EQUIPMENT FOR THE EMPLACEMENT OF HEAT-PRODUCING WASTE IN LONG HORIZONTAL BOREHOLES

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ABSTRACT

Emplacement of heat-producing waste in long horizontal holes may offer several technical and economic advantages over shallow vertical hole emplacement. Less of the host rock suffers damage as a result of drift construction; the heat from the waste can be isolated from the access drifts for long periods of time; and the amount of rock which must be excavated is much less than in traditional disposal scenarios.

One of the major reasons that has been used to reject the long hole concept in the past and adhere to the shallow vertical hole concept is the equipment required to drill the holes and to emplace and retrieve the waste. Such equipment does not currently exist. It clearly is more difficult to drill a 600 to 1000 foot horizontal hole, possibly 3 to 4 feet in diameter, and place a canister of waste at the end of it than to drill a 30 foot vertical hole and lower the waste to the bottom. A liner, for emplacement hole stabilization, appears to be feasible by adapting existing technology for concrete slip forming or jacking in a steel liner.

The conceptual design of the equipment to drill long horizontal holes, emplace waste and retrieve waste will be discussed. Various options in concept will be presented as well as their advantages and disadvantages. The operating scenario of the selected concept will be described as well as solutions to potential problems encountered.

INTRODUCTION

The Nevada Nuclear Waste Storage Investigations Project, managed by the Nevada Operations Office of the U.S. Department of Energy, is examining the feasibility of siting a repository for commercial high-level nuclear wastes at Yucca Mountain on and adjacent to the Nevada Test Site. This work, undertaken as a part of the conceptual design effort for the repository, was performed in a general study to evaluate the relative merits of vertical or horizontal emplacement of waste packages.

It appears that heat-producing radioactive waste can be emplaced more efficiently in underground repositories in long horizontal boreholes than in vertical boreholes. About four times more mining of drifts is required for vertical emplacement than for horizontal emplacement. In addition, the vertical emplacement scheme requires about 25 ft. of drilling for each canister versus about 15 ft. of drilling per canister for horizontal emplacement.

In the horizontal emplacement scheme, a blind hole is bored to a length of about 600 ft. and lined in preparation for receiving the waste canisters. Waste packages are emplaced in a head-to-toe configuration (Fig. 1) until about 500 ft. of emplacement hole is filled. The hole is then closed by a shield plug next to the last canister of waste with a possible second plug at the drift wall. The 100 ft. of rock between the last waste package and the emplacement drift wall acts as a thermal buffer to the emplacement drift.

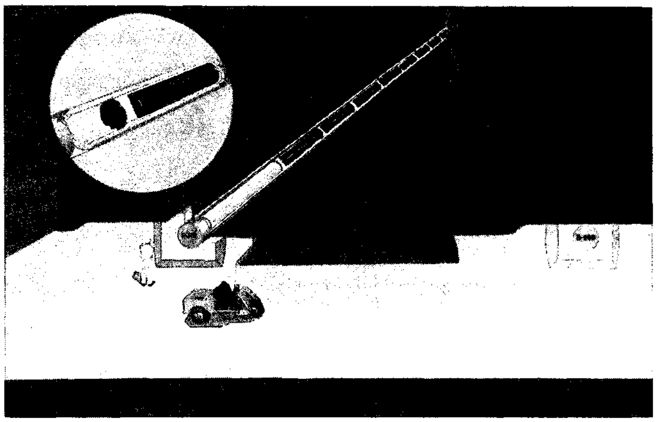

Fig. 1 Horizontal Emplacement

A major disadvantage of horizontal emplacement is that equipment for drilling horizontal boreholes and for emplacing and retrieving the waste is not yet available. This paper describes some innovative concepts equipment that can be used for these purposes.

The items discussed are principal sections of the horizontal boring machine including the cutterhead, the drive-train assembly, the steering control and guidance system, and the vacuum system for removing chips and muck. Also a transporter/emplacer for the waste canisters is discussed, followed by a description of a typical transport and emplacement cycle for this concept.

