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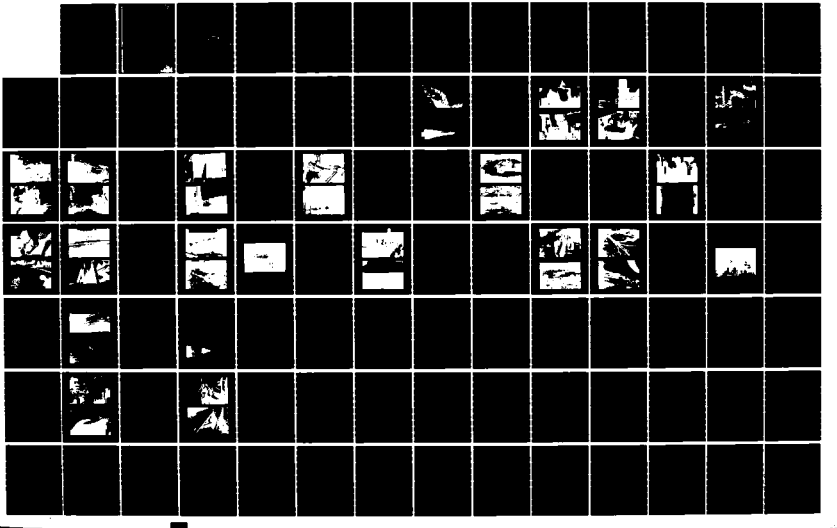

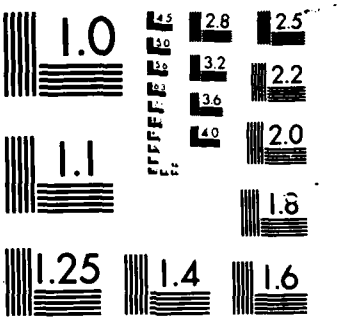

SQUAW MOORING PROJECT

FINAL REPORT

VOLUME I

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This report deals with the reinstallation of the SQUAW as a training device for submarine sonar operators and systems. The selected site was some 32 nautical miles southwest of Point Loma where the water depth was 6000 feet, the Squaw was to be submerged to a depth of 300 feet.

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SQUAW MOORING PROJECT
FINAL REPORT
VOLUME 1

FPO-1-78(18)

SEPTEMBER 1978

OCEAN FACILITIES ENGINEERING AND CONSTRUCTION PROJECT OFFICE
CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON, D. C. 20374

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PART I

BACKGROUND AND SUMMARY

BACKGROUND

In the early 1950's the U. S. Navy designed and constructed three model submarine hulls for structural testing during Operations *WIGWAM* and *HARDTACK*. For these operations, the submarine hulls were moored submerged in relatively shallow water. At the completion of these underwater nuclear weapons tests the model submarines were laid up.

In 1959 *SQUAW III* was put back in service as a submerged sonar target. For this service she was moored in 6000 feet of water southwest of San Diego, California at a depth of 200 feet and was used successfully for five years by the Commander, Training Force, Pacific (COMTRAPAC) before the padeye holding the after vertical leg failed and the *SQUAW* surfaced.

The submarine hull was reconditioned, the damage repaired, and she was remoored 20 miles off Point Loma in December 1965; the water depth was 3600 feet and the *SQUAW* was 200 feet below the surface. Again, she resurfaced after about five years of service as a sonar target and the source of the failure was attributed to a vertical leg wire rope break. This occurred in 1970 and the *SQUAW* was subsequently repaired and remoored in about the same area, 30° 51' N Latitude, 117° 44' W Longitude; the water depth was 3500 feet and the submergence, this time, was 300 feet below the surface.

Following the previous cycle, the *SQUAW* next surfaced during late 1975 and was towed to the Long Beach Naval Shipyard where, once again, she underwent overhaul and refurbishment before being towed back to the U. S. Naval Station, San Diego; since 1976 the *SQUAW* has been tied up there at Pier 13.

COMTRAPAC had a continuing requirement for the use of the *SQUAW* as a training device for submarine sonar operators and systems and therefore initiated the reinstallation of the *SQUAW*. This time, the selected site was some 32 nautical miles southwest of Point Loma where the water depth was 6000 feet; the *SQUAW* was to be submerged to a depth of 300 feet.

PARTICIPANTS

Program funding and overall direction for the 1978 *SQUAW* mooring was provided by the Commander-in-Chief, Pacific Fleet (CINCPACFLT). COMTRAPAC was the user agency, responsible for control and utilization of the sonar target once it was installed. The Public Works Center (PWC) San Diego was made responsible for the overall installation with the Chesapeake Division, Naval Facilities Engineering Command (CHESNAVFACENGCOM) designated as the installing activity.

The Supervisor of Salvage (SUPSALV) of the Naval Sea Systems Command (NAVSEASYSCOM) has existing long term contracts on both the east and west coasts with commercial salvage organizations for quick response salvage services. CHESNAVFACENGCOM was directed to utilize the SUPSALV west coast contractor for the 1978 *SQUAW* mooring operation and consequently a task order was negotiated with the Crowley Maritime Corporation of San Francisco for its subsidiary, Crowley Maritime Salvage, to carry out the installation.

PWC San Diego also negotiated separately with the Naval Ocean Systems Center (NOSC) to provide and install aboard *SQUAW* a special electronics training aid used to alter the acoustic characteristics of the sonar target.

The "Project Execution Plan for 1978 *SQUAW* Mooring" is included herewith as Appendix II and comprises Volume 2 of this report. It deals in great detail with the organizational interactions mentioned above and with the engineering planning that went into the project prior to the actual operations covered here in Volume 1.

SUMMARY OF OPERATIONS

The Project Execution Plan, Appendix II, covers the preliminary activities that took place up through early June 1978 with regard to the planning, ordering of material, funding, and organizational interactions. The operational phase summarized in this volume of the report covers what occured between mid-June and mid-July 1978 after which the attempt to moor the *SQUAW* was abandoned. The following is a brief summary of the events that took place during this period.

The Crowley vessel *M/V MANATI* was overhauled and equipped as the ocean

construction platform in San Francisco and then transitted to San Diego to be loaded out for the implantment. The *SQUAW* was fitted out at the U. S. Naval Station San Diego and departed under tow of the Crowley tug, *CHALLENGER*, on 26 June to rendezvous with the *MANATI* at sea at the mooring site on the morning of 27 June. Little work was accomplished this first day due to a failure of the *MANATI* steering system.

The mooring system was to comprise fore and aft mooring lines, designed to form catenaries with anchors 12000 feet apart, that would hold the *SQUAW* in a north-south orientation. In addition to the two mooring lines there were to be two vertical legs, comprising carefully measured lengths of wire which suspended heavy counterweights, that would control the vertical position of the *SQUAW* to the designated 300-foot submergence.

On 28 June the north mooring line was attached to the bow of the *SQUAW*, payed out and the anchor system attached. The anchor was to be lowered by a line attached to its crown with an acoustic release inserted so that the crown line could be retrieved after lowering. Lowering had just barely started when the acoustic release failed and the north anchor dropped to the bottom, fortunately right on target. However, during subsequent maneuvers the north anchor was dragged off the target position.

Most of the day of 29 June was spent attempting to set the north anchor and in determining its new position as well as reeling the south mooring line on the winch drum. (This was a double drum winch and each wire used had to be level wound under tension from the wire reels stored on deck.) In the evening the south mooring line was attached to the *SQUAW* and payed out over the stern of the *MANATI* to hang there for the night. On 30 June the south anchor system was made up and lowered on the crown line, without the acoustic release inserted, as the ship headed toward the designated drop point. However, before this point was reached, the stern sheave, over which the crown line was running, failed. It was then necessary to pay out the remaining crown line and buoy it off.

The buoyed crown line was then towed south to drag the south anchor into position. Slow towing was curtailed when it began to appear that the north and south mooring lines might be twisted around each other. However, the following morning the lines appeared satisfactory and towing was resumed.

The south anchor was dragged into position and the *SQUAW* appeared to be in a north-south moor. It was left in this condition while the *MANATI* returned to San Diego for a replacement stern sheave.

On returning to the site on 2 July, in heavy seas, there was evidence that the south mooring line had parted. It also was noted that the NOSC electronics package on the deck of the *SQUAW* had overturned and was damaged. However, a decision was made to continue after the seas had abated. On 3 July the make-up of the after vertical leg began but, during the early stages of the process, the winch failed and the *MANATI* returned to San Diego for repairs.

Repair of the winch was not effected until 10 July when the *MANATI* headed back for the mooring site but, shortly after arrival there, the port engine went out and, once again, the ship returned to San Diego for repairs. The *MANATI* was back on site on 11 July and the make-up and lowering of the after vertical leg was resumed. The strengthened 100 kip acoustic release, which had been tested, was inserted in the lowering line, but again it failed, and the after vertical leg counterweight was dropped (out of control) to its suspended position under the *SQUAW*.

On 12 July, preparations were made for lowering the forward vertical leg which, after an excessive amount of maneuvering of the *MANATI* around the *SQUAW*, was lowered into place late in the afternoon. The lowering line for this leg was secured to the after port bitts on the *SQUAW*. After this the *MANATI* went into San Diego for additional equipment, returning to the mooring site early on the morning of 13 July. That day and the next were occupied in determining that, indeed, the south mooring line had parted with the break some 220 feet below the *SQUAW*.

It was decided to replace the south mooring line with spare wire, chain, and anchors that had been carried aboard the *MANATI*. This effort began on the morning of 15 July and by midnight the replacement south moor was installed.

Because of heavy seas and the need to obtain additional gear, the *MANATI* returned to port on 16 July but was back on site by the morning of the 17th. The forward vertical leg lowering line was removed from the after port bitts and the *SQUAW* resumed a more normal attitude of list and trim. However, shortly thereafter, she gradually moved about 2500 feet to the south indicating that a significant change had taken place in the catenary of the foward mooring line.

Although the *SQUAW* was riding much higher in the water than she should have been at this point the decision was made to go ahead with the submergence. All of the ballast tanks were vented but the submarine failed to go down. Drafts in this ballasted condition indicated a possible weight loss on the vertical legs. The operation was terminated at this point. *SQUAW* was released from its moorings and returned to San Diego on 7/31/78. (See page 92.)

ELEMENTS OF THIS REPORT

There are many ramifications to this unsuccessful venture that are yet to be resolved. It is the purpose of this report to relate, in as much detail as possible, all of those elements that were factors in the final outcome of the operation up to the point of the attempted submergence of the *SQUAW*.

Part II is excerpted from a daily log of the events that occurred between 19 June and 17 July 1978 as recorded by the Navy on site representatives. The log is, of course, subject to bias and therefore any additions, revisions, or alternate interpretations by other observers would be a welcome addition to the documentation of the project. The complete log is included in Appendix I.

Part III is an analysis of draft, trim, and displacement information that begins with the first tests conducted by CHESNAVFACENGCOM in January 1978 and continues through to the final estimates made when the *SQUAW* failed to submerge on 17 July 1978. This is the supporting engineering information on which many of the procedural decisions were based during the installation attempt.

Part IV discusses the rigging, cable handling, and ship handling problems that were encountered during the course of the project. Some of these problems very probably contributed to the failure to carry out the mooring operation in the anticipated manner, whereas others may contain lessons that will be of value in the planning and execution of future operations.

In Part V the data obtained from Mini-Ranger plots of the *MANATI* positions and radar plots of the relative movements of the *SQUAW* are analyzed. This is an illustration of what happened on the surface to the *MANATI* and the *SQUAW* as the vessels were maneuvered during the mooring operation while various wires and hardware were suspended below. It will help in determining when and where possible interaction between weights and wires occurred and should also serve as an example of the kinds of maneuvers to be avoided.

PART II

DAILY LOG OF EVENTS DURING SQUAW MOOR OPERATIONS

The following edited log of the events during the 1978 attempt to moor the submarine *SQUAW* begins on Monday, 19 June 1978. At that time, the vessel designated as the ocean construction platform for the project, the *M/V MANATI* was nearing completion of overhaul and installation of project equipment at the Merritt Ship Repair Company, Oakland, California.

The *SQUAW* had been tied up at Pier 13 of the Naval Station, San Diego for eighteen months under the control of the Public Works Center (PWC). With the assistance and logistic support of PWC the *SQUAW* had been outfitted for the operation as described in the "Project Execution Plan for 1978 *SQUAW* Mooring", Appendix II. The CHESNAVFACENGCOM representatives involved in this preparatory work were Jack Baber, Engineer, and Christopher Schoen, Technician.

MONDAY, 6/19/78 - OAKLAND, CALIFORNIA

In the early afternoon, Harold P. Dorin and Richard C. Asher, the CHESNAVFACENGCOM Project Manager and Project Engineer respectively, arrived at the Merritt Shipyard. There they met with James Walker and Earl Lawrence of Crowley Maritime Salvage to talk over progress on the *MANATI*. The vessel and all deck outfitting underway for the job were inspected. In general, the deck equipment work was well in hand. All reel stands were installed and wire rope reels were loaded; the Skagit winch was installed. Both deck sheaves were fitted as were the four stern brackets for carrying clumps. The vans (sleeping quarters) were mounted. The shipyard was very busy working on ship systems. There was anticipated some delay due to problems with the rudder. The ship had a very poor appearance and would require a considerable effort to get it in shape for the job.

It was the impression of CHESNAVFACENGCOM representatives that the deck equipment for the project and ship deck modifications were well underway. However, there was concern about the material condition of the ship in general.

TUESDAY, 6 20 78 - OAKLAND, CALIFORNIA

Details of the project were reviewed by CHESNAVFACENGCOM and Crowley representatives. They discussed the CHESNAVFACENGCOM Project Execution Plan,

an internal government document. There was no obligation on the part of Crowley to follow the plan and no intention on the part of the government to impose the plan upon the contractor. This plan merely provided details of what had been discussed over the past several weeks with Crowley. It provided engineering information that would be useful during the project and provided a checklist to assist in ensuring an optimal final product.

The CHESNAVFACENGCOM representatives inventoried Government Furnished Equipment and checked fit or compatibility of various components.

WEDNESDAY, 6/21/78 - OAKLAND, LOS ANGELES, AND SAN DIEGO, CALIFORNIA

A morning meeting was held with Crowley representatives, with further discussions of ship delays and project events.

Asher departed for San Diego at 1130. Upon arrival, he proceeded to the Public Works Center at the Naval Station and briefed LCDR Palmborg on the project, timing, and possible requirements before project start. He also visited the Crowley yard in San Diego to determine its suitability for the staging of Government Furnished Equipment (GFE).

Dorin departed for Los Angeles where he met with representatives of Interstate Electronics relative to the acoustic releases to be used, with Tetra Tech relative to the depth measurement services, and with Navigational Services Inc. relative to the use of the Mini-Ranger aboard the *MANATI*.

THURSDAY, 6/22/78 - U. S. NAVAL STATION, SAN DIEGO

The *SQUAW* was examined for deck rigging of chain pendants and all project GFE at the Naval Station was inspected. All work was in-hand at the station. Certain equipment required relocation to the foot of Pier 13 for pick up by Crowley.

Naval Ocean Systems Center representatives were on site to rerig the electronics package at CHESNAVFACENGCOM's suggestion since, at present, the package was secured to the *SQUAW* only by three synthetic lines, each with turnbuckles. The deck attachments were felt to be inadequate (two were on rusted padeyes and one was around the deck grating). The NOSC representatives resecured the lines to two cleats just forward of the padeyes and around a deck support beam beneath the deck grating. They were advised that the *SQUAW* may take considerable water across its deck while being towed to the site. In particular,

THURSDAY, 6/22/78 (Cont'd.)

it appeared that the rigging installed did not support the bottom of the package and that it was possible that the bottom could kick out. The NOSC representatives were advised that during towing, no one would be able to see the *SQUAW* deck. It was suggested that they lash the package bottom to an adjacent stanchion for proper security. NOSC representatives stated that the installation was adequately secure and was, in fact, exactly identical to the previous installation in 1970 that lasted for five years.

FRIDAY, 6/23/78 - SAN DIEGO, CALIFORNIA

The day was occupied coordinating efforts to start the project on Monday, 6/26/78. Equipment was staged at the Naval Station for Crowley pick up.

SATURDAY, 6/24/78 - ABOARD SQUAW AT PIER 13, U. S. NAVAL STATION, SAN DIEGO

In the morning, CHESNAVFACENGCOM personnel involved in the *SQUAW* Mooring Project met with Robert Taggart (a marine architect consultant) of Robert Taggart Incorporated aboard the *SQUAW*. At 1100 they made draft checks in a rough ballasting experiment using midship draft marks (which are of doubtful accuracy since spacing is inconsistent and non-standard) and measuring freeboards fore and aft. The forward freeboard was taken mainly on the port side with a final check at the end on the starboard side - space between measurements athwartships was only 4 feet; these were at a point later determined to be 7'-11" abaft the bow. The after freeboards were measured at the after hatch location and both port and starboard measurements were made by pole spanning outboard the ballast tanks. The first measurements were made in the nominal "at sea" condition with ballast tanks 1, 2, 9, & 10 filled with fresh water, tanks 5 and 6 free flooding, and tanks 3, 4, 7, and 8 blown out at the existing waterline.

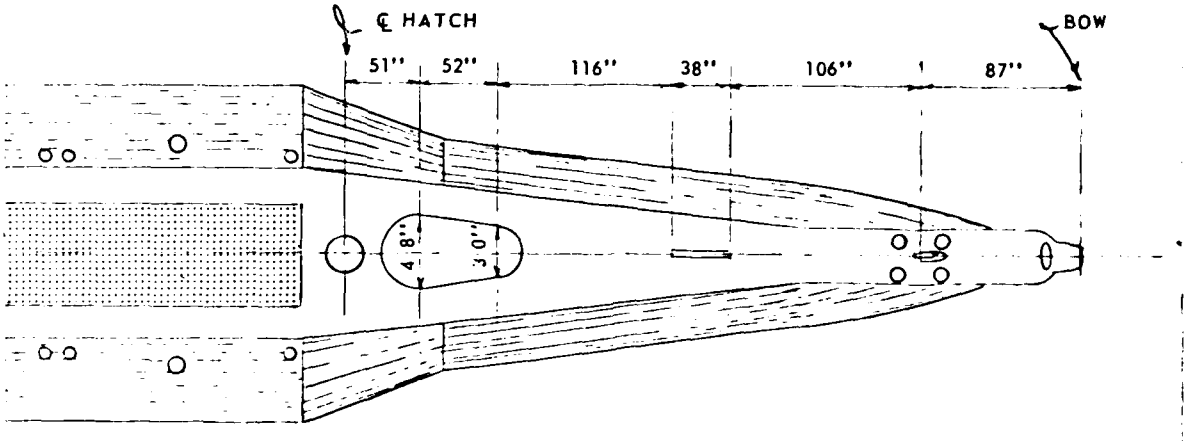
At 1112 started venting ballast tank #7; finished venting at 1122. At 1125 started venting tank #8 and finished at 1136. Made new draft measurements. At 1149 started venting ballast tank #3; finished venting at 1210 and started venting ballast tank #4; finished at 1233. At this point ballast tanks 1, 2, 9, & 10 were filled with fresh water and ballast tanks 3, 4, 5, 6, 7, & 8 were filled to level of outside waterline. At 1240, started blowing all tanks (3, 4, 7, & 8); finished blow with *SQUAW* back to "at sea" condition at 1300. Results of these experiments, together with subsequent displacement analyses are given in Part III.

During the course of making these ballast experiment measurements, several dimensions on the *SQUAW* were checked to verify drawings made for the Project Execution Plan. Some of the results of these measurements are as follows:

- Draft marks are 3'-8" aft of ⊗ at about intersections of ballast tanks 3 & 4 with 5 & 6.
- In January 1978 ballast and trim test measurements: The forward point was 87" abaft the bow and the after point was 171" abaft the after hatch; the location of the midship measuring point cannot now be determined.
- Overall length measurements done in sections were as follows:

Bow to ℄ Fwd hatch	37'-4"
℄ Fwd hatch to bhd between 3 & 4 and 5 & 6	38'-0"
Bhd between 3 & 4 and 5 & 6 to ℄ after hatch	30'-7"
℄ After hatch to stern (best guess)	29'-6"
Length Overall	135'-5"

Working forward from ℄ forward hatch, additional detailed measurements are given in the sketch below. This sketch was made to help clarify some of the location details that were unavailable from the few shipyard drawings of *SQUAW* furnished for this project. While these measurements were being made,



the running light supports for the *SQUAW* were rigged. Then measured buoy lines were rigged with floats to show the depth of *SQUAW* on final submergence. A photograph of the *SQUAW* alongside Pier 13 is given in Figure 1.

SUNDAY, 6/25/78 - SAN DIEGO

Calculations were made of the results of the ballasting experiment on the previous day with the conclusion that the average displacement for the *SQUAW* on departure for the mooring site was 491.77 tons, some seven tons less than what had been calculated in the Project Execution Plan, Appendix II.

A meeting was held to present the above results and to discuss various aspects of the project. Attending were the group involved in the previous day's activities plus Edmund B. Spencer, Director, Construction Division, CHESNAVFACENGCOM. It was decided to do whatever was possible to increase the weight of the vertical leg anchor clumps. (See page 36 for details.)

The *MANATI* arrived from San Francisco at the Crowley Pier in San Diego in the afternoon. The ship, as she tied up alongside the crane barge, is shown in Figure 2.

MONDAY, 6/26/78 - CROWLEY PIER, SAN DIEGO

At 0900 the CHESNAVFACENGCOM group that had met the previous day assembled aboard the *MANATI* and met with the other personnel who would be engaged in the mooring operations. In addition to the ship crew under Captain Joe Bradshaw, these personnel were:

Earl F. Lawrence, Consultant to Crowley Maritime Salvage and On-Site Project Director
James W. Walker, Corporate Representative, Crowley Maritime Salvage
Keith Moore, Chief of Rigging and Diving Crew and four ocean construction riggers/divers
Ronald Green, USN Supervisor of Salvage Representative
Jack Wilson, Navigational Services Incorporated, Navigator
Douglas Johnson, Interstate Electronics Corporation, Acoustic Release
David Lauer, Tetra Tech, Depth Sounding Equipment

The day was spent in loading operations, placing gear aboard *MANATI*, and

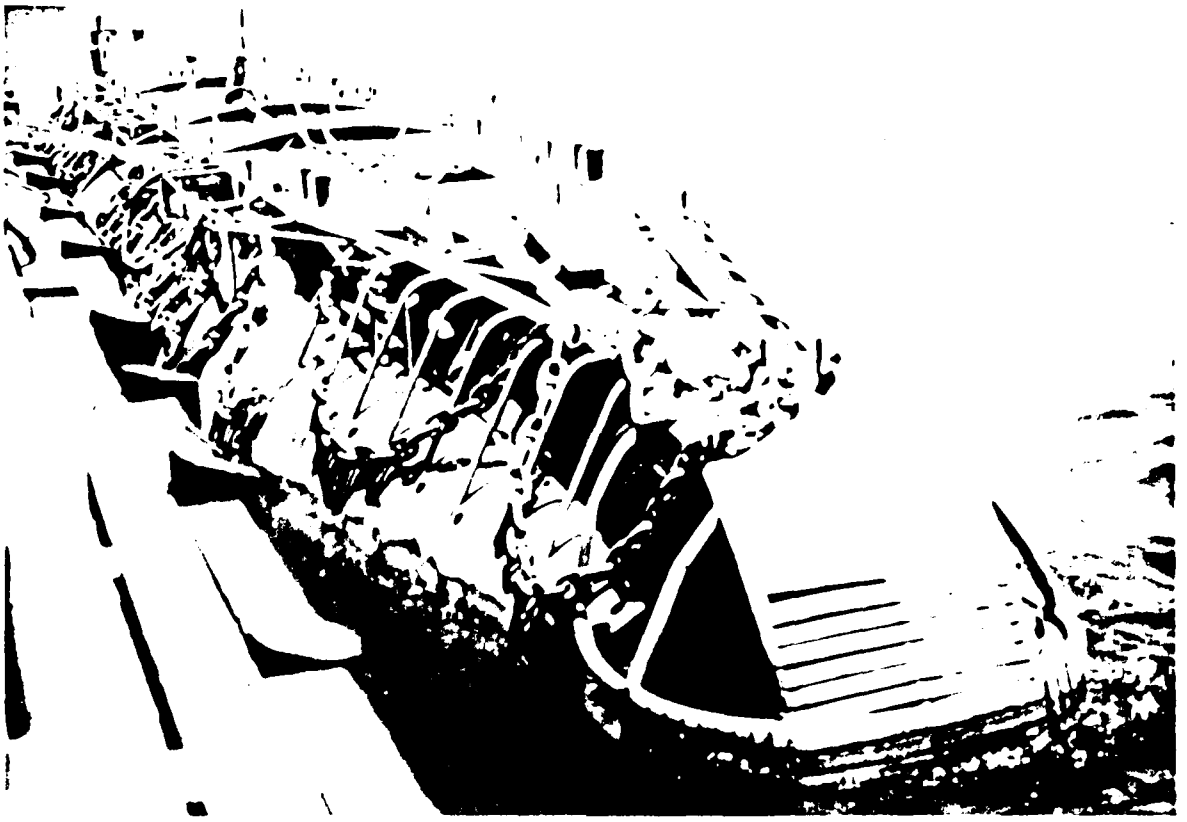


FIGURE 1. SQUAW AT PIER 13, U. S. NAVAL STATION, READY FOR SEA

FIGURE 2. MANATI TIED UP AT THE CROWLEY PIER, SAN DIEGO

winding cable from the cable reels on to the two drums of the Skagit winch. The winch is shown in Figure 3 with the reels empty and, in Figure 4, both drums are shown loaded ready for departure. The level winding system used for winding cable on the winch drums under tension is described in Part IV.

The Interstate Electronics representative assembled and tested the acoustic releases. The Mini-Ranger antenna mast was erected and all electronics installed by midnight on 6/26/78 and all loadout was completed. Brackets for the overboard pipe to support the fathometer were damaged (to be repaired later at sea). Official departure of the *MANATI* for the mooring site was to be 0100 on the 27th. The *SQUAW* had departed under tow of the Crowley tug *CHALLENGER* at about 1900 on the 26th.

TUESDAY, 6/27/78 - AT SEA NEAR MOORING SITE

Rendezvous of the *CHALLENGER* (with *SQUAW* in tow) and the *MANATI* occurred at first light. On the morning of the 27th the Mini-Ranger navigation system was not working. A backup LORAN C was not on the tug as expected. Also, the fathometer cable was damaged during the night requiring some repair. However, these were resolved by about 0930 and the *MANATI* started moving toward the assigned site.

The pipe supports for the fathometer were welded on, and the cable was checked out and readied for a depth survey. The transducer for the fathometer was lowered over the side, Figure 5, and bolted in place by about 1115. The fathometer system was checking out well with estimated depth of 860 fathoms so a test (with a plate target) was started at 1415. Measurements were made at 100, 200, and 300 feet below transducer. This exercise was completed at 1515.

During the morning, the *MANATI* steering system burst a hydraulic line and lost considerable fluid into the bilge. Spare oil aboard was not sufficient to bring the hydraulic system up to the dipstick level so underway operations were curtailed until additional oil could be brought from shore. The rudders, at this point were jammed at hard right and the ship could make no headway back toward the mooring site. However, this allowed time to perform deck rigging for the first moor and to r[illegible] additional equipment tests. Figure 6 shows the *ZODIAC* being inflated during this period.

There were two acoustic release transducers and one acoustic release transponder unit to be checked out acoustically in the water. One transducer had been

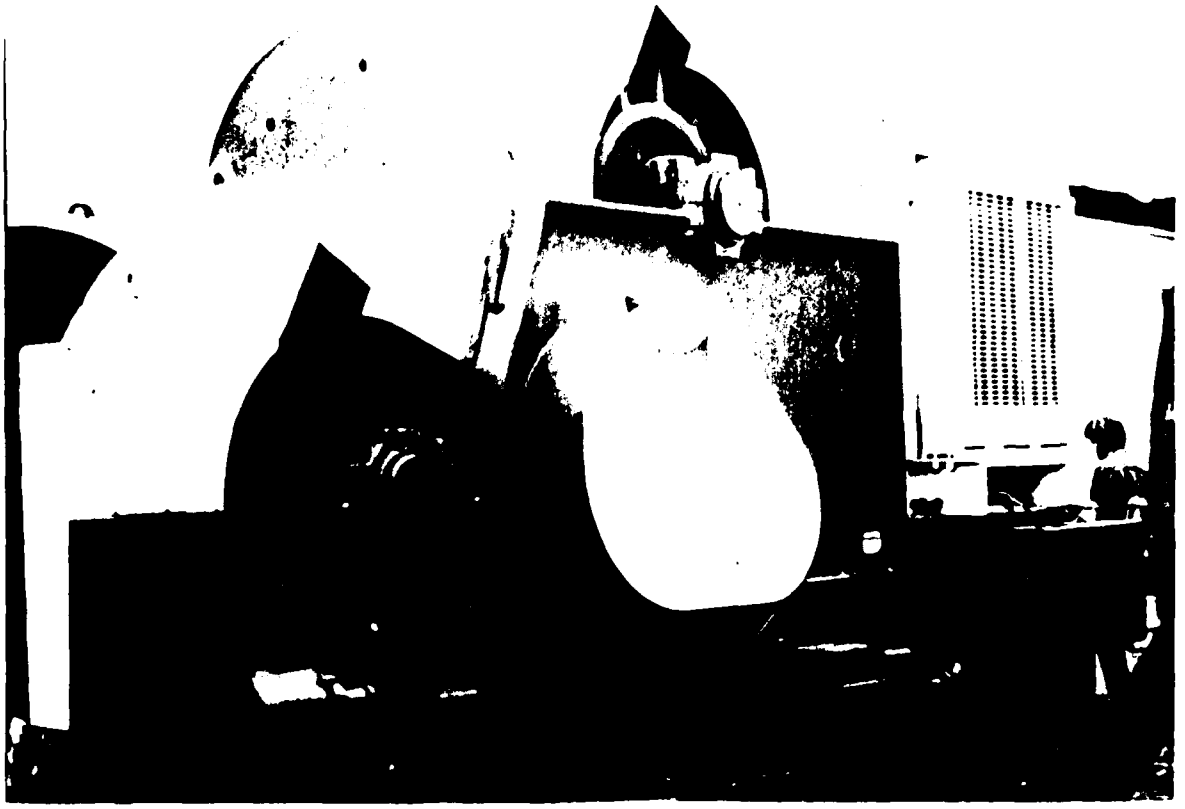


FIGURE 3. THE TWO-DRUM SKAGIT WINCH ABOARD THE MANATI

FIGURE 4. WIRE WOUND ON BOTH WINCH DRUMS FOR FIRST OPERATION

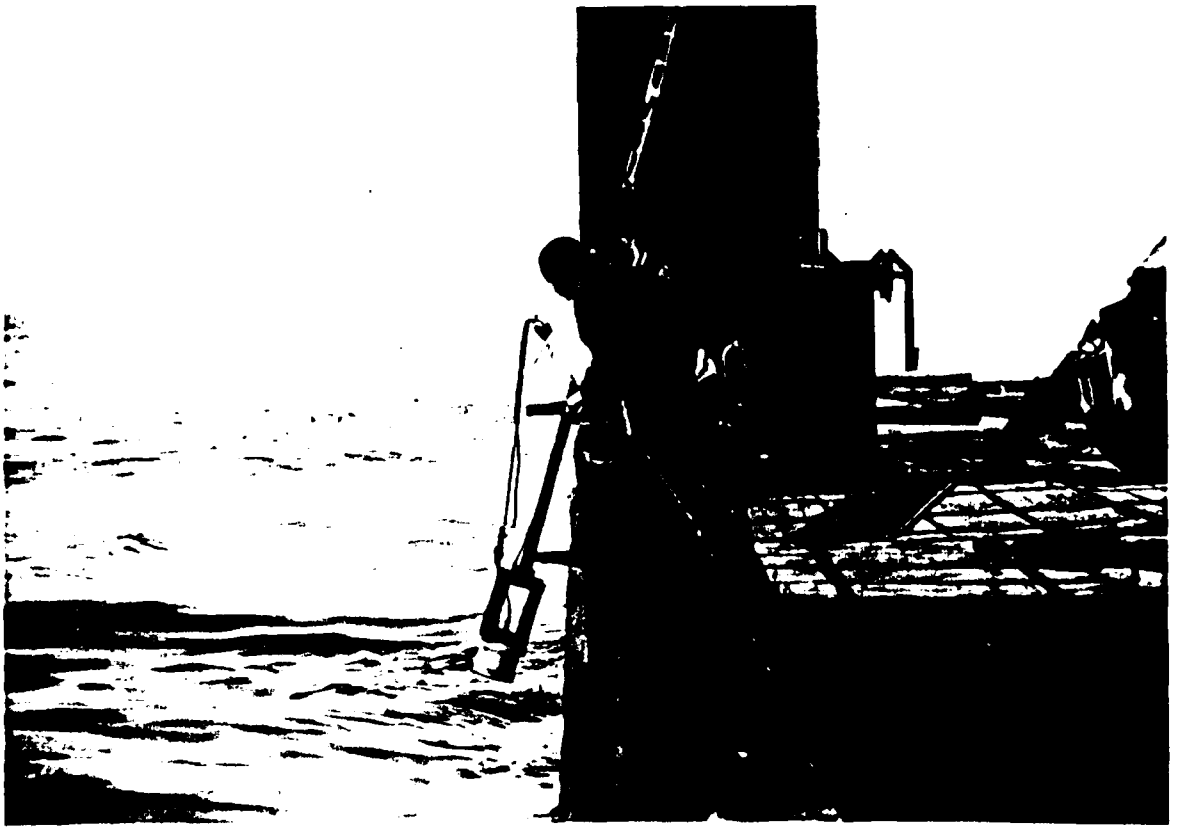


FIGURE 5. THE FATHOMETER TRANSDUCER BEING LOWERED OVER THE SIDE

FIGURE 6. INFLATING THE ZODIAC ON THE MANATI DECK

obtained from the NAVFAC Ocean Construction Equipment Inventory (OCEI) and the other from Interstate Electronics Corporation. The two acoustic release transducers were put over the port side at 1530 and the one working acoustic release unit was lowered over the starboard side near the fathometer transducer. The "enabling" system on the release was checked out with signals from both transducers and the distance and azimuth measuring systems were also checked and responded satisfactorily. These two units were operational when the test was completed at 1545.

At 1615, after the acoustic release system had been checked, with no notice, the *MANATI* suddenly accelerated to a speed in excess of 10 knots. At this point both the NAVFAC and the IEC acoustic release transducers and the fathometer transducer were in the water. The IEC and fathometer transducers were mounted on pipes and the NAVFAC transducer was suspended on a line. Both of the transducer support pipes were bent about 45° by the sudden relative water motion. The NAVFAC acoustic release transucer was damaged to an extent that could not be repaired aboard ship but the IEC unit was not apparently damaged.

The hydraulic fluid for the steering system arrived aboard by 2030, too late for any other operations.

WEDNESDAY, 6/28/78 - AT SEA NEAR MOORING SITE

The *MANATI* resumed operations at 0500. The fathometer transducer was placed in the water for depth surveys. One more steering failure occurred on the *MANATI*. Control was termporarily shifted from the lever pilot to the steering wheel while the problem was resolved.

At the two mooring points the fathometer showed depths of 1050 fathoms, coinciding with data obtained during the original survey, Appendix II.

The 45 feet of chain at the bow of the *SQUAW* was brought aboard the *MANATI* at about 0800. The length was quite short and drew the bow of the *SQUAW* almost snubbed up to the stern of the *MANATI* as the chain was made fast, Figure 7. The eye at the end of the 8570 foot mooring line was shackled to the chain and overboarded.

The *ZODIAC* placed men aboard the *SQUAW* where they attached line to the stern chain on the *SQUAW* and passed it to the tug. The line was pulled aboard,

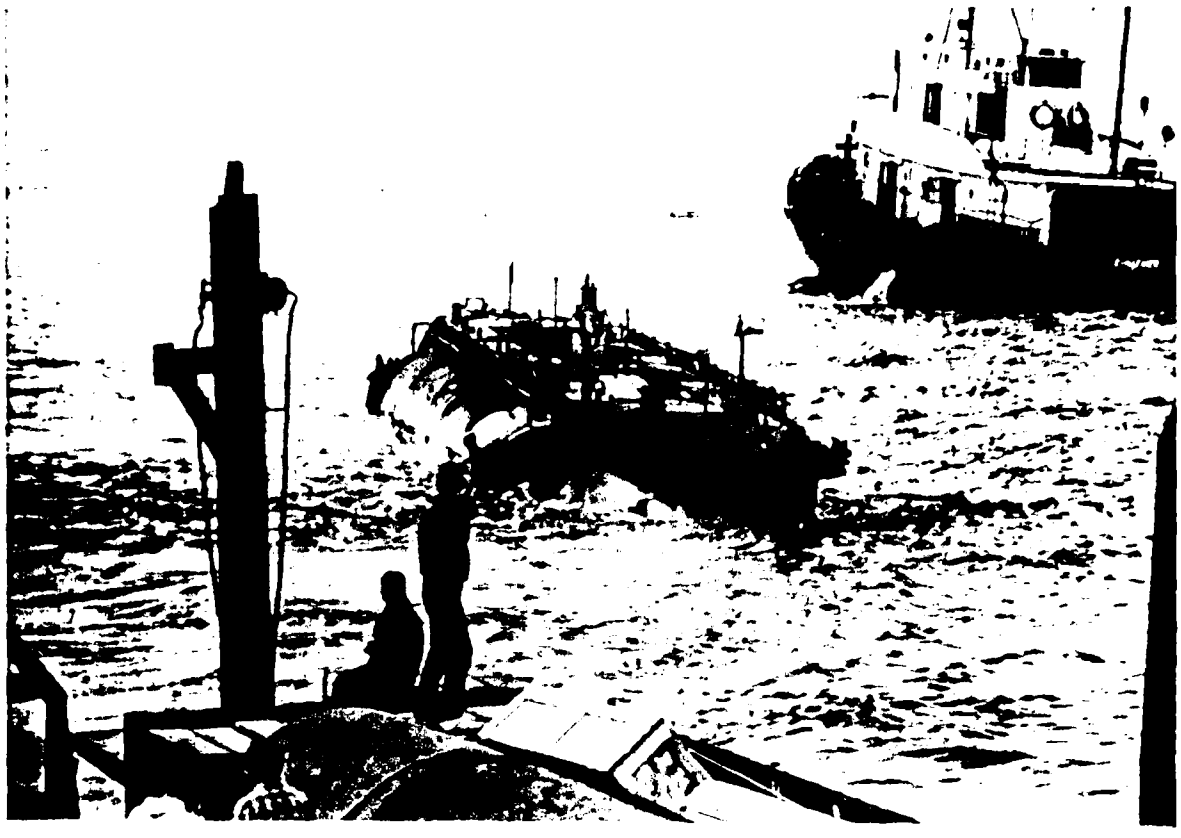


FIGURE 7. THE MANATI, SQUAW, AND CHALLENGER DURING HOOKUP

FIGURE 8. THE SQUAW AT SEA PRIOR TO START OF OPERATIONS

the stern chain tie line cut loose from the *SQUAW* side rail, and the tug started towing the *SQUAW* astern as the *MANATI* payed out the bow mooring cable. This part of the operation was completed at 0900; here the *SQUAW* is shown in Figure 8 just prior to cutting loose the stern chain.

The 8570 feet of mooring cable was then shackled to the 180 feet of anchor chain, Figure 9, which in turn was eased overboard using a padeye on deck attached to a pendant and pelican hook to hold the chain alternately as another pelican hook at the end of the 1 1/8 inch crown line was payed out and stepped back until the chain bitter end approached the stern. The bitter end was then shackled to a 6000 pound weight hanging over the stern in a specially formed rack, Figure 10. Another one shot of chain was connected between this weight and the anchor.

A line from the winch was then fed over the track at the top of the frame and the 6000 pound weight was lifted a foot or so. While in this position the diagonal support angles holding the bottom of the frame were burned through to clear a path for dropping the weight directly downward. The weight was lowered to the point where it was hanging on the chain that connected to the anchor and the anchor chain gradually fed out until it moved the anchor a short distance.

Angles were welded to the anchor flukes to permit it to skid more easily over the deck and stern. However, when tension on the line was eased, the anchor still toed into the pipe fairing over the stern and stood up on the tip of one fluke, Figure 11. The weight of the anchor, chain, and 6000 pound clump caused the 1 1/8 inch crown line to dig into the lower wraps on the winch drum.

Next the acoustic release was inserted in the line and put overboard, Figure 12. As lowering started the line jerked significantly as the wedged-in wraps on the winch drum came loose, causing the acoustic release to open and dropping the load to the bottom. This occurred at about 1530 when fortunately the *MANATI* was very close to the prescribed north anchor position, Part V.

The acoustic release was retrieved. The main casing had vibrated down the support frame to the point where a bolt on the casing head drove the trigger through the retaining cotter pin, Figure 13, and loosened the pelican hook which then released. The cylindrical electronic package was held to the frame by two bands, welded to the frame and each closed by a pair of bolts. There were two

FIGURE 9. WIRE SHACKLED TO CHAIN IN THE FORWARD MOORING LINE

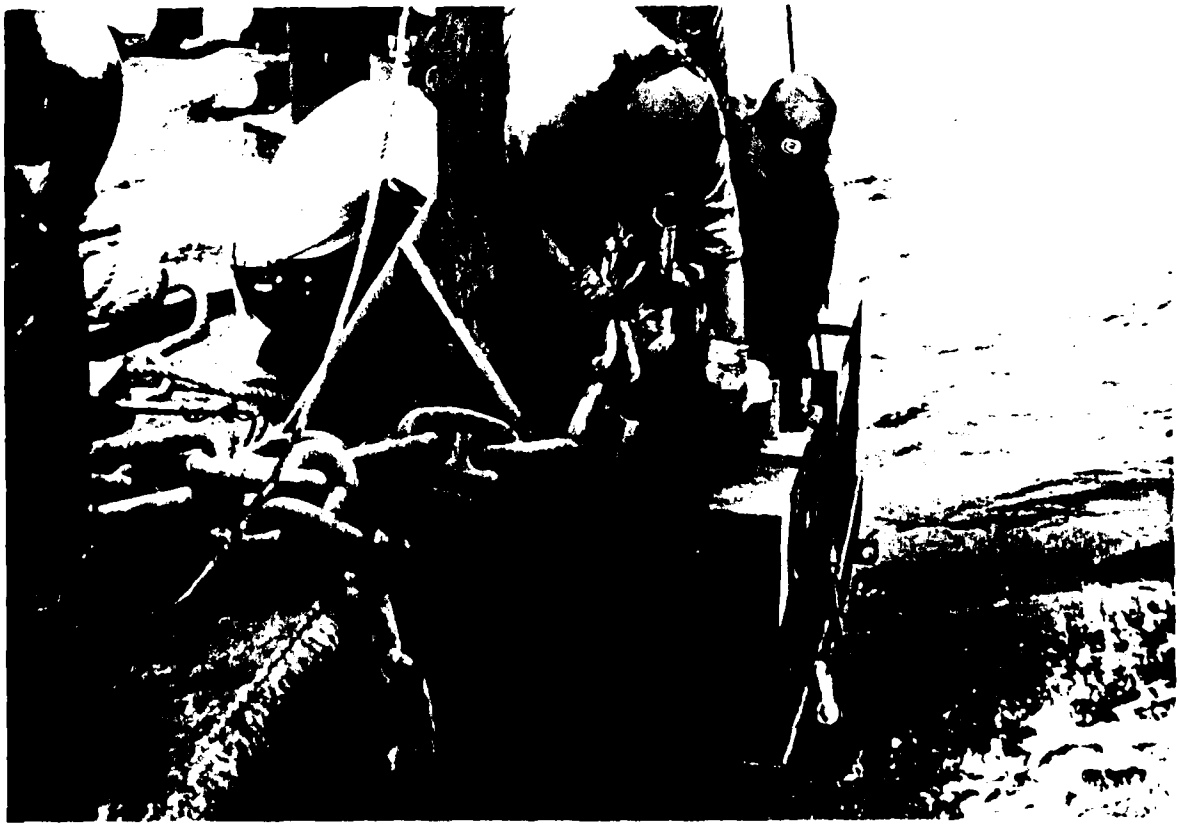


FIGURE 10. ATTACHING THE FIRST 6000 POUND CLUMP IN THE FORWARD MOORING LINE

FIGURE 11. OVERBOARDING THE FORWARD MOORING LINE ANCHOR

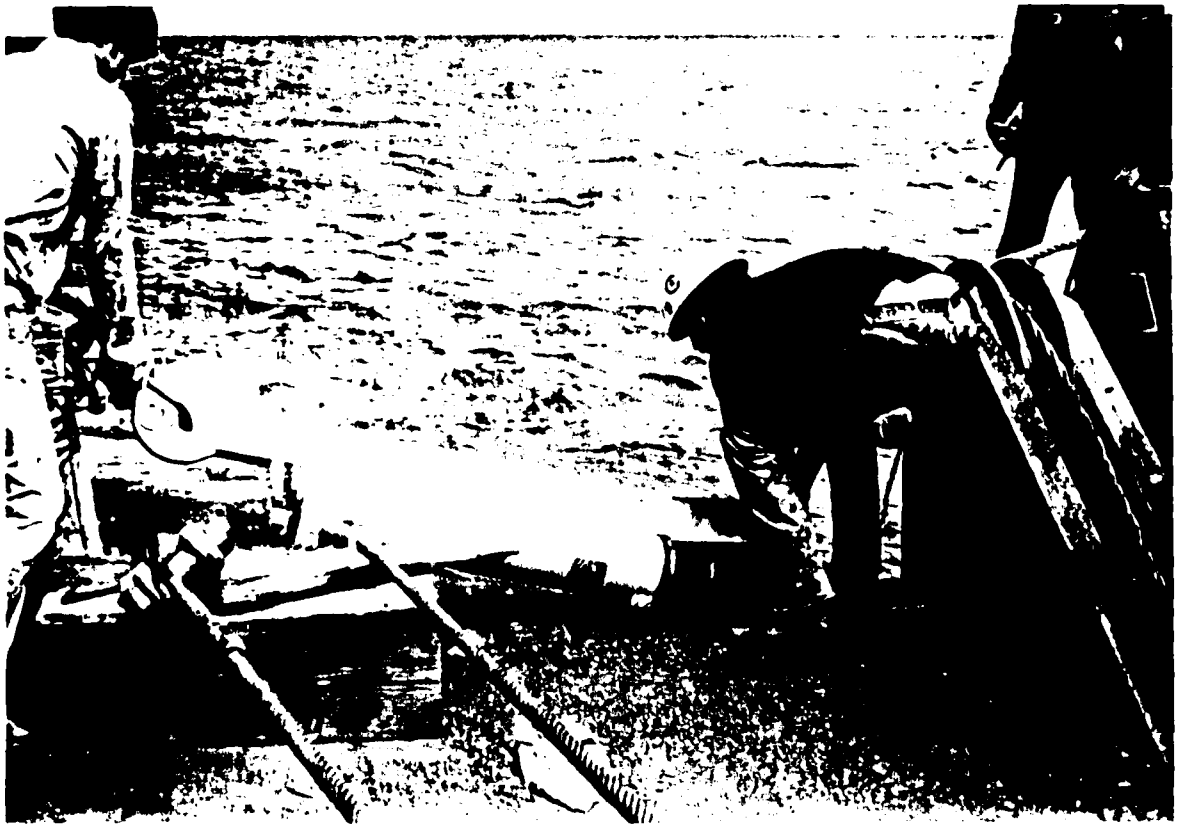


FIGURE 12. THE ACOUSTIC RELEASE INSERTED IN THE CROWN LINE

retaining keys, each a small cylinder about 3/8 inches in diameter and 3/8 inches long made of Fiberglas provided, along with the band tension, to prevent this occurrence. Both of these pins sheared off, Figure 14, under the mechanical impact loading of the jerking crown line.

