Slimhole Drilling and Directional Drilling for On-site Inspections Under a Comprehensive Test Ban — An Initial Assessment —

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1. Background

On-Site Inspection (OSI), under the Comprehensive Test Ban being negotiated in the Conference on Disarmament in Geneva, may include drilling at the site of a suspected clandestine underground nuclear explosion to recover radioactive samples.¹ It is in the interest of the drilling party to operate as light and compact a system as possible because it is likely that the drilling equipment will first be air-lifted to the country being inspected, and then will be carried by air or surface to the inspection site. It will be necessary for the inspection party to have the capability for more than vertical drilling since there may not be a drilling site available vertically above the suspected nuclear cavity location. This means having the ability to perform directional drilling and to obtain accurate positioning of the drilling tool. Consequently, several directions may be explored from a single surface drilling pad. If the target depth is expected to be at or less than 600 m (2000 ft), slant drilling may be required to a length well in excess of 600 m.

Clearly, the operation must be designed with health and safety features to prevent radioactive exposure if the drilling encounters a nuclear source region. The DOE/LLNL community has developed a strong expertise in this regard². In this initial assessment we focus on the portability and directionality of drilling systems.

2. Overview

In addition to the experience gained at the Nevada Test Site (NTS), the drilling expertise for rock drilling to the depths of interest also resides in two communities: mining exploration and oil-and-gas exploration. This eliminates from consideration the shallower operations such as water-well and urban-infrastructure drilling. The NTS-type of post-shot "re-entry" drilling is quite expensive and involves bulky equipment. Therefore it would be useful for OSI inspections to deploy cheaper and lighter drilling systems. So, a review of the state-of-the-art and of future trends in exploration drilling was performed. In addition, numerous drilling companies and other sources of information, such as publishers of drilling-related material, were contacted. The list of these contacts is given in Appendix A. This initial analysis seems to indicate that slimhole directional coiled-tubing (C-T) drilling shows great

¹ DOE NN-41 (1995) Draft memo to CTBT Backstoppers, May 3, 10 p.

² Butler, M.W. (1984), "Post-Shot Drilling Handbook", Lawrence Livermore National Laboratory, M-148, 50 p.

promise for meeting the objectives and constraints of OSI drilling. Directional C-T drilling is a new, rapidly expanding field. This is illustrated in Figure 1, and is reflected in the list of references which are all from the 1990's.

Figure 1: Directional C-T Drilling Evolution (after Schlumberger-Dowell).

3. Specifics

Based on the initial evaluation of the field, the following companies were retained as potential candidates to provide OSI-related services. Technical documentation was obtained concerning all the systems described below.

Baker-Hughes INTEQ, Houston, TX

Their Slimhole Drilling System can drill holes from 4.45 cm to 10.5 cm in diameter (1.75 to 4.125 in). An Eastman Navi-Drill downhole mud motor powers a Poly Diamond Crystalline (PDC) bit (Figure 2). Drilling fluids can be air, foam, mist, shear-thinning fluids, and drilling mud. Wireline logging tools can be used with the Baker-Hughes system.

Navi-Drill motors can be used with various adjustable subs and steering systems to achieve improved capabilities in a wide range of drilling applications.

Figure 2: The Baker-Hughes Navi-Drill downhole motor and bit.

Baker-hughes also performs directional drilling with coiled-tubing (Figure 3).

The headquarters of the company are in Houston, TX. The Drilling Research Center is based in Celle, Germany, where from the drilling systems can be deployed worldwide.

Figure 3: Baker-Hughes CT directional drilling.

SLIMDRIL International, Inc., Houston, TX

SLIMDRIL specializes in small hole drilling with coiled tubing (Figure 4). Positive displacement Moineau downhole motors are used. Motor size starts at 3.8 cm (1.5 in). The company uses both PDC bits and a new line of thermally-stable diamond (TSD) bits. Figure 5 shows a schematic of the Moineau motor and the adjacent table gives the range of specifications which are typical of downhole mud motors. SLIMDRIL's True Tracker system uses a stand-alone surface monitoring system to provide precise drill bit location. As with other directional drilling operators, SLIMDRIL can perform horizontal re-entry into a previously drilled hole. This would permit searching for an underground cavity in different azimuths from an initial vertical well section. The company's principals have published extensively about their drilling experiences. (References 10-14, 19, 20, 23, and 24) The company's headquarters are in Houston, TX and the equipment is based in the U.S.

