DEEP SEA DRILLING PROJECT
TECHNICAL REPORT No.2

RE-ENTRY
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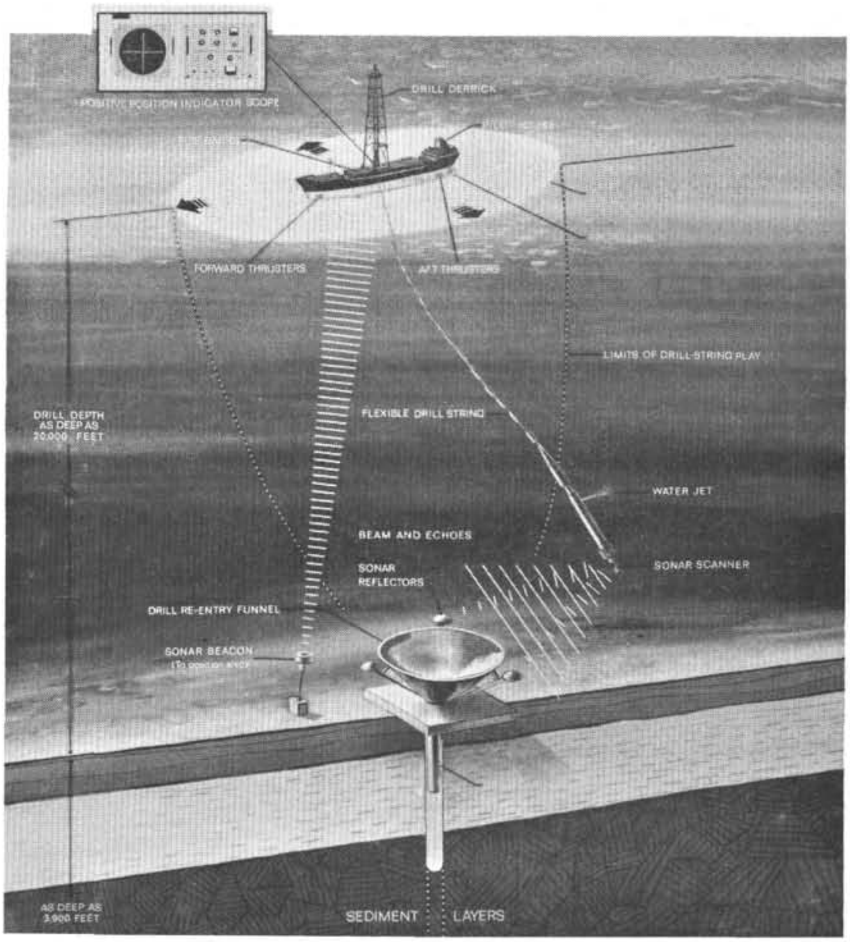
SCRIPPS INSTITUTION OF OCEANOGRAPHY
University of California at San Diego

ACOUSTICAL RE-ENTRY OF EXPLORATORY CORE HOLES IN THE DEEP OCEAN

DYNAMIC POSITIONING AND RE-ENTRY



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Deep Sea Drilling Project
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INTRODUCTION

When very hard layers of chert and flint, which prematurely dulled core bits, were encountered in the deep oceans worked by the Deep Sea Drilling Project, scientists and engineers realized that re-entry into a bore-hole thousands of feet beneath the surface of the oceans was a necessity to achieve scientific objectives.

An engineering study by Deep Sea Drilling Project indicated that the ability to re-enter a bore-hole, drilled without a riser or guide lines, could increase D/V Glomar Challenger's capabilities.

With re-entry, worn bits could be replaced, bottom-hole assemblies changed, protective casing strings could be run, full-size logging sondes could be run, and instrument packages could be implanted and recovered.

Encouraged by the National Science Foundation's willingness to amend the Prime Contract to allow the use of re-entry, Deep Sea Drilling set up a program to provide re-entry capabilities on D/V Glomar Challenger.

The re-entry program, from start to acceptance as a standard operational procedure, is discussed in this Technical Report.

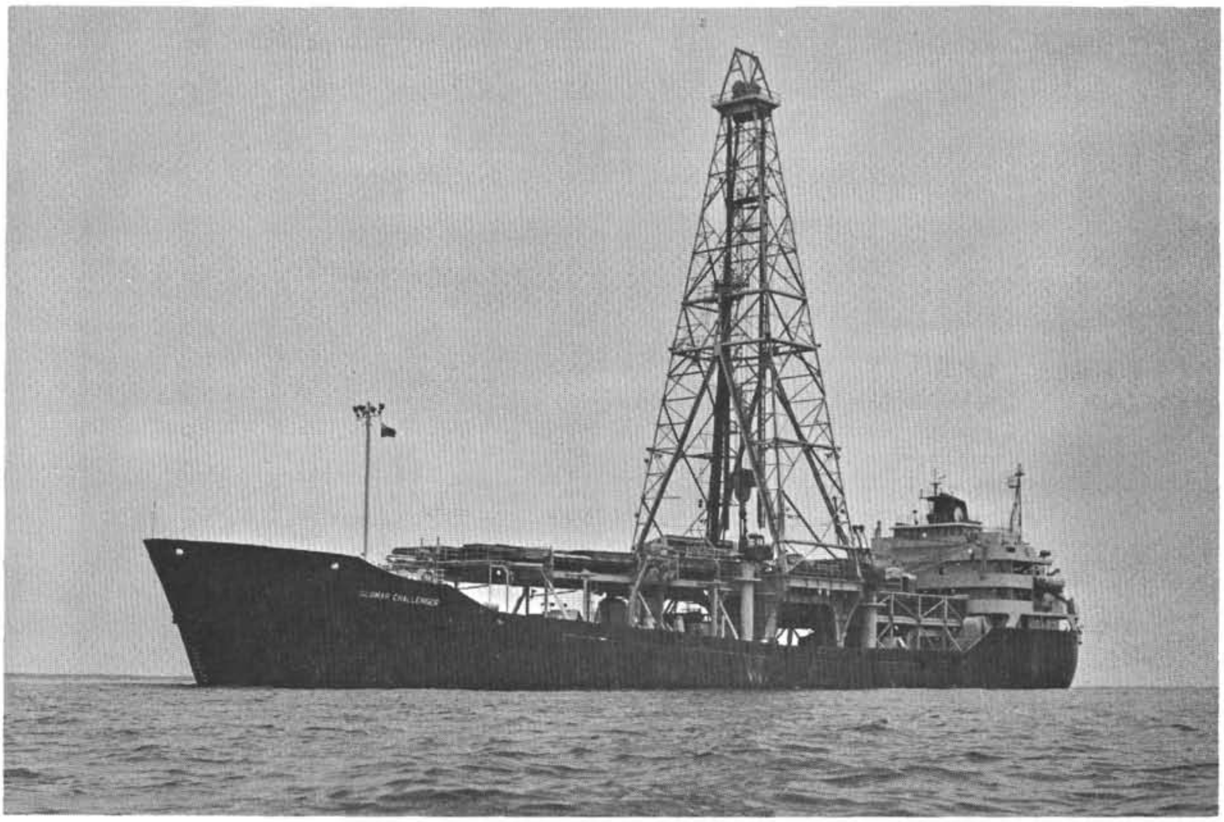

Figure 1

The Glomar Challenger is the drill ship from which re-entry was accomplished.

ACKNOWLEDGEMENTS

Overall management of re-entry by Project Engineer Darrell L. Sims, which resulted in the first successful re-entry of a bore hole during re-entry trials on June 14, 1970, in the Atlantic Ocean and the first operational re-entry on Christmas Day, 1970, in the Caribbean Sea, is gratefully acknowledged.

Our thanks for a successful re-entry system also go to Mr. John R. Eberhart, who was loaned to the Deep Sea Drilling Project for six months by Standard Oil Company of California. When he completed his work with Deep Sea Drilling Project on July 18, 1969, Mr. Eberhart had finished an exhaustive engineering study "Methods to Penetrate Hard Formation in Deep Oceans" in collaboration with Mr. Sims.

The study, which is a part of this technical report, contributed exceedingly to the overall technical success of re-entry.

We also recognize the invaluable technical assistance given by Mr. Tom Dixon and Mr. Leon Blurton, of Global Marine Inc.; Mr. Gary J. Behunin, of Edo Western; and Mr. Valdemar F. Larson, Deep Sea Drilling Project Operations Manager.

And we further acknowledge the continuing help of Mr. A.R. McLerran, National Science Foundation Field Project Officer for Deep Sea Drilling Project, and the support of the National Science Foundation. We also thank Dr. William Rand and Mr. Kenneth Brunot, prior Project Managers.

The recognition by scientists, on early cruises of D/V Glomar Challenger, of the imperative to penetrate beneath resistant layers, and the support and guidance of the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES) in fostering the entire Project and its response to these scientific imperatives, is fully acknowledged.

M.N.A. Peterson
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November, 1971

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ACOUSTICAL RE-ENTRY OF EXPLORATORY CORE HOLES IN THE DEEP OCEAN

On October 6-7, 1966, a prototype sonar high-resolution scanning re-entry instrument was successfully tested in the Santa Barbara Channel. This equipment was "mothballed" when Project Mohole was discontinued.

No further work was done on deep water acoustic re-entry until the Deep Sea Drilling Project re-activated the program.

During this interval, Edo Western, of Salt Lake City, Utah, and AC Defense Research Laboratory (ACDRL), of Goleta, California, a division of General Motors, upgraded the high resolution scanning sonar system for shallow water (366 meters) operation. Shell Oil Company successfully tested the Edo system in the Gulf of Mexico, while ACDRL tested its system in the Santa Barbara Channel.

EC & G Company, of Waltham, Massachusetts, built a system using a transponder array on a landing base. In addition to successful tests in the Gulf of Mexico, a group of oil companies evaluated the system in the Santa Barbara Channel during April 1968. Oceanic Enterprises, of Baltimore, Maryland, also built a bottom pinger array system, but Deep Sea Drilling Project is not aware of the results of any test - if any have been made.

The Program Plan for the initial phase of Deep Sea Drilling Project specifically excluded re-entry, as the Prime Contract reflected the statement by Congress that re-entry would not be used on this sediment coring program.

However, project engineers and scientists soon realized drilling and coring conditions were not as expected. A review of possible approaches to increase coring and drilling capabilities was summarized in the report, "Concept for Coring in Deep Ocean Waters From Self-Propelled Vessels", November 1968. This cited report specified re-entry as the most logical approach.

On November 6, 1968, Global Marine Inc. submitted an unsolicited proposal to furnish a re-entry system for D/V Glomar Challenger. The Project deemed the terms and conditions excessive, and did not seek National Science Foundation approval.

The Project negotiated with Standard Oil Company of California for a six-month loan of an engineer to work on re-entry. John R. Eberhart joined Deep Sea Drilling Project on January 14, 1969, and returned to Standard Oil on July 18, 1969. During his stay, he completed an extensive review of the state of the art for deep water re-entry. From this, he worked up a statement of work and request for quotation (RFQ) for a re-entry system for Deep Sea Drilling Project. Mr. Eberhart also collaborated on an engineering study, "Methods to Penetrate Hard Formations in Deep Ocean Basins", June 1969.

Deep Sea Drilling Project requested the Prime Contract be amended so that a re-entry system could be procured and used on D/V Glomar Challenger. This amendment was completed on September 15, 1969.

On August 22, 1969, Global Marine Inc. submitted a second unsolicited proposal. This proposal was designed around using the ACDRL high-resolution scanning sonar system which required a coaxial cable and special cable handling equipment. This proposal was rejected since industry review indicated the high-resolution scanning sonar was best suited for Deep Sea Drilling Project, but that the Edo Western system could be adapted to our logging cable and thereby reducing initial cost.

Since Global Marine Inc. would operate and maintain the re-entry system, it was decided to enter into a system contract with that firm. The statement of work was sent to Global Marine Inc. on December 8, 1969, with a request for quotation. The statement of work included a request to include a report on their industry review on re-entry systems. The Global Marine Inc. quotation was received by Deep Sea Drilling Project on December 15, 1969, and accepted on December 19, 1969. National Science Foundation approval was received by teletype on December 19, 1971.

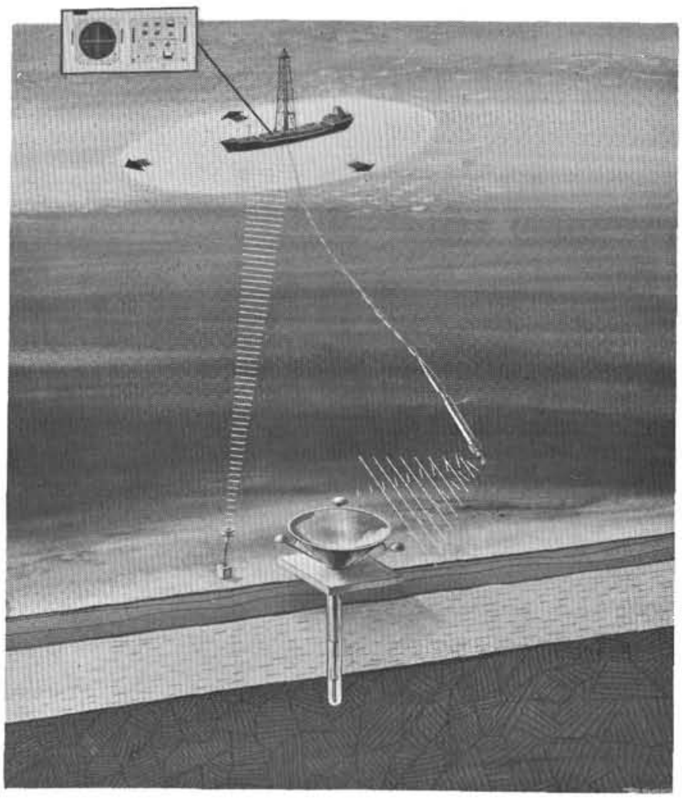

Figure 2
Artist concept of the acoustic re-entry system used by the Deep Sea Drilling Project.

Global Marine Inc. selected the following companies as their major lower tier subcontractors:

1. Edo Western - electronics

2. S. & R. Tool Company - re-entry cone and landing base

3. National Supply (Armco), of Houston, Texas - release hardware

4. Baker Oil Tool, of Los Angeles, California - release equipment and jet sub

A review of the release device (shear pins) indicated there might be a problem in getting enough drill collar weight or jar action to shear the pins and release the bottom hole assembly from the base if sufficient shear pins were used to wash in the casing string.

Deep Sea Drilling Project was in the process of testing an acoustic release for beacon recall. One release was modified so that on command it would fire one or more explosive shear bolts to release the bottom hole assembly.

The casing hangers and landing bases were modified so either release system could be run.

The cable runs for the surface equipment were installed during the port call at Galveston, Texas (February 5 to February 13, 1970).

The surface electronics was installed during the port call at Hoboken, New Jersey, June 1 through June 5, 1970. Two re-entry cones and the release gear also were loaded.

Figure 3
Positive Position Indicator (PPI) Scope which gives surface presentation of the target as to distance and bearing to the bit.

The next 12 days, (until June 17, 1970), were spent accomplishing the first re-entry.

The trip to the site was uneventful. The weather, in general, for the entire test was excellent. The sea did pick up to Sea State 4 during the actual re-entry.

After reaching our approximate location, the acoustical telemetering system, which was to fire the explosive shear bolts, was tested. The system would not work in 3048 meters of water. The hydrophone and release unit was rotated 45 degrees to the vertical but still could not fire, so additional tests indicated the unit would work at 610 meters but not at 914 meters.

After returning to location and dropping a beacon, a coring assembly was run into bottom to establish the depth below the mud line that could be penetrated without rotation, bit weight not to exceed 10,000 pounds and pump pressure not over 500 psi. This proved to be 252 feet which indicated six joints or 240 feet of casing should be run. A core was taken at maximum penetration.

Figure 4
The original cones were six sided. Shown here being rigged for an upright launch.

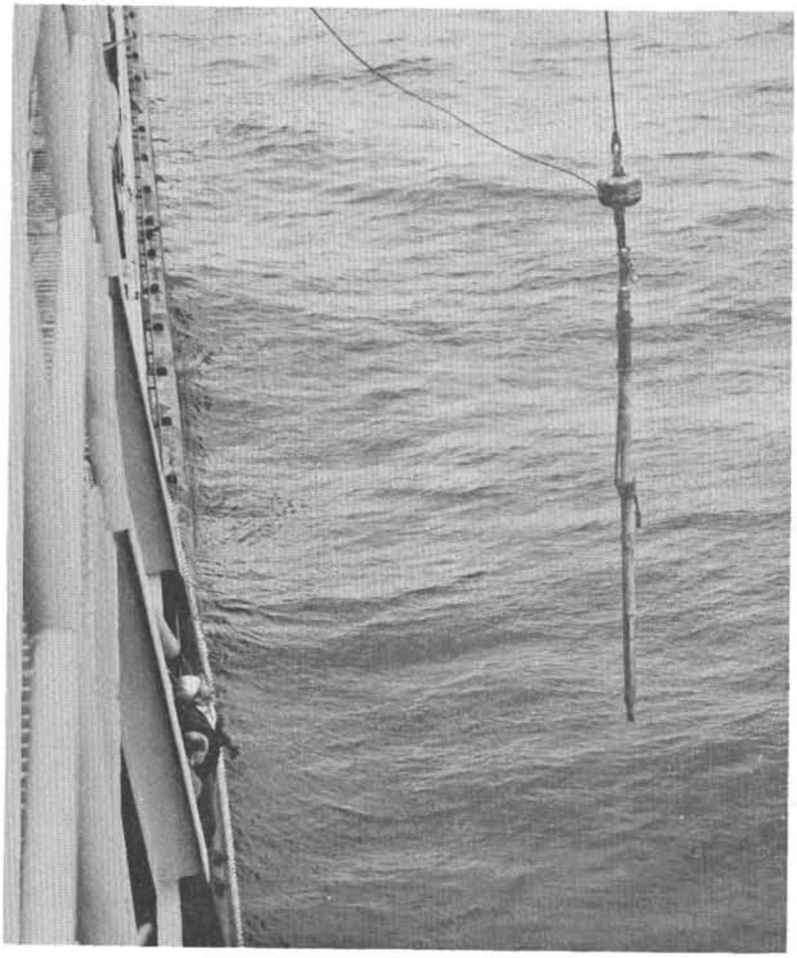

Figure 5 (left)
The high resolution scanning sonar downhole instrument being tested for signature of the target.

Figure 6 (below)
High resolution scanning sonar transducer head. The head has two selective beams. One to search for the target, and one to locate over the cone.

Before the bit was run into the ocean floor, an attempt was made to run the Edo to see if the beacon could be located. The bore plugger (attached to the Edo instrument to seal off the bit so all drilling fluid would pass through the jet when jetting) stuck in a tool joint and the Schlumberger line pulled out of the rope socket, dropping the instrument, which wedged five joints down. The keys on the collet of the bore plugger were found to be 4 1/4 inches outside diameter and were removed. Two more attempts were made to run the bore plugger, one with the seal mandrel turned down. The tool stuck on both tries, so was laid aside. The core barrel was blanked off for jetting on runs No. 2 and 3 by filling in the Hycalog landing seat (for the inner core barrel) and adding "O" rings.

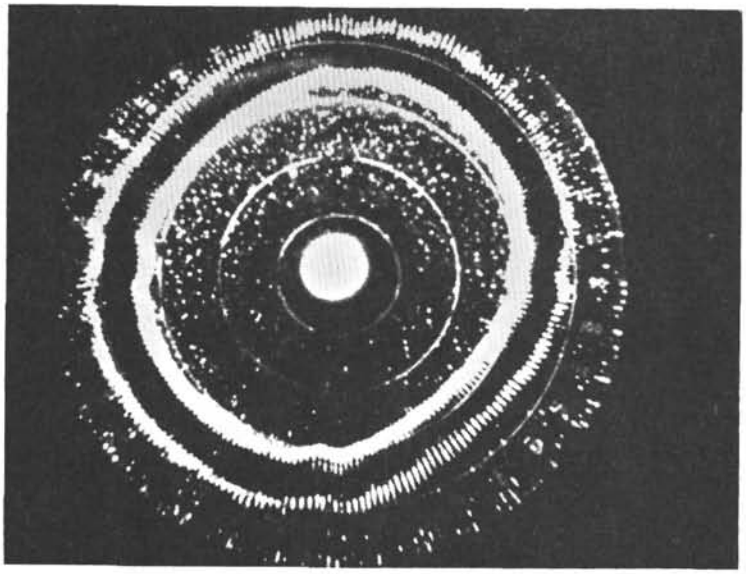

Figure 7
PPI display when transponder is approaching the ocean floor.

In addition to pulling out of the cable head, the Edo instrument housing was damaged. The cover plates over the expansion tube were loose. The instrument was placed back in service by resocketing the cable head and adding screws to the cover plates.

The Edo was run to bottom and the positioning acoustic beacon easily identified on the PPI scope.

At this point in the test the ship was moved on pre-determined tracks, and the track of the end of the drill string observed. These data were also recorded during the positioning of the vessel for actual re-entry (Figure 8).

The International Nickel Company has reviewed these plots and data to find if the movement of the drill string can be predicted from movement of the ship.

This report is included in the Appendix.

The next run for the Edo was after the landing base was dropped. If the casing was still attached to the drill collars, the scope would be blank.

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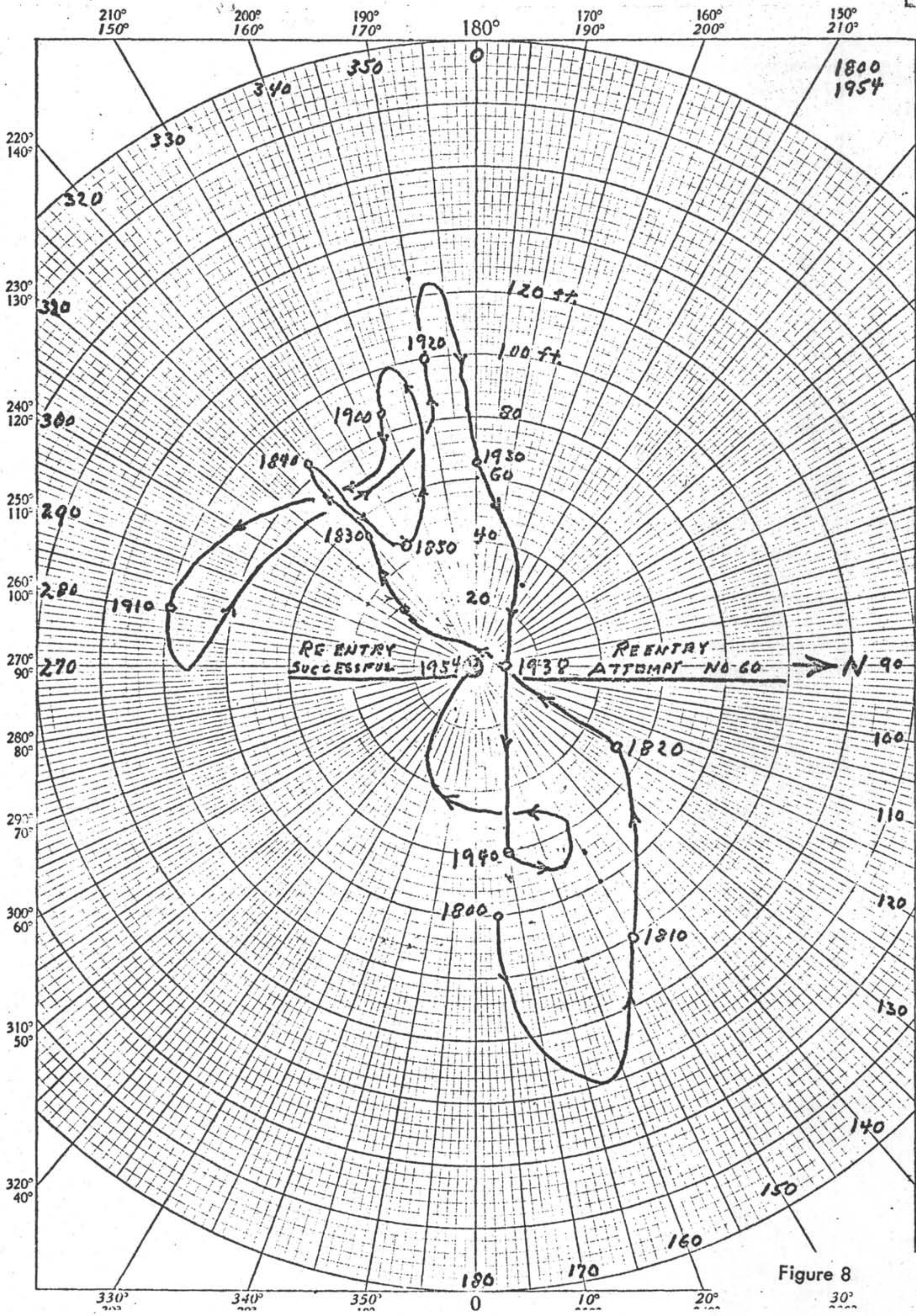

Figure 8

On reaching bottom, the Edo presented an excellent picture of the dropped landing base. Several hours were spent tracking the response of the drill string to the drill ship.

The Edo was run again when the second landing base was on bottom (new location). When on bottom (in the landing base) the Edo identified the eight-inch pipe "cross" (for cuttings disposal) in the base. The Edo was pulled above cone and ship and bit motion observed. An attempt was made to move the bit with the jet, resulting in a failure of the Edo.

The Edo was pulled and the motor-transducer section found to be flooded with sea water and the pressure equalizing bladder ruptured.

An attempt was made to clean, dry and refill the motor section. After a bench check, the Edo was started for bottom but would stop transmitting at approximately 30 meters below the surface. This failure would repeat indicating an air bubble in the housing.

The motor section was disassembled, vent holes added and refilled with a low viscosity fluid. The Edo was then run to bottom and performed flawlessly for approximately 15 hours.

The surface units performed as anticipated with the exception of the remote PPI on the drill floor which apparently had electrical interference.

As mentioned earlier, the first landing base was dropped. This base was hung over the port side and keelhauled in good time. It was pulled up under the ship and hung off. The clearance holes in the hull cover for the moon pool did not line up with the lifting pads on the cone and tended to pinch in the landing cone.

The casing was run and attached to the shear sub. When the casing was landed in the landing base, the base collapsed and the landing cone leaned over to the pipe. (Confirmed by divers and pictures.)

It was decided to run the base to bottom and shear. When about 300 meters of pipe had been run, the base and casing sheared off and fell to bottom (confirmed by the precision depth indicator). The pipe was run to bottom and the loss of the base and casing confirmed by running the Edo.

As the explosive shear bolts had proved to be inoperative, the "J" tool and "J" slot (used to land the casing on the expotential horn until the bottom hole assembly has been picked up) were modified to run the second landing base and re-entry cone.

The second base was reinforced by welding all bolted seams and adding supporting rods and gussets where needed. Collapsing pad eyes were added so the support slings would be in line with the holes in the keel plate. The slings were also re-rigged so the base could be released without sending a diver into the moon pool.

This base was hung over the side, keelhauled and hung off in good time. Some trouble was experienced in adapting the modified hangers to the casing and base plate.

The landing base (with four joints of casing) was carefully run to bottom and washed in to within ten meters of the mud line. No problem was experienced in releasing the base from the drill string.

While waiting for the Edo to be repaired, the pipe was pulled and the Armco landing sleeve attached to the shear sub (placed two feet above the bit). This would (and did) give a surface indication, when the subs sheared, when the bit had actually re-entered the cone.

The modified bearing support (making a seal between the outer core tube and Edo instrument) was left in the bottom hole assembly so the jet could be used if re-entry could not be accomplished with the positioning system.

When the repaired Edo was back in place in the core bit, a search pattern was run and the base located (Figure 9). The re-entry system does not have a remote compass or gyro reference. The orientation of the zero on the PPI (and scanning transducer) and the vessel heading are determined by moving the vessel along pre-selected tracks and plotting the changes in bearing on the PPI scope.

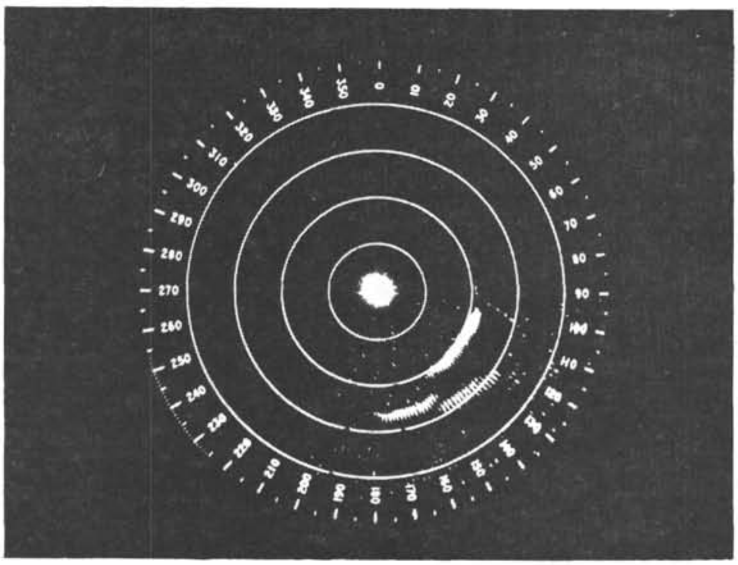

Figure 9
Target display on the PPI Scope. Targets are approximately 60 feet away from the transducer.

The trace of the bit was then established. The bit closely followed the ship's motion for normal positioning thrust corrections. As the positioning system does not signal thrust corrections until the ship has moved outside a 40 foot circle and as only 100 foot offset steps can be dialed into the computer, the ship had to be maneuvered until its meander pattern would carry the bit across the cone. The offset settings can be modified by varying the depth setting. This procedure was refined during the first operational re-entry and is fully explained in the re-entry manual.

The PPI display gave no doubt as to when the bit was passing over the cone and after establishing the necessary lead, the bit was successfully dropped into the cone.

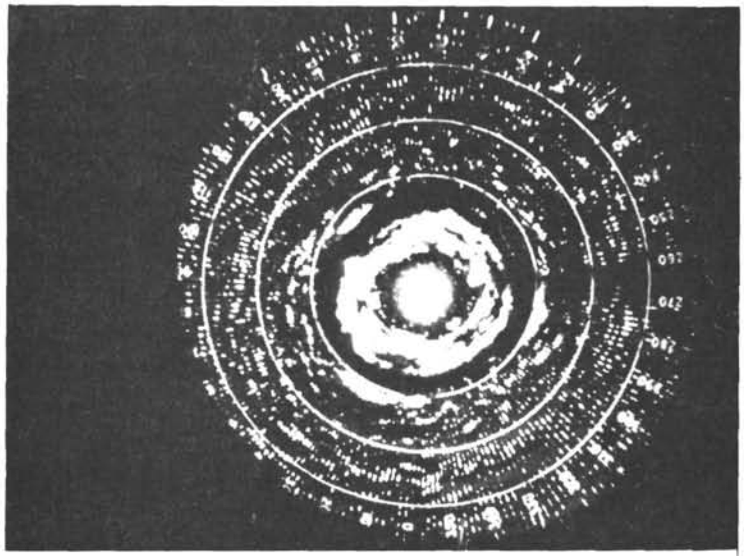

Figure 10
Target display on PPI Scope when the transponder (and bit) are over the cone.

For additional proof a second core was taken at the shoe of the casing string. Before pulling the pipe, the jet sub sleeve shifting tool was run in an attempt to close the sleeve. The tool became stuck, the sand line was cut, and pulled out. The tool was retrieved with the drill string.

In addition to these tests, an acoustic pulse generator was rigged up to determine the limits for pulse shape, frequency, and length acceptable to the positioning system.

As soon as the core from the bottom of the hole was on board, the drill string was pulled, all loose equipment secured, and the Glomar Challenger departed for Boston, Massachusetts, to load out for Leg 12.

All equipment was removed and returned to the original vendor. Deep Sea Drilling and Global Marine Inc. engineers met with these vendors to discuss problem areas encountered during trials and to plan for the equipment for Leg 15 scheduled to start December 2, 1970.

As is normal with prototypes, several changes were proposed and incorporated.

1. The Edo instrument outer case was strengthened for improved handling. A blip or marker azimuth line, was added to monitor alignment of PPI Scope

and rotating transducer. Minor changes were made in the electronics to improve reliability. Two additional instruments were ordered to the revised specifications.

Power to the remote unit was increased to increase the quality of the display.

2. The general configuration was retained for the landing base and re-entry cone. To increase strength the cone was changed from hexagonal with individual welded sides to two rolled sections flanged and welded.

3. The shear pin release system was obsoleted. Operations requested these be replaced with a mechanical system that could be released with the coring lines. We conducted an industry survey for such a release but found out in-house design to be superior. Two release subs with mating casing hangers were built for Leg 15.

4. The bore plugger design was discontinued. Deep Sea Drilling Project engineering designed a bore plugger with an expanding packer element. Baker Oil Tool, Inc. built two of these, incorporating the bore plugger with a retractable indexing finger to physically orient the Edo instrument to the drill string. We also built a backup bore plugger using the seals from a tubing seal assembly. This bore plugger seats in the core barrel hold down sleeve. The standard sleeve is replaced with a sleeve which has been internally honed.

The prospectus for Leg 15 included a site near Site 29 cored during Leg 4. As basement was not reached on Site 29, Deep Sea Drilling Project planned to use re-entry to accomplish this. As the Glomar Challenger was scheduled to depart San Juan, Puerto Rico, December 2, 1970, the time schedule was extremely tight. However, designs were completed, bids placed, and equipment built and delivered to meet this schedule. The re-entry cones and bases came the closest to missing the Glomar Challenger when a scheduled freight shipment was left on the dock at Houston. An alternate route was found and the cones arrived on time.

Although all equipment was individually tested, the tight schedule did not allow assembling all the gear in one yard for a systems test. This was done while the ship was dockside at San Juan. Several minor problems were noted and one major one.

The major one was that in the locked position the release sub could be rotated to the right releasing the paddles. The paddles were tapered with the matching locking pin face square. When fit snugly, this was a locking device, however, clearance from accumulated allowances would allow the paddle to rotate slightly which moved the contact points down the taper which would then roll out of the latch sub pockets.

The minor changes were done in a local machine shop. The release was modified on board the ship. The paddle taper was built back so the edges were square, the carburized pins were softened, and a 15 degree relief milled on the side of the head which held the paddle. A test indicated this did eliminate this problem.

Thruster trouble at the first site (re-entry was scheduled for the second site), forced the Glomar Challenger to go into Willemstadt, Curacao for drydock. This extra time was used to recheck the equipment and increase familiarity with the handling and operating tools.

When the thruster repair was complete, we proceeded to the re-entry site.

The following excerpt from the Operations Resume of Leg 15, gives an excellent report of this re-entry.

At 09:30 hours on December 15, 1970, the Glomar Challenger arrived on Site 146 in the Caribbean Sea at Latitude 15° 07' North and Longitude 69° 23' West, which is approximately midway between the northern coast of Venezuela and Puerto Rico. Water depth was measured at 3939 meters by precision depth recorder. A 16.0 kHz acoustic beacon with two batteries wired in a parallel circuit to provide a minimum of 12 days signal emission was dropped to the sea floor as a geographical reference for the ship's position which is automatically controlled by the computerized dynamic positioning system. Signal strength of the first beacon proved inadequate and a 13.5 kHz beacon with a single battery was dropped within the first hour.

Efforts were then concentrated on final stages of assembly of the re-entry cone, a five meter diameter by four meter high inverted cone with three acoustic reflectors spaced equidistantly around the circumference. All joints of the cone assembly were welded, wire cables were attached between the drop away pad eyes and the cone base for additional strength and doubled lifting slings were attached to each of the drop away pad eyes. A 50-foot sling was also attached to the top of each doubled lifting sling to allow the keelhaul lines, secured to the port rail, to be shackled into the loose ends of the 50-foot slings as the cone was lowered over and swung to the port rail at midship. The whip line of the 50-ton crane was attached to the doubled slings and the cone was lowered over the port side. The upright cone was momentarily buoyant until filled with sea water through the 16-inch opening in the base and the cuttings discharge slots in the lower apex of the cone. During the short period of buoyance, the cone surged heavily in the eight to ten foot swells. The surging fouled one of the 50-foot slings, to be attached to a keelhaul line, around one of the cones acoustic reflectors. The cone was raised back to the surface to facilitate unfouling of the 50-foot sling. A large swell surged the water filled cone making it extremely dangerous for equipment and personnel. Instead of lowering the cone below the wave action for reassessment of the situation, the cone was swung away from the ship at surf level and the next swell broke the whip line dropping the cone.

The Glomar Challenger was then positioned to the east with a 1,000-foot offset.

Twelve hours were required to assemble and weld the standby cone, which was completed at 01:00 hours. However, the Sea State had further increased and swells were then ten to 12 feet with an occasional 14-foot swell. It was then decided to rig the cone for keelhauling in a horizontal position. This necessitated new rigging of some of the keelhaul lines and structural reinforcement of the cone. Six hours were required to weld 3 inch x 1/4 inch angle iron braces around the mid-section of the cone and to reinforce and add pad eyes to one of the vertical (base and rim) members. All joints of the cone assembly were welded. By 14:00 hours, on December 16, the sea had abated slightly with swells estimated at ten to 12 feet and the decision was made to keelhaul the cone. The cone was rigged, picked up by attaching the block of the 50-ton crane to short slings fastened to the vertical member of the cone and by attaching the whip line to doubled keelhaul slings on the fall away pad eyes. The cone was raised vertically with the ship line and then the load was transferred to the block to turn the cone in a horizontal position and swing it to the port side. The cone was then brought to rest against the casing rack main deck and port rail where the ship line was disconnected from the keelhaul slings and attached to the vertical members. The keelhaul lines were shackled to the keelhaul slings and the block was disconnected from the vertical member. The cone was then picked up with the whip line, swung over the port side at midship and lowered into the water while slack was kept out of the keelhaul lines with the travelling block. The cone was lowered smoothly without buoyant effect or surging until the whip line hook was level with the main deck rail. After determining that the keelhaul lines were taut,

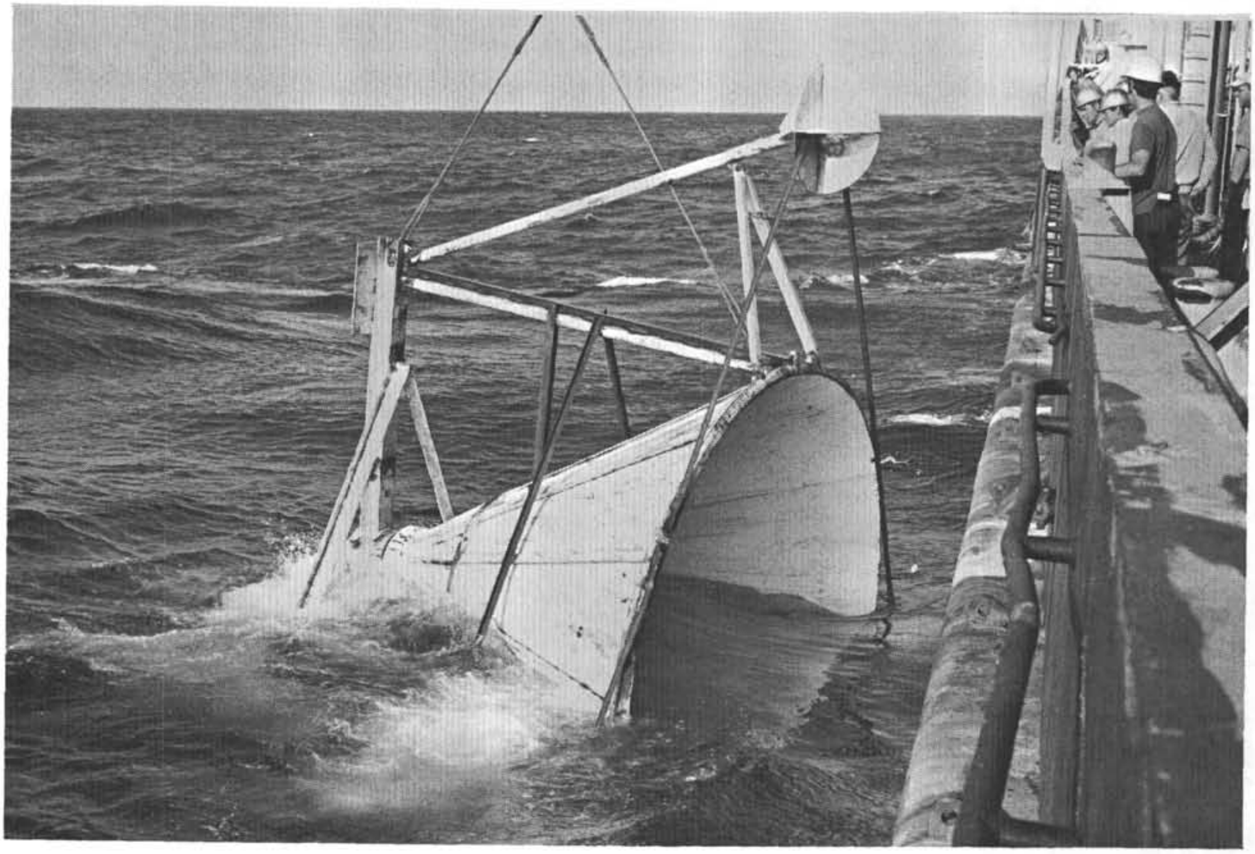

Figure 11 New style re-entry cone and base being lowered into the water with a side launch.

an eye of the doubled line from the whip line hook to the horizontal slings was cut and the cone swung to the vertical position under the moon pool and the doubled lines attached to the fall away pad eyes of the cone could be shackled into hangoff lines attached to the rotary beams. The weight of the cone was then transferred from the keelhaul lines to the hangoff lines and the keelhaul lines were disconnected. Good visibility existed below the moon pool and the cone appeared to be in perfect position with no handling damage and with no fouling of lines. One and one half hours had elapsed from cone pick up until it was secured on the hangoff lines at the moon pool. Another one and one half hours were required to rig down the keelhaul equipment and rig up to run the 13 3/8 inch casing.

The casing string consisted of a Baker guide shoe, muleshoed at a 30 degree angle to facilitate stabbing the casing through the base of the cone, four joints of 13 3/8 inch outside diameter, J-ff, 54.5 ft/lb buttress casing, and a casing hanger to latch into the base of the cone by means of spring loaded snap ring segment. All joints were thread locked and the casing was run and hung off on a spider and elevators setting on top of the hyperbolic guide cone at main deck level. Overall measurement of the casing assembly was 49.36 meters.

The bottom hole assembly was then run as follows: A (10 1/8 inch x 2 7/16 inch Smith four-cone tungsten carbide insert) core bit, one 8 1/2 inch outer core barrel, four 8 1/2 inch drill collars, and latch sub with profile locator sub on top were made up and run inside the 15 3/8 inch casing. Overall measurement of the jetting assembly was 46 meters. A lucite packoff was placed around the drill collars immediately below the latch sub and the latch sub was landed inside the casing hanger. The "dogs" or "gates" of the casing hanger were engaged with the latch sub. The Baker shifting tool was then made up and run on sandline for a satisfactory trial disengagement of the latch sub from the casing hanger. The latch sub was again engaged with the casing hanger and the casing and jetting assembly were lowered until the casing hanger latched into the base of the re-entry cone by means of snap ring segments engaging in a snap ring groove machined in the bottom of the casing hanger. The weight of the re-entry cone and casing string was 15,000 pounds.

After engagement of the casing hanger in the face of the re-entry cone, the weight of the re-entry cone was transferred to the bottom hole assembly and the doubled keelhaul slings, attached to the fall away pad eyes of the cone were cut and stripped through the fall away pad eyes.

The remainder of the bottom hole assembly was run above the latch sub and consisted of one Baash-Ross bumper sub, three 8 1/4 inch drill collars, two Baash-Ross bumper subs, two 8 1/4 inch drill collars, one 7 1/4 inch drill collar, and one joint of heavy wall five-inch drill pipe. The entire assembly, casing, re-entry cone, and bottom hole assembly, was lowered on drill pipe until sea floor was tagged at 3957 meters by drill pipe measurements which corresponded to 3949 meters measured by the precision depth recorder from the rotary table.

The casing was then jetted into the sea floor to place the shoe at 3998 meters, with the face of the cone at 3950 meters and the top; rim and reflectors of the cone at 3946 meters by drill pipe measurements. Jetting required 90 pump strokes per minute (720 gpm) and 15,000 to 20,000 pounds weight for the final ten meters penetration, indicating a fairly firm bottom for the casing seat.

The latch sub was then disengaged from the casing hanger by running the Baker shifting tool on the sandline and engaging the sliding sleeve of the latch sub. The sliding sleeve in the latch sub had six lug nuts that held the three, spring-loaded, hinged gates of the casing hanger in recesses of the latch sub when the sliding sleeve was in the "down" position. When the sleeve was shifted to the "up" position, the lug nuts on the sleeve matched with notches in the hinged gates, allowing the spring-loaded gates to swing on their hinge pins into recesses in the casing hanger. This released the latch sub from the casing hanger, which released the bottom hole assembly from the cone and casing. Two hours were required to run the shifting tool and release the latch sub, of which one half hour was spent in reciprocating and torquing the drill pipe after the sleeve was apparently shifted to the "up" position. Up to 25,000 pounds of pull and weight were alternately put on the latch sub along with alternate applications of right hand and left hand torque. Ultimately, the latch sub was released and the shifting tool was retrieved. Difficulty was encountered with the shifting tool hanging up during retrieval. Examiniation of the shifting tool, after retrieval, indicated that one of the three profile keys had broken and was apparently hanging in the tool joint recesses.

After release of the casing and cone, drilling with minimal circulation proceeded from 3998 to 4045 meters without difficulty. From 4045 meters a routine drilling and coring procedure was carried out to a depth of 4650 meters for 701 meters of penetration. The formation consisted of ooze, chalk, chert, marl, and limestone. Elapsed time, after release of the latch sub, was 86.5 hours and the bit had accumulated 29.8 rotating hours. This was estimated to be 70 to 75 percent of the maximum bit life and it was decided to pull out of the hole and replace the bit as a precautionary measure, even though no evidence of bearing failure had been indicated by the torque level.

The hole was filled with 10.0 pounds per gallon mud and over-displaced by approximately 50 barrels to clean the hole of cuttings. The bit was pulled up to 3960 meters and it was decided to run the Edo sonar scanning transceiver to scan for the re-entry cone as the bit was pulled above the cone. However, two attempts to run the Edo transceiver were aborted at approximately 800 meters depth due to an electrical short in the Schlumberger cable head. Since several hours were required to rehead the Schlumberger cable, the idea of scanning for the re-entry cone, as the bit was pulled above it, was abandoned.

At this point, the 16.0 kHz acoustic reference beacon signal strength became erratic and a 13.5 kHz beacon and battery were dropped.

The trip out of the hole was made and the latch sub, with profile locator sub, was removed from the string. Examination of the latch sub indicated no damage. The bit was graded at T-1, B-5, 1G.

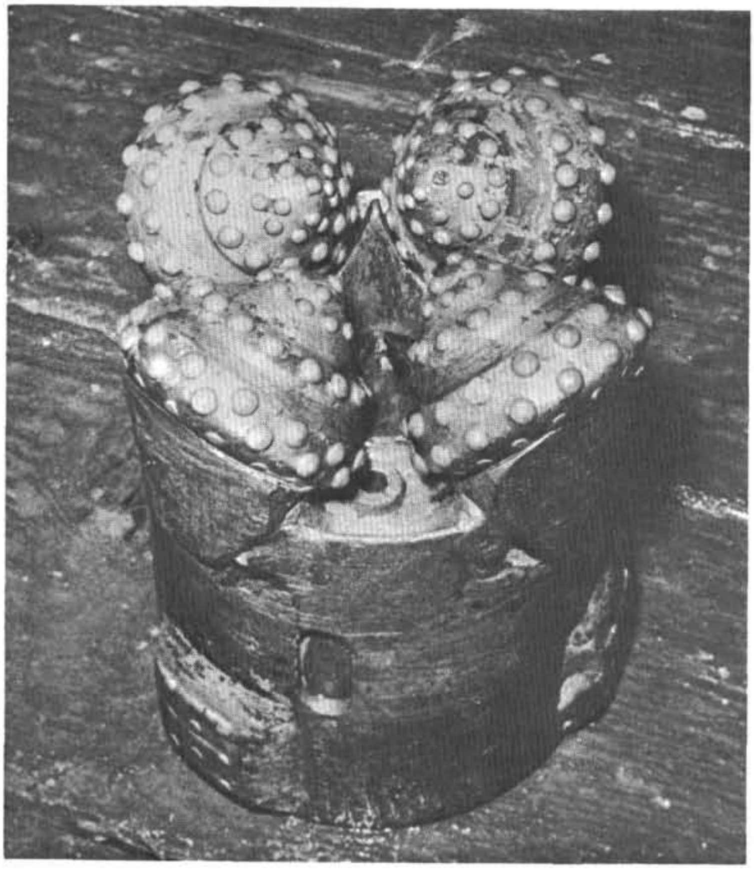

Figure 12
Four cutter carbide insert core bit used for first operational re-entry.

A new (Smith 10 1/8 inch x 2 7/16 inch four-cone tungsten carbide insert) core bit was made up on the bottom hole assembly consisting of the following: Outer core barrel, core barrel latch sub with special bore (3.87 inch inside diameter) latch sub sleeve for 3 1/2 inch Baker seal nipple, jet sub with sleeve in "down" (open) position profile locator sub, four 8 1/2 inch drill collars, one 8 1/2 inch bumper sub, three 8 1/2 inch drill collars, two 8 1/2 inch bumper subs, two 8 1/2 inch drill collars, one 7 1/2 inch drill collar, and one joint of heavy wall five-inch drill pipe. The bit was run to 3937 meters and spaced out to permit lowering to 3957 meters on re-entry.

The Edo sonar scanning transceiver with a 45 degree scanning head and bore plugger, were run on the Schlumberger cable and the re-entry cone was located 300 feet from the bit. The ship was maneuvered in the automatic mode by manually dialing 100-foot offset commands into the computer of the dynamic positioning system to place the bit at approximately 70 foot range to the cone. Attempts to move the bit nearer to the cone with the jet sub were unsuccessful. Displacement of the bottom hole assembly with the jet sub was, at most, 15 to 20 feet using 600 gpm and 1,000 psi maximum pump pressure with the 0.75 inch diameter jet. Rotation of the drill pipe to various quadrants with jetting resulted in average range variations of 50 to 90 feet. After approximately two hours, jetting was discontinued and the semi-automatic and manual modes of operation were attempted to maneuver the ship over the cone. After approximately two hours of semi-automatic and manual modes of operation without success, the mode of operation was returned to automatic and various combinations of offsets and water depth adjustments were utilized to maneuver the ship over the cone. Apparently re-entry was accomplished after 13 hours - at 06:58 hours - on December 23, 1970, as the drill pipe was lowered to 3957 meters.

The sonar transceiver and bore plugger were retrieved. The drill pipe was lowered 41 meters to 3997 meters with negligible weight on the bit. Vessel heave, estimated at five to six feet, made it difficult to monitor any signficant weight and the re-entry was thought valid. The Baker shifting tool was run to close the sleeve of the jet sub. The bore plugger, with Baker seal nipple, was run ro pressure test the drill string to insure closure of the jet sub. A pressure test could not be obtained and the bore plugger was pulled. The check valve of the bore plugger was modified and the bore plugger was rerun. Again, a pressure test was not obtained. The bore plugger was pulled and the shifting tool rerun. The shifting tool momentarily hung in the jet sub sleeve but was worked loose with reciprocation. On retrieval, another profile key of the shifting tool was found broken. The bore plugger, with Baker seal nipple, was rerun, a satisfactory pressure test of 2,000 psi was obtained, and the bore plugger was retrieved.

The inner core barrel was dropped and the drill pipe was lowered from 3997 to 4044 meters with 2,000 to 5,000 pounds weight on the bit. A core was cut at 4044 to 4053 meters and relatively undisturbed sediment was recovered,confirming that a misstab had occurred.

The drill pipe was pulled above the mud line and spaced out to put the bit at 3937 meters. It was decided to attempt the re-entry without jetting. This eliminated the need for the power sub and swivel and it would permit a 29-meter stroke for re-entry. The Edo sonar transceiver, with the 60-degree scanning head, was run. It apparently encountered a soft sediment plug at the bit since the only scan pattern monitored was similar to that monitored inside the drill collars. Since the swivel and power sub were not on the drill pipe, there was no means of circulation without pulling the wireline. Shaking the drill pipe and spudding the Edo transceiver proved unsuccessful. Eventually, all scan was lost indicating the scanning head had probably broken off. The Edo transceiver was recovered and the loss of the scanning head was confirmed.

At this point, it was decided to pull the drill pipe since it was impossible to determine if the transducer head was lodged at the bit. It was also decided to remove the jet sub from the drill string since the negligible benefit gained by jetting did not justify the difficulty caused by having the jet sub in the string.

A round trip was made with the drill pipe. No evidence of plugged bit or scanning head was found. The jet sub and profile locator sub were removed from the bottom hole assembly. The bit was spaced at 3947 meters and the swivel and power sub were installed. The Edo sonar transceiver, with the 45 degree scanning head,was run without the bore plugger. The re-entry cone was located at an average range of 95 feet from the bit. A systematic procedure, using automatic mode of operation, various combinations of offsets, water depth adjustments, and plotting average ranges and average bearings, proved highly successful in maneuvering the bit to within 40 feet average range. At this point, no combination of offset or water depth adjustment was effective in closing the range. It was concluded that the bit was at an excessive height above the re-entry cone. The bit was lowered in two meter increments to 3955 meters, as offset and water depth adjustments were made to close the range to within 18 or 20 feet. At this point, the bit was making a slow oscillation across the cone and the drill string was lowered to coincide with the bit being centered over the cone. As the bit was lowered from 3955 to 3964 meters, it suddenly took weight at 3961 meters and had 12,000 pounds weight at 3964 meters. Torque prevented rotation of the drill string. It was theorized that the bit had entered the cone at an angle and slid down the cone wall, lodging against the opposite side at the base of the cone. Based on this assumption, the drill pipe was picked up to 3961 meters at which point all the weight was off the bit, the drill string was rotated without torque, and the bit was lowered without weight to 3968 meters at 05:30 hours on December 25, 1970. Elapsed time from initial scan to re-entry was 2.5 hours. After recovery of the Edo transceiver, the bit was raised to 3964 meters to make a connection. Three doubles of drill pipe (56 meters) was run in the hole to lower the bit to 4021 meters without evidence of weight. The power sub and swivel were set back and the drill pipe was run into the hole, without obstruction, to 4635 meters where hard bottom was encountered.

Continuous coring was resumed at 4650 meters and continued to 4711 meters total depth for 61 meters of additional penetration and a total penetration of 762 meters. The hole was terminated in diabase with a 0.7 meter per hour penetration rate.

After two unsuccessful attempts to take sidewall samples due to an apparent obstruction at the bit preventing the sidewall samples from extending through the core bit, the hole was filled with 10.0 pounds per gallon mud and the drill string was pulled. Inspection of the second core bit revealed that it was virtually destroyed after 61 meters penetration in 17.1 rotating hours. One cone was gone, two of the remaining three cones were locked, all three cones had skidded, and inserts were broken on the remaining three cones. The cones were also pinched, which had prevented the sidewall sampler from extending through the core bit. It should also be noted that excessive torque, although unexplainable at the time, had been experienced throughout the second bit run.

A total of 295.5 hours had elapsed from launch of the first beacon to departure from the site.

From the above observations of the second bit and from the firm obstruction encountered at the base of the re-entry cone on re-entry, it must be concluded that the second bit was damaged at re-entry and the damage was most probably a pinched-cone, or cones, resulting in cone misalignment and roller cone interference.

If the above conclusion is valid, it must also be concluded that the re-entry cone and casing settled at least 11 meters. This observation and conclusion is substantiated by the fact that the top of the re-entry cone was released at 3946 meters, with the base at 3950 meters. However, on the valid re-entry, the bit was lowered from 3947 to 3955 meters while scanning continued, which placed the cone rim at some depth below 3955 meters. Also, if the obstruction encountered at 3961 meters were the base of the cone the top of the cone would have been at 3957 meters which coincides with the mud line by drill pipe measurements. And, if the rim of the cone were at the mud line partially or wholly obscured with sediment, it would account for the sonar transceiver never picking up the cone rim as was done on the experimental re-entry. Only the three acoustic reflectors, which are approximately one foot higher than the cone rim, were picked up by the sonar transceiver on re-entry of Site 146.

Assuming the above conclusions are valid, the first re-entry attempt could have been a technically valid re-entry. But, due to cone settling and drill pipe spacing, which allowed a net stroke from 3937 to 3957 meters, the bit could not be lowered enough to keep it inside the cone.

The drill string was pulled, the equipment secured, and the ship returned to Williamstadt to off load the re-entry personnel. As this transfer was accomplished by shore boat, no equipment was returned.

The operational personnel on this re-entry made the following recommendations:

1. D/V Glomar Challenger can be maneuvered over the re-entry cone and held with sufficient accuracy with the positioning system to allow stabbing the bit into the cone. The jet sub should be used as a backup system for unusual operating conditions.

Figure 13 Proof Positive. This core, taken after re-entry, is from the same formation as the core from the initial test hole.

Figure 14 Evaluating the dull four-cone carbide insert core bit used to successfully complete Site 146.

2. The Edo equipment is operational.

3. The mechanical release is an acceptable system. The design should be modified to give a more positive locking action. The acoustic link explosive bolt system should be deferred until the beacon recall system is operational. The "J" lock should be removed from the casing hanger.

The prospectus for Leg 17 (Circular Leg from Honolulu back to Honolulu) indicated the possible use of re-entry on four locations. Departure from Honolulu was scheduled for April 1, 1971.

The encouraging results from the re-entry accomplished on Leg 15 and the request for several re-entry, prompted the Project to prepare a request to the National Science Foundation for funding to insure re-entry could be available when required. This request was forwarded, in January, 1971, and approved on February 23, 1971.

Orders for eight cones, bases and casing hangers, were placed. These units were to be the same as the one used on Leg 15.

The Project had also been investigating a method of releasing the bit from the core barrel after the completion of the core hole to allow logging or other operations. A release, including a release tool sub, was built by Rotary Oil Tool Company.

As this tool seemed to be much simpler and more positive than the Baker shifting tool, we modified the shifting sleeve in the release sub to fit either the Baker or the Rotary shifting tools. At the same time, we changed the stop bolt design to eliminate selective assembly. The sleeve and bolts are interchangeable with the original design. An additional release sub assembly and two revised sleeves with stop bolts were built and placed on board the Glomar Challenger at Honolulu for Leg 17.

A review of the increased performance of carbide insert roller cutter core bits indicated basement could be reached on all proposed sites except Site 18.

As reaching basement was of particular interest at this site, re-entry was scheduled. As the crew on this leg had never performed re-entry, backup personnel were shceduled to join the cruise at this site.

The following excerpt from the Operations Resume of Leg 17 gives an excellent report of this re-entry attempt.

RE-ENTRY - NARRATIVE

The cone was picked up, laid on its side, keelhauled and suspended under the vessel with no problem. Five joints of 13 3/8 inch casing (61.41 meters) were picked up, the hanger made up on the top joint and set on a set of elevators on the platform under the floor at the top of the permanent section of the horn. The bottom hole assembly was run in and the latch sub positioned so that the bit would be approximately one foot above the shoe on the 13 3/8 inch casing.

When an attempt was made to attach the latch sub to the casing hanger, it was found that the paddles on the hanger slightly interferred with the "lug nuts" attached to the sliding sleeve on the latch sub and would not allow the sleeve to drop down into the lock position. In order to alleviate this problem the sides of all three paddles were ground off enough to allow the "lug nuts" to move down.

With the latch sub in the locked position, the whole assembly was lowered and latched into the cone. After latching, the entire assembly; cone, casing and bottom hole assembly, were picked up two feet and "shaken" to insure that the latch in the cone was secure.

The latch was pronounced secure, the assembly was picked up approximately two feet and the crew prepared to unhook the slings supporting the cone. Just at this time, the latch sub and the hanger suddenly unlatched from each other and the cone and the casing dropped. One sling was all that ended up supporting the cone and the casing. Evidently when the cone dropped, all the weight was momentarily supported by one sling, causing the fall away eye on the cone to break and release the sling.

The bottom hole assembly was pulled up and the latch sub removed. Examination of the latch sub showed that the "lug nuts" and the sleeve were still in the locked position. What had happened was that evidently grinding off of the paddles had changed the angle relationship between the paddles and the "lug nut" and had also introduced too much slack into the latch. These two conditions made it possible for the latch sub on the inside, to rotate in a right hand direction and release the paddles, dropping the cone and casing.

It was then decided to continue in the hole and drill as far as possible before the sling broke. When it broke, the cone and casing would fall to bottom and hopefully come to rest at the mud line in the required position.

This was done and four and one half days later the sling had not parted. Finally, while trying to ream back to bottom after cutting the second good core in the basalt, the drill pipe started rattling against the casing to such an extent that the noise was blocking out the beacon signal and was making positioning difficult. It was decided that in order to continue to drill, we would have to release the cone and casing. This was done.

It was determined by following the cone down with the Precision Depth Recorder (PDR) that the cone and casing fell at a speed of ten feet per second and took about 30 minutes to get to bottom. During the time that the cone and casing were falling, no undue noise was heard on the hydrophones nor was there any fluctuation in drill pipe weight.

Six hours later the bit was pulled out of the hole. There was no indication of any drag while coming through where the casing was thought to be, so it is safe to assume that the casing survived the fall without significant damage.

There was still time enough left on the site so it was decided to go back to bottom and attempt a re-entry. Since we had no idea of the exact depth of the cone, it was decided to attempt the re-entry without the Bowen sub in the string. This would allow a full 90 to 100 feet that the pipe could be raised or lowered while re-entering. It was thought that this would be more useful than the ability to pump through the drill pipe while the Edo tool was being lowered into the hole.

The re-entry attempt had to be scrubbed because of the malfunction of the Edo sonar scanning transceiver. It failed at 200 meters while being lowered into the hole. The tool was pulled from the hole, a broken wire on the torpedo repaired and re-run into the hole. Again, it malfunctioned at about the same depth. Emergency repairs were attempted but the tool could not be made to operate in the short time left for this re-entry attempt.

It is interesting to note that had the hanger and latch sub not become disengaged, we no doubt would have had trouble getting the cone seated successfully on bottom. We ran 62 meters of casing below the cone. When we spudded the hole and started taking cores, we found that the PDR showed bottom to be approximately 26 meters too shallow. In addition, an unexpected chert layer was found at 28 meters. It is entirely possible that we might have assumed bottom was at the PDR measurement, then when the chert was encountered 54 meters below, we would have thought we were off six meters in depth and assumed the cone was resting on bottom. In truth, the cone would have been 34 meters above the ocean floor.

This points up the problem of running the casing and cone without drilling a hole first to determine if re-entry is necessary, to find bottom, and to find a good seat for the casing.

It is felt that the Project has proved the feasibility of the idea of hanging the cone and casing below the vessel, drilling the hole and if a re-entry is necessary, drop the cone and casing before coming out of the hole. No one can be entirely sure that the cone and casing were completely undamaged and in the correct position after it was dropped, but all indications are it was undamaged. It will have to be left to a later test to completely prove out the idea.

The re-entry equipment and procedures as described in the re-entry operation manual, have been accepted as fulfilling re-entry requirements for the Deep Sea Drilling Project. Expendable equipment for four re-entrys is currently aboard the Glomar Challenger and will be replaced as used.

The present ocean floor hardware does not have the capability of being retrieved and reused. Also, although a sufficient size opening is incorporated in the landing base, hardware has not been provided to run multiple casing strings.

Retrieving the landing base was not incorporated in our design because:

1. The fixed drill pipe support horn makes it necessary to keelhaul any hardware over 30 inches in diameter run on the drill pipe. This means that a retrieved base would have to be released from the drill string with diver assist and keelhauled.

2. In addition to being a dangerous operation, the ship's time involved is worth much more than the cost of a re-entry cone and base.

Multiple casing strings have not been run because:

1. Holes drilled and cored in the deep ocean basins have proved remarkably stable and have not sloughed during the short time required to core and drill them, even using re-entry.

2. Although frequently mentioned, Deep Sea Drilling Project has not programmed a site for extensive coring of the basement basalt. When such a site is selected, the necessary casing string(s) will be programmed.

During the development of the re-entry system, Deep Sea Drilling Project entered into a contract with Southwest Research Industries (report published August 17, 1970) to determine the effect of removing or modifying the drill pipe support horn.

This study substantiated we could replace the present integral support horn with a removable support horn or combinations of removable pipe supports. This would allow running and retrieving re-entry cones and bases and other ocean floor equipment through the moon pool. Such capability would greatly simplify such operations and increase safety.

An unobstructed moon pool would also allow use of re-entry on an "as needed" basis without having to keelhaul and hang off a cone on the probability two or more bits will be required.

To date, Deep Sea Drilling Project has not made a proposal to the National Science Foundation for such a modification, as negotiations for a three-year extension of operations are still in process.

With the requirement for re-entry in sediment coring still undetermined and a rather large cost for modifying the vessel, it is difficult to justify such a modification without an extension.

The proposed extension will include an increase in sites where an appreciable amount of basement basalt will be cored. Also, it is proposed to core sites where continental type sediments would be encountered. Such sites would require re-entry.

The Program Plan included the use of conductor cable electric logging to supplement the coring. Several attempts were made to log during the first six legs. Results were not encouraging as only the small sondes could be used. These light weight sondes were affected by drill pipe motion, and core recovery was greater than anticipated, interest in logging decreased.

However, an active re-entry program in areas of thick sediments should be supplemented by logging. With re-entry the drill pipe can be run open ended giving 4 1/8 inch passage through the drill string. This is sufficient to run the larger heavier more reliable sondes.

This program has been watched very closely by the major oil companies. In addition, they assisted Deep Sea Drilling Project by reviewing and editing reports, statements of work and test schedules. The Cruise Operations Managers furnished by these oil companies were of great assistance in conducting the tests and in running the first operational cone.

One re-entry system, based on Deep Sea Drilling Project's design, is operating in Canada.

Other systems will undoubtedly be placed in service in the foreseeable future, as sea floor completions for oil wells are being planned for up to 762 meters of water.

APPENDIX A

ENGINEERING STUDY

Methods to Penetrate Hard Formations in Deep Ocean Basins

By
J. R. Eberhart, Staff Engineer
D.L. Sims, Project Engineer
Dr. N. T. Edgar, Coordinating Staff Geologist

June 30, 1969

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ABSTRACT

This engineering study reviews several methods that can be employed to increase the present capability of the Glomar Challenger to penetrate the harder formations that have been consistently encountered both in the Atlantic and the Pacific Oceans. The most economical method for extending the capability to penetrate these harder formations and the one that assures the most consistent results is a re-entry system that would utilize sonic techniques to display the position of the drill string in relation to the hole.

A survey made of the present state of art indicated that re-entry has been accomplished by this technique in shallower depths than we are now operating in by several companies. The survey also indicates that a re-entry system can be put together using present designs and equipment that will require only a minimum amount of re-design and will not require any research and development. The estimated time to put together the re-entry system is six to seven months. The estimated cost of the re-entry system is $95,000.00.

I. INTRODUCTION

Failure to consistently penetrate the harder formations encountered on both the Atlantic and Pacific prompted an engineering study to be undertaken that would determine the best method that could be utilized to extend the capability of the present drilling system to penetrate these harder formations.

This engineering report is a summary of that study and presents the conclusions and recommendations developed from the study for a re-entry system utilizing sonic techniques to display the position of the drill string in relation to the hole.

In addition to reviewing available information and determining the best method for extending the present drilling capability and the cost of the proposed re-entry system, this study has included the preparation of a specification for a system to accomplish re-entry in water depths up to 6096 meters.

II. CONCLUSIONS

The following conclusions have been reached as a result of this engineering study:

1. To accomplish the primary objective of the project, (penetrate all sediments, obtain cores of sediments, make shallow penetration of the basement and recover samples of the basement) additional drilling capability to penetrate the harder formations needs to be implemented.

2. A re-entry system utilizing sonic techniques is the least expensive and most reliable method that will extend the present drilling capabilities of the Glomar Challenger.

3. The "start of art" of electronics and hardware manufacturers is now at a point that they can put together a re-entry system using presently designed equipment with only a few modifications to operate in water depths up to 6096 meters.

4. A re-entry system can be fabricated and ready for the Project's proposed 30-month extension if funding can be obtained and request for quotation's sent out to industry by August 1, 1969.

5. The estimated cost of a re-entry system, as defined by the specification is $95,000.00.

6. The proposed re-entry system is a simpler less sophisticated system than the one that was proposed for Project Mohole.

7. The proposed 30-month extension will require the drilling of much thicker sediments than have been drilled to date and deeper penetration of the fresh igneous rocks to determine if significant amounts of sediment are buried within the basement. To achieve this objective parts of the hole will have to be cased and bit changes will be required.

III. RECOMMENDATIONS

The following are the Deep Sea Drilling Project's recommendations for increasing the drilling capability to penetrate the harder formations now being consistently encountered:

1. Obtain funding in the amount of $95,000.00 to purchase a re-entry system for the Glomar Challenger operation as soon as possible.

2. Select a re-entry system utilizing sonic techniques to display the position of the drill string in relation to the hole to accomplish re-entry.

3. Send out requests to industry for quotation for a re-entry system by August 1, 1969 in order to purchase, take delivery and shake down the system by, February 1970, the time of the proposed start of the Project's 30-month extension.

4. The scientific staff of the Deep Sea Drilling Project highly recommends the acquisition of a re-entry system in order to achieve the scientific objectives of the program extension.

IV. DISCUSSION

A. History of Operation

The primary objective of the Deep Sea Drilling Project, operationally speaking, is to penetrate all sediments, obtain cores of the sediments, make shallow penetration of the basement and recover samples of basement.

Since August 1968 to June 1969 five legs have been completed. A total of 43 sites consisting of 66 holes have been drilled. Seventeen of these sites required from one to as high as four holes to be drilled in an effort to achieve the primary objective. Twenty-three of the 66 holes drilled through Leg 5 required additional capability in some form, either re-entry, retractable bits, or other techniques to achieve the primary objective. Of these 23 holes 14 were additional holes drilled that did not reach the primary objective.

The additional costs incurred by drilling these extra holes amounts to $420,000. The time spent on these extra holes was 21 days.

The basic reason for not being able to consistently core through all sediments and into the basement has been the encountering of a chert layer on many of the holes in both the Atlantic and Pacific which has prematurely dulled the bit. This chert layer shows up on the seismic recordings as a strong reflector that has been called Reflector A. From the best information available at the time the Project was planned it was not anticipated anything but soft sediments would be encountered. Therefore, no provisions for re-entry or alternative methods for penetrating hard formations were considered during initial planning.

The experience gained during the first three legs clearly pointed out that additional capability was needed to penetrate the harder formations that were being consistently encountered. Therefore, in January 1969 the project manager initiated an engineering study to determine the most efficient way to extend the project's capability to penetrate these harder formations. This study was divided into two phases. A study of various types of re-entry systems (refer to section 4.2) and a study of alternative methods for penetrating hard formations (refer to section 4.4).

After reviewing Project Mohole studies of the above re-entry methods and our present state of the art survey of electronics and hardware manufacturers, the Deep Sea Drilling Project recommends that: The most feasible method to accomplish re-entry on board the Glomar Challenger is to use some form of acoustic or video technique to display the position of the guide base in relation to the drill string.

B. <u>Types of Re-entry Systems Studied</u>

The following is a discussion of re-entry methods studied to enable the changing of a drill bit and re-entering the hole to continue drilling. All previous studies of re-entry methods conducted by Project Mohole were reviewed to see if they would be applicable for use with the Glomar Challenger, these were:

- Acoustic Re-entry Systems
- V-Guide
- Spiral Guide
- Pipe Stripping Method
- Wire Guide Lines
- Funnel Type Bases
- Funnel Type Bases with Guide Lines

It was concluded from the study of re-entry methods that a system utilizing sonic techniques is the most feasible, reliable and least expensive to accomplish re-entry.

1. <u>State of Art Survey</u>

A state of the art survey of electronics and hardware manufacturers was made to establish information for the preparation of a re-entry system specification: (refer Memo J. R. Eberhart to D. L. Sims January 27, 1969). The following companies were contacted and the details of the Glomar Challenger operations discussed with them in order to develope the type of re-entry system they would propose, the estimated cost and delivery of a re-entry system:

1. Edo Western
2. E. G. & G.
3. Oceanic Enterprises
4. ACDRL
5. Honeywell
6. Amtek Straza
7. Bendix Pacific
8. O.R.E.
9. Regan Forge & Engineering
10. Shaffer Tool Company
11. Ventura Tool

From the information developed from the survey, the proposed methods for accomplishing re-entry by the use of sonar narrowed down to the following two approaches:

1. A high resolution scanning type sonar that could be lowered down the drill pipe on logging cable and by means of a jet sub the drill pipe could be maneuvered over the guide base and then lowered into the hole.

2. A short base navigation system that would incorporate: pingers or transponders on the guide base, a transducer lowered on logging cable down the drill pipe, a jet sub used to maneuver the drill pipe over the guide base.

The proposed hardware that is required by either type of sonar system's is essentially the same and consists of the following components:

1. A guide base and conductor pile assembly that will be lowered to the ocean floor on the drilling assembly and jetted or drilled in until the guide base rests on the ocean floor. The purpose of the guide base is to provide a guide funnel to guide the drill string into the hole, to provide a stop and support base for the conductor pile and to provide a housing for landing the conductor casing or protective casing strings.

2. All necessary casing hangers, running and retrieving tools including a jet sub that will be used to maneuver the drill string to position over the hole.

3. All necessary slings and handling equipment required to keelhaul the guide base.

2. Re-entry Cost Study

Cost studies indicate that the initial investiment for a sonic re-entry system will be approximately $95,000 and is broken down as follows:

1.	Electronics	$40,000
2.	Hardware	35,000
3.	Shipboard Installation	10,000
4.	Backup Equipment	10,000
	Re-entry System Total	$95,000

The cost per hole for re-entry based on a useful life of the equipment of 20 holes is:

Initial System Investment	$95,000
Amount saved by recovering ship's positioning beacon with guide base 20 x $2,000 =	$40,000
	$55,000
Net Cost for 20 holes equipment cost per hole: $\frac{\$55,000}{20 \text{ holes}}$ =	$ 2,750/hole
Additional rig time required to run and recover the re-entry equipment is 15 hours. 15 hours x $1,000/hr. =	$15,000
TOTAL additional cost per hole	$17,750

3. Delivery of Re-entry System

It will take six to seven months to take delivery and shake down the re-entry system after requests for quotation have been sent to the industry. In order to have a system ready for the proposed 30-month extension starting in February 1970 requests for quotation should be sent to industry no later than August 1969. Therefore, funding for a re-entry system should be obtained at the earliest date.

4. Re-entry System Specification

It was concluded from the state of the art survey that industry can now package a re-entry system for operation in water depths to 6096 meters without extensive research and using presently designed equipment. Therefore, using the information developed from the survey a set of specifications has been prepared and is now ready to be sent out to industry for quotation as soon as funding is available.

C. Scientific Justification for a Re-entry System

By Dr. Terry Edgar, Staff Coordinating Geologist, Deep Sea Drilling Project.

The primary scientific objective of the 18-months drilling program is the determination of the age and processes of development of the ocean basins. In addition, the cores will serve as reference sections for future studies in stratigraphy and paleomagnetism. In order to accomplish this ambitious program, sites were selected across the mid-ocean ridge system in four areas, and selected sites were proposed in the deep basin in the hope of recovering the oldest sediments in the ocean basin.

The program of drilling on the mid-ocean ridge was extremely successful and resulted in the collection of overwhelming data in support of the hypothesis of continental drift and sea floor spreading. Drilling conditions on the ridge were optimum; a thin blanket of soft sediments overlies an igneous rock basement in relatively shallow water. As a result, core recovery was high, providing a wealth of information that fulfilled most of the scientific objectives. However, the sediments on the ridge are young (post Mesozoic) and these were thoroughly samples, but the older Mesozoic sediments are found in the deep basins and recovery of these sediments was limited.

Although the oldest sediments ever recovered from the deep ocean were taken by the Glomar Challenger, layers of hard rock, such as chert, limestone and basalt, have prevented the recovery of even older sediment, or the establishment of a reference section of even the upper Mesozoic sediments. Chert is the barrier most commonly encountered and because of its extreme hardness, it has prevented deep penetration in both the east and west basins of the North Atlantic, the Caribbean Sea and is presently being found extensively in the Pacific Ocean. We have met with limited success in trying to penetrate the chert with diamond bits and are continuously trying to improve the bit design, but the ability to change bits would provide the most reliable opportunity for the penetration of such barriers.

The first 18 months program of drilling has concentrated the mid-ocean ridge and the deep-ocean basins, but a great emphasis on the 30 months extension is placed on investigating the nature of the continental margins and island arcs. Thick sediments are commonly associated with continental margins and island arcs and may provide valuable information concerning the interaction of the continental and oceanic crusts, as well as sedimentary diagenesis and stratigraphy. In order to achieve these objectives which require deeper drilling, experience gathered by the Deep Sea Drilling Project indicates that it may be necessary to case parts of a deep hole to prevent the sediment from closing in around the pipe. The re-entry system can provide the capability to set casing and will therefore be a major factor in ensuring the success of these significant objectives in the program extension.

Considerable interest was exhibited by scientists who contributed to the site proposals in the Scientific Plans of the Program Extension for deep penetration into basaltic rocks that lie beneath the sediments. Their request is attributed in part to the fact that the Glomar Challenger has recovered mostly "weathered" or altered basalt and interbedded basalt and sediments. Scientists, therefore, wish to drill deeper into fresh igneous rock and establish whether there are significant amounts of sediment buried within the basement. The drilling of basement rock will require bit changes and casing which will probably be required to maintain a clear hole during the drilling time.

In order to achieve the scientific objectives of program extension, which constitute the recommendations of the scientific community, a re-entry system is highly recommended by the scientific staff of the Deep Sea Drilling Project.

D. Alternatives to Re-entry Considered

Several alternative methods for extending the capability of penetrating the hard abrasive formations were considered. These methods are discussed briefly below:

1. Extend Capability of Bit Penetration (Bit Life) for Coring Hard or Abrasive Sediments

The core bits taken to sea on Leg 1 were of three types:

1. Sintered carbide drag core bit with tungsten carbide inserts in the cutting edges. (Figure 1)

2. Milled cutter roller core bits. These had two outside guage cutters, and two core guage cutters. The teeth were faced with hard metal (Figure 2). These bit designs were based on the best estimate of the scientific panel there would be few

if any hard or abrasive layers between the mud line and the basement, and the bits used in shallow sea floor coring on the Gulf of Mexico, and the Conslope Program.

3. Massive set diamond core bits (650 carats). (Figure 6) This bit design was placed on board for attempts at selected locations to core appreciable depths into the basaltic basement. In actual operations, none of the above bits were able to penetrate thick chert sections. The bits rapidly wore to destruction.

    a. Sintered Carbide - (Figure 3)
    b. Milled Cutter Roller - (Figure 4)
    c. Massive Set Diamond - (Figure 5)

    These failures are typical for bits of the above types run in cherty formations. Such a formation is normally drilled with a carbide insert roller bit (knobby bit) (Figure 6). After penetration of the chert section by conventional rotary drilling such as coring can be continued.

    Although not commercially available, carbide insert roller core bits have been built (Figure 7). Two such bits are being tested on Leg 6 of the Deep Sea Drilling Project, with an attempt to determine the footage of chert or abrasive formation this bit can cut. This bit is not adapted to coring soft or unconsolidated formations, as the cutters are not kept clean at low circulation rates, and soon fail to roll on the bottom of the hole. Wear is quite rapid if chert is then encountered.

CONCLUSIONS

1. The core bits now being used on the Deep Sea Drilling Project are not able to penetrate chert or hard abrasive formations.

2. A bit that will core and drill both the soft unconsolidated formations and the very hard formations is not now commercially available.

3. Establishing a source for such bits in the quantity used on the Deep Sea Drilling Project is, at this time, economically unfeasible.

RECOMMENDATIONS

1. Evaluate as soon as possible the performance of the carbide

insert roller core bits.

2. If the tests are promising, continue a search for a manufacturer.

NOTE

At present there are no roller cutter core bits capable of cutting a 2 1/2 inch core.

2. Use of Downhole Motors for Coring Alternating Hard and Soft Sediments in Deep Ocean Water

In the drilling industry three downhole motors have been used successfully for drilling and coring. These are:

1. Electrocorer (REDA)
2. Dynadrill (Smith Industries)
3. Turbodrill (Dresser or Eastman)

Of these, the last two are commercially available.

An electrocorer capable of operating - to a depth of 6706 meters - is not in existance. Although feasible[1] such a tool would require extensive development, and would requir either a riser system or re-entry for continuous drilling and/or coring.

The basic configuration of the Dynadrill prevents the cutting and retrieving of a core with a wireline inner barrel. Use of this tool on the Deep Sea Drilling Project would require either a riser system or re-entry for continuous drilling and/or coring.

The turbodrill has been modified for retrievable wireline coring, and has been used operationally in several instances.[2,3]

However, the large drilling fluid flow required to power the tool destroys soft or unconsolidated cores as they are being cut. In addition, the coring bits available to use on a turbocorer are unable to core chert, or abrasive formations of appreciable thickness.

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1 Feasibility study and recommendations for design and procurement of a downhole wireline electrodrill unit Mohole Phase II Vol. 403000.

2 Neyrpic turbocorer (France).

3 Stage a report downhole drilling tools Mohole Phase II Vol. 403000.

CONCLUSIONS

The use of downhole motors with the drilling equipment and drilling tools now in use on the Deep Sea Drilling Project would not increase our capability to penetrate chert or other hard and abrasive formations.

With a riser system, or the capability of re-entry, downhole motors such as the turbocorer, would increase the coring and drilling capabilities of the Challenger, and eliminate rotary motion of the drill string.

RECOMMENDATIONS

When a riser system or re-entry capabilities are available on a coring vessel engaged in deep ocean coring, program the acquiring of and use of turbocorers.

3. Use of Alternate Sampling Methods to Insure Penetration of Hard or Abrasive Sediments

There are methods of obtaining formation samples from a bore hole after the hole is drilled. These samples are obtained by punching, rotation of, slicing of, or impact of a core tube with the wall of a hole. At present none can be run through the bottom hole assembly in use on the Deep Sea Drilling Project, but could be used with re-entry capabilities. (Figures 8, 9, 10).

The side wall sampling system preferred by the drilling industry[1] is furnished by Schlumberger. This system uses an explosive charge to drive the core tubes into the wall of the hole. The tubes are retrieved by a short length of wire cable. Shooting is slectively controlled from the surface through an armoured conductor cable.

Samplers of this type could be made small enough to run inside five inch drill pipe. It would then be theoretically possible to drill the hole with a standard drill bit, (Figure 6 - Extend capability of bit penetration). Remove the bit with an explosive charge, and then take side wall samples as required.

Such a system is not recommended at this time as it involves the following:

1 Page 617 Subsurface Geologic Methods - Leroy

1. Extensive development program.

2. Shooting off the bit would leave a rough end. This is not compatible to running an armoured conductor cable.

3. The operating limits of running a cable in open hole below a dynamic positioned drilling vessel have not been established.

4. Holes drilled in these soft sediments are subject to bridging, preventing further sampling.

CONCLUSIONS

With the use of the drilling equipment and tools presently aboard the Challenger, the probability of recovering sufficient samples with side wall sampling to fulfill the scientific objectives is very small.

Re-entry capabilities, or the use of a riser system would greatly increase the probability of successful side wall sampling.

RECOMMENDATIONS

When a riser system or re-entry capabilities are available on a coring vessel engaged in deep ocean coring, select the most appropriate system, and procure this system to extend the sample recovery capabilities of the Deep Sea Drilling Project.

4. Use of a Core Bit With Retractable Cutting Elements to Penetrate Hard and Abrasive Sediments

The research companies of the oil industry have developed retractable bits using both roller cutters and blade cutters. During Phase II Project Mohole a core bit using retractable diamond set pads was developed through the model stage. (Figure 11).[1]

The retractable roller cutter bit requires a drill string with much larger inside diameter and outside diameter than the string in service on the Glomar Challenger. The retractable diamond pad core bit as designed could be run through this string. However, the use of diamond core bits to penetrate chert has not been successful and the existing pipe racking system cannot accept larger outside diameter pipe without extensive modifications. Also the retractable bit body is designed in such a way

1 Stage A Report Downhole Drilling Tools - Vol. 403000

that the fragmented chert cuttings would deform the body limiting the number of pads that could be replaced.

A retractable core bit, where it could be selectively run, as with a riser system or re-entry, could save appreciable trip time in coring massive formations such as limes or basalt.

CONCLUSIONS

A retractable core bit, in its present configuration, and used with re-entry, will not improve the capability of the Deep Sea Drilling Project to penetrate chert sediments.

RECOMMENDATIONS

After riser or re-entry capabilities are available on a deep ocean coring vessel, program the procurement of a retractable diamond core bit to expand the core taking capabilities of the Deep Sea Drilling Project.

