Development of the Cable-Controlled Underwater Recovery Vehicle System for Deep Operations (CURV III)

In the collection of the
U.S. Naval Undersea Museum

NUM.2019.013.012

UNITED STATES NAVAL
UNDERSEA
MUSEUM

NUC TN 707

NAVAL UNDERSEA RESEARCH AND DEVELOPMENT CENTER
San Diego, California

April 1972

DEVELOPMENT OF THE CABLE-CONTROLLED UNDERWATER RECOVERY VEHICLE SYSTEM FOR DEEP OPERATIONS (CURV III)

NOSC
72-01

NUC TN 707

NAVAL UNDERSEA RESEARCH AND DEVELOPMENT CENTER
San Diego, California

April 1972

DEVELOPMENT OF THE CABLE-CONTROLLED UNDERWATER RECOVERY VEHICLE SYSTEM FOR DEEP OPERATIONS (CURV III)

ABSTRACT

This report reviews the development of the Cable-controlled Underwater Recovery Vehicle deep operating system (CURV III), an advance in the state-of-the-art of operational unmanned systems. The primary development problem was attaining a depth capability of 7,000 feet, an increase of 4,500 feet over the capabilities of the predecessor CURV I and II systems. Major discussions cover the development need, major problems and design solutions, component development and testing, system checkout, and the CURV III operations that served as technical and operational evaluations.

The development was divided into three periods designated CURV IIIA, B, and C, based on major changes in the underwater vehicle portion of the system. A general description of the system and operating techniques of the final vehicle version, CURV IIIC, is included in the text. A detailed description and drawing list are supplied in the appendixes.

An assessment of vehicle performance and capabilities and the contribution to ocean technology that the CURV III development represents are also provided.

FOREWORD

The CURV III development was undertaken by the Naval Undersea Research and Development Center (NUC) in Fiscal Year 1967 under the sponsorship of the Naval Ordnance Systems Command (Task ORD 03C-203/200-1 F108-01-36). The development was also supported by the Naval Ships System Command's Deep Ocean Technology Project and the Office of the Supervisor of Salvage (Ships 00C). This report of the CURV III development and the recovery and underwater range work operations that constituted its technical and operational evaluations was prepared under CNM DLP Element No. 65801N, Task Area ZF099-02-03, FY 71. It documents the successful completion of the CURV III system development.

CURV III

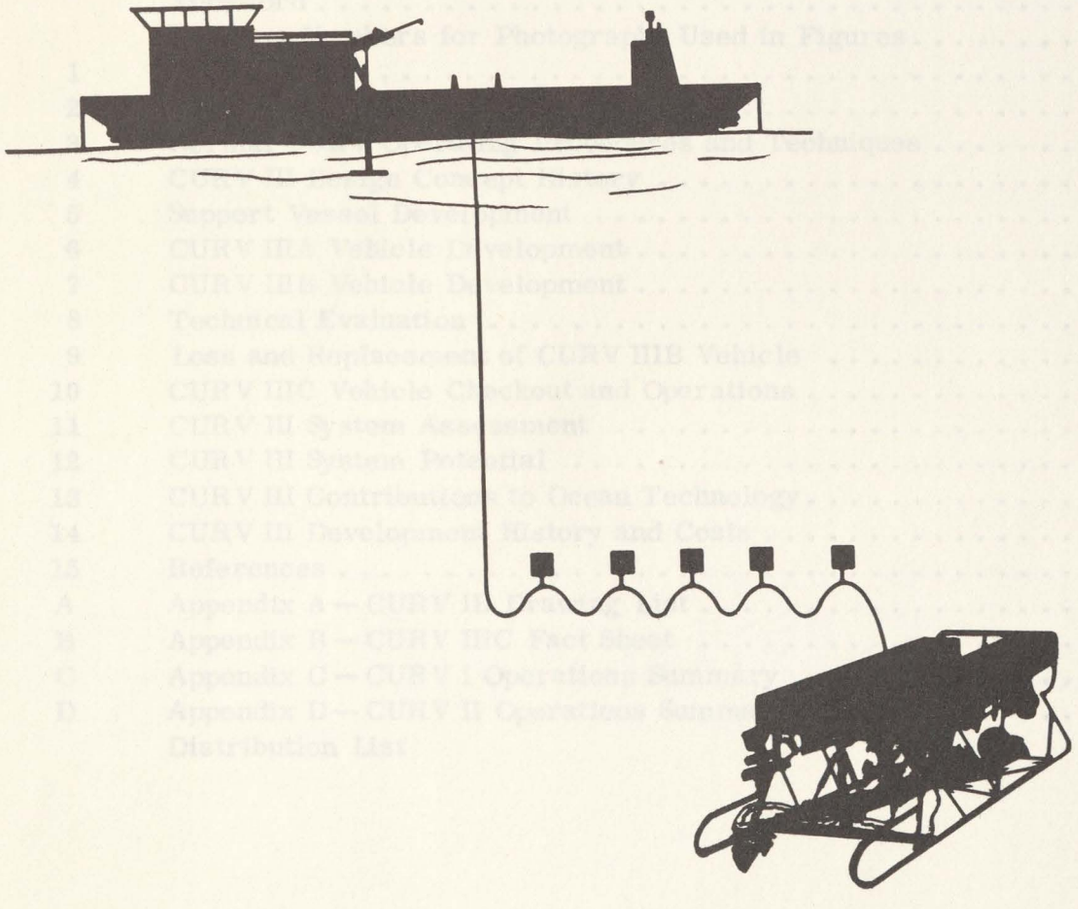


TABLE OF CONTENTS

Section	Title	Page
	Abstract	ii
	Foreword	iii
	Negative Numbers for Photographs Used in Figures	vi
1	Introduction	1-1
2	CURV IIIC System Description	2-1
3	Normal CURV Operating Procedures and Techniques	3-1
4	CURV III Design Concept History	4-1
5	Support Vessel Development	5-1
6	CURV IIIA Vehicle Development	6-1
7	CURV IIIB Vehicle Development	7-1
8	Technical Evaluation	8-1
9	Loss and Replacement of CURV IIIB Vehicle	9-1
10	CURV IIIC Vehicle Checkout and Operations	10-1
11	CURV III System Assessment	11-1
12	CURV III System Potential	12-1
13	CURV III Contributions to Ocean Technology	13-1
14	CURV III Development History and Costs	14-1
15	References	15-1
A	Appendix A — CURV III Drawing List	A-1
B	Appendix B — CURV IIIC Fact Sheet	B-1
C	Appendix C — CURV I Operations Summary	C-1
D	Appendix D — CURV II Operations Summary	D-1
	Distribution List	

NEGATIVE NUMBERS FOR PHOTOGRAPHS USED IN FIGURES

Fig. 2-3	LHM 6174-11-71
Fig. 2-4	LHM 6172-11-71
Fig. 2-5	LHM 6183-11-71
Fig. 2-6	LHM 6182-11-71
Fig. 2-7	LHM 6184-11-71
Fig. 2-8	LHM 6179-11-71
Fig. 2-9	LHM 34523-8-3-70
Fig. 2-10	LHM 34523-6-3-70
Fig. 2-11	LHM 6185-11-71
Fig. 2-12	LHM 34521-11-3-70
Fig. 2-13	LHM 6176-11-71
Fig. 2-14	LHM 6188-11-71
Fig. 2-15	LHM 6189-11-71
Fig. 2-16	LHM 6198-11-71
Fig. 2-17	LHM 6194-11-71
Fig. 2-18	LHM 6190-11-71
Fig. 2-19	LHM 6171-11-71
Fig. 2-20	NONE
Fig. 3-1	LHM 34034-26-6-69
Fig. 3-2	LHM 6191-11-71
Fig. 3-3	LHM 34034-24-6-69
Fig. 5-1	LHM 29741-8-8-68
Fig. 5-2	LHM 29741-29-8-68
Fig. 6-1	LHL-P 28660-4
Fig. 6-2	LHM 29808-12-9-68
Fig. 6-3	LHM 29808-5-9-68
Fig. 6-4	LHM 28929-2-12-67
Fig. 6-5	LHM 29734-10-8-68
Fig. 6-7	LHM 34523-8-3-70
Fig. 6-8	LHM 6178-11-71
Fig. 6-9	LHM 29842-1-10-68
Fig. 6-10	LHM 29842-8-10-68
Fig. 6-13	LHL-P 31074-3-9-69
Fig. 6-14	LHL-P 31058-1-7-69
Fig. 6-15	LBPL 29462-1-8-69
Fig. 6-16	LBPL 29462-4-8-69
Fig. 7-1	LHM 34743-2-11-70
Fig. 7-3	LHM 34511-3
Fig. 8-2	LHM 34521-30-3-70
Fig. 8-7	NONE
Fig. 9-1	LHM 6177-11-71
Fig. 9-2	LHM 6188-11-71

SECTION 1

INTRODUCTION

Section 1

TABLE OF CONTENTS

Section	Title	Page
1.1	CURV III Development Designations	1-1
1.1.1	CURV IIIA	1-1
1.1.2	CURV IIIB	1-2
1.1.3	CURV IIIC	1-2
1.2	Background	1-2
1.2.1	Need for CURV III	1-3
1.2.2	Development Plan	1-4
1.3	Funding	1-5

LIST OF FIGURES AND TABLES

Figure	Title	Page
1-1	CURV Program Summary	1-7

Table	Title	Page
1-1	CURV III Funding	1-9

Section 1

INTRODUCTION

The Cable-controlled Underwater Recovery Vehicle deep operating system (CURV III) is an engineering prototype model unmanned submersible system capable of performing small object recovery and other light work tasks such as bottom survey, equipment inspection, attaching or cutting line and cables, etc.

CURV III features the ability to provide an operator sitting at a surface console an extensive range of sensory and mechanical capabilities to a depth of 7,000 feet. The basic system includes a surface support vessel, control console, cable link, and underwater vehicle. The vehicle sensors include two black and white television cameras, a 35 mm color camera, lights, and active and passive sonar. It carries a six-function tool drive assembly that can be fitted with grasping claws, cable cutters, grapnels and a variety of other tools. The vehicle is propelled by three electrical motors and is kept at a slight positive buoyancy to enable sensitive maneuvering. A more complete description of a CURV III system is given in Section 2.

CURV III was developed primarily to provide recovery services for Navy underwater test ranges, but its versatility enables many types of work at virtually any accessible water area in the world.

1.1 CURV III DEVELOPMENT DESIGNATIONS

The CURV III development reported in this document has been completed successfully and the system is operational. For convenience of reference, the development has been divided into three periods, CURV IIIA, CURV IIIB, CURV IIIC. The basis of the use of these terms is explained below. Where no designation is used, the reference is to events or plans pertaining to the entire development, or to support components unchanged in the three periods, e.g., the CURV III support vessel.

1.1.1 CURV IIIA — CURV IIIA is used to refer to the vehicle and system design and development efforts prior to the first deep depth checkout in August 1968.

1.1.2 CURV IIIB — CURV IIIB refers to the system after redesign of the vehicle and replacement of damaged components. This system operated successfully in deep recovery operations which served as the system Technical Evaluation and are reported in Section 8. CURV IIIB was lost in heavy seas in October 1970 during a bottom search operation described in Section 9.

1.1.3 CURV IIIC — CURV IIIC refers to the system after a complete replacement of the lost vehicle. This system has conducted the most complex CURV tasks to date. It is the system used for the descriptions given in the text and appendixes.

1.2 BACKGROUND

The Cable-controlled Underwater Recovery Vehicle (CURV) program at the Naval Undersea Research and Development Center (NUC) was organized to develop unmanned systems for the specific range task of recovering test ordnance at NUC's Long Beach and San Clemente Island (SCI) test ranges. The first fully-operational CURV system, now referred to as CURV I, was developed to meet these range needs. This system made many successful recoveries at NUC ranges within its designed depth capability of 2,000 feet.

When the H-bomb was lost in the Mediterranean off Palomares, Spain in April 1966, CURV I was modified for a deeper capability and participated in the salvage operations, making the final recovery of the H-bomb from 2,850 feet. This successful recovery demonstrated the versatility and potential of unmanned systems, and a project to develop a CURV system with a deeper capability was undertaken.

Within the course of the planning for the deeper CURV system, it became evident that the existing CURV I system would not be able to continue meeting NUC range needs for the length of time required to complete development of a deeper system, due to normal component wear and reliability problems. It was therefore decided to undertake two new CURV projects — fabrication of a CURV II vehicle for 2,500-foot depths and development of a new CURV III system for deeper depths.

The CURV II vehicle was to retain most of the design features of the CURV I vehicle, with modifications as necessary to improve reliability and replace inadequate components. Portions of the CURV I vehicle were to be "cannibalized" wherever possible and the same cable support gear and support vessel were to be used. No increase in vehicle performance was planned other than the additional 500-foot depth.

CURV III was to be an entirely new system utilizing the successful concepts of CURV I wherever possible, but designed for depths in excess of 6,000 feet. Accounts of the CURV III development need, plan and funding, and a brief description of the CURV program are given below to provide further background to the details of the CURV III development.

1.2.1 NEED FOR CURV III — The need for a recovery system with depth capabilities exceeding the depths of NUC ranges was established by Specific Operational Requirement (SOR) 46-16 (Ref. 1) which appeared in 1964, when CURV I was already in development. Although this SOR specifically called for manned systems, it established small object recovery needs to 20,000 foot depths.

Definite need for a self-propelled, maneuverable, and economical recovery system such as CURV also existed at Navy Ordnance test ranges other than SCI and Long Beach, including the Atlantic Underwater Test and Evaluation Center (AUTEC) range; St. Croix, Puerto Rico Range; and Naval Torpedo Station, Keyport ranges. The depth at St. Croix, the deepest of these ranges, exceeded 6,000 feet. The trend on all ranges was to deeper testing.

The maximum depth on NUC ranges was 4,500 feet and projected test plans indicated a future need for recovery from these depths, which neither CURV I nor the planned CURV II system could meet.

Other existing recovery equipment at the Navy ranges were limited to surface vessels, divers at relatively shallow depths, or complicated moored attachment devices which were not self-propelled and required long periods of set-up and adjustment before recovery could be effected.

An unmanned system was considered suitable to meet these needs for the following reasons:

1. Relative economy of development in time and equipment cost when compared with manned systems.
2. Unlimited operational endurance on-site by virtue of the cable link to the surface.
3. Ability to perform in hazardous or dangerous areas without endangering personnel.
4. Ability to change or modify all system components to meet individual task or range needs without affecting system safety or certification stature.

5. Demonstration by CURV I of sensor information and control sensitivity comparable to manned systems.

1.2.2 DEVELOPMENT PLAN — The CURV III development was based on extending the CURV I capabilities to meet NUC needs, other Navy range needs and the SOR 20,000-foot small object recovery requirement. The CURV III development was viewed as an applied research task with an operative engineering prototype model as the development goal. (See Ref. 2).

1.2.2.1 OPERATIONAL OBJECTIVES — The CURV III goal was at first 6,000 feet and was changed early in the project to a 7,000-foot capability. This depth was chosen as an intermediate step attainable in a short term development. CURV III was planned as one project in a program that would extend the CURV I capability to 20,000 feet; at the same time that the depth was being increased, it was planned to investigate advanced concepts to broaden the work capabilities of CURV I. The operational objectives for CURV III were derived from CURV I performance: unaided recovery of a cylindrical, 12-3/4-inch diameter ordnance item with an in-water weight of less than 200 pounds; and recovery of larger/heavier objects by utilizing a surface support vessel to assist the lift.

In order to expedite development, the immediate goal for CURV III target location capabilities was limited to cooperative targets, i.e., objects equipped with pingers, marked by buoys, or plotted with accurate surface reference. This limitation was necessary because of the undeveloped state-of-the-art of accurate, economical underwater locating devices for depths to 7,000-feet. The objective of locating uncooperative targets within a 1 square mile area was planned to be a concurrent but separate exploratory development goal of the CURV III project, with underwater navigation and search gear to be incorporated into CURV III design when feasible.

The CURV III system was to include a support vessel capable of sustaining operations at-sea for a 30 day period, but the system was to be portable — easily removable from the vessel, capable of air-transport, and suitable for installation and operating on appropriate vessels of opportunity.

1.2.2.2 EXTENDING THE STATE-OF-THE-ART — To expedite development, the CURV III plan intended full use of existing CURV I and CURV II equipment, designs and concepts where practical. Wherever changes were necessary to meet the 7,000 operational requirement, however, the change was to be made to procure the best and deepest capability available within the state-of-the-art, in anticipation of a 20,000-foot system development. Where state-of-the-art capabilities

were not sufficient and hardware development had to be initiated, the goal of the new development item was to be 20,000 feet where possible.

1.2.2.3 IMPROVEMENTS TO CURV I CONCEPTS — Modifications to CURV I concepts that were nominally good to 7,000 feet were planned only where experience showed improved reliablility, maintainability, and performance could be achieved with state-of-the-art techniques within the period of development of the long lead items of the system.

1.2.2.4 OTHER CURV PROJECTS — Concurrent with the CURV III development project were the CURV II assembly and fabrication, development of the CURV II — NTS for the Naval Torpedo Station in Keyport, Washington, and various exploratory development projects, the most significant of which were the investigation of a 20,000-foot recovery system and shallow-water work systems for underwater tasks more complicated than recovery. A CURV Program Summary is shown in Fig. 1-1.

1.3 FUNDING

The CURV III development was originally funded in FY 67 by the Naval Ordnance System Command through a Task Assignment (Ref. 3) which called for extension of the CURV capability to 6,000 feet. In FY 68, the NAVORD Task Assignment (Ref. 4) changed to a 7,000-foot requirement. Investigation into increased detection, positioning and load handling, and feasibility studies in extending the CURV concept to 20,000 feet were also authorized by Ref. 3. In FY 68, the CURV III development also began to receive support for its NAVORD task from the Deep Ocean Technology (DOT) project of the Naval Ship Systems Command. The FY 69 and 60 NAVORD tasks were also funded jointly by NAVORD and DOT. After the CURV III system was proven operational in FY 70, the completion of development in FY 71 was funded by the Office of Supervisor of Salvage. A funding summary is shown in Table 1-1.

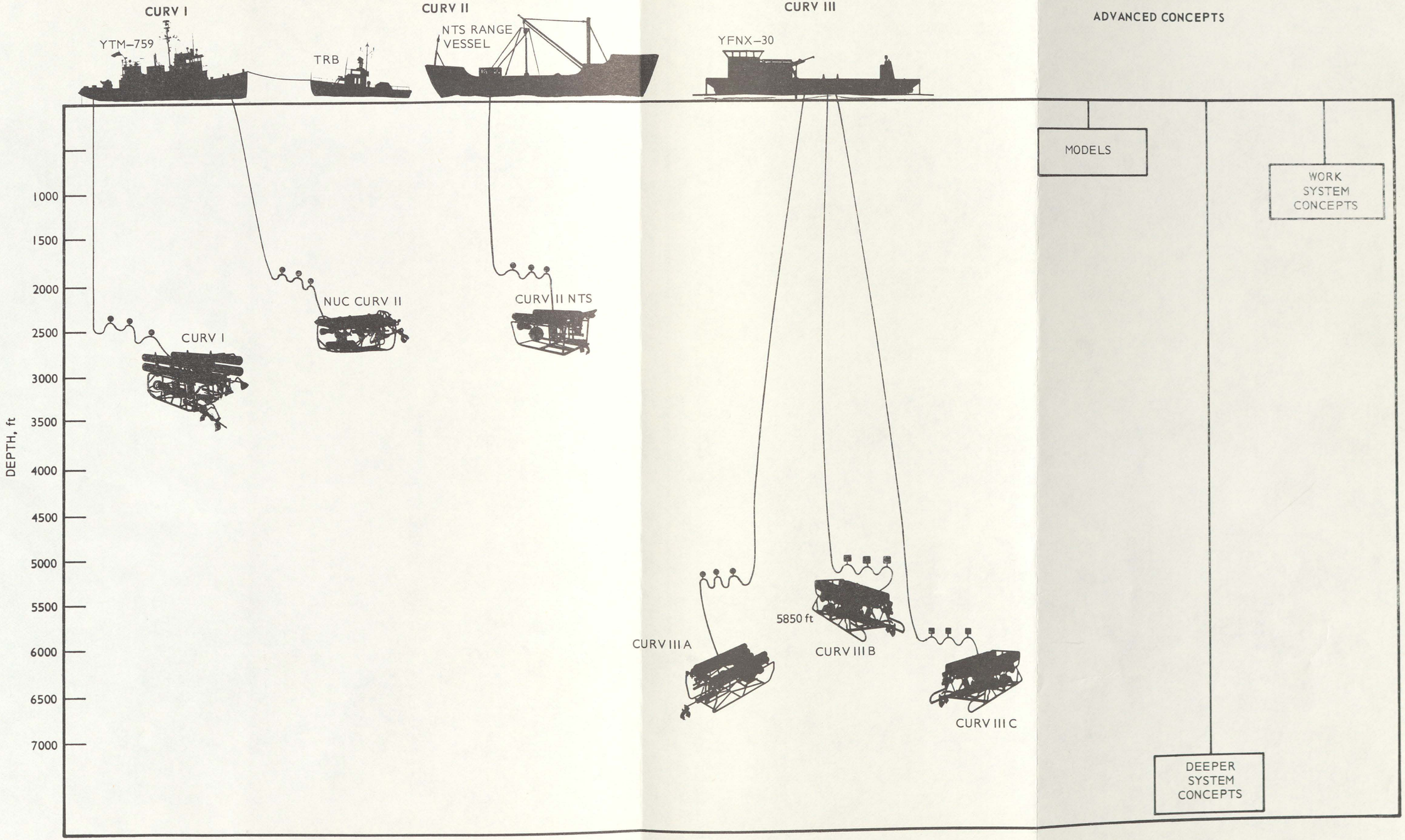


FIG. 1-1. CURV Program Summary

TABLE 1-1. CURV III Funding

	FY 67	FY 68	FY 69	FY 70	FY 71	FY 72	Total
Development Agencies							
NAVORD 03C	$250K	$ 260K	$ 450K	$440K			$1,400K
DOT Program (NAVSHIPS)		500K	1,000K	300K			1,800K
NUC					110K		110K
CURV II Users							
NUC Mk 46	30K	60K	60K	70K	125K		345K
OTHERS	100K	200K	240K	40K			580K
CURV III Users							
SUPSALV (SHIPS 00C)				75K	340K	65K	480K
PMO-402 (Mk 48)					225K		225K
AFAR (NUSC)						150K	150K
OTHERS				5K		5K	10K
	$380K	$1,020K	$1,750K	$930K	$800K	$220K	$5,100K

SECTION 2

CURV IIIC SYSTEM DESCRIPTION

20
-20

Page

2-3
2-5
2-6
2-7
-and Tilt 2-8
Camera
-and-Tilt 2-9
cer and
own) 2-10
rboard View 2-12
Housing,
2-13

Section 2

TABLE OF CONTENTS

Section	Title	Page
2.1	Vehicle	2-1
2.1.1	Optics	2-1
2.1.2	Search and Navigation	2-1
2.1.3	Propulsion	2-11
2.1.4	Hydraulics	2-11
2.1.5	Tool Assembly	2-11
2.1.6	Structures	2-11
2.2	Cable Assembly	2-11
2.3	Control Console and Van	2-20
2.4	Power Supply and Conversion Equipment	2-20
2.5	Support Equipment	2-20
2.5.1	Storage Equipment	2-20

LIST OF FIGURES AND TABLES

Figure	Title	Page
2-1	CURV IIIC Functional Block Diagram	2-3
2-2	CURV IIIC Vehicle Subsystems	2-5
2-3	CURV IIIC Vehicle-Starboard View	2-6
2-4	CURV IIIC Vehicle-Bow View	2-7
2-5	CURV IIIC Television Camera, Port Pan-and Tilt	2-8
2-6	CURV IIIC 35 mm Camera (lower), TV Camera (covered) and Lights — Starboard Pan-and-Tilt	2-9
2-7	CURV IIIC Sonar Projector, Transducer and Training Unit (SAR Strobe also shown)	2-10
2-8	CURV IIIC Propulsion Motors, Starboard View	2-12
2-9	Propulsion Motors and Spherical Housing, Stern View	2-13

LIST OF FIGURES AND TABLES (Cont'd)

Figure	Title	Page
2-10	Propulsion Motors and Spherical Housing, Port View	2-14
2-11	CURV III Tool Drive Assembly with Manipulator	2-15
2-12	Recovery Claw Tool	2-16
2-13	CURV IIIC Spherical Aluminum Housing	2-17
2-14	CURV IIIC Sonar Housing	2-18
2-15	CURV IIIC Spherical Magnetometer Housing	2-19
2-16	CURV III Control Console	2-21
2-17	Operator's Bay of Control Console	2-22
2-18	Cable Baskets — Whip Cable and Floats in Foreground, Main Cable in Background	2-23
2-19	Articulating Crane Hoisting CURV IIIC Vehicle	2-25
2-20	CURV III Support Vessel, YFNX-30	2-26

Section 2

CURV IIIC SYSTEM DESCRIPTION

A description is given below of the CURV IIIC system to familiarize the reader with the basic characteristics of a CURV system.

The CURV IIIC system, as operated on NUC ranges, is composed of the CURV IIIC vehicle, control cable, control console housed in a portable van, power supply and power conversion equipment, support and handling equipment, and support vessel. A block diagram of this system is given in Fig. 2-1.

2.1 VEHICLE

The vehicle (Figs. 2-2, 2-3 and 2-4) is a strictly functional design — an open frame with working subsystems and components. It is 6.5 feet by 6.5 feet by 15 feet long and weighs approximately 4,500 pounds in air. It is slightly buoyant in water. The principal subsystems are the optics, compass, sonar, propulsion, hydraulics, tool assembly, and structures.

2.1.1 OPTICS — Optical sensors include two vidicon television cameras, four mercury vapor headlights, two mercury vapor spotlights, and a 500-exposure 35 mm color camera and strobe light. These components are mounted on two pan-and-tilt units that each have 360 degrees pan and 180 degrees tilt capabilities to give the CURV IIIC full viewing and self-inspection capabilities. These components are in Figs. 2-5 and 2-6.

2.1.2 SEARCH AND NAVIGATION — The search and navigation equipment includes a compass; 800-yard range, 120-degree sector scan, Continuous Transmission Frequency Modulated (CTFM) active sonar; passive sonar capable of tracking 45 kHz pulses; 37 kHz vehicle-mounted pinger locator; pulse measurement altimeter for determining altitude off the bottom; and pressure transducer depthometer. The sonar projector and transducer are shown in Fig. 2-7.

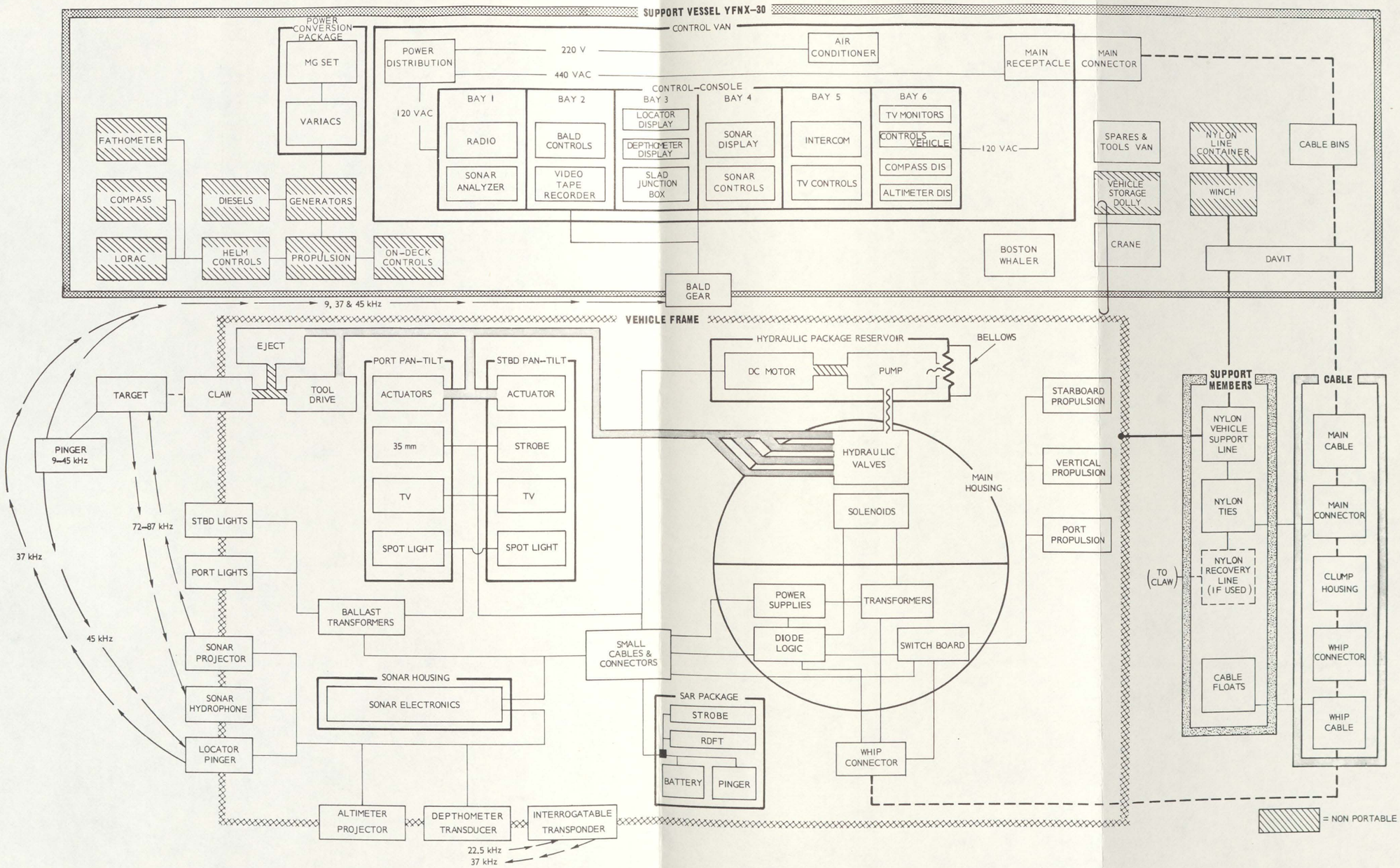


FIG. 2-1. CURV IIIC Functional Block Diagram

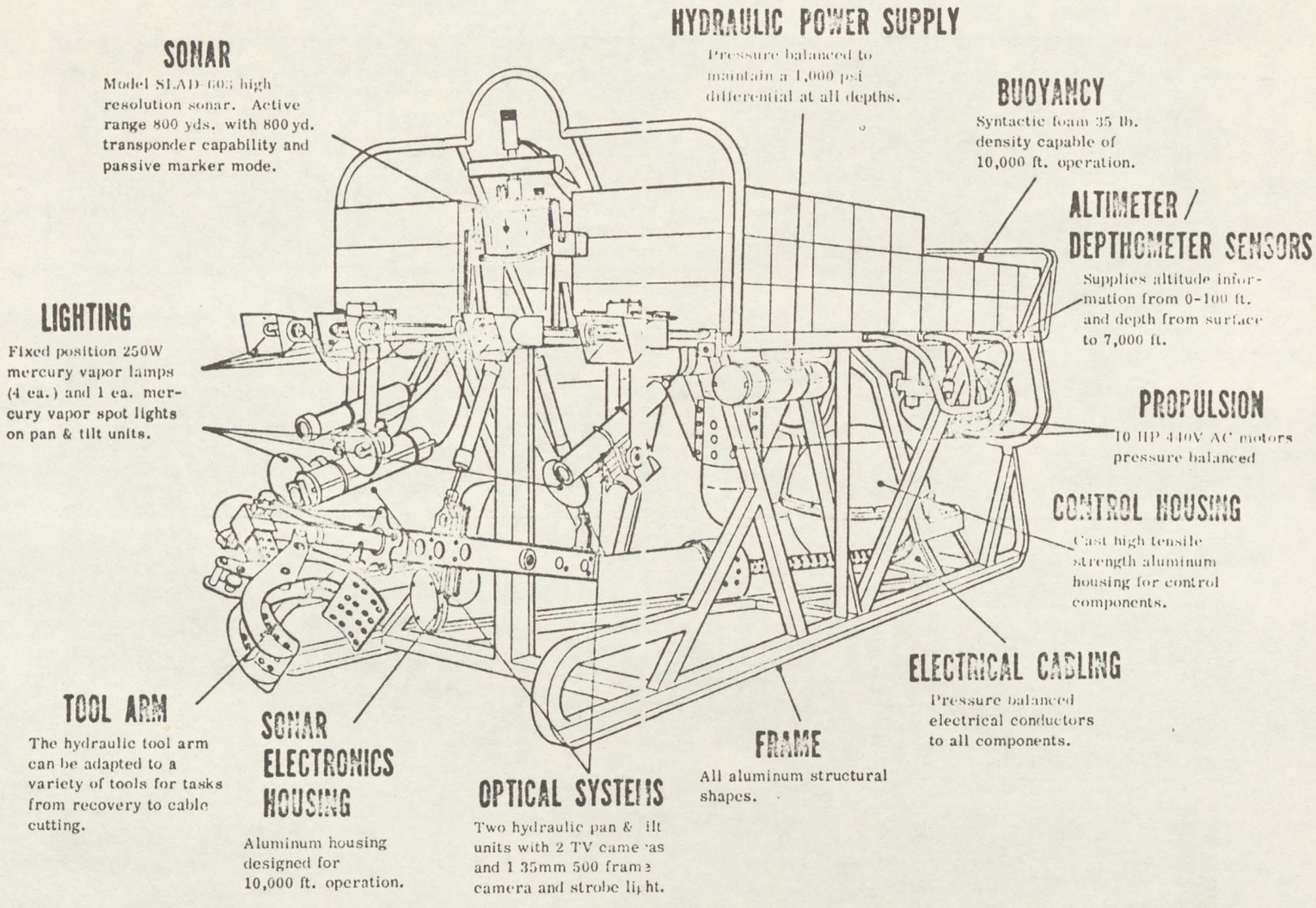


FIG. 2-2. CURV IIIC Vehicle Subsystems.

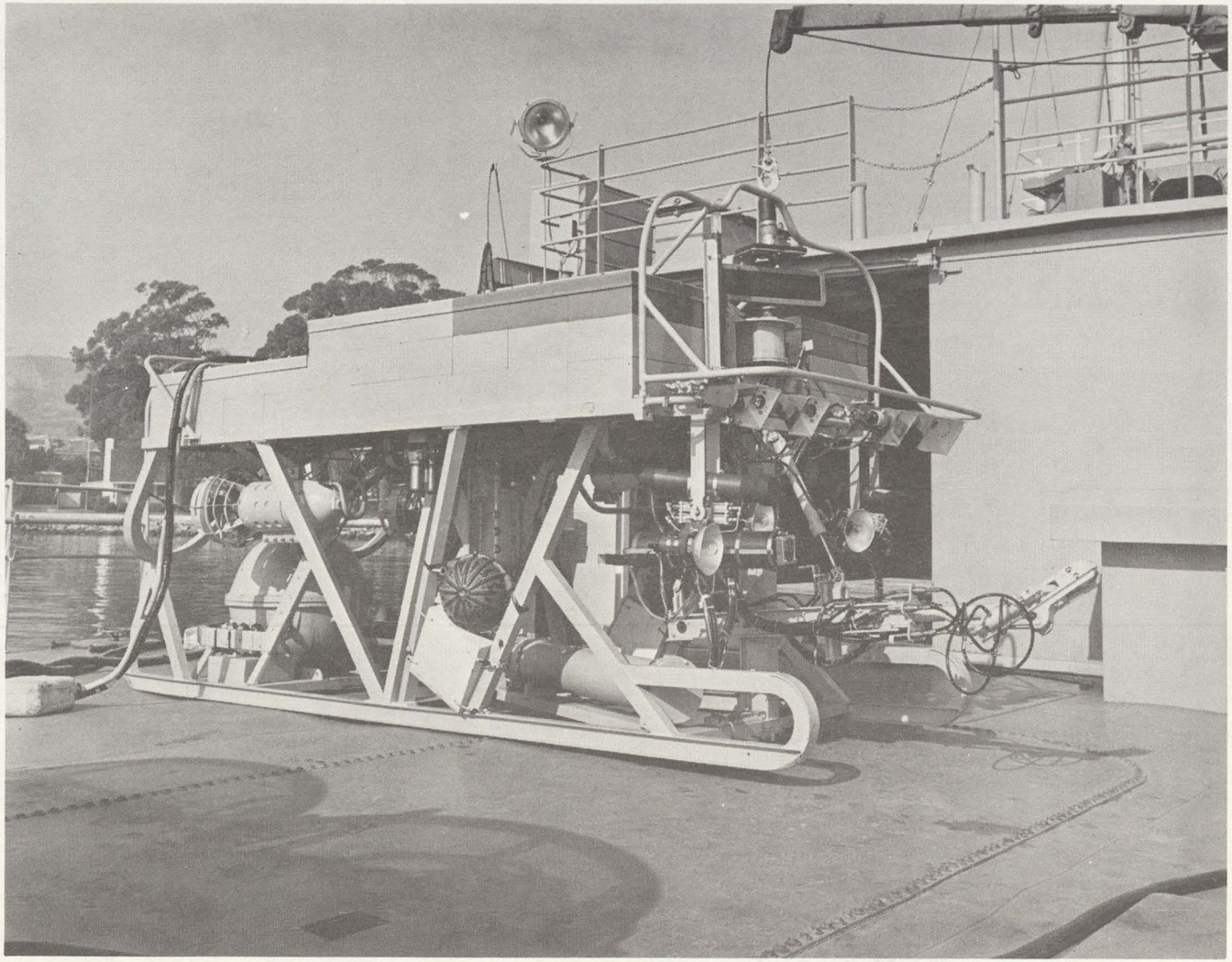


FIG. 2-3. CURV IIIC Vehicle-Starboard View.

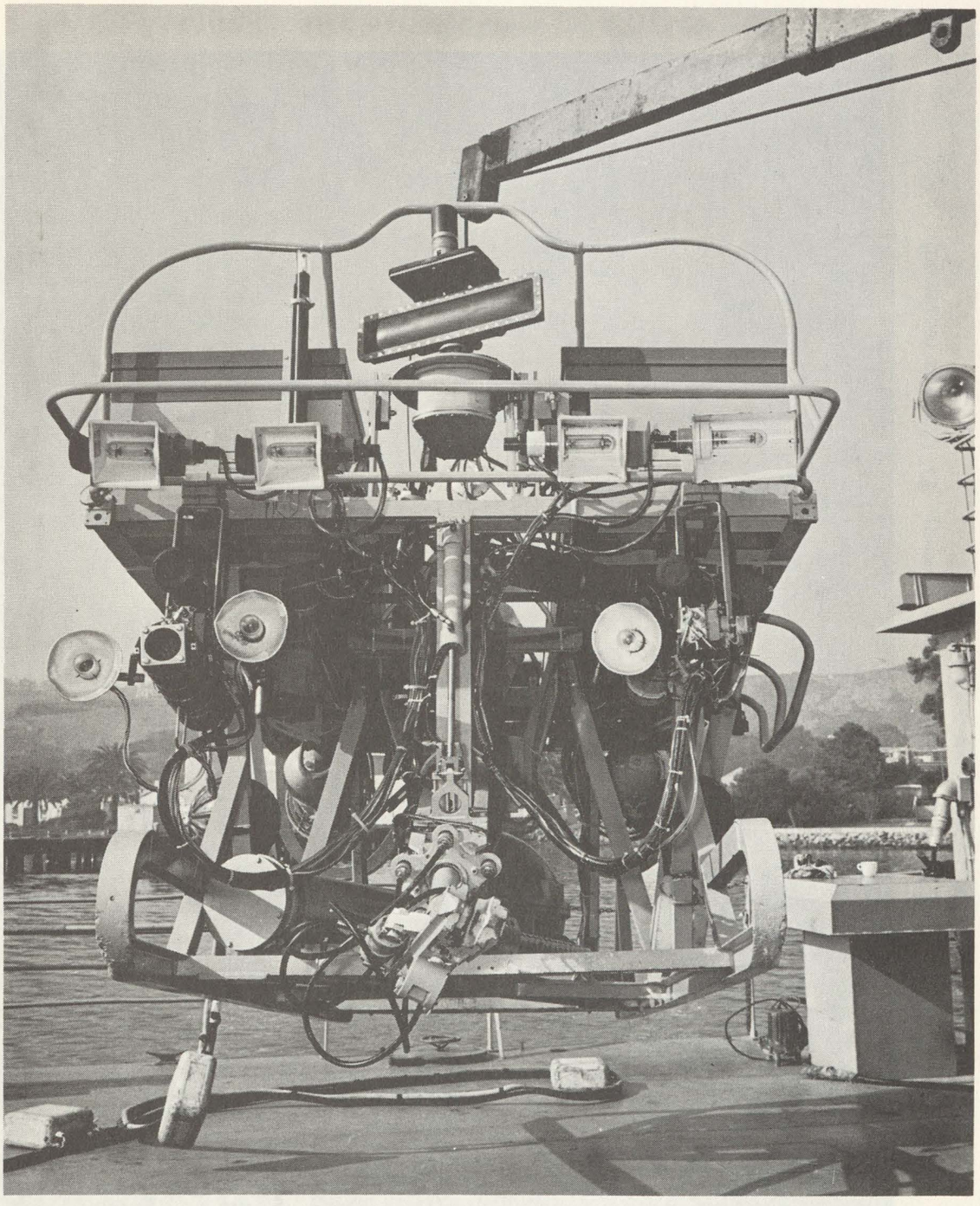


FIG. 2-4. CURV IIIC Vehicle-Bow View.

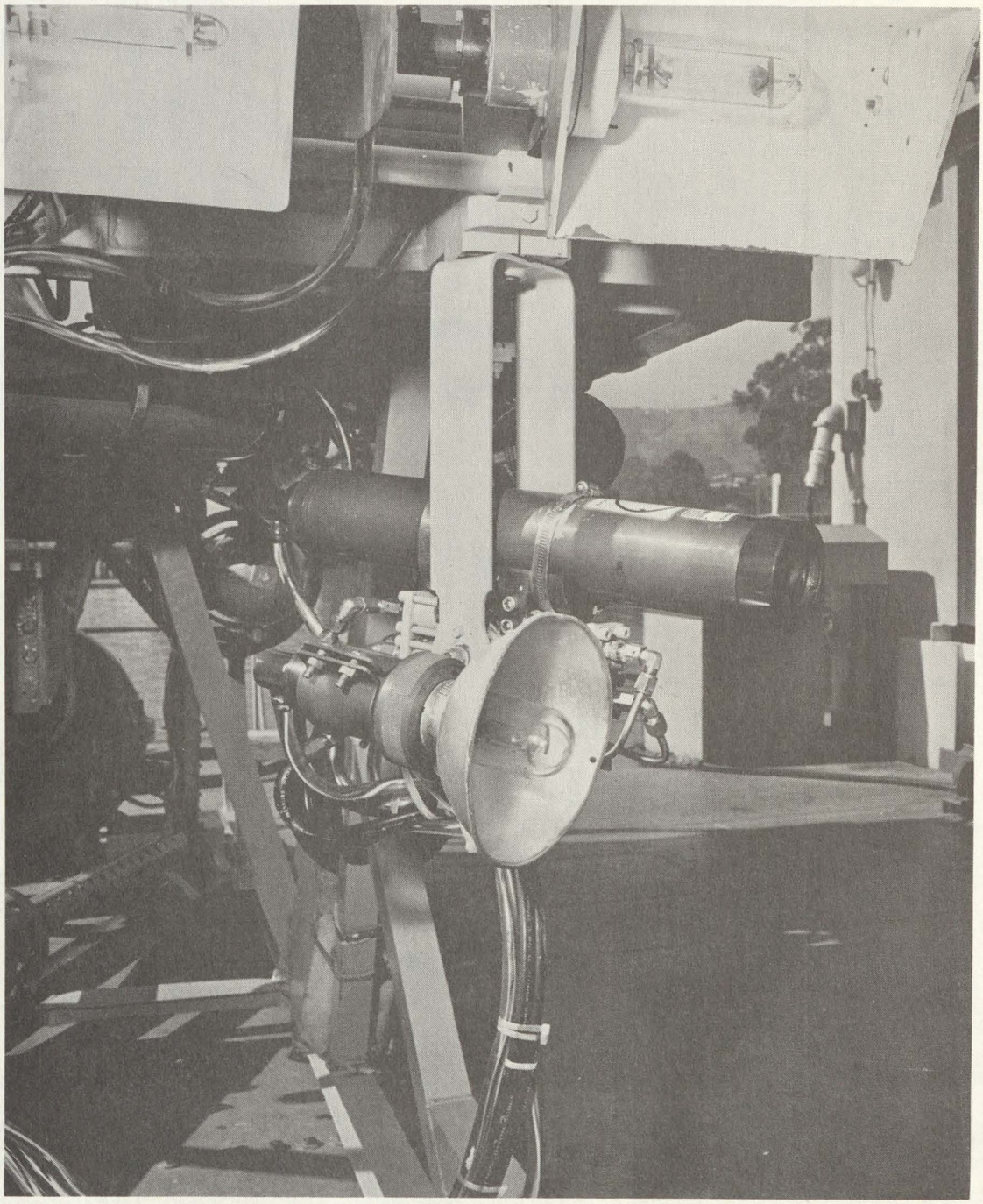


FIG. 2-5. CURV IIIC Television Camera, Port Pan-and-Tilt.

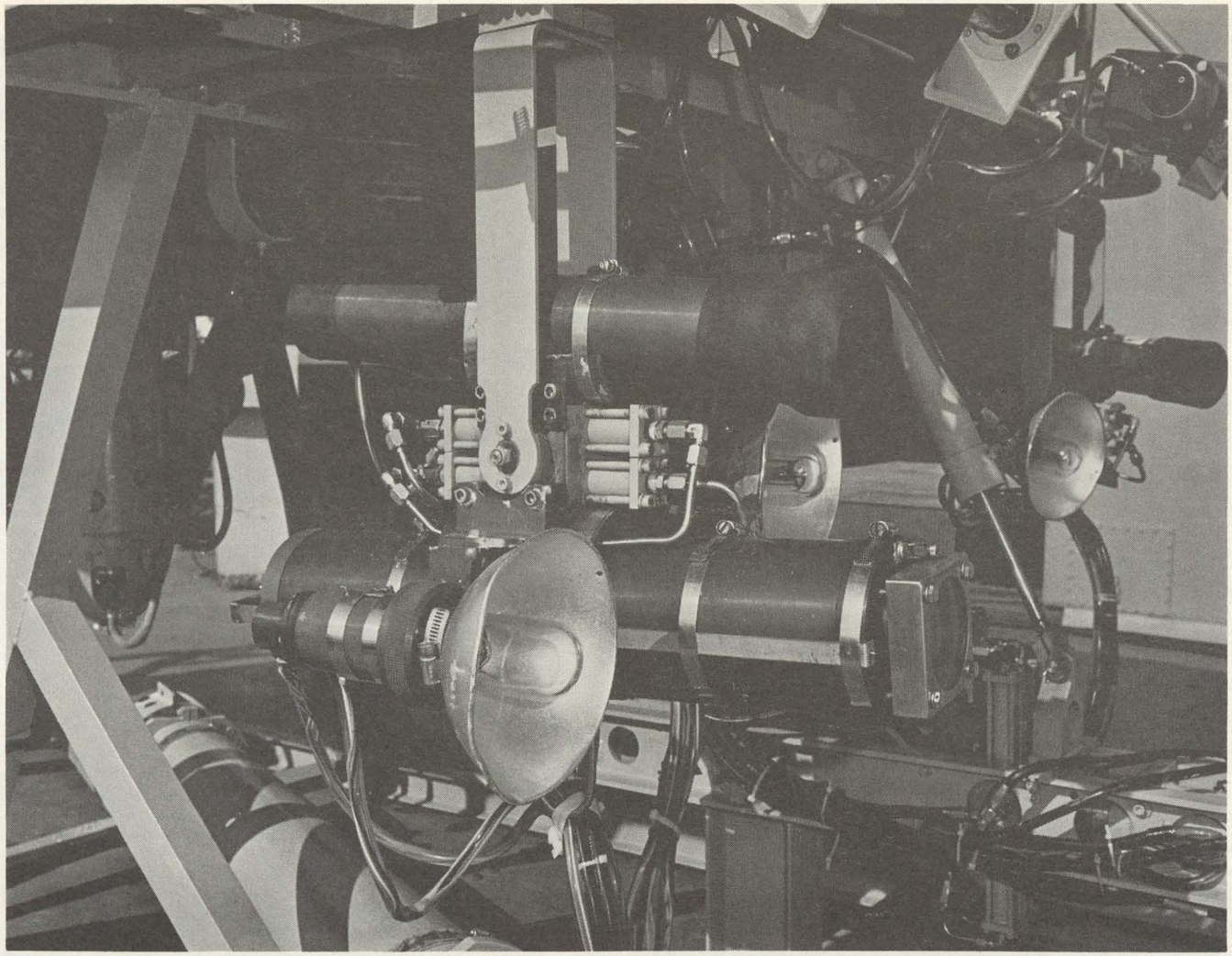


FIG. 2-6. CURV IIIC 35 mm Camera (lower), TV Camera (covered) and Lights — Starboard Pan-and-Tilt.

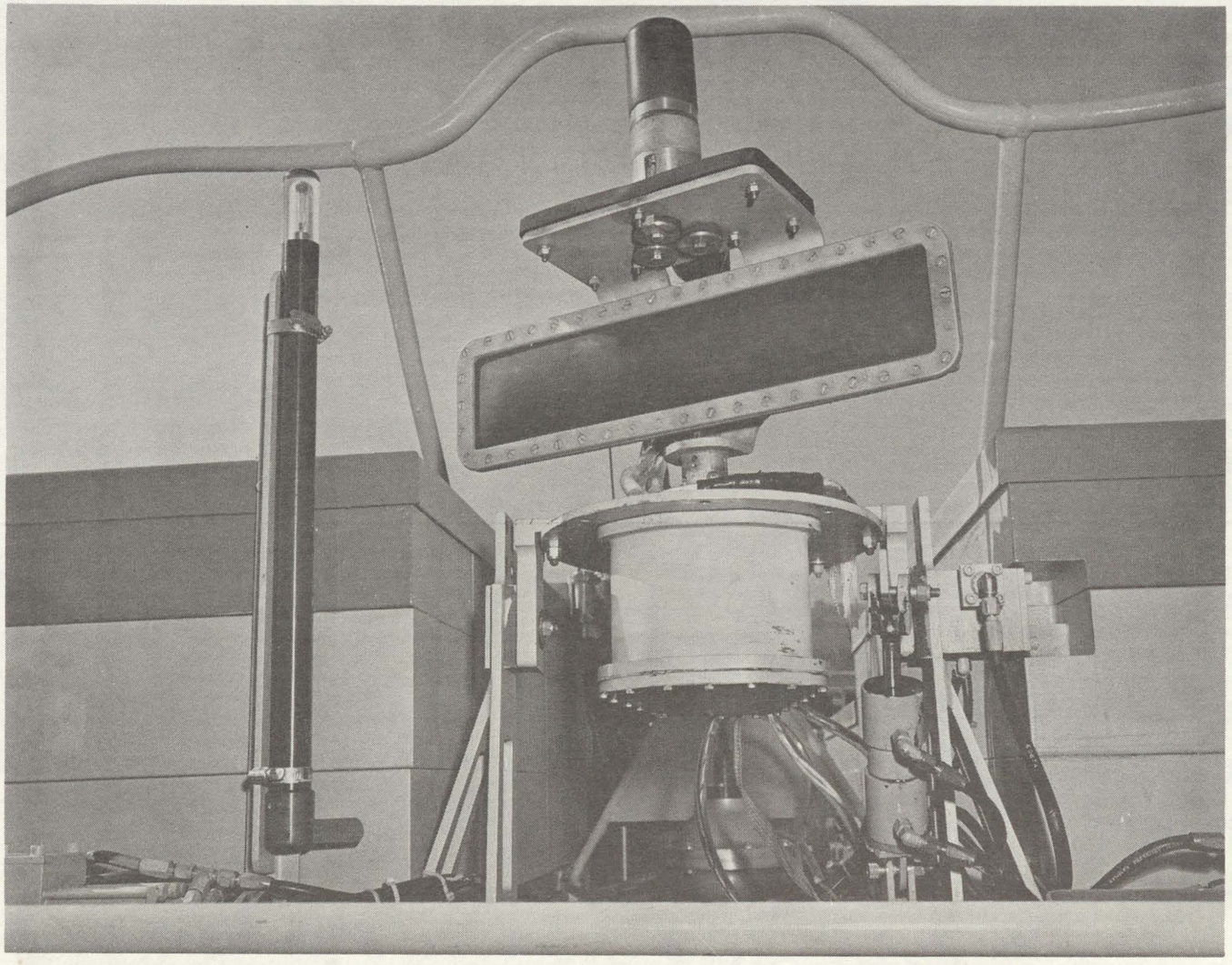


FIG. 2-7. CURV IIIC Sonar Projector, Transducer and Training Unit (SAR Strobe also shown).

2.1.3 PROPULSION — Three 10-horsepower 440 VAC reversible electric motors (Fig. 2-8) provide propulsion power. Their speed is infinitely variable, controlled by the voltage. They are pressure-compensated, oil-filled units rated for continuous service even if flooded with salt water. Each motor provides 400 pounds forward thrust and 200 pounds reverse thrust. Two motors are mounted to provide horizontal thrust on the port and starboard sides of the vehicle. The third motor is mounted in the center of the vehicle and provides vertical thrust. The mounting arrangement is shown in Figs. 2-9 and 2-10. Because the vehicle is maintained at 10-15 pounds positive buoyancy, the vertical motor is run constantly to keep the vehicle down. The combination of port, starboard, and vertical thrust, coupled with infinite forward and reverse controls, enables very fine maneuvering at close quarters.

2.1.4 HYDRAULICS — The hydraulic system is pressure compensated and provides 1,000 psi at all depths. Components include a 1/2-horsepower electric motor, a 0.64 gallon per minute pump, control valves and actuators. The hydraulic system operates the optical pan-and-tilt units and the tool assembly.

2.1.5 TOOL ASSEMBLY — The tool assembly (see Fig. 2-11)is a hydraulic-powered five-function unit with vertical and rotational movements, but it has no lateral movement capability. Interchangeable tools are used including the 13-inch diameter grasping claw (Fig. 2-12), snares, hooks, and grapnels. The tools can be ejected from the assembly by remote release.

2.1.6 STRUCTURES — The structural components include the frame, made of structural aluminum 6061-T6 shapes; fifty syntactic foam buoyancy blocks, 5-1/2 inches by 11 inches by 22 inches, held to the frame by tie-rods and brackets; and 1-atmosphere electronic housings. The housings are: a 28-inch OD spherical cast aluminum electronics/hydraulics housing (Fig. 2-13) and a 60-inch long 8-inch OD cylindrical aluminum sonar housing (Fig. 2-14). Other small housings, for the TV camera, 35 mm camera, strobe, and compass (Fig. 2-15), are all aluminum. All interconnecting cables and connections utilize pressure-balanced connectors to eliminate maintenance problems.

2.2 CABLE ASSEMBLY

The cable assembly is composed of the main cable, whip cable, main connectors, nylon support line, and cable floats.

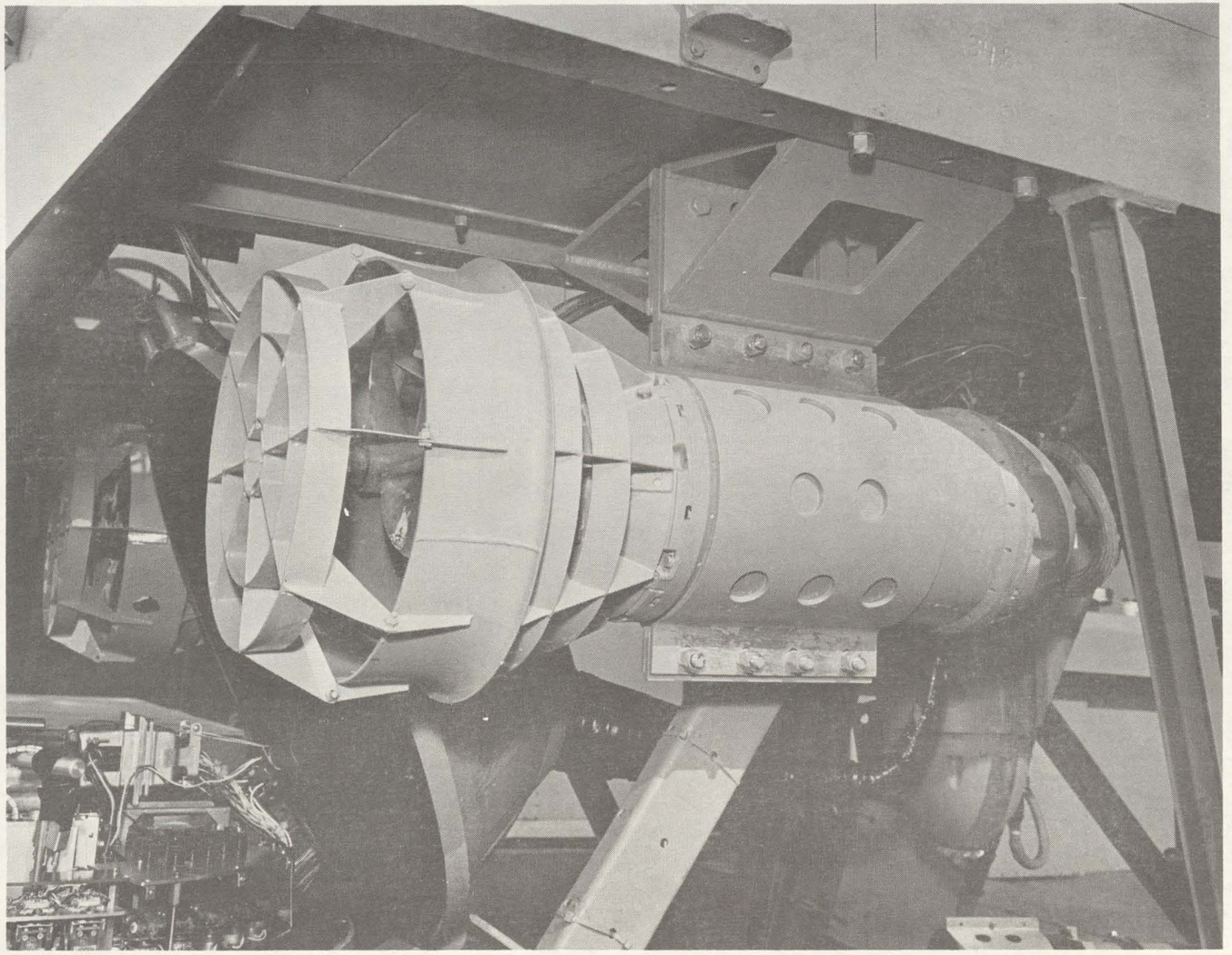


FIG. 2-8. CURV IIIC Propulsion Motors, Starboard View.

