Harding, B. W., Storms, M. A., et al., 1990
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3. REVIEW OF THE DIAMOND CORING SYSTEM[1]

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SUMMARY

This review is submitted in anticipation that the comments will contribute to an improvement in the diamond coring system (DCS) over and above its performance on Leg 124E. The review comments on deployment of the system, tripping the Hydril tubing, and rigging the DCS platform, and also comments on some of the operating aspects of the system.

The review reaches the conclusion that there is a great deal of further work to be undertaken before the system may be said to be acceptable in a deep-water offshore environment.

At the same time, ODP should keep its options open to improve core recovery in hard-rock formations by enhancing existing extended core barrel (XCB) and navidrill core barrel (NCB) techniques and also by considering the application of high-weight/low-speed "new generation" coring bits as opposed to the DCS low-weight/high-speed technique.

INTRODUCTION

The primary objective of the ENG-1 phase of Leg 124E was to "field test" ODP's diamond coring system (DCS). The DCS is a land-based mineral or mining exploration drilling and continuous-coring system. The "field test" was planned to assess the suitability of this high-speed diamond coring technique for continuous operations from a floating vessel. The DCS is seen by the ODP as a system which will greatly enhance core recovery in basement rock and, as such, better enable ODP to fully meet the ever-increasing demands of the program.

A total of eight holes were spudded at four different sites during the ENG-1 phase of Leg 124E (Table 1). None of these holes found suitable "hard rock" or basement, and therefore it was difficult to fully evaluate the DCS coring capability from an ocean-going vessel. Nevertheless, the DCS was deployed on two separate occasions in Hole 773B. The lessons learned from this limited "field test" are recorded under "Comment," which I trust will be of value in future deployments of the DCS.

Comment

For any given "field test," a number of unknown factors can be eliminated at the planning stage. In this case, sub-seabed lithology was obviously a major unknown factor. This can be eliminated by selecting a site where previous drilling has encountered basement at, say, between 100 and 200 mbsf. Alternatively, a full site survey must be undertaken at the proposed "field-test" location. Failure to do so for the ENG-1 sites greatly limited the effective deployment of ODP's DCS.

DEPLOYMENT OF THE DCS

In general terms, the deployment was a very time-consuming operation which needs to be streamlined to increase the productivity of the DCS (see Table 2).

Tripping the 3.5-in. Hydril Drill String

Assuming the ODP string has drilled, washed, and cored the 11.625-in. hole to 100 mbsf (98.7 mbsf in Hole 773B), then the ODP string is hung off at the rotary table with the bit 5 m off bottom (depending on rig heave).

Table 1. ENG-1 sites (10–24 Jan. 1989).

Hole	Spud	Water depth (m)	Total depth (m)	Position (lat., long.)
772A	2236 hr, 10 Jan.	1540	1900.97	16°39′N, 119°42′E
Start run in hole (RIH) @ 1330 hr on 10 Jan.				
Clear rotary @ 1015 hr on 12 Jan				
773A	2145 hr, 13 Jan.	1604	1741.40	20°12′N, 121°39′E
773B	14 Jan.	1604	1702.73 (1722.44)	
Start RIH @ 1230 hr on 13 Jan.				
Clear rotary @ 0610 hr on 21 Jan.				
Note: DCS rig deployed on this hole.				
774A	1920 hr, 21 Jan.	1089	1132.29	20°36′N, 121°44′E
774B	2245 hr, 21 Jan.	1089	1344.46	
Start RIH @ 1530 hr on 21 Jan.				
Clear rotary @ 0500 hr on 23 Jan.				
775A	2130 hr, 23 Jan.	506	512.00	19°51′N, 121°43′E
775B	0120 hr, 24 Jan.	506	526.53	
775C	0555 hr, 24 Jan.	506	517.30	
Start RIH @ 1330 hr on 23 Jan.				
Clear rotary @ 1125 hr on 24 Jan.				

