DRY DRILLING AND CORING DEVELOPMENT FOR UNSATURATED ZONE STUDIES

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ABSTRACT

Two areas of major difficulty associated with characterization of any unsaturated zone are the conventional drilling and coring processes used to acquire the samples. These processes are inherently contaminating processes if the circulation fluid used and the cuttings generated are not controlled. The Site Characterization Program at Yucca Mountain requires both uncontaminated core for analysis and a "near borehole environment" as close to in-situ conditions as possible for hydrologic testing. As a result, a prototype development program has been initiated to develop drilling and coring processes which allow for acquisition of uncontaminated core and which cause minimal disturbance of in-situ conditions within the formation exposed at the borehole wall.

INTRODUCTION

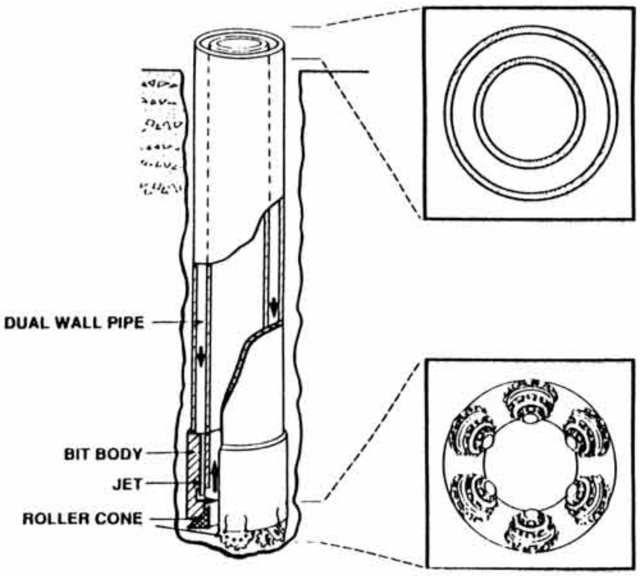
The U.S. Department of Energy, Yucca Mountain Project Office, concluded Phase One of its Prototype Drilling Program June 23, 1990, at Apache Leap, Arizona. The program tested the capability of a multicomponent prototype system designed for dry drilling/coring to acquire uncontaminated samples at depth in a volcanic sequence while minimizing borehole contamination. An additional design objective was to keep the discharge air in compliance with environmental requirements. The drill site at Apache Leap was selected because it provided the best available parallel to geologic and hydrologic conditions anticipated at Yucca Mountain. The dry drilling/coring technique was successfully tested to a depth of 1712 feet and demonstrated an excellent potential to resolve both scientific and regulatory requirements concerning the quality of the core, the borehole, and surface equipment.

DRILLING EQUIPMENT DESCRIPTION

Requirements for the site characterization of the thick unsaturated zone to approximately 2600 feet at Yucca Mountain, NV, have imposed significant scientific constraints that exceed the current capabilities of conventional drilling technology. Conventional oil industry technology uses a "normal" circulation path where the circulating medium carries the rock cuttings under pressure to the surface in the annular space between the drill pipe and the formation. Normal circulation using air or water/mud contaminates the formation fractures and rock matrix to an extent that a number of the site characterization test results for Yucca Mountain would be impaired.

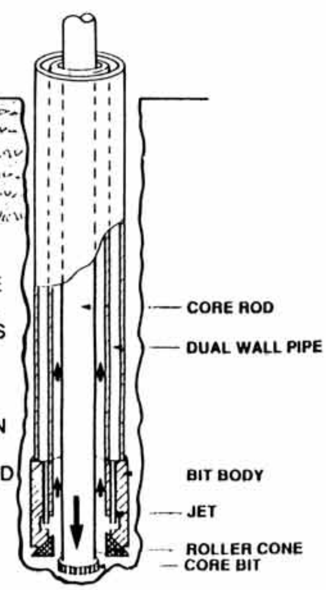
By comparison, the prototype dry drilling/coring system used a "top-head drive" drilling rig with dual wall drilling equipment and downhole tool designs modified from mining industry technology. The "top-head drive" drill rig was fabricated by Lang Exploratory Drilling and is referred to as a Lang LM-120 drill rig. The LM-120 designation refers to the rig's 120,000 pound pullback capability and classifies it as one of the largest rigs presently available for use by the mining and water well industry. The high pullback capability is required to drill with the 9-5/8 inch diameter, 60 pound per foot, dual-wall pipe to a depth of approximately 2000 feet.