5. Marine Riser System

The use of an abreviated riser system for use with the Challenger was considered. The inherent advantages of a riser system allow positive re-entry into the hole of not only the drill string but many other tools such as, a full suite of logging tools whose size would not be restricted to the 2 1/2 inch diameter that is presently being used, temperature measurement instruments, in situ instrumentation packages.

The high costs of a riser system and the problems of handling and tensioning that would be involved on board the Challenger led to the conclusion that this sophisticated method of re-entry would not be economical compared to the sonar assist type of re-entry.

E. Comparison Deep Sea Drilling Project Re-entry versus Mohole Re-entry

The re-entry system proposed for the Deep Sea Drilling Project operation requires that the hole be re-entered only a few times over a period of approximately seven days. Improvements in the "state of the art" of sonics now allows a considerably simpler approach.

The re-entry system that was proposed for Project Mohole required the hole be re-entered hundreds of times over a period of four years and was considerably more sophisticated.

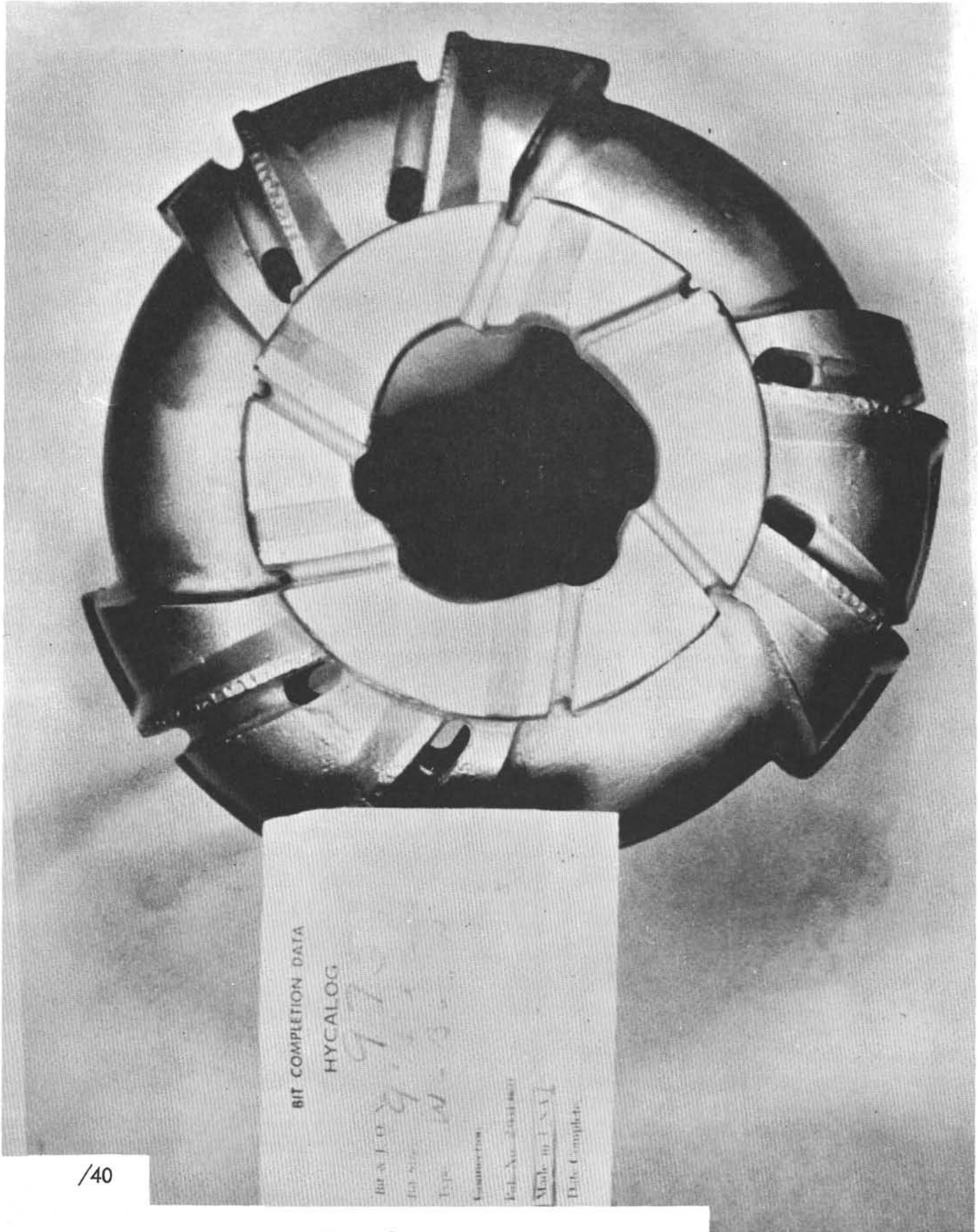

Figure #1 - Sintered Carbide drag bit

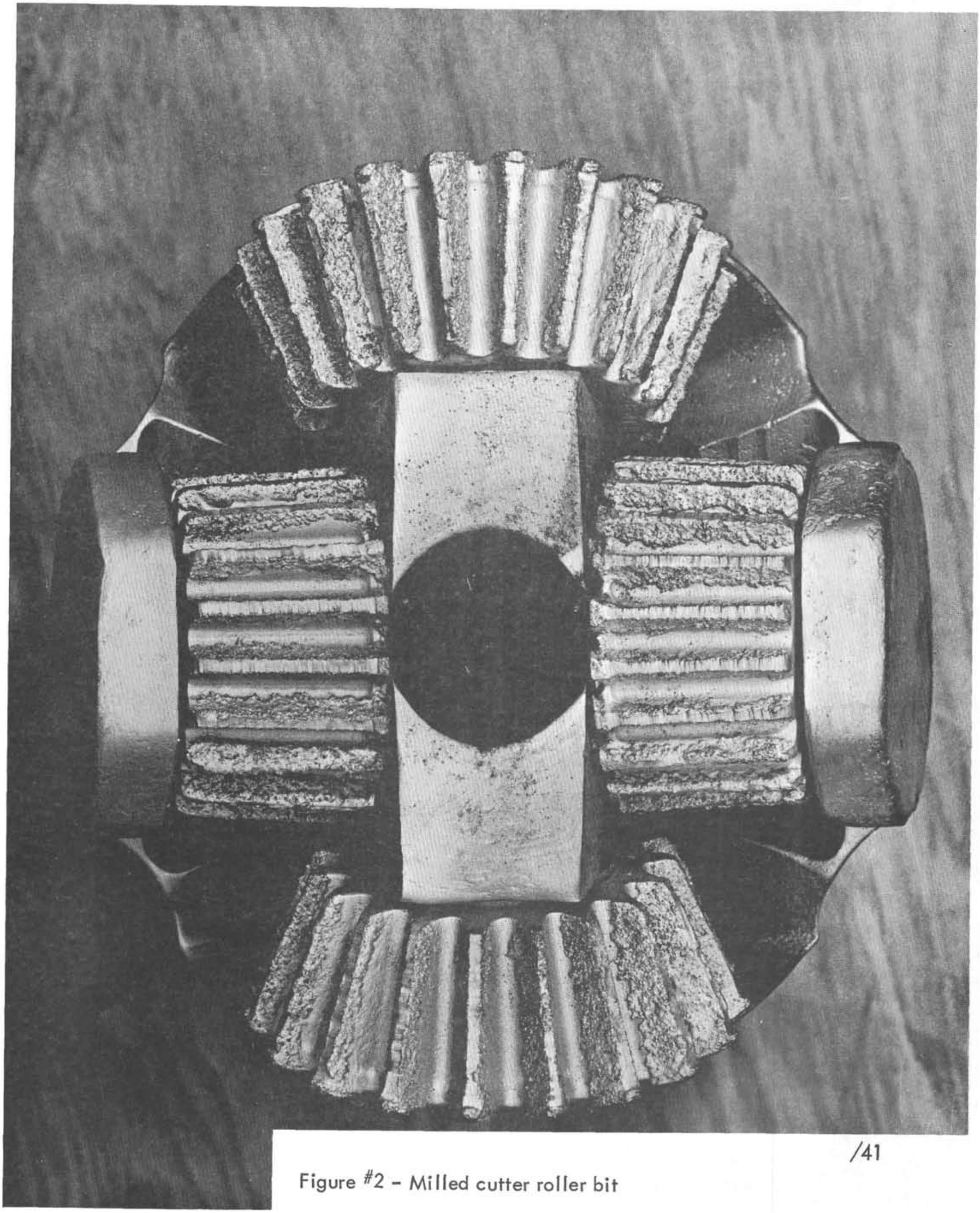

Figure #2 - Milled cutter roller bit

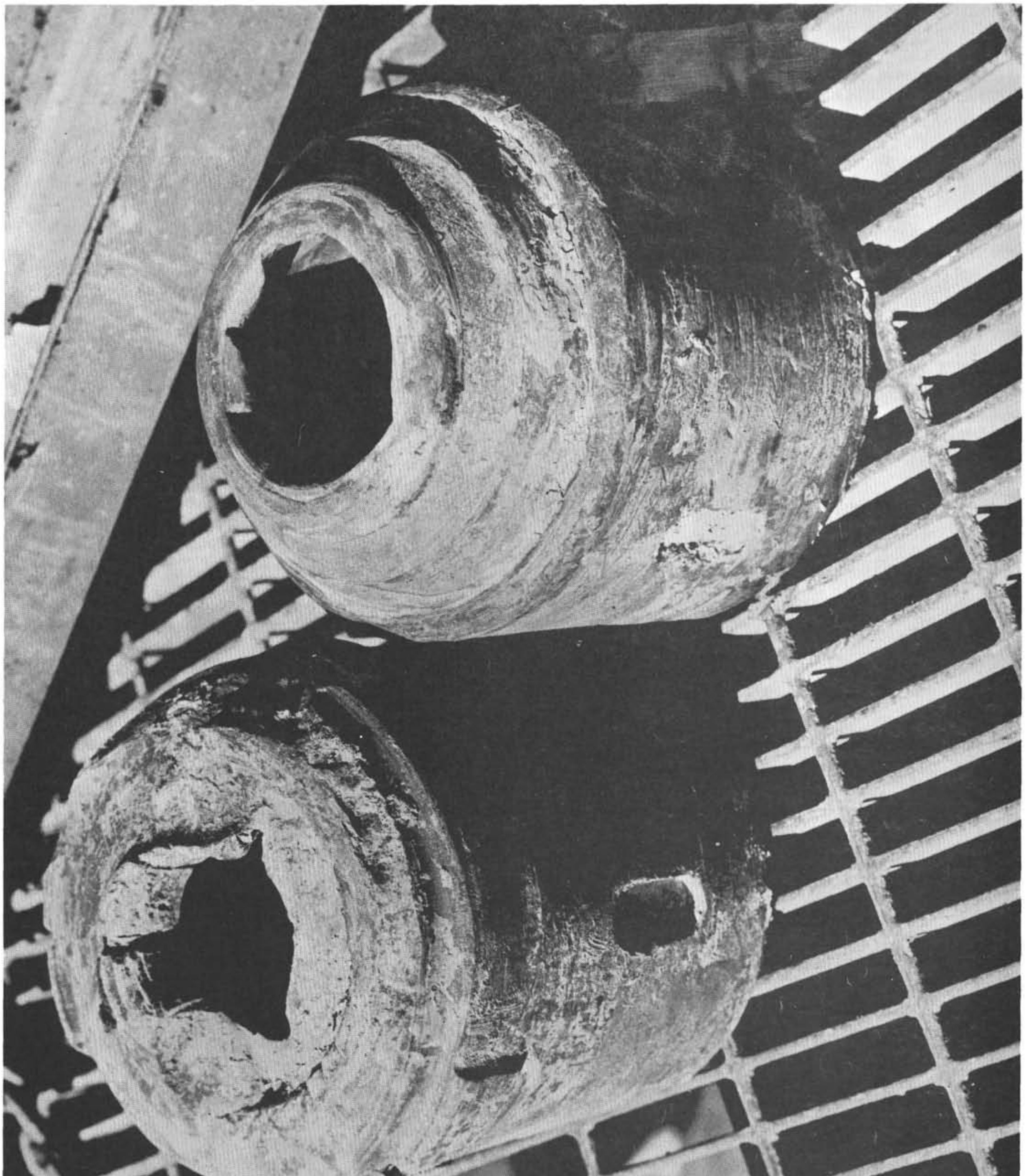

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Figure #3 - Sintered carbide drag bit worn to destruction

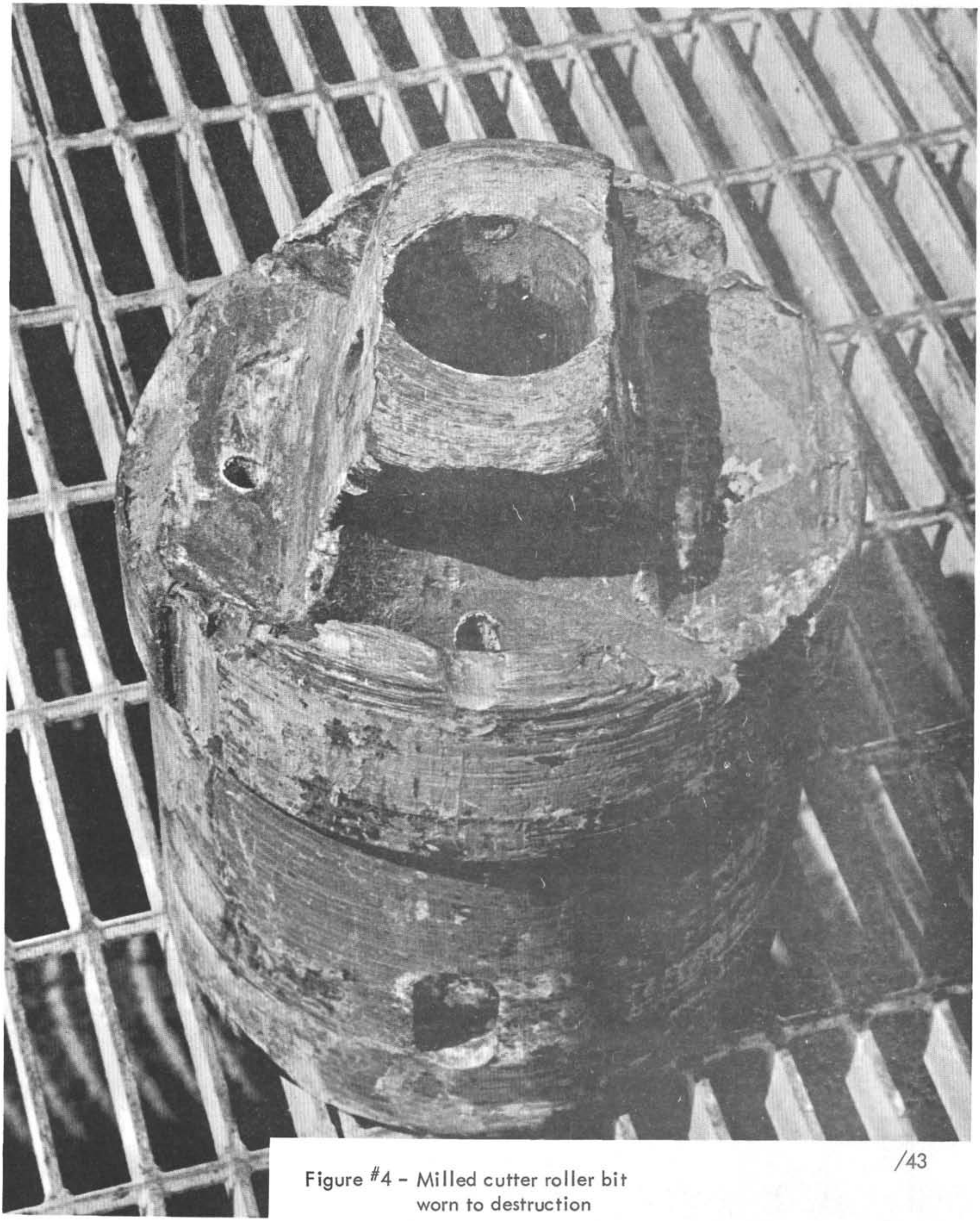

Figure #4 - Milled cutter roller bit
worn to destruction

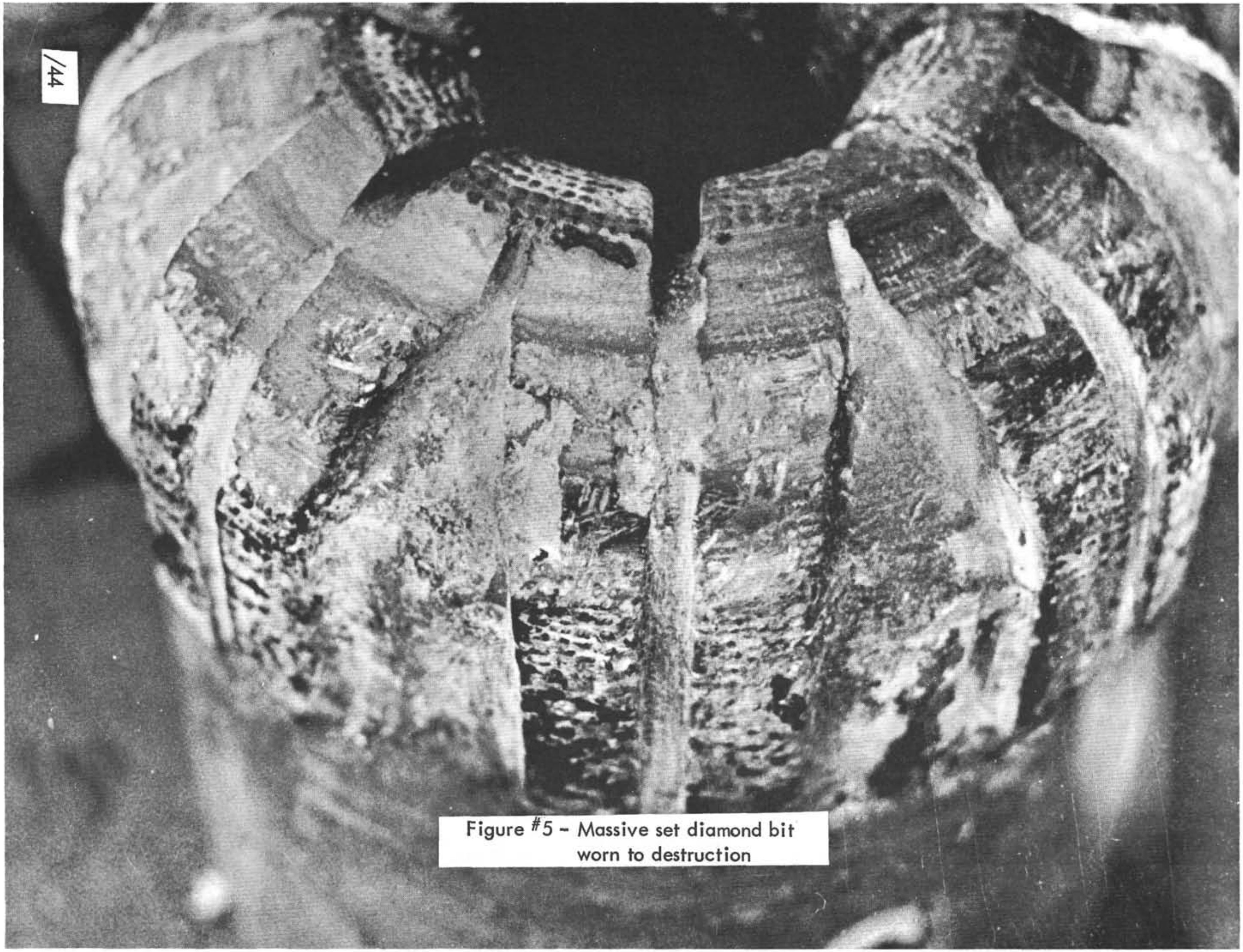

Figure #5 - Massive set diamond bit worn to destruction

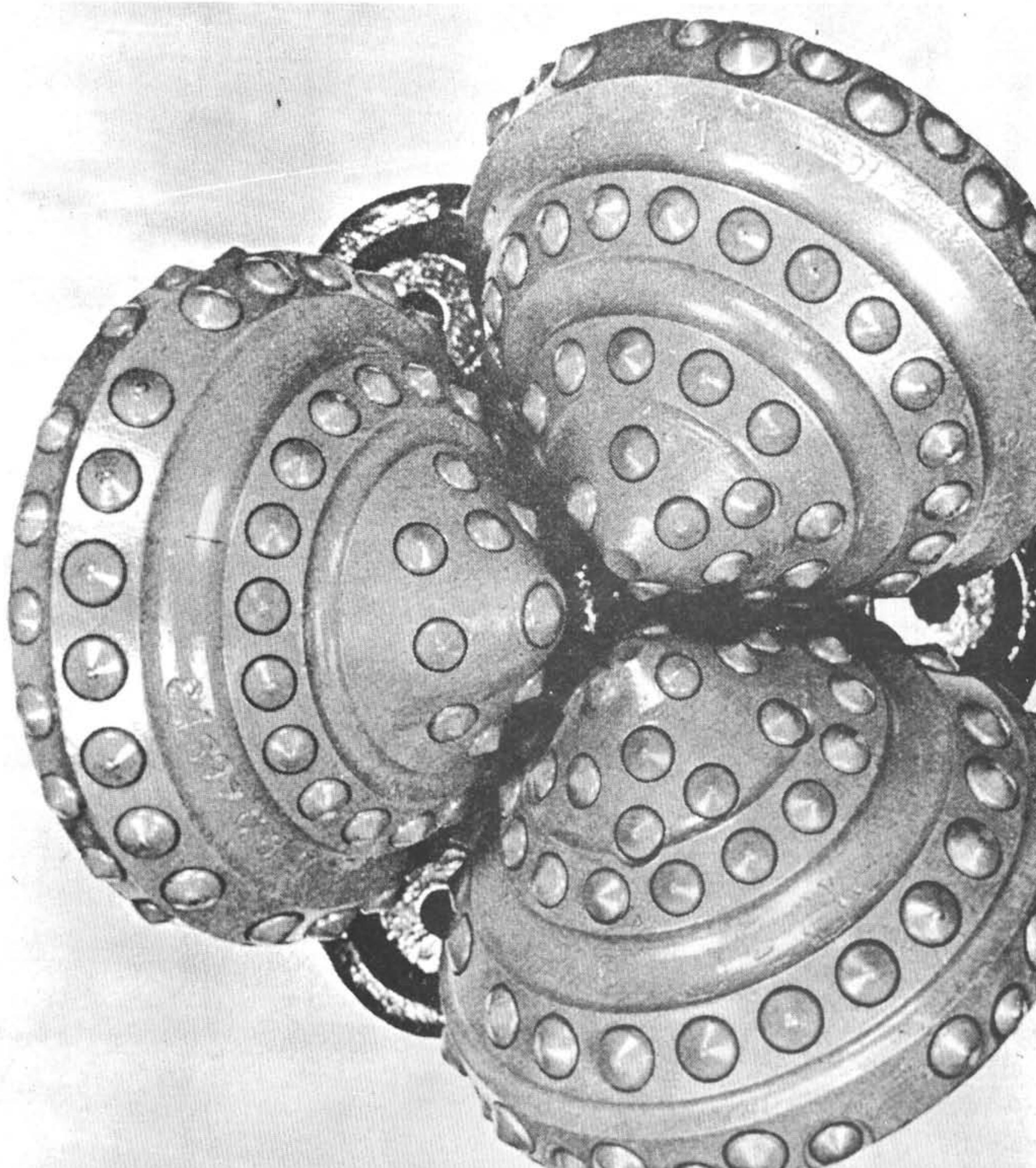

Figure #6 - Carbide insert roller bit

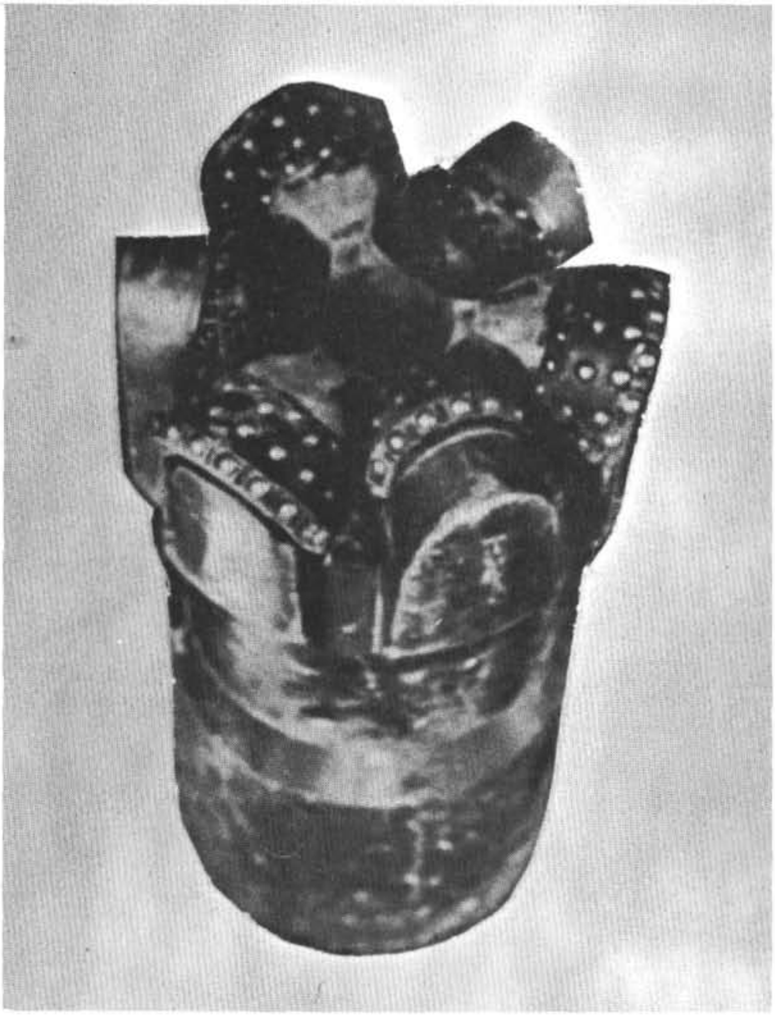

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Figure # 7 - Carbide insert roller core bit

A-1 ROTARY TYPE SIDE WALL CORE BARREL

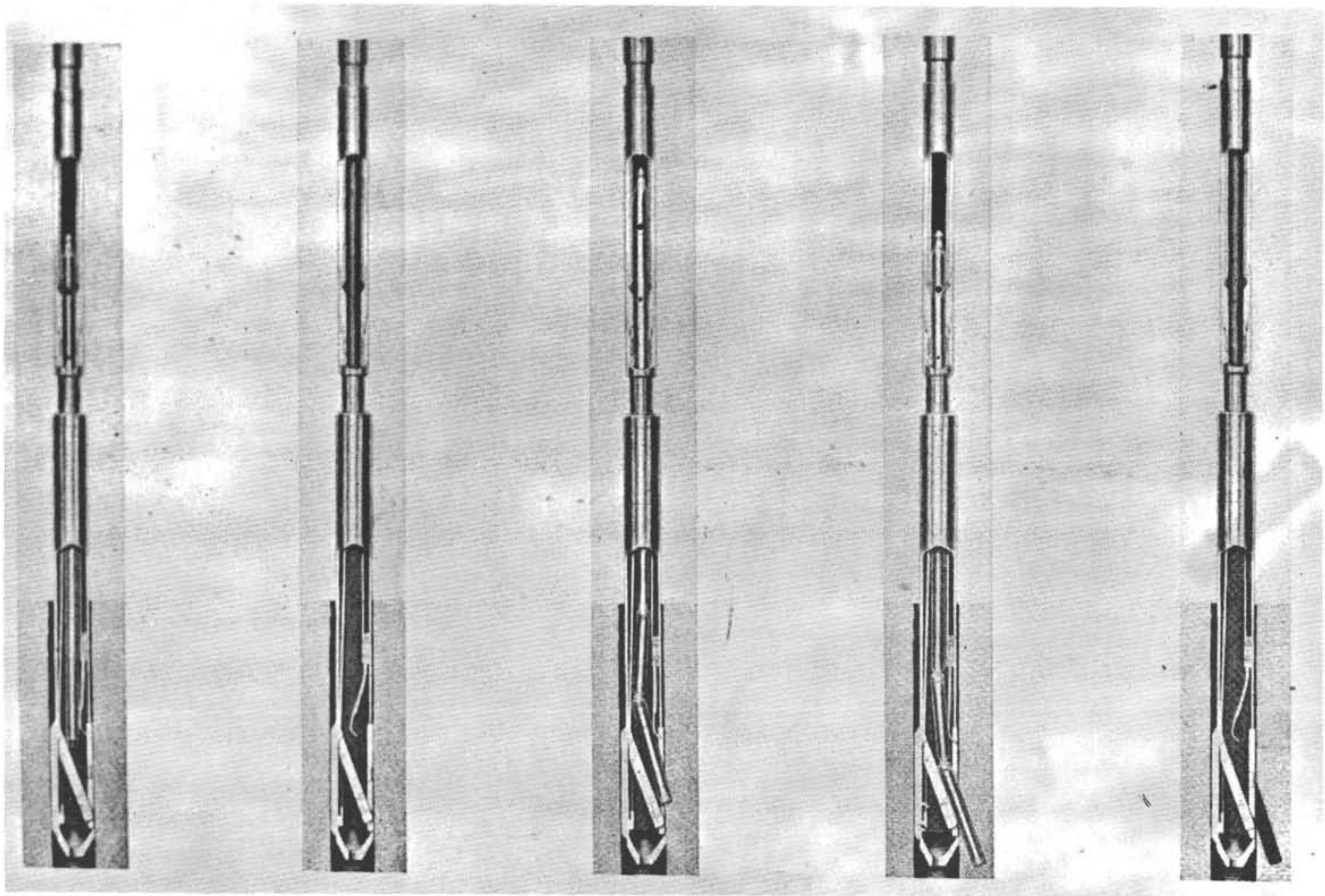
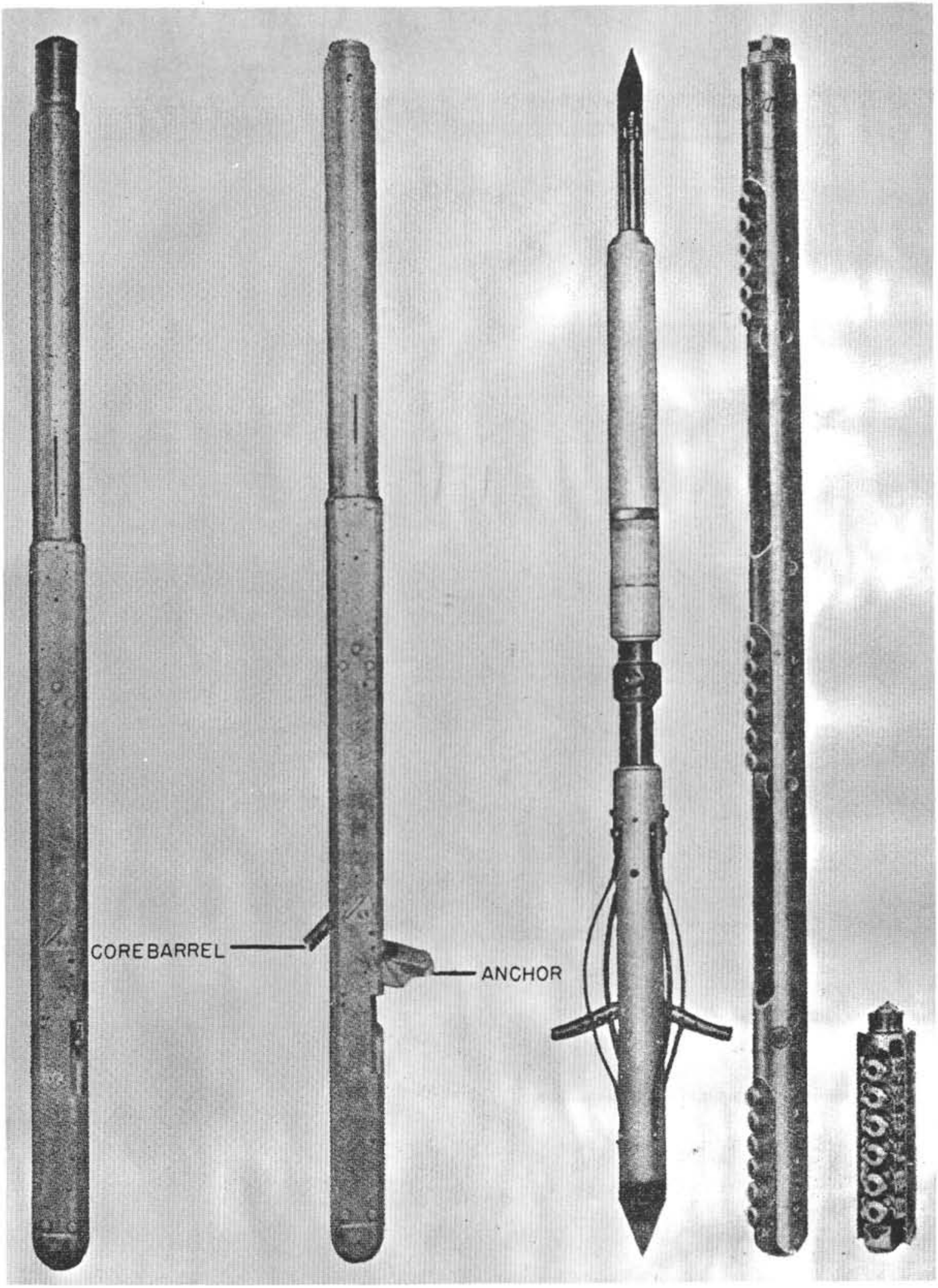


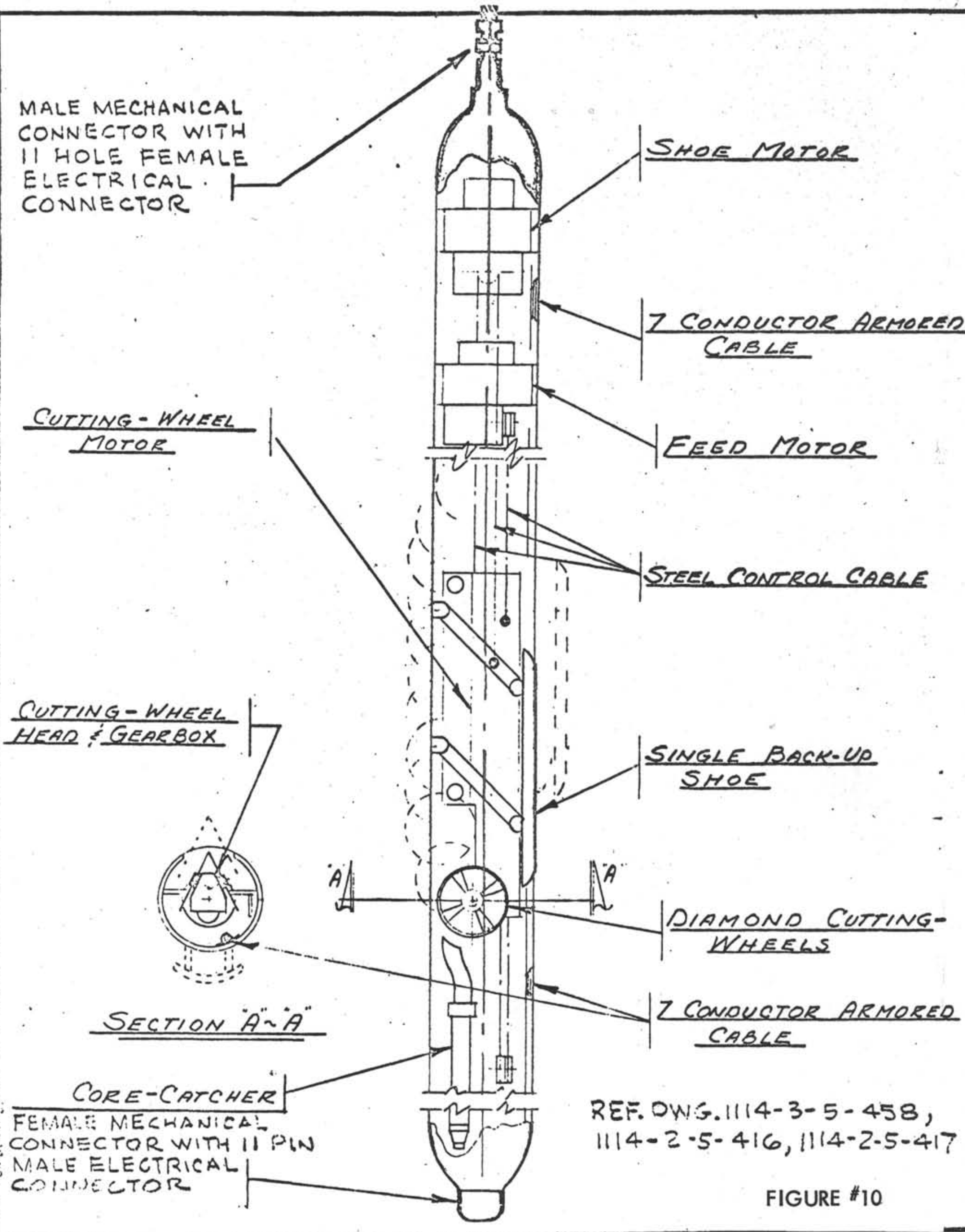
Figure #8 - Rotary type sidewall core barrel



A *B* *C*

/48 FIGURE 319. *A*—Hard-formation electric-motor-driven side-wall coring device. *B*, *C*—Side-wall coring tools in which core tubes are driven into formation by an electrically detonated charge.

Figure #9 - Miscellaneous type sidewall coring tools



REF. DWG. 1114-3-5-458, 1114-2-5-416, 1114-2-5-417

FIGURE #10

BROWN & ROOT Inc. ○ PROJECT MOHOLE HOUSTON, TEXAS		CONT. No. N.S.F.-C260
GENERAL ARRANGEMENT OF PROPOSED PROTOTYPE SIDEWALL CORING TOOL		DWG. No. 1114-1-5-415

SCALE NONE DRAWN BY CDM DATE 9-28-65 CHECKED ______ ENGINEER GIRALA REVISED ______ DATE ______

APPROVED FOR ______ BY ______ DATE ______

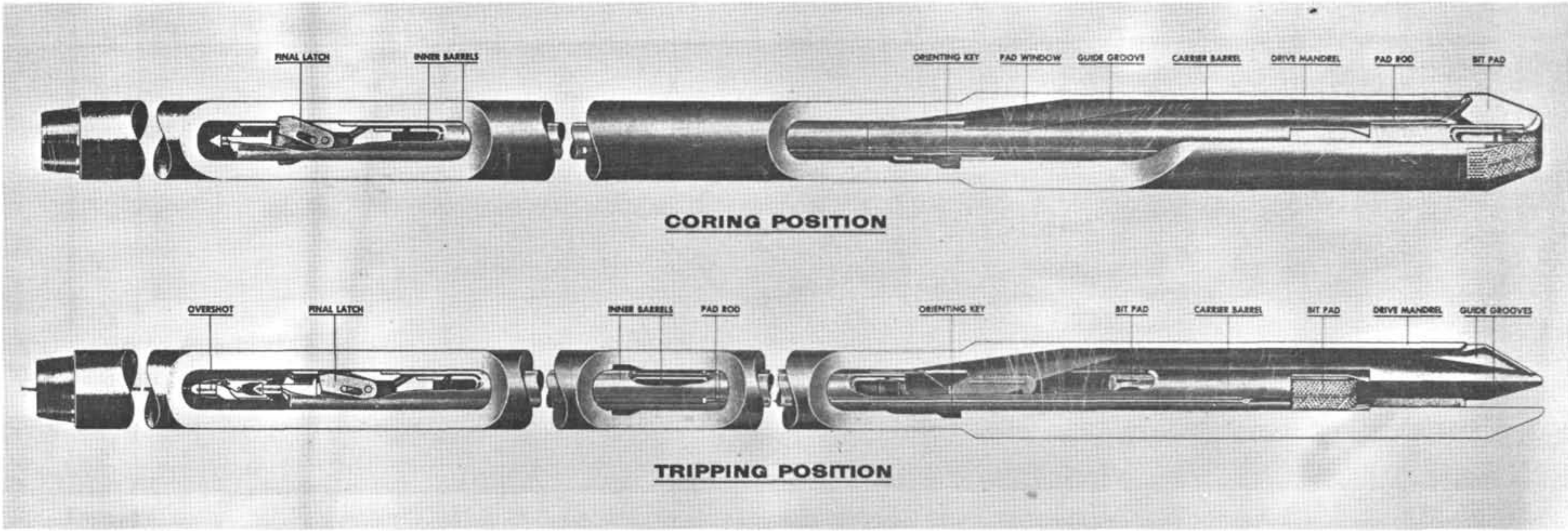


Figure #11 - Retractable core bit

REPORT ON STUDY OF ACOUSTIC RE-ENTRY SYSTEM

(For Deep Ocean Coring)

For
Scripps Institution of Oceanography

By
Global Marine Inc.
811 West Seventh Street
Los Angeles, California 90017

November 1969

Task Order No. 1
Subcontract UC NSF-C482-1

REPORT ON STUDY OF ACOUSTIC RE-ENTRY SYSTEM

INTRODUCTION

This report covers all sources of re-entry type sonar equipment of U.S. manufacture known to the task group performing the study. This report covers known details of each manufacturers equipment as well as his estimated engineering capabilities and probable performance in meeting delivery dates and field service engineer support needs. Previous studies by Global Marine Inc. were restricted to those vendors known to have an operating re-entry system that could be adapted to deep sea service with minor modifications. As a result of this earlier study, the system developed by ACDRL for the Mohole Program, was considered to be the sole system meeting the special requirements. The present study has been expanded to include those vendors having equipment requiring major re-design, or complete design and development. The vendors in the second category above were those considered capable of adapting portions of existing equipments to operate as units of a re-entry sonar.

INDUSTRY SURVEY

Manufacturers having equipment suitable for deep sea re-entry with minor or no modifications are the following:

1. ACDRL
2. Oceanic Enterprises
3. Edo Western

These three sources are compared in Table 1 and discussed in the body of the report.

The manufacturers discussed below were considered in this study and deleted from the list of the possible sources of equipment for the reasons shown:

Honeywell

The equipment proposed by this vendor is not suitable for re-entry in deep water because of the errors introduced by the short base line system. Briefly, the system utilizes the ship's positioning equipment, and alternately determines the location of a pinger attached to the re-entry cone and that of a pinger attached to the bottom section of drill pipe. When the two blips on the read-out oscilloscope are shown superimposed on one another, the two pingers are, hopefully, in line vertically. However, a study of the errors present when the ratio of the vertical axis to the horizontal is 400:1, indicates that successful re-entry is not feasible. It is considered that the maximum depth in which successful re-entry could be effected using this system would be approximately 1,000 feet.

Ametek-Straza
This vendor has, at the present time, no re-entry sonar equipment under design. However, they do manufacture sonar components, and have a quite capable engineering staff, given sufficient time for design and development, they could produce a successful system.

Bendix-Pacific
The statements above under Ametek-Straza apply as well to Bendix-Pacific. They are capable and are interested in developing a re-entry system, but to date have nothing on the boards.

E.G. and G.
It is understood that this firm is developing a classified re-entry system with engineering assistance from their customer, for use in up to 2,000 feet of water.

O.R.E.
No equipment suitable for re-entry is presently under development. Discussions were held with an O.R.E. Representative, Mr. David Porta, who indicated his company would be happy to begin development of a re-entry system.

Therefore, because of lack of suitability for deep sea re-entry, or inability to design and develop a system by a reasonably early date, further consideration of the Honeywell, Ametek-Straza, Bendix-Pacific, E.G. & G., and O. R. E. systems has been deferred.

SYSTEMS WORTH STUDY

Of the remaining systems, that proposed by Oceanic Enterprises is considered to be the more expensive and least acceptable. This system operates on the interrogator-transponder principle. An interrogator, which remains within the drill pipe, interrogates each of four (4) transponders attached to the re-entry cone. Each transponder is interrogated at a different frequency, (between 40 and 50 kHz) and replies on an alternate frequency. The time elapsed between interrogation and reply from each beacon is utilized to determine the distance to each transponder. This information is presented on indicating meters and an oscilloscope. When near, or over the re-entry cone, accuracy is quite high. However, the only method of obtaining directional information when some distance from the re-entry cone is to observe the readings on the display meter, move the drill pipe in any direction and note the change in meter readings. The slight difference in meter readings may be difficult to observe accurately under these conditions.

This system is not recommended for the deep sea drilling system for the following reasons:

a. Cost of transponders and possibility of loss of four (4) transponders at each site. The estimated cost of the transponders in small lots is $2,600.00 each.

Quantity procurement could reduce this to about \$2,000.00. Methods of releasing these transducers from the re-entry cone and surface recovery have been proposed. Because of the uncertainty of release and recovery methods it is felt that this proposal has low merit.

b. Lack of accurate directional information when drill pipe is some distance from re-entry cone.

c. No operationally proven systems are in existance using the four (4) transponders arrangement and it is felt that problems of coding and identification of transponder reply could develop.

Both systems proposed by ACDRL and Edo Western are considered acceptable. Each of these utilizes the principle of a rotating scanner extending through the drill bit. This scanner radiates a horizontal beam of sonar energy at a frequency of either 100 or 300 kHz in the case of the ACDRL equipment and between 300 and 500 kHz for the Edo Western unit. The Edo Western equipment also has provisions for bottom scanning as well, providing information regarding the distance between the scanner and the ocean floor.

Both systems utilize electronics packages lowered through the drill string by means of a combined control and suspension cable.

The Edo Western system makes use of the existing Schlumberger cable while the ACDRL package requires a special 12 to 14 conductor cable with one 75 ohm coax lead. The cost of this special cable is between \$21,000.00 and \$30,000.00 and delivery time is presently quoted at five (5) months after receipt of order. Further, when using this special cable, the handling requirements are complicated by the need to store it on the reel under low-tension conditions. This requirement makes it necessary to provide a special handling system, namely a Pengo winch designed to haul in the cable and transfer it to a storage reel under low-tension conditions. The cost of this Pengo winch is approximately \$35,000.00, plus the installation cost of \$10,000.00.

Table 1, provides a quick technical comparison between the Oceanics Enterprises, the ACDRL and the Edo Western systems. It is considered that, in addition to the apparent advantages of the Edo Western system, the engineering capabilities of the Edo Western Corporation are outstanding in the field of underwater acoustics, and the company is eminently qualified to carry out field service and initial check-out requirements.

The planning cost of the Edo Western system is approximately \$53,000.00 with delivery within five (5) months. The system proposed is the Model 298A Seaview II modified as follows:

a. The electronics unit to be lowered down the drill string would be re-packaged to fit within the smallest diameter of the drill string.

b. The transducer would be re-designed to pass through the 2 1/2 inch core hole in the bit and the upward looking section of transducer would be eliminated.

c. The magnetic direction portion (the compass) of the transducer would be eliminated.

d. The power input on the down hole package would be converted to fit the Schlumberger cable.

e. The scan rate would be increased to one (1) 360 degree revolution every two (2) seconds on the shortest range. The other ranges would likewise be furnished with faster scanning rates.

f. The beam width would be increased to 30 degrees.

g. The ability to manually position the transducer (in azimuth) would be included.

CONCLUSION

After thorough study of the capabilities of each available system, the initial costs and operating costs of each and the ability of the vendor to provide engineering and technical services it is our opinion that the system proposed by the Edo Western Corporation should be selected to fill the special requirements of the deep sea drilling project for the immediate future.

RECOMMENDATIONS

To provide re-entry capability for the Deep Sea Drilling Project at the earliest possible time, it is recommended that the Edo Western Corporation Seaview system be modified for use with conventional core bits and open ended drill pipe.

To provide re-entry capability including the use of regular rotary rock bits, the Oceanic Enterprises interrogator-transponder ranging system should be procured.

TABLE 1
Technical Comparison of Three Acoustic Re-Entry Systems

Technical Detail	Mod. AGS ACDRL	Mod. SPS Oceanic Enterprises	Mod. Seaview Mk. III - Edo Western	Remarks
Type	Scanning Pulsed xducer	Interrogator transponder	Scanning Pulsed xducer	
Max. Range	1,500 feet	2,000 feet	500 feet	All adequate
Min. range scale	10 feet	25 feet	25 feet	All adequate
Presentation	5 inch Oscilloscope	4 meters & 5 inch Oscilloscope	5 inch Oscilloscope	ACDRL & Edo Western - Adequate Oceanic - Fair
Scan Rate	Various Depending on Range scale selected. On 10' range - 1.8 sec for 360 degrees	2 sec. Repetition rate	Various Depending on range 2 sec. for 360 degrees on 25' scale	All adequate
Information presented	Bearing and range of target	Range of target. Some bearing info	Bearing & range of target. Depth below transducer to ocean floor.	ACDRL & Edo Western provide bearing info relative to position of electronic package in drill pipe. Oceanics system presents bearing info by meter only at long range
Cable requirements	Requires special 14 & 1 coax cable. (Cost 21 to $35,000) and special handling winch (Cost $35,000)	Uses existing Schlumberger cable	Uses existing Schlumberger cable	Cable requirement of ACDRL system increases cost about $70,000.00. Cable delivery about five (5) months.

TABLE 1 - Technical Comparison of Three Acoustic Re-Entry Systems concl.

Technical Detail	Mod. AGS ACDRL	Mod. SPS Oceanic Enterprises	Mod. Seaview Mk. III - Edo Western	Remarks
Frequency of operation	100 kHz on long range. 300 kHz on short range	45-55 kHz	300 - 500 kHz	
Power outputs in watts	200 watts - RMS- low freq. 85 watts high frequency	20 watts	80 watts	All adequate
Overall technical quality	Good-simple & straight forward Lab model converted to field use	Fair-equip. from Oceanics seen to date not too professional in appearance	Excellent factory type construction. Very professional, compact	
Delivery schedule	5-months ARO	5-months ARO-Dependent on work in hand. Earliest start now is Jan. 1, 1970	5-months ARO	ACDRL equipment modifications depends on receipt of certain items. Oceanics must develop. Edo Western must modify as described. No material problems.
Equipment cost & engr. service during installation	$74,000.00	*$31,800.00	$53,000.00	*Transponders are required, 4 to each site. Cost $2,200.00 to $2,600.00 each. These to be supplied by others.
Cost of ancillary equipment	$30,000.00 for cable $35,000.00 for winch	$500.00	$500.00	
Installation cost	$8,500.00	$1,200.00	$1,200.00	

OPERATIONS RESUME

LEG 11 C

RE-ENTRY SEA TRIALS

ABSTRACT

This report covers the sea trials of the high resolution scanning sonar re-entry system designed and built for the Deep Sea Drilling Project. The system which was installed aboard the Glomar Challenger at Hoboken, New Jersey during the port call at the end of Leg 11 was tested at sea from June 10 through June 16, 1970. A complete description of the system and complete logs and comments of operations, scientific, electronics, Edo representative and observers from major oil companies, are included in the appendix.

INTRODUCTION

Cherty and other hard formations in the soft deep ocean sediments were encountered early in the Deep Sea Drilling Project. These formations prevented the drill ship from coring through all sediments to the basaltic basement with a single bit. An engineering study concluded the most positive way to penetrate these hard formations was to equip the Glomar Challenger with the capability of running two or more bits in the same core hole. This would also allow deeper penetration into the basalt. Evaluations of existing and proposed re-entry systems were conducted independently by DSDP and Global Marine Inc.(GMI).

The extension of the DSDP and the increasing requests of the scientific community made it possible for DSDP to actively engage in the procurement and test of a re-entry system.

As GMI would be the operator of this system, a change order to the subcontract was negotiated between DSDP and GMI for GMI to design and build a re-entry system to operate from the Glomar Challenger.

This system was to incorporate the Edo high resolution scanning sonar operating through the core bit on 24,000 feet of Schlumberger seven conductor logging cable in 6096 meters of water. The lower drill string was to have a jet sub with a sliding Otis sleeve to close or open the jet. The landing cone was hexagonal and attached to the drill string with two sets of shear pins. Just before delivery a method was added to attach the base to the drill string with acoustically actuated explosive bolts.

It was decided to perform the sea trials of the system aboard the Glomar Challenger. This decision was based on: (1) the high level of training of DSDP and GMI personnel from using specialized equipment from a dynamically positioned drill ship in open water, (2) the capability of the ship to handle the system without modifications, (3) repair and modification capabilities aboard ship which would allow completing the test on one trip, (4) training of the personnel that would later run the equipment.

As the last available ship's time before the Glomar Challenger left for the North Atlantic was June 1 through June 16, all deliveries of equipment were expedited to Hoboken, New Jersey, even though this meant bypassing a surface test of all equipment.

The Scientific Mission was requested to select a site for re-entry tests. Requirements for this site were: (1) minimum 3048 meters water depth, (2) not in the Gulf Stream, (3) bottom sediments similar to deep ocean basins and without hard layers near the ocean floor. In addition, the site should be as near Hoboken, New Jersey and Boston, Massachusetts, as possible to reduce steaming time. Such a site was picked at 37° 59.39' North Latitude and 71° 46.65' West Longitude. Bottom conditions proved to be excellent.

CONCLUSIONS

1. The presentation at the surface on the Positive Position Indicator (PPI) scope by the high resolution scanning sonar transducer has sufficient contrast between target "signature" and background to enable an observer to positively identify the target and follow relative movement between the core bit and the target (re-entry cone).

2. In deep ocean water a re-entry cone can be keel hauled, casing run and landed in the base, attached to the drill string, lowered to the ocean floor, the casing washed into the ocean floor, and the drill string released from the base.

3. If the drill string is removed from the re-entry cone, the cone can be located with the high resolution scanning head by moving the ship.

4. The ships' positioning system can be used to position the bit over the re-entry cone for successful re-entry.

5. A controllable force near the lower end of the drill string is needed to shorten the time required for re-entry using the positioning system only. (The testing of the jet sub was not possible because of mechanical problems).

6. The downhole instrument will operate on a 24,000 foot seven conductor logging cable.

7. Physical alignment of the bottom hole instrument to the drill string (jet) is desirable.

8. Orientation of the transducer head and the PPI screen (0°00') would advise the operator of slip in either and also give a zero reference to rotate either image or transducer.

9. A means of rotating either the image (electronically) or the scope (physically) to allow the operator to keep the zero degree of the PPI sweep aligned with the ship's centerline.

10. The downhole instrumentation and drill string components are sufficiently different from existing equipment to be classified as prototype equipment.

11. Spare and/or replacement parts were far below a safe minimum to conduct tests at a location where supplies or replacements were not immediately available.

12. The sea trials demonstrated re-entry with a core bit, high resolution scanning sonar and a re-entry cone of at least 16 feet diameter is possible. This means re-entry capability be incorporated in planning DSDP coring legs and selecting scientific objectives.

RECOMMENDATIONS

1. Assume all downhole instruments and drill string components are prototypes and are to be evaluated and modified.

2. Return all instrumentation and hardware to manufacturers for evaluation. DSDP, GMI and Edo Western to then jointly evaluate equipment as to original design concepts, performance, and to evolve revised design concepts.

3. Negotiate for:

   a. Modification of existing instruments and hardware if economically feasible, or

   b. Re-design and construction of a modified instrument with sufficient replacement and spare parts.

   c. Design and construction of one or more surface controlled release systems to latch the re-entry cone to the drill string.

      (1) Hydraulically actuated.

(2) Acoustically actuated explosive bolts.

4. With all components assembled at one place thoroughly test:

   a. All equipment on surface.

   b. Downhole instrumentation in deep water.

5. Train DSDP and GMI electronic technicians at Edo factory for operation and maintenance of downhole instrument and surface. Train DSDP Cruise Operations Managers and GMI Pushers in the assembly, operation and maintenance of downhole instrument, drill string components, and the landing base.

6. Establish the ship's drill floor as the control center for re-entry and design surface displays to give necessary information to this center.

7. Modify existing downhole instrument and manufacture new base cone, release, jet sub and jet sub pack off in order that re-entry will be operationally available for Leg 15.

DISCUSSION

This is a brief discussion of the sea trials. Complete logs and comments from operations, scientific, electronics, the Edo project engineer, and observers from major oil companies are included in the appendix.

The trip to the site was uneventful, weather, in general, for the entire test was excellent. The sea did pick up to Sea State 5 during the trials for and actual re-entry.

After reaching our approximate location, we tested the acoustical explosive bolts release system which was to fire the explosive shear bolts. The unit would not work in 3048 meters of water. We later turned the hydrophone and release unit 45 degrees to the sand line with the booster and an explosive bolt. This would not fire at 3048 meters. We fired the bolt at 61 meters. Additional tests indicated the unit would work at 610 meters but not at 914 meters.

We returned to location and after dropping a beacon, ran a coring assembly into bottom to establish the depth below the mud line that could be penetrated without rotation, bit weight not to exceed 10,000 lbs and pump pressure not over 500 psi. This proved to be 77 meters which indicated six joints or 73 meters of casing should be run. A core was taken at bottom.

Before this hole was drilled, an attempt was made to run the Edo to see if we could locate the beacon. The bore plugger (attached to the Edo instrument to seal off the bit so all drilling fluid would pass through the jet when jetting) stuck in a tool joint and the Schlumberger line pulled out of the rope socket, dropping the instrument, which wedges five joints down. The keys on the collet of the bore plugger were found to be 4 1/4 inch outside diameter and were removed. Two more attempts were made to run the bore plugger, one with the seal mandrel turned down. The tool stuck on both tries, so was laid aside. The core barrel was blanked off for jetting on runs No.2 and 3 by filling in the Hycalog landing seat (for the inner core barrel) and adding "O" rings.

In addition to pulling out of the cable head, the Edo instrument housing was damaged. The cover plates over the expansion tube were loose. The cable head was re-socketed and the cover plates replaced and additional screws added.

The Edo was run to bottom and the positioning acoustic beacon easily identified on the PPI scope. The ship was moved to observe action of the bit.

The next run for the Edo was after the landing base was dropped. If the casing was still attached to the drill collars, the scope would be blank.

On reaching bottom, the Edo presented an excellent picture of the landing base. Several hours were spent tracking the response of the drill string to the drill ship.

The Edo was again run when the second landing base was on bottom (new location). When on bottom (in the landing base) the Edo was pulled above cone, and ship and bit motion observed. An attempt was made to move the bit with the jet, resulting in a failure of the Edo.

The Edo was pulled and the motor-transducer section found to be flooded with sea water and the pressure equalizing bladder ruptured.

An attempt was made to clean, dry and refill the motor section. After a bench check, the Edo was started for bottom but would stop transmitting at approximately 30 meters below the surface. This failure would repeat indicating an air bubble in the housing.

The motor section was disassembled, vent holes added, and refilled with a low viscosity fluid. The Edo was then run to bottom and performed excellent for approximately 15 hours.

The surface units performed as anticipated with the exception of the remote PPI on the drill floor which apparently had electrical interference.

As mentioned earlier we dropped the first landing base. This base was hung over the port side and keel-hauled in good time. The base was pulled up under the ship and hung off. These slings did not line up going through the hull cover for the moon pool and tended to pinch in the landing cone.

The casing was run and attached to the shear sub. When the casing was landed in the landing base, the base collapsed and the landing cone leaned over to the pipe. (Confirmed by divers and pictures).

It was decided to run the base to bottom and shear. When about 300 meters of pipe had been run, the base and casing sheared off and fell to bottom (confirmed by the precision depth indicator). The pipe was run to bottom and the loss of the base and casing confirmed by running the Edo.

As the explosive shear bolts had proved to be inoperative, the "J" tool and "J" slot (used to land the casing on the expotential horn until the bottom hole assembly has been picked up) were modified to run the second landing base and re-entry cone.

The second base was reinforced by welding all bolted seams and adding the rods and gussets where needed. Collapsing pad eyes were added, so the support slings would be in line with the holes in the keel plate. The slings were also re-rigged so the base could be released without sending a diver into the moon pool.

This base was also hung over the side, keel-hauled and hung off in good time. Some trouble was experienced in adapting the modified hangers to the casing and base plate.

The landing base (with four joints of casing) was carefully run to bottom and washed in to within ten meters of the mud line. No problem was experienced in coming out of "J" slot.

While waiting for the Edo to be repaired, the pipe was pulled and the landing sleeve attached to the shear sub (placed two feet above the bit). This would (and did) give a surface indication when the sub sheared if the bit had actually re-entered the cone.

The modified bearing support (making a seal between the outer core tube and Edo instrument) was left in the bottom hole assembly so the jet could be used if re-entry could not be accomplished with the positioning system.

When the repaired Edo was back in place in the core bit, a search pattern was run and the base located. As a field modification on the Edo bypassed the capability of electronically orienting the transducer and the PPI scan with the ship, it was necessary to find this orientation by moving the vessel along preselected tracks. The trace of the bit was then established. The bit closely followed the ship's motion for normal positioning thrust corrections. As the positioning system does not signal thrust corrections until the ship has moved outside a 40-foot circle and as only 100-foot offset steps can be dialed into the computer, the ship had to be manuevered until its meander pattern would carry the bit across the cone.

The PPI display gave no doubt as to when the bit was passing over the cone, and after establishing the necessary lead, the bit was successfully dropped into the cone.

For additional proof a core was taken at the shoe of the casing string.

Before pulling the pipe, the jet sub sleeve shifting tool was run in an attempt to close the sleeve. The tool became stuck, the sand line was cut, and pulled out. The tool was retrieved with the drill string.

In addition to these tests, we rigged up an acoustic pulse generator to determine the limits for pulse shape, frequency, and length acceptable to the positioning system. Two 13.5 kHz beacons were lowered through the moon pool and their acoustic pulses checked.

As soon as the core from the bottom of the hole was on board, the drill string was pulled, all loose equipment secured, and the Glomar Challenger departed for Boston, Massachusetts, to load out for Leg 12.

REFERENCES

1. Study - Methods to Penetrate Hard Formations in Deep Ocean Basins

2. Re-entry Study - Deep Sea Drilling Project

3. Re-entry Study - Global Marine Inc.

4. Edo Western Manual

5. Blueprint Bore Plugger

6. Blueprint Shifting Tool

7. Blueprint Landing Base

8. Stage "A" Report Re-entry Sonar, Phase II, Project Mohole

9. AC-DRL Acoustic Guidance Sonar

10. Trade Literature

11. Concept for Coring in Deep Ocean Waters from Self-Positioned Vessels.

APPENDIX

1. Passenger List - Scripps Personnel, Guests, and GMI Personnel On Board for Re-entry

2. Weather Summary

3. Log

4. Observers Comments

   (a) Captain J. Clarke, GMI

   (b) M.N.A. Peterson - N.T. Edgar, SIO

   (c) G. J. Behunin, Edo

   (d) J. Maheur, GMI

   (e) K. Barrett - C. Wells, GMI

   (f) L. Blurton - T. Rayborn, GMI

   (g) D. N. Smith, GMI

   (h) Observer, Major Oil Company

   (i) Observer, Major Oil Company

   (j) Observer, Major Oil Company

   (k) Observer, Major Oil Company

APPENDIX NO. 1

Passenger List - Scripps Personnel, Guests, and GMI Personnel On Board for Re-entry

1. Mr. K. E. Brunot - Project Manager DSDP
2. Mr. V. F. Larson - DSDP Operations Manager
3. Mr. D. L. Sims - DSDP Project Engineer
4. Mr. W. Schneider - Re-entry Consultant *
5. Mr. A. R. McLerran - NSF Observer
6. Mr. Daniel Hunt - NSF Observer*
7. Mr. Morris Phillips - NSF Observer*
8. Dr. M.N.A. Peterson - Co-Chief Scientist
9. Dr. N. T. Edgar - Co-Chief Scientist
10. Miss F. L. Parker - Paleontologist
11. Mr. C. L. Collier - Electronics Technician
12. Mr. P. J. Garrow - Electronics Technician*
13. Mr. L. L. Lauve - Photographer
14. Mrs. S. Thompson - Yeoman
15. Mr. T. B. Gustafson - Laboratory Officer
16. Mr. D. Bos - Marine Technician - Chemist
17. Mr. B. Hamlin - Marine Technician
18. Mr. R. W. Gilkey - Marine Technician*
19. Mr. T. J. Wiley, Jr. - DSDP Public Information Officer
20. Mr. R. Bowman - Weatherman
21. Mr. James Maher - GMI Observer
22. Mr. L. Blurton - GMI Engineer
23. Mr. Ken Barrett - GMI Electronics Technician
24. Mr. Bruce Erickson - GMI Coring Technician
25. Mr. Don Smith - GMI First Mate
26. Mr. G. J. Behunin - Edo

*Off loaded June 9, 1970; replaced by:

On loaded June 9, 1970

Mr. R. R. Angel - Phillips Petroleum Company
Mr. Jim Caldwell - ESSO Production Research Company
Mr. Peter Briggs - Writer, self-employed
Mr. John L. Shaw - International Nickel Company
Mr. J. J. Weirda - Standard Oil Company of California

APPENDIX NO. 2

WEATHER OBSERVATIONS ON RE-ENTRY SITE
POSITION 38.0°N to 71.8°W

Local Date and Time	Wind		Wind Waves	Swell	
6/06/70 - 20:00	SSW	- 20 knots	5 feet	No Swell	
6/07/70 - 08:00	NW	- 12 knots	2 feet	S	- 5 feet
6/07/70 - 14:00	WNW	- 10 knots	2 feet	S	- 5 feet
6/07/70 - 20:00	WNW	- 20 knots	3 feet	SSW	- 5 feet
6/08/70 - 08:00	WNW	- 12 knots	2 feet	S	- 3 feet
6/08/70 - 14:00	WNW	- 4 knots	----	S	- 3 feet
6/08/70 - 20:00	CALM		----	S	- 3 feet
6/09/70 - 08:00	E	- 17 knots	3 feet	----	
6/09/70 - 14:00	ENE	- 20 knots	3 feet	ESE	- 5 feet
6/09/70 - 20:00	ENE	- 15 knots	3 feet	ESE	- 5 feet
6/10/70 - 08:00	SSW	- 6 knots	2 feet	SE	- 5 feet
6/10/70 - 14:00	SSW	- 6 knots	2 feet	SE	- 4 feet
6/10/70 - 20:00	CALM		----	SE	- 5 feet
6/11/70 - 08:00	ENE	- 5 knots	----	S	- 3 feet
6/11/70 - 14:00	CALM		----	ESE	- 3 feet
6/11/70 - 20:00	W	- 7 knots	----	ESE	- 3 feet
6/12/70 - 08:00	SSW	- 10 knots	1 foot	ESE	- 3 feet
6/12/70 - 14:00	SSW	- 15 knots	2 feet	ESE	- 3 feet
6/12/70 - 20:00	W	- 9 knots	2 feet	SSE	- 3 feet
6/13/70 - 08:00	WNW	- 11 knots	2 feet	S	- 3 feet
6/13/70 - 14:00	NE	- 20 knots	4 feet	----	
6/13/70 - 20:00	NE	- 30 knots	5 feet	NE	- 7 feet
6/14/70 - 08:00	ENE	- 25 knots	5 feet	NE	- 6 feet
6/14/70 - 14:00	E	- 18 knots	4 feet	NE	- 6 feet
6/14/70 - 20:00	E	- 15 knots	3 feet	NE	- 5 feet
6/15/70 - 08:00	ENE	- 12 knots	2 feet	E	- 4 feet
6/15/70 - 14:00	E	- 15 knots	3 feet	E	- 4 feet

OFF STATION - UNDERWAY FOR BOSTON

APPENDIX NO. 3

RE-ENTRY LOG

June 6, 1970

Arrived re-entry site 10:00. Ran profile line across site and beyond about 10 miles. With vessel drifting, rigged Edo Model 337 transducer six meters below hull line through the moon pool. Transducer was driven by a pulse carrier system such that pulse width, pulse repetition rate, and carrier frequency could be accurately varied. These signals were used to test the positioning system procession. (1) Pulse width tolerances were four plus .1, minus .8 milliseconds. (Note: these values were for the most critical channels.) (2) Pulse repetition rate was 2.28 sec to 1.57 sec. Repetition rate that T_o pulse generated within the system triggered the computer rather than the sonar signal. (3) Frequency changes of the carrier that could be tolerated were 15.45 kHz to 16.58 kHz. The basic conclusion, therefore, is that the pulse width is the most critical parameter and was not identical on all channels. Attempted tests of the 13.5 kHz but was unable to conduct tests because only two channels received signals of sufficient strength to validate data.

Cruised back to re-entry site at location 37°59.39' North Latitude and 71°46.65' West Longitude. Dropped Burnett 16 kHz beacon.

Placed re-entry target over the side in water six meters to nine meters below hull with Edo scanning tool in normal running position below the bit. Signature of target was obtained and target could be seen for all variations in the target azimuth. Maximum range tested was approximately 61 meters. Note: Physically unable to move target further.

Hook up acoustic recall to sand line with 100 lb weight hanging below release. Note: Operation checked okay before lowering.

19:05 - Lowered command ducer over side of vessel and send command. Pull sand line. Sand line had been overrun approximately 183 meters. Badly kinked. Weight had not released and would not release at surface.

Pick up second release. Note: Third release was inoperative as received from Inter Oceans. Run in to approximately 2743 meters. Attempt release, no good. Run to 61 meters plus or minus. Release was made - shackle fouled in pelican hook.

June 7, 1970

Subsequent work on first release indicated limit switch had not tripped to reverse release motor.

Decision made to run drilling assembly and continue work on release. Favorable results will attempt acoustic link after trip.

Water depth 3053 meters, Precision Depth Recorder (PDR) 3053 meters. Made up bottom hole assembly, core barrel, index sleeve, three 8 1/4 inch outside diameter drill collars, two bumper subs, three 8 1/4 inch outside diameter drill collars, one bumper sub, two 8 1/4 inch outside diameter drill collars, one 7 1/4 inch drill collar, one joint 5 1/2 inch outside diameter drill pipe.

Strip in horn.

Run drill pipe. Lay down bad order drill pipe in hole at 04:30. Pick up Edo tool. Attempt to work bore plugger in drill pipe. Tool bull dogged on collet. Pulled out of socket at 4,300 lbs versus 3,750 lbs design.

Pull out of hole. Locate tool five joints down. Broke case at equalizing section while breaking stand. Tool had stopped at tool joint upset. Collet had jammed.

June 8, 1970

09:00 - Ran inner barrel - punch cored ocean floor 3053 to 3062 meters and continued to punch core to 3065 meters. Took 10,000 lbs weight. Pulled inner barrel - no recovery (all washed out). Calipered Edo tool - found lower dog assembly to be 4 1/4 inch outside diameter - modified tool by removing same. Found split sleeves over diaphragm section loose. Increased number of screws to four each for each sleeve 1/4 inch set screws. Repaired Schlumberger cable head.

10:00 - With 500 lbs pump pressure, no rotation, total depth 3130 meters (77 meters penetration). Dropped inner barrel and cored 3130 to 3139 meters (nine meters penetration).

12:30 - Pulled and recovered ten meters grey-green clay. Looks good for setting casing shoe at about 73 meters plus or minus.

13:00 - Electrically tested Edo tool- okay, both in air and over the side.

17:00 - Make-up dummy on bore plugger. Tool hung up several joints down. Pull out. O-ring missing. Circulate hole approximately one and one-half hours. Remove sleeve from bore plugger completely. String Schlumberger line through blocks. Make-up torpedo.

19:30 - Pick up and run Edo scanning sonar head - approximately two hours to run in. Lower drill pipe and logging tool in three meter increments down. Locate acoustic positioning beacon on scope. Move vessel - pipe movement seems to lag five minutes, however, appears to come to rest at new location with a minimum of overshoot.

22:30 - Pull Edo tool - 1067 m/hr 200 to 300 lb overpull.

June 9, 1970

01:30 - Lay down Edo - break torpedo. Cannot pull through blocks due to lubricator.

02:00 to 08:00 - Pull out of hole.

08:00 to 09:30 - Keelhaul base plate - very smoothly done.

09:30 to 13:00 - Make-up and run six joints 10 3/4 inch casing and hang in moon pool.

13:00 to 15:00 - Make-up core barrel and six drill collars - lowering too. Engage casing bowl with bumper sub.

15:00 - Pick up drill collar and lower and engage base plate not over 5,000 lbs down.

17:00 to 19:00 - Divers report base plate torn up - pad eye one side torn off. Cone disengaged from base. Divers took movies and unshackled line.

19:00 - Run in - lost 15,000 lbs at 1600 meters. Run in - began to take weight 15 meters in on casing or six meters in on core bit - circulated hole. (Weight of base plate 11,000 lbs and casing 8,750 lbs = 19,750 lbs in water).

Decided to run Edo to verify whether 10 3/4 inch casing still on.

Rig up and run Edo.

Found good reflector.

Positioning vessel and building improved re-entry cone.

June 10, 1970

Recovered Edo.

Pull out of hole.

10:00 - Divers hooked up keel-haul lines. Hook up acoustic release, boom box, and explosive bolt to sand line. Acoustic release transducer held at 45 degree angle. Run in to 2743 meters plus or minus on sand line. Run command hydrophone over side of vessel and attempt to fire bolt. Pull out; bolt had failed to fire. Run bolt to 61 meters plus or minus and fired successfully.

12:30 - Position vessel to determine response at different offsets. Run pattern to determine strength level of beacon. Very good 16 kHz beacon. Move to new location.

Drop new 16 kHz beacon.

Run two new 13.5 kHz beacon on sand line. Take photos.

Continue welding.

June 11, 1970

Run release.

Released at 610 meters failed 914 meters.

07:00 - Rig up and keel-haul baseplate without divers. Make up 3 and 1/2 joint of casing. Mashed X-over with tongs (homemade) lay down joint and weld collar to bottom of casing bowl.

Make up four joints or 48.21 meters of 10 3/4 inch 40.5 lbs new singles K-55 buttress casing. All joints glued. Bottom fitted with Larkin open guide shoe. Top fitted with National latching head. Latching head fitted with modified "J" slot. Lower casing to elevators supported on homemade spider on guide horn. Make up bottom hole assembly with lugs on lowering tool four collars above bit (bit eight meters from shoe).

Latch into "J" slot and tack weld shear bar across "J" to prevent re-entry cone from floating out while running in. Sealing sleeve tack welded in place.

June 12, 1970

Run in to 3048 meters and pick up swivel. Wash in. Casing began to take weight at 932 meters. Circulated with both pumps at 65 spm each. Maximum pressure 500 psi. Wash in to 3078 meters. Would not go deeper. Top casing at 3030 meters with top of re-entry cone at 3026 meters. Took one quarter turn left hand torque with power sub and came out of "J" slot.

Pull to 3032 meters rig up Edo. Followed re-entry cone while running in an PDR. Lost reflection approximately halfway in.

Core barrel was fitted with tungsten carbide (crushed) core bit. Lower bearing support was packed off.

Run Edo and locate descriptive "cross" that was supposed to represent mud cross. Pull to 922 meters and re-enter, unable to see "cross". Pull up and make two unverified re-entries.

Use jet sub - saw considerable motion; used 250 to 450 lbs.

Increased pressure to 1,000 psi and tool failed. Pulled out and found equalizing bladder failed.

June 13, 1970

While working on Edo tool trip drill pipe and installed shear sleeve and jet sub at bit so that we could verify re-entry without trip with Edo tool.

Re-run Edo - tool would stop transmitting when in the water 17 meters.

Pull Edo tool and attempt repairs. Lower seal apparently damaged.

Drilled and tapped several vent holes. Refilled equalizing section with oil. Found several sections with galled joints during disassembly. Dressed joints in machine shop.

June 14, 1970

03:00 - Run Edo. Tool operating successfully.

06:00 - On bottom with tool. Unable to find re-entry cone. Approximately two hours searching. Locate re-entry cone. Attempt to position vessel for re-entry.

At 19:53 re-enter cone on second try and shear pins with 30,000 lbs plus or minus. Very easy.

Pull Edo tool and lay down tool.

Run to bottom at 3078 meters and circulate hole clean. Drop core barrel and take 14 meter core.

Core No. 1, Site 110, 3083 to 3092 meters (nine meters) recovered nine meters. Run Baker shifting tool. Attempt to shift sleeve on jet sub. Tool became stuck on sleeve. Moved up hole nine meters.

Attempt to part line with 22,000 lbs. Cut line and pull out. Found tool stuck in jet sub with sleeve closed.

Noon - Underway.

s/ Mr. K. E. Brunot
t/ Mr. K. E. Brunot
Project Manager
Deep Sea Drilling Project

APPENDIX NO. 4(a)

RECOMMENDATIONS TO POSITIONING AND RE-ENTRY EQUIPMENT

1. It is my opinion, as I am sure that it was the original "intent" on planning re-entry, that the procedure would be as follows:

   a. The vessel would be positioned by the dynamic positioning within 50 feet of the sonar reflector target.

   b. We would then "jet" (first to see the direction of jet required).

   c. We would rotate pipe to orient the jet action in the direction desired to close the target.

   d. Using the remote display oscilloscope on the rig floor, the driller would jet to a position over re-entry cone.

   e. When the end of the string was in place we would lower away into the guide cone and accomplish re-entry.

2. Due to the fact that our "jet" capability was not functioning at the time of our re-entry trials, I endeavored to "spud in" using only the motion of the vessel 10,000 feet above the bottom hole assembly to accomplish re-entry. This method of operation proved extremely time consuming and with our present capabilities would only be recommended in emergencies.

3. The "fact" that this "can" be done has been proven.

4. In order to "minimize" the amount of jetting required, and for use in the event of a "jetting capability failure" I would recommend that the following modifications to our existing positioning and sonar scanning equipment be looked into bearing in mind engineering involved and financial feasibility.

   a. Modify the sonar scanning oscilloscope to present a "relative display" (i.e. relative to the ship's heading).

   b. Program, if possible, the bridge control console of the positioning system to include "smaller increments" of the offset capability as a "bias" control on the console. It might be suggested that the same "control" be accomplished using the "depth" control at present on the console. I do not concur, in that I can move only in two directions with this control (not then, necessarily the desired directions) whereby the "bias" control of smaller "increments" will allow me to move in any combination of eight cardinal and inter-cardinal points of the compass.

c. Install on the re-entry cone a magnetic or electronic "sensor" to assure that "positive" re-entry has been accomplished.

d. For items pertinent to modifications of re-entry cone, future use of same and procedures for keel-hauling, please refer to Mr. Blurton and Mr. Rayborn's report.

s/ Captain J. Clarke
t/ Captain J. Clarke
Master, Glomar Challenger

RECOMMENDED PROCEDURE FOR MANEUVERING WITH PRESENT EQUIPMENT

1. In Automatic mode search out and approach target within nearest 100 feet by offsets.

2. Weather permitting, place vessel on a cardinal heading (since offsets are true). This lines up compass to points with X and Y axis of the vessel.

3. Endeavor to close the target to 20 feet by the below listed methods:

   a. Alter depth reading on control console

   b. Alter offsets by one-half (this can be done by demanding a 100 foot offset and altering this offset when the move is half accomplished.

4. Now lower sonar scanner and pipe to within one meter of the top of acoustic reflector on guide cone (depending upon weather conditions and vertical displacement).

5. Normal movement of the vessel will bring string over target, if not try small changes in heading.

6. With present 45 degree down scanner presentation on oscilloscope, the target makes a definite pattern, quite contrary to that expected, as explained below and shown in accompanying photograph.

7. Thought has been given by the writer to making the last 20 to 30 foot move by changing to a semi-automatic mode of operation. This was not done for the following reasons:

   a. With Sea State 5, 20 to 28 mile an hour winds, and on a heading one point from the wind, the vessel requires a very steady thrust to keep it within the 40-foot circle on the beacon display oscilloscope in an "automatic" mode of operation.

   b. By changing to semi-automatic, the computer immediately bases its memory for this required thrust and holds "heading" only.

   c. The display on the sonar scanning oscilloscope does not present true or relative azimuth and, therefore, the required thrust direction is not known.

   d. Thus the operator must concentrate on the sonar scanning oscilloscope to make a movement both fore and aft and athwartship by use of the speed adjust thumb wheels. If the move is in the wrong direction, the vessel will rapidly fall off position. The vessel must then be brought back to equilibrium (in a semi-automatic mode) and the procedure tried again.

e. If we are able to "stab" the cone in this mode, then the vessel must be held well within the 40-foot circle while the sonar probe is pulled (approximately one and one-half hours), the tool joint pulled to within one meter below the apex of the cone and a connection made before "lowering away" to a safe depth. (All the above in a semi-automatic mode.)

f. Only then will it be "safe" to change to an "automatic" mode and let the vessel "yaw" while the computer builds up its memory.

g. In the future the string will be "made up" to allow deeper penetration on the first stab. Then, wind and weather conditions permitting, I will attempt stabbing in semi-automatic.

h. In my opionion, the use of a "manual mode" is not feasible as we then would not even have the "heading" control afforded by semi-automatic; and since "heading" is the only hint of an "azimuth" the re-entry procedure would be made even more difficult.

s/ Captain J. Clarke
t/ Captain J. Clarke
Master, Glomar Challenger

EXPLANATION OF PRESENTATION ON OSCILLOSCOPE OF RE-ENTRY CONE

1. Cone at 30 feet shows three distinct targets (however, not to scale).

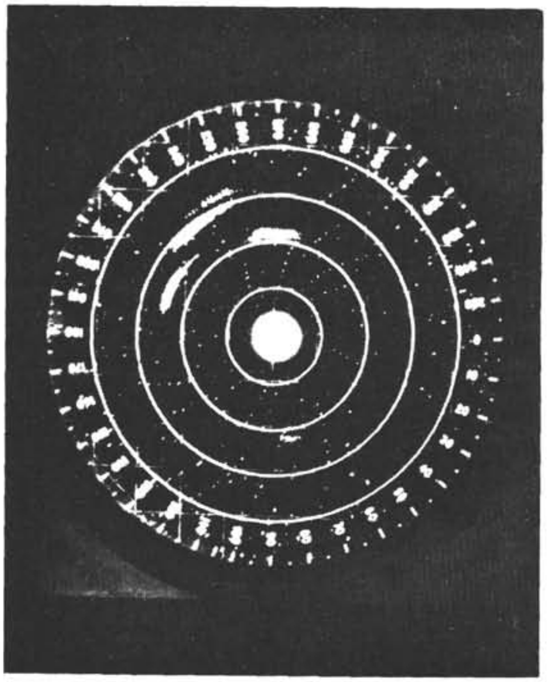
2. Upon closer approach to the target, the cone now begins to appear as a "triangle" (again not to scale).

3. As the string nears the center of the cone there appears a complete "circle" of targets on "all"sides. This is the point to drop the bottom hole assembly as rapidly as possible, leaving the sonar scanner on the Schlumberger line well up in the casing.

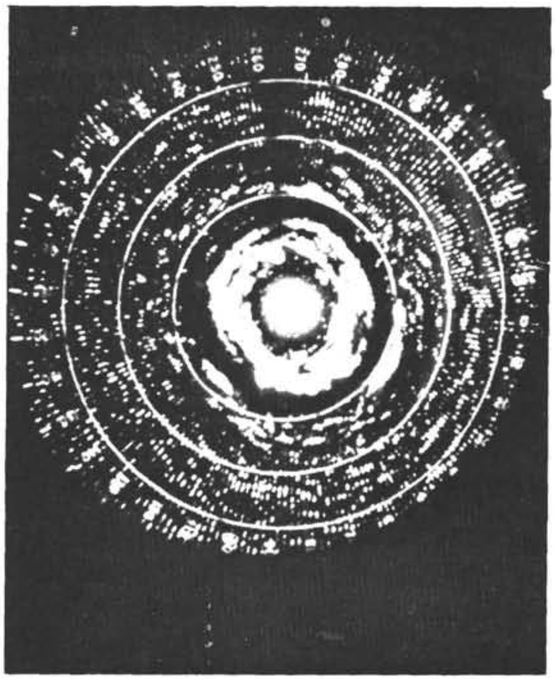
4. If attempted re-entry fails (and from time to time it will) pull up to one meter above sonar reflectors and re-seat sonar scanner to repeat procedure.

5. "Timing" is extremely important and I feel that with practice our percentage of "hits" will rapidly increase.

Direction of Ship's movement.



Approaching position to stab.



At position to stab.

s/ Captain J. Clarke
t/ Captain J. Clarke
Master, Glomar Challenger

NOTES ON VESSEL'S SUCCESSFUL RE-ENTRY OF JUNE 14, 1970

1. The following conditions existed at the time of attempt at re-entry:

   a. The sonar reflector re-entry cone had been on the bottom since 00:30 June 12, 1970.

   b. During this time the sea state had increased from one to five, the winds from "airs" to 28 mph.

   c. The drill string had to be "round tripped."

   d. The heading had been changed 180 degrees.

2. Sonar scanning for the target commenced at 05:30 hours.

3. At 06:08, the Schlumberger line was raised to 3014 meters.

4. At 06:20, offsets of 100' North and 100' East were introduced.

5. At 06:25, additional offsets of 100' North and 100' East were introduced.

6. Target was detected at 06:27, bearing 270 degress relative, range 300 feet.

7. At 06:30, additional offsets of 100' North and 100' East were introduced.

8. Total offsets of 400' North and 300' East were introduced at time of sighting.

9. From 06:50 to 13:16 and with intermittent loss of acoustics due to weather conditions, we used various offsets to approach target.

