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MSSA04-SYS-R003

REV 0

30 MARCH 1984

MARINE SEISMIC SYSTEM (MSS)
ADVANCED OPERATIONS EVALUATION, PHASE V MSS DEPLOYMENT

30 MARCH 1984

PREPARED FOR

NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY
NSTL STATION
BAY ST. LOUIS, MS 39529

N00014-83-C-0034

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: MSSA04-SYS-R003
2. GOVT ACCESSION NO.: AD-A142 243
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): Marine Seismic System (MSS) Advanced Operations Evaluation, Phase V MSS Deployment
5. TYPE OF REPORT & PERIOD COVERED: Technical Report, Mar.84
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): Robert L. Wallerstedt
8. CONTRACT OR GRANT NUMBER(s): N00014-83-C-0034
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Global Marine Development Inc., 2302 Martin Street, Irvine, CA 92715
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: ARPA Order 4152
11. CONTROLLING OFFICE NAME AND ADDRESS: Advanced Research Projects Agency, 1400 Wilson Boulevard, Arlington, VA 22209
12. REPORT DATE: March 30, 1984
13. NUMBER OF PAGES: Approx. 45 plus Appendices
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Naval Ocean Research and Development Agency, NSTL Station, MS 39529
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report): ~~See Reverse~~

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):
18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number):
Marine Seismic System (MSS)
Deep Ocean Seismic Instrumentation Deployment
Borehold Instrumentation Package (BIP)
20. ABSTRACT (Continue on reverse side if necessary and identify by block number):
This report provides information concerning the potential application of the MSS seismic and deployment technology to future DOD/USN operations. Technical considerations are also given to: reentry borehole emplacement; borehole package deployment; potential single development site tests; multiple operational stations, and alternate drillships.

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SECTION 1.0 - SUMMARY

This report provides information and background concerning the potential application of the Marine Seismic System's (MSS) seismic and deployment technology to future Department of Defense/U.S. Navy operations. The MSS '81, '82 and '83 operations have verified the capability to 1) effectively obtain short and medium period seismic data from within a deep ocean emplaced borehole and 2) deploy large sensitive instrument packages into emplaced reentry boreholes at water depths of 20,000 feet. Technical considerations involved with the reentry borehole emplacement and borehole package deployment are discussed. Potential single development site tests and multiple operational stations considerations are also reviewed. ROM costs for these possible projected test demonstrations are provided.

SECTION 2.0 - CONCLUSIONS

Based upon the technology developed jointly by the National Science Foundation's (NSF) Deep Sea Drilling Program (DSDP) and the Defense Advanced Research Projects Agency's (DARPA) MSS Program, a variety of deepwater borehole large instrument applications could now be scheduled. An 8-inch, 3,300 pound seismometer has been successfully deployed into a borehole at a depth of 19,000 feet. Potentially, instrument packages measuring up to 24 inches in diameter and weighing 10,000 to 20,000 pounds can now be deployed into encased reentry boreholes. These reentry borehole can be drilled and emplaced 1,000 to 2,000 feet below the seabed in water depths of 20,000 feet. The borehole instrument packages would be initially deployed utilizing a drillstring reentry technique. Associated seabed positioned or subsea buoy type recording packages can also be deployed at these water depths. Both borehole and recording instrument packages are also recoverable, if desired.

Future programs could also consider deployment of new instruments into existing boreholes without the use of a dynamic positioned drillship. This would require development of either a cable guideline or cable guided "fly-in" capability. The basic technology for either approach is available but has not been specifically demonstrated for deepwater applications. Development would take 1 to 2 years for the cable guideline and 2 to 3 years for a cable guided fly-in deployment technique.

A shallow water test deployment of an existing 8 inch diameter seismometer at depths of about 2,000 feet would require approximately 20 at-sea days at a cost of approximately $2 million. A similar deepwater test deployment at depths of about 15,000 feet would require approximately 30 at-sea days to accomplish and would cost approximately $6 million. These estimates exclude any specialized instrumentation development, data evaluation or management costs.

Installation of an 8 to 12 station, multiple deepwater site, operational deployment program could be accomplished within a year. Such an undertaking would be an extensive program employing sophisticated communications elements. Typical costs associated with only the deployment would be about $37 million including ship charter operations, deployment equipment, planning and engineering.

SECTION 3.0 - PROGRAM OVERVIEW[1/]

The MSS Program focused on developing a sensitive seismic Borehole Instrumentation Package (BIP) plus the associated support equipment which can be deployed into the basalt layer of the ocean floor in water depths to 20,000 feet. Deep boreholes were drilled and cased through the sediment and into the basalt layer by utilizing standard deep ocean drilling techniques and equipment which have been developed during the NSF-sponsored DSDP. The dynamically positioned drillship Glomar Challenger, operated by Global Marine Drilling Company (GMDC), was the vessel utilized for the program. Deployment was accomplished by lowering to the ocean floor a BIP mounted within a reentry sub at the lower end of a drillstring. The reentry sub incorporated a sonar controlled reentry tool which guided the BIP into a reentry cone which had previously been installed over the borehole as shown in Figure 3-1. The standard DSDP procedures were modified to accommodate the MSS configurations.

The major operational elements of the overall MSS Deployment Program are summarized as follows:

- MSS '81

  The MSS equipment was mobilized in San Juan, Puerto Rico, and was installed on the Glomar Challenger, which departed for the test site on 14 March 1981. The reentry site was located in the mid-Atlantic at a depth of 14,712 feet. Within 75 hours, the Glomar Challenger emplanted and recovered a BIP using an existing DSDP borehole. The at-sea-test demonstration was successfully completed on 30 March 1981. Feasibility of the BIP deployment concept (using the drillstring reentry technique) and of the basic capabilities of the seismic sensor when deployed in the deep ocean borehole was successfully demonstrated.
- MSS '82

  In August-September 1982, the Glomar Challenger crew attempted to drill a reentry borehole and to emplace a Configuration I BIP at a Northwest Pacific site. A 30-day special DARPA operation leg

1/ "Phase V Marine Seismic System (MSS) Deployment, Final Report," Report No. MSSA04-SYS-R001, Rev. 0, December 1983.

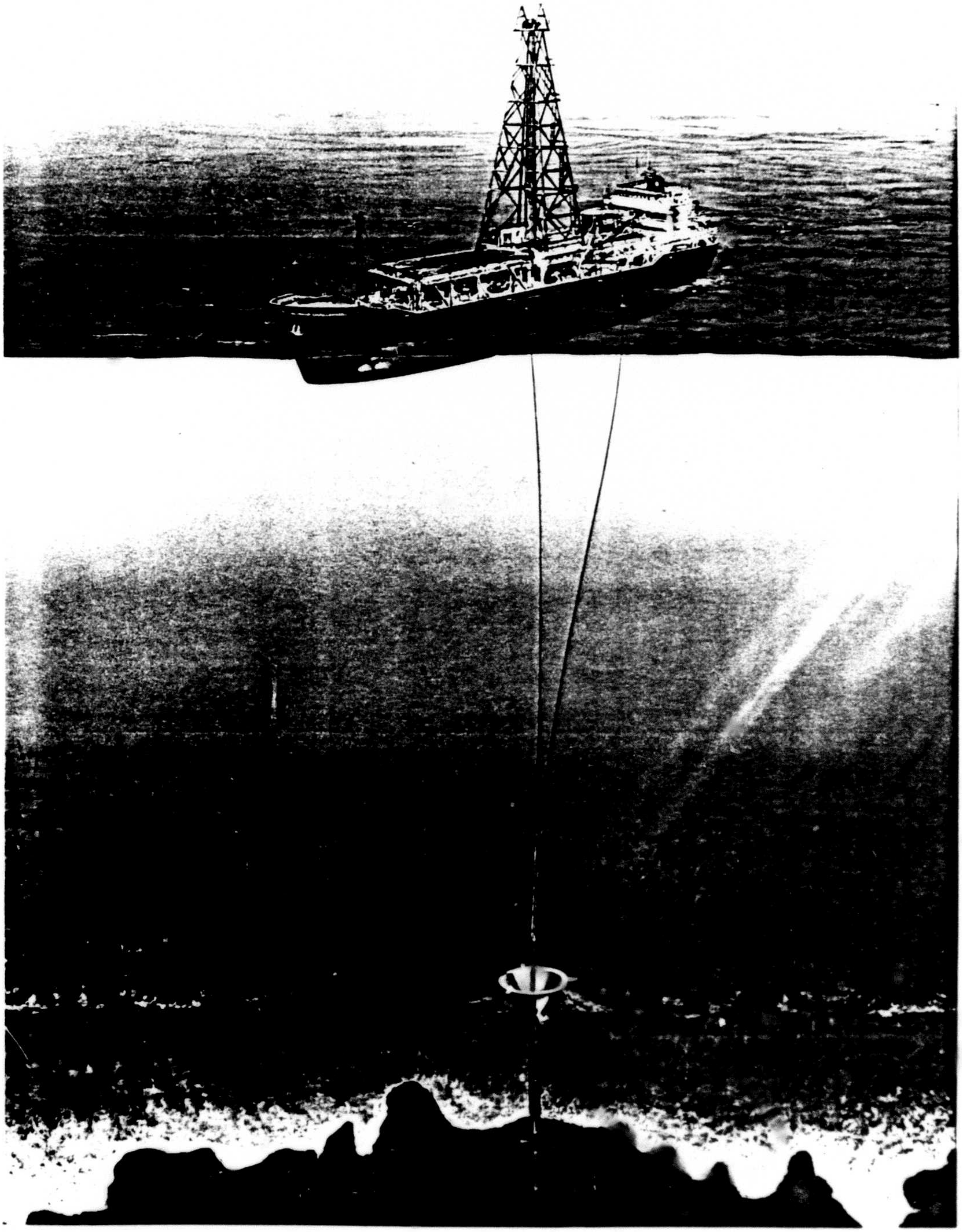


FIGURE 3-1 MARINE SEISMIC DEPLOYMENT SYSTEM

had been scheduled to deploy the BIP and the associated Installation, Recovery and Reinstallation (IRR) mooring equipment in 18,100 feet water depth. Due to adverse weather conditions and equipment malfunctions, drilling of the reentry borehole could not be successfully accomplished within the time period allotted. Deployment of a smaller, through-the-pipe seismometer with its 60-day recording package was achieved.

- MSS '83

  The MSS '83 operation was conducted at a new DARPA site in the South Pacific in January 1983. The Glomar Challenger transited to the site and emplanted a cased reentry borehole in approximately 18,500 feet of water. The BIP was deployed, and 5 days of seismic testing was accomplished. Subsequently, the Bottom Processing Package (BPP) and its associated IRR mooring system were then successfully deployed. During March 1983, the RV Melville returned to the DARPA site and successfully recovered the BPP and redeployed a dummy BPP.

Subsequent evaluations of the MSS data have indicated that 1) the noise level in the boreholes is lower, by approximately 30 dB, than corresponding Ocean Bottom Seismometer (OBS) readings, and 2) the shock levels for drillstring reentry were considerably below the defined 10G requirements. A broad band of seismic signals, down to 0.1 cps, can be accurately recorded. The seismometers were also able to detect ship noises over a very extended range.

Based upon this information, sensitive borehole instruments up to probably 24 inches in diameter can be confidently deployed and recovered from deepwater emplaced boreholes. The borehole sites can be potentially emplaced in most ocean areas, but particular attention must be directed to specific weather, current and seabed geologic conditions. The associated deepwater recording packages and mooring systems can also be installed, as required.

There are of course many factors to be specifically considered. The following potential problems need to be fully evaluated for each site:

- Drill String Failure
- Drill Out of Difficult Formations

- Drill String Dynamics
- Cable Overtension
- Cable Entanglement
- Reentry Shock Loadings
- Reentry Positioning
- Package Release

SECTION 4.0 - DEEP OCEAN SEISMOMETERS

4.1 GENERAL

A variety of seismometers could be potentially applied to deep ocean borehole applications. However, for this study, data is only presented for the most applicable units based upon seismic capabilities, configuration limitations, associated software and experience.

4.2 GEOTECH-TELEDYNE SEISMOMETERS

A range of potential seismometers produced by Geotech-Teledyne can be considered for any future MSS type application. Table 4.1 summarizes the sensors which all have been under development and/or are in use for various U.S. seismic programs.

The seismic equipment consists primarily of a Borehole Instrumentation Package, (BIP), and Shipboard Test Console (STC), Electromechanical (EM) cable and a Bottom Processor Package (BPP). Figure 4-1 is a simplified block diagram showing only the BIP, EM cable, and STC.

The primary function is to collect seismic data in an ocean bottom borehole. Thus, the BIP consists of a primary set of seismic sensors. Secondary sensors to aid in the installation, operation and maintenance of the BIP include accelerometers to record shock levels encountered during shipboard handling and deployment, and temperature, pressure, and state of health sensors to aid in operational analysis and maintenance. Sensor data is preconditioned and digitized by the appropriate analog to digital converter, all data merged into a serial digital data stream, frequency shift key (FSK) encoded and transmitted over the EM cable to the STC. The STC demultiplexes the data and displays via analog strip chart recorders, light emitting diode (LED) status panels and/or cathode ray tube (CRT) displays under operator control.

TABLE 4.1

POTENTIAL GEOTECH SEISMOMETERS PACKAGE CONFIGURATIONS

	531000/36000	531000/44000	44000	MULTIPLE S-750 VERTICALS	MULTIPLE S-500 VERTICALS
Diameter	8 in.	8 in.	4.25 in.	4.25 in.	3.75 in.
Length	33 ft	33 ft	2-12 ft packages separated by up to 1,000 ft Max.	1-12 ft, 1-6 ft, or 1-8 ft 1,000 ft suspension Max. 1-6 ft sensor separated by up to 1,000 ft Max.	2 packages 1-14 ft signal processor
Number of Sensors	Up to 6 3 primary 3 secondary or 3 primary 2 vertical backup	Up to 6 3 primary 3 secondary or 3 primary 2 vertical backup	3 primary only	Up to 6 verticals only	Up to 6 verticals
Response	Primary 1×10^6 per M/sec^2 Secondary 200V per M/sec^2	Primary 2×10^4V per M/sec^2 Secondary 200V per M/sec^2	2×10^4V per M/sec^2	200V per M/sec^2 typical acceleration 3×10^4V per M/sec typical velocity	500 V/G typical acceleration 450V per M/sec typical velocity
Bandwidth	Primary 0 to 20 Hz Secondary .01 Hz to 100 Hz	Primary 0 to 25 Hz Secondary .01 Hz to 100 Hz	0 to 25 Hz	.01 Hz to 100 Hz	1.0 Hz to 160 Hz
Comments	Built in backup sensors. Single deployment package. Technology and hardware exist. Reentry of hole necessary.		2-12 ft packages 1,000 ft separation max Deployed through drill string	Vertical only Single or dual packages Deployed through drill string	Vertical only Disposable sensor package Through the drill string deployment

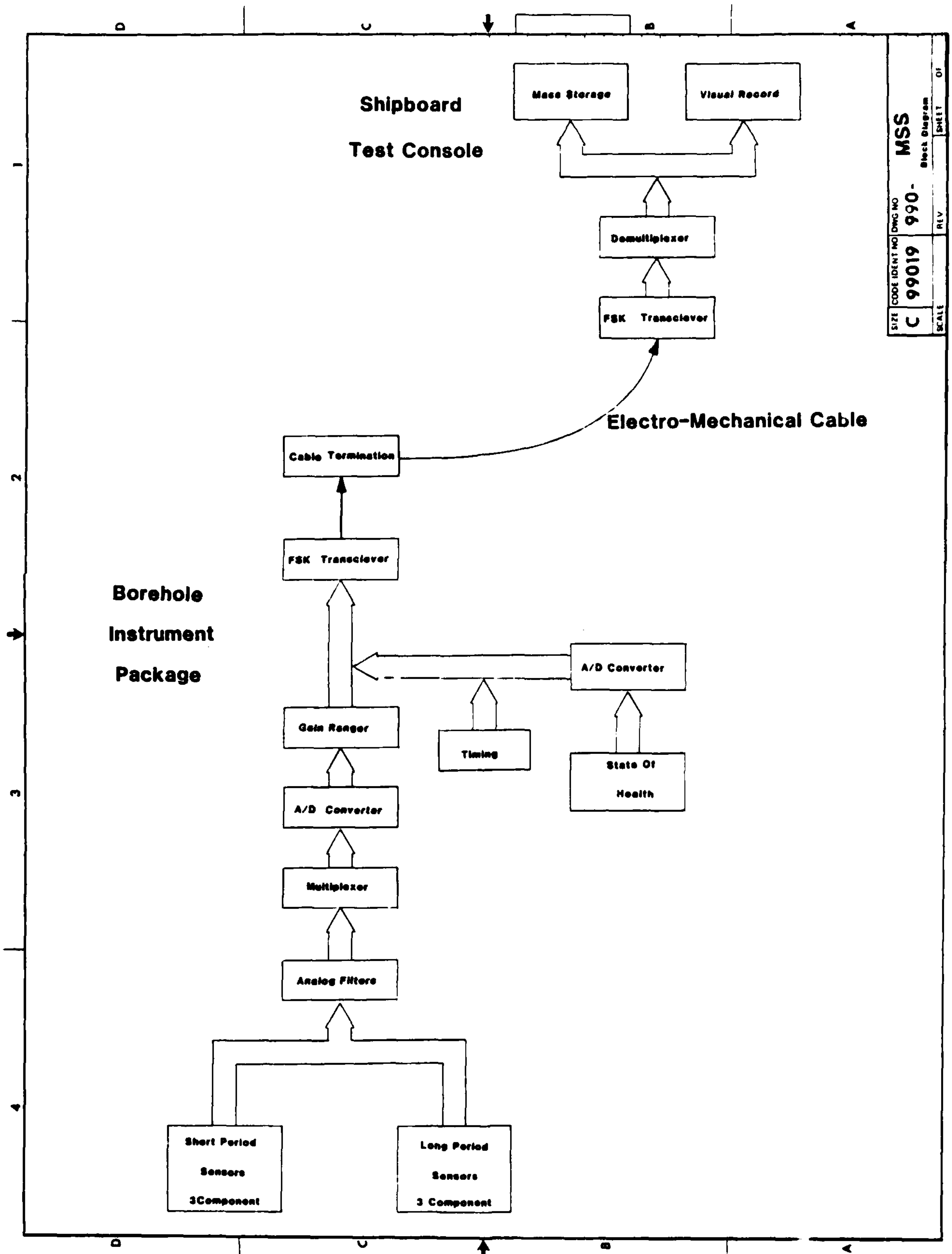


FIGURE 4-1 MSS SEISMOMETER SCHEMATIC

In parallel with the real time display, all data is recorded via mass storage devices (FM magnetic tape). The BPP (not shown in the diagram) provides long term data collection and storage in an unattended operating mode. The BPP is connected to the EM cable in place of the STC for final deployment. The same basic pressure vessel packages could be provided for the 531000/44000 unit.

The 44000 sensor could also be packaged within an approximate 4.25 OD pressure vessel configuration. Two separate 12 foot long packages would be involved.

4.3 OCEAN SUBBOTTOM SEISMOMETER[1/]

The Ocean Subbottom Seismometer (OSS) system developed by the Hawaii Institute of Geophysics (HIG) consists of a borehole package, recording package and recovery system. The borehole package is a 3-7/8 inches diameter by 8.2 foot length pressurized container enclosing a 3 geophone seismometer, auxiliary sensors, signal electronics, multiplex, A/D converter, telemetry and power conditioning electronics. The present configuration has three short period geophones, two bubble tilt meters, plus temperature sensors which are multiplexed into 16 data channels. Three 4.5 Hz Geopack geophones are presently used, but other configurations are possible. The recording package consists of two aluminum tubes, each 6 feet long. One tube contains D cell batteries to supply approximate 60 days of power, and the other tube contains electronics including 5 cassette tape recorders. The recovery subsystem consists of a polypropylene rope attached to a releasable anchor.

The system reportedly has a ± 0.6 micro V to 2.5 V capability, covering a dynamic range of 138 dB. A variable AGC system is used to accommodate the 40 dB dynamic range of analog tape recorders. Four tracks of data can be recorded.

1/ Isolated Sensor Ocean Bottom Seismometer, D. Byrne, et al., Marine Geophysical Researcher, 5 (1983) 437-449; and the Ocean Subbottom Seaismometer, F. Duennebier and G Blackenton, CRC Handbook of Geophysical Exploration at Sea.

SECTION 5.0 - DEPLOYMENT SYSTEM CAPABILITIES

5.1 INTRODUCTION

An alternative to (the through the drillstring) instrument deployment has been recently developed. The original approach involves drilling an uncased borehole into the sediment/basalt formation and then, without recovery, deploying the seismometer with its attached EM cable through the drillstring's internal bore. This requires subsequent stripping out the EM cable from the drillstring before deployment of a recording capability. In this approach, the seismometer package is limited by the pipe ID.

The recently developed approach requires drilling out and emplacing an encased borehole followed by deployment of the seismometer and its attached EM cable carried down at the bottom end of the drillstring. Several successive reentries are generally required. Upon release of the seismometer and EM cable, the recording package can then be installed. Table 5.1 summarizes the general considerations of both concepts.

5.2 DRILLSTRING CHARACTERISTICS

Within the foreseeable near future, only a small range of drillstring configurations can be practically considered for deep ocean (20,000 feet) operations. The size range is between 5 to 6-5/8 inches (nominal) based upon the available American Petroleum Institute (API) drill pipe sections. Smaller drillpipe sections cannot support the necessary weight or drilling functions. Larger sections would need to be specially made up from casing sections, would require new joints, and probably would require extensive shipboard handling capabilities.

A variety of considerations are involved with selection of a specific drillstring configuration. The drilling is accomplished by the

TABLE 5.1

DEPLOYMENT CONCEPT CONSIDERATIONS

THROUGH THE DRILLSTRING: • Package diameter constrained by drillstring ID • Only one drillstring trip required • Minimal extra handling equipment • EM cable must be stripped out of drillstring • Recovery of instruments may not be possible • Possible limit to penetration depth in basalt
DRILLSTRING REENTRY: • Multiple drillstring trips and reentries required • No practical package limits up to about 24 inches dia • Special subsea and shipboard handling equipment • Recovery of borehole package possible • Possible redeployment of new instrument into borehole • Cased or uncased borehole can be provided

ocean drilling and emplacement applications, the system's resonance and damping characteristics become of critical importance under even moderate weather conditions. Table 5.2 defines basic capabilities of four different drillstrings at three total depths.

Most existing DP drillships can accommodate 4, 5 or 5-1/2 inch pipe strings. A 6-5/8 inch drillstring will most probably require some modification to the drillship's pipe racker, derrick pipe handling, and power drilling subsystems. Basically, the drillships will all have sufficient derrick load capabilities.

The previous MSS deployment operations have indicated the need for drillstring heave compensation for operations at the deepest water depth. Where weather conditions are severe or allotted time is short, heave compensations of some type are definitely required. The heave compensation can be active or passive, with an active system being more desirable.

Of particular importance is the need for accurate pipe string load measurements. The equipment for such measurements must be able to record both static and dynamic load indication. Quite often it can be expected that operations will be near the limits of the pipe, particularly when all combined loadings are taken into account. Such data should be correlated with computerized load evaluation taking into account both axial and lateral dynamic effects.

5.3 REENTRY BOREHOLES

Over the past 13 years the DSDP has developed a remarkably successful reentry borehole technology. This technology has been demonstrated in over 50 sites under varying depths and geologic conditions. The basic reentry borehole guided cone assembly is shown in Figure 5-1.

This particular assembly is designed to provide a 16 inch surface conductor casing plus an interface with the 11-3/4 inch casing. The reentry cone and surface conductor are basically washed down into the top seabed sediment. Subsequently, the lower portions of the

TABLE 5.2

MSS DRILL STRING COMPARISON

DRILL STRING	4 INCH	5 INCH	5-1/2 INCH	6-5/8 INCH
ID (inches)	3.34	4.25**	4.50**	5.00
Joint OD (inches)	4.5	7.5	7.5	8
I ($inch^4$)	6.5	14.3	21.6	32.4
Dry Wt Per Ft (H/Ft)	15.6	19.50	24.7	25.2
*DS Load Capacity (Lbs)	514,000	712,000	895,000	881,000
*DS Torque Capacity (Ft/Lbs)	36,320	64,210	88,240	110,090
Drill Power Capacity (120 RPM) Ft/Lbs	86	151	192	240
Mud Velocity (500 GPM) Ft/Sec	18.5	11.3	11.3	8.1
BHA Weight (Lbs)	40,000	50,000	60,000	90,000
Topside DS Weight (Lbs)	25,000	30,000	35,000	40,000
TYPICAL HOOK LOADS				
2,000 Feet (Lbs)	98,000	115,000	135,000	175,000
10,000 Feet (Lbs)	208,000	250,000	305,000	350,000
20,000 Feet (Lbs)	341,000	425,000	525,000	575,000

* High strength S-135 drillstring
** Special tool joint

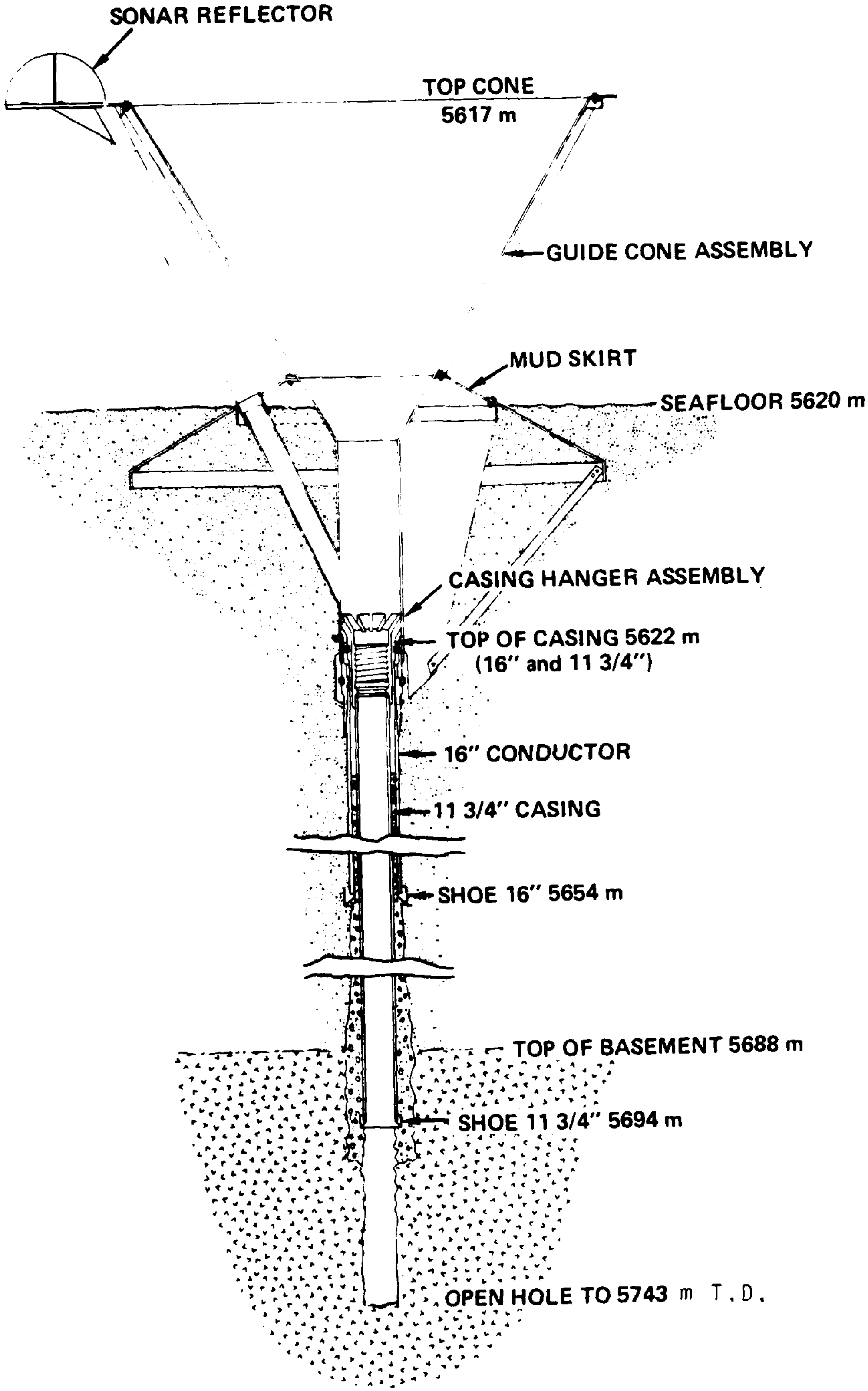


FIGURE 5-1 TYPICAL REENTRY BOREHOLE GUIDED CONE ASSEMBLY

borehole are successively drilled out and encased. Typically, the solid basalt regions are not cased. These latter operations usually employ drillstring trips and reentries.

