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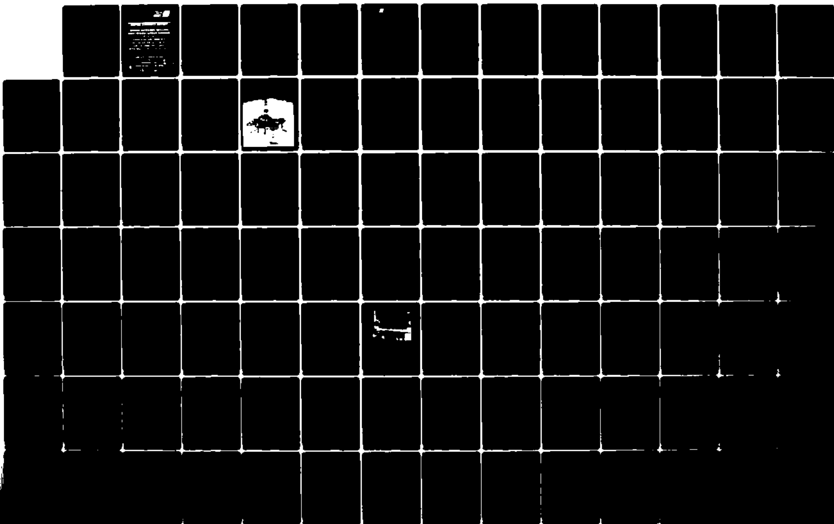

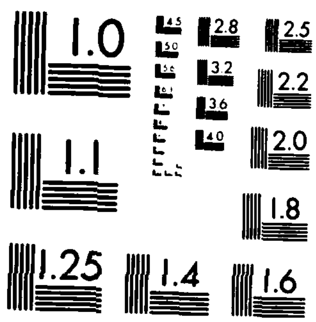

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MOBILE OFFSHORE DRILLING UNIT (MODU) OCEAN RANGER,
O.N. 615641, CAPSIZING AND SINKING IN THE ATLANTIC
OCEAN ON 15 FEBRUARY 1982 WITH MULTIPLE LOSS OF LIFE

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1. Report No. USCG 0001 HQS 82	2. Government Accession No. AD-A140 910	3. Recipient's Catalog No.
4. Title and Subtitle Marine Casualty Report Mobile Offshore Drilling Unit (MODU) OCEAN RANGER, O.N. 615641, Capsizing and Sinking in the Atlantic Ocean on 15 February 1982 with multiple loss of life		5. Report Date 20 May 1983 6. Performing Organization Code G-MMI-1/HQ14
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16. Abstract

At approximately 0052, 15 February 1982, the Mobile Offshore Drilling Unit (MODU) OCEAN RANGER, during a severe storm, commenced transmitting distress calls which indicated that the crew was abandoning ship. At or about 0307, 15 February 1982, the OCEAN RANGER capsized and sank in the Atlantic Ocean, approximately 166 miles east of St. John's, Newfoundland in about 260 feet of water. Inspite of the extensive rescue efforts of numerous vessels and aircraft, none of the 84 crew members survived. Contributing causes to the casualty include the severe storm; the lack of written casualty control procedures; the inadequate ballast system pump and piping design and arrangement for dewatering at excessive heel or trim angles; and the lack of a chain locker flooding alarm. Contributing causes to the loss of life include the adverse weather; the lack of exposure suits; the inadequate launching systems for the lifeboats; the ineffectiveness of the life rafts; and the apparent failure of rig personnel to allow sufficient lead time for evacuation. Twenty-two bodies were recovered between 15 February 1982 and 24 February 1982. This report contains the U. S. Coast Guard Marine Board of Investigation Report and the Action taken by the Commandant to determine the proximate cause of the casualty and provide a response to the recommendations to prevent recurrence.
The Commandant has concurred with the Board that the proximate cause of the casualty is the failure of the ballast control room portlight(s). The Coast Guard is working on changes to various regulations concerning lifesaving equipment, emergency procedures and manning standards on board MODUs.

17. Key Words Mobile Offshore Drilling Unit (MODU); capsizing;sinking;portlight;crew qualifications;stability;seakeeping; ballast control;forward list;exposure suits;hypothermia;lifeboats;life raft; rig console;brass control rods;heel;trim.	18. Distribution Statement This document is available to the public through the National Technical Information Service, Springfield, Virginia 22121

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PART I

U.S. Department of Transportation
United States Coast Guard

Commandant
United States Coast Guard

Washington, DC 20593
Staff Symbol: G-MMI-1/14
Phone: (202) 426-1455

16732/OCEAN RANGER

21 OCT 1983

Commandant's Action

on

The Marine Board of Investigation convened to investigate the circumstances surrounding the capsizing and sinking of the Mobile Offshore Drilling Unit (MODU) OCEAN RANGER, O.N. 615641, in the Atlantic Ocean on 15 February 1982 with multiple loss of life.

The report of the Marine Board of Investigation convened to investigate the subject casualty has been reviewed and the record, including the findings of fact, conclusions and recommendations, is approved subject to the following comments:

COMMENTS ON CONCLUSIONS

1. In concurrence with the Board, the proximate cause of the casualty is the failure of the ballast control room portlight(s) on the OCEAN RANGER which initiated a chain of events and concluded with the capsizing and sinking of the rig. This chain of events was not an inevitable progression and could have been broken by competent human intervention. The portlight failure allowed sea water to enter the ballast control room and, although the precise scenario could not be established, it is probable that the sea water splashed onto the ballast control console causing an electrical malfunction. The effect of this malfunction was either to cause the direct opening of several ballast control valves, or to cause the improper operation of the valve position indicator lights causing the perception of improper valve arrangement. As a direct or indirect result of the malfunction, several valves in the ballast control system opened or were opened allowing sea water to enter the forward ballast tanks and/or on-board ballast water to gravitate forward, either of which would have caused a substantial forward list. This list, combined with the adverse weather conditions, led to the flooding of the forward chain lockers and upper hull and the resultant loss of stability causing the capsizing and sinking of the OCEAN RANGER.

2. Contributing causes to this casualty include the following:

a. a major Atlantic cyclone which peaked approximately seven hours before the sinking of the OCEAN RANGER with sustained winds of 68 knots and seas to 50 feet. The boarding seas, not only caused the flooding of the chain lockers when the rig experienced a forward list, but also probably caused the initial portlight failure;

b. the apparent failure of the operating personnel to secure the deadlight covers for the portlights in preparation for the forecast heavy weather conditions. It is noted that securing of the deadlights is not specified in the section concerning Measures For Safe Operation (section K) in the OCEAN RANGER's operating manual.

c. the lack of written casualty control procedures and the lack of crew training in the routine and emergency operation of the ballast control system. The operating manual and other information available to the crew of the OCEAN RANGER lacked easily understood instructions on the ballast control system describing the design capability, both for normal operation and for alternative operations in the event of emergencies. The evidence clearly established that there was a lack of structured training for the ballast control room operators. The control room operators were not even required to read the Operating Manual in preparation for their duties. Had detailed written guidance concerning emergency procedures been provided and the crew properly trained, they may very well have been able to overcome the electrical malfunction of the ballast control console and break the chain of events that led to the capsizing and sinking of the rig;

d. the ballast system pump and piping design and arrangement was inadequate for dewatering at excessive heel or trim angles under emergency operating conditions. The ballast system pumprooms are located in the after ends of the port and starboard lower hulls of the OCEAN RANGER. The forward list that led to the flooding of the forward chain lockers also created vertical distances from the forward tanks that exceeded the net suction head limitations of the pumps located astern. While it was still possible to use the system to pump tanks closer to the center of rotation and then sequentially forward, the most immediate and substantial corrective action could not be taken since it was virtually impossible to pump out the forward-most tanks; and

e. the lack of a device installed to warn the crew of the flooding of the chain locker.

3. Contributing causes to the loss of life include a combination of the following:

a. the adverse weather which included not only the severe wind and sea conditions but also the relatively cold sea and air temperatures. These severe conditions precluded the safe abandonment of the rig and rendered personnel helpless from the effects of hypothermia;

b. the lack of exposure suits which resulted in the lack of thermal protection which would have extended crew survival time while in the water after abandonment and enabled the crew to help themselves when rescue vessels arrived. The 22 crew members from the rig whose bodies were recovered were found to have died as a result of hypothermia;

c. the inadequate launching systems for the lifeboats aboard the OCEAN RANGER which did not permit successful abandonment from the rig under adverse weather conditions. Of the four lifeboats aboard the OCEAN RANGER, three were recovered. Examination of these lifeboats revealed that two of the lifeboats were probably damaged during launching and the third was not used since it was stowed on deck and not in davits;

d. the ineffectiveness of the life rafts. Seven of the ten life rafts aboard the OCEAN RANGER were recovered. From the examination of the recovered rafts, there was no evidence found to indicate that they were used. This conclusion is consistent with the difficulty in launching and boarding these rafts when waterborne under the existing weather conditions; and

e. the apparent failure of rig personnel to allow sufficient lead time for evacuation. Specifically, helicopter evacuation under severe storm conditions would have required at least two hours lead time between the request for assistance and the probable arrival time of the helicopter on scene.

4. Conclusion 8: This conclusion is concurred with. Although the Board made no recommendations stemming from conclusion 8, a Notice of Proposed Rulemaking is being developed that will propose a revision to the MODU regulations, to require these vessels to have pumping systems which can transfer or dewater at excessive heel or trim angles under emergency operating conditions.

5. Conclusion 15: This conclusion is concurred with. The Board states that no exposure suits to protect against the effects of hypothermia were available to any of the rig's crewmen. While there were no exposure suits available, some of the crew members were wearing a type of waterproof, uninsulated immersion suit intended for use on helicopters. Information developed in Coast Guard testing and other research available to the Coast Guard indicates that these suits would extend survival time slightly in comparison with an unprotected person, but they would not provide the degree of survival time extension provided by approved exposure suits. The statement that the survival time of personnel in the water was a matter of seconds is considered misleading; the word minutes being more probable.

6. Conclusion 18: This conclusion is concurred with. While none of the life rafts were recovered intact, some of the rafts were observed to be fully inflated before they were recovered. It is apparent that at least some of the damage to the rafts occurred during their recovery.

7. Conclusion 19: This conclusion is concurred with. It was noted that some of the life jackets were not built in accordance with the approved plans. It has been determined that this was an isolated problem limited to a relatively few life jackets which were given pre-approval stamping at the factory. Such life jackets have been recalled and approval procedures have been improved to prevent the likelihood of a similar occurrence.

8. Conclusion 24: This conclusion is concurred with. The Operating Manual should be prepared with a goal to assist the user in performing his duties properly and efficiently. The Coast Guard has recently completed a study on the effectiveness of trim and stability booklets and the findings have been reported to the International Maritime Organization (IMO). The study concluded that more succinct data presentations for operating personnel are necessary.

9. Conclusion 27: This conclusion is concurred with. The licensing qualifications and examination requirements for master on mobile offshore units, which include mobile offshore drilling units, are part of a major project to revise the regulations found in 46 CFR Part 10 which was published as a Notice of Proposed Rulemaking on 8 August 1983. Within the Part 10 revision is a list of examination topics which include:

a. trim and stability;
b. damage trim and stability and countermeasures;
c. stability, trim and stress calculations; and
d. ballast control and operations.

These examination requirements should help to ensure the master is comp[illegible]t in matters concerning stability.

ACTION CONCERNING THE RECOMMENDATIONS

1. Recommendation 1:

Action: This recommendation is concurred with. The Coast Guard will continue to encourage the development and use of improved launching systems for MODUs. Once proven systems have been developed, the Coast Guard will consider proposing regulations that would require their use.

Launching systems with falls may be difficult to use on the high or weather side of a damaged MODU. On the lee side, the survival craft are also exposed to the effects of the weather due to the air gap under the rig. New higher speed winches may improve the performance of these systems by limiting the swing of the survival craft during launching.

Free-fall launching systems are gaining acceptance, but the system now being produced for ships is only intended for heights of up to approximately 20 meters. The Coast Guard is monitoring Norwegian development of a free-fall system for higher installations on MODUs. However, this system uses a vertical drop so it may not be much better than conventional falls for getting away from the damaged MODU on the high or weather side. Furthermore, all of the test drops and drills conducted with this system are known to have been made with the ship on an even keel in calm water.

Another type of system that has been proposed involves some type of boom or slide to launch the survival craft well away from the MODU. Structural design problems have prevented the development of a viable system of this type so far. Such a system would place the survival craft in the water away from the rig and would reduce the danger of damage from contact with the rig structure.

Initiation of a joint government/industry effort to address the problem of lowering lifeboats and life rafts from MODUs is being considered by the Coast Guard. The Coast Guard will support the review and revision of the lifesaving requirements of the IMO MODU Code, taking into consideration the revised lifesaving requirements in the new Chapter III of the 1974 Safety of Life at Sea Convention (SOLAS) which was approved by IMO in June 1983.

2. Recommendation 2:

Action: This recommendation is concurred with. The Coast Guard, representing the United States at IMO, supported the development of the new Chapter III SOLAS which was approved by IMO. These amendments will come into force on 1 July 1986 for new ships. The new chapter contains more extensive performance standards for life jackets. The Coast Guard will amend the regulations to reflect these standards and will continue to encourage the development of improved life jacket designs. To this end, the Merchant Vessel Inspection Division of Coast Guard Headquarters has just completed an initial life jacket rough water test which is being analyzed. After the analysis, a report will be prepared and distributed to manufacturers to foster improved designs.

3. Recommendation 3:

Action: This recommendation is concurred with. In light of the Chapter III revisions and the rough water tests mentioned under recommendation 2, the Coast Guard recognizes the need for a review of existing life jacket design and testing criteria. With regard to revising these criteria to accommodate entry into the sea from a significant height, Coast Guard regulation proposals will include a jump test from a height of 4.5 meters as required by the new SOLAS revisions. This test would be conducted with the subject's hands held overhead. The Coast Guard believes this test provides a good indication of whether or not the life jacket will come off over the head in rough seas or when jumping from a significant height.

4. Recommendation 4:

Action: This recommendation is concurred with. The amendments to SOLAS 1974 include a standard requirement for survival craft release gear to be able to release the craft at any time. In addition, the IMO MODU Code in section 10.5.4 already states that on-load type release gear should be used for rigid survival craft (lifeboats). United States regulations for approved lifeboats also require this type of release gear.

5. Recommendation 5:

Action: This recommendation is concurred with. The amendments to SOLAS 1974 also require that totally enclosed lifeboats attain a position affording an above-water escape for the occupants even if the boat is flooded. If flotation in the cover of OCEAN RANGER lifeboat #2 had been provided to comply with this requirement, the boat would probably have self-righted after it capsized.

6. Recommendation 6:

Action: This recommendation is concurred with. The Coast Guard has contacted the Canadian Royal Commission and requested that they provide the report on their findings concerning the condition of the life rafts. The Coast Guard will study this information and other information available concerning the life rafts to determine if a service life limit or some other action is appropriate. Normally, the annual inspection and servicing of the life rafts should indicate when deterioration is to the point where it is no longer serviceable.

7. Recommendation 7:

Action: This recommendation is concurred with. A Notice of Proposed Rulemaking is being developed that will propose improved stabilizing features on U.S. Coast Guard approved life rafts.

8. Recommendation 8:

Action: The intent of this recommendation is concurred with. The OCEAN RANGER was designed to survive most weather conditions encountered in the open ocean and was equipped with primary lifesaving equipment capable of evacuating the entire crew. As with other vessels of a more conventional hull design, a MODU should be self-sustaining and capable of providing its own means of abandonment in the event of an emergency. However, MODUs do differ from conventional ships in that the height above water is significantly greater. Transferring personnel directly from the MODU to a standby vessel would undoubtedly also prove hazardous under adverse weather conditions such as encountered by the OCEAN RANGER on 15 February 1982. The Coast Guard believes that the proper focus of our efforts, as a result of this investigation, should be directed toward improvements in lifesaving equipment and their launching systems. Recommendations 1,4,5,6, and 7 address the lifesaving equipment problems.

In addition, the nature of oil exploration operations is such that offshore supply vessels (OSVs) routinely operate in the vicinity of MODUs in most parts of the world. OSVs typically have a low freeboard aft and can be readily used to recover persons from the water, provided those persons are able to assist themselves. The vessels that tried to rescue the OCEAN RANGER victims were able to come close enough to toss lines to the victims, but the persons in the water were unable to help themselves. If these persons had been wearing exposure suits, they probably would have been capable of assisting themselves while being brought aboard the rescue vessel.

On 3 February 1983, the Coast Guard published a Notice of Proposed Rulemaking which would require exposure suits for personnel on MODUs and other types of vessels. The requirements would pertain to vessels operating in areas where the water temperature may fall below 60°F. There are no lifesaving appliances or survival equipment systems that can guarantee the survival of all personnel on board a vessel involved in a casualty. However, had the proposed requirement for exposure suits been in effect at the time of the OCEAN RANGER casualty, the number of lives lost could have been significantly reduced. With regard to proposing a specific regulatory change which would require all U.S. flag MODUs to have standby boats, the Coast Guard will initiate a comprehensive review of MODUs that operate in remote locations. Areas of greatest concern will be where the water temperature falls below 60° F and the volume of vessel traffic is limited. If regulations are proposed, certain MODUs in warm-water locations would be considered for exemption from standby vessel requirements. For example, in the Gulf of Mexico, hypothermia and MODU evacuation are not considered potential problems since crew boats and helicopters routinely make daily trips to numerous MODUs and platforms off the Gulf coast. In addition, certain companies' policies already require that standby boats be assigned to MODUs in the Gulf area.

9. Recommendation 9:

Action: This recommendation is concurred with. The Coast Guard published an advance Notice of Proposed Rulemaking for offshore supply vessels (OSVs) on 14 February 1983. The proposed rules would require OSVs to be equipped with rescue boats that must be capable of taking an unconscious person on board from the sea. The Coast Guard believes that most of the rescue boats for OSVs will be of the inflatable or rigid-inflatable type, similar to boats now being used on Coast Guard cutters for rescue purposes. The only OSVs that would be exempt from the rescue boat requirement would be those that carry lifeboats or those OSVs that are designed or modified to have the capability of recovering helpless persons directly from the sea. Any proposed rules regarding standby boats will include rescue equipment requirements similar to those for OSVs.

The Coast Guard has fostered development of rescue boats for commercial vessels through some preliminary studies on rescue boat effectiveness and on rescue boat seakeeping and stability and will continue this effort as research funds are made available. In addition, a series of at sea tests on similar rescue boats for use on Coast Guard cutters was recently conducted. The results of these tests are available for use in developing appropriate requirements for rescue boats on commercial vessels. The Coast Guard will propose rescue boat approval requirements as part of the regulatory project to incorporate the revised Chapter III of SOLAS 1974 into U. S. regulations.

10. Recommendation 10:

Action: This recommendation is concurred with. As discussed in recommendation 8, the Coast Guard has proposed carriage of exposure suits on ocean-going vessels and MODUs. The Coast Guard also proposed that the IMO Maritime Safety Committee reconsider the exposure suit exemption for ships with totally enclosed lifeboats. This proposal was considered at the June 1983 meeting of the Maritime Safety Committee. Although there was limited support of the United States proposal to eliminate the exemption for ships with totally enclosed lifeboats, the recommendation was not supported by the majority of the signatory countries.

Under the exposure suit rules proposed by the Coast Guard in February 1983, ships with totally enclosed lifeboats would not need to carry the suits. This proposed exemption attracted many negative comments from people concerned that there may not be enough time to launch a lifeboat so that exposure suits would be needed on any ship. Although the exemption is consistent with the proposed SOLAS rules, it is being carefully studied to determine if it should be revised or eliminated.

11. Recommendations 11 and 12:

Action: The intent of these recommendations is concurred with. Bilge system requirements for MODUs are scheduled for discussion at the 27th session of the Subcommittee on Ship Design and Equipment at IMO in March 1984. Based on these discussions, the Coast Guard will determine the need for separate rulemaking to provide flooding alarms for and means of dewatering normally unmanned spaces that are vulnerable to substantial undetected flooding.

12. Recommendation 13:

Action: This recommendation is concurred with. It has been an initiative of the United States delegation to the IMO subcommittee concerning loadlines to amend the loadline convention to include requirements for appropriate assessment of the hull integrity of all special purpose vessels and mobile drilling units. This effort will be continued. A revision, highlighting the variety of openings required to be watertight on special purpose vessels and MODUs, will be made to the Marine Safety Manual in the Inspection Standards section or another appropriate section of the Marine Safety Manual.

13. Recommendation 14:

Action: The intent of this recommendation is concurred with. However, the fail-safe state of a ballast or vessel positioning system is difficult to delineate. In many situations, the fail-safe mode as it relates to a ballast control system would be for the valves to close in the event of a loss of electrical power or control air. The system on the OCEAN RANGER was designed in this manner. The instant case may not have been a power failure but a short circuiting of the controls or indicators. The Coast Guard is considering requirements for watertight or splashtight enclosures, an independent main and alternative means of system control, and at least two independent indications of system or subsystem status. These requirements would be analogous to those for steering systems, throttle controls and other essential systems.

14. Recommendation 15:

Action: The intent of this recommendation is concurred with. Knowing the location of all electrical or mechanical system shutdowns is of vital importance in providing a timely response for emergency situations. Regulations are in place (46 CFR 109.109) which require that the master or person-in-charge be fully cognizant of the provisions in the operating manual. The operating manual must contain guidance for the safe operation of the unit under normal and emergency conditions (46 CFR 109.121).

As is the case with any U.S. flag vessel, the ultimate responsibility for ensuring that the MODU is adequately manned and operated rests with the master/person-in-charge. The safe operation of a MODU cannot be accomplished without a crew that is trained in, and familiar with, normal and emergency MODU procedures. This would include a knowledge of electrical and mechanical shutdowns for all systems, vital and non-vital, on the MODU. No further regulations regarding mechanical or electrical shutdowns are deemed necessary, as this information should be a part of the operating manual required by 46 CFR 109.121. However, operating manuals will be carefully reviewed with a checklist of important items to look for in the manual. This checklist shall include an easy to understand description and location of all electrical and mechanical emergency shutdown systems. Recommendation 18 of this report concerning the operating manual adequately covers the intent of this recommendation.

15. Recommendation 16:

Action: This recommendation is concurred with. A Notice of Proposed Rulemaking is being developed that will propose a revision to 46 CFR 113.30-5 to include a requirement for sound-powered phone communications between the ballast control room and spaces that contain ballast pumps and valves.

16. Recommendation 17:

Action: This recommendation is concurred with. A Notice of Proposed Rulemaking is being developed that will propose revisions to 46 CFR Subchapter I-A. As part of this project, a requirement will be proposed to provide onboard personnel with rig-specific information of vital systems (manufacturer's/designer's instruction books and manuals for equipment) to provide guidance during normal and emergency situations. Furthermore, proposed changes to the licensing regulations (46 CFR Part 10), which will apply to all licensed officers including those on MODUs, will require that personnel become familiar with all unique characteristics of each vessel served upon, as soon as possible after reporting for duty.

17. Recommendation 18:

Action: The intent of this recommendation is concurred with. The MODU regulations state that the operating manual should provide guidance for the safe operation of the unit under normal and emergency conditions. To be of use, the manual must be written and arranged in a manner easily understood by operating personnel. The Coast Guard will prepare guidance for the preparation of operating manuals for MODUs to achieve this purpose. The Coast Guard will then undertake a review of all MODU operating manuals to determine where improvements and revisions are necessary; including emergency closures. However, due to the varying levels of experience and education of operating personnel, it is not considered possible to prepare an operating manual which is easily understood by all personnel. It therefore remains the responsibility of management to ensure, through proper training or other means, that operating personnel are aware of and understand the purpose and contents of the operating manual.

18. Recommendation 19:

Action: The intent of this recommendation is concurred with. Information concerning the evacuation of a unit should be a part of the operating manual under regulations already in place. Evacuation would fall under guidance for the safe operation of the unit under emergency conditions. A project will be initiated to determine what specific information concerning evacuation should be included in a unit's operating manual.

19. Recommendation 20:

Action: This recommendation is concurred with. This is the intent of the section titled "Licenses for Master or Mate on Mobile Offshore Units Upon Oceans" in the proposed 46 CFR Part 10 revision. This revision requires the person-in-charge of a Mobile Offshore Unit (MOU) to be licensed and competent in all aspects of the operation of a Mobile Offshore Unit. This master is authorized service on non-self-propelled units while under tow or at the exploration site. This license does not authorize service in the capacity of master while the unit is underway independently as a self-propelled unit. The licensing qualifications and examination requirements for master on mobile offshore units, which includes mobile offshore drilling units, address many topics which pertain to mobile offshore units specifically. The proposed 46 CFR Part 10 revision includes, among other items, the following particularly germane examination topics:

a. trim and stability;
b. damage trim and stability and countermeasures;
c. stability, trim and stress calculations; and
d. ballast control and operations.

20. Recommendation 21:

Action: This recommendation is concurred with. A Notice of Proposed Rulemaking is being developed that will propose a revision to 46 CFR Subchapter I-A. As part of this project, 46 CFR 107.111 will be revised to indicate that the master of MOUs shall be the person-in-charge.

21. Recommendation 22:

Action: This recommendation is not concurred with. It is the position of the Coast Guard that the Unlimited Master's License is the superior license to all others. Any particular training or certification should be an employer requirement prior to hiring for or assignment to a rig. A section of the proposed regulatory changes to 46 CFR Part 10 states that any licensed officer must become familiar with the installed equipment and unique operating characteristics of any vessel to which assigned as soon as possible after reporting aboard for duty. Implicit in this familiarization requirement would be the need for the master to make initial and periodic reviews of the rig-specific descriptive manuals and related information.

22. Recommendation 23:

Action: This recommendation is concurred with in part. Proposed revisions to 46 CFR Part 10 will formalize the prerequisites for the issuance of licenses as Master or Mate of mobile offshore units. The Industrial Mobile Offshore Unit Master license is a non-navigating license which should not entail the same knowledge and skills of an Unlimited Master's License. The Industrial Master's License will be formalized in the Part 10 regulations and certain specific knowledge areas will be tested which are appropriate for that service. These knowledge areas include the following:

a. principles of vessel construction;
b. trim and stability;
c. damage trim and stability and countermeasures;
d. stability, trim and stress calculations; and
e. ballast control and operations

23. Recommendation 24:

Action: This recommendation is concurred with in part. While the Coast Guard presently does not require that the master or mate be the ballast control room operator, the Coast Guard envisions that the mate MOU license holder will serve as ballast control room operator; jack up control operator; and/or vessel positioning control operator on these vessels. Therefore, the manning requirements on MOUs may be changed to include two mates while on station. The appropriate topics will be addressed in the license examination proposed as a regulation change to 46 CFR Part 10. The licensing qualifications and examination requirements for masters and mates on mobile offshore units, which include mobile offshore drilling units, are included in the revision project on 46 CFR 10. Ballast control operations questions are included in the examination topics for masters and mates. Although the issues concerning jack-up control operators and vessel positioning control operators do not relate directly to the OCEAN RANGER, they are a logical extension of the review of the manning needs on the OCEAN RANGER to other types of MOUs.

24. Recommendation 25:

Action: This recommendation is not concurred with. The required licenses will attest to the level of training and experience of the MODU personnel. Further certification is not considered necessary. It shall be the responsibility of the owner/operator and the master that properly trained watchstanding personnel are aboard.

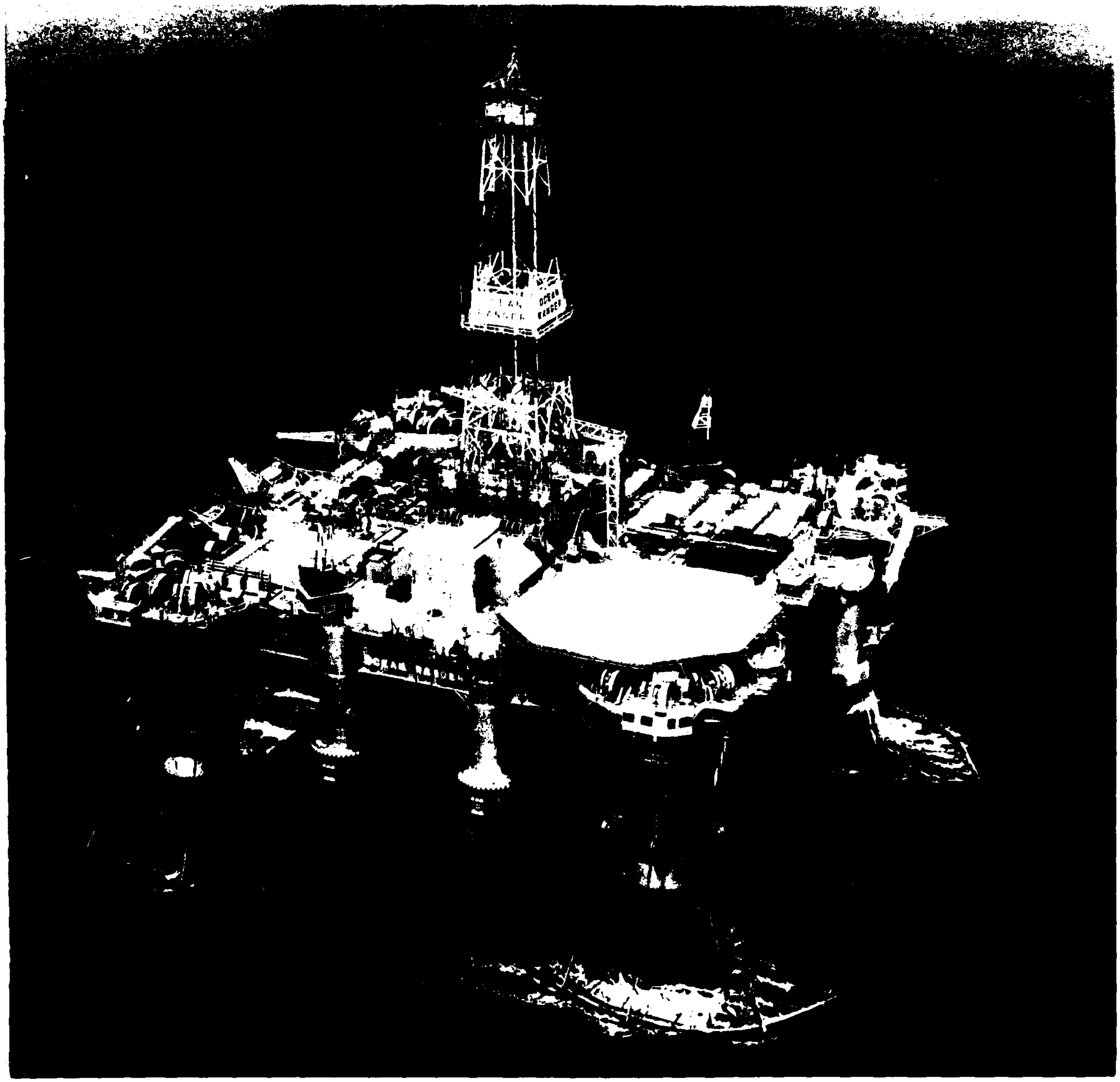
25. Recommendation 26:

Action: This recommendation is concurred with. The report of the Royal Commission will be reviewed when published.

J. S. GRACEY
Admiral, U. S. Coast Guard
Commandant

PART II

REPORT OF THE U.S. COAST GUARD MARINE BOARD OF INVESTIGATION CONCERNING THE MODU OCEAN RANGER, O.N. 615641; CAPSIZING AND SINKING IN THE ATLANTIC OCEAN ON 15 FEBRUARY 1982 WITH MULTIPLE LOSS OF LIFE



DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

Address reply to:
COMMANDER (d)
Ninth Coast Guard District
1240 East 9th St.
Cleveland, Ohio 44199

16732
20 May 1983

From: Chairman, U. S. Coast Guard Marine Board of Investigation
To: Commandant (G-MMI)

Subj: Report of Investigation concerning the Mobile Offshore Drilling Unit (MODU) OCEAN RANGER, O. N. 615641, capsizing and sinking in the Atlantic Ocean on 15 February 1982 with multiple loss of life.

Ref: (a) COMDT ltr 16732/OCEAN RANGER dtd 17 FEB 1982

1. The enclosed report is forwarded herewith in compliance with reference (a).

2. The Board has written this report based on its evidence of record, which contained all known relevant evidence pertaining to this casualty. However, additional evidence may be forthcoming in the future from other forums investigating this casualty, in particular the Canadian Royal Commission. Should this additional evidence support facts which substantially contradict the Board's findings or materially adds to the information contained in this report, it is recommended the Board be reconvened or a new Board be appointed to consider this evidence.

Henry H. Bell
HENRY H. BELL

FOREWORD

Due to the location of the casualty, the Board was confronted with a situation somewhat unique in marine casualty investigations, and was somewhat hampered in the discharge of its remand. The OCEAN RANGER was a United States registered vessel, with United States sovereignty in respect to the application of national statutes and regulation, and the discharge of obligations undertaken by international treaties. Deployment off Newfoundland in no way altered this relationship.

The OCEAN RANGER was at the time of the casualty engaged in oil exploration on the continental shelf of Canada. The Geneva Convention of the Continental Shelf[1] conferred on Canada certain sovereign rights while the OCEAN RANGER was so engaged. In the exercise of these rights, the Canadian Federal Government and the Provincial Government of Newfoundland had stipulated certain provisions with respect to the conduct of the exploration and the employment of Canadian citizens on the OCEAN RANGER. These provisions did not abrogate United States regulatory requirements or international obligations; rather they supplemented them.

After the casualty, the dual sovereign interests, the large number of witnesses who were Canadian citizens, and the fact that St. John's, Newfoundland was the port from which support to the rig had originated prior to the casualty and from which the rescue efforts were undertaken, posed some problems to the Board. It had none of the powers and autnorities it would normally exercise in the United States. It requested permission to take testimony under oath, voluntarily, in Canada. This permission was not received until mid June of 1982.

The Board also recognized that after the casualty there was a question of whether Canada continued to have any sovereign rights in respect to the sunken OCEAN RANGER. The Board concluded that seeking the answer to this question would not enhance its ability to carry out its assignment, since it's primary objective was the determination of the causal factors in the casualty.

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1 U.N. DOCA/Conf. 13/L.55, TIAS 5578

Immediately after the casualty, the Board sent two Coast Guard Marine Inspectors to St. John's, joined soon after by one Coast Guard Investigator and one National Transportation Safety Board Investigator who were members of the Marine Board.

In conjunction with Canadian Federal and Provincial officials, unsworn statements were taken from all personnel having information about the OCEAN RANGER prior to and during the casualty. Tape recordings of the interviews were made, and rough transcripts provided to the Board. Based on these interviews, witnesses were selected to give sworn testimony before the Board.

Lacking timely permission to conduct its hearings in Canada, hearings were held in Boston, Mass. in April and New Orleans, La. in June. The Boston hearing was for the receipt of testimony of those witnesses from St. John's, Newfoundland, and the New Orleans hearing for the receipt of testimony from witnesses residing in the Gulf area.

The Board would like to express its appreciation to Mobil Oil of Canada, Ocean Drilling and Exploration Company, Southeastern Drilling Company, and other associated interests, for making witnesses available to the Board. Without their assistance the work of the Board would not have progressed.

Finally, the Board wishes to acknowledge the excellent cooperation the involved Canadian and Newfoundland agencies gave the Coast Guard investigators and Board personnel. When the Royal Commission was convened, a productive liaison was established which contributed to the fact finding efforts of the Board.

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FINDINGS OF FACT

I PRELIMINARY STATEMENTS

1. Casualty Summary

On 15 February 1982 the MODU OCEAN RANGER O.N. 615641, the largest floating rig in the world, was located in the Hibernia Field, well No. J-34, approximately 166 miles east of St. John's, Newfoundland, at latitude 46'43.52'N, longitude 48'50.05'W. At approximately 0052 (local time zone description + 3 1/2) the OCEAN RANGER commenced transmitting a series of distress calls which indicated that the rig was listing badly and the crew was preparing to abandon ship. Subsequent efforts by responding vessels and aircraft failed to save any of the 84 crewmembers. An extensive search confirmed that the OCEAN RANGER had sunk. The rig was subsequently located by side scan sonar in an inverted position approximately 485 ft S.E. of the well head. Between 15 February 1982 and 24 February 1982 twenty-two bodies were recovered.

2. Personnel Casualty Data

Medical examinations disclosed that all of the 22 deceased crewmembers whose bodies were recovered died as a result of hypothermia. The remaining 62 crewmembers remain missing. On 22 March 1982 the Marine Board issued "Letters of Presumed Death" for all missing crewmembers (please see Appendix A for a listing of the dead and missing).

II RIG DESCRIPTION

3. Physical Characteristics.

The OCEAN RANGER was designed by ODECO[1] Engineers, Inc. and built in Mitsubishi Heavy Industries' Yard in Hiroshima, Japan, in 1976 as hull #241011. Construction was supervised by the American Bureau of Shipping (ABS) and, after completion, the OCEAN RANGER was classed by the ABS as AMS (MALTESE CROSS) A-1, CIRCLED M, and rated and approved for "Unrestricted Ocean Operations".

The OCEAN RANGER was a self-propelled, column stabilized, semi-submersible drilling rig, intended for deep water operations and designed to conduct drilling operations in water depths up to 3000'. The OCEAN RANGER was designed and built to withstand extremely harsh environmental conditions, including simultaneously occurring 100 knot winds, 3 knot surface current, and 110 foot waves.

The OCEAN RANGER was 398'9" long, 262' wide, and 151'6" high (excluding the derrick). The rig basically consisted of a platform, or upper hull, mounted atop eight vertical columns, which in turn were attached to a lower, catamaran-type hull, consisting of two parallel, oval pontoons. In general, the platform provided the crew with living and work areas; the columns provided support and stability to the platform and elevated it above the normal effects of the sea; and the hull pontoons provided flotation to the structure. The gross tonnage of the OCEAN RANGER was 14,913 tons; the net tonnage was 12,097 tons. (please see figures 1 to 3 on pages 4 to 6)

The platform consisted of an upper deck and a lower deck. Located on the upper deck were: the drill floor and derrick; the racks for storing drilling pipe, casing, and the marine riser; the cranes; the anchor windlasses; the crew's upper living quarters, office spaces, and work areas; the elevated helicopter deck; and the lifeboats. The lower deck held the cellar area, the generator room, the machine shops, the mud system, the storage areas, and the lower two floors of the crew's quarters.

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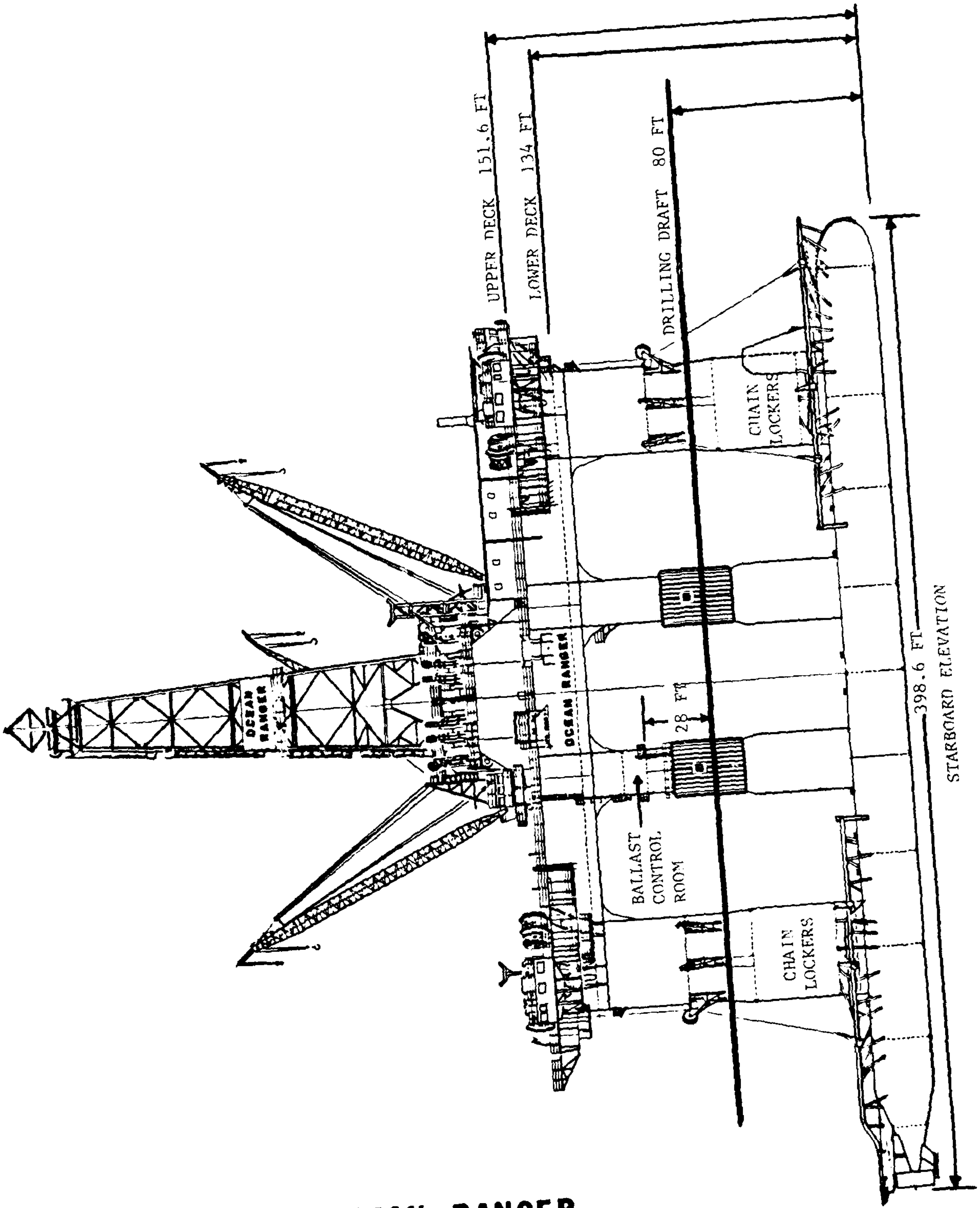
1 ODECO is an acronym for the parent corporation: Ocean Drilling and Exploration Company, Inc. The term ODECO is frequently used in witness testimony to refer to ODECO Canada and/or ODECO International and when used is assumed to refer to one or the other, or both of these corporations.

The eight columns supporting the platform were arranged in a rectangular pattern atop the two pontoons of the lower hull. The two pontoons were referred to as the port pontoon and the starboard pontoon, each supporting four vertical columns. Each column was denoted by a two-letter, sequentially numbered designator consisting of the letters "PC" or "SC" ("port column" or "starboard column", respectively) and a number from 1 to 4, beginning with #1 on the bow and continuing aft to column #4. A typical designator was SC-3, which denoted "starboard column #3", or the 3rd column from bow to stern on the starboard side. The four corner columns (PC-1, PC-4, SC-1, and SC-4) were 38 feet at the base tapered to 36 foot diameter cylinders, while the middle four columns (PC-2, PC-3, SC-2, and SC-3) were 25 feet at the base tapered to 18 foot diameter cylinders. The columns, pontoons, and platform were trussed together by four horizontal braces (two 12' diameter and two 14' diameter), four horizontal-plane, diagonal trusses (each 7' in diameter), and eight vertical-plane, diagonal trusses (each 7' in diameter).

Each corner column from the 35 foot level to the 70 foot level contained three chain lockers. The chain lockers were open at the top of the columns at the 151 foot level through three wire trunks and three chain pipes. The chain lockers were fitted with sounding tubes with access points on the lower deck level.

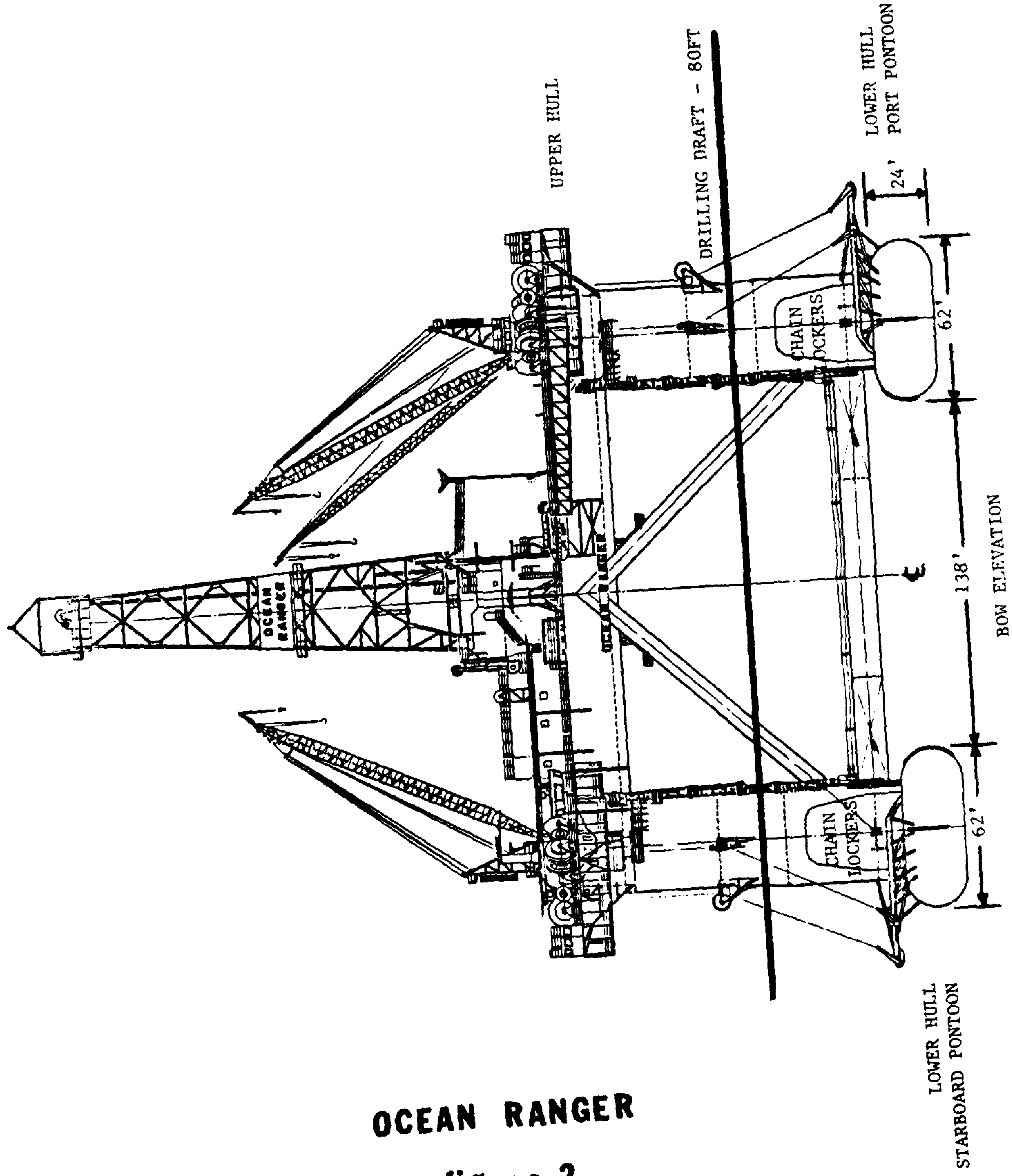
The port and starboard pontoons of the lower hull were each 398'6" long and had an ovular cross-section, 62' in width by 24' in depth. The two pontoons provided flotation to the structure and also contained ballast, fresh water, drill water, and fuel oil tanks. Each pontoon contained 16 tanks, which were denoted by a "P" or "S" ("P" for port pontoon tanks and "S" for starboard pontoon tanks) followed by a number (beginning with #1 for the bow tank on the center line forward and continuing aft) with even-numbered tanks on the inboard side and odd-numbered tanks on the outboard side (except for #16 which was on the outboard side). Aft of the tanks in each pontoon was a pump room; aft of the pump room was a propulsion room. Each of the propulsion rooms contained two 3500 H.P. DC electric motors which provided 14,000 total shaft horsepower drive to two steerable kort nozzles.

The draft of the OCEAN RANGER was regulated by changing the amount of ballast water in the port and starboard pontoons. The rig's



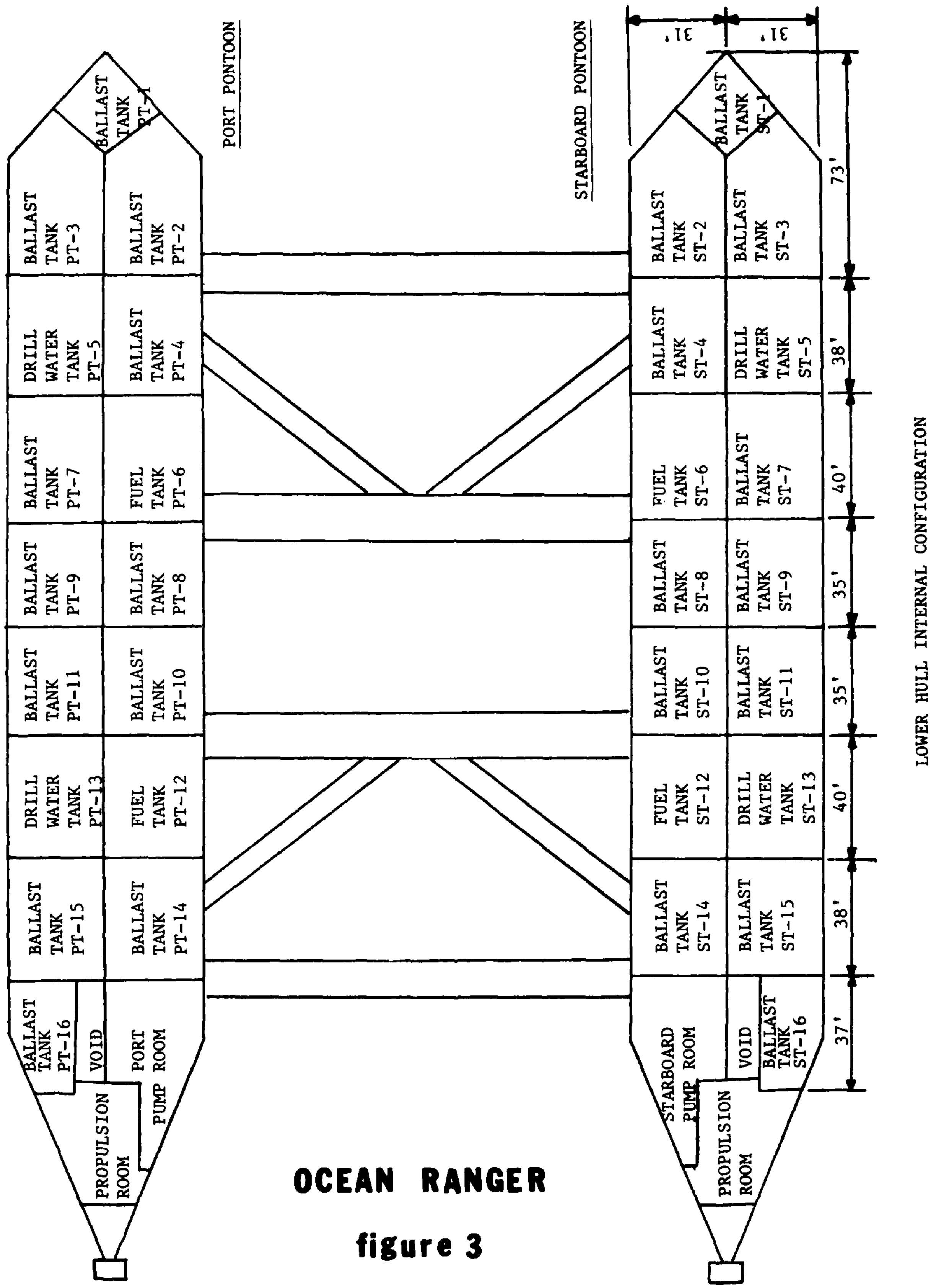
OCEAN RANGER

figure 1



OCEAN RANGER

figure 2



OCEAN RANGER

figure 3

ballast system was controlled from the "Ballast Control Room", which was located in column SC-3. From the ballast control room, the rig's personnel could open or close valves and operate ballast pumps by remote control. By adding or shifting ballast water, the ballast control room operators could increase the draft of the rig, induce or remove trim, and induce or remove heel.[1] The normal drilling draft of the OCEAN RANGER was 80' which corresponded to an "air-gap" (the distance measured from the water surface to the bottom of the platform) of 50'. (A more comprehensive description of the OCEAN RANGER's ballast control room, ballast system and it's operation follows in a later section of this report; please see section VI.)

The OCEAN RANGER was maintained in position at a drilling site by means of a 12 point, spread mooring system, consisting of 12-45,000 lb. anchors, ranged three each from the four corner columns: PC-1, PC-4, SC-1, and SC-4 (please see figure 4 on page 9). Each anchor was attached to 1600 ft of 3 1/4 inch link chain, which in turn was connected to 4500 ft of 3 1/2 inch wire rope. The anchor chains were stored in chain lockers in the corner columns, and ranged through individual chain pipe openings at the tops of the columns, each measuring approximately 6 sq ft. The connecting wire ropes were stored on drums located atop the columns, and were led down into the chain lockers through individual wire trunk openings at the tops of the columns, each measuring approximately 25 sq ft, to lower sheaves and out through the chain pipes (please see figure 5 on page 10). Each chain/wire rope was then led though hawse pipes, down the side of the column to a fairlead sheave, and away from the rig to the deployed anchor. Control of the chain/wire ropes was maintained through 12 winch-windlass units mounted atop the corner columns, each of which had a stall pull equal to half the breaking strength of the mooring lines, and a brake capacity exceeding the breaking strength of the mooring lines. The breaking strength of the wire rope was approximately 1,200,000 lbs. Remote read-out devices located in the Ballast Control Room (inoperative at the time of the casualty) and in

1 Throughout this report the terms heel, list, and trim are defined in offshore drilling industry terms. Heel is a static inclination about the centerline, trim is static inclination down by either the bow or stern, and list is a static inclination about any other axis, i.e. - a combination of heel and trim.

the Toolpusher's office indicated the tension on the wire rope/cables by means of tensionmeters located on each of the twelve winch-windlasses. Individual read-out devices were also located at each of the twelve winch-windlasses.

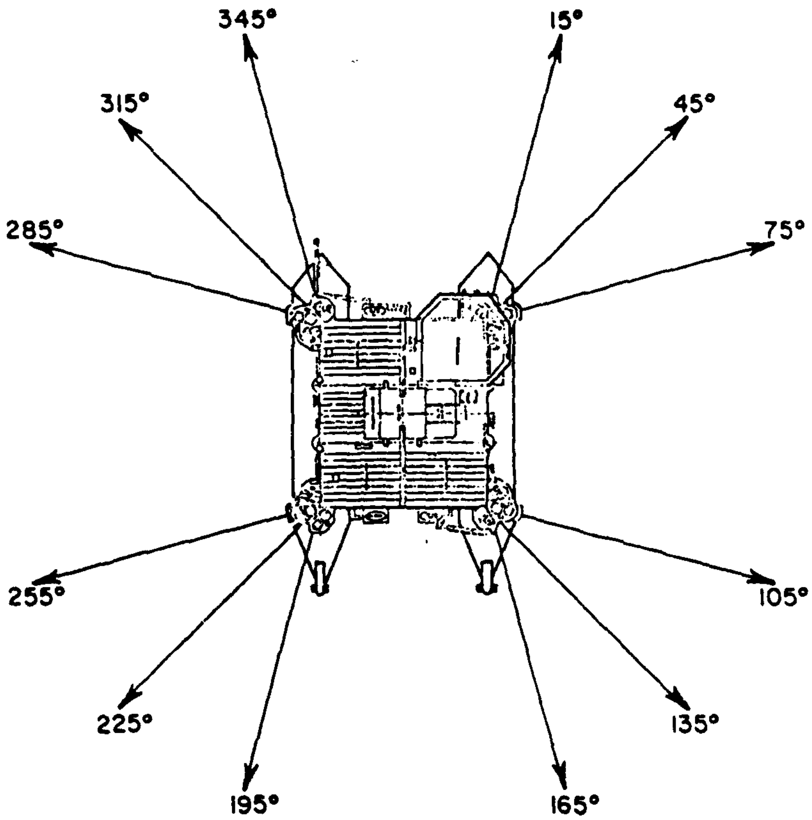
The anchors were normally hawsed on the rig by tensioning them up against the "anchor bolsters" located at the bases of the four corner columns. Deployment of the anchors required the assistance of anchor-handling boats which ran the anchors out from the rig and positioned them on location.

In conducting drilling operations, the OCEAN RANGER never came into direct contact with the seafloor but floated above it. The rig was connected to the well on the seafloor by means of an "umbilical-cord-like" unit called the marine riser. The marine riser acted as a rigid, vertical conduit and provided an annulus for the return of the drilling fluids from the well to the rig.

The drill string ran through the marine riser and into the well. The marine riser was connected to the well head by means of a "connector" located atop the blowout preventers (BOP). The well head, the blowout preventers, and their associated hydraulic equipment are collectively referred to as the "subsea stack". The marine riser in use on board the OCEAN RANGER was a 21" O.D. (outside diameter) by 1/2" wall (wall thickness) X-52 VETCO W/MR-6B CONNECTOR (please see figure 6 on page 12).

4. Sea Keeping Characteristics of the Hull

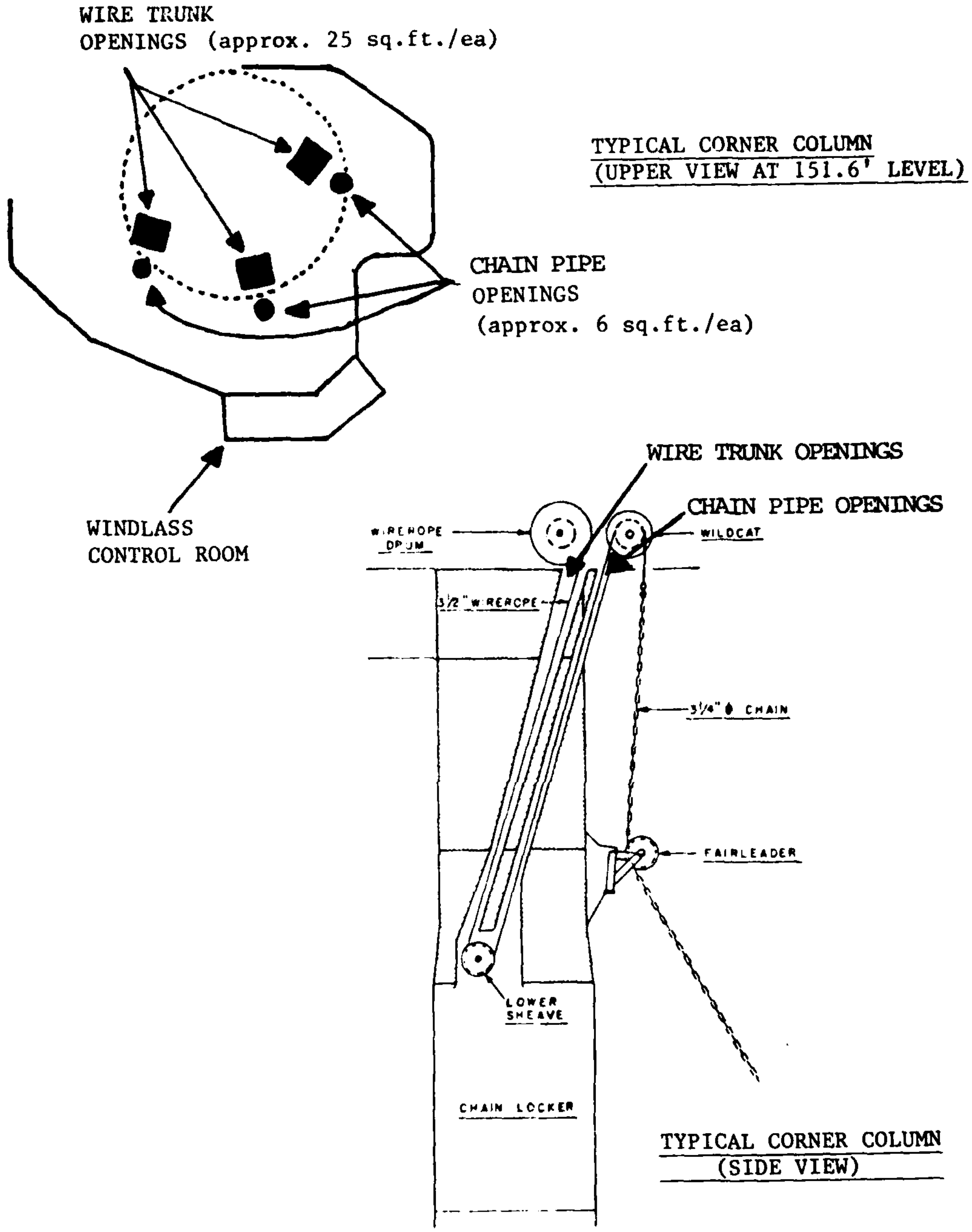
The integrity and performance of the platform was essential in order to facilitate an efficient drilling operation. The maintenance of it's heel and trim or list within the tolerable limits of the drill string required the close attention of the ballast control room operator. The rig was sensitive to lateral changes of load caused by the shift of liquids, moving materials around deck, consuming materials or by taking on supplies from the supply boats. These load shifts were readily compensated for by distributing ballast water in the ballast tanks. Such adjustments maintained the attitude of the rig to facilitate drilling operations. The OCEAN RANGER was a very stable platform in heavy seas compared to more conventional vessel hulls. Therefore, drilling could continue in adverse weather and sea conditions. The OCEAN RANGER rarely had to secure drilling because of



OCEAN RANGER MOORING PATTERN
(15°- 45°-75°)

OCEAN RANGER

figure 4



COMBINATION MOORING SYSTEM

OCEAN RANGER

figure 5

environmental conditions.

5. Motion Compensation.

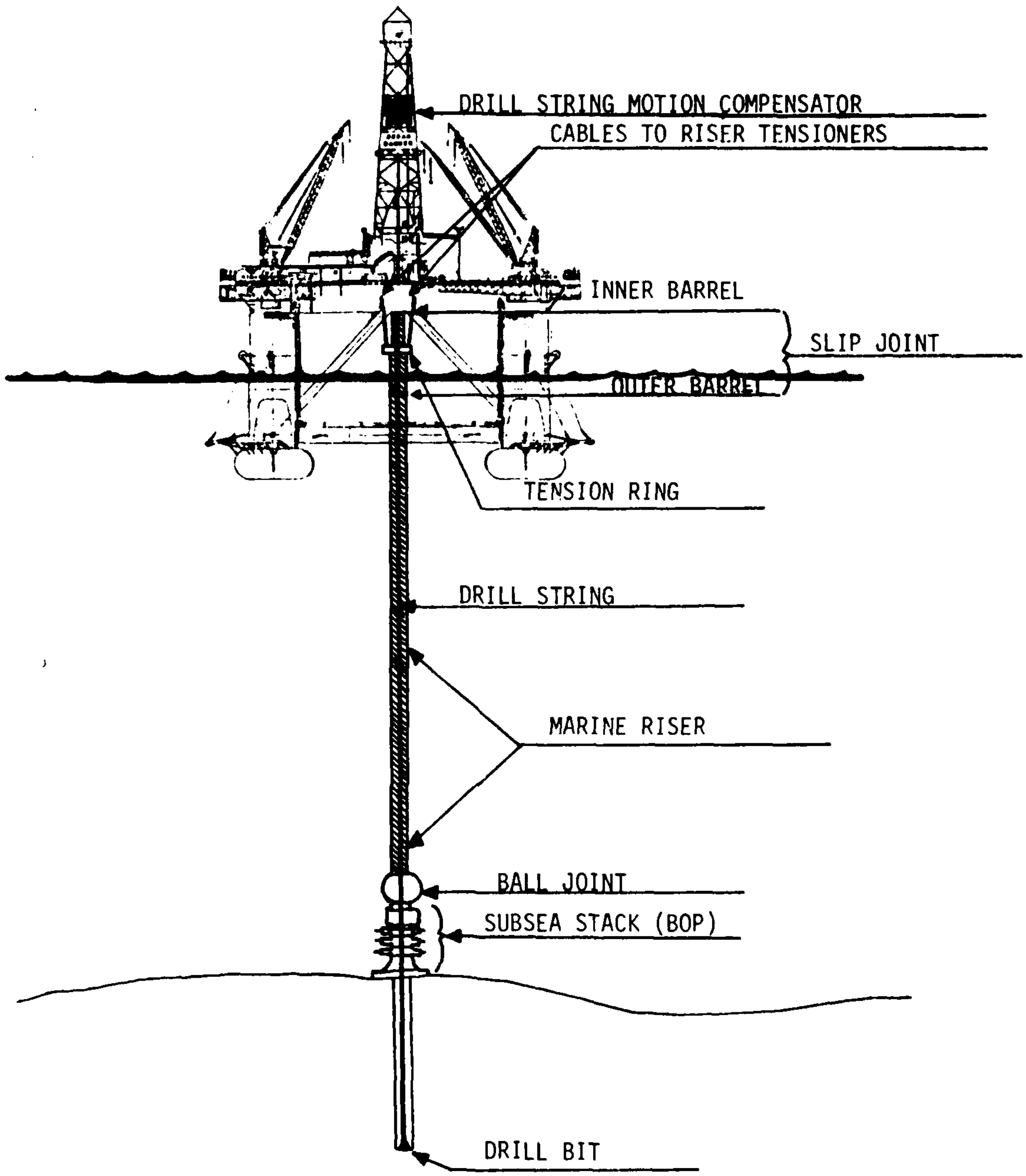
As noted previously, the OCEAN RANGER never came into direct contact with the seafloor and therefore moved in response to the forces of the wind and sea subject to the constraints of the mooring system. Much of this movement was eliminated by ballasting the rig down to a drilling draft of 80', but this did not eliminate all wind-and-sea-induced vessel movement of the rig. Since drilling operations require that the drill string be held relatively motionless, motion compensators were used to eliminate the remaining vessel movement effect on the drill string and also on the marine riser which was rigidly attached to the subsea stack.

Wind-and-sea-induced lateral movements (surging, swaying, and yawing) were relatively insignificant under most environmental conditions because the rig's mooring system maintained it on location. However, under extremely adverse environmental conditions, the anchor cable tensions could reach critical levels and the anchors had to be slacked-off to ease this tension to prevent damage.

Lateral movement effect on the drill string was not compensated for since minor lateral movements did not affect drilling. However, under extremely adverse environmental conditions the horizontal offset of the rig from the subsea stack would cause excessive wear on the marine riser and the subsea stack, and also generally preclude drilling operations. Lateral movement effect on the rigidly-connected marine riser was compensated for by a ball joint located above the connector which allowed for horizontal offsets from the subsea stack of up to 10 degrees in any direction. Movements in excess of this would damage the marine riser or the subsea stack and therefore the riser had to be disconnected before reaching this limit.

Since the derrick and well area (moon pool) were in the center of the rig, roll and pitch vessel movements normally had little effect on drilling. Also, the "bending flexibility" of the drill string accommodated these motions somewhat and tended to make their effects negligible, except under extreme environmental conditions.

Wind-and-sea-induced vertical movements of the rig (hereafter referred to as heave) had a critical effect on drilling operations. To compensate for heave in the drill string, a "drill string motion



OCEAN RANGER

figure 6

(heave) compensator" was located directly above the swivel hook from which the drill string was suspended. The drill string motion compensator on the OCEAN RANGER was a RUCKER 400,000 lbs., 18' stroke compensator. Heaves in excess of 18' exceeded the limit of this unit and drilling had to cease before this limit was reached.

The upper end of the marine riser did not connect rigidly to the drilling rig. Eight "riser tensioners" dampened out heave and held the upper end of the riser relatively motionless by means of wire cables. On the OCEAN RANGER, the "riser tensioners" were RUCKER 80,000 lbs., 50' stroke units. A stroke in excess of 50' exceeded the limits of the tensioners and the riser had to be disconnected from the subsea stack before reaching this limit to prevent damage. Integral with the use of the tensioning system on the riser was a telescoping joint or "slip joint" which allowed for the steady movement of drilling fluids from the well. The slip joint was in two sections; an inner barrel and an outer barrel. In design, the inner barrel slides freely within the outer barrel. The inner barrel connected directly to the bell nipple, which was rigidly attached to the rig itself. The outer barrel was rigidly attached to the top of the marine riser and held by the riser tensioning system. On the OCEAN RANGER, the "slip joint" was a 21" O.D. (outside diameter) x 1/2" wall (wall diameter) X-52 VETCO TYPE "WJ", with a 55' stroke. A stroke in excess of 55' exceeded the limit of the unit and the riser had to be disconnected before reaching this limit to prevent damage.

As discussed above, certain extreme conditions required the marine riser to be disconnected to prevent damage. By OCEAN RANGER policy, as set forth in the OCEAN RANGER Emergency Procedures Manual, these conditions were heaves in excess of 15 feet, and horizontal offset approaching 10 degrees. To disconnect the marine riser, several steps were required. First, drilling must cease (drilling had to cease before heaves reached the 18' stroke limit of the drill string compensator). Next, the drill string was partially withdrawn and a "hang-off" tool installed in the drill string. The drill string was then run back into the hole and the pipe rams of the blowout preventer were closed around the "hang-off" tool, thus "hanging-off" the drill string. Afterwards the drill string was disconnected above the hang-off tool and could then be removed from the riser. In an emergency, the hang-off tool could be dispensed with by closing the pipe rams around the drill pipe, thus hanging-off the drill string, and then the shear rams activated, cutting the drill string. After the hang-off had been completed, the marine riser could be disconnected from the subsea stack.

6. Inspection and Surveys of the Rig.

The OCEAN RANGER maintained American Bureau of Shipping classification status throughout it's existence. All periodic inspections and surveys required by the ABS were carried out without incident, and no significant discrepancies were found. A "special underwater examination in lieu of drydocking" survey was conducted by the ABS off Port Alberni, British Columbia, Canada, and completed on 5 July 1979. This examination was conducted in conjunction with "Special Survey No. 1" of the hull, machinery, and an "Annual Loadline Inspection". No significant discrepancies were found during any of these inspections, surveys, or examinations. Followup "Annual Loadline Inspections" were completed on 8 April 1979, and on 17 June 1981. "Annual Class Surveys of the Hull and Machinery" were conducted simultaneously with the "Annual Loadline Inspection", and no noteworthy discrepancies were found during either of these Inspections or Surveys. Also, an "Annual Cargo Gear Inspection" was completed on 16 June 1981 with no discrepancies noted.

The OCEAN RANGER held all required "International Convention for the Safety of Life at Sea, 1960" (SOLAS) Certificates. The SOLAS "Cargo Ship Safety Equipment Certificate" was issued by the U.S. Coast Guard Marine Safety Office (MSO) Providence, Rhode Island, on 27 December 1979 and was valid until 27 December 1981. The SOLAS "Cargo Ship Safety Construction Certificate" was issued by the American Bureau of Shipping's New York office on 28 April 1980 and was valid until 1 July 1984. The SOLAS 1974 "Cargo Ship Safety Radiotelegraphy Certificate" was issued by the Canadian Government on behalf of the U.S. Government on 16 April 1981 and was valid until 15 April 1982.

Upon entering active service, the OCEAN RANGER was registered in Panama and remained under Panamanian Registry until 1979, when ODECO decided to place it under United States Registry. The change of registry subjected the OCEAN RANGER to the Vessel Inspection and Manning Laws enforced by the United States Coast Guard.

In bringing the OCEAN RANGER into compliance with the Vessel Inspection and Manning Laws, the OCEAN RANGER was considered to be an "existing uncertificated mobile offshore drilling unit (MODU)" as defined in 46 CFR SUBCHAPTER IA, Appendix A. This designation permitted the OCEAN RANGER to receive a Coast Guard Certificate of Inspection largely based on her past record of safe and successful operations, and her status as an ABS classed vessel.

In October 1979, ODECO made application to the Coast Guard MSO Providence, Rhode Island, for an original Inspection for Certification of the OCEAN RANGER. This inspection was completed on 14 December 1979 and an original Certificate of Inspection (COI) issued on 27 December 1979 which was valid until 27 December 1981. The most noteworthy findings of this inspection were: the lack of davit launched life rafts for 100% of the personnel on board (or an acceptable substitute); and the need to replace the existing lifeboats and davits with Coast Guard approved equipment, or obtain approval for the use of the existing equipment. In response to these requirements, ODECO elected to retain the existing lifeboats on the OCEAN RANGER, and to acquire two additional 58-man lifeboats and davits as a substitute for the required davit launched life rafts. Coast Guard MSO Providence, Rhode Island, was in the process of accepting the existing lifeboats as suitable "existing safety equipment", pending an on-site inspection. MSO Providence, Rhode Island, also allowed the OCEAN RANGER until 27 December 1981 to complete the installation of the two additional lifeboats as a substitute for the required davit launched life rafts.

Title 46 CFR 107.269 states that the USCG reinspects (mid-period inspection) a MODU between the 10th and 14th months after the month in which the certificate is issued to determine if the unit continues to meet the requirements of the Certificate of Inspection. On 7 August 1980, the Commandant of the Coast Guard made mid-period inspections of MODU's operating overseas discretionary with the USCG Marine Inspection Office issuing the Certificate of Inspection. On 7 January 1982, the Commandant of the Coast Guard discontinued mid-period inspections worldwide for MODU's and stated that the Coast Guard regulations would be amended accordingly. However, on 5 April 1982, mid-period inspections of MODU's on the U.S. outer continental shelf were again reinstated by the Commandant. Because of budgetary contraints, mid-period inspections of MODU's in international service have seldom been conducted since the regulations affecting MODU's became effective in 1978. Because of these several policies the USCG did not perform a mid-period inspection on the OCEAN RANGER.

Based on a confirmation of the accuracy of the stability test performed on the OCEAN RANGER in Hiroshima, Japan, on 25 March 1976, and a preliminary review of her "Booklet of Operating Conditions",[1] the stability of the rig was considered acceptable to the Coast Guard. A Temporary Stability Letter was issued by Coast Guard MSO Providence, Rhode Island, on 26 December 1979. On 6 January 1981 the OCEAN RANGER's "Booklet of Operating Conditions" was approved by the Coast Guard on the basis that it "provided the Master with sufficient stability information to: determine the freeboard for any condition of vessel loading; and obtain, by rapid and simple processes, accurate guidance as to the stability of the vessel for any condition of loading and service". On 2 February 1981 Coast Guard MSO Providence, Rhode Island, issued a Permanent Stability Letter to the OCEAN RANGER "as presently outfitted, equipped, and manned". On 30 October 1981, the ABS issued the current "International Load Line Certificate" to the rig, which was valid until 5 July 1984.

On 4 April 1980 a "special examination in lieu of drydocking" was performed on the OCEAN RANGER in the Wilmington Canyon Area off of the East Coast of the United States. This examination involved an underwater survey by divers, and was attended by inspectors from the Coast Guard MSO Providence, Rhode Island, and the ABS; no discrepancies were noted.

In 1979, the OCEAN RANGER was admeasured by the Coast Guard Marine Inspection Office in New Orleans. In 1980, the rig was readmeasured by the Coast Guard Marine Inspection Office in Philadelphia. Based on these admeasurement surveys and the satisfactory material condition of the rig, as evidenced by the prior issuance of a Certificate of Inspection on 27 December 1979, the OCEAN RANGER was issued Permanent Certificate of Registry, No. 74.

1 A detailed discussion of the OCEAN RANGER's Booklet of Operating Conditions follows in section VI of this report.

In October 1981, LCDR PURTEL, U. S. Coast Guard, visited the OCEAN RANGER in connection with his Industry Training with ODECO[1]. During his stay of several days on board the OCEAN RANGER, LCDR PURTEL assisted the ODECO Industrial Relations Representative (IRR) in the preparations for the pending Coast Guard inspection. He accompanied the ODECO IRR man and pointed out to him various items that he thought would be noted as discrepancies during a Coast Guard inspection.

From this informal inspection LCDR PURTEL prepared a list of potential discrepancies. The list was not official since LCDR PURTEL's survey was made as a courtesy to the ODECO IRR man to assist him with his own responsibilities concerning the potential discrepancies. The Marine Board did not find that any of these discrepancies were relevant to the casualty. LCDR PURTEL departed the rig and in his considered judgement the rig was in good condition.