HORIZONTAL BORING MACHINE

Horizontal holes are drilled daily in the mining industry to take core samples and, in some cases, to exhaust methane gas ahead of a mining operation. Although these holes may be drilled to long distances, they are not precision drilled.

Various techniques have been used to attempt to bore holes accurately. Usually the bit is removed after a certain length is bored, and a survey device is installed to determine the true alignment of the hole. After removal of the survey device, a steering-correction device is installed, the bit is reinserted, and boring continues (presumably in the correct direction). This method is time-consuming and unsuitable for production drilling. Ideally, a guidance system for controlling direction should be used that continuously monitors the accuracy of the hole as it is bored and provides the appropriate corrections.

A conceptual horizontal boring machine that addresses both the problems of precision drilling and of a guidance system for controlling the direction of the hole is discussed in the following sections:

Cutterhead Assembly

The proposed horizontal boring machine (Figs. 2 and 3) consists of a cutterhead assembly that is rotated by an electric motor through a fixed-ratio gear train. This particular cutterhead is one of the smallest ever designed and mimics larger tunnel-boring machines. The cutterhead consists of a flanged-steel weldment with five saddles, each a two-row tungsten-carbide button cutter 12 in. in diameter. A fixture is machined in the center of the cutterhead to accept a standard 12 1/4-in.-diameter tricone bit. This bit is flushed and cooled by air. A bucket has been welded between each cutter saddle to pick up and transfer rock cuttings to the muck-handling system.

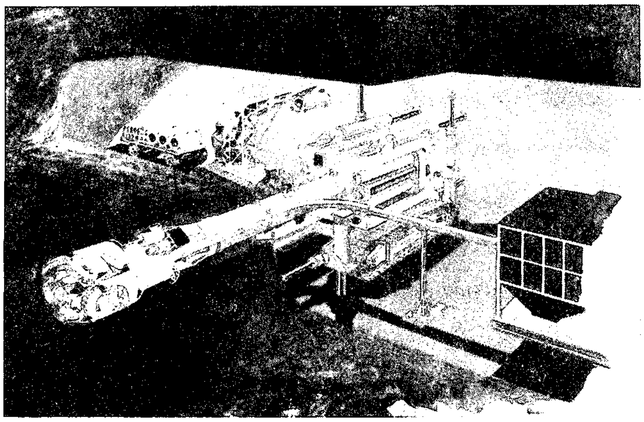
Fig. 2 Horizontal Boring Machine

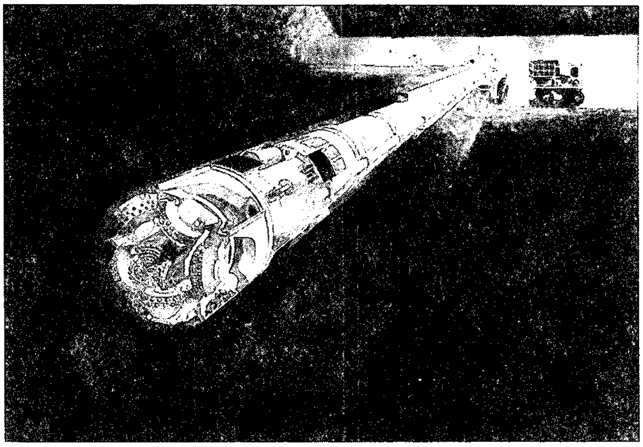
Fig. 3 Horizontal Boring Machine

The cutterhead, bolted to a drive-train output flange (described in the next section) is thrust against the rock face by a nonrotating drillpipe. This drillpipe also counteracts the torque developed by the cutting action of the cutters against the rock face. Thrust to the drillpipe is provided by hydraulic cylinders mounted in a derrick assembly in the access drift. While the machine is boring, the derrick is braced and held secure by hydraulic cylinders jacked against the roof and the ribs of the drift.