This depicted borehole arrangement can accommodate an instrument with a diameter up to 9 inches. Greater diameter packages would require larger entry borehole diameters plus associated casing strings. A 24 inch package would probably need an approximate 36 inch surface conductor.

Drilling requirements would obviously be increased. A large "Big Hole" land drilling technology exists with capabilities up to 96 inch diameters and can be transferred with some restrictions to ocean riserless drilling.

5.4 SUBSEA DEPLOYMENT EQUIPMENT

The external drillstring reentry deployment requires the use of a comprehensive Bottom Hole Assembly (BHA) which performs the following functions:

- Supports the seismometer or instrument package during initial deployment to the seabed
- Guides the reentry sonar tool during reentry
- Guides the drillstring into the reentry cone using a stinger
- Centers over and releases the seismometer into the borehole
- Guides the EM cable during final lowering
- Interconnects with the drillstring through appropriate bumper subs and transition elements

The BHA measures approximately 150 feet in length and can weigh 50,000 to 75,000 pounds. The custom lower reentry subassembly portion must be constructed to support and release instrument packages and to interface with the borehole reentry cone. The upper elements are generally standardized oil field components.

5.5 SHIPBOARD HANDLING EQUIPMENT

The deployment of sensitive instruments does not really require extensive equipment. The most expensive single element is the EM winch. This winch must be capable of handling 20,000 to 40,000 feet of EM cable. Along with the EM cable there is the additional handling of the specialized mooring line, if required.

For the external drillstring deployment, an A-Frame, an associated heave compensator, idler wheel, cable tension and cable payment measurement devices are required. All the above equipment can also be designed to handle the deployment of the subsea recording package plus associated mooring equipment. Figures 5-2 and 5-3 show a portion of a typical installation on the Glomar Challenger.

A through the pipe deployment requires an additional cable stripping equipment which is used to strip off the drillpipe from around the EM cable during recovery of the drillstring.

5.6 RECOVERY/REDEPLOYMENT CONSIDERATIONS[2/]

The reentry borehole concept affords the advantage of recovery and subsequent redeployment of another instrument package into the borehole. This capability could potentially be accomplished without the use of a dynamic positioned drillship. What would be required is the development of either a guided line reentry system or a fly-in reentry system. The deep ocean guided cable capability could possibly be available within 1 to 2 years. Development of the fly-in capability would probably take 2 to 3 years.

The guided cable reentry system is certainly the easiest to develop but has certain failure modes associated with entanglement which may limit its practical utility. The fly-in approach is in the long run more promising by having fewer operational constraints. Both approaches require accurate bottom positioning acoustic equipment.

2/ Marine Seismic System (MSS) Deployment Phase III," Report No. MSSA01-001, Rev 0, March, 1982.

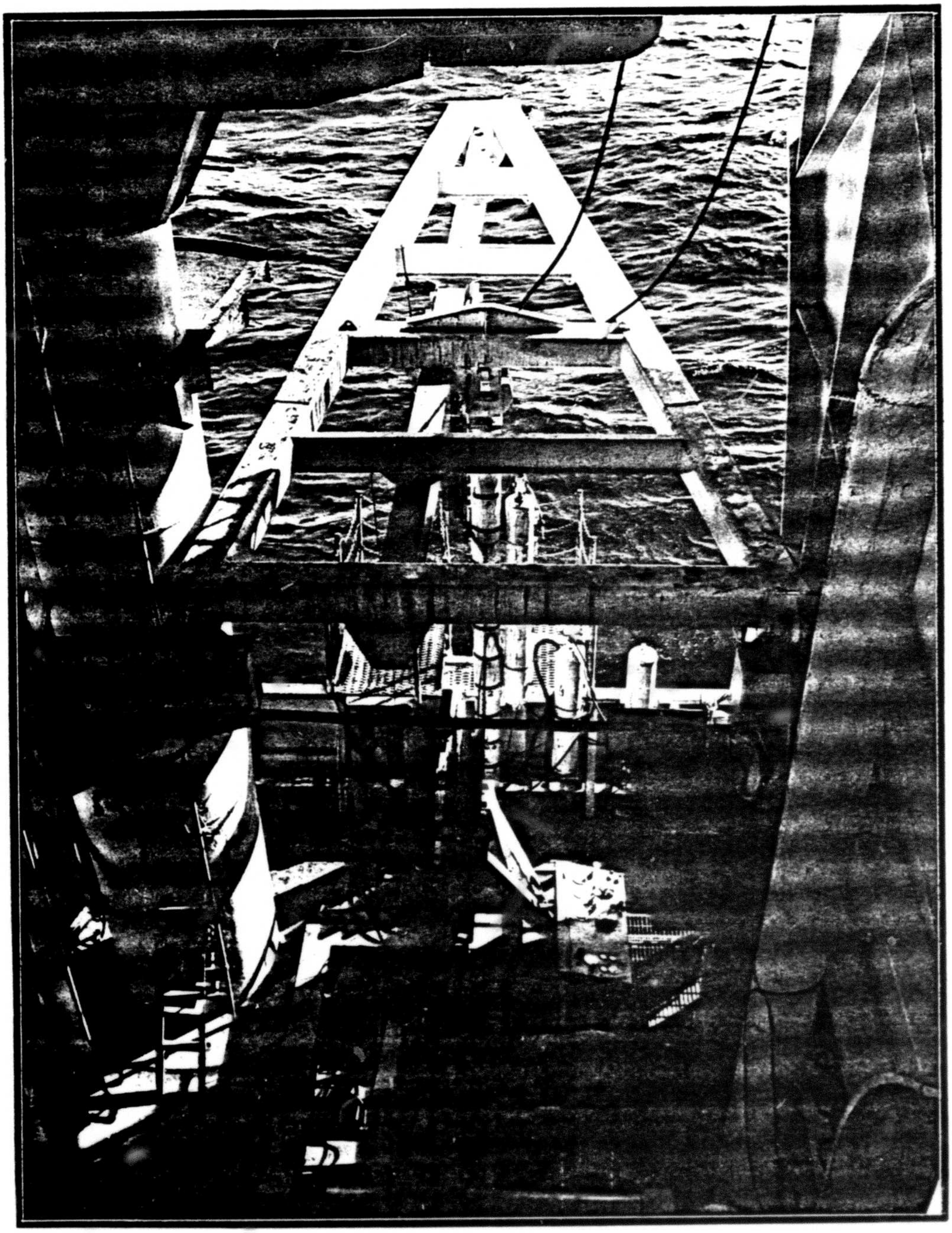


FIGURE 5-2 A-FRAME

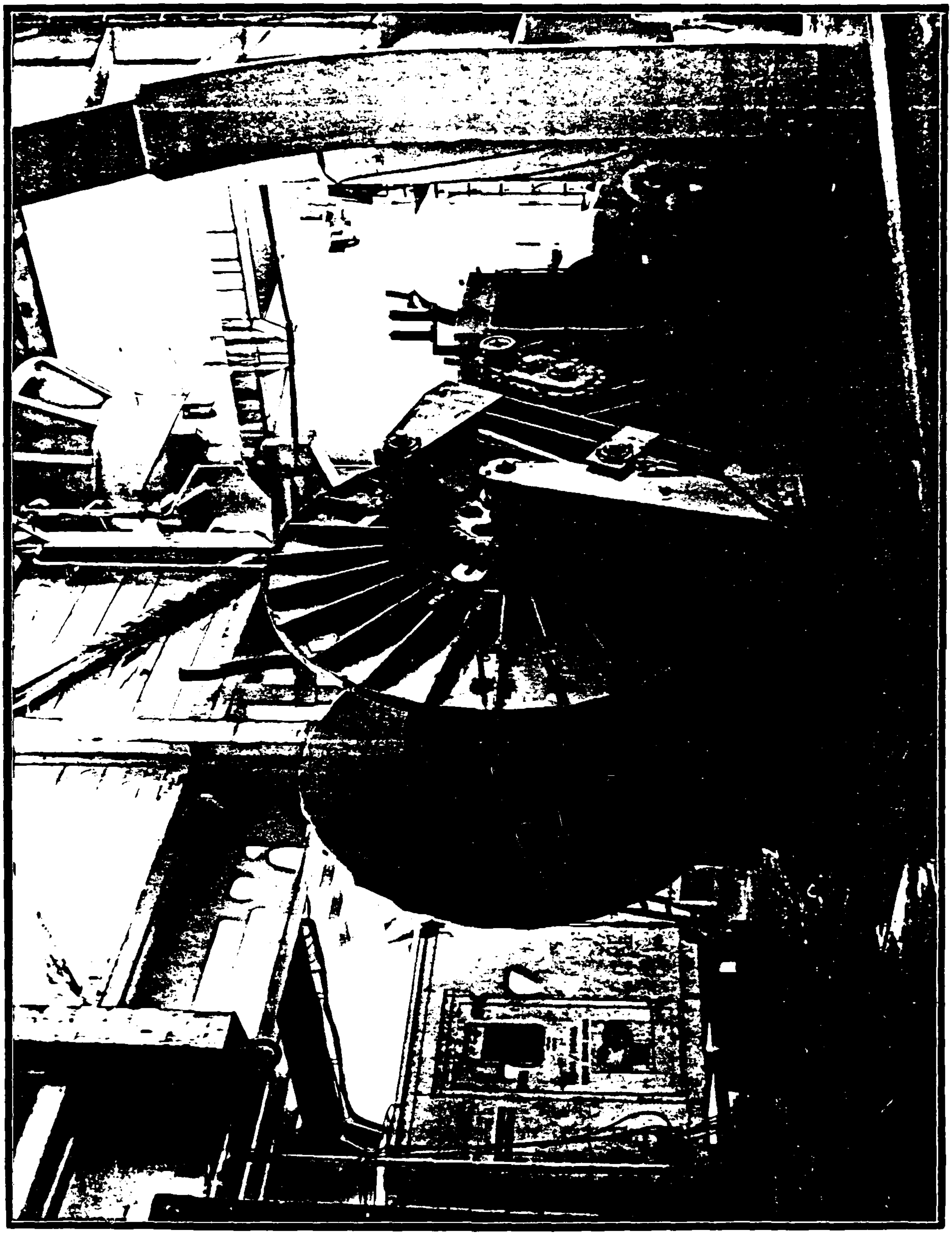


FIGURE 5-3 LH WINCH

SECTION 6.0 - DEPLOYMENT DRILLSHIPS

6.1 GLOMAR CHALLENGER

As noted earlier, all of the deep ocean MSS technology development was achieved on the DSDP vessel Glomar Challenger. Figure 6-1 depicts the Glomar Challenger in service. Although relatively small in size compared to newer dynamic positioned drillships, it conducted very successful operations throughout the world for over 14 years. The major attribute of the Glomar Challenger as compared to other vessels is its direct experience in deep ocean riserless drilling/coring and reentry borehole operations. The Glomar Challenger was removed from active service in November 1983, but today still retains the basic capability to perform the deep ocean deployments desired in this report.

In early 1984 attempts were made to set-up a special deep ocean coring program for the USGS and to utilize the Glomar Challenger. The ship was offered to the U.S. Government by Global Marine, Inc. to be used for oil reservoir surveys and specialized DOD type operations. Apparently, this USGS program will not be established.

The probable outcome for the Glomar Challenger is major conversion for another use or scrappage.

6.2 ALTERNATE DRILLSHIPS

A variety of alternate dynamic positioned drillships could be considered for future MSS type operations. Both drillships and semisubmersibles could be potentially utilized for the type of deployment operations herein considered. Tables 6.1 and 6.2 are a partial list of U.S. owned and foreign built vessels to be considered.

In fact, almost all the vessels listed have more extensive equipment and basic capabilities than the Glomar Challenger. Refer to

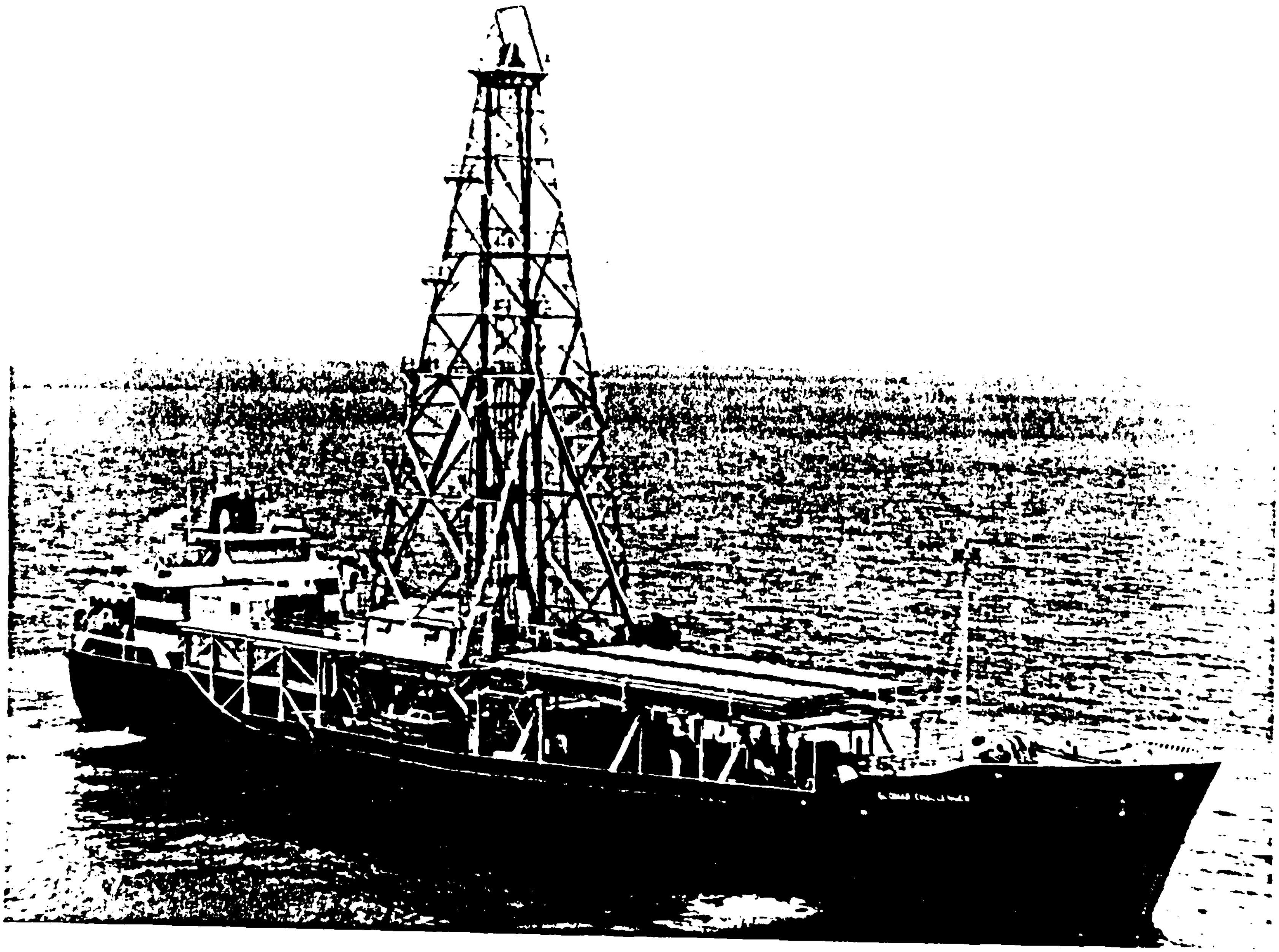


FIGURE 6-1 GLOMAR CHALLENGER

TABLE 6.1

U.S. FLAG DP DRILLING SHIP

VESSEL NAME	OWNER	DIMENSIONS (FEET)	DP SYSTEM	PROPULSION/THRUSTER (HP)	WATER DEPTH/ DRILLING DEPTH (FEET)	DERRICK CAPACITY
SEDCO 472	SEDCO	470 x 70 x 32	HONEYWELL ASK	9,000/9,600	6,000/25,000	1,000,000 LBS
GLOMAR PACIFIC	GLOBAL MARINE	452 x 72 x 35	DELCO	9,600/8,375	2,000/25,000	2,000/25,000 LBS
GLOMAR ATLANTIC	GLOBAL MARINE	452 x 72 x 35	DELCO	9,600/8,375	2,000/25,000	2,000/25,000 LBS
GLOMAR CHALLENGER	GLOBAL MARINE	400 x 65 x 26.75	DELCO	4,500/3,400	25,000/25,000	1,000,000 LBS

TABLE 6.2

FOREIGN BUILT-U.S. OWNED DP DRILLING SHIP OR SEMISUBMERSIBLE

VESSEL NAME	OWNER	DIMENSIONS (FEET)	DP SYSTEM	PROPULSION/THRUSTER (HP)	WATER DEPTH/ DRILLING DEPTH (FEET)	DERRICK CAPACITY
SEDCO 445	SEDCO	445 x 70 x 32	HONEYWELL ASK	9,000/9,000	3,000/20,000	1,000,000
SEDCO/BP471	OVERSEAS DRILLING COMPANY	470 x 70 x 32	HONEYWELL	9,000/9,600	6,000/25,000	1,000,000
DISCOVERER SEVEN SEAS	SONAT OFFSHORE DRILLING, INC.	534 x 80 x 32	HONEYWELL ASK	16,000/15,000	16,000/18,000	1,300,000
DISCOVERER 534	SONAT OFFSHORE DRILLING, INC.	534 x 80 x 32	HONEYWELL ASK	16,000/15,000	3,000/20,000	
BEN OCEAN LANCER	ODECO/BP	450 x 77 x 41	HONEYWELL ASK	8,750	3,000/20,000	-
SEDCO 709 (SEMI)	MARINE DRILLING	295 x 245 x 113	HONEYWELL ASK	20,000	6,000/25,000	1,100,000
SEDCO 710 (SEMI)	SEDPEX INC.	295 x 249	-	24,000	5,000/25,000	-
HENRY GOODRICH (SEMI)	SUNAT	316 x 246	-	-	10,000/30,000	-
(SEMI)	ODECO/BNOC	390 x 231	-	-	1,500/25,000	1,400,000

Appendix A for certain important data of these vessels. The modifications that would be required for a MSS type deployment are really quite minimal.

The charter vessel cost of the listed drillships will vary considerably depending on ship age, oil field economic conditions, season, length of charter, potential site hazards, etc. A typical projected short-term charter rate for an older vessel could be between $30,000 to $60,000 per day, while rates for the newer vessels could be in the $70,000 to $100,000 per day range. Additional considerations are fuel, supplies, mobilization, field office support and demobilization cost factors.

SECTION 7.0 - PROJECTED DEVELOPMENT TESTS

7.1 GENERAL

As noted earlier, several new applications of MSS technology are being considered. It is probable that single site development testing would be initially required in order to verify the sensor specific capabilities and to establish associated data hardware and software requirements. Deployment of instruments measuring up to 8 inches in diameter have been demonstrated. Borehole instruments up to 24-inch diameters can be potentially considered. Both shallow depths (to 2,000 feet) and deepwater sites may be programmed. The deepwater test can be a more expensive undertaking (by at least a factor of 2 to 3).

7.2 SHALLOW WATER TEST

A shallow water test of a borehole emplaced seismic system is currently under consideration by the U.S. Navy. This would be a specific test to correlate ASW parameters. Detailed seismic characteristics and instrumentation requirements have not yet been defined. A shallow water test can be easily accomplished at a number of U.S. offshore sites. A dynamically positioned drillship, although desirable, is not required for water depths approaching 2,000 feet. For shallow depths, however, most drillships carry adequate anchoring/mooring gear in order to maintain position over the site for short good weather periods. A high strength drill string would not be mandatory. The site should be at least 10 miles offshore to reduce shore and surf noise.

Either a reentry borehole or a through the pipe deployment can be considered, but a permanent test station site would require a reentry encased borehole. As noted in Section 4.0, there are many involved considerations with either approach, and the decision rests upon the projected use of the site and the size of instruments to be used.

A major consideration for even a relatively inexpensive test is the data recording capability. The basic requirements are established by the data format, range, sensitivity level, number of tracks and time period objectives. Fortunately, many recording packages which can be adapted to this type of application are available. The basic problem is deciding where to install the recording package, particularly for extended periods of time. Table 7.1 outlines some of the options. All of these options will probably fall within the same general cost range, considering all factors, except for the possible hard line tieup with a nearby (up to 5 miles away) existing platform or structure. Although each recording option has its specific concern, all can be quite readily accomplished using basically only the deployment vessel.

There are four offshore towers on the edge of the continental shelf which could be potentially used as instrument platforms. These towers form part of the Hatteras East Coast Tracking Range (HECTOR) operated by the DTNSRDC Command.

The project required to provide the necessary subsea equipment, to deploy that equipment and to record the data is not really extensive. The major cost elements, as summarized on Table 7.2, are for a permanent 1,000 foot deep emplaced reentry borehole located in 2,000 foot water depth. A 30-day in situ recording capability would be provided.

The general scenario would be to first define the specific equipment requirements and to select the borehole package and recording package configurations as well as the EM cable. Pressure vessel packaging of the various subsea components would then be undertaken. A deployment engineering and planning effort would be conducted. An appropriate standard drillship and mobilization base would be selected. Procurement of any long lead items (i.e., EM cable, reentry cone, reentry sonar, special drill string, fixtures, etc.) would be initiated. Refurbishment of existing MSS equipment would also be accomplished.

TABLE 7.1

SHALLOW WATER TEST RECORDING PACKAGE INSTALLATION OPTIONS

TYPE	PRESSURE VESSEL	MOORING/RETRIEVAL SYSTEM	DEPLOYMENT FUNCTIONS	RECOVERY FUNCTIONS	AVAILABLE UNITS	DATA FORMAT	REMARKS
Seabed	Moderate Wall	Possibly Riser Line	Lower Package to Seabed Controlled Freefall	Release Transponder will float Package Riser or Grapnel Line Lift	HIG OBS BPP	Tape	-
Subsurface Buoy	Light Wall	Anchor Cable Possibly Riser Line	Lower Package from Ship	Release Transponder Riser or Grapnel Line Lift	HIG * OBS * BPP *	Tape	-
Surface Buoy	Light Wall	Anchor Line	Deploy over side	Pickup Buoy	HIG * OBS * BPP *	Tape	Susceptible to Damage or Theft
Standby Ship	No	Anchor or DP	Cable terminated at Ship	NA	Many	Real-Time and/or Tape	Emergency release required Noise on ship
Platform	No	No	Deploy Cable to Platform	NA	Many	Real-Time and/or tape	Noise on Platform Site near platform
Shore Station	No	No	Deploy Cable to Shore	NA	Many	Real-Time and/or tape	Distance from Shore

*Could be configured surface or subsurface for buoy installation.

TABLE 7.2

SHALLOW WATER (2,000 FT) TEST COST PROJECTION*

(Commercial DP Drillship)

Borehole Package Procurement & Integration	$300,000
Recording Package Procurement & Integration	200,000
EM Cable/Winch Procure	60,000
Deployment Engineering and Planning	100,000
Deployment Equipment Refurbishment	90,000
Ship Charter (30 Days)	800,000
Test Equipment (Shipboard)	60,000
Mobilization and Conversion	80,000
Demobilization	40,000
Recovery Vessel Charter (15 Days)	60,000
Operations Support	120,000
Miscellaneous and Contingency	190,000
	$2,100,000

*Does not include Instrumentation Development, Data Evaluation or Management Costs.

At the selected mobilization port, all of the elements would be received and assembled. All the mechanical and electrical interfaces would be checked out. A dockside test would be conducted simulating to the greatest extent possible the at-sea operations.

The ship would then proceed to the site where a deepwater moor would be installed. A pilot core would be taken preparatory for the initial reentry cone/conductory casing installation. The borehole would then be drilled out to depth and encased as directed. Several reentries may be required for a deeply drilled borehole emplacement. The borehole package would be deployed at the end of the drillstring and after reentry, released and lowered into the borehole. Possibly 4 to 5 days of real time recording may be performed. The recording package or hard line interconnection would then be deployed with associated recovery equipment.

The drilling vessel would then return for demobilization. Subsequently, a small workboat type vessel would be chartered to recover the recording package and/or borehole package, as desired.

The overall integration and deployment would take 9 months to one year, assuming the borehole instrument could be provided within the initial 6 months. The drill ship charter is estimated at about 30 days necessary to cover mobilization, transit, on-site operations (estimated at 10 days) and demobilization.

7.3 DEEPWATER TEST

A deepwater test can be accomplished at a number of U.S. offshore sites. A dynamically positioned drillship is required for water depths over 2,000 feet. The site location should probably be at least 10 miles offshore to reduce shore and surf noise. At these depths, a high strength drill string is definitely required. Section 5.0 provides data on drillstring capabilities as a function of depth.

Either a reentry borehole or a through the pipe deployment can be considered. As noted in Section 4.0, there are many involved considerations with either approach. The decision rests upon the projected use of the site and the size of the selected instruments. A permanent, reusable test station site would require a reentry encased borehole.

Of prime importance are the depth of the site, seabed geologic conditions, and environmental factors. For deepwater sites the drillstring is probably the limiting shipboard handling element.

The recording capability becomes a major consideration due to pressure vessel and/or mooring system restrictions. The basic requirements are established by the data format, range sensitivity level, number of tracks and time period objectives. Only a few available recording packages can be adapted to this type of application unless a shallow subsurface buoy is utilized. The basic problem is deciding where to position the recording package, particularly for extended periods of time. Table 7.3 can be referred to for an indication of possible recording package installation concepts. These options will fall within the same general cost range. Although each recording option has its own specific concern, all can be quite readily accomplished using basically only the deployment vessel.

The availability of very long length, high strength, low impedance deepwater EM cable is very limited. The EM Cable becomes a critical element particularly if sophisticated and sensitive data recording is desired.

The project required to provide the necessary subsea deepwater equipment, deploy that equipment and record the data is rather extensive. The major cost elements, as summarized on Table 7.4, would be required for a permanent 1,000 foot emplaced reentry borehole located in 15,000 foot water depth. A 30-day in situ recording capability would be provided.

