Storms, M.A., Batiza, R., et al., 1993
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6. DESIGN AND PERFORMANCE OF SUBSEA HARDWARE[1]

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EXECUTIVE SUMMARY

The East Pacific Rise (EPR) provided a difficult and challenging arena in which to test the diamond coring system (DCS) and associated subsea hardware. Information gained from Ocean Drilling Program (ODP) Legs 124 and 132 proved invaluable in further developing hardware to withstand the difficult drilling conditions anticipated at the sediment-free fast-spreading mid-ocean ridge. The coordinates of the primary site (EPR-2) are latitude 9°30.85′N and longitude 104°14.66′W. Water depth at the site is approximately 9020 ft (2570 m). Recent surveys using ARGO and studies conducted from the submersible Alvin have confirmed the surface crust to be a layer of massive basalt. The location selected for drilling appears to be in a ponded lava flow with relatively zero relief. This ponded flow is underlain by 164–197 ft (50–60 m) of low-velocity material suspected to be very thin sheet flows, lobate pillows fragments, or intact lobate pillows filled with lava.

The reconfigured six-sided hard-rock guide base (mini-HRB) was used to establish a drilling template from which to initiate diamond coring. The mini-HRB provided a three-legged structure with counterbalanced reentry cone. The base was designed for seafloor slopes up to 25°. Because of the difficult drilling conditions expected at EPR, a nested drill-in bottom-hole assembly (DI-BHA) was developed after proving a single-stage version viable on Leg 132. The nested system provides two stages of casing which can be deployed to assist the DCS in isolating unstable formations. The drill-in concept is designed to eliminate any redrilling or reaming of the initial hole that might be necessary due to instability of the formation or size of borehole attempted. Auxiliary hardware to support the nested system components are also described in detail.

The ODP drill string was again used as a riser for supporting the DCS tubing. A comprehensive study conducted by an outside consultant of the whole mini-riser system was performed to verify the earlier studies conducted for Leg 132. Discussion of the findings and suggested improvements are described in detail. The drill string was again held in tension with a redesigned tensioning tool and new break-away safety joint. The safety joint provides the mechanical fuse to release from the mini-HRB in case a sudden drive-off situation were to occur from loss of the dynamic positioning system. This component replaced the shear bolts used on Leg 132 between the tapered stress joint (TSJ) and tensioning tool.

The equipment tested during Leg 142 performed without any mechanical problems throughout the entire leg. The fine volcanic glass did at times cause situations in which both tools and drill strings became stuck due to the problems associated with cuttings reentering the hole. Problems with fill reentering the borehole occurred to such an extent that the second-stage DI-BHA was installed to isolate the material. Some minor changes in hardware are suggested in order to enhance a system that appears to have survived the rigors of bare-rock spudding at the East Pacific Rise. This report provides general background information pertaining to the development of the hardware designed, along with technical and operational information gathered during the leg. Included where pertinent are sections on both the field performance and suggested improvements to the individual hardware components.

INTRODUCTION

The second sea trial of the diamond coring system Phase II has allowed much of the prototype equipment developed for Leg 132 to be tested in either a new or modified version. Leg 142 had a less ambitious and more realistic operational plan than that for the three sites chosen for Leg 132. One location with one primary objective was set forth in the "Leg 142 Engineering Prospectus." The main goal of the leg was to maximize coring time with the DCS. The expected formation at the EPR was young, fractured basalt. In order to accomplish this task the following operational plan was adopted for Leg 142:

1. Deploy hex-sided mini-HRB, un-jay and remove the running tool.
2. Reenter the guide base with the first stage of the drill-in BHA system. Drill in the primary BHA to approximately 13.1 or 16.4 ft below seafloor (4 or 5 mbsf) and back off in the HRB casing hanger.
3. Lower tensioning sub and reenter HRB with the bit guide. Deploy bit guide, recover center bit, and remove.
4. Lower tensioning sub and reenter HRB. Deploy the DCS and attempt to core out the bottom of the ponded lava flow into the underlying basaltic formation. The minimum desired penetration is 328 ft below seafloor (100 mbsf). (Note: If unstable hole conditions are prevalent in the low-velocity layer underlaying the ponded flow, the second-stage drill-in BHA may be deployed prior to achieving the DCS depth objectives.)
5. Upon achieving or exceeding the DCS depth objectives and prior to removing the DCS tubing from the hole, slimhole caliper logging will be attempted. If successful, slimhole temperature logging will be attempted.
6. Attempt to ream the 3.96-in. (100.6 mm) DCS hole to 7-1/4-in. (18.4 cm) using a special piloted diamond bit.
7. If reaming operations are successful and hole stability adequate, an attempt will be made to log the 7-1/4-in. (18.4 cm) hole with three conventional logging tool runs. These runs will consist of (a) resistivity/density/gamma suite, (b) velocity/gamma suite, and (c) FMS or borehole televiewer (BHTV) tool.
8. Once all efforts at reaming and/or logging have been complete, the second stage of the drill-in BHA will be deployed and backed off inside the primary drill-in BHA.

Ancillary engineering goals will be attempted, if available time exists beyond completion of those tasks described above. The primary objective will be to deploy a second HRB to evaluate the 7-1/4-in. (18.4 cm) diamond core barrel (DCB) system. This will not only allow direct core comparison between the DCS and DCB systems but also allow evaluation of how the two systems compare from an operational standpoint.

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[1] Storms, M.A., Batiza, R., et al., 1993. *Proc. ODP, Init. Repts.*, 142: College Station, TX (Ocean Drilling Program).

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The following report provides information pertaining to the design modification and/or refinement of subsea hardware developed to supplement the DCS. Included where pertinent are both equipment performance evaluations and suggested improvements for future DCS and conventional ODP operations that require bare-rock spudding.

COMPONENTS OF THE SUBSEA HARDWARE

Much the original engineering design for supporting the DCS subsea system was developed for Leg 132. Refinements in equipment and techniques lead to the development of some new components for Leg 142 which complement existing hardware. The primary hardware that makes up the seafloor components includes the following items:

1. Mini–hard-rock guide base,
2. Modified casing hanger with gimbal and counterweight,
3. Landing seat, and
4. Modified free-fall funnel cone.

A schematic representation of how the guide base fits into the scheme of the DCS program is illustrated in Figure 1.

The mini-riser system components are considered secondary since they complement the seafloor hardware. These components allow the transition from normal operations to that of the DCS. Hardware categorized in this group include:

1. Centralization sub,
2. Slip joint,
3. Bit-guide deployment sub,
4. Center-bit retrieval sub,
5. Tensioning tool,
6. Tapered stress joint, and
7. Break-away safety joint.

Figure 2 illustrates how these secondary components fit together and the available options.

The third area categorized under subsea hardware is that of the nested drill-in bottom-hole assembly. This hardware provides the mechanism to lock the gimbaled casing hanger and give the DCS tubing a stable and centralized hole from which to begin coring. The same design philosophy that was adopted for the development of the original drill-in bottom-hole assembly was carried forth in the design of the nested drill-in system. This drill-in method allows a single string to be drilled in, backed off, and left as a reentry casing through which to initiate DCS coring. However, in the case of the nested system, two casing strings (10-3/4 and 6-3/4 in. [27.3 and 17.2 cm]) can be deployed in this manner, with future enhancement planned for a third string. Additional discussion of the options available are presented in the "Back-off Hardware" section (this chapter).

RISER ANALYTICAL WORK

A comprehensive review of the seafloor template and mini-riser system was performed by Starmark Offshore. This study was initiated in order to reviewed the previous lateral and axial dynamics work performed in 1990 by Bryant and Associates, as some changes in the template and other subsea components had been made. In addition to examining the existing riser analysis, alternative relationships between the riser and seafloor template were also presented. The report by Starmark is broken down into four general areas of study:

1. Axial dynamics (hanging riser with HRB),
2. Lateral dynamics (connected riser),
3. Bottom mechanical fuse, and
4. HRB template weight.

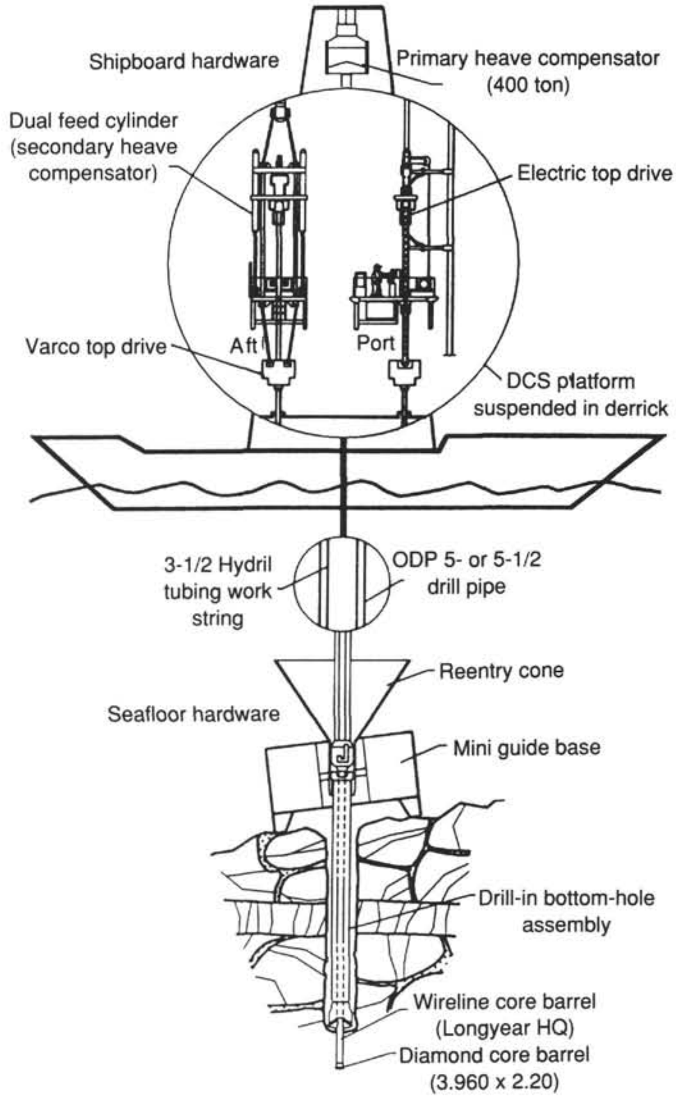


Figure 1. Diamond coring system, Phase II (4500 m). Dimensions in inches.

The majority of the work performed by Starmark was in agreement with the previous analysis conducted by Bryant and Associates, even though a different computer model was used. However, several conclusions were presented that did not support the previous work. These conclusions, along with other pertinent details as they relate to the riser analysis, are reported herein. Detailed discussion of the analysis and the analytical models used will not be presented in this report. Table 1 presents the physical properties of the riser and tubing string and Table 2 provides the riser-length make-up vs. water depth. The general riser arrangement is illustrated in Figure 3.

Axial Dynamics

The axial dynamic analysis simulates the response of the hanging drill string while it supports the HRB template. Figure 4 presents an idealized representation of the axial displacement of the guide base due to varying sea states. General agreement exists between the earlier work and the new study performed by Starmark when using similar input parameters, even though the earlier study's model is much more simplistic and the environmental data not as current. The main inconsistencies in the results are primarily due to differences in input data (i.e., wave and vessel motion data). Starmark used the computer pro-

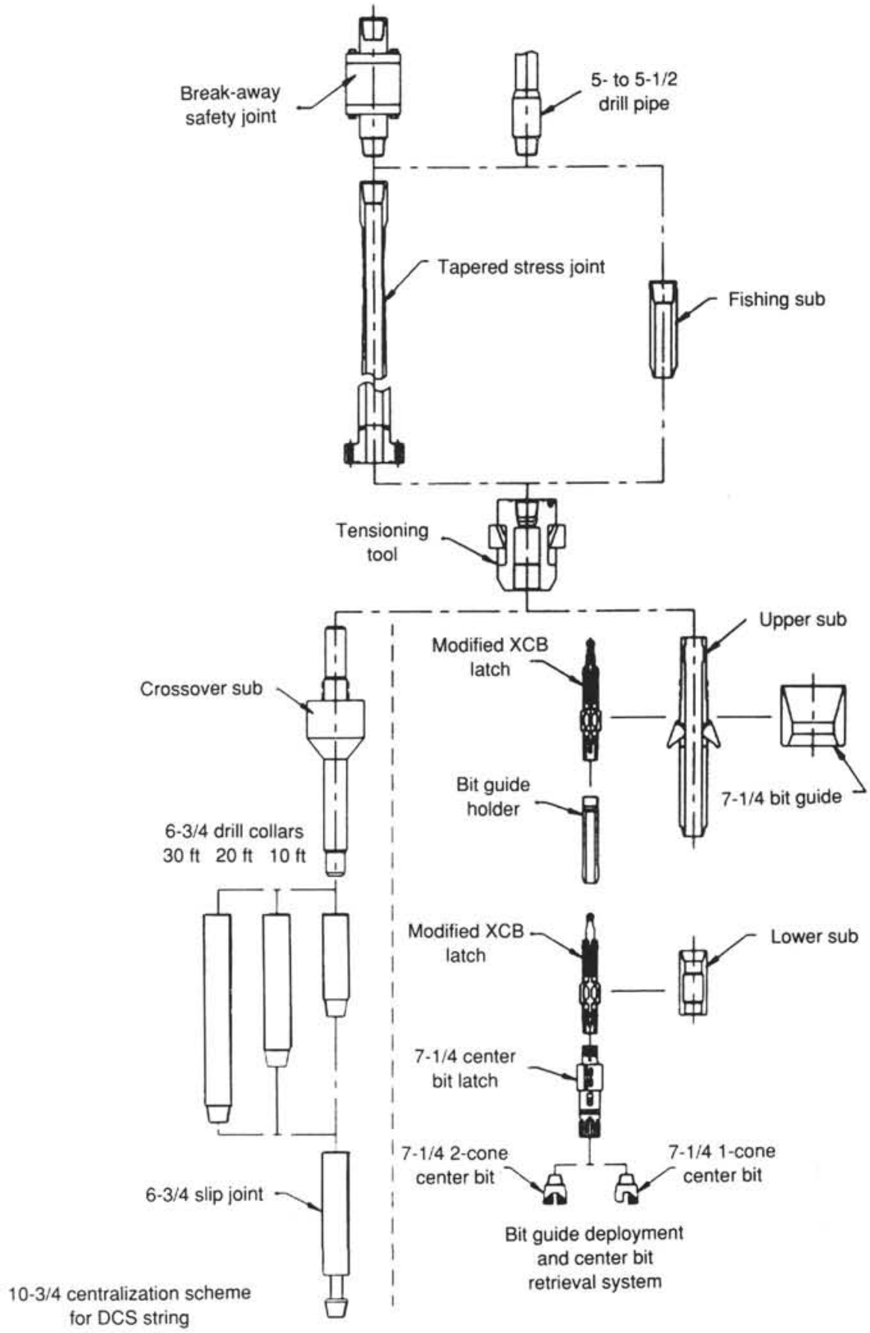


Figure 2. Seafloor hardware options for DCS coring set-up. Dimensions in inches unless otherwise noted.

gram STARIS to perform calculations for both regular and irregular (random) waves, along with the vessel-motion heave response amplitude operators (RAOs) used by Bryant. Even though the regular wave results were similar, results from the irregular wave results were significantly different. These results are presented in Table 3.

Another comparison is presented between the axial work performed by ODP and Starmark. In this study ODP used the Pierson-Moskowitz wave spectrum, whereas the STARIS program was input with a Bretschneider wave spectrum. For the wind-driven sea states, the Pierson-Moskowitz wave spectrum defines fully developed seas, whereas the Bretschneider wave spectrum is more applicable for developing seas. Starmark suggests that the Bretschneider wave spectrum is more realistic for actual ocean conditions. Comparison between the results of these two studies indicates the bottom displace-

Table 1. Riser pipe properties.

	General	Stress joint	5-in.	5.5-in.	3.5-in.
Input quantities:					
Pipe type (in.)			Drill pipe	Drill pipe	Tubing
Outer diameter (in.)			5.0000	5.5000	3.4000
Wall thickness (in.)			0.3620	0.5000	0.2540
Taper top OD (in.)		5.0000			
Taper top ID (in.)		4.2760			
Taper bottom OD (in.)		8.1250			
Taper bottom ID (in.)		4.2760			
Taper length (ft)		33.0000			
Taper weight (air) (lbf)		3,057			
Nominal weight (lb/ft)			19.5000	N/A	N/A
Plain end actual (lbf/ft)			17.9300	26.7000	N/A
Adjusted weight (lb/ft) (including pipe and tool joint)			22.1000	31.9000	9.3000
Wet weight factor		0.8700	0.8700	0.8700	0.8700
Joint length		33.0000	31.7000	31.7000	31.7000
Tool joint OD (in.)			7.0000	7.7500	3.8680
Tool joint length (in.)			18.0000	18.0000	N/A
Elastic module (psi)		30,000,000	30,000,000	30,000,000	30,000,000
Ultimate strength (psi)		N/A	150,000	150,000	N/A
Yield strength (psi)		12,000	140,000	14,000	130,000
Tensile strength (lbf)		N/A	738,443	1,099,557	N/A
Riser top above MWL (ft)	25.0000				
Riser bottom above seafloor (ft)	10.0000				
Derived quantities:					
OD (in.)			5.0000	5.5000	3.5000
ID (in.)			4.2760	4.5000	2.9920
d/f ratio			13.8122	11.0000	13.7795
Cross-section area (in.^{2})		5.2746	5.2748	7.8540	2.5902
Displaced area (in.^{2})			19.6350	23.7583	9.6211
Inside area (in.^{2})		14.3604	14.3604	15.9043	7.0309
Yield × area (lbf)		632.952	738.443	1,099,557	336,725
Weight (air) (lbf/ft)		92.6364	22.1000	31.9000	9.3000
Weight (sub) (lbf/ft)		80.5936	19.2270	27.7530	8.0910
Joint weight (air) lbf		3057	701	1,011	295
Joint weight (sub) lbf		2660	609	880	258

Notes: OD = outer diameter; ID = inner diameter, lbf = pounds force; d/f = diameter/force.

ment range is generally quite good in the lower range of the significant wave height (H_{sig}) but falls off somewhat as H_{sig} increases. Both studies exhibit the same general trend in behavior but differ somewhat in the actual values. These differences are attributed to:

1. Vessel heave RAOs,
2. Wave spectrum, and
3. Computer modeling (i.e., mesh size, damping, linearization methods for nonlinear terms).

Comparisons between the ODP work and work performed with the STARIS program is presented in Figures 5 and 6.

The two comparison studies mentioned above (Bryant and ODP) were performed primarily to calibrate the STARIS computer program and to see if similar results could be duplicated. Starmark presents a more detailed analysis with input data more suitable and realistic for current operational purposes. Both irregular swell and wind-driven cases are presented for water depths ranging from 4920 to 14760 ft (1500 to 4500 m). Wave height and period relationships used are presented in Figure 7A–B. The general results from this series of analysis can be summarized as follows:

1. No compression occurs in the hanging riser string with the HRB for swells and wind-driven waves for riser lengths from 4920 to 14,760 ft (1500 to 4500 m).
2. Stress does not exceed the 0.67 yield stress criterion.
3. Operational sea conditions for the hanging riser are limited by fatigue in the pipe threads.
4. Swell conditions are more severe than wind-driven waves.
5. Additional calculations are warranted in order to determine short riser response (i.e., less than 4920 ft [1500 m]).

Significant wave height vs. top tension for irregular wind-driven waves for the four water depths investigated are presented in Figures 8 through 11. Similar illustrations but for irregular swells are shown in Figures 12 through 15. The axial displacement curves vs. significant wave height for both irregular wind-driven seas and irregular swells are presented in Figures 16 through 23. An explana-

Table 2. Riser length vs. water depth.

Water depth (m)	1500	2500	3500	4500
Water depth (ft)	4921	8202	11483	14764
Total riser length (ft)	4936	8217	11498	14779
Length of 5.5-in. pipe (ft)	190	888	2790	4692
Length of 5.0-in. pipe (ft)	4713	7296	86675	10054
Length of stress joint (ft)	33	33	33	33
Length of 3.5-in. pipe (ft)	4936	8217	11498	14779

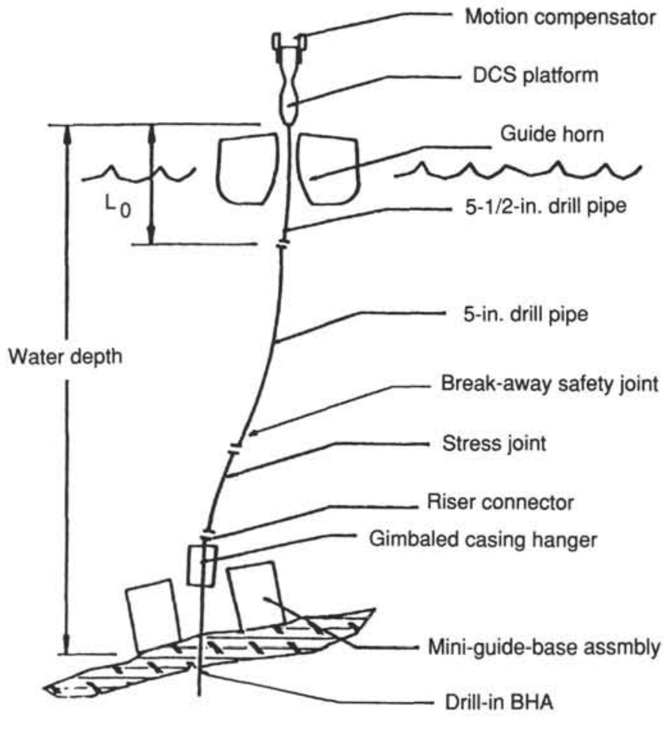


Figure 3. General riser arrangement. L_0 = length of 5-1/2-in. drill pipe.

tion of terms used on the above figures is presented in the captions to Figures 8 and 16.

Lateral Dynamics

An independent lateral motion analysis using the STARIS program, along with a comparison study to Bryant's work, was also performed. The results of the work performed by Bryant and Starmark generally agree quite well. Stress and angle at the top of the tapered stress joints are almost identical with stresses at the bottom of the tapered joint, varying only within a few kips per square inch. The most notable differences are in the effective riser tension at the top of the taper joint. The spread in values between the effective top taper tension between the two programs increases with water depth with the STARIS results generally being lower. The STARIS input ignored the 3-1/2-in. (88.9 mm) tubing string because it is not clear how to model it in order to simulate actual conditions. Table 4 presents the results of the two different approaches.

The previous work performed by Bryant using the DERP computer program also ignored the effects of lateral dynamics in all but one case run. The majority of the work was conducted using only a static domain analysis without considering any wave effects on the riser or vessel motion. Although the results of the two studies generally show good agreement between the static domain and frequency domain calculation methods, STARIS's sophisticated tapered element

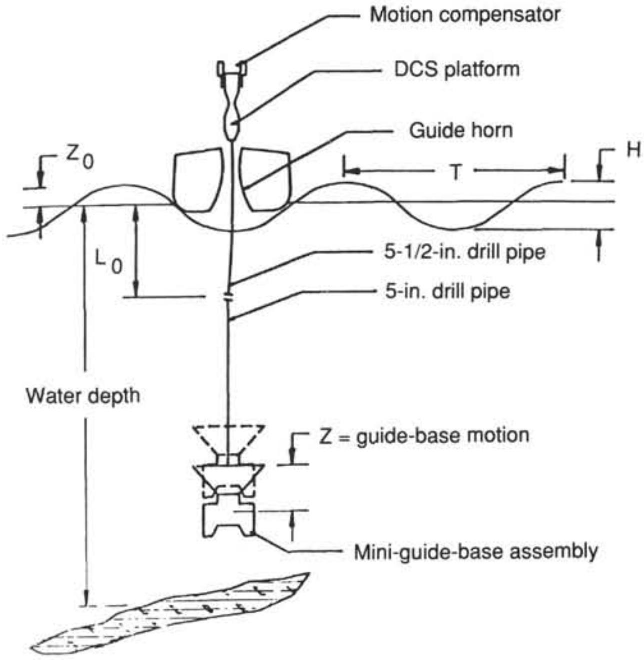


Figure 4. Axial motion analysis. L_0 = length of 5-1/2-in. drill pipe; Z_0 = one-half wave height; T = period, seconds; H = wave height.

formulation is believed to be more realistic near the top taper than DERP's calculations using a finite difference method to calculate the sensitive bending stresses.

In order to provide a useful and convenient means to present the massive amount of data for all four water depths, varying top tensions, surface currents, and mean vessel offsets between –10% to +10% of water depth in increments of 1%, a tension-offset envelope graph was developed with the STARIS computer program. The tension-offset envelope is a contour plot of the various criteria that show the limits of the riser operation. These envelopes are presented in Figures 24 through 27, with an explanation of terms presented in the caption to Figure 24. A summary of STARMARK's lateral dynamics (connected riser) conclusions is as follows:

1. For the environmental conditions considered, there is an acceptable operating envelope of tension and mean vessel offset for the water depths from 4920 to 14,760 ft (1500 to 4500 m).

2. The 0.67 yield stress criteria is not a limiting factor for any of the cases studied.

3. The 350 ft (107 m) minimum bending radius criteria limits the mean vessel offset.

4. The riser behavior becomes extremely sensitive and the offset envelope virtually closes when the bottom pipe-wall tension (approximately the riser string weight) is near zero.

5. Bending moment–induced fatigue-life damage for the connected riser does not appear to be a problem.

6. Excessive tensioner system variation for prolonged periods induce significant fatigue-life damage in the riser pipe threads and the tension safety joint shear pins.

7. Unplanned tensioner stroke-out instantly increases riser tension to the point that the tension safety joint parts and the riser disconnects.

8. Dynamic calculations are more appropriate than static domain calculations in revealing realistic riser behavior and dynamic sensitivity.

9. The tension safety joint limit of 100 kips (45.6 T) limits the maximum value of the applied tension.

10. The envelope of mean vessel offset as a percentage of water depth tends to decrease as the water depth increases.

Table 3. Comparison of axial dynamics calculations.

Wave period (s)	Wave height (ft)	Top displacement range (ft)	Bottom displacement range (ft)	Bottom/top ratio	Top tension (max kips)	Top tension (min kips)	Top tension range (kips)
Bryant's calculations							
4	3	0.40	0.56	1.40	491	482	9
6	5	1.80	14.84	8.24	587	386	201
8	11	4.00	8.24	2.06	524	448	76
10	15	8.60	13.04	1.52	528	445	83
Staris regular wave							
4	3	0.40	0.69	1.73	468	456	11
6	5	1.80	9.25	5.14	523	401	122
8	11	4.00	7.84	1.96	496	428	68
10	15	8.60	12.67	1.47	500	424	76
Staris irregular wave							
4	3	0.48	5.35	11.15	503	422	81
6	5	1.41	11.65	8.26	546	378	169
8	11	4.19	18.61	4.44	590	334	257
10	15	6.98	19.97	2.86	589	462	127

Note: Water depth = 14,760 ft (4500 m).

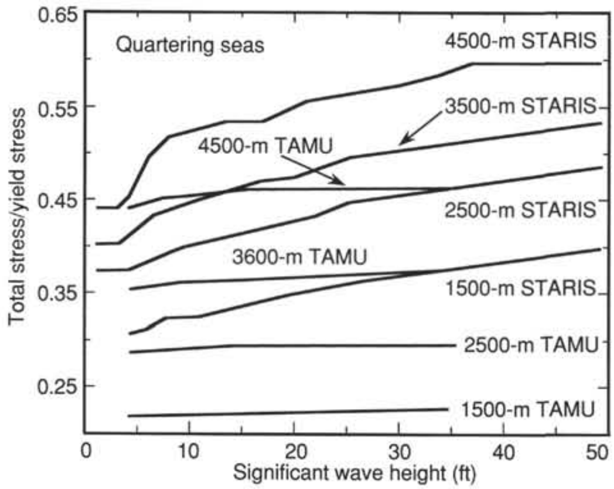


Figure 5. Comparison of axial dynamics stresses using STARIS and TAMU calculations.

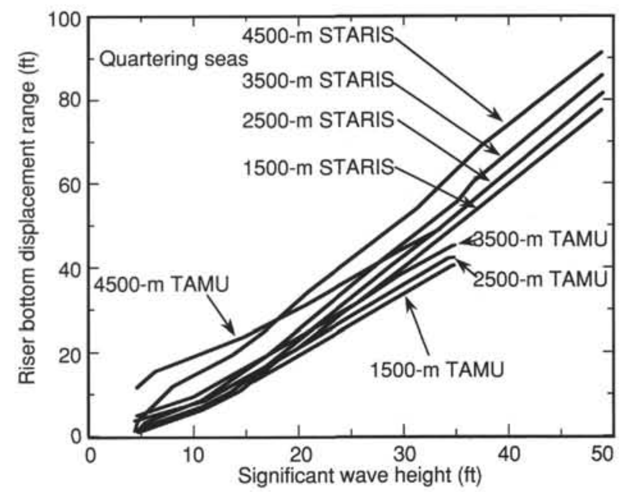


Figure 6. Comparison of riser base displacement using STARIS and TAMU calculations.

The tension envelope is used in the selection of the optimum riser tension and mean vessel offset range for proper drilling operation and to allow riser parting during emergency vessel drive-off. An example of using the tension envelope procedure to determine the optimum riser tension is presented in Appendix A.

Bottom Mechanical Fuse

A mechanical fuse designed to disconnect the riser in the event of an unplanned vessel drive-off was included as part of the work performed by Starmark. The original bolted connection concept used 16 1-1/4-in. (31.75 mm) shear bolts around the flange of the tapered stress joint as the mechanical fuse. These shear bolts where designed to fail when excessive riser-bending moment occurred during a vessel drive-off. It was observed during Leg 132 that torque recommendations for installation of the shear bolts exceeded the elastic limit and resulted in some of the bolts loosening around the flange after deployment. A thread lock compound was used to eliminate the problem but it was felt that this was only a quick-fix solution and that a more detailed study should be initiated after Leg 132.

Starmark references several sources that concur in the difficulty of designing a bolted connection that is both operationally reliable and fails in a consistently predictable manner. The occurrence of shear-bolt loosening is somewhat predictable in that the bolts experience plastic elongation, resulting in loosening of the connection. In an effort to improve confidence in the mechanical fuse concept, a detailed design investigation of the bolted connection's behavior and mechanics was made. The study recommended that because of the extreme complexity of the bolted connection and the critical operational restraints placed on the shear bolts, the shear-bolt concept should be abandoned. This was primarily due to uncertainties in the following areas:

1. Internal and external hydrostatic pressure effects,
2. Riser tension and bending-moment load path,
3. Bolted preload accuracy and variability,
4. Load path inside the connection and flange separation,
5. The amount of available tensioner stroke to generate the required bending moment during vessel drive-off, and
6. The ductility of the bolts themselves.

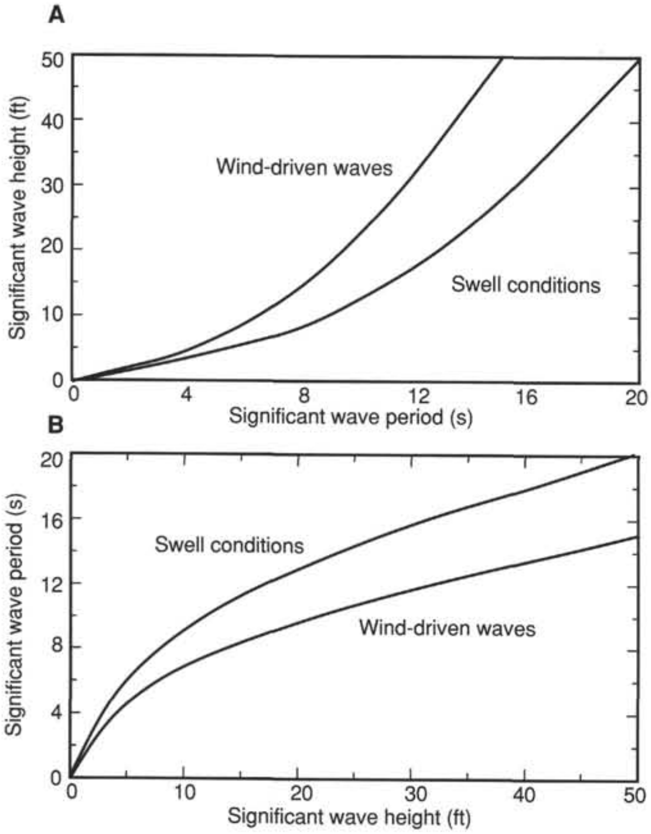


Figure 7. **A–B.** Wave height and period relationship.

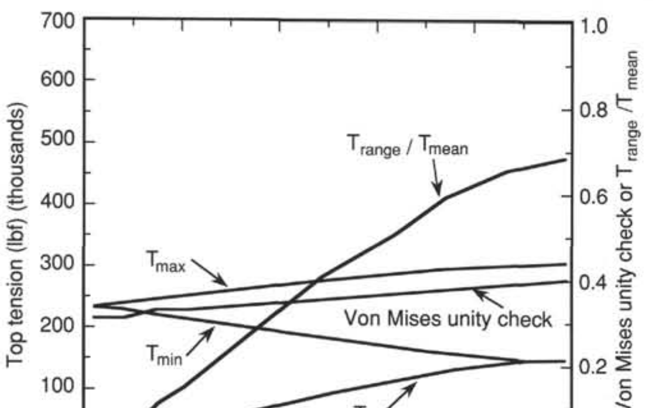


Figure 8. Tension response of hanging riser in irregular wind waves (1500-m water depth). For Figures 8–15, explanation of terms is as follows: T_{mean} is the mean top tension for hanging riser. This is the static hanging riser weight. T_{max} is the maximum top riser tension due to vessel motion and riser response (i.e., $T_{max} \geq T_{mean}$). T_{min} is the minimum top riser tension due to vessel motion and riser response (i.e., $T_{min} \leq T_{mean}$). If $T_{min} < 0$, then riser *buckling* or compression occurs. T_{range} is the difference between T_{max} and T_{min} (i.e., $T_{range} = T_{max} - T_{min}$). T_{range}/T_{mean} is the ratio that indicates the relative dynamic sensitivity of the riser tension response. VMUC is the maximum Von Mises unity check stress in the riser, usually at the top of the riser, due to static hanging weight and riser axial dynamics. If VMUC $\geq$ 1.0, then the riser material has yielded.

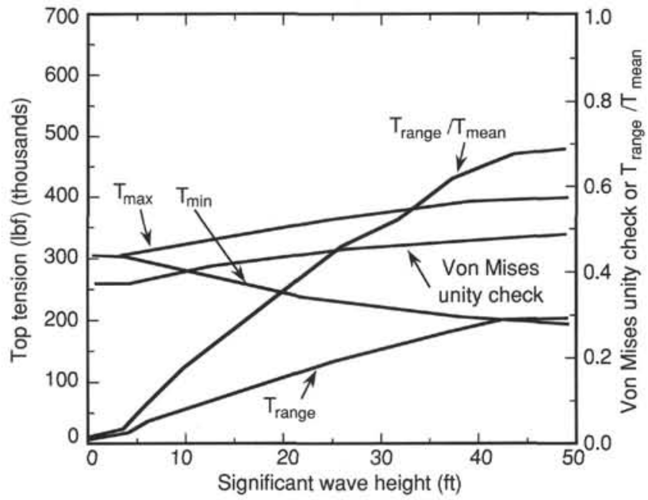


Figure 9. Tension response of hanging riser in irregular wind waves (2500-m water depth). See Figure 8 caption for explanation of terms.

In order to arrive at another mechanical fuse, two other concepts were investigated. These include a reduced spool-section piece and a tension safety joint. The spool-section piece was envisioned as a short length of tubular steel with a necked-down cross-section region. It would probably be located immediately below the tapered stress joint. The weakened section would act as a focus for bending-moment-induced buckling. Due to statistical variation, the exact value of the bending moment that causes local buckling is subject to considerable uncertainty. After the spool would buckle, the ductility of the steel would still require a large tensile force to totally part the spool. Even after buckling had occurred by bending moment, the failure mechanism changes to one governed only by tension. Thus, a large tension component would be required to actually part the buckled reduced spool-section piece. As a further obstacle the DCS tubing inside the riser would most likely prevent the initial spool buckling in the first place. Therefore, the reduced spool-section piece concept was also abandoned.

A third concept using a break-away tension safety joint developed by Hydrotech was evaluated. This method utilized the same concept of a pressure-balance safety joint designed for pipelines so that they separate at predetermined externally applied loads, independent of pipeline pressure. The safety joint uses pretested metal shear pins to link the inner sleeve to the body. Its proven design and reliability was the deciding factor in Starmark's recommendation that the shear bolts be replaced. Figure 28 presents a schematic of the break-away safety joint.

Recommendations and comments on the bottom mechanical fuse are as follows:

1. It is very difficult to design a bolted connection that is both operationally reliable and that will fail in a consistently predictable manner.
2. Some of the assumptions and methods used in the original design of the bolted connection are questionable.
3. The original bolted connection is inadequate and unreliable for normal operation and parting.
4. The tension safety joint mechanical fuse has a very reliable parting tension.
5. The tension joint operation and maintenance must be carefully controlled to avoid unplanned riser disconnection or damage to the safety joint.
6. Tensioner variation can cause significant fatigue damage in the connected riser's pipe threads and tension safety joint shear pins.

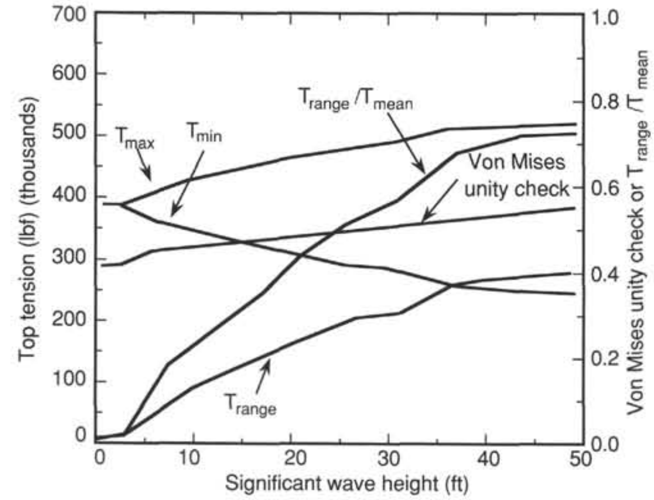


Figure 10. Tension response of hanging riser in irregular wind waves (3500-m water depth). See Figure 8 caption for explanation of terms.

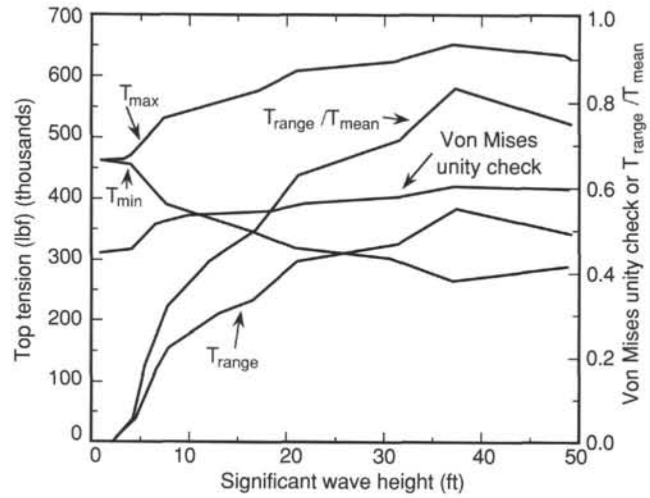


Figure 11. Tension response of hanging riser in irregular wind waves (4500-m water depth). See Figure 8 caption for explanation of terms.

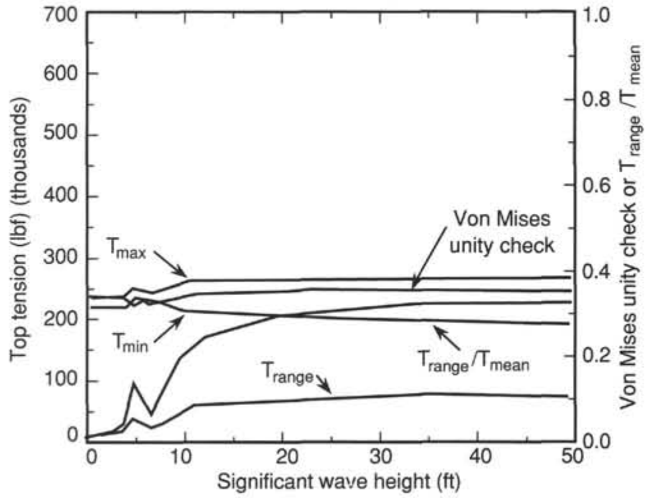


Figure 12. Tension response of hanging riser in irregular swells (1500-m water depth). See Figure 8 caption for explanation of terms.

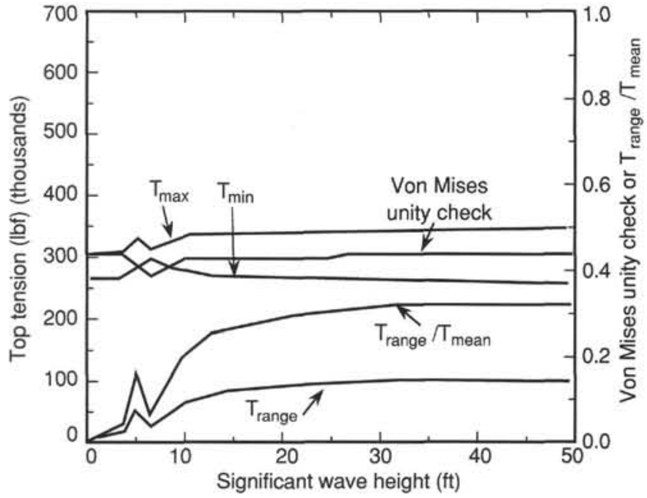


Figure 13. Tension response of hanging riser in irregular swells (2500-m water depth). See Figure 8 caption for explanation of terms.

It should be noted that it is extremely important to keep tensioner variations to a minimum. If the tensioner variation becomes too great, riser operation may be unsafe and prone to a sudden and catastrophic failure due to fatigue. Therefore, the shear pins in the safety joint should be replaced after every riser deployment as a safeguard against fatigue failure. Figure 29 presents an illustration of fatigue life vs. stress range for base metals, pipe threads, and welds. An example calculation using this chart is presented in Appendix B.

The safety joint should be positioned immediately above the tapered stress joint. This location will ensure that the safety joint is predominantly loaded with tension and would not have to rely on any bending moment to separate. Laboratory tests on a modified version of the safety joint designed for the DCS seafloor system confirmed its reliability and acceptability for replacement of the original shear-bolt concept. Further discussion of the tension safety joint and the laboratory tests performed is presented in a later section of this report.

Template Weight

One of the primary reasons for having an independent consultant review the methodology for ballasting the guide base was to determine if less ballast could be used to optimize the design. Since this optimization is so tightly related to the riser design, Starmark was asked to include a review of the HRB weight in the report on seafloor systems. The reduction in ballast not only plays a significant role in assembly time of the guide base offshore but also in finding suitable material for ballast and the expense in obtaining ballast in some remote areas.

The weight of the guide base is controlled by the following three factors. These include:

1. Resisting the upward pull of the riser by its dead weight without lifting off,
2. Resisting riser operating bending moment and tension without lifting, sliding, or overturning, and
3. Resisting the riser parting, bending moment, and tension during drillship drive-off without lifting, sliding, or overturning.

The previous work calculated the HRB weight by multiplying the riser overpull by a factor of safety. Because the HRB used on Leg 132 was a prototype version, a very conservative approach was taken. The new approach for load on the template is determined by the selected riser tension overpull with the upper limit determined

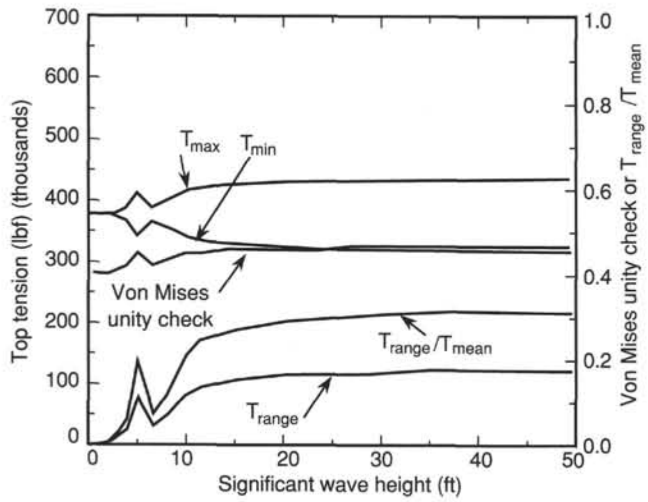


Figure 14. Tension response of hanging riser in irregular swells (3500-m water depth). See Figure 8 caption for explanation of terms.

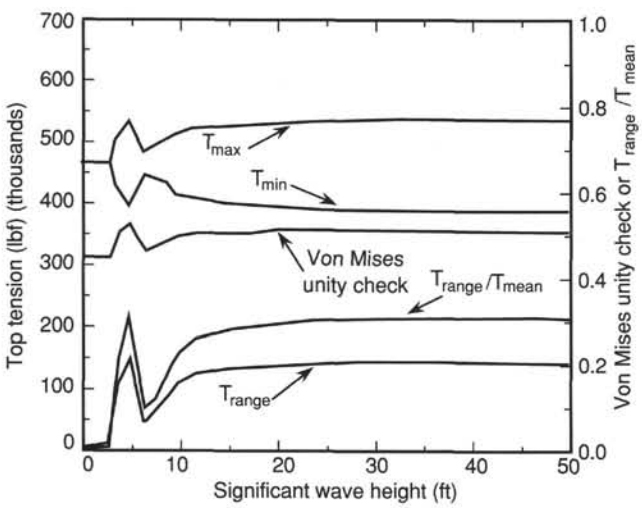


Figure 15. Tension response of hanging riser in irregular swells (4500-m water depth). See Figure 8 caption for explanation of terms.

by the safety joint parting tension (100 kips/45.6 T). To reflect the accuracy with weight determination, recent codes and standards place a small safety factor on dead weight. Since the riser overpull at the seafloor can be tightly controlled with the heave compensator, using a safety factor of 2 or 3 is not appropriate for setting the HRB weight. Instead of placing a safety factor multiplier on the weight of the whole guide base, it is recommended that an actual weight tolerance or margin of 25 to 50 kips (11.3 to 22.7 T) be added to the HRB weight as a factor of safety.

Recommendations for determining the minimum HRB weight are as follows:

1. Determine the safety joint parting tension, typically set at 100 kips (45.4 T).
2. Decide the actual HRB safety margin weight desired on the HRB weight, typically 25 to 50 kips (11.3 to 22.7 T).
3. Calculate the recommended minimum submerged HRB weight by adding the safety joint parting tension and the HRB safety margin weight.

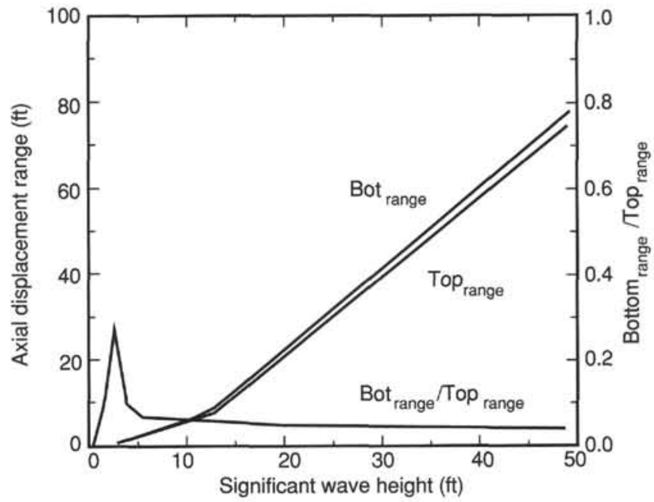


Figure 16. Displacement response of hanging riser in irregular wind waves (1500-m water depth). For Figures 16–23, explanation of terms is as follows: Top_{range} is the range of top riser axial motion due to wave excitation of the vessel. For a riser on the slips, Top_{range} is the range of vessel heave. Bot_{range} is the range of bottom riser axial motion due to top excitation of the riser and vessel. Bot_{range}/Top_{range} is the ratio that indicates magnification (i.e., dynamic sensitivity or RAO) of the bottom displacement range to the top riser displacement excitation.

It should be noted that the above calculations are not dependent on water depth or riser top tension. This is primarily due to the introduction of the controlled parting tension of the tension safety joint. Submerged HRB weight vs. water depth is presented in Figure 30. Conclusions and recommendations made for the submerged weight of the HRB are given as follows:

1. The previous safety factor multiplier method of determining appropriate HRB template weight is too conservative,
2. The simplified method to determine the HRB weight should be used, and
3. The HRB minimum submerged weight of 125 kips (56.7 T) is independent of water depth and smaller than previous required HRB weights.

MINI–HARD-ROCK GUIDE-BASE SYSTEM

The mini–hard-rock guide base is primarily used to provide reentry capabilities and lateral support for the bottom-hole assembly (BHA), along with bit confinement, in order to spud a hole on bare rock. Much of what was learned from previous legs (106, 109, 118, and 132) has been incorporated into the second generation of the mini-HRB. Probably the most notable change is the overall shape of the base and the reduction in reentry cone size. The problems experienced during Leg 132 with uprighting the reentry cone have all been corrected. The syntactic foam panels used for uprighting the large reentry cone have all been replaced with a mechanical counterweight system. Another noticeable improvement that contributes to the stability of the base is the introduction of three legs instead of four. There is a distance of 3 ft (0.92 m) beneath the base and the tip of the legs. This distance enables the base to be landed on fairly rough terrain with pillows and boulders approaching the length of the legs. A general schematic of the mini–hard-rock guide base is presented in Figure 31. The following sections provide additional detail pertaining to the design improvements for the new base.

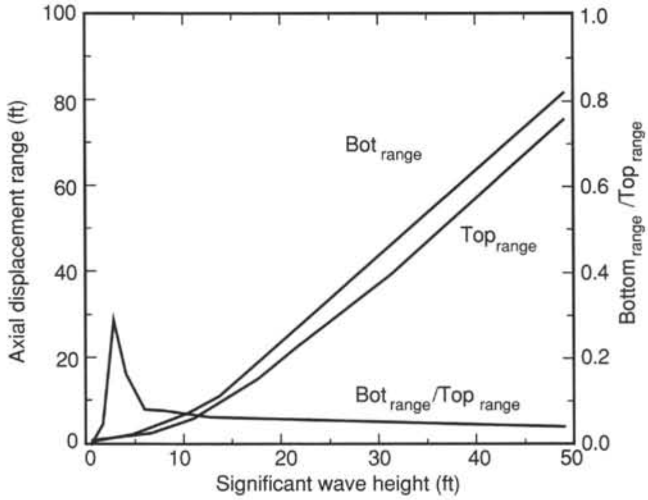


Figure 17. Displacement response of hanging riser in irregular wind waves (2500-m water depth). See Figure 16 caption for explanation of terms.

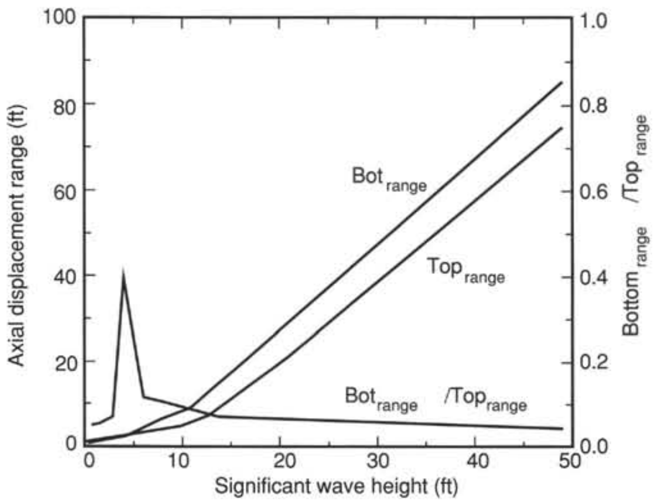


Figure 18. Displacement response of hanging riser in irregular wind waves (3500-m water depth). See Figure 16 caption for explanation of terms.

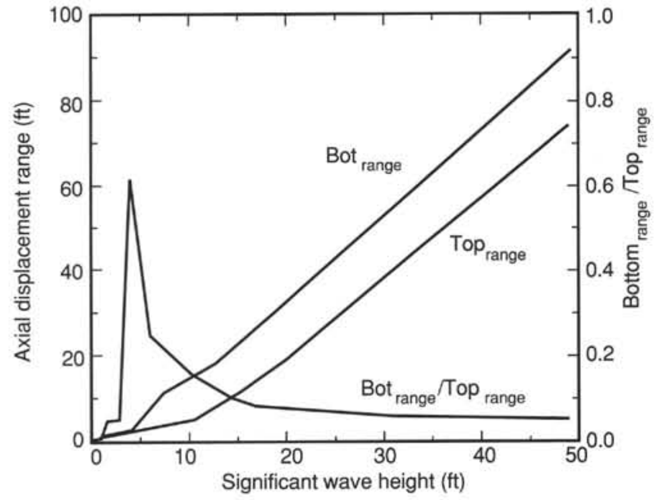


Figure 19. Displacement response of hanging riser in irregular wind waves (4500-m water depth). See Figure 16 caption for explanation of terms.