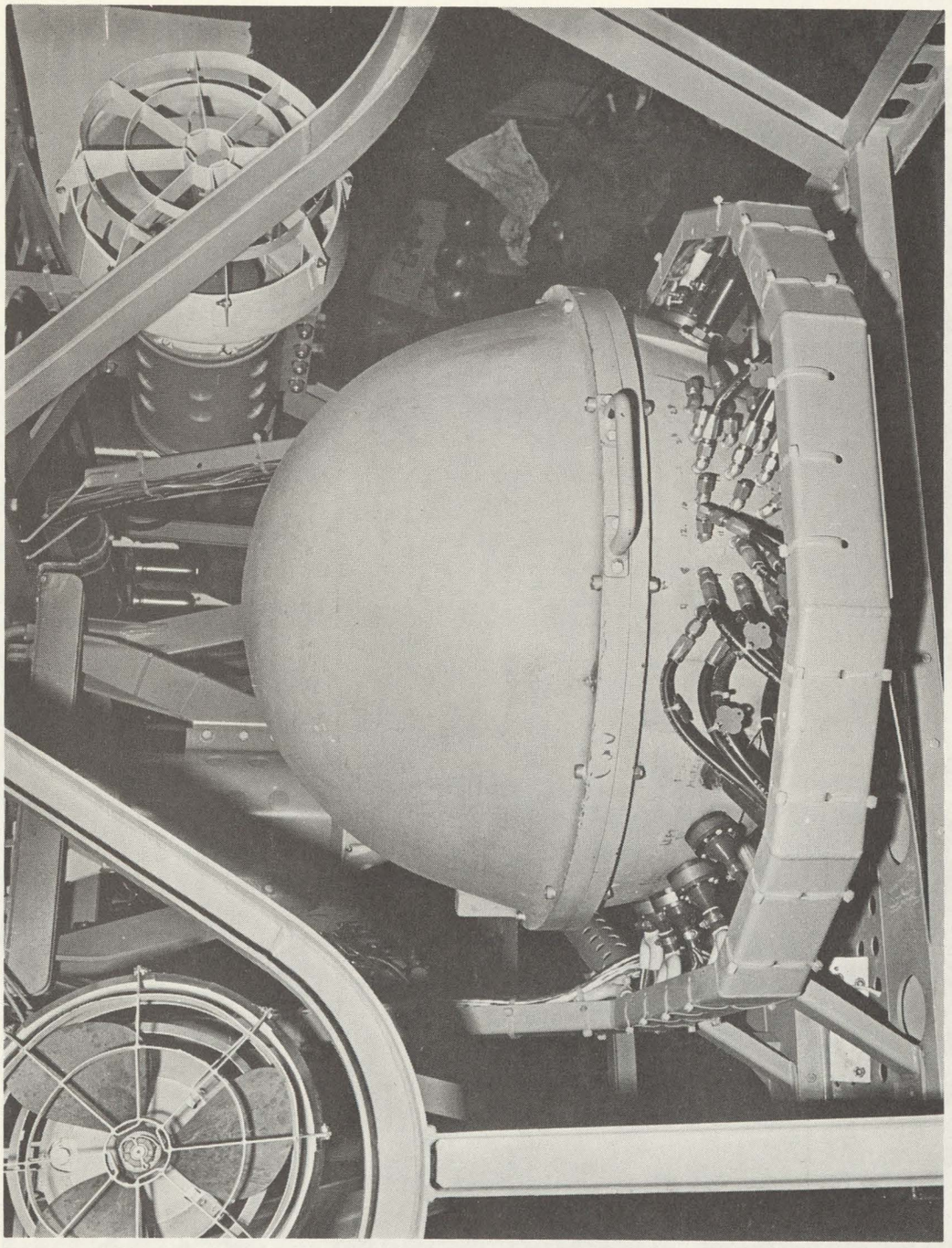


FIG. 2-9. Propulsion Motors and Spherical Housing, Stern View.

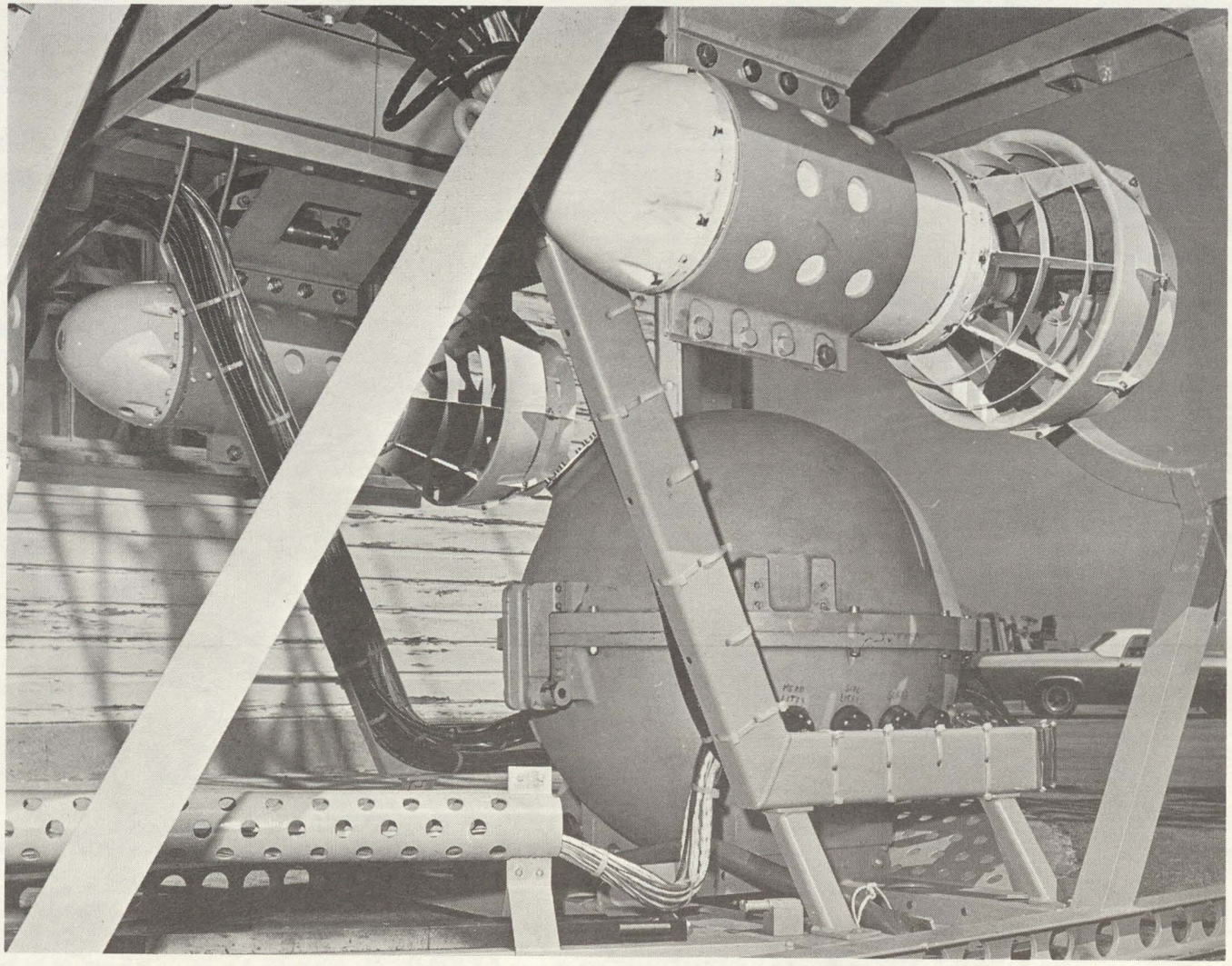


FIG. 2-10. Propulsion Motors and Spherical Housing, Port View.

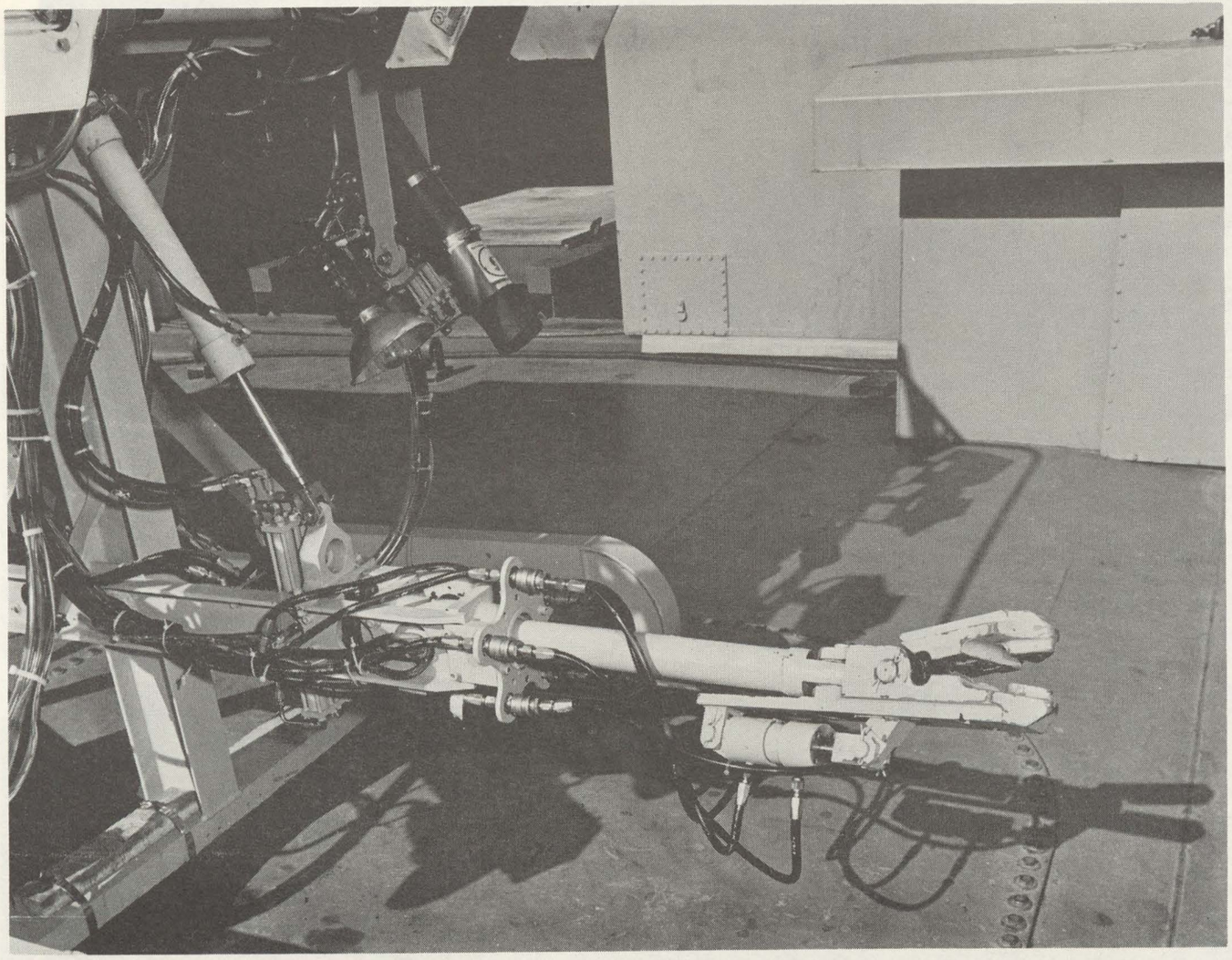


FIG. 2-11. CURV III Tool Drive Assembly with Manipulator.

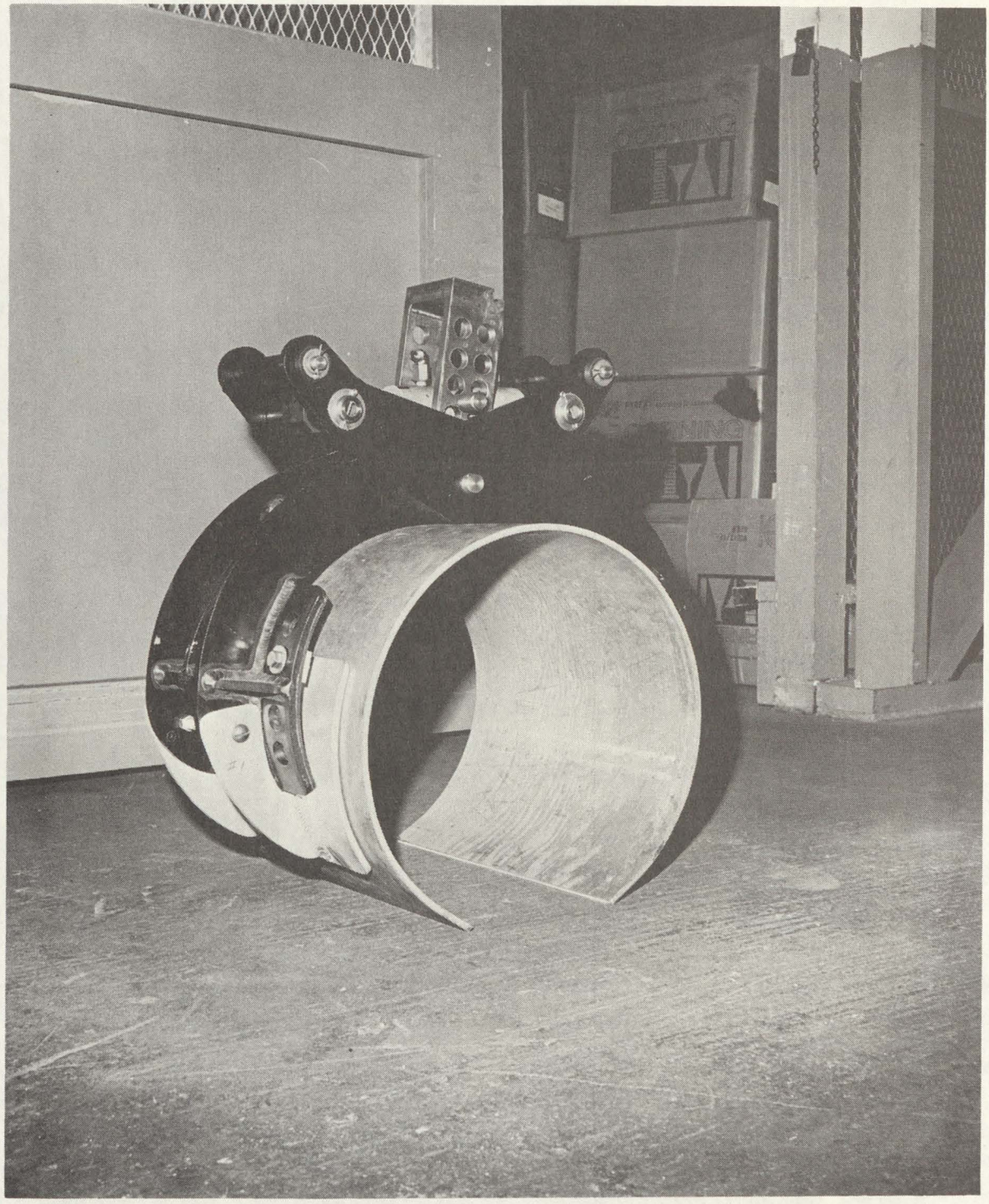


FIG. 2-12. Recovery Claw Tool.

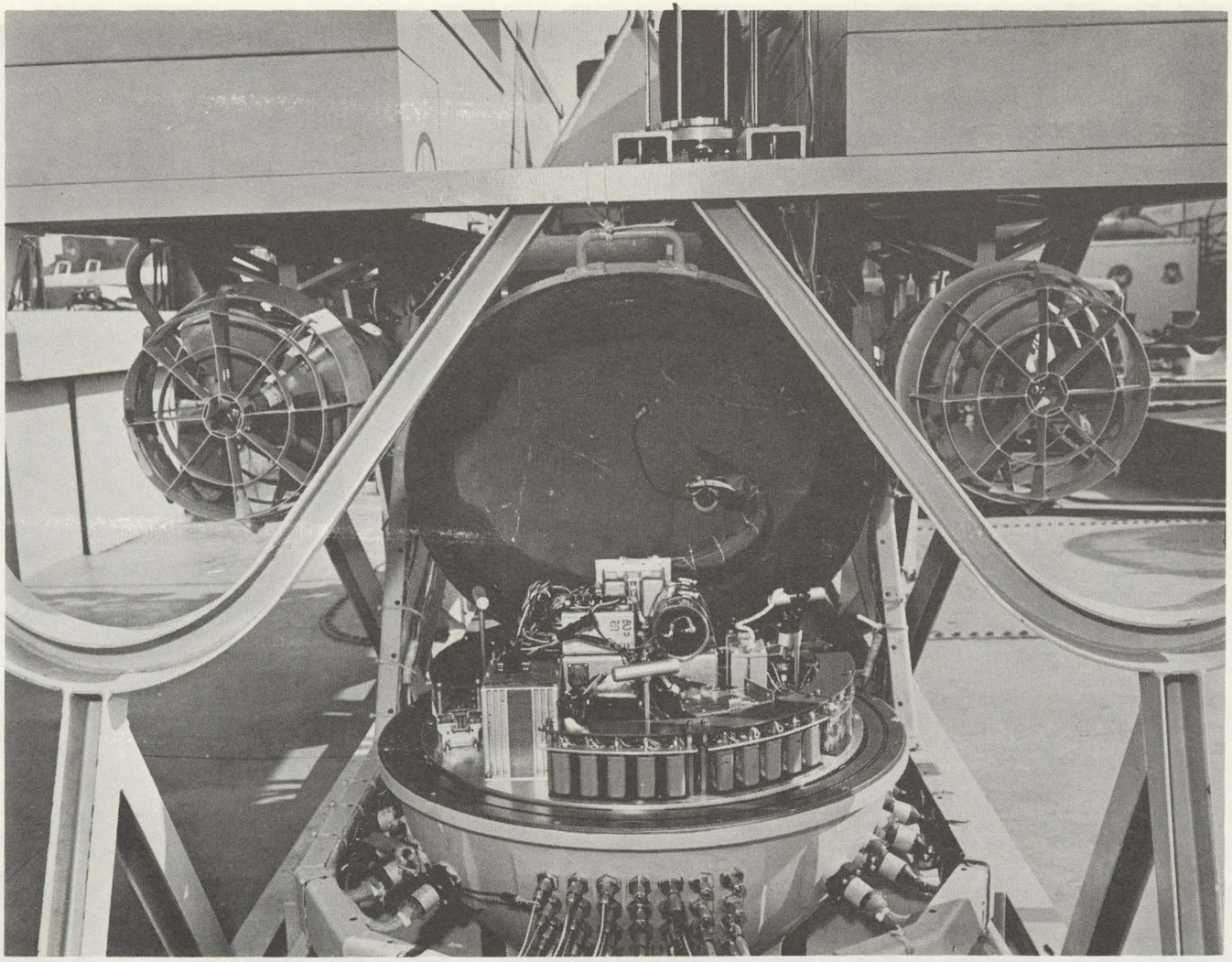


FIG. 2-13. CURV IIIC Spherical Aluminum Housing.

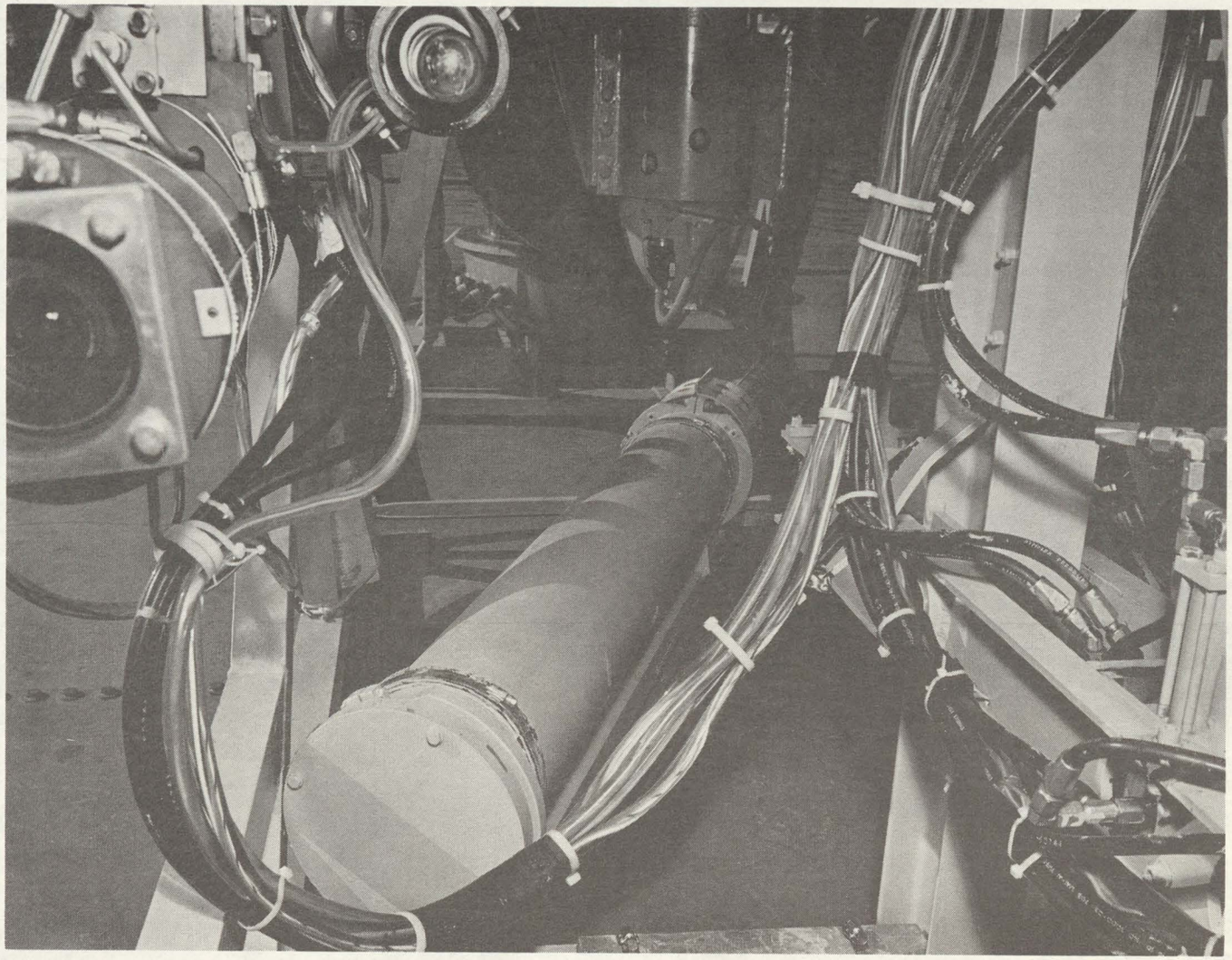


FIG. 2-14. CURV IIIC Sonar Housing.

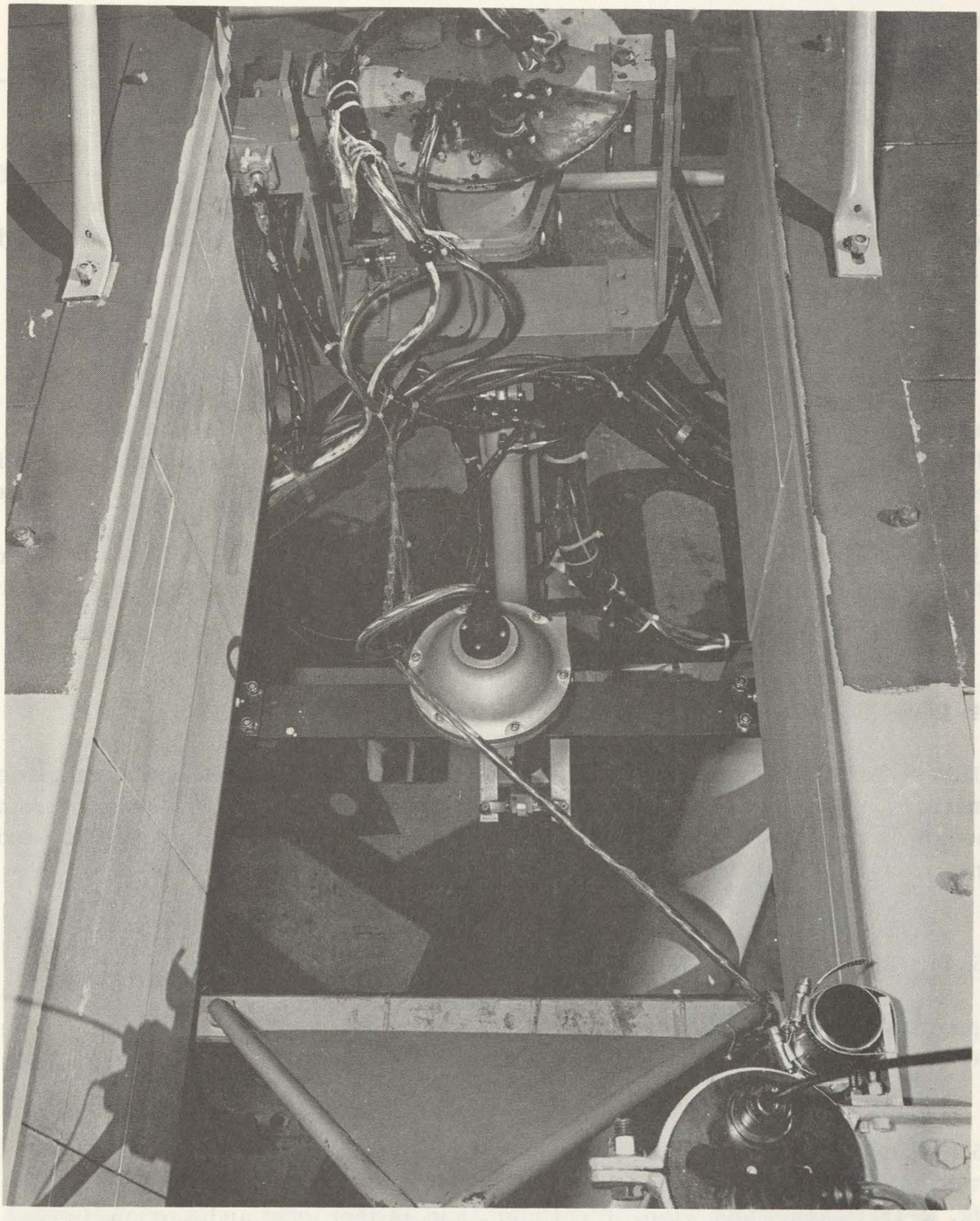


FIG. 2-15. CURV IIIC Spherical Magnetometer Housing.

The main cable is 7,000 feet long, 1-1/2 inches in diameter, nonhosing, with 58 conductors and an epoxied fiberglass strain member. The whip cable is 600 feet long, 1-1/4 inches in diameter, nonhosing, with 55 conductors and a stainless steel braid support member. Both cables weigh approximately 1/2-pound per foot in water and are supported by a 1-inch nylon line. This nylon line is tied to the cable by small nylon ties at 30-foot intervals and prolongs the life of the cables by taking the load off the conductors. The whip cable is supported underwater by syntactic foam floats spaced every 30 feet to give the whip a slightly positive buoyancy.

2.3 CONTROL CONSOLE AND VAN

The control console (Fig.2-16) is a six-bay unit with displays that include the following: active and passive sonar CRT, BALD (Boat-mounted Acoustic Locating Device) and locator CRT, two TV monitors, vehicle and ship's compass indicator (with cable twist counter), altimeter, and depthometer. The operator's bay (Fig.2-17) includes levers for each propulsion unit and toggle switches for other functions such as TV, claw, 35 mm camera, lights, etc. The console is contained in a 15-foot by 9-foot by 8-foot high air conditioned van.

2.4 POWER SUPPLY AND CONVERSION EQUIPMENT

CURV system power onboard the YFNX-30 is drawn from ship's electrical power generated by three 235-kw generators. One hundred kw is the system requirement. The power is converted for CURV III system use by a 5-kw motor generator and three variable transformers with 0 to 1,000V capacity.

2.5 SUPPORT EQUIPMENT

Support equipment is composed of storage equipment, handling equipment, and tracking equipment.

2.5.1 STORAGE EQUIPMENT — Storage equipment includes an electrically powered vehicle dolly/storage platform; two cable baskets welded together (Fig. 2-18), each 4 feet wide, 3 feet high, and 14 feet long; and a nylon line storage bin.

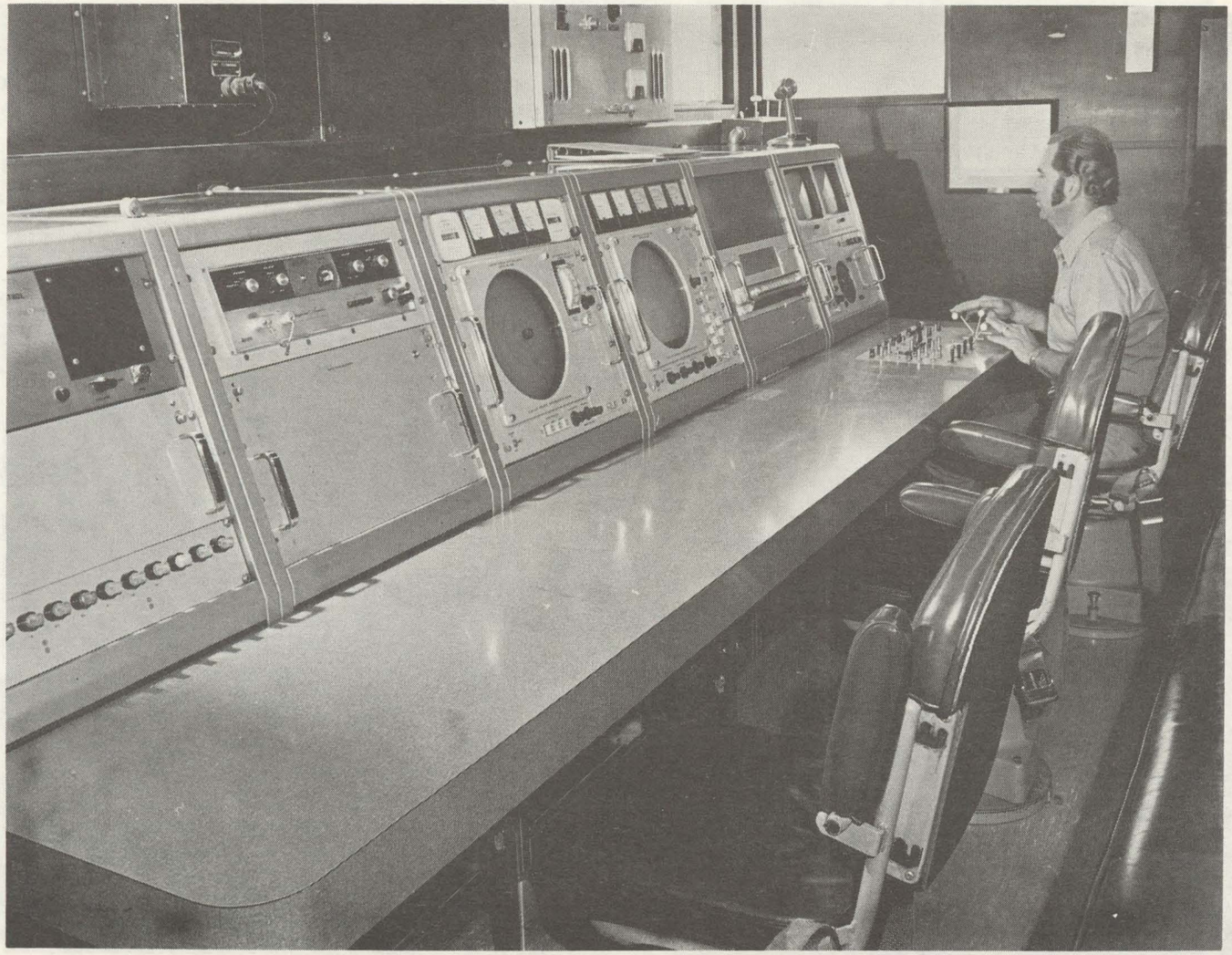


FIG. 2-16. CURV III Control Console.

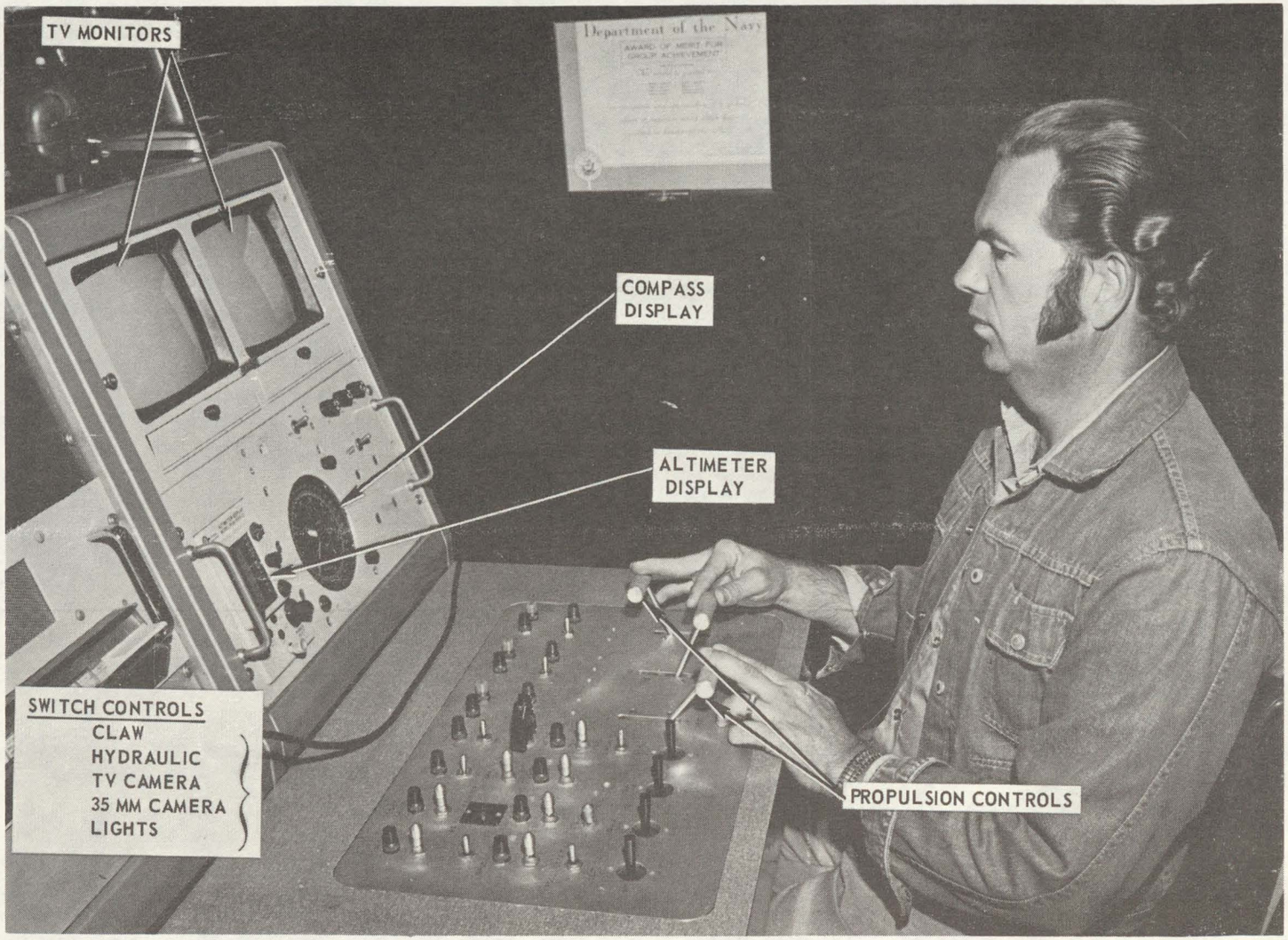


FIG. 2-17. Operator's Bay of Control Console.



FIG. 2-18. Cable Baskets — Whip Cable and Floats in Background Foreground, Main Cable.

2.5.2 HANDLING EQUIPMENT — Handling equipment includes a 19-foot articulating crane (Fig.2-19) for deploying and retrieving the vehicle, a hydraulic traction winch, and a davit and block for handling the nylon line and cable.

2.5.3 TRACKING EQUIPMENT — A Boat-mounted Acoustic Locating Device (BALD) is used to track the 37 kHz pinger on CURV or on a bottom target. It is a directional hydrophone that scans continuously in 360-degree azimuth and is tiltable to 0 to 90 degrees. It is mounted on a retractable over-the-side gear with a 20-foot shaft to enable lowering of the hydrophone below the hull of the vessel.

2.6 SUPPORT VESSEL, YFNX-30

The YFNX-30 (Fig.2-20) is a YFN barge converted to CURV III use. It has a flat hull, length of 110 feet, beam of 34 feet, draft of 5 feet and a displacement of 420 tons.

Its main feature is a propulsion system of two cycloidal propellers with variable pitch blades. This cycloidal system enables maneuvering in any direction and is compatible with automated station-keeping. Maximum vessel speeds are 5.5 knots ahead or astern, 2 knots athwartships and 1.5 rpm.

The YFNX is capable of berthing a crew of 16 military and 8 civilians and can support their activities for a month without refurbishment.

Its operational area is limited to Southern California waters because of its cruising speed, but it is amenable to tow to work sites in any portion of the world.

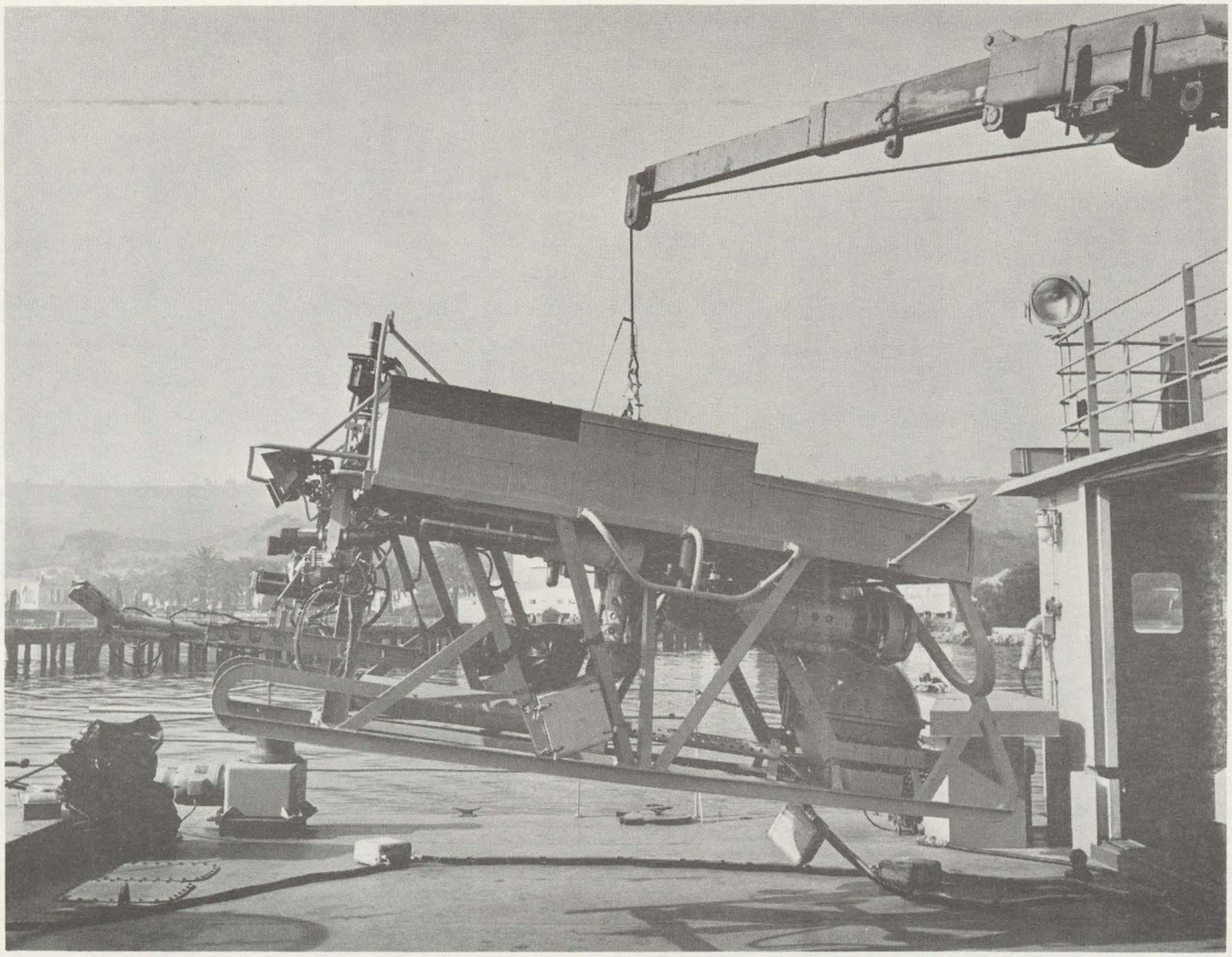


FIG. 2-19. Articulating Crane Hoisting CURV IIIC Vehicle.



FIG. 2-20. CURV III Support Vessel, YFNX-30.

SECTION 3

NORMAL CURV OPERATING PROCEDURES AND TECHNIQUES

3
-3
3-4
3-7

Section 3

TABLE OF CONTENTS

Section	Title	Page
3.1	Vehicle Deployment and Retrieval	3-1
3.2	Cable Handling	3-1
3.3	Maneuvering and Station-Keeping	3-5
3.4	Recovery of Pinger-Equipped Targets	3-5

LIST OF FIGURES AND TABLES

Figures	Title	Page
3-1	Nylon Line Container Aboard the YFNX-30	3-2
3-2	Overhead Traction Winch Aboard the YFNX-30	3-3 3-3
3-3	Cable Tying Operations	3-4
3-4	Separate Line Recovery/Lift Technique	3-7

Section 3

NORMAL CURV OPERATING PROCEDURES AND TECHNIQUES

An account of how the CURV IIIC system is normally operated from its support vessel YFNX-30 in small object recovery operations is given below to provide understanding of the development goals and problems.

3.1 VEHICLE DEPLOYMENT AND RETRIEVAL

The vehicle is rolled out on its dolly, deck-checked, hoisted by the articulating crane using a release hook and swung outboard. Once in the water, the crane hook is released and the vehicle is swum away from the vessel. On retrieval, the vehicle is swum alongside the vessel and a crane snap hook is attached to the lifting eye using a pole to which the snap hook is fastened by tape. Once the hookup is complete, the pole is pulled away breaking the tape holding it to the hook. The vehicle is then brought aboard ship.

No divers are employed in normal vehicle retrieval. The procedure outlined above is possible because of the low (6-1/2 foot) freeboard of the YFNX-30.

3.2 CABLE HANDLING

The cable and nylon line are stored below decks of the YFNX-30 in two cable bins and a nylon line container (Fig. 3-1). The nylon line is fed through an overhead traction winch (Fig. 3-2), up through the deck, over a deck fairlead pulley, over a pulley on the cable handling platform at the gunwale of the ship, and tied to the vehicle and to the connector between the "whip" and main cable. The cable is fed through the deck to the cable handling platform and over a roller chock.

As the vehicle descends, the nylon line and cable are tied together at 30-foot intervals by two men at the cable storage bins (Fig. 3-3) using 1/4-inch diameter nylon line ties. The line and cable are payed out by their own weight and restrained by the traction winch (the cable weighs 1/2 pound per foot in water).

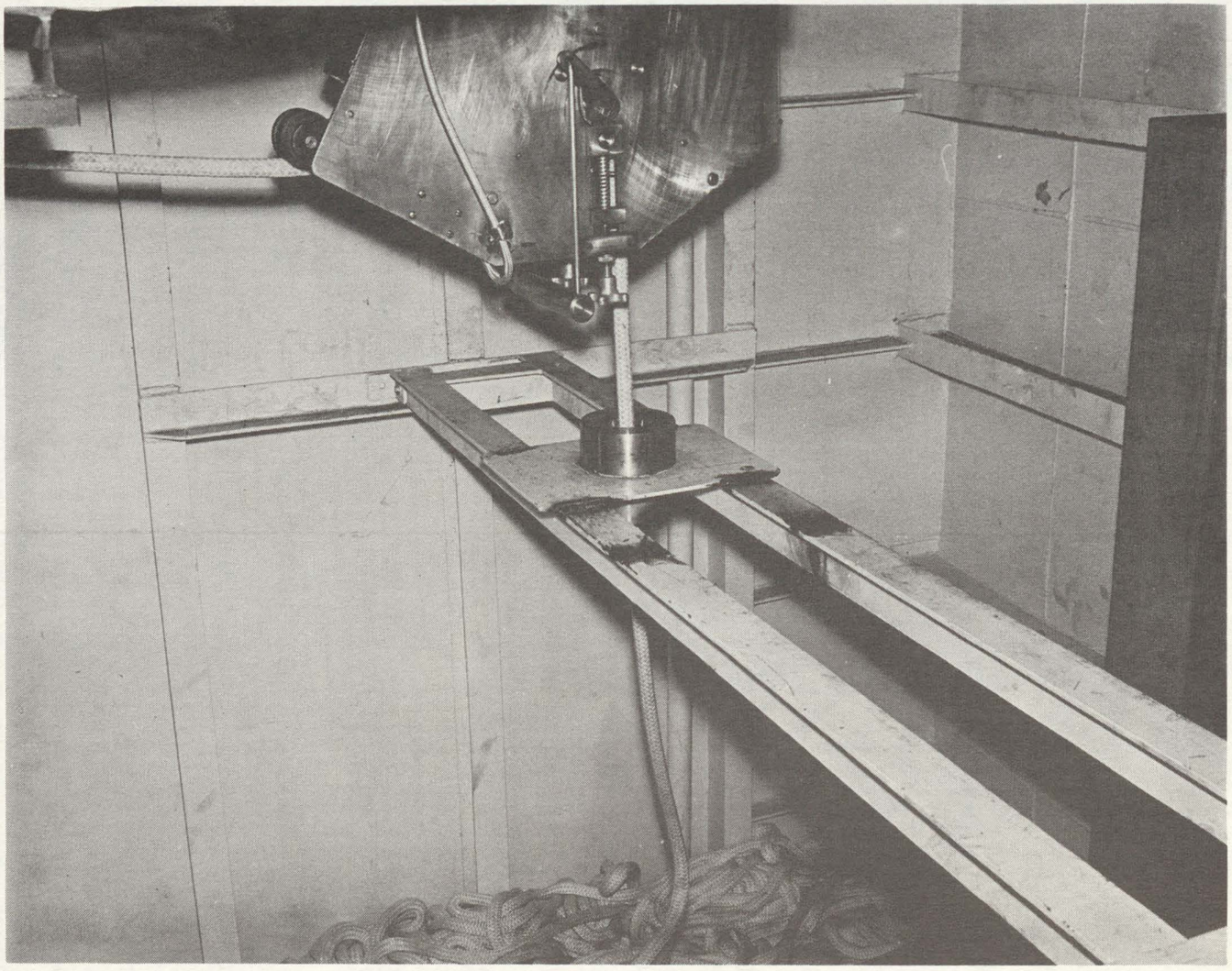


FIG. 3-1. Nylon Line Container Aboard the YFNX-30.

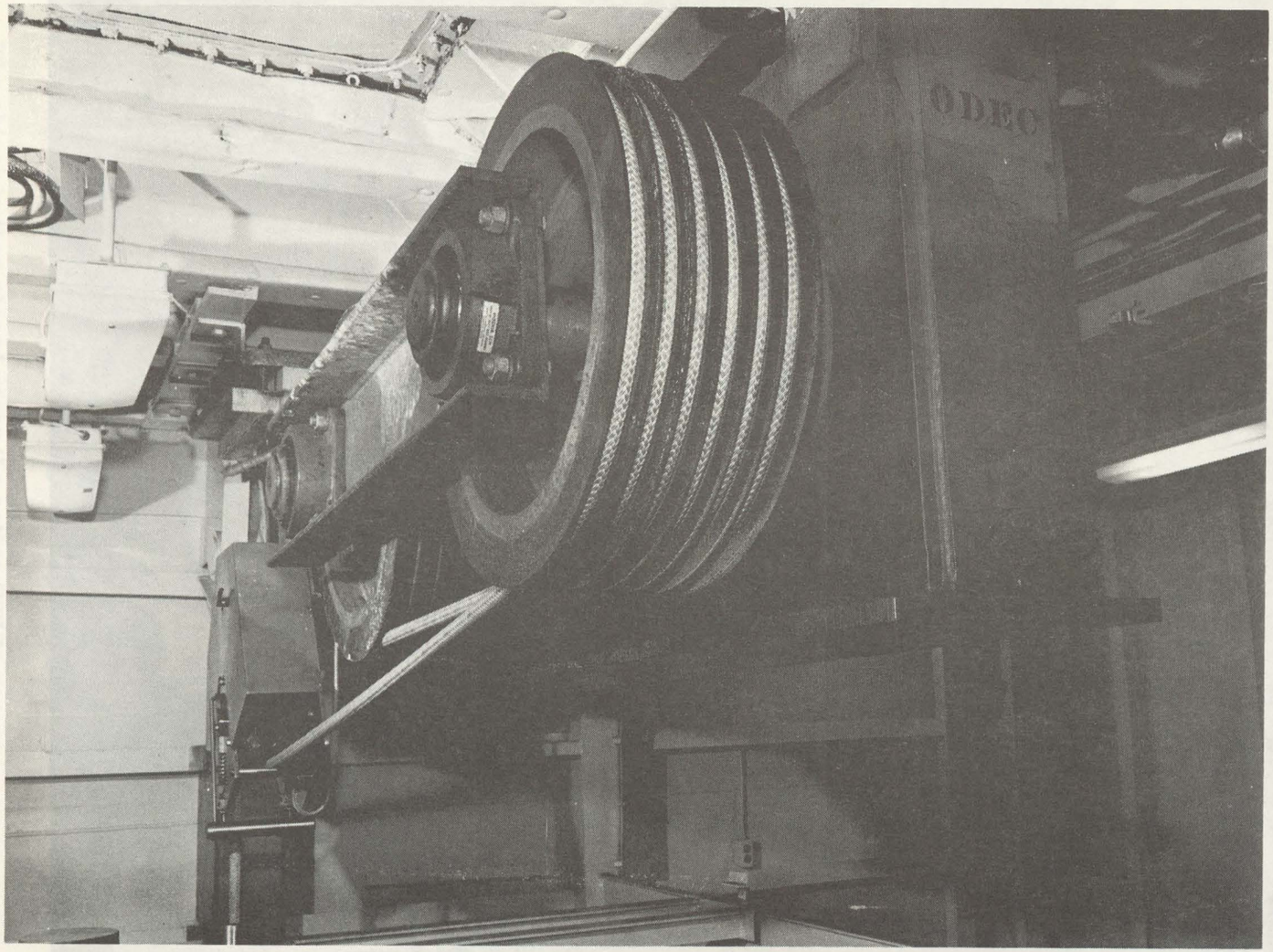


FIG. 3-2. Overhead Traction Winch Aboard the YFNX-30.



FIG. 3-3. Cable Tying Operations.

The first 600 feet of cable is buoyed by 1-foot by 1-foot by 1/2-foot syntactic foam blocks. Manual handling is required to pass the blocks through the deck and past the roller chock.

The cable is retrieved by lifting the nylon line with the traction winch. At each nylon tie the winch is stopped while the tie is untied or, in a rush operation, cut. The cable is flaked into its baskets manually by two tenders and the nylon line is allowed to spill into its bin.

Cable deployment and retrieval rates of about 50 feet per minute are possible using this technique.

3.3 MANEUVERING AND STATION-KEEPING

The main portion of the cable hangs supported by the nylon line. The buoyed portion of the cable, or whip, is made neutrally buoyant by the spacing of the cable floats. At the center of the whip, an extra cable float is added to give a slight positive buoyancy to the whip and keep it arced above the vehicle and off the bottom at all times to avoid fouling. The vehicle thus has an effective maneuvering area within a 600-foot radius around the main cable.

Unless station-keeping to a surface reference buoy or radio navigation position is required, the support vessel is kept as closely as possible directly over the vehicle at all times to ensure maximum whip freedom. If proper slack is not maintained, the vehicle can be pulled off site by drift of the support vessel. Before the recovery object is located, slack is usually maintained by moving the support vessel in the proper direction over the vehicle. Since the proper direction for movement of the support vessel to give slack cable is not always determinable, particularly when large amounts of cable are out, once the vehicle has the target in sight, slack is often maintained by feeding out more cable.

3.4 RECOVERY OF PINGER-EQUIPPED TARGETS

With a pinger-equipped target, approximate position is established near the target using BALD gear, which gives the bearing, but not the range, of the target. The CURV III vehicle is deployed and dives, descending on the bearing of the target, homing on the 45-kHz pinger using its passive sonar marker.

The object is then closed using the active CTFM sonar.

As the object is approached, it is classified with television and documented with 35 mm camera. Final maneuvering is accomplished to enable best claw access, then the claw is manipulated into position using the tool arm, and the claw is closed. The claw attachment is tested by claw arm lifts and/or vehicle maneuvering.

At this point the object is recovered by one of several techniques depending on the size, weight, and condition of the object.

If the object weighs less than 200 pounds, it is lifted by the claw arm, and the vehicle swims it to the surface in normal ascent procedure using its vertical motor.

If the object is 200-400 pounds in weight, vehicle ascent is assisted by the traction winch.

If the object is over 400 pounds, recovery is made using a separate line technique (see Fig.3-4). In these cases, the separate recovery line is attached to the claw prior to the operation. The recovery line is taped with masking tape to the cable/support line bundle as a third member. Once the claw attachment is made the claw is ejected and the vehicle backs away, breaking the tape and freeing the recovery line for lift by surface means. This approach was used by the CURV I in the recovery of the H-bomb off Palomares, Spain in April 1966.

Handling of the object at the air/sea interface, whether the lift is by the CURV III vehicle or surface means, is usually done by swimmers, who attach other recovery lines. Only very rarely are objects lifted aboard with the claw in place on CURV III because of: (1) the potential loss of the object by it slipping out of the claw or breaking the claw's grasp due to the increased claw-weight of the object as it is lifted from water to air, (2) the possibility of hitting the object on the vessel as the vehicle is swung onboard , and (3) the need to remove most objects from the claw prior to setting the vehicle down firmly on the deck, to avoid damage to the object or claw arm.

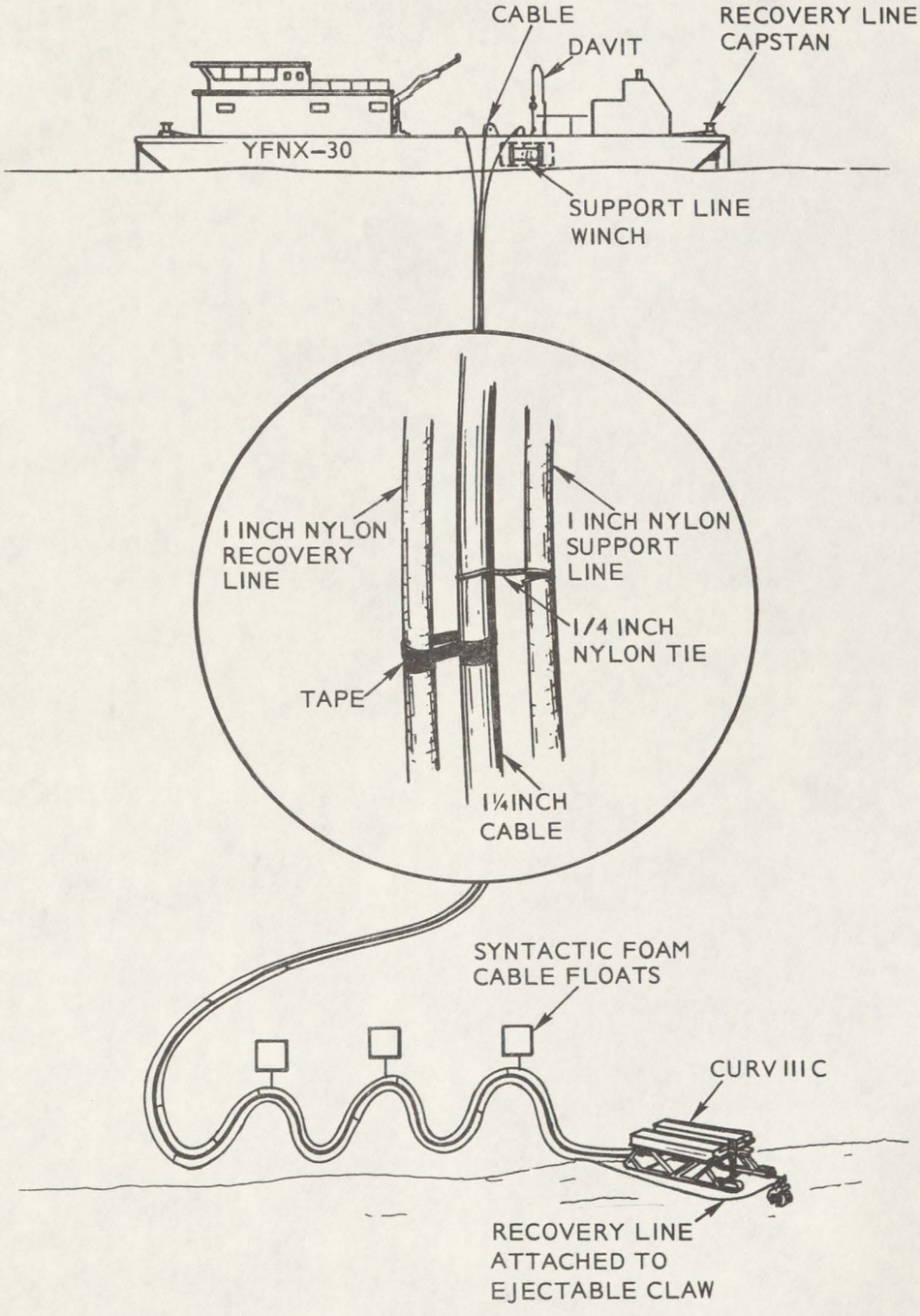


FIG. 3-4. Separate Line Recovery/Lift Technique.