The ODP bottom-hole assembly (BHA) in Hole 773B consisted of:

1. 11.625-in. × 4.05-in. × 4 (15/32) jets roller cone core bit (including float valve).
2. Long bit sub (OL 1029, 1.43 m).
3. Rotary core barrel (RCB) outer barrel (OL 1040, 9.14 m).
4. Special landing saver sub, with drillable insert (SK 0510, 1.05 m).
5. Long top sub (OL 1022, 0.96 m).
6. Head sub (OL 1010, 0.33 m).
7. 7 × 8.25-in. drill collars (OG 0210, 136 lb/ft) X/OVER to 1 × 7.25-in. drill collars (OG 0310, 95 lb/ft) X/OVER to ODP drill pipe at 31.7 lb/ft.

The DCS BHA is made up to allow either 1.52-m (5-ft) or 3.04-m (10-ft) wireline core barrels. The Hydril drill string,

[1] Harding, B. W., Storms, M. A., et al., 1990. *Proc. ODP, Init. Repts.*, 124E: College Station, TX (Ocean Drilling Program).

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Table 2. Overall time analysis of ENG-1 sites.

Hole	Days/hours	Hours	Percentage of time
772A	1/20.75	44.75	13.4
773A	1/4.75	28.75	8.6
773B	6/13.00	157.00	47.0
774B	1/13.50	37.50	11.2
775C	0/22.00	22.00	6.6
Underway time	1/20.00	44.00	13.2
Total time	13/22.00	334.00	100.0

which is racked vertically in the main rig derrick, is run in nominal 27.4-m (90-ft) stands to land out at the drillable insert in the landing saver sub of the ODP BHA. The drillable insert is located 11.44 m above the shoulder of the ODP core bit.

Comments

The height of the drillable insert is a critical dimension and must be taken into account when recording the DCS string tally figures. Pulling out the DCS string simply reverses the above sequence back to the main derrick.

The tripping operation is weather-sensitive to the roll, pitch, and heave of the ship and so can jeopardize safety. Consideration should be made for a "bolt-on" horizontal racking system for the Hydril drill string, similar in operation to the rig pipe-racking system. If the horizontal racking system cannot run the Hydril string in 27.4-m stands owing to excessive bending stresses, then the string could be run in 18.3-m (60-ft) stands.

I understand that the rig's iron roughneck can handle the 3.5-in. outside diameter of the Hydril string. If so, the iron roughneck could make and break the tubing string and eliminate the Weatherford tongs. Again, this will improve the safety aspects of the tripping operation.

The DCS BHA can be assembled to accept a 3.05-m (10-ft) core barrel. This would be preferred to a 1.5-m (5-ft) barrel.

In rigging up the DCS drilling platform, the DCS rig is skidded and centralized at the rotary table. This assumes that both the ODP and DCS strings are hung off at the rotary table, and that the iron roughneck and dual elevator handling system are removed from the rig floor.

The two I-beam skid rails, which run starboard/port across the rig floor, are cumbersome. The total weight of the DCS, platform, mast, and wireline winch is quoted as 39,000 lb. This weight can be easily supported by two standard railway tracks. The platform trolley could be eliminated and replaced by four skid shoes bolted to the underside of the platform legs. Greasing the railway tracks would allow the platform to be pulled into position by the rig-floor tuggers. The travel distance to skid is short. These minor modifications would reduce the stack-up height of the DCS platform above the rig floor.

Further reduction to the stack-up height of the DCS can be made by simply shortening the platform legs. Remove the extendable sections and terminate the fixed legs at a point just below the DCS power-pack support frame. These modifications to the platform legs may necessitate some modification to the DCS drill-rod cage, or simply lift the cage to the platform when the platform is at its operating height in the derrick.

These overall reductions to the platform stack-up height will better enable the platform to be stored under the starboard rig-floor roofing, assuming that one of the roof-support columns can be repositioned.

When the DCS is in position and aligned over the ODP drill string, then the upper set of 500-ton links are installed from the J-connector to the DCS upper mast cross member. The upper and lower DCS mast dollies are then installed to the main derrick guide track.

The installation of the upper and lower mast dollies is extremely time consuming. The dollies are stored forward of the rig floor on the main deck and brought to the floor when required. They are then fitted to the main rig guide track before final mating to the DCS mast.

A great deal of this installation time could be saved by leaving the dollies attached to the DCS mast at all times. Simply pivot the dollies from the horizontal to the vertical for storage, and from vertical to horizontal when installing to the main rig guide track.