The first moor was left in position, and the *MANATI* replaced the tug on the stern of the *SQUAW*. The stern mooring chain was transferred from the *CHALLENGER* to the *MANATI* and shackled to the 1 1/8 inch crown line. The *MANATI* then headed south reeling out the crown line astern. The *MANATI* was to back up to the *SQUAW* while winding the crown line back on the winch drum under heavier tension then could be applied by the gear described in Part IV. The mobile crane, with a pair of sliding blocks on the bumper, was to be used to control the level wind feature with the drum packed as tightly as possible.

This operation was started at about 1700 with the *MANATI* headed south unwinding wire. By about 1830 the rewinding had started, with tension on the drum estimated to be around 10000 pounds and was completed by 2400 despite the fact that the main ship's generator was down between 2000 and 2030. During the operation the *MANATI* was operating on one screw and it was difficult to maintain the 180° heading. At 2400 on the 28th, when operations had been completed, the *MANATI* was about 7000 feet southeast of anchor drop point.

THURSDAY, 6/29/78 AT SEA NEAR MOORING SITE

A check on the Mini-Ranger plot at 0900 showed the *MANATI* to be about 7000 feet northeast of anchor drop point. The various relocations of the north anchor are discussed in more detail in Part V. During the morning, 8570 feet of aft mooring line was reeled on the upper drum of the winch, and chain for the second anchor drop was rigged. The *MANATI* approached the *SQUAW* moored position to take horizontal force readings while pulling away from the initial anchor drop position with about 16000 pounds at about 135° and again at 180° from it. A 7000 foot arc could then be swung from each position where these readings were taken, and the intersection would determine the anchor position.

This maneuver was initiated but the maneuvering of the *MANATI* was unsatisfactory and the end result was that the north anchor was dragged south for about 15 minutes at an average speed of 1.6 knots - a total drag of about 2500 feet. Combining this anchor drag with that estimated during

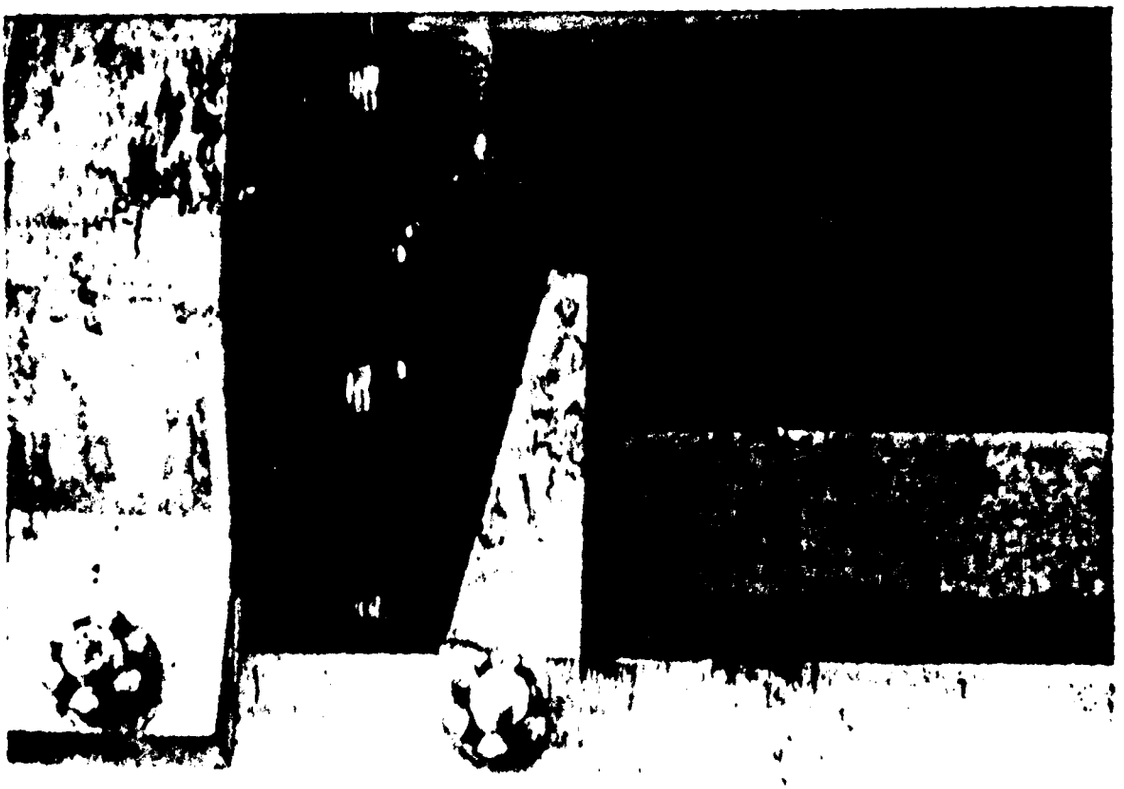


FIGURE 13. ACOUSTIC RELEASE AFTER TRIGGER WAS MECHANICALLY ACTUATED

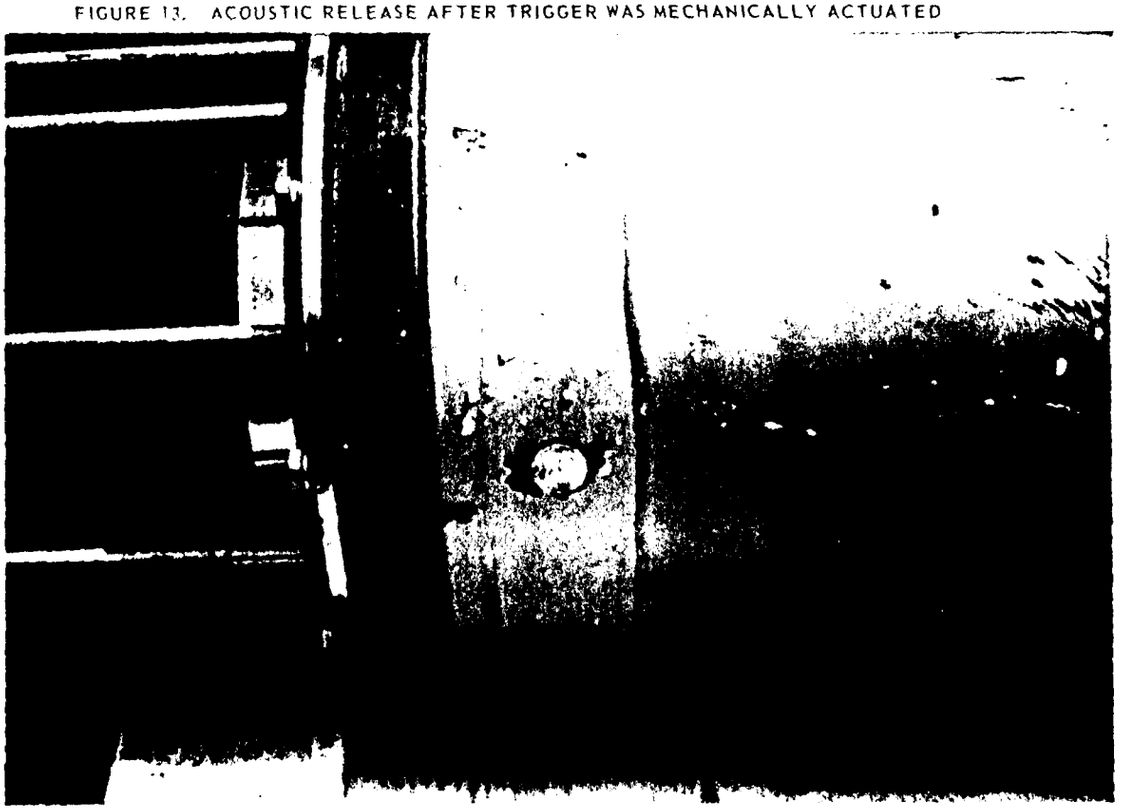


FIGURE 14. FIBERGLAS KEYS SHEARED OFF ACOUSTIC RELEASE CANNISTER

the night before, a new north anchor point estimate was made and a corresponding new south anchor target point was established.

The *SQUAW* was pulled in on the towline and the stern 45 feet of chain taken aboard the *MANATI*. The eye at the end of the 8750 feet of mooring line was shackled to the chain, that length of wire was payed out, and stoppered off for the night.

FRIDAY, 6/30/78 - AT SEA NEAR MOORING SITE

It was presumed that the *MANATI* hung downsea and downwind of the *SQUAW* for the night but in the morning, when the wind had died down, the *SQUAW* was practically alongside the *MANATI*. The *MANATI* then got underway and headed south to within about 5400 feet of the newly selected south anchor point and stopped engines while the rigging crew made up the anchor chain. The end of the first two shots of chain reached the stern at about 0800 in the morning ready to be attached to the 6000 pound clump.

By 0815 the clump was shackled to the chain by another short length of chain. The clump was then lifted out of its support brackets and moved over to the center of the transom; the clump went into the water at 0830. The two anodes were attached to the chain a short distance away from the clump and they were lowered into the water at 0845. Next the chain was lowered further down and the crawler crane moved over to pick up the anchor to put it in line for overboarding. The anchor chain was then eased on overboard and the anchor stopped just short of the transom. A sling was attached around the stock and shackled to the 1 1/2 inch wire on the upper drum of the winch. Tension was taken up on this line and the 1 1/8 inch crown line was shackled to the crown of the anchor. The anchor was then eased overboard, Figure 15, and the load transferred to the crown line with the sling being removed. This operation was completed and lowering started at 0930.

When about 4000 feet of crown line was out, the *MANATI* (at minimum rpm on one screw) headed for the newly designated south anchor drop point while paying out the 11000 feet of crown wire; this was calculated to bring the anchor to the drop point. However, at about noon the stern sheave bearings failed and it was necessary to hold up operations. The entire 11000 feet of crown line was eased out to place the anchor on the bottom. The line was run out on the winch brake and greased to slide over the frozen stern sheave. At

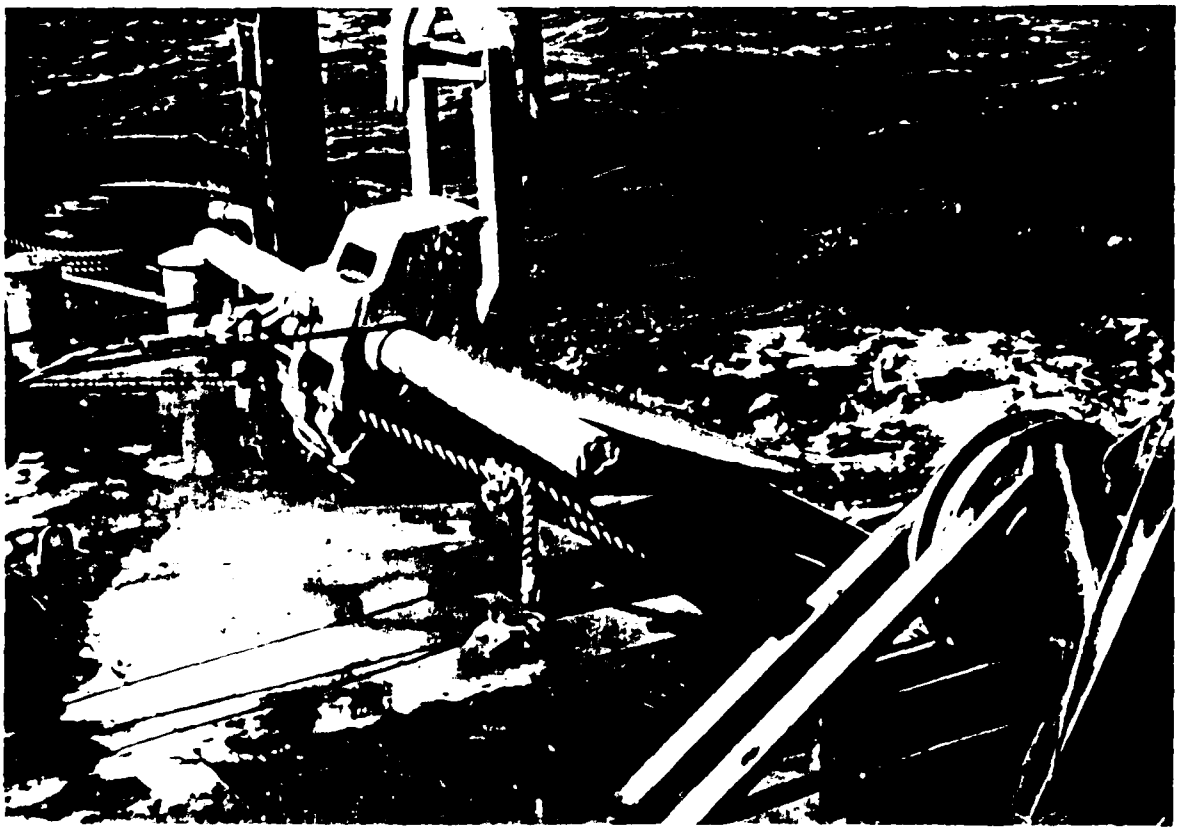


FIGURE 15. AFTER MOORING LINE ANCHOR GOING OVERBOARD

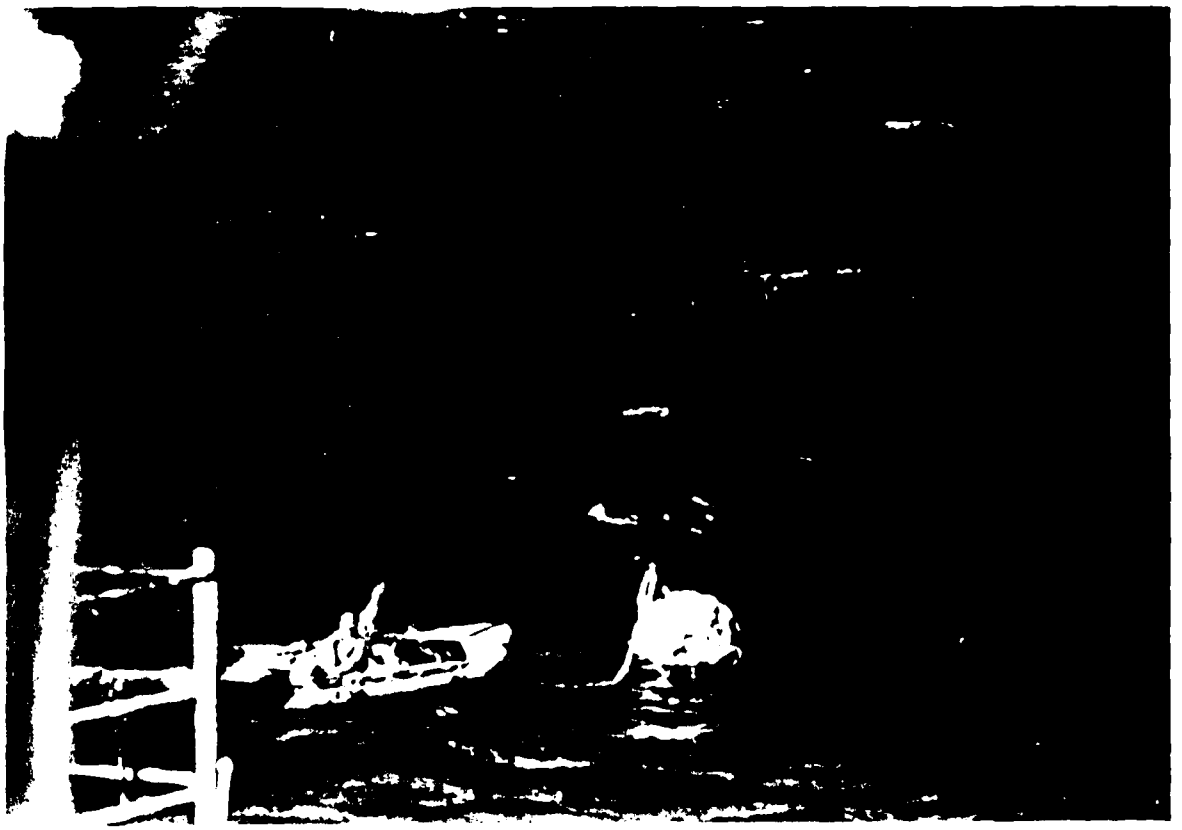


FIGURE 16. CROWN BUOYS AND MARKER BUOY ATTACHED TO CROWN LINE

1238 the anchor was felt to bottom out; by this time the *MANATI* had been pulled 4800 feet due north by the catenary in the line. The crown line remained connected to the winch.

Before the sheave failure at about 1120, the tension on the *SQUAW* dynamometer read 25000 pounds. The stern mooring chain was noted to be over the starboard side of the *SQUAW* and leading toward the bow; also the forward chain appeared to be angled somewhat astern. This led to concern that the fore and aft mooring lines were fouled around each other.

After the anchor drop at 1238 the *MANATI* drifted about 1800 feet due east. At 1319 the *MANATI* again attempted to pull the anchor down to the target position. Pulling toward the south continued until 1408 when the *MANATI* had reached a point 3250 feet due south of the target anchor position derived the night before. At this point pulling was stopped because: (1) the tension in the crown line appeared quite high, and (2) the fact that the *SQUAW* had remained broadside to the line of tow lent credence to the theory that the mooring lines were twisted below her. The remaining crown line was then run out and buoyed off, Figure 16.

Crowley and CHESNAVFACENGCOM representatives headed for the *CHALLENGER* to use that as a base for approaching the *SQUAW* for a close inspection of the situation. A diver dove to 140 feet on one of the lines and could see about 40 feet more below him. He saw no indication of twist and the line appeared to go straight down. The *CHALLENGER* crew supported the *MANATI* watch officers in saying there was no way the *MANATI* could have rounded the *SQUAW* during the night, and it was doubtful whether the *SQUAW* could have done a 360° turn in the sea that was running. A reanalysis of the situation ensued.

The stern sheave had been pulled down and it was found that the bearings were completely destroyed. The other two vertical legs could not be laid without a replacement. Crowley ordered one made up after considering substituting the identical fixed sheave on deck for the vertical sheave. It was concluded that, in the morning, we would tow the anchor to the final position and then proceed to San Diego on Saturday night, 1 July, to replace the sheave.

SATURDAY, 7/1/78 - AT SEA NEAR THE MOORING SITE AND RETURN TO SAN DIEGO

In the morning, the *MANATI* moved back to the buoys at the end of the south anchor crown line. These consisted of two 56 inch diameter cylinders and a small sphere which supported a pendant. The spherical buoy was hauled aboard and the pendant shackled to a line running through a snatch block to a bollard at the stern. The *CHALLENGER* was called over to take the *MANATI* in tow and headed southwest in a direction calculated to pull the south anchor over to the target position.

When the most southerly point of the previous evening run was reached, the tension built up considerably causing the two 10000 pound crown buoys to submerge almost totally. Southwesterly progress slowed considerably and the ships swung up to the west apparently on a radius swing about the south anchor position. The turns on the *CHALLENGER* were increased and the *MANATI* put on some power trying to get back down in a southerly course. Finally, at a little after 1300 the anchor seemed to break loose and the ships started moving in a more southerly direction. Towing ceased at 1400.

The *CHALLENGER* first went up to look over the *SQUAW* and found it to be on a generally north-south heading. Boarding was impossible because of the sea state but the draft marks indicated that the *SQUAW* was drawing almost 18.5 feet of water. Figures 17 and 18 illustrate the condition of the *SQUAW* at this time. At the *MANATI*, the crown line was then reattached to the spherical buoy and the buoy was overboarded. The *MANATI* then headed back to San Diego to have a new stern sheave fitted. Arrival at the Crowley pier was at about 1915. The replacement sheave was delivered about 2200.

SUNDAY, 7/2/78 - RETURN FROM SAN DIEGO TO THE MOORING SITE

Installation of the replacement sheave was completed at 0700 and at 0730 the *MANATI* departed San Diego to return to the site.

Back on station the seas were too rough to do any work. The *SQUAW* had moved about 3500 feet north of where it was left on 1 July, the day before. The crown buoy position was in the same general area where it had been cut loose. This indicated that the south anchor was where it had been left the day before. The *MANATI* proceeded then to make another check on the *SQUAW* and found it about 1000 feet from the earlier position. On the first sighting the *SQUAW* was headed 280° and on the second 315°, each time directly into the seas whereas when left on 7/1/78 she had a precise north-south orientation.

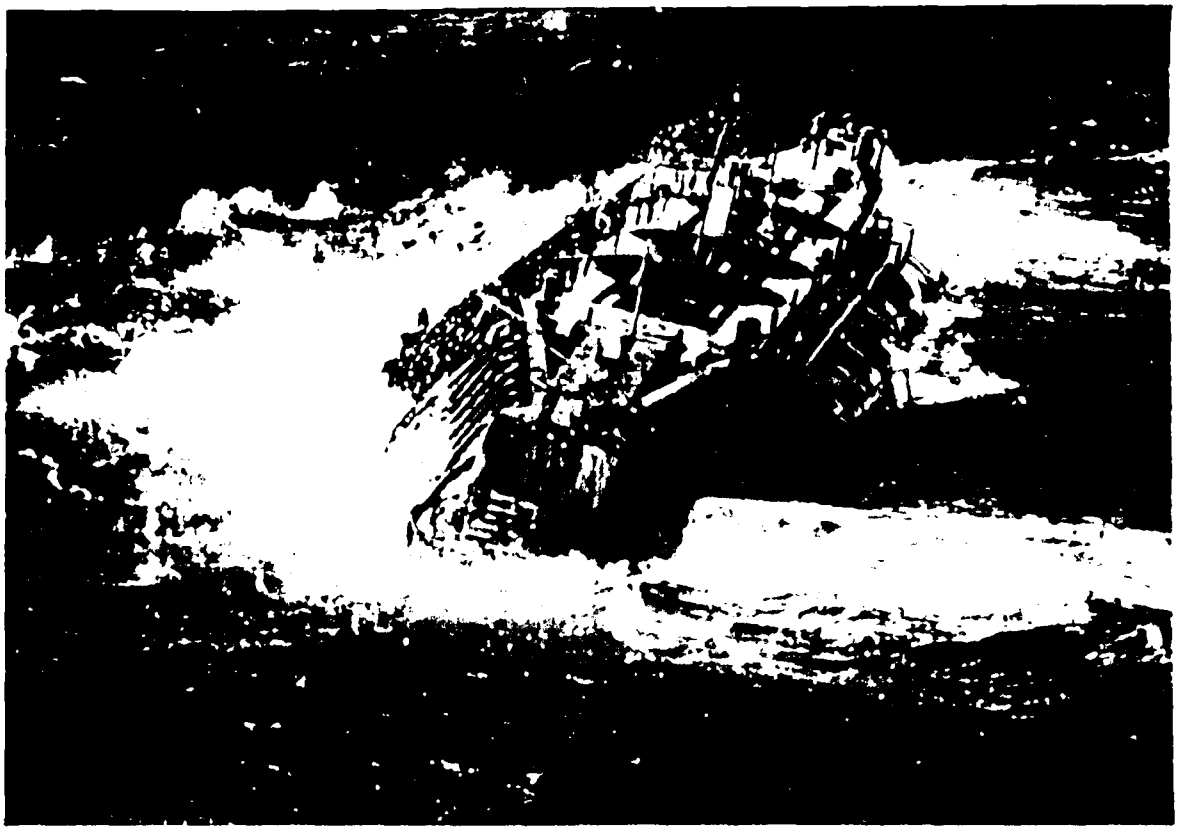


FIGURE 17. SQUAW WITH NORTH AND SOUTH MOORS IN PLACE

FIGURE [illegible] SQUAW AS SEEN FROM JULY WITH BATTERY CANNISTER STILL UPRIGHT

Taking all these things into consideration there seemed to be no other conclusion than that the *SQUAW* was no longer connected to the south anchor, but was hanging downsea from the north anchor. This was further confirmed by later positions; the *SQUAW* seemed to move up toward the north anchor as the wind and sea calmed and moved back downsea as the weather picked up.

When the *MANATI* departed the site on 7/1/78, at 1400 the positions of the north and south anchor points had been carefully estimated as had been the position of the *SQUAW* when the crown line to the south anchor had been buoyed off. The *MANATI* then went up alongside the *SQUAW* and, at 1520 on 7/1/78, got a fix on her position which was only 600 feet from where the *SQUAW* had been spotted by radar. On the morning of 7/2/78, upon return to the site, the *SQUAW* was 3500 feet north of the positions of the day before. A number of fixes were taken during 7/2/78 and 7/3/78 with the following results.

Measurement No.	Date	Distance in Feet from Anchors North	South	Total Distance
1	7/2 & 7/3	3589	10216	13805
2		3571	10093	13664
3		3279	9537	12816
4		4197	8434	12631
5		4316	7915	12231
6		4848	7758	12606
7		5530	7001	12531
8		6045	6452	12497
9	7/1/78 in Moor	6242	6132	12374

The design horizontal distance between anchors was 12000 feet and any situation where the distance from the *SQUAW* to anchor exceeds 6300 feet would be impossible with the amount of wire and chain out and a 6300 foot water depth. Thus, while it was evident that the north anchor had pulled somewhat south of its estimated position. It did not appear possible for the *SQUAW* and the south anchor to be connected. This was reported to the Crowley Project Director on 7/2/78; it was conjectured that the wires had indeed been crossed on the night of 6/29/78 - 6/30/78 and that the pulling on 6/30/78 and 7/1/78 had been sufficient to cause a break in the stern mooring wire sometime later on 7/1/78.

However, the Crowley decision was to proceed with the dropping of the

vertical legs since both drums of the winch were wound - one with the 8570 foot wire and the other with the 5740 foot wire for one vertical leg.

It was also noted on the morning of 7/2/78 that the battery cannister and electronics package, which had been installed at the Naval Station by Naval Ocean Systems Center personnel, was no longer upright as left on 7/1/78, shown in Figure 18. The battery cannister was on its side and the electronics package partially disconnected. CHESNAVFACENGCOM notified NOSC by radio telephone of these facts.

MONDAY, 7/3/78 - AT SEA NEAR MOORING SITE

At 0600 in the morning, the rigging crew prepared to lower the spare 6000 pound clump on the 8570 foot wire to respool it under tension for use in lowering the 28000 pound clump.

During the pickup the winch operated erratically. The riggers were unable to wrap the wire on the drum properly. After rewinding, it was decided necessary to go back into San Diego for repairs by a factory representative. An inspection of the *SQUAW* found the tensionmeter reading only 1500-2000 pounds indicating that only the weight of the chain was hanging on the stern padeye. This was evidence of a break or a malfunctioning tensionmeter.

Bow and stern drafts were estimated from the *MANATI* as 18.7 feet and 16.8 feet respectively for a ⌀ draft of 17.5 feet for a displacement of 499.24 tons. Checking the differences in displacement and trim from the initial "at sea" condition showed an additional weight of 7.47 tons at the bow which was the estimated weight of the bow mooring line. The indication here is that the weight of the bow mooring cable was acting on the bow with no added weight on the stern. It appeared the stern mooring parted at the bottom of the chain.

WEDNESDAY, 7/5/78 - SAN DIEGO

At 0800, calls to NOSC and PWC were made about the instrument package which revealed its formerly unknown importance to the project.

At about 0930 the CHESNAVFACENGCOM and Crowley representatives met to discuss the situation. The local Allison representatives were pulling the transmission out of the Skagit winch for determination of the extent of that problem. The winch, with the transmission removed, is shown in Figure 19. At this point it was not known when the repair might be effected.

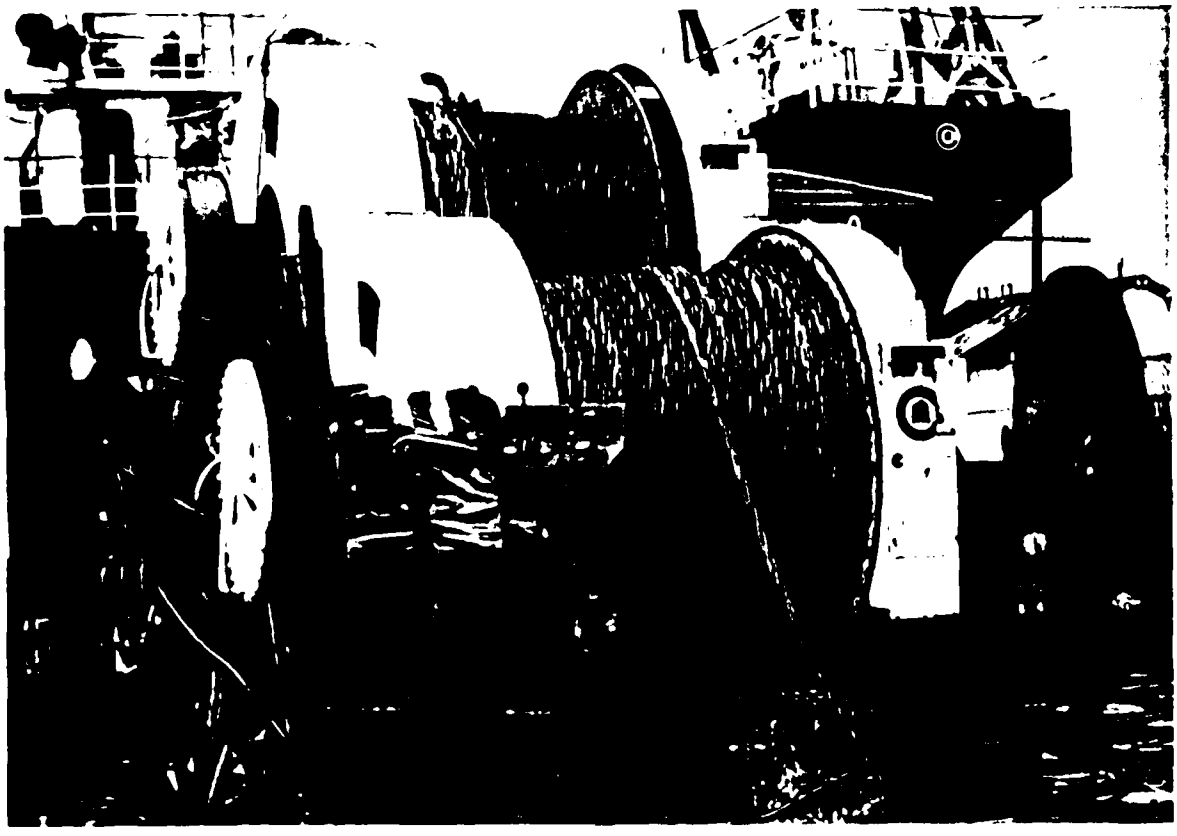


FIGURE 19. THE SKAGIT WINCH WITH TRANSMISSION REMOVED

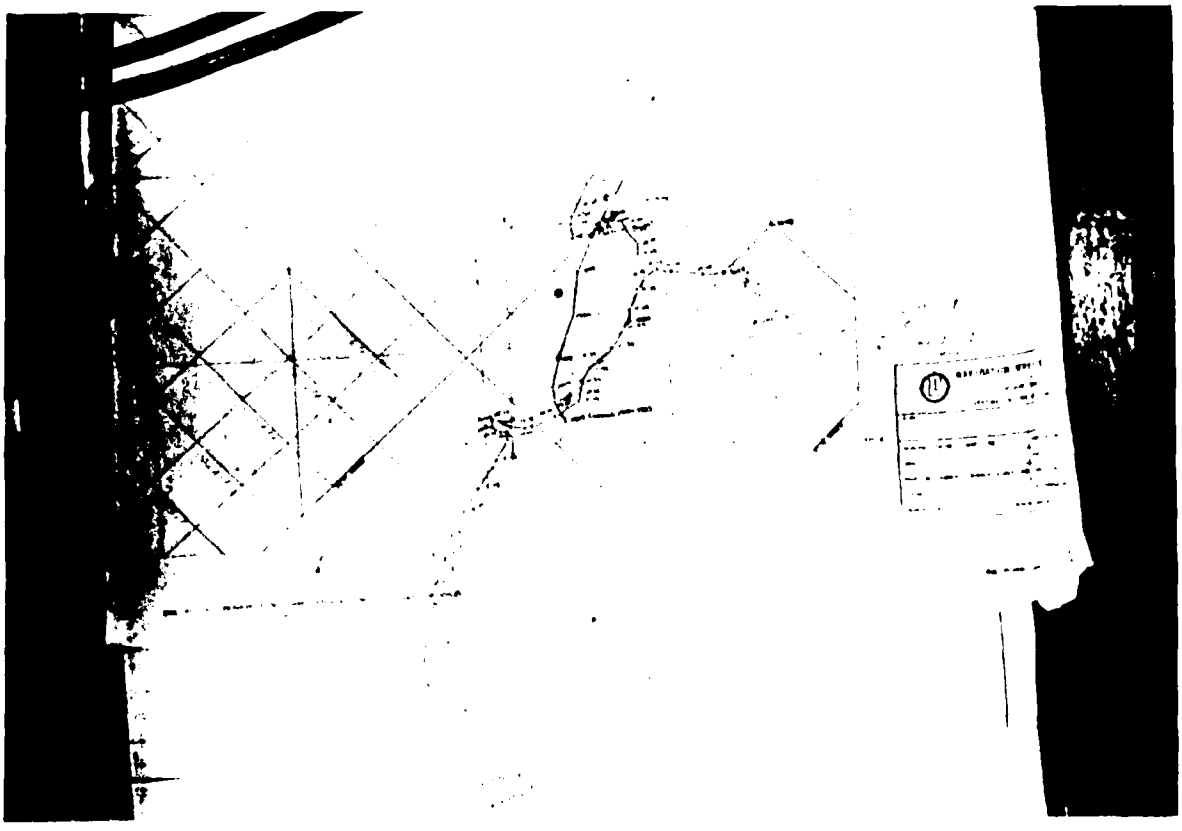


FIGURE 20. NSI PLOT OF MANATI POSITION ON WINDOW OF PILOT HOUSE

Crowley was again informed of the CHESNAVFACENGCOM positive conclusion that the stern mooring line was no longer connected to the *SQUAW* and the separation had occurred near the juncture of the wire and the chain. Additional data were extracted from the NSI chart on the window of the *MANATI* pilot house, Figure 20, for continuing position calculations.

A CHESNAVFACENGCOM representative and a NOSC contractor departed at 1500 aboard a NOSC torpedo recovery boat to meet the *CHALLENGER* at the *SQUAW* site. The *CHALLENGER* had two Crowley divers aboard. They helped the NOSC representative recover the instrument package from the *SQUAW* and one diver inspected the after mooring line. All of the fittings were on the chain and the wire was connected as far down as he could see. However, it did "feel" somewhat slack to him. The tensionmeter had completely self-destructed by this time and no reading from it was obtained. Return to the NOSC pier of the torpedo recovery boat was at about 2300 on the night of 7/5/78. As far as the after mooring leg continuity was concerned, the results were inconclusive.

THURSDAY, 7/6/78 - SAN DIEGO

It became evident that the Skagit winch transmission could not be repaired or replaced in less than four days. As a result, all personnel other than ship's crew were released to return to their home bases with the stipulation that they return ready to go to sea at 0100 on 7/10/78.

MONDAY, 7/10/78 - FROM SAN DIEGO TO MOORING SITE AND RETURN

Departed San Diego at 0100 and arrived at the site early in the morning. The rigging crew prepared the gear for the first vertical leg installation.

At 0900 the port engine went out and the *MANATI* headed back to San Diego. Caterpiller representatives boarded at the sea buoy and the ship berthed at the Crowley pier at about 1315. Engine repair continued for the remainder of the day.

TUESDAY, 7/11/78 - RETURN FROM SAN DIEGO TO MOORING SITE

Arrangements were made to defer installation of the electronics equipment until after the *SQUAW* submergence. A message was received changing the target depth from 300 feet to 250 feet $\pm$ 50 feet. PWC provided two 3000 pound buoys, thimbles, and wire rope clips for various sizes of wire. Thomas Salmon had replaced Ronald Green as the SUPSALV representative aboard the *MANATI*.

The *MANATI* was underway early in the morning, arriving back on site at 0730. The 6000 pound clump and acoustic release were lowered, Figure 21, on the 8570 foot wire to respool the wire under tension. This was satisfactorily accomplished and the acoustic release transponder was interrogated and responded all the way down and back. Therefore, it was decided to utilize it in the lowering line when installing the after vertical leg clump.

An accurate fathometer measurement was obtained of the depth at the site where the *SQUAW* would be moored. Five depth recordings were obtained between 1152 and 1200. There was practically no variation from the mean reading of 1049 fathoms (6293 to 6296 feet).

With the depth information obtained, calculations for the length of chain required to be added to the top of the vertical legs were as follows:

Depth of water	6294 feet
Length of wire rope	-5740 feet
Length of chain on clump	- 25 feet
Length of chain on *SQUAW*	- 90 feet
Shackle in system	- 5 feet
Swivel length	- 3 feet
Clump height above bottom	- 6 feet
Desired *SQUAW* depth	- 250 feet
Additional chain required	175 feet

Two shots of chain were added to each leg, i.e., 180 feet which should put the attachment padeyes on the bottom of the *SQUAW* 245 feet below the surface. With this added weight, the negative buoyancy that would be applied to sink the *SQUAW*, with all ballast tanks full while on the surface was calculated to be 19.02 tons. Results of the trim and buoyancy test at the Naval Station on 6/24/78 were again studied to derive an equivalent light ship weight for comparison with data given in the Project Execution Plan.

The after vertical leg was then made up adding 180 feet of chain to the 90 feet on the *SQUAW*, Figure 22. The *MANATI* went alongside the *SQUAW* to shackle in a hauling line and to cut loose the lashings on the 90 feet of chain, Figure 23. The 180 feet of chain on the *MANATI* deck was shackled to it and the 5740 foot length of 1 1/4 inch wire was connected to that. All of the wire was payed out as the *MANATI* moved away from the *SQUAW*. The lower end of the vertical leg was then made up and attached to the 12.45 ton clump and anchor combination. The acoustic release was attached, and to it was shackled the lowering wire which passed over the new stern sheave, Figure 24.

FIGURE 21. CHECKING ACOUSTIC RELEASE

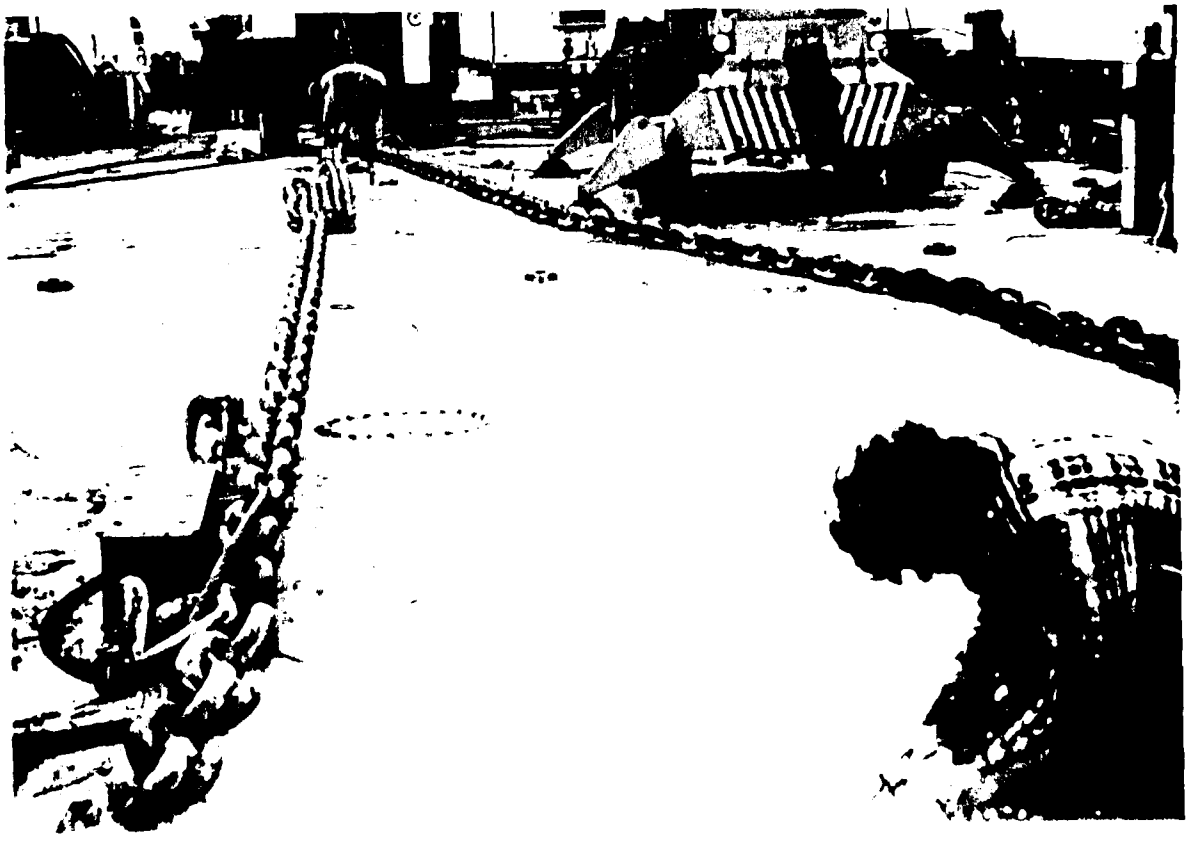


FIGURE 22. CUTTING CHAIN FOR THE AFTER VERTICAL LEG

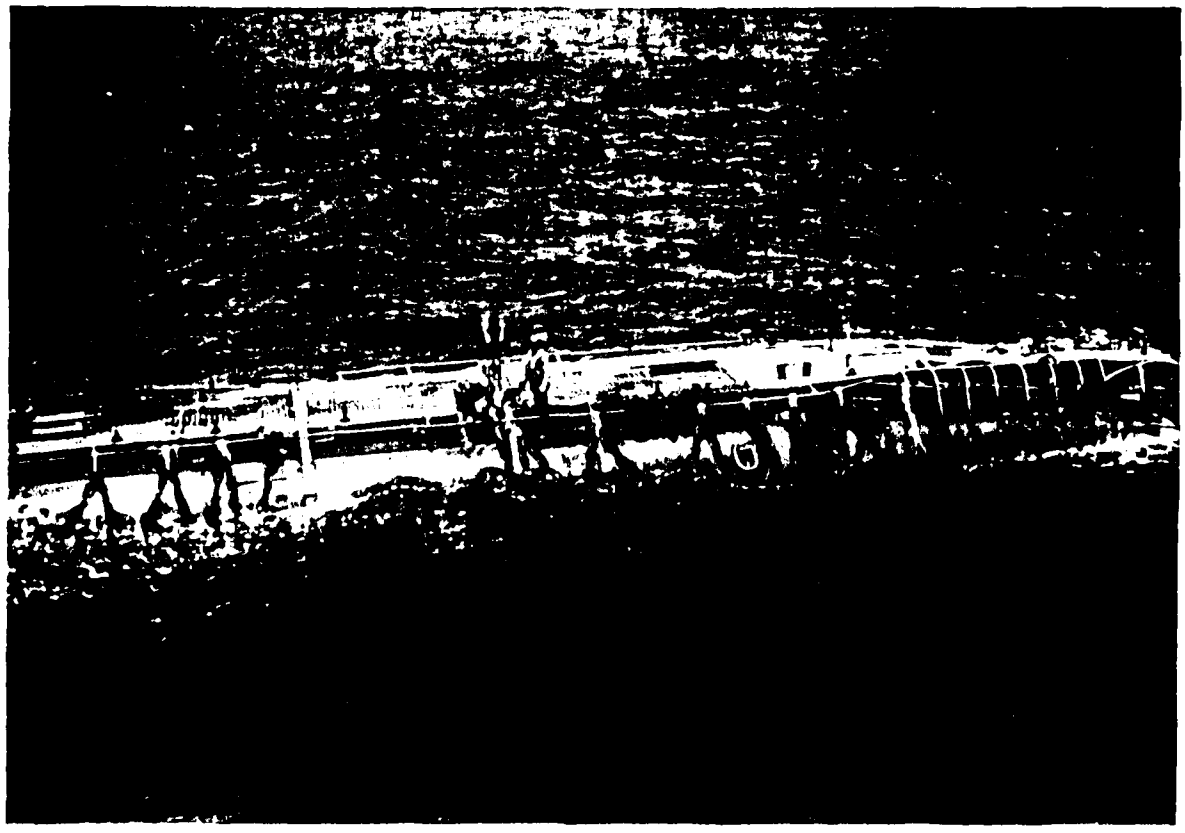


FIGURE 23. PREPARATIONS FOR CUTTING CHAIN ON AFTER VERTICAL LEG

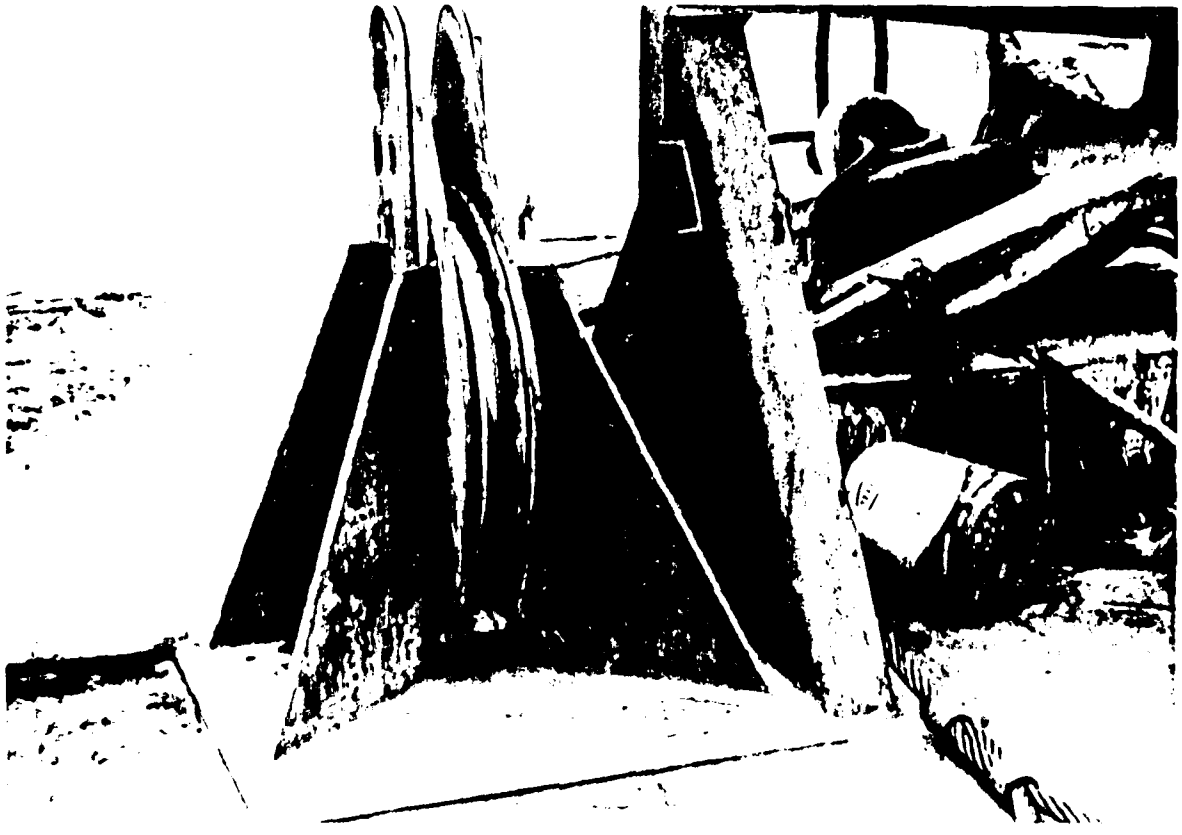


FIGURE 24. REPLACEMENT SHEAVE INSTALLED ON MANATI TRANSOM

The *MANATI* was about 3000 feet from the *SQUAW* when lowering started. After a few hundred feet of wire had run out, with some jerking as the brake was applied, the acoustic release let go and the weight free-fell down into position under the *SQUAW*. It took about five minutes for the *SQUAW* to trim down by the stern indicating that the weight was being supported by it. The drop occurred at 1813 with the *MANATI* at 083374 Alta and 109521 Woodson. Relative radar bearing on the *SQUAW* was 203°, range 2700 feet, and the *MANATI* heading 335° true. Approaching within 30 yards of the *SQUAW* at 1846 the position was 083851 Alta, 109873 Woodson and she was headed 158° true. Subsequent readings on her between then and sundown were as follows:

Time	Meters from Alta	Meters from Woodson	*SQUAW* Heading°
1922	084096	110101	115
1950	082789 Erroneous	110894	125
2010	084314	110034	345

During the attachment and making up of the vertical leg the *MANATI* had gradually turned the *SQUAW* approximately 180° in a clockwise direction. As can be seen above, after the *MANATI* was disconnected, the *SQUAW* swung herself around 180° in a counterclockwise direction. This could foul the bow mooring line and the after vertical leg if the *SQUAW* was far enough from the north anchor to pull a catenary in the line. However, there was no evidence of fouling of any cables.