The general scenario would include defining the specific equipment requirements and selecting the borehole package and recording package

TABLE 7.3

DEEPWATER TEST RECORDING PACKAGE INSTALLATION OPTIONS

TYPE	PRESSURE VESSEL	MOORING/RETRIEVAL SYSTEM	DEPLOYMENT FUNCTIONS	RECOVERY FUNCTIONS	AVAILABLE UNITS	DATA FORMAT	REMARKS
Seabed	Heavy Wall	Extensive Anchor and Riser Line	Lower Package to Seabed	Release Transponder with Package Float Riser or Grapnel Line Lift	HIG OBS BPP	Tape	
Subsurface Buoy	Moderate Wall	Anchor Cable Possibly Riser Line	Lower Package or Controlled Freefall	Riser or Grapnel Line Lift Release Transponder	HIG * OBS * BPP *	Tape	
Surface Buoy	Light Wall	Anchor Cable	Deploy over side	Pickup Buoy	Many	Tape	Susceptible to Damage or Theft
Seabed (Hard Line)	Heavy Wall	Riser Line	Lower Pack to Seabed	Riser or Grapnel Line Lift	HIG OBS BPP	Real-Time	Very long EM Cable Interconnection

* Could be configured for surface or subsurface buoy installation.

TABLE 7.4

DEEPWATER (15,000 FT) TEST COST PROJECTION*

(Commercial DP Drillship)

Borehole Package Procurement & Integration	$500,000
Recording Package Procurement & Integration	400,000
EM Cable/Winch Procure	150,000
Deployment Engineering and Planning	250,000
Deployment Equipment Refurbishment	120,000
Ship Charter (40 Days)	2,800,000
Test Equipment (Shipboard)	80,000
Mobilization and Conversion	120,000
Demobilization	50,000
Recovery Vessel Charter (15 Days)	80,000
Operations Support	380,000
IRR Mooring/Subsea Buoy	200,000
Miscellaneous and Contingency	480,000
	$5,610,000

* Does not include Instrumentation Development, Data Evaluation or Management Costs.

positioned drillship and mobilization base would be selected. Procurement of any long lead items (i.e., reentry cone, reentry sonar, special drillstring, fixtures, etc.) would be initiated. Refurbishment of existing MSS equipment would also be accomplished.

At the selected mobilization port, all of the elements would be received and assembled. All the mechanical and electrical interfaces would be checked out. A dockside test would be conducted simulating to the greatest extent possible the at-sea operations. A special shallow water checkout should be considered dependent on the complexity of the equipment and the experience of the crew.

The drillship would then proceed to the site where a subsea positioning beacon would be established. A pilot core would be taken preparatory for the initial reentry cone/conductory casing installation. The borehole would then be drilled out to depth and encased as directed. Several reentries would be required for a deep borehole emplacement. The borehole package would be deployed at the end of the drillstring and after reentry, released and lowered into the borehole. Possibly 4 to 5 days of real time recording may be performed. The recording package would then be deployed with associated recovery equipment.

The drilling vessel would then return for demobilization. Subsequently, a medium sized oceanographic research vessel or large workboat would be chartered to recover the recording package and/or borehole package, as desired.

The overall integration and deployment would take 18 to 24 months, assuming the borehole instrument could be provided within the initial 12 months. The drillship charter is estimated at about 40 days in order to cover mobilization, transit, on-site operations (estimated at 20 days) and demobilization.

SECTION 8.0 - DEEPWATER OPERATIONAL PROGRAM

8.1 INTRODUCTION

A string of deepwater operational borehole sites can be installed by basically utilizing the deployment and emplacement techniques already discussed. The major considerations are:

- Specific site(s) parameters
- Instrumentation package characteristics and capabilities
- Weather and environmental conditions
- Communication network

The MSS development program has demonstrated that the first three considerations can probably all be accommodated. However, the biggest unknown is the communications requirements, particularly if a rapid data feedback is necessary. The communications network can be either a recoverable recording package, a hard line link to existing subsea circuits, satellite communications, a long wave radio system or acoustic data transmission. Pop-up buoy systems can be utilized for either of the radio communications approaches. Each of the above networks presents different specific requirements, but all should be resolved, though with difficulty, as part of the deployment scenario herein envisioned.

8.2 PROGRAM ELEMENTS

A deployment program of 8 to 12 deepwater sites positioned across the Atlantic and Pacific Oceans has been projected. An operational deployment subprogram would be made up of the major cost elements as defined in Table 8.1. These elements would form part of a larger national strategic system.

8.3 SCHEDULE

The overall deployment of 8 to 12 stations herein considered would probably require about 30 months to accomplish assuming the sensor

TABLE 8.1

MULTIPLE SITE OPERATIONAL DEPLOYMENT PROGRAMS

(Commercial DP Drillship)

Instrument Package Develop & Hardware	$ 6,500,000
Communications/Data Recording Develop & Hardware	3,900,000
Deployment System Engineering	1,500,000
Shallow Water Checkout	600,000
Deployment Hardware Procurement	3,200,000
Ship Charter (9 months)	14,600,000
Mobilization	700,000
Operations, Fuel and Supplies	1,500,000
Demobilization	500,000
Recovery/Maintenance Support (1 year)	1,200,000
Miscellaneous and Contingency	3,300,000
	$ 37,500,000

The costs constitute only rough estimates of an 8-12 multiple deep ocean site deployment program but are indicative of the magnitude.

instrumentation needs only to be packaged into a deepwater configuration. Actual at-sea operations should be accomplished in an approximate 9-month period if the projected sites are near to each other. Figure 8-1 depicts a typical projected schedule.

8.4 BRIEF SCENARIO

Based upon specified requirements, deepwater packaging of the defined borehole instrument would be initiated. In parallel, development of either a recording package, a communications buoy or a hard line connection would begin. A comprehensive evaluation of all projected station sites would be undertaken, and a tentive schedule would be established taking into account difficult site and probable weather conditions. A preliminary operations plan would be prepared from which to establish specific vessel and support equipment requirements.

Upon selection of the deployment vessel, detailed design of the subsea and specialized shipboard handling would be accomplished. Major procurement action on long lead items (i.e., drill pipe, winches, BHA, etc.) would be initiated. A preliminary mobilization and logistics support plan would be prepared. A comprehensive ground test checkout and shallow water demonstration would be defined. A base port of operations would also be established.

At or near the selected port of operations, conversion of the drillship would take place including installation of special shipboard handling equipment. During this period final development and checkout functional testing would be accomplished. Dockside testing of various integrated equipment subsystems would be performed, as applicable. After necessary developmental and shore test checkout was accomplished, a shallow water demonstration would be performed to demonstrate the equipment capabilities, personnel training, procedures and data transmittal techniques. This demonstration would take about a month to accomplish and in some cases would perhaps initially utilize breadboard type hardware/software.

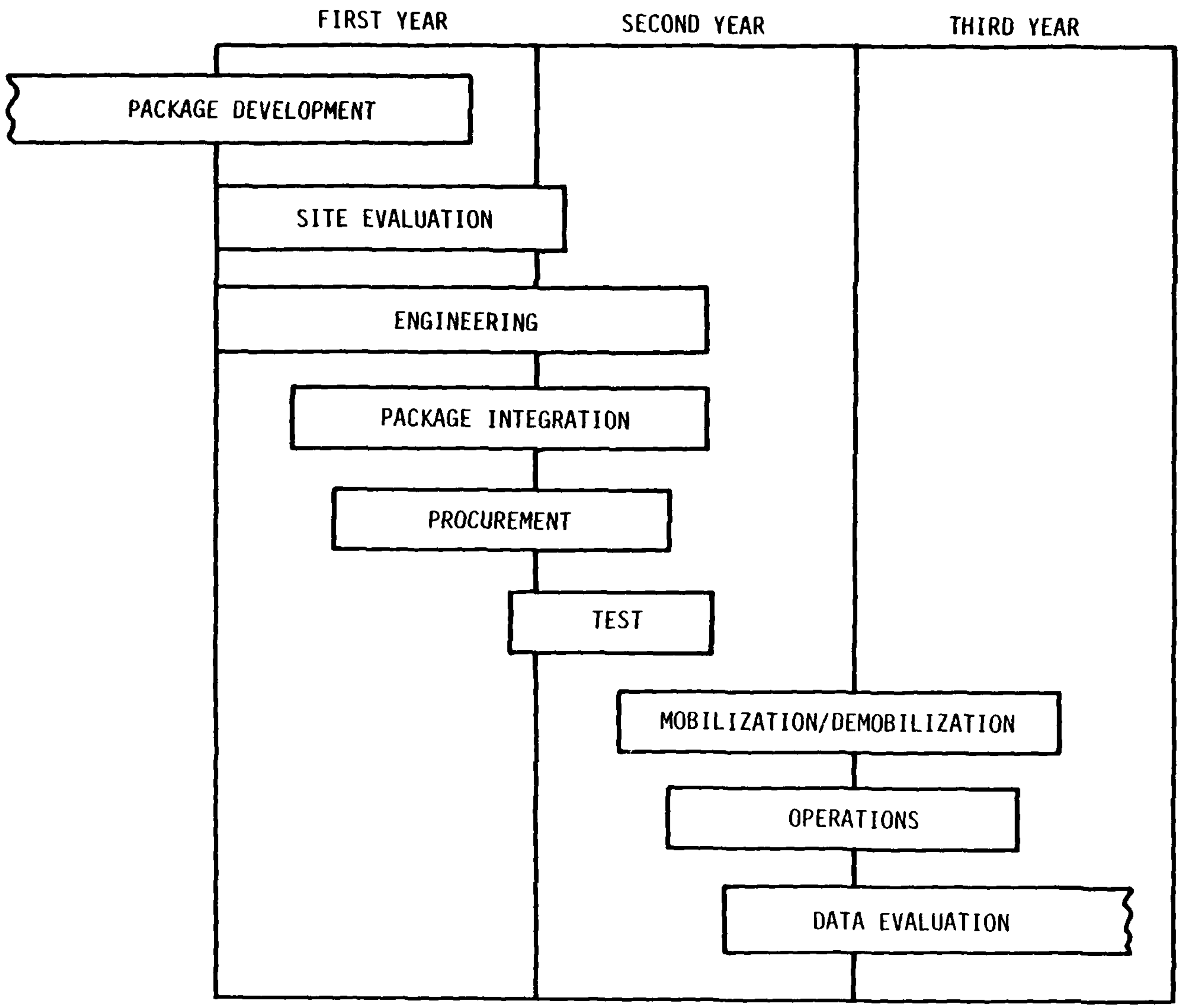


FIGURE 8-1 PROJECTED MULTIPLE SITE DEPLOYMENT SCHEDULE

015-010

possibly be conducted into Atlantic and Pacific legs. Each leg would be 4 to 6 months in duration. Crew changeover, refueling and resupply would be scheduled every 6 to 8 weeks and would be accomplished in foreign ports, as necessary. It is assumed that the drilling ship would require at least one trip through the Panama Canal.

Operations at each projected site would require an average of 20 days for borehole emplacement, deployment, plus real time recording. Certain stations may require up to 30 days to allow for possible severe weather holds. In addition to the program's specialized equipment, fuel, food, etc., the major expendables would include the casing, borehole cones, and cement.

The demobilization portion of the overall program would be completed with the reconversion of the drilling vessel. All program-procured shipboard handling equipment would be stored, as directed.

APPENDIX A

BROCHURES OF DRILLSHIPS

GLOMAR CHALLENGER

GLOMAR PACIFIC

GLOMAR ATLANTIC

SEDCO 445

SEDCO/BP 471

SEDCO 472

S-709

DISCOVERER SEVEN SEAS

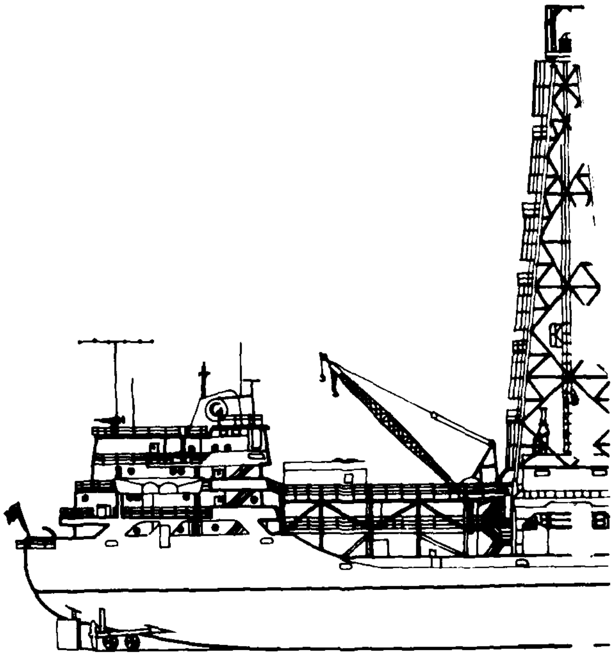
HENRY GOODRICH

ODECO

GLOMAR CHALLENGER

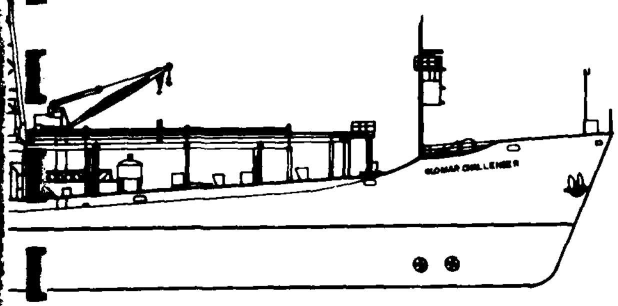
Length, Beam, Draft:
Length: 400' — Beam: 65'2" — Draft: 9'2" (Light ship)
Displacement
4,470 L.T. (Light ship)
Centerwell:
22' x 24'
Propulsion:
Diesel electric, twin screw, driven by GE 752 RI electric motors.
Ground Tackle:
3 — 111,000 lb. anchors with 900' 2" anchor chain.
Anchor Winches:
American Hoist and Derrick Company 2-1/16" galvanized wire, diesel driven.
Cranes:
1 — Mariner 500, 50 ton, diesel.
1 — 15 ton, diesel.
Auxiliary Pumps:
Fuel
Salt water
Fresh water
Compressed Air System:
1 — 3.2 CFM 100 PSI air compressor
2 — 358 125 PSI air compressors with after coolers
1 — 22 CFM 100 PSI emergency air compressor
Water Distillation Unit:
2 — Aqua Chem
Radio:
Northwest Instruments Model NW-38 radiotelephone and RCA type CRM CIC radiotelegraph.
Radar:
2 — Decca Model RM 914

Fathometer:
EDO Model 185
RDF Unit:
Bendix Model ADF-100
Intercom System:
Sound powered telephone system.
Welding Machine:
2 — Lincoln 300 amp. electric driven.
Reserve Mud:
2,490 barrels
Drilling Water:
4,769 barrels
Bulk Mud:
12, 300 cu. ft.
Bulk Cement:
N/A



Sack Material Storage:
12,000 sacks
Fuel:
16,568 barrels
Potable Water:
1,019.2 barrels
Derrick:
142' x 61' x 38' special design galvanized with 1,000,000 hookload capacity, API rating.
Drawworks:
National type, 1625 DE, with Elmagco type eddy current brake; driven by 2 GE 752 RI electric motors, with 1½'' drilling line and 26,000' ½'' sand line.
Rotary Table:
Power swivel

Mud Pumps:
2 — National type, N-1300 duplex power slush pumps driven by dual GE 752, 800 HP each.
Mud Mixing Pump:
2 — Mission 6 x 8R centrifugals, 75 HP each.
Traveling Block:
National, 500 ton cap. with special guide rail rollers.
Swivel:
National type N-1324, 335 ton.
National type NSF-650, 450 ton.
Air Tuggers:
8 — 2,000 lb. capacity
1 — 4,000 lb. capacity
3 — 4,000 lb. capacity
2 — 5,000 lb. capacity
Rotary Hose:
3½'' x 65'
Crown Block:
National 760-H, 500 ton capacity.
Master Bushing:
None
Drill Pipe:
5'' drill pipe, Grade S-135, 19.5 lb./ft., Range 2
Drill Collars:
8¼'' OD x 30'
7¼''OD x 30'
Logging Unit:
None
BOP Control System:
None
BOP Stack:
None
Riser Tensioning:
None



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GLOMAR PACIFIC

The GLOMAR PACIFIC is a self-propelled drillship that maximizes the advantages of the hull-shaped structure — capacity, mobility, safety, and fuel efficiency for automatic station keeping.

Equipped with both conventional mooring and dynamic positioning systems, this design provides for operations in water depths from 100 feet to 2,000 feet. Its loaded displacement of 14,751 tons and maximum speed of 14 knots make this exploratory vessel ideally suited to meet the growing demands of worldwide offshore exploration.

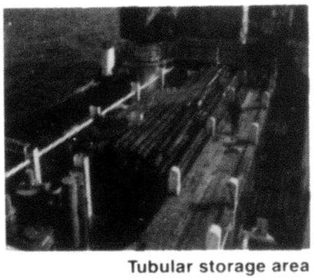
The GLOMAR PACIFIC has a hull configuration which incorporates a high freeboard-to-depth ratio which results in a high degree of stability and dryer working decks. Major design features include a wide beam; a rounded, modified cruiser stern; a semi-bulbous bow; a longitudinal frame with double bottom and wing tanks; and a concentration of mass near the boundaries of the hull. These design features provide for reduced hull resistance and a minimum of angular motion under normal operating conditions by lowering the center of gravity. Due to reduced windage and underwater areas in beam-on conditions, this drillship, using the main propulsion units and thrusters, requires a minimum of power to maintain position within allowable limits. Emphasis is placed on the GLOMAR PACIFIC's ability to sustain long term operations under demanding conditions with a minimum of support within a wide range of water depths.

When combined, the structural design, weight distribution, and excellent stability characteristics result in the assurance of a reliable, safe, and cost-effective floating drilling unit for offshore programs.

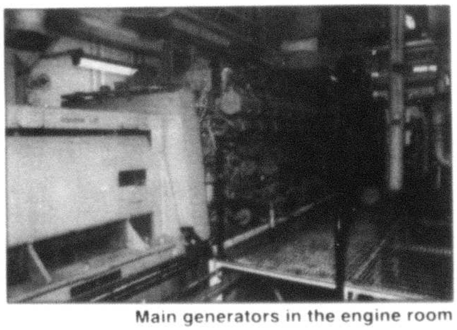
For further information please contact
Global Marine Drilling Company
7500 San Felipe, Houston, Texas 77063
Phone (713) 978-4204

Dynamic Positioning Control Station

Drilling floor area with the "Iron Roughneck" in foreground



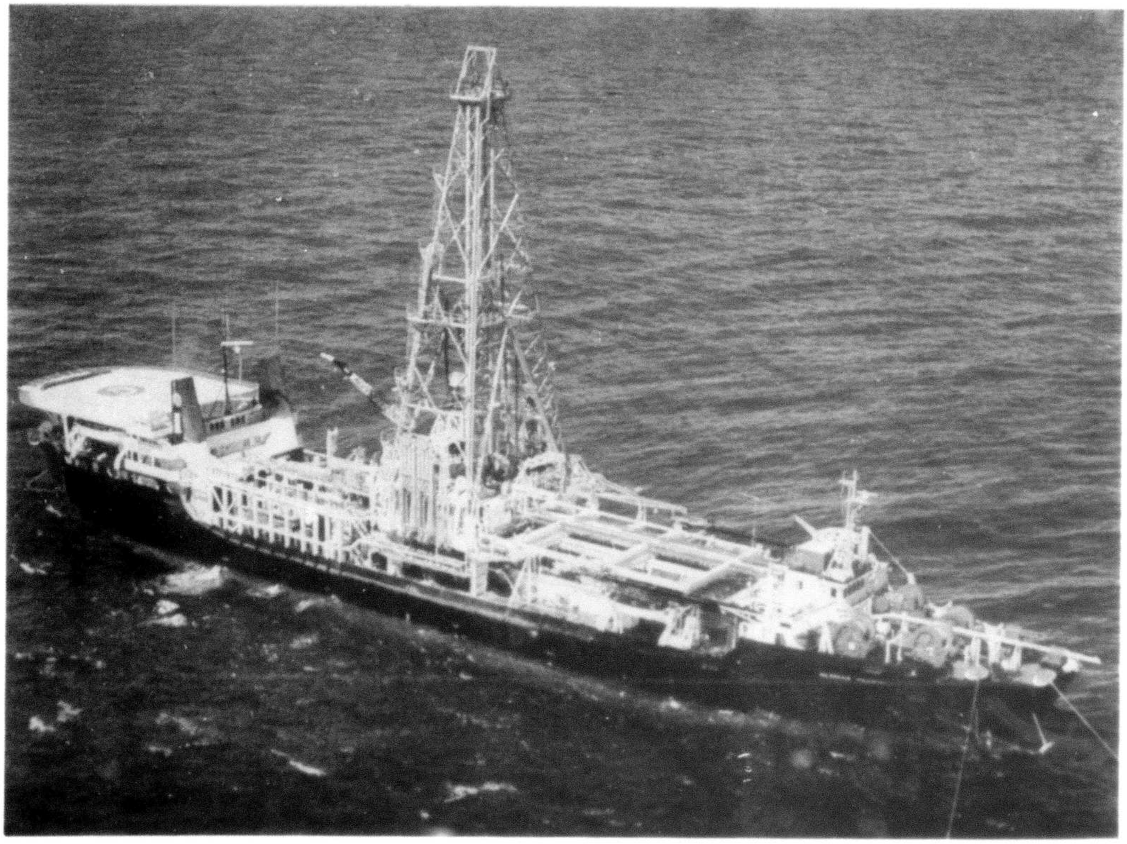
Tubular storage area



Main generators in the engine room

GLOMAR PACIFIC

GLOBAL MARINE DRILLING COMPANY



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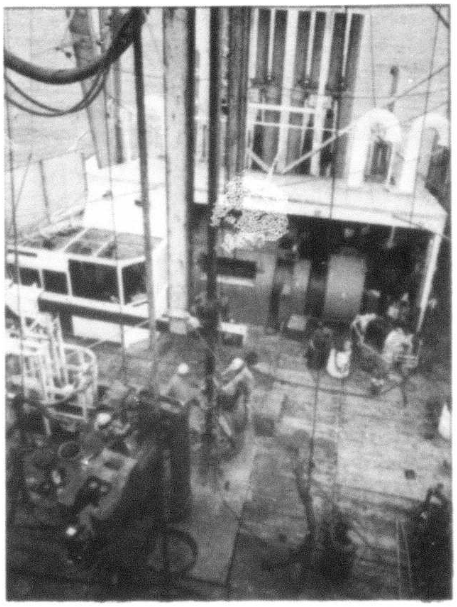
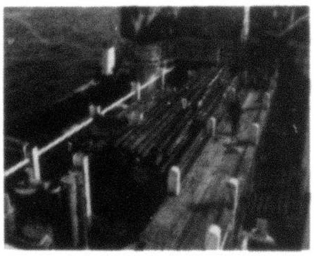
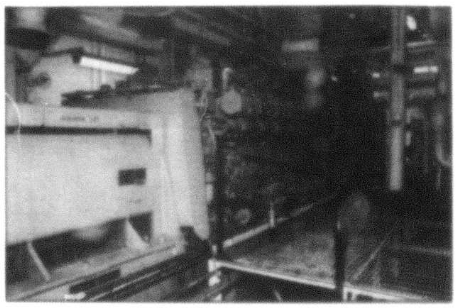


Drilling floor area with the "Iron Roughneck" in foreground



Tubular storage area



Main generators in the engine room

PRINCIPAL CHARACTERISTICS

Vessel Information

Classification:	A.B.S. ✱ A1 Ⓔ	**Maximum Speed:**	14 knots
Length Overall:	452 ft.	**Berths & Galleys:**	Air conditioned quarters and dining facilities certified for 101 persons.
Beam Overall:	72 ft.	**Heliport:**	83 ft. x 90 ft. designed for Sikorsky S-61 helicopter: 2,000 gallons fuel storage capacity.
Depth of Hull:	35 ft.	**Allowable Variable Load:**	7,400 tons (approx)
Draft (Loaded):	23 ft. 6 in.		
Displacement:	8,153 LT lightship		
Centerwell:	26 ft. x 26 ft.		
Water Depth Capability:	2,000 feet		
Drilling Depth Capability:	25,000 ft.		

Storage Capacities

General Cargo:	200 tons	**Active Mud:**	594 bbl.
Tubular Goods:	Casing Rack-400 tons Casing Hold-600 tons	**Reserve Mud:**	3,044 bbl.
Sack Materials:	15,000 sacks	**Potable Water:**	1,140 bbl.
Bulk Cement:	7,415 cu. ft.	**Wash Water:**	2,748 bbl.
Dry Bulk Mud:	16,800 cu. ft.	**Drilling Water:**	19,163 bbl.
Fuel:	15,751 bbl.	**Lube Oil:**	407 bbl.

Power Generation — Four GE type AT1 Generators rated at 2750 KW 600 Volts, each driven by a GE Diesel Engine rated at 3860 HP at 1200 RPM for main power.

Power Conversion — Ten Westinghouse SCR DC Power Conversion Units.

Emergency Power — One 600 KW Delco Generator driven by a V-12 Detroit Diesel Engine rated at 975 HP at 1,800 RPM.

Main Propulsion — Two 11 foot, four bladed, fixed pitch propellers, each driven by three GE 1600 HP DC motors developing 9600 SHP giving a maximum speed of 14 knots.

Thrusters — Five Schottel thruster units (three forward and two aft) each rated at 1675 HP.

Conventional Mooring System — **Anchors:** Eight 30,000 lb. Offdrill II anchors, each with 1,750 ft. x 2¾ in. stud link chain and 6,000 ft. x 3 in. wire rope.
Winches: Eight Skagit model ETW 300 mooring winches.

Dynamic Positioning — A Delco dual redundant computerized system. Complete with backup computer, high frequency acoustic beacons, hydraphone assemblies, taut wire sensor system and riser angle indicator.

Communications Equipment

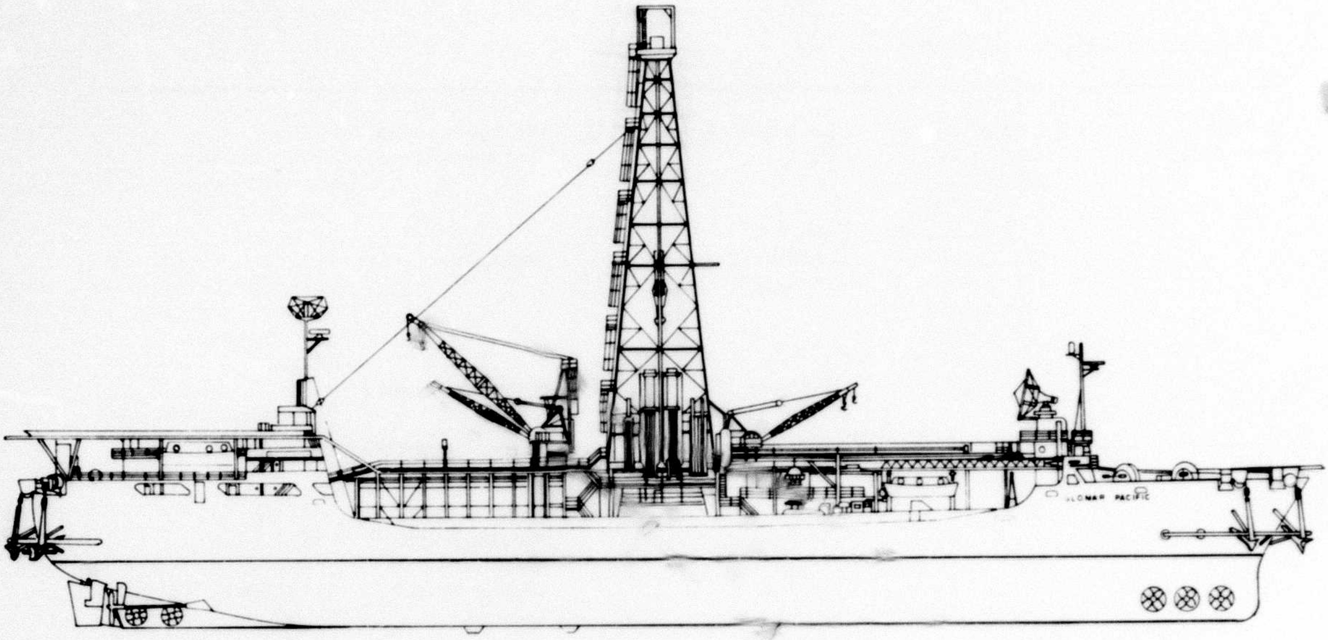
ITT McKay Main High Seas Radio System
Motorola Marine SSB Radio
Motorola VHF/FM Radio Telephone
ITT McKay portable lifeboat transmitter receiver.

