CONSTRUCTION OF A CYLINDRICAL BRINE TEST ROOM USING A TUNNEL BORING MACHINE*

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ABSTRACT

This paper discusses the construction of a horizontal cylindrical brine test room at the Waste Isolation Pilot Plant (WIPP). The room was constructed in the bedded salt formation at a depth of 655 meters with a tunnel boring machine. The machine leasing, technical and operational management, parameters involved, and successful completion of this effort are included.

INTRODUCTION

In 1988 a significant concern existed for the WIPP long-term performance as a nuclear waste repository for transuranic waste because of the potential for the inflow of large quantities of brine. The brine of concern is the small percentage contained interstitially within the rock that may potentially migrate into the waste storage rooms. The brine would then become a transport vehicle for radioactivity. To help resolve this concern, an additional test was identified by the project. The test consisted of a large diameter (2.7 to 3.0 meters) cylindrical room, constructed horizontally, with a length of approximately 107 meters. Appropriate measurements and data requirements, both before and during room construction and the instrumentation required as part of the experiment, were identified and provided, as necessary.

Additional information about the experiment and its purpose are available in the Draft Final Plan for the WIPP Test Phase: Performance Assessment (DOE/WIPP 89-011, December 1989). This plan is scheduled to be published in final form in March 1990. This paper will be limited to a discussion of the actual construction of the large cylindrical room, and the special needs and considerations involved.

DESIGN OF CYLINDRICAL BRINE ROOM

The design of the cylindrical brine room is shown in Fig. 1. The room was to be constructed in the bedded salt formation at the WIPP at the repository depth of approximately 655 meters and 2.7 to 3.0 meters in diameter, and approximately 107 meters long. To provide space for construction equipment setup, instrument hole drilling, and instrumentation after construction; an assembly/instrument room was constructed at the end of the room. This room was 9.1 meters long, 24.4 meters wide, and 4.9 meters high. In addition, the experiment required special and somewhat rigorous construction tolerances.

The cylindrical room walls had to be smooth, with deviation of less than 2.5 centimeters in 6 meters. The horizontal room was mined parallel to the natural bedding of the salt, which had an estimated slope of approximately one percent in this area. The centerline and grade could not deviate by more than 15 centimeters over the full length of the room. Further, the construction crew could not use any water, brine, or other liquids for dust control or aid in cutting, and all other foreign material that might compromise the experiment was to be kept from contacting the room. Note also that since the room was constructed in salt, the salt would creep to close the opening by approximately four to seven centimeters during the period of tunnel boring, and the machine had to be capable of removal while this closure occurred.

EQUIPMENT AND CONTRACTOR SELECTION

The construction shape and requirements ruled out the use of either the Marietta Model 3612 drum miner, or the AEC Model 330 roadheader, which are normally used for mining at the WIPP. The use of a tunnel boring machine was determined to be the only reasonable method. Because of the very limited one time use of this machine for this very short (107 meters long) room, the project leased a machine and hired two experienced operators and brought in a consultant with several years experience in tunnel boring, to oversee and provide technical direction for the operation. It was estimated that it would require approximately one month to download the machine to the underground and assemble it, one month to bore the cylindrical room, and one month to disassemble the equipment and return it to the surface.

Requests for proposals to construct the room were issued on December 1, 1988, and bids were received on January 2, 1989. The bids were evaluated relative to tunnel boring machine capability, its physical condition, technical support capability of the contractor, and price. Based on the above, a contract was awarded on February 6, 1989.

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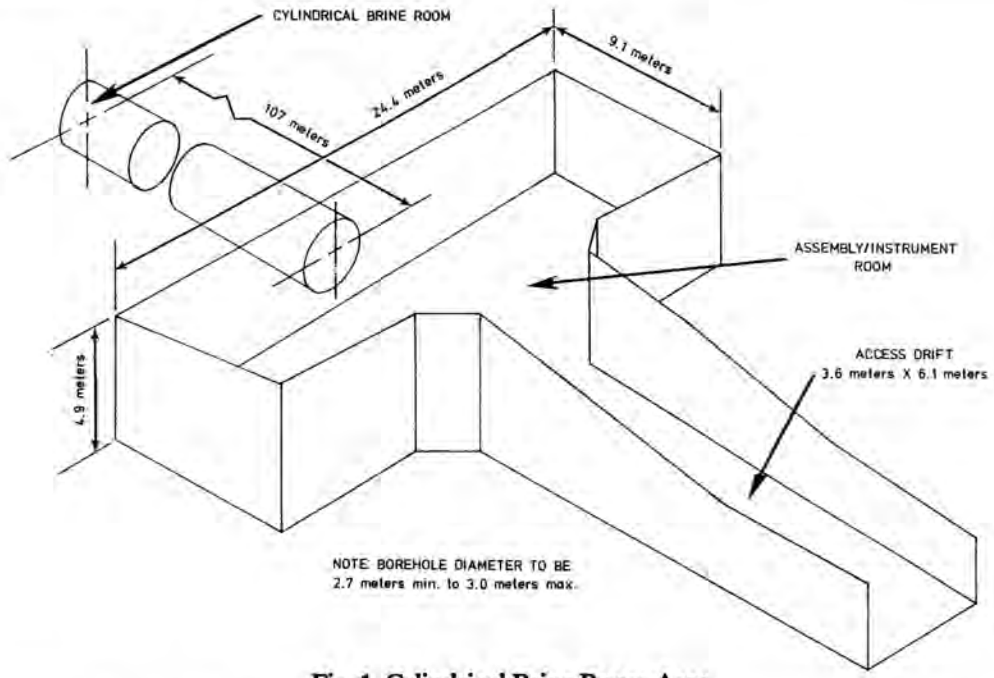