10. It is interesting to note that we now require 400' North and 100' East offsets to reposition the ship over the sonar reflector cone which 48 hours previously required no offsets (this no doubt due to 180 degree heading change and increase in wind and sea state.

11. With offsets of 400' North and 100' East at 13:20, a re-entry attempt was made. Target missed by approximately ten feet.

12. At 13:55, vessel passed directly over target and observations for "presentation" were made. (No attempt at re-entry made at this time.)

13. At 14:10, we again passed over or very close to target.

14. During above observations of the sonar scanning oscilloscope from 06:50 to 14:00, several direct 180 degree changes in azimuth were apparent and many minor changes in azimuth (by maneuvering board plot).

15. From 14:10 to 18:06 many combinations of offsets and course changes (as much as weather conditions would permit) were made, all from apparent movement required by maneuvering board plot. (These moves were impaired by the apparent change of azimuth in the presentation on the sonar scanning oscilloscope.)

16. At 18:48, depth settings were altered in an attempt to close target.

17. At 19:10, a final depth setting of 11,000 feet was introduced.

18. At 19:26, it was decided by myself to return to original settings of 400' North and 100' East, which placed us so close to target at 14:00 , as time was running short.

19. At 19:30, it was decided by all concerned and concured in by myself to try positioning in automatic for four hours, then semi-auto for four hours, then attempt jetting if all else failed.

20. At 19:30, we passed directly over target and re-entry attempt was made. My timing was late in informing the drill floor to "slack away." (It is apparent that this takes practice.) We again missed target by approximately ten feet.

21. At 19:54, we re-entered and sheared shear pins (timing was perfect this time and a lot of "luck" was involved).

22. Vessel held well in automatic mode while sonar probe was pulled and connection was made to commence coring.

s/ Captain J. Clarke
t/ Captain J. Clarke
Master, Glomar Challenger

APPENDIX NO. 4(b)

During the initial 18-month drilling program, coring in the young soft sediment has proven to be exceptionally rewarding, but within the older sediments penetration and recovery has been thwarted by the presence of widespread hard chert (flint) layers. Consequently, our knowledge of the early history of the ocean basin remains fragmentary. With a re-entry system, such as successfully tested by the Glomar Challenger, worn-out drill bits can be replaced and drilling continued until the layer is penetrated. Such a capability will enable the vessel to fully explore the older history of the entire Western Pacific, the eastern and western margins of the Atlantic and Indian Oceans as well as the smaller seas such as the Mediterranean, Caribbean and Coral Seas.

The re-entry system also provides the Glomar Challenger with the capability of placing long-term instrument packages at the bottom of the hole on completion of drilling. Downhole packages that have been considered in this context include seismographs, magnetometers and pressure sensors.

Recommendations for use and modification:

1. Some method to displace the ship's position, while retaining the essential elements of the fully automatic mode, from the 100 foot grid developed by the offset capability that now exists. Smaller increments, ideally of the order of one-tenth that which now exists in the offset capability, or a continually variable bias that could be optionally added to the computer commands for propulsion, would work very well.

2. Produce a relative azimuth presentation on the bridge, of the PPI display. This would ideally require known orientation of the transducer azimuth to the jet azimuth and also to the ship. Magnetic orientation from bottom sounds most simple way. Known azimuth is essential and can now be achieved experimentally, but requires time. It is absolutely essential that the azimuth not change, unpredictably; this requires firmly seating the transducer package at the bottom of the drill string.

3. Downward looking sonar. Would establish height of bit from bottom and locate edge of re-entry cone instantaneously.

4. Improve structural strength of re-entry funnel.

5. Design to allow jetting. It is anticipated that even movements of as little as ten feet would be an appreciable help.

6. Ability to mechanically turn drill string a small and controlled amount, for setting azimuth to produce relative azimuth presentation on bridge and for jetting. Perhaps a goniometer circle around the drill string and a brake in the power swivel would work.

/81

7. Sensing system to establish carefully relative heights of top of re-entry cone and termination of drill string. Clearance at top of cone of two meters appears good for search and approach, clearing edge by one meter on final closure before stabbing seems desirable, if weather permits. This requires precise knowledge of relative heights at bottom. The same sensor could be used to verify re-entry. Proximity switch in Edo instrument package with magnetic activator in base of cone may be most simple way; signal to surface would be to switch off Edo signal briefly.

8. Some method to introduce re-entry cone and short casing after drilling without providing for re-entry initially would be good long range improvement. Possible slide assembly down drill string using funnel as parachute, having keel-hauled but not lowered unit initially, might work.

9. Recommended inventory of underwater transmitter-receiver units for standard operations would be two completely assembled units and one more not assembled, but available or to be cannibalized for module replacement, plus assorted spares.

10. Detailed reviews of documentation of ship's motion, ship's response to commands of varying relationship to cardinal points, drill string motion and response to ship's motion, lag times etc., appearance of target, weather conditions.

s/ Dr. M.N.A. Peterson
t/ Dr. M.N.A. Peterson
Chief Scientist
Deep Sea Drilling Project

s/ Dr. N. T. Edgar
t/ Dr. N. T. Edgar
Coordinating Staff Geologist
Deep Sea Drilling Project

APPENDIX NO. 4(c)

GENERAL

The Edo Western scanning sonar system in general met the anticipated requirements and performed within the design specification with the possible exception of the mechanical strength of the diaphram cover plates.

The diaphram cover plates support the total weight of the motor section of scanning sonar and these plates were mounted with only six stainless steel screws each. This configuration seems to be inadequate in light of the handling it will probably see. A possible solution is to make the cover plates into a tube assembly and fasten with some kind of ring clamp, such as a Marman clamp.

Several system deficiencies which were not within the original design goals were also noted. The most important of these being that the underwater scanning sonar has no reference to true bearing, which complicates the use of ship's positioning in the re-entry process. Also of major concern is the re-entry cone display signature which, while it is not fully understood, does not appear as three distinct targets centered on the display, but appears as multi-targets centered on the display at un-real distances. Also increase display persistance.

HARDWARE

Suggest hardware changes or rework:

1. General clean-up of electronics.
2. Tear-down of motor selection for inspection and repair of salt water damage.
3. Re-design diaphram covers for better mechanical strength.
4. Add true bearing reference.
5. Restore azimuth sync capability on control unit.
6. Install high persistence oscilloscope tubes in both displays. Black-out hoods should be provided at display installation locations.

OPERATING PROCEDURE

Use ship's position system to move within 100 feet, then use water jetting for final maneuvering and re-entry. Coarse maneuvering should be controlled by the bridge by persons familiar with the ship's positioning system. The fine maneuvering and re-entry should be controlled by the drill rig tool-pusher from the drill rig floor. If other displays are required to better define "over the cone position", thought should be given to putting it on the drill floor also.

HANDLING PROCEDURES

Electronic instruments, no matter how well packaged, should still be treated with care. Some type of fixture could be built to aid insertion of the underwater unit into the drill pipe on the drill floor, but supervision and some degree of caution should be exercised.

STAND BY EQUIPMENT

The test equipment now available on the Glomar Challenger is more than adequate.

PERSONNEL TRAINING

Personnel training should consist of a two-level approach, which are:

1. Maintenance and trouble-shooting aided by manuals, schematics and possibly special instructions.

2. Operational - enough training and experience to operate controls and identify target signatures. These people could be trained by the maintenance personnel.

SPARE PARTS

The spare parts already obtained should be supplemented with one or two spare underwater transmitter-receivers, since the underwater unit has to operate in an environment where retrieval is somewhat uncertain. Also some spare printed cards might be useful to minimize downtime of any of the underwater packages.

s/ G. J. Behunin
t/ G. J. Behunin
Edo Western

EFFECTS OF SHIP'S MOTION

Ship's motion resulting from automatic dynamic positioning appears to describe a figure-eight with the maximum motion occurring athwartships. This characteristic motion is determined by the thrust to resistance-to-motion ratio (control authority) in the ship's horizontal axes. The control authority is much greater in the fore-aft (X) axis than in the athwartships (Y) axis. Therefore, the fore-aft deviation from desired position is generally held to much smaller amplitudes than the athwartships position error.

Offsets were commanded into the dynamic positioning computer to perturb the bottom of the pipe string. It was hoped that the resulting motion could be used to establish an azimuth for the sonar unit. Generally, the motion of the drill string versus time was not in a straight line. The vessel tends to react to a command along its fore-aft axis first, and the drill string reacts to this motion. The athwartships motion follows somewhat later.

In a relatively calm sea, little or no offset was required to position the pipe string near the re-entry cone. Ship's position was generally held to within a forty-foot radius of the beacon. Relatively slow motions about the beacon occurred, and the pipe string excursions remained within about 30 feet for periods of an hour or more. Under these favorable conditions, the motion of the pipe string follows the motion of the vessel with approximately a two to three minute lag. The pipe string motion approximates the motion of a damped pendulum. Little overshoot was observed, and pipe string motion seemed to stabilize within 20 to 30 minutes after an offset command.

In the Sea State 5 seas encountered at Site 110, offsets of 400 feet North and 100 feet East were required to position the pipe string near the cone. Under these conditions, motion of the pipe was much less predictable. Much larger overshoot was observed, and settling time was considerably increased. At times a figure-eight pattern seemed to predominate, probably resulting from the controlled motion of the vessel coupled through the drill string.

Ship's roll angles of plus or minus three degrees and pitch angles of plus or minus two degrees were observed during the re-entry trials. These disturbances occur at a relatively high frequency when compared to the frequency-pass band of the drill string, and the effect of these disturbances should be greatly attenuated by 10,000 feet of pipe. Therefore, these disturbances will have little effect on pipe bottom motion.

Pipe velocities exceeding one ft/sec were observed during the trials. These velocities generally occurred near the crossover of the figure eight patterns. Attempts to re-enter the cone during such transients should be avoided, if possible, to minimize the risk of damage to the sonar unit, the pipe, and the re-entry cone.

Rotation of the drill string will be necessary in later re-entry tests to reorient the thrust vector of the jet sub in the desired direction. This was accomplished easily with no measurable time lag or observed oscillation of the bottom of the drill pipe.

RECOMMENDATIONS FOR FUTURE RE-ENTRY TRIALS

1. The sonar unit must be equipped with an azimuth reference relative to ship's head. This may take the form of a true azimuth reference with provisions to align this with cardinal points obtained from the ship's gyrocompass.

2. The pipe should be brought as close as possible to the cone using the ship's automatic dynamic positioning. The terminal phase of homing should be performed using jetting at the bottom of the drill string. Therefore, provisions must be made to seal the sonar unit from the water pressure used for jetting to avoid a large pressure differential across the sonar unit. A water jet with several thousand pounds thrust may be necessary for positioning in heavy currents. Experiments to determine the size of the jet sub required should be conducted as soon as possible.

3. The ship's dynamic positioning computer should be re-programmed to provide offset increments smaller than 100 feet. The offset increments should be reduced to ten feet, if possible. It is recognized that this may exceed the memory capabilities of the computer.

4. A bottom-scanning sonar unit should be considered as an addition to the downhole unit. Presently, the cone cannot be seen when the sonar unit is one or two meters directly above it. Addition of the bottom scanning unit would provide position information in the critical seconds just before re-entry.

s/ James I. Maher
t/ James I. Maher
Global Marine Inc.

APPENDIX No. 4(e)

EDO WESTERN SONAR SCANNING RE-ENTRY EQUIPMENT

Following is a list of recommendations on operating procedures and proposed modifications.

1. Operating Procedures:

   a. Initially, ship has been positioning over beacon, cone is then lowered to the ocean floor and spudded in. At this time pipe should be pulled clear of cone and Edo gear should be lowered and offsets should be computed before any drilling is accomplished. After offsets have been computed, the initial drilling and coring can be done. Afterwards, in event of bit replacement or other failures requiring pulling of drill string, a reference has already been established.

   b. Before any re-entry is attempted, offsets should be established. Ship's positioning should be settled out where ship is positioning within plus or minus 40 foot. (Desired heading etc. has been chosen.)

      At this point (if using only the ship to guide drill string for re-entry) it would seem more feasible to position ship in semi-auto to accomplish re-entry.

      However, if jet sub is being employed, ship should be settled out in auto to position with plus or minus 40 feet and then jet sub could be employed.

2. Modifications:

   a. Believe that downhole assembly should incorporate a unit to make it possible to read out actual bearings (preferably relative bearings) to the target.

   b. Believe a three-position transducer should be employed vice a two-position. (Present one has an eight degree down and 45 degree down.) Propose eight degree down, 45 degree down and 90 degree down.

   c. On the downhole assembly: eliminate expansion boot and a watertight assembly be made. Otherwise, without this modification use of jet sub for any effect is virtually impossible.

d. Believe that sector scan could be eliminated and rotation time on 500 foot scale should be increased to sweep around faster. (Sector scan is only useful at 500 foot and 250 foot scales, providing there is no azimuth drift, which is non-existant.)

e. Display transmission to rig floor remote display with our present wiring is inadequate (rig floor display is not receiving the display as being received on the bridge).

s/Ken Barrett
t/Ken Barrett
Global Marine Inc.

s/Carl Wells
t/Carl Wells
Global Marine Inc.

APPENDIX NO. 4(f)

EQUIPMENT ITEMS, RE-ENTRY SYSTEM

1. Guide Base Center Ring - (National)

   No modification needed, operation good.

2. Casing Hanger - (National)

   a. Outside latch ring design satisfactory for re-entry program.

   b. Inside shear pin design not operational. Loads applied to shear pins not connected with total weights of drilling assembly and casing. Design should be controlled lock to prevent movement up or down between handling sub and casing hanger during desent to ocean floor. Release could be rotation to the right with load applied up or down. Second method could be internal release with wireline. Third method, free drop down drill pipe to ocean floor.

3. Drilling Sleeve - (National)

   a. Could be removed with new design but would call for extra trip to remove larger handling sub out of drilling assembly.

4. Handling Sub - (National)

   a. Shear pins not operational.

   b. See Section B on Item 2, Casing Hanger.

5. Bore Plugger - (Baker)

   a. Not operational body outside diameter to large for inside diameter of scaled drill pipe. Do not need index sub or collet index on bore plugger tool.

   b. Re-design of this tool could be incorporated in top assembly of Edo tool.

6. Jet Sub with Index Sub - (Baker)

   a. Bottom index in jet sub should be re-cut to fit new index dogs in shifting tool.

b. Design should be gone through with Baker representative, Ray Dean, Houston Plant, to find out why tool hung up in index sub after closing of sleeve.

c. For operation on lowering of casing jet sub can go down with drilling assembly in the open position.

d. With bore plugger or pack off designed in top section of Edo unit, jet sub should decrease time for re-entry into cone base.

7. Hex Re-entry Base (Global Marine design)

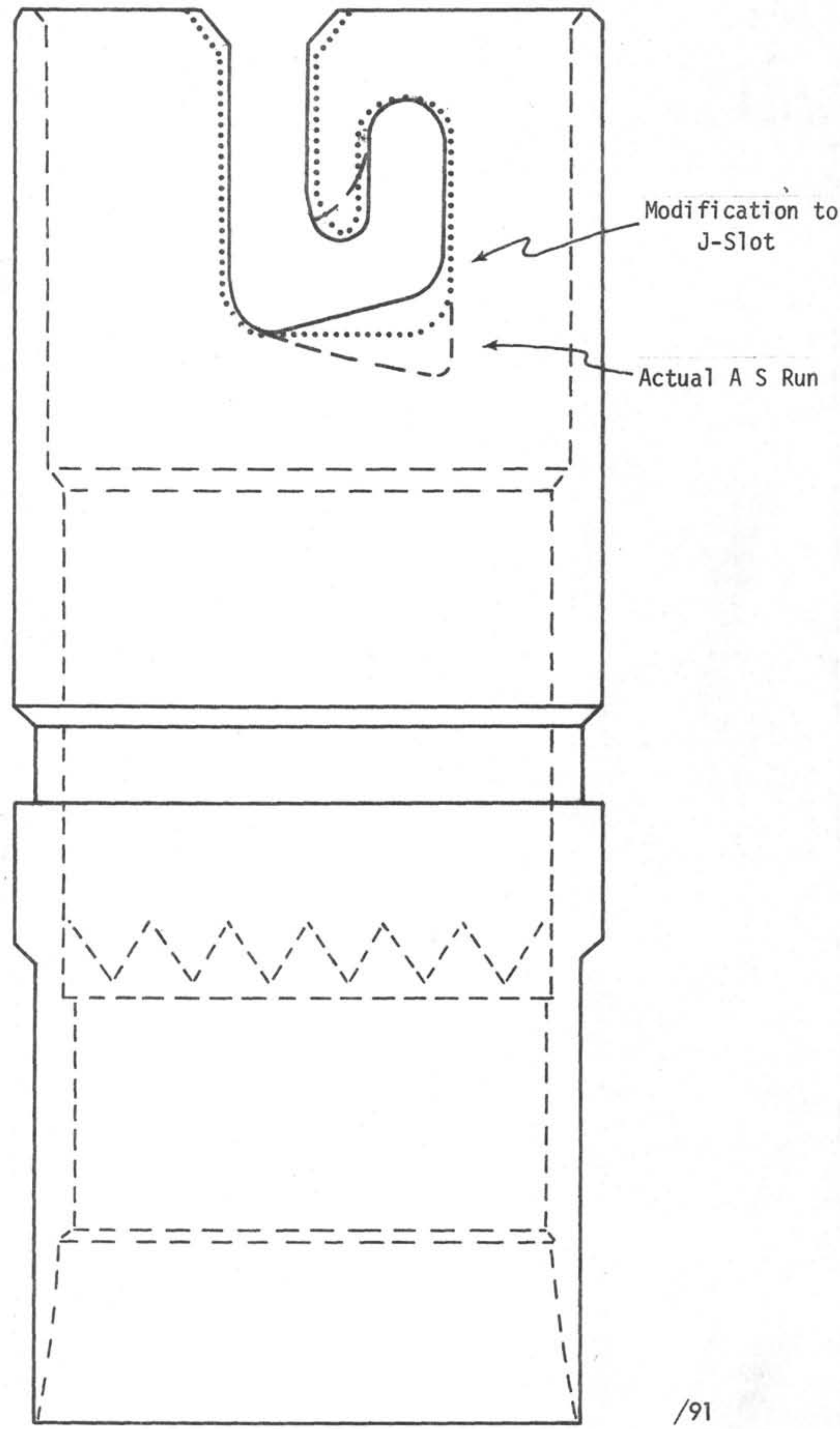
a. Construction design not heavy enough to carry loads applied by casing and drilling assembly in hanging position under ship. Pad eye loads applied on Unit No. 1 not a fair test due to location of pad eyes on base and location of holes in drill well in relation to location of pad eyes on box beams under rig floor.

b. Second unit constructed the same as the first, but gussets and cross members were added to strengthen cross section of base. All bolted sections were chain welded or welded completely. Fall away pad eye were also added four feet down from top edge of cone on 11 foot centers. These pad eyes were tied into bottom base by a diagonal brace. See attached drawings for modifications.

s/ Leon Blurton
t/ Leon Blurton
Global Marine Inc.

s/ Travis Rayborn
t/ Travis Rayborn
Global Marine Inc.

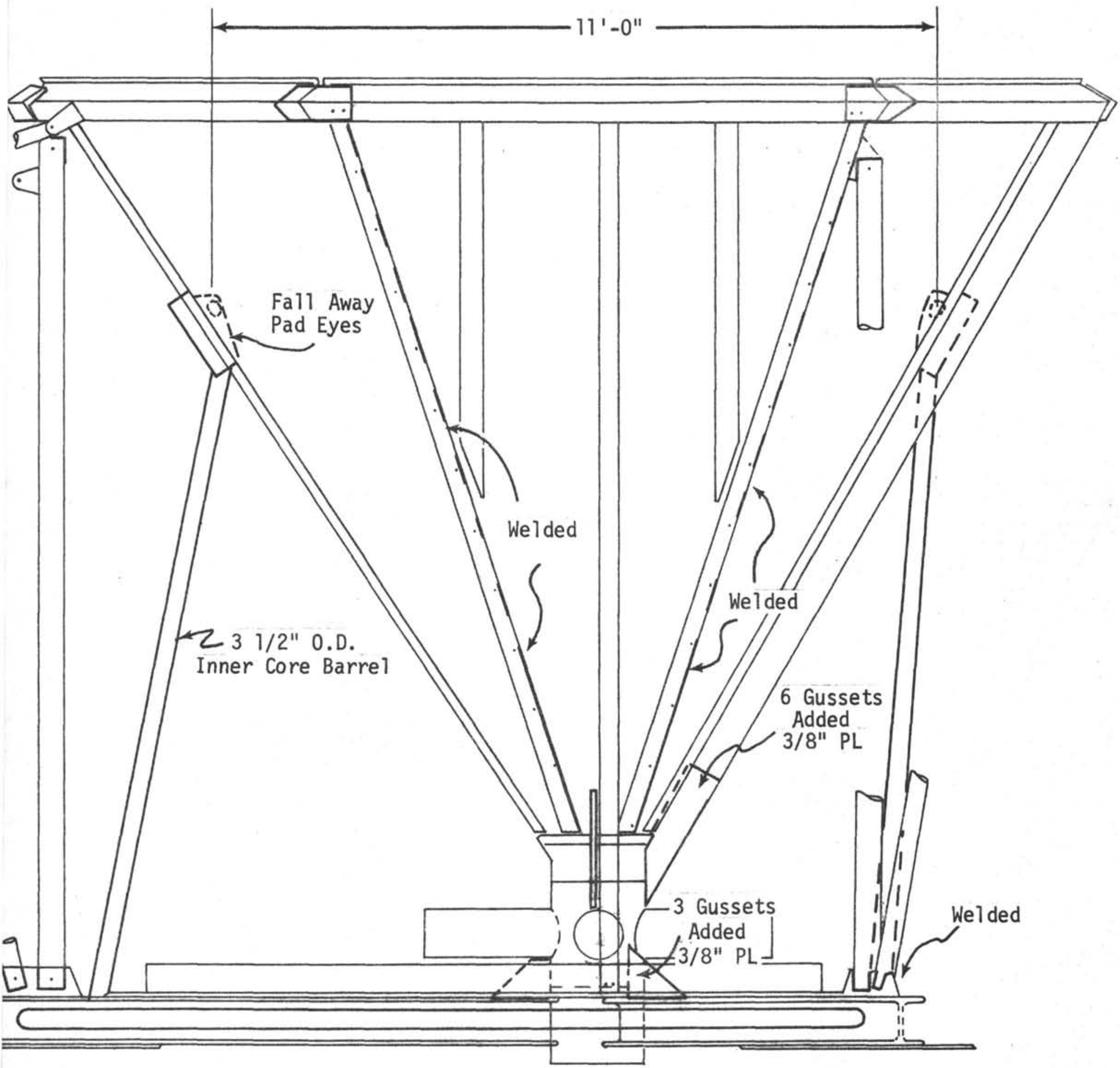
RE-ENTRY SYSTEM



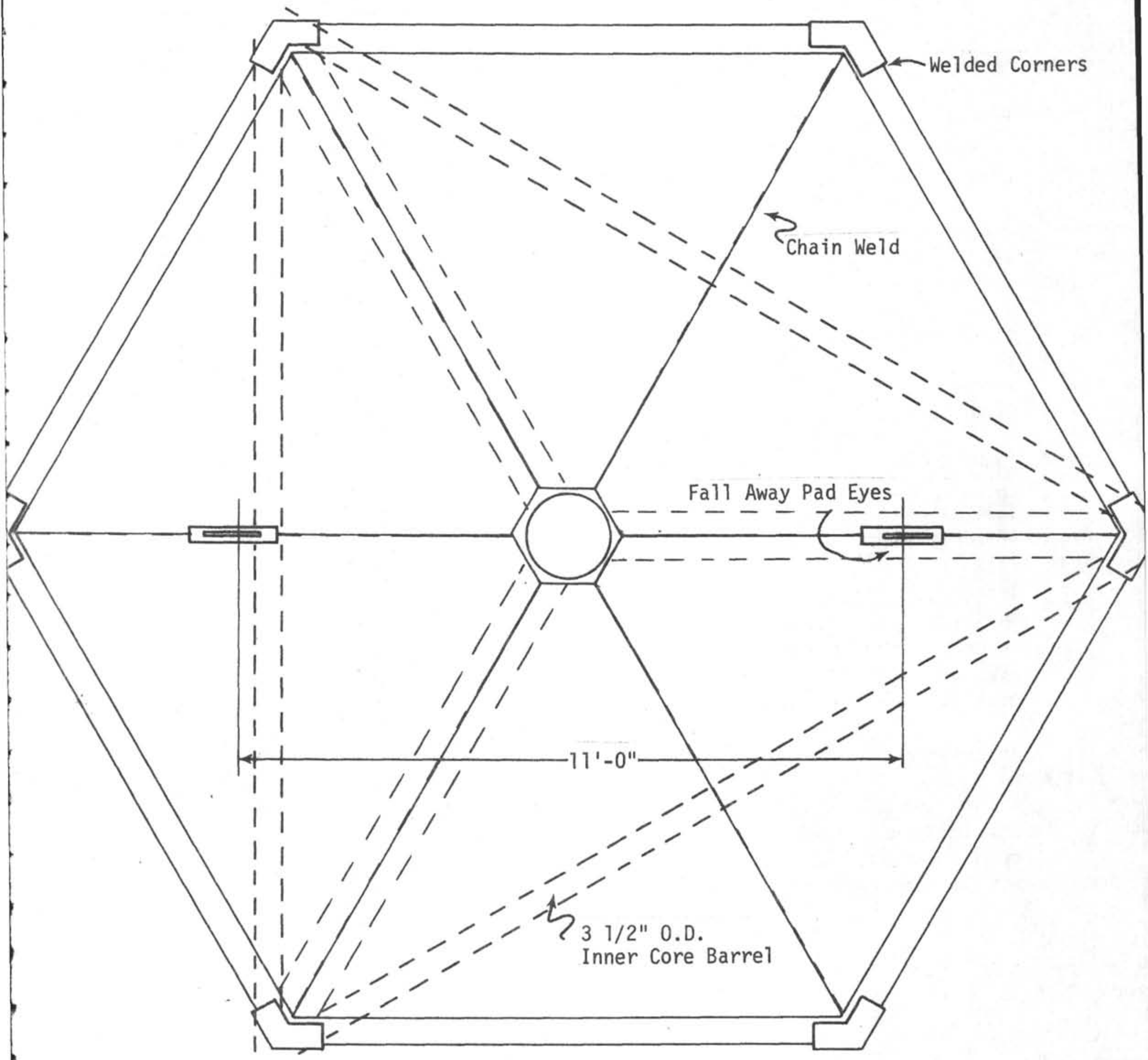
Added holding lugs under J-slot pins on handling sub after locking in J-slot in casing hanger.

Spot welded drilling sleeve to casing hanger to prevent movement.

Also cut-out drilling sleeve to match J-slot in casing hanger.



MODIFICATIONS TO RE-ENTRY BASE



MODIFICATION TO EXISTING RE-ENTRY BASE

APPENDIX NO. 4(g)

COMMENTS ON RE-ENTRY 14 JUNE 1970

The Edo sonar tool was run at about 05:30 on the 14th with drill string still latched to re-entry cone. The first operation consisted of taking pictures of the obvious four-leg pattern on the scope believed to be caused by mud vents on the re-entry cone. Next the drill string was raised to obtain a scope signature of the top of re-entry cone which was shown very clearly. Then the pipe was pulled clear of the cone and re-entry was begun in earnest.

Approximately 14 hours later re-entry was accomplished. The interim period was consumed attempting to move the vessel using offsets (increments of 100 feet). By plotting the relative bearing and range to the cone, a picture of the movement at the drill bit was obtained. Also tried was varying the depth setting on the positioning console and heading changes.

Conclusions:

In the automatic mode of operation, a plot of the bits movements must be kept to determine the effect of the offsets. This will enable the operator to visualize the movement of the pipe in relation to the re-entry cone. The general mode of operation should be to locate the target, close it as closely as possible, establish the pattern of swing of the drill bit, adjust pattern to pass over the cone (offsets, heading change or depth variations) and when ready lower the drill string. However, since pipe movement is relatively rapid, the time to lower the pipe must be anticipated and this action initiated early.

Suggestions:

Modify re-entry tool so that jet on drill string may be used. Then when pipe and cone are close, the jet may be used to position bit over the cone. This should speed up the operation considerably. The balance is simply training operators, which will come with practice.

s/ D. N. Smith
t/ D. N. Smith
Global Marine Inc.

APPENDIX NO. 4(h)

OBSERVATIONS AND COMMENTS ON DSDP WORK CONDUCTED JUNE 8 to 15

By Subject Classification:

Ship - Glomar Challenger: Well suited and rigged for the work - plenty of adequate gear and well staffed. Food and accommodations were outstandingly excellent.

Personnel: All aboard appeared competent and well qualified for their respective assignments. Everyone seemed knowledgeable and enthused about the common purpose of the voyage. The amicability of this somewhat confined group is noteworthy. Decisions and instructions were handled tactfully, and personnel appeared very agreeable. The drilling crews are probably the best I've seen.

Planning: In view of the extremely high cost of operation at sea, I would visualize the following as being the minimum for this subject:

1. Responsbile personnel would hold meetings well in advance of the voyage to prepare detailed mechanical programs and equipment lists and consider various alternates to these programs depending upon possible unexpected operational results.

2. To the greatest extent possible, all equipment would be fabricated and checked out on the beach.

3. Strong consideration would be given to backup equipment.

4. Meetings of concerned personnel in authority would be held as necessary during operations whenever previously established plans are altered.

   Some examples of deviation from the above which I believe "hurt" us are:

   a. Shear pin failure during running of the first cone base.

   b. Jay-slot modification at sea.

   c. Pulling out of cone during second re-entry operation without first jaying in and taking a strain on the pipe to obtain proof positive that re-entry had been attained.

Responsibility and Authority: Did not appear to be clearly delegated and known - as in the case with most offshore operations I have observed.

Ship's Positioning System: Did an excellent job, however, it should be convertable to semi-automatic or manual mode without loss of memory.

Re-entry Equipment: Performed very well for first trial (Edo). Mechanical equipment should be redesigned and thoroughly tested on the beach prior to the next attempt. Backup equipment should be preassembled. Some considerations for future operations are:

1. Use transmitters or transponders on the cone instead of reflectors to provide easier, more positive target identification.

2. Incorporate azimuth capabilities.

3. At a given location, three separate bottoms are observed as follows: Driller's , Edo's, PDR's. Care must be taken to insure the cone base reflectors are always set above Edo's bottom.

4. It may be found that manually controlling the ship's position is more reliable and expedient for re-entry. I would be interested in the results of any experimentation of this sort.

5. It would help if Edo could scan faster.

6. Edo should be made to disassemble faster for trouble shooting - possibly a spare tool could be kept on board.

7. Possibly, Edo output could be interfaced with "Elmer" to control ship's position automatically.

8. It will eventually be necessary to have a positive means of knowing re-entry has been accomplished without pulling out of the hole (other than drilled depth check). Under present system, if the hole sloughed in while making a bit change, we might not think we were back in the hole after a successful re-entry. Valuable time would be lost attempting to re-stab. Possibly the Edo tool could be adapted so that the reflectors could be observed above the tool after re-entry is accomplished.

9. I'm quite sure the scientists are interested in seeing the "surface" layers of the ocean floor. Therefore, it would be desirable to find a means of "coring in" the conductor rather than jetting it in.

Observer, Major Oil Company

APPENDIX NO. 4(i)

OBSERVATIONS AND COMMENTS ON DSDP WORK CONDUCTED JUNE 8 to 15

It has been an honor and a pleasure to witness the successful re-entry tests conducted on the Glomar Challenger. Certainly, a practical and economical re-entry concept has been demonstrated.

In addition to proving that the re-entry system is workable, the tests also point to a few minor improvements that promise to make future re-entry routine.

Equipment improvements that seem justified at this time are:

1. Modify the packoff around the Edo tool to permit jetting.

2. Provide for mechanical alignment of the Edo tool so that it can be set to sector scan a quadrant that is opposite the jet. Once the target is picked up on the Edo scope it can be placed in the reference sector by turning the drill pipe. With the tool scanning the reference sector, the bit can be jetted to the target. Steering of the bit can be accomplished by turning the drill pipe through small angles.

It may be advisable to provide a means of surveying the subsurface aligning device so that the scanning coordinates of the Edo scope can be referenced to the heading of the ship or to a compass heading. Available single shot surveying instruments can be adapted for this purpose. A non-magnetic collar can be employed or the survey instrument could be allowed to project through the bit.

Jetting and guidance can best be controlled from the rig floor since stabbing must be coordinated with these operations.

Observer, Major Oil Company

APPENDIX NO. 4(j)

Concerning the re-entry mission of this present leg of the Glomar Challenger, I would like to express my views of, first, the personnel relationships and, then, the technical aspect.

It appeared to me that there is a helpful working coordination among the ship's crew, rig's crew, and the scientific personnel. There seems to be an openness to exchange ideas among all the persons I came in contact with. I appreciated the briefing we "observers" had when we first got on board last Tuesday, June 9, via USS Fort Mandan. Your telling us of your technical progress along with the Challenger's accommodations was most helpful. However, I feel that not being told about the hard hat area or where your extra hard hats were stored was an oversight.

Also, since operations go on a 24-hour basis, it would have been more informative (not only to me but to all involved) to have a scheduled announced meeting from time to time in order to tell what has been done, what is being done, and what should be done. There was, of course, no problem in talking with any one person, if they weren't busy, but I think a "round table" discussion helps fill in the gaps.

As far as the technical aspect of re-entry is concerned, it was a great success. The important milestones were:

1. Getting the base funnel on the ocean floor.
2. Relocating the funnel's targets with Edo after re-running the pulled drill string.
3. The ship's motion is a figure eight.
4. The drill bit at 10,000 feet responds to the ship's motion some two to four minutes later in a highly over-dampened manner.
5. The drill bit responds immediately to rotation.
6. After 13 1/2 hours of learning 2 through 4, re-entry was accomplished by ship's displacement.

I am not in a position to know, but after re-entry it seemed to me that we should have tried the jet-sub in place of taking a core sample. As a result, we know very little about the jet-sub operation and have gained in its place even less additional information as far as core samples go.

Future designs needed for re-entry:

1. Edo direction relative to the ship must be know.

2. Mechanical redesign of Edo system to assure reliability when operating the jet-sub.

In conclusion, I consider this a most successful mission and I consider myself most fortunate to have been invited to be on this first re-entry leg.

Observer, Major Oil Company

APPENDIX NO. 4(k)

SUBJECT

Comments on Leg 11 C DSDP

Edo Unit

1. There should be added a crystal that looks straight down for positive location of the sea floor and relative position of the landing base.

2. Positive azimuth control is required. A magnet in the drill collar and a proximity switch in the unit would be a simple and reliable way. Position relative to North is probably too complicated and a simple movement of the ship can establish direction. If the magnet is in line with the jet hole that is also located.

3. A magnet in the landing base casing and a proximity switch would positively establish re-entry.

4. A longer persistance screen is needed.

5. If signals were brought up the line on a carrier (FM or AM), it would be more reliable and more channels would be available.

6. A proper hood for the scopes, a polaroid scope unit, and spare parts should be provided.

"Elmer"

1. The question of whether memory is the best way to control the ship should be addressed by control experts. The present system takes too long to settle down and overshoots its mark. A control system in which thrust is proportional to the distance off target might be a better method. Provision for manual correction for a fixed distance off target could be included.

2. If it is decided the present system should be rétained then provision to retain the memory, if manual maneuvers are made, should be added.

3. I believe the use of a jet-sub is preferable to providing finer increments in Elmer's control system.

4. The beacon should be on the landing base.

5. The beacon might operate in two modes:

   a. Depth-responding to PDR signal

   b. Location-continuous

The present beacon and a sonar transponder would serve the same purpose.

Operations

Since I have not seen normal operations, these comments apply to a special test on new operations such as we observed on 11C. There should be one person clearly in charge of all operations during the testing phase. The nature of the test will determine the appropriate person, in this case, I would have had the project engineer in charge. Planning sessions should be held to get input from the captain, chief scientist, and operations manager, but final decision should rest with the project engineer. He should not make substantial changes in the program without consultation with the others.

An open intercom should connect the drawworks, the bridge and the logging winch for rapid communications during the critical re-entry.

Engine Room

Future designs of the engine room, I think could provide a great deal more flexibility and convenience. For example, all DC generators should be able to be connected to any load, i.e.: the drawworks, the side thrusters, or the main propulsion. This would give the captain more options on ship operations. Generators could be switched from the bridge. Also all meters and signal lights should be visible from the engineers room, if not placed inside it.

The epoxy I mentioned is made by:

Tra-con Inc.
55 North Street
Medford, Massachusetts 02155

They put up many grades with different setting times in plastic bags called Bi-Pax. When required you remove a clamp that keeps the two components apart and knead the bag. It can be squeezed out of the bag for use. This would seem to be an easier and more accurate way of preparing epoxy on the drilling deck when sealing threads.

The effect I mentioned is the "Magnus Effect," and concerns the force developed when rotating a cylinder in a moving fluid. It might have some application to control of the drill string when making re-entry, but the jet-sub is probably simpler and more straight forward.

Observer, Major Oil Company

APPENDIX D

DEEP SEA DRILLING PROJECT

GLOMAR CHALLENGER

TECHNICAL EVALUATION REPORT

ON PHASE I OF RE-ENTRY SYSTEM

REPORT DESCRIPTION AND EVALUATION

I. Operations and Recommendations for Re-entry System

II. Global Marine Incorporated

- A. Re-entry on Glomar Challenger
- B. Glomar Challenger Running Procedure for the Deep Water Re-entry System
- C. Hex Landing Base

  Drawings (3)

III. National Supply Company

- A. Handling Sub
- B. Drilling Sleeve
- C. Casing Hanger
- D. Guide Base Latch Ring

  Drawings (7)

IV. Baker Oil Tool Company

- A. Jet Sub
- B. Bore Plugger

  Drawings (2)

V. Equipment Used - Re-entry System

VI. Review of Re-entry System

Edo Western Drawings (9)

I. OPERATIONS AND RECOMMENDATIONS FOR RE-ENTRY SYSTEM

The re-entry system equipment installation was completed on board the Glomar Challenger on June 5, 1970 in Hoboken, New Jersey. The ship departed Hoboken and arrived at the test location on June 6, 1970.

The purpose of the re-entry test was to evaluate the existing and proposed system. Equipment for the system had been designed and fabricated by National Supply, Edo Western, Baker Oil Tool Company, and S & R Tool Company.

The re-entry system, if successful, would allow a deeper penetration through cherty and other hard formations. The single bit application has in the past prevented coring into the harder formations. With the capability of more than one bit per core hole these formations could be penetrated.

The system consists of oil field proven well head casing equipment, with modifications for deep water application. The Latch Ring and Casing Hanger did perform satisfactory and with no further modifications can continue to be operational in the system.

The running tools which consist of a handling sub and drilling sleeve to lower the casing and re-entry cone to the ocean floor did not perform as designed. These tools need further engineering study to provide the correct tool for this application. A mechanical release or wireline packer type system is now being studied by National Supply Engineering. Also, further investigation into acoustic signal with explosive bolt release.

The re-entry system tools provided by Baker Oil Tool consisted of the jet sub with shifting tool and bore plugging tool. The bore plugging tool design was unsatisfactory, due to the machine surface necessary to seat this tool, which will not exist in normal drill strings. A new concept is now being proposed to Baker Tool Company, engineers which will be a cup type pack off. This tool will also have a rotation index and pressure release. The rotation index will reference a zero point for the Edo tool and jet sub outlet. This pack off tool will become a part of the top portion of Edo tool.

The shifting tool for the jet sub which opens and closes the sliding sleeve is also being reviewed for re-design due to the restricted tolerance inside the drill pipe. The shifting tool design is a proven tool used in the oil industry, but will need some engineering review to be operational in this system.

The Edo Western Tool operated within the design specifications and did meet the requirements called out in the purchase agreement. The Edo tool did have one failure in the support section between the electronics unit and the motor drive package. The system deficiencies were discussed with the engineering department of Edo Western on return of the tool to their plant in Salt Lake City. The comments of that meeting have been included in this report, outlining the modification and design corrections to be done before the next re-entry test.

The re-entry base was designed and fabricated to meet the specifications described in the Contract. The design did fail in the first operation which was due to the manner the base was suspended from the ship. In the discussions after the re-entry test about the design of the base, the problems that were expected to exist did not appear.

Thirty degree angle on the cone is not needed because the Edo tool will not be extending out of this bit on re-entry. The Edo tool will be stopped in the target scanning position while the bit is let down and away from the tool for entry.

The base re-entry cone can have a reduced angle and also be reduced in height. The base latch ring and outlets can remain the same with increase in size for larger casing. The beam support and reflectors can be a similar design except bolted for fabrication and welded for final assembly. If design of this re-entry unit can be reduced in size, height not diameter, they could be economically constructed in number at a lower cost. With cost at a reduced amount, recovery of this base would not be necessary when the ship's time and cost is added. The reflector and stanchions can remain the same as the original design. These parts could also remain bolted during assembly, but welded after complete fabrication.

All manufacturers of the equipment used on the re-entry system have been contacted and their equipments operation has been discussed. Re-designs, modifications and new concepts will be sent to Deep Sea Drilling Project for approval before any work is performed on existing tools or new equipment manufactured.

The following pages of this report consist of a description of the actual operation of the equipment used. Also included are equipment drawings, parts list and manufacturers running procedures.

II. Global Marine Incorporated

A. Subject: Re-entry on Glomar Challenger

June 6, 1970

Arrived re-entry site 10:00. Ran profile line across site and beyond about ten miles, with vessel drifting.

Cruised back to re-entry site at location 37°59.39' North Latitude and Longitude 71°46.65' West. Dropped Burnett 16 kc beacon.

Placed re-entry target over the side in water 20 to 30 feet below hull with Edo scanning tool in normal running position below the bit. Signature of target was obtained and target could be seen for all variations in the target azimuth. Maximum range tested was approximately 200 feet. Note: Physically unable to move target further.

Hook up acoustic recall to sand line with 100 lb. weight hanging below release. Checked operation before lowering, okay.

19:05 hours. Lowered command ducer over side of vessel and send command. Pull sand line. Sand line had been overrun approximately 600 feet. Badly kinked. Weight had not released and would not release at surface.

Pick up second release. Run in to approximately 9,000 feet. Attempt release, no good. Run to 200 feet plus or minus. Release was made - shackle fouled in pelican hook.

June 7, 1970

Decision made to run drilling assembly and continue work on release. If favorable results, will attempt acoustic link after trip.

Water depth 3053 meters PDR 10,016 feet. Made up BHA - core barrel, index sleeve, three 8 1/4 inch outside diameter drill collars, two bumper subs, three 8 1/4 inch outside diameter drill collars, one bumper sub, two 8 1/4 inch outside diameter drill collars, one 7 1/4 inch drill collar, one joint 5 1/2 inch outside diameter drill pipe.

Strip in horn.

Run drill pipe, lay down bad order drill pipe in hole at 04:30.

Pick up Edo tool. Attempt to work bore plugger in drill pipe. Tool bull dogged on collet. Pulled out of socket at 4,300 lbs. versus 3,750 lbs. design.

Pull out of hole. Locate tool five joints down. Broke case at equalizing section of Edo tool while breaking stand. Tool had stopped at tool joint upset. Collet had jammed.

June 8, 1970

09:00 Ran inner barrel - punch cored ocean floor 10,016 to 10,046 feet and continued to punch core to 10,056 feet. Took 10,000 lb. weight. Pulled inner barrel - no recovery (all washed out). Calipered Edo tool - found lower dog assembly to be 4 1/4 inch outside diameter - modified tool by removing same. Found split sleeves over diaphragm section loose on Edo tool. Increased number of screws to four each for each sleeve 1/4 inch set screws. Repaired Schlumberger cable head.

10:00 With 500 lb. pump pressure, no rotation, penetrated to 10,268 feet (252 feet). Dropped inner barrel and cored 10,268 to 10,299 feet (31 feet).

12:30 Pulled and recovered 31 feet grey-green clay. Looks good for setting cs shoe at about 240 feet plus or minus.

13:00 Electrically tested Edo tool -okay, both in air and over the side in water.

17:00 Make up dummy tool without collet on bore plugger. Tool hung up several joints down. Pull out. O-ring missing. Circulate hole approximately one and one-half hours. Remove sleeve from bore plugger completely. String Schlumberger line through blocks. Make up torpedo connection to Edo tool.

19:30 Pick up and run Edo scanning sonar head - approximately two hours to run in. Lower drill pipe and logging tool in three meter increments down. Locate acoustic positioning beacon on scope. Move vessel - pipe movement seems to lag five minutes. However, appears to come to rest at new location with a minimum of overshoot.

22:30 Pull Edo tool - 3,500 feet/hour. 200 to 300 lb. overpull.

June 9, 1970

01:30 Lay down Edo - break torpedo. Cannot pull through blocks due to lubricator.

02:00 to 08:00 Pull out of hole.

08:00 to 09:30 Keelhaul base plate - very smoothly done.

09:30 to 13:00 Make up and run six joints 10 3/4 inch csg. and hang in moon pool.

13:00 to 15:00 Make up core barrel and six drill collars - lowering tool. Engage csg. bowl with bumper sub.

15:00 Pick up drill collar and lower and engage re-entry cone not over 5,000 lbs. down.

17:00 to 19:00 Divers report base plate torn up - pad eye one side torn off. Cone disengaged from base. Divers took movies and unshackle line.

19:00 Run in - lost 15,000 lbs. at 1600 meters. Run in - began to take weight 15 meters in on casing or six meters in on core bit - circ. hole. (Weight of base plate 11,000 lbs., csg. 8,750 lbs. = 19,750 lbs.in water.)

Decide to run Edo to verify whether 10 3/4 inch casing still on.

Rig up and run Edo.

Found good reflector.

Positioning vessel and building improved re-entry cone.

June 10, 1970
Recovered Edo.

Pull out of hole.

10:00 Divers hooked up keelhaul lines. Hook up acoustic release, boom box, and explosive bolt to sand line. Acoustic release transducer held at 45 degree angle. Run in to 9,000 feet plus or minus on sand line. Run command hydrophone over side of vessel and attempt to fire bolt. Pull out; bolt had failed to fire. Run bolt to 200 feet plus or minus and fired successfully.

12:30 Position vessel to determine response at different offsets. Run pattern to determine strength level of beacon. Very good 16 kHz beacon. Move to new location.

Drop new 16 kHz beacon.

Run two new 13.5 kHz beacon on sand line. Take photos.

Continue welding on modification of re-entry base No. 2.

June 11, 1970
07:00 Rig up and keelhaul base plate with divers. Make up 3 1/2 joints casing - mashed X-over with tongs (homemade) lay down joint and weld collar to bottom of casing bowl.

Make up four joints or 144 feet of 10 3/4 inch 40.5 lb. new singles K-55 Buttress casing. All joints glued. Bottom fitted with Larkin open guide shoe. Top fitting with National latching head. Latching head fitted with modified "J" slot. Lower casing to elevators supported on homemade spider on guide horn. Make up bottom hole assembly with lugs on lowering tool four collars above bit (bit 24 feet from shoe).

Latch into "J" slot and tack weld shear bar across "J" to prevent re-entry cone from floating out while running in. Drilling sleeve tack welded in place.

June 12, 1970

Run in to 3048 meters and pick up swivel. Wash in. Casing began to take weight at 3057 feet. Circ. with both pumps at 65 spm each. Maximum pressue 500 psi. Wash in to 3078 meters. Would not go deeper. Top casing at 3030 meters with top of re-entry cone at 3026 meters. Took one quarter turn left hand torque with power sub and came out of "J" slot.

Pull to 3032 meters and rig up Edo. Followed re-entry cone while running in on PDR. Lost reflection approximately half way in.

Core barrel was fitted with T.C. (crushed) core bit. Lower bearing support was packed off.

Run Edo and located descriptive "cross" that was supposed to represent mud cross. Pull to 3,026 feet and re-enter, unable to see "cross". Pull up and make two unverified re-entries.

Use jet sub - saw considerable motion; used 250 to 450 lbs.

Increased pressure to 1,000 psi and tool failed. Pulled out and found equalizing bladder failed on Edo tool.

June 13, 1970

While working on Edo tool trip d.p. and install drilling sleeve with three 10,000 lb. shear pins and handling sub with six 10,000 lb. shear pins at bit so that we could verify re-entry without trip with Edo tool.

Re-run Edo - tool would stop transmitting when in the water 17 meters.

Pull Edo tool and attempt repairs. Lower seal apparently damaged.

Drilled and tapped several vent holes. Refilled equalizing section with oil. Found several sections with galled joints during disassembly. Dressed joints in machine shop.

June 14, 1970
03:00 Run Edo. Tool operating successfully.

06:00 On bottom with tool. Unable to find re-entry cone. Approximately two hours searching. Locate re-entry cone. Attempt to orient vessel with re-entry cone. In automatic attempt to position vessel for re-entry.

At 19:53, re-enter cone on second try and shear pins with 30,000 lbs. plus or minus. Very easy.

Pull Edo tool and lay down tool.

Run to bottom at 3078 meters and circ. hole clean. Drop core barrel and take 45 foot core.

June 15, 1970
Core No. 1, Site 110 3082 to 3092 meters (12 meters), recovered 12 meters. Run Baker shifting tool. Attempt to shift sleeve on jet sub. Tool became stuck on sleeve. Moved up hole 30 feet.

Attempt to part line with 22,000 lbs. Cut line and pull out. Found tool stuck in jet sub with sleeve closed.

Noon Underway to Boston.

LCB:mh

cc: R. B. Thornburg
J. A. Reed
R. C. Crooke
G. D. Knorr
R. E. Kunzi
T. F. Dixon

B. Glomar Challenger Running Procedure for the Deep Water Re-entry System

Ref: Drawings CC-2217-1 through CC-2217-6 and CC-2220

1. With the ship on location a core sample is taken to determine the amount of over burden. Pull drilling assembly.

2. Guide Base:
Check segments and make sure the nuts on the retracting bolts are loosened and snugged against the cotter pin allowing segment springs to push segments into latch position, then keelhaul the assembled guide structure and sling, centered below rotary.

3. With the information from Step 1 rig up and run 10 3/4 inch 32 lb. casing and install 10 3/4 inch casing hanger (532177-A) on the last joint.

4. Make up running tool (532179-A) on drill collar and install two each 532179-2 lifting pins and latch tool in the "J" slots in the casing hanger.

   Lower casing string through rotary and land in casing elevators in the moon pool area. Release tool and retrieve.

5. Make up drilling assembly and drill collars. When the point where the bit will be two to three feet out of the bottom of the casing when the running tool is latched into the casing hanger - (if a bumper sub is used just above the bit and coring collar, measurements should be at the closed position) install the running tool (532179-A). (Remove the two lifting pins, 532179-2.) Install a predetermined amount of shear pin (532180-A) assemblies.

   *(Example in following step) and a 530401-7 "O" ring.

6. Over the running tool install the drilling sleeve assembly (532178-A), this will be complete with a predetermined amount of shear pin assemblies and a 530018-7 "O" ring.

   *When calculating load values for the quantity of shear pins to be used one of the two weights will be a constant, that being the guide base plus wave action at 10,000 lbs. the other figure will be that of the casing string. This figure will vary due to the different lengths of casing strings.

   Example - If the ocean bottom has been found (Step 1) to have 160 feet of over burden (soft sediment) about 150 feet of 10 3/4 inch casing will be run. Therefore the shear values will be determined by adding the base weight 10,000 lbs. to 150 feet 10 3/4 inch 32 lb. casing - 4,800 lbs. totaling 14,800 lbs. Therefore the drilling sleeve assembly would require two shear pins 180 degrees apart for a shear value of 20,000 lbs. The running tool is to be set up to shear after the drilling sleeve so it would require three shear pin assemblies. Equally spaced around the outside diameter of the tool for a value of 30,000 lbs.

7. Make up another drill collar and lower running tool and bushing into the casing hanger when the shear pins on the bushing have latched into the casing hanger pick up the drill string with the casing string attached and remove the elevators. Lower the casing hanger assembly into the guide base until weight indicator shows a weight drop. Pick up to insure casing hanger is latched in place - remove slings and run drilling assembly plus guide base and casing string to the ocean floor.

8. Jet in casing string to the point of refusal. At this time the drilling sleeve will shear out of the casing hanger and then the running tool will shear out of the sleeve.

9. Commence normal coring operations until bit is dulled.

10. Retrieve drilling assembly.

    When the bit arrives at the drilling sleeve it will automatically retrieve the free floating sleeve.

11. If at this time it is determined that more than one more bit will be dulled in this hole the drilling sleeve and the running tool will not be rerun.

12. Retrieving Re-entry System.

    This step may be accomplished in one of two ways:

    1. When preparing to run last bit install the running tool just above the first drill collar. The running tool will be outfitted with two each 532180-A shear pin assemblies at 180 degrees apart. Next install the drilling sleeve assembly with all ten shear pins installed.

       (On the retrieving operation "O" rings will not be required.)

Run drill string to the bottom stabbing in guide structure. When the drilling sleeve reaches the casing hanger the ten shear pins will latch in the casing hanger and the running tool will shear out of the drilling sleeve upon downward movement.

Dull the Bit - Pick up to a predetermined point, lower a charge through the drill pipe and shoot off casing. Pull up until bit is topped on the drilling sleeve and retrieve guide system.

NOTE: Upon reaching the drilling sleeve with the bit keep an even pull so the wave action on the ship will not cause a jarring action that could shear out the drilling sleeve.

2. This second method is accomplished in the same way but would be a retrieving run only.

13. When guide system arrives below moon pool attach slings, retract segments in the latch ring and retrieve casing hanger and drilling assembly.

14. Make sure all equipment is washed with fresh water and greased thoroughly when not in use.

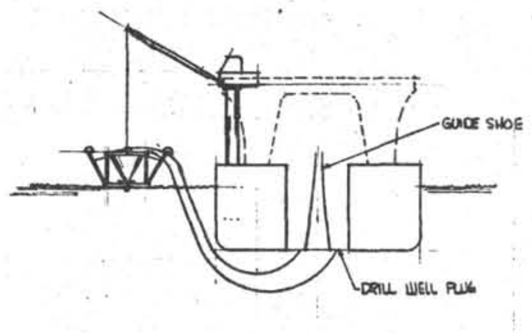
June 1, 1970

C. Hex Landing Base Dwg. #E-377-T004

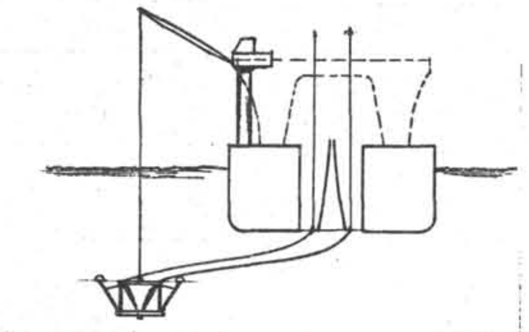
The "hex landing base" was designed by Global Marine Inc. per the specifications set down by Supplement Agreement Number 14. The re-entry cone was designed with a 30 degree incline on the cone to prevent damage to the transducer head extending out of drill bit during re-entry. The hex landing base was also designed in structural modules at a maximum size of eight feet x eight feet, that could be stored and assembled on board the drilling vessel.

The first unit was re-assembled on the dock and stored aboard ship out to the re-entry test location. The landing base unit was then keelhauled under the ship and hung off. The sling arrangement for hanging off the landing base was not a fair test for the structure or the load carrying ability of the unit. The slings holding the unit during the landing of the casing were secured to two (2) pad eyes on the main box beams of the sub-base, which were 14 feet apart. The sling ran through the bottom of the ship through two holes that were 12 feet center to center and then out to two (2) pad eyes on the landing base which were 16 feet apart. When the casing load was applied to the base, one pad eye on the landing base came off throwing the load onto a single pad eye, the landing base cone sheared off at the base of the structure collapsing the bottom structure of the unit. This unit was abandoned on the ocean floor and a second unit was assembled on board ship. To this landing base was added gusset plates and additional structures around the outside of the unit. The pad eyes were relocated to the center of the landing base on 11 foot centers. This base was keelhauled, casing landed in the base and lowered to the ocean floor. Re-entry was performed in this landing base. The two landing bases were fabricated by S & R Tool Company in Houston, Texas.

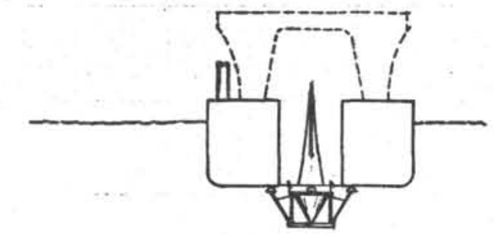
LIST OF MATERIALS			
ITEM	QTY	DESCRIPTION	MATERIAL



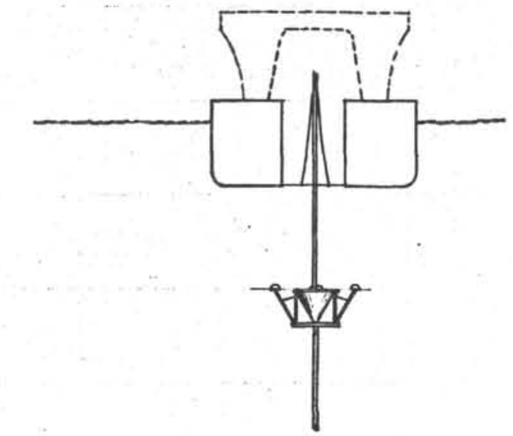
STEP 1 RIGGING LINES ARE LEAD FROM SELECTED HOLES IN BOTTOM OF DRILL WELL AREA



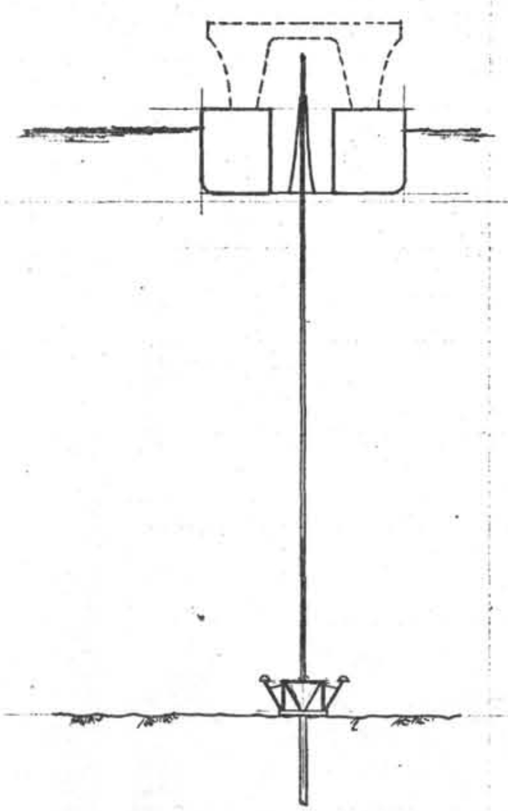
STEP 2 LANDING BASE IS THEN HOISTED OVER THE SIDE, LOWERED AND KEEL HAULED INTO PLACE



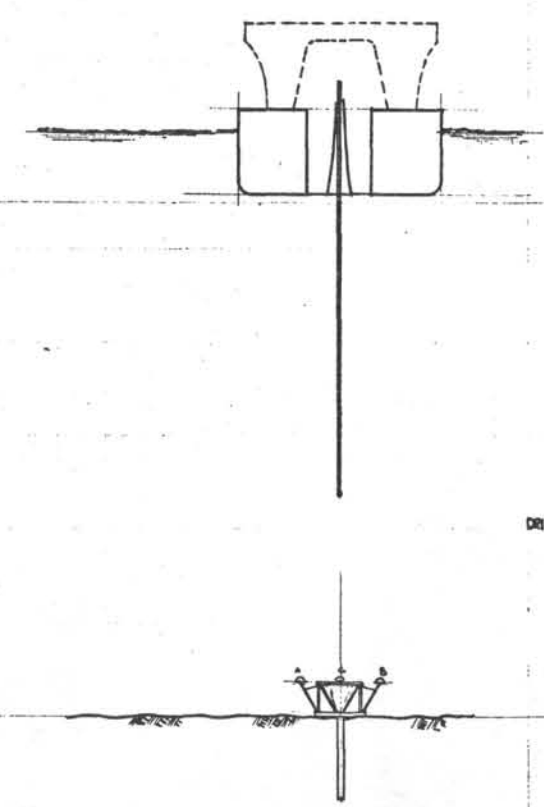
STEP 3 WHEN IN PLACE, TIE LINES ARE USED TO SECURE IN PLACE, AWAITING ENTRY OF CASING. MAKE-UP CASING AS REQUIRED AND SUSPEND TEMPORARILY UNDER ROTARY TABLE. MAKE UP DRILLING ASSEMBLY WITH CASING RUNNING TOOL



STEP 4 ENGAGE RUNNING TOOL IN TOP OF CASING. LAND CASING IN LANDING BASE. LANDING BASE AND CASING ARE LOWERED TO OCEAN FLOOR ON DRILL PIPE

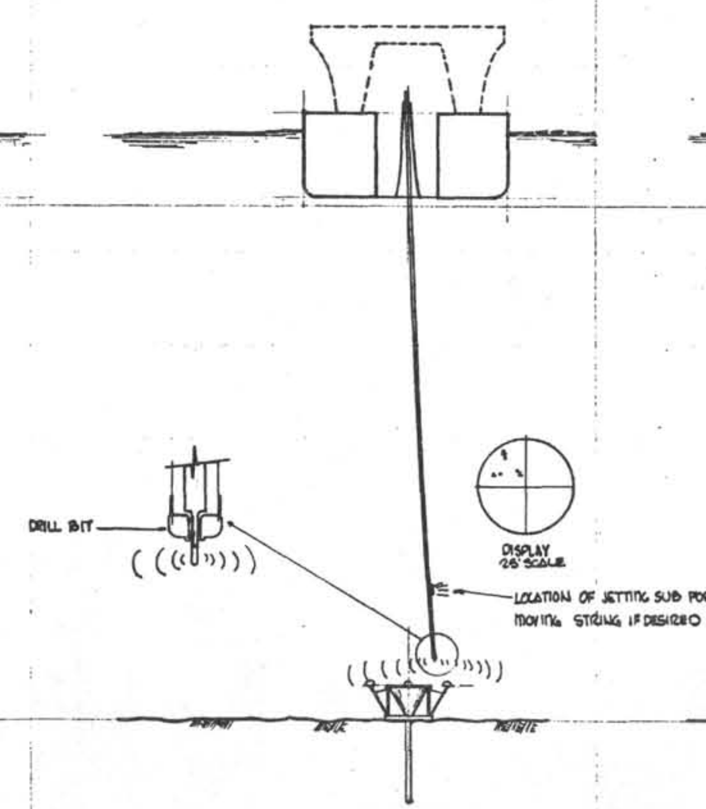


STEP 5 CASING FOLLOWS DRILL BIT INTO WELL BORE UNTIL LANDING BASE BOTTOMS ON THE MUD LINE. FURTHER DRILLING PROCEEDS UNTIL BIT REQUIRES CHANGE

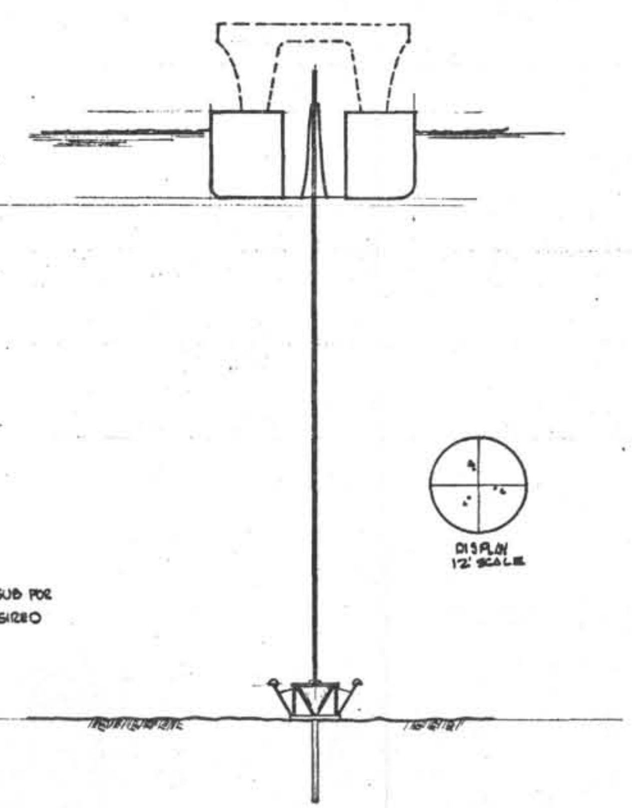


REPLACING BIT

STEP 6 REMOVE DRILL STRING AND REPLACE BIT. THEN LOWER TOWARDS OCEAN FLOOR



STEP 7 TO REENTER HOLE, THE SONAR SCANNING HEAD IS LOWERED THROUGH DRILL PIPE TO EXTEND BELOW BIT AS SHOWN. CORNER REFLECTORS A, B & C PROVIDE AN INDICATION OF BIT LOCATION IN REFERENCE TO HOLE



STEP 8 BIT ENTERS CONICAL RE-ENTRY BASE, SONAR EQUIP. IS WITHDRAWN AND DRILLING OPERATION RESUMES

NO	DATE	BY	DESCRIPTION	APPROVED

ALTERATIONS

NO REQ'D	NEXT ASSEMBLY
	ALTERATION
	DATE
	SHIPYARD
	LOS ANGELES
	HOUSTON
	PURCHASING
	ESTIMATING
	USCG
	ABS

GLOBAL MARINE INC.
Los Angeles, Calif.

GLOMAR CHALLENGER /116

HOLE REENTRY USING SONAR SYSTEM - SEQUENCE

	DATES
ENGR. [signature]	8-20-69
DFT. POLLACK	8-20-69
CHK. [signature]	8-21-69
APPR. [signature]	8-22-69
REL. [signature]	8-?-69

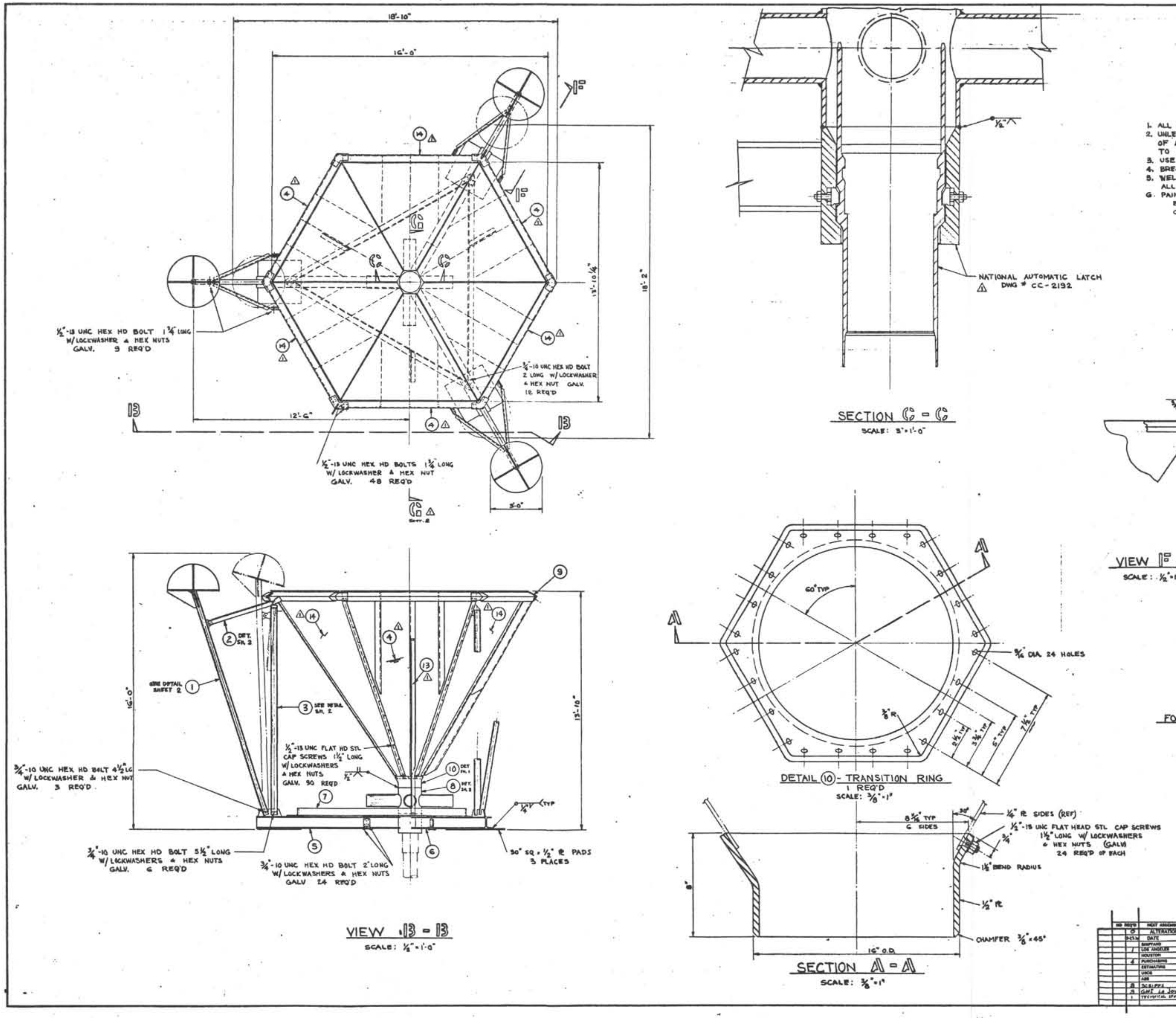
SCALE: ~

TOLERANCE UNLESS OTHERWISE NOTED
FRACTION ± 1/16" DECIMAL .00 = ± .03
ANGULAR ± ½° .000 = ± .010

JOB AUTH. 515

DWG. NO. D • 377 • T002

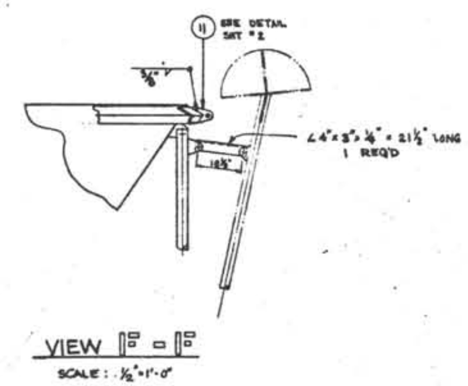
ALT 0



LIST OF MATERIALS			
ITEM	QTY	DESCRIPTION	MATERIAL

GENERAL NOTES
UNLESS OTHERWISE SPECIFIED

1. ALL PLATES & SHAPES TO BE PER ASTM A-7 OR A-36.
2. UNLESS SPECIFICALLY INDICATED OTHERWISE, LOCATIONS OF ALL PLATING BUTTS & SEAMS MAY BE MODIFIED TO SUIT AVAILABLE MATERIAL.
3. USE WELDING ROD SERIES E-60 OR EQUAL.
4. BREAK ALL SHARP EDGES & REMOVE ALL BURRS.
5. WELD, PAINT OR STAMP GMI PLAN NUMBER ON ALL MAJOR PIECES.
6. PAINTING: WIRE BRUSH CLEAN ENTIRE RE-ENTRY BASE OF RUST, SCALE & GREASE. APPLY ONE COAT RED LEAD PRIMER & ONE COAT OF WHITE.



FOR DETAILS SEE SHEET #2 OF DWG # E-377-T004

NO	DATE	BY	DESCRIPTION	APPROVED
1	5-13-70	RBK	MOD. DETAIL-4 ADDED DETAIL-13 AND 14 ADDED SECTION G-G	

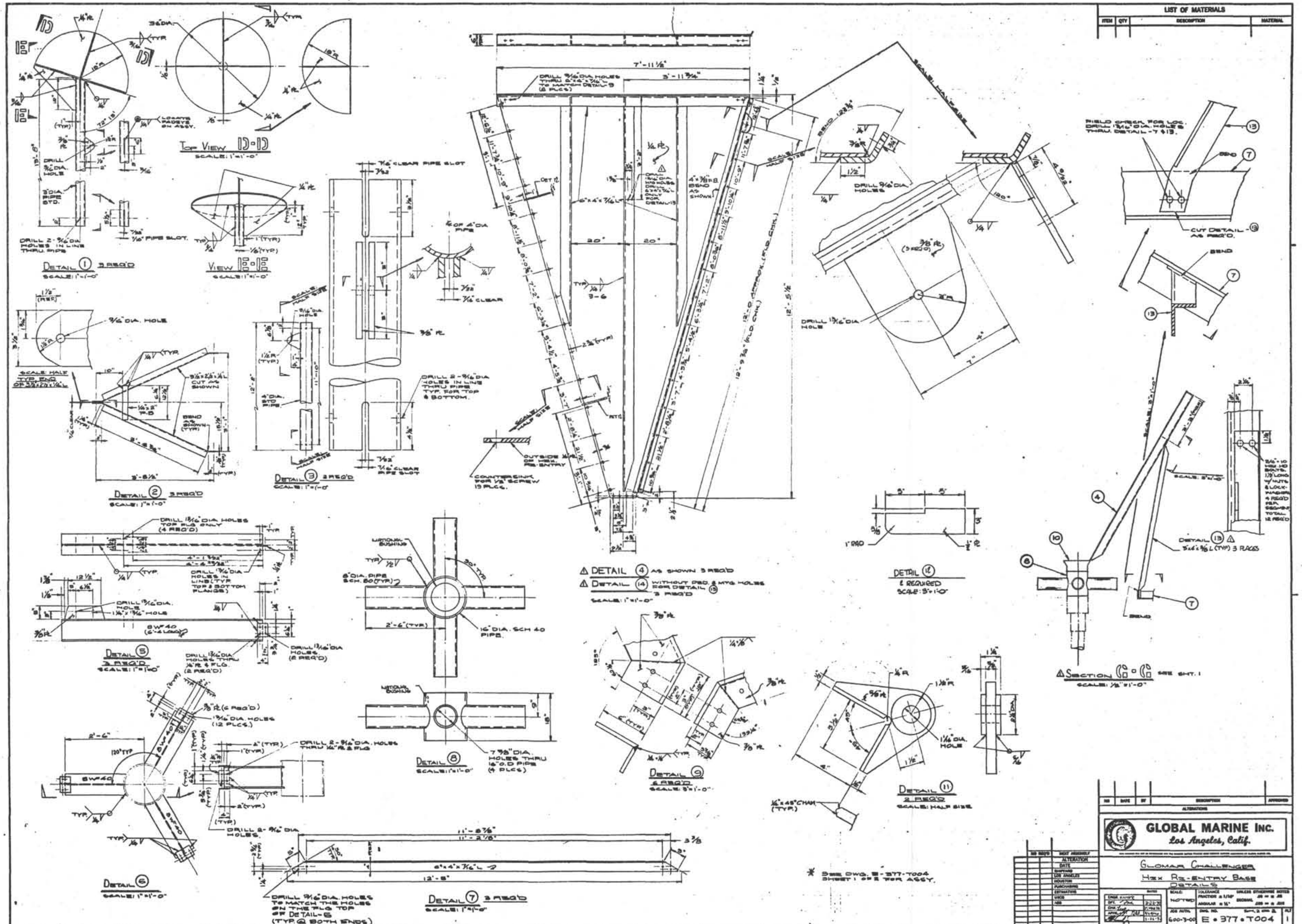
ALTERATIONS

GLOBAL MARINE INC.
Los Angeles, Calif.

GLOMAR CHALLENGER

HEX RE-ENTRY BASE - ASSY & DETAIL

SCALE: NOTED
JOB AUTH. 600-3-00
DWG. NO. E-377-T004 SHEET 1 OF 2 ALT 1



LIST OF MATERIALS
ITEM
QTY
DESCRIPTION
MATERIAL
TOP VIEW
SCALE: 1"=1'-0"
DETAIL ① 3 REQ'D
SCALE: 1"=1'-0"
DETAIL ② 3 REQ'D
SCALE: 1"=1'-0"
DETAIL ③ 2 REQ'D
SCALE: 1"=1'-0"
DETAIL ④ AS SHOWN 3 REQ'D
DETAIL ⑭ WITHOUT PAD & MTG HOLES FOR DETAIL ⑮ 3 REQ'D
SCALE: 1"=1'-0"
DETAIL ⑤ 3 REQ'D
SCALE: 1"=1'-0"
DETAIL ⑥
SCALE: 1"=1'-0"
DETAIL ⑦ 3 REQ'D
SCALE: 1"=1'-0"
DETAIL ⑧
SCALE: 1"=1'-0"
DETAIL ⑨ 6 REQ'D
SCALE: 3"=1'-0"
DETAIL ⑪ 2 REQ'D
SCALE: HALF SIZE
DETAIL ⑫ 6 REQUIRED
SCALE: 3"=1'-0"
DETAIL ⑬
SECTION G-G SEE SHT. 1
SCALE: ½"=1'-0"
16" DIA. SCH 40 PIPE
8" DIA. PIPE SCH. 80 (TYP)
8WF40
6"x4"x⅜"L
* SEE DWG. E-377-T004 SHEET 1 OF 2 FOR ASSY.
ALTERATIONS
GLOBAL MARINE INC.
Los Angeles, Calif.
GLOMAR CHALLENGER
HEX RE-ENTRY BASE
DETAILS
E • 377 • T004

III. National Supply Company

A. Handling Sub Part #532179-1

The "Handling Sub" designed and used to lower casing from the rotary table to the spider located on the upper part of the cone at the main deck. This lowering device has removable lugs in the "handling sub" which engaged into the J-slots cut in the "casing hanger". The "handling sub" was also designed with 1/2 inch shear pins six (6) at 10,000 lbs. shear each which could be reduced in number to carry the load required, "re-entry base" weight 13,056 lbs., 10 3/4 inch casing hanger and total amount of 10 3/4 inch casing to be run. Six (6) shear pins were installed on the first run. The weight of the load on the handling sub would be the hex re-entry base and 240 feet of 10 3/4 inch casing 40.5 ft./lb. and adds to a total weight of 18,776 lbs. in air. Also a modification was added to the design of the "handling sub", six (6) explosive bolts three inches long by 3/4 inch diameter. The purpose of the explosive bolts was to lower the "hex landing base" and casing hanger with 10 3/4 inch casing from the ship to the ocean floor. This method would tie the casing hanger to the handling sub through the drilling sleeve and would cause an additional trip with the drill pipe back up to the ship to remove the drilling sleeve for re-entry into the casing. These explosive bolts were tested at the drilling site on the sand line at 10,000 feet and up to 2,000 feet. The acoustic signal failed to explode the bolts at the depth required for release of the equipment. The "handling sub" was used to lower the "hex landing base" with the 10 3/4 inch casing attached, all the way to the ocean floor which was not the intent of the original design of this tool. This was brought about by the failure of the shear pins to carry the load they were designed for. There was a modification to the J-slot (on the casing hanger) which is shown on the attached drawings and details. The "handling sub" has a O-ring to pack off between the "drilling sleeve" during the jetting in of the casing.

B. Drilling Sleeve Part #532178-1

The drilling sleeve fits over the handling sub and is attached by shear pins or explosive bolts. On the outside of the drilling sleeve there is also 1/2 inch shear pins, ten (10) at 10,000 lbs. each which can be reduced in number per the load to be carried to ocean floor. This tool also has an O-ring to pack off between the drilling sleeve and casing hanger while jetting in casing. The "drilling sleeve" will not pass through the "casing hanger" because of the shear pin design and the friction ring at the bottom of sleeve. The friction ring on the "drilling sleeve" matches with a friction ring on the inside of the casing hanger which will engage to insure rotation of complete unit if drilling is necessary to get hex landing base down to the ocean floor. After shearing pins in the drilling sleeve and handling sub, the drilling sleeve will just float on the casing hanger. This tool will be returned to the ship when the drill bit is pulled for change. The drilling sleeve was also in the design for recovery of the landing base. When the last drill bit is run the drilling sleeve would be included on the drilling assembly with ten (10) shear pins. When this bit became dull, the bit would be pulled up an engaged into the drilling sleeve. An explosive charge would then be lowered on the sand line to part the casing and the landing base recovered back to the ship.

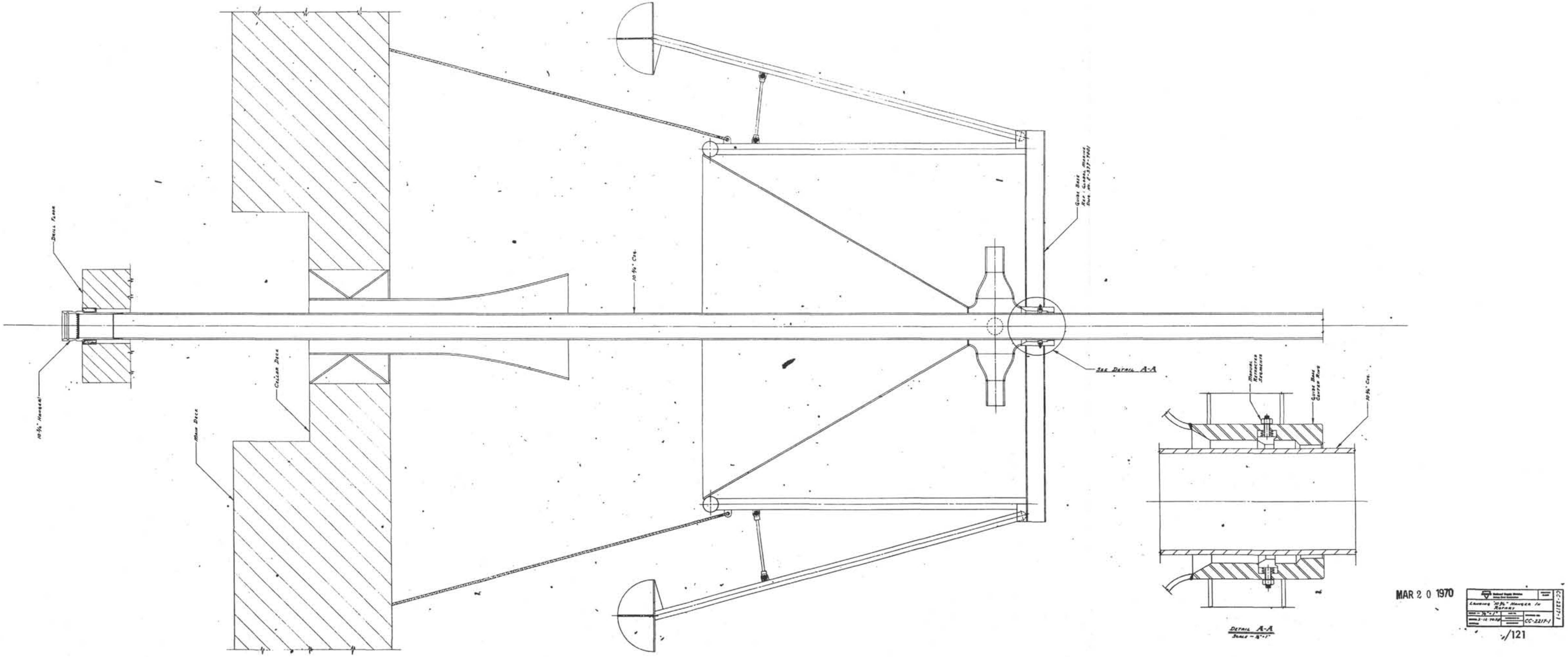
C. Casing Hanger Part #532177-1

The "10 3/4 inch casing hanger" was designed with J-slots to handle the hanger made up on 10 3/4 inch casing from the rotary table down to the spider located on the upper end of the guide cone in the drill well. The latching design on the hanger is a groove around the casing hanger which three latch segments engage into when the casing hanger lands on 45 degree seat in "guide base latch ring". The latch segments prevent the casing hanger from backing out of the latch ring during the jetting in of the casing.