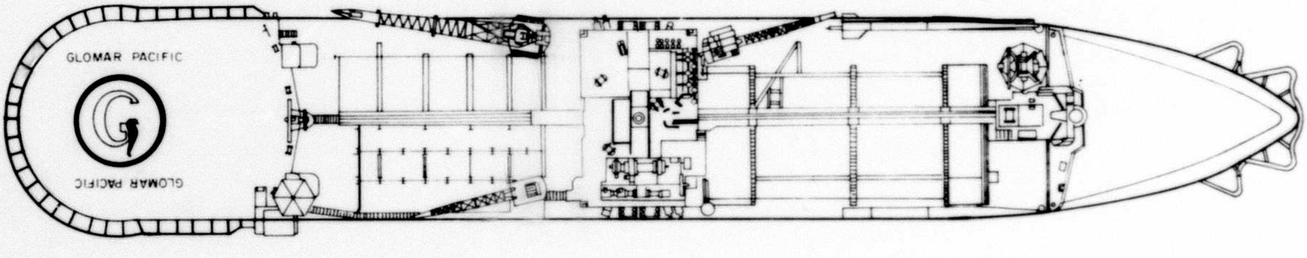
Navigational Equipment

LORAN "C" receiver
Tracor OMEGA Navigator II Receiver
Raytheon forward and aft radar units
ITT McKay type 4005A ARDF
ITT McKay EPIRB
EDO Western Fathometer
Sperry Gyro Compass

Lifeboats

Two 26 foot totally enclosed diesel powered lifeboats with a capacity of 42 persons each.
Two 30 foot totally enclosed diesel powered lifeboats with a capacity of 64 persons each.





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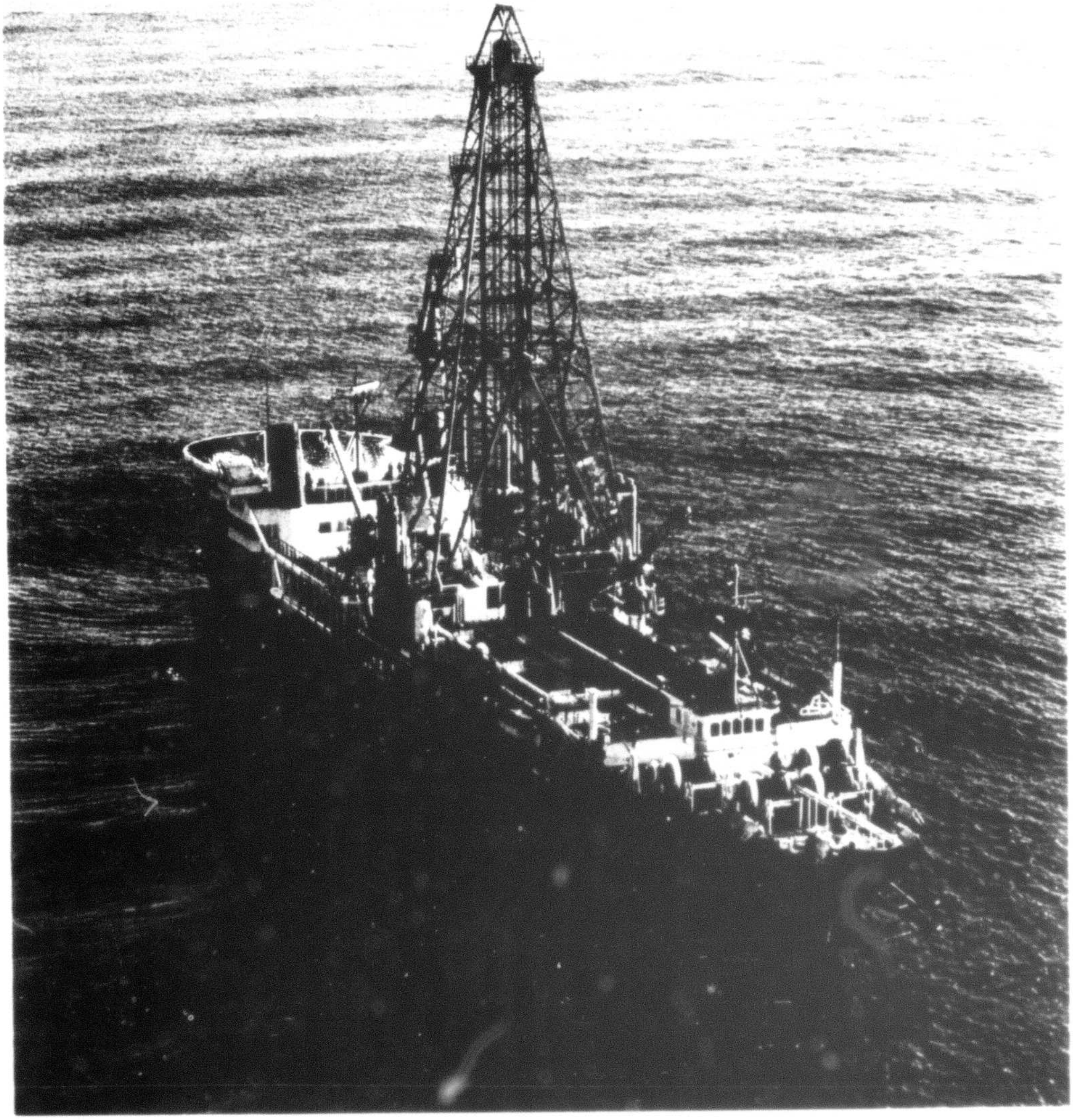
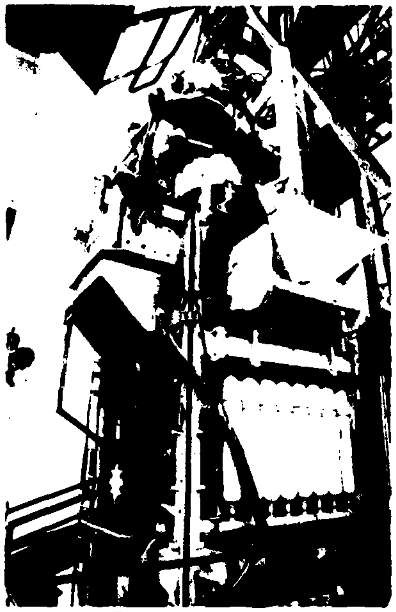
GLOMAR ATLANTIC

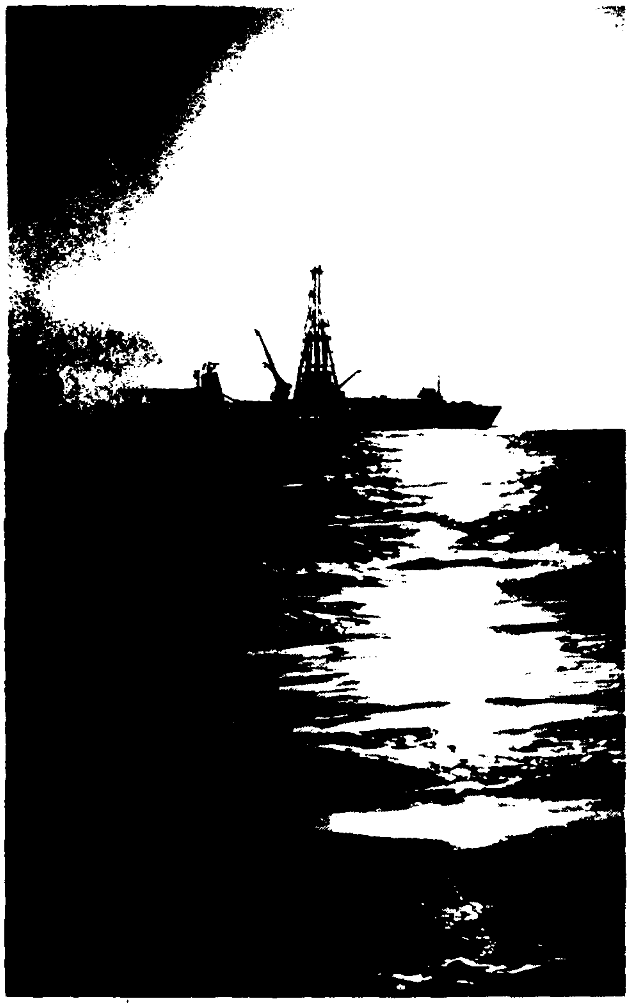
GLOBAL MARINE DRILLING COMPANY

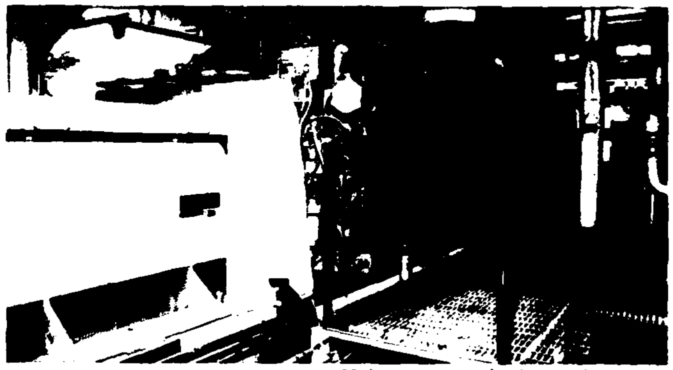




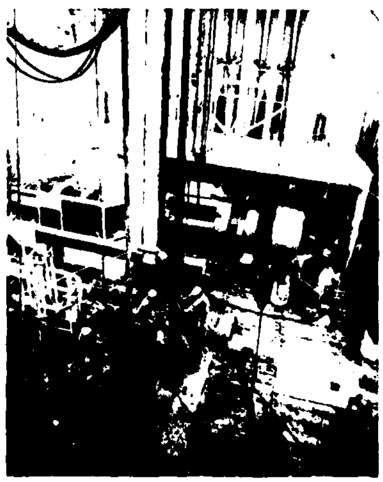
Guidelines BOP stack

Dynamic Positioning control station



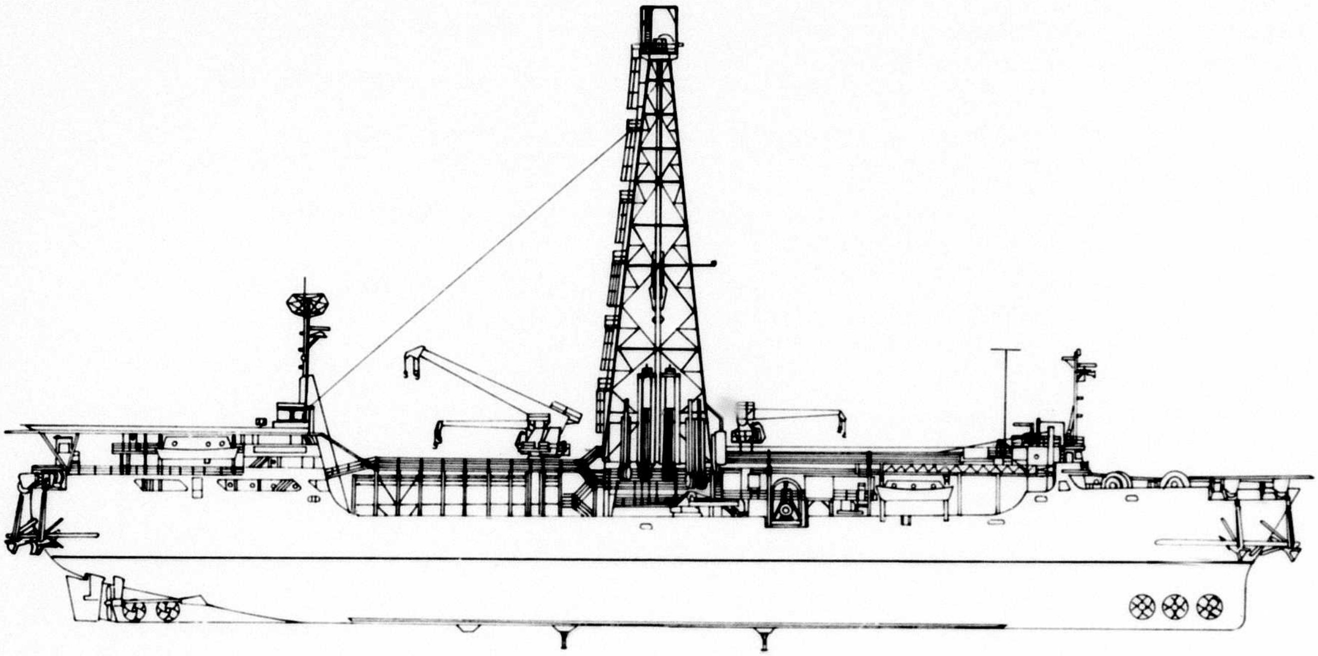


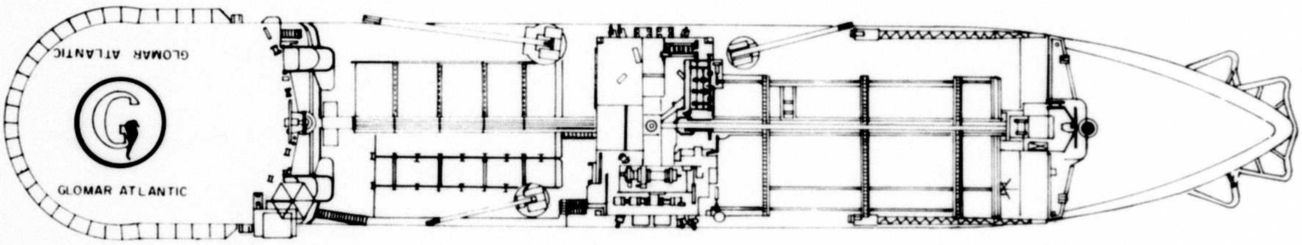
Main generator in the engine room



Drilling floor area with the "Iron Roughneck" in foreground

Drilling Equipment	**Drawworks:** National Type 1625 DE with Elmagco type 7838 electric brake driven by three GE 752 electric motors. **Derrick:** Global Marine design: 142 ft. x 61 ft. x 38 ft. galvanized with 1,000,000 lbs. hookload capacity. API rated. **Crown Block:** 650 ton capacity for use with a single piston motion compensator. **Motion Compensator:** Vetco single piston unit with a 20 ft. stroke and a 400,000 lb. capacity. **Swivel:** National P-650. **Rotary Table:** National C-495 independently driven by one GE 752 electric motor. **Weight Indicator:** Martin Decker, Type EB. **Kelly Spinner:** Varco 6500. **Pipe Racker:** Global Marine design, automatic, horizontal; 23,580 ft. capacity in triples. **Drill Pipe:** 10,000 ft. of 5 in. Grade E; 5,000 ft. of 5 in. Grade G. **Drill Collars:** Thirty 6½ in. x 30 ft., thirty 8 in. x 30 ft. **Mud Pumps:** Two National 12-P-160 Triplex pumps, each powered by two GE 752 electric motors. **Mud Mixing:** Two Mission 6" x 8" pumps. **Cementing Unit:** Twin Halliburton HT-400 skid mounted unit, driven by two GE 752 electric motors. **Degasser:** Wellco 5200. **Desander:** Pioneer T-10-6 rated at 1,100 gpm. **Desilter:** One Pioneer Model T-16-4 rated at 800 gpm. **Shale Shaker:** Brandt Dual Tandem. **Air Compressors:** Four Ingersoll-Rand and four Sullair air compressors.
Subsea Equipment	**BOP System:** Certified for H_2S service. **Stack Size/Rating:** 18¾ in. 10,000 psi W.P. guidelineless. **Ram Preventers:** One double type "LWS" and two single type "LWS." **Annular Preventers:** Two Shaffer 18¾ in. spherical blowout preventers rated at 5,000 psi W.P. **Wellhead Connector:** 18¾ in. 10,000 psi W.P. Regan. **Riser Connector:** 18¾ in. 10,000 psi W.P. Regan. **Choke and Kill Valves:** Eight McEvoy fail safe valves, five straight and three right angle. **BOP Control System:** Koomey dual pod hydraulic with acoustic and hot line backup, and a single function emergency wellhead disconnect system. **Choke and Kill Manifold:** 10,000 psi W.P. with two Swaco hydraulic, and two McEvoy manual adjustable chokes. **Diverter System:** Regan Model KFDH. **Marine Riser:** 21¼ in. Regan buoyant riser 10,000 psi W.P. integral choke and kill lines. **Riser Tensioners:** Four dual Vetco, each with a combined line pull of 150,000 lbs. and 50 ft. line travel. **Guide Line Tensioners:** Four Vetco single cylinder, each with 40 ft. line travel and a 16,000 lb. line capacity (for use if guidelines are required). **Pod Line Tensioners:** Two Vetco single cylinder, each with 40 ft. line travel and a 16,000 lb. line capacity. **Underwater Television:** Complete wellhead and dual lower marine riser package re-entry TV system. **Position Indicator:** Honeywell Model RS-505.
Auxiliary Equipment	**Water Distillation Unit:** Two Aqua Chem Model S-300 Spec-E, electric powered water distillation units. **Oily Water Separator:** Sarex, 20 gpm capacity. **Cranes:** Two Devault Model 50-15 with 35 ft. booms; and one Devault Model 120-15 with 60 ft. boom. **Welding Equipment:** Two 400 amp welding machines.
Onboard Facilities	Machine and Welding Shop Electronic Repair Shop Electrical Repair Shop Parts Storeroom





GLOBAL MARINE DRILLING COMPANY

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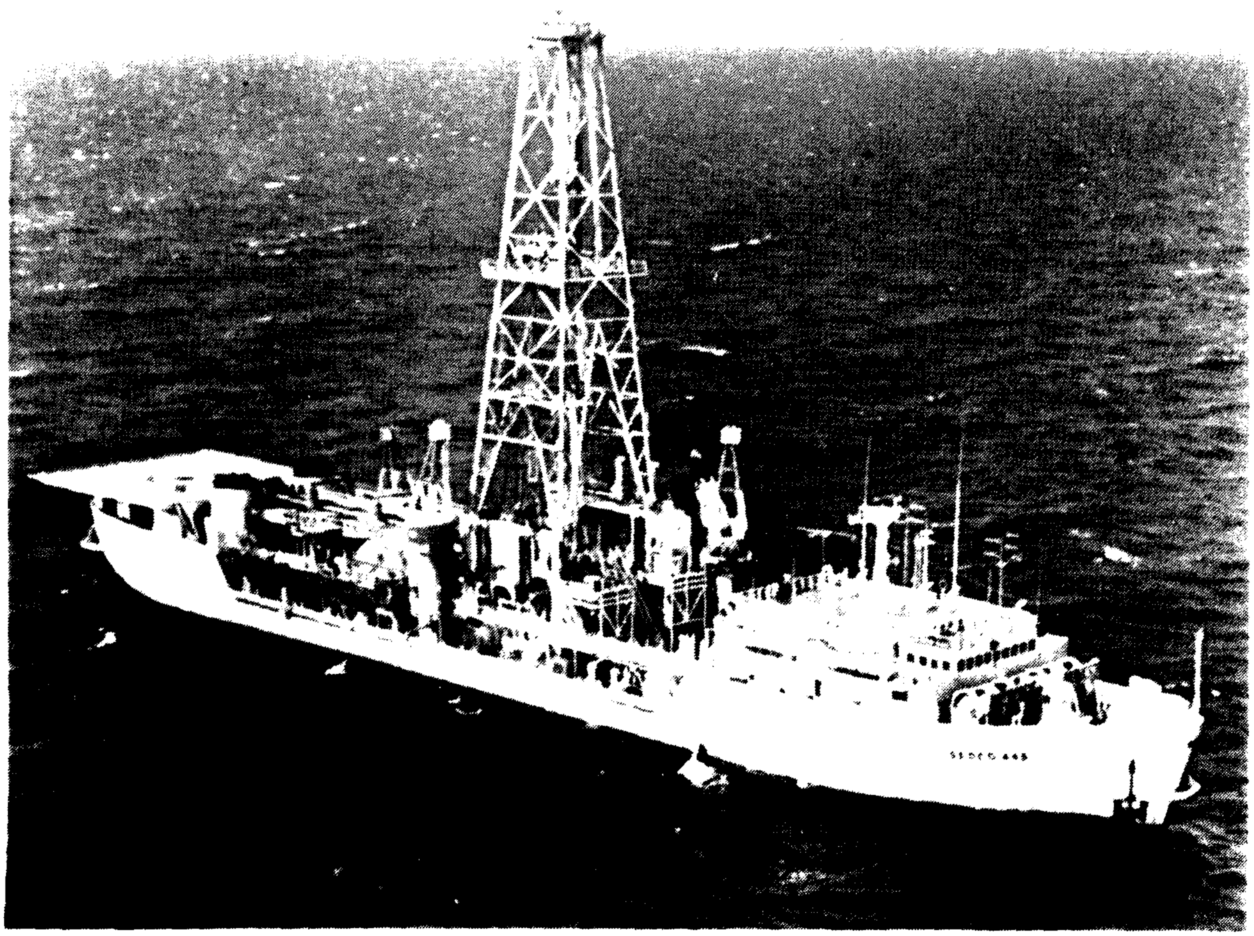
Printed in U.S.A.

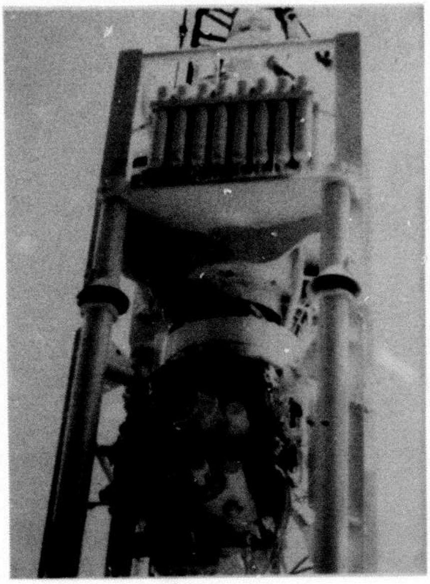
SEDCO INTERNATIONAL, S.A.

SEDCO 445



SEDCO 445

Full Dynamic Stationing in Water Depths to 6,000 feet for Worldwide Exploration. Operated by SEDCO, INC.



16¾" BOP Stack

Principal Cha

MAJOR DIMENSIONS

Length, Overall	445 ft
Beam, Mld	70 ft
Depth, Mld at side	32 ft
Draft, Max (Summer Load Line)	24 ft 6 in
Displacement at 24 ft. 6 in. draft	18,600 st
Displacement at 22 ft. (Avg op. Draft)	15,000 st
Light Ship Displacement	8,538 st
Max speed at 24 ft. 6 in. draft	14 kts
Moon pool diameter	32 ft

STORAGE CAPACITIES

Liquid Mud	3,000 bbl
Drill Water	10,000 bbl
Diesel Oil	12,000 bbl
Potable Water	1,000 bbl
Bulk Dry Mud	8,050 cu ft
Bulk Dry Cement	5,250 cu ft
Sack Storage	8,560 cu ft

EQUIPMENT

Power Generation

5 2100 KW EMD Engine Generator sets for main power

2 1500 KW EMD Engine Generator sets for ship's service

1 250 KW GM Emergency Generator Set

DC Conversion

24 Baylor Model 15000 Thyrig bays converting 600 V AC to 0-750 V DC

Main Propulsion

2 13 ft diameter, 4 bladed, fixed-pitch propellers each driven by 6-750 HP General Electric DC motors. A.B.S. approved.

Thrusters

11 Baylor Pleuger units, mounted in pairs, each unit driven by one 800 HP General Electric DC motor

Dynamic Positioning

Honeywell Automatic Station Keeping (ASK) with redundant H316 computers, RS-5 Acoustic Position Indicators, taut wire angle sensors and riser angle indicators.

Cranes

1 Bucyrus Erie M at 79 tons at 2

1 Bucyrus Erie MK at 79 tons at 25 f

1 Bucyrus Erie M at 58 tons at 20

Water Distillation

2 Meco electric tion units each

Compressors

2 Gardner-Denve each delivering general service an

1 Gardner-Denve emergency air HP motor

1 Gardner-Denver start air compre 200 PSIG.

Lifeboats

4 Totally enclo propelled wate capacity for 60 m Schat self-laun

DRILLING AND EQUIPM

147 ft Lee C. Moore we 1,000,000 lb. st

Oilwell E 3000 draw

Oilwell A 49½" rotary

Two Oilwell A 1700 P D-79 DC moto

Vetco 400,000 lb. 20 ft sator

8 Western Gear 80K in pairs.

4000 ft of Regan in 10,000 psi choke which is equi Cuming syntac modules

1-16¾" 5,000 psi C stack with three se of blind shear ra preventer.

#racteristics

.60 with 60 ft boom rated
oot radius
-60 with 80 ft boom rated
oot radius
-35 with 80 ft boom rated
oot radius

or ompression distilla-
ated at 600 gal/hr.

W G air compressors
82 cfm at 200 PSIG for
d control air
D electrically driven
mpressor driven by a 15

VEE diesel driven cold
or elivering 141 scfm at

self-righting, self-
raft lifeboats, each with
en and complete with
ng davits.

SSOCIATED ENT

.ded panel derrick with
hood load capacity
ork

Duplex mud pumps with

stroke heave compen-

ensioners, mounted

tegral marine riser with
and kill lines, 3000 ft of
d with Emerson and
tic foam buoyancy

n blowout preventer
ts of pipe rams, one set
ms and Hydril annular

1-16¾″ 10,000 psi Cameron blowout preventer stack with three sets of pipe rams, one set of blind shear rams and Hydril annular preventer.

Koomey EH/Hydraulic B.O.P. control system and RATAC acoustic back up

Halliburton HT 400 twin cementing unit with D-79 DC motors, recirculation pumps and 10,000 psi manifold.

Vetco 10,000 psi choke and kill manifold.

Western Gear pipe racker and stabber with a Western Gear riser handling support crane system.

Tubulars

15,000	5″ Grade E	19.5 lb/ft drill pipe
6,000 ft.	5″ S-135	19.5 lb/ft drill pipe
15,000 ft.	3½″ Grade E	15.5 lb/ft drill pipe
20 joints	5″ "Hevi-Wate"	50.0 lb/ft drill pipe
10	9½″ x 32 ft.	drill collars
40	8″ x 32 ft.	drill collars
47	6½″ x 32 ft.	spiral drill collars
30	4¾″ x 32 ft.	drill collars

ONBOARD FACILITIES

1 Co plete machine and welding shop
1 Air conditioned electronic repair shop
1 Motor rewind and electrical repair shop
1 Onboard warehouse storage facility complete with warehouse office

GENERAL

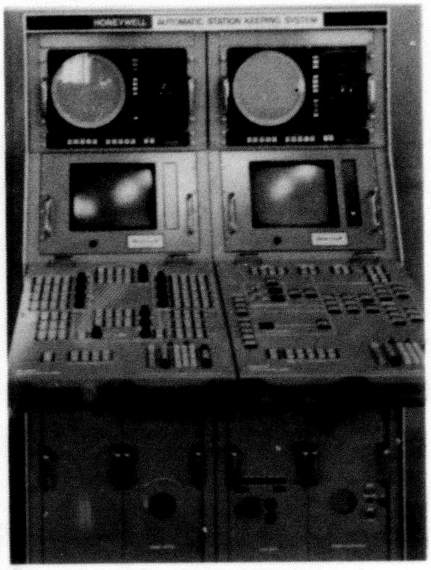
Accommodation

Total capacity - 93, not including 4-man hospital.