The basic concepts of the prototype drilling and coring processes are shown in Figs. 1 through 7. The primary modification made to the basic mining industry drilling system for prototype drilling (other than increased size) is the addition of an open center, shrouded, roller cone bit. The bit is open in the center to allow the coring assembly to pass through it and acquire core samples in advance of the reaming bit. The shroud on the bit channels the air flow across the roller cones for more efficient cleaning and cooling of bit cones. The air forces the cuttings up the inside of the dual-wall pipe to the surface and into the cuttings handling cyclones and dust suppression system. By applying a vacuum to the inner pipe of the concentric dual-wall system a preferential path is established for air and cuttings discharge.



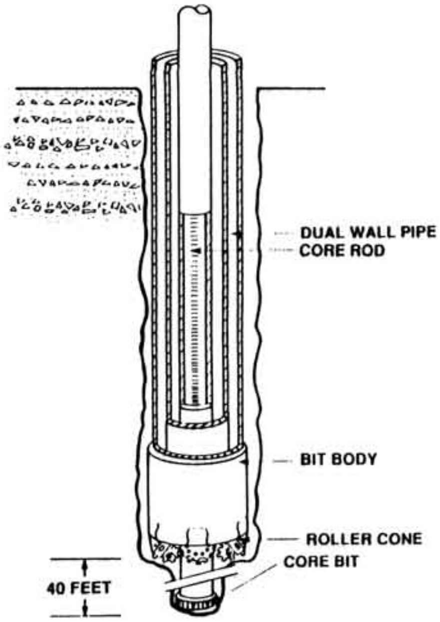
THE DUAL WALL PIPE HAS REAMED DOWN THE CORE TRACK FROM A PREVIOUS CORE RUN AND IS LEFT ON BOTTOM TO RESUME CORING OPERATIONS. THE BOLD ARROWS INDICATE THE DIRECTION OF AIR FLOW DURING REAMING.

Fig. 1. Step one.



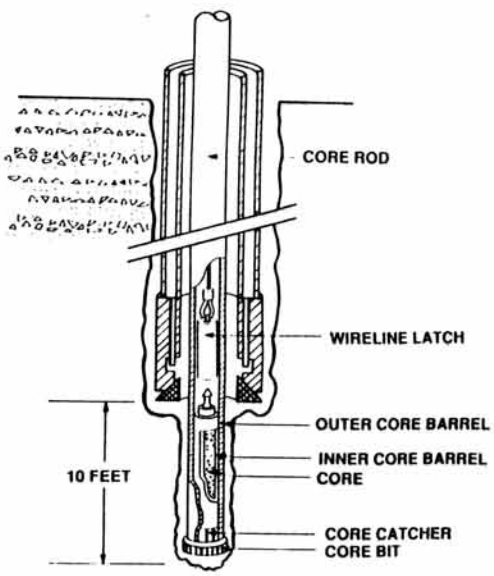
THE CORE ROD IS RUN IN THE HOLE INSIDE THE DUAL WALL PIPE. THE DRILLPIPE ACTS AS A PROTECTIVE CASING TO PROTECT THE CORE ROD FROM THE FORMATION AND TO PROTECT THE FORMATION FROM THE HIGH PRESSURE AIR AND CUTTINGS PRODUCED BY THE CORING OPERATION. ARROWS INSIDE AND ADJACENT TO CORING ASSEMBLY INDICATE DIRECTION OF AIR FLOW DURING CORING OPERATIONS.

Fig. 2. Step two.