D. "Guide Base Latch Ring" Part #532176-1

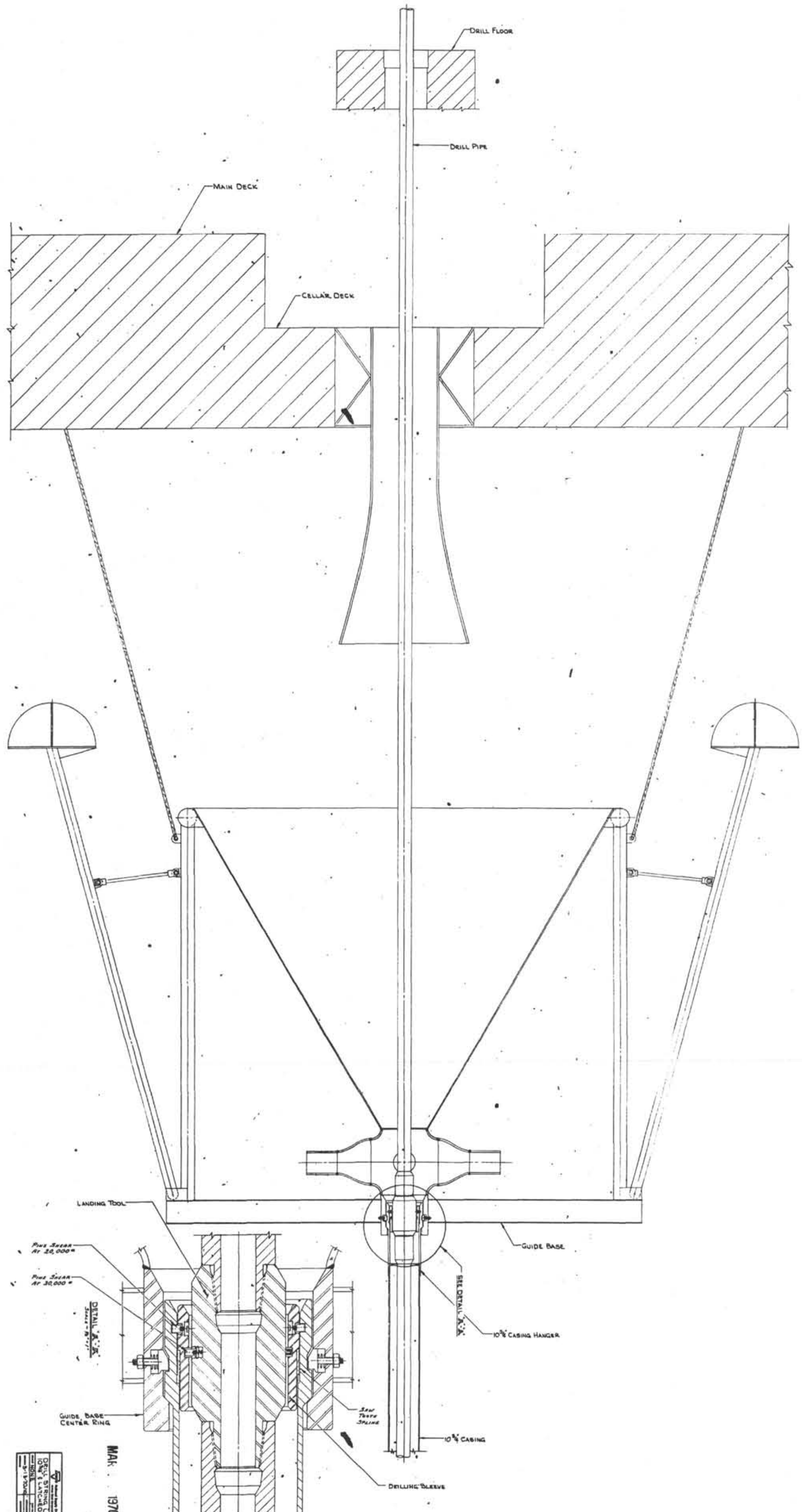
The "guide base latch ring" is welded in and becomes part of the bottom supporting section of the hex landing base. The casing hanger is landed and latched into this unit which has been covered above.

The consensus of all personnel involved in the test of the re-entry system aboard the Glomar Challenger June 4th through June 16th was that the National equipment did perform as designed.



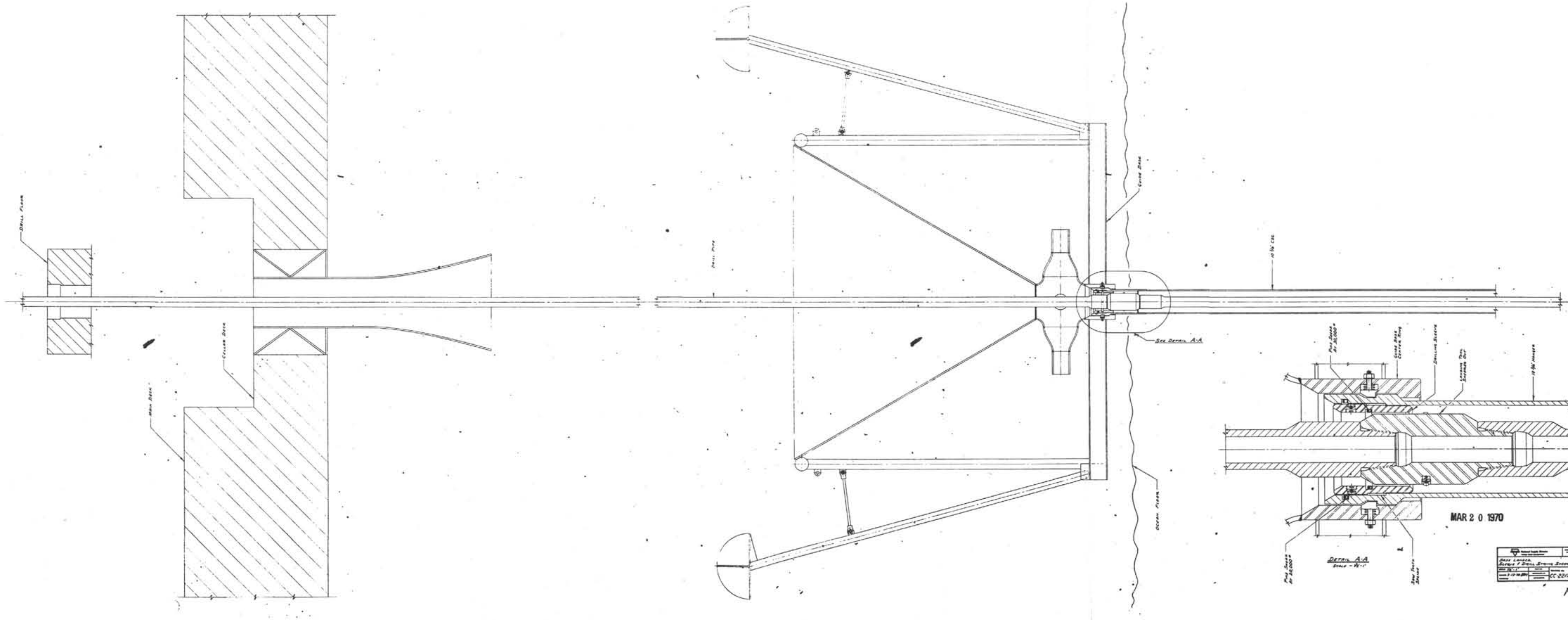
MAR 2 0 1970

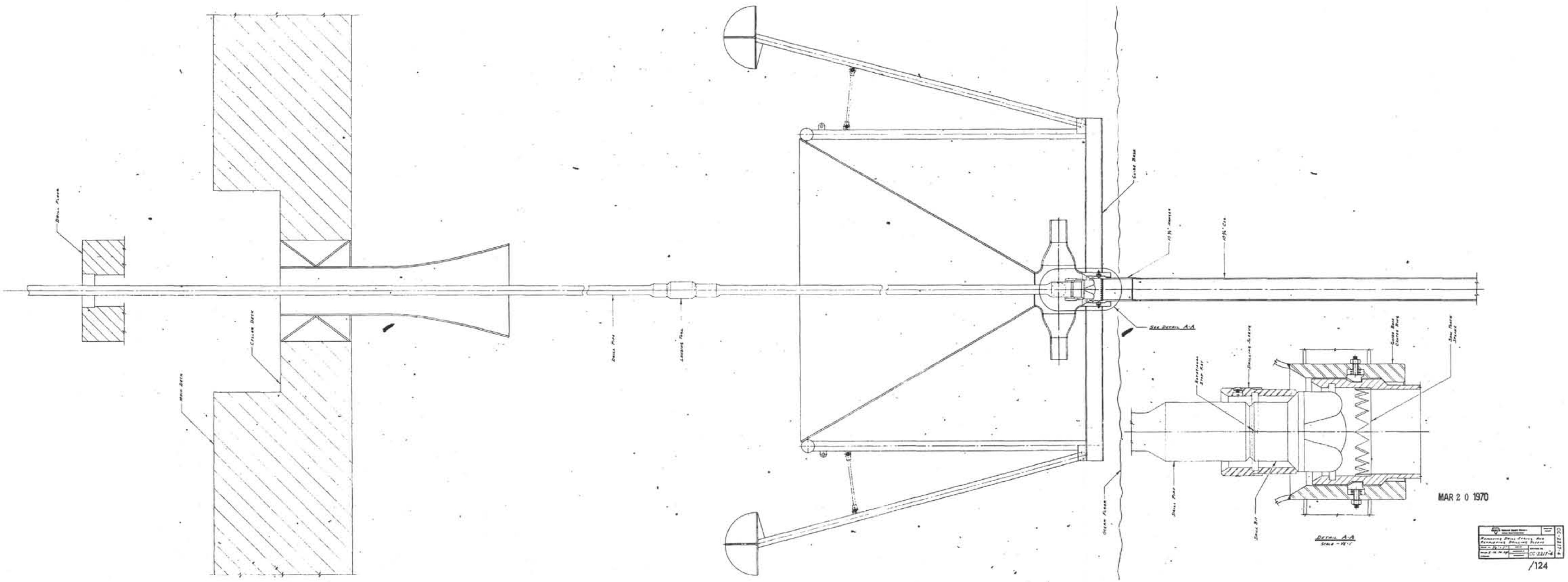
/121



DRILL FLOOR
DRILL PIPE
MAIN DECK
CELLAR DECK
LANDING TOOL
GUIDE BASE
SEE DETAIL "A"-"A"
10¾" CASING HANGER
10¾" CASING
PINS SHEAR AT 20,000#
PINS SHEAR AT 30,000#
DETAIL "A"-"A"
GUIDE BASE CENTER RING
SAW TOOTH SPLINE
DRILLING SLEEVE
MAR 1970
DRILL STRING LATCHED IN 10¾" & LATCHED IN BASE
CC-2217-2

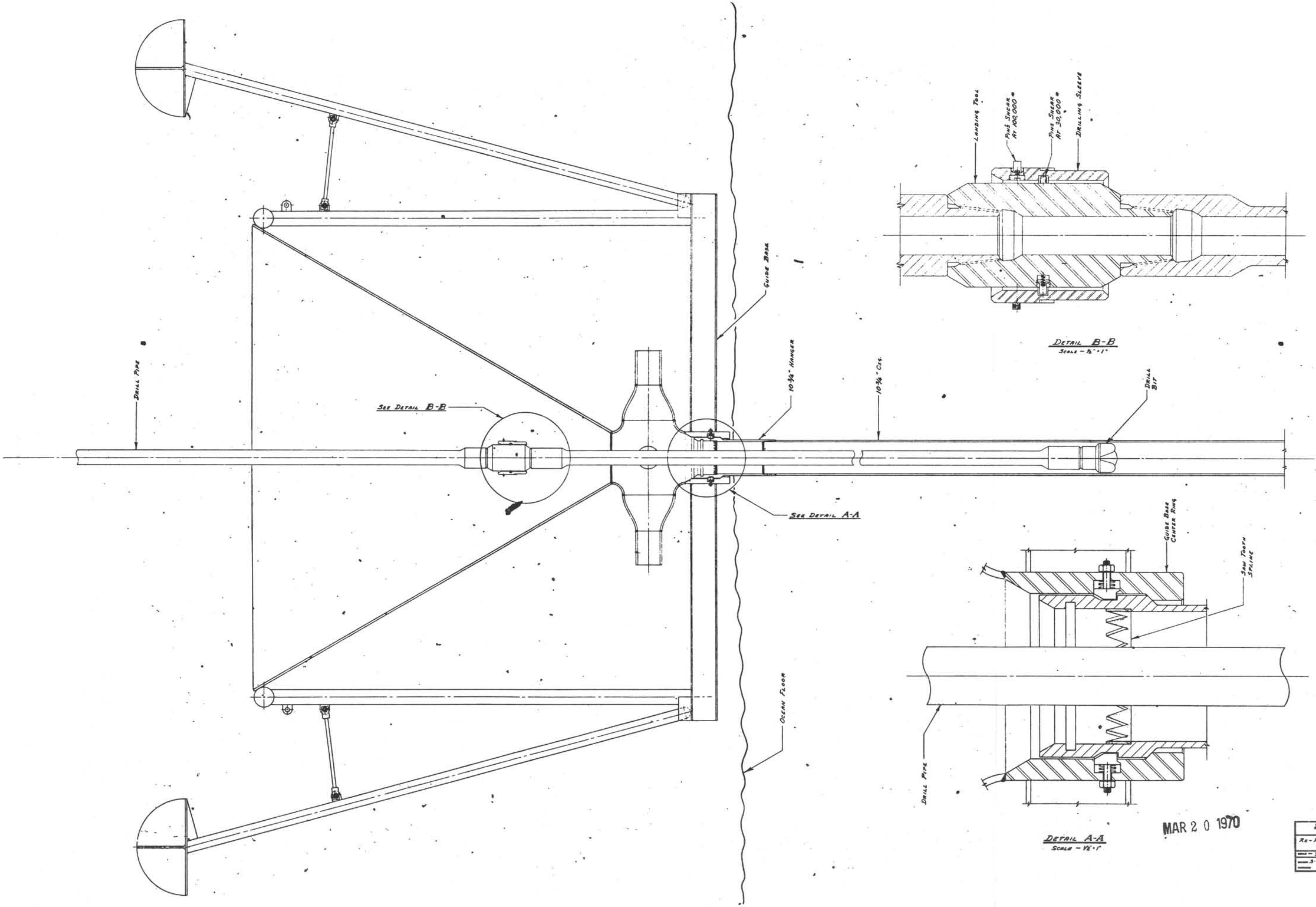
/122


MAR 2 0 1970
123



MAR 2 0 1970

/124



MAR 2 0 1970

Re-Running Drill String & Sleeve
Scale – ½" = 1"
3-13-70 SH
CC-2217-5

CC-2217-5

ILLUSTRATIVE DRAWINGS OF SPECIAL TOOLS AND METHODS

ENG. REPORT

BAKER OIL TOOLS, INC.
LOS ANGELES HOUSTON NEW YORK U.S.A.

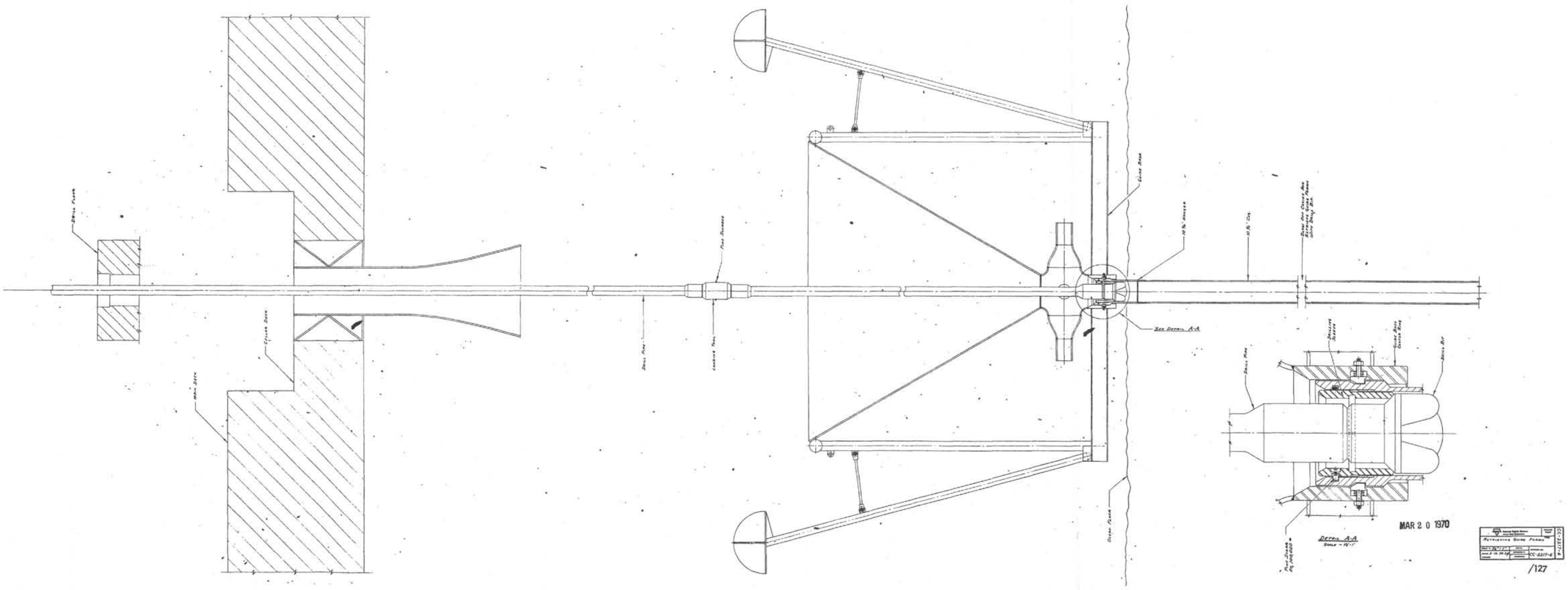
NAME MATERIAL LIST
F/JET SUB & 4.12 Model
'D-2' SHIFTING TOOL
PRODS. 995-01 & 810-72 SP.

DRAWING NO. 206 / 031-[illegible]

DATE

ITEM	PART NAME	REQ.	COMM. NO.
1	Indexing Sub	1	02-06031-00
2	Coupling	2	02-05996-00
3	Nylok Soc. Hd. Cap Scw.	2	1/4 - 20 X 1-1/4 Lg.
4	Mandrel	1	02-02932-00
5	Drag Blocks	3	Opening Block 02-04[illegible]33-00 Closing Block 02-04[illegible]34-00
6	Connecting Adjuster	1	02-04[illegible]35-00
7	Soc. Set Screw	4	1/4 - 20 X 1/4 Lg.
8	Nut	1	02-02[illegible]25-00
9	Soc. Set Screw	1	1/4 - 20 X 1" Lg.
10	Control Sleeve	1	02-02933-00
11	O-Ring	2	WW-B349-H40
12	Mandrel Spring	1	02-02934-00
13	Closing Sleeve	1	02-05995-00
14	Retractor	1	02-05999-00
15	Retainer Sleeve	1	02-06001-00
16	Soc. Set Screw	1	1/4 - 20 X 1/2 Lg.
17	Dog Spring	2	01-30741-00
18	Shifting Dog	2	02-06002-00
19	Pin	2	01-70231-00
20	Key	2	02-0599[illegible]-00
21	Shear Pin	3	01-70232-00
22	Dog Retainer	1	02-06000-00
23	Nylok Soc. Set Screw	1	1/4 - 20 X 7/16 Lg.
24	Housing	1	02-04[illegible]5[illegible]-00
25	Drag Block Retainer	1	02-04[illegible]35-00
26	Outer Drag Block Ret Ring	1	01-43130-00
27	Outer Drag Block Spring	6	01-46139-00
28	Inner Spring	6	[illegible]

DRAWN BY APPROVED BY /126



SEE DETAIL A-A
DETAIL A-A
SCALE = 1/2"=1'
MAR 2 0 1970
RETRIEVING GUIDE FRAME
CC-2217-6

/127

IV. Baker Oil Tool Company

A. Baker Oil Tool Jet Sub   Dwg. #206/081-1

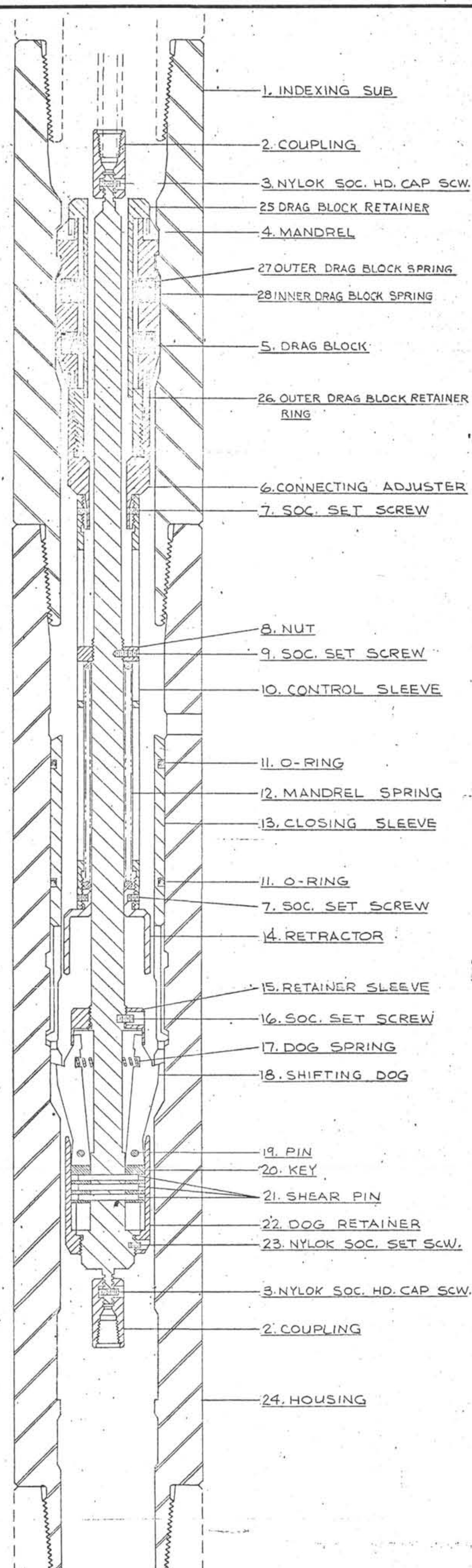
The jet sub was designed and built with a sliding sleeve to open and close a 3/4 inch jet nozzle. The index to open the shifting tool to the jet nozzle was cut in the jet sub pin end. An index sub was fabricated to make up into the top of the jet sub which would index the shifting tool in the closing position. The collet design on the original shifting tool was changed to three (3) spring loaded drag blocks due to the bore back NC-61-82 threads on the drill collars. The sliding sleeve did close when the shifting tool was run in and indexed into position. The shifting tool could not be retrieved after closing the sleeve, recovery of tool was made by cutting the sand line and pulling the drill pipe. It appeared the drag blocks on the shifting tool had jammed in the top index sub. This problem may be corrected by reducing the outside diameter of the drag blocks because of the reduced inside diameter of the drill pipe on the Glomar Challenger. Changes and modifications have been discussed with Baker Oil Tool representatives.

B. Baker Oil Tool Bore Plugger / Jet Sub

The bore plugging tool was designed to plug the pipe between the jet sub and Edo tool which would allow salt water to be pumped down the drill pipe and out through a 3/4 inch nozzle. This would propel the drill pipe in a selected direction and distance to assist in re-entry of the drilling assembly into landing base cone. When the bore plugger tool was made up on the top end of Edo tool and run in the drill pipe it travelled down about two (2) joints and stopped. The collets on the latch end of tool measured 4.250 inches outside diameter in open position and 4. 125 when in closed or running position. The drill pipe inside diameter with the scale build up measures four inches plus or minus 1/32 inch which would cause the tool to drag and stick in the drill pipe. Also the head of the bore plugger tool measured 4.05 which would tend to drag in the existing drill pipe. The collets were removed and the head of the tool was reduced in outside diameter but the O-rings rolled off the head while running down through the drill pipe. This tool was not run during the remainder of the re-entry test. This tool should be redesigned to resemble a swab cup type tool and be incorporated in the top spacer sub of the Edo tool.

BAKER OIL TOOLS, INC.
LOS ANGELES HOUSTON
NEW YORK
U. S. A.

ILLUSTRATIVE DRAWINGS
OF SPECIAL
TOOLS AND METHODS



ENG. REPORT NO. 461-1

NAME JET SUB - PROD. 995-01
& 4.12 MOD. 'D-2' SHIFTING TOOL
PROD. 810-72 SP.

DWG. NO. 206 081-1

DRAWN Pat Decker
APPROVED
DATE 5-15-70

REVISION DATES: 5-25-70 B.C.L.

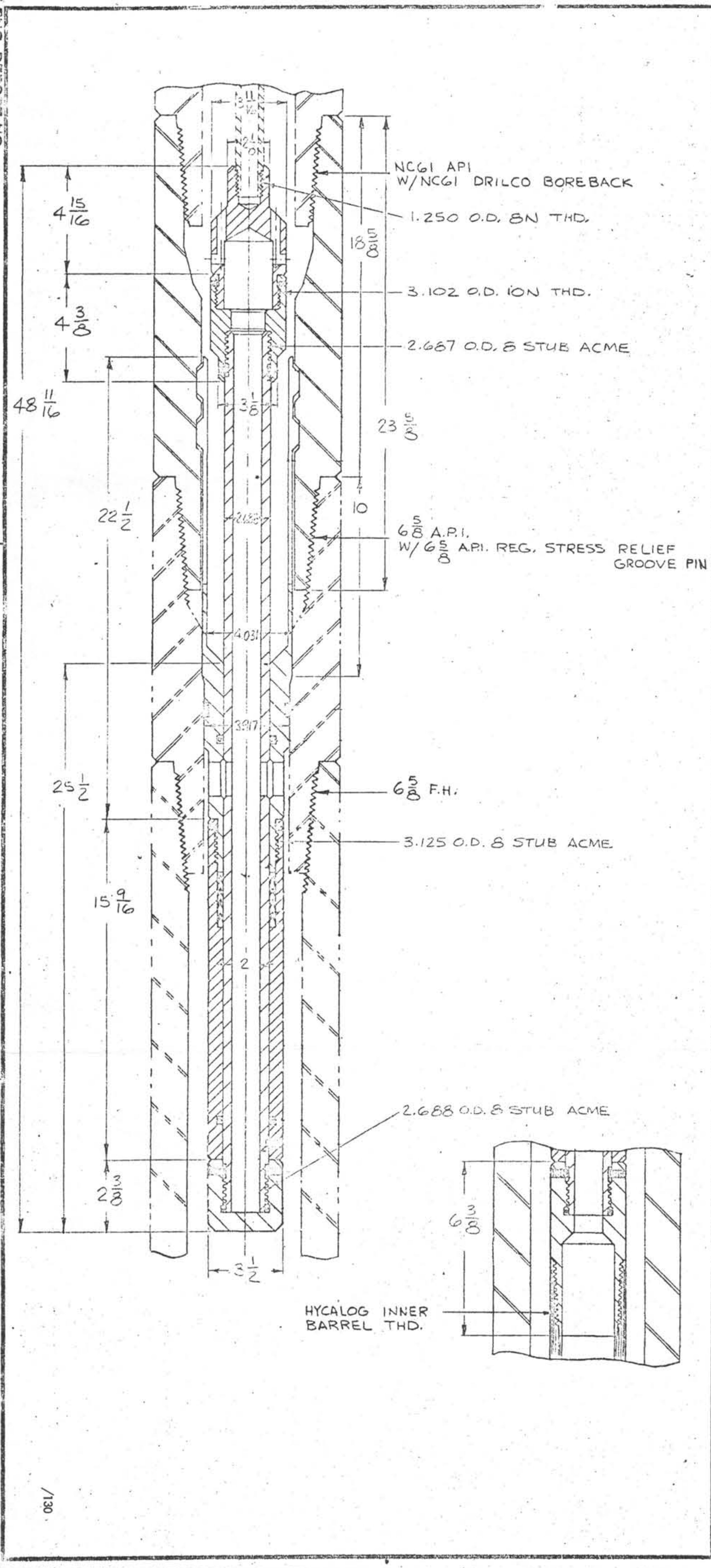
/129

DWG. NO. 206 081-1

BAKER OIL TOOLS, INC.
LOS ANGELES HOUSTON
NEW YORK
U. S. A.

ILLUSTRATIVE DRAWINGS
OF SPECIAL
TOOLS AND METHODS

ENG. REPORT NO. 4G1-1



/130

NAME BORE PLUGGER F/JET SUB
F/GLOBAL MARINE - DIM. DATA
PROD. No 995-01

DWG. NO. 206 018-3

DRAWN Pat Decker
APPROVED [signature]
DATE 7-15-70

REVISION DATES:

DWG. NO. 206 018-3

V. Equipment Used - Re-entry System

A. Guide Base Center Ring - National

1. No modification needed, operation good.

B. Casing Hanger - National

1. Outside latch ring design satisfactory for re-entry program.

2. Inside shear pin design not operational. Loads applied to shear pins not connected with total weights of drilling assembly and casing. Design should be a controlled lock to prevent movement up or down between handling sub and casing hanger during descent to ocean floor. Release could be rotation to the right with load applied up or down. Second method could be internal release with wireline. Third method, free drop down drill pipe to ocean floor.

C. Drilling Sleeve - National

1. Could be removed with new design but would call for extra trip to remove larger handling sub out of drilling assembly.

D. Handling Sub - National

1. Shear pins not operational.

2. See Section 2 on Item B, Casing Hanger.

E. Bore Plugger - Baker

1. Not operational, body outside diameter too large for inside diameter of scaled drill pipe. Do not need index sub or collet index on bore plugger tool.

2. Redesign of this tool could be incorporated in top assembly of Edo tool.

F. Jet Sub with Index Sub - Baker

1. Bottom index in jet sub should be re-cut to fit new index dogs in shifting tool.

2. Design should be gone through with Baker representative, Ray Dean, Houston Plant, to find out why tool hung up in index sub after closing of sleeve. Upper dog assembly could have packed off with scale from

inside drill pipe not allowing dogs to release after closing sleeve.

3. For operation on lowering of casing, jet sub can go down with drilling assembly in the open position.

4. With bore plugger or pack off designed in top section of Edo unit, jet sub should decrease time for re-entry into cone base.

G. Hex Re-entry Base - Global Marine design

1. Construction design not heavy enough to carry loads applied by casing and drilling assembly in hanging position under ship. Pad eye loads applied on Unit No. 1 not a fair test due to location of pad eyes on base and location of holes in drill well in relation to location of pad eyes on box beams under rig floor.

2. Second unit constructed the same as the first, but gussets and cross members were added to strengthen cross section of base. All bolted sections were chain welded or welded completely. Fall away pad eyes were also added four feet down from top edge of cone on 11 foot centers. These pad eyes were tied into bottom base by a diagonal brace. See attached drawings for modifications.

VI. Review of Re-entry System

A number of items, reportedly unsatisfactory, were discussed during a meeting on 9 July 1970, at the Edo Western plant.

Present during the discussion were:

James Foster	-	Contract Admin., Edo
Darrell Sims	-	Project Eng., Scripps
Howard Jones	-	Chief Eng., Edo
Gary Behunin	-	Project Eng., Edo
Leon Blurton	-	Project Eng., GMI
Tom Dixon	-	Project Eng., GMI

The unsatisfactory items are listed below, with final conclusions:

1. Operation of sector scan facility of equipment. It was reported that sector scan was not used during re-entry tests because operating personnel and Edo engineers were uncertain as to the reliability of the system if the sector scan mode was selected. It was stated that the possibility existed that switching into this mode might cause the equipment to malfunction, preventing operation in any mode. Our discussion disclosed that this was not the case, that failure to utilize sector scan mode was based on an operational decision to proceed with a successful re-entry without delaying for other tests, such as sector scan. This operational decision was made by those in charge of the test. It was agreed by those present at the Edo meeting that the sector scan problem was solved in Hoboken when the alteration to the "Continuous" - "Sector Scan" switch was performed. The failure of the sector scan to operate, as well as loss of continuous scan signals, was determined to have been caused by mutual capacitance between the adjacent leads in the 250,000 feet Schlumberger cable. This capacitance allowed signals from the motor stepping pulse to override the scan selector signals. This was corrected by altering the scan selector switch to kill the motor stepping pulse during scan selection. Edo will also investigate methods of improving the selectivity of the coders used to isolate various command signals carried through the control cable.

2. Loss of sync between transducer rotator and scan display. This problem was associated with the sector scan problem and the steps taken to correct that malfunction corrected the sync loss as well. In addition to the modification to the scan selector switch, a capacitor was added to stabilize the sync pulses. This last item was accomplished after departure from Hoboken and prior to arrival at the re-entry site. Any apparent loss of sync, i.e. roving targets, was believed to have been caused on

the site by the figure eight swing of the bottom end of the drill pipe in deep water. Such a swing pattern was actually plotted.

3. Distorted sweep pattern on remote indicator. The exact cause of this distortion is not apparent as of now, but it is believed to be due to certain grounding conditions. GMI is to loan 200 feet of TTRSA-4 cable to Edo to conduct tests in an effort to correct this condition.

4. Poor sealing of electronics component section of cone. Galling of threads on the stainless steel male section was noted, as well as some damage to the O-rings. This was corrected on board the Challenger during tests.

5. Beam patterns are being provided.

Repairs - chargeable.

The following repairs necessitated by the flooding of the electronics and motor section must be accomplished.

1. Remove transducer drive motor, disassemble, replace bearings and any other parts damaged.

2. Replace transducer drive shaft.

3. Replace all seals.

Total quoted price = $1,654.00

Modifications

Darrell Sims detailed a number of desirable modifications that, if finally approved, were to be incorporated in the re-entry system. These were:

1. Increase the overlap of the clamshell section to provide greater strength when a bending force is applied to the side of the tool, as occurs when one end is lifted, with the other still on deck. This overlap is minimal now - about 3/4 inch and would be increased to about two to 2 1/2 inches. This is a needed modification.

Cost $1,774.00

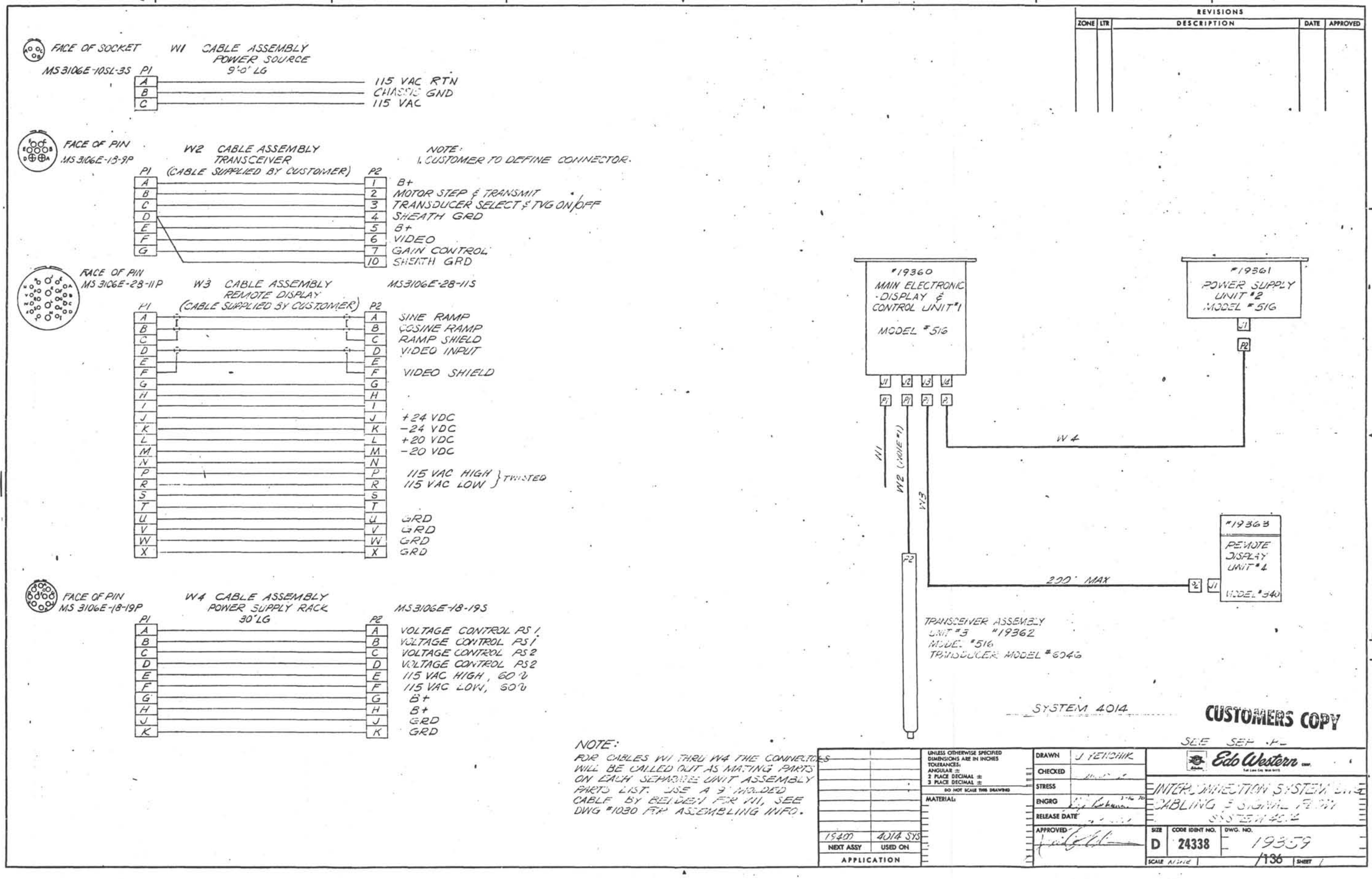
2. Provide ships head flasher facility on the tool to give a visual indication at the same point on each actual 360 degree rotation of the ducer. This

would give a check on the true follow up of the scan display, as well as an assist to the operator in moving his bottom equipment in relation to the target.

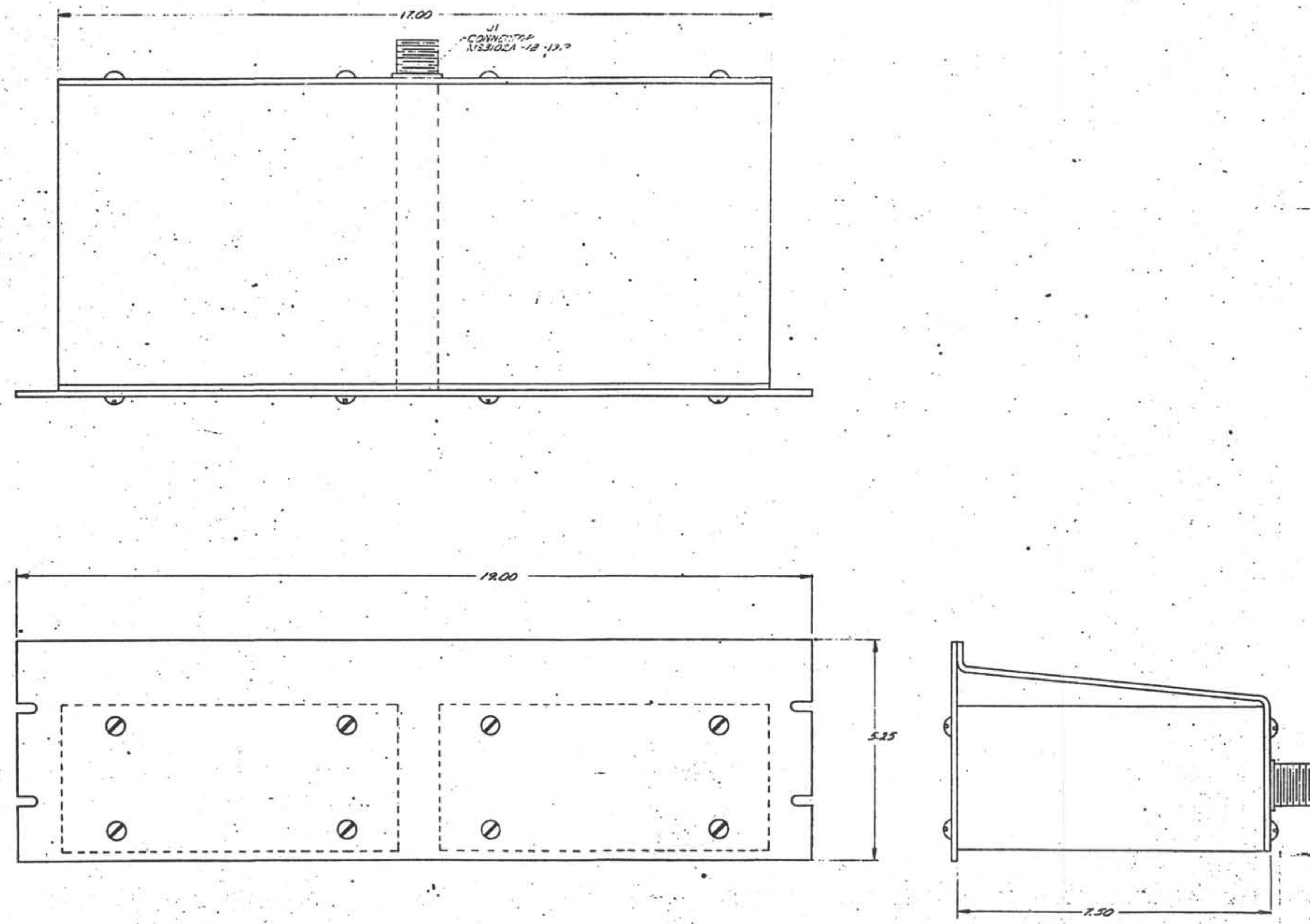
Cost $4,991.00

3. Provide longer persistent scope. This subject was not fully resolved.

All the above modifications and repairs were to be accomplished prior to 1 September 1970 and the equipment delivered to Scripps by that date. Edo will be responsible for satisfactory operation of items under paragraph one (sector scan, sync, and remote display symmetry) until finally acceptable to the Scripps representative.



REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED
FACE OF SOCKET
MS3106E-10SL-3S
W1 CABLE ASSEMBLY POWER SOURCE 9'-0" LG
P1
A — 115 VAC RTN
B — CHASSIS GND
C — 115 VAC
FACE OF PIN
MS 3106E-13-9P
W2 CABLE ASSEMBLY TRANSCEIVER (CABLE SUPPLIED BY CUSTOMER)
NOTE: 1. CUSTOMER TO DEFINE CONNECTOR.
P1 P2
A 1 B+
B 2 MOTOR STEP & TRANSMIT
C 3 TRANSDUCER SELECT & TVG ON/OFF
D 4 SHEATH GRD
E 5 B+
F 6 VIDEO
G 7 GAIN CONTROL
10 SHEATH GRD
FACE OF PIN
MS 3106E-28-11P
W3 CABLE ASSEMBLY REMOTE DISPLAY (CABLE SUPPLIED BY CUSTOMER)
MS3106E-28-11S
P1 P2
A SINE RAMP
B COSINE RAMP
C RAMP SHIELD
D VIDEO INPUT
E
F VIDEO SHIELD
G
H
I
J +24 VDC
K −24 VDC
L +20 VDC
M −20 VDC
N
P 115 VAC HIGH
R 115 VAC LOW } TWISTED
S
T
U GRD
V GRD
W GRD
X GRD
FACE OF PIN
MS 3106E-18-19P
W4 CABLE ASSEMBLY POWER SUPPLY RACK 30' LG
MS3106E-18-19S
P1 P2
A VOLTAGE CONTROL PS 1
B VOLTAGE CONTROL PS 1
C VOLTAGE CONTROL PS 2
D VOLTAGE CONTROL PS 2
E 115 VAC HIGH, 60 ~
F 115 VAC LOW, 60 ~
G B+
H B+
J GRD
K GRD
#19360 MAIN ELECTRONIC DISPLAY & CONTROL UNIT #1 MODEL #516
J1 J2 J3 J4
P1 P2 P3 P4
W1
W2 (HOLE #1)
W3
W4
#19361 POWER SUPPLY UNIT #2 MODEL #516
J1
P2
#19363 REMOTE DISPLAY UNIT #4 MODEL #340
200' MAX
P2 J1
TRANSCEIVER ASSEMBLY UNIT #3 #19362 MODEL #516 TRANSDUCER MODEL #6046
SYSTEM 4014
CUSTOMERS COPY
NOTE:
FOR CABLES W1 THRU W4 THE CONNECTORS WILL BE CALLED OUT AS MATING PARTS ON EACH SEPARATE UNIT ASSEMBLY PARTS LIST. USE A 9' MOLDED CABLE BY BELDEN FOR W1, SEE DWG #1030 FOR ASSEMBLING INFO.
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES: ANGULAR ± 2 PLACE DECIMAL ± 3 PLACE DECIMAL ±
DO NOT SCALE THIS DRAWING
MATERIAL:
19400 NEXT ASSY
4014 SYS USED ON
APPLICATION
DRAWN J YENCHIK
CHECKED
STRESS
ENGRG
RELEASE DATE
APPROVED
Edo Western
INTERCONNECTION SYSTEM DWG CABLING & SIGNAL FLOW SYSTEM 4014
SIZE D
CODE IDENT NO. 24338
DWG. NO. 19359
SCALE NONE
/136
SHEET



DRAWN	J. YENCHIK
CHECKED	
STRESS	
ENGRG	[illegible]
RELEASE DATE	3-3-70
APPROVED	[illegible]

NEXT ASSY	USED ON
12961	516

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR ± 3 PLACE DECIMAL ± 2 PLACE DECIMAL ± DO NOT SCALE THIS DRAWING

MATERIAL:

Edo Western

INSTALLATION DWG.
POWER SUPPLY

SIZE	CODE IDENT NO.	DWG. NO.
E	24338	X11558

SCALE 1/1 SHEET

REVISIONS

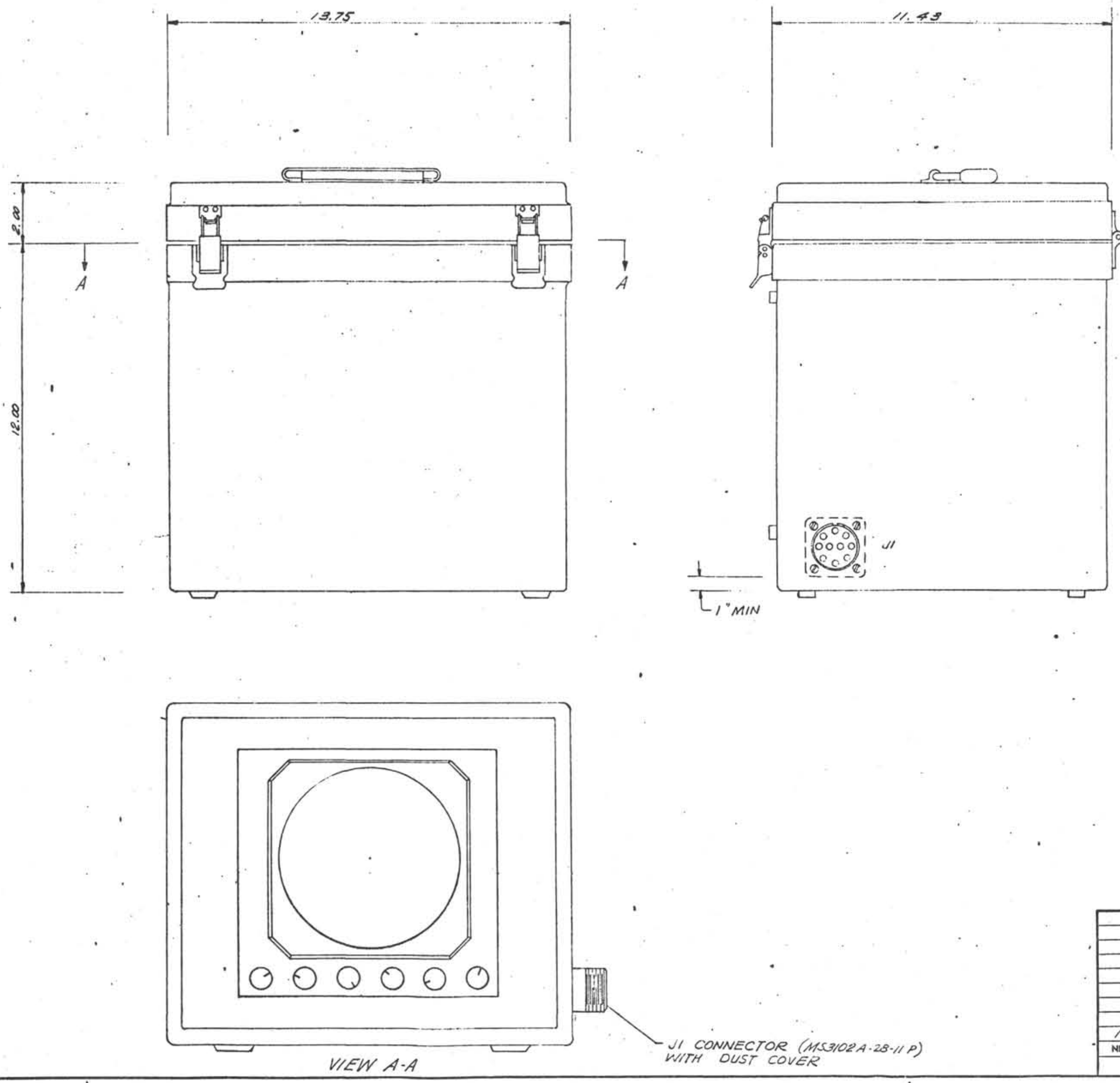
ZONE	LTR	DESCRIPTION	DATE	APPROVED

DWG NO. E X11558

CUSTOMERS COPY /137

ZONE	LTR	DESCRIPTION	DATE	APPROVED

REVISIONS



CUSTOMERS COPY

19363	516
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR ±
2 PLACE DECIMAL ±
3 PLACE DECIMAL ±
DO NOT SCALE THIS DRAWING

MATERIAL:

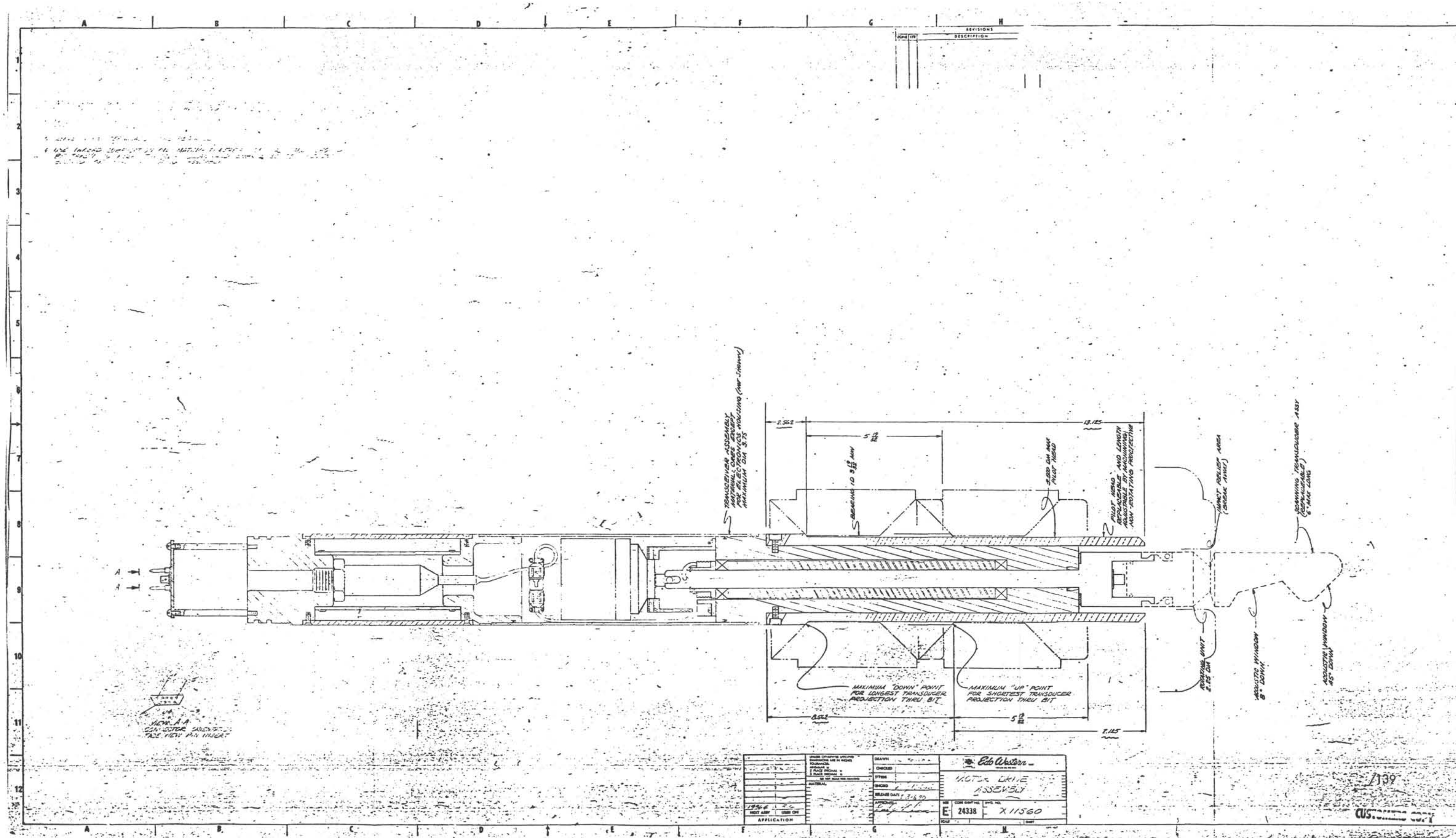
DRAWN	J. YENCHIK
CHECKED	
STRESS	
ENGRG	
RELEASE DATE	
APPROVED	

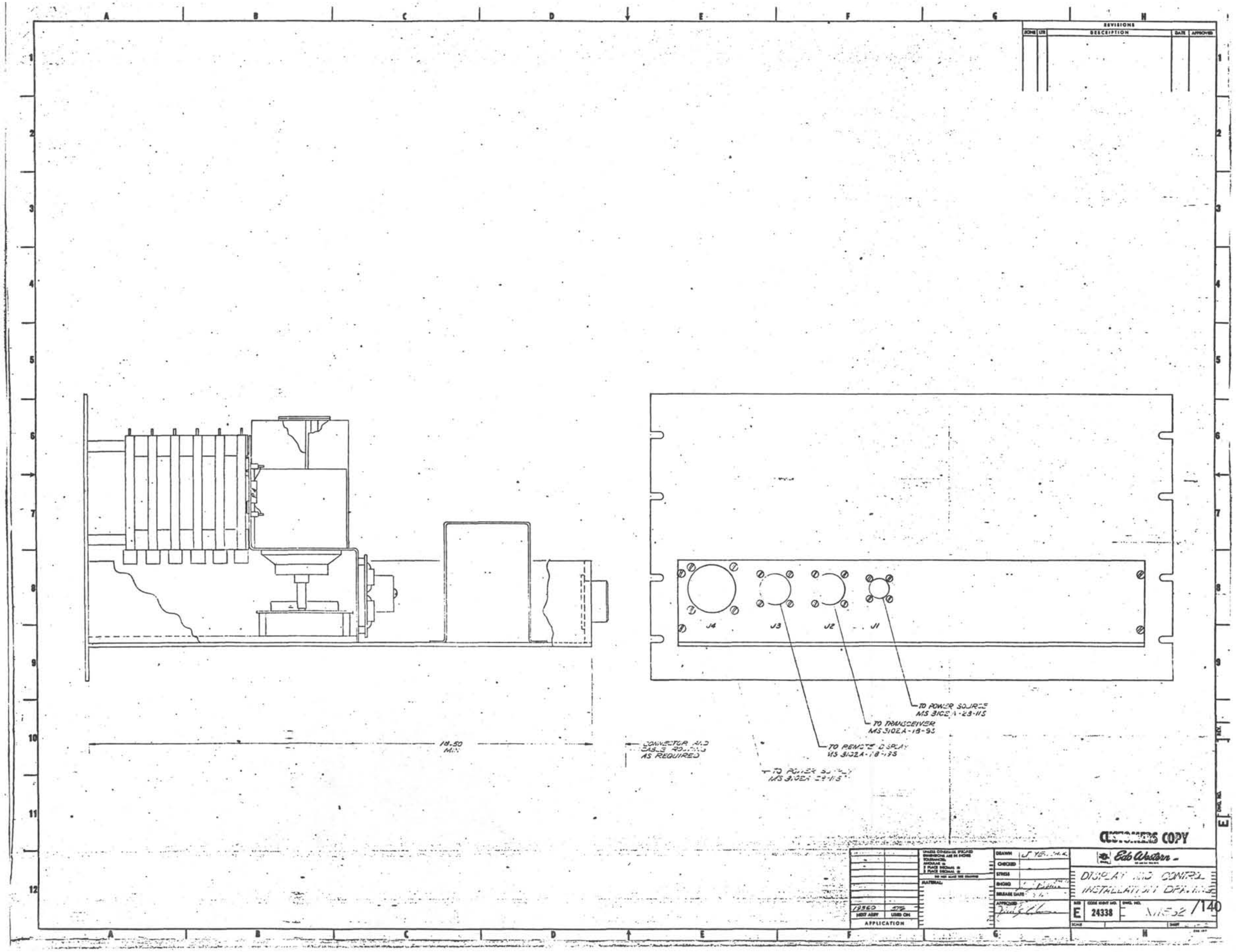
Edo Western Corp.

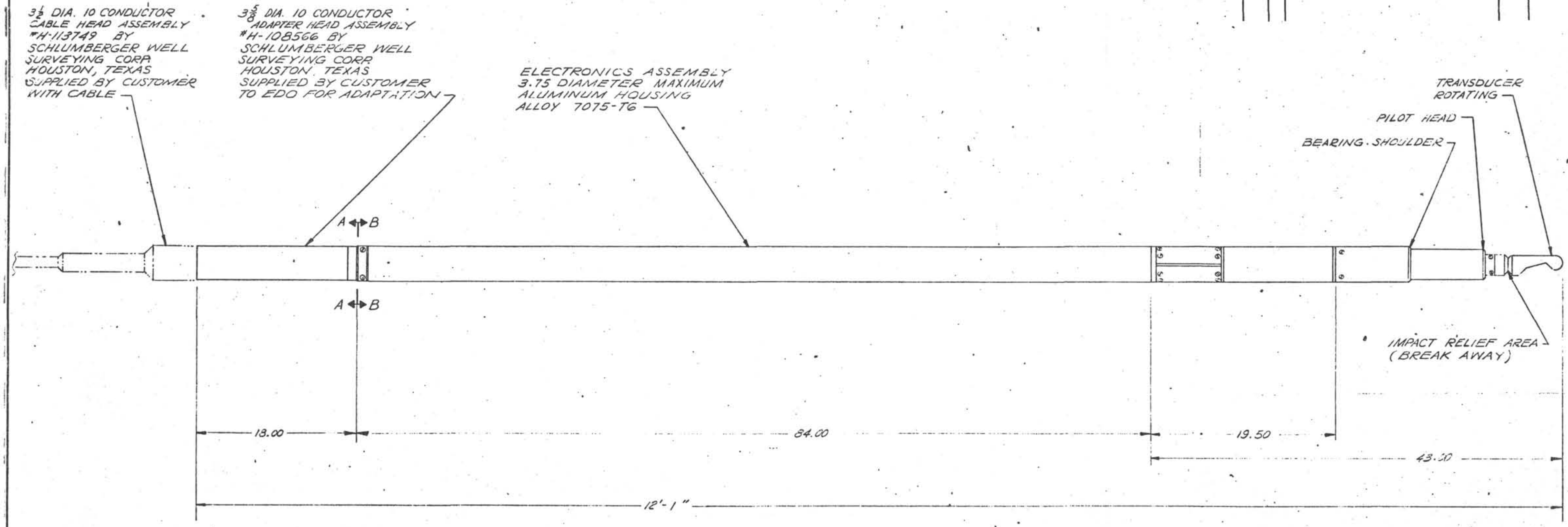
INSTALLATION DWG
REMOTE DISPLAY
A MODEL 340 UNIT

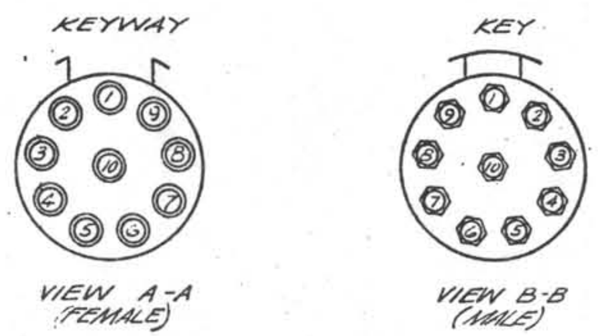
SIZE	CODE IDENT NO.	DWG. NO.
D	24338	X11559 /138

SCALE 1/2 SHEET 1


REVISIONS
DESCRIPTION
MAXIMUM "DOWN" POINT FOR LONGEST TRANSDUCER PROJECTION THRU BIT
MAXIMUM "UP" POINT FOR SHORTEST TRANSDUCER PROJECTION THRU BIT
2.562
8.562
13.125
7.125
VIEW A-A
Edo Western
MOTOR DRIVE ASSEMBLY
E
24338
X 11560
APPLICATION
MATERIAL
DRAWN
CHECKED
RELEASE DATE
APPROVED
NEXT ASSY
USED ON
19344
CUSTOMER COPY


J4
J3
J2
J1
TO POWER SOURCE
TO TRANSCEIVER
MS 3102A-18-9S
CONNECTOR AND
AS REQUIRED
18.50
CUSTOMERS COPY
Edo Western
DRAWN
CHECKED
STRESS
ENGRG
RELEASE DATE
APPROVED
MATERIAL:
USED ON
APPLICATION
E
24338
/140





PIN NUMBERING AND ORIENTATION FOR SCHLUMBERGER CONNECTOR

PIN NO.	DESCRIPTION - SIGNAL
1	B+
2	MOTOR STEP & TRANSMIT
3	TRANSDUCER SELECT & TVG ON/OFF
4	GAIN CONTROL
5	B+
6	VIDEO
7	SHEATH GRD
8	NO CONNECTION
9	NO CONNECTION
10	SHEATH GRD

CUSTOMERS COPY

NEXT ASSY	USED ON 516	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR ± 2 PLACE DECIMAL ± 3 PLACE DECIMAL ± DO NOT SCALE THIS DRAWING	DRAWN J. YENCHIK
APPLICATION		MATERIAL: STAINLESS EXCEPT AS NOTED AND ON TRANSDUCER HOUSING & ROTATE SHAFT	CHECKED / STRESS / ENGRG 4/16/70 / RELEASE DATE / APPROVED

Edo Western Corp.

INSTALLATION DWG FOR TRANSCEIVER ASSEMBLY /141

SIZE D | CODE IDENT NO. 24338 | DWG. NO. X11586

SCALE NONE | SHEET 1

REVISIONS: ZONE | LTR | DESCRIPTION | DATE | APPROVED

Edo Western CORP.

ACOUSTIC CALIBRATION FACILITY NO.______

Figure ________

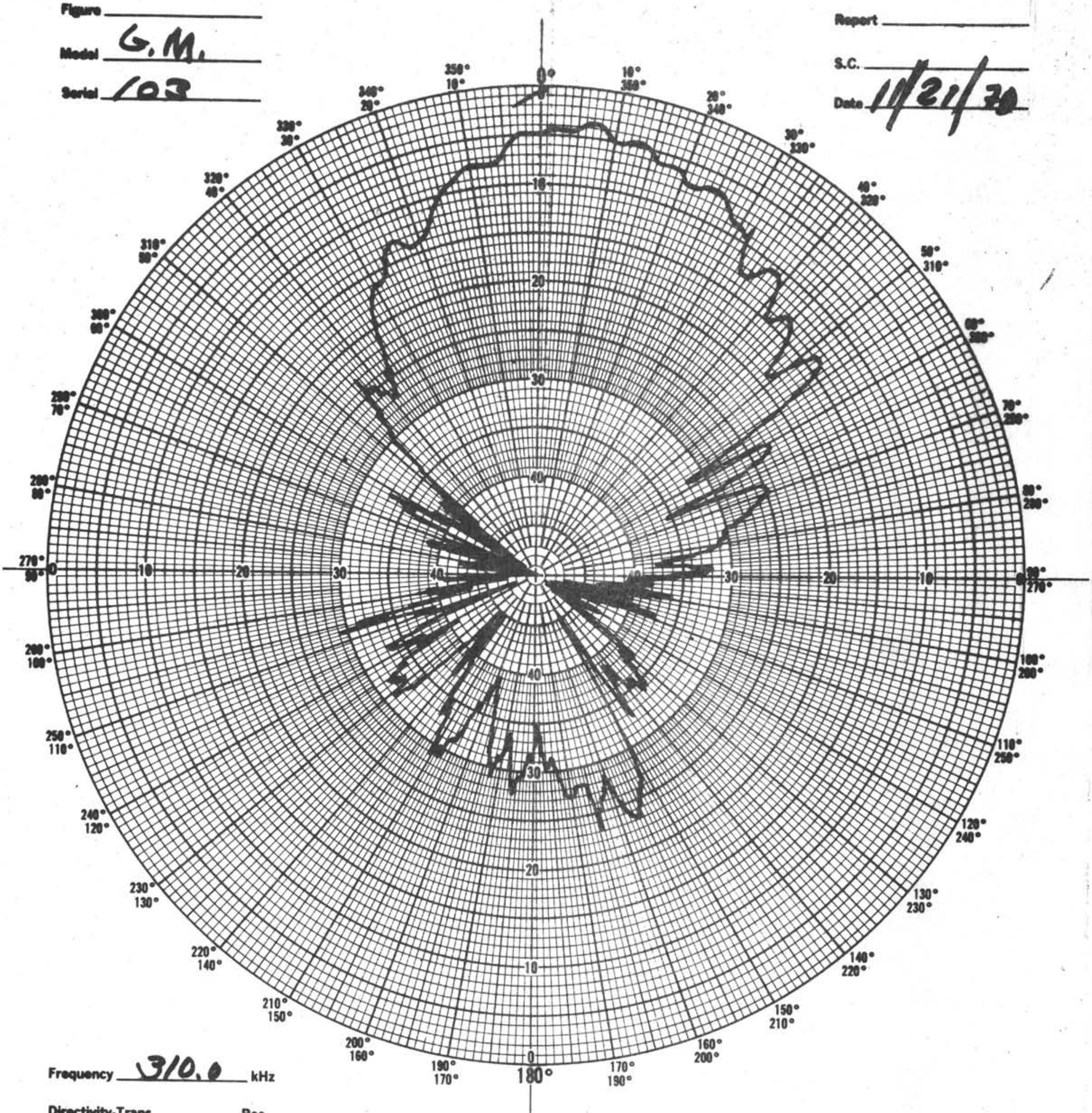
Model G. M.

Serial 103

Report ________

S.C. ________

Date 11/21/70



Frequency 310.0 kHz

Directivity-Trans ______ Rec. ______

Transducer Orientation 8° DOWN

Test Depth 10 ft.

Test Distance 18 ft.

Xmit = 30 v p/p
Rec = 14 mv p/p
5-5 TR/V = 59.4 dB

Standard Model ________

Water Temperature ______ °F

Remarks /142

EDO 2009

Edo Western CORP.

ACOUSTIC CALIBRATION FACILITY NO. 2

Report ______

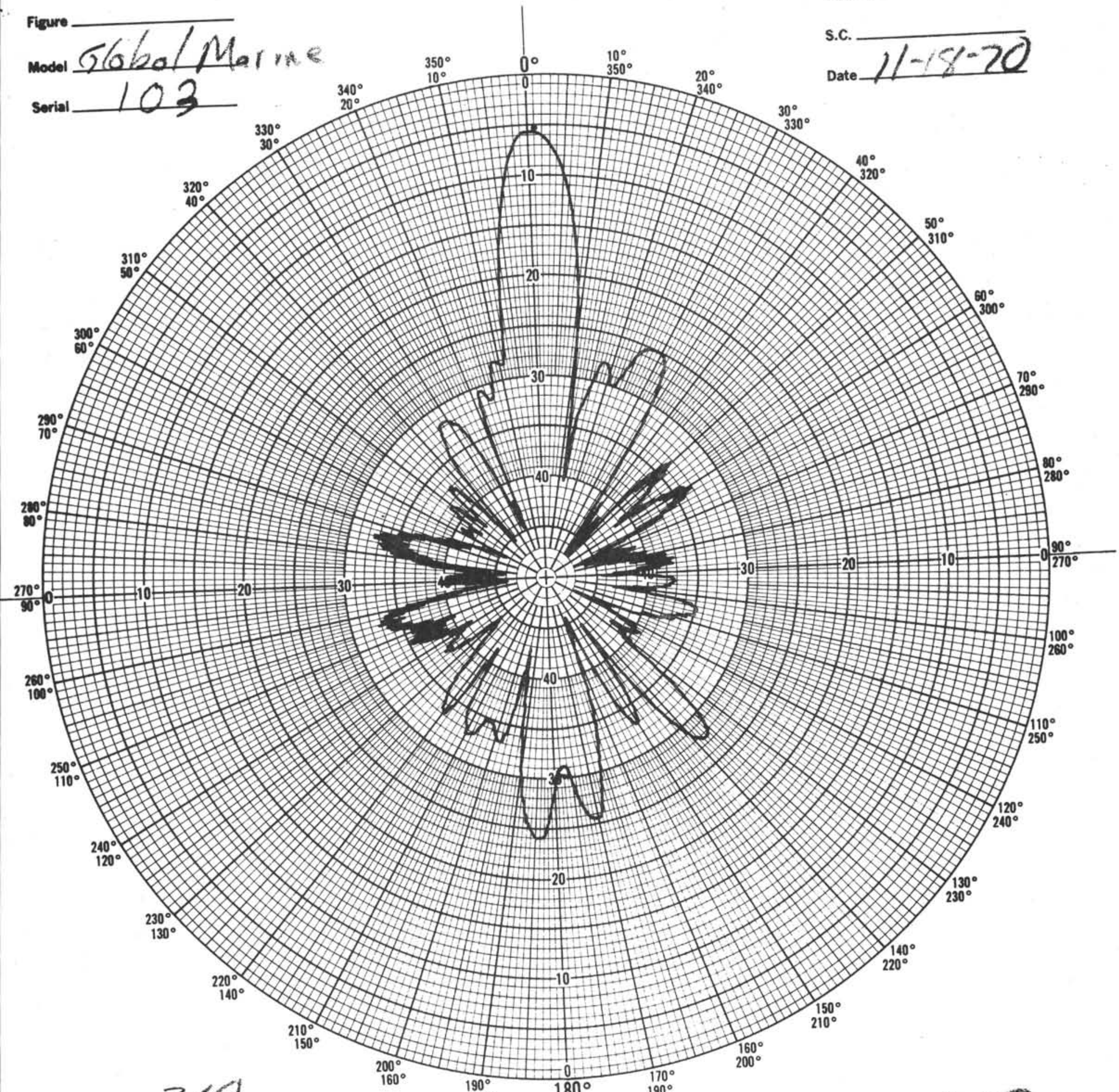
S.C. ______

Date 11-18-70

Figure ______

Model Global Marine

Serial 103



Frequency 310 kHz

Directivity-Trans ______ Rec. ______

Transducer Orientation Narrow

/143

Test Depth 10 ft.

12 ft.

Standard Model E-27

Water Temperature 45 °F

Remarks

Edo Western corp.

ACOUSTIC CALIBRATION FACILITY NO. ______

Figure ______

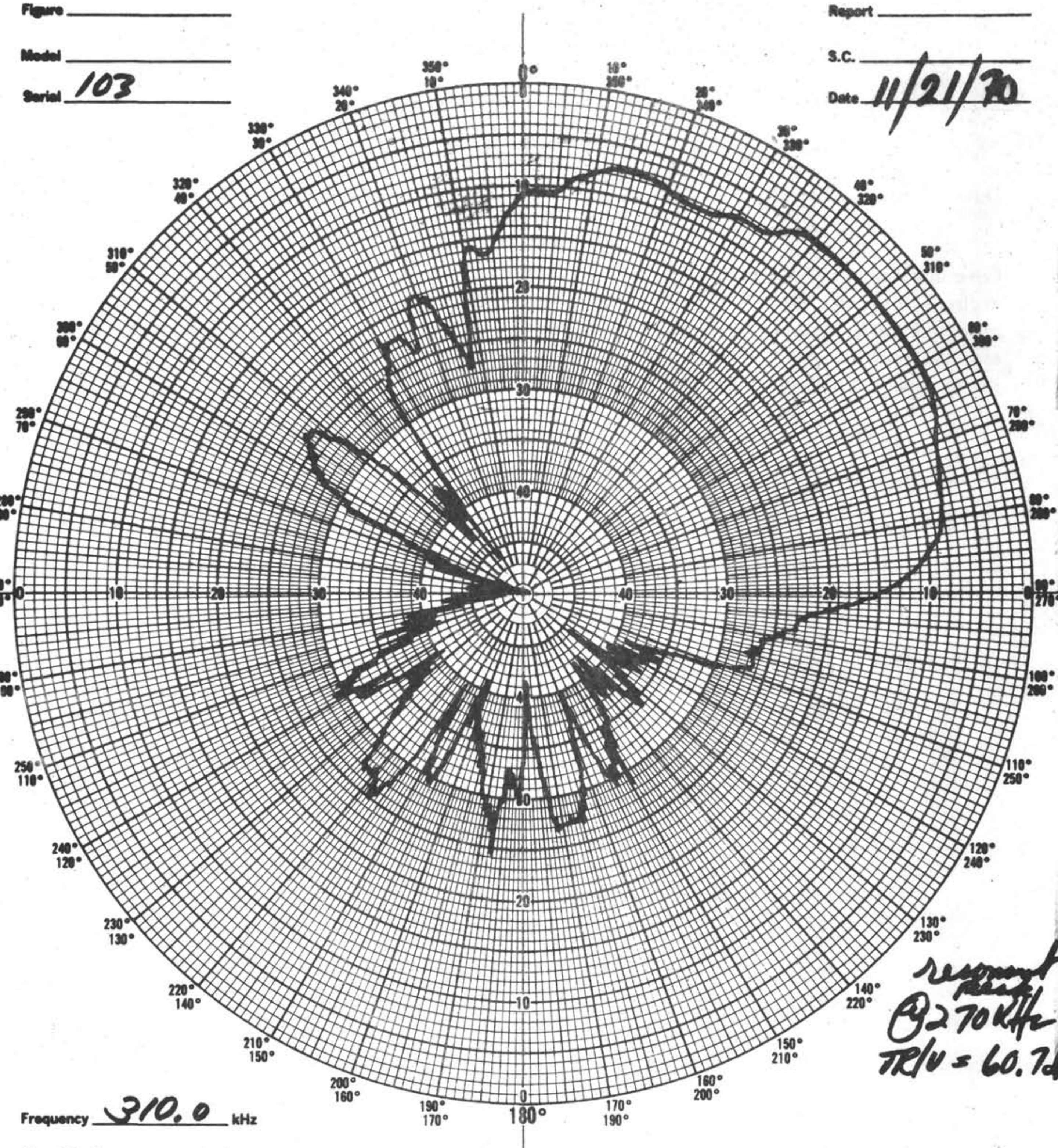
Model ______

Serial 103

Report ______

S.C. ______

Date 11/21/70



resonant peak @ 270 kHz
TR/V = 60.7 dB

Frequency 310.0 kHz

Directivity-Trans ______ Rec. ______

Transducer Orientation 45° DOWN

Test Depth 10 ft.

Test Distance 12 ft.

416
5-6

Xmit = 30 vp/p
Rec = 53.3 dB

Standard Model ______

Water Temperature /144 °F

Remarks ______

EDO 2009

APPENDIX E

To: M.N.A. Peterson

From: V. F. Larson

Subject: Re-entry - Site 146
Report on Operational Testing

Date: January 27, 1971

Re-entry was used for the first time as an operational tool on Site 146 in the Caribbean during December 1970. Based on this work, the following summary has been prepared along with conclusions and recommendations. A detailed review of the operation is also included, along with memoranda from the Captain and Drilling Superintendent of the Glomar Challenger, on ship's positioning and keelhaul operations.

SUMMARY

1. A procedure for keelhauling the re-entry cone was developed which will allow this operation to be accomplished in seas of ten to 12 feet with no personnel over the side or in the water. Major change was the lowering of the cone into the water on its side.

2. The attachment of the casing to the re-entry cone was effective and simple. The mechanical strength of the cone and its connection to the casing are adequate. Only minor modifications are required.

3. Washing in casing was done with the bit approximately four meters above the casing shoe. The pack-off was ineffective. The last ten meters washed in with difficulty.

4. Attachment of the casing and cone to the bottom hole drilling assembly was effective. Mechanical release was made with one trip with the sand line. The shifting tool was modified to correct many faults, however, the confidence level remains low.

5. Re-entry was made, without the aid of jetting, by ship's positioning alone. Techniques were developed which should, ultimately with experience, allow re-entry to be accomplished in less than three hours of positioning in seas of up to 12 feet.

6. No valid evaluation of jetting effectiveness was made. Use of required bore pluggers increases round trip time with scanning sonar approximately one hour. The jet sub failed to close on the first attempt with the shifting tool.

Approximately 3 1/2 hours are required to close and test the sub. It appears possible to open the sleeve of the present jet sub with wireline coring tools.

7. The scanning sonar performed well. A weak point is the torpedo connection, which must be disconnected on each trip because of the bore plugger. Experience was gained in interpreting the height of the drill string above the guide cone. This information is essential in re-entry.

8. Mechanical indication of re-entry was attempted. Tools utilized were crude and ineffective. Because of the crucial importance of verification of re-entry to the utilization of the ship's time, this aspect must be improved.

9. More equipment was expended than anticipated. Some of these losses were due to inexperience. Some due to poor judgement. Some were not foreseen. Many tools can be eliminated or simplified.

10. Chert stringers were first encountered at a sub-bottom depth of 406 meters. Continuous coring followed until the core bit had 29 rotating hours at a penetration of 702 meters. The bit bearings were loose, however, several hours of life remained. Experience on the Glomar Challenger has revealed the bearing life of present insert core bits to be as great as 40 hours (average 30 hours). Smith Tool will furnish sealed bearing bits for Leg 16. We are hopeful that experience will reveal extended bearing life. Recent advances by Hughes Tool in journal bearings indicates that within a year we should expect a bearing life greatly in excess of present sealed bearing bits (up to 100 percent plus). The re-entry bit was used for 17 hard rotating hours and one cone was lost. Approximately ten hours were spent drilling on basement. The formations near basement were a dense silicified rock and many chert stringers were penetrated.

11. The amount of casing used (50 meters) was based on Site No. 29 some 25 miles distant. No preliminary investigation of bottom was made. PDR (sonic) measurement of ocean floor was 3949 meters. Drill pipe measurements of the ocean floor were five to eight meters lower. This difference caused the failure of the first re-entry attempt. No sloughing of the upper hole was noted.

CONCLUSIONS

1. That we now have a simple operational re-entry system that will work in almost all sea conditions encountered by the Glomar Challenger.

2. That the ship's crew now working on the Glomar Challenger (odd numbered legs) has the training and experience to conduct re-entry without special

assistance. Some assistance will be required for the alternate crew.

3. That no major modifications are required in the present re-entry system.

4. Some equipment designs and operational techniques need to be simplified and/or made more reliable.

5. That a need for jetting does not appear to exist, however, tools are aboard to utilize jetting if needed.

6. That previous cost estimates are valid.

7. That an exploratory hole prior to commitment of re-entry would be highly desireable to determine:

   a. Need for re-entry.

   b. That required hole stability exist.

   c. Approximate life to expect of core bits.

   d. Depth of ocean floor referenced to drill pipe.

8. That a knowledge of the ocean floor depth referenced to drill pipe measurements is essential.

RECOMMENDATIONS

1. Dependent on funding, that re-entry be made available as required.

2. That plans be made to schedule re-entry training when required on even numbered legs. That we provide required supervision and technical backup needed to thoroughly train the even numbered leg personnel.

3. That no additional major research and development effort be expended on re-entry.

4. That present designs and techniques be reviewed, simplified and standardized as possible. Some items would be:

   a. Modify cone for handling on its side and increase bearing capacity.

   b. Remove fall away pad eyes.

c. Design better shear pin re-entry indicator.

d. Eliminate backup lowering systems.

5. That development work on jetting be discontinued until a demonstrated need is shown.

6. That a continued re-evaluation of need for re-entry be made by our scientists based on recent improvement in penetration ability.

7. That this re-evaluation along with previous cost analysis be reviewed in determining proper priority to give to any additional re-entry expenditures.

   NOTE: One set of re-entry equipment is now aboard the Challenger. Estimate a minimum of four months to provide additional equipment.

8. Unless an area has been previously cored with insert bits, that a run be made with a core bit without re-entry to ascertain actual bottom conditions, ocean floor depth as reference to drill pipe and actual need for re-entry.

DETAIL

KEELHAUL PROCEDURES

A procedure was developed which appears suitable for use in most sea states to be encountered with the Glomar Challenger. The system requires no men over the side nor any diver assistance.

A first keelhaul attempt failed and a cone was dropped when procedures similar to those used during mechanical re-entry trials were utilized. Actual failure occurred when the re-entry cone was raised out of the water to free lines fouled on the reflectors. Failure occurred in the 3/4 inch whip line on the crane. As the breaking strength of this line is approximately 20 tons and the safe working capacity of the after crane (used in handling) at the required boom angle is the same, it was concluded that the 3/4 inch line be retained as the weak point in the handling system.

The procedure used is detailed below. When entering the water the cone is on its side and allows the water to quickly move out when raising and vice versa. (Failure of a cone to do this in an upright position was the apparent cause of failure druing lowering of the first re-entry cone).

Step No. 1

Assemble re-entry cone in an upright position. Weld seams and bolted joints. Reinforce leg to be lifted with. Place one inch doubled slings in each lifting eye (each sling 56 feet long or 28 feet effective) and shackle into crane whip line. Make up short bridle on reinforced leg and shackle into crane block.

Step No. 2

Pick up cone with ship line. Use air tuggers to restrain cone. (Use tuggers both from rig floor and main deck.) Pick up on crane blocks and turn cone on its side. Remove whip line and secure doubled slings inside cone.

Step No. 3

Swing cone onto port side of main deck with open end facing towards the starboard bow. Keep strain on crane block to avoid damage to reflectors.

Step No. 4

Hook up keelhaul lines to main doubled lifting slings. Use at least one inch keelhaul lines rigged up to derrick travelling blocks (should be 120 feet long).

Step No. 5

Hook up doubled 3/4 inch line to crane. Whip line and shackle bight into lifting bridle (length of 3/4 inch line 110 feet or 55 feet doubled). Take load with whip line and remove crane block. Take up slack on keelhaul lines.

Step No. 6

Swing cone over the side with open end facing the moon pool. Keelhaul line act to keep cone facing correctly.

Step No. 7

Assure lines are not fouled on reflectors. Lower cone quickly while hauling in on keelhaul lines. When ball on whip line even with bulwark cut one 3/4 inch line with cutting torch and retrieve same.

Step No. 8

Pick up on keelhaul line carefully and shackle doubled lifting slings from cone onto sling prepared to receive same.

Step No. 9

When ready to lower cone one eye on each doubled lifting sling is cut and the wire retrieved.

RUNNING CASING AND CONE

Four joints of Range three 13 3/8 inch outside diameter casing were run. The shoe of the casing was cut on a taper to facilitate entering the cut-out in the cone. No problems encountered. The hanger was made up on top of the casing.

The casing was then lowered to the top of the permanent section of horn in the moon pool using long slings on the casing elevators. A core barrel and three d.c.'s were made up which located the bit approximately 15 feet above the shoe. The latch sub and latch sub index were then added and lowered to the casing hanger.

A plexiglas pack-off was affixed below the latch sub. It was difficult to install due to relative motion of casing and drill collars. It appeared later that the pack-off failed.

Latching of the casing to the drill collars was done with dispatch in the moon pool area. The casing was then lowered into the re-entry cone and latched securely. The supporting slings were released by cutting one eye with a cutting torch.

The re-entry cone and casing were then lowered slowly with the Rotary Table locked to minimize any possible loss. Casing was then washed in from 3949 to 3999 meters. PDR ocean floor measurement was 3949 meters. Some resistance appeared at 3954 meters drill pipe measurement. The casing took considerable weight to penetrate the last 18 meters (up to 10,000 lbs) with full pump 60 spm 6 1/2 inches x 16 inches. It now appears that the pack-off failed. In future jobs it would seem prudent to locate the bit at the shoe of the casing and discontinue use of a pack-off. (This is reported to be a common Gulf Coast practice when washing in conductor.)

The Baker shifting tool was then run on wireline and the latch sub shifted. Approximately one half hour was spent in releasing from the cone. In the process of releasing, the base of the cone appeared to move down to at least 3954 meters. The shifting tool was difficult to retrieve and only came free after an hour of working and circulating. When recovered, one of the profile keys was found to be broken. It had the appearance of a brittle failure at an area of minimum thickness.

RE-ENTRY

After three days of coring (approximately 29 rotating hours on the bit), the drill string was pulled. The latch sub spacer was pulled out on the latch sub and found to be in good condition. The latch sub also appeared in good condition, however one retaining bolt had turned slightly and was somewhat loose.

A new bit was run with a jet sub directly above the core barrel. An attempt was made to improvise a shear type re-entry indicator, however it was fruitless. The Edo tool (scanning sonar) was run with the bit at 3940 meters which would allow lowering for re-entry to 3958 meters. (Eighteen meters is maximum that can be handled with the swivel on.) The Edo tool was equipped with the seal assembly bore plugger and by-pass. Seal was

/150

effected on the latch sleeve of the core barrel (special 3.87 inches inside diameter sleeve).

The target was sighted 300 feet plus away and the ship quickly maneuvered to within 100 feet of the cone. Jetting was then attempted. No apparent motion attributable to jetting was observed. (60 spm 825 psi with 6 1/2 inches x 16 inches pump 400 gallons per minute plus.) (When tool was pulled it was noted that the by-pass had probably not closed.)

