EXPERIMENTAL SUCTION DRILLING IN BASALTS AT THE IDAHO NATIONAL ENGINEERING LABORATORY, IDAHO

By Warren E. Teasdale and Robert R. Pemberton

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 90-4206

Denver, Colorado
1990

U.S. DEPARTMENT OF THE INTERIOR

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U.S. GEOLOGICAL SURVEY

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FIGURES

CONVERSION FACTORS

Multiply	By	To obtain
foot (ft)	0.3048	meter
cubic foot per minute (ft^3/min)	0.4720	liter per second
foot-pound (ft-lb)	0.3048	joule
inch (in.)	25.40	millimeter
milliliter (mL)	0.001	liter
pound, avoirdupois (lb)	4.536	kilogram
quart (qt)	0.9464	liter
pound per square inch (lb/in^2)	6.895	kilopascal

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ABSTRACT

This report describes results of a suction-drilling (vacuum-drilling) experiment conducted in the basalts of the Snake River Plain at the Idaho National Engineering Laboratory, Idaho. This drilling technique, which uses high-pressure, high-volume air and a steam ejector-eductor siphon, requires no downhole drilling fluids to be introduced into the borehole. Consequently, it would be an excellent drilling method for use in studies of flow in the unsaturated zone, particularly in areas of suspected contamination.

Lost circulation is not a problem because the advancing borehole is always cased with the drill rod. Continuous cuttings samples are obtained using the suction-drilling method. The cuttings are dropped into a changeable jar or like receptacle in the sample-collection device. These samples can be inspected visually as drilling progresses.

INTRODUCTION

In response to the increasing emphasis being placed on studies of flow through the unsaturated zone, the U.S. Geological Survey conducted a suction-drilling experiment in the basalts of the Snake River Plain at the Idaho National Engineering Laboratory, Idaho (fig. 1). This report describes the equipment used, the drilling techniques, and the results of the drilling.

DRILLING EQUIPMENT

Commercially Available Equipment

The suction drilling was done using a truck-mounted Central Mine Equipment 75 (CME-75) drilling rig.[1] Two water-cooled compressors, each rated at 600 ft^3/min and 250 lb/in^2, supplied the air-circulation media used for drilling. The hole was drilled with 2-3/8 in. diameter drill rod. A 9-7/8 in. diameter (4-cone), hard-formation roller-cone bit (fig. 2) was used.

[1]Any use of trade names and trademarks in this publication is for descriptive use only and does not constitute endorsement by the U.S. Geological Survey.

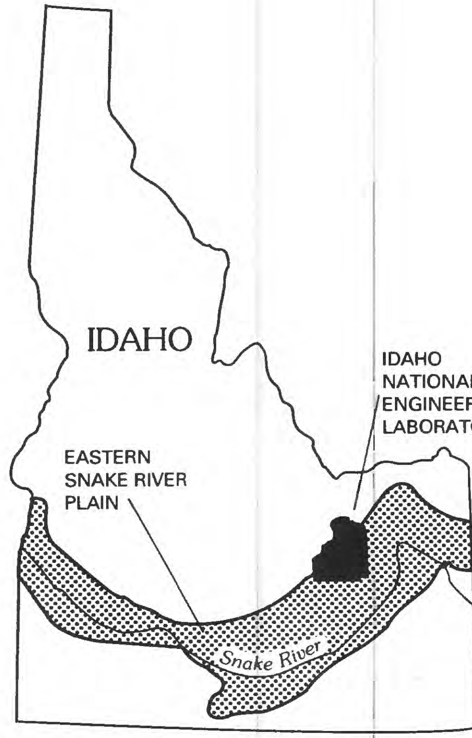

Figure 1.--Location of the Idaho National Engineering Laboratory (INEL).

Figure 2.--Two 9-7/8-in. diameter roller-cone bits.

Downhole suction (vacuum) was developed by a high-capacity ejector/eductor steam siphon. The device has 6-in. diameter suction connection and 6-in. diameter discharge connection ports and an overall length of 27-1/2 in. All compressor air-supply hoses were 1-1/2 in. diameter, double steel braided, high-pressure rating type. A sample-collection device, affixed with a replaceable 250 milliliter capacity sample-collection jar (fig. 3), was connected inline to the 1-1/4 in. diameter drill-cuttings discharge pipe. Two automotive-type vacuum gages were installed in the system to monitor the vacuum developed. One was placed near the drillers' platform and in line with the rig standpipe. The second gage was installed in the steam siphon housing near the cuttings-discharge end of the system (fig. 4).

The wellhead assembly, constructed of an 18-in. long piece of 10-in. diameter casing, served to inhibit release of airborne drilling dust around the borehole and rig. A non-overloading blower-fan assembly, powered by a 1-1/2 horsepower electric motor was connected to the wellhead device by a quick-coupled, 6-in. diameter hose (fig. 5). The fan's function was to assist in the bit-cooling process and drill-cuttings removal as drilling progressed.