WEDNESDAY, 7/12/78 - AT SEA NEAR MOORING SITE

In the morning, the rigging crew reeled the 5740 foot, 1 1/4 inch vertical leg wire on to the winch drum in preparation for lowering the forward vertical leg. The 8570 foot wire was already wound on the other drum for use as a lowering line from the previous day. The *MANATI* got underway about noon and moved over to the *SQUAW*, Figure 25. At 1229 the *SQUAW* was heading 105°, 185 feet astern of the *MANATI* with coordinates of 084186 Alta, 109448 Woodson. The additional 180 feet of chain had been shackled to the 90 foot length on the *SQUAW* and shackled to the end of the vertical leg wire on the port side of the *SQUAW*. At the time the *SQUAW* was headed downsea from the north anchor and the north mooring line ran down and under the submarine. The *MANATI* started off to the south of the *SQUAW* and had to swing to the east, to the north, and

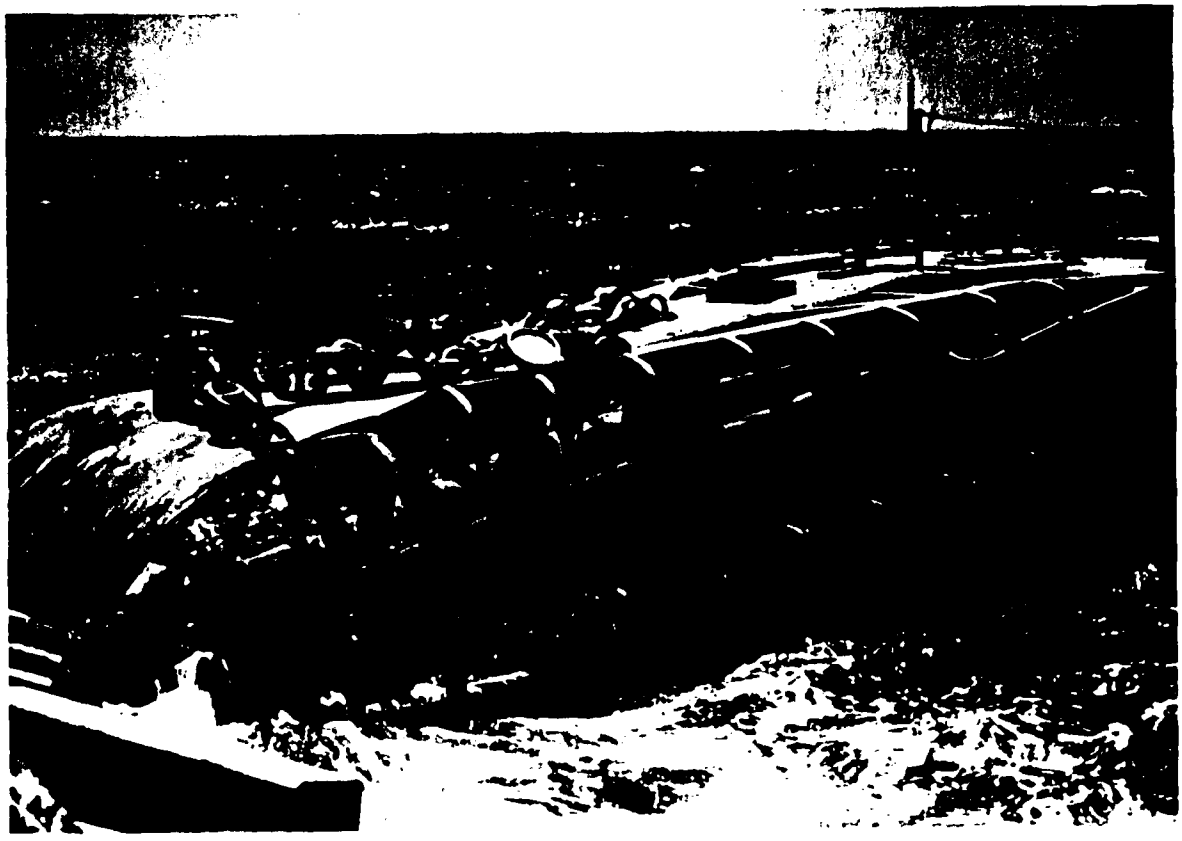


FIGURE 25. THE SQUAW SHOWING THE STERN MOORING CHAIN OVER THE STARBOARD SIDE

FIGURE 26. SWIVEL INSTALLED ABOVE THE AFTER VERTICAL LEG CLUMP

to the west of the *MAWAW* to turn it around and to get on the forward port quarter of the *MAWAW* for the lowering operation. These maneuvers are discussed in Part V.

As the *MANATI* moved counterclockwise around the *MAWAW* the 180 feet of anchor chain and the 5740 feet of wire were payed out. At the end of the wire a swivel was installed, Figure 26, which was in turn connected by a 25-foot length of anchor chain to the forward vertical leg clump, Figure 27. The

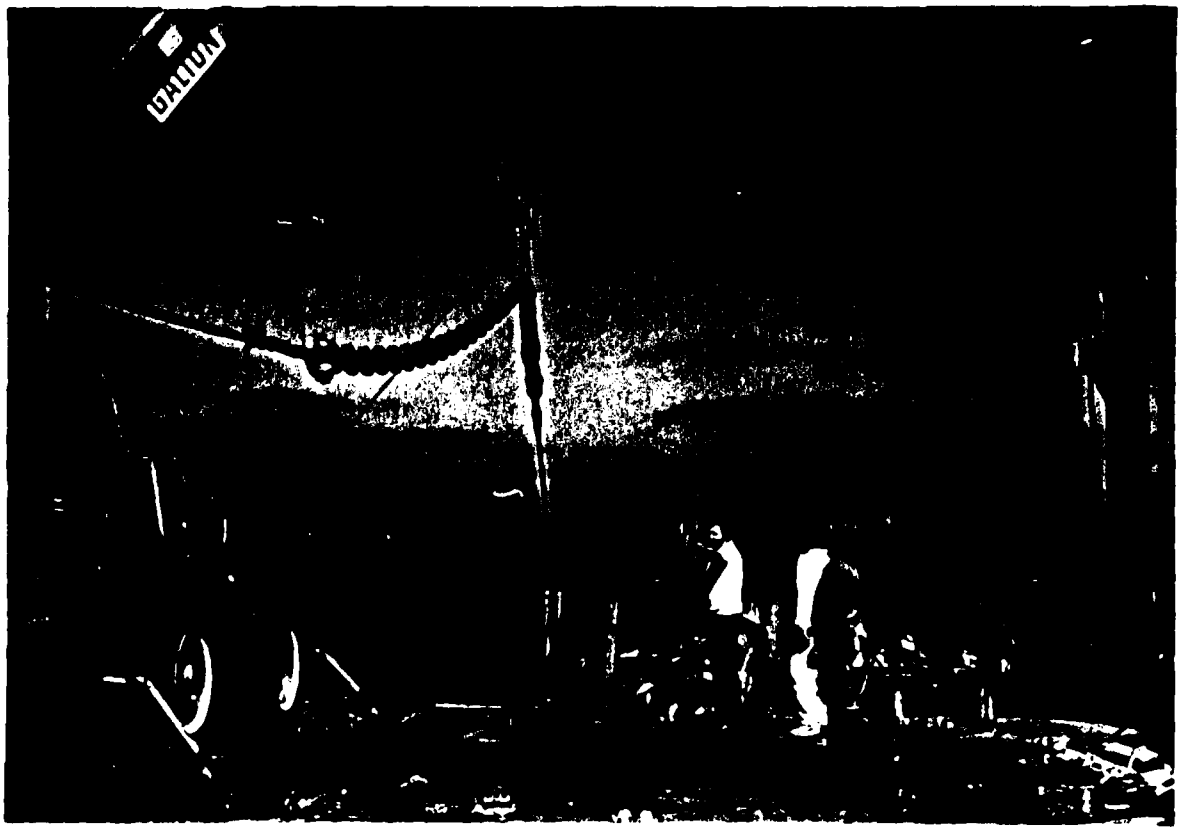


FIGURE 27 ATTACHING SHORT LENGTH OF CHAIN TO AFTER VERTICAL LEG CLUMP

calculated weight of the clumps in water was 10.12 tons instead of the 12.50 tons required. To correct this, a 6000 pound anchor was welded to the top of each clump, bringing the total weight in water of each clump up to 12.15 tons. The 8570 foot, 1 1/4 inch lowering line was also attached to this clump. (Note that the acoustic release was not to be used and the lowering line was to be sacrificed).

Lowering of the anchor clump started at about 1540 after the "[illegible]" had crossed the bow of the [illegible] toward her port side. Prior to this, as the

vertical leg wire was being payed out and the *MANATI* circled around it, the *SQUAW* rapidly changed her heading to the northwest. Thus, the chain on the forward vertical leg led around the bow mooring chain from the port side to the starboard side of the *SQUAW*. However, it seemed to unwrap as the *MANATI* circumnavigated the *SQUAW*. By 1350 or 1400 the *MANATI* was holding position to the northwest of the *SQUAW*. This relative position was held until 1445 when the tug (now the *CONTENDER* which had replaced the *CHALLENGER* pulled the *MANATI* south in an attempt to get to the port side of the submarine. However, the submarine continued to swing in the direction of the *MANATI* to the point where, at 1600, the *MANATI* was directly south of the submarine and the *SQUAW* was headed 180°. During these maneuvers, the towline from the *CONTENDER* snapped. The *CONTENDER* was utilized to pull the head of the submarine around to the north. This was done and the lowering of the clump continued with the *MANATI* gradually being pulled toward the *SQUAW*. The relative positions of the two vessels and the suspended lines are discussed in Part V.

The end of the lowering line was transferred over to the bitts on the *SQUAW* to keep this wire from dragging on the bottom and affecting the clump positioning during the final orientation and location of the *SQUAW*. The lowering line was stoppered off and cut, and an eye was fashioned in the end of it using wire clips, Figure 28. Then the eye was passed over to riggers on the deck of the *SQUAW*. This operation took a significant amount of time because of ship handling problems and the seaway acting on the two vessels in such close proximity.

When the eye was finally fitted over the after port bitts on the *SQUAW*, the stopper was released on the lowering line and it went overboard from the *MANATI*. When the load was transferred to the *SQUAW*, the submarine heeled to port and trimmed down by the stern. She was left for the night within 20° heading of her position and attitude when picked up in the morning, Figure 29.

The *MANATI* headed for San Diego at 1910 arriving at the Crowley pier at about 2300 to pick up the buoys and wire fittings needed for the electronics package subsurface replacement and the spare 10000 pound anchor.

THURSDAY, 7/13/78 - RETURN TO THE SQUAW MOORING SITE

The *MANATI* departed the Crowley pier at 0100 and returned to the *SQUAW* mooring site. The coordinates of the submarine were 83972 Alta, 109404 Woodson at 0826 with the *SQUAW* heading 065°. The *MANATI* proceeded to the crown buoys

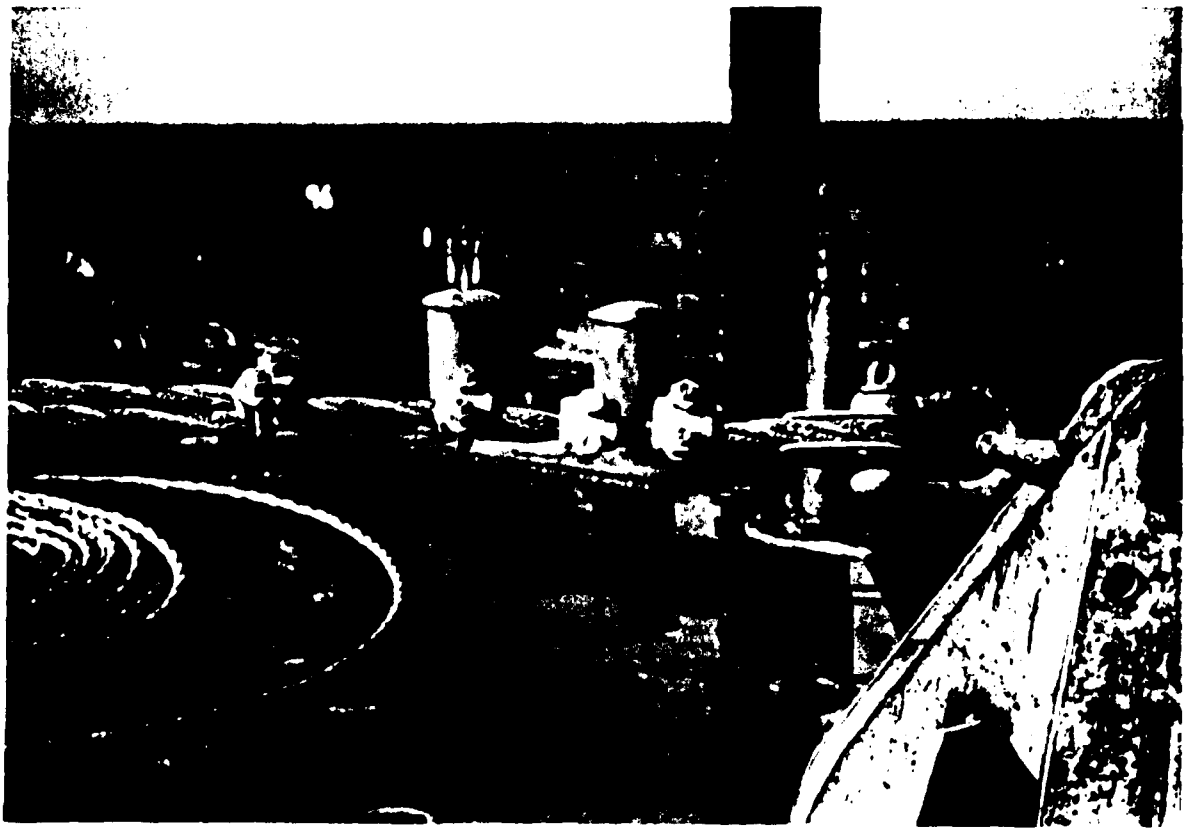


FIGURE 28. EYE FORMED IN THE SUBSTITUTE LOWERING LINE FOR THE AFTER VERTICAL LEG CLUMP

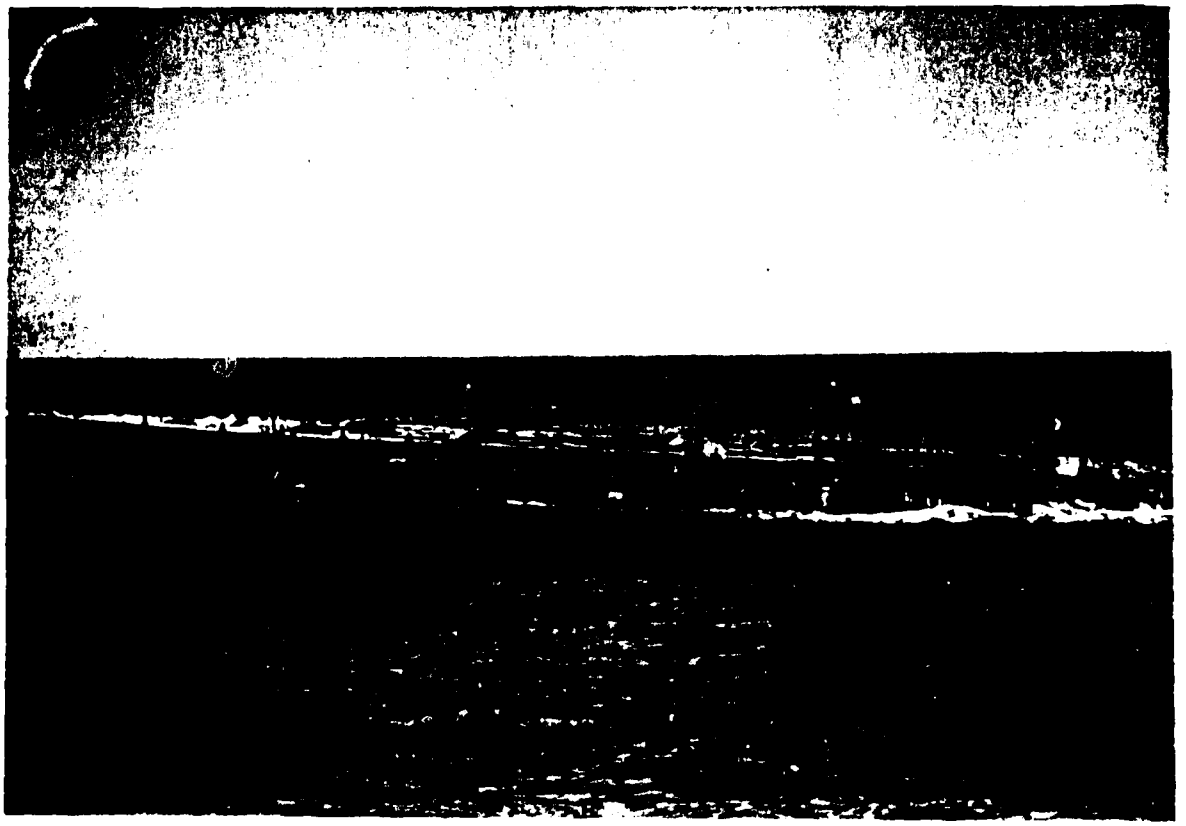


FIGURE 29. SQUAW WITH THE FORWARD VERTICAL LEG LOWERING LINE HUNG ON THE AFTER PORT BITTS

attached to the south anchor crown line. The spherical buoy was brought aboard and at 1041 the *MANATI* moved to the south towing the crown line and obtaining Mini-Ranger fixes on the *MANATI*, and radar ranges and bearings on the *SQUAW*. The object of this exercise was to tow the south anchor further south to see if the *SQUAW* would follow, and thus determine if the *SQUAW* was connected to the anchor. The ranges progressively increased as follows:

Time	Range Feet	Relative Bearing°	*MANATI* Heading ° True	Speed
1041	15422	165	195	2.02 K
1047	17074	161	201	2.85 K
1051	18160	163	198	2.51 K
1100	19048	160	200	2.39 K
1100	19792	165	198	1.41 K
1103	20134	170	184	1.22 K
1105	20134	185	170	0.36 K

The ship moved south to a point near where the *MANATI* had been when the south anchor was released on 7/1/78. At this point enough strain was picked up on the crown line to pull the crown buoys under but the *SQUAW* had not moved. It was finally obvious that the south anchor was no longer connected to the *SQUAW*.

Next the *MANATI* moved on up to the *SQUAW* to determine where the break in the mooring wire had occurred by underrunning the wire with a shackle attached to a line to the *MANATI*. Divers installed the shackle and the *MANATI* barely got underway before the shackle dropped off the end of the stern mooring line. This indicated a break in the line no more than a few hundred feet below the submarine.

Replacement of the stern mooring line and anchor system was accomplished by marrying three of the lengths of polypro-covered 1 inch wire that had been brought along as backup. This totalled 8700 feet in length to replace the 1 1/4 inch mooring line. Adequate lengths of chain were on board to make up the 270 feet needed. A spare 6000 pound clump and a 10000 pound anchor were also on board. It would be necessary to retrieve the crown line to be used for a lowering wire using the previous technique. This would mean dropping the remaining stern mooring wire length attached to the anchor system as well as the 6000 pound clump, 6000 pound anchor, and three shots of chain.

It was possible to get all three lengths of the rubber covered wire on the upper drum of the winch, including connecting fittings, since this wire would be spooled out under its own weight only.

FRIDAY, 7/14/78 - AT SEA NEAR SQUAW MOORING SITE

The first operation in the morning was to retrieve the crown buoys to pick up the crown wire. This started at about 0600. The buoys were brought aboard and the crown line was wound on the lower winch drum. The wire was pulled up to where the anchor crown surfaced, Figure 30, and the connecting link was then burned off dropping the remainder of the equipment to the bottom.

Next the *MANATI* headed back for the *SQUAW* to check out the nature of the break in the wire. Divers shackled a lifting line to the bottom of the 45 feet of chain and it was hauled on deck, Figure 31. Then a shackle was fitted around the 1 1/4 inch vertical leg and attached to the crown line. The first 90 feet were hauled aboard by the winch and the remainder was pulled aboard by hand. There was about 220 feet of wire down to the break. The strands were unravelled for several feet back from the break and were flattened near the break. Two strands were broken cleanly and the third had a few wires frayed as shown in Figures 32 and 33. It was impossible to determine the cause.

It was thus necessary to inspect the bow mooring wire at about the same depth, i.e., 250 feet. If a twist had caused the wire to kink and then to break it is probable that the bow wire was also damaged. Divers attached a carpenters' stopper to the bow wire at about 100 feet. This could then be lifted on deck and the wire could be examined by divers down to an additional 150 feet.

The efforts to put a stopper on the bow mooring line wire at 100 feet were unsuccessful so that any possible break could not be examined directly by divers. They did, however, go down to 160 feet and found no indication of damage. A weighted shackle was then fitted around the wire and attached to a light nylon line. From the deck of the *MANATI* this line was payed out to 350 feet and run up and down the mooring line. There was no evidence of any kink or any broken wires sticking out from the mooring line.

SATURDAY, 7/15/78 - AT SEA NEAR THE SQUAW MOORING SITE

In the morning the *MANATI* proceeded to the *SQUAW* position. At this point the *SQUAW* was 2700 feet downsea (ESE) of the estimated north anchor point with her stern upsea. The new coated, 1-inch line was shackled to the bow mooring chain but this was paralleled with a length of rope that was meant to take the load as the *SQUAW* was pulled out to make a further test on whether the bow mooring line was damaged.

FIGURE 30. RETRIEVAL OF THE FIRST STERN MOORING CROWN LINE AND ANCHOR PRIOR TO CUT OFF

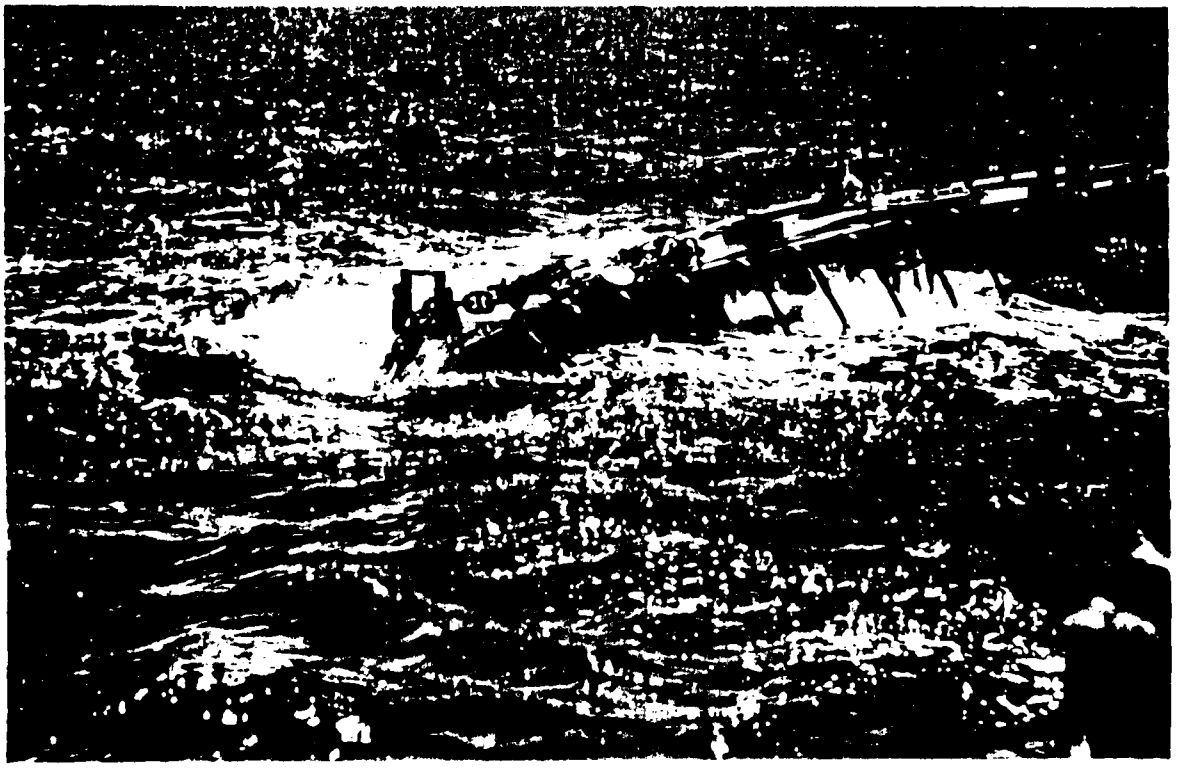


FIGURE 31. HAULING IN THE STERN MOORING LINE CHAIN OVER SQUAW STERN

FIGURE 32. RETRIEVAL OF THE BROKEN STERN MOORING WIRE

FIGURE 33. ENDS OF THE STERN MOORING WIRE ON MANATI DECK

The *MANATI* started pulling at 0910 heading south. At 0927, after towing for about 600 feet, the rope parted. The strain was then taken on the 1 inch wire. At 1323 it had reached the target position for the *SQUAW* when in the moor. This would indicate a full 6000 foot extension of the north mooring line, but there was still no lead angle on the chain off the bow. However, there was little doubt that the bow anchor was in position and that the mooring line was holding its design load. Yet, at this point, the submarine was still perpendicular to the line of tow, so it was towed broadside. Pulling was then slacked off and the *MANATI* was gradually hauled to the north by the force of the *SQUAW* and the north (bow) mooring line.

The one-inch wire was payed out to the end of its 8700 feet and the 180-foot length of chain attached and stoppered off. By the time this was completed the *MANATI* was 4500 feet to the southwest of the *SQUAW* which, in turn, was at about its earlier position 2700 feet ESE of the north anchor.

During this period, two of the divers had been observing the *SQUAW* both from the *ZODIAC* and from the deck of the *SQUAW*. They continually checked on the angle of the chain at the bow and on the attitude of the submarine. Throughout this tow she remained broadside and there was no lead angle on the bow. As previously noted the submarine was trimmed well down by the stern which was attributed to the weight of the forward vertical leg lowering wire hanging on the after port bitts. The divers also reported hearing a pronounced rubbing or scraping noise in the bow mooring line and the chain was vibrating to the extent that a backed off shackle pin nut would vibrate its way back into position. The divers returned to the *MANATI* at about the time the tug was released, around 1630.

When the tug was reattached to the bow of the *MANATI* at 1730, a CHESNAVFACENGCOM representaitve accompanied the divers back up to the *SQUAW* to investigate the vibration in the bow mooring chain and to look at the lead angle. When they arrived at the *SQUAW* she had swung around headed north, the vibration had stopped, and she had developed a slight (15°) lead angle of the mooring chain off the bow.

During this period the *MANATI* and tug continued pulling to the south. The course made good by the *MANATI* averaged 180°, with the *SQUAW* continuing to track along sluggishly on a 225° course. At 1927 the *MANATI* seemed to hang up on the towline (still the one-inch covered wire of the stern mooring leg)

and swung on the end of the line to the east about 750 feet; the [illegible] followed suit. Then at 1911 the whole system started to move more easily. The [illegible] course made good changed to about 115° and the submarine moved directly south about 1000 feet west of its target position. At 2005 the towline pull was reduced with both the tug and the [illegible] dropping to idling speed on the engines to maintain headway while the anchor (10000 pound navy stockless) was dropped over, Figure 34, and paying out of the 1 1/8 inch crown line began. The idea was to run out 8700 feet of crown line to lower the anchor to the bottom while moving the [illegible] to the south. When the 8700 feet was out and the crown line under tension, the anchor should be just above the bottom and would be dropped. The [illegible] was ordered back to the [illegible] as the sun was setting.

FIGURE 34. SECOND STERN MOORING ANCHOR GOING OVERBOARD

It was calculated that the north anchor had been dragged about 1000 feet south during the breakaway period between 1911 and 2015 so a new south anchor position was selected at 1,000 feet south of the north anchor position. By the time the anchor planting run started at 2111 the [illegible] was about 1000 feet

south of the target anchor position and the *SQUAW* was 13000 feet north of the *MANATI*. This run went as planned with the *MANATI* making good a course of 180° and the *SQUAW* doing the same. The run was terminated at 2228 and the anchor dropped to the bottom.

The *MANATI* then released the tug *CONTENDER* as the *MANATI* was being dragged back to the north by the catenary in the 1 1/8 inch crown line. The crown line was then reeled in as the *MANATI* backed to the north toward the anchor point in an attempt to recover as much of the line as possible. When the *MANATI* was judged to be above the south anchor point the crown line was burned off and 7000 feet or more dropped to the bottom.

Mini-Ranger coordinates of the *MANATI* were 088178 Alta, 114539 Woodson at 2228 when the anchor was dropped; 087344 Alta, 113892 Woodson at 2300 when the crown line was cut; and 085188 Alta, 111282 Woodson at 2315 when the *MANATI* pulled up alongside the *SQUAW*. This completed the work on 7/15/78 with the submarine in a moor.

SUNDAY, 7/16/78 - AT SEA NEAR THE SQUAW MOORING SITE

In the morning, the swell and wind waves had picked up considerably, making it impossible to do any work. At 0717 the position of the *SQUAW* was obtained; it had moved only 800 feet to the east indicating that the moor was holding. However, she was still trimmed well down by the stern, more so than the day before. This was an obvious "weather day" and it was also felt necessary to go back to San Diego to get additional gear to cope with the removal of the weight of the forward vertical leg clump from the stern bitts. The *MANATI* therefore got underway and arrived in San Diego around noon. Shortly after arrival, a call was received from the *CONTENDER* saying that, on their last pass by the *SQUAW*, it had come up to practically an even keel attitude with the entire deck above water.

Plans were changed to get back out in the early morning to continue work, weather permitting. The *CONTENDER* was asked to check the lead angle of the bow and stern chains and also to look at the draft marks amidships. They reported the bow chain angling off to port and the stern chain angling off to starboard but the heading was still generally a north-south orientation. Draft marks on the starboard side read about 19 feet but were difficult to estimate because of the weather. Arrangements were made to contact *CONTENDER*

again at 2200 to get an update on both the *SQUAW* condition and the weather. If the weather looked favorable, the *MANATI* would depart again for the site at 0400. This proved to be the case and the departure time was set for that hour in the morning.

MONDAY, 7/17/78 - RETURN TO THE SQUAW MOORING SITE

Departure from the Crowley Pier was at 0430 and the *MANATI* arrived at the site at 0850. A Mini-Ranger fix was taken on the *SQUAW* and it was found that she had moved only a few hundred feet overnight. Her heading was still about 000 but the attitude was not quite as level as had been indicated by the *CONTENDER*. She was still down by the stern and heeled to port. Although the seas were quite calm it was extremely difficult to get any reliable draft measurement in this condition. In the north-south orientation she was rolling somewhat in the trough of the swell and, with the port list and wave motion at bow and stern, any draft estimates were only accurate within $\pm$ one foot which was not sufficiently accurate to make dependable displacement calculations. Primarily, from the changed attitude, it was assumed that both vertical legs were in place but that the weight of the forward leg might be carried on the after bitts.

Prior to cutting the forward vertical leg 1 1/4 inch lowering line off the after bitts, divers went down to secure a carpenter stopper on the line about 100 feet below the surface. They went aboard the submarine with a burning torch and proceeded to cut the wire just outboard of the bitt, Figure 35. When the wire was cut through and dropped, the line from the *MANATI* to the carpenter stopper went slack almost immediately. The carpenter stopper did not hold the load. The *SQUAW* gradually trimmed up to an even keel condition and the list to port came off to be replaced by a slight list to starboard. In retrospect this is a possible point in time when the after vertical leg parted and the submarine was relieved of the weight of the 28000 pound clump.

About fifteen minutes later, Mini-Ranger fixes were taken on the *SQUAW* position when the *MANATI* was directly alongside. At 1215 it had fallen 2000 feet south of the 0850 fix. The trend continued to a distance of about 2500 feet south where the position again stabilized. This position held for as long as the *MANATI* stayed alongside the submarine. At 1445 the fix on the submarine with the Mini-Ranger was 085950 Alta, 111888 Woodson. This drop back in position was probably due to the removal of a weighted-down lifting

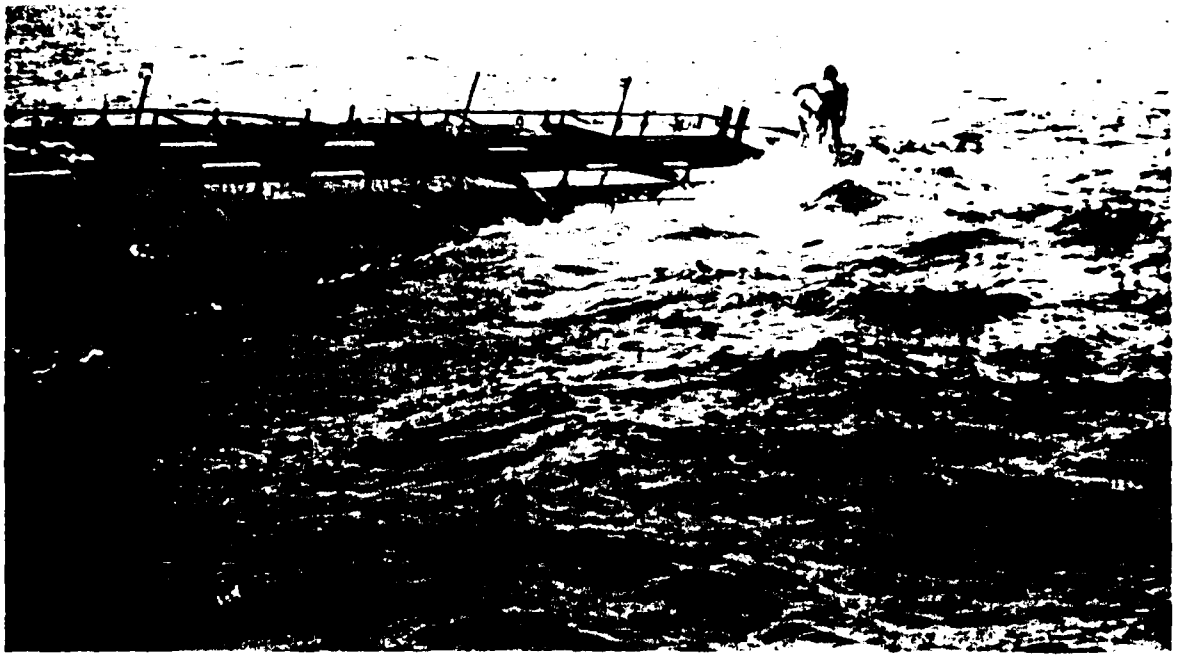


FIGURE 35. SQUAW PRIOR TO CUTTING LOWERING LINE FROM AFTER BITTS

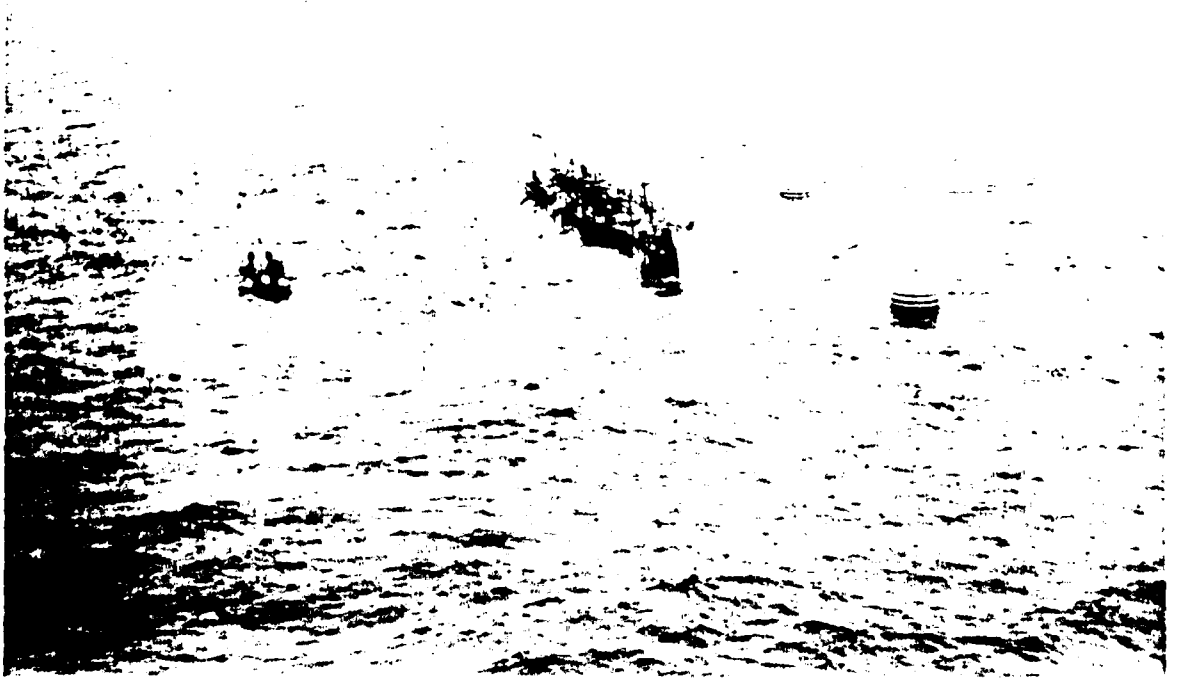


FIGURE 36. DEPLOYING ELECTRONICS PACKAGE MARKER FLOATS PRIOR TO SINKING ATTEMPT

line from around the mooring line, which had restrained it from assuming a normal catenary. When the restraint was released the line formed a catenary lifting about 2500 feet off the bottom accounting for the movement to the south. Although the submarine was observed to be in a very light, slack moor, it was decided to proceed with the sinking operation.

The above change in the after vertical line did not apparently relieve the downward loading on the bow mooring line that would permit it to assume a normal catenary. The indication was that the lowering line, secured to the after bitts, passed around the bow mooring line on its path downward to the forward vertical leg clump. When the lowering line was cut off from the bitts, it was thought that the load on the bow mooring line was relieved, and that the clump weight was transferred to the forward vertical leg wire. It later appeared that the vertical leg support had parted sometime previously and that, when the lowering line was burned off, the line and clump went to the bottom. The probability is that at this point, i.e., noon on 7/17/78 the *SQUAW* had lost both vertical leg clumps and was being held in a very slack moor by a possibly damaged bow mooring line.

CHESNAVFACENGCOM representatives, along with three divers, went aboard the submarine and started deploying the depth marker buoy strings. The buoys and line for use in lowering the electronics package were connected to the submarine and the buoys rolled overboard, Figure 36. The submarine was marked to indicate the electronics package target location. Fore and aft freeboards were read and measured as well as possible and radioed to the *MANATI*. The freeboard was estimated 5'-2" forward and 3'-6" aft. The mean draft was considerably less than what had been calculated for the surface condition just prior to venting the tanks. However, since everything else seemed satisfactory the choice was made to proceed with the venting of the tanks. Also the valves on tanks 1, 2, 9, & 10 were opened to the sea.

After the venting of ballast tanks 3, 4, 7, & 8 the *SQUAW* gradually settled down. Air came out of the vent valves with a blast at first but venting slowly came to a halt well before the pressure hull and ballast tanks went under. The valve covers were taken off the 6 inch blow valves on all four tanks and the valves opened, but still no further venting could be detected. Obviously the *SQUAW* was not carrying enough weight to sink her.

The depth measuring floats were recovered, and the buoys and lines for electronics package lowering were recovered and hauled back aboard the [illegible]. An attempt was made to blow the ballast tanks before leaving, but the air hose on board the [illegible] could not reach the [illegible]. A careful measurement was made of the freeboard at the bow, and the waterline at the after end of the ballast tanks was estimated both from aboard the *MANATI* and aboard the [illegible]. The mean draft was 20.76 feet, well short of the 22.00 feet needed to submerge the ballast tanks.

On the return trip to San Diego, a calculation was made of the additional weight that would be required to sink the [illegible] based upon the final draft measurements, with the conclusion that the [illegible] would need 27.19 tons to sink her. The vertical leg clump weight was 12.45 tons each, and the total weight of each leg was 21.47 tons. The indication was that both vertical leg clumps were missing and probably some fittings and wire were lost as well. Since the moor was quite loose there was probably a part of the two mooring lines as well as all of the 360 feet of mooring chain lying on the bottom. This information was passed on to Crowley when the *MANATI* arrived in San Diego. Meanwhile, the *CONTENDER* remained at sea attending the still surfaced [illegible], Figure 37.

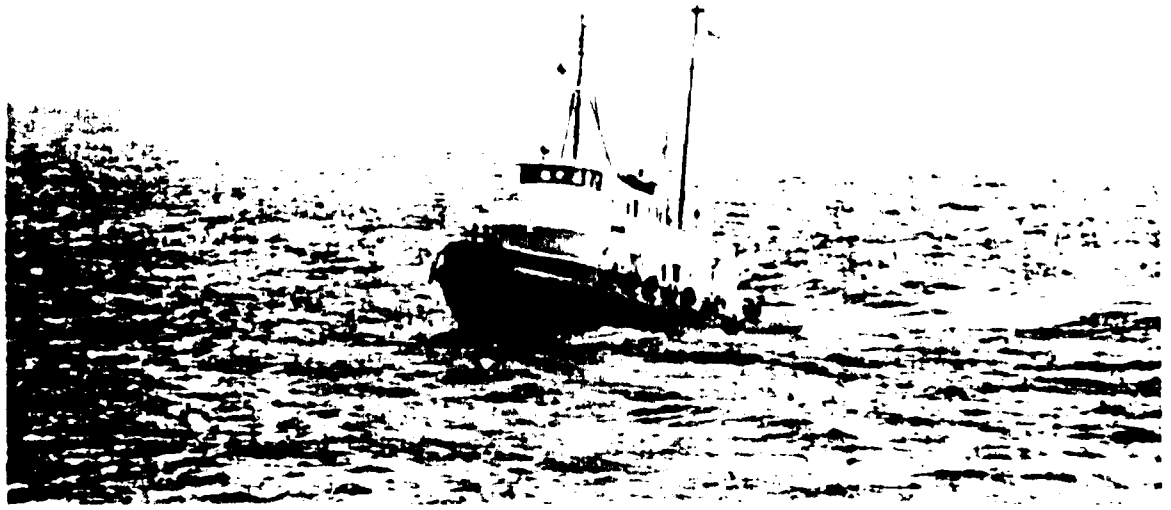


FIGURE 37. THE CONTENDER AT SEA

PART III

ANALYSIS OF DRAFT, TRIM, AND DISPLACEMENT DURING MOORING ACTIVITIES

JANUARY 1978 TRIM AND BUOYANCY TEST

An early step in the evaluation of the *SQUAW* relative to the 1978 mooring project was the conducting of a trim and buoyancy test in January 1978. The test is described and the results are analyzed in pages A-1 through A-25 of Volume II. The intent of the January test was to simulate each buoyancy condition to be encountered during installation, according to a planned scenario. This was accomplished by adding water to trim tanks and weight to the deck. Subsequent to the test, it was decided to analyze the data taken to project various buoyancy configurations not originally contemplated. Therefore, certain data pertinent to the analysis was not available, causing the analysis to be based on information taken from original drawings.

On 24 June 1978 a number of measurements were made of the *SQUAW* configuration which served to clarify some of the questions raised with regard to the earlier tests. These measurements permitted the earlier test data to be reanalyzed and the results obtained thereby give some added insight into the actual condition of *SQUAW* when the mooring operations were underway.