The drillpipe is constructed from standard tubing with cast flanges welded to each end. The overall length between abutment flanges is 48 in.; the outside diameter is 18 in. Male splines are machined into one flange and female splines are machined into the other flange. This allows the mating of successive pipes to form a continuous stiff tube that can react to the cutterhead torque. Provision is also made for bolting successive pipe lengths together at three points, 120° apart. Stabilizers to support the drillpipe in the hole are also pinned at the 120° points. The bolts and stabilizers prevent the drillpipe from buckling under the gigh compression loads generated by thrusting the cutterhead against the rock face.

The topmost stablizer fins cover and protect the cables and hoses that lead from the cable car and hose reel to the cutterhead. Curved brackets are affixed for supporting the muck pipe along the length of the drill pipe.

Drive-Train Assembly

The drive-train assembly consists of a totally enclosed, water-cooled induction motor (125 hp, 480 V, 60 Hz, 3 ph) that operates at 885 rpm. The drive shaft is hollow, to allow passage for the airlines to the tricone bit. The front-end cover is flanged to allow for bolting the bell housing containing the oil pump, oil filter, manifold block, solenoid directional-control valves, and plumbing for the steering jacks and roof-jack cylinders. The bell housing is then bolted to the planetary gearbox, which has an overall gear-reduction ratio of 2644:1. The output end of the gearbox is bolted to the cutterhead. A keyed spherical coupling is attached to the rear of the motor to facilitate the movement of the motor and gearbox assembly when the machine is being steered.

Steering Control and Position Monitor System

The unique feature of this type of boring machine is its steering control and guidance system.

Steering Control--Steering control is obtained through the front support shoes, the roof jacks, and the steering jacks. The three front support shoes, spaced at 120° on either side of the vertical, are firmly welded to the front underside of the outer housing. The single roof jack, a curved shoe welded to two double-acting machined wedge slides, is diametrically opposite the front supports on the vertical centerline. A 3-in.-bore hydraulic cylinder moves the shoe up or down a pair of inclined planes that are cast with the outer housing.

Similarly machined inclined planes are located to the rear of the outer housing, but at 45° on either side of the vertical centerline. Steering-jack shoes like the roof-jack shoes are attached to each inclined plane and are actuated by a 2 3/4-in.-bore hydraulic cylinder.

The purpose of the roof jack, when pushed against the roof of the bored hole under light pressure, is to stabilize the cutterhead and reduce its vibration. The jack also acts as a fulcrum about which the steering jacks (when forced against the rock walls in various combinations) can pivot the cutterhead.

The cylinders operating the jacks are controlled by solenoid-actuated directional-control valves. Hydraulic oil pressure is supplied by the multiaxial piston pump driven by the gear reducer. An operator at the control console delivers electrical signals to the solenoids through a control cable attached to the boring machine.

Position Monitor System--The operator uses a Zed Instruments, Ltd., series TG 26E (modified) laser guidance system to monitor the position of the cutterhead. The target for this system is mounted on the right-hand side of the outer housing. The laser is mounted on a steel bracket at the entrance to the bored hole.

Vacuum System for Removing Chips

A vacuum chip removal system appears superior to other methods studied. Among the benefits are a higher drilling penetration rate, dust is trapped in the vacuum inlet and cannot exit the borehole, and seals are not needed (as they would be in a positive-pressure system). The main disadvantage of the vacuum system is the practical limit to pressure differentials.

Component sizes are selected based upon engineering computations and existing pneumatic muck-handling equipment. The vacuum pipe will be a 6-in.-ID pipe from the collection hopper at the head of the boring machine to the exit of the bored hole. Four ft. lengths will allow adding a section of vacuum line for each additional length of drill stem. When the vacuum-chip-removal line exits the emplacement hole, the pipe diameter changes to 8 in.; this allows reduction of the velocity of the muck before it enters the separator. The separator allows bulk rock to settle out of the air stream, and filters remove the remaining dust from the air.

The 1307 cubic foot per minute pumping system with a 6-in. pipe produces a pickup velocity of 124 fps. With 18.3 in. Hg vacuum at the cutterhead a chip removal of about 4.25 tons per hour is achieved. This requires a 20 in. Hg vacuum blower and a motor of about 250 hp.