7 Single rooms
29 Two-man rooms
7 Four-man rooms
1 Four-man hospital

Heliport

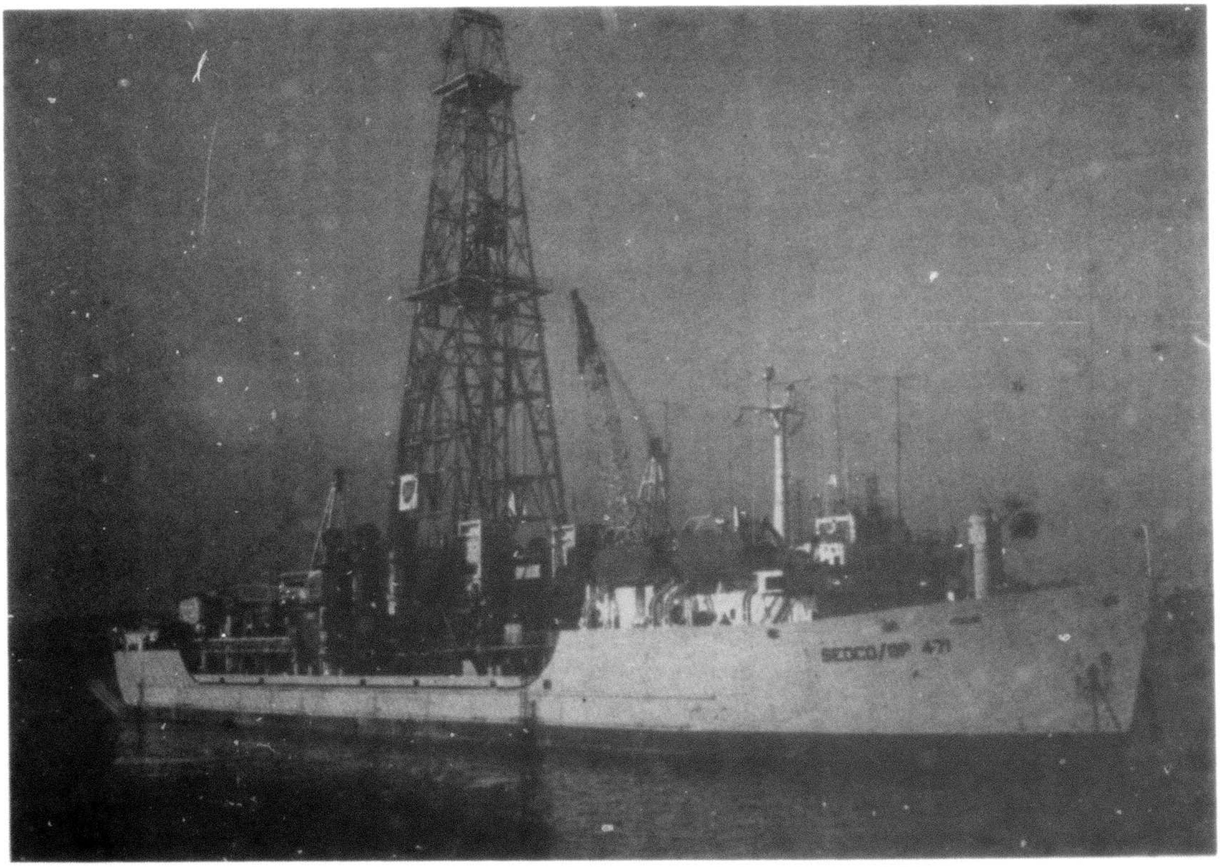
70′ x 70′ for Silorsky S61 wheeled helicopter.



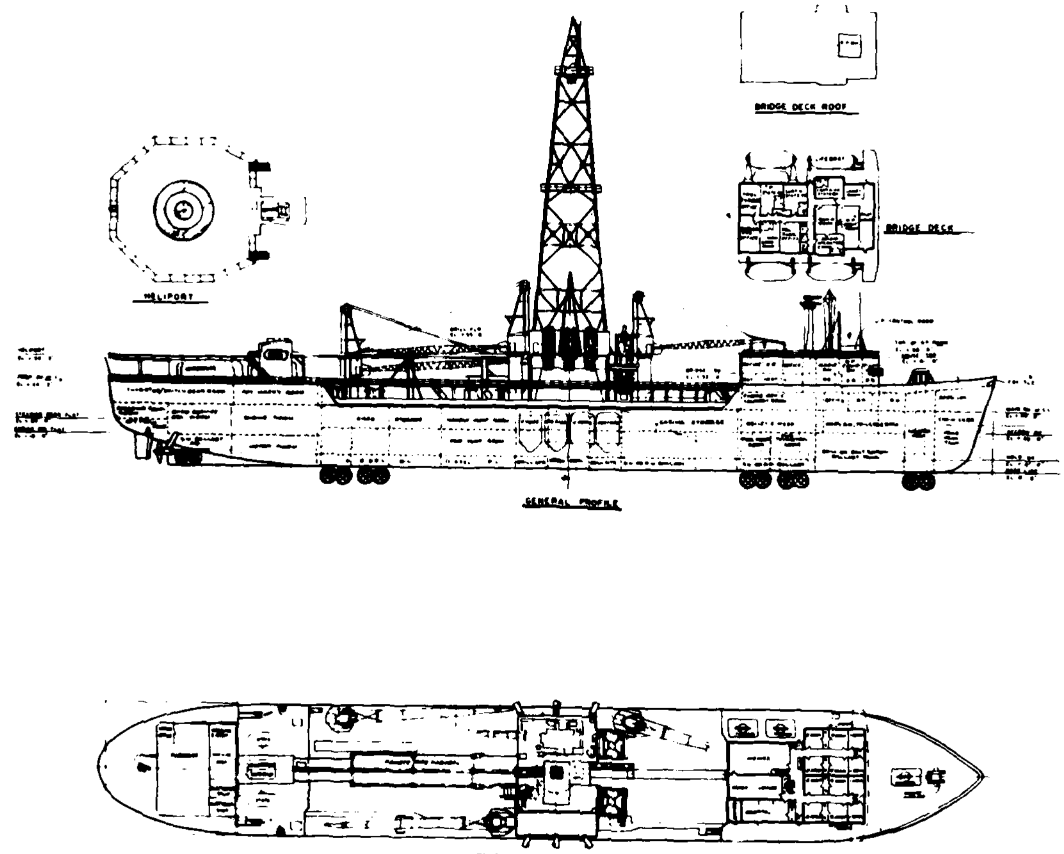
HONEYWELL ASK SYSTEM

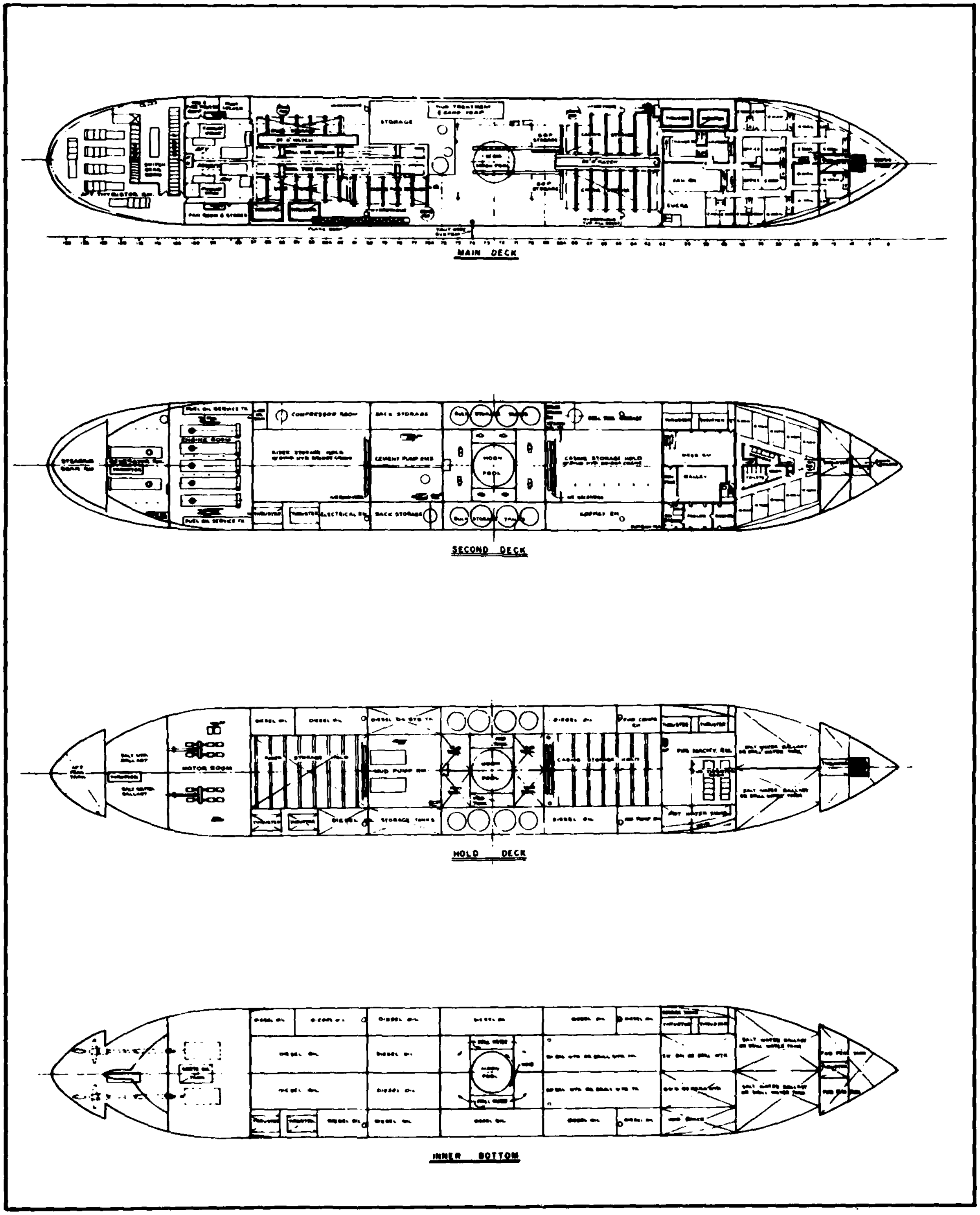
OVERSEAS DRILLING LIMITED

SEDCO/BP 471



Full Dynamic Stationing in Water Depths to 6,000 feet for Worldwide Exploration, Operated by SEDCO, INC.


BRIDGE DECK ROOF
BRIDGE DECK
HELIPORT
GENERAL PROFILE


MAIN DECK
SECOND DECK
HOLD DECK
INNER BOTTOM

SEDCO/BP 471

Sample Load for a Two Well Program (90 Days)

Wellhead and Guidance Equipment

3	30" wellheads and extensions	13 st
3	$16\frac{3}{4}$" wellheads and extensions	20 st
3	Permanent Guide Bases	57 st
3	Temporary Guide Bases	10 st
		100 st

Casing

400 ft	30" Conductor	310 lb/ft	62 st
2,000 ft	20" Casing	94 lb/ft	94 st
7,000 ft	$13\frac{3}{8}$" Casing	68 lb/ft	238 st
18,000 ft	$9\frac{5}{8}$" Casing	47 lb/ft	423 st
25,000 ft	7" Casing	29 lb/ft	362 st
			1,179 st

Drill Pipe

15,000 ft	19.5 lb/ft	5" Grade E	146 st
6,000 ft	19.5 lb/ft	5" S 135	59 st
10,000 ft	15.5 lb/ft	$3\frac{1}{2}$" Grade E	78 st
30 Joints of "Heviwate" Drill Pipe			23 st
			306 st

Drill Collars

6	$9\frac{1}{2}$" Drill Collars	20 st
28	8" Drill Collars	63 st
6	8" Drill Collars with $3\frac{1}{2}$" Bore	13 st
48	$6\frac{1}{2}$" Drill Collars	66 st
24	$4\frac{3}{4}$" Drill Collars	18 st
		180 st

Riser

60	50 ft Joints of Buoyed Riser	422 st
27	50 ft Joints of Unbuoyed Riser	112 st
	Various Pup Joints	12 st
2	Telescopic Joint	28 st
		514 st

B.O.P. Stacks

2	$16\frac{3}{4}$ 10,000 psi W.P. Blowout Preventers	330 st
		330 st

Mud and Cement

5250 cu ft Cement at 94 lb/cu ft	242 st
3850 cu ft Bentonite at 60 lb/cu ft	116 st
4200 cu ft Barite at 135 lb/cu ft	284 st
7500 cu ft Sack Material	281 st
	923 st

Tank Storage

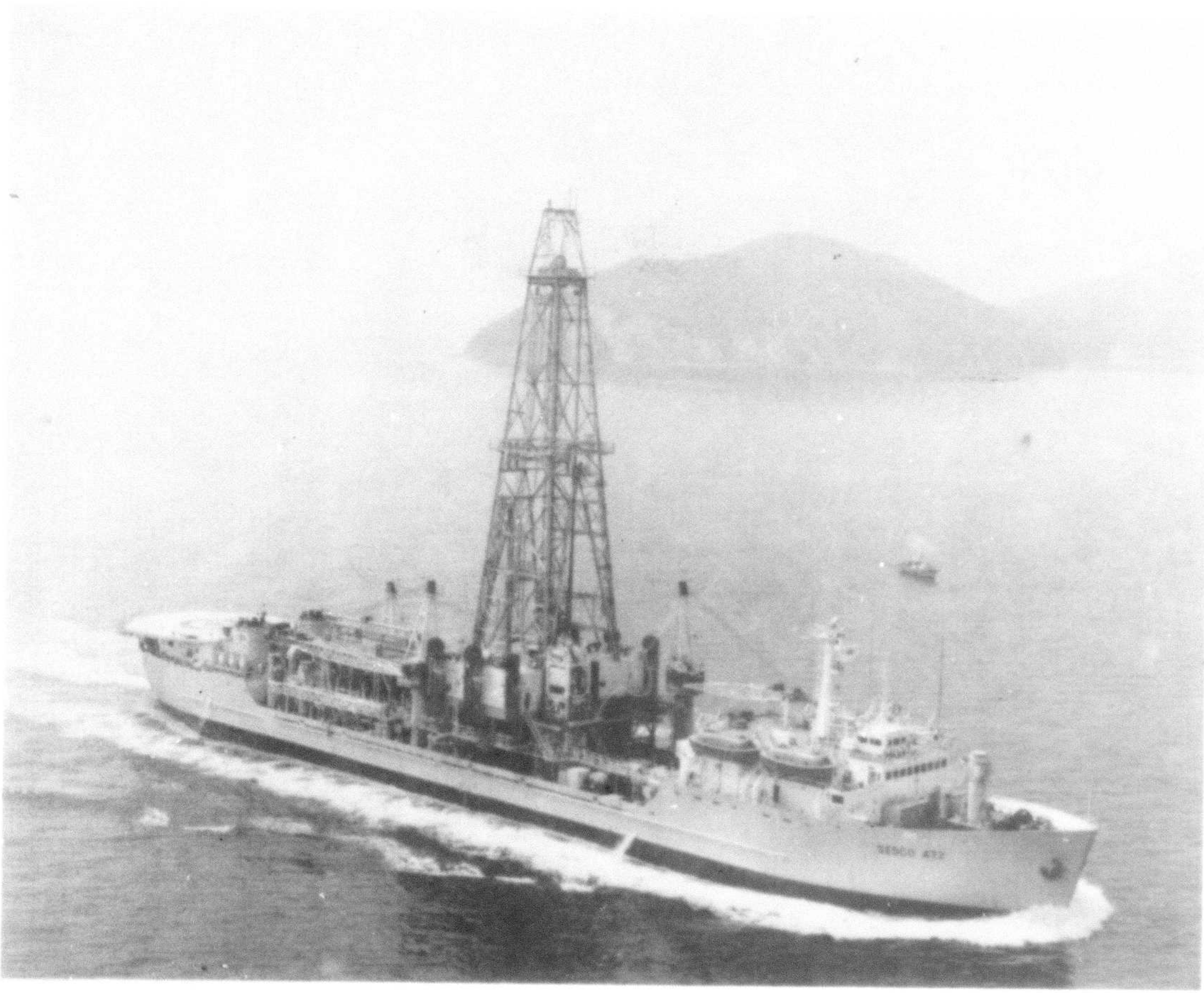
Fuel and Lube Oil	3,079 st
Salt Water Ballast	614 st
Drill Water	1,862 st
Potable Water	150 st
	5,705 st

Miscellaneous

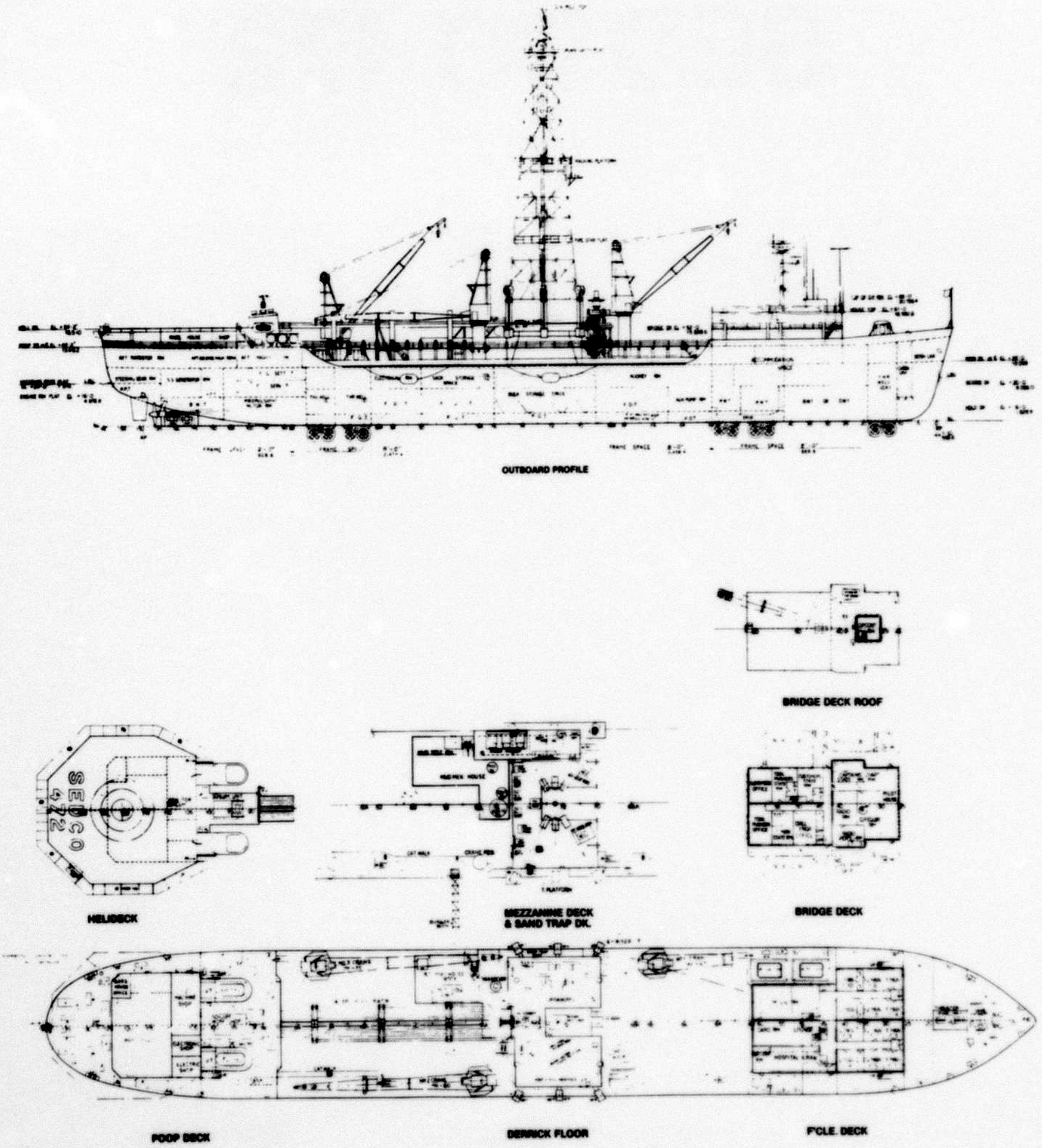
Provisions	30 st
Personnel and Effects	25 st
Various Tools	180 st
	235 st
Total Load	**9,532 st**
Total Displacement	**18,431 st**

SEDCO, INC.

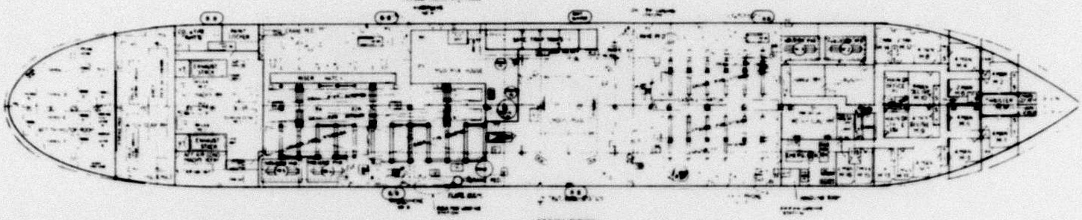
SEDCO 472



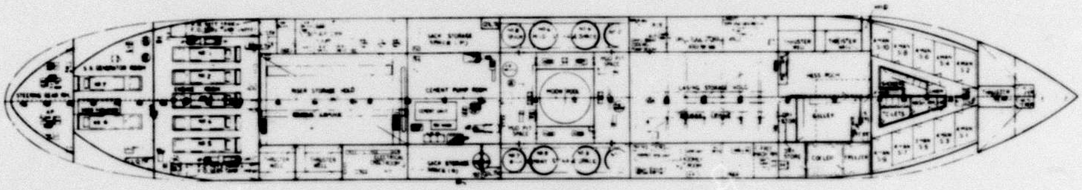
Full Dynamic Stationing in Water Depths to 6,000 feet for Worldwide Exploration, operated by SEDCO, INC.



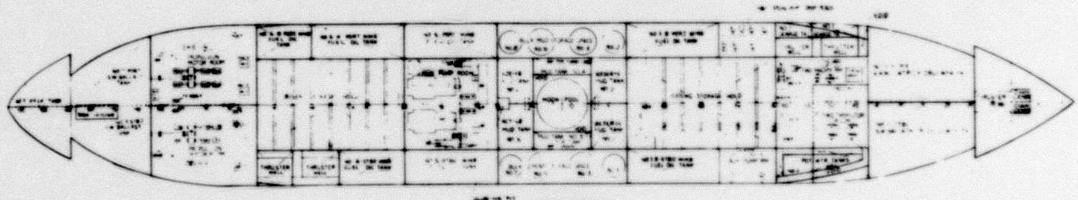
OUTBOARD PROFILE
BRIDGE DECK ROOF
SEDCO 472
HELIDECK
MEZZANINE DECK & SAND TRAP DK.
BRIDGE DECK
POOP DECK
DERRICK FLOOR
F'CLE. DECK



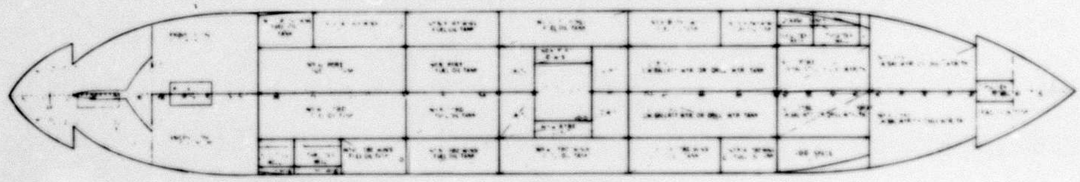
MAIN DECK



SECOND DECK



HOLD DECK



INNER BOTTOM

SEDCO 472

Sample Load for a Two Well Program (90 Days)

Wellhead and Guidance Equipment

3	30" wellheads and extensions	13 st
3	16¾" wellheads and extensions	20 st
3	Permanent Guide Bases	57 st
3	Temporary Guide Bases	10 st
		100 st

Casing

400 ft	30" Conductor	310 lb/ft	62 st
2,000 ft	20" Casing	94 lb/ft	94 st
7,000 ft	13⅜" Casing	68 lb/ft	238 st
18,000 ft	9⅝" Casing	47 lb/ft	423 st
25,000 ft	7" Casing	29 lb/ft	362 st
			1.179 st

Drill Pipe

15,000 ft	19.5 lb/ft	5" Grade E	146 st
6,000 ft	19.5 lb/ft	5" S 135	59 st
10,000 ft	15.5 lb/ft	3½" Grade E	78 st
30 Joints of "Heviwate" Drill Pipe			23 st
			306 st

Drill Collars

6	9½" Drill Collars	20 st
28	8" Drill Collars	63 st
6	8" Drill Collars with 3[illegible]" Bore	13 st
48	6½" Drill Collars	66 st
24	4¾" Drill Collars	18 st
		180 st

Riser

60	50 ft Joints of Buoyed Riser	422 st
27	50 ft Joints of Unbuoyed Riser	112 st
	Various Pup Joints	12 st
2	Telescopic Joint	28 st
		574 st

B.O.P. Stacks

1	16¾ 10,000 psi W.P. Blowout Preventers	**207 st**
		207 st

Mud and Cement

5250 cu ft Cement at 94 lb/cu ft	242 st
3850 cu ft Bentonite at 60 lb/cu ft	116 st
4200 cu ft Barite at 135 lb/cu ft	284 st
7500 cu ft Sack Material	281 st
	923 st

Tank Storage

Fuel and Lube Oil	3,079 st
Salt Water Ballast	614 st
Drill Water	1,862 st
Potable Water	150 st
	5.705 st

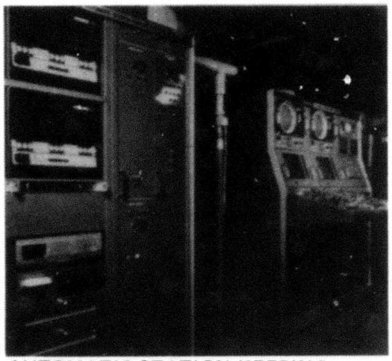
Miscellaneous

Provisions	30 st
Personnel and Effects	25 st
Various Tools	180 st
	235 st
Total Load	**9,409 st**
Total Displacement	**18,097 st**

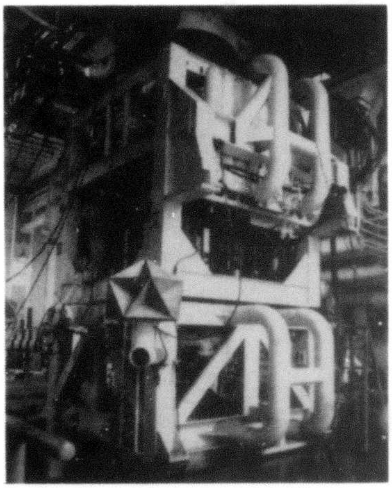
MARINE DRILLING, S.A.