On 27 December 1981 the Coast Guard Certificate of Inspection on the OCEAN RANGER expired. Normally a Certificate of Inspection is renewed by the owner submitting the vessel for an inspection at any time during the sixty day period preceeding the certificate's expiration date; there are no provisions in the law which permit the Coast Guard to extend the expiration date of a Certificate. Owners of mobile offshore drilling units are required to file an "Application for Inspection" (Form: CG-3752) in order to renew a vessel's Certificate of Inspection (See 46 CFR 107.215(a)). The Coast Guard does not initiate vessel inspections without this application, although they will accept verbal requests for an inspection with the understanding that such requests must be subsequently confirmed in writing.

An official from ODECO testified that the failure to request an inspection prior to the expiration date of the Certificate was as a result of their desire to have the new lifeboat installations completed for the inspection. Regardless of the reasons for the delay, on 27 January 1982 ODECO verbally requested the Coast Guard MSO Providence, Rhode Island, to schedule an inspection for the

1 Industry training is a formal program whereby Coast Guard Officers are assigned to work with a company for 6-12 months to gain an appreciation for their day-to-day operations. This training and exposure is intended to broaden Coast Guard Officers' experience and make them more proficient as regulators of the Marine Industry. During this training Coast Guard Officers continue as Coast Guard employees and are not permitted to occupy a position in the host company's staff or to be paid by them.

OCEAN RANGER. The Coast Guard could not provide inspectors for this purpose until the week of 15 February 1982. The Coast Guard inspection team was preparing to depart for St. John's, Newfoundland, on 15 February when word of the casualty was received.

7. Communications Equipment

The OCEAN RANGER was equipped with a variety of equipment for external communication, including single side band (SSB) radio telephone with telex capability, VHF radio, and Maritime Satelite (Marisat) Communications System with telephone and telex capability. For internal communications the rig had a sound powered phone system, a public address (PA) and intercom system, and a number of handheld VHF transceivers (walkie-talkies).

There were two SSB radio telephone systems on the OCEAN RANGER at the time of the casualty. Both systems were used to conduct the normal business of the rig with shore based personnel, including ordering supplies, parts, equipment, and subcontractor services; making arrangements for rig personnel rotations, reliefs, and similiar transactions; discussions regarding the general operation, management, and maintenance of the rig; and for personal calls ashore. One SSB telephone system radio was specifically dedicated for ODECO Canada's use while the other was for MOCAN's[1] use. The ODECO Canada SSB radio telephone system had transceivers located in the OCEAN RANGER's radioroom and in the toolpusher's office; they were used primarily for communicating with ODECO Canada's St. John's Office. The ODECO SSB transceiver in the radioroom also had Telex capability. The MOCAN SSB had radio telephone system transceivers located in the OCEAN RANGER's radioroom as well as in the MOCAN drilling foreman's office; it was used for communicating with MOCAN's St. John's office, and also for communicating with the MOCAN drilling foremen assigned to the SEDCO 706 and the ZAPATA UGLAND. The MOCAN SSB transceiver in the radioroom also had telex capability. The ODECO Canada St. John's office radio was manned only during working hours while the MOCAN St. John's office radio was guarded 24 hours a day. Both the MOCAN SSB and the ODECO Canada SSB radio telephone system were monitored 24 hours a day by radio telephone operators assigned to the radioroom on the OCEAN RANGER.

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1 MOCAN is Mobil Oil of Canada, Ltd.

The Marisat Communications System had terminals in both the MOCAN foreman's office and in the radioroom. The Marisat also had telex capability from the radioroom. The primary purpose of this system was to afford the top level management of the rig with direct two-way telephone communication with personnel ashore. The Marisat system was primarily used to discuss matters of an important nature where direct two-way communications were considered essential.

The VHF radio transceivers were located in the radioroom, in the pilothouse, and in the ballast control room. The VHF radio's primary purpose was to afford the personnel in the ballast control room with a communications link to the various supply/standby vessels which provided transportation and service to the rig. VHF radios were also available in similar locations on the SEDCO 706 and the ZAPATA UGLAND for the same purposes. A VHF radio was also located in MOCAN's St. John's office to communicate with the various supply/standby vessels when they were in the near-shore vicinity. The handheld VHF radio transceivers were normally used by personnel on the rig to commu·icate with each other during vessel towing, cargo/fuel/water transfer operations, and also to communicate with personnel on the supply vessels.

8. <u>Lifesaving Equipment.</u>

The primary lifesaving equipment on board the OCEAN RANGER consisted of two 50 man Norwegian-built, "Harding" totally enclosed lifeboats, built by Bjorke Batbyggeri (now Harding AS) of Rosendal, Norway. Both boats were identical, and were made of fibrous glass reinforced plastics. The boat name plate data listed: the length (8.00 meters), the breadth (3.00 meters), the depth (1.20 meters), the cubic capacity (706 cubic feet), and the capacity (50 persons). This lifeboat was designed to be self-righting, providing all personnel were strapped in their seats and there was no significant accumulation of water inside the boat. The releasing gear fitted for the two boats was designed to disengage only when there was no load on the falls. The design of the releasing gear provided for a single handle to release both the forward and after falls simultaneously. These Harding lifeboats were located on the upper deck, one just left of the centerline on the bow (this boat was referred to as "Lifeboat #1"); the second boat was located just left of the centerline on the stern (this boat was referred to as "Lifeboat #2). These two lifeboats provided sufficient seating capacity for 100% of the total number of persons allowed (100) on board the OCEAN RANGER, as specified in the Certificate of Inspection.

In addition to the two Harding lifeboats, the OCEAN RANGER was in the process of installing two additional lifeboats as the approved substitute for davit launched life rafts. These boats were identical 58 man, American-built, "Watercraft" totally enclosed lifeboats, built by Watercraft America of Edgewater, Florida. The construction of the boats was of fibrous glass reinforced plastic. The name plate data listed: the USCG Approval number (160.035/484/0), the length (27.89 ft), the breadth (9.74 ft), the depth (4.07 ft), the cubic capacity (707.6 cubic ft), the bouyancy capacity (180.6 cubic ft), the "A" weight (8,700 lbs), the "B" weight (20,045 lbs), and the capacity (58 persons). The Watercraft boat was designed to be self-righting, providing the personnel were strapped in their seats and there was no significant accumulation of water inside the boat. The releasing gear for the Watercraft boats differed from the releasing gear on the Harding Boats in that, as required by U.S. Coast Guard Regulations, it is designed to release under load (i.e. the boat could be released at any time, regardless of whether it was waterborne or not). The releasing gear was actuated from a single point which simultaneously released the forward and after falls. Both Watercraft boats were on board the OCEAN RANGER at the time of the casualty on 15 February 1982, but only one of the boats was installed in the davits; the other was lashed to the deck awaiting installation. The installed boat was referred to as "Lifeboat #4" and was located on the upper deck, just starboard of the centerline on the stern. The stowed lifeboat was referred to as "Lifeboat #3" and was to be located on the upper deck, just starboard of the centerline on the bow.

In addition to the lifeboats, there were ten Coast Guard approved, 20 man inflatable life rafts on board the OCEAN RANGER with a total capacity of 200 persons. Nine of the rafts were built by C. J. Hendry Co. of San Francisco, California; the tenth was built by B. F. Goodrich. All of the life rafts were located on the upper deck; four were located on the stern, two on the starboard side, two on the port side, and two on the bow. None of them were of the davit launch design. All of the life rafts were serviced between 20 April 1981 and

31 July 1981 at IMP Group, Limited; Beclin Industrial Park, Topsail Road, St. John's, Newfoundland. This facility was not approved by the U.S. Coast Guard for servicing U.S. Coast Guard approved life rafts. There were also 127 U.S. Coast Guard approved adult life preservers, 25 approved work vests, and 15 ring lifebuoys on board. Several insulated suits were available to the rig's personnel for flying to and from the rig by helicopter, but there were no exposure suits designed to afford protection against hypothermia.

9. Evacuation Plans

The OCEAN RANGER was provided with an Emergency Procedures Manual. Incorporated into this Manual was an evacuation plan which specified:

> PHASE III - EVACUATION
> It should be noted that ODECO's Toolpusher is responsible for any decision to abandon the rig.
>
> For any storm with forecast winds of 100 m.p.h or more, consider evacuation of personnel and act as follows:
>
> 1. Confirm forecast, alert Contractor's Shore Base Manager of environmental condition.
> 2. Request additional forecast from appropriate Weather Center for rig location at 3 hour intervals.
> 3. Review the present and past sea conditions to determine if they are rising or falling and to determine what effect the storm is likely to have on the sea conditions.
> 4. Determine if sea and wind conditions will permit a safe evacuation.
> 5. Determine if evacuation is necessary or possible.
> 6. Discuss with Contractor's Shore Manager, and mutually decide if evacuation is necessary or possible.
> 7. Review procedure for rig evacuation with Barge Master.
> 8. Prepare rig for total evacuation.
> 9. Check on availability of tug boats.
> 10. As conditions warrant
>
>   (i) Evacuate nonessential personnel
>   (ii) Evacuate all personnel except skeleton crew
>   (iii) Complete evacuation

III PRIOR DEPLOYMENT HISTORY

10. Drilling Locations

During its operating history, the OCEAN RANGER was usually deployed at a drilling location, underway between sites, or at a standby location. The following is a listing of the periods of time and geographic areas where the OCEAN RANGER was engaged in offshore drilling operations:

YEAR	Length of time	Geographical Areas
1976	99 days	Bering Sea
1976/1977	232 days	Gulf of Alaska
1977	111 days	Lower Cook Inlet
1979/1980	166 days	Baltimore Canyon
1980	126 days	Off coast of Ireland
1980-1982	465 days	Grand Banks off Newfoundland

11. Hull and Machinery History

As evidenced by American Bureau of Shipping and U.S. Coast Guard inspection reports, the OCEAN RANGER had no history of structural failure or repairs as a result of latent construction defects detected by the surveys and inspections. One operational casualty resulted in the rig sustaining minor damage to column PC2 in way of the boat bumper when the area was struck by the supply vessel VOLUNTEER on 9 September 1976. Repairs were completed to the satisfaction of the American Bureau of Shipping on 6 March 1979. No significant machinery deficiencies were experienced. The anchor winch/windlasses were replaced by new units in 1979.

12. Severe Weather History

Review of the OCEAN RANGER logs and reports for weather and sea data revealed that over 50 significant storms were experienced by the rig while on drilling locations described above (Please see figure 7 for a listing of the significant storms). Except for the casualty, the most severe weather encountered by the OCEAN RANGER occurred

SUMMARY OF OCEAN RANGER DAILY LOGS (Morning Reports, Evening Reports, Ballast Control Room Reports) from JUNE 1976 TO FEBRUARY 1982 WHEN SIGNIFICANT STORMS OCCURRED

Date	Location	Draft	Max Wave Height	Max Heave	Max Wind Speed	Comments (...see notes below...)	GMD	GML	Swell	Max Roll (......Degrees	Max Pitch ....)	Rig Dir	Wind Dir
16OCT76	Gulf of Alaska	55'	16-20'	N/A	65-72MPH	W.O.W.	22.25'	29.95'	18-20'	3.2	2.0	320	ENE
17OCT76	Gulf of Alaska	77'	8-10'	N/A	86MPH	W.A.D.	7.29'	4.39'	18'	2.0	1.5	338	ENE
28OCT76	Gulf of Alaska	80'	7-8'	1'	45-50MPH	W.A.D.	5.90'	4.57'	15-18'	0.5	0.5	333	ENE
29OCT76	Gulf of Alaska	80'	4'	1-2'	25-55MPH	W.A.D.	6.01'	4.65'	7-8'	1.0	1.0	333	ENE
30OCT76	Gulf of Alaska	80'	10-12'	7-8'	45-55MPH	W.A.D.	5.54'	4.02'	25'	1.5	2.5	333	ENE
01NOV76	Gulf of Alaska	80'	5'	1-2'	51MPH	W.A.D.	6.53'	5.03'	6'	0.5	0.5	333	ENE
02NOV76	Gulf of Alaska	80'	10-12'	4-5'	65MPH	W.O.W.	6.56'	5.06'	10-12'	1.0	1.0	333	ENE
06NOV76	Gulf of Alaska	80'	9-10'	5'	67MPH	W.O.W.	6.14'	4.69'	9-10'	1.0	1.2	333	ENE
09NOV76	Gulf of Alaska	80'	8-9'	3-4'	59MPH	W.O.W.	6.22'	4.76	10-12'	1.0	1.5	333	ENE
14NOV76	Gulf of Alaska	80'	8-9'	4'	39MPH	W.A.D.	5.63'	4.21'	10-12'	1.5	1.2	333	ENE
15NOV76	Gulf of Alaska	80'	8'	10'	67MPH	W.O.W.	5.78'	4.38'	10-12'	1.5	1.2	333	E
14DEC76	Gulf of Alaska	78.5'	10'	8.7'	74MPH	W.A.D.	3.87'	2.36'	22'	3.7	1.9	332	ENE
15DEC76	Gulf of Alaska	78'	10'	9.9'	82MPH	W.A.D.	2.77'	2.26'	28'	2.5	4.2	332	ENE
19DEC76	Gulf of Alaska	78'	16'	6'	66MPH	W.A.D.	3.50'	2.00'	18'	1.5	1.5	332	SE
20DEC76	Gulf of Alaska	77'	8'	5'	29MPH	W.A.D.	3.50'	2.00'	8-10'	1.5	0.5	332	E
21DEC76	Gulf of Alaska	77'	8'	5'	75MPH	W.A.D	4.45'	2.90'	12-14'	1.5	1.5	332	ENE
04JAN77	Gulf of Alaska	77'	9'	5'	75MPH	W.A.D.	——	1.84'	14'	2.0	2.0	332	E
05JAN77	Gulf of Alaska	77'	8'	4'	60MPH	W.A.D.	——	1.78'	12'	1.0	1.0	332	E
05JAN80	Baltimore Canyon	78'	8-10'	6-10'	45-50MPH	W.A.D.	5.60'	3.60'	26-30'	4.3	5.1	225	N
06JAN80	Baltimore Canyon	78'	6-8'	5-6'	40-45MPH	W.O.W.	4.58'	2.58'	18-24'	2.9	4.0	225	N
07JAN80	Baltimore Canyon	78'	10-12'	4-6'	40-50MPH	W.A.D.	6.50'	4.50'	8-12'	2.1	3.5	225	WSW
08FEB80	Baltimore Canyon	78'	12-16'	8-14'	28-35MPH	W.A.D.	4.01'	2.01'	8-10'	3.0	3.5	225	NW
28FEB80	Baltimore Canyon	78'	7'	1-2'	38-40MPH	W.A.D.	4.90'	2.90'	9-11'	3.6	3.5	225	WNW
14MAR80	Baltimore Canyon	78'	8-10'	12'	35-45MPH	W.A.D.	5.38'	3.38'	10-15'	3.3	3.1	225	W
23MAR80	Baltimore Canyon	78'	6-10'	8-14'	30MPH	W.A.D.	5.31'	3.31'	6-10'	1.3	2.2	225	NW
11SEP80	Ireland	78'	5'	15'	50MPH	W.A.D.	5.13'	3.13'	30'	4.5	3.0	187	WNW
12SEP80	Ireland	78'	16'	9.5'	60MPH	W.A.D.	5.16'	3.16'	30'	5.0	2.5	187	WNW
15SEP80	Ireland	—	4'	4.3'	58MPH	W.O.W.	4.87'	2.87'	12'	2.5	1.5	187	NW
07OCT80	Ireland	78'	14'	14.8'	80MPH	W.O.W.	3.80'	1.80'	11'	5.7	5.0	187	NW
08OCT80	Ireland	78'	40'	18.4'	75MPH	W.O.W.	5.78	3.78	11'	7.0	3.5	187	NW
19NOV80	Newfoundland	78'	6-8'	8.1'	47-55MPH	W.A.D.	6.29'	4.29'	10-12'	2.6	3.2	230	E
20NOV80	Newfoundland	78'	8'	5.8'	68MPH	W.A.D.	6.07'	4.07'	18'	4.3	5.2	230	WNW

OCEAN RANGER WEATHER HISTORY

Figure 7

Date	Location	Draft	Max Wave Height	Max Heave	Max Wind Speed	Comments (..See notes below.)	GMD	GML	Swell	Max Roll Degrees	Max Pitch Degrees	Rig Dir. ...Degrees	Wind Dir.
21NOV80	Newfoundland	78'	8-12'	12.7'	30MPH	W.O.W.	5.71'	3.71'	18-20'	4.3	5.2	230	WNW
19JAN81	Newfoundland	80'	12'	4.5'	72MPH	W.A.D.	3.53'	1.70'	10'	2.3	1.3	230	SE
20JAN81	Newfoundland	80'	20'	8.5'	47MPH	W.A.D.	3.47'	1.64'	10'	3.9	3.6	230	SW
21JAN81	Newfoundland	80'	14'	4.5'	29MPH	W.A.D.	3.72'	1.70'	—	1.7	2.4	230	WSW
27SEP81	Newfoundland	80'	23'	16'	60MPH	W.A.D.	3.75'	2.00'	—	2.1	3.2	310	WNW
28SEP81	Newfoundland	80'	15'	15'	40MPH	W.O.W.	4.01'	2.48'	—	1.5	1.8	310	WNW
29SEP81	Newfoundland	80'	10'	6'	30MPH	W.A.D.	4.01'	2.50'	8'	0.8	0.8	310	SE
09NOV81	Newfoundland	80'	18'	10'	45MPH	W.A.D.	3.51'	1.73'	15'	3.4	1.8	310	S
27DEC81	Newfoundland	80'	18'	14'	55MPH	W.A.D.	3.90'	2.13'	16'	1.8	2.8	311	WNW
31DEC81	Newfoundland	80'	25'	9'	60MPH	W.A.D.	3.74'	2.02'	10'	2.5	2.1	311	WSW
02JAN82	Newfoundland	80'	21'	13'	32MPH	W.A.D.	2.53'	1.50'	18'	1.6	1.5	311	N
15JAN82	Newfoundland	80'	20-34'	5-8'	55-65MPH	W.A.D.	3.01'	1.98'	13-17'	1.2-3.4	1.0-4.0	311	SSW
16JAN82	Newfoundland	80'	28-47'	16-22'	60-80MPH	W.O.W.	2.99'	1.96'	20-25'	2.3-5.5	2.0-4.5	311	WSW
17JAN82	Newfoundland	80'	18-39'	8-15'	50-60MPH	W.A.D.	3.20'	2.17'	15'	1.5-3.0	3.5	311	SE
18JAN82	Newfoundland	80'	18-39'	8-18'	50-60MPH	W.O.W.	3.26'	2.23'	10'	1.5-4.5	1.5-4.5	311	WSW
19JAN82	Newfoundland	80'	22-36'	8-15'	45-55MPH	W.O.W.	3.09'	2.06'	—	1.1-4.0	1.1-3.5	311	WxS
20JAN82	Newfoundland	80'	18-30'	6-12'	53-64MPH	W.A.D.	2.94'	1.91'	—	1.0-4.0	1.0-3.5	311	WxS
22JAN82	Newfoundland	80'	15'	4-8'	29MPH	W.A.D.	2.96'	1.93'	14'	1.0-1.8	1.5-2.5	311	W
14FEB82	Newfoundland	80'	32-34'	3-5'	72MPH	W.A.D.	5.00'	2.04'	10'	2.0-3.0	1.4	311	W *

* For period ending 1600 on 14 February 1982.

Notes: W.O.W. - Waiting on weather
W.A.D. - Working as directed
GMD - Diagonal metacentric height
GML - Longitudinal metacentric height

OCEAN RANGER WEATHER HISTORY

Figure 7

occurred on 16-20 January 1982 while working in the Hibernia Field on the Grand Banks.

That storm's fury had little effect on the OCEAN RANGER except that the anchor tensions were not set high enough to keep the rig positioned over the well within acceptable operating limits of the marine riser ball joint. Also, the slip joint tension ring was close to hanging up on the edge of the moon pool. To alleviate future problems associated with maintaining the rig's position within acceptable limits, anchor tensions were increased to 250,000 p.s.i. Twice during this five day period the marine riser had to be disconnected due to vessel heave. These evolutions proceeded normally and drilling was resumed when the weather and seas subsided.

IV ORGANIZATIONAL RELATIONSHIPS

13. ODECO and Mobil Relations

The owner of the OCEAN RANGER was ODECO International, Inc. a subsidiary corporation of ODECO, Inc., whose corporate headquarters is at 1600 Canal St., New Orleans, LA 70161. At the time of the casualty of 15 February 1982, the OCEAN RANGER was under a demise charter (bareboat charter) from ODECO International, Inc. to ODECO Drilling of Canada, Ltd. (hereafter referred to as ODECO Canada)[1] a subsidiary corporation of ODECO, Inc. registered to do business in Canada. ODECO Canada in turn leased the OCEAN RANGER under a time charter to Mobil Oil of Canada, Ltd. (MOCAN),[2] whose corporate headquarters is in Calgary, Alberta, Canada.

Under the leasing agreement between ODECO Canada and MOCAN, ODECO Canada was responsible for manning, operating, and navigating the OCEAN RANGER. MOCAN was responsible for: providing transportation for men and materials to and from the rig; providing all materials necessary to complete the well including the mud, casing, and cement; and supervising the design, construction and completion of the well. In general, operations that affected the rig were the responsibility of ODECO Canada, and operations that affected the well were the responsibility of MOCAN. However, since rig and well operations frequently overlaped and interacted with one another, a more exact delineation of the responsibilities of ODECO Canada and MOCAN is difficult.

Almost all decision making by one party within his sphere of responsibility required close consultation and coordination with the other party. This relationship is of paramount importance in understanding the relationships between the actual individuals on board the OCEAN RANGER.

The senior representative of MOCAN in St. John's at the time of the casualty of 15 February, was Mr. Merv Graham, whose title was Grand Banks Drilling Superintendent (hereafter referred to as the MOCAN Superintendent). ODECO Canada's senior representative in

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1 The term ODECO is frequently used in witness testimony to refer to ODECO Canada and/or ODECO International and when used is assumed to refer to one or the other, or both of these corporations.

2 The term Mobil is frequently used in witness testimony to refer to MOCAN, and where used is assumed to refer to that corporation.

St. John's at the time of the casualty was Mr. Jimmy Counts, whose title was Drilling Superintendent (hereafter referred to as the ODECO Canada Superintendent). Both the MOCAN Superintendent and the ODECO Canada Superintendent were normally stationed ashore in St. John's, Newfoundland, but had on occasion visited the OCEAN RANGER in connection with their responsibilities.

The direct senior representative of MOCAN on board the OCEAN RANGER at the time of the casualty of 15 February was Mr. Jack Jacobson, whose title was Senior MOCAN Drilling Foreman. Under Mr. Jacobson on the OCEAN RANGER, was another MOCAN Drilling Foreman, Mr. Robert Madden. Also on board the OCEAN RANGER was a MOCAN Drilling Engineer, Mr. Joseph Fenez.

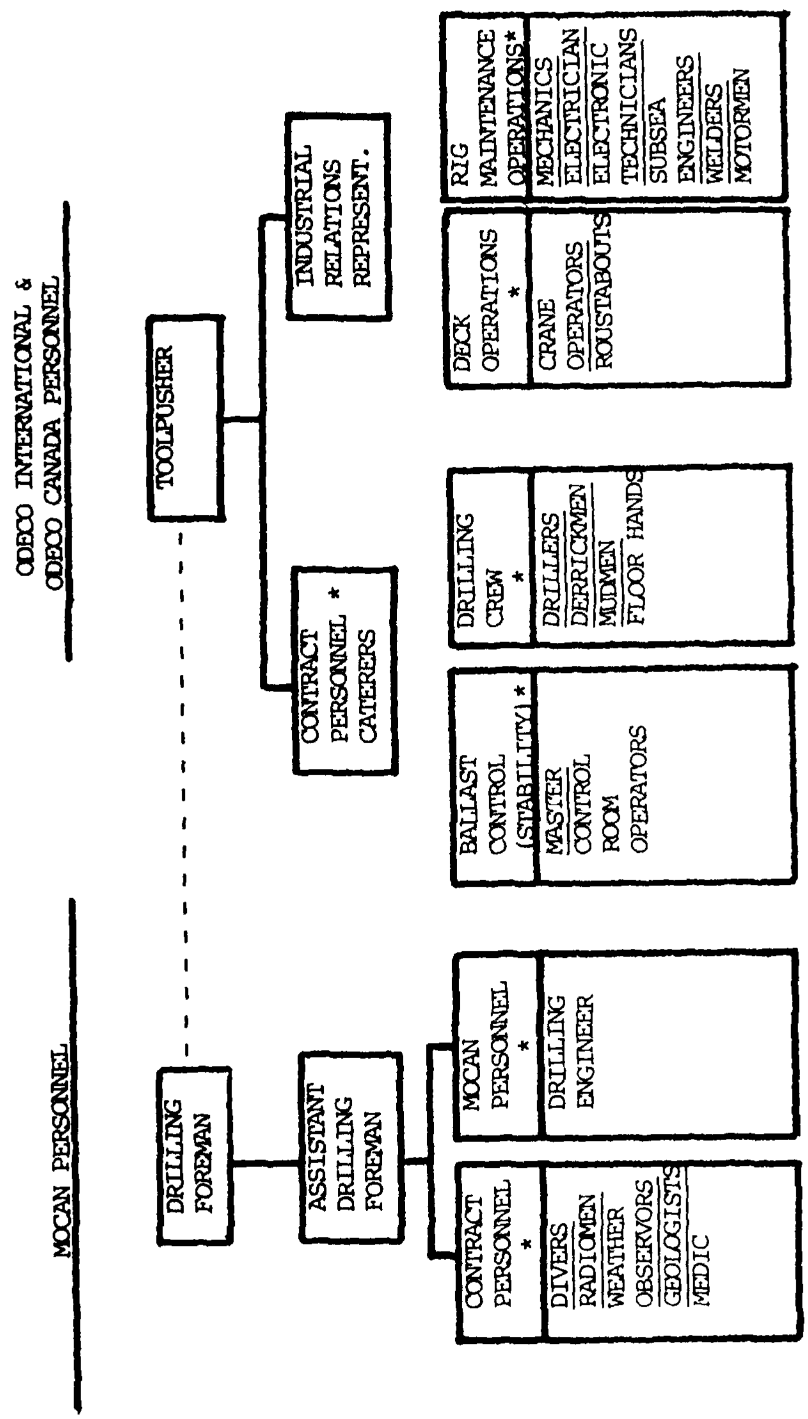
The direct senior representative of ODECO Canada on board the OCEAN RANGER was Mr. Kent Thompson, whose title was Toolpusher. Directly under Mr. Thompson at the time of the casualty were 45 employees of ODECO, including: drillers, floor hands, roustabouts, derrickmen, crane operator, electricians, radiomen, electronics technicians, mechanics, medic, welders, subsea technician, and control room operators. Also responsible to the toolpusher were the vessel Master, and the Industrial Relations Representative. All of the remaining personnel on the OCEAN RANGER at the time of the casualty were various subcontractor personnel hired by either MOCAN or ODECO Canada for specialized services. Subcontract personnel on board for MOCAN included: divers, weather observers, geologists, mud and cement technicians, and well logging technicians; on board for ODECO Canada were: catering personnel, cooks, stewards, and welding personnel (please see figure 8 on page 28).

14. Makeup of the crew

Of the 84 persons on board the OCEAN RANGER at the time of the casualty of 15 February, 15 were U.S. citizens, 68 were Canadian citizens, and 1 was a British citizen. All 15 U.S. citizens were employees of ODECO (ODECO Canada or ODECO International). There is no evidence that the multi-national make up of the crew had any adverse effect on the rig's operations.

15. Toolpusher and Master relationship

As previously stated, the senior representative of ODECO Canada on



OCEAN RANGER ORGANIZATION FOR DRILLING

*Descriptive titles assigned by the Board to group functionally related jobs

figure 8

board OCEAN RANGER at the time of the casualty was the Toolpusher, Mr. Kent Thompson. The position of Toolpusher at the time of the casualty was senior to all other ODECO positions on the rig, including the vessel Master, Captain Clarence Hauss. This seemingly rather anomalous situation for a vessel is permitted by U.S. Coast Guard regulation 46 CFR 109.107, which specifies:

> "The owner of a unit or his agent shall designate an individual to be the master or person in charge of the unit."

The OCEAN RANGER's Booklet of Operating Conditions specified that while underway the person in charge shall be the Master, but while anchored on location for the purpose of drilling the person in charge shall be the Toolpusher. The person in charge holds the ultimate responsibility for decision making affecting the rig. However, it is commonly recognized within the drilling industry that the Toolpusher is more expert at drilling operations, while the Master is more expert at navigating and vessel operations. However, since the operation of a complex vessel like the OCEAN RANGER frequently involves operations that affect both of these areas of expertise, close coordination and consultation between the Master and the Toolpusher is absolutely necessary regardless of who is the person in charge.

16. Person in Charge

The U. S. Coast Guard did not license the person in charge on the OCEAN RANGER nor did it specify any minimal training or experience requirements that had to be met by an individual before he could hold that position. This was also true of the position of Toolpusher. In contrast to this, the U. S. Coast Guard did impose specific experience and knowledge requirements on the position of Master. Because of this practice, individuals filling the position of person in charge varied markedly in their backgrounds, level of knowledge, and types of professional credentials (licenses) held. From the evidence developed none of the Toolpushers holding the position of person in charge on the OCEAN RANGER held Coast Guard issued licenses, while all Masters holding this position held such licenses.

On the OCEAN RANGER, many of the responsibilities imposed on the person in charge by 46 CFR 109 were delegated to the Industrial Relations Representative (IRR) who dealt with them on a daily basis. This is not a prohibited practice, but it does diminish the need for the individual actually holding the position of person in charge to be familiar with such regulations. During testimony before the Board, one former Toolpusher off of the OCEAN RANGER, who frequently held the position of person in charge, testified that he had never read the Coast Guard regulations applicable to MODU's.

17. Required Manning

The Coast Guard Certificate of Inspection for the OCEAN RANGER required the following marine crew while the rig was anchored on location for the purpose of drilling:

1 Master (with an "Industrial License")[1]
2 Able Seamen
1 Ordinary Seaman

In addition, the rig was required to have on board sufficient Certificated Lifeboatmen to man the primary lifesaving equipment. As previously noted in this report, the primary lifesaving equipment included two 50 man, Harding lifeboats. By virtue of their size, each lifeboat would require 2 Certificated Lifeboatmen (see 46 CFR 109.323) for a total of 4 Certificated Lifeboatmen. However, 46 CFR 109.323 allows Able Seamen and licensed officers to act as lifeboatmen. Since the OCEAN RANGER was already required to carry a Master and 2 Able

1 The "Industrial License" has no definition or status in law or regulation. It was developed by The Coast Guard Marine Inspection Office in New Orleans, LA as a license for offshore oil field personel employed on semi-submersible drilling rigs who passed the test administered by that office. Passing the test and obtaining the license is not a legal or regulatory requirement for employment on board a semi-submersible drilling rig as Master. However, the Coast Guard accepts the Industrial License on self-propelled, semi-submersible drilling rigs in lieu of the normally required Unlimited Master License while such rigs are on location for the purpose of drilling.

Seamen, only 1 Certificated Lifeboatman would have been required to meet the lifeboatmen manning standard.

At the time of the casualty of 15 February, the OCEAN RANGER's marine crew consisted of:

1 Master (with Unlimited, OCEANS License)
2 Ordinary Seamen

The Master was Captain Clarence Hauss and the Ordinary Seamen were Mr. William Dugas and Mr. George Gandy. Accordingly the OCEAN RANGER was short 2 Able Seamen and 1 Lifeboatman at the time of the casualty.

As established by testimony, it was not ODECO Canada's policy on the OCEAN RANGER to employ marine personnel, aside from the Master, to specifically meet the manning requirements of the Coast Guard Certificate of Inspection. The marine crew consisted of individuals from within the industrial personnel force (i.e. all personnel not specifically and exclusively dedicated to the marine crew) who held the required Merchant Mariner's Documents. In other words, individuals were primarily employed on board the OCEAN RANGER for specific industrial capacities, such as Toolpusher, driller, roustabout, electrician, etc. It was only by coincidence that any of these individuals held Merchant Mariners Documents.

Besides being a highly imprecise practice for complying with the manning standards of the Certificate of Inspection, this practice also created some curious hierarchical anomalies on the OCEAN RANGER while she was anchored and drilling, since traditionally all marine personnel are responsible to the Master. Specifically, Mr. Dugas who was a crane operator and Mr. Gandy who was the rig mechanic would both normally have been accountable directly to the Toolpusher. However, since both men were also Ordinary Seamen, they were also theoretically accountable to the Master. In actual practice on board the OCEAN RANGER, the Master exercised immediate supervision only over the ballast control room operators when the rig was anchored and drilling. However, the ballast control room operators were not required by the Certificate of Inspection and did not form a part of the marine crew except by coincidence. Normally there were two ballast control room operators assigned to the rig while on drilling location. (Please see section VI on Ballast Control).

V. BACKGROUND OF KEY PERSONNEL

18. Toolpusher.

The Toolpusher on the OCEAN RANGER was Mr. Benjamin Kent Thompson. Mr. Thompson was born 18 January 1946 and resided in Hattiesburg, Mississippi. He had a grade school education and extensive work experience in the drilling industry. After working for Noble Drilling Co. as a roughneck and driller, he joined ODECO and served on a number of ODECO rigs, including the OCEAN DRILLER, OCEAN CHAMPION, OCEAN PATRIOT, and ST LOUIS as a floorman, derrickman, driller, and Toolpusher. He had been employed on board the OCEAN RANGER as a Toolpusher since 15 January 1981. Mr. Thompson received the following formal job training:

Toolpusher Level - ODECO Training Course.

The Prevention of Oil & Gas Well Blowouts - University of Oklahoma.

Rig Team Management Program - ODECO Training Course.

Comprehensive Well Control Training - ODECO Training Course.

He did not hold any Coast Guard issued Merchant Mariner's Licenses or Documents.

19. Master.

The Master on the OCEAN RANGER was Captain Clarence Eugene Hauss. Captain Hauss was born 10 October 1923 and resided in Baltimore, Maryland. He graduated from the University of Maryland in 1943. He had experience as a vessel master and held a license as Master of Steam and Motor Vessels, Any Gross Tons Upon Oceans, with Radar Observer endorsement, issued in Baltimore, Maryland, on 10 October 1978. He has had extensive experience sailing for Bethlehem Steel Corporation in a variety of capacities, including Master, from 1956 to 1971. He had previously served as a Master for ODECO on board the OCEAN VICTORY and the OCEAN BOUNTY. He reported on board the OCEAN RANGER as Master on 26 January 1982.

20. Senior Ballast Control Room Operator.

The senior[1] ballast control room operator on the OCEAN RANGER at the time of the casualty of 15 February 1982 was Mr. Donald J. Rathbun. Mr. Rathbun was born 11 September 1951 and resided in Narragansett, Rhode Island. He was a high school graduate and attended Bryant College from June 1971 to February 1972. Prior to working for ODECO he was a self employed lobsterman. He had worked for ODECO since January 1980 and been assigned to the OCEAN RANGER since his employment. He had been a control room operator on the OCEAN RANGER since 23 March 1980. Mr. Rathbun received ODECO training as a "Beginning Roustabout" and as an "Intermediate Roustabout". He did not have any Coast Guaru issued Merchant Mariners Licenses or Documents.

21. Ballast Control Room Operator.

The other ballast control room operator on the OCEAN RANGER at the time of the casualty of 15 February was Mr. Domenic Hugh Dyke. Mr. Dyke was born 29 May 1952 and was a Canadian citizen residing in East Port, Bonavista Bay, Newfoundland. He had 3 years of undergraduate study at the Waterloo University in Ontario, Canada, but did not graduate. He worked for Crosby Offshore as a deckhand from April 1979 to October 1979, and as a roustabout for SEDCO in May 1980. He began work for ODECO as a roustabout on the OCEAN RANGER on 22 December 1980 and continued in that capacity until 31 December 1981 when he was promoted to ballast control room operator. His only preparation for that job had been on-the-job training. There is no record that Mr. Dyke ever held a Merchant Mariner's License or Document.

22. Rig Electrician.

The rig electrician on board the OCEAN RANGER at the time of the casualty of 15 February was Mr. Thomas R. Donlon. Mr. Donlon was born 21 February 1947 and resided in Sumter, South Carolina. Mr. Donlon was a graduate of the Sumter Area Technical College, and had extensive

1 The term "Senior" is used by the Marine Board to denote that ballast control room operator who was the more experienced operator on board the OCEAN RANGER at any given time.

work experience as an electrician, including: motor trouble shooting, building and wiring magnetic starters up to 2500 H.P. for AC and DC generators, and motor control troubleshooting. He had worked on board the OCEAN RANGER as an electrician since 1977. Mr. Donlon did not hold any Coast Guard issued Merchant Mariner's Licenses or Documents.

23. Rig Mechanic.

The rig mechanic on board the OCEAN RANGER at the time of the casualty of 15 February was Mr. George Leroy Gandy. Mr. Gandy was born 28 November 1925 and resided in Logansport, Louisiana. He was a high school graduate and had extensive mechanical experience, including: diesel operator, motorman, baroid and cement pumper, hydraulic mechanic, barge captain, and jackmaster. He had worked for Reading & Bates Drilling Co. from 1958 to 1973. Since working for ODECO, he had been assigned as rig mechanic on the OCEAN PROSPECTOR, OCEAN VICTORY, OCEAN LANCER and OCEAN RANGER. He had been rig mechanic on the OCEAN RANGER from February 1977 to October 1977, and again from March 1980 on. Mr. Gandy held a Coast Guard issued Merchant Mariner's Document as an Ordinary Seaman.

VI BALLAST CONTROL

24. Ballast Control Room.

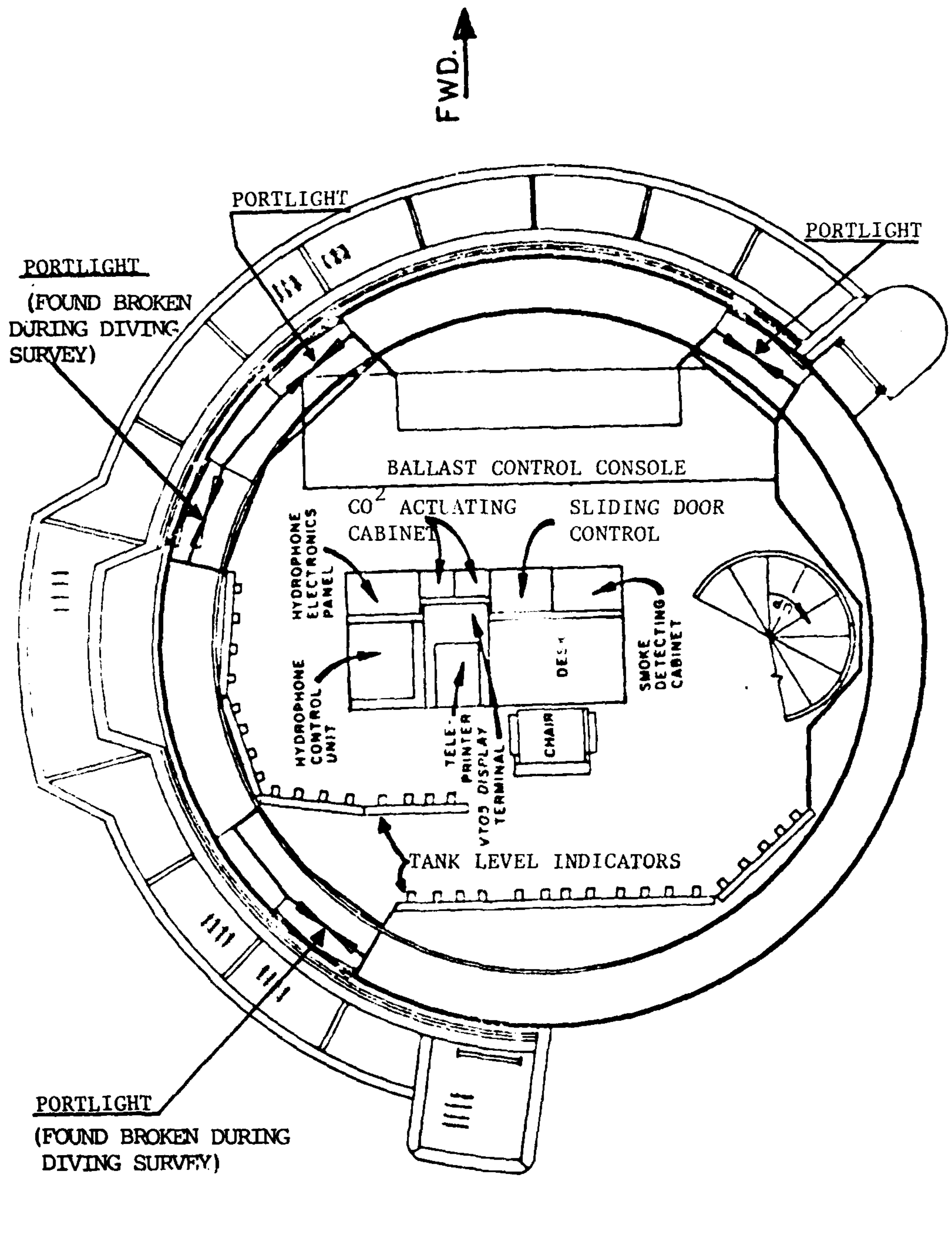
The ballast control room was located in column SC-3, the third column aft, starboard side of the OCEAN RANGER. The control room deck was approximately 28 ft above the drilling draft water line. The general arrangement of the ballast control room is depicted in figure 9.

The ballast control room operator was able to view sea conditions and the vessels draft through four portlights[1] installed in the column. The installed portlights were manufactured to standards established by the Japanese Standards Association. Each portlight was permanently installed in the column and could not be opened. Each portlight assembly was made tight by the installation of through bolts around the periphery of the portlight. Post casualty video tapes confirmed that all deadlights had been closed from the inside. [2] Underwater surveys confirmed that the two portlights located on the portside of the ballast control room were broken (Please see Figure 9).

The ballast control console was located across the forward section of the ballast control room such that the operator faced forward when operating the console (Please See Figure 10). The mimic displays were arranged on the console with respect to port and starboard. The port hull mimic display was on the port side of the panel to the operators left, with the starboard hull mimic display being on the starboard side of the panel to the operators right. However, the mimic displays had the pontoons facing each other (bow to bow). Among other information, each mimic display depicted the relative locations of the hull tanks and included one line piping diagrams of the ballast and drill water systems. The pushbutton control switches, which controled the remotely operated valves located in the ballast pumproom in the pontoon hulls, were each located on the mimic board within the outline of the tank they controlled. The pushbutton portion of the switches were colored and illuminated from within. The valve <u>open</u> pushbuttons were <u>green</u> and remained illuminated when the corresponding valves were opened. The valve <u>close</u> pushbuttons were <u>red</u> and remained illuminated

1 Portlights are glass "windows".

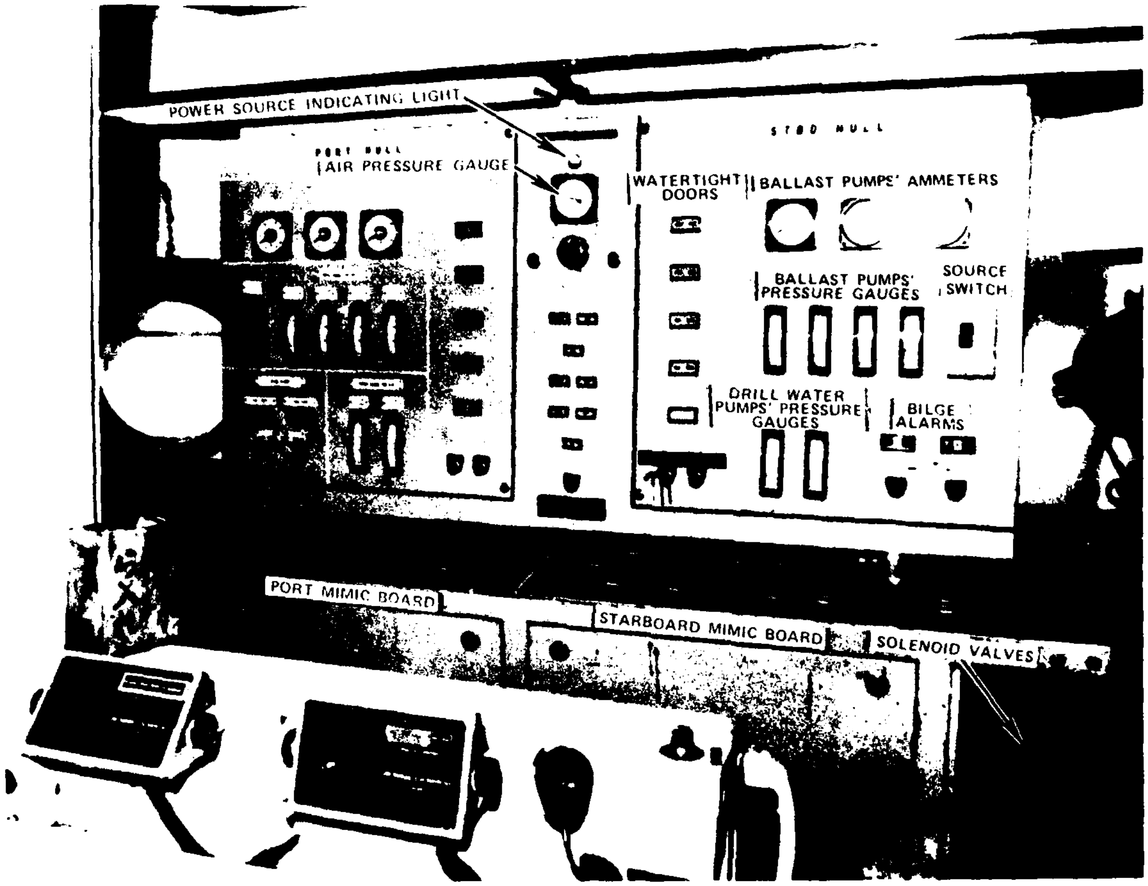
2 Deadlights are interior metal closures which, when shut, covered the portlights.



BALLAST CONTROL ROOM ARRANGEMENT

OCEAN RANGER

figure 9



BALLAST CONTROL ROOM

OCEAN RANGER

figure 10

when the corresponding valves were closed. When a valve was between the open and closed position, both lights were extinguished. The normal condition was for all red lights to be lit as all ballast valves were normally closed.

Figure 11 depicts a typical control circuit. When an open pushbutton switch (PBN II) was depressed, an electric solenoid valve (SOV I) within the control console was energized by a holding relay (RI 5) and remained energized until the close button (PBF II) was depressed, interrupting the holding relay circuit. When energized, the solenoid valve admitted air under pressure to a copper tube connected to an air operator assembly, which operated the associated butterfly stop valve. The butterfly valve would then remain open until the close pushbutton was depressed, at which time the solenoid valve was de-energized. Upon being de-energized the solenoid valve closed the air supply inlet port and also allowed air under pressure from the operator assembly to exhaust to the atmosphere in the ballast control room. As the pressurized air was exhausted, a spring in the operator assembly returned the butterfly valve to its original (closed) position. It took approximately 40 seconds for the butterfly valve to fully open and 20 seconds for it to close. In the event of an electrical or air pressure failure, all open valves in the system closed.

Also located on the ballast control panel were: six remote ballast pump start/stop buttons, ballast pump motor ammeters, ballast pump pressure gauges, and remote start/stop buttons for 2 drill water pumps, 4 bilge pumps and a fuel oil transfer pump. In addition, pump indicating lights, watertight door controls with indicating lights and alarms, bilge level alarms, and deck tank level alarms were provided. The ballast control console power supply could be secured by either an engineroom switchboard circuit breaker or a circuit breaker located behind a front panel of the console. The location of the main power cutoff installed inside the console was not marked or identified. Witness testimony, including that of a former rig electrician, indicated an unawareness of the location of this circuit breaker inside the console. Some control room operators believed that the circuit breakers labeled as "source" on the face of the panel secured all power, when, in fact, they merely cut off power to the ballast and drill water pump pressure indicators. Figure 11 also shows the wiring arrangement for the three circuit breakers installed in the console.

Other equipment installed in the control room included a unit referred to by the control room operators as a ballast control computer, [1] communications equipment (VHF marine tranceiver and internal rig communications equipment), smoke detecting cabinet, sliding watertight door control panel, hydrophone control unit and electronics panel, CO2 actuating cabinet, and gas detection panel.

The rig's angle of inclination was measured by means of two pairs of "Bubble type" inclinometers installed in the control room in the fore and aft and athwartship directions. The range of each was 0^{o}-5^{o} and 0^{o}-15^{o}. A similar arrangement of inclinometers was installed in the toolpushers space. The liquid levels in the pontoon tanks were measured by tank level indicators (Mercury Manometers) located in the ballast control room (Please see Figure 9). These indicators were installed in the after area of the room, opposite and facing the ballast control console. They were arranged so that the port tank indicators were on the starboard side of the room, and the starboard indicators were on the port side of the room.

In the event of a loss of electrical power to the control console for any reason, it was possible to activate the air solenoids by the insertion of brass actuating rods. Witness testimony indicated that these rods were normally stowed inside the console. Air solenoid valve actuation was effected by inserting and threading these rods into an opening in the solenoid. An examination of an actual air solenoid valve assembly by the Board disclosed that it was not readily apparent at what point the rod had been threaded into the bushing sufficiently to cause the valve to open. In addition to manually actuating the air solenoid valves with the brass rods, the ballast valves could be physically opened in the ballast pumprooms by turning each valve stem with a wrench, compressing the operating assembly spring.

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1 This equipment was used to obtain readout of the anchor windless tensions, among other things. It did not control or monitor any function of the ballast control console. It had been inoperative since December 1981.

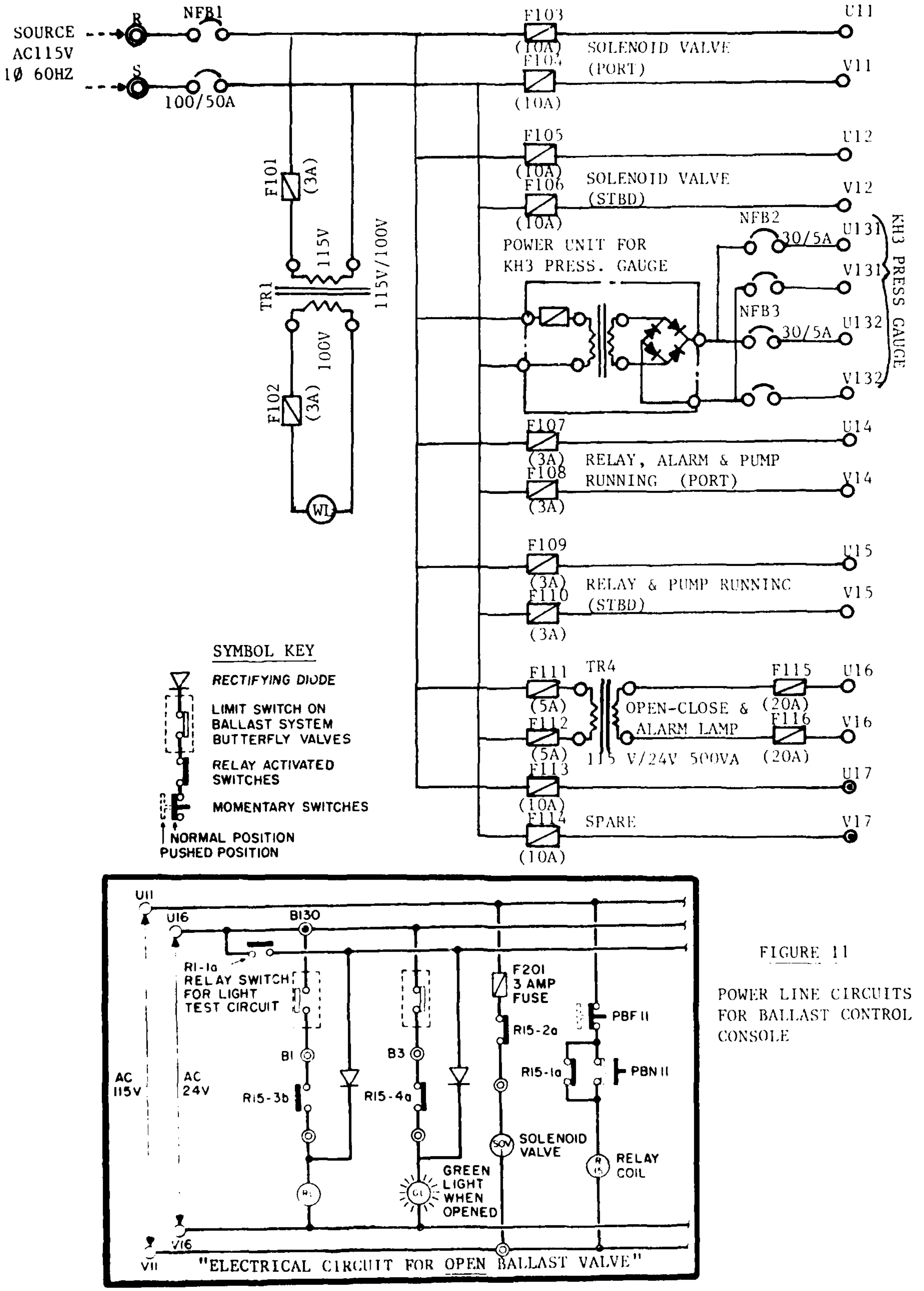

FIGURE 11

POWER LINE CIRCUITS
FOR BALLAST CONTROL
CONSOLE

All ballast valves, except the two manually operated sea inlet gate valves, were of the butterfly type and were located in the ballast pump rooms and propulsion rooms of each pontoon. Water ballast transfer was effected by means of six ballast pumps of the two-stage propeller type fitted with an integral stripping stage. Two pumps were installed in the pump room and one pump in the propulsion room. Propeller type pumps cannot operate with an excessive suction lift. Experienced control room operators and engineers testified that pump performance was enhanced by maintaining a slight trim by the stern when de-ballasting the forward ballast tanks. Trim by the bow would increase the pump suction lift and reduce the pumping rate from the forward ballast tanks. This reduction in pumping rate would be reflected in reduced pump motor current as indicated by ammeters on the ballast control console. Testimony from an ODECO Staff Engineer disclosed that the pumping system would perform more efficiently when pumping two or more tanks simultaneously. However, the testimony of several former OCEAN RANGER ballast control room operators and Masters disclosed that their normal pumping practice was to pump out one tank at a time in order to change trim. When trimmed by the bow, pumping from the forward tanks could be enhanced by opening the sea inlet valve as a means of priming the operating pump. One control room operator emphasized however, that the sea inlet valve, when used for priming, should be closed before the ballast tank valves were opened. None of these pumping "enhancements" or cautionary procedures were described in the OCEAN RANGER's Booklet of Operating Conditions.

25. Booklet of Operating Conditions.[1]

The American Bureau of Shipping "Rules for Building and Classing Offshore Drilling Units - 1973" and the U. S. Coast Guard stability requirements contained in 46 CFR Subchapter I-A, "Mobil Offshore Drilling Units", requires that a "Booklet of Operating Conditions" be provided for the information of OCEAN RANGER personnel. This booklet was approved by the U. S. Coast Guard on 6 January 1981. A careful review of this voluminous publication by the Marine Board disclosed the following:

1 The term Booklet of Operating Conditions is sometimes used interchangeably with the term Operating Manual.

a. No mention or reference was made in the Damage Control Plan to the three 25 square foot wire trunk openings atop each of the four corner columns.

b. No specific guidance was given concerning the securing of the chain locker/wire rope openings, a total of 93 sq ft per corner column, against significant flooding by wave action, nor was there any information provided on how to pump out the chain lockers if they were flooded.

c. No mention was made of any limitations on the capability of the ballast pumps to pump out forward tanks at large angles of trim, nor was any guidance provided concerning pumping sequence procedures.

d. No mention was made in the booklet, or in any other publication or instruction that the Marine Board could find, concerning the manual operation of the ballast control system, nor were there any guidelines or precautions noted concerning the use of emergency actuating rods in the air solenoid valves.

e. A suggestion that at the 80 ft. operating draft PT8, PT9, ST8 and ST9 should always be kept empty; PT10 and ST10 should be kept empty, if possible; that PT4 and ST4 should be kept between 73 percent and 100 percent full; and PT7 and ST7 kept between 96 percent and 100 percent full. (An experienced former Master stated that it was the practice aboard the OCEAN RANGER to carry ballast in PT8, PT9, ST8, and ST9.)

26. Ballast Control Room Operator

The ballast control room operator was responsible for maintaining the vessel in a level condition at the specified drilling draft by making ballast changes as were necessary. He also made frequent minor changes in vessel attitude (heel and/or trim) to facilitate the ongoing drilling operation. He was concerned with the vessel's stability condition at all times, especially the vertical center of gravity (KG). Accordingly, he had to be cognizant of the location and amount of transient weights. He was usually more active when the rig was receiving drilling pipe, drill water, mud, fuel, etc. He had to be aware of the status of all tanks when a need arose for a timely change. The control room operator was required to make basic stability calculations which included a determination of longitudinal and transverse KG, and maintained a ballast control room log during his watch of twelve hours duration. He also provided information and data for the morning and evening reports. Whenever he left the control room for any significant period of time it was customary for the Master to relieve him.

The Marine Board determined that the training received by prospective ballast control room operators was ordinarily by the on-the-job method with no formal training requirements. If a roustabout was interested in becoming a control room operator he would have to observe control room operations during his off-duty hours on his own initiative. If management was aware of a future opening, they would select a candidate who would then be allowed to spend a portion of his work period in the control room to become further oriented to the control room operation and undergo a period of evaluation. The testimony disclosed that the Toolpusher, Master and shore-based management officials participated in the decision to hire control room operators. A recently qualified ballast control room operator testified that after his orientation/evaluation period, a serious 84 hour on-the-job training session took place between 10 December 1981 and 17 December 1981. After this period, he was assigned to stand watch as a control room operator without further direct supervision. However, there was a more experienced control room operator and the Master onboard for consultation in the event it was necessary. He also stated that he was not required to read any technical material; however, he did so on his own initiative.

The ballast control room operator was required to be sensitive to any alignment problems which might have affected the drilling operation. The Toolpusher or his subordinates made frequent requests to the control room operators for minor trim changes to facilitate drilling operations. Also the ballast control room operator was accountable to the Master for the overall stability condition of the vessel. Testimony from former ballast control room operators established that in the normal course of their duties they received directions from both the Toolpusher and the Master.

VII DEPLOYMENT OFF NEWFOUNDLAND

27. Drilling Location

OCEAN RANGER began drilling operations on 6 November 1980 on the Grand Banks off Newfoundland under contract to MOCAN. It worked at two well sites in the Hibernia Field before drilling the well designated Hibernia J-34 on 26 November 1981. The location, shown on figure 12, was in approximately 260 ft of water with the OCEAN RANGER on a heading of 310 degrees. Figure 12 also shows the location of two other semi-submersible rigs, SEDCO 706 which was 8.5 miles NxNE and ZAPATA UGLAND which was 19.2 miles N of OCEAN RANGER. Drilling operations continued around the clock by two crews alternately working a tour of 12 hours. Generally the rig's complement of personnel worked 21 days on and 21 days off.

28. Listing Incident of 6 February 1982

On 6 February 1982 at approximately 0645 the OCEAN RANGER had completed taking on fuel and was still taking on drill water. The ballast control room operator, Mr. Bruce Porter, was temporarily relieved by the Master, Captain Clarence Hause, and departed the ballast control room for the port pump room to close the fuel manifold valves. This trip took Mr. Porter up the spiral ladder in the column above the control room, onto and across the platform deck to the portside column and down into the column to the pumproom. When he arrived at the pumproom door he experienced difficulty opening the electric/hydraulic watertight door. He called the duty electrician who successfully opened the door for him. Subsequently Mr. Porter began securing the fuel manifold when he felt the OCEAN RANGER begin to list over. As he became immediately concerned with this development, he quickly departed the pumproom to return to the ballast control room. Mr. Porter testified that the OCEAN RANGER "incurred a 5 to 5 1/2 degree list and that was quite out of the ordinary". When he entered the ballast control room he saw Captain Hause standing at the rear of the ballast control room and the off watch senior ballast control room operator, Mr. Don Rathbun, activating the ballast control switches to correct the listing condition. During this time an announcement was made by the IRR over the public address system

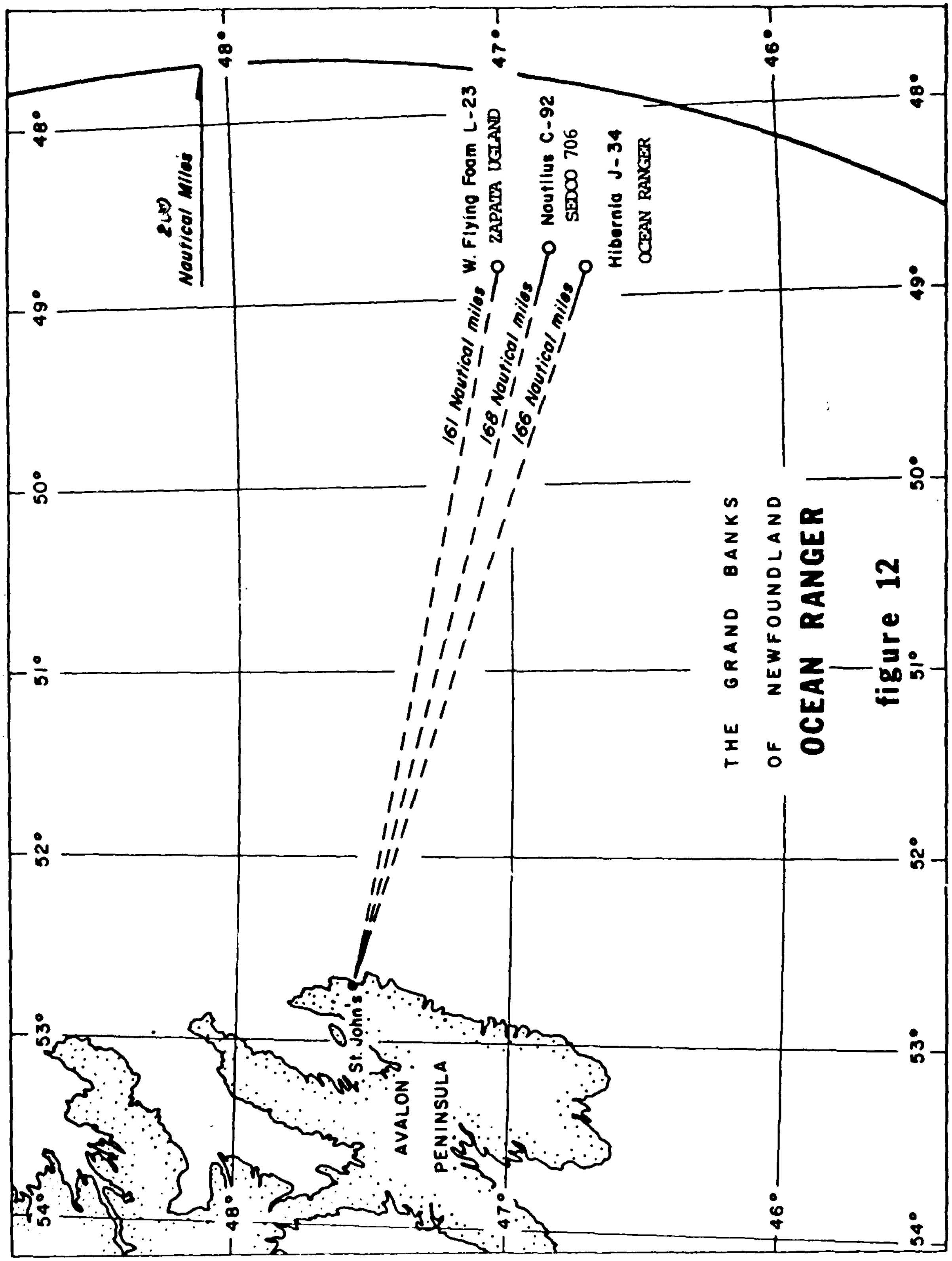
THE GRAND BANKS
OF NEWFOUNDLAND
OCEAN RANGER
W. Flying Foam L-23
ZAPATA UGLAND
Nautilus C-92
SEDCO 706
Hibernia J-34
OCEAN RANGER
161 Nautical miles
168 Nautical miles
166 Nautical miles
200 Nautical Miles
St. John's
AVALON
PENINSULA
46°
47°
48°
49°
50°
51°
52°
53°
54°

figure 12

that the crewmembers should don life jackets and go to the boat stations and standby.

Subsequent to the incident, Captain Hause indicated in a written report that he had opened tank valves without noticing that the remotely operated sea chest inlet butterfly valve was in the open position. It was not determined why the sea chest valve had been left in the opened position or who had left it opened. Shortly after this incident the Toolpusher, Mr. Benjamin Kent Thompson, called Captain Hause and Mr. Bruce Porter into his office where he chastised both of them in front of others. He advised the Master not to touch the ballast control switches unless he knew what he was doing or he had a ballast control room operator alongside him. Mr. Porter testified that the Master told the toolpusher "I think the best thing to do here is for me not to operate the console" and the toolpusher replied "yes, I think so." Mr. Porter stated that the master gave the impression that he was not "going to touch that console for quite awhile."

29. Logistic Support

Logistic support was provided by supply helicopters and boats. Expendable materials such as drilling mud, ship stores, food, water, and fuel were transported by supply boats from a base at St. John's, Newfoundland, and transferred to the rig to meet the unit's requirements. Heavy drilling equipment and drill pipe was provided in the same manner. Several supply boats worked between OCEAN RANGER, SEDCO 706, and ZAPATA UGLAND. The Canadian government required a standby vessel to be in attendance in the vicinity of each rig for emergency purposes. On 14 February 1982, the following supply boats were assigned to each rig as standby vessels:

RIG	STANDBY VESSEL
OCEAN RANGER	SEAFORTH HIGHLANDER
SEDCO 706	BOLTENTOR
ZAPATA UGLAND	NORDERTOR

All three standby vessels were very similar in their design, arrangement, capabilities, and size. The vessel particulars of the OCEAN RANGER's standby vessel were as follows:

Name: SEAFORTH HIGHLANDER
Llyod's Registration Number: 7400388
Service: Tug/Supply ship
Gross Tons: 1376
Net Tons: 528
Length overall: 221 ft
Breadth extreme: 48 ft
Draft maximum: 16 ft
Propulsion: Motor; Diesel (Reduction gear)
Port of Registry: Aberdeen, United Kingdom
Owner: Seaforth Maritime (Highlander) Ltd. and Glesstrips Ltd.
Manager: Seaforth Maritime, Ltd.
Master: Ronald Stewart Duncan

Helicopters were used principally for personnel transportation including crew changes. Several flights a day might be necessary to accomodate the rig's requirements for people or small parts or supplies needed in a hurry.

VIII WEATHER OF 14/15 FEBRUARY 1982

30. Weather date

The following environmental conditions were forecasted and experienced at the area where the OCEAN RANGER was located.

a. NORDCO Ltd, a private weather forecasting company under contract to MOCAN, issued forecasts for the OCEAN RANGER, SEDCO 706, and ZAPATA UGLAND locations. These forecasts were issued every six hours, were valid for an average of forty hours (depending on the issue time) and included an outlook for three days following the issue date. Actual weather on scene is tabulated adjacent to the corresponding forecast times. (Actual weather observed is from the SEDCO 706 which was located approximately nine miles from the OCEAN RANGER). Sea water temperature was 29 degrees F.

WEATHER DATA

TIME FORECAST ISSUED	FORECAST VALID UNTIL TIME	WIND DIR/SP		SEA WAVES		SWELL
FORECAST ISSUED 0730/14 FEB	2030/15 FEB	FORECAST DIR/AVG/MAX	ACTUAL DIR/AVG/MAX	FORECAST/ AVG.HT/PD	ACTUAL/ AVG.HT/PD	FORECAST DIR/HT/PD
1430/14 FEB		180/65/90	200/68/91	22/37/10	29/49/9	140/10/9
2030/14 FEB		300/45/55	250/68/75	14/24/8	30/50/11	180/16/10
0230/15 FEB		200/40/50	270/44/50	16/27/9	28/46/10	360/10/10
0830/15 FEB		270/35/45	280/51/44	18/31/9	27/45/10	300/10/10
FORECAST ISSUED 1330/14 FEB	VALID UNTIL 0830/16 FEB					
2030/14 FEB		288/70/90	250/68/75	28/35/10	30/50/11	
0230/15 FEB		310/68/38	270/44/50	23/40/10	28/46/10	
0830/15 FEB		340/55/65	280/51/44	26/46/10	27/45/10	
FORECAST ISSUED 1930/14 FEB	VALID UNTIL 0830/16 FEB					
2030/14 FEB		270/75/90		25/44/9	30/50/10	329/15/9
0230/15 FEB		330/70/80		33/59/10	28/46/10	
0830/15 FEB		330/60/75		30/54/10	27/45/10	

The storm associated with the OCEAN RANGER casualty was a major Atlantic cyclone. Figure 13 shows the storm track and the on-scene weather at the site of the casualty.

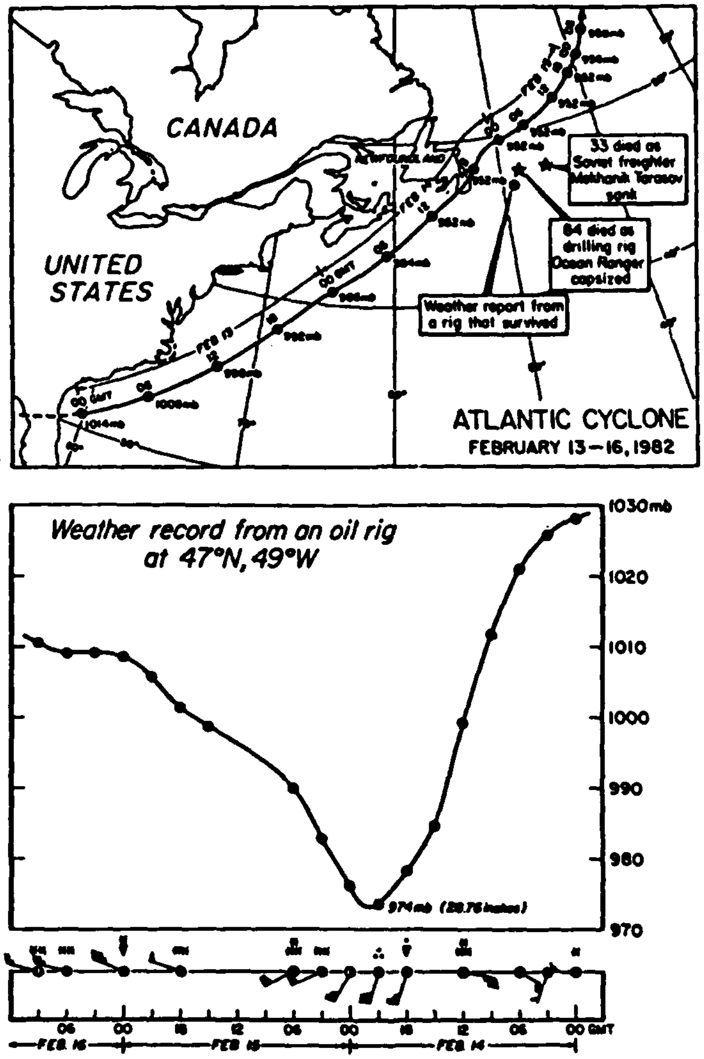

Figure 38.—The track of this vicious storm with 6-hr pressures, and the weather record from a nearby oil rig (47°N, 49°W). A total of 117 deaths resulted from this storm. From <u>Storm Data</u>, Feb.1982, prepared by Prof. T.T. Fujita, <u>University of Chicago</u>.

<u>MARINER WEATHER LOG</u> (1SSN:0025-3367), Summer 1982, Vol. 26, No. 3, page 143; National Oceanographic Data Center, Environmental Data and Information Service, NOAA, Washington, DC.

Figure 13

IX EVENTS OF 14 FEBRUARY 1982

31. Morning Events

On 14 February 1982 the OCEAN RANGER, SEDCO 706 and ZAPATA UGLAND were engaged in normal drilling operations at the described locations off the coast of Newfoundland. During the morning the SEAFORTH HIGHLANDER assumed the duty as standby vessel for the OCEAN RANGER. Routine conversations took place via Marisat between the MOCAN Superintendant, Mr. Merv Graham, and the MOCAN Drilling Foreman on the three rigs; Mr. Ken Lovell, ZAPATA UGLAND; Mr. Keith Senko, SEDCO 706; and Mr. Jack Jacobson, OCEAN RANGER.

32. Afternoon Events

Mr. Graham testified he received a Marisat call from the ZAPATA UGLAND at 1200.

> "Received a call from Ken Lovell, ZAPATA UGLAND. He was still stuck in the hole and we discussed the procedure to be followed in view of the forecasted 90-knot winds. We discussed hanging off in the upper and lower rams and decided to slack the pipe off and land the lower rams and shear the pipe if it became necessary. He indicated his barometer was dropping at this time with 15 to 20 foot maximum combined seas."

Mr. Graham testified that at 1400:

> "I had discussions with both rigs in the area of 1400/1415 hours. First the OCEAN RANGER, Jack Jacobson, indicated they were drilling at 18 feet per hour with the diamond and turbine. They had made 78 feet in four and a quarter hours with a pressure of 3,700 psi with 530 gallons per minute. The ZAPATA UGLAND, Ken Lovell, indicated they were free and rotating the pipe with the bit at 13,090 feet. The weather he gave me at this time is as follows: Winds, 62 knots, barometer dropping; maximum combined seas, 27 foot; heave, 3 feet, pitch, 3 degrees; row (SIC; assumed to mean roll) 3 degrees...."

Additional conversation discussed possible methods of freeing the ZAPATA UGLAND drill pipe from its tight hole.

Again at 1545, Mr. Graham received another information call:

> "Received call from Ken Lovell, UGLAND. He advised me they had hung the pipe in the lower pipe ram, sheared off the pipe, pulling the pipe out of the hole. The winds were at 100 knots, maximum combined seas 35 feet. They were getting

lateral motion of four degrees off location and had disconnected the riser. The 706 had hung off and their winds were about 85 and increasing...."

33. Evening Events

The next call Mr. Graham received was at 1845:

> "Received call from OCEAN RANGER, Jack Jacobson. He advised me they had hung off in the middle rams, the bit was in the casing, sheared the drill pipe with the shear rams. The riser was disconnected and they were riding out the storm. He also advised me that the tensioning ring had hung up once on the spider deck area and at the time of disconnect they were getting 20-foot heaves, with spray up into the spider deck area to the rig floor. Jack advised me the rig lost time with the compensator hoses hanging up in the derrick resulting in not hanging off normally and forced to shear the drill pipes. Jack also advised the storm had built extremely fast during the half hour before disconnecting."

Between 1900 and 1930, as estimated by Mr. Jimmy Counts, ODECO Canada Superintendent, (Marisat bill indicates call was placed at 1858), he received a call from Mr. Kent Thompson, Toolpusher, OCEAN RANGER:

> "He just informed me that he had suspended operation at, that they had hung off the drill pipe and sheared the drill pipe and unlashed the rod and they were waiting on the weather."

Mr. Keith Senko, Senior MOCAN Drilling Foreman, SECDO 706, testified that at approximately 1900, Mr. Jack Jacobson, Senior MOCAN Drilling Foreman, OCEAN RANGER, called:

> "He just called and said that he was attempting to hang off. I suppose he was checking on our status as well, what we were doing at the time and he called and said that he was attempting to hang off but he had got his compensator hoses fouled in the derrick and he was having a problem getting that sorted out and at the same time he mentioned that a window had been knocked out of the control room and there was some water and glass and such."[1]

1 Note: The terms Control Room, Ballast Control Room, and Barge Control Room used in testimony should be considered synonymous with reference to that space on the OCEAN RANGER where the ballast controls for the rig were located.

The second MOCAN Drilling Foreman on the SEDCO 706, Mr. Rod Fraser, testified as to overhearing this conversation:

> "The compensator hoses, the wind was blowing the compensator hoses into the derrick. As a result they couldn't pull the pipe if they were blocked. They would have pulled the hoses. They were trying to get them out of the derrick before they proceeded pulling up the casing to get in a position to hang off....I think in that conversation, too, he had mentioned that window had been knocked in, lost the window....That the window had been knocked out. There was no problem, they had just had some water to mop up and I believe he said everything is okay."

Mr. Donald King, Barge Engineer, SEDCO 706, and Mr. Fred Hatcher, Control Room Watchstander, SEDCO 706 testified that at approximately 1900 the SEDCO 706 experienced a large wave of "more force than the others."