The lower 500-ton links are attached to the underside of the DCS platform. The DCS mast and platform are picked up with the rig draw works (compensator locked) until clear of the main rig top drive. The top drive is swung to its drilling position, and the lower links, from the DCS, are attached. The DCS is now ready for ODP string and Hydril coring-string space-out.

The space-out of the two strings relative to each other is critical. It is vital to keep precise records of the total length of each string and its corresponding bit or core-bit position at all times.

A 9.1-m (30-ft) knobby joint is then picked up and made up to the top-drive saver sub. The tubing string is run through the top drive and knobby joint in 3-m (10-ft) sections. While holding the tubing string at the DCS drivehead and table, the connection is made up at the rotary table and the slip-bowl assembly removed. The knobby joint is then made up to the ODP string, the rig compensator aired up, and the 500-ton elevators removed. The DCS is now ready to core ahead. Secondary compensation to the DCS string is effected by the Westech computer control, which is programmed to allow fluid to flow above/below the DCS drivehead cylinder ram and thereby maintain a given constant weight on bit (WOB) of 3000 lb for coring ahead. The ODP bit is set on bottom prior to drilling or coring ahead.

During both of the above-mentioned operations—running the tubing string and rigging the DCS—the ODP bit has been heaving up/down in the open hole. Hole fill is almost a certainty, and therefore it should be necessary to circulate and rotate to bottom. Once the hole is clean, then the ODP string/hole annulus is filled with good high-viscosity mud (120 Marsh) before setting the bit on bottom at around 20,000 lb. WOB is maintained in the hole throughout the DCS coring operations.

OPERATIONAL DATA

The DCS was deployed on two occasions in Hole 773B. The initial hole at this site was abandoned owing to hole instability, and Hole 773B was spudded at 1715 hr on 14 January 1989. The hole was drilled to 1686.59 m, and two XCB cores were cut to 1702.73 m (98.73 mbsf). That depth was considered enough to maintain hole stability during the DCS operations, i.e., burying the ODP string collars (bit to top 7.25-in. D.C. at 85.81 mbsf). The first deployment of the DCS commenced on 15 January, with the second on 18 January. The following is a time breakdown for each of these deployment periods.

	Hours
Spud 773B (1715 hr on 14 Jan.)	
Drill/core to 1702.74 m. Condition hole	9.75
Run 3.5-in. Hydril tubing	11.75
Rig up DCS	16.25
Drill ODP insert	2.00
Trial-run DCS winch. Repair winch. Repair hydraulic hoses.	
Free ODP stuck pipe.	
Monitor DCS/rig heave	18.75

	Hours
Spud 773B (1715 hr on 14 Jan.)	
Wash and ream ODP string 1698.33–1702.73 m. Set down 20,000 lb	1.00
Cut core 1702.73–1704.33 m. Recover core.	
Cut core 1704.33–1705.77 m. Attempt to recover	4.00
Fishing for DCS core-retrieval tools	13.75
Start round trip DCS (2230 hr on 17 Jan.)	
Rig down DCS and skid back	6.50
Pull out of hole (POOH) with 3.5-in. Hydril string	9.00
Drill/condition 11.625-in. hole 1702.73–1721.44 m	4.00
Run 3.5-in. Hydril tubing	7.00
Rig up DCS	9.25
Free ODP stuck pipe	3.75
DCS tag fill at 1716.12 m. Troubleshoot DCS.	
DCS washed 1716.12–1717.13 m	10.00
Worked and reamed DCS string inside ODP BHA	12.75
Lay down DCS	5.25
POOH with 3.5-in. Hydril string	4.00
Prepare DCS for transit	2.00
POOH with ODP string (clear rotary at 0615 on 21 Jan.)	6.25
Total time: Spud 773B to clear rotary	157.00

Comments

Of the 157 hr spent at Hole 773B, a total of 135 hr was spent in the deployment of the DCS, including running and pulling the tubing string. Of these hours, only 4 hr may be claimed as effective coring. On the face of it, this is not an effective percentage of coring. However, the overall "field-test" time for the DCS served to highlight many areas for future improvement.

