Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 12-13, 2016

Analyses of the deep borehole drilling status for a deep borehole disposal system

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1. Introduction

The purpose of disposal for radioactive wastes is not only to isolate them from humans, but also to inhibit leakage of any radioactive materials into the accessible environment. Because of the extremely high level and long-time scale radioactivity of HLW(High-level radioactive waste), a mined deep geological disposal concept, the disposal depth is about 500 m below ground, is considered as the safest method to isolate the spent fuels or high-level radioactive waste from the human environment with the best available technology at present time. However, if these high-level radioactive wastes can be disposed of in deeper and more stable rock formation than mined deep geological disposal depth, it has several advantages. Therefore, as an alternative disposal concept, i.e., deep borehole disposal technology is under consideration in number of countries in terms of its outstanding safety and cost effectiveness.

In this paper, the general status of deep drilling technologies was reviewed for deep borehole disposal of high level radioactive wastes. Based on the results of these review, very preliminary applicability of deep drilling technology for deep borehole disposal analyzed.

2. Concept of Deep Borehole Disposal

2.1 General Concept

A recent deep borehole disposal concept consists of drilling a borehole (or array of boreholes) into crystalline basement rock to a depth of about 5,000 m, emplacing canisters containing spent nuclear fuels or high-level waste in the lower 2,000 m of the borehole, and sealing the upper 3,000 m of the borehole[2].

The waste packages would be emplaced individually or as a string of 10-20 packages. A single borehole could contain up to 400 waste packages, each approximately 5 m in length. The sealing material for the borehole can be compacted bentonite, asphalt and concrete (Figure 1.)

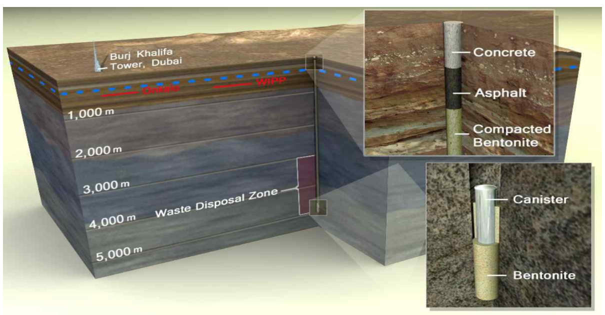

Figure 1. General concept of deep borehole disposal [2]

2.2 Potential advantages

Because the proposed disposal zone in a deep borehole disposal concept is significantly deeper than that of a deep geological disposal, waste isolation from the biosphere and ground water systems could be enhanced by several factors(Figure 2).

- The greater depth of emplacement
- The low permeability of the host rock at depth, as well as longer distances to the surface, which would result in very long travel times
- Deep fluids also resist vertical movement because they are density stratified.
- The reducing conditions (i.e., low concentrations of oxygen), which would result in greater geochemical isolation of the waste due to the lower solubility and mobility of some radionuclides, such as the actinides.

And also, multiple disposal sites could be located near nuclear power plants with suitable geologies, thus reducing the need to transport spent fuels.

3. Deep drilling status

Deep drilling status was reviewed from the data of the reference industries, such as oil-gas industries, geothermal, geoscientific and research etc.

3.1 Oil gas storage drilling

Oil and gas drilling is the most important source of data, equipment and technology for deep drilling. This is a mature industry with over 100 years of history, but with continuing and relatively rapid developments in technology, equipment, tools, drilling fluids, processes and data transmission over recent years. However whilst oil and gas drilling offers a wealth of knowledge, wells drilled for hydrocarbons are of generally small diameter with the diameter at total depth generally in the range of 150 mm (6.00 in) to 215 mm (8.50 in) with some wells drilled in 'slim hole' sizes with typically 121 mm (4.75 in) or smaller. Gas storage wells by the nature of their service requirements tend to be larger with final hole sizes typically of 311 mm (12.25 in) diameter.

Depths of hydrocarbon wells are generally in the range of 500 m to 5 km with a few wells drilled towards 6 km. For the directional drilling today, inclined, long reach and wells started vertically with a final trajectory horizontal are common place. Data transmission technology, steering system development and improved mud systems coupled with a better understanding of wellbore physics and hole stability have also been important improvements which has made the drilling of these exotic directionally drilled holes achievable.