The principal differences were that the height from the bottom of the ballast to the deck line was determined to be 23.00 feet rather than the 22.83 feet used previously, the distance between fore and aft measuring points was 112.92 feet vice the 118.46 feet used previously, and the forward measuring point was 1.42 feet closer to the bow. The *SQUAW* test conditions are related to alphabetical designations on page A-14 of Volume II and the recalculated test results are summarized in Table 1 below:

TABLE 1. RECALCULATION OF JANUARY 1978 TRIM AND BUOYANCY TEST RESULTS

TEST	DRAFT FEET	TRIM INCHES	Δ_{SW} TONS	LCB FROM ⊗	MTI FT. TONS	LCG FROM ⊗	TOTAL BALLAST TONS	TOTAL BALLAST LCG	LIGHT SHIP TONS	LIGHT SHIP LCG
A	15.48	- 1.5	426.5	-2.27	32.3	-2.16	5.13	-34.21	421.37	-1.77
B	16.50	-47.0	481.1	-2.12	30.6	0.87	53.16	16.89	427.94	-1.12
C	17.04	- 8.1	509.0	-2.06	29.2	-1.60	89.97	- 4.58	419.03	-0.96
D	18.27	-35.1	566.3	-1.95	25.1	-0.39	159.82	0.06	406.48	-0.57
E	19.58	-41.1	621.0	-1.92	19.9	-0.60	197.42	- 1.79	423.58	-0.05
F	19.12	+ 0.8	602.5	-1.92	21.9	-1.95	200.07	- 4.45	402.43	-0.71
G	19.38	-24.4	612.7	-1.92	20.8	-1.09	212.38	- 2.32	400.32	-0.44
H	19.49	- 5.6	617.0	-1.92	20.4	-1.73	224.37	- 4.24	392.63	-0.30
I	19.71	-11.9	626.0	-1.92	19.4	-1.55	234.38	- 4.19	391.62	-0.03
J	19.71	- 7.8	626.0	-1.92	19.4	-1.68	234.38	- 4.19	391.62	-0.18
K	21.31	+41.7	681.0	-1.95	9.9	-2.56	281.53	- 5.32	399.47	-0.61

The overall average for these tests indicates a total sea water displacement in the light ship condition of 406.95 tons with the center of gravity located 0.62 feet abaft the midship section as compared with the 400.40 tons at 0.74 feet aft derived on page A-23 of Volume II and as compared with the 409.55 tons used by SUPSALV in deriving their weight estimates for the 1970 submergence of the *SQUAW*. It might be noted that SUPSALV had to add weight to sink the *SQUAW* after which they indicated that the submarine was some 2.96 tons lighter than the figure on which their calculations were based. This would give a revised 1970 light ship weight of 406.59 tons which is very close to the 406.95 tons derived from the January 1978 tests.

SQUAW TRIM AND BUOYANCY PRIOR TO DEPARTURE

On 24 June 1978, when the *SQUAW* was alongside Pier 13 at the U. S. Naval Station in San Diego, another set of measurements was made to get a final estimate of her trim and buoyancy condition before departure to the mooring site. At this time she was outfitted as depicted earlier in Figure 1. Freeboards were measured fore and aft with a rod and tape measure and the draft marks on the hull were read for four conditions:

a. *SQUAW* in the "at sea" condition as readied for departure. Ballast tanks 1, 2, 9, and 10 were filled with fresh water. Ballast tanks 5 and 6 were free flooding to the outside waterline. Ballast tanks 3, 4, 7, and 8 were blown void. Various items of equipment were installed on deck.

b. Same as a. with ballast tanks 7 and 8 vented and flooded with sea water to the outside waterline.

c. Same as b. with ballast tanks 3 and 4 vented and flooded with sea water to the outside waterline.

d. Same as a.

The results of these tests are tabulated below in Table 2. In addition to the above fresh and salt water ballast, the removals included 270 feet of 2-inch chain on deck, anodes, and the battery cannister.

TABLE 2. RESULTS OF 24 JUNE 1978 TRIM AND BUOYANCY TESTS

TEST	DRAFT FROM F.B.	DRAFT MARKS	Δ_{SW} TONS	LCB FROM ℄	MTI FT.TONS	LCG FROM ℄	TOTAL REMOVALS TONS	TOTAL REMOVALS LCG	LIGHT SHIP TONS	LIGHT SHIP LCG
A	17.53	17.21	533.0	-1.94	28.2	-1.13	122.3	-4.30	410.7	-0.19
B	18.46	18.02	574.1	-1.95	25.0	-2.95	162.0	-8.49	412.1	-0.77
C	19.89	19.62	631.4	-1.92	19.4	-1.99	231.7	-4.99	399.7	-0.26
D	17.62	17.18	536.7	-1.96	28.0	-1.23	122.5	-4.31	414.2	-0.32

These results give average values of a light ship displacement of 409.17 tons with the center of gravity located 0.38 feet abaft the midship section.

To summarize the data on the *SQUAW* displacement available at the start of the 1978 mooring attempt we then have the following values of light ship weight:

Data given SUPSALV prior to 1970 mooring	409.55 tons
Corrected SUPSALV data based on 1970 sinking	406.59 tons
Average of CHESNAVFACENGCOM 1/78 test data	406.95 tons
Average of CHESNAVFACENGCOM 6/78 test data	409.17 tons

The relatively small spread of these displacement data provided a reasonable level of confidence in the ability to sink the *SQUAW* with the designed excess weight of the counterweights and to provide adequate reserve buoyancy to maintain the submarine at the prescribed depth. For use in the ensuing discussions and analyses it can be assumed that the light ship condition of the *SQUAW* during the 1978 mooring activities was the average of the last two values, i.e., 408.0 tons centered at 0.50 feet aft of the midship section. With this as a basis, the displacement of the *SQUAW* on departure from the Naval Station for the mooring site, with the added gear and ballast aboard, would have been 530.4 tons with the center located at 1.38 feet abaft the midship section. This would give a mean draft as derived from freeboard measurements of 17.50 feet and a draft as read on the marks of 17.12 feet.

It should be noted that when the *SQUAW* left San Diego, ballast tanks 3, 4, 7, and 8 were blown void when the outside pressure was equivalent to the head above the bottom of the tank at the 17.50 foot draft. When the ship sank deeper in the water, due to the addition of other weights, some water would enter these ballast tanks because of the increase in outside pressure, assuming no leakage. At the same time, in ballast tanks 5 and 6 which were free flooding, the water level would rise or fall to the level of the water outside.

TRIM AND BUOYANCY ESTIMATES DURING OPERATIONS

The first instance where an estimate of weight change was required at the mooring site was on 2 July 1978 when a question arose as to whether the after mooring line had failed and if the *SQUAW* was being held by the north anchor only. At this point the elements installed in the two mooring legs were identical each comprising those listed in Table 3.

TABLE 3. DESIGNED WEIGHTS PER MOORING SYSTEM - SQUAW ON SURFACE

45 FEET OF 2" CHAIN AT TOP	=	0.68 TONS
8570 FEET OF 1 1/4" WIRE	=	8.43 TONS
180 FEET OF 2" CHAIN AT BOTTOM	=	2.74 TONS
PARTIAL WEIGHT OF 6000# CLUMP	=	1.10 TONS

This total vertical force per moor of 12.95 tons would apply when the submarine was on the surface and when the mooring was stretched out to the designed separation of 12000 feet between north and south anchors. When the moor was completely slack, that is when the wire dropped directly to the bottom without any catenary, and without lifting the bottom chain and clump, the total vertical force per moor comprised only 45 feet of chain and 6300 feet of wire for a total of 6.88 tons. If the *SQUAW* were hanging downsea of the moor with just enough horizontal force applied by the sea to lift all of the wire off the bottom, the vertical force on one moor could be as high as 9.11 tons. Thus, if the after mooring line were broken at some point below the submarine it should be possible to calculate, from the draft and trim of the *SQUAW*, whether these weights were acting on the bow and stern and thus whether indeed such a break had occurred.

On 2 July 1978 it was first suspected that the south mooring line had parted and on 3 July the reading on the tensionmeter at the stern of the *SQUAW* was between 1500 and 2000 pounds. This would indicate that not much more than the weight of the chain was hanging from the stern mooring padeye. From the deck of the *MANATI* the bow and stern drafts of the *SQUAW* were estimated to be 18.7 feet and 16.8 feet respectively. This gave a displacement some 7.5 tons greater than upon departure from San Diego and the increased trim by the bow indicated that the center of this added weight was located well forward of the midship section. This was considered to be reasonably good corrobation of the other evidence that indicated the stern mooring was parted a short distance below the *SQUAW*.

The next point at which it appeard necessary to analyze the draft and trim condition of *SQUAW* was on 13 July 1978. By this time the forward and after vertical legs had been installed, the forward mooring line and anchor were in place, and it had been definitely determined that the stern mooring line was parted. However, when the forward vertical leg had been installed the day before, a length of 1 1/4 inch wire was used as a lowering line for the counterweight. This line was cut off at an estimated length of 6300 feet, and an eye was fitted in the end to be hung over one of the after port bitts.

It was thought that the length of lowering line cut was ample so that, when the eye was secured on the bitts, the total weight of the vertical leg would be supported by the forward padeye and the bitts would carry only the weight of the lowering line. However, when this action occurred, the *SQUAW* trimmed excessively by the stern and heeled well over to port. This indicated that considerably more weight than anticipated was hanging on the stern. The drafts of the *SQUAW* were estimated from the *MANATI* for this condition as 15.30 feet forward and 21.66 feet aft. The analysis made at that time indicated that there was a total weight of 10.15 tons on the forward padeye and a weight of 18.75 tons hanging on the after port bitts.

This would indicate that the entire weight of the counterweight was carried on the after bitts and that only the weight of the forward vertical leg, comprising chain and wire, was carried on the forward padeye. However, because of later events in the mooring sequence and the ultimate failure of the system, this particular incident now appears considerably more significant. Thus it would be well to reanalyze the situation in much greater detail than was possible during the operations. For this purpose there are listed in Table 4 the lengths and weights of the vertical leg elements that were supposed to be suspended from the *SQUAW* at this point in time.

TABLE 4. WEIGHTS SUSPENDED FROM SQUAW ON 13 JULY 1978

	AFT VERTICAL LEG		FWD VERTICAL LEG		LOWERING LINE	
	LENGTH'	TONS	LENGTH'	TONS	LENGTH'	TONS
CHAIN AT TOP	270	4.11	270	4.11	6300	6.20
WIRE ROPE	5740	5.65	5740	5.65		
CHAIN AT BOTTOM	25	0.38	25	0.38		
FITTINGS	8	0.50	8	0.50		
ANCHOR ON CLUMP	-	2.33	-	2.33		
CONCRETE CLUMP	6	10.12	6	10.12		
TOTALS	6049	23.09	6049	23.09	6300	6.20

The bow mooring line was estimated to be exerting a vertical force of 8.00 tons at 71.30 feet forward of the midship section at this point. The forward and after vertical leg padeyes are centered at 36 feet forward and 40 feet aft of the midship section respectively and the after port bitt, on which the lowering line eye was hung, is centered at 35.50 feet abaft the midship section.

SQUAW CONDITION PRIOR TO SUBMERGENCE - ASSUMING ALL WEIGHTS ATTACHED

By the time the *SQUAW* was presumed ready to be submerged,the weights aboard the submarine, and the distribution of those weights, had changed from the design conditions cited in the Project Execution Plan, Appendix II. The submarine as to be moored at a depth of 250 feet instead of 300 feet to accommodate the later installation of the electronics package. For this, more chain had been added to the vertical legs and additional chain was required in these legs to compensate for a slight difference in the measured depth at the installation site. Also the two vertical leg counterweights weighed slightly less due to a change in design occasioned by failure to put chain in with the concrete as the clumps were poured; this was corrected by placing 6000 pound anchors atop the clumps.

The substitute stern mooring line also differed from the initial design. From a weight standpoint the only difference was the change from 8570 feet of 1 1/4 inch wire to 8700 feet of 1 inch covered wire. In addition, the 1000 pound electronics package and battery cannister were not on board.

If it is assumed that all weights, with the changes cited above, were aboard or suspended from the *SQUAW* and that the moor was pulled out to the designed separation of anchors and corresponding tension in the mooring legs, the surface weight condition, Table 5, can be derived. The summary of these weights indicates that there would be 22.64 tons of negative buoyancy available to sink the *SQUAW* if all weights were attached and if the mooring were implanted with the designed separation of the north and south anchors.

However, it is known that the mooring was not configured so that the anchors were spread the total distance required. The fact that the *SQUAW* moved some 2500 feet to the south after the forward vertical leg lifting line was cut off the after bitts is indicative that the forward counterweight line must have been drastically altering the catenary of the forward mooring line. When this lowering line was cut, the moor slackened significantly;

TABLE 5. REVISION OF PRE-SUBMERGENCE SURFACE WEIGHTS FROM DESIGN CONDITION

ITEM	TONS	LCG
SUBMARINE - LIGHT SHIP WEIGHT	408.00	- 0.50
BALLAST TANKS 1 & 2, F.W.	46.83	22.35
BALLAST TANKS 3 & 4, S.W.	69.85	6.04
BALLAST TANKS 5 & 6, S.W.	43.65	- 9.67
BALLAST TANKS 7 & 8, S.W.	48.03	-22.35
BALLAST TANKS 9 & 10, F.W.	35.89	-35.60
ANODES	1.79	0
BOW MOORING LINE, VERTICAL FORCE	12.95	71.45
STERN MOORING LINE, VERTICAL FORCE	9.88	-63.17
FORWARD VERTICAL LEG (+ 250' WIRE)	23.34	36.00
AFTER VERTICAL LEG	23.09	-40.00
TOTAL WEIGHT	723.30	- 1.78
TOTAL BUOYANCY	700.66	
NEGATIVE BUOYANCY	22.64	

however, the difference in vertical forces applied to the *SQUAW* is difficult to quantify. To use an extreme, suppose that both the bow and stern mooring lines dropped directly from the submarine to the bottom. The total weight would then be 6.88 tons at the bow and 4.57 tons at the stern. The negative buoyancy would be changed by 11.45 tons to a new total of 11.19 tons, still enough to sink the submarine, even though the fore and aft mooring lines were completely slack.

Another problem was to determine, over this same spread of vertical mooring line forces, what would be the buoyant forces acting on the *SQUAW* in the submerged moored condition. The initial calculations for the designed condition assumed that the entire weight of the two 6000 pound clumps would be transferred to the bottom along with 60 feet of chain in both the fore and aft mooring lines. If this same assumption is made, the vertical force on the mooring lines would reduce the downward pull on the submerging *SQUAW* by a total of 2.92 tons. Also the weight of the two counterweights for a total of 24.90 tons and the 250 feet of lifting wire would be removed for a total reduction of 28.07 tons in the downward force. This would give the *SQUAW* a net positive buoyancy of 5.43 tons if it were still held in a taut moor as initially designed.

If the moor was slack, as in the other case cited for the surface condition, the loss of weight would be the sum of the weights of 750 feet of 1 1/4 inch wire, and the 24.90 tons of counterweights; this weight loss totals

25.64 tons. Under this condition the net positive buoyancy submerged would be 14.45 tons.

From this it can be concluded, regardless of how taut or how slack the moor might have been, the *SQUAW* would have submerged had all weights been attached and it would have had ample buoyancy after the counterweights bottomed out to support it at the designed submergence level. Table 6 summarizes the above discussion as it relates to what conditions would have existed had all weights been attached to the *SQUAW*.

TABLE 6. SURFACED AND SUBMERGED FORCES ON SQUAW - ALL WEIGHTS ATTACHED

	TAUT MOOR	SLACK MOOR
NEGATIVE BUOYANCY, SURFACE CONDITION	22.64 TONS	11.19 TONS
POSITIVE BUOYANCY, SUBMERGED CONDITION	5.43 TONS	14.45 TONS

The above supposed surface conditions just prior to submergence can be translated back to the conditions that should have existed just before the vents on ballast tanks 3, 4, 7, and 8 were opened. This calculation was made on 14 July 1978 when it was known that the south mooring line would be replaced with the one inch wire but it was assumed that both mooring lines would be relatively taut, i.e., that the 180 feet of chain at the bottom of each mooring line would be lifted off the bottom by the catenary forces. These calculations indicated that, when ready for tank venting, the *SQUAW* would have a draft forward of 19.98 feet and a draft aft of 17.94 feet. This was a mean draft of 18.88 feet with a trim down by the head of 24.5 inches.

ACTUAL CONDITIONS BEFORE AND AFTER VENTING TANKS

On 17 July 1978 the drafts of the *SQUAW* were estimated from the *MANATI* as a mean of 18.50 feet with a trim 20 inches down by the stern. This indicated that the weight of the *SQUAW* and the mooring system was between 10 and 22 tons less than it should have been at that point, depending upon whether a taut or a slack moor were assumed. Also the trim was by the stern instead of by the bow as it would have been if all weights were properly distributed. However, despite the obvious loss of weight forward, it was decided to go ahead with the sinking and ballast tanks 3, 4, 7, and 8 were vented.

When the *SQUAW* failed to submerge after the tanks were vented, the draft forward was measured as carefully as possible with the seas that were running.

The recorded bow freeboard was very close to four feet. By viewing through an opening in the deck grating, it appeared that the waterline aft was right at the top of the intersection of ballast tanks 7 and 8 with 9 and 10 which would be a draft of 21.50 feet. From these data it was calculated that the mean draft was 20.76 feet and the displacement was 663.5 tons which was 37.16 tons less than the total buoyancy of the *SQUAW*. However, it was also calculated that continued flooding of ballast tanks 3 through 8 would add another 9.67 tons of weight; therefore, the weight deficit for sinking the *SQUAW* was 27.49 tons.

This weight deficiency may be compared with the weight that had been anticipated for the system as given in Table 5 for a taut moor and as modified in subsequent discussion for a slack moor. The calculations show that, if the moor were taut, as designed, the weight deficiency (when submergence was attempted) was 50.13 tons centered 12.05 feet forward of amidships. If the moor was completely slack, the missing deficiency is calculated to be 38.75 tons centered at 12.99 feet forward of amidships.

One could postulate that, at this point, the entire forward vertical leg and its 250 feet of lifting wire had dropped to the bottom and that, of the after vertical leg, the clump, fittings, and lower chain were missing. The result would be a total loss of weight of 36.67 tons centered at 8.4 feet forward which is very close to the calculated result given above for what was known to be a very slack moor.

PART IV

RIGGING, CABLE HANDLING, AND SHIP HANDLING DURING MOORING OPERATIONS

During the June and July 1978 attempt to moor the *SQUAW* there were a number of problems associated with the rigging system, with the handling of the ship, and with the coordination between the working deck and the bridge. Each element possibly contributed to the ultimate failure of the project and it is felt that these three areas should be discussed in some detail to aid both in analysis of this particular failure and to serve as "lessons learned" for the planning of future ocean construction projects.

RIGGING AND CABLE HANDLING EQUIPMENT

The large majority of operational problems associated with rigging and cable handling were due entirely to the type of equipment installed and provided aboard the *MANATI* for the job. The performance and capability of the rigging crew and their supervision was excellent in the opinion of all observers. Even the manner in which the available equipment was arranged and utilized was ingenious and commendable.

The *MANATI*, if all of its control, propulsion, and maneuvering equipment had been in operating condition, with adequate provision for maintenance and repair, would have been a viable, basic ocean construction platform as far as job performance was concerned. The accommodations, logistics and habitability arrangements for the number of personnel involved in this operation did not meet acceptable standards for ocean construction projects of this magnitude.

All of the preliminary planning for this project called for four 1 1/4 inch wire cables to be used as the basic elements for *SQUAW* mooring. These comprised two 8570 foot lengths and two 5740 foot lengths, each to be supplied on a wooden cable reel; a spare 8570 foot length was also supplied. In addition there was supplied a reel containing 12000 feet of 1 1/8 inch cable and four spare reels of 1 inch covered cable in 2900 foot lengths. All this wire was government furnished equipment.

Except for small line-handling capstans on the after port corners of the *MANATI* fantail, the only powered line handling machine provided by Crowley

was a two-drum Skagit winch installed on the main deck amidships. The beach gear winch and tackle shown in Figure 4-6 of Appendix II were not made available for this operation. In order for the Skagit winch to be utilized, the wire cable had to be unreeled from the cable reels and reeled on to one of the two winch drums.

For handling weights of any significant magnitude, the wire should be level wound on the winch drum under heavy tension. The provision for this heavy tension level winding is shown in Figure 38. Essentially, the wire was fed off the cable reel and around a horizontal sheave welded to the deck near the stern on the centerline. From there the wire passed through a pair of wooden blocks that were bolted to a frame welded to the deck; the bolts could be tightened to increase the friction loading on the wire passing between the blocks. Leading from the fixed tensioning blocks, the wire passed through a similar pair of blocks that were affixed to the bumper of a mobile crane, passing from there to the winch drum. As the wire was wound on to the drum, the crane would be driven back and forth across the deck in an attempt to achieve a tightly wrapped level wind.

Many deficiencies of this tensioning-level wind system existed. It was inadequate as far as tensioning was concerned and any cable wrapped in this manner could not be used to lower a load of any significant magnitude. Furthermore, to achieve any reasonable tightness of the wrap in an axial direction, the mobile crane had to be jockeyed back and forth and sledges were used to drive the wraps together on the winch drum. This process was extremely slow and inefficient.

One way that a wire could be wound on a winch drum under a workable tension was first to wind it on to the reel as described above, then use it to lower a medium sized clump overboard, unwinding the entire drum. Then the drum would be respooled under the combined tension of the clump and cable weight, using the mobile crane to get a level wind. Figure 39 shows that a tight level wound spooling job could be done in this manner but the time consumed in doing so was disproportionate to the results obtained. An alternative tensioning means was to connect the wire to another of the vessels, reel it out, and then reel it back in under tension while towing the other vessel. This technique was used once successfully but proved equally time consuming.

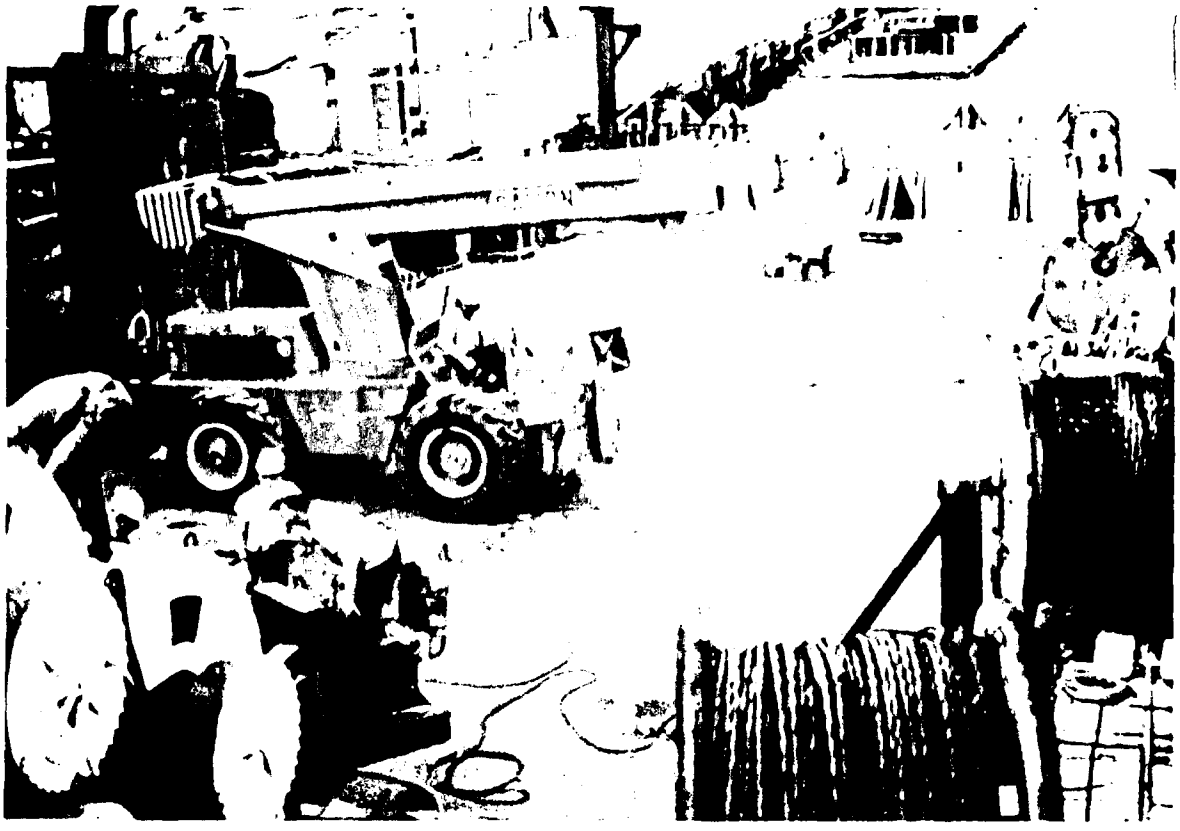


FIGURE 38. TENSIONING AND LEVEL WINDING SYSTEM

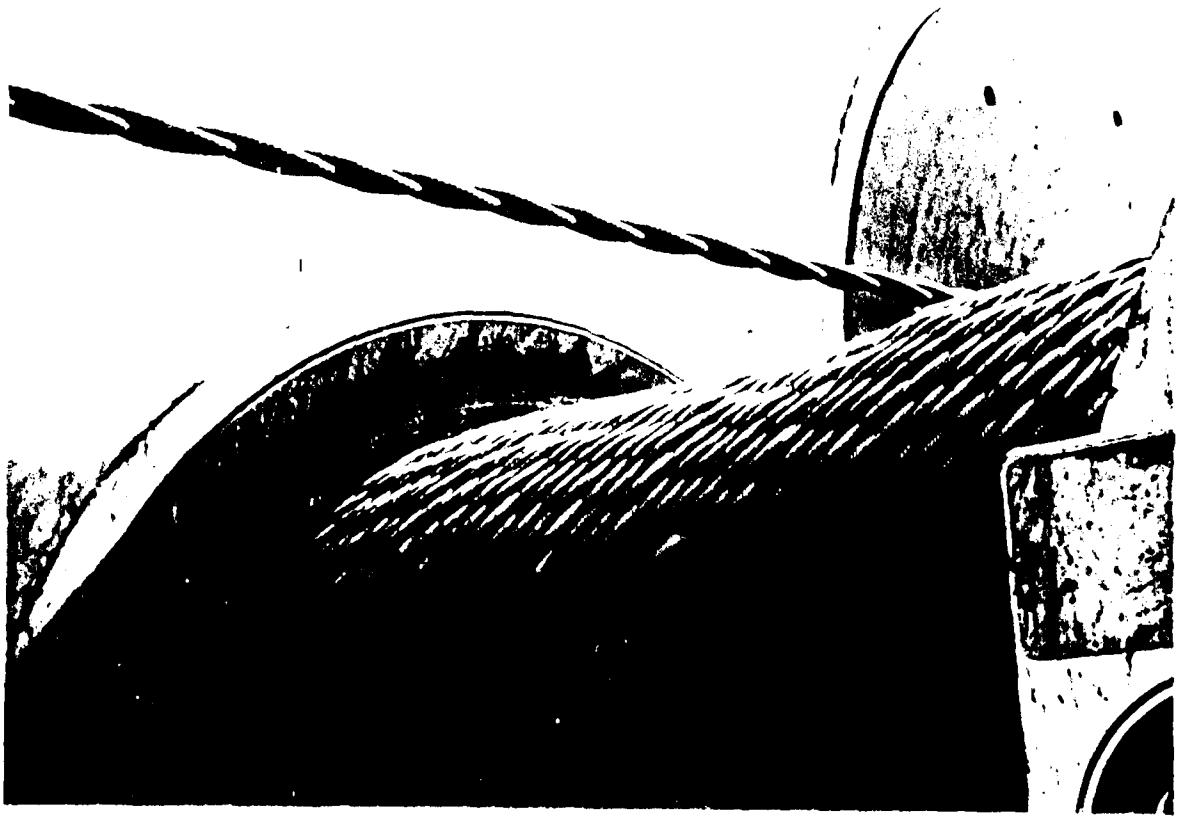


FIGURE 39. TIGHT WRAPS OF CROWN LINE ON LOWER WINCH DRUM

In the mooring system as designed, each mooring leg contained 270 feet of 2 inch chain that had to be connected in and run over the fantail of the *MANATI*. Also each vertical leg eventually contained 205 feet of the same size chain that had to be run overboard. The *MANATI* was not fitted with a stern roller, now practically conventional on ocean construction platforms, nor was there any provision for lowering chain other than the Skagit winch. This had to be done in a hand-over-hand fashion using pelican hooks and a deck-mounted chain stopper. The process was slow and the chain rotated 90° as each link went over the small radius ramp welded to the transom. Furthermore, the working overboard of a length of chain tied up one winch drum which had to be wound with a wire suitable for the chain handling process.

For lowering wire-supported loads over the stern, a fixed vertical sheave was installed on the fantail, Figures 40 and 41. The unit shown is the one that failed when the south anchor was being lowered; its replacement was shown earlier in Figure 24. The use of a fixed sheave of this type meant that every time a heavy load was to be lowered, the connection had to be made with the wire from the winch to the weight, and then the wire had to be lifted over the sheave. This meant that either the weight to be lowered had to be supported outboard over the stern in line with the sheave as the connection was made up, or the mobile crane had to be used to pick up the weight and wire to place it over the sheave; this latter type of operation was of course limited by the 12 ton capacity of the mobile crane.

To carry the heavy weights, or clumps, that were to be part of the total mooring system, the over-the-stern racks shown in Figure 41 were devised. The smaller units on the starboard side were designed to carry the 6000 pound (in water) weights that were a part of the mooring system and the larger units on the port side were designated to carry the large (28000 pounds in water) clumps used for counterweights in the vertical legs. The curved, half-pipe sections over the top of the racks were arranged for a supporting wire rope that could hold the weight of the clump and lower it down to where the weight could be transferred to a wire over the stern sheave. The diagonal support brackets leading to the bottom of the rocks were arranged to be burned off when the weight was transferred from the rack to the cable above. These clump support brackets are of a more recent design that what had been proposed originally and are shown in the Project Execution Plan, Appendix II.

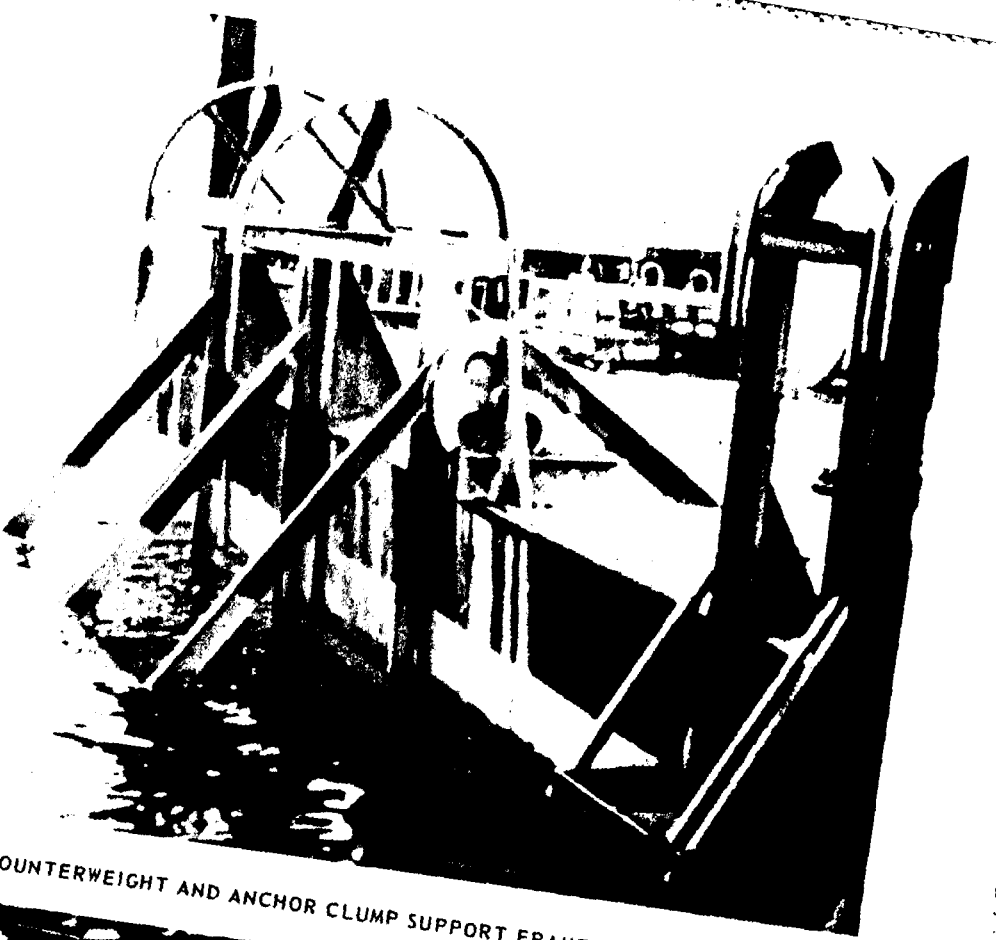


FIGURE 40. COUNTERWEIGHT AND ANCHOR CLUMP SUPPORT FRAMES

FIGURE 41. FIRST VERTICAL SHEAVE FOR RUNNING WIRE OVER STERN

RIGGING AND CABLE HANDLING DURING NORTH ANCHOR DEPLOYMENT

In spite of the long, arduous, and dedicated effort of the rigging crew, the working deck operations were slow, inefficient, and frequently hazardous, primarily due to the equipment that was provided. The first equipment failure that occurred during the mooring operations was the premature triggering of an acoustic release during the lowering of the north mooring anchor.

The acoustic release with strongback was rigged into the mooring from the crown of the LWT anchor on a 15-foot pendant. The end of the 12000 foot crown line was attached to the top of the acoustic release. The mooring load was transferred to the crown line through the acoustic release. At this time the tension on the release was 30,300 pounds (75% of 40 kip rated capacity).

When the load was transferred to the crown wire, the tension caused the wire to dig into the loosely wound wire on the winch. The *cutting in* was caused by bow tension spooling of the wire on the drum. As the crown wire was payed out, the wire would remain trapped by the cutting in until the drum rotated 30 to 90 degrees; then it would pop out due to the tension. Each time this happened, approximately one to three feet of wire was released, allowing the load to drop this distance. After approximately 300 feet of crown wire had been deployed, with this jerking repeated numerous times, the pay load suddenly dropped. The acoustic release was operational until just prior to the load dropping.

The crown line was recovered to see what had failed. The acoustic release was intact but the release had opened. The release mechanism (squib) had not fired. The trigger had opened and caused load release by shearing a cotter pin retainer. Examination of the release showed that the acoustic housing had moved vertically down within the strongback thereby forcing failure of the cotter pin and load release. The keys (Fiberglas cylinders) used to prevent the above had been sheared by the large dynamic loads imposed by the jerking. Internal examination of the electronics revealed damage to battery packs. These packs had been pounded into brackets causing delamination and loss of continuity.

It was concluded that the acoustic release failure was caused by the numerous snap loads imparted by the wire cutting in on the winch drum.

Although the clump/chain/anchor were dropped together the effect on the moor was not considered significant. The anchors were dropped within a few hundred feet of

their planned position. This type of anchor deployment has been used in the past (known as anchor-last deployment). Additionally, the drop was followed by a procedure to determine the holding power of this anchor leg using tug and tensionmeter.

After the anchor drop, the tug took a strain on the *SQUAW* to set the anchor. The tensionmeter indicated a 20000 pound load but was vibrating significantly. It was felt that the anchor was set and holding, however, it was impossible to be sure of the 20000 pound reading due to the vibration.

This failure due to the loose wrapping of the crown line on the winch drum occasioned the use of the *SQUAW* as a towed vehicle to rewrap the crown line under the tension for the deployment of the south anchor.

CABLE HANDLING EFFORTS DURING SOUTH ANCHOR DEPLOYMENT

Despite the fact that the crown line was tightly wrapped on the winch drum prior to the first south anchor deployment there had not been time to upgrade the acoustic release assembly before lowering the south mooring system. Therefore, the acoustic release was not employed in this operation.

This did not, however, avoid other cable handling problems that arose. During the paying out of the crown line from the lower winch drum, shown in Figure 39, the bearings failed in the stern sheave which froze in a fixed position. There was no alternative but to pay out the remainder of the crown line, greasing it to slide over the frozen sheave.

The reason for failure of the sheave could not be ascertained on site except that, on disassembly, the bearings appeared to have been pounded to pieces. One interpretation might be that they had been damaged by the cutting in of the wire and subsequent application of severe impact loads to the sheave during the initial lowering of the north anchor. It may be noted that at this point total weight hanging over the sheave was more than 34000 pounds. When this load was dropped one to three feet and brought up short, the impact loading on the sheave bearings was the resultant of the vertical load downward and the horizontal load in the wire running back to the winch drum. A similar load was being applied torsionally to the winch at maximum radius.

If this interpretation is indeed correct, it would be the second failure attributable to the inadequacy of the cable handling equipment. Furthermore, this failure did cause a significant delay in project execution and forced a revision in the operational planning.

CABLE HANDLING RELATED TO THE AFTER VERTICAL LEG DEPLOYMENT

The next operational use of the cable handling system under load was on the morning of 3 July 1978, after replacement of the stern sheave in the early morning of 2 July. In order to respool an 8570 foot length of 1 1/4 inch wire on the winch drum under tension, a 6000 pound weight was lowered to the bottom, the remaining 2200 feet of wire payed out, and then the respooling under tension began. This was done in preparation for using that particular wire as a lowering line for the after vertical leg counterweight. The 100 kip acoustic release was also installed in-line.

During the lifting of the weight the winch transmission failed. The maximum load during this operation would have been about 20000 pounds, well within the rated capacity of the winch. In both lowering and raising there were no noticeable impact loads applied. However, the winch failure was subservently responsible for a seven day delay in the project execution.

After the winch repair the above operation was repeated on the morning of 11 July 1978 without further incident and by late afternoon the lowering of the after vertical leg counterweight began with the 100 kip acoustic release being used.

The lowering of the after vertical leg was planned to be done slowly with pay-out under power. But, because of some lack of coordination, on deck the winch operator let the anchor to free-fall. The system was falling at a high speed when the operator hit the brakes and stopped the drum rapidly for a few seconds. He then released the brake and allowed the anchor to free-fall again. Shortly thereafter, the load was released. Upon recovery of the acoustic release, it was seen that a cotter pin had been sheared allowing the load to drop. The lowering wire was very tight on the drum but there was still some cutting in during pay-out. The free-fall combined with vibration of the system apparently caused the failure of the acoustic release and premature release of the load.

The free-fall pay-out was unintended, and may have contributed to the problems of the project. As will be discussed in following parts of this report, the relative positions of the *MANATI* and the *SQUAW* when the drop occurred could have permitted the wrapping of the after vertical leg wire around the bow mooring wire. Whether the free-fall was due to acoustic release failure only or whether the winch operation was a contributory factor cannot be determined.

COORDINATION OF SHIP MOVEMENTS WITH MOORING OPERATIONS

There were a number of incidents that occurred during the attempt to moor the *SQUAW* that indicated a lack of coordination between the working deck and the bridge and a lack of understanding on the part of the ship operators as to what was intended. A few such examples are sufficient to illustrate the problems that were created by this lack of coordination and understanding.

On 27 June at 1615, while the acoustic release system was being checked and without notice to the people on deck, the *MANATI* suddenly accelerated to a speed in excess of 10 knots. Acoustic release transducers and the fathometer transducer were in the water and, as described in the daily log of events, one acoustic release transducer was damaged to an extent that it could not be repaired aboard ship. There were a number of other instances with lines over the stern and when people were working on deck when unannounced ship maneuvers caused drastic movements of wire, equipment, and personnel. In one rapid turn the mobile crane, supported on its wheels alone, moved out of control across the deck, fortunately without serious consequences. Such actions constituted a severe safety hazard throughout the operation as well as the equipment damage noted above.

Also mentioned earlier was the apparent 1000 foot movement of the north anchor that occurred during the night of 28 June. In spite of the fact that orders had been left on the bridge to hold a slight pull on the anchor to the southeast all night, there was evidence that the anchor was moved some 1000 feet to the northeast during the night. This would have required a pull in that direction of something on the order of 20000 pounds.

The final operation for the next day, 29 June, was to attach the stern mooring wire to the *SQUAW* and to pay it out to form a large catenary. The *MANATI* was to hang on the moor over night. In the evening, the *SQUAW* was between the *MANATI* and the place where the north anchor was estimated to be. From all later observations this estimate seemed reasonably accurate. At dark the *SQUAW* was well to the southeast of the anchor point and the *MANATI* was well to the southeast of the *SQUAW*. Between the *SQUAW* and the anchor point was 45 feet of chain, 8570 feet of wire rope, and then 180 feet of chain to the anchor clump. Between the *MANATI* and the *SQUAW* was 8570 feet of wire rope plus 45

feet of chain. The water depth was 6300 feet. On the morning of 30 June, the *SQUAW* was just off the starboard beam of the *MANATI* and both vessels were within 2500 feet of the estimated anchor position. The proximity of the vessels and anchor is shown in Figure 42.

The proximity of the *SQUAW* and the *MANATI* created a good deal of concern as to whether the bow and stern mooring lines might have intertwined during the night. However, the contractor personnel insisted that the vessels could not have turned about each other nor could the *SQUAW* have rotated during the night. Yet there was no deck log maintained that would bear out this contention, no headings were recorded, nor was there any assurance that when the *MANATI* got underway in the morning it did not move between the *SQUAW* and the north anchor position.

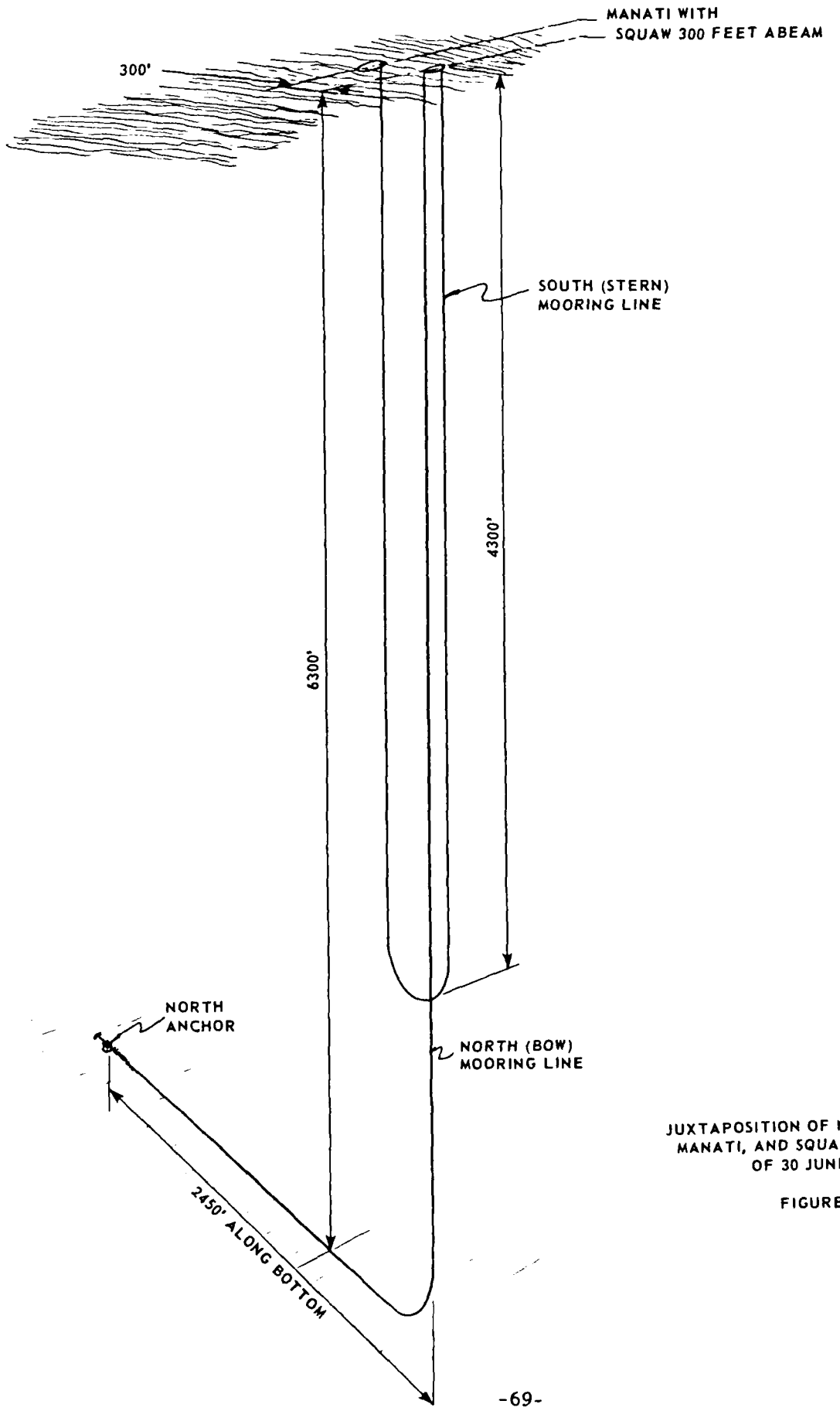
It was certainly not the contractor's intent to permit this potential intertwining of the bow and stern mooring lines but, due to some misunderstanding on the part of the ship operating personnel, it is probable that this was the time when the twisting occurred that ultimately resulted in the parting of the south mooring line.

OPERATION OF THE MANATI IN TOWING SITUATIONS

The *MANATI* is a twin screw vessel, with a total of 2300 horsepower, and rudders abaft each screw. With this arrangement the ship should be capable of developing a dead pull thrust of at least 45000 pounds and a side force at the rudder posts of comparable magnitude. Thus, without the assistance of any other vessel, the *MANATI* had the propulsive and maneuvering capability to cope with any towing situation that could have been encountered during the operations.

Despite these characteristics there were few times during the operation when the *MANATI* towed the *SQUAW* or pulled on a mooring system that she was handled in such a manner as to demonstrate her inherent capabilities. Only when the *CHALLENGER* or the *CONTENDER* was controlling her bow was the *MANATI* able to move a towed system in the desired direction.

The majority of pulling operations could have been handled quite satisfactorily with both engines idling, clutched in ahead, using the rudders on manual control. Instead, the practice throughout was to run primarily on one engine and to attempt to change heading by operating one propeller ahead and the other astern. This latter mode of operation of a towing vessel is not



JUXTAPOSITION OF NORTH ANCHOR, MANATI, AND SQUAW ON MORNING OF 30 JUNE 1978

FIGURE 42

only futile but results in overworking clutches and engines to the point where clutches overheat and engines may break down.

