DEEP ISOLATION: AN INNOVATIVE HORIZONTAL DRILLHOLE SOLUTION

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Abstract

Deep Isolation brings technical innovation and creative design to the nuclear waste disposal impasse. Deep Isolation offers a solution for safe, secure, and permanent deep geological disposal of nuclear waste while reducing the time and cost of licensing, packaging and transportation. Deep Isolation uses established directional drilling technology from the oil and gas industry to drill a vertical drillhole 1 km to 2 km deep that transitions to a horizontal drillhole 1 km to 3 km in length. The target disposal media are geologic formations whose stability has endured for millions of years. Deep Isolation proposes the direct disposal of spent nuclear fuel assemblies – or other high-level waste – in specially designed canisters in the horizontal section of the drillhole. Disposal of nuclear waste in horizontal drilled holes increases the effectiveness of both the engineered and natural barriers preventing the release of radionuclides from the nuclear waste into the biosphere. The availability of this suitable geology throughout the world allows for disposal at multiple locations. The horizontal emplacement allows for appropriate spacing given the heat generation of the canisters and minimizes the potential migration of radioactive contamination. Deep Isolation is committed to listening to and learning from the public and interested parties in the pursuit of disposal solutions. As such, our approach mirrors our values of openness and transparency. At present, Deep Isolation is actively listening to and exploring public and stakeholder attitudes toward the deep horizontal drillhole disposal concept more generally. Recently, Deep Isolation completed a self-funded demonstration of its technology. A prototype canister was placed into the horizontal section of an existing drillhole. The canister was released, and the installation equipment returned to the surface. Subsequently, the recovery equipment was then sent into the drillhole, captured the canister and returned to the surface successfully demonstrating retrievability.

1. INTRODUCTION

Deep Isolation's patented waste disposal concept leverages proven drilling technology to emplace nuclear waste—including spent nuclear fuel —thousands of meters underground in horizontal drillholes thousands for meter in length within highly stable geologic formations.

Deep Isolation's disposal technology uses well-understood and existing mature directional drilling technology to drill a vertical access hole thousands of meters deep. At depth, the drillhole would begin a gradual curve and become horizontal. The drilled hole would then continue horizontally with a slight upward tilt (1°–3°) for one to three kilometers.

Once the hole is drilled, a continuous pipe called a casing is inserted into the length of the hole. This casing consists of long segments (typically made of steel, although other metals or alloys can be used) that are joined together and then lowered into place. The curved part of the hole typically has a radius of 200 -300 meters. Once the casing is in place, it is common to fill the space between the casing and the surface of the drillhole with cement.

Specially-designed and sized (based on the type of nuclear waste) corrosion-resistant waste canisters containing the nuclear waste would then be lowered into the casing and pushed (using wireline tractor equipment or coiled tubing) so that they are placed end-to-end within the horizontal section of the drillhole. The tilt in this section provides additional isolation from the vertical access drillhole because mechanisms that transport radioisotopes vertically upward will move to the terminal end of the horizontal section; away from the vertical access hole. Once the waste canisters are in place, the drillhole would be backfilled and sealed with rock, cement, bentonite and other materials.

The Deep Isolation approach builds on two key features. The first is the very compact nature of spent nuclear fuel. A typical one gigawatt (1000-megawatt) nuclear power plant produces 20 metric tons of spent nuclear fuel

every year. A single drillhole of an appropriate length, which can vary, could provide enough space for 20 reactor-years of waste.

The second key feature is the evolution of inexpensive but precise technology for directional drilling that enables far deeper placement of nuclear waste than prior conventional mined repository designs. At depths of a thousand meters or more in stable sedimentary formations, the billions of tons of rock between the surface and the waste provide a robust natural geologic barrier that, combined with the engineered barrier of the corrosion-resistant canister, minimizes risks to human health and the environment. Drilling and canister placement and retrieval techniques are proven, reliable, and low risk as demonstrated by their extensive use in the oil and gas industry.

2. ADVANTAGES of the DEEP ISOLATION DISPOSAL CONCEPT

Compared to a conventional mined geological repository, which has been the default disposal concept in the United States and several other nations with civilian nuclear energy programs, the Deep Isolation concept offers a number of potentially important advantages. The disturbance of the host rock is minimal compared to a large mined repository that fundamentally perturbs the system by the mining activity.

Specifically, a reducing environment at depth becomes oxidizing once there is a mined repository. Sealing a mine is a complex problem with many variables. The Deep Isolation approach essentially avoids the issues of a mined repository including complex performance assessments.

In addition, Deep Isolation's approach has significant advantages compared to traditional borehole concepts, which envision vertical emplacement of waste canisters within the host rock. The vertical emplacement results in great long-term stress in the "stacked" canisters due to their weight and requires a robust canister design to handle the stress. Horizontal emplacement of canisters avoids the stress that results from vertical emplacement and allows for appropriate spacing based on thermal characteristics.

The most important consideration for any disposal concept is safety. This is because isolating radioactive waste away from possible contact with humans and the environment over very long timescales is an inherently challenging task. In this regard, the use of small-diameter horizontal drillholes to dispose of spent nuclear fuel and other high-level radioactive waste has important advantages because it provides for much deeper isolation compared to other disposal strategies. With minimal perturbation to the host rock, it is possible to leverage the exceptional isolation properties of deep geologic formations whose stability has endured for hundreds of millions of years or more and maximize the effectiveness of both engineered and natural barriers in terms of preventing the release and transport of radioisotopes from the repository to the biosphere.