TRANSPORTER/EMPLACER AND TRANSPORTER CASK

In this section, the transporter/emplacer will be described followed by a description of a typical transport and emplacement cycle.

Transporter/Emplacer

The transporter/emplacer (Fig. 4) is a unique 8-wheeled vehicle with superior traction. The four wheels on each side are interconnected through a drive chain, permitting simple and effective skid steering in both forward and reverse. The unit is powered by an MSHA-approved eight-cylinder diesel engine rated at 365 hp continuous and 475 hp intermittent which provides vehicle performance of 8 mph on a 10% grade. A fail-safe braking system is capable of a full dead stop from 15 mph within 100 ft on a 10% grade either forward or backward.

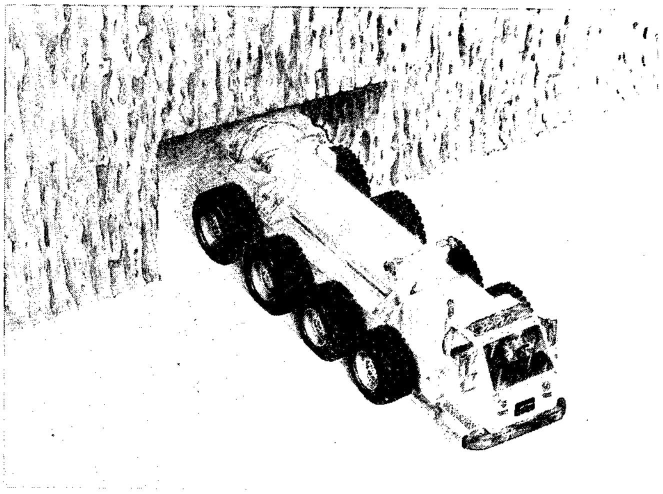

Fig. 4. Transporter/Emplacer.

The transport cask is designed for a surface dose rate of less than 50 mrem/h at the surface. Each cask is a massive cylinder, whose 10-in. wall consists of five concentric layers of the following material, starting from the inside: 3/4 in. of steel, 6 in. of lead, 1 in. of steel, 1-1/2 in. of polyethylene, and 1 in. of steel. The plug lid fits into one end and is held in place by two power screws. Two manually operated latches hold the lid in place in addition to the power screws. The plug lid and the cask are mated in a labyrinth-type joint, effectively preventing leakage of radiation. Inside the cask, the canister rests on a powered roller conveyor. Both the conveyor drive and lid latches are located outside the shielded volume and have provisions for manual override in case of an emergency.

TRANSPORT/EMPLACEMENT CYCLE

Canister Loading

To receive a canister from the hot cell, the transporter driver backs up to within about 20 ft of the hot-cell door. Centerline alignment within ± 12 inches allows the engagement of the transporter frame with a simple and permanent centering/alignment system that assures perfect alignment of the cask with the door. The centering/alignment system consists of a platform containing a series of support rollers positioned to engage along the full length of the underside of the vehicle chassis. As the vehicle "climbs" onto these rollers, its weight is transferred from the tires to the fixed rollers. The corner wheels of the vehicle are lifted free of the platform, leaving only the four lower center tires engaged. Most of the weight of the vehicle and the transporter cask is then borne directly and rigidly through the chassis by the low-friction alignment rollers in the platform. Enough weight remains on the four center tires to retain traction (hence locomotion), and the cask is accurately and repeatably positioned vertically.

Lateral and angular alignments are achieved simply through fixed-guide ribs or rollers that progressively center the transporter as it backs up. Once the cask is engaged with the hot-cell door frame, canister loading can commence.

Canister Emplacement

After the canister is loaded, the transporter travels to the emplacement location and turns 90° into an alcove opposite the emplacement hole. The transporter then backs up until it engages first the docking platform, and then the emplacement door.