Design

Base

As mentioned above, the single most noticeable difference between the earlier prototype base and the new mini-HRB is the shape. The previous mini-HRB deployed on Leg 132 was composed of four independent rectangle sections that when bolted together formed a 10-ft^2 box. The new guide base is composed of two sections which form a six-sided base. This configuration can be run with as few as three legs or as many as six. The open space that exists in the center of the two base sections when they are fully assembled has been increased to accommodate installation around the upper guide horn. This feature allows the HRB to be assembled in port or while under way instead of having to wait until the ship is on location in order to remove the upper guide horn to begin the HRB assembly procedure.

It was noted during Leg 132 that the four sections were cumbersome to handle and caused some assembly problems in matching up bolt holes on the uneven moonpool doors. Larger bolts (1-1/4 in./31.75 mm) were used on this base without back-up nuts having been pre-installed inside the opposite mating section. This allowed the holes to be used with alignment pins to bring the sections together. Also, without the nuts pre-installed inside the mating base section, there is less chance of fouling a bolt due to corrosion of the nut. The volume of the new base is approximately 460 ft^3 (13 m^3). The total dry weight of the four-sided base, including all components, was 30,715 lb (13.9 T), whereas the new six-sided base and components weighed 41,400 lb (18.8 T). Figure 32 illustrates how the base might be situated on a typical seafloor slope. Included in this figure are additional facts pertaining to factors of safety and a breakdown of the individual components' weights.

Another improvement to the base was the strengthening of the legs and leg guides. One of the problems experienced on the previous leg was that one of the legs pulled out of its track while being lowered into running position. This has been corrected with wider guide tracks in order to prohibit to legs from fouling. The same leg configuration was again used but the length was increased to 3 ft (0.92 m) from 2.5 ft (0.76 m). Eight bolts were used to hold the legs in place once they were dropped into running position. The legs were increased in size to 1-1/2-in.-thick (38.1 mm) plate to strengthen and better distribute the load of the guide base.

The previous mini-HRB allowed a maximum seafloor slopes up to 20°. The new base can be deployed up to a 25° seafloor slope. This angle can be slightly increased (up to 30°) if the base is positioned so that the casing hanger tilts into the corner instead of the side of the base section. The additional tilt was accomplished partly by raising the gimbal attachment point and secondly by increasing span distance between the box sections. Even though 25° to 30° of tilt is available, the base should always be positioned on as flat an area as possible to lessen the possibility of the base shifting or beginning a nonvertical hole.

Gimbal

The gimbal used during Leg 132 proved satisfactory for uprighting the cone and provided 360° of rotational freedom. A small modification was made to in order to move the pivot point up higher so that less righting counterweight would be required. This essentially consisted of positioning both sets of trunnions in the same plane by redesigning the inner box section of the gimbal. The gimbal attachment point on the base section was also moved higher, along with lengthening the trunnion brackets. The gimbal was fabricated from structural tubing with gusset plates added for rigidity. The pivot pins attached to either side were made from 4-in. (10.2 cm) bar stock. Two 2-in. (5.08 cm) stud bolts were used to connect the pivot blocks together.

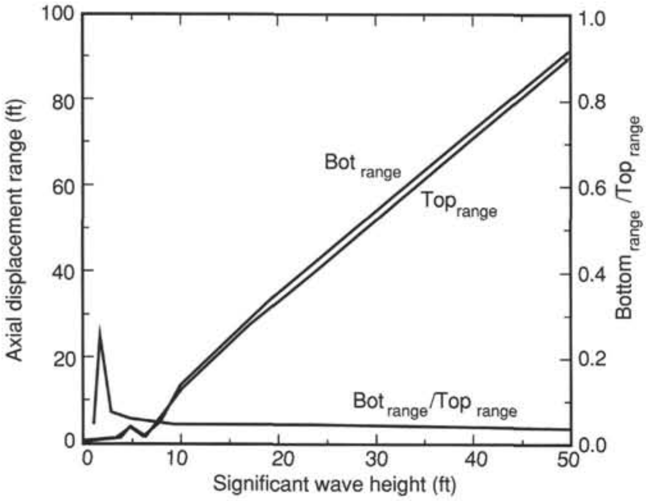


Figure 20. Displacement response of hanging riser in irregular swells (1500-m water depth). See Figure 16 caption for explanation of terms.

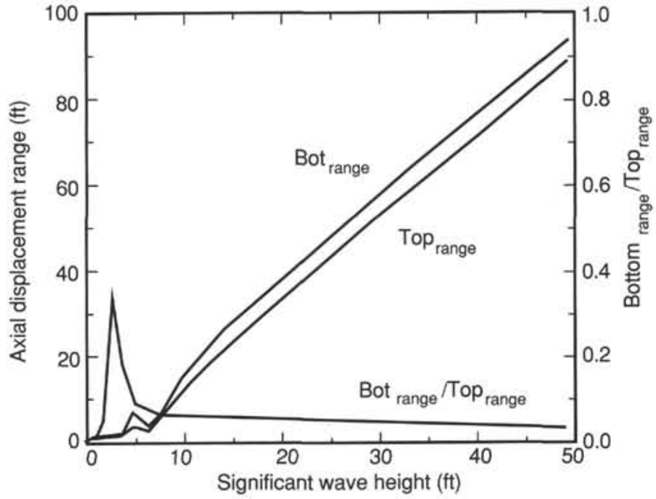


Figure 22. Displacement response of hanging riser in irregular swells (3500-m water depth). See Figure 16 caption for explanation of terms.

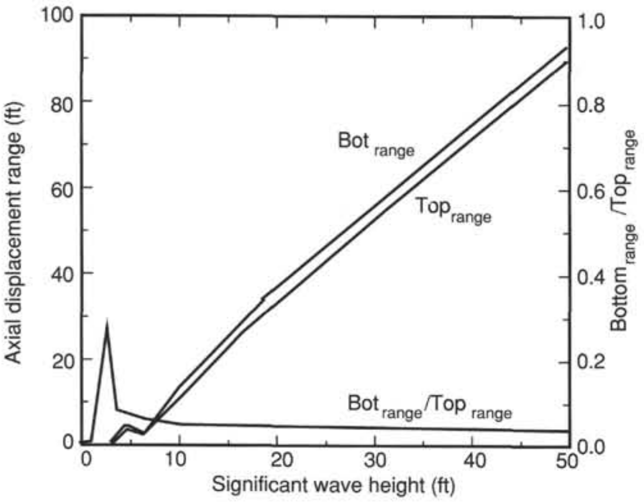


Figure 21. Displacement response of hanging riser in irregular swells (2500-m water depth). See Figure 16 caption for explanation of terms.

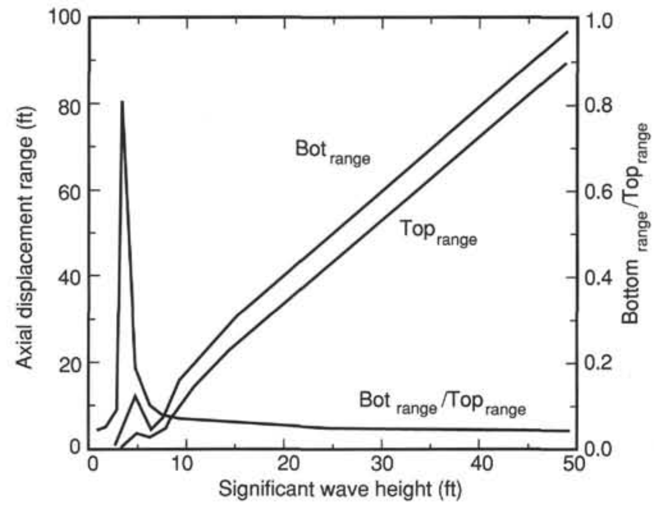


Figure 23. Displacement response of hanging riser in irregular swells (4500-m water depth). See Figure 16 caption for explanation of terms.

Casing Hanger/Counterweights

Modification to the casing hanger included moving the trunnions higher and eliminating the lower threads for running a 16-in. (40.6 cm) casing, along with the lower grooving details for snapping into a 20-in. (50.8 cm) casing hanger. These latter two modifications were done strictly as a cost-saving measure. The most significant modification to the casing hanger itself was the addition of the counterweight. The counterweight added 5350 lb (2427 kg) to the weight of the casing hanger. The primary function of the counterweight was to provide a righting moment to keep the casing hanger vertical regardless of seafloor slope. The amount of counterweight added to the lower portion of the hanger provided a safety factor of 2.5 for uprighting. The counterweight was made from stacked 3- and 4-in. (76.2 and 101.6 mm) plate cut in a circular pattern. Eight layers of plate were used in diameters ranging from 34 to 38 in. (0.86 to 0.97 m).

Slots for the two diametrically opposed 1/4-in. (6.35 mm) keys were milled through the entire lower portion of the hanger. Keys were then added into the slots and welded secure. Previous attempts at using keys which were welded only onto the inner diameter of the casing hanger resulted in the landing seat shearing the keys as the back-off nut came in contact. Figure 33 presents a schematic of the casing hanger, along with the optional landing seat bushings for the smaller sized bottom-hole assemblies.

Landing Seat

Three modifications were made to the landing seats remaining from Leg 132. The first change consisted of enlarging the inner diameter (ID) so that a 12.5-in. (31.75 cm) bit could pass. This entailed opening up the ID of the landing seat to 12-9/16 in. (31.91 cm). The internal C-ring groove was also moved lower within the landing seat in order to allow the back-off nut to completely unscrew before the C-ring would engage. The third change consisted of altering the internal taper where the back-off nut landed. Some sticking between the surfaces of the nut and the landing seat during Leg 132 caused the landing seat to shear out of the casing hanger and be removed as the back-off sub was withdrawn. This problem was corrected by increasing the taper angle from 7° to 10°. Laboratory tests conducted while

Table 4. Comparison of lateral dynamics calculations.

Case ID	Water depth (ft)	Depth (m)	Top tension (kips)	Current profile	Vessel offset (% WD)	Wave height (ft)	Computer program	Effective tension top taper (kips)	Angle top taper (degrees)	Stress top 5-1/2-in. string (ksi)	Stress top 5-in. string (ksi)	Stress top taper (ksi)	Stress bottom taper (ksi)	Minimum radius of curvature (ft)
1	4920	1500	130	I	3.0	0.0	DERP	37.8	3.20	16.6	23.7	21.0	19.1	442
							STARIS	31.2	3.07	16.6	23.8	19.0	16.8	479
2	4920	1500	180	I	5.0	0.0	DERP	87.8	4.30	22.9	31.2	26.8	35.0	328
							STARIS	81.1	4.07	22.9	33.2	24.2	31.8	365
3	8194	2498	205	I	3.0	0.0	DERP	45.1	4.02	26.1	32.8	23.8	26.1	395
							STARIS	35.3	3.89	26.1	34.1	22.1	22.8	405
4	8194	2498	250	I	5.0	0.0	DERP	90.1	5.27	31.8	41.3	28.7	43.6	266
							STARIS	80.3	4.94	31.8	42.6	26.0	38.9	302
5	11472	3497	300	I	3.0	0.0	DERP	65.3	4.32	38.2	40.9	24.2	33.2	370
							STARIS	49.0	4.25	38.2	41.8	23.0	29.0	430
6	11472	3497	330	I	5.0	0.0	DERP	95.3	6.10	42.0	46.5	30.2	52.1	225
							STARIS	79.0	5.79	42.0	47.5	27.8	45.6	259
7	14752	4496	375	I	3.0	0.0	DERP	67.9	4.97	47.7	45.7	25.5	39.0	318
							STARIS	42.8	5.17	47.8	45.8	26.4	33.6	341
8	14752	4496	415	I	5.0	0.0	DERP	107.9	6.66	52.8	53.2	31.5	60.8	194
							STARIS	82.8	6.47	52.8	53.4	29.4	52.5	227
9	4920	1500	130	I	3.0	19.0	DERP	37.8	3.43	16.6	23.9	22.0	20.3	424
							STARIS	31.2	3.13	16.6	24.4	19.3	17.1	469

Notes: WD = water depth; ksi = kips per square inch.

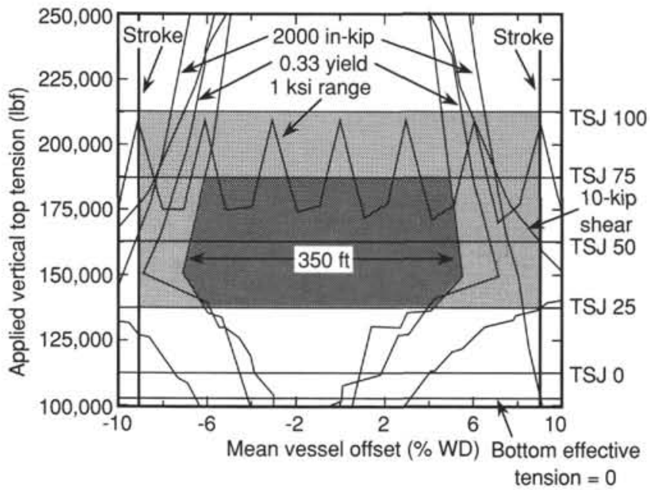


Figure 24. Connected riser tension-offset envelope (1500-m water depth [WD]). For Figures 24–27, H_{sig} = 10 ft and current = 3 kt. Explanation of terms is as follows: 0.33 and 0.67 yields are the Von Mises unity check values, respectively, for 0.33 and 0.67 yield stress (for information only). 1-ksi and 2-ksi ranges are the bending stress ranges, respectively, of 1 ksi and 2 ksi (for information only). Stroke is the approximate limit for ±20 ft stroke on compensator. 2000 in-kip is the bottom bending moment in tapered stress joint at bolted connection (for information only). 10-kip shear is the bottom shear force in tapered stress joint (for information only). TSJ 0 is 0-kip tension in the tension safety joint, which also roughly corresponds to the *zero pipewall tension* at the bottom of the riser. At low values of tension there is a danger of *buckling* the riser. TSJ 25 is 25-kip tension in the tension safety joint, the *lower* limit for normal operations. TSJ 50 is 50-kip tension, the *normal* desired operation point, TSJ 75 is the *upper* limit for normal operations, and TSJ 100 is the *parting* tension. Bottom effective tension = 0 means that the effective tension at the bottom of the riser is zero. There is a danger of buckling the riser. 350 ft is the minimum riser bending radius.

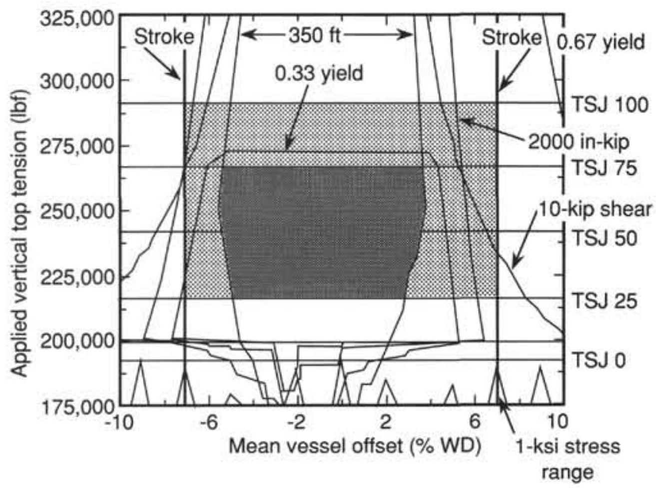


Figure 25. Connected riser tension-offset envelope (2500-m water depth). See Figure 24 caption for explanation of terms.

attempting to make the nut stick to the landing seat confirmed that the increased taper angle was sufficient to eliminate the problem. The primary landing seat is illustrated in Figure 34. Two smaller versions are available that bolt into the primary landing seat should either the 9-7/8 or 6-3/4-in. (25.1 or 17.2 cm) drill-in BHA be substituted as the initial stage. Illustrations of these two landing-seat bushings are presented in Figure 35A–B.

Reentry Cone

The HRB deployed on Leg 132 used a standard reentry cone funnel for reentry purposes. The funnel was approximately 13 ft (4 m) in diameter and almost 7 ft (2.13 m) tall. It was assembled from eight identical steel panels. The assembly process was time-consuming and had to be done as one of the last steps due to the amount of space it took up on the *JOIDES Resolution* when assembled. The new mini-HRB eliminated the large cone and adapted a smaller version resembling the free-fall funnel cone. This cone is assembled from two identical sections. It has a diameter of 8 ft (2.43 m) at the uppermost end with an overall height of 3.25 ft (0.99 m). The cone is assembled with eight bolts on each side. No provisions were made for reentry with the Mesotech since any additional weight such as sonar panels would adversely affect the righting moment. A schematic of the reentry funnel along with the assembled base is presented in Figure 31.

Ballast Requirements

Ballast for the mini-HRB was sourced locally in the Chilean port city of Valparaiso. Sections of steel pipe were loaded with used rebar and welded on both ends with cap plates. A short handle was welded

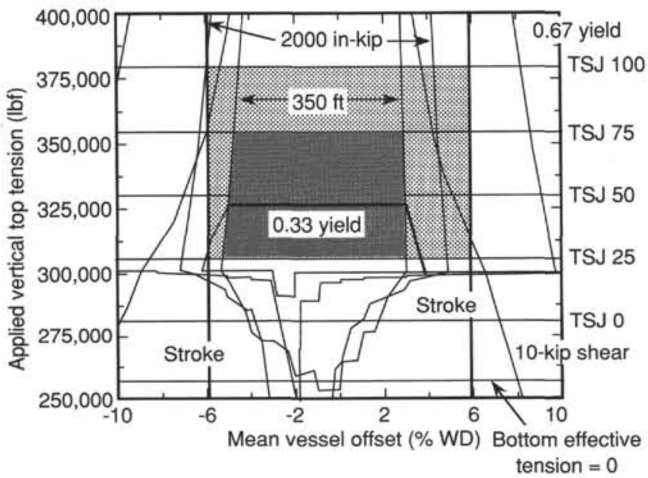


Figure 26. Connected riser tension-offset envelope (3500-m water depth). See Figure 24 caption for explanation of terms.

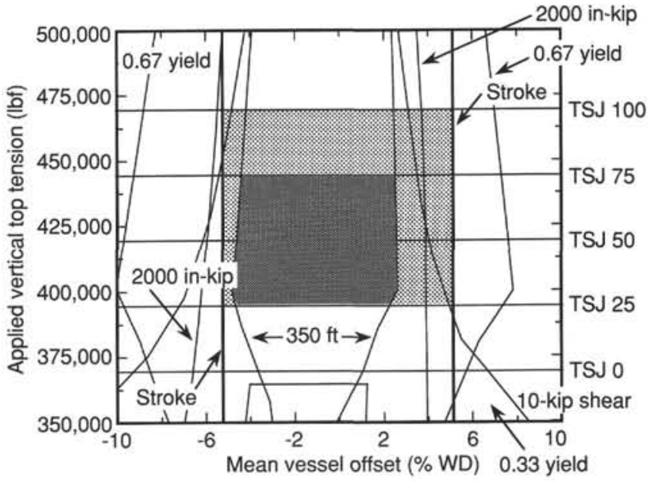


Figure 27. Connected riser tension-offset envelope (4500-m water depth). See Figure 24 caption for explanation of terms.

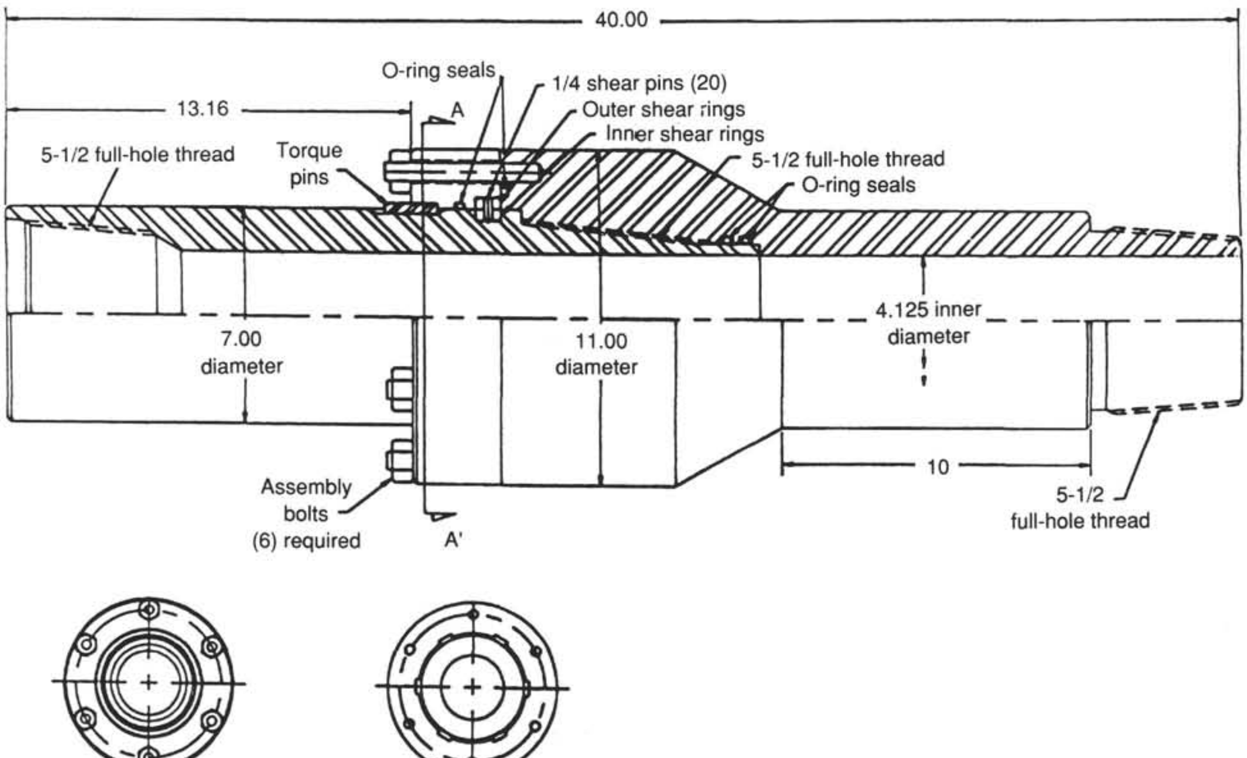


Figure 28. Breakaway safety joint. Dimensions in inches.

on one end of the pipe section for ease of loading into the guide base. Typical pipe dimensions were 8.62 in. (21.9 cm) outer diameter (OD) × 8.22 in. (20.9 cm) ID × 5.58 ft (1.7 m) long. Weights ranged between 770–800 lb (350 to 363 kg) for each pipe. A total of 108 pipes could be loaded into each of the two halves of the HRB base. Total dry-weight contribution of the steel ballast accounted for approximately 88,160 lb (40 T). The voids remaining between the steel ballast pipe were to be filled with barite or cement, which would add another 29,500 lb (13.4 T) before submergence. Figure 36 presents an idealized representation of how the ballast pipes were loaded. Additional information pertaining to both dry and submerged weights are included in the figure.

Assembly and Deployment

Assembly

The mini-HRB is composed of three major components: the base, reentry funnel, and casing hanger. The new, lower profile reentry

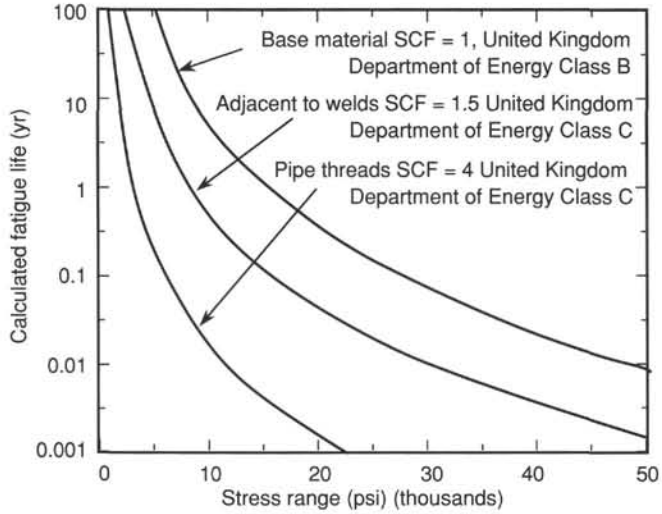


Figure 29. Calculated fatigue life, continuous 7.5-s wave cycle.

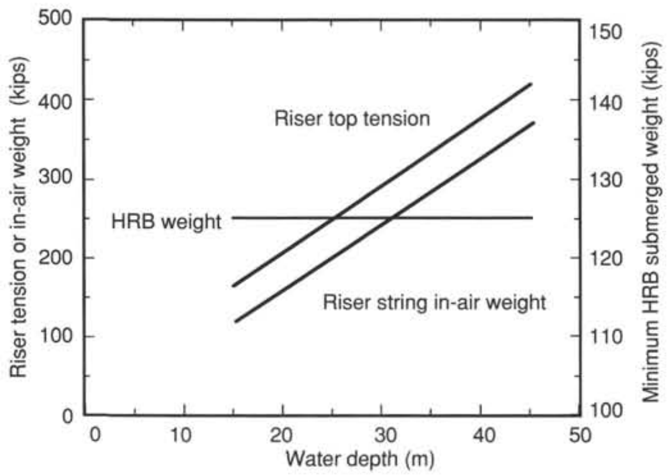


Figure 30. Riser tension vs. water depth. TSJ tension = 50; HRB margin = 25; tension variance = 3%.

funnel allows the mini-HRB to be completely assembled before arrival on location if sea conditions are favorable for removable of the upper guide horn. The moonpool doors were originally designed to handle blowout-preventer (BOP) stacks in excess of 400,000 lb (181.5 T). Therefore, the 150,000-lb (68 T) weight in air of the ballasted guide base was not an issue.

Prior to departing from dock, the base sections were placed in the moonpool area on two I-beams that spanned the moonpool doors. The I-beams were used to level the base halves so bolt holes would align properly. Several days before arriving on location the upper guide horn was removed and the base halves skidded across the I-beams and brought together for bolting securely. The hanger was installed in a single lift since the counterweights, landing seat, and gimbal were pre-assembled onto the hanger. An illustrated assembly procedure is outlined in Figure 37. The actual assembly scenario performed during Leg 142 varied slightly from the illustrative example. The same general steps were required but were performed in a different sequence. The actual order of events for assembling the mini-HRB on Leg 142 is outlined below:

1. Remove upper guide horn,
2. Assemble base halves on moonpool doors,
3. Ballast base section (Fig. 38),
4. Install casing hanger, bolt securely (Figs. 39 through 41),
5. Assemble funnel sections,
6. Attach funnel to casing hanger,
7. Weld funnel to hanger,
8. Add barite to base to fill voids (Fig. 42),
9. Add tilt beacon and bull's-eye,
10. Lift base with running tool,
11. Drop legs into position, bolt/weld securely,
12. Open moonpool doors while removing I-beams, and
13. Rotate 90° and lower to seafloor (Fig. 43).

The time necessary to assemble the base from start to finish required 31.5 hr. The new base design proved easier to assemble and was completed in about 2 hr vs. 18 hr for the same procedure with the four-section prototype mini-HRB version. This time savings was primarily due to problems associated with base-section alignment caused by unevenness of the moonpool doors. There were no real problems reported with the six-sided base alignment or bolt holes not matching up during the assembly procedure. A few of the leg bolts were difficult to get started. Only two bolts on a single leg were not successfully assembled. To prevent the leg bolts from taking all the load in the event of a hard impact on the seafloor, steel blocks were welded above the top of each leg. Since weather conditions were favorable during the transit, no time was required once on site to complete the assembly process. This allowed more time to be devoted the drill-in BHA and DCS systems. Attachment of several additional pad eyes on the casing hanger and cone was noted by the crew as beneficial for future assembly. A complete breakdown of the assembly procedure is as follows:

Task description	Time (hr)
1. Base section assembly	2
2. Steel ballasting operations	6
3. Barite ballasting operations (see note 1)	7
4. Hanger installation (see note 2)	2
5. Cone assembly/installation	2.5
6. Weld out (see note 3)	6
7. Final preparation/tilt beacon attachment (see note 4)	6
Total	31.5

Notes:
1. Dry barite was added by individual buckets rather than blown in or mixed in a slurry.
2. Four hours were lost when the base needed to be raised 2 in. (50.8 mm) due to interference problems associated with the casing hanger and upper guide-shoe hub on the cameron clamp.
3. Welding was not required but was added as insurance against bolt failure.
4. Required fabrication/attachment of bull's-eye brackets.

The above time breakdown is also presented in Figure 44.

The ballasting operation required about 3 hr more to complete than the same operation on the prototype base. This was due to the ballast bars weighting approximately 800 lb (363 kg) each, which required more time and care while handling, especially since this task was performed while under way. A two-point pick-up routine was devised with the moonpool air tuggers so that the ballast bars could be accurately placed into their respective position inside the guide base. In order to achieve a denser packing between the steel bars in the base, barite was added in dry form instead of slurry. This added to the preparation time of the base since the only convenient means of performing this task was by adding the barite one bucket at a time.

A second HRB needed to be assembled and run to the seafloor near the end of Leg 142. This was required after the first borehole established for the DCS had to be abandoned. Several of the DCS core bits were destroyed and left in the bottom of the borehole

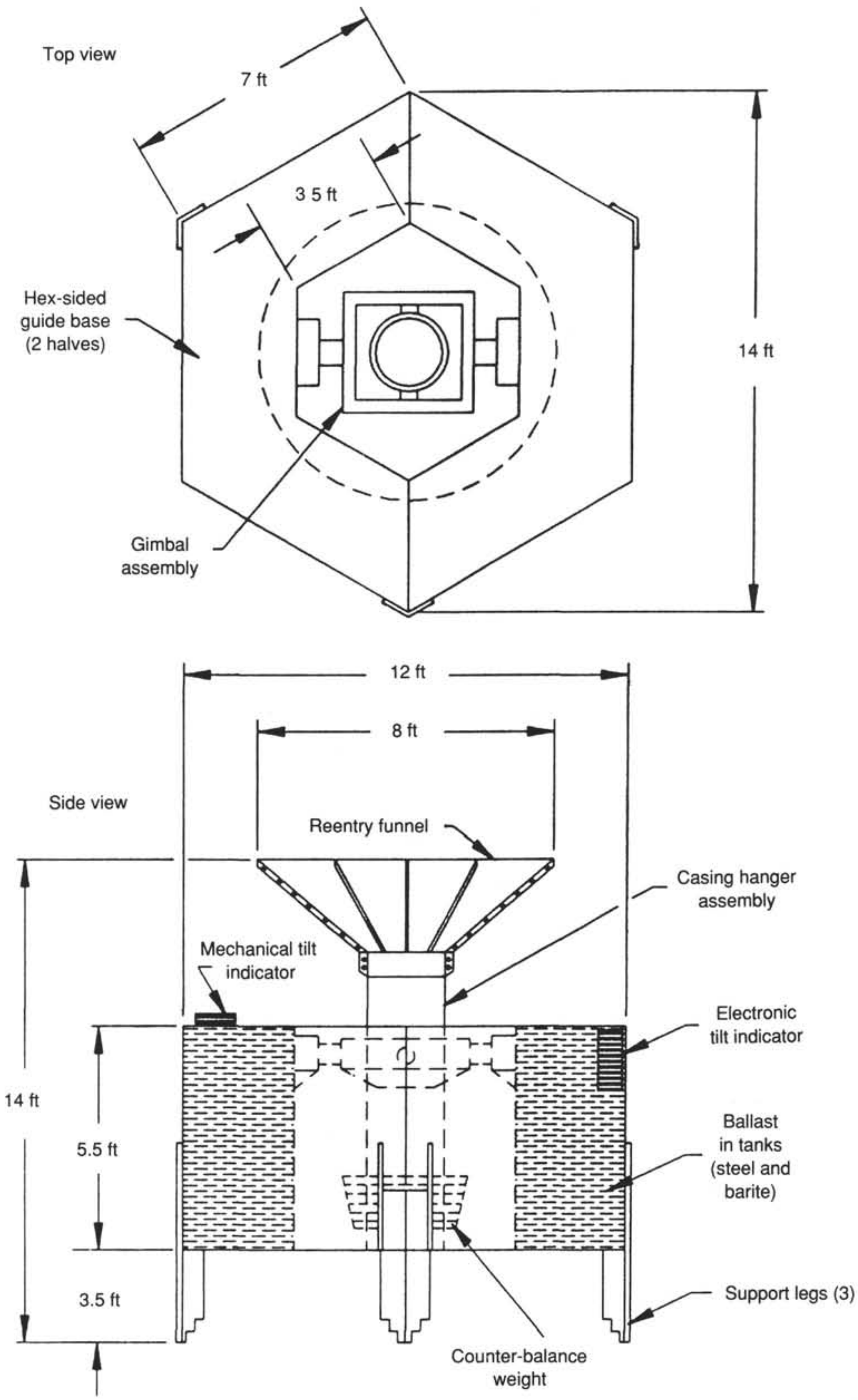


Figure 31. Mini–hard-rock guide-base hexagonal design scheme. Dimensions are approximate.

because the secondary heave compensator was unable to maintain constant contact between the bit and the bottom of the hole.

The time required to assemble the second base was 30.75 hr, which was only slightly less than the first time the base was put together even though the drill crew was already familiar with the operation. The time reflected in this second assembly is somewhat misleading because many of the activities could not be performed concurrently as before since the rig crew was still busy pulling drill pipe. Three additional hours of rigging were required in retrieving the components that were staged in various locations aboard the *Resolution.* The steel ballasting took slightly longer since the ballast bars had to be double-handled due to their storage location on the ship. However, this was somewhat offset by the barite ballasting operation since it was added in liquid form rather than loaded in dry bulk.

Only 8 days remained in the schedule on site before preparations to begin rigging down the DCS hardware had to begin. Therefore, this base was set up for deployment with the smaller second-stage DI-BHA as the primary stage. This required that the centralizing bushing for use with the 7-1/4-in. DI-BHA be welded into the landing seat. The time breakdown for assembly of the second HRB is presented below and shown in Figure 45.

Task description	Time (hr)
1. Base staging in moonpool area	5.5
2. Base section assembly	1.5
3. Steel ballasting operations	8
4. Barite ballasting operations (see note 1)	0.75
5. Hanger installation	2
6. Cone assembly/installation	1.5
7. Weld out (see note 2)	7.5
8. Final preparation (see note 3)	1.0
9. Rigging	3.0
Total	30.75

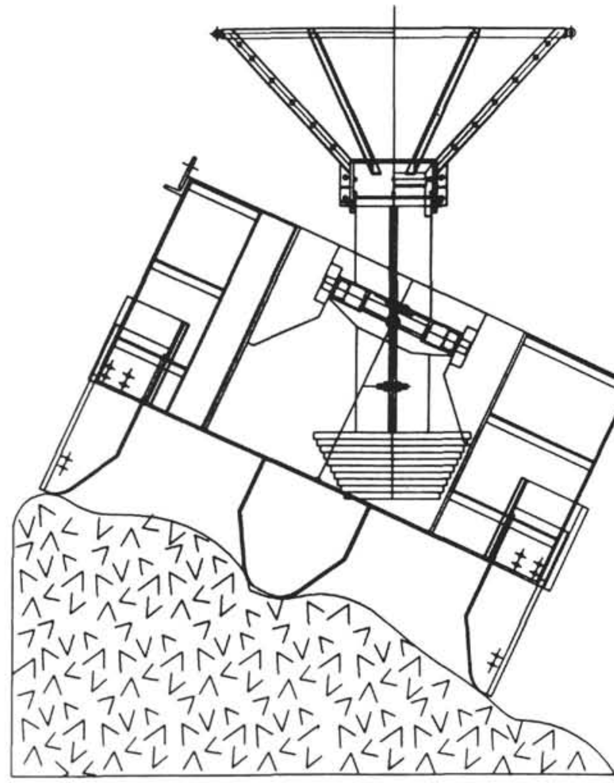
Notes:
1. Barite was placed in a slurry consisting of 12.5 lb/gal (1498 kg/cm) mud.
2. The HRB was designed to be assembled without welding but it was done as insurance against bolt failure. Much of the welding was performed concurrently with the ballasting operations.
3. Attachment of bull's-eye brackets.

Deployment

Hole 864A

Once the base was picked up and lowered into the moonpool, it was obvious that the passage through the lower guide horn would be extremely tight due to the protrusion of the locking fingers on either side of the guide horn. Total weight of the base dry was reported as 157,000 lb (71.2 T). This was within 2% of the calculated weight. In an attempt to reduce the possibility of becoming stuck, the base was brought back up above the moonpool doors and two of the six leg guide brackets were removed. Prior to running the base, the two angle brackets used to hold the base while resting on the moonpool doors were also removed in anticipation of the tight restraints through the lower guide horn. With the leg brackets removed and one side of the legs welded onto the base, lowering resumed through the moonpool. Even though surge in the moonpool was light, the base tried to rotate during descent causing interference with locking fingers. Two tugger lines were placed diagonally on the base to correct the rotation. With the base aligned parallel to the doors, passage was completed through the hull without further difficulty. The tugger lines looped through the base were cut loose and brought back to the surface once the base cleared the hull and before running the second stand of collars.

It appeared that the upper level of locking fingers provided the tightest restriction through the lower guide horn. This was observed by the base swinging from side to side with the ship's roll as it descended beneath the surface. Once past the upper level of fingers, there was ample clearance for the base to pass. The moonpool doors were closed as soon as the base cleared the hull to further restrain the movement of the base from the roll of the vessel. Descent to the seafloor with the base took approximately 7 hr. This included time to launch the vibration-isolated televiewer (VIT) frame so that real-time video could be observed of the base landing on the seafloor and to aid in the selection of the prime target area. Once submerged, the base weighed approximately 128,000 lb (58 T). Target range for seafloor weight was 125,000 lb (56.7 T). This provided 28,000 lb (12.7 T) ballast above the break-away tension safety joint limit of 100,000 lb (45.4 T).



Design requirements:

Base bolts 1-in. A372 (18 total)
Leg bolts 7/8-in. A372 (8 per leg)
Safety factor for uprighting movement: 2.5
Safety factor of base bolts vs. shear: 19:1
Maximum tilt (into side): 25° (into corner): 30°

Dry-base component weights:

Base sections (2):	26,500 lb
Gimbal:	1,075 lb
Casing hanger:	4,250 lb
Legs (3):	2,250 lb
Cone:	1,600 lb
Counterweight:	5,350 lb
Landing seat:	375 lb
Total:	41,400 lb

Figure 32. Mini-HRB specifications.

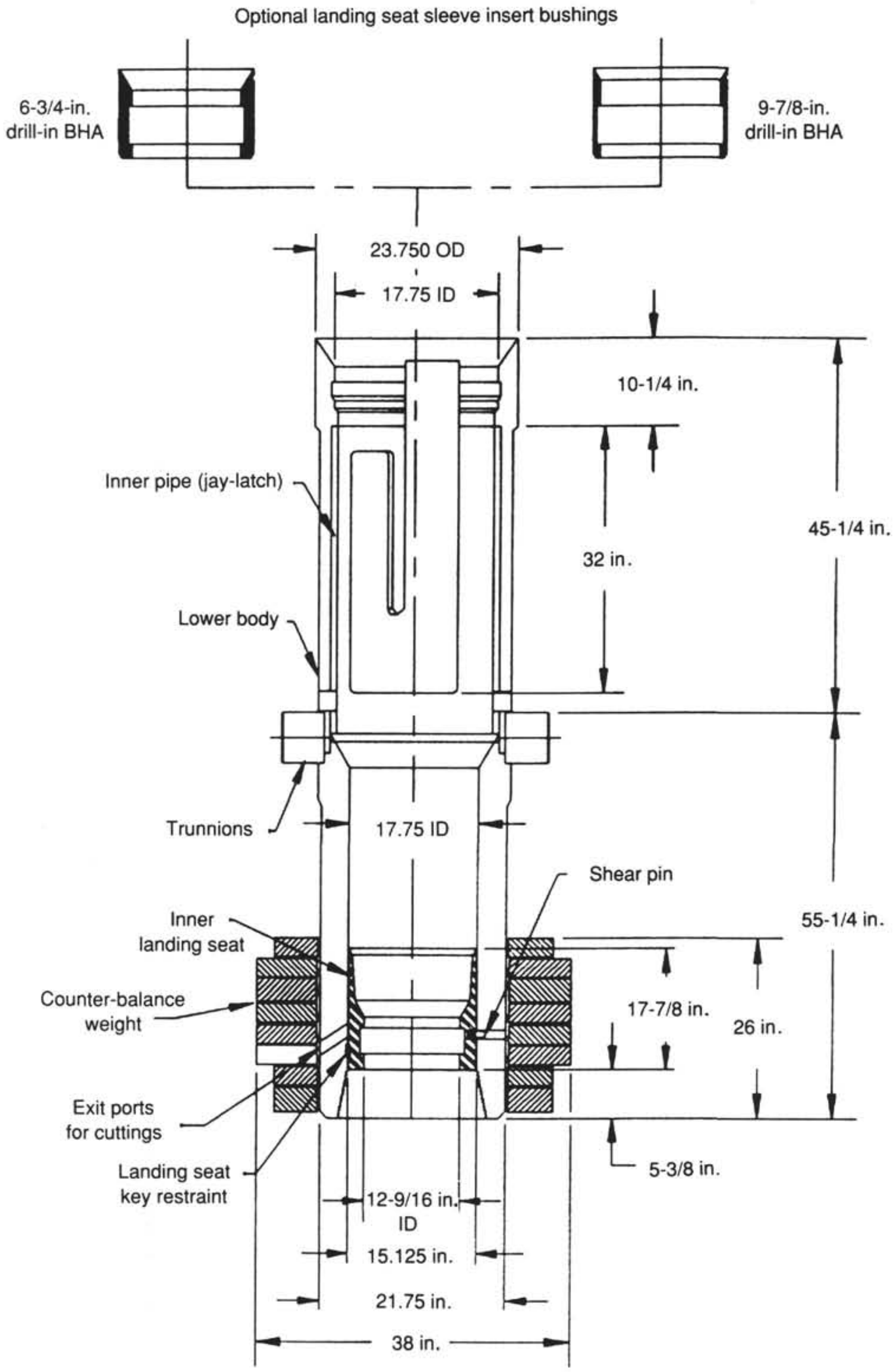


Figure 33. Mini-HRB modified casing hanger.

It was discovered after deployment that the base had not been rotated into the most advantageous position for deployment through the moonpool. The position in which the base was lowered through the moonpool was the worst possible scenario. The oversight was probably caused by the base not being assembled and ballasted as proposed in the original plan. The base was ballasted on the moonpool doors and never lowered into the moonpool and hung off onto the I-beams. Deviation from the original plan and the illusion of the narrowest portion of the base having to pass the widest section across the moonpool doors added to the confusion. Cross-sectional profiles of the two scenarios for deployment the mini-HRB are presented in Figure 46A–B.

After running the base to the seafloor, it was landed without difficulty despite sea states of 8-ft (2.5 m) swells. Upon unlatching from the base, a TV survey confirmed that the base was located just off the desired flow unit in the trough along the west wall of the axial

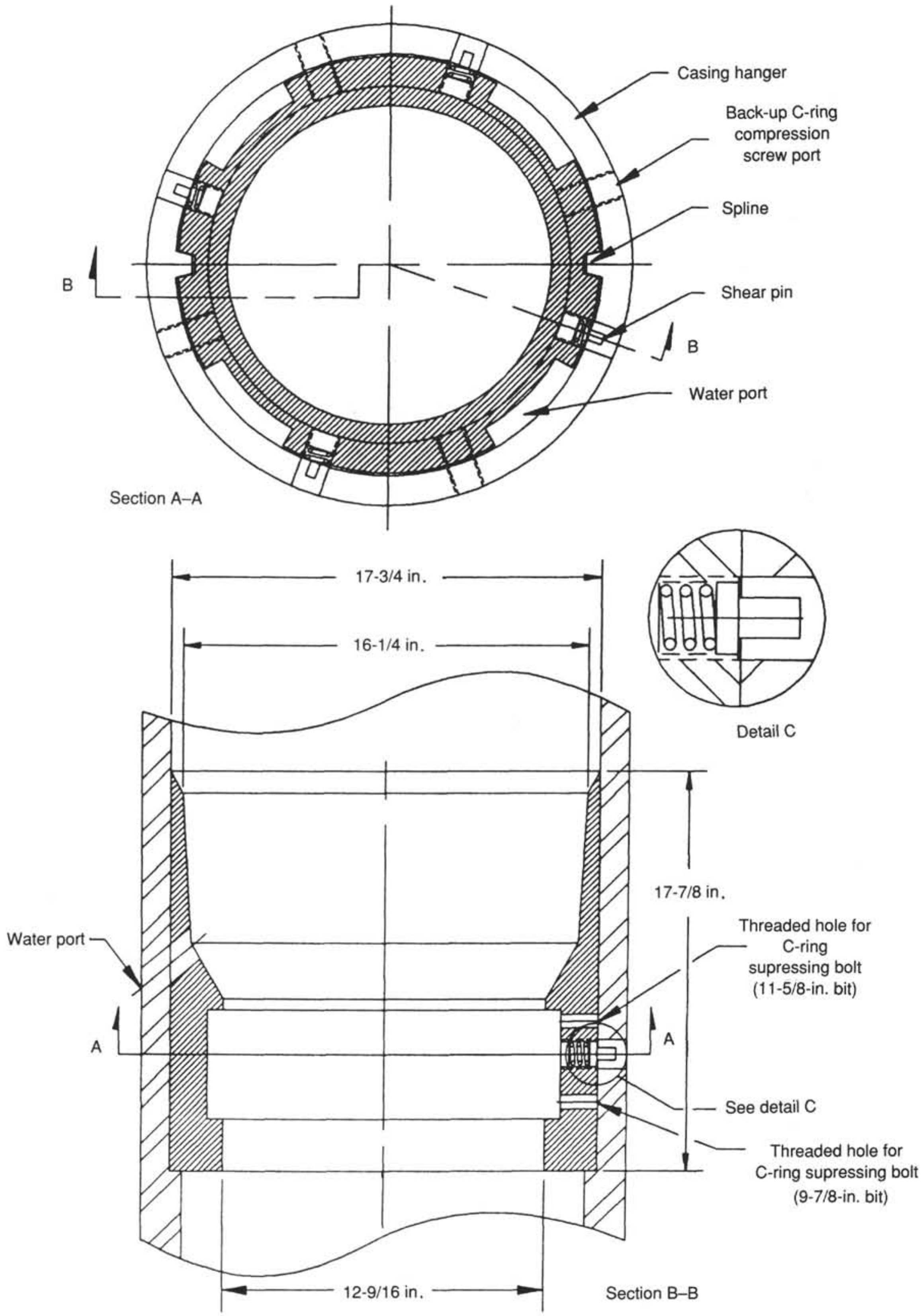


Figure 34. DCS landing seat for 12-1/2, 11-5/8, and 11-1/4-in. bits. Dimensions in inches.

summit caldera. Base tilt angle was recorded as 1.9° on the x-axis and 4.9° on the y-axis by the tilt beacon attached to the side of the HRB. After reviewing the seafloor and the relative position of the base to the desired location, the shipboard scientific party decided to reposition the base more to the east. The base was reentered with the running tool, picked up, and moved to the east approximately 145 ft (44 m). Upon releasing the jay-tool from the casing hanger, the seafloor slope of the base was measured as 0.1° on the x-axis 1.8° on the y-axis. The scientific party accepted the base location and tilt after another TV survey around the landing area was completed. Further inclination was noted after drilling operation commenced. Final tilt was recorded as 4.4° on the x-axis and 6.0° on the y-axis.

Hole 864B

The second mini-HRB was deployed with less difficulty than the first while passing through the upper portion of the lower guide horn. The base was again not deployed in the most favorable position. It was thought that the base could be run with leg 3 positioned on either side of the lower horn. However, it was not known until the doors were opened that the port guide horn was outfitted with two hydraulic cylinders used to lock the lower guide-horn section. These cylinders were the cause of a slight interference with one of the leg guides. The base should have been rotated 180° to allow leg 3 to ride in the starboard guide-horn section. However, SEDCO elected to proceed in the same manner as before and make the base fit. About 2 in. (50.8 mm) of the leg guide bracket were removed to eliminate the interference problem. Tugger lines were attached to the four corners to help stabilize the base as it descended into the moonpool. Despite the fact that the base was deployed almost in the optimum position, it was still tight while passing through the moonpool.

Since the second mini-HRB was to be positioned near the first, the electronic tilt beacon was not run. The two bull's-eyes were added as a visual reference check with the VIT. The dry weight of the base before the liquid ballast was added amounted to 130,000 lb (59 T). Total submerged weight of the fully ballasted base was about 120,000 lb (54.4 T). This was about 8000 lb (3630 kg) less than the first base. The difference can be attributed to the barite being added dry for the first deployment vs. being pumped into the base as a slurry for the second base.

Despite the fact that heave on the rig floor was running 6.6 to 9.9 ft (2 to 3 m), the second HRB base was landed as gently as the first. The second base was placed within 40 ft (12.2 m) of the first base. Dual bull's-eye indicators recorded the seafloor slope again as almost level in both axes. Unlatching from the casing hanger with the running tool did not produce any noticeable movement of the cone. Subsequent reentries with the drilling assemblies did not present any problems.

Hole 864C

The second base was moved after a male stem from an upper 6-3/4-in. (17.2 cm) back-off sub was left in the hole. Attempts to fish the small stem were unsuccessful. The hole was abandoned after a grabble sleeve was also lost in the hole during the fishing operation. The base was picked up with a shortened tensioning tool so that the 6-3/4-in. (17.2 cm) lower back-off sub would not interfere with the tool in the jay-down position. The base was initially moved 656 ft (200 m) north of Hole 864B. A total of five deployments were made before a satisfactory location was suitable to the scientific party. The final resting position of the base was approximately 59 to 65.6 ft (18 to 20 m) north of Hole 864A. Several of the locations where the base was temporarily located registered maximum HRB tilt angles. These angles were recorded from visual observations on the bull's-eyes from the camera mounted on the VIT.

Performance

The mini-HRB provided a stable seafloor base. The counterweight system that was developed to upright the cone worked as designed. On several occasions the BHA did drag across the reentry cone, allowing the VIT to record the reentry cone lying over and uprighting itself after the BHA cleared the cone funnel. Leg design also proved adequate despite the fact that brittle basalt was present at the location. The base legs did not puncture or penetrate the seafloor as was anticipated. The HRB also did not require extensive welding but relied on the 18 1-in. A-372 bolts to keep the two base sections together. This greatly reduced the time required to assemble the base. Some welding was added to one set of the gimbal blocks for which smaller bolts were used than on the other set of blocks. This was primarily due to the particular HRB that was run. The first base was modified from the earlier prototype version (Leg 132), which had smaller components throughout. Due to the number of reentries anticipated for this location, some stitch welding was added to the two sections of the funnel cone. Overall, the base functioned exactly as designed and without any problems.

Suggestions for Improvements

Few changes are suggested for the refined mini-HRB. The overall width of the base should be reduced to aid in the recovery if proper orientation cannot be maintained while retrieving the base through the moonpool. However, with the aid of the VIT the base can be run and recovered as designed but the dimensions are extremely tight. The remainder of the base components fit together and functioned as designed. The suggested improvements and recommendations for future HRBs include:

1. Add lifting eyes on the casing hanger above the gimbal.
2. Place alignment holes in the base legs to aid in starting the bolts once the legs are dropped into position.
3. Install plugs in the upper bolt holes on the base prior to running (i.e., eliminate barite from washing out).
4. Add additional pad eyes on the cone for easier handling.
5. Extend lower portion of landing seat to provide additional wear surface.
6. Fabricate a template to check all casing hanger dimensions prior to acceptance.
7. Investigate the use of a larger drill bit (14-3/4 in. [37.46 cm]) with the existing HRB hardware.
8. Develop alternative running tools for deployment of the HRB.
9. Add additional hardware options for crossing between conventional ODP casing strings and the newer DI-BHA hardware.
10. Redesign the casing hanger jay-slots so the running tool can enter into the slots at any orientation on the throat of the hanger.

A future modification to the guide base might include a larger drill-in casing. This addition would allow the HRB to have three large strings of casing before using the DCS tubing as a fourth string. This casing would be drilled in only a short distance of 6.5–13.1 ft (2–4 m), primarily to stabilize the base and gimbal arrangement. A locking mechanism would have to be devised to lock the casing into the gimbal as it is drilled past. This locking device would also have to be unlockable so that the initial casing could be retracted in case the base needed to be moved. The internally slotted casing drilled without a center bit might use welded, segmented diamond pads as the cutting medium. A landing seat for the next-size casing might also be pre-installed inside the new first stage. The running tool might be modified to take torque so that it could be used to drill the initial stage. Once the initial large-diameter casing is set, the existing 10-3/4-in. DI-BHA could be drilled in and backed off before switching to the DCB or setting the 6-3/4-in. DI-BHA system.