In a towing situation it is immaterial where the towing vessel is heading; it is its direction of translation that is important. When control is attempted by running propellers in opposite directions the net ahead thrust is only the difference between the ahead thrust of one propeller and the astern thrust of the other. The astern force applied by the towline must be exceeded by this propeller thrust difference. The torque on the ship, created by reversing one propeller, is opposed by the moment of the towline pull about the centerpoint between the propellers. Side force, which is essential to translation of the system, is limited to the small component of the thrust difference in the desired direction of travel.

When rudders only were used in attempts to translate the towed system in a given direction, they were invariably turned in the wrong direction to achieve the desired motion. The tendency was always to turn the rudders so as to head the *MANATI* in the desired direction of travel. In a free-running ship, this applies a side force to the stern so that the bow swings in the opposite direction from the stern side force. In a towed system, the entire towed system swings in the direction of the applied side force. Several examples of this movement in a direction opposite to that intended are pointed out in Part V.

During the *SQUAW* mooring operations this inability to maneuver the *MANATI* as required was overcome by using a tug for maneuvering assistance. However, on more than one occasion the tug being so employed could have been serving a useful purpose elsewhere in the operation, such as observing or turning the *SQUAW*. Had the tug been available for such activities, some of the problems encountered might well have been avoided.

PART V

TRACKING OF THE SQUAW AND MANATI DURING MOORING OPERATIONS

NAVIGATIONAL SERVICES, EQUIPMENT, AND TECHNIQUES

At the suggestion of CHESNAVFACENGCOM, Crowley Maritime Corporation had contracted with Navigation Services, Inc. of Ventura, California to provide equipment and personnel aboard the *MANATI* for precise geographical location of the ship throughout the operation. The system furnished included a Motorola Mini-Ranger with a rotating antenna that could pick up signals from two NSI transmitting stations. One, designated ALTA was located on San Clemente Island, some 83 kilometers from the mooring site, and the other designated WOODSON was located near the town of San Clemente on the mainland some 110 kilometers from the mooring site. These stations were so located that almost exactly perpendicular fixes could be obtained from the range-range output information. A Hewlett-Packard computer provided this output that could be plotted directly on charts furnished by NSI.

In addition, there were available computer programs to convert successive position fixes into speed and course made good and distance travelled. From these data it was possible to program a hand calculator to convert to an x-y plot of the positions, both true and relative, to the target mooring position or other vessels.

It was found that the radar on the *MANATI* was sufficiently accurate so that it could be used to get the relative bearing and range of the *SQUAW* or the tug from the *MANATI*. The calculation of x-y coordinates of all ships could therefore be programmed for hand computation and this technique was used extensively during and after each event of the operation. The plots made using this technique form the bases for much of the discussion in the following sections.

PLANTING, SETTING, AND LOCATING THE NORTH MOORING ANCHOR

The first element of the *SQUAW* mooring system implantment operation was to be the installation of the north mooring anchor. The Project Execution Plan, Appendix II, called for this anchor to be located 6000 feet directly north of the specified *SQUAW* moored position. The anchor system was made up during the day of 28 June 1978 and lowering started at 1530. As related earlier, the

acoustic release used in the system triggered prematurely and the anchor fell directly to the bottom. At this time the *MANATI* was within about 300 feet of the target anchor position so it is presumed that the location of the drop point was as close as could possibly be expected.

After the *MANATI* released the moor, plans called for the tug to apply a 16000 pound load on the *SQUAW* and mooring line toward the south in order to set the north anchor. It took a strain on the towline and the tensionmeter in the towline built up to a 20000 pound reading. Although the tensionmeter was vibrating significantly, it was felt that the north anchor was set and holding. After this the *MANATI* took over the *SQUAW* stern mooring chain from the tug and secured it to the crown line in order to carry out an unplanned unspooling and respooling operation which concluded at 2330 on the 28th with the *MANATI* some 7000 feet southwest of the initial north anchor drop point. Adding up the lengths of wire between the anchor and the *SQUAW*, the *SQUAW* and the *MANATI*, and the distance of the Mini-Ranger antenna from the *MANATI* stern, this indicated about the right distance from the anchor. It was therefore concluded that the anchor had not moved and that the *SQUAW* and *MANATI* were hanging downsea of it.

There was a fairly heavy sea running and the forward mooring line, in resisting the downsea force applied to both the *SQUAW* and the *MANATI* angled out from the bow indicating that the loading was significant that night. However, on the morning of 29 June the seas were down and the chain at the bow of the *SQUAW* hung straight down. Yet the Mini-Ranger showed us to be 7000 feet northeast of the anchor drop point and it was reported that during the night we had been pulling *SQUAW* at *MANATI* headings of 060 and 070. Although there was no way of making a rational analysis of just what had happened to the anchor during the night, the best estimate was that it had moved 1000 feet to the northeast of the drop point as shown in Figure 43.

It was obviously highly desirable to know with more certainty where the north anchor was actually located before attempting to set the south anchor. The means proposed for making this determination was for the *MANATI* to move the *SQUAW* to a point southeast of where the north anchor was estimated to be. At that point the mooring line could be pulled out to the southeast with a 16000 pound force as measured on the dynamometer at the stern of the *SQUAW*. With this horizontal force, the distance from the *MANATI* antenna to the anchor point was calculated to be about 7000 feet which would place the north anchor somewhere

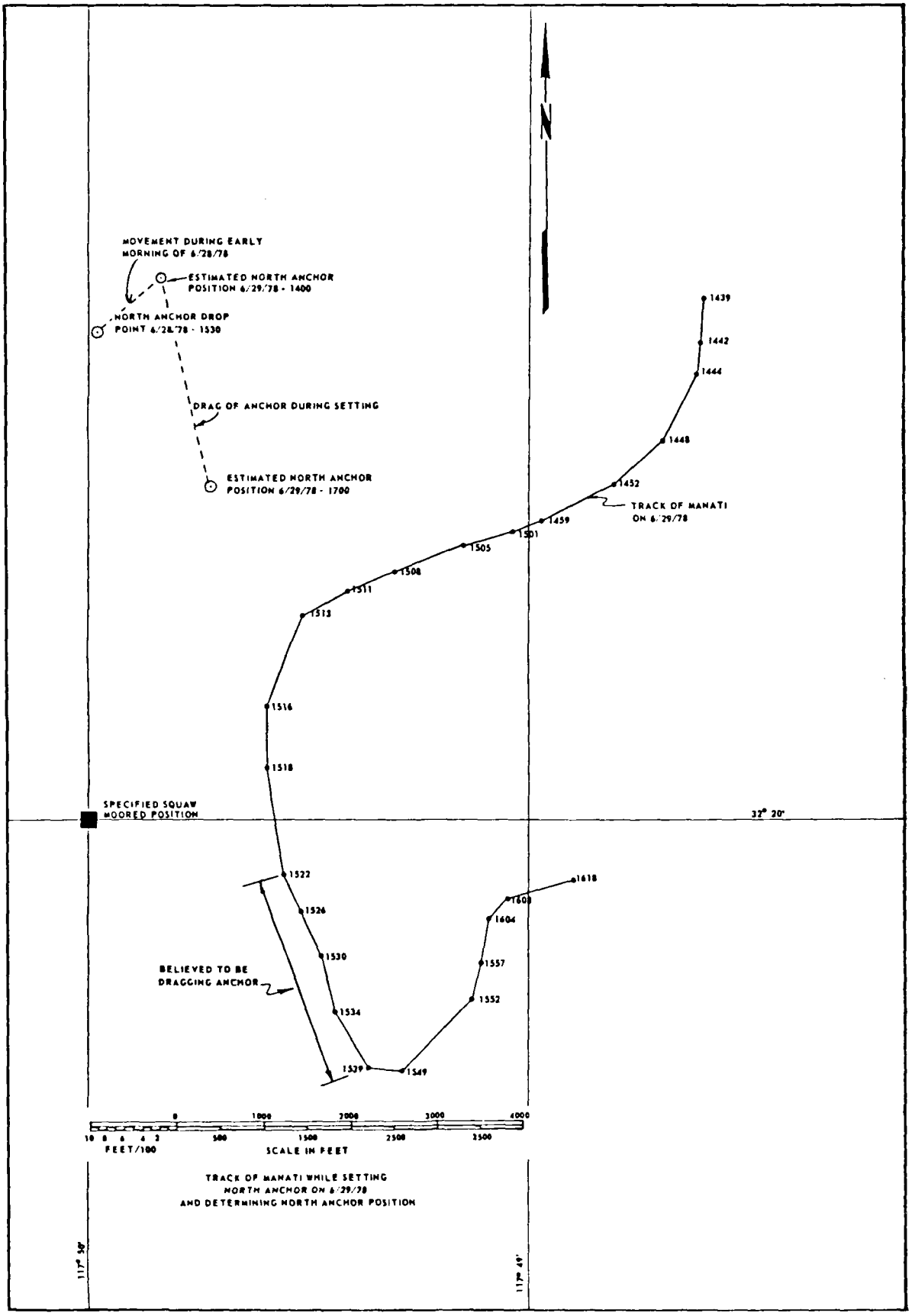


FIGURE 43. TRACK OF THE MANATI ON 29 JUNE 1978

on a 7000 foot radius from the *MANATI* location. After determining the arc from the first point, the *MANATI* would then move to the south of the estimated north anchor point, pull to the south with a 16000 pound force, and then swing a second 7000 foot arc from that point. The intersection of the two would then give the north anchor location with some precision.

The maneuver shown in Figure 43 is the *MANATI* track that resulted from this planned exercise which started at about 1400 on 6/29/78. Then it was discovered that the *MANATI* by itself, with the *SQUAW* in tow, was incapable of executing the necessary maneuver as discussed earlier in Part IV. When the *MANATI* got to the point at 1500 where it should have headed southeast, a left rudder order was given. This caused the ship and tow to translate to the west and the planned 16000 pound pull to the southeast was never applied. During this period, the *CHALLENGER* was attached to the bow of the *MANATI*, mainly in an attempt to control her heading but at 1513 the *CHALLENGER* was ordered to pull the *MANATI* to the south. At this point the speed picked up from 2.11 knots to 3.45 knots until 1522 when the three vessels slowed down abruptly to a speed of 1.46 knots. During the period from 1522 to 1539 it was apparent that the north anchor was being dragged south with a pull of up to 25000 pounds or more being exerted as read on the *SQUAW* tensionmeter.

Thus, because of lack of control over ship maneuvers, and an apparent lack of communication as to the purpose of the exercise, the only outcome of this afternoon's work was to drag the north anchor to a point some 2200 feet southeast of where it was intended to be. Its estimated position at the end of the exercise is shown on Figure 43.

PLANTING, SETTING, AND LOCATING THE FIRST SOUTH MOORING ANCHOR

On the morning of 6/30/78 the *SQUAW* and the *MANATI* were next to each other in close proximity to the new north anchor position. The bow mooring line system connected the *SQUAW* to the anchor and there was 8570 feet of 1 1/4 inch wire hanging between the stern of the *SQUAW* and the stern of the *MANATI*. The remainder of the stern mooring line system including chain, clump, and anchor was made up as the *MANATI* moved slowly in a southeasterly direction. The anchor was lowered overboard at 0930 and about 4000 feet of crown line payed out. At about 1100 the *MANATI* got underway on one screw headed to the southeast as shown in Figure 44.

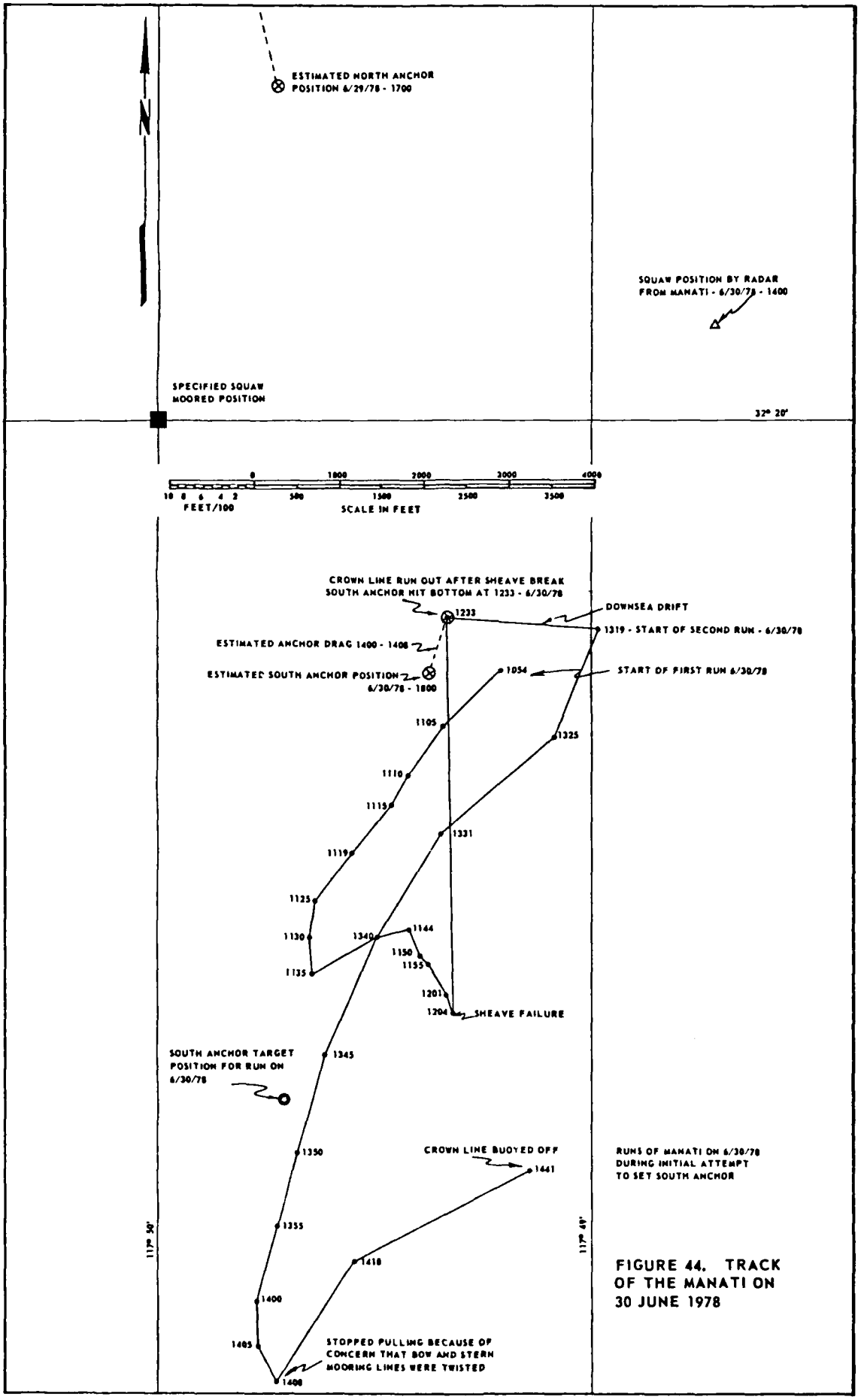


FIGURE 44. TRACK OF THE MANATI ON 30 JUNE 1978

A new south anchor point had been established 12000 feet due south of the recently estimated north anchor position as shown. The plan was to run some 8700 feet south of this point while paying out 11000 feet of crown line. This crown line plus the length of wire in the stern mooring system was calculated to position the anchor on the bottom 6000 feet south of the *SQUAW* with the required tension of 33400 pounds in the north and south mooring lines with the anchors spread 12000 feet apart.

As can be seen in Figure 44 the *MANATI* started to slow perceptibly at 1125 as the *SQUAW* started to move. Up to this point the advantage of tracking the *SQUAW* with radar had not been realized but the submarine was kept under visual observation throughout. When the *SQUAW* started to move, the *MANATI* started to head away from the target position. Right rudder was ordered, and naturally the *MANATI* translated to port. At 1144 the rudder was moved amidships and the other propeller was cut in. For twenty minutes the *MANATI* was making headway to the south but at 1204 the stern sheave failed and the propellers were stopped. The horizontal force in the line due to the catenary immediately pulled the *MANATI* practically due north at an average speed of 1.6 knots for a half hour before the anchor was felt to hit bottom. At that point the remainder of the crown line was payed out and the south anchor position established.

By 1319 the *MANATI* drifted downsea about 1800 feet and a new run to plant the south anchor was initiated. The *SQUAW*, in the meantime, had drifted about 4500 feet east of a point halfway between the two anchor positions, approximately where it is shown at 1400 on Figure 44. The *MANATI* again headed for the south anchor target point, passing it at a speed of about 2.7 knots. This speed dropped to one knot when the *MANATI* was about 3000 feet south of the target point. A radar reading taken on the *SQUAW* showed it to be at a distance of about 13000 feet; at this point there was about 20000 feet of line out between the two vessels and the *SQUAW* was obviously moving, but broadside to the line of tow. Because of concern that the north and south mooring lines might be crossed and twisted, the towing for the day ceased and the crown line was buoyed off. After analyzing the data from the day's activities, a new position for the south anchor was estimated as shown in Figure 44.

On the morning of 1 July another attempt was initiated to pull the south anchor into its final position. Learning from the day before, the

CHALLENGER was tied to the bow of the *MANATI* to permit it to stay on course. At 0557 the *SQUAW* had been located at 1500 feet due east of the midpoint between the estimated north and south anchor positions, as shown in Figure 45B. By the time the first radar reading of the pulling operation was taken, 1113, the weather had picked up some and the *SQUAW* moved another 1500 feet east along the same line which put her just 4600 feet from each of the anchor positions. This placed a high level of confidence on the previous estimates of anchor location.

At about 1100 the *MANATI* picked up the crown buoys within about 1500 feet of where they had been dropped off the day before. The spherical float was taken aboard and pulling on the crown line started at 1113 with the *CHALLENGER* and *MANATI* moving generally to the southwest. Radar ranges and relative bearings were taken on the *SQUAW* and the *MANATI* position and true headings were recorded at about five minute intervals. The track of each ship is plotted in Figures 45A and B; the *MANATI* headings designated by arrows.

It can be noted that, as the *MANATI* moved southwest for the first hour there was essentially no movement of the *SQUAW*. The small position variations are probably due to range or bearing error which are minor. At 1200 the movement began to slow and for the next hour the *MANATI* and *CHALLENGER* seemed to swing on the south anchor with little forward progress. Then both ships increased turns and the south anchor quite obviously broke loose. At 1300 the progress of both ships to the southwest resumed and the *SQUAW* began to track behind them.

The *SQUAW* gradually picked up speed and between 1325 and 1335 she was moving as fast as the *MANATI*. However, at that time the *SQUAW* travel slowed and it was postulated that the north anchor began dragging about due south. Between 1335 and 1400, when towing stopped, it was estimated that the north anchor and the south anchor had both dragged 3400 feet south of their morning positions.

To indicate the level of horizontal force acting on the system catenaries, when towing stopped and the *CHALLENGER* cut loose at 1400, the *MANATI* was pulled astern at an average initial speed of 3.75 knots. Also the total distance between the *SQUAW* and the *MANATI* at this point was 16200 feet when the total length of line between the two ships was 11000 feet of crown line

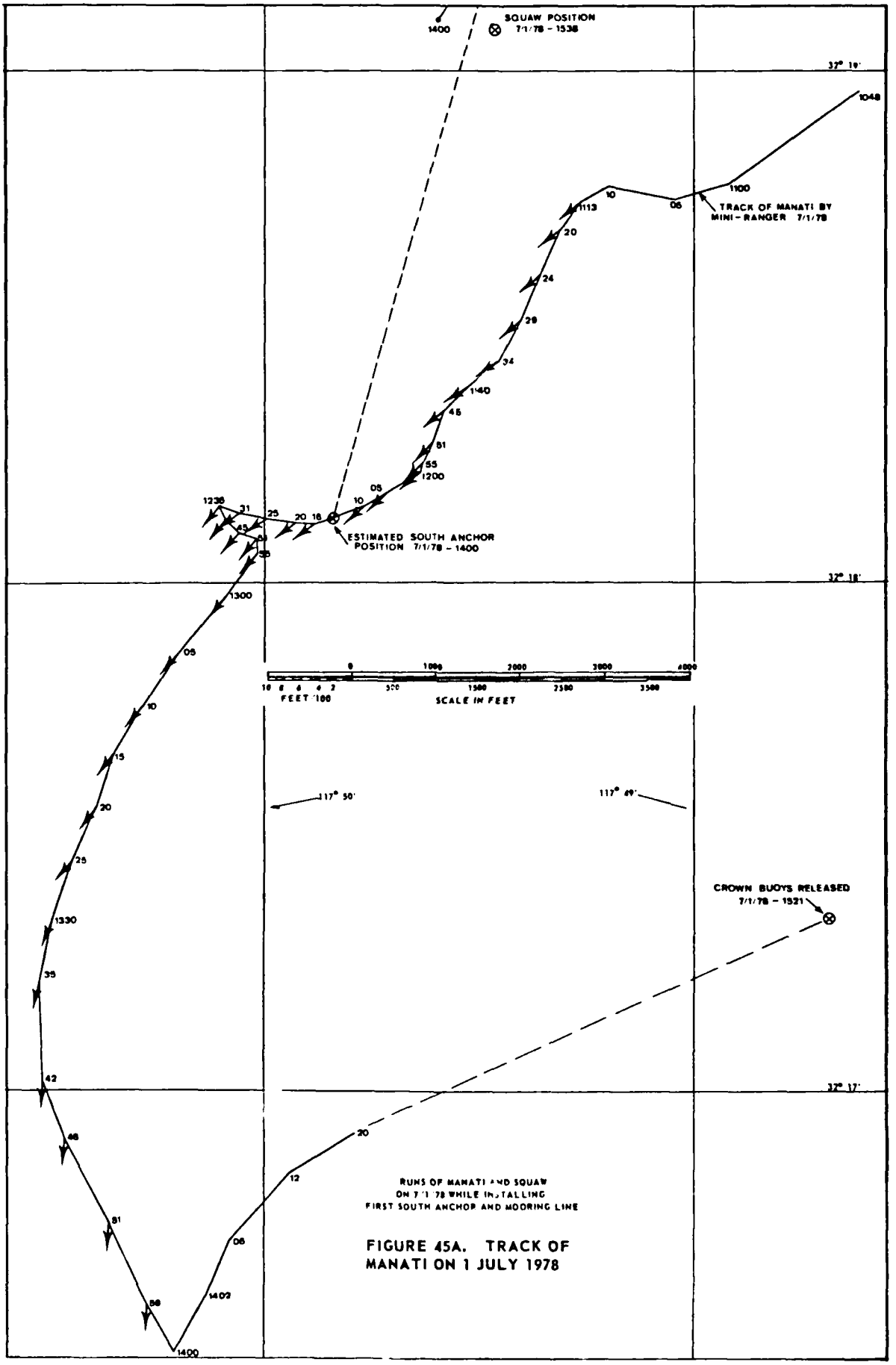


FIGURE 45A. TRACK OF MANATI ON 1 JULY 1978

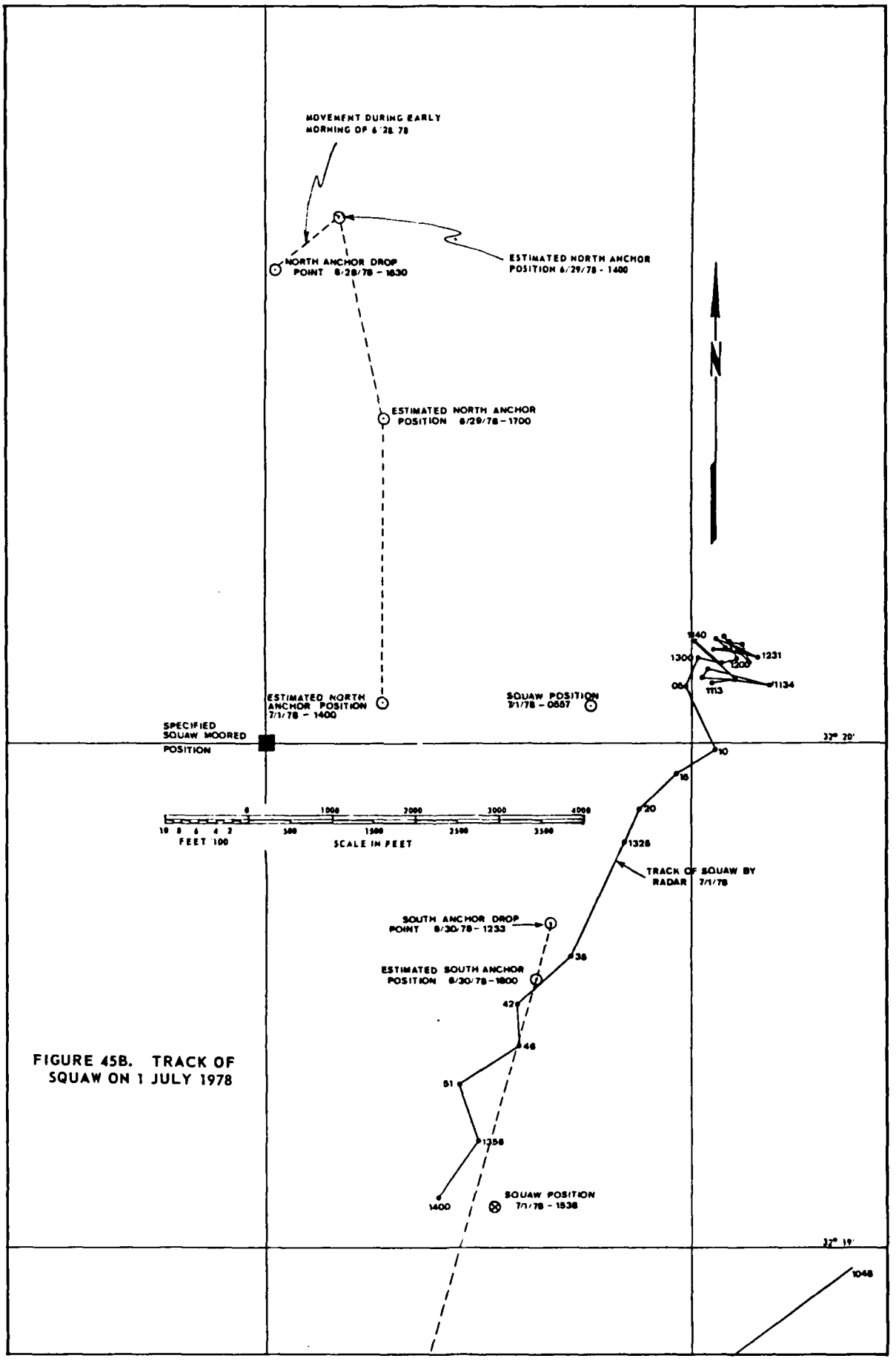


FIGURE 45B. TRACK OF SQUAW ON 1 JULY 1978

plus 8900 feet of mooring wire and chain for a total of 19900 feet. This meant that the south anchor had to be lifted at least 650 feet off the bottom.

With the data available it would be possible to calculate what were the forces acting on the entire system at this point. This may be the subject of a later study since these are the forces that must have been the cause of the later parting of the south mooring line.

When the *MANATI* ceased being pulled to the north of the south anchor it drifted to the northeast and finally cast loose the crown buoys at 1521. It then proceeded north to get a fix on the *SQUAW* which was found to be within a few hundred feet of its last radar position. Also the *SQUAW* was at that time in a true north-south orientation and there is no question but what she was securely moored between the north and south anchors. Furthermore, it was felt that, at this point, the locations of both anchors, and particularly the south anchor, were quite precisely determined as shown in Figures 45A and B.

MOVEMENTS OF THE MANATI DURING INSTALLATION OF AFTER VERTICAL LEG

The next set of movements of the vessels involved in the mooring operations that suggest analysis are those which took place on 11 July 1978 when the after vertical leg was installed. It should be noted that at this time the south mooring line connection was believed to have parted and, although obvious to some participants, this failure was not recognized by the contractor personnel in charge of the operation. Therefore, it was assumed that, during the period when the vertical leg was being made ready for lowering, the *SQUAW* was being held by the mooring lines in a generally north-south orientation. No attention was paid to compass headings during this period and, since the *SQUAW* was alongside during most of the operation, radar fixes were not obtained.

After taking soundings at the proposed *SQUAW* moored location the *MANATI* headed for the *SQUAW* at noon, backed down on the port side of the submarine, and at 1356, as shown in Figure 46, started making up the after vertical leg. During the period between noon and 1356 a 180 foot length of chain had been cut and the end of the 5740 foot vertical wire was shackled to it. When the *MANATI* backed down on the submarine, the 90 feet of chain secured to the after padeye on the bottom of the *SQUAW* was cut loose from it. deck lashings. The end of the 90 feet was then pulled aboard the *MANATI* and secured to the 180 foot chain. The chain was then eased overboard.

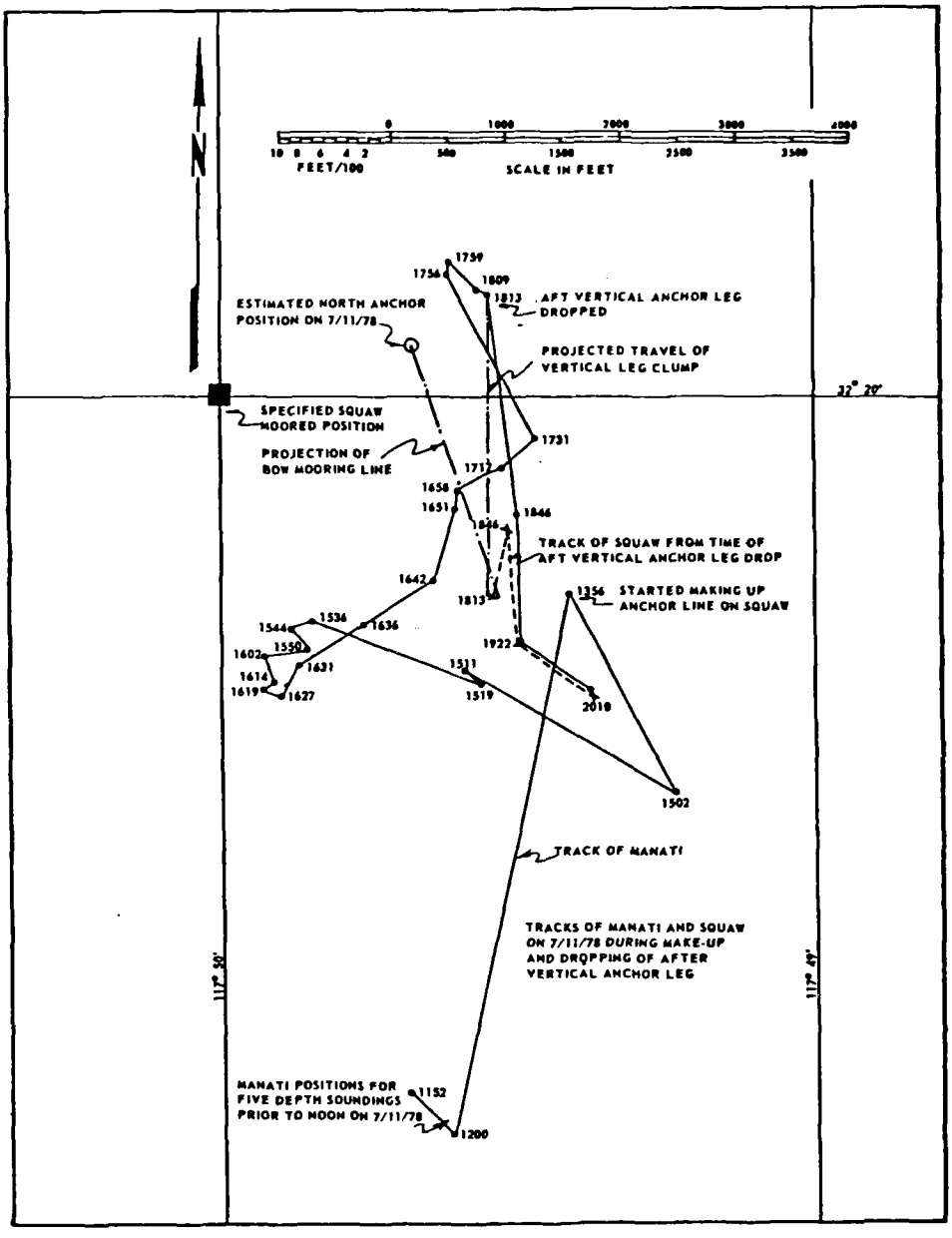


FIGURE 46. TRACKS OF THE MANATI AND SQUAW ON 11 JULY 1978

During all of this operation the *SQUAW* and the *MANATI* could have been no more than 270 feet apart. During this make-up the *MANATI* first moved about 2000 feet southeast over a period of about an hour with the *SQUAW* increasing its southeast distance from the north anchor from 2600 feet to 4700 feet. Then the *MANATI* moved west northwest as it payed out the 5740 feet of vertical leg wire. It can be assumed that this wire was run out between 1502 and 1536 and that the next hour was used in making up the lower section of the after vertical leg including chain, swivel, and clump.

By 1631 the *SQUAW* had again been drawn up to the stern of the *MANATI* as the connecting vertical leg wire dropped down. At this point the stern of the *SQUAW* was being drawn toward the *MANATI* and the bow was held by the north mooring line so the heading of the *SQUAW* was nearly due east; the horizontal distance of the bow from the north anchor was about 3000 feet.

Since it was desired to lower the after vertical leg down from the port side of the *SQUAW*, and because it was intended to get some distance away so the leg would swing down should the acoustic release fail again, the *MANATI* moved in a generally northerly direction and, when she was about 3000 feet north and off the port beam of the *SQUAW*, lowering started. At this point the *SQUAW* was headed approximately east and the *MANATI* headed north.

As related earlier, the acoustic release did fail at 1813 and the vertical leg and clump dropped into position. At the instant of release, the Mini-Ranger position and heading of the *MANATI*and the radar range and bearing of the *SQUAW* were recorded. *MANATI* heading was 335° True, *SQUAW* range was 2700 feet, and relative bearing was 203°. The potential for interference between the bow mooring and the after vertical leg is shown graphically in the projections of the mooring line and the travel of the vertical leg clump given in Figure 46.

MOVEMENTS DURING INSTALLATION OF FORWARD VERTICAL LEG

Just before noon on 12 July 1978, the *MANATI* moved over to the *SQUAW* to shackle up the chain on the forward padeye below the submarine to the chain on the deck of the *MANATI*. At this time the *SQUAW* was headed at 105° true with its stern upsea toward the north anchor about 3000 feet from the estimated anchor position as shown in Figure 47.

When the chains had been connected and overboarded, the *MANATI* got underway to the southeast with the idea of turning the *SQUAW* around so that the forward vertical leg could be lowered from the port side with the *SQUAW* headed north toward the anchor point. However, almost as soon as the pulling started the *MANATI* crossed the bow of the *SQUAW* from port to starboard. This meant that the forward vertical leg chain (which was 270 feet in length) was crossing over the bow mooring chain (45 feet in length). To avoid this, the *MANATI* swung to a northerly course to try to unwrap the vertical leg from the mooring. However, shortly thereafter, at 1316, the *SQUAW* began to rotate counterclockwise and, by 1318, it had turned 180° and was headed upsea toward the north anchor but the *MANATI* was on the starboard side of the *SQUAW* instead of on the port side as intended. While this was going on, as the *MANATI* was paying out the vertical leg wire, it turned to the northwest at 1318, and to the west at 1339, still trying to work its way back around to the port side of the *SQUAW* for the vertical leg counterweight lowering. By 1356 the *MANATI* had passed between the *SQUAW* and the north anchor position but the submarine continued to turn and the *MANATI* could not work its way from the starboard side around to the port side of the *SQUAW* bow.

The bow crossing did not finally occur until 1408. At that time the navigator was requested to attempt to maintain the relative position; this he did until 1444, when the orders were changed. During this period, when position was held relatively well, the swivel, lower chain, and anchor clump were attached and readied for lowering. However, during this period the *SQUAW* also continued to rotate and to head directly for the *MANATI*.

Throughout this exercise the *CONTENDER* had been controlling the bow of the *MANATI*. In a somewhat desperate attempt to get around to the port side of the *SQUAW*, at 1444, the *CONTENDER* was ordered to pull first to the south and then to the southeast but, by 1601 the *MANATI* was directly south of the *SQUAW* and the submarine was headed directly toward her, i.e., a heading of 180°.

This strategy was an obvious failure so the *CONTENDER* was ordered to move the *MANATI* back up to the area southwest of the north anchor point where the *MANATI* had successfully maintained position between 1408 and 1444. At about 1630 the towline to the *CONTENDER* parted so the *MANATI* continued on course while the tug was sent over to the *SQUAW* to turn her around to a

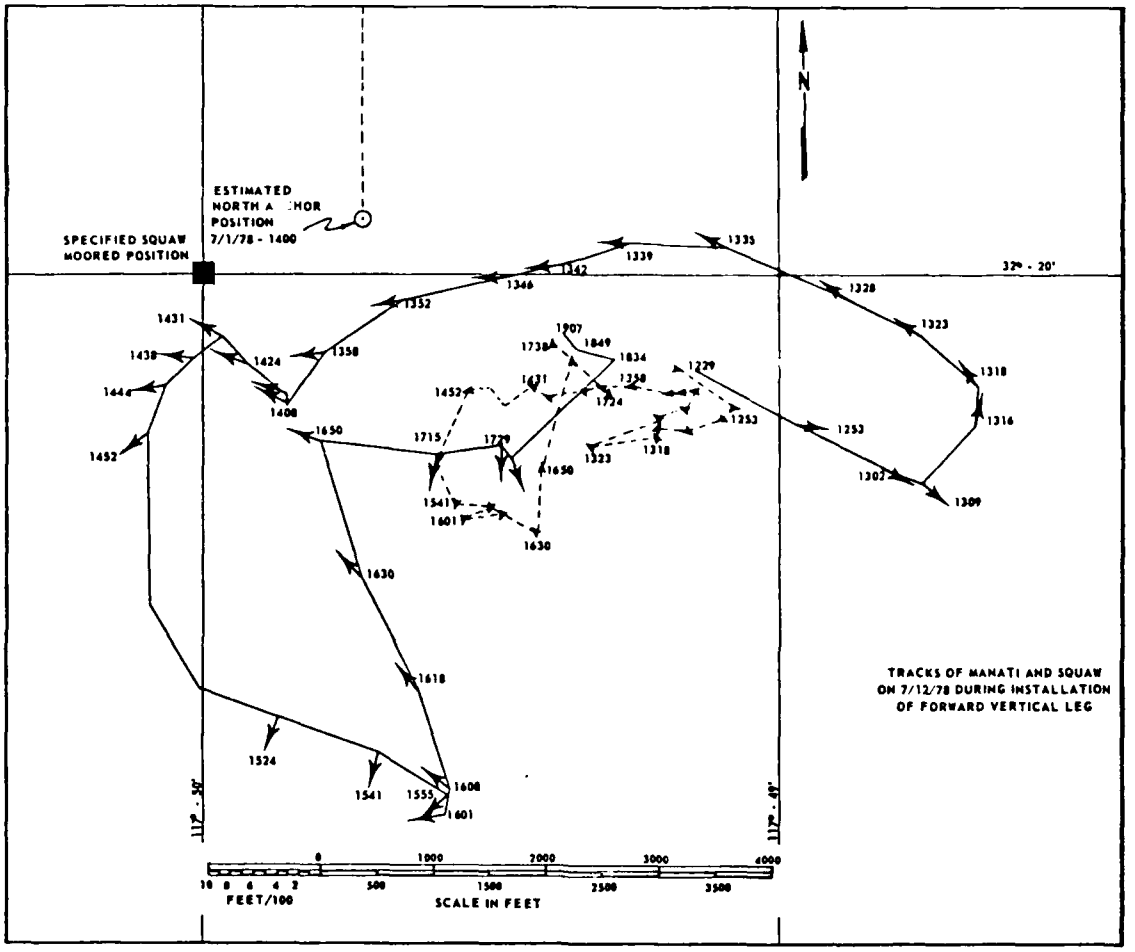


FIGURE 47. TRACKS OF THE MANATI AND SQUAW ON 12 JULY 1978

northerly heading so the forward vertical leg could be lowered on the port side of the submarine. This was done and lowering of the clump started at 1650 when the *MANATI* and *SQUAW* were about 2000 feet apart. As the weight of the lowering clump was gradually transferred to the *SQUAW*, the *MANATI* was pulled toward the submarine until, at 1735, the two vessels were in close proximity, perhaps 500 feet apart; the *SQUAW* was headed north and the *MANATI* headed south. During the next hour the end of the vertical leg clump lowering line was transferred from the *MANATI* to the *SQUAW*. In the interim, the *SQUAW* eased around in a counterclockwise turn while the *MANATI* stayed off her port beam during the attachment of the lowering line to the after port bitts. The *SQUAW* ended up heading about 125° true when the operation was completed at 1907.

It may be noted that during this six hour period, when the bow mooring was attached to the north anchor and the after vertical leg was attached to its padeye below the submarine hull, the *SQUAW* started at a heading of 105°, away from the north anchor point with the bow mooring line below the submarine. It made a fairly rapid counterclockwise turn toward the north anchor and then continued to be pulled counterclockwise around to a 180° heading. The tug then turned it back clockwise to a northerly heading and the counterweight was lowered. The *SQUAW* resumed its clockwise rotation and, for the last 125°, the counterweight was 250 feet off the bottom with the *SQUAW* about 2000 feet from the anchor and the mooring line again running under the submarine.

MOVEMENTS DURING INSTALLATION OF ECOND SOUTH MOORING SYSTEM

The next significant set of maneuvers of the *MANATI*, *CONTENDER*, and *SQUAW* took place on 15 July 1978 when the replacement south anchor system was being installed. At the start of these maneuvers, the *SQUAW* was presumed to be supporting its forward and after vertical legs and the bow mooring line which was connected to the north anchor. As shown in Figure 48, the north anchor was believed to be at the same point as was estimated at 1400 on 1 July 1978.

Between 0600 and 1000 the new one inch wire had been shackled to the stern mooring chain of the *SQUAW* and paralleled with a towrope. During this operation the *SQUAW* again had its bow downsea headed southeast with its stern angled toward the north anchor.

The first part of the operation was a pull intended to make an additional check on the integrity of the bow mooring line. As shown in Figure 48 this basic run was made between 1144 and 1323. During this period the *SQUAW* was close astern of the *MANATI* so its track is not shown. The north mooring line and anchor appeared to be satisfactory so the *MANATI* then began paying out the new stern mooring line as it moved back toward the north anchor. By the time the 8700 feet of mooring line and 180 feet of chain had been payed out, the *MANATI* was 4500 feet to the southwest of the *SQUAW*, and the submarine had been drawn back to its earlier position, 2700 feet east southeast of the estimated north anchor position.

The maneuver to bring the *SQUAW* to its target moored position and to drop the new south anchor on its target begain at 1401. Although the *MANATI* was headed to the southwest it actually moved initially to the northwest and, as can be seen in Figure 48 the *SQUAW*, still heading southeast, moved northwest toward the anchor position. This gave a fairly good indication of where the anchor was at this point.

The *MANATI*, under the heading control of the *CONTENDER*, then eased around to a path that would take it across the target point for the south anchor. The *SQUAW* was gradually tracking along the planned path, but it was moving broadside to the line of tow. At 1617 the *CONTENDER* was released from the bow of the *MANATI* to go up to line up the *SQUAW*. The ensuing track of the *MANATI* in Figure 48 shows graphically the ship handling problem that resulted. The *MANATI* used left rudder to try to continue moving toward the south anchor target and immediately began to translate to starboard as it swung on the end of the towline. The tug was ordered back immediately and attached to the *MANATI* bow at 1730; then the path of the two ships was changed to a southerly direction.

At this point, the *ZODIAC* returned to the *SQUAW* and it was found that she had assumed a north-south orientation, that underwater noises at the bow mooring line connection had ceased, and that there was now about a 15° lead angle with the vertical of the bow mooring chain. As will be discussed in Part VI, this was a probable point of a major failure in the system.