Figure 5 shows how the transporter/emplacer looks after it has been aligned, docked, and locked. Portions of the alignment/centering platform are shown, including the support rollers that locate the vehicle/cask vertically and allow easy and gentle positioning fore and aft.

The next step is to unlock and remove the plug lid on the cask. This is done with two power screws, mounted within the sides of the cask, which eject the lid axially from the cask and concurrently engage the cask lid with the emplacement door. The weight of the lid is carried on low friction rollers within two cantilevered "shelves" protruding from the end of the cask. Radiation leakage is prevented by a labyrinth seal between the cask and the emplacement door housing.

Once the lid is positioned against the hole door, the door and lid can both be raised by power screws. Fully raised, there are no restrictions in the passageway between cask and hole. The hardware is simple, occupying very little axial space, and all drives are simple single-degree-of-freedom mechanisms. The power screws are within the shielded space defined by the door housing and the cask. But the remainder of the drive train, including the electric prime movers, are located outside the shielded volume where servicing is easy and manual overrides can be readily applied.

With the door and lid open, the canister can then be transferred by activating the roller conveyor within the cask. This conveyor propels the canister out of the cask, through the hole doorway (which may contain some idler transition rollers), and onto the roller conveyor in the hole. The drive train for the in-hole conveyor passes through the housing of the hole door (the drive unit is not visible in Fig. 6). Once the canister is inside the hole door a foot or so, the door and lid are closed in a reverse of the opening process. The transporter/cask is then undocked, freeing the vehicle to return to the hot cell for another waste canister. Safety interlocks assure that undocking cannot occur until both doors are closed.

Final emplacement of the canister is accomplished by activating the in-hole roller conveyor. Placement is controlled by simple mechanical logic built into each conveyor section. The rollers, whether powered or idler, are ganged in each conveyor section by a collapsible linkage. This linkage initially maintains the roller line in an upper position so that the passing canisters clear all portions of the conveyor as well as the hole lining. Up to this point, the conveyor is reversible, and the canister can be withdrawn from the hole.

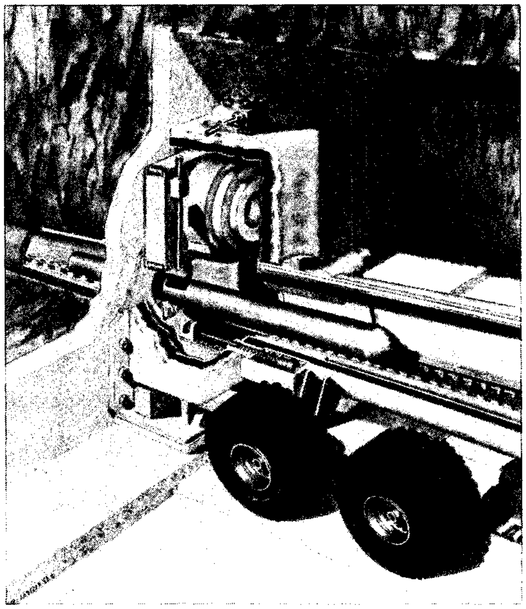

Fig. 5. Canister Emplacement.

When a canister reaches its final location in the 600-ft long hole, it trips a single lever at the in-by end of the conveyor section on which it is rolling. The lever in turn allows the roller linkage to collapse which places the canister on resting blocks beside the conveyor. The collapse-and-lower cycle of any conveyor section, driven by the presence and the weight of the canister, performs one additional function. It mechanically sets and arms the trip lever of the next out-by conveyor section, readying it to receive the next canister.

This process continues until the hole is filled with canisters. The conveyor remains in the hole during the entire process, since placed canisters do not interfere with collapsed conveyor sections. Canister spacing within the hole is controlled automatically by the spacing of the trip levers and hence by the length of the conveyor sections.

The next operation is retrieval of the in-hole conveyor. This is done by a separate machine that mates with the hole door in the same manner as the cask, and that retracts and decouples the entire string of conveyor sections. If buffer zone plugs are used, this machine may need only shadow shielding to protect its operators.