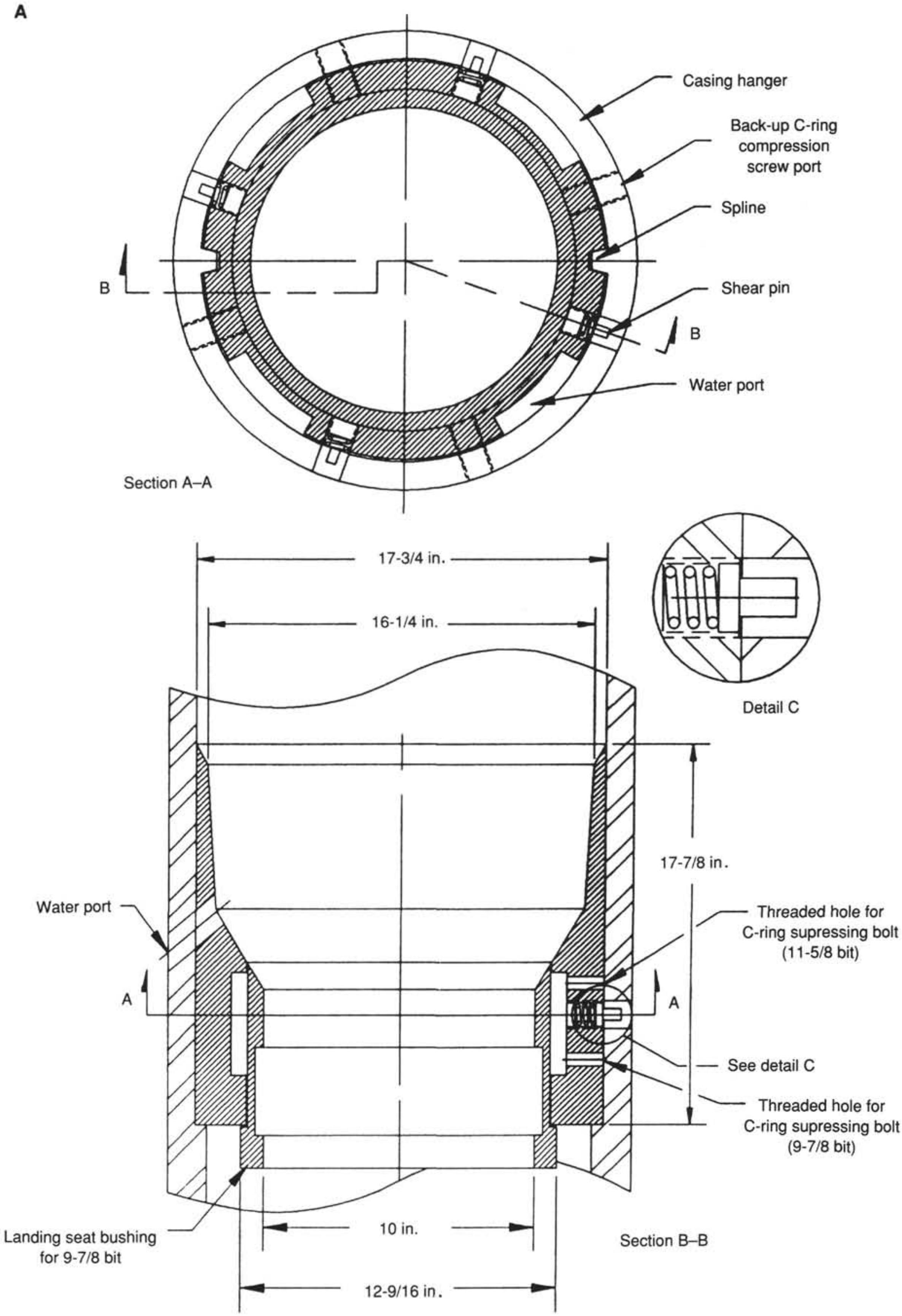


Figure 35. **A-B**. DCS landing seat with bushing for 9-7/8-in. bits. Dimensions in inches.

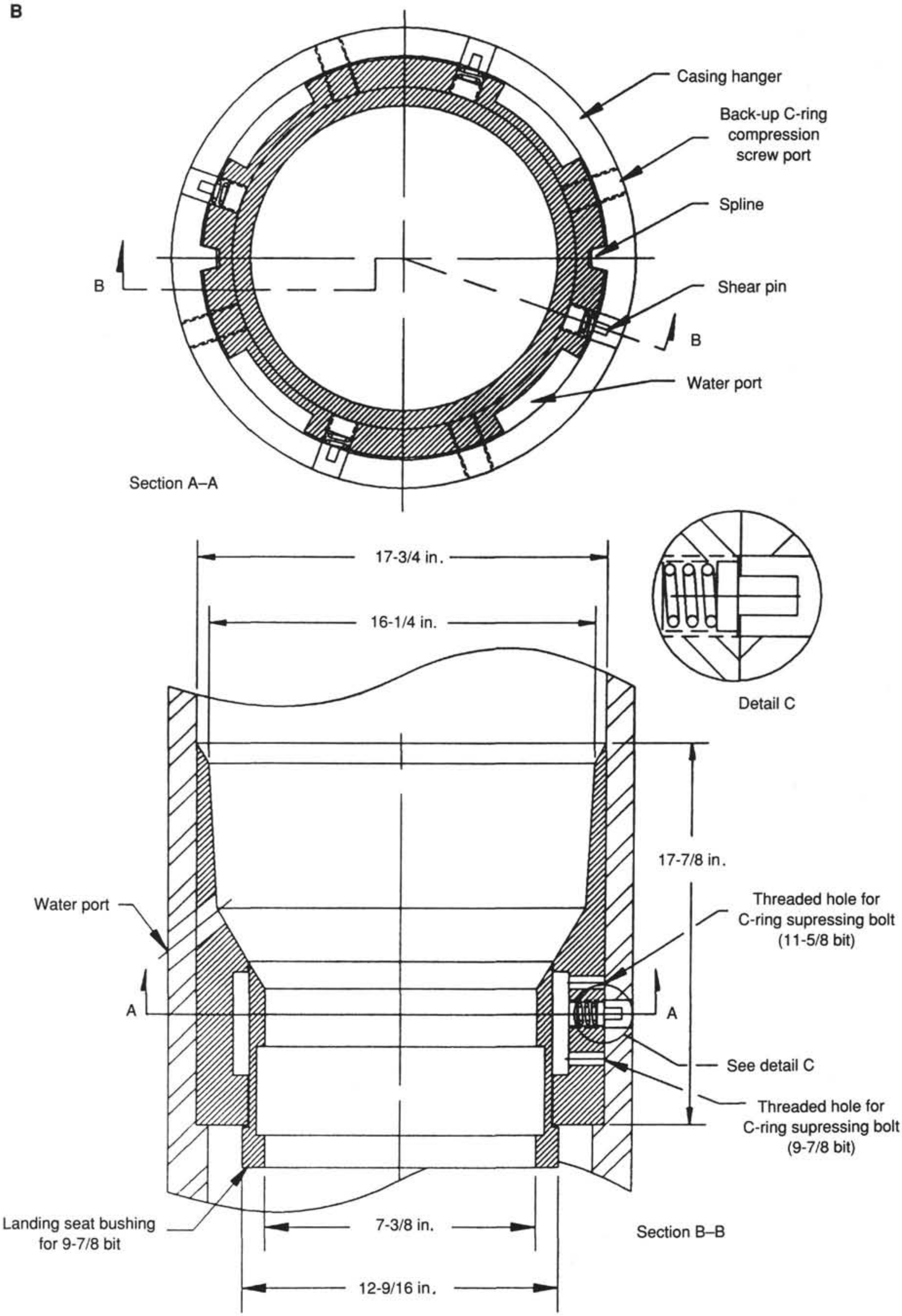


Figure 35 (continued).

MINI-RISER/TENSIONER SYSTEM

Background

The mini-riser system (MRS) deployed with the DCS is not a conventional oil-field riser in which drilling fluids are recirculated. The MRS does not require a conduit for control lines since a BOP is also not used in the diamond coring program. The primary purpose of the mini-riser is to provide lateral support for the 3-1/2-in. (88.9 mm) DCS tubing. This is accomplished with the 5- and 5-1/2-in. API drill pipe aboard the *JOIDES Resolution.* The actual drilling fluids that are pumped through the DCS tubing are expended on the seafloor as part of normal ODP drilling practices. A small annular flow of friction reducer is pumped between the two strings to reduce frictional drag and chatter during the actual drilling operations with the DCS. Both a polymer and a mud lubricant are used to decrease the frictional build-up between the two strings. Two levels of hardware make up the mini-riser system. These are the primary component hardware and sub-assembly components. Discussion of these components and how they fit into the whole scheme of operations is presented in this section.

Primary Component Hardware

The primary hardware components of the riser system are the tensioning tool, tapered stress joint, and break-away safety joint. These items, assembled from bottom to top, are attached beneath the API drill pipe. The drill pipe is connected to the top drive, which is held in tension by the rig's main compensator. The DCS platform is spaced out between the rig's top drive and primary heave compensator. A schematic of the riser and rig stack up is illustrated in Figure 47.

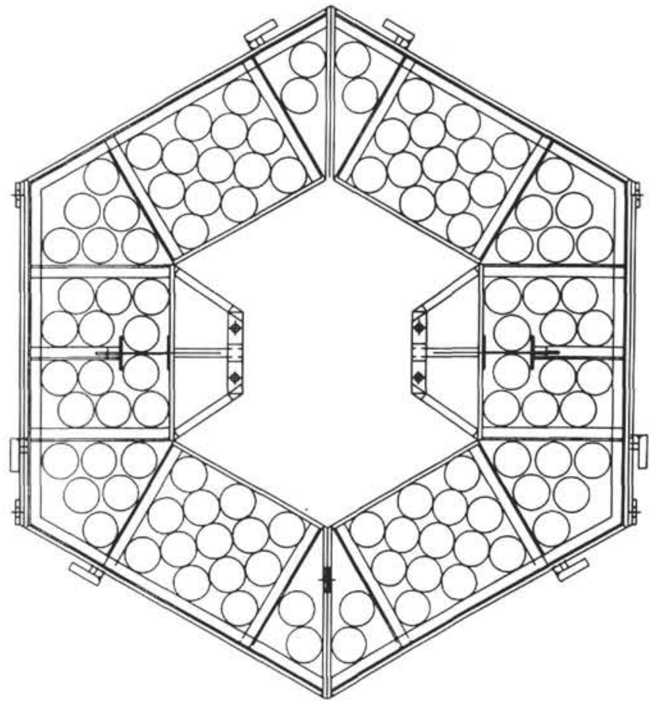
The tensioning tool and tapered stress joint were used on Leg 132 as part of the riser make-up. Modifications to the tensioning tool were made for Leg 142 in order to simplify the design and eliminate the shearable jay-dogs pins in the tool body and shear bolts in the stress joint flange. The new break-away safety joint is manufactured by Hydrotech. This tool accomplishes the same function as the tension tool but with 20 shear pins. These shear pins provide the mechanical fuse to separate from the guide base in case an emergency drive-off situation were to occur.

Stress Joint

The tapered stress joint was designed to provide a smooth transition in bending stiffness from the bottom of the riser to the seafloor template. Figure 48 is a schematic representation of the stress joint. Evaluation on Leg 132 indicated that the stress joint worked as designed and did not present any limitations to the operation of the seafloor system. Wall thickness measurements made by Baker Hughes Tubulars along the length of the stress joint verified that it was not subjected to any unusual stresses that plastically deformed the joint. The shear bolts used in the flange were replaced with solid high-strength steel bolts which exhibited less than 12% elongation at maximum load. The SAE J429 bolts were rated at 165,000 lb (74.83 T). No other changes were made to the stress joint for operations during Leg 142. Additional information pertaining to the stress joint can be found in the "Seafloor Component Hardware" chapter of the Leg 132 *Initial Reports* volume.

Tensioning Tool

The two-level, break-away tensioning tool developed as a prototype model for Leg 132 operations was thought to be too complex for the operations it was intended to serve. Therefore, it was completely disarmed of any mechanical fuse operations for future service with the DCS system. The retractable shear-lug concept was deemed under-designed for the torsional forces it could experience during the latching-in process. The four dogs on the tensioning tool have been welded out so that the tool has essentially become a running tool for the HRB. The second mechanical fuse incorporated into the tensioning tool has also been disarmed by changing the shear bolts to solid high-strength bolts.



Ballast

Steel pipe: 8.62 in. (21.9 cm) x 8.22 in. (20.9 cm) x 5.58 ft (1.7 m)
Total weight per pipe: 350–360 kg
Maximum allowable pipes per base: 108
Tank volume: 493 ft ^{3}

Dry weight:		Submerged weight:	
Steel pipes:	83,160 lb	Steel pipes:	72,350 lb
Cement:	29,500 lb	Cement:	13,500 lb
Base:	41,400 lb	Base:	36,020 lb
Total:	154,060 lb	Total:	121,870 lb

Figure 36. Mini-HRB ballast arrangement.

Another modification to the tensioning tool involved removing the 5-1/2-in. full-hole (FH) pin connection on the lower portion and replacing it with a 6-3/4-in. (17.2 cm) acme thread on the inside of the lower portion of the tool. This modification reduces the overall length of the tool to 24 in. (0.61 m) and allows for a variety of different deployment subs to be attached. The addition of the box connection to the lower end of the tool has not altered the internal 5-1/2-in. FH connection cut into the upper portion of the tool. The BX-156 ring gasket groove also remains intact even though the incorporation of mud returns to the surface still have not been planned for the near future. A schematic of the modified tensioning tool is presented in Figure 49.

Break-away Safety Joint

One of the new pieces of hardware that was developed for Leg 142 was the break-away safety joint. The safety joint is a disconnect device that is installed in the mini-riser just above the tapered stress joint that senses tension in the riser. The joint will automatically disconnect the riser from the flex joint when a preset value of tension is exceeded (Fig. 50). This joint replaced the two mechanical fuses that had been incorporated into the tensioning tool developed for Leg 132. Analytical work performed by Starmark verified that the flanged shear-bolt concept introduced uncertainty into an already complex design and should be abandoned. The newly adopted design uses 1/4-in. (6.35 mm) shear pins that have been extensively tested and are reliable to less that 6%. Actual test performed on the safety joint reported results with a variability of less than 2%. The break-away safety joint is designed to withstand 8000 ft-lb (10,400 Newton-meters [Nm]) of torque and a maximum allowable bending load of 15,000 ft-lb (19,500 Nm).

The safety joint is composed of an upper and lower sub that are held together with a bolted retainer flange and upper retainer ring. The upper sub is threaded with a 5-1/2-in. FH box with the lower sub threaded with a 5-1/2-in. FH pin. The retainer flange is attached to the bottom sub by six 3/4-in. 10 UNC all-threaded studs and nuts. The upper retaining ring prevents the six torsion pins from falling out of the circular groove formed by the semicircular slots in the OD of the top sub and ID of the retainer flange. Inside the retainer flange is a split two-piece shear-ring assembly. This shear ring is installed in a groove milled on the outside of the top sub and an internal groove on the inside of the retainer flange. The shear-ring assembly has room for twenty 1/4-in. (6.35 mm) shear pins to achieve a nominal 100-kip (45.4 T) disconnect load. A schematic of the break-away safety joint is presented in Figure 28.

When a tension load is applied to the riser the load will pass directly through the shear pins. The safety joint supports bending moment by a reaction couple between the top-sub and the bottom-sub ID and the ID of the retainer ring. The safety joint also incorporates two O-ring primary seals and a PolyPak water seal to restrict the free circulation of seawater in the area of the shear-ring assembly. The PolyPak seal is positioned to allow seawater to enter the internal cavity as the mini-riser is lowered to the seafloor. This allows the internal cavity to equalize with depth pressure. The pressure trapped in this inner cavity will vent to ambient by leaking past the interface surface between the retainer flange and bottom sub during recovery of the string. It should be noted that the different seals used in the TSJ cannot be interchanged. Switching of the seals can alter the separation load and/or develop enough hydraulic force to cause separation during riser retrieval.

Sub-Assembly Components

The sub-assembly components are used as supplemental hardware to enhance operations in the secondary stage of the nested DI-BHA and DCB or to provide a stabilized string for the DCS to core through. A bit guide positioned inside the casing hanger is used to guide the 6-3/4-in. (17.2 cm) string through the landing seat or into the lower sub of the 10-3/4-in. (27.3 cm) DI-BHA. Hardware used to recover the 7-1/4-in. (18.4 cm) center-bit assembly is part of the bit-guide deployment hardware. Centralization hardware and the introduction of a slip joint provide a smaller diameter string through the 10-3/4-in. (27.3 cm) DI-BHA to stabilize the DCS tubing during coring operations. These sub-assembly components and other pieces of support hardware are described in more detail in the following sections.

Bit-Guide Deployment Scheme

A bit-guide and installation scheme was developed in order to provide a smooth transition section for reentry of the 6-3/4-in. (17.2 cm) centralizing string or diamond core barrel inside the 10-3/4-in. (27.3 cm) DI-BHA. The ID of the casing hanger is 17.75 in. (45 cm) with a 10-3/4-in. (27.3 cm) lower back-off sub centered once it is drilled into the formation. Controlled reentries into the guide base are not always possible since sea states usually dictate how easy or difficult this operation will be. Two types of reentries are required after the primary BHA has been installed: running in with the DCB and reentering with the centralization sub for supporting the DCS tubing while coring through the 10-3/4-in. (27.3 cm) casing.

After the 10-3/4-in. (27.3 cm) BHA is drilled to depth, the center-bit latch assembly must be removed prior to initiating the next phase of advancing the DCS or DCB string past the primary DI-BHA bit. It is before this operation that the bit guide is deployed. The tensioning tool is outfitted with a sub (upper sub) that has four sets of hinged dogs about mid-length. Slots slightly wider than the dogs are cut through the body of the upper sub. This allows the dogs access to swing into the ID of the upper sub. Above these slots are another set of slots that are used to position the bit-guide-holder release latch (Fig. 51). The release latch is a modified version of ODP's extended core barrel (XCB) latch. Attached to the bottom of the latch is a bull-nosed shaft. The bit guide is positioned snug against the lower end of the tensioning tool with the upper sub protruding through the middle of the bit guide. When positioned, the bull nose attached to the end of the XCB latch inside the upper sub forces all four of the hinged dogs outward, capturing the bit guide.

The tensioning tool is then lowered into the casing hanger (Figs. 52 and 53) with the bit guide riding on the dogs of the upper sub. Upon latching the tensioning tool into the jay-slots, an overshot is lowered on the wireline. Once the bit-guide latch is connected to the overshot, it is pulled back to the surface inside the API drill string. As the bit-guide latch is shifted upward, the four hinged dogs swing into the body of the upper sub, releasing the bit guide to drop into place around the 10-3/4-in. (27.3 cm) lower DI-BHA sub.

If the 6-3/4-in. (17.2 cm) string becomes the primary BHA, the bit guide must still be deployed. However, in this case it can be pre-installed inside the casing hanger above the landing seat and bushing for the 7-1/4-in. (18.4 cm) diamond bit. The bit guide is made from a moldable Andur polyester. Because the specific gravity of the material is near 1, it is weighted with a section of 16-in. (40.6 cm) line pipe and a lower back-off ring from the prototype back-off sub deployed on Leg 132. Overall dimensions of the bit guide are 17 in. (43.2 cm) in diameter and 22 in. (55.9 cm) long. A length-to-width ratio of 1.3 was maintained in order to reduce the potential of the guide cocking as it was being released in the casing hanger. The general ID of the opening size is 10 in. with eight 1-1/8-in. (3.2 mm) radius grooves placed 45° apart. The radius grooves were added as a means to dissipate cuttings should returns exit at the throat of the 10-3/4-in. (27.3 cm) lower sub. The polyester material is quite durable and exhibits less than 1% shrinkage with pressure and temperature. It was selected for its energy absorption characteristics, which made it ideal should a diamond bit impact it while entering the casing hanger. The bit guide is illustrated in Figure 54.

7-1/4-in. Center-Bit Retrieval System

As described above, the retrieval of the 7-1/4-in. (18.4 cm) center bit must be performed prior to initiating the next phase of coring. This operation is performed immediately after the bit guide is released. Since the center-bit latch assembly for the 10-3/4-in. (27.3 cm) DI-BHA is larger than the ID of the API string, it cannot be retrieved through the pipe in the conventional manner. A schematic of the center-bit latch assembly is presented in Figure 55. As shown, the smaller, modified XCB latch is positioned on top of the larger casing-advancer latch. This second latch provides the mechanism for recovery of the center-bit latch assembly.

Attached to the upper bit-guide deployment sub is a lower latch sub. This latch sub has an internal groove which is used to capture the

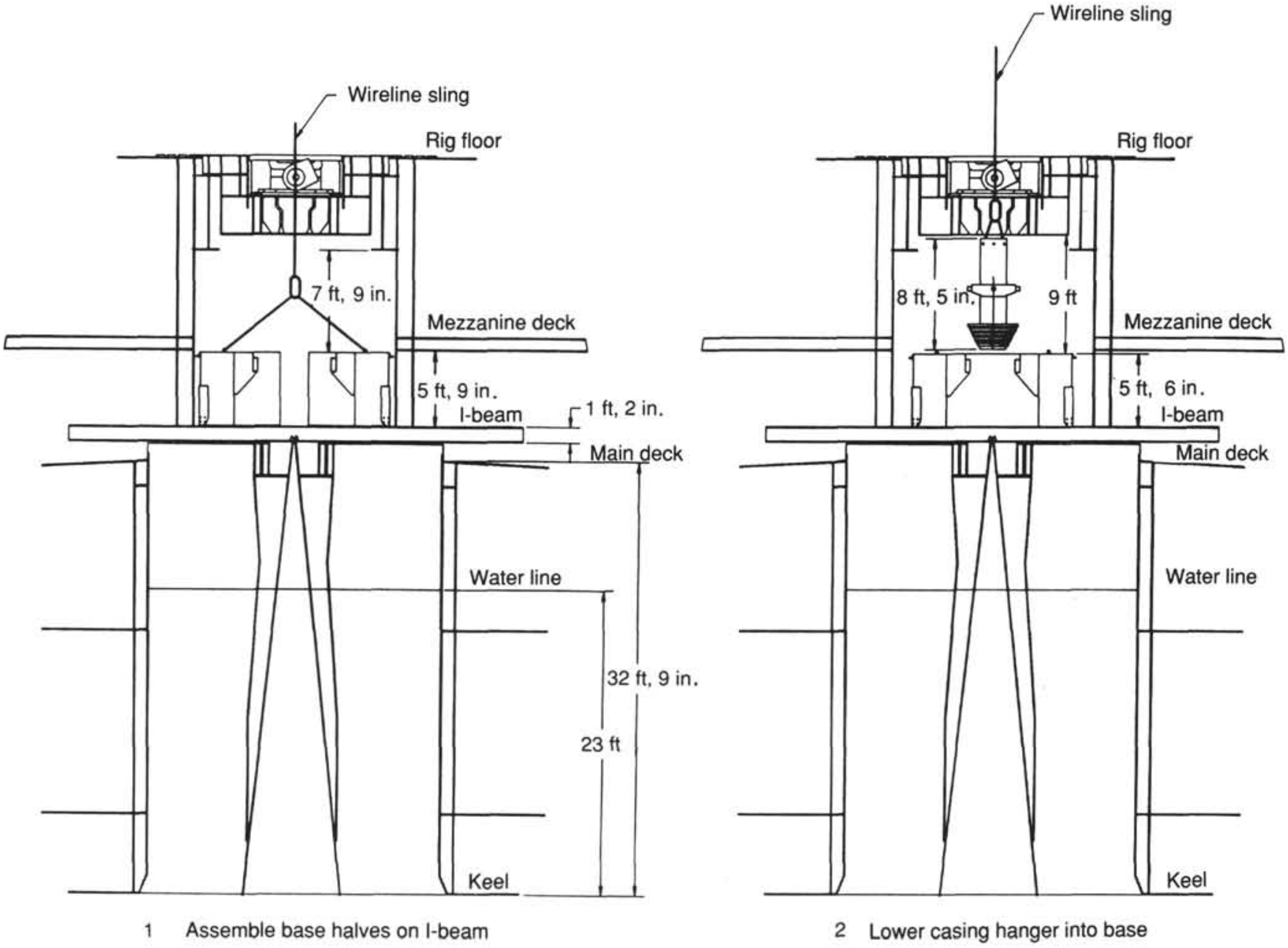


Figure 37. HRB moonpool assembly.

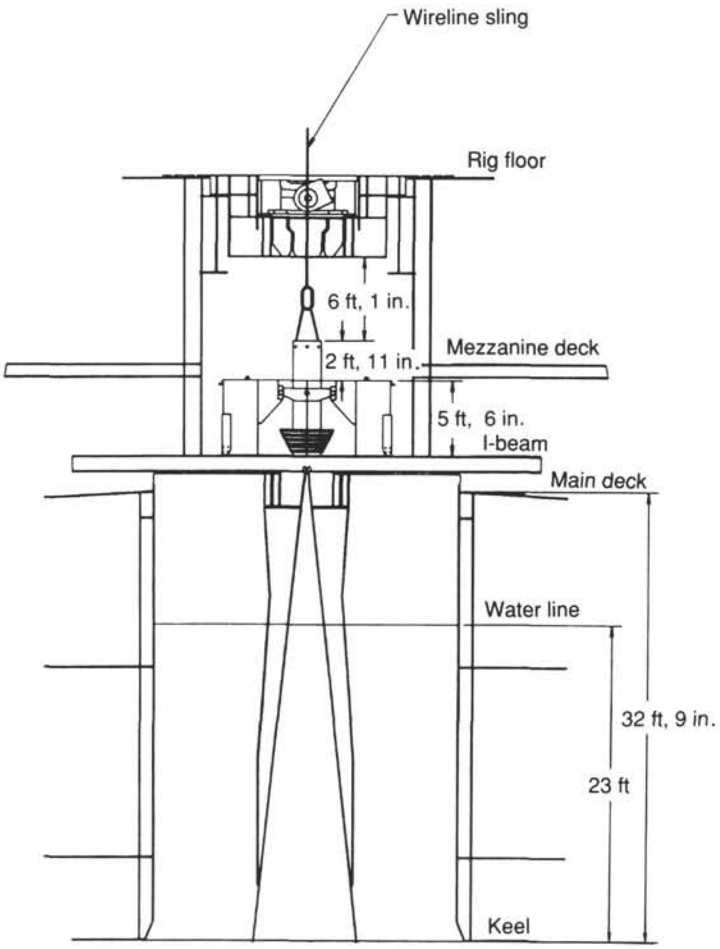
dogs of the modified XCB latch. Both of these subs (upper and lower) are run underneath the tensioning tool. A schematic of the two subs attached to the tensioning tool is presented in Figure 52. The large center bit is retrieved by the wireline overshot which latches onto the smaller XCB latch. The whole assembly is then retrieved through the DI-BHA until the smaller latch is pulled up and into the lower latch sub. The tensioning tool is then unlatched from the casing hanger and offset from the HRB. The overshot is jarred off the XCB latch as the larger casing-advancer latch bottoms out against the lower latch sub. The upper latch-assembly dogs are captured in the lower sub groove as the latch slides down after being jarred off the overshot. A schematic illustration of this operation is presented in Figure 56.

An alternative method of center-bit retrieval is available if wireline overpull is insufficient to release the large center-bit latch. This optional method requires an extra pipe trip to latch onto the center-bit assembly but uses the drill string to retrieve the center-bit assembly in place of the wireline overshot set-up. This procedure is accomplished by reentering the primary DI-BHA with 6-3/4-in. (17.2 cm) drill collars above the lower latch sub. The overshot is then latched onto the upper XCB latch in order to retract the dogs. Once the dogs are retracted the lower latch sub and drill collars are lowered until they bottom out against the large center-bit latch. The wireline overshot is then jarred off, releasing the dogs to spring back into the locking position once the latch sub cavity is brought upward over the dogs. The drill collars/latch sub is raised until the dogs come into contact with the circular latch cavity. A schematic of this operation is presented in Figure 57.

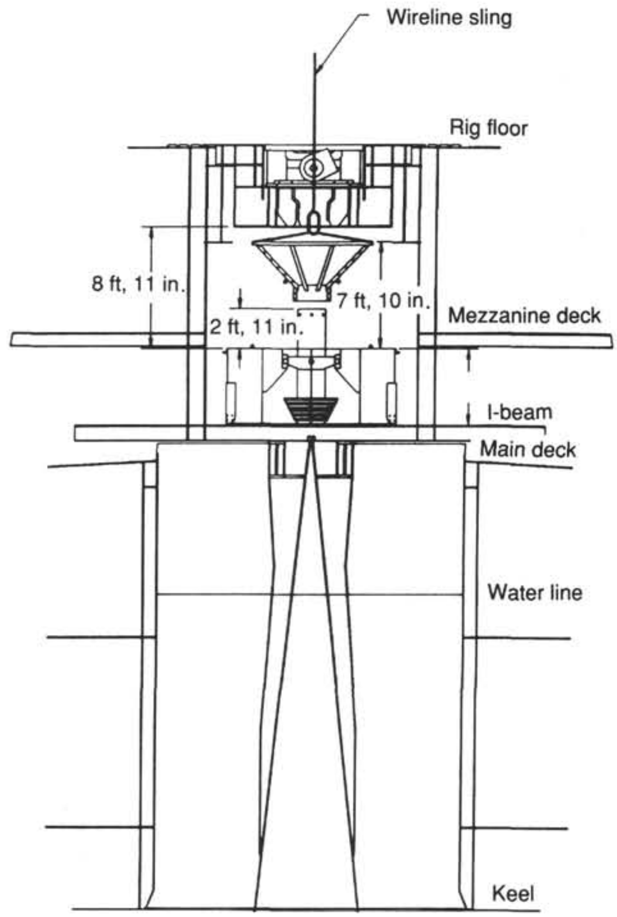
Centralization Scheme

In order to core effectively and achieve high recovery rates, the DCS tubing string must be supported the entire length. This is normally accomplished with the wall of the borehole once the DCS string enters into the formation, since the annulus between the pipe and hole size is relatively small. The differences in diameter between the API string and DCS tubing also does not present stability problems. However, this is not the case when the DCS is deployed through the 10-3/4-in. (27.3 cm) drill-in BHA. This amount of annular area required a centralization scheme to be devised in order to support the smaller 3-1/2-in. (88.9 cm) tubing inside the 7-3/8-in. (18.7 cm) ID of the primary DI-BHA casing. This consisted of using the 6-3/4-in. (17.2 cm) drill collars (secondary string) spaced out to the appropriate length and connected to the bottom of the tensioning tool. This centralization string is then deployed as the final stage before tensioning the mini-riser with the DCS platform in series.

A 6-3/4-in. (17.2 cm) slip joint is added to the lowermost portion of the centralization string. This slip joint has an overall length of 11 ft (3.35 m) with a stroke length of 48 in. (1.22 m). The slip joint provides the necessary stroke to close the gap created when the tensioning tool is latched into the jay-slot of the casing hanger. The jay-slot allows the tensioning tool to descend 22 in. (0.56 m) into the casing hanger before being rotated 90° and tensioning up. Closure of the gap especially near the bit interface is thought to be critical in order to keep the tubing/core barrel centralized and fully supported. The slip joint also prohibits a dog-leg deviation from occurring at this position



3 Secure casing hanger



4 Lower guide funnel onto casing hanger

Figure 37 (continued).

during the initial spudding operations, should the placement of too much weight on the bit allow it to favor one side of the 7-3/8-in. (18.7 cm) borehole through the bit.

The nose of the slip joint is tapered from 7 in. (17.7 cm) to 6-1/4 in. (15.9 cm) so that it will centralize itself inside the ID of the primary drill-in bit. Two PolyPak seals are positioned on the upper portion of the stabilizer ring to reduce the potential for cuttings to fill in behind the ring and capture the slip joint. The tip of the stabilizer ring is externally fluted with 8-1/2-in.-diameter (12.7 mm) slots spaced at 45° apart approximately 4 in. (10.2 cm) long. The first inch of these slots is milled the entire distance through the stabilizer ring, thus providing a direct flow path for cuttings from the DCS to exit around the primary drill-in BHA bit.

The slip joint is also equipped with a shear pin so the joint can be locked closed before entering the casing hanger. This option was added in an attempt to limit the potential for damaging the mandrel of the slip joint while reentering the cone. A plastic disk may be installed on top of the inner mandrel and pumped open when the joint is ready to be activated. The slip joint is illustrated in Figure 58.

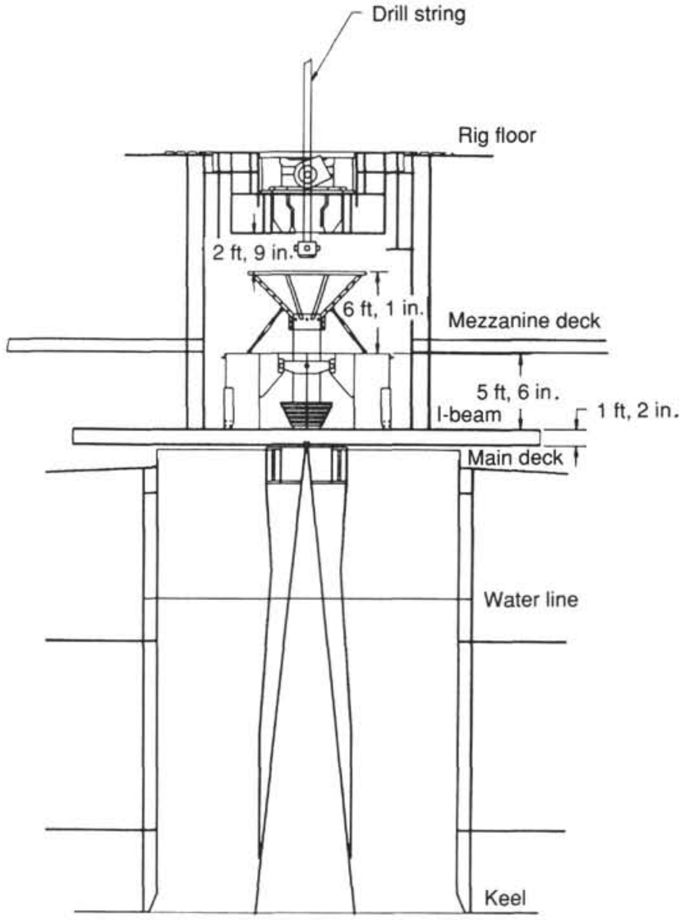
The transition section from the tensioning tool to the 6-3/4-in. (17.2 cm) drill collars/slip joint is provided by a crossover sub. A schematic of the sub is illustrated in Figure 59. The length of this crossover sub, when coupled with the slip joint and additional 6-3/4-in. (17.2 cm) drill collars (10, 20, 30 ft [3.05, 6.1, 9.15 m]), provides the necessary space-out and gap closure when the tensioning tool is being latched into the casing hanger.

Diamond Core Barrel

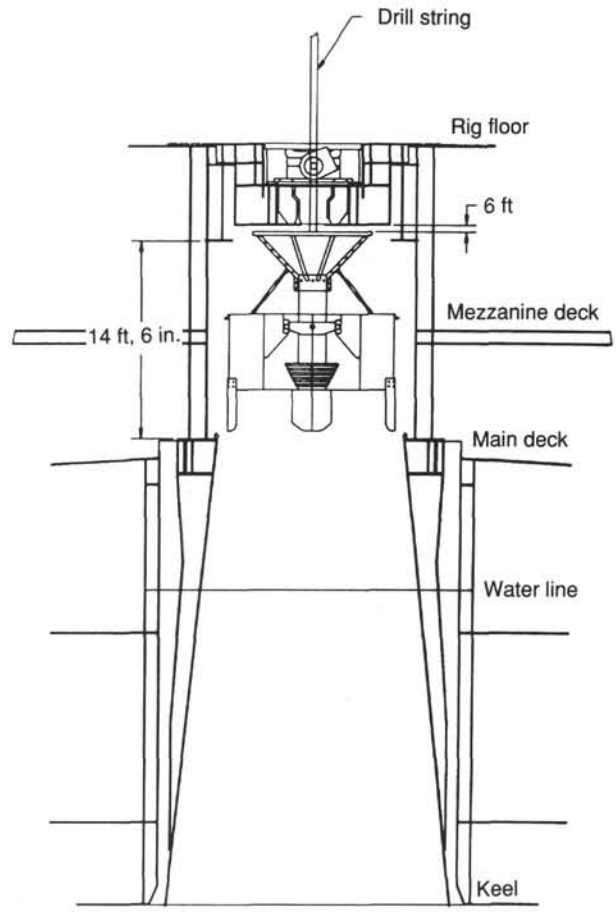
The diamond core barrel was designed with two purposes in mind. First, it can be deployed as the second-stage drill-in BHA or operated as a complete coring system by itself. The DCB uses the same inner barrel as ODP's rotary core barrel (RCB). The main difference between the RCB and the DCB is the OD of the outer barrel. The RCB uses a conventional 8-1/4-in. (21 cm) drill collar, whereas the DCB uses the smaller 6-3/4-in. (17.2 cm) drill collar with the same 4-1/8-in. (10.5 cm) ID bore. Another difference between the two outer barrels is that the DCB has vertical stabilizer pads placed mid-span on the core barrel. These stabilizer pads were added to increase the rigidity of the slimmer collar and to enhance core recovery. Similar stabilizers are added to the long top sub and long bit sub.

Due to the size of the smaller outer barrel, the same float valve and bearing assembly from the RCB could not be run in the DCB. A smaller version of each has been designed specifically for the DCB. The two-piece adjustable latch sleeve was also scaled down from the RCB. The DCB uses a 5-1/2-in. FH-modified connection throughout except for the connection on the bit sub. This connection has a modified Hycalog #263 thread form (60° stub V) reduced in diameter to fit the smaller 6-3/4-in. (17.2 cm) core barrel. The bit size used for the DCB is 7-1/4 in. (18.4 cm). Several bit types and matrix hardness are available depending on the material to be cored.

Because the size of the DCB is so much smaller than ODP's conventional string, special 6-3/4-in. (17.2 cm) drill collars were also manufactured. The bending strength ratio of the 5-1/2-in. FH-modi-



5 Install guide funnel and supporting turnbuckles



6 Jay-in, pick-up, remove I-beams, lower legs, open moonpool doors

Figure 37 (continued).

fied connection is 2.5. This is slightly less than ODP's normal drill string. However, as long as the string is moderately supported (i.e., no long, unsupported bare-rock spud-ins), the connection should be more than satisfactory. Three sizes are available in lengths of 10, 20, and 30 ft (3.05, 6.1, 9.84 m). Crossover subs to either 6-5/8-in. FH-modified or 5-1/2-in. internal flush (IF) are available depending upon the application and/or hole size being reentered. Zip lift subs were manufactured for handling 90-ft (27.5 m) stands of the 6-3/4-in. (17.2 cm) drill collars. A schematic of the 6-3/4-in. (17.2 cm) diamond core barrel is presented in Figure 60. Drilling options with the DCB as part of the nested DCS drill-in system are illustrated in Figure 61.

Performance

All of the primary components and sub-assembly hardware were used during Leg 142 in Hole 864A except the diamond core barrel. It was attempted twice while deepening Hole 864B. The following section presents an evaluation of the equipment and problems that were noted during deployment or during the time the equipment was in operation.

Tapered Stress Joint

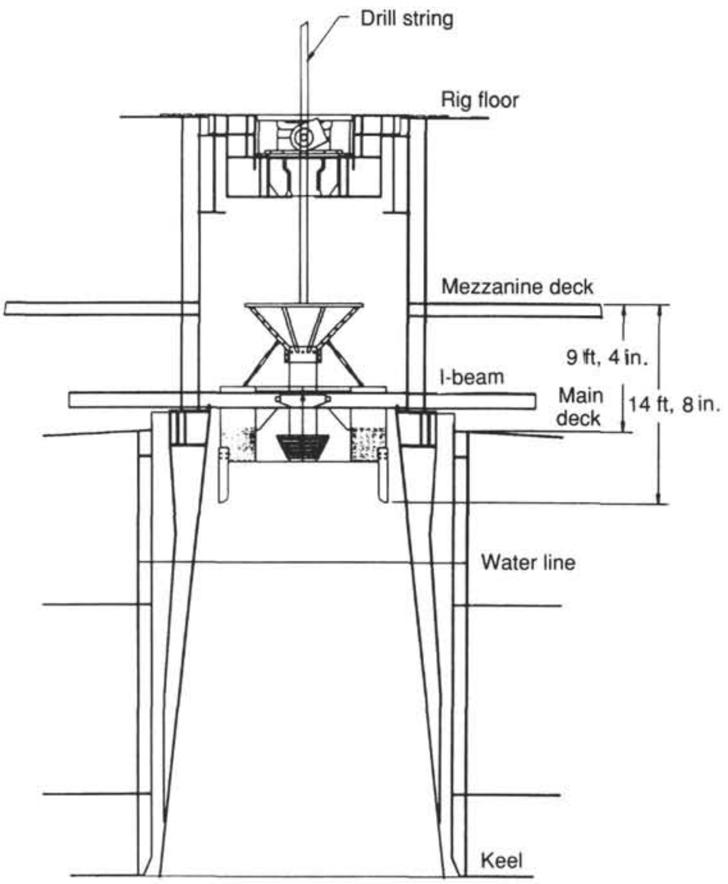
The stress joint has been a reliable part of the mini-riser system since the system was initiated on Leg 132. It was again tested to only the minimal operating conditions for which it was designed. Vessel offsets typically remained less than 1% of water depth (260 ft [79.3 m]) the entire time the stress joint was attached to the base. Total operational time amounted to 148 hr. This time was accumulated over 5 days and 3 operating windows. The periods of operation are summarized as follows:

Period	Days	Drilling depth range (mbsf)	Hole	Time (hr)
1	3.29	6.6–8.5	864A	79
2	1.93	13.3–15.0	864A	46.5
3	0.94	15.0–15.0	864A	22.5
			Total	148 hr

With no mechanical or moving parts, the stress joint has performed the function of reducing the amount of bending moment which is transferred into the base and DI-BHA. Upon completion of Leg 142 operations, the wall thickness of the stress joint should be checked thoroughly for any permanent deformation which may have occurred again during the time of operation. Bolts used to connect the stress joint onto the tension tool should be replaced, and several back-up sets should be obtained.

Tensioning Tool

The tensioning tool modified from Leg 132 did not present any real operational problems once deployed in the tension mode. How-



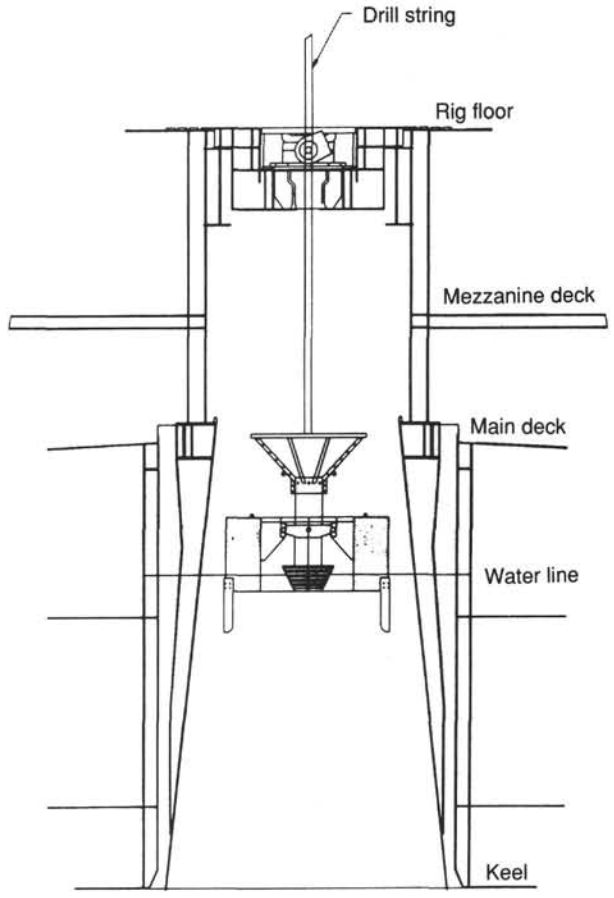


Figure 37 (continued).

ever, it was difficult to engage the dogs into the respective slots on several occasions, causing some lost time. The dogs on the tool were painted, along with matching stripes on the cone, so that visual observation with the VIT would enable the driller to know when proper alignment was made between the jay-slots and the dogs. Even though both tools were checked and fitted in the jay-slots of the casing hanger before the mini-HRB was placed on the seafloor, additional beveling and grinding of the square-shaped dogs were required to aid in making the reentry effortless. Engagement problems with the same two tensioning tools were not experienced on Leg 132. However, the dogs were removed and welded out between Legs 132 and 142 when the mechanical fuse to shear the dogs was disarmed. Because the HRBs were shipped to the port of call for Leg 140, the tensioning tool could not be checked inside the casing hanger to assure that they fit properly. This most likely resulted in some misalignment and out-of-gage dimensions by poor quality-control on the part of the manufacturer. The only other explanations offered for the difficulty with the dogs not properly engaging the slots on the casing hanger were:

1. Some damage may have been sustained by the jay-slots during the prolonged rotation of the heavy reinforced stabilizer blades on the spiral bit subs,
2. The deeper water depth (8436 ft vs. 5904 ft [2572 m vs. 1800 m]) produced additional catenary, requiring more accurate positioning over the base than on Leg 132, and
3. Currents may have been constantly holding the tool onto one side of the cone, requiring the vessel to be offset in order to get the tool into the throat of the cone.

The casing hanger for the second mini-HRB was again fitted with both the SEDCO running tool and the tensioning tool before deployment. No problems with the running tool were encountered; however, the tensioning tool again had to be ground down to allow the dogs access into the slots. The dogs were out of round approximately 3/16 in. (4.8 mm) on the diameter. This discrepancy might be easily explained if the casing hanger and tensioning tool had not been manufactured by the same vendor. It would be highly unusual that once the tensioning-tool dogs were fitted into a casing hanger they would not fit into the next hanger manufactured. The first hanger run was one of the original hangers developed for Leg 132. The other casing hanger built for Leg 142 was manufactured in late 1991 and possibly had an ID out of tolerance. This may be the most likely scenario of the misalignment problem. In any case, the manufacturer will be contacted to sort out this quality-control problem.

Near the end of the leg one of the tensioning tools was further modified when interference with a DI-BHA prevented it from reaching the bottom of the jay-slots. The tool was shortened 13 in. (33 cm) to provide additional clearance which enabled the dogs to be rotated at the bottom of the slots. A more detailed explanation of the events leading up to modification of the tool is presented under the subheading "6-3/4-in. Back-off Sub" in the "Back-off Hardware" section (this chapter).

Break-away Safety Joint

The safety joint was exposed to a considerable amount of bowing and dynamic loading when the centralization string begin bottoming

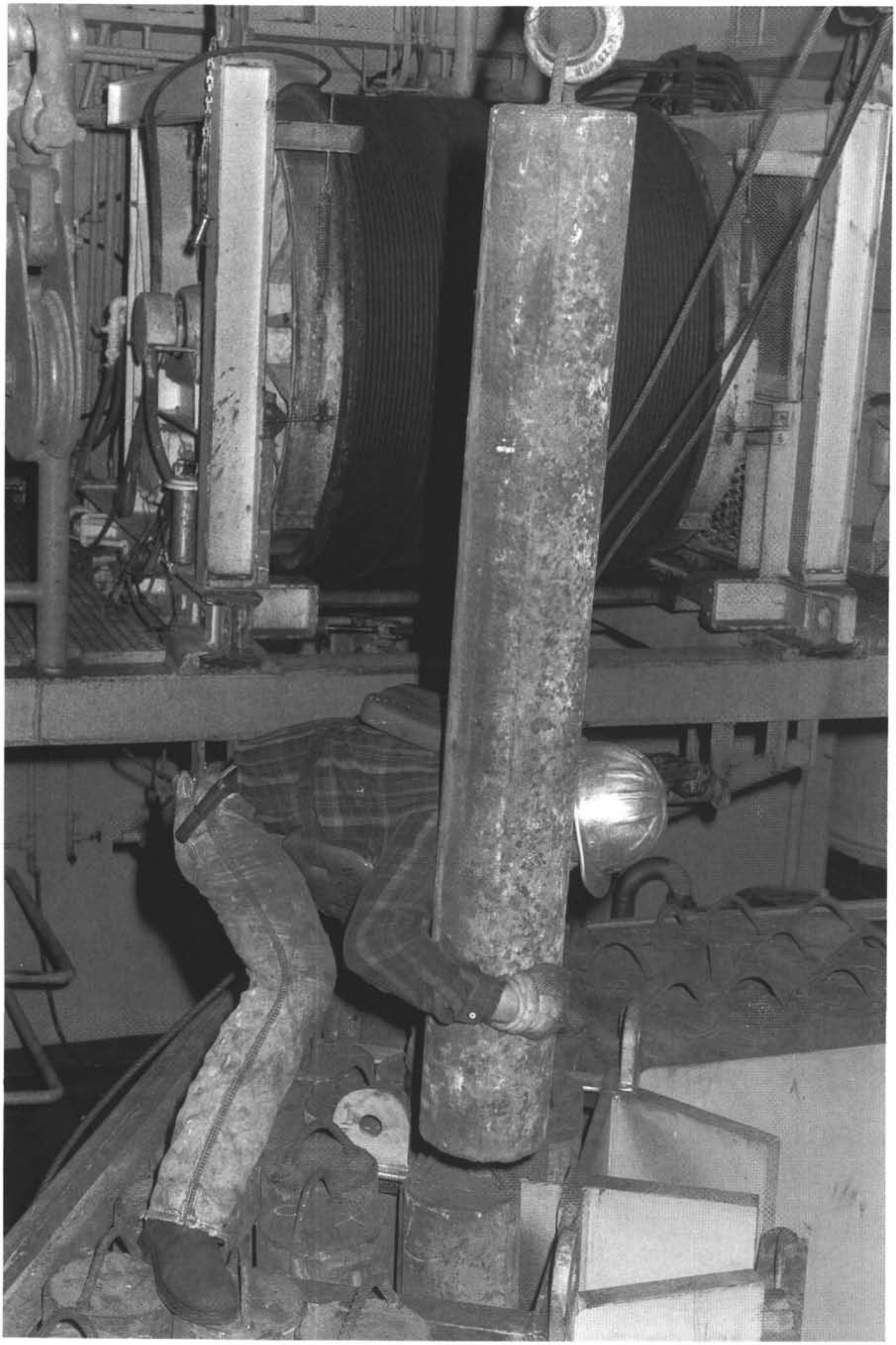


Figure 38. Ballasting operation.

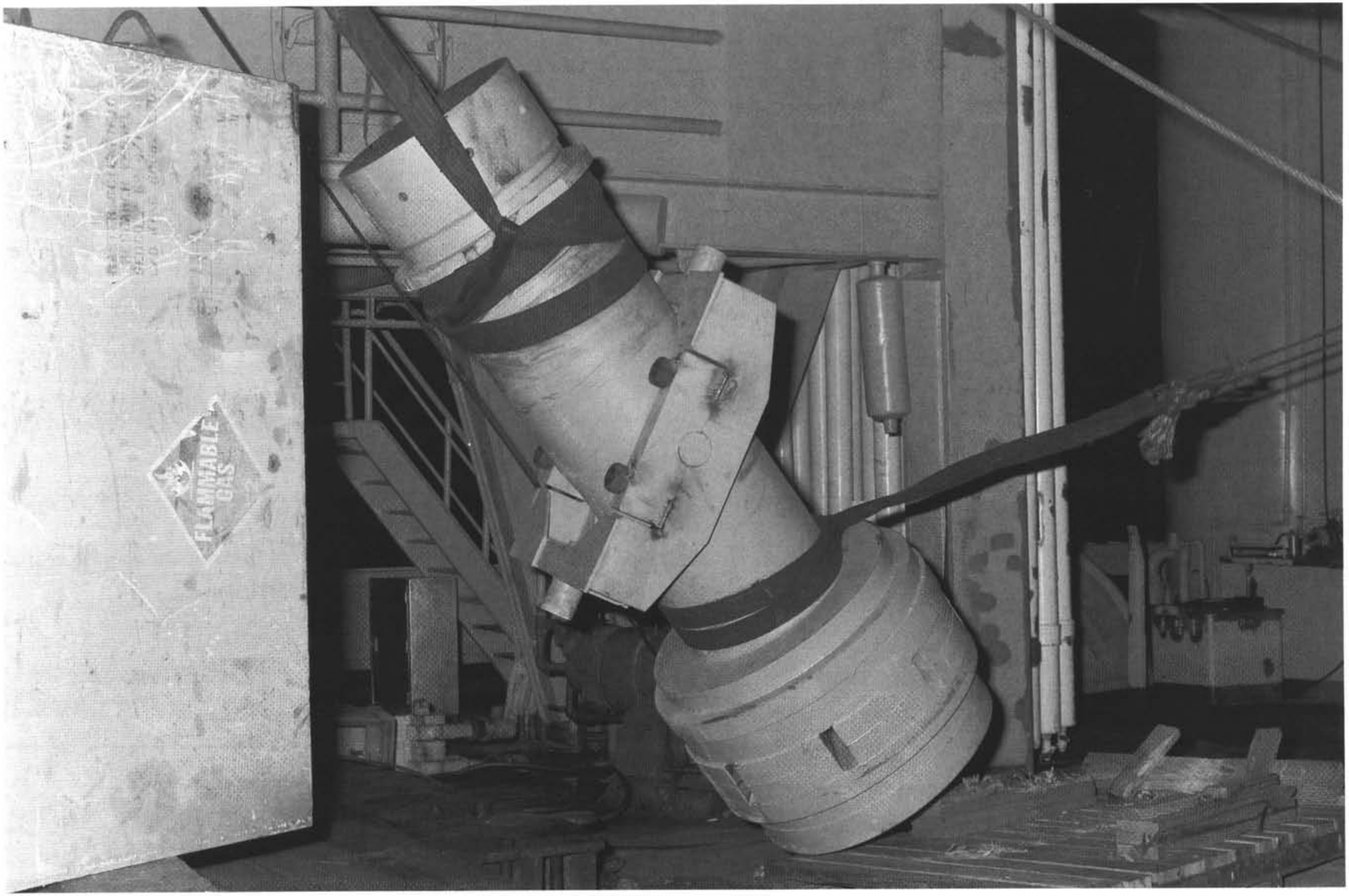


Figure 39. Lifting casing hanger.