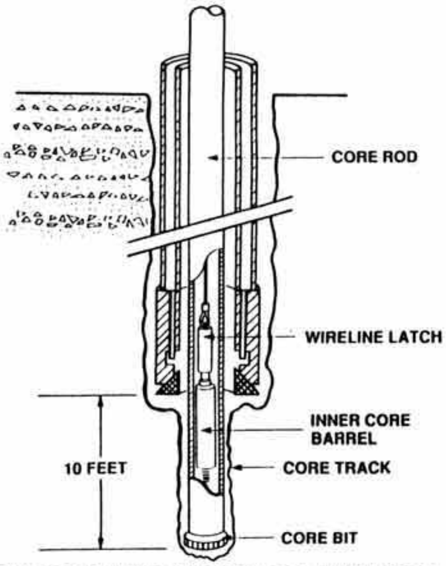
CORING OPERATIONS ARE COMMENCED AND THE CORE ROD IS ADVANCED 40 FEET AHEAD OF THE DUAL WALL PIPE IN 10 FOOT INCREMENTS (10 FOOT CORES). THE CORES ARE RETRIEVED BY CONVENTIONAL WIRELINE WHILE THE CORE ROD IS LEFT IN THE HOLE FOR THE DURATION OF THE 40 FOOT CORE RUN. THE 40 FOOT LIMIT IS USED TO PREVENT THE MORE FLEXIBLE CORE ROD FROM INITIATING A DEVIATION IN THE BOREHOLE AND CAUSING THE DRILLPIPE TO FOLLOW A DEVIATED PATH RESULTING IN BINDING OF THE DUAL WALL PIPE.

Fig. 3. Step three.



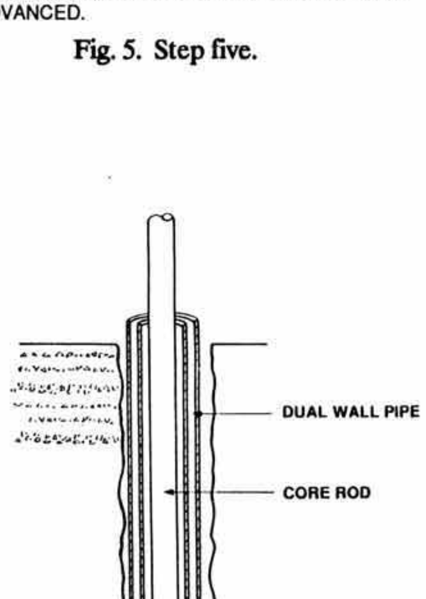
AT THE END OF EACH 10 FOOT CORED INTERVAL THE CORE ROD IS PICKED UP SLIGHTLY AND THE CORE IS BROKEN BY THE CORE CATCHER JUST ABOVE THE CORE BIT. THE CATCHER IS A DEVICE WHICH ALLOWS THE CORE TO ENTER THE INNER BARREL BUT PREVENTS IT FROM BACKING OUT. A WIRELINE LATCH (OVERSHOT) IS THEN RUN INSIDE THE CORE ROD AND THE TOP OF THE INNER BARREL IS "CAUGHT" WITH THE WIRELINE.

Fig. 4. Step four.



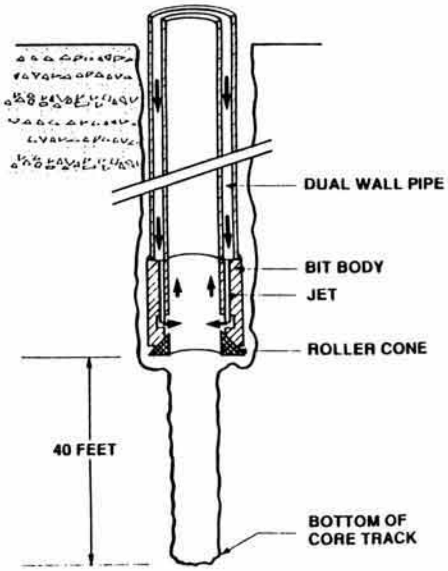
AFTER THE CORE IS BROKEN, THE INNER BARREL (WITH CORE HELD IN BY THE CORE CATCHER) IS PULLED OUT OF THE HOLE BY WIRELINE. A NEW (EMPTY) INNER BARREL IS THEN RUN IN HOLE, LATCHED INTO THE OUTER BARREL, AND THE WIRELINE IS REMOVED. THIS SEQUENCE IS REPEATED EACH TIME THE CORE TRACK IS ADVANCED.