SECTION 4

CURV III DESIGN CONCEPT HISTORY

Section 4

TABLE OF CONTENTS

Section	Title	Page
4-1	Final CURV IIIC System Design	4-1

LIST OF FIGURES AND TABLES

Table	Title	Page
4-1	CURV IIIA Component Concepts Essentially Unchanged From CURV I or CURV II	4-2
4-2	CURV III System Major Component Developments, Modifications, and Changes	4-3

Section 4

CURV III DESIGN CONCEPT HISTORY

The formulation of a CURV III design concept was begun prior to the decision to build a CURV II system. Since CURV III was a system in development, the design was never considered "frozen," even within the A, B, or C vehicle configurations, and changes and improvements were made throughout the program, the ease of such modifications being one of the principle advantages of an unmanned system development. The changes in the CURV III concept were brought about by factors such as the increased performance requirements from 6,000 to 7,000 feet, which was shown to be feasible by design studies; by program considerations such as findings from the advanced concept investigations into a 20,000 foot system; and by funding and schedule changes. In addition, when CURV II became operational, it served as a test bed for many components such as the hydraulic and sonar systems and provided inputs to the CURV III design.

This design included four major categories of components: proven components unchanged from CURV I or CURV II (see Table 4-1); CURV I and II components similar in concept but modified in design, structure, etc. to meet CURV III needs; components replaced by better hardware or concepts; and development items for which no proven workable CURV system component existed. The developments, modifications, and changes for CURV IIIA, B, and C are categorized in Table 4-2.

Because of the many subsequent changes, details of the designs and rationale behind the designs of this equipment are not discussed here, but where necessary these details are explained in the account of the development and checkout occurrences and problems.

4.1 FINAL CURV IIIC SYSTEM DESIGN

A detailed CURV III as-built drawing list and complete description of all components of the final CURV IIIC system are provided in Appendixes A and B of this report.

TABLE 4-1. CURV IIIA Component Concepts Essentially Unchanged From CURV I or CURV II

From CURV I	From CURV II
1. Electronic Control System Diode Logic	1. Frame
2. Propulsion Motors	2. Pan-and-Tilt Units
3. 35 mm Camera and Strobe	3. Hydraulic Actuators
4. BALD Gear	4. TV Cameras and Power Supply
	5. Mercury Vapor Lamps
	6. Recovery Claw and Tool Drive Assembly

TABLE 4-2. CURV III System Major Component Developments, Modifications, and Changes

	CURV IIIA Period (FY 66-69)	CURV IIIB Period (FY 70)	CURV IIIC Period (FY 71-72)
Development Items	1. Syntactic Foam/Glass Sphere Buoyancy Modules 2. Spherical Aluminum Main Housing 3. Flux-Gate Magnetometer (compass) and Display 4. Underwater Navigation and Locating (UNLOC) System 5. Support Vessel 6. Traction Winch 7. Pressure Balanced Main Cable Connector 8. Pressure Balanced Lights 9. Pressure-Balanced Small Connectors	1. Frame and Brackets 2. Solid Syntactic Foam Buoyancy Units 3. Cable Ring	1. Pyronol 1 in. Cable Cutting Tool 2. Head Coupled TV Controls 3. Failure Activated Search and Rescue Package
Modifications to Existing CURV Concepts	1. Main Cable with Glass-Epoxy Strain Member 2. Hydraulic System (from 750 to 1,000 psi) 3. Straza Sonar, Location, Altimeter, Depthometer (SLAD) 603 System (from 503 for greater depth and accuracy) 4. Three 235 kw AC Generators (from two 100 kw) 5. 7.5 kw MG set (from 5 kw) 6. 1,000 VAC Power Supply (from 600 VAC) 7. Articulating Crane Radius 19 feet (from 16 feet) 8. Control Van 9. Glass Sphere Cable Floats (from plastic)	1. Syntactic Foam Cable Floats 2. Main Connector Boot Clamp 3. Cable Baskets for Stacked Loading	1. Active Sonar Frequency 87-72 kHz (from 485-455 kHz), Range 800 yards (from 300 feet) 2. Elimination of 9 kHz from Passive Sonar 3. Relocation of Strobe Electronics (from pan-and-tilt mount to frame)
Changes	1. Six Bay Electronic Console (from four) 2. Dual TV Cameras (from one) 3. Cable Basket 4. Nylon Line Container	1. Spare Main Cable Added 2. Portable 100 kw Generator Added	1. Brantner Small Connectors (from NUC type) 2. Lights 3. Straza 703B Interrogatable Transponder

SECTION 5

SUPPORT VESSEL DEVELOPMENT

Page

5-3

Section 5

TABLE OF CONTENTS

Section	Title	Page
5.1	Support Vessel Design and Development	5-1
5.1.1	Requirements	5-1
5.1.2	Selection of Vessel	5-2
5.1.3	Design	5-2
5.1.4	Fabrication	5-7
5.2	Vessel Operational Evaluation	5-7

LIST OF FIGURES AND TABLES

Figure	Title	Page
5-1	YFN-1186 During Conversion to YFNX-30	5-4
5-2	Voith Schneider Cycloidal Propulsion Unit	5-6
5-3	YFNX-30 Design Concept Profiles	5-8
5-4	YFNX-30 Design Concept Deck Arrangements, Plan Views	5-9

Table	Title	Page
5-1	Study of Candidate CURV III Support Vessels	5-3

Section 5

SUPPORT VESSEL DEVELOPMENT

CURV III development had three significant identifiable activities which will be discussed separately:

1. Development of the support vessel
2. Development of the CURV IIIA vehicle (Section 6), CURV IIIB vehicle (Section 7), and CURV IIIC vehicle (Section 9)
3. Pressure and operational testing of all underwater components (whether development items or not) (Subsection 6.7)

The development activities will be discussed in detail only for components listed as development items in the Design Concept Section (Table 4-2, page 4-3). The details of design modifications to CURV I and II components are not discussed.

5.1 SUPPORT VESSEL DESIGN AND DEVELOPMENT

The CURV III support vessel development included definition of CURV III requirements, selection of appropriate vessel, vessel modifications, design, fabrication, and checkout.

5.1.1 REQUIREMENTS — Because the CURV III system was to operate in 7,000 feet of water, the support vessel had to be capable of operating in open ocean areas. Since the CURV III vehicle and console were to be portable, the primary function of the support vessel was envisioned as support of NUC range work. The design requirements were set to accommodate operations in a Pacific Ocean area of 6,500-foot depths off San Clemente Island. The minimum safe operating capability was therefore set at a sea state 3 with 4-foot maximum height of significant waves.

At-sea operations time for CURV III was expected to increase considerably over CURV I operations because of the deeper operating depths, which would lengthen underwater time, and because of the greater distance from shore of 7,000-foot

areas, which would preclude daily returns to home port. The logistics and supply goal for the vessel, therefore, was that it be self-sustaining for continuous CURV III operations at-sea over a 30-day period. The logistics requirement included provisioning the ships complement plus a round-the-clock CURV III crew, which was estimated at 10 men.

Propulsion and station keeping requirements were set at maintaining a fixed position over a recovery site within at least ±100 yards in a 20-knot wind and 1-1/2 knot surface current, occurring simultaneously in the least favorable directions.

5.1.2 SELECTION OF VESSEL — The criteria for selection of the CURV III vessel were: capability to support CURV III operations, availability, and cost to modify and operate.

Table 5-1 summarizes the study that was conducted to select the vessel. The vessels considered were: the NUC CURV I support vessel, YTM-759; the NUC Pop-Up range monitor barge, which had been used for Polaris testing but was since mothballed; the NUC range boats YFU-53, YFU-44, AN-9 (Butternut); a YF barge; and an EX-YNG (Panama Barge), an oil work barge available through commercial sources. The EX-YNG was the only non-NUC vessel considered because of the prohibitive costs involved in obtaining and converting a vessel.

The YFN-1186 (Fig. 5-1) was chosen as the most appropriate vessel. All of the vessels with the exception of the YTM-759 could have been modified to be an acceptable support craft for $400-450K. The YFN-1186, however, had the advantage of the best availability and shortest preparation time and was chosen primarily on those considerations. These advantages are accounted for in part by the fact that it is the least developed of the vessels; i.e., it had no existing propulsion, project equipment, or facilities on board, etc. This was a benefit since it enabled much more tailoring of the designs of the craft to CURV needs.

5.1.3 DESIGN — Design of the support vessel was accomplished under NUC direction by Ocean Design Engineering Corporation of Long Beach, California. A study and preliminary design contract was let first and the design completed on a separate contract.

The most significant design study task was the selection of the propulsion system to achieve proper station keeping. The station-keeping requirements of the CURV III support vessel are unique due to the cable link between the vessel and vehicle and the depth involved. If proper positioning is not maintained over the 600-foot diameter circle of buoyed cable, the support vessel can drag the vehicle

TABLE 5-1. Study of Candidate CURV III Support Vessels

	YTM (CURV Tug)	YFN (Monitor Barge)	YFU (53)	YFU (44)	YNG (Panama Barge)	AN (Butternut)	YF
SIZE	NO	GOOD	GOOD	(OK)	GOOD	(OK)	GOOD
STABILITY	POOR	CAN CORRECT	GOOD	(OK)	CAN CORRECT	(OK)	GOOD
SEA WORTHINESS	POOR	GOOD	POOR	?	?	GOOD	?
POWER	(OK)	CAN CORRECT	GOOD	GOOD	CAN CORRECT	CAN CORRECT	CAN CORRECT
FACILITIES	POOR	CAN CORRECT	(OK)	CAN CORRECT	CAN CORRECT	(OK)	GOOD
PORTABILITY	POOR	GOOD	GOOD	GOOD	GOOD	POOR	POOR
UPKEEP	13 CREW	13 CREW	16 CREW	16 CREW	13 CREW	39 CREW	(20) CREW
STATION KEEPING	NO	CAN CORRECT	CAN CORRECT	CAN CORRECT	CAN CORRECT	CAN CORRECT	CAN CORRECT
AVAILABILITY	NO	GOOD	NC	NO	(OK)	NO	(OK)
READINESS	∞	12 MO.	18+ MO.	18+ MO.	18+ MO.	18+ MO.	18+ MO.
COST	∞	450K	400K +	400K	450K	400K	450K

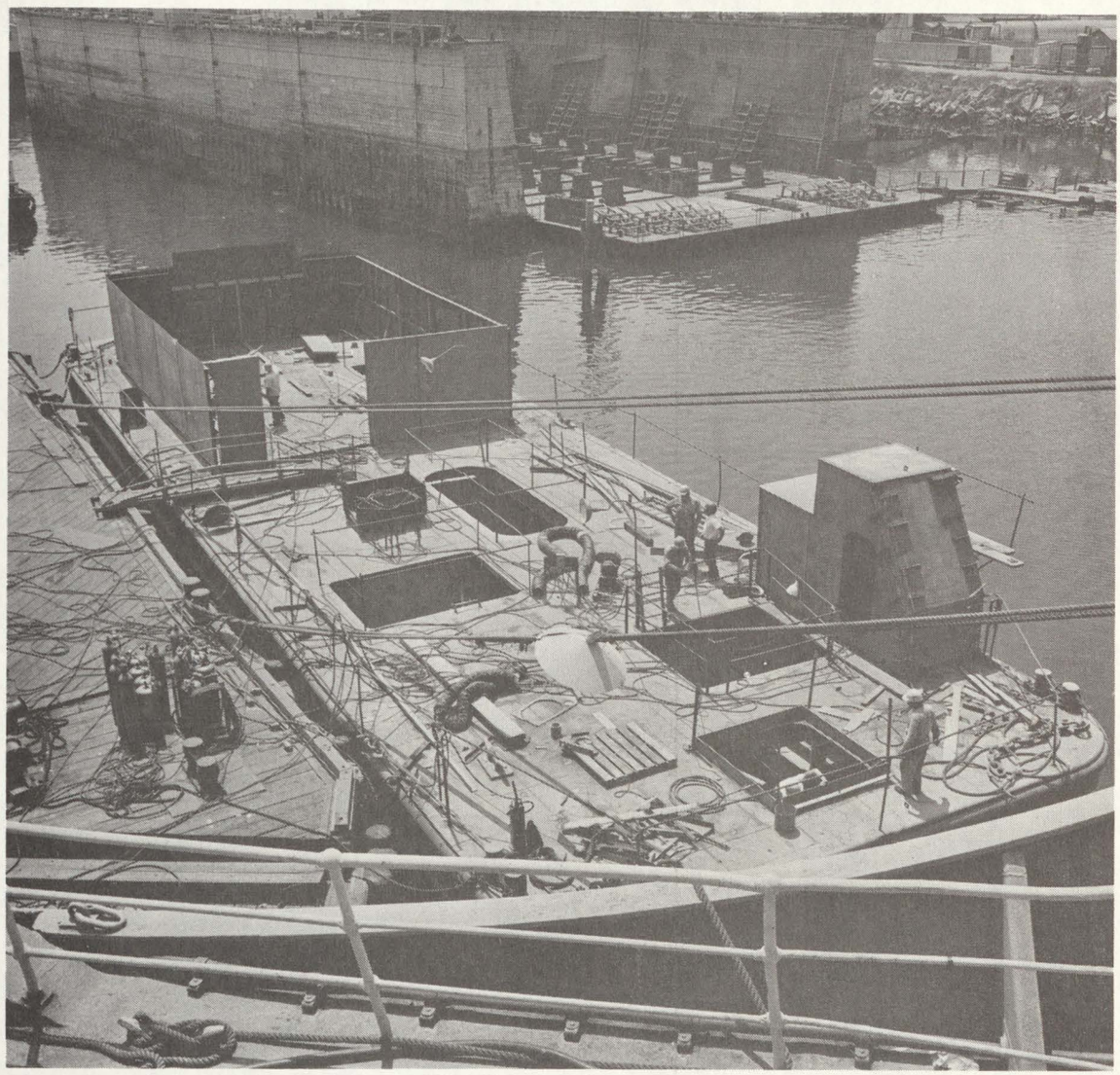


FIG. 5-1. YFN-1186 During Conversion to YFNX-30.

off the work site. If the vehicle has to move out of the 600-foot radius, the vessel must be able to go with it on the surface. This requires sensitive station-keeping.

For CURV I operations, the station-keeping and maneuvering was accomplished using one or more small boats to tow the YTM-759, or the YTM-759 was placed in a moor. This assistance was needed to enable station-keeping and maneuvering the YTM was not capable of and to prevent its unprotected screws from cutting the cable.

The goal for CURV III was to enable sensitive station-keeping of the CURV III support vessel without other vessels. This meant a type of propulsion capable of thrust in any direction and which would not endanger the cable. Five types of available propulsion systems were investigated: (1) retractable outboard motors with pivotable lower shafts; (2) submersible electric motors and variable pitch propellers mounted in 360° pivotable ducted kort nozzles; (3) submersible 360°-pivotable hydraulic powered screws; (4) an axial pump and 360° nozzle; (5) cycloidal propellers (i.e., vertical variable pitch blades rotating as a unit). All the systems considered would have had at least two thrusters mounted fore and aft on the centerline of the barge to give the necessary coupling for maneuvering in all directions.

The propulsion system chosen was Voith-Schneider cycloidal propulsion (Fig. 5-2). Its major advantages were as follows:

a. Infinite thrust variation for 360° maneuvering

b. Constant speed for control even when idling

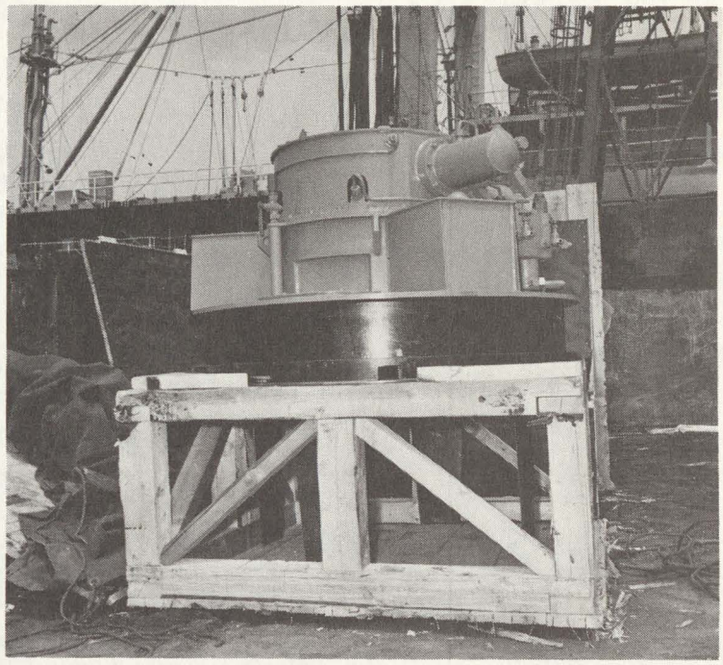
c. Power efficiency (200 Hp electric motors required to drive each thruster)

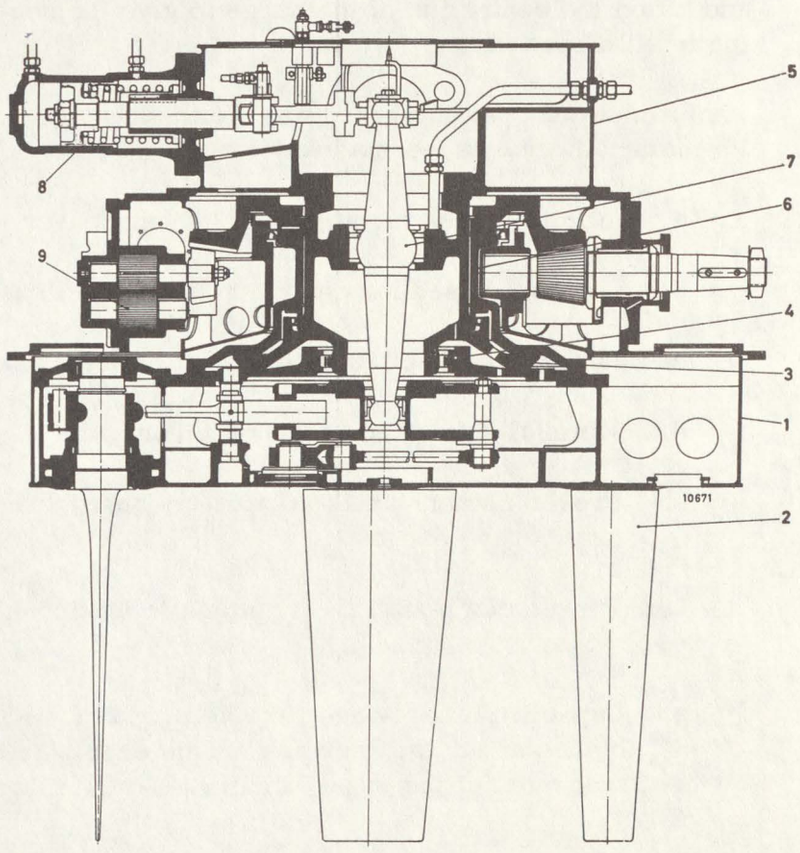
d. Minimal shipboard space requirements

e. Proven performance on craft in sensitive maneuvering situation (ferries, tugs, crane barges)

f. Proven compatibility in automatic station-keeping with Decca and Lorac system

g. Capability for giving effective propulsion when mounted with propeller blades above the keel line. This enabled a barge design provision for transport of the vessel in an LSD or similar large vessel.





18. Section through VS Propeller, series E with bell crank lever type kinematics

1 rotor casing
2 blade
3 bearing lantern piece
4 roller bearing
5 propeller casing
6 driving sleeve
7 control rod
8 servomotors
9 gear oil pump

FIG. 5-2. Voith Schneider Cycloidal Propulsion Unit.

h. Capability for effective propulsion when mounted well within perimeter of vessel. This avoided shrouding the blades to prevent cable damage. The shrouds would have reduced propulsion efficiency.

i. Availability of a proven control system and linkages to enable coordinated control of two units from either central or remote control sites.

j. Proven experience on several US craft, in particular the YD-171 "German Crane" barge at Long Beach Naval Shipyard, one of the two largest floating cranes in the world. NUC was familiar on first-hand basis with the excellent performance of the Voith-Schneider units on this craft.

The final design concept of the CURV III support vessel is shown in Figs. 5-3 and 5-4.

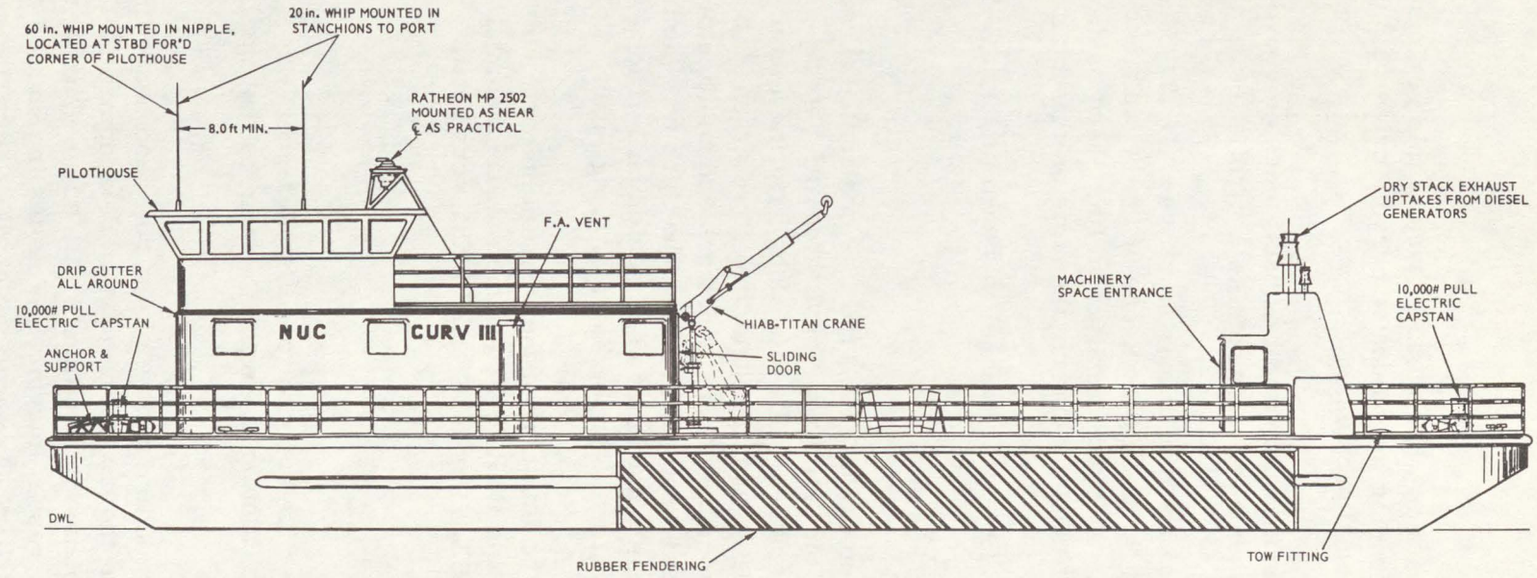
5.1.4 FABRICATION — The conversion of the YFN-1186 was contracted through the 11th Naval District Supervisor of Shipbuilding, Conversion and Repair (SupShip 11). It was done in three increments of work. The first increment included below deck modifications to the supporting structure by Larson Boat Works, Long Beach, California; the second increment was deck work and addition of the new superstructure including pilot-house and workrooms; the third was plumbing, electrical wiring and installation of basic machinery and equipment. These two increments were accomplished by California Shipbuilders of Long Beach, California.

After the conversion was complete, the finishing of the vessel compartments, galley, etc., and installation of portable CURV III equipment were accomplished in the Long Beach Naval Shipyard (LBNSY) by NUC and LBNSY personnel.

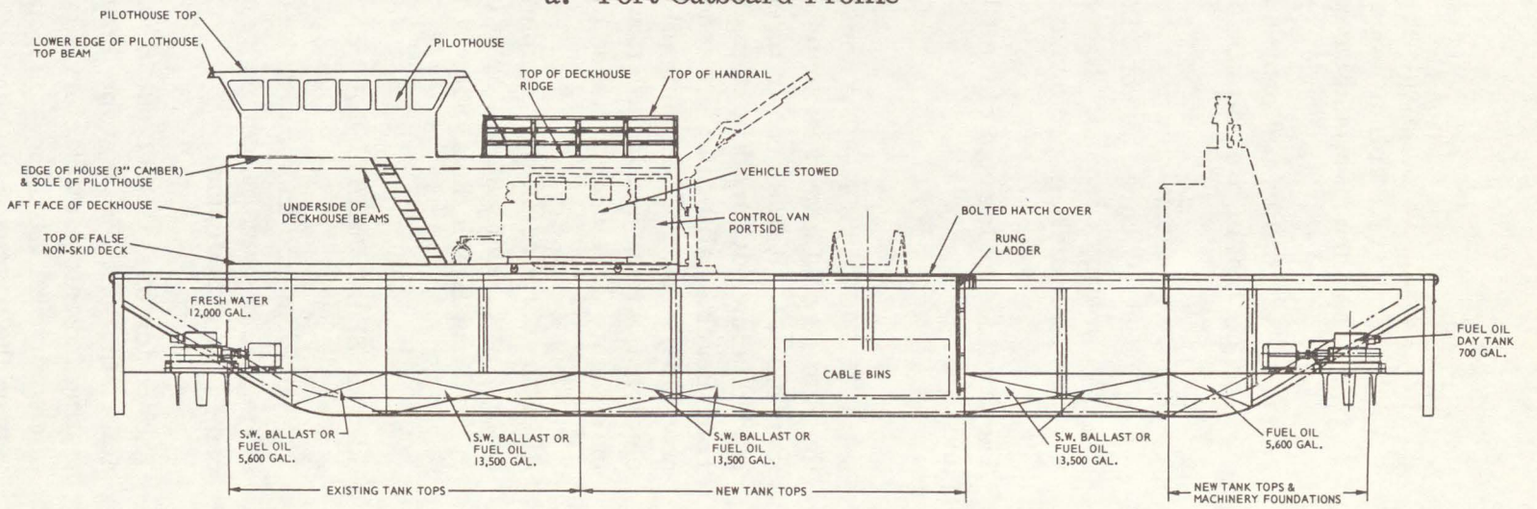
5.2 VESSEL OPERATIONAL EVALUATION

The performance and seaworthiness of the support vessel as designed was tested during the conversion period by model testing at General Dynamics test facility, San Diego, California.

The testing was carried out in part to determine the pitch, roll, and heave characteristics of the vessel for input into the navigation system development. This testing indicated satisfactory performance in sea state 4 with acceptable heave, pitch, and roll from the standpoint of vessel integrity. This testing showed no reason the vessel would not support CURV III operations in a sea state 3.

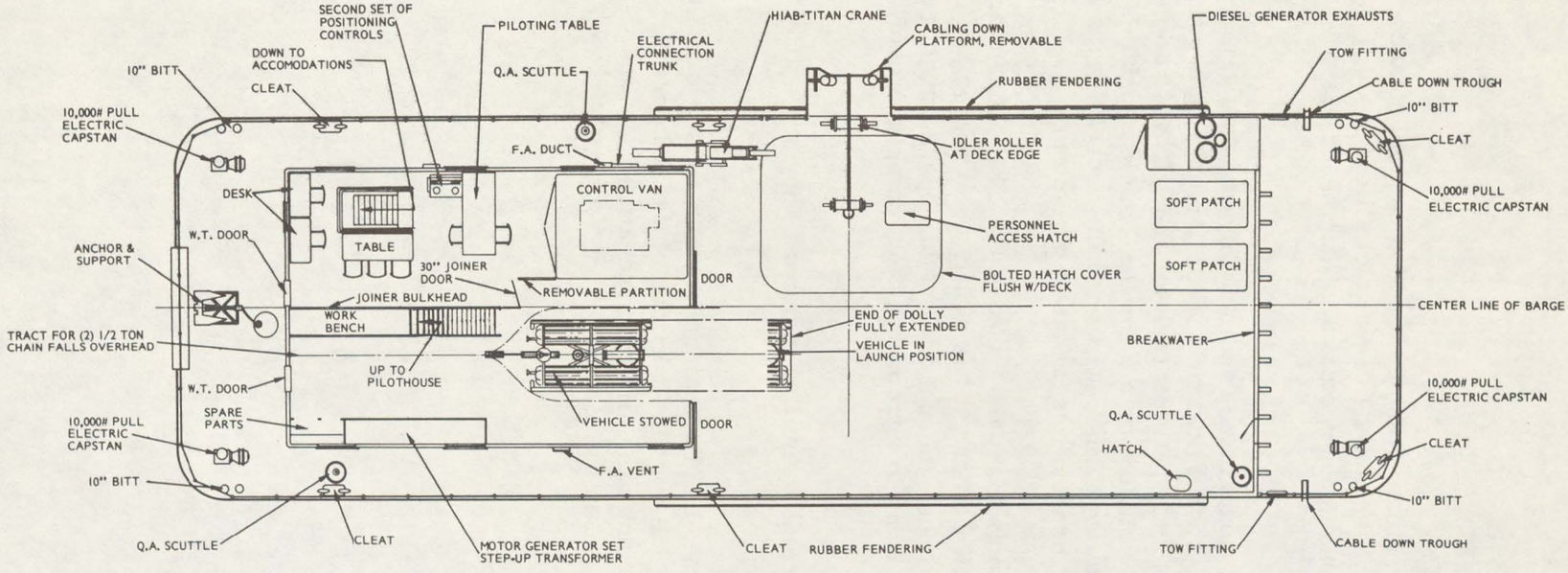


a. Port Outboard Profile

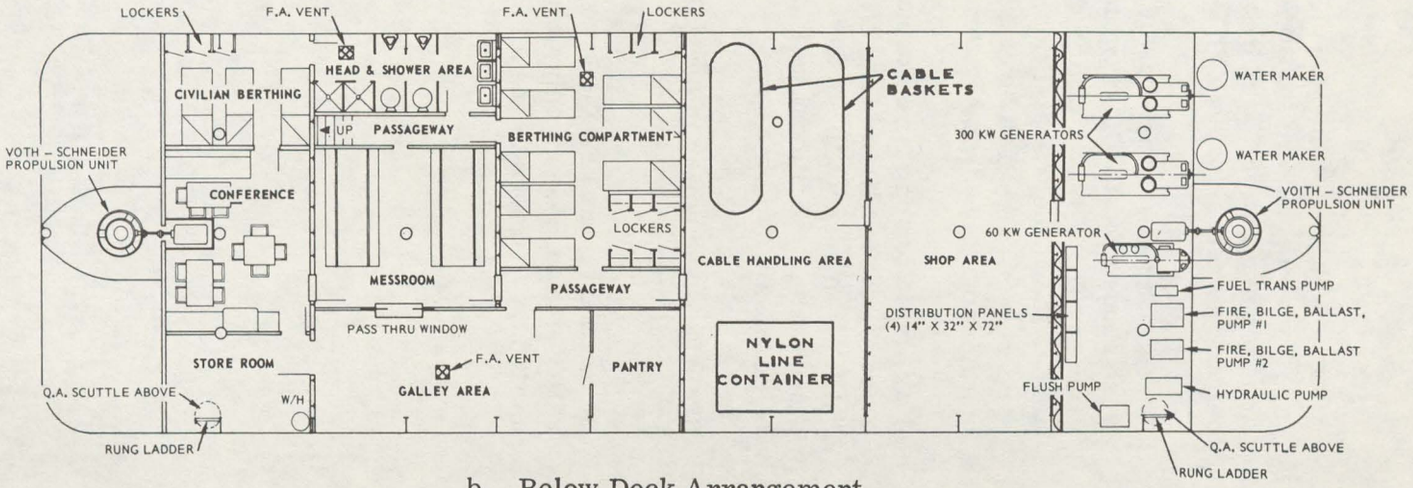


b. Port Inboard Profile

FIG. 5-3. YFNX-30 Design Concept Profiles.



a. Main Deck Arrangement



b. Below Deck Arrangement

FIG. 5-4. YFNX-30 Design Concept Deck Arrangements, Plan Views.

After completion of the vessel, conversion incline tests and at-sea acceptance trials were performed by LBNSY and NUC and the vessel met all test specifications for support of CURV III operations in a sea state 3. The vessel was accepted and redesignated YFNX-30.

Three independent analyses of vessel performance and stability and safety aspects were conducted at NUC request by the vessel designer Ocean Design Engineering Company (Ref. 6), by LBNSY (Ref. 7) and by Tetra Tech Inc., (Ref. 8) to define further the vessel capabilities. These studies also found the vehicle capable of supporting CURV III in sea state 3; however, they stipulated the vessel always be maintained head-on or stern on to the wind in sea state 4 or better.

This limitation on its performance stems from the fact that the YFN-30 remains a barge with the limitations of this hull design. It has a sharp roll period and is "stiff" with respect to surface disturbance. In order to sustain operations above a sea state 3, additional hull modifications to introduce motion damping would be necessary.

The speed and power in heavy seas are also limiting factors. They are sufficient for local operations only.

In summary, the YFNX-30 was designed and built as the support vessel for NUC CURV III range needs only, assuming the portable portions of the system utilized aboard an appropriate vessel of opportunity for all other operations.

Page

SECTION 6

CURV IIIA VEHICLE DEVELOPMENT

-4

6-5

6-7

6-8

6-9

Section 6

TABLE OF CONTENTS

Section	Title	Page
6.1	Buoyancy Units	6-1
6.1.1	Glass Ball/Syntactic Foam Casting Process Development	6-2
6.1.2	Fabrication	6-6
6.1.3	Mounting	6-6
6.2	Spherical Main Watertight Housing	6-6
6.3	Pressure Balanced Main Connector	6-10
6.3.1	Design	6-10
6.4	Lights	6-10
6.5	Small Connectors	6-15
6.6	Vehicle Magnetometer and Indicator	6-19
6.7	Component Testing	6-20
6.8	System Checkout and Buoyancy Unit/Frame Failure	6-26

LIST OF FIGURES AND TABLES

Figure	Title	Page
6-1	CURV IIIA Four Module Syntactic Foam Glass Buoyancy Unit after Test Failure	6-3
6-2	CURV IIIA Buoyancy Module During Casting	6-4
6-3	CURV IIIA Two Halves of Syntactic Foam Buoyancy Module and Glass Ball	6-5
6-4	CURV IIIA Three Stacked Buoyancy Modules Showing Configuration and Restraining Straps	6-7
6-5	CURV IIIA Vehicle with Glass Ball Syntactic Foam Buoyancy Units	6-8
6-6	CURV IIIA Main Housing Concepts	6-9

LIST OF FIGURES AND TABLES (Cont'd)

Figures	Title	Page
6-7	CURV IIIA Spherical Aluminum Main Housing-Closed	6-11
6-8	CURV IIIA Open Spherical Main Housing and Electronics Section	6-12
6-9	CURV IIIA Pressure Balanced Main and Whip Connectors Components and Test Plate	6-13
6-10	CURV IIIA Assembled Main Connector and Whip Connector	6-14
6-11	CURV IIIA Pressure Balanced Light Concepts	6-16 6-16
6-12	CURV IIIA Pressure Balanced Small Connector Concept	6-17
6-13	CURV IIIA Light and Small Connector Test Unit	6-18
6-14	CURV IIIA Component Test Fixture	6-21
6-15	CURV IIIA Vehicle After First Deep Checkout Dive	6-31
6-16	CURV IIIA Collapsed Frame and Fragment of Syntactic Foam from Buoyancy Modules	6-32

Table	Title	Page
6-1	CURV III Components Hydrostatic Pressure Testing	6-23
6-2	Strain Test on 2-in-1 Samson Nylon Braided Rope — 1 inch Diameter	6-25
6-3	CURV IIIA Checkout Report	6-27

Section 6

CURV IIIA VEHICLE DEVELOPMENT

Vehicle development was carried out in three separate periods, CURV IIIA, B, and C. These CURV III periods are separated by two vehicle calamities: the implosion of the bouyancy tanks during a CURV IIIA deep checkout, which resulted in the CURV IIIB vehicle design; and the loss of the CURV IIIB vehicle during operation, which resulted in the CURV IIIC design. The development efforts described here are those conducted prior to the first vehicle calamity.

6.1 BUOYANCY UNITS

The CURV III buoyancy units became a development item because the aluminum cylinders used on CURV I and II were marginal as to strength and buoyancy yield at 7,000 foot depths.

Calculations showed that eight tanks similar in size to those of CURV I and II (on which four tanks were used) would be necessary due to increases in wall thickness and the number of reinforcing strength rings that were required. Although aluminum tanks could have been built for CURV III, several considerations pointed up the advisability of seeking another form of buoyancy. First, many CURV vehicle components were increasing in size and, more critically, weight, in order to meet CURV III pressures. This build-up boded ill for overall vehicle control, response, speed, and performance. The remedies for this build-up were reduced component weight and size and increased buoyancy yield, both of which could be implemented by a more efficient buoyancy concept than aluminum tanks. Second, while the aluminum tanks could be used for CURV III, they obviously would not be practical at depths beyond 7,000 feet, and a buoyancy development would eventually be required for the CURV program. Third, because the aluminum tank technology was already well developed, straightforward, and inexpensive to implement, the tank concept could remain as a back-up while development in other forms were carried out. Fourth, improvements in buoyancy were necessary to offset degraded system performance (with respect to CURV I and II capabilities) due to other factors such as the mass and drag of 5,000 additional feet of cable.

The primary candidate for alternative buoyancy units was syntactic foam (glass microspheres in a resin matrix) which was being developed at NUC. Two concepts were investigated; solid syntactic foam modules, and a combination of 8- or 10-inch Corning glass spheres imbedded in NUC syntactic foam.

The syntactic foam available at the time had a density of 42 pounds per cubic foot. In solid modules, this foam would not significantly improve size and weight over the aluminum cylinders.

Syntactic foam/glass ball modules had a design density of 32 to 36 pounds per cubic foot, depending on whether 8 or 10-inch balls were used and the amount of foam required for added support. The design operating depth of the glass balls was 20,000 feet and the syntactic foam was 10,000 feet. The combination of balls and foam appeared the most promising and represented a contribution to the state-of-the-art if successful, so it was pursued as the primary buoyancy tank concept.

6.1.1 GLASS BALL/SYNTACTIC FOAM CASTING PROCESS DEVELOPMENT — After tests and studies to select proper glass spheres and the proper composition of the NUC syntactic foam, the major work with the glass ball units was developing the manufacturing technique for casting the balls in cylindrical modules of syntactic foam. The balls were cast in individual modules of syntactic foam for later assembly in eight module sections on the vehicle.

The initial castings failed in pressure tests at relatively low pressures of 1,360 psi. The unit that was tested (Fig. 6-1) had four modules. The two balls that failed were at opposite ends of the unit. A new curing technique was devised. Subsequent tests of a three module casting resulted in implosion of the two end balls at 2,850 psi. There was no sympathetic implosion of the middle ball and no evidence of any damage to the balls prior to testing. The failure was traced to shrinkage of syntactic foam during curing which applied uneven external pressure to the balls.

A new casting method was developed to eliminate the stress built up during the process of casting and period of curing. A dispersion coating was applied to the balls prior to casting. After casting in a specially designed aluminum mold (Fig. 6-2), a stress relief groove was cut in the syntactic foam completely around the ball circumference. The syntactic foam was thus in two halves (Fig. 6-3) that would be clamped together on the vehicle. The stress relief groove allowed the dispersion coating to see ambient pressure and apply the force equally over the entire ball. The casting process is given in detail in Ref. 5.

Several modules thus formed were pressure tested to 5,000 psi with no failures.

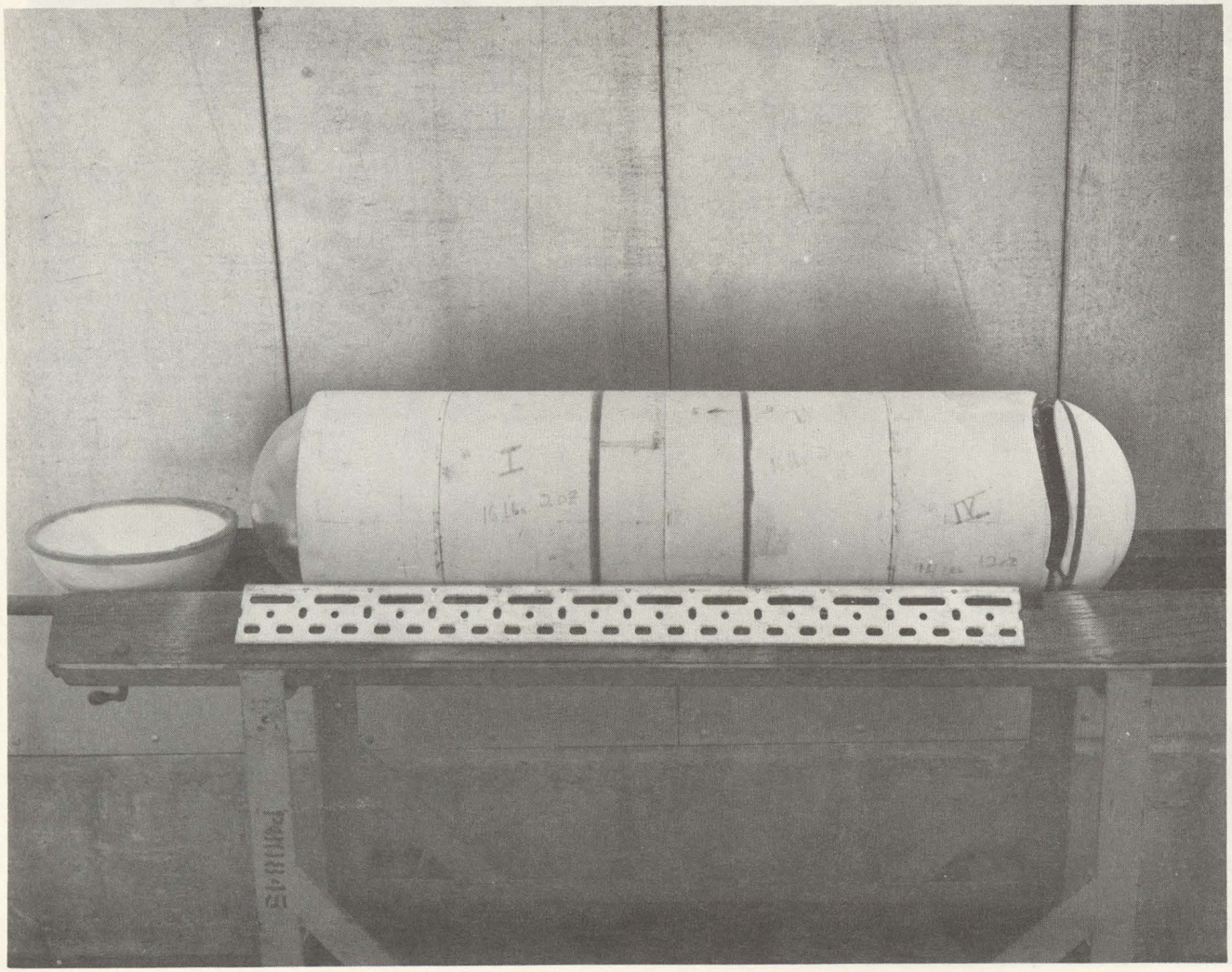


FIG. 6-1. CURV IIIA Four Module Syntactic Foam Glass Buoyancy Unit after Test Failure.

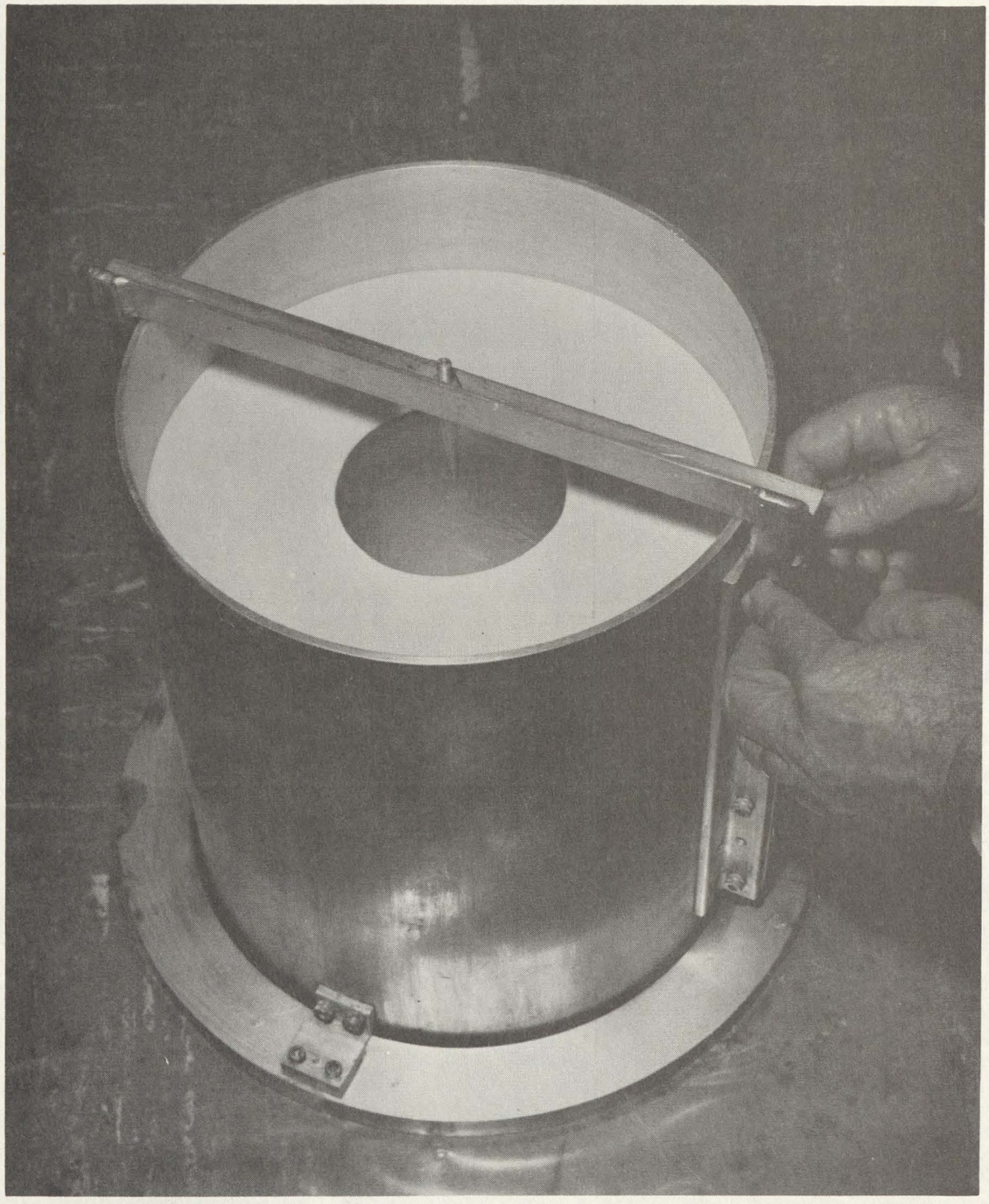


FIG. 6-2. CURV IIIA Buoyancy Module During Casting.

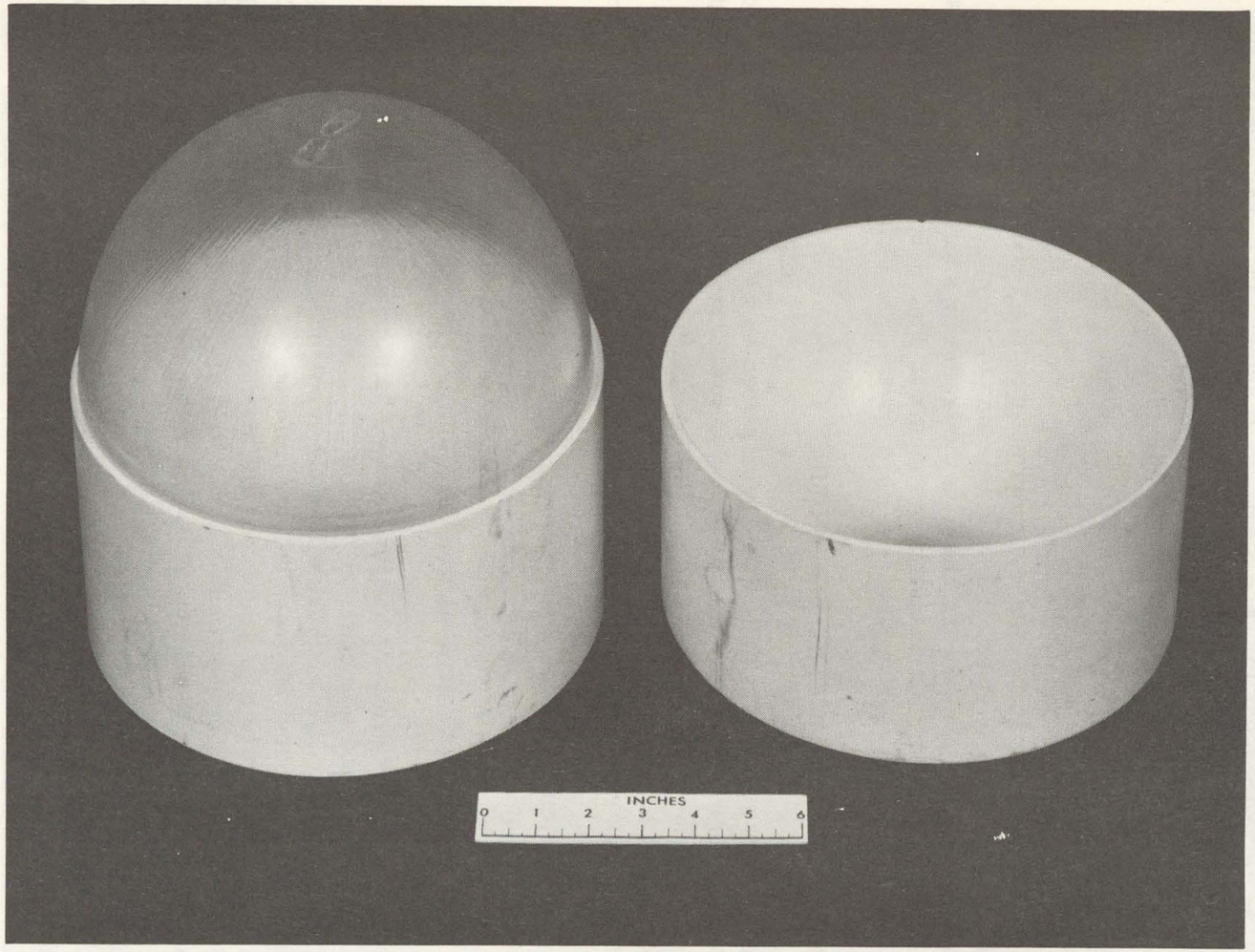


FIG. 6-3. CURV IIIA Two Halves of Syntactic Foam Buoyancy Module and Glass Ball.

6.1.2 FABRICATION — Fabrication of the CURV IIIA modules was then begun. Forty-eight modules mounted in six rows of eight were required for CURV IIIA buoyancy. Seventy-two modules were prepared to supply necessary spares and capability for additional buoyancy as required. Each of the 10 inch o.d. glass balls was pressure tested to 5,000 psi prior to casting. After casting each of the modules was tested to 5,000 psi prior to mounting on the vehicle.

6.1.3 MOUNTING — The modules had a modest interlocking fit and formed cylinders 124 inches long and 10 inches in diameter. The six cylinders were stacked as shown in Fig. 6-4, and clamped together by longitudinal bolts and end holding plates. They were restrained on the frame by stainless steel straps (see Fig. 6-4). The entire tank assembly is shown in Fig. 6-5.

6.2 SPHERICAL MAIN WATERTIGHT HOUSING

The stainless steel cylindrical T-shaped housing used on CURV I and II to protect the vehicle electronics and hydraulic valves from pressure could not withstand the pressure of 7,000 foot depths. Several concepts were investigated trading off weight, size, configuration, materials, payload and ease of penetration. The major concepts were the three shown in Fig. 6-6. The primary candidate materials were titanium, steel, and aluminum. Titanium offered light weight, but little proven experience in working with this material and using it underwater could be found. Steel was the heaviest, but also the most proven, material. Aluminum had advantages in weight over steel and in workability over titanium, but it was also new to this type of application.

The concept of a large sphere made of two hinged hemispheres was chosen to maximize the payload and minimize the weight of the structure. Aluminum was picked as the material. The manufacture of the hemispheres required advanced state-of-the-art techniques that were being developed for torpedo bodies by NUC. The method of manufacture was sand casting. In order to insure structural integrity, tolerances of ±0.011 inches had to be adhered to. Machining and welding after casting had to be kept at a minimum. The sphere is 1 inch thick, 26 inches i.d., 28 inches o.d. (30 inches at hinge) of aluminum alloy No. 354 class 1, anodized. The minimum design depth of the sphere was 7,000 feet with yield at 8,000. Subsequent calculations and testing have shown it good to 10,000 feet with a calculated yield at 13,500 feet.

The sphere encloses most one-atmosphere vehicle electronics and the hydraulic valves and solenoids. The interior is designed so that on opening the top hemisphere the electronics section is most readily serviceable. The top plate of the

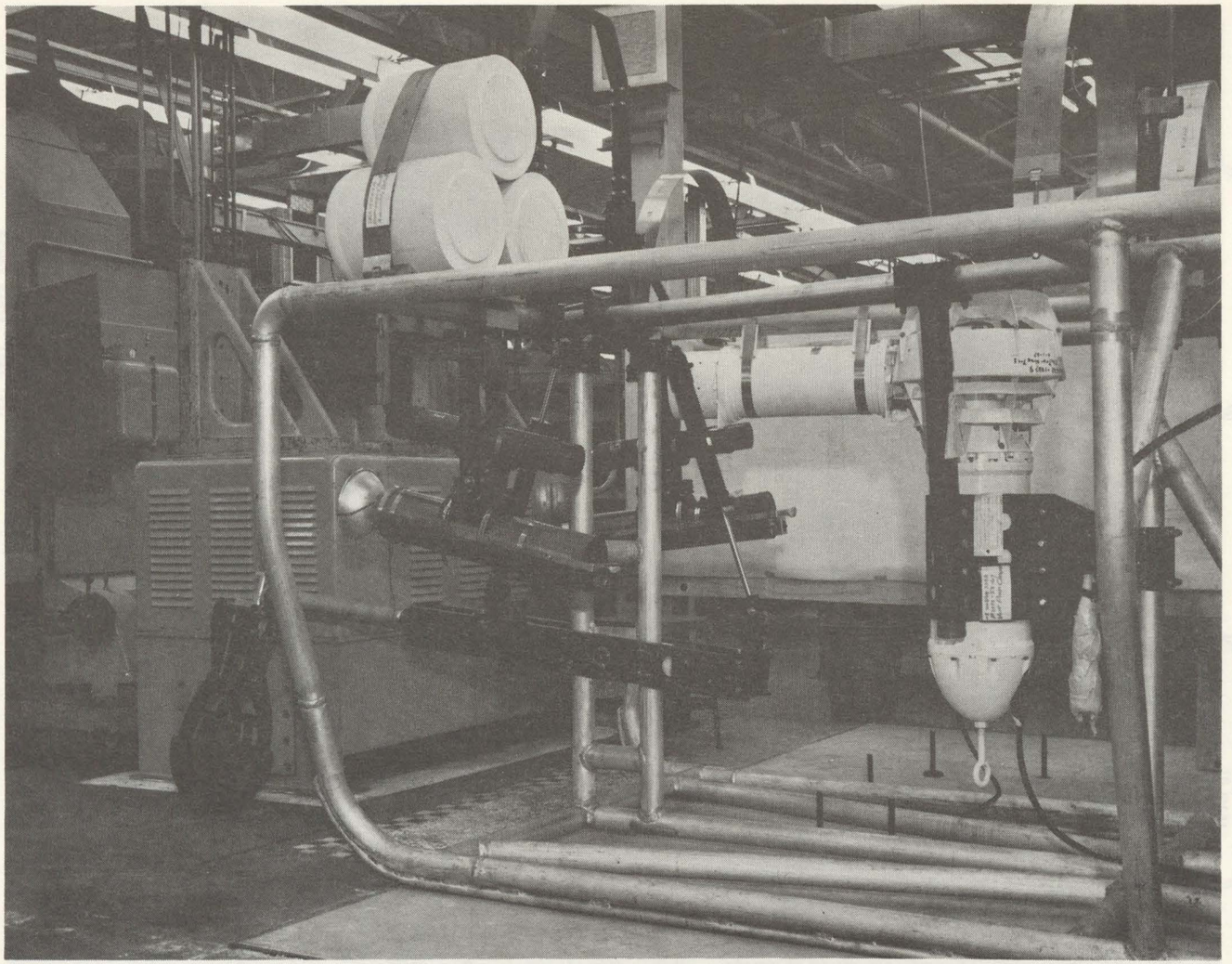


FIG. 6-4. CURV IIIA Three Stacked Buoyancy Modules Showing Configuration and Restraining Straps.