Figure 40. Installation of casing hanger.

Figure 41. Bolting casing hanger into base sections.

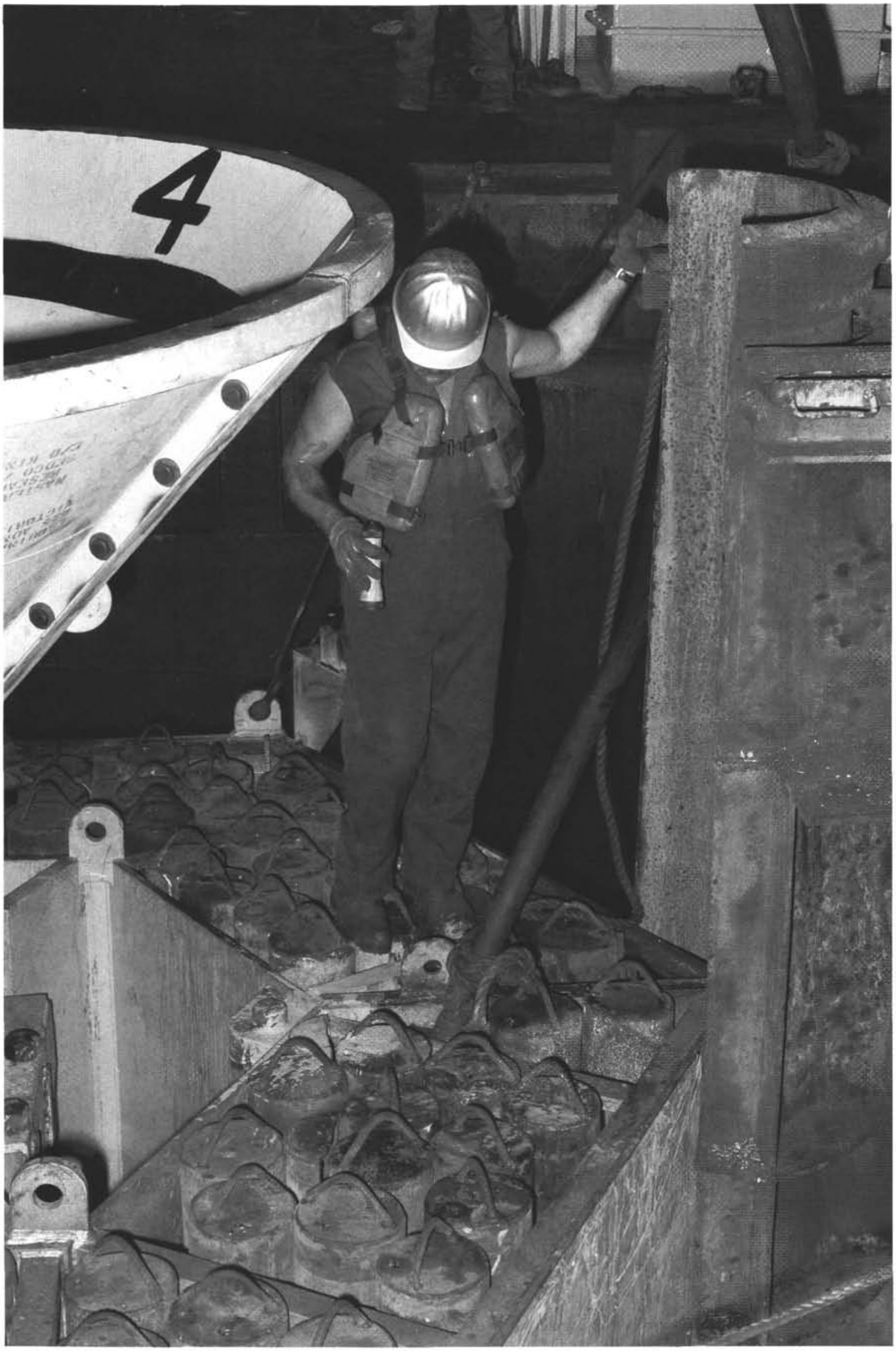


Figure 42. Introduction of barite into base sections.

Figure 43. Lowering HRB to seafloor.

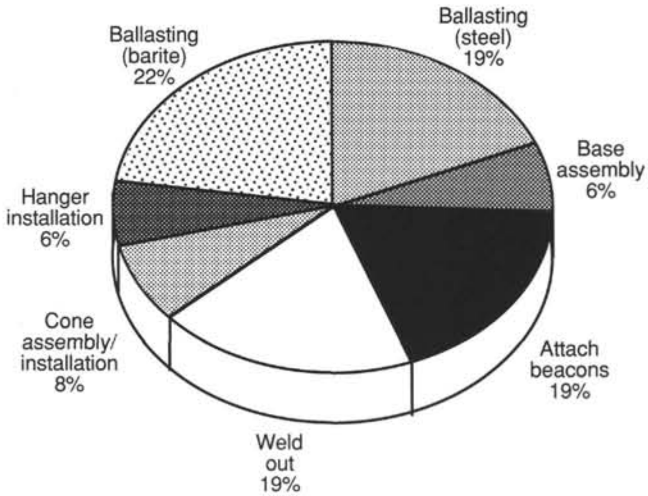


Figure 44. Breakdown of the first guide-base assembly time. Total assembly time is 31 hr.

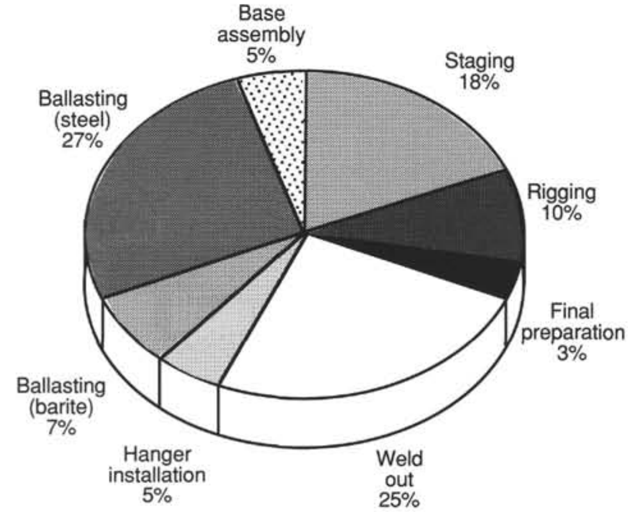


Figure 45. Breakdown of the second guide-base assembly time. Total assembly time is 30.75 hr.

out as fill was introduced into the 10-3/4-in. (27.3 cm) DI-BHA during the latter stages of the stripover operation. The safety joint, which is subject to fatigue at high concentrations of stress, never saw wide variations in the overpull of 50 kips (22.7 T). Typical variations for the 500-kip (227 T) top tension was less than 1% for the relatively calm sea state experienced during Leg 142. Pipe-thread fatigue resulting from tensioner variations also was not considered a problem for the amount of fluctuation being seen. As described in the "6-3/4-in. Back-off Sub" subsection, the joint was subjected to full-scale load-testing both in tension and with a bending moment applied prior to deployment in the field. The safety joint never had to be activated during the time the DCS platform was in operation during Leg 142. The tool appears to have performed satisfactorily the task for which it was designed. It is recommended that the tool be completely disassembled in order to check for any appreciable wear and to replace the shear pins before being placed in service again.

Bit Guide

The bit-guide deployment scheme was accomplished without any problems. The polyester bit guide positioned beneath the tensioning tool centered itself as the tensioning tool was lowered into the casing hanger jay-slots. The bit guide was dropped into place by retrieval of the wireline go-devil. Effortless reentries with the guide in place of the smaller 6-3/4-in. (17.2 cm) string confirmed that the guide was providing proper clearances.

Future modifications should include reducing the go-devil in size and using a softer spring in the XCB latch in order to allow complete passageway through the WKM (WKM Industries) valve and wireline packer assembly situated on the Varco top drive. This modification would require the flipper dogs on the deployment tool to be adjusted to compensate for the reduction in the go-devil ID.

The bit guide was also recovered from the throat of the casing hanger with a tool fashioned similar to a hook-type spear. This operation was necessary on Leg 142 in order to have access to the landing seat once it was determined that the 10-3/4-in. (27.3 cm) lower sub had been lost beneath the casing hanger. The bit guide provided an easy fish, especially with the thick polyester skin allowing the hooks on the spear to catch the guide once the fishing tool was pulled back after being initially pushed through. The guide was speared on the first attempt and was recovered back to the ship. There was only surface damage on the guide which could easily be ground or filed before being re-deployed. This concept of recovering the bit guide/centralizer ring so that 11-3/4-in. (29.2 cm) casing strings may be installed through the casing hanger after initial RCB/DCB operations are suspended, could become standard operating procedure once the hard-rock base is phased into the ODP hardware inventory.

7-1/4-in. Center-Bit Retrieval

The scheme and hardware devised to retrieve the large center-bit assembly was tested in both retrieval scenarios. Some initial problems with centralization of the wireline overshot assembly inside the 7-3/8-in.-ID (18.7 cm) primary DI-BHA allowed about 1.5 days to elapse before the center bit could actually be caught. Several factors may have contributed to the misalignment of the overshot and pulling neck of the center-bit latch. The problems cited were:

1. Catenary effects of the drill string being slightly offset from the base.
2. Small diameter (1.75 in. [4.45 cm]) of the RS pulling neck on top of the modified XCB latch inside the 10-3/4-in. drill collar.
3. Top drive is unable to accept a sinker-bar assembly larger than 3.5 in. (88.9 mm).
4. Sinker bar is too short to allow the 3.5-in. (88.9 mm) diameter to partially remain inside the 4-1/8-in.-diameter (10.5 cm) section of the recovery string.
5. Borehole may be slightly deviated.

Three of the five misalignment problems were dealt with effectively, which resulted in the pulling neck being caught by the overshot. Modifications were made to the overshot to provide a larger target area. This was accomplished by adding a 3.5-in. (88.9 mm) short-throat-diameter funnel to the bottom of the 2.25-in. (5.7 cm) overshot. The other corrections that allowed capture of the pulling neck were vessel offsets around the base to reduce the catenary of the drill string and the addition of a longer sinker-bar assembly to keep the 3.5-in. (8.89 cm) diameter centered inside the 4-1/8-in. (10.5 cm) bore.

Once the latch was engaged, overpulls of 5–6 kips (2.3–2.7 T) were tried but were unsuccessful. Circulation of water into the drill string to clear any fill which had settled around the latch was also not very effective. This technique failed because most of the pressure available was lost through the oil-saver packing rubber and the majority of flow was routed out the lower slots in the upper latch sub. The overshot was jarred off and the retrieval string pulled in an attempt to obtain the center bit by an alternate plan.

The lower latch sub attached to the end of a 6-3/4-in. (17.2 cm) drill collar was then used to engage the center-bit assembly. The operational plan for this technique is outlined in detail in the "6-3/4-in. Back-off Sub" subsection and illustrated in Figure 57. The primary advantage of this technique is that it provides a better opportunity to reestablish circulation around the latch and remove any fill which might be impairing the retrieval process. This method also allows the latch to be pulled with the drill pipe in place of a wireline overshot. This alternative method proved effective in clearing the sharp volcanic glass from around the latch. With circulation established, approximately 5 kips (2.3 T) of overpull were required to break the latch free. As soon as the weight fell off the load indicator, the latch was pulled out of the DI-BHA and mini-HRB. The VIT was used to confirm that all the latch components were still attached before tripping the drill string. The stripover recovery method proved effective and was easily initiated between the driller and wireline operator.

Centralization Scheme

The centralization scheme devised for the primary DI-BHA system was modified slightly in actual practice due to the fine cuttings and fill that were continually plaguing the hole-cleaning operations. The nose of the slip joint was removed in anticipation that cuttings could fill in behind and capture the slip joint within the 10-3/4-in. (27.3 cm) back-off sub. Approximately 6-in. (15.2 cm) of mandrel still protruded beyond the end of the slip joint after the nose section was removed.

Upon reentering the cone, the centralization string appeared to go all the way to bottom of the hole, indicating a clear hole. However, because the top drive was too close to running out of travel in the guides, the latching operation/space-out was aborted and the string pulled up so that a 5-ft (1.52 m) pup joint could be added. During the time the pup joint was being added, the 6-3/4-in. (17.2 cm) centralization string and 7-in.-OD (17.7 cm) slip joint continued to stroke inside the 10-3/4-in. (27.3 cm) backed-off BHA. With the addition of the pup joint complete, an attempt was again made to lower the string into the jay-slots to check for proper space-out dimensions.

The casing was reentered but it was obvious that the jay-tool was not properly aligned in the throat of the casing hanger from observation with the VIT. The tensioning tool continued to sit on the lip of the casing hanger despite repeated attempts to rotate the tool. Problems with proper vessel alignment were known from earlier attempts with latching into the jay-slots. Attempts to offset the vessel in order to help the tensioning tool fall into the jay-slots were unsuccessful. It was suspected that a combination of two or more factors prohibited the tensioning tool from dropping into the jay-slots. These factors were:

1. The addition of tapered stress in the string added to the misalignment by bowing every time any appreciable amount of weight was placed down onto the tensioning tool.
2. Currents and catenary effects kept the tool on one side of the cone.
3. Fill was introduced into the bottom of the 10-3/4-in. (27.3 cm) back-off sub by the hypodermic effects of the 6-3/4-in. (17.2 cm) string and 7-in. (17.7 cm) slip joint heaving inside. This prevented the centralization string from having enough clearance to land out and allow the tensioning tool into the respective jay-slots.
4. Potential damage to the jay-slots from drilling operations.
5. The back-off sub and landing seat moved upward, preventing the jay-tool from bottoming out.
6. The borehole was slightly deviated.

The attempt to space out the mini-riser was aborted after trying for 4 hr to offset the vessel in order to get the tensioning tool to drop into the jay-slots. Once the assembly was on deck, the only positive indication on the hardware of what may be causing the problem was that the slip joint had been jammed shut, apparently indicating that fill was up inside the bottom of the 10-3/4-in. (27.3 cm) cased hole. The jamming problem was caused when 6 in. of exposed mandrel was pushed into the slip joint body, causing it to stick together. The problem was corrected by freeing the mandrel and attaching a stop ring to the mandrel so that the retainer plate could not come into contact with the top sub. The dogs on the tensioning tool were again checked and found to be in gage. However, some additional beveling on the sides of the dogs was performed to ensure that they were not causing the problem.

The assembly was again run into the hole but this time with almost 4 m of fill found in the bottom of the 10-3/4-in. (27.3 cm) string. Using low pump pressures, the assembly was finally washed down less than 12 in. (30.5 cm) above the bottom of the jay-slots. Repeated attempts to jay into the slots were unsuccessful. The operation was again aborted and the string was pulled out of the hole. A 20-bbl slug of 12-lb/gal (34.3 kg/cm) mud was spotted in the hole as a means of preventing the hole from being refilled with additional cuttings. Observations made on deck of the tensioning tool and crossover sub revealed that the crossover sub was bottoming out on the bit guide. Eight distinctive marks on the diameter of the sub matched the pattern of the grooves on the bit guide. The problem was not that the back-off sub and bit guide were too high but that the large-diameter neck on the crossover sub was machined improperly. This allowed the crossover sub to bottom out on the bit guide, preventing the tensioning tool full access into the jay-slots.

In an attempt to correct this deficiency, the upper latch sub used to deploy the bit guide was modified to replace the crossover sub. The flipper dogs were removed and the slots welded shut. The assembly was then run back to bottom without any fill being found in the hole. The reentry took less than 5 min, with the latching into the jay-slots complete several minutes later. A 50-kip (22.7 T) overpull was held approximately 30 min to check for space-out of the mini-riser and to allow another slug of heavy mud to be displaced into the borehole. Approximately 1-1/2 days were lost before the machining error was discovered and corrected.

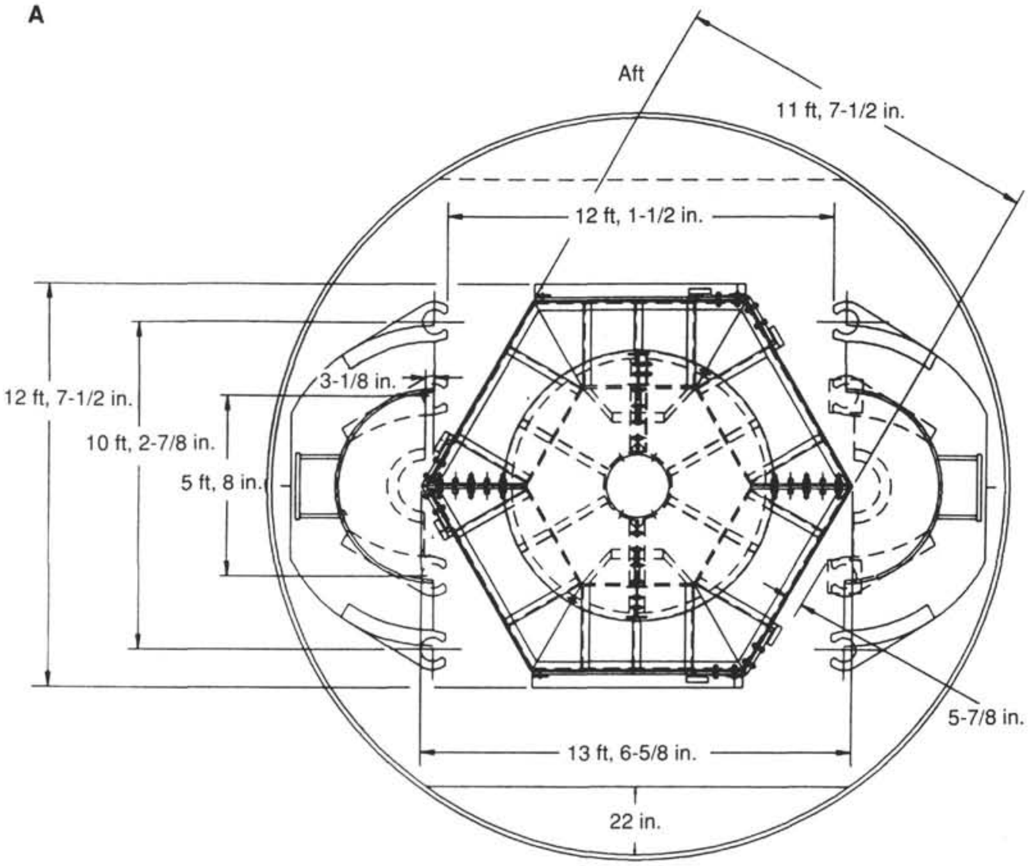
Once the tubing was run the stripover operation begin. The final stage required the slip joint to be again placed into the bore of the 10-3/4-in. (27.3 cm) DI-BHA until the final length of drill pipe could be lowered to latch the tensioning tool into the jay-slots. During the stripover operation the slip joint and centralization string were heaving inside the DI-BHA. Visual observation with the VIT confirmed that the centralization string was free-floating inside the 10-3/4-in. (27.3 cm) string. The time required to make the final connection during the stripover operation should have required less than half an hour; however, several joints of DCS tubing were dropped, which caused a delay of several hours.

After about 2 hr, the centralization string begin to bottom out or hang up on something inside the DI-BHA. It was surmised that fill was again being introduced into the 10-3/4-in. (27.3 cm) casing by the heaving action between the 7-in.-OD (17.8 cm) slip joint and the 7-3/8-in. (18.7 cm) bore of the DI-BHA. This was confirmed once the stripover operation was completed and the drill pipe was being lowered into the borehole. Approximately 13.1–16.4 ft (4–5 m) of fill were again present, confirming that the hypodermic effects of the inner string caused the fill to reappear. The mud pump on the DCS platform was used to wash out the fill before the centralization string and tensioning tool could be lowered to bottom. Two 30-bbl slugs of prehydrated bentonite were used to help remove the fill.

Once the centralization string was in place, DCS pumping tests to establish baseline flow rates were initiated. Circulation was lost between the annulus of the 10-3/4-in. (27.3 cm) string and the centralization string during recovery of a core barrel when a sudden rise in pressure was noted. The barrel apparently was pulled too fast, resulting in swabbing of the flow path between the annulus. This was confirmed when an attempt to stroke down with the tensioning tool was unsuccessful while trying to reestablish the flow path.

At this point, the only option left short of abandoning the mini-HRB was to reconfigure the mud pump manifold to allow the returns

A



B

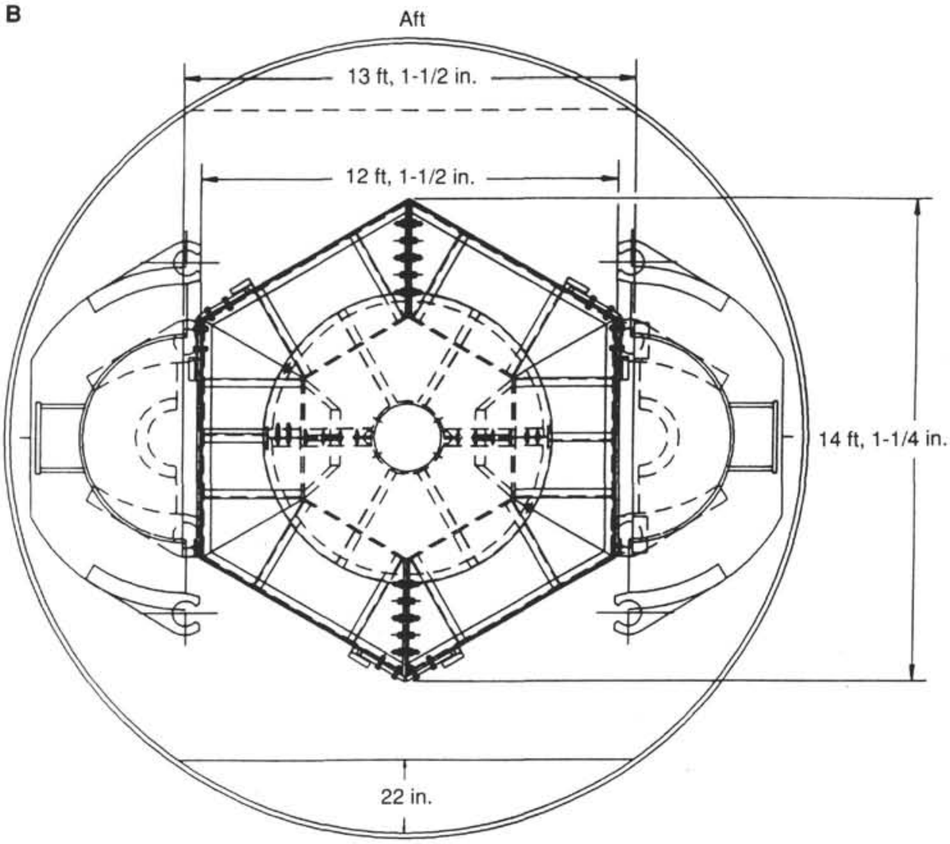


Figure 46. **A–B.** HRB clearance through lower guide horn. Figure 46B illustrates worst case geometry.

from the DCS to travel up the mini-riser and back to the *Resolution*. This operation, although risky, proved successful. As returns were being circulated up the riser the DCS core barrel with center bit was advanced. Secondary heave compensation was not attempted during this process since seas and weather conditions were favorable for washing the fill out of the hole. Approximately 23 ft (7 m) of fill were recorded inside the centralization string which had been brought in by the initial core barrel swabbing the hole. Once the bit passed the end of the slip joint, cuttings began to appear from the throat of the cone. This provided a positive indication that the original flow path was reestablished and that the tensioning tool was probably free to move. Several times during the cleaning process, complete circulation was lost back to the ship along with a significant loss of pressure.

Since it appeared that the circulation path could be cleaned out with the DCS string at any time by circulating beneath the slip joint, DCS coring was initiated. It was hoped that at least one bit run of 65.6–164 ft (20–50 m) could be drilled in the worst case scenario even if the tensioning tool could not be unlatched and the hole had to be abandoned. However, the secondary compensator on the DCS platform had trouble adjusting to the pressure differences brought on by the flow paths constantly changing between the two different annuluses. It is hypothesized that this varying pump pressure may have contributed to a variable string weight which caused the secondary heave compensator to damage the bit by not being able to properly maintain a constant weight. Several instances in this short coring run of less than 1 hr were recorded where the bit actually came off bottom. The core run was ended prematurely by a sudden pressure increase, indicating a core blockage. However, once the core barrel was pulled it was obvious that the core bit was totally destroyed since the tip of the core-lifter case was missing a 1/4-in. (6.35 mm) section. The core-lifter case on the core barrel is positioned approximately 1 in. (2.54 cm) behind the face of the bit crown. For the core-lifter case to be damaged, the whole bit matrix and part of the bit body had to be missing. At this point there was no alternative left but to attempt to unlatch from the casing hanger.

The core barrel was positioned well inside the slip joint before an attempt to unlatch was initiated. The procedure was accomplished without the pumps needing to clear any additional material beneath the slip joint. It appeared that the recirculation established with the core bit was successful in removing the cuttings well enough beneath the slip joint and around the annulus to allow the tensioning tool to unlatch.

Diamond Core Barrel

The DCB was never put into a position where it could be actually be operated as designed. It was used to spud a hole on bare rock on one occasion and wash through 19.7 ft (6 m) of fill on a second occasion before coring. The three levels of integral blade stabilizers (near bit, mid body, and upper) were designed on the barrel to be run inside a cased and stabilized hole and not to be rotated through the casing hanger or the 7-3/8-in. (18.7 cm) bushing as attempted during Leg 142. The passage of the stabilizers though the tight confines of the bushing without sufficient rat hole beneath and without being able to place any significant weight on the bit diminished any chance whatsoever of the core barrel succeeding. It is recommended that the barrel not be run in future applications without the whole barrel being beneath the seafloor or unless the square-pad-type stabilizer are replaced with either slick-walled subs or spiral-type stabilizers. It is hoped that another opportunity will arise in the near future where the core barrel's full potential can be realized.

Suggestions for Improvements

Much of the supporting equipment designated as sub-assemblies to the mini-riser are new to the DCS seafloor hardware and still in the first phase of testing as prototype equipment. The break-away tension safety joint, which replaced the shear bolts in the stress-joint flange, underwent extensive laboratory testing before being put into operation. All of the equipment and schemes devised to supplement the DCS were eventually made to work as designed. Several improvements are cited along with additional hardware requirements noted in the following sections.

Tapered Stress Joint

Bolt untightening during deployment of the bit guide and recovering the center bit were again observed during Leg 142 despite using a thread-locking compound. The bolts were originally tightened to 900 ft-lb (1170 Nm) of torque using a star-pattern sequence. After the first deployment, the bolts were tack-welded to the stress joint flange. While this procedure is not ideal, it again served the purpose preventing the bolts from backing out. Additional research into flange and bolt connection design is needed to determine if a better approach can be adopted for preventing loosening of the connection bolts.

Tensioning Tool

Based on the level of difficulty experienced in aligning the square dogs into the casing hanger it is suggested that other running-tool options be investigated. There are several other types of tools on the market such as the cam-actuated types that might provide a better, more positive means of engagement for deeper water depths with less accurate positioning required. This type of running tool also requires less overall length in which to operate. The present jay-slot requires the tool to be stroked down 22 in. (55.9 cm) before being rotated 90° to reengage the dogs. This length was designed into the system so that the jay-slots would function similar to a bumper sub during the reentry process. The shortened length of the cam-type tool is an added benefit when several string of casing are nested together. Another possible solution would be to replace the square-shouldered dogs and jay-slots with either rounded or diamond pattern configurations. The older style square jay-type tools were adopted for the prototype equipment developed for Leg 132 since much of the conventional running tool hardware was already existing on the *Resolution*. Future modifications to casing hanger might include a dual latching/running system where either the older style jay-slots and possibly the newer cam-type tool can be run. This would allow the jay-slot to be used as back-up until the cam-type latch can be fully implemented. The cam-actuated device might possibly be positioned above jay-slots in the upper throat of the existing casing hanger where the latch rings for the 11-3/4-in. (29.9 cm) casing now reside. Discussion with manufacturers should be initiated in order to investigate if both types of latches can be designed to work together. The cam technology would require a large comment on the part of both ODP and SEDCO to modify all associated hardware which presently work with the square shouldered jay-type tools.

Break-away Safety Joint

The only complaint concerning the break-away safety joint was that the length needed to be slightly longer on the lower section to facilitate use of the hydraulic pipe make-up device aboard the *Resolution*. An additional 6 in. (15.2 cm) would be sufficient to accommodate this piece of hardware. The safety joint operated a total of 148 hr with 50 kips (22.7 T) of tensile overpull. As discussed in the earlier section on equipment design, the shear pins are susceptible to fatigue failure if the tool is subjected to wide variance of load while being held in tension. It is suggested that the tool actually used in the field be again tested in the laboratory to determine if the shear pins have been weakened from any fatigue experienced during operation.

Bit Guide

As mentioned above in the "Bit-Guide Deployment Scheme" subsection, there were no real problems associated with either de-

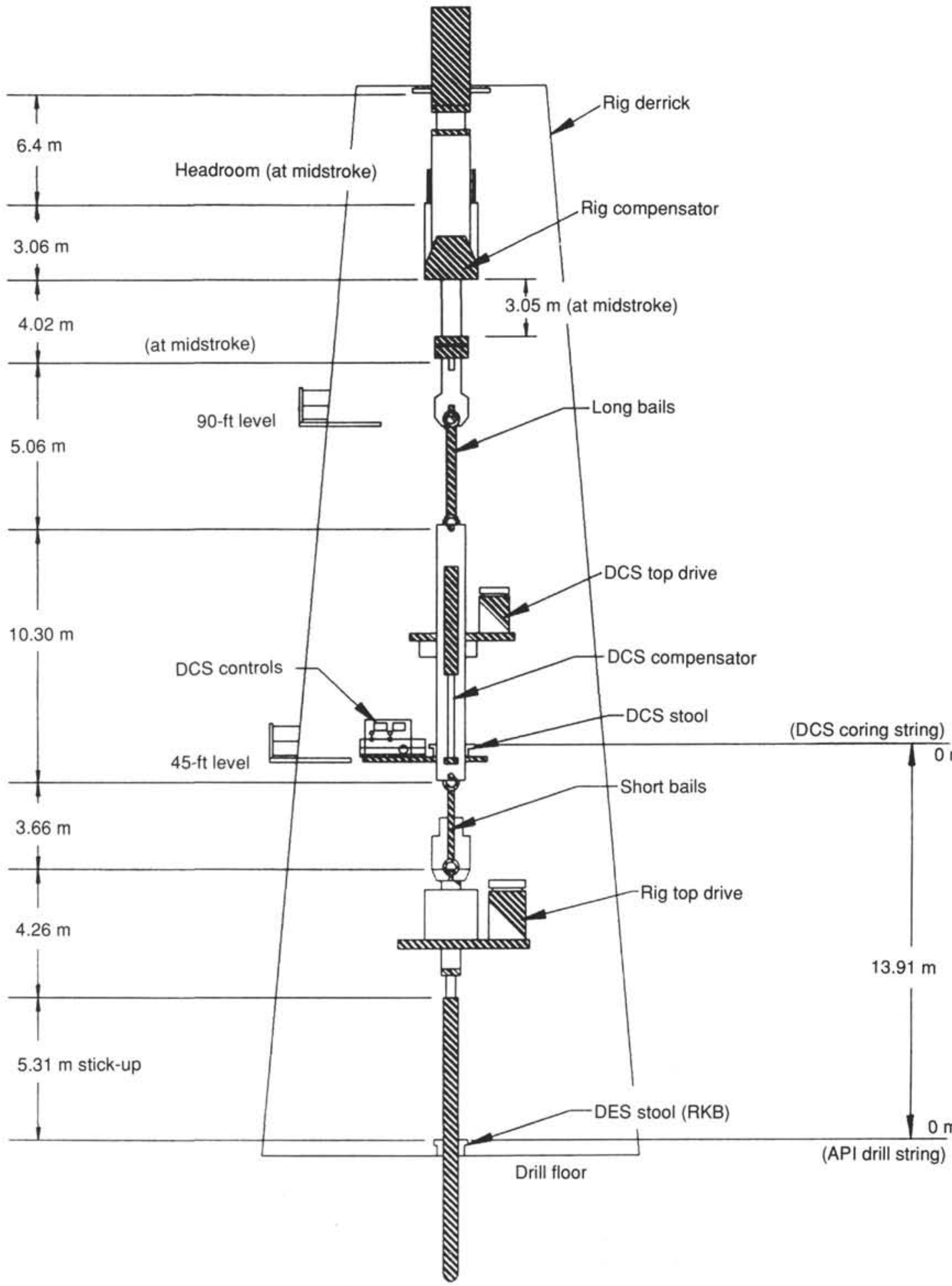


Figure 47. DCS derrick stack-up.

ployment or operation of the bit guide. Additional weight might be added internally to reduce the potential for dislodging the guide during times of high flow rates and to prevent the guide from riding up on the deployment tool due to excessive surge while being lowered through the moonpool. The overall length-to-diameter ratio (1:3) proved satisfactory in that the bushing did not become stuck or hang up in the casing hanger during reentry or once dropped from the deployment tool. The upper throat might be shortened 1 to 2 in. (25.4 to 50.8 mm) on future bit guides in order to eliminate some of the lateral movement the guide could experience when held in position against the tensioning tool. A tool should also be develop to retrieve the bit guide should access to the 10-3/4-in. (27.3 cm) string be required. Some difficulty was experienced in getting the go-devil and latch assembly through the top drive and WKM valve during retrieval operations. The problem appeared to be not so much the diameter of the 4-in. (101.6 cm) go-devil as not being able to retract the dogs of

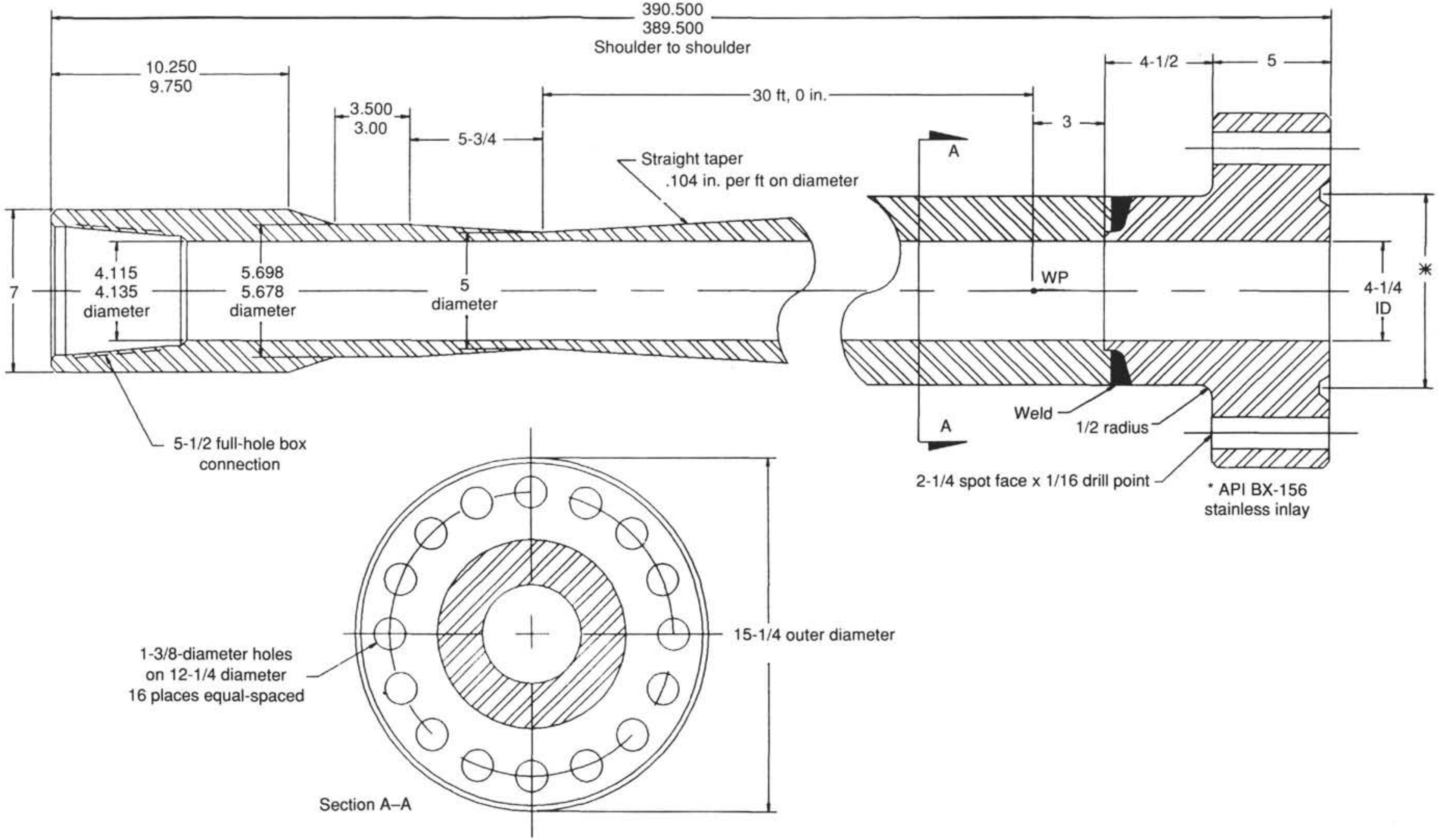


Figure 48. Tapered stress joint. Dimensions in inches unless otherwise noted.

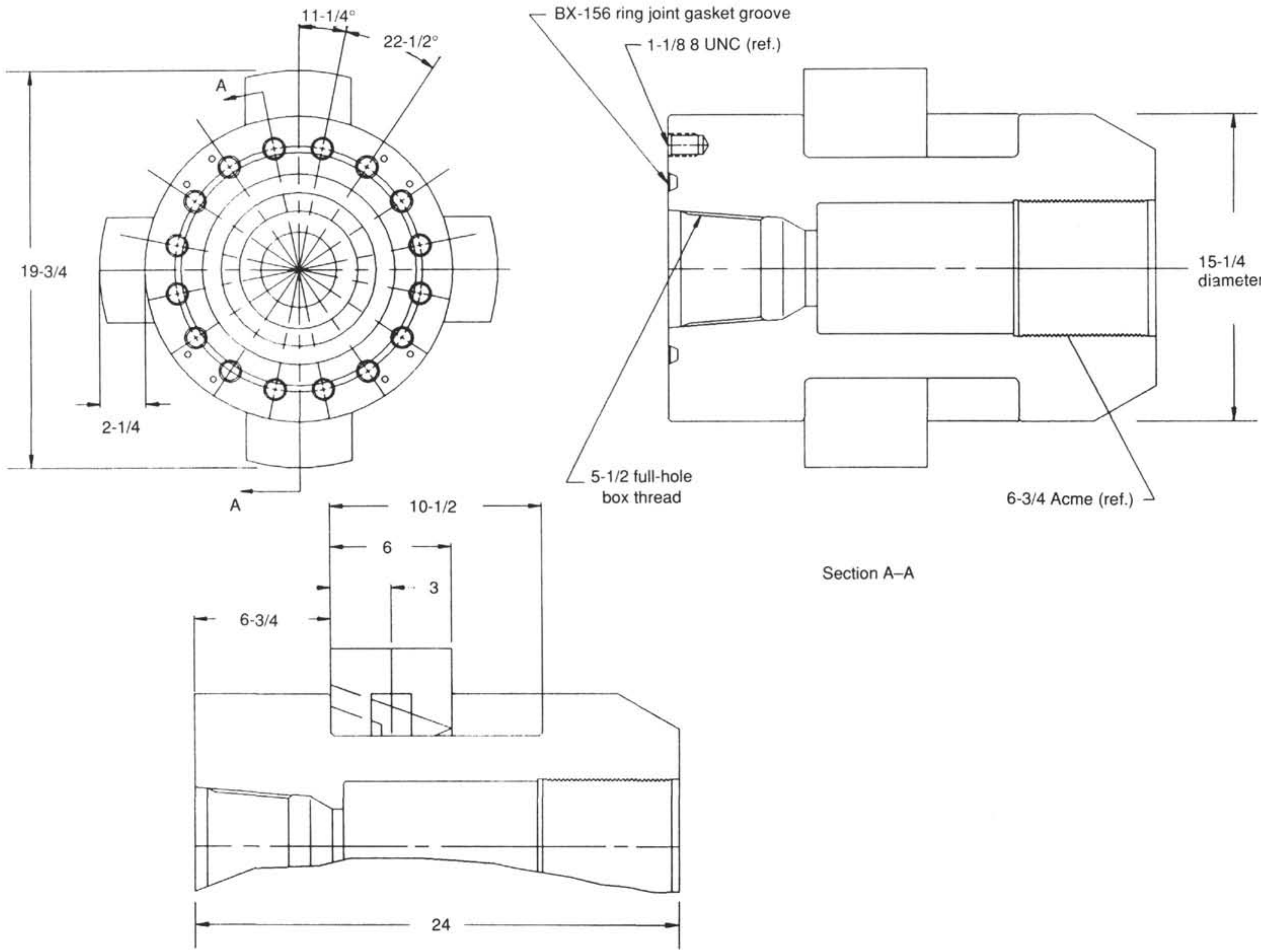


Figure 49. Tensioning tool assembly. Dimensions in inches.

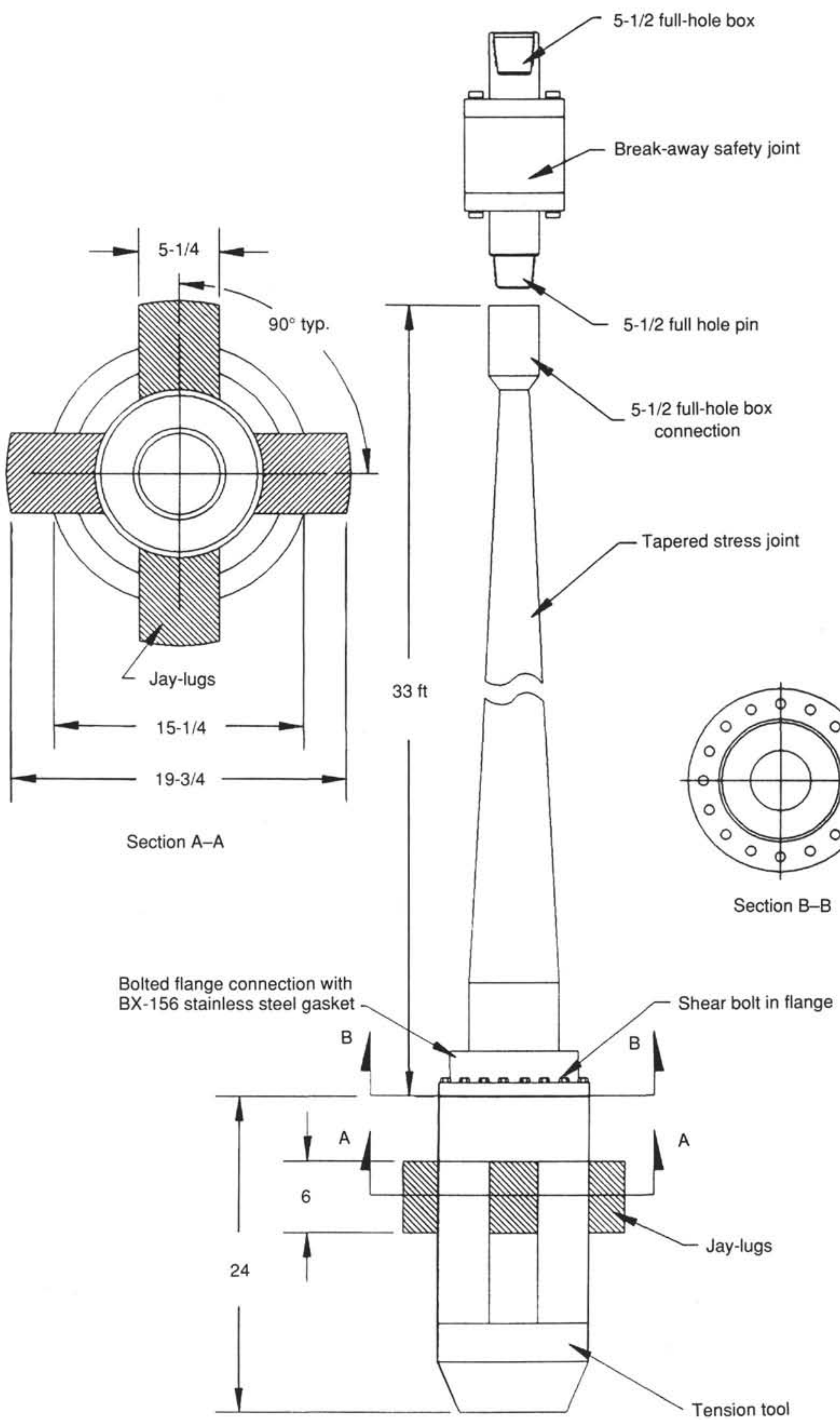


Figure 50. Tensioning tool with stress joint attached. Dimensions (in inches) are approximate.

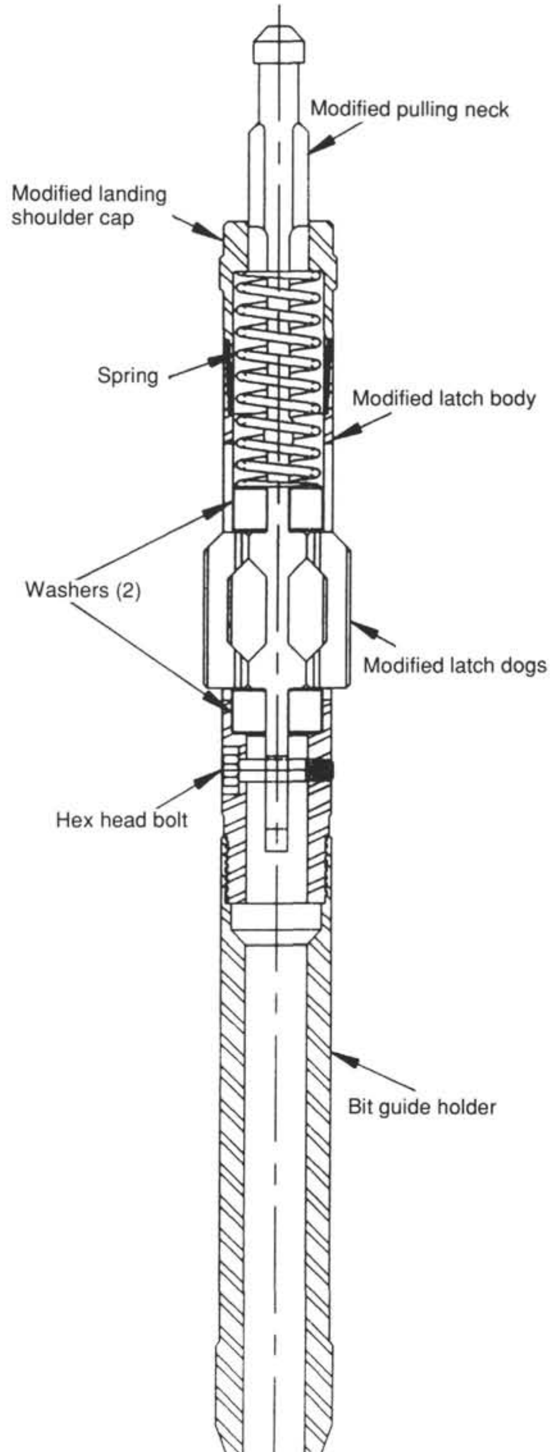


Figure 51. Bit guide release latch.

the latch itself. It is suggested in the future that the spring rate be changed so that this latch will open under its own weight and that of the bull-nose plug.

7-1/4-in. Center-Bit Retrieval Hardware

Both of the methods available to retrieve the center-bit latch were attempted during Leg 142. The second drill-string method proved the more successful of the two. However, the wireline retrieval method should not be ruled ineffective, as fill prevented the center bit from being pulled. Probably the most important aspect of the wireline method is that the time between deployment and retrieval should be kept to a minimum in order to limit the amount of material falling out of suspension and trapping the assembly downhole. One noted improvement might be a larger pulling head and overshot assembly to provide more centralization and a bigger target area for the overshot to catch. Another time-saving measure might be to add a latch cavity into the upper sub of the back-off assembly. This might allow the center bit to be retrieved immediately after the back-off nut has been disengaged.

The use of a small wash string is also recommended in place of the 6-3/4-in. (17.2 cm) drill collars for the purpose of flushing fill from around the center-bit assembly should the formation provide a medium for that condition to occur. High flow rates between the two strings are not possible due to the tight annulus of the 6-3/4-in. (17.2 cm) drill collars inside the 7-3/8-in. (18.7 cm) ID of the primary DI-BHA. Hydraulic pump-off occurred with flow rates greater than 80 strokes per minute (spm). Low flow rates were effective in removing the cuttings between the two strings. This technique was effective for the short assembly deployed on Leg 142; however, longer DI-BHAs may present additional problems where higher flow rates are necessary in order to carry the cuttings out of the hole.

Centralization Scheme

The scheme devised to provide centralization for the DCS tubing inside the 10-3/4-in. (27.3 cm) DI-BHA appeared to perform as designed. However, several minor problems were cited which will have to be addressed before the next DCS leg. The primary modification will be to either reduce the OD of the slip joint or to provide a fluted OD surface. It may also be wise to reposition the slip joint immediately beneath the crossover sub to the tensioning tool. This modification is necessary in order to reduce the potential of the slip joint for acting as a hydraulic piston. Presently, the space-out joints of the centralization string use the secondary stage 6-3/4-in. (17.2 cm) drill collars of the nested DI-BHA connected to the bottom of the tensioning tool. These space-out joints could also be substituted for a smaller diameter string which would reduce the piston effects during the time the centralization string must heave inside the bore of the primary DI-BHA. This smaller string could also be used as a wash/drill-down string for instances in which the DI-BHA may have filled with cuttings before pulling the large center-bit assembly or where the centralization string does not provide enough annular clearance for effective cutting removal.

Another possible solution for eliminating the piston effects would be to detach the centralization string from the bottom of the tensioning tool altogether. This would eliminate the problem of fill being sucked into the primary DI-BHA during the final stages of the stripover operation. This operation can be done now in the second stage of the DI-BHA; however, it would commit the second stage to being used for centralization in place of borehole stabilization. There would be no guarantee that the two strings could be separated if cuttings were to fill the annular cavity between the two strings. It is possible that using a smaller centralization string on the running tool and repositioning it higher in the string might be an easier, more effective option. If a smaller string is deployed in this mode, it will still need to be rotated and circulated through. The merits of both options should be investigated prior to the next deployment of the nested DI-BHA.

In addition to modifications to the OD of the slip joint, the hydraulic piston effects produced by the nose cone and body in its present form should be reevaluated if this concept is retained. Complete removal or redesign of the end section should be investigated before the slip joint is used again. Many of the problems and solutions described above are dependent on formation. Should the first stage be drilled into a massive rock where the hole is clean and

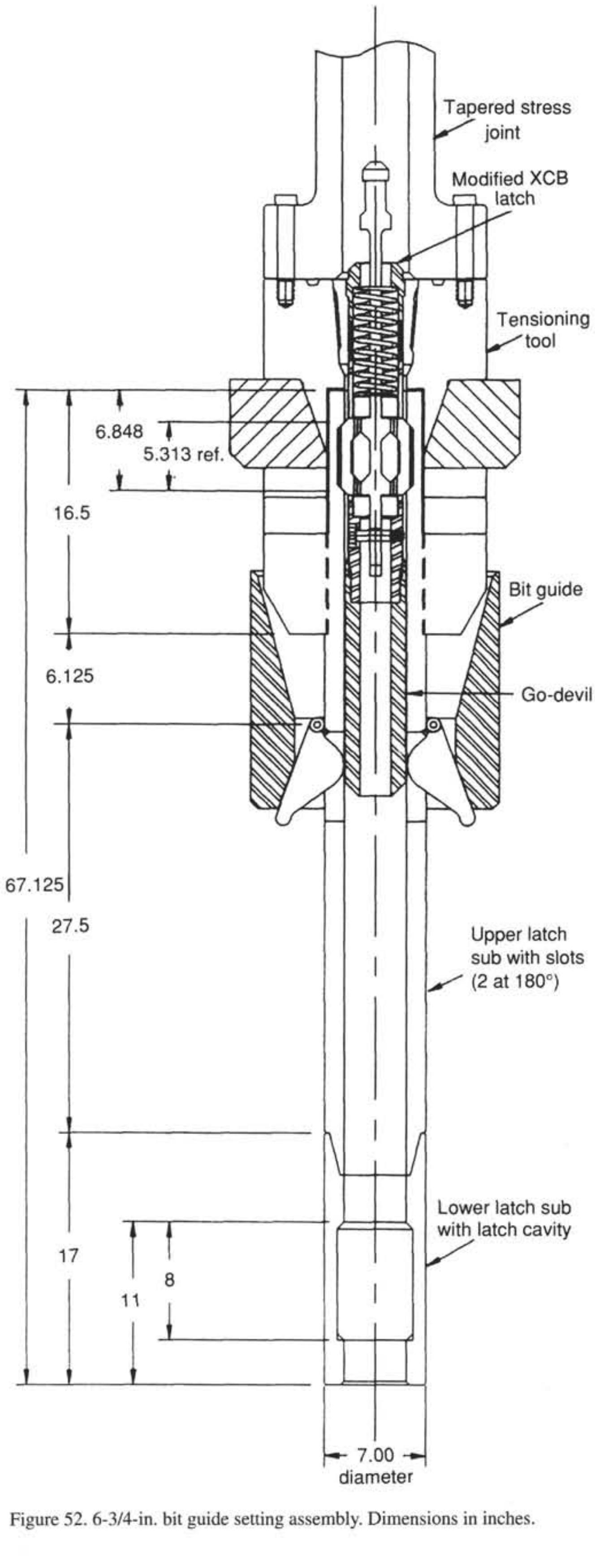


Figure 52. 6-3/4-in. bit guide setting assembly. Dimensions in inches.

free of cuttings and fill, the designed system might still be a viable option for centralization.