Mr. Donald King:

> "We were at a eighty-foot draft at that point. The wave came across our port side and we had containers tied and chained to our rail and these containers were broken free and they were moved up to forty feet across our deck and did some damage to our wind walls. We damaged a life raft, lost one life raft and lost an aviation fuel tank, a spare aviation fuel tank. Mostly just facial damage to our wind wall....When it struck I was on the phone talking to one of our Toolpushers. We were in the process of disconnecting from the well and at that point our anchor tensions had come up. We were preparing to disconnect and we just disconnected just before or just after the wave came across. We brought the rig up five feet, up to a seventy-five foot draft. We looked at it there and if we thought we had to we would have run up to seventy feet, but we stayed at seventy-five and we were going to ride the storm at that draft."

Both men testified it took around twenty minutes to deballast the rig from an eighty to seventy-five foot draft.

Over a period of time, SEDCO 706 personnel, Mr. Donald King, Barge Engineer, and Mr. Fred Hatcher, Control Room Watchstander, overheard conversations on Channel 6 VHF. Both men were in the SEDCO 706 barge control room.

Mr. Donald King:

> "...We overheard conversations that they were

> mopping up water and cleaning up broken glass. In this time frame from ten to eight until nine, a little after nine, we picked up two or three different conversations. One being the broken glass and water, another being that their P.A. system was knocked out. Their gas detection system was knocked out, everything appeared to be okay. They were cleaning, they said everything looked okay. We are still cleaning up water'."

Mr. Fred Hatcher:

> "Well, first I heard was we had water and glass on the floor down there."

Mr. John Ursulak, the third MOCAN Drilling Foreman, SEDCO 706, also overheard parts of these conversations and testified:

> "We heard the voice on the radio and upon listening recognized the voice of Kent Thompson on the radio that was unclear, it was weak, a weak signal. The other voice was from, was very clear and sounded as though it came from the control room. Now, when I say coming from the control room, well, I am guessing that it came from the control room....Well, Mr. Thompson on the weak radio asked something to the affect, how was everything and the voice I believe coming from the control room said that there was a wet panel in the control room and I believe it was a gas panel. Well, something makes me think that it is a gas panel that he was talking about, and he said that he was working on it and getting shocks off it....I am positive I heard the voice also addressed the voice I believe to be Kent Thompson as Kent's....The clear transmission addressed the other party as Kent....And also Mr. Thompson had an unusual voice and accent and I believe it was Mr. Thompson on the radio."

In response to questions as to who else was on the radio, Mr. Ursulak testified:

> "Well, after thinking about it, I believe the other voice on the radio was that of Don Rathbun, Barge Engineer."

At 2045 Mr. Merv Graham, MOCAN Superintendent, had a conversation with Mr. Jack Jacobson, Senior MOCAN Drilling Foreman, OCEAN RANGER:

> "At 2045 hours, received call from OCEAN RANGER, Jack Jacobson. I do not know if I initiated the call or not. It was on the MARISAT. Jack advised me they had 50 foot plus maximum combined seas and winds in the 90/100 knot range. He advised me that one wave had taken a window out of the barge control room. He advised me there

> was no problem with this window outing and from memory he advised me that all that was required was to mop up a little bit of water in the room and that all of the equipment was functioning properly at that time. He advised me that the anchor tensions were all in the 240,000 range. Also that the barometer had leveled off, everything was normal at the rig. They had no problems. The remainder of our discussions at that time centered around the equipment he would require to mill off the top of the sheared drill pipe and the overshot and tools necessary to recover his drilling string in view of a plane waiting to bring extra fishing equipment from Drillrite in Edmonton, Alberta. I requested Jack Jacobson at this time to talk to the foreman at the 706 and the UGLAND and discuss with them their anchor tension and how they were riding out the storm and call me back."

At some point during this time period, Mr. Ursulak, MOCAN Drilling Foreman, having left the barge control room of the SEDCO 706, returned and "overheard the OCEAN RANGER a second time".

> "There again Mr. Thompson came on the radio and asked how something to the effect of how is it going, and the reply was given that everything is fine, that they are mopping up water and picking up glass, there seemed to be some relief in their voices, everything seemed to be fine in the control room."

Mr. Donald King, Barge Engineer SEDCO 706, testified as to other overheard conversations on Channel 6 VHF.

> "Sometime after 9 o'clock we heard they were getting shocks off of different panels and they wanted the E.T. man, electronic technician to come down to the control room and at some point along there they said valve or valves were opening and closing on their own....This was a voice on a portable VHF radio and I, myself, and the watch on duty we recognized the voice as being Nick Dyke." (Note: Mr. Nick Dyke was a ballast control room operator, OCEAN RANGER)

Mr. Fred Hatcher, Control Room Watchstander SEDCO 706, testified as to this overheard conversation:

> "Yes, I heard an ashore (sic) after that all the valves on the port side are open by themselves....Yes, in the minute or two passed and next thing I heard was received the okay and the next thing after that he said he needed an electrician down here because of the water, shock

> because of the water in the ballast....In the panel....I heard a voice that I took to be Nick Dyke saying everything seemed to be okay down here and I am going to get her all cleaned up and everything seemed to be okay. That was around 9:30, maybe quarter of ten, somewhere around that area. But I recognized Nick Dyke at that time."

Captain Jim Davidson, Master of the M/V BOLTENTOR, was standing the 2000-2400 watch and overheard the following on Channel 6 VHF:

> "At about the mid-watch. I cannot place it any closer than that, we heard some conversations on what I took to be hand-held VHF sets, walkie-talkies, to the effect that or initially establishing contact. Can you hear me; Yes, I can hear you now, whatever. And then a voice said, Well, there is broken glass in here and there is water in here and another voice said, I will get it cleaned up, get some guys in there and get it cleaned up. Then another voice yet, a third voice, said, Well, there is some high-powered cables down there. And the second voice came back and said, Well, don't have anybody injured or killed, but obviously still get the water cleaned up. And the last thing I heard was another voice saying, Well, there is some valves operating or opening or closing. I can't remember the exact words, but it was to do with valves operating."

Asked if he could identify or describe the voices he overheard, Captain Davidson testified:

> "Well, the only one that I would say was the one giving the command to get the water and glass cleaned up would be somebody from the southern states. The others, whether they were Canadian or Northern Americans, I couldn't say."

Mr. Merv Graham, MOCAN Superintendent testified that at 2200:

> "I received a call from the OCEAN RANGER, Jack Jacobson, as requested previously to inform me of the status of the other two semi submersibles. On the OCEAN RANGER, Jack advised me the maximum combined seas were in the 55 foot, the odd wave going up in the 65-foot range. I asked Jack if he was having any problems in the barge control room with the window being taken out, and he assured me that all of the equipment was functioning normally. On the UGLAND he advised me they had lost one guide line, that the winds were in the 80-85 knot range, maximum combined seas in the 35-55 foot and some higher.

> The SEDCO-706 had disconnected and they had the thrusters on 75 percent power. I do not have it noted nor can I remember which call, but I was aware, which is normal procedure, that once the rigs have disconnected the riser they will deballast the rig up five to ten feet to gain more air gap and also to lessen the chance of seas breaking on the main-deck level. I ended my conversation with Jack Jacobson with us both in agreement at that time that the rigs were all riding out the storm with no problems, and Jack indicated that the wind and the sea had come down slightly from what they had been previously. All that we could do was ride the storm out for the night and I would talk to them in the morning."

Subsequent to this call, there were three radio communications involving the OCEAN RANGER that evening. The first was at approximately 2250, when a service call was made by the SEDCO 706 to Mr. Richard Flynn, Mobil Radio Operator in St. John's that both the OCEAN RANGER and SEDCO 706 radio operators were going off the air for coffee. At approxiamtely 2300, a routine position report was requested of the SEAFORTH HIGHLANDER. Finally at 2330, Mr. Richard Flynn received a routine weather report from the weatherman on the OCEAN RANGER. These three calls were routine, and conveyed no indication of an extra ordinary condition on the OCEAN RANGER. It is to be noted that the weatherman made no personel comments or observations whatsoever, as had been done occasionally in the past.

X EVENTS OF 15 FEBRUARY

34. Distress Calls

No radio transmissions were made from the OCEAN RANGER subsequent to the 2330 weather report of 14 February until 0052, 15 February. Mr. Baxter King, Radio Operator SEDCO 706, testified:

> "The next thing I heard from the OCEAN RANGER, sir, was 0422 Zulu (0052 local time) and that was all stations a MAYDAY...standard MAYDAY call....The international call MAYDAY three times, all stations three times, the OCEAN RANGER three times, stated his position, he had a severe list and he required immediate assistance. At the time that the MAYDAY was going out, Jack Jacobson called me on the SEDCO-706 and asked me to put up MAYDAYS on their behalf. I asked him the nature of the problem, and he said they had a severe list and that is all he said....He kept putting them out every couple of minutes....It went on until 0500 Zulu when they went to life raft stations." (0500 Zulu is 0130 local time)

Mr. Merv Graham, MOCAN Superintendent testified:

> "0100 hours, one or two minutes either side as I had just glanced at my watch, I received a call from the OCEAN RANGER, Jack Jacobson. He was calling to request me to alert the Coast Guard. The OCEAN RANGER was listing to the bow eight to ten feet which I am sure is degrees. I did not question Jack on it. They had 75 to 80 mile an hour winds. They were attempting to isolate the problem. They did not know what the problem was. The stand-by boat was the HIGHLANDER. I did request from Jack how many people were on board, and he advised me 84 men on board. Jack Jacobson at this time was cool, calm and collected. I recognized from the tone of his voice and from the information he had given me that they had a serious problem. I advised him that I would have work boats on the way to him and that our helicopters would be activated and that I would proceed to the office and that is where he would be able to get in contact with me next."

Mr. Graham testified he notified the Canadian Coast Guard at 0105 and at 0110 alerted the helicopters.

Captain Duncan, Master of the SEAFORTH HIGHLANDER testified:

> "At 0105 hours on the 15th of February, THE OCEAN RANGER called up the SEAFORTH HIGHLANDER again on Channel 6 VHF and asked the HIGHLANDER if she

would come in a little closer. I'll try to remember his exact words for you. He said, 'SEAFORTH HIGHLANDER, will you come in a little closer, please?' He said, 'We've got a problem here on the rig,' and I said, 'Yes certainly I'll start coming in closer now.' I said, 'Would you like to discuss this problem with me?' He said, 'Stand by,' and approximately half a minute later he came back on the radio and he said, 'Yes. We have a list.' or, 'We are listing to port and all countermeasures are ineffective, so if you could come in close as soon as you can make it.' and I said. 'Right. I'm on my way. We are coming in now,' and that was the end of my communication with the OCEAN RANGER and in fact that was the last communication I ever had with the OCEAN RANGER."

At 0109, the Marisat operator received a distress message from the OCEAN RANGER, "ARE EXPERIENCING A SEVERE LIST UNABLE TO CORRECT PROBLEM." The Marisat operator connected the OCEAN RANGER with U.S. Coast Guard Rescue Coordination Center (RCC) in New York at 0112 and the following message was sent:

WE ARE THE ODECO OCEAN RANGER KRTB LOC 46.43.33N 48.50.13W AND ARE EXPERIENCING A SEVERE LIST OF ABOUT 10-15 DEGREES AND ARE IN THE MIDDLE OF SEVERE STORM AT THE TIME 12 DEGREES AND PREGRESSING. MREQUEST ASST ASAP MWEL ARE AN OFFSHORE DRILLING PLATFORM. WE WILL STAND BY AS LONG AS POSSIBLE. MIDWINDS AT THIS TIME ARE APPROX FROM THE WEST AT APPROX 75 KNOTS.
RIG IS OF SEMI-SUBMERSIBLE BUILD AND IS LISTING SEVERELY 12-15 DEGREES TO THE PORT SIDE. M GENL INFO... WE CHECK THAT ALL AVAILABLE WORKBOATS IN THE IMMEDIATE AREA ARE COMING TO OUR ASST. THERE ARE TWO OTHER SEMI-SUBMERSIBLES IN THE AREA AND WILL DO ALL POSSIBLE TO ASSIST.

At 0121 New York RCC passed this message to the Canadian Coast Guard RCC in Halifax, Nova Scotia. At 0130 the MARISAT connection was disconnected and the Marisat operator tried 13 times to contact the OCEAN RANGER without success.

Captain Duncan, Master of the SEAFORTH HIGHLANDER, testified:

"At 0110 hours I overheard on VHF Channel 6 the OCEAN RANGER calling the SEDCO 706. SEDCO 706 immediately replied, and the OCEAN RANGER advised the SEDCO 706 to send out a mayday relay regarding OCEAN RANGER immedia_ely. SEDCO 706 questioned this by saying, 'You want me to send out a mayday relay now?' The OCEAN RANGER said, 'Yes, send it out now, and if you try calling us back afterwards and don't get any reply from us, then you know we have already taken to the lifeboats.'

I believe the SEDCO 706 said something like, 'Okay. I'll send it out now,' and that was the end of that transmission. Immediately we overheard on 2182 kilohertz the mayday relay being broadcast by SEDCO 706 for the OCEAN RANGER. He broadcast that message immediately afterwards. He was very very quick to do it. At this time the SEAFORTH HIGHLANDER was on full maximum speed heading in to the OCEAN RANGER."

Mr. Richard Flynn, MOCAN Radio Operator in St. John's:

"At 10 after 1 the radio operator called. I forget the exact words he used, but he advised that he had a MAYDAY, they were listing badly and were to notify Search and Rescue and the 706 picked up the message at the same time and he began to put out a MAYDAY on 2182 and I called the Coast Guard at St. John's Search and Rescue on the telephone and advised them.

The drilling foreman came on with him, almost like together, they have the radios in the radio room and they have what you would call an extension in the foreman's office. So, I am not sure if he was in his office or they were both on there in the radio room, but the foreman came on and he just repeated they had a MAYDAY and the rig was listing badly and that they were going to want to evacuate.

I had Search and Rescue on the phone between 1:10 and 1:30 and phone patched them into the OCEAN RANGER. The contact wasn't very good. I believe they could hear the OCEAN RANGER fairly well, but he couldn't hear them too good. They didn't give any details at all. They just said they were listing badly, wanted to evacuate and they wanted three or four helicopters, Chinooks to come out and take them off....He said something like, "That is the only thing that will get out here in this kind of weather".

Mr. John Ursulak, MOCAN Drilling Foreman, SEDCO 706 testified he overheard a communication from the OCEAN RANGER during this period of time (assumed by the Board to be approximately 0115):

"...Mr. Jacobson said that the rig was listing and he was looking for our work boats, our standby vessels. He said there was a list to the rig that he said he mentioned search and rescue and Chinook helicopters, and he said that it would be, it could be serious. Now, he said the rig was at a list, developed a list, and was listing, seemed to be stabilized at about 10 degrees and that there were, they were trying to isolate the problem and doing what they could to correct the situation."

Mr. Merv Graham, MOCAN Superintendant:

"...0120 hours I called Rod Fraser at the 706. Advised him of the status of the OCEAN RANGER. I advised him to send his standby boat as well as the standby boat from the ZAPATA UGLAND to the OCEAN RANGER immediately. I advised him to monitor the radio and give them any assistance they could, and I was proceeding to our office."

Mr. John Ursulak, MOCAN Drilling Foreman, SEDCO 706:

"...we were all present in the Mobil office and at 1:30 or a short time later after this conversation we were talking over the situation and kind of bewildered by it all, and I heard a voice on our single side band saying it was the OCEAN RANGER calling Mobil base and they got an answer and we heard the voice on the RANGER say 'OCEAN RANGER is going to' - no, he said 'There will be no further radio communications from the OCEAN RANGER. We are going to lifeboat stations'....the thing I distinctly heard him say 'Going to lifeboat stations' and then there was radio silence and we immediately called them back and, of course, got no response...."

XI RESCUE OPERATIONS

35. M/V SEAFORTH HIGHLANDER

The M/V SEAFORTH HIGHLANDER was the assigned standby boat for the OCEAN RANGER; Captain Ronald Duncan was Master. After having been requested by the OCEAN RANGER to "come in a little closer please", Captain Duncan proceeded towards the drilling rig location. Captain Duncan testified:

> "Well, the seas were terrible, and we were rolling and pitching extremely heavily, very violently. I gave instructions that nobody on board the SEAFORTH HIGHLANDER should venture out on the deck until I permitted then to. We proceeded in to the rig to a distance of approximately two cables off the rig. I should say that we sighted the rig visually at approximately half a mile off, and until that time we had been closing the rig by using our radar.
>
> We had driving snow conditions, a lot of spray from the sea, and visibility was very very poor indeed. We came to a position approximately two cables off the rig, downwind of the rig, and we could see the rig apparently illuminated as normal, fully illuminated, with the derrick illuminated, all the decks, the accommodation illuminated. We could not tell if the rig was listing because we ourselves were performing in such a way that it would be extremely difficult to judge if the rig was listing.
>
> We arrived at the close standby position two cables downwind of the rig at 0150 hours, and almost immediately at that time we observed small lights in the water approximately four, five points on the starboard bow, and we sighted a red distress flare approximately four points on the starboard bow at the same time. I proceeded towards the red distress flare, and while proceeding to it another flare from the same source went up. Probably about three minutes after sighting the first flare we visually sighted a lifeboat which at first appeared to be in good shape riding high on the water, and I maneuvered my ship very close downwind of the lifeboat. The lifeboat was under power because he steamed across a swell, across my stern from starboard side to port side, and he maneuvered his lifeboat down the port side of my vessel on to the port quarter. He came alongside us, and my men, who by this time had gone out on the deck, threw lines to the lifeboat, lines with life rings attached. One lin^ was made fast on

the lifeboat, and the other ring was made fast to my ship. Then some men began to come out of the enclosed boat, and they stood on the port side of the lifeboat, which was the side away from my vessel -- four or five, maybe six men came out and stood on the port side.

Sometimes the lifeboat was just touching the SEAFORTH HIGHLANDER but not especially violently. At other times she was about six feet off the SEAFORTH HIGHLANDER. She was moving in and out a little. It was at that time that the lifeboat began to capsize to port in a very slow manner, like watching a slow motion picture. The men standing on top of the boat were thrown into the sea. The boat remained capsized. I believe during the capsize of the lifeboat the line we had made fast to it parted. After it had capsized it was approximately 12 feet maybe off the SEAFORTH HIGHLANDER, and I could see what I estimate to be eight or nine men clinging to the boat in the water. I could see all these men. They had life jackets on, and there was a light on each life jacket.

At about this time I was taking heavy seas in the after deck of my vessel which was sterned to wind and sea. The mate and one of the seamen were washed up the deck, but they were both okay, although they suffered some bruising. The gangway net was washed over the side. We were still along the lifeboat, and after maybe a minute and a half or two minutes -- it is very difficult to estimate -- the men clinging to the boat began to let go, and they drifted down my port side. At that point I shouted down to the mate on the deck via the loud hailer system to throw over a liferaft. I saw the men running up forward on my deck to go for the life raft, and they threw a life raft over the side, which inflated right beside the men in the water. No effort was made by any man in the water to grab hold of the life raft. No effort was made by any of the men in the water. No apparent effort was made by any of the men in the water to reach the lines which my men had been throwing to them after the boat capsized.

I saw a life ring with line attached landing close to the men clinging to the boat, and they didn't make any effort to reach the life ring. At this time there were some men drifting down my port side, but the lifeboat was still off the port quarter of the ship with two or three men clinging to it. It was close to my port propeller at this time, so I had to stop my port propeller in case the men got caught in it. At that time the SEAFORTH HIGHLANDER was forced off the location by the heavy seas, and we could no

> longer maintain our position alongside the men in the water or the lifeboat. Once we were clear of all the men I was able to use the port propeller again, and I maneuvered the ship back around to an upwind position from the lifeboat and steamed down close to the lifeboat, the men and the life jackets in the water. There was no sign of life at all. We could see all the men floating with their heads under the water, some of them with their arms outstretched, no sign of life, and the men on the deck were trying to pick up bodies. We couldn't get close to any of the bodies. It was very difficult. We were washing the bodies away with the motion of the ship, and for the rest of that morning we kept searching that area for any live personnel which might have been found.
> We saw many bodies in the water, bodies which had obviously not come from the lifeboat which had capsized alongside us, but there were no signs of life at all."

Captain Duncan estimated that at least twenty bodies, life jackets, or life jacket lights were sighted.

36. M/V BOLTENTOR

The M/V BOLTENTOR was the assigned standby boat for the SEDCO 706; Captain Jim Davidson was Master. At approximately 0100 the BOLTENTOR was about a nautical mile south of the SEDCO 706. At this time the second officer overheard sufficient radio communications to believe the OCEAN RANGER was possibly having difficulties, and shortly thereafter awoke Captain Davidson. Captain Davidson testified:

> "Around ten past one I was called by Alan Martin and he had been contacted a little bit before that. I don't know, fifteen minutes before that, and told me that the BOLTENTOR should make her way over towards the OCEAN RANGER because they were possibly having difficulties over there and as soon as the situation was made a little more plain to him, he called me and we tried to make a little bit more speed than we were doing, still with the safety of our vessel in mind and proceeded towards the OCEAN RANGER....It is a little bit vague, now, but after I had been on the bridge five or ten minutes, say around twenty, twenty-five past one, the situation was obviously becoming more and more urgent and we then attempted to make as much possible speed towards the OCEAN RANGER's location at which time we would probably be six miles away from her. We were in contact at that time with the

SEAFORTH HIGHLANDER, he was on the other side of the rig making his way across and all the way over we were in contact with the 706 and the time we were, the time we expected to be there we were getting no contact at all with the OCEAN RANGER. We weren't calling them directly, we were hearing nothing from them. And the SEDCO-706 started putting out MAYDAY relays on 2182. The NORDERTOR was making her way down from the UGLAND. He contacted or attempted to contact St. John's Coast Guard radio to tell them he was proceeding and Alan Martin also attempted to contact St. John's and tell them that we were proceeding to the OCEAN RANGER as well. We were approximately two, two and a half miles off, something like this when I heard the SEAFORTH HIGHLANDER saying SEDCO-706 from the first thing I recall he called in from the cable off and said he had no visual contact with it at all then about half mile he said, yes, I can see the rig. I can see the lights of the rig. And then he said, Oh, there is lights in the water. There is flares going off and I assumed then he proceeded to that point where the lights were in the water. We continued to make our way to the radar target the OCEAN RANGER. We were approaching the rig from the starboard quarter, possibly just about the beam on the starboard beam of the rig. I could see from about two or three cables off, probably three cables off, two lights, that's all. The rest, the normal rig working lights were all extinguished. To the forward end of the rig there was one small white light, fairly low down near the water and at the aft end I saw one large round greenish tinged light. We didn't have a searchlight on at that time, so I can't say that these lights were on the deck, maindeck level. Whether the rig was tilted forward or not, I couldn't say. I didn't actually see it. They asked me from the SEDCO-706 if the rig was still upright enough to handle a helicopter on the deck. I proceeded then around the starboard quarter, around to the aft end of the rig, i.e. the downwind side of the rig for the safety of my vessel and proceeded to within about one cable off the stern shown by searchlights which the second officer was operating and when we were head on at the stern of the rig he had the searchlight up and shown it right across the aft end of the rig two or three times and then coming around I let the wind get on the port bow and it blew me over almost beam on the port side so I put full barrel and brought it back head to wind and swung around the other way so we had another good look at the rig and we saw the main deck of the rig from the aft end was, appeared to be

> horizontal. I.e. the rig appeared to be upright. The light definitely shown on the drilling tower which was still there and that appeared to be upright, naturally. And then I called back and said, Yes the rig is upright enough to land a helicopter on the deck. In hindsight possibly it wasn't but from my aspect at that point, yes it was still upright and it was still there. There were no other lights from the aft end. We could only see this greenish light that I have described and I placed that on the main deck level, just to the starboard side of midships at the aft end. About that time the SEAFORTH HIGHLANDER got in contact with me on Channel 6 and said presumably after I called the 706 to tell them about the helicopter that I should proceed down to his location which was a mile, mile and a half downwind because he was alongside a lifeboat that was overturned. There were bodies in the water and if I got down there maybe I could assist."

As the M/V BOLTENTOR proceeded two deckhands observed that the OCEAN RANGER was listing down by the bow. One of the deckhands, Thomas Kean, recalled that the drilling tower was inclined approximately 35 degrees from the vertical and that the rig's air gap was reduced in the direction of the tilted drilling tower and that the end of the OCEAN RANGER was being pounded by the seas.

Captain Davidson continued:

> "...When he called us we turned the ship head downwind, proceeded first at full speed and then cautiously to the location of the SEAFORTH HIGHLANDER and as we approached we were sighting the life jackets, lights in the water. We proceeded downwind past his port side such that he was on our starboard side. We were both stern to wind, stern to sea which is the only stable way of maneuvering those ships when the accommodations - on the approach to the OCEAN RANGER when it became clear that there was a full scale emergency on that, I called all my crew, had them dress up in the exposure suits or survival suits that we have on board and had them all ready, had them rig lifelines for themselves. We had eight brand new life rings on board for each, secured lines to a boat hook and shortly after that we made a sort of grapnel with the line on it and when we got down to the SEAFORTH HIGHLANDER's location we sort of edged in towards the outskirts of where the bodies were and attempted to get alongside one of these survivors, bodies, whatever they were at that

time, and attempted to hook them with the boat hook or throw the life rings over, but it was to no avail. The wind was too strong. It was too much. At the time we were having to, I was having to maneuver the stern with my port engine possibly half straight all the time in order to stay in that position and not be blown downwind. We attempted to do the normal sideways screw towards where the bodies were. I would say trying to, but there were seas sweeping over the stern and I had to have, well, my men on deck organized. One man would maintain a lookout for the seas coming down so that the boys on deck could actually make themselves secure when one was coming down. But it was very, very stormy and very bad and extremely cold, too....I didn't see any signs of life when we arrived on the scene. A couple of my crew say they thought they saw one of them sort of limply lift an arm like this (indicating) a couple of times, but that could have been wave action or it could have been a sign of life....We must have arrived in the location of the bodies at 3:15, 3:20, 3:30. I don't know, somewhere about there. And we were then working until around 6 o' clock when four of my men were violently thrown or three of them violently thrown into the winch house, another one was dumped on top of the tugger and I think they were all getting pretty scared by this time and they were achieving *absolutely nothing*, really, although I have every admiration for the attempts they made."

37. M/V NORDERTOR

The M/V NORDERTOR was the assigned standby boat for the ZAPATA UGLAND; Captain Baxter Allingham was master. At approximately 0120 the SEDCO 706 relayed the OCEAN RANGER's request for standby boat assistance and instructed the NORDERTOR to proceed. Captain Allingham estimated that the position of the NORDERTOR at about 0130, when he began the trip south toward the OCEAN RANGER, was approximately 2 miles north of the ZAPATA UGLAND, which was approximately 19 miles north of the OCEAN RANGER. He first observed the OCEAN RANGER on radar at a range of about 13 nautical miles as the NORDERTOR proceeded south against the wind and seas. As the NORDERTOR proceeded further south Captain Allingham observed that the OCEAN RANGER disappeared from the scope. He noted that at the time the OCEAN RANGER disappeared from the scope it was at a distance of 6-7 miles. He observed that when the target disappeared from the scope it was momentarily replaced by two small targets that were spaced approximately the same width as the original target and perpendicular to the heading flasher. These smaller targets then also disappeared and no further trace could be seen on the radar scope. When the NORDERTOR arrived at 0340 at a position approximately 2 miles north of where the rig had been located, he could not find any trace of the OCEAN RANGER. The NORDERTOR subsequently proceeded eastward to join the efforts of SEAFORTH HIGHLANDER and BOLTENTOR to recover bodies and lifesaving equipment.

Captain Allingham testified:

> "...(At) approximately 7 o'clock in the morning we found an overturned lifeboat with the life ring from the SEAFORTH HIGHLANDER attached to it...the lifeboat was damaged. There was a large hole in the bow of her and she was cracked down the bottom, there was a crack in the bottom. Water just passing right through and we made three attempts to recover her but all failed...While we were involved in trying to hook a rope on her there were several bodies came out of the hole in the boat....Approximately seven or eight, probably came out through the hole in the boat at that time." On the third attempt to recover the life boat: "...after we got the line on her she came up, when the ship was even, she came up to our rail it was a good view you could see right down through the boat... there were several bodies there strapped in by the seat belts they have in the boat. I would say a rough number of maybe twenty".

No sign of life was observed.

At one point while attempting to haul the lifeboat onboard, the cable pulled the lifeboat propeller shaft free. This propeller shaft was recovered and later identified as having come from a Harding Boat (#2 lifeboat).

During the third recovery attempt, due to the motion between the lifeboat and the NORDERTOR, the wire rope became caught in the starboard propeller and the lifeboat broke free again. While freeing the wire rope from the propeller, the lifeboat drifted away. After freeing the propeller, the NORDERTOR was called to investigate some life rafts with possible life onboard, and they did not see this lifeboat again.[1]

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1 Examination of recovered lifeboats and parts of lifeboats accounted for Nos. 1,2, and 3 lifeboats. No. 4 lifeboat was never found.

38. Helicopter Operations.

The following information was obtained during unsworn interviews with two pilots from Universal Helicopters. Two helicopters were dispatched as requested by the OCEAN RANGER by Mr. Merv Graham, MOCAN Superintendent. Due to the severe storm in St. John's on the morning of 15 February, the first helicopter did not take off until 0322 and arrived on scene at 0430. The second helicopter was airborne at 0343 and arrived on scene at 0455.

These two helicopters were routinely employed to transport personnel from St. John's to and from the rigs. They were not equipped for search and rescue work, nor equipped with radios that had frequencies to permit direct communications with the standby boats. Their role in the rescue consisted of searching for possible survivors and directing the standby boats via radio communications with the SEDCO 706 to various locations where possible survivors were located.

While the role the helicopters played in the search and rescue efforts added little to the information sought by the Board, the pilots did their job under exceedingly trying circumstances and their performance was a credit to their skill and bravery and that of their crews. The Board would note the following:

a. In response to questions, Mr. Bob Gervaes, Universal Pilot, estimated he could have ferried 30 persons at a time from the OCEAN RANGER to the SEDCO 706 under the conditions he experienced that morning, and could have accomplished such an operation with about 12 degrees of list of the helicopter deck.

b. In response to questions, Mr. Kerry Wilson, Universal Pilot, stated that the life jacket lights and retroreflective tape, as illuminated by the helicopter landing lights, made it possible to locate the life jackets during the hours of darkness. With the arrival of daylight it was no longer possible to locate the life jackets or bodies in the water.

XII POST CASUALTY

39. Search for other Communications.

The Board was unable to find evidence of any communications from the OCEAN RANGER indicative of a problem of major significance immediately preceeding the distress messages, notwithstanding the earlier reports of flooding and electrical malfunctions in the ballast control room. From the evidence available, the flooding and electrical malfunctions in the ballast control room were apparently not considered to be major incidents at the time to the witnesses and parties involved with them. If these incidents were directly related to the casualty the Board was also unable to determine why no further communications relative to them were received subsequent to 2215. In an effort to ascertain if there were any such communications, the Board initiated a check of governmental, commercial, and amateur radio stations in the United States and Canada, but could not establish that any communications, other than those of which the Board had knowledge, were made subsequent to 1800, 14 February 1982. All the communications described in this report were cross-checked by a careful review of Telex messages, Marisat Bills, Phone Bills, and the testimony of radio operators in order to more accurately affix times, lengths of communications and content.

40. Underwater Surveys.

A side scan sonar search for the OCEAN RANGER and survey of the surrounding sea floor was conducted between 16 February and 8 March 1982. The OCEAN RANGER was found in an inverted position approximately 485 feet southeast of the well head. The survey disclosed major items of debris including the drilling derrick and a large area exhibiting localized superficial disturbances between the well head and the inverted rig. The wreck was also surveyed by use of an unmanned submersible equipped with television and still photography equipment. This survey disclosed that two of the four ballast control room portlights were broken and that all four deadlights were closed. It was also found that the forward areas of both pontoons had been damaged during the capsizing. There was no evidence of damage or derangement to the underwater portion of the hull which would have permitted flooding.

In July 1982 a more extensive survey was made of the wreck utilizing divers and remotely controlled television cameras. To facilitate this survey marine growth was removed from selected areas of the underwater body. This survey included a detailed examination of the lower hull and column structures. Access was gained into the ballast control room where certain ballast control system components and control room records were removed. In addition, the two broken portlights, one intact portlight and the console mimic board and all solenoid controlled air valves were removed for analysis. Significant findings included:

a. That the pontoon hulls and columns were not fractured or holed. While the forward areas of the pontoons were deformed they were not holed. No structural fractures were found with the exception of an unexplained torn main girder and a hole in the platform structure aft of starboard column No. 3.

b. Physical examination confirmed the accuracy of prior video tapes in that two of the four portlights were in fact broken.(Please see figure 9 for the location of the broken portlights.)

c. Inspection of the ballast control console disclosed that the lower access panels were open exposing the air solenoid valves. A number of these valves had been fitted with manual actuating rods. Some of the console switches and/or associated wiring were burned. Various panel push button switch caps had been removed.

d. Both sea chest strainers were removed and the manual sea chest valves in each hull were found to be closed.

e. Pontoon tanks and compartments were sounded by external means in order to estimate the liquid level in each tank and compartment.

XIII STUDIES

41. Purpose of the Studies

The fact finding efforts of the Board looked into relevant issues that were involved in the OCEAN RANGER casualty. Several areas involving the rigs characteristics and potential behavior of its equipment, machinery and the hull were not completely explained by witnesses since their experience involved basically normal operations or the matters in question were beyond their technical knowledge. Professional assistance was requested from the technical staff of the U. S. Coast Guard Office of Merchant Marine Safety or contracted to evaluate and analyze the following areas of interest with respect to a set of conditions which were likely to be experienced.

42. Stability Study

This study was conducted by the U. S. Coast Guard Merchant Marine Technical Office in New Orleans. It's purpose was to determine the effect on the rig's attitude in calm water of shifting and/or adding various weights. This study is reproduced in it's entirety in Appendix B of this report.

43. Seakeeping Studies

Two studies of the OCEAN RANGER's seakeeping ability were conducted to evaluate the effects of the seaway on the rig. One of those studies was performed by the U. S. Coast Guard Marine Technical and Hazardous Materials Division in Washington DC, while the second was performed by the U. S. Navy David W. Taylor Naval Ship Research and Development Center. Both of those studies are reproduced in their entirety in Appendicies C and D, respectively, of this report.

44. Ballast System Studies

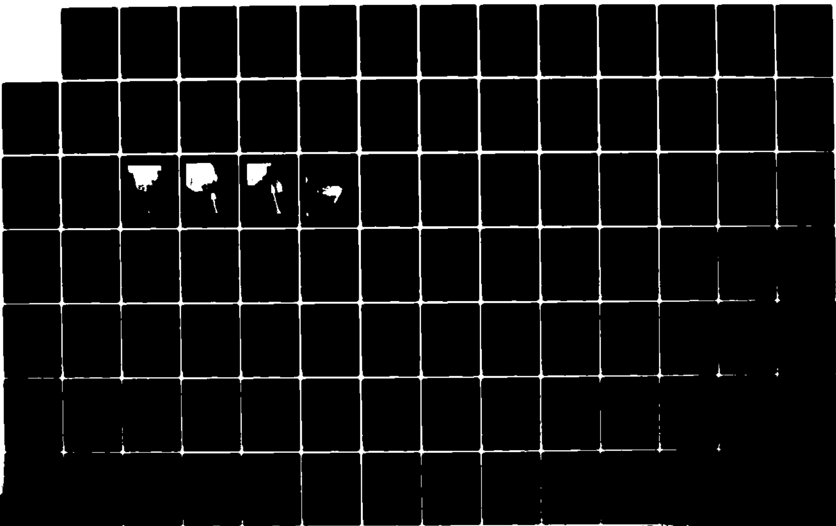
Two studies were conducted of the OCEAN RANGER's ballast pumping capabilities and limitations, given certain attitudes of list. One of these studies was performed by the U. S. Coast Guard Marine Technical and Hazardous Materials Division in Washington, DC, while the second was performed by the U. S. Navy David W. Taylor Naval Ship Research and Development Center. Both of these studies are reproduced in their entirety in Appendicies E and F, respectively, of this report.

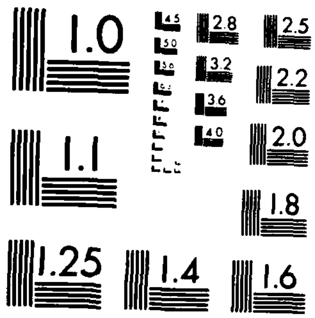
45. Lifesaving Equipment Performance Study

This study was conducted by the U. S. Coast Guard Headquarters in Washington, DC to evaluate the performance of the OCEAN RANGER's lifesaving equipment and determine, if possible, how and why it sustained damage. This study is reproduced in it's entirety in Appendix H of this report.

AD-A140 910 MOBILE OFFSHORE DRILLING UNIT (MODU) OCEAN RANGER ON 2/4
615641 CAPSIZING AND..(U) COAST GUARD WASHINGTON DC
20 MAY 83 USCG-16732/0001-HQS-82

UNCLASSIFIED F/G 13/12 NL




1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

ANALYSIS

I TIME OF DISCONNECT/PORTLIGHT FAILURE

Time of Disconnect

One of the focal points of the Board's inquiry was the question of what time the OCEAN RANGER actually disconnected the marine riser on the 14th of February. The disconnect time may be important because the timing and circumstances surrounding the disconnect operation may have been directly or peripherally related to the time of the failure of the ballast control room portlight(s). This sequence of events was possibly part of a scenario that led to the loss of the rig itself.

All of the evidence relative to the disconnect time is in the form of witness testimony concerning conversations with various personnel on board the OCEAN RANGER. It is corroborated in some cases by radio log times or telephone billing statement times. For the sake of clarity in the following analysis of this evidence, some of the testimony referred to in the factual section of this report is repeated here. To the extent possible, the testimony is discussed according to the rough chronological order in which the conversations were alleged to have taken place. For ready reference and to facilitate the reader's conceptualization during this analysis, the names and positions of the witnesses who gave testimony concerning the time of disconnect are listed below:

NAME	POSITION	LOCATION
Peter Kapral	MOCAN Drilling Engineer	ST. JOHN'S
Merv Graham	MOCAN Superintendent	ST. JOHN'S
Jimmy Counts	ODECO Superintendent	ST. JOHN'S
Donald King	Barge Engineer	SEDCO 706
Rod Fraser	MOCAN Drilling Foreman	SEDCO 706
Keith Senkoe	MOCAN Drilling Foreman	SEDCO 706
John Ursulak	MOCAN Drilling Foreman	SEDCO 706
Ken Lovell	MOCAN Drilling Foreman	ZAPATA UGLAND

Almost all of the testimony received from the above individuals dealt with conversations with the following individuals on the OCEAN RANGER:

NAME	POSITION	LOCATION
Jack Jacobson	MOCAN Drilling Foreman	OCEAN RANGER
Robert Madden	MOCAN Drilling Foreman	OCEAN RANGER
Kent Thompson	ODECO Toolpusher	OCEAN RANGER

The first conversation in which the OCEAN RANGER is alleged to have been in the process of disconnecting occurred at 1642, 14 February during a radio transmission between Mr. Peter Kapral and Mr. Robert Madden, in which hanging off was discussed. In his deposition, Mr. Kapral offered:

Question: Which notation would that be, sir?
Kapral: That would be memo, 1642 from Robert Madden.
Q: What is the purpose of that call?
A: He was hanging off at the time and called to inform me that he was having a few problems with the winds.
Q: Was he more specific than that?
A: Yes, he was.
Q: Could you tell me what he said, please.
A: He said that he, the wind was gusting to 70 knots and blowing the compensator hoses out the side of the derrick.
Q: Please go on. Was that it?
A: That was it. But, he had the situation under control by attaching the air tuggers or air winches to the hose to pull it back into, into to where they could use the traveling block compensator.
Q: Had that already been accomplished or that was in progress?
A: They were in the progress of doing that.
Q: So, they had not completed the hang off procedure?
A: At that time not entirely.
Q: They had begun it, though?
A: They had begun. They were in the process.
Q: Did you relay that information to anyone else ashore?
A: To Merv Graham.

(See Vol. XVIII, Kapral, pages 7 & 8)

Mr. Kapral's testimony on this point was not contradicted by other testimony, nor was he discredited during cross-examination or redirect questioning. His demeanor was sincere and straightforward. On analysis, Mr. Kapral's testimony is precise: the OCEAN RANGER was in the process of hanging-off (hanging-off is a preliminary step to disconnecting) at 1642, but this process was not complete at the time. Also, the rig was experiencing a complicating factor in hanging-off because of the fouled compensator hoses.

During his testimony before the Board in Boston, Mr. Merv Graham was questioned about a prior statement he gave in St. John's regarding the OCEAN RANGER hanging-off at 1600 or 1630. His testimony on this point was:

Question: My question was, do you recall testifying before the informal inquiry in which you indicated that Jack Jacosbon had been talking to you sometime before five?
Graham: Yes, where is that stated in here?
Q: Down at the bottom, right there.
A: Yes, I do recall making the statement there. What I did, but I did not have any note and what I have written down in here is a reference to memory-jogger notes. I knew that they had hung off, be it from the call from Jack at the OCEAN RANGER or Peter Kapral who had been in our office most of the day, I am not certain.
Q: You are not certain when you knew they had hung off?
A: I knew in the area of four, four thirty that they had hung off. How, I am not sure.
Q: You are not sure how you knew that?
A: I do, memory, I do not have any notes to that effect.

(See Vol. X, Graham, page 58)

While seemingly offering to the preliminary inquiry in St. John's that the OCEAN RANGER had hung-off at 1600 or 1630, Mr. Graham qualified this prior statement by saying that he had not made any notes recording how he knew the OCEAN RANGER had hung-off then. He also offered that he thought he had received this information from either Mr. Jacobson or Mr. Kapral. Mr. Graham's testimony was not self-contradicted, nor was he discredited during cross-examination or redirect questioning. His demeanor during testimony was straightforward and sincere, but he made repeated references to his notes because of his expressed lack of independent recollection of the events surrounding the casualty. In analyzing his statement and considering it along with Mr. Kapral's, it is most probable that Mr. Graham had been told by Mr. Kapral that the OCEAN RANGER was in the process of hanging-off at 1630. Due to his lack of notekeeping on this point, Mr. Graham's exact memory of this conversation was probably confused.

The first conversation in which the OCEAN RANGER is reputed to have disconnected took place during a Marisat call from Mr. Jacobson to Mr. Graham. Mr. Graham's testimony on this point is:

> Graham: At 1845 hours, "Received call from OCEAN RANGER, Jack Jacobson. He advised me they had hung off in the middle rams, the bit was in the casing, sheared the drill pipe with the shear rams. The riser was disconnected and they were riding out the storm. He also advised me that the tensioning ring had hung up once on the spider deck area and at the time of disconnect they were getting 20-foot heaves, with spray up into the spider deck area to the rig floor. Jack advised me the rig lost time with the compensator hoses hanging up in the derrick resulting in not hanging off normally and forced to shear the drill pipes. Jack also advised the storm had built extremely fast during the half hour before disconnecting."
>
> (See VOL X, Graham, page 59)

Mr. Graham's testimony on this point is very specific and supported by his personal notes which he made at the time of the conversation. His estimate of the time of this conversation is corraborated by a similar time (1844) recorded by the Marisat bill. Mr. Graham's testimony on this point was not self-contradicted, nor was he discredited during subsequent examination.

The next conversation testified to did not involve disconnecting on the OCEAN RANGER, but rather drilling. This conversation took place via radio, and its contents were testified to by Mr. Donald King, as follows:

> Question: Now, Mr. King, on another matter, do you recall on the afternoon of the 14th or any time during the evening of the 14th, hearing any conversations concerning the drilling operation on the OCEAN RANGER, as to whether or not she was drilling?
>
> King: Around suppertime, a little after I had gone into the Mobile office, there were several people sitting around there talking. The

Mobile foremen had talked to each other, the three rigs were talking back and forth and had indicated we were hung off. The 706 was hung off, the UGLAND was preparing to hang off or was just about hung off and the RANGER was drilling at that point.

Q: Now, you heard these conversations?

A: I had overheard the Mobil foreman talking about it in the Mobil office.

Q: Which Mobil foreman are these that you are referring to?

A: The Mobil foreman on our rig at that point Rod Fraser, Keith Senkoe and John Ursalak.

Q: And this conversation that you had heard, was it on the radio, telephone on the single side band?

A: Single side band.

Q: And who actually was talking from the SEDCO 706?

A: At that point I think Keith was sitting at the chair talking and he was talking to Jack Jacobson on the RANGER and on the UGLAND was Ken Lovell.

Q: And you could hear Ken Lovell's voice and Jack Jacobson's voice answering as Keith Senkoe talked to them?

A: Yes.

Q: And when you overheard this, what you heard was that at the time they were still drilling on the *OCEAN RANGER?*

A: Yes.

Q: And approximately what time was that?

A: Sometime after 6, 1800. Between then, between then and 7.

(See VOL III, King, pages 19-21)

Mr. King was a sincere, straightforward witness. His testimony on the above point was not self-contradicted, nor was he discredited during cross-examination or redirect questioning. However, in analyzing his testimony it is readily apparent that Mr. King is unsure of the exact time of this conversation he had overheard. It is also readily apparent that he was an unconcerned witness to this conversation and had merely overheard it. Therefore, Mr. King's account of the content of this conversation must be viewed with some reservation. Also, in considering the testimony of Mr. King with that of other witnesses, Mr. King's account creates considerable conflict. Specifically, it would have been unlikely that the OCEAN RANGER was drilling during the time cited by Mr. King in view of the testimony of Mr. Kapral that they were attempting to hang-off earlier at 1630. Mr. King's testimony on this point is further contradicted by Mr. Senkoe and Mr. Fraser (see pages 78 to 81 on Mr. Senkoe and Mr. Fraser in this section) who testified that the OCEAN RANGER was not drilling during the time period cited by Mr. King (1700 to 1900), but attempting to hang-off. Furthermore, Mr. King's account of this conversation is not corraborated by any other evidence or testimony, and is therefore considered to be unreliable.

The next conversation involving disconnect was testified to by Mr. Jimmy Counts. This conversation was between Mr. Counts and Mr. Thompson on the OCEAN RANGER and took place via Marisat. Mr. Count's testimony is as follows:

Question: And you estimate that to be about 7:30?
Counts: Yes, between 7 and 7:30.
Q: Who was that call from, Mr. Counts?
A: Kent Thompson.
Q: Can you tell us what he said?
A: He just informed me that he had suspended operation at, that they had hung off the drill pipe and sheared the drill pipe and unlashed the rod and they were waiting on the weather.
Q: Waiting on weather. Did he indicate when he had done that?
A: No, he didn't give me no specific time.
Q: Is that all he had to say?
A: Yes, that's about it. He said he didn't have any problems, everything was going good.

(See VOL V, Counts, page 159)

Mr. Counts testified in a straightforward, sincere manner. His testimony was not self-contradicted, nor was it discredited under cross-examination, or redirect questioning. His estimate of the time is corroborated by the time on the Marisat bill, which indicated a time of 1858.

The next conversation regarding the disconnecting process on the OCEAN RANGER occurred during a radio transmission and was testified to by Mr. Keith Senkoe. This conversation allegedly takes place between Mr. Senkoe, Mr. Jacobson, and possibly Mr. Lovell, and involves hanging-off. Mr. Senkoe's testimony regarding this conversation is as follows:

Question: Brought the rig up five feet. On the afternoon or the early evening of the 14th of February, 1982,did you have an occasion to speak with Jack Jacobson on the OCEAN RANGER?
Senkoe: Yes, at about 1900 hours.

Q: At about 1900 hours. And how did you communicate with Jack Jacobson?
A: On the Mobil radio, single side band radio.
Q: And were you just communicating solely with Jack Jacobson? Was he the only other one you were talking to on the single side band?
A: At the time. I thought the drilling foreman of the ZAPATA UGLAND was there, too, but I am not sure about that. He would be talking, if I was talking to the OCEAN RANGER, he would be there maybe listening but not talking.
Q: So you don't recall that the---
A: No.
Q: --- foreman on the ZAPATA UGLAND was on the line? Who would be this foreman you have in mind?
A: Ken Lovell.
Q: Ken Lovell. But do you recall that about 7 or 1900 local time talking with Jack Jacobson on the OCEAN RANGER?
A: Yes.
Q: Would you tell me, trying to recall as accurately as possible, what took place in that conversation?
A: He just called and said that he was attempting to hang off. I suppose he was checking on our status as well, what we were doing at the time and he called and said that he was attempting to hang off but he had got his compensator hoses fouled in the derrick and he was having a problem getting that sorted out and at the same time he mentioned that a window had been knocked out of the control room and there was some water and glass and such.

(See VOL VI, Senkoe, pages 104, 105)

Mr. Senkoe was a sincere witness and testified on the above matter in a straightforward manner. However, some doubt was cast on this portion of Mr. Senkoe's testimony when he was cross-examined. The cross-examination testimony revealed:

Question: Mr. Senkoe, when did you prepare the notes that you have used as a reference here today to testify?
Senkoe: Just this morning.
Q: Just this morning. And for reference in preparing these notes, what did you use?
A: Basically that, this here.
REAR ADMIRAL BELL: Sir, can you speakup a little louder because we are having a little trouble hearing you.
A: This other testimony that was taken in St. John's and the radio log and barge reports.

Q: So you used those to help refresh your recollection?
A: Right, to get a more accurate time.
Q: Particularly with respect to accuracies on the times?
A: Yes.
Q: But am I correct that you have a distinct recollection that in the call that came sometime around 7 o'clock in the evening that there was a description by Mr. Jacobson on the 706 of an operation attempting to hang off and coming out of the hole?
A: Yes, attempting to hang off.
Q: That's your recollection of that conversation?
A: Yes.
Q: And in fixing the time at 7 o'clock, it's not a precise time, I take it. It is an estimate of the approximate time of that communication?
A: Yes, along with the radio band.
Q: Along with the radio log.
A: Radio log of what time the call was made.
Q: The radio log indicated 1900?
A: Yes.
Q: And which radio log was that, sir?
A: 706.

CAPTAIN BLOMQUIST: We have that as an exhibit.

MR. FRILOT: Yes, I know we do.

CAPTAIN BLOMQUIST: Would you like to see that?

Q: Referring to the radio log, sir, which is Coast Guard Exhibit No. 11, can I show you the entry which is at 2230 Zulu which indicates that the 706 was talking to the UGLAND and it shows Ken Lovell and yourself, is that one of the calls that you referenced to?
A: Yes.

CAPTAIN BLOMQUIST: Answer so everyone can hear.

A: What time is this in regular time?
Q: 2238, my understanding would be 7 o'clock in the evening.
A: It is probably one of the calls, yes.
Q: Then the second call I take it would be when the 706 and the OCEAN RANGER it shows it Mobil foreman talking to yourself at 0036?
A: Yes.
Q: Zulu time, which would be six minutes past 10 o'clock local time. That would be the second call.

MR HUNTER: I believe that would be six minutes past nine.

Q: Six minutes past nine. I accept the correction and apologize. That would be the second call you described?
A: Yes.
Q: And then the third call would have been at approximately one o'clock in the evening, in the morning of the 15th is that correct?
A: Yes.
Q: At any time before you came to testify today had you written out any notes of what your recollection was?
A: No.

(See VOL VI, Senkoe, pages 128-130)

The doubt as to the accuracy of Mr. Senkoe's statement is clearly raised by his rather untimely note keeping (done just prior to his testimony before the Board in late April 1982, over two months after the casualty), and the SEDCO 706 radio log notation, which indicated that at 1900, 14 February, Mr. Senkoe had been talking with Mr. Lovell on the ZAPATA UGLAND and not Mr. Jacobson on the OCEAN RANGER.

Mr. Rod Fraser also testified to hearing the radio conversation discussed by Mr. Senko in the preceding paragraph. His testimony is essentially identical to Mr. Senkoe's, both with respect to the time of the conversation (1900-1930), the content, and the parties to it. His testimony is not cited here, but can be found in: VOL VI, Fraser, pages 138-140.

Mr. Fraser was a sincere witness who testified to in a straightforward manner. His testimony was not self-contradicted, but was somewhat cast into doubt by his untimely note keeping (done just prior to his testimony before the Board in late April 1982, over two months after the casualty). It is also noteworthy that while his testimony corroborates Mr. Senkoe's testimony, he expresses considerable doubt as to his time: "I don't think my times are going to (sic) very exact". (See VOL VI, Fraser, page 138, line 4).

The next conversation testified to did not involve disconnecting, but is chronologically relevant to a succeeding conversation testified to which did. This next conversation took place via Marisat between Mr. Graham and Mr. Jacobson. Mr. Graham testified to its time and content as follows:

Question: And what would have been the next call that you received from the OCEAN RANGER?
Graham: The next call was at 2045 hours.

Q: Will you please tell me what you said and what, was it Mr. Jack Jacobson calling again?

A: At 2045 hours, "Received call from OCEAN RANGER, Jack Jacobson. I do not know if I initiated the call or not. It was on the MARISAT. Jack advised me they had 50 foot plus maximum combined seas and winds in the 90/100 knot range. He advised me that one wave had taken a window out of the barge control room. He advised me there was no problem with this window outing and from memory he advised me that all that was required was to mop up a little bit of water in the room and that all of the equipment was functioning properly at the time. He advised me that the anchor tensions were all in the 240,000 range. Also that the barometer had leveled off, everything was normal at the rig. They had no problems. The remainder of our discussions at that time centered around the equipment he would require to mill off the top of the sheared drill pipe and the overshot and tools necessary to recover his drilling string in view of a plane waiting to bring extra fishing equipment from Drillrite in Edmonton, Alberta. I requested Jack Jacobson at this time to talk to the foreman at the 706 and the UGLAND and discuss with them their anchor tension and how they were riding out the storm and call me back".

(See VOL X, Graham, pages 60 & 61)

Mr. Graham's testimony on this point is supported by his personal notes, which he made at the time of this conversation, and by the time on the Marisat bill which indicated the conversation took place at 2044. Mr. Graham's testimony on this point was not contradicted nor discredited.

The next conversation regarding disconnecting on the OCEAN RANGER took place by radio. This conversation was testified to by Mr. Keith Senkoe, as follows:

Senkoe: Yes, we talked again at approximately, I am not really sure, about 2130 to 2200.

Question: 2130 to 2200?

A: Yes.

Q: And how did that conversation come about that you called Jack Jacobson or did Jack Jacobson call you?

A: He did call me.

Q: He called you. And how did you communicate? On what kind of equipment?
A: *The same radio as before.*
Q: And would you, thinking back as accurately as you can, describe it to us, what was, how did that conversation go both what you said and what he said?
A: He had just finished talking with Merv Graham and Merv asked him to contact the other two rigs to see how everybody was doing, so he did. He talked to the UGLAND first, I am pretty sure, and then me second. During that conversation he just commented that he had sheared and disconnected and basically that was it, but a few comments about the weather.

(See VOL VI, Senkoe, page 112)

Mr. Senkoe's testimony on this point is corroborated by the SEDCO 706's radio log, which indicated that a radio conversation between the OCEAN RANGER and the SEDCO 706 took place at 2106, 14 February. Mr. Senkoe's testimony on this point was not contradicted, nor was it discredited in cross-examination or redirect questioning.

Mr. Senkoe's testimony in the preceeding paragraph is further corroborated by Mr. Fraser's testimony, who testified as follows:

Question: Now if you would just think ahead to the second conversation. Now, who was involved in that conversation with Jack Jacobson?
Fraser: Keith Senkoe and Ken Lovell.
Q: And do you recall about when that was?
A: That was 9:30, 10 o'clock.
Q: 9:30 or 10. Now, would you tell us as accurately as you can describe it what was said?
A: Okay. Well in that conversation we had hung off and had unlatched the marine riser.
Q: When you say we---
A: The 706 hung off and unlatched the riser, the ZAPATA UGLAND had done the same and the OCEAN RANGER had sheared the pipe and in fact I can remember Jack Jacobson saying to Ken Lovell on the ZAPATA UGLAND, 'don't feel bad we did it too'. In other words we sheared the pipe also. They had on the 706, on the OCEAN RANGER had sheared the pipe also.

(See VOL. VI, Fraser, pages 141 & 142)

Mr. Fraser's testimony on this point was not contradicted, nor was it discredited during cross-examination or redirect questioning.

Further corroborating Mr. Senkoe's testimony regarding this conversation was Mr. Ursulak's statement given in deposition. Mr. Ursulak testified:

Question: Do you recall if the 706 or Mobil foreman specifically talked to either one or both of the other two rigs during the remainder of that evening?
Ursulak: Yes.
Q: Do you recall what time that may have been?
A: I believe it was 9:30, the 706 talked to both rigs at 9:30.
Q: Were you doing the talking or was someone else?
A: No, I believe Mr. Senkoe was on the radio.
Q: You were in the same room?
A: The same room.
Q: You indicated that was 9:30 thereabouts?
A: About 9:30, yes. I was making no record of time.
Q: I understand. Do you recall what was discussed?
A: All three rigs talked to each other and all three rigs were in the same storm. We talked to the UGLAND about them shearing and us hanging off and disconnecting and the OCEAN RANGER on going from drilling ahead to shearing off.
Q: Was there any indication in that conversation at what time the OCEAN RANGER sheared off?
A: No mention was made. I have no idea what time they sheared.
Q: Do you know who on the OCEAN RANGER was talking?
A: Jack Jacobson.
Q: He was the Mobil foreman on board the OCEAN RANGER?
A: That's correct.
Q: Did Jacobson in that conversation mention anything about control room problems?
A: No, sir.
Q: Was there any mention of a porthole being broken?
A: Not to my knowledge.

(See VOL. XV, Ursulak, pages 25 & 26)

Mr. Ursulak was a straightforward, sincere witness. His testimony on this point was not contradicted, nor was it discredited during cross-examination or redirect questioning.

Still further corroborating Mr. Senkoe's testimony regarding this conversation was Mr. Ken Lovell's testimony:

Question: And that conversation that you had at 10:15 p.m., was it just a conversation simply between you and Mr. Jacobson?
Lovell: No, it was a common three-way conversation with Mr. Senkoe.
Q: Mr. Senkoe was involved with that?
A: Yes.
Q: Now, would you please describe to us how that conversation went as far as you can remember; what everybody said?
A: To the best of my recall Keith and I struck up the conversation initially. We just identified the status of each of our respective rigs. Jack came in we and asked him what his status was. And he said to the best of my recall, he said don't worry about it, Ken, we had to snip our pipe off, too, or something to that effect. And both Keith and myself wondered why he had, in fact sheared his drill pipe and felt that he should have been able to get his hang off tool in the hole and hangoff, back off that tool bit without shearing the drill pipe.
Q: Tell me, excuse me, why did you and Keith Senkoe---

MR. HUNTER: I am not sure the witness has finished his answer.
Q: Please continue.
A: Both Keith and I felt that he would have been in the best position to get hung off in a normal conventional manner and back off the drill pipe and avoid shearing off and so we pursued that with him and he suggested that they had a problem with the compensator and they lost their ocean compensator function and were forced to shear.

(See VOL VIII, Lovell, pages 140 & 141)

Mr. Lovell's time for this conversation (2215) is considerably different from that cited by the previous witnesses; however, he does offer that it is approximate. Mr. Lovell was straightforward, and sincere in his testimony. Other than the time he cites for this conversation, his testimony on the above matter was not contradicted, nor was it discredited during cross-examination or redirect questioning. Mr. Lovell also recalled hearing Mr. Jacobson referring to a broken portlight during this conversation. He testified on this further point as follows:

Lovell: And there was the porthole we discussed previously and put aside as being no problem. The water had been mopped up and that took place, the conversation at 10:15.
Question: What did Mr. - as far as you can recall is this Mr. Jacobson telling you about the porthole?
A: Yes.
Q: What did he say? What were his words as far as you can recall?
A: Well, they just said that they had knocked the window out and they were taking on some water, but they mopped it up and there was no problem.
Q: That they had knocked the window out?
A: It had been.
Q: I was just trying to capture the words that he used as far as you can remember.
A: Yes, the window had been knocked out, I guess.

(See VOL VIII, Lovell, page 144)

The final conversation cited in this section does not involve disconnecting, but is relevant chronologically and contextually to the preceding conversations. This conversation took place via single side band radio between Mr. Jacobson and Mr. Graham, who testified as follows:

Question: What is the next call that you received from the OCEAN RANGER or the next conversation that you had with anyone on the OCEAN RANGER?
Graham: At 2200 hours.
Q: And would you please tell me what you said and you were speaking with Mr. Jacobson?
A: At 2400 (sic) hours, "I received a call from the OCEAN RANGER, Jack Jacobson, as requested previously to inform me of the status of the other two semi-submersibles. On the OCEAN RANGER, Jack advised me the maximum combined seas were in the 55 foot, the odd wave going up in the 65-foot range. I asked Jack if he was having any problems in the barge control room with the window being taken out, and he assured me that all of the equipment was functioning normally. On the UGLAND he advised me they lost one guide line, that the winds were in

80-85 knot range, maximum combined seas in the 35-55 foot and some higher. The SEDCO 706 had disconnected and they had the thrusters on 75 percent power. I do not have it noted nor can I remember which call, but I was aware, which is normal procedure, that once the rigs have disconnected the riser they will deballast the rig up five to ten feet to gain more air gap and also to lessen the chance of seas breaking on the main-deck level. I ended my conversation with Jack Jacobson with us both in agreement at that time that the rigs were all riding out the storm with no problems, and Jack indicated that the wind and the seas had come down slightly from what they had been previously. All that we could do was ride the storm out for the night and I would talk to them in the morning."

(see VOL. X, Graham, pages 63-65)

This testimony is supported by Mr. Graham's personal notes made at the time of the conversation. Mr. Graham's testimony on this point is not contradicted, nor was it discredited during cross-examination or redirect questioning.

In summary, the times of the disconnect conversations (excluding Mr. Don King's account) are as follows:

1642 - Peter Kapral called by Robert Madden; hang-off on the OCEAN RANGER in progress, compensator hoses snarled.

1845 - Jack Jacobson calls Merv Graham; OCEAN RANGER disconnected.

1858 - Kent Thompson calls Jimmy Counts; OCEAN RANGER disconnected.

1900 - Jack Jacobson calls Keith Senkoe (Rod Fraser witness); OCEAN RANGER attempting to hang off, describes portlight failure.

2044 - Jack Jacobson calls Merv Graham; OCEAN RANGER portlight out, Graham asks Jacobson to check on other rigs.

2106 - Three-way conversation between Jack Jacobson, Ken Lovell, and Keith Senkoe (John Ursulak and Rod Fraser witness); conversation centers on; hanging-off, disconnecting, and weather; Jack Jacobson discusses portlight incident with Ken Lovell.

2200 - Jack Jacobson calls Merv Graham back.

There is obviously a conflict between Mr. Senkoe's 1900 conversation, and Merv Graham's 1845 conversation and Jimmy Counts' 1858 conversation. This conflict can be resolved in one of two ways. The first would be to move Mr. Senkoe's 1900 conversation chronologically back in time so that it precedes Mr. Graham's 1845 conversation. The second would be to discredit either the Senkoe/Fraser accounts of Mr. Senkoe's 1900 conversation, or Mr. Graham's account of his 1845 conversation and Mr. Counts' account of his 1858 conversation. It is tempting to resolve this conflict by moving Mr. Senkoe's 1900 conversation back in time so as to precede Mr. Graham's 1845 conversation, but this is not a viable option because it raises additional conflicts with another focal point of the investigation; the time of the OCEAN RANGER's portlight failure. Discrediting witnesses accounts of conversations at this point is premature without an analysis of the testimony regarding the failure of the OCEAN RANGER's portlight.

Time of PortLight Failure.

The analytical methodology followed in the "TIME OF DISCONNECT" analysis section will be followed in this section. The following individuals offered testimony regarding the failure of the OCEAN RANGER's portlight:

NAME	POSITION	LOCATION
Keith Senkoe	MOCAN Drilling Foreman	SEDCO 706
Rod Fraser	MOCAN Drilling Foreman	SEDCO 706
Merv Graham	MOCAN Drilling Superintendent	St. John's
Don King	SEDCO Barge Engineer	SEDCO 706
Fred Hatcher	SEDCO Watchstander	SEDCO 706
John Ursulak	MOCAN Drilling Foreman	SEDCO 706
Ken Lovell	MOCAN Drilling Foreman	ZAPATA UGLAND
Jim Davidson	Captain	M/V BOLTENTOR

The first conversation regarding the failure of the OCEAN RANGER's portlight occurred during a radio transmission between Jack Jacobson on the OCEAN RANGER and Keith Senkoe on the SEDCO 706 at 1900. For an account of this conversation see page 79 in the TIME OF DISCONNECT ANALYSIS section.

The next account of a portlight failure on the OCEAN RANGER was testified to by Mr. Don King. Mr. King's testimony is as follows:

Question:	Quarter to or ten to eight. So what you are indicating to me, as I get, it is that the wave struck approximately at 7; that you deballasted, you completed at about 7:20, you went out to make an outside inspection and then you came back in. It was approximately - - -
King:	Quarter to eight, ten to eight.
Q:	Quarter to eight, ten to eight. Would you tell us what you saw or heard after that?
A:	After I come back in we had our four thrusters running then. I checked those, checked our anchor tensions. We were riding the storm fairly well. At that point we started hearing conversations on our VHF Channel 6. We could overhear somebody on the OCEAN RANGER talking.
Q:	Where were you located when you heard these?
A:	In barge control.
Q:	In the barge control room?
A:	Yes. We overheard conversations that they were mopping up water and cleaning up broken glass. In this time frame from ten to eight until nine, a little after nine, we picked up two or three different conversations. One being the broken glass and water, another being that their P.A. System was knocked out. Their gas detection system was knocked out, everything appeared to be okay. They were cleaning, they said everything looked okay. "We are still cleaning up water." Sometime after 9 o'clock we heard they were getting shocks off of different panels and they wanted the E.T. man, electronic technician to come down to the control room and at some point along there they said valve or valves were opening and closing on their own.
Q:	Valve or valves were opening and closing on their own. This was a voice transmission that you heard, is that correct?
A:	This was a voice on a portable VHF radio and I, myself, and the watch on duty we recognized the voice as being Nick Dyke.

(See VOL. III, King, Pages 17 & 18)

Question: Mr. King, I want to get a sense of time span involved in these happenings and particularly the radio conversation you have heard. I believe you testified that it was at about 1930 or 1945 when you first heard conversations which you took to be coming from the OCEAN RANGER, is that correct?

King: A little later than 1930, after the rig was deballasted to seventy-five feet I went outside and I was probably outside twenty-five to thirty minutes. After I came back inside, it may be a little less than a half hour or twenty minutes after I saw what damage we did have on our port side, and that would have put it quarter to eight, ten to eight, something like that. And it was shortly after that we started picking up some conversation.

Q: And if I understood your testimony correctly, you actually heard these conversations then over a time period of something in the neighborhood of two hours, is that correct?

A: Bits and pieces or from quarter to eight until a little after 9, 9:30, something to ten.

Q: And what was the last thing you heard in this particular series of conversations which took that two-hour or so period?

A: It was the watch stander, Nick Dyke, talking to somebody else on the rig indicating that everything looked okay and they had the water cleaned up and the glass cleaned up.

Q: So then you were hearing conversations which led you to believe that there was a problem and it was being dealt with over a roughly two-hour time period and the last thing you heard was everything appears to be okay, is that correct?

A: The problem as such was just indicated water and broken glass and the shorting out of their gas detection system and P.A. system. Nothing said about trouble at all.

Q: And once again, about what time was it you heard that last bit that everything appeared to be okay?

A: Probably around, I had gone for coffee just shortly around 9, a little after, and I was back in the control room for just a few minutes and it was after that, a short time after that, probably 9:30, quarter to ten, in that area.

(See Vol. III, King, pages 65 & 66)

Mr. King was a straightforward, sincere witness. His testimony was not self-contradicted, nor was he discredited under cross-examination or redirect questioning. The times Mr. King cited for these conversations, especially the first, appear to be very reliable.

Mr. Fred Hatcher corraborates the testimony of Mr. King with respect to these transmissions. He also was a straightforward, sincere witness. His testimony was not self-contradicted nor discredited under cross-examination or redirect questioning. (See VOL III, Hatcher, pages 88-90)

Mr. Ursulak also testified to overhearing several of the transmissions heard by Mr. King and Mr. Hatcher. His testimony was that he stopped by the SEDCO 706's ballast control room at the time Mr. Don King and Mr. Fred Hatcher were listening to several of these transmissions. However, his account, while not in conflict with Mr. Don King's and Mr. Fred Hatcher's, is considerably sketchier in it's detail, but there is little doubt that he heard the same transmissions that they did. Mr. Ursulak is also considerably less certain as to the time of the transmissions and cites a time period between 1630 and 1900. Based on his uncertainty as to exactly when he heard these transmissions, his testimony with regards to the time of these transmissions is unreliable (See Vol.XV, Ursulak, pages 15-19).

The next conversation regarding the failure of the OCEAN RANGER's portlight occurred at 2044 during a Marisat call between Mr. Jacobson on the OCEAN RANGER and Mr. Graham. For an account of this conversation, see page 81 in the TIME OF DISCONNECT ANALYSIS section.

The next conversation regarding the failure of the OCEAN RANGER's portlight occurred at 2106 during the conversation between Mr. Jacobson on the OCEAN RANGER, and Mr. Lovell on the ZAPATA UGLAND. For an account of this conversation, see page 86 in the TIME OF DISCONNECT ANALYSIS section.

The last account of a portlight failure on the OCEAN RANGER was testified to by Captain James Davidson. Captain Davidson's testimony follows:

Question: Now, you came on watch at 8 P.M. Were you on watch continuously until midnight?
Davidson: Yes, sir.
Q: Were you guarding any frequencies on the bridge of the BOLTENTOR?
A: Yes, sir, we have two VHF and we guard both working frequencies, Channel 6 for the

OCEAN RANGER and the SEDCO 706 and we also have the other one on Channel 12 for the ZAPATA UGLAND. We also listen on 2182.

Q: Now, Captain, with regard to Channel 6, you have indicated you were listening on Channel 6. What, if anything, did you hear on Channel 6 which was unusual during your watch?

A: At about the mid watch. I cannot place it any closer than that, we heard some conversations on what I took to be hand-held VHF sets, walkie-talkies, to the effect that or initially establishing contact. Can you hear me; yes, I can hear you now, whatever. And then a voice said, Well, there is broken glass in here and there is water in here and another voice said, I will get it cleaned up, get some guys in there and get it cleaned up. Then another voice, yet, a third voice, said, Well, there is some high-powered cables down there. And the second voice came back and said, Well, don't have anybody injured or killed, but obviously still get the water cleaned up. And the last thing I heard was another voice saying, Well, there is some valves operating or opening or closing. I can't remember the exact words, but it was to do with valves operating.

(See Davidson, Vol. VIII, page 6 & 7)

Captain Davidson was a straightforward, sincere witness. His testimony was not self-contradicted, nor was he discredited under cross-examination or redirect questioning.

In summary, the times of the portlight failure accounts and conversations (excluding Mr. John Ursulak's 1630-1900 account), along with the times of the disconnect conversations (excluding Mr. Don King's account) are shown below:

1642 - Peter Kepral called by Robert Madden; hang-off in the OCEAN RANGER in progress, compensator hoses snarled.

1845 - Jack Jacobson calls Merv Graham; OCEAN RANGER disconnected

1858 - Kent Thompson calls Jimmy Counts; OCEAN RANGER disconnected.

1900 - Jack Jacobson calls Keith Senkoe (Rod Fraser, witness); OCEAN RANGER attempting to hang-off, describes portlight failure.

1945 - Don King and Fred Hatcher begin overhearing several transmissions from the OCEAN RANGER regarding a portlight failure.

2044 - Jack Jacobson calls Merv Graham; OCEAN RANGER portlight out, Graham asks Jacobson to check on other rigs.

2106 - Three-way conversation between Jack Jacobson, Ken Lovell, and Keith Senkoe (John Ursulak and Rod Fraser, witness); conversation centers on: hanging-off, disconnecting, and weather; Jack Jacobson discusses portlight incident with Ken Lovell.

2200 - Jack Jacobson calls Merv Graham back; reports on status of rigs.

2200 - Jim Davidson overhears transmissions from the OCEAN RANGER regarding a portlight failure. (time approximate)

In final analysis, the Senkoe/Fraser account of the 1900 Senkoe/Jacobson conversation cannot be moved back chronologically so as to precede the 1845 Merv Graham conversation because:

a. The 1945 conversation testified to by Mr. King and Mr. Hatcher appears to be an initial survey of the broken portlight incident. It is unlikely that Jack Jacobson would discuss a failed portlight with Keith Senkoe prior to 1845 and then have it take over an hour for the personnel on board the OCEAN RANGER to undertake such a survey.

b. If he had knowledge of it, it is unlikely that Jack Jacobson would not report the failed portlight to his supevisor, Merv Graham,during his 1845 conversation with him if it had occurred just prior to this conversation. Similarly it is unlikely that Kent Thompson would not report the incident, if he had knowledge of it, to his supervisor, Jimmy Counts, during their 1855 conversation. Testimony shows that neither Mr. Graham nor Mr. Counts received such reports.

c. Mr. Graham was not notified of the incident until 2044. This 2044 notice to Mr. Graham is chronologically consistant with the time lapse that would have been expected to occur between the time of the initial survey, which Mr. King overheard at 1945, and the time Mr. Jacobson should have had a clearer account of what had happened (after 1945, but prior to 2044).

Since Mr. Senkoe's 1900 conversation cannot be moved back chronologically, either Mr. Senkoe's and Mr. Fraser's testimony regarding the hang-off time must be discredited, or both Mr. Graham's account of his 1845 conversation with Jack Jacobson, and Mr. Counts' account of his 1858 conversation with Mr. Thompson must be discredited. The Senkoe/Fraser accounts of the 1900 conversation with Mr. Jacobson are discredited for the following reason:

a. Mr. Graham's testimony is supported by timely note keeping and a Marisat bill. Mr. Count's testimony is corraborated by a Marisat bill. Mr. Senkoe's and Mr. Fraser's accounts are corraborated only by their untimely note keeping, done some two and a half months after the casualty.

b. Mr. Senkoe and Mr. Fraser most probably confused the substance of Mr. Senkoe's 2106 conversation with Mr. Jack Jacobson, during which hanging-off was discussed, with some earlier conversation with him which occurred "around 1900". It is also far more reasonable to assume that Mr. Jacobson would not discuss the portlight failure with the other two rigs until after he had notified his superior of it at 2044. Indeed, Mr. Lovell's testimony reflects this and is probably the more accurate account of the 2106 conversation between Mr. Senkoe, Mr. Lovell, and Mr. Jacobson.

The remaining conflict in the chronology of the portlight failure is the estimated 2200 time cited by Captain Davidson for this incident. Captain Davidson adamantly stood by this time, basing it largely on his impression that the single transmission which he heard had occurred at about the middle of his four hour watch from 2000-2400. Captain Davidson's testimony was very detailed and considered by the Board to be very credible. This makes it somewhat difficult to reconcile the conflict that it creates with the testimony of Mr. King and Mr. Hatcher. However, in considering the substance of the transmission heard by Captain Davidson and comparing it with that of the one of the last transmissions heard by Mr. King and Mr. Hatcher between 2100 and 2145, the two accounts appear to be very similar. The only exception to this is in Captain Davidson's account where he mentions that the persons participating in the transmission seemed to him to be "initially establishing contact", This impression of Captain Davidson's could have quite possibly resulted from a communications problem on board the OCEAN RANGER in that they might have periodically had to reestablish communications with the walkie-talkie radios which the crewmen were using. Therefor, in the considered opinion of the Board, Mr. King, Mr. Hatcher, and Captain Davidson all probably heard the same single transmission from the OCEAN RANGER and that it occurred at approximately 2100-2200.

Summary of Time of Disconnect/Port Light Failure Analysis

In final analysis, the best available evidence supports a finding that the OCEAN RANGER began hanging-off around 1630, but due to the complication of the snarled compensator hoses, did not complete the operation until sometime later. When the hang-off was completed, it was done under emergency conditions because of the worsening weather conditions, which required that the drill string be sheared. Also, the best available evidence supports a finding that immediately prior to 1845 the OCEAN RANGER disconnected her marine riser from the subsea stack.