The three vessels continued along the same general course until 1927 when another sudden change took place. It appeared in Figure 48 that the tautness of the connecting lines from the north anchor to the *SQUAW* to the

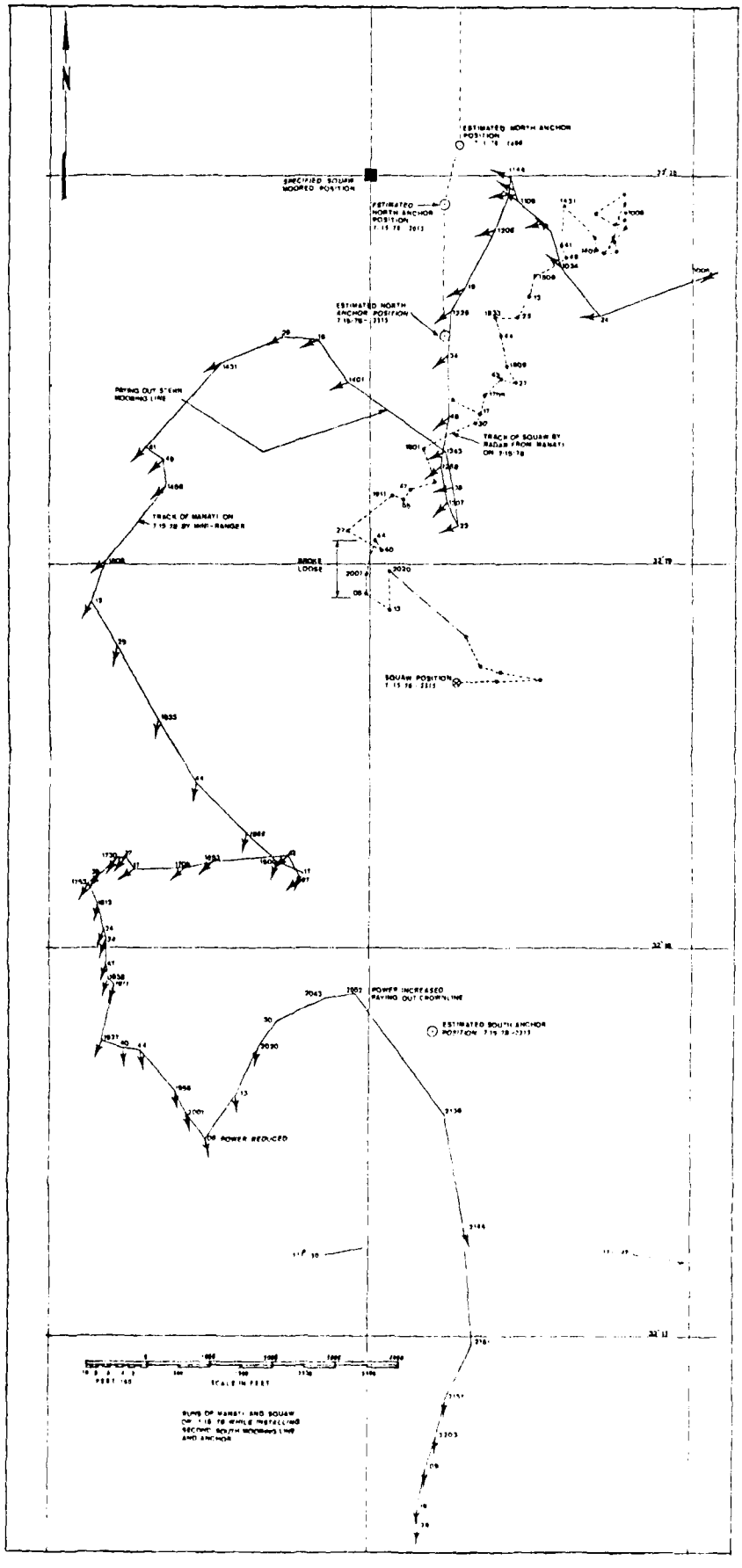
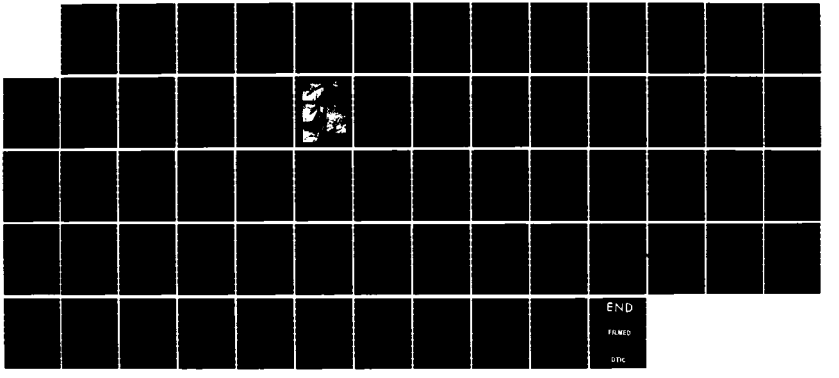
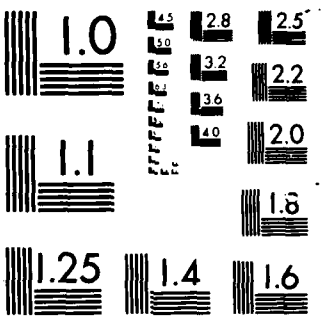


FIGURE 48. TRACKS OF MANATI AND SQUAW ON 15 JULY 1978

AD-A163 347 SQUAW MOORING PROJECT VOLUME 1(U) NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON DC CHESAPEAKE DIV SEP 78 CHES/NAVFAC-FPO-1-78(18)-V-1 2/2

UNCLASSIFIED F/G 13/10 NL





MANATI had reached a maximum level and the entire system swung to the east on a radius that had the north anchor as a center; the *MANATI* moving about 750 feet. Then the north anchor seemed to let go and, by the resulting movement of the *SQUAW*, the anchor was dragged about 1000 feet between 1944 and 2013.

When this movement was first observed, propulsive power on both the *MANATI* and *CONTENDER* was immediately reduced. As a result the *SQUAW* moved back toward the new north anchor position and the *MANATI* moved back toward the *SQUAW*. The new south anchor system was then put overboard and paying out of the crown line started as the *MANATI* negotiated into a position just south of the south anchor target.

At 2144 the run south was inititated when sufficient crown line had been payed out. At 2228 power was cut and the anchor dropped to the bottom. The drop was slightly delayed and so it appeared that the north anchor had been dragged another 2000 feet south. The estimated positions of the north and south anchors and of the moored *SQUAW* are shown in Figure 48. This completed the new south mooring implantment operations.

NORTH AND SOUTH ANCHOR LOCATIONS

During the various movements of the *MANATI* and of the *SQUAW*, the various positions of the north anchor have been shown on the track plots in what are labeled as estimated positions. From the instant of the first precipitous drop at 1530 on 28 June the north anchor was not seen again. Therefore, its true location could not be known with any total degree of certainty.

Yet during the entire period of the operation it was possible through various means to make fairly rational estimates as to where this anchor was located. During intermediate periods, when the *SQUAW* was moored to this anchor alone, the submarine movements and its heading lent further confirmation to the accuracy of the location estimates. This series of locations are depicted in Figure 49.

However, many of these position estimates were made on the assumption that the bow mooring line dropped in a continuous catenary down to the chain, the clump, and the anchor. It now appears that the after vertical leg crossed over the bow mooring line when it was lowered and therefore, the weight of the counterweight significantly altered the bow mooring line catenary. Later, the forward vertical leg and its lowering line also apparently crossed the bow

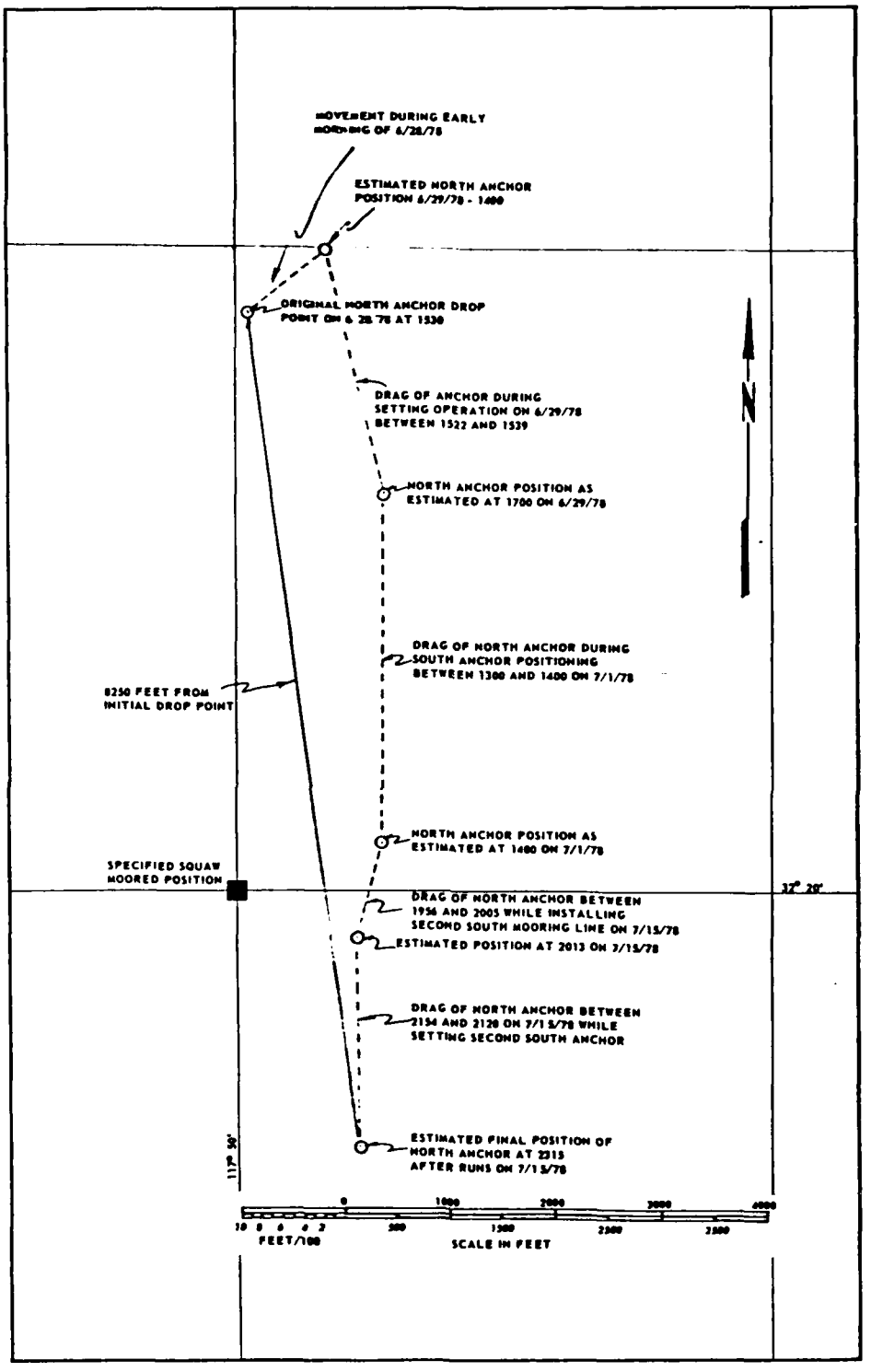


FIGURE 49. VARIOUS MOVEMENTS OF THE NORTH ANCHOR

mooring line with a corresponding effect on its catenary contour. It is therefore probable that on the first southerly pull after the dropping of the after vertical leg the true position of the north anchor was on the order of 1200 feet south of the positions shown in Figure 49.

The position of the first and second south anchors, on the other hand, while not known as precisely originally were subjected to far less movement. Therefore, the positions shown in Figure 50 are probably reasonably accurate.

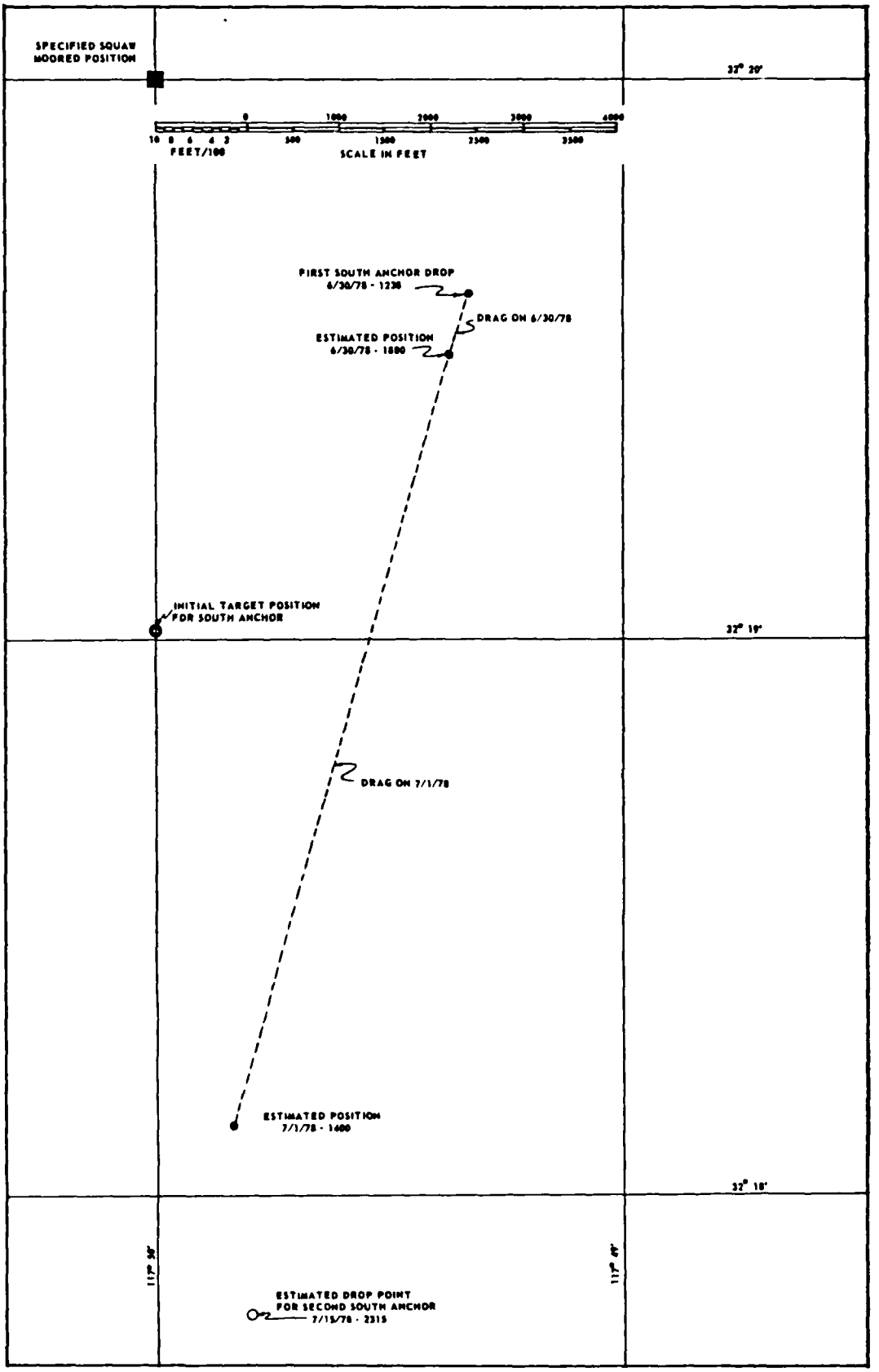


FIGURE 50. POSITIONS OF THE TWO SOUTH ANCHORS

PART VI

SUBSEQUENT EVENTS RELATIVE TO SQUAW

RETRIEVAL AND DISPOSITION OF SQUAW HULL

At the completion of the effort by the Crowley Maritime Corporation to install the *SQUAW* moor, the *SQUAW* submarine hull, then in a two point moor, was left on station at sea. Subsequently, the Navy Public Works Center, San Diego, coordinated efforts to install navigational warning lights aboard the submarine which was lying on the surface with decks awash, about 40 miles southwest of San Diego.

Subsequently, COMSERVRON ONE, under orders from CINCPACFLT, through COMTHIRDFLT, cut the mooring lines, retrieved the *SQUAW* hull, and towed it to Pier 13, U. S. Naval Station, San Diego

Contractual disputes arose between the Government (NAVSEASYSCOM-SUPSALV) and the Crowley Maritime Corporation. Because of these disputes, NAVSEA requested that CHESNAVFACENGCOM conduct a test submergence of the *SQUAW* hull to determine the exact weight necessary to sink the submarine.

At the completion of the submergence test the *SQUAW* submarine hull was released by CHESNAVFACENGCOM and by NAVSEA-SUPSALV. COMTRAPAC regained control of *SQUAW* and, as directed by CINCPACFLT, is in the process of determining what shall be the disposition of the submarine hull. The final determination had not been made when this completion report was being prepared.

Events relative to the *SQUAW* project activities just described with corresponding dates are chronologically detailed as follows:

17 July 1978 - Installation of *SQUAW* moor proved unsuccessful. Crowley Maritime Corporation vessel *MANATI* returns to San Diego.

18 July 1978 - Crowley tug, which had been standing by moored *SQUAW* submarine hull, also returns to San Diego, thus abandoning the *SQUAW*, and creating an unmarked hazard to navigation.

20-30 July 1978 - PWC, San Diego took unilateral action to provide navigation lights aboard *SQUAW*, and to alert Coast Guard, notice to Mariners, etc.

30-31 July 1978 - *U.S.S. ABNAKI ATF-96* retrieves *SQUAW* submarine hull, towing it to Pier 13, U. S. Naval Station, San Diego.

17 August 1978 - NAVSEA requests that CHESNAVFACENGCOM perform test sinking of *SQUAW*.

1 September 1978 - CINCPACFLT officially terminates *SQUAW* Mooring Project.

28 September 1978 - CINCPACFLT requests that COMTRAPAC dispose of *SQUAW* hull after CHESNAVFACENGCOM/NAVSEA submergence tests.

1 October 1978 - CHESNAVFACENGCOM funded by NAVSEA-SUPSALV to perform pierside test submergence of *SQUAW* to determine weight required to sink hull.

24 October 1978 - Test submergence successfully accomplished by CHESNAVFACENGCOM with the support of PWC, alongside Pier 13, U. S. Naval Station, San Diego.

31 October 1978 - CHESNAVFACENGCOM notifies NAVSEA of successful submergence test and that the test completes the CHESNAVFACENGCOM use of the *SQUAW* submarine hull.

22 November 1978 - NAVSEASYSCOM releases *SQUAW* submarine hull to COMTRAPAC for final disposition in accordance with CINCPACFLT direction.

In addition to conducting the submergence tests on the *SQUAW* hull, another investigation was launched into the reasons for the system failure. The Civil Engineering Laboratory was asked to conduct a study of the probability of snap loads in the mooring legs. The results of this study are given in the following section.

PROBABILITY OF SNAP LOADS IN THE SQUAW MOORING'S VERTICAL LEGS

This study was conducted by Francis C. Liu of the Civil Engineering Laboratory in response to a request from the Chesapeake Division Naval Facilities Engineering Command FPO-1 in connection with the attempted deployment of the *SQUAW* mooring in July 1978. The *SQUAW* mooring consists of a buoyant submerged submarine hull, bow and stern mooring lines and bow and stern vertical cable legs with weights. The *SQUAW* mooring was to be deployed in 6,000 feet of water with the hull suspended at a depth of 300 feet. One of the vertical legs parted at the hull during an eight day period between 11 July and 17 July 1978. During this period the *SQUAW* hull was moored at the surface by the bow and stern mooring lines; both vertical legs with weights were suspended below the hull.

The objective of this study was to obtain predictions of the line tensions in the vertical legs during the stated eight day period. Surface wave-induced hull motions can cause motions of the vertical leg clumps relative to the hull of sufficient magnitude to create slack in the cable with subsequent high snap loads. Since snap loads can result in cable failures, the probability of snap loading is of great importance in determining the possible failure modes of the vertical leg in the *SQUAW* mooring.

A complete computer simulation of the *SQUAW* mooring system requires a computer model which can accurately simulate the interactions between the four mooring lines and the hull motion. Such a model is not available. In conventional ship motion programs, mooring line interaction is crudely simulated by a spring. Extensive analytical work is needed just to determine the equivalent spring constant for a catenary mooring. However, the motion of the *SQUAW* hull is only weakly influenced by the tension variations in the mooring lines. The bow and stern mooring lines can be considered as a couple of soft springs which introduce no significant tension change as a result of the hull motion. On the other hand, the vertical legs have a much higher dynamic tension response due to the potential out of phase motion of the suspended clumps. Even these high dynamic tensions are relatively small compared with the hydrostatic uplift force produced by the surface waves. Therefore, the dynamics of the vertical legs can be analyzed using a decoupled two-stage method. First, the hull motion can be computed at the vertical leg support with the wave height as the only time dependent input variable; secondly, the vertical line dynamic tension can be computed based on the vertical displacement at the support. This two-stage computation was used in this report.

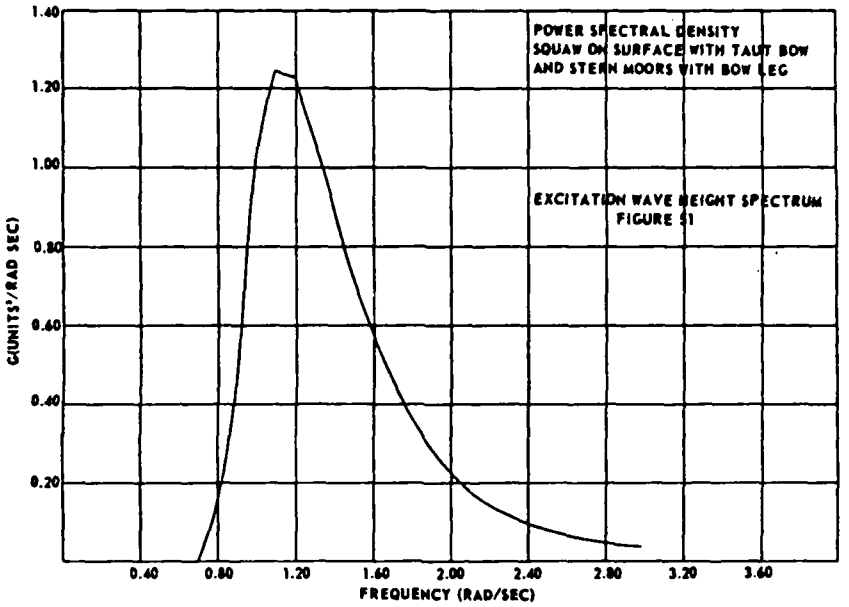
The vertical displacement of the mooring leg support at the *SQUAW* hull was computed using CEL computer program RELMO. Program RELMO requires input on the wave spectra and the hull characteristics. Since the wave height was not recorded during the time period of interest, design wave spectra corresponding to significant wave heights of 2, 4, and 6 feet were used to compute the line tension and snap load probability. Sea direction was also varied. Although the *SQUAW* mooring was deployed in the North-South direction, rotation of the *SQUAW* away from this orientation was observed. Also, the sea changed direction with time. Thus, computations were repeated for head, beam, and quarter seas.

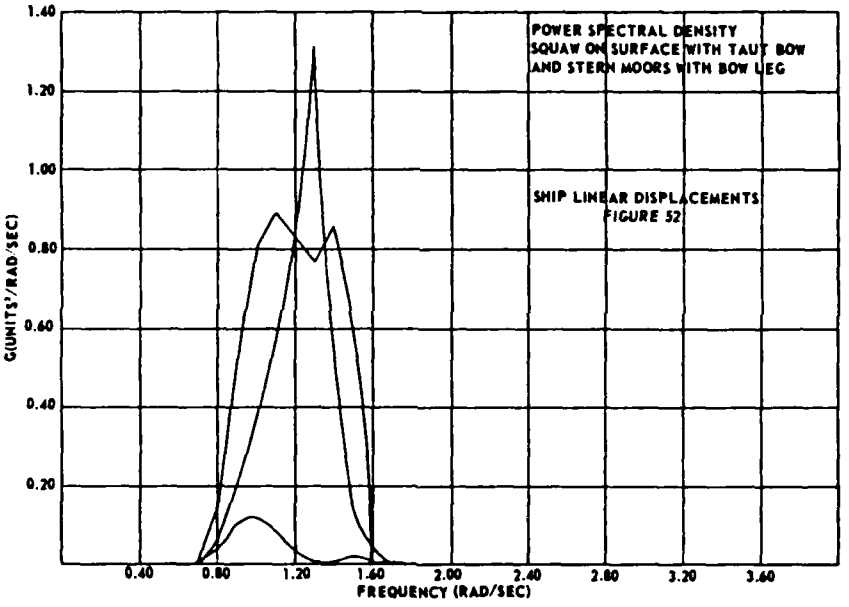
The ship-shaped hull was approximated by three circular cylinders and a parallelepiped. The bow and stern sections were simulated by 14 ft diameter x 34 ft long circular cylinders. The center section was simulated by a 20 ft diameter x 58 ft long circular cylinder and a 11.6 ft wide x 3.5 ft deep x 58 ft long parallelepiped directly under the circular cylinder. Due to the lack of information on ship motion characteristics for the particular draft, trim, and external load distribution, only approximate values were used. The trim and loading condion of the *SQUAW* hull of Figure 4-11, page 39 of Appendix II was used. The computer hull motion differs little from that of Figure 4-12, Appendix II.

The second step involves computing the tension in the vertical line. The vertical displacement power density spectral function at the vertical leg support point was used as input excitation to compute the line tension probability distribution function by the CEL computer program CABANA. The program has a one dimensional frequency domain solution for a given excitation, the probability of a range of line tensions are computed. Snap loads are considered likely when the dynamic tension peak exceeds the static tension at the top end. The probability of snap loads occurring is defined as the probability of exceeding a tension level that equals the total static weight of the suspension system (Cable plus Clump weight).

The results of the computer analyses are presented in Table 7. The main variables were wave direction (or heading) and the significant wave height with a total of nine combinations. The third column is the probability of snap loads occurring. The 4th and 5th columns are the dynamic tension (peak variation about static) and total tension (sum of dynamic and static) at 90% probability of exceedence, respectively. Columns 6 and 7 are the same tensions at a probability of exceedence of 1%. That is, if the clump were allowed to hang under the hull for a period of 8 days the likelihood of the tension exceeding the stated value is one out of one hundred.

One important input is the wave height spectral density. Figure 51 is the wave spectrum generated by Program RELMO for a four foot significant wave height. Figures 52 and 53 are the resultant six degree of freedom motion spectra generated by RELMO for the bow support point of the vertical leg with the *SQUAW* hull at a 135 1/4 heading to sea which is represented by the spectrum of Figure 51.


POWER SPECTRAL DENSITY
SQUAW ON SURFACE WITH TAUT BOW
AND STERN MOORS WITH BOW LEG
EXCITATION WAVE HEIGHT SPECTRUM
FIGURE 51
G(UNITS²/RAD SEC)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.40
0.80
1.20
1.60
2.00
2.40
2.80
3.20
3.60
FREQUENCY (RAD/SEC)


POWER SPECTRAL DENSITY
SQUAW ON SURFACE WITH TAUT BOW
AND STERN MOORS WITH BOW LEG
SHIP LINEAR DISPLACEMENTS
FIGURE 52
G(UNITS²/RAD/SEC)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.40
0.80
1.20
1.60
2.00
2.40
2.80
3.20
3.60
FREQUENCY (RAD/SEC)

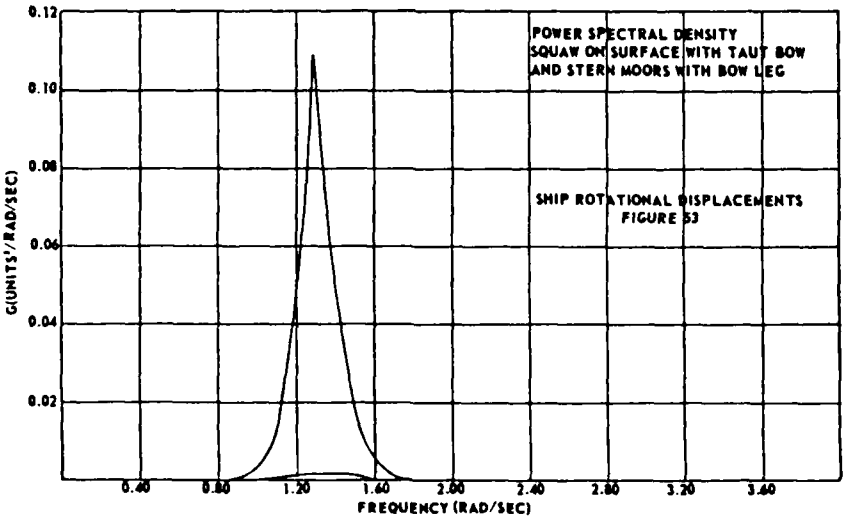

POWER SPECTRAL DENSITY
SQUAW ON SURFACE WITH TAUT BOW
AND STERN MOORS WITH BOW LEG
SHIP ROTATIONAL DISPLACEMENTS
FIGURE 53
G(UNITS²/RAD/SEC)
0.12
0.10
0.08
0.06
0.04
0.02
0.40
0.80
1.20
1.60
2.00
2.40
2.80
3.20
3.60
FREQUENCY (RAD/SEC)

Table 7. SQUAW Tension Summary

(Time period = 8 days.)

Heading (deg)	Wave Height (ft)	Probability of Snap Load	Dynamic Tension* 90% Probability (lb)	Total Tension 90% (lb)	Dynamic* Tension 1% (lb)	Total Tension 1% (lb)
90	6	0.9437	120,000	161,100	140,000	181,100
90	4	0.8972	92,000	135,100	110,000	151,100
90	2	0.0	27,000	68,100	32,000	73,100
180	6	0.9673	73,000	114,100	87,000	128,100
180	4	0.9367	56,000	97,100	67,000	108,100
180	2	0.0	15,000	56,100	17,000	58,100
135	6	0.9376	92,000	133,100	110,000	151,100
135	4	0.9396	70,000	111,100	83,000	124,100
135	2	0.0	19,000	60,100	22,000	63,100

*Obtained from probability distribution function.

Table 8. Vertical Displacement Spectrum at Equal Frequency Interval of 0.1 rad/sec

INPUT MOTION SPECTRUM

29

0. 0. 0. 0. 0. .80000E-05 .75700E-02 .13800E+00
.49290E+00 .80850E+00 .89720E+00 .83190E+00 .76890E+00 .86890E+00 .57700E+00 .32400E-01
.10000E-02 .11000E-03 .68000E-04 .53000E-04 .22000E-04 .10000E-05 .50000E-05 .18000E-04
.23000E-04 .16000E-04 .10000E-04 .80000E-05 .10000E-05

DURATION OF SUSPENSION= 11520.00MINUTES

SIGNIFICANT FREQUENCY= 1.140

DYNAMIC RESPONSES OF A 5700 FT LONG 1.250 IN DIAMETER
1-1/8 WIRE ROPE WITH ALOUNTEN WT LOAD

LD-WT	SUB LD-WT	CM	CD	LD-A	UD	DENS-W	FREQ	FREQ-F	FREQ-IN
83000.0	28000.0	1.0	1.0	36.0		64.0	.1	3.0	.1
WT/FT		DIAMETER		X-AREA		DENS-LINE		ELASTIC-INDEX	
2.540	2.200	1.250		.725		508.567		13300000.000	
DEPTH	TOP ANG	TENSION		CROS VEL	DRAG COEF				
6000.000	0.000	0.000		0.000	0.000				

FREQUENCY HZ	FREQUENCY RAD/SEC	D-AMPLIF RATIO	FORCE/AC LB/FT/SEC2	FORCE/D LB/FT	PT-MXFOR FT
.159E-01	.100E+00	0.	0.	0.	.570E+04
.31AE-01	.200E+00	0.	0.	0.	.570E+04
.477E-01	.300E+00	0.	0.	0.	.570E+04
.637E-01	.400E+00	0.	0.	0.	.570E+04
.796E-01	.500E+00	.127E+01	.281E+04	.702E+03	.570E+04
.955E-01	.600E+00	.185E+01	.516E+04	.114E+04	.570E+04
.111E+00	.700E+00	.172E+01	.372E+04	.182E+04	.570E+04
.127E+00	.800E+00	.220E+01	.489E+04	.300E+04	.570E+04
.143E+00	.900E+00	.319E+01	.669E+04	.542E+04	.570E+04
.159E+00	.100E+01	.627E+01	.130E+05	.130E+05	.570E+04
.175E+00	.110E+01	.149E+02	.302E+05	.365E+05	.561E+04
.191F+00	.120E+01	.505E+01	.101E+05	.145E+05	.522E+04
.207E+00	.130E+01	.254E+01	.494E+04	.842E+04	.487E+04
.223E+00	.140E+01	.164E+01	.321E+04	.629E+04	.455E+04
.239E+00	.150E+01	.121E+01	.232E+04	.522E+04	.428E+04
.255E+00	.160E+01	.984E+00	.179E+04	.459E+04	.403E+04
.271E+00	.170E+01	.772E+00	.144E+04	.417E+04	.381E+04
.286E+00	.180E+01	.647E+00	.120E+04	.389E+04	.361E+04
.302E+00	.190E+01	.555E+00	.102E+04	.368E+04	.343E+04
.31AE+00	.200E+01	.484F+00	.883E+03	.355E+04	.327E+04
.334E+00	.210E+01	.42AE+00	.775E+03	.342E+04	.312E+04
.350E+00	.220F+01	.383E+00	.689E+03	.334E+04	.299E+04
.366E+00	.230E+01	.346E+00	.619E+03	.32AE+04	.286E+04
.382E+00	.240E+01	.315E+00	.561E+03	.323E+04	.275E+04
.39AE+00	.250E+01	.289E+00	.513E+03	.321E+04	.264E+04
.414E+00	.260E+01	.267E+00	.472E+03	.319E+04	.254E+04
.430E+00	.270E+01	.249E+00	.437E+03	.31AE+04	.245E+04
.446E+00	.280E+01	.232E+00	.407E+03	.319E+04	.237E+04
.462E+00	.290E+01	.218E+00	.380E+03	.320E+04	.229E+04

Table 9. Table of Response Operator

STANDARD DEVIATION= 13922. LB
TIME PERIOD= ***** MIN
LIFT LINE=1-1/8 WIRE 5700.00 FT LONG

PROBABILITY

PROBABILITY	DYN FORCE(LB)	0.0 0.2 0.4 0.6 0.8 1.0
.98E+00	.78E+05	. X
.90E+00	.77E+05	. X
.80E+00	.72E+05	. X
.70E+00	.73E+05	. X
.60E+00	.74E+05	. X
.50E+00	.74E+05	. X
.40E+00	.74E+05	. X
.32E+00	.74E+05	. X
.25E+00	.74E+05	. X
.19E+00	.77E+05	. X
.14E+00	.77E+05	. X
.11E+00	.78E+05	. X
.80E-01	.78E+05	. X
.59E-01	.80E+05	. X
.43E-01	.80E+05	. X
.32E-01	.81E+05	. X
.23E-01	.82E+05	. X
.17E-01	.83E+05	. X
.12E-01	.83E+05	. X
.87E-02	.84E+05	X

PROBABILITY OF HIGH SNAPPING LOADING IS .9396

Figure 54. Probability distribution function for tension

TIME(S)	TENSION(LB)
0.	-.954E+04
.10AE+01	-.966E+04
.21?E+01	.377E+04
.32SE+01	.102E+05
.43SE+01	.780E+04
.542E+01	-.107E+05
.650E+01	-.176E+05
.75AE+01	-.197E+04
.867E+01	.180E+05
.97SE+01	.160E+05
.10AE+02	-.569E+04
.119E+02	-.201E+05
.13AE+02	-.118E+05
.141E+02	.906E+04
.152E+02	.207E+05
.162E+02	.103E+05
.173E+02	-.131E+05
.184E+02	-.245E+05
.19SE+02	-.586E+04
.206E+02	.208E+05
.217E+02	.235E+05
.227E+02	-.109E+05
.23AE+02	-.312E+05
.249E+02	-.726E+04
.260E+02	.261E+05
.271E+02	.212E+05
.282E+02	-.122E+05
.292E+02	-.258E+05
.303E+02	-.382E+04
.314E+02	.190E+05
.325E+02	.147E+05
.336E+02	-.547E+04
.347E+02	-.158E+05
.357E+02	-.719E+04
.368E+02	.700E+04
.379E+02	.128E+05
.390E+02	.286E+04
.401E+02	-.988E+04
.412E+02	-.969E+04
.422E+02	.281E+04
.433E+02	.100E+05
.444E+02	.396E+04
.455E+02	-.581E+04
.466E+02	-.610E+04
.477E+02	.672E+03
.487E+02	.814E+04
.498E+02	.203E+04
.509E+02	-.934E+02
.520E+02	-.236E+04
.531E+02	-.354E+04
.542E+02	-.141E+03
.552E+02	.525E+04
.563E+02	.364E+04
.574E+02	-.487E+04
.585E+02	-.707E+04
.596E+02	.287E+04
.607E+02	.970E+04

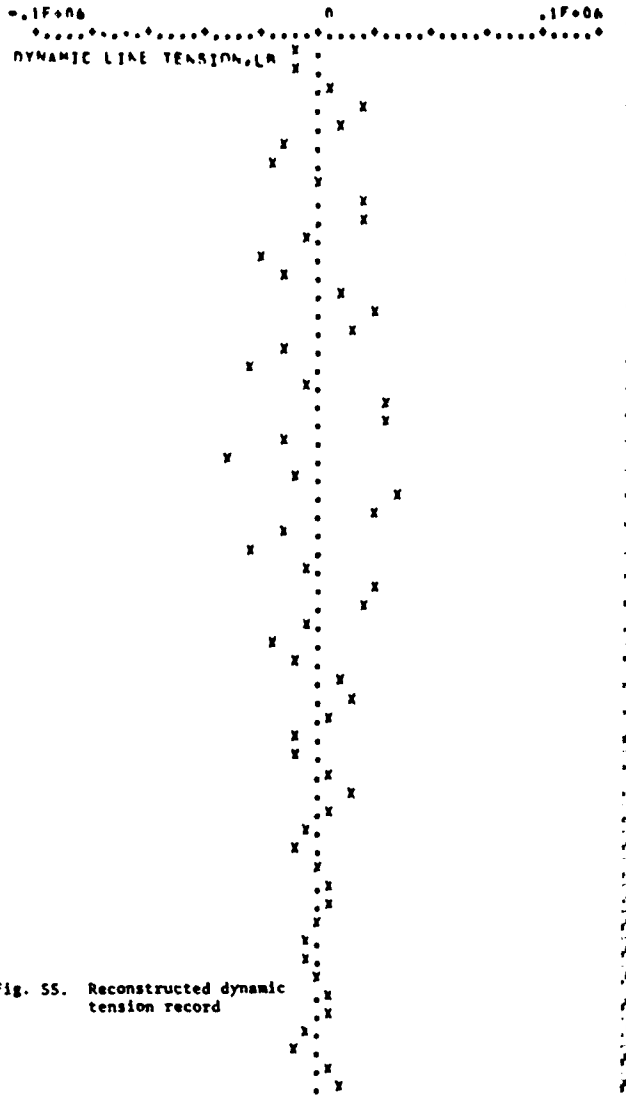


Fig. 55. Reconstructed dynamic tension record

Tables 8 and 9 and Figures 54 and 55 are copies of outputs from computer program CABANA. Table 8 lists the ordinates of the vertical displacement spectrum of the support point in equal frequency increments of 0.1 rad/sec. The duration of vertical leg suspension is 11,520 minutes or 8 days. The significant frequency is the frequency having the highest concentration of energy. Table 9 lists the transfer function in column 5. The line tension spectrum is obtained by multiplying the input displacement spectrum by the transfer function. The variance of the line tension was then used to compute the probability distribution function shown in Figure 54. Notice that a note was printed under the graph to indicate that the probability of snap load is 0.9396. Dynamic tensions in Table 7 were obtained from Figure 54. Figure 55 is a one-minute time history of line tension generated by CABANA to show the expected tension variation for a short duration.

The results of the computer analysis have shown that snap loads are likely for significant wave heights of 4 feet or higher. Snap loads appear to be more likely in beam seas than head seas. It is expected that the probability of snap loads will reduce as the time period of exposure is shortened.

Table 10 is a daily wave forecast taken between 11 July 1978 through 17 July 1978. The minimum sea was 2 feet and the minimum swell was 3 feet. By superimposing the sea on the swell the wave height may be considered to be 4 feet. The energy containing periods correspond well with the wave frequency used in the foregoing analysis. In conclusion, a snap load probability of nearly one was predicted for 4 foot waves and a minimum 4 foot waves were forecast during the time period and area of interest. Thus the occurrence of snap loads in one of the vertical legs during the period in question was very likely.

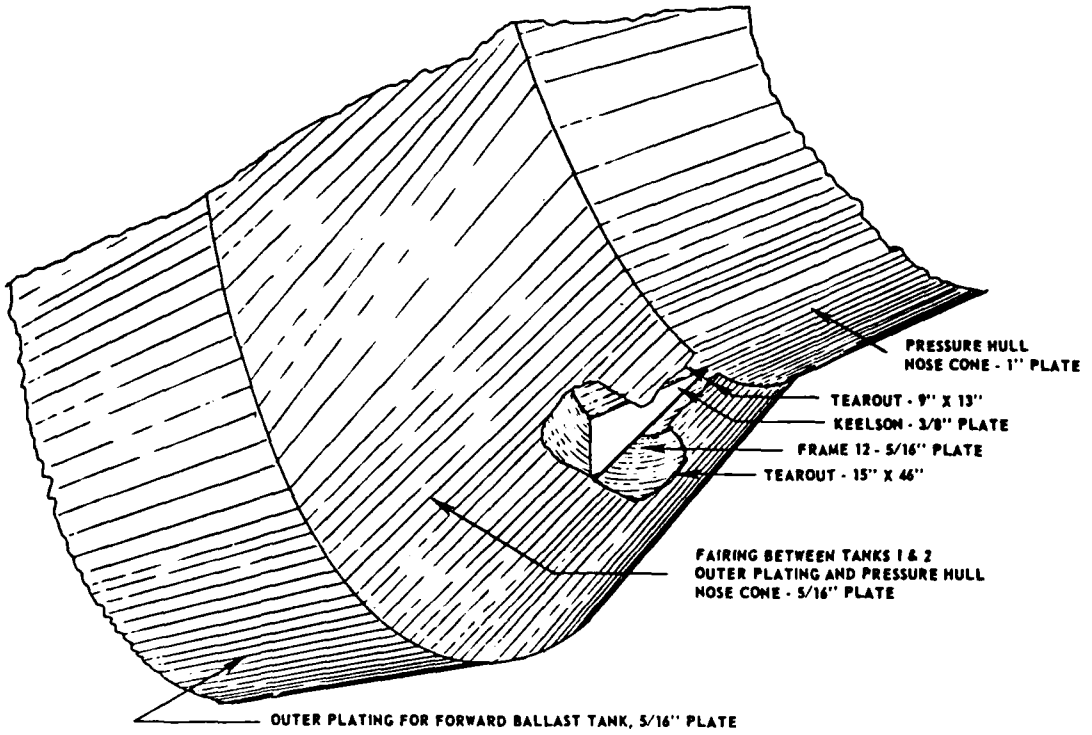
Table 10. San Diego Wave Forecast in Operation Area

Date	Direction (deg)	Period (sec)	Height (ft)	Remark
Jul 11	320	4	2	sea
	320	8	3.5	swell
	180	12	3	secondary s.
Jul 12	320	4	2	sea
	180	10	5	swell
	320	8	4	secondary s.
Jul 13	320	4	2.5	sea
	320	8	4.5	swell
	200	12	4	secondary s.
Jul 14	310	3	2	sea
	310	8	3	swell
	200	12	2.5	secondary s.
Jul 17	330	3	2	sea
	330	8	3	swell
	180	10	1	secondary s.

LOSS OF THE FORWARD VERTICAL LEG

During the period 30 to 31 July 1978, when the *ATF-96* retrieved the *SQUAW* from its moored position, three of the four chains shackled to the hull were disconnected using explosives. The fourth chain, that of the forward vertical leg, was already disconnected from the hull due to the fact that the connecting padeye and its doubler plate had been torn out of the hull and approximately 800 square inches of the fairing plate to which the doubler was welded was also ripped out.

The torn area of plating, as best it can be reconstructed from the reports of divers and photographs at the scene, is illustrated in Figure 56.



LOOKING UP AT THE AREA WHERE THE FORWARD VERTICAL LEG PADEYE AND ITS DOUBLER PLATE WERE TORN FROM THE HULL

FIGURE 56

The actual shape of the doubler plate is not known but it is obvious that the applied load exceeded the shear strength of the 5/16 inch plate. Since the keelson fairing between Frame 12 and the fairing piece remained intact, it is fairly obvious that the two were not welded together.

In spite of the suggestion in the previous section that this separation might have been due to snap loads imparted by seaway motions it is doubtful that this was the reason for the failure. A more likely reason for the loss of the forward vertical leg is postulated below.

As described earlier, and as depicted in Figure 47, it is almost certain that, when the forward vertical leg was lowered it was actually wrapped clockwise, looking downward, around the bow mooring line. Furthermore, it is believed that the lowering line, connected to the forward counterweight, then followed a path upward and counterclockwise to the point where it was secured to the after port mooring bitts of the *SQUAW*. Thus, both the vertical leg and its lowering line were wrapped around the bow mooring line. The mooring line generally followed a catenary from the bow chock to its anchor, and since the forward leg was hanging directly down from a point on the bottom 35 feet aft of the bow, thus the chains at the tops of the vertical leg and the mooring line probably crossed a short distance below the hull whereas the crossing of the lowering line and the bow mooring line was probably far below the surface.

The fact that the *SQUAW* continued to hang downsea from its bow mooring line, indicating that the line was tending aft, and the fact that during later pulling on the stern, the *SQUAW* remained broadside to the direction of motion are fairly good indications of lines twisted below. This was the condition on 15 July when the second stern mooring line and anchor were implanted.

Furthermore, the account of this operation in Appendix I, page 34 gives some insight into the loss of the forward vertical leg padeye. As a pull was applied to the after mooring line, and the forward mooring line was stretched out, divers aboard the *SQUAW* remarked on the rubbing noises and vibrations of the bow mooring chain and the fact that this chain was hanging straight down without any lead angle. Between 1630 and 1730 on 15 July the vibration stopped, the mooring chain took on a 15° lead angle, and the towing speed in the direction of tow increased markedly.

It is quite within reason to assume that this is the point where the forward vertical leg padeye broke loose from the hull. The combined forces of vertical leg weight and vertical and horizontal pull on the bow mooring line wrapped around the vertical leg could well have exceeded 80000 pounds under these conditions. This would have been sufficient to cause the observed damage

since the padeye doubler plate was not welded to any structural members but was entirely supported by 5/16" plate.

During this same period on 15 July the *SQUAW* changed trim to some extent indicating that some of the load of the forward vertical leg could have transferred to the after port bitts to which the lifting line was secured. This provides some further corroboration that this was the period when the separation took place.

WEIGHT OF THE SQUAW DURING MOORING ATTEMPT

After the forward vertical leg padeye tore loose from the hull, the forward counterweight was still connected to the after port bitts of the *SQUAW*. It may either have been suspended from the hull or resting on the bottom after separation occurred since the lowering line had been cut with what was believed to be sufficient length to reach the bottom. However, as noted above, this lowering line very probably made a turn over the bow mooring line. When the bow mooring line was under tension, the combined action of the two lines could still lift the counterweight off the bottom.

Regardless of whether the counterweight was at that time on the bottom or suspended, it definitely went to the bottom, along with the lowering line, when this latter line was cut from the after port bitts on 17 July 1978. At that point the *SQUAW* was lacking more than 50000 pounds of the weight designed for its sinking. However, the contractor still contended that there was a distinct possibility that the forward vertical leg had not been lost and that the failure of the *SQUAW* to submerge was due to insufficient weights being provided in the design. As a first step, the following examination was conducted comparing the current mooring attempt with the previous mooring of the *SQUAW*.

A comparative analysis between the 1970 mooring by SUPSALV and the 1978 attempt by CHESNAVFACENGCOM in regard to weight applied during mooring has been made. There are no known significant weight changes to the *SQUAW* subsequent to the 1970 mooring. Examination of the shipyard (Long Beach) worksheet shows only replacement of deteriorated deck plating and superstructure. Therefore, comparison of weights applied during mooring provide the best information as to whether the *SQUAW* would have submerged according to the CHESNAVFACENGCOM design.

The CHESNAVFACENGCOM design (if installed according to specifications) yields 35,376 pounds greater weight when compared to the 1970 SUPSALV mooring

system (see Table 11). This weight difference is reduced by approximately 6,880 pounds because of the substituted 1 inch wire rope installed as the stern mooring leg. Considering this substitution, the weight difference becomes 28,496 pounds (CHESNAVFACENGCOM design heavier).

Navigation records indicate that the mooring was not fully tensioned by the contractor at the time of the attempt to submerge the *SQUAW*. In a worst case analysis assuming both mooring legs were slack (hanging vertically), the 1978 mooring system was still heavier than the 1970 mooring by 2,910 pounds. Therefore, even in the worst case with all lines vertical, the *SQUAW* should have submerged if all lines were attached.