The final operation is recovery of the door system and the docking/alignment platform. A permanently grouted concrete plug is placed just inside the door before this final operation. All emplacement hardware becomes reusable in another hole.

Canister Retrieval

For any waste repository, the issue of waste retrieval must be addressed. Retrieval for the horizontal-emplacement scheme is characterized by two types, normal and adverse. For normal retrieval the canister is not grouted in place, and the emplacement hole is intact allowing the retrieval to be merely the reverse of emplacement (Fig. 6). Adverse retrieval must be used if the waste canisters are grouted in place, or if the emplacement hole has lost its integrity. For the adverse retrieval case an overcore drill (Fig. 7), with a rotating drill stem is being considered. The preliminary concept of the drill bit is to utilize an outer rotating shell to drive the cutters and a nonrotating inner barrel to contain the core and canister. The nonrotating inner barrel is used to prevent damage to the canister during capture. Drag bits will be used as the principle cutting tool and will be sized to cut around the canister with a sufficient margin of safety. The material being cut by the overcore drill will be of lower strength in comparison to the host rock; therefore, the drill bit will utilize the original bored hole for its alignment during the drilling process.

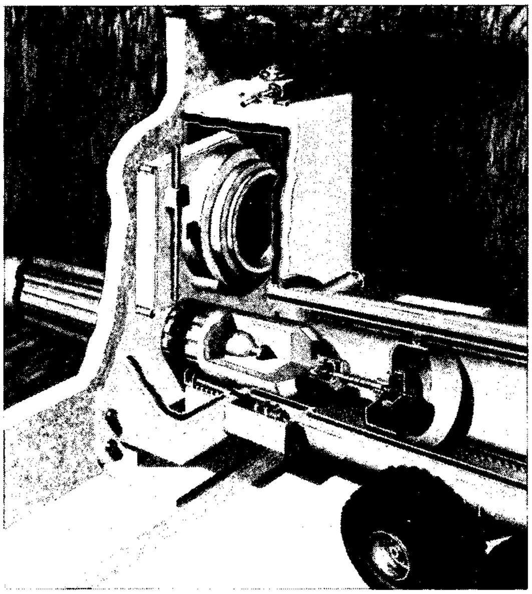

Fig. 6. Canister Retrieval.

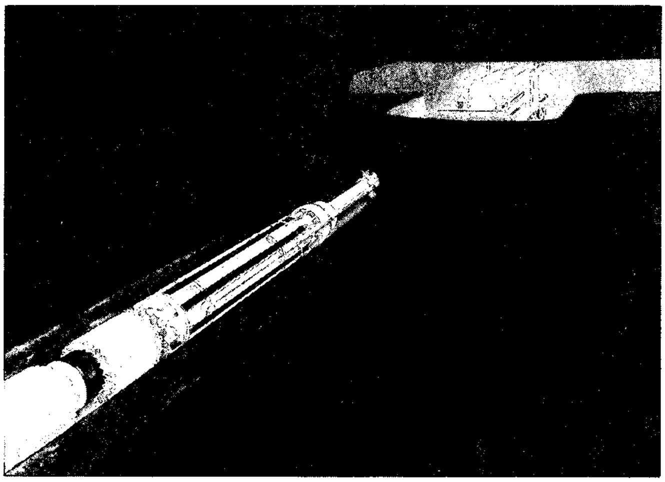

Fig. 7. Retrieval Overcore Drill.

When the core drill captures a canister, the drill is then withdrawn from the emplacement. As the drill is withdrawn, the drill string passes through a radiation shield door (Fig. 7) where the sections of drill stem is encountered. Then the drilling equipment is removed from the area, and the waste retrieval transporter is positioned at the emplacement hole. When all shielding is in place, the shield door is opened and the drill with the waste canister inside is drawn into the transfer cask. The transfer cask is then sealed and uncoupled from the emplacement hole. The retrieval transporter transports the drill and canister to the retrieval processing area, where the canister plug is removed from the drill bit. The drill bit is decontaminated, if required, and returned to the retrieval area for reuse.