsulation of spent nuclear fuel in copper-steel canisters the height of which is about 4.5 m and diameter about 1 m. These canisters (nearly 2000 canisters in total) will be put in holes at the bottom of deposition tunnels to be excavated at a depth of about 500 m in crystalline bedrock. There are especially two areas in which electromagnetism plays an important role. These are (1) electromagnetic characterization of fractured rock before any constructions are made and during the construction of the repository, and (2) electromagnetic safeguards monitoring of a repository.

1 Electromagnetic characterization of fractured rock

The crystalline bedrock is characterized by fractures on different geometrical scales. One of the basic problems is to acquire data about the fracturing because fractures control groundwater flow and radionuclide migration, which are the central issues in the safety analyses of disposal. Fractured rock behaves anisotropically when it is studied electromagnetically by DC and AC methods. Especially electrical conductivity anisotropy is an important property. Thus, the anisotropic structural models are relevant in the study of fractured rock mass. STUK has had a research project in collaboration with the Electromagnetics Laboratory of the Helsinki University of Technology from 1991 onwards in the calculation of electromagnetic fields of anisotropic models. The project has been described in [1]. Many basic problems were treated by image theory. These geometries included a half-space bounded by a *perfect electric conductor*, by *a perfect magnetic conductor*, and by *an impedance boundary*. Furthermore an anisotropic *layer* model was studied and finally, after various sequential relaxations, a *very general anisotropic half-space prob-*

lem could be solved by Heaviside operational calculus. Also an anisotropic, *inhomogeneous medium* could be handled with *integral equations*. A *wedge* geometry was treated as an extension to the traditionally used two parallel plate model of a fracture. The transformation of fracturing to anisotropy is also an important area of research. This is done by using so called *electromagnetic mixing formulas or rules* originally developed for microwave technology.

During various phases of disposal investigations we have varying possibilities to be in contact with fractured rock mass. In the preliminary investigation phase when only surface or bore hole measurements can be made, the half-space with air-Earth boundary forms one of the basic geometries. This corresponds to the perfect magnetically conducting boundary. When shafts and tunnels are constructed we can make measurements on the surfaces of the shafts and tunnels within the Earth. Because of excavation, there forms a so called *excavation disturbed zone (EDZ)* around the shafts and tunnels. Depending on the scale, this zone corresponds electrically to an impedance layer the conductivity of which differs from that of beneath it. The zone is also fractured and therefore anisotropic in character.

The vicinity of a deposition hole should be carefully studied in terms of fracturing before it can be accepted to host a copper-steel canister containing spent fuel. It is probable that some sort of electromagnetic systems will be used in this context to infer the fracturing.

2 Electromagnetic safeguards monitoring

The purpose of safeguards monitoring is to reveal and prevent unauthorized transfer of nuclear material from the repository to nuclear explosives or to other unknown purposes. Safeguards related to a geological repository can concern either an open repository or a closed repository. In the use of an open repository, the verification of the presence of copper-steel canisters is more or less a straightforward task where different geophysical methods can be utilized, e.g. electrical, inductive and radar methods. On the other hand, the verification of copper-steel canisters in a closed repository is a much more difficult problem.

It has been suggested that electromagnetic methods could be used also in the case of a closed repository. Requirements for the reliability and resolution capabilities of the monitoring systems are strong. The Finnish disposal plans, however, rest on the principle that no active monitoring is needed after the closure of the repository.

The main preconditions to study the potential use of geoelectromagnetic methods for monitoring purposes lie in the following facts. (1) The electrical conductivity of copper is very high (ca. 10^8 S/m), (2) the electrical conductivity of the surrounding granite-type rock mass on the other hand is very low as compared to that of the copper (ca. 10^{-7} to 10^{-3} S/m) depending, however, mainly on the water-content, i.e. fracturing and porosity of the rock mass, and the temperature, (3) the great variety of geoelectromagnetic methods as regards sources, measuring frequencies (from pure DC to radio waves), measuring configurations, and the use of time domain and frequency domain, and (4) advanced mathematical modelling techniques and procedures for electromagnetic fields and for their inversion.

Finland has made a proposal to the international safeguards community to study the potential of electromagnetic methods for closed repositories [2].

References

[1] Eloranta, E., Ermutlu, M., Flykt, M., Lindell, I., Nikoskinen, K. and Sihvola, A., 1998. *Electromagnetic characterization of fractured rock for geological disposal studies of spent nuclear fuel.* Radiation and Nuclear Safety Authority, Report STUK-YTO-TR 145, April 1998.

[2] Eloranta, E.H., Ruokola, E. and Tarvainen, M., 1997. *Post-closure monitoring of a spent fuel repository using geophysical techniques.* IAEA Symposium on International Safeguards, 13–17 October 1997, Vienna, Austria, Extended Synopses, IAEA-SM-351, p. 21.