Some of the equipment used for the suction-drilling project was not commercially available and had to be fabricated beforehand. These fabricated units included the blower-fan assembly and the wellhead device. In addition, the roller-cone bits needed modification.

Equipment Fabrication And Modification

Blower-fan Assembly

The rectangular-shaped discharge port on the blower-fan assembly was modified. A sheet-metal duct was fabricated to fit over the original discharge port, and a short 6-in. diameter pipe nipple was welded to the end of the duct. This assembly was then welded over the original exhaust port of the blower unit. A 6-in. diameter pipe-to-hose, quick-coupling hose connector was threaded on the 6-in. diameter nipple to facilitate coupling the blower-fan assembly hose to the wellhead casing (see fig. 6).

An adjustable, four-legged stand was made for mounting the blower-fan assembly. Before adjustment, the stand raised the fan unit about 10 ft high and could be adjusted to about 15 ft above land surface. The fan was raised to prevent the fan rotor from drawing any ground-surface contaminants through the air intake and introducing them into the borehole while drilling.

Figure 3A.--Sampling device.

Figure 3B.--Closeup view.

Figure 4.--Vacuum gage near ejector siphon.

Figure 5.--Blower-fan assembly.

Figure 6.--Wellhead device and hose.

Wellhead Assembly

The wellhead assembly (fig. 6), designed by Robert Pemberton, served to: (1) minimize airborne dust contamination, and (2) direct the air from the blower fan downhole. The main body of the assembly was constructed of a 3-ft long piece of 10-in. diameter steel casing. The dust packing-gland part of the unit was similar to that previously built and described by Teasdale and Pemberton (1984). The packing seals consisted of two, 1/4-in. thick mylar disks with 5/32-in. thick by 5-7/8-in. diameter rubber washers sandwiched between them. The mylar disks and rubber washers had a 3-1/2-in. diameter access hole to allow introduction and rotation of the quill rod through the packing gland. A threaded-steel packing plug was periodically tightened to compress the rubber washers between the mylar disks as they became worn by the rotation and advancement of the quill rod. This assembly formed the dust seal at the wellhead. The rubber washers were replaced when they became excessively worn and could not be further compressed to form an effective dust seal.

Roller-cone Bits

Only minor modification to the roller-cone bits was necessary. Because the bits were configured for air-rotary drilling, the circulation ports were located several inches from the bottom of the cones. To direct the suction toward the hole bottom through the bit-circulation ports and to optimize cuttings-pickup efficiency, a steel plate was welded to the main bit body between the cones (see fig. 7). Without such bit modification, the applied suction would not effectively lift and transport the cuttings out of the hole.

DRILLING TECHNIQUES

Before starting the drilling, it was necessary to install 10-in. diameter surface casing through the 21 ft of surficial alluvium. After setting the casing, the wellhead device (with dust seal) was threaded to the casing (see fig. 6). The rig was positioned and leveled over the wellhead device, and drilling began following connection of the compressors, steam eductor/ejector siphon, blower assembly, and cuttings discharge hoses.'

Several mechanical problems occurred during the initial phase of the drilling. These included leakage of the sample-collection device and extreme abrasion of the inside of the cuttings discharge hose. To remedy the situation, a tighter fitting block was made to hold the sample-collection jar cap (see fig. 3), and the steel-braided cuttings-discharge hose was replaced with 30 ft of 1-1/2 in. diameter steel pipe (fig. 5).

Figure 7.--Bit-modification plate.

The two compressors were coupled together to provide 1,200 ft^3/min of air capacity. Enough sections of 2-3/8-in. diameter drill rod and several 3-1/2-ft lengths of smooth-walled, flush-jointed, 3-1/2-in. diameter quill rod were coupled to the bit sub to enable setting the entire string of tools on hole bottom. The threaded steel packing plug, mylar disks, and rubber washers were then placed over the quill rod and coupled to the wellhead device. The uppermost section of quill rod was attached to the kelly. The compressors were then adjusted to their maximum output so that their combined discharge pressure ranged from about 135 to 150 lb/in^2 and averaged about 140 lb/in^2. At this operating pressure the vacuum gage near the rig standpipe registered between 6 and 8 lbs vacuum while the gage located near the ejector siphon indicated about 11 lbs vacuum. The bit was rotated at a rate of about 100 revolutions per minute with a pulldown pressure of about 1,400 lb/in^2. The rock sequences drilled varied in degrees of hardness, ranging from extremely hard and dense basalt to relatively soft scoria and unconsolidated interflow sediment. As a consequence, bit penetration rates also varied from several inches per hour to about 20 ft/hr (similar to penetration rates to be expected when using conventional air-rotary drilling techniques). However, cuttings circulation was continuous and never presented any problems even when extremely fractured basalt was penetrated.

SUMMARY AND CONCLUSIONS

This initial attempt at suction drilling proved to be quite effective in this basaltic rock and sediment. Usually, circulation is lost quite frequently when drilling basalts, particularly in fractured or scoriaceous zones in the borehole. When circulation is lost into the formation, cuttings are not removed from the borehole by the drilling fluid and remain in the hole or are forced into the formation. Normally, lost circulation results in stuck drill tools and, perhaps even loss of the hole. During suction drilling, however, the advancing borehole is always cased with drill stem and lost circulation is not a problem.