Diamond Core Barrel

The outer 6-3/4-in. (17.2 cm) core barrel itself fitted together perfectly and spaced out with the existing RCB inner barrel with only the adjustable latch sleeve needing to be shortened by 2 in. (50.8 mm). The float valve was used only as a spacer with the three flapper fingers left out at this time. The new lower support bearing allowed the barrel to land out and provided adequate flow around and through the bearing assembly. Total rotational time on the support bearing was over 5 hr without any noticeable wear. Aside from developing bits for different formation types, we will need to closely monitor the support bearing and float in the future to ensure that adequate strength is available for the rigors of offshore coring. Some additional types of bit subs and top subs with different stabilizer configurations might be added for running the barrel in other applications or formation types. Specifically these might include spiral blades and subs without any blades at all. One other area related to the DCB is the addition of a collet type of core catcher for the inner barrel to be run in tandem with ODP's standard eight-finger core catcher. A fixed cutter-style center bit should be investigated for use when initially spudding on bare rock.

BACK-OFF HARDWARE

A mechanical back-off sub was developed for Leg 132 which would allow a bottom-hole assembly to be drilled in, backed off, and left in the formation in one continuous operation. This new system developed for spudding on bare rock isolates the upper unstable portion of a formation. This drill-in hardware eliminates the need to set casing in the conventional manner. The back-off hardware proved to be extremely important in fractured formations in which material would refill into the borehole as soon as the bit was removed. A prototype version was tested during Leg 132 with good success. There were several areas identified that needed additional attention and refinement. Details of the back-off hardware have been described by the Leg 132 shipboard scientific party (Storms, Natland, et al., 1991). Additional details are given in the ODP in-house "Engineering and Operations Manual," along with a "Maintenance and Operations Manual" provided by Houston Engineers.

The back-off sub employs two splined subs that are held together with a large-diameter tapered locking nut. Inside the large nut is a smaller ring nut with an external key mated into the inner diameter of the tapered nut. The large tapered nut and upper splined sub are made up onto the lower sub by screwing the internal nut onto the lower sub and making up to the proper torque requirements. An exploded view of the 10-3/4-in. (27.3 cm) back-off sub is illustrated in Figure 62.

The sub is then drilled into a casing hanger where the large tapered nut comes into contact with a mating tapered receptacle termed a landing seat. As the two surfaces (tapered nut and landing seat) come into contact and lock together, the internal nut begins to unscrew and rides up the keyed shaft inside the tapered nut as the BHA continues to rotate. Depending on rotational speed, the internal nut completely unscrews within a few seconds. At this point, rotation can be discontinued and the upper sub picked up, leaving behind the lower sub and remaining BHA. Both a pressure drop and weight loss are noticeable as the two subs separate. A schematic of the back-off operation is presented in Figure 63.

The larger sizes of the back-off sub are drilled in with a positive displacement coring motor (PDCM), which puts out approximately 6160 ft-lb (8008 Nm) of torque. The back-off nut is made up to slightly less than 6000 ft-lb (7800 Nm) of torque so that the motor will unscrew the back-off sub as soon as contact is made. As a preventive measure against insufficient torque, the PDCM is equipped with a positive lock-out device that allows the motor shaft to be locked out so that the

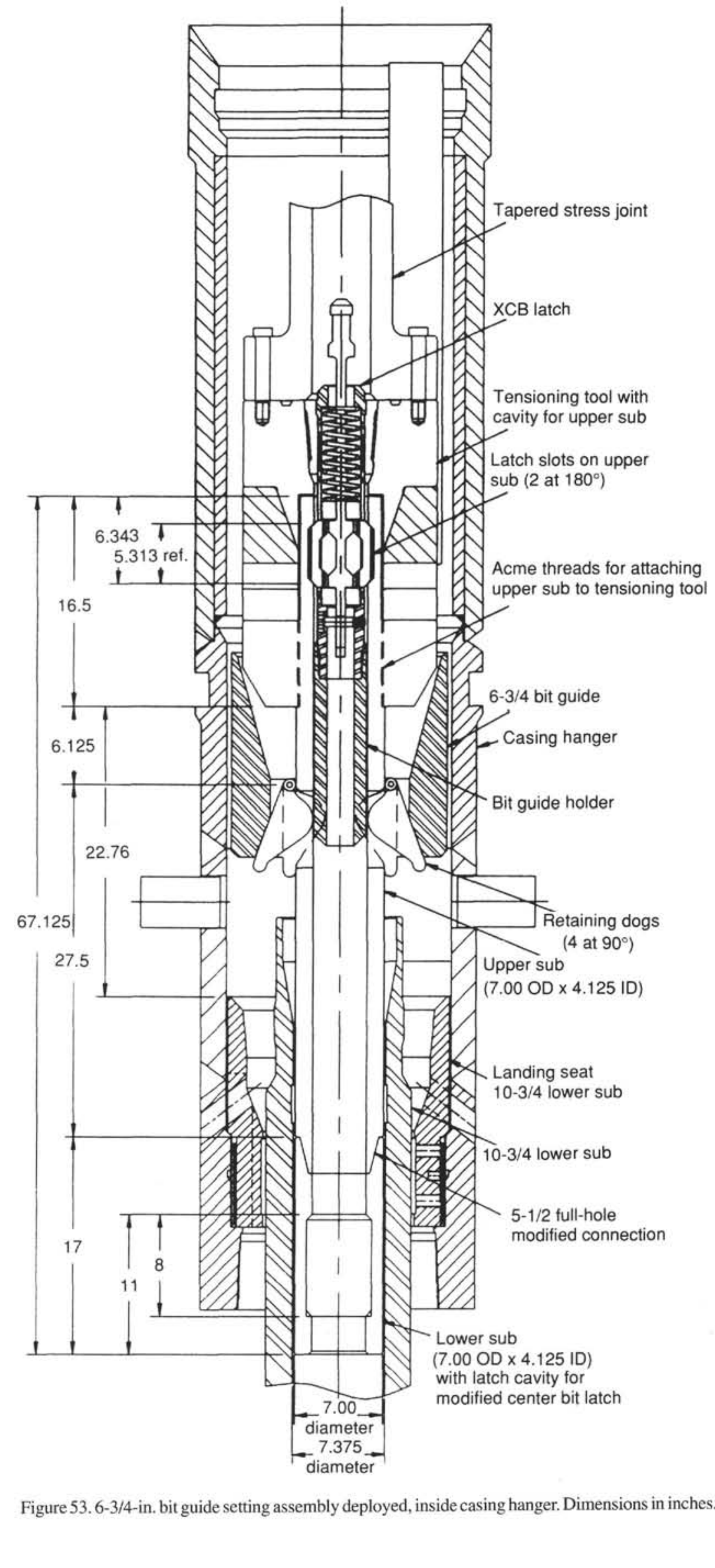


Figure 53. 6-3/4-in. bit guide setting assembly deployed, inside casing hanger. Dimensions in inches.

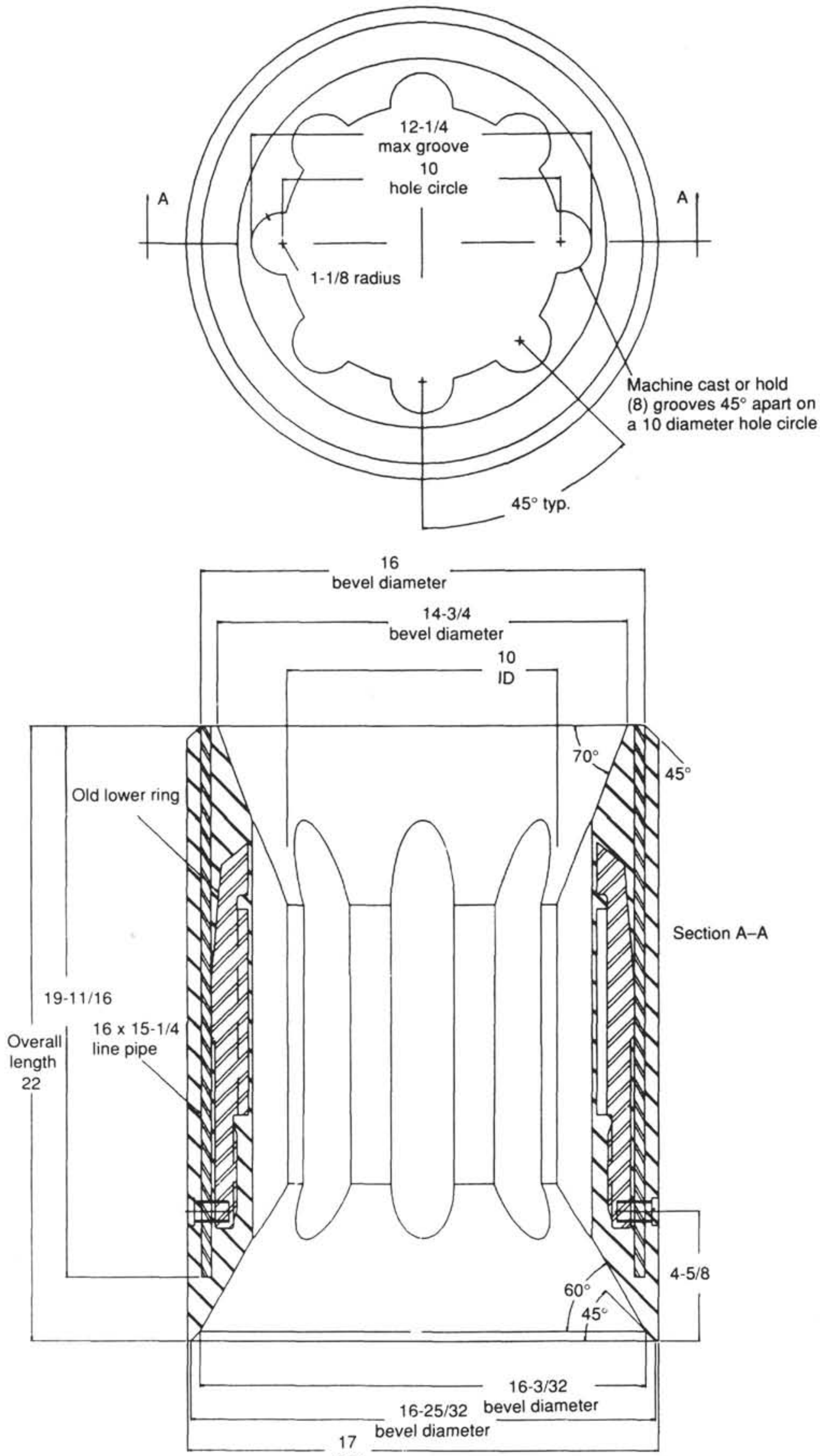


Figure 54. Bit guide. Dimensions in inches.

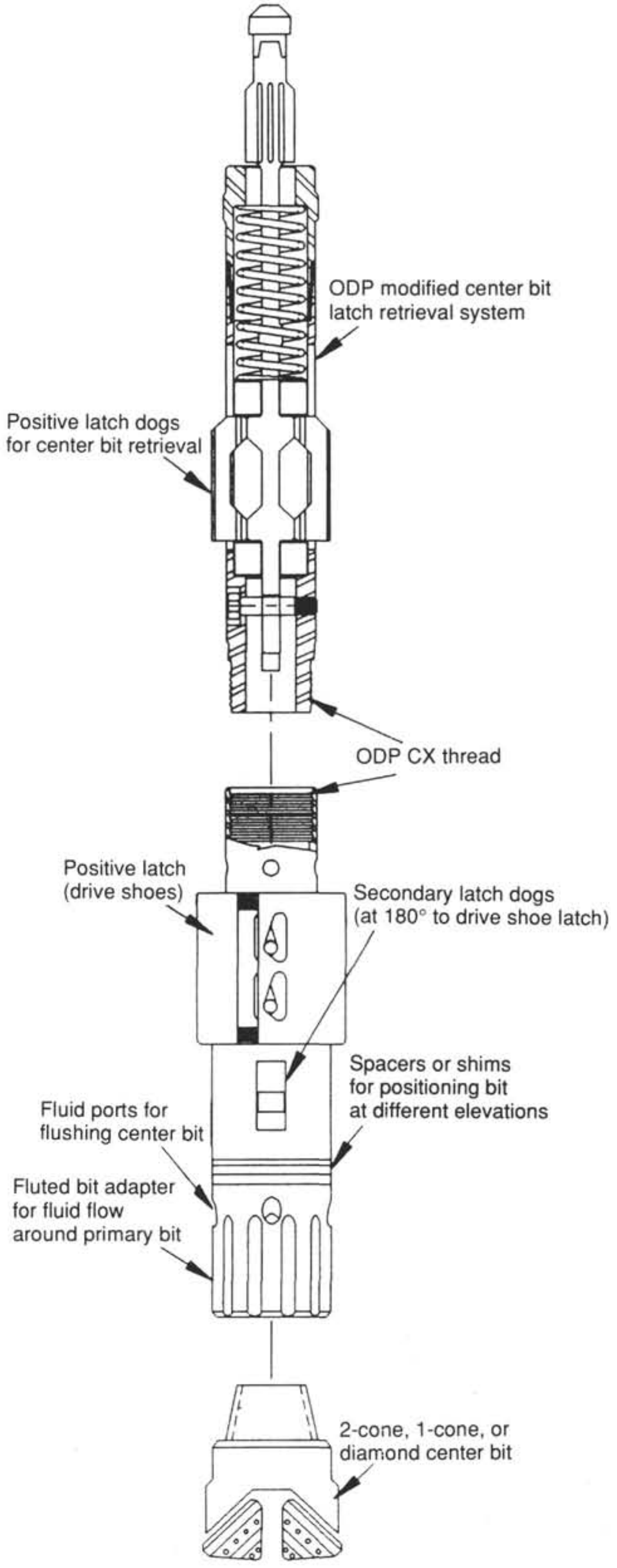


Figure 55. 7-1/4-in. center bit latch assembly.

top drive on the *JOIDES Resolution* can be used to unscrew the back-off sub. The maximum output of which the Varco top drive is capable is approximately 33,000 ft-lb (42,900 Nm). The torque limit of the PDCM when locked out is approximately 20,000 ft-lb (26,000 Nm).

Original Design

Two sizes were made for the initial prototype evaluation on Leg 132. These included a 9-7/8-in. (25.1 cm) and 11-5/8-in. (29.5 cm) size. The back-off subs were identical except for the lower drill-in sub portion that was to be left in the seafloor. The hardware was compatible with existing drill collars and crossover subs aboard the *JOIDES Resolution*. The bore through the back-off sub maintained an inner diameter of 4-1/8 in. (108 mm). This inner diameter of the back-off sub would accommodate the 3.96-in. (100.6 mm) DCS core bit to pass without any interference. Both of these back-off subs have been retained as a back-up system to the newer nested system. These two systems are presented in Figure 64. Modifications made to the original hardware included:

1. Extending the upper stabilizer to cover more of the tapered nut in order to reduce the potential of premature back-off,
2. Increasing the taper angle of the back-off nut and landing seat from 7° to 10°,
3. Adding a C-ring centralizer, and
4. Moving the C-ring groove lower on the landing seat so that an additional 3 in. (76.2 mm) of penetration was required after back-off had occurred before the C-ring would be activated.

Nested Design

After Leg 132, it was evident that a nested drill-in casing system would be needed if deep penetrations were ever going to be attempted with the DCS. The system developed was modeled after the original prototype version. Two sizes were selected that would be compatible with each other but still allow the DCS to be used with either system independently. System flexibility was a primary goal to be maintained throughout the whole design. The different seafloor spudding options available with the nested system are presented in Figure 65 with the different parameters and spudding options listed in Figure 66. The same modifications made to the original system were incorporated into the design of the nested hardware. Figures 61 and 67 present the different back-off subs available with the nested system.

10-3/4-in. Primary Drill-in System

The first or primary stage was designated as the 10-3/4-in. (27.3 cm) back-off sub. It could be used to anchor the guide base and provide enough rat hole for the DCS to be initiated at a shallow depth or drilled to a depth to isolate an initial fractured zone. The 10-3/4-in. (27.3 cm) back-off sub uses the same upper stabilizer components and nut of the original system but a different upper and lower sub. The lower sub has an ID of 7-3/8 in. (18.7 cm). This large ID was required to allow clearance for the 6-3/4-in. (17.2 cm) second-stage DI-BHA to pass. The 10-3/4-in. (27.3 cm) system used the same back-off nut and landing-seat arrangement (10° taper) as the smaller 11-5/8 in. (29.5 cm) and 9-7/8 in. (25.1 cm), even though the bore through the sub was substantially larger. A schematic in Figure 68 illustrates the 10-3/4-in. (27.3 cm) back-off sub landing and backing off inside the casing hanger. The compression load required to generate sufficient friction to back off the nut, assuming a coefficient of friction of 0.16, is 10,275 lb (4460 kg), based on a make-up torque of 6000 ft-lb (7800 Nm).

Because of the size requirements for the 10-3/4-in. (27.3 cm) system, a special thread was developed to accommodate the size of the connection. The thread uses the same form as a 6-5/8-in. FH-modified but scaled up to the larger diameter of the 10-3/4-in. (27.3 cm) drill collar. It was designated as the 10-3/4-in. RSC (rotary shouldered connection). The bending strength ratio of the connection was calculated as 2.5. Due the ID requirements for the 10-3/4-in. (27.3 cm) back-off sub, special drill collars and bit subs were also manufactured to be used as the drill-in BHA.

6-3/4-in. Secondary Drill-in System

The inner diameter throat of the lower sub for the 10-3/4-in. system was designed with a 10° taper. This provided a similar type of landing seat for the 6-3/4-in. (17.2 cm) second-stage DI-BHA to be backed off into, should hole conditions dictate that a second casing string be necessary to isolate downhole problems. The compression load required to generate the enough friction to back off the nut is approximately 18,365 lb (8330 kg), when assuming a coefficient of friction of 0.16 and a make up torque of 6000 ft-lb (7800 Nm). If the coefficient of friction is reduced to 0.08, the compression load increases to 36,730 lb (16660 kg) for the same amount of make-up torque. The 6-3/4-in. (17.2 cm) back-off sub was mechanically identical to the larger back-off sub, but only scaled down into a smaller version. The sub maintains the same 4-1/8-in. ID as the original system once the upper sub is removed. A 5-1/2-in. FH-modified thread was adopted for use with this system. This modified thread form has an extended pin length of 6 in. (15.2 cm). Bending strength ratios calculated at 2.5 for this connection were similar to the larger 10-3/4-in. (27.3 cm) connection.

The 6-3/4-in. (17.2 cm) sub could be nested inside the 10-3/4-in. (27.3 cm) hardware or drilled in independently. Figure 69A illustrates the 6-3/4-in. (17.2 cm) hardware being backed off in the throat of the 10-3/4-in. (27.3 cm) lower sub. Should initial drilling conditions prohibit the large 10-3/4-in. (27.3 cm) string from being successfully drilled in, the 6-3/4-in. (17.2 cm) string can be operated as the first or primary-stage drill-in BHA. Drilling centralization for the small 6-3/4-in. (17.2 cm) string can be accomplished by pre-installing a bushing into the landing seat before the guide base is lowered to the seafloor. A schematic of this set up is presented in Figure 69B.

The nested system can be run with or without a C-ring to lock the BHA into the hanger or outer casing string. Deployment without the C-ring allows the guide base to be stripped over the drilled-in BHA and moved to another location without having to return the guide base to the ship. Installation of the C-ring provides a permanent attachment to the guide base. This scenario may be required if the strength of the formation beneath the backed off portion is not sufficient to support the BHA. Both the landing seat, bushing, and the 10-3/4-in. (27.3 cm) lower sub have taped holes so that jack bolts may be inserted into the back of the C-ring grooves to compress the C-ring in order to disassemble the components, if retrieved.

Testing Program

A full-scale testing program was conducted at Houston Engineers' test facility with the nested system components. Four separate test were performed, two with each system, to confirm that the hardware operated as designed. The first test of each series was performed by gently lowering the back-off nut into the mating receptacle to simulate hard-rock drilling. The second test series was a bit more violent, with the back-off nut being jammed into the landing seat. The second test scenario might arise where a void is encountered or where loose material is drilled out rapidly. The 6-3/4-in. (17.2 cm) bushing was used on one test series where the 6-3/4-in. (17.2 cm) back-off sub was the primary stage. The other test with the 6-3/4-in. (17.2 cm) string was made by backing off inside the 10-3/4-in. (27.3 cm) lower sub. C-rings were used on all the test subs as another means to check alignment and the disassembly procedures with the jack bolts.

Both series of test confirmed the new taper angle (10°) prevented the matched surfaces (back-off nut and landing seat) from sticking. All dimensions and tolerances of the subs, landing seats, and accessory hardware were confirmed. The C-ring centralization scheme, using a wave spring behind the C-ring, was also verified in the testing program.

Performance

10-3/4-in. Back-off Sub

A 10-3/4-in. (27.3 cm) back-off assembly was selected as the first stage of the drill-in BHA to be run. The BHA was further composed of a 11-1/2-in. (29.2 cm) spiral bit sub and a 10-3/4-in. (27.3 cm) drill collar. Bit selection included a 12-1/2-in. (31.75 cm) roller-cone bit and a 7-1/4-in. (18.4 cm) 2-roller-cone center-bit assembly. Total length of the BHA below the back-off nut was approximately 24.5 ft (7.47 m). This length corresponded to a drill-in depth below seafloor of 20.5 ft (6.25 m). Because drilling conditions and rates were unknown the back-off sub was initially run without a C-ring so that the base could be easily moved should downhole conditions determine that the hole should be aborted.

Drilling conditions proved to be extremely hard on the volcanic flow area with penetration rates reported as low as 0.5 ft/hr (0.15 m/hr). The penetration rate was a direct function of the amount of weight that could be placed on the bit. Light bit weights in the range of 2–10 kips (0.91–4.54 T) were all that was possible without putting the BHA into compression. Compression loading on the BHA could severely shorten the life of the string or cause a sudden and catastrophic failure of the bottom-hole assembly. After 24 hr of rotation, the penetration rate had dropped to essentially zero, indicating that there was little left of the cutting structure on the bit. Total depth of penetration made in the 24 hr of rotation amounted to only 11.5 ft (3.5 m). Several times during the drilling operation, a 20 kips (9 T) of overpull were required to free the string. The bit was lifted off the bottom of the hole in order to re-tag the bottom as an indication of the amount of fill that might have to be contended with on the reentry. Little or no fill was recorded in the bottom of the hole.

The string was pulled so that the BHA could be shortened to 10.67 ft (3.25 m), which corresponded to slightly less than the amount of hole drilled in the first 24 hr. This allowed the shorter assembly (less than 10-ft drill collar) to be tripped back into the hole and backed off without additional lost time in attempting to drill out the remaining 9.84 ft (3 m) of the massive basalt flow. Review of the performance of the 12-1/2-in. (31.75 cm) 6-cone roller bit left little doubt that it was incapable of making additional penetration into the hard basalt. The bit returned with only one of 6 roller cones remaining. A mill and junk basket then needed to be run to ensure that the borehole was clear. The three hybrid wear pads placed 120° apart also appeared to have worn extensively. Complete discussion of the bit and center wear patterns, along with performance of the center-bit latch, is presented in a separate Leg 142 report. A 12-1/2-in. (31.75 cm) tricone bit was also run on the second attempt to guarantee the removal of any junk left in the hole after milling. The tricone bit immediately broke through the massive basalt and into sheeted, collapsed lobates, which could be drilled at a much faster rate than the basalt. The hole was then drilled down to a depth thought to be enough to run the original 20.5-ft (6.25 m) DI-BHA.

Several additional attempts were made with both a 12-1/2-in. (31.75 cm) tricone and another 12-1/2-in. (31.75 cm) 6-cone roller bit to deepen the hole from 10.8 ft (3.3 m) to an actual 20.67–21.65 ft (6.3–6.6 mbsf). Problems with fill and junk left in the hole from both bits accounted for several days of additional drilling/milling until the DI-BHA could be rerun. Only two 6-cone roller bits were brought on the leg and both had been damaged while attempting to drill to depth in order to back off the DI-BHA. The hole was finally deepened to approximately 21.65 ft (6.6 mbsf) with the 12-1/2-in. (31.75 cm) tricone bit. A heavy 12.5-lb/gal (1498 kg/cm) mud was pumped into the borehole in an attempt to stabilize the formation well enough to reenter with the DI-BHA. The original back-off assembly was de-

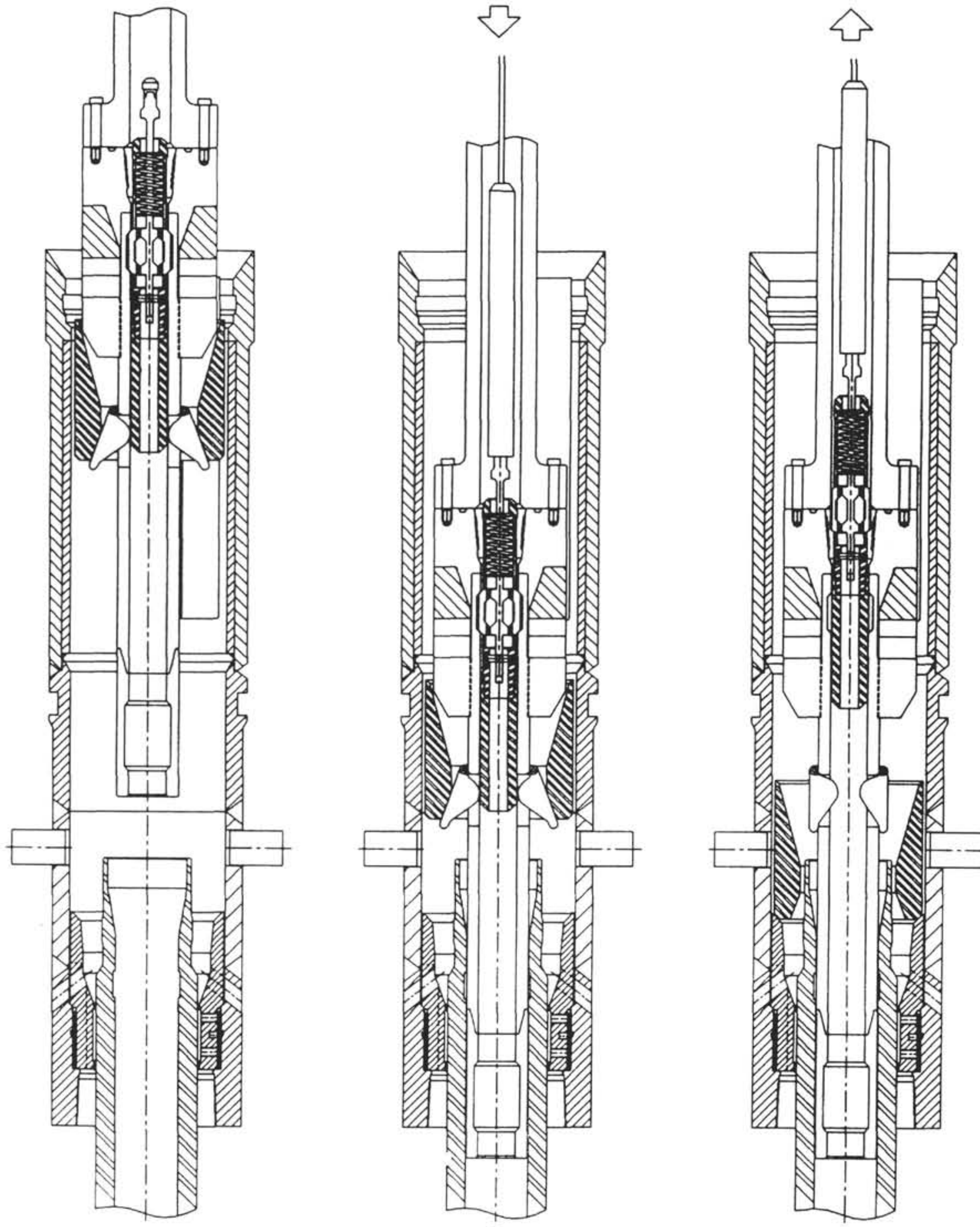


Figure 56. Deployment sequence for 6-3/4-in. bit guide assembly. Dimensions in inches.

ployed with a 10-3/4-in. (27.3 cm) slick-wall bit sub that replaced the 11-1/2-in. (29.2 cm) stabilized bit sub.

The DI-BHA was then deployed into the pre-drilled 21.65-ft (6.6 mbsf) hole. The PDCM was intentionally left out of the string since it was limited in the amount of output flow and it was unknown if high flow rates would be required to sweep the hole if fill were indeed found while attempting to get back to bottom. It was also thought that excessive amounts of pipe whip due to the operation of the PDCM at high flow rates might further aggravate the borehole walls to a point at which the hole might have to be abandoned.

The heavy mud placed in the hole before pulling out with the last tricone run allowed the BHA to be lowered all the way to the bottom

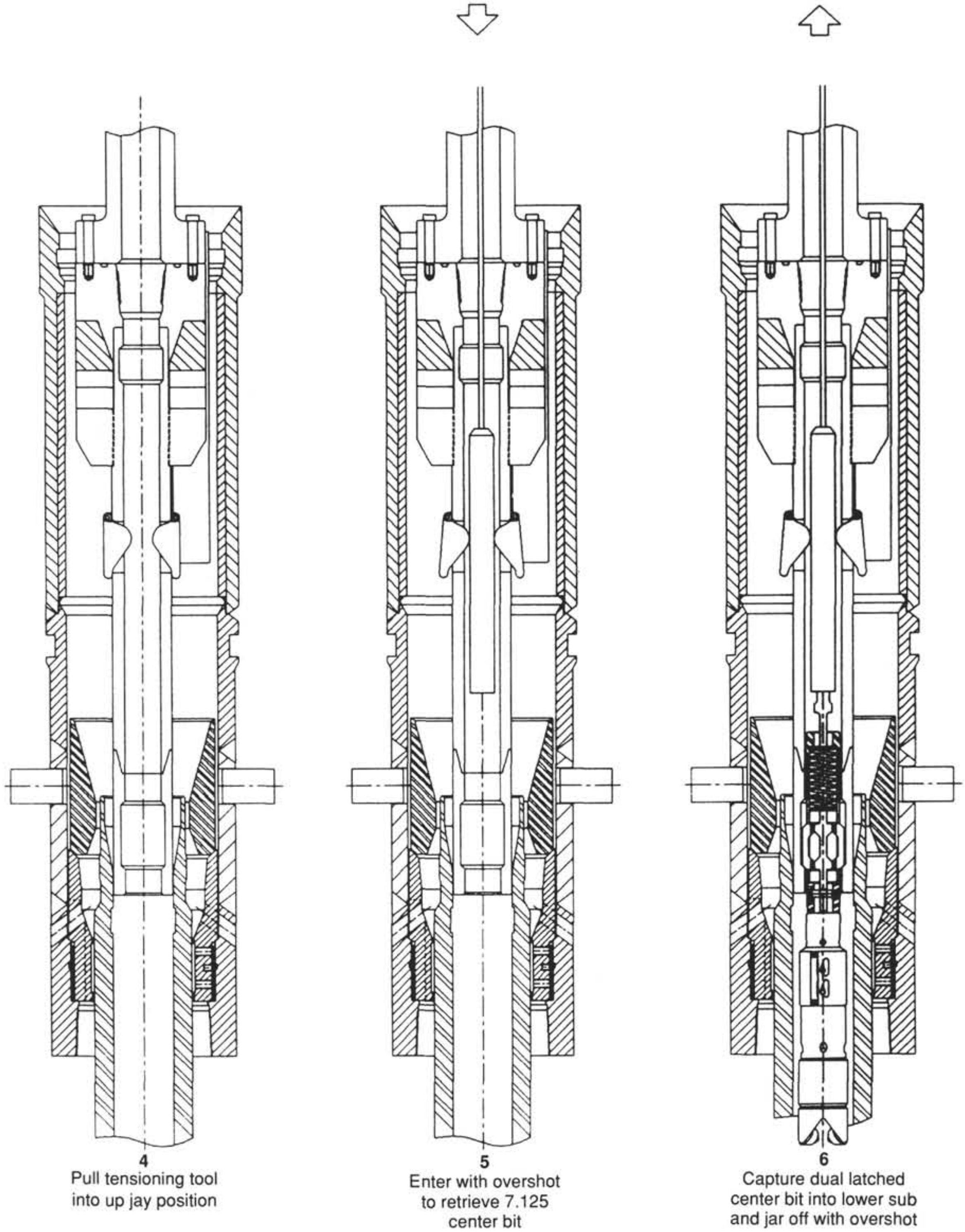


Figure 56 (continued).

of the hole without pumping. Once the back-off nut was seated into the landing seat the string was rotated with 4–6 kips (1.8–2.7 T) of weight down. There was no clear indication of the back-off nut separated at this weight. The weight was brought up to between 8 and 10 kips (3.6–4.5 T) and the drill string again rotated at 10 rpm. A pressure drop and sudden loss of weight indicated the back-off nut had parted. The drill string was then lifted out of the borehole. Confirmation of the correct back-off position was planned to be performed by reentering and tagging the landing seat. However, after nearly 1 hr trying to relocate the mini-HRB the operation was aborted. Several days later it was confirmed to have landed in the correct position.

In anticipation of the hole being slightly overdrilled to 21.65 ft (6.6 mbsf), the C-ring was installed onto the 10-3/4-in. (27.3 cm) lower sub. Since we were unsure if all the junk in the hole had been cleared,

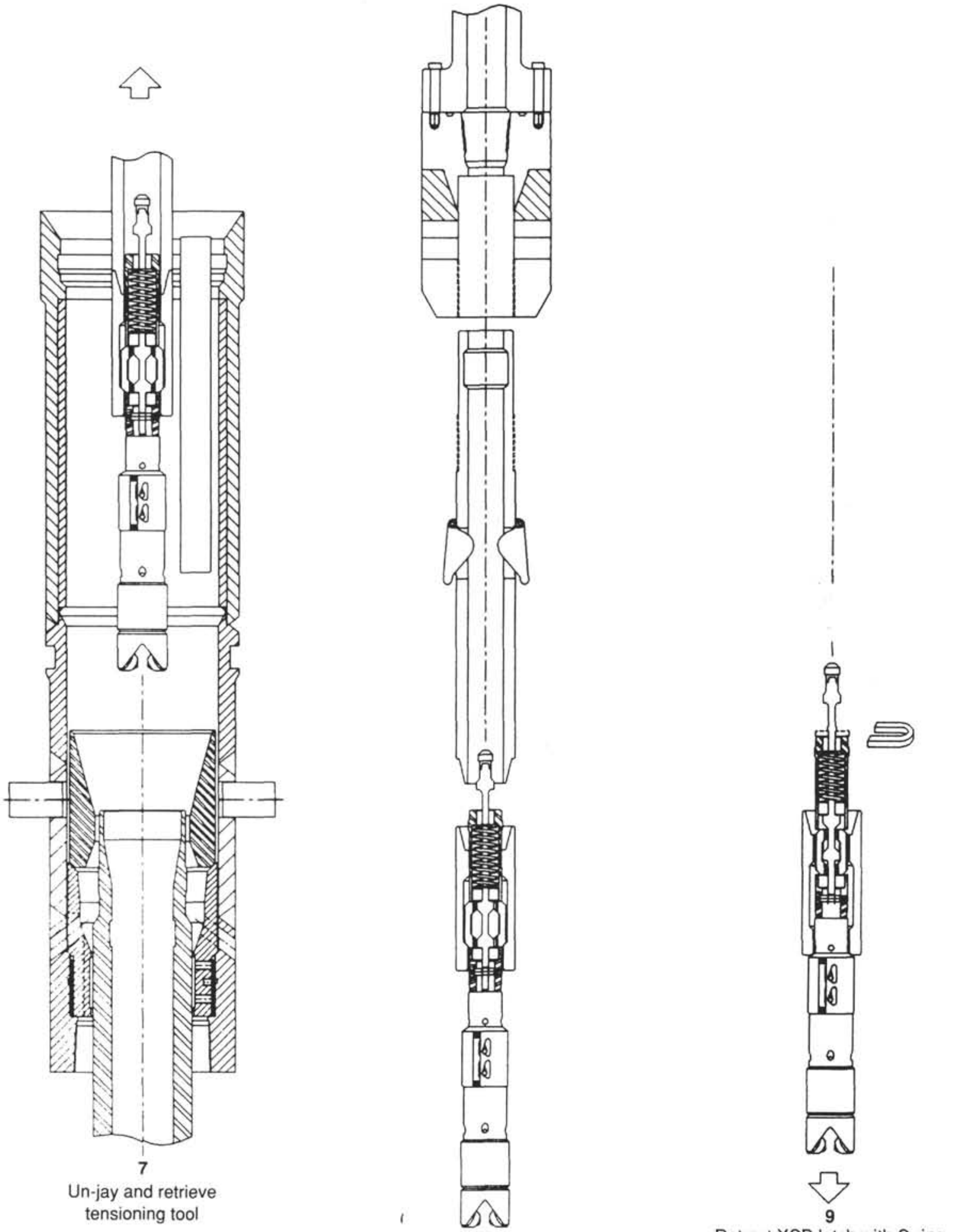


Figure 56 (continued).

the C-ring was modified slightly before installation to allow recovery without pulling the base back to the vessel. This was accomplished by beveling the top side of the C-ring so that the sub could be lifted out of the landing seat and retrieved if the base needed be moved. The decision to bevel the upper portion of the C-ring with such a short BHA proved not to be a factor in establishing the first stage of the DI-BHA. However, there were several instances when the addition of the whole C-ring would have lessened the potential for pumping the BHA out of the hole at high flow rates and/or would have provided more reaction for the center bit to be pulled against. Operational ramifications for either the modification and/or use of the C-ring should be thoroughly evaluated before running the DI-BHA hardware.

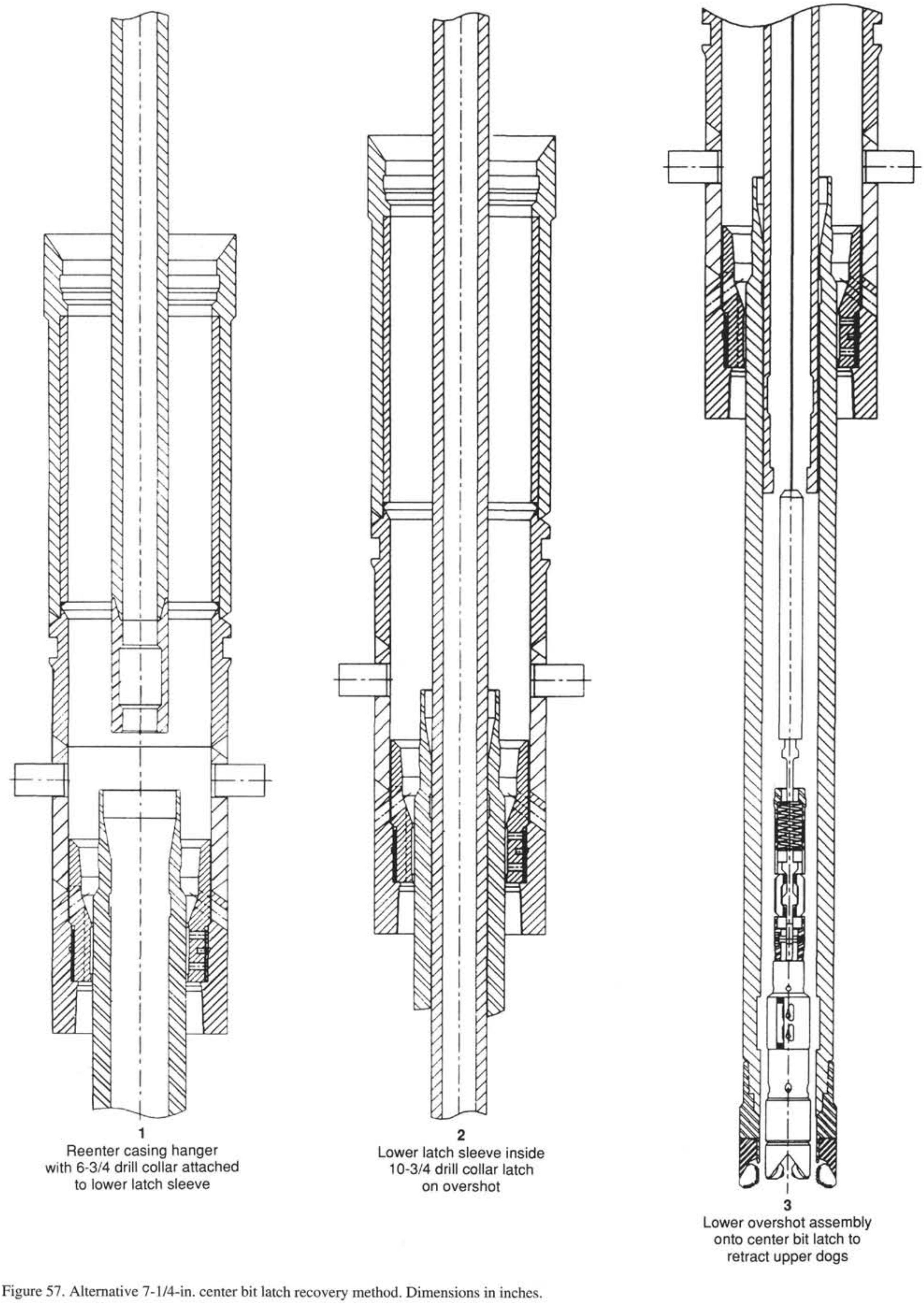


Figure 57. Alternative 7-1/4-in. center bit latch recovery method. Dimensions in inches.

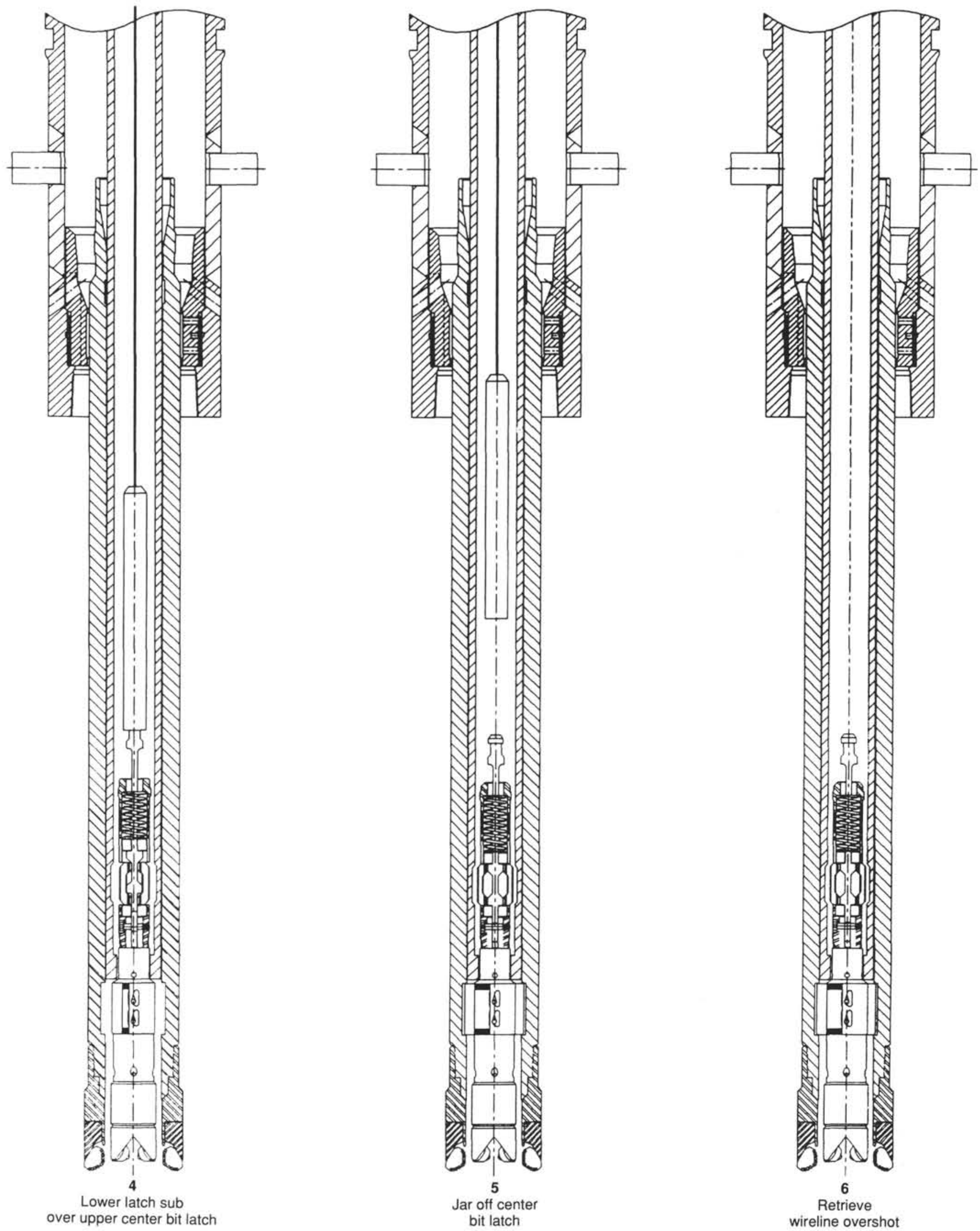


Figure 57 (continued).

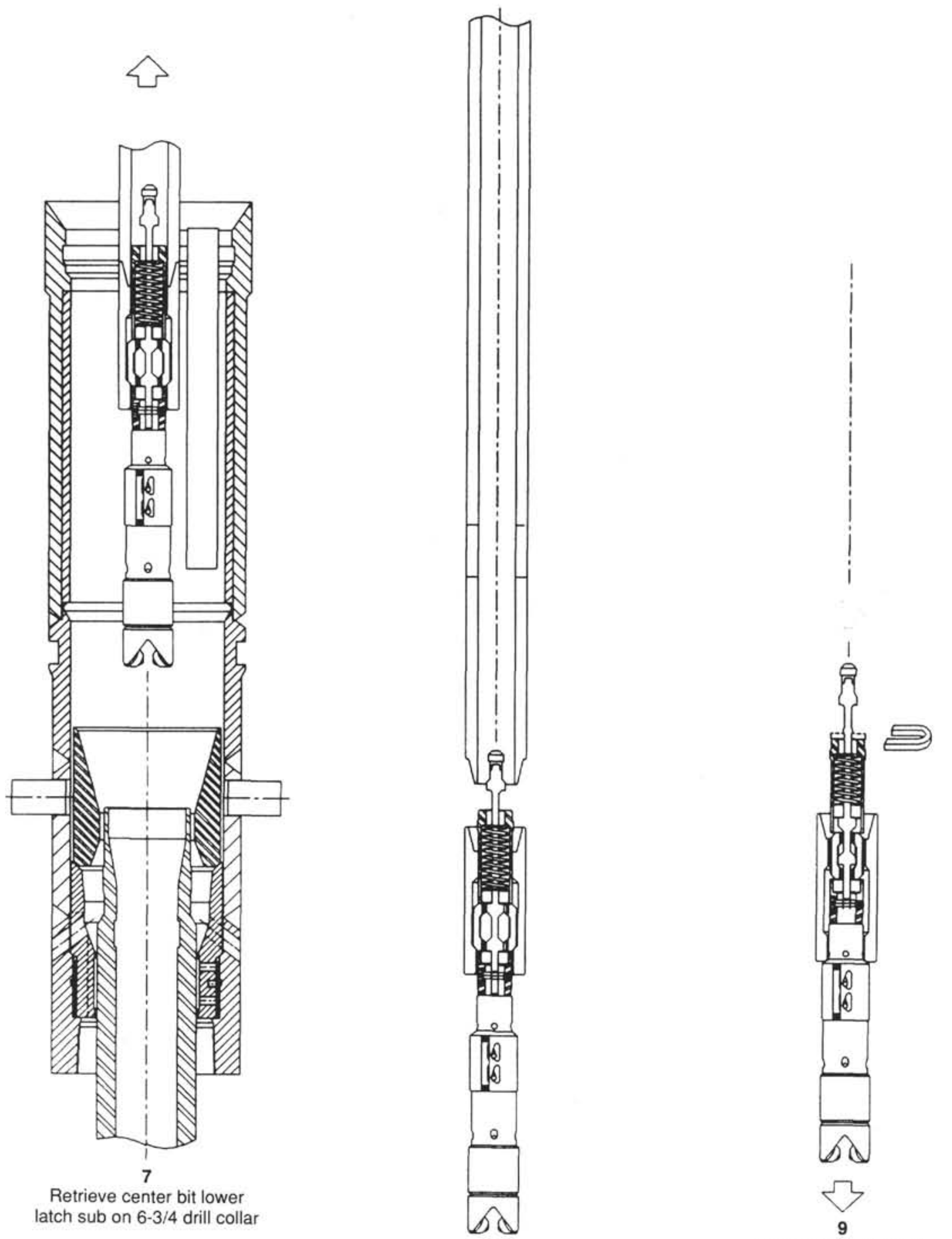


Figure 57 (continued).

6-3/4-in. Back-off Sub

Hole 864A

The second stage of the nested DI-BHA was deployed after fine volcanic fill continued to caused hole problems despite attempts to core with the DCS. It was concluded that some of the secondary heave compensator problems were caused by the flow channels varying during the course of the fluids exiting the borehole. This differential change in pressures directly correlates to the amount of weight on bit that the compensator was attempting to hold constant. Thus, as the flow paths changed between returns exiting the *Resolution* and those on the seafloor (or somewhere in between), large fluctuations in pressure gave the compensator conflicting signals that the program was not designed to interpret. In an attempt to eliminate this as a potential source of problems for the DCS to overcome, and to ensure that there was not any bit matrix remaining

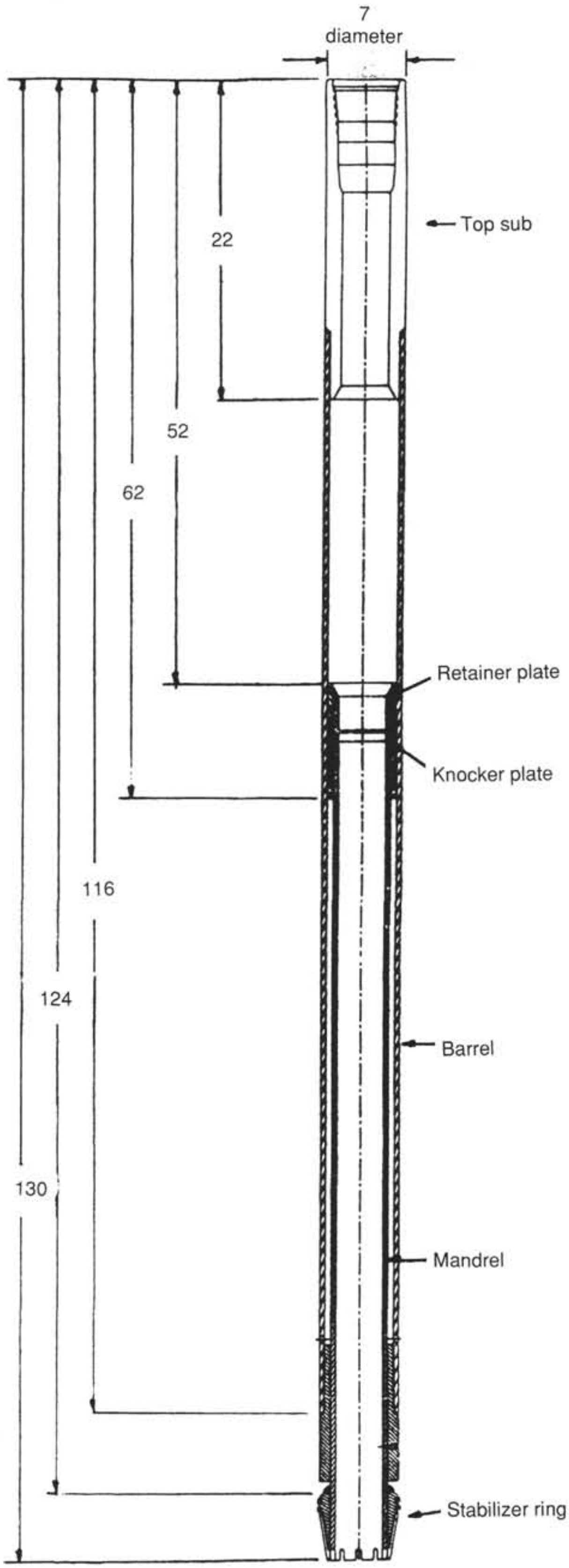


Figure 58. Slip joint. Dimensions in inches.

in the hole from the first DCS bit destroyed, we elected to run the second-stage DI-BHA.