Similarly, the best available evidence supports a finding that there was only one portlight failure incident and that this incident involved one or two portlights. Also, the best available evidence supports a finding that this portlight failure incident occurred before 1945. However, it cannot be entirely dismissed that one of the portlights may have failed subsequent to the last overheard transmissions heard from the OCEAN RANGER but was not reported, or that it broke during the capsizing and sinking of the rig. The only evidence that supports the latter possibilites is the physical evidence of the second broken portlight itself.

In view of the above, the time of disconnect and the time of the portlight failure probably are not directly related. Based on the evidence available to the Board, the OCEAN RANGER could have deballasted immediately after disconnecting had they chosen to do so.

II CAUSE OF LIST

Preliminary Conclusions.

The Board is of the considered opinion that the sinking (capsizing) of the OCEAN RANGER was the result of an initial list forward, with a possible increase in draft, and the consequent flooding of the chain lockers in one or both of the forward columns. This sequence of events produced a list sufficient to immerse the upper hull, which, as it flooded, resulted in a loss of bouyancy sufficant to cause the rig to capsize.

In support of this conclusion the Board would cite the Intact Stability Study of the OCEAN RANGER (Appendix B) and the two Seakeeping Studies (Appendices C&D) performed at its direction. (Please see the following section for comments in respect to the Seakeeping Studies).

From these three studies the Board was able to draw two other conclusions.

One is that the OCEAN RANGER did not achieve a reduction in draft after disconnect. It can be determined from an analysis of these studies that even a modest draft reduction probably would have insured survival, in view of the lack of evidence of hull damage and shifting heavy loads. The reason(s) for the OCEAN RANGER not achieving a reduction in draft cannot be determined by the Board, but is probably a consequence of one or both of the following:

a. The onboard personnel failed to understand the need to reduce draft in the face of the environmental conditions the OCEAN RANGER was experiencing;

b. An attempt at draft reduction after the porthole failure(s) was unsuccessful due to ballast control panel malfunction and/or personnel error.

The second conclusion is that the OCEAN RANGER had to assume an initial list forward with a possible increase in draft, in order for flooding of the chain lockers to have occurred. The Board is unable to determine with certainty how the initial list occurred but offers the following analysis based on the evidence available. The Board wishes to emphasize that much of the testimony it received in respect to events occurring on the OCEAN RANGER subsequent to the disconnect and prior to the sending of the MAYDAY was based on overheard radio communications. The personnel hearing these communications were not directly involved with the OCEAN RANGER. Depending upon their position of authority and background, varying degrees of interest in the information being received may be inferred. Until the initial distress call was made by the OCEAN RANGER, the importance of the overheard information was not evident and the exact wording and times as testified to should be viewed with caution.

Possible scenarios resulting in list.

With this caution in mind, it is the board's considered opinion that the porthole failure(s) admitted sufficient water to cause a ballast control panel malfunction. The Board offers for consideration the following scenarios based on the conviction that the initial list was caused entirely by ballast control panel malfunction (electrical), entirely by personnel error, or by some combination thereof.

a. The ballast control panel malfunctioned prior to being deenergized, causing valves to open which resulted in:

A. The transfer of onboard ballast water forward, and/or,

B. Admission of additional sea water to the ballast tanks.

b. The ballast control panel malfunctioned and was deenergized, but no change of trim or draft occurred. Subsequent:

i. Attempt(s) to reenergize the panel to reduce draft resulted in:

A. The transfer of onboard ballast water forward, and/or,

B. Admission of additional sea water to the ballast tanks.

ii. Attempts to prepare the air solenoid valves for manual control, due to lack of knowledge, training, and instruction on proper procedures, inadvertently actuated the air solenoid valves which resulted in:

A. The transfer of onboard ballast water forward, and/or,

B. Admission of additional sea water to the ballast tanks.

iii. Attempts to manually operate the ballast system valves or activate the air solenoids resulted in:

A. The transfer of onboard ballast water forward, and/or,

B. Admission of additional sea water to the ballast tanks.

c. The ballast control panel did not malfunction and was de-energized. During attempts at reenergizing, the ballast control panel malfunctioned which resulted in:

A. The transfer of onboard ballast water forward, and/or,

B. Admission of additional sea water to the ballast tanks.

d. Personnel actions due to their lack of full knowledge, training, and instruction on the operation of the ballast system and how the electrical circuits functioned resulted in:

A. The transfer of onboard ballast water forward, and/or.

B. Admission of additional sea water to the ballast tanks.

In support of these hypotheses, the following is noted:

a. As established by the stability analysis, relatively small liquid movements produced relatively large amounts of trim, up to approximately 17 degrees when the shape of the righting arm curve changed substantially.

b. Testimony established uncertainties as to the function of the "source" disconnect switches on the ballast control panel front which may have precluded timely manual securing of electrical power.

c. Testimony established lack of instruction, training, and knowledge as to the location of the circuit breaker energizing the valve control portions of the panel which may have precluded timely manual securing of electrical power.

d. The valve control indicating lights were on the same electrical circuit as the valve control push buttons and relays. With this circuit deenergized, manual control of the air solenoids would have been very difficult without visual indication of the valve positions.

e. Testimony established the lack of instruction, training, and knowledge of how the solenoids were to be operated in event of loss of ballast control panel electrical power.

f. The OCEAN RANGER was provided with a manual means of opening the normally closed electro-pneumatic control valves. These were referred to as "brass operating rods". Testimony established that these rods, between 17 and 20 in number, were manufactured by Mitsubishi for initial installation tests of the ballast control system. They were retained onboard in case of future needs for manual override devices. This original purpose was subsequently and apparently lost and succeding generations of OCEAN RANGER ballast control room operators instead erroneously presumed their purpose to be for the manual control of the solenoids in the event of an electrical malfunction or failure of the ballast control console.

A brass operating rod consisted of a brass bushing with external tapered pipe threads permitting it to be inserted into the threaded opening in the solenoid housing. The bushing had an internal machine thread of a fine pitch into which could be inserted a mating brass rod with a corresponding machine thread along part of its length. (please see figures 14 a,b,&c,).

The bushing and brass rod were a loose fit on the sample examined by the Board. Because of this loose fit, there was no binding when threading the brass rod in to the bushing, and the fit would tolerate a degree of corrosion, extent undetermined, before hand operation would have been difficult.

On test with the sample available to the Board, it was extremely difficult to determine when the brass rod contacted the solenoid plunger and when the solenoid was being opened. Only when the solenoid was fully in the open position, and at the extent of the plunger travel, was one able to ascertain the action of the rod. This was due to the fine threads machined in the bushing and rod, providing a high mechanical advantage (as compared to a coarse thread) and a distinct lack of "feel".

The Board was initially unable to ascertain who furnished the rods and bushings for the OCEAN RANGER. After considerable correspondence with the Japanese manufacturer of the valve, the Board was referred to the American manufacturer who furnished an entirely different manual solenoid opening device. (Please see figures 14 b,c, & d). This device requires one to push in the center section, overcoming the resistance of the solenoid return spring, and then rotate the center piece to lock it in place. As compared to the brass bushing and rod assembly of the OCEAN RANGER, the device furnished by the manufacturer is (1) positive in that the solenoid cannot be inadvertently opened and placing same in the locked open position requires rotation of the center section; and (2) the manufacturer furnished device gives a ready indication of the position of the solenoid. Unless two adjacent solenoids were fitted with brass rods permitting a comparison of lengths, it would have been very difficult to determine if a solenoid on the OCEAN RANGER was opened or closed.

Based on the examination by the Board of one brass rod and bushing, and with no reason to believe the others are not of the same design and manufacture, it is evident to the Board that a person not cautioned in respect to their use could easily open the solenoids and be unaware that such had happened.

g. The ballast system pump and piping design and arrangement severely limited the ability to dewater the forward ballast tanks under forward trim conditions of any magnitude.

h. Testimony established that onboard personnel felt they had at some time, or for some period of time at least, stabilized the listing situation.

i. There were no installed devices to make the crew aware of the flooding of the chain lockers.

j. Testimony and evidence established that the crew was unaware of the potential for the flooding of the chain lockers.

k. The range of motion of the OCEAN RANGER during this period was in excess of any previously experienced by those on board, and would have masked small rates of increase in trim.

l. At some point in time the increasing trim was recognized and incorrectly attributed to ballast tanks flooding rather than the

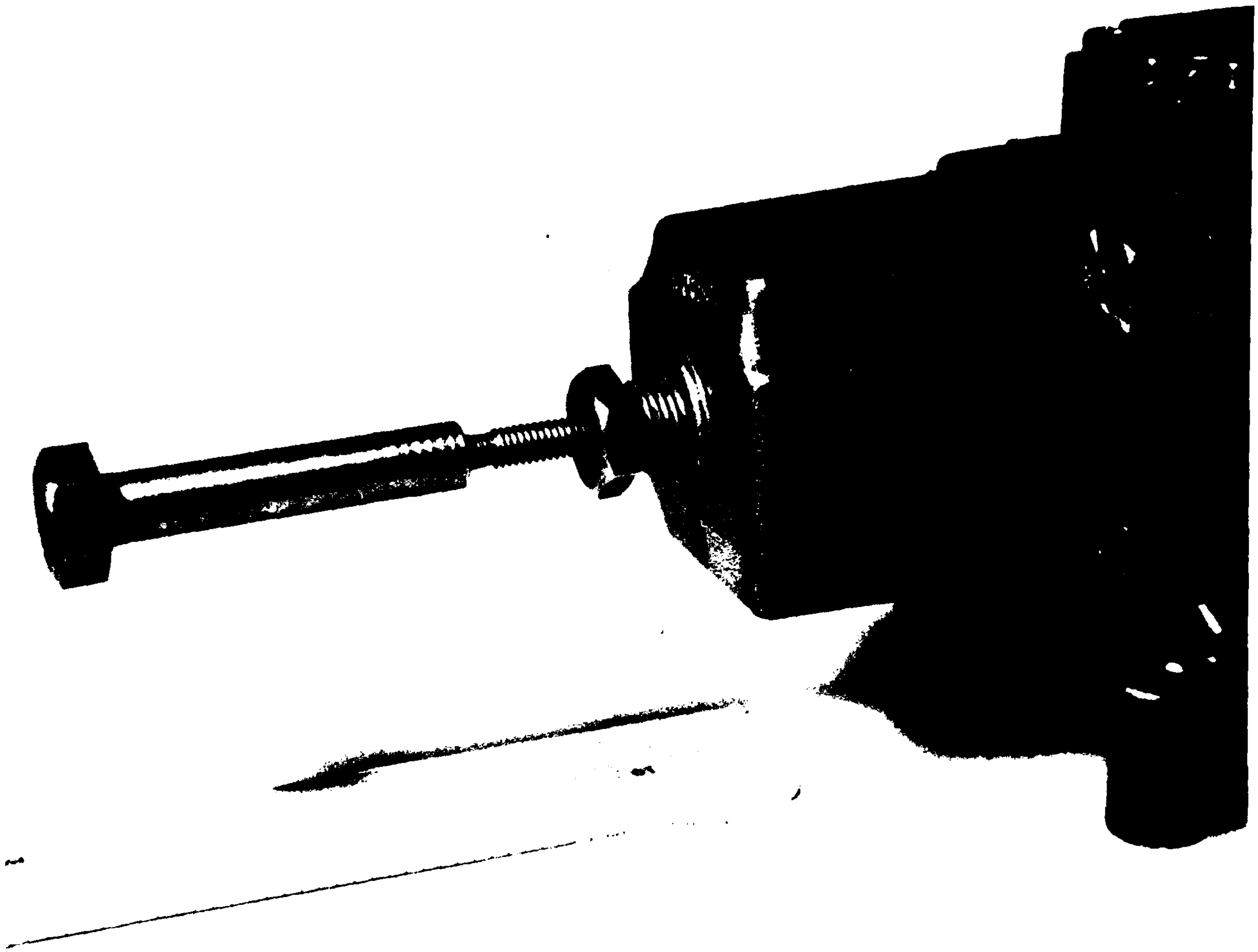


Figure 14a - Brass operating rod screwed in solenoid valve to activating position.

Figure 14b - Brass operating rod and solenoid valve with manufacturers operating device in retracted position

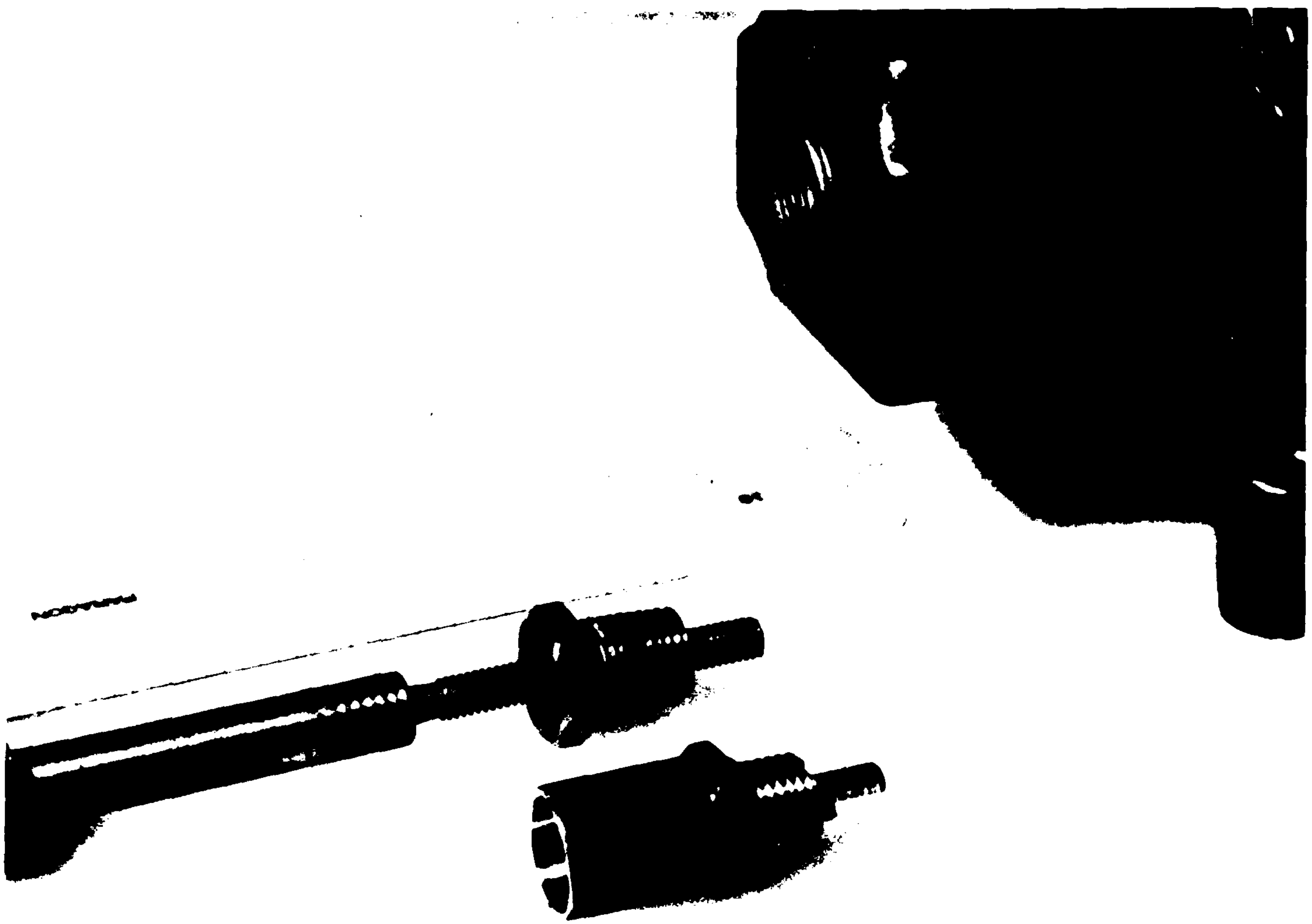


Figure 14c - Brass operating rod and manufacturers operating device in activating position.

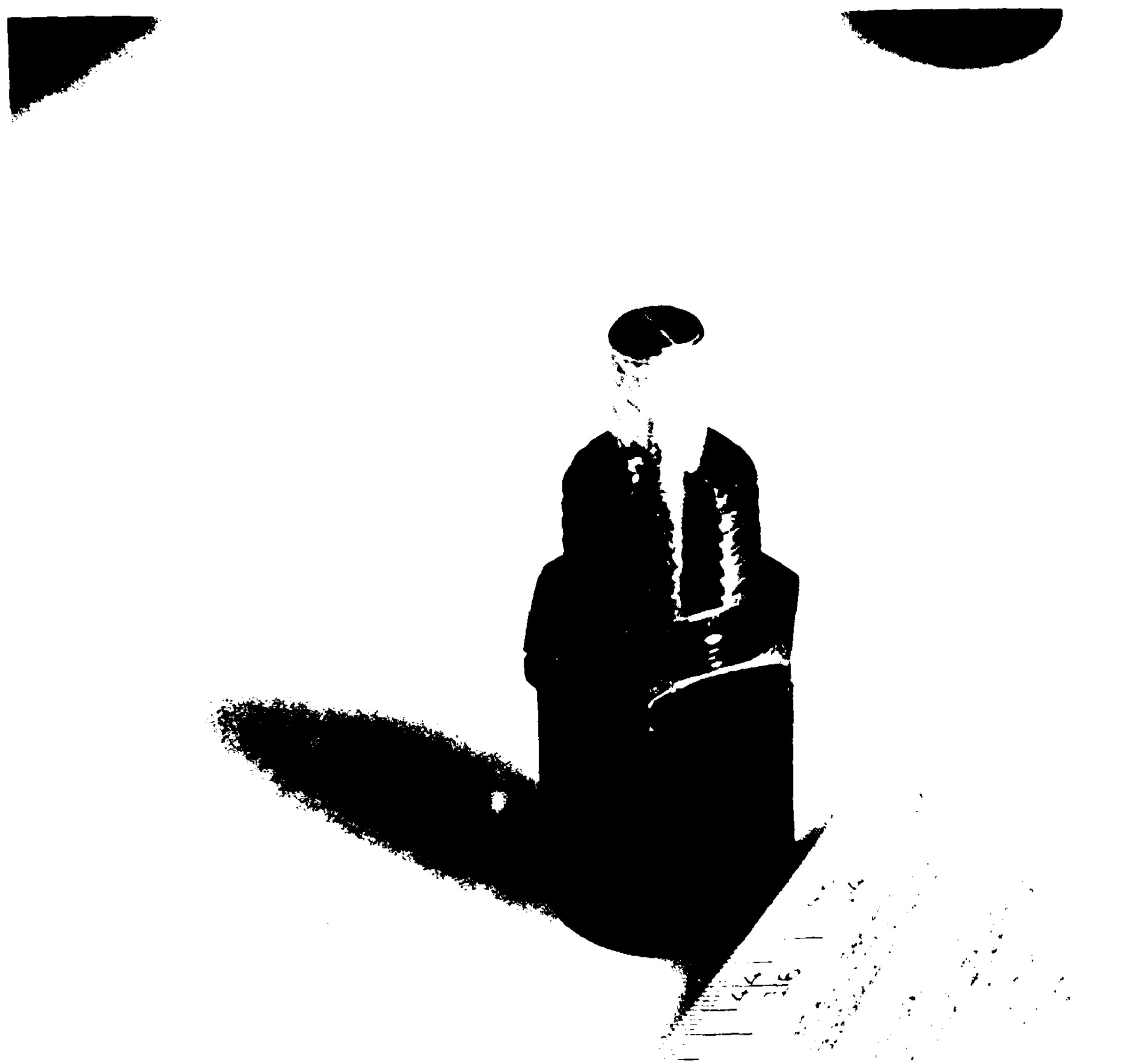


Figure 14d - Manufacturers operating device in locked the activated position.

flooding of the chain lockers. The crew probably closed the manual sea valves at this time.

m. The inclinometers installed on the OCEAN RANGER had a maximum range of 15°. Given the motions the OCEAN RANGER was experiencing, and the probable state of mind of those onboard, it is possible that the range of movement reported (12-15°) in actuality exceeded the 15° limit of the inclinometer by several degrees.

n. In an attempt to better understand the ballast control panel electrical circuitry, as it related to the control of the ballast valves, the Board obtained push button switches, relays and air solenoids of the kind installed on the OCEAN RANGER. These components were electrically connected as shown in Appendix G duplicating the electrical portion of the electric-pneumatic control for one valve. The Board observed that the circuit reacts instantaneously when the normally open "open" push button is depressed, energizing the holding relay. The "hair trigger" action immediately bypasses the push button switch, opens the air solenoid, and admits air to the ballast control valve pneumatic operating cylinder. Testimony established that it takes approximately forty seconds before the ballast valve is fully open. The Board believes that this valve opening sequence could be initiated by inadvertant depression of the push button switch, or momentary bridging of the push button or holding relay electrical terminals or wiring by sea water. Neither the panel nor its components were water resistant or watertight. (For a more detailed analysis of the specific ways electrical faults could occur, see Appendix G).

The Board is mindful that other scenarios of the events causing the initial trim are possible, but the available evidence does not favor them over those presented.

III CASUALTY CONTROL PROCEDURES NECESSARY TO ELIMINATE A SEVERE LIST

General assessment.

This analysis assesses the capabilities of the personnel and machinery to recover from a trim or listing condition as a result of an initial casualty to the ballast control panel. The extent of the combined knowledge of the master, ballast control room operators and electrician was limited by lack of experience, training, operational instructions and a lack of casualty control guidance. Had they understood the capabilities of the ballast system, techniques in using the control panel in the manual mode and the characteristics of the rig, recovery might have been achieved. Measures they might have used to restore the rig to a normal trim are discussed below.

Assessment of knowledge, experience and instructions available.

The evidence reveals that the ballast control room operators understanding of the ballast system's operational capabilities and methods of control was limited to the routine operation of this system. At the 80 foot drilling draft, they kept the rig on an even keel by either pumping ballast water out of a ballast tank at the low side of the rig or taking on ballast water at the high side of the rig. Unless completely deballasting to the transit draft of 30 feet, a ballast pump was lined up to only one tank at a time. The ballast control room operators experience with forward trim down by the bow indicated that pumping from number 2 or 3 ballast tanks was slow with 2 or 3 degrees of trim and several hours were required to pump these tanks out from a 5 degree trim until the rig was on an even keel. A study performed for the Board by the David W. Taylor Naval Ship Research and Development Center, (NSRDC) entitled, "OCEAN RANGER, Ballast Pump Analysis" (Appendix F) explains why pumping from ballast tanks 2 and 3 with one pump with a forward trim was a slow process. The length of ballast piping and the verticle lowering of the tank suctions below the ballast pump created system head losses which caused the pump to cavitate. If the ballast control room operator pumped from both adjacent tanks simultaneously, the ballast piping friction losses due to water velocity would have been reduced and the pump output would have doubled. The ballast control room operators did not understand the theories behind net positive suction head, suction lift, reasons for cavitation and line losses. They knew from experience that forward trim was difficult to eliminate by pumping, therefore, they depended on maintaining ullage in an after ballast tank, No. 14 for example, so that they could take on sea water to adjust trim.

The Master had been on board OCEAN RANGER only 3 weeks and his understanding of the rig's ballast system and control panel and his familiarity with the Booklet of Operating Conditions would have been very limited. His instructors were the ballast control room operators who also had a narrow understanding of the operation of the system. He did not have the benefit of any operating instructions and the Booklet's description of the ballast system was limited to piping diagrams. The Booklet contained guidance for calculating stability in any condition but always with reference to an even keel. Change in moments could be determined as a result of transferring topside liquids to the pontoon hull tanks. There were no written instructions on casualty control procedures for the ballast control panel.

The rig mechanic and electrician carried out maintenance and repair of the ballast system and control room machinery and equipment but they were not normally involved with its operation. It is not known if the rig electrician was familiar with the brass control rods and how they should be used or the control panel power source circuit breaker which was located behind the port control panel access door.

Casualty situation.

Figure 15 depicts the liquid levels in the ballast tanks on 14 February 1982 as indicated in the weekly ballast report work sheets recovered from the OCEAN RANGER. The report indicated that the after ballast tanks used for adjusting trim, PT 14 and ST 14 were respectively 67.9% and 57.0% of capacity. The ullage provided a potential moment to correct trim of 58,000 foot/long tons (F/LT). During the evening, the control panel was doused with sea water entering a broken porthole causing an actual or perceived panel malfunction. At the time of malfunction or when personnel attempted to correct the malfuction, the OCEAN RANGER either took water into the ballast tanks or water shifted to the forward tanks, or both, causing a list by the bow. At some point, the crew had taken the measure of closing the two manually operated sea inlet gate valves. Evidence indicates the rig may have had a 10 degree list for a period of time which the crew believed had stabilized. An approximate moment of 17,000 (F/LT) was required to cause a 10° trim by the bow.

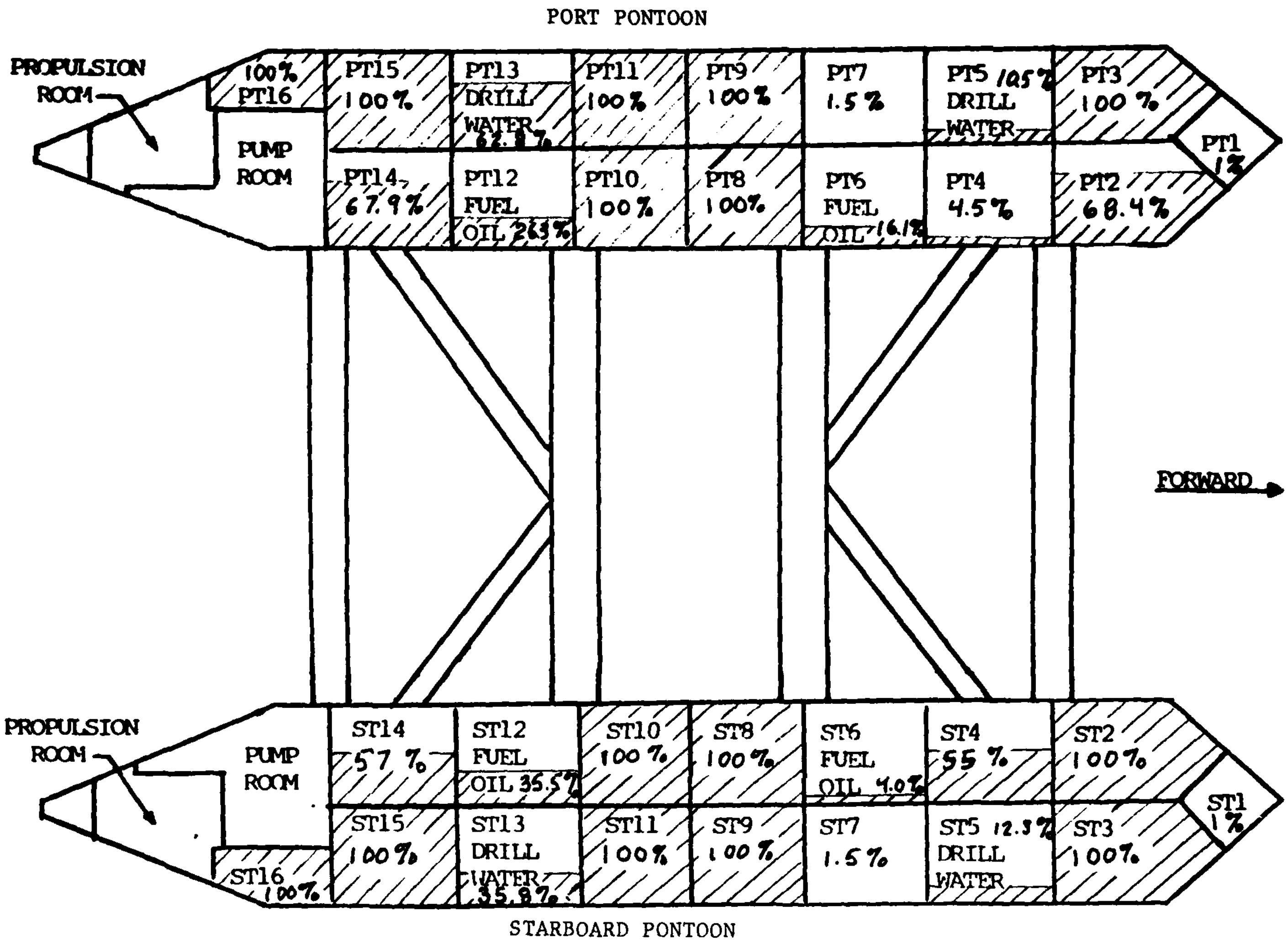


Figure 15: PERCENTAGE OF LIQUIDS IN OCEAN RANGER PONTOON TANKS, MORNING OF 14 FEBRUARY 1982

This moment is equivalent to the transfer of 80 LT of water from ballast tank PT 16 to ballast tank PT 1. More likely, the list was caused by the simultaneous transfer of water from several of the full tanks aft to forward empty tanks that provided the 17,000 F/LT moments. Later the list was reported to be 10 to 12 degrees and the last report list before abandoning the rig the list was reported to be 12 to 15 degrees. It was also apparent that manual control of the solenoid activated air valves in the control panels was attempted as a means of opening the ballast valves. Figure 16, page 112, shows the solenoid valves and the extent that the brass rods were used at the time they were recovered by divers. No specific logic can be attributed to the position of the brass rods except that their use indicated the control panel electric circuits were not useable or perceived to be unuseable and an attempt was being made to pump ballast. However, none of the rods were in a position to activate the ballast pump manifold valve or ballast pump discharge valves. It is also possible that brass rods were being inserted in the solenoid valves in preparation to use the pumps. Seventeen of the rods were screwed in all the way against the solenoid valve plunger which would have opened the air valve allowing activation of a ballast valve unless control air had been purposely cutoff. One rod was screwed partway in. Given the ballast control room operator's, Master's, and electrician's inexperience, they may not have realized how far to screw in the rods without opening the solenoid valve. A practiced sense of feel would have been required to do this properly. The opening of the 17 solenoid valves would have resulted in gravitation of ballast to the bow increasing the list to the severe condition which caused the OCEAN RANGER personnel to abandon the rig. It is not known if they operated any of the butterfly valves manually in the pump room. This procedure would have depended on the P.A. system or walkie talkie for communication.

<u>Procedures to remove list and trim.</u>

The ullage available in ballast tanks PT 14 and ST 14 provided the easiest means of correction of a trim of 10^{o} by the bow. Up to 58,000 F/LT positive triming moments was possible by admission of seawater into these tanks by gravity flow or, by use of the ballast pumps. However only an approximate 17,000 F/LT correcting moment was required to change the trim 10° which would have resulted in only a one foot increase in draft.

Pumping out forward tanks was another alternative. The NSRDC study and analysis of the ballast system explained the performance characteristics of the ballast pumps and the system. It showed that with the OCEAN RANGER listing about a 45 degree axis, the angle beyond which no water could be pumped from ballast tanks 2 and 3 was 13.6 degrees. This angle is equivalent to a 10.5 degree angle of trim by the bow. Therefore, with a 9 degree trim by the bow, some amount of water, approximately 4% of tank capacity, equivalent to 40 tons of water, could be pumped out from ballast tanks 2 and 3. The ballast control room operators and the Master probably did not realize that pumping of tanks forward of the longitudinal center of gravity could be performed as illustrated below:

Angle of trim by bow	B.T. pumped	% pumped out
10°	4	10%
	7	30%
	8 & 9	60% each
12°	7	12%
	8 & 9	30% each
15°	8 & 9	10% each

At 10° one ballast pump could effectively take suction from No. 4 tank and a significant amount of water could be removed from tank 7 before the pump would cavitate. By pumping both tanks at once, line friction losses would be reduced improving the pumping efficiency and pumping rate. The rate was important since time was an element in the casualty. Removal of ballast from these tanks would tend to reduce the triming moments forward so it was likely pumping could continue as water was removed. Even at 12° a significant result could be achieved by pumping tanks 8 and 9 together if they were full to begin with. However, at angles greater than 10° the forward movement of the longitudinal center of buoyancy (LCB) would have to be taken into account before removing water from tanks 8 and 9.

Transferring water by gravity flow through the ballast manifold would allow a substantial movement of water from a full tank to a partially empty tank. By draining water aft, a correcting moment to trim by the bow was possible. With the bow down 10^{o}, a siphon effect would work provided the piping to the tanks and the ballast manifold was full of water. Referring to the ballast configuation shown in figure 1, the following sequence could have been used.

Step	B.T. Beginning	B.T. End
1	PT-3 100% full	PT-3 90% full
	PT-4 45% full	PT-4 50% full
2	PT-4 50% full	PT-4 30% full
	PT-7 1.5% full	PT-7 20% full
3	PT-3 90% full	PT-3 80% full
	PT-4 30% full	PT-4 50% full

The sequence started with ballast tank PT-3 full. It drained aft into PT-4 which was 45% full. The difference in water level equalized with PT-4 gaining 5%. After PT-4 drained into PT-7, its water level dropped lower than PT-3 allowing another sequence to be followed. Ballast in the starboard (could be shifted) tanks in the same manner.

This method enabled a transfer of water beyond the effective suction lift of the ballast pumps. It provided a shift of weight aft which should have reduce the angle of trim. If the angle changed just 2 degrees, the process could be applied again. PT-7 might not work in this case because the tank didn't have enough water to keep its piping to the manifold sealed. Also the pitching of the vessel could break the water seal at the ballast line suction in the after end of the tank as slack water surged back and forth in the tank. If the water in the line was able to drain back into the tank and was replaced by air, the siphon effect would not work. Though the manifold section of the piping system was stated to be maintained well, any air leaks would threaten the accomplishment of this water transfer procedure.

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P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9	P 10
○	⚲	●	○	○	○	○	●	●	●

P 11	P 12	P 13	P 14	P 15	P 16	S 1	S 2	S 3	S 4	S 5
⚲	⚲	⚲	⚲	⚲	⚲	⚲	⚲	⚲	●	○

S 6	S 7	S 8	S 9	S 10	S 11	S 12	S 13	S 14	S 15	S 16
⚲	⚲	⚲	⚲	⚲	⊠	⊠	⊠	⚲	⚲	⚲

P 17	P 18	P 19	P 20	P 21	P 22	P 23	P 24	P 25	P 26
●	●	○	○	○	●	●	●	●	●

P 27	P 28	P 29	P 30	P 31	P 32	S 17	S 18	S 19	S 20	S 21
●	○	●	○	○	●	○	●	●	●	○

S 22	S 23	S 24	S 25	S 26	S 27	S 28	S 29	S 30	S 31	S 32
○	●	○	●	○	●	●	○	○	○	○

Notes: P 13 operating rod screwed in halfway.
P 2, P 11, P 12, P 16, S 3, S 6 operating rods broken off at bushing.

Symbols:
- ○ Rubber dust cover missing.
- ● Rubber dust cover on.
- ⚲ Brass operating rod screwed in.
- ⊠ May have had brass bushing in place for operating rod at one time.

Figure 16: OCEAN RANGER BALLAST CONTROL PANEL SOLENOID VALVE BANKS SHOWING THE POSITION OF BRASS OPERATING RODS AS FOUND BY THE ROYAL COMMISSION DIVING SURVEY OF JULY - AUGUST 1982

Other steps which could have been taken to redistribute loads to reduce forward trim included:

Action	Results
Dump mud pits 1 & 2	Removes weight forward of LCB
Transfer fuel from F.O. overflow tank, settling tank and day tank No. 1 to hull tank ST-12.	Shift weight aft
Transfer drill water from drill water tank to hull tanks PT 13 & ST 13	Shift weight aft

To carry out effective damage control procedures would have required that the ballast control room operators be trained in the manual operation of the ballast control system and in the theory and application of damage control information which should have been available in the Booklet of Operating Conditions. The OCEAN RANGER ballast control operators were trained to plug numbers in a format by rote which allowed them to compare VCG with the allowable KG curve. This mechanical process followed a routine which required only a rudimentary understanding of what was happening to the center of gravity (CG) and center of bouyancy (CB). In a damaged situation, recovery from a list would require an understanding of effects on metacentric height (GM), CG and CB. Also, they needed hydrostatic curves or tables of the vessel which would enable them to determine the moment to change trim or list one degree.

IV PERSONNEL TRAINING AND QUALIFICATION IN STABILITY

Rig Master.

The Master on board the OCEAN RANGER was directly responsible for the stability of the rig at all times. This responsibility included: daily calculations of the transverse and longitudinal verticle centers of gravity, maintaining the verticle center of gravity within the limits allowed by the safety curve contained in the rig's Booklet of Operating Conditions, maintaining the rig on an even keel with no trim, moment calculations for adding or subtracting rig stores and drilling supplies, and draft change calculations for adding or subtracting weights. The experience and qualifications in stability possessed by a Master assigned to the rig varied according to the type of U.S Coast Guard issued license held. While the rig was on location for drilling purposes, the Master was required to hold either a Master, Any Gross Tons Upon Oceans License (colloquially referred to as an Unlimited Master's License), or a Master of Column-Stabilized Drilling Rig License (colloquially referred to as an Industrial Master's License).

Almost all individuals with U. S. Coast Guard issued Unlimited Master's Licenses have had extensive seagoing experience on a variety of ships, and a solid understanding of stability, both from a theoretical and practical standpoint. Their practical experience in stability comes from their years of experience as Merchant Marine Officers in the lesser ranks of Third Mate, Second Mate, and Chief Mate. This is particularly true of Chief Mates, who are by common practice directly involved with the stability of U. S. merchant vessels. In order to gain a License as a Chief Mate, an applicant is required to successfully pass a battery of tests, including a rigorous examination in practical and theoretical stability. While formal training or instruction in stability theory is not a prerequisite for a Chief Mate's License, the scope and depth of the U. S. Coast Guard's test makes it markedly difficult for an individual to pass it without some type of formal instruction or a considerable self-help effort. An individual seeking an Unlimited Master's License generally must have a Chief Mate's License and one year's sailing experience in that rank before being permitted to take the examination for Unlimited Master, which would again involve testing in stability. The theoretical knowledge and practical experiences in stability possessed by an individual with an Unlimited Master's License would generally have enabled him to assume his stability responsibliiites on the OCEAN RANGER with only minimal additional theoretical stability knowledge notwithstanding the unique size and shape of a drilling rig such as the OCEAN RANGER in comparison with that of conventional merchant ships. Stability experience and knowledge is readily transferrable. The only aspect of stability on the OCEAN RANGER that may have been unfamiliar to an individual with an Unlimited Master's License and no prior experience on drilling rigs, would be the importance of longitudinal and diagonal stability. These considerations are normally of little or no importance on a conventional vessel. However, an Unlimited Master should have little or no difficulty in acquiring the necessary additional theoretical knowledge to deal with these considerations.

In the case of individuals with U. S. Coast Guard issued Industrial Master's Licenses, the great majority have had extensive experience on a variety of mobile offshore drilling units (MODU's) in a number of rolls including: floorman, derrickman, driller, toolpusher, and rig superintendant, among others. However, few of these individuals have had any conventional merchant marine experience. As a result, few of them have had any experience in stability either from a theoretical or practical standpoint. Also, there are no experience or background prerequisites established by the U.S. Coast Guard for this License which would require an individual to have stability experience. The U. S. Coast Guard's examination for the Industrial Master's License includes a section on stability, but it is considerably less rigorous than the test required for either an Unlimited Chief Mate's or Unlimited Master's License. Regardless, it is just as difficult for an individual to pass the test for Industrial Master without some type of formal instruction or a considerable self-help effort as it is to pass the tests for the Unlimited Licenses. However, there is no prerequisite requirement that an applicant for this License have formal training of any kind in stability. An individual who successfully passes the U. S. Coast Guard examination for an Industrial Master's License should possess sufficient theoretical knowledge to successfully discharge his stability responsibilities on a rig such as the OCEAN RANGER. However, in general the experience levels in stability possessed by individuals with the Industrial Master's License is insufficient to meet these responsibilites. Theoretical knowledge of stability must be complemented by practical experience before an individual can gain confidence in the practice of stability and the necessary insight into it's meaning to effectively meet his responsiblities.

The Master on board the OCEAN RANGER at the time of the casualty of 15 February was Captain Clarence Hauss, who held a License as an Unlimited Master. Absent any evidence to the contrary, and based largely on the traditional reliance on the competancy of an individual to which such a License attests, Captain Hauss should have been fully capable of discharging his responsibilities for stability on the OCEAN RANGER, provided, of course, he had acquired the minimal additional theoretical stability knowledge in diagonal and longitudinal stability on such a rig.

Control Room Operators.

The ballast control room operators on the OCEAN RANGER were directly responsible to the Master for the stability of the rig. This responsibility involved: taking tank soundings; counting drill pipe, sacked mud and cement, and other drilling supplies; making minor trim adjustments to keep the OCEAN RANGER in a no-trim status; loading fuel, drill water, drilling mud, and fresh water from supply boats; making daily calculations of the transverse and longitudinal vertical centers of gravity for the Master; and changing the amount and location of ballast water to maintain the rigs draft, trim, and stability, among others. From the standpoint of actual practice, they functioned as "stability journeymen" working for the OCEAN RANGER's Master.

Training for control room operators on the OCEAN Ranger was almost entirely by the on-the-job method and varied in length depending on the individual concerned. The training program was almost totally unstructured and relied extensively on the trainees' self-help efforts. ODECO had no requirements that a control room operator have experience of any kind in stability prior to becoming a control room operator nor did they require him to read any material including the rig's Booklet of Operating Conditions (Operating Manual) to prepare himself for his duties. ODECO operated a stability training school in

New Orleans, but attendance was not mandatory. Qualification to be a control room operator was largely determined by a consensus opinion of the current ballast control room operators and rig supervisors; there were no formal qualification requirements. The U. S. Coast Guard does not License or Document individuals as control room operators and did not require that such individuals be on board the OCEAN RANGER under the terms of the manning requirements they set forth on the rig's Certificate of Inspection. The Coast Guard presently does not require such individuals on board any rig.

Applicants for the position of control room operator on the OCEAN RANGER generally came from within the rig's industrial complement. Individuals who showed an interest in the position were required to train for it during their off-duty time. If a vacancy occurred, a replacement was selected from amongst the applicants largely based on the initiative an individual showed and the opinions of the control room operators and the Master of his abilities. An applicant would then be assigned as a trainee.

Proficiency in the practice of stability and insight into it's meaning amongst the control room operators on the OCEAN RANGER varied from individual to individual, and depended largely on the individual's level of curiosity, and ability to read and understand the rig's Booklet of Operating Conditions (Operating Manual). No formalized method existed for evaluating their capabilities or their understanding of their jobs beyond the "good, bad, or indifferent" judgments of their performance as voiced by others. Absent more formalized evaluation criteria, the Board must content itself with these extremely subjective evaluations in gauging the capabilities of the control room operators who were on board the OCEAN RANGER at the time of the casualty of 15 February. The two control room operators on board the OCEAN RANGER at the time of the casualty were Mr. Don Rathbun and Mr. Nick Dyke. Mr. Rathbun had been a control room operator on the OCEAN RANGER since March 23, 1980 and his performance and capabilities were considered by his peers and supervisors to be very good. He had attended an ODECO stability school. Mr. Dyke had been a control room operator on the OCEAN RANGER since December 31, 1981 and he was considered by his peers and supervisors to be relatively inexperienced. He did not have any formal training in stability.

Master/Control Room Operators Working Relationships.

The lack of a more formalized stability training and qualification program for the control room operators on the OCEAN RANGER was not in and of itself a questionable practice, considering their "journeymen" status in relation to the rig's Master. However, this relationship made it absolutely essential that the Master's knowledge of stability and his practical experience were sufficient to meet the stability needs of the OCEAN RANGER. As noted previously in this section, the experience and knowledge of an individual with an Unlimited Master's License should have been sufficient to meet these responsibilities, while that of an individual with an Industrial Master's License would not have been in most cases. Since the OCEAN RANGER was allowed by it's Certificate of Inspection to have an Industrial Master on board in lieu of an Unlimited Master, the combination of the Industrial Master with the "journeymen" status of the control room operators could have created a situation whereby the stability needs of the OCEAN RANGER were not properly met.

Assuming he had acquired the necessary additional theoretical knowledge of longitudial and diagonal stability, the presence of Captain Hauss on board the OCEAN RANGER should have insured that the rig's stability needs were adequately met, regardless of the noted shortcomings in the training and qualifications of the control room operators. His experience and qualification, as attested to by his Unlimited License, should have enabled him to properly discharge his stability responsibilities. However, two questions about Captain Hauss' ability to meet these responsibilities arose during the Board's hearings: 1.) his apparent insufficient familiarization with the rig and its operations (based on his assignment to the rig less than three weeks prior to the casualty of 15 February 1982, and his inadvertant listing of the rig on 6 February 1982) and 2.) the constraint that he may have been working under in discharging his responsibilities as a result of the toolpusher's intervention after the 6 February listing incident, when he was told not to touch the ballast control console unless he knew what he was doing or he was in the company of an experienced control room operator.

With respect to Captain Hauss' apparent insufficient familiarization with the rig prior to his assuming responsibility for his duties, Captain Hauss was in the same predicament a lot of other

Merchant Mariners find themselves in when transferred to a new vessel. There is little or no period of familiarization given to a Merchant Officer prior to his assignment to duty. There are no provisions in current law or regulation requiring an individual tc undergo a minimal familiarization period prior to assuming responsibility. These statements are not offered in defense of this practice, but rather to show its almost universal nature; it was by no means unique to ODECO or the OCEAN RANGER. However, on a conventional merchant vessel there is a considerable depth of experienced personnel upon which a newly assigned Master can confidently rely upon to compensate this lack of familiarity with the vessel. This "depth of experience" is frequently not present on a semi-submersible offshore drilling rig due to the very small marine crew carried. The principle inherent danger in such a practice is readily apparent; an individual who is otherwise fully qualified to serve as the Master on board a rig such as the OCEAN RANGER, needs a period of familiarization in order to learn the rig's unique handling and response characteristics. Until such familiarization is completed, an individual such as Captain Hauss would not be working at his full potential. This lack of familiarization most probably was the cause of Captain Hauss' inadvertant listing of the rig on 6 February 1982. No evidence exists to indicate that it was caused by any other possible shortcoming on the part of Captain Hauss.

With respect to the constraint imposed on Captain Hauss by the Toolpusher after the 6 February listing incident, no further evidence exists to show what impact it had on Captain Hauss personally or on his subsequent ability to meet his assigned responsibilities. Viewed in it's full context and in the atmosphere surrounding the listing incident, the constraint appears to be a justifiable precaution and not an ill conceived attempt to intervene in Captain Hauss' responsibilities. No evidence exists to suggest the constraint interferred with Captain Hauss' relationship with the ballast control room operators.

V SEAKEEPING STUDY

Evaluation of study.

The Board wished to determine if there were sequences of events other than those set forth in the Intact Stability Study (Appendix B) which could have led to the capsizing of the OCEAN RANGER. To this end, two Seakeeping Studies, referred to in the previous section, were commissioned (Appendicies C & D).

Neither of these studies duplicates the real life situation the OCEAN RANGER was experiencing the night of the casualty. The reader is cautioned to review thoroughly the assumptions necessary to carry out each study, for only then can the results be interpreted properly. Nevertheless, the Board feels both studies are a valid analysis of the potential for flooding of the chain lockers in one or both of the forward columns in the OCEAN RANGER by boarding seas, subject to the limitations of each study noted therein. The Board does not subscribe to any of the initial flooding angles or times to flood the chain lockers, but would note the following.

a. The studies establish that it is possible and probable that boarding seas flooded the chain lockers in one or both of the forward columns. This means that the flooding of the chain lockers and immersion of the upper hull need not have been the direct consequence of the transfer forward of on-board ballast water or the admission of additional ballast water.

b. In order for the seas to commence flooding the chain lockers, an initial list of some magnitude was necessary with a possible increase in draft. A corollary to this observation is that a modest reduction in draft, except in the case of extreme list, would have precluded flooding of the chain lockers.

c. There is only a small change in the angle of list while the chain locker(s) is filling to the point of upper hull immersion.

d. Depending upon the angle of the initial list and draft at that time, the flooding of the chain locker(s) could have occurred over a relatively short or relatively long time. The latter, coupled with the small angular change involved, may account for the impression of some personnel onboard the OCEAN RANGER that the listing had been stabilized.

e. While it cannot determine the actual initial angle or draft at that time, the Board believes the necessary angle for chain locker(s) flooding to be somewhere between the two parameters established by the studies.

The Board would remind the reader that the analyses in these studies terminates when the upper hull is immersed. The Board cannot ascertain what the watertight integrity of the upper hull was, nor its rate of flooding. Suffice it to say the Board believes these studies establish that boarding seas could flood the chain lockers in one or both of the forward columns, and favors a scenario involving an initial list and draft of a magnitude to commence such flooding as having occurred during the casualty.

VI NUMBER OF CREW WHO ABANDONED RIG

No. 2 lifeboat, which was never recovered intact, contained approximately 36 men at the time this boat approached the M/V SEAFORTH HIGHLANDER. This estimate is based on the 9 men seen by the crew of the SEAFORTH HIGHLANDER after the boat capsized; the 7 bodies seen in the vicinity of this boat by the crew of the M/V NORDERTOR; and the 20 bodies seen strapped in the boat by the Captain of the M/V NORDERTOR while his vessel was alongside the lifeboat. Other eye witnesses testimony establishes that approximately 20 or more lifejacket lights were sighted in the water at the time No. 2 lifeboat was underway. Therefore witness testimony establishes that at least 56 men abandoned the OCEAN RANGER prior to the sinking. There is no evidence that any of the crewmembers remained onboard the OCEAN RANGER.

VII TIME OF SINKING

The time of the sinking of the OCEAN RANGER is bracketed by the visual and radar sightings of the standby vessels NORDERTOR, SEAFORTH HIGHLANDER, and BOLTENTOR; the NORDERTOR being the most significant.

Relevant facts from NORDERTOR:

(1) Start 2 mi North of ZAPATA UGLAND at 0130.

(2) OCEAN RANGER 19.2 mi south of ZAPATA UGLAND.

(3) Arrived 2 mi North of OCEAN RANGER at 0340.

(4) Distance from OCEAN RANGER when sinking occurs 6-7 miles.

Therefore:

(1) Avg. speed of NORDERTOR; 2 mi & 19.2 mi - 2 mi= 19.2 mi divided by 2.16 hrs (0130-0340) = 8.8 mph

(2) Estimated time elapsed from start to sinking

<u>(a) 7 miles away</u>

14.2 mi divided by 8.8 = $1^h 36.6^m$

0130 + 1h 36.6m = $3^h 6.6^m$

<u>(b) 6 miles away</u>

15.2mi divided by 8.8= $1^h 43.2^m$

0130 + 1h 43.2m = $3^h 13.2^m$

(3) Time of Sinking = 0307 - 0313.

VIII LIFESAVING EQUIPMENT

Debarkation

Either environmental conditions, or a loss of well control could preclude personnel transfer by either the standby vessel or by helicopter. Additionally, an excessive list would preclude air evacuation. In those situations the crewmembers are left with only one option, debarkation over the side by davit launched lifeboats. This requires lowering the lifeboats from a higher platform than that found on most conventional vessels. Also, because of the open trussed construction of most mobile offshore drilling units there is no lee. Exacerbating this situation, are the variances found on the releasing gear.

Life rafts that are not of the davit launched type have to be dropped over the side and boarded at the water surface which would require the rig's personnel to climb down a substantial, exposed vertical distance to reach them. In many cases this would also require that the rig's personnel enter the water to reach the deployed life rafts.

Debarkation from a rig is often hazardous even under the best of conditions. Illustrative of the dangers associated with lowering lifesaving equipment over the side from a rig is a frequently stated opinion by personnel in the offshore drilling industry that it is better to deploy the lifesaving equipment on deck and await the sinking of a rig rather than attempting a conventional deployment.

Debarkation from the OCEAN RANGER from approximately a 70-100 ft (depending on the draft and trim) height into 50 ft seas was an extremely dangerous operation. There is evidence that at least one lifeboat did manage to get away from the OCEAN RANGER; however, it was holed and flooded, and subsequently capsized with the loss of all onboard. At the time this lifeboat was first sighted, at least 20 men were also sighted floating in the water. These crewmembers either chose to enter the water directly or were thrown into the sea as a consequence of unsuccessful lifesaving equipment launching.

The debarkation problems experienced by the OCEAN RANGER personnel were similiar to those which occurred in the ALEXANDER L. KIELLAND disaster. One hundred and twenty three men died in the latter accident which occurred in the North Sea during storm conditions.

There were many specific debarkation problems cited by the official inquiry into that disaster. Lifeboat Number 1 would not release and was damaged when the waves threw the boat against the platform. Lifeboat Number 2 could not be used because of the list of the platform. Lifeboat Number 3 would not completely release and was also severely damaged when it was thrown against the platform by waves. Lifeboat Number 4 was lowered and crushed against the platform. In the case of Lifeboat Number 5, numerous crewmembers declined to enter the boat because they feared it would be crushed against the platform. This boat capsized when the platform sank and was subsequently righted by a crewmember who swam to the boat. The Royal Norwegian Commission in its reports dated March 1981 stated:

> "The Commission would like to emphasize that it's recommendation as concerns the lifeboat coverage is based on the lifeboat types and launching systems existing at present. If one should arrive at a system with better launching possibilities in the future, the question of the degree of coverage should be reassessed on the basis of the possibilities then available. In this connection, the Commission would like to emphasize the importance of facilitating the conditions for further development of lifeboat type and particularly the launching arrangements."

Recovery of personnel from the sea.

Many men were sighted floating in the sea after the OCEAN RANGER was abandoned. While some may have entered the water as a consequence of a lifeboat capsizing, others may have entered as a consequence of either an unsuccessful lifeboat launching or they may have simply chose to jump into the water rather than utilize the davit launched lifeboats. The rescue efforts made by the crews of three standby boats failed to save any of these men. The recovery techniques which failed included the use of ring lifebuoys, the deployment of rafts and the use of grappling hooks. At times the victims were endangered by the propellers of the standby boats.

These occurrences and the fact that none of the crewmembers floating near the standby vessels were saved is a clear indication that these standby vessels were either not configured or equipped to recover men from the sea in the conditions which prevailed. The situation might have been different if the victims had been wearing exposure suits [1] which would have retarded the effects of hypothermia to the extent they could have assisted themselves by responding to the efforts of the crews of the standby vessels to recover them. It is likely that recovery efforts could have been enhanced by the use of nets or rescue baskets designed to catch and lift the victims from the sea.

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1 On 26 April 1982 the Board made an advance recommendation to the Commandant that exposure suits be mandatory for all inspected U.S. vessels operating beyond the 35 North and South Latitudes.

CONCLUSIONS

1. The OCEAN RANGER casualty did not occur as a consequence of a structural failure.

The OCEAN RANGER did not suffer any structural damage or derrangement which affected it's ability to weather the storm of 14 and 15 February 1982.

This storm, while the most intense the rig ever experienced, did not exceed the rig's design environmental parameters.

Structurally the OCEAN RANGER was fully capable of surviving this storm. Mute testimony to this conclusion is the fact that two smaller semi-submersible rigs, the SEDCO 706 and the ZAPATA UGLAND, both located only several miles from the OCEAN RANGER, survived the same storm with only superficial damage.

2. The disconnect of the OCEAN RANGER's marine riser was not a factor in this casualty.

The disconnect, while complicated by the fouled compensator hoses and the resultant necessity to shear the drill string rather than the conventional method of hanging-off, was a successful evolution and not related to the casualty, either directly or indirectly. The OCEAN RANGER disconnected it's marine riser from the subsea stack just prior to 1845 on 14 February.

3. The OCEAN RANGER's ballast control room portlight(s) failed[1] prior to 1945 on 14 February initiating a chain of events leading to the loss of the rig.

Based on all available evidence, the Board finds that the initial event that led to the loss of the OCEAN RANGER was the failure of the portlight(s) in the ballast control room. The exact cause of failure is unknown, but may subsequently be determined by future laboratory testing contemplated by the Canadian Royal Commission. Regardless of the cause, the failure of the portlight(s) initiated an unbroken chain

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1 For casualty investigation purposes this is the proximate cause.

of events which concluded with the capsizing and sinking of the rig. This chain of events was not an inevitable progression and could have been broken by competent human intervention. The exact time of the portlight failure(s) is unknown but most probably occurred prior to 1945 on 14 February.

4. The OCEAN RANGER's ballast control console and ballast control room installed communications equipment malfunctioned.

Subsequent to the failure of the ballast control room portlight(s) an indeterminate quantity of sea water entered the ballast control room through the opening(s) created by the broken portlight(s).

This ingress of sea water was sufficient in quantity to precipitate a major electrical malfunction of the ballast control console, or to create the perception of such a major malfunction in the minds of those rig crewmen who responded to the incident.

This same ingress of sea water also disabled the rig's installed internal communications with the ballast control room which necessitated the use of walkie-talkie's in order for those crewmen in the ballast control room to communicate directly with the other personnel on board the rig.

While there is no evidence to support it, the Board concludes that the deadlights covering the portlights most probably were closed shortly after this ingress of sea water.

5. Several ballast system valves opened allowing water to enter the OCEAN RANGER's forward ballast tanks.

As a direct or indirect result of this malfunction or perceived malfunction of the ballast control console, several valves in the rig's ballast system opened, or were opened, which either allowed on-board ballast water to gravitate to the forward ballast tanks, or allowed additional sea water to enter into one or more of the rig's forward ballast tanks. No definitive scenario for this introduction of water into the rig's forward ballast tanks can be made. There is insufficient evidence to favor support for any one of the several possible scenarios for this event developed by the Board in the Analysis Section of this report. As previously noted in the Analysis Section, these possible scenarios range between two extremes. The first possibility was that an entirely electrical malfunction occurred which directly caused several ballast system valves to open. The second possibility was that those individuals who were attempting to correct an actual or perceived malfunction of the console, or who were attempting to operate the system by manual control, made an error which had the same end result of opening several ballast system valves and allowing water to enter the forward tanks. A number of other possible and entirely plausible scenarios can be made by combining various aspects of these two extremes. Regardless of the exact scenario of events, a substantial quantity of water entered the rig's forward ballast tanks. The times for these events are unknown.

Possibly prolonging the effect of any actual electrical malfunction of the ballast control console that may have occurred was the suspected inability of the crew to locate the correct circuit-breaker switch to secure electrical power to the console. This may have prevented timely securing of electrical power to the console and the resultant automatic closing of the ballast valves.

6. The OCEAN RANGER assumed a substantial forward list and possibly an increase in draft.

The degree of list and the magnitude of any possible draft increase cannot be determined but was sufficient to permit initiation of flooding of the rig's forward chain locker(s) through the chain pipe and wire trunk openings atop the corner columns.

7. Boarding seas commenced flooding OCEAN RANGER's forward chain locker(s).

The boarding seas flooded the rig's chain locker(s) through their unprotected openings atop one or both of the forward corner columns. The Board concludes that substantial down flooding was initially confined to the port forward column, but that subsequently both the port and starboard forward columns were involved.

Testimony by former rig crewmen disclosed that they had never secured these openings against the action of the seas, nor did they have any appreciation for the flooding potential which these unsecured openings posed to the rig. There was no history of flooding of these chain lockers. Testimony by former rig crewmen was confused as to whether or not there were actually covers provided for the purpose of securing these openings.

There were no installed alarm systems which would have signalled the rig's crew that flooding of the chain lockers was occurring. The lack of an installed alarm system allowed the flooding of the chain locker(s) to continue with the crew probably totally unaware that it was occurring.

The flooding of the chain locker(s) continued to the point where it noticably exacerbated the forward list of the rig.

8. The forward list of the OCEAN RANGER precluded the crew from pumping out the forward ballast tanks.

The testimony of former OCEAN RANGER ballast control room operators and masters disclosed that their normal practice was to pump from one tank at a time in order to change trim or reduce draft.

The magnitude of the forward list necessary to induce down flooding of the forward chain lockers created vertical distances between the forward tanks and the ballast pumps located astern which would have precluded the pumping of these tanks using the pumping method favored by the ballast control room operators. This preclusion developed because the vertical distances involved exceeded the net suction head limitations of the ballast system's pumps.

The ballast system of the OCEAN RANGER had considerable power and flexibility and could have been utilized to correct this situation if the crew had been sufficiently familiar with the system. Sequential pumping of those forward tanks closer to the rig's center of rotation, for which the net suction head had not been exceeded, would have reduced the list (and draft) and eventually permitted pumping from the forward-most tanks. Testimony from former OCEAN RANGER ballast control room operators and masters established that the average control room operator or master would not have had the necessary sophistication or insight into the system's capabilities in order to take full advantage of it's power and flexibility.

9. The lack of detailed instructions regarding the use of, and training in the operation of, the OCEAN RANGER's ballast system significantly contributed to this casualty.

While the level of understanding of the OCEAN RANGER's ballast control room operators and masters of the rig's ballast system was adequate for routine day-to-day operations, it was inadequate to deal with extraordinary situations or emergencies. Had a training program and detailed instructions on the use of the ballast system been available it is quite likely that the chain of events leading to the loss of the OCEAN RANGER could have been broken at any time from the malfunction of the ballast control console to the point where substantial flooding of the chain locker(s) had occurred.

10. At some point during the development of the previous events the electrical portion of the ballast control console was considered to be inoperable by the rig's crew.

As a consequence, the crew attempted to manually operate the ballast system by using the brass control rods specifically designed to manually operate the system's air control solenoids, which in turn controlled the opening and closing of the ballast system's valves. However, no instruction were available to the rig's crew on how to accomplish this operation, nor is there any evidence that they had ever practiced such a procedure before. Also the design of the control rods had a considerable potential for inducing inadvertant human error.

Specifically, an individual inserting these rods into the solenoids had no direct means of knowing whether he was only screwing the rods into a threshold position to make them available for use, or alternatively, was exceeding this threshold position and actually moving the solenoid plunger, thus inadvertantly opening the valves. The only positive means whereby an individual could know exactly what position the control rods were in was by reference to the ballast control console's valve position indicating lights. Since these were inoperable or secured, a crewman attempting to manually control the ballast system would have been operating completely in the blind as to the results of his actions in using these control rods. Based on the placement of these rods in the solenoids, as they were found in July 1982, the Board can draw no reasonable conclusion as to the operation being attempted by the rig's crew in their use of them.

11. At some point during the progression of the previous events, the manually operated sea valves in both pontoons were closed.

The Board is unable to determine the exact reason for closing the sea valves, but concludes that there are three possibilities:

a The valves were closed to prevent a continuing ingress of water into the rig's pontoons.

b The valves were closed because of the erroneous presumption that the rig's increasing list was caused by a continuing ingress of water into the pontoons when, in reality, it was caused by the flooding of the forward chain lockers.

c The valves were closed in accordance with the provision in the rig's Emergency Procedures Manual which specified that the valves were to be closed by the crew prior to their evacuation of the rig.

12. Commencing at 0052 on 15 February a series of Mayday broadcasts were made by the OCEAN RANGER requesting assistance and evacuation.

The events which led up to this decision to request evacuation may have occurred over a period of three to five hours and the on board management personnel, for whatever reasons, may have failed to appreciate the full extent of the dangers facing them during the development of the list, therefore perceiving no need to report on their situation in a more timely manner. Alternatively, they may have occurred rapidly, within an hour or less, giving the rig's onboard management personnel very little time to determine exactly what was causing the increasing and apparently uncontrollable list. Regardless, the reason(s) for the almost total lack of communication from the rig concerning the listing problem is unknown.

The OCEAN RANGER's Emergency Procedures Manual sets forth specific procedures to be followed for an evacuation of the rig, but does not discuss, or warn of, the lead times necessary to effect such an evacuation. Specifically, a decision to request helicopter evacuation under storm conditions similar to those of 15 February required approximately a two hour lead time between the request for helicopter assistance and the probable arrival time of the helicopters on scene. Similarly, a request for the SEAFORTH HIGHLANDER to lend assistance to evacuate the rig that night required approximately a 40 minute lead time. The OCEAN RANGER's personnel may not have had a full appreciation for these lead times. Had more timely requests for evacuation been made, they may have resulted in the saving of some or all of the OCEAN RANGER's crew.

13. The crew of the OCEAN RANGER commenced abandoning the rig at approximately 0130, 15 February.

The exact reason(s) for this decision to abandon the rig at this time is unknown. After the rig was abandoned it remained afloat for approximately an hour and a half.

14. The OCEAN RANGER capsized by the bow and sank at approximately 0310, 15 February.

The immediate cause of the loss of the OCEAN RANGER was the progressive downflooding of the chain lockers in the forward columns and the subsequent flooding of the rig's upper hull which resulted in the capsizing of the rig by the bow. This capsizing motion caused the rig's pontoons to make contact with the sea floor as the rig turned over, damaging the forward ends of both pontoons.

15. All 84 crewmen on board the OCEAN RANGER died as a result of this casualty.

Of the 22 crewmen from the rig whose bodies were recovered, all were found to have died as a result of hypothermia. It is highly probable that the missing 62 crewmembers also died from hypothermia. No exposure suits to protect against the effects of hypothermia were available to any of the rig's crewmen. Such equipment would have substantially increased the likelihood of personnel surviving the extreme cold conditions present at the time and would have contributed to their being successfully rescued.

Correspondingly, the lack of such equipment reduced the potential survival time of personnel in the water to a matter of seconds, essentially precluding any reasonable possibility of rescue and directly resulting in the heavy loss of life in this casualty.

16. There is no evidence that any of the crew remained on board the OCEAN RANGER.

17. The OCEAN RANGER's primary lifesaving equipment, including the launching arrangements, proved to be ineffective.

The method of lowering the lifeboats from the upper deck of a drilling rig such as the OCEAN RANGER to the water's surface under adverse environmental conditions similar to those being experienced by the OCEAN RANGER is extremely hazardous. Lowering lifeboats under such conditions from these heights can subject them to violent swinging and severe impact damage if contact is made with the rig's structure. A reliable means for controlling this swinging, or a more effective launching arrangement, would contribute significantly to the ability of the personnel to safely launch lifeboats. The exact cause of the damage to OCEAN RANGER's lifeboat #2, as described by the crewmembers on board the M/V SEAFORTH HIGHLANDER, is unknown, but most probably occurred during the lowering and launching evolution. Possibly contributing to the damage sustained by #1 and #2 lifeboats was the design of their releasing mechanism which precluded the boats from detaching from their falls, except in a no-load condition. This feature may have aggravated any problems associated with violent swinging because of the inability to release the boat while under load. If such violent swinging did develop during the lowering and launching evolution, there would have been no way to prevent impact with the rig by releasing the boat unless the boat was fully waterborne at the time. Similarly, this feature may have delayed release from the falls after the boat was waterborne and precluded possible manuevering to avoid contact with the rig's structure.

18. The OCEAN RANGER's life rafts failed under the environmental conditions on the 15th of February.

None of the OCEAN RANGER's life rafts were recovered intact. All of the life rafts exhibited significant damage which can be attributed to one or more of the following causes:

a.) The life rafts were structurally deteriorated and weakened due to their age.

b.) The periodic servicing performed on the life rafts was improper and/or inadequate.

c.) The excessive stresses imposed on the life rafts by the storm of 15 February.

As has been noted in previous marine casualties, the OCEAN RANGER's liferafts were highly susceptible to being upset and driven by the wind, greatly diminishing their effectiveness as lifesaving devices.

<u>19. There is no evidence that the performance of the life jackets contributed to the loss of life in this casualty.</u>

Of the twenty two bodies recovered, the cause of death for all of them was attributed to hypothermia and not drowning. However, according to eye witness testimony, many of the bodies were sighted floating facedown and others were recovered and found hanging by the body straps beneath the floating life preservers. Under the latter circumstances, the life jackets apparently came off over the heads of the wearers at a time when the wearers were either dead or unable to help themselves due to the effects of hypothermia.

No definitive conclusion can be made regarding the reason for those life jackets coming off of the wearers because the life jackets may not have been properly secured or the wearers may have jumped into the water from substantial heights. Similarly, no definitive conclusion can be made as to why some of the life jacket wearers were found floating face down because there is no evidence to indicate whether or not the life jackets were properly secured. However, these incidents may be indicative of a need to review the existing design and testing criteria for USCG approved life jackets.

20. The quick response and professionalism of the rescue forces under the extremely adverse environmental conditions of 15 February were commendable.

The ability of the M/V SEAFORTH HIGHLANDER to arrive on scene so quickly demonstrates the wisdom of assigning standby vessels to mobile offshore oil rigs. If the OCEAN RANGER's personnel had been equipped with exposure suits, the ready availability of the M/V SEAFORTH HIGHLANDER probably could have permitted a successful lifesaving effort. Not to detract from the valiant efforts of all of the rescue forces, the attempt of the crewmembers of the M/V SEAFORTH HIGHLANDER to rescue the OCEAN RANGER crewmen from lifeboat #2 was admirable under the circumstances and their efforts are considered to have been all that was humanly possible.

21. Standby vessel's personnel recovery equipment proved to be ineffective.

The inability of the standby vessels to recover any of the crewmembers from the sea shortly after the arrival of those vessels on scene, even though the victims were in close proximity, was a clear indication of the inadequacy of the devices employed. It is possible that some crewmembers, even though suffering the effects of hypothermia, might have been saved had these vessels been equipped with rescue devices that did not require the active participation of the victims.

22. The capsizing of the #2 lifeboat was caused by the personnel shift towards the boat's port side.

Lifeboats are designed to have a positive righting ability only if all personnel on board are evenly distributed and strapped into their seats, and there is no appreciable quantity of water on board. The #2 lifeboat was extensively damaged and holed in the bow area which allowed flooding to occur. The movement of a number of the onboard personnel towards the boat's port side in prepartion for transfer to the M/V SEAFORTH HIGHLANDER started a slow roll to port which resulted in the capsizing of the lifeboat.

23. The lack of written casualty control procedures may have seriously contributed to this casualty.

Had detailed casualty control procedures been available to the rig's crew, the problems associated with the malfunction(s) of the ballast control panel could have been readily addressed. Such procedures would also have minimized any concurrent problems which may have arisen, especially with respect to the attempt to manually operate the ballast system. An actual emergency caused by damaged or malfunctioning essential equipment is not a time for experimenting to determine effective alternate methods for accomplishing the purpose served by the affected essential equipment. Such alternate methods should be determined ahead of time and specified in written casualty control procedures.

24. The OCEAN RANGER's Booklet of Operating Conditions was not a readily usable document for onboard personnel.

The Booklet of Operating Conditions (Operations Manual) provided to the crew of the OCEAN RANGER was difficult to read by those individuals charged with using it, and was not presented in a format suitable for ready reference. While the rig's Operations Manual satisfied all applicable regulatory requirements, it was clear from witness testimony by former crewmembers that it was produced primarily to fulfill the regulatory requirement rather than to be a usable document for field personnel. The true value of documents such as the Operations Manual is that they assist the user in the performance of his job. If they are not produced with the user's needs and capabilities in mind their value is considerably diminished and whatever regulatory intent that exists mandating them is frustrated. Simply stated, ODECO's naval architects and marine engineers should have communicated with the masters and ballast control room operators on the OCEAN RANGER in the development of this Manual so that the latter individual's needs were met. Similarly, the Manual should have been written in a language and presented in a format which was readily understood by the masters and ballast control room operators. Also, the ballast control room operators and masters should have received specific formal instruction and training in the use of the Operations Manual.

25. Possible violation of 46 USC 222 for marine crew shortages.

The OCEAN RANGER's marine crew, as specified in the manning requirement of the U.S. Coast Guard Certificate of Inspection, was short 2 Able Seamen and 1 Lifeboatman at the time of the casualty of 15 February 1982. In aggravation of this, the Board notes that there is no evidence that the hiring practices to man the OCEAN RANGER were designed to insure that these manning requirements were properly met. There is evidence of a violation of 46 USC 222 by ODECO International Inc. because of these crew shortages. This matter has been forwarded to the Commander, First Coast Guard District for further investigation under the civil penalty proceedings.

26. Possible violation of 46 USC 367 for expired Certificate of Inspection.

The failure of ODECO International Inc. to maintain a current U.S. Coast Guard Certificate of Inspection on the OCEAN RANGER did not contribute to this casualty. However, there is evidence of a violation of 46 USC 367 by ODECO International Inc. because of their failure to maintain the OCEAN RANGER in an inspected status subsequent to the expiration date of the Certificate (27 December 1981). This matter has been forwarded to the Commander, First Coast Guard District for further investigation under the civil penalty proceedings.

27. Industrial Master's License prerequisites for stability are deficient.

While unrelated to this casualty, the Board notes that the current experience and training prerequisites for the U.S. Coast Guard issued Industrial Master's License are inadequate. Specifically the existing experience and training prerequisites for stability are insufficient to insure that an individual receiving a license as an Industrial Master is possessed of a suitable level of understanding and experience in stability in order for him to successfully discharge his responsibilities for stability on board a drilling rig such as the OCEAN RANGER.

28. OCEAN RANGER Toolpushers, though designated "Person in Charge" by ODECO as provided in 46 CFR Subpart 109.107, were unfamiliar with the regulations they were responsible for in 46 CFR Part 109.

The toolpusher's responsibilities included such things as conducting fire and boat drills, and insuring the required lifeboatmen were on board and assigned to lifeboats. Though toolpushers were well trained in the drilling operations aspects of a MODU, there was no indication they were familiar with or trained in the Coast Guard regulations or the marine aspects of the rig in order to properly discharge their duties as a "Person in Charge".

29. Final conclusion.

With the exception of the above, there is no evidence of actionable misconduct, inattention to duty, negligence, or willful violation of law or regulation on the part of licensed or certificated personnel; nor evidence of failure of inspected equipment or material; nor evidence that any personnel of the Coast Guard or of any other Federal agency, or any other person contributed to this casualty.

RECOMMENDATIONS

It is recommended that:

1. The U. S. Coast Guard continue, with a high priority, to promote the improvement of the present methods, or development of alternate methods, of abandoning MODU's by lifeboats and inflatable life rafts.

The problem of lowering lifeboats and life rafts from MODU's, due to the heights involved and due to the lack of a lee because of the open construction of the rig, has not been satisfactorily solved. A joint government-industry effort on an international scale through the International Maritime Organization (IMO) should be initiated to address this problem.

2. The U. S. Coast Guard continue, with a high priority, the development of life jackets which address the conflicting demands for adequate, properly positioned buoyancy, and the needs of the wearer to assist himself.

3. The U. S. Coast Guard review the existing life jacket design and testing criteria to ascertain their adequacy in insuring that jacket securing devices hold the life jacket properly positioned on the wearer against the forces exerted by rough seas or during an entry into the sea from a significant height.

4. No davit launched lifesaving devices be permitted which require the device be waterborne before disengagement of the falls or lowering wire.

The U. S. Coast Guard should strive, through IMO, for a standard for lifesaving devices which will permit disengagement from the falls or lowering wire at any time. Similarly, any device which is designed for automatic disengagement when waterborne must have override capability by the persons using the device.

5. The U. S. Coast Guard continue efforts at IMO to have adopted a requirement that lifeboats have flotation in the covers to preclude remaining in an inverted position.

With the extensive damage of #2 lifeboat from the OCEAN RANGER, it could not have been expected to remain upright and stable. If, however, flotation in the cover had been provided, it might have come to rest on its side.

6. The U. S. Coast Guard investigate the failures suffered by the OCEAN RANGER's inflatable life rafts to determine if the design and construction standards are adequate. If the investigation produces evidence of deterioration due to aging, even with a proper servicing history, establish a limit on the service life of these rafts.

7. The U. S. Coast Guard continue evaluation of the inflatable life raft designs incorporating water ballast to ascertain if that feature solves the major shortcomings of wind driving and tumbling.

8. The U. S. Coast Guard initiate a regulatory project to require owners and/or operators of MODU's to provide a standby vessel.

The primary purpose of standby vessels is to assist in abandoning a MODU due to:

a) A well control problem, or

b) A stability problem.

It also can assist in the event of a helicopter crash in the vicinity of the unit.

To accomplish the above, the standby vessel must be of a design and size, and with proper crew, to properly execute the task. To meet this criteria, it should be of the size and type employed to service the MODU.

9. The U. S. Coast Guard initiate a regulatory project to establish the type and number of devices and equipment on standby vessels to properly effect a rescue. The U. S. Coast Guard should foster the development of rescue devices and techniques that require less active participation by the person in the water.

10. The U. S. Coast Guard continue to pursue the promulgation of regulations requiring personal exposure suits for all personnel on

board all vessels operating in geographic locations where cold water temperatures exist.

The Board notes that the U. S. Coast Guard has already initiated a regulatory project to accomplish this recommendation. (please see Federal Register Vol. 48, No. 24 of February 3, 1983). However, the Board does not subscribe to the theory that covered lifeboats or life rafts are a suitable alternative to exposure suits. It is further recommended that the U. S. Coast Guard propose a similar motion to the IMO.