Fig. 1. Cylindrical Brine Room Area

The contractor used a Robbins Model 91, Tunnel Boring Machine. It bores a nominal 2.9 meter diameter, and has an overall length of 14.3 meters and weight of 52,600 kilograms. The cutterhead used 30-centimeter-diameter roller disc cutters and 445 horsepower was available for boring. The machine auxiliary was powered by four 75-horsepower electrical motors which drive hydraulic pumps.

The machine was shipped to the WIPP site in five major assemblies. The downloading at the WIPP was accomplished with the waste hoist, which could handle a maximum weight of 40,800 kilograms and a maximum size envelope of 4.6 meters long by 7.3 meters high by 2.7 meters wide.

TUNNEL BORING MACHINE INSTALLATION

In recognition of this, the contractor has ascertained that the main beam of the tunnel boring machine was too long, and it would be easier to cut the beam and incorporate a new splice joint than to develop special handling methods to take it underground. The contractor completed this modification before shipment of the equipment to the WIPP site. Also, since the waste hoist conveyance is rope guided, it was important that loads be placed on it to reasonably balance the conveyance and ensure it does not tilt. Therefore, each major item was carefully checked to ensure proper placement of its center of gravity on the waste hoist conveyance to ensure safe handling.

In the underground the equipment was moved to the Instrument/Assembly Room, which was constructed at the starting location for the cylindrical brine room. The room had been outfitted with two A-frame cranes running on steel channels that had been grouted to the salt floor of the room. One crane had a 4,500 kilogram capacity and one crane had a 9,000 kilogram capacity. Also, a winch and appropriate pulleys were installed with a pull point on the wall at the location of the start of the cylindrical brine room to provide horizontal pulling capability. Each large and heavy component was skid mounted to enable the winch or other equipment to pull each large and heavy component into approximate position for assembly. Assembly was accomplished using floor jacks for heavy lifts, the A-frame crane for lighter lifts, and the winch and come-alongs for horizontal pulls. Assembly began with placement of the cutterhead/cutterhead support assembly at the initial point for boring of the cylindrical brine room. This component was then carefully aligned with the desired axis for the cylindrical brine room since once assembly is completed, major movement for realignment is difficult. Assembly continued with the Main Beam Assembly, the Gripper Carrier Assembly, the Rear Platform Assembly, and the Conveyor Assembly.

TUNNEL BORING MACHINE OPERATION

The tunnel boring machine cutterhead had fifteen 30-centimeter-diameter disc cutters installed. Cutting is accomplished by rotation of the cutterhead while applying horizontal force. The horizontal force for boring is applied by two large hydraulic rams, which react against two large gripper assemblies, located approximately six meters behind the cutterhead. A maximum force of 302,000 kilograms can be exerted for boring. The gripper assemblies are two large plates, with external surfaces arched to match the diameter of the bored hole, which are extended by hydraulic rams horizontally against the wall of the bored hole. These grippers can exert a maximum of 404,000 kilograms of horizontal force on the walls of the tunnel, which by friction, can resist the forces applied for boring the hole. The grippers can also be used to move the centerline of the machine slightly to the right or left, thus providing some minimal steering capability. In addition, a hydraulic jack on the rear of the machine is used to position the centerline of the machine upward or downward, again providing a limited steering capability.

The cylindrical brine room required that special measures be taken to start the boring operation to ensure that the initial entry into the room did not break out or destroy the circular cross-section and render the initial length of the room unusable for the experiment.

To start the machine into the salt formation, the machine was assembled in a special launch frame, as shown in Fig. 2. The launch frame consisted of a support structure mounted on two beams bolted and grouted to the floor and was held tightly against the roof with jacks. The support structure mated with the gripper assembly of the tunnel boring machine to support the machine and allow it to guide the initial boring. Because the machine is mounted to the floor beams and held tightly against the roof, it provides the resistance for the horizontal force to bore the hole. The cutterhead assembly was positioned and aligned with the borehole centerline on a track and roller support frame. This support frame positioned and provided support and guidance for the cutterhead until it was in the bored hole and was self-supporting and self-guiding.