Continuous cuttings samples were recovered from the borehole in the sample-collection device. Because no drilling fluids (such as air, water, foam, or polymers) were introduced downhole, cuttings samples were not contaminated with these common drilling fluids. Therefore, suction drilling appears to be an excellent drilling technique to be applied for drilling and sampling in areas of suspected contamination.

Although this unique drilling method offers many advantages--for example, no lost-circulation problems, no sample contamination with drilling fluids, and minimal airborne-dust pollution at the wellhead--there are also problems associated with the method. However, difficulties encountered during this experiment were primarily mechanical in nature. For instance, the cuttings discharge hose became extremely abraded (internally) early in the drilling and was replaced with steel pipe. Other steel pipe fittings (elbows, nipples, and so on) on the rig standpipe system also became cuttings-abraded and required periodic replacement. A sudden drop in vacuum pressure occurred several times during the drilling. Such drops in vacuum pressure were usually caused by leak(s) in the vacuum-line system and were indicated by vacuum-gage readings or by a sharp decrease in cuttings volume being discharged into the sample-collection receptacle and out the siphon. When drilling was not stopped immediately and the vacuum leak(s) repaired, the bit and lower sections of drill rod became jammed with cuttings. This necessitated removing the tools from the borehole and removing the blockage.

The old drill rod used in this experiment caused major problems that resulted in drilling down time required for fishing. Besides being metal fatigued and over stressed from much prior field use, the drill rod was far too small and weak for drilling with the large, 9-7/8 in. diameter bit. As a consequence, the rod failed several times in the borehole and had to be fished out. The fishing tool(s) had to be fabricated and, depending on the vertical position of the fish in the borehole, needed to be modified each time they were used. However, since cuttings were always removed from the borehole through the drill rod, the broken tools were never stuck by cuttings falling back down the annulus and on top of the bit. In one instance, after the broken string of drill tools had been retrieved from the borehole, a borehole television camera was run downhole to determine the borehole condition. The resulting video tape revealed the borehole to be in excellent condition, extremely clean, and with no cuttings in the bottom.

Suction drilling of the borehole was continued using the CME rig and the small drill rod to a depth of 134 ft. At that point, the old drill rod kept breaking and it became doubtful that the borehole could be successfully completed. A larger drill rig (capable of developing 15,000 to 20,000 ft-lb of torque) was then moved on the hole and suction drilling continued using the old drill rod to 180 ft. Larger diameter (3-1/2 in.) drill rod was obtained and the borehole deepened to 360 ft using the 9-7/8 in. diameter roller-cone bit and conventional air-rotary drilling method. The suction-drilling system was successfully tried again at the 360-ft depth until another leak occurred in the discharge line and the drill stem became plugged. The drill rod was pulled, the blockage removed, and the large bit replaced by a 5-7/8 in. diameter, hard-formation tricone bit. The borehole was then completed to a depth of about 445 ft using conventional air-rotary drilling method. Six-inch diameter casing was installed to 360 ft and the annulus was pressure cemented; the depth to water below land surface was about 368 ft.

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GLOSSARY

(Commonly used Drilling terms)

Annulus.--The annulus or annular space is the space between the outside diameter of the drill rods, or casing, and the borehole wall.

Bit.--A steel tool attached to the bottom end of the drill rod which performs the actual drilling. Made in a variety of sizes, types, and shapes depending on type of lithology drilled, method of drilling, and depth and size of borehole.

Drill rod.--A special pipe, hollow, flush-jointed or coupled rods joined and threaded at each end, used to transmit rotation from the rig rotation mechanism (rotary table); thrust weight to the bit; conveys drilling fluid or air to remove cuttings from the borehole and cool and lubricate the bit.

Drilling fluid.--A liquid or gas medium used for cleaning drilled cuttings from the borehole being drilled; stabilizes borehole wall; cools and lubricates bit and drill tools.

Fish.--Debris in a borehole, such as broken bits, drill rod, and tools which might have broken off or fallen into the hole.

Fishing.--The attempt to recover debris from a borehole.

Fishing tools.--Special tools (overshot, spear, junk basket, magnet) used to recover debris from a borehole.

Kelly.--A formed or machined section of hollow drill steel which is connected directly to the swivel at the top and the drill rod below. Flutes, flats, or splines of the kelly engage the rotary table to transmit rotation to the kelly which is, in turn, transmitted to the quill rod(s), drill rods, and bit.

Quill rod.--Drill rod(s) having a smooth exterior wall (having no break-out lugs or flats on its surface). Regular drill rods are added to the quill rod as drilling progresses.

Sub.--A substitute or adaptor used to connect from one size or type of threaded drill rod or tool connection to another.

U.S. Government Printing Office: 1991-573-207/40011