11. The U. S. Coast Guard initiate a regulatory project to require that all normally unmanned spaces onboard MODU's that are vulnerable to substantial undetected flooding be equipped with flooding alarms, or suitable alternative means of accomplishing the intent of this recommendation.

12. For those spaces described in recommendation 11, a readily available means of dewatering should be required by regulations.

13. The U. S. Coast Guard pursue in IMO a proposal that the 1969 Load Line Convention address the unique conditions for weathertight integrity of special purpose vessels which should be considered in the assignment of loadlines.

The U. S. Coast Guard should also highlight in the Marine Safety Manual, Section 30-6-25B Inspection Standards, the variety of openings required to be watertight that are encountered in the unique and various hull configurations of special purpose vessels such as MODU's.

14. The U. S. Coast Guard review the Electrical Engineering Regulations, Title 46 CFR, Subchapter J and the Machinery Regulations, Title 46 CFR, Subchapter F to insure that each piece of equipment or a component in systems used to control or monitor an essential function on board a MODU be designed and engineered such that it fails-safe, and:

a. The failure will not preclude continuing the monitoring or control function or

b. Alternative means be provided to safely accomplish the essential function.

Essential systems such as a Ballast Control System, a Jack-up System, and a Dynamic Vessel Positioning System are examples to which the criteria should apply. Fail-safe is considered to mean that upon failure of an item of equipment or component it will not cause an unintended or unsafe result.

15. The U. S. Coast Guard develop regulations which would be applicable to all inspected vessels to require that all electrical or mecnanical system shutdowns (e.g. circuit breakers, switches, valving) be readily locatable by a watchstander or person responding to an emergency situation and attempting to secure a particular system to prevent or terminate an unintended adverse result. If these shutdowns cannot be so located, a readily available and concise set of instructions to locate them should be posted.

16. The U. S. Coast Guard amend 46 CFR 113.30-5 to require a sound powered telephone system between the ballast control space and the spaces that contain the ballast valves and ballast pumps.

17. The U. S. Coast Guard require by regulation that descriptive manuals and instructions be provided for use by the crew on each MODU describing the major vessel systems and their design capabilities in respect to normal operation, operations not encounted during day to day operations, and operations during emergencies or casualties including alternative means of operations.

The intent of this requirement is to provide onboard personnel with rig specific information, including both capabilities and limitations, to enhance their knowledge of the rig and provide guidance during emergency and other than normal conditions.

18. The U. S. Coast Guard require that the Operating Manuals provided for MODU's in accordance with 46 CFR 109.121 be arranged and written in a manner that is easily understood by the MODU's operating personnel. Because of the importance of this information existing manuals should be reviewed by the U. S. Coast Guard on a priority

basis to ascertain that they are in substantial compliance with this requirement.

19. The U. S. Coast Guard amend 46 CFR 109.121 to include information which should be specified in the MODU's evacuation plans to facilitate a timely and safe evacuation of personnel under all conditions.

The criteria should include as a minimum:

a. Proximity of land

b. Type of weather phenomenom for the location

c. Quality of weather forcasting

d. Availability and Capabilities of standby boat and other rescue forces including lead time necessary to arrive on scene.

e. Proximity of other units in the drilling location

20. The U. S. Coast Guard establish by regulation a method of ascertaining that the person in charge of a MODU has the necessary prerequisite professional knowledge as set forth in Title 46 CFR, Subchapter IA. The Board submits that until all aspects of the methods of ascertaining the necessary prerequisite knowledge have been considered, no preference can be expressed for licensing, certification or registry.

The Board considers that extensive knowledge of drilling operations and procedures is necessary to fill the position of the person in charge. With the implementation of this recommendation, the Board considers that the past practice of designating as the person in charge those individuals with extensive drilling knowledge will provide a person capable of addressing the problems associated with the operation of a MODU.

21. U. S. Coast Guard regulations, Title 46 CFR, Subchapter IA Subparts 109.107 and 109.109 be amended to provide for only a "Person in Charge" in lieu of a "Master or Person in Charge".

22. The U. S. Coast Guard require by regulation that, prior to assignment to a MODU, the owner shall certify in writing to the U. S. Coast Guard that an Unlimited Master, hired to satisfy the requirements of the Certificate of Inspection has received sufficient additional training to familiarize him with those aspects of MODU's

that are unique and beyond the knowledge and skills one would normally possess by virtue of the license he holds. These regulations should also require that the owner shall specify, in the Booklet of Operating Conditions, that the Master make initial and periodic reviews of the rig specific descriptive manuals and information.

23. The U. S. Coast Guard formalize by regulation the Industrial Master's License and upgrade the prerequisite criteria for issuance to insure that the holder possesses the same necessary knowledge and skills as that of the holder of an Unlimited Master's License while serving in the same capacity onboard a MODU.

The intent is that there be no difference in the level of competence of individuals serving as Masters of MODU's. This would require the application of recommendation No. 22 to Industrial Masters.

24. The U. S. Coast Guard establish a regulatory program which identifies and requires minimum levels of skill, knowledge and experience for ballast control, jack up control, and vessel positioning control operators onboard MODUs.

The Board considers this necessary prerequisite knowledge to include stability, pumping systems and operations, casualty control procedures, and other task functions associated with these positions.

25. The U. S. Coast Guard develop regulations which require that written certification be made by the vessel owner to the Officer in Charge, Marine Inspection issuing the vessels Certificate of Inspection, explicitly attesting to the training of the persons described in recommendation No. 24 in vessel specific subject matter pertaining to the identified task functions. This certification shall be made prior to the assignment of any person to a vessel for watchstanding purposes.

26. The Commandant of the U. S. Coast Guard obtain and review the report of the Royal Commission on the OCEAN RANGER Marine Disaster when it is issued to determine whether additional evidence and information relevant to marine safety issues became available subsequent to the submission of the report of this Board.

27. The case be closed.

Submitted this date 20 May 1983

RADM H. H. BELL, USCG

Chairman

CAPT P. J. CRONK, USCG

Member

CAPT H. T. BLOMQUIST, USCG

Member and Recorder

APPENDIX A

RECORD OF DEAD AND MISSING

APPENDIX A

RECORD OF DEAD AND MISSING

The following dead crewmembers were recovered by searching vessels between 15 February 1982 and 24 February 1982 None of the listed were required to have USCG Licenses or Documents

	NAME	AGE	HOME ADDRESS	NEXT OF KIN
1	AUGUT George F	29	Bauline Line Torbay NF	Wife
2	BLACKMORE Kenneth	33	P O Box 74 Norris Arms NF	
3	BLEVINS Thomas A	35	35 Second St Plainfield CT USA	Wife
4	BRINSTON Wade A	25	P O Box 202 Arnolds Cove NF	Wife
5	BURRY Joseph C	43	Normans Cove Trinity Bay NF	
6	CHAFE Kenneth	39	Topsail Conception Bay NF	Wife
7	CLARKE Gerald	33	148 Watson St St John s NF	Wife
8	DAWE Norman	31	Riverhead Harbour Grace NF	
9	DRODDY David L	25	812 Christopher Circle Albertsville AL USA	Wife

10	ESCOTT Derrick	27	25 Jubilee PL Mount Pearl NF	Wife
11	FOLEY Ronald	47	37A Ross Rd St John s NF	
12	FREID Melvin J	32	18 Leslie St St John s NF	Wife
13	HEFFERNAN Ronald E	28	11 Reid St St John s NF	Wife
14	HICKS Robert L	42	113 Mellard Dr Goose Creek SC USA	Wife
15	KUHL Cliff	33	16 Kara Crescent Brooks Alberta	
16	MILLER Wayne T	26	34 Morris Ave St John s NF	
17	O BRIEN Kenneth J	22	P O Box 5414 St John s NF	
18	PUTT Douglas	33	P O Box 117 Goulds NF	Wife
19	SMITH William D	44	10314 Moonlight Way Valley Station KY USA	Wife
20	TILLEY Craig M	19	75 Pearson St St John s NF	
21	WARFORD Woodrow W	35	General Delivery Carbonear NF	Wife
22	WILSON Robert	30	5647 60th St NW Calgary AL	Wife

The following crewmembers remain missing and are presumed dead

F	NAME	AGE	HOME ADDRESS	NEXT OF KIN
1	ARSENAULT Robert J SR	43	57 Boyle St St John s NF	Wife
2	BALDWIN Nicholas R	46	P O Box 62 Carbonear NF	Wife
3	BOUTCHER David L	24	79 Caribou Rd Corner Brook NF	Father
4	BURSEY Paul W	30	Site 62 Box 56 St John s NF	Mother
5	CAINES Gregory A	30	31 Johnson Cresent St John s NF	Mother
6	CHALMERS David G	26	1AA Kingsbridge Ct St John s NF	Father
7	CONWAY Daniel F	42	20 Doyle Street St John s NF	Wife
8	CRAWFORD Gary E	35	8D The Boulevarde St John s NF	
9	DAGG Arthur W	28	28 Pasadena Cres Apt 306 St John s NF	Father
10	DODD Jim		172 Main St East Berwic Nova Scotia	Father

11	DONLON Thomas R	40	1000 W Sherwood Dr Sunter SC USA	Wife
12	DRAKE Allen W	35	92 Old Petty Hr Rd Killbride NF	Father
13	DUGAS William J	56	1109 Oak St Abbeville LA USA	Wife
14	DWYER Terrance	46	P O Box 1052 20 London Rd Carbonear NF	Wife
15	DYKE Domenic H	29	P O Box 93 Eastport NF	Wife
16	EVOY Andrew J	36	P O Box 396 Mt Carmel NF	Wife
17	FENEZ Joseph R	25	1 Blake Place St John s NF	Wife
18	FERGUSON Randell H	49	503 North Pearl Natchez MS USA	Wife
19	FOGG Peter	24	14 Jubilee Place Mt Pearl NF	Mother
20	FRY Carl W	26	18 Raleigh Street St John s NF	Mother
21	GANDY George L.	56	Rt 1 Box 25 Logansport LA USA	Wife
22	GARBEAU Guy C E.	34	540 Taillion Apt 3 Montreal Quebec	Sister
23	GORUM Reginald K	35	5305 Raymond Pelles El Paso TX USA	

24	GREENE Cyril G	22	P O Box 204 RR 2 Piccadilly NF	Mother
25	HALLADAY Normam J	25	21 Lascelles Blvd #1104 Toronto Ontario	
26	HARNUM Fredrick L R	31	15 Tunnis Court St John s NF	
27	HATFIELD Thomas G		P O Box 301 Wolfville Nova Scotia	Wife
28	HAUSS Clarence E	58	6409 Pinehearst Rd Baltimore MD USA	
29	HICKEY Gregory J.	23	Box 12 Site 84 Torbay NF	Father
30	HOLDEN Derrick J.	25	Site 9 Box 22 Mt Pearl NF	Father
31	HOWELL Albert F	31	9A Glendenning Place Mt Pearl NF	Wife
32	HOWELL Robert E.	31	1268 Jalmal Blvd. London Ontario	Mother
33	HOWLAND Charles R	35	215 Delcastle St. Northwest NF	Wife
34	JACOBSEN Jack	39	P O Box 9 Tusket Yarmouth County Nova Scotia	Wife
35	LEDREW Harold	27	3A Wireless Rd. Botwood NF	Wife

36	LEDREW Robert J	23	17 Staff Rd Botwood NF	Father
37	MADDEN Robert C	35	107 Bermuda Way NW Calgary Alberta	Wife
38	MAURICE Michael S	31	5 Wickham Place St. John s NF	Wife
39	MELENDY Ralph	52	53A Stamps Lane St John s NF	Son
40	MITCHELL Gordon	21	P O. Box 832 Lacombe Alberta	
41	MORRISON James P	24	33 Manor Hampton Westen Ontario	
42	NOSEWORTHY Randy S	28	2 Curling Place St John s NF	Wife
43	O NEIL Pasuhal J	30	Fermeuse Southern Shore NF	Wife
44	PALMER George P	35	48 Cookstown Rd. St. John s NF	Wife
45	PARSONS Clyde M	31	P.O. Box 325 Foxtrap NF	
46	PIEROWAY Donald G	26	Barachois Brook St. John s NF	Mother
47	PINHORN John R	25	49A St. Michael s St. St John s NF	Father
48	POWELL Willie E	29	56 Box 64 E" Franklington LA USA	

49	POWER Gerald T	28	P O Box 21 Site 81 St John s NF	Mother
50	RATHBUN Donald J	30	609 Point Judith Rd. Narragansset RI USA	Father
51	REID Darryl R	19	General Delivery Upper Gullies NF	Father
52	RYANN Dennis	37	160 Parker St. Medford Ontario	Wife
53.	SHEPPARD Rick L	25	15B Longs Hill St. John s NF	Father
54.	SMIT Frank F.	30	6 Rawlins Place Killbride NF	
55	SMITH William	32	5 Mitchell Ct. St. John s NF	Wife
56.	STAPLETON Ted F.	39	5 Munden Drive Mt Pearl NF	Wife
57	THOMPSON Benjamin K.	36	Rt. 4 Box 160X Hattiesburg MS USA	Wife
58	TILLER Gregory P	21	38 Sunrise Ave Mt. Pearl NF	Mother
59.	VAUGHN Gerald R.	36	Rt. 4 Collins NS	Wife
60	WATKINS Michael	29	1265 Foy St. New Orleans LA USA	Mother

61	WINSOR Robert P	23	Box 4 Site 10 RR 1 Paradise NF	Father
62	WINSOR Stephen C	19	Box 4 Site 10 RR 1 Paradise NF	Father

APPENDIX B

REPORT ON THE STABILITY OF THE MODU OCEAN RANGER

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

ADDRESS REPLY TO
COMMANDER (mmt)
EIGHTH COAST GUARD DISTRICT
HALE BOGGS FEDERAL BLDG
500 CAMP ST
NEW ORLEANS LA 70130
(504)589-6266

5420
18 March 1982

From: LT W. A. HENRICKSON, USCG
To: Chairman, Marine Board of Investigation, MODU Ocean Ranger

Subj: Preliminary Report on Stability

A study of the following three issues was conducted at the request of Mr. Ralph E. Johnson of the Marine Board of Investigation. Preliminary conclusions are given below. Detailed results will be included in the final report on stability.

(1) Is the "100 Knot Wind Safety" curve shown in section 'F' of the operating manual valid?

Conclusion: Yes. The critical axis for wind heel analysis i· approximately 45 degrees off the centerline. Our independent study confirmed the operating manual curve. See Figure 1. The dashed curve is based on adjusted flat plate shape coefficients. The shape coefficient of each flat plate, normally 1.0, was adjusted by the cosine(sine) of the incident wind angle to reflect its reduced drag when skewed to the wind. In developing the broken curve, no such adjustment was made. In all cases, downflooding was assumed to occur at the chain pipe openings on the 151.5 foot level. All curves are based on rotating the port bow down.

(2) Is it possible by shifting or adding ballast water in the lower hulls to cause the rig to capsise by rolling over forward?

Conclusion; When all the ballast tank contents on the port side were shifted as far forward into empty ballast tanks as possible, (Cases 1 and 3, Table 1), the bottom edge of the upper hull was immersed forward. Downflooding did not occur through the forward chain pipe openings. Since the additional reserve bouyancy of the upper hull was required to avoid downflooding in this condi-, tion (see Figure 2), the watertight integrity of the upper hull was important. For this reason, this condition was categorized as "capsize possible". Capsize was considered unlikely in the remaining conditions shown in Table 1.

Case 7 considered the effect of flooding all empty ballast tanks on the port side. With the upper hull totally watertight, the rig came to equilibrium along the port bow diagonal at an angle of 24 degrees. See Figure 3. In this condition, the chain pipe openings on the forward port column were immersed by 17 feet. Downflooding to the forward port chain lockers increased the heel angle along the port bow diagonal to 26 degrees. The final LCF draft was approximately 100 feet. Since the residual righting energy of the rig depended entirely on the closure of the upper hull, the top of which was partially immersed, capsize was considered imminent for this case.

(3) Given the best estimate of loading at the time of the casualty, (80 foot draft), would it have been possible to reduce the vertical center of gravity (VCG) to meet the 100 Knot Wind Safety curve without deballasting to the survival

5420
18 March 1982

Subj: Preliminary Report on Stability

Conclusion: In order to meet the 100 Knot Wind Safety curve requirements without deballasting, the following actions were required:

a. Dump the following liquids overboard from deck tanks:
   1/2 of all salt water cooling
   3/4 of all potable water
   all drill water
   all liquid mud

b. Transfer all fuel oil except 10 LT to lower hulls.

c. Dump all sack storage overboard.

d. Jettison all pipe in setback area overboard.

W. A. HENRICKSON

Enclosures:
(1) Figures 1 through 4 and Table 1

Copy to:
COMDT (G-MMT), with one copy of enclosures Figures 1 through 4 and Table 1

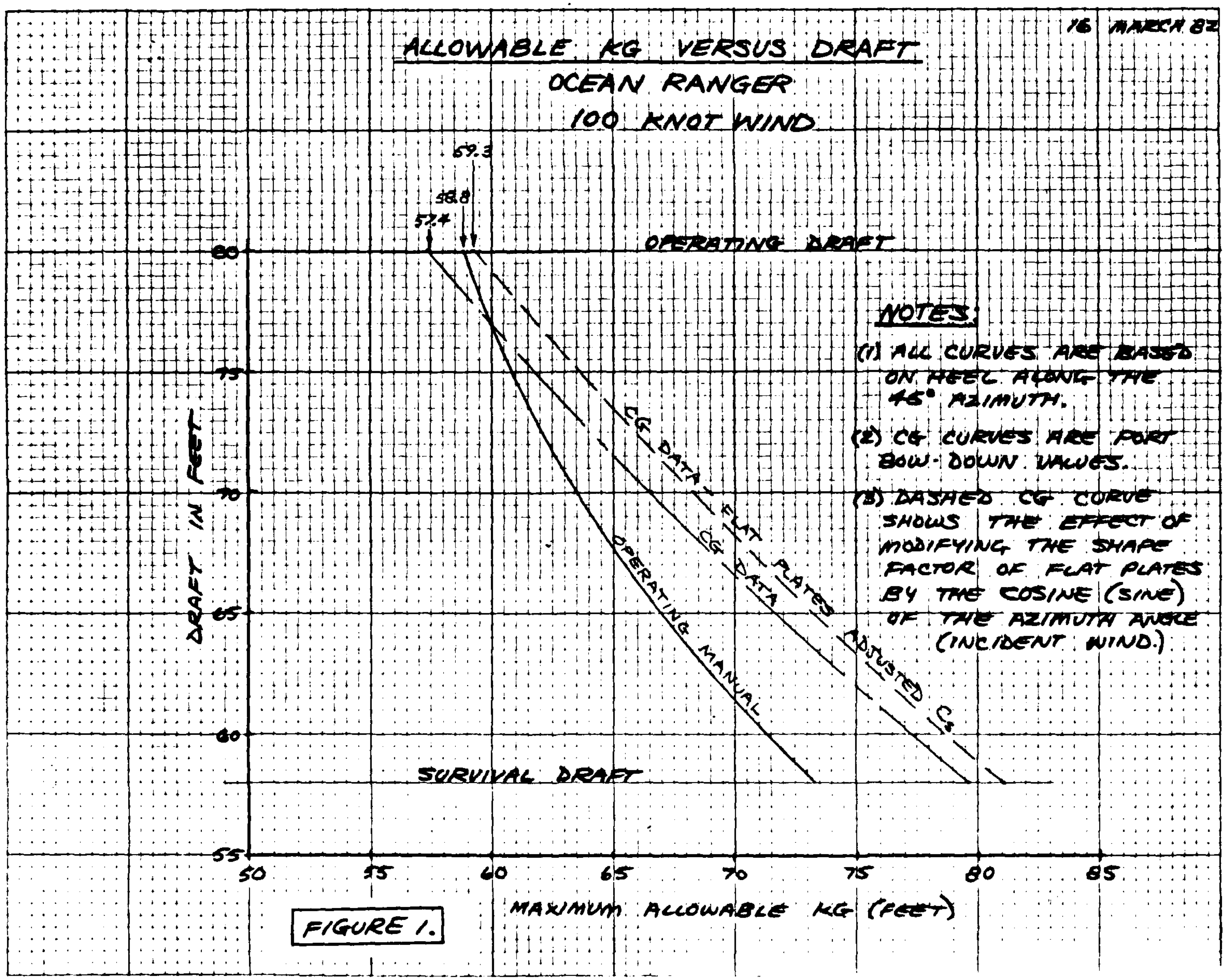
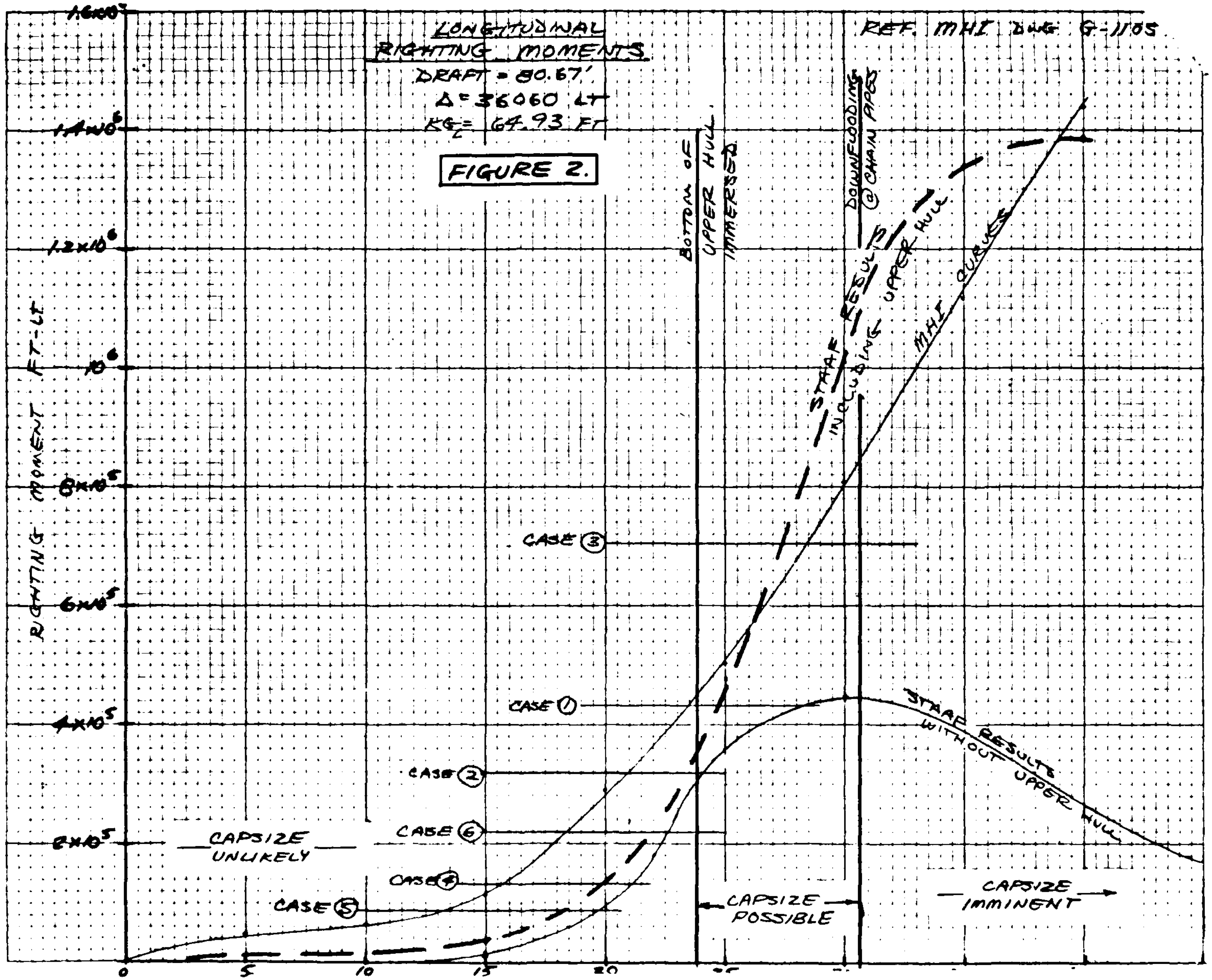

16 MARCH 82
ALLOWABLE KG VERSUS DRAFT
OCEAN RANGER
100 KNOT WIND
59.3
58.8
57.4
OPERATING DRAFT
NOTES:
(1) ALL CURVES ARE BASED ON HEEL ALONG THE 45° AZIMUTH.
(2) CG CURVES ARE PORT BOW-DOWN VALUES.
(3) DASHED CG CURVE SHOWS THE EFFECT OF MODIFYING THE SHAPE FACTOR OF FLAT PLATES BY THE COSINE (SINE) OF THE AZIMUTH ANGLE (INCIDENT WIND.)
CG DATA - FLAT PLATES ADJUSTED Cs
CG DATA
OPERATING MANUAL
SURVIVAL DRAFT
DRAFT IN FEET
80
75
70
65
60
55
50
55
60
65
70
75
80
85
MAXIMUM ALLOWABLE KG (FEET)

FIGURE 1.



LONGITUDINAL RIGHTING MOMENTS
DRAFT = 80.67'
Δ = 36060 LT
KG = 64.93 FT
FIGURE 2.
REF. MHI DWG G-1105
BOTTOM OF UPPER HULL IMMERSED
DOWNFLOODING @ CHAIN PIPES
STAAF RESULTS INCLUDING UPPER HULL
MHI CURVES
STAAF RESULTS WITHOUT UPPER HULL
CASE 1
CASE 2
CASE 3
CASE 4
CASE 5
CASE 6
CAPSIZE UNLIKELY
CAPSIZE POSSIBLE
CAPSIZE IMMINENT
RIGHTING MOMENT FT-LT
1.6x10^6
1.4x10^6
1.2x10^6
10^6
8x10^5
6x10^5
4x10^5
2x10^5
0
5
10
15
20

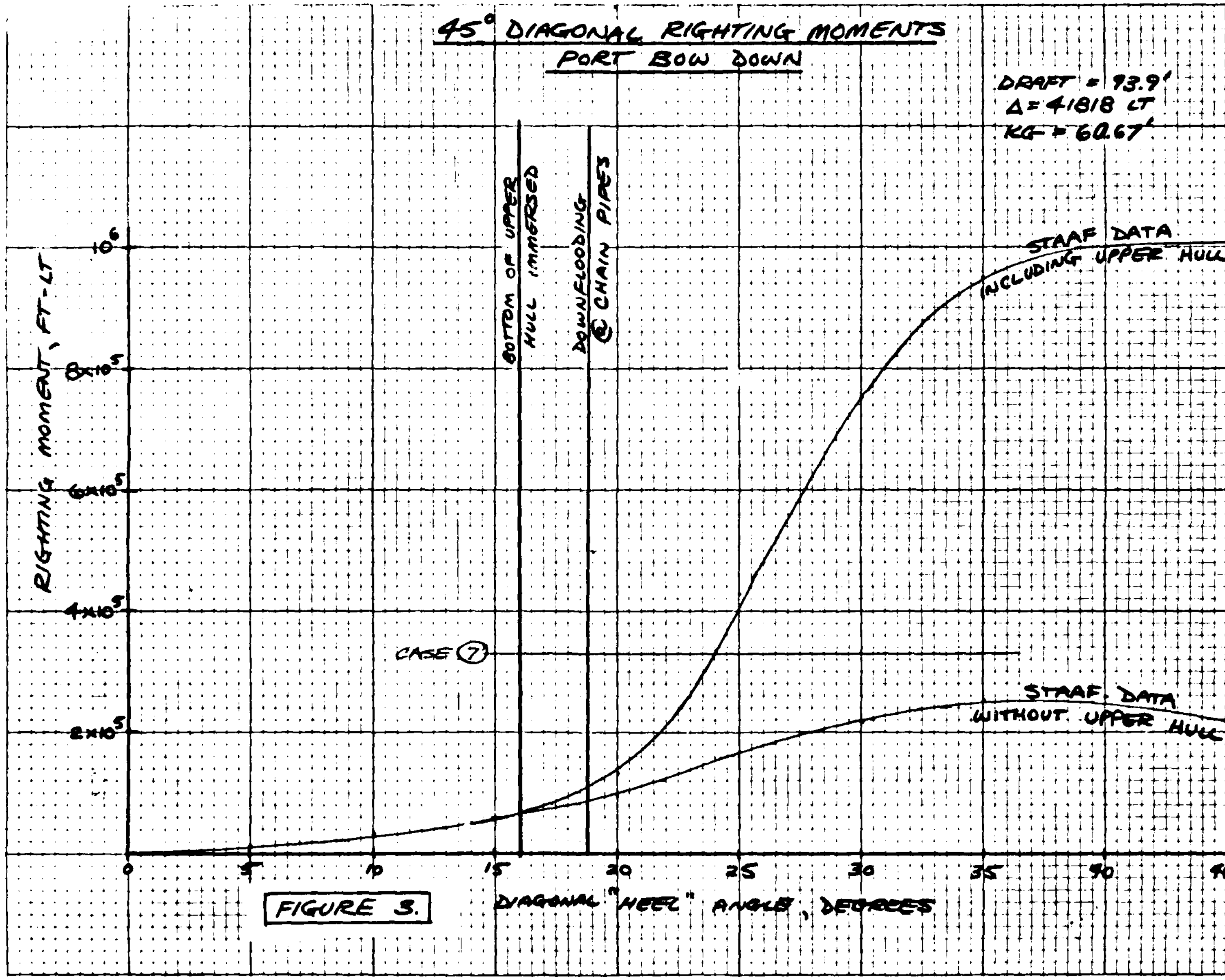

45° DIAGONAL RIGHTING MOMENTS
PORT BOW DOWN
DRAFT = 93.9'
Δ = 41818 LT
KG = 60.67'
BOTTOM OF UPPER HULL IMMERSED
DOWNFLOODING @ CHAIN PIPES
STAAF DATA INCLUDING UPPER HULL
STAAF DATA WITHOUT UPPER HULL
CASE 7
RIGHTING MOMENT, FT-LT
10⁶
8x10⁵
6x10⁵
4x10⁵
2x10⁵
0
5
10
15
20
25
30
35
40
45
DIAGONAL "HEEL" ANGLE, DEGREES

FIGURE 3.

OCEAN RANGER 2/9/82 BALLAST CONFIGURATION

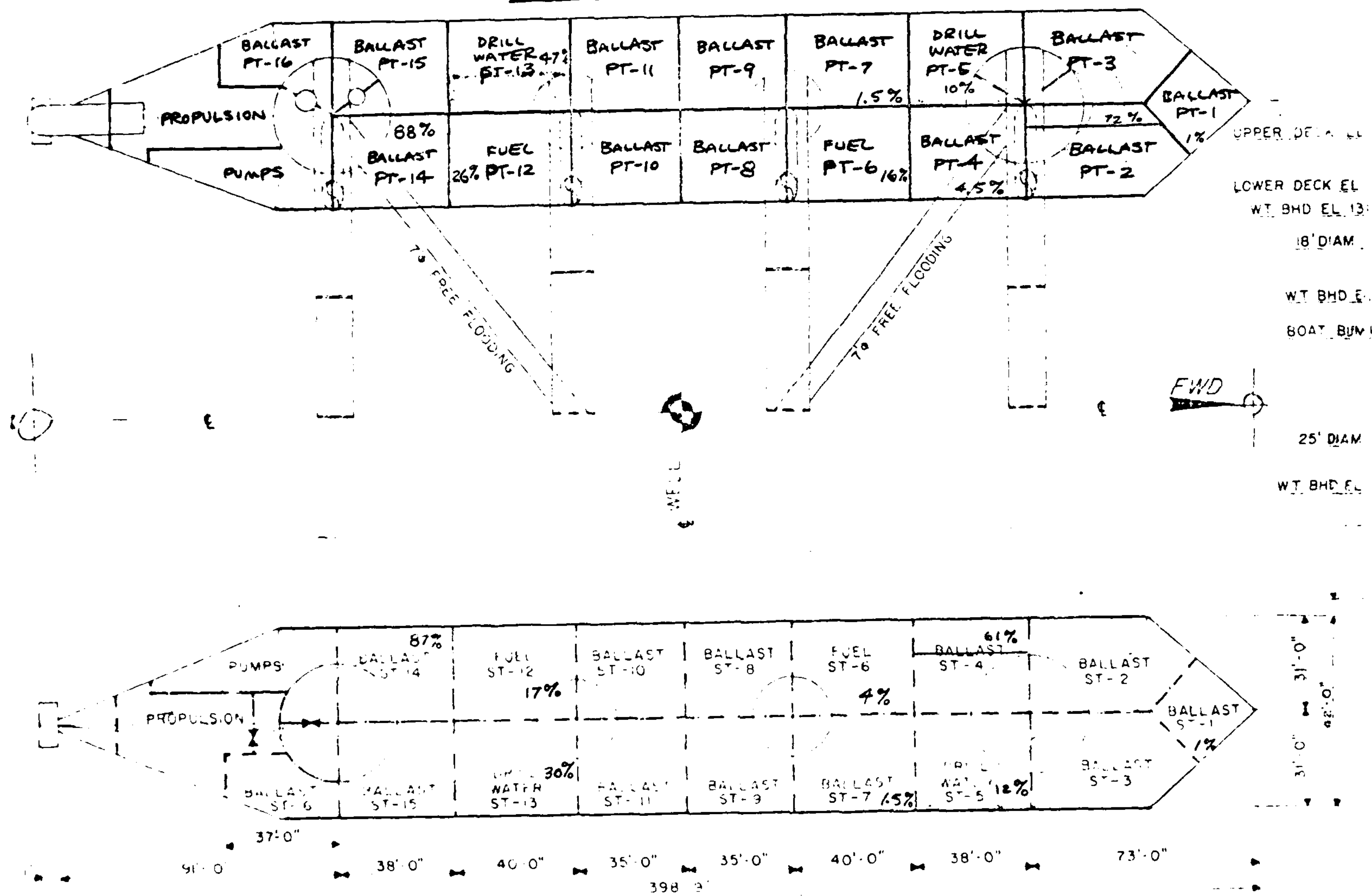


FIGURE 4.

Table 1

SUMMARY OF CASES EXAMINED

LONGITUDINAL STABILITY

Case 1: Extreme shift, port ballast only. Starting with the after-most tank, all ballast in the port lower hull was shifted to the forward-most empty tank. The final condition represented filling the ballast tanks in order from forward-most to after-most, with no net increase in total ballast aboard.

Case 2: Extreme shift, starboard ballast only.

Case 3: Extreme shift, both port and starboard ballast.

Case 4: Reasonable shift, port ballast only. In the starting condition, the four center tanks in each lower hull, No. 8 through No. 11, were full (see Figure 4). The most likely deballasting sequence to reach the 58 foot survival draft would involve dewatering them. This case considered shifting the water in No. 8 through No. 11 as far forward as possible.

Case 5: Reasonable shift, starboard ballast only.

Case 6: Reasonable shift, both port and starboard ballast.

45 Diagonal Stability

Case 7: Flood port ballast tanks. All empty ballast tanks in the port hull were assumed filled.

Key Assumptions

a. The ballast configuration was based on the weekly stability report of 9 February. See Figure 4. The VCG was based on the morning report of 14 February.

b. A still water condition was examined. Wind, wave, current and mooring forces were not considered.

c. The downflooding point was the forward port chain pipe openings at the 151.5 foot level.

27 MAY 1982

REPORT ON THE STABILITY OF THE MODU OCEAN RANGER

1. ABSTRACT

A study was made to determine how sensitive the stability of the rig was to changes in wind, loading, and mooring. The figures on the following pages address each of the tasks outlined by the Marine Board of Investigation. For clarity, each task statement is reiterated with pertinent observations. Conclusions have not been drawn in any case.

2. GENERAL OBSERVATIONS

The following observations apply to more than one figure.

a. Critical stability axis. The critical axis for intact stability is approximately along the 45° diagonal. The intact stability of a mobile offshore drilling unit is assessed based on the ratio of the righting energy of the rig to the heeling energy of the wind, up to the angle of downflooding. Although the equilibrium heel angle due to the wind overturning moment is less for the OCEAN RANGER when the wind is blowing along the 45° diagonal than it is for a beam wind, the righting energy/heeling energy ratio is also less, due in part to the lower downflooding angle. The net result is a more critical intact stability condition with a 45° diagonal wind.

b. In the assumed operating condition a relatively small shift in the transverse center of gravity, (TCG), or longitudinal center of gravity, (LCG), resulted in large heel or trim angles. A static list of 15 degrees was possible with a total shift of TCG or LCG of less than 1 foot. Mooring forces reduced this tendency to list.

c. Capsize due to the wind overturning moment was not indicated in any case.

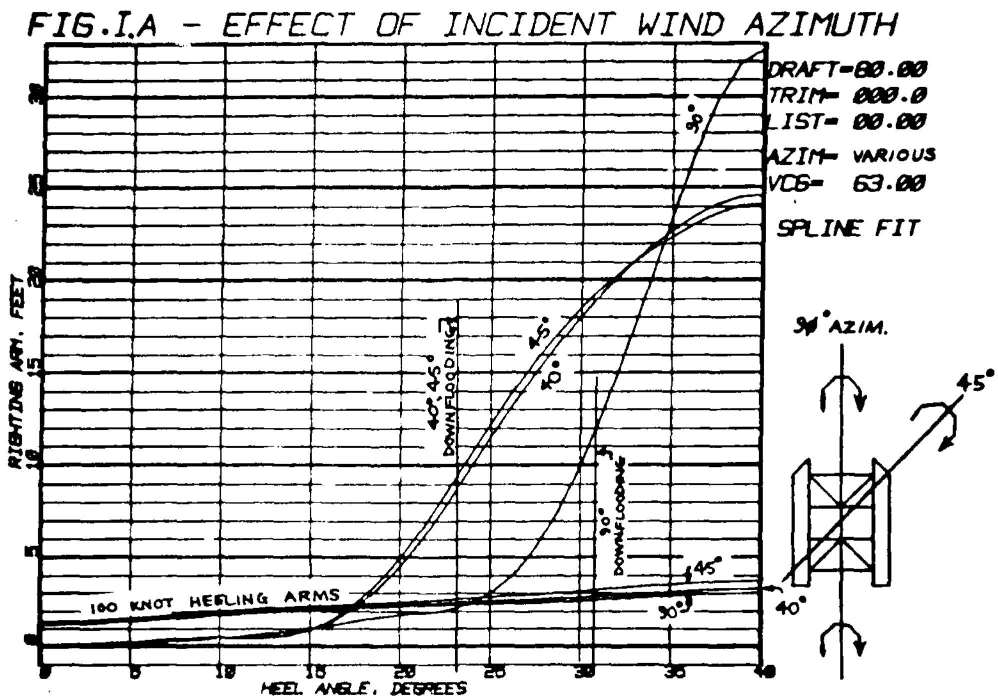
d. Except for Task II, all righting moment and wind overturning moments were calculated ignoring the effect of the mooring lines. Actual righting moments including moorings were greater, as shown in Figure II. The actual wind overturning moments were less than those shown. As discussed in Section 5, the WINDHEEL computer program used in this analysis computes the overturning moments using the center of lateral resistance of the underwater area. Since the mooring fairleaders on the OCEAN RANGER were above the waterline, the calculated moment arm between the center of wind pressure and the center of resistance is higher than the actual arm.

e. Lift forces on the upper hull underside were negligible. At a 20° heel angle, lifting reduced the overturning moment by approximately 5%.

3. RESULTS

Figures I.A - VIII Show the results for each task.

Note: Task III was deleted by Marine Board Memo dated 8 March 1982.



Task I.a - Vary wind direction. Make checks with wind 40° and 90° off the port bow.

Observations:

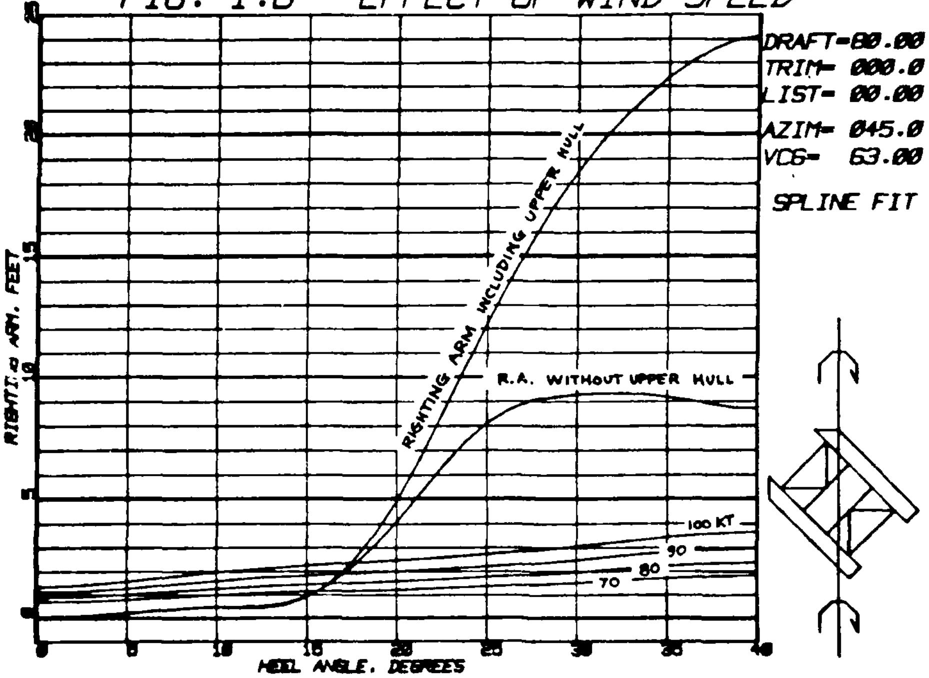
(1) As discussed in Section 2, the 45° azimuth is critical. Pure rotation about this axis is not an equilibrim condition for the unrestrained rig. If the rig was rotated about the 45° axis without restraint, it would trim longitudinally to an even keel condition with a static inclination about the centerline, which is the axis of minimum righting energy. Under the influence of a steady wind, the rig would shift its heading to a corresponding beam wind condition. However, the OCEAN RANGER was restrained from appreciable changes in heading angle by its moorings. Additionally, the wind loads in the longitudinal and transverse directions are approximately equal for this rig with a wind along the 45° diagonal, providing further restraint. The assumption of pure rotation about the 45° axis is therefore justified in this case.

(2) The wind overturning moment is affected little by changes in wind azimuth from 40° to 90° off the beam. The static list angle was about 38% greater for the beam wind condition, (90° azimuth), than for the 45° diagonal wind.

(3) Since the 45° axis was the critical stability axis, it was used throughout this study in lieu of the 40° axis originally specified by the Marine Board. The 40° and 45° diagonal righting arms shown indicate rotation down by the starboard quarter.

(4) The resultant static list angle along the 45° diagonal is 17.5 degrees.

FIG. I.B - EFFECT OF WIND SPEED



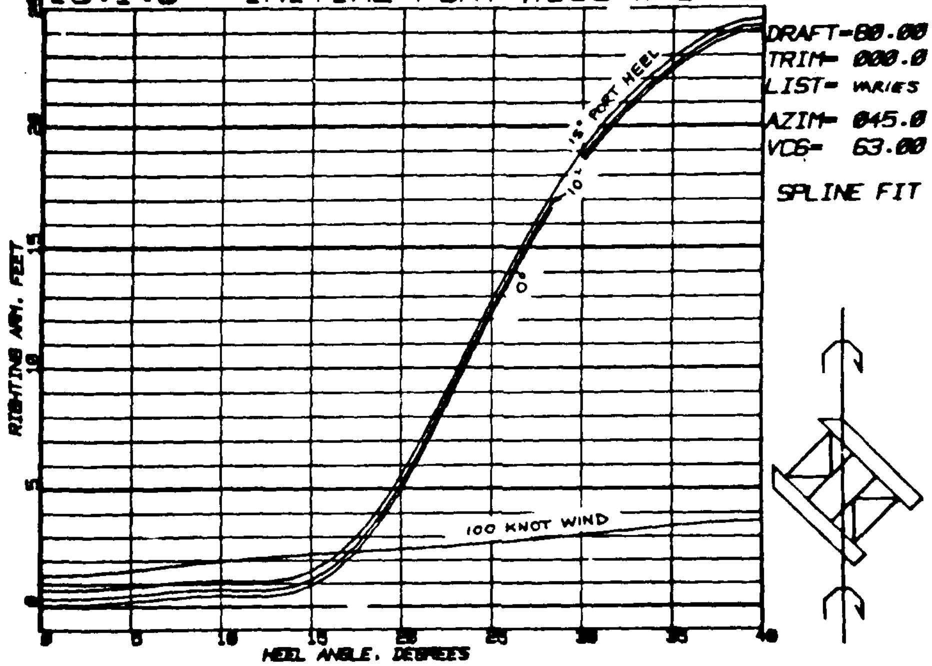
Task I.b - Vary wind speed.

Observations:

(1) Wind was from 45° off the port bow.

(2) Increasing the wind speed from 70 to 100 knots resulted in a 2° increase in static list along the 45° diagonal.

FIG. I.C INITIAL PORT HEEL W/UPPER HULL



Task I.c - Port heel. Righting arms were calculated for the 45° diagonal with an initial port heel of 0°, 10°, and 15°.

Observations:

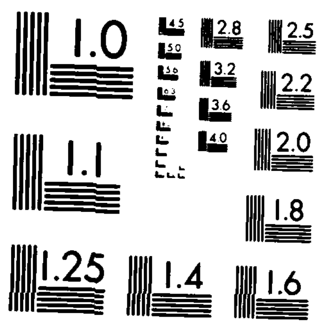
(1) Wind is from 45° off the port bow.

(2) Righting arms are positive with rotation down by the starboard quarter.

(3) Upper hull considered fully buoyant.

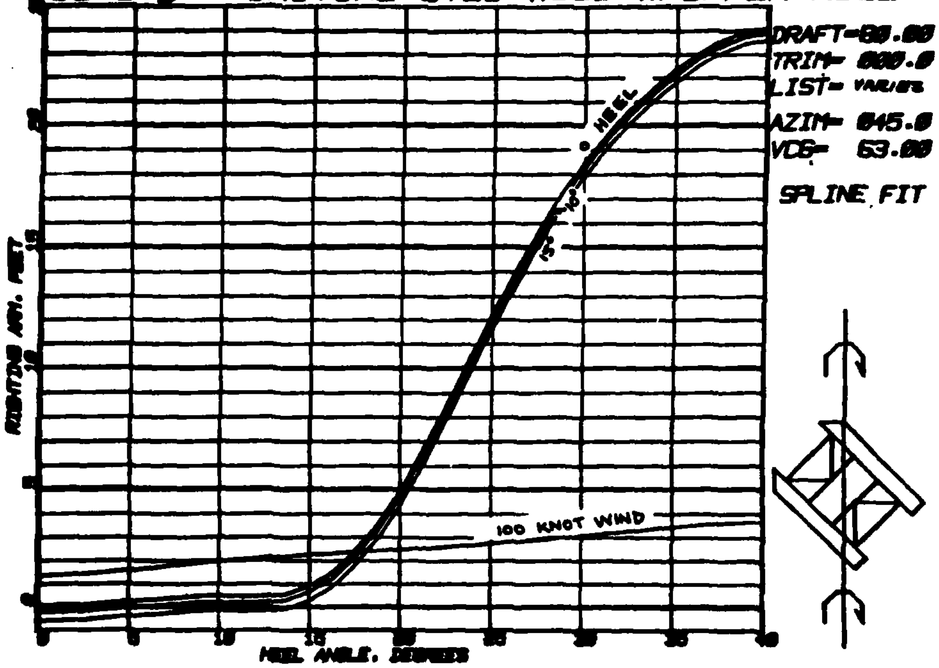
AD-A140 910 MOBILE OFFSHORE DRILLING UNIT (MODU) OCEAN RANGER ON 3/4
615641 CAPSIZING AND..(U) COAST GUARD WASHINGTON DC
20 MAY 83 USCG-16732/0001-HQS-82

UNCLASSIFIED F/G 13/12 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

FIG. I.D INITIAL STBD HEEL W/UPPER HULL



Task I.d - Starboard heel. Righting arms were calculated for the 45° diagonal with an initial starboard heel of 0°, 10°, and 15°.

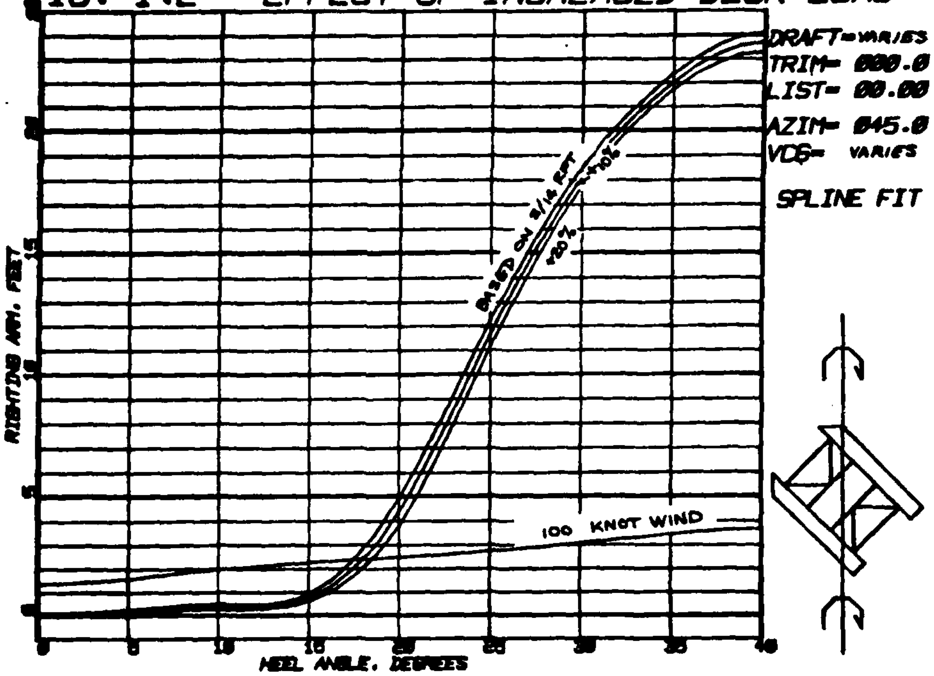
Observations:

(1) Wind is from 45° off the port bow.

(2) Righting arms are positive with rotation down by the starboard quarter.

(3) Upper hull considered fully buoyant.

FIG. I.E - EFFECT OF INCREASED DECK LOAD



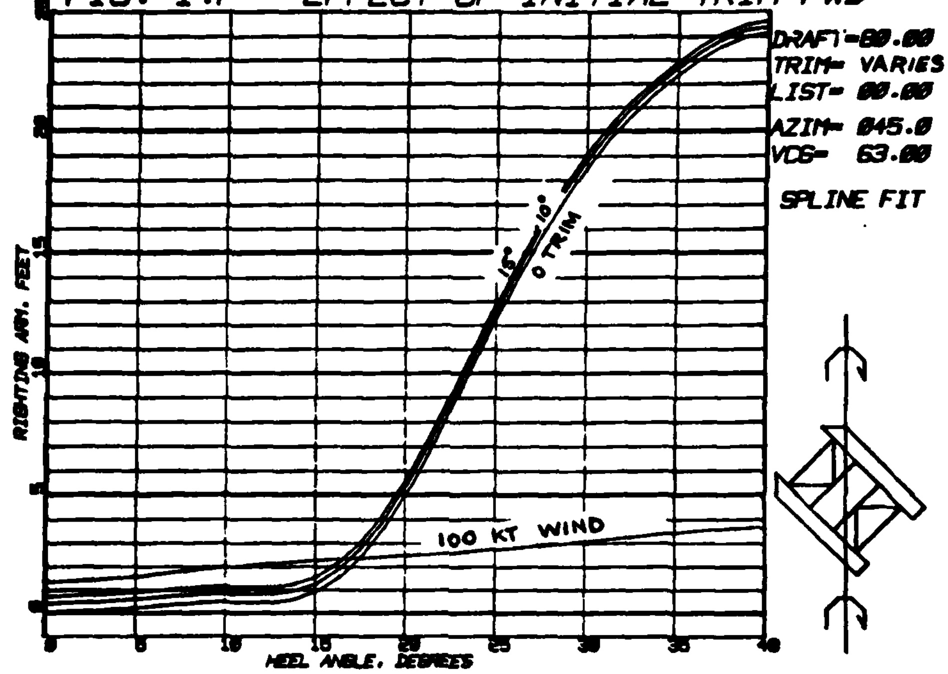
Task I.e - Deck load increase. Determine righting arms with deck load increased by 10 and 20 percent.

Observations:

(1) A 20% increase in deck load above that shown on the 2/14/82 morning report resulted in an additional 1.5 degrees in static list on the 45° diagonal under the influence of a 100 knot wind from the port bow.

(2) See Section 4 for a discussion of the assumed loading condition.

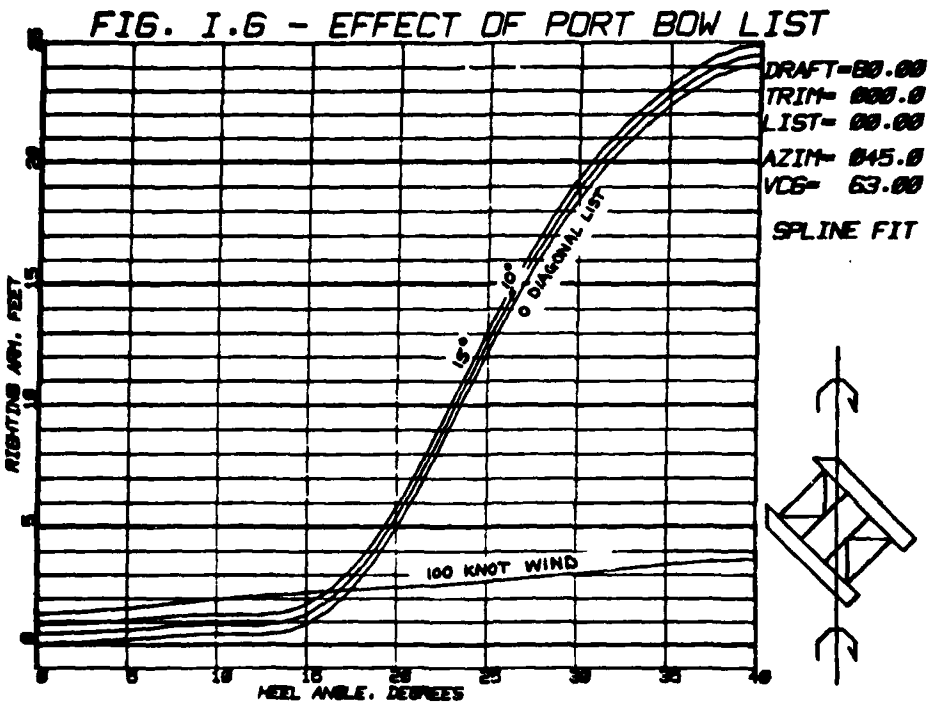
FIG. I.F - EFFECT OF INITIAL TRIM FWD



Task I.f - Trim by the bow. Righting arms were calculated for the 45° diagonal with an initial trim of 0°, 10°, and 15° down by the bow.

Observations:

(1) Righting arms shown are positive with rotation down by the starboard quarter.

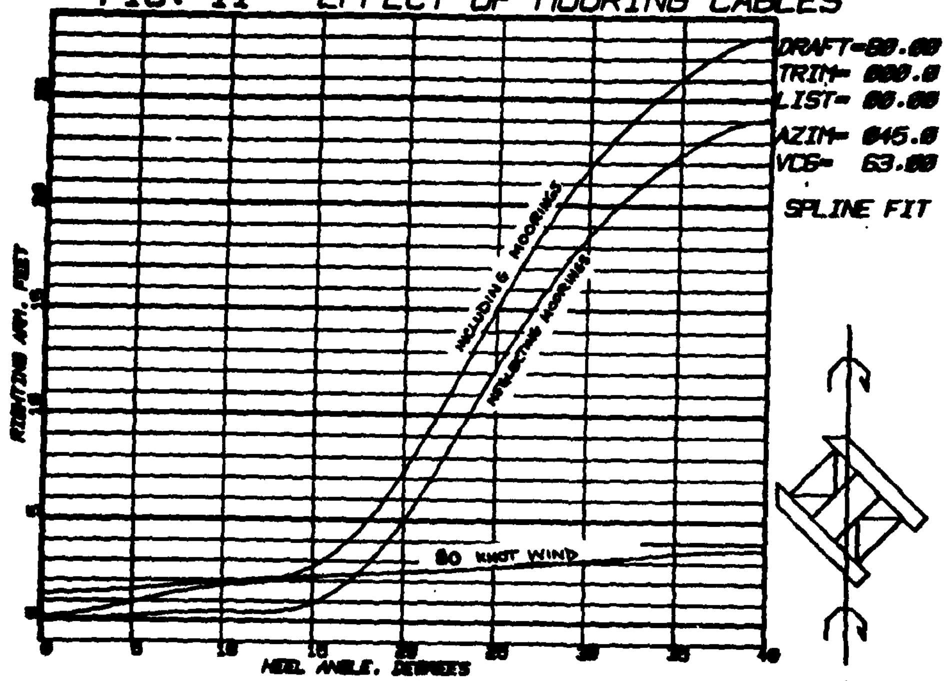


Task I.g - Diagonal list. Calculate righting arms with an initial list down by the port bow of 10° and 15°.

Observations:

(1) Rotation shown is down by the starboard quarter.

FIG. II - EFFECT OF MOORING CABLES



Task II - Effect of mooring system.

Observations:

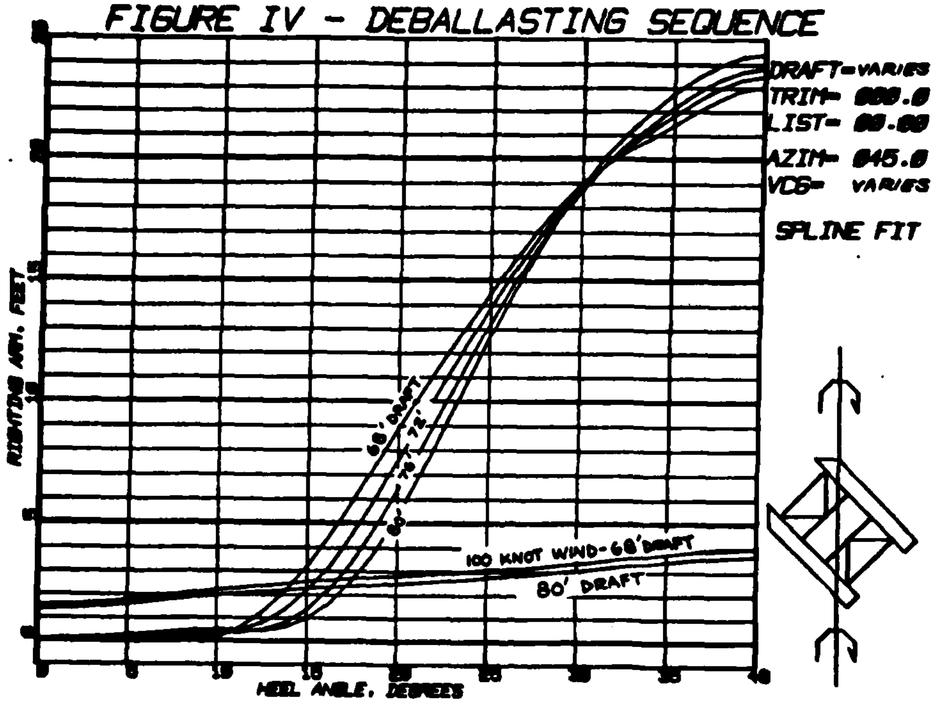
(1) Rotation is down by the starboard quarter under the influence of an 80 knot wind from 45° off the port bow.

(2) The wind heeling arms shown are higher than actual values. The lateral center of resistance of the underwater body was used in lieu of the mooring attachment point in determining the overturning moment arm. See Section 2d.

(3) Mooring line tensions were calculated assuming a steady 80 knot wind, 30 foot significant wave height (58 foot maximum wave) and 1.0 knot current all acting from 45° off the port bow. Changes in catenary and tension were calculated based on pure rotation about the heel axis with these loads superimposed. See Section 4 for further discussion.

(4) Righting moments from the mooring pull-down had their greatest effect at low heel angles.

(5) The maximum calculated mooring line tension was less than 1/2 the breaking strength. The actual line tensions were much higher. This analysis neglected the additional mooring load due to increased wind overturning moment and lateral drag at large heel angles.



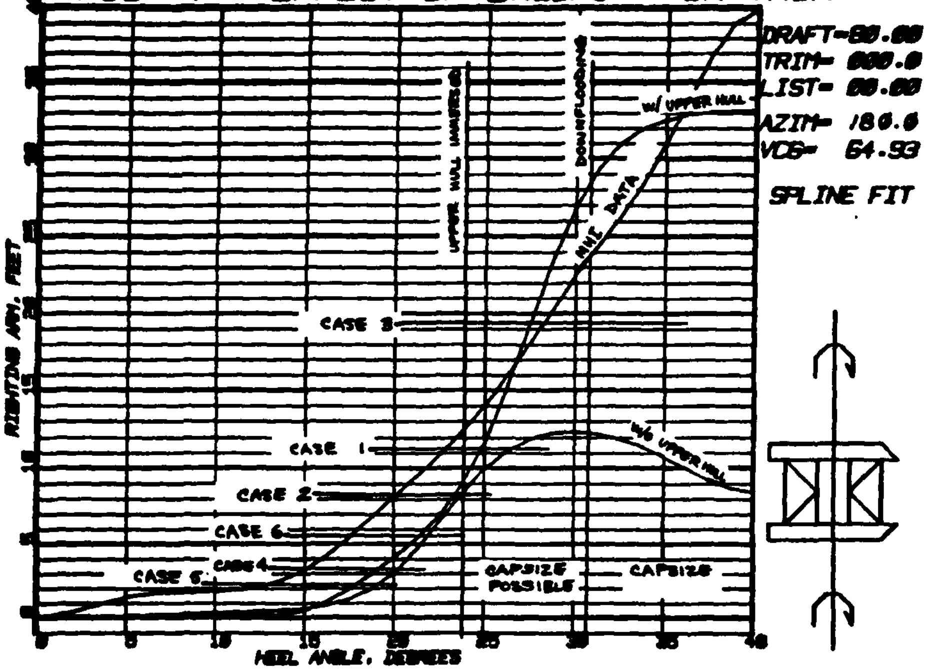
Task IV - Deballasting. Determine righting arms and wind heeling arms for various drafts as the unit is deballasted from the 80' drilling draft toward the survival draft. Use the operating manual deballasting sequence and investigate at 4 foot increments between 80 foot and 68 foot drafts.

Observations:

(1) Deballasting was assumed from tanks PT-8, ST-8, PT-10, and ST-10. No other weight removal or relocation was assumed. These curves therefore should represent the worst case. The initial loading is described in Section 4. At the 68 foot draft, approximately 16% remained in the four deballasted tanks, all of which were initially full.

(2) As the deballasting sequence progressed, the rig became more sensitive at heel angles less than 10°. Conversely, it became more stable in the range from 10°-30°, showing a reduced equilibrium heel angle under the influence of a 100 knot wind from the port bow.

FIG. V - EFFECT OF BALLAST ON TRIM



Task V - Effect of Ballast Shifting on Trim

a. The assumed loading condition for 14 February, discussed in Section 4, was used as a starting point. The starting ballast configuration is shown in Figure 1. Two ballast shifting scenarios were studied. In the first, Cases 1-3, ballast was shifted from after-most to forward-most tanks. The final condition for this "extreme ballast shift" represented filling the ballast tanks in order from bow to stern, with no increase in the total ballast aboard. Case 1 was such a shift of port hull ballast only, Case 2 was starboard hull ballast only, and Case 3 was ballast in both hulls.

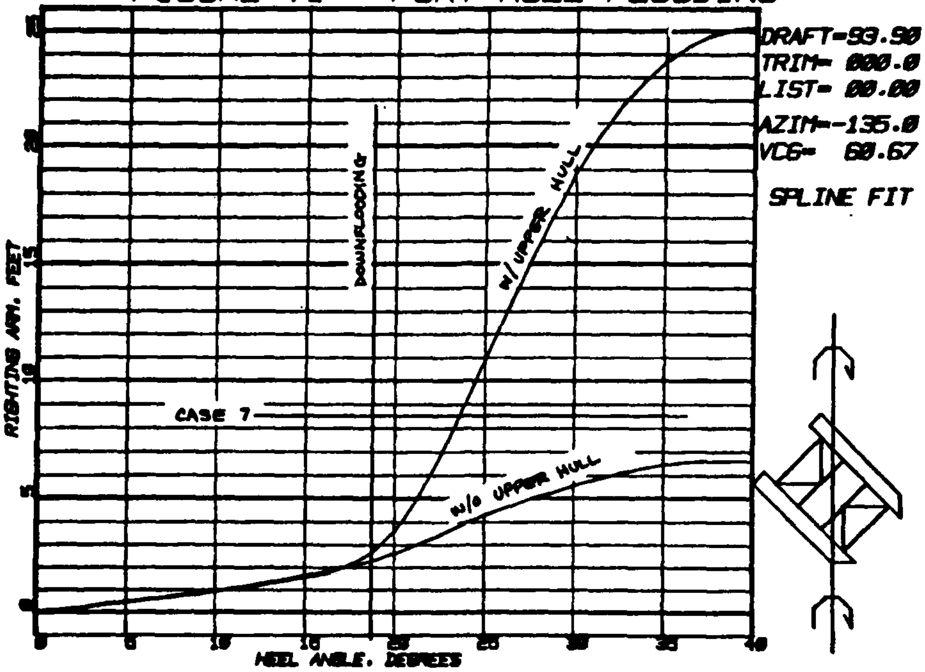
b. The second shifting scenario assumed a reasonable deballasting sequence was attempted, but the ballast water was shifted to empty forward tanks rather than overboard. The four center tanks in each lower hull, Nos. 8 through 11 were emptied and their contents shifted as far forward as possible. Case 4 was such a shift for the port hull ballast only, Case 5 was starboard hull ballast only, and Case 6 was ballast in both hulls.

c. Because ballast was shifted entirely in the forward direction, only pure rotation down by the bow resulted. Since no ballast was added or removed, there was no draft change. All cases assumed a still water condition. Wind, wave and mooring forces were not considered. At 23.8° the lower edge of the upper hull was immersed. At 31° downflooding began through the hawse pipe openings on the main deck.

(continued)

d. In all cases except those involving an "extreme ballast shift" of the port hull ballast, (Cases 1 and 3), the rig came to rest with the upper hull clear of the water. In Cases 1 and 3 the watertight integrity of the partially immersed upper hull became important since its reserve buoyancy was necessary to prevent further inclination down by the bow. In these cases, capsize was considered possible si[illegible]ce the actual wind and sea conditions could cause downfloo[illegible]ng and further inclination. In case 3, the watertight inte[illegible]ty of the upper hull was required to prevent capsizing.

FIGURE VI - PORT HULL FLOODING



Task VI - Effect of Port Hull Flooding

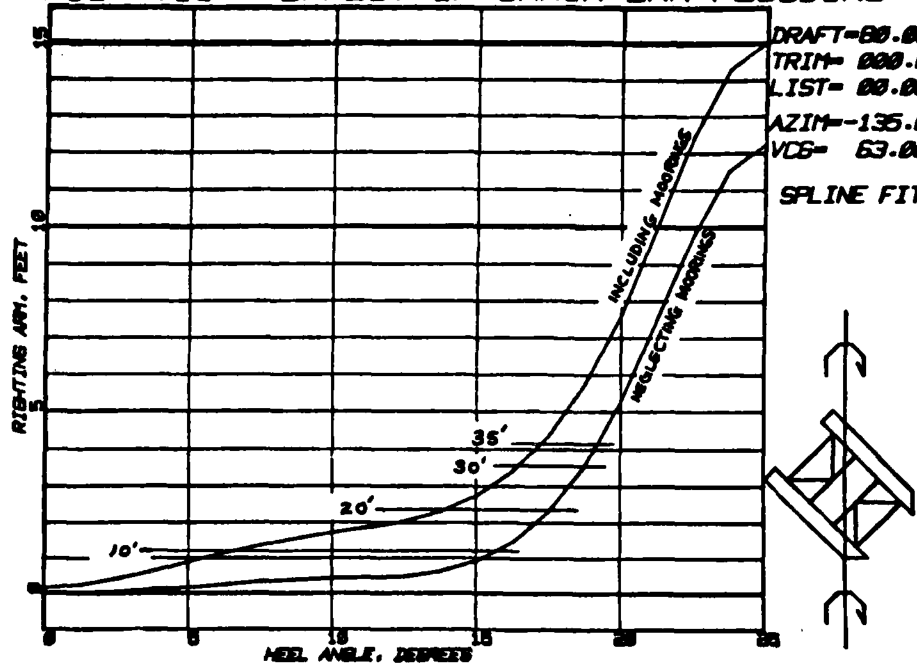
a. The assumed loading condition for 14 February, discussed in Section 4, was used as a starting point. The ballast configuration of the lower hulls is shown in Figure 1. Flooding was assumed in all empty ballast tanks in the port lower hull. Rotation down by the port bow resulted with a mean draft increase at the longitudinal center of flotation (LCF) to 93.9 feet. Because of the draft increase, the downflooding angle to the hawse pipe openings was reduced to 18.7°.

b. After flooding, the rig came to rest with a list of 23.5° down by the port bow. In this condition, the hawse pipe openings on the port forward column were immersed by 17 feet. Downflooding to the chain lockers occured, resulting in an increase to 26° list, down by the port bow.

c. In this condition all reserve buoyance was contained in the upper hull. If the upper hull was not maintained watertight, capsize would result.

d. This study assumed a still-water condition. Wind, wave and mooring forces were not considered.

FIG. VII - EFFECT OF CHAIN LKR FLOODING



Task VII - Effect of Chain Locker Flooding

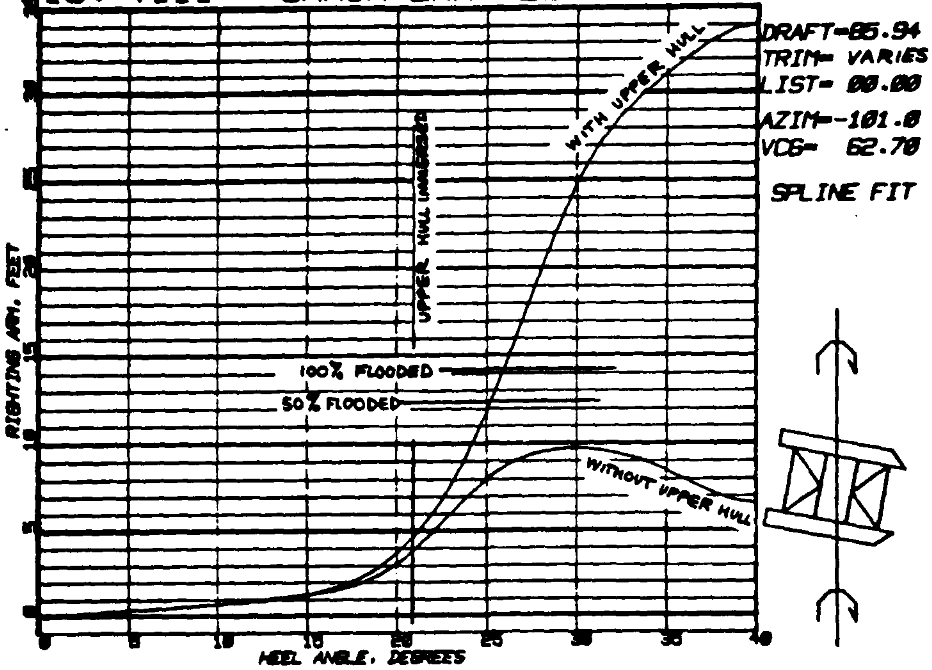
a. The port forward column chain lockers were assumed to flood. The resultant list along a 45° diagonal axis is shown above for various flooding levels. Rotation is down by the port bow.

b. The combined capacity of the three chain lockers in each column is :

Flooding Level	Long Tons, S.W.	Gallons
5'	154	40,320
10'	308	80,640
15'	462	120,970
20'	615	161,030
25'	769	201,350
30'	923	241,670
100% - 35'	1077	282,000

c. Assuming the hawse pipes serving each chain locker are 12" in diameter, a 5 foot head of water over their openings would allow about 150 gallons/second of inflow. The chain lockers would fill up at a rate of about 1 foot per minute of submersion under a 5 foot head.

FIG. VIII - CHAIN LKR FLOODING W/TASK V.



Task VIII-Chain locker flooding combined with Case 1 of Task V.

a. The "extreme ballast shift" of Case 1, Task V was assumed as a starting point. This corresponds to shifting all the ballast in the port lower hull as far forward as possible. Downflooding to the port forward chain lockers was then assumed as a result of green water over the hawse pipe openings. The curves above represent still water conditions. Wind, wave and current forces were not considered.

b. The results indicate rotation down by the port bow along an axis 11° off the centerline with the three port forward chain lockers flooded to 100% of their capacity. For the 50% flooded condition, rotation is closer to pure trim, and the righting arms are slightly higher than those shown above.

c. With the port forward chain lockers 100% flooded and all ballast in the port hull shifted as far forward as possible, the rig came to rest down by the port bow along an axis 11° off the centerline with a static list of 26°. With the chain lockers 50% flooded and the same ballast shift, the static list was reduce to approximately 25°. At 21° the lower edge of the upper hull was immersed. In both the 50% and 100% flooding cases, the watertight integrity of the upper hull was necessary to prevent capsizing.

d. The righting arms of the rig decrease with increasing draft. As a result, the 100% flooded condition shown above is a worst case. The effect of ballast shifting with no chain locker flooding is shown in Figure V.

4. SUMMARY OF ASSUMPTIONS

a. Loading Condition. The liquid loading of the lower hull shown in the weekly stability report of 9 February, reference 1, was assumed. See Figure 1. The morning reports for 9-14 February were studied to arrive at an assumed KG of 63.0 feet. This corresponds to the drilling condition with riser suspended and 12 anchors deployed, each with 4035 feet of cable and 1650 feet of chain outboard of the fairleader. Small changes (plus or minus 2 feet) in KG had little effect on the righting arms for heel angles greater than 5 degrees.

b. Wave and current loads were not considered except during the mooring load analysis.

c. Downflooding was considered to occur when the upper end of the hawse pipes at the 151.5 foot elevation were submerged. The total displaced volume of the chain lockers in each column is approximately 1080 long tons.

d. Cargo and equipment shifting at large angles of heel was not considered.

e. Throughout this report the terms heel, list and trim are defined in offshore drilling industry terms. Heel is a static inclination about the centerline, trim is static inclination down by either the bow or stern and list is a static inclination about any other axis, i.e. - a combination of heel and trim.

f. Two hull models were developed to compute righting arms. The first included the upper hull between the 130 foot and 151.5 foot levels. The second ignored the upper hull entirely. A comparison is shown in Figure I.B.

g. The mooring loads in Task II were calculated based on the OCEAN RANGER's Operating Manual, reference 9. The loading information in references 1 and 2 was used to determine the catenary length, fairleader angle and pretension. From this data the mooring pull-down and catenary tension loads were computed. The high line tension was calculated for the assumed environmental conditions, (see Figure II), using ODECO's charts in the Operating Manual and the explanation of their derivation in references 4-8. The righting moment due to the modified pull-down and line tension loads was then computed as a function of the heel angle. Pure rotation about the 45° diagonal axis was assumed. The calculated high line tension was assumed in the three upwind mooring lines. No additional mooring load was calculated to account for the added lateral drag load as the list angle increased. As a result, the calculated line tensions were lower than actual.

5. COMPUTER PROGRAMS USED

The following are brief descriptions of computer programs used in this analysis.

a. STAAF (Stability Analysis of Arbitrary Forms). Developed by CADCOM, Inc., 1976. This program has options to compute hydrostatic properties and righting arms about any heel axis. The input is offset half-breadths and heights at longitudinally-spaced transverse sections. A trapezoidal integration scheme was used for both station areas and longitudinal integration.

STAAF Anomalies:

(1) Input by station offsets makes it impossible to describe circular cylinders such as columns and truss members exactly. Equivalent rectangular or polygonal cylinders must be used with similar waterplane area and inertia characteristics. Differences in output are negligible.