Alternate means of positioning were then tried. Both semi-automatic and manual modes of operations used. In semi-automatic loss of computer memory caused an excursion of several hundred feet on return to automatic. After manual, excursion on return to automatic was less than 200 feet. In retrospect it appears that maneuvering was too fast in both modes of operations to fully evaluate effectiveness.

Hydrophone displays were shifted to give a 54 foot shift in automatic and water depths were varied. After some trial and error the mechanics of maneuvering in automatic were determined (see memo by Captain Clarke).

It was noted that, as the drill pipe approached the re-entry cone, the near reflectors would fade. The drill pipe was successively lowered to 3949 meters. A good display of all targets was found on the 25 foot range setting on the oscilloscope and a re-entry was attempted. Later it was concluded that the attempt was futile as the top of the cone was approximately 3957 meters and the length of pipe available to lower was 3958 meters. These depths are only approximations based on calculations from ranges to reflectors from the scanning sonar.

As a re-entry was thought successful the Edo instrument was pulled and the drill pipe lowered 40 meters. Some resistance to penetration was observed, however it was thought to be cavings.

The shifting tool was then run to close the jet sub. The tool again required considerable working and circulating to free. The profile keys came out in tact (they had been annealed after the run to release the casing). The bore plugger was dropped and circulation rates or 1,150 psi at 60 spm observed indicating that the jet sub was still open. This operation was repeated as a double check with similar results. Cores recovered from the bore plugger clearly indicated recent sediments and an abortive re-entry.

A second run with the shifting tool was made to close the jet sub. The bore plugger was then run on wireline and closure verified.

A second try at re-entry was then attempted. The Edo tool was run with 60 degree transducer and a try made to watch for signs of a cone as we pulled out of the mud. This operation failed when the transducer broke off when encountering mud.

Primarily due to concerns with the jet sub possibly opening when dropping a core barrel, a trip was made and the jet sub removed. A single was added to the string to allow a depth re-entry attempt.

The Edo tool was run and the target sighted approximately 90 feet from the vessel. The ship was positioned over the cone in two hours and 20 minutes and re-entry made. When the drill pipe was lowered weight was taken at 3961 meters and the same weight (10,000 lbs plus or minus) observed at 3965 meters. The drill pipe would not rotate. Upon raising the drill pipe the weight on the bit remained constant until 3961 meters at which time it quickly fell off. The drill pipe was then lowered freely to 3967 meters.

It was concluded that the bit had stopped at the base of the cone and subsequent lowering was compensated for by curvature in the drill string.

The Edo sonar tool was then pulled and several doubles added to verify re-entry. The hole was free to within 15 meters of bottom. After cleaning out , the hole was cored to basement. (Seventeen hours of rotating.)

Two sidewall samples were unsuccessfully attempted. However, when the bit was recovered, one cone was missing and the center was found distorted.

s/ V. F. Larson
t/ V. F. Larson
Operations Manager
Deep Sea Drilling Project

VFL/pd

Proposed Method for Re-entry Using Vessel's Positioning Equipment Only

1. Leave vessel in automatic mode of operation during all operations and leave vessel on same heading.

2. During all observations make frequent notation of blip heading on sonar oscilloscope to assure that Edo tool has not slipped in azimuth. Also be certain that all observations of range and bearings are taken with the vessel centered over beacon display of computer oscilloscope.

3. All movements of vessel, range and bearing of target should be plotted on U.S. Navy maneuvering board HO 2665-20 with original positioning beacon plotted as center and the vessel's position in relation to this beacon plotted using any offsets previously put into computer. This must be done so that the final movements of the vessel by use of depth changes will be along a path angle in direct relation to the true position of the positioning beacon.

4. Using 500 feet scan on sonar oscilloscope and with vessel directly centered over positioning beacon display on computer take initial range and bearing of re-entry cone target. Plot the circle of observed range from the vessel's plotted position.

5. Make an arbitrary move of vessel by using offsets in one direction only, preferably as near as possible to the vessel's heading. (Vessel's heading will of necessity be existing elements and has no significant effect upon the operation.)

6. Observe whether offset move has increased or decreased the range of re-entry cone target. If vessel's move has increased range it immediately becomes obvious that the arbitrary move was in the wrong direction and in this case the offsets should be removed and opposite direction offsets should be put into computer. Offsets of 200 to 400 feet should be used depending upon the distance of the original range of target. If there has been a substantial decrease in range of target allow sufficient time for vessel and drill pipe to settle and then by an average of new ranges on target draw another circle of range from the vessel's newly plotted position. This circle will intersect the original plotted range circle at two locations either of which could be the potentially true position of re-entry cone.

7. The approximate true position of the re-entry cone target may now be ascertained by having observed the apparent relative motion of the re-entry target either to the right or left, the correct position may be selected.

8. Having ascertained the true position of the re-entry cone, now draw a line from the center of the plotting sheet (i.e. true position of the beacon) through the true position of the re-entry cone.

9. Now! Before any further movement of the vessel plot three or more alternate coordinates of 100 foot offsets adjacent to the position of the re-entry cone. Now draw a dotted line from the center of the plotting sheet disecting these coordinates to the outer edge of the plotting sheet. (It is along these lines that the vessel may be moved by altering depth settings.)

10. If desired, at this point the drill pipe may be rotated to display true azimuth as follows:

    a. Plot the true position of the re-entry cone target.

    b. Calculate the relative bearing.

    c. Rotate the drill pipe with chain tongs until the relative azimuth of the re-entry cone is displayed in its proper position on the sonar oscilloscope.

    (Please note that the above procedure may be desirable to the master, however in our present stage of evaluation of re-entry capabilities it is not a requisit.)

11. Now! By visual inspection of the plotted alternate coordinates, select that set of coordinates whose azimuth will most closely approach the target by adjustment of depth selections.

12. Now move the vessel in 100 foot increments by "offsets" to your selected coordinates.

13. At this point a brief explanation of the movements of the vessel by depth adjustments is appropriate.

    a. To decrease range along plotted azimuth to beacon "increase" water depth.

    b. To increase range from beacon "decrease" water depth.

    c. The following formula may be used to pre-compute "closest point of approach" of re-entry cone target.

$$\text{Depth setting required} = \text{True Depth} \times \frac{\text{Range} \quad \text{Beacon}}{\text{New Range Desired}}$$

$$\text{or } X = \text{true Water depth} \times \frac{\text{Coordinate selected range from beacon}}{\text{Desired range over cone from beacon}}$$

EXAMPLE

In attached "example plot" the water depth is 13,000 feet. The coordinate selected range from beacon is 590 feet, the position of re-entry cone target from beacon is 450 feet. $X = 13{,}000 \text{ feet} \times \frac{590}{450} = 16{,}900 \text{ feet}.$

(16,900 feet = required depth setting to place vessel over sonar re-entry cone within ten feet in example.)

14. Now after the vessel and bottom hole assembly has settled over new offset coordinates, increase or decrease depth settings as required to approach "CPA" of re-entry cone target.

15. A third alternate should always be borne in mind and that is our capability of moving "forward" or "aft" along a line of azimuth with our heading a distance of approximately 54 feet by selecting alternate hydrophone selections.

16. The above explained method of re-entry using vessel positioning only, does not preclude the future possibilities of movement in semi-automatic or manual modes of operation as our evaluation of ideas and techniques develope. However, at our present stage of development of techniques it is the firm belief of the writer that an automatic mode of operation is by far the most expeditious and desirable.

17. Please refer to attached plotting sheets for a graphic display of vessel and target movements. Also an approximate evaluation of the time required to re-enter using this system.

18. The writer would like to acknowledge the fact that the "maneuvering board" techniques, the "line of azimuth" by depth settings, the "change of hydrophones" technique were in no way solely the "concept" of the writer and each of the following persons spent many long hours and much research to make this concept of re-entry by "vessel positioning only" a reality. Mr. "Swede" Larson, Mr. Roy Anderson, Mr. Bruce Leavitt, Mr. Carl Wells, and Dr. Terry Edgar.

This method also does not preclude the future possibility of "jetting" using a "jet sub" on which Mr. Darrell Sims and Mr. "Swede" Larson spent many long hours of hard work. And last, but certainly not least, it is needless to say that without the advice, help, close cooperation and just plain "hard work" on the part of Mr. Travis Rayborn and his superb crews, not only re-entry but our entire program could not exist. The techniques in assembly and keelhauling of the re-entry cone was by far one of the finest pieces of "rigging know-how" I have ever seen.

Respectfully submitted,

s/ Captain Joseph Clarke
t/ Captain Joseph Clarke
Master , Glomar Challenger

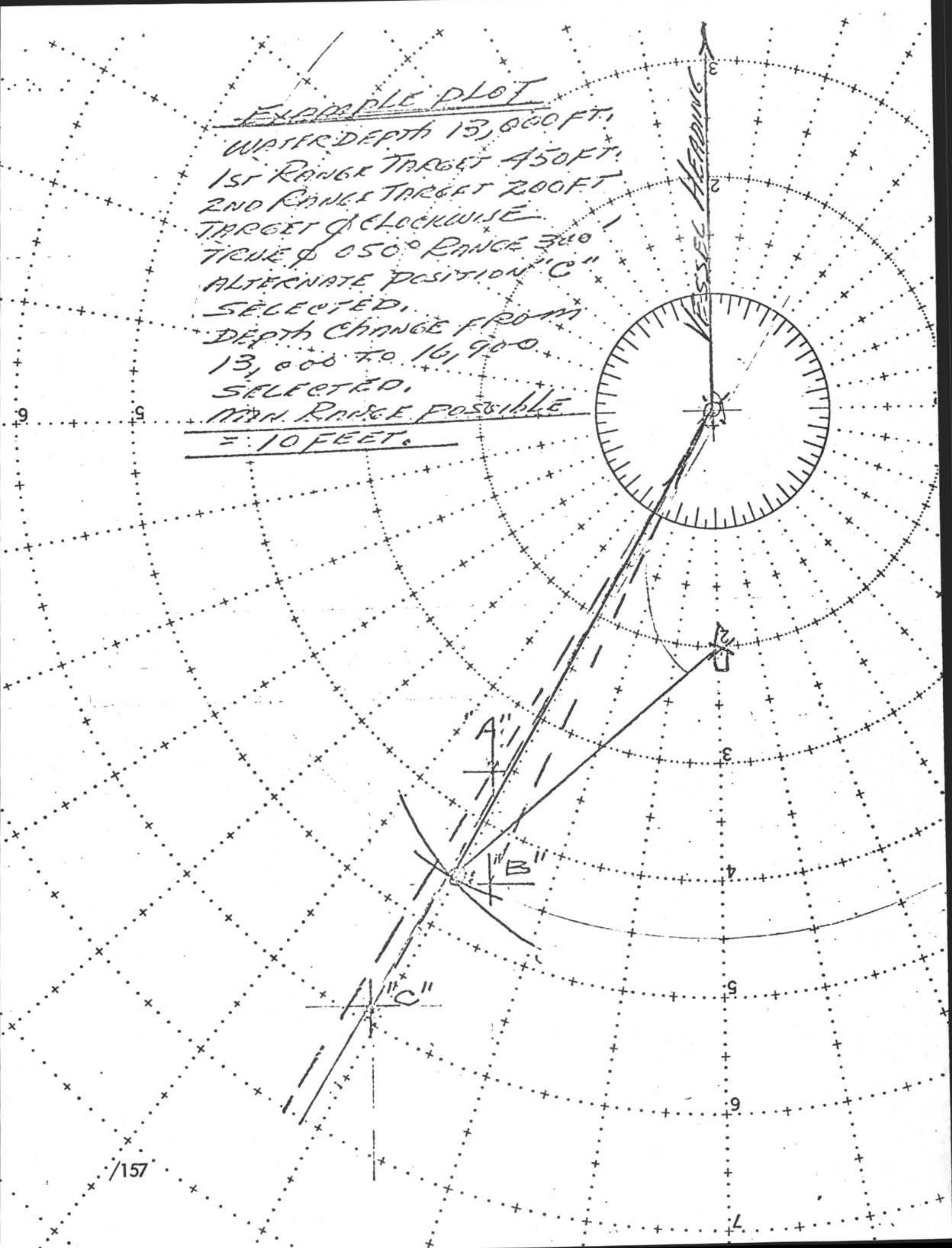
TIME ESTIMATE

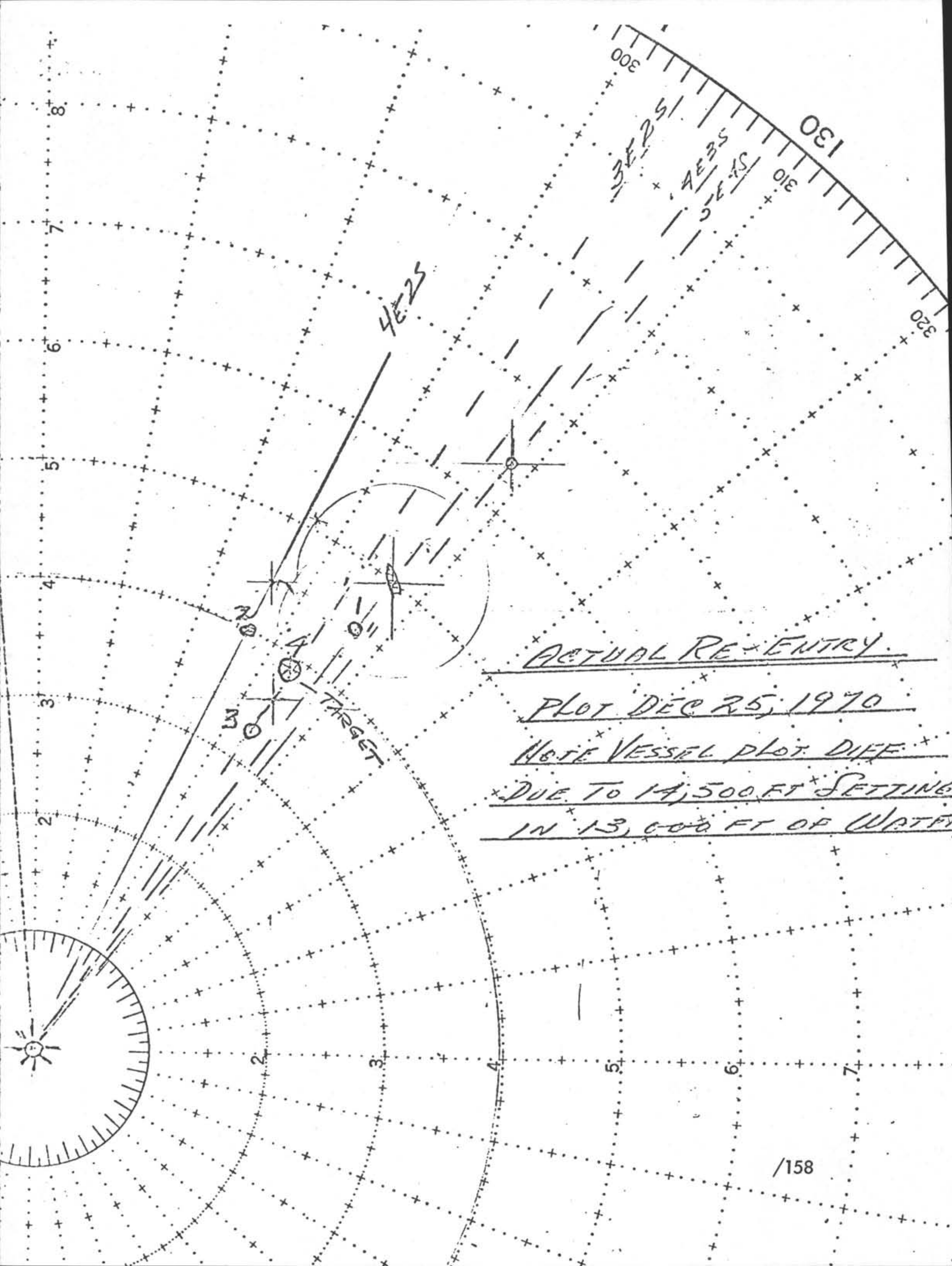
1.	Sight sonar target	20 minutes
2.	Initial move	10 minutes
3.	Second move and plotting	20 minutes
4.	Third move and plotting	30 minutes
5.	Fourth move and settling	30 minutes
6.	Close by depth	10 minutes
	Total time	2 hours

With an estimated time of first pass over target of two hours, it is reasonable to assume that three hours is a fairly accurate estimate of time required to stab re-entry cone with present techniques. This of course will vary with wind and weather conditions, currents, heading changes that may be required during pulling and running string, etc.

Respectfully submitted,

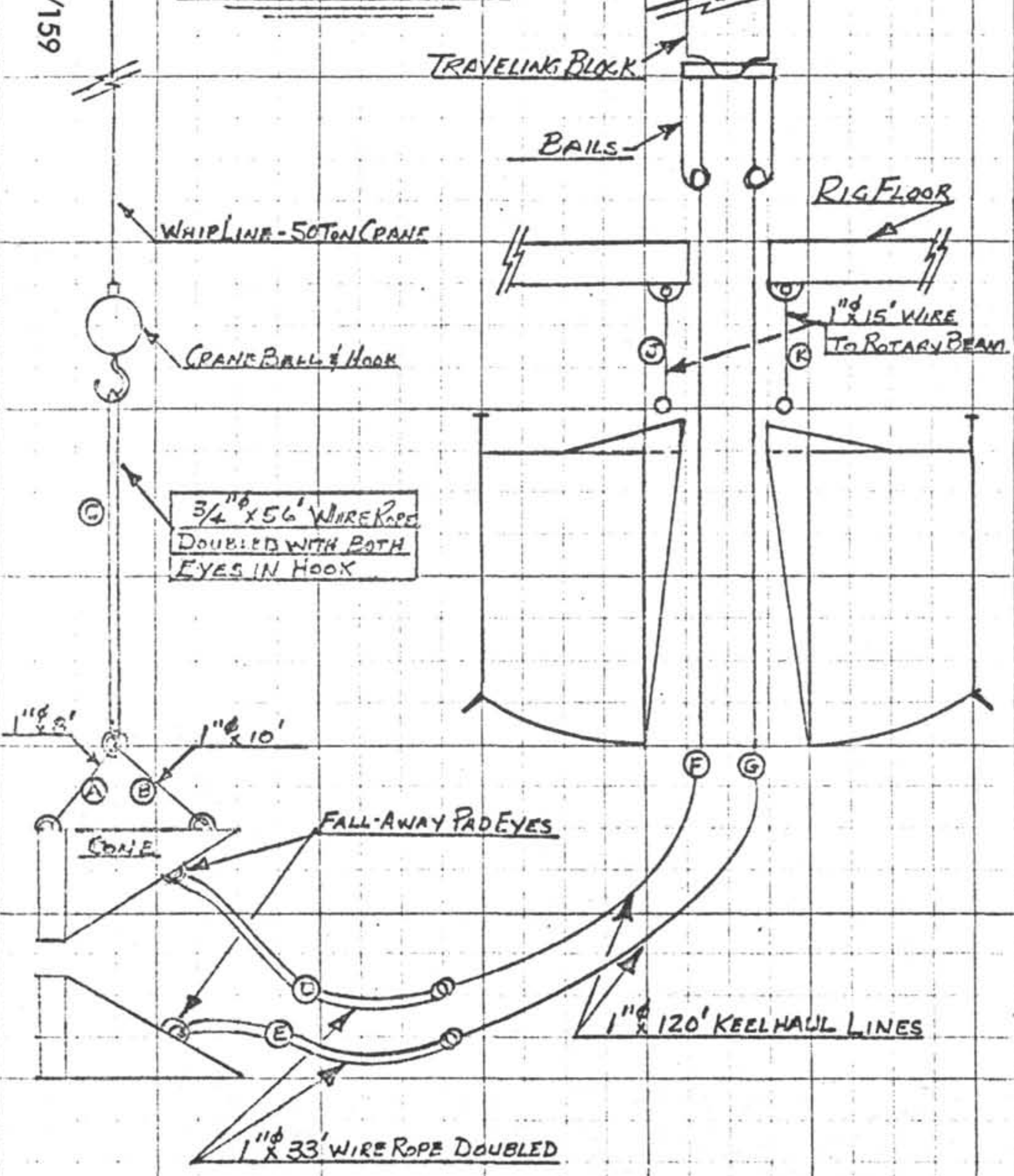
s/ Joseph Clarke
t/ Joseph Clarke
Master, Glomar Challenger


EXAMPLE PLOT
WATER DEPTH 13,000 FT.
1st RANGE TARGET 450 FT.
2ND RANGE TARGET 200 FT
TARGET φ CLOCKWISE
TRUE φ 050° RANGE 300
ALTERNATE POSITION "C"
SELECTED.
DEPTH CHANGE FROM
13,000 TO 16,900
SELECTED.
MIN. RANGE POSSIBLE
= 10 FEET.
VESSEL HEADING
"A"
"B"
"C"


ACTUAL RE-ENTRY
PLOT DEC 25, 1970
NOTE VESSEL PLOT DIFF
DUE TO 14,500 FT SETTING
IN 13,000 FT OF WAT
4E2S
3E2S
4E3S
5E1S
TARGET
130
300
310
320

ATTACHMENT-II

KEELHAUL SKETCH



"TRAVIS"
12/16/70

KEELHAUL PROCEDURE

1. MODIFY CONE TO BE KEELHAULED IN A HORIZONTAL POSITION.

2. WITH LINES (D) & (E) IN PLACE, HOOK CRANE BLOCK TO LINES (A) & (B). MOVE CONE TO PORT SIDE & LAND ON PIPE RACK, DECK, & PORT RAIL

3. PICK UP LINE (C) WITH "WHIP LINE" & REMOVE CRANE BLOCK FROM LINES (A) & (B)

4. SHACKLE LINES (F) & (G), CONNECTED TO BAILS OF TRAVELING BLOCK, TO LINES (D) & (E).

5. PICK UP WITH "WHIP LINE", SWING CONE TO MID-SHIP AND LOWER INTO WATER TO WHERE "WHIP LINE" HOOK IS AT RAIL ON MAIN DECK. KEEP CONE BELOW WAVE ACTION.

6. PICK-UP ON LINES (F) & (G) WITH TRAVELING BLOCK UNTIL ALL SLACK IS OUT OF LINES.

7. WITH CUTTING TORCH, CUT ONE EYE OFF LINE (C) AT "WHIP LINE" HOOK TO LET LINE (C) STRIP THRU RING ON LINES (A) & (B).

8. PICK-UP ON LINES (F) & (G) UNTIL LINES (D) & (E) MAKE UP WITH LINES (J) & (K).

9. REMOVE LINES (F) & (G).

APPENDIX F

SITE 146 - RE-ENTRY SUMMARY

LEG 15 - CARIBBEAN SEA

DEEP SEA DRILLING PROJECT

DECEMBER 15 - 27, 1970

March 11, 1971

SITE 146 - RE-ENTRY SUMMARY

Table of Contents

SITE 146 - RE-ENTRY SUMMARY

SUMMARY

The first operational re-entry of the Deep Sea Drilling Project was accomplished at 05:30 hours on December 25, 1970, at Site 146 of Leg 15 in the Caribbean Sea. An experimental re-entry had been accomplished in June 1970 in the Eastern Atlantic.

The Glomar Challenger arrived at Site 146 at 09:30 hours on December 15, 1970. A five meter diameter by four meter high re-entry cone was attached to 50 meters of 13 3/8 inch casing which was lowered to the sea floor at 3949 meters with the drill string. The casing was jetted into the sea floor to place the base of the re-entry cone at the mud line. After mechanically releasing the casing and cone assembly, routine coring and drilling operations were carried out to a depth of 4650 meters for 701 meters penetration through ooze, marl, chert, chalk, and limestone. The dull bit was then pulled, replaced with a new bit, and the drill string was rerun to 3937 meters. An Edo sonar scanning transceiver was then lowered through the five-inch drill pipe on a conductor cable to place the scanning head approximately eight inches below the core bit. Scanning with the transceiver located the acoustic reflectors of the re-entry cone approximately 300 feet from the bit. The ship was then maneuvered to position, the bit immediately above the cone and the drill pipe was lowered for an apparent re-entry. However, resistance to lowering the bit and a core, recovering undisturbed sediment, later indicated that a false re-entry had been made. An attempt to pull back above the mud line, rerun the sonar transceiver and make a second re-entry attempt, was terminated after attempts to run the transceiver were stymied by a plugged core bit. A round trip was made to check the drill string for obstructions and to remove a jet sub. The drill string was rerun to 3947 meters, the sonar transceiver was lowered into position, and the re-entry cone was located at 95 foot range from the bit. The ship was again maneuvered to place the bit above the cone and the drill string was lowered for a valid re-entry. The drill string was lowered to 4635 meters without resistance, 15 meters of fill were washed from 4635 to 4650 meters and routine coring operations were resumed at 4650 meters. The hole was continuously cored to total depth of 4711 meters, terminating in basement (diabas), after 762 meters total penetration. The hole was then filled with 10 pounds per gallon mud and the drill string was recovered for departure from the site.

Total time required for the site was 295.5 hours. The total time requirement for re-entry was 147.5 hours. The time required for the first re-entry attempt, from sighting of cone to lowering of drill string, was 13 hours, while the same operation was accomplished in 2.5 hours on the valid re-entry.

Ironically, the objective of Site 146 could probably have been accomplished without re-entry. The first bit, upon inspection after recovery, had an estimated 25 to 30

percent additional life and probably could have made the 61 meters of additional penetration accomplished with the second bit. Although the second bit was virtually destroyed after only 17.1 rotating hours compared to 29.8 rotating hours on the first bit, it is believed that cone damage occurred to the second bit as it was obstructed in the base of the re-entry cone on stab-in.

Regardless of whether re-entry was or was not required to accomplish the scientific objectives of Site 146, the re-entry technique was established as a working operational technique which provides the project with the capability of exploring the deeper horizons of harder formations, which heretofore have been inaccessible.

CONCLUSIONS AND RECOMMENDATIONS

The re-entry procedure, as utilized on Site 146, is a workable system which is technically sound and the basic equipment is adequate. However, minor modifications of equipment and procedures should drastically reduce the time required for future re-entry.

Recommendations for modifications are as follows:

1. The re-entry cone settled an estimated 11 meters on Site 146 which was the primary factor for the false re-entry. Additional bearing area of 200 to 300 square feet needs to be fabricated into the base of the cone. Round cutting discharge parts of at least four inches diameter should be fabricated into the cast housing at the base of the cone above the casing hanger and the bearing plate. The acoustic reflectors should be braced at the top of the cone with steel plate which is streamlined around the reflector to reduce the hazard of fouled keelhaul lines.

2. The keelhauling procedure, using the side launch technique, is satisfactory for keelhauling in ten to 12-foot seas. However, keelhauling, using an inverted launch technique, appears to offer all the advantages of the side launch plus reduced tendency for fouling of keelhaul lines, reduced handling, additional safety for personnel, and a reduction in time.

3. The casing hanger, after modification at Site 146 to reduce thebevel in the leading edges of the "gates", appears adequate. There are no recommendations for further modification.

4. The latch sub, although providing a mechanical release at Site 146, should be modified to hold the sleeve in the "up" position, once shifted, so that torque can be applied to assist in the mechanical release of the latch sub from the casing hanger.

The explosive bolt release for the latch sub appears to offer a potential means of positive release if a reliable acoustic system can be developed to detonate the explosive bolt. It is recommended that the acoustic release system be developed since the same system could be utilized for release of the acoustic reference beacons used for ship positioning.

5. The casing program and jetting procedure appear to be adequate. It does not appear that the casing frictional forces developed in soft sediments contribute substantially to the vertical support of the re-entry cone. Hence, the casing provides hole stability through the soft sediments at the mudline and keeps the re-entry cone oriented in the upright position. Based on project experience to date, it appears that 30 to 40 meters of casing would be adequate in most areas. There is generally sufficient thickness of transparent sediment to permit jetting to 30 to 40 meters without undue resistance. The bit of the jet string should be positioned within four or five meters of the casing shoe. The packoff used on Site 146 was satisfactory. A segmented, wrap-around packoff with seal rubber and tapered base should be provided for future re-entry work.

6. The Baker shifting tool, although sufficient to accomplish re-entry on Site 146, is not satisfactory. It should be replaced with a shifting tool which will permit more positive control from the surface and which will provide more positive surface indications. The proposed shifting tool should be designed to shift a sleeve and hold it in the "up" position without automatic release of the "shifting-dogs". The "shifting-dogs" should release only with the application of force in excess of that required to shift the sleeve.

7. The jet sub was ineffective in providing significant lateral displacement of the drill string. Qualitative evaluation indicated that maximum displacement was approximately 20 feet. Since the jet sub necessitates the use of a bore plugger and shifting of the jet sub sleeve, the negligible benefit gained doesn't justify the added rig time. Re-entry, both false and valid, was accomplished without the jet sub. It is recommended that the jet sub be eliminated for future re-entry work.

8. The bore plugger, both cup and seal nipple, were satisfactory with minor modifications to the check valve assembly. However, the bore plugger is not required if the jet sub is eliminated from the string.

9. The indexing sub, designed to index the Edo sonar transceiver, was unsatisfactory and was not required. Re-entry was accomplished without evidence of Edo sonar transceiver rotation and it is recommended that further efforts for indexing be suspended.

10. The Edo sonar scanning transceiver was satisfactory. The only difficulty encountered was the breaking of a scanning head when it was attempted to spud the Edo transceiver through a soft sediment plug in the drill collar assembly. Although re-entry was accomplished with the 45 degree scanning head on both attempts, the 45 degree head leaves a 15 degree from vertical "blind spot" in its vertical scan sector. The 60 degree scanning head covers a 30 to 90 degree from horizontal scan sector, thus eliminating the "blind spot". This should provide better resolution for the actual stab-in, although a slight reduction in scan range will be sacrificed.

11. The Glomar Challenger was successfully maneuvered in the automatic mode to successfully place the bit over the re-entry cone. The false re-entry required 13 hours of maneuvering to position the bit, of which two hours were utilized in jetting efforts. The valid re-entry required only 2.5 hours to position the bit. The significant reduction of time is attributable to development of a systematic method of ship maneuvering in the automatic mode using offsets, water depth adjustments and plotting of average range and bearing to the cone for each step of the maneuver. The ability to adequately maneuver the ship eliminates the need for jet sub and bore plugger.

12. Depth Correlation of drill pipe measurements with the top of the cone, just prior to pulling out of the hole, is a necessity. Inadequate depth correlation, due to cone settling, is the primary factor for the misstab on the first re-entry attempt. It is recommended that a magnetic collar survey be run prior to pulling the bit above the cone to correlate the base of the drilling assembly with a 13 3/8-inch casing coupling. This correlation can then be referred back to the top of the cone.

13. There is presently no means for positive identification of a valid or false re-entry. A means of positive surface indication at re-entry could have saved several hours rig time on Site 146 when the false re-entry occurred. Positive indentification may be ascertainable from different scan patterns of the sonar transceiver as additional experience is gained. However, it is recommended that a shear pin centralizer or shear pin stablizer be utilized in the near future to provide positive surface indication for a valid re-entry.

The elimination of the jet sub and bore plugger, the procedure developed for maneuvering the ship, a means of depth correlation between drill pipe and re-entry cone at time of stab and a means for positive surface indication for a valid re-entry could conceivably reduce the actual re-entry time (time off bottom to time back on bottom), to about eight hours plus trip time. The time required for keelhauling the re-entry cone, running casing, and for running the jetting assembly was 11.5 hours, exclusive of the time lost for the first keelhaul attempt and the assembly time for the second re-entry cone. With practice this may reduce 25 to 30 percent. The jetting procedure and release of the cone and casing required four hours. This could be reduced 25 percent with modification of the latch sub sleeve and shifting tool. Thus, the incremental total time required to accomplish re-entry can conceivably be reduced to 18 or 20 hours plus the round trip time.

The decision for a pre-committed re-entry needs to be continually evaluated in view of the improved core bits which exist today. As mentioned in the summary, hindsight indicates that the scientific objectives of Site 146 could probably have been accomplished without re-entry. To substantiate this thinking, a very similar objective was accomplished in similar formations at Site 153 where 776 meters were penetrated in 46.13 rotating hours with one bit and in 105.5 hours on site. This compares with 762 meters penetration, a total of 46.9 hours rotation on two bits and 295.5 hours on site for Site 146. The most recent improvement in bit bearing designs should provide even greater bit life and should be evaluated at the earliest possible date.

If re-entry proves to be a frequent requirement for the project's future program, consideration should be given to modification of the drilling vessel which would make the hyperbolic guide and moon pool plug removable. This would permit launching of the re-entry cone through the moon pool and it would expedite casing handling and jet string assembly. It should also make possible the development of a technique which would permit re-entry to be instigated after a valid need for re-entry had been established in the course of normal drilling and coring without sacrificing the hole already drilled.

DISCUSSION OF EQUIPMENT AND PROCEDURES

RE-ENTRY CONE (Photos No. 1 and No. 2)

The re-entry cone is basically adequate and requires no major revisions. Minor modifications are suggested as follows:

1. Bearing area needs to be incorporated into the base of the cone. The three main members on the base of the cone should be extended to provide an eight to ten foot radius circle and the area between the main members should be covered with light gauge steel plate. This would require only angle iron bracing between the main members to which 1/8 inch to 1/4 inch steel plate is welded. The fabrication can be done aboard ship. This would place the bearing area of the cone below any cuttings discharge ports. With the present cone, the cuttings discharge slots in the apex of the cone tend to erode any bearing area as the cone settles into the sea floor. It is doubtful that the frictional forces on the casing are adequate to support the combined weight of casing and cone in the soft sediments. On Site 146, it was definitely established that the cone and casing assembly settled approximately 11 meters. The settling of the cone and a lack of correlation between cone depth and drill pipe measurements were the primary factors contributing to the misstab in the first re-entry attempt. The drill pipe was simply spaced too high to permit it to stab into the cone as it was lowered from 3937 to 3957 meters, since the top of the cone had settled from 3946 to 3957 meters by drill pipe measurements. The final depth for the top of the cone also coincided with the drill pipe measurements for the mud line. Aside from the depth correlations that were established on the second re-entry attempt, the cone settlement was further substantiated by the fact that the sonar transceiver never provided a reflection of the cone rim as was done on the experimental re-entry in June 1970. Only the three acoustic reflectors, which are approximately one foot higher than the cone rim, were detected by the sonic transducer on Site 146. This fact substantiates that the cone rim was at the mud line and covered with sediment and cuttings. It is conceivable that, without adequate bearing at the cone base, settling of the cone and casing could be severe enough to bury the acoustic reflectors which would preclude re-entry.

2. The cuttings discharge slots at the apex of the cone used for Site 146 are probably ineffective due to the relatively large cuttings that are developed from fast penetration and the use of salt water as the circulating fluid. However, if the present cuttings discharge slots were significantly widened they would provide a potential snag for the bit cones at stab-in. It is

recommended that the cost and machined base of the cone be lengthened to provide room for approximately four four-inch diameter discharge ports at the base of the cone above the casing hanger and above the recommended bearing plate. These could be added for negligible cost and without significant reduction in structural strength of the cone base. The existing cone slots can be retained in the lower part of the cone apex and may be beneficial in discharging the smaller cuttings.

3. The acoustic reflectors, with their present angle iron bracing and lack of streamlining, present a potential source for snagging of keelhaul lines. It is also conceivable that the bit could be lowered between the reflector and the outside rim of the cone on a misstab. It is recommended that plate material be used to brace the reflectors to the top of the cone and that it be streamlined around the reflector to eliminate potential snags for keelhaul lines. The plate will also eliminate the possibility of a misstabbed bottom hole assembly going between the cone on the reflector which could seriously damage the reflector, the guide cone, or the bit.

4. After loss of the first cone launched in the normal upright position, the side or horizontal launch of the second cone proved very effective in eliminating the buoyant effect and in getting the cone below wave action in minimum time. The cardinal rule for keelhauling any object in significant seas is to get it through the surf as quickly as possible and keep it there. However, the side launch does require structural reinforcement on the vertical member used for lifting and at the midsection to prevent possible collapse. The side launch also required that the cone be picked up then turned to the horizontal position and set down while the block is removed and the whip line is attached to the horizontal left slings and the keelhaul slings are shackled to the keelhaul lines. The required turning and handling presents a serious hazard to personnel, expecially if vessel motion is of significant magnitude. The side launch keeps the top of the cone leading in the proper direction at all times, which reduced potential line fouling as compared to the upright launch. However, an inverted launch would provide all the advantages of the side launch. There would be no buoyant effect, the possibility of line fouling is even further reduced, the cone doesn't require turning, assuming the cone was assembled in the inverted position and bearing plate is fabricated aboard ship, which reduces the handling hazard to personnel, the necessity for changing from block to whip line is eliminated which reduces personnel exposure, the requirement for additional structural reinforcement is eliminated and a time saving would be realized. In summary, the side launch is preferable to the up right launch, however, the inverted launch appears to offer some advantages over the side launch and should be considered in the future.

CASING HANGER (Photos No. 3 and No. 5)

The casing hanger required modification of the hinged gates. The gates were initially fabricated with a significant bevel on the leading edge to assist with release from the latch sub. However, on assembly and testing the bevel proved to be too great and allowed the gates to turn out of the latch sub with right hand rotation similar to gear tooth action. Consequently, the gates were built up and squared off on the leading edge. Otherwise, no difficulties were encountered. The snap ring groove for latching the hanger into the base of the re-entry cone was effective and satisfactory.

LATCH SUB (Photos No. 4 and No. 5)

Although the latch sub did provide a mechanical release between the casing and cone assembly and the jetting string, the releasing action is not positive enough, as was noted in the operational discussion. Approximately 30 minutes of torquing and reciprocation of the drill pipe along with several passes of the shifting tool to shift the latch sub sleeve, was required to release the latch sub. The difficulty apparently is due to the following causes:

1. The present (Baker) shifting tool automatically releases the shifting dogs from the sleeve when the sleeve reaches the limits of its' "up" travel.

2. The latch sub had no means of holding the sleeve in the "up" position once shifted and upon release of the sleeve by the shifting tool gravity causes the sleeve to instantaneously drop to the "down" position.

3. In assembly and pretesting of the latch sub, it was noted that the gates of the casing hanger would disengage instantaneously if the alignment between the latch sub and casing hanger was perfect and if they were in a neutral weight position. If there was mis-alignment or differential weight between the latch sub and casing hanger, the frictional force on the tops or bottoms of the gates was sufficient to prevent one or more of the gates from swinging out of the latch sub into their respective hanger recesses. The latch sub sleeve would then fall back to the "down" position and the lug nuts locked the remaining gate or gates in the engaged position.

4. If the latch sub sleeve was momentarily held in the "up" position by the shifting tool, the application of right hand torque pivoted the gates out of the latch sub recessed into their casing hanger recesses to release the latch sub.

Since it is virtually impossible to obtain perfect alignment and zero differential weight at depth, the frictional forces on the gates held them in place and the latch sub sleeve fell back into "down" position before torque could be applied. Only through repetitive shifting of the sleeve and repetitive applications of torque and reciprocation was it possible to pivot all of the gates into their hanger recesses and release the latch sub from the casing hanger and cone assemble.

In view of the above, the following recommendations are made:

1. Modify the latch sub sleeve with a collet, or snap ring latch which will hold it in the "up" position, once shifted, until torque can be applied to pivot the gates back into their casing hanger recesses.

2. An alternate would be to provide a shifting tool which would not release automatically at the upper limit of travel until additional force was applied to release the shifting dogs. This would also permit the latch sub sleeve to be held in the "up" position until torque could be applied to pivot the gates.

The latch sub was also designed with two alternate means of release, namely, a "J" slot arrangement and an explosive bolt arrangement. The "J" slot arrangement requires a round trip and re-entry after release of the casing and cone assembly. Thus, it is the least desirable method due to the additional rig time required. The explosive bolt arrangement was not tested due to the unreliability of the present acoustic equipment required to detonate the explosive bolts. If a reliable acoustic system is developed the explosive bolt should provide the most positive release mechanism.

ANNULAR PACKOFF FOR JET STRING

The lucite packoff was too fragile and it was fabricated with a square, full diameter base which made it extremely difficult to stab into the casing hanger with the relative motion existing between the jetting string and the casing string. A segmented, wrap around packoff with tapered base similar to a wrap around casing or tubing hanger is preferable. It could be made of cast aluminum hard moulded rubber or bakelite and a rubber insert. A packoff is desirable to eliminate annular flow between the jet string and casing. Even minor annular flow can carry drill solids that could settle around the latch sub difficult or impossible. If fabrication of a packoff developes to be difficult and/or expensive, a satisfactory packoff can probably be accomplished with "soft-line" and "rags" in view of the restricted flow area around the latch sub and the low differential pressure involved.

BAKER SHIFTING TOOL (Photo No. 6)

Although the Baker shifting tool accomplished the assigned tasks, it is considered unsatisfactory and should be modified or replaced with a more reliable and more "positive" tool. Difficulty experienced with the shifting tool is as follows:

1. The tool is designed to automatically release the shifting dogs once the sleeve travels its' limit. This type of tool doesn't provide a positive surface indication that the sleeve has been shifted.

2. The profile locator keys were inadequately secured in the body of the tool, which would let the keys turn along their longitudinal axis. The protrusion of the turned key caused the tool to hang in tool joint recesses. The profile locator keys were extremely brittle, which caused several keys to break at their minimum cross sectional area.

Another shifting tool needs to be provided for shifting the latch sub and jet sub sleeves. The design of the tool should incorporate a means of providing a more positive indication at the surface when the sleeve has shifted. Namely, a tool which will engage the sleeve, shift the sleeve, and then release only with the application of additional force which will "cam" or shear a pin to let the shifting keys recess into the mandrel.

JET SUB

The jet sub consisted of a drill collar sub with a 0.75 inch diameter jet port and sliding sleeve. A profile locator sub was run on top of the jet sub for locating the Baker shifting tool. The jet sub was designed to provide lateral displacement of the drill string with jump pressure and to control the direction of the lateral displacement by rotation of the drill string. As mentioned in the operational discussion, the jet sub was ineffective in providing significant lateral displacement of the drill string. In view of its' ineffectiveness and in view of the ability to maneuver the ship to place the bit over the guide cone, the jet sub is not considered necessary for re-entry. The elimination of the jet sub from the re-entry system eliminates the necessity for a bore plugger on top of the Edo transceiver which reduces wireline time for running the Edo transceiver by an estimated 50 percent. It also eliminates the necessity for a wireline trip with the shifting tool to close the jet sub sleeve following stab-in and it eliminates a wireline trip with the bore plugger to pressure test the drill string to assure that the jet sub was ineffective, it complicates the re-entry procedure and it consumes a significant amount of time.

INDEXING SUB

An indexing sub was designed to orient the Edo transceiver and bore plugger so as to align and hold the Edo transceiver in a fixed and relative position with the port of the jet sub. On the experimental re-entry, the Edo sonde reportedly turned inside the drill collars which prevented the establishment of a reliable relative bearing reference. On pretest of the indexing sub, it was ineffective in orienting the sonde. The indexing lug on the bore plugger mandrel was spring loaded and the spring did not have sufficient compressional force to keep the lug protruded when it contacted the indexing incline in the sub. The indexing incline also appeared to be of inadequate length. Consequently, there was no attempt to index the transciever on the re-entry work of Site 146. Also, there was no evidence of the transceiver rotation inside the drill collars. If the transceiver is allowed to rest on the face of the core bit, it is inconceivable that the transceiver could rotate considering its' weight and assuming there is ample slack in the conductor cable. Therefore, it doesn't appear that indexing of the Edo transceiver is necessary and it is recommended that further efforts toward development of an indexing sub be discontinued.

BORE PLUGGER (Photos No. 7 and No. 8)

Two types of bore pluggers were provided. One was fabricated from a conventional Baker seal nipple assembly and packed off in a special bore (3.87 inch inside diameter) latch sub sleeve for the inner core barrel. The other consisted of a packer cup and tapered mandrel which packed off against the drill collar wall as the mandrel weight and fluid pressure forced the tapered mandrel inside the cup. With minor modification of the check valves for fluid by-pass while running, both tools performed satisfactorily holding 2,000 psi maximum pressure. The bore plugger is run on top of the Edo transceiver to packoff below the jet sub and permit jetting. It was also used, without the Edo transceiver and spaced out with inner core barrel sections, to obtain a pressure test of the drill string to assure that the jet sub sleeve was in the closed position.

EDO SONAR SCANNER (Photos Nos. 9, 10, 11, 12)

The sonar scanner worked satisfactorily. The only failure experienced on Site 146 was the breaking of a scanning head when it was attempted to spud the tool through a soft sediment plug in the bottom of the drilling assembly. Both the apparent and the valid re-entries were made using the 45-degree scanning head. However, it appears that the 60-degree scanning head would be more appropriate for most re-entry attempts. Although the horizontal range is slightly reduced, the 60-degree head provides a vertical plane scan-sector of 15 to 75 degrees from horizontal. Therefore, using the 45-degree scan head can result in a 15-degree "blind spot" when the scan head is directly above the re-entry cone. A 60-degree scan head should be procured to replace the one lost and it should be the primary tool with the 45-degree head serving as the stand-by head.

MANEUVERING OF SHIP

The re-entry, both valid and apparent, made at Site 146 was accomplished by maneuvering the ship to place the bit over the cone. This was also the case with the experimental re-entry. A giant step was made in the progress of maneuvering the ship on Site 146 with the development of a systematic procedure where the automatic mode of operation, offsets, and water depth adjustments were used with plotting of all ship movements and average range and bearings of the target for each movement. This method permits an expedient and systematic method of maneuvering the bit over the target. This technique is described indetail in Attachment III. Although the semi-automatic and manual modes of maneuvering were traced briefly in the false re-entry attempt, these attempts were too hurried and weren't systematically plotted. Although the automatic mode described above would appear to cover all conceivable circumstances, there just isn't enough experience, to date, to make this a valid conclusion. However, from using this technique with automatic mode of operation, it would appear that re-entry could be accomplished in approximately three hours after the target has been located by the sonic transducer, therefore, with elimination of the jet sub and bore plugger, future re-entry could conceivably be accomplished in six to eight hours plus trip time, allowing two hours for rig up and running of the streamlined sonic transducer, three hours for maneuvering and two hours to retrieve and rig down the sonic transducer.

DEPTH CORRELATION REQUIRED BETWEEN CONE AND DRILL PIPE MEASUREMENTS

As mentioned earlier, settling of the cone and the casing assembly between time of release and re-entry attempt probably caused the false re-entry on Site 146 and it is anticipated that this will be the usual phenomenon although the recommended addition of a bearing plate on the cone base should reduce the amount of settling. Thus, a real need exists for adequate correlation of drill pipe measurements with the casing and cone assembly. It appears that such a correlation could be obtained economically and expediently with a conventional 2 1/8 inch outside diameter or 1 11/16 inch outside diameter magnetic collar locator survey on the Schlumberger line just prior to the drill bit being pulled from the hole. If the bit were pulled to within approximately 20 meters of the top of the hole, the collar locator survey should identify the bottom of the drill collar assembly and identify one or more collars of the 13 3/8 inch casing. If the collar locator survey proved inadequate in the large diameter casing, the use of a radioactive marker in both casing string and drill collar string along with a small diameter gamma sonde should definitely accomplish the task. Once this correlation is established, the round trip for a new bit is completed and the bit can then be accurately placed eight to nine meters above the top of the cone for re-entry.

It would also be of assistance to accurately correlate sea floor depth with drill pipe measurement. Generally there is five to 15 meters discrepancy between drill pipe measurements and precision depth recorder measurements. This always poses the questions of how far has the drilling or jetting assembly penetrated the soft sediments prior to measurable indication on the weight indicator and at what depth should the casing and cone assembly be released to put it at mud line. It was probably coincidence, but on Site 146 the drill pipe measurement with the casing and jetting string tagged bottom at 3957 meters, which was generally accepted as the mud line after the valid re-entry. Also, experience may prove that release of the cone at the precision depth recorder measurement, which is generally a few meters less than drill pipe measurements, is adequate. If the cone is released a few meters high and allowed to settle to the ocean floor, it only affects the reference for re-entry measurements, which can be checked with the collar locator survey as described above. However, it may be desirable to acquire a narrow-focus, vertical-beam transceiver head which could be run to the bottom of the jet string and casing assembly. This survey would provide a return from the sea floor as the jet string and casing assembly are lowered to within 30 meters of bottom to provide an accurate depth correlation between mud line and drill pipe measurements. This would assure that the cone is released at the mud line.

POSITIVE DETERMINATION OF VALID RE-ENTRY

A positive indication of re-entry is required. This may be done by a simple mechanical means such as a shear pin centralizer or a shear pin stablizer, which will give a surface indication on the weight indicator when the bit passes through the casing hanger. Also, with experience, a difference of scan pattern between drill collar and 13 3/8 inch casing may be detectable. If the re-entry is valid lowering the transducer to read the casing scan would identify a valid re-entry. If the re-entry is a misstab it would appear that the soft sediment in the drill collars would hold the transducer up in the drill collars providing only the drill collar scan. This technique was not evaluated on Site 146.

CASING PROGRAM

The 50 meters of casing used on Site 146 was adequate. Hole stability in most areas is surprisingly good and it is doubtful if additional casing will prevent settlement in the soft sediments generally encountered without cementing. Since the purpose of the casing is to provide a stable conduct through the very soft sediments at the mud line and to keep the cone properly oriented, it would appear that 30 meters would be adequate in most cases. As mentioned previously, it is doubtful if the frictional forces developed around the casing in soft sediment provide appreciable vertical support to the casing and cone assembly. If the recommended addition of bearing area to the base of the cone is effective in preventing settling of the cone assembly, 30 to 40 meters of casing should adequately stablize the top of the hole and keep the cone properly oriented. Also, most areas will permit jetting of 30 to 40 meters of casing based on project experience to date and on the profile data taken at each site.

ATTACHMENT I

SITE 146 - RE-ENTRY SITE

DRILLERS LOG

December 15, 1970

00:00 to 09:30	Enroute from Curacao to Site 146. Beacon away at Site 146 at 09:30.
09:30 to 12:00	Assemble and weld re-entry cone reflectors.
12:00 to 13:00	Attempted to keelhaul cone. Keelhaul line fouled on reflector. Raised cone to surf to unfoul keelhaul line. Swell (eight to ten feet) surged cone and broke crane whip line. Dropped cone.
13:00 to 24:00	Assemble, reinforce, and weld stand by cone for keelhauling. Rig up to launch cone on its side to reduce surge effect.

December 16, 1970

00:00 to 08:00	Finish assembly of cone and welding of connections while waiting on weather. Swell of ten to 14 feet.
08:00 to 14:00	Rig up to keelhaul cone on its side.
14:00 to 15:30	Keelhauled cone in ten to 12 foot seas.
15:30 to 17:00	Rig down keelhaul equipment and rig up to run casing.
18:00 to 20:30	Run four joints 13 3/8 inch casing with muleshoe and casing hanger (49.36 meters) and land on elevators at moon pool.
20:30 to 24:00	Space drill collars inside casing (46 meters), make up casing hanger latch sub and test operate same. Assemble latch sub to casing and lower casing and hanger to latch up into re-entry cone.

December 17, 1970

00:00 to 01:30	Cut keelhaul lines to re-entry cone and run remaining drill collar of bottom hole assembly.

01:30 to 10:00	Run in hole with drill pipe, bottom hole assembly, casing and re-entry cone.
10:00 to 10:30	Rig up Bowen power sub.
10:30 to 14:30	Work on power unit of Bowen sub. Found safety switch on rig floor in "off" position. Circulate through drill pipe and bottom hole assembly.
14:30 to 15:00	Tag bottom at 3957 meters. Drill pipe measurement. (3949 meters PDR.)
15:00 to 15:30	Jet casing setting shoe at 3988 meters, base of re-entry cone at 3950 meters and top of cone at 3946 meters.
15:30 to 17:30	Run in hole with shifting tool. Shifted sleeve in latch sub and released latch sub from casing hanger.
17:30 to 19:00	Pull out of hole with shifting tool. Had to pull sandline slow due to shifting tool hanging up in drill pipe while pulling out of hole.
19:00 to 20:00	Wash and rotate from 3988 to 4045 meters.
20:00 to 21:00	Core No. 1 cut from 4045 to 4054 meters with eight meter recovery.
21:00 to 23:00	Drill with center bit from 4054 to 4203 meters.
23:00 to 24:00	Retrieve center bit.

December 18, 1970

00:00 to 02:00	Cut core No. 2 from 4203 to 4212 meters. Recovered nine meters.
02:00 to 06:30	Drill with core bit from 4212 to 4355 meters.
06:30 to 09:00	Cut core No. 3 from 4355 to 4362 meters with zero recovery.
09:00 to 24:00	Cut core No. 4 from 4362 to 4416 meters.

December 19, 1970

00:00 to 24:00	Cut cores No. 10 through No. 22 from 4416 to 4533 meters.

December 20, 1970

00:00 to 24:00	Cut cores No. 23 through No. 32 from 4533 to 4623 meters.

December 21, 1970

00:00 to 09:30	Cut cores No. 33 to No. 35 from 4623 to 4650 meters.
09:30 to 11:00	Circulate and fill hole with 250 barrels of 9.8 pounds per gallon mud, with bit at 4650 meters.
11:00 to 12:30	Rig down power sub and pulled out of hole to 4050 meters.
12:30 to 13:00	Spot 100 barrels of 9.8 pounds per gallon mud.
13:00 to 13:30	Pull out of hole to 3960 meters.
13:30 to 15:00	Rig up Schlumberger unit and Edo sonic tools.
15:00 to 17:00	Run Edo to 800 meters. Edo quit functioning.
17:00 to 18:30	Rig down Edo. Drop 16.0 kHz beacon to replace 13.5 kHz beacon.
18:30 to 24:00	Pull out of hole for new bit.

December 22, 1970

00:00 to 02:00	Finish pulling out of hole.
02:00 to 04:00	Lay latch sub out of bottom hole assembly. Pick up jet sub and make up in bottom hole assembly. Operate jet sub sleeve with shifting tool - okay. Change bit.
04:00 to 11:00	Run in hole.
11:00 to 11:30	Slip drill line.
11:30 to 12:00	Rig up Bowen power sub.
12:00 to 12:30	Go in hole with power sub.
12:30 to 14:30	Rig up Schlumberger unit and Edo tool.

14:30 to 18:00	Run Edo to bottom of drill pipe.
18:00 to 24:00	Scanning with Edo and attempting to position ship over cone.

December 23, 1970

00:00 to 07:00	Maneuvering ship in various modes and jetting to position bottom hole assembly over re-entry cone. Made apparent re-entry at 06:58.
07:00 to 09:00	Recover Edo tool and rig down Edo tool.
09:00 to 09:30	Lower drill pipe 40 meters without taking weight.
09:30 to 12:30	Run in hole with sandline and shifting tool to close sleeve of jet. Shifting tool dragging coming out of hole.
12:30 to 14:00	Run bore plugger with Baker seal sub on sandline and pressure tested jet sub. Failed to hole pressure. Jet sub open.
14:00 to 18:00	Retrieve, modify and rerun bore plugger and test jet sub. Failed to get satisfactory pressure test.
18:00 to 19:30	Rerun shifting tool and attempted to close jet sub sleeve. Shifting tool momentarily hung in jet sub retrieved same. Profile key missing from shifting tool.
19:30 to 21:30	Run bore plugger (Baker Seal) and pressure tested drill pipe with 2,000 psi. Jet sub sleeve closed.
21:30 to 22:00	Drop core barrel and wash 3995 to 4044 meters with 2,000/5,000 pounds weight on bit.
22:00 to 24:00	Core from 4044 to 4053 meters and recover undisturbed sediment indicating not stabbed in old hole.

December 24, 1970

02:00 to 08:00	Run in hole with Edo. Unable to get Edo out bottom of drill pipe trhough bit. Worked pipe and spud Edo without success indicating bit plugged. Pull out of hole with Edo and found 60 degree transducer broken off and left in hole.

08:00 to 09:00	Rig down Edo and Schlumberger.
09:00 to 14:00	Pull out of hole with drill pipe. Slip drill line.
14:00 to 15:00	Set back bottom hole assembly and removed jet sub from string.
15:00 to 15:30	Rig up floatation ball on bit and outer core barrel.
15:30 to 22:00	Run in hole to 3947 meters.
22:00 to 24:00	Rig up Schlumberger and Edo.

December 25, 1970

00:00 to 01:00	Run in hole with Edo to 800 meters. Developed short in Schlumberger cable. Pull out of hole.
01:00 to 01:30	Repair short in Schlumberger torpedo.
01:30 to 03:00	Run in hole with Edo.
03:00 to 05:30	Maneuver ship over cone (95 foot range) using offsets and water depth changes in automatic mode of operation. Made re-entry at 05:30 lowering bit from 3955 to 3964 meters. Bit took 12,000 pounds weight from 3961 to 3964 meters. (Indication of bit hung in base of cone.) Picked up four meters to take weight off bit and rotated pipe. Lowered drill pipe to 3964 meters without taking weight.
05:30 to 08:30	Pull out of hole with Edo and rig down Schlumberger.
08:30 to 09:00	Run in hole with three doubles (50 meters) without taking weight.
09:00 to 12:00	Rig up power sub and running in hole.
12:00 to 13:00	Replace hydraulic hose on bumper sub.
13:00 to 14:00	Finish in hole to 4635 meters. Hit obstruction.
14:00 to 14:30	Wash out fill from 4635 to 4650 meters.
14:30 to 15:30	Pull inner core barrel and drop new barrel.
15:30 to 24:00	Cut cores No. 36 through No. 38 from 4650 to 4668 meters.

December 26, 1970

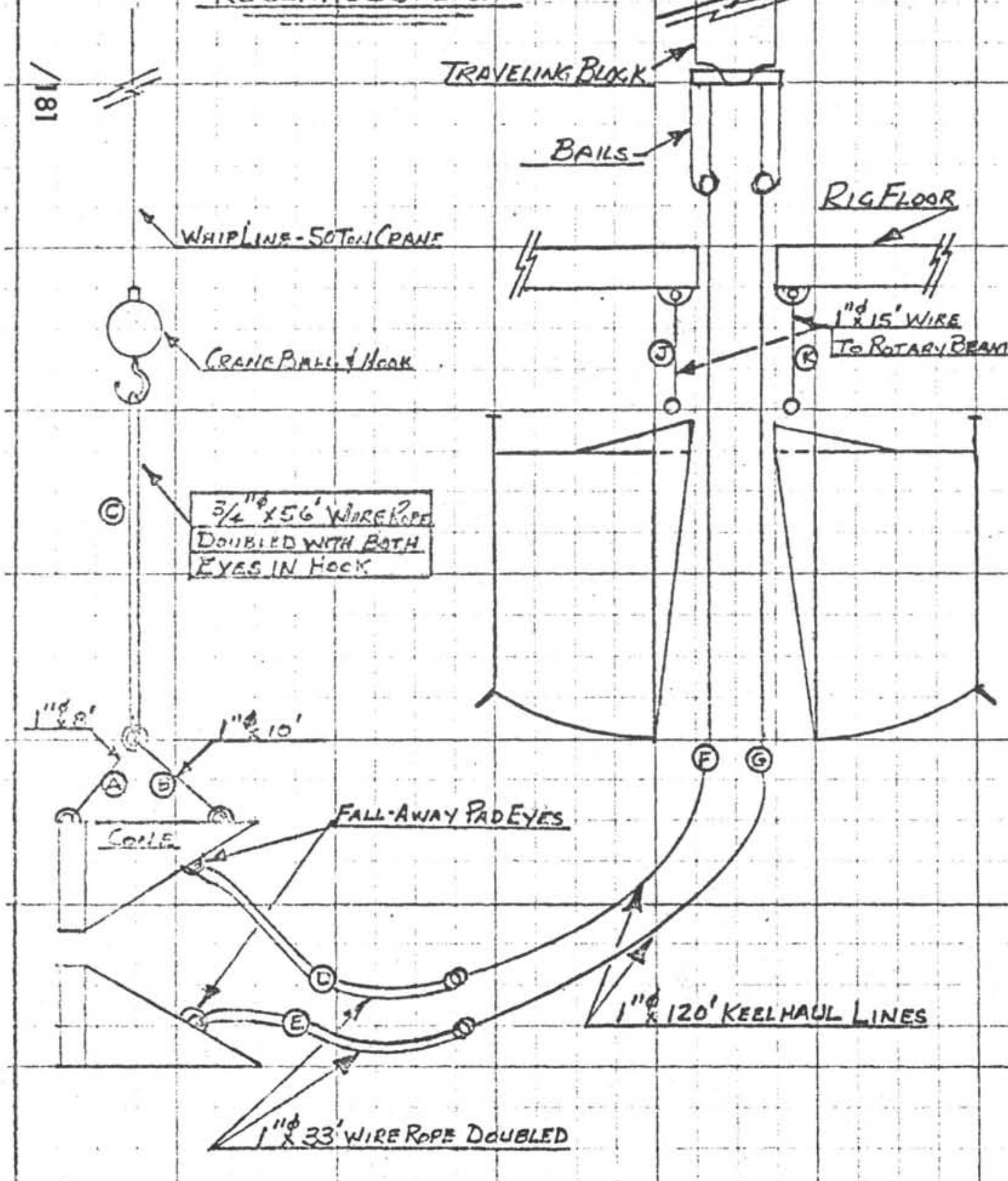
00:00 to 24:00	Cut cores No. 39 through No. 44 from 4668 to 4711 meters in basement.

December 27, 1970

00:00 to 03:00	Spot 130 barrels mud in hole and pull up to 4307 meters.
03:00 to 05:00	Attempt sidewall core. Barrel stuck momentarily. Pull out of hole with no recovery.
05:00 to 06:30	Pull up to 4297 meters with drill pipe. Make second attempt for sidewall core. No recovery.
06:30 to 07:30	Spot 73 barrel mud in hole.
07:30 to 09:00	Pull up to 4050 meters and spot 17 barrel mud in hole.
09:00 to 12:00	Cut drill ine.
12:00 to 13:30	Pull up to plus or minus 1500 meters.
13:30 to 15:00	Test cup type bore plugger with 2,000 psi.
15:00 to 17:00	Finish pulling out of hole.
17:00 to 24:00	Depart site at 17:00 for rendezvous at Curacao.

ATTACHMENT-II

KEELHAUL SKETCH



"TRAVIS"
12/16/70

KEELHAUL PROCEDURE

1. MODIFY CONE TO BE KEELHAULED IN A HORIZONTAL POSITION.
2. WITH LINES Ⓓ & Ⓔ IN PLACE, HOOK CRANE BLOCK TO LINES Ⓐ & Ⓑ. MOVE CONE TO PORT SIDE & LAND ON PIPE RACK, DECK, & PORT RAIL.
3. PICK UP LINE Ⓒ WITH "WHIP LINE" & REMOVE CRANE BLOCK FROM LINES Ⓐ & Ⓑ.
4. SHACKLE LINES Ⓕ & Ⓖ, CONNECTED TO BAILS OF TRAVELING BLOCK, TO LINES Ⓓ & Ⓔ.
5. PICK UP WITH "WHIP LINE", SWING CONE TO MID-SHIP AND LOWER INTO WATER TO WHERE "WHIP LINE" HOOK IS AT RAIL ON MAIN DECK. KEEP CONE BELOW WAVE ACTION.
6. PICK-UP ON LINES Ⓕ & Ⓖ WITH TRAVELING BLOCK UNTIL ALL SLACK IS OUT OF LINES.
7. WITH CUTTING TORCH, CUT ONE EYE OFF LINE Ⓒ AT "WHIP LINE" HOOK TO LET LINE Ⓒ STRIP THRU RING ON LINES Ⓐ & Ⓑ.
8. PICK-UP ON LINES Ⓕ & Ⓖ UNTIL LINES Ⓓ & Ⓔ MAKE UP WITH LINES Ⓙ & Ⓚ.
9. REMOVE LINES Ⓕ & Ⓖ.

ATTACHMENT III

Proposed Method for Re-entry Using Vessel's Positioning Equipment Only

1. Leave vessel in automatic mode of operation during all operations and leave vessel on same heading.

2. During all observations, make frequent notation of blip heading on sonar oscilloscope to assure that Edo tool has not slipped in azimuth. Also, be certain that all observations of range and bearings are taken with the vessel centered over beacon display of computer oscilloscope.

3. All movements of vessel, range and bearing of target should be plotted on U.S. Navy Manuevering Board HO 2665-20 with original positioning beacon plotted as center and the vessel's position in relation to this beacon plotted using any offsets previously put into computer. This must be done so that the final movements of the vessel by use of depth changes will be along a path angle in direct relation to the true position of the positioning beacon.

4. Using 500 foot scan on sonar oscilloscope and with vessel directly centered over positioning beacon display on computer, take initial range and bearing of re-entry cone target. Plot the circle of observed range from the vessel's plotted position.

5. Make an arbitrary move of vessel by using offsets in one direction only, preferably as near as possible to the vessel's heading. (Vessel's heading will of necessity be determined by existing elements and has no significant effect upon the operation).

6. Observe whether offset move has increased or decreased the range of re-entry cone target. If vessel's move has increased range it immediately becomes obvious that the arbitrary move was in the wrong direction and in this case the offsets should be removed and opposite direction offsets should be put into computer. Offsets of 200 to 400 feet should be used depending upon the distance of the original range of target. If there has been a substantial decrease in range of target, allow sufficient time for vessel and drill pipe to settle and then by an average of new ranges on target draw another circle of range from the vessel's newly plotted position. This circle will intersect the original plotted range circle at two locations either of which could be the potentially true position of re-entry cone.

7. The approximate true position of the re-entry cone target may now be ascertained by having observed the apparent relative motion of the re-entry target either to the right or left, the correct position may be selected.

8. Having ascertained the true position of the re-entry cone, now draw a line from the center of the plotting sheet (i.e. true position of the beacon) through the true position of the re-entry cone.

9. Now! Before any further movement of the vessel, plot three or more alternate coordinates of 100 foot offsets adjacent to the position of the re-entry cone. Now draw a dotted line from the center of the plotting sheet disecting these coordinates to the outer edge of the plotting sheet. (It is along these lines that the vessel may be moved by altering depth settings).

10. If desired, at this point the drill pipe may be rotated to display true azimuth as follows:

    a. Plot the true position of the re-entry cone target.

    b. Calculate the relative bearing.

    c. Rotate the drill pipe with chain tongs until the relative azimuth of the re-entry cone is displayed in its proper position on the sonar oscilloscope.

    (Please note that the above procedure may be desirable to the Master, however in our present stage of evaluation of re-entry capabilities it is not a requisit.)

11. Now! By visual inspection of the plotted alternate coordinates, select that set of coordinates whose azimuth will most closely approach the target by adjustment of depth selections.

12. Now move the vessel in 100 foot increments by "offsets" to your selected coordinates.

13. At this point a brief explanation of the movements of the vessel by depth adjustments is appropriate.

    a. To decrease range along plotted azimuth to beacon "increase" water depth.

    b. To increase range from beacon "decrease" water depth.

    c. The following formula may be used to pre-compute "closest point of approach" of re-entry cone target.

$$\text{Depth Setting Required} = \text{True Depth} \times \frac{\text{Range From Beacon}}{\text{New Range Desired}}$$

$$\text{or } X = \text{True Water Depth} \times \frac{\text{Coordinate Selected Range From Beacon}}{\text{Desired Range Over Cone From Beacon}}$$

EXAMPLE

In attached "example plot" the water depth is 13,000 feet. The coordinate selected range from beacon is 590 feet, the position of re-entry cone target from beacon is 450 feet. $X = 13{,}000 \text{ feet} \times \frac{590}{450} = 16{,}900 \text{ feet}$

(16,900 feet = required depth setting to place vessel over sonar re-entry cone within ten feet in example.)

14. Now after the vessel and bottom hole assembly has settled over new offset coordinates, increase or decrease depth settings as required to approach "CPA" of re-entry cone target.

15. A third alternate should always be borne in mind and that is our capability of moving "forward" or "aft" along a line of azimuth with our heading a distance of approximately 54 feet by selecting alternate hydrophone selections.

16. The above explained method of re-entry using vessel positioning only, does not preclude the future possibilities of movement in semi-automatic or manual modes of operation as our evaluation of ideas and techniques develope. However, at our present stage of development of techniques it is the firm belief of the writer that an automatic mode of operation is by far the most expeditious and desirable.

17. Please refer to attached plotting sheets for a graphic display of vessel and target movements. Also an approximate evaluation of the time required to re-enter using this system.

18. The writer would like to acknowledge the fact that the "maneuvering board" techniques, the "line of azimuth" by depth settings, the "change of hydrophones" technique were in no way solely the "concept" of the writer and each of the following persons spent many long hours and much research to make this concept of re-entry by "vessel positioning only" a reality. Mr. V. F. Larson, Mr. Roy Anderson, Mr. Bruce Leavitt, Mr. Carl Wells, and Dr. Terry Edgar.

This method also does not preclude the future possibility of "jetting" using a "jet sub" on which Mr. Darrell Sims and Mr. Larson spent many long hours of hard work. And last, but certainly not least, it is needless to say that without the advice, help, close cooperation and just plain "hard work" on the part of Mr. Travis Rayborn and his superb crews, not only re-entry but our entire program could not exist. The techniques in assembly and keelhauling of the re-entry cone was by far one of the finest pieces of "rigging know-how" I have ever seen.

Respectfully submitted,

s/ Captain Joseph Clarke
t/ Captain Joseph Clarke
Master, Glomar Challenger

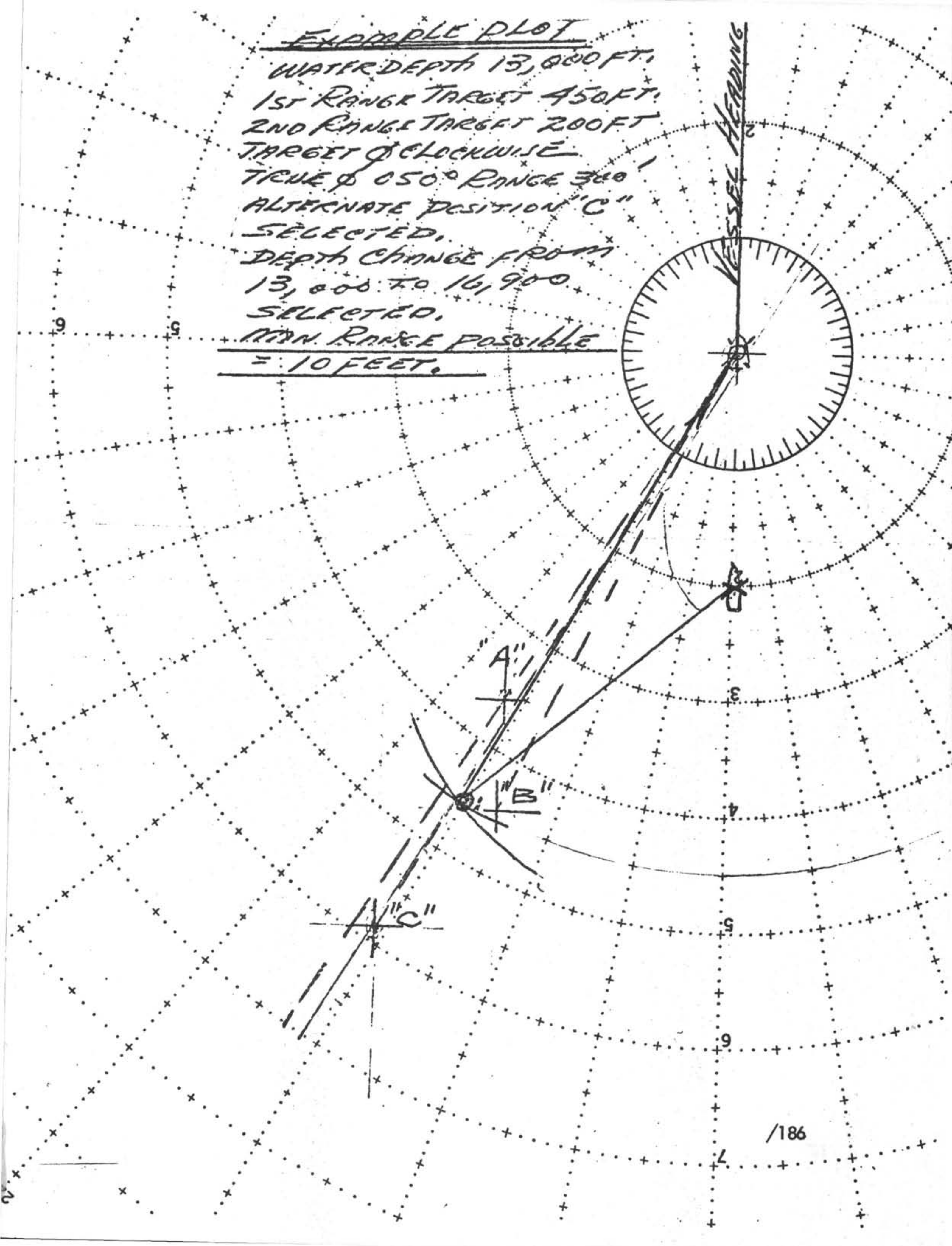
TIME ESTIMATE

1.	Sight Sonar Target	20 minutes
2.	Initial Move	10 minutes
3.	Second Move and Plotting	20 minutes
4.	Third Move and Plotting...............	30 minutes
5.	Fourth Move and Settling	30 minutes
6.	Close by Depth	10 minutes
	Total Time.........................	2 hours

With an estimated time of first pass over target of two hours, it is reasonable to assume that three hours is a fairly accurate estimate of time required to stab re-entry cone with present techniques. This of course will vary with wind and weather conditions, currents, heading changes that may be required during pulling and running string, etc.

Respectfully submitted,

s/ Captain Joseph Clarke
t/ Captain Joseph Clarke
Master, Glomar Challenger


EXAMPLE PLOT
WATER DEPTH 13,000 FT.
1ST RANGE TARGET 450 FT.
2ND RANGE TARGET 200 FT
TARGET Ø CLOCKWISE
TRUE Ø 050° RANGE 300'
ALTERNATE POSITION "C"
SELECTED.
DEPTH CHANGE FROM
13,000 TO 16,900
SELECTED.
MIN. RANGE POSSIBLE
= 10 FEET.
VESSEL HEADING
"A"
"B"
"C"

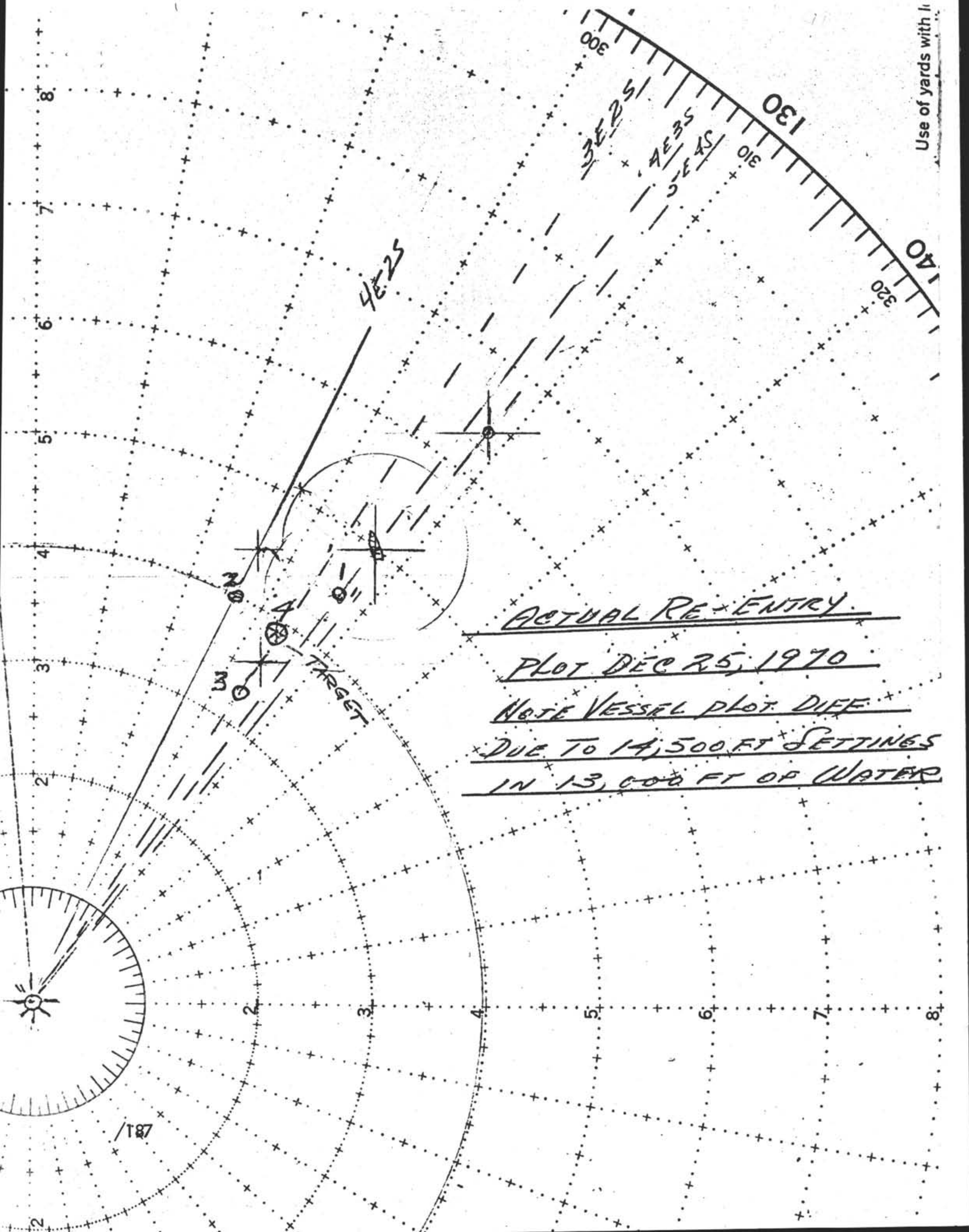

ACTUAL RE-ENTRY
PLOT DEC 25, 1970
NOTE VESSEL PLOT DIFF
DUE TO 14,500 FT SETTINGS
IN 13,000 FT OF WATER
4E2S
3E2S
4E3S
5E4S
TARGET
130
140
300
310
320
Use of yards with l
/T87

Photo #1 - Re-entry Cone Assembled on Dock in San Juan

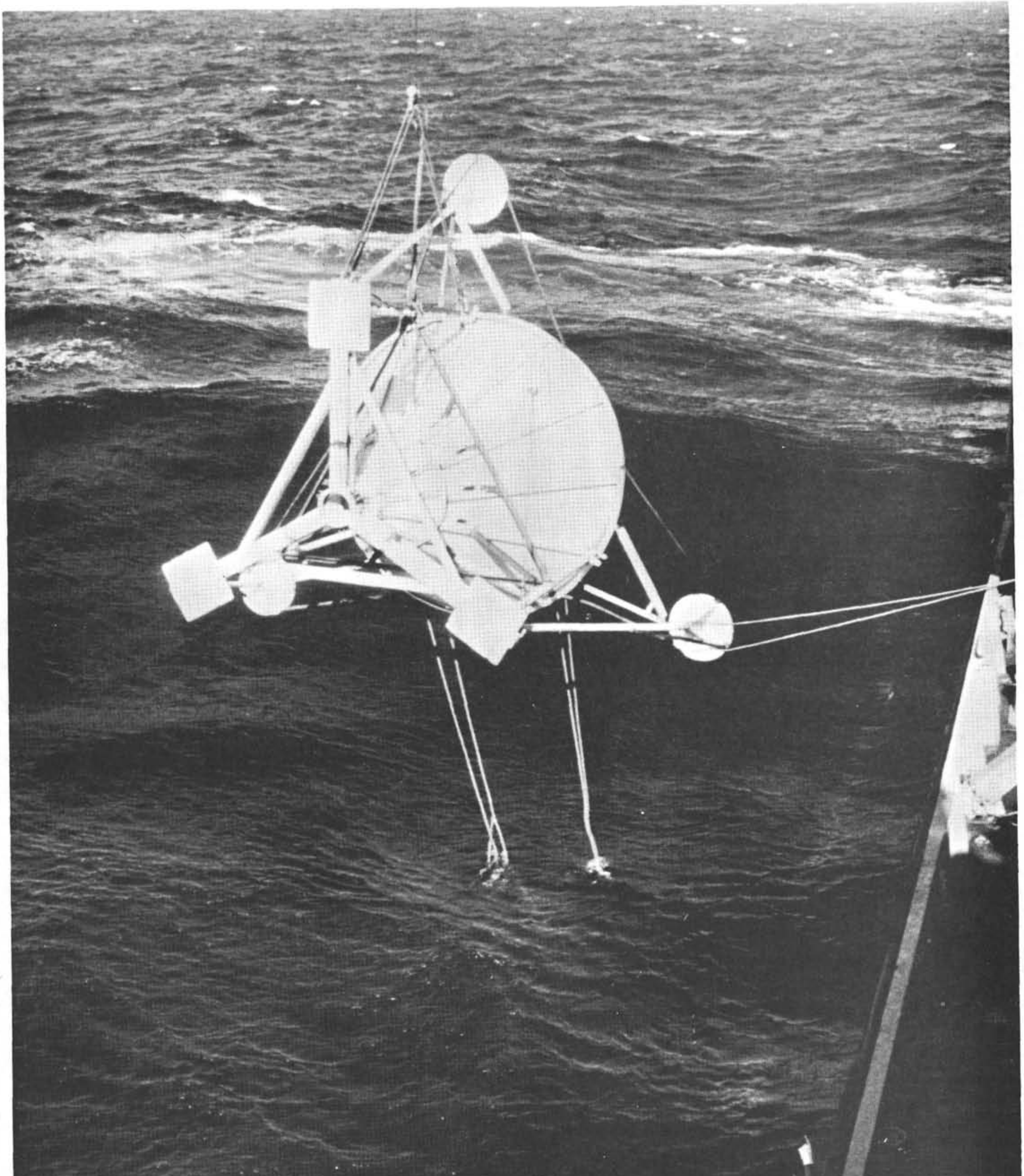


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Photo #2 - Keelhauling Re-entry Cone Using Side Launch

Photo #3 - Casing Hanger

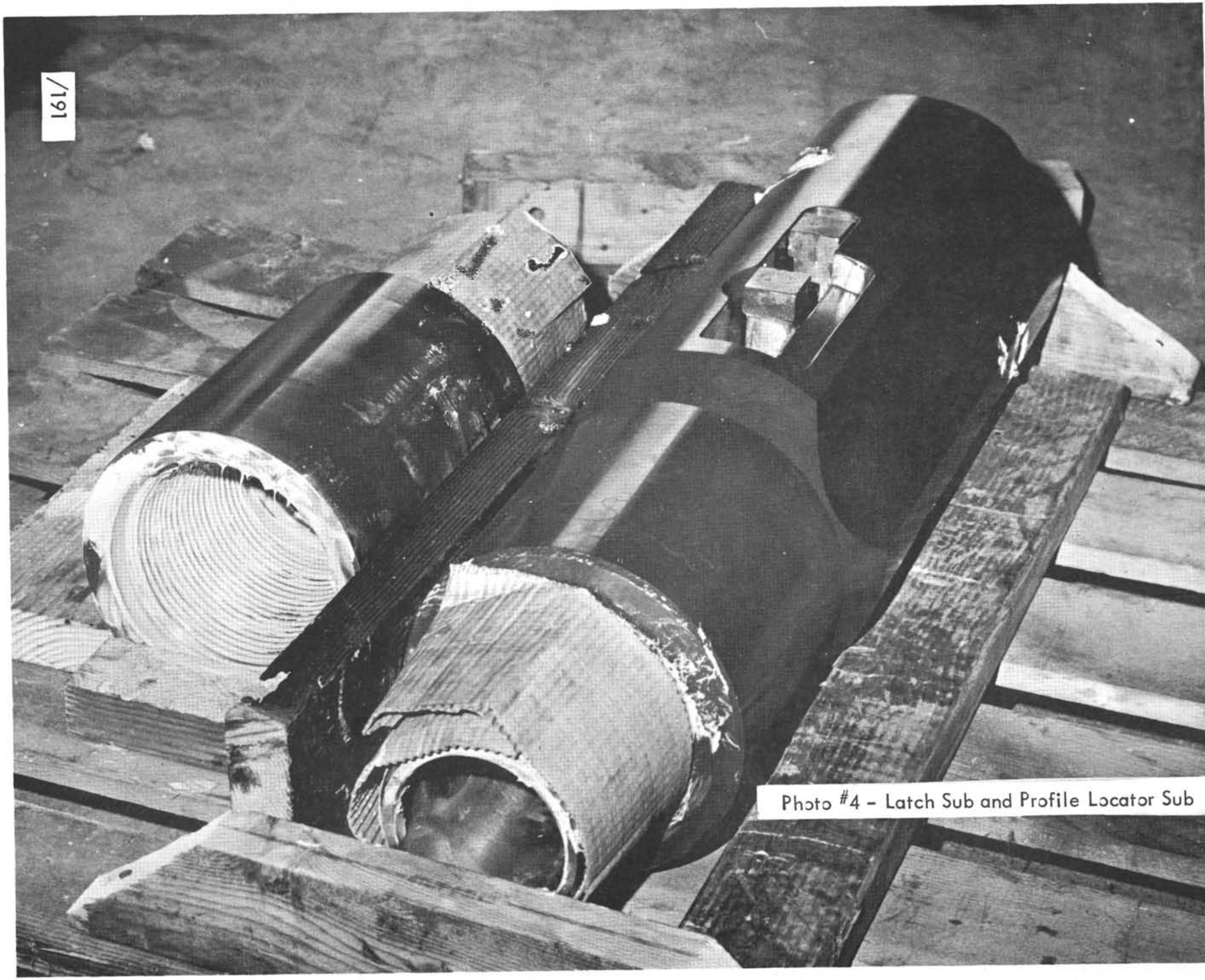

Photo #4 - Latch Sub and Profile Locator Sub

Photo #5 – Casing Hanger Assembled with Latch Sub

For Photo #6 - See Appendix G, in this report, entitled "Re-entry Operating Manual", Figure #11.