The ODP pipe became stuck on two occasions: (1) during initial testing of the DCS winch system and (2) just prior to attempting to core during the second deployment of the DCS. These sticking incidents are difficult to understand, as the ODP pipe was in fact heaving up and down relative to the hole during the rig-up and rig-down of the DCS. The heave must have resulted in well-bore breakout and hole fill. There are two possible solutions to the problem:

1. Completely flush the hole with mud prior to hang-off of the ODP string for DCS deployment. Live with the hole fill and again flush out and completely fill with mud prior to setting the ODP bit on bottom. Hole flush and fill must use high-viscosity (120 Marsh) mud.
2. Case the hole to bottom prior to deployment of the DCS. This solution is time-consuming and expensive; however, the casing should not heave and thus will minimize potential hole instability.
3. The positive aspect of the sticking problems, as they occurred in Hole 773B, was that the position could be recovered with the rig top drive. This clearly vindicated deploying the top drive below the DCS platform.

Running the 3.5-in. tubing proved to be time-consuming. There were, however, a number of reasons:

1. Marginal weather and a general lack of crew experience with vertical tripping.
2. The need to check tool-joint dimensions on part of the first trip in the hole.
3. Problems with the 3.5-in. tubing elevators.

All three are clearly avoidable for future work. There is also the possibility of using a horizontal-to-vertical racking system as with the ODP 5.5-in. string. Notwithstanding the above, the times to trip the tubing did improve during Hole 773B:

1st run in the hole:	11.75 hr
1st trip out:	9.00 hr
2nd run in the hole:	7.00 hr
2nd trip out:	4.00 hr
Total tripping time:	31.75 hr

An attainable target for tripping this tubing should be 600 m/hr.

Two hours was required to drill out the drillable inserts set in the ODP BHA, one in the special landing saver sub (SK 0510) and one at the ODP bit. While the landing shoulder, part saver sub body and part drillable insert, is used to land the XCB coring assembly, I fail to see the need for the "drillable insert." Simply incorporate the shoulder in the "saver sub" and allow a throughbore at 4.125 in. sufficient to pass the DCS core bit (nominal OD of 3.96 in. for a 4.00-in. hole), saving "drilling time" and more importantly saving wear on the DCS core bit.

The DCS winch line parted on one occasion and required resplicing. The winch has no positive braking mechanism. The winch is also slow when compared to the main-rig coring winch. The DCS winch needs to be upgraded for offshore duty. Possibly consider rigging the DCS to enable using the main-rig coring winch to recover DCS cores.

The Westech computer, used to drive the secondary compensation for the DCS drive head, appears to have been a success. The computer was able to control the DCS weight on bit to within acceptable limits (±500 lb for a nominal 3000-lb WOB). Nevertheless there was considerable downtime associated with the Westech equipment. This equipment needs a complete review and must be containerized and made more rugged for offshore application.

Coring with the DCS, albeit in soft clay as opposed to hard rock, appeared to be acceptable at nominally 3000 lb WOB, 60 rpm, and 25 gpm mud flow. However, little actual coring time was achieved and was not in the low-weight/high-speed hard-rock drilling category.

One must pose the question, "What if the DCS string becomes stuck at 50 m into the 4-in. hole?" This may be caused by breakaway of rock at the interface between the bottom of the ODP hole and the top of the DCS hole. There are then a number of options:

1. Pull free with the DCS drivehead.
2. Pull free with the main rig. The DCS string may part anywhere!
3. Washover and clear with the ODP string.
4. Cut the DCS string and abandon.

As previously stated, DCS core recovery (1702.73–1704.33 mbsl) was slow. The second core was not recovered with the DCS wireline winch. The DCS recovery tools need to be upgraded for ocean-going operations, i.e., made far more robust!

The second deployment of the DCS core bit achieved very little, except to completely wear away the face of the bit and leave the core barrel in the hole. It is difficult to say exactly what happened. The events of this particular bit run need to be fully analyzed to avoid the same outcome again.

In general, the rig-up/rig-down of the DCS improved with practice (Table 3). However, the possibility of tripping the tubing string without rigging down the DCS should be given further study.

Table 3. Time analysis for Hole 773B.