(2) When a heel axis other than the centerline is described, longitudinal equilibrium is not satisfied. The draft alone is varied for displacement equilibrium. The righting arms may not be representative of the lowest energy condition of the vessel for all types of overturning moments. However, if the unit is constrained to rotate about the non-equilibrium axis by moorings or wind loading, STAAF correctly models the physical conditions. This was the case with the OCEAN RANGER. See the discussion of Figure I.A.

(3) Initial heel normal to the trim axis cannot be input. Consequently, it was impossible to model directly righting arms taken about a 45° diagonal when an initial heel to port or starboard was specified. A separate program was developed for this report to account for the initial TCG offset.

b. WINDHEEL. Developed by 8th Coast Guard District (mmt). A three-dimensional image of the rig is input by directly digitizing profile and plan views. For any combination of draft and trim, initial list, wind azimuth angle (heel axis orientation) and heel angle, the wind overturning moment is calculated. The total moment is calculated by summing the wind pressure drag moments on each component area. The lateral center of resistance is calculated as the centroid of the projected underwater area. A point-to-point integration scheme is used to compute exactly the centroid and area of each projected component area. A full graphic image of the unit is generated for visual verification, as shown in Figure 2.

WINDHEEL Anomalies:

(1) Shielding is not considered. The rig is transparent to the incident wind; therefore downwind areas are not affected by upwind areas. This approximation is only slightly conservative, since the columns and bracing, derrick, and upper hull sides and bottom, which account for 80 % of the total overturning moment, are in reality affected little by the presence of other areas.

(2) Lift forces are ignored. Only lateral drag forces and moments are computed. Lift forces on the upper hull underside reduces the overturning arm by approximately 5% at a heel angle of 20°.

(3) Because the program is based on the existing USCG drill rig stability criteria, the rig is assumed to be drifting downwind and heeling under the influence of the wind. The lateral center of resistance of the underwater projected area is used to find the overturning arm for each area. As discussed in Section 2d., in the case where a rig is moored with above-water fairleaders, such as the OCEAN RANGER, this arm would be less.

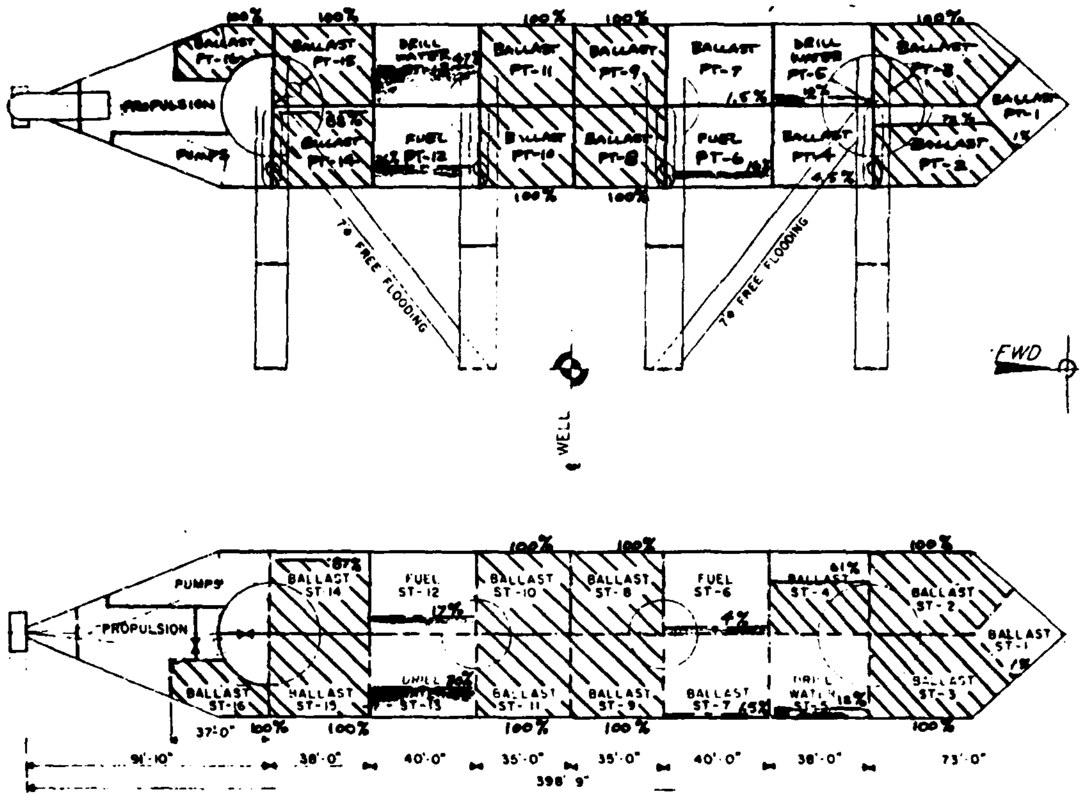


FIGURE 1

2/9/82 BALLAST CONFIGURATION

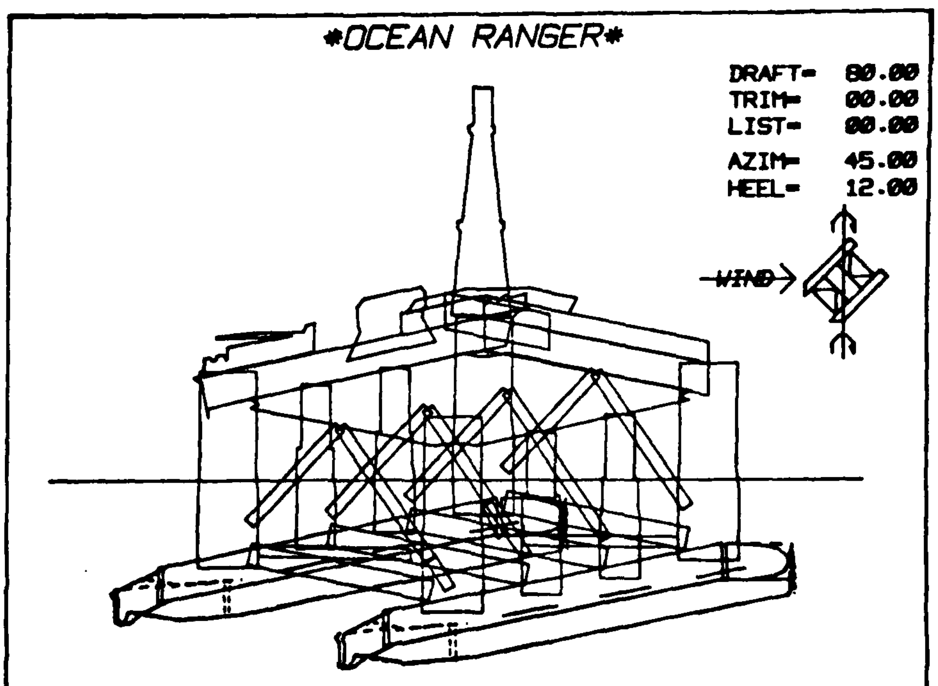


FIGURE 2

6. REFERENCES

1. Weekly Stability Report of MODU OCEAN RANGER dated 9 February 1982

2. Morning Reports of MODU OCEAN RANGER dated 9-14 February 1982

3. Korkut, M. D. and Hebert, E. J. "Presenting in Condensed, Usable Form Equations to Find Anchor Chain Curve", OCEAN INDUSTRY

4. Childers, M. A. "Mooring Systems for Hostile Waters", PETROLEUM ENGINEER, September 1974

5. Childers, M. A. "Environmental Factors Control Station Keeping Methods", PETROLEUM ENGINEER, September 1974

6. Childers, M.A. "The Ultradeep Water Spread Mooring System", PETROLEUM ENGINEER, October 1974

7. Childers, M.A. "Equipment for Handling the Ultradeep Water Spread Mooring System", PETROLEUM ENGINEERING, May 1975

8. Krogstad, I. "New Chain/wire Mooring Systems Meet Challenge of Ultradeep Water", The Oil and Gas Journal, January 17, 1977

9. Preliminary OCEAN RANGER Booklet of Operating Conditions bearing U. S. Coast Guard approval stamp dated 13 December 1979

HULL DIGITIZING:

10. ODECO Dwg., unnumbered, OCEAN RANGER General Configuration from Operating Manual

11. MHI Dwg. No. G-0103, Sheet 3 of 8, Rev. 0 - General Arrangement - Lower Hull Exterior Fitting

WIND HEEL ANALYSIS:

MHI Dwgs. Nos.

12. G-01[illegible] Sheet 3 of 8, Rev. 0 - Lower Hull Stbd. Ext[illegible] Fitting

13. G-0[illegible]t 6 of 8, Rev. 0 - Upper Deck and Drill Flo[illegible]al Arrangement

14. W-0162, Sheet 2 of 4, Rev. A - Hazardous Area Plan, Starboard Elevation

15. W-0162, Sheet 3 of 4, Rev. A - Hazardous Area Plan, Forward Elevation

INTACT STABILITY REVIEW (Original Study)

MHI Dwgs. Nos.

16. 1104, Rev. A - Curves of Form

17. 1105, Sheets 1-5, Rev. 0 - Cross Curves of Stability

18. 1106, Rev. A - Wind Heel Moment Curves

Submitted, 27 May 1982

W. A. HENRICKSON, LT, USCG
Eighth Coast Guard District (mmt)

APPENDIX C

AN EVALUATION OF THE EFFECTS OF THE SEAWAY ON THE MODU OCEAN RANGER IN A SEVERE STORM

AN EVALUATION OF THE EFFECT OF THE SEAWAY ON THE MODU OCEAN RANGER IN A SEVERE STORM.

Prepared by
Marine Technical and Hazardous Materials Division
Office of Merchant Marine Safety
United States Coast Guard

August 1982

For

The Marine Board of Investigation

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INTRODUCTION

The U.S. registered Mobile Offshore Drilling Unit (MODU) OCEAN RANGER sank about 170 nautical miles off the coast of the Canadian Province of Newfoundland in a severe storm on 15 February 1982. See Figure (1). The early morning casualty took the lives of 84 persons. A joint U. S. Coast Guard and National Transportation Safety Board, Marine Board of Investigation was convened on February 19, 1982. The Canadian Government has appointed a Royal Commision to investigate this accident.

The Board requested the Marine Technical and Hazardous Materials Division of the Office of Marine Safety to perform a number of studies. These include:

* Extensive investigation of the stability;
* Effect of the seaway related to flooding of the chain locker;
* Ballast system and pumping capabilities under listing conditions;
* Survival system equipment conditions.

This report provides the results of The Effect of the Seaway Related to Flooding the Chain Locker (second above). It is a static condition study which extends the stability study (first above). It is organized as follows: an explanation of the approach, an explanation of the assumptions which were made, the results, and a list of the tasks requested by the Marine Board along with answers based on the results of the study.

STATEMENT OF THE PROBLEM

To aid the Marine Board in their investigation into the sinking of the OCEAN RANGER, the Office of Merchant Marine Safety was asked to perform some studies related to wave effects (a).

The studies reported here are an extension of a study conducted by the Eighth Coast Guard District (mmt)(b). That report evaluated the static stability of the OCEAN RANGER under a variety of scenarios.

(a) Letter from the Marine Board of Investigation to Chief, Marine Technical and Hazardous Materials Division, dated 28 May 1982.

(b) Henrickson, W.A., "Report on the Stability of the MODU OCEAN RANGER," Eighth Coast Guard District (mmt), 27 May 1982, Board Exhibit 43.

APPROACH

To provide the Board with a credible tool to aid in analysis of the loss of the OCEAN RANGER, a simple approach was chosen to describe wave theory. Numerous assumptions were necessary, but these have all been documented for further review by the Board.

The approach is based on the definition of significant wave height: the average height of the one-third highest waves. In each hour there will be about 360 waves of varying heights. Through many years of studies and full scale measurements the statistical nature of each hour of waves has been quantified. The wave heights follow a so called Rayleigh distribution (c),(d).

In this study the one-third highest waves were divided into six wave groups. The highest wave group was twice the significant wave height. Figure (2) illustrates the distribution of these six wave groups for 30, 35, and 40 foot significant wave heights. The figure shows the quantity and amplitudes (one-half the wave height) of waves per wave group in each significant wave height category over a one hour time period. Table (1) outlines the height and number dimensions of the six wave groups for each of the significant wave heights. These significant wave heights were chosen based on reported actual conditions at the time of the accident (e). See Figure (3).

Figure (4) shows a schematic of the six wave groups that comprise the one-third highest waves for a 35-foot significant wave, poised with the OCEAN EXPRESS at a 15 degree list. This condition was chosen for illustration because it shows the minimum list at which a group of waves boards the upper hull of the OCEAN RANGER in a 35 foot significant wave height condition. In this report, the term "green water occurrence" refers to waves boarding the upper hull of the OCEAN RANGER.

The upper hull of the OCEAN RANGER has three large openings in each of the four columns of the platform for ground tackle chain and cable storage. The total opening area in each column is 93 square feet with a volume below sufficient to retain over one thousand tons of water. Since a green water occurrence would cause at least one of these chain storage lockers to collect a significant amount of water, the primary interest in this study was to determine the time it would take under various static stability conditions to reduce the freeboard to 21.5 feet (measured to main deck where chain locker openings are located). This corresponds to the level at which the bottom of the upper hull would become immersed.

(c) Gran, S., "Statistical Description of Wave Induced Vibratory Stresses in Ships," CG-M-2-81, December 1980, NTIS AD A111186.

(d) Lindemann, K., "Summary of a Course in Shiphandling in Rough Weather," CG-M-7-81, September 1981, NTIS AD A115175.

(e) "Meteorological Report", National Transportation Safety Board, 7 April 1982.

A simple simulation computer program was developed to simulate the effect of green water occurrences under various conditions on the OCEAN RANGER. It operates on the PDP/11-34 computer which is part of the Coast Guard Maneuvering Simulator (f). This program determines the number of green water occurrences in each five minutes on an hour-by-hour basis and outputs freeboard until the 21.5 feet level is reached.

ASSUMPTIONS

1. The analysis was conducted considering only static effects. The effects of heave and roll were neglected.

2. Throughout this report list is used to indicate a combination of heel and trim about the 45 degree axis.

3. Wind effects were not directly considered. The initial angle of list was assumed to be caused by ballast shifting, flooding, or a combination of both. The actual cause of the initial list was not important to this analysis. List was assumed to occur about an axis 45 degrees from the centerline.

4. The simulation was run for a maximum time period of seven hours, or when the bottom of the upper hull entered the water, whichever occurred first.

5. In order for green water to enter the chain locker, it was assumed that the wave amplitude must be at least two feet greater than the freeboard. For a two foot head of water over the chain locker openings with a total area of 93 square feet, approximately five tons of water will enter the chain locker. It was assumed that the deck machinery would restrict the inflow such that a head greater than two feet over the openings would not result in significantly greater flooding for each occurrence of green water. Therefore, it was assumed that for each occurrence of green water with a head of two feet or greater, five tons of water would enter the chain locker and that a head of less than two feet would not result in any flooding.

6. List effects from flooding the chain locker included the effects of the moorings on the righting arm. Values for list angle versus weight in the chain locker were obtained from the stability study of the OCEAN RANGER by the Eighth Coast Guard District. A piecewise linear relationship between list angle and weight of water in the chain locker was used.

(f) Walden, D.A. and Gress, R.K., "A Survey of Coast Guard Simulator Development Research and Simulator Applications," MarSim 81, Kings Point, New York, June 1981.

RESULTS

Figures (5), (6), (7), (8), (9), and (10) show the results of the simulation. These figures plot the freeboard as a function of the local time, starting at 2100 (which is 0030 Greenwich Standard Time) for various initial list angles. When the freeboard is reduced to 21.5 feet, the upper hull is assumed to be immersed, and the simulation is stopped.

As an example of the process, we draw the readers attention to the curve for an initial list angle of 15 degrees in Figure (5). The computer output appears in Table (2). The steady reduction in freeboard before 2320 is caused by two green water occurrences per hour. At 2325, the freeboard has been sufficiently reduced to cause the next wave group (of seven per hour) to enter the chain locker. At 0045 the weight of water in the chain locker has increased to 130 long tons and the freeboard is less than 21.5 feet.

Table (3) outlines the results of the OCEAN RANGER simulation runs. Note that in no case does the final weight in the chain locker go over 205 long tons.

TASKS

The Chairman of the Marine Board requested a response to the following specific tasks. See Attachment (1). The tasks are provided below, with the response and a short explanation based on this study.

Task I

At what static list angle will significant green water begin to enter the forward port column chain pipe and wire trunk openings, and at what angle will the forward starboard column chain pipe and wire trunk openings begin to fill with water.

*A 35 feet significant wave height was used to answer each Task

At an initial list angle of 14.5 degrees and a draft of 80 feet, green water will begin to enter the forward port column chain locker at a rate of two occurrences per hour for five hours. Then, when the chain locker has accumulated 50 tons of water and the freeboard has been reduced to less than 27 feet at that column, the rate of green water occurrences per hour increases to seven. Consequently, the freeboard is reduced more rapidly and the bottom of the upper hull is submerged in just over an hour and 45 minutes later with 160 tons of water in the chain locker.

At an initial list angle of 12.5 degrees and a draft of 85 feet, the forward port column will fill at a rate of two green water occurrences per hour. The chain locker accumulated 70 tons of water after seven hours. The freeboard is never reduced enough in that amount of time to cause the rate of green water occurrences to increase, therefore, the simulation ended after seven hours at a final freeboard of 26.57.

At an initial list angle of 12.5 degrees and a draft of 90 feet, green water will begin to enter the forward port column chain locker at a rate of seven occurrences per hour. After only one hour and 25 minutes the chain locker has accumulated 80 tons of water and the bottom of the upper hull is submerged.

At an initial list angle of 9.5 degrees and a draft of 93 feet, the forward port column will fill at a rate of two green water occurences per hour for five hours. Then, when there are 50 tons of water in the chain locker, the freeboard is reduced to 26.57 feet and the rate of green water occurrences is increased to seven. The upper hull bottom becomes immersed one hour and 45 minutes later with a total of 160 tons of water in the chain locker.

It is beyond the scope of the computer program used in this study to calculate the OCEAN RANGER's reactions once the bottom of the upper hull is submerged. Therefore, the second part of Task I must be left unanswered in this report.

Task II

How long would it take to fill the forward port column chain locker using the initial static list angle determined in Task I?

The forward port dolumn chain locker would never fill using the initial static list angles determined in Task I. The most water accumulated in the chain locker at any of the initial list angles used in Task I is 160 long tons or 16 percent of the total volume of space. In each case either the freeboard was reduced to 21.5 feet and the simulaticn stopped because the upper hull became immersed, or the simulation stopped because the seven hour time limit was reached.

Task III

Assuming the port column chain locker filled within two hours, what would the initial static list angle have been?

The port column chain locker never filled according to the simulations conducted, however it could be observed that the OCEAN RANGER upper hull became submerged in less than two hours under the following conditions with the chain locker only partially filled.

For an initial 80 foot draft, an initial list angle of 15.5 degrees would result in immersion of the upper hull in one hour and 45 minutes. The weight of water in the chain locker was 105 long tons (10 percent of total capacity).

For an initial 85 foot draft, an initial list angle of 14.0 degrees would result in immersion of the upper hull in one hour and 30 minutes. The weight of water in the chain locker was 90 long tons (9 percent of total capacity).

For an initial 90 foot draft, an initial list angle of 12.5 degrees would result in immersion of the upper hull in one hour and 25 minutes. The weight of water in the chain locker was 80 long tons (8 percent of total capacity).

For an initial 95 foot draft, an initial list angle of 10.5 degrees would result in immersion of the upper hull in one hour and 40 minutes. The weight of water in the chain locker was 105 long tons (10 percent of total capacity).

Task IV

Assuming a 12 degree initial list angle, how long would it take to fill the port column chain locker?

An initial list of 12 degrees would not result in significant green water in the vicinity of the anchor windlass for either the 80, 85 or 90 feet drafts. There would be significant green water in the vicinity of the anchor windlass for the 80 feet draft at an initial list angle of 12 degrees if a 42 siginifiant wave height was assumed.

For the 95 foot draft an initial list of 12 degrees would result in immersion of the upper hull in 5 minutes with only 10 tons of water in the chain locker.

The port chain locker never fills in a 35 foot significant wave height with an initial list of 12 degrees.

REFERENCES

Gran, S., "Statistical Description of Wave Induced Vibratory Stresses in Ships," CG-M-2-81, December 1980, NTIS AS A111186.

Henrickson, W. A., "Report on the Stability of the MODU OCEAN RANGER," Eighth Coast Guard District (mmt), 27 May 1982, Board Exhibit 43.

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Lindemann, K., "Summary of a Course in Shiphandling in Rough Weather," CG-M-7-81, September 1981, NTIS AS A115175.

"Meteorological Report," National Trasnsportation Safety Board, 7 April 1982.

Walden, D. A. and Gress, R. K., "A Survey of Coast Guard Simulator Development Research and Simulator Applicatons," MarSim81, Kings Point, New York, June 1981

MHI DWGS Nos.
F-4100 Anchor Handling Arrgt. 1/14
F-4100 Anchor Handling Arrgt. 5/14

APPENDIX

Figure 1 is a location drawing showing the three MODUs off the coast of Newfoundland.

Figure 2 shows the Rayleigh distribution of the highest one-third waves in three different significant heights. Note that the number of waves in each group increases rapidly with decreasing group height.

Figure 3 provides the wave conditions for the period from 14 February up to the time of the casualty. The waves were recorded from wave rider buoys near the OCEAN RANGER and the ZAPATA UGLAND.

Figure 4 is a drawing of the OCEAN RANGER at a nominal 15 degree list. The wave heights for the one-third highest waves in a 35 foot significant wave condition have been drawn to scale next to the location of the forward chain lockers.

Figure 5 graphically shows results of the simulator runs for an 80 foot initial draft in a 35 foot significant wave height condition. Curves have been drawn for each initial list angle.

Figure 6 illistrates the sensitivity of the assumed wave conditions on the OCEAN RANGER at an initial draft of 80 feet and initial list of 15 degrees.

Figure 7 is similar to Figure 5, but with an initial draft of 85 feet rather than 80 feet.

Figure 8 is similar to Figure 5, but with a 40 foot significant wave height rather than 35 feet

Figure 9 is similar to Figures 5 and 7, but with an initial draft of 90 feet.

Figure 10 is similar to Figures 5, 7 and 9, but with an initial draft of 95 feet.

Table 1 gives the mean heights, and the range of amplitudes for the six wave groups for the three significant waves heights.

Table 2 is a sample simulation for the 15 degree initial trim angle at a draft of 80 feet.

Table 3 provides the results of the simulation. It includes the time for the upper hull to immerse, and the final trim conditions at the end of each simulation. It should be noted that the greatest weight of water in the chain locker was just over 200 long tons.

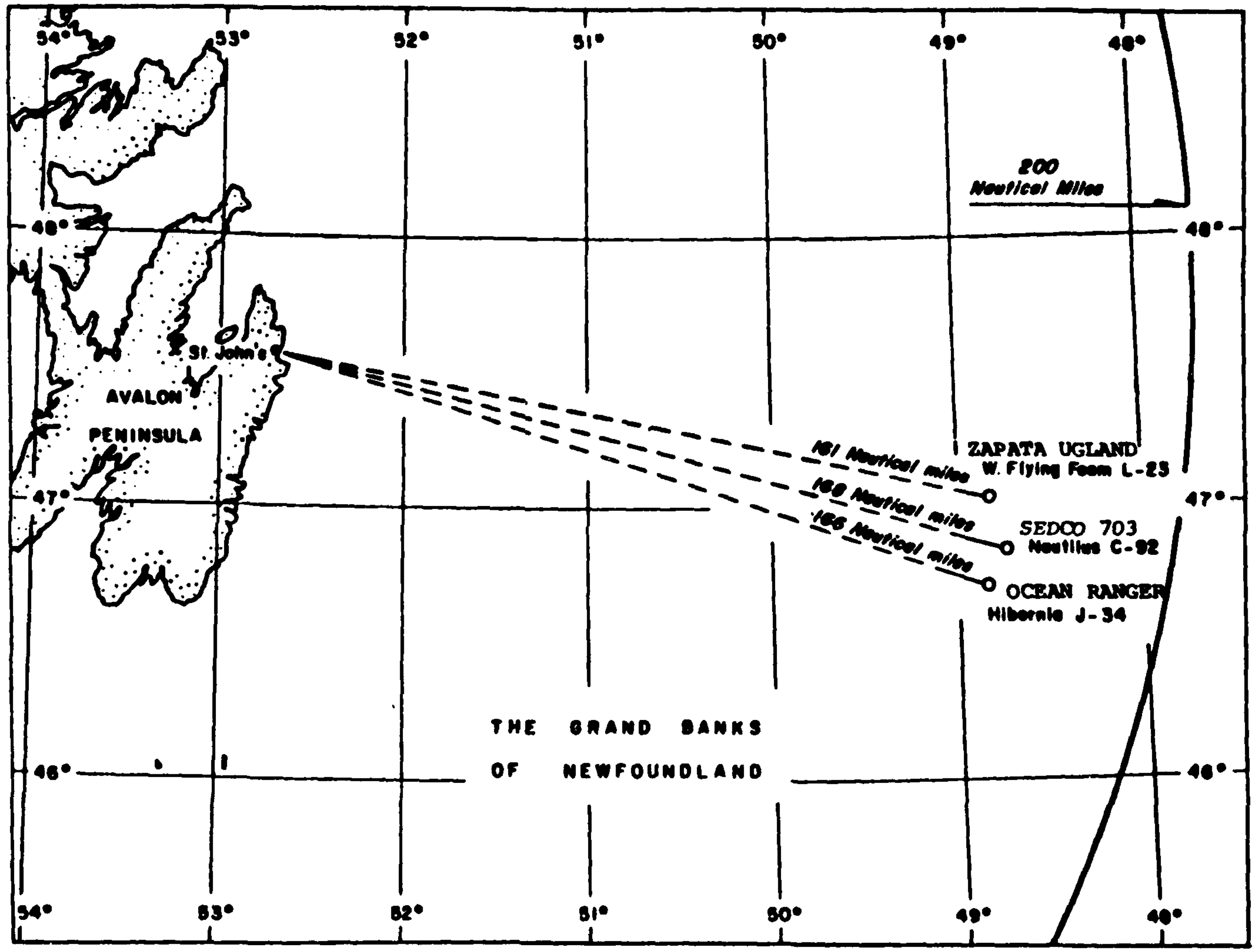

FIG. 1

LOCATION OF PLATFORMS OFF NEWFOUNDLAND, FEBRUARY 1982

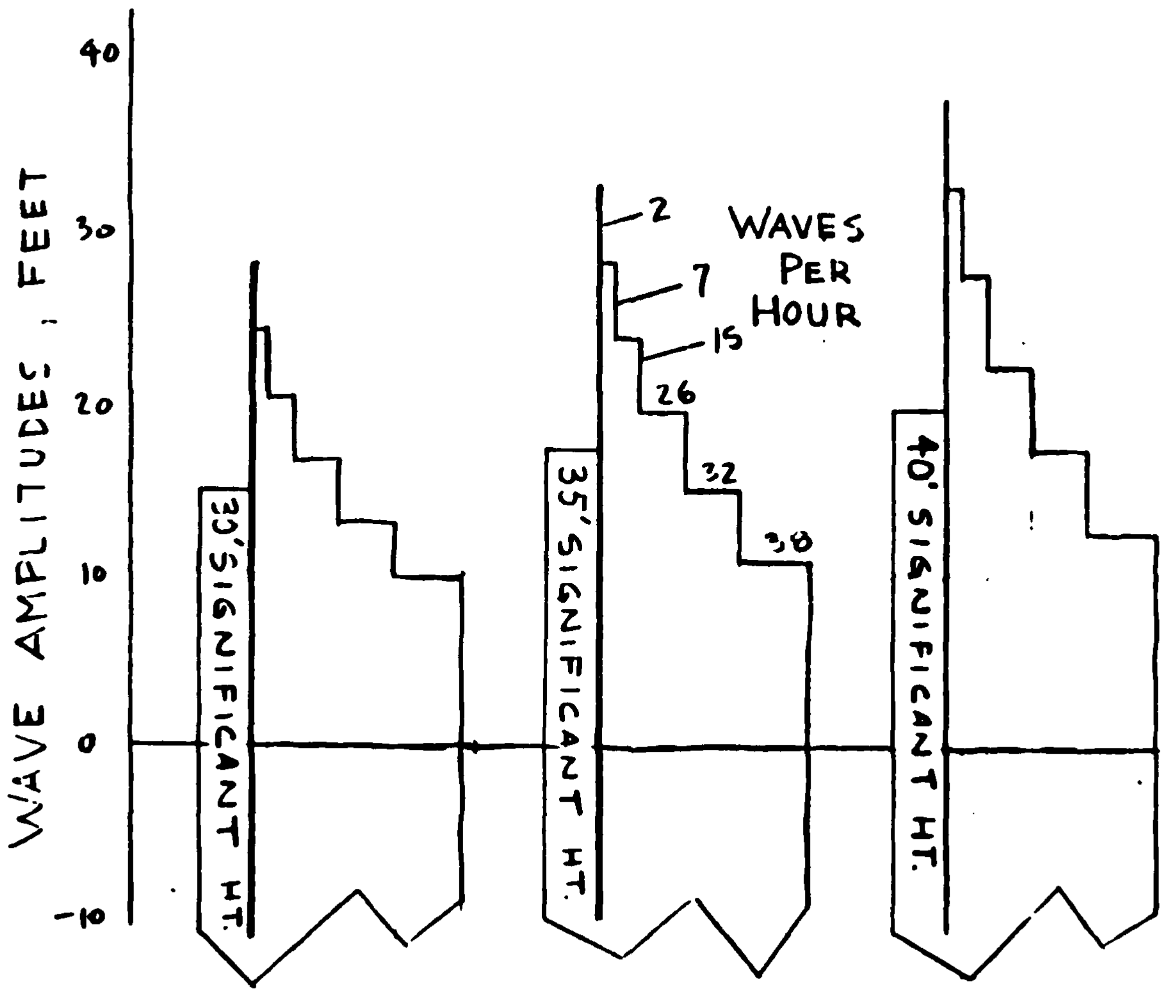

FIG. 2 DISTRIBUTION OF THE HIGHEST ONE-THIRD WAVES INTO SIX WAVE GROUPS FOR THREE SIGNIFICANT WAVE HEIGHTS

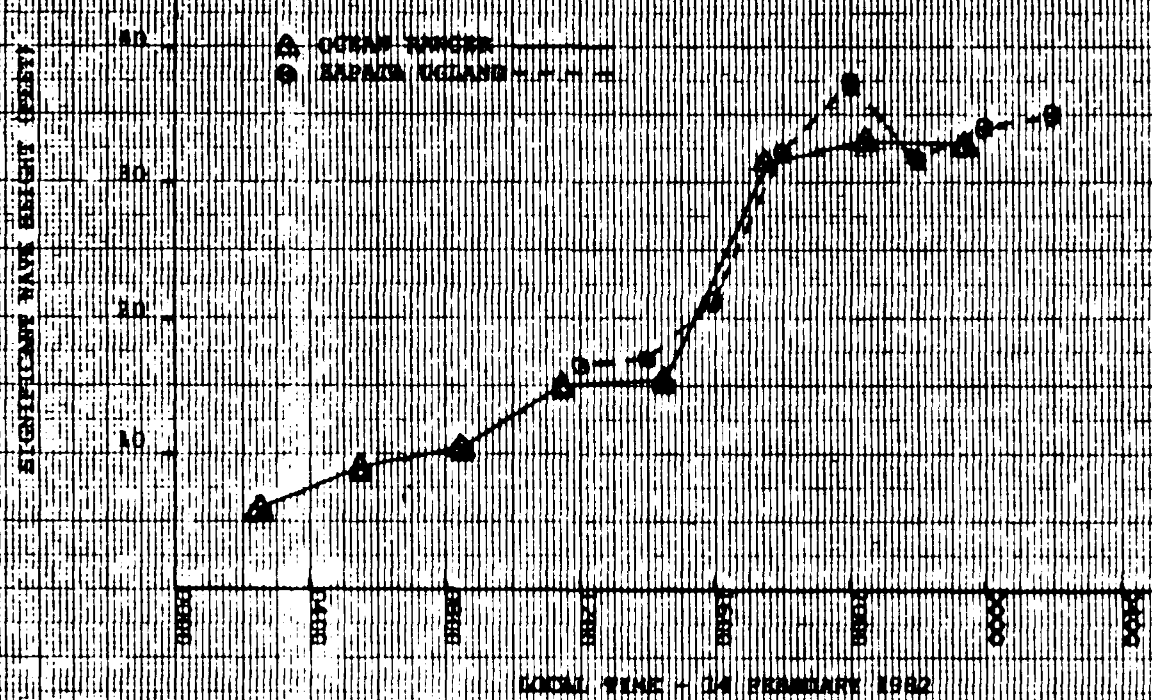

FIG. 3

REPORTED WAVE CONDITIONS FOR 14 - 15 FEBRUARY 1982 FROM "METEOROLOGICAL REPORT", NATIONAL TRANSPORTATION SAFETY BOARD, 7 APRIL 1982

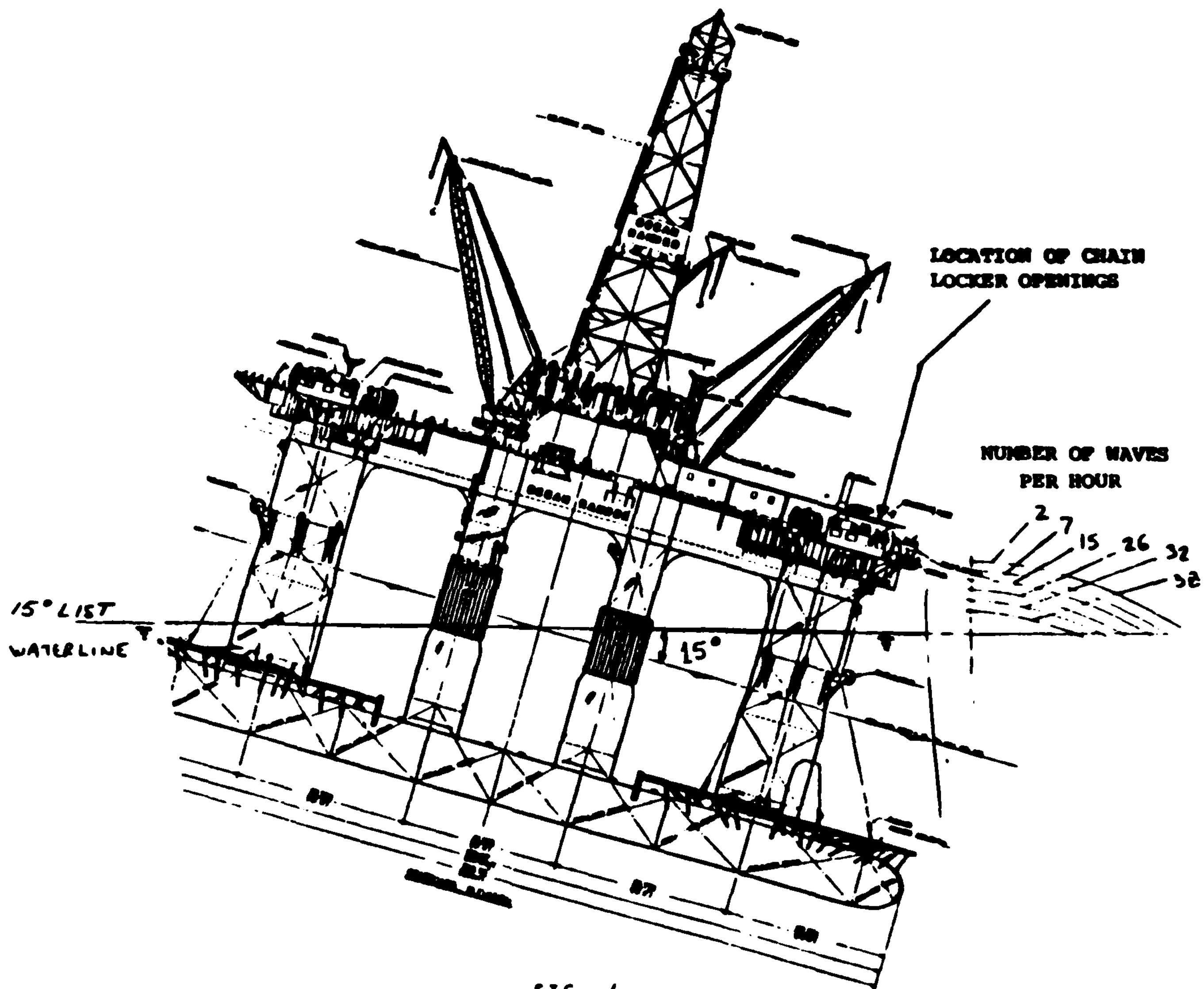

FIG. 4

SIX WAVE GROUPS COMPARED TO THE OCEAN RANGER AT 80 FEET DRAFT AND A NOMINAL 15 DEGREE LIST

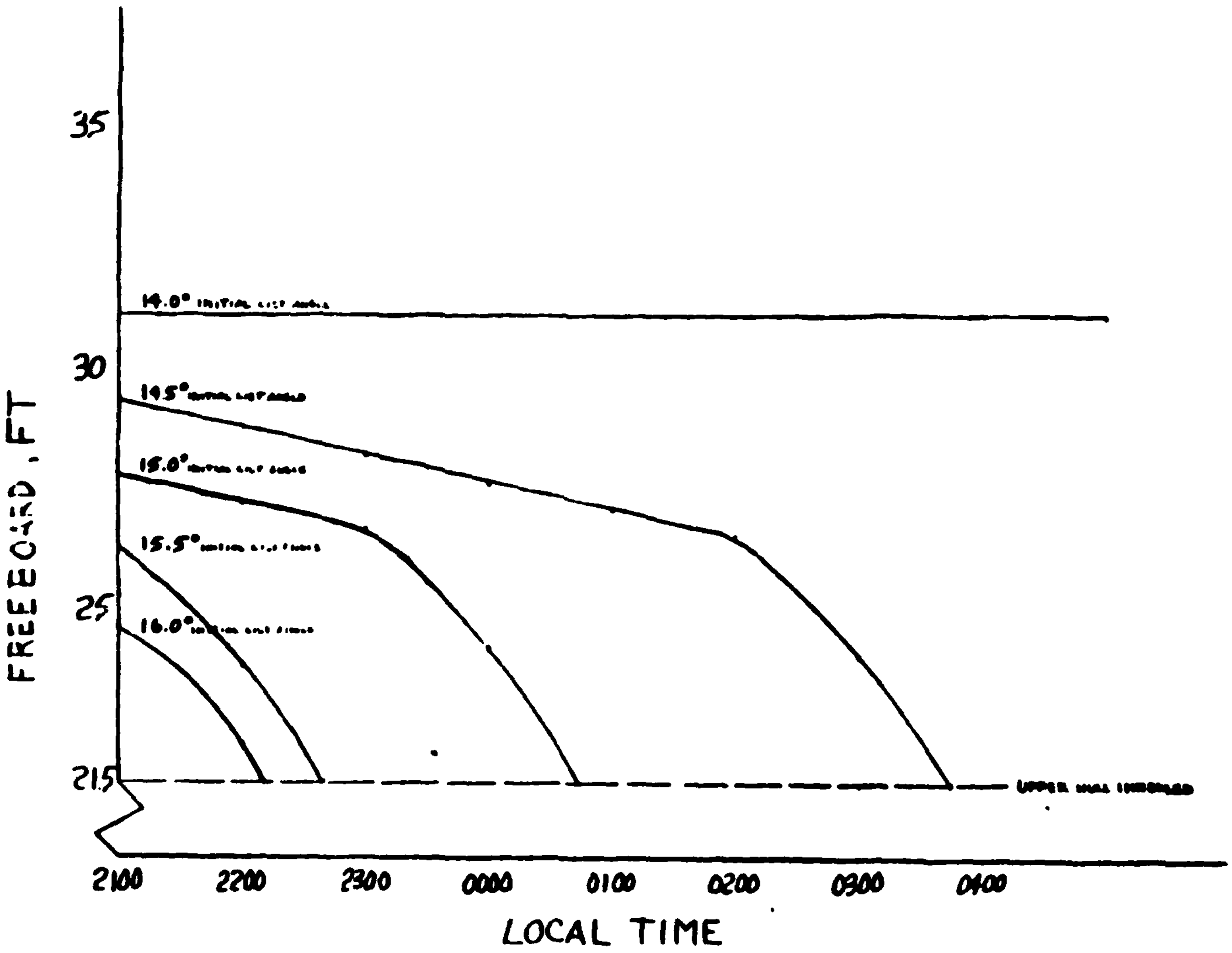

FIG. 5 COMPARISON OF FREEBOARD WITH TIME FOR 80 FEET DRAFT IN A 35 FEET SIGNIFCANT WAVE HEIGHT

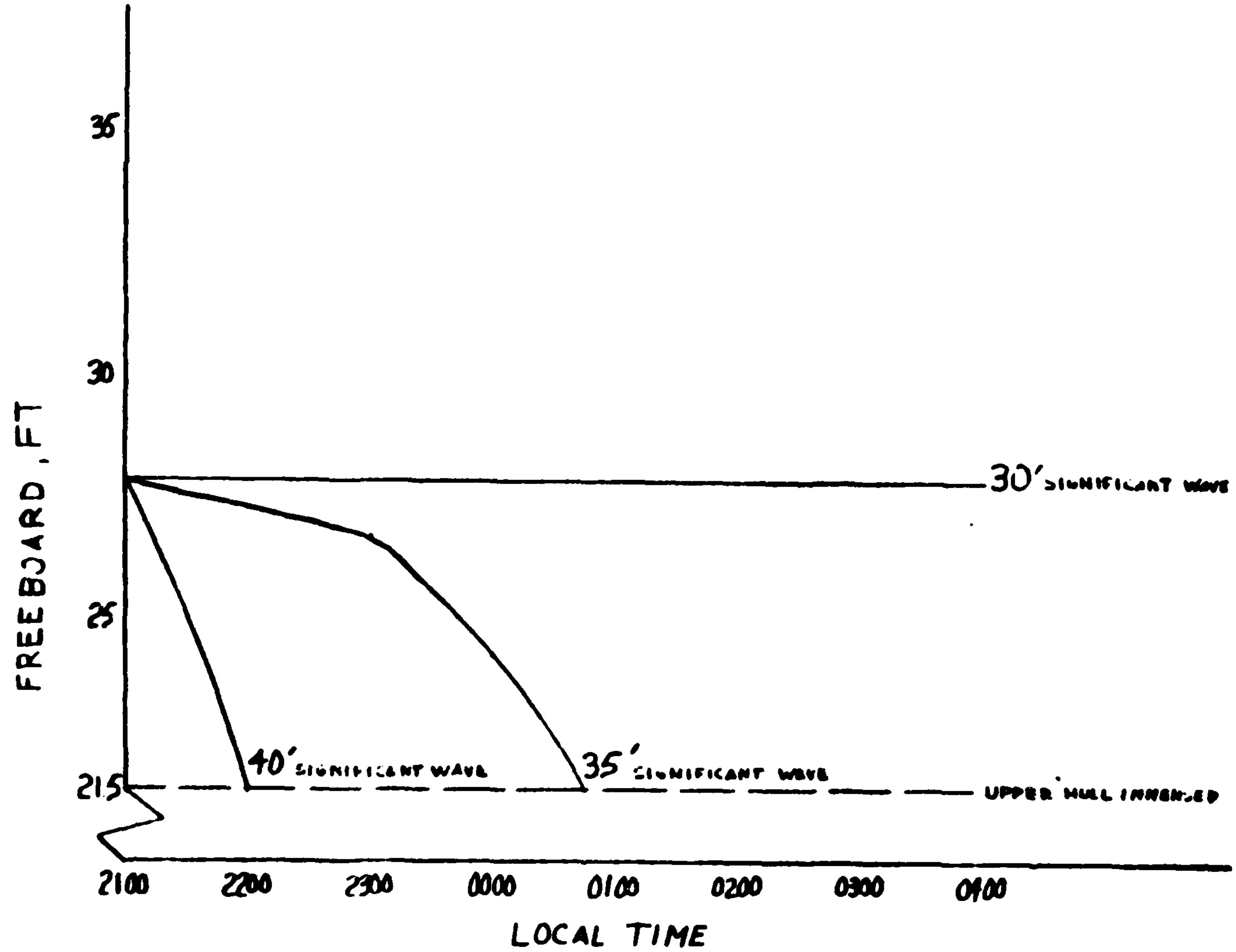

FIG. 6 COMPARISON OF FREEBOARD WITH TIME IN THREE DIFFERENT WAVE CONDITIONS AT A 15 DEGREE INITIAL LIST ANGLE

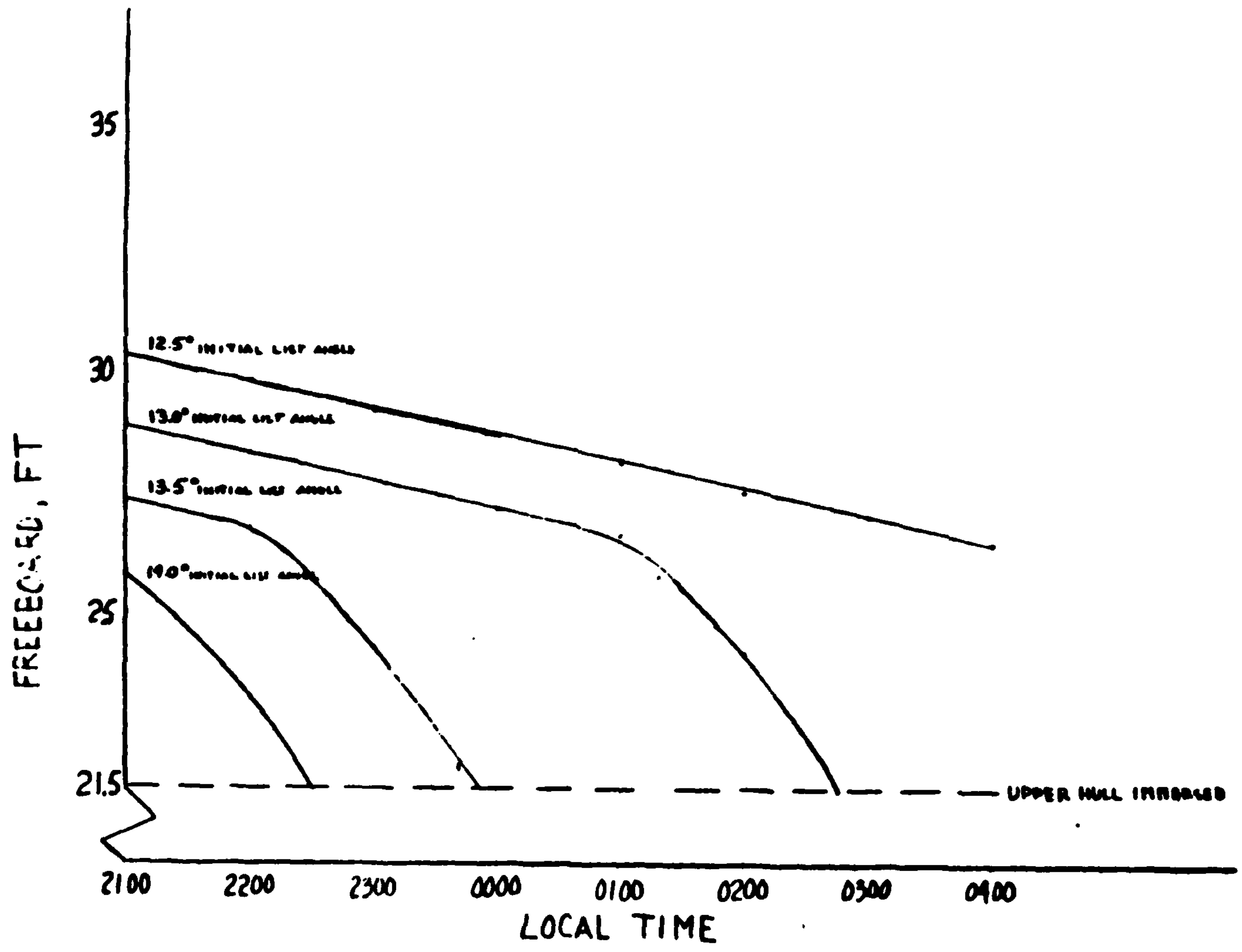

FIG. 7 COMPARISON OF FREEBOARD WITH TIME FOR 85 FEET DRAFT IN A 35 FEET SIGNIFICANT WAVE HEIGHT

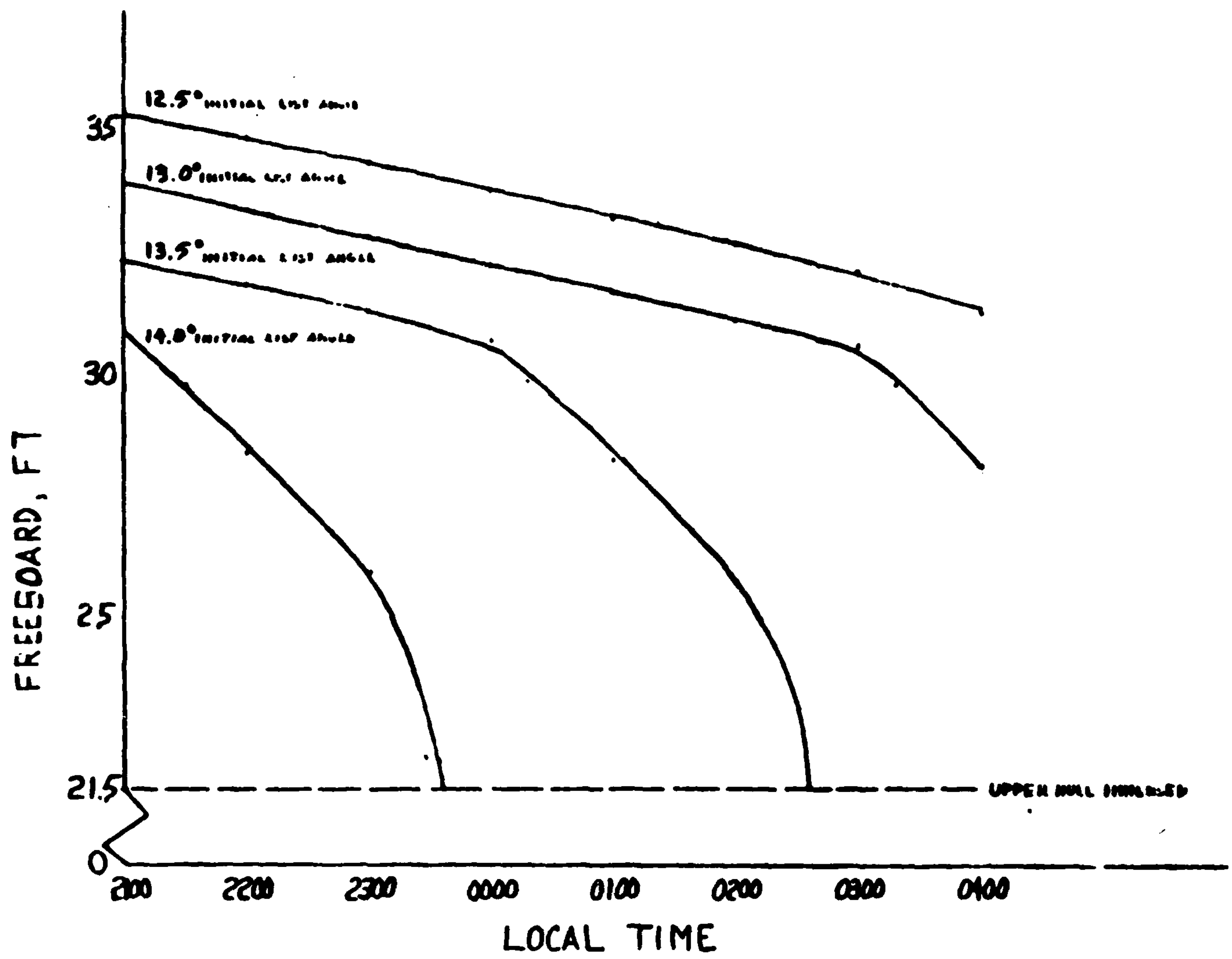

FIG. 8 COMPARISON OF FREEBOARD WITH TIME FOR 80 FEET DRAFT IN A 40 FEET SIGNIFICANT WAVE HEIGHT

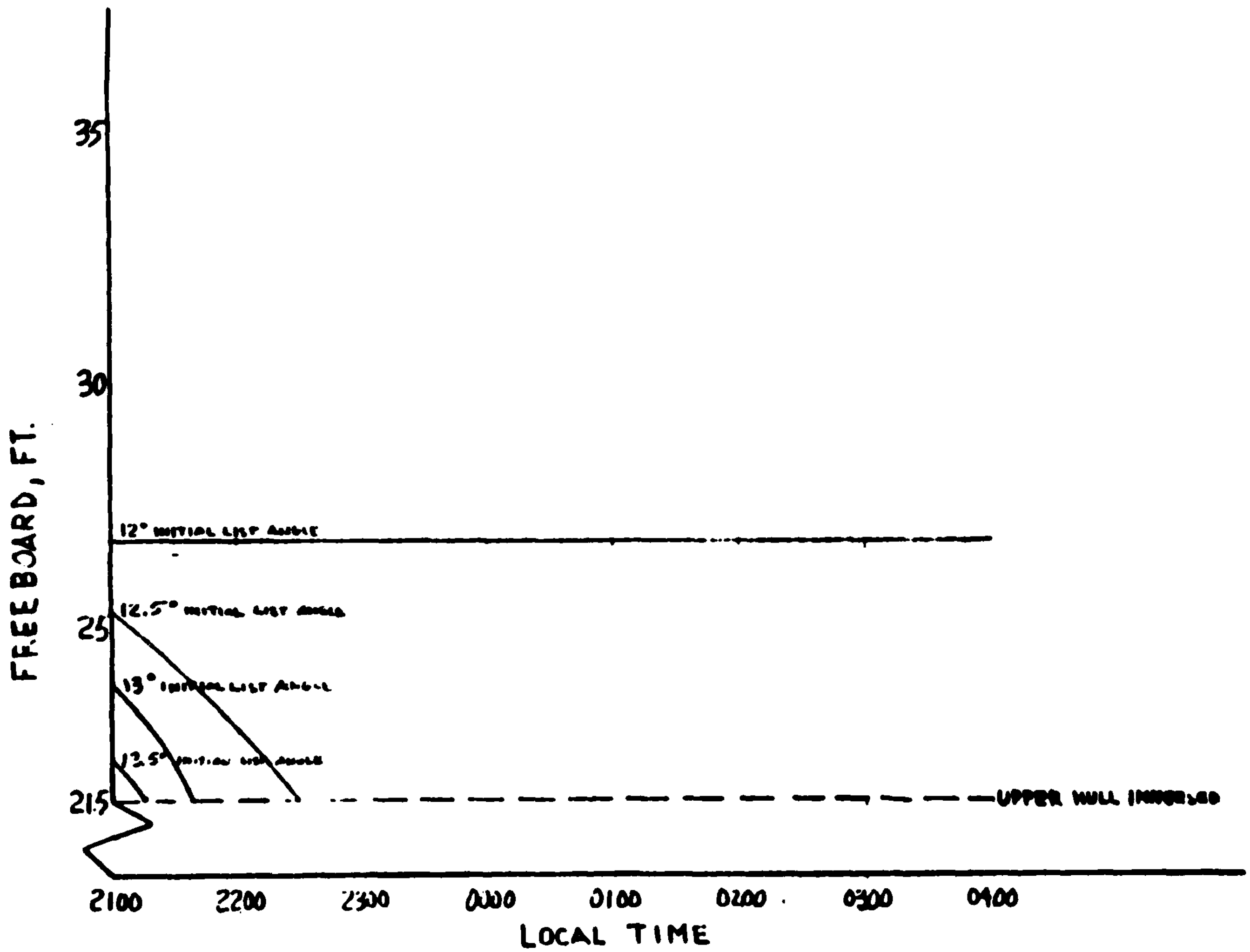

FIG. 9 COMPARISON OF FREEBOARD WITH TIME FOR 90 FEET DRAFT IN A 35-FEET SIGNIFICANT WAVE HEIGHT

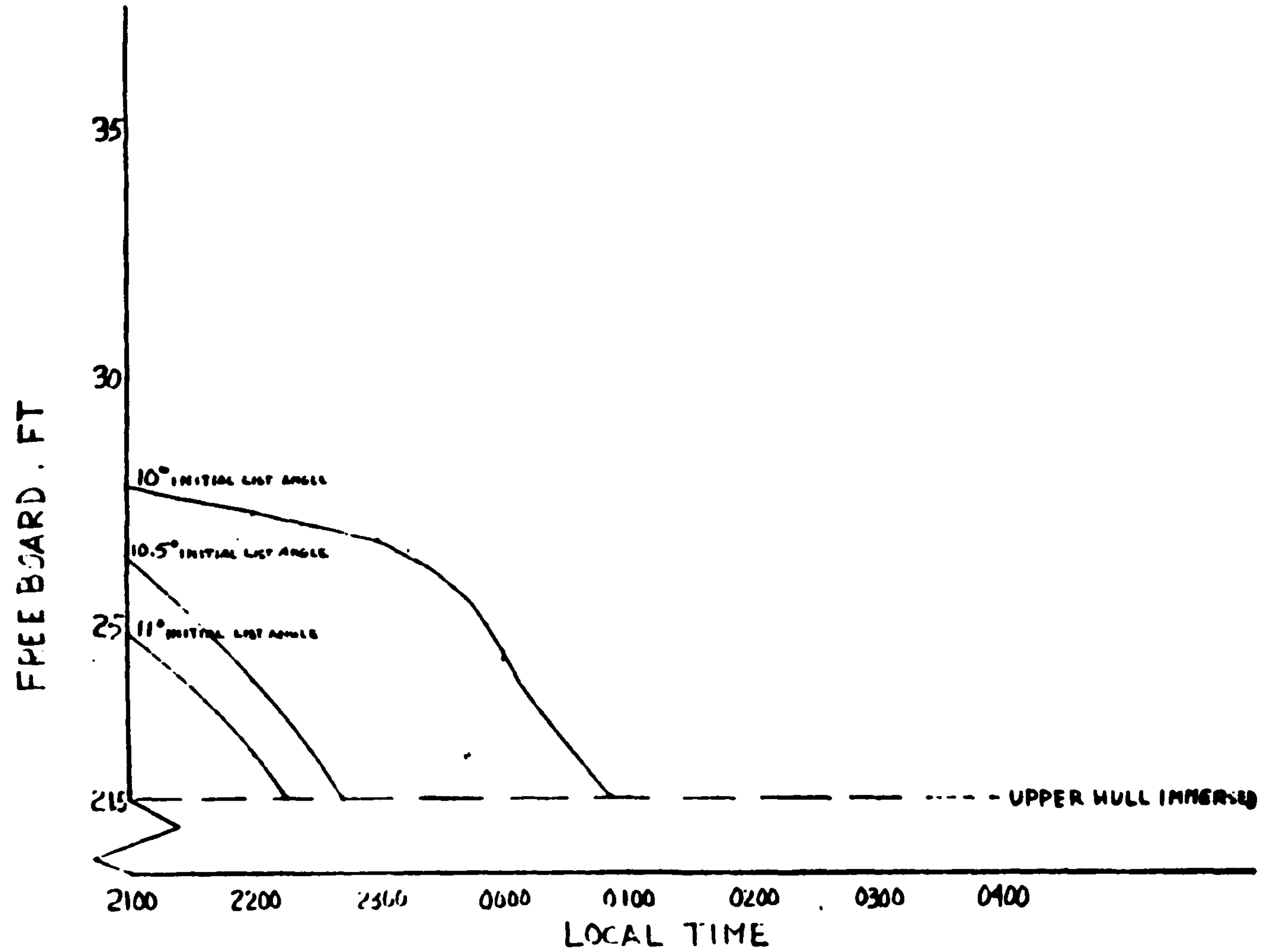

FIG. 10 COMPARISON OF FREEBOARD WITH TIME FOR 95 FEET DRAFT IN A 35 FEET SIGNIFICANT WAVE HEIGHT

TABLE 1

WAVE STATISTICS BASED ON THE SIGNIFICANT HEIGHT

30 FT SIGNIFICANT HEIGHT — **10 SEC. AVERAGE PERIOD**

MEAN HEIGHT	NO.	RANGE: HEIGHTS		RANGE: AMPLITUDES	
56.25	2	52.50	60.00	26.25	30.00
48.75	7	45.00	52.50	22.50	26.25
[illegible]	15	37.50	45.00	18.75	22.50
33.75	26	30.00	37.50	15.00	18.75
26.25	32	22.50	30.00	11.25	15.00
18.75	38	15.00	22.50	7.50	11.25

35 FT SIGNIFICANT HEIGHT — **10 SEC. AVERAGE PERIOD**

MEAN HEIGHT	NO.	RANGE: HEIGHTS		RANGE: AMPLITUDES	
65.62	2	61.25	70.00	30.63	35.00
56.88	7	52.50	61.25	26.25	30.63
48.13	15	43.75	52.50	21.87	26.25
39.38	26	35.00	43.75	17.50	21.87
30.63	32	26.25	35.00	13.13	17.50
21.87	38	17.50	26.25	8.75	13.13

40 FT SIGNIFICANT HEIGHT — **10 SEC. AVERAGE PERIOD**

MEAN HEIGHT	NO.	RANGE: HEIGHTS		RANGE: AMPLITUDES	
75.00	2	70.00	80.00	35.00	40.00
65.00	7	60.00	70.00	30.00	35.00
55.00	15	50.00	60.00	25.00	30.00
45.00	26	40.00	50.00	20.00	25.00
35.00	32	30.00	40.00	15.00	20.00
25.00	38	20.00	30.00	10.00	15.00

TABLE 2

SAMPLE SIMULATION RUN

02 AUG 8[illegible]

WAVE STATISTICS BASED ON THE SIGNIFICANT HEIGHT

	SIGNIFICANT (FT)	AVERAGE PERIOD (SEC)
	35.00	10.00

MEAN HEIGHT NO. RANGE: HEIGHTS, AMPLITUDES

MEAN HEIGHT	NO.				
65.63	2	61.25	70.00	30.63	35.00
56.88	7	52.50	61.25	26.25	30.63
48.13	15	43.75	52.50	21.87	26.25
39.38	26	35.00	43.75	17.50	21.87
30.63	32	26.25	35.00	13.13	17.50
21.87	38	17.50	26.25	8.75	13.13
34.05	120	17.50	70.00	8.75	35.00

HRS.MIN.SEC	DRAFT	LIST	FRWRD	DISPL	LOCKER	GR WATER
21. 0.00	80.00	15.00	27.83	38940.0	0.0	
21. 5.00	80.00	15.00	27.83	38940.0	0.0	0
21.10.00	80.00	15.00	27.83	38940.0	0.0	0
21.15.00	80.03	15.08	27.55	38945.0	5.0	1
21.20.00	80.06	15.16	27.28	38950.0	10.0	1
21.25.00	80.06	15.16	27.28	38950.0	10.0	0
21.30.00	80.06	15.16	27.28	38950.0	10.0	0
21.35.00	80.06	15.16	27.28	38950.0	10.0	0
21.40.00	80.06	15.16	27.28	38950.0	10.0	0
21.45.00	80.06	15.16	27.28	38950.0	10.0	0
21.50.00	80.06	15.16	27.28	38950.0	10.0	0
21.55.00	80.06	15.16	27.28	38950.0	10.0	0
21.60.00	80.06	15.16	27.28	38950.0	10.0	0
22. 5.00	80.06	15.16	27.28	38950.0	10.0	0
22.10.00	80.06	15.16	27.28	38950.0	10.0	0
22.15.00	80.08	15.24	27.00	38955.0	15.0	1
22.20.00	80.11	15.32	26.73	38960.0	20.0	1
22.25.00	80.11	15.32	26.73	38960.0	20.0	0
22.30.00	80.11	15.32	26.73	38960.0	20.0	0
22.35.00	80.11	15.32	26.73	38960.0	20.0	0
22.40.00	80.11	15.32	26.73	38960.0	20.0	0
22.45.00	80.11	15.32	26.73	38960.0	20.0	0
22.50.00	80.11	15.32	26.73	38960.0	20.0	0
22.55.00	80.11	15.32	26.73	38960.0	20.0	0
22.60.00	80.11	15.32	26.73	38960.0	20.0	0
23. 5.00	80.11	15.32	26.73	38960.0	20.0	0
23.10.00	80.11	15.32	26.73	38960.0	20.0	0
23.15.00	80.14	15.40	26.45	38965.0	25.0	1
23.20.00	80.17	15.49	26.17	38970.0	30.0	1
23.25.00	80.20	15.57	25.90	38975.0	35.0	1
23.30.00	80.23	15.65	25.62	38980.0	40.0	1
23.35.00	80.25	15.73	25.34	38985.0	45.0	1
23.40.00	80.28	15.81	25.07	38990.0	50.0	1
23.45.00	80.31	15.89	24.79	38995.0	55.0	1
23.50.00	80.34	15.97	24.51	39000.0	60.0	1
23.55.00	80.37	16.05	24.23	39005.0	65.0	1
23.60.00	80.37	16.05	24.23	39005.0	65.0	0
0. 5.00	80.39	16.13	23.96	39010.0	70.0	1
0.10.00	80.42	16.22	23.68	39015.0	75.0	1
0.15.00	80.45	16.30	23.40	39020.0	80.0	1
0.20.00	80.48	16.38	23.12	39025.0	85.0	1
0.25.00	80.51	16.46	22.84	39030.0	90.0	1
0.30.00	80.53	16.54	22.57	39035.0	95.0	1
0.35.00	80.56	16.62	22.29	39040.0	100.0	1
0.40.00	80.59	16.70	22.01	39045.0	105.0	1
0.45.00	80.73	17.11	20.61	39070.0	130.0	5

UPPER HULL IS NOW IN THE WATER

* * END OF SIMULATION * *

```
000480             27, "Design ...............",                      :
000490             28, "Length in feet........",                      :
000500             29, "Gross tons ...........",                      :
000501             16, "Year vsl was built ...",                      :
000502             99, "EOD"
000520Z70:
000530    RESTORE          /*Return data pointer to first item in list.*/
000540    INIT (HEX(20)) STR(KEYMASK$,I,(32 - I))    /*Fill with spaces*/
000550    END                                                  /*Done!*/
```

TABLE 3

Results of OCEAN RANGER Computer Simulation Runs

Run Number	Significant Wave Height (ft)	Initial Draft (ft)	Initial List (deg)	Final Draft (ft)	Final List (deg)	Final Freeboard (ft)	Weight in Chain Locker (long tons)	Duration of Simulation (hrs:min)
1	35	80	14.0	80.00	14.00	31.00	0	7:00
2	35	80	14.5	80.90	17.09	20.48	160	6:45
3	35	80	15.0	80.73	17.11	20.60	130	3:45
4	35	80	15.5	80.59	17.20	20.45	105	1:40
5	35	80	16.0	80.37	17.05	21.14	65	1:10
6	30	80	15.0	80.00	15.00	27.83	0	7:00
7	35	80	15.0	80.73	17.11	20.61	130	6:45
8	40	80	15.0	80.70	17.02	20.89	125	1:00
9	35	85	12.5	85.39	13.63	26.57	70	7:00
10	35	85	13.0	85.84	15.43	26.67	150	5:45
11	35	85	13.5	85.73	15.61	20.24	130	1:50
12	35	85	14.0	85.51	15.46	20.92	90	1:30
13	40	80	12.5	80.39	13.63	31.57	70	7:00
14	40	80	13.0	80.59	14.70	28.15	105	7:00
15	40	80	13.5	81.15	17.00	20.51	205	5:35
16	40	80	14.0	80.99	16.84	21.20	175	2:35
17	35	90	12.0	90.00	12.00	26.87	0	7:00
18	35	90	12.5	90.45	13.55	21.03	80	1:25
19	35	90	13.0	90.34	13.57	21.61	60	0:40
20	35	90	13.5	90.14	13.90	21.01	25	0:15
21	35	95	10.0	95.79	12.27	20.27	140	3:50
22	35	95	10.5	95.59	12.20	20.67	105	1:40
23	35	95	11.0	95.39	12.13	21.06	70	1:15

APPENDIX D

OCEAN RANGER CHAIN LOCKER FLOODING IN SEVERE WAVES

DTNSRDC/SPD-1069-01

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Bethesda, Md. 20084

OCEAN RANGER CHAIN LOCKER FLOODING IN SEVERE WAVES

By

Young S. Hong

and

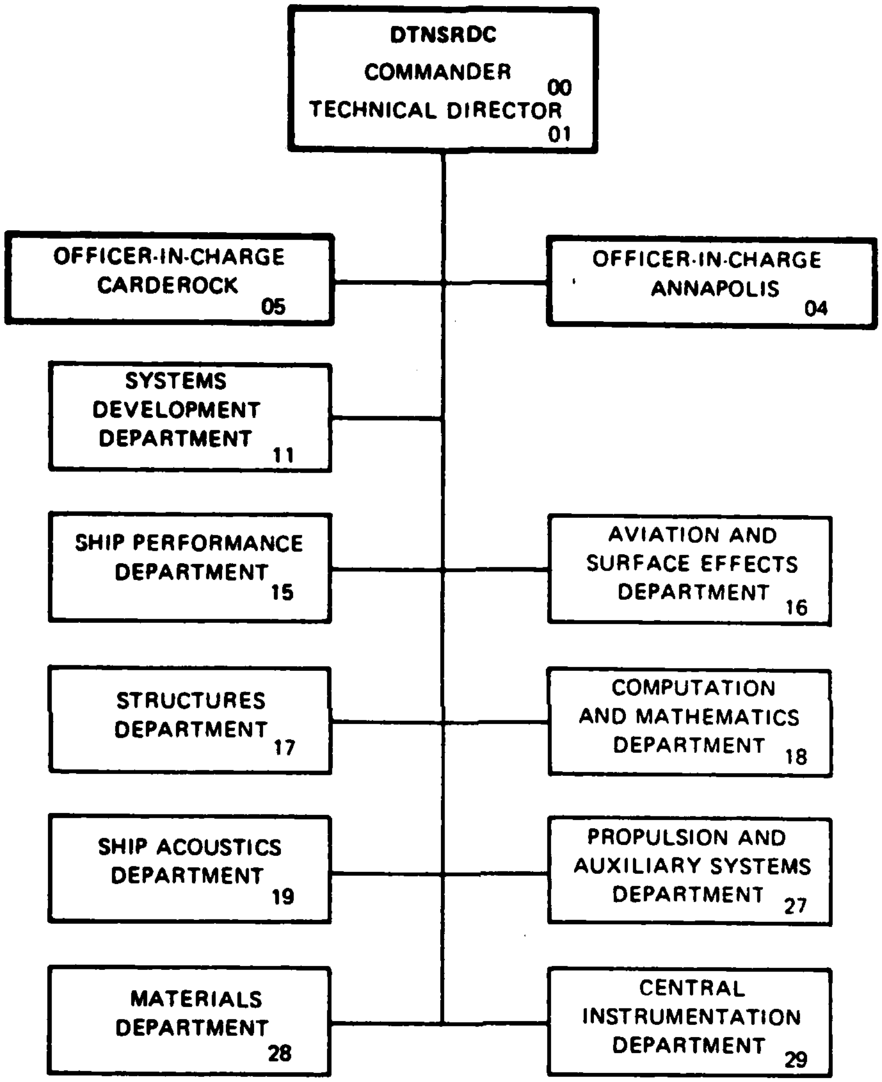
Alvin Gersten

Ship Performance Department

January 1983 DTNSRDC/SPD-1069-01

OCEAN RANGER CHAIN LOCKER FLOODING IN SEVERE WAVES

MAJOR DTNSRDC ORGANIZATIONAL COMPONENTS



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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Drilling Platforms; OCEAN RANGER Capsize; Drilling Platform Stability; Drilling Platform Motions

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A computer program has been used to determine motions for OCEAN RANGER drilling platform which capsized and sank off the coast of St. Johns, Newfoundland on 15 February 1982. The purpose of the investigation was to calculate the time required for waves that impinged on the upper deck to fill the forward, port chain locker. The water could enter the locker through chain pipes and wire trunks that extended to the upper deck. It is thought that such flooding contributed to the capsizing. The results of the investigation show that for the wave conditions existing at the time of the sinking, the maximum time

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BIOGRAPHICAL SKETCH OF AUTHORS

Dr. Hong received his Ph.D. degree in Naval Architecture (Hydrodynamics) from the University of California, Berkeley. Prior to his current employment as a Senior Project Manager with the Ship Performance Department of the David Taylor Naval Ship R&D Center (DTNSRDC), he held several positions as a Naval Architect at shipyards abroad, and was employed by a private consulting firm. He is a member of the Society of Naval Architects and Marine Engineers.

Mr. Gersten received a Bachelor of Science degree from the City University of New York and a Bachelor of Mechanical Engineering degree from the George Washington University. He has also done graduate work in engineering at the latter university. He is a Senior Project Manager at DTNSRDC specializing in ship dynamics.

NOTATION

DA	double amplitude
DTNSRDC	David Taylor Naval Ship R&D Center
$\bar{H}$	average wave height
$\bar{H}_{1/3}$	average of the one-third highest (significant) wave heights
$\bar{H}_{1/10}$	average of the one-tenth highest wave heights
$\bar{H}_{1/100}$	average of the one-hundredth highest wave heights
H_{MIN}	smallest wave height which will produce chain locker flooding
RM	relative motion

ABSTRACT

A computer program has been used to determine motions for the OCEAN RANGER drilling platform which capsized and sank off the coast of St. Johns, Newfoundland on 15 February 1982. The purpose of the investigation was to calculate the time required for waves that impinged on the upper deck to fill the forward, port chain locker. The water could enter the locker through chain pipes and wire trunks that extended to the upper deck. It is thought that such flooding contributed to the capsizing. The results of the investigation show that for the wave conditions existing at the time of the sinking, the maximum time required to fill the locker is approximately 22.5 minutes when the platform list angle is 17.4 deg. If the list angle were 15 deg or less, and the draft 80 ft (24.4 m), frequent water entry would not have occurred.

ADMINISTRATIVE INFORMATION

The work described herein was performed for the United States Coast Guard (USCG), Office of Merchant Marine Safety. Funding was provided by the USCG under Work Unit Number 1562-203.

BACKGROUND

The mobile offshore drilling unit (MODU) OCEAN RANGER capsized and sank about 170 nautical miles off the coast of St. Johns, Newfoundland on 15 February 1982. The sinking caused the loss of 84 lives. The Commandant of the Coast Guard convened a Marine board of investigation which is seeking information concerning downflooding into the OCEAN RANGER's chain lockers since this may have been a factor contributing to the sinking.

The OCEAN RANGER was approximately 399 ft. (121.6 m) in overall length at the lower hulls; the overall beam to the outer edges of the lower hulls was about 262 ft. (79.9 m). Figure 1 shows a profile view of the platform, with the chain locker region cross-hatched. Some calculations were done previously by the Office of Merchant Marine Safety, U.S. Coast Guard to determine conditions (eg., static list angle, wave height) for the inception of chain locker flooding, and length of time required to fill the chain locker[1]*. This earlier investigation did not consider the motions of the platform in the seaway. Instead, the OCEAN RANGER was assumed fixed at several drafts and list angles, and various wave crests were positioned on the platform to find the number of green water occurrences. This approach could be improved upon because relative motion between the platform and waves was neglected.

The present investigation uses a computer program which takes into account the motions (pitch, heave and roll) of OCEAN RANGER, and combines the effect of these motions to compute the relative motion between the assumed point of water entry on the port column and the wave surface. If one is interested in knowing the degree of contact between two surfaces (one on the platform, and one on the wave) and both are moving, it is necessary to find out if their relative motion toward each other exceeds their initial separation (freeboard). Once the relative motions are known, the rate of water entry into the chain locker can be computed from the depth of water (head) over the openings leading to the chain locker.

* References are listed on page 13.

ASSUMPTIONS

The following assumptions were made in carrying out the numerical analysis:

- The heading of the OCEAN RANGER was 311 degrees.
- The waves came from the west (270 degrees).
- The wave period was 16.7 seconds. This is the period of maximum energy (modal period) for the wave spectrum representing the most severe wave condition encountered[2]. The maximum spectral density for the time of interest occurred at 0100 of February 15, 1982. A plot of this spectrum is given in Figure 2. The waves were measured by means of a waverider buoy located approximately 20 nautical miles to the north of the OCEAN RANGER, and should closely describe the seaway in which the OCEAN RANGER was operating during the early part of its crisis period.
- Platform list angle and $\overline{GM}$ are constant while the chain locker is filling with water.
- For this dynamic analysis, only the two lower hulls and eight vertical columns are included in the computations. The cross-bracing, which is relatively small in volume, is not considered. The effect of the mooring system was also not included in the final calculations since it was found to have a negligible effect on the platform motions. This was checked by computer analyses which will be discussed in the Computational Procedure section of this report.
- Deck machinery does not restrict flow into the chain locker openings.