The primary DI-BHA had been set to 20.5 ft (6.25 m) with overdrill/DCS advancement estimated to be between 21.65 and 27.88 ft (6.6 and 8.5 m) below seafloor. The discrepancy in hole depth was partially due to tidal fluctuations that were ranging from 1.64 to 5.58 ft (0.5 to 1.7 m) while on location at EPR. The shortest assembly that could be run which would cover the uncertainty between the two depths would place the second-stage bit at approximately 32.47 ft (9.9 mbsf). Because of this discrepancy in hole depth, it was uncertain whether the bit selected would have to drill 4.5 or 11 ft (1.37 m or 3.37 m). The only available bit option that provided the necessary ID for the second-stage DI-BHA was the 7-1/4- × 4.05-in. (18.4 × 10.3 cm) diamond bits. However, 7-1/4-in. (18.4 cm) tricone bits were also designed for this leg to serve as a drill-ahead option before drilling in and backing off the second-stage diamond-bit assembly. The diamond bits were an unknown factor that had not been run before or tested. To ensure that the hole could be advanced to the proper penetration without premature bit failure, the tricone bit was selected to be run first with the diamond-style DI-BHA bit to follow for the last few feet to be drilled. The BHA selected for the drilling operation consisted of the following items before crossing back to 5-in. drill pipe:

Drilling hardware	Length (m)
1. 7-1/4-in. tricone bit	0.2
2. Bit sub	0.61
3. 30-ft 6-3/4-in. drill collar	9.12
4. 20-ft 6-3/4-in. drill collar	6.10
5. Crossover sub	1.81
6. Five 8-1/2-in. drill collars	45.76
7. Crossover sub	0.74
8. One 7-1/4-in. drill collar	9.62
9. Crossover sub	0.78
10. Twenty-one 5-1/2-in. drill pipe	202.70
11. Crossover sub	0.79

The tricone drilled the first 9.84 ft (3 m) in 1.5 hr at a rotational speed of 50 rpm and pump rate of 50 spm. At the end of the first 9.84 ft (3 m) the material did not appear competent. Therefore, another 9.84 ft (3 m) were drilled in anticipation that massive basalts would again be encountered. At approximately 38.7 ft (11.8 mbsf) the dense basalt was tagged. This dense material continued until a void was located at 43 ft (13.1 mbsf). The total depth required for the back-off sub was set at 43.6 ft (13.3 mbsf). The second 9.84 ft (3 m) were drilled in the same amount of time as the first 9.84 ft (3 m) but bit weight was increased from the 4–6 kips (1.8–2.7 T) to 10 kips (4.54 T). Once the drilling was completed several wiper trips were planned, along with filling the hole with 12.5-lb/gal (1498 kg/cm) mud to help preserve the integrity before reentering with the back-off sub. On the first wiper trip uphole the bit could not advance past the 23-ft (7 mbsf) mark. Repeated attempts were tried but with no success. The VIT was deployed in order to observe whether the 10-3/4-in. (27.3 cm) DI-BHA could have possibly been dragged up with the 6-3/4-in. (17.2 cm) string, preventing the assembly from being lowered back into the hole. Observations revealed that the HRB was in good order and that the DI-BHA was not sitting high. The drill string was pulled up into the casing hanger and attempted to be lowered again into the seafloor. Once at this elevation the bit could not even be lowered beyond the seafloor, much less back to the original 23 ft (7 mbsf) where it originally began to hang up. It was observed that the cone was gimbaling on each repeated attempt to reenter the seafloor. The string was pulled at this point since additional attempts at reentering the 10-3/4-in. (27.3 cm) lower sub were futile.

After reviewing the sequence of events, we surmised that the 10-3/4-in. (27.3 cm) lower sub which had been latched into the

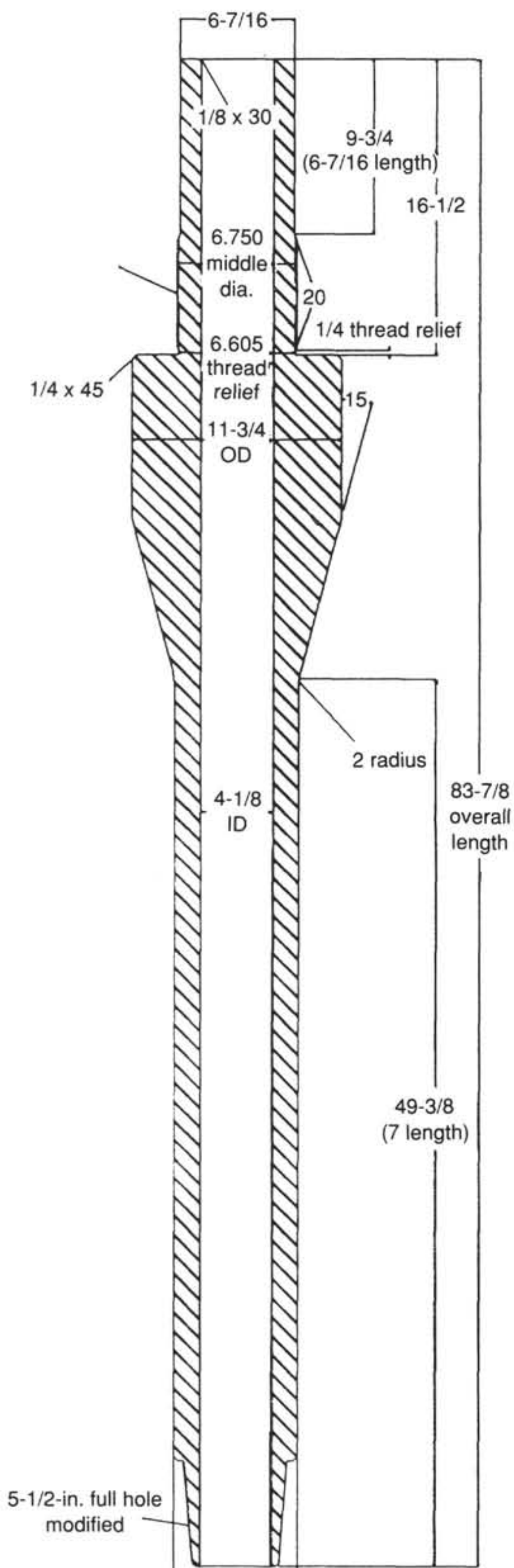


Figure 59. Crossover sub. Dimensions in inches.

landing seat by a C-ring was now free. It had passed out the bottom of the landing seat and possibly tilted in the larger diameter hole, making reentry into the seafloor difficult. The removal of material underneath the DI-BHA occurred from the hole drilled with the 7-1/4-in. (18.4 cm) tricone bit. The only explanation as to how the 10-3/4-in. (27.3 cm) lower sub was lost beneath the landing seat was that the centralization string bottomed out inside the lower sub from fill entering while heaving inside during the stripover operation. This bottoming out consequently drove the steel retaining ring out of the C-ring groove. It is also possible that the C-ring grooves may have been damaged while drilling the DI-BHA and spiral-bladed stabilizers through the landing seat. The exact position of the lower sub beneath the landing seat was unknown; however, for the cone to become free the lower sub had to have moved down approximately 24 in. (0.61 m).

The mini-HRB provided two options for reestablishing a hole to initiate DCS operations. The first option was to move the guide base and redrill a short 6-3/4-in. (17.2 cm) DI-BHA prior to setting up for DCS. The second option was to attempt to reenter the existing DI-BHA and back-off the secondary DI-BHA before setting up the DCS for coring operations. We selected to try the second option first, as many of the difficult steps of starting a new hole had already been accomplished and there were no guarantees that similar problems would not again delay the DCS from beginning operations.

Three operations had to be performed before the hole could again be set for DCS coring. The first operation involved removing the bit guide from the throat of the casing hanger. This was accomplished by fabricating a simple hook-spear-type fishing tool to latch into the bit guide. Upon deployment, the bit guide was captured on the first attempt and pulled out of the casing hanger. The next operation consisted of attaching the large 10-3/4-in. (27.3 cm) back-off nut onto the smaller 6-3/4-in. (17.2 cm) back-off assembly. The landing seat for the 6-3/4-in. nut to back off against was in the throat of the 10-3/4-in. (27.3) sub. Since the 10-3/4-in. (27.3 cm) lower sub was beneath the casing hanger, backing off into it would not provide the necessary centralization for the DCS tubing or lock out the gimbal. Therefore, a conversion was required so that the original landing seat could be used for the 6-3/4-in. (17.3 cm) string. This was accomplished by attaching the large nut and stabilizer assembly onto the smaller nut, along with providing a stop ring so that the 6-3/4-in. (17.2 cm) lower sub could not fall out the bottom of the casing hanger. The final operation was to reenter the 10-3/4-in. (27.3 cm) casing string with the smaller 6-3/4-in. (17.2 cm) second-stage bit, which was beneath the casing hanger some unknown distance and possibly at an obscure angle. The back-off string was composed of the following hardware before crossing back to the 5-in. drill pipe:

Drilling hardware	Length (m)
1. 7-1/4-in. impregnated diamond bit	0.36
2. Bit sub	1.43
3. 30-ft 6-3/4-in. drill collar	9.12
4. 10-ft 6-3/4-in. drill collar	3.30
5. 6-3/4-in. back-off sub modified with large nut assembly	0.98
6. Crossover sub	0.92
7. Crossover sub	1.81
8. Five 8-1/2-in. drill collars	5.76
9. Crossover sub	0.74
10. One 7-1/4-in. drill collar	9.62
11. Crossover sub	0.78
12. Twenty-one 5-1/2-in. drill pipe	202.70
13. Crossover sub	0.79

A center bit or stinger guide was not run inside the 7-1/4-in. (18.4 cm) bit since removal could not be performed until after back-off had occurred with the smaller 6-3/4-in. (17.2 cm) system. Earlier problems with fill entering into the annular space around the latch and causing the assemblies to become stuck were a concern, especially

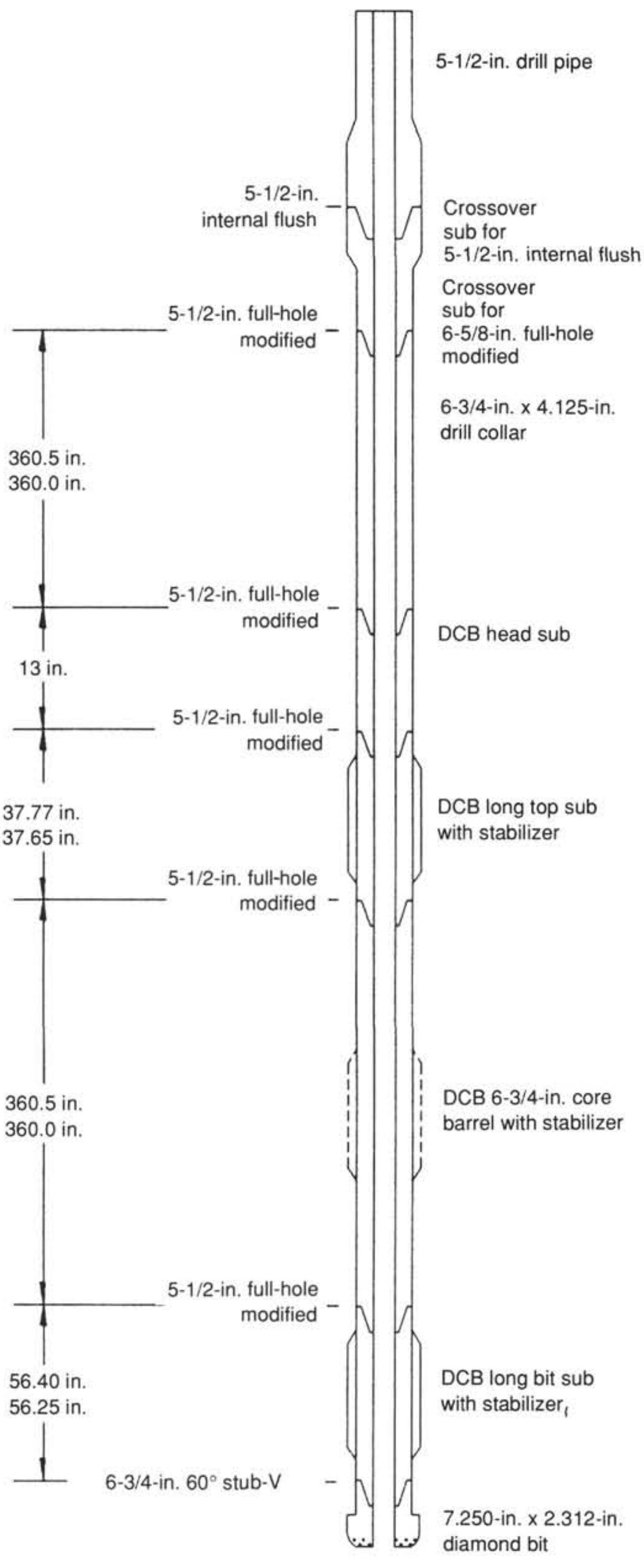


Figure 60. 6-3/4-in. diamond core barrel. Dimensions in inches.

without any way to remove the fill inside the smaller system. Several attempts at entering the 10-3/4-in. (27.2 cm) casing were made until observations from the VIT confirmed from the size and shape of the cuttings plume that reentry into the casing was accomplished. From all indications the 10-3/4-in. (27.3 cm) casing was slightly below the seafloor after having been dislodged about 4.9 ft (1.5 m) from the original position. The 6-3/4-in. (17.2 cm) string continued to be washed down at 100 spm with 10-bbl mud sweeps all the way to the 43-ft (13.1 mbsf) mark. Rotation was initiated once on bottom with the modified 6-3/4-in. (17.2 cm) back-off nut landed into the landing seat. Pump pressure dropped slightly with a gradual torque spike of about 7500 ft-lb (9750 Nm). The upper portion of the back-off assembly was then lifted and removed from casing hanger. From all indications the modified 6-3/4-in. (17.2 cm) back-off was deployed and ready for DCS operations to begin once again. The hole was eventually abandoned after problems with the DCS secondary compensator continued, causing two more bit to be destroyed before any core was cut.

Hole 864B

The 6-3/4-in. (17.2 cm) DI-BHA was deployed in Hole 864B as the primary string. This was done partially to determine if the smaller hole would present a more stable environment and to test the hardware itself. The 6-3/4-in. (17.2 cm) system was first used on Hole 864A with a modification made to adapt the larger back-off nut to the smaller system. This was necessary since the primary 10-3/4-in. (27.3 cm) DI-BHA was dislodged from the casing hanger and the larger landing seat had to be used for the back-off operation in place of the throat of the 10-3/4-in. (27.3 cm) lower sub itself. Two attempts at spudding Hole 864B with diamond bits (impregnated and surface set) were tried prior to using a tricone bit. The hole was finally drilled with a 7-1/4-in. (18.4 cm) tricone bit to approximately 23 ft (7 mbsf). Fill problems prevented the hole from remaining open even after two wiper trips with heavy mud were displaced into the hole. An attempt with the DCB followed the two wiper trips but fill and rubble in the hole prevented the core barrel from ever reaching the bottom. The core barrel was rotated 2.5 hr, with a penetration of less than 9.84 ft (3 mbsf) before being pulled. Upon recovering the barrel a short piece of core (3.15 in. [8 cm]) was recovered while drilling through the rubble. The bit showed very few signs of additional wear after the initial run with the DCB at the seafloor.

The 7-1/4-in. (18.4 cm) tricone was rerun into the hole in an effort to clean the hole and prepare it for drilling in the 6-3/4-in. (17.2 cm) DI-BHA. Four wiper trips were made with the tricone over a 5-hr period. Fill in the hole was reported after each wiper trip. The operation was aborted after it was thought that continued rotation on the tricone might be detrimental to the DCS should compacts be lost off the bit.

The 6-3/4-in. (17.2 cm) DI-BHA was made up and run back into the hole. It consisted of the following assembly before crossing back to 5-in. drill pipe:

Drilling hardware	Length (m)
1. 6-3/4-in. sawtooth bit	0.29
2. Bit sub	1.43
3. 20-ft 6-3/4-in. drill collar	6.10
4. 6-3/4-in. back-off sub	0.98
5. Crossover sub	0.92
6. Crossover sub	1.81
7. Five 8-1/2-in. drill collars	45.76
8. Crossover sub	0.74
9. One 7-1/4-in. drill collar	9.62
10. Crossover sub	0.78
11. Twenty-one 5-1/2-in. drill pipe	202.70
12. Crossover sub	0.79

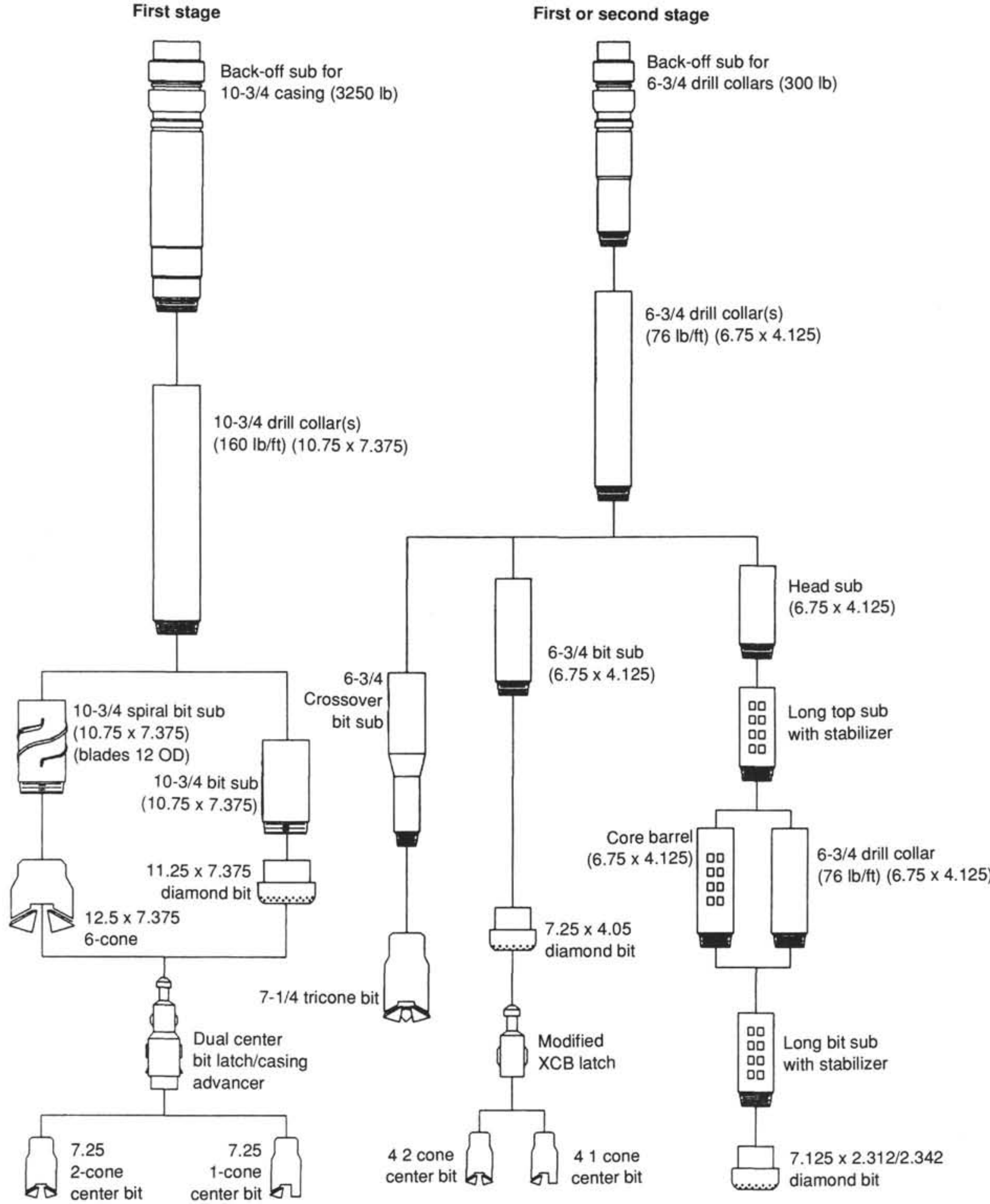


Figure 61. Nested drill-in BHA options (modified Leg 132 system). Dimensions in inches unless otherwise noted.

The DI-BHA was washed down approximately 15.2 ft (4 mbsf) before encountering material which prevented it from advancing further without rotation. Total length of the BHA beneath the tapered shoulder of the 6-3/4-in. (17.2 cm) back-off nut was measured at 27.4 ft (8.34 m). Subtracting the distance above seafloor where the nut would land produced a BHA length beneath the seafloor of 23.5 ft (7.17 m). The hole appeared to have been drilled to 24 ft (7.3 mbsf). This was measured with the drill pipe during the previous tricone run.

The drill bit run on the bottom of the DI-BHA was a modified 7-1/4-in. (17.2 cm) carbonado diamond bit previously used to spud Hole 864B (Fig. 70). The bit was turned down to 6-3/4-in. diameter to allow as much annular clearance as possible. The bit crown was removed and a six-bladed sawtooth mill profile was replaced. Hardfacing material was then applied onto the sawtooth blades as added protection against wear.

The DI-BHA was rotated at 60–70 rpm with circulation rates of 55 spm (280 gallons per minute, or gpm [17.7 L/second]). The DI-BHA

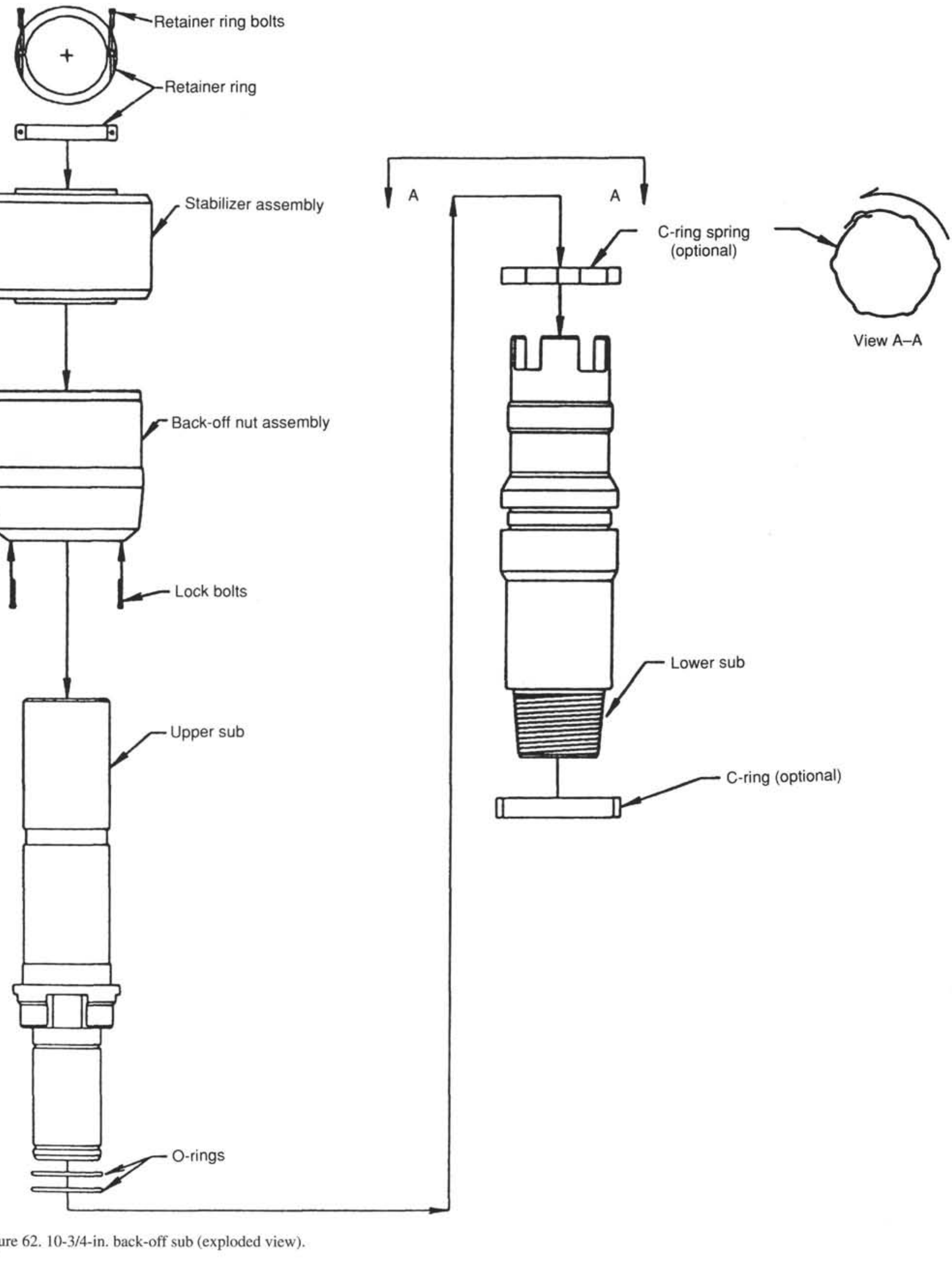


Figure 62. 10-3/4-in. back-off sub (exploded view).

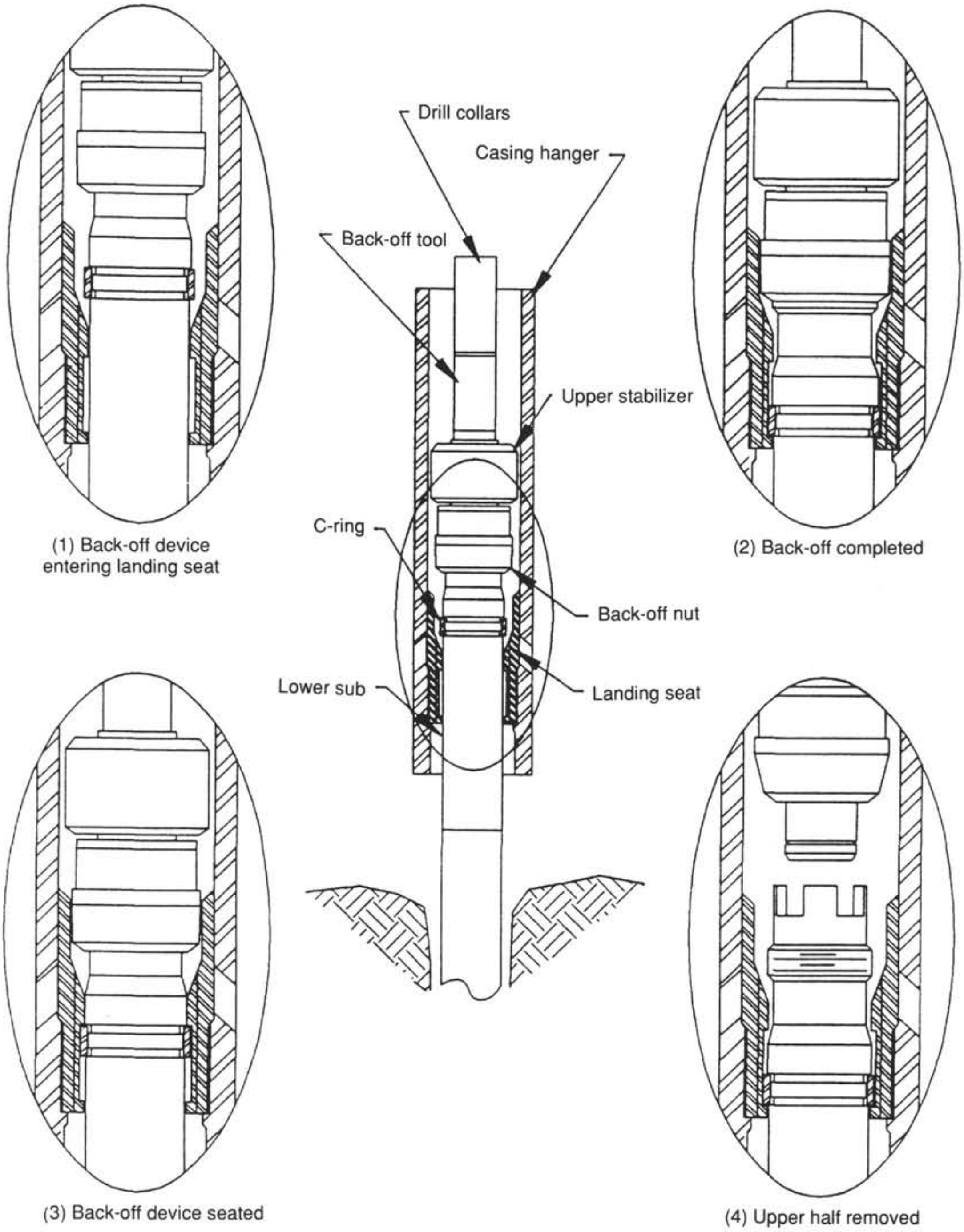


Figure 63. Deployment scheme for mechanical back-off device.

was washed to approximately 13.1 ft (4 m) above the bottom of the hole. At that point rotation was initiated to drill the BHA onto the bottom of the hole. After 30 min of rotation the VIT was redeployed to verify the elevation of the back-off sub. From all indications the painted mark on the drill pipe was still high, indicating the back-off nut had still not landed. The camera was again pulled and the bit rotated another 45 min. Approximately 1 ft (0.31 m) of penetration was noted after 20 min of rotation when pump pressures fell from 375 psi to 125 psi (2586 to 862 kPa). Torque levels were still fluctuating between 100 and 300 amps after the significant pressure drop. Rotation was continued another 25 min to see if the torque would smooth out. The relatively light string weights of the drill-in assemblies were no help in providing a positive indication of when the back-off was complete. The VIT was jumped again to verify that the position of the paint mark on the BHA was at the throat of the casing hanger/cone interface. The elevations appeared correct, so the drill pipe was raised to verify that the back-off sub had separated. The back-off nut was raised and lifted out of the casing hanger, indicating what was thought to be a proper separation.

The drill pipe was tripped out of the hole in order to prepare to set up the DCS drilling rig for the fourth time. However, once the upper portion of the back-off sub was raised above the rotary table it was obvious that the male stem had broken off below the splines. It appeared that the back-off nut separated as designed but the continued

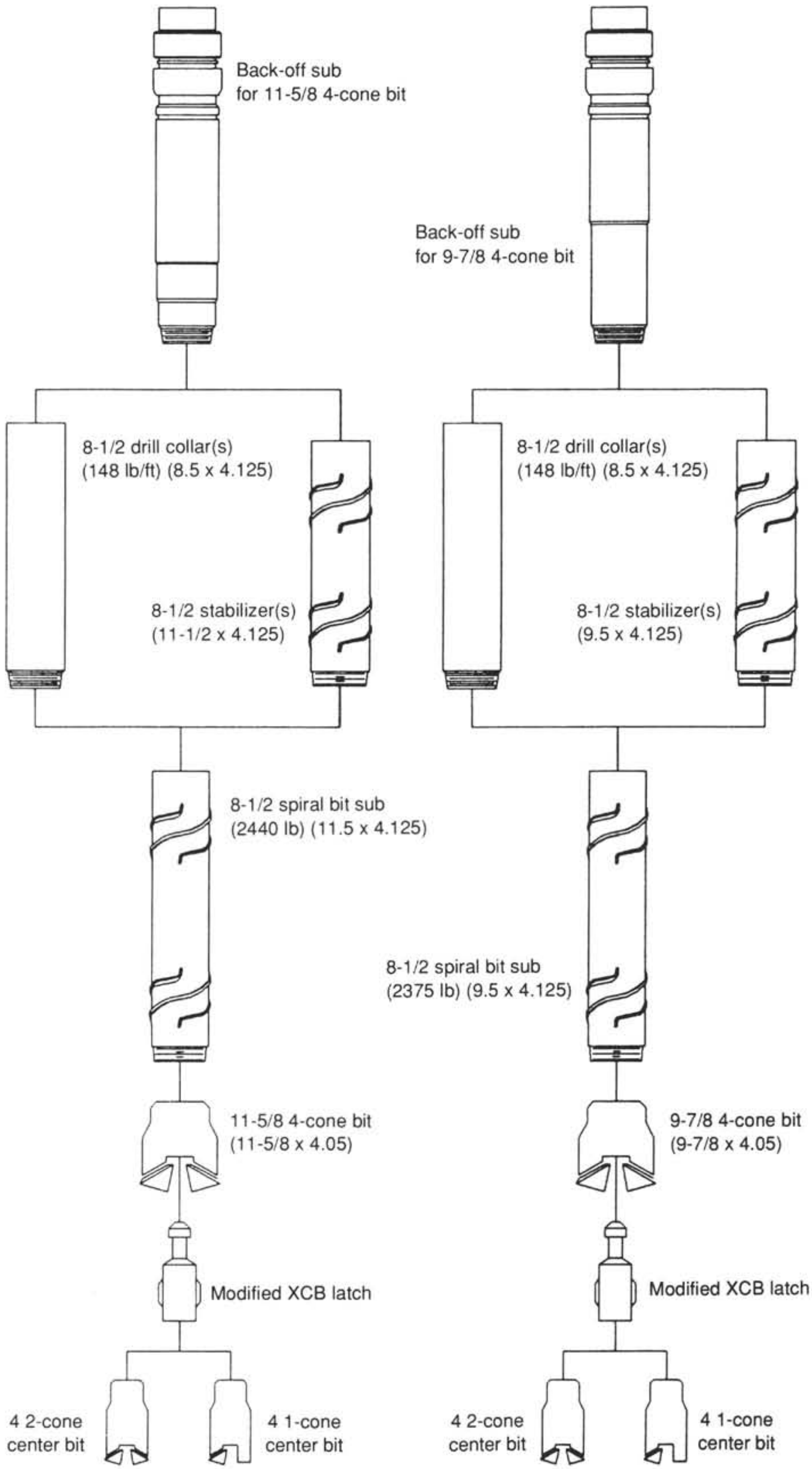


Figure 64. Original drill-in back-off system. Dimensions in inches unless otherwise noted.

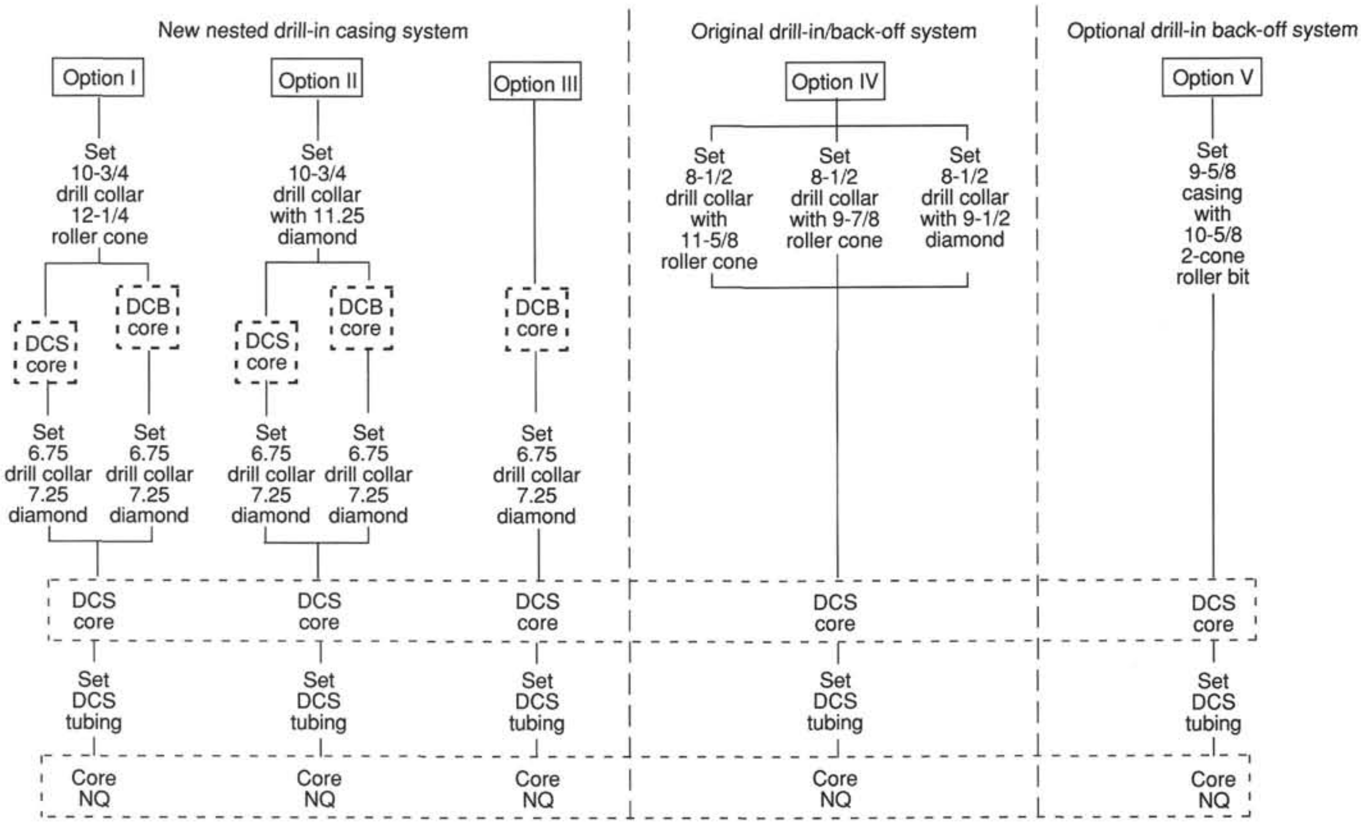
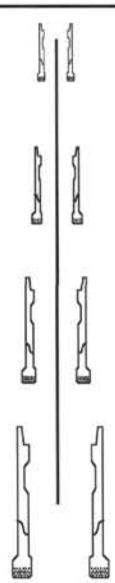


Figure 65. Seafloor spudding options for hard rock locations. Dimensions in inches. (Note: NQ cores not available for Leg 142.)



Casing stage	Coring stage	Description	Hole size (OD, in.)	Core size (OD, in.)	Collar/casing tubing size (in.) (ID)	(OD)	Weight lb/ft [dry]
N/A	Coring stage 3	NCQ rods	2.98	2.06	2.375	2.750	4.4
Casing stage 3	Coring stage 2	DCS – coring string Hydril tubing	3.96	2.2	2.942	3.868	9.5
Casing stage 2	Coring stage 1	6.75-in. drill collar	7.25	2.312 2.342	4.125	6.750	76.0
Casing stage 1	N/A	10.75-in. drill collar	11.25 12.5	N/A	7.375	10.750	160.0

Figure 66. DCS/DCB drill-in casing/coring options. "NCQ rods" denotes optional coring system not yet developed.

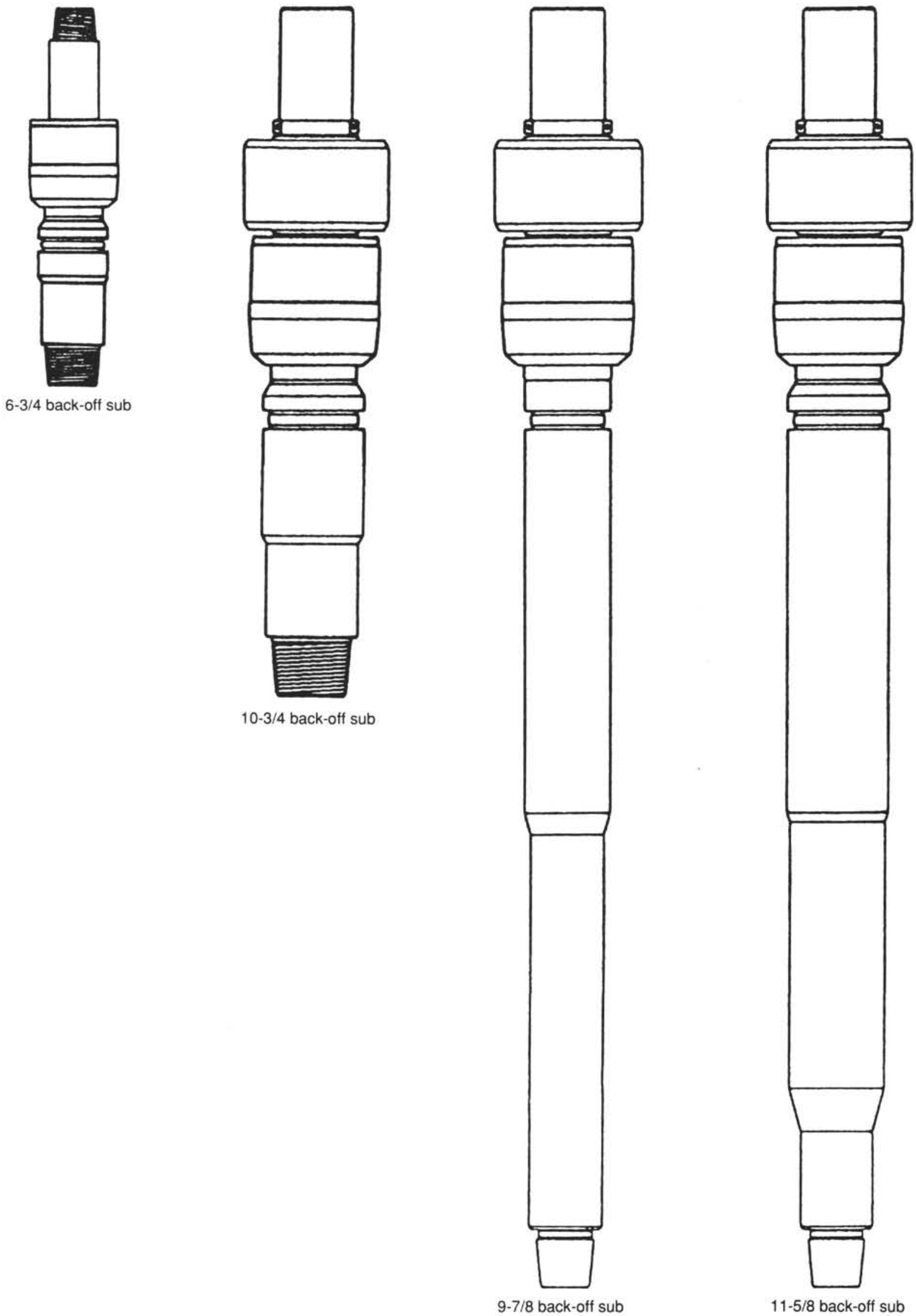


Figure 67. Drill-in back-off hardware. Dimensions in inches.

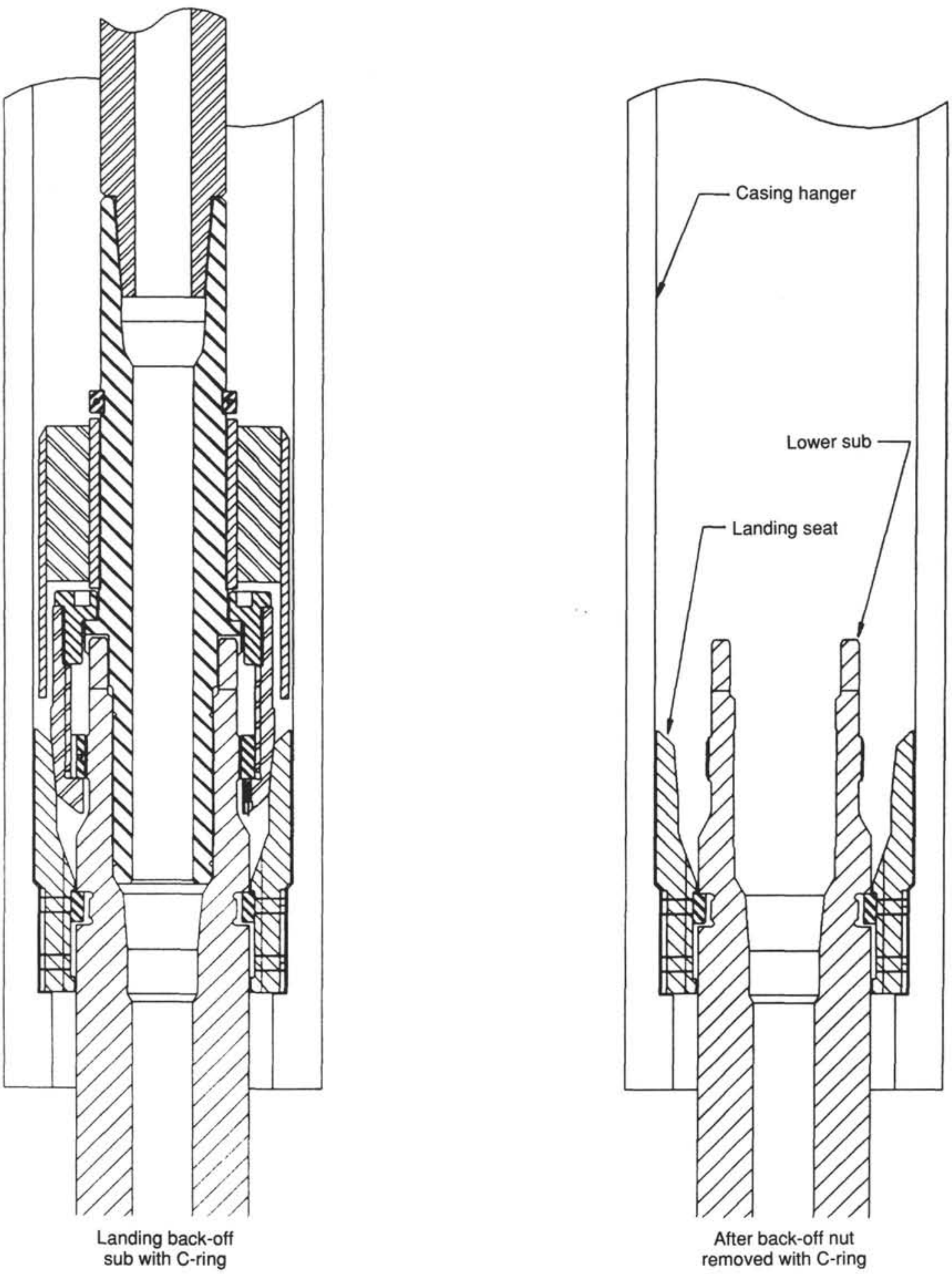


Figure 68. Back-off sub before and after deployment.

rotation after separation fatigued the male stem across the upper O-ring groove. The upper ring was also cracked across the small hole used for the grease fitting insert. The outward edge of this section of the ring was slightly flattened, indicating that it had failed by being pulled apart. The breakage of the male stem and separation of the upper nut most likely was the result cyclic fatigue caused by the offset of the drillship and the drill string laterally whipping during rotation. The whipping of the drill string was observed a number of times throughout the leg when the drill string was rotated in a bowed position when too much weight was placed on the bit.

The circular piece (4.48-in. OD × 2.625-in. ID [113.8 × 66.7 mm]) which had broken off the male stem was about 7-1/2-in. (19 cm) long. A fishing spear was set up on the wireline assembly in order to retrieve the broken stem. In an attempt to save an extra trip, the mini-riser (break-away safety joint, stress joint, and tensioning tool) was run to the seafloor so that if the male stem were successfully removed from

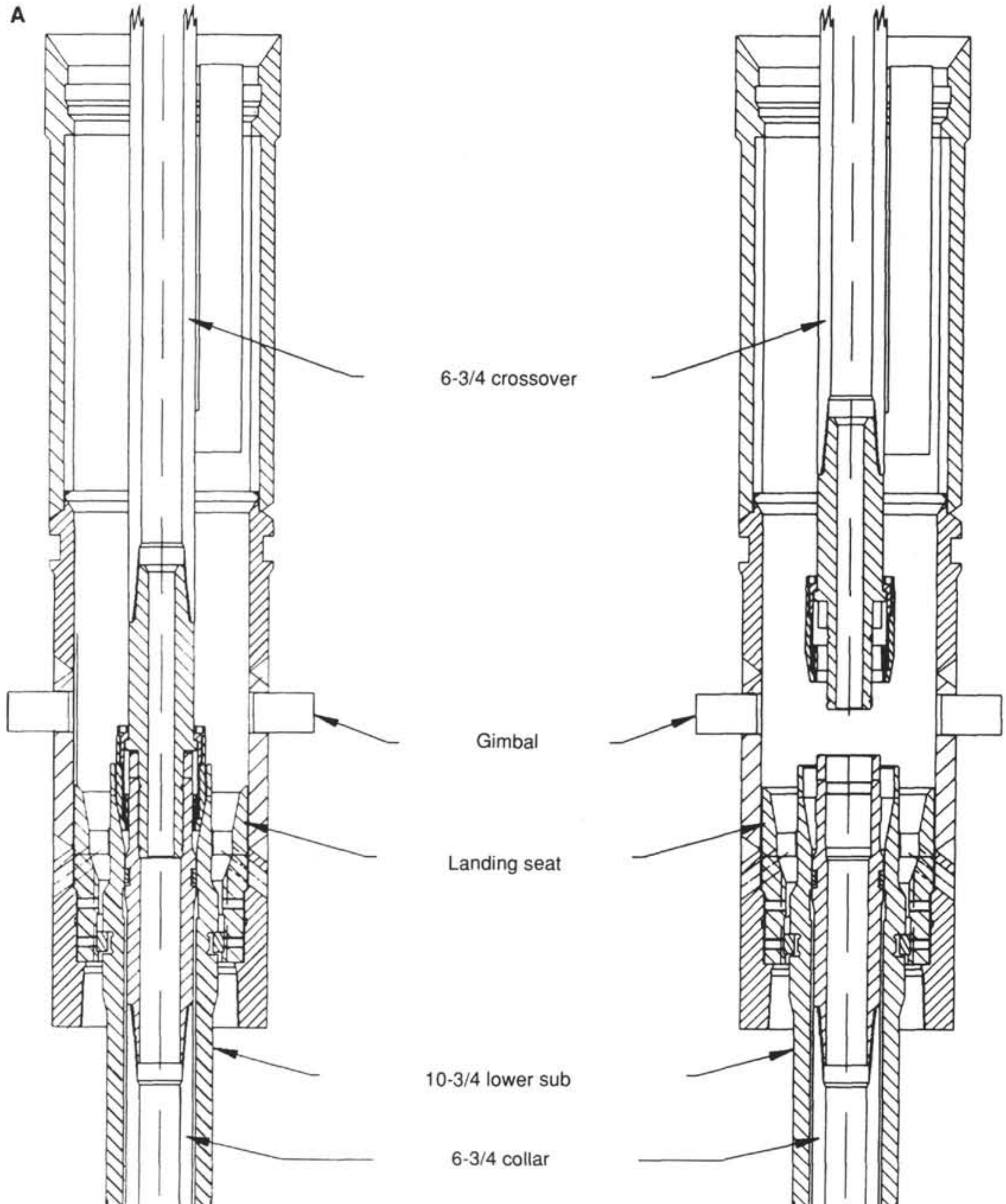


Figure 69. Deployment scheme for 6-3/4-in. drill-in BHA system. **A.** Second stage. **B.** Primary stage.

the hole, the DCS tubing could be immediately run. The cone was reentered and the tensioning tool lowered to the bottom of the jay-slots. From all indications the tensioning tool bottomed out in the jay-slots but could not be rotated to be tensioned up. It appeared that something was preventing the tensioning tool from going all the way to the bottom of the slots. In an effort to solve one problem at a time, attempts to jay into the slots were suspended until the fish could be removed. A small amount of weight was placed down the tensioning tool to hold it stationary while the fishing operation was attempted. It was surmised that either the jay-slots were damaged during reentry and drilling operations or the DI-BHA was pulled out of position with the upper portion of the back-off sub as it was being recovered.