Fig. 5. Step five.



THE CORING STRING IS PULLED OUT OF THE HOLE AT THE END OF THE 40 FOOT CORE RUN IN PREPARATION FOR REAMING DOWN THE CORE TRACK WITH THE DUAL WALL PIPE.

Fig. 6. Step six.



ONCE THE CORING ASSEMBLY IS OUT OF THE BOREHOLE, IT IS DRILLED/REAMED WITH THE DUAL WALL DRILL STRING TO THE BOTTOM OF THE CORE TRACK. THE FORMATION IS PROTECTED FROM CONTAMINATION NORMALLY ASSOCIATED WITH DRILLING BY CIRCULATING THE CUTTINGS UP THE CENTER OF THE DUAL WALL PIPE. CONTAMINATED FORMATION CAUSED BY THE CORING OPERATION IS REMOVED WHEN THE CORE TRACK IS REAMED DOWN. THE BOLD ARROWS INDICATE THE DIRECTION OF AIR FLOW DURING REAMING.

Fig. 7. Step seven.

The Longyear CHD-101 (2.4 inch diameter core) or CHD-134 (3.27 inch diameter core) wireline coring system retrieves the core in a solid core barrel with a split stainless steel inner liner. The system is designed to obtain HQ and PQ core sizes using a Longyear surface set carbonado diamond bit coring ahead of the 12-1/4 inch open center reaming bit and the dual wall drillpipe. The drillpipe protects the coring assembly from borehole failure and protects the borehole wall from contamination by cuttings and the air used in the coring operation. Once a section has been cored, the cored interval is reamed out using the 12-1/4 inch open centered reaming bit. This technique maintains the core in a protected environment and produces a "clean" borehole free of drilling contaminants, such that no air or liquid is injected into the formation and no mud cake is formed on the borehole walls. This quality of core and borehole is not required in the mining, water well, or oil industries but is required for the site characterization of Yucca Mountain.

RESULTS

The Prototype Drilling Program at Apache Leap consisted of: 1) drilling and coring a 12-1/4 inch diameter borehole to approximately 1100 feet; 2) drilling and coring a 9-1/2 inch borehole from 1100 to 1700 feet; and 3) moving the rig and drilling/coring an 8 inch borehol from 0 to 225 feet. The primary objective of the program was to demonstrate that the combination dual-wall drilling and wireline coring systems could obtain core at depth, and provide an uncontaminated borehole for site characterization testing. The larger system successfully produced PQ core (3.27 inch diameter) from a 12-1/4 inch borehole to a depth of 1108 feet. The smaller system successfully produced HQ core (2.24 inch diameter) from a 9-1/2 inch borehole from 1108 to 1712 feet.

Some of the problems encountered at depth in the 9-1/2 inch borehole included excessive backpressure on the sealed borehole annulus during coring and marginal bit life with the 9-1/2 inch open centered bit. However, the video film and caliper log indicated exceptionally good holes for hydrologic testing. The borehole deviation survey (summarized in Figs. 8 and 9) indicated a lateral displacement of 16.2 feet at 1700 feet. A trend noted with the present system indicates some lateral "walk" of the borehole should be expected with all boreholes drilled with this system.

If the borehole is required to be as vertical as possible, such as for test boreholes adjacent to the exploratory shafts, an alternative drilling system using an open center air hammer may be required. This alternative system does not produce core samples with the present technology.

The continued use of compressed air in conjunction with a surface vacuum system for borehole cleaning and dust control was successfully tested during the drilling of the dry sections of both boreholes. Some dust was occasionally noted in the vacuum system exhaust primarily due to an inefficient water spray system within the primary separator. Additional modifications to this system to improve the efficiency of the water spray system over a wider range of operating conditions and reduce the total space required for the cutting handling and dust control systems are planned.