For Photo #7 - See Appendix G, in this report, entitled "Re-entry Operating Manual", Figure #12.

For Photo #8 - See Appendix G, in this report, entitled "Re-entry Operating Manual", Figure #13.

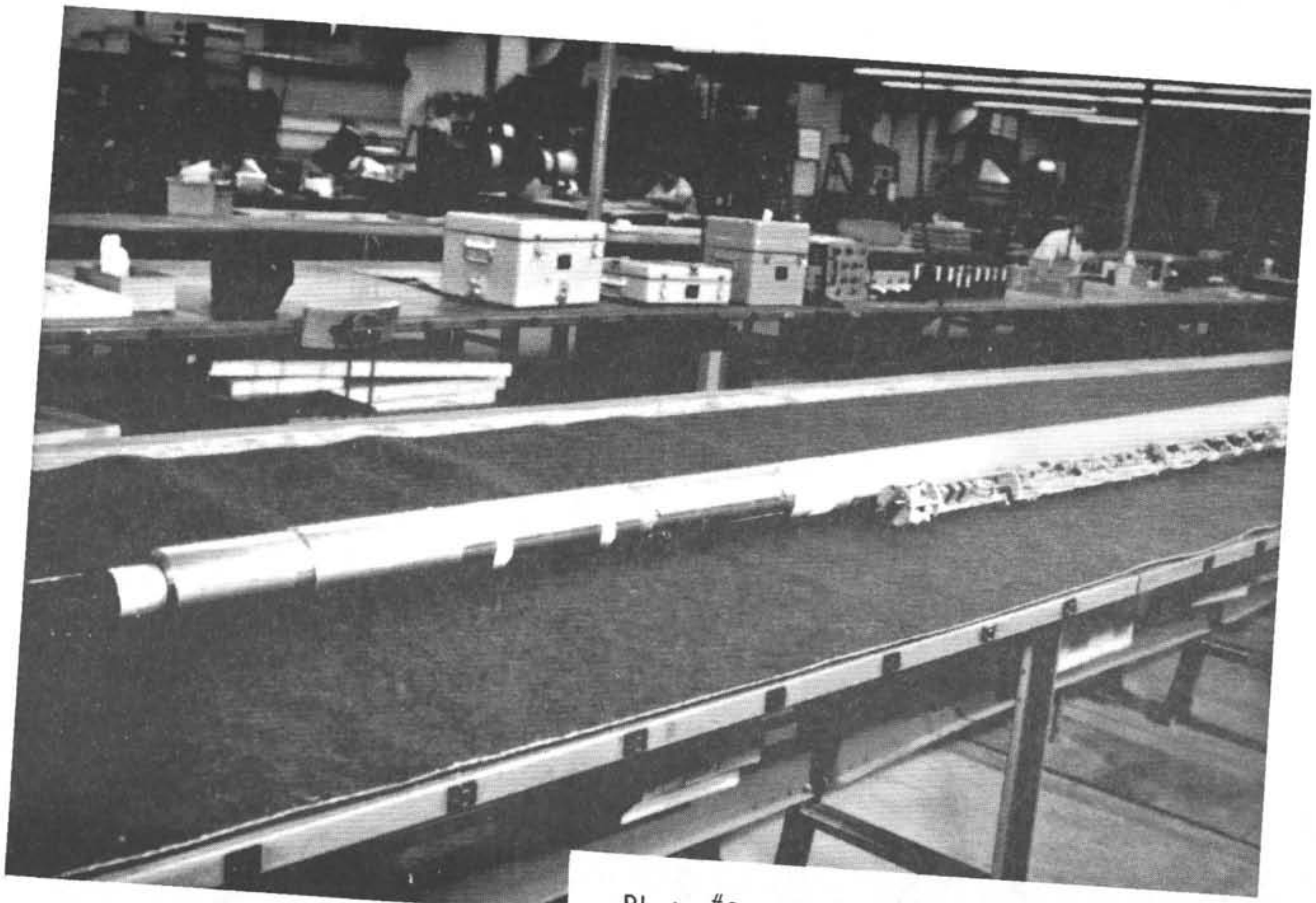

Photo #9 - Edo Sonar Scanning Transceiver

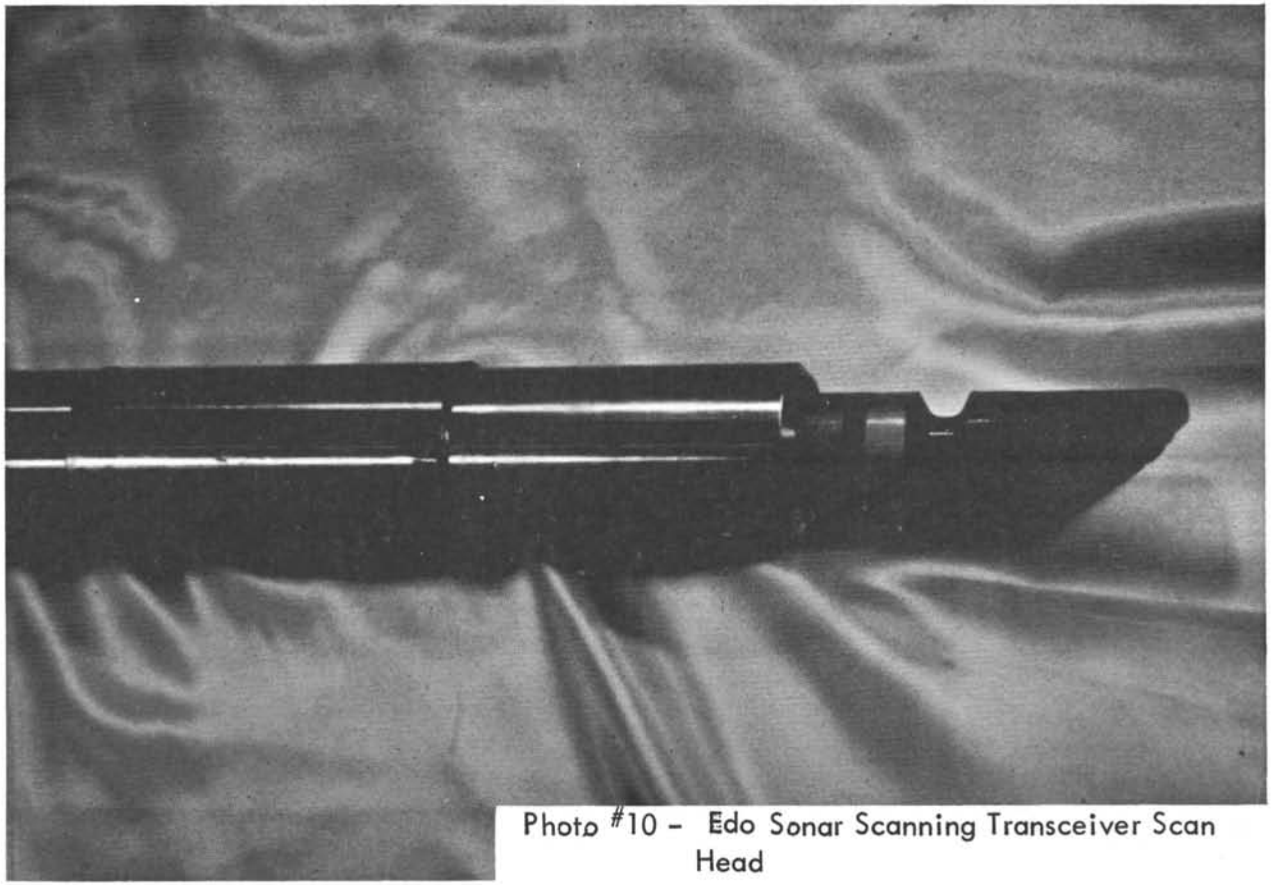

Photo #10 - Edo Sonar Scanning Transceiver Scan Head

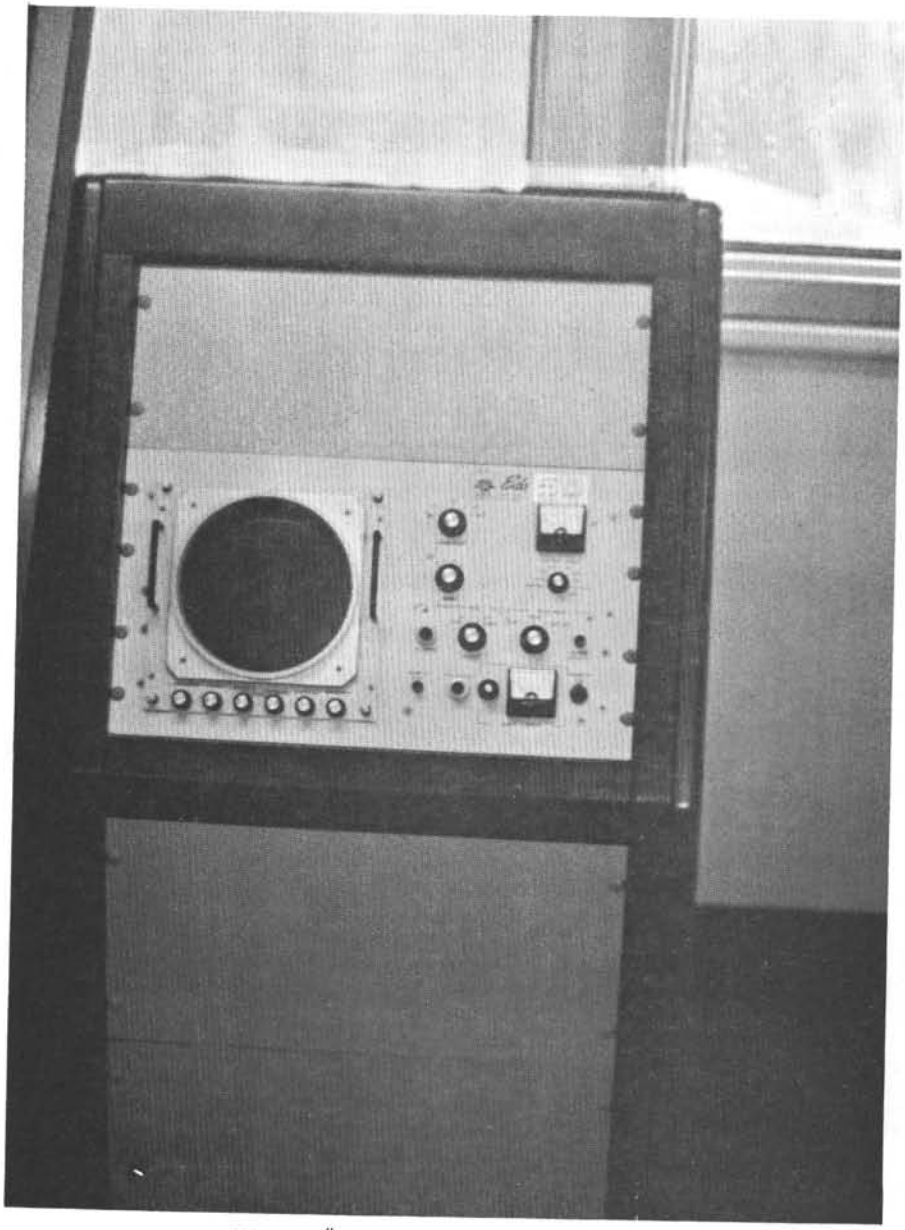

Photo #11 - Edo Sonar Scope Bridge Console

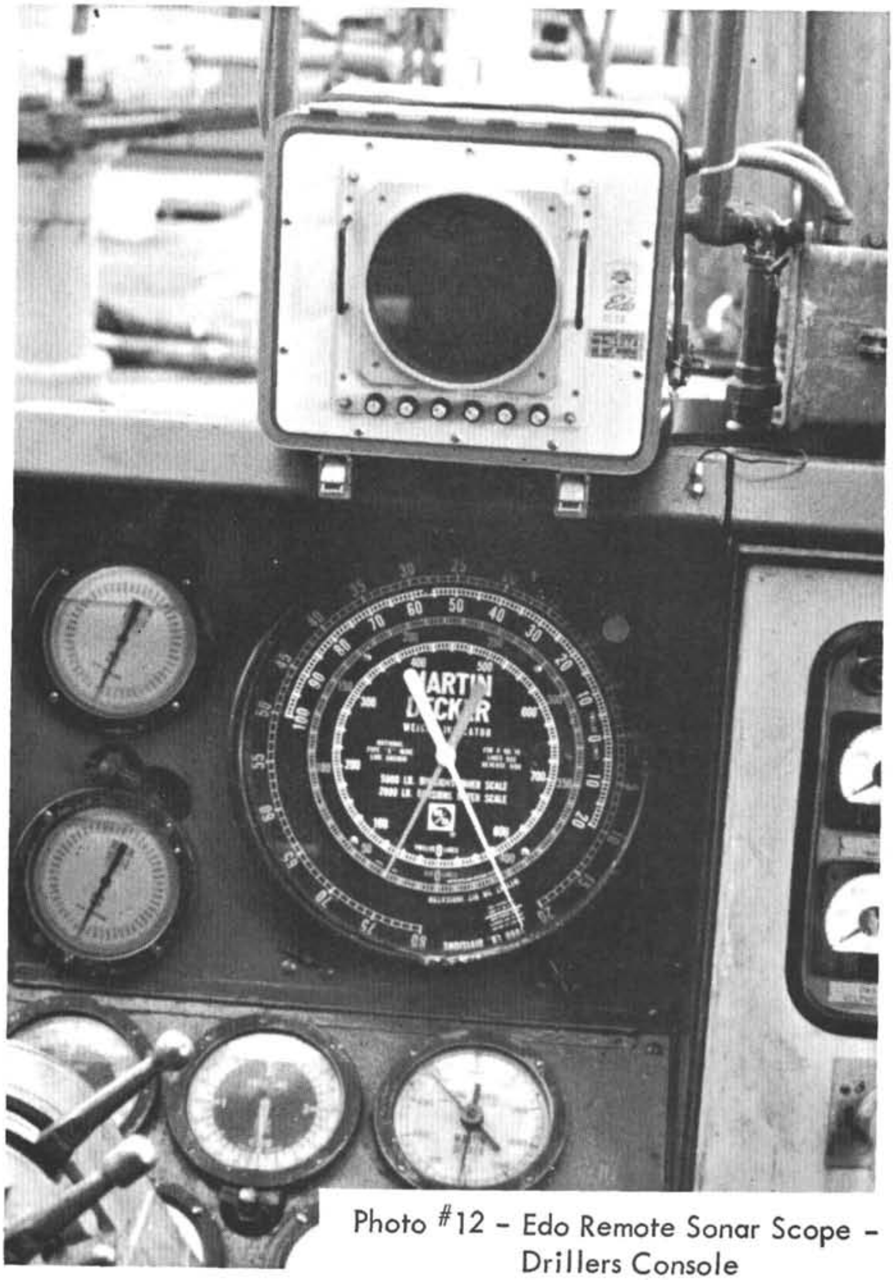

Photo #12 - Edo Remote Sonar Scope - Drillers Console

APPENDIX G

DEEP SEA DRILLING PROJECT

RE-ENTRY
OPERATING MANUAL

CONTENTS

I. GENERAL DESCRIPTION - Deep Sea Drilling Project Re-entry System

The Deep Sea Drilling Project's re-entry system consists of the following:

A. Re-entry Hardware

1. Conical Re-entry Base with Latches
2. Casing Hanger Assembly with Bushing
3. Release Sub
4. Shifting Tools (Coring Line)
5. Handling Tools

B. Re-entry Electronics

1. Edo Western Model 516 High Resolution Scanning Sonar (Complete)
2. Logging Cable and Logging Unit

A brief description of these components follows:

A.1 Conical Re-entry Base

The concial re-entry base (Figure 1) is fabricated from mild steel plate and structurals. The bases are shipped disassembled but require a minimum of field welding. The assembled base is approximately 13 feet high with a cone diameter of approximately 14 feet. The cone angle is 60 degrees to reduce scanning transducer breakage.

Estimated weight - 5 short tons.

Three releasable latches in the latch ring retain the casing hanger after the hanger is landed in the base.

A.2 Casing Hanger Assembly

The casing hanger assembly supports the casing string in the base and attaches the casing and base to the bottom hole assembly. In the running position rotatable paddles hinged in the hanger are locked in the pockets of the release sub (Figure 2). In the release position the paddles are free to rotate out of the pockets of the release sub releasing the bottom hole assembly from the base (Figure 3). The casing hanger is for 13 3/8 inch casing and will accept up to and including 12 1/4 inch bits. A bushing is used to centralize the release sub in the casing hanger (Figure 4). The bushing is recovered with the release sub. The casing length is selected to fit ocean floor sediments as determined by an exploratory hole and to place the core bit approximately at the casing shoe.

A.3 Release Sub

The release sub is placed (spaced out) in the bottom hole assembly so that the core bit will be at the casing shoe, preferably immediately below a bumper sub. This sub has three pockets on the outside into which the paddles of the casing hanger are rotated into. The paddles are locked in place by moving stop bolts alongside the paddles. These stop bolts are screwed into a sleeve in the bore of sub. The sleeve is shifted (moved up) by a special tool run on the 1/2 inch wire coring line. When the sleeve is up the paddles are free to rotate out of the pockets and when the sleeve is down, the paddles are locked in the pockets. Catches on the sleeve hold it in the up position after shifting. (Item No. 5 - Figure 7).

A.4 Shifting Tools

A shifting tool, similar to those used to open and close sleeves in oil field production tubing, is used to release the downhole assembly from the base. The shifting sleeve (with stop bolts) is machined so that either the Rotary Oil Tool (Figure 8) or the Baker Oil Tool (Figure 11) shifting tool, will engage, shift, and release.

The tool is run in and retrieved with the same wireline used to retrieve cores. The Baker shifting tool has had a history of broken profile keys, and should only be considered as a backup to the Rotary tool.

A.5 Handling Tools

In general, standard rig equipment is used to assemble and run the re-entry hardware. Wire rope slings used to keelhaul the base are furnished to specified lengths.

B.1 Edo Western Model 516 High Resolution Scanning Sonar consists of the following units:

a. Surface Control Unit

b. Power Supply

c. Remote Display

d. Downhole Scanner-Transceiver

This equipment will locate and range underwater targets at ranges from two feet to 500 feet. The scanner-transducer must see the target and will operate through a 2 7/16 inch core bit. The signal is transmitted to the surface through a standard 7-conductor logging cable.

Edo Western's instruction manual No. 13096, complete with blue line prints, covers the operation and maintenance of this equipment. A copy is on board the Glomar Challenger.

B.2 Logging Cable and Logging Unit

The logging cable is standard 7-conductor double armour 15/32 inch diameter. The logging unit is the special unit designed by Schlumberger for Project Mohole. Instruction manuals for this unit are on board the Glomar Challenger.

II. ASSEMBLY - Re-entry Hardware

NOTE: Use grease and/or rust preventatives on all moving parts.

A.1 Conical Re-entry Base, Ref. Figure 1, B/P Assembly RE-030 and RE-020 Sheets 1,2,3.

The guide base latches (Ref. RE-030) are normally assembled in the lower cone before shipping. If not in place, assemble before assembling the cone. The lip of the latch groove has been removed sufficiently to allow the latch segments (3) to be inserted and moved around until the threaded holes in the latches are opposite the pipe nipples on the base. Remove pipe cap. The latch rod is then screwed into the latch using a jam nut to tighten. Remove nut, slip the stop washer and spring over the latch rod and replace the pipe cap. The spring should snap the latch forward. Tension can be increased by adding 7/16 inch washers behind the stop washer. Screw on the 7/16 inch hex nut and stake for safety. This nut is used to retract and hold the latches if removal of the casing hanger is required. The re-entry base will normally be delivered to the ship unassembled. All sections have been pre-fitted and assembly bolt holes drilled. After assembly with bolts, the lower and upper cones and all intersections of beams and braces are welded together. To prevent fouling the keelhaul line, braces are added to the reflector on the side the lowering sling is attached.

A.2 Casing Hanger Assembly, Ref. Dwg. RE-013 and Figure 5,6.

The casing hanger is assembled as follows (normally shipped assembled):

a. Slip the torsion spring (5) over the hinge pin until the radial end of the spring engages the hole in the pin. Thread on nuts 6 and 7 and jam them together (Figure 5).

b. Insert the paddle (2) into the window of the hanger lining the hole up with the hinge pin holes in the hanger. The chamfered end of the paddle goes down with the chamfer on the inside (Figure 6).

c. The hinge pin (3) is run through the hinge pin holes in the hanger and the paddle. A wrench is used to turn the hinge pin (3) until the spring end "B" is seated in locating hole "A" in the hanger.

d. The hinge pin is further turned until the drive loc pin holes in the paddle line up with the holes in the hinge pin. Two drive loc pins are then driven flush (Figure 6).

CAUTION: Be sure all moving parts or internal surfaces are coated for rust prevention.

A.3 Release Sub Assembly, Ref. Dwg. RE-040 and Figure 2,7.

The release sub is assembled as follows:

a. Fit "O" rings (4) to the "O" ring grooves.

b. Place the sleeve with "O" rings inside the release sub (7). Line up latch slots with windows.

c. The spring catches are fastened to the sliding sleeve with No. 10-32 flat head screws. Screws are set with Bakerlok or equivalent.

d. Ref. Dwg. RE-026. Screw the stop bolt (1) into sliding sleeve. Set with Bakerlok and make up tight with Allen wrench.

e. Slip the stop bolt sleeve onto the stop bolt. Lock in place with truarc snap ring (3).

CAUTION: Be sure all moving or internal surfaces are coated for rust prevention.

A.4 Shifting Tools, Ref. Dwg. RE-019 Figure 8.

The Rotary Oil Tool sleeve shifting tool is assembled as follows:

a. Place dog spring (3) in spring cavity in shifting dog (2). Insert dog and spring in slot in shifting tool body (1). Push forward until end of dog is under retainer lip of slot. The pin holes in the body and dog should now line up.

b. The dog pivot pins are next driven through the body and dog. If it is desired to have the pivot pins shear and release the dogs before parting the coring line, pins with reduced shear area can be selected. The pin is retained by a 1/4 inch NC socket head cap screw. Drift holes are continued through one boss, so sheared sections of the pivot pin can be removed with a drift.

The backup shifting tool (Baker) is described in Appendix I.

SHEAR PIN CALCULATIONS FOR ROTARY MODIFIED SHIFTING TOOL

I.	Material: Mild Steel			
II.	Ultimate Shear Strength (s)			58,000 psi
III.	1.	1/16 inch diameter	Single Shear	178 lbs.
			Double Shear	356 lbs.
		Total Shearing Force for 3 Pins		1,068 lbs.
	2.	3/32 inch diameter	Single Shear	420 lbs.
			Double Shear	840 lbs.
		Total Shearing Force for 3 Pins		2,520 lbs.
	3.	1/8 inch diameter	Single Shear	710 lbs.
			Double Shear	1,420 lbs.
		Total Shearing Force for 3 Pins		4,260 lbs.
	4.	1/4 inch diameter	Single Shear	2,850 lbs.
			Double Shear	5,700 lbs.
		Total Shearing Force for 3 Pins		17,000 lbs.

A.5 Handling Tools, Ref. Dwg. RE-39 and Figures 2,9.

a. The bolts and cam sleeves ("A", Figure 2) are used to support the downhole assembly while aligning the paddles with the slots in the release sub.

b. Three one and one-quarter inch sockets with extensions and ratchet handles are required to swing the paddles into the locked position.

c. The following wire rope slings are required for keelhauling:

(1) 2 each 1" x 15' long

(2) 2 each 1" x 120' long

(3) 2 each 1" x 66' long

(4) 1 each 1" x 10' long

(5) 1 each 1" x 8' long

(6) 1 each 3/4" x 112' long

All slings to be made up with eyes both ends and to use shackles from ship's stores.

III. OPERATION

The following procedure has been successfully used to accomplish re-entry and is presented as a guide for future operations. Experience has shown that an exploratory hole is essential to determine the characteristics of the ocean floor and amount of casing to be used. The exploratory also provides a means of establishing need and bit life to be expected.

A. Keelhaul Re-entry Cone, Ref. Figures No. 9, 19

1. Rig re-entry cone in an upright position. Place one inch doubled slings in each lifting eye (each sling 56 feet long or 28 feet effective) and shackle into crane whip line. Make up short bridle on reinforced leg and shackle into crane block.

2. Pick up cone with whip line. Use air tuggers to restrain cone. (Use tuggers both from rig floor and main deck.) Pick up on crane blocks and turn cone on its side. Remove whip line and secure doubled slings inside cone.

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3. Swing cone onto port side of main deck with open end facing towards the starboard bow. Keep strain on crane block to avoid damage to reflectors.

4. Hook up keelhaul lines to main doubled lifting slings. Use at least one inch keelhaul lines rigged up to derrick travelling blocks (should be 120 feet long).

5. Hook up doubled 3/4 inch line to crane whip line and shackle bight into lifting bridle (length of 3/4 inch line 110 feet or 55 feet doubled). Take load with whip line and remove crane block. Take up slack on keelhaul lines.

   NOTE: Keelhaul lines should be run prior to these operations. Small diameter manila pull lines have been installed without the aid of divers by positioning the Glomar Challenger so that the ocean current is running thwart ship from the starboard. The manila line is lowered along with a small diameter rubber air hot hose attached through the proper openings in the moon pool. A fabric bag (pillow case) secured to the end is then inflated and floats alongside on the port side where it is retrieved.

6. Swing cone over the side with open end facing the moon pool. Keelhaul line acts to keep cone facing correctly.

7. Assure lines are not fouled on reflectors. Lower cone quickly while hauling in on keelhaul lines. When ball on whip line is even with bulwark, cut one 3/4 inch line below eye with cutting torch and retrieve entire line.

8. Pick up on keelhaul line carefully and shackle doubled lifting slings from cone onto sling prepared to receive same in moon pool.

9. When ready to lower cone, one side of each doubled lifting sling is cut below the eye and the wire retrieved.

B. Running Casing

The casing hanger is bored to accept 13 3/8 inch casing. Smaller sizes may be run if the proper adapters are made available. Thirteen and three-eighths inch casing is kept aboard the Challenger to allow maximum flexibility of bit sizes. The length of the casing string is determined by ocean floor conditions as determined by an exploratory hole (i.e., the depth of penetration possible without rotation).

1. After the casing length is selected, the lower joint is cut to fit, keeping in mind that the bit must be spaced out just inside the casing shoe.

2. The casing shoe is welded on the lower joint.

3. The selected number of joints of casing are run in the normal manner using Bakerlok on connections. (Casing has been provided with collars tack welded in place. This should be verified.)

4. The assembled casing hanger is made up on the upper joint.

5. The casing is then lowered on elevators held with slings through the table and hung off on a spider placed across the top of the permanent section of the horn in the moon pool.

C. Bottom Hole Assembly

1. The bottom hole assembly is made up including the latch sub and release sub. The length to the release sub should space the core bit just inside the casing shoe. The bushing is placed on top of the latch sub. (No pack-off is provided.)

2. A drill collar is added to the bottom hole assembly and release sub for handling and the assembly is lowered through the table until the sub is just above the casing hanger.

3. The 1 1/2 inch bolts with cam sleeves are inserted and the bottom hole assembly lowered until the cams rest on top of the hanger.

4. The release sub is adjusted vertically with the cams and by rotating until the windows in the casing hanger and the slots in the release sub line up.

5. The sliding sleeve is raised until the latches hold it in the up position. The rollers are aligned correctly and the paddles turned to the in or latched position using three 1 1/4 inch sockets and ratchet wrenches. The latches holding the sliding sleeve are depressed allowing the sleeve to slide down locking the paddles in place.

6. Releasing is checked by lowering the shifting tool into place with the sand line and releasing the paddles.

7. The paddles are re-engaged and checked for latching by attempting to rotate the release sub in the casing hanger.

NOTE: This operation is critical as excessive tolerances caused by wear will lead to premature unlatching.

8. One-half inch shear bolts are inserted through the casing hanger into the bushing.

9. The 1 1/2 inch bolts and cam sleeves are removed.

10. The bottom hole assembly and casing string are picked up and the casing elevators and spider removed.

11. The casing hanger is lowered until it seats and latches in the cone base.

NOTE: Set down carefully to avoid excessive strains on slings.

12. Positive latch action is checked by picking up the bottom hole assembly and seeing if the cone is lifted.

NOTE: Check latches by simulating action of tripping drill pipe.

D. Releasing the Cone

1. With the cone slightly raised, the doubled lifting slings are released by cutting off one side of each sling below the eye and retrieving the slings.

E. Running to Bottom

1. The remainder of the bottom hole assembly is picked up and the re-entry base run to bottom in the normal manner, care being exercised not to lower the base too rapidly.

NOTE: The lowering can be watched on the PDR to 6,000 feet plus .

2. When the casing shoe is a few meters off bottom, the swivel and power sub are picked up. Circulation is started and the casing string is washed in until the base of the re-entry cone is resting on the ocean floor.

3. The shifting tool is run in on the 1/2 inch coring line with the normal retrieving hook-up (the shifting tool is fitted with an Otis pulling neck on top). It is lowered until the dogs are below the sliding sleeve. The coring line is pulled up until:

a. The line pulls tight and releases indicating the sliding sleeve moved to the release position.

b. The line pulls tight and holds, indicating the sliding sleeve is in a bind. Normally, rotating the pipe left and right and raising and lowering the drill string will free the sleeve. As soon as the sleeve has been moved up rotating the drill string to the right will force the paddles to rotate, freeing the drill string from the cone and base.

F. Drilling and coring are continued until the bit is dull and the drill string pulled out of the hole. The release sub is broken out of the bottom hole assembly.

NOTE: With insert bits due regard to bearing life is required.

G. A spiral stabilizer is added to the outer core barrel between the bit sub and the outer core tube (drill collar). The inner barrel is respaced to fit. The hanger bushing, RE-7 (which was retrieved with the dull bit) is fastened to the stabilizer with three 1/2 inch NC mild steel bolts. These bolts may be nicked to reduce the weight required to shear. The bolts are sawed to be flush with the stabilizer blades. The bottom hole assembly is picked up and the bit is run and spaced above the re-entry cone so the bit can be lowered into the cone without adding drill pipe to the drill string. The hanger bushing will shear when re-entry is made and verification aboard the ship will be seen on the weight indicator.

H. The Edo high resolution sonar scanning instrument is attached to the Schlumberger cable head. The instrument and surface electronic gear are checked per the Edo Instruction Manual. The instrument is run to bottom and seated in the core barrel. Care must be exercised while running in so that the conductor cable does not overrun the instrument.

I. When the instrument is seated and scanning the bit is guided over the cone by maneuvering the vessel (Appendix II), the bit height above the cone should be three to four meters. When the bit is directly over the cone, the drill string is slacked off, allowing the bit to slide down the cone and be guided into the casing. As the drill string is lowered, the hanger bushing will seat and the stabilizer will shear out of the bushing. This will show on the weight indicator, indicating that the bit actually is in the casing and re-entry has been made.

J. The bit is run to bottom and drilling and coring continued.

IV. APPENDIX I

Baker Oil Tool Company Equipment

In addition to the above equipment, the following is available for backup or modification of operational procedures as required.

A. The Baker Shifting Tool, Ref. Baker Oil Tool Dwgs. 204/865, DSDP Dwg. RE-12 and Figure 11, is designed to move the shifting sleeve in the release sub to release the bottom hole assembly from the re-entry cone.

A positioning groove is machined in the crossover sub on top of the release sub. Spring loaded profile keys "A" Figure 11, in the Baker shifting tool expand into this groove when the tool is run in on the sand line. This stops downward motion of the tool and positions the shifting fingers, "B" Figure 11, slightly below the shifting sleeve in the release sub to engage the sleeve. An upward pull on the sand line moves the sleeve to the release position and then collapses the fingers so the tool can be retrieved.

CAUTION: The spacing of the positioning groove, shifting sleeve, and profile keys and fingers on the tool are very critical. If the shifting tool jams the keys ride up the taper in the positioning groove. Jarring action releases the fingers by shearing pivot pins.

B. Jetting Capabilities, Ref. Baker Oil Tool Dwgs. 204/865, 206/031, 206/281-1, 206/281-2, DSDP Figures 12 and 13.
A jet sub to move the bottom of the drill string with pumping action is aboard. A sliding sleeve to close (or open) the jet is required to be run in the bottom hole assembly. The sleeve is moved with the same Baker tool described in (A) above, using a positioning groove to stop the shifting fingers below the sleeve.

The jet must be isolated from the Edo high resolution scanning sonar head with either of two styles of bore pluggers. Both are run above the Edo tool and pack off between the bottom hole assembly and the logging head. One, Figure 12, has an expandable packer which is expanded and seals by jar action of the tool when the tool is seated on the bit. Picking up with the logging line collapses the packer and opens a bypass.

The second, Figure 13, seats in a special honed outer core barrel drive sleeve. There is no seal expansion and the chevron rings seal from pressure. Picking up with the logging line, opens a bypass. Lower inner barrel subs must be turned down to operate with this sleeve in the core barrel.

DETAIL ON BAKER BORE PLUGGER FOR JET SUB

The Baker bore plugger, used in conjunction with a sonar device attached to the lower end, is designed to perform two functions. One, to index the directionally beamed sonar device in alignment with a port in a sub made up in the drill pipe above the bore plugger, and two, to block the flow of fluid below the bore plugger for establishing a seal between the drill pipe and the cup-type packing element and closing the circulating port between the mandrel and the shut-off sleeve.

OPERATION

The indexing sub is made up into the drill string and the indexing sleeve rotated to provide alignment between a slot in the indexing sleeve and the port in the drill pipe jet sub above it. This alignment is maintained by tightening the hex socket set screw, Item 15, and installing the Stat-O-Seal, Item 16,and socket head cap screw, Item 17, to prevent leakage. The drill pipe is now run to a depth which positions it a few feet above the top of the funnel on the ocean floor. A 7-conductor wireline is run through the bore plugger and, with suitable spacers (inner barrels) attached to the sonar device with a leak-proof connection (threaded onto logging head). Install the clamp, Item 6, on the cable in such a position as to be just supporting the weight of the bore plugger on the internal shoulder in the retrieving head, the conductor cable being tight between the sonar device and the bore plugger. This assembly is now lowered into the drill pipe. Just before the sonar device shoulders out, the drag block, Item 13, will contact the mule-shoed bevel on the top of the indexing sleeve and rotate into the vertical slot as it is lowered. CAUTION: Subs of the proper length must be introduced between the sonar device and the bore plugger to position the drag block approximately in the center of this vertical slot to the dimension shown on T/M drawing 206/281-1. (At present, index subs are not available on the Glomar Challenger. Additional work will be required to make the index unit functional, however the pack-off unit is workable.) Additional downward movement of the cone, Item 31, is provided by a weight or jars fastened to the retrieving head. The weight should be between 500 and 1,000 lbs., or the jars capable of delivering that amount of impact force. Jarring down will now shear the brass shear screw, Item 26, permitting the cone to move into the packing element, expanding it outward against the inside diameter of the indexing sub and closing the circulating ports below the packing element. Fluid trapped between the advancing cone and the packing element inside diameter is vented by passing underneath the insert, Item 21, along the circular threaded path and vented to the annulus below the cup. With pack-off now achieved, pressure can be built up inside the drill pipe to force fluid through the drill pipe jet sub port and provide the force required to move the drill pipe. Directional orientation of the movement of the drill pipe can be achieved by rotating the drill pipe while monitoring its movement on the read out screen aboard ship.

After the drill pipe is positioned over the funnel, it will be lowered and a tensile load applied to the wireline conductor cable. The clamp, Item 6, previously attached to the cable, shoulders out on the inner shoulder of the retrieving head, Item 1, and pulls the cone out of the packing element, simultaneously reopening the circulating port below the packing element. The entire assembly is now retrieved slowly. Fluid passes into the inside diameter of the tool through the port above the packing element and out through the circulating ports below the packing element.

After each run, the tool should be disassembled, cleaned, suitably protected against rust and redressed for subsequent runs. All "O" rings should be carefully inspected and the drag blocks reworked or replaced as necessary. The packing element may also require replacement along with the brass shear screws. Make sure the key, Item 29, is installed, for this is the means for transmitting the rotation effected by the drag block in the indexing sleeve to the bottom sub and thence to the sonar device.

V. APPENDIX II

METHOD FOR RE-ENTRY USING VESSEL'S POSITIONING EQUIPMENT ONLY

1. Leave vessel in automatic mode of operation during all operations and leave vessel on same heading.

2. During all observations, make frequent notation of blip heading on sonar oscilloscope to assure that Edo tool has not slipped in azimuth. Also, be certain that all observations or range and bearings are taken with the vessel centered over beacon display of computer oscilloscope. Observations on range and bearing should be made only after the drill pipe motion due to vessel excursion is minimal. (Normally this requires a minimum of 15 minutes without a major change in position.)

3. All movements of vessel, range and bearing of target should be plotted on U.S. Navy maneuvering board HO 2665-20 with original positioning beacon plotted as center and the vessel's position in relation to this beacon plotted using any offsets previously put into computer. This must be done so that the final movements of the vessel by use of depth changes will be along a path angle in direct relation to the true position of the positioning beacon.

4. While using 500 foot scan on sonar oscilloscope locate target. With vessel directly centered over positioning beacon display on computer take initial range and bearing of re-entry cone target. Plot the circle of observed range from the vessel's plotted position.

5. Make an arbitrary move of vessel by using offsets in one direction only, preferably as near as possible to the vessel's heading. (Vessel's heading will of necessity be determined by existing elements and has no significant effect upon the operation.)

6. Observe whether offset move has increased or decreased the range of re-entry cone target. If vessel's move has increased range, the arbitrary move was in the wrong direction. In this case, the offsets should be removed and opposite direction offsets should be put into computer. Offsets of 200 to 400 feet should be used depending upon the distance of the original observed range of the target. If there has been a substantial decrease in range of target, allow sufficient time for vessel and drill pipe to settle (minimum of 15 minutes) and then, by an average of new ranges on target, draw another circle of range from the vessel's newly plotted position. This circle will intersect the original plotted range circle at two locations either of which could be the potentially true position of re-entry cone.

7. The approximate true position of the re-entry cone target may now be ascertained by observing the apparent relative motion of the re-entry target either to the right or left. The correct position is now selected.

8. After ascertaining the true position of the re-entry cone, draw a line from the center of the plotting sheet (i.e., true position of the beacon) through the true position of the re-entry cone.

9. Before any further movement of the vessel, plot three or more alternate coordinates of 100 foot offsets adjacent to the position of the re-entry cone. Draw dotted lines from the center of the plotting sheet to the outer edge of the plotting sheet which passes through these coordinates. (It is along these lines that the vessel may be moved byaltering depth settings.)

10. If desired, at this point the drill pipe may be rotated to display true azimuth as follows:

    a. Plot the true position of the re-entry cone target.

    b. Calculate the relative bearing.

    c. Rotate the drill pipe with chain tongs until the relative azimuth of the re-entry cone is displayed in its proper position on the sonar oscilloscope.

    NOTE: The above procedure may be desirable, however, in our present stage of evaluation of re-entry capabilities, it is not a requisite.

11. By visual inspection of the plotted alternate coordinates, select that set of coordinates whose azimuth through the center of the plotting board most closely approaches the target. The vessel can be made to move in and out along these lines of azimuth by adjustment of water depth selections (approximately).

12. Now, move the vessel in 100 foot increments by "offsets" to your selected coordinates.

    NOTE: A study is in process to modify the positioning system so that offsets as small as 10 feet can be used.

13. A brief explanation of the movements of the vessel by depth adjustments follows:

NOTE: This formula is approximate, but sufficiently accurate when used with small offsets in deep water.

a. To decrease range along plotted azimuth to beacon "increase" water depth.

b. To increase range from beacon "decrease" water depth.

c. The following formula may be used to pre-compute "closest point of approach" of re-entry cone target.

$$\text{Depth Setting Required} = \text{True Depth} \times \frac{\text{Range From Beacon}}{\text{New Range Desired}}$$

or

$$\text{Depth Setting Required} = \text{True Water Depth} \times \frac{\text{Coordinate Selected-Range From Beacon}}{\text{Desired Range (Over Cone) From Beacon}}$$

EXAMPLE

In attached "example plot" the water depth is 13,000 feet. The coordinate selected range from beacon is 590 feet, the position of re-entry cone target from beacon is 450 feet.

$$X = 13{,}000 \text{ feet} \times \frac{590}{450} = 16{,}900 \text{ feet}$$

16,900 feet = required depth setting to place vessel over sonar re-entry cone within 10 feet in example.

14. Now, after the vessel and bottom hole assembly has settled over new offset coordinates, increase or decrease depth settings as required to approach "CPA" of re-entry cone target.

15. A third alternate should always be borne in mind and that is our capability of moving "forward" or "aft" along a line of azimuth with our heading a distance of approximately 54 feet by making alternate hydrophone selections.

16. The above explained method of re-entry using vessel positioning only, does not preclude the future possibilities of movement in semi-automatic or manual modes of operation as our evaluation of ideas and techniques develop. However, at our present stage of development the automatic mode of operation appear by far the most expeditious.

17. Please refer to attached plotting sheets for a graphic display of vessel and target movements.

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VI. Figures 1 through 13

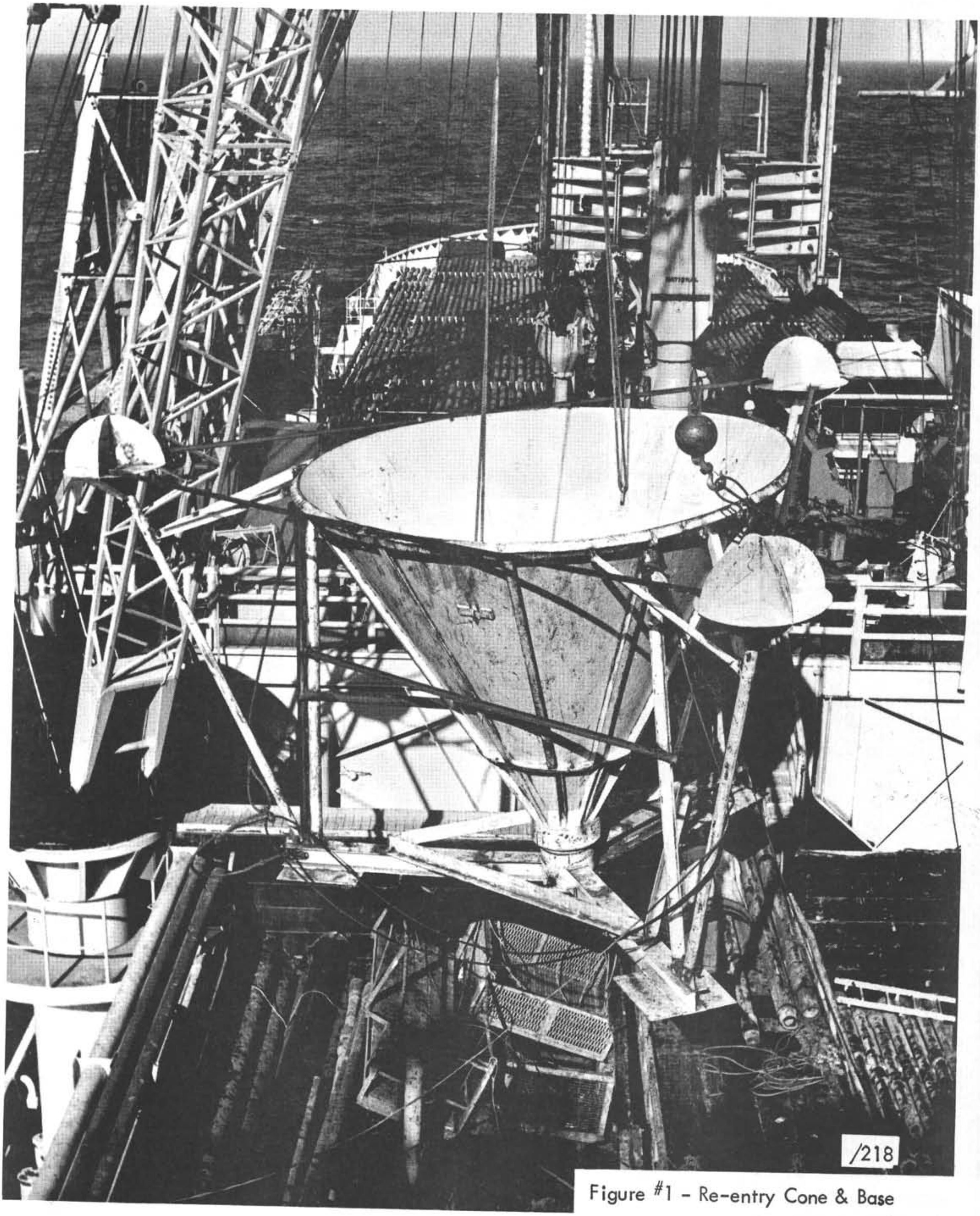
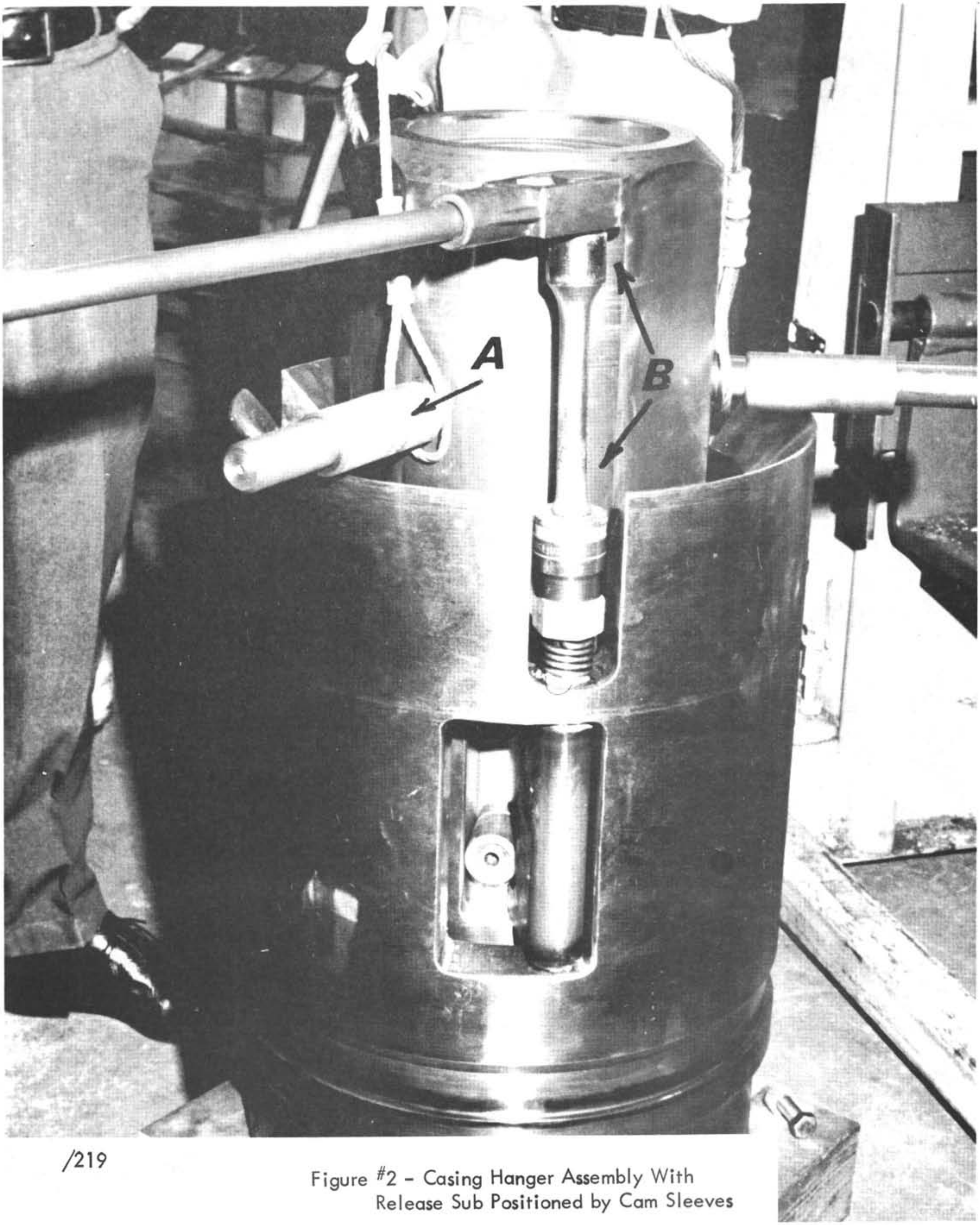


Figure #1 - Re-entry Cone & Base

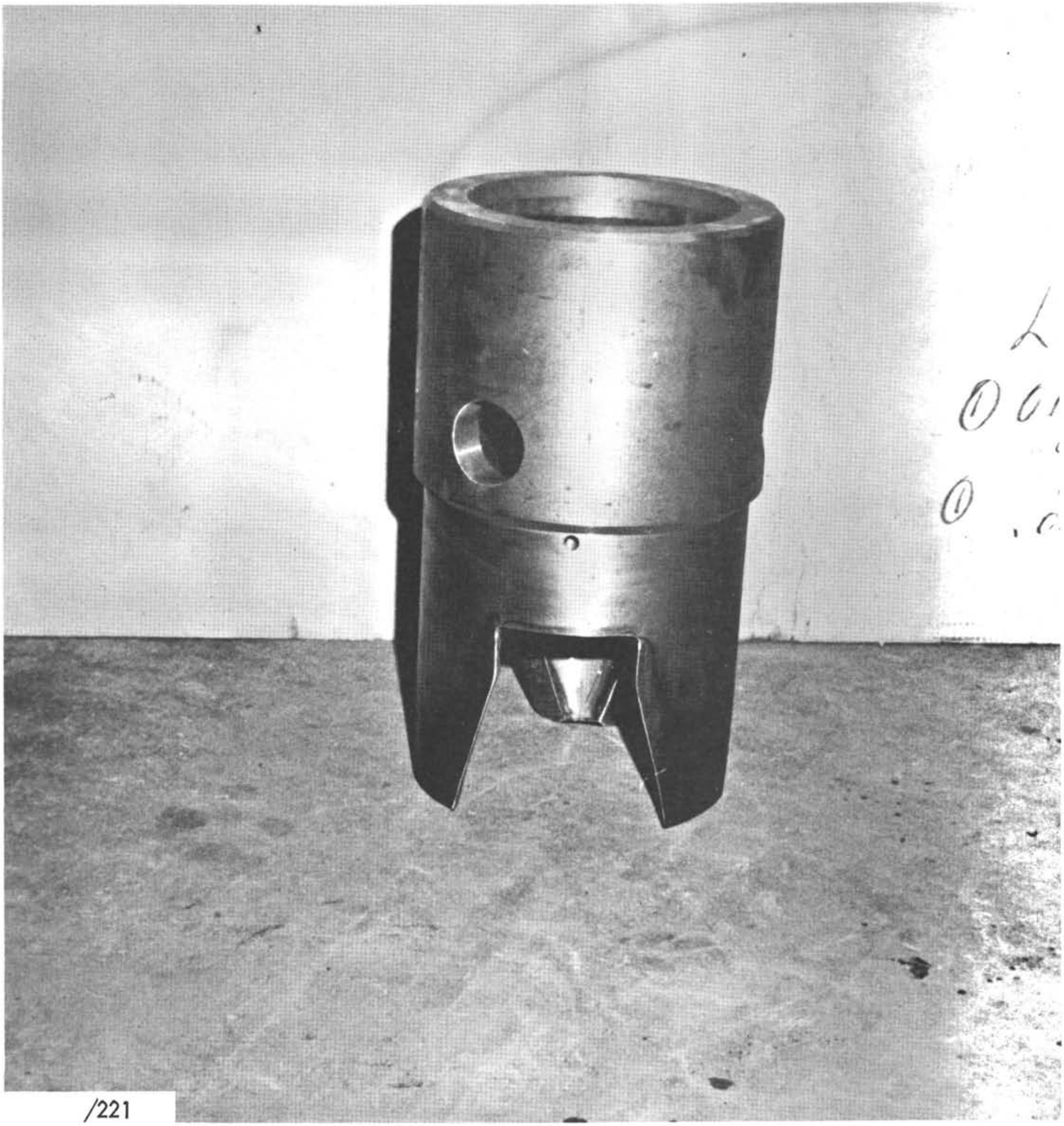


/219

Figure #2 - Casing Hanger Assembly With
Release Sub Positioned by Cam Sleeves

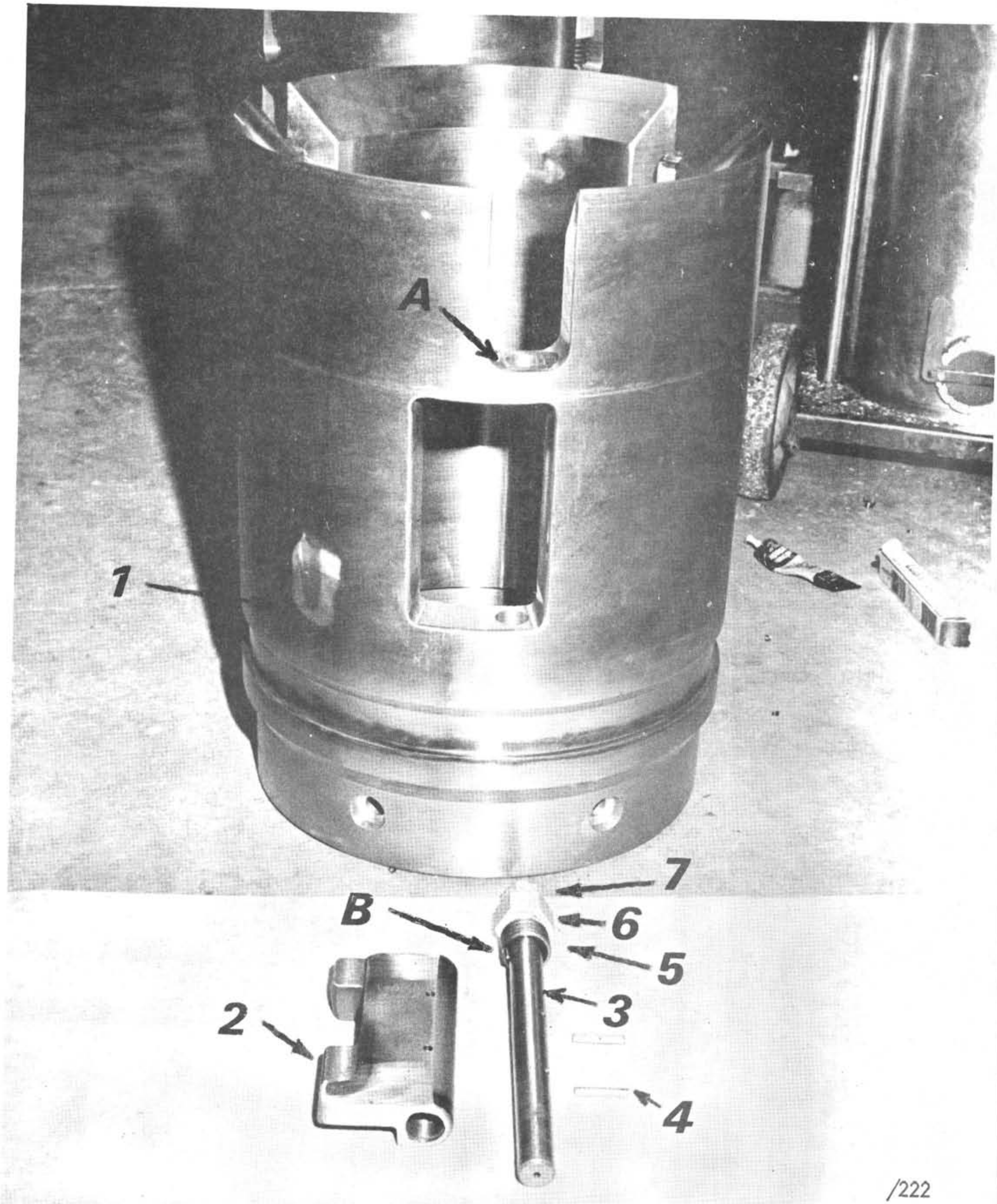
/220

Figure #3 - Release Sub With Stop Bolts in Release Position



/221

Figure #4 - Casing Hanger Bushing



/222

Figure #5 - Casing Hanger Exploded View

/223

Figure #6 - Casing Hanger Assembled

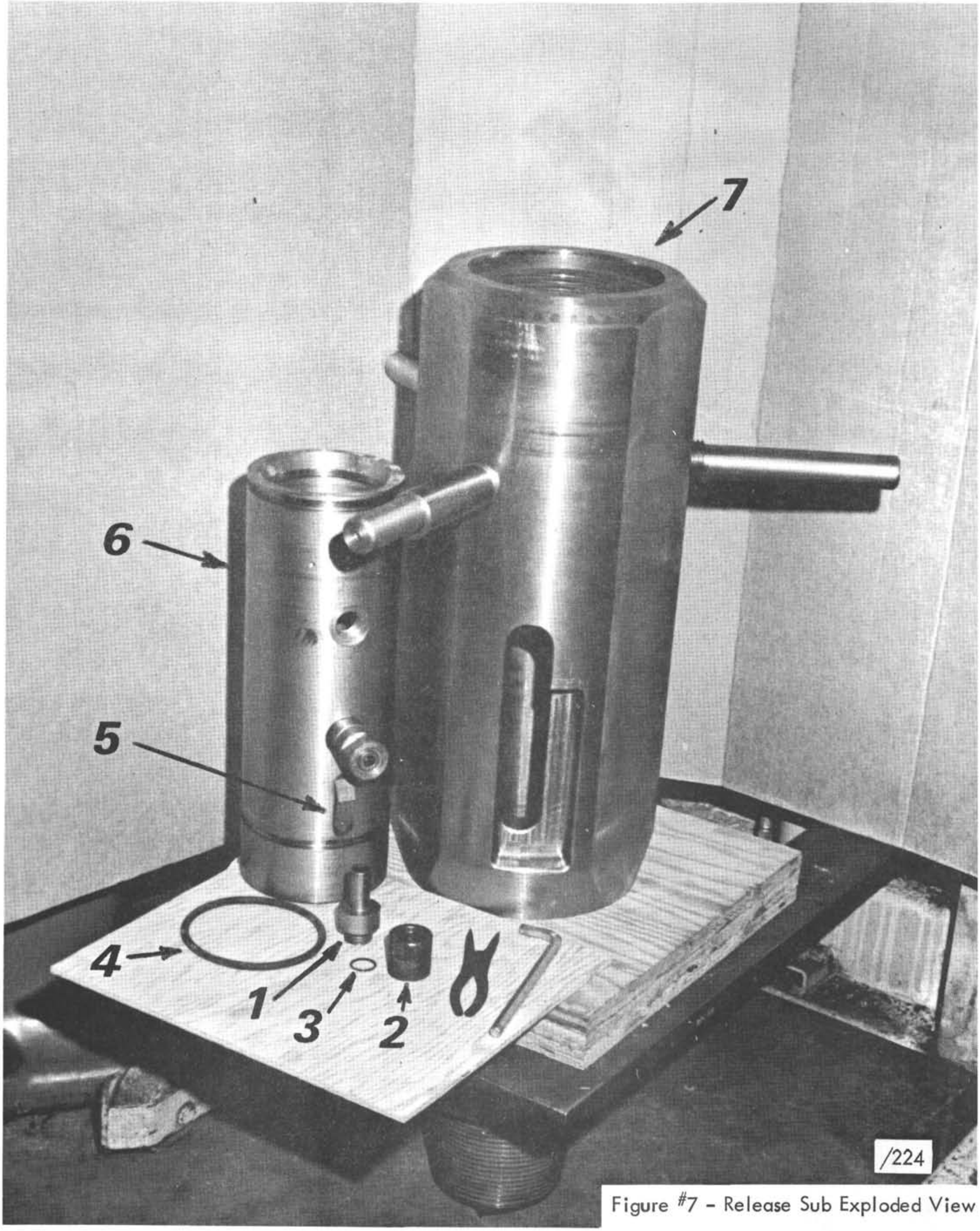


Figure #7 - Release Sub Exploded View

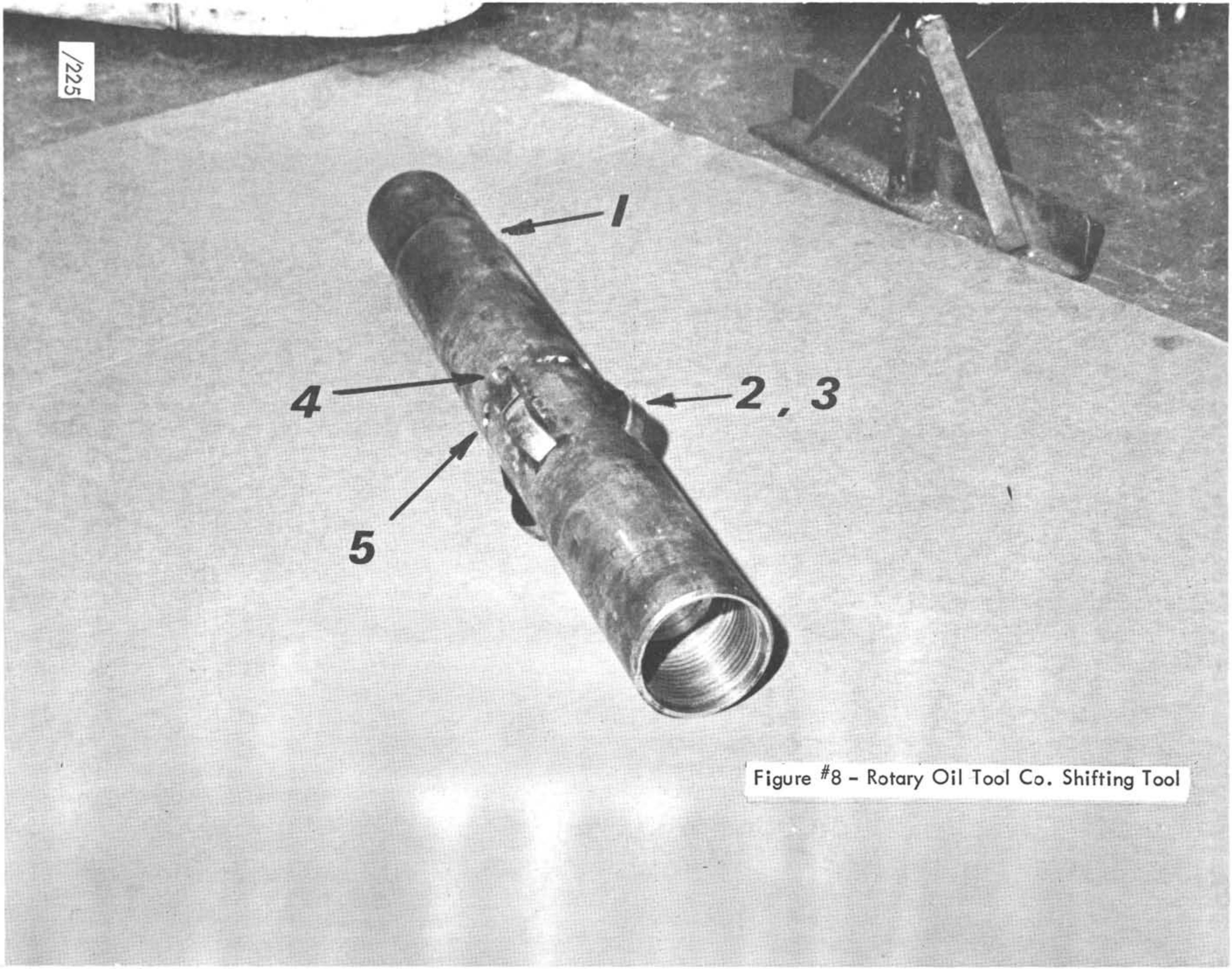
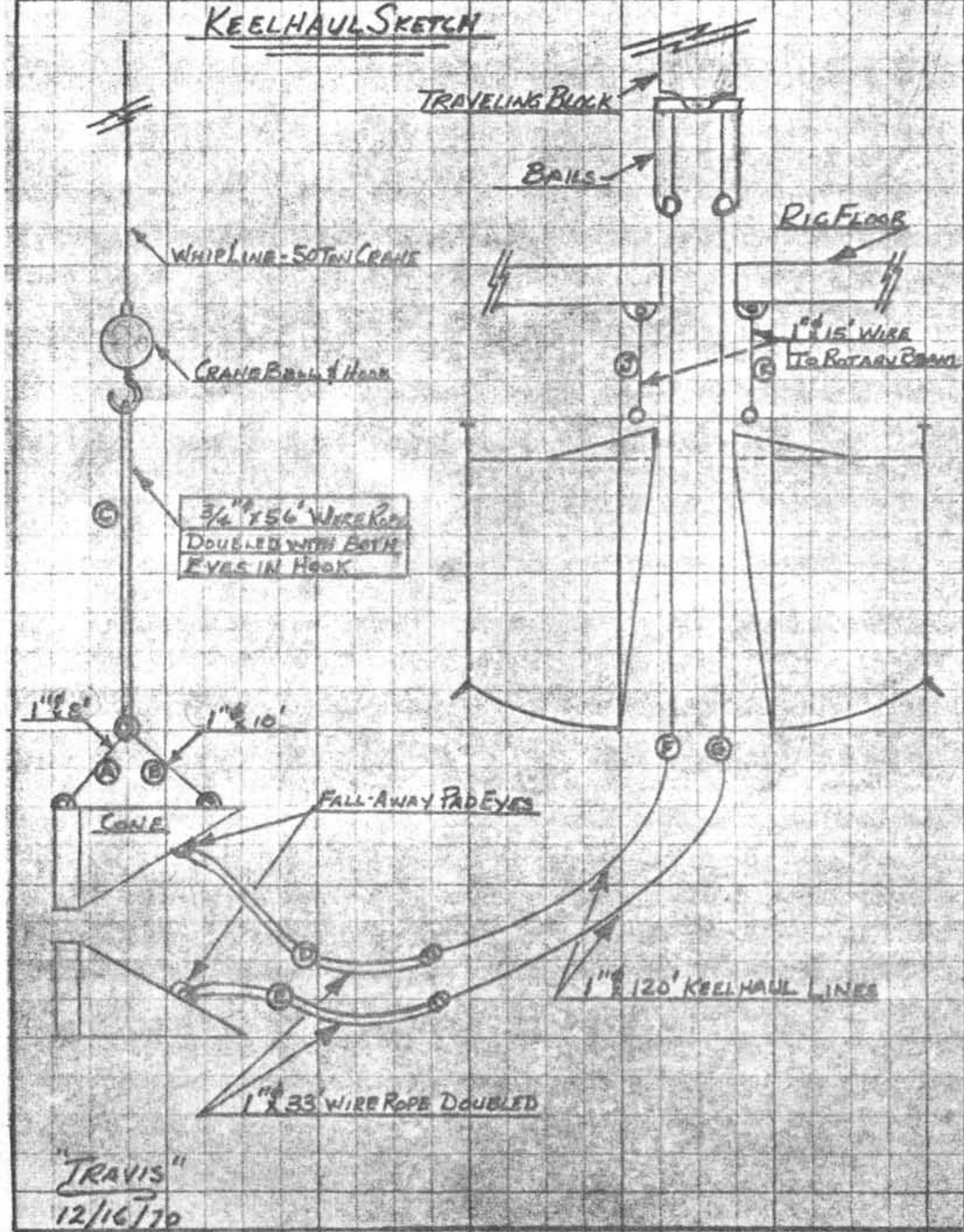


Figure #8 - Rotary Oil Tool Co. Shifting Tool

ATTACHMENT-II



KEELHAUL PROCEDURE

1. MODIFY CONE TO BE KEELHAULED IN A HORIZONTAL POSITION.

2. WITH LINES Ⓓ & Ⓔ IN PLACE, HOOK CRANE BLOCK TO LINES Ⓐ & Ⓑ. MOVE CONE TO PORT SIDE & LAND ON PIPE RACK, DECK, & PORT RAIL.

3. PICK UP LINE Ⓒ WITH "WHIP LINE" & REMOVE CRANE BLOCK FROM LINES Ⓐ & Ⓑ.

4. SHACKLE LINES Ⓕ & Ⓖ, CONNECTED TO BAILS OF TRAVELING BLOCK, TO LINES Ⓓ & Ⓔ.

5. PICK UP WITH "WHIP LINE", SWING CONE TO MID-SHIP AND LOWER INTO WATER TO WHERE "WHIP LINE" HOOK IS AT RAIL ON MAIN DECK. KEEP CONE BELOW WAVE ACTION.

6. PICK-UP ON LINES Ⓕ & Ⓖ WITH TRAVELING BLOCK UNTIL ALL SLACK IS OUT OF LINES.

7. WITH CUTTING TORCH, CUT ONE EYE OFF LINE Ⓒ AT "WHIP LINE" HOOK TO LET LINE Ⓒ STRIP THRU RING ON LINES Ⓐ & Ⓑ.

8. PICK-UP ON LINES Ⓕ & Ⓖ UNTIL LINES Ⓓ & Ⓔ MAKE UP WITH LINES Ⓙ & Ⓚ.

9. REMOVE LINES Ⓕ & Ⓖ.

Figure #9

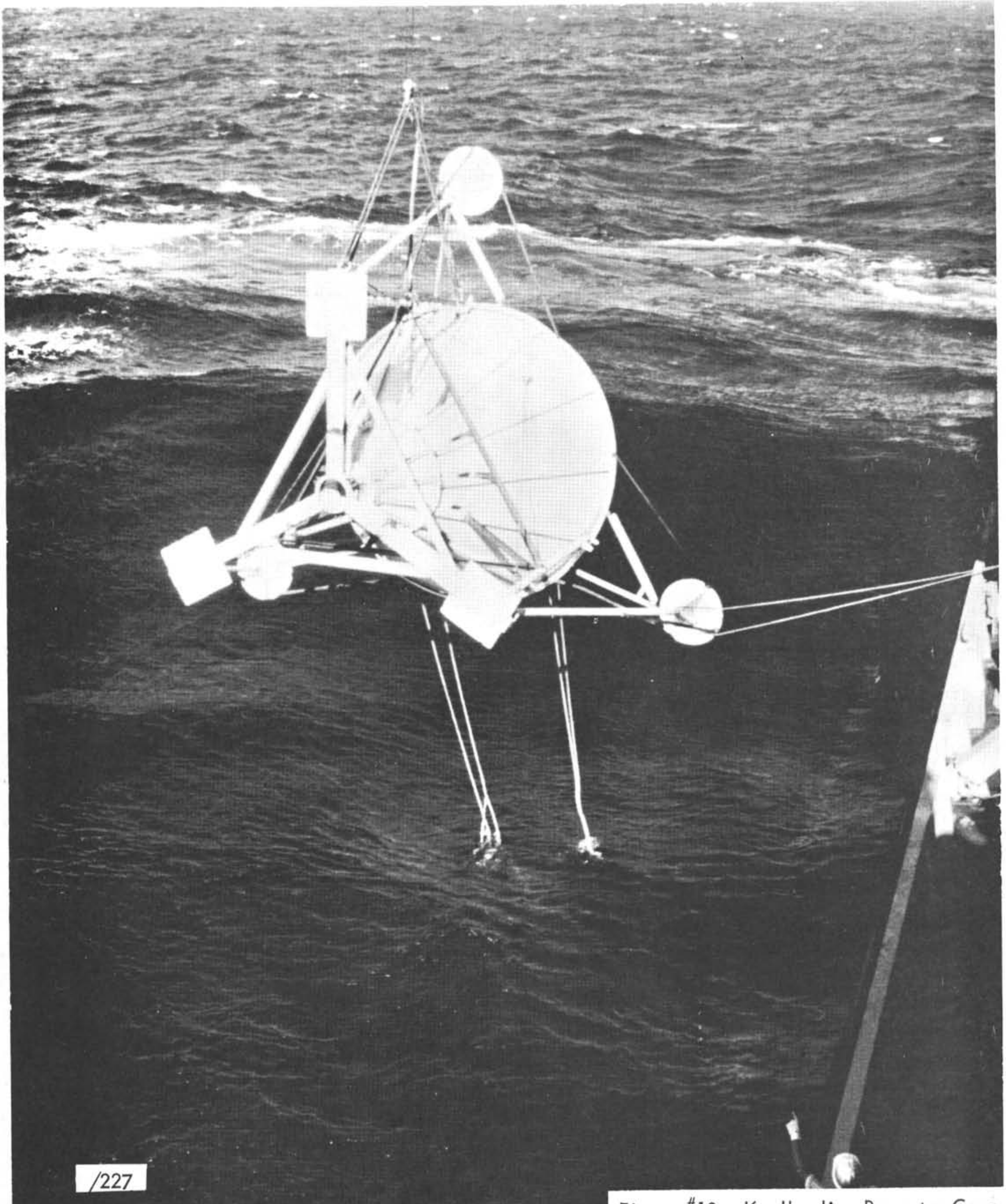


Figure #10 - Keelhauling Re-entry Cone
Using Side Launch

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Figure #11 - Baker Shifting Tool

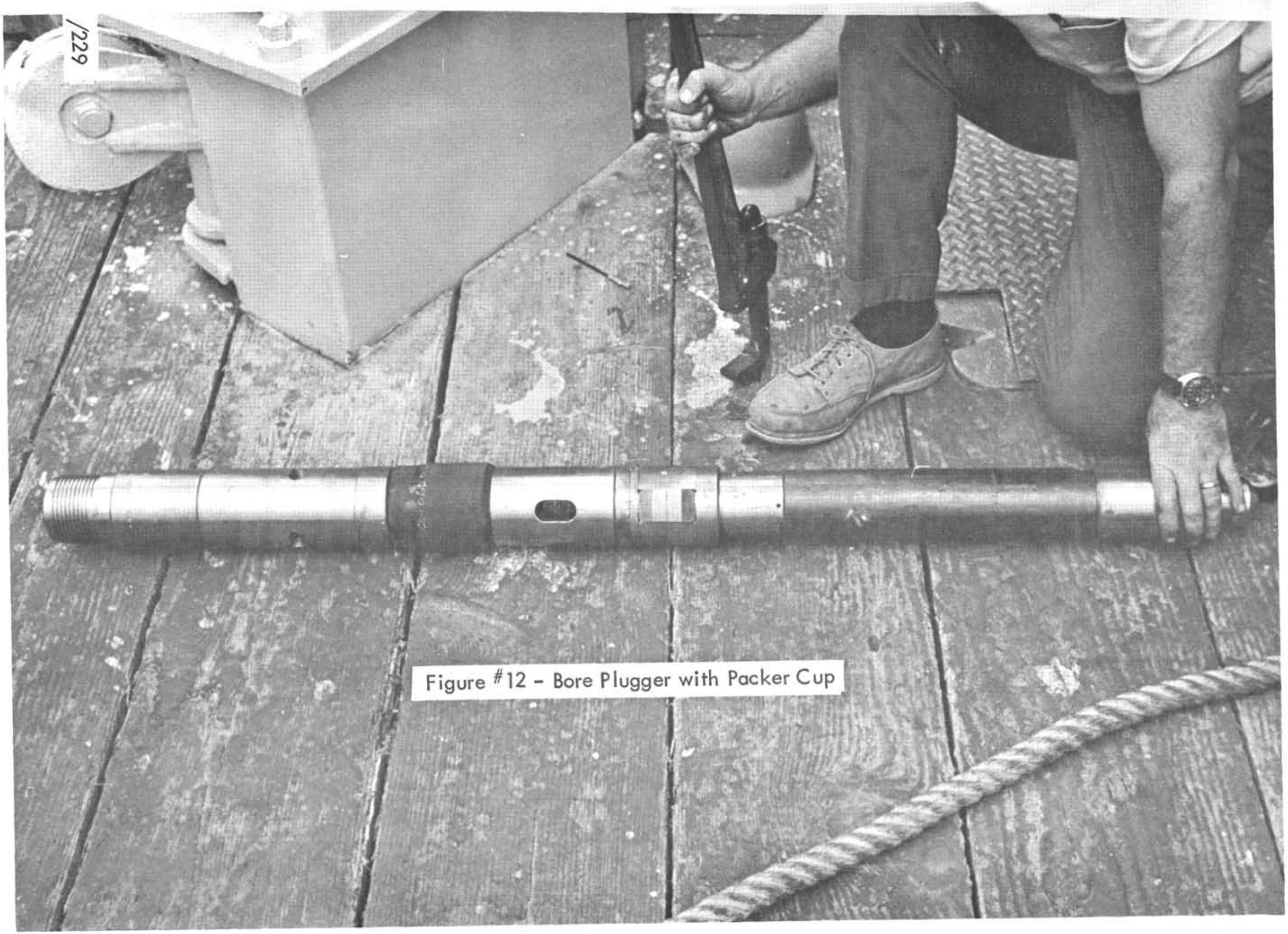


Figure #12 - Bore Plugger with Packer Cup

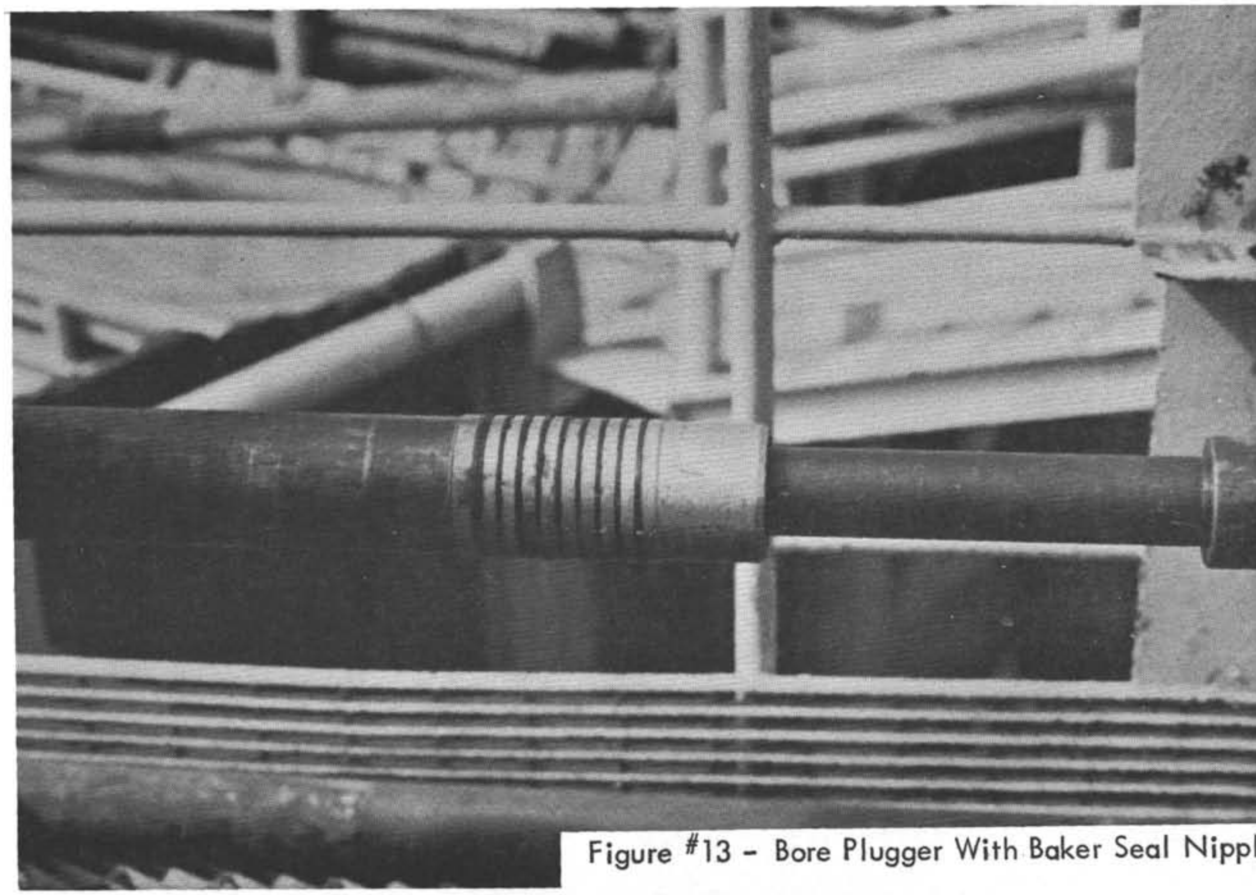
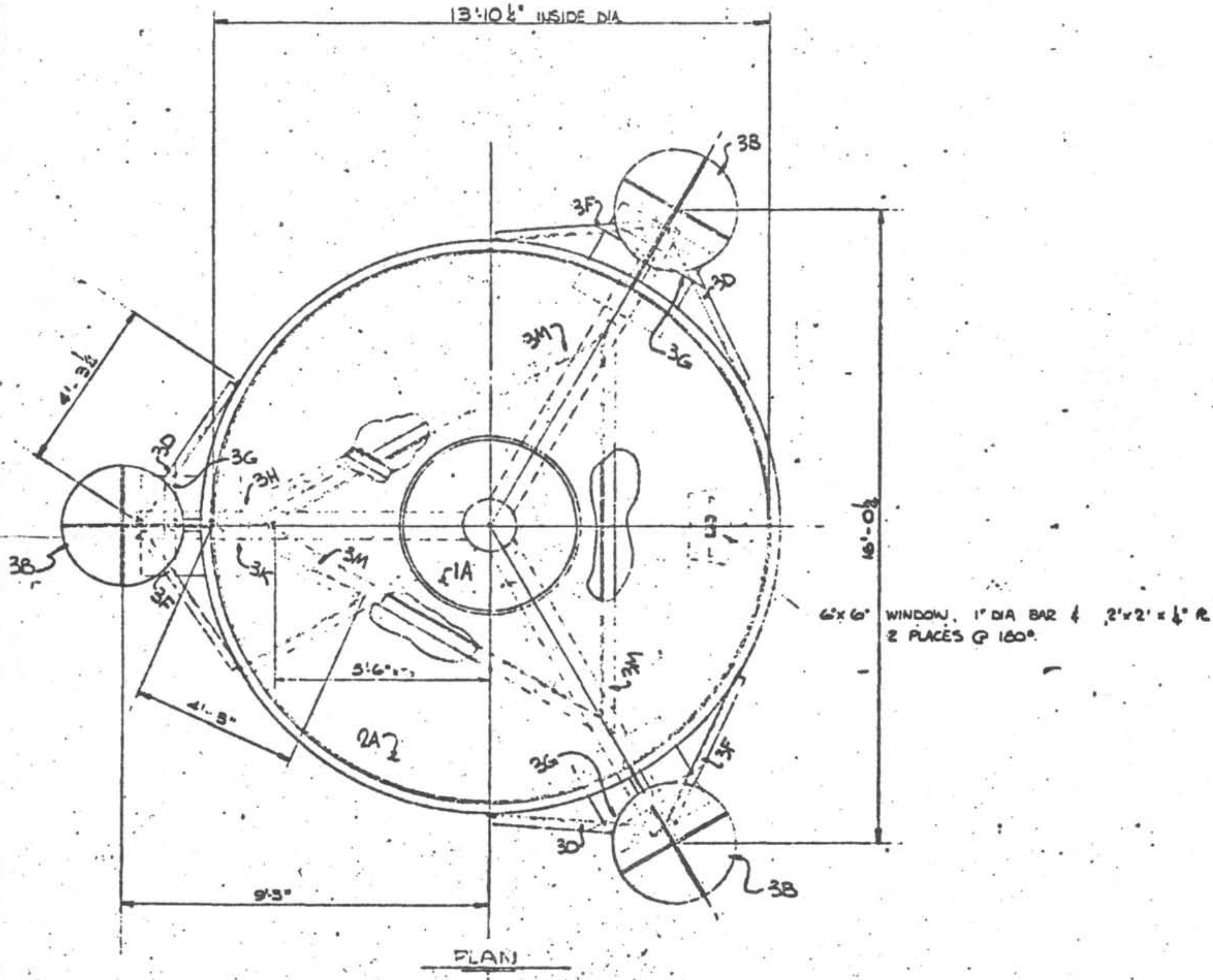