Several tries were made with the fishing spear but either the barbs on the spear would not positively engage the stem or the stem had been dislodged and was no longer positioned in the throat of the lower sub. Attempts with the spear were discontinued after an hour without any positive indication of engagement. An ITCO-type grapple was tried next as another means to recover the fish. The grapple latched onto the male stem several times but each attempt to raise it off the lower sub resulted in the stem being dropped. The lower nut on the grapple was

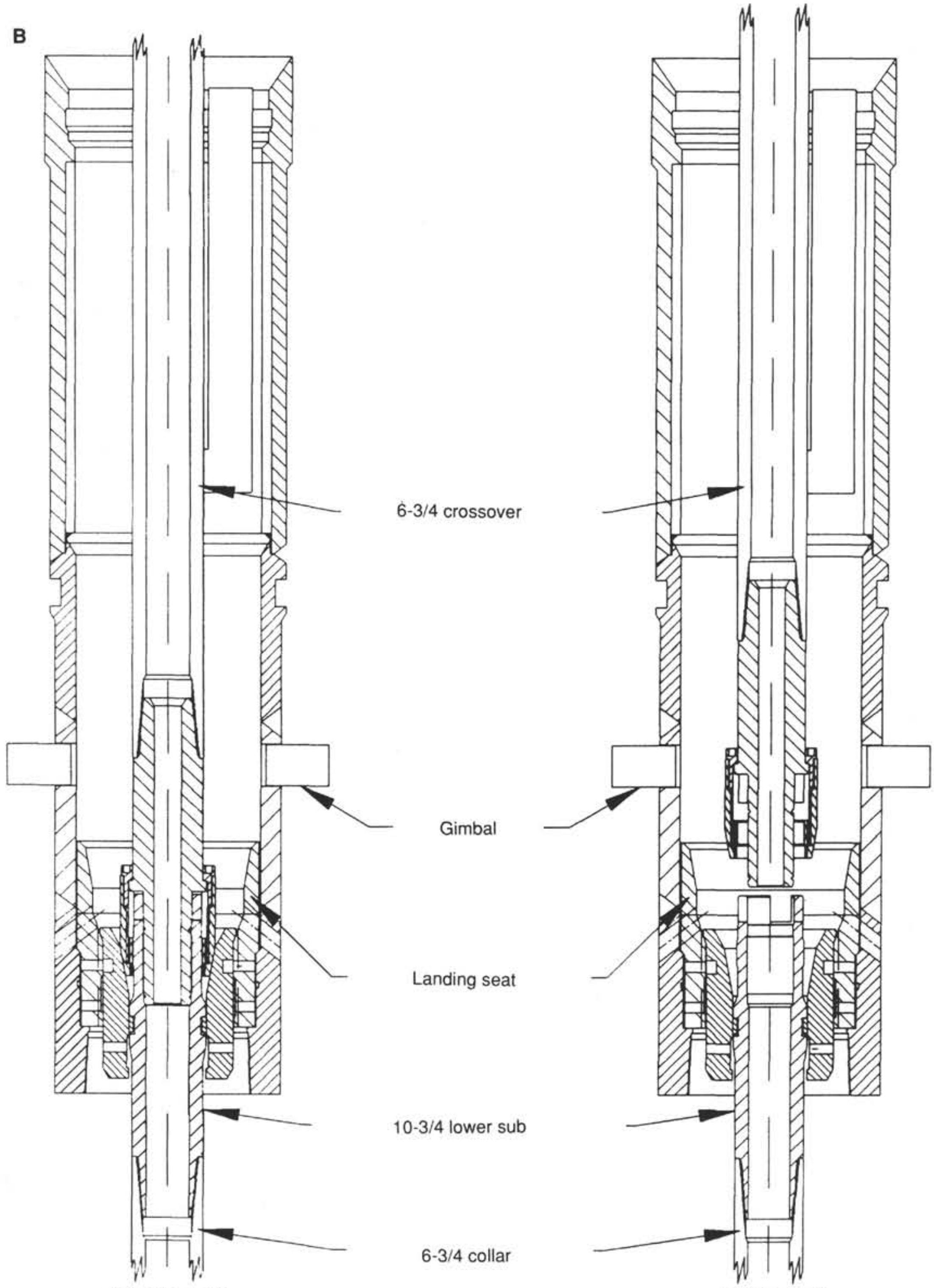


Figure 69 (continued).

tapered as a means to help the tool into the fish. The attempt was finally aborted after the grapple sleeve itself was broken off.

With both pieces of steel in the hole the only alternative to salvage the base for other operations was to move it. This required the base to be picked up and stripped over the 6-3/4-in. (17.2 cm) DI-BHA since it was not connected to the HRB with a C-ring. However, before this operation could be performed the problem with the tensioning tool being unable to jay into the slots had to be addressed. The tool could freely stroke down into the jay-slots; therefore, the possibility of damage to the other portion of the slots was thought to be low. Attempts with the VIT to look into the throat of the casing hanger were useless because the camera's orientation on the VIT was not commandable. The only option left to move the base was to shorten the tensioning tool as much as possible so that it would not contact the 6-3/4-in. (17.2 cm) lower sub in the jay-down position if indeed it was denying the tensioning tool access into the bottom of the slots. The second tensioning tool was modified as the mini-riser was pulled. The tool was basically cut in half, removing approximately 13 in. (33 cm) beneath the jay-dogs. The jay-dogs were also ground down in order to fit the second casing hanger. The diameter across the jay-slots for the second hanger required the dogs to be reduced from 19-3/4 to 19-5/8 in. (50.2 to 49.85 cm). Once on deck the bottom of the tensioning tool was checked for any evidence of impact with the 6-3/4-in. (17.2 cm) lower sub. Three distinct marks resembling the three splines were clearly seen as final proof that the lower sub was interfering with the tensioning tool in the jay-down position.

The second tensioning tool was dressed and made up onto a crossover sub before connecting back to the two stands of drill collars and 5-in. drill pipe. The second guide base was reentered and latched in without any difficulty with the shortened tensioning tool. The base was picked up and moved a total of five times before a final resting place was selected that was approximately 59 to 65.6 ft (18 to 20 m) north of Hole 864B location. The Hole 864C location was primarily used to test other drill bits because not enough time remained during the leg to pick up the DCS hardware again.

Modifications and Additional Testing Requirements

The second generation of the back-off sub has eliminated many of the earlier problems associated with the prototype model developed for Leg 132. The 10-3/4-in. (27.3 cm) version was rotated for almost 30 hr in severe drilling conditions with the wide swings in torque produced by the PDCM without any mechanical difficulties. The 6-3/4-in. (17.2 cm) DI-BHA system was also required since hole conditions beneath the primary casing continued to cause drilling problems in the unstable formation. The majority of the suggestions and improvements listed below are for small enhancements to the system. These include:

1. Add an internal latch cavity to upper subs for all sizes of DI-BHA.
2. Provide lift subs for easier-handling short BHAs.
3. Fabricate sections of 6-3/4-in. (17.2 cm) drill collars in lengths of 2 and 5 ft (0.61 and 1.52 m).
4. Modify existing crossover sub for use with the bit-guide assembly.
5. Design and fabricate a new lower latch sub that is threaded on both ends for added versatility.
6. Investigate why back-off torques appear less than make-up torques and if rotational hours of drilling with a PDCM influences set torques.
7. Conduct additional testing (field or laboratory) with the smaller version to verify ruggedness during long hours of operation.
8. Purchase a releasing spear-type recovery tool for the 10-3/4-in. (27.3 cm) DI-BHA system.
9. Fabricate 12-1/2-in. (31.75 cm) junk mills to aid in clearing the borehole if debris is left from roller-cone bits.
10. Eliminate the tungsten carbide or use less abrasive material on the spiral-bladed stabilizers.
11. Lengthen lower section of landing seat to provide additional material beneath the C-ring groove.
12. Design a scheme to deploy the 6-3/4-in. (17.2 cm) system (bushing) without first committing the landing seat for the smaller bushing size.
13. Enhance item 12 to allow bushing to be removed without recovering base.
14. Investigate possibility of developing larger size DI-BHA.
15. Modify the 11-3/4-in. (29.85 cm) casing hanger with a tapered landing seat to enable back-off of 9-7/8, 11-5/8, or 6-3/4-in. (25, 29.5, or 17.2 cm) DI-BHAs.
16. Develop bolt-on/weld-on large back-off nut for 6-3/4-in. (17.2 cm) assembly.
17. Review the 6-3/4-in. (17.2 cm) upper back-off sub design from a fatigue and excessive bending moment standpoint.
18. Investigate the possibility of having a positive indication when back-off occurs for both 6-3/4-in. and 10-3/4-in. (17.2 and 27.3 cm) systems.

POSITIVE DISPLACEMENT CORING MOTOR

Background

An Eastman Christensen 9.5-in. (24.1 cm) Mach 1 positive displacement coring motor (PDCM) was used for spudding the primary drill-in BHA at Hole 864A. The use of the PCDM for unsupported exploratory drilling offers a reliable way to spud holes in areas of unusual seafloor relief. Light bit weights in the range of 5000 to 10,000 lb (2.27 to 4.54 T) were recommended to keep the neutral point in the BHA as low as possible so as not to put the motor into compression. The stability of the BHA that is provided by not rotating the entire drill string from the surface minimizes overloading of the drilling assembly during early phases of unsupported spudding operations. Details of PDCM spudding techniques have been described in Howard (1989) in the Leg 118 *Initial Reports* volume.

Performance

Several BHA combinations are available for the drill-in system, along with a variety of bit types. Figures 61, 65, and 71 present the different combinations of drill-in back-off hardware along with drilling options for the PDCM itself. The drill-in BHA, when deployed with the PDCM, consisted of the following components:

Drilling hardware	Length (m)
1. 12.5 × 7.92-in. (6-cone) roller bit	0.41
2. 10.75 × 7.375-in. spiral bit sub	3.36
3. 10.75 × 7.375-in. drill collar	3.07
4. 10-3/4-in. back-off sub	1.81
5. Crossover sub	0.55
6. PDCM	10.27
7. Crossover sub	0.92
8. Three 8-1/2-in. drill collars	18.3
9. Crossover sub	0.74
10. 7-1/4-in. drill collar	9.62
11. Crossover sub	0.78
12. Six 5.5-in. drill pipe	47.83
13. Crossover sub	0.79

The confinement by the casing hanger and landing seat within the guide base prevented the drill bit from walking across the seafloor during the initial spud-in attempt; in addition, it kept the hole straight. The piloted center bit also helped to establish the hole quickly. Initial drill-in BHA penetration was limited to 10.5 ft (3.2 m) in an attempt to prevent breaking out of the shallow ponded lava known to exist at Hole 864A (EPR-2).

As described in an earlier section, the first 6-cone roller bit came apart after drilling 3.5 m in 24 hr of rotation, leaving cones and tungsten carbide inserts in the hole. Operations with the PDCM were abandoned for cleaning out the hole or for further advancement, since a rat hole was already established. The PDCM was picked up only once more on Leg 142 in a second attempt to back off the DI-BHA. Upon reentering the hole, fill was tagged about 13.1 ft (4 m) from the bottom. The maximum flow available through the PDCM could not remove the cuttings from the bottom of the hole. At this point it was obvious that higher flow rates obtainable only with the rig's mud pump and top-drive system would allow the hole to be adequately cleaned.

Detailed PDCM information pertaining to operating pressures as a function of flow rate is presented in Figure 72 for deck tests performed

Figure 70. Modified 7-1/4-in. sawtooth bit.

prior to arrival at the EPR location. Penetration curves vs. time are illustrated in Figures 73 and 74. Table 5 presents a summary of all the information gathered during the PDCM run for Hole 864A. The motor operated over 24 hr without any mechanical problems. Bearing wear clearance was measured at 0.183 in. (4.7 mm) for the first run with a maximum allowable tolerance for the 9-1/2 Mach I of 0.200 in. (5.08 mm). An additional .009-in. (.24 mm) of bearing wear was reported on the second run. The significant amount of wear may be attributed to the dynamic impact that the motor experienced during the drilling operations. Even though the compensator was being used during the spudding operations, the small amount of weight on bit (2–8 kips [0.91–3.63 T]) was nearly lost in minimal friction and stiction of the drilling system. This allowed the motor to experience wide swings in weight on bit, which resulted in the bit sometimes being picked off the bottom of the hole and impacted upon the return cycle.

The PDCM is still recommended for use with bare-rock spudding, especially for unsupported attempts or where guide bases are not deployed. Once enough rat hole is established or with the first bit change, it is suggested to switch from the PDCM to the rig's top drive. Spare parts for the PDCM are expensive because the motors that ODP own are one of a kind. Having an adequate inventory to support the motors while at sea is probably best accomplished by using the second motor. Repair of the motors aboard the *JOIDES Resolution* would be difficult since an adequate work area and the necessary tools of the trade are not available. The top drive offers many advantages over the PDCM, especially in the amount of regulated flow, torque limits, and constant rotational speed.

SEAFLOOR DEPLOYMENT SEQUENCE

There are two deployment sequences for the seafloor hardware. The first scenario involves coring with the DCS as soon as the HRB is set and the initial stage of the back-off hardware deployed. This mode of operation reserves the 6-3/4-in. (17.2 cm) string for use only if downhole problems require a second string for isolating the formation. The second operational mode would deploy the DCB prior to picking up the DCS after the seafloor template and initial DI-BHA have been established. In this scenario the DCS is only picked up if hole problems begin while coring with the DCB. Since the core size is essentially the same (2.312 in. [58.7 mm] vs. 2.20 in. [55.9 mm]) for the DCB and DCS, the DCB may be preferred since it does not require the DCS platform and is operated with the rig's top drive. Several other variations to the above-described deployment sequence are available if the primary 10-3/4-in. (27.3 cm) string cannot be drilled in. The seafloor spudding options for the DCS are presented in Figure 65. The actual hole and core sizes for each of the available strings are summarized in Figure 66. The following series outlines the steps and procedures required to initiate DCS for both operations.

DCS and Ream

The operational plan to initiate coring with the DCS as soon as the guide-base template is set and the bottom-hole assembly drilled in is presented in the following steps. This is the plan that was adopted for Hole 864A at EPR. A schematic series illustrating the operational sequence of the deployment plan is provided in Figure 75.

1. Lower HRB to seafloor with running tool and verify acceptable orientation,
2. Un-jay and trip running tool string back to vessel,
3. Reenter cone with primary drill-in BHA,
4. Drill in primary BHA to pre-set depth,
5. Back-off primary string and trip back to ship,
6. Lower tensioning tool with bit guide and reenter HRB,
7. Latch into casing hanger with tensioning tool and pull tension against HRB,
8. Release bit guide with wireline assembly,
9. Retrieve center bit into lower bit-guide sub,
10. Un-jay and move off cone,
11. Jar off center bit and trip string back to vessel,
12. Lower tensioning tool with 6-3/4-in. (17.2 cm) drill collars and slack joint attached,
13. Lower DCS tubing in 90-ft (27.4 mm) stands inside API string to just above tensioning sub,
14. Reenter HRB and tension to desired level with DCS platform activated,
15. Lower DCS tubing from platform floor in 10-ft (3.05 m) increments to just above drill-in BHA bit,
16. Pump down DCS barrel and latch in,
17. Activate secondary compensator and begin coring with DCS, and
18. Core with DCS to desired penetration in 10-ft (3.05 m) increments or until hole problems necessitate setting the 6-3/4-in. (17.2 cm) string.

If drilling conditions limit further advancement of the DCS hole and additional penetration is required, the following steps outline the next series of operations:

1. Retrieve DCS tubing to just above seafloor in 10-ft (3.05 m) increments,
2. Un-jay tensioning tool, lay down DCS platform, and offset from HRB,
3. Pull DCS string in 90-ft (27.4 m) stands and rack back in derrick, and
4. Pull API string and lay down.

Two options are available prior to initiating reaming operations with the 6-3/4-in. (17.2 cm) string. Option 1 allows for the hole to be reamed with the reaming string backed off once the zone causing the drilling difficulties is isolated. Option 2 is similar to option I, but instead of backing off the reaming string it is pulled and DCB coring is initiated once the DCS hole is reamed to the larger size. Option 2 depends on the formation remaining open during and after the reaming string is being pulled.

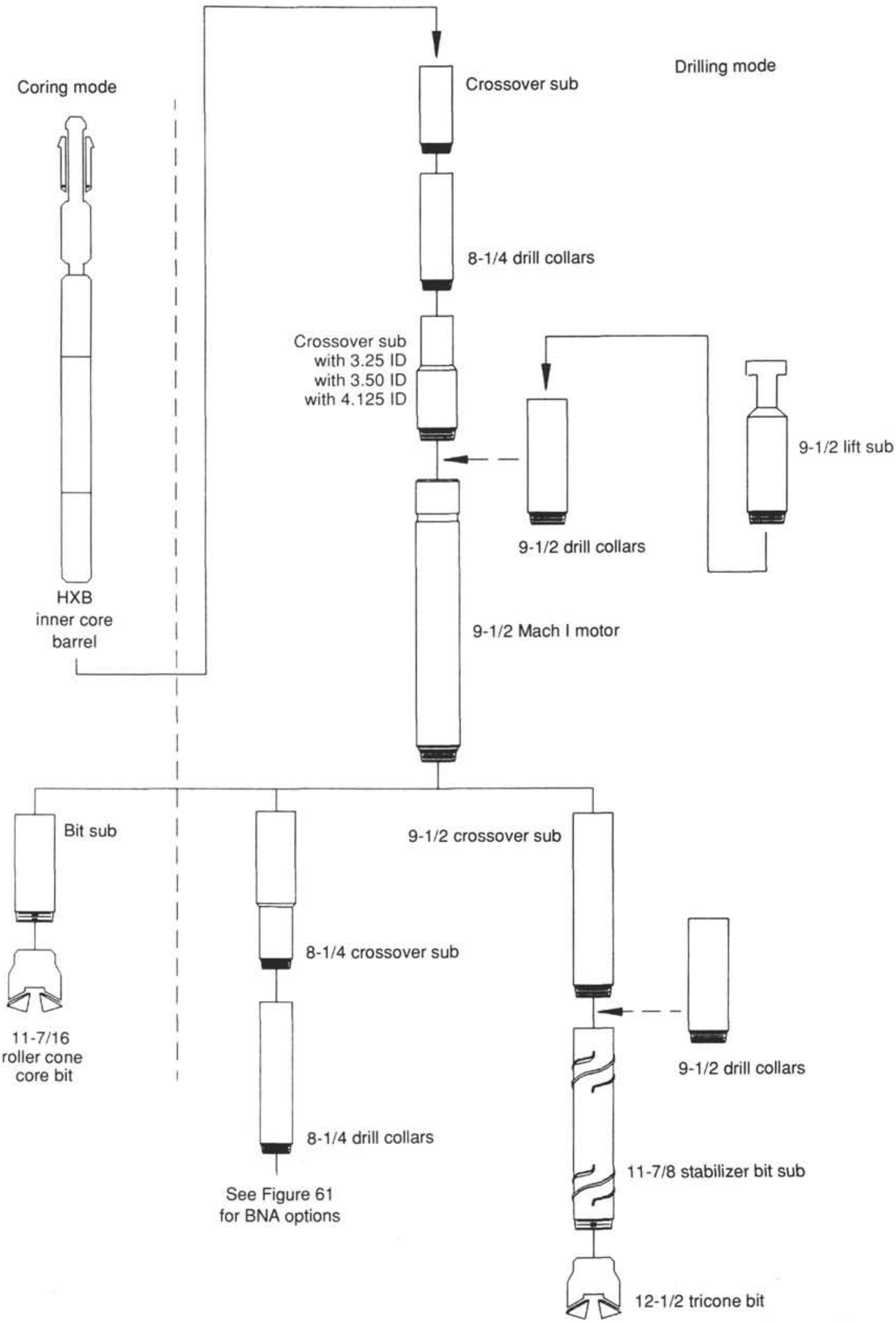


Figure 71. Drilling options with the positive displacement coring motor. Dimensions in inches.

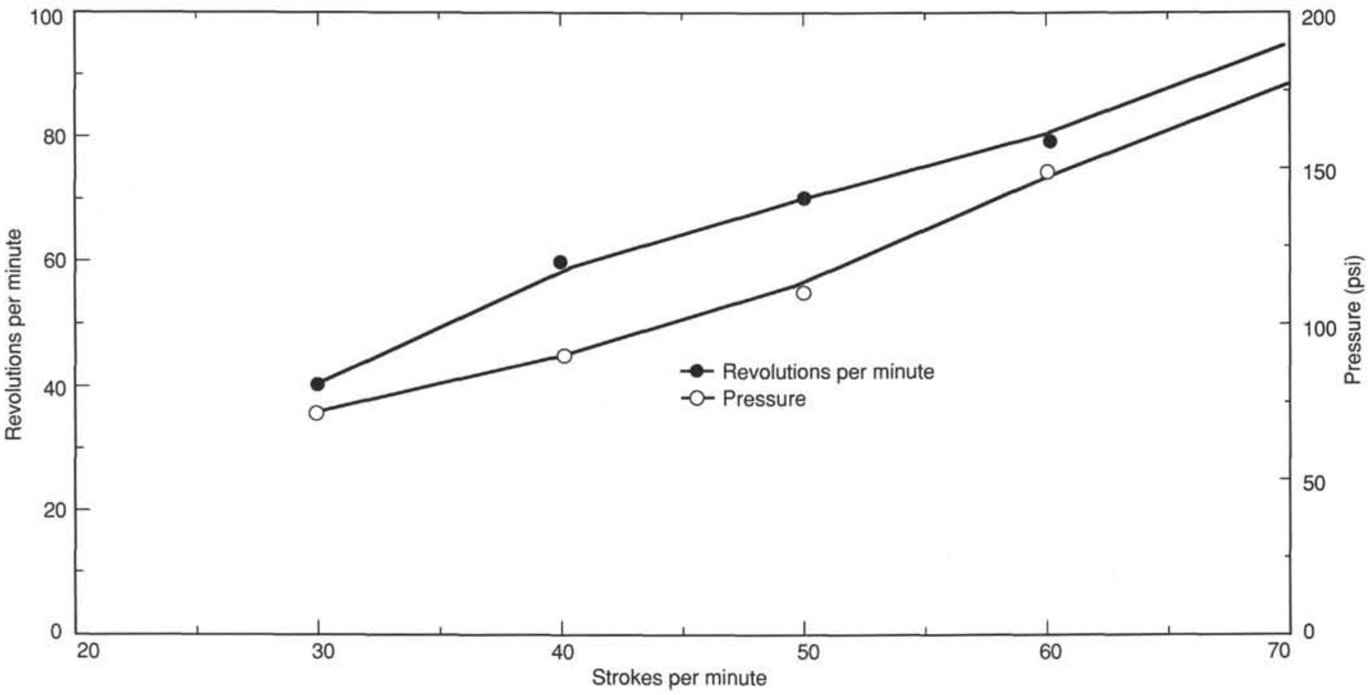


Figure 72. Strokes per minute vs. revolutions per minute.

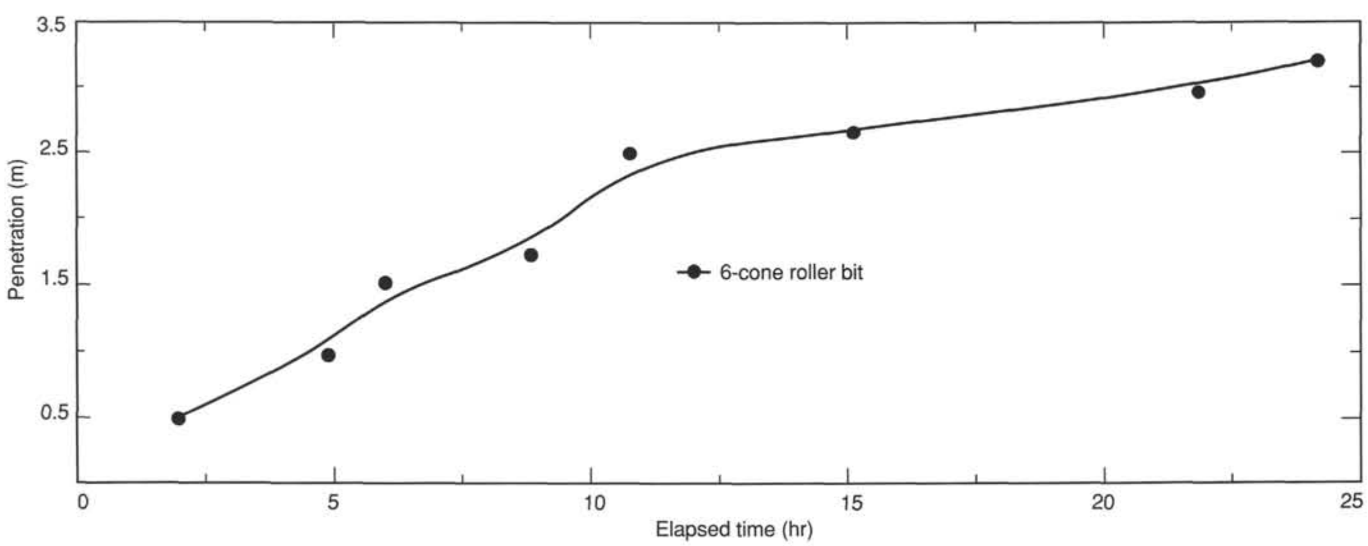


Figure 73. PDCM penetration and bit weight vs. time. (Note: 2–2.5 m of heave; massive flow unit.)

Option 1: Ream and DCS Core

1. Trip in with the 6-3/4-in. (17.2 cm) reaming BHA with the back-off sub positioned at a preselected location,
2. Ream hole to predetermined depth,
3. Back off 6-3/4-in. (17.2 cm) string,
4. Retrieve the pilot bit from the reaming string,
5. Pull the API string and lay down, and
6. Repeat steps 12–18 above.

Option 2: Ream, DCB, and DCS

1. Trip in with the 6-3/4-in. (17.2 cm) reaming string,
2. Ream hole to selected depth,
3. Pull reaming string and lay down,
4. Trip in with DCB,
5. Core with DCB to selected depth,
6. Trip out DCB string and lay down,
7. Trip in with 6-3/4-in. (17.2 cm) drill-in BHA,
8. Drill in secondary BHA and back-off,
9. Trip out API string, and
10. Repeat steps 12–18 above.

DCB Followed by DCS

The operational plan outlined in this scenario is to progressively step down in core size as hole conditions dictate the use of smaller coring equipment. The preceding string is then used as casing for the next smaller size core attempted. This is the conventional program outlined in most oil-field and mining drilling plans. The following steps outline the sequence of events to be performed in this program. A step-by-step schematic illustration is presented in Figure 76 to coincide with the sequenced steps below:

1. Lower HRB to seafloor with running tool and verify acceptable orientation,
2. Un-jay and trip running tool string back to vessel,
3. Reenter cone with primary drill-in BHA,
4. Drill in primary BHA to preset depth,
5. Back off primary string and trip back to ship,
6. Lower tensioning tool with bit guide and reenter HRB,
7. Latch into casing hanger with tensioning tool and pull tension against HRB,
8. Release bit guide with wireline assembly,
9. Retrieve center bit into lower bit-guide sub,
10. Un-jay and move off cone,
11. Jar off center bit with wireline assembly and trip string back to vessel,
12. Make up DCB string and reenter HRB,
13. Pump down DCB core barrel and latch in,
14. Activate primary compensator and begin coring with DCB,
15. Core with DCB to a predetermined depth or until hole problems dictate a smaller core size,
16. Pull DCB string and lay down,
17. Make up secondary drill-in BHA and center-bit assembly,
18. Trip in, drill to depth, and back off,
19. Retrieve string,
20. Make up tensioning tool and trip in API string,
21. Reenter HRB and tension up,
22. Retrieve center bit with wireline assembly,
23. Un-jay and offset from HRB, and
24. Repeat steps 13–17 in the "DCS and Ream" subsection.

SUMMARY AND CONCLUSIONS

Leg 142 has allowed several new prototype pieces of equipment and some modified versions of existing hardware to be tested and proven in the field for hard-rock drilling. There were a few minor problems during the leg; however, the majority of these were formation-related, not hardware problems. Drilling difficulties and hole stability will continue to play a big role in achieving the desired results when attempting to spud a hole and core in fracture basalts. Many of the steps taken and the methodology adopted for the direction of the equipment under development has eliminated many of the problems which have plagued legs in the past. The most significant step demonstrated during the leg has been the successful deployment of the nested drill-in BHA system. This concept has proven that downhole instability can be eliminated with installation of a deeper casing to isolate the section of formation causing drilling difficulties.

The principal area that still needs the most development is in the design of more robust and longer-life drill bits. Even though significant strides have been made in bit and bearing design since Legs 106 and 109, there still exists a need for better designs which will allow the nested DI-BHA to be utilized to its full potential. An effective solution to this problem will require continued research efforts and testing in order to provide a system that will be rugged and adaptable to drilling in the difficult types of formations that have eluded ODP in the past. Many of the improvements for the individual pieces of hardware have already been presented. Several new areas suggested for continued research and development to complement the DCS operations include:

1. Investigate use of the DCS tubing as a third stage for the nested drill-in BHA system,
2. Pursue the development of an alternative type of running/tensioning tool for HRB operations,
3. Perform an extensive testing program on the drill bits developed for the nested-stage DI-BHA to develop bits with longer life for harsh environments,
4. Pursue an association and work with drilling mud and/or chemical companies in developing new techniques or injections to stabilize troublesome formations,
5. Adapt the mini-HRB for use with standard ODP drilling operations,
6. Perform field tests on the diamond core barrel to develop it as an alternative coring system to complement the rotary systems that ODP presently uses, and
7. Retest the break-away safety joint to determine if the loading conditions that it was subjected to while in service weakened the shear pins.
8. Develop alternative options with the DI-BHA so that it can be crossed over to and used with standard ODP casing strings.

REFERENCES

Howard, S.P., 1989. Advances in hard-rock drilling and coring techniques, ODP Leg 118. *In* Robinson, P.T., Von Herzen, R., et al., *Proc. ODP, Init. Repts.*, 118: College Station, TX (Ocean Drilling Program), 25–38.

Storms, M.A., Natland, J.H., et al., 1991. *Proc. ODP, Init. Repts.*, 132: College Station, TX (Ocean Drilling Program).

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APPENDIX A

Recommended Design Procedure for Using Tension-Offset Envelopes

The following example calculation is used to assist the operations superintendent or engineer in ensuring that the tension overpull selected for use on the mini–guide base is sufficient to remain inside safe operating limits set forth for the water depth in which the base is situated and for the offsets to which the vessel may be subjected.

Input values:

1. Water depth (m)
2. Select the safety-joint parting tension, typically 100 kips. Note that this number can be increased or decreased based on the number of shear pins used.
3. Select the normal desired operating point of the safety joint.
4. Specify the upper limit for the operating safety joint.
5. Specify the lower limit for normal operations with the safety joint. This value will be the lowest acceptable riser overpull at the seafloor, as determined from the tension-offset envelopes. Avoid zero overpull and stay away from regions in the tension-offset envelopes where there are rapid changes.
6. Select the tensioner variation due to the expected range or tensions. Usually the tension variation is expressed as a percentage of the top tension.
7. Determine the zero pipe-wall tension at the bottom of the riser roughly equal to the in-air weight of the riser.

Calculations:

1. Calculate the set or normal riser tension by adding the safety-joint target operating value to the in-air weight of the riser.
2. Calculate the amount of single-amplitude tension variation by multiplication of the set riser tension value with the percentage of tension variation.
3. Calculate the maximum riser tension by adding the set riser tension and tension variation. Check the appropriate tension-offset envelope at this tension and verify that the tension-offset region is acceptable.
4. Calculate the minimum riser tension by subtracting the set riser tension and tension variation. Check the appropriate tension-offset envelope at this tension and verify that the tension-offset region is acceptable.
5. Calculate safety-joint maximum tension by adding the safety-joint operating tension and the single-amplitude tension variation.
6. Calculate safety-joint minimum tension by subtracting the safety-joint operating tension and the single amplitude tension variation.

Notes:

1. If for any reason the calculations produce values outside acceptable limits of the tension-offset envelopes, return to step 1 and select new values. This is also true if the safety joint's maximum tension exceeds the allowable operating tension and if the safety joint's minimum tension is less than the minimum allowable operating tension.
2. Actual riser string weight must equal the design string weight.
3. Riser tension must not exceed the design tension value.
4. Tension variation from the compensator must not exceed the design tension variation percentage.

The in-air weight or zero bottom pipe-wall tension is required in the calculation. These values are almost the same and can be used interchangeably.

The following values were calculated with the computer program STARIS, which takes into account the external and internal pressure (buoyancy) surfaces along the riser, such as that which occurs when there is a change in cross section. These values are compared to the in-air weight.

Water depth (m)	In-air riser weight (lb)	STARIS riser value (lbf)
1500	112,682	112,513
2500	192,062	191,107
3500	283,217	280,117
4500	374,372	369,127

Input values:

1. Water depth: 2500 m
2. 100 kips
3. 50 kips
4. 75 kips
5. 25 kips
6. 3%
7. 192 kips

Calculations:

1. Set operating riser tension: 50 + 192 = 242 kips
2. Tension variation: 242 × 0.03 = 7.26 kips (single amplitude)
3. Maximum riser tension: 242 + 7 = 249 kips. Check Figure 25 if tension-offset envelope is acceptable.
4. Minimum riser tension: 242 – 7 = 235 kips. Check Figure 25 if tension-offset envelope is acceptable.
5. Maximum tension on the safety joint: 50 + 7 = 57 kips. This is acceptable since 57 < 75 kips.
6. Minimum tension on the safety joint: 50 – 7 = 43 kips. This is acceptable since 43 > 25 kips.

APPENDIX B

Recommended Design Procedures for Using Calculated Fatigue Curves

Typically fatigue life is not a problem for the connected riser's lateral dynamics (i.e., bending stress range), even with very conservative assumptions if wave conditions do not exceed an equivalent maximum regular wave of H_{max} = 19.33 and T = 7.54 seconds (s). This sea state was computed from the computer program STARIS using a wind-driven wave of H_{sig} = 10.4 ft and T_{sig} = 7.06 s. This value of H_{sig} was assumed to be a typical offshore storm. Tensioner variations can cause significant fatigue damage to the tension safety shear pins if this variation goes unchecked. An example illustrating the fatigue life of the break-away safety joint is provided below.

1. Water depth: 4500 m (Fig. 27)
2. Normal operating point of the safety joint: 50 kips
3. In-air weight of the riser: 374 lbf
4. Normal riser top tension: 50 + 374 = 424 kips
5. Tensioner variation: 3%
6. Single-amplitude tensioner variation: 0.03 × 424 = 12.7 kips
7. Total tension variation: 2 × 12.7 = 25.4 kips
8. Area of 1/4-in. shear pin: 0.049 in^2
9. Load variation per pin: 25.4 ÷ 18 = 1411 lbf
10. Shear stress range/pin (4/3 × V/A): 4/3 × 1411/0.049 = 38,400 psi
11. According to Figure 29, the calculated fatigue life for base material is 0.026 yr, or 9 days.

This example points out the necessity of reducing tensioner variations to a minimum. *If the tensioner variation becomes too great, riser operation may be unsafe and prone to sudden catastrophic failure due to fatigue.* To reduce the potential of fatigue failure, the shear pins in the tension safety joint should be changed on a routine basis or after a threshold of accumulated hours has been placed on the riser.

Table 5. Drilling data for 9-1/2-in. coring motor, Site 864.

Item	WOB (kips)	Flow rate (spm)	Flow rate (gpm)	Operating pressure (psi)	Stall pressure (psi)	Penetration (m)	Time (hr)	Comments
1	0–2	30	155.1	100–115		0	0908	Start
2	0–5	40	206.8	160–210			0927	
3	0–5	50	258.5	250–275			0942	
4	0–5	60	310.2	275–295			0956	
5	4–10	60	310.2	270–290			1000	
6	4–8	70	361.9	350–410			1007	
7	4–10	70	361.9	375–460			1028	
8	4–9	70	361.9	600–650	800		1049	
9	4–9	70	361.9	550–600	800	0.5	1100	
10	4–9	70	361.9	600	800		1113	
11	4–10	70	361.9	500–600	900	1	1345	Stalling
12	4–8	70	361.9	600–700	900	1.5	1500	
13	4–8	80	413.6	500–700	1000			Increase rpm
14	4–8	90	465.3	600–750	1200	1.75	1750	
15	5–10	90	465.3	550–850	1200	2.5	1945	
16	5–10	90	465.3	550–850	1200		2200	Sweep hole
17	5–10	90	465.3	650–800	1200	2.7	0000	
18	5–10	90	465.3	500–900	1200		0050	Sweep, overpull 20,000 lb
19	5–10	80	413.6	500–700	1200		0123	
20	5–10	90	465.3	550–800	1200		0215	
21	2–10	90	465.3	600–800	1200		0517	
22	5–10	90	465.3	500–950	1200	3	0643	
23	5–10	90	465.3	500–900	1200		0806	Overpull 15,000 lb
24	5–10	90	465.3	500–900	1200		0845	
25	5–10	90	465.3	500–900	1200	3.25	0900	Overpull 60,000 lb
26							0930	Pull out of hole

Notes: Bit size: 12.5 in./7.25 in. Water depth: 2600 m. Bit type: Security/M89TF.

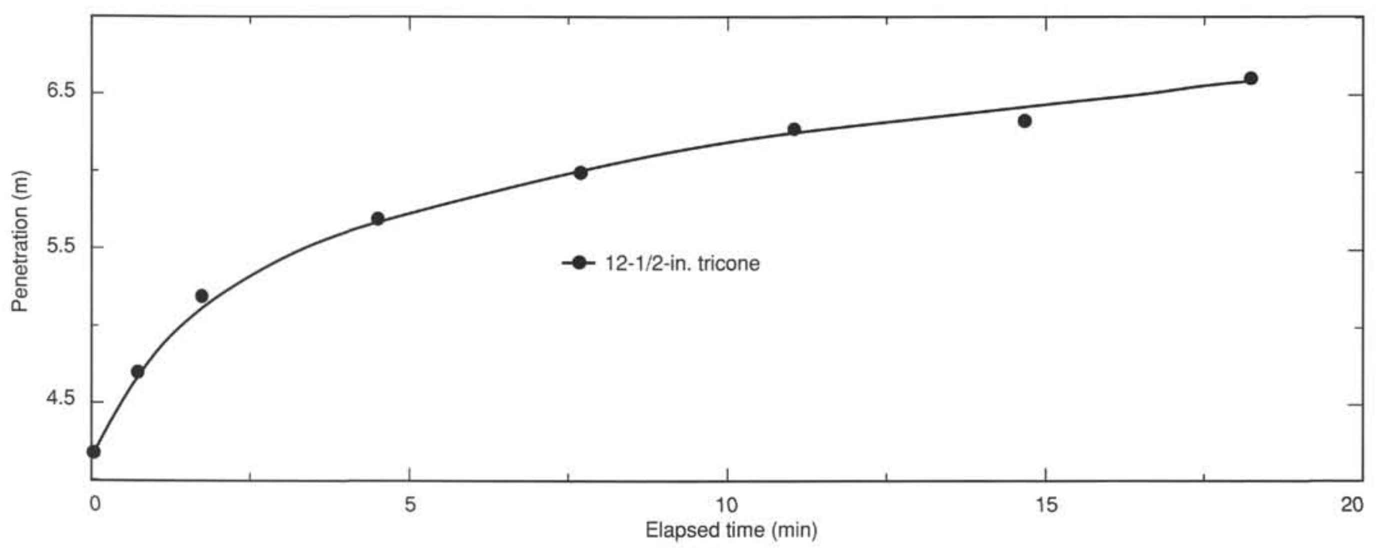


Figure 74. PDCM penetration and bit weight vs. time. (Note: Heave less than 1 m; broke out of massive flow at 4.2 mbsf.)

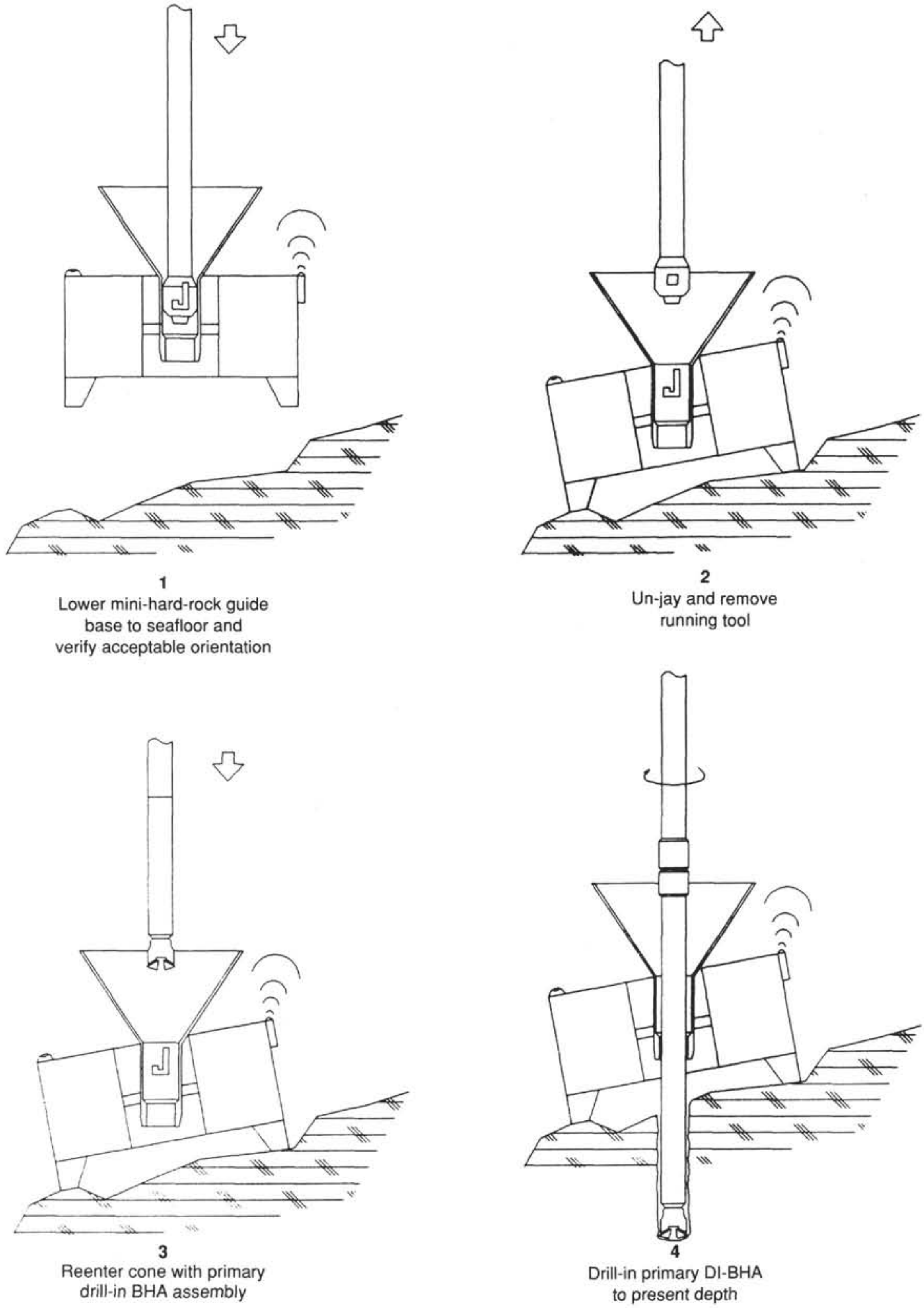


Figure 75. Deployment sequence for nested drill-in BHA system (DCS and ream).

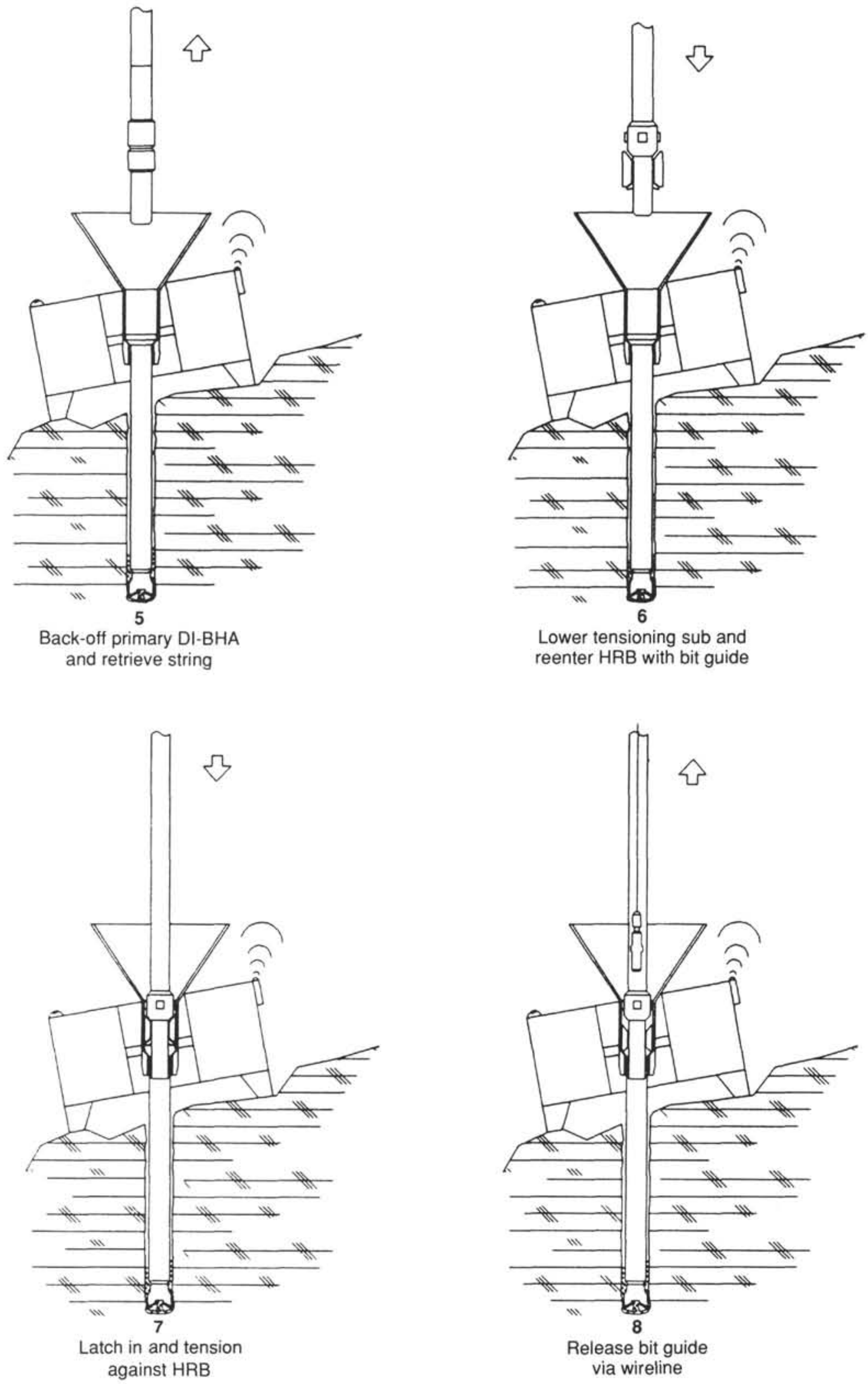
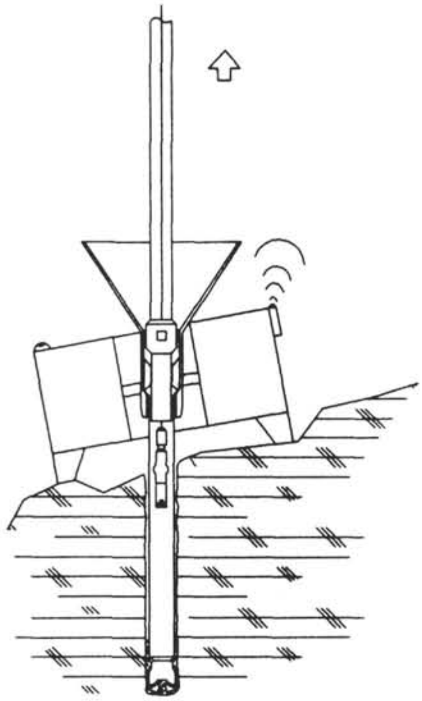
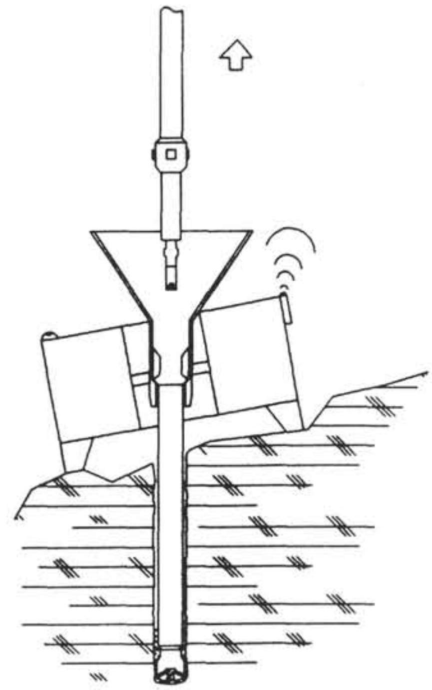


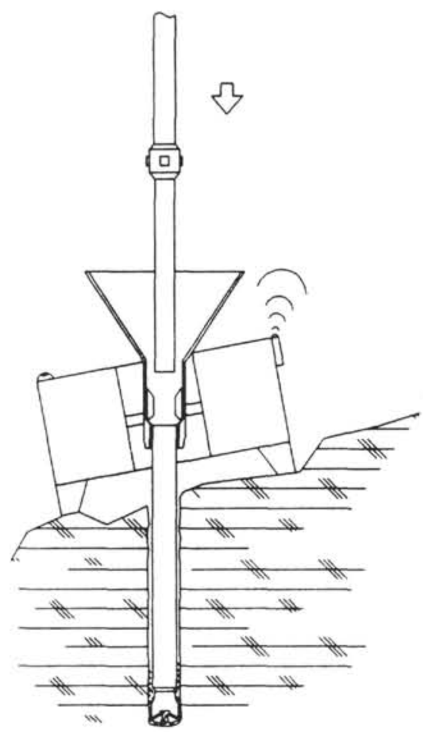
Figure 75 (continued).



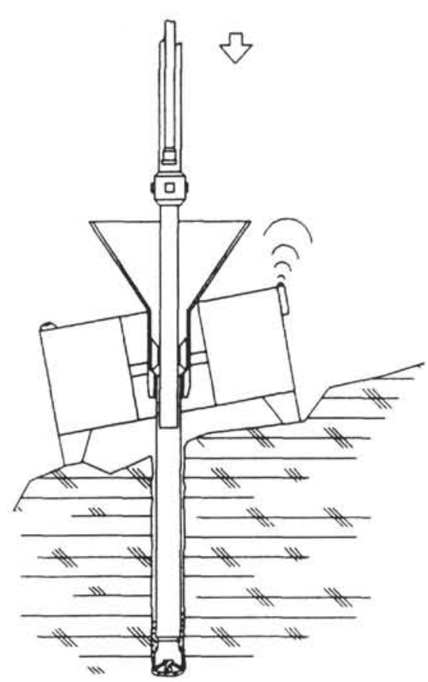
9
Retrieve center bit into
bit guide sub and jar off



10
Un-jay and trip out string
with center bit attached



11
Lower tensioning sub with 6-3/4
drill collars attached



12
Trip in DCS tubing to
just above tensioning sub

Figure 75 (continued).

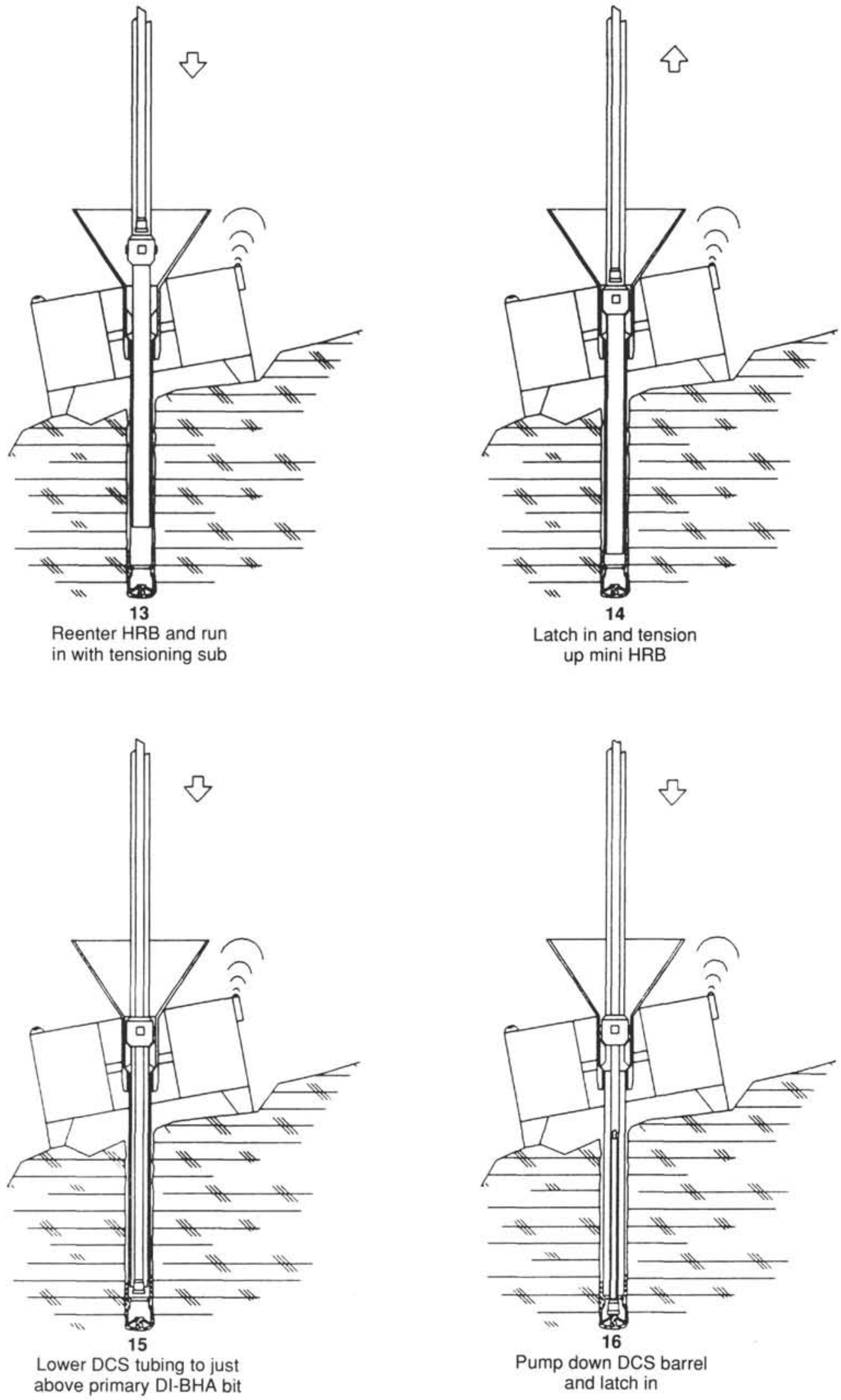
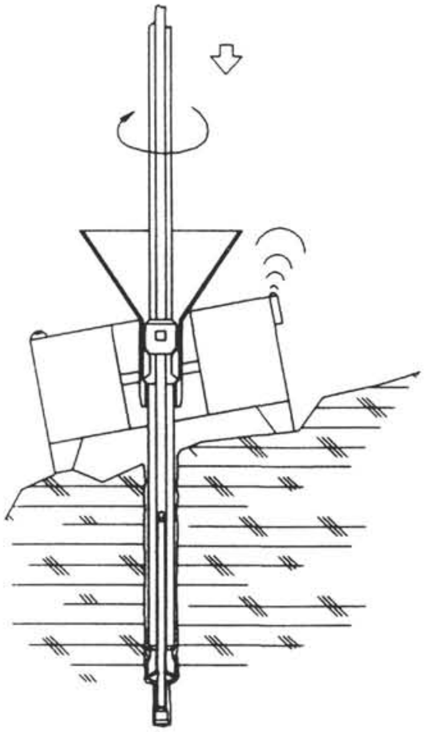
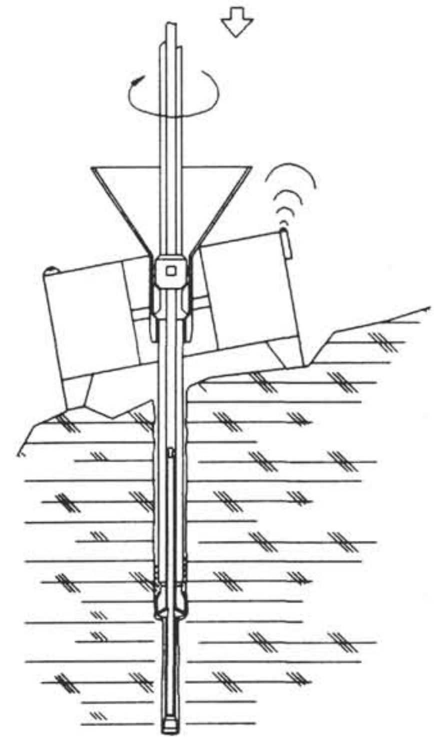


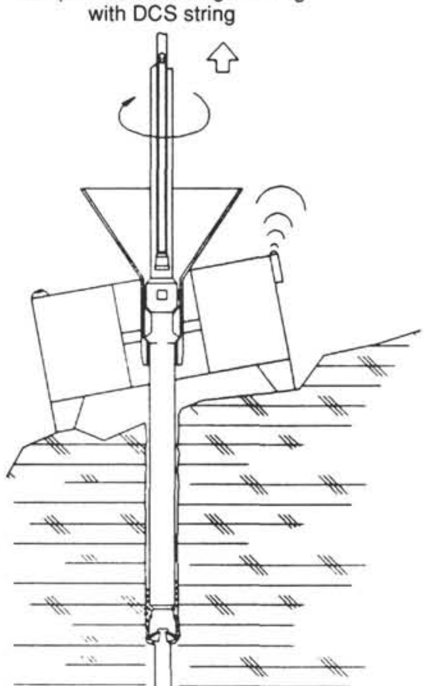
Figure 75 (continued).