Any effort to license a horizontal drillhole disposal repository would involve preparing a rigorous safety case that would carefully consider the whole range of risks and uncertainties involved, including the risk of "fast path" leakage channels that could allow for more rapid migration of leaked radioisotopes to the surface or to groundwater supplies. With the proper selection of drillhole sites and host rock formations, however, the general safety advantages of the deep horizontal drillhole approach can be summarized as follows:

- Greater depth allows for placement well below aquifers, in deep geological formations where the mobility of water is very low.
- Greater depth provides a very slow transport time to surface.
- Ability to place waste below a layer of "tight," low-permeability cap rock with demonstrable barrier characteristics (e.g. shale formations that hold natural gas).
- End-to-end horizontal emplacement of waste canisters, which reduces heat load relative to denser configurations in a mined repository.
- Horizontal emplacement of canisters essentially eliminates the stress resulting from vertical "stacked" canister emplacement in boreholes.

Beyond these characteristics, the Deep Isolation disposal concept offers additional advantages in terms of cost, modularity, and siting that are potentially quite important, particularly considering the difficulties encountered

over several decades of attempting to site and license a mined geological repository in the United States and elsewhere around the world.

An improved safety performance, coupled with the fact that drillhole sites can be restored to near-pristine surface conditions without any need for extensive permanent infrastructure at the site, could make such repositories far more acceptable to local communities. Greater siting flexibility and a wider geographic distribution of disposal facilities would in turn reduce the need to transport nuclear waste over long distances, thereby avoiding or limiting the need for related safety precautions, and saving time and money.

Though cost has been viewed as a potential concern in earlier proposals for borehole disposal, recent advances in directional drilling mean that the Deep Isolation concept holds promise for substantially reducing nuclear waste disposal costs. The oil and gas industry routinely drills very deep holes with greater than three kilometer horizontal sections at a cost of a few million dollars. Individual drillholes can store a significant quantity of spent nuclear fuel or other high-level waste.

3. STAKEHOLDER ENGAGEMENT

The potential benefits and advantages offered by the technical viability and relatively low cost of the deep horizontal drillhole concept can only be realized by conducting a sound and robust public and stakeholder engagement process. For this reason, Deep Isolation has developed a detailed plan for outreach and engagement that is equal in measure to the importance of the technical components.

A Public and Stakeholder Engagement (PSE) plan has been developed to create a framework for Deep Isolation's engagement with stakeholders with the long-term goal of consensus for the emplacement of nuclear waste in horizontal drillholes for permanent disposal. The purpose of the engagement strategy is to build stakeholder support for the effort by their active integration into the planning process. By doing so the aim is to consider their input as a "value added" feature and when practical adapt design and implementation plans to include such input. This will be accomplished by engagement with stakeholders at the local, regional, tribal, and state level and their inclusion as active and collaborative team members.

The PSE plan outlines Deep Isolation's project and potential communities, states, and Native American tribes, and will guide our efforts to effectively engage with these stakeholders.

The primary objectives for stakeholder engagement are:

- To create relationships with interested members of the public, stakeholders, tribes, and elected officials and engage with them to better understand their values, concerns, and inputs;
- To consider and address the inputs expressed such that the final resolution accurately reflects the community values and aspirations;
- To continually be available and accountable for our actions and steps taken in order to create the level of trust and confidence that will be needed to form a lasting partnership with the community; and
- To provide an opportunity to make communities better off with a Deep Isolation solution than they were before.

4. DEMONSTRATION

In January 2019, Deep Isolation publicly demonstrated that a mock canister built for nuclear waste can be successfully placed hundreds of meters underground and retrieved. With over 40 observers from multiple countries, attendees included representatives from the U.S. Department of Energy, nuclear and oil & gas industry professionals, investors, environmentalists, and local citizens.

The canister held no waste, but a steel rod simulated the weight of true waste. The canister was lowered almost 700 meters into an existing drillhole using a wireline cable, and then pushed using an underground "tractor" 150 meters into a long horizontal storage section. The canister was released and the tractor and cable withdrawn.

Several hours later, the tractor was placed back in the hole, where it latched and retrieved the canister, bringing it back to the surface.

5. CONCLUSION

Deep horizontal drillholes are a promising concept for the permanent disposal of spent nuclear fuel and other high-level radioactive waste that offers substantial advantages relative to previously considered disposal strategies. The ability to use established directional drilling technology from the oil and gas industry to permanently isolate the nuclear waste from the biosphere at multiple locations near existing nuclear sites sets this solution apart from the more traditional solution of a mined repository. Deep Isolation's demonstration in January was key to moving forward by demonstrating the ability to emplace a canister hundreds of meters underground and retrieve it.

Not every community will be willing to support a deep horizontal drillhole for disposal, so this is a complementary solution to a centralized mined repository. Deep Isolation is committed to partnering with communities, local jurisdictions, states, and Tribes to determine a path forward for the best locations to deploy a Deep Isolation solution using an open and transparent process. Deep Isolation – using private funds – has already begun to engage with stakeholders and communities across the United States using its PSE plan.

A deep horizontal disposal solution offers safe, secure, and permanent deep geological disposal of nuclear waste while reducing the time and cost of licensing, packaging, and transporting it.