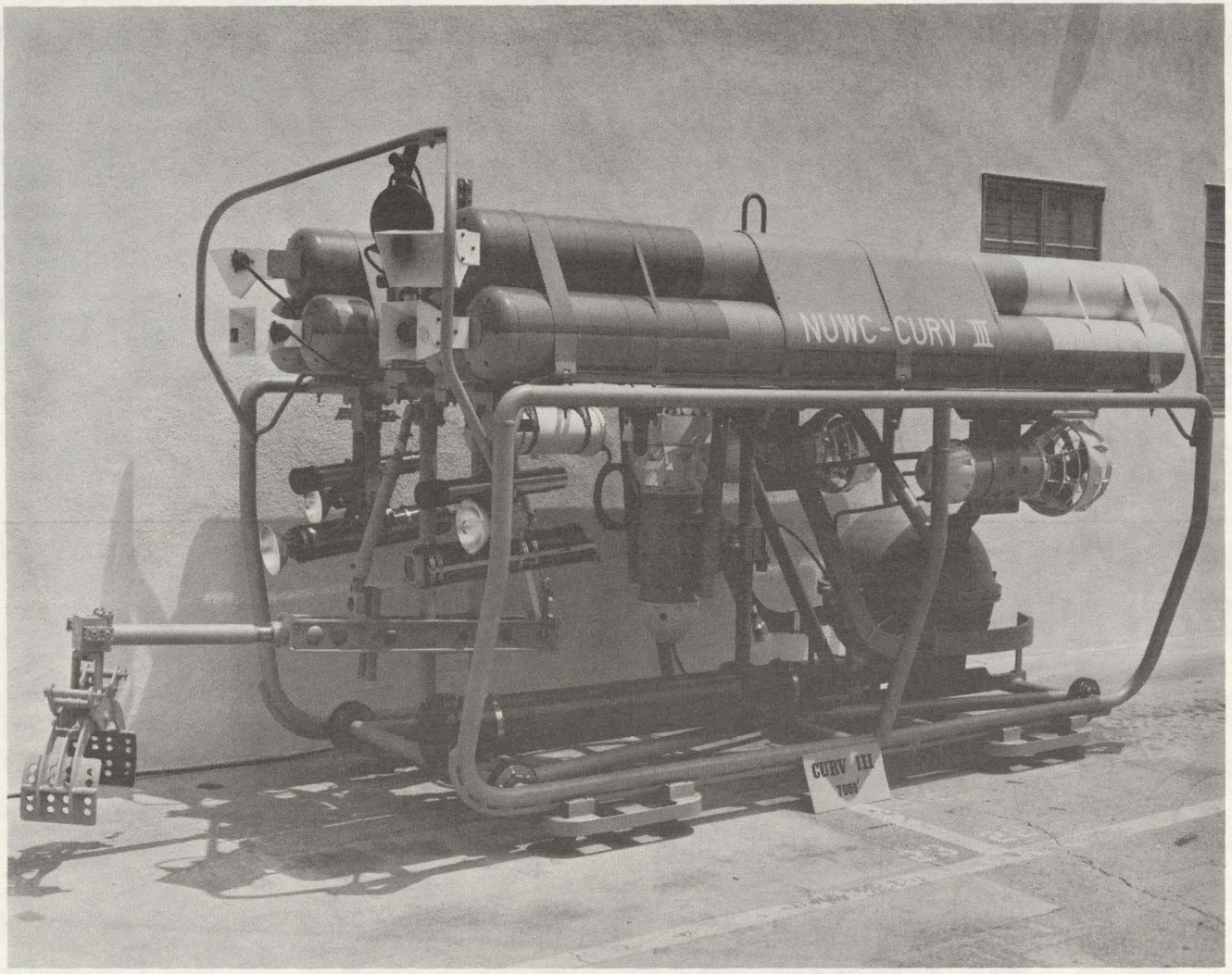
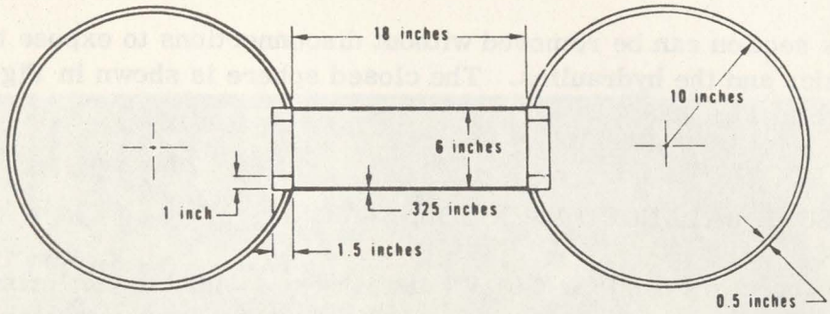


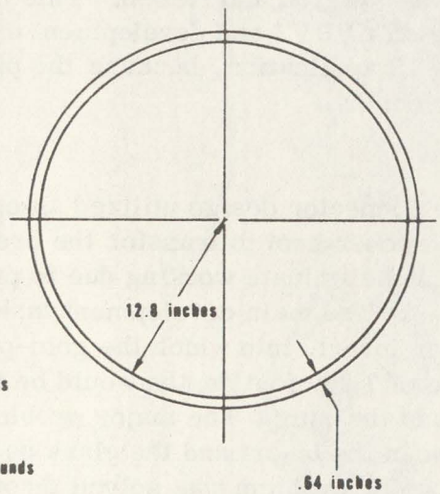
FIG. 6-5. CURV IIIA Vehicle with Glass Ball Syntactic Foam Buoyancy Units.



Volume : 8900 cubic inches

Design Depth : 7000 feet

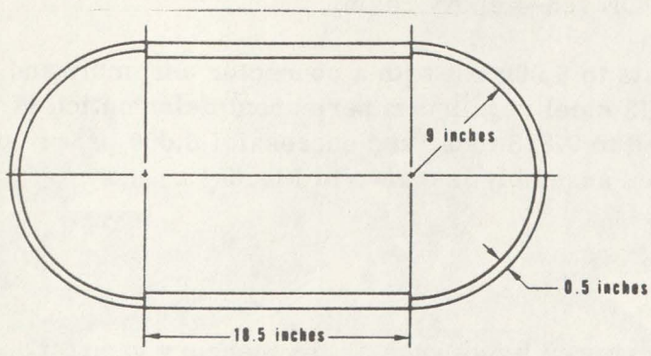
Estimated Weight : 124 pounds



Volume : 8900 cubic inches

Design Depth : 7000 feet

Estimated Weight : 123 pounds



Volume : 8900 cubic inches

Design Depth : 7000 feet

Estimated Weight : 141 pounds

FIG. 6-6. CURV IIIA Main Housing Concepts.

electronics section can be removed without disconnections to expose the remainder of electronics and the hydraulics. The closed sphere is shown in Fig. 6-7 and the open sphere in Fig. 6-8.

6.3 PRESSURE BALANCED MAIN CONNECTOR

The main connectors used for CURV I and II were molded to the terminations of the cable. The ambient pressures were taken by these conductors above the moulding and the outside of the connector moulding resisted the pressure somewhat, causing the conductors to be pushed into the molding in a "piston effect." This effect worked the soldered connection of cable conductors and connector pins as the vehicle was lowered and raised. This piston effect had been a cause of electrical failures on CURV I and development of a better connector was necessary for the CURV III application, because the piston effect would be more severe at the deeper depths.

6.3.1 DESIGN — The connector design utilized an open frame filled with grease and surrounded by a rubber boot to transfer the pressure equally all around the conductors and pins and eliminate working due to pressure. The components are shown in Fig. 6-9. The main development task was design of the nickel-plated steel connector insert, into which the gold-plated conductor pins were fixed. The pressure of 7,000 foot depths would be taken entirely by the insert and glass seals around the pins. The major problems were the insert material and the bonding between the insert and the glass used to affix and seal the connector pins. The bonding problem was solved through the use of Corning 910 glass and EPON 185-4 epoxy resin.

Pressure tests to 5,000 psi with a connector assembly and 0.525-inch thick insert made of B-113 steel resulted in permanent deformation of the insert. The thickness was increased to 0.828 inch, and successful 5,000 psi pressure tests resulted. The completed assembly is shown in Fig. 6-10.

6.4 LIGHTS

Existing underwater lights such as the mercury vapor lights used on CURV I and II were subject to frequent failure at depths less than 2,500 feet due to pressure cycling. The most common problems were spalling and breakage of the bulb glass where the threaded base joined the bulb, and moisture collecting between the bulb base and socket. The spalling of the glass at the base was caused in pressure cycling by the working of the epoxy used to fill the void between the

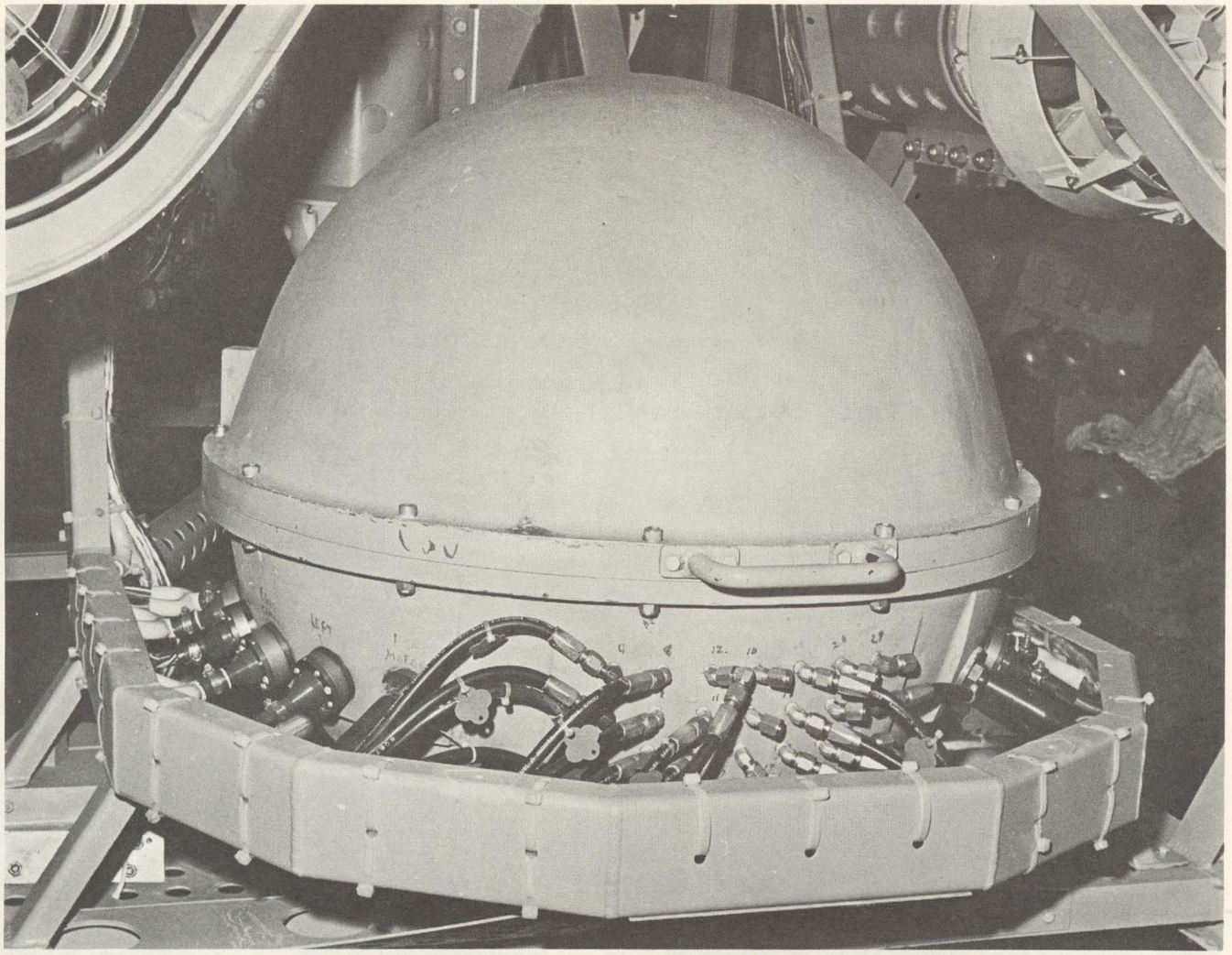


FIG. 6-7. Spherical Aluminum Main Housing-Closed.

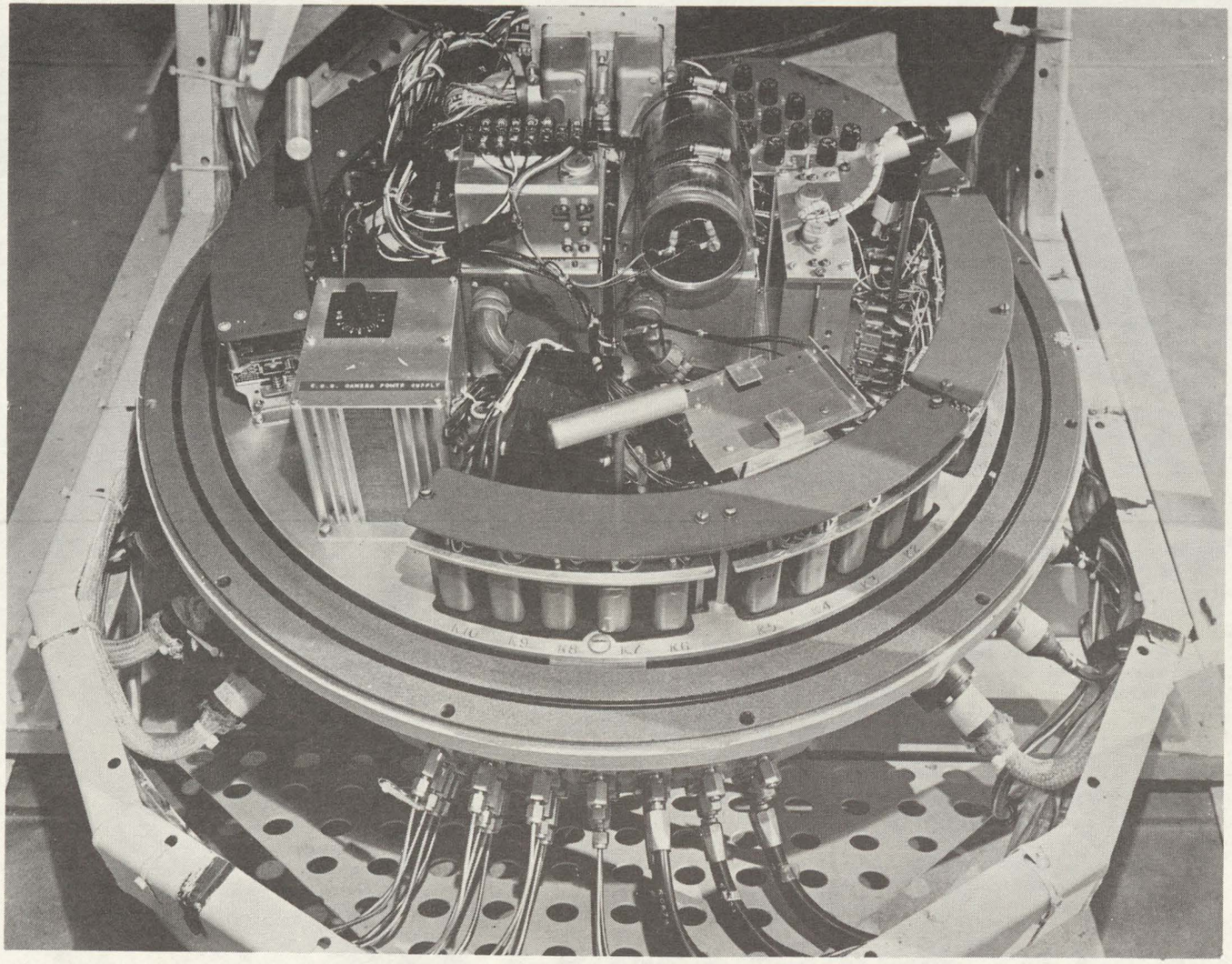


FIG. 6-8. Open Spherical Main Housing and Electronics Section.

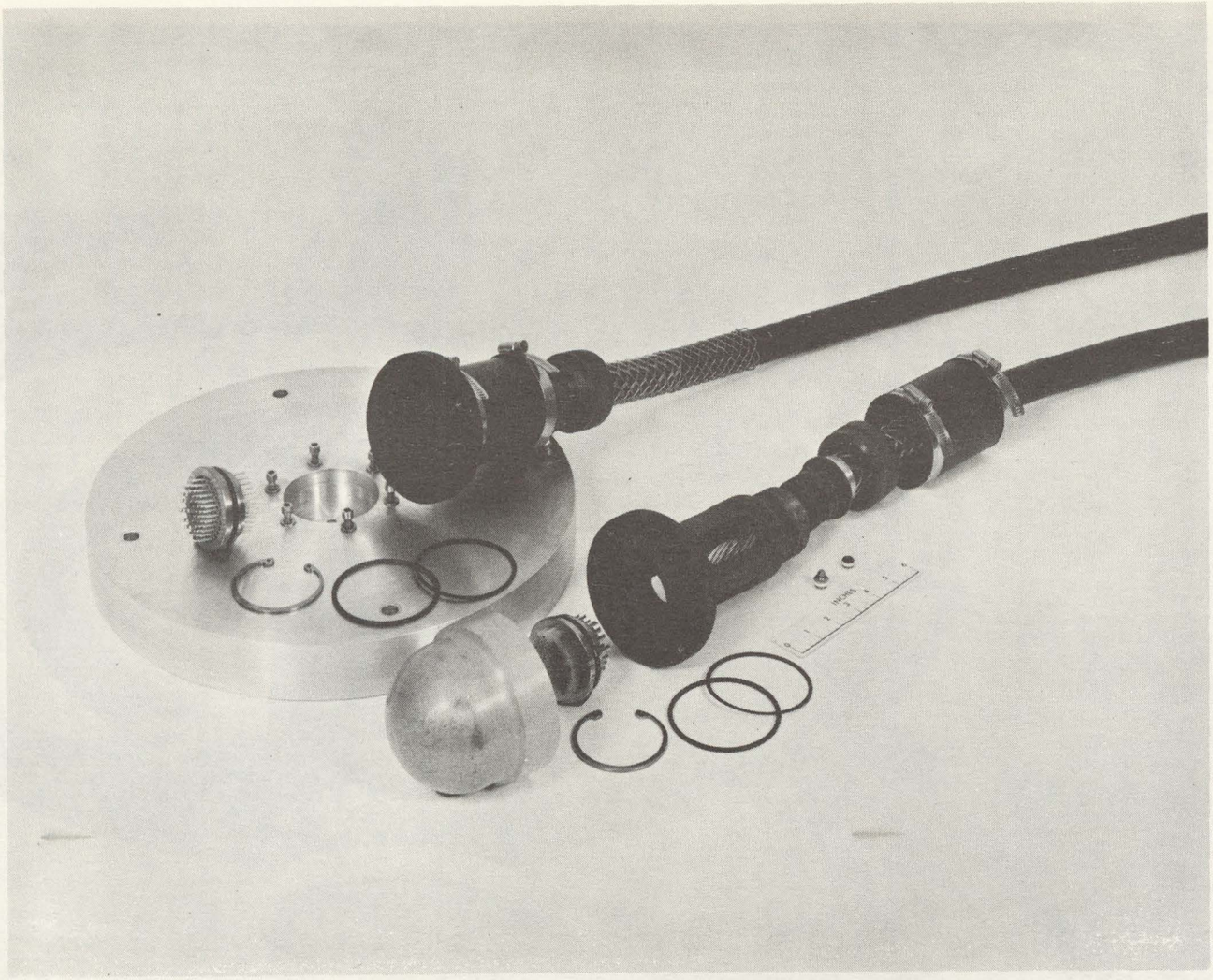


FIG. 6-9. CURV IIIA Pressure Balanced Main and Whip Connectors Components and Test Plate.



FIG. 6-10. CURV IIIA Assembled Main Connector and Whip Connector.

thread base and bulb. The moisture came from "breathing" of the rubber boot which surrounded the bulb and socket. The moisture problem was compounded by the difficulty of making good O-ring seals within the socket caused by the necessity of using silicone grease to fill voids.

An attempt to solve these problems by constructing glass housings around the bulbs proved ineffective because of the difficulty in sealing the housings. The bad seals caused electrical leaks in the surrounding water, which affected sonar and compass performance and caused high rate of component corrosion.

The NUC CURV III development remedy (Fig. 6-11) consisted of eliminating the threaded base and socket from the bulb entirely and fusing the CURV electrical system conductors directly into the glass. The conductor end of the bulb was put into a housing filled with electrically resistant fluid. The conductors were run through fluid-filled flexible tubing to the ballast transformers which were also housed in a fluid filled case. The fluid was filled through alemite fittings in the lamp housing and was free flowing between the tube and both housings. The intent was that as the vehicle descended, the flexible tubing would act as a bellows to pressure balance the O-ring seal around the base of the bulb, keeping even pressure over the bulb with no wearing or spalling of the glass.

6.5 SMALL CONNECTORS

The idea of utilizing a fluid-filled flexible tube on the lights as a bellows to balance pressure was expanded to other components by development of a small pressure balanced connector. Existing small molded connectors had the problems of conductor breakage due to pressure cycling and of electrical leakage; in fact, these small connector problems had been by far the largest source of CURV I maintenance and repair tasks. A small housing (see Fig. 6-12) was designed to attach to a connector insert. Screw-in plug type feedthroughs were placed in the insert for the required number of conductors. Conductors were soldered to the pins. The insert plate was screwed to the small housing and sealed with a low pressure O-ring across which the pressure was balanced. The tubing and conductors were fitted at both ends with these connectors. The component wires were then soldered to the other side of the feedthroughs and the insert pressure plates were attached to the component pressure housing (e.g., the TV housing). A similar connection was also made at the power source (usually the main pressure housing).

A pressure-balanced connector and lights (Fig. 6-13) were tested to 5,000 psi successfully in tests involving repeated pressure cycling with no failures and the concept was introduced on all components that were being developed or

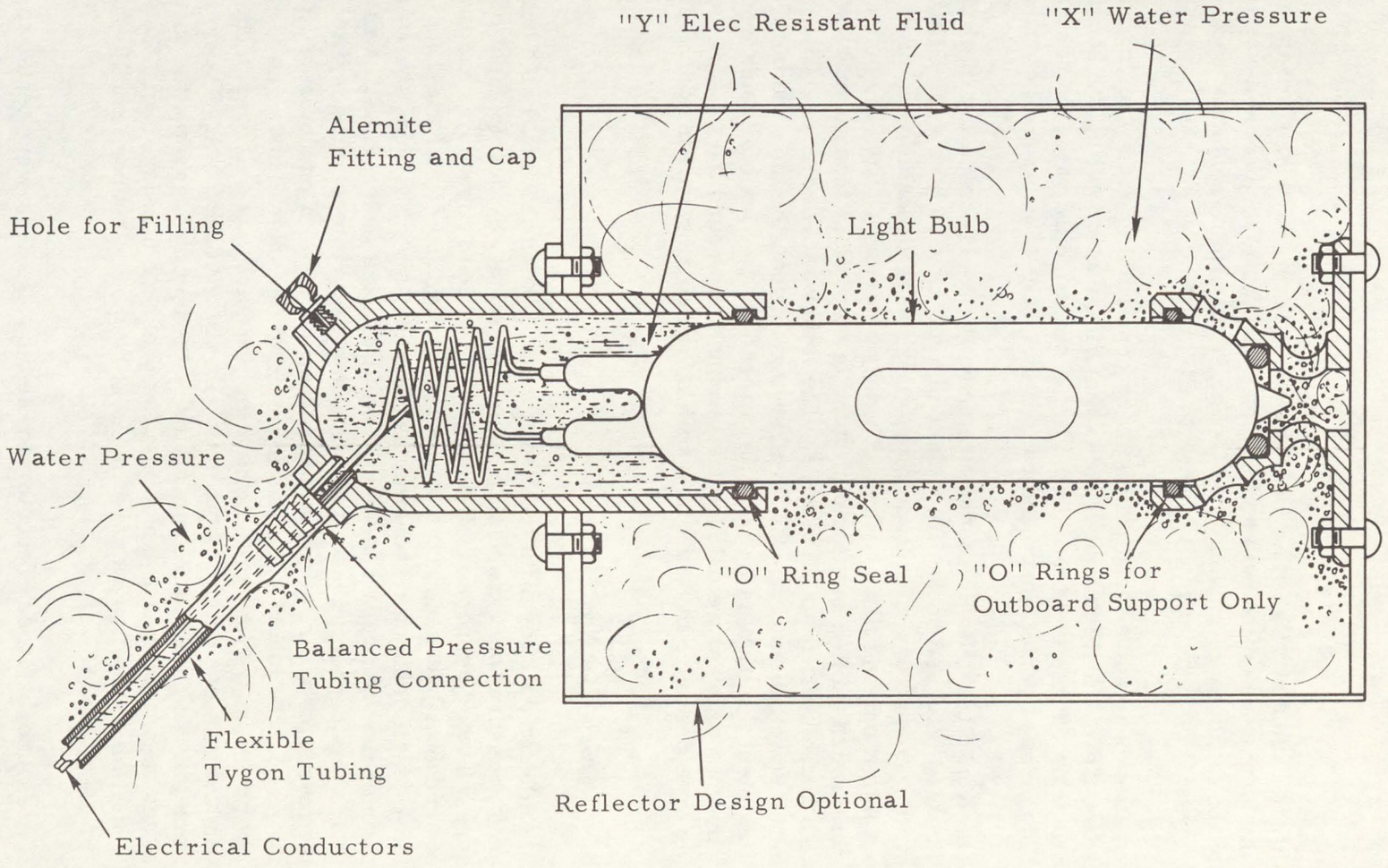


FIG. 6-11. CURV IIIA Pressure Balanced Light Concept.

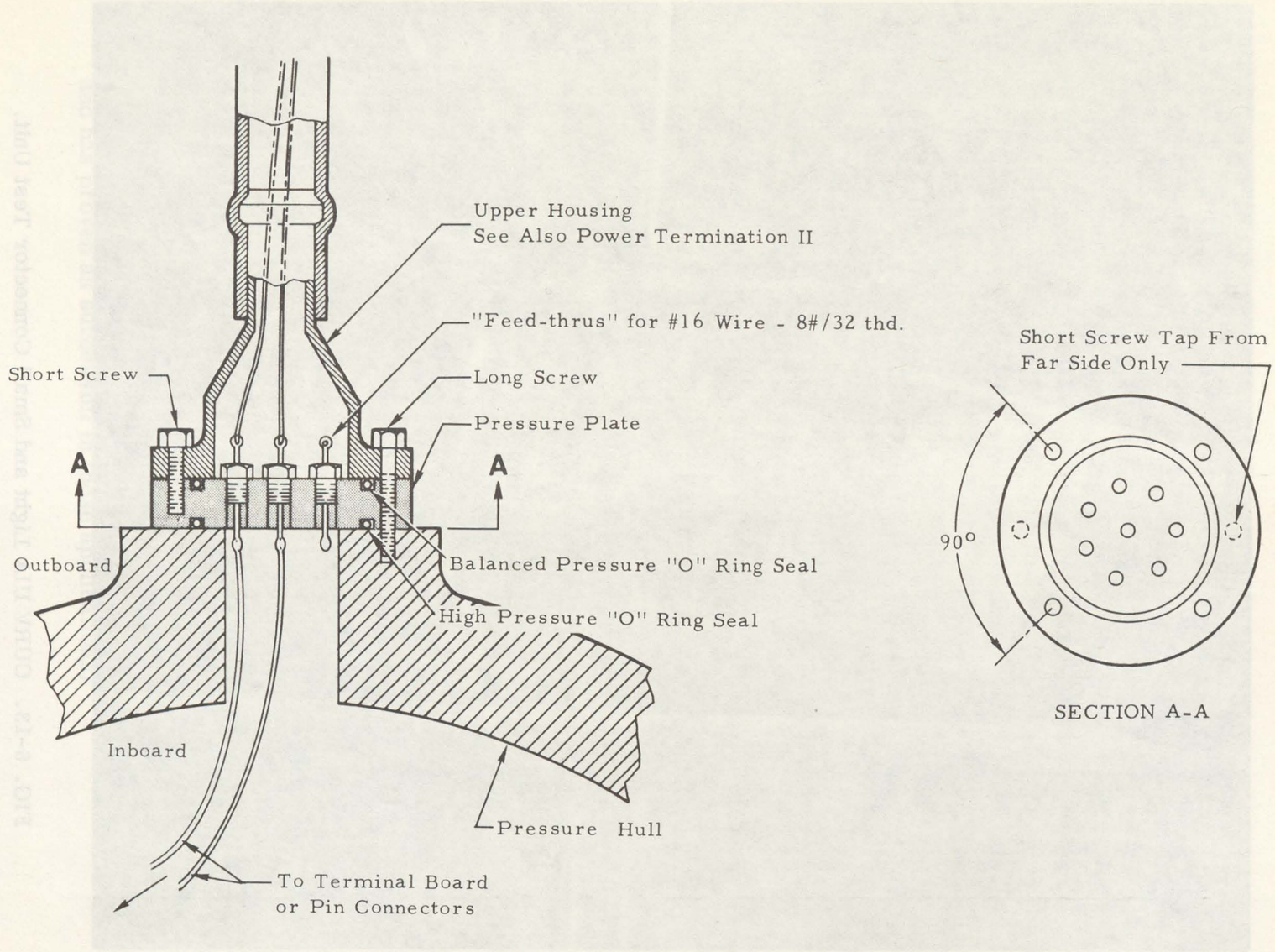


FIG. 6-12. CURV IIIA Pressure Balanced Small Connector Concept.



FIG. 6-13. CURV IIIA Light and Small Connector Test Unit.

modified. Many of the components that were not changed from CURV I such as the 35 mm camera were not modified to accept the new connectors and they retained the old style connectors.

6.6 VEHICLE MAGNETOMETER AND INDICATOR

The compass used on CURV I had been designed for surface ship and airplane applications with minimal transmission distances between sensor and indicator. It never worked due to a combination of transmission problems, vehicle in-water electrical interference, and various compass sensor and indicator parts failures.

A ring-core flux gate magnetometer concept was chosen for the CURV III underwater sensor. This approach senses the direction of the earth's magnetic field by measuring its effects on electrical current rather than registering the mechanical positions of a magnetic seeker.

CURV III was the first underwater long line cable transmission application of this concept, and it was necessary to develop a system with a ring-core flux gate sensor gimballed mount (±30°); oil-filled spherical pressure housing with internal air bladder pressure compensator; vehicle electronics to modulate, amplify and synchronize the signal; and a surface synchro converter.

The development also included modification of a Kearfott compass indicator to accept the vehicle inputs and the ships Mk 15 compass repeater inputs and display the relative position of the CURV III vehicle and the ship. The indicator was further modified to display the number of "twists" in the cable, i.e., 360° turns by the vehicle in either direction, to help the vehicle operator avoid fouling or damaging the cable.

The system accuracy of the developed system is ±1°, more than adequate for CURV III needs. The magnetometer has no moving parts in the sensor and therefore an unlimited duration and high reliability. No failures have been reported in tests or operations to date, other than erratic readings due to electrical leakage in the water from other CURV III component malfunctions. The compass line transmission problems have not recurred and the indicator has substantially enhanced operations.

The design was also incorporated in the NUC CURV II and CURV II-NTS vehicles and has proven as successful in those applications.

6.7 COMPONENT TESTING

Three types of component test programs were carried out on CURV IIIA underwater components prior to system assembly.

The first was conducted to verify components' capability for withstanding the 3,000 psi pressures at 7,000 foot depths. This testing consisted largely of pressure testing at various Navy and contractor facilities including the NUC Morris Dam Hydrostatic Chamber, the NCEL test chamber at Port Hueneme, and the Southwest Research Institute (SWRI) test chamber. The testing was conducted to 5,000 psi to provide a safety factor of two.

Wherever feasible the actual hardware to be used on the CURV III vehicle was tested for integrity and performance under pressure. The TV cameras, lights, pan-and-tilt units, hydraulic accumulator, and other items of small enough size were tested as functioning intact units. A special test fixture (Fig. 6-14) was designed to enable multiple function tests such as pan-tilt of an operating TV camera and lights. Larger items such as the vehicle frame and buoyancy tanks had critical or representative sections pressure-tested. Table 6-1 is a summary of CURV III component pressure testing.

The second type of testing was laboratory functional evaulation conducted to either aid in the selection of components or to verify the operating characteristics of a modified or developed component. This work for the most part was conducted in NUC's CURV laboratory, which was established in the inactive NUC Hydroballistics Laboratory, primarily for advanced concepts investigation. Examples of these tests are as follows:

1. Nylon Line Strength and Elongation Test (see Table 6-2)
2. CURV III Component Fitment Tests
3. Flux Gate Compass Operability Tests
4. Whip Cable/Connector Clamp Flexibility and Strain Tests
5. Frame Paint Temperature Test (prior to heat treating)
6. Syntactic Foam Temperature, Environmental, and Ruggedness Tests
7. Main Cable Nylon Boot Test
8. CURV IIIB Frame Weight Deflection Lift Test

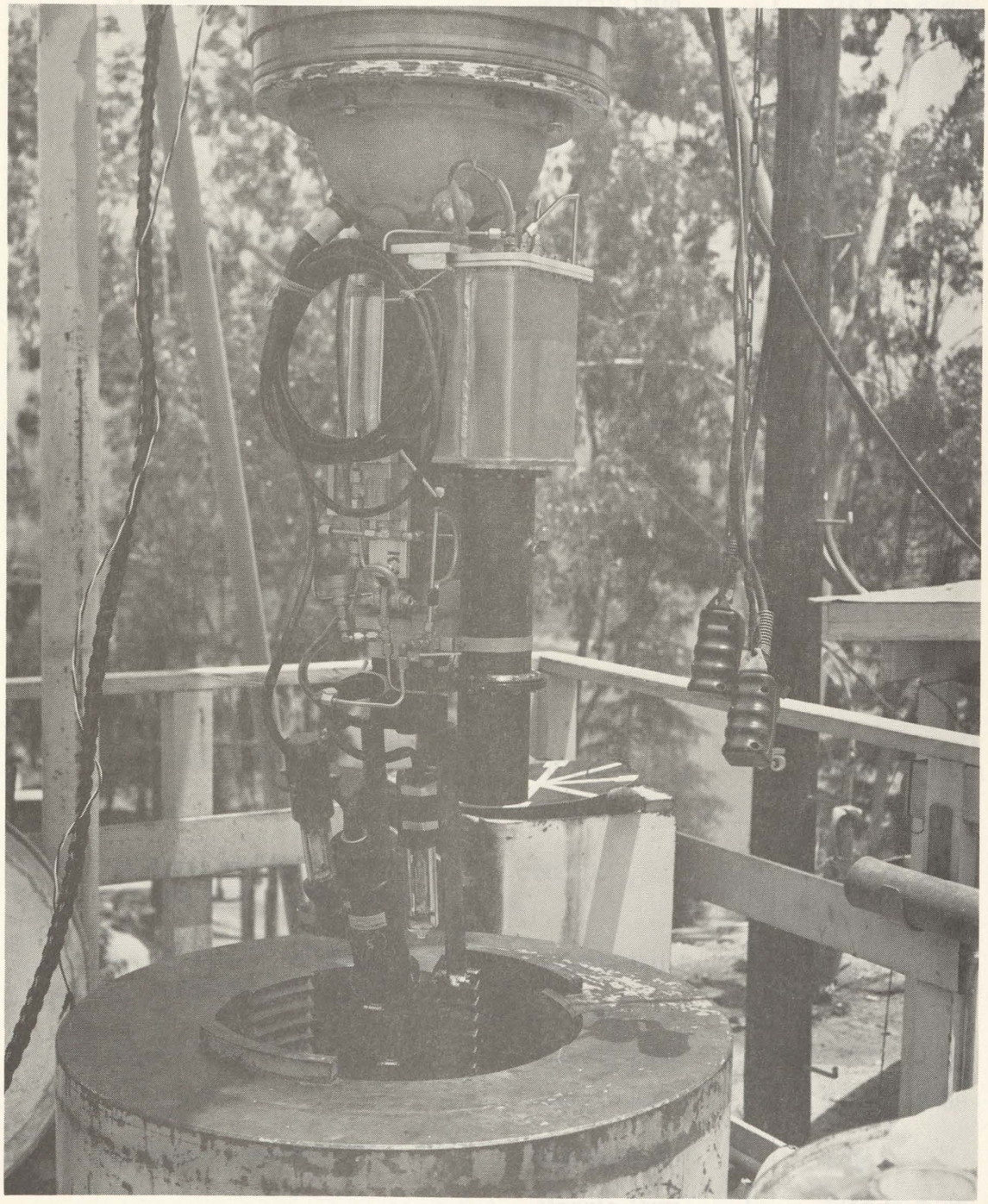


FIG. 6-14. CURV IIIA Component Test Fixture.

TABLE 6-1. CURV III Components Hydrostatic Pressure Testing

Component	Number of Units	psi	Results	Facility	Dates
1. Glass Spheres (10 in.)	85 (approximately)	5,000	OK	Morris Dam	3/67 to 8/69
	1	10,000	OK	NCEL	1/70
2. Prototype Buoyancy Modules	4	1,360	Two spheres cracked, spalling	NCEL	3/67
	3	2,850	Two end spheres imploded; middle sphere OK	NCEL	6/67
3. CURV IIIA Buoyancy Modules	80	5,000	No failures	NCEL	7/67 to 7/69
	3	20,000	Syntactic foam failed 11,000 psi; spheres OK	NCEL	1/70
	17	3,000	OK	NCEL	1/70
4. Pressure-Balanced Lights System — Lamp Bulb, Tygon Conductors, Connectors, Oil-Immersed Relays	35 (approximately) (including bulb-only tests)	3,500 to 5,000	35 to 50 percent of lamps failed until lamp manufacturing and selection processes perfected. Lamp failures caused connector failures	Morris Dam	7/68 to 1/70
5. Tubular Frame	5 sections (untreated)	3,500 to 4,650	OK at 3,500 psi, weld failed at 4,400 psi, tube at 4,650 psi	Morris Dam	8/67
	Whole frame (heat treated)	3,000 (6,500 ft depth)	OK	SCI	8/69
6. Spherical Main Housing	1	4,400	OK	NCEL	2/68 to 9/69
	2	5,500	OK	NCEL	2/68 to 9/69
7. Main and Whip Connectors and Main Cable Section	8	4,400 to 5,500	OK	NCEL	2/68 to 9/67
8. Hydraulic Actuators, Fittings, Accumulator, Pump and Motor	3	5,000	OK	Morris Dam	2/69 to 9/69
9. TV Cameras	1	5,000	Lens failed 3,000 psi	Morris Dam	2/69
	3	5,000	OK new type camera	Morris Dam	3/69 to 7/69
10. Small Connectors	6	5,000	Commercial types. Some Failures	Morris Dam	2/69
	20	5,000 to 10,000	NUC pressure-balanced type OK	Morris Dam	5/68 to 7/69
11. Sonar Housing	1	5,000	OK	Morris Dam	9/69
12. Cable Floats — Glass Spheres (10 in.) and Protective Covers	20	10,000	OK	Morris Dam	8/69

TABLE 6-2. Strain Test on 2-in-1 Samson Nylon Braided Rope — 1 Inch Diameter

Applied Load in Pounds	Axial Elongation in Inches	Change in Axial Elongation	Radial Diameter Due to Applied Load	Amount of Change in Radial Diameter	Axial Strain	Radial Strain
0	20.000	0	0.950			
100	20.062	0.062	0.940	0.010	0.0031	0.0105
500	20.500	0.500	0.920	0.030	0.0250	0.0315
1,000	20.875	0.875	0.908	0.042	0.0438	0.0442
2,000	21.500	1.500	0.880	0.070	0.0750	0.0736
3,000	22.250	2.250	0.860	0.090	0.1125	0.0947
4,000	22.750	2.750	0.850	0.100	0.1375	0.1052
5,000	23.250	3.250	0.825	0.125	0.1625	0.1315
6,000	23.625	3.625	0.815	0.135	0.1802	0.1421
7,000	24.000	4.000	0.810	0.140	0.2000	0.1473
8,000	24.375	4.375	0.800	0.150	0.2188	0.1578
9,000	24.625	4.625	0.795	0.155	0.2313	0.1631
10,000	24.750	4.750	0.790	0.160	0.2375	0.1684
10,500	Cracking in Knots					
12,000						
13,000						
14,000						
15,000						

The third type of testing was conducted by CURV II in actual operations. The primary tests were of sonar and hydraulic systems. Also verified by CURV II tests were the crane, pan-and-tilts, claw and tool drive assembly, magnetometer, use of two television cameras, and pressure-balanced mercury vapor lights. CURV II was also useful in pointing up further deficiencies noted in CURV I in the small cables and connectors.

6.8 SYSTEM CHECKOUT AND BUOYANCY UNIT/FRAME FAILURE

At the conclusion of the design, development, and procurement activities described above, the CURV IIIA vehicle was assembled, given dry checkout and installed on the YFNX-30. A series of 13 at-sea tests at progressively deeper depths was commenced. Several component failures were encountered during this testing (as shown in Table 6-3) which combined to require a second stage of vehicle development. The failures which affected development were the collapse of sections of the frame on a 4,500 foot dive, various component connector failures at all depths, a broken coax at the main cable/whip connection, and implosion of some or all of the buoyancy modules on the first deep depth dive to 6,500 feet.

In this last incident all 48 buoyancy modules were destroyed and/or carried away, and their restraining straps were twisted and torn (Fig. 6-15). Several other components were damaged, the most significant of which was the vehicle frame, sections of which again were collapsed. Pieces of syntactic foam were wedged into open cracks in the frame (Fig. 6-16).

TABLE 6-3. CURV IIIA Checkout Report

Dive No.	Date	Purpose	Depth (ft)	Water Time (hrs:min)	Total Water Time (hrs:min)	Malfunctions (Cause)
1	21 May 1969	Shallow Checkout	500	1:20		Noisy Hydraulic Motor Sonar Out (Connector) Starboard Side Light Causing Compass Irregularity (Connector) Noise from YFNX-30 on Passive Sonar (Sonar Misalignment)
2	3 Jun 1969	Shallow Checkout	500	2:40	4:00	Port Side Light Out (Connector) Starboard Headlight Out (Connector) Lights Aimed Wrong Active Sonar Noisy (Connector) Sonar Mounting Plates Binding
3	4 Jun 1969	Shallow Checkout	470	0:50	4:50	Active Sonar Noisy (Connector) Altimeter Out
4	16 Jun 1969	Shallow Checkout	120	1:10	6:00	Altimeter 10-foot Range Out
5	17 Jun 1969	Shallow Checkout	120	0:45	6:45	Altimeter 10-foot Range Out
6	19 Jun 1969	Shallow Checkout	1,300	3:25	10:10	Altimeter 10-foot Range Out Port Spot Light Out (Connector)
7	23 Jun 1969	Mid-Depth Checkout	2,500	5:50	16:00	Altimeter 10-foot Range Out (Altimeter Mounting Improper) Claw Open/Close Out (Solenoid) Port Spot Light Out (Connector Port TV Out at 1,700-feet (Connector)
8	25 Jun 1969	Shallow Water Checkout	600	2:35	18:35	Port TV Intermittent (Connector)
9	26 Jun 1969	Mid-Depth Checkout	2,950	4:50	23:25	Depthometer Out (Transducer) Port TV Out (Broken Coax at Main Cable Clump Connector)
10	7 Jul 1969	Deep Depth Checkout	5,900	10:35	34:00	Compass Out in Two Quadrants (Noisy Connector on Other Components) Sonar Scan Reverse Out at 4,500 feet Noisy Sonar/Frame Collapse 4,700 to 4,800 feet Hydraulic Motor Out at 5,800 feet (Lack of Fluid) Housing Leak Detector on at 5,800 feet (Leaky Hydraulic Valve) Depthometer Out (Transducer — No Spare) Starboard TV Out at 2,200 feet (Break in Coax at Main Cable Clump Connector) Port TV Out at 1,800 feet (Same as Above)

TABLE 6-3. CURV IIIA Checkout Report (Cont'd)

Dive No.	Date	Purpose	Depth (ft)	Water Time (hrs:min)	Total Water Time (hrs:min)	Malfunctions (Cause)
11	7 Aug 1969	Shallow Water Checkout	1,500	2:30	36:30	Sonar Tilt Hydraulic Function Fast Port Motor Out (Short Main Cable Clump Connector) Compass Erratic (Above)
12	11 Aug 1969	Shallow Water Checkout	1,500	3:00	39:30	Dead Spot in Sonar Sweep to Port (Connector)
13	11 Aug 1969 to 12 Aug 1969	Deep Water Checkout	6,200	7:10	46:40	Sonar Sweep Out at 5,000 feet System Failure at 6,000 feet Damage: 1. Buoyancy Units Missing, Retaining Straps Twisted 2. Frame Collapsed, Torn, and Distorted 3. Brackets Bent, Mounting Holes Elongated 4. Several Interconnecting Cables Cut and Broken 5. Port Side and Headlights Missing 6. Two Pingers Missing 7. Both TV Vidicon Tubes Broken; Connections Loosened, Transistors Broken 8. EG&G Camera Electronics Damaged 9. Strobe Cabling Blown Out of Housing 10. Sonar Training Mechanism Damaged 11. Several Sonar Electronic Components Out 12. Compass Gimbal and Bearings Broken 13. Electronic Housing Jammed; Ring Forcing Plate Loosened; Transformer Mounting Screws Pulled Loose; Air Duct Broken

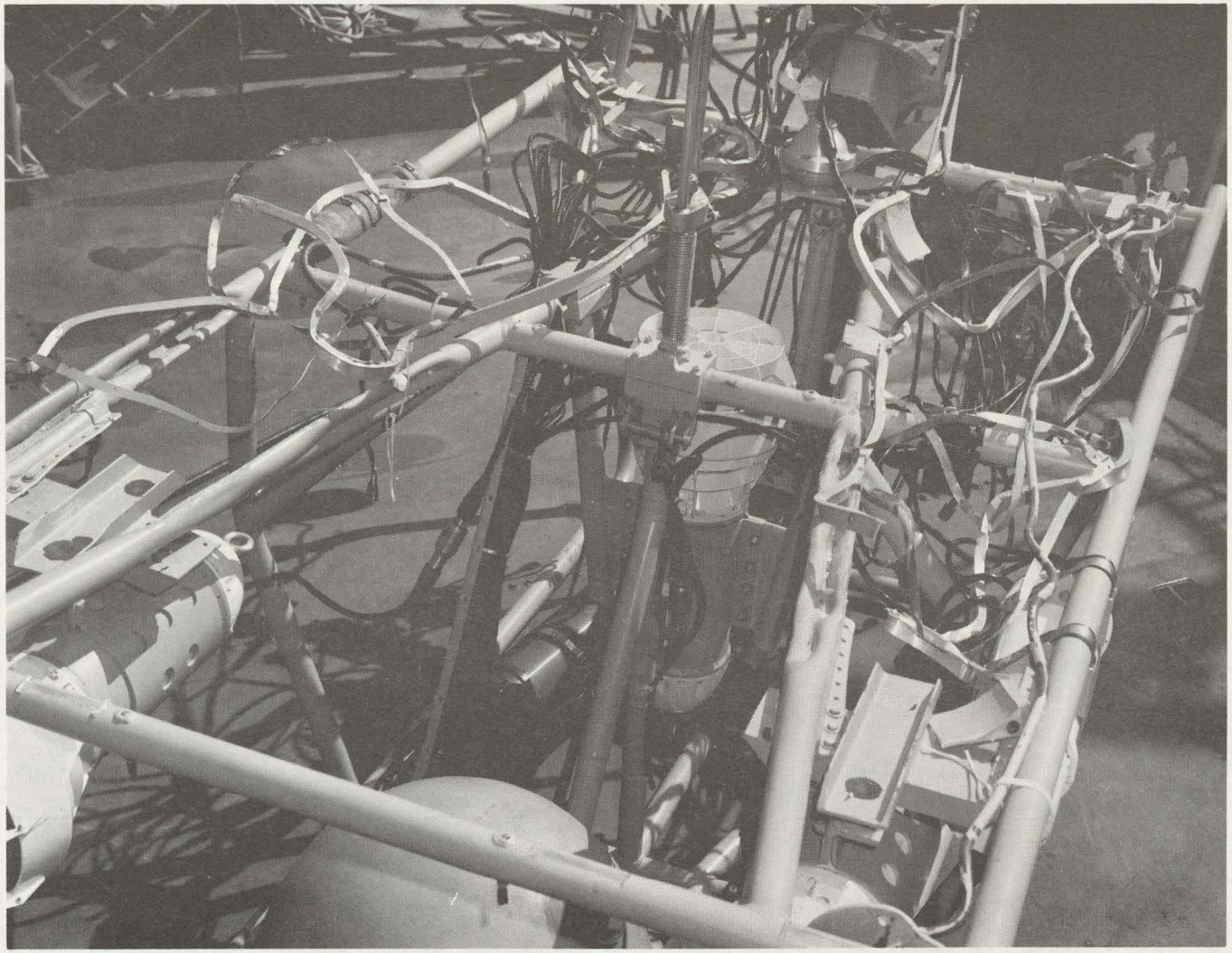


FIG. 6-15. CURV IIIA Vehicle After First Deep Checkout Dive.

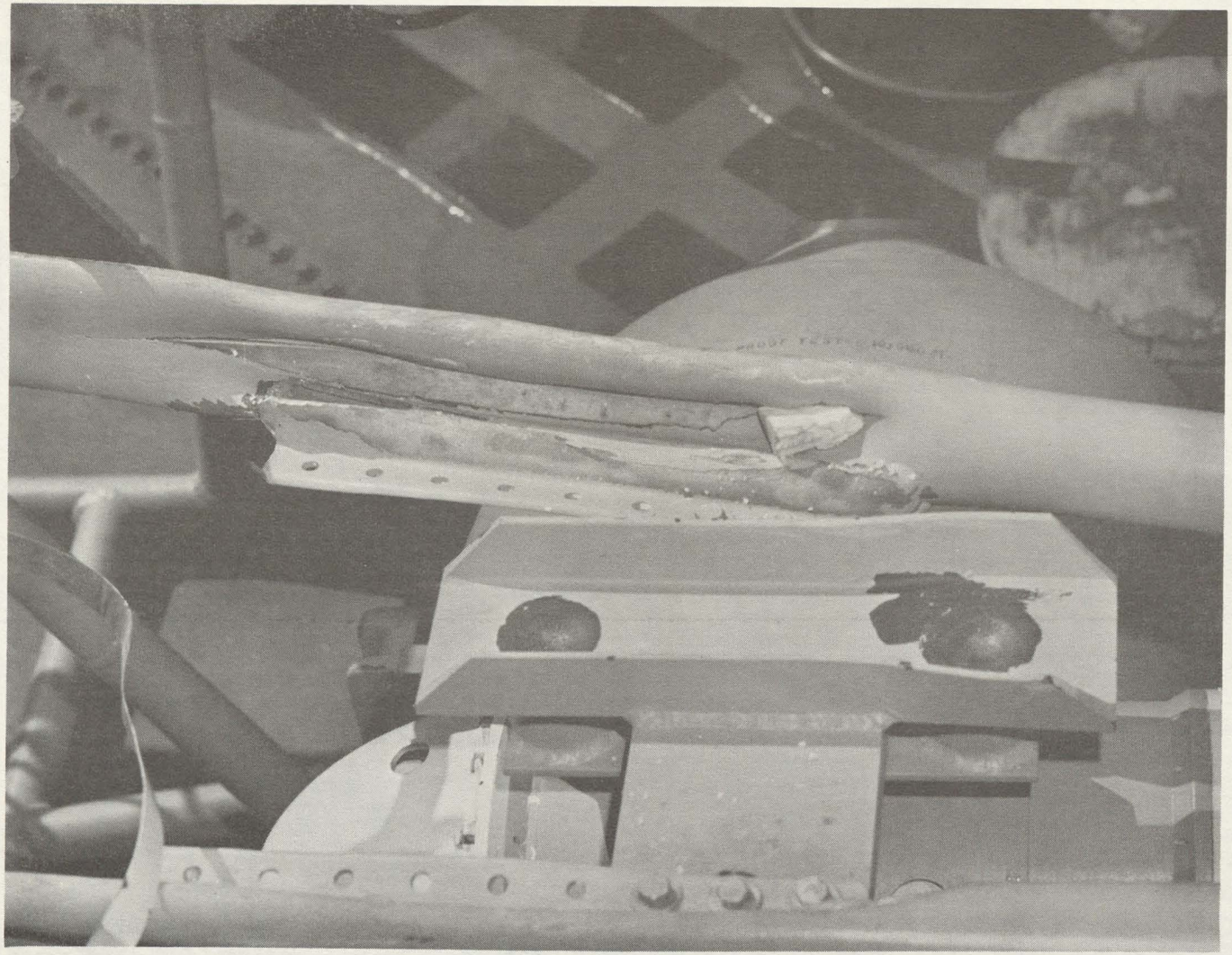


FIG. 6-16. CURV IIIA Collapsed Frame and Fragment of Syntactic Foam from Buoyancy Modules.

Page

7-1
7-1
-3

SECTION 7

CURV IIIB VEHICLE DEVELOPMENT

7

Section 7

TABLE OF CONTENTS

Section	Title	Page
7.1	Frame	7-1
7.2	Buoyancy Units	7-1
7.3	Cable Foats	7-3
7.4	Small Connectors	7-3
7.5	Main Connector	7-6

LIST OF FIGURES AND TABLES

Figure	Title	Page
7-1	CURV IIIB Frame	7-2
7-2	CURV IIIB Concept	7-4
7-3	CURV IIIB Vehicle	7-7

Table	Title	Page
7-1	Effect of Vehicle Changes	7-5

Section 7

CURV IIIB VEHICLE DEVELOPMENT

The major damage caused by the buoyancy tank implosion occasioned a thorough-going review of the CURV III vehicle design to define what improvements must or might be made in addition to necessary repairs and replacement of the buoyancy units. The end result was in effect a redevelopment of the vehicle, known as CURV IIIB. The prime objects of this second development effort were the frame, buoyancy units, main connectors, small connectors, and cable floats.

7.1 FRAME

Analysis after the first frame failure on dive No. 10 (see Table 6-3) at 4,500 feet had determined that the collapse was in areas weakened by excessive welding heat during fabrication. The damaged sections were replaced, the entire frame heat treated, and a dunk test of the frame to 6,500 feet was conducted successfully before the vehicle was reassembled for dives Nos. 11, 12, and 13. It could not be determined if the collapse of the frame on dive No. 13 was attributable to implosion of the buoyancy tanks or vice versa, so the frame was redesigned to employ structural aluminum shapes (I beams, channels, etc.) to replace the schedule 80 aluminum tubing. This design using structural shapes (see Fig. 7-1) eliminated the possibility of collapse at the sacrifice of the buoyancy and greater rigidity of the tubular frame. The frame was made larger to accommodate the new buoyancy units, which had the side benefit of providing better maintenance access to the components, particularly the main spherical housing.

7.2 BUOYANCY UNITS

Theories as to the cause of the buoyancy tank failure included: (1) frame failures; (2) undetected damage to a glass ball in disassembly and reassembly during the replacement of the frame and failure of that ball, triggering sympathetic implosion; (3) improper manufacture of the modules; (4) inadequate mounts and support of the buoyancy units that allowed them to "work" while in operation; (5) undetected damage to one or more glass balls during vehicle operational deployment and retrieval in previous checkout dives.