TABLE 11: COMPARISON - 1970 MOORING VS 1978 DESIGN

1970 MOORING * (SUPSALV)		1978 MOORING (CHESNAV-FACENGCOM)
23,500 LBS	VERTICAL COMPONENT BOW MOORING LEG	29,050 LBS
23,500 LBS	VERTICAL COMPONENT AFT MOORING LEG	29,050 LBS
11,420 LBS	COUNTERWEIGHT LEG BOW	23,273 LBS
11,420 LBS	COUNTERWEIGHT LEG STERN	23,273 LBS
0	FWD TRIM TANK	0
11,490 LBS	AFT TRIM TANK	0
(CHAIN) 6,630 LBS	WEIGHT INSTALLED ON DECK	4,390 LBS(ANODES)
0	FRESH WATER IN BALLAST TANKS	-4,816 LBS(TANKS (1,2,9,10)
36,660 LBS	COUNTERWEIGHTS (2)	55,776 LBS
124,620 LBS		159,996 LBS

CHESNAVFACENGCOM DESIGN 35,376 LBS
HEAVIER THAN SUPSALV

*DATA TAKEN FROM "THE *SQUAW* TECHNICAL REPORT ON SUBMERGED SUBMARINE HULL TARGET," NAVSHIPS 0994-011-2010

In order to confirm the fact that the weights included in the system design were adequate to sink the *SQUAW* it was decided to conduct a pierside submergence test at the Naval Station, San Diego. Prior to the tests the weights listed in Table 12 were assumed to represent the condition of the *SQUAW* with decks awash. It may be noted that for these tests the fresh water in Tanks 1, 2, 9, and 10 had been replaced by sea water and all mooring weights were removed.

Table 12. Dockside Condition of *SQUAW* with Decks Awash

	Weight Pounds	Longitudinal C.G. Feet from ⊗
Light Ship Weight	913,920	0.50
Tanks 1 & 2, S.W.	107,587	22.35
Tanks 3 & 4, S.W.	156,464	6.04
Tanks 5 & 6, S.W.	97,776	- 9.67
Tanks 7 & 8, S.W.	107,587	-22.35
Tanks 9 & 10, S.W.	82,454	-35.60
Anodes	4,010	0
Total Weight	1,469.798	- 2.31

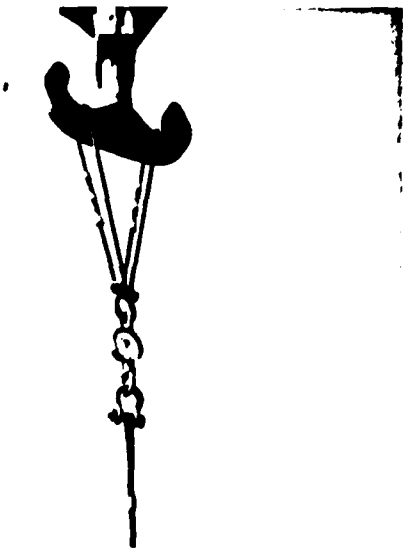
The total *SQUAW* buoyancy given in the SUPSALV report referenced in Table 11 was 700.66 tons or 1,569,478 pounds which would indicate a requirement for an addition of 99680 pounds centered at 2.31 feet abaft amidships to sink the *SQUAW* at pierside. However, that same report had shown that an additional 2.96 tons was required to sink the *SQUAW* in 1970 indicating that the hull buoyancy was greater, i.e., 703.62 tons. This would mean that the total weight needed to sink the *SQUAW* at pierside would be 106310 pounds.

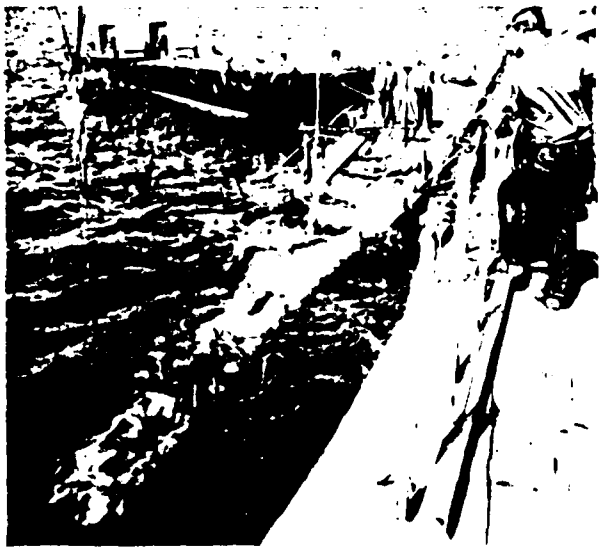
The pierside submergence tests were conducted with the *SQUAW* loosely moored outboard of Navy Crane Barge *YD-252* at the end of Pier 13 of the U. S. Naval Station, San Diego on 24 October 1978.

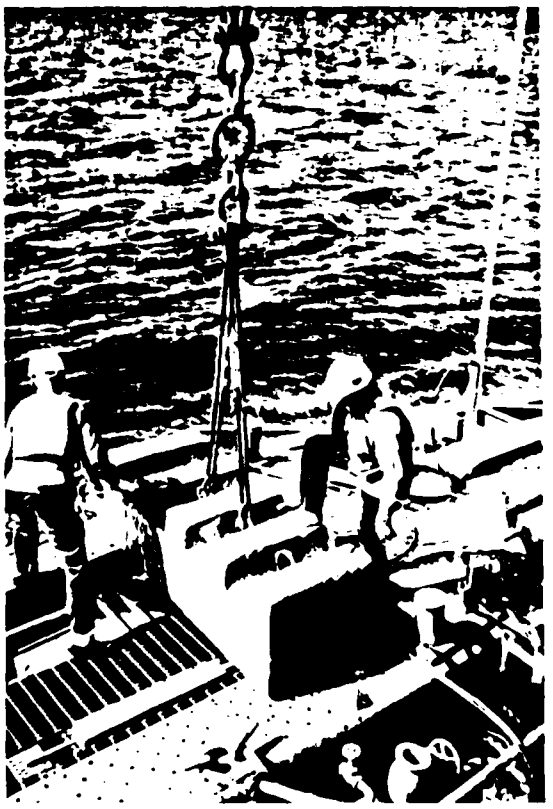
Water in all of the *SQUAW* ballast tanks was blown out and refilled twice to insure homogeneous bay water in all tanks. Bottom plates to all ten ballast tanks had been removed, and were inspected by Navy divers. The top cover plates on all ten main ballast valves (6" valves) had been removed, and all valves were left open.

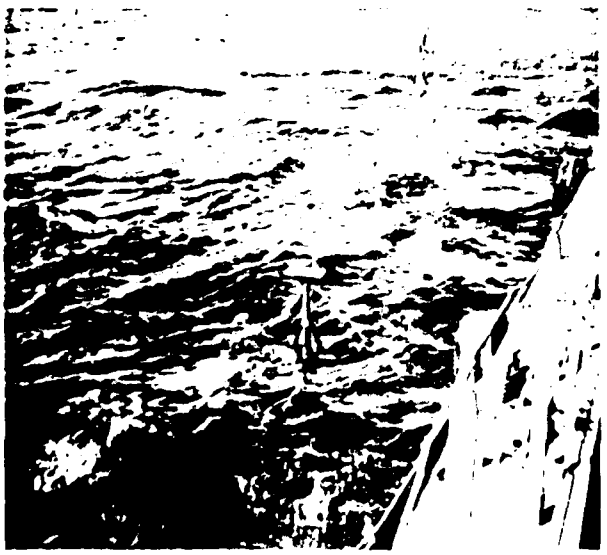
A calibrated 50000 pound dynomometer was hung from the crane hook and read as each weight was handled. As a back-up, the tension read-out system on the crane barge was checked each time a dynomometer was read. In each case the two readings were identical, or no more than 200 pounds different. Photographs of these operations are shown in Figure 57.

As demonstrated in the copy below of the test certification, the total weight required to submerge the *SQUAW* was 107000 pounds. The minimal difference









SQUAW SUBMERGENCE TESTS

FIGURE 57

between this value and the CHESNAVFACENGCOM mooring system design assumption is clear evidence that the system design had a valid basis and that the *SQUAW* characteristics were basically unchanged since 1970.

CERTIFICATION OF TOTAL WEIGHT REQUIRED TO SUBMERGE SQUAW SUBMARINE

Weight No.	Weight In Lbs. Stamped on Lead Clump	Weight Certified	Air Weight Measurement	In Water Weight Measurement	Weight Placement Location
E-7	19,990	12/75	20,000	18,000	Bitts on Port Bow
E-6	19,610	12/75	20,500	19,000	Bitts on Stbd Quarter
E-9	19,400	12/75	20,000	18,500	Bitts on Port Quarter
E-4	19,600	12/75	20,300	18,700	Bitts on Stbd Bow
C-10	3,960	10/74	7,500	7,000	Bitts on Stbd Quarter
C-7	3,610	12/75			
C-9	3,920	10/74	7,500	7,000	Bitts on Port Quarter
(No Plate on Weight)		-			
E-1	19,915	12/75	20,200	18,800	*
TOTAL WEIGHT PLACED ON SQUAW 107,000 LBS (In Water Weight)					

* - Final Weight Placed immediately after of 3rd major frame evident on SQUAW Deck.

- When final weight placed on SQUAW Deck, SQUAW slowly submerged until bow deck was approximately 5 feet below water, and stern deck was approximately 2 feet below water. The SQUAW was slightly negatively buoyant (with no reading on dynomometer); Restrained only by the mooring lines from the crane barge.

WITNESSES

E. B. SPENCER, CHESNAVFACENGCOM

[illegible] DORIN, CHESNAVFACENGCOM

J. BABER, CHESNAVFACENGCOM

D. J. O'Neal, Master of Navy Crane Barge YD-225 Public Works Center

B. E. McCOY, Journeyman Rigger, Navy Crane Barge YD-225

APPENDIX I

SQUAW MOOR JOURNAL

A RECORD OF EVENTS RELATED TO THE
MOORING OF THE SUBMARINE SQUAW FROM
6/24/78 TO 7 /17/78 AS RECORDED BY ROBERT TAGGART

CHESNAVFACENGCOM contracted with Robert Taggart Incorporated to assist in the preparation of the Project Execution Plan and the Final Report on the *SQUAW* Mooring Project. As a part of the latter effort, Robert Taggart participated in the installation phase of the project from 24 June through 17 July 1978. The events recorded by him during this period were contained in a journal which is reproduced in this Appendix. As might be expected, the journal entries cover several aspects of the mooring operations in which Mr. Taggart was directly involved and therefore are not entirely pertinent to the overall perspective of project operations. However, the entire journal, as recorded, is reproduced herein so that all meaningful information will be available for any future analyses of the project.

SQUAW MOOR JOURNAL

Starting 6/24/78

6/24/78 - Saturday

Reported in to the U. S. Naval Station, San Diego at 0900 on 24 June 1978. After considerable time lost trying to locate the SQUAW, was escorted to Pier 13 by CWO Shaw, an ex-submarine sonar man who had used it as a target during earlier submergences. He said that with the sonar they can get a fair picture of its north-south orientation but can't tell the amount of trim it may have.

Took several pictures from pier and looked for air pressure test connections. Dick Asher arrived shortly followed by Hal Dorin and Chris Schoen and I learned that they had finally decided not to pressure test. After getting nearly set up the workmen were reluctant to drill into the hull for fear there might be explosive gasses inside.

At 1100 we started making draft checks in a rough ballasting experiment using midship draft marks (which are actually 3'-8" abaft the ⊗ and are of doubtful accuracy since spacing is inconsistent and non-standard) and measuring freeboards fore and aft. The forward freeboard was taken mainly on the port side with a final check at the end on the starboard side - space between measurements athwartships was only 4 feet; these were at a point later determined to be 7'-11" abaft the bow. The after freeboards were measured at the after hatch location and both port and starboard measurements were made by pole spanning outside of ballast tanks. The first measurements were made in the nominal "at sea" condition with ballast tanks 1, 2, 9, & 10 filled with fresh water, tanks 5 and 6 free flooding, and tanks 3, 4, 7, and 8 blown out at the existing waterline. Measurements in this condition were:

Forward Freeboard: 4'-10 1/2"
Midship Drafts: 17'-4" Port, 17'-1" Stbd; 17'-2 1/2" Mean
After Freeboards: 5'-8" Port, 5'-11" Stbd; 5'-9 1/2" Mean
List to port was because of added chain weight on that side

At 1112 started venting ballast tank #7. Water mixed with air came out of vent. Finished venting at 1122. No drafts measured. At 1125 started venting tank #8

and finished at 1136. Water mixed with vented air on this tank also. Suspected pipes filled with water were cause. Made new draft measurements as follows:

Forward Freeboard: 5'-5 1/4"
Midship Drafts: 18'-2" Port; 17'-10 1/2" Stbd; 18'-0 3/4" Mean
After Freeboards: 3'-10 1/2" Port; 4'-3" Stbd; 4'-0 3/4" Mean

At 1149 started venting ballast tank #3 which also had water mixed with air. Finished venting at 1210 when we started venting ballast tank #4 which finished at 1233. At this point ballast tanks 1, 2, 9, & 10 were filled with fresh water and ballast tanks 3, 4, 5, 6, 7, & 8 were filled to level of outside waterline. Drafts as follows:

Forward Freedboard: 3'-2 1/2"
Midship Drafts: 19'-9" Port; 19'-6" Stbd; 19'-7 1/2" Mean
After Freeboards: 2'-10 1/2" Port; 3'-3" Stbd; 3'-0 3/4" Mean

At 1240 we started blowing all tanks (3,4,7,&8). Finished blow with SQUAW back to sea condition at 1300. Drafts were recorded as follows:

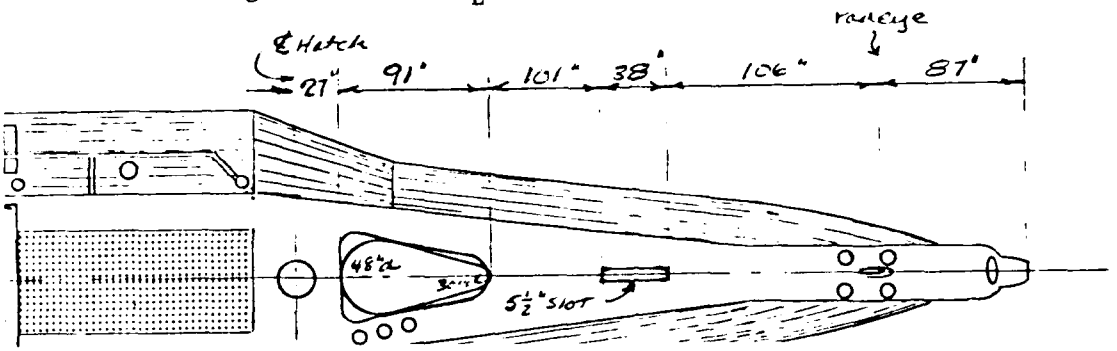
Forward Freeboard: 4'-9" Port; 4'-11" Stbd; 4'-10" Mean
Midship Drafts: 17'-3 1/4" Port; 17'-1" Stbd; 17'-2 1/8" Mean
After Freeboards: 5'-6 1/4" Port; 5'-10" Stbd; 5'-8 1/8" Mean

During the course of making these ballast experiment measurements, several dimensions on the SQUAW were checked to verify drawings made for the Project Execution Plan. Some of the results of these measurements are as follows:

1. Draft marks are 3'-8" aft of ⊗ at about intersection of ballast tanks 3 & 4 with 5 & 6.
2. In January 1978 ballast and trim test measurements:
   The forward point was 87" abaft the bow and the after point was 171" abaft the after hatch. The location of the midship point cannot now be determined.
3. Overall length measurements done in sections were as follows:

Bow to ℄ Fwd hatch	37'-4"
℄ Fwd hatch to bhd between 3 & 4 and 5 & 6	38'-0"
Bhd between 3 & 4 and 5 & 6 to ℄ after hatch	30'-7"
℄ After hatch to stern (best guess)	29'-6"
Length Overall	135'-5"
Vice given	134.62'

4. Also working forward from ℄ forward hatch:



While this was going on, Hal rigged the running light supports for the SQUAW. Then Hal, Dick, and Chris rigged the measured buoy lines with floats to show the depth of SQUAW on final submergence. Also Ed Spencer flew in and came down to the SQUAW. I returned to the hotel and started calculating results of the foregoing tests. Considering the four measured conditions to be:

	Draft at Marks	Av.Fore & Aft Draft
Cond. 0 - Ready for Sea	17.2'	17.34
Cond. 1 - 7 & 8 filled to WL	18.06	18.32
Cond. 2 - 3, 4, 7, & 8 filled to WL	19.63	19.72
Cond. 3 - Ready for Sea	17.18	17.43

Revised displacement program to correct for errors in pressurization tonnages at drafts > 17.42' and then calculated each of the above measured conditions back to the ready for sea condition. Came to conclusion drafts at marks were erroneous and developed the following corrected results from tests:

Cond. 0: T = 17.34' Δ_{SW_o} = 491.91 tons

Cond. 1: T = 18.32' Δ_{SW} = 532.98 - 38.1 + 0.93 Δ_{SW_o} = 495.81 tons

Cond. 2: T = 19.72' Δ_{SW} = 582.05 - 41.6 + 2.3 - 60.5 + 3.33 Δ_{SW_o} = 483.28 tons

Cond. 3: T = 17.43' Δ_{SW_o} = 496.06 vs. calc. wt. of 498.92 tons

6/25/78 - Sunday

Calculations continued on 6/25/78 when changes to displacement program for pressurization errors were made. This means adding 2.57 tons @ 17.5' to the plotted displacement curves down to 2.34 tons @ 21.5'. Foregoing displacements included this correction. These tests on 6/24/78 give us an average displacement in the seagoing condition of 491.77 tons versus the 498.92 tons calculated from weight information for a difference of 7.15 tons. However, this is based on assumptions or perhaps erroneous calculations on tank capacity curves. Note that the final difference is only 2.86 tons which would give us a range of reserve buoyancy (originally figured at 7.95 tons) of from 10.81 to 15.10 tons which is on the safe side and still will not pick up anchor clumps.

Met with Ed, Hal, Dick, and Chris at 1100 on 6/25/78 and presented the foregoing results. It was decided that we would do whatever possible to increase the weight of the vertical leg anchor clumps - apparently they may be able to get a shot of 2 1/4" chain on each. Also we will assume for now that we have adequate reserve buoyancy. Ed would prefer to open up the flanges and valves on tanks 1, 2, 9, & 10 so that the fresh water would gradually be replaced by sea water. I objected to this potential loss of buoyancy but Ed fears that there may be a structural distortion at depths with a consequent strain placed on the pressure hull. The final agreement was to take the flange plates off the 6" valves. Thus, if we have trouble sinking the SQUAW, and therefore have excess buoyancy, we can open the valves.

Dick also informed us of a change in procedure in that the tensionmeter would be on the stern mooring line only and that the tensionmeter on the tug would be used to guide them in applying the horizontal force required to set the forward anchor. The main reason is that there is just not enough working room forward on the SQUAW.

6/26/78 - Monday

Met aboard the MANATI at 0900 on 6/26/78 and talked with other participants. Had taken remaining part of first roll of film on evening of 6/25/78 of Crowley Yard and crane barge from outside gate. On morning and afternoon of 6/26/78 took a long series of photos of the MANATI during loading operations

and used up most of second roll. The rig for level winding of cable is crude and very slow. It also does not seem to apply sufficient tension but they are being extremely careful to get wraps as tight as possible.

Took pictures of ship, bridge, overboarding apparatus for weights and acoustic release. Acoustic release, one unit, did not check out properly so Doug Johnson from Interstate Electronics finally tried triggering the explosive unit which did not work. He stripped it down again and checked all elements but could not get satisfactory results. It will be necessary to use a retrieved unit rearmed for later drops.

The Mini-Ranger antenna mast was erected and all electronics installed by midnight on 6/26/78 and all loadout was completed. Brackets for overboard pipe to support fathometer were damaged during day and night but it was decided to fix these at sea in the morning. Official departure of the MANATI for the mooring site was 0100 on the 27th. The SQUAW had departed under tow at about 1900 on the 26th. Met her at first light on the 27th.

6/27/78 - Tuesday

On the morning of the 27th things looked rather fouled up aboard the MANATI. The Mini-Ranger navigation system was not working, it turned out that a backup LORAN C to be on the tug was not there, and someone had closed a door on the fathometer cable during the night. However, all of these were resolved by about 0930 and the MANATI started moving toward the assigned site. Meanwhile the pipe supports for the fathometer cable were being welded on, the cable checked out and readied for a depth survey. Finished second roll of pictures and started third roll with shots of SQUAW and tug in distance. Took additional shots on deck and of transducer for fathometer being lowered over the side and bolted in place. This was finished at about 1115.

There arose some question as to whether the crown line buoys are adequate to have one alone support 11000' of crown line. However, they will give it a check and two buoys can be put on if necessary. (10000#/buoy)

Fathometer system was checking out well with estimated depth of 860 fathoms so test with plate target was started at 1415 on 6/27/78. Made measurements at 100, 200, and 300 feet below trandducer and finished at 1515.

Steering system burst hydraulic line in morning and lost considerable fluid into bilge. Spare oil aboard was not enough to bring it up to dipstick

so we were stuck until extra oil could be brought from shore. Rudders were at hard right so it was only possible to go in circles. Therefore could make no headway back toward mooring site. However, this allowed time to get deck rigging done for first moor. Took pictures of layout.

Put acoustic release tranducers over on port side at 1530 and one of the acoustic release units over on the starboard side. Checked out enabling system and distance and azimuth measuring systems and all responded satisfactorily. Apparently this unit is ok. Completed test at 1545. Took pictures on both sides of ship and in after end of port trailer where instrumentation for unit was located. Remainder of day spent awaiting arrival of hydraulic fluid for steering system which finally made it aboard by 2030.

6/28/78 - Wednesday

Got underway again at 0500 on 28th and put fathometer transducer back in water for making depth surveys. Had one more steering failure but it was due to overheating from too frequent activation of lever pilot. Went on steering wheel to avoid this problem.

At the two mooring points the fathometer showed depths of 1050 fathoms, just about what was given during the original survey. Decided to add about 115 feet of chain to the 90 feet of chain now on each of the vertical legs.

At about 0700 the tug Challenger with the SQUAW in tow started closing with the MANATI. The tug came alongside and tossed a heaving line to the MANATI and then passed over the bitter end of the towline. Using a capstan and snatch blocks the line was flaked out on the MANATI deck and later hauled up to an upper deck to get it out of the way. Several pictures taken during this operation.

The 45' of chain at the bow of SQUAW came aboard the MANATI at about 0800 on 28 June. The length was quite short and drew the bow of the SQUAW in almost snubbed up to the stern of the MANATI as the chain was made fast. The pelican hook on the towline to the chain was then broken off and the eye at the end of the 8570' mooring line was shackled to the chain and overboarded.

ZODIAC took Asher and two others to the SQUAW where they attached line to the stern chain on the SQUAW and carried it over to the tug. The line was

pulled aboard, the stern chain cut loose from the SQUAW side rail,and the tug started towing the SQUAW astern as the MANATI payed out the bow mooring cable. This part of the operation was completed at 0900.

The 8570 feet of mooring cable was then shackled to 180' of anchor chain which in turn was eased overboard using a padeye on deck attached to a pendant and pelican hook to hold the chain alternately as another pelican hook at the end of the 1 1/8" crown line was payed out and stepped back until the chain bitter end approached the stern. The bitter end was then shackled to a 6000# weight hanging over the stern in a specially formed rack. Another one shot of chain was already connected between this weight and the anchor.

A line from the winch was then fed over the track at the top of the frame and the 6000# weight was lifted a foot or so. While in this position the diagonal support angles holding the bottom of the frame were burned through to clear a path for dropping the weight directly downward. The weight was lowered to the point where it was hanging on the chain that connected to the anchor and the anchor chain gradually fed out until it moved the anchor a short distance.

At this point, angles were welded to the anchor flukes to permit it to skid more easily over the deck and stern. However, when it was allowed to go it still toed into the pipe fairing over the stern and stood up on the tip of one fluke. Getting it overboard wedged the 1 1/8" crown line deeply into the wraps on the winch drum which was the start of a considerable amount of trouble.

Next the acoustic release was inserted in the line and put overboard. As lowering started the line jerked significantly as the wedged-in wraps on the winch drum came loose. Then the acoustic release opened and dropped the load to the bottom. This happened at about 1530 when fortunately we were very close to the prescribed position.

The acoustic release was retrived and it was found that the electronic package casing had vibrated down the support frame to the point where a bolt on the casing head drove the trigger through the retaining cotter pin and loosened the pelican hook which then released. The cylindrical electronic package was held to the frame by two bands, welded to the frame and each closed by a pair of bolts. There were two retaining keys, each a small cylinder about 3/8" diameter and 3/8" long made of plastic which were all that was

provided, except for the band tension, to prevent this occurrence - very poor design.*

The first moor was then left in position and it was decided to take the MANATI around to replace the tug on the stern of the SQUAW. We took over the stern mooring chain from her and shackled it to our 1 1/8" crown line. The MANATI then headed south reeling out the crown line astern. The idea was to then haul the MANATI back up to the SQUAW while winding the crown line back on the winch drum at a heavier tension than was applied by the gear that had been rigged at the Crowley pier. The mobile crane, with a pair of sliding blocks on the bumper, was still to be used to control the level wind feature with the drum packed as tightly as possible.

This operation was started at about 1700 with the MANATI headed south unwinding wire. By about 1830 the rewinding had started with light tension on the drum - estimated to be around 10000# - and was completed by 2400. (Main generator down 2000-2030.) However, during the operation the MANATI was operating on one screw and it was difficult to maintain the 180° heading. As a result, by morning, it was necessary to do some remaneuvering as the mooring wire was made up.

At 2330 on the 28th when pulling for spooling the wire had stopped we were about 7000' SE of anchor drop point. Earl Lawrence left orders on the bridge to just clutch in one engine and hold heading at 135° but during the night there were various reported headings of 070 and 060 which would account for the drastic change in position.

6/29/78 - Thursday

Checked Mini-Ranger plot at 0900 and found we were about 7000 feet NE of anchor drop point. Total distance about 200' + 30' + 600' + 135' = 965' or say 1000'. This would have required 16000# horizontal force to put us where we were if the anchor were still in place and at the time there was no apparent tension in the towline. Thus, it appeared that the anchor had moved considerably.

*For additional problems with acoustic release see Note 1 on Page I-39.

During morning of the 29th they reeled the 8570' mooring line on the upper drum and started rigging chain for the second anchor drop. Meanwhile, we discussed various alternative means of checking out where the anchor was actually located. It was decided to move the MANATI back down toward the SQUAW moored position and to take two horizontal force readings while pulling away from the initial anchor drop position with about 16000# at about 135° and again at 180° from it. We could then swing a 7000' arc from each position where these readings were taken and the intersection would determine the anchor position.

After finishing up on deck we initiated this maneuver but for some reason the measurement at 135° was dropped. Also the captain tried to bring the MANATI around to a 180° heading by running his starboard engine astern and port engine ahead. This torque on the ship obviously had no effect with the SQUAW hanging on the stern. * Finally they called in the CHALLENGER to put a line on our bow and haul us and the SQUAW around. The tug put a line on at 1430. The SQUAW was actually pulled broadside from an initial heading of 090° around to a heading of about 170°; the tug and MANATI were both headed about 180° with the tug doing most of the pulling. The tow then picked up speed as the catenary came out of the SQUAW anchor line and then slowed again. At this point we later decided that we were again dragging anchor.

Asher went in the ZODIAC to the SQUAW and read the tension force on the dynamometer. He got readings between 15000 and 25000 pounds. The tug continued pulling to the south for a short time after the measurements were made. From the plot we calculated he was dragging the anchor south for about 15 minutes at an average speed of 1.6 knots - a total drag of about 2000 feet.

We replotted the entire exercise and then calculated the speeds during this operation. From the results Asher and I estimated the final anchor position to be about 2000' southeast of the initial drop point. If we can put the moor in a north-south direction the SQUAW should end up about 2500 feet off the target point which is within the prescribed half mile radius.

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*See additional Note 2 on page I-39 for analysis.

While this was going on, the SQUAW was pulled in on the towline and the stern 45' of chain taken aboard the MANATI. Since the padeye to which the chain was secured was more than 15' forward of the SQUAW stern, this left less than 30' of chain for handling on deck and for separating the two vessels. The seas were running fairly heavy and the MANATI was downsea of the SQUAW so there was a large amount of relative motion between the two sterns and the seas hitting the broad flat stern of MANATI threw considerable green water on deck. It was a fairly hairy operation. Finally the eye at the end of the 8570' of mooring line was shackled to the chain, that length of wire was payed out, and stoppered off for the night.

6/30/78 - Friday

The MANATI hung downsea and downwind of the SQUAW for the night but in the morning, when the wind had died down, the SQUAW was practically alongside. No Mini-Ranger points were taken after 1715 but up to that point the selected spot for the probable north anchor location still looked good. In the morning the first reading was taken at 0630; after the wind had eased off we drifted up closer to the anchor spot.* The MANATI then got underway and headed south to within about 5400 feet of the newly selected south anchor point and stopped engines while the rigging crew went back to work making up the anchor chain. The end of the first two shots of chain reached the stern at about 0800 on the morning of 6/30/78 ready to be attached to the 6000# clump.

By 0815 the clump was shackled to the chain by a short length of chain. The clump was then lifted out of its support brackets and moved over to the center of the transom. The clump went into the water at 0830. Next the two anodes were attached to the chain (picture) a short distance away from the clump and they were lowered into the water at 0845. Next the chain was lowered furtner down and the crawler crane moved over to pick up the anchor to put it in line for overboarding. The anchor chain was then eased on overboard and the anchor stopped just short of the transom. A sling was attached around the stock and shackled to the 1 1/2" wire on the upper drum of the winch. Tension was taken up on this line and the 1 1/8" crown line was shackled to the crown of the anchor. The anchor was then eased overboard and the load transferred to the crown line with the sling being removed. This operation was

*See Note 3 on page I-41 for discussion on this situation.

completed and lowering started at 0930. Got two pictures of the crown line coming off the drum to show the tightness of the wraps. When about 4000 feet of crown line was out the MANATI got underway at 1059 at minimum RPM on one screw headed for the newly designated south anchor drop point. The idea was to move to about 8700 feet south of this point while paying out 11000 feet of crown wire which was calculated to bring the anchor to the drop point. However, at about noon the bearings failed on the stern sheave and it was necessary to hold up operations. At this point in time, 1203, it was decided to pay out the entire 11000 feet of crown line and thus put the anchor on the bottom.

The line was run out on the winch brake and greased to slide over the stern sheave. At 1238 the anchor was felt to bottom out; by this time we had been pulled 4800 feet due north by the catenary in the line. The navigator, Jack Wilson, spotted in this point and we decided the anchor must be directly below us. The crown line remained connected to the winch.

In the meantime, before the sheave failure at about 1120, Asher had gone aboard the SQUAW to read the tension. The reading he got was 25000# but he also noticed that the stern mooring chain was leading back toward the bow on the starboard side of the SQUAW; also the forward chain appeared to be angled somewhat backward. This led to concern that somehow the lines were twisted.

After the anchor drop at 1238 the MANATI drifted about 1800 feet due east. At 1319 we started off again at a 220 heading to attempt to pull the anchor down to the target position. We continued pulling toward the south until 1408 when the MANATI had reached a point 3250 feet due south of our target anchor position that we had derived the night before. At this point we stopped pulling because of two concerns: (1) the tension in the crown line appeared quite high, and (2) the fact that the SQUAW had remained broadside to the line of tow lent credence to the theory that the mooring lines were twisted below her. During this time the remaining crown line was run out and buoyed off.

Earl Lawrence, Dick Asher, and two divers headed for the CHALLENGER to use that as a base for going over to the SQUAW for a closer look at the situation. Meanwhile aboard the MANATI we debated what might have happened the night before that could have allowed either the MANATI to transit around the SQUAW or the SQUAW to make a 360° turn on her own.

SQUAW MOOR JOURNAL - 6/30/78-Friday (Cont'd.)

The diver went down one of the lines to 140' and could see about 40' more below him. He saw no indication of twist and the line appeared to go straight down. Also the tug crew supported the MANATI watch officers in saying there was no way the MANATI could have rounded the SQUAW during the night and it was doubtful whether the SQUAW could have done a 360° turn in the sea that was running.

We decided that Asher and I should analyze the SQUAW situation while the riggers stripped down the stern sheave and Earl Lawrence would make a decision relative to how the operation would continue.

We obtained from Jack Wilson the track points for the day and plotted them up. Based on the assumption that we had pulled a full catenary on the 11000 feet of crown line, our travel south would place us 8700 feet from the point to which the anchor had been dragged. This meant that the south mooring anchor had been moved only 650' during the operation. Also Dorin had obtained a radar fix on the SQUAW at our most southerly point of travel and placed it at 13000 feet. Based on our previous estimate of the north anchor location we then spotted in where the SQUAW must be. This placed it only 4000' from each of the anchors which meant that there would have been very little leadoff angle during the pulling and a horizontal force of less than 4000#. Based on this we agreed that the wires probably were not twisted or at least that twisting could not be accounted for by the SQUAW failing to track behind the MANATI.

In the meantime, Earl had pulled down the sheave and found the bearing completely destroyed. We could not lay the other two vertical legs without a replacement. He ordered one made up and also considered substituting an identical fixed sheave on deck for it. We ended this discussion on the night of 6/30/78 with the conclusion that in the morning we would tow the anchor to the final position and probably go to San Diego on Saturday night, 1 July,to replace the sheave, get potable water which was running low, and replace portable "Economy Sanitaries" which were running high.

During the evening of 6/30 the riggers wound the 8570 feet of 1 1/4" cable on the winch as tightly as possible. However, this will have to be rewound under tension before it is used for lowering the large vertical leg clumps.

SQUAW MOOR JOURNAL (Cont'd)

7/1/78 - Saturday

On the morning of 1 July we moved back to the buoys at the end of the crown line. These consisted of two 56" diameter cans and a small sphere which supported a pendant. The spherical buoy was hauled aboard and the pendant shackled to a line running through a snatch block to a bollard at the stern. The CHALLENGER was called over to take us in tow and we headed southwest in a direction calculated to pull the south mooring anchor over to the target position.

When we reached the maximum southerly point of the previous evening the tension built up considerably causing the two crown buoys to submerge almost totally. Our southwesterly progress slowed considerably and we swung up to the west apparently on a radius swing about the south anchor position. The turns on the tug were increased and the MANATI put on some power trying to get back down in a southerly course. Finally, at a little after 1300 we seemed to break loose and started moving in a more southerly direction. Data on this run are as follows from 1300 on:

Time	Speed Knots	Course Degrees T	Travel Feet	Time	Speed Knots	Course Degrees T	Travel Feet
1305	1.79	219.51	902	1346	1.67	159.43	743
1310	1.54	214.64	754	1351	2.28	150.94	1148
1315	1.31	212.55	669	1356	2.20	155.70	1075
1320	1.32	198.94	691	1400	1.66	150.98	704
1325	1.50	204.55	682	1402	3.75	29.88	784
1330	1.43	200.88	741	1405	2.20	21.93	715
1335	1.60	189.71	804	1412	1.53	40.75	1064
1342	1.70	178.51	1149	1420	1.22	59.37	963

It is fairly obvious from the above data that we ceased pulling at about 1400 when the speed changes from 1.66 knots ahead to 3.75 knots astern. We should be able to calculate from the coordinates of these points and an estimate of the tension on the wire a guess as to where the two anchors are now located.

The CHALLENGER first went up to look over the SQUAW and found it to be on a generally north-south heading. Boarding was impossible because of the sea

state. The crown line was then reattached to the spherical buoy and the buoy was overboarded.

The MANATI next executed a full speed 180° turn and headed for the SQUAW to get her position and true heading. She was rolling heavily and draft marks were difficult to read but it looked like an average of around 18.5 feet. We then headed back to San Diego to have a new stern sheave fitted and the other matters previously mentioned attended to. We arrived there at about 1915.

The replacement sheave did not arrive until about 2200 but the riggers spent the time cutting off the old sheave and cleaning up the deck with a grinder.

7/2/78 - Sunday

The leveling problem was significant and it was not until 0330 on 7/2/78 that they actually could start welding down the replacement sheave. The work was completed at 0700 and at 0730 we departed San Diego to return to the site. Potable water tanks were refilled and the leaking Economy Sanitary was left at the Crowley pier; the other one, still full went back out with us.

Back on station the seas were too rough to do any work so it was probably a weather day and we steamed slowly on an east-west heading back and forth past the SQUAW. On the first pass we found that the sub had moved about 3500 feet north of where we left it on 1 July, the day before. We then went down to check the crown buoy position and found it in the same general area that it had been cut loose in. This indicated that the south anchor was where it had been left the day before. Proceeded then to make another check on the SQUAW and found it about 1000 feet from the earlier position to the south. On the first sighting the SQUAW was headed 280° and on the second 315°, each time directly into the seas whereas when left on 7/1/78 she had a precise north-south orientation.

Taking all these things into consideration there seemed to be no other conclusion than that the SQUAW was no longer connected to the south anchor but was hanging downsea from the north anchor. This was further confirmed by later positions where it seemed to move up toward the anchor as the wind and sea calmed and moved back downsea as the weather picked up. A more detailed analysis of this is in preparation.* In the meantime, it was agreed

*See Note 4 on page I-42.

that there was nothing to do but proceed with the dropping of the vertical legs since both drums of the winch were wound - one with the 8570' wire and the other with the 5740' wire for one vertical leg.

7/3/78 - Monday

At 0600 on the morning of 7/3/78, the rigging crew prepared to lower the spare 6000#clump on the 8570' wire. This was necessary because that wire had to be respooled under tension since it was to be used in lowering the 28000# clump. An attempt was made to judge when the weight hit bottom to get a check on the fathometer. A calculation of length on the spool was used as an estimate of wire out when bottom contact occurred. However, this guess came out to 5393 feet as opposed to a fathometer measurement of 1043 fathoms (6258 feet). But a reasonably good check of total wire length versus number of layers counted (16) was obtained - calculated data follows:

Layer No.	Layer Length '	Cumulative Length '	Layer No.	Layer Length '	Cumulative Length '
1	340	340	9	550	4005
2	366	606	10	576	4581
3	393	1099	11	602	5183
4	419	1518	12	628	5811
5	445	1963	13	654	6465
6	471	2434	14	681	7146
7	497	2931	15	797	7853
8	524	3455	16	733	8586
				vs	8570

During the pickup the winch fouled up and lifting was stopped. The riggers managed to get it running again but it was working only in the ahead direction and neither drum could be reversed. The rewinding was continued but could not be wrapped properly because they dared not stop the winch once it was winding. Once the wire was wound and the 6000# weight aboard they started pulling down the winch but it was decided necessary to go back into San Diego to get it fixed by the Skagit representative.

Asher went aboard the SQUAW to replace batteries in the lights. He found the tensionmeter reading only 1500-2000 pounds indicating that only the weight of

the chain was hanging on the stern padeye. This indicated that the break was around the end of the chain.

Bow and stern drafts were estimated from the MANATI as 18.7' and 16.8' respectively for a ⌀ draft of 17.5' for a displacement of 499.24 tons. The difference from the selected seagoing condition gives 499.24 - 491.77 = 7.47 tons. MTI = 27.6 ft. tons. Moment for this condition is 629 ft. tons. In the seagoing condition at Δ = 491.77 tons, T = 17.34', MTI = 28.15, the average trim was 16.5" and corresponding moment 464 ft. tons. The moment difference is 165 fet. tons which, divided by 7.47 tons is 22.08 ft. This means the added weight was 22.08 ft. fwd of the LCG in the seagoing condition. The indication here is that the total weight was acting at the bow, i.e., the weight of the bow mooring cable is acting on the bow with no added weight on the stern. It looks like the mooring parted at the bottom of the chain.

After getting a final fix on the SQUAW, the MANATI headed for San Diego at about 1500 arriving at the Crowley pier at about 1730. Winch people came aboard right away and started examining the winch. They worked on it until 2300 but were unable to get it repaired.

7/4/78 - Tuesday

Lawrence called Dorin and set up a meeting for 1000 on 7/4/78 but this was altered on the morning of the 4th to 0900 on 7/5/78. Apparently they will not be able to get competent people there from Skagit until the morning of the 5th and we probably will not know anything positive until afternoon.

Went down to Crowley for the meeting at 1000 on 7/4/78 and waited for an hour before learning it had been cancelled. Learned the information given above from the chief engineer of the MANATI. In late afternoon and evening spent time calculating MANATI and SQUAW positions during the south run on 7/1/78 and derived estimates of the two anchor positions and the means by which the tow got the anchors to where they were. The Mini-Ranger coordinates of the estimated anchor positions are as follows

North Anchor - 109750 Woodson 83340 Alta
South Anchor - 112470 Woodson 85830 Alta

The horizontal distance from the MANATI to the SQUAW was 16320 feet comprising 10160 feet from the MANATI to the anchor and 6160 feet from the anchor to the

SQUAW. This was determined by extrapolation of the radar plot and by assuming a 33000 pound pull (H_{force}) on the after mooring line which gave the maximum stretch of the crown line and the stern mooring line. The north anchor position was obtained by assuming a 6000 foot horizontal distance between the SQUAW and the anchor and the initial position of the north anchor before the tow was that estimated on 6/29/78. It was assumed that the north anchor had been dragged by the SQUAW at a constant rate along a line between the initial anchor position and the final SQUAW position.

During the afternoon of 7/4/78, Dorin had talked with the NOSC people concerned with the instrument package and gave them further information on its condition. He was unable to get in touch with anyone at PTC.

7/5/78 - Wednesday

On the morning of 7/5/78, Asher, Dorin, and I went to the Crowley office at 0800. Dorin and Asher made several calls to NOSC and PTC about the instrument package and it was evident that this was extremely important to the project. Dorin prepared and sent out a message relative to the instrument status and the SQUAW situation after checking it out with Ed Spencer. Asher arranged to get NOSC people out to the SQUAW in the afternoon to retrieve their instrument package and inspect their battery cannister.

At about 0930 we met with Earl Lawrence and Jim Walker to discuss the situation. The local Allison representatives were pulling the transmission out of the winch to take it into the shop to determine the extent of the problem. At this point we did not know when the repair might be effected. Dorin had lined up an 8000 foot length of 1 1/4" 6 x 37 wire at Cheatham Annex and this was to be trucked out to be used as a spare and Lawrence was so informed. It was agreed that our next step should be to proceed as planned (when the winch was fixed) with lowering the 8570' wire with 6000# clump in order to respool it under tension. When this was done the 100 kip acoustic release would be inserted in the line at the clump for a survival test during the lowering and raising. Earl had decided to parallel the release with a pendant so that we would get the weight back even if the release gave way. Doug Johnson had taken the unit to Interstate Electronics the night we came in (7/3/78) and devised a cushioning for the batteries and a stopper had been welded to the frame to

prevent the package from mechanically triggering the release. It was agreed that upon retrieval after the spool rewind, Doug would test fire the unit and then pull it down to check for damage. If it appeared OK we would then trust it for the lowering of the vertical leg weights.

Asher then informed Lawrence and Walker of our conclusion that the stern mooring line was no longer connected to the SQUAW and that the separation had occurred at the juncture of the wire and the chain. It was agreed that this must be checked out by a diver and arrangements were made to send the CHALLENGER back out with a diver to follow through on this inspection. We had learned just that morning (7/5/78) that Walker had ordered the CHALLENGER back in on 7/4/78 and that the SQUAW had been unattended for a day and night. Dorin expressed his sincere concern over this situation and let Walker know that he had a responsibility for the SQUAW that had been ignored.

It was agreed to coordinate the return of the CHALLENGER to the site with the trip of the NOSC vessel so that the latter could bring back the diver and Asher who would make the trip to corroborate the diver's findings and to assist in the removal of the NOSC instrument package. Some concern was expressed by Dorin and Asher as to whether the CHALLENGER could find the SQUAW without a gyrocompass, radar, or LORAN C.

I returned to the hotel to write up the progress to this point and to continue calculations and plotting of data taken from the NSI chart on the window of the MANATI pilot house. This included the various points where the SQUAW fixes had been obtained on 7/2/78 and 7/3/78 and the spot where the crown buoys had been sited on 7/2/78.

Dorin spent the afternoon getting his message out and then returned to Crowley to find that the repairs on the winch would take at least three days. We made the decision to return to Washington on the 6th if this prognosis held up on further examination of the unit.

Asher departed at 1500 aboard a NOSC torpedo recovery boat with one NOSC contractor to meet the CHALLENGER at the site. The CHALLENGER had two divers aboard. They helped the NOSC representative recover the instrument package from the SQUAW (which the CHALLENGER had no trouble finding) and then one diver went down the after mooring line. All of the fittings were on the chain

and the wire was connected as far down as he could see. However, it did feel somewhat slack to him. Asher said that the tensiometer was completely self-destructed by this time and could get no reading from it. They returned to the NOSC pier at about 2300 on the night of 7/5/78. As far as the after mooring leg continuity is concerned the results are completely inconclusive.

7/6/78 - Thursday

On the morning of 7/6/78, Ron Green of SUPSALV extracted pertinent information from this journal on the 3 days for which Crowley was considering asking for "weather days." Completed a few additional calculations on the MANATI and the SQUAW movements and then went down to the Crowley office. It was evident that the transmission could not be repaired or replaced in less than four days so we decided to return to Washington. This was confirmed on the telephone with Ed Spencer and Dorin, Asher, Green, and Taggart departed on the 1300 plane. Arrangements had been made for continuous telephone contact.

7/7/78 - Friday

At 1300 on 7/7/78 met with Spencer, Dorin, and Asher at CHESDIV to discuss the situation and to brief Spencer on status. Dorin had been in contact with TRAPAC and NOSC and it had been decided that they wanted the MANATI to go out and retrieve the battery cannister off the SQUAW. TRAPAC made these arrangements directly with Crowley. Made arrangements and got travel orders to return to San Diego on 7/9/78.

Returned to RTI office and made working plots of MANATI and SQUAW tracks and plotting sheets for making Mini-Ranger plots. Reorganized data and supplies for return to San Diego.

7/8/78 - Saturday

Made up plotting device for use with NSI charts and Mini-Ranger. This helps interpolate between lines on chart for plotting ship tracks.

7/9/78 - Sunday

Met Dorin and Asher at airport and departed for San Diego at 1745 on 7/9/78. Arrived aboard MANATI at 2230. Everything seemed to be ready for departure at 0100.

SQUAW MOOR JOURNAL (Cont'd.)

7/10/78 - Monday

Departed San Diego on time at 0100 on 7/10/78. Arrived at site early in morning and rigging crew went to work at first light laying out the gear for the first weight drop. The idea was to lower a 6000# clump on 8570' of wire, reeling out all of the wire, and then rewinding it under tension to get a good tight level wind. The acoustic release was to be inserted between the wire and the clump with a pendant around it to see how it would survive the operation. (Start of roll A pictures.)