Operation	Time (hr)	Percentage of time
Spud and drill Hole 773B, including free and trip ODP pipe	24.75	15.8
1st RIH 3.5-in. string	11.75	
1st POOH 3.5-in. string	9.00	
2nd RIH 3.5-in. string	7.00	
2nd POOH 3.5-in. string	4.00	20.2
1st rig up DCS	16.25	
1st rig down DCS	6.50	
2nd rig up DCS	9.25	
2nd rig down DCS	5.25	23.7
DCS testing	28.75	18.3
Drill ODP inserts and core	6.00	3.8
Fish for DCS tools	13.75	8.8
Work and ream DCS string	12.75	8.1
Prepare DCS for transit	2.00	1.3
Totals	157.00	100.0

CONCLUSIONS

The results of ODP's offshore "field test" are not entirely conclusive. It may be claimed that the high-speed/low-weight DCS is an effective coring system in hard rock on fixed land locations. However, when deployed from a floating vessel in deep water the system has yet to prove itself. Other systems, upon which this field trial was based, appear to be effective in the shallower water depths of the Norwegian and U.K. continental shelves, say, as deep as 300 m. There are, however, large differences between this and 1604 m or even greater water depths. One must question what influence the lateral excursions of the outer 5.5-in. ODP string (riser) had on the effective cutting/coring capability of the DCS 3.5-in. string. The DCS system may be good for 2000 m on land; however, I suggest that the more dynamic environment offshore will reduce this depth capability. Effective downhole WOB and torque will be reduced. The 2000-m system may be good for, say, only 1500 m offshore, while a nominal 4000-m system may be good only for 3000 m.

Notwithstanding the aforementioned, the system was deployed offshore, and some basic lessons were learned:

1. The overall deployment times for the system, tripping the 3.5-in. string and rigging the DCS platform, need to be streamlined.

2. The secondary compensation of the DCS drivehead cylinder, which is used to maintain an acceptable constant weight on the coring bit, appears to have functioned well. However, the excessive damage to the second DCS bit may have been caused by bit bounce or, indeed, bit hang-up. This would indicate that what appears at the surface may not be a true reflection of the downhole conditions with regard to heave motion at the bit. This problem must be fully resolved, and brings into question the overall concept of the low-weight/high-speed technique.

3. The DCS core-recovery system must be made more reliable. As with the application of slim-hole techniques to oil-field drilling, fishing operations can vary from difficult to virtually impossible in these small-hole-size geometries. The effective coring lengths must also be improved from 1.5 m to the ODP standard of 9.6 m. This will necessitate a radical redesign of the DCS mast.

4. Hole instability will continue to be a problem and can really be minimized only by improving the properties of the mud used to fill the ODP hole or ultimately to design the hole to include a string of casing across the sediment/hard-rock interface.

There are a number of more fundamental questions to be answered before committing the DCS or an equivalent system to further offshore coring operations. The actual objectives for the DCS must be clearly defined. Is the system to be capable of coring basement "hard rock" or "chalk/chert" sequences, or indeed both? Assuming the latter to be the case, the system must be fully tested at selected land drilling sites. It is proposed to test the system in chalk/chert formations on the U.K. mainland. Such a test could be extended to include hard rock or granite in Cornwall or Scotland. These land tests can also be used to optimize core-bit selection for hard-rock and chalk/chert sequences, and to optimize the major coring parameters of WOB, rpm, and mud-flow rate. At the same time, it will most certainly be worthwhile to compile a dossier of other mineral or mining operators' experiences in similar lithologies. Much valuable information can be gained from the experience of others, which, when combined with the proposed ODP land tests, will make a considerable contribution to improving any future performance of the system in the offshore environment.

The experience gained from Leg 124E and the aforementioned land studies must be fully documented and used to compile a detailed set of operating procedures for the system offshore. The demands of the ODP scientific program may call for the DCS to be upgraded to a 4000-m depth capacity. This could be retained as a long-term goal, but the short-term target must be to make the 2000-m system operate in a reliable and effective manner. ODP must be receptive in regard to other systems to achieve the objectives of recovering core from hard rock or chalk/chert formations. For example, the XCB or the NCB coring system, with new-generation core heads, may well prove to be more effective than the DCS. Indeed, it may be feasible to discount the low-weight/high-speed technique and revert to RCB coring by the development of a large-diameter (±10-in.) diamond-matrix or stratapax core bit with wear properties which would cut rock at low speed but with high weight on bit.

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