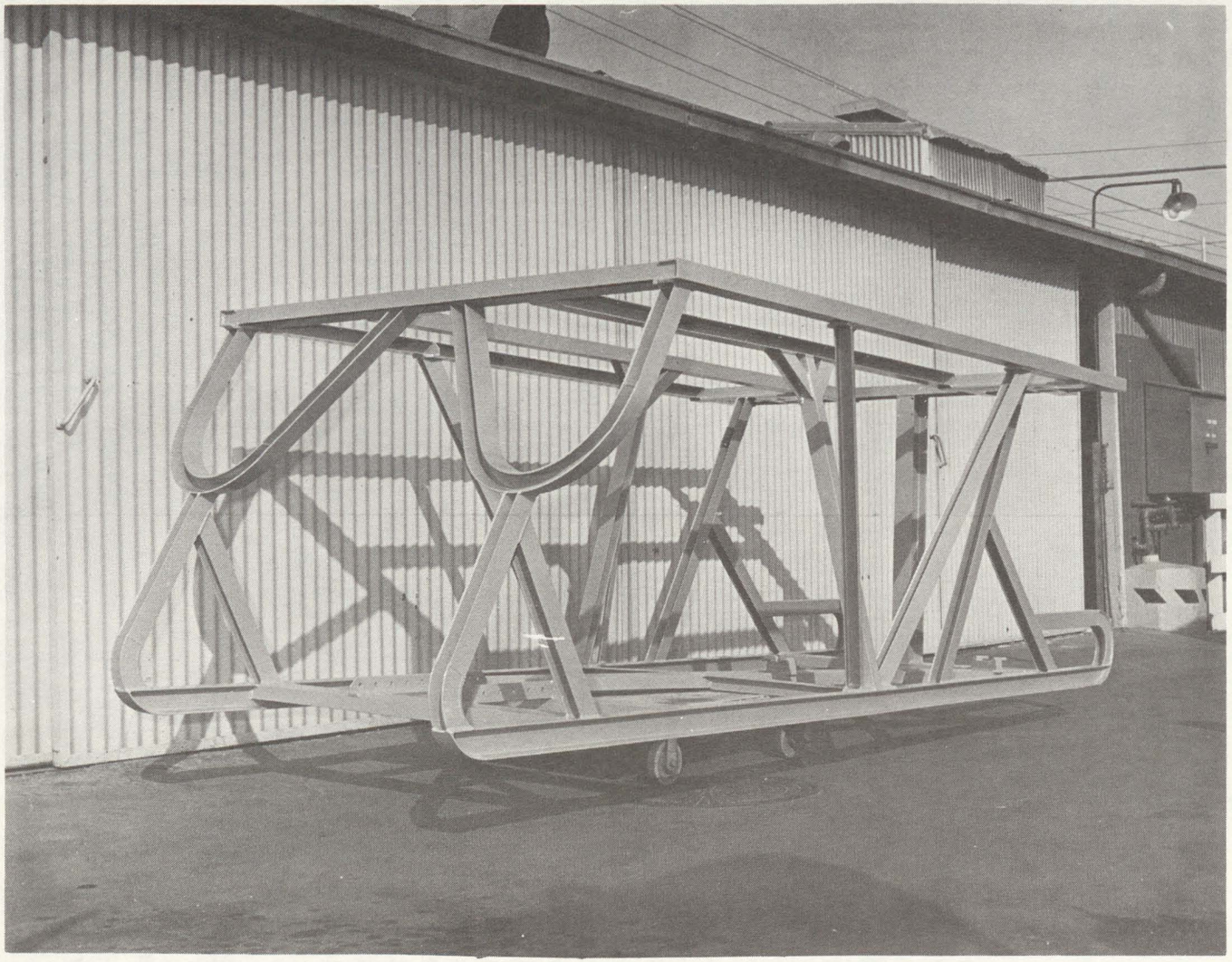


FIG. 7-1. CURV IIIB Frame.

This uncertainty led to the use of solid syntactic foam blocks as the vehicle buoyancy material. This change was made possible by an advance in the state-of-the-art of syntactic foam since the beginning of CURV III development, namely the existence of more efficient syntactic foam (38 pounds per cubic feet density) which could provide the necessary buoyancy without a prohibitive increase in size and mass of the vehicle.

The design for the CURV IIIB buoyancy units consisted of two groups of 3M Company syntactic foam blocks stacked in two layers along the upper frame as shown in Fig. 7-2. The blocks were clamped and bolted in place. No bonding agent was used in order that removal or addition of blocks could be made to trim the vehicle or compensate for additions or deletions of components. Each block was 5.75 by 11.75 by 22.00 inches (0.83 cubic feet) and provided a net buoyancy of 26 pounds. The effect of the changes of buoyancy units and frame on the vehicle mass was a net overall increase of 670 pounds in air as shown in Table 7-1.

Analysis and further testing was carried out to further define the glass ball/syntactic foam technology. This study did not reveal that these modules are unsuitable for underwater use. Twenty spare glass ball/syntactic foam units were tested at NCEL, Port Hueneme at 3,000 and 20,000 psi under various cycling conditions as reported in Ref. 9. In one case, a glass ball previously pressurized to 20,000 psi underwent 25 cycles from 0 to 10,000 psi without evidence of spalling. In none of the 3,000 psi tests was there a failure of any kind. In all 20,000 psi tests, the syntactic foam failed by cracking and absorbing water, but in no tests was there an implosion, spalling or other visible damage to the balls.

7.3 CABLE FLOATS

To avoid any possible risk to the CURV III cable, the 10-inch glass balls enclosed in protective helmets which had been utilized as cable floats for CURV IIIA were replaced by solid syntactic foam blocks 5.75 by 11.75 by 11.00 inches (one-half of one of the blocks used for the vehicle). The net buoyancy of each of these blocks was less than a glass sphere so more floats were required. Approximately 13 blocks were used over the 600 feet of buoyed cable, spaced at 50 foot intervals, with two at the center position to give the cable an arc and keep it above the vehicle's level.

7.4 SMALL CONNECTORS

The many connector failures in CURV I and II operating experience had promoted interest in applying the pressure balanced principles used for the CURV III lights

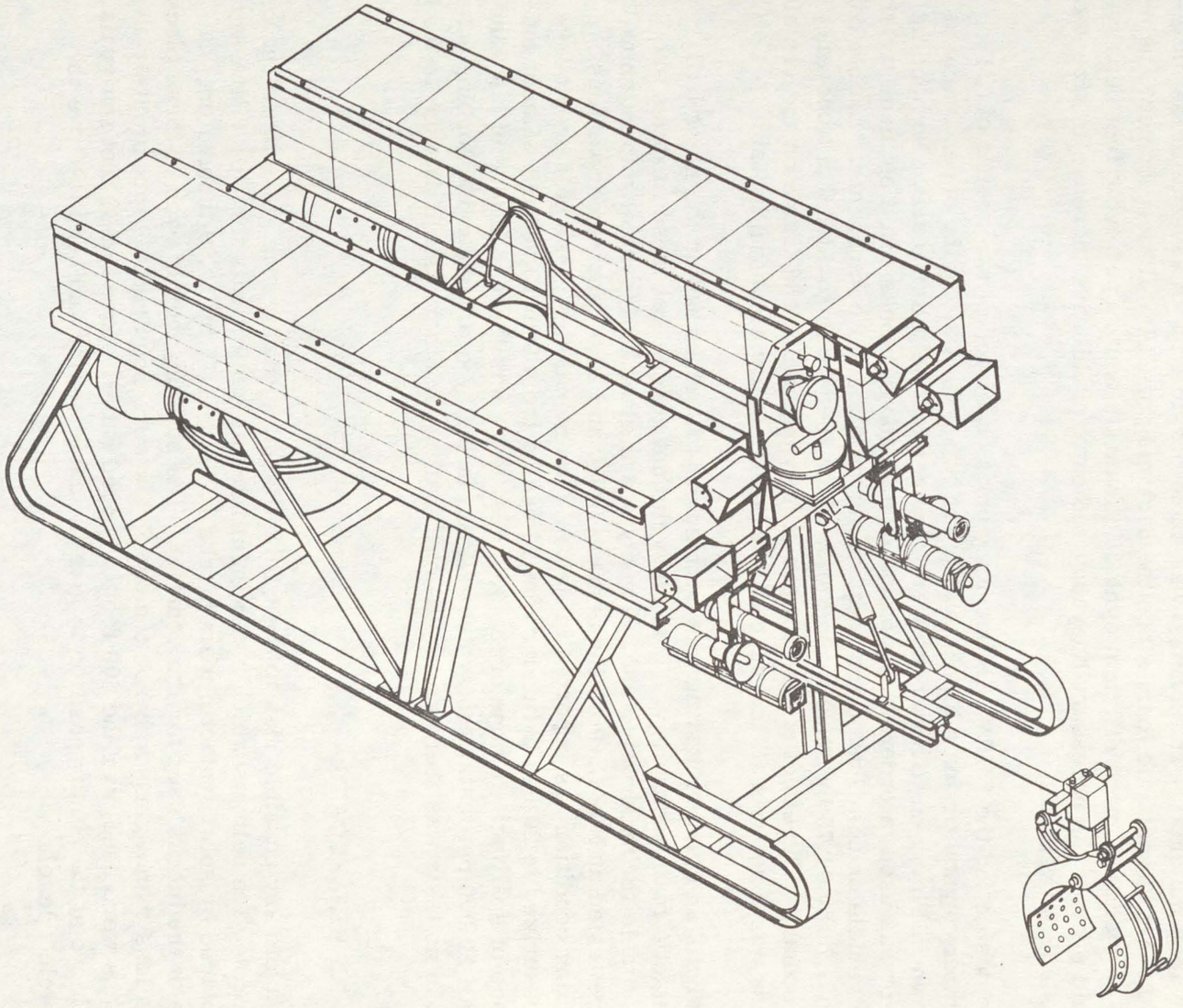


FIG. 7-2. CURV IIIB Concept.

TABLE 7-1. Effect of Vehicle Changes

	Old	New	Effect
BUOYANCY MATERIAL			
Weight in Air (lbs/cu ft)	32	38	+6
Weight in Water (lbs/cu ft)	+32	+26	-6
Total Weight in Air (lbs)	1200	1950	+750
Net Positive Buoyancy (lbs)	1200	1320	+120
FRAME AND BRACKETS			
Total Weight in Air (lbs)	350	325	0
Total Weight in Water (lbs)	0	200	+200
VEHICLE			
Approx Total Weight in Air (lbs)	3650	4400	+750
Lead Ballast (lbs)	150	70	-80
Positive Buoyancy of Vehicle (lbs)	50	50	0

METHOD OF VEHICLE TRIM	Old	New
	Move lead ballast or components	Add or remove syntactic foam; move components; and add, move, or remove lead ballast

to all the small connectors on the vehicle. The principle described above under light and small connector development was applied universally to the vehicle components and modifications made to all sensor, housings, the spherical main watertight housing and the sonar electronics housing to accommodate the new connectors.

7.5 MAIN CONNECTOR

Laboratory tests were conducted utilizing a custom test set-up to determine why the coax had failed on Dive No. 9. The cause was discovered to be flexing of the cable on the boot clamp. Several methods were attempted to restrain movement of the cable including shrink tubing, structural supports and molded supports, but the most successful method was a simple Kellums grip. These wire mesh grips distributed the flexing adequately and were simple to use. They were employed at all three underwater connections — between the main cable/clump, clump/whip, and whip/vehicle.

The configuration of the new vehicle, CURV IIIB after these components changes is shown in Fig. 7-3.

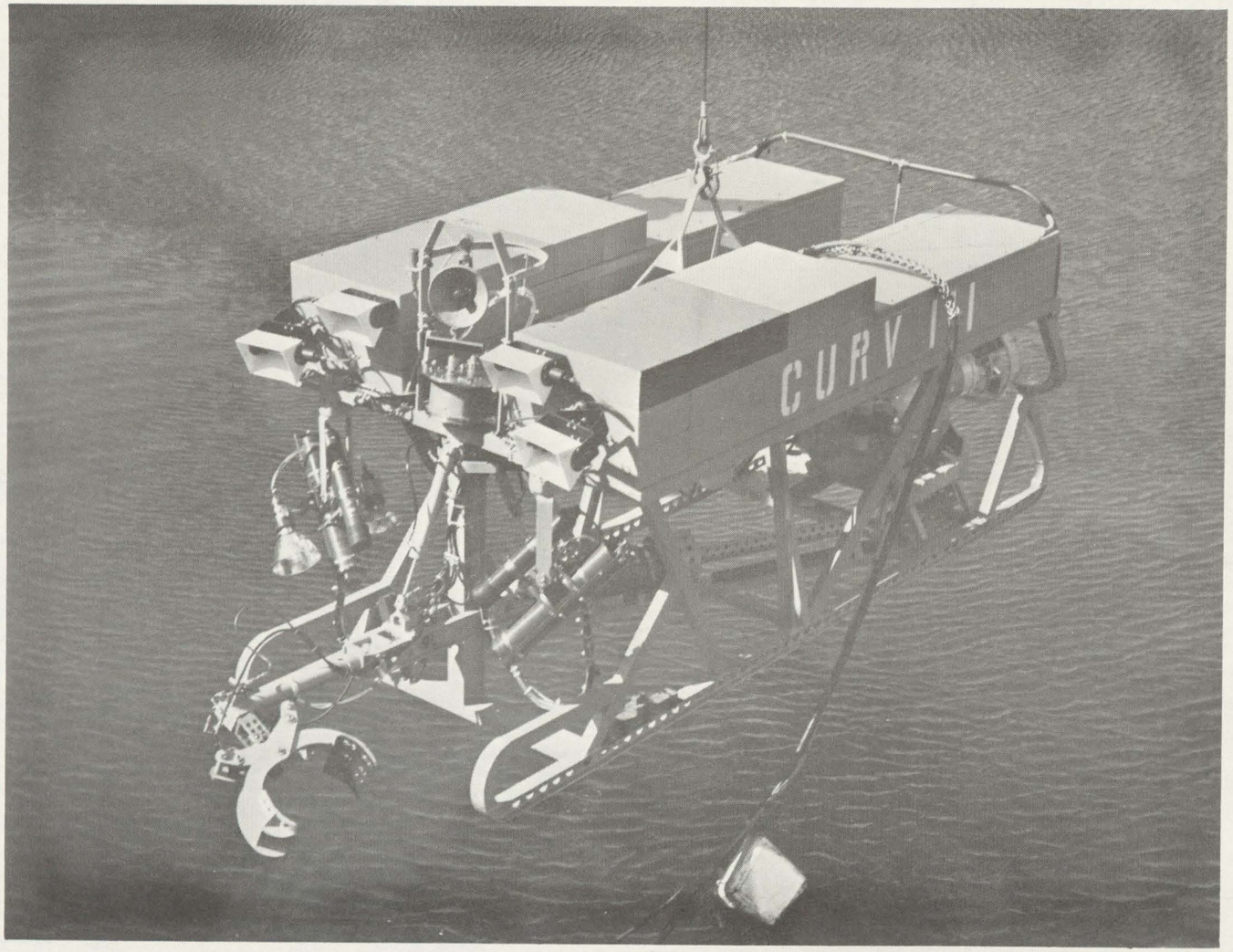


FIG. 7-3. CURV IIIB Vehicle.

Page

8-1

8-1
8-3
3

SECTION 8

TECHNICAL EVALUATION

Section 8

TABLE OF CONTENTS

Section	Title	Page
8.1	System Portability	8-1
8.1.1	Off-Loading, Packing, and Other Preparation	8-1
8.1.2	Equipment Modifications	8-3
8.1.3	Transportation	8-3
8.1.4	Installation and Training	8-3
8.2	Operational Performance	8-3
8.2.1	Depth Capability	8-7
8.2.2	Search Capability	8-7
8.2.3	Endurance	8-7
8.2.4	Recovery	8-7
8.2.5	Cable Deployment/Retrieval	8-7
8.2.6	Vehicle Handling	8-9
8.2.7	Performance in Heavy Seas	8-15
8.2.8	Support Vessel/CURV III Compatibility	8-15
8.2.9	Crew	8-15
8.3	Conclusions Regarding Portable System Evaluation	8-17
8.4	Support Vessel Technical Evaluation	8-17
8.5	CURV IIIB System Improvements After NASA Operation	8-18

LIST OF FIGURES AND TABLES

Figure	Title	Page
8-1	Cable Ring Use in NASA Operations	8-4
8-2	Stacked Cable Baskets	8-5

LIST OF FIGURES AND TABLES (Cont'd)

Figure	Title	Page
8-3	Initial CURV IIIB Equipment Locations on USS OPPORTUNE	8-6
8-4	Search Method Used to Find NASA Instrumentation Pod	8-8
8-5	Revised CURV IIIB Equipment Locations in Effect During NASA Recovery	8-10
8-6	NASA Pod Retrieval Technique	8-11
8-7	NASA Pod Recovery	8-12
8-8	Attachment of Boom Hook to Nylon Loop in CURV III Lift Eye	8-13
8-9	Retrieval of CURV III After Recovery of NASA Pod	8-14

Table	Title	Page
8-1	CURV III Basic On-Deck System	8-12
8-2	CURV Crew for NASA SERO Operations	8-16

Section 8

TECHNICAL EVALUATION

A formal technical evaluation of the CURV III System was not performed because the system became operational while still in the checkout phase. The system was called on to conduct an emergency deep sea retrieval of a NASA solar eclipse photographic instrumentation package lost in the Atlantic Ocean before any deep water evaluation other than a quick checkout dive to 6,500 feet could be performed. Since the NASA operation was successful and had included requirements for system portability, deep ocean capability, operations from a support vessel of opportunity, limited area search and work in heavy seas, it was considered a proper test for evaluation of all system capabilities except the support vessel. The technical evaluation of the support vessel was drawn from previous successful CURV III checkout operations, CURV II operations and other NUC range support operations. The details of the system and support vessel evaluations are given below.

8.1 SYSTEM PORTABILITY

At the time the request was made for CURV III services for the NASA recovery, 1000 hours 12 March 1970, the system was operating aboard the YFNX-30 at San Clemente Island. Since CURV III was still in checkout stages, no off-loading plans, packing accessories or shipping procedures had been finalized and had to be evolved in process. Response time was of the essence since valuable pictures of the ultra violet spectrum had been obtained by the NASA package, and the film was subject to deterioration in about 2 weeks time.

8.1.1 OFF-LOADING, PACKING, AND OTHER PREPARATION — The equipment to be removed from the YFNX-30 was carefully selected based on the capabilities of the support vessel USS OPPORTUNE (ARS-41) which would be used. The list of major items taken is shown in Table 8-1. The crane, winch and support vessel compass were left, because it was felt the OPPORTUNE's 10-ton cargo boom, capstan and compass could provide adequate substitutes. Off-loading of equipment required 10 hours, the greatest portion of time being required to unload the 8,000 foot control cable which had to be manually flaked out of the below deck cable bins

TABLE 8-1. CURV III Basic On-Deck System

Component	Deck Volume (feet high)	Weight (pounds)	Significant Interfaces or Specifications
Supplied by NUC			
Vehicle (and Platform)	14 x 6 x 6	4,000	
Van — Control Console (MG Set and Variacs)	12 x 9 x 8	10,000	Need 440 VAC, 120 VAC
Boat-Mounted Acoustic Locating Device (BALD)	6 x 4 x 16		Retractable over side gear — at gunwale
Power Conversion Package (MG Set and Variacs)	6.5 x 4.5 x 3.5	5,000	
Cable Bins (including 8,000 feet of cable)	14 x 10 x 4	8,000	
Spare Parts Van	12 x 7 x 7		
Tool Locker	4 x 4 x 6		
Cable Ring	60 in. dia. x 20 in. thick ring; 20 in. hole in center	3,900	(Not standard gear)
Nylon Line Bin	7 x 7 x 5	1,500	
Hydraulic Power Supply	2 x 2 x 2		For crane and traction winch
Davit	6 x 3 x 6		Welded to deck
Diesel Generator (leased)	9 x 5 x 5		100 KW, 3ϕ, 440 VAC
Supplied by OPPORTUNE/NASA			
Gyro Compass			
Winch/Capstans			
Crane/Boom			
Raydist Navigation			

to remove it. Fifty hours were required for packing, which included compilation of inventory and shipping lists, disassembly and preparation of equipment, and fabrication of over 25 special containers and pallets.

8.1.2 EQUIPMENT MODIFICATIONS — Because the OPPORTUNE had twin, unshrouded screws, a 3,900 pound cable ring was fabricated to keep the cable hanging directly below the vessel (Fig. 8-1). The CURV III recovery claw's 12.75-inch grip was modified to accept the 15-inch diameter NASA photo pod.

8.1.3 TRANSPORTATION — The CURV III equipment was loaded on four flat bed trucks at Long Beach and trucked to Norton Air Force Base, near San Bernardino, California. The system had been designed for air transport in one C-141. A difficulty in loading was encountered from the stacked transport configuration of the cable baskets (Fig. 8-2). While within proper dimension tolerances for the interior of the plane, the baskets could not clear the C-141 loading gate and had to be loaded separately. A second C-141 was then required to ship the system. The first C-141 arrived at Norfolk, Virginia at 2125 hours EDT, Sunday, 15 March 1970; the second arrived at 0300 hours EDT, Monday, 16 March, less than 90 hours after the formal request for CURV III services.

8.1.4 INSTALLATION AND TRAINING — The OPPORTUNE reached Norfolk at 0700 hours, Monday, 16 March, with special Raydist navigation gear already aboard. The CURV III gear was installed in the configuration shown in Fig. 8-3 by 2050 hours, Monday.

From 0730 to 1630 hours, Tuesday, 17 March, operational training was conducted to familiarize the OPPORTUNE crew with CURV operations and to develop cable handling procedures using the new cable ring. A test dive was made to 810 feet without incident.

By 2100 hours on 17 March the OPPORTUNE was on-site at the initial search point ready to begin operations. By 2230 hours CURV III was in the water — 123 hours after word was received to send the system.

8.2 OPERATIONAL PERFORMANCE

The CURV III NASA Recovery demonstrated satisfactory system performance in all aspects of operations — depth, search, endurance, recovery, cable deployment/retrieval, vehicle handling, rough weather operations, support vessel compatibility, and portability.

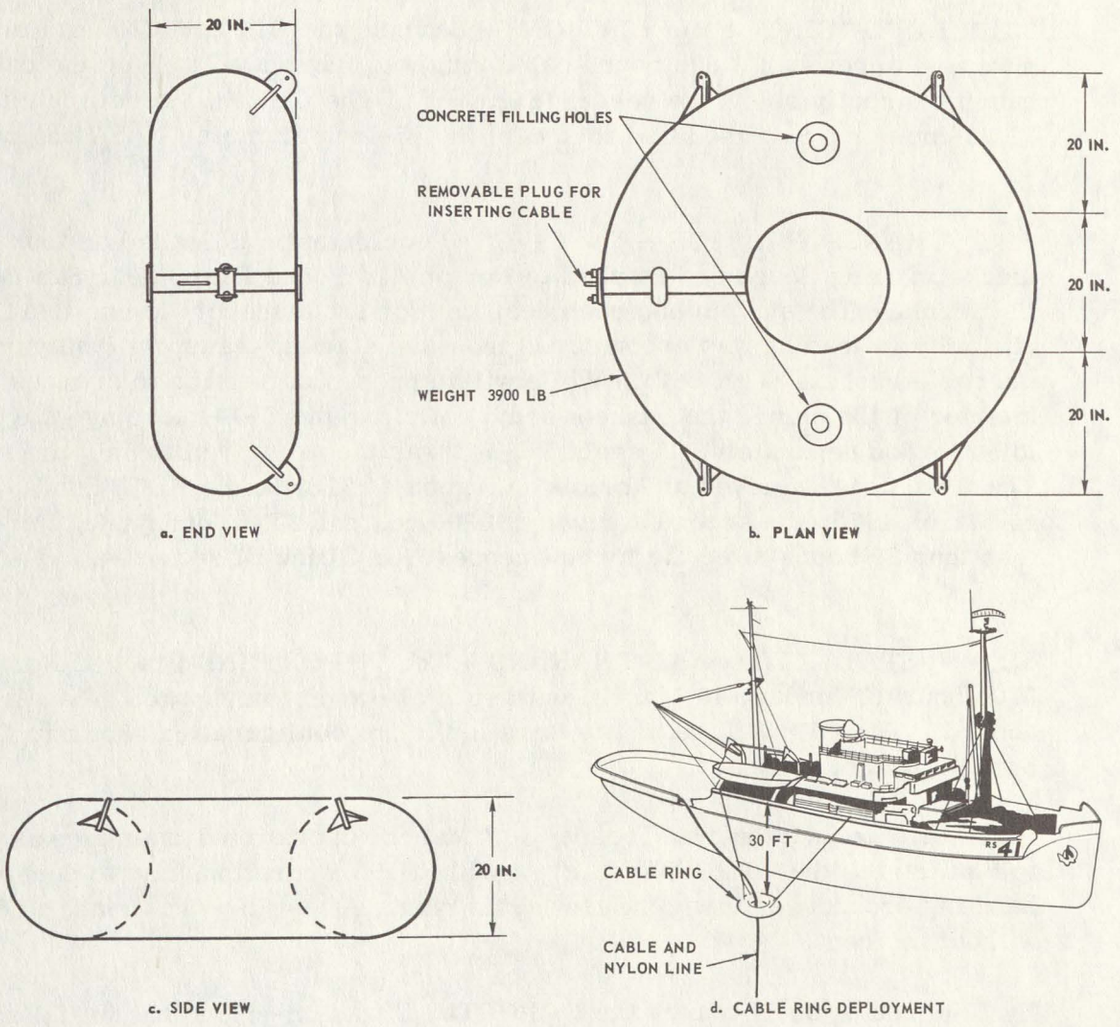


FIG. 8-1. Cable Ring Use in NASA Operations.

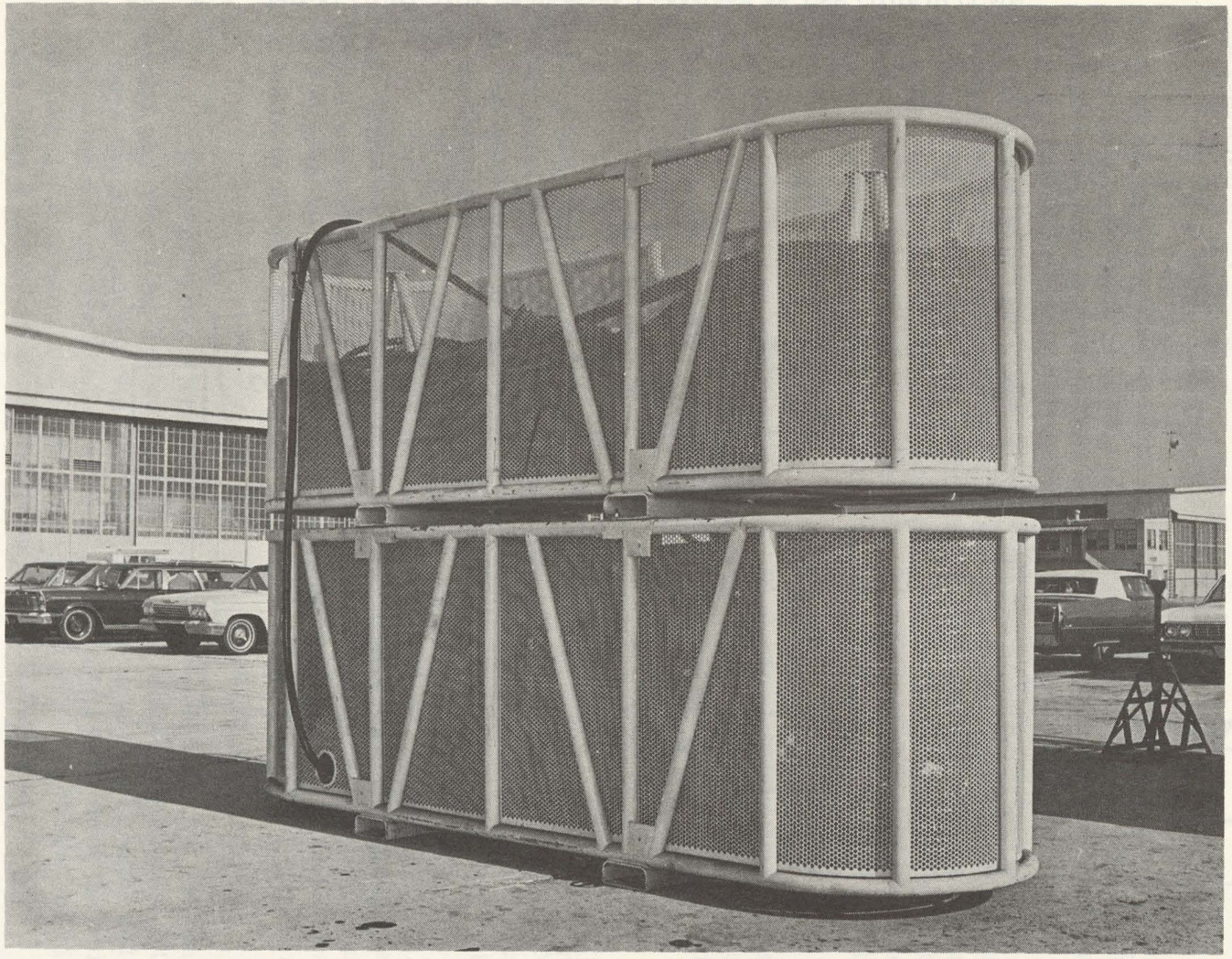


FIG. 8-2. Stacked Cable Baskets.

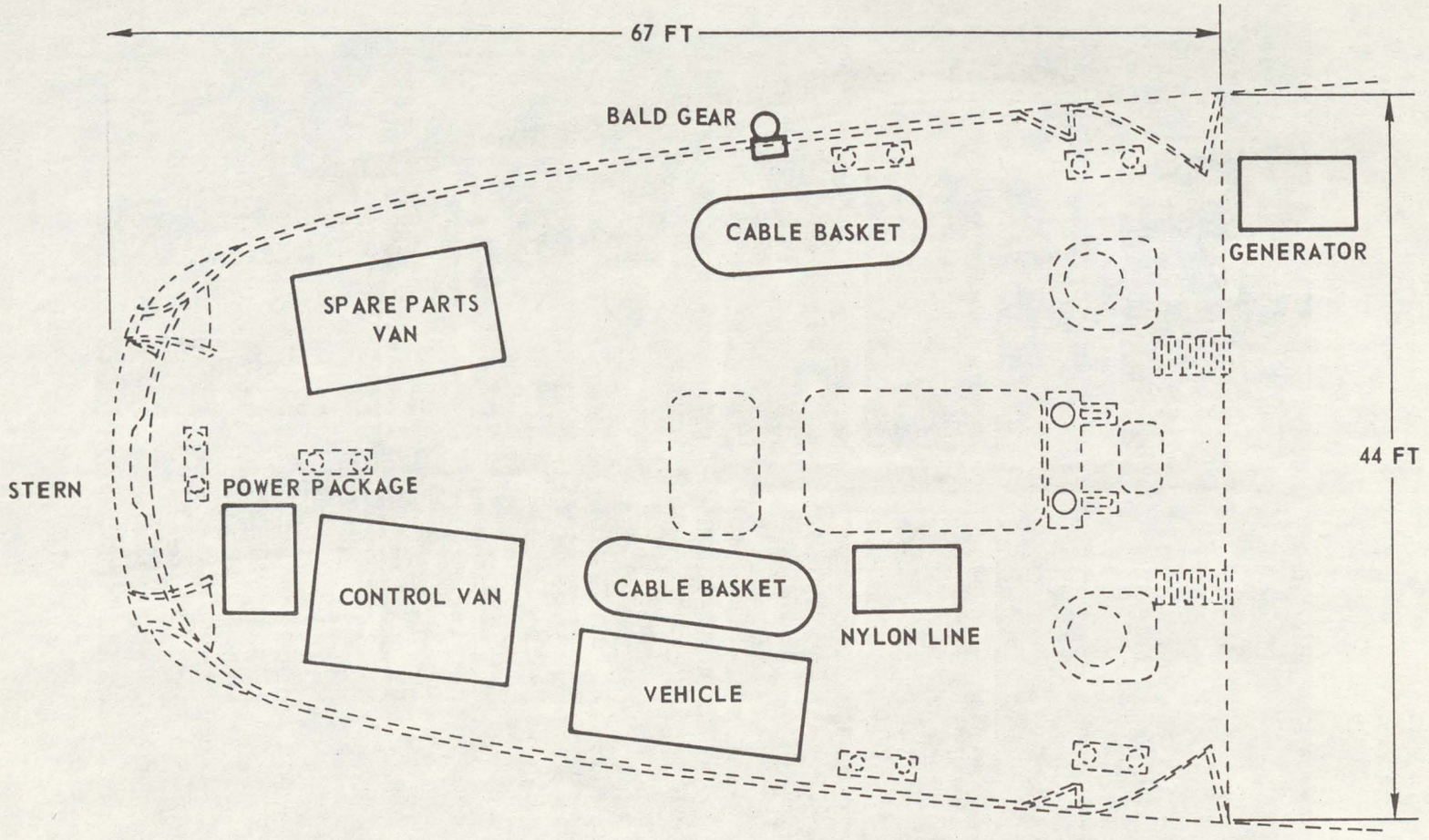


FIG. 8-3. Initial CURV IIIB Equipment Locations on USS OPPORTUNE.

8.2.1 DEPTH CAPABILITY — Operations were conducted to 5,850 feet with no component failures, navigation or cable drag difficulties.

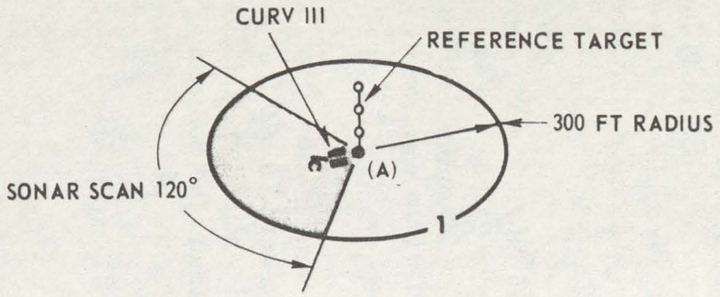
8.2.2 SEARCH CAPABILITY — The NASA instrumentation package that was to be recovered was not equipped with a pinger and, although the approximate location of impact was known, active sonar search had to be carried out. The search method, developed in CURV II operations, begins with the CURV vehicle placing a reference target in the center of a search area. This reference target is usually a hollow body with good acoustic reflection properties and is equipped with a 45 kHz pinger. The vehicle searches around the reference target within the range of the CURV III active sonar, plots all other active sonar targets with respect to the reference target, then investigates the targets. The reference target is then moved to an adjacent area and the search continued. This method is illustrated in Fig. 8-4.

This type of search was conducted around four reference target positions, with the NASA pod being discovered on the fourth. The total area covered was three 1,200 foot circles or approximately 4,000,000 square feet, the time required was 37 hours in two dives of 21 and 16 hours each.

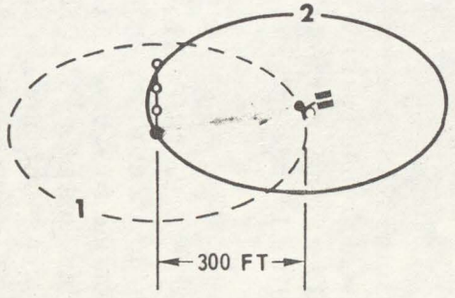
8.2.3 ENDURANCE — The CURV III system provided 42 hours of water time at depths greater than 5,000 feet without interruption due to actual component failure. System electrical difficulties did interrupt operations, but the trouble was traced to accidental grounding of the diesel generator and was not a system malfunction.

8.2.4 RECOVERY — Once the NASA pod was located, only 15 minutes were required to maneuver the vehicle into position and attach the claw. The pod was 15 inches in diameter, 6 feet long, and weighed 160 pounds. The unit was brought on board on 21 March 1970, 10 days after the request for CURV III was received.

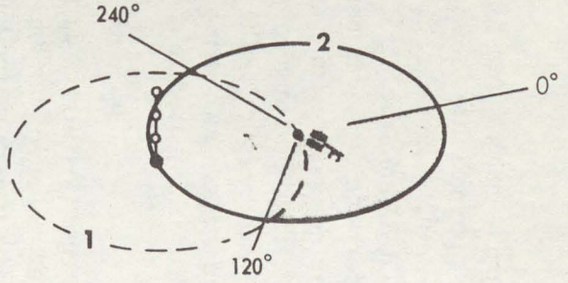
8.2.5 CABLE DEPLOYMENT/RETRIEVAL — Cable deployment, exclusive of vehicle and cable ring deployment time, enabled vehicle descent to 5,850 feet in 2 hours and 20 minutes on the first dive in a sea state 1 and 3 hours and 15 minutes on the second dive in a sea state 3. Cable retrieval without the pod in a sea state 3 was 3 hours and 30 minutes. Cable retrieval with the pod in a sea state 5 was 6 hours and 15 minutes from bottom to surface.



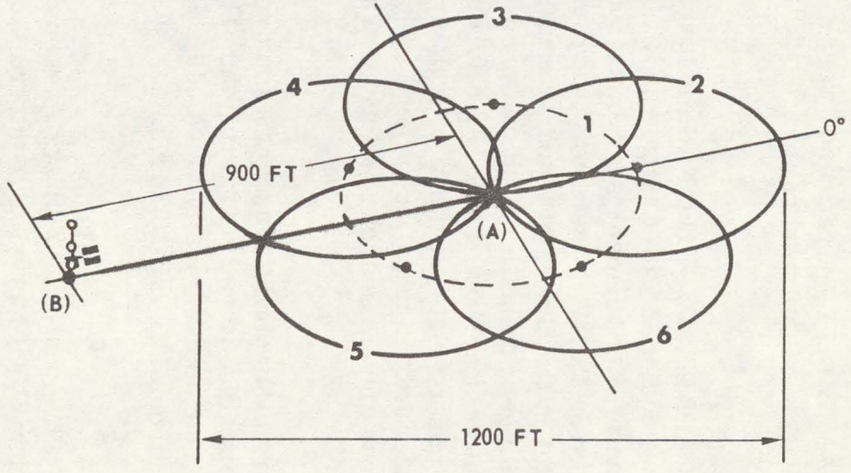
a. SEARCH AREA 1 AROUND REFERENCE TARGET WITH THREE 120° SONAR SCANS. PLOT AND INVESTIGATE OBJECTS WITHIN 300 FT RADIUS.



b. BACK CURV III OUT 300 FT ON 0° HEADING. ESTABLISH SEARCH AREA 2.



c. SEARCH AREA 2. PLOT AND INVESTIGATE OBJECTS IN THREE 120° SONAR SCAN AREAS.



d. COMPLETE SEARCH OF SIX OVERLAPPING AREAS. CURV III MOVE REFFERENCE TARGET FROM SEARCH POINT A TO POINT B, REPEAT PROCEDURE

FIG. 8-4. Search Method Used to Find NASA Instrumentation Pod.

The sea state directly affected cable handling time on the final retrieval by hampering the cable handlers who were manually unticing the cable and support line at a station at the vessel rail. Cable handling in the two dives was accomplished from two different parts of the ship due to a change in cable handling equipment location from the stern to bow as shown in Fig. 8-5. The skipper of the OPPORTUNE felt the change was necessary to improve his vessel's station keeping. This change is not thought to have significantly affected the cable handling rate; however, the capstans used instead of the CURV III winch to handle the support line were not as responsive as the winch and accounted for some extra time in deployment and retrieval. Some extra time was also attributable to care taken in raising the damaged pod. It can be concluded, however, that adverse sea states significantly retard the normal cable handling rates for CURV III.

8.2.6 VEHICLE HANDLING — The use of the 10-ton cargo boom to handle the vehicle presented some difficulties as the control of the boom and hook was less sensitive than with the hydraulic articulating crane on the YFNX-30. During recovery of the vehicle after the first dive the vehicle swung into the control van and both vehicle and van suffered minor damage.

Recovery of the vehicle after the second dive in sea state 5 required over 2 hours. Much difficulty was experienced maneuvering the vehicle into position for hoisting on board due to winds, waves, and currents which the vehicle was not powerful enough to overcome. During the recovery swimmers were used to attach lines to the payload and vehicle. The first attempt followed normal at-sea procedures, i.e., to recover on the leeward side. The diver was fighting the current and the vehicle was in danger of being overrun by the vessel, which was drifting because the screws had to be secured during recovery for safety. This situation is illustrated in Fig. 8-6a. The attempt was then made from the windward side, enabling CURV III to be held steadily away from the drifting ship and the swimmer to swim with the current to it. Lines were then easily attached to the pod and it was recovered (Fig. 8-7).

The vehicle was brought alongside where considerable difficulty was encountered trying to attach the boom hook into the recovery hoop on the vehicle because of motion of the heavy "headache ball" above the hook. Finally a rope loop was tied to the vehicle and thrown over the boom hook (Fig. 8-8). A greater number of restraining lines were attached than had been used on the first vehicle recovery and the vehicle was shipped aboard without incident despite the heavy seas (Fig. 8-9).

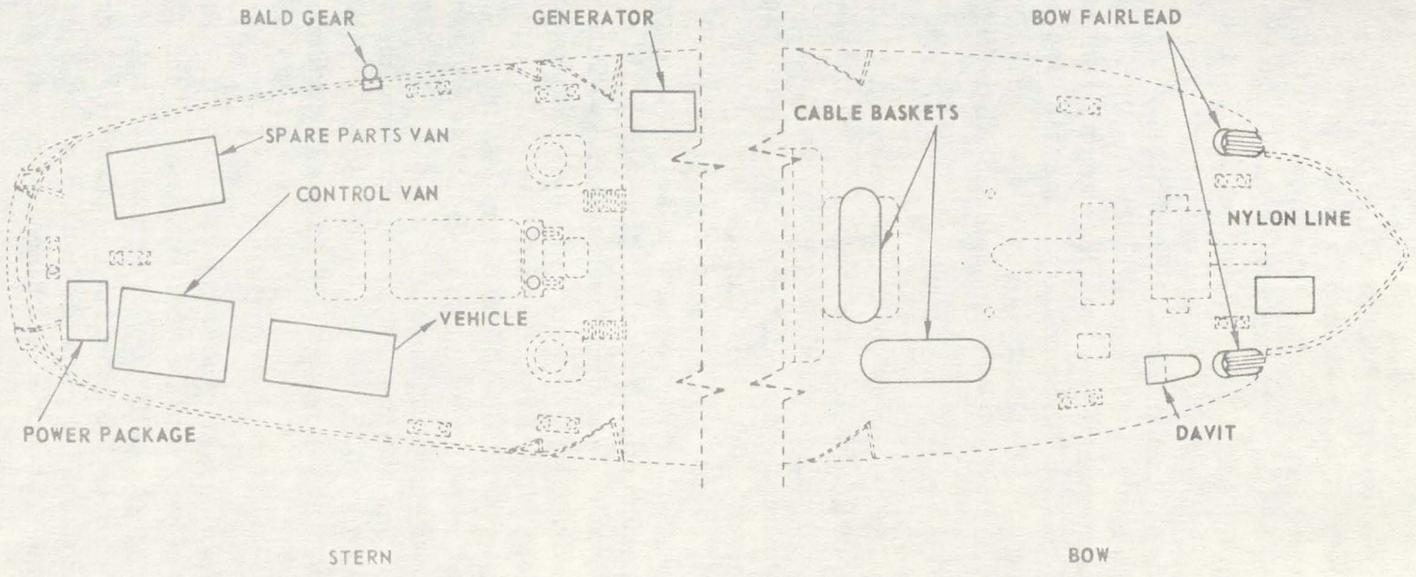
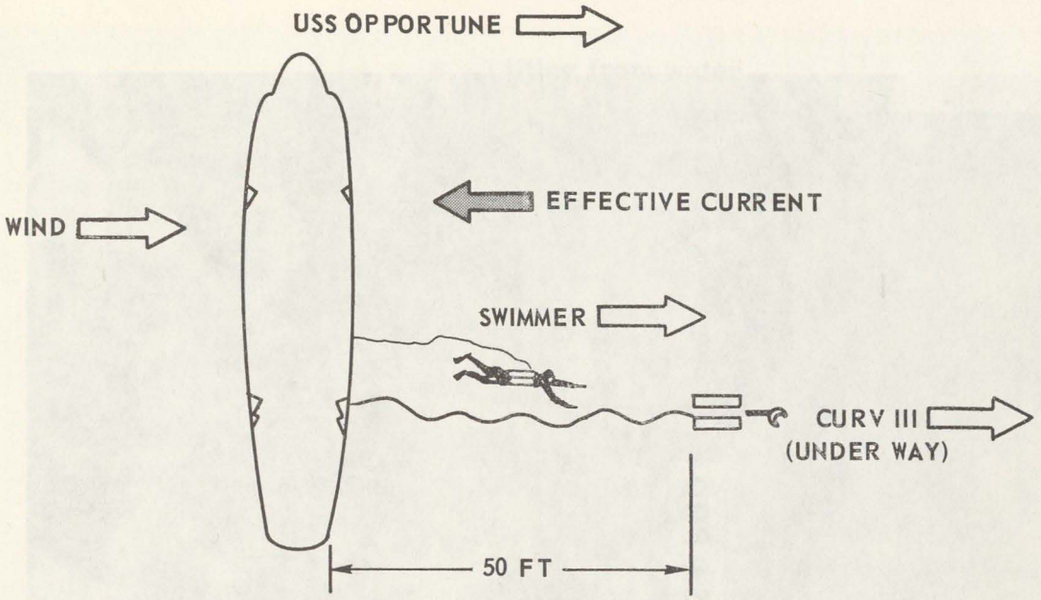
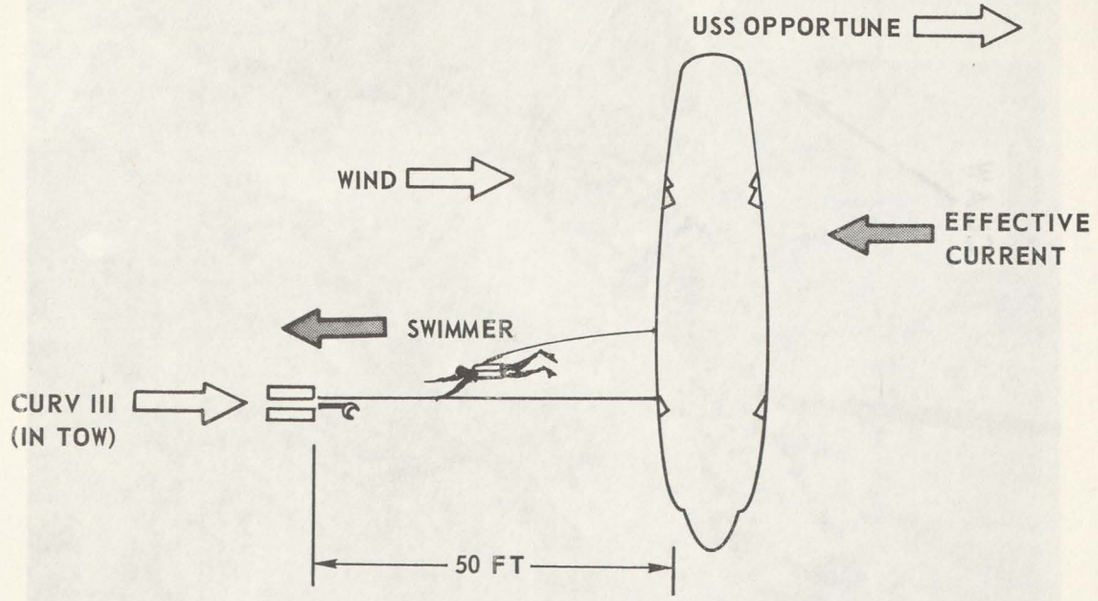


FIG. 8-5. Revised CURV IIIB Equipment Locations in Effect During NASA Recovery.



a. LEEWARD RETRIEVAL ATTEMPT



b. WINDWARD RETRIEVAL TECHNIQUE

FIG. 8-6. NASA Pod Retrieval Technique.

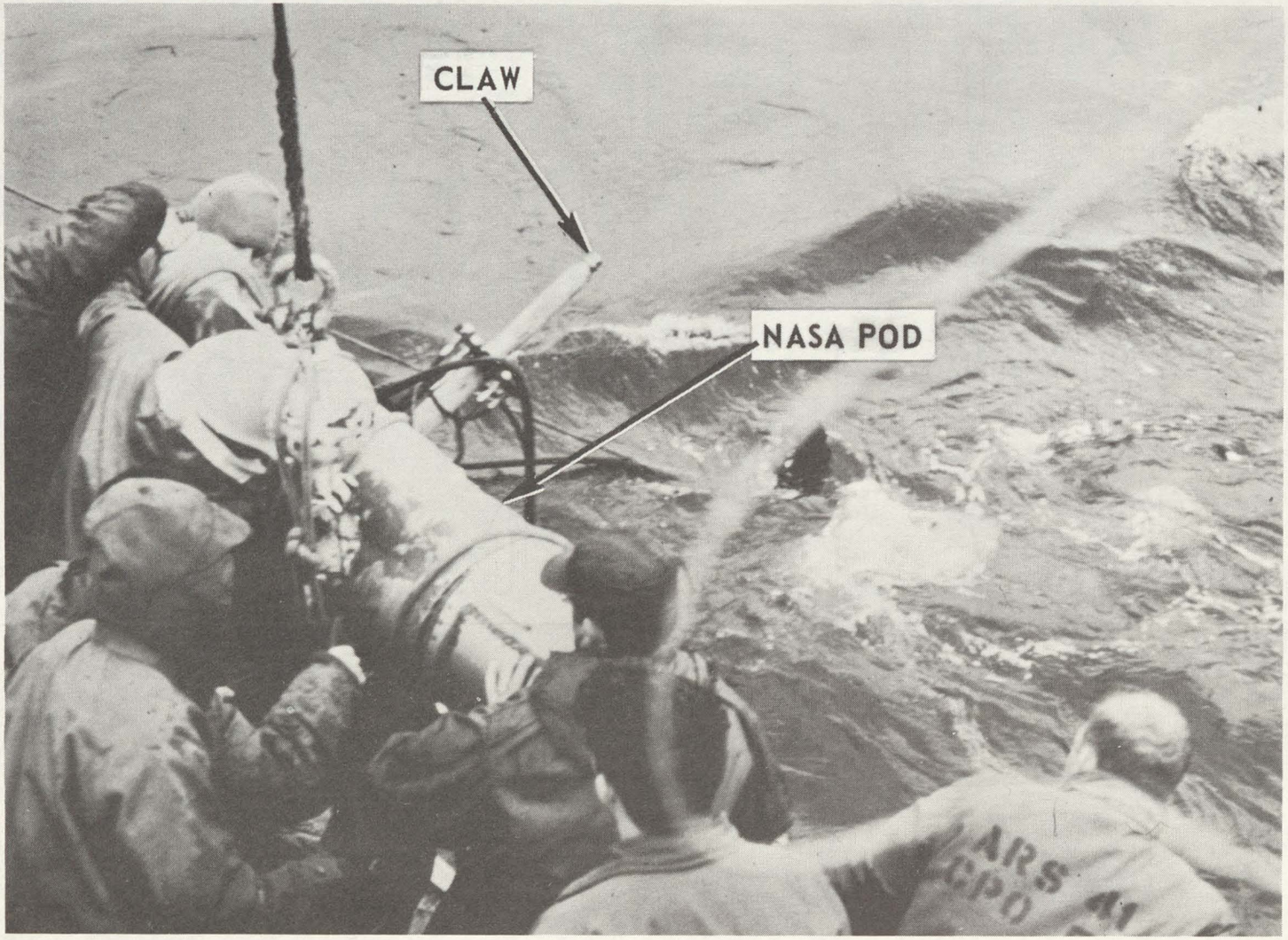
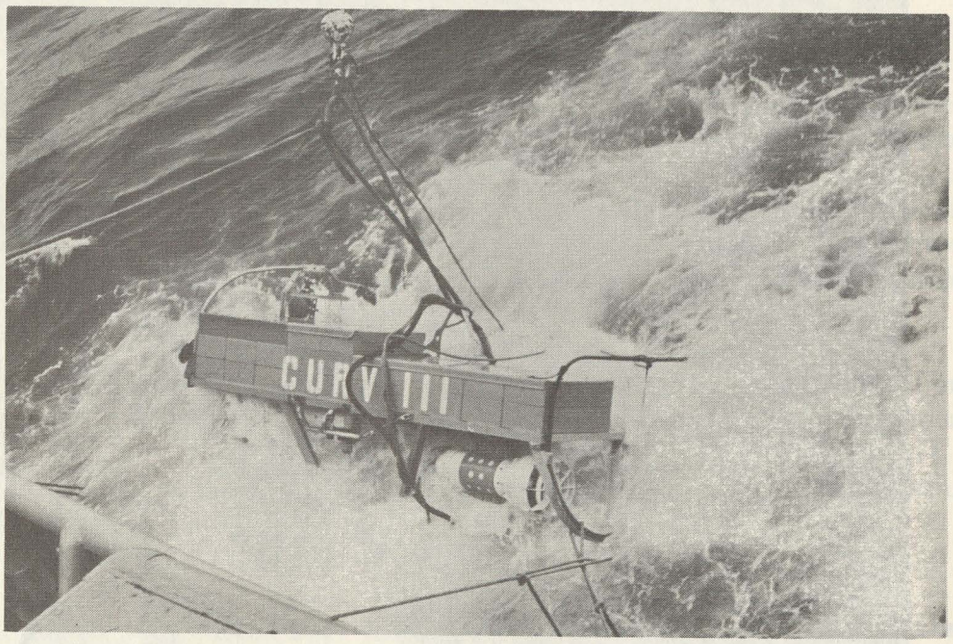


FIG. 8-7. NASA Pod Recovery.

a. Lifting from water



b. Hoisting on board

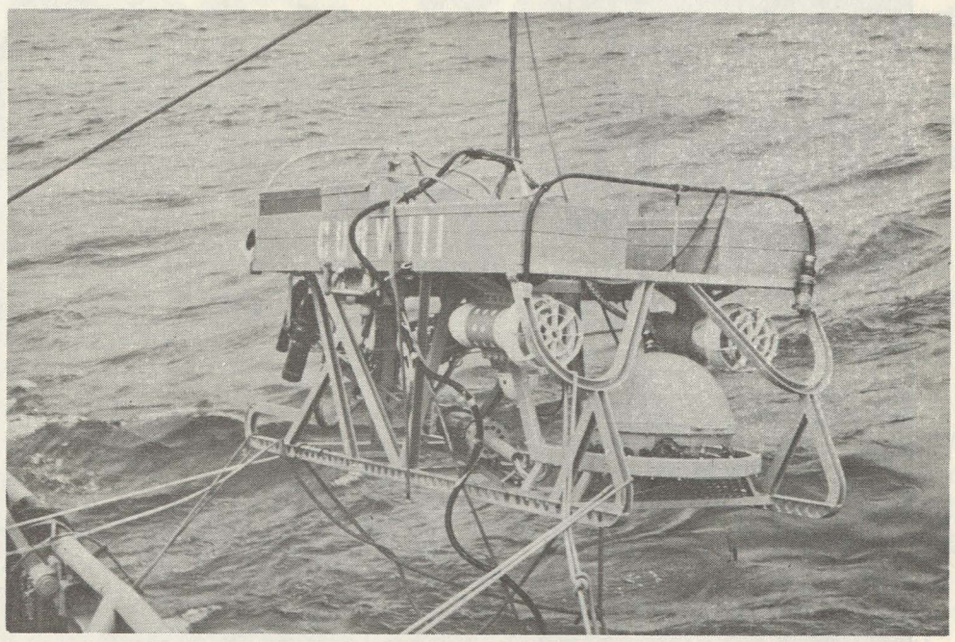


FIG. 8-8. Attachment of Boom Hook to Nylon Loop in CURV III Lift Eye.

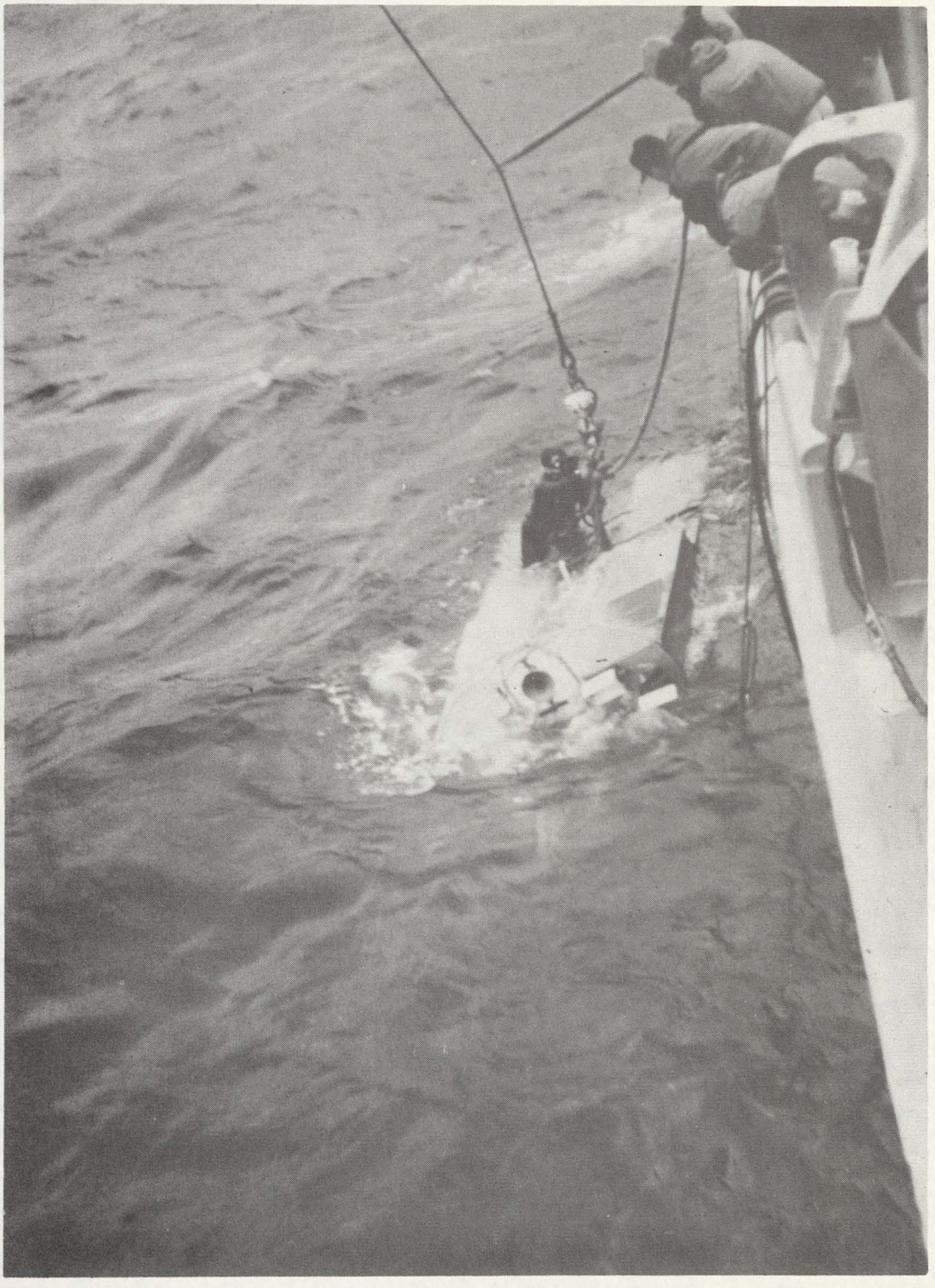


FIG. 8-9. Retrieval of CURV III After Recovery of NASA Pod.