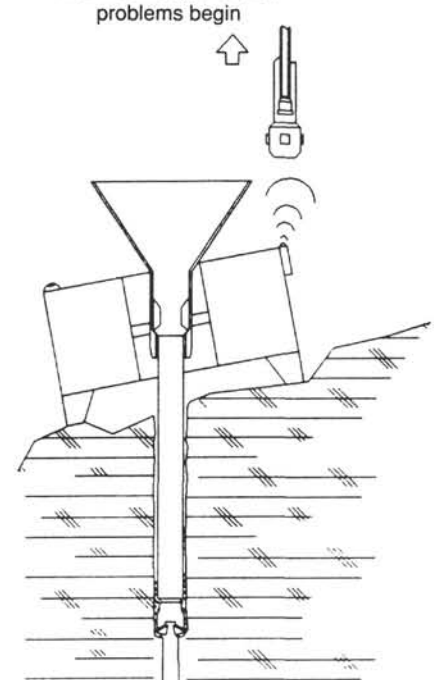
17
Activate secondary compensator and begin coring with DCS string



18
Core with DCS string to maximum depth or until problems begin



19
Pull DCS string just above tensioning sub



20
Un-jay and offset from HRB

Figure 75 (continued).

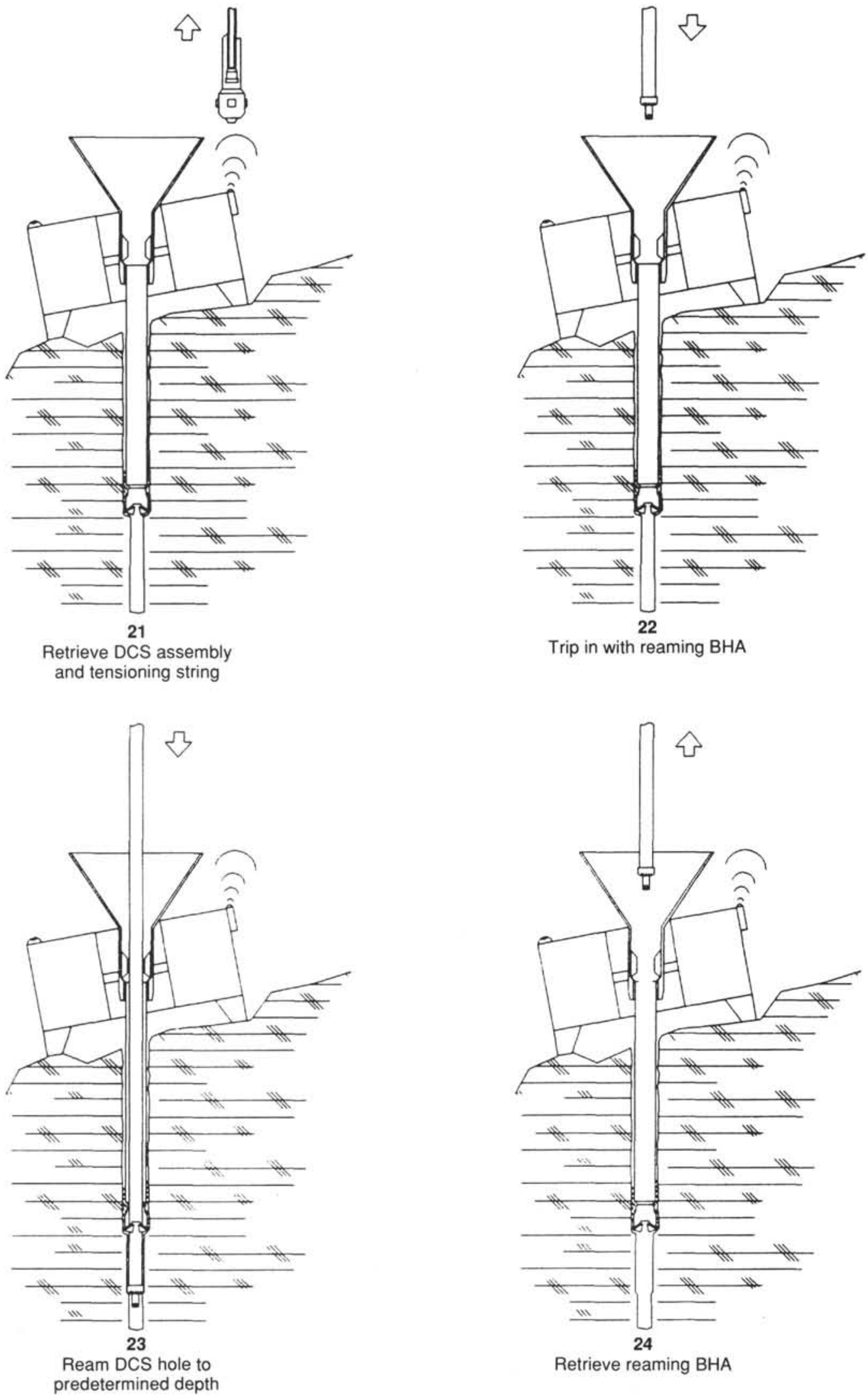
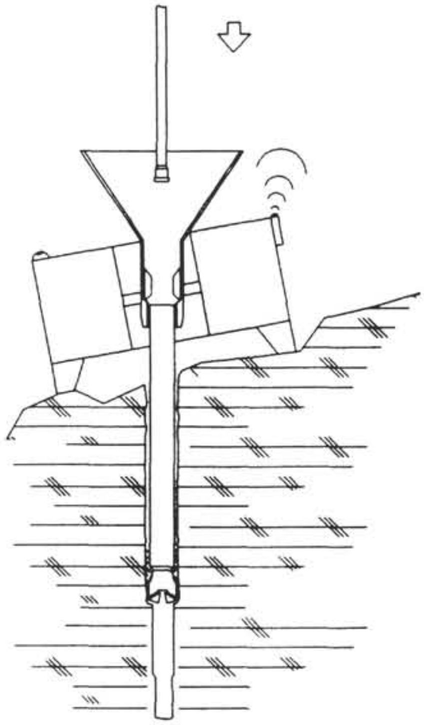
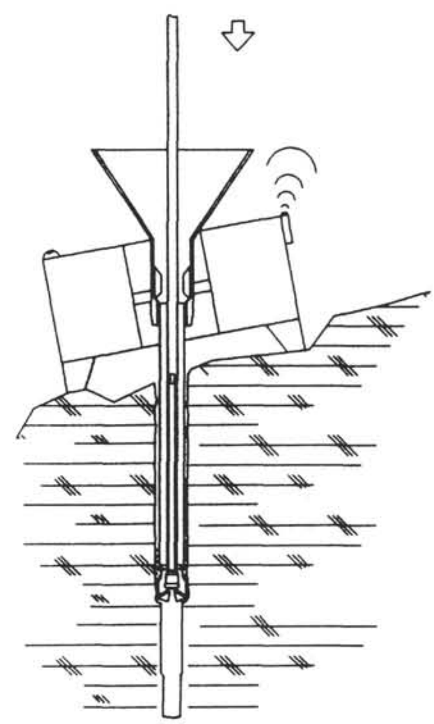


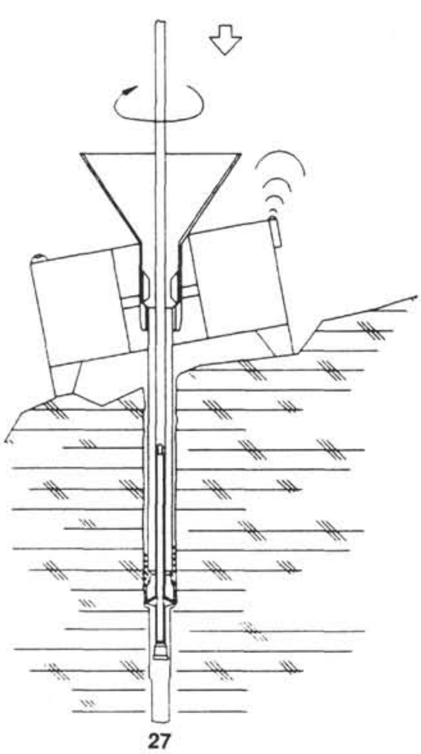
Figure 75 (continued).



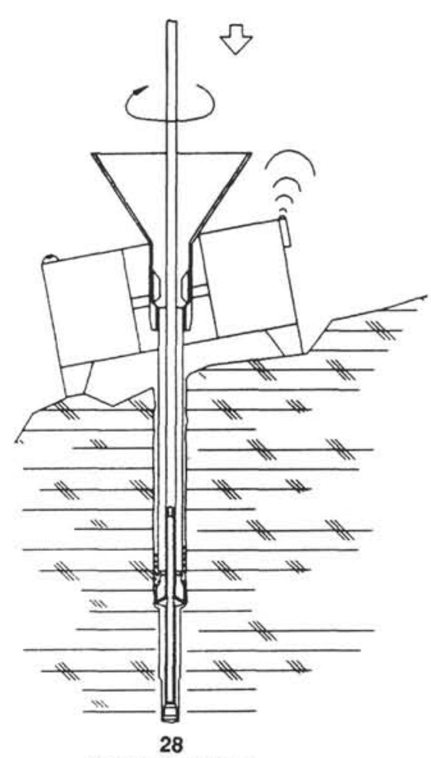
25
Reenter with diamond core barrel coring assembly



26
Pump down DCB inner barrel and latch in

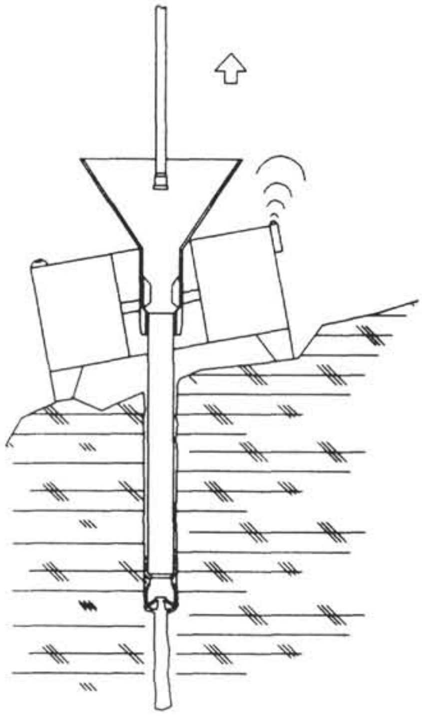


27
Activate primary compensator and begin coring with DCB string

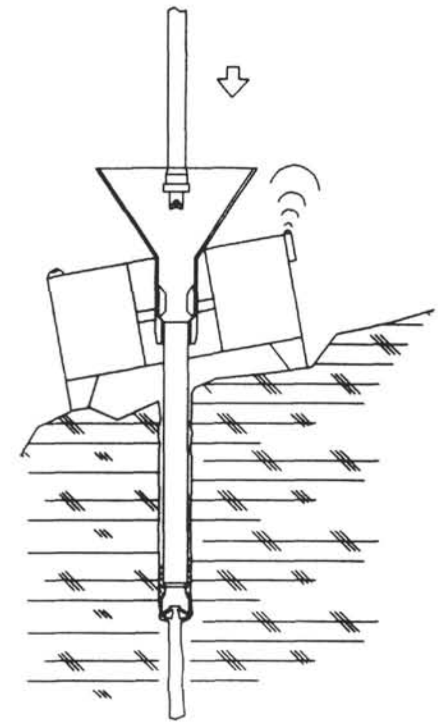


28
Core with DCB to determined depth

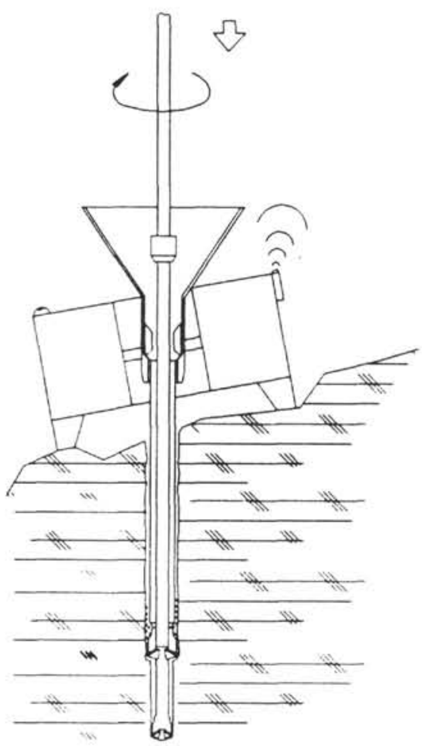
Figure 75 (continued).



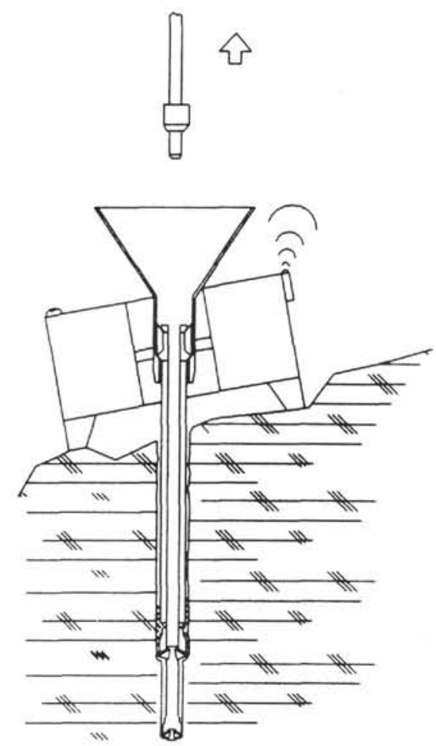
29
Retrieve DCB assembly



30
Reenter with secondary
DI-BHA and center bit assembly

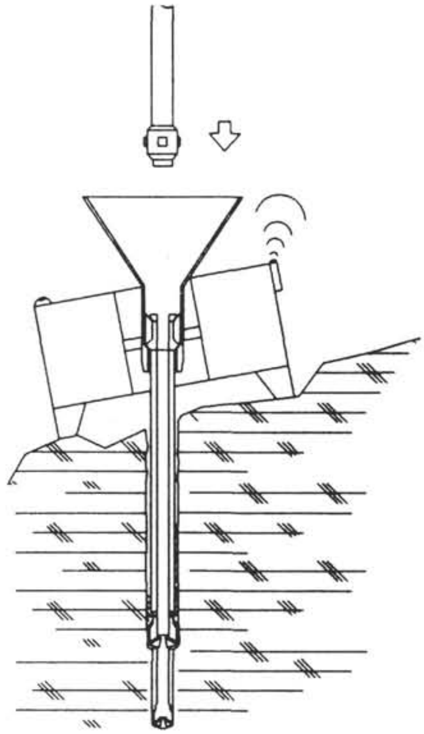


31
Drill in secondary DI-BHA
to predetermined depth

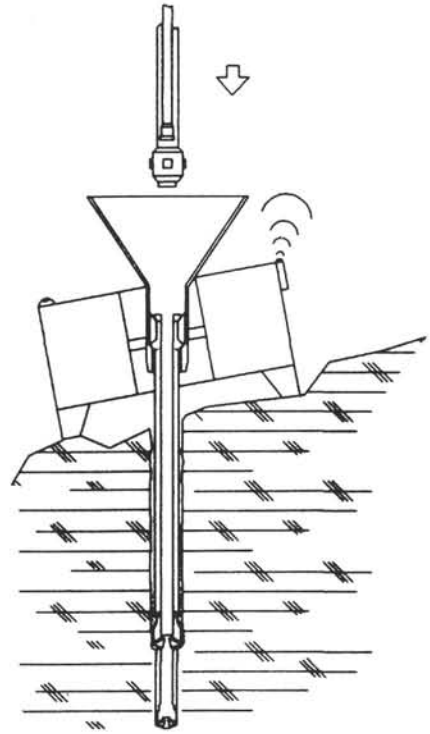


32
Back off secondary DI-BHA
and retrieve string

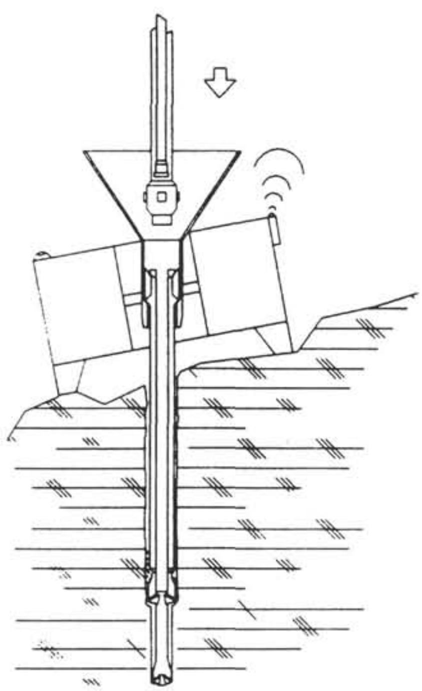
Figure 75 (continued).



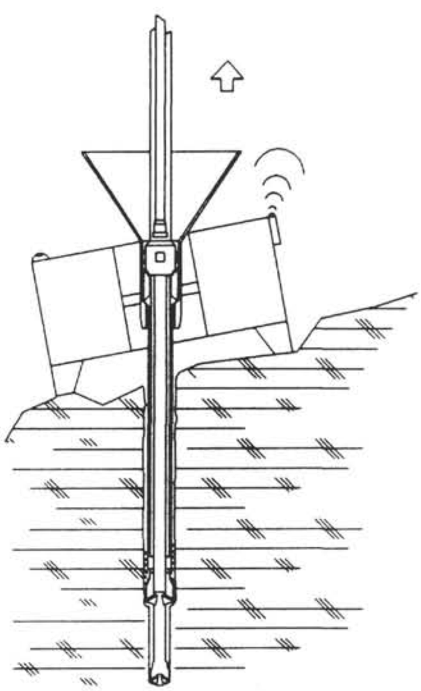
33
Lower tensioning sub



34
Trip in DCS tubing to just above tensioning sub

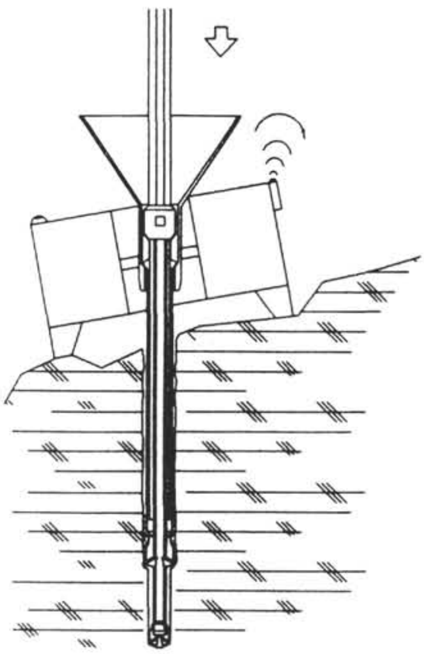


35
Reenter HRB and run in with tensioning sub

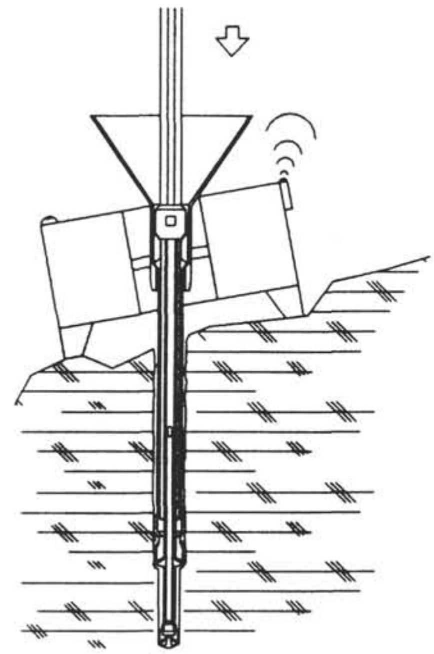


36
Latch in and tension up mini-HRB

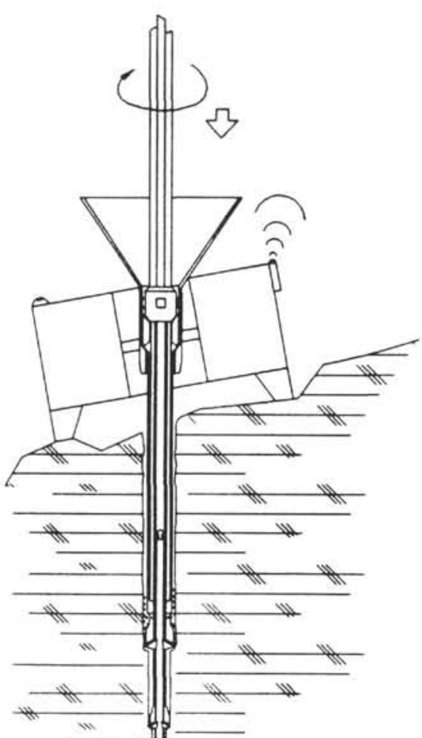
Figure 75 (continued).



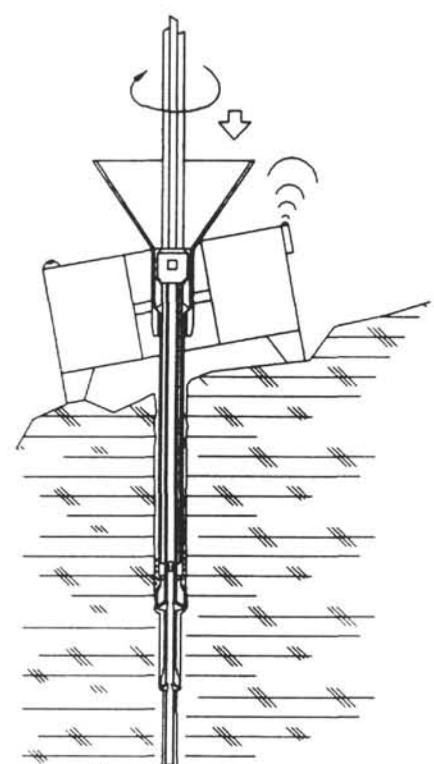
37
Lower DCS tubing to just above primary DI-BHA bit



38
Pump down DCS barrel and latch in



39
Activate secondary compensator and begin coring with DCS string



40
Core with DCS string to maximum depth or until problems begin

Figure 75 (continued).

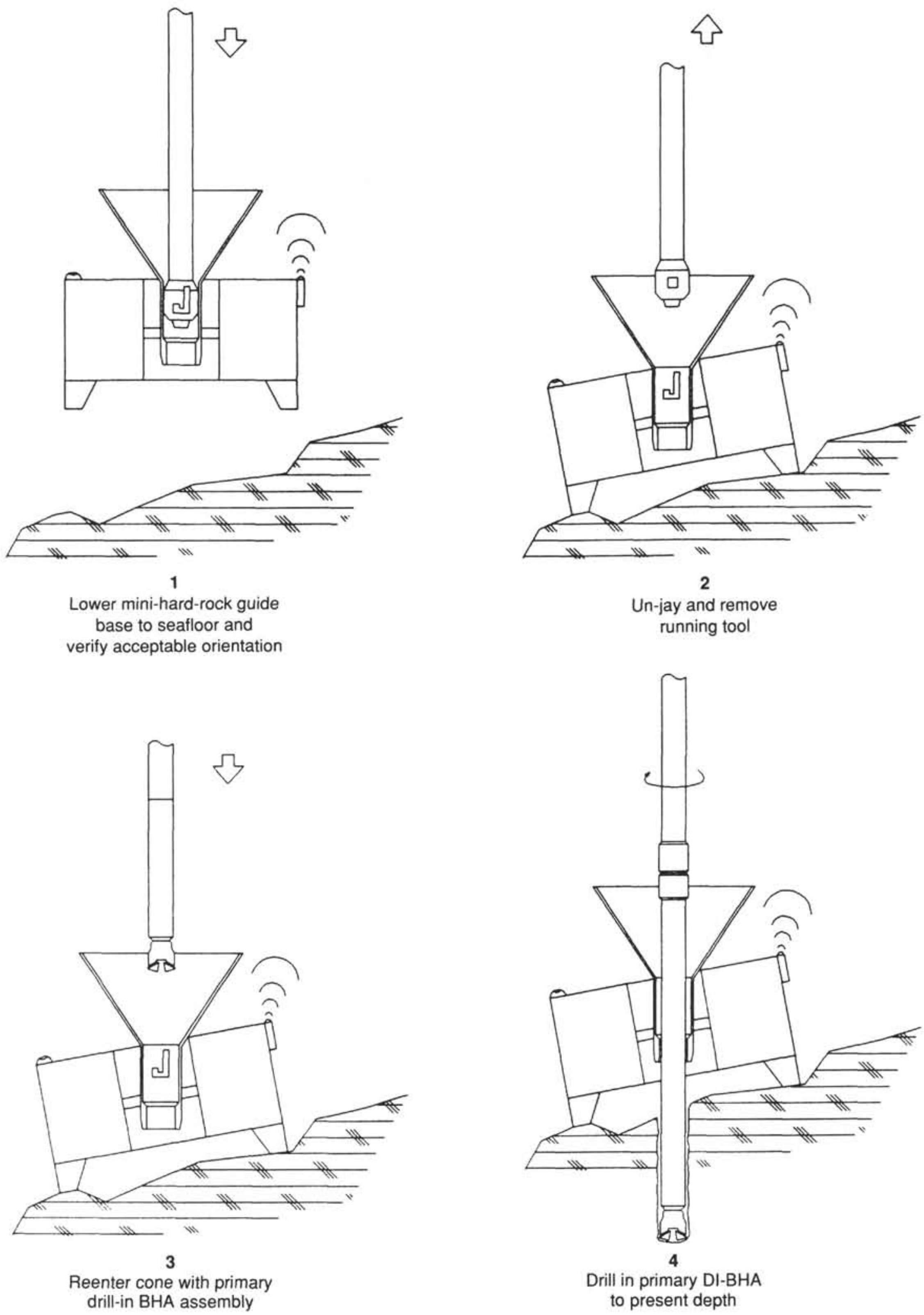


Figure 76. Deployment sequence for nested drill-in BHA system (DCB followed by DCS).

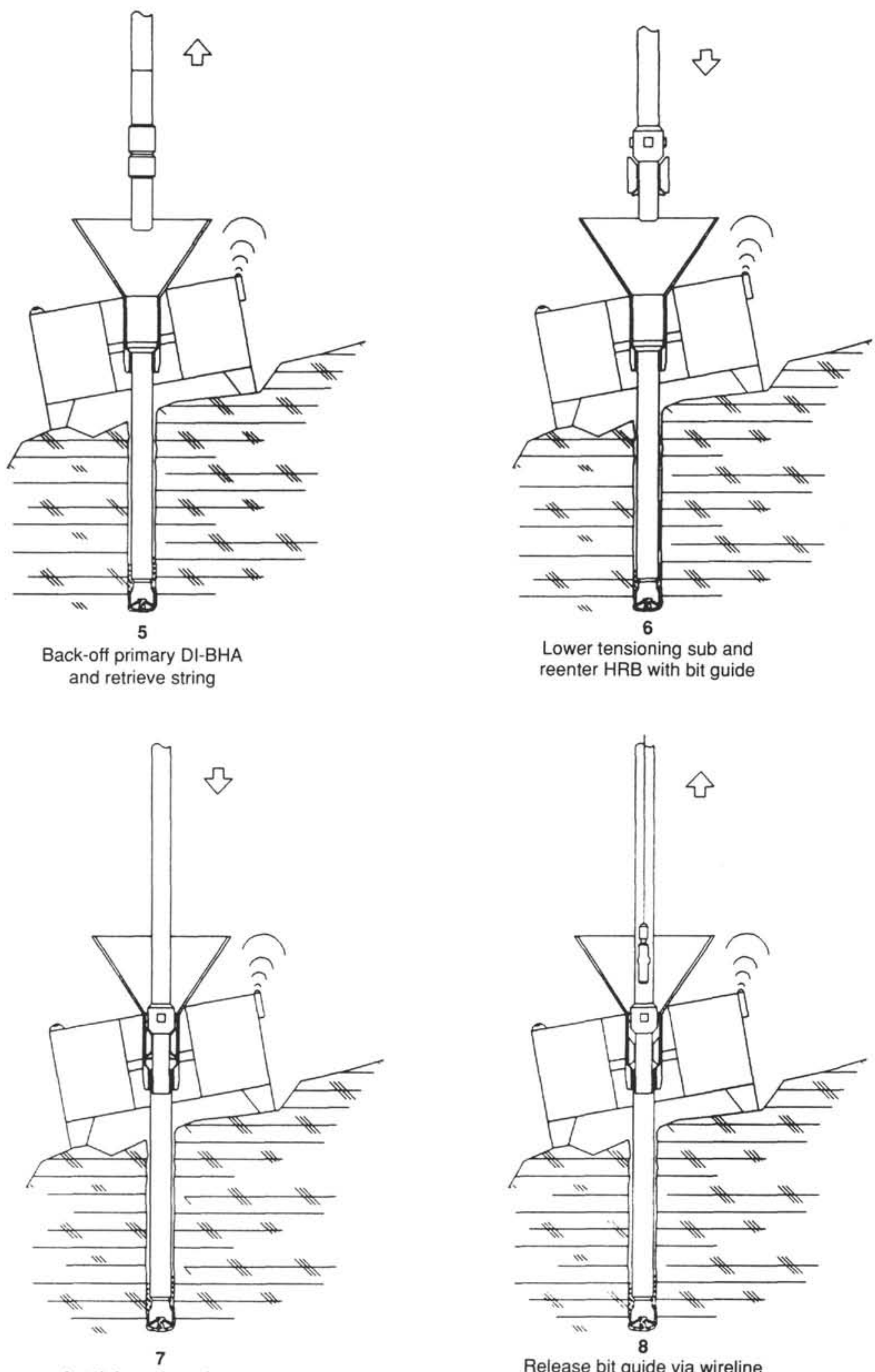
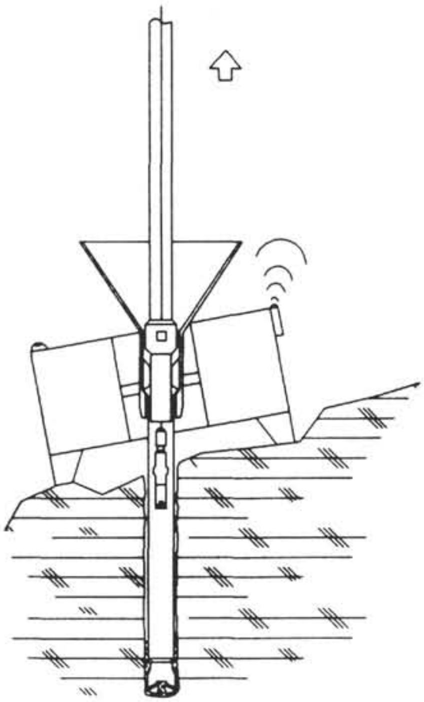
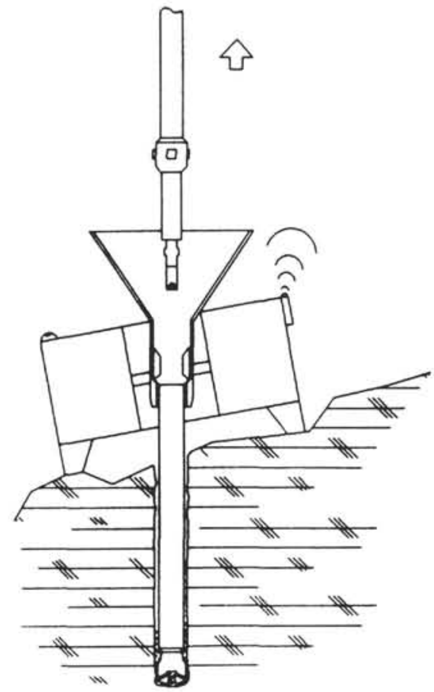


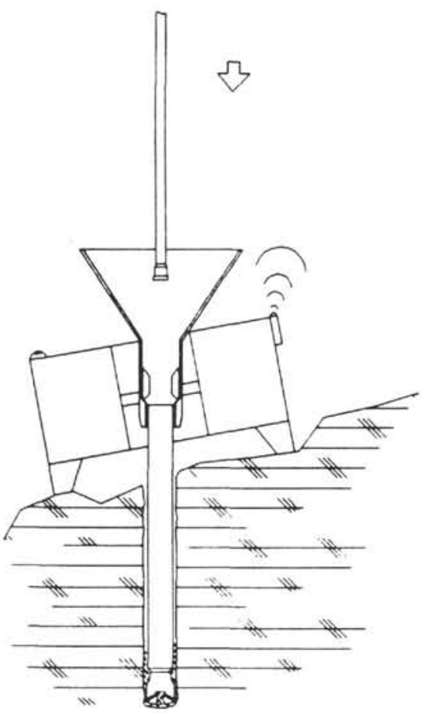
Figure 76 (continued).



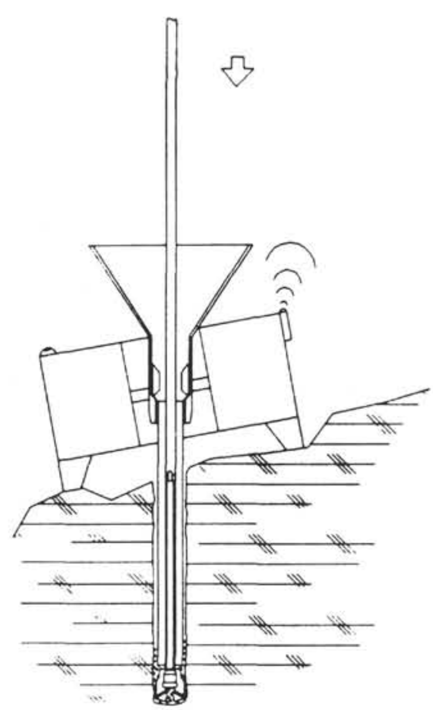
9
Retrieve center bit into bit guide sub and jar off



10
Un-jay and trip out string with center bit attached

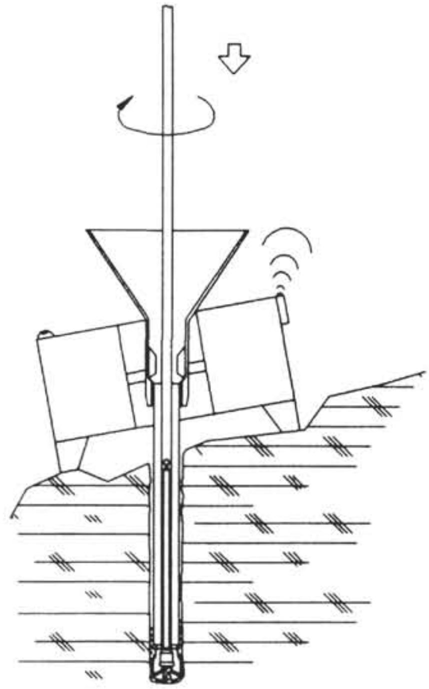


11
Reenter with diamond core barrel coring assembly

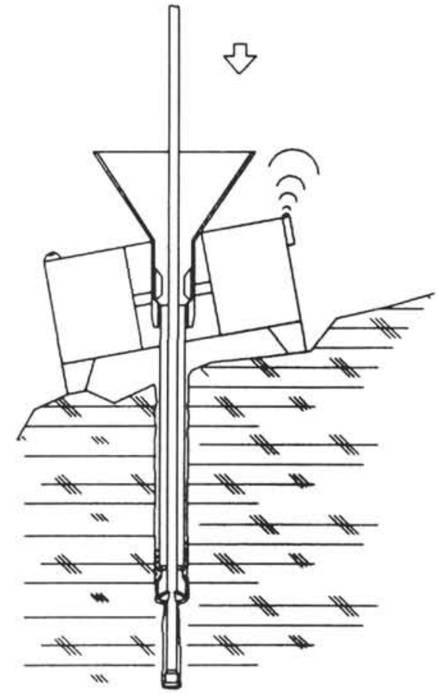


12
Pump down DCB inner barrel and latch in

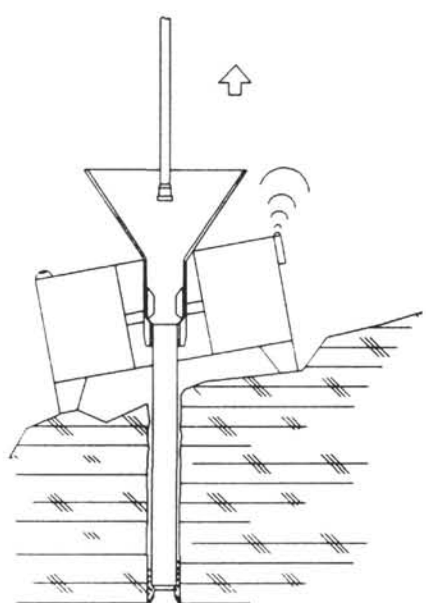
Figure 76 (continued).



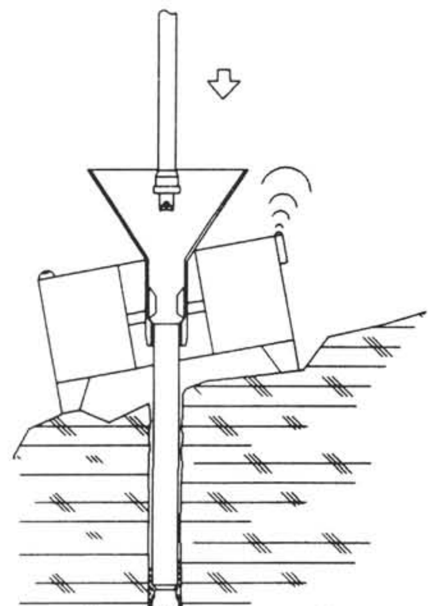
13
Activate primary compensator
and begin coring with DCB



14
Core with DCB to
determined depth

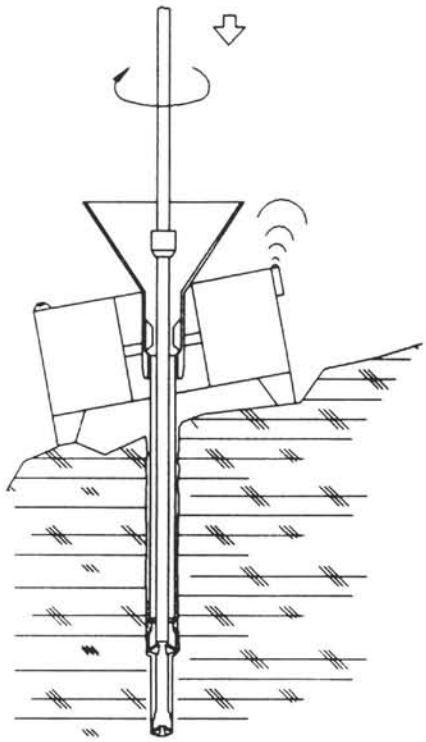


15
Retrieve DCB assembly

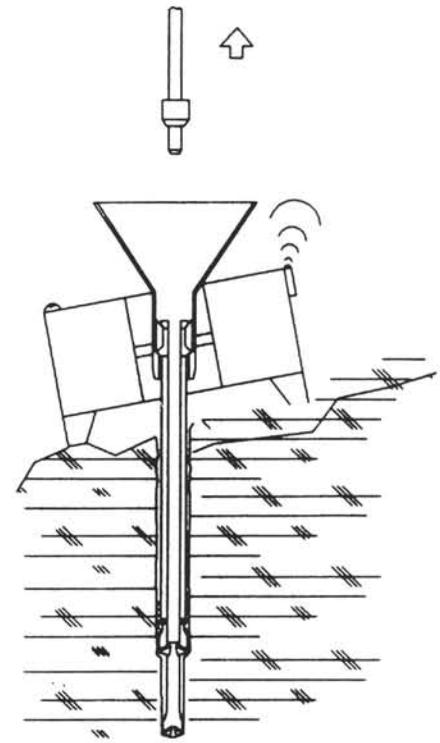


16
Reenter with secondary DI-BHA
and center bit assembly

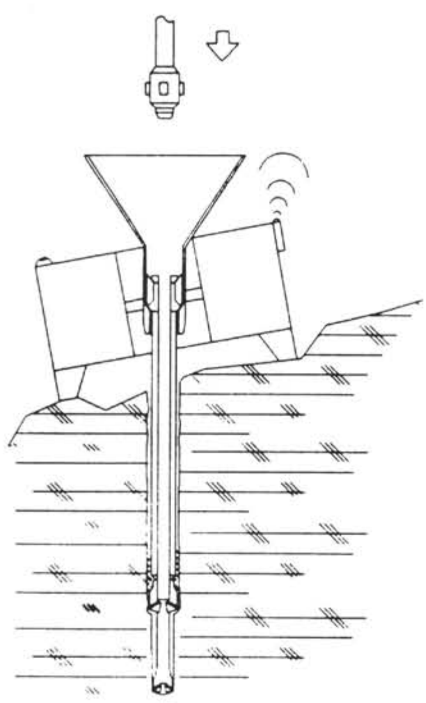
Figure 76 (continued).



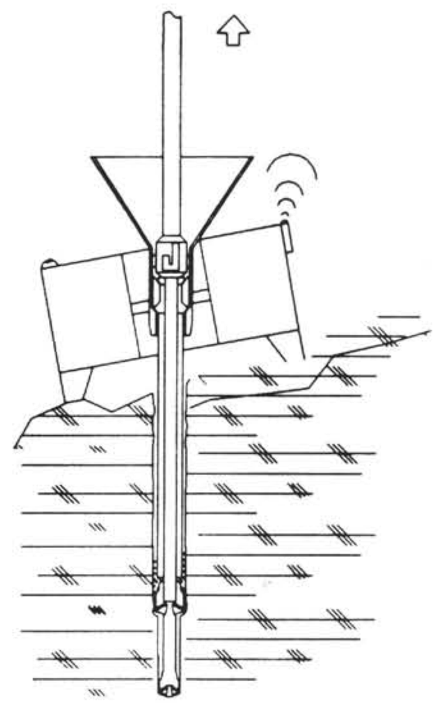
17
Drill in secondary DI-BHA
to predetermined depth



18
Back off secondary DI-BHA
and retrieve string



19
Lower tensioning sub
to just above HRB



20
Latch in and tension
up mini HRB

Figure 76 (continued).

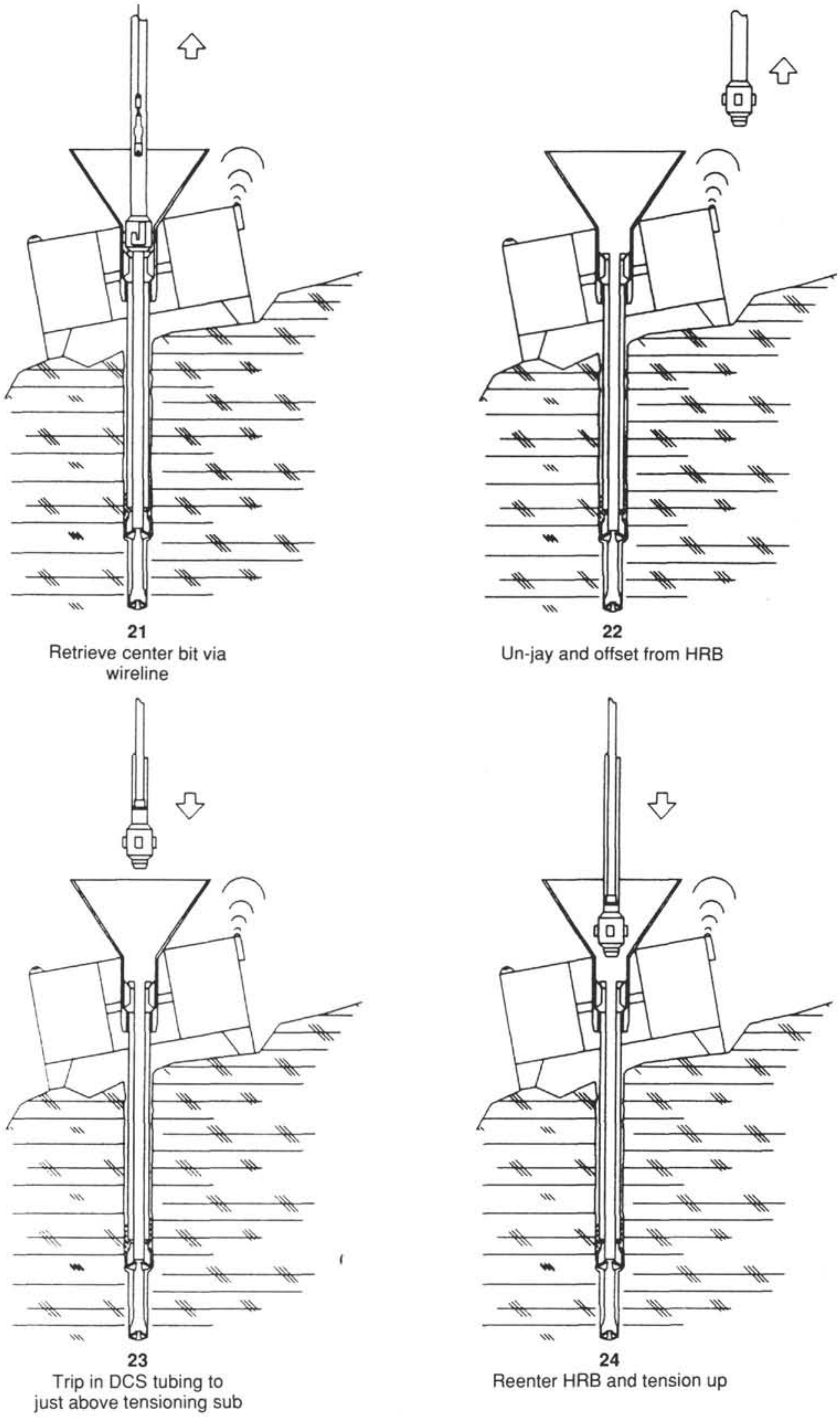
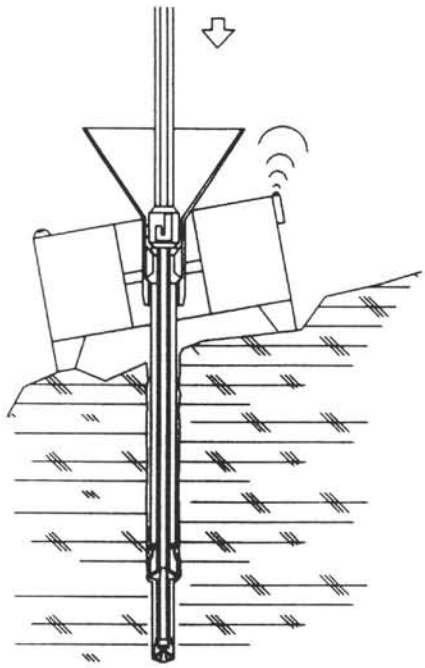
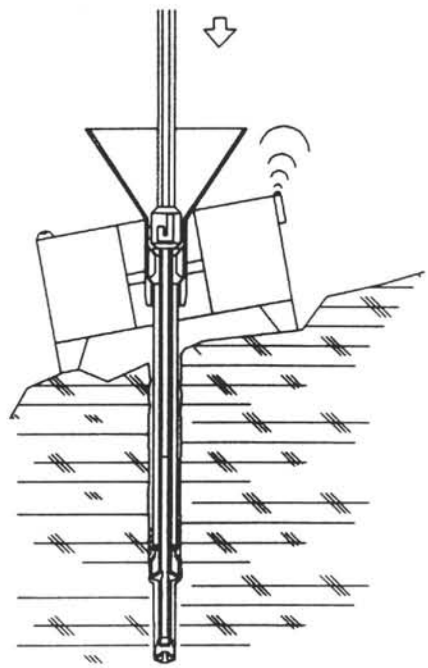


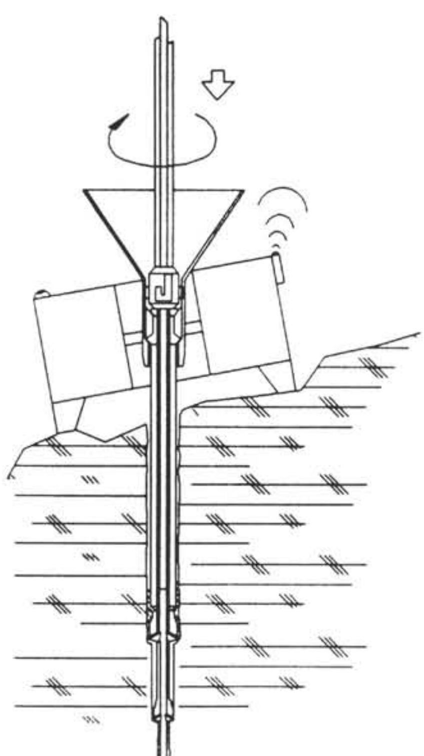
Figure 76 (continued).



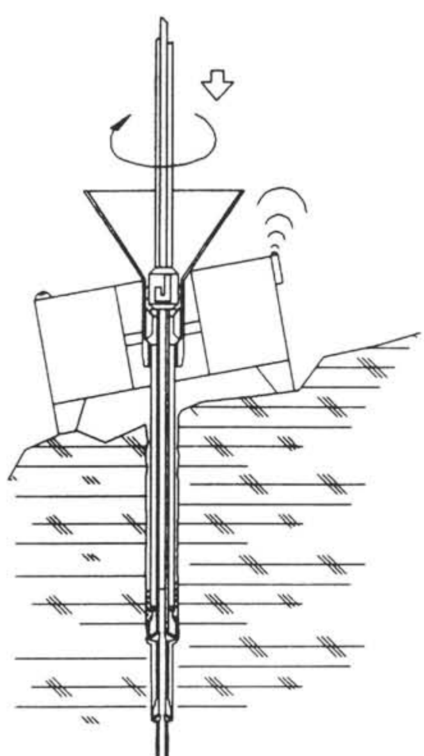
25
Lower DCS tubing to just above secondary DI-BHA bit



26
Pump down DCS inner barrel and latch in



27
Activate DCS secondary compensator



28
Begin coring with DCS string

Figure 76 (continued).