Figure 4: The SLIMDRIL coiled-tubing drilling system.

SLIMHOLE MOTOR PERFORMANCE DATA												
MOTOR SIZE (INCHES)	RECOMMENDED BIT SIZE (INCHES)	BOX UP CONNECTION	BOX DOWN CONNECTION	LENGTH (FEET)	WEIGHT (POUNDS)	PUMP RATE (G.P.M.)		BIT SPEED (R.P.M.)		MOTOR PRESSURE ΔP.S.I.	TORQUE @ ΔP FT-LBS	HORSE POWER
						MIN	MAX	MIN	MAX			
1.50	1.505 - 2	¾ CSH	¾ CSH	8.6	30	20	35	885	1550	800	45	13
1.695	1.700 - 2¾	AW ROD	AW ROD	8.7	60	25	35	1100	1550	800	45	13
1¾	1¾ - 2¾	AW ROD	AW ROD	8.7	60	25	35	1100	1550	800	45	13
2¾	2¾ - 4¾	BW ROD	BW ROD	11.0	110	30	50	1090	1820	1200	81	28
2¾	3¾ - 4¾	2¾ REG	2¾ REG	9.5	120	30	70	275	625	425	114	14
2¾L	3¾ - 4¾	2¾ REG	2¾ REG	13.7	200	30	70	275	625	850	227	28
3¾	3¾ - 6½	2¾ REG	2¾ REG	18.2	370	90	170	550	1030	800	289	63
3¾	4¼ - 6½	2¾ REG	2¾ REG	21.8	400	100	200	400	800	750	460	70
4	5¼ - 8½	2¾ I.F.	3½ REG	23.3	720	100	220	400	850	750	460	77
3¾M	3¾ - 6½	2¾ REG	2¾ REG	15.5	340	30	110	98	360	725	553	38
3¾M	4¼ - 6½	2¾ REG	2¾ REG	17.6	380	80	160	130	260	510	770	49
4¾M	5½ - 8½	2¾ IF	3½ REG	17.0	850	100	250	100	260	500	1200	60
6¾M	7¾ - 9¾	4½ IF	4½ REG	24.1	1100	300	600	150	300	700	3400	200

Figure 5: The SLIMDRIL downhole Moineau motor, and specifications.

Halliburton Energy Services, Houston, TX

Halliburton completed in 1993 what was the world's biggest coiled tubing drilling project. One-hundred fifteen wells with 5 cm (2 in) tubing were drilled in the McKittrick oil field of Shell Western, near Bakersfield, CA (Figure 6). The depth of drilling was 293 m (960 ft). When using conventional rotary drilling, Halliburton is self-sufficient because it acquired Dynadrill and its downhole motor system in April 1993. Incidentally, these are the motors used for re-entry at the Nevada Test Site (NTS) in the '80's and '90's. However, when Halliburton wants to use coiled tubing they work with a partner which is:

ENSCO Technology Company, Houston, TX

ENSCO provides the drilling motor and steering tool. ENSCO has drilled over 600 horizontal and directional wells in the U.S. with diameters of 9.6 cm (3.785 in) and above.

Figure 6: C-T drilling by Halliburton Energy Services in the McKittrick oil field of Shell Western, near Bakersfield, CA

Schlumberger-Dowell, Houston, TX

As shown earlier, in Figure 1, Schlumberger-Dowell is a major player in directional C-T drilling. It also performed coiled tubing drilling for Shell Western in California. Four wells were completed with 5 cm (2 in) tubing, to a depth of 468 m (1,532 ft). The spool could hold 915 m (3000 ft) of tubing (Figure 7). This length is in the range of those considered for OSI drilling.

As does Halliburton, Schlumberger-Dowell, has a partner for the downhole operations. It is:

Anadrill Company, Houston, TX

which uses a Power-Pak steerable motor. Complete specifications on it are at hand. The motor comes in sizes from 5.4 to 8.9 cm (2.125 in to 3.5 in).

Figure 7: C-T drilling by Schlumberger-Dowell in the South Belridge oil field of Shell Western, in California.