8.2.7 PERFORMANCE IN HEAVY SEAS — Operations were conducted in sea conditions varying from calm to heavy seas with winds of 20 to 25 knots and waves of 10 to 12 feet.

The principal problem in the sea state was a sea anchor effect of the CURV III cable on station-keeping when it was payed out from the stern of the OPPORTUNE. The OPPORTUNE was a twin-screwed vessel and station keeping was conducted without additional assistance, but when the cable was tended from the rear, the sea anchor reduced the coupling of the two screws and hampered maneuvering. When the cable was moved forward after the first dive, the sea anchor effect was far enough from the screws so that it could be used to advantage as a point to maneuver against and station keeping was much improved.

Vehicle bottom performance was not noticeably affected by sea state, but surface wave effects in the sea heavy seas during recovery caused definite additional damage to the NASA pod (which had been partially crushed by the pressure of the depth) while it was in the CURV III claw. The occurrence of the additional damage was visible on the CURV III monitors.

8.2.8 SUPPORT VESSEL/CURV III COMPATIBILITY — Equipment space on board was sufficient after the cable handling was moved to the bow area. Through the use of the Raydist tracking gear, the station keeping of the vessel was also sufficient. Continuous readings were taken from Raydist position plots maintained with respect to a predetermined point, and vessel maneuvering was conducted around the point. This worked well enough to keep the vessel within a 100 yard radius of the point and prevented the CURV III vehicle from being pulled out of the working area; although on a few occasions during rough seas, the vehicle was fighting for cable or was pulled slightly off-site before corrections could be made. This situation was completely relieved when the cable was tended from the bow. The only unresolved support vessel difficulties were the use of the cargo boom as vehicle crane and the slow response of the capstans as mentioned in the discussions above.

8.2.9 CREW — The CURV personnel required to support the NASA activities are shown in Table 8-2. The crew of 16 persons was larger than the six man crew required for normal operations for the following reasons: (1) round-the-clock operations were anticipated in order to meet the deadline recovery date; (2) the system had not been fully checked out and on-site repairs and adjustments were expected; (3) the exact support vessel capabilities, mission requirements and task team responsibilities were not known at the time of departure; (4) the system had not been air transported before. All personnel performed useful functions, but the size of the crew for this first operation does not necessarily indicate the crew needed for other types of operations.

TABLE 8-2. CURV Crew for NASA SERO Operations

The following personnel were on-scene participants from NUC:

1. CURV Program Manager
2. CURV III Project Engineer
3. Range Engineer
4. Onboard Military Liaison
5. Vehicle Operator
6. Sonar Operator
7. Electronic Technician
8. Vehicle Handling and Deck Supervisor
9. Vehicle and Cable Handler
10. Hydraulic Technician
11. Navigation Technician
*12. Onshore Liaison
13. Bald Gear Operator
*14. Transport and Shipping Supervisor
*15. Transport and Shipping
**16. Compass Operator/Engineer

(Plus six deck hands from vessel crew)

---

*Not onboard USS OPPORTUNE during operation.

**Called out to assist in repairs.

The OPPORTUNE's normal complement was able to quickly learn and fully support the activity required for handling station-keeping, etc. Six deck hands, a Commanding Officer and OIC were the normal support crew. Up to five other personnel participated in the NASA operations including Raydist operators and technicians and NASA consultants.

8.3 CONCLUSIONS REGARDING PORTABLE SYSTEM EVALUATION

By the end of the NASA operation the new CURV III vehicle, console and support equipment had logged a total of 11 dives and over 75 hours of operating time without interruption for major repair, including the time for a deep checkout dive and a shallow operation at NUC ranges. This pre-NASA operation consisted of search and recovery of a pinger-equipped ordnance item.

All difficulties encountered in the NASA operation were attributable to support vessel characteristics, sea states beyond the design goals of the system, or unfamiliarity of the support vessel crew with CURV rough-water operations. Many equipment and procedure innovations such as the cable ring and cable handling changes were made during the course of the operation, which demonstrated that two of the characteristics for which an unmanned system had been chosen — versatility and ease of modification — had been attained by CURV IIIB. Most importantly, the recovery operation was a success and was conducted within a rigorous time frame. The portion of the system involved was therefore considered to have passed the equivalent of a technical evaluation.

8.4 SUPPORT VESSEL TECHNICAL EVALUATION

The YFNX-30 also became operational without a formal technical evaluation and has proved itself capable of meeting the design requirements of CURV III. It was used for the 13 checkout dives of the CURV IIIA vehicle, for seven checkout dives and the shallow depth ordnance recovery by the CURV IIIB vehicle prior to NASA operations, for a CURV II support vessel during five search operations while CURV IIIB was on the East Coast, and for a support craft for various other NUC range activities including an implacement and cable laying operation for DSRV UQC transponder and a torpedo launching operation.

In all instances the maneuverability, station keeping and sea worthiness of the vessel were as expected and more than sufficient to support CURV III NUC range activities.

During the DSRV cable laying operations, the vessel was held on station ±50 yards while a transponder frame was implanted, and, following verbal radio commands from SCI land-based radar operators monitoring a radar beacon onboard the YFNX-30, it layed over 0.5 mile of cable in a direct line to within 3,000 feet of shore while crabbing sideways.

CURV II and III operations from the YFNX-30 were in all cases without incident attributable to the support craft. Vehicle handling, deployment and retrieval were accomplished without divers' assistance in weather including sea state 3. The total cable deployment and retrieval time on the YFNX-30 for 6,000-foot dives averages approximately 4 hours as compared to an average of 3 hours for CURV II on 2,500-foot dives from its support vessel YTM-759.

The only problem evidenced with the YFNX-30 is its cruising speed of 5 knots, which often requires tow at 10 knots from Long Beach by the YTM-759 if quick response to NUC ranges needs is required.

8.5 CURV IIIB SYSTEM IMPROVEMENTS AFTER NASA OPERATION

Following the NASA operation several improvements were made to the CURV III system, primarily to increase portability response time.

The cable baskets were modified so that they could be loaded onto a C-141 in a side by side configuration. A loading plan was devised that enabled shipment of all portable components in a single C-141, including the vehicle crane, which was determined to be a necessary part of the portable system from the NASA experience, and a 100 kW generator, which was procured to be part of the portable system to ensure system compatibility.

A spare main cable was procured so that it could be stored in the cable baskets ready to be shipped as part of the portable system. This was done to prevent the time-consuming off-loading of the cable from the YFNX-30 that added 8 hours to the response time in the NASA operation.

Page

9-1
9-2
9-2
9-5
9-6

SECTION 9

LOSS AND REPLACEMENT OF CURV IIIB VEHICLE

Section 9

TABLE OF CONTENTS

Section	Title	Page
9.1	Loss of Vehicle	9-1
9.2	Replacement Vehicle Changes	9-2
9.2.1	Vehicle Changes	9-2
9.2.2	System Changes	9-5
9.2.3	Implementation of Changes	9-6

LIST OF FIGURES AND TABLES

Figure	Title	Page
9-1	CURV IIIC Search and Rescue Pinger	9-3
9-2	CURV IIIC Radio Direction Finder Transmitter	9-4

Section 9

LOSS AND REPLACEMENT OF CURV IIIB VEHICLE

After the NASA recovery, CURV IIIB conducted several NUC range missions then was requested to conduct an operation to search and recover a University of Washington Oceanographic instrumentation package about 50 miles west of Vancouver Island. The system was trucked to Washington and installed on the U. S. Coast and Geodetic Survey ship, USS FAIRWEATHER (MSS-20). On 4 October 1970, during a search for the instrument, the weather deteriorated rapidly, the operations were ceased, and the vehicle was brought to the surface in the dark.

9.1 LOSS OF VEHICLE

In attempting to bring the CURV IIIB vehicle onboard the FAIRWEATHER, difficulty was experienced keeping the vehicle away from the ship in heavy seas variously reported from 8 to 12 feet and in winds reported from 30 to 40 knots. Recovery could not be made on the windward side as had been successfully accomplished with the OPPORTUNE in the NASA recovery because the vessel had to be headed into the wind for safety. The stern was at times awash even when heading into the wind. The vehicle and cable handling area was on the starboard side at the stern, and the cable ring was employed. As the vehicle reached the surface and the cable ring was being recovered, the cable floats and vehicle were on the surface and being driven by the wind toward the vessel. The vehicle operator was attempting to drive the vehicle away at a 45 degree angle from the stern. As per prearranged plan, when the cable ring was being brought aboard, the order was given to secure the starboard screw of the twin-screwed FAIRWEATHER. The vehicle was not able to make the headway necessary to keep the 600 feet of buoyed cable away from the vessel, and the whip cable was severed approximately 600 feet from the vehicle.

After the vehicle was lost, the FAIRWEATHER stood off for fear of running over the vehicle in the dark, since CURV IIIB had no failure lights—only an interrogatable transponder. At dawn, visual search was commenced by the FAIRWEATHER in seas which remained high. The FAIRWEATHER navigation gear failed that

day and the vessel put into port for repairs. While in port, sonar equipment was also installed on the FAIRWEATHER to enable interrogation of the vehicle rescue transponder.

The FAIRWEATHER returned for sonar and surface search. Extensive air and surface searches were conducted under direction of the Coast Guard along drift routes predicted by University of Washington experts and along the coast at predicted landfalls. Reward posters were distributed along the coast. No sighting or other report of the vehicle was ever received.

An informal investigation (Ref. 10) was conducted by NUC to establish how CURV III was lost in order to improve operations in the future. It was never definitely determined if the cable was cut by the starboard screw under power, by the starboard screw "windmilling" as the vessel moved into the sea under port screw power, by the port screw (which was under power at the time) or if the cable was caught between the cable ring and vessel hull and severed.

The findings of the study were that the seas were too heavy for operation of the CURV IIIB/FAIRWEATHER combination. The weather's deterioration and severity were localized and could not have been anticipated on-board the FAIRWEATHER soon enough to enable safe recovery of the CURV IIIB vehicle. The remediable causes of the loss were determined to be: (1) lack of sufficient propulsion power on the CURV IIIB vehicle, (2) the necessity of handling of the vehicle, cable ring, and cable from the stern of the vessel near the unprotected screws due to limited space on the bow, (3) lack of failure-activated search aids such as pingers and lights.

9.2 REPLACEMENT VEHICLE CHANGES

Design of a replacement vehicle, CURV IIIC, was commenced by analyzing the loss and determining recommended design changes to the vehicle and system.

9.2.1 VEHICLE CHANGES — The principle vehicle design change consisted of adding a failure-activated rescue package to broaden the search area. The SAR package (Fig. 9-1) contains a strobe light, 9 kHz pinger, a surface Radio Direction Finding Transmitter (RDFT) (Fig. 9-2) and an interrogatable underwater transponder that responds to a 22.5 kHz call with a 37 kHz answer. All elements of the SAR package are battery powered, and activated on failure of system power.

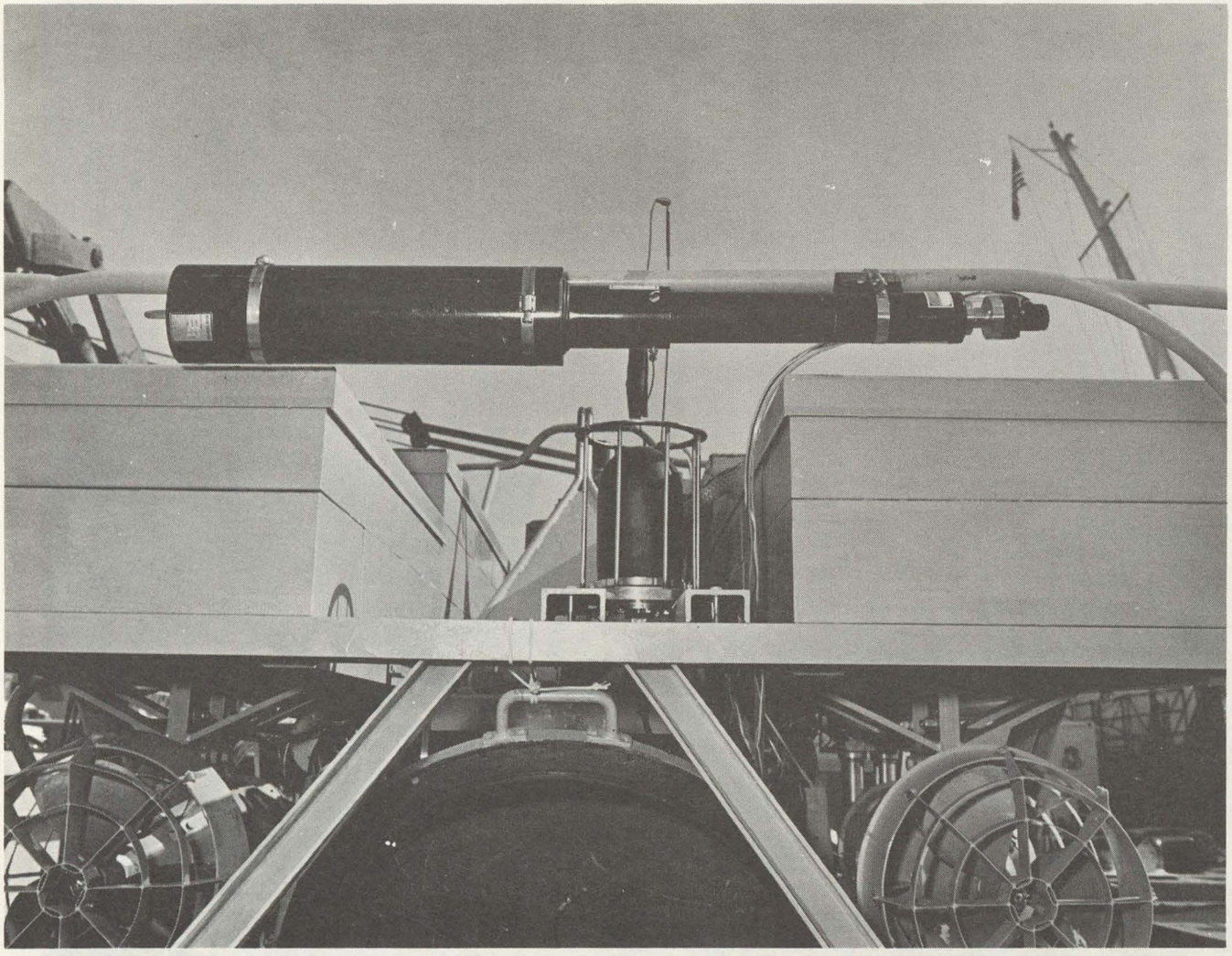


FIG. 9-1. CURV IIIC Search and Rescue Pinger.

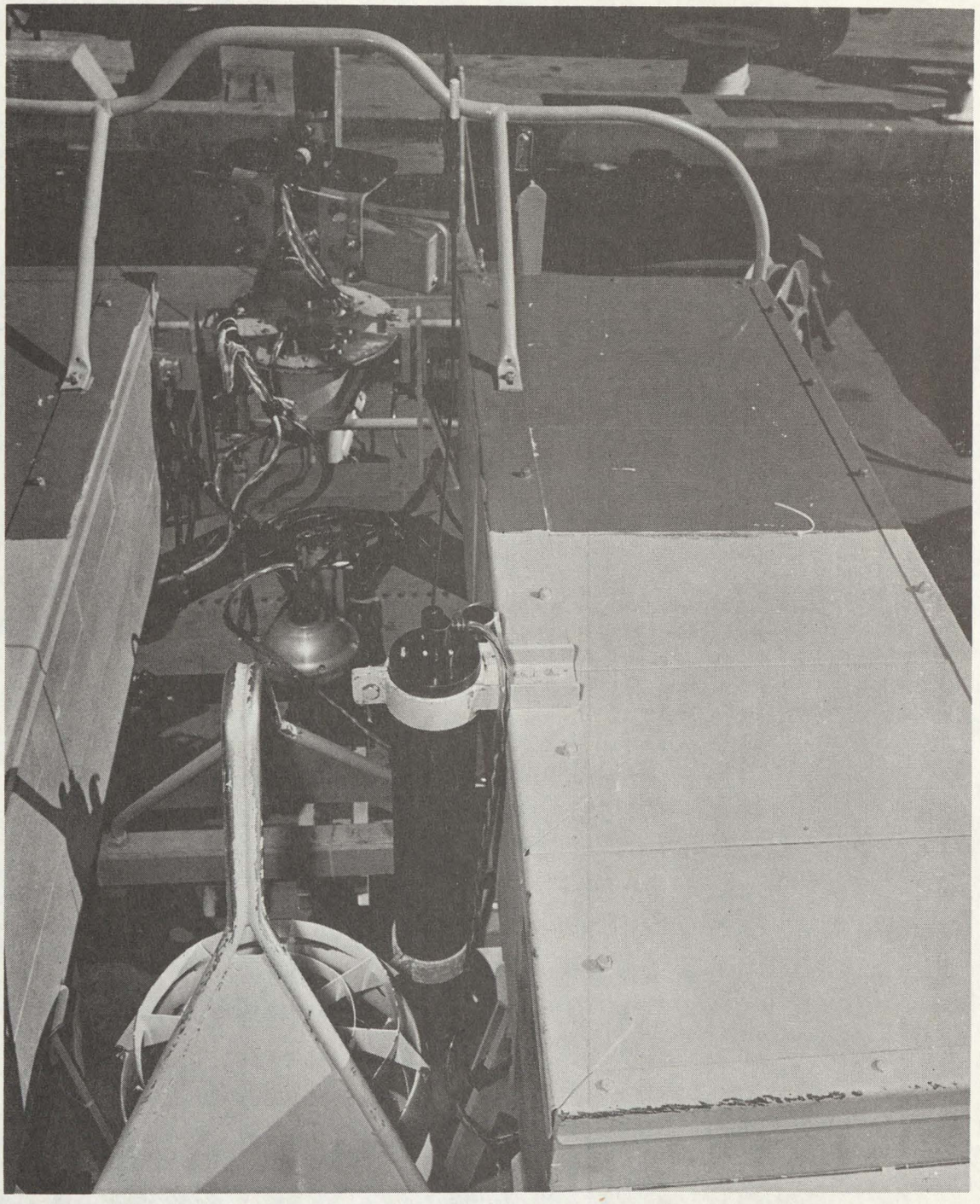


FIG. 9-2. CURV IIIC Radio Direction Finder Transmitter.

It was determined not to increase vehicle propulsion power because of the extensive system modifications it would entail and inability to determine the degree of improvement required to permit satisfactory operations in heavy seas.

All small connectors of the NUC pressure balanced type were replaced with a commercial pressure balanced connector built to NUC specifications by Brantner, Incorporated. The primary modifications in these connectors were the addition of a ball-check valve in the oil-filled lines to allow disconnection without loss of oil and use of a plug-in type connection rather than the hard wired type. The effect of both improvements was to reduce maintenance and repair time by making connection and disconnection faster.

9.2.2 SYSTEM CHANGES — Based on the NASA and University of Washington operations, vehicle recovery was viewed as the crucial system problem.

System changes were made to give flexibility in vehicle recovery procedures. In the University of Washington operation, the only alternatives had been to leave the vehicle deployed on the bottom or recover it. In heavy seas both were equally dangerous. One system change, therefore, was to enable alternate methods of recovery.

Given various alternative recovery procedures, another problem that was seen was understanding and communicating the desirable recovery procedure for a given situation among a CURV crew and support vessel crew, who would in most portable operations be unaccustomed to working with each other.

The efforts in system changes, therefore, were to codify operational procedures for various weather circumstances; define the vehicle handling methods to accompany the procedures; and design equipment to effect the various recovery methods.

The major recommended equipment changes were: combining the winch and davit into a portable davit/hoist that in rough weather could pull the vehicle directly out of the water using the nylon support line, instead of having to attach the crane hook and cable; modifying the main connector to enable buoying off the vehicle at the whip/main cable junction in extreme emergency with specially designed buoy equipment with search and tracking aids; and adding a failure-activated SAR package.

9.2.3 IMPLEMENTATION OF CHANGES — The system procedures and vehicle recovery methods were documented in a CURV III Search and Rescue (SAR) plan. The SAR vehicle package change described above has been incorporated in the new vehicle. The other proposed system changes are being developed further and will be further evaluated in CURV IIIC vehicle operations.

SECTION 10

CURV IIIC VEHICLE CHECKOUT AND OPERATIONS

Section 10

TABLE OF CONTENTS

Section	Title	Page
10.1	Initial Operations	10-1
10.2	AFAR Operations	10-1
10.3	Other Operations	10-19
10.4	System Modifications	10-19
10.5	Conclusions	10-20

LIST OF FIGURES AND TABLES

Figure	Title	Page
10-1	AFAR Layout	10-8
10-2	Echo Tower Padeye Arrangement	10-9
10-3	Echo Tower Lift Sequence	10-10
10-4	CURV III Echo Tower, AFAR Operation	10-11
10-5	Bravo Buoy Layout	10-13
10-6	CURV IIIC NAUBUC Layout for AFAR	10-15
10-7	AFAR Cable Cutting and Retrieval	10-18

Table	Title	Page
10-1	CURV IIIC Operations	10-3

Section 10

CURV IIIC VEHICLE CHECKOUT AND OPERATIONS

The CURV IIIC vehicle was assembled and in the water for checkout on 12 April 1971, 6 months after the CURV IIIB vehicle was lost. It proceeded through checkouts of 120, 2,000, 4,000, and 6,000 feet without incident, and began its first operation from the YFNX-30 on 26 April.

10.1 INITIAL OPERATIONS

The first CURV IIIC operation was at NCEL for the SEACON project and included a foundation implantment monitoring task at 1,200 feet, a foundation inspection dive to 600 feet and a 20-hour search for a submersible test stand at 6,000 feet. This operation lasted 8 days and was accomplished without interruption due to CURV IIIC component failure.

In May, training and equipment evaluation dives in preparation for a portable operation to the Azores were conducted. These dives developed the CURV III Pyronol torch tool for cutting cables up to 3.5 inch in diameter, rigging techniques for a powered shackle specially designed by the Supervisor of Salvage Office, and a custom cable grapnel.

The initial CURV IIIC operations are discussed in the detailed summary of CURV IIIC operations provided by Table 10-1 (see Dives 5 through 10).

10.2 AFAR OPERATIONS

The Azores Fixed Acoustic Range (AFAR) is being developed through an international effort by agencies and contractors of the French, German, Italian, United Kingdom, Canada, Portugese, and United States Governments. The leading US Navy participant is the Naval Underwater Systems Center (NUSC). The purpose of the development is to establish an acoustic range with several large underwater transmitting and receiving towers with trainable antennas.

TABLE 10-1. CURV IIIC Operations

Date	Dive No.	Purpose	Location	Depth (ft)	Sea State	Water Time (hrs:min)	Water Time Total to Date (hrs:min)	Results
4/19/71 to 4/23/71	1 to 4	System checkout	SCI	500 to 5,500	1	14:28	14:28	Successful, minor electrical noises
4/27/71	5	Recover monitor from SEACON foundation	NCEL, Santa Barbara Channel	1,200	1	3:34	18:02	Successful
4/27/71	6	Release SEACON transponder	NCEL	600	1	0.57	18:59	Transponder gone
4/28/71	7	Place marker buoy at SEACON site	NCEL	600	1	4:06	23:05	Unsuccessful
4/29/71	8	Locate NCEL STU 1-6	NCEL	5,800	3	20:27	43:32	Unsuccessful
5/4/71	9 and 10	Attach recovery device to SEACON vibratory anchor	NCEL	600	Calm	2:05	45:37	Successful
5/13/71 to 5/25/71	11 to 27	AFAR training	SCI	100	Calm	18:35	64:12	Develop torch cutting and shackel placement techniques
6/23/71 to 6/25/71	28 to 32	Cut Echo Tower cable; monitor planting of transponder	AFAR	1,900	Calm	22:25	86:37	Successful cut after difficulty locating tower and fouling in transponder wire rope. Cut free wire rope using pyronol torch.
6/26/71	33 and 34	Cut November Tower cable	AFAR	1,200 to 2,153	Calm	13:02	108:54	Successful. Cut cable in two places. Triplane marker placed.
6/27/71	35	Recover piece of BRAVO buoy shore cable	AFAR	2,460	Calm	5:42	114:36	Control panel junction box flooded by air conditioner.
7/11/71	36	Practice Echo Tower recovery	AFAR	946	Calm	6:54	121:30	Successful
7/12/71	37	Attach shackle to Echo Tower and monitor recovery	AFAR	1,790	2	7:50	129:20	Successful
7/13/71	38 and 39	Attach grapnel to tower end of November cable	AFAR	1,225	Calm	2:49	132:09	Successful
7/13/71	40	Bottom survey of November cable site	AFAR	1,275	Calm	4:20	136:29	Sonar map enabled discovery of gradual rise in area of steep cliffs.
7/14/71	41 to 43	Cut Bravo Tower cable and recover shoreward cable end	AFAR	1,270 to 1,900	1	11:42	148:11	Cut successful on second attempt. Recovery successful
7/15/71	44 and 45	Recover Bravo seaward cable and electronics	AFAR	2,100	1	6:49	155:00	Cable locate attempt unsuccessful due to surface currents

TABLE 10-1. CURV IIIC Operations (Continued)

Date	Dive No.	Purpose	Location	Depth (ft)	Sea State	Water Time (hrs:min)	Water Time Total to Date (hrs:min)	Results
7/20/71	46 and 47	Destroy 45 kHz pingers on November and Sierra Towers	AFAR	950/ 2,500	1	6:15	161:15	Torch unsuccessful; broke off pingers with manipulator; one pinger recovered.
7/21/71 to 7/26/71	48 to 50	Recovery Bravo seaward cable end and electronics	AFAR	2,100	1	15:22	176:37	Vehicle fouled in Bravo cable twice; concurrent recovery of vehicle and cable failed the first time; successful the second.
7/27/71	51	Inspect reimplanted Echo Tower	AFAR	1,896	Calm	1:53	178:30	Successful
9/8/71	52	Locate EX-MORAY, inspect	SCI	180	Calm	1:30	180:00	TV inspection hampered by surface glare
9/12/71	53	Monitor camera placement	SCI	186	Calm	2:40	182:40	Successful
9/13/71 to 10/6/71	54 to 64	Demonstrations	SCI	180	Calm	26:00	208:40	---
10/20/71	65	Train vehicle and sonar operators	SCI	105	Calm	4:45	213:25	---
10/27/71	66 and 67	Inspect SEACON foundation, adjust bale, recover monitor	NCEL	600	Calm	5:48	219:13	Successful
11/16/71	68 and 69	Locate and recover DSRV UQC Tower	SCI	396	Calm	11:10 (3:36 average)	230:23	Successful

Prior to CURV IIIC involvement, two receiving antenna towers, Sierra Tower and November Tower, had been implanted in proper position, but their undersea cables had been damaged in the process and neither tower was functioning. The source tower, Echo Tower, had to be lowered by its electrical cable during implantment after deployment lifting lines parted. The tower was on the bottom, 0.5 mile from its proper site with its electrical cable damaged. A portion of cable for a proposed instrumentation buoy, BRAVO Buoy, had been layed.

10.2.1 PROPOSED AFAR TASKS—NUC was contacted by the Supervisor of Salvage (SUPSALV) to assist AFAR in getting the towers operational. The layout of the range and summary of CURV IIIC AFAR tasks is given in Fig. 10-1. The details of the CURV IIIC tasks were as follows:

1. Echo Tower—Depth 1,900 feet
   a. Inspect tower and cable
   b. Cut 1 inch wire and polypropylene lines from lift eye (Fig. 10-2)
   c. Attach lift grapnel and buoyed lift line to the tower electrical cable
   d. Attach lift line to tower with SUPSALV shackle (Fig. 10-3) for surface ship lift
   e. Cut cable
   f. Retrieve buoyed cable grapnel line for surface ship lift (Fig. 10-4)
2. Sierra Tower — Depth 2,250 feet
   a. Inspect tower and cable
   b. Attach lift grapnel and buoyed lift line to seaward portion of cable grapnel line
   c. Retrieve buoyed cable lines for surface lift

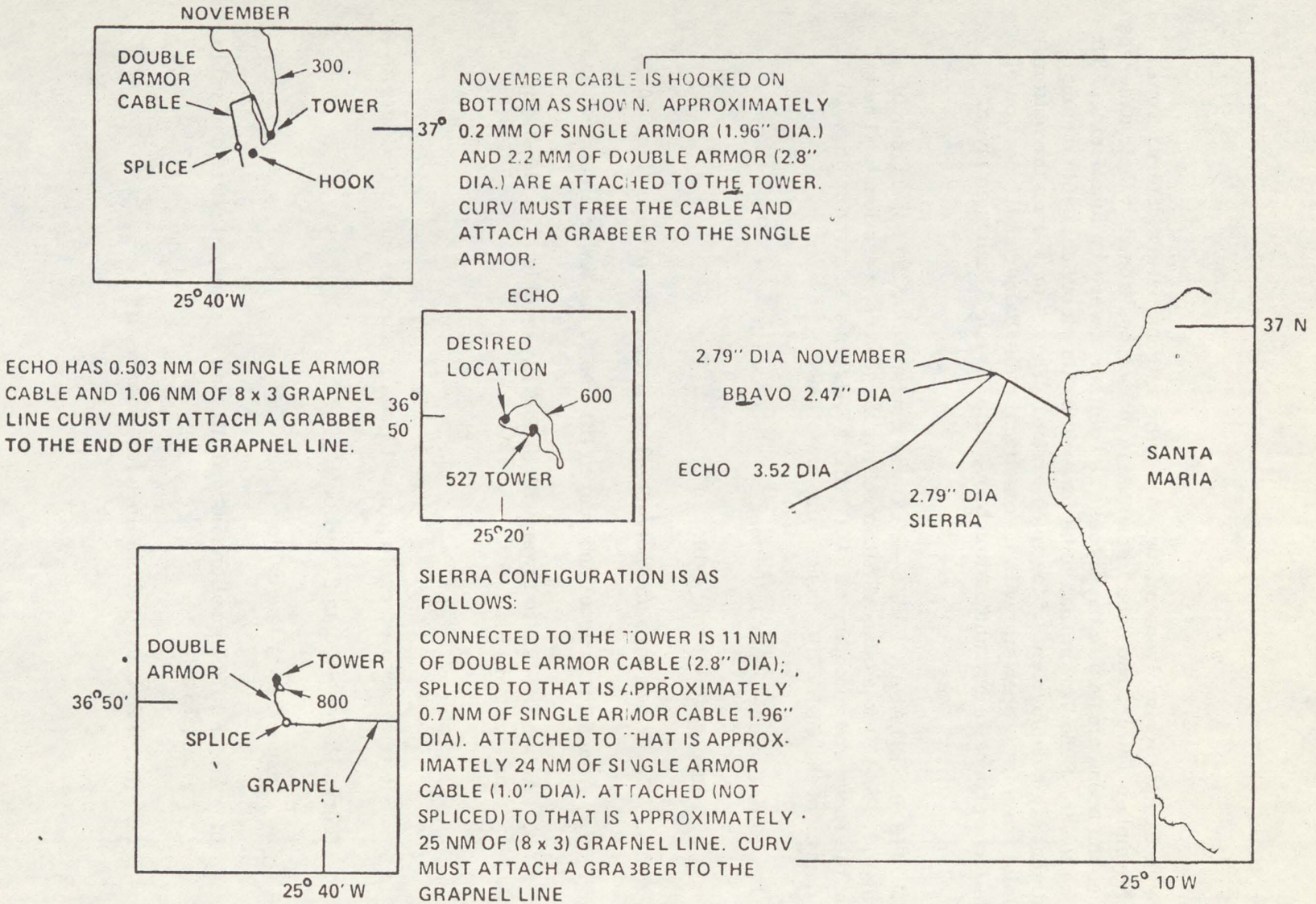


FIG. 10-1. AFAR Layout.

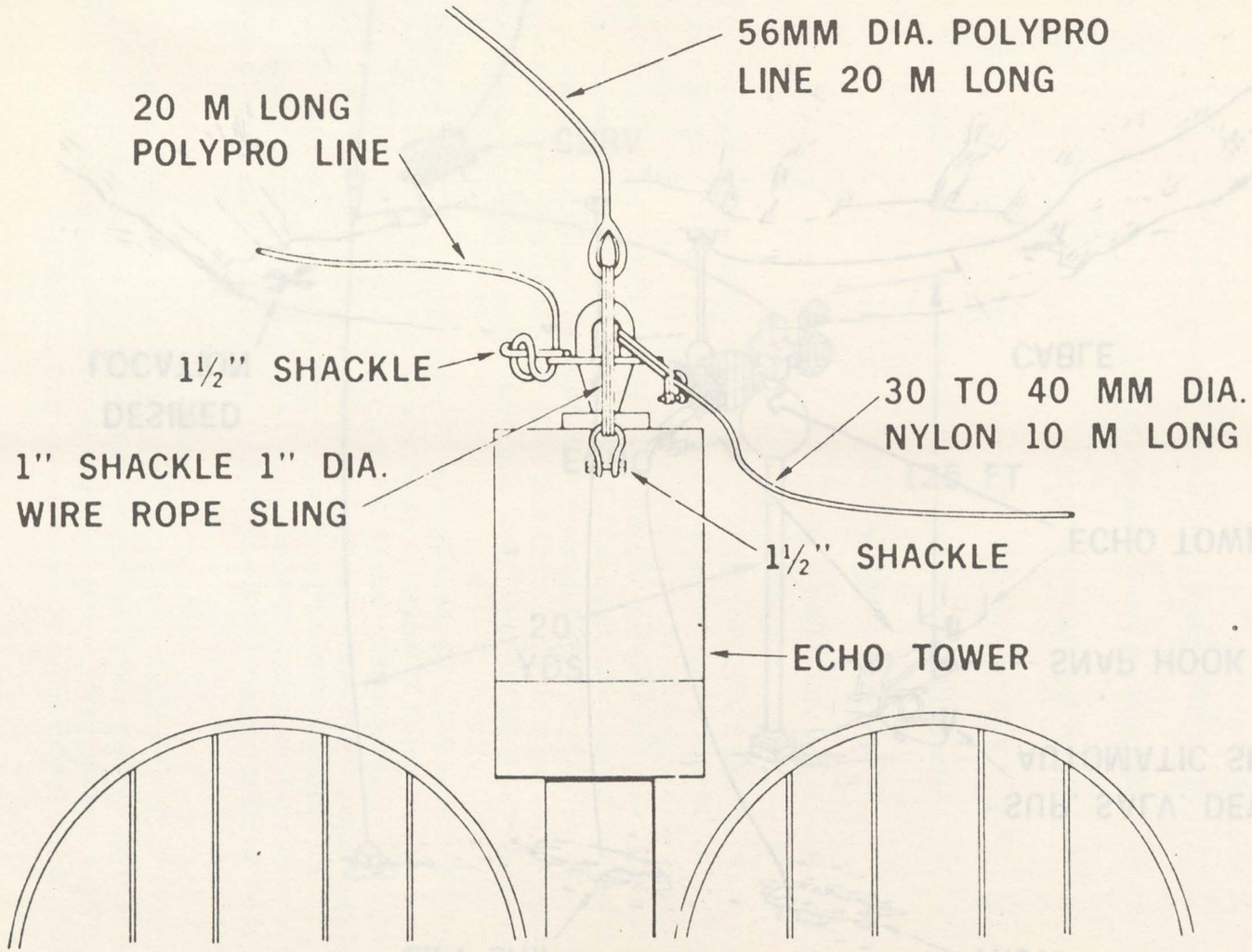


FIG. 10-2. Echo Tower Padeye Arrangement.

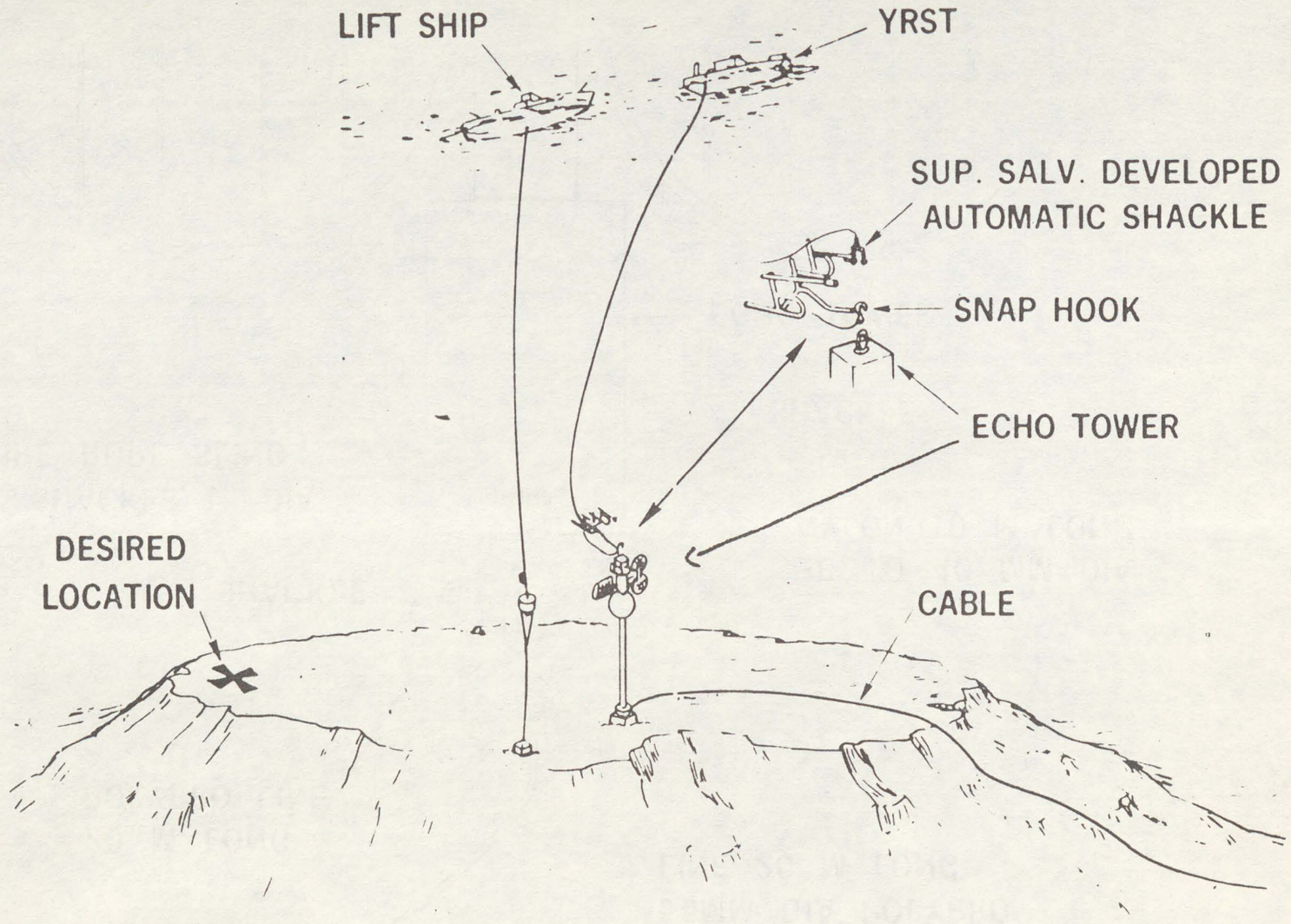


FIG. 10-3. Echo Tower Lift Sequence.

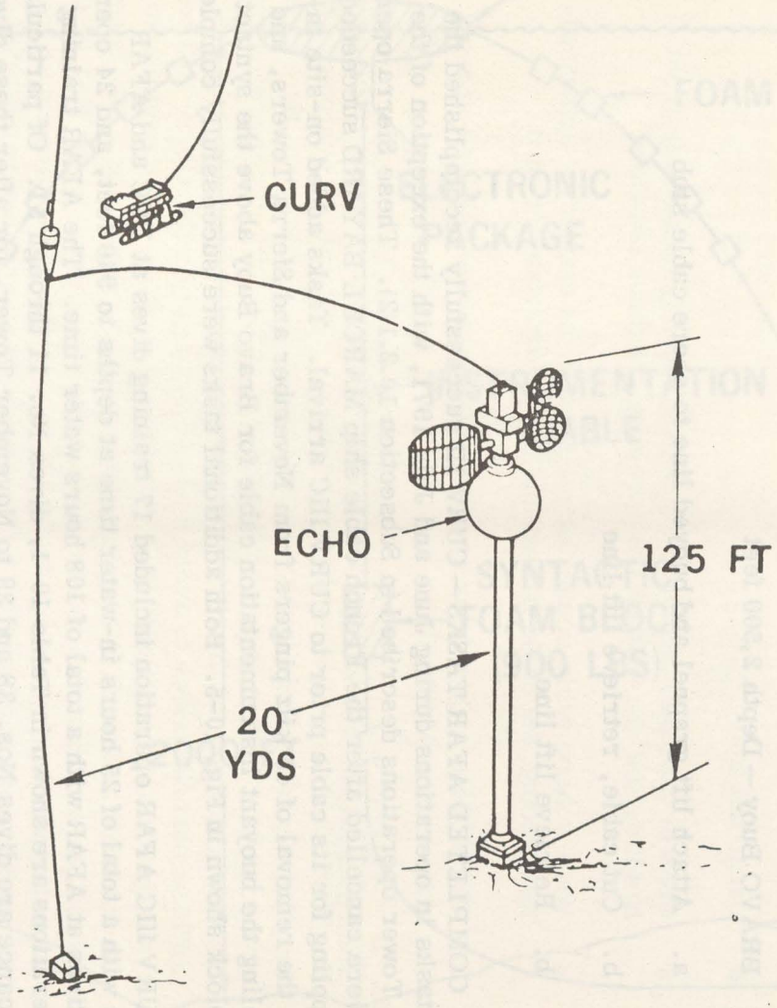


FIG. 10-4. Echo Tower Array.

3. November Tower — Depth 1,275 feet

   a. Inspect tower and cable

   b. Attach lift grapnel and buoyed line to cable

   c. Cut cable, retrieve buoyed lift line

   d. Survey November cable path

4. BRAVO Buoy — Depth 2,500 feet

   a. Attach lift grapnel and buoyed line to shore cable stub

   b. Cut cable, retrieve lift line

   b. Retrieve lift line

10.2.2 COMPLETED AFAR TASKS — CURV III successfully accomplished the above tasks in operations during June and July 1971, with the exception of the Sierra Tower operations described in Subsection 10.2.1(2). These Sierra operations were cancelled after the French cable ship MARCEL BAYARD succeeded in grappling for its cable prior to CURV IIIC arrival. Tasks added on-site included the removal of 45 kHz pingers from November and Sierra Towers, and grapneling the buoyant instrumentation cable for Bravo Buoy above the syntactic foam block shown in Fig. 10-5. Both additional tasks were successfully completed.

The CURV IIIC AFAR operation included 17 training dives at NUC and AFAR ranges with a total of 25 hours in-water time at depths to 946 feet, and 24 operations dives at AFAR with a total of 108 hours water time. The AFAR training and operations are shown in Table 10-1, dives No. 11 through 51. Of particular significance are dives Nos. 38 and 39 to November Tower, for after these dives AFAR personnel were able to hook up and operate the November Tower, which marked the first proper functioning of the new acoustic towers at the AFAR range.

10.2.3 EVALUATION OF AFAR OPERATIONS — The successful completion of the AFAR tasks represented a significant challenge and operational test for the new CURV IIIC vehicle in three major areas: (1) portable operations; (2) underwater work, and; (3) coordinated operations with surface ships.

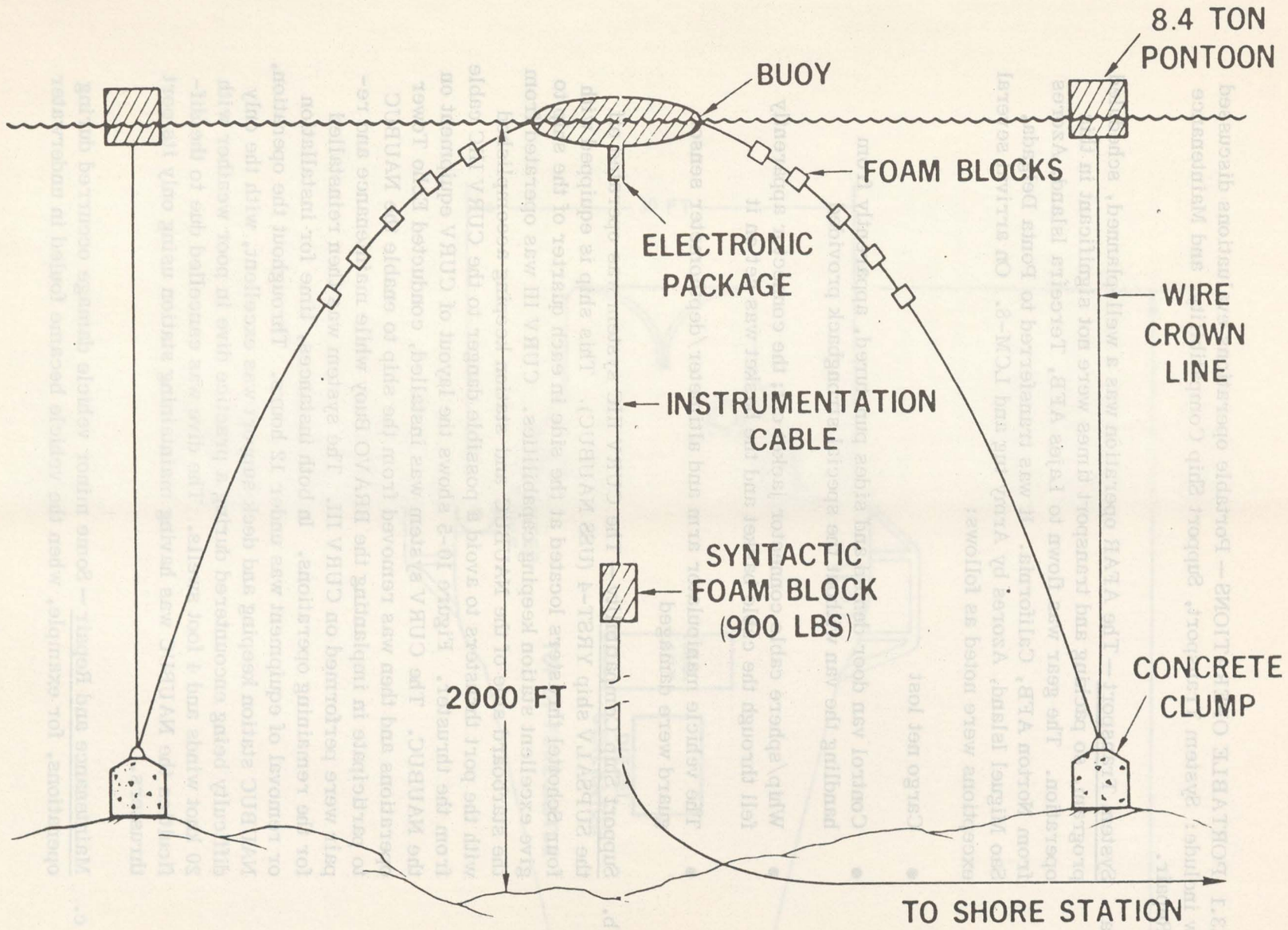


FIG. 10-5. Bravo Buoy Layout.

10.2.3.1 PORTABLE OPERATIONS — Portable operations evaluations discussed below include: System Transport, Support Ship Compatibility, and Maintenance and Repair.

a. System Transport — The AFAR operation was a well-planned, scheduled program, so packing and transport times were not significant in this operation. The gear was flown to Lajes AFB, Terceira Island, Azores from Norton AFB, California. It was transferred to Ponta Delgada, Sao Miguel Island, Azores by Army tug and LCM-8. On arrival several exceptions were noted as follows:

- Cargo net lost
- Control van door dented and sides punctured, apparently from handling the van without the special strongback provided
- Whip/sphere cable connector jacket cut; the connector apparently fell through the cable basket and the basket was set on it
- The vehicle manipulator arm and altimeter/depthometer sensor guard were damaged

b. Support Ship Compatibility — The CURV IIIC system was operated off the SUPSALV ship YRST-4 (USS NAUBUC). This ship is equipped with four Schottel thrusters located at the side in each quarter of the ship to give excellent station keeping capabilities. CURV III was operated from the starboard side of the NAUBUC and station keeping accomplished with the port thrusters to avoid a possible danger to the CURV IIIC cable from the thruster. Figure 10-5 shows the layout of CURV equipment on the NAUBUC. The CURV system was installed, conducted Echo Tower operations and then was removed from the ship to enable the NAUBUC to participate in implanting the BRAVO Buoy while maintenance and repair were performed on CURV III. The system was then reinstalled for the remaining operations. In both instances, time for installation or removal of equipment was under 12 hours. Throughout the operation, NAUBUC station keeping and deck support was excellent, with the only difficulty being encountered during a practice dive in poor weather with 20 knot winds and 4 foot swells. The dive was cancelled due to the difficulties the NAUBUC was having maintaining station using only its port thrusters.

c. Maintenance and Repair — Some minor vehicle damage occurred during operations, for example, when the vehicle became fouled in underwater

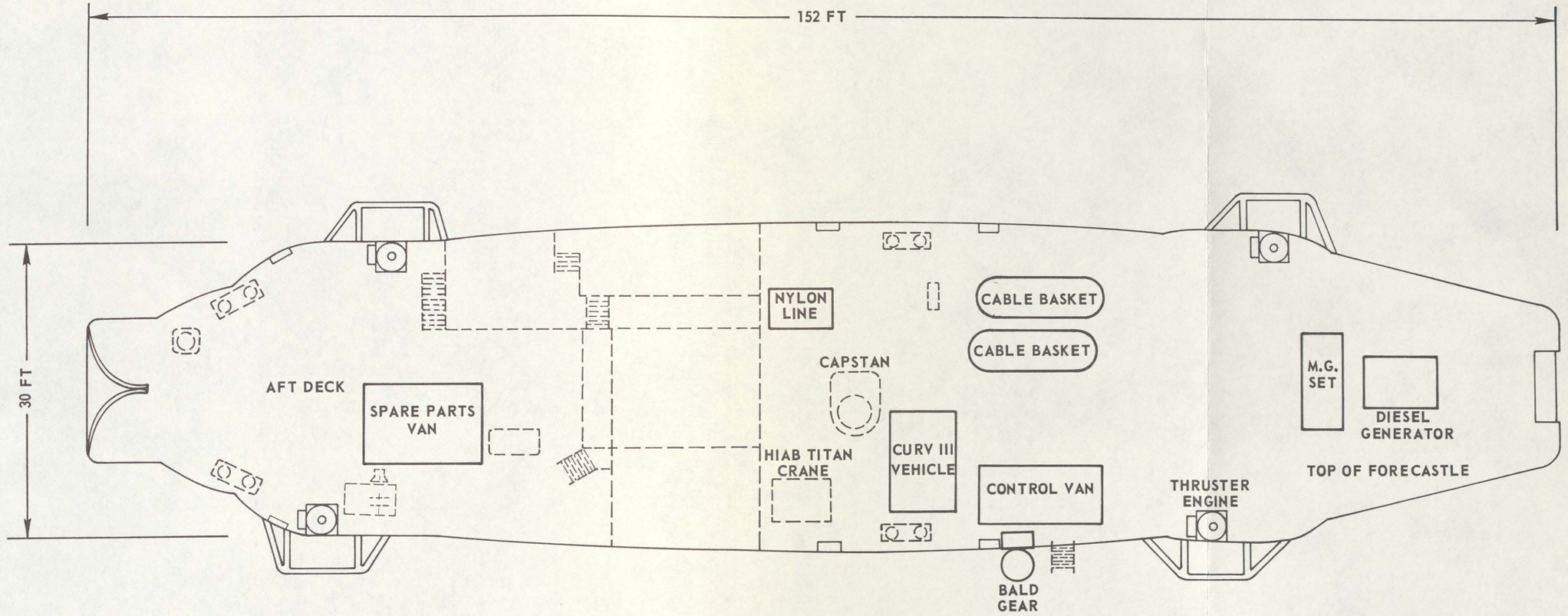


FIG. 10-6. CURV IIIC NAUBUC Layout for AFAR

cables on dive No. 31 and its cable was chafed, a light reflector was torn away and the Automatic Direction Finder of the SAR package was torn off. There were also some component failures such as blown fuze due to improper connection to the ships gyro, altimeter power supply failure, TV camera failure, and an electrical system failure, which was dramatically manifested when the operator turned on the 35 mm camera and a pyronol cable cutting torch in the vehicles claw ignited instead. The problem was traced to flooding of the control van junction box by a faulty air conditioner drip pan (possibly due to damage en route). Most repairs were made at sea; however, the flooding of the junction box forced cancellation of any operations because it was necessary to remove CURV IIIC to make the junction box repairs while the NAUBUC completed the BRAVO Buoy installation. This caused another problem: the CURV 100 kW generator could not be removed from the NAUBUC since it was to be used to operate the NAUBUC cable machine. A 35 kW generator that was obtained for the CURV IIIC shore power supply during repair arrived from Lajes AFB with no battery acid or fuel, so checkout had to wait until the NAUBUC return and repair had to be conducted in a hotel room.

10.2.3.2 UNDERWATER WORK — The AFAR operation required implementation of several new skills for CURV vehicles, including the development of both tools and the operational techniques required to utilize them effectively.

a. Pyronol Torch Cable Cutter — A custom adapter and igniter controls were devised to enable CURV IIIC to carry two 1,200 gram pyronol torches on its tool arm. The technique for attaching the torches to the cable was worked out at NUC ranges. This system (Fig. 10-7) proved successful in severing the single- and double-armored AFAR cables, which were up to 1 inch in diameter, although the hardware was modified on-site at AFAR to handle four pyronol torches to ensure completion of a cut in a single dive. The pyronol torch tool provided an unexpected benefit on dive No. 31, when the vehicle was able to free itself from a 3/8 inch wire rope by cutting the rope.

b. Cable Grabber — A special small diameter hydraulic claw assembly was developed to attach to the underwater AFAR cables. Like the regular claw, it was ejectible and was fitted with a separate recovery line that led either to a buoy or surface lift ship.

c. Shackle Adapter — A special arm was fabricated to attach the SUPSALV developed shackle to the Echo Tower lift eye, then release it. This enabled CURV IIIC to assist the lift ship in rigging Echo Tower for lift, the principal CURV IIIC achievement of the AFAR operations.

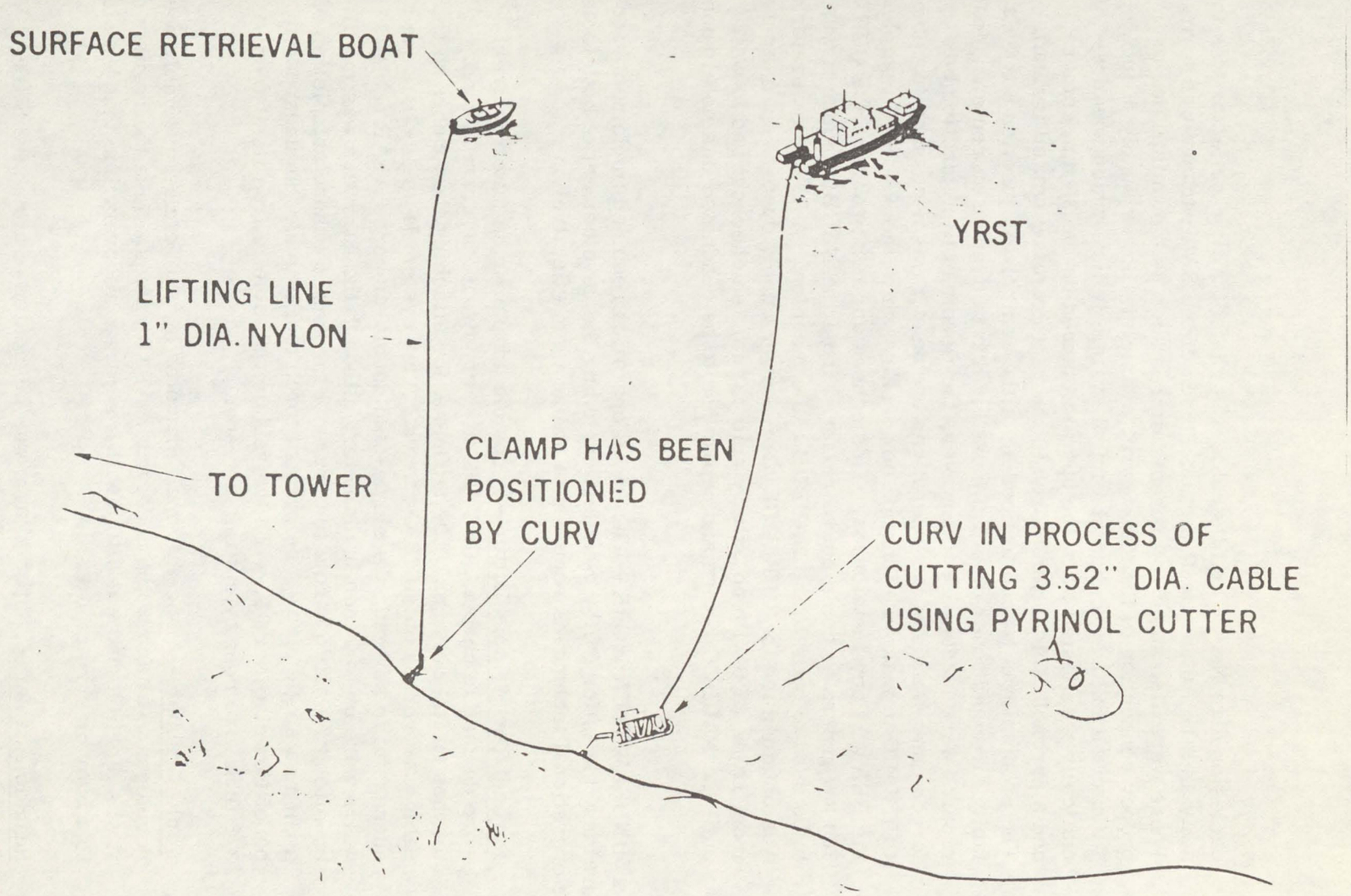


FIG. 10-7. AFAR Cable Cutting and Retrieval.