Initial boring proceeded slowly and carefully, with minimal boring force, to ensure that the hole did not deviate from the required centerline. The boring machine has a one-meter stroke, that is, the machine can advance this distance and then the grippers must be retracted, advanced, and reset. To accomplish this advance during the launching phase, the machine was supported by the hydraulic jack at the rear of the machine, and the grippers retracted and repositioned forward. The support structure was then unbolted from the floor beams and the roof jacks retracted. The support structure was then relocated forward to the new gripper position, and rebolted to the floor beam and jacked against the roof. The rear jack was then retracked to allow the gripper assembly to support the machine. This process was repeated, as necessary, until the gripper assemblies entered the bored hole. Care was exercised to ensure that when the gripper assembly initially entered the bored hole, it fully entered, so that when the grippers were extended into contact with the hole, they did not break or fracture the initial length of the hole.

The boring of the hole then continued in a routine manner. The force used for boring was approximately 130,000 kilograms, and the force exerted by the grippers was approximately 265,000 kilograms. The cutterhead was rotating at approximately eight revolutions per minute (RPM). Machine guidance and direction was checked and determined by laser beam and two targets on the tunnel boring machine. The pre-aligned laser beam passed through a transparent target on the gripper assembly and struck a target on the cutterhead assembly. The machine was then guided left and right by the gripper assembly, and vertically by the rear support jack. Muck removal was accomplished by a set of rotating muck buckets immediately behind the cutterhead, which rotated in the same plane as the cutterhead. The muck buckets picked up muck when they passed the lower portion of the hole, and then as the muck buckets rotated to the top of the hole and inverted, they dumped the muck onto the muck conveyor, which transported the muck through and to the rear of the machine for disposal.

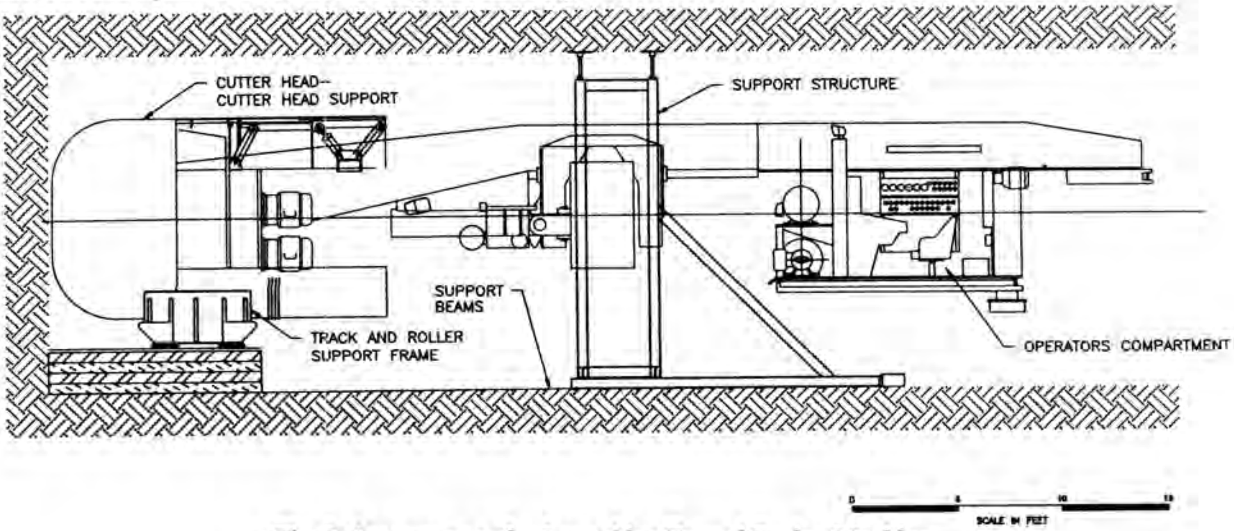

Fig. 2. Arrangement for Launching Tunnel Boring Machine

After 10 meters of boring, personnel checked to confirm that the borehole inclination that was previously determined was in fact parallel to the bedding planes of the salt. This was accomplished by checking the location of an orange marker band in the salt, which runs throughout the WIPP facility horizon, and which is routinely used to confirm the tilt of the salt bed. A check of this orange marker band determined that only a minor correction in tunnel boring machine direction was required.

Also, at borehole depths of 23 meters, 46 meters, and 69 meters, boring was halted and the cutterhead retracted slightly to provide access to the bored hole just ahead of the machine. Personnel were then able to pass through accessways in the cutterhead to install closure points in the circular wall and record initial measurements. These measurements would then be used to provide valuable data on the early creep closure of salt in this bored hole.