Figure #13 - Bore Plugger With Baker Seal Nipple

VII. Blue Prints

DRAWING INDEX

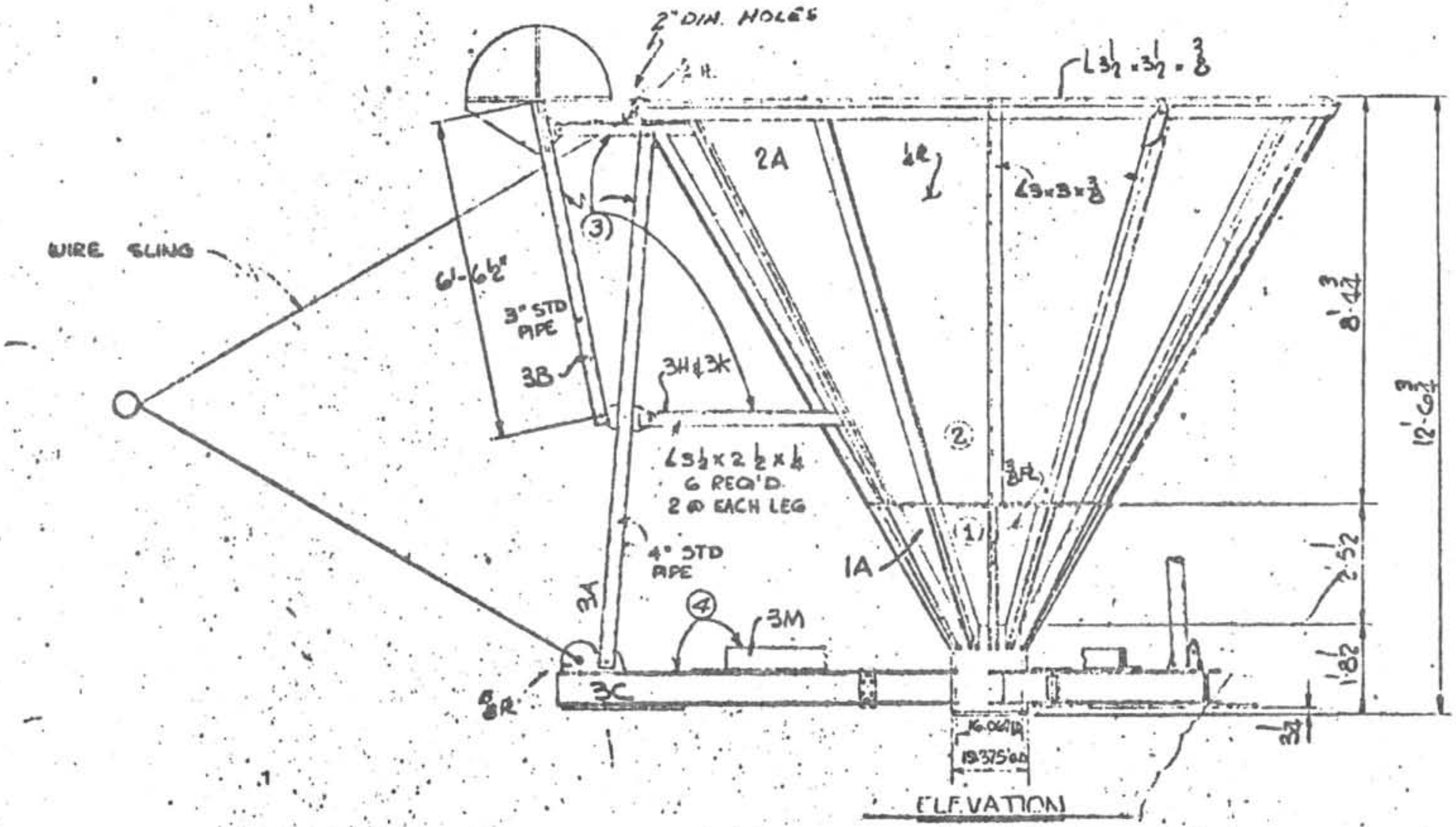
Title		Dwg. No.	Rev. No.
1.	Conical Re-entry Base	RE-020A	
		RE-020B	
2.	Guide Base Latch Installation	RE-030	
	Guide Base Latch	RE-31	
	Latch Rod	RE-32	
	Latch Spring	RE-33	
	Latch Spring Retainer	RE-34	
	Stop Washer	RE-35	
3.	Re-entry Release Assembly	RE-040	
	Casing Hanger Assembly	RE-015	#1
	Detail of Casing Hanger	RE-9	#1
	Detail of Paddle	RE-17	#1
	Detail of Hinge Pin	RE-16	
	Paddle Shaft Spring	RE-18	
4.	Hanger Bushing	RE-7	#2
5.	Index Sub	RE-12	
	Index Sub Sleeve	RE-13	
6.	Release Sub	RE-010	
7.	Sliding Sleeve	RE-36	
	Spring Catch	RE-29	
8.	Stop Bolt Assembly	RE-026	#1
	Stop Bolt Sleeve	RE-27	#1
	Stop Bolt	RE-28	#1
9.	Bolt and Cam Sleeve	RE-39	#1
10.	Shifting Tool (and sleeve)	RE-019	
	Shifting Tool Body	RE-020	
	Shifting Tool Dog	RE-021	
11.	Jet Sub	204/865-1	
	Indexing Sub, Jet Sub	206/031	
	Bore Plugger	206/281-1	



REVISIONS	DESCRIPTION	BY	DATE

UNIVERSITY OF CALIFORNIA, SAN DIEGO
SCRIPPS INSTITUTION OF OCEANOGRAPHY
DEEP SEA DRILLING PROJECT

TITLE CONICAL RE-ENTRY BASE		
DATE 11 JAN. 71	SCALE 1/2" = 1'	DWG NO RE-020 A
DWN BY W. L. SMITH	ENGR DLS	



REVISIONS	DESCRIPTION	BY	DATE

UNIVERSITY OF CALIFORNIA, SAN DIEGO
SCRIPPS INSTITUTION OF OCEANOGRAPHY
DEEP SEA DRILLING PROJECT

TITLE: CONICAL RE-ENTRY BASE

DATE: 11 JAN. 71 | SCALE: ½" = 1' | DWG. NO.: RE-020 B

DWN. BY: W. L. SMITH | ENGR.: DLS

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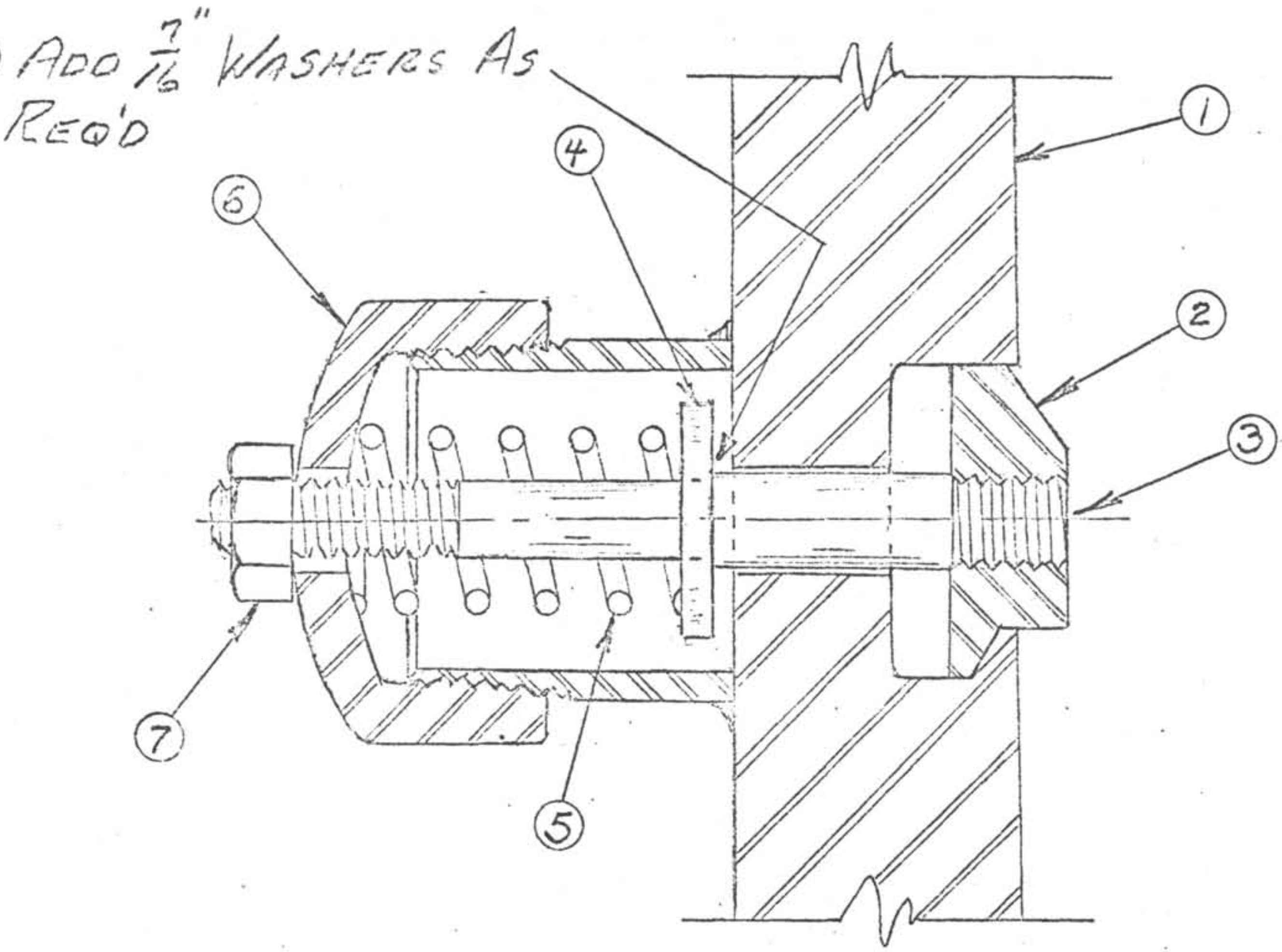
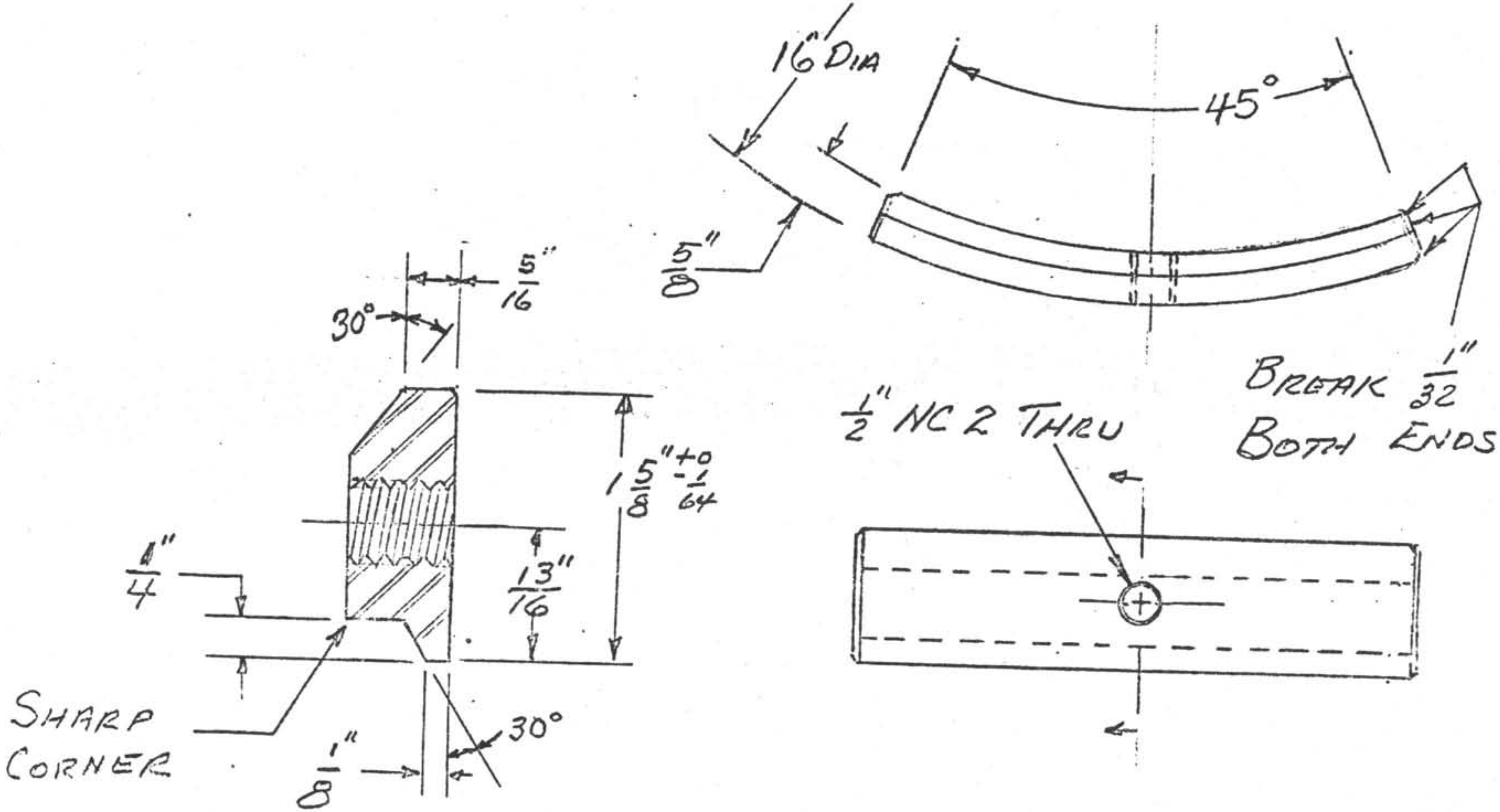
/235



ITEM	DESCRIPTION	REQ'D
1	GUIDE BASE	REF
2	GUIDE BASE LATCH	1
3	LATCH ROD	1
4	STOP WASHER	1
5	LATCH SPRING	1
6	LATCH SPRING RETAINER	1
7	7/16 NC HEX NUT	1
8	7/16 STEEL WASHER	-

UCSD - SIO
DEEP SEA DRILLING
GUIDE BASE LATCH INSTALLATION
2-18-71 DLS SCALE 1"=1"
RE - 030



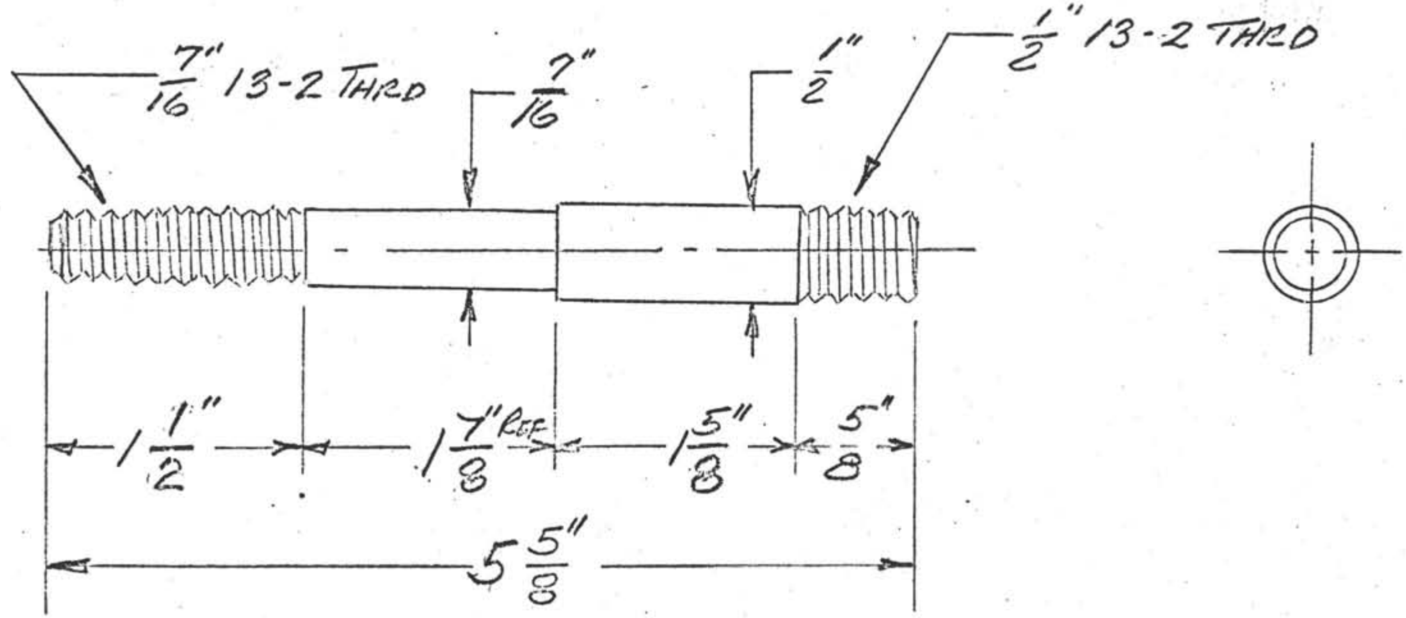
3 REQ'D PER ASB'LY

MAT'L - 4140 OR EQ.
HT 36 Rc
FINISH 125

UCSD - SIO
DEEP SEA DRILLING
GUIDE BASE LATCH
2-16-71 DLS SCALE - NONE
RE - 31

1236

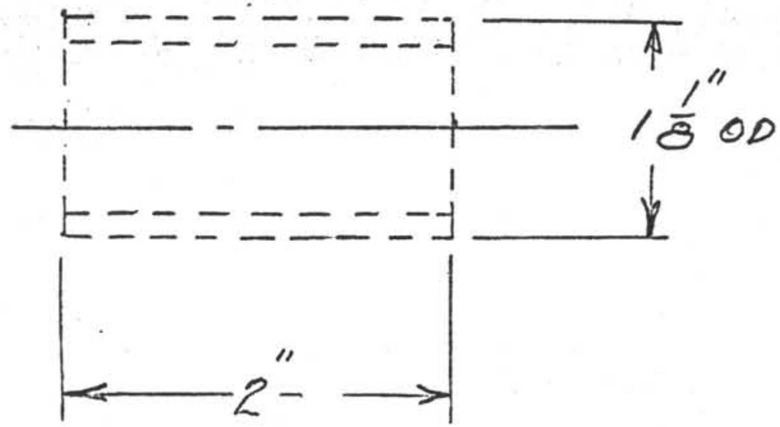
1237



MATL - C.R. BAR
.2 CARB. MIN
H.T. NONE
FINISH - 125√

UCSD - SIO
DEEP SEA DRILLING
LATCH ROD
2-19-71 DLS SCALE - 1" = 1"
RE - 32

REV. #1 28 APRIL 71 MMS



COMPRESSION SPRING

MAT'L - 1/8 SPRING STEEL

CAD. PLATE

SOLID HEIGHT .855"

SPRING RATE 79 #/in

3 REQ'D PER ASBLY

USSD SIO

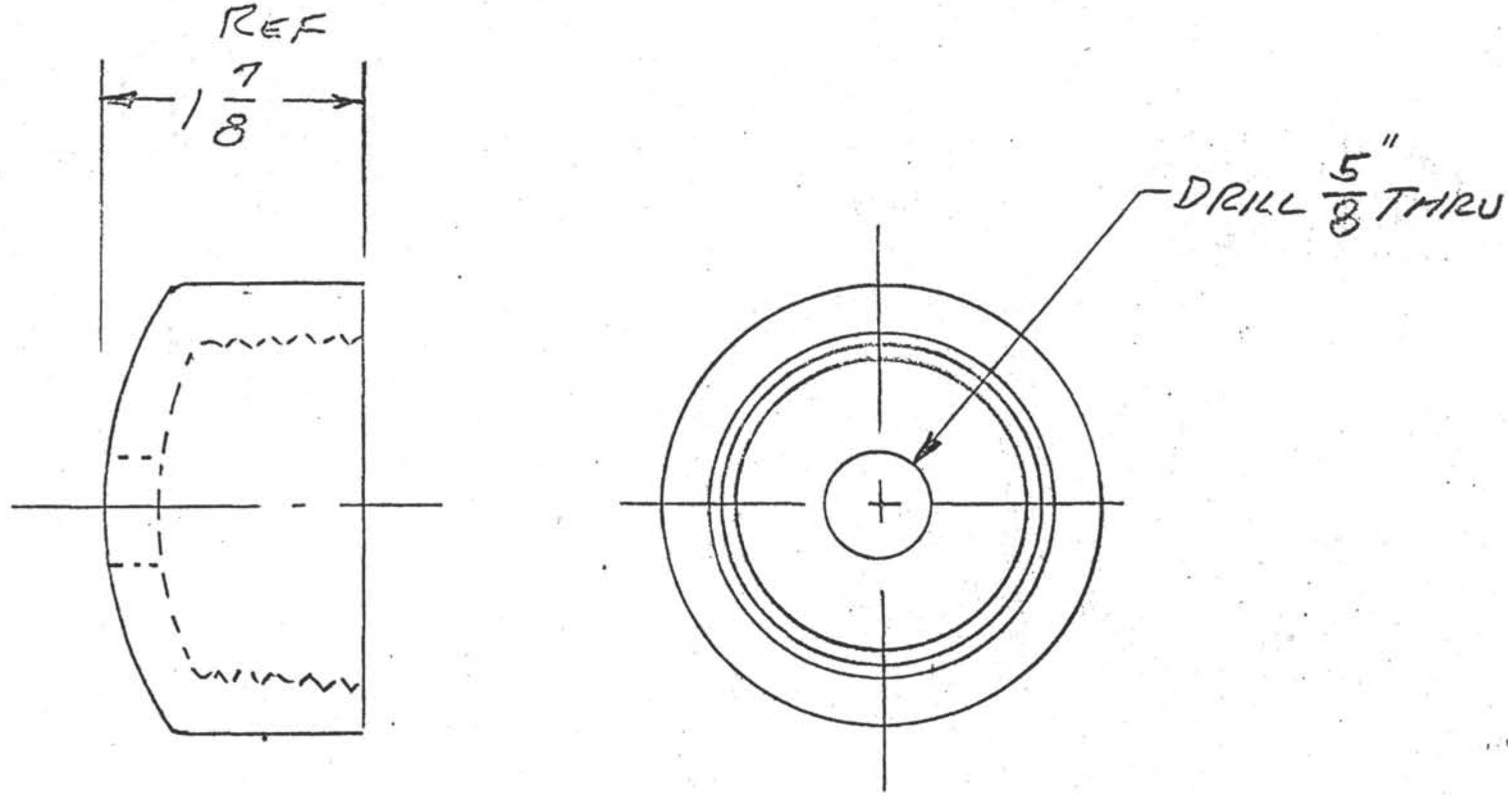
DEEP SEA DRILLING

LATCH SPRING

2-18-71 DCS SCALE NONE

RE-33

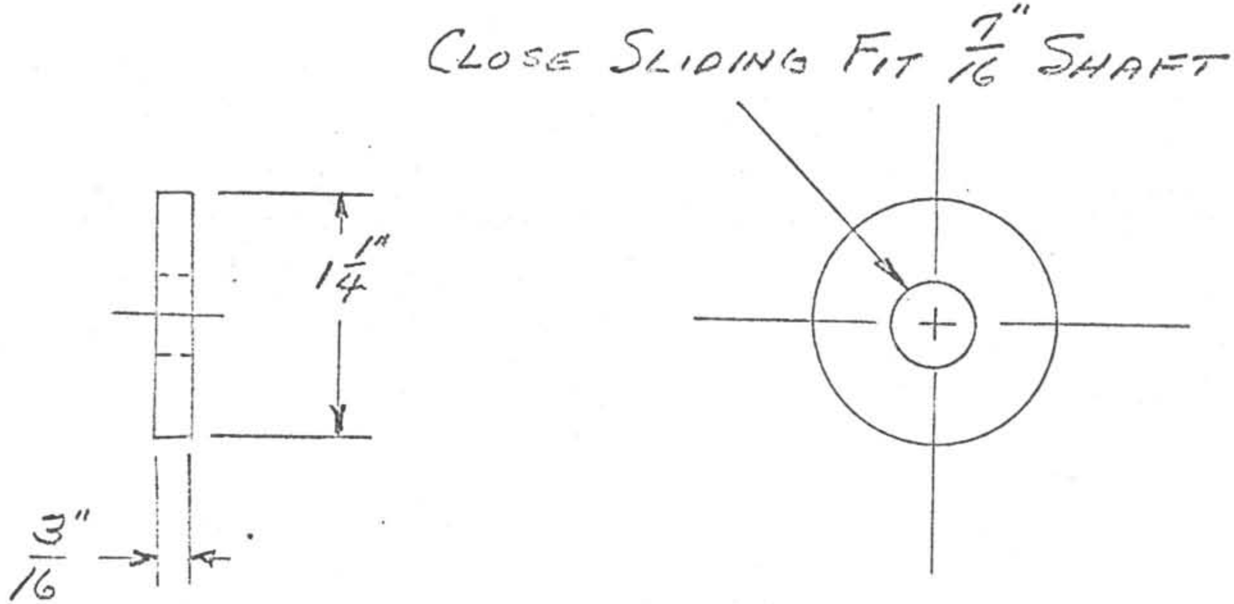
/239



MATL - 1 1/2" STEEL PIPE CAP
GALVANIZED
3 REQ'D PER ASBLY

UCSD-510
DEEP SEA DRILLING
LATCH SPRING RETAINER
2-19-71 DLS SCALE-NONE
RE-34

REVISED 28 APRIL 71 [illegible]



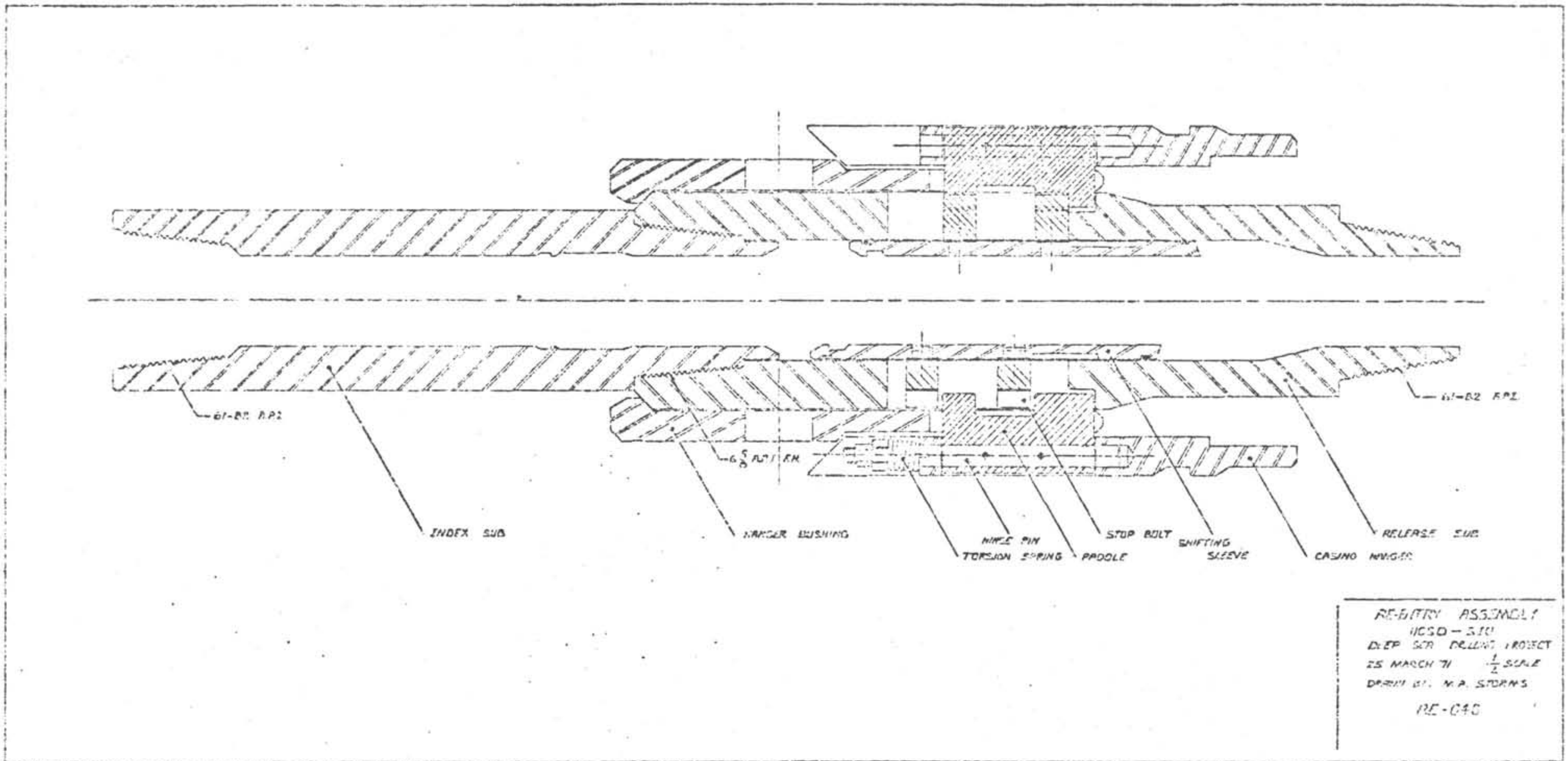
MAT'L - C.R. BAR
.2 CARB MIN.
HT NONE
FINISH 250

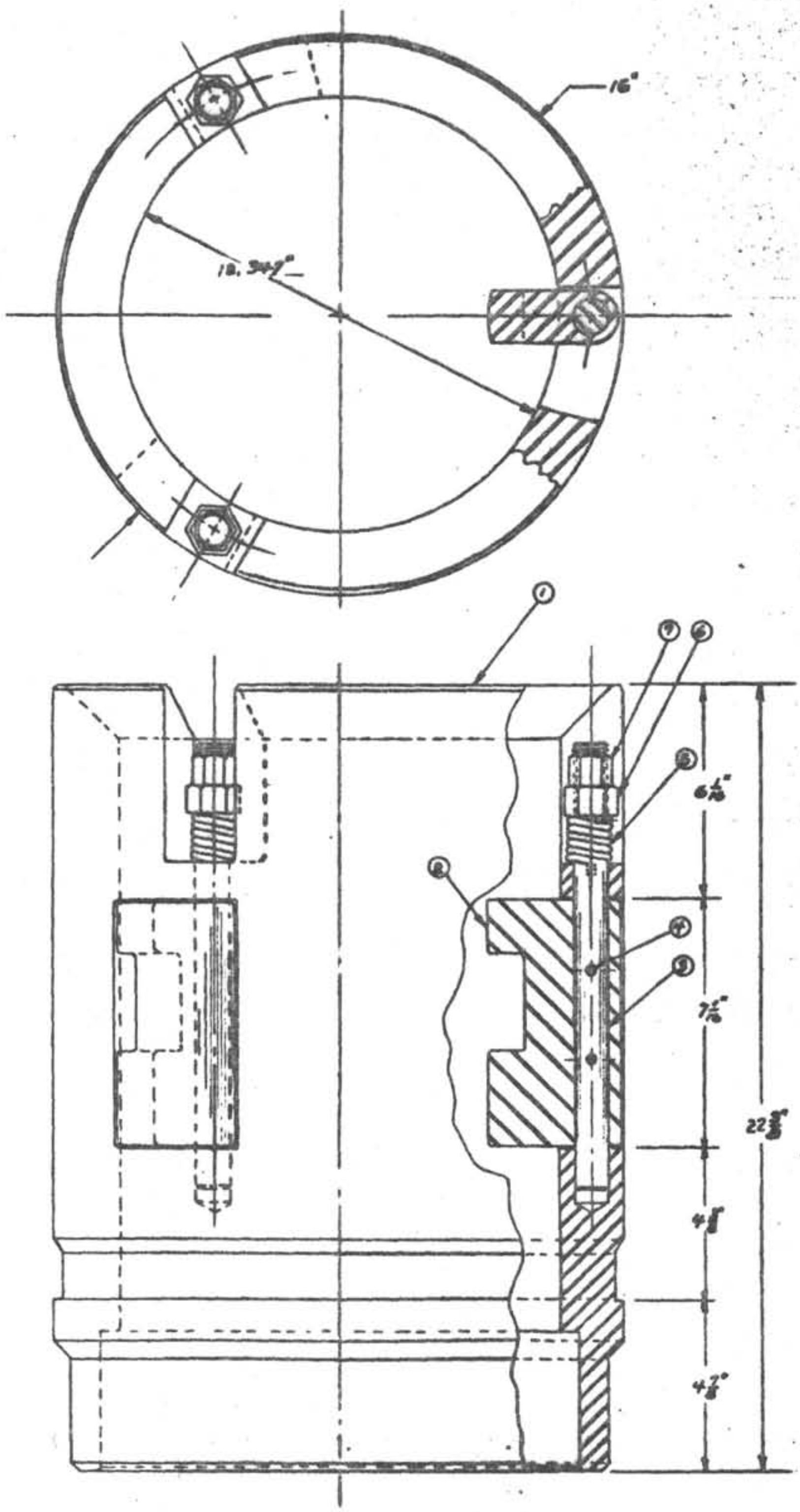
3 REQD PER ASBLY

UCSD - SIO
DEEP SEA DRILLING
STOP WASHER
2-19-71 DLS SCALE-1"=1"
RE-35

/240

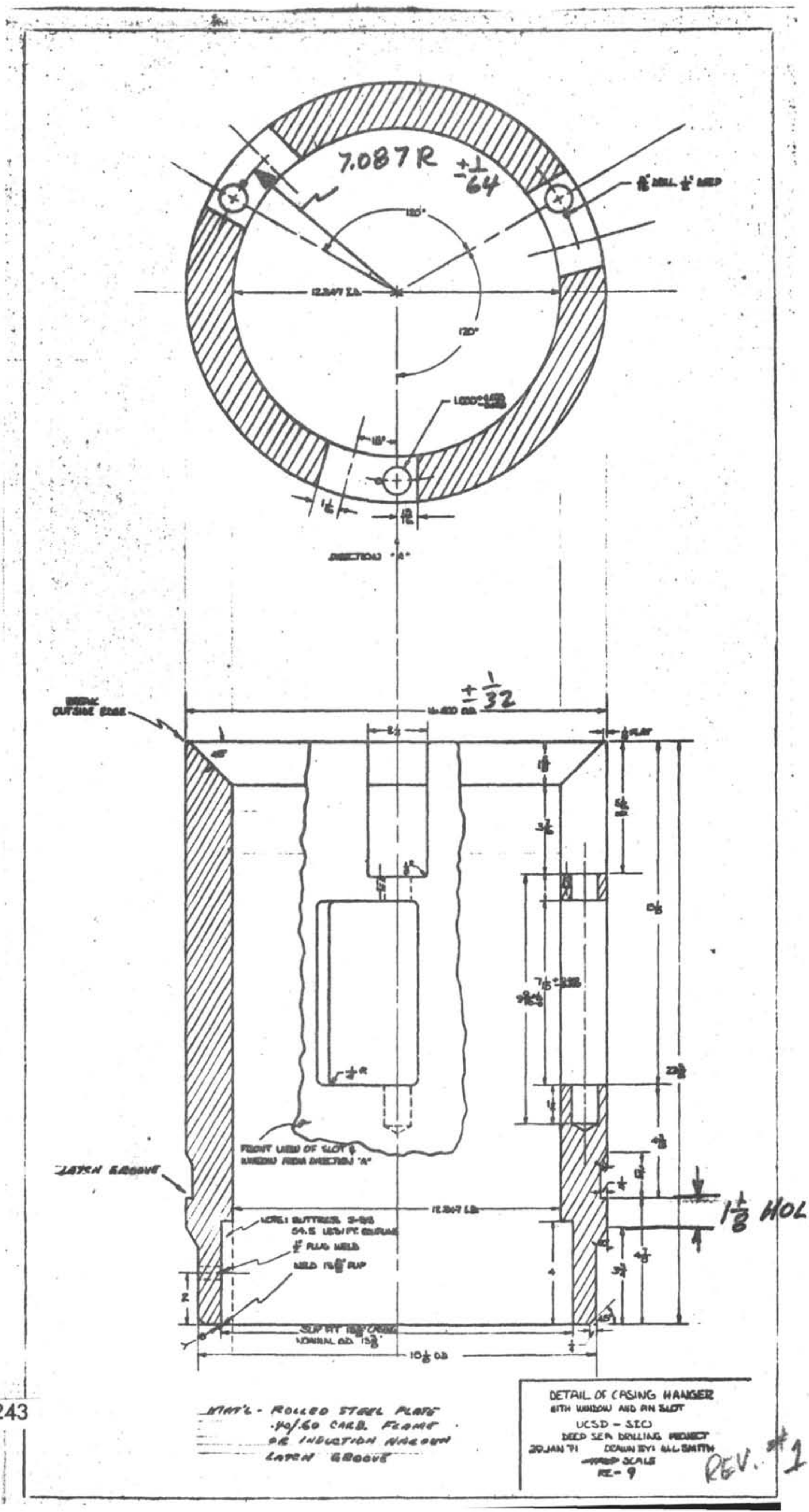
/241


INDEX SUB
HANGER BUSHING
HINGE PIN
TORSION SPRING
PADDLE
STOP BOLT
SHIFTING SLEEVE
CASING HANGER
RELEASE SUB
RE-ENTRY ASSEMBLY
UCSD – SIO
DEEP SEA DRILLING PROJECT
25 MARCH 71
DRAWN BY. M.P. STORMS
RE-040

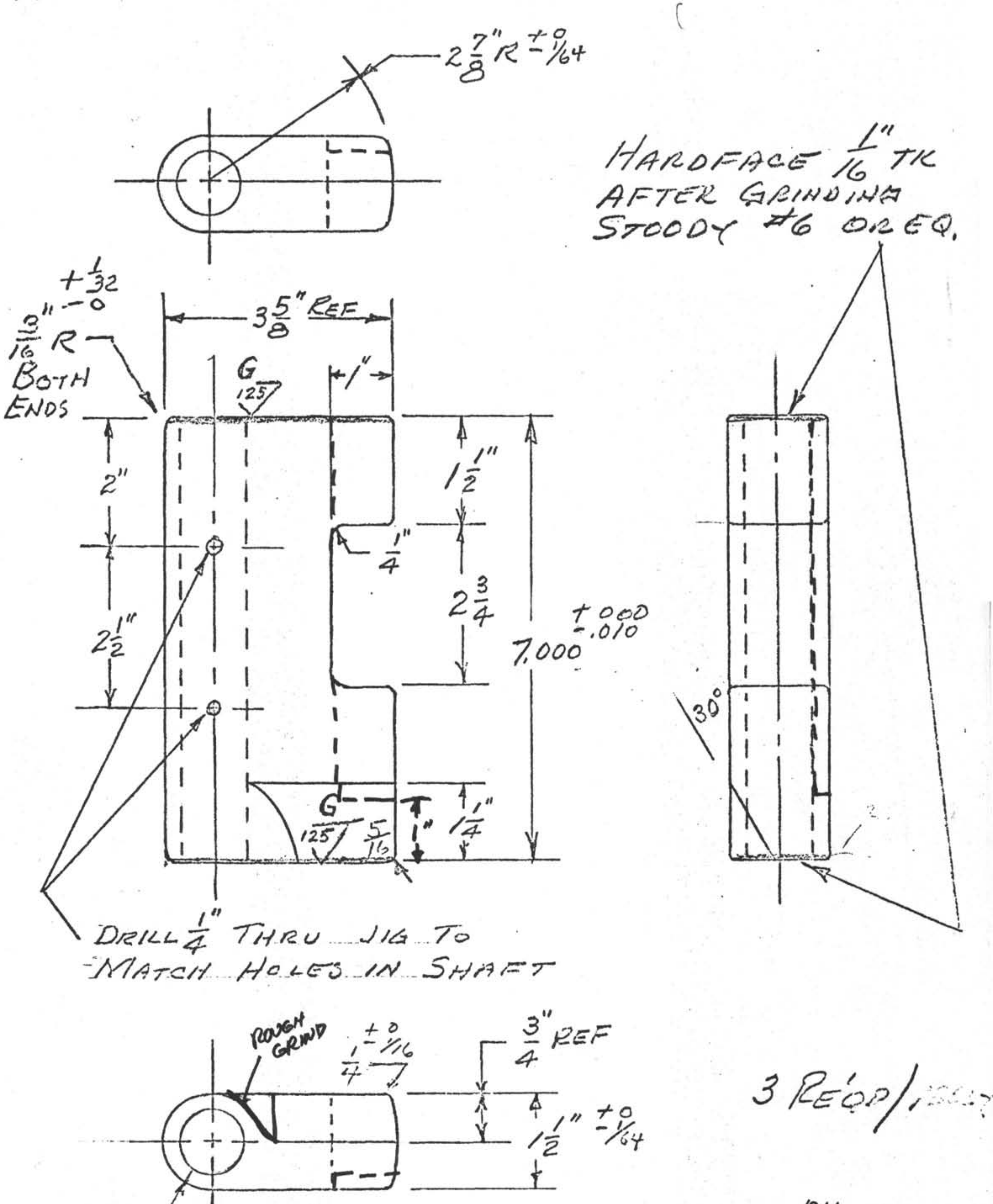


ITEM	DESCRIPTION	[illegible]
1	CASING HANGER	1
2	PADDLE	3
3	HINGE PIN	3
4	DRIVE LOC PIN	6
5	TORSION SPRING	3
6	1"-8 STD. NUT	3
7	1"-8 x 1½" [illegible]	3

UCSD - SIO
DEEP SEA DRILLING
CASING HANGER ASSY
1-29-71 [illegible] SCALE [illegible]
[illegible]


7.087 R ± 1/64
120°
12.347 I.D.
± 1/32
16.000 O.D.
BREAK OUTSIDE EDGE
LATCH GROOVE
FRONT VIEW OF SLOT & WINDOW FROM DIRECTION "A"
12.347 I.D.
1 1/8 HOLD
10 1/8 O.D.
MAT'L - ROLLED STEEL PLATE
.40/.60 CARB. FLAME OR INDUCTION HARDEN LATCH GROOVE
DETAIL OF CASING HANGER
WITH WINDOW AND PIN SLOT
UCSD - SIO
DEEP SEA DRILLING PROJECT
20 JAN 71
DRAWN BY: BILL SMITH
RE-9
REV. #1

/243



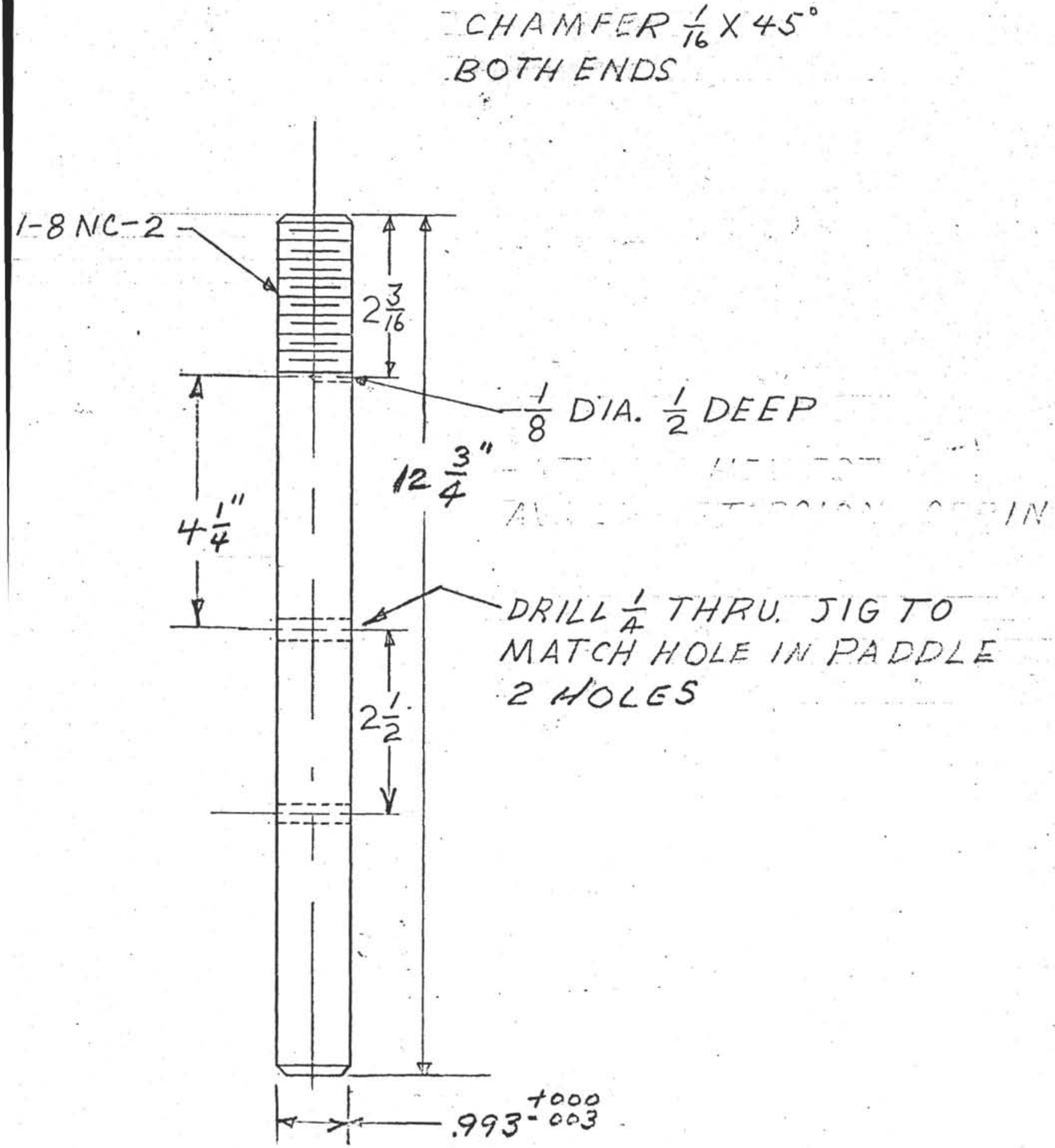
/244

DETAIL OF PADDLE

DEEP SEA DRILLING

UCSD-SIO RE-17

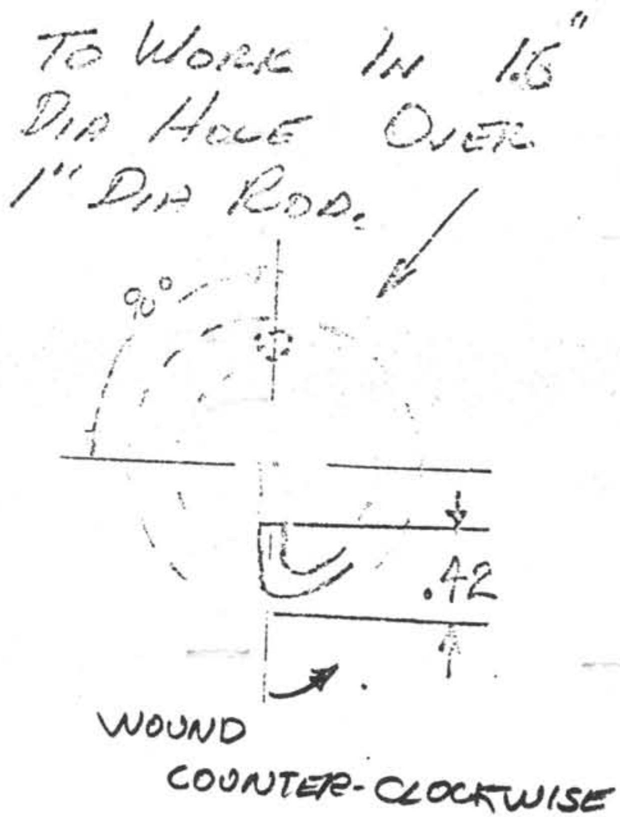
MATL - 4340 OR 4140

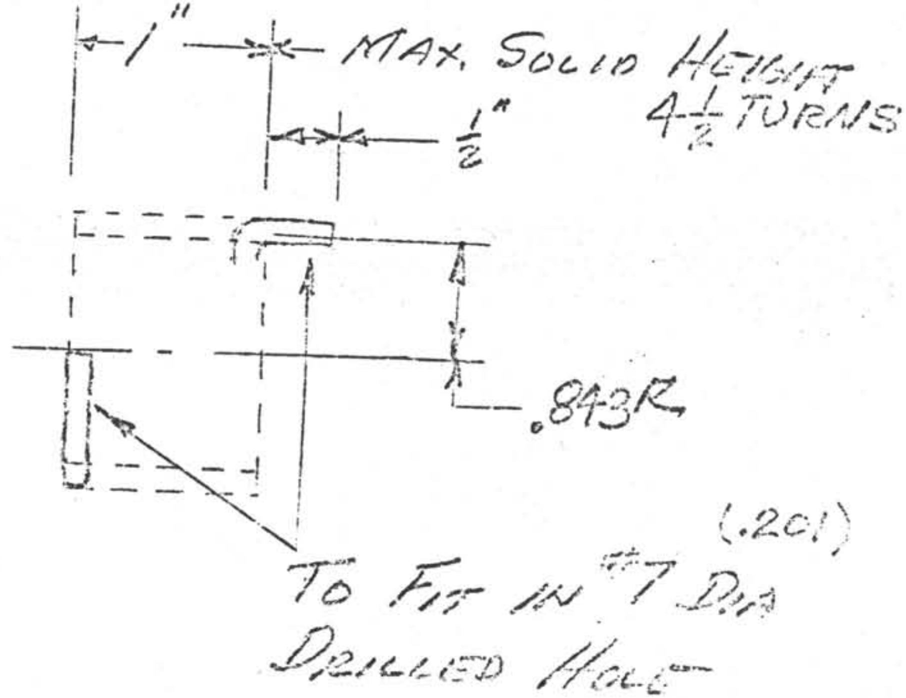


DETAIL OF SHAFT
3 REQ'D
MATERIAL: 4340 OR 4140
HARDEN: 30-32 RC
FINISH 125

/245

DETAIL OF HINGE PIN
DEEP SEA DRILLING
UCSD-S.I.O. RE 16 - REV-1
25 JAN. 71 SCALE: NONE





TORSION SPRING

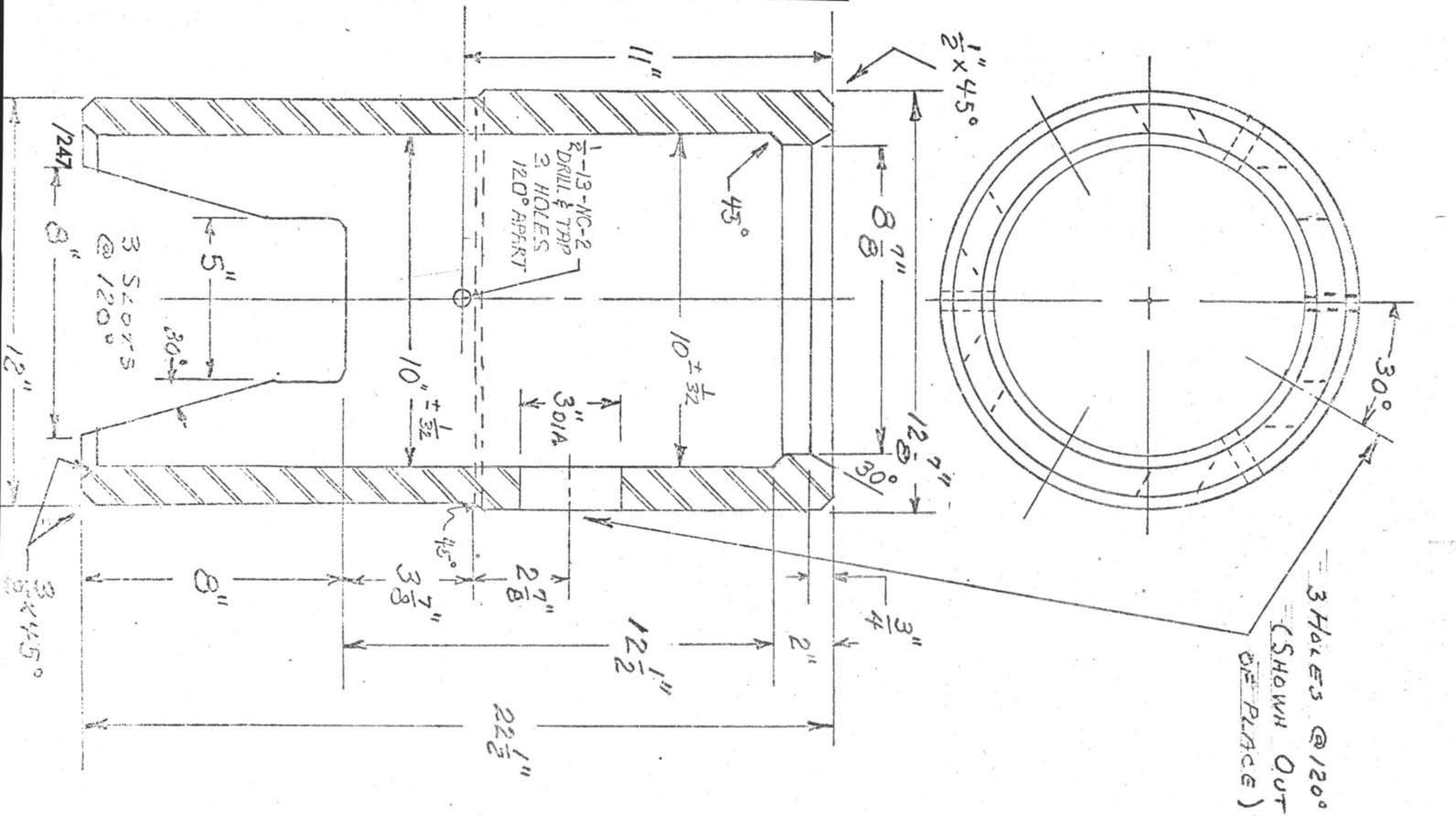
3/16 STEEL SPRING WIRE

/246

UCSD-510
DEEP SEA DRILLING
PADDLE SHAFT SPRING
1/28/71 DLS SCALE-NONE

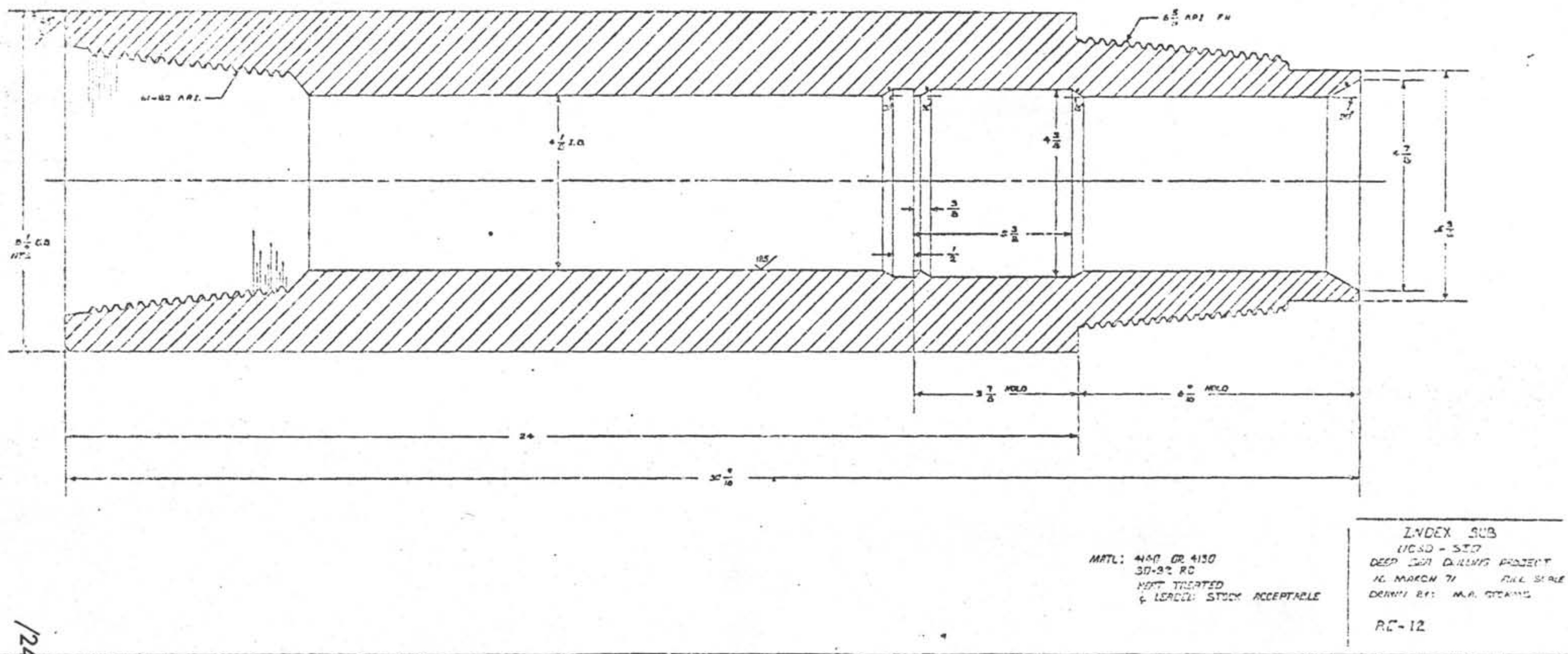
3 REQD / ASSLY

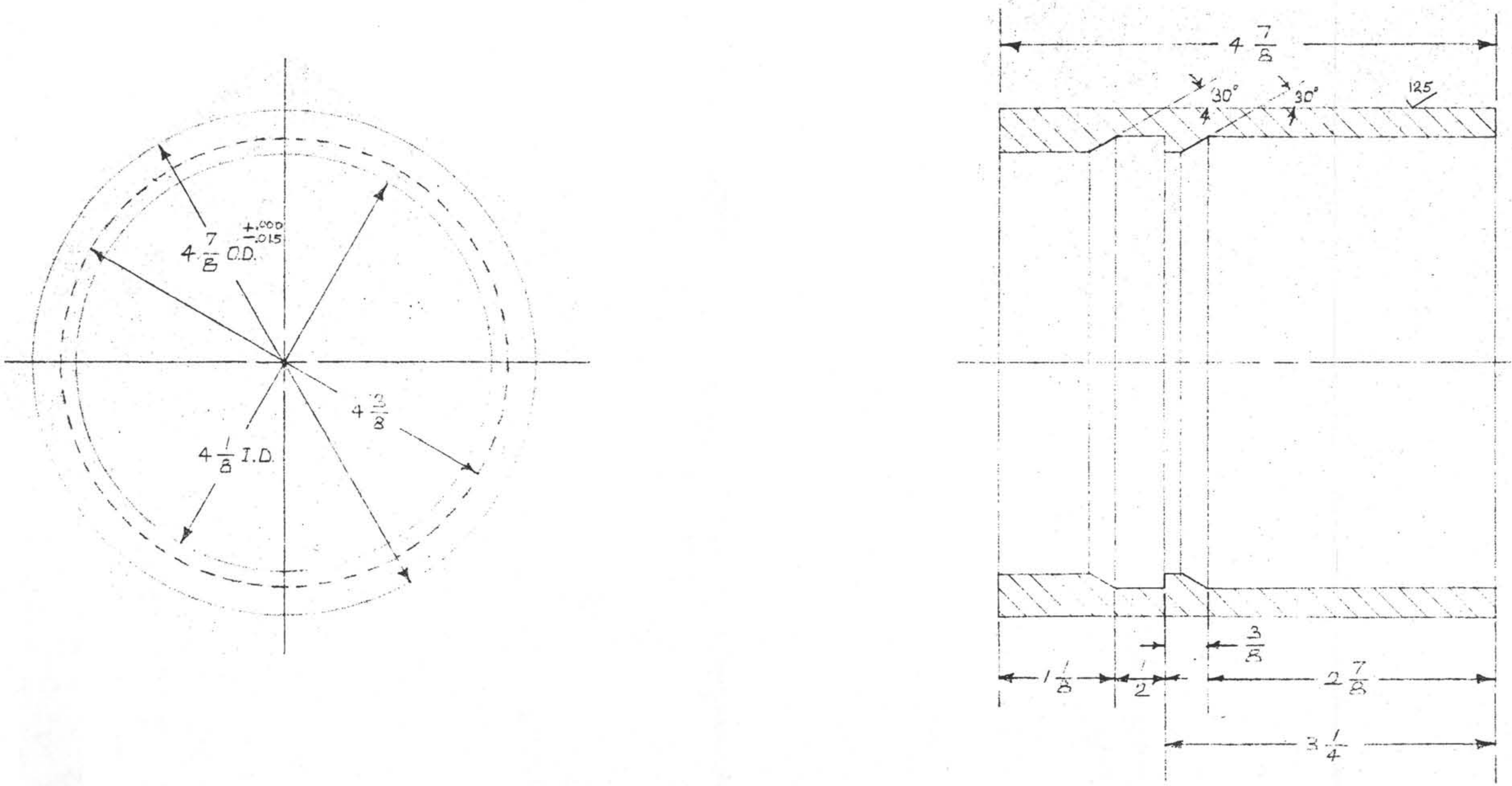
RE-18



MAT'L
ROLLED STEEL PLATE
.40 / .60 CARB.
FINISH - 125
SLOTS + HOLES MAY BE FLAME CUT

UCSD S/O
DEEP SEA DRILLING
HANGER BUSHING
2-7-71 OLS SCALE 1/4"=1"
RE-7
REV. #2


24
MATL: 4140 OR 4130
30-32 RC
HEAT TREATED
& LEADED STOCK ACCEPTABLE
INDEX SUB
UCSD - SIO
DEEP SEA DRILLING PROJECT
16 MARCH 71
FULL SCALE
DRAWN BY:
RC-12

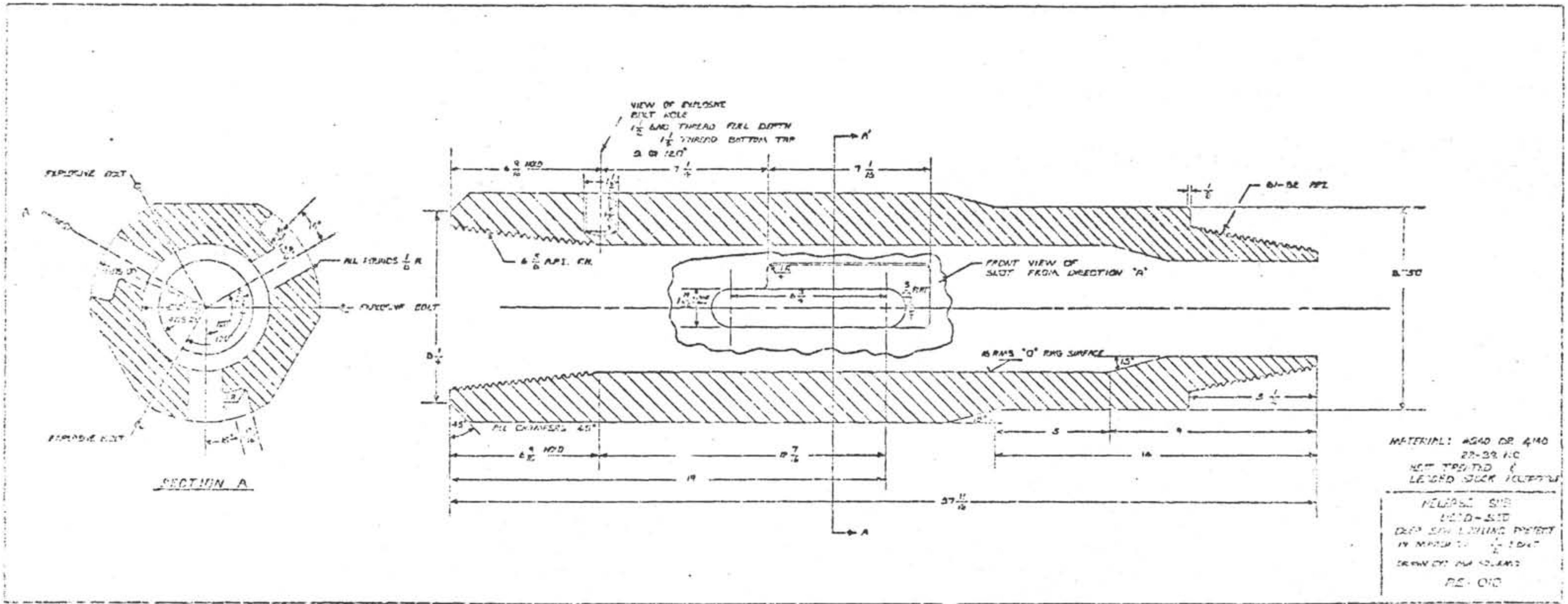


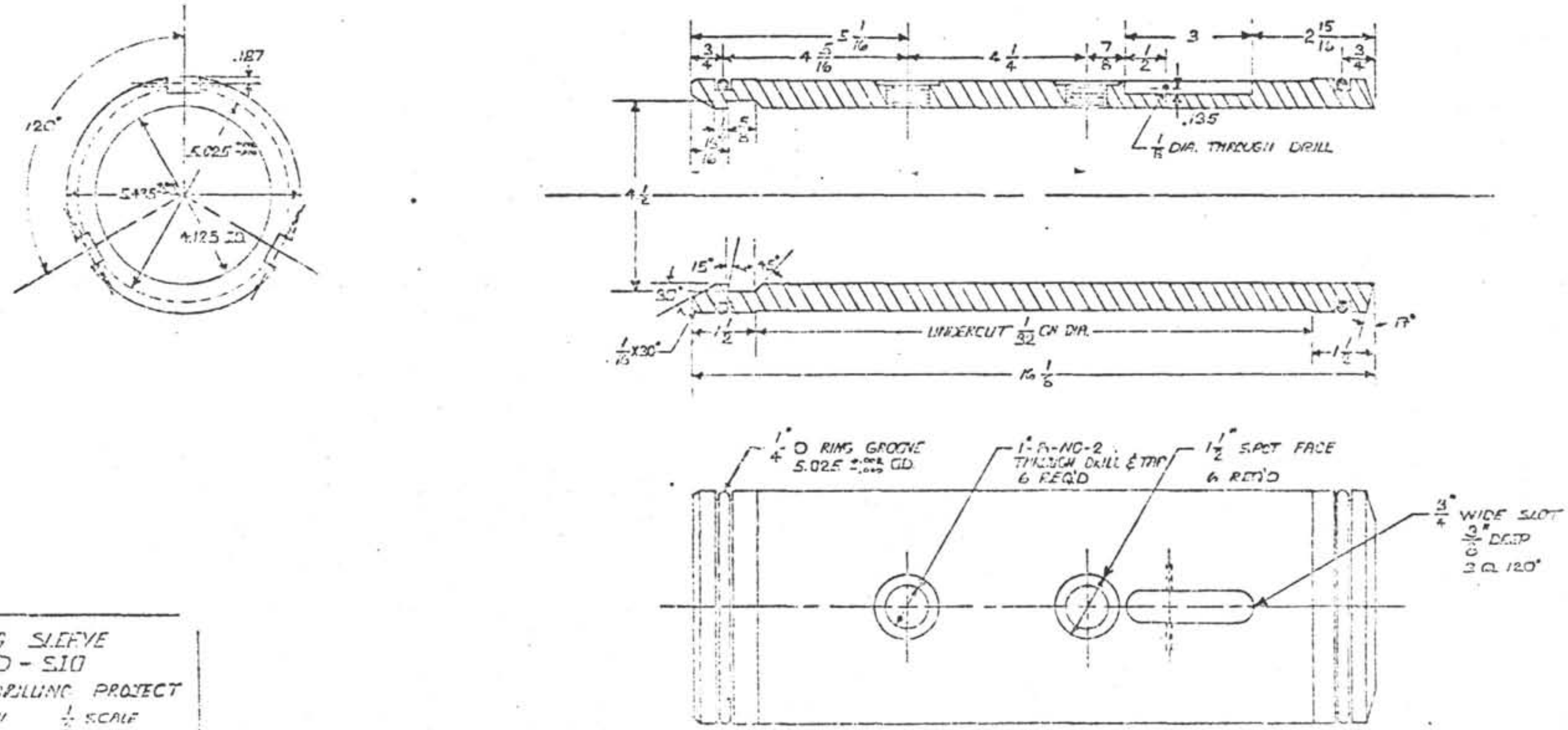
MATL: 4340 OR 4140
30-32 RC
HEAT TREATED & LEADED STOCK ACCEPTABLE

INDEX SLEEVE
UCSD - SIO
DEEP SEA DRILLING PROJECT
16 MARCH 71 FULL SCALE
DRAWN BY: M.A. STORMS

RE-13

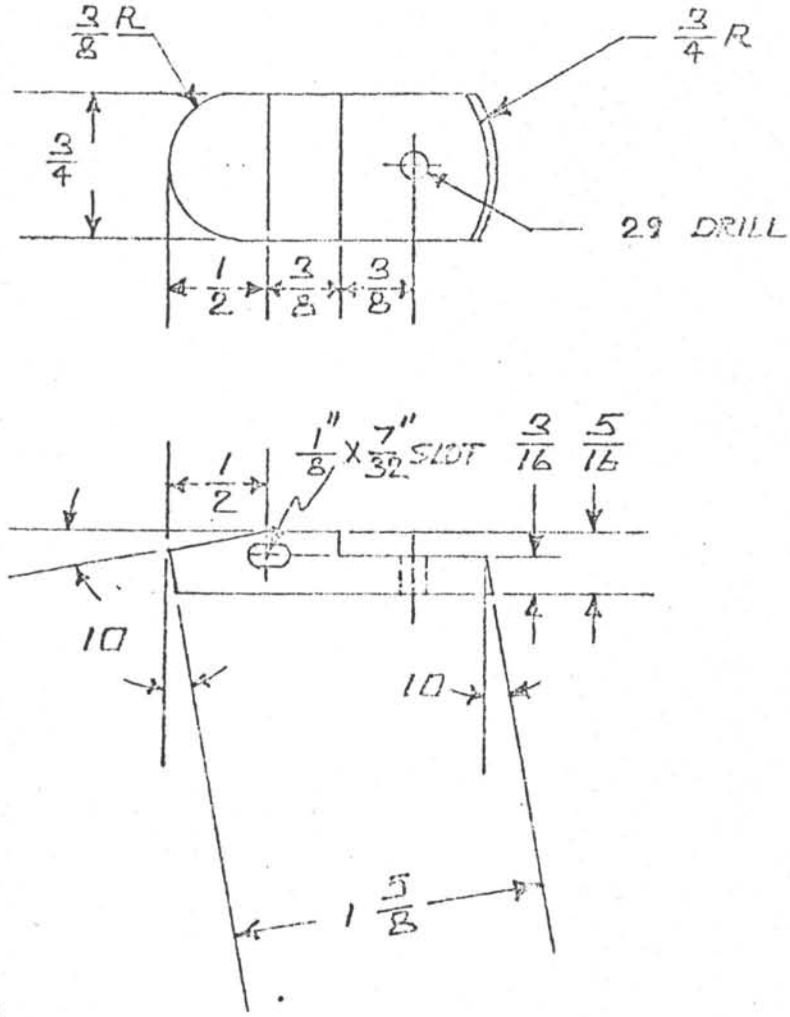
/249


EXPLOSIVE BOLT
VIEW OF EXPLOSIVE BOLT HOLE
FRONT VIEW OF SLOT FROM DIRECTION "A"
ALL CHAMFERS 45°
SECTION A
MATERIAL: 4340 OR 4140
RS-010



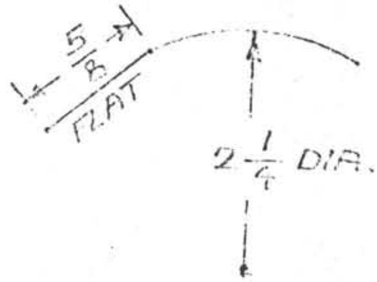
SHIFTING SLEEVE
UCSD - SIO
DEEP SEA DRILLING PROJECT
26 MARCH 71 1/2 SCALE
DRAWN BY: M.A. STORMS

RE - 36
REVISION 1



ROLL PINS: $\frac{1}{8}$" X 1" (3 REQ'D)

SPRINGS: $\frac{3}{4}$ X $1\frac{3}{4}$ X .020
BERYLLIUM-COPPER
(3 REQ'D)

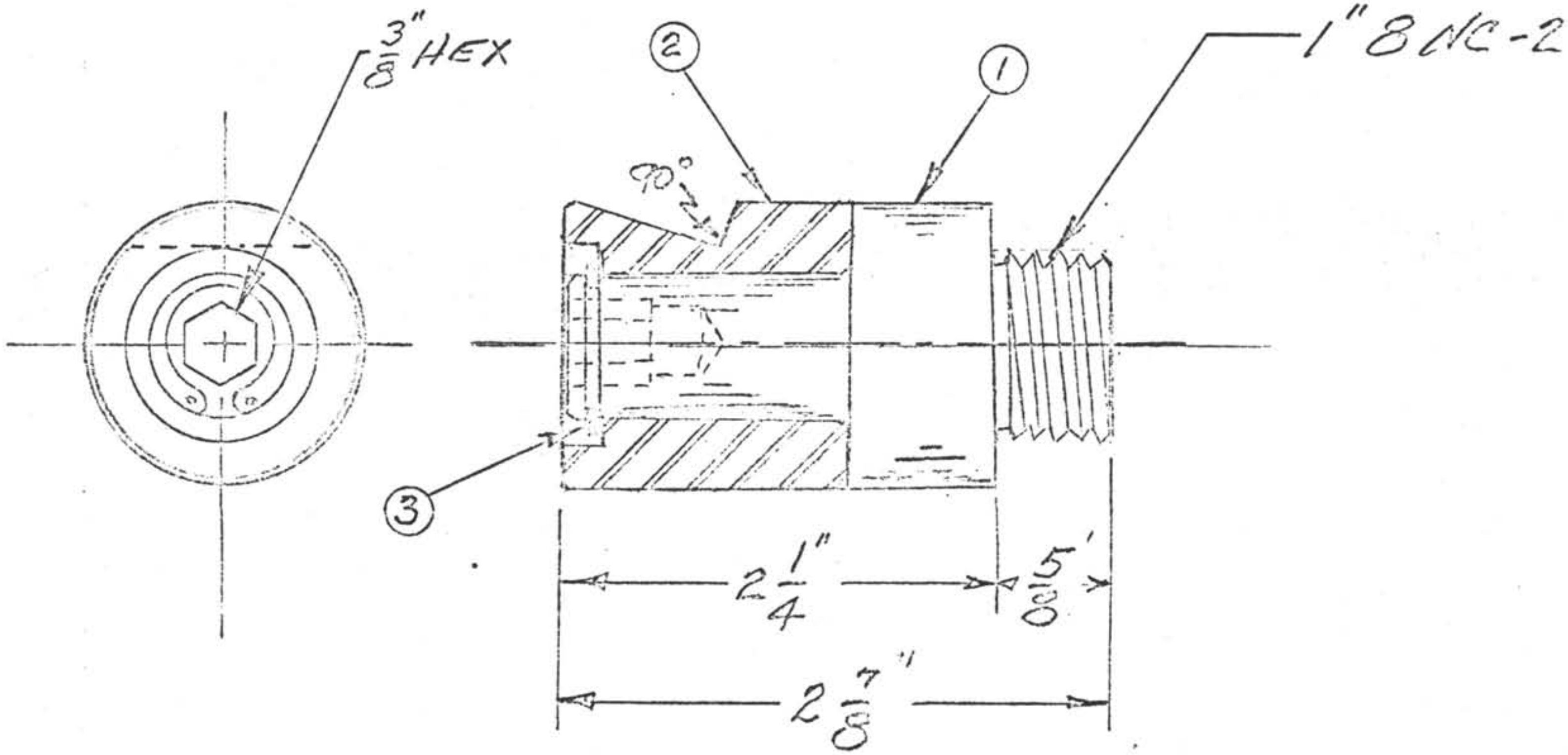


SPRING CATCH
UCSD-SIO
DEEP SEA DRILLING PROJECT
30 MARCH 71 FULL SCALE
DRAWN BY: M.A. STOLIAS

RE-29 /252

MATL: 4130

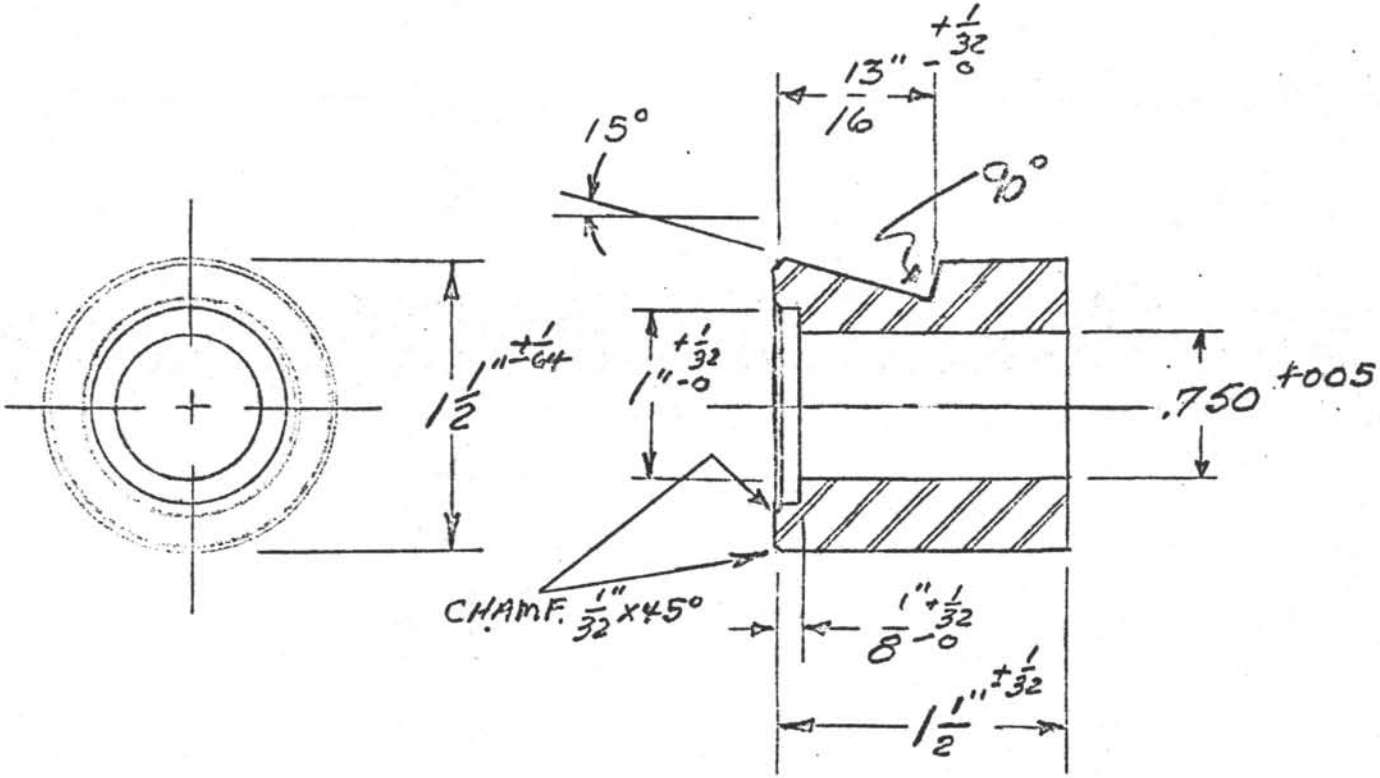
/253



ITEM	REQD.	DESCRIPTION
1	1	STOP BOLT
2	1	SLEEVE
3	1	TRUARC 5108-75

6 REQD / ASBLY

UCSD - SIO
DEEP SEA DRILLING
STOP BOLT ASBLY
1/27/71 DLS SCALE-1"=1"
RE-026
REV #1



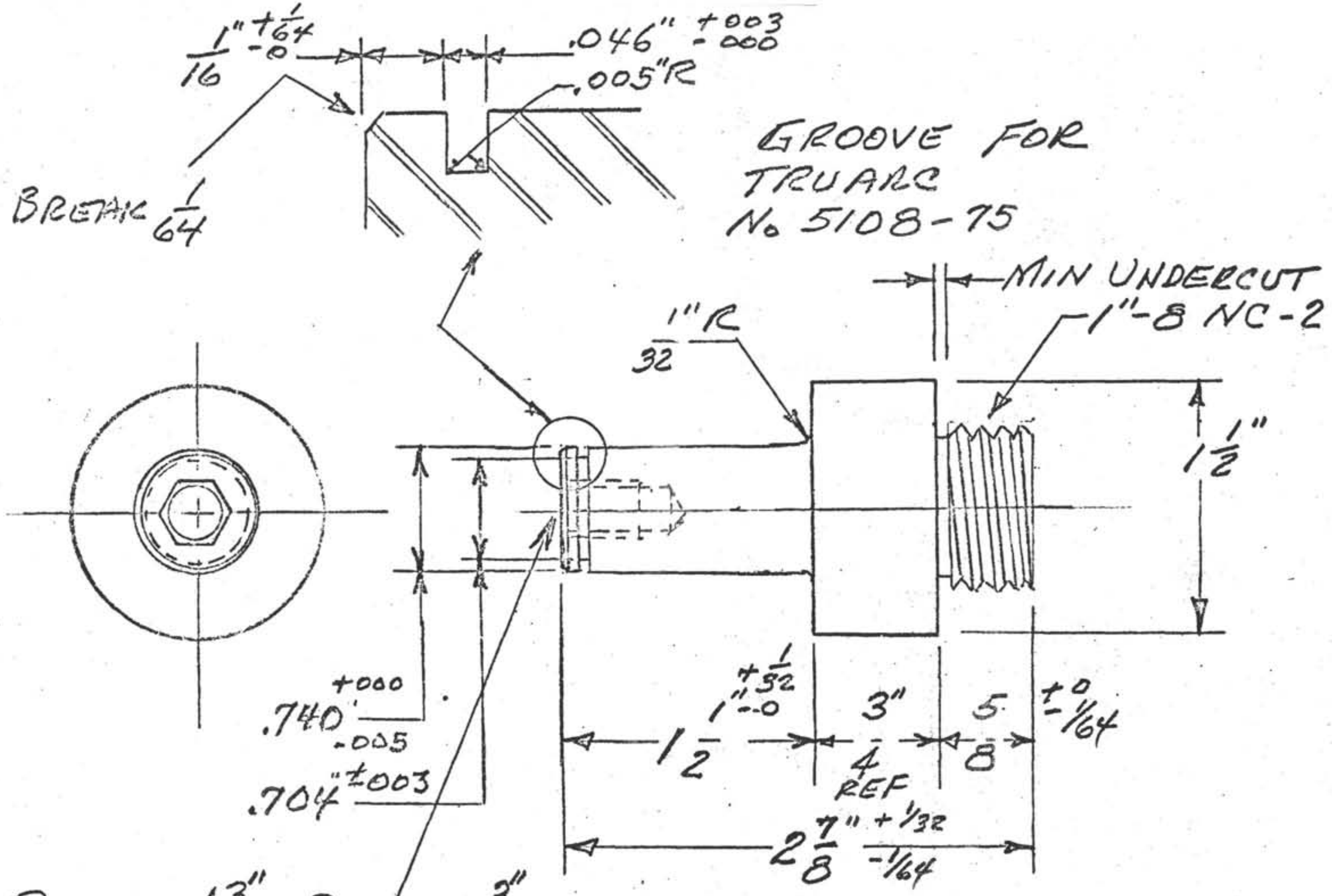
SCALE - 1" = 1"

FINISH 125 √ ALL OVER
MAT'L 8620
CARB. .015 EXCEPT BORE
HT. 28-30 RC

UCSD - SIO
DEEP SEA DRILLING
STOP BOLT SLEEVE
1/28/71 OCS
RE-27

1254

/255



DRILL 13/32" DEPTH 3/4"

3/8" BROACH 1/2" DEEP

SCALE - 1" = 1"