S-709

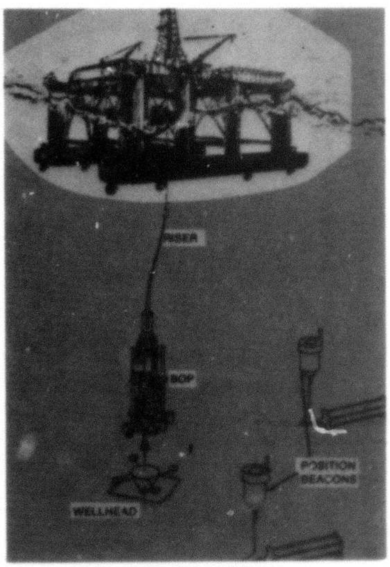
Full Dynamic Stationing in Water Depths to 6,000 feet for Worldwide Exploration, operated by SEDCO, INC.



AUTOMATIC STATION KEEPING



10,000 PSI BLOWOUT PREVENTER



NO GUIDELINES REQUIRED

Principal Chara

MAJOR DIMENSIONS

Lower Hulls (Two)

Length Overall	295 Ft.
Width Overall	245 Ft.
Depth	21 Ft.
Width	50 Ft.

Stability Columns

Four Corners, Diameter	30 Ft.
Four Intermediate, Diameter	18 Ft.

Main Deck

Length Overall	231 Ft.
Width Overall	197 Ft.

Heights

Keel to Main Deck	112 Ft. 6 in.
Main Deck to Helicopter Deck	20 Ft.
Main Deck to Pipe Rack Deck	17 Ft.
Main Deck to Derrick Floor	37 Ft.

Drafts

Normal Transit Draft	21 to 26 Ft.
Operating Draft	70 to 80 Ft.
Minimum Survival Draft	42 Ft.

Weights

Lightship Weight	14,917 S.T.
Lightship Center of Gravity	71.2 Ft. Above Keel

STORAGE CAPACITIES

Hull Compartments

TYPE	TOTAL CAPACITY
Ballast Tanks	62,200 bbls.
Fuel Oil Tanks	12,700 bbls.
Drill Water Tanks	5,800 bbls.
Total Displacement of Lower Hulls	16,905 S.T.
Total Displacement at 80 Ft. Draft	25,110 S.T.

Deck Tanks and Storage

TYPE	
Active Mud Tanks	1,000 bbls.
Reserve Mud Tanks	1,000 bbls.
Bulk Cement Storage Pods	1,600 cu. ft.
Bulk Barite Storage Pods	1,600 cu. ft.
Pipe Rack Areas Available	13,500 sq. ft.
Sack Storage Area	1,800 sq. ft.

Column Tanks (18-ft. dia. colu ns)

TYPE
Bulk Barite Stora e Pods
Bulk Cement Storage Pods
Bulk Gel Storage Pods

Column Tanks (30-ft. dia. colu ns)

TYPE
Potable Water (Port Fwd.)
Reserve Mud (Aft, P/S)

Deck Load Capacity
(Column Tanks Included)

EQUIP MENT

Engine House
1 – 550 KW Generator
7 – 500 KW G erators
2 – Hot Wate
2 – Steam G
9 – ir Comp
2 – resh W
1 – H.P. Air Compresso

Switchgear Room
416 V and 4 Switchgea
500 KW Auxi Tr sforme
8 – hruster
2 – 3 Bay Th Co versio Pow r Ma System

Dynamic Positioning
Hon ywell St ion K (ASK) Sy

Mud House
– 700 HP Pumps
1 – 350 KW En ne-G
– ementi

Characteristics

ks
colu ns)

e Stor e
9,900 cu. ft.

ent
Pods 4,400 cu. ft.

Pods 4,400 cu. ft.

ks
colu ns)

ater
d.) 1,180 bbls.
ud
2,340 bbls.

Capacity
anks
3,200 S.T.

QUIPMENT

e 1 – 550 KW Engine Generator
7 – 500 KW Engine Generators
2 – Hot Water Boilers
2 – Steam Generators
9 – ir Compressors
2 – resh Water Makers
1 – H.P. Air Compressor

Room 16 and 480V **Switchgear**
500 KW Auxiliary Tr sformer
8 – hruster Starters
2 – 3 Bay Thyrister DC **Co version Units**
Po r Management System

g **Hon well Automatic St ion Keeping (ASK) System**

– 00 HP Mud **Pu ps**
1 – 350 KW Emergency **En ne-Generator**
– ementing System

1 — Mud Solids Removal System
1 — Bulk Air Compressor

Pipe Racks Mud House Roof — 1000 T of Drill Pipe, Casing and Drill Collars
Main Deck — 800 T of Riser Pipe

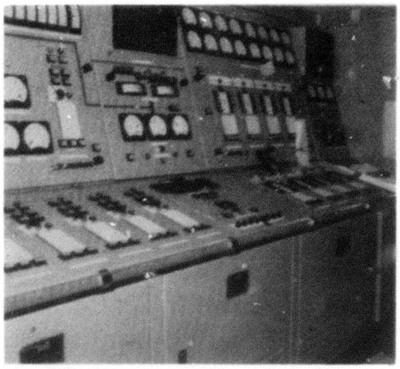
Quarters 2 Decks of Accommodations
14 Men on Upper Deck
80 Men on Main Deck

Heliport For Sikorsky S-61 Wheeled Helicopter

Revolving Cranes 2 — 45 T Capacity at 50 Ft. Radius, 120 Ft. Booms

Anchoring System 8 — 30,000 lb. LWT Anchors
8 — 500 Kip Capacity Anchor Windlasses
8 — 5000 Ft. Lengths, 3 in. Diameter, Stud Link Chain
8 — Hinged Fairleads
4 — Anchor Racks Above Water Level When Floating on The Hulls (2 Anchors Each Rack).

Drilling Area Drawworks for 25,000 Ft. Hole Depth
Drilling Mast — 160 Ft. High with Heave Compensator — Hook Capacity 1,100,000 lb. Compensating Capacity 400,000 lb. Setback Capacity 600,000 lb.
2 — 16¾ in., 10,000 psi Blowout Preventers
Subsea Controls Multiplex Control, 100% Redundancy
Riser — 4,000 Ft., 18-5/8 in. Integral with Buoyancy

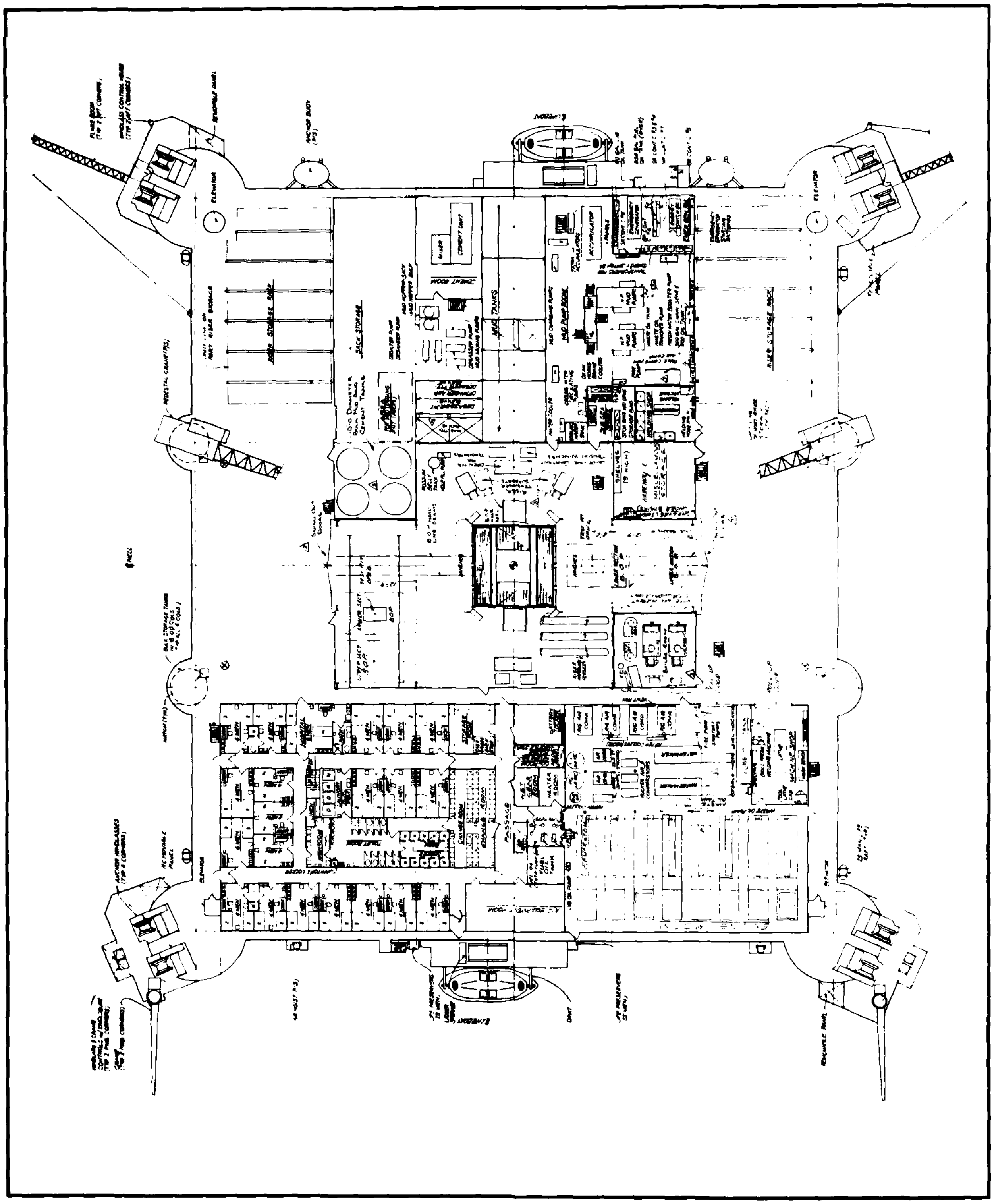


POWER MANAGEMENT SYSTEM

2,500 HP AZIMUTHING THRUSTER

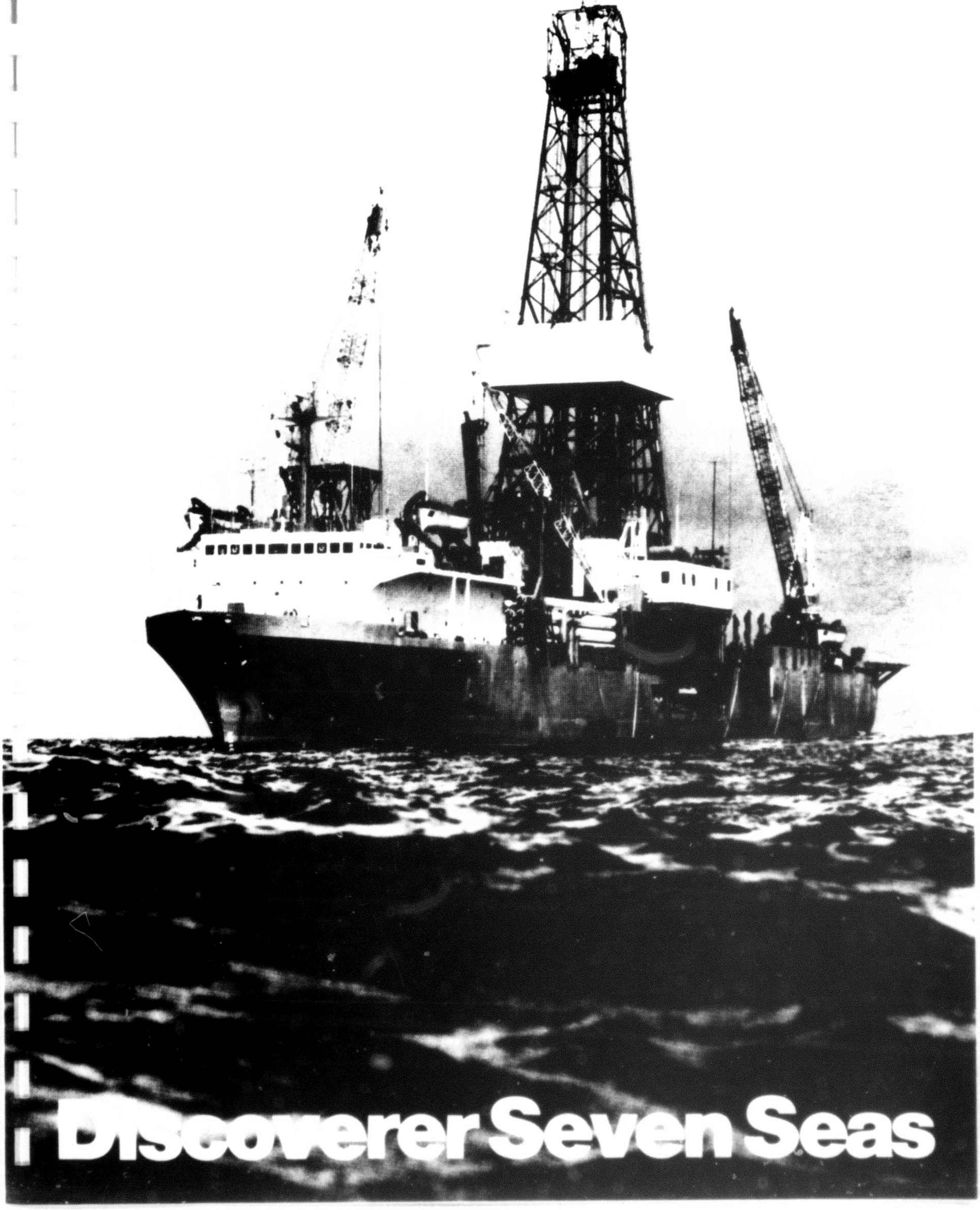
Re-Entry — Thru Drill Pipe TV/Sonar
Riser Tension — (12) 80,000 lb. Units
2 — 65 T Capacity Travelling Bop Bridge Cranes

Lower Hulls 8 — 2500 HP Azimuthing Thrusters
4 — 2500 GPM Ballast Pumps



S-709 MAIN DECK ARRANGEMENT

SONAT OFFSHORE DRILLING



DISCOVERER SEVEN SEAS
SELF-PROPELLED DYNAMICALLY POSITIONED DRILLSHIP

Rated Drilling Depth: 25,000 feet

Principal Particulars

Length Between Perpendiculars ....486 feet
Length Overall ....534 feet
Beam Overall ....80 feet
Hull Depth ....32 feet
Draft, Drilling ....24 feet 9 inches
Draft at Loadline ....24 feet 9 inches
Lightship Displacement ...12,708 long tons
Moon Pool ....26 feet diameter
Propulsion ....Twin propellers, 15 ft. 6 in. diameter, powered by eight (8) 2,000 hp GE CD9664 D.C. motors, providing a total input of 16,000 hp to twin Falk marine reduction gears (5.85 to 1 ratio)
Calm Water Speed ....14 knots

Regulatory Body Classification

American Bureau of Shipping (ABS) Ice Class 1A ✠ A1 ✠ AMS (E) (M) Mobile Drilling Unit for unrestricted worldwide ocean use
Lloyd's Register of Shipping

Regulatory Body Approvals

Meets United States Coast Guard standards
Panama and Suez Canal Tonnage Regulations
DEN Certificate of Fitness

Registry

Panama

Owner

Offshore International, S.A.

Capacities

Variable Load Capacity ...8,508 long tons
Tubular Storage ....400 ft. of 30 in. casing, 2,500 ft. of 20 in. casing, 8,000 ft. of 13⅜ in. casing, 20,000 ft. of 9⅝ in. casing, 15,000 ft. of 7 in. casing, 15,000 ft. of 4½ in. casing, 20,000 ft. of 2⅞ in. tubing, 23,000 ft. of 5 in. drill pipe
Bulk Mud ....12,000 cu. ft.
Bulk Cement ....4,800 cu. ft.
Sack Material ....22,000 cu. ft.
Liquid Mud ....Active: 1,800 bbls. Reserve: 2,400 bbls.
Diesel Fuel Oil ....22,297 bbls.
Drilling Water ....12,683 bbls.
Potable Water ....1,400 bbls.

Positioning

Dynamically positioned with six (6) 3,000 hp Bird Johnson controllable pitch right angle thrusters and twin main propulsion screws

Stationkeeping System ...Honeywell computerized Automatic Station Keeping system (ASK) using acoustic reference with hard wired ball joint angle indicators as backup sensors.

Drilling Equipment

Derrick ....Pyramid, 46 ft. x 54 ft. base x 170 ft. high, 665-ton GNC
Substructure ....54 ft. x 46 ft. x 39 ft., special design to allow storage of B.O.P. stack at deck level
Drawworks ....Continental Emsco C-3, type II, 3,000 hp with special grooving for 1¾ in. drilling line, Elmagco 7838 eddy current brake, TCB Crown-O-Matic
Rotary ....Continental Emsco 49½ in. with 3.96 to 1 reduction ratio powered by 750 hp motor
Prime Movers ....Six (6) EMD MD 20E9, 2,500 KW, 4,160 volt, 3-phase diesel electric generators and one (1) EMD MD 12E8, 1050 KW generator
Auxiliary Power ....One (1) Caterpillar D398 V-12 with 550 KW A.C. generator
Emergency Power ....One (1) Caterpillar D3304, 90 KW A.C. generator
D.C. Power Distribution ...GE SCR Modules, GE 752 drilling motors
Crown Block ....Pyramid, 665-ton capacity
Traveling Block ....Continental Emsco RA-60-6, six (6) 60 in. sheaves, 650-ton capacity
Hook ....Byron Jackson, 550 Dynaplex, 500-ton capacity
Swivel ....Continental Emsco LB-650, 650-ton nominal capacity, 471-ton API bearing rating capacity
Mud Pumps ....Two (2) Gardner Denver 1,600 hp PZ-11, 7 in. bore x 11 in. stroke
Degasser ....One (1) Wellco series 5200, 1,400 GPM capacity
Desander ....One (1) Pioneer S 3-12, 1,500 GPM capacity
Desilters ....Two (2) Pioneer T-16-4, each rated at 800 GPM
Shale Shaker ....One (1) Brandt dual tandem rated 1,600 GPM at 20/40 mesh and 800 GPM at 40/80 mesh based on 16.0 PPG mud

Operating Water Depth: **Minimum: 250 feet** **Maximum: 6,000 feet**

Centrifuge .... Pioneer decanting

Gas Detection System ..... Sieger 1300 for combustible and H_2S gas detection

Drill Pipe .... 13,000 ft. of 5 in. O.D., Grade "G" 19.50 lbs./ft., internally plastic coated drill pipe, 4½ in. I.F. connections; 7,000 ft. of 5 in. O.D., Grade "S-135" 19.50 lbs./ft. internally plastic coated drill pipe, 4½ in. I.F. connections

Motion Compensator ...... HSMC, 400,000 lbs. nominal operating capacity with pinned capacity of 1,200,000 lbs., 18 ft. nominal, 20 ft. maximum stroke

Riser Tensioners .... Ten (10) HSMC riser tensioners each rated at 100,000 lbs. pull, 65 in. sheaves

Pipe Handling System ..... Byron Jackson automatic 3-arm pipe handling system consisting of upper, intermediate and lower racker arms

Subsea and Well Control Equipment - H_2S Service

Riser .... 6,000 ft. of Regan FCF-8, 18¾ in. O.D., 0.688 in. wall thickness. Special 42 in. flotation cans, with adjustable air columns. All riser components suitable for H_2S service. Two (2) 50 ft. stroke Regan telescopic joints.

Diverter System .... Regan KFDS

Ram Preventers .... Two (2) Cameron type "U" double, 16¾ in., 10,000 psi w.p.

Annular Preventers .... Two (2) Hydril GL, 16¾ in., 10,000 psi w.p., two (2) Vetco H-4 hydraulic connectors and a special design Vetco flex joint in lieu of a standard pressure balanced ball joint

Spare BOP Stack .... Identical to equipment listed above

B.O.P. Control System ..... Stewart & Stevenson multiplex system with acoustic backup

Choke and Kill System ..... McEvoy 10,000 psi dual choke and kill manifold with McEvoy valves, two (2) McEvoy manually adjustable chokes, and two (2) IMCO remote controlled chokes

Auxiliary Equipment

Accommodations .... Air-conditioned quarters for 134 persons, galley and messroom facilities, five (5) berth hospital

Cranes .... Two (2) Bucyrus Erie MK-35 with 80 ft. booms and two (2) MK-60 with 120 ft. booms

Helicopter Deck .... 83 ft. x 83 ft. to accommodate Sikorsky S-61 helicopter, refueling station with 2,000 gal. storage tank

Navigation Equipment .... Complete high seas navigation equipment, environmental motion monitoring system and data recording

Communication Equipment .... Conquerer SD-1500 W SSB main transmitter, two (2) single sideband systems, Watch Receiver, one (1) marine VHF-FM radio, two (2) portable lifeboat radios, sound powered telephone, P.A. system

Water Distillation Units ... Two (2) waste heat Nirex units capable of 600 GPH

Waste Treatment .... Two (2) Sasakura-Trident T-100 units

Lifesaving Equipment ..... Four (4) 64-person diesel powered lifeboats, two (2) 25-person life rafts, two (2) 15-person life rafts, two (2) 6-person life rafts

Firefighting Equipment ... Firefighting system with seventy-nine (79) hydrants, seventy-eight (78) dry powder fire extinguishers, twenty-four (24) CO_2 fire extinguishers, seventy-six (76) bottle fixed CO_2 firefighting system, one (1) 640 gal. fixed foam system for helideck

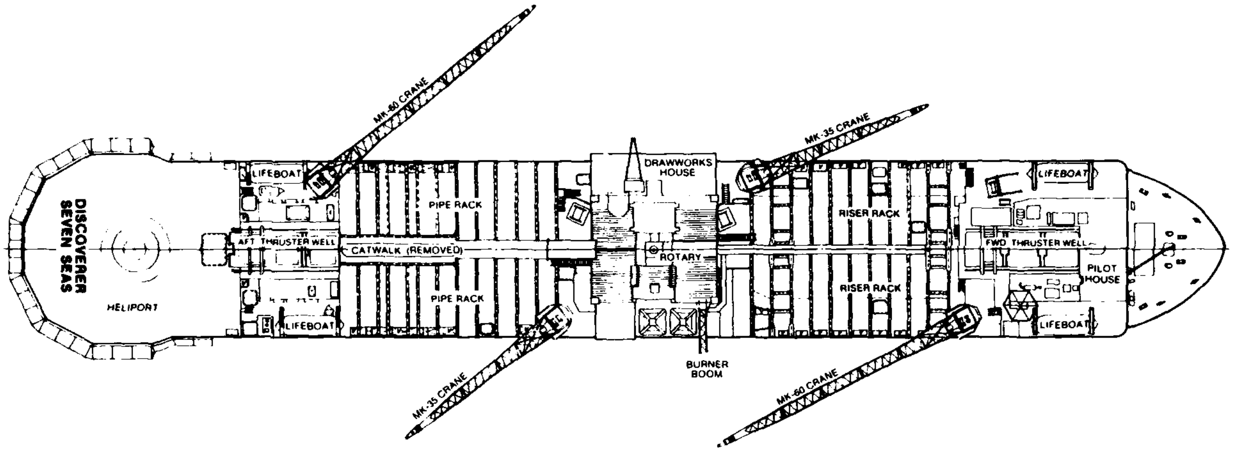
Special Features and Equipment

Guidelineless Re-entry .... Special down hole TV and outside-the-drill pipe TV with integrated acoustic beacon

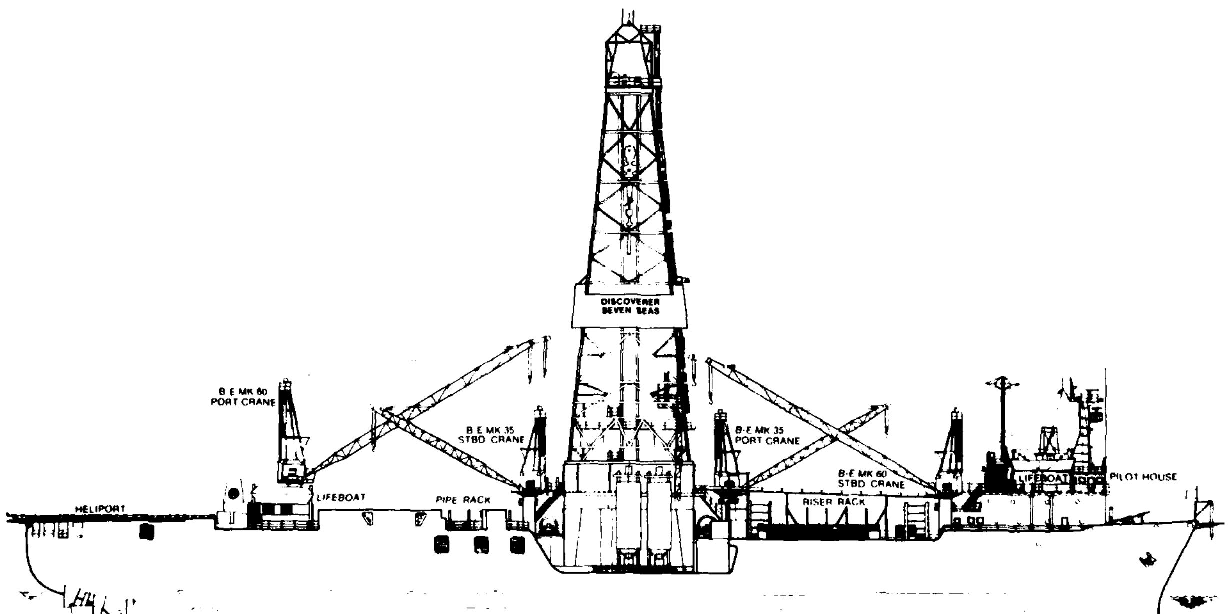
Emergency Disconnect System .... Parameters tied into alarms and automatic sequence will activate specified B.O.P. functions and disconnect the riser

Video Displays .... Current drilling parameters displays at four (4) locations on the vessel, B.O.P. TV and diver TV displayed at four (4) locations

Prime Power Management System .... Power distribution/allocation managed by Honeywell computer. Power requirements are predicted by continuous analysis of environmental conditions, and a control system adjusts engine loads accordingly. A limiting control loop prevents drilling machinery from using power required for station keeping. Should this occur, another prime mover is automatically started.