3.2 Geothermal drilling

Geothermal experience also dates back over 100 years. The drilling systems used in this application of deep drilling are largely the same as for oil and gas wells, but the rock conditions are generally more hostile and wells are of course hot providing the catalyst to develop processes and tools suitable for drilling hot, abrasive and fractured rock wells. Some of this experience relates to drilling in competent granite.
Depths of geothermal wells range from about 1 km to 5 km with diameters at the final depth of between 215 mm (8.50 in) and 311 mm (12.25 in).

3.3 Geoscientific drilling

Deep boreholes drilled for geoscientific and other research purposes have contributed much to the understanding of the geotechnical constraints which apply to deep drilling and the processes that control penetration deep into the basement. A number of very deep, superdeep and ultradeep boreholes were drilled and several boreholes were in the former USSR. The deepest well, Kola drilled in the Murmansk peninsula in the former USSR (Russia) into the Baltic Shield eventually achieved a depth of 12.22 km with a 215 mm (8.50 in) final diameter. In Europe the KTB superdeep borehole in Bavaria was drilled to 9.1 km with a final diameter of 165 mm (6.50 in). This deep geoscientific superdeep borehole in Germany was preceded by a fully cored borehole to 4 km at the same location. Main borehole was originally planned to be drilled to 12 km, but the project was stopped at 9.1 km due to funding limitations together with the foreseeable difficulties of drilling much deeper [KTB 1996].

4. Analyses from the actual deep drilling

4.1 Relation between depth and diameter

From the above actual drilling, the relationship between depth and diameter was drawn as shown in figure 2.

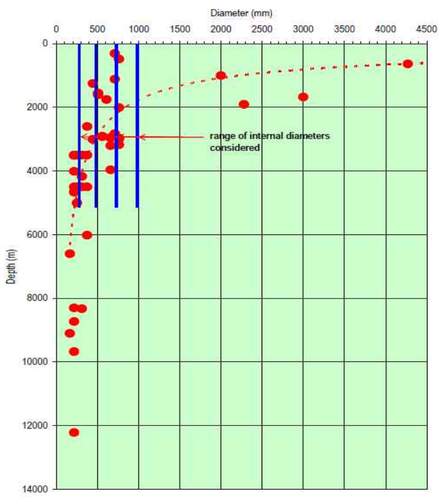

Figure 2 Relationship between depth and diameter

4.2 Time estimate

Regarding the time required to drill a deep borehole for the sizes considered, figure 3 shows a guide for drilling time for a 4 km borehole assuming some drilling in the crystalline basement.

Clear hole size at TD mm	Penetration rate m/hr	Time to drill and complete days
1000	1.00	500
750	2.50	200
500	3.75	135
300	5.00	100

Figure 3 Time estimates for borehole to 4 km

4.3. Preliminary classification of deep drilling feasibility

To summarize the current status of experience, technology and practicability for the different borehole diameters that have been considered, a simple classification of the feasibility of deep boreholes is presented in figure 4 for different diameters and depths

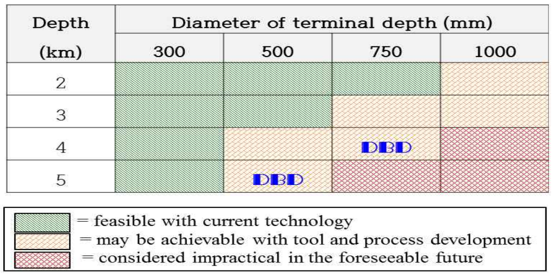

Figure 4 Classification of deep borehole feasibility

5. Conclusions

Even though a deep geological disposal system is considered as the safest disposal method at present time, as an alternative disposal concept to deep geological disposal concept, a deep borehole disposal concept is under consideration in number of countries in terms of its outstanding safety and cost effectiveness. In this paper, as one of key technologies of deep borehole disposal system, the general status of deep drilling technologies in oil industry, geothermal industry and geo scientific field was reviewed for deep borehole disposal of high level radioactive wastes. Based on the results of these review, the very preliminary applicability of deep drilling technology for deep borehole disposal such as relation between depth and diameter, drilling time and feasibility classification was analyzed.

REFERENCES

[1] Brady, P. V., Arnold, B. W., Swift, P. N., Deep Borehole Disposal of High-Level Radioactive Waste, SAND2009-4401, SNL, Albuquerque, NM, 2009

[2] John Beswick, STATUS OF TECHNOLOGY FOR DEEP BOREHOLE DISPOSAL, EPS International Contract No NP 01185 April 2008