COMPUTATIONAL PROCEDURE

Before proceeding with the calculations of relative motion and flow into the chain locker, several preliminary steps were taken. First, the computer program was exercised using the same platform and wave conditions previously employed during model experiments[3]. This was done to check the accuracy of the program for the particular configuration being considered. Comparisons between the calculated and measured motions are given in Figure 3. For waves approaching 45 degrees off the forward end of the platform, pitch compares quite well. Heave and roll, though lower for the calculations, compare well enough to insure that subsequent calculations of relative motion will be reliable. In beam waves, the agreement between calculation and measurement is again satisfactory.

As noted in the Assumptions section presented above, the effect of mooring forces on platform motions was found to be small. Table 1 shows a comparison of platform motions predicted using both the computer program of principal application in this report, that is, the David Taylor Naval Ship R&D Center (DTNSRDC) Motions Program (which does not take into account mooring forces), and the American Bureau of Shipping program[4] (which does). The results are almost identical.

Modifications to the original DTNSRDC program were made so that it could be used for the asymmetric immersed volume condition that exists when the platform is listing about an axis which introduces both trim and heel. Finally, an integration sub-program was written to determine the total flow into the chain locker during a wave cycle.

RELATIVE MOTION

The relative motion per unit wave amplitude (transfer function) was initially computed for the OCEAN RANGER at even keel using the original DTNSRDC frequency-domain Motions Program for semi-submersible platforms. This program develops six-degree-of-freedom motion transfer functions in regular waves. The platform is divided into longitudinal sections and hydrodynamic forces (i.e., added mass, damping and wave excitation) are computed. The sectional forces are integrated along the length of the platform to obtain three-dimensional forces. Once the forces are computed, the following equations of motion are solved:

$$\sum_{j=1}^{6} \left[(M+A_{ij}) \ddot{X}_j + B_{ij} \dot{X}_j + C_{ij} X_j \right] = F_i \qquad (1)$$

for $i = 1,2, \ldots 6$

where
M = mass of platform
A_{ij} = added mass
B_{ij} = damping coefficients
C_{ij} = hydrostatic coefficients
F_i = exciting forces
X_j = translational motion for $i = 1,2,3$: surge, sway, heave; angular motion for $i = 4,5,6$: roll, pitch, yaw

Relative motion (RM) is computed by

$$RM = A\,(X_3 + \ell_1 X_4 - \ell_2 X_5 - \eta) \qquad (2)$$

where
A = wave amplitude
X_3 = heave transfer function
X_4 = roll transfer function
X_5 = pitch transfer function
η = wave surface profile of amplitude A
ℓ_1 = transverse distance to point where RM is computed
ℓ_2 = longitudinal distance to point where RM is computed

Dimensional relative motion (RM) was obtained by multiplying the RM transfer function for the modal period of 16.7 seconds by wave amplitude. That is,

$$\text{RM transfer function} \times \text{wave amplitude} = \text{RM amplitude} \qquad (3)$$

The clearance between the point of interest on the platform column and the wave surface is the freeboard during the motion cycle. The upper deck level located 151.5 ft (46.2m) above the lower hull bottom was considered. Water can enter the chain locker through three chain pipes and three wire trunks that extend to the upper deck. As the platform moves in the waves, a wave crest will move up the column, sometimes reaching a point above the upper deck and water will flow down into the chain locker.

LIST ANGLE

When the relative motion calculations for zero list angle were completed for the four drafts of interest [viz., 80,85,90 and 95 feet (24.4, 25.9, 27.4 and 29.0 m)], the list angle required to bring the freeboard to zero at one instant in the motion cycle was calculated for each of the four drafts and the wave amplitudes of interest*. Thus, the list angle for the upper deck level was computed by means of the equation:

$$\text{list angle} = \sin^{-1} \frac{151.5 - \text{draft} - \text{RM}}{\ell} \qquad (4)^{**}$$

* Equation (3) shows that the relative motion, and therefore available freeboard, are a function of wave amplitude.

**Note: $\sin^{-1}$ means "the angle whose sine is", and 151.5 feet is the height of the upper deck above the lower hull bottom.

where ℓ is the diagonal distance between the platform origin and the center of the port column. The quantity (151.5 - draft - RM) is, as discussed above, the clearance available between the port column at the upper deck level and the wave crest when the initially level platform undergoes motion in waves. If the list angle given by equation (4) is introduced, the level of water entry (i.e., 151.5 feet on the port column) will just contact the wave crest.

New platform offsets were then generated for the list condition. These offsets are no longer symmetric with respect to the centerplane because the platform is now assumed to list about an axis at 45 degrees to the centerplane. Relative motion for the list condition was computed with the same computer program described above.

IMMERSION AND FLOW RATE

The water head above the level of interest at the port column is given by a cosine function (whose amplitude is the RM calculated for that level, wave condition and platform condition) diminished by the initial freeboard when listed in calm water. In equation form this is represented as:

$$h = (RM \cdot \cos \omega t) - d \qquad (5)$$

where h is the head and d is the freeboard.

The flow rate through the openings in the upper deck was computed by means of an equation which is a special case of Bernoulli's equation[5]*. It is developed as follows:

At a given instant of time, the water piled up above the deck openings during passage of the wave crest can be considered to have zero velocity relative to the platform (as if it were stored in a reservoir), except near the openings. Writing Bernoulli's equation between the "reservoir" and the openings,

* Bernoulli's equation applies to incompressible, ideal (inviscid) fluids. In the present case it will provide a solution of adequate accuracy for practical use.

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = h = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 \tag{6}$$

where p_1 is the static pressure in the reservoir

p_2 is the static pressure at the openings

γ is the specific weight of water

V_1 is the fluid velocity in the reservoir = 0

V_2 is the fluid velocity at the openings

Z_1 is the potential head in the reservoir

Z_2 is the potential head at the openings

g is the acceleration due to gravity

h is the depth of water in the reservoir

With the datum taken at the level of the openings, Z_2 is equal to zero. The static pressure p_2 throughout the flow leaving the openings is small relative to the static pressure in the reservoir (p_1) and can be assumed equal to zero. Then, since $\frac{p_1}{\gamma} + Z_1$ in the reservoir is equal to h we obtain

$$h = \frac{V_2^2}{2g} \tag{7}$$

or

$$V_2 = \sqrt{2gh} \quad \text{in ft/sec or (m/sec)} \tag{7'}$$

The value of h in equation (7′) varies over a wave cycle in accordance with equation (5). This is shown graphically in Figure 4. The integration of $\sqrt{2gh}$ over $0\text{-}T_1$ and $T_2\text{-}T$ is the total flow rate per unit area per wave cycle (Q′).

FLOODING TIME

The time to fill the chain locker is given by

$$\text{Time} = \left(\frac{\text{chain locker volume}}{Q' \times \text{total opening area}} \right) \times 16.7 \text{ seconds} \qquad (8)$$

where Q' is the total flow rate per unit area per wave cycle, and where 93 ft^2 (8.6 m^2) is the total opening area* and 39,694 ft^3 (1,124.1 m^3) is the chain locker volume. Use of a wave period of 16.7 seconds was explained previously in the Assumptions section. Equation (8) shows that the time required to fill the locker is equal to the product of the total number of cycles of wave encounter during the filling process (which is given in the parenthesis) times the wave cycle period of 16.7 sec.

Platform characteristics used in the computations are given in Table 2. The length shown is the distance between the forward end of the lower hull and the rudder stock.

COMPUTATIONAL RESULTS

The calculated chain locker filling times for water entry at the upper deck level are presented in Table 3. The results are given for several platform drafts and wave heights. Values of wave height which were used are defined as follows:

$\bar{H}$ = average wave height

$\bar{H}_{1/3}$ = average of one-third highest (significant) wave heights

$\bar{H}_{1/10}$ = average of one-tenth highest wave heights

$\bar{H}_{1/100}$ = average of one-hundredth highest wave heights

$H_{MIN.}$ = smallest wave height which will produce chain locker flooding (for conditions specified)

---

* Each of the three chain pipe openings per column has an area of 6.0 ft^2 (0.56 m^2), and each of the three wire trunk openings has an area of 25.0 ft^2 (2.3 m^2).

It is evident (see list angle column) that for the 80 ft (24.4 m) draft, list angle must exceed 20 deg for the upper deck to just contact the wave crest in accordance with equation (4). This is true even if $\bar{H}_{1/100}$ of 61.2 ft (18.7 m) is the wave height used to obtain RM amplitude in equation (3). Line 8 in Table 3 shows that if the list angle is close to 15 deg* the wave height would have to be 125.0 ft (38.1 m) or greater for water to enter the chain locker. The probability of encountering a wave this large or larger is extremely small (approximately 8×10^{-11}).

The longest time it would take to fill the chain locker for the cases examined is 1,347 sec (22.5 min): this occurs for a draft of 95 ft (29.0 m) and a list of 17.4 deg when operating in wave of significant height ($\bar{H}_{1/3}$) equal to 36.7 ft (11.2 m). If the method discussed under Computational Procedure is adhered to, we find that when draft is constant at 80 ft (24.4 m), the time to fill the chain locker becomes shorter as the wave height increases and list angle decreases slightly. Also, for constant wave height [$\bar{H}_{1/3}$ = 36.7 ft (11.2 m)] there is for the most part a trend towards increased time to fill the chain locker as the list angle becomes smaller and draft increases.

It is known that wave heights in a seaway vary according to a Rayleigh distribution[6] rather than having a single value. The time to fill the chain locker was re-computed for the 95 ft (29.0 m) draft and 17.4 deg list angle (line 7 in Table 3) using such a distribution

*This is less than the angle for wave crest tangency for the platform and wave conditions assumed, and was not determined by equation (3). It is, however, the list angle observed on OCEAN RANGER at approximatly 0100 on Feb. 15.

of wave heights in order to verify that the time predicted by our method is a good estimate. The wave statistics used are as follows:

WAVE HEIGHT, FT	NO. OF OCCURRENCES PER HOUR
75	2
65	7
55	15
45	26
33	32
25	38

These are the largest 120 waves in a population of 360 waves. They are the ones making up a significant wave height of roughly 38 ft (11.6 m), which is close to the value associated with the wave spectrum of Figure 2, [viz. 36.7 ft (11.2 m)]. It was assumed that lower waves in the population do not contribute to chain locker flooding as they pass by the platform; they do however add to the time required to fill the locker. The time to fill was found to be 11.9 min (711 sec) which is significantly shorter than the 22.5 min computed previously for $\bar{H}_{1/3} = 36.7$ ft (11.2 m).

CONCLUSIONS

The principal findings of this investigation with regard to water entering through chain pipe openings and wire box openings located on the upper deck [151.5 ft (46.2 m) above the baseline] when the OCEAN RANGER operates in a heavy seaway are:

1. The maximum time required to fill the chain locker is 22.5 minutes when a wave height of 36.7 ft (11.2 m) is encountered. This assumes that the platform draft is 95 ft (29.0 m) and its list angle is 17.4 deg.

2. If the list angle were 15 deg when the platform draft is 80 ft (24.4 m), the wave height would have to be at least 125 ft (38.1 m) for water to enter the chain locker via topside openings. Because of the large wave height required, frequent water entry would not occur in this condition.

3. If the distribution of wave heights found in nature (Rayleigh) substituted for a constant wave height in determining locker filling time, the time tends to be decreased.

LIMITATIONS OF THE COMPUTATIONAL PROCEDURE

Several factors combine to make the results derived from this study a good engineering estimate of the platform dynamics rather than an exact prediction. Some of these factors were made necessary by time and funding limitations which, for example, prescribed the use of an existing analysis procedure and computer program with only minor modifications rather than development of a new program. Although computer runs were made to insure that chain locker filling time would not be much different in irregular waves, the existing frequency-domain program is better suited to handling regular waves. The limitation in resources also precluded examination of several wave periods of encounter. Thus, a resonance condition, producing somewhat greater platform motions than computed, may have occurred. In addition, as has been stated in the Assumptions section, platform list angle and $\overline{GM}$ were assumed constant during locker flooding to facilitate the computation of flooding time. Obviously, these vary somewhat as water is taken on board.

Other deficiencies exist because of limitations in the state-of-the-art. For example, it is not possible to accurately predict the effect of deck machinery, railings, deck houses, etc. in either deflecting impinging waves away from the chain pipe and wire trunk openings, or trapping water which subsequently reaches the openings, except through detailed model tests. The effect of waves breaking prior to or during arrival at the upper deck region is also not considered, and similarly requires model testing to adequately predict platform stability.

The wave records available from the waverider buoy located close to OCEAN RANGER have not been examined in detail for the existence of extreme waves which, if encountered, could be incorporated in the motions program. Should there be interest in pursuing this approach, DTNSRDC can proceed with an analysis technique which facilitates the identification of such extreme waves.

REFERENCES

1. "An Evaluation of the Effect of the Seaway on the MODU OCEAN RANGER in a Severe Storm", prepared by Marine Technical and Hazardous Materials Division, Office of Merchant Marine Safety, U.S. Coast Guard, Report No. CG-M-82-3 (16732), Aug. 1982.

2. "Interim Wave Data Report, Station 104 - Zapata Ugland, Feb. 11-15, 1982", Marine Environmental Data Service, Government of Canada (Feb. 18, 1982)

3. "Model Tests of the OCEAN RANGER a Semi-Submersible Drilling Rig", Offshore Technology Corp. Report No. OTC-74-14 (May 1974)

4. Hong, Y.S., et al, "Analysis of Semisubmersible Catamaran-Type Platforms", Proceedings of Offshore Technology Conference, Houston, OTC Paper 2975 (1977)

5. "Elementary Fluid Mechanics", by J.K. Vennard, published by John Wiley and Sons, Inc., 4th edition (1961), p. 104.

6. "Dynamics of Marine Vehicles", by R. Bhattacharyya, published by John Wiley & Sons (1978) p.107

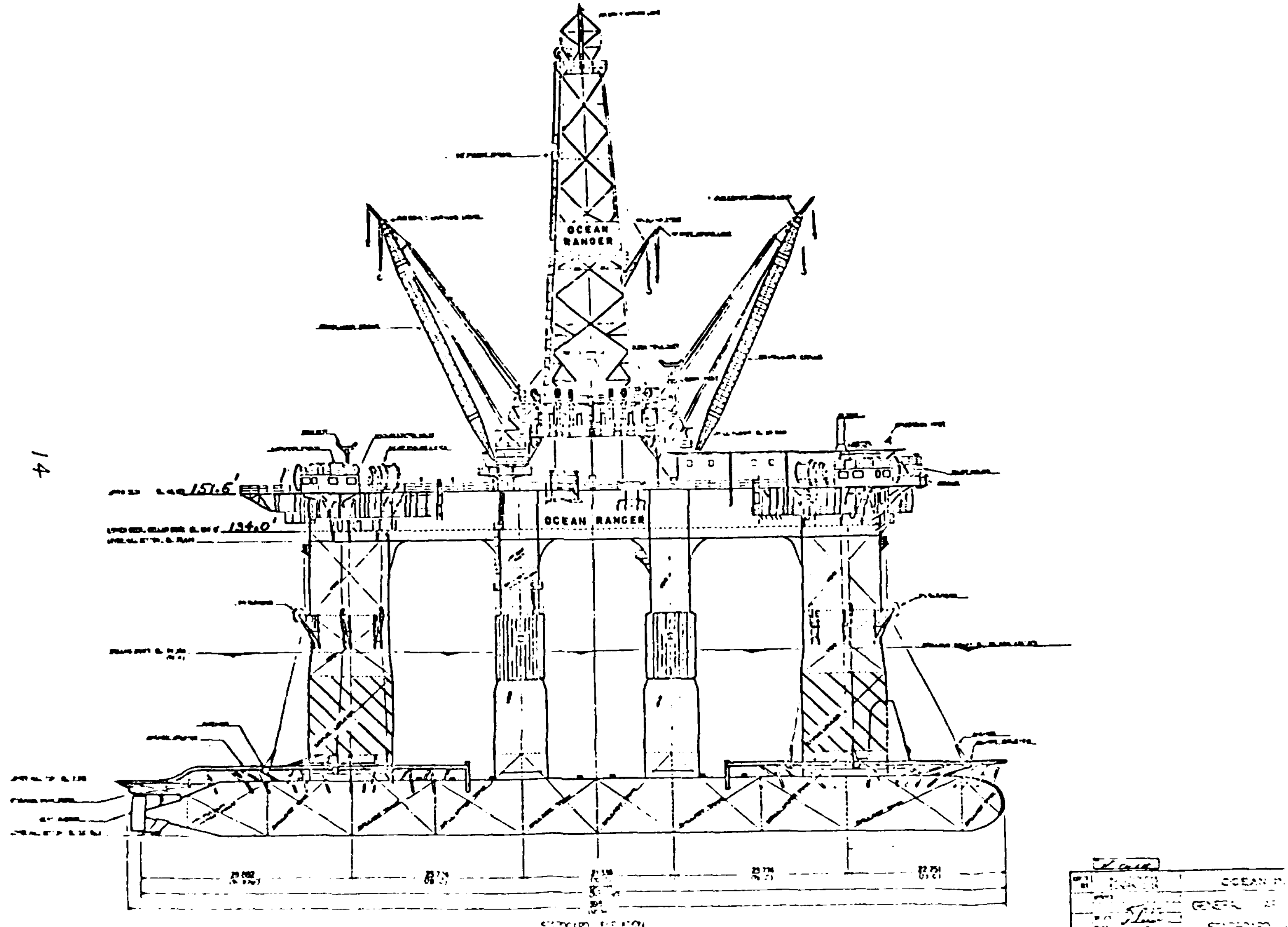

Figure 1 - Profile View of OCEAN RANGER

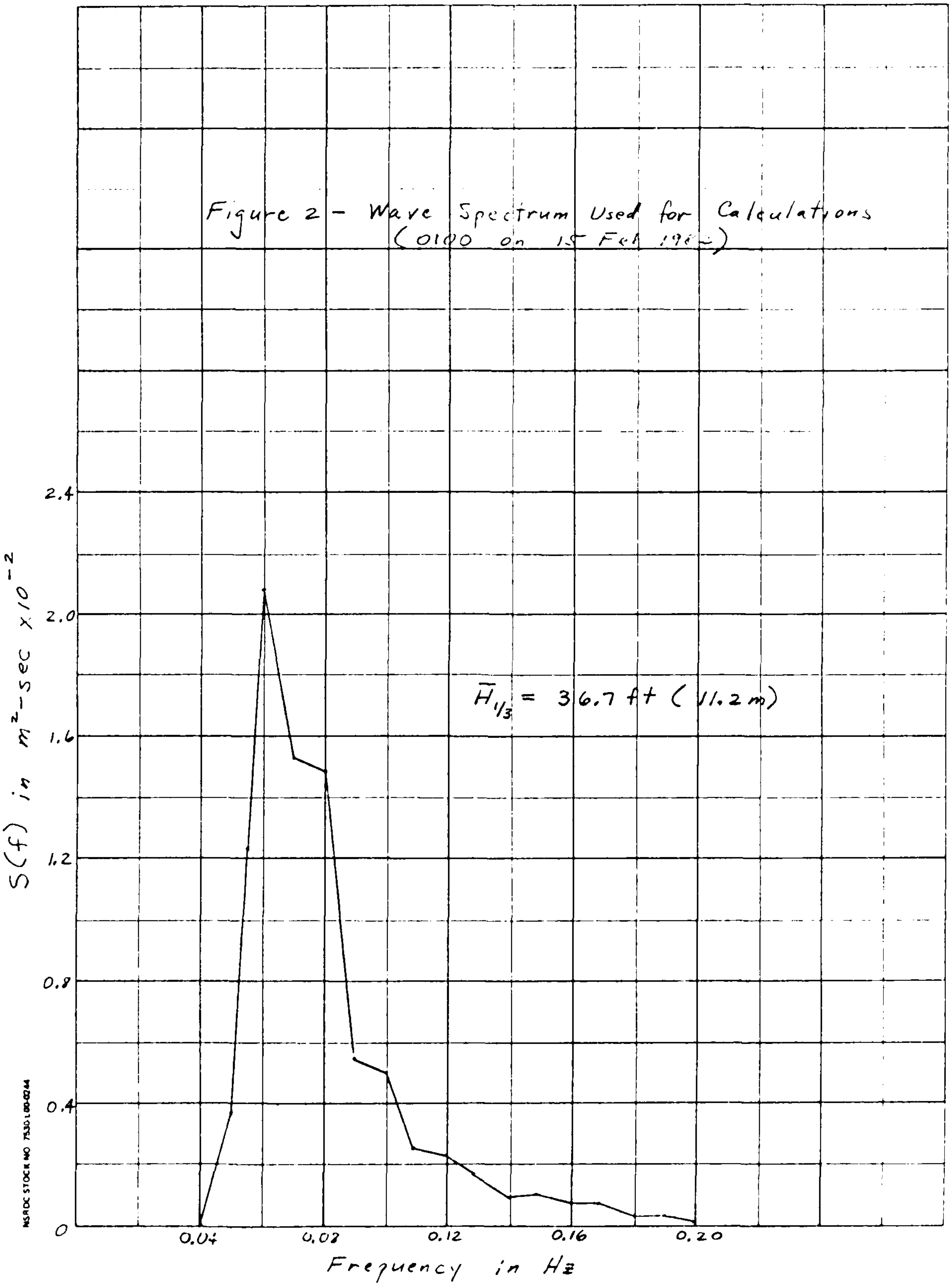

Figure 2 - Wave Spectrum Used for Calculations (0100 on 15 Feb 196-)

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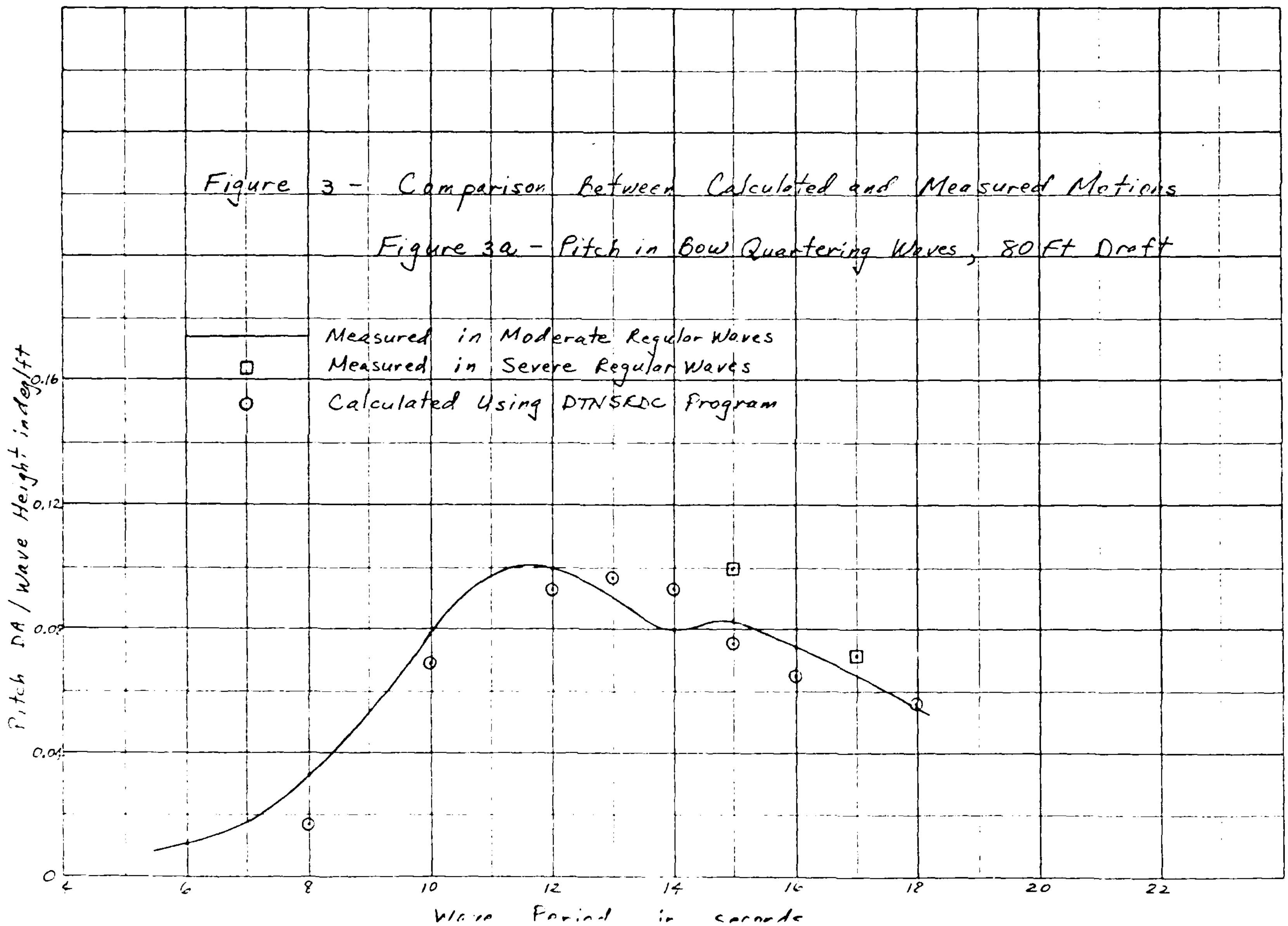


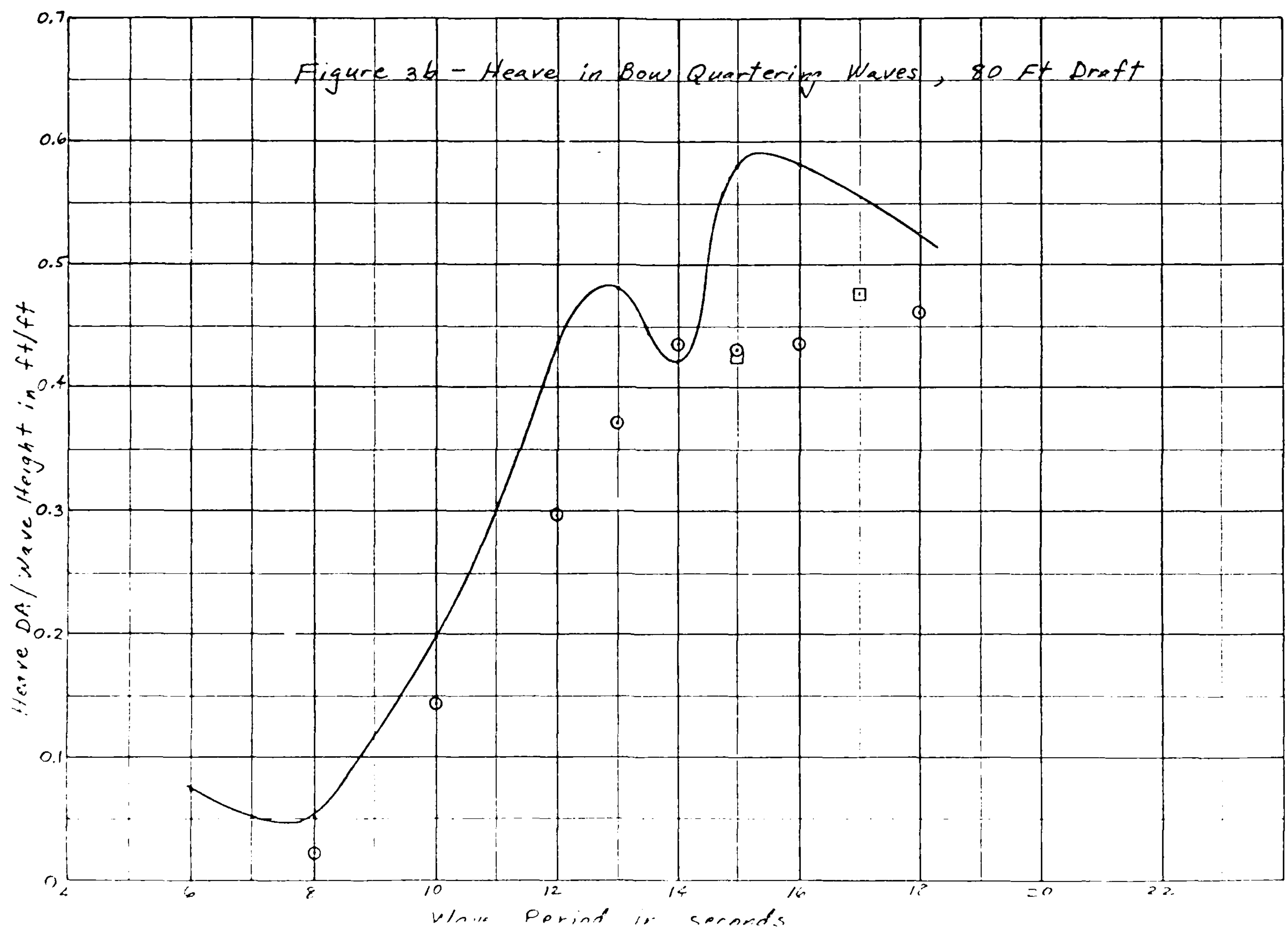


Figure 3b - Heave in Bow Quartering Waves, 80 Ft Draft
Heave DA / Wave Height in ft/ft
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4
6
8
10
12
14
16
18
20
22
Wave Period in seconds

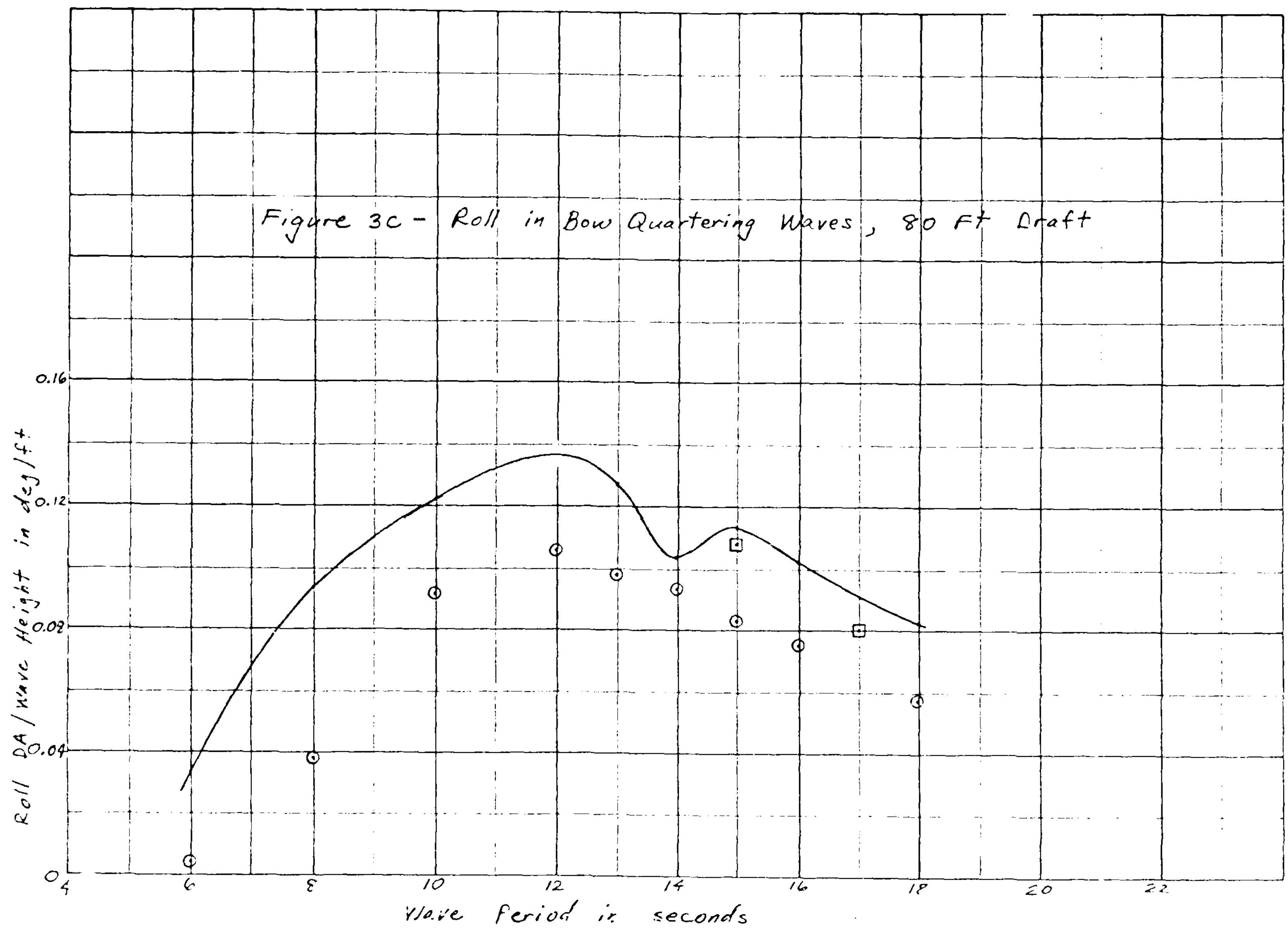
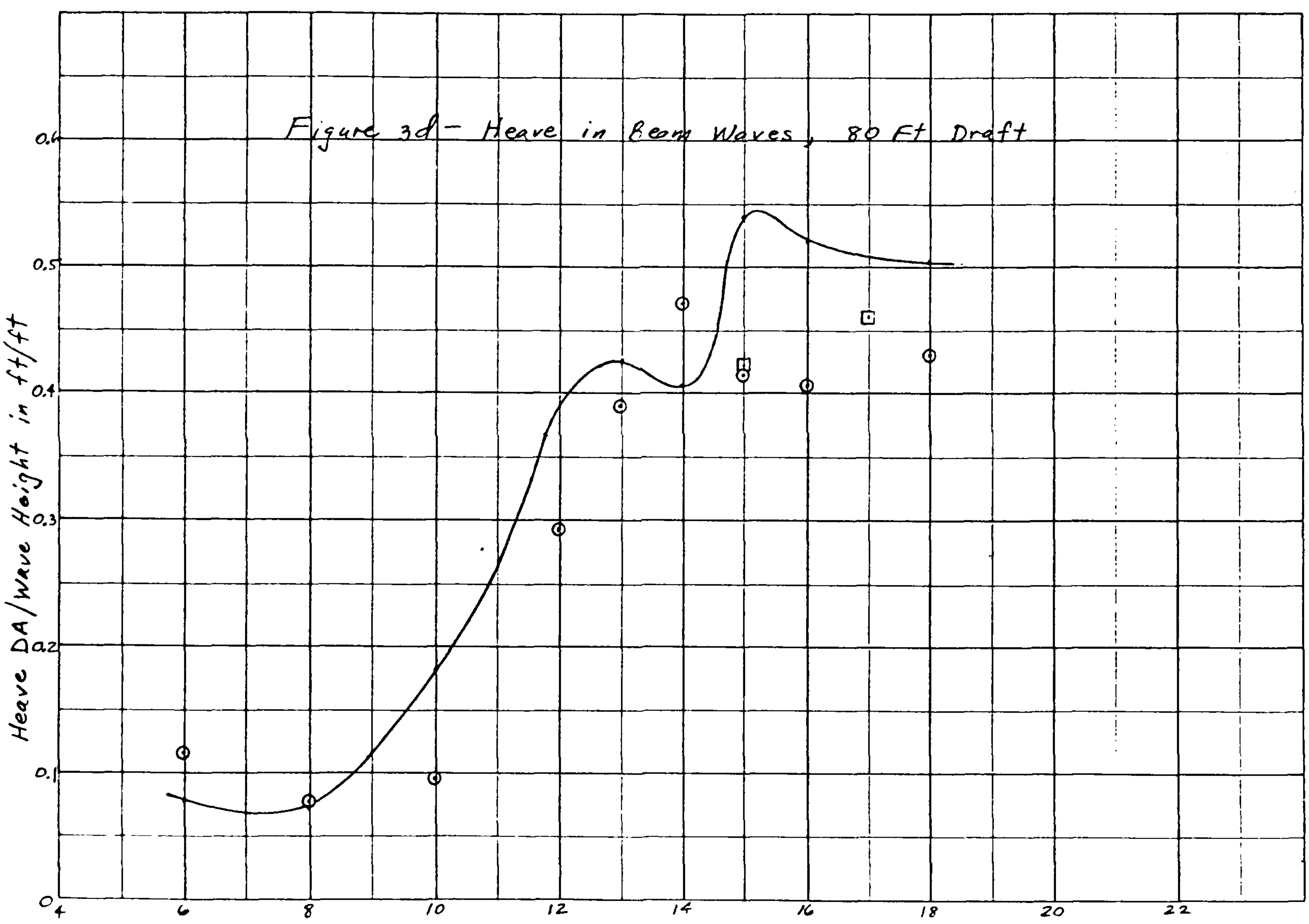


Figure 3C - Roll in Bow Quartering Waves, 80 Ft Draft
0.16
0.12
0.08
0.04
0
4
6
8
10
12
14
16
18
20
22
Wave Period in seconds
Roll DA/Wave Height in deg/ft

Figure 3d – Heave in Beam Waves, 80 Ft Draft



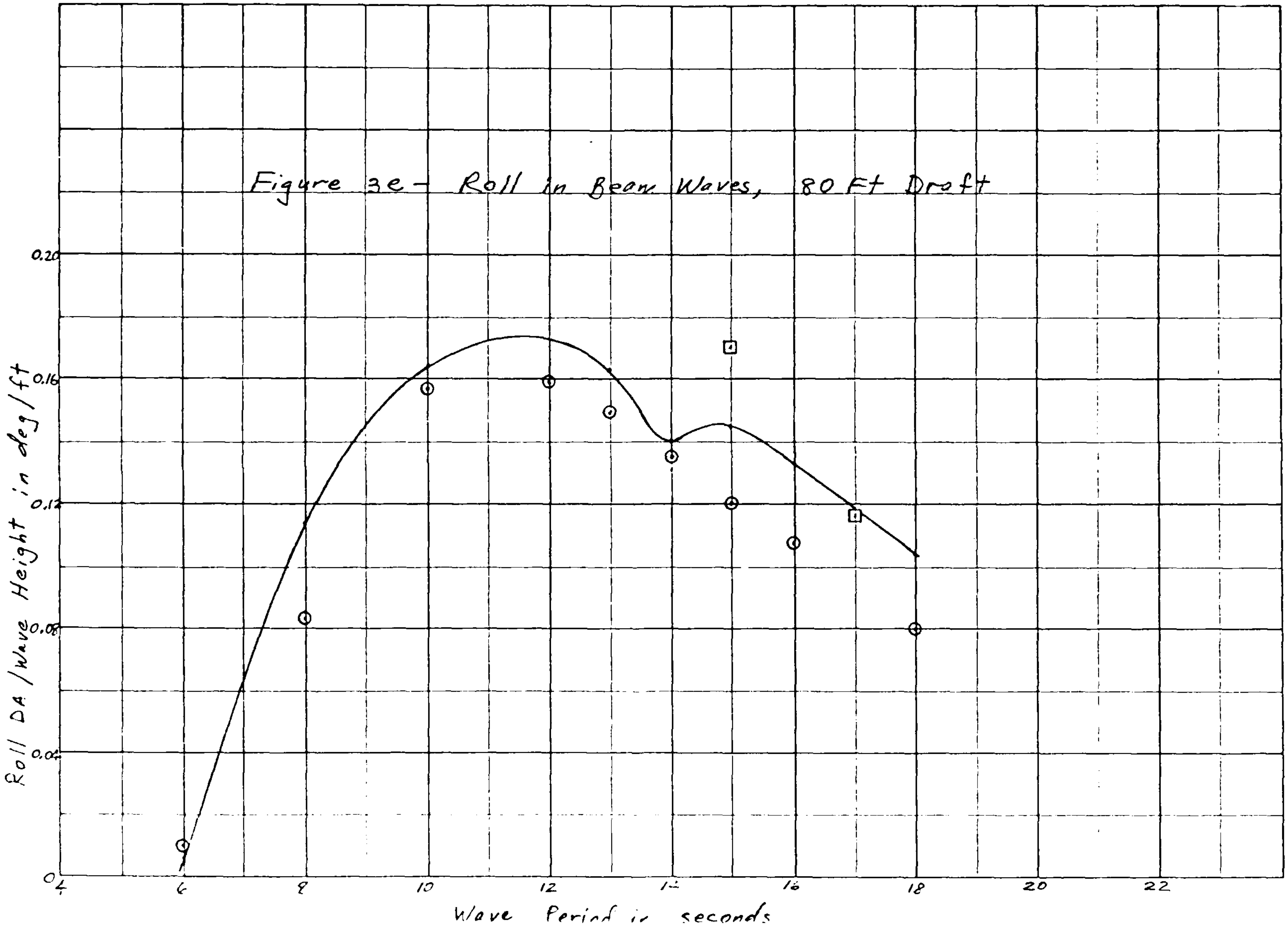


Figure 3e - Roll in Beam Waves, 80 Ft Draft
Roll DA / Wave Height in deg/ft
0
0.04
0.08
0.12
0.16
0.20
4
6
8
10
12
14
16
18
20
22
Wave Period in seconds

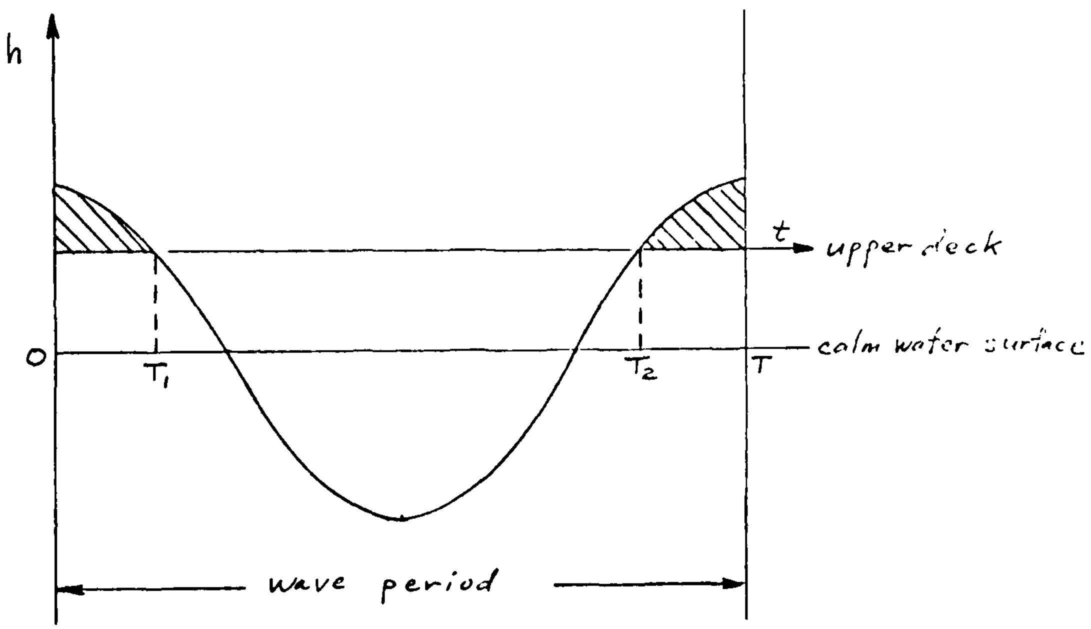


Figure 4 – Sketch of Area Integrated to Obtain Total Flow Rate

TABLE I

RESULTS OF MOTION TRANSFER FUNCTION CALCULATIONS WITH AND WITHOUT MOORING FORCES *

PERIOD, SEC	HEAVE, FT/FT		PITCH, DEG/FT		ROLL, DEG/FT		SWAY, FT/FT	
	WITHOUT MOORING	WITH MOORING	WITHOUT MOORING	WITH MOORING	WITHOUT MOORING	WITH MOORING	WITHOUT MOORING	WITH MOORING
8	0.019	0.019	0.0154	0.0154	0.0387	0.0387	0.005	0.006
10	0.141	0.142	0.0684	0.0684	0.0893	0.0893	0.175	0.187
12	0.296	0.297	0.0917	0.0917	0.1030	0.1029	0.312	0.324
13	0.371	0.372	0.0955	0.0955	0.0986	0.0984	0.369	0.379
14	0.434	0.436	0.0931	0.0931	0.0914	0.0911	0.416	0.425
15	0.427	0.429	0.0733	0.0732	0.0826	0.0822	0.455	0.462
16	0.436	0.438	0.0640	0.0638	0.0733	0.0728	0.486	0.492
18	0.459	0.463	0.0515	0.0512	0.0559	0.0552	0.533	0.537

* DRAFT = 80 FT, EVEN KEEL, $\overline{GM}_t$ = 12.43 FT, $\overline{GM}_l$ = 10.37 FT, $\overline{KG}$ = 56.6 FT, BOW QUARTERING WAVES

TABLE 2

OCEAN RANGER CHARACTERISTICS

LENGTH		DRAFT		DISPLACEMENT		$\overline{GM}_T$		$\overline{GM}_L$		$\overline{KG}$	
FT	M	FT	M	LONG TONS	METRIC TONS						
393.8	120.0	80	24.4	38,940	39,563	6.03	1.84	3.97	1.21	63.30	19.29
↓	↓	85	25.9	39,828	40,465	7.09	2.16	5.17	1.58	61.84	18.85
↓	↓	90	27.4	40,715	41,366	8.42	2.57	6.69	2.04	60.76	18.52
↓	↓	95	29.0	41,602	42,268	9.96	3.04	8.51	2.59	59.74	18.21

TABLE 3

TIME TO FILL CHAIN LOCKER

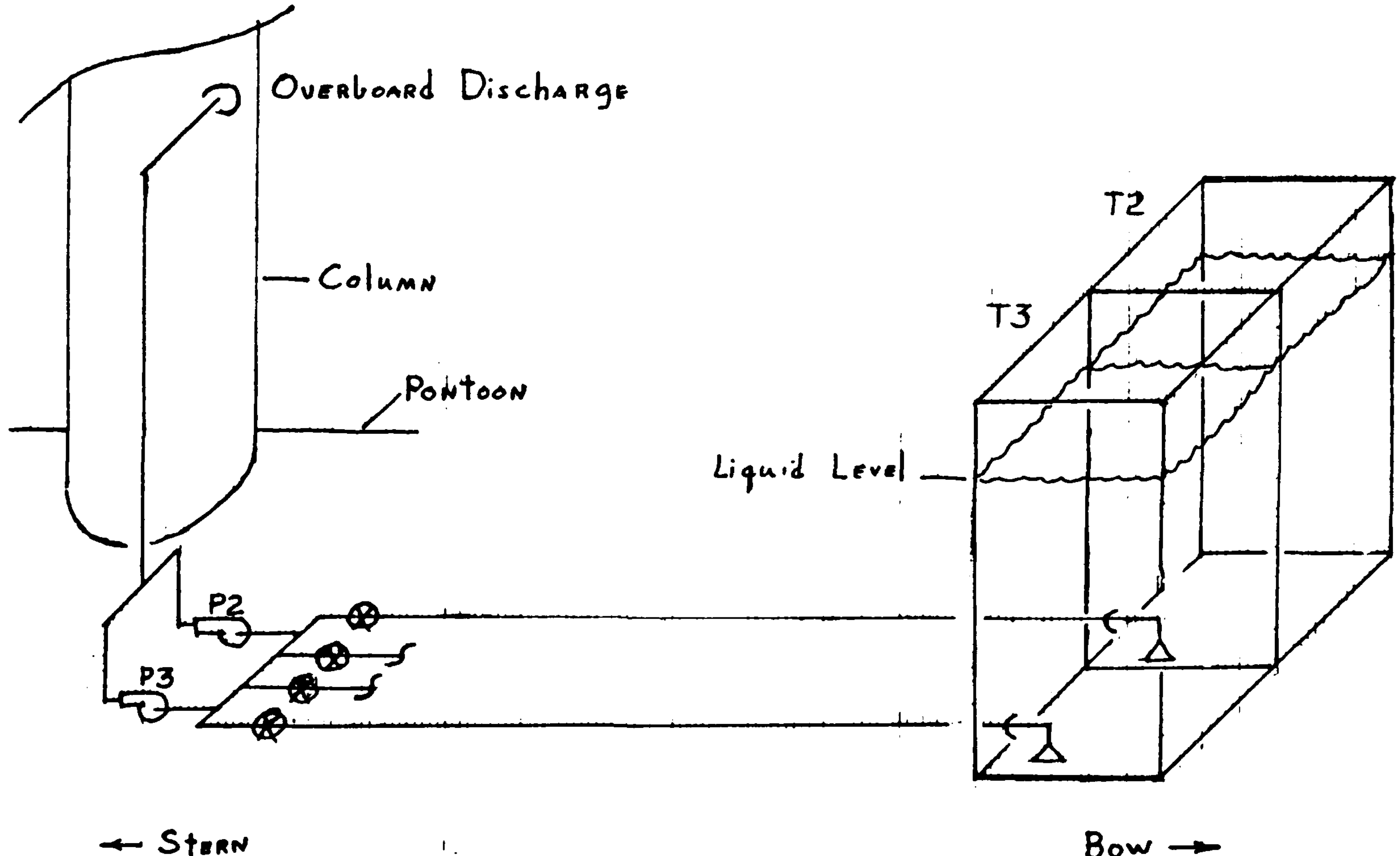
FOR OPENINGS AT 151.5 FT (46.2 M) LEVEL

	DRAFT		DISPLACEMENT	LIST ANGLE	$\overline{KG}$		WAVE HEIGHT		WAVE 1) PERIOD	TIME TO FILL
	FT	M	LONG TONS	DEG	FT	M	FT	M	SEC	SEC
1	80	24.4	38,940	25.8	63.0	19.2	$\bar{H}$ = 22.9	7.0	16.7	587
2	80	24.4	38,940	24.4	63.0	19.2	$\bar{H}_{1/3}$ = 36.7	11.2	16.7	469
3	80	24.4	38,940	23.4	63.0	19.2	$\bar{H}_{1/10}$ = 46.7	14.2	16.7	384
4	80	24.4	38,940	21.9	63.0	19.2	$\bar{H}_{1/100}$ = 61.2	18.7	16.7	269
5	85	25.9	39,828	22.0	61.9	18.9	$\bar{H}_{1/3}$ = 36.7	11.2	16.7	354
6	90	27.4	40,715	19.7	60.8	18.5	$\bar{H}_{1/3}$ = 36.7	11.2	16.7	870
7	95	29.0	41,602	17.4	59.7	18.2	$\bar{H}_{1/3}$ = 36.7	11.2	16.7	1,347
8	80	24.4	38,940	14.9	63.0	19.2	H_{MIN} = 125.0	38.1	16.7	866

1) The period of maximum wave energy when the most severe wave conditions occur for the time of interest (at 0100 on Feb 15, 1982).

APPENDIX E

OCEAN RANGER BALLAST SYSTEM ANALYSIS



ORIENTATION
SKETCH

FIG. 1

Pump Operation

A pump moves a substance from the low pressure (suction) side of a piping system to the high pressure (discharge) side. To do this the pump must overcome the total "head" of the system in which it is installed, and provide adequate suction lift to move the substance through the suction side of the system to the pump. The term "head" is commonly used in dealing with pumps and is normally expressed in feet of water. Pressure, velocity changes, elevation changes, and friction losses are all commonly expesed in terms of head.

In evaluating pump performance there are three primary concerns; pump discharge head, system head, and pump suction lift capability. The pump head promotes flow; the system head resists flow. Pump head and system head are normally balanced to provide steady pump performance. Since the pump suction lift capability is an important consideration in the ballast system of the OCEAN RANGER, it will be discussed in more detail.

The suction lift of a centrifugal pump is very limited, and can be shown to have a value of about 13.4 feet of water for ballast pumps 2 and 3 on the OCEAN RANGER. Suction lift may be viewed as the amount of head available to lift water from the surface level in the tank to the elevation of the pump, plus overcome friction losses in the suction piping. Since the suction lift is limited, the level of the water below the pump is critical. If the water level is too far below the elevation of the pump, the pump will not be able to lift the water from the tank. If the water level in the tank is higher than the pump, additional head is provided by virtue of this higher water level to help feed the pump and overcome friction loses. With the OCEAN RANGER on an even keel the top of ballast tanks 2 and 3 are about 33 feet above pumps 2 and 3, so the pumps can be expected to discharge water from these tanks without difficulty. However, with the tanks nearly empty, the water level falls below the pumps leaving less suction lift available to overcome friction. Pump suction should not be a problem with the vessel on an even keel, but trim on the vessel can cause problems. With the tanks located well over 200 feet forward of the pumps, the elevation of the tanks relative to the pumps drops about 4 feet for each degree of trim by the bow. Thus, the pumps will lose suction on a near empty tank at about 2.7 degrees trim, and on a full tank at about 10.9 degrees trim. Flow will be reduced as the trim approaches these limiting angles because of limited head available to overcome friction.

Two other considerations that affect the performance of a pump are the need of the pump to be primed and the problem of pump cavitation. For a pump to function it must be primed, i.e.,the suction piping must be flooded completely to the pump impeller. Since centrifugal pumps are not self-priming, if the pump is lifting liquid from a level lower than itself, a means external to the pump must be available to flood the suction piping. Cavitation is caused by water flashing to vapor in the pump, and can be expected to occur when the local pressure is reduced to the vapor pressure of the water at the local temperature. In cases (1) through (6) below, cavitation will always occur before flow is lost, and will adversely affect the pump performance.

Evaluation Procedure

1. From the pump curve (discharge head vs capacity) provided, an additional pump curve is developed to represent the performance of two identical pumps operated in parallel.

2. System head curves are developed to represent the approximate resistance of the piping to flow at various angles of vessel trim and with the pump(s) lined up to either one ballast tank, or to two ballast tanks simultaneously. The factors contributing to the piping resistance are the friction losses in the piping and the difference in elevation between the liquid level of the tanks and the location of the overboard discharge. The system is modeled for each case evaluated as a length of single diameter piping which would have frictional characteristics equivalent to those of the respective piping arrangement being considered.

3. The system curves are then superimposed on the pump curves so the approximate actual flow rates can be determined for various combinations of vessel trim, number of pumps, and number of tanks being emptied. The intersections of pump and system curves indicate actual flow and head conditions assuming the pump(s) maintains adequate suction.

4. Next the pump's performance is checked relative to limitations on the suction side of the system. The pump's required Net Positive Suction Head (NPSH) of 19 feet of water is adjusted to account for atmospheric pressure acting on the liquid surface in the tank, and for the vapor pressure of the water. The result is the limiting difference between the elevation of the pump and the tank liquid level for the pump to maintain suction assuming no friction losses in the piping, i.e., how high the pump can be positioned above the water level in the tank and still pump water. From this information the limiting angle of vessel trim can be determined for various tank liquid levels.

5. When the actual difference between the pump elevation and the tank liquid level is less than the limiting value for the pump to maintain suction, a residual suction lift is available to sustain flow in the pipe by overcoming friction losses. By applying this residual lift to overcome friction, a corresponding fluid velocity through the pipe, and hence, the suction capacity of the pump can be estimated.

6. For various combinations of pumps, tanks, and vessel trim the respective limitations on pump discharge and suction capabilities can be compared to determine which is controlling and, therefore, determine the actual flow rate through the system.

7. Finally, at various trim angles the corresponding tank liquid levels required for the pump to maintain suction are determined.

Assumptions

A key assumption in this analysis is that the suction piping has no air leaks and that valves to tanks other than those being emptied are closed tightly. Absence of either of these conditions could adversely affect the ability of the pumps to empty the desired ballast tanks. The rated Net Positive Suction Head (NPSH) of the pump is taken as 19 feet of water as is shown on the pump characteric curve developed by the pump manufacturer.

Several assumptions were made for simplicity of analysis. These assumptions may have a minor effect on results, which should be viewed only as close estimates of system performance. The tank bell suctions are taken as being located at the bottom aft end of the tanks two feet below the elevation of the pump inlets when the vessel is on an even keel. The friction factor used to determine friction losses in the piping is considered to be constant over the velocity range under consideration. The arrangement of the discharge piping between the pumps and the overboard discharge was not clearly shown on available drawings and, therefore, was assumed to rise vertically above the pumps into the aft column and then directly overboard at the 105 foot elevation. The system in each case is modeled as a length of single diameter pipe that has frictional properties equivalent to those of the actual system.

Ballast System Performance Summary

I. Cases when ballast tanks are full

Case 1. Pump nos. 2 and 3 on tank no. 2 (tank full)

Case 2. Pump nos. 2 and 3 on tank nos. 2 and 3 (tank full)

Case 3. Pump no. 2 tank nos. 2 and 3 (tank full)

In cases 1, 2, and 3, the limiting vessel trim by the bow at which pumps will lose suctions approximately 10.9°.

Case 1. Pumps will likely be cavitating at all trim angles with flow limited by suction side losses.

Flow Rates (gpm)

Trim (degrees)	Pump Suction Capability	Pump Discharge Capability	Actual Flow
0.0	2756	4000	2756
3.0	2349	3800	2349
5.0	2036	3720	2036
9.0	1170	3480	1170
10.9	Zero	3350	Zero

Case 2. Pumps will operate at rated capacity at even keel, but will be limited by suction side loses and will begin cavitating as trim by the bow increases.

Flow Rates (gpm)

Trim (degrees)	Pump Suction Capability	Pump Discharge Capability	Actual Flow
0.0	5300	5090	5090
3.0	4531	4950	4531
5.0	3948	4820	3948
9.0	2263	4600	2263
10.9	Zero	4420	Zero

Case 3. The pump will operate near rated capacity to about 7.5° trim by the bow, and will then begin to lose capacity due to suction side loses.

Flow Rates (gpm)

Trim (degrees)	Pump Suction Capability	Pump Discharge Capability	Actual Flow
0.0	5300	3100	3100
3.0	4531	3020	3020
5.0	3948	2930	2930
9.0	2263	2810	2263
10.9	Zero	2680	Zero

II. Cases when ballast tanks are nearly empty.

Cases 4. = Case 1 with nearly empty ballast tanks

Cases 5. = Case 2 with nearly empty ballast tanks

Cases 6. = Case 3 with nearly empty ballast tanks

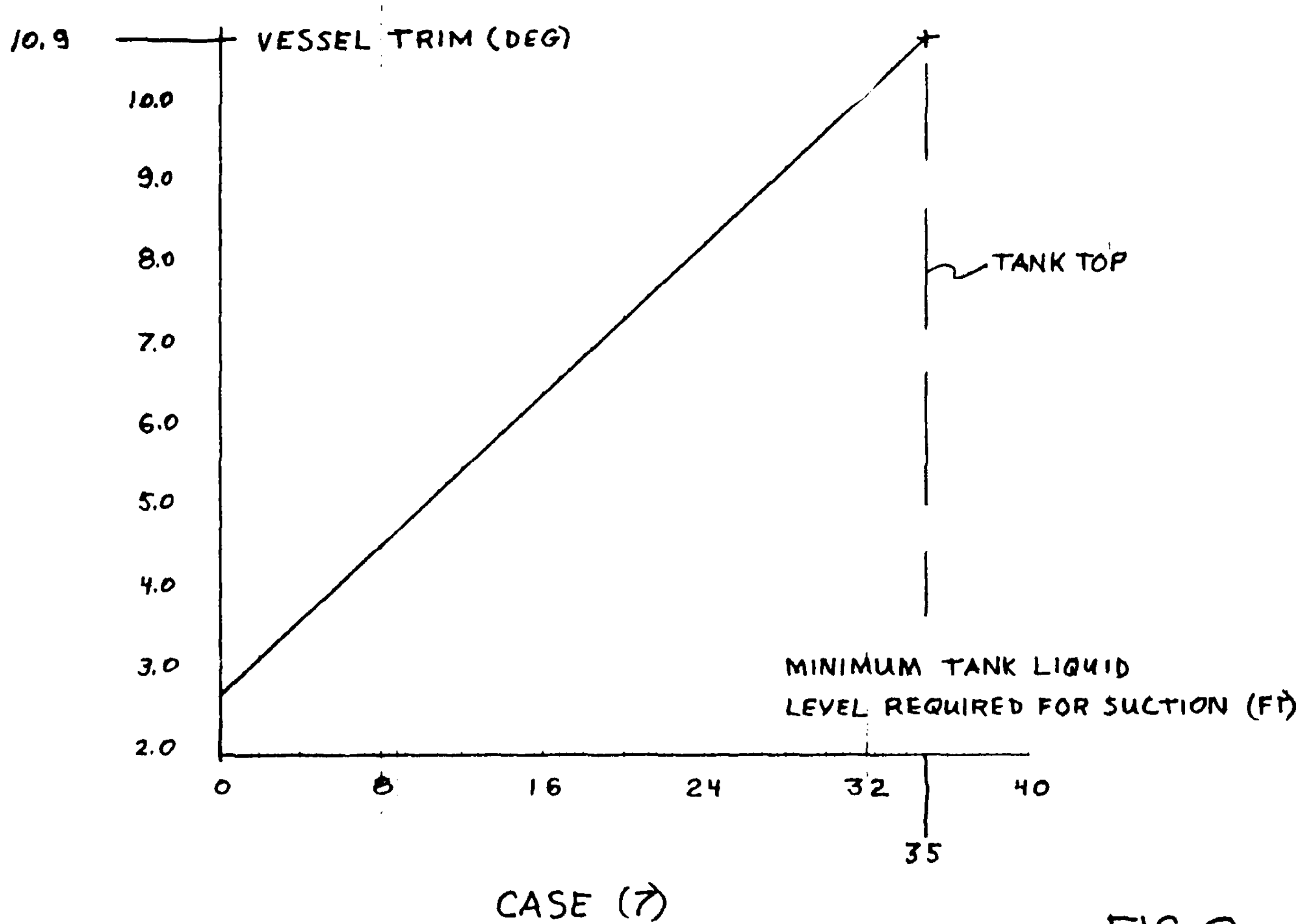
In cases 4, 5, and 6 the limiting vessel trim by the bow at which pumps will lose suction is about 2.7°. Flow will always be limited by suction side loses, and pumps will be cavitating.

Flow Rates (gpm)

	Trim (degrees)	Suction limit	System limit	Actual Flow
Case 4	0.0	1364	4000	1364
Case 5	0.0	2650	5090	2650
Case 6	0.0	2650	3100	2650

IV. Limiting tank liquid levels

Case 7. As long as the ballast pump(s) is lined up only on tanks 2 and/or 3 the minimum required tank liquid level to maintain pump suction can be seen from figure 2 as a function of vessel trim.



10.9
VESSEL TRIM (DEG)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
TANK TOP
MINIMUM TANK LIQUID
LEVEL REQUIRED FOR SUCTION (FT)
0
8
16
24
32
40
35
CASE (7)

FIG. 2

APPENDIX F

OCEAN RANGER BALLAST PUMP ANALYSIS

14 July 1982

OCEAN RANGER BALLAST SYSTEM ANALYSIS

References

a. Layne and Bowler Pump Curves for Discharge and NPSH
b. OCEAN RANGER Drawings P-4101 REV.A, and P-4103 REV.B
c. OCEAN RANGER General Configuration Drawing

Purpose

This study examines the performance of the ballast system of the OCEAN RANGER. The intent is to estimate the limitations and operating characteristics of the system for certain combinations of vessel trim, number of pumps on-line, and number of tanks being emptied.

Cases Studied

Only ballast pumps (2) and (3) and ballast tanks (2) and (3) are included in the cases considered. See the orientation sketch in figure 1. In all cases the pump(s) is discharging water overboard from the ballast tank(s). The system performance was checked for the following cases:

Case	Vessel Trim	Pumps On-line	Ballast Tanks	Tank Liquid Level
1	various	2 and 3	2	full
2	various	2 and 3	2 and 3	full
3	various	2	2 and 3	full
4	various	2 and 3	2	near empty*
5	various	2 and 3	2 and 3	near empty*
6	various	2	2 and 3	near empty*
7	various	2 and/or 3	2 and/or 3	minimum required

*"near empty" is considered to be with the tank suction barely immersed

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26 JAN 1983

From: Commander, David Taylor Naval Ship R&D Center
To: Commandant, U. S. Coast Guard (Capt Peter Cronk)

Subj: OCEAN RANGER ballast system analysis; forwarding of final report

Encl: (1) DTNSRDC TM-27-82-114
(2) Professional Qualifications of Author

1. Enclosure (1) includes additional information and clarification and is being forwarded herein. This report contains capabilities and limitations of the OCEAN RANGER ballast pumps under normal and trim conditions. This work was performed under Job Order number 1-1562-203-02.

2. Enclosure (2) is also furnished as requested.

3. If there are any questions please contact our Dr. Edmund J. Jarski on (301) 267-2845 or Mr. A. B. Neild on (301) 267-2263.

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By direction

OCEAN RANGER Ballast Pump Analysis

by

Edmund J. Jarski

This study examines the performance of the ballast system of the OCEAN RANGER. Its purpose is to estimate the characteristics of the system and determine its limitations when the vessel is not on an even keel. The references used in this study do not give sufficient detail to obtain accurate values so that the results presented are only approximate. Details of the assumptions made and calculations leading to these results are given in Appendix A.

The ballast tanks under consideration are numbers 2 and 3 located at the forward end of the vessel and the pumps are located aft in the pump room (Figure 1). The vessel is listing about an axis which is 45° off the fore and aft center line so that the suction line inlets drop about 3.4 feet with respect to the pumps for each degree of list. This drop has several consequences with regards to the pumping system.

1. System head is increased which means the pump has to work harder to raise the water up to the overboard discharge. This, however, is within the capacity of the pump and should be of little concern.

2. The pump suction head decreases and will eventually become lower than that required by the pump for cavitation-free operation. Cavitation causes the pump to operate below its rated capacity and could eventually destroy the pump. At a high enough list angle the pump will not operate at all.

Requests for this document must be referred to U.S. Coast Guard Commandant (GMT), Room 2417, Washington, DC 20593.

When the vessel is on an even keel, the system characteristics for either one or two pumps taking suction from either one or two ballast tanks can be summed up by the curves shown in Figure 2. The pump capacity curve, supplied by the pump manufacturer (reference 3) gives the relationship between head rise and flow for cavitation-free operation. Reference 3 states that this curve is only guaranteed at 2000 GPM and 170 feet. Deterioration over the years can also change the pump characteristics so that the location of this curve in Figure 2 is only approximate. The system head is made up of an increase in static head, i.e., lifting the water from the tank surface level to the overboard discharge at the 105 ft level (zero level is the bottom of the ballast tank), plus the resistance in the suction line. When the tank is full the tank surface level is 35 ft and near empty is taken as 3 ft. If the level falls below 3 ft a vortex (whirlpool) is likely to form around the inlet bellmouth, thereby allowing air to enter the suction line. The static head rise is the same for each pump/tank configuration-the suction line resistance depends on the particular pump/tank alignment.

The 'maximum system head' curve (dashed line at 116 feet) indicates the maximum head the pump can supply without cavitating. This curve is based on a constant required NPSH (net positive suction head) of 19 ft, and was obtained from reference 1. This reference only gives NPSH values for flow rates above 3000 GPM so that the NPSH requirement for the lower flow rates may possibly be lower, thereby raising the 'maximum system head' curve a few feet at the lower end.

The normal operating point for a given pump/tank configuration is at the intersection of the particular system head curve and the pump capacity curve. For example, one pump taking suction from two full tanks will supply a total head of 85 feet and flow 2800 GPM. As the tanks empty the operating point moves up the pump capacity curve until the empty tank system head curve is reached at 115 feet and 2580 GPM. If one pump is used to take suction from one full tank, the intersection is at 118 feet and 2250 GPM. However, 118 feet is in the cavitation region, where the pump capacity curve is not valid, so that the operating point will be not too far above the 'maximum system head' curve, or 116 feet and 2480 GPM. As the tank is drained the operating point moves along the 'maximum system head' curve to 116 feet and 1380 GPM.

When the vessel is listing, as shown in Figure 1, the system head curves must be raised by an amount equal to the vertical drop of the suction line inlets. Referring to Figure 2, the starting points for the empty tank and full tank system head curves must be raised to the levels indicated by the list angle scales. A list angle of 4.1 degrees is enough to raise the empty tank curves above the 'maximum system head' curve. For list angles greater than 13.6 degrees the pumps will not even start to dewater a full tank. The minimum level to which the tanks can be pumped for intermediate values of list angle is shown graphically in Figure 3.

APPENDIX A

ASSUMPTIONS AND CALCULATIONS

1. Suction Lift Capability. This can be defined as the maximum distance below the pump inlet from which liquid can be pumped.

$$L = \frac{P_s - P_v}{\gamma} - (NPSH)_r \tag{A-1}$$

L	is suction lift capability
P_s	is the absolute pressure at the liquid surface
P_v	is the vapor pressure of the liquid
$(NPSH)_r$	is the net positive suction head required for cavitation-free pump operation
γ	is the specific weight of the liquid

The ballast tanks are vented to the atmosphere so $P_s = 14.7$ psi; the vapor pressure for 40°F water is 0.12 psi and the specific weight of seawater is 64 lb/ft^3. The $(NPSH)_r$ for the pump propeller is 19 feet for the range of flows that are expected.

$$L = \frac{(14.7 - .12) \times 144}{64} - 19 = 13.8 \text{ ft} \tag{A-2}$$

2. Suction Line Losses. Details of the piping system were obtained from reference (2). The suction piping from the ballast tank to the pump manifold consists of approximately 260 ft of 8 inch schedule 80 steel pipe, a bell mouth inlet, a butterfly valve, several 90° and 45° elbows, and various other pieces of plumbing hardware. The head loss is given by the formula,

$$h_L = \left(f \times \frac{L}{D} + \sum K\right) \times \frac{v^2}{2g} \ . \tag{A-3}$$

Where, h_L is the head loss in feet

f is the pipe friction factor

L is the pipe length

D the pipe diameter

$\sum K$ is the sum of the resistances of elbows, valves, etc.

and $(v^2/2g)$ is the velocity head in the pipe. This equation may be written,

$$h_L = f \times \left(\frac{L}{D}\right)_e \times \frac{v^2}{2g} . \qquad \text{(A-4)}$$

Where $(L/D)_e$ is an equivalent (L/D) which accounts for all losses. For the suction piping $(L/D)_e = 575$ (410 for the actual pipe and 165 for the remaining restriction to flow). The friction factor for new 8 inch steel pipe is .014, however several years of use have most probably doubled the pipe roughness increasing f to about 0.017. Therefore the suction line loss is,

$$h_L = 0.017 \times 575 \times \frac{v^2}{2g} . \qquad \text{(A-5)}$$

or

$$h_L = 7.5 \left(\frac{Q}{1000}\right)^2 \qquad \text{(A-6)}$$

where Q is the flow in GPM. It is assumed that the resistance of both suction lines are equal.

3. Discharge Line Losses. Reference (2) does not give sufficient detail to accurately define all of the elements of the discharge line. However most of the discharge line is 16 inch pipe with the overboard discharge at the 105 ft level almost directly above the pumps. Assuming that $(L/D)_e = 200$ (which is probably on the high side) and $f = 0.017$, the discharge line loss is,

$$h_L = 0.2 \left(\frac{Q}{1000}\right)^2 . \qquad \text{(A-7)}$$

This loss is very small compared to other system losses and can be neglected without significantly effecting calculated results.

4. <u>System Models</u> Three system configurations are considered:

(a) One pump/one tank

(b) One pump/two tanks

and (c) One tank/two pumps

The model for configuration (a) is also valid for a two-pump/two-tank configuration. Configuration (a) is straight forward-the system head is the sum of the static head (difference in elevation between the overboard discharge and the tank surface) and the suction line loss.

$$H_{sys} = H_s + 7.5 \left(\frac{Q}{1000}\right)^2 \qquad \text{(A-8)}$$

This equation is plotted in Figure 2 for,

H_s = 70 ft (full tank)

and H_s = 102 ft (near empty tank).

For configuration (b) it is assumed that the surface level in both tanks is the same. Thus, since the line resistances are the same, the pump flow will be equally divided between the two suction lines, or (Q/2) in each line. The system head is then,

$$H_{sys} = H_s + 7.5 \left(\frac{\frac{1}{2} Q}{1000}\right)^2 \qquad \text{(A-9)}$$

or

$$H_{sys} = H_s + 1.875 \left(\frac{Q}{1000}\right)^2 . \qquad \text{(A-10)}$$

If the levels are not equal, the tank with the higher level will pump faster.

For configuration (c) one suction line must feed two pumps so the line loss is,

$$h_L = 7.5 \left(\frac{2Q}{1000}\right)^2 \qquad \text{(A-11)}$$

and the system head is,

$$H_{sys} = H_s + 30\left(\frac{Q}{1000}\right)^2 . \qquad \text{(A-12)}$$

5. <u>Maximum System Head</u> Reference (1) gives the required NPSH of 19 ft at the pump propeller. References (4), (5), and (6) locate the propeller about three feet above the tank bottom, or 102 feet below the overboard discharge. Therefore the maximum system head is 102 ft plus the 13.8 ft of lift capability or 116 ft total.

REFERENCES

(1) Layne and Bowler Propeller 10P NPSH curve.

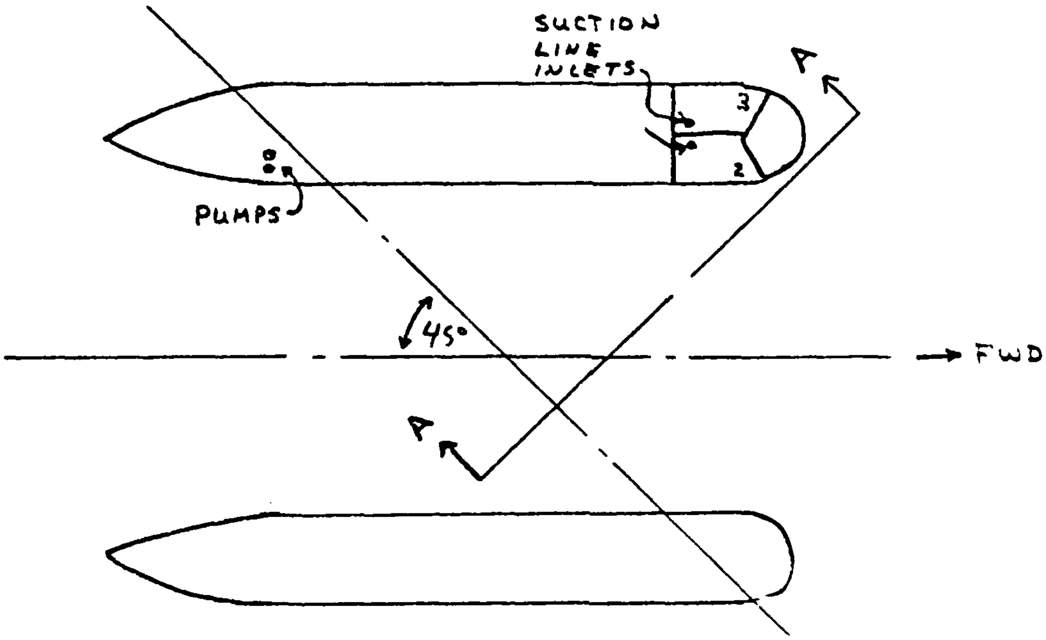
(2) Hiroshima Ship Yard and Engine Works drawing numbers P-4101, P-4103, and G-3161-1.

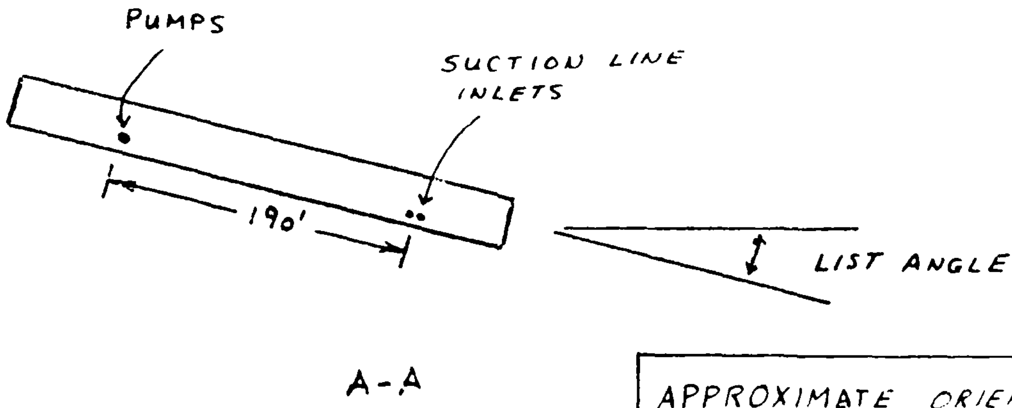
(3) Aurora Pump - Head Capacity curve.