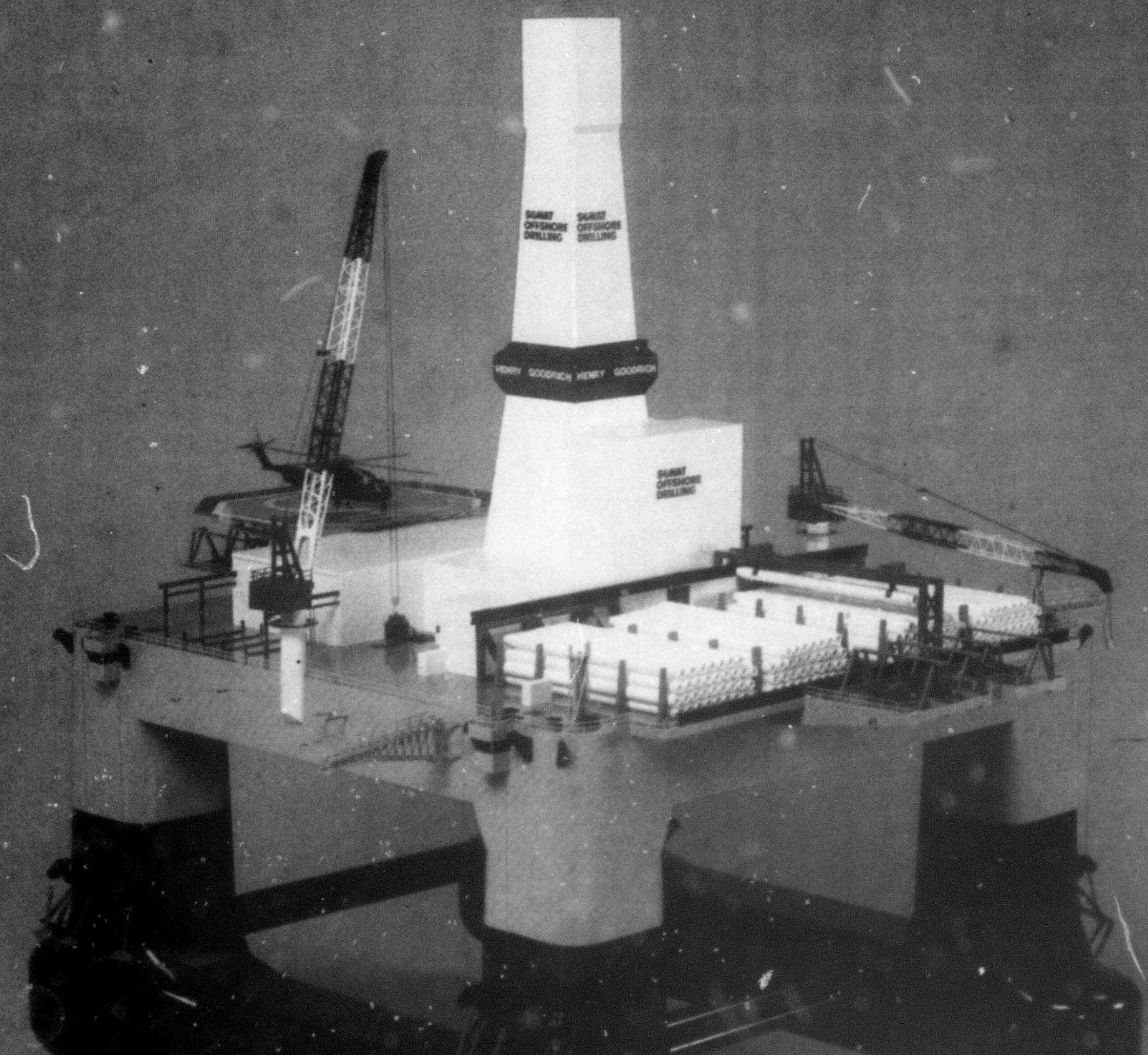


PLAN VIEW



OUTBOARD PROFILE

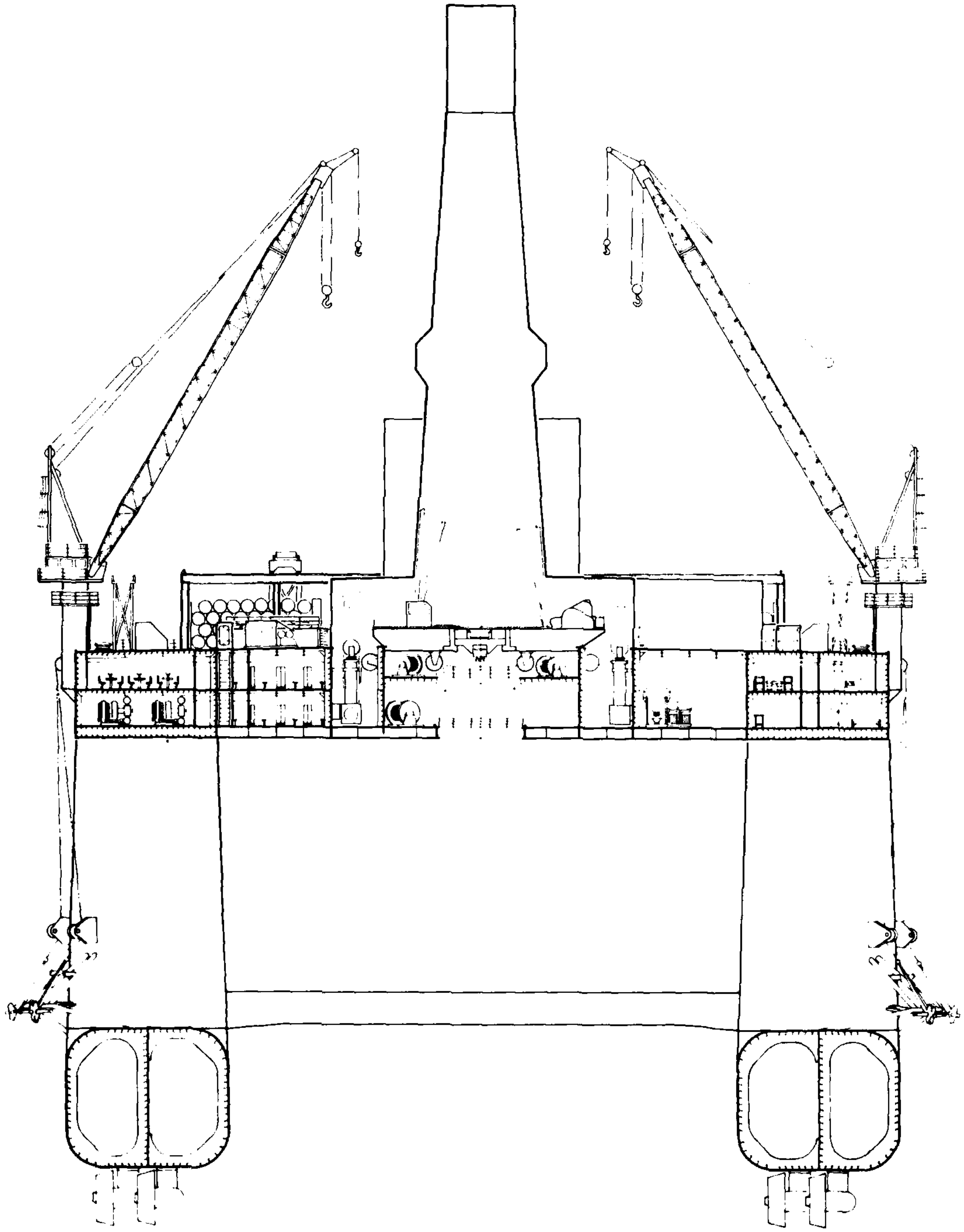
SONAT OFFSHORE DRILLING



Henry Goodrich

Semisubmersible for Severe Environment

SEVERE ENVIRONMENT SELF PROP



TRANSVERSE SECTION

Character

- Drilling de
- Ice strengt
- Operating
- Helideck to or Sikorsk
- Accommo
- Eight thru

Regulator

The **Henry G** States flag a pliance with t regulatory a

- United St
- Canadian
- Newfound torate
- Departme
- Norwegia Petroleum
- SOLAS

Environm

Wave Heigh
Wind Spee
Current

Water D

Condition

Sit on Bot
Chain Mod
Dynamical Positioned

F-PROPELLED SEMISUBMERSIBLE

Characteristics

- Drilling depth to 30,000 feet.
- Ice strengthened pontoons and columns.
- Operating draft of 29 meters (95 feet).
- Helideck to accommodate Boeing Chinook 234 or Sikorsky S-61.
- Accommodations for 110 to 150 persons.
- Eight thrusters.

Regulatory Bodies

The **Henry Goodrich** will be registered under United States flag and designed and constructed in compliance with the current regulations of the following regulatory agencies:

- United States Coast Guard
- Canadian Oil and Gas Lands *Administration*
- Newfoundland and Labrador Petroleum Directorate
- Department of Energy — United Kingdom
- Norwegian Maritime Directorate/ Norwegian Petroleum Directorate
- SOLAS

Environmental Conditions

Wave Height	33.5 meters
Wind Speed	115 knots
Current	2.5 knots

Water Depth Capability

Condition	Minimum (meters)	Maximum (meters)
Sit on Bottom	15	30
Chain Moored	92	610
Dynamically Positioned	92	3048+

Variable Capacities

Condition	Deck Load (metric tons)
Transit	5,000
Operating	5,000
Survival	5,000
Deck Icing	500

Maximum Storage Capacities

	Capacity	Unit
Drill Water	15,000	bbls.
Potable Water	4,000	bbls.
Fuel Oil	22,500	bbls.
Liquid Mud	5,500	bbls.
Bulk Mud	708	cu. meters
	25,000	cu. feet
Bulk Cement	283	cu. meters
	10,000	cu. feet
Sack Storage	12,000	sacks

Draft and Displacement

Condition	Draft (meters)	Displacement (metric tons)
Transit	12.7	33,100
Drilling	29	45,000
Survival	24	41,200

Principal Particulars

	Length (meters)	Breadth (meters)	Depth (meters)
Machinery Deck	75	75	8
Pontoons	96.4	15	13
Column Spacing	62	62	
	Pontoons (meters)	**Deck (meters)**	**Length (meters)**
Column Size	15	13	27

SEVERE ENVIRONMENT SELF-PROPELLED SEMISUBMERSIBLE

The Henry Goodrich represents a new generation of semisubmersible designed to meet the growing needs of the offshore industry in severe and arctic climates worldwide. The twin hull, self-propelled semisubmersible is a world class vessel, capable of drilling in any environment with a maximum of safety and personnel comfort.

The flexible operating characteristics of the unit include the ability to drill in three different modes: resting on the seabed in shallow water depths, conventionally moored in depths to 610 meters, or dynamically positioned in 3,050 meters of water.

A high variable capacity of 5,500 metric tons allows the Goodrich to move on location, drill and complete an average well without resupply.

ACCOMMODATIONS

The Henry Goodrich is designed with the utmost in crew safety and comfort in mind. Up to 150 people can be accommodated in one and two man rooms, each with a private bath. To insure high crew morale during long winter months in northern latitudes, crew facilities are designed to include a gymnasium, sauna, whirlpool, cinema, electronic game room, and four recreation rooms.

SAFETY EQUIPMENT

All safety equipment meets the latest requirements of national authorities. Lifeboat platforms are covered to prevent icing and to allow for timely, safe debarkation in extreme conditions.

Large warehouses and other storage areas are arranged to facilitate loading from either side of the platform.

CENTRALIZED CONTROL AREAS

The bridge, ballast control, and electrical control areas are centralized to minimize supervisory personnel requirements. In addition to modern navigation and communications equipment, the Goodrich employs a computer based monitoring and control system with capabilities ranging from power management and engine alarm monitoring to inventory control and satellite data transmission. Multiplexed control signals are transmitted over fiber optics to eliminate electrical interference.

POWER GENERATION

The rig power package comprises eight large bore, medium speed four cycle diesel engines with a combined generating capacity of approximately 37,400 KW. The engines operate well under minimum loads and have efficient fuel consumption rates, two essential characteristics for a dynamically positioned rig. The diesels are capable of burning heavy fuels or high sulfur fuels. Engine waste heat can be recycled in colder climates to generate steam, and assist in making potable and drill water, and preheating fuel.

MUD SYSTEM

The mud system will accommodate both water based and oil based muds. The state-of-the-art system includes provisions for five shale shakers, two centrifuges, and three slush pumps. Enclosed mud pits can handle 5,500 barrels of liquid mud.

BOP HANDLING SYSTEM

The BOP house is arranged for two 18¾ inch, 15,000 psi guideline or guidelineless BOP's. The overhead handling equipment is designed to lift the BOP stack in one piece. A special moveable guide structure provides controlled recovery of the BOP through the splash zone to the drill floor. Because the stack is deployed through the drill floor, the integral rotary table and riser spider are mounted to skid quickly out of the way. Ten riser tensioners, with a total capacity of 1.6 million pounds, are enclosed to simplify winterization and maintenance problems. The riser rack can accommodate more than 10,000 feet of air can or syntactic foam riser in 75 foot joints.

MOORING SYSTEM

The platform mooring system employs vertical shaft type windlasses. This design allows the operator and all machinery to work below decks. Only the chain and wildcat are exposed to the outside environment.

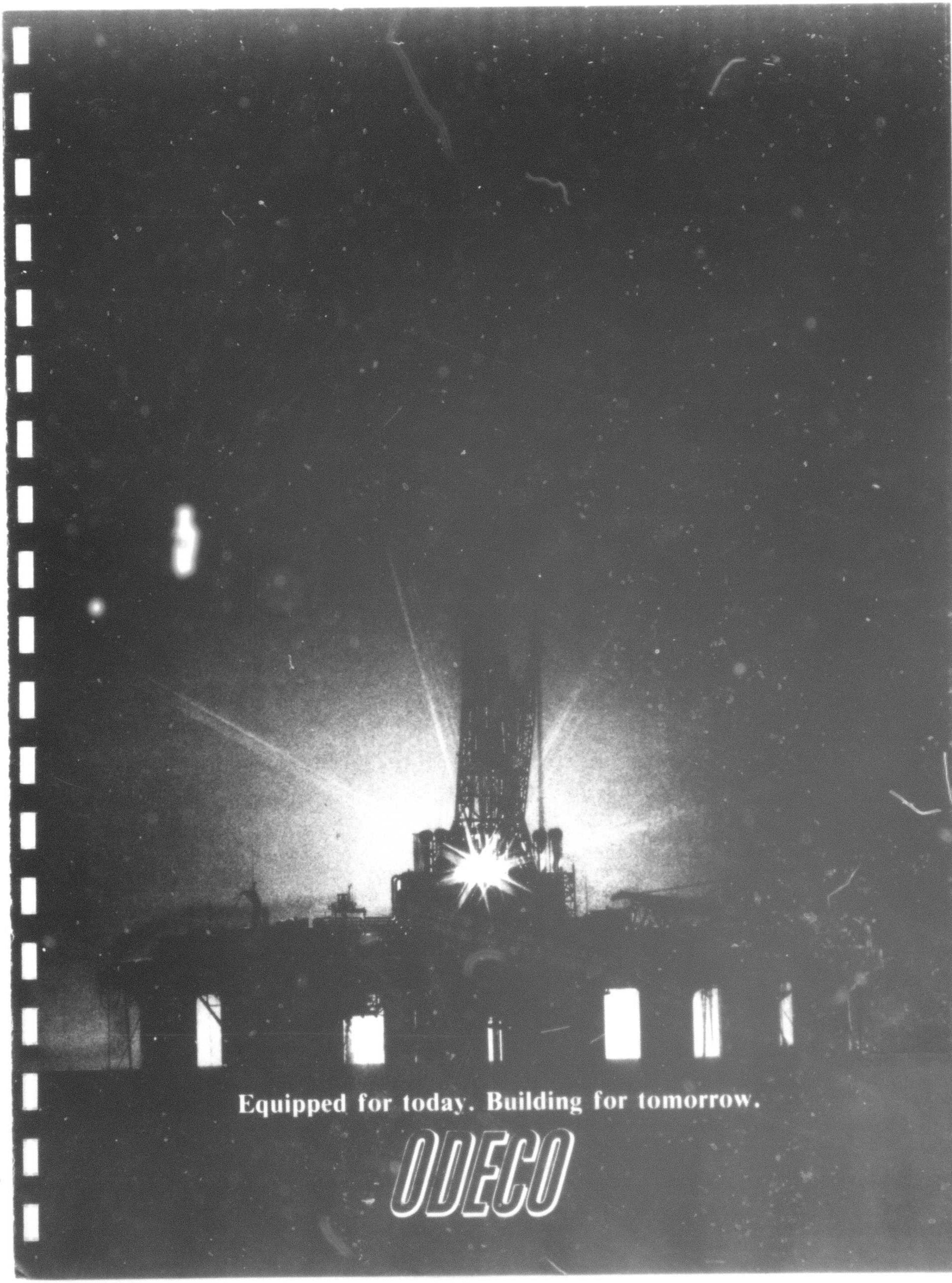
OTHER FEATURES

The drill floor, BOP enclosure, pipe rack and heavy tool store are located on the same deck level to allow easy access to the drill floor. Bridge cranes over both the riser and pipe racks insure safe handling of tubulars in severe sea states.

Sheltered access from below decks facilitate simple transfers of equipment and enable rig personnel to work efficiently in a shirt sleeve environment year round.

The deep draft and efficient design of the pontoons and columns provide exceptional motion characteristics in any sea state. Dynamic positioning capabilities and ice strengthened columns and pontoons enable the Goodrich to extend its drilling season in arctic regions.

The Henry Goodrich is under construction at Mitsui Engineering and Shipbuilding's Tamano Works, and will be delivered on July 18, 1985.


Equipped for today. Building for tomorrow.
ODECO

ODECO has pioneered the design and development of mobile offshore drilling equipment since its founding in 1953.

The company's first unit, the submersible drilling barge Mr. Charlie, was a significant contribution to a fledgling industry in 1954. In 1963 ODECO designed and built the Ocean Driller, the world's first column-stabilized semi-submersible, to meet the challenge of drilling in water depths beyond the capabilities of bottom-supported units. These units continue in service today.

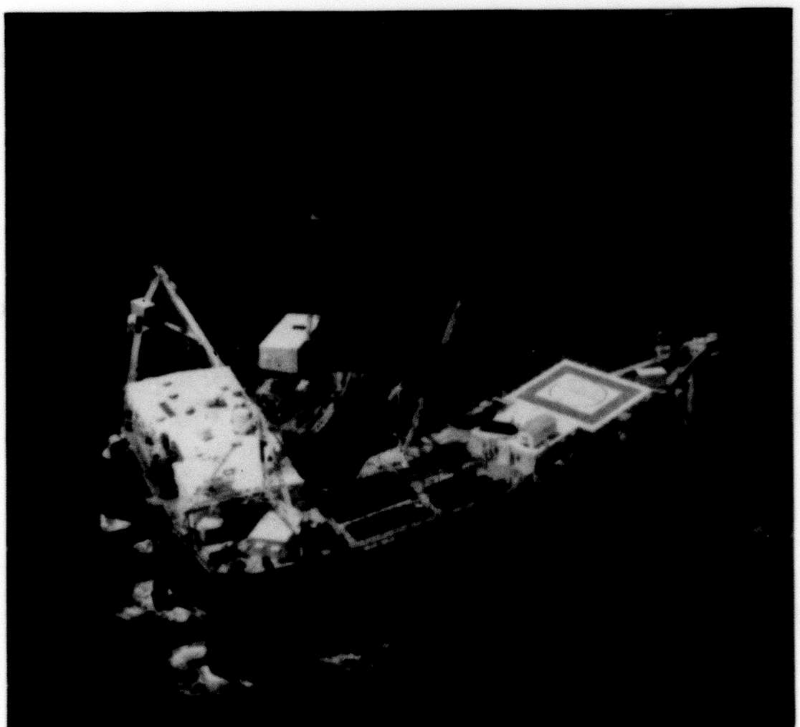
To satisfy the demand for improved transit time ODECO produced a series of parallel-hulled semi-submersibles which pioneered development of the North Sea. In 1971 ODECO made still another significant contribution to offshore rig development by designing and building the Ocean Prospector, the world's first semi-submersible to incorporate a propulsion-assist system.

Today ODECO operates one of the largest and most versatile fleets of offshore drilling units in the world. Balanced in class and geographic distribution, the company's 39 unit fleet consists of six submersibles, 16 semi-submersibles, 12 jack-ups, and five drillships, operating in most of the world's major offshore drilling theaters.

Drilling pioneers.

MR. CHARLIE

ers. Design innovators.



OCEAN DRILLER

ODECO's commitment to develop the technology to meet the challenges of a dynamic industry will insure a leadership role in the years ahead.

Reflecting this commitment the Company currently has under construction two severe environment semi-submersibles: a conventionally moored unit, at Sumitomo Heavy Industries in Oppama, Japan, and a dynamically positioned unit at Scott-Lithgow in Greenock, Scotland. These units are due to be delivered in early 1983 and mid-1984, respectively.

To meet the personnel demands of rapid expansion and technological advancement, ODECO has developed a comprehensive rig training and safety program. This program combines the benefits of in-house government-approved classroom instruction, involving rig floor simulation equipment and specifically designed text, with on-the-job training administered by supervisory personnel and industrial relations representatives aboard the individual rigs. A series of outside schools provide further technical training for senior operations personnel.

In recent years ODECO has emerged as a significant energy producer with interests in oil and gas production in the Gulf of Mexico, offshore Gabon in West Africa, and in the North Sea. Company exploration programs are underway in these and other areas worldwide. Additionally, the company participates in the diving industry through its 50% ownership of Sub Sea International and in the insurance industry through Mentor Insurance Limited.

Ben Odeco/BNOC DP Semi

The dynamically positioned drilling unit currently under construction at Scott-Lithgow, Greenock, Scotland, is the first of a new generation of deep-water, severe environment semi-submersibles. The rig will be constructed and operated under a joint venture arrangement involving Ben Odeco Limited, a 50% owned ODECO company, and the British National Oil Corporation.

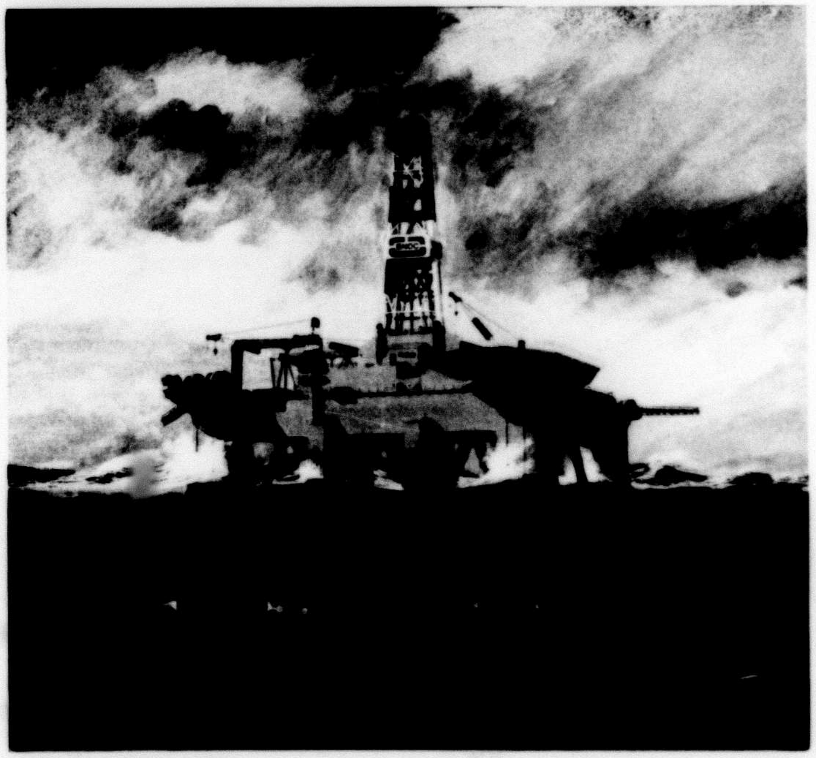
The vessel will be a 390′ long and 231′ wide, twin hull design with a 32,000 horsepower dynamic positioning system. The hull will consist of 2 ship-shape parallel pontoons which will enable a calm water transit speed of 10 knots. The rig will be a U.K. flagged vessel fully certified by the United Kingdom Department of Trade and Industry, and classed ABS-AMS ✠ A-1 for unrestricted worldwide ocean service. The rig's structure is designed to simultaneously withstand 100 knot winds, a 3-knot current and 110′ waves. The design criteria for continued operations in a D/P mode are the simultaneous effects of 65 knot winds, gusting to 81 knots, a 2-knot current and a 26′ significant wave height.

The rig will accommodate 110 men in its living quarters and will drill at the 81.5′ draft in water depths to 4,500′. It will also be equipped with a conventional mooring system consisting of 8 windlass units equipped with 5,500′ of 3¼″ special strength chain per windlass for operating in water depths to 1,500′. Drilling depth capability will be 25,000′. Three revolving cranes will service the main deck and peripheral areas and the rig will have a riser handling system to handle the marine riser in extreme wind and sea conditions.

The drilling equipment will include a derrick rated at 1,400,000 lbs. static hook load, a 4-speed, 3,000 horsepower drawworks assembly, a 49½″ 1,200 horsepower rotary, and 2 triplex mud pumps each driven by 2 - 850 horsepower DC motors. Well control equipment will include an 18¾″ x 15,000 psi WP BOP stack. Power will be supplied by 4 turbocharged 12 cylinder (7,415 continuous brake horsepower) engines and 2 turbocharged 6 cylinder (3,707 continuous brake horsepower) engines. Each of these engines is capable of operating on either diesel or heavy fuel oil. DC power for rig service is provided through an AC switchboard and SCR drive system. All equipment and systems are designed for service temperatures down to -20 degrees Centigrade.

CAPACITIES

Bulk Storage	26,200 cu. ft.
Liquid Mud	4,100 Bbls.
Sack Storage	22,300 Sacks
Heavy Fuel Oil	16,000 Bbls.
Diesel Fuel Oil	6,500 Bbls.
Drill Water	16,400 Bbls.
Potable Water	1,450 Bbls.



Delivery in mid-1984.

APPENDIX B

API DRILL PIPE/DRILL COLLAR DATA

Dimensions and Data

Dimensions[4] and Data On Tool Joint Pin and Box Threaded Connections

Nominal Size Inches	Type of Connection	Conn. O.D. Inches	Pin Bore: I.D. Inches	Pin Bore: Area Sq. Ins.	Pitch Diam. at Gage Point Inches	Thread Data: No. Threads per Inch	Thread Data: Taper per Foot on Diam. Inches	Thread Data: Thread Form	Theoretical Properties of Pin at Gage Point: Tension Area[1] Sq. Ins.	Theoretical Properties of Pin at Gage Point: Tensile Strength at Yield Point Lbs.	Theoretical Properties of Pin at Gage Point: Polar Section Modulus Cu. Ins.	O.D. of Pin at Base Inches	Diam. of Counterbore in Box at Shoulder Inches	Radial Width of Box Shoulder Before Beveling Inches	Radial Width of Box Shoulder Contact Face Inches
2⅜	Slimline H 90	3⅛	1 13/16[3]	3.126	2.578	3	1¼	Mod. H90	2.250	270,040	2.140	2.625	2 49/64	.242	.178
	NC26 (Int. Flush)	3⅜	1¾	2.405	2.668	4	2	V.038R (V .065)	2.614	313,680	2.444	2.876	2 15/16	.219	.164
2⅞	Slimline H 90	3⅞[2]	2.151	3.634	3.049	3	1¼	Mod. H90	3.206	384,675	3.622	3.096	3 19/64	.320	.242
	NC26 (Slim Hole)	3⅜	1¾	2.405	2.668	4	2	V.038R (V.065)	2.614	313,680	2.444	2.876	2 15/16	.219	.164
	NC31 (Int. Flush)	4⅛	2⅛	3.547	3.183	4	2	V.038R (V .065)	3.726	447,125	4.217	3.391	3 29/64	.336	.250
3½	Slimline H 90	4⅝	2 11/16	5.673	3.688	3	1¼	Mod. H90	4.450	533,950	6.231	3.735	3⅞	.375	.281
	NC31 (Slim Hole)	4⅛	2⅛	3.547	3.183	4	2	V.038R (V .065)	3.726	447,125	4.217	3.391	3 29/64	.336	.250
	Full Hole	5	2⅛	3.547	3.734	5	3	V .040	6.642	797,025	8.062	3.994	4 5/64	.477	.313
	XTRAHOLE	4¾	2⅛	3.547	3.604	4	2	V .065	5.623	698,800	6.932	3.812	3⅞	.438	.328
	NC38 (Int. Flush)	4¾	2 11/16	5.673	3.808	4	2	V.038R (V .065)	4.894	587,300	6.897	4.016	4 5/64	.336	.250
	H 90	5¼	2¾	5.940	3.929	3½	2	H90	5.526	663,125	8.013	4.000	4 3/16	.531	.398
4	Slim Hole	4⅝	2 7/16	4.666	3.604	4	2	V .065	4.703	564,425	6.084	3.812	3⅞	.375	.234
	NC40 (Full Hole)	5¼	2 13/16	6.213	4.072	4	2	V.038R (V.065)	5.930	711,600	8.812	4.280	4 11/32	.453	.336
	NC46 (Int. Flush)	6	3¼	8.296	4.626	4	2	V .038R (V .065)	7.510	901,150	12.843	4.834	4 29/32	.547	.407
	H 90	5½	2 13/16	6.213	4.304	3½	2	H90	7.613	913,475	11.572	4.375	4 7/16	.469	.352
4½	Full Hole	6	3	7.069	4.532	5	3	V .040	8.135	976,150	13.108	4.792	4⅞	.563	.422
	NC46 (XTRAHOLE)	6¼	3¼	8.296	4.626	4	2	V .038R (V .065)	7.510	901,150	12.843	4.834	4 29/32	.672	.407
	NC50 (Int. Flush)	6⅜	3¾	11.045	5.042	4	2	V .038R (V.065)	7.826	939,100	15.203	5.250	5 5/16	.531	.305
	H 90	6	3¼	8.296	4.638	3½	2	H90	7.818	938,150	13.411	4.709	4 25/32	.555	.414
5	NC50 (XTRAHOLE)	6⅜	3¾	11.045	5.042	4	2	V .038R (V.065)	7.826	939,100	15.203	5.250	5 5/16	.531	.305
5½	Full Hole	7	4	12.566	5.591	4	2	V .050	10.548	1,365,800	22.084	5.825	5 29/32	.547	.406
6⅝	Regular API	7¾	3½	14.756	5.758	4	2	V .050	14.939	1,792,600	29.065	5.992	6 1/16	.844	.633
	Full Hole	8	5	19.635	6.320	4	2	V .050	12.074	1,448,900	31.056	6.753	6 27/32	.578	.434

Connection types connected by brackets are interchangeable (i.e., will screw together without interference).