FINISH - 125√ ALL OVER

MATL - 4340 OR 4140

HT 30-33 RC

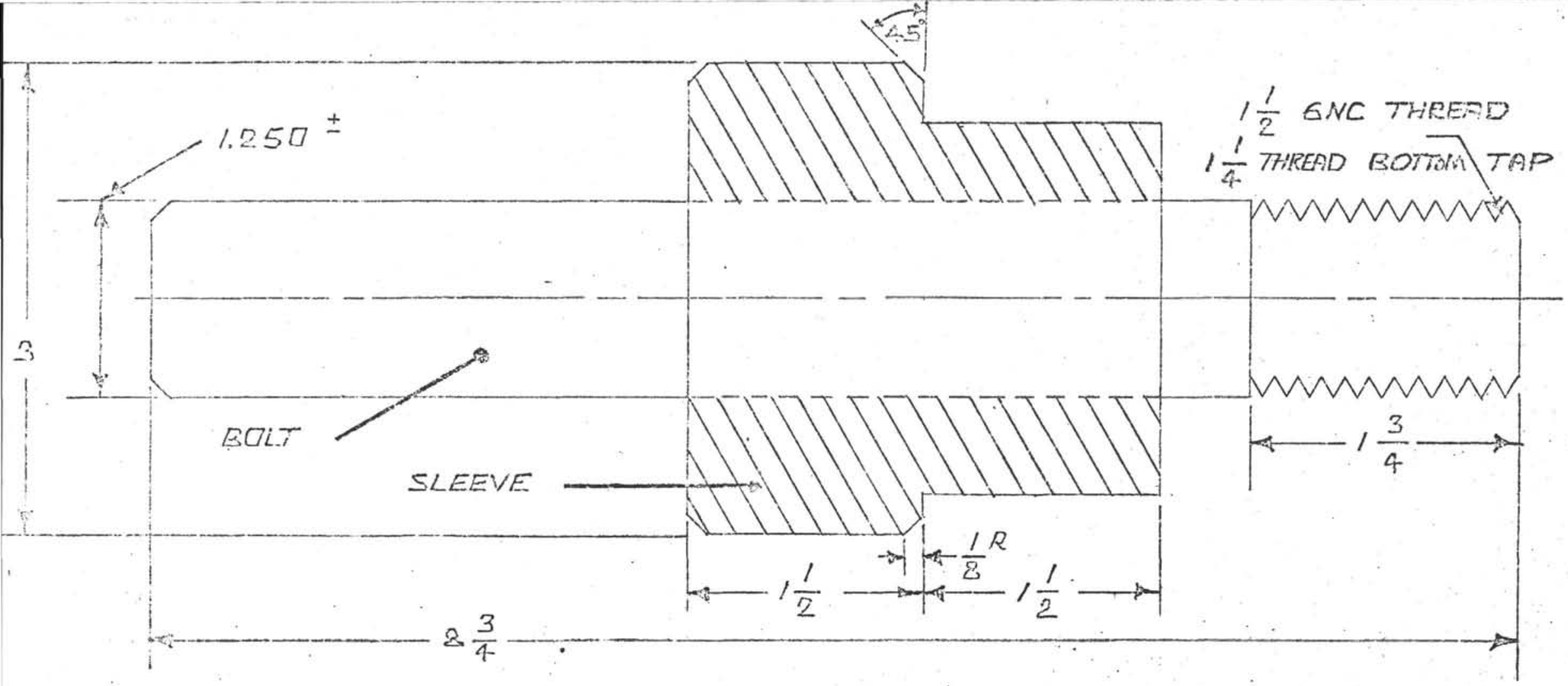
UCSD - S10

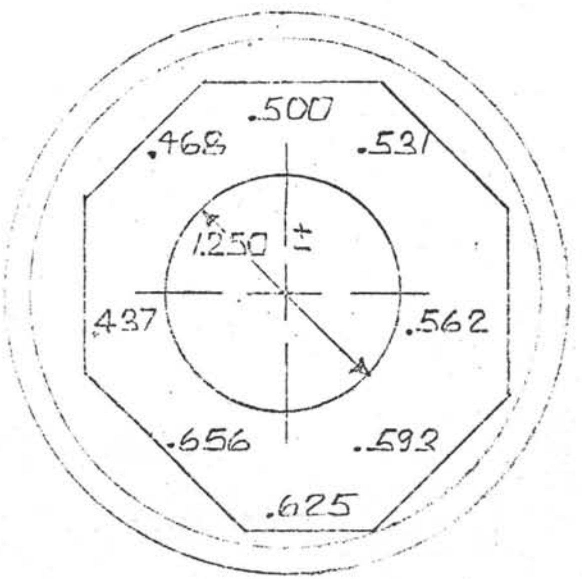
DEEP SEA DRILLING

STOP BOLT

1/28/71 OLS

RE - 28





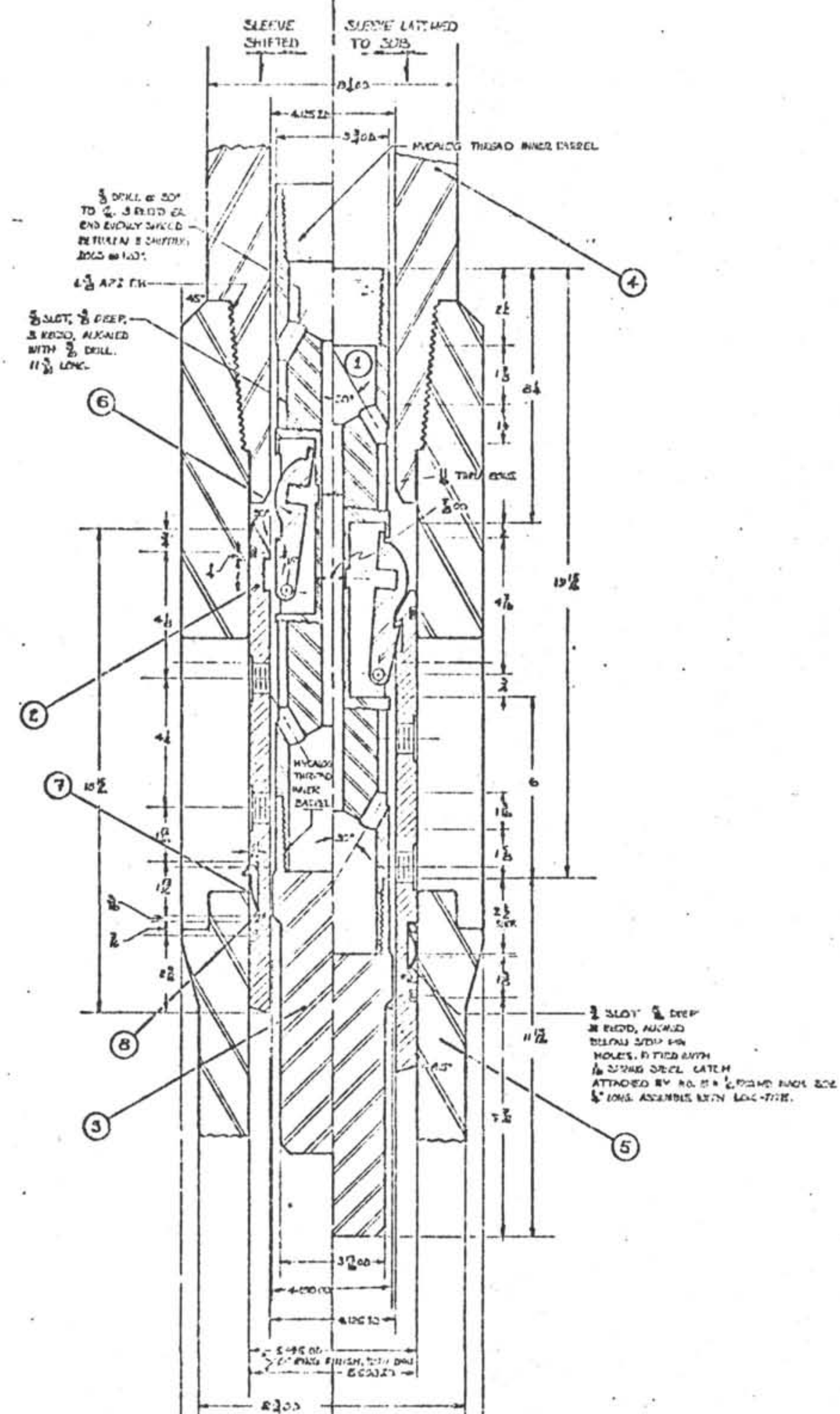
/256

MATL: HOT ROLLED STEEL

BOLT & CAM SLEEVE
UCSD-SIO
DEEP SEA DRILLING PROJECT
19 MARCH 71 FULL SCALE
DRAWN BY: M.A. STORMS

RE-39

REVISION 1

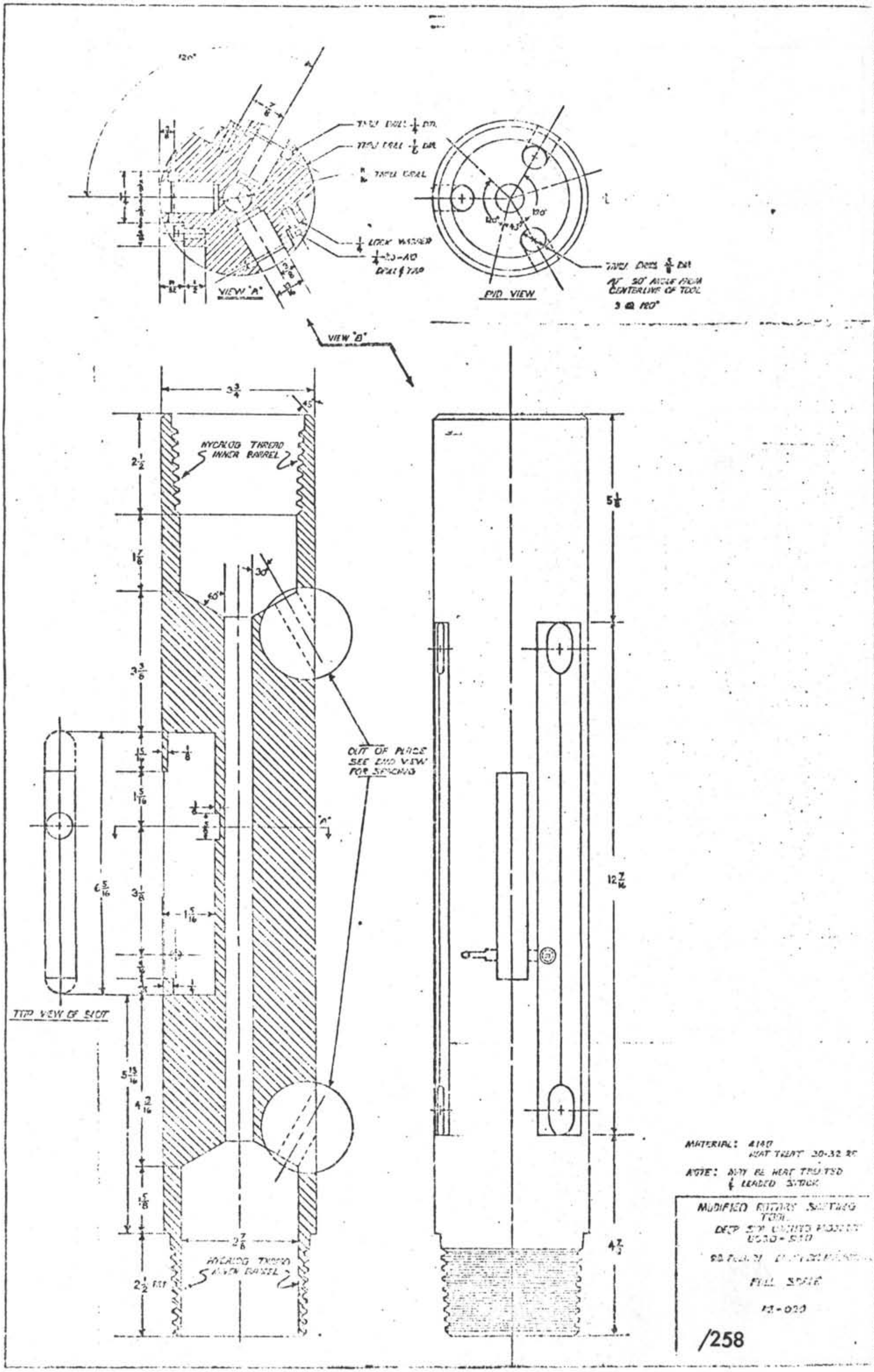


ITEM	DESCRIPTION	REQ'D
1	[illegible] SHIFTING TOOL	1
2	SLEEVE	1
3	INDEX SECT. SHIFTING TOOL	1
4	INDEX SUB	1
5	[illegible] SUB	1
6	SHIFTING DOG	3
7	SPRING STEEL CATCH	3
8	NO. 8 ROUND HEAD SCR.	3

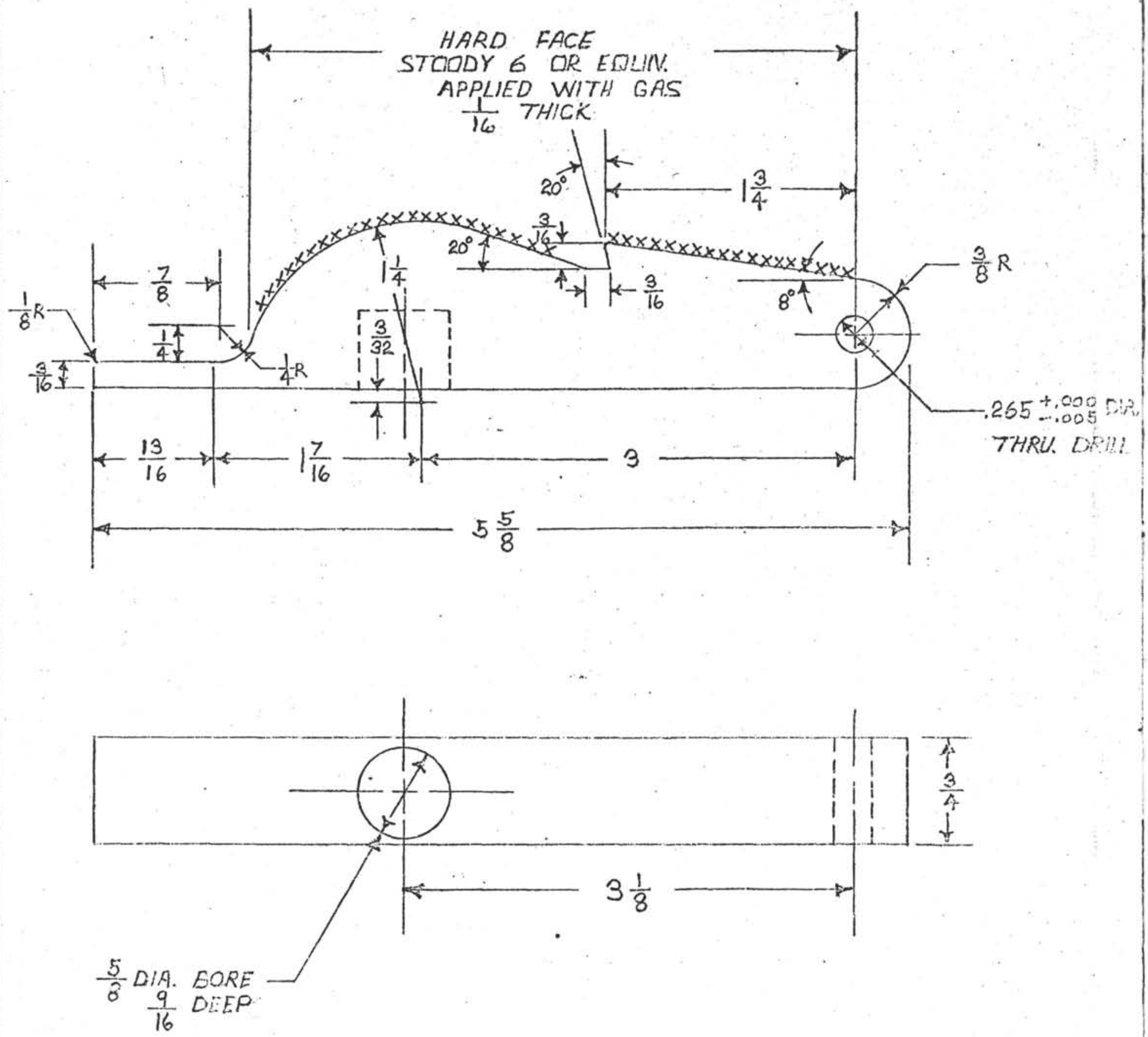
MATERIALS:

SHIFTING TOOL & SLEEVE
UCSD - SIO
DEEP SEA DRILLING PROJECT
4 FEB '71 DRAWN BY: W. SMITH
HALF-SCALE
RS-019

8½ x 11



VIEW "A"
END VIEW
VIEW "B"
HYDRILL THREAD INNER BARREL
OUT OF PLACE SEE END VIEW FOR SPACING
TOP VIEW OF SLOT
LOCK WASHER
MATERIAL: 4140
NOTE: MAY BE HEAT TREATED
MODIFIED ROTARY SHIFTING TOOL
FULL SCALE
/258



SHIFTING DOG
DEEP SEA DRILLING PROJ.
UCSD - SIO
1 MAR. 71 FULL SCALE
DRAWN BY: M.A. STORMS

RE - 021

(FOR MODIFIED TOOL)

MATERIAL: 4140
FINISH : 125 (EXCEPT HARD FACE)

/259

BAKER OIL TOOLS, INC.
LOS ANGELES HOUSTON
NEW YORK
U. S. A.

ILLUSTRATIVE DRAWINGS
OF SPECIAL
TOOLS AND METHODS

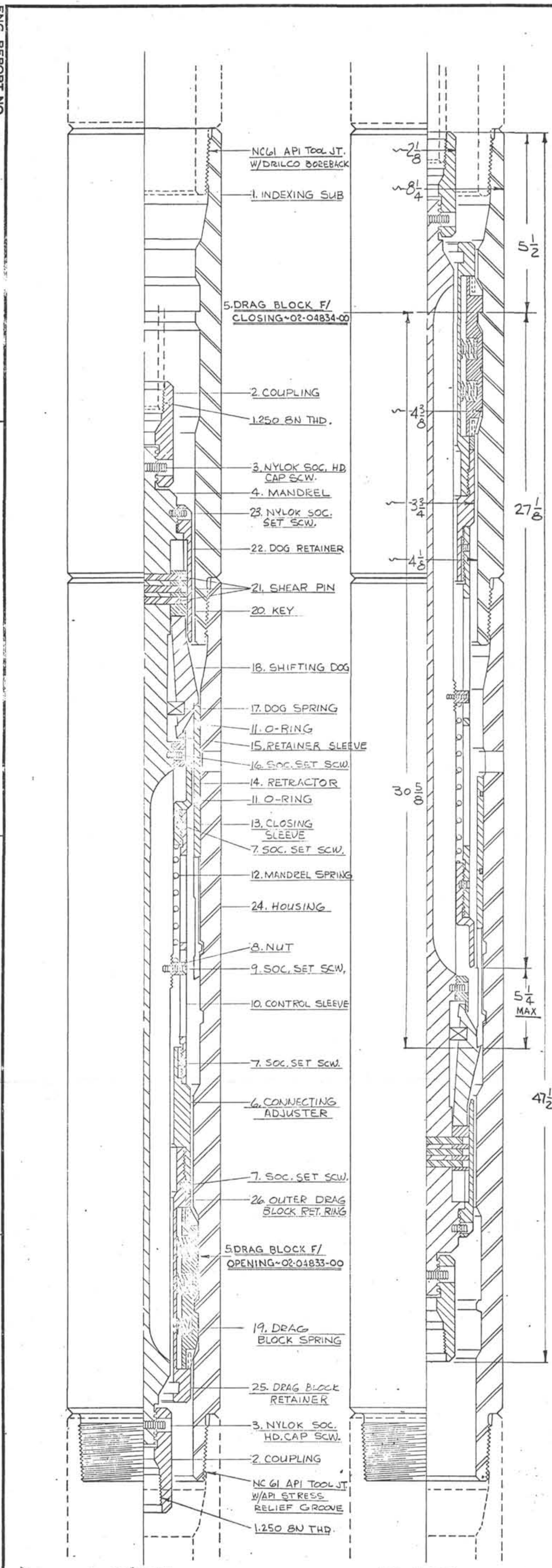
NAME: JET SUB W/4.12 MOD. 'D-2' SHIFTING TOOL
PRODS. 995-01 & 810-72 SP.

DWG. NO. 204 865-1

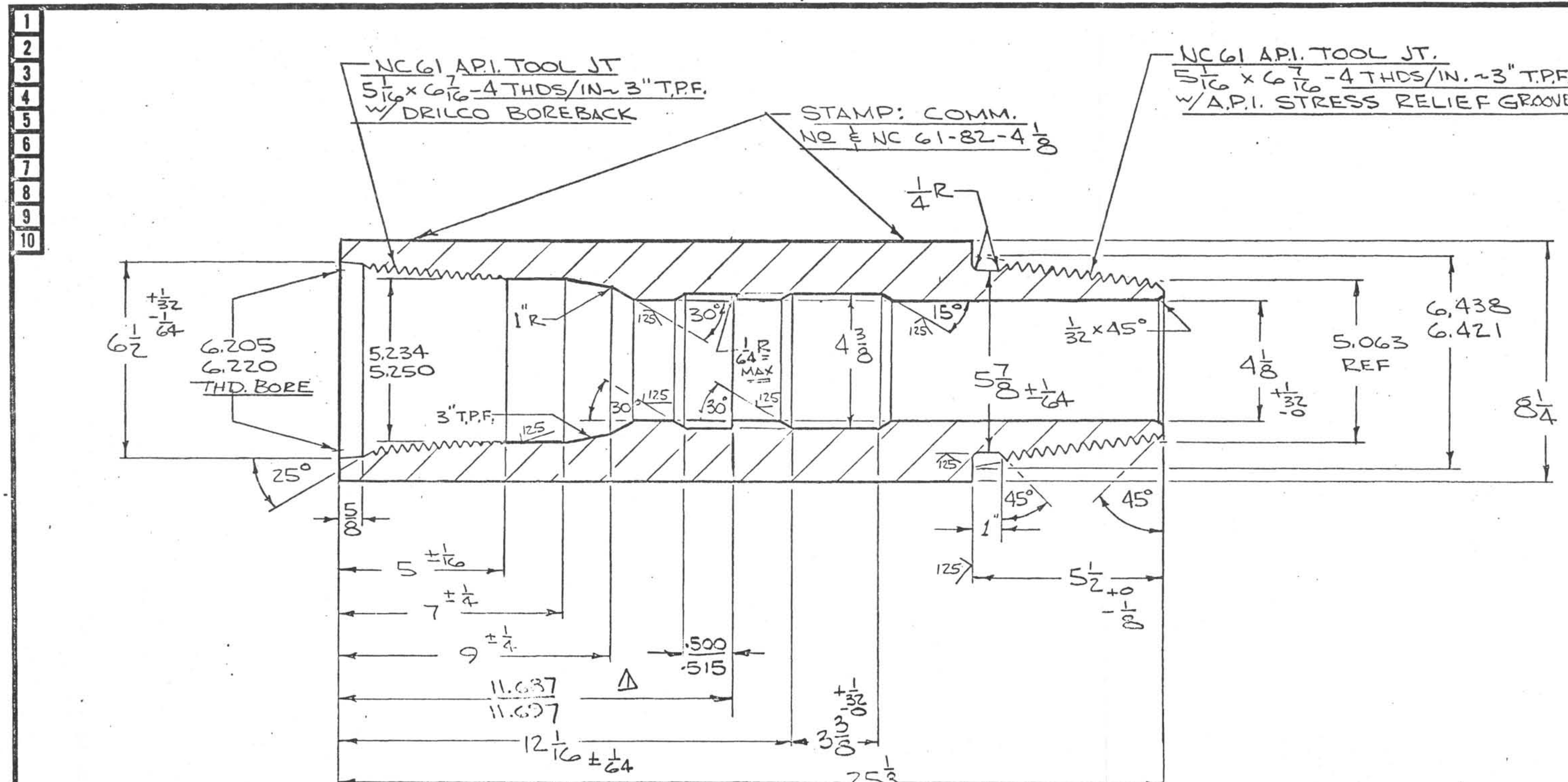
DRAWN J.H. Skinner
APPROVED
DATE 5-26-70

REVISION DATES: P.D. 11-11-70
P.D. 11-24-70

ENG. REPORT NO. 4G1-1



DWG. NO. 204 865-1



285-341 BHN											
BR 101						5/21/??	1	–	CHANGED GROOVE CONFIG.	??
HEAT TREAT	DATE	NO	LETTER	REVISIONS	BY	DATE	NO	LETTER	REVISIONS	BY

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TITLE: INDEXING SUB JET SUB.

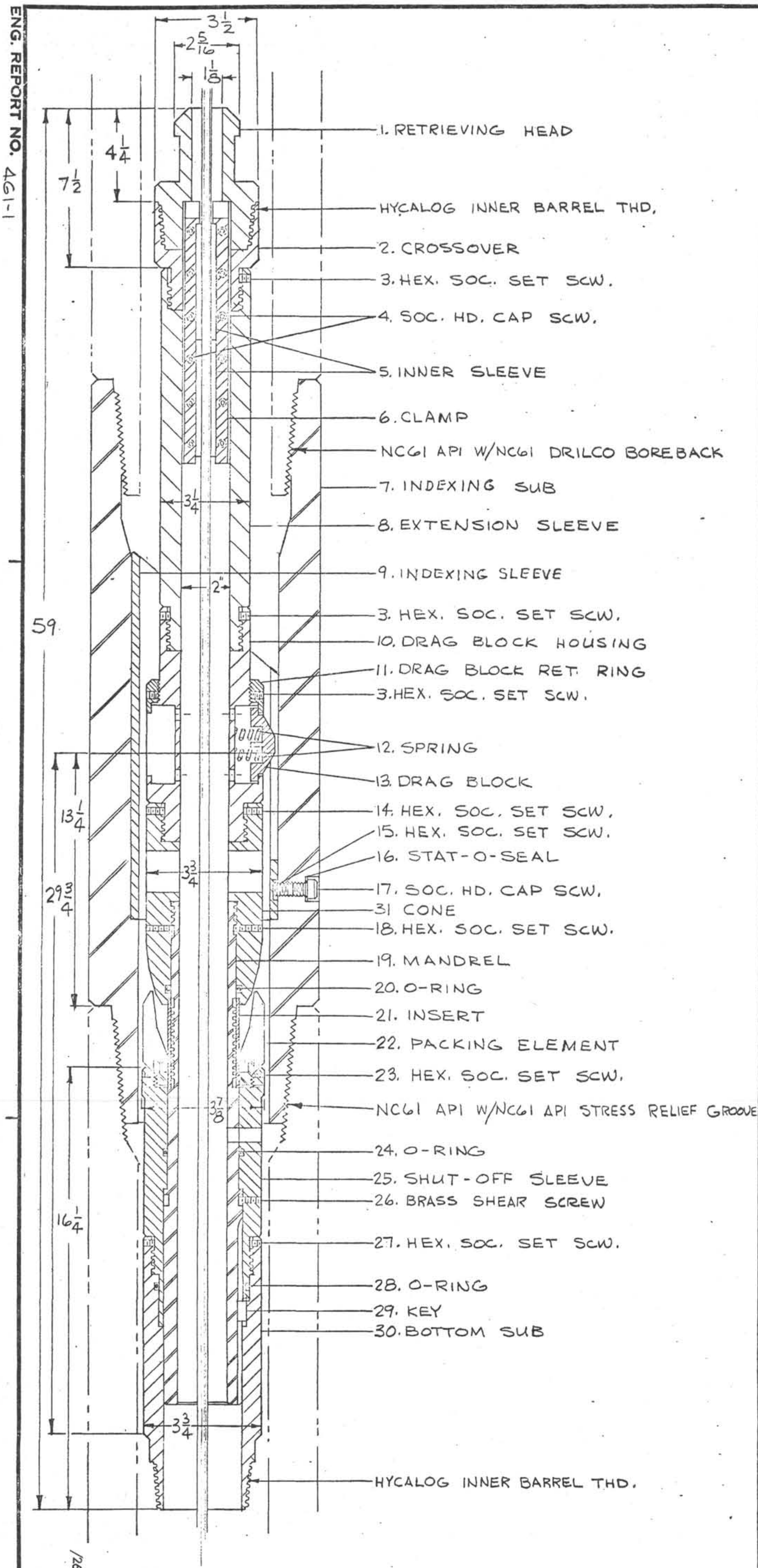
MATERIAL: A.I.S.I. 4135-4142 STL.
8 1/4 ODF x 4 1/8 IDF x 25 1/8 LGF.

UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS ARE IN INCHES
DO NOT SCALE FOR DIMENSIONS
REMOVE ALL BURRS
BREAK SHARP EDGES MAX. 1/64

TOLERANCES	
FRACTION	± 1/32
ANGULAR	± 0° 30'
MACHINED SURFACES	250

BAKER DIVISION – BAKER OIL TOOLS, INC. U. S. A.

OLD DRWG. 205994	DATE 4-23-70	206
COMM NO 02-06031-00	PROD. NO 095-01	031 /261 OF
DRAWN BY R. SNYDER	CHECKED	APPROVED



NAME BORE PLUGGER F/JET SUB
F/DEEP SEA DRILLING PROJECT
PROD. No 995-01

DWG. NO. 206 281-1

DRAWN Pat Decker
APPROVED [signature]
DATE 10-21-70

REVISION DATES: 10/29/70 P.D.
11/2/70 P.D.
11/5/70 P.D.
11/20/70 P.D.

DWG. NO. 206 281-1

APPENDIX H

MOTIONS OF A DEEP SEA DRILL STRING

CALCULATED AND ACTUAL

Peter M. Riede

May, 1971

KENNECOTT EXPLORATION, INCORPORATED

OCEAN OPERATIONS DIVISION

TABLE OF CONTENTS

I. BACKGROUND FROM THE DEEP SEA DRILLING PROJECT

There is only one ship equipped to perform drilling on the deep ocean floor, down to depths of 6096 meters. This ship, Glomar Challenger, is owned by Global Marine, Inc. She has been engaged in drilling for core samples as part of the United States' Deep Sea Drilling Project. The Project is being managed by Scripps Institution of Oceanography under contract with the National Science Foundation. To date some 15 cruises have been accomplished providing a wealth of scientific information in the fields of marine geology and biology.

M.N.A. Peterson and N. T. Edgar have written a most interesting and detailed account of the ship, its equipment, its capabilities, and some of its accomplishments. (Reference 1) The following excerpt from this reference is pertinent to the present study.

"Glomar Challenger has a length of 400 feet and a displacement of 10,500 tons. Her profile is unforgettable: amidships towers a 142-foot drilling derrick, its top almost 200 feet above the water line.

"Aside from an unusual appearance, the ship necessarily possesses rather remarkable operating capabilities. She maintains position dynamically-with an accuracy of a few hundred feet-above a drilling site by referring to an acoustical signal from a sound source (a sonar beacon) emplaced on the ocean bottom at the drill site. The signal is processed by a computer system that commands the main propulsion screws and "side thrusters". There are four side thrusters (so-called "tunnel thrusters" - large propellers in tunnels that lead from one side of the hull to the other-that enable the ship to steam sideways if necessary). Their effectiveness is elegantly demonstrated when Glomar Challenger maneuvers alongside a dock without assistance from tugboats."

Of particular interest to the present study is the nature of the drill string itself. The string is made up of 90 foot sections of standard steel drill pipe, 5 1/2 inches outside diameter by one half inch wall thickness. Over 23,000 feet of this drill pipe is carried by the ship. The sections are connected to each other by threaded couplings. The string is suspended from the drilling derrick and controlled from the drilling floor. Handling the string, extending it, withdrawing it, turning it, etc. are similar to deep drilling techniques practiced on land.

A requirement, not relevant on land, is the method used to pass the drill string through the ship's bottom into the ocean. The drilling floor is above water level and the drill string extends downward through a flared tube shaped somewhat like the throat of a horn. This prevents excessive stresses in the string as it bends to follow the motion of the ship. The arrangement is illustrated in Figure 1.

With this unique combination of ship and long, lean drill string the obvious question comes to mind: When the ship moves or stops what is the subsequent motion of the string? Before attempting an answer a short explanation is given on why the answer is important as well as interesting.

II. THE RE-ENTRY PROBLEM

When drilling in the ocean floor the depth of hole possible is often limited by dulling of the drill bit. This is typically true when chert, a flint-like material, is encountered. It is very hard and dulls even diamond drills rapidly. To continue drilling to a greater depth it is desirable to pull the whole drill string, replace the bit, relower the string, and have it re-enter the same hole for continued drilling. Thus we have a ship two or more miles above a hole several inches in diameter in the ocean floor. How to maneuver the ship so the snake like string will move till its end is over the hole, then lower the string for re-entry, is the problem.

The remarkable feat of re-entry was accomplished by the scientists and crew of Glomar Challenger for the first time on June 14, 1970. The techniques utilized combined intuitive maneuvering skill and sophisticated sonar instrumentation.

On the first lowering of the drill string a funnel shaped "target" is also lowered on the end of the string. On raising the string the target is left on the ocean floor. Then on re-entry there is 16 foot diameter instead of a 6 inch diameter target to shoot for. Attached to the target are three equilaterally spaced sonar reflectors. At the end of the drill string is mounted a sonar scanning instrument developed especially to measure the distance and direction from the target. This data was obtained almost continually on the day of re-entry and provided the basic time-position record that allows analysis of the actual motion of the end of the string.

During the same time period data was taken on the position of the ship relative to the sonar beacon dropped to the ocean floor before the commencement of drilling. With these two sets of data we have, for the first time, information on the motion of an actual drill or pipe string in the deep ocean.

III. MATHEMATICS OF DRILL STRING MOTION

A. Response Distance and Response Time

To understand and calculate the motions of interest let us initially assume the ship stationary on the ocean surface with the long drill string hanging in a straight vertical line below it. This corresponds to Position O and time t. as illustrated on Figure 2. Now assume the ship starts to move and continues at a constant velocity V. The top end of the string must of course move with the ship, but the bottom end will not immediately start to move.

Since the string can be considered completely flexible because of its great length to diameter ratio, the upper increment of its length will stream behind the ship making an angle $\emptyset$ with the vertical. See Position 1 on Figure 2. This is dictated by force balance considerations wherein the horizontal component of the weight of incremental length of string must equal the drag force of this length moving at velocity V.

$$w \Delta S \sin \emptyset = h \; d \Delta S \; V^2$$

Since $\emptyset$ is a small angle

$$\sin \emptyset = \emptyset = \frac{h \; d \; V^2}{w}$$

where:

$\emptyset$ = angle between inclined portion of string and vertical . radians
w = weight per unit length of string in water . 22.6 ft/lb
h = drag coefficient for a cylinder in water. 1.2
d = diameter of string. 0.46 ft
V = velocity of ship. ft/sec
S = length of drill string. 10,000 ft

For the Glomar Challenger the angle $\emptyset$ is limited to a maximum of ten degrees as this is the angle at the throat of the horn. A greater angle would result in sharp bending or breakage of the string where it left the bottom of the ship. From the above equation this limits the speed of the ship with drill string extended to 2.67 ft/sec, 1.58 knots. Practically it would be less since the ten degree flare angle would be effectively reduced by the amount of roll or pitch.

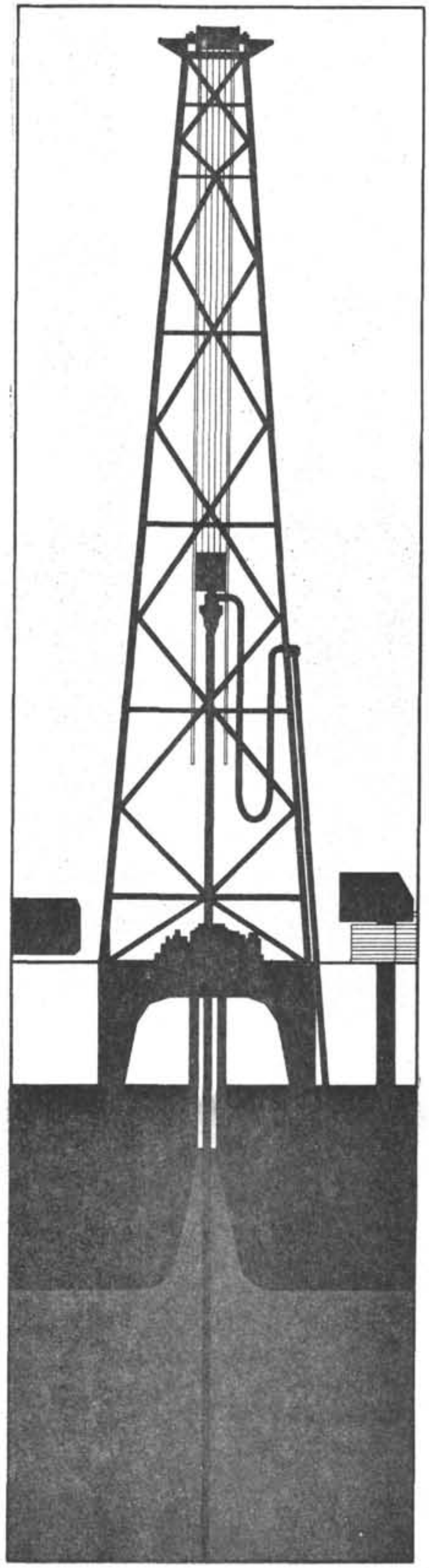
To return to the ship proceeding at velocity V, angle $\emptyset$ remains the same but the length of string at that angle, $D/\emptyset$, increases until the whole string is at this angle. This occurs at Position 2, Time t_2. At this point the bottom of the string starts to move at the same velocity as the ship and they continue in this configuration as for example in Position 3.

Following the sequence outlined above it can be seen that the ship moves from Position 0 to Position 2 before the bottom of the drill string starts to move. This distance D_2 is called the response distance. It is equal to $S\emptyset$ where S is the total length of the drill string. The corresponding Response Time is defined as the elapsed time between the moment the ship starts to move and the moment the bottom end of the drill string begins to move. It is simply, Response Distance divided by velocity, D_2/V.

Response Time and Response Distance for the drill string of Glomar Challenger have been calculated from the above equations and are plotted as a function of ship speed on Figure 3. Comments by individuals participating in the re-entry

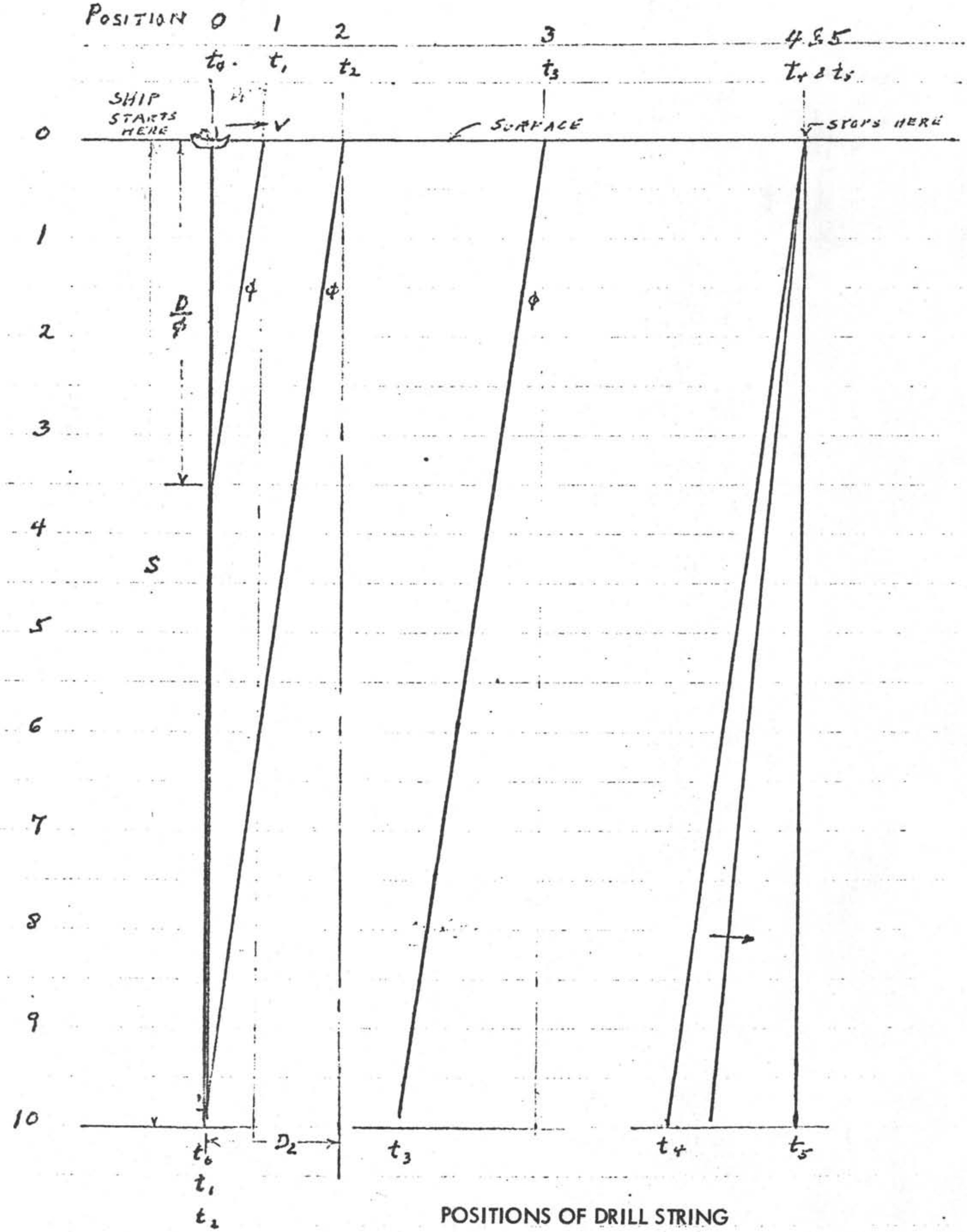
Left: This scale drawing of the Drilling Vessel Glomar Challenger shows proportions with a water depth of 5486 meters (18,000 feet). Even so, the line width for the drill string is greatly exaggerated (so that it can be seen).

Right: In this cross-section diagram, the exponential horn shown beneath the derrick distributes the drill pipe bending when the ship rolls and pitches on the rolling sea. Her gyroscopically controlled roll stabilizing system keeps the ship remarkably stable, even in heavy weather. Above can be seen the crown block at the top of the derrick and the travelling block and power swivel with the large hose for pumping seawater to wash the drill cuttings to the top of the hole.



Cross Sections - Drill String and Ship
(From Reference 1)

Figure 1



POSITIONS OF DRILL STRING

Figure 2

experiment were that the string usually followed the ship in one to two minutes. From Figure 3 this indicates that the maneuvering velocity of the ship was between 1/4 and 1/2 ft/sec which checks reasonably well with typical actual data.

B. Traverse Time

The foregoing examined the motion of the drill string when the ship starts and continues moving at constant speed. The other question is what is the motion of the string when the ship stops, specifically, how long after the ship stops will it be till the string swings all the way to a vertical position directly under the ship.

Suppose, as the first example, that the ship stops before it has proceeded the full Response Distance, that is it stops before the string has had time to extend backward in a straight line at angle $\emptyset$. This is illustrated in Figure 2 where the ship stops at Position 1. Now the time t_1 required for the string to move to a vertical position directly under the ship, called the Traverse Time, can be arrived at by an energy balance technique.

The string, in Position 1, has a potential energy greater than when it is hanging vertically since its center of gravity is higher. This energy, in the movement to vertical, is converted to heat by drag in the water.

Equating the expressions for these two energies we have:

$$\frac{(1 - \cos \phi)\ D_1 Ww}{\sin \phi}\left[\frac{D_1^2}{2\phi} + \left(S - \frac{D_1}{\phi}\right) D_1\right] = \frac{2hdD_1^2}{t_1^2}\left[\frac{D_1^2}{4\phi} + \left(S - \frac{D_1}{\phi}\right) D_1\right]$$

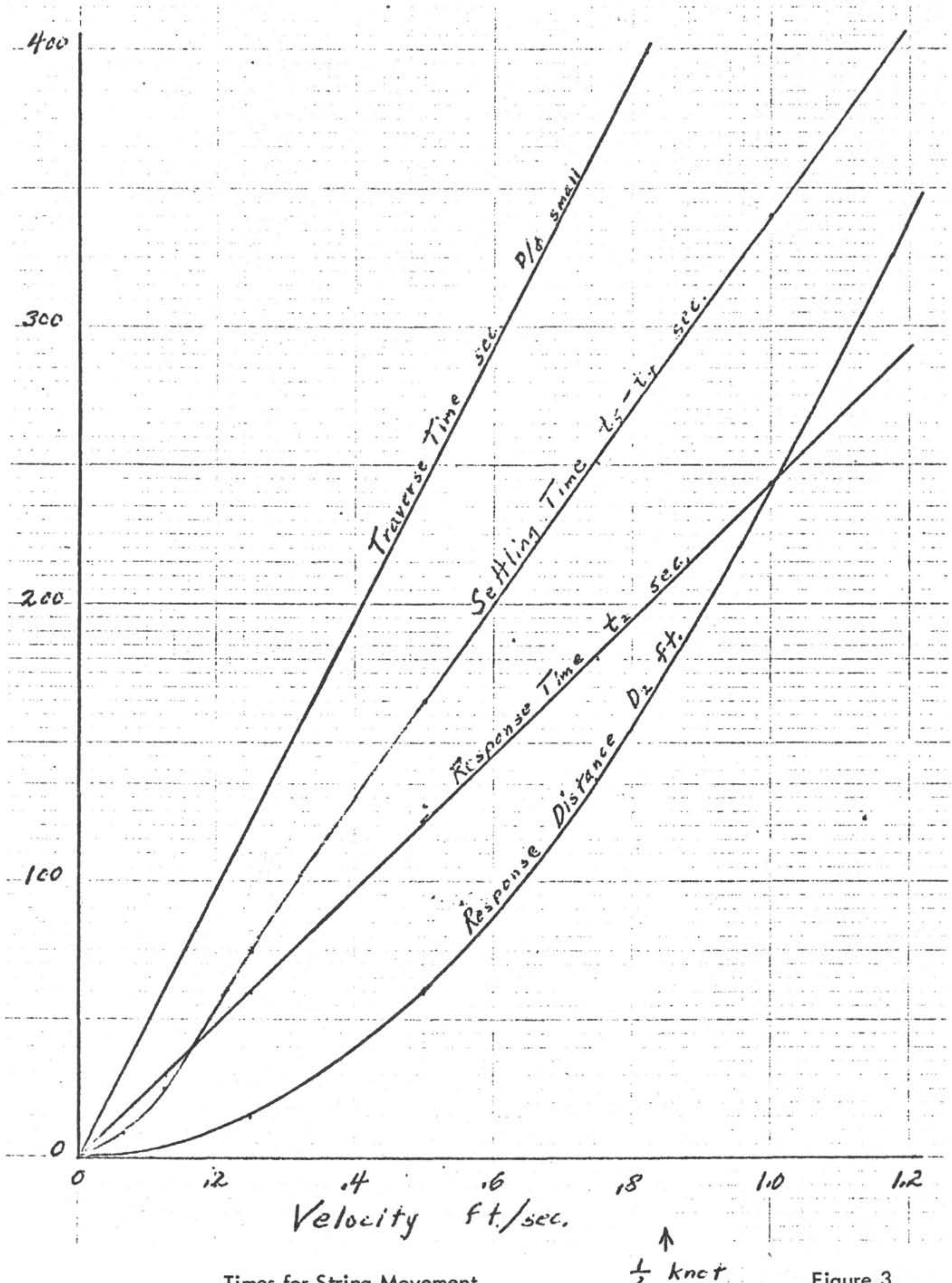
Recognizing that for small angles $\frac{1 - \cos \phi}{\sin \phi} = \frac{\phi}{2}$

and solving for the Traverse Time, t_1 :

$$t_1 = 2D_1\sqrt{\frac{hd\ (S - 3D_1/4\phi)}{w\phi\ (S - D_1/2\phi)}}$$

For the Glomar Challenger drill string this traverse time is plotted on Figure 3 for the case when D/ϕ is small, that is when the slanted portion of the line in Position 1, Figure 2 is small in comparison to the total length of the line.

C. Settling Time



Times for String Movement

Figure 3

The alternative case to that discussed in the previous section is when the ship stops after it has proceeded far enough for the string to be completely extended behind it, in a straight line. This is illustrated as Position 4 in Figure 2. After the ship stops the time required for the line to swing directly below it can again be determined by the energy balance technique. The energy in the string consists of its potential energy related to its higher center of gravity and its kinetic energy moving at the ship's velocity. These are balanced by the hydrodynamic friction as the string sweeps back to a vertical position. The equation for this energy balance is:

$$\frac{1}{2}\ W_a/g\ V_o^2 + \frac{1}{4}\ W_w D_2 \phi = \frac{1}{2}\ hd\ D_e^2 / t_s^2\ D_2$$

where:

W_a = weight per unit length of drill string in air
W_w = weight per unit length of drill string in water
g = acceleration of gravity
V_o = velocity of ship before stopping
D_2 = response distance: Total string length x angle, $S\phi$
ϕ = string angle with vertical
h = drag coefficient, cylinder in water
d = diameter of drill string
t_s = settling time, also $t_5 - t_4$ on Figure 2

solving for the settling time we have:

$$t_s = \frac{D_2}{V_o}\sqrt{\frac{D_2}{W_a/ghd + D_2/2}}$$

Results for the Glomar Challenger string are plotted on Figure 3.

D. Experimental Analogy

It is interesting to note that the action of the full size string can be rigorously simulated by a light weight string in still air, for example, a piece of sewing thread suspended from the ceiling. Such a simple experiment vividly portrays the shapes taken by the string as it is moving from one position to another.

One instance is when the string moves as from Position 1, Figure 2. The string motion, as confirmed experimentally, is characterized by a pulse moving down the string. The time sequence of the motion is illustrated on Figure 4.

Curiosity prompted a use of the equations developed above to the motion of a thread in air. The experimental check was, not unnaturally, quite close.

For example, the settling time for a thread 16 feet long starting at an angle, ϕ, of 30 is 3.8 seconds. Of course corresponding experiments using fine wires in water instead of air could also be designed.

IV. ACTUAL MOTION OF SHIP AND DRILL STRING

On the day re-entry was first accomplished, June 14, 1970, extensive information was accumulated on the positions occupied by the ship and lower end of the drill string. Dr. M.N.A. Peterson collected this data as well as much ancillary information. These personal notes, Reference 5, have served as the basis for the present study and analysis.

Data on the ship's positions are relative to the sonar beacon which was dropped to the ocean floor. Data on the positions of the end of the drill string are from the sonar scanning instrument that was mounted in the end of the drill string. This measured azimuth and distance from the target funnel. Note that the relative positions of the sonar beacon and target were not known.

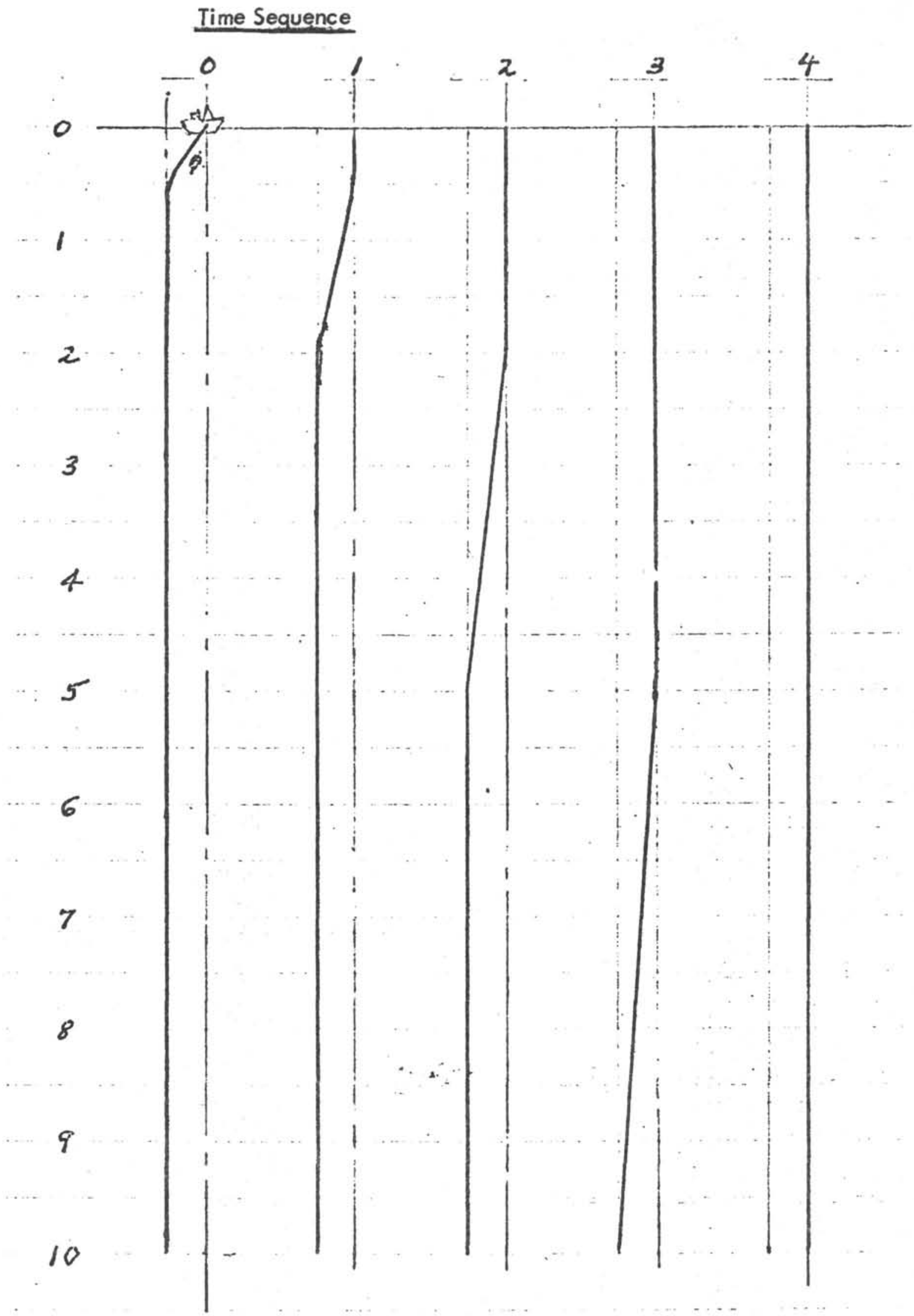
Search for the target started at 05:35. It was first detected by the sonar scanner at 06:27 after the ship had moved about 200 feet NE. Maneuvering to achieve re-entry continued until success was attained at 19:54.

A. Movement of Ship

The sea was rather rough, Sea State 5, with a wind of 28 knots. Glomar Challenger was headed into the wind at 040 degrees and positioned almost directly over the beacon, actually about 100 feet to port. At this time, 05:35, scanning for the target was started.

Maneuvering was now principally by Glomar Challenger's unique automatic positioning system which was described in Section I. In practice, an order to move a certain distance and direction can be "set in" the automatic system and it, by reference to the sonar beacon input will cause activation of a main propeller and side thrusters to move the ship to the new location. Each movement is limited to a minimum of 100 feet and in a cardinal heading. It should be noted that the movement to a new position is not necessarily or even probably in a straight line. Also the movement usually required five to seven minutes to execute. During the day there were 31 movements or "offsets" carried out.

The ship's positions during the day as determined by these offsets is plotted on Figure 5. The time each movement was initiated is marked adjacent to the point from which it started.



Pulsed String Movement

Figure 4

B. Relative Movement of Ship and String

Plots of the positions of the end of the drill string are given on Figures 6 through 12. Together they give, chronologically, the motion for the complete re-entry experiment.

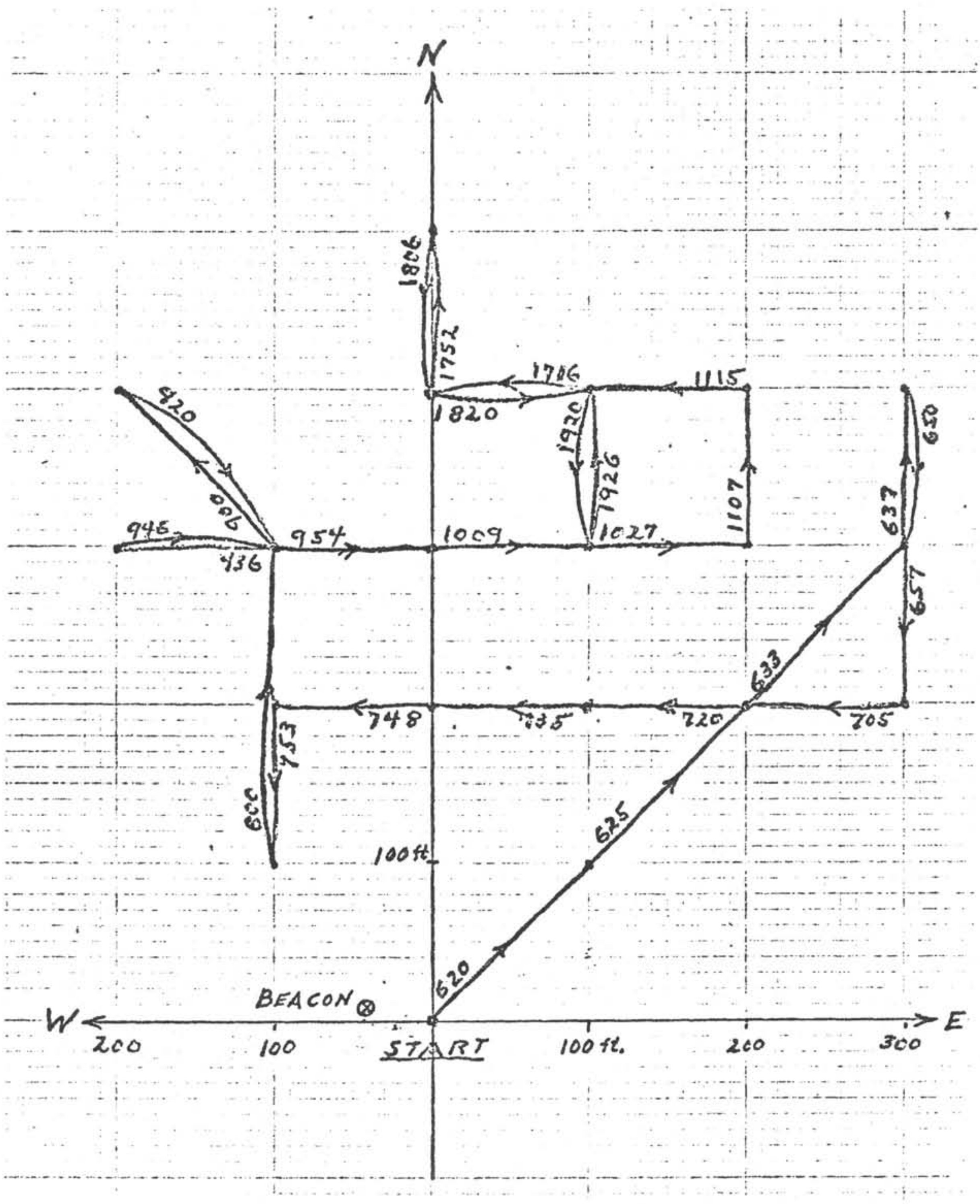
With these two sets of data, the ship's and the string's, we can attempt to correlate the movements of one with respect to the other. On Figure 6 the time period 06:50 to 07:56 is covered; the solid line represents the successive positions of the drill string relative to the target. During the same time period the positions of the ship are given relative to the beacon on Figure 5. However, at this point the relative positions of the target and beacon were not known.

To correlate the two movements as best possible we superimpose the ship's plot on the string's plot on Figure 6 in the most feasible manner. As a result the ship's probable positions are now also indicated on Figure 6 by the dotted line. Remember that the ship did not move in a straight line between points, offset positions, as shown by the dotted lines but went sideways at various times by at least as much as 50 feet. Nevertheless the correlation is remarkably good, particularly during the 400 foot east-west excursion between 07:05 and 07:53.

The average velocity during this excursion was 0.14 ft/sec made up of spurts up to 0.50 ft/sec or more and periods of remaining stopped particularly at the offset points. Contributing to the variation is the fact that, in an automatic 100 foot offset the speed of the ship fore and aft is greater than side to side by a factor of four or five. Since at 0.5 ft/sec the calculated response time is 120 sec. and the response distance 60 feet, (See Figure 3), this explains why there can not be an exact concurrence between the ship's and string's positions. All in all the actual positions confirm quite well what might have been expected from the calculations.

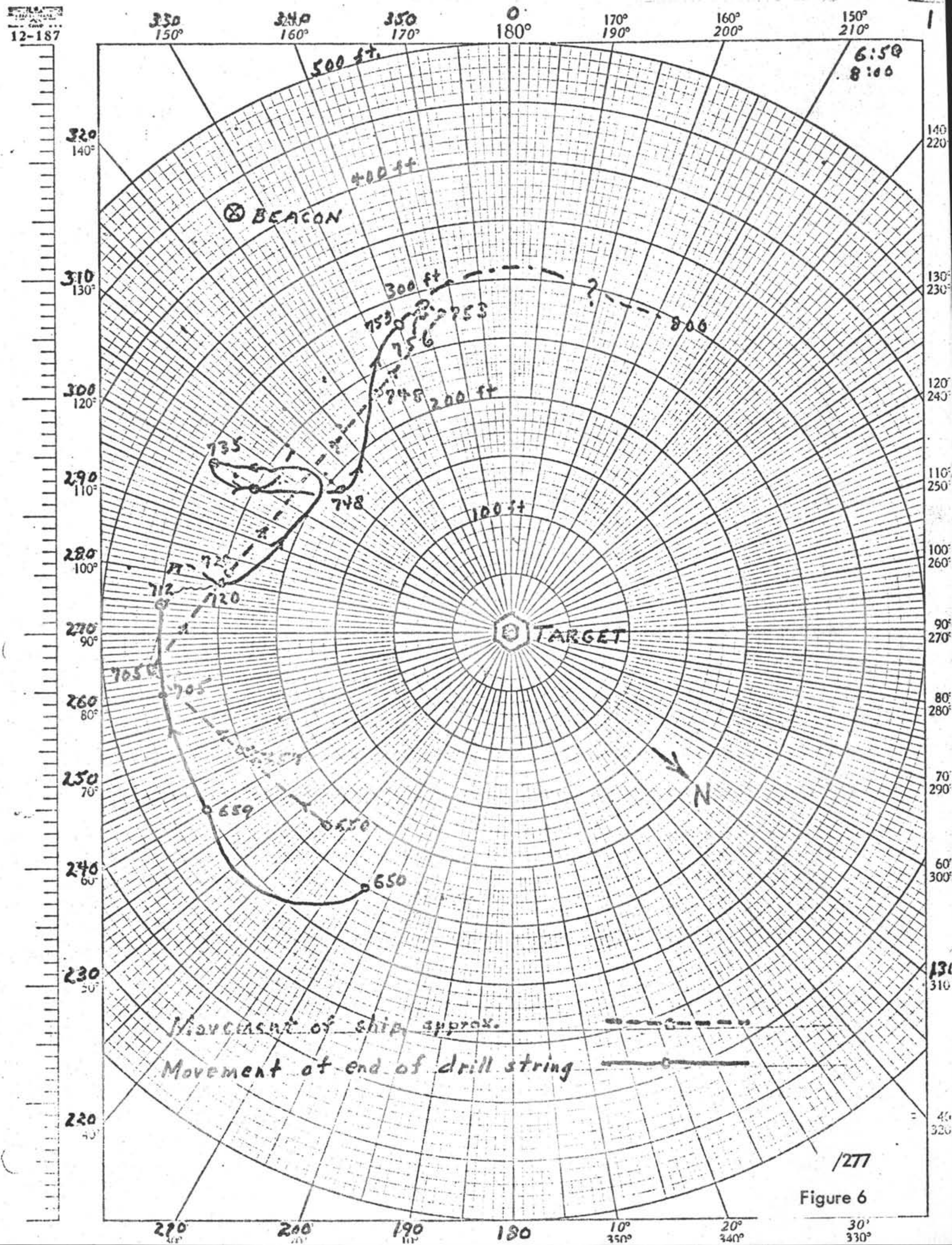
On Figure 7 the time period 09:35 to 11:20 is covered. Here again the ship's positions were superimposed on those for the drill string. The correlation between the two is similar to that observed for Figure 6 and the same comments apply. Note that on Figure 6 the drill string was always in excess of 200 feet from the target whereas on Figure 7 an approach to within 50 feet has been made. Note also that correlating the two movements has now allowed plotting of the beacon relative to the target.

During one period of the day more accurate data on the ship's movement was obtained than that described above from the automatic positioning system's 100 foot offsets. It was recorded by hand from the sonarscope giving beacon locations. This more detailed data from 14:31 to 15:06 is plotted superimposed on the string's movement on Figure 10.



Positions of Ship - 14 June 1970

Figure 5



12-187
6:50
8:00
500 ft
400 ft
300 ft
200 ft
100 ft
BEACON
TARGET
N
650
659
705
712
720
735
748
753
756
800
Movement of ship, approx.
Movement of end of drill string

/277

Figure 6

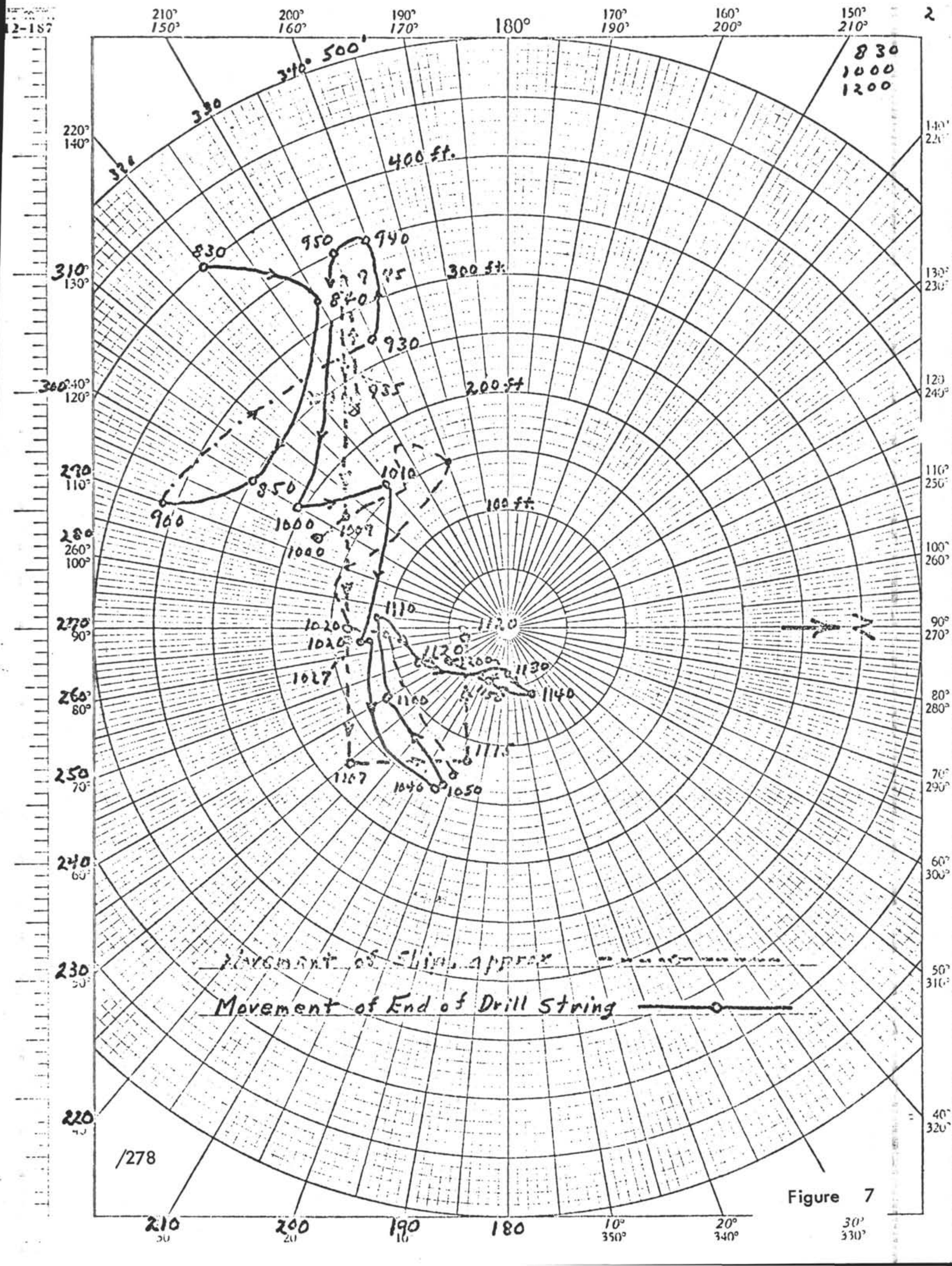

180°
500'
400 ft.
300 ft.
200 ft
100 ft.
830
1000
1200
Movement of End of Drill String

Figure 7

From 14:31 to 14:47 the movement of both is generally easterly but far from being a straight line for either. The distance the ship moved east, disregarding its side excursions, is 215 feet. The drill string end during the same time moved 200 feet. The average easterly component of the ship's velocity was 215/60 (14:47 to 14:31) = 0.22 ft/sec.

Following this, from 14:47 to 15:06, the movement of both was generally westerly, both moving 220 feet. Again velocity varied from about 0.2 average to perhaps 1.0 ft/sec maximum. Calculated response distances for these velocities are ten and 60 feet. Response times are respectively 47 and 120 seconds.

Thus it is shown that the positions of the ship and string end correspond within the range expected from the calculated response distances. Also the positions correspond within what must be the probable error of the data defining them. An error of plus or minus 20 feet is probably not unusual for either the sonar scanning instrument or the sonar beacon read-out.

From the data available further correlations similar to those above could be made. For the purposes of the present study, however, it is believed the correspondence between calculated and actual motions has been adequately demonstrated.

V. OBSERVATIONS

The remarkable re-entry achieved on June 14, 1970 was an accomplishment utilizing both the art and science of undersea drilling. Hopefully this study will contribute toward making re-entry a shorter and more easily executed operation.

Simple equations have been developed to calculate the response of a long drill or pipe string to the motion of its ship. These can be further developed to cover a wider range of conditions.

Based on Dr. Peterson's data a good correlation between the ship's and drill string's positions has been established.

The actual motions as delineated by the data generally confirm motions calculated from the equations presented. A precise concurrence could not be established because the ship's positions relative to time could not be recorded precisely.

It would be desirable to run some further experiments to more closely check the calculated and actual motions. This would involve, preferably in a quiet sea, maneuvering the ship in controlled straight line distances at controlled velocities and measuring the response of the lower end of the drill string.

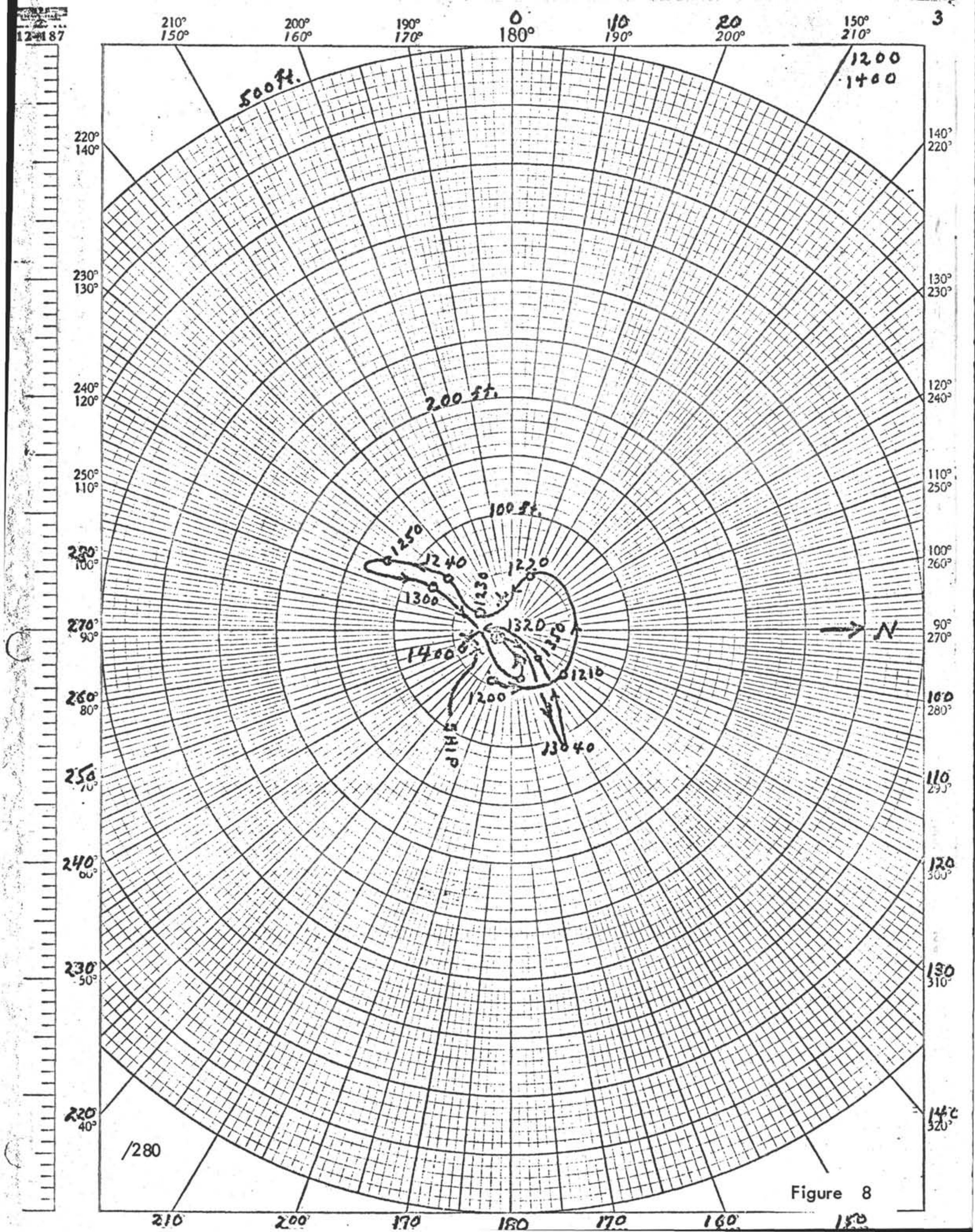

12-187
0
180°
1/0
190°
20
200°
210° 150°
200° 160°
190° 170°
150° 210°
1200
1400
500 ft.
200 ft.
100 ft.
1250
1240
1300
1230
1220
1320
1350
1210
1400
1200
1340
SHIP
N
/280

Figure 8

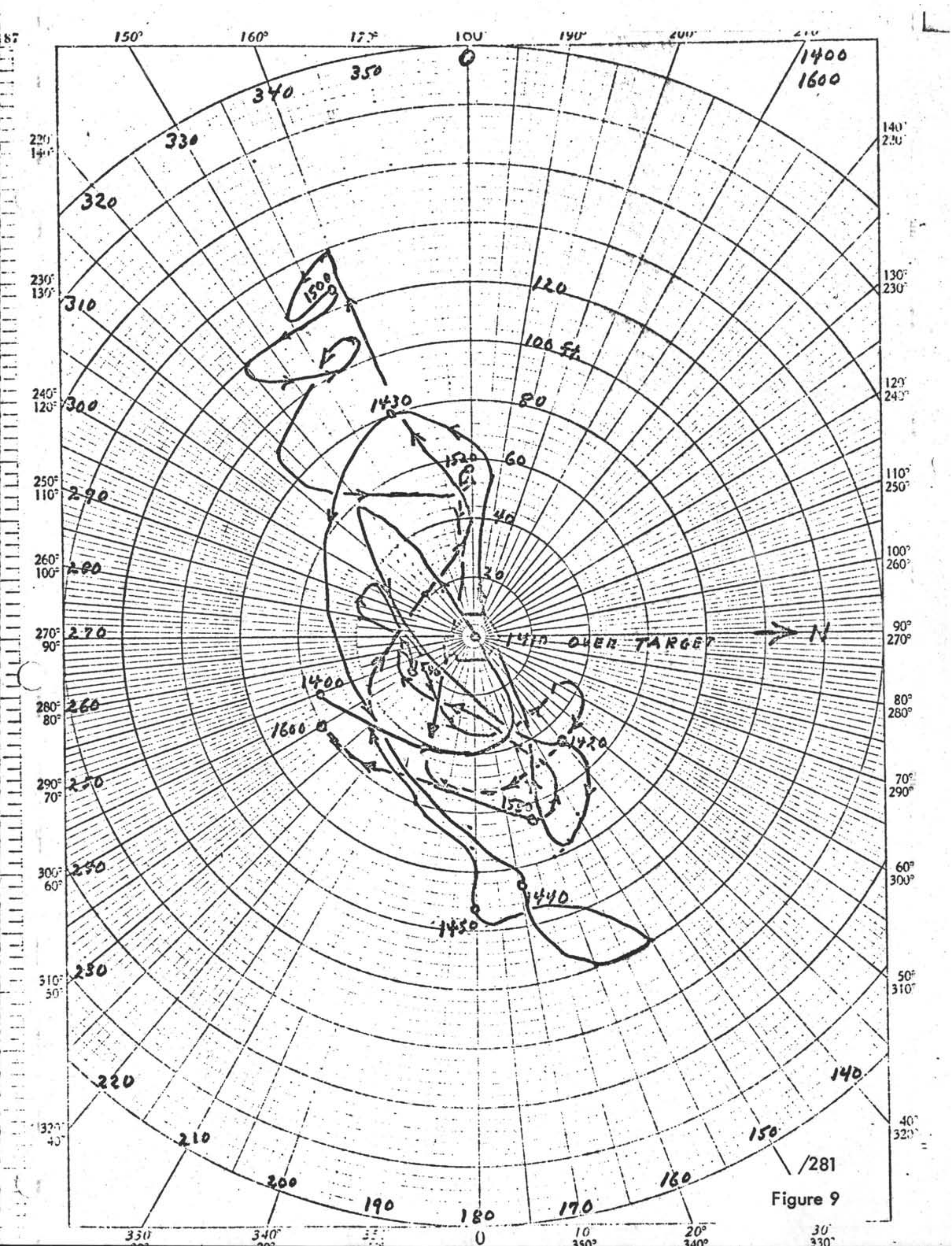
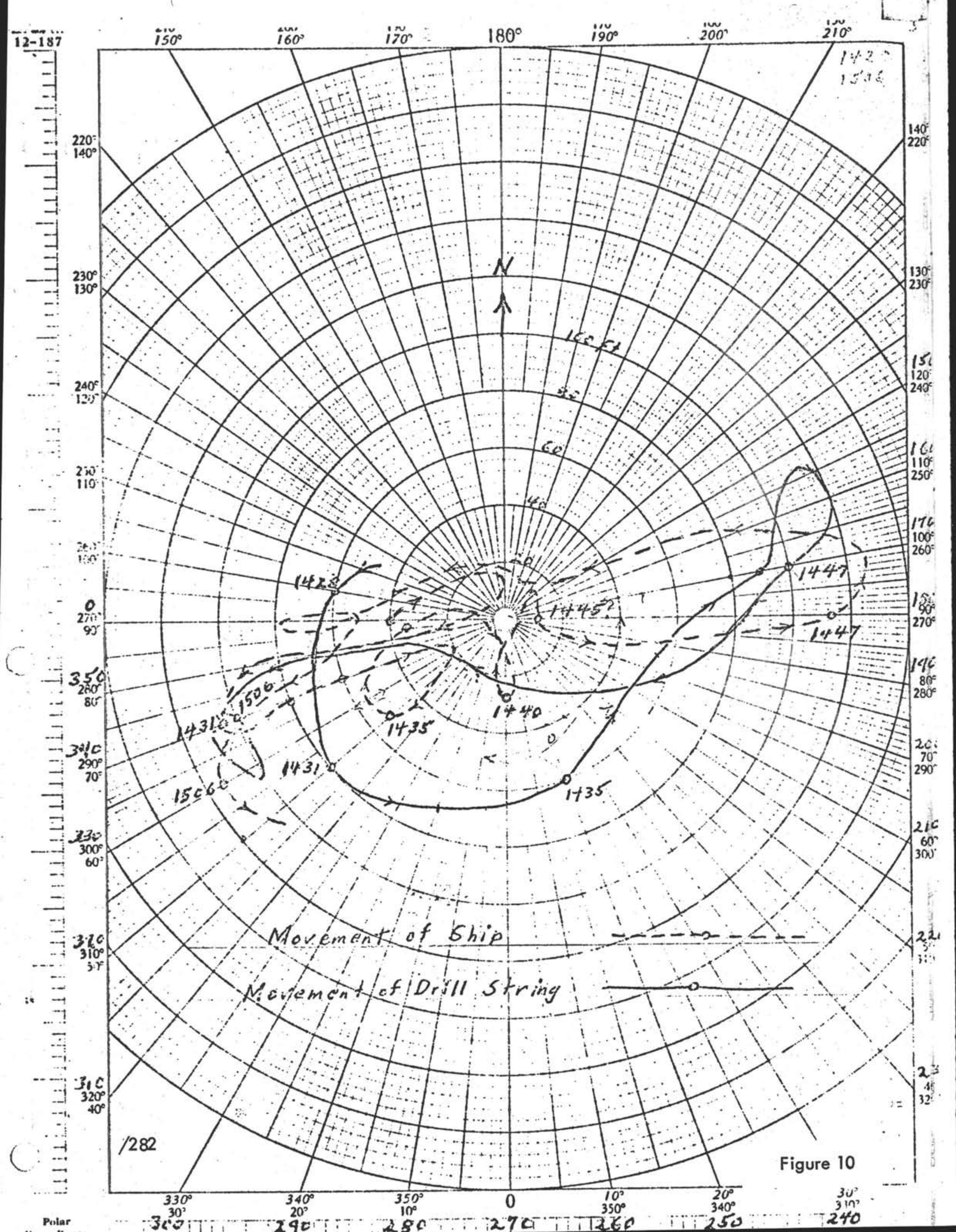

1400
1600
100 ft.
1430
1500
1520
1410 OVER TARGET
N
1400
1600
1420
1530
1440
1450

Figure 9



12-187
N
Movement of Ship
Movement of Drill String
1428
1431
1435
1440
1445
1447
1506
/282

Figure 10

As others have suggested, this study confirms that the automatic positioning system should have capability to perform shorter than 100 foot offsets. It might then be possible to obtain re-entry based on calculated response of the drill string end. Arranging to have the end "settle" over the target at 0 or very low velocity should enhance the probability of a successful drop into the target.

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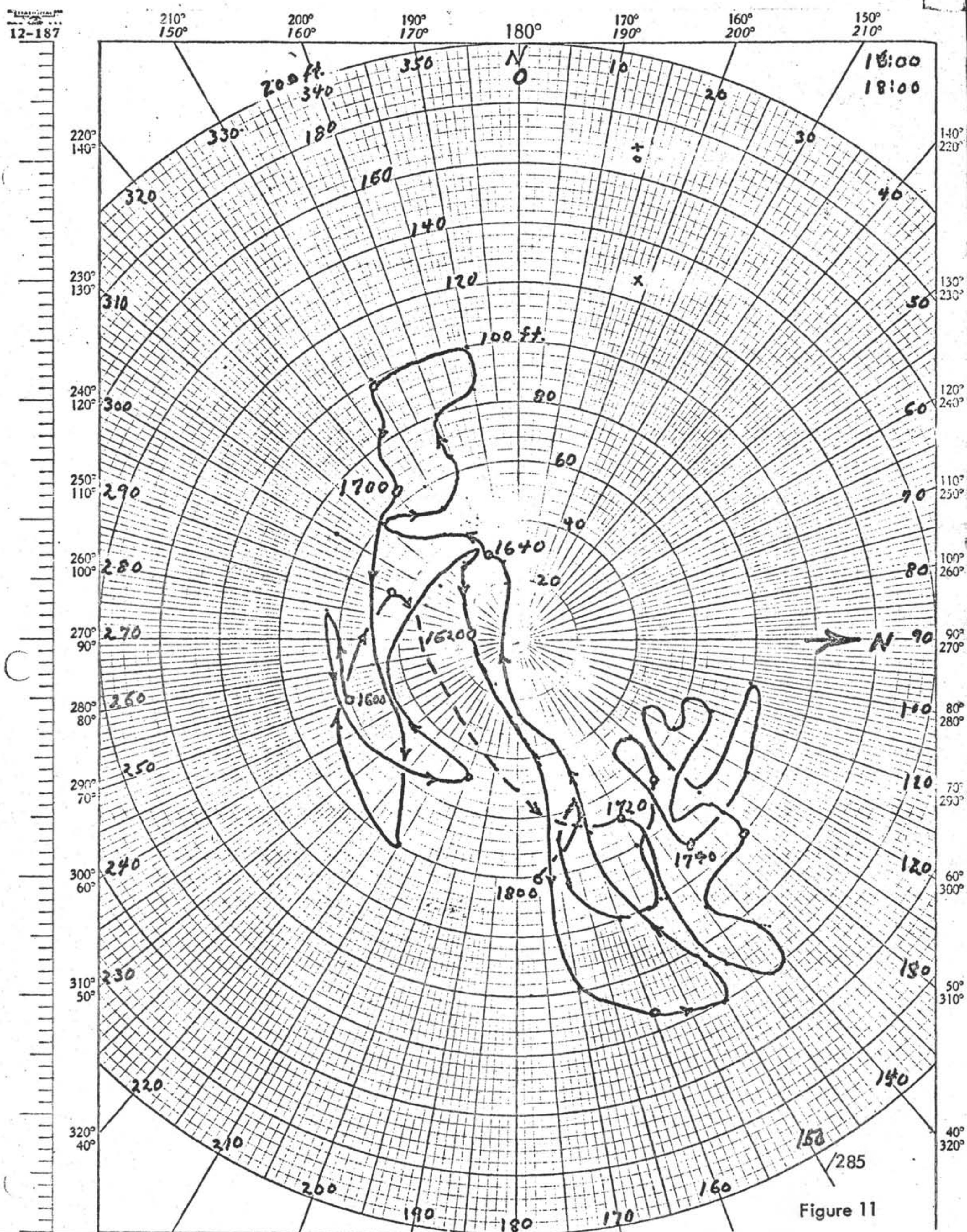
12-187
180°
N
0
200 ft.
100 ft.
18:00
18:00
1700
1640
1620
1600
1720
1740
1800
N
285

Figure 11

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