CONCLUSIONS

In summary, this phase of prototype drilling has shown that the dual-wall drilling/coring system can provide core and cuttings from depth and boreholes suitable for site characterization activities at Yucca Mountain. Planned improvements will continue to be evaluated and incorporated into the surface support equipment, including an air processing system and a dust/sample handling system. A primary goal is to keep the system flexible and maintain an ability to move the cuttings to a collection point at the perimeter of the drillsite with no fugitive dust.

Short term effects of drillstring vibration on the life of the 12-1/4 inch open centered reaming bits were not observed. However, the downhole drillstring vibration may have contributed to the failures of some of the 9-1/2 inch bits. Low rotary speed (40-60) revolutions per minute [RPM]) was required on all reaming bits to keep the rotation of the individual cutters within their design limits.

Core bit testing was primarily based on comparison of surface set and impregnated diamond coring bits typically

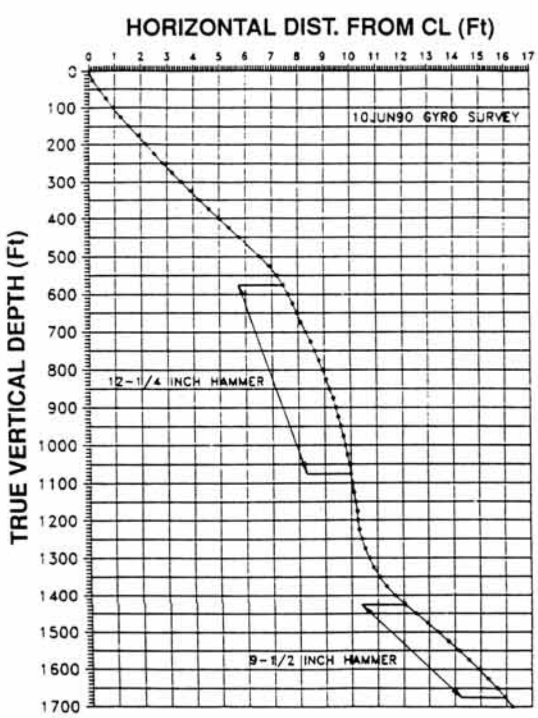


Fig. 8. USW UZP4: Departure profile.

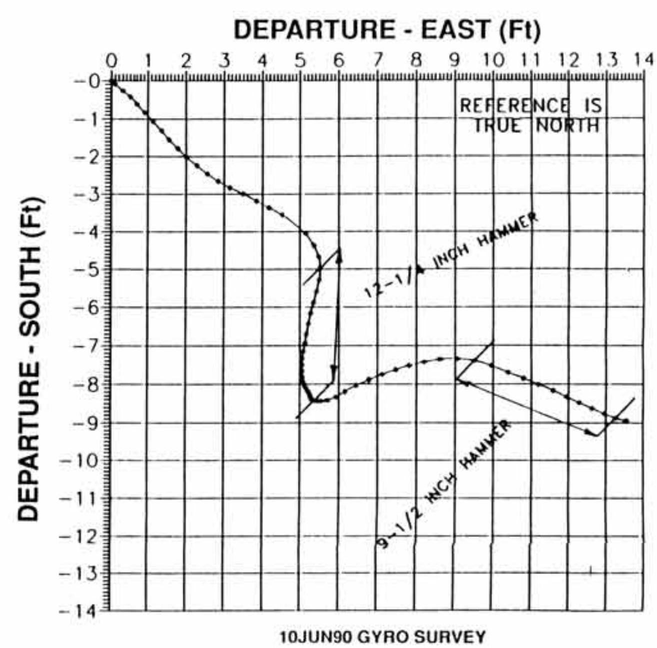


Fig. 9. USW UZP4: Horizontal section.