(4) Layne and Bowler Pump No. 464-00938 drawing.

(5) Hiroshima Ship Yard and Engine Works drawing number P-2023.

(6) Layne and Bowler Bulletin numbers 1120 and 1160





A-A

APPROXIMATE ORIENTATION OF OCEAN RANGER AT LAST OBSERVATION

FIGURE 1

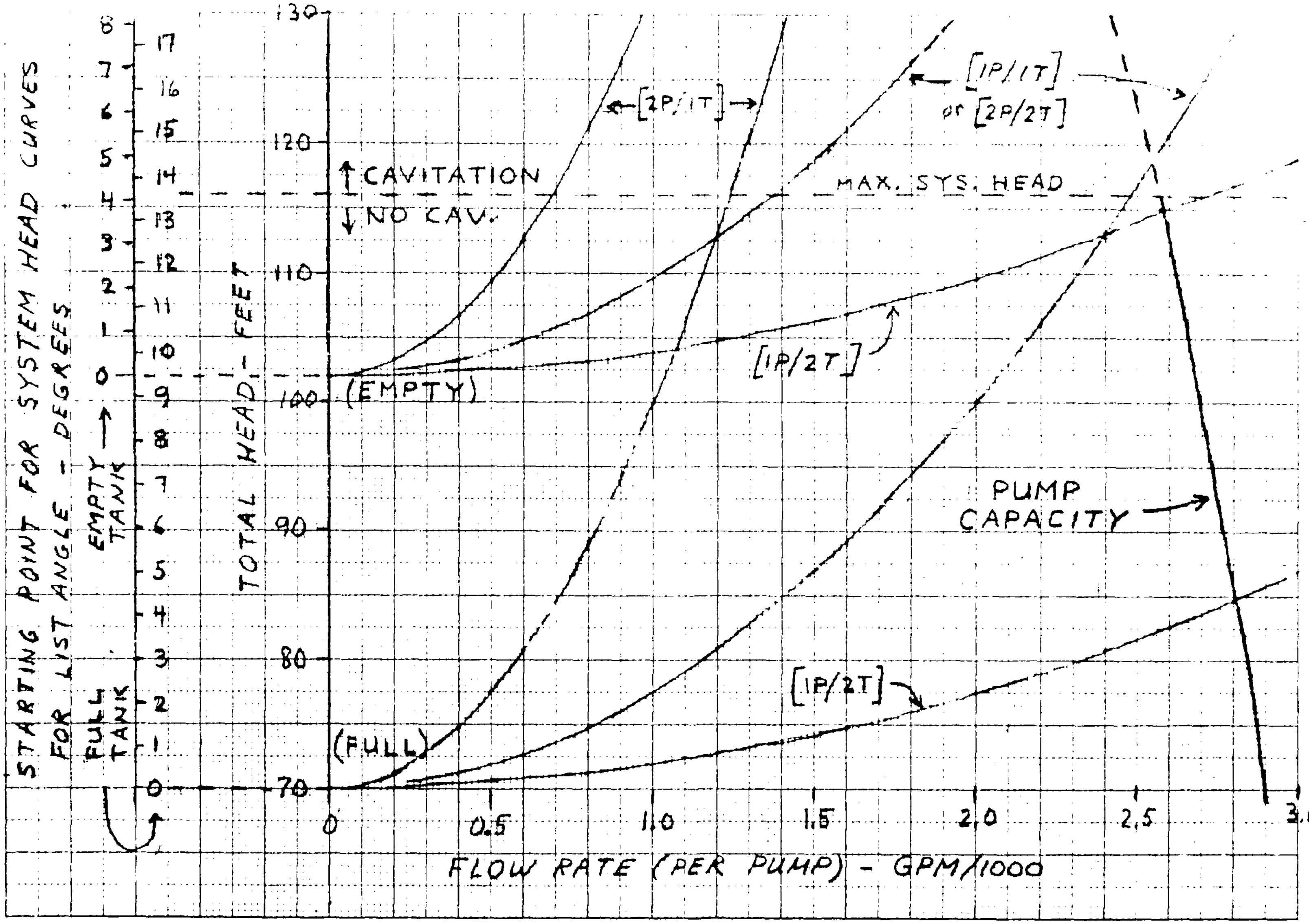


FIGURE 2 - SYSTEM HEAD FOR VARIOUS [PUMP/TANK] CONFIGURATIONS

AD-A140 910 MOBILE OFFSHORE DRILLING UNIT (MODU) OCEAN RANGER ON 4/4
615641 CAPSIZING AND..(U) COAST GUARD WASHINGTON DC
20 MAY 83 USCG-16732/0001-HQS-82

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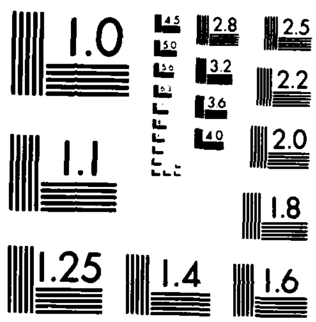


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963 A

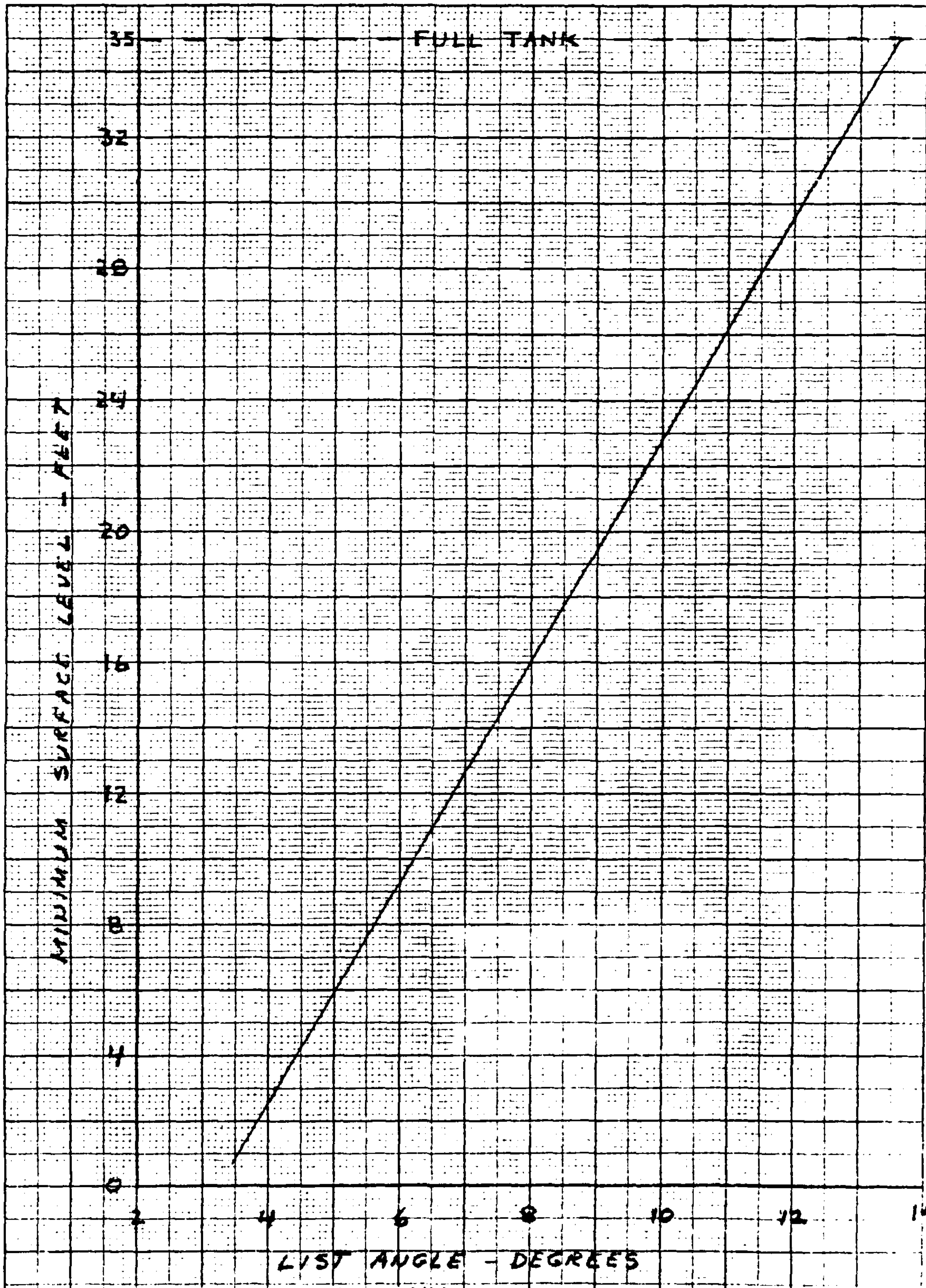


FIGURE 3 - MINIMUM LEVEL ABOVE TANK BOTTOM FOR PUMPING

Professional Qualifications of Author

Edmund J. Jarski has been a Research Mechanical Engineer in the Propulsion and Auxiliary Systems Department of the David W. Taylor Naval Ship R&D Center since 1962. He has a Bachelor of Marine Engineering degree from New York State Maritime College (1957), a Master of Science degree in Mechanical Engineering (Energy Conservation) from Stevens Institute of Technology (1959) and a PhD in Mechanical Engineering (Fluid Mechanics) from the University of Maryland (1970). Dr. Jarski was an Associate Professor at the United States Naval Academy from 1977 to 1979 where he lectured in thermodynamics, fluid dynamics, and engineering design. He also held a 3rd Assistant Engineer's license in the U. S. Merchant Marine.

Enclosure (2)

APPENDIX G

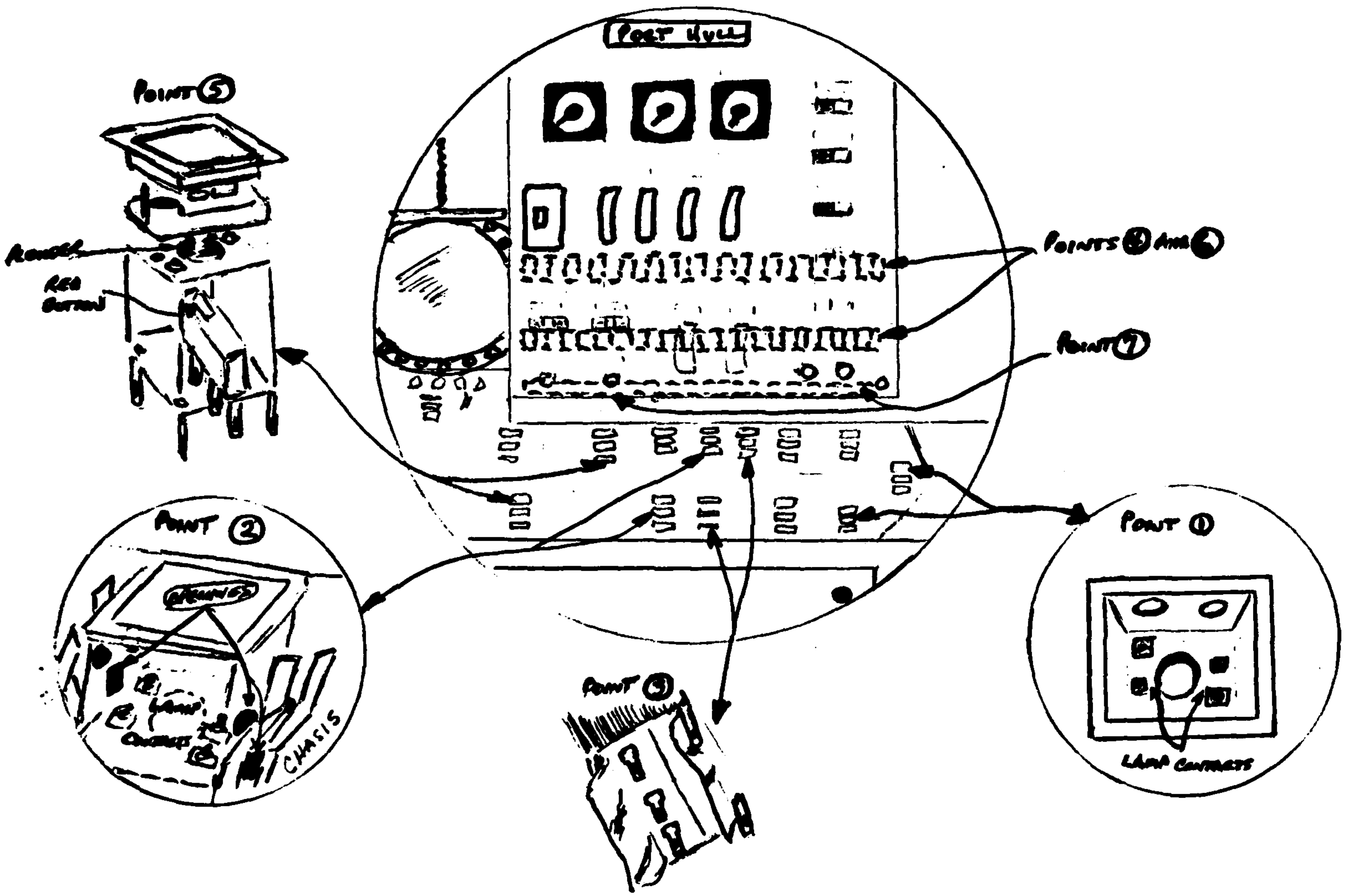
ELECTRICAL ANALYSIS OF BALLAST CONTROL CONSOLE

POINTS IN BALLAST CONTROL CONSOLE CIRCUITRY WHERE
SALTWATER (SW) COULD CAUSE MALFUNCTION
(Note: Points are not listed in order of probability)

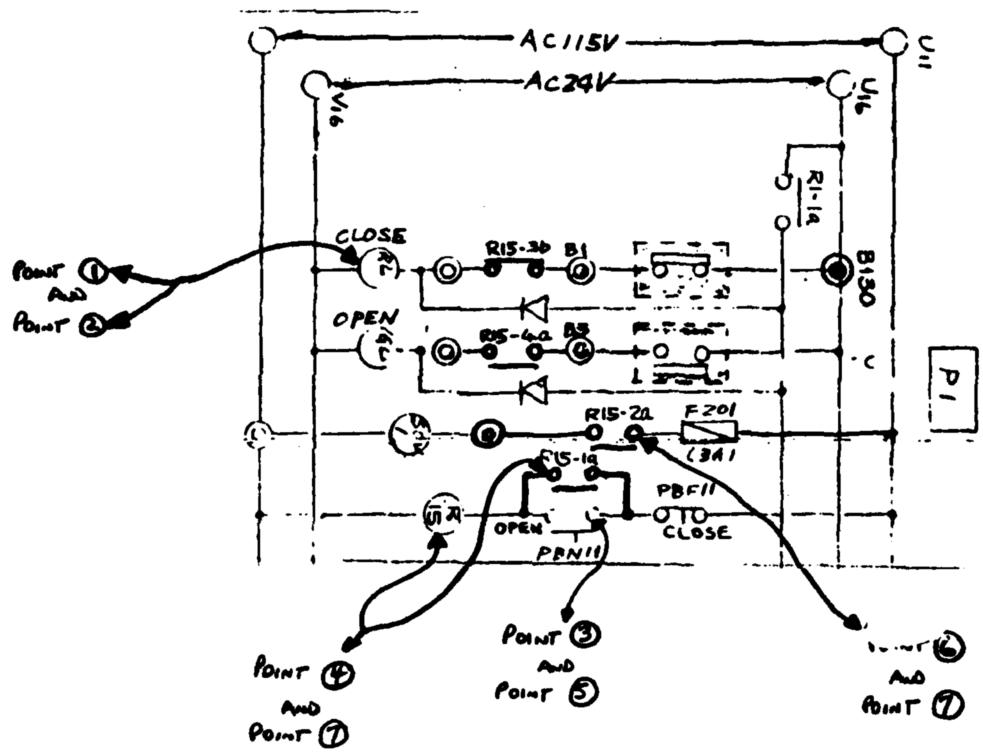
POINT	EFFECT	POSSIBLE RELATIONSHIP TO TESTIMONY
1) Open lamp socket in upper chamber of P.B. SW can collect/flow in bottom of upper chamber bet. both sides of line for indicating lamps.	Short circuit blows 20a. fuse(s) in secondary 24v. circuit fm 500 va transformer causing all indicating lights to go out for port and stbd hulls. Other console circuits are not interupted.	All ballast valve indicating lights go out simultaneously. The operator may erroneously conclude that all power had been terminated to the Ballast Control Console. If a "bridging" of bottom P.B. assembly terminals (115v.) as described in point 3) below occurs, his first indication that ballast valve(s) were open would be when he sees ballast tank levels rising according to the king gauges. He then reports that "valves are opening on their own". If tank levels are changing only in the port hull, he may Report that "all valves are opening on the port side".
2) Bottom of upper P.B. chamber, SW can complete circuit between one side of indicating lamp circuit and mechanical "leaf" (which holds P.B. assb'ly tight in chasis) via openings in side of P.B. casing.	Ground current reduced for all indicating lights intermittently causing lights to dim and blink on and off, fuse may not blow.	Operator observes scattered red lights dim or go out and relight. He erroneously concludes that these indicating light changes reflect actual movement of the ballast valves and so he reports that "the valve(s) are opening on their own".

3) SW flows down exterior side of P.B. assb'ly and across bottom of P.B. momentarily completing circuit (115v.) to holding relay.	Completes or "bridges" circuit holding relay closes by-passing P.B. and opening air solenoid valve and ballast valve	In this case affected ballast valves would open and stay open. He would then correctly report "the valve(s) are opening on their own". If normally opened points remain bridged then attempts to open the ballast valve (by depressing the open push button) would not succeed. Holding relay and air solenoid would re-energize when P.B. is released.
4) SW "bridges" 115v. holding relay terminals by-passing P.B thereby causing same action as depressing P.B.	Same as (3).	Same as (3).
5) SW leaks fm upper P.B. chamber through small clearance around plunger into lower chamber, where it ingresses into small clearance around tiny red button into 115v switch component and completes 115v circuit to holding relay solenoid (note: if tiny holes in bottom of P.B. casing were plugged with dirt, oil, then water could collect in lower chamber).	Same as (3).	Same as (3).

6) SW "bridges" holding relay terminals momentarily completing circuit to air solenoid	Completes or "bridges" circuit. Air solenoid remains open as long as contacts remain bridged, ballast valves would begin to open. If SW dissipates ballast valves would then close. If a circuit is "established" between 1/4" space through dirt, oil and/or melted terminals then ballast valve will open and remain open.	Operator observes scattered red lights go out as air solenoid valves activate causing ballast valves to start opening (which opens micro-switch red lamp circuit. If "bridging" is only temporary valve(s) close again and operator hears air exhausting. He then reports. If bridging establishes circuit then ballast valves remain open.
7) SW splashes onto "terminal" connecting pushbottoms to holding relays and "bridges" either 115v holding circuit, (i.e. P.B. by-pass circuit) or air solenoid circuit.	Completes or "bridging" circuit air solenoid activates ballast valve opens. If P.B. by-pass circuit is bridged, air solenoid will stay open. If air solenoid circuits are intermittently "bridged" by SW then air solenoid valves and ballast valves will "open and close on their own" If port pontoon terminals were primarily affected then <u>many</u> of the port valves would open.	If numberous port pontoon terminals are primarily affected and P.B. by-pass contacts are even temporary "bridged" then numberous port ballasts valves will open and will stay open until they are either individually closed by depressing close P.B.'s or power is shut off to console. If the operator sees <u>many</u> port hull red lights go out simultaneously, he may report "all the valves are opening on the port side".
8) If saltwater splashes on the port hull area on the console some/or all of the above scenarios are possible. Water penetrating the mimic board (horizontal level) would affect the P.B. assemblies. Water ingressing behind the vertical face of the port hull panel could reach the holding relays and the terminals connecting the holding relays to the P.B.'s	Grounds develop and disappear, some circuits are completed or "bridged". Red indicating lamps would dim or blink off and on for the port and starboard hulls. However some port hull red lights would not re-light because some port ballast valves were actually opening. Some of the port hull green lights might light as the ballast valves completed opening, this would draw the operators attention to the port hull lights to the extent he might not notice that the stbd hull lights were also dimming.	One can visualize a situation where an operator is startled by the changes in indicating lights which are occuring primarily in the port hull section of the console. When some green lights go on while other red lights are dim or out he might quickly conclude that "all valves are opening on the port side". As grounds clear up it would be apparent that not all valves were affected. At that point he would refine his earlier report to "some" valves are opening.


POINT 5
RED BUTTON
PORT HULL
POINTS 4 AND 6
POINT 7
POINT 2
LAMP CONTACTS
CHASIS
POINT 3
POINT 1
LAMP CONTACTS

TYPICAL BALLAST CONTROL CIRCUIT



APPENDIX H

ANALYSIS OF LIFESAVING EQUIPMENT PERFORMANCE

SINKING OF THE OCEAN RANGER, 15 FEBRUARY 1982 -
ANALYSIS OF LIFESAVING EQUIPMENT PERFORMANCE

29 November 1982

R.L. MARKLE
Acting Chief, Survival Systems Branch
Merchant Vessel Inspection Division
Office of Merchant Marine Safety
U.S. Coast Guard

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SINKING OF THE OCEAN RANGER, 15 FEBRUARY 1982 - ANALYSIS OF LIFESAVING EQUIPMENT PERFORMANCE

INTRODUCTION

The Mobile Offshore Drilling Unit OCEAN RANGER sank in the early morning hours of 15 February 1982 in the Atlantic Ocean about 175 nautical miles east of St. John's, Newfoundland. All 84 persons aboard are presumed to have died as a result of the casualty; 22 bodies were recovered. The major contributing cause of death for all 22 was identified as hypothermia (loss of body heat, in this case due to immersion in cold water). The prevailing water temperature at the time of the casualty was approximately 31°F (-0.7°C). As a result of this casualty, both the U.S. Coast Guard Marine Board of Investigation and the National Transportation Safety Board have recommended that exposure suits be provided for all persons on board such units that operate in waters where hypothermia is a severe hazard.

The OCEAN RANGER was built in Japan, initially for Panamanian registry. As such, the lifesaving equipment on board did not necessarily comply with U.S. Coast Guard requirements. In 1979, it was registered as a U.S. vessel, and at that time it would have been required to comply with U.S. Coast Guard requirements for lifesaving equipment (46 CFR 108.501 - 108.527, and Navigation and Vessel Inspection Circular (NVC) 3-78). For the OCEAN RANGER, these regulations require totally enclosed lifeboats for 100% of the persons on board (100 persons), davit launched liferafts for 100% of the persons on board (or additional totally enclosed lifeboats for 100% of the persons on board), and life preservers for 125% of the persons on board. (A number of other items which were not factors in the survival aspects of the casualty are also required.) The Coast Guard Marine Inspection Office in Providence, RI issued a letter dated 18 December 1979 after the initial inspection for certification that required the OCEAN RANGER to be equipped with the required U.S. Coast Guard approved totally enclosed lifeboats and davit launched liferafts prior to the next inspection for certification (due December 1981) (reference 15). At the time of the casualty, the lifesaving equipment included:

- 2 Unapproved totally enclosed lifeboats installed in davits and operational (total capacity 100 persons)

1	U.S. Coast Guard approved totally enclosed lifeboat installed in davits and operational (this installation had not been inspected or accepted by the Coast Guard at the time of the casualty) (total capacity 58 persons)
1	U.S. Coast Guard approved totally enclosed lifeboat stowed on deck, not operational (total capacity 58 persons)
10	U.S. Coast Guard approved inflatable liferafts (not davit launched - total capacity 200 persons)
127	Life preservers labeled as U.S. Coast Guard approved (see section on LIFE PRESERVERS), equipped with lights and retroreflective material
-	U.S. Coast Guard approved work vests (quantity unknown)

In light of the failure of this equipment to save anyone on board the OCEAN RANGER, the Marine Board of Investigation requested that this analyis of the performance of the equipment be prepared. This analysis was made through examination of exhibits and records of the Coast Guard Marine Board of Investigation, and through inspection and testing of the lifesaving equipment recovered from the OCEAN RANGER.

LIFEBOATS

At the time the OCEAN RANGER was constructed, it was equipped with two Harding totally enclosed lifeboats built by Björke Bätbyggeri (now Harding AS) of Rosendal, Norway. These boats were identical, 26 ft. long and had a rated capacity of 50 persons. This lifeboat design has a fibrous glass reinforced plastic (FRP) hull and cover made using methods and materials that are typical for this type of construction. Power is provided by a Sabb diesel engine capable of propelling the boat at a speed of approximately 6 knots. The boat is nominally self-righting, in that if capsized it returns to an upright position, provided that all persons inside are secured to their seats with the seat belts and that there is no significant accumulation of water inside the boat.

The release gear on the Harding boats was of the Mills type, allowing the boat to be disengaged only when the weight of the boat is not supported on the falls (off-load release). The purpose of this arrangement is to prevent the boat from being released before it is waterborne. A single handle located near the release gear support bar inside the boat at the aft end controls this release gear. Cables are attached to this handle which are connected to both the fore and aft release hooks. When the load of the boat is off of the hooks, pulling on the handle overcomes the force of the hook counterweights and opens the hooks simultaneously. When the load of the boat is on the release gear, the force required to open the hooks exceeds that which can be applied manually, so the release does not work in the on-load mode.

One of these boats (#1) was installed on the forward end of the OCEAN RANGER, just to the port side of center. The other boat (#2) was installed on the aft end, also on the port side of center. In order to comply with the regulations requiring 200% capacity in a combination of lifeboats and davit launched liferafts, the owners of the OCEAN RANGER contracted with Watercraft America to provide Coast Guard approved boats (reference 6). At the time of the casualty, one of these boats (#4) had been installed on the aft end of the unit, just to the starboard side of the centerline. The other boat (#3) was to have been installed on the forward end just to the starboard side of the centerline, but this installation had not been completed and this boat was stowed on the deck of the OCEAN RANGER at the time of the casualty (reference 11c, pp. 24-25).

The Watercraft America lifeboats were built by Watercraft America, Inc. of Edgewater, Florida. These boats were identical, 28 ft. long and had a rated capacity of 58 persons. This lifeboat design is similar to the Harding in that FRP is used in construction of the hull and cover. Power is provided by a Westerbeke (marinized Perkins) diesel engine capable of propelling the boat at a speed of approximately 6 knots. The boat is nominally self-righting to the same degree as the Harding boat. The release gear in this boat is a Rottmer Gear which is an on-load release. On load release gear allows the boat to be disengaged from the falls at any time, even with the weight of the boat on the falls.

In October 1981, the U.S. Coast Guard published NVC 10-81 on certification and inspection of certain categories of existing vessels, including foreign flag vessels brought under U.S. flag. This NVC contains a section on acceptance of existing lifeboats which were not built under Coast Guard approval and inspection. It lists the features which are regarded as critical to satisfactory lifeboat performance. If the lifeboats on an existing vessel comply with all of these critical requirements, the lifeboats can be used on the vessel as long as they remain in good and serviceable condition. Had this NVC existed at the time the OCEAN RANGER was brought under U.S. registration and the lifeboats reviewed under its provisions, the following deficiencies would have been noted:

a. The release gear is of the Mills type (see preceding discussion). NVC 10-81 requires that the release gear be controlled from a single point, providing simultaneous release of the hooks while supporting the full weight of the boat (on-load release). The most common release gear of this type is the Rottmer mechanical disengaging apparatus, but recently other types of release gear have been approved that perform the same function. This type of release gear has been required on U.S. Coast Guard approved lifeboats for ocean-going vessels since the 1940's because it allows the boat to be released if the vessel is underway or stationary in a current, and it also allows a carefully timed release for rising and falling water in heavy seas. Retrofit of an on-load release for the Harding boats would have been a major modification.

b. Compared with similar Coast Guard approved boats, the rated capacity of the Harding boat appears to be slightly high at 50 persons. Application of NVC 3-79 (referenced in NVC 10-81) could possibly have resulted in a reduction in capacity of 1 to 3 persons.

c. Under NVC 10-81, the engine is required to start by hard or by a hand-energized system at 20°F without starting aids. Alternatively, engine starting depending on cold starting aids is permitted if the aids are of the permanently installed type and if starting can be accomplished at 5°F with aids and 40°F without aids. The Sabb engine is equipped with a hand crank starting system, but it is not known if it would function at 20°F without aids. If aids were necessary, the type provided on the engine would not be acceptable as a permanently installed type because two screw-in plugs on the side of the engine block must first be removed with a wrench, followed by injection of oil into the holes or insertion of a "cigarette" into the hole, and then replacement of the the plugs. Testimony before the Marine Board indicated that on the OCEAN RANGER, heat lamps were kept in the lifeboat engine boxes to facilitate cold starting, and that a can of ether was also kept available (reference 11g, pp. 31 - 34).

Lifeboat #1

When lifeboat #1 was first sighted and recovered the day after the casualty, it was flooded, right side up, and down by the stern. There was a large hole in the bow where the forward release gear support cut through the hull and was torn out, and there was a hole in the cover in the area where the rear hatch and helmsman's tower should be. No one was inside the boat when it was recovered and there were no signs of bodies or lifejackets in the vicinity. (references 11d, p.

27; 11h, p. 34) Only 8 of the required 12 hand flares were found in this boat, but testimony indicates that the flares sighted by the standby boats were probably from boat #2 (references 11g, p. 38; 12, p. 10).

In the process of recovering the boat with cables, the boat suffered additional damage. This is apparently when the cover was crushed and the hull damaged in a number of places (reference 11d, p. 27). In addition to the damage caused by the release gear, there were two other areas of damage that apparently did not occur during recovery. These are two "L" shaped inward fractures on either side of the hull several feet aft of the bow. These fractures match the position of the davit chocks on the launching platform and indicate that the launching sequence for this boat may not have begun, or had just begun when it was separated from the launching platform. The boat and its release gear arrangement are shown in figure 1. Figures 2a through 2d depict a series of events which could account for the damage sustained by this boat. Note that there were no surviving witnesses to the release of this boat or any of the other boats, and consequently no testimony to support this scenario. It is deduced from the damage found during the post-casualty inspection of the boat, and in the opinion of the author represents the most probable series of events. The following is a description of the events depicted in Figures 2a through 2d:

a. Boat #1 was at the port bow, the area of the OCEAN RANGER which is believed to have been the first area of the main deck to enter the water. Seas were heavy at the time, so as the launching platform with the boat approached the water, it would have been struck by a series of waves. The waves were such that the boat would have been subject to severe forces as is evident by the distortion and damage in the aft release hook supporting structure and surrounding FRP laminate. The waves would have lifted and dropped the boat repeatedly, and when the boat was supported by a wave the load would be off the release hook and it could be easily moved to the open position by overcoming the force of the counterweight on the hook. This apparently happened to the aft hook while the boat was being battered by the waves resulting in release of the aft hook. The damage to the rear helmsman's tower and hatch could have occurred at this point since the aft release gear is adjacent to this area.

b. Supported only by the forward hook, the davit chocks on the launching platform lost contact with the gunwale and dug into the hull below and behind their normal position, as the boat was wedged between the chocks on

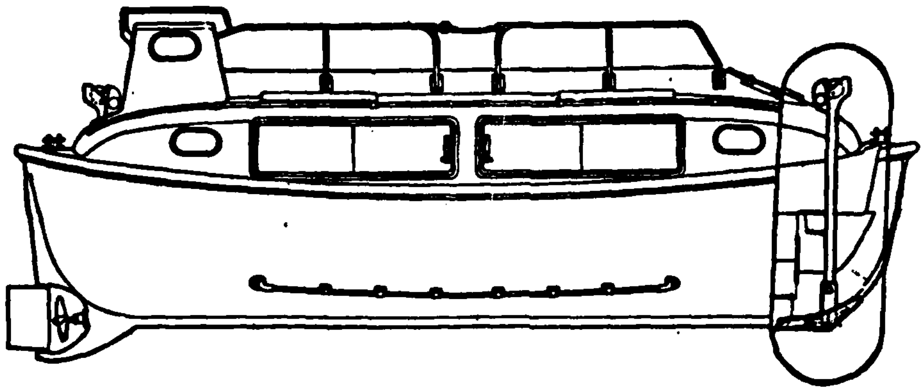


Figure 1. Harding 26 ft. totally enclosed lifeboat. Internal view at forward end shows release gear arrangement. The hook is attached to a support bar which is in turn attached to the keel show by a pin joint. The keel shoe is "glassed in" at the keel and is the means of transferring the load of the boat to the release gear. The support bar is held vertically by a flange bolted to the fiberglass at the point where the support bar penetrates the cover.

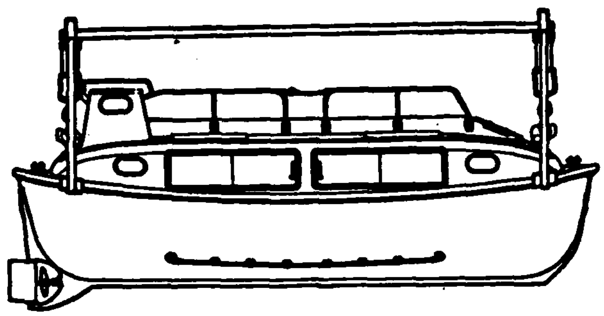


Figure 2a. Harding lifeboat #1 shown in normal stowage position in davit.

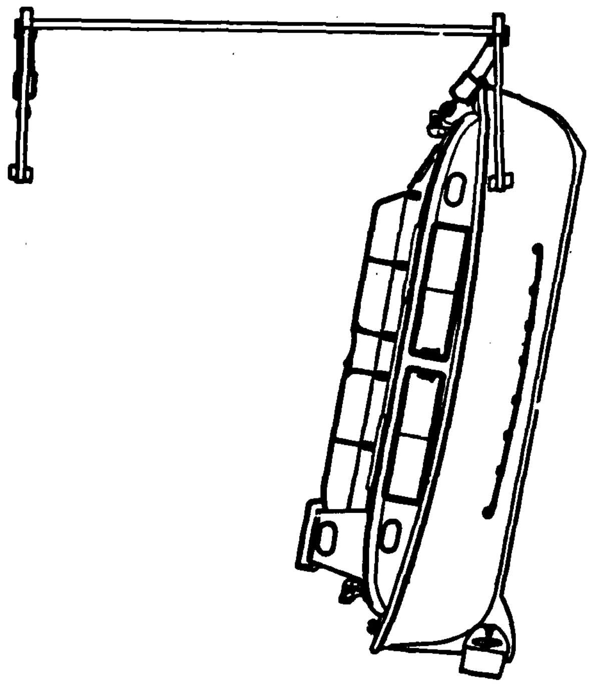


Figure 2b. Aft release hook has been opened, allowing aft end of boat to fall. Davit chocks at forward end normally in contact with gunwale dig into hull, leaving "L" shaped inward fractures on both sides of the hull.

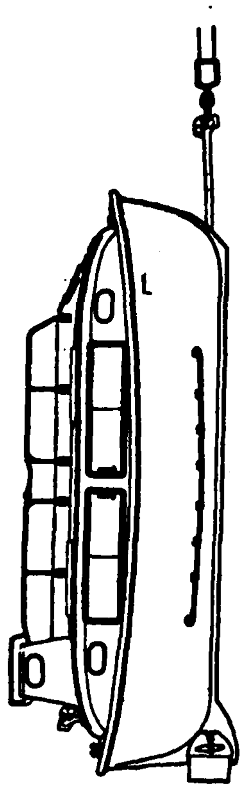


Figure 2c. (Davit omitted for clarity) Release support bar connection to cover is intended to stabilize the support bar in the vertical position in normal circumstances. It is unable to support the boat hanging from one end, so it pivots on the pin connecting it to the keel shoe, ripping out the stem area of the hull as it goes.

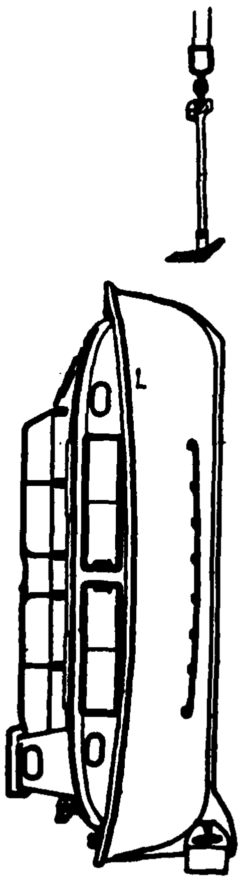


Figure 2d. The glassed in keel shoe is unable to support the boat in this position and is torn out, allowing the release gear to separate from the boat which enters the water stern first.

either side. This caused the "L" shaped fractures discussed above. Had the launching sequence been started, the davit chocks would not have contacted the hull in this manner.

c. Hanging vertically from the forward hook, and possibly aided by leverage on the hull by the davit chocks as well as continued battering by the waves, the forward release gear structure began to slice through the bow.

d. Finally, the support shoe was torn out of its keel connection. This allowed the boat to separate completely from the unit and float away. Damage to the helmsman's tower could also have occured at this point since the boat dropped stern first.

In this damaged condition, the boat would have been open to the sea and flooded, and would have been stable floating either right side up or capsized due to the arrangement of the foam filled flotation compartments along either side of the hull. Because of the immediate flooding of the boat as soon as it fell from the launching platform and entered the water, it would have been very difficult for anyone inside to start the engine or keep the engine running and get underway.

In addition to the damage, another item that suggests that launching preparations had not been completed is the battery charger. This was connected to power aboard the rig by a conventional extension cord. The cord was apparently led out through one of the hatches and the hatch closed over the cord. The charger was found in the boat still plugged into the extension cord, and the extension cord was severed at approximately the place where it would have been led through the closed hatch. Apparently the closed hatch severed the cord as the boat separated from the launching platform. There was no trace of a heat lamp in the engine box or its electrical supply, however.

A telex from the OCEAN RANGER to Odeco on 11 January 1982 indicated that there was a problem with the lowering control wire on boat #1 chafing on an obstruction. This is the wire that leads inside the boat which must be pulled and held to cause the boat to lower. The telex stated that a modification to rectify the problem could be carried out aboard, but there was no subsequent verification that this modification was completed, and there was no discussion about how or if this interfered with the lowering of the boat (reference 5). There was no discussion found in testimony as to whether or not this was a problem.

The seat belts in the boat would have been useless in their primary role as part of the re-righting system since the boat was flooded, however, the seat belts could have lessened injury during the time the boat was separating from the launching platform. One seat belt mounting plate in this boat has been bent inward, and the FRP structure that secures the stud for the mounting shows evidence of distress from this inward pull. This seat is near the engine box and the boat operator's position where one of the first few persons aboard the boat might sit. There is, however, no way to determine if this damage to the seat belt mounting occurred during the abandonment of the OCEAN RANGER.

The seat belt and mounting designs appear to have shortcomings. The buckles are of a conventional aircraft design with a lift latch buckle that appears to operate easily. This attaches to the other belt-half that includes a sliding adjuster. This adjuster belt does not have a tab at the end, and the adjuster can easily be slipped off the end of the belt by holding the belt and shaking it. It was also noted that it is easy to replace the adjuster mechanism on the belt incorrectly, and if this is done, the adjuster will slide off the belt easily as well. Many of the belt adjusters were found in the boat separated from the belts. Other than simply falling off the belts, another possible explanation for the separation of so many belt adjusters could be that the adjusters were not adequate for holding the passengers in place. There are no known standards that apply to lifeboat seatbelts, but there are standards that apply to automotive seatbelt assembly strength. In order to determine the suitability of the adjuster mechanism, three belt sets were removed from the boat and sent to United States Testing Laboratory to be subjected to the belt assembly test from Federal Motor Vehicle Safety Standard (FMVSS) 209 of the National Highway Traffic Safety Administration (NHTSA). This involves application of a 5000 lb. load to a loop formed by the belt. One of the seat belt sets passed the test, and the other two failed in the stitching, but not in the adjuster mechanism (reference 17). Since there was no evidence of stitching failure in any of the belts that were examined in the boat, it is probable that the belt adjusters did not fail under load.

The seat belt mounting arrangements on the thwarts appear to be inadequate. These are simply studs threaded into a blind hole in the FRP thwart structure and a backing plate which appears to be about 1/8 in. to 3/16 in. thick, so that only two or three stud threads would be engaged in the backing plate. The FRP would have little value in holding the stud threads. The studs had been torn out of a number of these holes and the threads were stripped. One thwart recovered from boat #2 showed similar damage to these mountings, and one of the stripped holes had been drilled all the way through to the inside of locker underneath the thwart and a bolt used to replace the stud. This indicates that these mountings were a problem before the casualty, and that it can not be concluded that all of these mountings failed in the course of the casualty.

In summary, there is no physical evidence sufficient to draw a conclusion as to whether or not boat #1 was ever occupied.

Lifeboat #2

Boat #2 was first sighted underway. It came alongside the SEAFORTH HIGHLANDER and capsized slowly as four to five men scrambled out of the boat. Between four and nine men were seen shortly after clinging to the overturned boat. None of these persons were able to be recovered because of the heavy seas and their inability to assist in their own rescue (references 11b, pp. 17, 40, 45; 12, pp. 11-12). In a later recovery attempt, seven bodies floated out through the hole in the bow and approximately 20 more bodies were seen through an open hatch still belted to their seats. It is known that this was the same boat because the SEAFORTH HIGHLANDER ring buoy that had been secured to the boat just before it capsized was still attached (reference 11e, pp. 97 - 99). This boat was therefore launched with approximately 31 people or more aboard.

The slow capsizing suggests that the boat was partially swamped as does the testimony indicating that the boat was being bailed as it approached (references 11b, pp. 15, 74, 78; 12, p. 29). The shift of the weight of the persons leaving the boat on one side was apparently enough to capsize the boat which had diminished stability due to the water inside. If dry inside, a boat like this would not be expected to capsize due to the weight of extra persons on one side. Partial flooding is also suggested by the damage to the bow area that was noted. Witnesses aboard the SEAFORTH HIGHLANDER recalled the damage being on the waterline on each side of the bow, "smashed inward", but the top deck appeared okay. None of the witnesses before the Marine Board stated whether or not the release hook was present in the bow (references 11b, p. 15; 12, pp. 25-26). After the boat capsized, a crack was noted in the hull running fore and aft, parallel to the keel with water passing through (reference 11e, pp. 97, 106 - 107). The cause of the damage to boat #2 can not be determined from the information available for this analysis, but the damage was probably not as extensive as that to boat #1 since #2 was observed to be underway and "riding high" (references 11b, p. 78; 12, p. 10). Bailing a boat as extensively damaged as boat #1 would also have been a futile effort since the bow was open from gunwale to keel. Boat #1 had assumed a position in the water that would have swamped its engine.

During the NORDERTER's attempt to recover boat #2, a rope was passed around the prop shaft resulting in the shearing of the pin that held the shaft to the engine coupling, allowing the shaft to pull out of the boat. The boat was not recovered (reference 11e, pp. 97 - 100). Later, two pieces of flotation foam and a thwart with its attached locker were recovered. These items were definitely identified as coming from a Harding boat since they were identical to similar components in boat #1. Boat #1 was also found not to be missing any of these components. In addition, a checklist was found in the thwart locker that contained identification of boat #2. The only way that the thwart and locker and the flotation foam could have been separated from the boat is if the boat hull had been broken apart. Since it was intact when the attempt was made by the NORDERTER to recover the boat, it must be concluded that some time after the recovery attempt, this boat suffered extensive damage. During the two days following the attempt to recover boat #2, several sightings of half of a lifeboat were reported (references 7, p. 9/2; 8). This wreckage may have been part of boat #2.

Lifeboat #3

This is the Watercraft boat that was stowed on deck. This boat was discovered with hull intact and capsized. The cover of this boat was almost totally torn away. Recovery was accomplished by cables wrapped around the boat, and during various moves, one cable eventually cut through the hull and severed it about 1/3 length aft of the bow. This boat contained no fuel, provisions or other equipment. Many of the seat belts were still rolled-up and secured by rubber bands. The boat shows no evidence of having been occupied. It appears likely that it slid or rolled off the deck as the OCEAN RANGER pitched forward, and that the cover was destroyed in the process. This is an opinion based on the examination of the boat and the knowledge that the boat was stowed on deck, not in its launching platform. None of the witnesses giving testimony to the Marine Board of Investigation saw this boat enter the water. Once in the water, the boat would have behaved essentially as an open lifeboat, flooding in the heavy seas and eventually capsizing. Like the Harding boats, this boat would be relatively stable in the capsized position.

Lifeboat #4

No trace has been found of boat #4. It could possibly still be secured to its launching platform, although one witness reported seeing no lifeboats on the stern of the OCEAN RANGER (reference 11d, p. 47). The testimony of the alternate Master of the OCEAN RANGER stated that as of three weeks before the casualty, boat #4 had not been included in the muster list (reference 11c, p. 36). If the boat had been released, or if it had broken free of its launching platform, the boat or large portions of the boat would have floated to the surface due to its inherent buoyancy. The only sightings of a lifeboat that could be connected with boat #4 were the half lifeboat sightings, although the circumstances suggest that this wreckage was in fact part of boat #2.

Lifeboat Design and Performance

The primary purpose of an off-load release gear such as the Mills Gear on the Harding boats, is to allow the boat to be released when the weight of the boat is off the falls. One characteristic of the Mills Gear design is that when the weight of the boat is taken off a hook, the hook can be easily moved to the open position (even independently of the other hook) by overcoming the force of the hook counterweight. In the case of a Rottmer gear and other on-load releases approved by the U.S. Coast Guard, the hook is locked in the closed position until the operator throws the release handle. Additionally, no manufacturer of U.S. Coast Guard approved lifeboats uses a "glassed-in" connection for the keel shoe as in the Harding boat. All keel shoes are connected to the keel by through-hull bolts. The Mills type release gear operating characteristic and method of construction may have therefore led to the premature release of the aft hook of boat #1 with subsequent separation of the forward release mechanism, along with the severe damage it caused to the bow. It can not be definitely concluded that a Rottmer gear would not have failed under the same circumstances, but it would not have failed in the same way. There have been reports of lifeboats on U.S. vessels being swept away by boarding seas, so failure of a Rottmer gear under similar circumstances can not be ruled out. Even if boat #4 which is equipped with Rottmer gear is found still on the OCEAN RANGER, it must be noted that this boat was on the aft end of the unit, and would not have been subject to the same kinds of forces experienced by boat #1.

The lifeboat installation drawings for the OCEAN RANGER show that the boats would clear the the transverse tube connecting port and starboard columns up to an adverse trim of 12°. Since the OCEAN RANGER is believed to have gone down by the bow, boat #2 on the stern would have had to be launched against an adverse trim. If the trim exceeded 12°, or if the boat was swinging as it approached the transverse tube, some impact damage might have occurred and might account for the damage noted to boat #2. The length of the falls at the level of the transverse tube would have been approximately 100 ft. which in combination with the heavy seas would have made some swinging a realistic possibility.

In March, 1980, the Norwegian semi-submersible ALEXANDER L. KIELLAND suffered a broken column, heeled to 30°-35°, continued to heel until 20 minutes later when it capsized. This unit had seven totally enclosed 50 person lifeboats on board which are believed to have been essentially identical to boats #1 and #2 on the OCEAN RANGER. The following is extracted from a summary of the report prepared by the Norwegian government Commission investigating the casualty:

> Four of the boats were lowered without problems. However, there were problems with the release of the lifeboat hooks. The hooks, equipped with simultaneous release mechanisms, could not be disengaged under load, a circumstance difficult to avoid because of the rough seas on the day of the accident. For this reason three of the boats were blown against the platform and damaged. On the fourth boat, the after part of the wheelhouse was crushed. Through an opening caused by the impact, a man managed to release the aft hook by hand. Before that, someone had somehow suceeded in releasing the forward hook. A fifth boat fell into the water bottom-up when the platform capsized. In some unknown way, the hooks had been released. People in the boat and people outside it, managed by common effort to right it. (reference 4)

The type of problems experienced with the off-load release gear and the subsequent damage to the boats in the ALEXANDER L. KIELLAND case may be relevant in explaining the damage to OCEAN RANGER boats #1 and #2.

Some concern was expressed in testimony that the FRP structure of the lifeboats was inadequate due to the extent of damage that was incurred (reference 11d, pp. 84-85). There is no reason to conclude this when all of the damage is analyzed. The damage to the FRP in the bow of boat #1, the damage around the rear release hook, the "L" shaped fractures on either side of the bow, and possibly the damage to the helmsman's tower and hatch were apparently directly and indirectly the result of the premature release of the aft release hook. The crushing of the cover occurred when the boat was retrieved by cables. Other damage to the hull also appeared to be cable damage, some of which could have been caused by the lashing cables on the launching platform.

Boat #2 had some damage to the bow of the boat, but the reason for this can not be conclusively determined. It may have been associated with the characteristics of the release gear, impact on the transverse tube on launching, or some other unknown reason. The reason for the apparent subsequent destruction of the hull has not been determined.

The cover of boat #3 was completely torn away, but since this boat was not was not in a launching platform, this damage probably occurred as the boat slid or rolled off the deck. The hull was subsequently cut in two by a cable used in recovery. The hull is significantly damaged in only one other place, which was a fracture that did not penetrate the buoyancy foam and inner hull. No loss of integrity would have resulted from such damage. This damage may also have occured when the boat came off the OCEAN RANGER, or upon recovery.

Self-righting of Flooded Lifeboats

After the loss of the OCEAN EXPRESS in 1976, the U.S. Coast Guard approached the Lifesaving Appliances Subcommittee of IMCO (Inter-Governmental Maritime Consultative Organization, now International Maritime Organization - IMO) and lifeboat builders with a proposal that would require totally enclosed lifeboats to provide an above-water escape in the event of a capsizing in the flooded condition. In most cases, this would be accomplished by the addition of flotation foam to the inside of the cover, so that it would not remain underwater in the event of a capsize. This would raise the hatches on one side out of the water, and in some cases might result in re-righting of the boat. This would prevent persons inside the boat from being trapped underneath with no way out. This approach seems to be accepted by the boat builders and will probably be part of the requirements of a revised lifesaving chapter of the International Convention for the Safety of Life at Sea (SOLAS). This feature might have allowed more of the people inside the lifeboat that capsized alongside the SEAFORTH HIGHLANDER to get out of the boat, or it might have caused the flooded boat to reright itself.

Alternate Launching Methods

The damage to lifeboat #2 may have been caused by contact with some part of the rig structure during the launching sequence. This possibility seems even more likely when the events during the abandoment of the ALEXANDER L. KIELLAND are considered. The type of release gear used on boats #1 and #2 is not Coast Guard approved because it will not release the boat when there is a load on the falls. Nevertheless, Coast Guard approved systems still depend on lowering by wire which can result in the lowering of the boat onto some part of the lower structure of the rig, or swinging into some part of the structure. At the present time, alternatives to lowering by wire are limited.

One new system developed in Norway allows a specially designed lifeboat to slide down a short ramp and free fall into the water. The shape of the boat, its angle of entry into the water, and the motion imparted by the ramp all work to cause the boat to move away from the casualty, even if the engine is not operating. Persons in the boat are secured in specially designed, energy absorbing, aft-facing seating. A number of these systems have been installed on Norwegian ships. The current state of the art limits this system to a launching height of approximately 20 m (66 ft.). Another version of the system is being developed for use on rigs. This system may be able to be used at heights of up to 30 m (99 ft.). Unlike the shipboard system, no ramp would be used and the boat would drop vertically. The shape of the boat and its angle of attack would still result in movement away from the rig. The vertical drop would eliminate the swinging problem of wire systems, but it could still allow the boat to be dropped onto some part of the structure especially in the case of a boat on the high side of a listing rig. Also, if the launch is on the weather side, the boat can be driven into or under the rig as in wire launch systems.

Another system that has been considered would involve the use of some type of boom or slide that allow the survival craft to be launched well away from the structure of the rig. Such a system was proposed in the mid 1970's by the Red Adair Co., and a similar system has been recently proposed by Conoco. Such systems would seem to offer a significant improvement in the ability to launch survival craft from rigs under adverse conditions, however, neither of these systems is beyond the conceptual stage. Development of the Adair system stopped when it became evident that there would be significant structural problems. Inflatable slides have been used to launch inflatable liferafts, however, tests and observations of these systems made it evident they were not suitable for use in heavy winds and seas. At the present time, there are no known raft slide installations on any U.S. registered vessels. Nevertheless, slide or boom launch systems may offer a good launching alternative if the present problems can be overcome.

Another type of release system has been developed by the Whittaker Corp. for their survival capsules launched on single fall systems. This type of release can best be described as semi-automatic. Like the Mills gear, it uses a counterweighted hook that is designed to open when there is no load on the hook, but it is set during lowering by pulling a handle which is connected to a pin that holds the hook in place. When the boat enters the water, the load is momentarily off the hook, and it releases at that instant. If the hook is not set, and the boat becomes waterborne, or if the operator intentionally wants to release the boat before it reaches the water, a lever is provided that can be used to release the boat under load. This design is intended to combine the best features of off-load and on-load release gears. Model tests in a wave tank have shown this system to reliably provide automatic release of the boat. It is of course still a wire launch system, and therefore subject to the same limitations as other systems of that type.

LIFERAFTS

Soon after the casualty, four inflatable liferafts were recovered. One raft was complete with some damage to its canopy and damage to one of the inflation tubes which occurred during recovery. Another raft was complete, but the upper and lower tube had separated from each other over about 75% of the circumference of the raft and some damage to the canopy. The third raft was complete with its floor separated about 80% of its circumference. The floor became completely separated in the process of moving and inspecting the raft. The fourth raft consisted only of an upper buoyancy tube and canopy support, and a floor which was completely separated from the tube except for the inflation hose connection. This raft's canopy and lower buoyancy tube are missing. One of the witnesses reported seeing one partially inflated raft and two fully inflated rafts, one of which was blowing over and over. It is not known if any of these rafts were recovered. One raft was observed to sink the day after the casualty, and another five days after (references 7, p. 20/6; 8). A sunken raft was recovered in June 1982 about 60 miles from the scene of the casualty at a location different from the sites where the other two rafts were seen sinking. The five recovered rafts and the two sunken rafts not recovered account for seven of the ten rafts aboard the OCEAN RANGER, although there is a chance that one of the rafts sighted but not recovered was one lost from the SEDCO 706 several hours before the sinking of the OCEAN RANGER (reference 11a, p. 15).

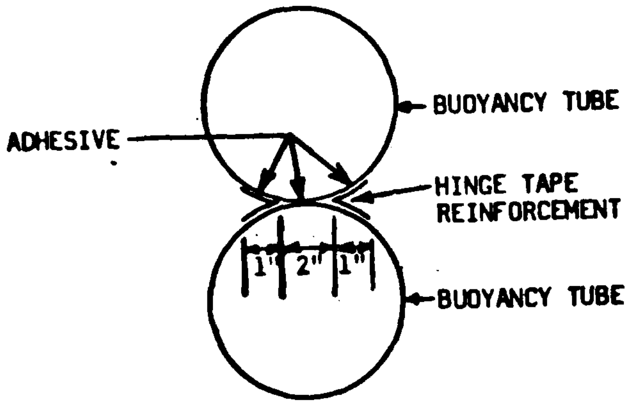
Three of the rafts and the separated floors had separated at the joints that hold the floor to the buoyancy tubes and that hold the buoyancy tubes to each other. Only one of the painter lines was complete from the raft to the point of the weak link. The other painters were severed at a point short of the weak link. Some damage to the rafts was incurred on recovery. Testimony from persons on-scene indicates that some rafts were properly inflated and others were damaged before they were picked up. One was described as being a few bubbles of jumbled liferaft material with ropes wrapped around it (references 11d, p. 33; 11e, p. 101).

There was no evidence that suggests that the rafts were ever occupied. Some equipment bags were open, but since they were made to be readily opened, this is not significant. There was no evidence of the use of flares. None of the liferaft relief valves had plugs screwed into them. While this would not necessarily be done by survivors, any plug found in a relief valve would suggest that the raft had been occupied since the rafts are packed with the plugs out of the valves. All doors were tied in the open position the way they should be when packed.

Liferaft Design and Performance

Nine of the ten rafts involved were built in 1974 for C.J. Hendry Co., of San Francisco, California. The tenth raft was a B.F. Goodrich raft which was one of the rafts not recovered. Inflatable liferafts are typically considered to last roughly 10 years, so these rafts may have been nearing the end of their useful lives. Because of the extent of joint separation, attention was focused on the performance of the joints and adhesive. Raft seams are required to have a strength greater than that of the base fabric, however, these requirements are intended primarily for the seams in the buoyancy tubes, rather than the joints that assemble tubes, floor, and canopy into a complete raft. These joints between upper and lower buoyancy tubes, and between lower buoyancy tube and floor were the primary problem areas. Joint samples have been cut from the recovered rafts and tests are to be performed on them by Technitrol Canada, Dorval, Quebec. At this writing, those tests have not been completed.

Examination of the areas of the raft that had joint separation showed that in most cases, adhesive adhered to one side of the joint, but not the other. Failure appeared to be in the peel mode, but it could not be conclusively determined by examination where the peeling began or why. Glued joints are generally weakest in the peel mode. Figure 3 illustrates the normal method of joining upper and lower tubes. On raft 715, the central area shown as 2 in. wide in the figure was actually much narrower and did not have any evidence of adhesive joining upper and lower tubes directly. Adhesive was evident only on the reinforcement. If the tubes are directly joined, forces tending to separate upper and lower tubes would be resisted by a tensile load on the adhesive joining the tubes. As built, the forces pulling the tubes apart are resisted by the reinforcing tape in the peel mode. If the tubes had been joined in the central area, the resulting structure may have been more resistant to separation.



Not to scale

Figure 3. Normal construction of liferaft.

In its examination of the rafts, Technitrol Canada repaired some of the ripped tubes and attempted to inflate the rafts. Several rafts showed blistering where inner and outer coating had separated from the base fabric. Some of these blisters exhibited pinhole leaks. It has not been determined how or when these blisters occurred, or if they contributed to deflation of some of the rafts soon after the casualty.

In order that inflatable liferafts function properly when needed, they are required to be serviced annually by an approved service station. According to the records, the rafts on the OCEAN RANGER were serviced between 20 April 1981 and 31 July 1981 by an organization in St. John's, Newfoundland (reference 3). This organization was not an approved servicing facility for either C.J. Hendry or B.F. Goodrich rafts and as such would probably not have had the necessary repair parts, manuals, servicing bulletins and packing instructions. A raft which is improperly serviced may not inflate or deploy properly, leading to rafts which can not be used. There were and are no approved servicing facilities in

St. John's for U.S. Coast Guard approved rafts. The closest facility was in the Boston, Massachusetts area.

One of the problems with inflatable liferafts that has been recognized for some time is their tendency to be carried away from the scene of an accident before survivors can reach them, and to capsize in high winds and heavy seas. In recent years, a new type of "heavily ballasted" liferaft has been developed and promoted primarily for its resistance to capsizing in heavy seas. In an Advance Notice of Proposed Rulemaking dated 29 June 1981, the U.S. Coast Guard announced that it was considering amendment of the approval requirements for inflatable liferafts to include requirements for such ballast systems. Capsizing of liferafts has been recognized as a problem, but if no one can reach the raft in the first place it is only an academic interest. Perhaps a more important characteristic of such rafts is their tendency to drift with the current rather than being carried away at high speed by wind and waves. Survivors in the water will also drift with the current, so the probability that survivors could reach the rafts is increased.

Even if all of the rafts had floated free, inflated, and had been in the vicinity of persons in the water, it is doubtful that many persons would have been able to reach and board them, although those wearing helicopter-type immersion suits would have had a better chance (see following discussion of exposure protection). The paralyzing effect of the cold water would have made it difficult for anyone in the water without exposure protection to pull themselves aboard a raft. This was illustrated by the inability of any of the persons that entered the water alongside the *SEAFORTH HIGHLANDER* to board the liferaft deployed by that vessel or to assist themselves in any way (references 11b, pp. 17, 41; 12, p. 33). Some type of effective personal hypothermia protection would have to be provided in order for these persons to help themselves to the extent necessary to board a liferaft.

The fact at least three rafts sank should not be taken as conclusive evidence that they were severely damaged. These rafts are equipped with relief valves to prevent the raft from exploding due to a pressure build-up from excess inflation gas. Once inflated and boarded, occupants should plug the relief valves to prevent loss of gas as the raft flexes in the waves. Unoccupied rafts may eventually deflate even if undamaged. It is not possible to conclusively determine what happened to the liferafts. In the opinion of the author, the available evidence suggests one or a combination of the following may explain why some rafts were damaged before they were recovered:

a. The liferafts may have floated free of their stowed positions as the OCEAN RANGER sank. A few became entrapped in the rigging and appendages of the unit and never got to the surface. Others did inflate and rise to the surface, but some were damaged as they came in contact with various parts of the structure. This would account for damage to the raft joints and severed painter lines.

b. The liferafts may have floated free of their stowed positions, inflated, and risen to the surface. Some of the rafts had aged sufficiently to cause deterioration in the glued joints. These rafts then suffered damage in the heavy seas.

c. The liferafts may have floated free of their stowed positions, inflated, and risen to the surface. The joints had not significantly deteriorated, but the joint design was not adequate for the stresses encountered. These rafts then suffered damage in the heavy seas.

d. The rafts may not have been properly serviced and repacked, leading to non-inflation in some cases, and damage upon inflation in other cases.

e. Rafts damaged as described above would have been readily swamped. When swamped, these rafts would have behaved in a manner similar to heavily ballasted liferafts, drifting with the current and staying near the site of the casualty. Undamaged rafts would have been quickly carried away from the scene by the wind and waves, so that they were difficult to locate by the time daylight arrived.

Davit Launched Liferafts

Under Title 46 of the Code of Federal Regulations, § 108.506 and NVC 3-78, sec. 3.d.(8), the OCEAN RANGER was required to have a combination of lifeboats and davit launched inflatable liferafts sufficient to accommodate 200% of the persons on board. The owner intended to comply with this requirement by the addition of the Watercraft lifeboats, which in combination with the Harding lifeboats would bring total lifeboat capacity to 200% (references 11b, p. 156; 6). This solution did not address the fact that the Harding lifeboats were not acceptable under Coast Guard regulations or under NVC 10-81.

In order to fully comply with the Coast Guard requirements, the owner would have had to replace or upgrade the Harding lifeboats, or else remove them and replace the liferafts with davit launched liferaft installations. Had davit launched liferafts been on board, these could have been boarded and launched from the deck in a manner similar to the lifeboats. The approved release hook system automatically releases the raft when the hook is set during lowering and the raft becomes waterborne. Operation of the hook is similar to the system described for the Whittaker survival capsules in a preceding section, except that it may not possible to release the raft when the hook is loaded. The davit launching system would have made the liferafts more readily available for use since the conventional liferafts could not be boarded until they were waterborne and inflated. On a rig like the OCEAN RANGER or any vessel with a high freeboard, this is a very difficult operation, made more difficult by the weather, sea state, and sea temperature. On the other hand, the davit launched liferafts are subject to the same launching problems on MODUs as the lifeboats are. The air gap under the rig results in full exposure to wind and sea regardless of where located, and there is the risk that the raft will be driven into some part of the structure during or after launching. Nevertheless, since davit launched liferafts would have been more likely to have been boarded than the conventional rafts, if follows that they could possibly have saved some lives.

LIFE PRESERVERS

Of the bodies recovered after the casualty, 21 were wearing Billy Pugh Model 200 life preservers and one was wearing a Billy Pugh Model WVO-100 work vest. All but two of the life preservers were equipped with ACR model L8-2 water-activated personal flotation device lights. The lights apparently worked well and were useful for locating persons in the water. Many of the bodies (actual number unknown) were found face-down and some were underwater, hanging by the body strap underneath the floating life preserver (references 11b, pp. 18-20; 11d, p. 37). Under the latter circumstances, the life preserver apparently came off over the head of the wearer who did not put it back on, indicating that when the life preserver came off, the wearer was already dead or was unable to help himself due to the effects of hypothermia.

The Billy Pugh Model 200 life preservers that were recovered were examined and were found to fall into two distinctly separate groups. One group of devices that came from lot 1A were noticably heavier than the other devices and were of a different design. The other group was comprised of devices from various lots produced later than lot 1A. The initial certificate of approval for the Model 200 was issued 17 February 1977, however, the lot 1A devices were inspected and passed by a Coast Guard inspector from the Corpus Christi, TX Marine Safety Office on 15 July 1976. These devices had the Coast Guard approval number on them because the manufacturer had been told what the approval number would be. This is frequently done in advance of actual approval so that the manufacturer can plan equipment markings and promotional material. The fact that they were inspected and passed by a Coast Guard inspector would indicate that they were found to have the proper buoyancy and to conform with the manufacturer's plans and specifications, although this inspection marking is usually not applied until a device is actually approved. Nevertheless, the lot 1A devices were a pre-approval design of 98 units and would not normally have been sold or used as Coast Guard approved devices. It is not known how these devices came to be released.

One pre-approval Model 200 was tested by Coast Guard Headquarters personnel in May 1976. At that time, a tendency for the device to come off over the wearer's head when jumping into the water was noted, but the turning moment (the force that turns the wearer from a face-down to a face-up position) appeared to be acceptable (reference 13). In August, 1976, the company was informed that the device fell short of life preserver performance requirements in that it had a lack of turning moment and that it did not keep the wearer's head far enough out of the water (reference 14). The differences in the designs tested at these two times and their exact relationship with the lot 1A design are not known, however, sketches enclosed with the August 1976 letter show a design similar to the lot 1A design. The design finally approved in February 1977 resolved these problems sufficiently to allow its approval (reference 9). The Model 200 devices from the OCEAN RANGER that were from lots other than 1A appear to conform with the approved design. No correlation between bodies found face-down and those wearing lot 1A devices can be made from the information available for this analysis.

Rough water performance of life preservers has recently become a matter of concern to the Coast Guard. The person in the water will not rise as fast as the water on the face of a wave and therefore may be submerged momentarily. Depending upon the combination of person, life preserver and sea state, this may develop into a plunging action. One witness reported the heads of the persons in the water constantly washing underwater (reference 12, p. 31). On yoke-type life preservers like the Billy Pugh devices, this action may result in the life preserver being pulled off over the head if the device is not secure under the chin or around the body. One of the tests that has been used to determine the acceptability of life preservers is a jump test from a height of 3 m into a pool. Although this is intended as a test of the performance of the life preserver when the wearer is jumping into the water, it may also prove to be useful in evaluating the tendency of the device to come off in rough water. During the approval testing of the Model 200 (approved version), 26 persons performed the jump test in the device. It came off over the heads of three of the test subjects and tended to ride up on a fourth. These subjects jumped a second time wrapping their arms around the device (a procedure generally recommended for jumping into the water in any life preserver), and in each case it stayed on. The test report does not record the way in which the body strap was adjusted (reference 9). Recently, as part of the OCEAN RANGER lifesaving analysis, a Model 200 (approved design) was subjected to the jump test on five different test subjects. With the body strap secured tightly, the device tended to rise to the subject's eye or ear level, but did not come off. With the body strap adjusted to a "comfortable" position as judged by the subject, the device came off over the heads of four out of the five subjects. The same test was performed with a yoke-type life preserver of "standard" design which was found to stay on the same subjects with the body strap in the tight and and also in the comfortable positions.

Samples of the Model 200 life preservers from the OCEAN RANGER were obtained and subjected to further examination and a buoyancy test (reference 10). Examination of the devices and Coast Guard files indicates that the lot 1A devices are made of polyvinyl chloride (PVC) flotation foam rather than polyethylene (PE) foam as prescribed for the approved design. The PVC has a higher density which accounts for the apparent weight difference in the two groups of devices. The neck opening in the lot 1A devices is of a different design and slightly larger than the approved design. PVC foam is also more flexible than PE foam, and the flotation pads on the lot 1A devices are thinner than on the approved devices. All of these factors would contribute to the tendency to allow the wearer's head to slip out of the lot 1A devices. The buoyancy test showed that the lot 1A devices had a buoyancy loss of about 6-1/2 % as compared to their original buoyancy. One of the three lot 1A devices tested was 1 oz. under the 22 lb. minimum buoyancy required for new devices. The other two were 6 oz. under the minimum. Some degradation of life preserver buoyancy is expected with age, and the losses on these devices would not be considered critical. The other three devices of the approved design were all above the 22 lb. minimum by 1 oz., 27 oz., and 28 oz.

As a result of these findings, the manufacturer of the life preservers was advised that the unapproved devices had been discovered to be in use and should be recalled or destroyed. The manufacturer's approval of the device was suspended pending improvement in its performance in the jump test (reference 16). The manufacturer did institute a voluntary recall of devices from lots 1 and 1A, comprising 172 unapproved devices (reference 1). The design of the approved device was also altered so that it performs properly in the jump test. The approval certificate was subsequently reinstated.

EXPOSURE PROTECTION

At least two of the bodies recovered were wearing some type of exposure protection garment. In photographs, these appeared to be uninsulated immersion suits of the type sometimes used on offshore helicopters. A quantity of these suits issued by the helicopter operator were normally kept onboard the OCEAN RANGER. These devices were apparently returned as personal effects and were not available for examination. It was reported that at least one person in one of these suits sank when he came out of his life preserver (reference 12, p. 33). Unlike the U.S. Coast Guard approved exposure suits, these devices do not have the buoyancy and insulation provided by flotation foam. They are waterproof garments that must be used in conjunction with a life preserver. The purpose of these garments is to keep the wearer dry, so that loss of body heat through direct contact with the water is prevented. To protect from conductive heat loss through the suit, as much clothing as possible should be worn underneath the suit.

One recent study compared heat loss rates of different types of exposure protection in calm 11.8°C (54°F) water. All of the test subjects wore the same type of clothing -- underwear, long sleeve shirt, denim trousers, socks, and sneakers. The average cooling rate for the subjects wearing only a life preserver in addition to the basic clothing ensemble was 2.30°C/hr. Subjects wearing uninsulated immersion suits averaged 1.07°C/hr. loss rate (2.15 times "better" than the subjects with only a life preserver). Those wearing insulated exposure suits averaged a loss rate of 0.31°C/hr (7.35 times "better" than the subjects with only a life preserver). This study also estimated the time to "incipient death" with different types of exposure protection in the 11.8°C water. For those in life preservers, this time was 3.4 hr. For those in uninsulated immersion suits, it was 7.0 hr. For insulated exposure suits, it was 23.1 hr. (reference 2)

From this data, it can be seen that those persons wearing the immersion suits should have been able to survive perhaps twice as long as those with life preservers alone. These suits obviously did not provide the margin of exposure protection needed in the conditions that existed following the abandonment of the OCEAN RANGER. Insulated exposure suits of the type that are U.S. Coast Guard approved might have extended survival time six or seven times that of persons wearing life preservers alone.

EMERGENCY RADIO COMMUNICATION EQUIPMENT

An ACR RLB-14 Emergency Position Indicating Radio Beacon (EPIRB) was on board the OCEAN RANGER. It was recovered after the casualty indicating that it had floated free. The signal from the EPIRB was received by rescue aircraft flying to the site of the casualty, however, since the standby boats had already been alerted to the problems being experienced by the OCEAN RANGER and since its position was known, the EPIRB did not appear to be a factor in this casualty.

A JVC portable lifeboat radio (Japanese - not FCC approved) was found in boat #1. There was no evidence that indicates any attempt was made to use this radio.

A VHF-FM two-way radio was also found inside boat #1. There were no radio transmissions during the casualty identified as having come from this radio.

APPENDICES

APPENDIX 1

REFERENCES

1. Billy Pugh Co., letter, "Recall Model #200 Life Preservers Lot 1 and Lot 1A," 12 October 1982.

2. J.S. Hayward, et al., "Survival Suits for Accidental Immersion in Cold Water: Design-Concepts and their Thermal Protection Performance", University of Victoria, Victoria, B.C., Canada, January 1978.

3. IMP Group Ltd., Liferaft certificates of inspection, OCEAN RANGER Marine Board of Investigation file 4.57A.

4. Torgeir Moan, "The Alexander L. Kielland Accident," proceedings from The First Robert Bruce Wallace Lecture, Massachusetts Institute of Technology, June 1981. p. 12.

5. OCEAN RANGER telex to Odeco, St. John's and New Orleans offices, dated 11 January 1982, U.S. Coast Guard Marine Board of Investigation Exhibit 47.

6. Odeco Drilling and Exploration Co., letter to Commander (mmt), Eighth Coast Guard District, dated 14 January 1980, U.S. Coast Guard Marine Board of Investigation Exhibit 12p.

7. Rescue Co-ordination Center Halifax, Nova Scotia, "Search and Rescue Special Report, SAR Ocean Ranger," undated.

8. SEDCO 706 Radio Log, U.S. Coast Guard Marine Board of Investigation Exhibit 11.

9. Underwriters Laboratories, letter, "Performance Testing of Billy Pugh Adult Life Jackets, 12 November 1976.

10. Underwriters Laboratories, letter, "Test Results: Weight Determination and Buoyancy Tests on Six Billy Pugh PFD's," 19 August 1982.

11. U.S. Coast Guard, Marine Board of Investigation. Certified Transcript of Proceedings in the Matter of Investigation of the sinking of the Mobile Offshore Drilling Unit OCEAN RANGER in the Atlantic Ocean on 15 February 1982.
    a. Volume III, testimony of Donald King, 20 April 1982.
    b. Volume IV, testimony of Rolf W. Jorgensen, 21 April 1982.

c. Volume V, testimony of Geoffrey Dilks, 22 April 1982.
d. Volume VIII, testimony of James Davidson, 27 April 1982.
e. Volume VIII, testimony of Baxter Allingham, 27 April 1982.
f. Volume XI, testimony of Kalvin Gernandt, 7 June 1982.
g. Volume XII, testimony of Ronald Green, 8 June 1982.
h. Volume XVI, deposition of Thomas Kane, 21 July 1982.

12. U.S. Coast Guard, Marine Board of Investigation. Investigation of the sinking of the Mobile Offshore Drilling Unit OCEAN RANGER in the Atlantic Ocean on 15 February 1982 (transcript), Exhibit 53A, deposition of Ronald Duncan, 21 May 1982.

13. U.S. Coast Guard (G-MMT-3), memorandum, "Swim Test Results," file 5946/160.055/113, 6 May 1976.

14. U.S. Coast Guard (G-MMT-3), letter to Billy Pugh Co., file 16714/160.053/GENERAL, 2 August 1976.

15. U.S. Coast Guard Marine Inspection Office, Providence, RI, letter to Odeco Drilling and Exploration Co., dated 18 December 1979, U.S. Coast Guard Marine Board of Investigation Exhibit 121.

16. U.S. Coast Guard (G-MVI-3), letter to Billy Pugh Co., file 16714/160.055/113, 22 September 1982.

17. United States Testing Co., Inc., "Report of Test; Seat Belt Assemblies," Test Number 83428-82, 19 August 1982.

APPENDIX 2

ABOUT THE AUTHOR

Mr. Robert L. Markle, Jr. has been the Acting Chief of the Survival Systems Branch, U.S. Coast Guard Headquarters since May 1982. He is responsible for administration of the Federal regulatory and approval program for lifesaving, fire protection and pollution prevention systems. This program includes developing and maintaining the Federal regulations for these systems, review and approval of systems designed to meet the regulations, and analysis and resolution of problems. In addition to his duties as Acting Branch Chief, Mr. Markle also continues as the staff mechanical engineer responsible for regulation and design review of Coast Guard approved lifeboats, exposure suits, and related equipment; a position he has held since his initial employment with the Coast Guard in 1975. From 1968 to 1975, he was employed by the U.S. Army Mobility Equipment Research and Development Center, Ft. Belvoir, VA as a project engineer on a wide variety of construction and materials handling equipment used by the Army Corps of Engineers and Transportation Corps.

Mr. Markle is a graduate of the Pennsylvania State University, with a Bachelor of Science in Mechanical Engineering degree. He also holds Master of Business Administration degree from George Washington University. Since 1975, he has served on U.S. delegations to the International Maritime Organization's (IMO) Lifesaving Appliances Subcommittee, first as an advisor, and then as the alternate U.S. representative. He has been the primary spokesman for the U.S. in these meetings since 1979, and has been one of the primary drafters of the revised Chapter III (Lifesaving Appliances) of the Safety of Life at Sea Convention now under consideration by the IMO Maritime Safety Committee.

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