10.2.3.3 COORDINATED OPERATIONS WITH SURFACE VESSELS — CURV IIIC demonstrated several significant advances in combined activity of underwater and surface work systems including:

a. Rigging of Echo Tower with lines from the French lift ship TEREBEL using the SUPSALV shackle.

b. Retrieval of November Tower cable, survey of cable site and monitoring activities of French cable layer MARCEL BAYARD.

c. Use of a small boat from the USS KIOWA to tend the nylon recovery line carried by CURV IIIC and attached to the BRAVO Buoy cable.

10.3 OTHER OPERATIONS

Since the AFAR operations, CURV IIIA has conducted several operations from the YFNX-30 (see Table 10-1, dives Nos. 51 through 71) including more NCEL SEACON work, participation in NUC's Ocean Engineering Demonstration at SCI and recovery of a UQC. Through December 1971, 69 dives and 230 hours of water time had been logged.

10.4 SYSTEM MODIFICATIONS

Since CURV III became operational, several modifications have been made to improve capabilities or resolve problems. The major changes are:

a. Increase in active sonar range from 300 feet to 800 yards, accomplished by change in transmission frequency from 485-455 kHz to 87-72 kHz.

b. Addition of interrogatable transponder to 800 yards through the use of a Staza 7030B transponder.

c. Elimination of 9 kHz capability from passive sonar marker to allow for transponder mode.

d. Replacement of NUC pressure-balanced main and whip connectors by molded connectors to eliminate conductor breakage due to flexing.

e. Transfer of the strobe electronics from the pan-and-tilt unit to eliminate wear and malfunctions.

f. Replacement of NUC pressure-balanced connectors with Branter pressure-balanced connectors, which offer quicker assembly connection and disconnection and equal reliability.

10.5 CONCLUSIONS

The CURV IIIC vehicle has performed successfully near its design depth in operations comparable to those accomplished by previous CURV vehicles and, in the AFAR operation, successfully completed tasks more complex than those undertaken by previous CURV vehicles. System modifications have made the CURV IIIC system more safe, reliable, and effective than CURV IIIA or B, and it is concluded that the qualities demonstrated by CURV IIIB in the NASA operation, where not improved, are possessed by CURV IIIC; and further, that the NASA and AFAR operation constitute valid technical and operational evaluations for a laboratory-operated engineering prototype system.

It is therefore concluded that the development phase of the CURV III project has been successfully completed. In the following sections the CURV III system and its potential are assessed to indicate possible avenues to more widespread use of its unique capabilities.

SECTION 11

CURV III SYSTEM ASSESSMENT

Page

11-3

11-6
11-8

Section 11

TABLE OF CONTENTS

Section	Title	Page
11.1	Operational Capabilities	11-1
11.1.1	Operations Summary	11-1
11.1.2	Vehicle Underwater Performance	11-1
11.1.3	System Performance With YFNX-30	11-5
11.1.4	System Performance Off Other Ships	11-7

LIST OF FIGURES AND TABLES

Table	Title	Page
11-1	CURV IIIB Operations	11-3
11-2	List of CURV III Work Capabilities as Demonstrated in Actual Operations by Various CURV Systems	11-6
11-3	Scope of Sample Portable Operation	11-8

Section 11

CURV III SYSTEM ASSESSMENT

This assessment of the CURV III system is made using data from CURV IIIA, B, and C vehicle operations. Successful development and implementation of the various equipments and procedures described in Section 9 for safe operation from vessels of opportunity is assumed.

11.1 OPERATIONAL CAPABILITIES

The CURV III system in its first two configurations, CURV IIIA and IIIB, conducted over 10 days of operations, 30 days of testing and logged over 150 hours of in-water time. Of this, 10 days of operations, 10 days of testing, and 70 hours of water time were with the CURV IIIB vehicle that was lost, i.e., the same basic configuration as the CURV IIIC using solid syntactic foam floats and structural aluminum frame.

11.1.1 OPERATIONS SUMMARY — The operations have included recovery of an ordnance item, a DART rocket, and the NASA pod. Bottom surveys and equipment inspections have made up the remainder of CURV III operations. The CURV IIIA and CURV IIIC operations were given in Tables 6-3 and 10-1, respectively. CURV IIIB operations are detailed in Table 11-1.

11.1.2 VEHICLE UNDERWATER PERFORMANCE — CURV IIIB vehicle underwater performance, i.e., exclusive of support vessel considerations, met all design requirements. The vehicle was operated to 5,850 feet and 5,088 feet and tested to 6,500 feet. It has recovered pinger equipped targets and located successfully in a limited area the NASA pod which had no pinger. CURV IIIC Azores operations were successfully conducted to 2,500-foot depths and encompassed the most complex tasks an unmanned vehicle has undertaken.

The vehicle has an estimated underwater speed of 4 knots maximum and has operated in bottom currents estimated at 1/2 knot (in the NASA operation). Maneuverability at the target site within the range of the buoyed cable whip has been comparable to CURV I and II with no appreciable effects due to the length of cable deployed, other than those attributable to support vessel station-keeping and maneuvering difficulties.

TABLE 11-1. CURV IIIB Operations

Date	Dive No.	Purpose	Location	Depth (ft)	Sea State	Water Time (hrs:min)	Water Time Total to Date (hrs:min)	Results
Jan 1970	1	Vehicle Test	Catalina Channel	500	1	1:10	1:10	Hydraulic Penetrator Short
30 Jan 1970	2	Ordnance Recovery Attempt	Catalina Channel	1,700	1	4:55	6:05	Vehicle Pinger Wiped Out Target Pinger. Cable Caught in Screw, No Damage
3 Feb 1970	3	Ordnance Recovery Attempt		1,290	1	1:25	7:30	Main Cable Connector Leaked
6 Feb 1970	4	System Test	Catalina Channel	3,000	1	3:55	11:25	UNLOC (Navigation) Inoperative, Rest OK
13 Feb 1970	5	System Test		4,000	1	4:50	16:15	UNLOC (Navigation) Inoperative
17 Feb 1960	6	System Test		6,000	1	5:20	21:35	UNLOC (Navigation) Inoperative
26 Feb 1970	7	UNLOC Test		4,000	1	4:45	26:20	UNLOC Unsatisfactory
4 Mar 1970	8	Ordnance Recovery		1,200	1	3:10	29:30	Successful Recovery
17 Mar 1970	9	NASA SALVOPS Training	Atlantic E. of Norfolk	810	2	4:00	33:30	USS OPPORTUNE Station-Keeping Good
17 Mar 1970 to 18 Mar 1970	10	Search for NASA Package	Atlantic E. of Norfolk	5,800	3	21:00	54:30	Six Search Patterns — No Unit
21 Mar 1970	11	Search/Recovery NASA	Atlantic E. of Norfolk	5,850	4 and 5	21:00	75:30	Unit Recovered
20 Apr 1970	12	Demonstration	San Diego	600	1	0:40	76:10	Completed
22 Apr 1970	13 and 14	Inspect DSRV UQC	San Clemente Island	2,000	1	3:35	79:45	Sonar Sweep, Right TV Erratic
27 May 1970	15	Demonstration	Long Beach	1,200	1	1:05	80:50	Completed
25 Jun 1960	16	Gather Sea Urchins	Catalina Channel	750	1	2:30	83:20	Successful
6 Jul 1970 to 7 Jul 1970	17 and 18	Checkout Spare Cable	Catalina/SCI	2,900/ 4,000	1	8:20	91:40	Hydraulic Malfunction at Depth
8 Jul 1970	19	Gather Sea Urchins	SCI	600	1	2:10	94:00	Successful
8 Jul 1970	20	Inspect Sunken Submarine	SCI	180	1	1:30	95:30	Collision with Submarine; Minor Damage
9 Jul 1970	21	Demonstration	SCI	650	1	1:15	96:45	Complete
9 Jul 1970	22	Cable Test	SCI	6,600	1	5:40	102:25	Cable Load Test Successful, Hydraulics Sluggish at Depths
14 Jul 1970 to 28 Aug 1970	23 thru 30	Hydraulic Tests	SCI	3,000	1	23:10	125:35	Sluggish at Depths. Fixed after Valve and Manifold Overhauls
2 Sep 1970 to 3 Sep 1970	31 and 32	Ordnance Recovery	Long Beach	4,500	1	11:30	137:05	Successful
4 Oct 1970	33	Search for Ocean Instruments	W. of Washington State	?	5	?	?	Vehicle Lost During Retrieval in Storm

The versatility of methods of recovery is also equal to CURV I or II, the recoveries to date having been made by carrying the payload of less than 400 pounds to the surface. The "third line technique" for recovery of heavier objects (carrying down a separate recovery line to attach to the object for surface ship retrieval) was rigged on the University of Washington operation and the third line did not prove hindrance to operations. The recovery tools have been modified and interchanged for the various recoveries. The cable-cutting and tower inspection and rigging operations by CURV IIIC evidenced capabilities never attained by other CURV vehicles.

In summary, CURV III vehicle performance at 7,000-foot depths has been comparable in control, maneuvering and on-bottom time with CURV I and CURV II operations at 2,500-feet, which fulfills the basic development goal for CURV III.

A list of CURV I and CURV II operations is included in Appendixes C and D. Taking the operations CURV III vehicles have already performed successfully and assuming operations similar to those conducted by other NUC CURV vehicles can be conducted by CURV IIIC, a sizable variety of operations can be considered feasible for CURV III, as shown in Table 11-2.

11.1.3 SYSTEM PERFORMANCE WITH YFNX-30 — The CURV III system operated from the YFNX-30 has been proven effective in a sea state 2 and is considered effective in a sea state 3. In a sea state 4 operations can be conducted but are not recommended as they are limited by the necessity to head the vessel into the wind.

System deployment and retrieval rates to 6,000-foot depths can be expected to average 1.5 hours and 2.5 hours, respectively. On-site YFNX-30 endurance is effectively 2 weeks of round-the-clock operations, 30 days of normal work.

The scope of a 6,000-foot, normal operation at NUC ranges is as follows:

6 man CURV crew, 13 man vessel crew

1 day to prepare normal equipment

"X" days to prepare special equipment (usually concurrent with other preparations)

1 day to 6,000 foot site from San Diego

TABLE 11-2 List of CURV III Work Capabilities as Demonstrated in Actual Operations by Various CURV Systems

	CURV I	CURV II	CURV III
Small Object Recovery (< 200 lbs)	•	•	•
Small Object Recovery (200-400 lbs)	•	•	•
Attach Lines for Surface Lift	•	•	•
Bottom Survey	•	•	•
Underwater Equipment Inspection	•	•	•
Collect Rock Samples	•		
Collect Fauna Samples	•	•	•
Cooperative Target Location	•	•	•
Uncooperative Bottom Search (1 sq mi)		•	•
Combined Ops with Manned Submissile	•		
Test Frame for U/W Equipment	•	•	•
Monitor Drilling	•	•	
Inspect and Document Sunken Vessels		•	
Monitor Equipment Implantment		•	•
Monitor Cable Laying		•	•
Inspect and Document Cable Route		•	•
Combined Ops with Surface Work Ship	•	•	•
Work Amid Vertical Risers	•	•	•
Rig Underwater Equipment			•
Cut Cable Underwater		•	•
Retrieve Cable			•
Test Sediment Hardness	•	•	
Inspect and Document Biological Subjects	•	•	

1/2 day retrieval, securing CURV system

1 day transit to San Diego

1 day maintenance and repair

Total 5 days + X days special preparation + 1-20 days work

6 civilians, 13 Navy

This type of operation could be performed within an 80-mile radius of San Diego. Longer transit time would be required for areas beyond this. Transit would normally not be considered beyond a 250 mile range, instead the portable portion CURV III system would be flown or trucked for use on another vessel or tow of the system would be accomplished.

11.1.4 SYSTEM PERFORMANCE OFF OTHER SHIPS — CURV I was operated off the YTM-759 for NUC operations and from USS PETREL (ASR 14) in the H bomb recovery operation in April 1966. CURV II has been operated from the YTM-759, YFNX-30, YFU-44 (NUC acoustic range boat) and the USS PRESERVER (ARS). CURV III has been operated off the YFNX-30, USS OPPORTUNE (ARS-41), and USC GSS FAIRWEATHER (MSS-20). In addition, a study (Ref. 10) was performed for NAVSHIPS after the CURV III NASA operation on the feasibility of operating from five vessels: ARS type, ASR type, Oil Work Boat of the SEARCH-TIDE-type, the USS NAUBUC (YRST) and ATF-type.

All of the vessels studied or operated from were found capable of supporting CURV III operations. All were sufficient regarding deck-space, ability to provide or have installed appropriate equipment, and ability to provide or arrange living quarters. There was variance in the amount of CURV equipment required, types of station-keeping available and length of operating time expected, all of which would vary with specific missions. Because of the variables and changes in support equipment and procedures in development as a result of the CURV III loss, no attempt has been made to catalogue the capabilities of various support vessels.

It can be said, however, that with a week's preparation time any of the aforementioned vessels could be utilized for routine CURV recovery operations.

Based on NASA and other portable operations, a typical operation with round-the-clock work days for the vessels described would be as given in Table 11-3.

TABLE 11-3. Scope of Sample Portable Operation

12 man CURV crew

1/2 day offloading and packing

"X" day special equipment fabrication/modification

1/2 day truck loading and truck transport to airport

1/2 day air loading, transport

1/2 day truck loading transport to site

1 day installation on vessel (2 days preparation concurrent with transport)

1/2 day steering to site

"X" days work at-site

1/2 day return to port

1 day removal of equipment

1/2 day truck loading and transport

1/2 day air loading and transport

1/2 day truck loading and transport to NUC

1 day unpacking

2 days (minimum) maintenance, repair

2 day installation on YFNX-30

2 days system checkout and tests

---

14 days + "X" days preparation of special equipment + "X" days of operations
12 man CURV crew + 6 vessel crewmen

The sample operation used is an air-transport to the East Coast. Other alternatives are possible. For example, for the University of Washington operations, the equipment was trucked to Washington, a process which required 5 days from go-ahead to unloading.

This type of operation with appropriate adjustments in transport and preparation time could be performed from any Naval Base in the world with nearby landing field to accommodate C-141 transports.

SECTION 12

CURV III SYSTEM POTENTIAL

Section 12

TABLE OF CONTENTS

Section	Title	Page
12.1	System/Fleet Capabilities	12-1
12.1.1	Maintenance and Reliability	12-1
12.1.2	Ruggedization of Components	12-2
12.1.3	Documentation	12-2
12.1.4	Conclusion	12-2
12.2	System Potential	12-2
12.2.1	Extending the Depth Capability	12-3
12.2.2	Improving Work Capability	12-3
12.3	Improving Operational Efficiency	12-4
12.4	Conclusion on Potential	12-5

Section 12

CURV III SYSTEM POTENTIAL

12.1 SYSTEM/FLEET CAPABILITIES

The capability to operate off various types of ships suggests the possibility of improving the CURV III systems for the fleet.

It is beyond the scope of this report to investigate the advisibility, design, operational need, unit cost, and various fleet interfaces of such a fleet CURV. This would more properly be done in a feasibility study which NUC could undertake with appropriate funding. It can be demonstrated here, however, that such a fleet CURV is possible and an indication can be given of what areas would require the major effort.

Assuming that duplication of the present system for similar recovery type operations would be the goal of a fleet CURV development, the most pressing areas would be improvements in system maintenance and reliability, ruggedization of some components, and preparation of production documentation.

12.1.1 MAINTENANCE AND RELIABILITY — The CURV system maintenance is presently conducted on-shore by three specialists — one electronic technician, one mechanical technician, and one sonar technician, who also serve a part of the operating crew and can make emergency repair at sea. Complete at-sea maintenance by a single technician could be realized through modest modularization of the sonar and vehicle electronics. It is felt this would be necessary to make the placement of a CURV on a fleet vessel cost-effective by reducing the shipboard complement of full time CURV personnel to two — an operator and technician. The rest of the CURV personnel would be drawn as needed from the vessel crew.

CURV III reliability has been greatly improved by the development of pressure-balanced small connectors and lights. No operations since CURV IIIA have been interrupted yet for component failure. With the maintenance modularization explained above, reliability would not be a problem for fleet use.

12.1.2 RUGGEDIZATION OF COMPONENTS — The CURV III design at present assumes handling by experienced crew and continual maintenance. If CURV III were to be permanently placed on a vessel with other primary tasks, for a considerable portion of the time, it could be inactive with resultant deterioration and/or changes of cognizant personnel. On the other hand, a Fleet CURV III might also be in constant use for long periods with little time for maintenance and/or minor repairs. In either event, some ruggedization and/or relocation of components would be advisable. The lights perhaps should be brought within protective perimeter of the vehicle, the frame, and the components guards, strengthened, and additional handling lift points, eyes, etc., added. A self-contained weathertight vehicle/spares/tools storage van might also be considered. A corrosion study was conducted of CURV III underwater components which indicates that some materials might be changed to extend the life and reduce maintenance of components.

12.1.3 DOCUMENTATION — Present CURV III documentation consists of a full set of as-built drawings which are listed in Appendix A. These drawings, when combined with the experience and records of NUC, are sufficient to procure another identical CURV IIIC system in the event of a loss. The present documentation, however, is after-the-fact documentation of a prototype system still in development and does not have consistent safety factors, acceptance test requirements, fabrication and assembly procedures, adherence to military standards and specifications, and other factors necessary to insure the production of working CURV III systems by another Navy agency or outside contractor. A complete procurement/fabrication specification and drawing package would have to be prepared. In addition, the manuals, procedures, and other system documentation are at present adequate only for use by the developing agency and would require further work to be suitable to accompany a production model.

12.1.4 CONCLUSION — It is felt a Fleet CURV III is conceivable with the present configuration; however, first a thorough study should be made of the feasibility, desirability, and recommended system changes for a fleet system.

12.2 SYSTEM POTENTIAL

The potential for expansion of CURV III capabilities has been investigated as a regular feature throughout the CURV III development program. In some cases the investigations were to define the capabilities of existing components beyond CURV III requirements; in others it was to develop full capability while replacing inadequate CURV I components; in still others, it was purely investigating the possibility of adding a capability to CURV III.

These investigations fall into three general groups: extending the depth capability, improving work capability, and improving operational efficiency.

12.2.1 EXTENDING THE DEPTH CAPABILITY — A study was conducted during CURV III development that indicated the limit of a CURV III system using modest component redesigns and existing technology was 10,000 feet. The significant criteria were degradation of the television and control signals with the present electronics and cable concepts and the margin of safety on the major housings (some of the small housings would have to be replaced to attain 10,000 feet).

Another investigation into increased depth capabilities included testing of various electronic components and immersion fluids preparatory to designing pressurized electronics and hydraulic valves. This investigation proved the feasibility of this concept which would eliminate the large spherical housing; but did not develop a pressurized electronic/hydraulic package.

Investigation was also made of the various long line transmission problems involved with cables over 8,000 feet long and various means of reducing the size of the cable and the transmission load. A design for a multiplex control system was made but was not implemented due to other development considerations. Various television techniques to reduce the bandwidth required by the present system were also investigated.

12.2.2 IMPROVING WORK CAPABILITY — Various concepts for enhancing CURV work capabilities were investigated.

12.2.2.1 SENSORS — The feasibility of several sensor improvements have been studied including dual television, 3-D television, color television, head-coupled television control, movie cameras, slow scan acoustic link television. Of these, the dual television head-coupled TV and movie camera concepts have reached CURV hardware stages, while the others were operated on small test bed vehicles.

12.2.2.2 CONTROL AND PROPULSION — Various control and propulsion techniques have also been examined by test bed vehicles. A small hydraulically propelled water jet vehicle with trainable nozzles and joystick control operated successfully.

A full scale vehicle nicknamed Kluge I was built on the old CURV I frame, to test the concept of powering CURV screws with hydraulic motors. The use of a single

large 30 hp electric motor to run the pump represented a large saving in power conductors in the cable over the three 10 hp electric motors presently used in CURV IIIC.

The hydraulic motors also utilized the power provided more efficiently, were smaller and enabled finer control. Kluge I operated successfully to 1,000 foot depths, although it was acoustically noisy. Acoustic tests showed the noise level was marginal as to affecting CURV III sonar, so further development would be required to reduce the noise.

12.2.2.3 MANIPULATOR/TOOLS — The Kluge I experiment was pursued in part to determine if the single large power source used for propulsion could be converted to power to drive tools once on the work site. At the same time, various type of tools including drill, cable cutter, saw and power conversion gear were being tested. A manipulator was designed for testing CURV II and built. Although prohibitively heavy for normal operations at its completion, the feasibility of a manipulator was demonstrated.

12.3 IMPROVING OPERATIONAL EFFICIENCY

The primary effort in this area was developing a bottom navigation concept. Various available concepts were investigated including deployable bottom transponder systems, ship-mounted transponders, bottom reference beacon systems, and Doppler systems. The system chosen for development was the ship-mounted transponder system. Three types of ship-mounted systems were pertinent to the CURV III needs — the pulse position measurement system (PPM), pulse position measurement system with lane count (PPM-H), and phase comparison technique (PCT). Existing hardware for the PPM and PPM-H was expensive and required mounting over 30-foot intervals on the support vessel. The PCT system was chosen for development as it was contained in a single quartered hydrophone, was the most accurate and prototype underwater components were available through the Navy. The comparison of the various systems is detailed in Ref. 12. The PCT concept was developed by NUC to the point where it was shown feasible for CURV III operations, when the development of prototype hardware was taken over by the manufacturer of the torpedo guidance units. The capabilities of the NUC system are described in Ref. 13. A future development task to realize the potential of the CURV III system would be to integrate such a navigation system into the CURV III operational components.

12.4 CONCLUSION ON POTENTIAL

CURV III has proved its ability to operate as required for deep recovery needs. Throughout the CURV III development program, the potential to expand capabilities has been demonstrated, even after the system had been developed to its design goals. The potential of CURV III at present is not limited except by the development goals, i.e., its full potential has not been attained. These goals were set to meet current needs. Whether further capabilities are needed currently or not, or if they are worth the expense of development has not been demonstrated. In this regard, however, the most important point to be made about system potential is the rapid development, versatility and ease of modification of an unmanned system as has already been proven in CURV III development. The CURV III vehicle concept has survived two catastrophic losses, because of its ability to withstand major component improvements or changes without affecting other components or necessitating entire system redesign. Once the limits of the existing designs become known and operational capabilities are defined, further modifications and developments can easily be backfitted into CURV systems, expanding capabilities to the limits of most operational requirements.

Its application to various range tasks, therefore, is not limited to present uses.

CURV III's contributions to further expanding underwater technology can also be significant. Because it is unmanned, it can safely serve as a test bed for concepts of new components or concepts for its own use as well as for other manned or unmanned systems under development.

SECTION 13

CURV III CONTRIBUTIONS TO OCEAN TECHNOLOGY

Section 13

TABLE OF CONTENTS

Section	Title	Page
13.1	Advances in States-Of-The-Art	13-1
13.2	Contributions to States-Of-The-Art	13-1
13.3	New Unmanned Submersible Applications	13-1
13.4	Enhancement of the Ocean Capabilities of Others	13-1

LIST OF FIGURES AND TABLES

Table	Title	Page
13-1	CURV III Contributions to Ocean Technology	13-2

Section 13

CURV III CONTRIBUTIONS TO OCEAN TECHNOLOGY

The CURV III system development has contributed to ocean technology in advances in states-of-the-art, contributions to state-of-the-art, new unmanned submersible applications and enhancement of ocean capabilities.

13.1 ADVANCES IN STATES-OF-THE-ART

CURV III has advanced states-of-the-art in ocean engineering through the development of hardware items in functions or applications for which hardware had not previously been successfully operated. These items are listed in part A of Table 13-1. The details of these items have been discussed in the pages of the text indicated in the table.

13.2 CONTRIBUTIONS TO STATES-OF-THE-ART

CURV III has added to the knowledge of hardware performance in deep ocean applications in many areas through testing, applied research, laboratory tests, and development of prototypes that did not become operational. These items and the page numbers in the text where they are discussed are given in Table 13-1, part B.

13.3 NEW UNMANNED SUBMERSIBLE APPLICATIONS

Many existing surface and underwater hardware devices and standard operations have proven difficult to apply to the deep submergence requirements of the CURV III missions, so their successful modification for employment in the CURV III system has provided definite breakthroughs in ocean technology. These items are listed in Table 13-1, part C.

13.4 ENHANCEMENT OF THE OCEAN CAPABILITIES OF OTHERS

In this category of contribution by the CURV III development to ocean technology are noted the indirect, but equally significant and important, benefits that the

TABLE 13-1. CURV III Contributions to Ocean Technology

Part A — Advances in States-of-the-Art		Page Number in Text
1.	Support vessel cycloidal propulsion	5-2, 5-5
2.	Solid syntactic foam buoyancy and cable float applications	7-1, 7-3
3.	8,000-foot underwater transmission of power, TV and control signals in maneuverable bundle	4-3, 12-3
4.	Large aluminum pressure sphere casting	6-6
5.	Pressure balanced lights	6-10
6.	Pressure balanced large and small connectors	6-15
7.	Ring-core flux gate magnetometer for underwater use	6-19
8.	Manipulator (unmanned)	12-4
Part B — Contributions to States-of-the-Art		
1.	Short baseline underwater navigation and location	12-4
2.	Glass ball cable float performance	4-3, 7-3
3.	Glass ball/syntactic foam module casting process	6-2
4.	20,000 foot power, TV, and control signal transmission	12-3
5.	Hydraulic propulsion systems concepts	12-3
6.	Ambient pressure solid state electronics testing	6-23, 12-3
7.	Hydraulic tool drive system concepts	12-4
Part C — New Unmanned Submersible Applications		
1.	7,000 foot operations	11-3
2.	Pyronol torch cable cutting tool	10-17
3.	Head-coupled TV controls	12-3
4.	8,000 foot nylon line cable support	6-25
5.	Traction winch handling system	3-1
6.	Underwater rigging capabilities	10-19

TABLE 13-2. CURV III Contributions to Ocean Technology (Continued)

Part C — New Unmanned Submersible Applications (Continued)	Page Number in Text
7. 72-hour quick response portability	8-1
8. Failure-activated SAR package	9-2
9. Uncooperative small object recovery	8-7
Part D — Enhancement of the Ocean Capabilities of Others (Indirect Benefits)	
1. Deep depth explorations, testing, and operations	13-4
2. More complex underwater work	13-4
3. Economy in underwater work	13-4
4. Safety in both hazardous and routine missions	13-4
5. Net effect is more ambitious, versatile, and progressive ocean technology program	13-4

existence of a deep underwater unmanned recovery and work system offers to progress in ocean development.

The most important factor is depth: the 7,000 foot capability of CURV III permits ocean science, ocean engineering, and weapon system projects to undertake exploration, developmental testing and operations in deep areas that were previously avoided, or in which the loss of important equipment or data, and the attendant schedule delays and increased costs were irremediable risks.

As the NASA and AFAR operations attest, the second CURV III indirect benefit is the ability to conduct more complex operations, involving a variety of underwater and surface equipments. The ability to conduct complicated emergency and repair tasks such as these suggests that more complicated, preplanned range tasks can also be successfully accomplished.

A third indirect benefit is the economy of operations that CURV III has demonstrated. Many underwater tasks that would not be attempted by previous methods can conceivably be within reason because CURV III can be adapted to a variety of tasks without major modifications, quickly transported to site, work off available vessels, endure long, continuous operations with maintenance and repair on-site, and work for reasonable daily rates with a modestly-sized support crew. By being an existing Navy in-house capability, it offers even greater advantages to Navy, DOD, and Government projects.

A fourth benefit is the ability to undertake hazardous missions, or participate at sea in normal missions without fear for human life in the event of underwater system failure. The advantages of this prospect in planning operations, making on-site tactical decisions, recovering from misfortune, and in expanding the frontier of ocean technology cannot be overemphasized.

The net effect of CURV III's indirect benefits as summarized in Table 13-1, part D, is to enable a more ambitious, versatile, and progressive technology to develop in ocean projects across the whole spectrum of their activities — from funding and planning, to learning from mistakes and recovering otherwise lost knowledge.

SECTION 14

CURV III DEVELOPMENT HISTORY AND COST

Section 14

LIST OF FIGURES AND TABLES

Table	Title	Page
14-1	CURV III Development History	14-3
14-2	CURV III Development Costs	14-5

Section 14

CURV III DEVELOPMENT HISTORY AND COSTS

A summary of the major CURV III milestones is given in Table 14-1.

A summary of costs for the CURV III program and three vehicle periods is given in Table 14-2. Because CURV III development was conducted concurrently and on the same NAVORD tasks (Refs. 3 and 4) with other CURV Program development and operations (which it both benefitted from and contributed to) an exact accounting of development manpower and hardware costs is not possible. Also, because the development included three major versions of the vehicle and other changes during the period FY 1967-FY 1971, the costs shown in Table 14-2 should not be interpreted as the cost to duplicate a CURV III System or to develop an improved version.

In particular, the hardware costs shown in Table 14-2 should not be considered a complete accounting of CURV III hardware, since the cost of hardware items fabricated by NUC in many cases cannot be separated from Civil Service labor and overhead categories. Examples of items of this type are: the control console, the vehicle frame, and the claw and tool drive assembly. Also, procurement and shop items less than $1,000 have not been considered. Further, because of the interchangeability of CURV System parts, common procurement and stores were maintained for many items.

TABLE 14-1. CURV III Development History

	1966	1967	1968	1969	1970	1971
JANUARY						
FEBRUARY			Aluminum Sphere Tests		CURV IIIB Shallow Ops at NUC	
MARCH					CURV IIIB NASA Ops	
APRIL	CURV I H-Bomb Recovery			YFNX-30 Checkout		CURV IIIC Operational
MAY				CURV III Dockside Checkout		
JUNE	CURV III Proposal			CURV IIIA At-Sea Checkout		AFAR Ops
JULY	First NAVORD CURV III Funding	First DOT CURV III Funding		CURV IIIA Frame Collapse	First SUPSALV CURV III Funding	
AUGUST				CURV IIIA Buoyancy/ Frame Failures		
SEPTEMBER	CURV III Concept	CURV I Retired	CURV II NTS Operational			
OCTOBER		NUC CURV II Operational		CURV IIIB Design	CURV IIIB Lost	
NOVEMBER						
DECEMBER	CURV III Plan				CURV IIIC Design	

TABLE 14-2. CURV III Development Costs

Item	CURV IIIA PERIOD				CURV IIIB PERIOD	CURV IIIC PERIOD	
	FY 1967	FY 1968	FY 1969	Subtotal	FY 1970	FY 1971	Total
Hardware							
Cables/Connectors	$ 50K	$ 30K	$ 60K	$ 140K	$ 10K	$ 15K	$ 165K
Electronics		15K	20K	35K	15K	10K	60K
TV & Optics		25K	10K	35K	15K	20K	70K
Propulsion Motors	20K	65K	10K	95K			95K
Buoyancy Units		10K	40K	50K	30K	30K	110K
Hydraulics	25K	15K	25K	65K	5K	5K	75K
SLAD	95K		30K	125K	5K	15K	145K
Frame and Mounts		40K	20K	60K	35K	25K	120K
Housings		25K	50K	75K		15K	90K
Compass		5K	10K	15K			15K
Console/Van		15K	10K	25K			25K
Power Equipment	10K	95K		105K	15K		120K
Handling Equipment		20K	20K	40K	20K	5K	65K
Support Vessel		300K	400K	700K	60K		760K
Navigation			75K	75K			75K
Miscellaneous		40K	120K	160K	20K	30K	210K
Subtotal	$200K	$ 700K	$ 900K	$1,800K	$230K	$170K	$2,200K
Services							
1. Engineering Contracts	80K	160K	400K	640K	210K	140K	990K
2. LBNS			40K	40K	35K	10K	85K
3. LBNSY			60K	60K	30K	10K	100K
4. Military					25K	10K	35K
NUC Civil Service	100K	160K	310K	570K	325K	340K	1,235K
Operations			40K	40K	75K	120K	235K
Total	$380K	$1,020K	$1,750K	$3,150K	$930K	$800K	$4,880K

SECTION 15

REFERENCES

ng

. J. Duran,

Section 15

REFERENCES

1. SOR 46-16 "Deep Submergence-Object Location and Small Object Recovery System (U)", OP-701E/56, Ser. 0228P70, 8 October 1964, CONFIDENTIAL.

2. NUC ltr, Ser. 4108 to CNM, "CURV with 7,000-foot Capability; proposal for ", 7 December 1966, UNCLASSIFIED.

3. NAVORDSYSCOM TASK ORD-030-206/200-1/F108-01-33, "Deep Recovery System (Unmanned)", 7 August 1966, UNCLASSIFIED.

4. NAVORDSYSCOM TASK ORD-03C-203/200-1/F108-01-36, "Deep Recovery System (Unmanned)", 15 August 1967, UNCLASSIFIED.

5. NUWC (NUC) TN 215 "Procedure for Manufacture of Buoyancy Modules for the Cable-controlled Unmanned Research Vehicle (CURV) Project 8-68," J.W. Taylor and H. Miller, November 1968, UNCLASSIFIED.

6. Ocean Design Engineering Corporation "Safety Program Study-Installation and Operations of the CURV SUPPORT Vessel (YFN-1186", NUC Contract N66001-69-C-1294, p-158, 3 July 1969, UNCLASSIFIED.

7. Long Beach Naval Shipyard, Code 2535c, YFNX-30 CURV Support Platform Calculated Motion Angle Curves", 15 July 1969, UNCLASSIFIED.

8. Tetra Tech Inc., "Review of CURV Support Platform Stability Calculation", No. TC-110, 6 November 1969, UNCLASSIFIED.

9. NCEL ltr Ser. 431, "Syntactic Foam Buoyancy Modules; pressure testing of", 2 March 1970, UNCLASSIFIED.

10. NUC "CURV III Loss; Informal Investigation; report of" CW0-2 J. J. Duran, USN (Code 8021), 28 October 1970, UNCLASSIFIED.

11. NUC TN 391 "Study of Proposed Adaption of the CURV III System to Various Ships", R.E. Pace and S.O. Stimson, Code 2531, June 1970, UNCLASSIFIED.

12. NUC TN 385 "Study of Underwater Navigation and Locating (UNLOC) Systems" L.T. Campbell, Code 25314, June 1970, UNCLASSIFIED.

13. NUC TN 462 "Description and Operating Instructions for the Underwater Navigation and Locating (UNLOC) System", L.T. Campbell, Code 25314, November 1970, UNCLASSIFIED.

APPENDIX A

CURV III DRAWING LIST

Appendix A

TABLE OF CONTENTS

A-1.	Frame	A-2
A-2.	Buoyancy	A-2
A-3.	Claw	A-2
A-4.	Electronic Housing	A-4
A-5.	Electronics	A-5
A-6.	Sonar	A-6
A-7.	Depthometer	A-6
A-8.	Altimeter	A-7
A-9.	Compass	A-7
A-10.	Propulsion	A-8
A-11.	Pan and Tilt	A-8
A-12.	Optics (None)	A-9
A-13.	Lights	A-9
A-14.	Main Connector	A-9
A-15.	Small Cables	A-10
A-16.	Hydraulic Tests	A-10
A-17.	Hydraulic System	A-11
A-18.	Main Cable Assembly	A-11
A-19.	Whip Cable Assembly	A-12
A-20.	Clump Assembly	A-12
A-21.	Miscellaneous	A-13
A-22.	Control Console	A-13
A-23.	Van	A-13
A-24.	Vehicle Handling Dequipment	A-14

Appendix A

CURV III DRAWING LIST

A—1 FRAME

Dwg. Number	Description	No. of Shts.
SK690590	CURV IIIB—Cable Float	
SK690726	Lifting Assembly	2
SK690919	Cable Way	
SK690924	Frame	
SK697637	Frame—Weld Assembly—Isometric	1
SK697667	Guard Rails	6
SK690925	Frame—Construction	4
LAYOUTS	SS10269 -1, -2, -4, -17, -18, -19	6

A—2 BUOYANCY

SK690590	Cable Floats	1
SK690918	Buoyancy Block Assembly	5
LAYOUTS	SS10269-7, -11, -14	3

A—3 CLAW

SK673144	Plate—Quick Disconnect Hyd. Lines	1
SK673145	Clamp—Quick Disconnect	1
SK673146	Mount—Plate	1
SK673159	Channel—Housing Weld Assembly—Tool Drive	1
SK673160	Slug—Boss Pivot Tool Drive	1
SK673163	Bearing—Torque Tube Tool Drive	
SK673164	Washer—Torque Tube Tool Drive	
SK673167	Pad—Tool Drive	1
SK673168	Plate Spacer—Tool Drive	1
SK673169	Bracket—Pivot Hydrualic Cylinder Aft Tool Drive	1
SK673173	Claw Inner Half	1
SK673174	Claw Outer Half	1
SK673175	Claw Arm Detail	1
SK673178	Claw—Fork Finished Machined	1
SK673179	Claw—Fork Weld Assembly	1
SK673180	Claw—Key	1

Dwg. Number	Description	No. of Shts.
SK673181	Washer—Thrust	1
SK673182	Bushing—Bearing	1
SK673183	Plate—Clamp	1
SK673184	Pad—Claw	1
SK673185	Pin—Pivot	1
SK673187	Pin—Lift—Claw	1
SK673188	Spacer—Lift	1
SK673189	Spacer—Lift—Pin	1
SK673190	Claw—Cable—Lift Link	1
SK673191	Hydraulic Cylinder Pivot Pin	1
SK673192	Cylinder Pivot Spacer	1
SK673193	Spacer—Pivot	1
SK673194	Washer—Bearing	1
SK673195	Spacer—Pivot	1
SK673202	Shaft Pivot—Tool Drive Installation	1
SK673203	Bushing—Bearing	1
SK673204	Washer—Pivot	1
SK673205	Pin—Pivot	1
SK673297	Bracket—Mounting Pivot Hydraulic Cylinder	1
SK673298	Bracket—Rod End Pivot	1
SK673356	Tube—Bearing Assembly Torque—Tool Drive	1
SK673357	Tube—Housing Torque Bearing—Tool Drive	1
SK673358	Tube—Bearing Torque—Tool Drive	1
SK673360	Bracket — Pivot and Housing Torque Drive	1
SK673361	Clamp—Locking "C" Clamp	1
SK673362	Screw—Shoulder, Pivot Pin	1
SK673363	Bearing	1
SK673364	Washer—Bearing	1
SK673365	Shaft	1
SK673366	Plate—Slide	1
SK673367	Pin—Eject	1
SK673368	Plate—Mounting Hydraulic Cylinder	1
SK673369	Washer—Shear Pin	1
SK673370	Pin—Shear	1
SK673371	Shaft—Drive—Lock and Release Tool	1
SK690940	Claw and Tool Drive Assembly	1
SK690941	Shaft—Radial Drive	1
SK690942	Claw Shaft Torque Assembly	1

A—3 CLAW (Cont'd)

Dwg. Number	Description	No. of Shts.
SK697441	Stud	1
SK697442	Bracket—Pivot	1
LAYOUTS	SS10269-3	1

A—4 ELECTRONIC HOUSING

SK673116	Box—Chassis, Assembly, Power Supply Still Camera Electronic Package Sphere	1
SK673117	Plate—Mounting, Box, Power Supply Still Camera Electronic Package Sphere	1
SK673118	Heat Sink—Box, Chassis, Power Supply, Still Camera Electronic Package—Sphere	1
SK673119	Channel—Box, Chassis, Power Supply, Still Camera Electronic Package—Sphere	1
SK673120	Cover—Box—Power Supply, Still Camera Electronic Package—Sphere	1
SK673121	Plate—Extension, Box, Power Supply, Still Camera Electronic Package—Sphere	1
SK673122	Schematic—Power Supply Still Camera Electronic Package—Sphere	1
SK673126	Bracket—Connector Mounting Electronic Package Sphere	1
SK673127	Handle—Lifting, Chassis Electronic Package Sphere	1
SK673128	Bar—Threaded, Lifting Handle Electronic Package Sphere	1
SK673135	Schematic—Power Supply, TV Camera Electronic Package Sphere	1
SK673215	Schematic Diagram Speaker Amplifier/Line Driver	1
SK674220	Electronic Housing Details	9
SK674389	"0" Ring Seals—Electronic Housing	1
SK674422	Electronic Housing Mounting Plate	7
SK677279	Qualification Test—Electronic Housing	1
SK677488	Handle—Electronic Housing Details and Installation	1

A—4 ELECTRONIC HSG. (Cont'd)

Dwg. Number	Description	No. of Shts.
SK677529	Mounting Bracket Hydraulic and Solenoid	1
SK677540	Relief Valve — Modified and Mounting Bracket	1
SK687063	Electronic Housing Transformer Assembly	1
SK687350	Leak Detector	1
SK690043	Sphere Modification	1
SK690713	Hinge Block	1
SK690714	Sphere Penetration and Tygon Tubing Guard	2
SK690919	Cable Way Assembly	4
LAYOUTS	SS10269-20	1

A—5 ELECTRONICS

SK673103	Chassis—Assembly, Electronics—Sphere	1
SK673104	Box—Chassis, Assembly, Power Supply, TV Camera Electronic Package Sphere	1
SK673105	Plate—Mounting, Box—TV Power Electronic	1
SK673106	Plate—End, Box—TV Power Electronic Package Sphere	1
SK673107	Plate—Side, Box—TV Power Electronic Package Sphere	1
SK673108	Cover—Box—TV Power Supply Electronic Pkg—Sphere	1
SK673123	Plate—Relay Guard—Phenolic Electronic Package Sphere	1
SK673124	Plate—Relay Guard, Phenolic Electronic Package Sphere	1
SK673125	Plate—Relay Guard, Phenolic Electronic Package Sphere	1
SK673129	Screen—Vent Electronic Package—Sphere	1
SK673131	Stand—Off, Tube, Relay Guard Electronic Package Sphere	1
SK673132	Cover—Relay Protector—Lucite Electronic Package—Sphere	1
SK673133	Clip Angle—Relay Protector Cover Electronic Package—Sphere	1
SK673375	Plate—Mount, Relay Electronic Package—Sphere	1

A—5 ELECTRONICS (Cont'd)

Dwg. Number	Description	No. of Shts.
SK673376	Plate Mount, Relay Electronic Package Sphere	1
SK673377	Plate Mount, Fuse Electronic Package Sphere	1
SK673378	Pad—Neoprene, Relay Mount Electronic Package Sphere	1
SK673379	Pad—Neoprene, Relay Mount Electronic Package Sphere	1
SK673381	Stand—Off, Hex Bar Electronic Package—Sphere	6
SK673383	Diagram—Schematic Main Power Package	1
SK687063	Transformer Assembly	14
SK687270	Electronics System	1
SK687906	Marotta Valve Fixture	1
SK687993	Pressure Balanced Electric Conductor Details	1
SK690110	Installation of Fusite Terminals	1
SK690313	Penetration Plates and Housings	12
SK690314	Pressure Balanced Electronic System	1

A—6 SONAR

SK673210	Submersible—Elect. Container Sonar Package	1
SK677678	Pinger Transducer 3 kHz and Installation	1
SK687463	Sonar Electronics Package Mounting Details Sheets 2, 4, 5, and 6	4
SK690313	Pressure Balance Electronic System Details	8
SK690591	Sonar Assembly	7
SK690738	Sonar Penetration and Tygon Tubing Guard	3
SK690916	Sonar Electronics Package Mountings	1
SK697791	Sonar Electronic Assembly	1
SK697796	Base—Sonar Mounting	1
LAYOUTS	SS10269-8 and 13	2

A—7 DEPTHOMETER

SK678478	Altimeter and Pressure Depth Transducer Installation	1

A—7 DEPTHOMETER (Cont'd)

Dwg. Number	Description	No. of Shts.
SK687758	Altimeter and Pressure Depth Transducer Installation	1
SK690313	Pressure Balanced Electronic System Details	10

A—8 ALTIMETER

SK687478	Altimeter and Pressure Depth Transducer Installation	1
SK690917	Altimeter and Pressure Depth Transducer Installation	1
LAYOUT	SS10269-16	1

A—9 COMPASS

PL1210326	Housing Upper	1
PL1210327	Housing Lower	1
PL1210328	Support Compass	1
PL1210329	Support Gimbal	1
PL1210374	Insulator	1
PL1330604	Parts List	3
PL1330604	Compass Assembly	2
PL1330605	Transducer Assembly	1
PL1330681	Pressure Balanced Housing	1
PL1330682	Housing Upper	1
PL1559814	Plug Oil	1
PL1559815	Gimbal	1
PL1559816	Screw Modified	1
SK673109	Box—Chassis, Assembly, Compass Amplifier Supply Electronic Package—Sphere	1
SK673110	Plate—Mounting, Box, Compass Amplifier Electronic Package—Sphere	1
SK673111	Channel, Aft—Box, Chassis Compass Amplifier Supply Electronic Package—Sphere	1
SK673112	Channel, Fwd—Box, Chassis Compass Amplifier Supply Electronic Package—Sphere	1

A—9 COMPASS (Cont'd)

Dwg. Number	Description	No. of Shts.
SK673113	Cover—Box—Compass Amplifier Supply Electronic Package—Sphere	1
SK673114	Tube—Stand—Off, Connector Mounting, Compass Amplifier Supply—Electronic Package—Sphere	1
SK673115	Bracket—Potentiometer Mounting, Compass Amplifier Supply—Electronic Package Sphere	1
SK673130	Rod—Threaded, Clamp, Compass Amplifier Electronic Package—Sphere	1
SK673397	Schematic—Power Supply Compass Line Amplifier	1
SK690755	Mounting Assembly—Compass Bracket	2
LAYOUTS	SS10269-9	1

A—10 PROPULSION

SK687459	Propulsion Unit—Envelope Dimensions	1
SK690671	Horizontal Motor Bracket Assembly	2
SK690672	Vertical Motor Bracket Assembly	4
LAYOUTS	SS10269-5 and 10	2

A—11 PAN AND TILT

SK668118	Bracket—"U" Mount	1
SK668119	Bracket—Still or Strobe Light	1
SK668120	Bracket—Mount—TV Camera	1
SK668121	Bracket—Weld Assembly	1
SK668122	Shaft—Pan—Hydraulic Actuator	1
SK668123	II—Plate—Mount, Hydraulic Actuator, Camera	
SK668124	Bearing—Pan—Camera	1
SK668125	Lug Drive—Pan Camera	1
SK668126	Bushing—Split	1
SK668127	Lug—Drive—Tilt	1

A—11 PAN AND TILT (Cont'd)

Dwg. Number	Description	No. of Shts.
SK668128	Plate—Connecting—Bracket to Hydraulic Actuator	1
SK668129	Sleeve—Shaft	1
SK668130	Shaft—Tilt	1
SK668131	Washer—Bearing	
SK673274	Bracket—Support and Drive, Pan and Tilt Cameras	
SK673275	Insert—Flow Tork—Tilt Modifier	1
SK676958	Miscellaneous Components	
SK690632	Plate—Sealing	1
SK690813	Pan and Tilt Assembly	1
SK697610	Mounting Bracket	1
SK697785	Camera Mounting Bracket	1
SK697687	Bracket Pan and Tilt	1
LAYOUTS	SS10269-9	1

A—12 OPTICS (None)

A—13 LIGHTS

SK673064	Adaptor—Socket Lamp and Socket Strobe	1
SK677499	Strobe Light	1
SK687176	Spot Light Installation	1
SK687177	Flood Light Assembly	1
SK687340	Pressure Balanced Flood Light Assembly and Details	1
SK687420	Lamp—Assembly Mercury Vapor	1
SK687500	Balanced Pressure Floodlight Schematic Installation	1

A—14 MAIN CONNECTOR

SK670995	Connector—Pressure Balanced	3
SK673095	Wire List, Main Connector Van Junction Box	1
SK673126	Bracket—Connector Mounting Electronic Package Sphere	1
SK673382	Wire—List—Connector Vehicle—1000 ft. Whip	1

A—14 MAIN CONNECTOR

Dwg. Number	Description	No. of Shts.
SK677650	Connector Pressure Balanced Main Cable Housing Detail	1
SK677654	Connector Pressure Balanced Whip Cable Housing Detail	1
SK677788	Connector Pressure Balanced Main and Whip Cable Connector Details	1
SK677789	Connector Pressure Balanced Main and Whip Cable Neoprene Boot Detail	1
SK677790	Connector Pressure Balanced Main and Whip Cable Packing Male Adapter	1
SK677791	Connector—Pressure Balanced Main Cable Assembly	1
SK677792	Connector—Pressure Balanced Whip Cable Assembly	1
SK687702	Connector Pressure Balanced Whip Cable Clamp	1
SK687759	Connector—Pressure Balanced Main Cable Clamp	1
SK687828	Spacer, Balanced Connector—Main and Whip Cable	1
SK690171	Connector Pressure Balanced Whip Cable Assembly	1

A—15 SMALL CABLES

SK687350	Leak Detector	1
SK687828	Spacer, Balanced Connector—Main and Whip Cable	1
SK687915	High Reliability Underwater Splice	1
	Small Cable Dwg's Replaced With New Pressure Balanced Connectors Shown In Section A—5	

A—16 HYDRAULIC TESTS

SK677143	Component Tests	1

A—16 HYDRAULIC TESTS (Cont'd)

Dwg. Number	Description	No. of Shts.
SK687478	Altimeter and Pressure Depth Transducer Installation	7
SK687903	Adaption of Franklin Motor to Hydraulic Power Unit	4
SK687906	Marotta Valve Test Fixture Sheets 1, 3, 4, and 5	4
SK687908	Hydraulic Test Equipment	2
SK687993	Pressure Balanced Electrical Conductor Details for 10,000 ft.	1

A—17 HYDRAULIC SYSTEM

SK672999	Power Unit	1
SK676914	Hydraulic Actuator Assembly (Aluminum Flo—Tork)	3
SK677169	Flo—Tork Actuator Modified Restricted Orifice	1
SK677529	Mounting Bracket, Hydraulic Solenoid Valve	1
SK677540	Relief Valve—Modified—and Mounting Bracket	
SK677627	Hydraulic System	1
SK677649	Flo—Tork Modification	1
SK677676	Pressure Depth Transducer and Installation	1
SK687478	Altimeter and Pressure Depth Transducer Installation	1
SK690756	Hydraulic Power Unit Mounting Bracket	1
LAYOUTS	SS10269-14 and 15	2

A—18 MAIN CABLE ASSEMBLY

SK673300	Cable Main Control	1
SK673382	Wire List—Main Connector Vehicle—1000 Foot Whip	
SK677650	Connector Pressure Balanced Main Cable Assembly Housing Detail	1

A—18 MAIN CABLE ASSEMBLY (Cont'd)

Dwg. Number	Description	No. of Shts.
SK677788	Connector Pressure Balanced Main and Whip Cable Connector Detail	1
SK677789	Connector Pressure Balanced Main and Whip Cable Boot Detail	1
SK677790	Connector Pressure Balanced Main and Whip Cable Packing	1
SK677791	Connector Pressure Balanced Main Cable Assembly	1
SK687759	Connector Pressure Balanced Main Cable Assembly Clump Assembly	2
SK690227	Graphs—Nylon Line to Cables	2
SK690918	Buoyancy Tank Edge Protector	

A—19 WHIP CABLE ASSEMBLY

SK673301	Cable—Whip Control	1
SK677654	Connector Pressure Balanced Whip Cable Housing Detail	1
SK677792	Connector Pressure Balanced Whip Cable Assembly	1
SK687702	Connector Pressure Balanced Whip Cable Clump Assembly	2

A—20 CLUMP ASSEMBLY

SK687178	Junction—Main to Whip Cable Rigging Assembly	2
SK687828	Spacer—Balanced Connector Main and Whip Cable	1
SK698688	Cable Ring Assembly	5
LAYOUT	J. T. 31270 CURV Cable Ring NASA SALVOPS	1

A—21 MISCELLANEOUS

Dwg. Number	Description	No. of Shts.
SK676958	Miscellaneous Components	1
SK697470	Adaption of CURV III System to Various Ships	5

A—22 CONTROL CONSOLE

SK673095	Wire List, Main Connector—Van Junction Box	1
SK673096	Diagram—Interconnection, Van Wiring	1
SK673097	Diagram—Interconnection, Cabinet No. 1 Console	1
SK673098	Diagram—Interconnection, Cabinet No. 2 Console	1
SK673099	Diagram—Interconnection, Cabinet No. 3 Console	1
SK673100	Diagram—Interconnection, Cabinet No. 4 Console	1
SK673101	Diagram—Interconnection, Cabinet No. 5 Console	1
SK673102	Diagram—Interconnection Cabinet No. 6 Console	1
SK673215	Schematic Diagram, Speaker Amplifier, Line Driver	1
SK673299	Console—Installation in Van, Operations	1
SK673317	Rail—Mounting, Console	1
SK673318	Washer—Special, Anchor	1
SK673323	Rail—Anchor, Control Console	1
SK673324	Plate—Base Support Shock Mounting Console	1
SK673383	Schematic Diagram, Main Power Package	1

A—23 VAN

SK673058	Van—Control Operations	2
SK673095	Wire List, Main Connector Van Junction Box	1
SK673096	Diagram—Interconnection, Van Wiring	1
SK673097	Diagram—Interconnection, Cabinet No. 1 Console	1

A—23 VAN

Dwg. Number	Description	No. of Shts.
SK673098	Diagram—Interconnection, Cabinet No. 2 Console	1
SK673099	Diagram—Interconnection, Cabinet No. 3 Console	1
SK673100	Diagram—Interconnection, Cabinet No. 4 Console	1
SK673101	Diagram—Interconnection, Cabinet No. 5 Console	1
SK673102	Diagram—Interconnection, Cabinet No. 6 Console	1
SK673299	Console—Installation in Van Operations	1
SK673317	Rail—Mounting Console	1
SK673318	Washer—Special Anchor	1
SK673321	Van—Control Operations	1
DWG1100	Van—Control Operations	2
SK673322	Link—Adapter Van Lift	2
SK673323	Rail—Anchor Control Console	1
SK673324	Plate—Base Support Shock Mounting Console	1
SK673325	Panel Housing—Connector Control Van, Installation	1
SK673326	Angle—Frame, Connector Panel	1
SK673327	Channel—Sides	1
SK673328	Panel—Connector Port Van	1
SK673329	Panel—Cover Housing	1
SK673330	Gasket—Connector Panel	1
SK673334	Panel, Housing—Connector Control Van Installation	1

A—24 VEHICLE HANDLING EQUIPMENT

SK673322	Link Adapter Van Lift	
SK677220	Basket—Cable Container	7

B-2
B-3
B-7
9

APPENDIX B

CURV IIIC FACT SHEET

Appendix B

TABLE OF CONTENTS

B-1.	System	B-2
B-2.	Vehicle	B-3
B-3	Cable Assembly	B-7
B-4.	Support Vessel YFNX-30	B-9

Appendix B

CURV IIIC FACT SHEET

Appendix B

CURV IIIC FACT SHEET

B-1 SYSTEM

RECOVERIES: (As of 1 Dec 1971)	3 Small Objects 1 NASA Solar Eclipse Instrumentation Package 4 Cables
OPERATING CREW:	6 Civilians - 1 Range engineer - 1 Vehicle Operator - 1 Sonar operator - 1 Deck supervisor - 1 Crane operator/ line handler - 1 Traction winch operator 4 Military - 1 Positioning units operator - 3 Line handlers
TYPICAL OPERATIONS:	Small object and cable recovery Bottom survey Salvage (with salvage ship support) Underwater inspections Marine organism collecting Miscellaneous range work Rigging underwater towers
PORTABILITY:	Operational components exclusive of support vessel, transportable in one C-141, or three flat-bed trucks. Twelve on-scene personnel required for Atlantic Coast operations with 24-hour work day.