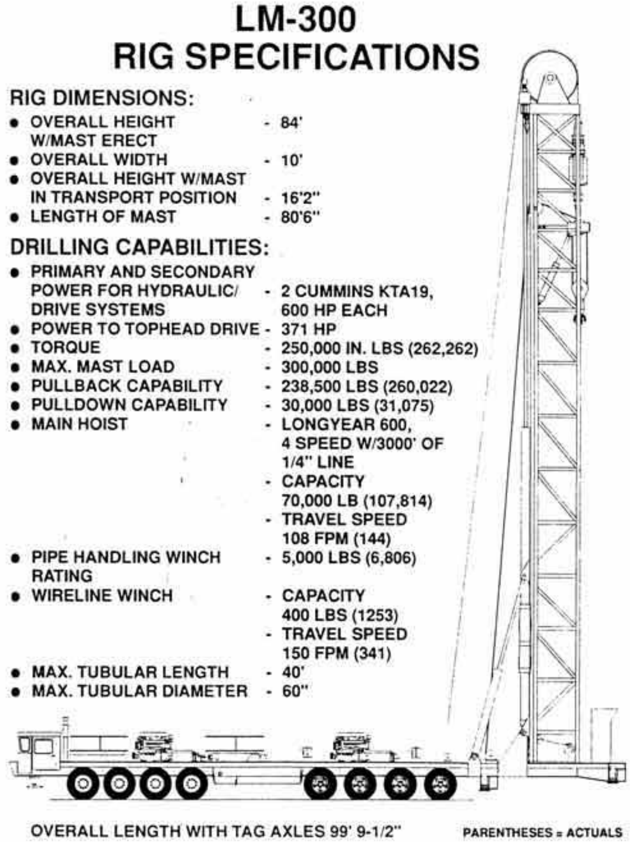


Fig. 10. LM-300 rig specifications.

used in the mining industry. The surface set carbonado diamond core bits were significantly more durable than the impregnated core bits under similar conditions. Core rod vibration was noticeable on the rig floor when the core rod rotation exceeded 80 RPM. Typical diamond impregnated coring bits are designed to operate in liquid fluid at speeds above 200 RPM. These bits drilled slowly perhaps because of the reduced rotary speed and air filled borehole. The surface set carbonado diamond core bit had significantly higher penetration rates at the same rotary speeds. Based on these test results, some variation of the carbonado bit design may be used at Yucca Mountain.

In addition to the Phase 1 Program objectives, the following significant observations were made:

1. Coring with air on high humidity days resulted in water condensing on the core. The condensed water will compromise the core for some of the hydrologic and geochemical studies. Design guidelines are being developed for equipment to insure water condensation is controlled during coring.
2. A tungsten carbide "drag bit" design was found effective for coring the softer formation at shallow depths. The design produced high penetration rates and low surface circulating pressures. The lower circulating pressure of the air resulted in reduced water condensation on the core.
3. Successful recovery of lost downhole drilling equipment was demonstrated with the dual wall drilling system on two occasions. Items recovered included one core barrel and three roller cones from a drill bit.

Information from this prototype program has provided a basis for design and prototype testing of a newly manufactured rig capable of drilling to depths required for site characterization. Lang Manufacturing Company recently completed construction of the LM-300 drill rig for the Yucca Mountain Project (specifications shown in Fig. 10). This large drill rig is capable of drilling to a depth of approximately 3500 feet. In addition, the LM-300 is designed for a pipe handling system for removal and stacking of the dual wall drill pipe when the pipe is brought to surface to change drill bits. The pipe handling system is designed to operate with tubulars as small as 3-1/2 inches in diameter, but is primarily intended for increased efficiency and safety when handling the 9-5/8 inch diameter pipe which weighs 1200 pounds per 20 foot joint. Another prototype program is planned with the new drill rig and includes the following development/tests:

- Development of an integrated skid mounted cuttings/sample handling system

- Integration of the vacuum dust separator into the cuttings/sample handling system
- Design and fabrication of an air processing system to control humidity/water in the "near core environment" downhole during the coring process
- Preliminary testing of the LM-300 drill rig and pipe handling system near Salt Lake City, Utah
- Prototype drilling of a borehole at least 2000 feet deep (possibly 2700 feet) with the LM-300 drill rig using 12-1/4 inch diameter open center reaming bits set up for HQ core with the Longyear CHD-101 coring system.