[1] Tensile yield point of material 120,000 psi
[2] 3⅝" O.D. optional
[3] 1.995 bore available for light weight pipe
[4] Tool joint O.D. and bore listed are recommended for grade E assemblies.

PIPE O.D.

PIPE I.D.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
4 1/2	13 75	12 74	3 958	New	3 600	4.500	4.1/2	234 0	342.0	306.0	360.0	432.0	540 0	16460	22450	31430	40410
				90	3 240	4.449	4.29/64	210.6	307.8	275.4	324.0	388.8	486 0	14800	20190	28260	36340
				80	2 880	4 397	4.25/64	187.2	273.6	244.8	288.0	345.6	432 0	13140	17910	25080	32250
	16 60	14 98	3.826	New	4 407	4.500	4 1/2	286.5	418.7	374.6	440.7	528.8	661.0	19580	26700	37370	48050
				90	3 966	4.437	4.7/16	257.8	376.8	337.1	396.6	475.9	594.9	17580	23970	33550	43140
				80	3 526	4.374	4.3/8	229.2	335.0	299.7	352.6	423.1	528.9	15610	21290	29800	38320
	18 10	16 44	3 754	New	4 836	4 500	4.1/2	314.3	459.4	411.1	483.6	580.3	725.4	21140	28830	40370	51900
				90	4 352	4 431	4.7/16	282.9	413.4	369.9	435.2	522.2	652.8	18980	25880	36230	46580
				80	3 869	4.361	4.23/64	251.5	367.6	328.9	386.9	464.3	580 4	16830	22950	32130	41310
	20 00	18 69	3 640	New	5.498	4.500	4.1/2	357.4	522.3	467.3	549.8	659.8	824.7	23450	31980	44770	57560
				90	4 948	4 421	4.27/64	321 6	470.1	420.6	494.8	593 8	742 2	21010	28660	40120	51580
				80	4 398	4.342	4.11/32	285.9	417.8	373.8	439.8	527.8	659 7	18640	25420	35590	45760
5	16 25	14 87	4 408	New	4 374	5.000	5	284.3	415.5	371.8	437.4	524.9	656.1	22270	30370	42510	54660
				90	3.937	4.944	4.15/16	255.9	374.0	334.6	393.7	472.4	590.6	20020	27290	38210	49130
				80	3 499	4 887	4.57/64	227.4	332.4	297.4	349.9	419.9	524.8	17760	24210	33900	43580
	19 50	17 93	4 276	New	5 275	5.000	5	342.9	501.1	448.4	527.5	633.0	791.2	26160	35670	49940	64210
				90	4.748	4.932	4-15/16	308.6	451.1	403.6	474.8	569.8	712 2	23480	32020	44830	57640
				80	4.220	4.864	4-55/64	274.3	400.9	358.7	422.0	506.4	633 0	20860	28440	39820	51180
5 1/2	21 90	19 81	4 778	New	5 828	5.500	5.1/2	378.8	553.7	495.4	582.8	699.4	874.2	32220	43940	61520	79100
				90	5.245	5.432	5.7/16	340.9	498.3	445.8	524.5	629.4	786.8	28940	39460	55240	71060
				80	4 662	5.363	5.23/64	303.0	422.9	396.3	466.2	559.4	699.3	25680	35020	49020	63030
	24 70	22 54	4 670	New	6 630	5.500	5-1/2	431.0	629.9	563.6	663.0	795.6	994.5	35950	49020	68630	88240
				90	5 967	5 423	5.27/64	387.9	566 9	507.2	596.7	716.0	895.0	32290	44030	61650	79280
				80	5 304	5.344	5.11/32	344.8	503.9	450.8	530.4	636 5	795 6	28620	39030	54640	70260
6 5/8	25 20	22 19	5 965	New	6 526	6.625	6.5/8	424 2	620.0	554.7	652.6	783.1	978 9	44850	61160	85630	110090
				90	5 873	6.562	6.9/16	381.7	557.9	449.2	587.3	704 8	881.0	40330	54990	76980	98990
				80	5.221	6 498	6.1/2	339.4	496.0	443.8	522.1	626.5	783.2	35790	48800	68320	87850

IMPORTANT NOTES:

- All listed strengths are calculated values, offered as a guide only, subject to the judgement of those in charge of operations

  It is recommended that reference be made to the latest developments in the API-AAODC Drill Pipe grading system and its influence on the design and use of new and used drill strings.

Note – Dinging has a more serious effect than wear on collapse resistance of used pipe

† The outside diameters have been calculated from the percentages of cross sectional area and are shown both in exact decimal and rounded to the closest 64th inch for convenience. Note that several measurements of OD should be made near the mid-point of lengths, since wear is greatest there. Internal wear (negligible) disregarded

‡ The pull listed is that exerted on the pipe. No allowance has been made for the weight of blocks, hook, lines, etc

▲ Pipe pulled to these values may be subject to a slight permanent stretch.

• These values, based upon minimum tensile strengths, are extreme emergency values which may part the string.

● Tentative - Grade G values listed are calculated on the basis of 105000 psi Minimum Yield, 120000 psi Average Yield and 120000 psi Minimum Tensile Strengths

Grade S values listed are calculated on the basis of 135000 psi Minimum Yield, 150000 psi Average *Yield and* 150000 *psi* Minimum Tensile Strengths.

■ Values shown are for pipe - modern drill pipe to tool joint connections are considered to have torque resistance equal to or greater than the *pipe body*

Shrink Thread, Spangweld and API Flashweld Drill Pipe

APPROXIMATE AVERAGE WEIGHT PER FOOT EQUIPPED WITH TOOL JOINTS

Internal Upset — Full Hole ♦

Drill Pipe Size OD (Inches)	Drill Pipe Weight Per Foot Nominal (Pounds)	Tool Joint Class	Tool Joint OD (Inches)	Wt. Per Foot* Range 2 (Pounds)	Wt. Per Foot* Range 3 (Pounds)
3-1/2	• 9.50	STD	▲ 4-5/8	10.6	10.1
	13.30	STD	4-5/8	13.9	13.5
		OPT	4-7/8	14.3	13.8
	15.50	STD	4-5/8	16.1	15.7
		OPT	4-7/8	16.4	15.9
4	• 11.85	STD	▲ 5-1/4	12.7	12.1
	14.00	STD	5-1/4	15.1	14.5
		OPT	5-1/2	15.5	14.8
4-1/2	• 13.75	STD	▲ 5-3/4	15.0	14.3
	16.60	STD	5-3/4	17.8	17.0
		OPT	6	18.2	17.3
		OPT	6-1/4	18.7	17.7
	20.00	STD	5-3/4	21.3	20.6
		OPT	6	21.7	20.9
		OPT	6-1/4	22.2	21.3
5-1/2	21.90	STD	7	24.0	22.9
		OPT	7-1/4	24.6	23.3
	24.70	STD	7	26.5	25.4
		OPT	7-1/4	27.1	25.9

Internal Upset — Extra Hole ♦ / Slim Hole ▲

Drill Pipe Size OD (Inches)	Drill Pipe Weight Per Foot Nominal (Pounds)	Tool Joint Class	Tool Joint OD (Inches)	Wt. Per Foot* Range 2 (Pounds)	Wt. Per Foot* Range 3 (Pounds)
Extra Hole ♦					
4-1/2	16.60	STD.	6	18	17.2
		OPT.	5-3/4	17.6	16.9
	20.00	STD.	6	21.4	20.7
		OPT.	5-3/4	21.0	20.4
5	• 16.25	STD.	▲ 6-1/4	17.6	16.9
	19.50	STD.	▲ 6-1/4	20.7	20.0
		OPT.	6-1/2	21.2	20.3
Slim Hole ▲					
2-7/8	10.40	STD.	3-3/8	10.4	10.2
3-1/2	13.30	STD.	4	13.4	13.1
		OPT.	4-1/8	13.4	13.1
	15.50	STD.	4	15.5	15.3
		OPT	4-1/8	15.6	15.3
4-1/2	16.60	STD	5	17.0	16.5
	20.00	STD.	5	20.5	20.0
5-1/2	21.90	STD.	6	22.9	22.1
		OPT.	5-3/4	22.4	21.7
	24.70	STD.	6	25.4	24.6
		OPT.	5-3/4	24.9	24.3

External Upset — Internal Flush ♦

Drill Pipe Size OD (Inches)	Drill Pipe Weight Per Foot Nominal (Pounds)	Tool Joint Class	Tool Joint OD (Inches)	Wt. Per Foot* Range 2 (Pounds)	Wt. Per Foot* Range 3 (Pounds)
2-7/8	• 6.85	STD.	▲ 4	7.1	6.8
	10.40	STD.	4-1/8	10.9	10.6
		OPT	4-1/4	11.0	10.7
		OPT	4-3/8	11.2	10.8
3-1/2	• 9.50	STD.	▲ 4-5/8	10.1	9.8
	13.30	STD.	4-3/4	13.8	13.4
		OPT.	5	14.2	13.7
	15.50	STD.	4-3/4	16.0	15.6
		OPT.	5	16.4	15.9
4	• 11.85	STD.	▲ 5-1/2	12.5	12.0
	14.00	STD.	5-3/4	15.6	14.9
		OPT.	6	16.0	15.2
4-1/2	• 13.75	STD.	▲ 6	14.5	13.9
	16.60	STD.	6-1/8	17.7	17.0
		OPT.	6-1/4	17.9	17.1
		OPT.	6-1/2	18.4	17.5
	20.00	STD.	6-1/8	21.2	20.5
		OPT.	6-1/4	21.4	20.7
		OPT	6-1/2	21.9	21.0

♦ The approximate weights shown, except items noted, vary less than 1% from the calculated values for Double Seal Shrink Thread, Spangweld and API Flashweld. Weights shown for noted items are as calculated.

• Tentative lightweight items and values.

▲ Spangweld only. Values shown are as calculated.

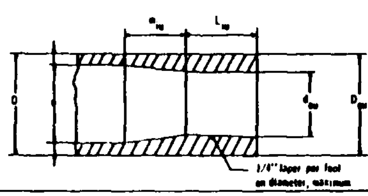
* Range 2: Based on lengths measured at 30'-0", shoulder to shoulder.
  Range 3: Based on lengths measured at 41'-0", shoulder to shoulder.

API Drill Pipe

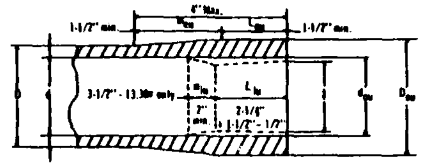
PIPE UPSET DIMENSIONS FOR WELD-ON TYPE TOOL JOINTS

Grades D and E

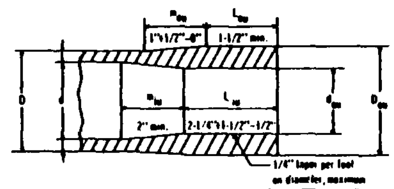
INTERNAL UPSET



EXTERNAL UPSET



EXTERNAL-INTERNAL UPSET



Pipe					Internal Upset					External Upset §			External-Internal Upset §		
Size D	Wt/Ft (Nominal)	Wall t	ID d	Wt/Ft Plain End (Calculated)	Weight Factor ■ e_w	OD +1/8Δ -1/32 D_{ou}	ID ± 1/16 d_{ou}	Length +1-1/2 -1/2 L_{iu}	Taper (Minimum) m_{iu}	Weight Factor ■ e_w	OD +1/8 -1/32 D_{ou}	ID ± 1/16 d_{ou}	Weight Factor ■ e_w	OD +1/8 -1/32 D_{ou}	ID ± 1/16 d_{ou}
Inches	Pounds	Inches		Pounds	Pounds	Inches		Inches		Pounds	Inches		Pounds	Inches	
2-3/8	* 4.85	.190	1.995	4.43	...	...	...	...	...	1.80	2.656	1.995	...	...	...
	6.65	.280	1.815	6.26	...	...	...	...	...	1.80	2.656	1.815	...	...	...
2-7/8	* 6.85	.217	2.441	6.16	2.80	2.875	1-7/8	1-3/4	...	2.40	3.219	2.441	...	...	...
	10.40	.362	2.151	9.72	3.20	2.875	1-5/16	1-3/4	1-1/2	2.40	3.219	2.151	...	...	...
3-1/2	* 9.50	.254	2.992	8.81	4.40	3.500	2-1/4	1-3/4	...	2.60	3.824	2.992	...	...	...
	13.30	.368	2.764	12.31	4.40	3.500	1-15/16	1-3/4	1-1/2	4.00	3.824	‡2.602	...	...	...
	15.50	.449	2.602	14.63	3.40	3.500	1-15/16	1-3/4	1-1/2	2.80	3.824	2.602	...	...	...
4	*11.85	.262	3.476	10.46	4.20	4.000	2-15/16	1-3/4	...	5.00	4.500	3.476	...	...	...
	14.00	.330	3.340	12.93	4.60	4.000	2-3/4	1-3/4	2	5.00	4.500	3.340	...	...	...
4-1/2	*13.75	.271	3.958	12.24	5.20	4.500	3-3/8	1-3/4	...	5.60	5.000	3.958	...	...	...
	16.60	.337	3.826	14.98	5.80	4.500	3-5/32	1-3/4	2	5.60	5.000	3.826	...	...	...
	20.00	.430	3.640	18.69	...	...	...	...	...	5.60	5.000	3.640	8.60	4.781	3.000
5	*16.25	.296	4.408	14.87	6.60	5.000	3-3/4	1-3/4	...	...	...	...	...	...	...
	19.50	.362	4.276	17.93	...	...	...	...	...	...	...	...	8.60	5.188	3-11/16
5-1/2	21.90	.361	4.778	19.81	...	...	...	...	...	...	...	...	10.60	5.563	4.000
	24.70	.415	4.670	22.54	...	...	...	...	...	...	...	...	9.00	5.563	4.000

* Tentative weight, applicable to grade E only.
Δ May be furnished with slight external upset within the tolerance shown.
■ Weight gain per piece over plain end piece weight due to end finish.

§ See individual illustrations for length dimensions and tolerances.
‡ Note that the 3-1/2" – 13.30 Lb. External Upset item has an Internal Upset contour as shown in illustration.

Double Seal Shrink Thread, Spangweld and API Drill Pipe

INTERNAL AND EXTERNAL UPSET

Properties—Based on Pipe Body

Size OD	Drill Pipe: Weight Per Foot, Nominal	Weight Per Foot, Plain End	Wall	Inside Dia.	Collapse – Resistance To External Pressure - Minimum: D/t Ratio	Grade D	Grade E	Grade G ▲	Grade S-135 ▲
Inches	Pounds	Pounds	Inches	Inches		Pounds Per Square Inch			
2 3/8	• 4 85	4 43	190	1 995	12 500	. . .	9380	13250	16560
	6 65	6 26	280	1 815	8 482	10140	13260	18720	23400
2 7/8	• 6 85	6 16	217	2 441	13 249	. . .	8900	12560	15700
	10 40	9 72	362	2 151	7 942	10730	14030	19810	24760
3 1/2	• 9 50	8 81	254	2 992	13 780	. . .	8580	12110	15140
	13 30	12 31	368	2 764	9 511	9170	12000	16940	21170
	15 50	14 63	449	2 602	7 795	10900	14260	20130	25160
4	• 11 85	10 46	262	3 476	15 267	. . .	7330	10310	12820
	14 00	12 93	330	3 340	12 121	7300	9650	14630	17030
4 1/2	• 13 75	12 24	271	2 958	16 605	. . .	6440	8920	10910
	16 60	14 98	337	3 826	13 353	6760	8830	12470	15590
	† 18 10	16 44	373	3 754	12 064	7410	9690	13680	17100
	20 00	18 69	430	3 640	10 465	8420	11020	15560	19450
5	• 16 25	14 87	296	4 408	16 892	. . .	6260	8640	10550
	19 50	17 83	362	4 276	13 812	6550	8560	12090	15110
5 1/2	21 90	19 81	.361	4 778	15 235	5750	7350	10350	12870
	24 70	22 54	415	4 670	13 253	6800	8890	12560	15700
6 5/8	25 20	22 19	330	5 965	20 076	3840	4670	6160	* 6430

Size OD	Nominal	Tension – Load At Minimum Yield Strength: Area A	Grade D	Grade E	Grade G ▲	Grade S-135 ▲	Internal Pressure – Resistance At A Fibre Stress Equal To 87-½% of Minimum Yield Strength: t/D Ratio	Grade D	Grade E	Grade G ▲	Grade S-135 ▲
Inches	Pounds	Sq In	1000 of Pounds					Pounds Per Square Inch			
2 3/8	• 4 85	1 304	. . .	98	137	176	08000	. . .	10500	14700	18900
	6 65	1 843	101	138	194	249	11789	11350	15470	21660	27850
2 7/8	• 6 85	1 812	. . .	136	190	245	.07548	. . .	9900	13870	17830
	10 40	2.858	157	214	300	386	.12591	12120	16530	23140	.9750
3 1/2	• 9 50	2.590	. . .	194	272	350	07257	. . .	9530	13340	17140
	13 30	3.621	199	272	380	489	.10514	10120	13800	19320	24840
	15 50	4 304	237	323	452	581	12829	12350	16840	23570	30310
4	• 11 85	3 077	. . .	231	323	415	.06550	. . .	8590	12040	15470
	14 00	3 805	209	285	400	514	08250	7940	10830	15160	19500
4 1/2	• 13 75	3 600	. . .	270	378	486	06022	. . .	7900	11070	14230
	16 60	4 407	242	331	463	595	07489	7210	9830	13760	17690
	† 18 10	4 836	266	363	508	653	08289	7980	10880	15230	19580
	20 00	5 498	302	412	577	742	.09556	9200	12540	17560	22580
5	• 16 25	4 374	. . .	328	459	591	05920	. . .	7700	10880	13980
	19 50	5 275	290	396	554	712	.07240	6960	9500	13300	17100
5 1/2	21 90	5 828	321	437	612	787	06564	6320	8620	12060	15500
	24 70	6 630	365	497	696	895	.07545	7260	9900	13860	17820
6 5/8	25 20	6 526	359	489	685	881	04981	4800	6540	9150	11770

Size OD	Nominal	Torsion – Resistance At Minimum Yield Strength: Grade D	Grade E	Grade G ▲	Grade S-135 ▲	Moment of Inertia I	Section Modulus S = I/Y	Radius of Gyration R = √(I/A)	Polar Moment of Inertia J = 2I	Polar Section Modulus Z = 2S
Inches	Pounds	Foot - Pounds								
2 3/8	• 4 85	. . .	4130	5780	7430	784	660	.775	1.568	1.321
	6 65	3970	5420	7580	9750	1.029	867	.747	2 058	1.733
2 7/8	• 6 85	. . .	7000	9810	12610	1.611	1.121	.943	3 222	2.241
	10 40	7340	10010	14020	18020	2.303	1.602	.898	4.606	3 204
3 1/2	• 9 50	. . .	12060	17160	22070	3.432	1.961	1 151	6.865	3.923
	13 30	11790	16080	22510	28940	4 501	2.572	1.115	9 002	5.144
	15 50	13400	18270	25580	32890	5 116	2.923	1.090	10 232	5.847
4	• 11 85	. . .	16880	23630	30380	5 400	2 700	1 325	10.800	5.400
	14 00	14800	20180	28250	36320	6.458	3.229	1 303	12.915	6.458
4 1/2	• 13 75	. . .	22450	31430	40410	8 082	3.592	1.498	16.164	7.184
	16 60	19580	26700	37370	48050	9.611	4 271	1 477	19.221	8 543
	† 18 10	21150	28830	40370	51900	10 380	4 610	1 465	20.760	9 227
	20 00	23450	31980	44770	57560	11 512	5.116	1.447	23 023	10.232
5	• 16 25	. . .	30370	42510	54660	12.147	4.859	1.666	24 294	9.718
	19 50	26160	35470	49940	64210	14 269	5.708	1 645	28 538	11 415
5 1/2	21 90	32220	43940	61520	79100	19 335	7 031	1.821	38 670	14 062
	24 70	35950	49020	68630	88240	21.571	7.844	1.804	43 141	15 688
6 5/8	25 20	44850	61160	85630	110090	32 416	9 786	2 229	64 831	19.572

• Tentative API Weight ▲ Non API Grade † Discontinued API Weight * Elastic Collapse

Make-up Torque for Tool Joint Connections

Recommended Minimum OD* and Make-up Torque of Weld-on Type Tool Joints Based on Torsional Strength of Box and Drill Pipe

DRILL PIPE DATA			NEW TOOL JOINT DATA					PREMIUM CLASS			CLASS 2		
Nom. Size in.	Nom. Wt. lb/ft	Type Upset and Grade	Conn.	New OD in.	New ID in.	Torsional Yield Strength ft-lb	Make-Up Torque ft-lb	Min. OD Tool Joint in.	Min. Box Shoulder With Eccentric Wear in.	Make-Up Torque For Min. OD Tool Joint ft-lb	Min. OD Tool Joint in.	Min. Box Shoulder With Eccentric Wear in.	Make-Up Torque For Min. OD Tool Joint ft-lb
5	19.50	I.E.U. 75	API NC50(X.H.)‡	6-3/8	3-3/4	37700	18900	5-7/8	15/64	15800	5-25/32	3/16	13300
	19.50	I.E.U. 95	API NC50(X.H.)‡	6-3/8	3-1/2	44900	22400	6-1/32	5/16	20200	5-29/32	1/4	16700
	19.50	I.E.U. 105	API NC50(X.H.)‡	6-1/2	3-1/4	51400	25800	6-3/32	11/32	21900	5-31/32	9/32	18400
	19.50	I.E.U. 135	API NC50(X.H.)‡	6-5/8	2-3/4	63400	31800	6-5/16	29/64	28400	6-1/8	23/64	22900
	19.50	I.E.U. 135	5-1/2 F.H.	7-1/4	3-1/2	72500	36300	6-3/4	3/8	288[illegible]	6-19/32	19/64	23400
	25.60	I.E.U. 75	API NC50(X.H.)‡	6-3/8	3-1/2	44900*	22400	6-1/32	5/16	20200	5-29/32	1/4	16700
	25.60	I.E.U. 75	5-1/2 F.H.	7	3-1/2	62200	31500	6-1/2	1/4	20200	6-3/8	3/16	16100
	25.60	I.E.U. 95	API NC50(X.H.)‡	6-1/2	3	57000	28600	6-3/16	25/64	24700	6-1/32	5/16	22000
	25.60	I.E.U. 95	5-1/2 F.H.	7	3-1/2	62200	31500	6-21/32	21/64	25500	6-1/2	1/4	20200
	25.60	I.E.U. 105	API NC50(X.H.)‡	6-5/8	2-3/4	63400	31800	6-9/32	7/16	27500	6-1/8	23/64	22900
	25.60	I.E.U. 105	5-1/2 F.H.	7-1/4	3-1/2	72500	36300	6-23/32	23/64	27700	6-9/16	9/32	22300
	25.60	I.E.U. 135	5-1/2 F.H.	7-1/4	3-1/4	77700	38900	6-15/16	15/32	35500	6-3/4	3/8	28800
5-1/2	21.90	I.E.U. 75	F.H.	7	4	56300	28000	6-15/32	15/64	19200	6-3/8	3/16	16200
	21.90	I.E.U. 95	F.H.	7	3-3/4	62200	31500	6-5/8	5/16	24500	6-1/2	1/4	20300
	21.90	I.E.U. 105	F.H.	7-1/4	3-1/2	72500	36300	6-23/32	23/64	27700	6-9/16	9/32	22400
	21.90	I.E.U. 135	F.H.	7-1/2	3	86800	43700	6-15/16	15/32	35500	6-3/4	3/8	28800
	24.70	I.E.U. 75	F.H.	7	4	56300	28000	6-17/32	17/64	21300	6-7/16	7/32	18200
	24.70	I.E.U. 95	F.H.	7-1/4	3-1/2	72500	36300	6-23/32	23/64	27700	6-9/16	9/32	22400
	24.70	I.E.U. 105	F.H.	7-1/4	3-1/2	72500	36300	6-25/32	25/64	29900	6-5/8	5/16	24500
	24.70	I.E.U. 135	F.H.	7-1/2	3	86800	43700	7-1/32	33/64	39000	6-27/32	27/64	32100

1 The use of outside diameters (OD) smaller than those listed in the table may be acceptable on Slim Hole (SH) tool joints due to special service requirements.
2 Tool joint with dimensions shown has a lower torsional yield ratio than the 0.80 which is generally used.
3 Recommended make-up torque is based on 72,000 psi stress.
* Tool joint diameters specified are required to retain torsional strength in the tool joint comparable to the torsional strength of the attached drill pipe. These should be adequate for all service. Tool joints with torsional strengths considerably below that of the drill pipe may be adequate for much drilling service.
‡ Tool joint diameters specified are recommended by API Spec 7.

Minimum OD, for box shoulder, and makeup torque values listed were determined using the following criteria:

a. Calculations for recommended tool joint makeup torque are based on the use of a thread compound containing 40-60% by weight of finely powdered metallic zinc containing no more than 0.3% total sulfur applied to all threads and shoulders. Calculations are also based on a tensile stress of 50% of the minimum tensile yield for new joints and 60% for used joints.
b. In calculation of torsional strengths of tool joints, both new and worn, the bevels of the tool joint shoulders are disregarded.
c. Premium Class Drill String is based on drill pipe having uniform wear and a minimum wall thickness of 80%.
d. Class 2 Drill String allows drill pipe with a minimum wall thickness of 65% with all wear on one side.
e. The tool joint to pipe torsional ratios that are used here (≥0.80) are recommendations only and it should be realized that other combinations of dimensions may be used. A given assembly that is suitable for certain service may be inadequate for some areas and over-designed for others.