B-2 VEHICLE

(All Vehicle Items Part of Portable System)

SIZE:	6.5 ft x 6.5 ft x 15 ft
WEIGHT:	4,500 lbs (approx.)
OPERATING DEPTH:	7,000 ft
PAYLOAD:	200 lbs max (vehicle only) 400 lbs max (with assist on strength member) 10,000 + lbs (with separate surface recovery line)
SUBMERGED SPEED (max):	4 kts (estimated)
OPERATING ENDURANCE:	Unlimited
POWER REQUIREMENTS:	50 KW; 440 VAC, 120 VAC

VEHICLE SUBSYSTEMS AND COMPONENTS:

Propulsion:	Three 3-phase, 440 VAC, 10 HP, oil-filled, pressure-equalized Electro-Kinetics motors with fixed-pitch screws; thrust varied by voltage, max 400 lbs forward, 250 lbs reverse (each)
Search and Navigation:	Straza SLAD-603 - Active Sonar: CTFM 78-82 kHz, ranges 50 yd, 250 yd, 800 yd - Passive Sonar: 45 kHz - Transponder Mode: 50 yd, 250 yd, 800 yd - Sonar Training Mechanism: Projector, hydrophone, receiver, and passive listening hydrophone; automatic scan 120° at 26°/sec, manual reverse; tilt ±15° - Locator: Pinger with 36.5 kHz, 1.5 sec pulse interrupted by 37.2 kHz, 10 msec pulse - Altimeter: Transducer 100 kHz, 100 msec pulse, ranges 0-10 ft and 0-100 ft, accuracy ±0.5 ft

	Compass -	Gimballed ring-core, flux gate magnetometer
Optics:	Television Cameras -	Two Hydro Products solid state, standard scan vidicon cameras; water corrected lens, 54° view angle, aluminum housing
	Television Lights -	- Four stationary, pressure-balanced mercury vapor 250 watt flood lights at front of vehicle. Two 100 watt pressure-balanced mercury vapor spotlights mounted with TV cameras - Four 250W and 100 W, GE ballast transformers
	Documentary Camera -	One EG&G Model 214,200 watt/sec strobe, 1 flash every 8 secs
	Optical Pan-and-Tilt Units -	Hydraulically-actuated 360° pan, 90° tilt
Hydraulics:	Power Unit -	Oil-filled, pressure-compensated Electro-Kinetics unit; 1/2 HP electric motor, 1-1/2 gal per minute pump. Operating pressure 1,000 psi at all depths, 2 gal. reservoir
	Control Valves -	Marotta solenoid-controlled 3 way-2 position valves coupled in pairs to a blocking valve to give 4 positions
	Actuators -	Linear: Racine hydraulic piston Rotary: Flo-tork
Tool Assembly:	Actuator -	Hydraulic five-function unit. Arm UP-DOWN, Arm rotate: CLOCKWISE-COUNTER-CLOCKWISE; Arm eject; Wrist: CLOCKWISE-COUNTERCLOCKWISE (axis 90° to arm); Claw: OPEN-CLOSE

Tools -	13 in. claw, snare, grapnel hook, noose, marine orgamism basket, manipulator, pyronol torch
Structural Components:	
Housings -	Main electric/hydraulic: Spherical cast aluminum 31 in. O. D.
-	Compass: 6 in. O. D. aluminum sphere
-	Sonar: Aluminum cylinder 8 in. O. D. 60 in. long
Buoyancy -	50 3M Co. Syntactic foam slabs. Each slab: 5-3/4 x 11-3/4 x 22 in. (0.83 cu ft), 38 lbs/cu ft (26 lbs/cu ft buoyancy)
	Hydrostatic crush: 11,000 max. 2.1% average minimum
	Water absorption: 3.0% minimum; 2.1% average @ 4,500 psi
Total Buoyancy -	With approximately 70 lbs forward lead trim; vehicle 40-50 lbs buoyant
Frame -	Main structure, exclusive of brackets and bumpers, 6 ft wide, 4 ft high, 11 ft long of welded 6061 aluminum structural shapes
Interconnecting Cables:	Cables are pressure-balanced, immersed in oil inside flexible tygon tubing. Pressure-balanced connectors based on NUC designs.

Search and Rescue Package:

Interrogator Transponder:	Receive — 22.5 kHz Output — 37.5 kHz Rep Rate — 2 pings/sec Omnidirectional Depth — 10,000 feet Range — 3 miles
Power Loss Pinger:	9 kHz, Omnidirectional Range: 6 miles
Automatic Flasher Light:	Xenon Beacon ON at 25 foot depths OFF at 35 foot depths Visibility: 10 miles surface, 25 aircraft 300 hours endurance One flash every 2 secs
Automatic Radio Direction Finder:	Military Compatible 276.8 mHz RF signal 15 secs. ON, 60 sec OFF
Transmitter —	100 milliwatts Activated by antenna leaving the water
Control/Indicator —	CRT Tube, Channel Selector, Relative Field Strength Indicator, Receiver Audio Output. Directional Accuracy Directional Accuracy: ±3-5° Range 6-10 miles

B-3 CABLE ASSEMBLY

(All Cable Assembly Items Part of Portable System)

MAIN CABLE:

Length:	7,000 ft
Diameter:	1-1/2 in. O. D.
Weight:	1.25 lb per ft in air, 0.6 lb per ft in water
Conductors:	55 conductors - Ten No. 10, - Twenty-four No. 18, - Three No. 24 coax (RG-59 type) - Three No. 18 shielded pair (alum-mylar shield) - One No. 18 shielded triad (alum-mylar shield) - One No. 16 pair - One No. 16 triad
Internal Support:	7/32 in. central epoxied fiberglass strain member, tensile strength 6,000 lbs (min)
Jackets:	Inner jacket 1/8 in. polyurethane; reinforcing nylon braid; outer jacket 0.031 in. polyurethane bonded to inner jacket through braid
Water-Blocking:	Nonhosing to 300 psig, max leakage 1 cu in. in 2 hrs

WHIP CABLE:

Length:	1,000 ft
Diameter:	1-1/4 in. O. D.
Weight:	1 lb per ft in air, 1/2 lb per ft in water
Conductors:	55 conductors - Nine No. 12 - Two No. 24 coax (RG-59 type) - One No. 16 triad, - One No. 18 shielded triad - Four No. 22 shielded pair (alum-mylar shield) - Twenty-three No. 20

Internal Support:	0.040 in. SS strength braid surrounding inner jacket
Jackets:	Inner jacket 1/8 in. polyurethane, outer jacket 0.040 polyurethane
Water-Blocking:	Nonhosing to 300 psig, leakage 1 cu in. in 2 hrs (max)
MAIN CONNECTOR:	55 pin double O-ring seal molded connector
MAIN CABLE-WHIP JUNCTION:	Fitted with male/female connectors identical to main connector
SUPPORT MEMBER:	Samson 2-in-1 nylon braid, 1 in. O.D., 28,000 lbs average strength (intended CURV working load 5,000 lbs)
CABLE FLOATS:	30-40 floats, spaced at 30' intervals on whip. Each float composed of 1/2 3M Co. syntactic foam slab of same type used for vehicle buoyancy.

B-4 SUPPORT VESSEL YFNX-30

(* = Items Included in Portable System)

VESSEL CHARACTERISTICS:

Hull:	Flat
Length:	110 ft
Beam:	34 ft
Draft:	5 ft
Displacement:	420 tons
Freeboard:	6-1/2 ft
Height (keel to top of pilot house):	20 ft, 8 in.
Speed:	5.5 kt (max) ahead-astern; 3 kt (max) port-starboard; 1.5 rpm (max)
Cruising Range:	Limited to LB - SCI area
Means of Transport:	Tow, LSD
Crew:	13 military
Berthing:	Crew - 16 Civilian - 8
Deck House:	37 ft x 25 ft
Pilot House:	20 ft x 12 ft
Fuel Oil Capacity	30,000 gals
Wash-Water Capacity:	14,000 gals
Potable Water Capacity:	770 gals + 70 gals per hr

VESSEL MACHINERY:

Electrical Power:	Three 235 KW Delco brushless generators driven by V-1271 GMC 2-cycle diesel engines, 340 HP (each).
Propulsion:	Two Voith-Scheider cycloidal propellers Model 12-3 each with four-variable-pitch 30 in. vertical blades. Propellers mounted fore and aft on centerline; each driven by a 200 HP 800 RPM Delco AC motor controlled from pilot house or plotting room.

Capstans:	Four 10,000 lb pull hydraulic capstans
Hydraulic:	One 40 HP AC motor and two pumps
Water-Makers:	Two 35 gal per hr Douglas watermakers
Miscellaneous:	Two 7-1/2 HP fire pumps Two 3 HP bilge pumps Two 1-1/2 HP fuel oil transfer pumps Two fresh water pumps Two 52 gal wash water heaters One 20 gal potable water heater Seven ventilating fans

VESSEL INSTRUMENTATION:

Navigation:	LORAC
Fathometer:	EDO Western sounding unit, Model 185
Radio:	Two Motorola 40 watt, 2 channel radios

AUXILIARY CRAFT: One 16 ft Boston Whaler with 100 HP outboard
Two 16-man inflatable liferafts

CURV III SUPPORT AND POWER CONVERSION EQUIPMENT:

*Instrumentation Van: 15 ft long, 9 ft wide, 8 ft high with air conditioner removed

*5 bay electronic control console:

Displays -	Sonar, altimeter, depthometer, locator, vehicle tracker, TV monitors, vehicle and ship's compass (with cable twist counter)
Vehicle Operator Controls	Propulsion, TV, 35mm lights, claw
Sonar Operator Controls	Sonar mode and range scan frequency, assist on TV and claw
Communication -	Ships intercom, radio remote station

* = Part of Portable System

*Vehicle & Target Tracking Gear:

- BALD Gear (Directional Hydrophone)
- NUC UNLOC
- Honeywell Sea-Scannar II-F sonar

*Instrument Power Conversion and Isolation Package:

- One 5 KW motor generator
- Three Superior Electric variable transformers for output of 1000V (max)

CURV III HANDLING EQUIPMENT:

*Crane:	Hiab Titan articulating crane with manually-telescoping boom; 5,000 lbs at 19 ft
Strength Member Winch:	Hydraulic traction winch designed for 10,000 lb pull at 120 ft/min; presently 7,000 lb pull at 100 ft/min
Cable Davit:	7 foot arch-frame with handling platform
*Cable Storage Bins:	Two bins 4 ft high, 4 ft wide, 14 ft long
Miscellaneous:	Vehicle storage area with powered dolly; maintenance shop with drill press, *portable welder, band saw, grinder

VESSEL LAYOUT:

Below Deck:	Frames 0 (aft) to 3	- Aft propulsion unit, machinery space
	Frames 3 to 5	- Machinery switch-board and shop area
	Frames 5 to 7	- Cable and strength member handling area, technical sea chest
	Frames 7 to 9	- Crews quarters, galley, pantry
	Frames 9 to 11	- Galley, mess room, showers, head
	Frames 11 to 12-1/2	- Storeroom, freezer, civilian conference room and quarters
	Frames 12-1/2 to 14	- Fwd propulsion unit potable water tanks

* = Part of Portable System

Main Deck:	Frames 0 to 3	- Two capstans, ventilator cover and ventilator house
	Frames 3 to 5	- Cable handling room and work platform
	Frame 8	- Crane, dolly door, deck house wall
	Frames 8 to 12-1/2	- Deck house
	Frames 8 to 10	- (Deck house) stbd side - control van, port side - vehicle storage
	Frames 11 to 12-1/2	- (Deck house) stbd side - plotting room, port side - vehicle maintenance
	Frames 12-1/2 to 14	- Two capstans, anchor, anchor shop
Deck House 01 Level:	Frame 9	- Boston Whaler
	Frames 10 to 12-1/2	- Pilot house

APPENDIX C

CURV I OPERATIONS SUMMARY

Appendix C

CURV I OPERATIONS SUMMARY

CURV I Operations Summary

DATE	VEHICLE USED	PURPOSE	RECOVERY NO.	LOCATION	DEPTH, FT	BOTTOM CONDITIONS	SEA CONDITIONS	TYPE OF MOOR	VEHICLE CONDITION	PINGER EFFECTIVENESS		LOCATION ACCURACY	TIME, HRS:MIN					REMARKS
										9 KC	45 KC		ON STATION	IN WATER	IN WATER TO LOCATION	LOCATION TO ATTACH	ATTACH TO SURFACE	
19 FEB 65	CURV I	RECOVERY	1	SCI	550					GOOD	GOOD		1:27	0:57	0:27	0:20	0:10	75# PULL ASSIST NEEDED TO RAISE UNIT. VEHICLE CAPABILITY 1000'.
23 MAR 65	CURV I	RECOVERY	2	SANTA BARBARA	470	LARGE BOULDERS	SEA STATE ±2 8-10 KT WIND	SINGLE	HYDROPHONE REPLACED CLAW DAMAGED	ONLY	NONE	BUOY ± 150'	6:00	1:30	0:45	0:25	0:20	175# PULL ASSIST TO RAISE UNIT. VEHICLE CAPABILITY 1000'.
24 SEP 65	CURV I	RECOVERY	3		1740	SOFT GOOEY MUD			VERTICAL MOTOR OIL LEAK SALT WATER IN HYDRAULIC SYSTEM	WORKING	NONE		5:50	5:05	3:40	0:20	1:00	2 HR SEARCH FOR PINGER. ATTACHED BY GRASSHOPPER TECHNIQUE. VEHICLE CAPABILITY 2000'.
29 SEP 65	CURV I	RECOVERY	4	WEST OF SCI	1700	SANDY		SINGLE		WORKING	NONE		8:47	6:00	4:13	1:00	1:47	UNIT IN CANYON. 9 KC HEARD 50' FROM BOTTOM BUT NOT ON IT. ACTIVE SONAR HELPFUL IN CANYON.
14 OCT 65	CURV I	RECOVERY	5	PP 17	1350	MUDDY GOOEY		SINGLE		GOOD	GOOD		—	2:45	1:10	0:30	1:05	9 KC & 45 KC RECEIVED AT DEPTH OF 150'. SHIPBOARD GENERATOR FAILURE.
28 OCT 65	CURV I	RECOVERY	6	PP 17	1300	NUMEROUS SMALL ROCKS		UNMOORED TRB ASSIST	GOOD	NONE	BALD SLAD STRONG		3:30	2:15	0:49	0:24	0:47	INSUFFICIENT AC FROM SHIPBOARD GENERATORS.
29 OCT 65	CURV I	RECOVERY	7	PP 17	1300	SOFT MUD		UNMOORED TRB ASSIST	GOOD	VERY WEAK	STRONG		2:35	1:45	0:29	0:16	0:55	INSUFFICIENT AC FROM SHIPBOARD GENERATORS.
5 NOV 65	CURV I	RECOVERY	8	PP 18	1470	SOFT MUD		UNMOORED TRB ASSIST	GOOD	NONE	STRONG		3:10	2:50	1:29	0:16	1:00	INSUFFICIENT AC FROM SHIPBOARD GENERATORS.
5 NOV 65	CURV I	RECOVERY	9	PP 18	1580	SOFT MUD		SINGLE	FAIR, HYDRAULIC SYSTEM SLUGGISH.	WEAK ON SLAD	STRONG		5:00	4:40	1:40	2:50	1:10	LIGHT TORPEDO IN VERTICAL POSITION MADE ATTACHMENT DIFFICULT. INSUFFICIENT AC.
10 NOV 65	CURV I	RECOVERY	10	SAN NICHOLAS	300	ROCKY, FIRM SAND, VEGETATION	5-6 FT SWELLS	UNMOORED TRB ASSIST	GOOD, SLAD HYDROPHONE WEAK	GOOD	GOOD		17:25	1:45	1:15	0:05	0:08	RECOVERY DELAYED 15 HRS BY 12' SWELLS. RECOVERY MADE IN 5' - 6' SWELLS.
27 NOV 65	CURV I	RECOVERY	11	CATALINA CHANNEL	1650	SOFT MUD, NO ROCKS	SEA STATE ±2	UNMOORED TRB ASSIST	GOOD	NONE	GOOD		4:25	3:45	1:45	0:30	1:05	SHIPBOARD GENERATOR PROBLEMS.
30 NOV 65	CURV I	RECOVERY	12	WEST SIDE SCI	1400	FIRM SAND	SEA STATE ±2	UNMOORED TRB ASSIST	GOOD	GOOD	GOOD		2:25	2:10	0:52	0:08	0:55	WATER IN HYDRAULIC SYSTEM. ACTIVE USED FROM 300'
2 DEC 65	CURV I	RECOVERY CET 119	13	SAN NICHOLAS	300	ROCKY, SANDY	SEA STATE ±1	UNMOORED TRB ASSIST	STARBOARD LAMP BRACKET BROKEN	GOOD	GOOD		1:11	0:58	0:31	0:09	0:09	
2 DEC 65	CURV I	RECOVERY TP 133	14	SAN NICHOLAS	500	ROCKY, FIRM SAND	SEA STATE ±1	UNMOORED TRB ASSIST	GOOD	NONE	GOOD		13:30	6:40	5:26	0:04	0:40	SMASHED NOSE FLOODED UNIT. RECOVERED WITH AID OF CREW PULLING ON CABLE.
3 DEC 65	CURV I	RECOVERY TP 122	15	SAN NICHOLAS	340	ROCKY, FIRM SAND	SEA STATE ±1	UNMOORED TRB ASSIST	GOOD, REPLACED PORT MV LAMP	GOOD	GOOD	9 KC RECEIVED 2 MI, 45 KC RECEIVED 1000 FT FROM UNIT	8:10	3:45	3:00	0:13	0:20	
4 DEC 65	CURV I	RECOVERY T 107	16	CATALINA CHANNEL	1400	SOFT MUD, CLEAR	SEA STATE ±1	UNMOORED TRB ASSIST	GOOD	GOOD	GOOD		6:30	6:15	3:31	0:40	0:40	MV LAMP INTENSITY LOW. CHANGED LAMPS. FLUSHED HYDRAULIC SYSTEM.
4 DEC 65	CURV I	RECOVERY CVT 124	17	CATALINA CHANNEL	1330	SOFT MUD, CLEAR	SEA STATE ±1	UNMOORED TRB ASSIST	GOOD	VERY WEAK	SLOW RATE	BUOY ± ¼ MILE	2:15	2:05	1:04	0:14	0:32	

CURV I Operations Summary

DATE	VEHICLE USED	PURPOSE	RECOVERY NO.	LOCATION	DEPTH, FT	BOTTOM CONDITIONS	SEA CONDITIONS	TYPE OF MOOR	VEHICLE CONDITION	PINGER EFFECTIVENESS		LOCATION ACCURACY	TIME, HRS MIN					REMARKS
										9 KC	45 KC		ON STATION	IN WATER	IN WATER TO LOCATION	LOCATION TO ATTACH	ATTACH TO SURFACE	
6 DEC 65	CURV I	RECOVERY 132	18	CATALINA CHANNEL	1475	SOFT MUD, NO ROCKS	SEA STATE ≈1	UNMOORED TRB ASSIST	GOOD	GOOD	GOOD		4 50	4 15	3 04	0 04	0 57	SONAR DISPLAY WENT OUT AT 1000 HRS, COULD NOT TRACK VISUALLY. REPAIRED ITSELF AT 1015 HRS.
6 DEC 65	CURV I	RECOVERY 131	19	CATALINA CHANNEL	1250	SOFT MUD, NO ROCKS	SEA STATE ≈1	UNMOORED TRB ASSIST	GOOD	VERY WEAK	GOOD		2 45	1 55	0 38	0 04	1 08	UNIT FLOODED. VERY HEAVY.
6 DEC 65	CURV I	RECOVERY 105	20	CATALINA CHANNEL	1560	SOFT MUD, NO ROCKS	SEA STATE ≈1	UNMOORED TRB ASSIST	GOOD	WEAK	GOOD		2 40	2 25	0 36	0:06	1 33	UNIT IMBEDDED IN 18 - 24 IN. OF MUD.
9 DEC 65	CURV I	RECOVERY T 134	21	CATALINA CHANNEL	1500	SOFT MUD, NO ROCKS	SEA STATE ≈1	UNMOORED TRB ASSIST	GOOD	GOOD	GOOD		2.40	2 10	0 55	0:09	0 51	CLOSED WITH ACTIVE SONAR AT 240' RANGE.
9 DEC 65	CURV I	RECOVERY 126	22	CATALINA CHANNEL	1080	SOFT MUD, NO ROCKS	SEA STATE ≈2	UNMOORED TRB ASSIST		GOOD	NO DIRECTION	BUOY 2½ MI FROM GIVEN CO-ORDINATES	3:20	2.45	1 37	1 23	0 32	TAIL STUCK IN MUD. UNIT AT 20° ANGLE.
17 DEC 65	CURV I	RECOVERY 116	23	CATALINA CHANNEL	1500	SOFT MUD, NO ROCKS	SEA STATE ≈1	UNMOORED TRB ASSIST	GOOD	GOOD	GOOD	BUOY ± 1,000 FT	3:50	3:05	1 35	0:05	1 15	3 DIVES NECESSARY BECAUSE OF LINE FOULING MOTOR, VEHICLE BUOYANCY.
23 DEC 65	CURV I	RECOVERY 114	24	CATALINA CHANNEL	1540	SOFT MUD, NO ROCKS	SEA STATE ≈1 SLIGHT SWELL	UNMOORED TRB ASSIST	GOOD	GOOD	SLOW RATE		6:10	2:40	1 15	0:05	1 13	4 DIVES NECESSARY BECAUSE OF TRB ENGINE FAILURE, MOTORS FOULED BY LINE, TV FAILURE.
14 JAN 66	CURV I	RECOVERY 125-4	25	PP 17	1440	SOFT DEEP MUD, NO ROCKS	SEA STATE ≈1	UNMOORED TRB ASSIST	FAIR – DEPTHOMETER BAD	GOOD	GOOD	BUOY ± 1,300 YDS	4.00	3:15	0:54	1:06	0:35	VERY LIGHT TORPEDO RETRIEVED VERTICALLY. B.W. USED TO SECURE. GENERATORS ERRATIC.
14 JAN 66	CURV I	RECOVERY 112-5	26	PP 17	1686	SOFT DEEP MUD, NO ROCKS	SEA STATE ≈1	UNMOORED TRB ASSIST	FAIR – DEPTHOMETER BAD	VERY WEAK	GOOD	BUOY WITHIN 300'	6:05	5:35	0.50	2 40	1 45	SHIPBOARD GENERATORS ERRATIC. UNIT IN MUD TAIL-FIRST AT 90° ANGLE. CLOUDS OF MUD OBSCURED TV.
JAN 66	CURV I	SURVEY.		POP-UP RANGE OFF SCI									5 DAYS					TV ALLOWED RANGE ENGINEERS TO OBTAIN FIRST-HAND INFO ON CONDITION OF STAKE PILES. I.D. # CARRIED TO PILING BY CURV BEFORE PICTURE TAKEN.
11 FEB 66	CURV I	RECOVERY LDTV-1	27	POP-UP RANGE OFF SCI	372	SOFT MUD, SOME DEBRIS	SEA STATE ≈1 8 - 12 KT WIND LIGHT CHOP	UNMOORED TRB ASSIST	GOOD	GOOD	GOOD		4:15	1 10	0:28	0.06	0:16	TRB DELAYED BY WIND. DIVER APPLIED NOSE CAGE TO UNIT.
15 MAR 66	CURV I	RECOVERY	28	POP-UP RANGE OFF SCI	1488	SOFT MUD, NO LARGE ROCKS	SEA STATE ≈1	UNMOORED TRB ASSIST	GOOD	VERY WEAK	GOOD		2:45	2:35	1:02	0:11	1:02	GENERATOR MALFUNCTIONING.
7 APR 66	CURV I	SEARCH & RECOVERY ROBERT	29	PALOMARES, SPAIN	2850	SOFT MUD, HILLY	LIGHT SWELL & CHOP	UNMOORED 2 LCM ASSIST	DIVE ≈1 – GOOD DIVE ≈2 - FAIR DIVE ≈3 – GOOD	NONE	PINGER PLACED BY ALVIN		1 - 10:57 2 - 7 45 3 - 9 00	9:30 7 36 7:20	2:35 4:00 1 39	0:53 — —	— — —	≈1 – ATTACHED GRAPNEL TO CHUTE – SOLID HOOK-UP. ≈2 – ATTACHED 2ND GRAPNEL TO CHUTE SHROUDS. ≈3 – RELAY OUT – AFFECTED SONAR TILT, OFF-ON CLAW OPEN CLOSE, PORT & STBD MOTORS FOULED W CHUTE. RECOVERED.
10 JUN 66	CURV I	RECOVERY CTV 107	30	PP 17	1400	SOFT DEEP MUD	LIGHT SWELL	UNMOORED TRB ASSIST	FAIR – SONAR DEFECTIVE	NONE	SLOW RATE		3:45	3 30	1:40	0:10	1:20	SONAR SHOWED TARGET TO SHIFT 10° – 15° THROUGH EACH SWEEP.
14 JUN 66	CURV I	RECOVERY STV 111	31	PP 18	1590	SOFT MUD	CALM	UNMOORED TRB ASSIST	FAIR – BAD CABLE	WEAK	VERY WEAK		10:25	10:15	8:30	0:07	1:23	BALD GEAR RECEIVER TROUBLE AND WEAK PINGER CAUSED CAUSED LONG & DIFFICULT SEARCH.
15 JUN 66	CURV I	RECOVERY CTV 131	32	PP 18	1360	SOFT MUD	CALM	UNMOORED TRB ASSIST	FAIR – POOR CABLE	GOOD	GOOD		12 15	2.00	0 33	0 02	1 10	3 PREVIOUS DIVES CUT SHORT DUE TO BAD CABLE.
30 JUN 66	CURV I	RECOVERY 201	33	PP 17	1750	SOFT MUD	CALM	UNMOORED TRB ASSIST	GOOD	GOOD	SLOW RATE		4:25	4.00	1:50	0:25	1:20	SONAR WENT OUT ON APPROACH. SECURED. RESTARTED AFTER 15 MINUTES, WORKED EFFECTIVELY.

CURV I Operations Summary

DATE	VEHICLE USED	PURPOSE	RECOVERY NO.	LOCATION	DEPTH, FT	BOTTOM CONDITIONS	SEA CONDITIONS	TYPE OF MOOR	VEHICLE CONDITION	PINGER EFFECTIVENESS		LOCATION ACCURACY	TIME, HRS MIN					REMARKS
										9 KC	45 KC		ON STATION	IN WATER	IN WATER TO LOCATION	LOCATION TO ATTACH	ATTACH TO SURFACE	
29 JUL 66	CURV I	RECOVERY 214	34	PP 17	1050	SOFT MUD	LIGHT SWELL	UNMOORED TRB ASSIST	GOOD	POOR	GOOD		3:30	3:15	2:15	0:02	0:43	NO PICTURES MADE AS NOTHING WAS UNUSUAL.
25 AUG 66	CURV I	SURVEY		SCI	450	FIRM SAND	CALM, CLEAR	3 PT	DIVE #1 - GOOD DIVE #2 - NO CAMERA OR LOCATOR	NONE	ONLY FOR 45 MIN		31:15	1 - 2:42 2 - 2:05	--	---	—	BARREL WITH FLOATS EXCELLENT SONAR TARGET. BOTTOM CONDITION DETERMINED BY TV AND SONAR.
1 SEP 66	CURV I	RECOVERY 206	35	PP 17	1386	SOFT MUD	CALM	UNMOORED TRB ASSIST	GOOD	WEAK	GOOD		2:45	2:27	0:57	0:04	0:51	NO PARACHUTE IN IMMEDIATE AREA.
9 SEP 66	CURV I	RECOVERY DTV 119	36	PP 17	1680	SOFT SAND AND MUD	SEA STATE #1 LIGHT SWELL WITH CHOP	UNMOORED TRB ASSIST	GOOD	NONE	GOOD	CO-ORDINATES GIVEN 27-C 3 MI OFF, CAUSED 1 HR DELAY. MARKER BUOY LINE WAS CUT	3:55	2:55	1:10	0:05	1:00	
15 SEP 66	CURV I	RECOVERY 206	37	PP 17	1584	SOFT MUD SOME DEBRIS	SEA STATE #1 LIGHT SWELL	UNMOORED TRB ASSIST	GOOD	VERY WEAK	FADING		3:20	3:00	0:47	1:03	1:00	UNIT UPRIGHT ON TAIL. 35MM CAMERA MALFUNCTIONING.
28 SEP 66	CURV I	RECOVERY CTV 127	38	PP 17	690	SOFT MUD POOR VISIBILITY	SEA STATE #1	UNMOORED TRB ASSIST	GOOD	GOOD	SLOW RATE		3:40	3:00	0:35	1:50	0:25	ALL BUT 2' OF UNIT BURIED IN MUD. CLAW ATTACHED THROUGH MUD. UNIT FLOATED AWAY WHEN RAISED. 2ND ATTACHMENT MADE ON THE RUN.
25 OCT 66	CURV I	RECOVERY 138	39	PP 17	1500	SOFT MUD LOW HILLS	SEA STATE #2	UNMOORED TRB ASSIST	GOOD	GOOD	SLOW RATE		6:20	5:50	3:25	0:42	1:23	EXTREMELY ERRATIC POWER FROM 30 KW GENERATOR HAMPERED ENTIRE OPERATION.
4 NOV 66	CURV I	RECOVERY CTV 200	40	PP 18	1380	SOFT MUD	SEA STATE #1	UNMOORED TRB ASSIST	GOOD	NONE	GOOD		2:25	2:15	0:25	0:25	0:55	TWO DIVES NECESSARY DUE TO BAD CONNECTOR.
4 NOV 66	CURV I	RECOVERY 2110	41	MM 1	1680	SOFT MUD HILLY	SEA STATE #1	UNMOORED TRB ASSIST	GOOD	GOOD	WEAK		2:40	2:20	0:52	0:03	1:25	UNIT FLAT ON SIDE.
4 NOV 66	CURV I	RECOVERY 218	42	PP 18	1386	SOFT MUD SOME DEBRIS	SEA STATE #1	UNMOORED TRB ASSIST	GOOD	WEAK	SLOW RATE		1:50	1:45	0:30	0:03	0:57	UNIT ON TAIL AT 30° ANGLE.
4 NOV 66	CURV I	RECOVERY LDTV	43	PP 17	600	SOFT MUD LOW HILLS	SEA STATE #1	UNMOORED TRB ASSIST	GOOD	NONE	WEAK		3:15	2:45	0:28	0:07	0:45	VERY HEAVY UNIT. MANUAL PULL ON CABLE NEEDED: CURV & UNIT PULLED APPROX 200' ON BOTTOM. UNIT'S NOSE BROKE OFF DURING ASCENT. WAS RECOVERED NOV 8.
20 DEC 66	CURV I	TAKE ROCK SAMPLES		SCI OFF EEL PT.	800	FIRM SAND	CALM	UNMOORED TRB ASSIST	GOOD	---	---			4:55				SAMPLING FOR ROCK SITE PROJECT. VERY FEW ROCKS. NO OUTCROPPING OF SHELF. NO SAMPLES TAKEN.
21 DEC 66	CURV I	TAKE ROCK SAMPLES		SCI OFF LOST PT.	350	FIRM SAND, ROCKS	CALM	UNMOORED TRB ASSIST	GOOD	---	---			3:40				TWO TYPES OF ROCK SAMPLES TAKEN. PHOTOS ALSO MADE FOR ROCK SITE.
14 FEB 66	CURV I	TAKE PHOTOS		POP-UP RANGE STAKE PILES #5 & #9	250	SANDY	SEA STATE #1	2 PT. & 1 PT.	GOOD	---	---			2:00 TOTAL				TWO DIVES. TOOK PICTURES OF SHACKLES, MOORINGS, HARDWARE TO DOCUMENT CONDITION.
16 & 20 FEB 2 & 7 MAR 67	CURV I	SEARCH		PP 17	1560-1700	SOFT, MUDDY, DEBRIS	SEA STATE #1	UNMOORED TRB ASSIST	GOOD	OUT ALMOST IMMEDIATELY	NONE			24.00 TOTAL				UNIT EQUIPPED WITH SCUTTLE VALVE IN PLACE OF 45 KC. VALVE ACTIVATED 24 HRS. AFTER RUN. SEARCH WITH ACTIVE SONAR. MANY RETURNS FROM DEBRIS.
21 & 22 FEB 67	CURV I	SURVEY		AREA OKLAHOMA	1500	CLEAN, LEVEL, SANDY	SEA STATE #1	UNMOORED TRB ASSIST	GOOD	---	---			15.00 TOTAL				PERFORMED FOR DSSP OVER 3 SQUARE MILE AREA TO CHOOSE SITE FOR EXERCISE WITH TRIESTE
23 FEB 67	CURV I	TAKE PHOTOS		POP-UP RANGE STAKE PILES #13 & #14	245	SANDY, HEAVY DEBRIS (CABLES, ROPES)	SEA STATE #1	2 PT.	GOOD	---	---			3:45				TWO DIVES MADE. ON THE SECOND, CURV FOULED IN A NYLON LINE, HAD TO BE HAULED UP AND FREED. INSPECTION WAS ALSO MADE OF A FOULED BUOY & PHOTOS TAKEN.

CURV I Operations Summary

DATE	VEHICLE USED	PURPOSE	RECOVERY NO.	LOCATION	DEPTH, FT	BOTTOM CONDITIONS	SEA CONDITIONS	TYPE OF MOOR	VEHICLE CONDITION	PINGER EFFECTIVENESS 9 KC	PINGER EFFECTIVENESS 45 KC	LOCATION ACCURACY	TIME, HRS:MIN ON STATION	TIME, HRS:MIN IN WATER	TIME, HRS:MIN IN WATER TO LOCATION	TIME, HRS:MIN LOCATION TO ATTACH	TIME, HRS:MIN ATTACH TO SURFACE	REMARKS
28 & 29 FEB 67	CURV I	SEARCH FOR LOST TRANSPONDER		KK 15	480	HILLY, SOFT MUD, LARGE ROCKS	SEA STATE #1	UNMOORED TRB ASSIST	GOOD	----	----	RADAR FIX CORRESPONDED WELL	6:00 TOTAL					BOTH DAYS TRIED TO FOLLOW COAX CABLE TO TRANSPONDER TERRAIN TOO ROUGH, DEPTH INCREASING, CABLE LOST, VEHICLE HITTING ROCKS, SEARCH ABANDONED.
13 MAR 67	CURV I	RECOVERY 216	44	PP 17	1344	MUDDY	SEA STATE #1	UNMOORED TRB ASSIST	VEHICLE COMPASS NOT WORKING	GOOD	GOOD		2:50	2:30	40	30	1:15	
14 MAR 67	CURV I	TAKE PHOTOS		POP-UP RANGE STAKE PILES #5 & #9	240	SOFT SAND SOME DEBRIS	SEA STATE #1	2 PT	GOOD	---	---		---	2:05 TOTAL				TWO DIVES MADE. PHOTOS TAKEN.
30 MAR 67	CURV I	SEARCH FOR DEAD UNIT		PP 17	2448	SOFT SAND NO DEBRIS	SEA STATE #1	UNMOORED TRB ASSIST	GOOD	NONE	NONE	NO FIX AVAILABLE	1:55	1:50				DESCENDED TO 1000' TO LISTEN FOR UNIT. NOT ABLE TO LOCATE. SEARCH ABANDONED.
30 MAR 67	CURV I	RECOVERY 166	45 46	PP 18	1230	SOFT SAND NO DEBRIS	SEA STATE #1	UNMOORED TRB ASSIST	GOOD	WEAK	WEAK		11:02	3:20 1:35	1:45 1:10	1:05 0:03	1:15 0:25	TWO DIVES NECESSARY. UNIT RECOVERED TWICE, UNIT SEPARATED FROM TRB NOSE CAGE AFTER FIRST DIVE.
3 APR 67	CURV I	SEARCH FOR DEAD UNIT		PP 17	1704	SOFT SAND NO DEBRIS	SEA STATE #1	UNMOORED TRB ASSIST	GOOD	----	NONE		2:25	2:15				DESCENDED TO 600' TO LISTEN FOR UNIT. NOT ABLE TO LOCATE. SEARCH ABANDONED.
4 APR 67	CURV I	RECOVERY 2-D ARRAY	47	KK 15	300	SOFT SAND	SEA STATE #2	UNMOORED TRB ASSIST	POOR	---	---		3:15	2:45	0:35	0:15	1:40	TRANSPONDER IN AN UPRIGHT POSITION.
14 APR 67	CURV I	TAKE PHOTOS		POP-UP RANGE STAKE PILES #14 & #15	210	FIRM SAND MUCH DEBRIS	SEA STATE #1	2 PT	GOOD	---	---		1:55	1:38				
14 APR 67	CURV I	TAKE PHOTOS		POP-UP RANGE STAKE PILES #13 & #15	210	FIRM SAND MUCH DEBRIS	SEA STATE #1	2 PT	GOOD	---	---		2:45	2:20				
14 APR 67	CURV I	RECOVERY UNIT 366	48	KK 21	1296	FLAT SOFT MUD	SEA STATE #1	UNMOORED TRB ASSIST	GOOD	---	SLOW RATE		2:55	2:50	0:25	0:01	1:19	UNIT VERY HEAVY.
25 APR 67	CURV I	RECOVERY TRANSPONDER	49	KK 21	840	SOFT SAND ALSO FIRM AREAS, ROCKS	SEA STATE #1	UNMOORED TRB ASSIST	GOOD	---	---		6:00	5:40	3:22	0:01	2:02	VEHICLE ENTANGLED IN GRAPPLING HOOK LINE ATTEMPTING TO BREAK AWAY AFTER FLAW EJECT. DIVERS NEEDED TO FREE.
26 APR 67	CURV I	SURVEY FOR SEALAB III		N. OF POP-UP RANGE	450	FIRM SAND NO DEBRIS	SEA STATE #1	2 PT	GOOD	---	---		5:20	2:35				
8 MAY 67	CURV I	LIGHT TEST		PP 17	612	SAND NO DEBRIS	SEA STATE #1	4 PT	GOOD	---	---		1:37	1:22				TEST COMPARED QUARTZ IODIDE & MERCURY VAPOR LAMPS. ONLY DIFFERENCE NOTED WAS O.I. REFLECTOR CONCENTRATED LIGHT BETTER.
18 MAY 67	CURV I	SEARCH FOR LOST UNIT		PP 17	2466	SOFT SAND HILLY SOME DEBRIS	SEA STATE #1	UNMOORED TRB ASSIST	GOOD	GOOD	SLOW RATE		2:45	2:40				PLASTIC CABLE FLOAT IMPLODED AT 2100 FT. CUTTING CABLE JACKET AND SEVERAL CONDUCTORS.
19 MAY 67	CURV I	RECOVERY UNIT 222	50	PP 17	2466	SOFT SAND HILLY SOME DEBRIS	SEA STATE #1	UNMOORED TRB ASSIST	SEE REMARKS	GOOD	GOOD		15:35	3:20 3:30	1:09	0:11	1:55	MAIN CABLE TEMPORARILY SPLICED AFTER CUT OF 5,18. WORKED O.K. HYDRAULIC MOTOR CABLE SHORTED OUT ON 1ST DIVE. REPLACED MOTOR, RECOVERED UNIT ON 2ND DIVE.
8 JUN 67	CURV I	TAKE PHOTOS		KK 15 POP-UP RANGE	250	FIRM SAND SOME DEBRIS	SEA STATE #1	1 PT	GOOD	---	---		6:30	3:25				ANCHOR LYING FLAT, NOT DUG IN. SLACK IN CHAIN FROM ANCHOR TO CLUMP AND 3 LOOPS IN CHAIN FROM CLUMP TO FISHHOOK.
14 JUN 67	CURV I	SURVEY		KK 15 POP-UP RANGE	250	FIRM SAND	SEA STATE #1	2 PT	GOOD	---	---		10:10	8:10				MANY PICTURES TAKEN

CURV I Operations Summary

DATE	VEHICLE USED	PURPOSE	RECOVERY NO.	LOCATION	DEPTH, FT.	BOTTOM CONDITIONS	SEA CONDITIONS	TYPE OF MOOR	VEHICLE CONDITION	PINGER EFFECTIVENESS		LOCATION ACCURACY	TIME, HRS/MIN					REMARKS
										9 KC	45 KC		ON STATION	IN WATER	IN WATER TO LOCATION	LOCATION TO ATTACH	ATTACH TO SURFACE	
15 JUN 67	CURV I	SURVEY		KK 15 POP-UP RANGE	700	ROCKY AND SANDY	SEA STATE #1	2 PT	GOOD	---	---		5:15	4:12				VEHICLE CAUGHT ON SUPPORT BUOY CABLE WHILE SURFACING. ABLE TO FREE IN 2 HRS. USING CLAW AND MANEUVERABILITY.
21 JUN 67	CURV I	BALD GEAR TEST		PP 17	1200	SOFT MUD, SOME ROCKS, DEBRIS	SEA STATE #1	UNMOORED TRB ASSIST	GOOD	---	---							BALD GEAR PROVIDED WITH MECHANISM FOR 0°-90° VARIABLE TILT. SIGNAL RECEPTION IMPROVED 100%. SIGNAL BEARING DETERMINATION ±25° WITHOUT, ±5° WITH, TILT.
9 JUL 67	CURV I	INSPECT & TAKE PHOTOS		POP-UP RANGE ANCHOR LEG #2	300	FIRM SAND NO DEBRIS	SEA STATE #1	2 PT	GOOD				2:10	[illegible]				ANCHORS AND CHAINS UNCHANGED SINCE LAST INSPECTION
9 JUL 67	CURV I	INSPECT & TAKE PHOTOS		POP-UP RANGE ANCHOR #1 STAKE PILE #3	300	FIRM SAND NO DEBRIS	SEA STATE #1	2 PT	GOOD				5:00	2:30				ANCHORS, CHAINS, STAKE PILES UNCHANGED SINCE LAST INSPECTION
26 JUL 67	CURV I	DEMONSTRATE RECOVERY		PP 17	610	SOFT SAND NO DEBRIS	SEA STATE #1	UNMOORED TRB ASSIST	GOOD	POOR	FAIR		4:00	3:50	3:15	10	1:10	DEMONSTRATION PERFORMED FOR VISITING NAVAL TORPEDO STATION, KEYPORT, PERSONNEL
14 AUG 67	CURV I	TV & PHOTO SUPPORT OF DRILLING		SEALAB II, STAKE PILES	750	SOFT SAND SOME ROCKS	CALM	2 PT	GOOD					4:00				CURV FOULED WITH STAKE PILE ATTEMPTING TO FOLLOW VISUALLY TO BOTTOM. DIVERS FREED
15 AUG 67	CURV I	TV & PHOTO SUPPORT OF DRILLING		SEALAB III STAKE PILES	750	SOFT SAND SOME ROCKS	CALM	2 PT	GOOD					1:15				CURV FOLLOWED STAKE PILE SUCCESSFULLY USING 100 RANGE SONAR. DRILL SHIP LA CIENTA BROKE OFF DRILL. CURV LOCATED BROKEN DRILL STRING
15 AUG 67	CURV I	RECOVERY OF DRILL BIT	51	SEALAB III STAKE PILES	750	SOFT SAND SOME ROCKS	CALM	2 PT	GOOD					3:50				CURV GUIDED DRILL PIPE WITH SNARE TO BROKEN DRILL BIT. MANIPULATED SNARE OVER B.T. BIT WAS RECOVERED FIRST FROM THAT DEPTH. UNIT 80 FEET LONG. 4,200 LBS.
16 AUG 67	CURV I	TV & PHOTO SUPPORT OF DRILLING		SEALAB III STAKE PILES	750	SOFT SAND SOME ROCKS	CALM	2 PT	GOOD					8:35				OBSERVED AND DOCUMENTED DRILLING OPERATION AND STAKE PILE INSTALLATION
17 AUG 67	CURV I	TV & PHOTO SUPPORT OF DRILLING		SEALAB III STAKE PILES	750	SOFT SAND SOME ROCKS	CALM	2 PT	GOOD					3:05				LA CIENTA UNABLE TO RETRIEVE DRILL CAUGHT ON STAKE PILE. EFFORTS TO RETRIEVE CREATED HAZARD TO CURV MISSION SECURED
28-31 SEP 67	CURV I	SEARCH FOR UNIT			2500	SOFT MUD	SEA STATE #1	3 PT	GOOD			RADAR FIXES GIVEN .007° TRUE 2.3 NAUTICAL MILES OFF OF INTENDED POSITION		10:00				28, 29 & MOST OF 30 AUG REQUIRED TO MOOR DUE TO SNAGGED MOOR. CURV IN WATER 2 HRS. AUG 30, STARBOARD MOTOR FOULED BY CLOTH. 31 AUG 7 HRS. SEARCH CONDUCTED OVER TWO AREAS. NO CONTACT. POS. ERROR ONFMC. MOS SECURED

APPENDIX D

CURV II OPERATIONS SUMMARY

Appendix D

CURV II OPERATIONS SUMMARY

Date	Dive No.	Purpose	Location	Max. Depth (ft)	Sea State	Water Time (Hrs: Mins)	Water Time Total To Date (Hrs: Mins)	Remarks
30 Sept. — 18 Oct. 67	1 — 8	Check-out	LBNS and SCI	2,000	1	13:10	13:10	
23 Oct. — 31 Oct. 67	9 — 18	Search for Ordnance Unit	SCI	1,600	1	100:50	114:00	First CURV Systematic Search for Uncooperative Target
2 Dec. 67	19	Recover Ordnance Unit	Catalina Channel	1,300	1	2:35	116:35	
5 Dec. 67	20 — 26	Inspect SEALAB Stakepiles & Cable Run	SCI	450	1	11:08	127:43	
8 Dec. 67	27	Recover Ordnance Unit	Catalina Channel	1,980	1	5:00	132:43	
12 Dec. 67	28	Search for Ordnance Unit	SCI	1,600	1	14:15	146:58	
27 Dec. 67 — 9 Jan. 68	29 — 31	Check-out Components	Long Beach Harbor		1	5:28	152:26	
16 — 17 Jan. 68	32 — 33	Inspect/Survey	SCI	450	1	4:45	157:11	
27 Jan. 68	34	Recover Ordnance Unit	Catalina Channel	2,315	1	3:50	161:01	
31 Jan. 68	35	Demonstration	SCI	600	1	1:15	162:16	
13 — 14 Feb. 68	36 — 38	Search/Recover Ordnance Unit	SCI	630	1	10:25	172:41	New Recovery Snare and Nylon Lift Line Used
15 Feb. 68	39	Recover Ordnance Unit	SCI	400	1	1:40	174:21	
17 Feb. 68	40	Recover Ordnance Unit	Catalina Channel	1,200	1	2:55	177:16	
20 Feb. — 20 Mar. 68	41 — 45	Search for Ordnance Unit	SCI	200	1	28:15	205:31	
25 Mar. 68	46	Evaluate Stereo TV	Long Beach Harbor	100	1	2:00	207:31	
5 Apr. 68	47	Recover Ordnance Unit	Catalina Channel	225	1	4:24	211:55	
5 — 7 Apr. 68	48 — 51	Search/Recover Ordnance Unit	Catalina Channel	1,320	1	11:07	223:02	
18 Apr. 68	52	Recover Ordnance Unit	Catalina Channel	1,650	3	3:35	226:37	
19 Apr. 68	53	Recover Ordnance Unit	Catalina Channel	1,296	1	3:05	229:42	
24 Apr. — 16 May 68	54 — 65	Search for Ordnance Unit	SCI	400	1	25:33	252:10	Tested EDO Sonar and Washout Tool
17 May 68	66	Recover Ordnance Unit	Catalina Channel	2,550	1	3:38	255:48	
22 — 23 May 68	67 — 69	SEALAB Survey	SCI	744	1	5:45	261:33	
17 June 68	70	CURV II-NTS Equipment Test	Catalina Channel	624	1	5:05	266:38	
18 June 68	71	Demonstration	SCI	108	1	1:10	267:48	
9 July 68	72	Recover Current Meter	Catalina Channel	1,500	1	5:45	273:33	

Date	Dive No.	Purpose	Location	Max. Depth (ft)	Sea State	Water Time (Hrs: Mins)	Water Time Total To Date (Hrs: Mins)	Remarks
9 Aug 68	73 — 74	Recover Ordnance Units	Catalina Channel	348	1	1:49	275:22	Two Units Recovered
15 — 26 Aug. 68	75 — 76	Sound Test	Long Beach Harbor	78	1	2:50	278:12	
4 Sept. 68	77 — 78	Recover Ordnance Unit	Catalina Channel	1,350	1	9:10	287:22	
17 Sept. 68	79 — 81	Demonstrations	SCI	300	1	2:00	289:22	
18 — 19 Sept. 68	82 — 83	Urchin Collecting	SCI	700	1	3:15	292:37	
1 Oct. 68	84 — 85	Sound Test/Training	Catalina Channel	90	1	3:44	296:21	
16 Oct. 68	86 — 91	Inspect SEALAB Anchor	SCI	1,100	1	6:55	303:16	
23 Oct. — 14 Nov. 68	92 — 96	Training/Anchor Inspection	Catalina Channel	300	1	11:57	315:13	
18 Nov. 68	97	Recover Ordnance Unit	Catalina Channel	2,300	1	6:45	321:58	
20 — 21 Nov. 68	98 — 100	Stadia Rod Survey, Monitor Coring Operation	Santa Barbara Channel	1,500	1	11:54	333:52	NCEL
3 Dec. 68	101 — 102	Stakepile Inspection, Bottom Survey	SCI	200	2	1:21	335:13	
9 — 14 Dec. 68	103 — 104	ASW Core Sample Observation	Redondo Canyon	228	1	8:15	343:28	
7 Feb. 69	105 — 106	Recover Ordnance Unit	Catalina Channel	1,440	1	6:12	349:40	
19 Mar. 69	107	Tracking Test	Long Beach	1,150	1	2:21	352:01	
20 Mar. 69	108	Recover Ordnance Unit	Catalina Channel		1	8:30	360:31	
2 — 9 Apr. 69	109 — 111	Urchin Collecting	SCI	780	1	8:35	369:06	
22 Apr. — 22 May 69	112 — 119	Deep Ocean Transponder Recoveries	Santa Barbara Channel	1,550	1	28:15	397:21	Two Units Recovered
28 May — 3 June 69	120 — 123	16 mm Camera Tests	Catalina/SCI	250	1	4:10	401:31	
5 — 8 June 69	124 — 128	Search/Recover Ordnance Unit	Catalina Channel	1,410	1	22:30	424:01	
11 — 13 June 69	129 — 135	NCEL Survey	Santa Barbara Channel	630	1	18:10	442:11	
18 — 19 June 69	136 — 145	Observe Coving Device	Pt. Loma	276	1	7:09	449:20	
28 June — 15 July 69	146-153	Document Sunken Navy Helo	San Diego	240	1	12:45	462:05	
23 July 69	154	Measure Kluge I Hydraulic Noise	Long Beach Harbor	75	1	:25	462:30	
23 July 69	155	Recover Ordnance Unit	Catalina Channel	1,200	2	4:35	467:05	
19 — 28 Aug 69	156 — 159	Ocean Floor Survey	SCI	1,800	1	11:45	478:50	

Date	Dive No.	Purpose	Location	Max. Depth (ft)	Sea State	Water Time (Hrs. Mins)	Water Time Total To Date (Hrs: Mins)	Remarks
14 Oct. 69	160	Monitor UQC Tower Installation	SCI	300	1	1:00	479:50	
14 — 15 Oct. 69	161 — 163	Inspect Stakepile	SCI	190	1	4:55	484:45	
4 Nov. 69	164 — 167	Pyronol Cable Cutter Test	SCI	620	1	3:35	488:20	
5 Nov. 69	168	Biological Bottom Survey	SCI	1,820	1	7:10	495:30	
19 Nov. 69	169	Recover Ordnance Unit	SCI	1,536	1	3:30	499:00	
20 Nov. — 4 Dec. 69	170 — 174	Locate & Document EX-BURRFISH	SCI	1,600	1	25:45	524:45	
11 Dec. 69	175	Check-out Connector	Catalina Channel	2,000	1	3:10	527:55	
24 Dec. 69	176	Demonstration for Japanese TV	Long Beach Harbor	100	1	1:00	528:55	
30 — 31 Dec. 69	177 — 178	Recover Sonar Target	SCI	600	1	5:10	534:05	
6 — 7 Jan. 70	179 — 182	Survey EX-BURRFISH	SCI	1,600	1	12:55	547:00	
12 Jan. 70	183 — 184	ASW Coring Survey	Santa Barbara Channel		1	5:30	552:30	NCEL
15 Jan. 70	185	Recover Ordnance Unit	Catalina Channel	1,240	1	2:40	555:10	
27 Jan. 70	186 — 187	Recover Ordnance Units	Catalina Channel	1,500	1	5:43	560:53	Two Units Recovered
29 — 30 Jan. 70	188 — 189	Train NTS Crew	Catalina Channel	138	1	4:15	565:08	
30 Jan. 70	190 — 191	Recover Ordnance Units	Catalina Channel	1,770	1	6:40	571:48	Two Units Recovered
31 Jan. — 3 Feb. 70	192 — 196	Recover Ordnance Units	Catalina Channel	1,320	1	15:50	587:38	Two Units Recovered
17 Mar. 70	197	Test UNLOC	Long Beach	2,000	1	3:10	590:48	
19 Mar. — 5 May 70	198 — 206	Search for Ordnance Units	Catalina Channel, SCI	2,340	1	45:20	636:08	No Pinger Heard
6 May — 3 June 70	207 — 211	Inspect 3-D Range, Collect Urchins	SCI	1,500	1	5:55	642:03	
4 June 70	212	Inspect EX-BURRFISH	SCI	1,500	1	8:30	650:33	
8 July 70	213 — 214	Recover Ordnance Units	Catalina Channel	600	1	4:53	655:26	Two Units Recovered
22 July 70	215	Check Pyronol Torches	Catalina Channel	300	1	1:15	656:41	
26 Aug. 70	216 — 217	Recover Ordnance Units	Catalina Channel	1,650	1	4:24	661:05	Two Units Recovered
15 Sept. 70	218	Document Ecology Near EX-MORAY	SCI	180	1	2:10	663:15	

Date	Dive No.	Purpose	Location	Max. Depth (ft)	Sea State	Water Time (Hrs. Mins)	Water Time Total To Date (Hrs: Mins)	Remarks
22 Sept. 70	219	Locate and Recover Test Vehicle	Pend Oreille Lake, Idaho	750	1	1:45	665:00	
20 — 21 Oct. 70	220 — 222	Shallow Water Acoustics	Santa Barbara Channel	140	1	9:35	674:35	
24 Nov. 70	223	Sonar Test	Catalina Channel	150	1	5:10	679:45	
8 Dec. 70	224	Inspect EX-BURRFISH	SCI	1,500	3	3:30	683:15	
9 Dec. 70	225	Collect Urchins	SCI	620	1	2:50	686:05	
10 Dec. 70	226	Recover Ordnance Unit	Catalina Channel	1,260	1	3:15	689:20	
11 Dec. 70	227	Recover Ordnance Unit	SCI	160	1	1:10	690:30	
17 Dec. 70 — 18 Jan. 71	228 — 229	Test Connectors	Catalina Channel	2,100	2	6:05	696:35	
12 — 14 Jan. 71	230 — 235	Deploy SEACON Foundation and Anchor Monitors	Santa Barbara Channel	600	1	20:50	717:25	NCEL
28 Jan. 71	236 — 237	Test Generator, Collect Urchins	Pt. Fermin	600	1	5:05	722:30	
22 Feb. 71	238 — 239	Recover Ordnance Units	Atlantic — Off Maine Coast	1,410	1	3:15	730:50	
11 — 12 Mar. 71	241 — 248	Recover Foundation Monitor, Deploy 3 Transponders, Observe Array and Monitor Implantment	Santa Barbara Channel	650	2	14:10	745:00	NCEL
29 Mar. 71	249	Recover Units	Catalina Channel	420	1	4:45	749:45	
13 — 14 Apr. 71	250 — 252	Inspect EX-MORAY, Plant Specimen Frame	SCI	150	1	6:45	756:30	
20 Apr. 71	253	Implant 45 kHz Transponder at EX-BURRFISH	SCI	1,600	1	5:05	761:35	
12 May 71	254 — 255	Survey SEACON Site, Implant Monitor	Santa Barbara Channel	600	2	8:50	770:25	
19 May 71	256	Survey EX-BURRFISH	SCI	1,600	1	6:40	777:05	
25 May 71	257	Training	LBNS	40	1	2:00	779:05	
8 — 10 June 71	258 — 260	Implant Speciment Frame and Document EX-BURRFISH	SCI	1,600	2	16:15	795:20	
15 July 71	261	Recover Ordnance Device	Catalina Channel	860	1	3:00	798:20	
18 — 25 Aug. 71	262 — 263	Shallow Acoustics Tests	Catalina Channel	290	2	5:30	803:50	

CURV II OPERATIONS (Cont'd)

Date	Dive No.	Purpose	Location	Max. Depth (ft)	Sea State	Water Time (Hrs: Mins)	Water Time Total To Date (Hrs: Mins)	Remarks
25 Aug. 71	264	Recover Ordnance Unit	Catalina Channel	1,050	2	3:05	806:55	
27 Aug. 71	265	Recover Ordnance Unit	Catalina Channel	300	1	0.55	807:50	
31 Aug. — 2 Sept. 71	266 — 267	Recover Ordnance Unit	Catalina Channel	1,440	2	4:40	812:30	
3 Sept. 71	268	Recover Ordnance Unit	Catalina Channel	300	2	1:45	814:15	
9 Sept. 71	269	Search for Ordnance Unit	Catalina Channel	1,200	2	5:30	819:45	No Pinger Heard, Hilly Bottom
15 Sept. 71	270	Recover Ordnance Unit	Catalina Channel	300	1	1:30	821:15	
17 Sept. 71	271	Search for Ordnance Unit	Catalina Channel	2,000	Calm	7:50	829:05	No Pinger Heard, Hilly Bottom
21 — 22 Sept. 71	272 — 273	Recover Ordnance Unit	Catalina Channel	300	Calm	1:15	830:20	
24 Sept. 71	274	Search for Ordnance Unit	Catalina Channel	2,000	1	7:00	837:20	
30 Sept. 71	275	Recover Ordnance Unit	Catalina Channel	1,600	Calm	6:00	843:20	
5 Oct. 71	276	Collect Urchins	Catalina Channel	1,300	Calm	2:20	845:40	
15 Oct. 71	277	Recover Ordnance Unit	Catalina Channel	1,600	1	5:45	851:25	
19 Oct. — 10 Nov. 71	278 — 279	Collect Urchins	Catalina Channel	300	Calm	6:20	857:45	
30 Nov. 71	280	Recover Ordnance Unit	Catalina Channel	300	1	0:40	858:25	
14 — 16 Dec. 71	281 — 284	Shallow Water Acoustic Tests	Santa Barbara Channel	300	2	5:20	863:45	

DISTRIBUTION LIST (April 1972)

Chief of Naval Material (CNM-034)
Naval Ordnance Systems Command (03C)
Naval Ships Systems Command (NAVSHIPS 00C)
Naval Material Command Headquarters (NAVMAT 03L-1)
Chief of Naval Operations (OP-23)