At 0900 the port engine went out and we headed back to San Diego. Caterpiller representatives boarded at the sea buoy and we finally berthed at the Crowley pier at about 1315. It was estimated that the engine repair would take six hours so all hands were ordered to be back aboard by midnight. The problem with the engine was a valve that broke and went into the cylinder, cracking the piston, liner, and head. Fortunately spares were readily available but a day of beautiful working weather was lost as had been the preceding week.

While the repairs were being effected, Dorin and Asher went first to PWC at the Naval Station to determine the status of the instrument package and battery cannister. It was found that it would be Friday before there was even a chance of getting an estimate of the time required for repair or replacement. It was agreed that the mooring of the SQUAW should continue but that perhaps the depth should be less so that divers could install the electronics equipment at a later date.

Dorin and Asher then went to SUBDEVGRU I to discuss a reasonable working depth. It was finally agreed that they should try to limit the moored depth of the SQUAW to 250 feet so that divers could make the installation. The DEVGRU people checked with the HCU-1 who were at that time very interested in doing the job but later turned it down.

7/11/78 - Tuesday

On 7/11/78 further arrangements were made relative to the deferred installation of the electronics equipment until after the SQUAW submergence. A message was received changing the target depth from 300 feet to 250 feet ± 50 feet. Also Dorin requested from PWC two 3000# buoys, thimbles, and wire

rope clips for various sizes of wire. PWC obtained these and they are to be made available at the Crowley pier.

With engine repaired the MANATI got underway early in the morning and arrived back on site at 0730. The first exercise was to lower the 6000# clump and acoustic release on the 8570' wire and to respool the wire under tension. This was satisfactorily accomplished with the release transponder being interrogated and responding all the way down and back. Therefore, it was decided to insert it in the lowering line when putting down the after vertical leg clump. An attempt was made during this lowering to get a measure of water depth but it was impossible to tell when the 6000# weight touched bottom or was lifted off.

The next step was to get a good fathometer measurement of the depth at the site where the SQUAW would be moored. Gave to Jack Wilson the coordinates of the spot halfway between where the 7/1/78 estimates show the north and south anchors to be. These were 84750 Alta and 111100 Woodson. The Alta station had run out of fuel and ceased transmitting in the morning but he was able to get precise fixes using another station, Scott, located on St. Nicholas Island. (Alta was back on the air by 1500.) Dave Lauer took five depth recordings between 1152 and 1200. There was practically no variation from the mean reading of 1049 fathoms (6293 to 6296 feet).

When getting underway for the above measurements, Doug Johnson had forgotten to pull his acoustic release transducer out of the water and there was a fair amount of banging of the pipe against the hull. However, the ship was stopped right away and there appeared to be no damage to the unit.

With the depth information obtained, Asher and I worked out the length of chain required to be added to the top of the vertical legs as follows:

Depth of water	6294 feet
Length of wire rope	-5740 feet
Length of chain on clump	- 25 feet
Length of chain on SQUAW	- 90 feet
Shackle in system	- 5 feet
Swivel length	- 3 feet
Clump height above bottom	- 6 feet
Desired SQUAW depth	- 250 feet
Additional chain required	175 feet

Based on this we decided to use two shots of chain on each leg, i.e., 180 feet which should put the attachment padeyes on the bottom of the SQUAW 245 feet below the surface.

The negative buoyancy that would be applied to sink the SQUAW, with all ballast tanks full while on the surface would be as follows:

Sea Condition derived from Naval Station Measurements	491.77 tons
Fill tanks 3, 4, 7, & 8	117.88
Add 360 feet of chain @ 34.08 #/ft.	5.48
Air to water difference in 270' chain on the SQUAW	-0.61
Vertical leg wire	11.30
Vertical leg concrete clumps	20.24
Anchors attached to clumps	4.66
Vertical leg fittings	0.50
Bow and stern moorings vertical force	24.50
Less electronics	-0.45
Vertical leg bottom chain 50' @ 34.08 #/ft	0.76
Total	676.03 tons
Buoyancy (700.66 - 43.65 for tanks 5 & 6)	657.01
Negative buoyancy for submergence	19.02 tons

Additionally the test results of the trim and buoyancy test at the Naval Station on 6/24/78 were looked at again to derive an equivalent light ship weight for comparison with data given in the Project Execution Plan. These calculations showed the following:

Sea condition derived from Naval Station tests	491.77 tons
Less F.W. in tanks 1, 2, 9, 10	-82.69 tons
Less 270' chain in air	- 4.72 tons
Less anodes and electronics	- 2.41 tons
Equivalent Light Ship	401.95 tons
Light Ship in P.E.P.	409.10 tons
Difference	- 7.15 tons

Actually, if last weight on page 3 were used, there would be virtually no difference. There is thus the possibility that we will have as much as 26 tons negative buoyancy when about to submerge.

The after vertical leg was then made up using 180 feet of chain to be added to the 90 feet already on the SQUAW at the top and 25 feet at the bottom. The MANATI went alongside the SQUAW and Asher and some of the riggers went aboard to shackle in a hauling line and to cut loose the lashings on the 90 feet of chain. The 180 feet of chain on the MANATI deck was shackled to it and the 5740 foot length of 1 1/4" wire was connected to that. All of the wire was payed out as the MANATI moved away from the SQUAW. Then the lower end of the vertical leg was made up and attached to the 12.45 ton clumps and anchor combination. The acoustic release was attached and to it was shackled the lowering wire.

The MANATI was about 3000 feet from the SQUAW when lowering started. After a few hundred feet of wire had run out, with some jerking as the brake was applied, the acoustic release let go and the weight free-fell down into position under the SQUAW. It took about five minutes for the SQUAW to sink down and to trim down by the stern indicating that the weight was being supported by it. The drop occurred at 1813 with the MANATI at 083374 Alta and 109521 Woodson. Relative radar bearing on the sub was 203°, range 2700 feet, and the MANATI heading 335° True. Approaching within 30 yards of the sub at 1846 the position was 083851 Alta, 109873 Woodson and she was headed 158° True.* Subsequent readings on her between then and sundown were as follows:

Time	Meters from Alta	Meters from Woodson	Heading°
1922	084096	110101	115
1950	082789 Erroneous	110894	125
2010	084314	110034	345

Actually, during the attachment and making up of the vertical leg the MANATI had gradually turned the SQUAW around approximately 180° in a clockwise direction. As can be seen above, after the MANATI was disconnected, the SQUAW swung herself around 180° in a counterclockwise direction. This would unwind any crossing of the bow and stern mooring lines (if the after line is still connected) but could foul the bow mooring line and the after vertical leg if the SQUAW was far enough from the north anchor to pull a catenary in the line. However, at the time of the vertical leg drop, the SQUAW was only 1700 feet down from the estimated anchor position and it would appear that the

*See Note 5 on page I-43.

bow mooring line should have dropped directly to the bottom and then should lie along the bottom to the anchor. There was no evidence of fouling of any wires at this point.

Later in the evening Lawrence, Dorin, Asher, and Taggart discussed how we should proceed the next day. First there was the question of whether the dropping of the weight could have caused any damage to the mooring system or to the sub support. Taggart and Asher calculated a terminal velocity for the weight of 19.2 ft/sec which gave a drop time of 4.82 minutes, just about as observed. Assuming this was decelerated to zero within the 30 ft stretch of the wire we got a deceleration force for the mass of 17000 pounds which is not excessive and is subject to decrease from the down heave spring action of the SQUAW when the load was applied. We therefore did not believe there could be any damage from the drop alone.

Next there was the question of whether to use the acoustic release which had already failed twice. Although Doug Johnson had continued to beef it up we decided the risk was too great. If we did not use it we would have to jettison the lowering wire which was also our only spare 8570', 1 1/4" mooring line to replace the after moor should it be necessary. However, there was a spare 8000 feet of 6 x 37 wire being delivered to Crowley which we thought we could use. As additional backup we might recover the existing after mooring line or use the crown line. Therefore, it was felt we could afford to discard it.

Dorin raised the question if, when more than 6000 feet of line connected to the anchor clump was dropped to the bottom, how much would the clump be displaced when we moved the SQUAW to its final position. This was calculated by two methods. A catenary calculation yielded a displacement of 750' and a straight line approach gave 910'. This was unacceptable. I suggested we hang the line on the sub and then drop it after we got the sub into final position. This was accepted and Earl Lawrence said he could figure out how to do it.

The possibility of first going down to the crown buoys to pull for a check on the after moor status was discussed but was rejected as unnecessary at this time. It would be most efficient to get the forward vertical leg in first. This then decided the program for the following day.

SQUAW MOOR JOURNAL (Cont'd.)

7/12/78 - Wednesday

On the morning of 7/12/78 the riggers reeled the 5740',1 1/4" vertical leg wire on to the winch drum in preparation for lowering the forward vertical leg. The 8570' wire was already wound on the other drum for a lowering line from the previous day. The MANATI got underway about noon and moved over to the SQUAW. At 1229 the sub was heading 105°, 185' astern of the MANATI with coordinates of 084186 Alta, 109448 Woodson.* The additional 180 feet of chain had been shackled to the 90 foot length on the SQUAW and shackled to the end of the vertical leg wire on the port side of the sub. At the time the sub was headed downsea from the north anchor and it had the north mooring line running down and under the sub. The MANATI started off to the south of the sub and had to swing to the east, to the north, and to the west of the sub to turn it around and to get on the forward port quarter of the sub for the lowering operation.

Lowering of the anchor clump started at about 1340 after the MANATI had crossed the bow of the sub toward her port side. Prior to this, as the vertical leg wire was being payed out and the MANATI circling around it, the sub rapidly changed her heading to the northwest. This meant that the chain on the vertical leg led around the bow mooring chain from the port side to the starboard side of the sub. At one point it was also bearing on the after vertical leg. However, it seemed to unwrap quite nicely as the MANATI circumnavigated the SQUAW. By 1350 or 1400 the MANATI was holding position nicely to the northwest of the sub. This continued until 1445 when Dorin and Lawrence became concerned that the SQUAW heading kept changing toward the MANATI. They requested the skipper to have the tug (now the CONTENDER had replaced the CHALLENGER) pull her south in an attempt to get to the port side of the sub. This maneuver was ordered with the thought that there was a stern moor which would hold the stern of the sub in a north-south alignment. However, the sub continued to swing in the direction of the MANATI to the point where, at 1600, the MANATI was directly south of the sub and the SQUAW was headed 180°. Here I suggested we swing back up to the northwest of the sub to get upsea of her again so that there would be no interference with the bow mooring line. This course was followed until 1650 when the MANATI was about 2000 feet due west of the sub. At some point along this line the towline from the CONTENDER snapped. It was then suggested that she go over and pull the head

* See Note 6 on page I-44.

of the sub around to the north since the sub was still wallowing in the trough of the seas. This was done and the lowering of the clump could continue with the MANATI gradually being pulled toward the SQUAW.*

The next problem was to cut off the lowering line, put an eye in the end of it, and transfer it over to the bitts on the SQUAW. There was an attempt to determine the amount of wire payed out so that there would be enough to ensure that the load of the clump was taken completely by the vertical leg. The lowering line was stoppered off and cut, an eye fashioned in the end of it using wire clips, and then the eye was passed over to riggers on the deck of the SQUAW. This operation took a significant amount of time because of ship handling problems and the seaway acting on the two vessels in such close proximity.

When the eye was finally fitted over the after bitts on the SQUAW, the stopper was released on the lowering line and it went overboard from the MANATI. When the load was transferred to the SQUAW it was readily evident that the line had been cut too short and that it was supporting the weight of the clump and anchor at the bottom. The SQUAW heeled to port and trimmed down by the stern. She was left for the night within 20° heading of her position and attitude when picked up in the morning.

The MANATI then headed for San Diego at 1910 arriving at the Crowley pier at about 2300. She came in to pick up the buoys and wire fittings needed for the electronics package subsurface replacement and the spare 10000# anchor along with the 8000 feet of wire that had been shipped by truck from Cheatham Annex. It was found that the reel on which the wire was wound had disintegrated beyond the point where it could be successfully unspooled with the equipment aboard the MANATI so it was decided to leave it on the beach. Departure for the return trip to the site was scheduled for 0100.

7/13/78 - Thursday

The MANATI left the Crowley pier at 0100 on 7/13/78 and returned to the SQUAW site. The coordinates of the sub were 83972 Alta, 109404 Woodson at 0826 with the sub heading 065°. We then proceeded to the crown buoys which were located at 86623, 112901 at 0941. The spherical buoy was brought aboard and at 1041 we moved to the south towing the crown line and getting Mini-Ranger

*See Note 7 on page I-44.

fixes on the MANATI and radar ranges and bearings on the SQUAW. The ranges progressively increased as follows:

Time	Range	Relative Bearing	MANATI Heading	Speed
1041	15422	165	195	2.02 K
1047	17074	161	201	2.85 K
1051	18160	163	198	2.51 K
1055	19048	160	200	2.39 K
1100	19792	165	198	1.41 K
1103	20134	170	184	1.22 K
1105	20134	185	170	0.36 K

We moved south to a point near where the MANATI was when the south anchor was released on 7/1/78 and we picked up enough strain on the crown line to pull the crown buoys under. It was obvious to all that the south anchor was no longer connected to the SQUAW.

Next we moved on up to the SQUAW to get an idea of where the break had occurred by underrunning the wire with a shackle attached to a line to the MANATI. Divers installed the shackle and we barely got underway before the shackle dropped off the end of the stern mooring line. This indicated that there was a break in the line no more than a few hundred feet below the sub.

The question then to be decided was how best to replace the stern mooring line and anchor system. Several possibilities were considered but the final decision was to marry together three of the lengths of polypro-covered 1" wire that had been brought along as backup. This totalled 8700 feet in length to replace the 1 1/4" mooring line. Adequate lengths of chain were on board to make up the 270 feet needed and we had a spare 6000# clump and had the 10000# anchor. We would have to retrieve the crown line to be used for a lowering wire in the same method used previously. This would mean dropping the remaining stern mooring wire length attached to the anchor system as well as the 6000# clump, 6000# anchor, and three shots of chain.

It was possible to get all three lengths of the rubber covered wire on the upper drum of the winch including connecting fittings since this wire would be spooled out under its own weight only. This was completed and then the wire

remaining on the lower drum was dumped overboard. This completed the work on deck for the day.

During the day I took the Mini-Ranger data, radar ranges, and distances and course information supplied by Jack Wilson and computed the tracks of the MANATI and of the SQUAW on the preceding day. These were plotted. Also, from observations of the draft and trim of the sub when she was alongside, calculated the weight distribution on different suppositions regarding the points at which the forward vertical leg was attached. Came to the conclusion that the forward padeye was supporting only the weight of the chain and vertical leg wire and that the bitts aft were supporting the lowering wire and the clump at the bottom. The drafts in this condition are 15.30' fwd, 21.66 ft aft, and 18.75' at LCF. The displacement in this condition is 548.74 tons.

I also became concerned, because of the weight distribution above, as to whether the addition of the weight of the stern mooring line might upend the SQUAW. The results of this calculation were drafts of 13.81 ft fwd, 23.14 ft aft, and 19.11 ft at the LCF with a displacement of 561.01 tons. In this condition there still appears to be sufficient longitudinal stability.

We decided that in the morning I should calculate the amount of 1 1/8" wire per wrap being wound on the winch drum so that when using it as a crown line we could run out 8700 feet to match the catenary of the bow mooring line. This would give us a means of determining position to set the stern anchor.

7/14/78 - Friday

The first operation on the morning of 7/14/78 was to head for the crown buoys to pick up the crown wire. This started at about 0600. The buoys were brought aboard and the crown line was wound on the lower winch drum. Dorin counted the wraps per layer and I calculated the length per layer for each wrap. The 7th layer was spray painted to show where the lowering should stop. The total length checked out fairly well with the calculation.

Next we headed back for the SQUAW to check out the nature of the break in the wire. Divers shackled a lifting line to the bottom of the 45 feet of chain and it was hauled on deck. Then a shackle was fitted around the 1 1/4" vertical leg line and attached to the crown line. The first 90 feet were

hauled aboard by the winch and the remainder was pulled aboard by hand. There was about 220 feet of wire down to the break. The strands were unravelled for several feet back from the break and were flattened near the break. Two strands were broken cleanly and the third had a few wires frayed. It was impossible to tell just what was the cause. Pictures on Roll C.

It was then decided that it would be necessary to take a good look at the bow mooring wire at about the same depth. If a twist had caused the wire to kink and then to break it is probable that the bow wire is also damaged. The question was how to examine the wire since 250 feet is too great a depth to handle in this type of operation. Lawrence decided to have the divers attach a carpenters stopper to the wire at about 100 feet. This would then be lifted on deck and the wire could be examined by divers down to 150 feet more.

While this was going on I made some more calculations on the SQUAW conditions when submerged and the draft and trim anticipated just before tanks are vented. The results of these calculations are given below:

SQUAW Condition When Submerged

	Tons	
Sea Condition	491.77	
Fill tanks 3, 4, 7, & 8	117.88	
Add 360 ft. chain to vertical legs	5.48	
Air to water difference chain on deck -270'	-0.61	
Vertical leg wire	11.30	
Vertical leg chain at bottom -50'	0.76	
Vertical leg fittings	0.50	
Bow mooring wire- 1 1/4" (chain on bottom)	8.43	
Stern mooring wire - 1" (chain on bottom)	5.28	
Less electronics & battery can	-0.45	
Total	640.34	tons weight
Buoyancy (700.66 - 43.65 (tanks 5 & 6)	657.01	tons buoyancy
Net positive buoyancy	16.67	tons buoyancy
Possible variations - weight off by 7.15 tons	9.52	tons buoyancy
Weight off by 7.15 & chain off bottom (5.48 tons)	4.04	tons buoyancy

SQUAW Condition in Moor Just Before Venting Tanks

	Tons	LCG
Sea condition	491.77	- 0.88
Aft vertical leg	21.47	-40.00
Fwd vertical leg	21.47	36.00
250' of 1 1/4" wire on clump	0.25	36.00
Bow mooring wire + chain	11.17	71.30
Stern mooring wire + chain	8.02	-63.30
Air to water diff of 270' chain	-0.61	0.0
Less electronics & battery can	-0.45	0
	553.09	- 0.399

Mean draft	18.88'
Trim down by head	2.04'
Draft fwd	19.98'
Draft aft	17.94'

The submerged condition indicates adequate reserve buoyancy to support the SQUAW at depth even if the light ship weight used is in error or if the moor is taut enough to pick all the chain off the bottom or both. The surface condition given next was prepared in chart form for Asher to check out the submarine before opening the vents on tanks 3, 4, 7, & 8.

The efforts to put a stopper on the bow mooring line wire at 100 feet were unsuccessful so any possible break could not be examined by divers. They did, however, go down to 160 feet and found no indication of damage. A weighted shackle was then fitted around the wire and attached to a light nylon line. From the deck of the MANATI this line was payed out to 400 or 500 feet and run up and down the mooring line. There was no evidence of any kink or any broken wires sticking out from the mooring line. Since there was no other way to examine the mooring wire, this would have to be considered adequate.

It was decided to go ahead with the mooring operations in the morning. As a first step the SQUAW would be pulled down from the north anchor to see if a lead off angle developed at the bow. This would indicate that the line was falling into its design catenary and that there was no hang-up of vertical legs on the mooring line.

7/15/78 - Saturday

On the morning of 7/15/78 at 0600 we proceeded to the SQUAW position to make the hookup. At this point she was hanging 2700 feet downsea (ESE) of the estimated north anchor point with her stern upsea. The new coated 1" line was shackled to the bow mooring chain but this was paralleled with a length of rope that was meant to take the load as we pulled out the bow mooring line to make a further test on whether it was damaged.

The MANATI started pulling at 0910 heading south. At 0927, after towing for about 600 feet/ the rope parted. The strain was then taken on the 1" wire. In order to keep the lead-off angle to a minimum the MANATI circled 180° around the sub to a point 1800 feet WNW of it. The course was then changed to head south when the MANATI was 1000 feet SE of the estimated north anchor position at 1144. The MANATI then proceeded south along the pre-established mooring line. At 1323 it had reached the target position for the sub when in the moor. This would indicate a full 6000 foot extension of the north mooring line but there was still no lead angle on the chain off the bow. However, there was no doubt that we had a bow anchor in position and that the mooring line was holding its design load. But at this point the sub was still perpendicular to the line of tow so it was towed broadside. Pulling was then slacked off and the MANATI was gradually pulled to the north by the sub and the north anchor.

Satisfied that we had a north mooring line in reasonably good condition, the 1" wire was payed out to the end of its 8700 feet and the 180 foot length of chain attached and stoppered off. By the time this was done the MANATI was 4500 feet to the southwest of the sub which, in turn, was at about its earlier position 2700 feet ESE of the north anchor.

Pulling started at 1401 with the CONTENDER at the bow of the MANATI to control heading. The MANATI then was 2800' NNW of the latest established implantment target point for the SQUAW. At this time the SQUAW was 6000' NNE of the target point. The MANATI swung around to the west following roughly a 5000' radius circle around the sub target point. It was planned to move it along a course that would cross the south anchor target position 6000' south of the SQUAW target point. However, before this point was reached a decision was made to release the tug from the MANATI and send it up to pull

the stern of the SQUAW around since the sub was still broadside to its line of travel. The MANATI increased turns to take over the full load but put on full left rudder. This was the opposite of the required control actuation as explained on page I-39.

Instead of continuing in the same direction the MANATI moved to its starboard, due west, some 3500 feet. It was finally brought back under control when the tug was reattached to the bow and movement in a southwesterly direction resumed. Meanwhile the sub, still broadside, continued following a course that would have brought it about 1500 feet west of its target position.

In the meantime divers Mark and John had been observing the SQUAW both from the ZODIAC and on deck of the SQUAW. They continually checked on the angle of the chain at the bow and on the attitude of the sub. Throughout this tow she remained broadside and there was no lead angle on the bow. As previously noted the sub was trimmed well down by the stern which was attributed to the weight of the forward vertical leg hanging on the after port bitts. The divers also reported hearing a pronounced rubbing or scraping noise in the bow mooring line and the chain was vibrating to the extent that a backed off shackle pin nut would vibrate its way back into position. The divers returned to the MANATI at about the time the tug was released, around 1630.

When the tug was reattached to the bow of the MANATI at 1730, Dick Asher accompanied the divers back up to the SQUAW to investigate the vibration in the bow mooring chain and to look at the lead angle. When they arrived at the SQUAW she had swung around headed north, the vibration had stopped, and she had developed a slight (15°) lead angle of the mooring chain off the bow.

During this period the MANATI and tug continued pulling to the south. The course made good by the MANATI averaged 180° with the SQUAW continuing to track along sluggishly on a 225° course. At 1927 the MANATI seemed to hang up on the towline (still the 1" wire of the stern mooring leg) and swung on the end of the line to the east about 750 feet; the SQUAW followed suit. Then at 1944 the whole system started to move more easily. The MANATI course made good changed to about 145° and the sub moved directly south about 1000 feet west of its target position. At 2005 the towline pull was reduced with both the tug and the MANATI dropping to idling speed on the engines to maintain

headway while the anchor (10000# Navy stockless) was dropped over and paying out of the 1 1/8" crown line began. The idea was to run out 8700 feet of crown line to lower the anchor to the bottom while moving the MANATI to the south. When the 8700 feet was out and the crown line under tension, the anchor should be just above the bottom and would be dropped. The ZODIAC was ordered back to the MANATI.

It was assumed that the north anchor had been dragged about 1000 feet south during the breakaway period between 1944 and 2013 so a new south anchor position was selected at 12000 feet south of the north anchor position. By the time the anchor planting run started at 2144 the MANATI was about 1000 feet south of the target anchor position and the SQUAW was 13000 feet north of the MANATI. This run went about as planned with the MANATI making good a course of 180° and the SQUAW doing the same. The run was terminated at 2228 and the anchor dropped to the bottom.

The MANATI then released the tug CONTENDER as the MANATI was being dragged back to the north by the catenary in the 1 1/8" crown line. The crown line was then reeled in as we backed to the north toward the anchor point in an attempt to recover as much of the line as possible. When the MANATI was judged to be above the south anchor point the crown line was burned off and 7000 feet or more dropped to the bottom.

Mini-Ranger coordinates of the MANATI were 088178 Alta, 114539 Woodson at 2228 when the anchor was dropped; 087344 Alta, 113892 Woodson at 2300 when the crown line was cut; and 085188 Alta, 111282 Woodson at 2315 when the MANATI pulled up alongside the SQUAW. This completed the work on 7/15/78 with sub in a moor.

7/16/78 - Sunday

On the morning of 7/16/78 the swell and wind waves had picked up considerably making it impossible to do any work. At 0717 the position of the SQUAW was obtained and it had moved only 800 feet to the east indicating that the moor was holding. However, she was still trimmed well down by the stern, more so than the day before, since the entire vertical force of the stern mooring line was now applied in addition to the after vertical leg on the padeye and the foward counterweight supported on the stern bitts. Although

drafts were difficult to judge in the seas that were running, it looked like the calculation made on 7/13 (p. I-30) where the trim was 9.33 feet was about right.

This was an obvious "weather day" and it was also felt necessary to go back to San Diego to get additional gear to cope with the removal of the weight of the forward vertical leg clump from the stern bitts. We therefore got underway and arrived in San Diego around noon. Shortly after arrival, Earl Lawrence received a call from the CONTENDER saying that on their last pass by the SQUAW it had come up to practically an even keel attitude and that you could now walk along the entire deck.

It sounded as if some twisted cable had become untwisted somewhere down in the moor with a resulting weight transfer that had taken the trim off the boat.* This might have been wishful thinking but it also could be rationalized as a change in luck which up to this point had been all bad. Plans were changed to get back out in the early morning to continue work, weather permitting. The CONTENDER was asked to check the lead angle of the bow and stern chains and also to look at the draft marks amidships. They reported the bow chain angling off to port and the stern chain angling off to starboard but the heading was still generally a north-south orientation. Draft marks on the starboard side read about 19 feet but were difficult to estimate because of the weather. Lawrence arranged to contact them again at 2200 to get an update on both the SQUAW condition and the weather. If the weather looked favorable we would depart again for the site at 0400. This proved to be the case and the departure time was set for that hour in the morning.

7/17/78 - Monday

Departure on 7/17/78 was at 0430 and we arrived at the site at 0850. A Mini-Ranger fix was taken on the SQUAW and it was found that she had moved only a few hundred feet overnight. Her heading was still about 000. The attitude was not quite as level as had been indicated by the CONTENDER. She was still down by the stern and heeled to port. However, it did look better than the day before. Although the seas were quite calm it was extremely difficult to get any reliable draft measurement in this condition. In the north-south orientation she was rolling somewhat in the trough of the swell and with the port list and wave motion at bow and stern any draft estimates were only

* See Note 8 on page I-45.

accurate within ± one foot which was not good enough to make displacement calculations that could be depended upon. Primarily from the changed attitude we assumed that both vertical legs were in place but that the weight of the forward leg was still carried on the after bitts.

Prior to cutting the 1 1/4" lowering line for the forward vertical leg off the after bitts, the divers went down to secure a carpenter stopper on the line about 100 feet below the surface. They went aboard the sub with a burning torch and proceeded to cut the wire just outboard of the bitt to which it was secured. When the wire was cut through and dropped, the line from the MANATI to the carpenter stopper went slack almost immediately indicating a break. The sub gradually trimmed up to an even keel condition and the list to port came off to be replaced by a slight list to starboard.

About 15 minutes later, Asher started taking Mini-Ranger fixes on the SQUAW position when the MANATI was directly alongside. At 1215 it had fallen 2000 feet south of the 0850 fix. The trend continued to a distance of about 2500 feet south where the position again stabilized. This position held for as long as we stayed with the sub. At 1445 the fix on the sub with the Mini-Ranger was 085950 Alta, 111888 Woodson.*

Although drafts still could not be read accurately I concluded the the sub was in the moor and that the counterweights were in place. The drop back in position mentioned above was obviously due to the removal of a weighted down lifting line from around the mooring line which had restrained it from assuming a normal catenary. When the restraint was released the line formed a catenary lifting about 2500 feet off the bottom which would account for the movement to the south. Although the sub was obviously in a very light, slack moor it was decided to go ahead with the sinking operation.

Dorin and Asher, along with three divers, went aboard the sub and started deploying the depth marker buoy strings. The buoys and line for use in lowering the electronics package were connected to the sub and the buoys rolled overboard. The sub was marked to indicate the electronics package target location. Fore and aft freeboards were read and measured as well as possible and radioed to me aboard the MANATI. The freeboard forward was estimated at 5'-2" and aft 3'-6". This indicated a mean draft considerably less than the 18.88 feet

*See Note 9 on page I-45.

derived on page 30, e.g., 18.50 feet. However, since everything else seemed all right the choice was made to go ahead with the venting of the tanks which Asher and Dorin proceeded to do. Also the valves on tanks 1, 2, 9, & 10 were opened to the sea.

With the venting of ballast tanks 3, 4, 7, & 8 the SQUAW gradually settled down. Air came out of the vent valves with a blast at first but venting slowly came to a halt well before the pressure hull and ballast tanks went under. The valve covers were taken off the 6" blow valves on all four tanks and the valves opened but still no further venting could be detected. Obviously the SQUAW was not carrying enough weight to sink her.

The depth measuring floats were recovered, the buoys and lines for electronics package lowering were recovered and hauled back about the MANATI. An attempt was made to blow the ballast tanks before leaving but the air hose on board the MANATI was not long enough to reach the SQUAW. Asher made a careful measurement of the freeboard at the bow, and the waterline at the after end of the ballast tanks was estimated both from aboard the MANATI and aboard the SQUAW.

On the return trip to San Diego I calculated the additional weight that would be required to sink the SQUAW based upon the final draft measurements. Results are as follows:

Mean draft = 20.76 feet	
Displacement of entire hull at this draft	= 663.50 tons
Buoyancy of entire hull submerged	= 700.66 tons
Difference	= 37.16 tons
Additional ballast to fill tanks	= 9.67 tons
Additional weight required to sink	= 27.49 tons

The vertical leg clumps' weight is 12.45 tons each and the total weight of each leg is 21.47 tons. The indication is that both vertical leg clumps are missing and probably the fittings and wire are lost as well. Since the moor is quite loose there is probably a good part of the two mooring lines as well as all of the 360 feet of mooring chain lying on the bottom which would account for the loss of additional weight required for sinking the SQUAW. This information was passed on to Earl Lawrence when the MANATI arrived in San Diego.

SQUAW MOOR JOURNAL

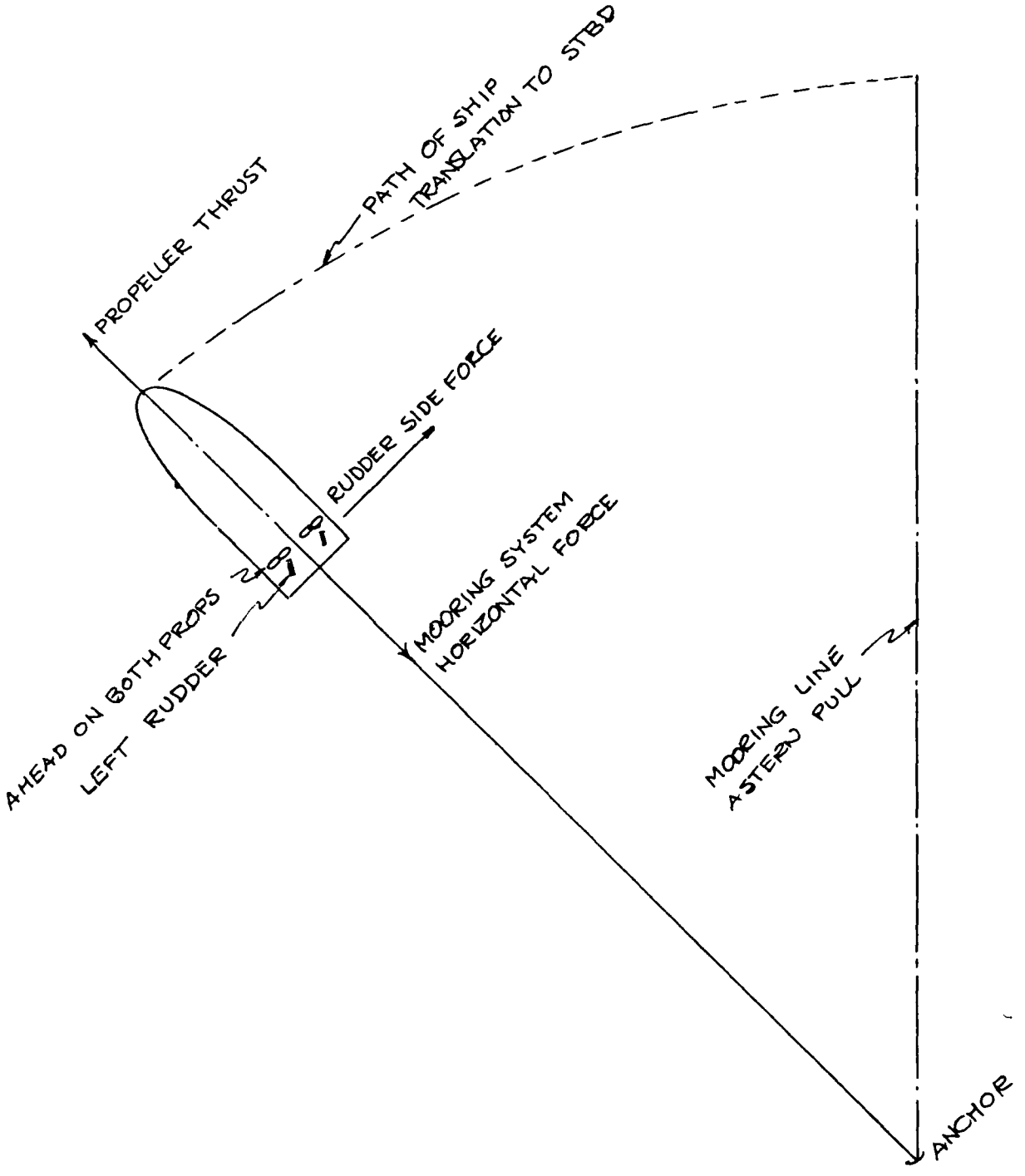
Ship Handling Problems - MANATI

Note 1.

On 6/28/78 at 1615, while the acoustic release system was being checked, without any notice to the people on deck the MANATI suddenly accelerated to a speed in excess of 10 knots. At this point both the NAVFAC and the IEC AMF acoustic release transducers and the fathometer transducer were in the water. The IEC and fathometer transducers were mounted on pipes and the NAVFAC transducer was suspended on a line. Both of the transducer support pipes were bent about 45° by the sudden relative water motion but these transducers were not apparently damaged. The NAVFAC acoustic release transducer was damaged to an extent that could not be repaired aboard ship. There were a number of other instances with lines over the stern and when people were working on deck when unannounced ship maneuvers caused drastic movements of wire, equipment, and personnel. Such actions constituted a severe safety hazard throughout the operation as well as the equipment damage noted above.

Note 2.

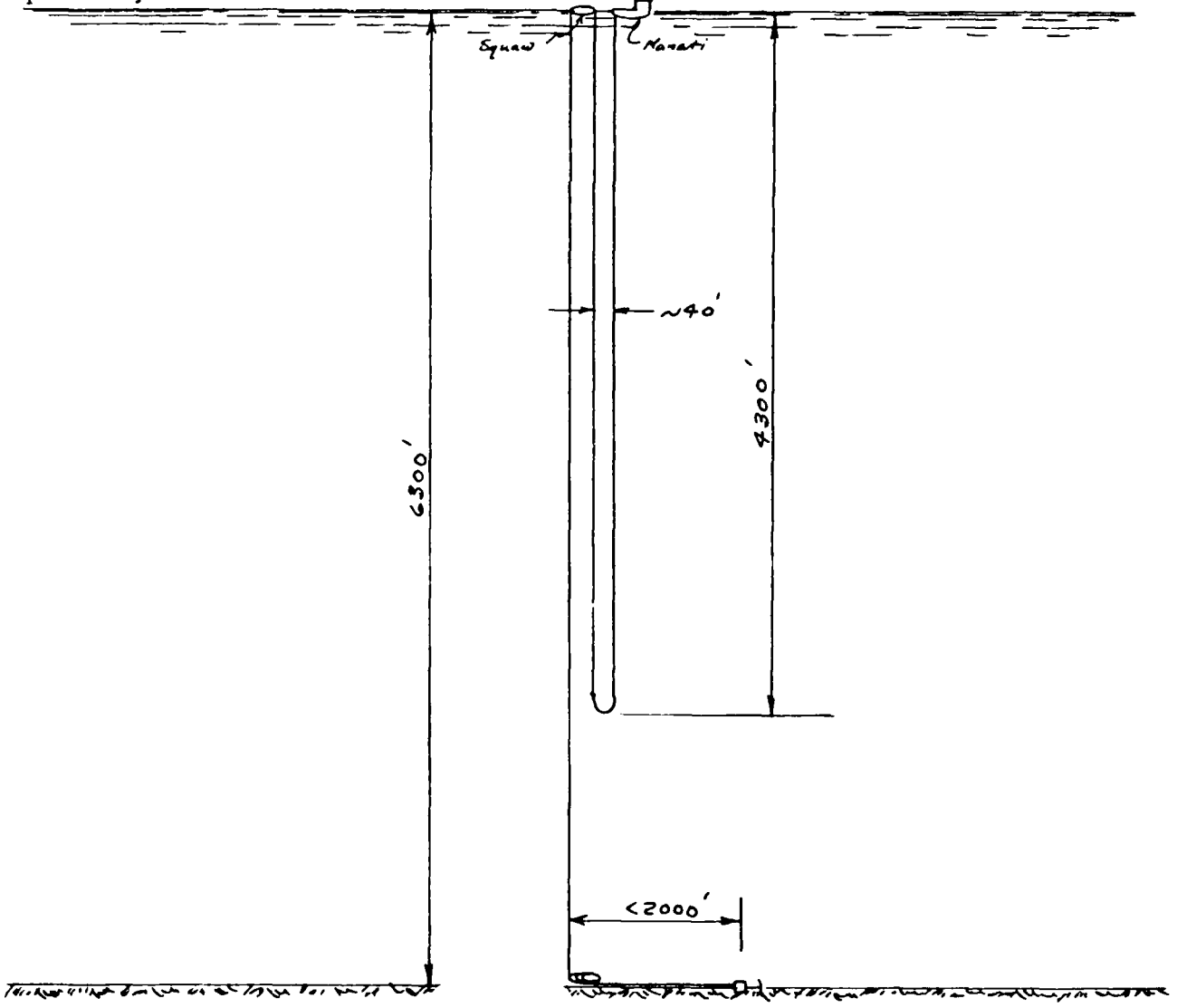
The control of maneuvers when the MANATI was connected to the bottom through the SQUAW mooring system left something to be desired. The tug CHALLENGER was called upon to tow the MANATI on several occasions when it was really not necessary. Furthermore, the resulting movements of the system were not well controlled resulting in anchor movements to unplanned locations. When attempting to pull out an anchor line catenary the tendency was to try to rotate the MANATI to a desired heading by using the engines - one prop ahead and the other reversed. This applies a minimal torque to the hull which is opposed by the athwartships component of the mooring line pull times the distance between the propellers and the point of attachment of the mooring lines. The mooring line force wins every time. Actually the way such an operation should be conducted is to run the two screws of the MANATI ahead to apply an ahead thrust and to swing the rudders to apply a side force acting in the direction of desired movement. This rudder motion is the opposite of what would be used to head the MANATI toward the target. This is illustrated in the following diagram of a typical moor towing situation.


PROPELLER THRUST
PATH OF SHIP TRANSLATION TO STBD
RUDDER SIDE FORCE
MOORING SYSTEM HORIZONTAL FORCE
AHEAD ON BOTH PROPS
LEFT RUDDER
MOORING LINE ASTERN PULL
ANCHOR

Ship Handling Problems - MANATI (Cont'd)

Note 3.

On the evening of 6/29/78 the SQUAW was between the MANATI and the place where we estimated the north anchor to be. From all later observations this estimate seemed reasonably accurate. At dark the SQUAW was well to the southeast of the anchor point and the MANATI was well to the southeast of the SQUAW. Between the SQUAW and the anchor point was 45 feet of chain, 8570 feet of wire rope, and 180 feet of chain. Between the MANATI and the SQUAW was 8570 feet of wire rope plus 45 feet of chain. The water depth was 6300 feet. On the morning of 6/30/78 the SQUAW was just off the starboard beam of the MANATI and both vessels were within 2000 feet of the estimated anchor position. The proximity of the vessels and anchor is shown in the sketch below.



Ship Handling Problems - MANATI (Cont'd.)

Note 3. (Cont'd.)

When two lines are suspended from the surface about 40 feet apart and hang down more than 4000 feet the chances of the wires intertwining is far from remote. It is highly probable that the night of 6/29/78 and the morning of 6/30/78 was the period during which the bow and stern mooring lines crossed; or it could have happened when the MANATI got underway in the morning.

From the time the stern mooring wire was payed out until the MANATI got underway in the morning the bow and stern mooring lines should have been stretched out by the MANATI running on one engine - at idling speed - and maintaining a downsea heading of 135°. Had this been done there would have been no twisting of the bow and stern mooring lines which apparently led to the loss of the stern line on the night of 1 July after the two lines had been pulled out to maximum tension.

Interaction Between Lines

Note 4.

When the MANATI departed the site on 7/1/78, at 1400 the positions of the north and south anchor points had been carefully estimated as had been the position of the SQUAW when the crown line to the south anchor had been buoyed off. The MANATI then went up alongside the SQUAW and, at 1520 got a fix on her position which was only 600 feet from where the SQUAW had been spotted by radar. On the morning of 7/2/78, upon return to the site, the SQUAW was 3500 feet north of the positions of the day before. A number of fixes were taken during 7/2/78 and 7/3/78 with the following results.

Interaction Between Lines (Cont'd.)

Note 4. (Con'td.)

Measurement No.	Date	Distance in Feet from Anchors North	South	Total Distance
1	7/2 & 7/3	3589	10216	13805
2		3571	10093	13664
3		3279	9537	12816
4		4197	8434	12631
5		4316	7915	12231
6		4848	7758	12606
7		5530	7001	12531
8		6045	6452	12497
9	7/1/78 in Moor	6242	6132	12374

The design horizontal distance between anchors was 12000 feet and any situation where the distance from sub to anchor exceeds 6100 feet would be impossible with the amount of wire out and a 6300 foot water depth. Thus, while it was evident that the north anchor had pulled somewhat south of its estimated position, there was no way in which the SQUAW and the south anchor could be connected. This was reported to Earl Lawrence on 7/2/78 and it was conjectured that the wires were indeed crossed on the night of 6/29/78 - 6/30/78 and that the pulling on 6/30/78 and 7/1/78 had been sufficient to cause a break in the stern mooring wire.

Note 5.

At the time the after vertical leg free-fell down into position, the SQUAW was headed downsea away from the north anchor estimated position and about 1800 feet from it. This meant that the forward mooring line dropped directly to the bottom and ran along the bottom to the anchor. In this condition the after vertical leg would have cleared the mooring line unless it overshot a point directly below the sub as it fell which is unlikely. However, the SQUAW then moved downsea to a point 3500 feet from the anchor and more to the east of it while at the same time changing its heading 180° toward the north

Interaction Between Lines (Cont'd.)

Note 5. (Con'd.)

anchor. At this distance the majority of the line would be picked up off the bottom and as it lifted and the sub turned counterclockwise it is possible that the bow mooring line could have made a 180° counterclockwise turn around the after vertical leg.

Note 6.

At this point on 7/12/78 with the sub swinging on the bow moor to the north anchor with the after vertical leg below her she was about 3000 feet from the north anchor with the mooring line running below the sub. If the sub had continued to turn counterclockwise after being left the night before, the bow mooring line could have made a full 360° turn around the after vertical leg. Thus, there is a fairly good chance that when the implantment of the forward vertical leg started, the forward mooring line and the after vertical leg were already intertwined.

Note 7.

After the vertical leg chain and wire were attached to the forward pad-eye chain on the SQUAW, the MANATI moored to the ESE crossing the bow of the sub from starboard to port. At this point the sub was headed ESE and was 4300 feet from the estimated north anchor point; this would be sufficient to lift most of the forward mooring line off the bottom so that it would be higher than the after vertical leg clump. While paying out the forward vertical leg wire the MANATI swung north when it was 2000 feet east of the SQUAW and shortly after the sub made a rapid counterclockwise turn to the north. This would have caused the bow mooring line to make another half turn around the after vertical leg for a possible total of 540° around it. As the MANATI continued to swing counterclockwise around the SQUAW attempting to unwrap the forward vertical leg and to get on the port side of sub for lowering the leg the sub continued to track around always heading for the MANATI. The SQUAW distance from the estimated north anchor point varied from 2500 to 4500 feet so that the bow mooring wire would always have been well off the bottom beneath the sub. At one point the MANATI was 2700 feet due south of the sub and the sub was headed 180°. By this time the wrapping of the bow mooring line around the after vertical leg

Interaction Between Lines (Cont'd.)

Note 7. (Cont'd.)

could have been as much as two complete turns, i.e., 720°. This would have backed off about 180° again as the MANATI turned and headed NNW toward the anchor point. When the CONTENDER was secured to the bow of the SQUAW and headed her to the north the MANATI was 2000 feet due west of the sub when the lowering wire was let out. As the MANATI approached the sub to secure the end of the lowering wire to the after bitts the SQUAW again rotated more than 180° counterclockwise so that, at the time the forward vertical leg clump was dropped, there was a possible 720° + wrapping of the bow mooring wire around the after vertical leg. The forward vertical leg was then dropped into this mess of wires and weights. Note that at this time the trim of the sub indicated that both vertical leg clumps were supported well aft on the sub, probably at the after vertical leg padeye and on the after bitts.

Note 8.

In retrospect this is probably the point in time when the after vertical leg parted and the sub was relieved of the weight of the 28000 pound clump.

Note 9.

The above loss of the after leg clump still did not apparently relieve the downward loading on the bow mooring line that would permit it to assume a normal catenary. The indication is that the lowering line secured to the after bitts passed around the bow mooring line on its path downward to the forward vertical leg clump. When the lowering line was cut off from the bitts it was thought that the load on the bow mooring line was relieved and that the clump weight was transferred to the forward vertical leg wire. It now appears that the vertical leg support had parted sometime previously and that, when the lowering line was burned off, the line and clump went to the bottom. The probability is that at this point, i.e., noon on 7/17/78 we had lost both vertical leg clumps and were being held in a very slack moor by a badly damaged bow mooring line.

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