4. Summary and Recommendations

It appears that a short list of four suppliers should be further evaluated to formulate OSI-applicable packages. They are Baker-Hughes INTEQ, SLIMDRIL International, Halliburton Energy/ENSCO Technology, and Schlumberger-Dowell/Anadrill. It is noteworthy that all of them are headquartered in Houston, TX, making it a logical place to present the OSI requirements to a community of expert drillers. We have requested from these companies that they let us know of operations with coiled-tubing to be conducted in California, so as to use such opportunities to view the systems in action. On such job was just completed by Schlumberger-Dowell near Bakersfield, and they have another one coming up in late July in Long Beach. Figure 8 shows an example of the "footprint" of such a C-T drilling operation.

The Verification community also can take advantage of drilling conferences to keep up with the state-of-the-art. The next such meeting, co-sponsored by the International Association of Drilling Contractors (IADC) and the Society of Petroleum Engineers (SPE), is scheduled for March 12–15, 1996, in New Orleans.

Figure 8: C-T drilling minimum footprint lay-out (after Schlumberger-Dowell).

The next step in this study should be to determine an optimal combination of the new drilling methods with the health and safety procedures and the diagnostics which are required when drilling in a radioactive environment. This will involve bringing together the expertise of the NTS/National Laboratories with those of the exploration/production drillers.

The final outcome will be the formulation of drilling systems which have significant cost and weight advantages over those of the equipment previously used at NTS.

5. Recent References on Slim-Hole Drilling and Directional Drilling

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6. Appendix A: List of Companies and Institutions Contacted

Concerning OSI-Related Drilling

Drilling Companies

Anadrill (+ Schlumberger)
200 Gillingham Lane
Sugarland, TX 77478

Trevor Burgess
Ph: 713-275-8202
713-275-8000 Op.

Baker-Hughes INTEQ
17015 Aldine-Westfield Rd.
Houston, TX 77073

Les Shale, Sr. Technical Advisor
Ph: 713-625-4603
Fx: 713-625-5201

Boart-Longyear
Salt Lake City, UT

John Master
Ph: 800-453-8740

Boart-Longyear Canada
North Bay, Ontario

Loris Pascoli
Ph: 705-474-2800

Schlumberger-Dowell
100 Macco Rd.
Sugarland, TX 77478

Denis Doremus
Ph: 713-275-8055
Fx: 713-275-8039
doremus@sugar-land.dowell.slb.com

ENSCO Technology Co.
1776 Yorktown, Suite 750
Houston, TX 77056-4114

Bob Lenhart
Ph: 713-961-8800
Fx: 713-626-0123

Halliburton Energy Services
Bakersfield, CA

David Ewert
ph: 805-393-8111

Halliburton Energy Services
Houston, TX

Bob Launhard
Ph: 713-624-3475

Jensen Drilling Co.
1775 Henderson Ave.
Eugene, OR 97403

John & Jerry Jensen, Co-owners
Ph: 503-726-7435
Fx: 503-726-6140

Layne Western Exploration
12030 East Riggs Rd.
Chandler, AZ 85249

Steve Alford; Del Gilbranson
Ph: 602-895-9336
Fx: 602-895-9536

Longyear Core Drilling
Dayton, NV

Steve Barnwell
Ph: 702-246-0296

Maurer Engineering Co.
Houston, TX

Bill Maurer, President
Bill McDonald (Guided Boring Systems)
Ph: 713-683-8227
Fx: 713-683-6418

Slimdril International Inc.
4723 Pinemont Dr.
P.O. Box 924328
Houston, TX 77292-4328

Fred Pittard, President
Ph: 713-957-0727
Fx: 713-957-8145

Tonto Drilling
P.O. Box 25128
Salt Lake City, UT 84125

Nguyen Do
Ph: 801-974-0645
Fx: 801-973-2994

Western Utilities
P.O. Box 50415
Sparks, NV 89435-0415

Ken Rose
Ph: 702-331-1191
Fx: 702-331-0110

Other Institutions

Sandia National Laboratory
Albuquerque, NM

John Finger
Ph: 505-844-8089

Gulf Publishing Co.
P.O. Box 2608
Houston, TX 77252-2508

Ph: 713-520-4430
Fx: 713-520-4438

LLNL/Nevada Test Site
Mercury, NV

Mike Butler
Ph: 702-295-6325

Geo-Drilling Magazine
475 West 55th St., #209
Countryside, IL 60525

Kevin Lapham
Ph: 708-579-9730

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