CONCLUSION

Work proceeded on a one-shift-per-day, five-day-per-week basis managed by the project personnel. The machine was operated by the two employees furnished by the tunnel boring machine contractor. Overall technical advice was furnished by the experienced tunnel boring consultant. The project provided all additional equipment and personnel to assist in the assembly, boring, maintenance, etc. Boring of the cylindrical brine room was initiated on July 12, 1989 and was completed on August 8, 1989. The operation was completed with no significant delays or breakdowns. The final condition of the cylindrical brine room was surveyed and found to meet the straightness requirement of less than 15 centimeters deviation over full 107 meter length of the room, and the wall smoothness requirement of less than a 2.5 centimeter deviation over any six meter length. The construction was considered to be significant and an important success. Figure 3 is a photo of a portion of the completed room and the tunnel boring machine.

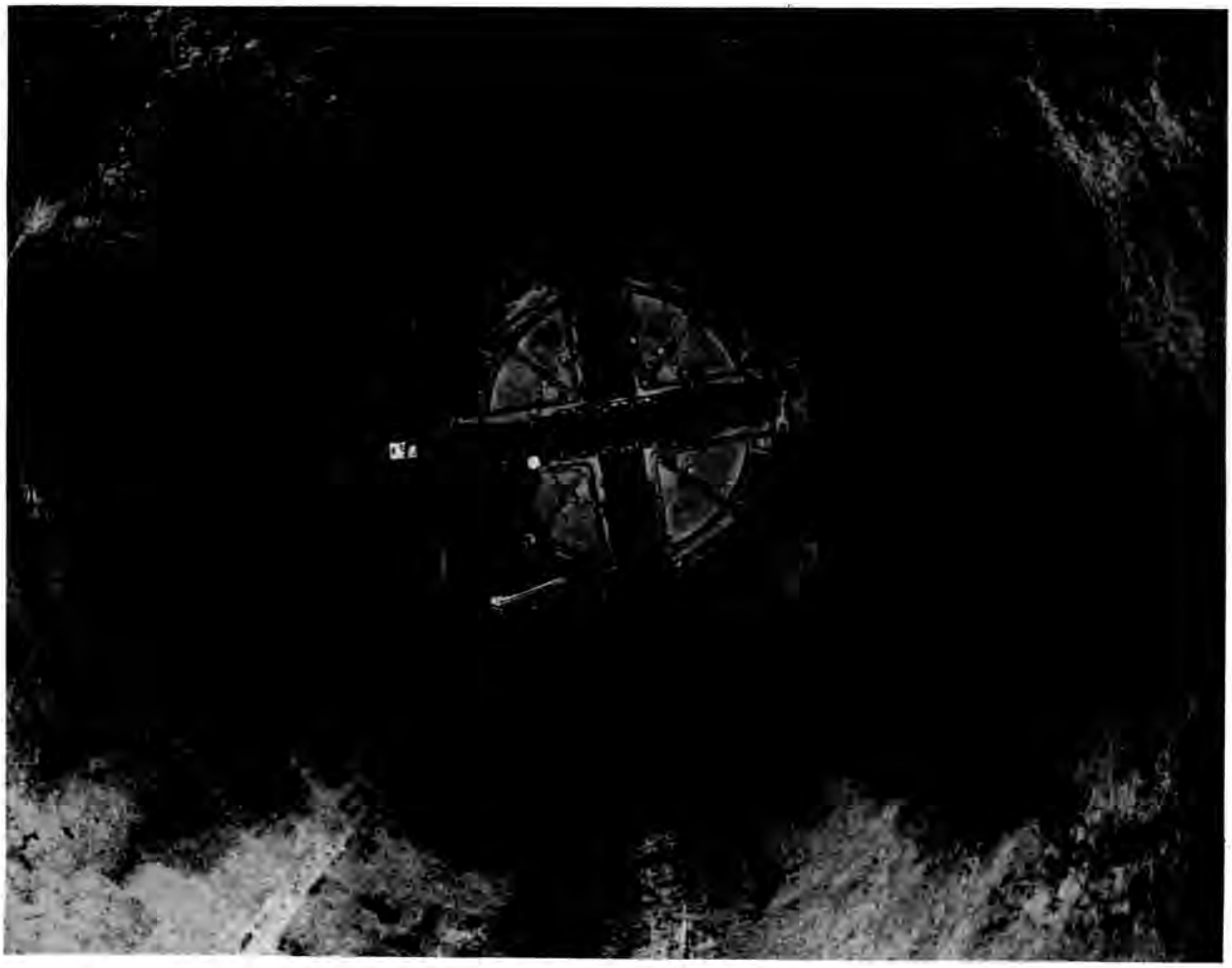

Fig. 3. Completed Cylindrical Brine Test Room